Addressing Neonate Mule Deer Survival in the Piceance Basin

Principal Investigator
Chuck Anderson, Mammals Research Leader, Colorado Parks and Wildlife

Cooperators
Ron Velarde, Northwest Regional Manager, Colorado Parks and Wildlife
Bill deVergie, Area 6 Wildlife Manager, Colorado Parks and Wildlife
Darby Finley, Wildlife Biologist, Colorado Parks and Wildlife

STUDY PLAN APPROVAL

Prepared by: Chuck Anderson Date: January 28, 2016
Submitted by: Chuck Anderson Date: September 28, 2016
Reviewed by: Eric Bergman Date: February 17, 2016
Mat Alldredge Date: February 9, 2016
Darby Finley Date: February 8, 2016
Biometrician: Jon Runge Date: September 26, 2016
PROGRAM NARRATIVE STUDY PLAN
FOR MAMMALS RESEARCH
FY 2016-17 – FY 2018-19

Addressing Neonate Mule Deer Survival in the Piceance Basin

A Study Plan Proposal Submitted by:
Chuck Anderson, Mammals Research Leader, Colorado Parks and Wildlife

A. NEED

The Piceance Basin in northwest Colorado (GMU 22) represents winter range supporting the largest migratory mule deer (*Odocoileus hemionus*) population in Colorado. This area has been the focus of research and monitoring efforts since the late 1940’s and likely represents one of the best documented mule deer populations in North America. Research efforts conducted during the 1980s (Bartmann et al. 1992) documented a high density deer population (mean winter density = 63/km²) that appeared to be at or near carrying capacity. During the early 1990s, this population declined to about 1/3 of the previous winter range density (mean winter density = 23/km²; White and Bartmann 1998), likely due to exceeding the forage capacity on winter range. Due to historic mule deer population declines, total mule deer licenses in the area have been reduced by 85% since 2007 and female licenses specifically have been reduced by about 99%; current license allocation in GMU 22 consists of 590 antlered deer and 20 antlerless deer licenses.

Thirteen years later (January 2008), another research effort was initiated to address mule deer/energy development interactions in the Piceance Basin (Anderson 2015; Federal Aid Project No. W-185-R), where similar data are being collected to provide comparisons to mule deer demographic data from the 1980s and early 1990s. In comparing data between the 2 time periods (1982-1990 before the decline and 2008-present from unmanipulated control areas): (1) December fawn weights have increased (averaging 3.7 kg heavier), (2) over-winter fawn survival (Dec – June) has more than doubled (averaging 0.737 versus 0.351), and (3) winter starvation has become rare (<3% of collared fawns), which was common during the 1980s (averaging 33% annually), which suggests mule deer in the Piceance Basin are no longer limited by habitat conditions. Further evidence that this population is no longer limited by forage conditions is evident in the animal-indicated Nutritional Carrying Capacity (NCC; Monteith et al. 2014) from doe body condition measurements providing annual lambda estimates ranging from 1.01 – 1.04 (values >1.00 suggest the population is below NCC), except during 2011 when lambda was slightly below 1.00.

While current research (Anderson 2015; Federal Aid Project No. W-185-R) indicates habitat no longer appears to be the limiting factor, annual winter fawn recruitment has declined from ~73 fawns/100 does to ~49 fawns/100 does, and the average mule deer densities since 2008 (mean late winter density = 19.1/km²) are comparable to the relatively low levels observed during 1994 and 1995 (mean mid-winter density = 23.5/km²; White and Bartmann 1998). Because over-winter fawn survival is high, but early winter fawn recruitment appears low, there is need to discern why fewer fawns may be arriving on winter range in the Piceance Basin. Data collected during the ongoing research largely rules out issues surrounding low fecundity as measured pregnancy and twining rates have been consistently high averaging 95% since 2009 and 1.75 in utero fawns/doe. Thus, evidence suggests that wildlife biologists need information to better understand early fawn survival, from birth until December.

Newborn fawn survival has been addressed in the Piceance Basin the past 5 years (in partial collaboration with Colorado State University). Thus far, neonate survival has been relatively low
(~40%) with a large portion of mortality attributed to predation (at least 49% of collared fawns) and low frequency of malnutrition (<4%). This suggests predation may be limiting neonatal (i.e., 0–6 months old, June – December) survival and recruitment to winter range if predation is additive to other types of mortality (e.g., disease, starvation). Monteith et al. (2014) reported high predation rates of mule deer neonates in California (>60% bear predation) and document that predation rather than nutrition was at least partially limiting the population.

Past research evaluating success of predator reduction to enhance ungulate populations has provided mixed results. Hurley et al. (2010) addressed coyote (Canis latrans) and cougar (Puma concolor) reduction to enhance mule deer populations in Idaho. They reported that coyote predation of mule deer was related to lagomorph abundance and coyote control exhibited no influence on early winter fawn recruitment. However, cougar reduction resulted in increased survival and winter fawn recruitment, but was largely ineffective when environmental factors (drought, severe winters) limited mule deer populations. Keech et al. (2011) addressed wolf (C. lupus) and bear (Ursus spp.) predation on moose (Alces alces) in Alaska and noted that predator reduction enhanced moose populations when environmental factors were non-limiting (i.e., during summer, fall). Predator reduction may benefit prey populations when they are not limited by habitat/environmental conditions, when predation is identified as a limiting factor, and when predator reduction is focused in scale to effectively reduce predation rates and timed to address critical periods in prey survival (Mule Deer Working Group 2012).

To address the reason for declining winter fawn recruitment in the Piceance Basin and identify potential management options, we propose to continue monitoring newborn fawn survival for another 3 years, while simultaneously implementing short-term and focused predator control in a treatment area and comparing fawn survival to an unmanipulated control area (Figure 1). This information will provide evidence to determine if predation is additive or compensatory to other types of mortality (e.g., disease, starvation). If neonate predation appears additive to other forms of mortality, focused predator reduction during mule deer parturition may be useful to enhance neonate survival and recruitment in mule deer populations experiencing decline and not limited by environmental conditions. If, on the other hand, neonate predation appears compensatory, predator management should be disregarded as a management option to enhance neonate survival and recruitment. Conditions in the Piceance Basin are comparable to other western Colorado mule deer populations where high winter fawn survival and low starvation frequency has been documented and this information will likely be applicable to declining or below objective deer herds in the western third of the state exhibiting factors inconsistent with climate or habitat limitations (e.g., low starvation frequency, good forage conditions).

B. OBJECTIVES

By June 30, 2019 CPW will be able to . . .

- Assess neonate mule deer survival and recruitment in the Piceance Basin in response to predator control of black bears (U. americanus) and cougars.

C. EXPECTED RESULTS OR BENEFITS

CPW will be able to:

1) Address additive or compensatory nature of predation relative to neonate mule deer survival and recruitment.
2) Evaluate the utility of spring predator management in enhancing mule deer fawn survival and recruitment.

D. APPROACH

**Summary:** This project will evaluate focused predator removal efforts just prior to and during the spring birthing period on a summer range treatment area for the next 3 years and comparing neonate survival rates to an unmanipulated control area. Comparisons to 5 years of pretreatment survival rates in the treatment and 3 years in the control area (Peterson 2016) will also be available to address the additive or compensatory nature of predation on neonate mule deer survival.

**Doe Captures and Demographic Data**

Ongoing research to address mule deer/energy development interactions (Anderson 2015; Federal Aid Project No. W-185-R) will support adult female capture efforts early March 2017 to attach GPS radio-collars (G-2110D, Advanced Telemetry Systems, Isanti, MN, USA) and provide dam specific data for pregnancy status, fetal counts, and adult female body condition. Specific capture and handling procedures are addressed in Anderson and Freddy (2008) and Anderson (2015). Pregnant females on winter range will be equipped with vaginal implant transmitters (VITs; MOD M3930, Advanced Telemetry Systems, Isanti, MN, USA) to facilitate spring neonate capture and collaring efforts following birth on the predator reduction summer range (Fig. 1).

**Neonate captures and monitoring**

Daily fixed-wing aircraft flights will be used to monitor VITs and identify birth sites and timing on the predator treatment summer range. Once expelled VITs are detected, field crews will be directed to birth site locations to locate and capture newborn fawns. Neonate searches will typically last up to 30–45 minutes and will not exceed 1 hour. Due to past logistical complications during neonate captures on the control summer range (being more widely dispersed with private and remote land access complications), we plan to focus neonate capture efforts in a few high density areas targeting collared and uncollared adult females during parturition without the aid of VITs. Each neonate will be handled with sterile nitrile latex gloves to minimize the transfer of human scent, blindfolded, and placed in a cloth bag to measure body mass. Hind foot length, chest girth, age (days), and sex will also be recorded. Each neonate will be fitted with an expandable radio-collar (M4210, ATS, Isanti, MN, USA) with a 4 hour mortality sensor and designed to drop off after 8-10 months; radio-collars will be modified for drop-off by splicing the collar and inserting 2 lengths of rubber surgical tubing. Handling time will be ≤ 5 minutes and neonates will be placed in the precise location where they were located to minimize abandonment.

Neonate collar signals will be monitored daily from fixed wing aircraft while monitoring doe VITs and collar signals. After all VITs are expelled and/or accounted for, monitoring of neonate collar signals will continue daily from the ground and from fixed wing aircraft weekly. Daily monitoring will afford us the ability to detect mortalities and assess fetal survival within 24 hours. Monitoring of neonate signals will continue until a mortality signal is detected. Once detected, neonates and/or collars will be located from the ground or air and if any part of a carcass is present a thorough field necropsy will be conducted to determine cause-specific mortality.

**Addressing Differences in Survival**

Preliminary results will be reported annually using age-specific Kaplin-Meier survival estimation. Final analyses will be conducted using multi-state survival estimation methods (Lebreton et
al. 2009) in Program MARK (White and Burnham 1999). Each neonate mortality will be assigned one of three states including predation, starvation, and other assuming a reduction in predation concurrent with an increase in survival. Sibling dependency and overdispersion in survival estimates will be addressed by conducting data-bootstrap analyses in Program MARK (Bishop et al. 2008).

**Sample Size**

A total of 55-60 pregnant females will receive VITs during March captures from the winter range study areas (Fig. 1). Because past fetal counts have averaged 1.75 (C. Anderson, unpublished data) and assuming a small number of VIT failures and that some adult females will be inaccessible on summer range, we conservatively estimate a minimum of 60 neonate captures on the predator treatment summer range (Fig. 1). A minimum of 40 neonates will be targeted from the control study area. Bishop et al. (2009) reported statistical power (1-β) of 0.81 to detect a 15% difference in neonate survival assuming survival of control fawns = 0.40, which is consistent with previous neonate survival rates in the Piceance Basin. Thus, sample sizes from the previous 4 years (n = 55 – 85) and proposed sample sizes for the next 3 years should be sufficient to conservatively detect a 15% increase/difference in fawn survival following predator control assuming this mortality is additive.

**Predator Reduction**

Following guidelines from the Mule Deer Working Group (2012) to address the likely factor limiting fawn survival/recruitment (predation), applying focused predator reduction to sufficiently reduce predation rates (≥20%), and identifying the critical survival period when habitat is non-limiting, we will focus predator control efforts on a relatively small summer range parturition area (1,277 km², Figure 1) during a 2 month period (May 1 – June 30) just prior to and during mule deer parturition. Because this area consists primarily of private lands limiting hunter access and spring hunting seasons are currently unavailable, USDA Wildlife Services (WS) will be contracted to address spring predator reduction efforts. A large portion of summer range in the predator treatment study area is owned by energy companies, most of which have been collaborators with the current mule deer/energy development research since 2008 (Anderson 2015). Ron Velarde (Northwest Regional Manager, CPW) will take the lead in arranging agreements between agencies and energy companies to conduct predator control efforts.

Because black bear predation has been most prevalent from 2011–2015 (averaging 14% of collared neonates), predator control efforts will focus on this species. Cougar (*Puma concolor*) predation has also been notable (averaging 8%) and therefore will be a secondary species for control efforts. Predation from other predatory species (coyotes, bobcats, golden eagles) has been relatively minor (averaging ≤5% per species) and therefore these species will not be targeted during predator control efforts; coyote (Hurley et al. 2010) and bobcat predation of mule deer may be more compensatory than cougar and black bear predation. Although average predation rates of 23% have been documented from black bears and cougars combined, a large portion of unknown predation (11%) and unknown mortality (9%) of neonates documented the first 4 years is likely also related to these predators. To illicit a significant effect on predation rates to adequately address the additive or compensatory influence on neonate survival, predation should be reduced by 20%. The level of predator removal required to achieve this reduction in overall predation is currently speculative given that we are not aware of published research to addressed individual cougar and black bear predation rates for mule deer neonates; recently completed research by CPW (M. Alldredge, in preparation) suggests average individual cougar predation accounts for at least 35 young mule deer (0-3 months old) and we suspect individual black bears take at least that number given that (1) twins are common and both are typically
consumed at predation sites, (2) predatory black bears actively seek newborn fawns during the month of June, and (3) predatory black bears would require >1 fawn/day given their small size (~1-3 kg of protein) and assuming that other food sources are minimally exploited during the birthing period. However, we propose that focal removal (targeting areas of past predation activity) of 5-10 cougars and 10-20 black bears annually will provide the desired predation rate reduction (assuming 35 fawns/predator represents 700–1050 surviving fawns). Our approach will need to be flexible to insure we achieve the desired predation rate reduction of ≥20%. While the objective is to reduce cougar and black bear densities in this focal area, overall densities at the much larger Data Analysis Unit (DAU) scale (representing population level biological units) should be minimally influenced; the predator treatment summer range area (Fig. 1) represents 6% mountain lion DAU L-7 and 16% of black bear DAU B-1.

Cougar and black bear removal methods employed by WS will consist of cage traps, culvert traps, foot snares, and trailing hounds for capture and a firearm will be used for euthanasia. Although probability of capturing non-target species is low, the non-lethal capture methods employed will provide for immediate release during daily trapping efforts. NEPA requirements for this project are currently under review in an Environmental Assessment prepared by USDA Wildlife Services. All bears and cougars killed by WS personnel will be reported to CPW within 5 working days of the taking. Reporting shall consist of a CPW Bear and Lion Form completed by WS personnel and forwarded to CPW personnel. Required sample collections from each carcass will include meat and blood samples for stable isotope diet analysis and a first premolar for aging. WS personnel will make every effort to salvage all black bear and cougar hides and meat for CPW disposal or distribution. If the carcass is not salvageable, the entire carcass, including hide, head, feet, skull and gall bladder will be destroyed in the field immediately upon taking possession of the animal. WS personnel will destroy all bear gall bladders in the field. Whenever feasible, the carcass of bears and cougars will be properly cared for and transported to CPW, meat will be donated to needy families, and other parts will be destroyed or used for educational purposes. Family groups (females with young) will not be euthanized and will be translocated and released at least 50 km from the capture site. Remote cameras will be placed at trap sites to enhance detection of carnivore family groups prior to handling. CPW plans to translocate black bear and lion family groups at least 30 miles distant; translocation sites will be chosen to minimize potential conflicts with other human activities (e.g., livestock, close proximity to human foods).

E. Location

This research will occur on summer ranges for mule deer that occupy the Piceance Basin winter range in northwest Colorado (portions of Game Management Units 22, 31 and 32 in Moffat and Garfield counties; Fig. 1). Detailed study area and habitat descriptions are provided by Anderson (2015).

F. Schedule of Work

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult female captures on winter range (from ongoing research)</td>
<td>March 2017–2019</td>
</tr>
<tr>
<td>Black bear and cougar removal</td>
<td>May 1–June 30, 2017–2019</td>
</tr>
<tr>
<td>Neonate capture and collaring efforts</td>
<td>Late May–June 2017–2019</td>
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Neonate survival monitoring  
Late May–mid Dec. 2017–2019

Data analyses and manuscript preparation  
Dec. 2019–2020

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**G. Detailed Project Estimated Costs**

FY 2016-17 (field work beginning May 2017)

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit cost</th>
<th>Sub total</th>
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</thead>
<tbody>
<tr>
<td>Temporary personal services</td>
<td>14 technicians for 6 weeks</td>
<td>$48,091</td>
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<tr>
<td>Contract personal services</td>
<td>WS predator control</td>
<td>$ 50,000</td>
</tr>
<tr>
<td>Operating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VITs</td>
<td>60 X $250</td>
<td>$ 15,000</td>
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<tr>
<td>Neonate collars</td>
<td>40 X $234</td>
<td>$ 9,360</td>
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<tr>
<td>Fixed-wing flights</td>
<td>48 hours X $314</td>
<td>$ 15,072</td>
</tr>
<tr>
<td>Rental trucks</td>
<td>3 X $3,300</td>
<td>$ 9,900</td>
</tr>
<tr>
<td>Rental truck tires</td>
<td>8 X $250</td>
<td>$ 2,000</td>
</tr>
<tr>
<td>Temp truck fuel</td>
<td>2 X $1,500</td>
<td>$ 3,000</td>
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<tr>
<td>Misc. equipment</td>
<td></td>
<td>$ 5,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$157,423</strong></td>
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FY 2017-18 – FY 2018-19

<table>
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<th>Sub total</th>
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<tr>
<td>Temporary personal services</td>
<td>14 technicians for 6 weeks</td>
<td>$48,091</td>
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<tr>
<td>Contract personal services</td>
<td>APHIS predator control</td>
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<tr>
<td>VITs</td>
<td>60 X $250</td>
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<td>Fixed-wing flights</td>
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<td>Temp truck fuel</td>
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<tr>
<td>Misc. equipment</td>
<td></td>
<td>$ 5,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$148,063</strong></td>
</tr>
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Additional expenses for FY 2018-19

<table>
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<th>Description</th>
<th>Unit cost</th>
<th>Sub total</th>
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<tr>
<td>Temporary personal services</td>
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<tr>
<td>Contract personal services</td>
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<tr>
<td>Operating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPS collar refurbs</td>
<td>60 X $800</td>
<td>$ 48,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$130,673</strong></td>
</tr>
</tbody>
</table>

Indirect Costs Assessed on Project Grant Funded Labor:

| FY 2016-17 Temporary personal services | 14 technicians for 6 weeks | $ 48,091 |
| FY 2017-19 Temporary personal services | 28 technicians for 6 weeks | $ 96,182 |
| FY 2018-19 Temporary personal services | 2 technicians for 10 months | $ 50,873 |
| **Total Labor Costs =**               |                        | **$195,146**|

CPW FY 2016-17 Indirect Cost Rate = 34.37%; $196,146 x 34.37% = **$60,071.68**

Cost Summary –

$157,423
$148,063
$148,063
$130,673
$60,071.68
$644,293.68

OVERALL PROJECT COSTS:

<table>
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<tr>
<th>Federal (75%)</th>
<th>State (25%)</th>
<th>TOTAL (100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$483,220.30</td>
<td>$161,073.40</td>
<td>$644,293.68</td>
</tr>
</tbody>
</table>
H. Related Federal Projects

This project will primarily occur on energy development company and BLM properties, including a small amount of private lands. The study does not involve formal collaboration with any federal agencies, other than contracting predator control efforts with WS, nor does the work duplicate any ongoing federal projects.

PERSONNEL:

Chuck Anderson, CPW, Mammals Research Leader; 970-472-4335; chuck.anderson@state.co.us
Paula Nicholas, CPW, Federal Aid Coordinator, 303-866-3203 x 4677; paula.nicholas@state.co.us

PROGRAM INCOME:

No revenue will be generated as part of this grant project.

MAINTENANCE:

No maintenance costs are associated with this project.

LAND CONTROL:

No land control issues are associated with this project.

RELATION TO OTHER FEDERAL PROJECTS:

This project will have no known or identifiable impacts on any other federal projects.

PRIME/UNIQUE FARMLANDS:

This project will have no impact on prime or unique farmlands.

FLOODPLAINS/WETLANDS:

This project will have no impact on any floodplains or wetlands.

ENDANGERED SPECIES:

This project will have no impact on state or federally listed endangered species. *A list of Federal and State threatened (T), endangered (E), and candidate (C) species is attached for the State of Colorado.*

The project work in this proposal does not include any ground disturbing activities and therefore will not disturb any sensitive plant species in the area. Trapping activities could influence medium to large
mammal species. Sensitive mammal species in Colorado that could be influenced by trapping efforts include Canada lynx (*Lynx Canadensis*), wolverine (*Gulo gulo*), and gray wolf (*Canis lupus*). Potential occurrence of these species in the predator treatment study area is extremely low given that the area represents low quality lynx habitat and that no records of these species have been documented in this area in recent history. In the unlikely event that one of these species is caught during trapping efforts, the trapping methods employed are non-lethal and captured animals will be immediately released during daily trapping efforts.

**ENVIRONMENTAL ASSESSMENT:**

NEPA requirements for this project are currently under review in an Environmental Assessment prepared by USDA Wildlife Services.

**ENVIRONMENTAL JUSTICE** (Executive Order 12898):

This project will not have disproportionately high and adverse human health or environmental effects on low-income populations, minority populations or Indian tribes.

**INVASIVE SPECIES** (Executive Order 13122):

The proposed activities of this project will not result in the introduction of any invasive species and not impact the status of an existing invasive species.

**AMERICANS WITH DISABILITIES ACT:**

When hiring personnel as part of this project, qualified individuals will not be discriminated against based on disability. No structures or access points will be constructed as part of this research, and thus accessibility is not applicable.

**ANIMAL WELFARE ACT:**

Neonate captures in the predator treatment area have been addressed through an extension of CPW ACUC protocols 01-2012 below. Additional neonate capture and handling protocols for the control area and WS trapping and euthanasia protocols will be addressed through an addendum submitted to the CPW ACUC committee prior to project initiation.

**HISTORICAL/CULTURAL RESOURCES:**

The proposed activities of the project are expected to have no impact on historical or cultural resources. No ground disturbance, inundation with water, or prescribed burning will be conducted as part of this project so this project will not require any further review by the State Historical Preservation Office.
Literature Cited
natural gas resource extraction and mitigation efforts to address human activity and habitat
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Keech, M. A., M. S. Lindberg, R. D. Boertje, P. Valkenburg, B. D. Taras, T. A. Boudreau, and
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Sheet #1.  www.muledeerworkinggroup.com
Peterson, M. E.  2016.  Reproductive success, habitat selection, and neonatal mule deer mortality
in a natural gas development area.  Dissertation, Colorado State University, Fort Collins, USA.
United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife
USDA, APHIS, Grand Junction, CO USA.
White, G. C., and R. M. Bartmann.  1998.  Effect of density reduction on overwinter survival of
of marked animals.  Bird Study 46:120-139.
Figure 1. Mule deer winter and summer ranges, Piceance Basin, northwest Colorado. Pregnant adult females on winter range (orange boundary) will receive vaginal implant transmitters to facilitate neonate capture and collaring efforts in the predator treatment area (green boundary). Neonates in the control area (blue boundary) will be opportunistically captured to provide survival rate comparisons between summer ranges with and without focused predator reduction. Circles represent neonate mule deer predation site locations from bears (red) and cougars (Lion, blue) from 2011–2016 in the predator treatment summer range. Black lines depict mule deer Game Management Unit boundaries.
COLORADO PARKS AND WILDLIFE ANIMAL CARE AND USE COMMITTEE (CPWACUC)
ADDENDUM TO ONGOING, APPROVED WILDLIFE RESEARCH PROJECTS

Note: This form may not be used for new wildlife research projects.

1. CPW ACUC File # 01-2012
   Principal Investigator(s): Chuck Anderson    Phone: 970-472-4335

2. Title of project: Effects of natural gas development disturbance on neonatal mule deer survival

3. Fiscal year of this project’s initiation: 2012

4. List names of all new personnel associated with this project:

5. Are sample sizes or numbers of animals to be used the same as originally described with no substantive changes (i.e., 10% of original proposal)? If sample sizes or animal numbers are substantially greater or less than described in original study plan, provide a justification for this change.

   Maximum sample size will be reduced from 120 to 80 neonate captures annually due to reduction from 4 to 2 study areas. The 2 study areas removed proved to be too logistically difficult to maintain adequate sample sizes. This project will continue through 2018.

6. Is the animal component of the project the same as originally described with no substantive changes (e.g., anesthesia, analgesia, capture methods, euthanasia, species, surgical procedures, etc.)?
   Yes   X   No ______   If No, describe changes:

7. Will the foregoing changes result in greater levels of pain, suffering, stress, discomfort, deprivation, etc., experienced by experimental animals than those originally described and approved?
   Yes   No    X

   If answered yes, attach detailed justification and indicate here the date of search, source of literature search, date range searched, and key words an combination of key words searched to document the lack of alternative methods:

8. Will additional pain and suffering be controlled?    Yes   No    N/A   X
   If answered no, attach a detailed justification.

   If answered yes, attach a detailed description of how pain and suffering will be controlled.

9. If required, was the attending veterinarian consulted when planning these changes?
   Yes   No

10. Does the proposed project now include planned euthanasia of animals?  Yes   No

    Date:  5/25/2015    Signed:  [Signature]
    Principal Investigator

    Date:  5/1
    Signed:  [Signature]
    ACUC Attending Veterinarian

    Date:  5/25/15    Signed:  [Signature]
Mule Deer Population Response to Cougar Population Manipulation

Principal Investigator
Mat Alldredge, Mammals Research, Colorado Parks and Wildlife
Brian Dreher, SE Region Senior Biologist, Colorado Parks and Wildlife

Cooperators
Chuck Anderson, Mammals Research Leader, Colorado Parks and Wildlife

STUDY PLAN:

STUDY PLAN APPROVAL

Prepared by: Mat Alldredge Date: November 18, 2016
Submitted by: Mat Alldredge Date: August 26, 2016
Reviewed by: Ken Logan Date: September 2, 2016
          Jake Ivan Date: September 15, 2016
          Brian Dreher Date: September 15, 2016
Mammals Research Leader: Chuck Anderson Date: November 18, 2016
Biometrician: Jon Runge Date: September 21, 2016
Mule Deer Population Response to Cougar Population Manipulation

A. NEED
The recently adopted Colorado mule deer strategy identifies predation as one of the potential factors limiting Colorado mule deer populations. Since the adoption of the mule deer strategy by the Parks and Wildlife Commission, members of the Leadership Team developed a plan for the implementation of the strategy. As part of the implementation strategy, staff examined existing predator and deer research and monitoring data to identify areas where predation may be most limiting to mule deer, which in turn could be used to inform predator harvest/management decisions. In June 2015, CPW personnel from the SE Region, Terrestrial, and Research branches met to explore the concept for a project that examines how deer demographic parameters may change following cougar population suppression.

Deer data analysis unit (DAU) D-16 is comprised of game management units (GMUs) 49, 57, 58 and 581 which are located on the north side of the Arkansas River between the towns of Leadville and Canon City (Figure 1). Beginning in 1999, D-16 was added as one of 5 intensive deer monitoring DAUs in the state. Under the intensive monitoring protocol, we typically monitor 80-90 adult does to determine annual survival rates and 60 fawns annually to determine over winter fawn survival rates. Since 1999, we have radio collared 1,086 adult does and 898 fawns in D-16 to examine annual adult survival and winter fawn mortality.

From 1999-present, averaging across all years, the leading known cause of both doe (6.4%) and fawn (7.5%) mortality has been cougar predation (Figure 3, 4 and Table 1, 2). Cougar predation has ranged from 0 to 60% (avg. 28%) of the total mortality for does and 0 to 64% (avg. 32%) of the total mortality for fawns. Currently, the population is below the long-term population objective (current objective 16,000-20,000 deer) and based on survival data, population growth might partially be limited by cougar predation on fawns and adult does (Figures 3 and 4).

Predation on mule deer is often identified as one of the potential reasons that populations are depressed or below the long-term objectives (Colorado West Slope Mule Deer Strategy http://cpw.state.co.us/Documents/MuleDeer/MuleDeerStrategy.pdf, Ballard et al. 2001). In D-16, the adult survival data and relatively high predation rates from 2008-2012 suggests that cougar predation could be contributing to this lower than objective mule deer population.

Overwinter fawn survival has shown similar patterns to annual doe survival ranging between 59.2% and 86.2%. Since 2013, overwinter fawn survival has been near 80% (Table 2). However, early winter fawn:doe ratios have averaged 54.7 fawns per 100 does (range 38.5 to 68.0) since 1995 (CPW, unpublished data). Assuming fetal rates for adult (≥ 2 years old) mule deer of 1.8 (Bishop et al. 2008), it would appear neonate survival is a bigger issue for population growth and recruitment than other demographic rates, unless doe survival drops below 80%. Using the above fetal rate, early winter fawn:doe ratio, and overwinter survival of 80%, survival from birth to age one for mule deer would be 24.4% in this area. Variability in fawn survival typically has a larger effect on population rates of change than does stable adult survival (Forrester and Wittmer 2013), such as the variability seen in D-16.

The success of a project to control predators to increase a population of mule deer is dependent upon the deer population in relation to the habitat carrying capacity (Ballard et al. 2001). If the population is at, or surpassed the habitat carrying capacity, it is likely that increases in survival rates caused by predator control will be compensated by other factors of mortality, such as malnutrition (Bartman et al. 1992). Conversely, if the population is below the habitat carrying capacity, reduction in mortality caused by predation could provide an additive response to increase survival rates of a mule deer population (Bleich and Taylor 1998; Hurley et al. 2004).
Examination of the malnutrition rates of fawns in D-16 can give some indication about whether a given population is at or exceeds carrying capacity. Since 1999, the highest rate of malnutrition was observed in 2004, when 5 of 57 (9%) fawns died from malnutrition causes. Bartman et al. (1992) observed significantly higher rates of malnutrition in a NW Colorado mule deer herd, in which they documented reductions in predation rates being compensated by higher rates of malnutrition. Given our relatively low rates of malnutrition, we suggest that at current population densities, we may be below carrying capacity and may increase the population size in D-16 if we can minimize limiting factors for mule deer population growth in the DAU, such as predation.

Numerous studies have been conducted to investigate the effects of predation on mule deer. However, results have been inconclusive or confounded with other factors, such as habitat condition and weather, resulting with weak inference about the true impacts of predation (Ballard et al. 2001, Forrester and Wittmer 2013). For example, Hurley et al. (2011) showed that cougar removal increased fawn survival but population level effects were minimal compared to weather events. Many of these past studies have also been conducted on deer populations at or near carrying capacity, when mortality associated with predation is likely to be compensatory. Recent research is identifying these complex relationships, suggesting that some levels of predation are additive, depending on conditions, and that higher predation levels will be increasingly additive. Limitations of past research has also been related to limited spatial and temporal scales and the lack of manipulative experiments (Ballard et al. 2001, Forrester and Wittmer 2013, Bergman et al. 2015). These reviews suggest that further investigation is needed to understand the interactions between predation, habitat and weather using manipulative experiments over sufficient temporal and spatial scales.

As Forrester and Wittmer (2013) identified, variable fawn survival generally has a larger effect on population change than other demographic impacts. Cause specific mortality on fawns, and therefore, fawn recruitment into the adult portion of the population is one of the primary response variables that we are interested in. To demonstrate the potential impacts of fawn recruitment on the deer population and the impacts of cougar predation on recruitment we have simulated this dynamic process under various assumptions. We assume that 1.6 live fawns will be produced per doe each year, which accounts for still births. Deer monitoring in D-16 estimates 6,500 adult does in the population and over-winter fawn mortality from sources other than cougars is approximately 17%. Neonate mortality from birth to December from sources other than cougars has been estimated at approximately 40% in the Piceance Basin (Anderson, unpublished data). Cougar mortality on fawns for their first year of life is approximately 35 fawns per cougar per year (unpublished data from the Front-Range Cougar Study). Using these data, and assuming the mortality from cougars could be additive (100%), partially additive (75%, 50%, or 25%), or compensatory (0%), we estimated the potential effects on fawn recruitment and survival to age 1, for various cougar population sizes (Figure 5). This demonstrates that if cougar predation is completely additive and we can effectively manipulate the cougar population from the potential population size of 120 cougars to half of that, as proposed, we would expect a change in recruitment of 272 fawns at high cougar density and 2,372 at half of that density. This is a change in overall survival from 0.03 to 0.23. However, if cougar predation is only 50% additive, then we would expect a change in recruitment from 2,372 fawns at high cougar density increasing to 3,422 fawns at half of that density. This corresponds to a change in survival from 0.23 to 0.33. This simulation also exemplifies the need for a very significant manipulation in the cougar populations because detecting a 10% (0.23 to 0.33) difference in fawn survival will be difficult given the natural variability in predation rates and other sources of mortality.

In order to assess the effect of management manipulations it is necessary to do this in an experimental framework with a control and treatment study area, otherwise the magnitude of the effect will be unknown as other limiting factors fluctuate. D-34 (GMUs 69, 691, 84, 86, and 861) is an adjacent mule deer DAU to the south of D-16, which has a similar mule deer population size and habitat.
suggest that demographic rates are similar in terms of population ratios. Using D-16 and D-34 in a crossover design will allow for the manipulation of a potential limiting factor for mule deer population growth or survival and examining similarities in the response as the control and treatment is switched between the areas.

A research project will be conducted (pending Commission approval), beginning in the winter of 2016/2017, to examine the mule deer population response to cougar suppression. The study will be conducted in D-16 and the adjacent DAU, D-34. A crossover design will be used to examine the effects of cougar suppression in three stages. In stage one (years 1-3), cougar populations in D-16 will be suppressed (i.e., harvest to maintain population at ~50% of the potential population), while cougar populations in D-34 will be allowed to increase towards habitat potential (harvest ~10% of potential population of independent-age cougars). Stage 2 (years 4-6) represents a recovery stage where both populations will be allowed to increase towards habitat potential (~10% harvest). The final stage (years 7-9) represents the crossover where D-34 cougar populations will be suppressed (harvest to maintain population at ~50% of the potential population), while D-16 will continue to be allowed to increase towards habitat potential (~10% harvest).

The objectives of this research are to 1.) Evaluate the effects of cougar population size on mule deer demographic parameters, 2.) Evaluate the effectiveness of sport hunting to achieve high rates of cougar harvest, and 3.) Determine cougar density estimates both pre and post suppression periods. However, we also intend to study the cougar population with respect to cougar density and harvest levels.

The impact of cougar hunting on cougar populations, especially high levels designed to suppress populations, can be varied and is not well understood, because studies have been over small spatial and temporal scales and harvest levels in relation to population size are not reliable. Anderson and Lindzey (2005) demonstrated that a Wyoming cougar population could be significantly suppressed (~60% reduction) through 2 years of heavy harvest. Human-caused mortality (primarily harvest) rates of approximately 20-30% of the population or 20-25% of the adult female population have generally been shown as the tipping point between maintaining stable populations and decreasing populations (Anderson and Lindzey 2005, CMG 2005). However, the percent adult female harvest is the crucial factor in population change (Anderson and Lindzey 2005).

The direct effect of harvest on population size is intuitive but more subtle impacts on other demographic parameters (i.e., survival, productivity, dispersal, infanticide, human interaction) is less clear, primarily due to a lack of information on these parameters. Cougars are inherently difficult to study because of their reclusive nature, small population sizes and large movement patterns. Technological advances, such as GPS collars, are only now allowing for the detailed study of cougars to understand these more subtle impacts, such as intraspecific interactions and infanticide in relation to changing cougar density and harvest rates. Past research has been hindered by small sample sizes and case studies of a few events observed during the course of monitoring studies.

Harvest structure can be a useful tool for monitoring and managing cougar populations (Anderson and Lindzey 2005). Because the sex and age classes of cougars exhibit different behaviors and movement patterns (Barnhurst 1986) they also tend to differ in their vulnerability to harvest. The management experiment being conducted provides a unique opportunity to more completely develop our understanding of the relationship between harvest structure and the cougar population structure. Understanding this relationship as populations are manipulated throughout the management experiment will provide critical information for management in the future as decisions are made about suppressed, stable or increasing cougar populations.
In addition to furthering our understanding of harvest structure, this management experiment will provide us information on population level responses to various harvest strategies within a crossover design. Several studies have examined the impacts of harvest on cougar populations (Anderson and Lindzey 2005, Cooley et al. 2009, Ruth et al. 2011, Wielgus et al. 2013, Maletzke et al. 2014, Logan 2015), however no study that we are aware of has examined the impact of hunting at these two extremes in harvest level within a controlled crossover design. These studies were also over small spatial and temporal extents which limits population level inference. Such a design should allow us to definitively attribute mule deer survival to cougar predation, or to definitively exclude it as an important factor. Inferences drawn from previous work are inherently weaker due to the lack of such a design and the small spatial and temporal scales over which they were conducted.

Density-dependent population regulation has a rich history and provides much of the basis for sustainable hunting and game management (Caughley 1977, Caughley and Sinclair 1994, Strickland et al. 1994). Compensatory mortality would predict that harvest mortality would be offset by density-dependent responses in reproduction, cub survival, and female population growth if harvest is primarily males because of reduced competition for resources. However, Wielgus et al. (2013) suggest that harvest of male cougars is not compensatory but is additive or possibly even depensatory.

One aspect of this study will be to closely examine cause specific mortality and develop a thorough understanding of levels of mortality in relation to population size and hunting pressure. Previous studies have suggested that male survival is lower in hunted populations (Lambert et al. 2006, Robinson et al. 2008, Ruth et al. 2011) but that female survival is lower in non-hunted populations (Logan and Sweanor 2001). Part of this is due to hunter selectivity on males but under situations of heavy harvest selectivity may decrease (Anderson and Lindzey 2005). The progression of the management experiment will directly allow us to measure cause specific survival so that we can determine how non-hunting mortality rates, such as disease, intra-specific strife, or other natural mortality vary during declining and increasing phases of a cougar population and under heavy and light harvest scenarios.

Similarly, cause specific survival of kittens throughout the stages of the project will provide essential information for management as this directly relates to population growth and recovery. Past research has suggested that increased harvest has actually led to decreased kitten survival because of infanticide (Cooley et al. 2009, Ruth et al. 2011). Increased infanticide has been suggested to relate to high male harvest as this leads to an increase in subadult males in the population and territorial instability (Logan and Sweanor 2010, Ruth et al. 2011). However, recent cougar research in Colorado have shown higher infanticide rates during a 5 year non-hunting period than the subsequent 5 year hunting phase of the study (Logan 2015).

Other aspects of cougar population growth are reproductive rates and immigration/emigration rates. Theory behind density-dependent relationships would suggest that reproductive rates would increase during scenarios of increased harvest. Increased male immigration has been documented as a result of increased harvest levels (Cooley et al. 2009, Wielgus et al. 2013). Almost all males disperse, regardless of cougar density, with typical dispersal distances of 85 to 100 km (Sweanor et al. 2000). However, 50 to 80% of females remain in their natal range, establishing overlapping home-ranges with other breeding females (Sweanor et al. 2000). In a recent cougar study in the Front-Range of Colorado, a significant portion of subadult males did not disperse (Alldredge, unpublished data). It is unclear how various levels of harvest will impact immigration/emigration rates and the potential impact that this could have on reproductive rates. Wielgus et al. (2013) suggest that increased immigration actually decreased female reproductive success.

There is also the perception that high immigration rates of subadult males will lead to increases in human conflict and livestock depredation. Some studies have indicated that harvest and subsequent increases in
subadult males have correlated with human-cougar conflict (Peebles et al. 2013, Maletzke et al. 2014). However, Kertson et al. (2013), suggest that demographic class did not relate to human-cougar interaction. This management experiment will provide direct information on human-cougar interactions with respect to changes in cougar populations, age structure, and immigration rates.

Cougar hunting has also been linked to changes in movement patterns, home-range size and diet composition. Keehner et al. (2015) suggested that female cougars will switch primary prey in an attempt to avoid conflict with male cougars in a hunted population. Increased hunting pressure was also suggested to increase home-range size and overlap in Washington (Maletzke et al. 2014) suggesting increased intraspecific conflict. Avoidance behaviors, increased space use and changes in movement patterns could all impact energetic demands of cougars, which could then alter foraging behavior.

Estimating cougar population size or density is also very useful for management purposes but has proven to be difficult and expensive. Historically mark-recapture techniques have been used, which require the physical capture and handling of animals and is therefore time intensive and expensive. Some consider a complete enumeration approach (marking all individuals and identifying unmarked animals by tracks) as the best option for reliable estimates of cougar density (CMG 2005). More recently developments have been made for noninvasive genetic sampling of cougars to get population estimates using scat detection dogs or hair snags (Davidson et al. 2014). Alldredge (unpublished data) has been developing the hair snag approach and it is showing promising results. The use of a predator call in conjunction with a camera trap has revealed that >80% of collared cougars were detected each year during the evaluation of this technique. However, obtaining a hair sample and actually being able to uniquely identify the individual from DNA in the hair sample has not been nearly as reliable (~25% of hair samples produced a usable genotype). Because of this we will use mark-resight techniques (White and Shenk 2001, McClintock and White 2009, 2012) to estimate cougar density within the study areas. The collaring effort for cougars will provide a sufficient marked sample for estimation, using unique markings on the collar and GPS locations to identify each individual. Resighting occasions will include the harvest and a late winter camera resight using predator calls and remote camera detections.

B. OBJECTIVES
The primary objective of this study is to examine the effects of cougar population size, and by extension, cougar predation on mule deer survival in order to develop a better understanding of how cougar management strategies can impact deer management. Specifically we will examine cause specific mortality rates on mule deer does and fawns as well as fawn recruitment rates relative to cougar density. Secondarily we want to evaluate the effectiveness of sport hunting in achieving sufficient rates of cougar harvest. As part of this we will need to determine cougar density estimates both pre and post suppression periods.

In addition, we also intend to develop a better understanding of cougar harvest structure and population responses to varied levels of harvest. Age/sex structure of the harvest will be examined relative to cougar density and harvest levels in order to inform future management of the relationship between cougar population demographics and harvest. Harvest information will also be used to estimate population density through statistical population reconstruction. If possible, we will also try to estimate cougar mortality, reproduction, immigration/emigration. In addition to this, movement patterns, nuisance behavior, and diet composition will be examined in relation to cougar density and harvest pressure.

C. EXPECTED RESULTS OR BENEFITS
Predator control is often raised as a management option to attain management goals for prey populations. Past research has not produced definitive results, especially at large scales (Ballard 2001, Forrester and
Wittmer 2013, Bergman et al. 2015). This study is designed to directly assess management strategies in a predator-prey system and the feasibility of such strategies. The primary results and benefits are:

1. Understanding the effects on mule deer population demographics relative to changes in cougar density.
2. Determination of our ability to manipulate cougar populations through harvest.

Cougar hunting is an ever increasingly contentious issue among our stakeholders. Unfortunately information on the subject is limited, conflicting, or based on small sample size. For example, the Washington research on the effects of hunting on cougar populations is based on 6 study areas with differing levels of harvest but all areas are <1000 km² and population densities are the same (1.7 adults/100 km²) regardless of harvest levels (Cooley et al. 2009, Beausoleil et al. 2013). This study is designed to address some of the specific concerns raised about hunting and provide managers with tools to evaluate the success of future management strategies at a scale comparable to that at which management decisions are being made. The primary results and benefits with regards to cougar population management and research are:

1.) Harvest information that can be utilized for future management of cougars,
   a. Evaluation of harvest structure relative to cougar population density and harvest levels during decreasing and increasing phases.
   b. Examination of population recovery following heavy harvest.
2.) Demographic information on cougar populations relative to cougar density and harvest regime.
   b. Cause specific mortality of adults and subadults.
   c. Cause specific mortality of kittens, including infanticide rates.
   d. Reproductive rates.
   e. Immigration/emigration rates.
   f. Movement patterns.
   g. Diet composition.
   h. Nuisance behavior.
3.) Further refinement of population estimation techniques.
   a. Statistical population reconstruction based on hair snag and harvest data.

D. APPROACH

Cougar Suppression

Both D-16 and D-34 have cougar hunt codes that are inclusive of all the GMUs within the DAU. Beginning in November 2016, we will initiate suppression in D-16 for a 3 year period to suppress lion populations in the GMUs included in D-16. To suppress cougars we will increase lion harvest to a level which we presume would have a significant impact on the density of cougars in the DAU (harvest rate of approximately 50% of the potential population during the first year and less in years 2 and 3 to maintain the population at approximately half the potential). The potential population is based on an average of 30 independent adult cougars per 1,000 km² of available cougar habitat (CMG 2005). In years 1-6, D-34 would serve as the unsuppressed cougar population for this experiment, where harvest quotas would be set to 3 lions per 1,000 km². It is expected that this rate of removal will reflect a reduction in the historic quota in D-34 and would result in an increasing cougar population. In years 4-9, harvest quotas would be decreased in D-16 to 3 cougars per 1,000 km² in order to allow the population to recover to a high level by year 7. In years 7-9, we would suppress lion populations in D-34 similar to years 1-3 in D-16. If suppression levels are not reached by hunter harvest, other approaches will be used, such as contracting with hunters, to reduce population densities. Over the course of the study, we will examine the effects of
cougar population density on mule deer demographic parameters using the crossover in cougar harvest in D-16 and D-34.

<table>
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<tr>
<th>Deer DAU</th>
<th>Total Area km²</th>
<th>Lion Habitat km²</th>
<th>Potential Populationa</th>
<th>Suppressed Quota</th>
<th>Unsuppressed Quota</th>
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<tr>
<td>D16</td>
<td>6,138</td>
<td>4,096</td>
<td>123</td>
<td>61</td>
<td>12</td>
</tr>
<tr>
<td>D34</td>
<td>6,536</td>
<td>4,913</td>
<td>147</td>
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<td>15</td>
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*aAssumes a potential cougar density of 30 cougars/1,000 km² of suitable habitat.

**Cougar Monitoring**

Recently, CPWs Mammals Research Section developed a sampling methodology and protocol for estimating cougar densities non-invasively through the collection of hair samples at hair snags. Capturing cougars with the camera trap is reliable but actually genotyping individuals is less successful so we will utilize this approach with collared cougars in a mark-resight framework. We will use this methodology to estimate cougar density for both D-16 and D-34 throughout the study. Sampling will be conducted in D-16 during years 2, 4, 6 and 8 to capture the high and low population sizes. Monitoring in D-34 will occur in years 3, 5, 7 and 9 to match up with the changes in harvest to capture the high and low population sizes as well. We can use this information to examine changes in cougar populations and also changes in gender and age class structure of the population both pre and post-harvest treatment. High lion harvest rates will be required to successfully reduce the population and it will be important to know if standard harvest management is successful in achieving this objective, or if other management options should be considered to provide the desired response. An added benefit of monitoring the lion population under a suppression management objective would be evaluation of this approach for statewide lion management application.

A typical grid cell size used for population surveys is one that is equal to a quarter of the average home-range size for the species of interest (Otis et al. 1978, White et al. 1982, Williams et al. 2002). The average home-range size for female cougars on the Front-Range is about 100 km² (Alldredge, unpublished data), so we will use a 5 km by 5 km grid cell size as our primary grid (Figure 5). A 1 km by 1 km grid will be overlaid within the primary grid and one of these smaller cells will be randomly selected within each primary grid. Within each selected cell, specific sites will be selected based on likely areas to attract a cougar, property access, and field logistics. A minimum of 80 sites (2000 km²) will be used during each survey focused over the area with collared deer.

Resight sampling will occur for a minimum of 8 weeks during February and March. This time period was chosen because bears will not be active at this time and most of the cougar harvest will be completed at this time. Therefore, cougar density will represent a post-hunt estimate. Calls and cameras will be placed at all sites with sufficient battery power to last throughout the sampling period. Calls will be placed in trees and securely fasten and cameras (Reconyx® PC85 Rapidfire® or PC800 Hyperfire®, set to take 5 picture bursts) will be placed in an adjacent tree approximately 10 feet away. A visual lure may also be used but experience suggests that cougars will investigate the call directly. Calls will have a light sensor so that they will only broadcast during the night. Spatially explicit mark-resight models will be used to address the spatial component of the camera grid (Chandler and Royle 2013, Sollmann et al. 2013)

**Monitoring Mule Deer Population Demographics**

Since 1999, CPW biologists have been monitoring a sample size of approximately 80 adult does in D-16 to examine annual deer survival. They have also collared 60 fawns in the month of December annually to examine over-winter fawn mortality. For this project, we will maintain a similar sample size in D-16.
addition, we will capture and monitor a sample size of 80 adult does annually in D-34 to examine cause-specific adult doe annual survival. In both D-16 and D-34 we will conduct aerial surveys in the month of December annually to examine post-hunt fawn:doe:buck ratios. These values will be used to examine any potential changes in population performance as a result of this management experiment. Expectations are that doe survival in the heavily harvested area will maintain at or near 90%, while doe survival in the lightly harvested area will be lower, if predation is an additive factor. However, our ability to detect a statistical difference will be limited to differences greater than 15%.

Fawn survival is typically highly variable and can have large effects on population change (Forrester and Wittmer 2013). In D-16, over-winter fawn survival has ranged from 59-85%, with cougar related mortality ranging from 0-64%. In this area, pre-hunt fawn:doe ratios are approximately 50 fawns per 100 does, indicating high rates of fawn mortality prior to the hunt. In the Piceance Basin study neonate survival to December is only 42% on average (Anderson, unpublished data). Given this information it would appear that the greatest and most variable mortality rates are on fawns from birth to recruitment at age one. Therefore, it is likely that the greatest response to changes in cougar population density will be realized in changes in cause specific fawn mortality. As discussed previously, the impact of cougar predation rates on fawn survival will depend on the amount of mortality that is additive, but could have a significant influence on recruitment to the adult population (Figure 5).

Using collared does to locate neonates, we will GPS collar 60 neonates, in each study area, within the first few days after birth and monitor fawn survival rates to age one. Bishop et al. (2009) suggested that a sample size of 40 neonates per group per year provided power of 0.81 to detect a difference of 0.15 in survival. All mortalities will be investigated and cause of death determined. We will use a competing risks model (Heisey and Patterson 2006) to examine cause specific mortality rates. This will allow us to directly estimate mortality due to cougar predation and compare between years and study areas to determine if cougar harvest levels are influencing this mortality vector. Cougar population estimates may also be used in these models as covariates to examine the effect size of the cougar population on potential deer mortality.

Throughout this proposal we have advocated that the deer response to the predator population could be additive or compensatory and that this response is driven by the deer population’s position relative to carrying capacity. Measuring carrying capacity of the landscape and relating that to multiple herbivore populations is difficult, especially since this will vary annually in relation to climate, herbivory and other land use. Monteith et al. (2014) proposed an approach to estimate the animal-indicated nutritional carrying capacity, suggesting that the position of a population to its annual food supply is reflected by seasonal patterns of nutritional condition and population performance. Their approach represents the short-term capacity of the environment to support population growth as a function of resource availability and animal density and will therefore fluctuate from year to year tracking environmental differences. They also suggest that nutritional condition can be indicative of top-down forcing by predators when mortality is additive and population limitation is not a result of habitat. During adult doe captures in late February or March we will measure deer body condition and follow the approach described by Monteith et al. (2014) to estimate the animal-indicated nutritional carrying capacity. This parameter can be compared with changes in mortality rates and an assessment of additive versus compensatory mortality.

Capture and Handling of Cougars

In order to have sufficient power to detect changes in demographic parameters we need a large sample size. For example, current deer monitoring in Colorado use samples sizes of at least 50 does to detect changes in annual survival. In comparison, for D-16 and D-34 during the heavy harvest phase of the study we expect cougar population size to be ~61 and 74 individuals, respectively. Because cougars exist at very low densities the majority of the population will have to be monitored during the heavy harvest

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phases of the study and a similar sample size (approximately 1/3 of the population) will be maintained throughout.

Estimating infanticide rates relative to harvest levels is one of the key objectives of the study and likely the most difficult. Past studies have recorded a few cases of infanticide but generally not sufficient to calculate rates or compare differences. Because of this, we will attempt to maintain a minimum of 20 collared adult females in each study area. Assuming birth intervals of 18 months, sample size of litters at risk will still be low over the course of the study. Kittens will be collared in all litters detected. Collaring adult and subadult males will also be important as these animals represent the mortality vector and it will be important to determine if infanticide is related to the age of the male. Such intensive collaring efforts should be sufficient to address the other objectives of the study, such as movement patterns and immigration/emigration rates.

Capture efforts will be conducted year-round, with the primary effort occurring between November and April. Capture with dogs and cage traps will be the primary methods for capturing adult and subadult cougars, but foot-hold snares and free-range darting may also be used if dogs or cage traps are not feasible. Capture of young kittens will be done by hand. A detailed description of CPW approved capture methods and handling procedures is provided (Appendix I).

Cougars will be ear-tagged in each ear with uniquely identifiable numbers marked with the withdrawal date, and a genetic sample collected using a 6 mm biopsy punch from each ear. A blood sample (approximately 6 ml) will be collected and archived for future use. All cougars will also be PIT tagged for individual identification by injecting a PIT tag in the back of the neck between the ears. Sex, approximate age from tooth wear, weight and morphometric measurements will be recorded. Vital signs will also be monitored during handling of cougars.

Adults, subadult females (over 1 year old) and subadult males (over 2 years old), will be fitted with satellite GPS collars equipped with proximity sensors. Subadult males estimated to be less than 2 years old will be fitted with expandable GPS collars equipped with proximity sensors because their neck size is still increasing at this age.

Den sites will be identified from clustering of GPS locations of the female. Once identified, dens will be investigated to determine the number of kittens in each litter. Kittens will be collared using expandable VHF collars equipped with proximity sensors following procedures outlined in CPW approved capture and handling procedures (Appendix I). The proximity sensors found on all marked animals will allow for an assessment of interactions among individuals, especially in relation to the kittens. Proximity sensors on kitten collars will allow for an assessment of how much time the mother is with the kittens and will immediately send an alert when an unrelated individual comes in close contact with the kittens. A mortality alert will also be sent when the mother has been away from the kitten for more than 12 hours. At this time the kitten can be located using VHF telemetry to determine the status of the kitten and the cause of mortality if it is found dead. From this information kitten survival rates and cause specific mortality can be estimated.

*Harvest Structure of Cougars*

It is mandatory in Colorado to check all harvested cougars. Age and sex structure of the harvest will be obtained through this mandatory check process. The relationship of the age and sex structure of the harvest will then be examined relative to cougar density, harvest regime and time since implementation of the harvest regime. A model will then be developed based on the harvest structure to predict current population characteristics. This will work in conjunction with the population reconstruction model.
Genetic samples will also be collected from all harvested cougars in the study area and surrounding DAUs by extracting DNA from the tooth collected for aging. These samples will be genotyped and analyzed for genetic relatedness within the study areas. We will also use genotype information to examine immigration/emigration at a larger extent. The specifics of this are not yet known but may actually require examining viral DNA to understand dispersal and source areas.

**Demographic Rates of Cougars**

We will use Bayesian statistical inference to estimate the cumulative incidence or cause-specific mortality function for adults, subadults and kittens (Heisey and Patterson 2006, Heisey 2009). Population density and harvest regime will be used as covariates in the model to determine if these factors have significant effects on cause specific mortality rates. Other factors that will be included are study area, time of year, landscape features, and human density. GPS data will be used to assess immigration/emigration rates between the two adjacent study areas. GPS data will also be used to evaluate dispersal patterns and distances. This will also be evaluated with respect to cougar density and harvest pressure. Genetic assessment of subadult males over a broader geographic area will be used to investigate the general dispersal patterns over a larger area that is more representative of typical dispersal distances.

Movement models will be used to assess landscape level factors that are driving the movement patterns of cougars on the landscape (Hanks et al. 2015). These movement patterns will be compared among harvest strategies and population densities to determine impacts of social structure and hunting pressure. Movement models will also include comparisons of individual cougars to determine if avoidance or spatial segregation occurs as population structures change in response to harvest. Female movement patterns will also be examined relative to life stage to determine the effects that kittens have on movement patterns and energetic demands.

**E. Location**

This work will be conducted in deer Data Analysis Units (DAU) D-16 and D-34 (Figures 1 and 2), located in the foothills and mountainous regions of south-east Colorado. D-16 consists of the Buffalo Peaks game management units (GMU) 49, 57, and 58, and one of the Cripple Creek/Pikes Peak GMU 581. Elevations in D16 range from 5,250 feet to 14,200 feet characterized by valley bottoms and canyons rising up to steep mountains. Vegetation ranges from grass/shrub communities and pinon/juniper and lower elevations and includes aspen, pine, and spruce/fir as elevations increase up to alpine communities. Public land in these units ranges from 35% to 80% of the area. Total area of D-16 is 6,138 km² with approximately 4,096 km² considered potential cougar habitat, with an estimated potential population of 123 independent-age cougars.

D-34 consists of the Wet Mountains/Sangre De Cristo GMUs 69, 691, 84, 86, and 861. Elevations range from 5,168 feet to 14,064 feet characterized by prairie, foothill, rocky canyons at lower elevations and rising up to steep mountainous terrain. Vegetation ranges from short grass prairie, pinon/juniper, shrub communities at low elevations and includes aspen, pine and spruce/fir as elevations increase to alpine communities at higher elevations. Public land ranges between 30% to 70% of the area in these units. Total area of D-34 is 6,536 km² with approximately 4,913 km² considered potential cougar habitat, with an estimated potential population of 147 independent-age cougars.
F. Schedule of Work

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Plan/ACUC</td>
<td>March-August 2016</td>
</tr>
<tr>
<td>Continued deer monitoring in D-16</td>
<td>December 2016, ongoing</td>
</tr>
<tr>
<td>Initiate deer monitoring in D-34</td>
<td>February 2017, ongoing</td>
</tr>
<tr>
<td>Suppress cougars in D-16</td>
<td>December 2016-April 2019</td>
</tr>
<tr>
<td>Suppress cougars in D-34</td>
<td>December 2022-April 2025</td>
</tr>
<tr>
<td>Cougar Hair Snag D-34</td>
<td>January-March 2018</td>
</tr>
<tr>
<td>Cougar Hair Snag D-16</td>
<td>January-March 2019</td>
</tr>
<tr>
<td>Cougar Hair Snag D-34</td>
<td>January-March 2021</td>
</tr>
<tr>
<td>Cougar Hair Snag D-16</td>
<td>January-March 2022</td>
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<tr>
<td>Cougar Hair Snag D-34</td>
<td>January-March 2024</td>
</tr>
<tr>
<td>Cougar Hair Snag D-34</td>
<td>January-March 2025</td>
</tr>
<tr>
<td>Initial Capture efforts in D-16 and D-34</td>
<td>December-April 2016/17</td>
</tr>
<tr>
<td>Kitten capture</td>
<td>December 2016, ongoing</td>
</tr>
<tr>
<td>Harvest Genetic Collection/Age-Sex Structure</td>
<td>December 2016 ongoing throughout study</td>
</tr>
<tr>
<td>Capture efforts in D-16 and D-34 to attain target sample size</td>
<td>December 2017-April 2017/18</td>
</tr>
<tr>
<td>Capture efforts to maintain sample size</td>
<td>December 2018, ongoing</td>
</tr>
</tbody>
</table>

G. ESTIMATED COSTS

1. Mule Deer Strategy and D-16 Monitoring Budget

**Cougar Density Monitoring (Cost per DAU per year; Game Cash and Federal Aid):**
- Temporary employee: $43,691
- Lion monitoring supplies: $4,000
- Lion genotyping: $12,000
- Temporary vehicle: $7,200

**Total: $66,891**

**Initiation of Mule Deer Neonate Monitoring in D-16 and current monitoring(Game Cash and Federal Aid, $41,500 existing in monitoring budget):**
- Radio Collars GPS (20): $13,000
- Radio Collars VHF (10): $0
- Neonate Collars (60): $39,000
- Deer Capture (Does): $21,500
- Neonate Capture temps: $36,000
- Monitoring temp: $10,000
- GPS Airtime: $8,000
- Flight time: $7,000
- Temp Vehicle: $5,000
- Miscellaneous: $2,000

**Total: $141,500**
Initiation of Mule Deer Neonate Monitoring in D-34 (Game Cash and Federal Aid):
Radio Collars GPS (40): $44,000
Radio Collars VHF (40): $10,000
Neonate Collars (60): $39,000
Deer Capture (Does): $42,000
Neonate Capture temps: $36,000
GPS Airtime: $10,000
Flight time: $7,000
Miscellaneous: $4,000
Total: $192,000

Annual cost of Mule Deer Neonate Monitoring in D-16 (Game Cash and Federal Aid):
Radio Collars GPS (5): $5,500
Radio Collars VHF (5): $1,250
Neonate Collars (60): $39,000
Deer Capture (Does): $10,500
Neonate Capture temps: $36,000
Capture for maintenance of over-winter fawn sample: $18,000
GPS Airtime: $10,000
Flight time: $7,000
Monitoring temp: $10,000
Miscellaneous: $4,000
Total: $141,250

Annual cost of Mule Deer Neonate Monitoring in D-34 (Game Cash and Federal Aid):
Radio Collars GPS (5): $5,500
Radio Collars VHF (5): $1,250
Neonate Collars (60): $39,000
Deer Capture (Does): $10,500
Neonate Capture temps: $36,000
GPS Airtime: $10,000
Flight time: $7,000
Miscellaneous: $4,000
Total: $113,250
2. Predatory Mammals Research Budget

Startup costs on this project will be high as collars must be purchased. After the initial startup costs will largely involve technician time and some expenses to replace or refurbish damaged collars. The following budget is broken into these phases of the project and does not account for potential changes in costs.

Year 1

<table>
<thead>
<tr>
<th>Collar and Marking</th>
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<th>Unit</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Adult Collars—proximity sensors</td>
<td>20</td>
<td>$3,294.45</td>
<td>$65,889.00</td>
</tr>
<tr>
<td>Kitten Collar—proximity</td>
<td>20</td>
<td>$151.49</td>
<td>$3,029.74</td>
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<tr>
<td>Refurb old collars</td>
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<td></td>
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<tr>
<td>Capture</td>
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<td></td>
</tr>
<tr>
<td>Equip</td>
<td></td>
<td></td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Med/ket</td>
<td></td>
<td></td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Airtime</td>
<td></td>
<td></td>
<td>$4,000.00</td>
</tr>
<tr>
<td>Temp Time</td>
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<td></td>
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</tr>
<tr>
<td>Tech II</td>
<td>12 months</td>
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Year 2—Attaining a potential of 40 collars in each study area.

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</thead>
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<tr>
<td>Adult Collars—proximity sensors</td>
<td>20</td>
<td>$3,294.45</td>
<td>$65,889.00</td>
</tr>
<tr>
<td>Kitten Collar—proximity</td>
<td>20</td>
<td>$151.49</td>
<td>$3,029.74</td>
</tr>
<tr>
<td>Capture</td>
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</tr>
<tr>
<td>Equip</td>
<td></td>
<td></td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Med/ket</td>
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<td>$1,000.00</td>
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<tr>
<td>Airtime</td>
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<td></td>
<td>$12,000.00</td>
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<td>Temp Time</td>
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<tr>
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**Year 3-9—Maintaining sample sizes in both areas.**

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<td>$3,294.45</td>
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<td>Kitten Collar—proximity</td>
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<tr>
<td>Equip</td>
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</tr>
<tr>
<td>Med/ket</td>
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<td>$1,000.00</td>
</tr>
<tr>
<td>Airtime</td>
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<tr>
<td>Tech II</td>
<td>12 months</td>
<td></td>
<td>$3,267.92</td>
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<tr>
<td>Tech I</td>
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<td>$3,038.26</td>
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<tr>
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<td>$133,133.56</td>
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## Total Yearly Budget Summary

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<tr>
<th>Activity</th>
<th>Funding</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
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</thead>
<tbody>
<tr>
<td>Deer Monitoring D-16</td>
<td>Deer Monitoring and Strategy</td>
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<td>$141,250</td>
<td>$141,250</td>
<td>$141,250</td>
<td>$141,250</td>
<td>$141,250</td>
<td>$141,250</td>
<td>$141,250</td>
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<tr>
<td>Deer Monitoring D-34</td>
<td>Deer Strategy</td>
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<td>$113,250</td>
<td>$113,250</td>
<td>$113,250</td>
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<td>Cougar Monitoring</td>
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<td><strong>Total</strong></td>
<td></td>
<td>$476,500</td>
<td>$466,200</td>
<td>$466,200</td>
<td>$399,300</td>
<td>$438,100</td>
<td>$438,100</td>
<td>$371,200</td>
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</table>
**H. Related Federal Projects**

Our research will be conducted on federal (i.e., BLM, USFS), state and private lands. The study does not involve formal collaboration with any federal agencies, nor does the work duplicate any ongoing federal projects.

**I. LITERATURE CITED**


the readability and usability of microsatellite analyses performed with two different allele-sizing methods. Biotechniques 31:24+.


# J. Tables and Figures

Table 1: Doe mortality in D16, 1999-2014

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Mort N</th>
<th>Survived</th>
<th>Coyote</th>
<th>Mtn Lion</th>
<th>Other/Ukn Pred</th>
<th>Road Kill</th>
<th>Other</th>
<th>Malnutrition</th>
<th>Harvest</th>
<th>UKN</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>49</td>
<td>6</td>
<td>43</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>87.8%</td>
</tr>
<tr>
<td>2000</td>
<td>47</td>
<td>7</td>
<td>40</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>85.1%</td>
</tr>
<tr>
<td>2001</td>
<td>40</td>
<td>12</td>
<td>28</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>2</td>
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<td>0</td>
<td>0</td>
<td>70.0%</td>
</tr>
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<td>2002</td>
<td>43</td>
<td>13</td>
<td>30</td>
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<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>69.8%</td>
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<tr>
<td>2003</td>
<td>47</td>
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<td>3</td>
<td>0</td>
<td>3</td>
<td>83.8%</td>
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<tr>
<td>2008</td>
<td>80</td>
<td>20</td>
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<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
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<td>83</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>88.6%</td>
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</table>

Total 1086 218 868 19 69 10 22 6 12 2 78
% 100% 20.1% 79.9% 1.7% 6.4% 0.9% 2.0% 0.6% 1.1% 0.2% 7.2%
Table 2: Fawn mortality in D16, 1999-2014

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Mort N</th>
<th>Survived</th>
<th>Coyote</th>
<th>Mtn Lion</th>
<th>Ukn Pred</th>
<th>Road Kill</th>
<th>Other</th>
<th>Malnutrition</th>
<th>Harvest</th>
<th>UKN</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>53</td>
<td>18</td>
<td>35</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16</td>
<td>66.0%</td>
</tr>
<tr>
<td>2000</td>
<td>49</td>
<td>20</td>
<td>29</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>12</td>
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<tr>
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<td>81.4%</td>
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<tr>
<td>2003</td>
<td>60</td>
<td>9</td>
<td>51</td>
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<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
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% 100% 24.1% 75.8% 3.8% 7.5% 0.7% 1.1% 0.4% 1.6% 0.0% 9.0%
Figure 1. Deer DAU D-16, which includes game management units 49, 57, 58 and 581 in central Colorado.
Figure 2. Deer DAU D-34, which includes game management units 69, 84, 86, 691, and 861 in central Colorado.
Figure 3. Annual doe survival and cause specific mortality for mule deer in D-16 from 1999-2015.

Figure 4. Overwinter fawn survival and cause specific mortality for mule deer in D-16 from 1999-2015.
Figure 5. Simulated fawn recruitment and survival estimates to one year of age assuming a population of 6,500 does producing 1.6 live fawns per doe. Mortality from sources other than cougar predation were assumed to be 57% based on neonatal mortality estimates from the Piceance Basin and from over-winter mortality estimates from D-16 monitoring. Cougar mortality was assumed to be 35 fawns per year per cougar based on data from CPW’s Front-Range cougar research project.
Figure 6: Sampling grid on D-16 for noninvasive genetic sampling of cougars.
K. Appendix I.

Compliance

Endangered Species Act

The project work in this proposal is non-invasive in nature and does not include any ground disturbing activities. The only on-the-ground activity associated with this project will be the capture of cougars using hounds, cage traps, foot hold snares and free-range darting. This project does not involve aquatic work therefore there will be no effect to aquatic species.

Capture of cougars may result in minor disturbance to some threatened species, Gunnison prairie dog, Boreal toad, Mexican spotted owl, and Canada lynx. Because all these species and/or their habitat are conspicuous and easily recognized, if any of these species are encountered, researchers will avoid capture activities in the area near these animals to limit disturbance. Cougar capture has routinely been conducted throughout Colorado, across the range of all these species, and no negative effects have been documented. Therefore, we have determined this project may affect but is not likely to adversely affect the above listed species.

Animal Welfare Act

Prior to capture, this study will gain capture approval through Colorado Parks and Wildlife’s Animal Care and Use Committee. Once gained, project approval numbers will be provided. Capture and Handling guidelines are already approved.

NEPA

Pursuant to 516 DM 8.5 Section B1, this action (or these actions) are categorically excluded from further consideration under the National Environmental Policy Act. Additionally, the individual actions do not meet the criteria pursuant to 43 CFR 46.215, Extraordinary Circumstances.

Other Landscape-Oriented Federal Acts

This project will have no negative impact on the landscape, therefore it will not violate provisions of Federal Legislation governing floodplains, wetlands, historical sites, and prime and unique farmlands.

Americans With Disabilities Act

When hiring personnel as part of this project, qualified individuals will not be discriminated against based on disability. No structures or access points will be constructed as part of this research, and thus accessibility is not applicable.

Federally listed, proposed and candidate species considered for: Teller, Park, Freemont, Chaffee, Custer, Pueblo and Huerfano counties.

Gunnison Prairie Dog
Lynx
Mexican Spotted Owl
Boreal Toad
K. Appendix II. CPW ACUC approved capture and handling guidelines for deer.

ACUC protocol #__10-2008__ Updated _6/10/15_

DEER CAPTURE AND HANDLING
GUIDELINES
# DEER CAPTURE AND HANDLING GUIDELINES

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DEER CAPTURE AND HANDLING GUIDELINES

INTRODUCTION

Delivery of anesthetic drugs via projectile syringe, clover traps, drop nets, and net gunning may be used for mule (*Odocoileus hemionus*) and white-tailed (*Odocoileus virginianus*) deer capture. All of these techniques have proven effective and safe for capturing deer under field conditions commonly encountered in Colorado. Colorado Parks and Wildlife’s (CPW) Animal Care and Use Committee (ACUC) has already reviewed and approved all of these capture methods for deer under previous research protocols. This document is intended to serve as a comprehensive reference for future deer studies to avoid unnecessary complexity in study protocols submitted for ACUC review. A description of handling, injury and euthanasia procedures, emergency services, and marking methods are common to all capture techniques and are described in detail below.

CHRONIC WASTING DISEASE PRECAUTIONS

To prevent inadvertent spread of Chronic Wasting Disease (CWD), all nets used in an area (i.e. DAU) where CWD is known or suspected to occur must remain in that area and only shared among other DAUs that are known to have CWD. Equipment from known CWD positive DAUs should not be used in areas where CWD has not been detected. Any equipment used in CWD known areas also needs to be regularly disinfected with a 10% Clorox solution, LPH (nonalkaline phenolic product), especially prior to moving the equipment to new areas. Equipment used to open and keep an animal’s mouth open (i.e., mouth gate) must be disinfected by soaking in disinfectant solution for 30 minutes before use on a different animal.

AMBIENT TEMPERATURE PRECAUTIONS

Deer capture and handling is generally acceptable between the temperatures of -15°F and 60°F following the guidelines listed throughout this document. Deer capture in temperatures less than -15°F should be avoided. If captures are absolutely necessary, deer should not be slung beneath helicopters in temperatures <-10°F. In the rare instances that deer must be captured and transported via helicopter when temperatures are <-10°F, deer need to be transported inside the fuselage of the aircraft. If temperatures are below -10°F, thermal blankets should be available and only drugs that can be reversed should be used. If temperatures are >60°F then capture times should be limited, animal body temperatures need to be monitored, water must be available to cool animals, and only drugs that can be reversed should be used.

CAPTURE TECHNIQUES

Delivery of anesthetic drugs via projectile syringe

Darting will be accomplished via ground approaches, either in a slow moving or stationary vehicle, on foot, or from a helicopter. Apple pulp, alfalfa or corn/grain mix may be used to bait deer into an area from which they can be darted with an adjustable air-powered or powder charged rifle. Note: alfalfa can be used as a pre-bait, but bait should be switched to hay at least 1 day prior to capture to prevent bloat.

Adult deer of either sex may be captured by intramuscular (IM) injection via projectile syringe using one of the following combinations:

Telazol 3-4 mg/kg in combination with xylazine (2-4 mg/kg); xylazine can be antagonized with tolazoline 4mg/kg either via intravenous (IV) or intramuscular (IM) injection.
Medetomidine (0.2 mg/kg) in combination with ketamine (3.5 mg/kg); Medetomidine can be antagonized with atipamazole 1mg/mg.

Butorphanol (0.4 mg/kg) in combination with Azaperone (0.25 mg/kg) and Medetomidine (0.15 mg/kg). Medetomidine can be antagonized with atipamazole 1mg/mg Medetomidine.

New drugs/drug combinations are constantly being developed and drug doses refined, so the use of any other drug/drug combination must be approved by the consulting veterinarian.

Capture operations will be halted if the ambient temperature falls below -15°F or rises above 60°F or if light is insufficient to allow darted animals to be adequately monitored and followed adequately. Based on previous field experience by CPW employee’s using these methods, capture related mortality rarely exceeds 3%. Capture related mortality should not exceed 5%.

Deer receiving drugs must be marked with an ear tag or collar with the following wording:

“If killed before (write in date) do not consume.”

The date is based on approved withdrawal time for drugs used. The withdrawal time for the drug combinations listed above is 30 days. Pre-planned capture operations that will knowingly utilize drugs should take withdrawal time into account and be completed >30 days prior to hunting seasons.

**Clover Trapping**

Deer may be trapped in Clover live traps (Clover 1956). Trapped deer are confined in a small area to minimize injuries due to fighting against the trap. Traps will be positioned so that they are not readily visible from public roads and are not visible from one site to another.

Clover traps for deer are a single-gated trap, approximately 1.5 m long by 0.84 m wide by 0.97 m high, designed to catch one animal at a time. Clover traps consist of a plastic pipe or steel frame covered with string nets or webbing (Clover 1956). To minimize injury to deer, each trap should be secured to an 8 foot long T-post driven into the ground at each corner with an additional T-post as a “Deadman” secured to each corner post. The trap is baited with apple pulp and alfalfa hay or corn/grain mix, and closes when a deer enters to feed and trips the trap.

Traps will be set in the evening and tied open after being checked by mid-morning each day. Captured deer will be physically restrained by personnel on site, blindfolded, and hobbled. Capture operations will be halted if ambient temperature falls below or is expected to fall below -15°F or exceed the temperature for 6 traps are set for capture. Based on previous experience by DOW personnel using these methods, capture related mortality should not exceed 5%.

**Drop Netting**

Baited drop nets have proven to be an effective and safe technique for capturing deer and other ungulates (Ramsey 1968, Schmidt et al. 1978, Bartmann et al. 1992). Drop-netting is typically less efficient than helicopter net-gunning for capturing deer (White and Bartmann 1994). However, deer residing in populated areas cannot be captured by helicopter netgunning. Drop-netting affords researchers the opportunity to capture animals in more populated areas, while also allowing for multiple captures and control over the age and sex composition of captures. That is, a researcher can watch the net and wait to drop it until an acceptable number of deer are present under the net.
Drop nets are approximately 21 m square, suspended by a center pole and 4 corner poles. All poles are fiberglass or metal pipe, 5-10 cm in diameter, and have hooks at the top to hang release mechanisms, (solenoids); the center pole is approximately 5 m long and corner poles are approximately 3 m long. The solenoids have a hook that releases upon signal from a remote transmitter. The net is suspended 2.5-4.5 m off the ground. If center poles are designed to fall with the net then this pole must be fiberglass (typically a pole-vaulting pole) to avoid injury to animals. If the center pole is designed to remain standing (such as using a pulley system) then anchored metal center poles are acceptable.

Drop net sites should be baited on a daily basis for 3-4 days prior to capture. Deer response to pre-bait is commonly observed within 2-3 days. The net will be set up prior to the capture date so that animals grow accustomed to accepting bait underneath the erected net. Erected nets will be secured such that there is no possibility of an accidental release. More than one net may be set up at any given time. Alfalfa hay and apple pulp or corn/grain mix or other suitable bait may be used as bait. Capture crews will remain at a distance from the trap site to avoid disturbing animals. Once a desirable number and sex/age composition of deer are under the net, the observers will drop the net by remotely activating servos/solenoids.

Once the net is dropped, the capture crew will immediately go to the net and begin handling deer. Netted animals will be physically restrained, blindfolded and hobbled as soon as possible, and freed from the net. After processing, all deer will be moved away from the net prior to release using stretchers. Using stretchers minimizes injury risks to the animals and crew while deer are being carried, and ensure that animals are a safe distance from the net and other crew members when released. All captured deer will be handled, processed, and released as quickly as possible, unless otherwise indicated to meet study-specific needs.

Deer are typically captured with drop nets in mornings and evenings, which minimizes the risk of hyperthermia as temperatures are cool. Capture operations will be halted if ambient temperature falls below -15°F or exceeds personnel, capture related mortality should not exceed 5%.

A minimum of 1 handler per animal is needed to assure that all deer captured in a single net drop can be safely and quickly handled and removed from the net. If all animals cannot be safely handled and released within 25 minutes, dropping the net should be delayed until fewer animals will be captured. All field assistants will be instructed to minimize stress and injury to the animals, particularly in terms of safe handling procedures. Training will include how to approach netted animals, free animals from the net, and safely restrain the animals. Also, the capture crew will be instructed on safety procedures when working in and around the drop net to avoid any potential injuries to personnel.

**Net-Gunning**

Helicopter net-gunning will be contracted out to private vendors, but CPW personnel are responsible for assuring compliance with capture and handling protocols. Once a group of deer are located and an animal is selected from the group, it is pursued (typically <1 min) until the net-gunner can fire a net over the deer. During instances in which deer are in trees and reticent to flush, the helicopter can be use to herd animals to a suitable capture site. Time spent herding animals should be <5 minutes. Once a targeted animal is selected, it will be actively chased for <3 minutes or until active panting is observed. Once these criteria are met, active pursuit of the animal will be terminated. Total time spent disturbing the initial group should be <10 minutes. No more than 2-3 animals should be captured from a unique group, thereby minimizing stress on non-target animals. Care will be taken by the helicopter crew to avoid chasing animals into fences, roads, rivers, or unfavorable terrain. Once the deer becomes entangled in the net, it is physically restrained, blindfolded, hobbled, and untangled from the net; typically this process takes <5 minutes. The deer is then handled at the site of capture or ferried to a nearby site for processing. Once an animal is processed, it may be released at the processing site or ferried back to capture location.
depending on the study protocol. To minimize stress and injury to deer, the following protocols will be followed for net-gunning capture.

**Command Post:** Net-gunning will be done at specified locations. No more than 2 deer will be ferried at a time. Only trained personnel will be involved in the actual capture of deer. Other field assistants should be staged nearby during the operation, and may be responsible for sampling and marking to meet study needs. Staging areas will change to remain close to the net-gunning operation, ideally no more than 5 miles. Two-way radio contact between the staging area and helicopter crew will be maintained throughout the capture operation.

**Capture Conditions:** Capture operations will be halted if ambient temperature falls below -15°F or exceeds 60°F for 0.5 hours. Pursuit Time: Individual deer will not be actively pursued for >3 minutes and chase time will be recorded and reported by a helicopter crew member for each animal. Chases will be aborted if signs of excessive exertion (e.g., open-mouthed breathing, stumbling) are noticed, or if a deer appears headed for a potentially dangerous situation (e.g., fence, road, etc.).

**No-Fly Zones:** Deer captures will take place on public land or private land where approved by the landowner. Captures will take place away from roads and man-made structures.

**Notification of Affected Parties:** It is encouraged that local residents and federal, state, and local agencies be notified for the time and general area of capture activities. However, this recommendation falls outside the purview of ACUC.

**Emergency Services:** As part of pre-capture safety and training, capture personnel should be instructed where the nearest medical and emergency services are located. Capture crews will have communications (i.e., radio contact or cellular phone coverage) contact with CPW service centers and Colorado State Patrol.

**ANIMAL CARE AND HANDLING**

Deer anesthetized via darting will be blindfolded and vital signs checked. Trapped deer will be physically restrained, and blindfolded. Hobbling often is not necessary for anesthetized animals, but it can be used to restrict movement if sedation appears mild and giving additional drugs to an animal is undesirable. When necessary, IV anesthetics can be administered once deer are adequately restrained. During processing and recovery each deer can be monitored, ear tagged and biological samples taken according to the specific study plan. At all times, minimizing noise during processing is desirable.

Once processing is completed, deer will be released immediately. When used, anesthesia will be antagonized as described above; appropriate antagonists will be administered immediately to any deer showing apnea, severe respiratory depression, or other complications of anesthesia or recovery. If rectal temperature exceeds 105°F, then water will be administered to facilitate cooling; deer that fail to respond to cooling efforts will be immediately released on site. If rectal temperature falls below 95°F, they will be wrapped in blankets and assessed; hypothermic deer will not be released until the body temperature is within normal range (99.5°F – 103.5°F).

**MARKING GUIDELINES**
All translocated deer should be tagged in at least one ear. For research/management studies not involving translocation, project specific protocols and objectives will determine marks.

Because of over-winter weight loss and collar shape differences due to collar type (e.g., VHF vs GPS), collar fit can vary, but collar circumference can be standardized to account for maximum neck sizes during late fall/early winter. Anderson and Bishop (2010) noted collar injuries to adult mule deer does (n = 9) collared during March and recaptured the following December. March collars were attached too tight to the throat ranging from 29-32 cm in circumference (mean = 31.2 cm). Collar attachment protocols were increased to prevent further injuries, where collar circumferences averaged 34.2 cm (range = 29—38 cm; n = 95); smaller circumferences (29-31 cm) were typical of younger does (2.5—3.5 yrs). However, final collar sizing should be based on final assessments in the field. Collar hole spacing should be measured pre-capture to enhance collaring efficiency. Advanced Telemetry System collars fit for mule deer does, for example, begin at 27.5 cm and increase in 1.5 cm increments.

Fitting collars more loosely when deer are in their poorest condition will prevent subsequent collar injuries as deer gain weight from annual cycles in improved forage availability. During early winter collars on does and adult bucks (>3 years old) should fit snug such that two fingers can be placed underneath the collar, above or below the neck, when the animal’s head is held in a raised position (Figures 1a and 1b). Some collar shapes do not conform well to deer neck shapes (e.g., GPS collars with flat dorsal antennas), and using the throat or top of the neck for spacing should minimize abrasions. In late winter, as deer loose condition, fitting a full palm width under the collar (along the neck) is suggested (Figure 2).
Figure 1. For early winter captures, radio collars on deer should be placed on the top of the neck and fitted snug such that two fingers can be placed underneath the collar. Spacing at the dorsal region (top photo) or ventral (bottom photo) can avoid potential abrasions from collar shapes that do not conform well to deer neck shapes (e.g., GPS collars with flat dorsal antennas). Deer shown in pictures are being given supplemental oxygen. Supplemental oxygen, while not required, can help reduce physiological stress and regulate breathing by reducing the potential for hypoxia. Photos by Joe Northrup
Figure 2. For late winter captures, a full palm width, on the side of the neck, should be used for collar spacing. This will prevent subsequent collar injuries as deer body condition improves with forage availability. Photo courtesy of CPW Piceance Basin Mule Deer Project.

For yearling, 2 and 3-year old bucks, collars should fit more loosely to accommodate growth. Collars used on bucks must be expandable to accommodate neck swelling during the rut.

Deer are moderately long lived animals with high adult survival rates and it is not unusual for does to live past 10 years, yet radio collar battery life is rarely more than 5 years. Unless deer are going to be recaptured to remove radio collars, drop-off mechanisms (mechanical or fabric based) should be incorporated into all collar designs. Surgical tubing may be used to facilitate collar drop off if the collar is needed for 10 months or less.

Alpha-numeric marks on collars allow visual identification of individual animals and mark-resight population estimation techniques (Figures 1 and 2). Large pre-numbered ear tags or other plastic material can be attached by rivets, adhesives, or sewn onto collars. Placement of marks will differ depending on whether animals will be resighted from the ground or from aircraft. If resightings will be made from aircraft, marks should be placed on the top of collars. If resightings will be from ground positions, marks should be placed on both sides of the collar. Marks should be attached to collars prior to capture day to minimize handling time for deer.

The marking process often causes a bottleneck in handling captured animals. Extra ear tag backs, ear tag applicators, radio collar nuts, plates and nut drivers should be available at capture operations, especially when working in snow.
EQUIPMENT COMMON TO ALL CAPTURE METHODS

Prior to each use, all equipment other than nets should be washed with soap and warm water to minimize potential for disease transmission.

**Stretcher or Carrying Tarps**
Specialized tarps with handles or stretchers reduce risk of injuries to animals and handlers. Specialized tarps are preferred for carrying immobilized animals on slopes or in tight spots. Six tarps or stretchers are adequate for a standard drop-net capture of 20-30 animals.

**Hobbles**
At drop net and net gun capture operations there should be more hobbles available than the greatest number of deer expected to be captured at one time. Two types of hobbles are used to restrain deer.

One type consists of a single strap of leather or nylon with a D-ring buckle. Alternatively, the strap can have holes punched and a buckle on one end. Two straps are required per animal: one on each side of the animal to secure the front and rear leg together (Figure 3). This type of hobble is faster to apply and remove by experienced handlers, but can be awkward when used on animals under drop nets.

Figure 3. A mule deer with front-to-back leg hobbles. These hobbles consist of single straps of leather or nylon with a buckle or D-ring attached to one end. Two straps are required per animal. Photo by Chuck Anderson.

Another type of hobble consists of four nylon straps permanently fastened to a center O-ring. Each strap has a buckle and holes punched at ½ - ¾ inch intervals. Each leg is held by one of the four straps so only
a single hobble is needed per animal (Figure 4). This type of hobble is easier to apply with drop net captures and by inexperienced handlers. Both types of hobbles should be secured below the knee/hock joint, but above the dew claws (Figure 5).

Figure 4. A single hobble of this type will restrain a deer. Photo by L. Wolfe.

Figure 5. Hobbles should be secured above the dew claws. Photo by Chuck Anderson
Blindfolds
Blindfolds should be made of nonabrasive material and cover an animal's eyes, but leave the mouth and nose unobstructed for breathing and panting (Figure 1). Blindfolds should be easy to apply and remove. Straps that fasten behind the ears/antlers provide a secure fit when animals are being transported by helicopter, but are not preferred for other types of handling because they will not slide off in case of an accidental release or escape. Knit neck gaiters are effective blindfolds for does, fawns and young bucks when animals are not transported by helicopter, but require frequent repositioning on mature bucks.

Water Containers
Water should be available at deer captures for cooling animals. A clean 2.5 or five gallon weed sprayer with spray nozzle can be used to apply water to restrained animals.

INJURIES AND EUTHANASIA

Injuries and mortalities are hazards of any animal capture procedure. All of the methods described have been safely used for deer capture. Any mortality is regrettable and each mortality incident should be evaluated immediately to determine whether capture or handling procedures need to be modified. If the mortality rate exceeds the guideline of 5%, operations will be suspended and capture procedures will be evaluated and corrected as needed.

If an animal is seriously injured (e.g. fractured or broken appendage, vertebrae, pelvis, or jaw, severe dislocation, laceration or any other injury that compromises its ability to survive and/or causes severe pain or distress) during capture or recovery, then it will be quickly and humanely euthanized. Deer will be deeply anesthetized with ketamine or Telazol® and xylazine (IV or IM) and euthanized via KCl administration (400-800 mEq IV). Alternatively, if injured deer cannot be handled (e.g., deer that fractures its leg) or is injured when a veterinarian is not present (e.g., during helicopter net-gunning), then euthanasia will be a gunshot to the head or neck with a 0.22 caliber rifle. An animal tranquilized will not be donated for human consumption and should be disposed of in a landfill or buried.

POST CAPTURE MONITORING

Upon release, each deer will be observed for injuries that may have gone undetected. If there is an injury that meets euthanasia criteria noted previously, the animal will be recaptured and euthanized according to guidelines described above. If the deer is in good condition and leaves the capture location, aerial or ground monitoring will be used to follow up on deer condition and survival. All animals will be monitored at least once within 10 days of capture. Any mortality will be immediately investigated for cause of death. If cause of death is not evident and deer are not too remote, the carcass will be recovered for necropsy by trained personnel. If deer cannot be brought in, field personnel will check for physical injuries and capture myopathy. Any mortality that might be associated with the capture process will be documented and information on cause of death made available for future reference.

LITERATURE CITED

response to natural gas resource extraction and mitigation efforts to address human activity and habitat degradation. Job Progress Report, Colorado Division of Wildlife, Fort Collins, USA.
K. Appendix III. CPW ACUC approved capture and handling guidelines for felids.

ACUC protocol # 03-2007
Updated Feb. 2015

MOUNTAIN LION/CANADA LYNX/BOBCAT CAPTURE AND HANDLING GUIDELINES

Prepared by:
Ken Logan
Lisa Wolfe
Mat Alldredge
Jake Ivan
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INTRODUCTION

Mountain lions (*Puma concolor*), Canada lynx (*Lynx canadensis*) and Bobcat (*Lynx rufus*) may be captured for legitimate research activities by trained personnel using approved methods to enhance safety to animals and people. A variety of methods, including the use of trained dogs, cage traps, foot-hold snares, and hand captures, in combination with appropriate use of anesthetic drugs and delivery systems, have been used in lion research. Modified cage traps (see below) have proven most effective for capturing lynx, although trained dogs and snares can work as well, depending on conditions. This document serves as a comprehensive reference for mountain lion, lynx and bobcat capture and handling protocols approved by ACUC for felid research in Colorado.

ANESTHESIA AND GENERAL HANDLING

Field anesthesia will be delivered to captured felids by trained personnel. Anesthesia is determined under the supervision of the attending veterinarian. Anesthetic drugs will be administered intramuscularly (preferably the caudal thigh, but other large muscle will work) via projectile syringe using a gas-powered projector, jab-pole, or hand injection. For capture, felids may be anesthetized with Telazol® (5-9 mg/kg) and xylazine HCl (1.0-2 mg/kg) or ketamine (10-11mg/kg) and xylazine HCl (1.8-2mg/kg) (Shaw 1979, Logan et al. 1986, Kreeger 2002). The ketamine and medatomidine combination is preferred for all felids, see drug dosages (Table 1, Appendix A). Emergency drugs are also included in Table 1, Appendix A. Atropine is used to treat bradycardia, dopram is used to treat respiratory depression (use of intranasal oxygen insufflation is also recommended) and fluid therapy is used to treat dehydration and hyperthermia. Other drugs may be recommended at the discretion of the attending veterinarian.

When handling the anesthetized felids, hobbles may be applied to the four feet, snug, but not tight. Apply artificial tears or an antibiotic eye ointment and a blindfold to reduce visual stimuli and protect the eyes from bright sunlight and debris and evaluate the vital signs. Normal signs for lions: pulse ≈ 70—80 bpm, respiration ≈ 20 bpm, capillary refill time ≤2 sec., rectal temperature ≈ 101°F average, range = 95—104°F (Kreeger et al. 2002). Normal signs for bobcat and lynx are similar: pulse ≈ 100—115 bpm, respiration ≥ 16 bpm, rectal temperature range = 99—104°F. In temperatures near or sub-freezing lay anesthetized felids on a thermal blanket. Wrap it in blanket if necessary. For lynx captures during winter, lay a space blanket down at the handling site, then a foam sleeping pad, and place the lynx in a sleeping bag on top of pad. Keep the animal covered except when collecting samples and taking measurements. Erect a tarp over the handling site during heavy snows. In hot temperatures, the felids should be treated with water on the head, abdomen, and inguinal area. Packing the abdomen and inguinal area with snow is also effective and if possible, using snow in plastic bags is preferable as this will avoid soaking the fur. Cats that receive lacerations during capture will be given antibiotics (Table 1, Appendix A). Antiseptic cream will be applied to all lacerations found on the animal and to the ear-tag puncture sites. In addition to this, lidocaine cream will be applied to the ear-tag puncture sites to reduce irritation of ear-tags immediately following capture. When the cat is being sampled it should be moved from one side to the other or in sternal recumbency about every 20 minutes to prevent hypostasis in the downside lung.

Radio/GPS collars, ear-tags, ear-tag transmitters, and PIT tags are all potential marking methods for felids. The weight should not exceed 3% of the animal’s body weight and the use of marks that exceed this will require justification. Radio/GPS collars should fit snuggly (2 to 3 fingers under the collar) around the animal’s neck. Avoid collaring young animals that are potentially still growing as this
may cause the collar to cut into the animal’s neck. As a general rule do not collar female lions that are under 1 year old and do not collar male lions that are under 2 years old (or under 130 pounds), because the collar will cut into their neck as they continue to grow. All mountain lions (since they are consumed when harvested) that have been anesthetized must be ear-tagged in at least one ear with the withdrawal period (30 days for ketamine/medetomidine) clearly written on the tag. Ear-tags should not be significantly larger than the ear to avoid irritation, which may lead to the tag being pulled out. Ear-tag transmitters may also be used, but the transmitter weight should not exceed 30g to avoid excessive bending of the ear (C. Anderson personal comm.). PIT tags may also be used to mark animals. PIT tags may be placed at the mid-line between the ears for felids over 12 months of age, or between the shoulder blades. PIT tags should not be placed between the ears on kittens as the skull is still soft and sutures are not completely closed.

When sampling procedures are completed, remove the blind-fold and leg restraints (e.g. hobbles) and the felid will be allowed to recover from the sedation either naturally or with the aid of an antagonist. Tolazine (4 mg/kg IM) will be used to antagonize xylazine sedation and atipamezole (0.45 mg/kg) will be used to antagonize medetomidine sedation, although actual doses are given based on the actual amounts of xylazine or medetomidine given (see Table 1, Appendix A). Attention should be given to the location for recovery. If necessary, the animal should be moved away from creeks, rivers, cliffs, and roads to minimize hazards during recovery. When possible, place lynx back in trap to fully recover before they are released. This will prevent them from floundering in deep, soft snow.

CAPTURE TECHNIQUES

Trained Hound Pursuit

Experienced houndsmen with trained dogs and working with the principal investigator, assigned technician(s), or with an attending veterinarian can be an effective method to capture felids. Note, however, that pursuit of lynx via hounds during winter is often difficult and inefficient due to deep snow conditions. This technique can be useful for targeting specific individuals or new individuals by turning dogs out on fresh tracks. Pursuit of a denning female or one with dependent young may pose a risk to kittens if they are too young to climb trees. Do not turn dogs out on tracks of any individual that is suspected of having young that are not capable of climbing trees as the dogs may kill the young. If capturing a previously marked individual do not use dogs if you know that the animal has recently denned. Before release of dogs, attention should be given to track sizes and stride lengths of the cat targeted for capture to estimate its age and sex. If multiple tracks are seen then it is likely a family group so care should be taken to estimate the age of all individuals. When younger felid kittens are involved, tracks may be followed with dogs on leashes until the adult clearly separates from the kittens or kittens have been treed. In these cases, personnel need to quickly capture dogs that get back onto the kittens’ tracks.

Careful assessment of the capture situation needs to be made by a trained/experienced person before an attempt is made to anesthetize a bayed cat. All dogs should be securely tied to a solid tether prior to darting to avoid injury to a sedated animal if it should jump from the tree. There should be a clear, unobstructed shot at the cat. Characteristics of the tree should be evaluated to ensure that an anesthetized cat will be able to stay in the tree or will not be hurt if it should fall from the tree after being darted (Fig. 1 and 2, Appendix B). The tree must be safely and quickly climbed by a person to secure the cat with ropes and lower it to the ground. In addition, the capture site should be far enough from cliffs, creeks, rivers, roads, and highways so that if the cat leaves the tree under partial anesthesia it will not immediately be subject to those hazards. If it is not safe to anesthetize the cat it can be encouraged to leave the tree under its own power (backing dogs off, lobbing snow into tree above the cat, pounding on
the tree, or climbing adjacent trees to get above the cat), and another attempt made to catch the cat at a safe location. In addition, cats bayed on the ground at the edge of cliffs should not be anesthetized.

If the treed animal remains in the tree until almost completely anesthetized, then someone wearing climbing gear will climb to the cat and attach a Y-rope or hobble to both hind legs and quickly lower the animal to the ground. For faster acting drug combinations (med/ket), it is necessary to begin climbing the tree immediately after the cat has been darted. Once the cat is on the ground, the rope or hobbles should be loosened to facilitate blood circulation to the feet. If possible, other personnel will hold a taut net below to break the cat’s fall should it slip before a rope can be secured. If there aren’t enough people to hold the net, anchor the net about 2 m above the ground on adjacent trees. Sharp logs, stumps, and rocks should also be removed from the immediate area to avoid injury in case of a fall.

Felids may jump from the tree immediately after being darted. If there is snow cover, the cat should be tracked without the dogs. Attention should be given to changes to the cat’s gait and direction of travel. When anesthesia is effective, the cat’s tracks will weave and show signs of stumbling. If after snow-tracking it over 500 m, and it appears that the cat is traveling normally (i.e. was not drugged), then dogs can be released on the cat’s tracks again to encourage it to tree. If the ground is bare and researchers cannot ground-track the cat, then a dog on a leash can be used to track the cat. Alternatively, after waiting 7 minutes for the drug to take effect, at least one non-aggressive dog can be released on the lion’s trail to find the cat. Researchers need to follow the dog(s) posthaste to prevent a partially anesthetized cat from harming the dog. If the cat is radio-collared, radio-telemetry can be used to track it.

**Cage Trapping**

Cage traps can be a safe alternative method for capturing felids. There have been several different designs of cage traps, all of which are effective. In general a cage trap is any metal cage that can safely and securely trap a felid. Design considerations are generally based on size, transport and safety. Smaller traps are easier to transport but may be restrictive for larger animals. For smaller felids (bobcats) a cage trap should be about 36 inches long, 15 inches wide and 24 inches tall. Mountain lion cages should be at least 60 inches long, 22 inches wide and 28 inches tall. Larger traps are also acceptable. Safety concerns are anything within the trap that a captured animal could hurt themselves on. Generally this consists of anything that they can chew on or hook their canines on and break their teeth. Mountain lions have broken teeth on trap treadles, triggers, and cage mesh that exceeds 1”x1”. We recommend external triggering devices for all cage traps and require that mesh sizes for traps be no larger than 1”x 1”. Below are examples of cage traps that have been used effectively and safely to capture these felids (figures 3,4,5,9,10). Minor modifications to these designs are acceptable but should maintain appropriate levels of safety for the cats, such as avoiding heavy guillotine-type doors that could injure or crush animals. Any major modification, such as a different type of trap door, requires prior approval by ACUC. An example of a minor modification is a remote monitoring device that minimizes the amount of time an animal remains in the trap. At minimum, lion and bobcat traps should be closed or monitored during the day if temperatures are warm and checked at first light if left open during the night. Lynx are docile when trapped. Therefore, lynx traps can be checked once per day (as long as they are provided hares or other meat to sustain animals for up to 24 hrs), and entrapped lynx can be left overnight for handling the following day (again, provided they have sufficient food). Minimizing time spent in traps is always encouraged.

M. Alldredge has designed a mountain lion trap that consists of a steel frame with a 1”x1” steel mesh welded to the inside of the trap. The trap has a swinging door with steel rings to lock the door closed. There is nothing inside the trap that an animal could chew on or hook with its teeth. The triggering mechanism is an archery release that holds the door cable in the caliper and the bait is tied to
the trigger. These traps weigh approximately 70 lbs. and no injuries have been reported with extensive
the use of these traps. A similar, but larger trap, has also been made for black bears.

A cage trap designed specifically for the capture of mountain lions has been used to manage lion
human conflicts in California since the late 1980s (Shuler 1992). A similar cage trap was used to safely
capture lions for research on lion-human interactions in San Diego County, California (Sweanor et al.
2008). The cage trap for that study measured 48 in. tall, 40 in. wide, and 10 ft. long. It was built on a
frame of 1 ½ in. angle iron with 2 in. by 4 in. grid horse panel made of 3/16 in. welded steel rod for the
walls, floor, door, and roof. It had a drop-down door. Mass was about 250 lb (113kg). A similar cage trap
designed by K. Logan (CDOW), which is 8 ft. long and has a center-pivot door, has been used to safely
capture lions on the Uncompahgre Plateau Mountain Lion Project (Fig. 3 and 4, Appendix B).

Commercially manufactured traps for mountain lions are the Tru-catch Traps (Belle Fourche, SD)
models 60D Maxie Deluxe and the 72D. The model 60D measures 60” x 22” x 28” and weighs 48.4 lb
(22 kg). It has been used to safely capture lions on the U.P. Mountain Lion Project and the Front Range
Mountain Lion Project (Fig. 5, Appendix A). The model 72D is a 72 inch-long version of the 60D,
weighing 70 lb. (31.8 kg), and requires the same modification (reinforced back door). Given its structure
, it is necessary to reinforce the back sliding door on these traps. Various trigger mechanisms are used on
these traps. Mountain lions have been known to break their teeth on these traps, as the mesh size (1” x
2”) allows them to hook their teeth on the wires. Lions have also broken their teeth on traps with internal
mechanisms such as treadles to release the door. It is possible to remove the treadle and use an external
triggering device, such as an archery release, for these traps.

A cage-type trap for live capture of bears was developed by Beck (1993). The trap measures
1.8m long and 1.0m high and wide. The frame is constructed of angle iron, and all side and top panels are
wire mesh of 1.9cm mesh size. The floor is 16-gauge steel. A spring-powered, solid aluminum door is
mounted on a full-length hinge at one end. A full-length latching mechanism holds the door closed. The
door is triggered via a treadle pedal mounted on the floor 1.0m from the door. A standard garage door
coil spring provides the closing power. Along one side of the trap is a hinged panel measuring 1.8m by
0.3m. Vertical bars placed on 0.3m centers behind this panel. Swinging the window up allows access
through the barred area for administering immobilizing drugs by jab-pole. Each trap weighs
approximately 519 lb (236kg). In the first study in which these traps were used, there was only one injury
to a bear in 134 captures. An adult male broke a canine tooth while in the trap. Of the limited number of
times these trap have been used for mountain lions, no known injuries have occurred to date (T. Beck,
pers. comm.). Grating width (~<1 inch) should be small in order to limit the possibility of an animal
biting the trap and breaking its canines.

Lynx have been successfully captured using commercially available Tomahawk Model 109.5 live
traps (42L x 15W x 20H) or similar. However, custom box traps constructed according to Kolbe et al.
(2003) provide plenty of space, soft walls, packability, and improved reliability in winter conditions.
Thus, these traps, or modifications thereof (T. M. Shenk, unpublished data) have become the preferred
method for capturing lynx in Colorado for research purposes over the past decade.

Mountain lion or bobcat traps are normally set during evening, night and early morning hours
when animals are most active (Sweanor et al. 2008). A cage trap will be baited, preferably with the kill or
bait previously being consumed by the animal. Usually, animals are caught at night, some soon after
night-fall. Lion and bobcats will be immobilized with a jab-pole or hand syringe, with anesthetics and
handling procedures described previously. Lynx traps can be set and checked during any time of day
although captures generally occur from early evening to early morning. Lynx traps will be most
successful if baited with hares or rabbits. However, deer or elk legs can be effective as well. Visual
attractants such as a grouse wing or compact disc, strung from a nearly branch and allowed to move in the
breeze, can improve capture success for lynx, as can the use of commercial scent lures. Lynx should be immobilized with a jab pole loaded with anesthetics and handled following the procedures described previously. Traps are too large to use a hand syringe.

**Foot-hold Snares**

Foot-hold snares can be an effective, relatively safe technique for capturing felids, particularly in areas not conducive to using trained hounds (Logan et al. 1999), and where cage traps cannot be hauled. Logan et al. (1999) found life-threatening injuries occurred in 5 of 209 captures. The majority of these injuries were fractures to ulna and/or radius of the snared leg. However, minimizing cable length and carefully selecting sites will minimize injury. Close monitoring to minimize the time an animal is in the snare will also minimize potential injury. Foot-hold snares have long been used by trappers to capture lynx, but have been used only sparingly for research.

The snares are constructed to minimize injuries to the felid (Fig. 6, Appendix B). The snare, also called the Aldrich foot snare, was originally designed for the capture of bears. The spring activated snare secures a 3/16 inch steel cable around the foot of the animal, closing tight with the action of a small piece of angle iron fashioned into a sliding lock mechanism. The snares have been modified considerably for lions by incorporating a large steel spring or bungee cords to diminish force applied to the foot and absorb shock. Minimizing snare length is critical to reducing stress/force on the snared foot. Duct tape is wrapped along 13-14 cm of the end of the foot loop adjacent to the angle-iron lock to a thickness that will stop the lock and prevent the foot-loop from closing further. This length can be modified if the researcher has prior knowledge of the targeted animal’s size (i.e., males have bigger feet than females). This slide stop constrains the size of the closed foot-loop to 18- to 19 cm circumference to allow circulation to the animal’s foot. It also allows smaller footed non-target animals (e.g., deer, canids) to pull free from the loop. An in-line swivel is placed in the cable directly behind the foot-loop to avoid torsion of the foot and potential bone fracture. The snare is secured to a tree 4 inches or greater in diameter with 3/16 in. (preferred as abrasions are less frequent compared to smaller diameter) or ¼ in. steel cable clamped and stapled to the base of the tree so the cat cannot climb the tree with the snare. Branches of the tree are lopped off with a saw or an axe about 8 ft. up the tree so the cat cannot hang itself from a branch by the snare cable. An area of 5 meters or more is cleared around the snare site to eliminate potential leg fractures resulting from a fulcrum situation in conjunction to an adjacent tree (Duggins Wroe, pers. comm.) or torque on the leg bones caused by revolutionary twisting of the cable when the swivel is isolated by the foot-loop cable becoming wrapped around stout vegetation. Secure the snare to a solid anchor. Drags are not recommended as they could allow a captured animal to travel to an unsafe location, such as a cliff, stream, road, residential area or to climb a tree and hang itself.

Other modifications have been made to avoid capturing non-target animals. The trigger on the spring mechanism is positioned over a hole dug in the ground and filled with a 12 x 12 x 4 inch piece of high density foam. This foam prevents smaller animals from triggering the snare. Large branches are angled over the snare to force ungulates to jump over or go around the snare. The foot loop size of 10 in. (25 cm) dia. is set smaller than for a black bear. However, there is a possibility of catching a smaller-footed black bear (Duggins Wroe, pers. comm.). Bears will be drugged and released if caught. Any other non-target animals caught will be examined and treated for injuries and released with snare poles.

Snares will be checked as quickly as possible after sunrise every morning to reduce stress and possibility of hyperthermia or hypothermia, depending on ambient temperatures. Capture operations will be halted if ambient temperatures fall below 32°F or rise above 90°F over extended periods. Snaring for felids during extended periods of freezing ambient temperatures is not recommended because the animal’s capture foot might freeze (Logan et al. 1999) and would require continuous monitoring. Snares
will be checked at least twice a day when ambient temperatures range between 80–90°F. Continuous remote monitoring of snares (e.g., with radio-telemetry beacons) is recommended to minimize response time when ambient temperatures are more extreme. Adult lions will be immobilized with anesthetics delivered by jab-pole or projectile syringe as described previously.

**Delivery of Anesthetic Drugs via Projectile Syringe**

In situations where pursuit by hounds is not possible and snaring or trapping is difficult due to the high abundance of non-target animals, a lure may be used to bring a cat in close proximity to dart with a projectile syringe fired from a gas-powered projector. Lures may include a fresh kill made by the target animal, a deer carcass placed out as bait, or a predator call. A hound on a lead will be available to track the animal once it has been darted. If there is snow cover, the animal can be snow-tracked (as described previously). Alternatively a transmitter dart can be used to track the animal. The caudal thigh is the preferred target for the dart.

**Hand Capture Kittens**

Nursing kittens can be safely captured by hand or with a catch-pole at nurseries when they are 4 to 10 weeks old (Logan and Sweanor 2001). Nurseries can be located when radio-collared mothers are present, or by using GPS data from GPS-collared mothers. Wait for a time when the mother is away from the nursery, as determined by radio-telemetry, in order to capture the kittens. Kittens should be handled with clean leather gloves. They can be picked up and cradled in gloved hands (Figure 7, Appendix A). A catch-pole may be necessary to extract kittens from holes and crevices. Kittens should be contained together, or in pairs, in new burlap bags to allow ample air circulation (Figure 8, Appendix A). The kittens should be moved about 100 m from the nursery for examination and sampling to minimize human activity, disturbance, and odors at the nursery. Individual kittens that are being examined can be held in a separate burlap bag. Once the kittens are processed, they should be returned to the exact nursery, and the researchers should leave the area immediately. Burlap bags should not be re-used on other litters to eliminate the chance that pathogens might be passed from one litter to another.

Throughout this process, a receiver tuned to the frequency of the radio-collared mother should be constantly monitored. If it appears that the mother is returning, the kittens should be put back in the nursery immediately, and researchers should vacate the area.

Lynx kittens can be easily handled at their natal den from early May through the end of June (Fig. 11 and 12). After that time kittens are moved often between subsequent temporary den sites and soon begin accompanying their mother on foraging bouts and travel. No anesthesia is necessary or recommended for handling kittens. Den sites generally occur in thick, blow-down areas on steep slopes and can only be located by tracking a radio-collared female and/or plotting her GPS locations. It is easiest to locate a den (almost impossible otherwise) if the female is present at the den (in contrast to lions when it is advised to wait until the female leaves the den). Kittens are generally immobile and may or may not even have their eyes open. They can be handled near the den site, taking care to keep them warm on cold days. As with lions, kittens should be returned to the exact den site as quickly as possible, no more than ½ hr after they were first discovered. Attendant females may vacate the area while kittens are being handled, but they will often circle within sight.

**INJURIES AND EUTHANASIA**

If an animal is seriously injured (e.g. fractured or broken appendage, vertebrae, pelvis, or jaw, severe dislocation, laceration or any other injury that compromises its ability to survive and/or causes severe pain or distress) during capture or recovery, then it will be quickly and humanely euthanized. Animals will be
deeply anesthetized with ketamine, Telazol® and xylazine or ketamine and metetomidine (IV or IM) and euthanized via rapid IV KCl administration (400-800 mEq) or by a gunshot to the head or neck. Alternatively, if an injured animal cannot be handled, then euthanasia will be a gunshot to the head or neck with a >0.22 caliber magnum rifle or pistol.

As with all wildlife studies, handling related mortalities may occur, which may lead to orphaning dependent young. The following procedures will be followed for dependent young should they be orphaned by research related activities. Independence generally occurs at 11 months of age, so if orphaned young are estimated to be 11 months or older, young will be left alone or if captured, released on site. Orphaned lions between the ages of 6 months and 11 months have lower survival rates but have also been documented to survive in the wild (C. Anderson and K. Logan personal obs.). Therefore, in remote forest or wilderness situations no intervention is recommended. In rural situations young animals in this age group are likely to interact with humans and become a management issue requiring direct intervention. In these situations the Area Wildlife Manager will be consulted to determine the proper course of action which may be monitoring, rehabilitation, or euthanasia. Kittens less than 6 months of age have a very low probability of survival and the course of action for orphaned kittens in this age class should be specified by each research project, but the options include monitoring, rehabilitation, or euthanasia.

LITERATURE CITED

# Drug Dosage for Mountain lions, Canada lynx and Bobcat

Table 1: Drug dosage by weight for felids as recommended by CDOW veterinarian L. Wolfe.

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*Each M-K kit contains the following:

- #1, 10ml vial containing:
  Medetomidine HCl 5 mg/ml (50 mg total) & Ketamine 150 mg/ml (1,500 mg total)
- #1, 10 ml vial Atipamezole 25 mg/ml (250 mg total)
APPENDIX B.

Mountain lion and Canada lynx capture methods. (K. Logan, J. Ivan photos)

Figure 1. An anesthetized mountain lion cradled in the branches of a tree.

Figure 2. An anesthetized mountain lion could fall from this tree before a researcher could climb up to secure it with ropes.

Figure 3. Mountain lion cage trap designed by K. Logan with center pivot door.

Figure 4. Adult female mountain lion caught in the same cage trap baited with a mule deer carcass. Note radio-transmitter rigged on top near door to notify researchers that the door is closed.
Figure 5. Female mountain lion caught in Tru-catch Maxie D, baited with a mule deer fore-quarter.

Figure 6. Adult female mountain lion caught by foot-hold snare by her left fore-foot. Note safe zone around snare site.

Figure 7. Four-week-old mountain lion cub captured at nursery, requires no anesthesia.

Figure 8. Four-week-old mountain lion cubs held in burlap bags.

Figure 9. Lynx being released from custom box trap according to Kolbe et al. 2003

Figure 10. Lynx released from a CPW lynx trap, modified from Kolbe et al. 2003
| Figure 11. Lynx kittens found at dens generally weigh <600g and require no anesthesia for handling. |
| Figure 12. Lynx den sites are generally unexcavated spaces below dead trees in areas of heavy downfall. |
ANIMAL CARE AND USE COMMITTEE REVIEW

Date: ______ Signed: __________________________ Approved ____ Denied ___ (see explanation)
Reviewer, Animal Care and Use Committee

Date: ______ Signed: __________________________ Approved ____ Denied ___ (see explanation)
Reviewer, Animal Care and Use Committee

Date: ______ Signed: __________________________ Approved ____ Denied ___ (see explanation)
ACUC Attending Veterinarian

Date: ______ Signed: __________________________ Approved ____ Denied ___ (see explanation)
Chairperson, Animal Care and Use Committee

Updated ___________, M. Michaels