Mountain Lion Ecology in Rocky Mountain National Park

Summary Report 2004-2007

U.S. Fish & Wildlife Service
Rocky Mountain Cat Conservancy

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Acknowledgments

Foremost, we would like to thank the staff and management of Rocky Mountain National Park for granting us the opportunity to conduct this research. We consider it a privilege to work in a national park, where our skills are challenged for the benefit of wildlife and contribute to protecting a national treasure. Dr. Terry Terrell, retired former research director, made the initial invitation for our research proposal. Her steadfast support and encouragement helped us through the first few years when the study fell short of getting funded. Judy Visty, ROMO's current research director and assistant Cheri Yost inspired us to greater accomplishment through exceptional assistance at every turn, provided with genuine concern for the park, our study animals, and our personal safety. We were delighted that Terry and Judy were both present during the historic first capture. Dr. Mike Miller and Dr. Lisa Wolfe, Colorado Division of Wildlife (CDOW), gave freely of themselves and their incredible veterinary skills during many nights, weekends, and holidays. Often assisting were CDOW field technicians Michael and Tracy Sirochman. Also with CDOW, District Wildlife Manager Rick Spowart helped in the field and with his support. As the Estes Valley's highly respected wildlife ambassador and protector, Rick's favorable opinion of this study set a positive and professional tone for our interaction with ROMO staff and Estes residents. We thank all of our more than a dozen volunteers, with special thanks to Jayne Zmijewski for her tireless and continual help with telemetry monitoring. We would like to especially thank Eric Adams, executive director of the historic MacGregor Ranch, for opening up the ranch for research and often providing safe harbor for us and our horses. Similarly, Jeffery Youngbluth, manager of the Lost Antler Ranch, graciously assisted our study on behalf of the ranch owner.

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Executive Summary

This study launched a long anticipated scientific focus on mountain lions (*Puma concolor*) in Rocky Mountain National Park (ROMO). Objectives centered on gaining a better understanding of its general ecology, including its role as ecosystem modulator. A tragic death in the park and increased sightings brought into perspective also that mountain lions are on occasion dangerous, posing a real threat to visitors and staff. Even though this study fell short of its full term, it produced significant, new information that should help the park to better manage its mountain lion population.

All captured lions were in good physical condition. From the first animal collared, it became apparent that lions move freely in and out of the park, ranging throughout the Estes Valley and beyond. All study lions ranged outside the park and at least two traveled south nearly 90 km. Home range data on three lions, though not enough for strong statistical inference, showed significant territorial overlap for both males and females, possibly a reflection of abundant prey. Home range for the male was calculated at over 200 km^2, and the two female home ranges were calculated at 50-100 km^2. Results showed approximately a 2:1 preference for elk over mule deer, also typical for lions in a heavily dominant elk population. As elk numbers drop under the pending reduction plan mountain lions will shift toward a more substantial population regulator. Unfortunately, insufficient data were collected on abundance, prey preference, and kill frequency to determine this threshold.

Capturing mountain lions also proved difficult. It took two years and considerable effort to learn that baiting was ineffective, and snare sites were limited—though this is worth knowing. Improved capture success came late in the study, using off-trail snare sets in combination with a call box. This method also proved highly successful in a collaborative study in South America. Similarly, hound use came late to the study but holds promise for specific areas as shown by success in the nearby CDOW study. The high expectations of state-of-the-art Argos-GPS radio collars were never realized. On the contrary, the study suffered from faulty collars, vastly reducing the amount of data collected and requiring recaptures that added undue stress on study animals and the study team. However, history suggests that these technologies will eventually become more reliable.

Mountain lions studies are difficult, complex, and expensive and will never become less so, especially in the urban-wildlife interface. Property access, safety, liability, agency constraints, population growth, and differing public views on live animal studies will make it increasingly harder to mount these studies. Yet, conflict between humans and mountain lions in ROMO and along the Front Range will continue and likely increase. This study does not resolve the impending tension between lions and people, but it does show that with the adequate resources and targeted methods, such studies are possible.
Key words: ***mountain lion, ROMO, capture techniques, human-wildlife interface***

Chapter 1 - Introduction

Rocky Mountain National Park (ROMO) is famous for unmatched scenic grandeur of wild, mountain-alpine ecosystems. As the largest protected area in the region, surrounded by Colorado's rapidly growing Front Range, it has become a critical enclave for embattled wildlife, especially wide-ranging species such as the mountain lion. ROMO's mountain lion population faces an uncertain future, especially in the areas surrounding the park where habitat loss continues. As ROMO's apex predator, the mountain lion also regulates ecosystem dynamics, modulating the population of prey such as elk, mule deer, and bighorn sheep which in turn have an affect on vegetation.

In addition to being a critical link in natural western ecosystems, mountain lions bring another unique feature to national parks: as large, wild carnivores they are, on occasion, dangerous. Of only two human mortalities in the state, one occurred in ROMO in 1997. While most of the park's 3 million annual visitors like to know the mountain lion is "out there," it's the park's job to keep visitors and staff safe from harmful encounters. The park's 400 mi.² has no natural physical barriers such as large rivers at its borders that prohibit wildlife movement. As a result, park ungulates, the primary prey of mountain lions as well as this predator move freely in and out of the park, throughout the Estes Valley and south into Boulder County where human-mountain lion encounters documented are on the rise.

Rocky Mountain National Park -- Unmatched scenic grandeur of wild, mountain-alpine ecosystems.

Figure 1. Photo of Long's Peak in ROMO

Today in the park, elk are highly overpopulated, mule deer have been stricken by chronic wasting disease, and bighorn sheep teeter on a low unsustainable population. This combined with an increase in the frequency of mountain lion sightings over the past decade has led to the concern of park managers who struggle to find the right balance between fostering natural ecosystem dynamics and assuring pubic safety.

Mountain lions are charismatic, they are dangerous, and they are vital to a healthy ecosystem.

Prior to this research, the ecological role of mountain lion in the ROMO ecosystem had never been studied. Mountain lion research, including safety issues, is not an easy or inexpensive undertaking. Most mountain lion experts agree that research on these solitary and elusive cats demand a long-term commitment of at least seven to 10 years and typically cost about $100,000 per year. After four years of unsuccessful attempts at securing funds, this study, "Mountain Lion Ecology in Rocky Mountain National Park", was launched in 2004 with a six-year commitment of park funds. This report summarizes our results and findings from 2004 through 2007. Two significant events prompted the timing for an Interim report: Early in 2007 out year NPS funding and the continued support of USGS became uncertain. As an Interim report, we recognize data sets are small for what is needed as strong statistical inference. Given the future uncertainty of the study, especially at its present scope, we felt it necessary to present a comprehensive report, including personal observations, trial and error results, and heuristic opinion. We have tried to characterize our experiences and findings in a way that will aid park managers and others conducting similar research. A complete set of data will be transferred to ROMO, including raw telemetry data and camera trap photographs.

Chapter 2 - Background

A Brief Summary of Project Initiation

In 2000, ROMO solicited research proposals for mountain lion research in the park. For more than a decade park managers had sought to conduct research on the park's top predator, but cost and time commitment prevented any serious attempts. At the time, there were no studies anywhere in Colorado on the mountain lion and there had never been a study along the Front Range. On responding to the solicitation the principal investigator (PI) submitted a five-year research plan, detailing a park-wide study with a budget of well over 1 million dollars: "Distribution, Abundance, and Management Plan for the Mountain Lion (*Puma concolor*) in Rocky Mountain National Park." While unfunded in 2001, the proposal was modified and reduced in scope (east side of the park only) and cost and resubmitted in 2002 and 2003. With the commitment of ROMO's research staff the study was successfully funded in 2004. The study was launched with $50,000 in 2004 with a five-year minimum commitment of $25,000/year with potential $25,000/year matching from a non-government, "friends of the park" organization. The research staff realized that the funding may not be sufficient to complete all the work put forward in the proposal, but recognized the importance of taking the first steps to move the research forward with what ROMO was able to provide.

In addition, funds from other sources had greatly leveraged the research team. The PI had received more than $100,000 in grants from the National Park Monitoring Fund in 2002 and 2003 for a study entitled "Non-Invasive Monitoring Techniques for Mountain Lions (*Puma concolor*) in National Parks." With the ROMO park proposal pending, the PI learned of the Colorado Division of Wildlife's study "Testing for Selective Predation by Mountain Lions upon Chronic Wasting Disease-Infected Mule Deer." With many common objectives, these two studies and research teams merged in 2003, leading to the preparation of the successfully funded 2004 ROMO proposal now entitled "Mountain Lion Ecology in Rocky Mountain National Park." Under the combined studies, mountain lion capture would focus in and around the eastern half of ROMO but continue also in the northern Front Range. Merging the two studies made possible the array of field equipment needed to adequately take on this type of animal research. The CDOW not only contributed additional resources but also added valued expertise to our research team.

Field Equipment:
- 2 – 4WD Jeeps
- 2 – 4WD Trucks
- 2 – ATVs
- 30' Research Trailer
- Dart Rifle
- Dart Pistol
- Handgun
- Video Camera
- Digital Camera Traps
- 2 – Laptop computers
- 4 – GPS Units
- 4 – Mobile Radios
- 12 – Leg-hold Snares
- Drug Kit
- First Aid Kits (people& animals)
- 2 – Binoculars
- Capture Cage
- Horses and trailer
- Trained hounds

Research Team:
- Principal Investigator
- 2- Co-Investigators
- 2- Research Vets[1]
- Modeling Expert
- CDOW field techs[1]
- ROMO Volunteers
- CSU Engineering student

[1]as needed

Figue 2. List of research assets at start of study 2004

At the onset of the study in 2004, the study team was assisted by two research veterinarians, a full time researcher (and MS student), a capture specialist with more than 20 years of field experience, the PI with 15 years of cat experience (mostly central Asia), a Ph.D. modeler from the University of San Paulo, and a host of volunteers and part time field technicians. The members of this well qualified team were all eager to work on the project because of the historic lack of research and information on mountain lions. With similar eagerness expressed by the park's officials, the research team decided to proceed even though out-year funding was uncertain.

In hind sight, the decision to move ahead with the study would have unforeseen consequences for the study, the study team, and other scientists engaged in live-animal studies.

For more than two years the research study operated with adequate funds and field resources but was limited on its research methods. Sensitive to the issues of dogs inside national parks, using trained hounds, the preferred method of capture, was deferred until other methods were tried such as cage traps and leg-hold snares. By the winter of 2006, these methods were proven unsuccessful so the team was granted provisional permission to use hounds for the study. Though hounds were initially unsuccessful, our team had begun to experience increased capture success with a combination of snares and audible lures. Unfortunately, at the same time CDOW's study ended as well as support from the National Park Monitoring Fund, leaving the team with promising methods but short of any guaranteed, long-term funds. A summary of preliminary findings was submitted to ROMO in 2006 and posted on the project web site. This report adds greater detail to that summary, including other activities and accomplishments of the research team such as publications, presentations and community outreach.

A common syndrome of well-meaning but impatient scientists and managers is to adjust research scope to match available but inadequate funding, thinking under funded research is better than no research at all.

Since implementing this research, two other studies on mountain lions have begun in Colorado, one on the West Slope and a second that recently began in Boulder and Jefferson Counties. Both are sponsored and funded by CDOW, and have at least 10-year time horizons. The studies are relying on hounds as their primary capture method. The PI who started this study while in USGS has transferred to the U.S. Fish & Wildlife Service (FWS). The FWS has actively supported the continuation of this study.

"…under funded research is better than no research at all."

Figure 3. Picture of young mountain lion

Chapter 3 - Objectives (the full study plan is on file with ROMO)

The objectives for this study morphed slightly over time as each year of effort produced a different set of management and field conditions. To a large degree, there are few "research questions" posed in a general ecology study that call for traditional hypothesis testing. But rather, this study and the needs of ROMO called for "on-the-ground" professional fieldwork that was well documented and analyzed**.** And given a six-year immediate timeframe, mountain lion studies seldom produce sufficient data for rigorous, statistically supported hypothesis testing. Every effort has been made to produce meaningful products annually that support management needs but also feed into the growing body of scientific knowledge of mountain lions in ROMO and con-specific cats worldwide.

Primary Objectives:

1. Estimate the abundance and distribution of ROMO's mountain lion population (east side only).
2. Characterize and quantify the mountain lion prey and predation rates in ROMO (including testing for selective predation by mountain lions on CWD-infected mule deer and elk).
3. Survey human attitudes and perceptions of park staff, visitors, and local residents toward the mountain lion.
4. *Develop and test mountain lion spatial models, including human-mountain lion interactions, potential habitat, and prey preference.

   *Modeling is perhaps the most non-invasive form of wildlife censusing but as we learned early on it requires a skilled modeler to build and parameterize a model. Additionally, wide-ranging, opportunistic hunters are difficult to simulate in models. Dr. Katia Farraz with the University of San Paulo conducted most of the modeling work as a volunteer but unfortunately, after she returned to Brazil the modeling portion of this study received little attention.

Another objective not listed in our primary study plan and treated somewhat separately is the development and testing of a safe and efficient capture cage. We have appended a separate report "Building a Safe and Effective Cage Trap for Capturing Mountain Lions (*Puma concolor*) in National Parks (Appendix I).

Chapter 4 - Study Area

The study area was limited to the eastern portion of ROMO, roughly the Estes Valley to the Continental Divide and south to the Larimer County border; the overall area is approximately 350 km². Adjacent areas outside the park boundary may be included depending on movement patterns of the collared mountain lions included in this study (see Figure 4).

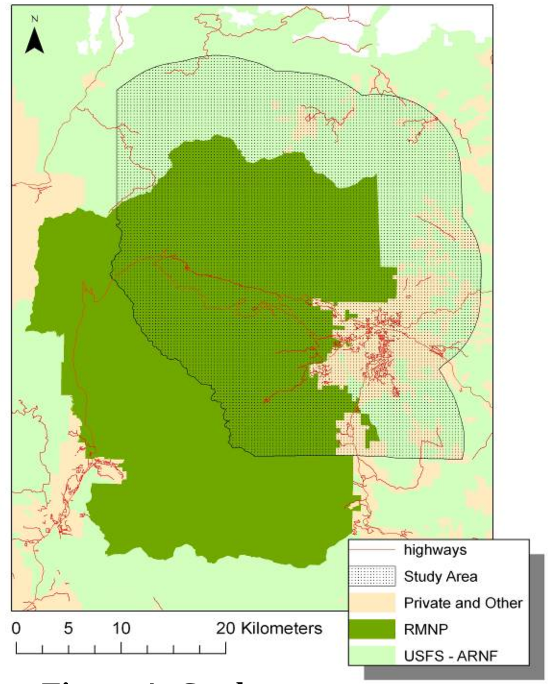


Figure 4. Study area

The study area presents an array of terrain and a quilt-like pattern of land ownership. In contrast to contiguous wildlands, the mountain lions in this study have ranges that include a national park, a state park, county parks, city parks, a national forest, and an assortment of private land from large ranches to city neighborhoods. While this vast area may appear open for study, in reality only a small percentage of the overall area is available and accessible, especially with regard to capture opportunities.

Habitat varies with elevation in the study area. Sagebrush (*Artemisia tridentate*) grasslands transition to the ponderosa pine-mountain mahogany-shrub (*Pinus ponderosa-Cercocarpus montanus*) foothills community at approximately 1,500 meters (5,000 ft.). Ponderosa pine communities transition to spruce-fir (*Picea engelmannii-Abies lasiocarpa*) stands in progressively higher terrain. Spruce-fir transitions to alpine tundra and high mountain peaks at more than 4,270 meters (14,000 ft). The lower and middle plant communities are considered very good mountain lion habitat, with the higher areas being intermediate in quality.

Relative to studies in other areas of the West, prey numbers in the study area are moderate to high. While most of the literature on mountain lions does not include actual estimates of deer density, parts of the Colorado Front Range can arguably have deer densities exceeding those found by Logan and Sweanor (2001) in the San Andres Mountains of New Mexico, and likewise may have lion densities at the higher end of the spectrum. On the other hand, areas that have undergone deer population reductions support lower levels of lions, deer and elk. Relative to other parts of the Colorado Front Range, overall ungulate densities are moderate with localized areas of high concentration in ROMO.

Chapter 5 - Methods

To achieve the objectives of this study, we concluded it would necessitate the capture of ≥90% of all mountain lion in the ROMO east side study area. Our original plan called for the majority of the capture work to take place in the first two years. Per ROMO direction, all other capture methods were utilized before hounds were permitted to assist in lion capture. Thus, the first two capture seasons focused on snaring and baiting cats to a capture cage. In addition, the research team choose a telemetry company, Habits (cite), that had just begun producing lighter weight GPS-Argos collars, under 500 grams and suitable for medium to large cats. Downloadable collars were necessary for meeting our research objectives, especially precise location information on prey. After considerable deliberation and research of other collars we made this choice based on the overwhelming potential savings in field time and expense. We also talked with many of our colleagues to gain their insights into quality and reputation of different collars and manufactures. We went through similar deliberations in choosing the remote cameras and call boxes needed for the study.

The following outlines the types of capture methods used for mountain lion research.

<u>Capture Methods – Hounds</u>
Though there had been no previous studies of mountain lions in ROMO there had been several prior studies in western Colorado and an ongoing study in the Medicine Bow mountain range near the Colorado-Wyoming border. All of these studies relied on hounds as the primary capture method. Co-PI, Duggins Wroe was the houndsman for the Wyoming study, a Ph.D. project of student Chuck Anderson and advised by Dr. Fred Lindzey with the Wyoming Coop Unit. The research team also consulted with Dr. Kerry Murphy who had recently completed what is considered a hallmark study of mountain lion in Yellowstone National Park that relied on trained hounds. Dr. Murphy was strongly in favor of using hounds in ROMO but was also aware of the general aversion toward hounds by most national parks.

On using hounds, Dr. Terry Terrell, research director for ROMO, at the onset of the study made it clear to us that park management was generally not in favor of using hounds inside the park, requiring that we first exhaust all other means of capture before hounds would be considered. This condition shaped the capture efforts of our first two field seasons.

After two years of very poor capture success, the research team made a case to park management that without hounds it would be impossible to meet any of our research objectives. Late in the winter of 2006, park managers granted the team permission to use hounds under the “provisional” conditions that prior approval would be required and that areas near the main roads through the park would be off limits. It was late February before the weather conditions and readiness of our team fell into place. Winter use of hounds calls for specific conditions: a light to moderate snow that ends by mid-day so that trackers can spot tracks and call in the hound team in time to put the hounds onto the fresh tracks. Prior to our first use of hounds we also had to train and coordinate a crew of volunteers who would visit specified routes looking for tracks and report back to us.

Capture Methods – Snares
Wroe's early assessment of ROMO's terrain concluded that the most advantageous locations for snares were along footpaths used for hiking. Also, the optimum snare sites takes advantage of natural terrain squeeze points where cats and prey are channeled into a narrow "pinch" that can be further channeled with brush, directing the cat even more precisely to the snare. These optimum sites are limited in the park and in most cases are where hiking trails are located. Snares cannot be used in snow conditions, adding a temporal limit to this method.

Capture Methods – Cage
Though hounds were our preferred method of capture, we were hopeful alternative methods, especially baiting mountain lions to our new capture cage, would provide satisfactory capture results. The research team learned of this method first hand from Dr. Ken Logan, newly-hired mountain lion expert with the CDOW, when he visited and toured our study area in the summer of 2003. He had just concluded a study in California, which revealed that mountain lions readily scavenged deer carcasses placed in strategic locations. Once a cat finds the carcass and begins feeding, the carcass is then moved into a capture cage and the returning lion is generally caught the same evening. Given Logan's success in California and optimism for similar results in ROMO, we moved ahead with baiting efforts. Also per Logan's advice and the advice of animal control specialist James Shuler with APHIS, who designed the capture cage used in California, the research team decided to design and build a more advanced and safer cage with the idea that other parks might benefit from its use. Further discussion on this cage is provided in Appendix II.

In addition to selecting a capture method, the team also needed to purchase other equipment necessary for the proposed research. The larger items purchased included collars, cameras, and call boxes. These are described in detail below.

Technology – Collars
There is no single or reliable source of information on animal radio collars, so each researcher must conduct their own investigation on collars and make their own choices specific to their own projects needs. Like others, the research team consulted with colleagues, read journals, and talked directly with manufacturers before choosing our collars. Researchers with the CDOW chronic wasting disease study were using Lotek downloadable GPS collars at about 900 grams. These researchers were the first to use downloadable collars on mountain lions, a necessary feature to locate kill sites in a timely fashion. At about the same time we were evaluating collars for this study, Lotek reduced the size of its collar to less than 500 grams. However, our analyses lead us to another company, HABIT Research Ltd. that advertised Argos-GPS collars, at fewer than 500 grams for about the same price as the Lotek collars. The Argos addition to downloadable GPS collars meant that the data would be automatically uploaded to a polar orbiting satellite then transferred to the team's work computers, thus greatly

reducing time in the field attempting to locate study animals. Given the nature of this study, (within the boundaries of a national park with limited access), the team believed this was a powerful feature because it greatly reduced our time traversing the park. These particular collars were advertised to have the duel download capability, using Argos satellites, as well as a VHF transponder, activated downloads similar to the Lotek collars (which served as a backup should the Argos feature fail). The research team decided upon the Argos-GPS collars and purchased only two at the onset of the project because they had not been previously used on mountain lions.

From our experiences and after discussions with many colleagues it appears wildlife researchers are especially susceptible to manufacturer rhetoric, promising more than they can deliver on unproven or little tested devices.

For this study we concluded the GPS-Argos satellite collars produced by HABIT Research Ltd (Victoria, British Columbia; www.**habitresearch**.com) were best suited to meet ecological objectives and minimize field activities in a national park. Two collars were ordered with the following technical specifications: 1. Weight less than 500 grams; 2. Frequency range 150-152 MHz; 3. Functional life of 1.5 years; 4. GPS data (20 sets) sent via PTT every 2 days; 5. Upload two hours on 49 hours off; 6. VHF location on 6am to 10pm; 7. last 20 GPS data sets transmitted every other day for two hours. Each collar cost about $3,500 and receiver $2,000.

Technology – Cameras
With a proliferation of remote cameras on the market, several type and models were purchased. For remote cameras traps we used Camtrakker www.**camtrakker**.com, Trailmaster www.**trailmaster**.com, StelthCam www.**stealthcam**.net, and Osprey www.fairchildimaging.com. ROMO purchased a remote video camera set up; a Sony video camera attached to heat/motion sensors and camera housing made by Camtrakker.

Over the course of the study from 2003 through 2006, we established more than 24 sites for camera captures. Sites were selected based on one or more of the following characteristics/criteria: presence of lion sign, animal travel corridor, lion kill site, or desired lion capture site. Some camera sites were set in combination with lures. Lures included visual (hanging metal plates, hanging deer hide), commercial scent lures, and audible call box (deer fawn distress, lion kitten, rabbit distress, male lion aggression).

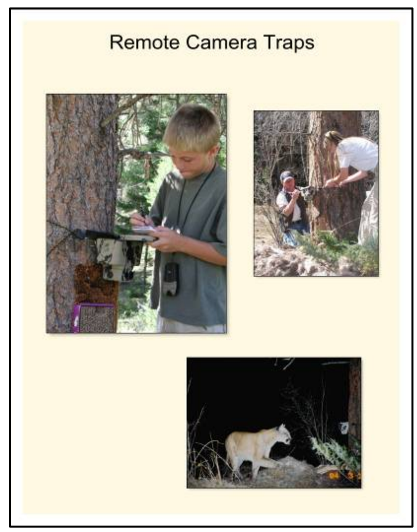


Figure 5. Photos of setting camera traps and one lion photo from a trap

Technology – Call Box
Our research on wildlife calls led us to Wildlife Technologies (www.widlifetech.com), a company that specialized in wild animal vocalizations. They produced studio grade calls packaged in solid state equipment. We purchase two systems from this company and used them extensively in this study and in collaborative studies in Brazil and Peru.

Chapter 6 - Results

Captures- Hounds

Trained hounds were used in the park on four occasions in 2006; all four were attempts at recapturing Female 207 whose Habit radio collar was malfunctioning. Though hounds were unsuccessful at treeing Female 207, we must note the extenuating circumstances: Foremost among the circumstances/conditions of using hounds in the park would be to acknowledge the extreme rugged terrain of Cow Creek and Lumpy Ridge. Lumpy Ridge, known for world class rock climbing, presents formidable conditions for hounds (and humans). The extreme terrain impedes the pace of a dog chase. Mountain lions tend to tree only when pressured by "heated" pursuit. On Lumpy Ridge, Female 207 could move much easier through the terrain than the hounds. Also, each use of hounds was attempting to tree the same cat, an adult female who, like us, learns from each chase. Professional houndsmen agree that adult females are the most capture savvy of all age and sex groups.

Our results constitute a very small data set with very little inference value and should not be interpreted as a defining judgment against using hounds. Like technology failures, the research team views our unsuccessful hound chases as another set of experiences to learn from; such experiences deepen our respect for the animal and for the difficulty of the job at hand. The research team had many successful chases outside the park and virtually all of the approximately 350 mountain lions harvested each year in Colorado are with the use of hounds. Dr. Kerry Murphy's successful study of mountain lions in Yellowstone also suggests hounds can be used without incident in national parks. The Boulder County study, not too distant from ROMO, safely captured 15 animals in 45 days with 10 receiving radio collars and demonstrates the value of using trained hounds as a capture method for mountain lions.

Of the concerns raised by ROMO regarding the use of hounds on park service lands, it is important to note that no hounds were lost, no visitors were encountered, and there were no noise complaints. The team received exceptionally helpful responses from the several landowners around the Carlson home and worked very smoothly with park dispatch and ranger staff in this effort. With a little more experience and with increasingly better trained volunteer trackers, the research team believes the use of hounds in the park could be performed smoothly and without incident.

Mountain lions studies can be very humbling: from methods that fit nicely on a sheet of paper to a rocky, snowy, ledge and vanishing tracks.

Captures – Snares
A second capture of an adult female (Female 207, 4-6-year-old) took place just outside the park using a leg snare in September of 2004. The female was fitted with a Lotek GPS collar. The collar had a drop-off mechanism that should have deployed by September 2006.

We captured three more adult lions on private property just outside the park in 2006. A 4-6-year-old male (Male 208) was captured in April in a leg snare off an elk kill and fitted with a Lotek GPS collar. He was killed by a landowner four months after capture in a depredation incident.

A 2-year-old female (Female 209) was captured in an off-trail leg snare using a call box lure in July. She was fitted with a Lotek GPS collar. She is currently still collared and being monitored, however her collar is transmitting a low battery signal and therefore not collecting GPS data.

A 2-year-old male (Male 297) was also captured in an off-trail leg snare using the call box in October. He was fitted with a HABIT Argos/GPS collar. Unfortunately, the Argos portion failed early on. No signal has been received in several months, and a complete collar failure is suspected.

Three sub-adult lions were captured between 2003 and 2006. Two male sub-adults were captured in leg snares just outside the park and fitted with ear tag transmitters. Both animals left the study area within four weeks after capture. One was harvested south of Evergreen, CO (more than 60 miles away) several months later. The third sub-adult was captured in the cage trap and released without handling.

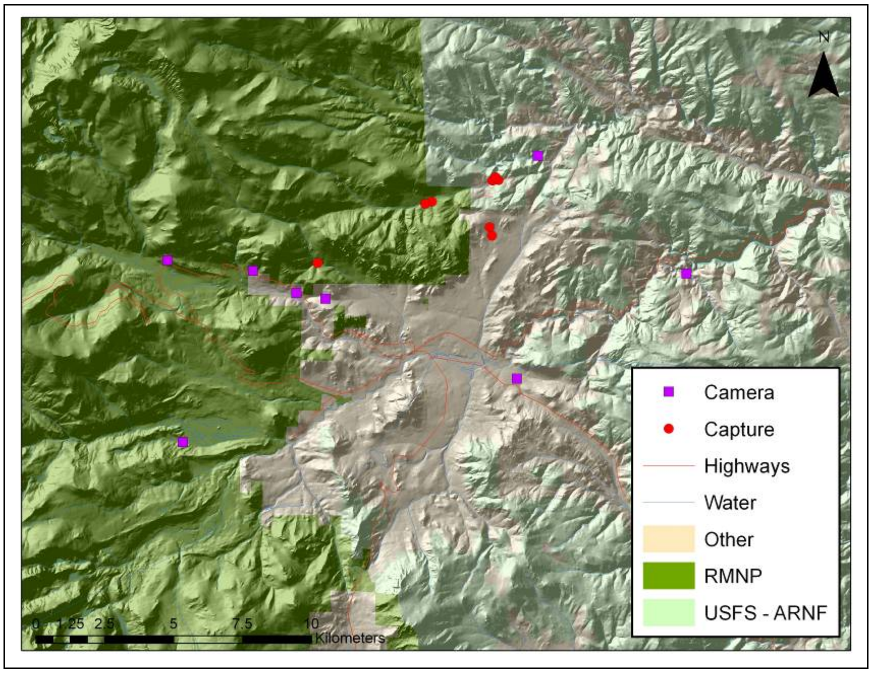


Figure 6. Map depicting locations within study area of mountain lion captures and camera trap captures

Shortly after our trial use of hounds in ROMO, two adult males were captured on Bobcat Ridge within a week of using a call box to lure them into snares. Call lures appear much more promising than baiting as results showed 170 bait nights produced no adult capture. This approach, while successful in other regions, seems ineffective where natural prey is over abundant.

<u>Captures – Cage</u>
The first capture of a mountain lion in ROMO was in February of 2004 and involved an adult male (Male 399, 6-8-year- old) captured in a cage trap off an elk kill along the Cow Creek Trail, within the park's boundary. He was fitted with a VHF collar to ensure that he was a resident male. Once residency was established, the research team recaptured him using hounds outside the park and fitted him with a HABIT GPS collar. The GPS collar is thought to have failed, however recent photos from remote cameras have confirmed that he is still in the study area. The cage used to capture Male 399 was a CDOW cage designed for capturing bears. For future captures we felt this design was unsafe for research animals and began a new cage design study with Colorado State University (see Appendix II).

Through two seasons of effort we learned that neither optimism nor baiting can lead to the successful capture of mountain lions. We speculate that the lions of ROMO disinterest in baiting may be associated with an over abundance of ungulates. The mountain lions in our study area simply don't need to scavenge, even in winter.

2004

Type	**Locations**	**Days of Effort**	**Results**
Snares	**6**	**72**	**1 (Female 207)**
Cage Trap	**4**	**22**	**1 Male (Male 399)1 kitten in Cow Creek**

2005

Type	**Locations**	**Days of Effort**	**Results**
Snares	**8**	**84**	**0**
Cage Trap	**5**	**12**	**0**

Table 1. Breakdown of capture effort for the first (2004) and second year (2005) of the study.

<u>Technology Results and Summary</u>

<u>Technology - Collars</u>
On Dec. 2, 2004 the research team received two collars hand delivered by HABITs' chief engineer. One collar was put on a llama owned by the PI to observe and test its performance. Both collars failed to communicate with the Argos satellites and were sent back to the company with the assurance that two new collars with added features would be quickly returned. Since it appeared only the Argos part of the collar wasn't working

we asked for and received the old collars for use as interim collars. We tested these collars thoroughly before putting them both out on mountain lions in April of 2005. By June both were mostly non-functional for obtaining GPS fixes but both continued to transmit a VHF signal. In the meantime, the replacement collars arrived and were similarly tested before putting them on study animals. The first collar worked well for hours in the research truck just before we deployed it on our study animal. Once deployed, however, it never transmitted to the Argos satellites and transmitted data via VHF signal only once. A week later we recaptured a male outside the study area, retrieving the first generation HABIT collar. Its external VHF antenna had been sheared off at the tip of the conical base of glue where the antenna exits the collar, thus rendering the collar useless. Speculating an antenna design flaw HABIT agreed to modify our last collar, channeling the antennas differently, instead of out the tip. Fully tested by HABIT and ourselves, we put this collar on an adult male on Oct. 14, 2006. The VHF portion of the collar worked right away but, disappointingly, the Argos transmissions didn't occur until about two weeks after deployment. This last collar functioned for several months as it was designed, then transmissions to the Argos satellites began to decrease then stop altogether.

The HABIT collars were field tested on llamas before used on mountain lions

Figure 7. Photo of collar on domestic llama for testing

Needless to say, collar failure is extremely frustrating, costly, and subjects study animals to a higher risk from multiple captures. Our experiences, however, are not altogether unlike the "normal" experiences of other live animal studies. A colleague in India, just undertaking a major tiger study shared his frustration with the same company and collars we chose for this study: Of 10 Argos-GPS and 15 GPS collars, he experienced 90% failure within a month of deployment and 99% within 6 months.

For the short time this collar worked as designed, the benefits and efficiencies were impressive—from our computers each morning we could monitor the precise location and movement of our study animal.

Technology – Cameras

Overall, we obtained 349 photos of mountain lions and 260 photos of non-target animals. Non-target animals included bears, elk, deer, coyote, fox, skunk, mouse, and a variety of birds.

Technology – Call Box

The call box proved to be a very valuable aid in snaring. Only through trial and error did we lean how to effectively integrate the call box with snaring and visual lures in order to "lead" animals away from commonly used foot trails. We also used the same type of call box with our collaborative studies in Brazil and Peru. It was exceptionally successful in Peru where it advanced capture success from one animal/year to five animals in one month. This level of improvement in capture success points to the need for more research on audible lures.

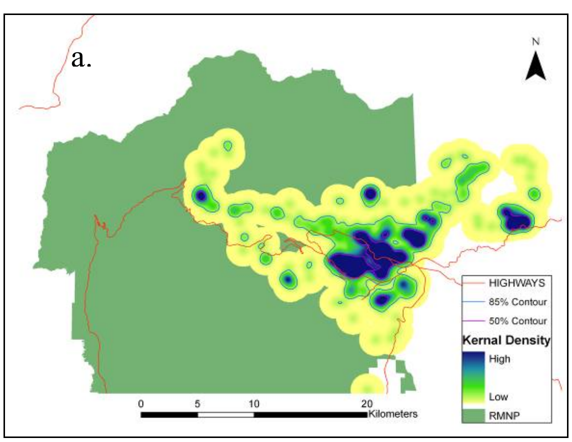
Methods for Telemetry and Home Range Analysis

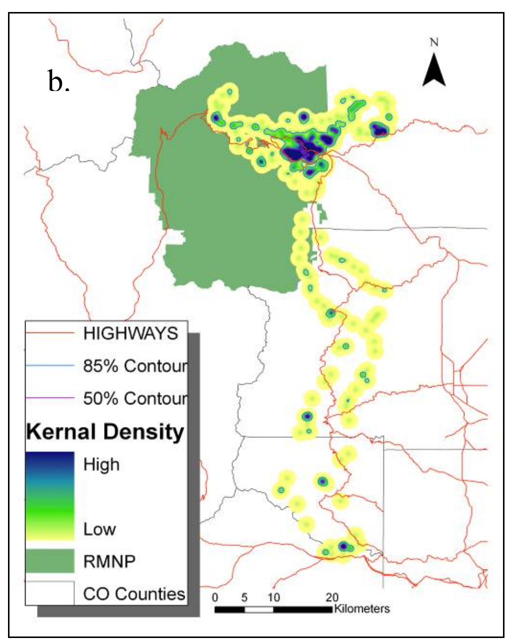
Telemetry Analyses

GPS Data. Of the five lions collared with GPS collars, GPS data was intermittent from animal to animal due to difficulties with technology, the animals' habits, rugged terrain, and limited research resources. When data were available, GPS locations were used to estimate home ranges, determine travel corridors and movement patterns, and locate kill sites. All collars were programmed to attempt to obtain a minimum of seven GPS locations per day. Due to limitations in the technology, however, this was rarely the case. The success of GPS acquisitions varied from collar type, time of day, and the individual animal. The GPS data we have collected have been used to estimate home ranges and determine and locate kill sites.

Home Range Analysis: A wide variety of methods exist for estimating an animal's home range, including minimum convex polygon, bivariate ellipse, and fixed kernel. More often researchers are using fixed kernel for analyses (Seaman and Powell 1996). Kernel estimators are based on probability "kernels," which are regions around each point (GPS location, in our case) containing some likelihood of animal presence. The width of the kernel is based on a smoothing parameter or bandwidth (h). For our data, we used h=500m and h=1000m based on the distribution and clustering of the GPS data. Using an animal movement analysis extension in ArcGIS, the research team calculated contour lines at 50%, 85%, and 95% fixed kernel home ranges. The research team reports the 50% home range as 'area of care utilization,' 85% home range as 'area of ecological importance,' and the 95% as 'total area used.' A grid cell size of 35 m x 35 m was used and based on analyses done in other mountain lion home range studies (Dickson and Beier 2002).

Figure 8. Image showing kernel density analysis for Female 209 (a.) zoomed to core home range (b.) over extent of use area.





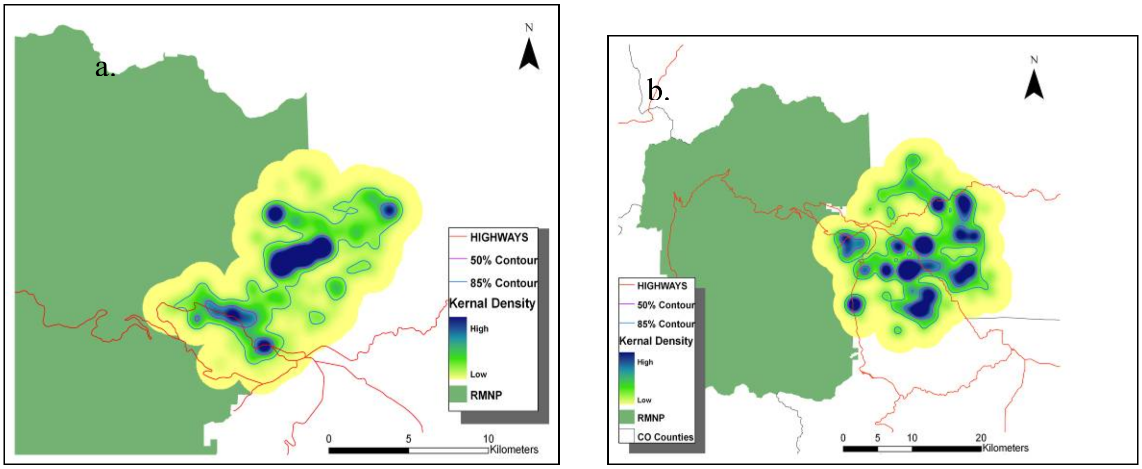


Figure 9. Image showing kernel density analysis for Female 207 (a.) and Male 208 (b.).

	Female 209	Male 208	Female 207
Months of collar data	**8**	**6**	**7**
Number of locations	**998**	**479**	**662**
Grid size (m)	**35 x 35**	**35 x 35**	**35 x 35**
Bandwidth (m)	**500**	**1000**	**500**
50% contour (km^2)	**21.616**	**72.644**	**11.048**
85% contour (km^2)	**101.324**	**221.063**	**44.184**
95% contour (km^2)	**197.307**	**330.237**	**71.065**

Table 2. Results of kernel density analysis for data from 3 collared lions.

Results of Telemetry and Home Range Analysis

Home Range Analysis: The 85% and 50% core home range was less for the two females than the male (Table 2). Male 208's 85% home range and area of ecological importance was more than double Female 209, and more than five times the area of Female 207. Some of the differences in home range estimates are due to the total amount of data collected and the number of months collared. Males typically have home ranges that are 2-4 times larger than those of females in the same area. The home range estimates for Female 209 include a three week "wandering" period where the lion traveled more than 90 linear kilometers before returning to her core area and typical home range. In order to produce statistically valid estimates of home range, multiple years of data for individual lions would need to be collected. The research team would also examine using a smoothing level selected by least-squares, cross-validation (Seaman and Powell 1996) and examine more rigorous analyses to account for clustering of data.

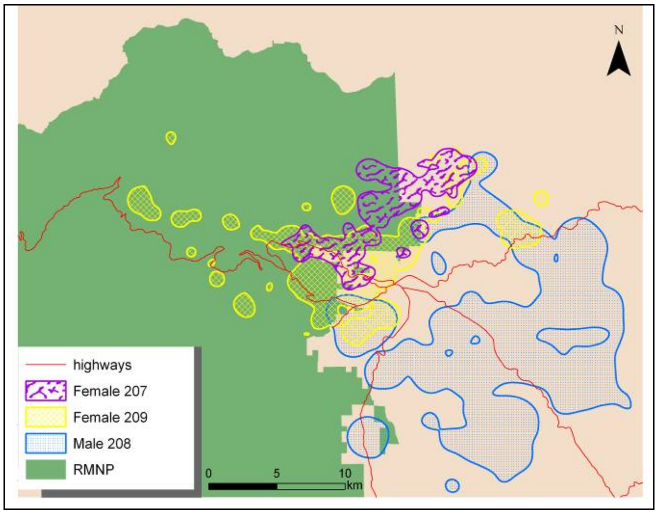


Figure 10. Map showing overlap of 85% contour home range of Female 207, Male 208 and Female 209.

Telemetry Results: Kill Site Examination: The research team used radio-telemetry to locate GPS-collared mountain lions on the ground. Attempts were made on a weekly basis, at minimum, to locate individuals. GPS data was obtained through remote download whenever possible. Individual data points were plotted in ArcView® (Environmental Systems Research Institute 1999), and we used cluster analysis (Anderson and Lindzey 2003) to determine locations of possible kill sites. A cluster was defined as >2 location data points within 200 m within a 24-hr period. Once a cluster was identified, a circle was drawn to include all points in the cluster. The research team then used the location of the center of the circle to attempt to locate the kill site on the ground using a handheld GPS receiver. If no kill was located at the center of the cluster, the research team searched for prey remains and mountain lion sign by walking transects 5 m apart and up to 200 m from the center of the cluster. Characteristics (such as vegetation, aspect, slope, terrain, and distance to human activity) of each site searched were recorded. If prey remains were present, the team recorded the percentage of carcass consumed, species/age/sex of prey, and evidence of scavenging. Physical condition of the prey prior to death was also determined, if possible, by examining bone marrow from a long bone (Zar 1984). In addition, evidence of mountain lion presence such as caching of the kill, scat, scrapes, and tracks was also recorded. If the prey killed was a mule deer <1 year of age samples were collected, when possible, to test for chronic wasting disease

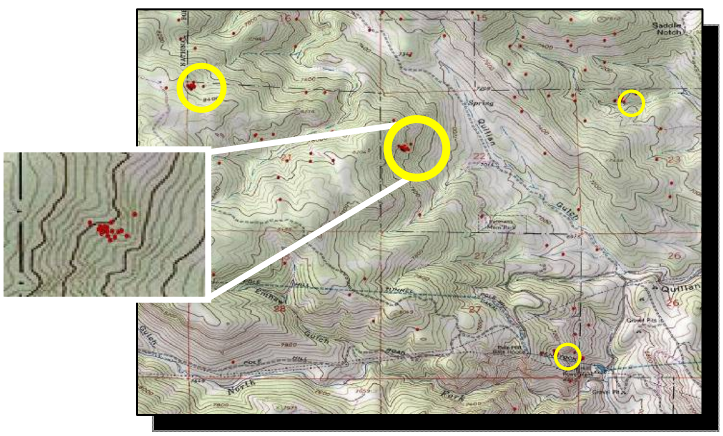


Figure 11. Map showing GPS data from one collared lion to demonstrate identification of clusters (inset) to find kill sites.

(CWD). When present, brain stem, tonsils and retro-pharyngeal lymph nodes were collected and teeth were taken for aging. Diagnostic methods to test for CWD are described elsewhere (Miller et al. 2000, Miller and Williams 2002, Wolfe et al. 2002, Hibler et al. 2003).

Kill Site Results. The research team was able to investigate more than 60 clusters for all five GPS radio-collared lions. Only 25 of those sites had identifiable kills present. Other clusters were either not kill sites, too old upon investigation to have any kill remaining, or the kill was overlooked at the site. Table 3 presents the number of kills located by lion and by prey species (MD F = mule deer female, MD M = mule deer male, MD>1 = mule deer fawn, E F = elk female, E M = elk male, E>1 = elk calf, BHS = bighorn sheep, Other = other species). Mule deer comprised only 32% of the total kills, where elk, at 56%, comprised of over half the total kills. Samples for testing for CWD were taken at all adult deer and elk kills. Results of these samples will be presented in an upcoming publication.

	Female 207	**Female 209**	**Male 208**	**Male 399**	**Male 297**	**TOTALS**
MD F	**2**		**1**			**3**
MD M			**1**			**1**
MD >1	**2**	**2**				**4**
E F	**3**		**2**	**1**	**1**	**7**
E M				**2**		**2**
E >1	**4**		**1**			**5**
BHS	**1 (ewe)**					**1**
Other	**1 (raccoon)**	**1 (rabbit)**				**2**
TOTALS	**13**	**3**	**5**	**3**	**1**	**25**

Table 3. Results of kills by species for all 5 collared lions

Other Results

Community Outreach: In an attempt to communicate and collaborate with other mountain lion researchers and projects the research team prepared a web site and established the Colorado Mountain Lion Research Group (CMLRG) in 2004. The Web site and CMRG remained active up until when USGS dropped its support of the study in February of 2006. The CMLRG concept was an attempt to broaden the collaborative, informational, and funding raising efforts of Colorado's mountain lion research groups. The research team received positive feedback from the web site and though many agreed to the principles outlined in the CMLRG mission statement, no single group emerged to lead the multi-agency funding proposal. With several new studies getting underway in Colorado and human-mountain lion encounters persisting, the research team believes CMLRG or a similar group is needed to coalesce research-management interests and to reach out to communities. The newly formed Rocky Mountain Cat Conservancy (www.catconservancy.org) holds promise as an agent of support for continuing this research and other related studies.

Significant Events/Presentations: As a research team, we share the belief that research in a national park is a privilege and that part of our job is to covey our knowledge and experiences with park staff and the community at large. From the beginning of this study, we cannot recall any one member of our team turning down an opportunity or request to give a talk or write a report. Many park staff and Estes' residents have reached out to help our work, freely allowing property access and other means of support. Without the support of several prominent landowners in the valley we would have faced even more difficult conditions in our capture efforts. Our interaction with park staff and the Estes Park community provided us with many unexpected positive experiences. At the request of ROMO we participated in the filming of an Animal Planet series entitled "Get Out There." The nature-reality program filmed outdoor neophyte families enjoying the wonders of a featured national park. We spent two days with the film crew and family filming segments of a family learning about this study.

For the past three years, we have conducted a two-day seminar on mountain lion ecology in the park sponsored by the Rocky Mountain Nature Association (RMNA). Each course, filled to capacity, reported the highest regards for course content and instructional competence. In addition, participation in the Animal Planet "Get Out There" program helped shed a positive light on ROMO and our research. From talks and programs up and down the Front Range to that few extra minutes with an interested landowner, we have strived to promote an awareness and understanding of what our research is all about and its value to conserving and managing mountain lions for the long-term.

During the winters of 2005 and 2006, we engaged over a dozen ROMO volunteers to help with snow track surveys. All volunteers underwent field safety and track identification training prior to the field work. Pairs of volunteers were assigned "routes" (trails or roads within or bordering the park). The teams hiked or drove their routes after fresh snow, documenting, identifying, and measuring tracks encountered on those routes. Data forms were collected by the research team and entered into a central database. Over the two winters, the volunteers went out on 13 separate occasions, covering 10 different routes. They covered a total of 12-20 linear miles on any given field day. A total of seven mountain lion track sets were identified by our volunteers. This information helped us to target areas for capture and camera traps, as well as provided additional data for future population analysis.

Other presentations and accomplishments and are noted in Appendix II.

Chapter 7 - Discussion and Management Recommendations

Field Equipment:
2 laptop computers
2 NPS receivers
Research Team:
Principal Investigator
One Co-PI
Volunteers

Figure 12. List of research assets 2007

With only three full years of effort[1] and five study animals, this study fell short meeting its objectives. It suffered setbacks from faulty technology and unsuccessful capture methods in the first two years. Without an earnest effort, however, we would not have learned that baiting doesn't work in ROMO. From the onset, we learned that mountain lions move freely in and out of the park. The interaction of the study team with the surrounding land owners galvanized community support for ROMO's first study of the area's top predator. And in spite of setbacks and funding shortages, this did succeed in revealing a great deal of new information about mountain lions in ROMO. We now know they eat elk and deer and at least on one occasion bighorn sheep. We know ROMO's mountain lions move great distances—more than 60 miles—and have home ranges that extend outside the park, making ROMO park "management" of this species a collaborative effort with the Estes Park community. We've documented several females with three litters and overlapping home ranges of males and females, a possible indicator of a healthy population. All of the cats captured were in good health and physical condition. And we learned capturing cats in ROMO is not easy but the use of hounds, a new way of snaring and advances in cage technologies holds promise. There is also a lot we still don't know: Where do ROMO cats migrate to? What are age and sex ratios? Average life span, average litter size, diet, and so forth. We cannot say also with any certainty what ROMO management should do or not do to improve the management of the species and better ensure the safety of its visitors and staff. Thus, with considerable more research needed we offer the following recommendations:

1. Continue monitoring the existing study cats for as long as possible. Re-capture all cats with inoperable collars and replace with new collars—only with adequate funds and NPS commitment to assure monitoring through the life of the collar.

2. Continue winter track surveys aided by volunteers and park staff as means of estimating a minimum population estimate (maybe extend to the west side, as well).

3. Support the continuation of this study, allowing an appropriate combination of capture methods, including trained hounds (the use of hounds in the Boulder Country study indicates the capture targets of this study can be achieved with a combination of hounds in the winter and snare-lure combination the rest of the year).

[1]Research progress stalled in February of 2007 from disruptions caused by the PI's transfer to the U.S. Fish and Wildlife Service (FWS) and subsequent closing-out of U.S. Geological Survey (USGS) participation in the study. The loss of USGS support severely limited day-to-day monitoring and prevented recaptures for collar replacement/upgrade.

The study team remains committed to the project and the belief that live animals studies are vital in the early stages of autecological discovery. We're equally committed to the notion these studies should take place only under conditions of full funding and full agency commitment through the life of the study: No animal should be collared unless there are adequate funds and agency commitment though the life of the collar, including re-capture, if necessary. While not an indictment against government funded studies it is worth noting that well-intentioned people move on and agency priorities change.

Difficult, dangerous, and costly—no doubt studies of mountain lion will become increasingly harder to mount, yet the need for such studies grows as human encroachment continues to restrict these large predators to the few remaining islands of refuge such as ROMO.

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Appendix I: Building a Safe and Effective Cage Trap for Capturing Mountain Lions (*Puma concolor*) in National Parks

Abstract: Recent evidence suggests cage traps can be used successfully for live-trapping mountain lions (*Puma concolor*). Traditional capture methods such as foot-hold snares and hounds are becoming less acceptable methods in national parks. However, current cage designs, used mostly for removing problem animals from urban settings, are outdated, having limited mobility and inadequate safety features. This study focused on building and nominally testing two cage designs.
Key words: *mountain lion, Rocky Mountain National Park, capture techniques*

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Purpose and Need

Mountain lions occur in over half of the 200+ national parks in the West. With millions of annual visitors to national parks, human-mountain lion encounters are steadily increasing throughout the mountain lion's range. Thus, an emerging issue in national parks is how to manage human-mountain lion interactions. In addition, over the next several years most parks will be conducting species inventories as part of the National Park Service's (NPS) Inventory and Monitoring (I&M) program. In order to manage these interactions, further research on mountain lion behavior is required. One of the most challenging facets of mountain lion research is capturing mountain lions either for research and monitoring efforts. Because the most common capture methods—treeing with hounds or foot-hold snares—are highly invasive, they are less desirable for national parks with high public use and visibility. Recent evidence suggests cage traps might be a reliable, less invasive method for capturing mountain lions in national parks. Existing cage designs, however, are not suited for use in national parks, lacking adequate safety features and portability for use in remote areas.

The objectives of this study are to:

1. Build a cage trap that is effective and portable, and minimizes capture trauma; and
2. Test the cage in Rocky Mountain National Park (ROMO) for safety, effectiveness, and costs compared to other methods;

Background

Under a study funded in FY03 by the USGS-NPS National Park Monitoring Project, some progress has been made toward evaluating non-invasive capture and monitoring techniques for mountain lions. In particular, several agencies interested mountain lion research, especially non-invasive approaches, joined together, informally, to form the Colorado Mountain Lion Research Group (CMLRG). This collaborative research effort included NPS, ROMO; USGS-Fort Collins Science Center; USDA Forest Service, Canyon Lakes Ranger District (CLRD); Colorado Division of Wildlife; and the Colorado State University, Mechanical Engineering Department (MED). MED joined the group in October of 2003, agreeing to design and build an “advance engineered” cage trap. MED produced a prototype cage trap in February of 2004, which coincided with ROMO approval in March of a new research study on mountain lion ecology in the park. This report summarizes the progress made to date on building, testing, and refining a capture cage for mountain lions. Also included are sufficient engineering specifications for replicating the cage trap.

Our original intent was to design a new-generation cage that uses all-weather materials (Hoeltge 1961), telemetry to immediately notify the capture team at the point of capture (Condy et al. 1975), and for the cage to be lightweight and modular (McKenzie 1993) for easy transport into remote areas. Such a cage could become a new “soft-invasive” tool that could be adopted by all parks with the need to capture mountain lions, and ultimately becoming a tool for I&M protocol.

The USDA-Animal Plant Health Inspection Service’s California Animal Damage Control (ADC) unit have used cage traps to capture problem mountain lions since 1986 (Shuler 1992). After several iterations, the current ADC cage design is of 4’x4’x10’ angle iron-horse wire construction, with an internal down-swinging door that is tripped by the lion’s weight on a trip pan located near the rear of the cage where bait is placed. In California, ADC captures about 100 mountain lions per year, of these, about one-quarter are cage-trapped. Though their animal injury rate is low, they typically trap single animals where the danger of a second lion entering the cage is also low. Because these cages are large and heavy, ADC uses a pickup truck to transport them, deploying the cages near roads as close as possible to an identified mountain lion kill site, using the carcass as bait. In most cases, the lion is captured the first night (pers. comm. James Schuler).

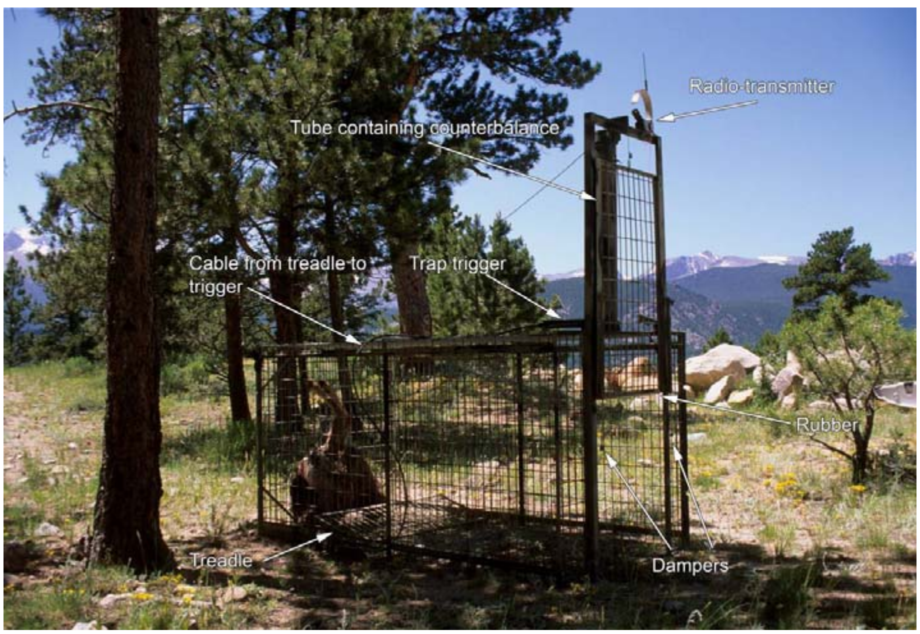
A cage trap similar to the ADC design was used to capture mountain lions for a research study in southern California (pers. comm. Ken Logan). In addition to trapping at kill sites, during Logan’s study his team successfully “lured” mountain lions to cage traps. To do this, they first stake or tie deer carcasses to trees in an area known to have mountain lion activity as evidenced by sign such as scrapes, scat, or pugmarks. Once a lion finds and begins to feed on a carcass, the capture team baits the cage trap using the carcass being fed upon, attaches a radio-collar to the closing device, and then stations themselves nearby. Like the ADC captures, the lion is usually caught the first night. The main concern with these cages, aside from size and weight, is the door design. The door closes with enough force to injure a kitten or a second lion entering the cage as the door is closing, and it may also injure a lion’s tail as it closes. MED’s design vastly improves the door, eliminating all safety issues along with the loud “bang” as the door closes, further reducing the stresses that can lead to capture myopathy. With the new design, it is quite possible the lion will not realize it has been captured until the capture team arrives. If successful, this type of new cage trap might be useful to all national parks and state fish and wildlife agencies throughout the West. Of secondary scientific interest, this study will shed light on the validity of the theory that mountain lions are not scavengers.

Procedures/Methods

MED delivered the cage trap in February 2004. The new trap underwent thorough "dry testing" before being used in live tests. Presented are two stages of use and design enhancement.

<u>Phase 1 Design</u>

The cage-trap is built with pre-manufactured steel horse panels with a 2"x4" grid pattern made using a 0.225" rod. The structure is rectangular in shape with a height of 44 ¾", a width of 45", and a length of 87 5/8" to provide adequate room for an adult lion. (Note: All assemblies are fastened with ¾" X ¼"-20 UNC nuts and bolts through .226" diameter holes.)



At one end, an opening 10 3/8" from the edge on either side exists, allowing for an entryway 23 ¾" wide. On either side of the opening there is a track that allows a door, made of the same pre-manufactured horse panel, to slide up and down. The track is extended beyond the height of the cage creating a framework for the door to be pulled well above the entrance. When set, the trigger will hold the door open with a rod protruding forward, preventing the door from shutting. The triggering mechanism swings closed once the door is released.

The entire triggering mechanism consists of a 30 lbs/ft^2 treadle spanning the width of the cage (also made from the same pre-manufactured panel) placed approximately 1 ½ feet from the end opposite of the one with the door. Bait is placed inside in front of the treadle and tied with cotton rope. Once pressure is applied to the angled treadle as the lion approaches the bait, rendering it horizontal, it pulls a cable extending from the treadle to the trigger at the door. The rod protruding from the trigger is then retracted, allowing the door to close.

To prevent injury, a 30 lb counterweight placed in a large tube next to the doorway framework (based at the top of the cage) is attached to the top of the door itself using a cable. As the door is triggered to shut, the weight slows the rate at which it closes. There are also two dampers that are placed on the edges of the door opposite one another, further slowing the closing rate of the door. Additionally, rubber padding is fastened to the base of the door and once closed there is a 2" gap between the door and the base of the opening.

Finally, a radio-transmitter is placed at the top of the doorway framework. Breakable twine is fastened to the door as well as a trigger that tells the transmitter to send signals once the door is closed. This alerts researchers so that they may respond to the captured lion as quickly as possible, creating only a minimal amount of time the lion has to remain in the cage.

<u>Phase 1 Results</u>

Table 1. Use and results of cage trap.

	No. of Days	**Success**
Baiting	252	2 young lions
Open Baited Trap	26	5 captures (2 bears, 3 young lions, 1 adult lion)

In the fall of 2005, though baited for mountain lion, a bear was captured in the cage near the north entrance of the park. Bear biologists safely immobilized and radio-collared the bear. The second night once opened again, another, apparently larger bear was captured but managed to escape by ripping open the cage door. The incident prompted another evaluation of cage safety and design: Phase 2 Design.

Phase 2 Design

As a result of the bear damage, the cage was of out-of-service for several months undergoing modifications that included a completely new door design engineered and constructed by Paul Erwin with the Agriculture Research Service (ARS). The new designed included a stronger door made of aluminum and a new, less complex trigger mechanism. The foot treadle was eliminated and replaced with a more simple mechanism. Also, a lighter aluminum door eliminated the need for a counterweight mechanism reducing weight and lowering the overall height of the cage.

The triggering mechanism uses the same cable from Phase 1 situated on top and center of the cage. When set, the trigger will hold the door open with a rod protruding forward, preventing the door from shutting. The door itself has three holes situated in a vertical fashion that hold the protruding rod, allowing for changes in the height of the entrance.

The triggering mechanism is attached to a cable leading to a drop pin positioned toward the opposite end of the cage. This is attached to the base of a lever positioned further back, via a nylon cord. On the outside of the doorless panel at the opposite end of the cage, two spools are positioned vertical to one another 9 1/8" apart. Another nylon cord is attached to the top of the previously mentioned lever, placed down over each spool, and then threaded through the panel's grid into the cage. The end of the cord in the cage is then fastened to bait. When the lion begins to feed on the bait, the pulling motions from the lion forces the lever back, which pulls at the release pin, causing the cable to retract. The rod protruding from the trigger is consequently retracted, allowing the door to close.

To prevent injury, there are two dampers placed on each panel on either side of the door, consequently slowing the closing rate of the door. This is accomplished by pulling the tips of the dampers up until they touch the base of an aluminum block attached horizontally to the upper portion of the door that protrudes wider than the door itself. Additionally, rubber padding is fastened to the base of the door and once closed there is a 2" gap between the door and the base of the opening.

Finally, same as the Phase 1 cage, a radio-transmitter is placed at the top of the doorway. Breakable twine is fastened to the door as well as to a magnetic trigger on the transmitter.

Phase 2 Results

ARS completed the Phase 2 cage in late 2006. Other than a small amount of "dry testing" the Phase 2 cage was stored at the beginning of 2007 at USGS and later moved to ROMO. USGS suspended the mountain lion ecology research study in March 2007 at which time further tests or use of the cage were not possible. Thus, to date, there are no data on the Phase 2 design.

Discussion

From the limited number of opportunities for actual use and our experiences working with the cage under varied field conditions there have been a few observations worthy of noting. Though originally intended for remote use, the cage was far too heavy to move very far from a truck. On one occasion the cage was transported on a wilderness gurney to a site in Cow Creek approximately 1 mile from the truck. This experience proved difficult and far too labor intensive for subsequent use in remote locations. Also, it was larger than necessary, adding to the weight and portability issue. We believe a 2/3 mock up or smaller would likely suffice[1]. With such a paucity of data on safe, reliable cage traps and the need for live-trapping mountain lions on the rise inside outside national parks, we are hopeful future research will benefit from what this study has revealed to date.

[1] CDOW appears to have successfully used commercially available, large dog traps—1/2 or less the size of our cage trap—to capture mountain lions in its Boulder-Jefferson county study.

Acknowledgements

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Appendix II: Chronology of Products and Accomplishments:
"Mountain Lion Ecology in Rocky Mountain National Park" – Don O. Hunter, Caroline Krumm, and Duggins Wroe

06-03	Judy Visty loans equipment, proposals pending
10-03	Presentation to ROMO staff on CWD and non-invasive studies (CK, DH, DW)
02-04	Captured Frank in Cow Creek
03-04	Lyceum talk at ROMO (DH, CK)
03-04	Terry Terrell calls with 50K start-up funds with 5-year commitment ($25K ROMO-$25K RMNA proposal)
06-04	Cage-capture kitten in Cow Creek
09-04	Krumm, C. E., M. M. Conner and M. W. Miller. 2004. Susceptibility of chronic wasting disease (CWD) - infected mule deer to vehicle collisions. Wildlife Disease Association Annual Conference. San Diego, CA.
10-04	Snare-capture Muriel
00-04	2004 IAR Submission (attached)
02-05	Presentation to CSU students for Project Wild (DH)
04-05	Brasil training Sao Francisco de Paulo National Park (DH, DW, Dr. Peter Crawshaw)
04-05	Re-capture Frank
05-05	CDOW sponsored presentation to Front Range organizations/communities (DH)
08-05	Assist SAR for Jeff Christensen
08-05	RMNA sponsored seminar on mountain lions and ROMO study (DH, CK)
09-05	Animal Planet filming (DH, CK)
10-05	Cage capture a black bear at McGregor Lodge (10-07 damaged)
10-05	Duggins Wroe assists Dr. George Powell WWF-Peru
10-05	Article in "People, Land, and Water" (attached)
10-05	Article in RMNA Quarterly (attached)
00-05	Krumm, C. E., D. O. Hunter and M. W. Miller. 2005. Mountain lion research in Colorado's Northern Front Range: testing new global positioning system (GPS) technology. 8th Mountain Lion Workshop. Leavenworth, WA.
11-05	Presentation to ROMO management on using dogs (2nd presentation 12-1)
00-05	Colorado Mountain Lion Research Group Website developed and posted
12-05	2005 IAR Submission (Attached)
02-06	First dog run in ROMO
03-06	Presentation to CSU's Zoology Club
04-06	Animal Planet Program "Get Out There"
04-06	Interim Results posted on website (attached)
04-06	Presentation at RMNP Research Conference (DH, CK)

04-06	Snare/call box capture Pat at Bobcat Ridge—first GPS-Argos collar (DH, DH)
05-06	Snare-kill site capture Buck
06-06	Rocky Mountain National Park Kawuneeche Visitor Center Interpretive Ranger Seminar (CK)
07-06	Presentation for "Science Behind the Scenery" (DH, CK, DW)
07-06	Snare/call box capture Patty
08-06	2nd RMNA sponsored seminar on mountain lions and ROMO study (DH, CK, DW)
09-06	Presentation to Eco-week class at Covenant Heights
10-06	Snare-call box capture Tango (2nd GPS-Argos collar)
10-06	Buck killed by landowner
00-06	2006 IAR Submission (attached)
03-07	Presentation at Poudre High School Pace students (DH, CK, JC)
08-07	3rd RMNA sponsored seminar on mountain lions and ROMO study (DH, CK, DW)

Appendix III: Referenced Figures Enlarged

Field Equipment:
- 2 – 4WD Jeeps
- 2 – 4WD Trucks
- 2 – ATVs
- 30' Research Trailer
- Dart Rifle
- Dart Pistol
- Handgun
- Video Camera
- Digital Camera Traps
- 2 – Laptop computers
- 4 – GPS Units
- 4 – Mobile Radios
- 12 – Leg-hold Snares
- Drug Kit
- First Aid Kits (people& animals)
- 2 – Binoculars
- Capture Cage
- Horses and trailer
- Trained hounds

Research Team:
- Principal Investigator
- 2- Co-Investigators
- 2- Research Vets[1]
- Modeling Expert
- CDOW field techs[1]
- ROMO Volunteers
- CSU Engineering student

[1]as needed

Figure 2. List of research assets at start of study 2004.

Field Equipment:
- 2 laptop computers
- 2 NPS receivers

Research Team:
- Principal Investigator
- One Co-PI
- Volunteers

Figure 12. List of research assets 2007.

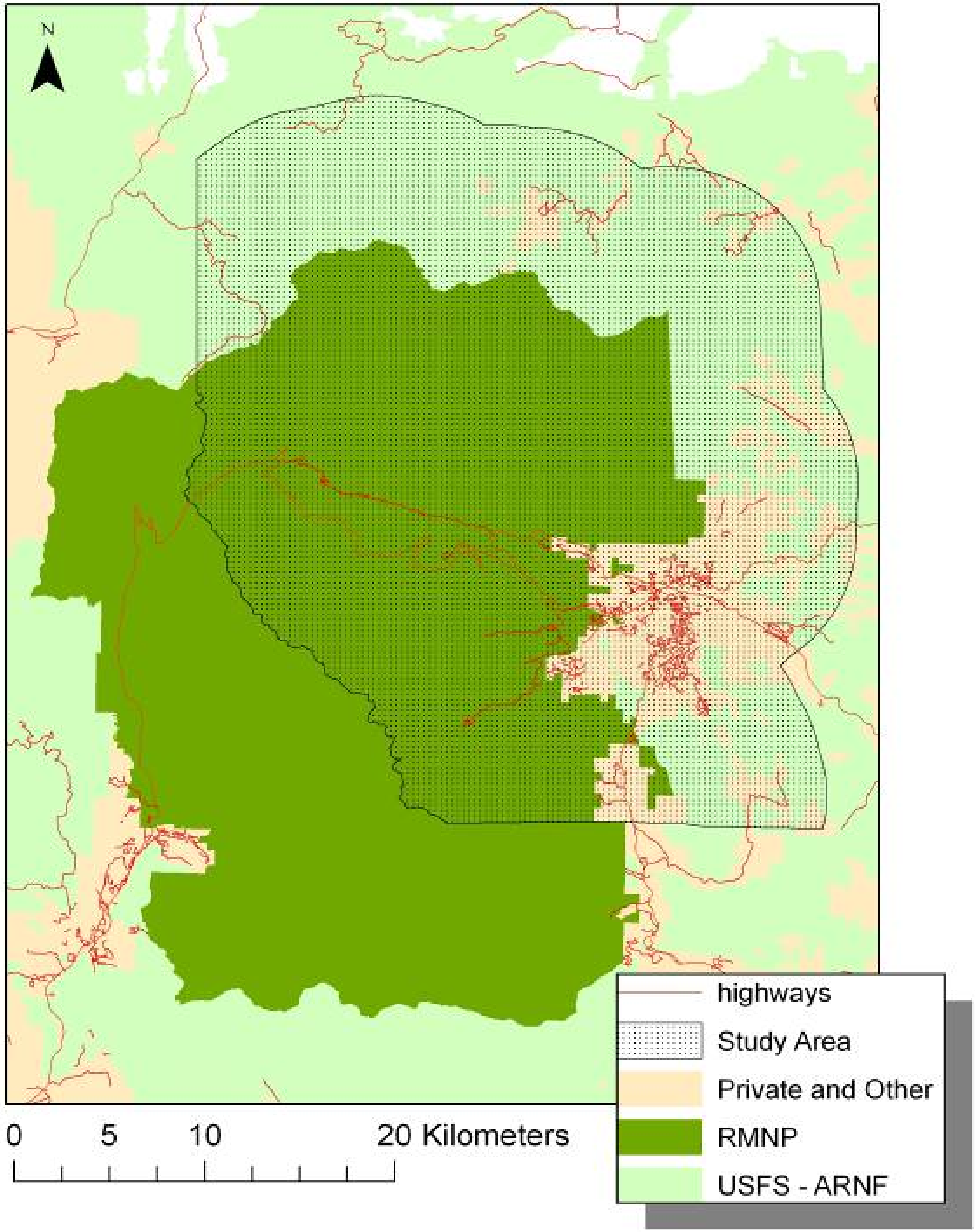

Figure 4. Study area

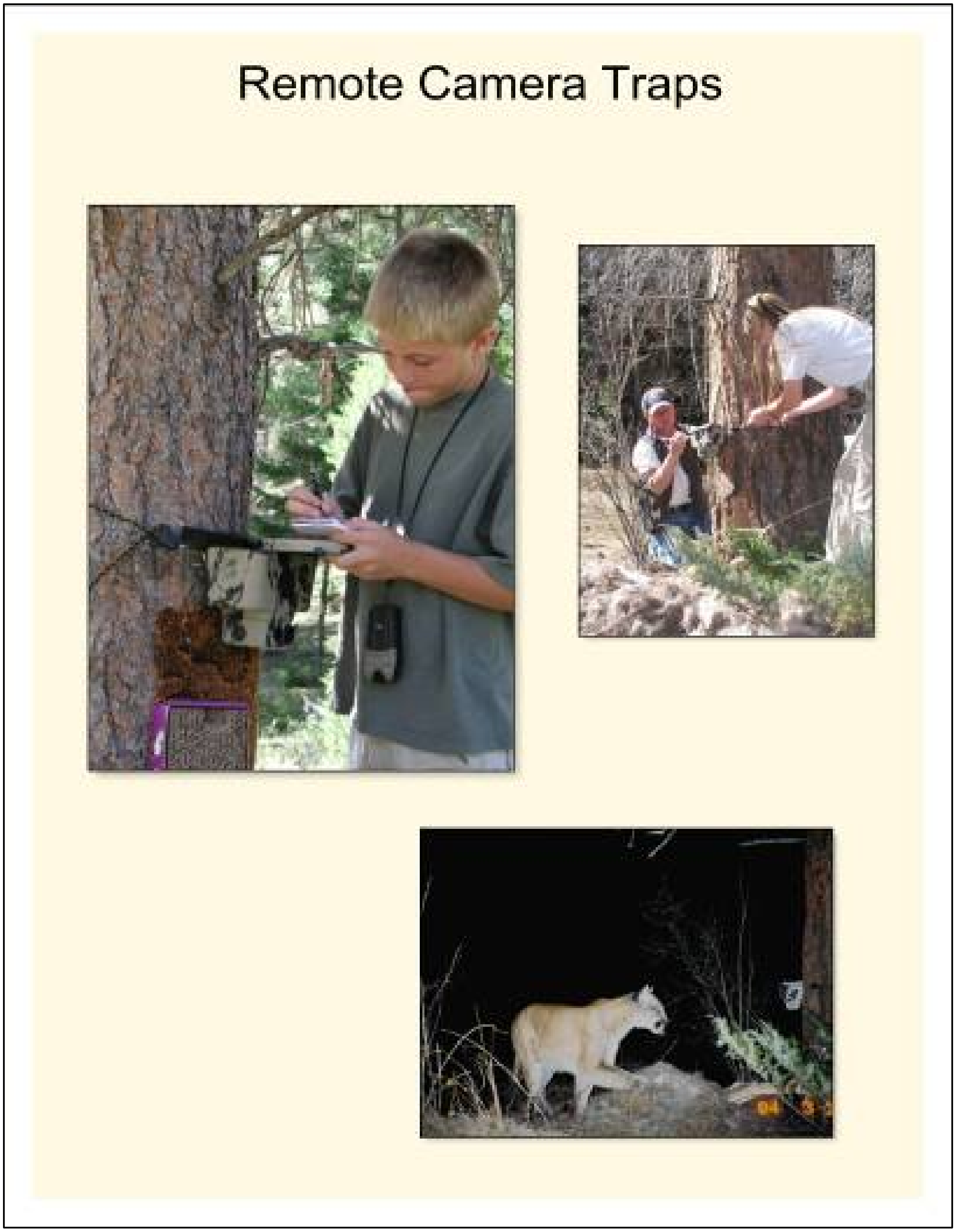

Figure 5. Photos of setting camera traps and one lion photo from a trap.

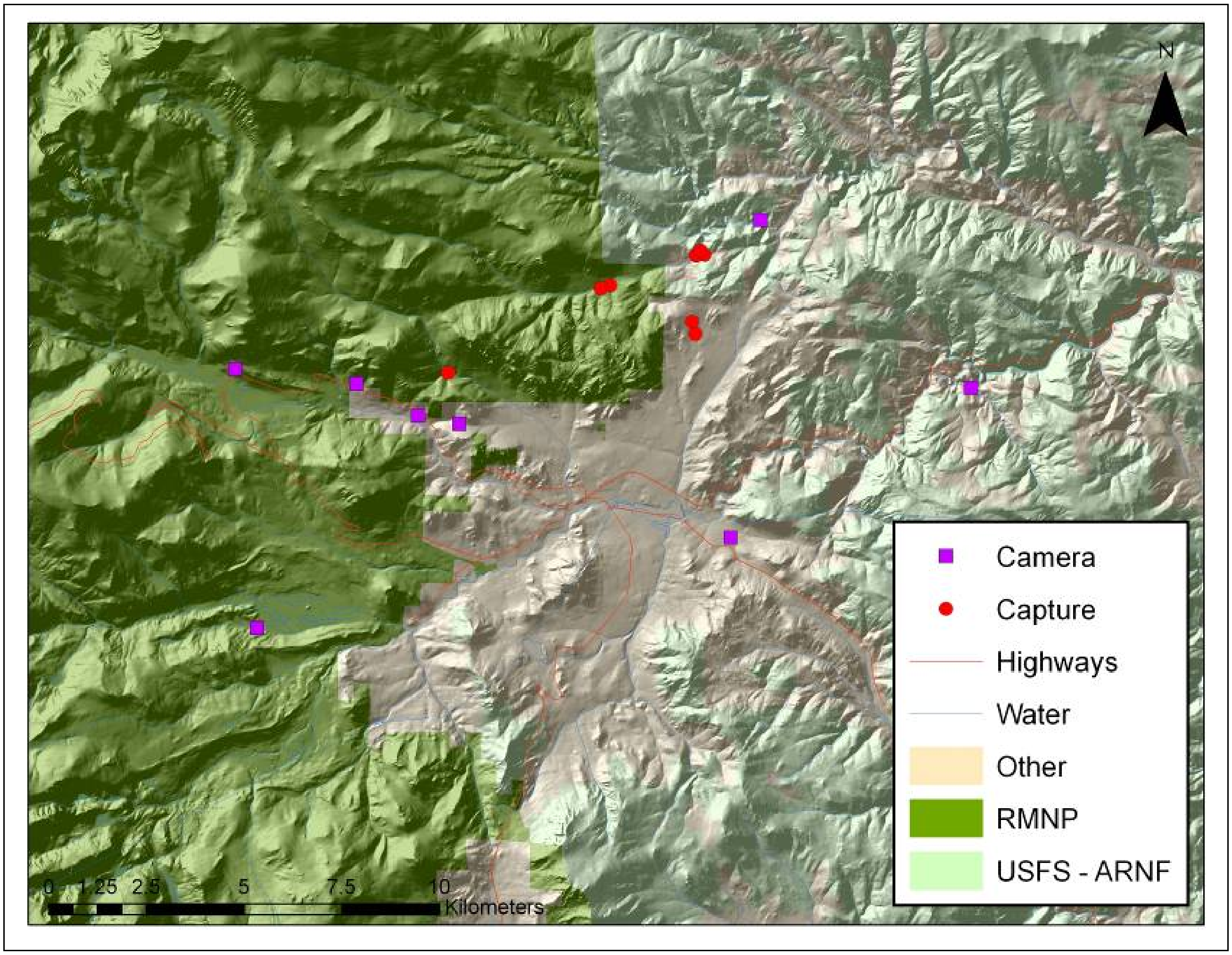

Figure 6. Map depicting locations within study area of mountain lion captures and camera trap captures.

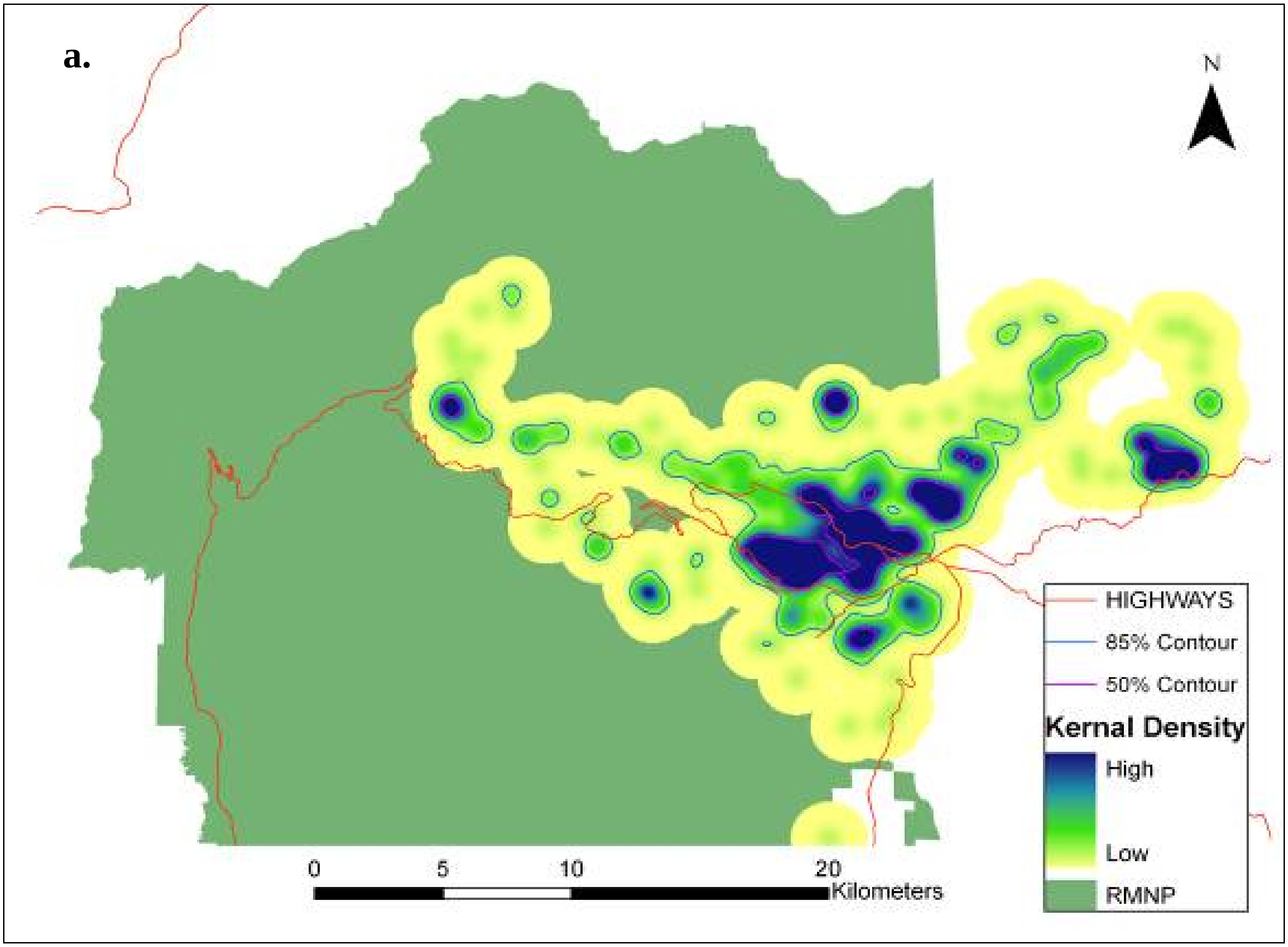

Figure 8. Image showing kernel density analysis for Female 209 (a.) zoomed to core home range.

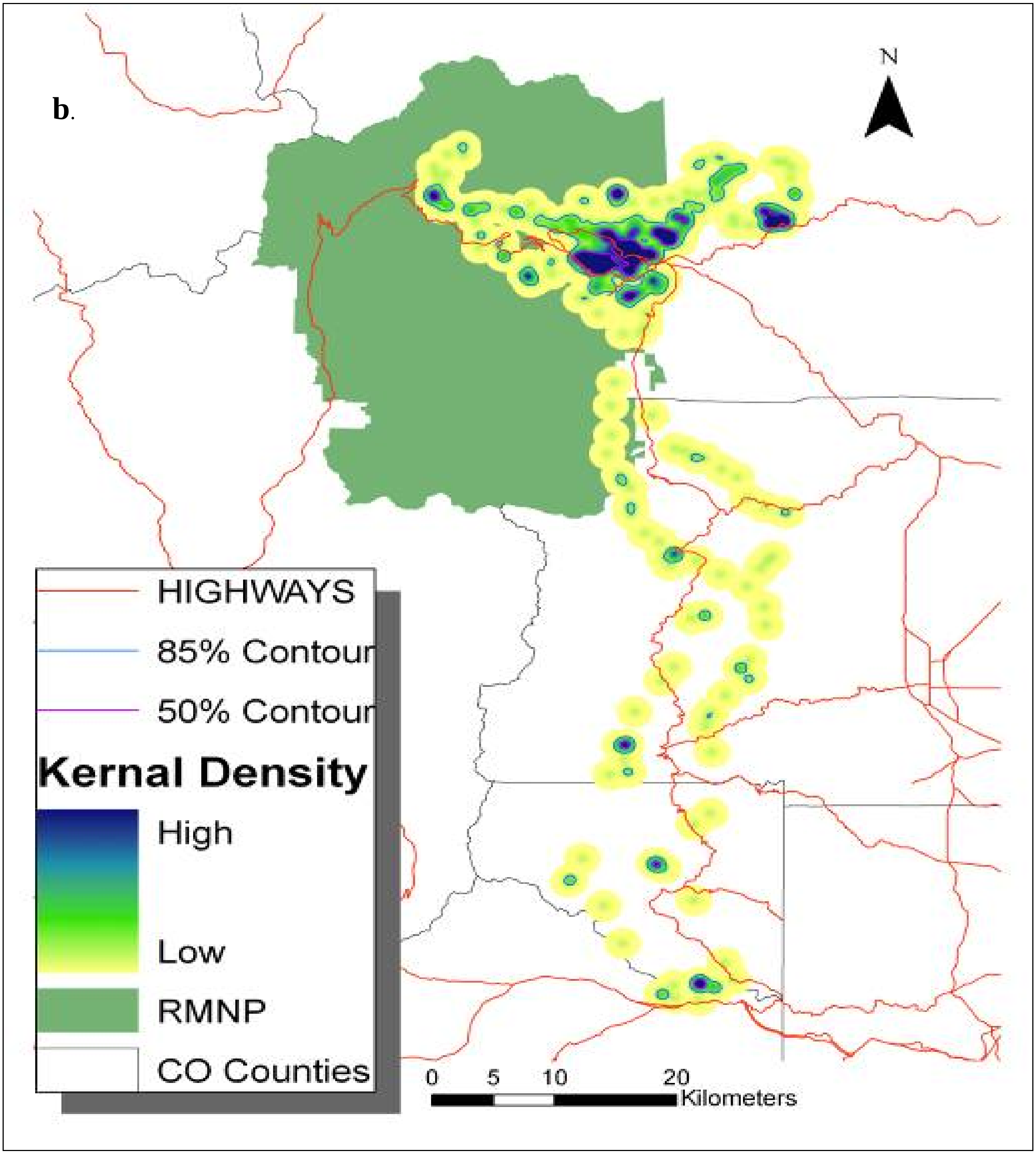

Figure 8. Image showing kernel density analysis for Female 209 (b.) over extent of use area.

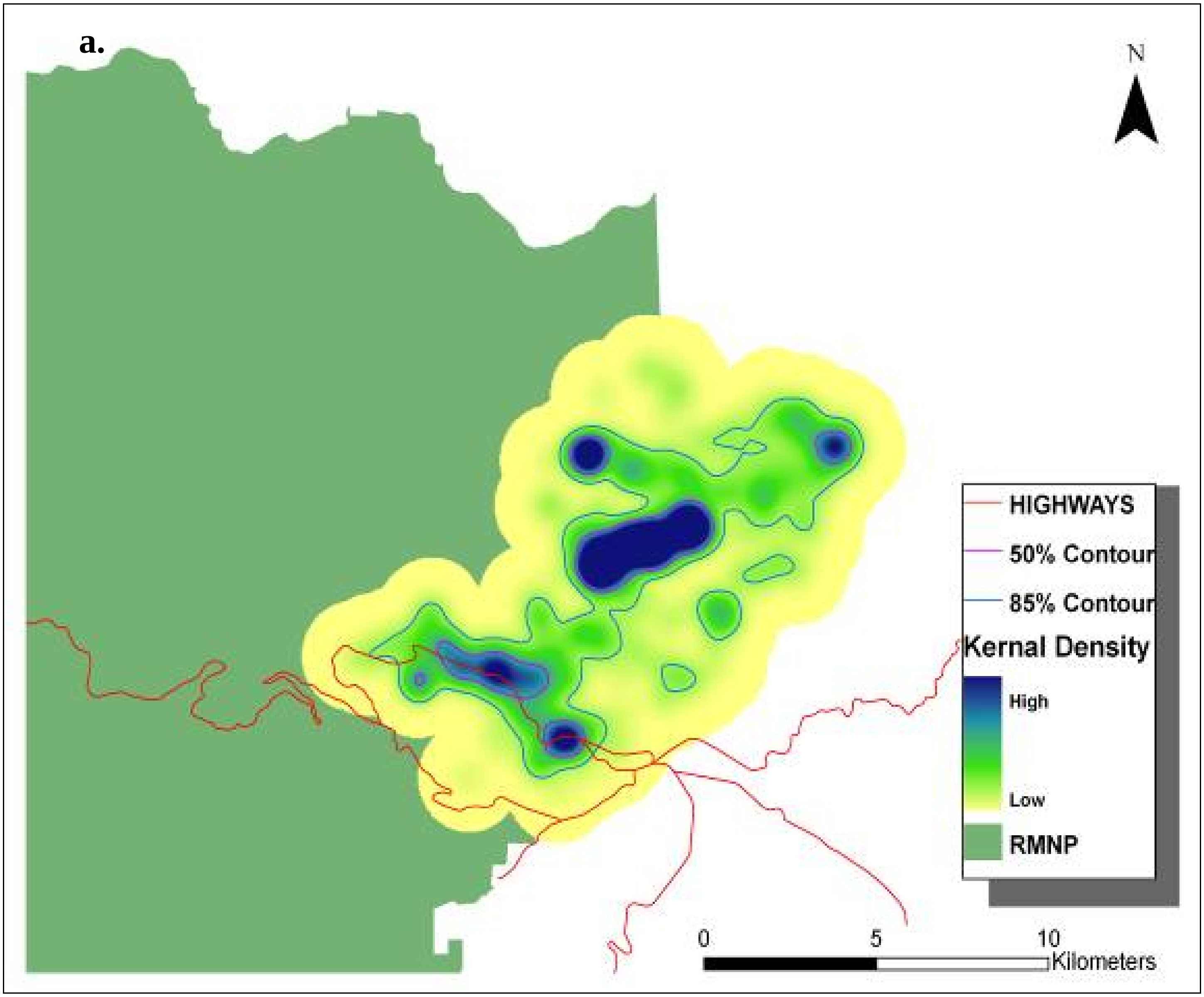

Figure 9. Image showing kernel density analysis for Female 207 (a.).

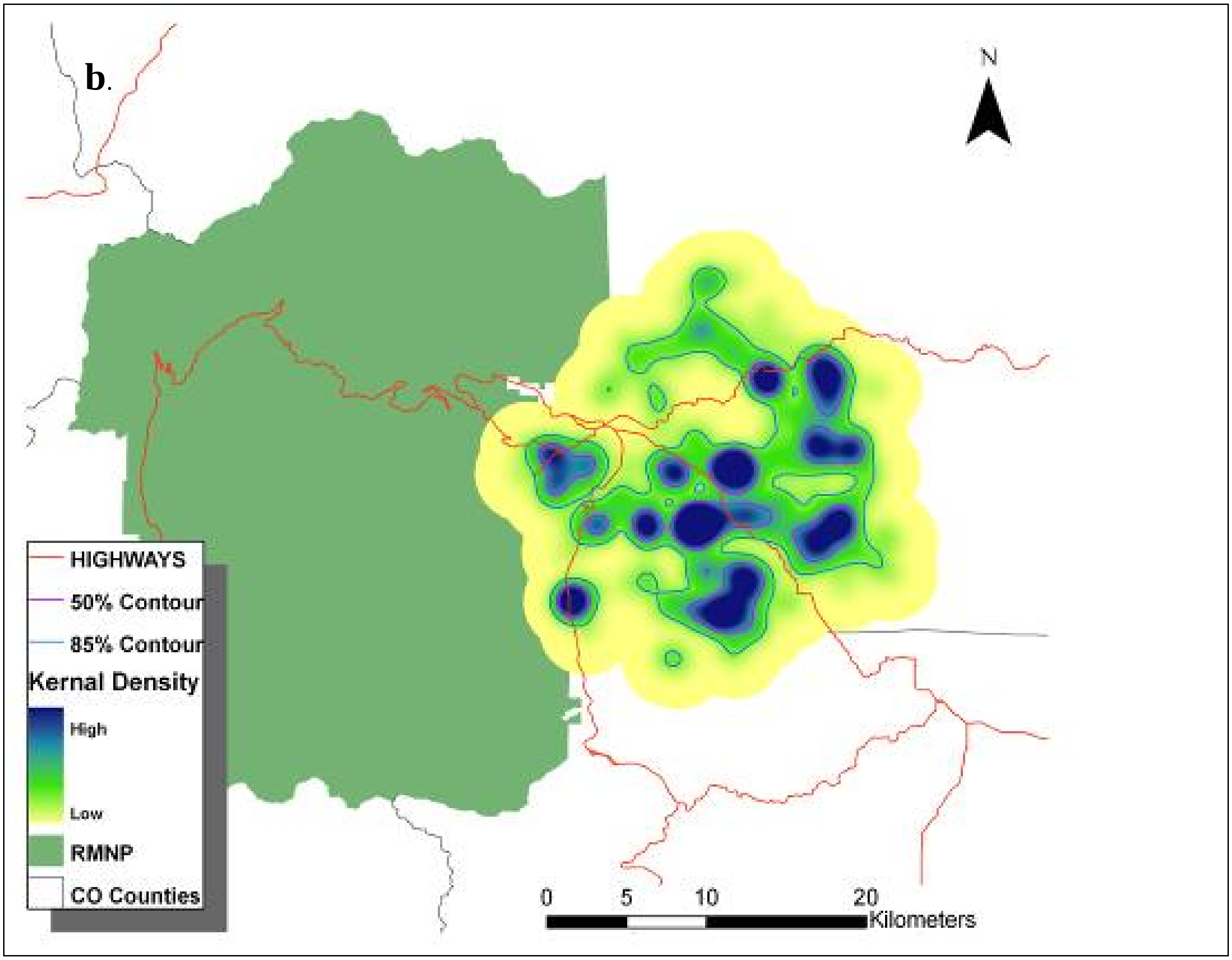

Figure 9. Image showing kernel density analysis for Male 208 (b.).

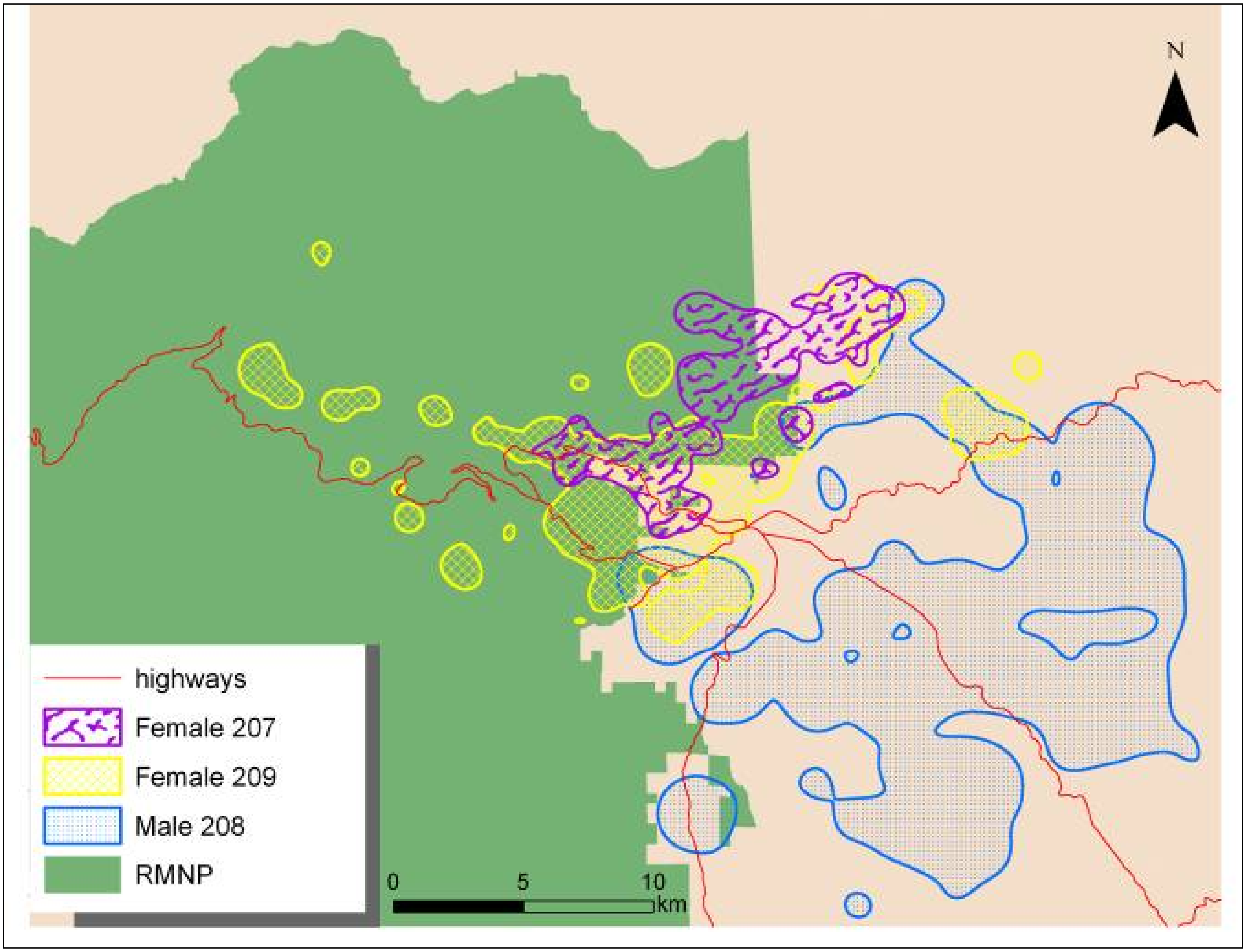

Figure 10. Map showing overlap of 85% contour home range of Female 207, Male 208 and Female 209.

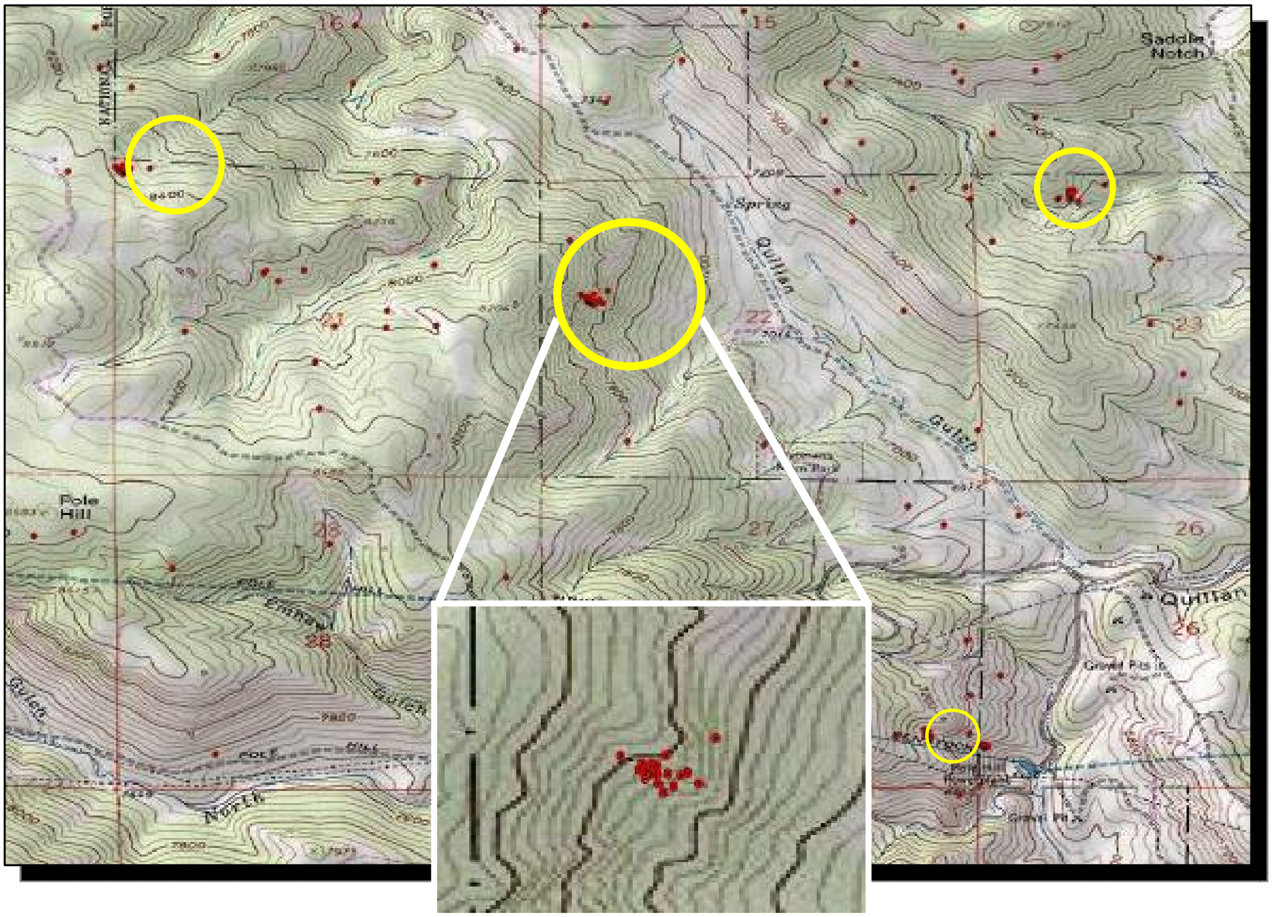

Figure 11. Map showing GPS data from one collared lion to demonstrate identification of clusters (inset) to find kill sites.