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Research Article

Using Radio Telemetry and Geographic Information Systems to Map and Estimate the Home Range Size and Daily Movement Patterns of Female Cheetahs on Namibia's Commercial Farmland

—Elisabeth Wise

Into the Bush

Standing in the bed of a truck while driving through the rugged terrain was no easy feat. Let alone holding a metal antenna and receiver, listening for the slightest “beep” in hopes of finding the direction toward the cheetah and her cubs. Dust was flying, and my balance was failing. The sun had begun to descend, cascading a red light across the high-desert, thornbush savanna. As hope began to fade, there it was. The slightest and nearly undetectable beep. I adjusted the antenna and the beep grew louder. The truck jolted, changing direction, almost sending me flying out. As we weaved left and right, my heart quickened. Beep . . . Beep . . . Beep . . . Was this the moment I would see a cheetah in the bush on a reserve near Otjiwarongo, Namibia?

Seizing an Opportunity

My journey to Namibia began 7,000 miles away at the University of New Hampshire (UNH), where I am a senior majoring in biomedical science medical and veterinary sciences. My dream growing up watching the Big Cat Diaries by Jonathan Scott was to become a veterinarian working with African wildlife species. UNH has provided various opportunities to broaden my animal experiences, including traveling to South Africa during the summer of 2015 with Vets-in-the-Wild Expeditions and the Care for Wild Africa program. There, I learned about wildlife conservation, assisted a



The author with Peter, her favorite among the captive cheetahs at the Cheetah Conservation Fund.

wildlife veterinarian, and helped to rehabilitate orphaned rhinos. Back at UNH my animal experiences moved from large animals to working at a small animal and exotic animal (birds, rabbits, ferrets, rodents, etc.) clinic. But it was not enough. My junior year, I applied to the International Research Opportunities Program (IROP) to expand my horizons in wildlife conservation before heading off to veterinary school. With the help and guidance of Dr. Drew Conroy and my foreign mentor, Dr. Laurie Marker, I planned a research project to be conducted at the Cheetah Conservation Fund (CCF) near Otjiwarongo, Namibia.

My research would attempt to answer these questions: Does the home range and movement patterns of female cheetahs change seasonally? What does this mean for the conservation of the cheetah?"

The Cheetah Conservation Fund

It all started while working with my adviser, UNH professor Drew Conroy, who I met in my first year during an introductory course in Dairy Cattle Selection. After learning about my passion for African wildlife species, he introduced me to the Cheetah Conservation Fund (CCF). Located near Otjiwarongo, Namibia, the CCF is a nonprofit research and educational facility that works with local communities to create a peaceful balance between cheetahs and livestock farmers through livestock and wildlife management and education. The CCF provides information about the biology and ecology of the cheetah and secures habitat to conserve the remaining population of free-ranging cheetahs. The cheetah, known for being the fastest mammal in the world, has begun to dwindle in numbers due to human-wildlife conflict, loss of habitat, and the illegal wildlife trade (2, 4). Dr. Laurie Marker, founder and director of the CCF, created the organization in 1990 to "win the race" on the survival of the cheetah (2, 3). My interest in African animals has always revolved around big cats, specifically the cheetah, so my goal was set. I was going to conduct a research project on cheetahs. Namibia, being the country with the highest population of cheetahs, was the perfect fit.

Even though I had experience traveling to South Africa, I was to learn that Namibia was vastly different. As I landed in Windhoek, Namibia, I felt that I was truly in the middle of nowhere. There were no houses or asphalt roads in sight. Only the thick acacia bush and the red sand dusted across the savannah. The Cheetah Conservation Fund was four hours from the airport. During the drive, I was quickly exposed to the diverse and abundant wildlife, including wart hogs and an oryx that sprinted so close to the car we nearly ran it over.

The History of Namibia and the Cheetah

The range, territorial sizes, and population of cheetahs (*Acinonyx jubatus*) have been affected over time by a number of factors, including habitat, accessibility of prey, available water sources, and human-wildlife conflict (2, 8). The population of originally 100,000 cheetahs spread throughout Africa, Asia, and the Middle East during the 1900s has now rapidly decreased to approximately 10,000 cheetahs in the wild of sub-Saharan Africa, endangered in genetic variation and vulnerable to environmental and ecological changes (1, 2, 3, 8). Over the last century, loss of habitat due to

fragmentation and degradation by human expansion had resulted in the separation of predators and prey species in Namibia (1).

Namibia gained independence from South Africa's Apartheid rule in 1990, and by 2015 much of its land was designated as either communal conservancy land or commercial farmland under the Community Based Natural Resources Management (CBNRM) program (7, 11). This led to economic growth from ecotourism on the conservancy land, as well as economic growth from hunting on commercial farmland. Conservancies differed from the commercial farmlands in that their boundaries were monitored to prevent poaching and to estimate the number of prey and predator species present by using camera traps and performing game counts (7). Commercial farmlands, on the other hand, consisted of livestock farms (cattle) and game farms, the latter of which are used for selling wildlife and trophy hunting (8). Research shows that 90 percent of cheetahs in Namibia live on commercial farmlands (3).

Conservancies, including national parks and other protected areas, contain a high population of cheetah predators, such as lions and spotted hyenas, who see cheetahs as competition. In these areas there is an increase in the cub mortality rate of the cheetah due to conflict with predators (6, 7, 11). Most commercial farmlands have eliminated cheetah predators with traps and lethal force (6, 8). Cheetahs therefore have avoided the threat of large predators by moving their territories to primarily within commercial farmlands, where they are considered a threat to livestock due to real or perceived conflict with livestock farmers (1, 2, 3, 9). Game farmers also view cheetahs as a threat to their wild game that are valuable for hunting, auctions, and tourism, so there is no economic incentive not to kill the cheetahs (6). This human-wildlife conflict revolves around the misperception of cheetahs as pests (6). By increasing knowledge about the cheetahs' movements and improving the communication with livestock farming communities, the CCF aims to reduce the human-wildlife conflict.



The entrance to the Cheetah Conservation Fund (CCF) in Namibia.

Radio Telemetry and Geographic Information Systems

In preparation for my journey I worked closely with my UNH advisor, Dr. Drew Conroy, who has worked extensively in Africa. In addition I worked with my father, Robert Wise, who taught me how to properly use and understand computer mapping software, and Dr. Marker, director of the CCF, who was my mentor while in Namibia. My goal was to map the movements of nine female cheetahs in order to analyze whether their home range sizes had changed over time and seasonally. This involved using ArcGIS software and radio telemetry data from the CCF. I used this data to map and compare home ranges of nine female cheetahs, six of which were rewilded. Rewilded cheetahs are

those that were held in captivity for a few years before being released back into the wild. The other three cheetahs in my study were wild.

Radio telemetry, or homing, is a common method using GPS (Global Positioning System) satellite or VHF (Very High Frequency) to track radio-collared wildlife. In *Aspects of the Ecology of the Cheetah (Acinonyx jubatus) on North Central Namibian Farmlands*, Dr. Marker describes the average home range size determined for both male and female cheetahs that were tagged and radio collared from 1993 to 1997 (5). During this time, the CCF tracked from a “fixed-wing airplane” eight female cheetahs and twenty male cheetahs across commercial farmland using both GPS and VHF (5). The female cheetahs overall had a larger home range size than the male cheetahs (5). The GPS satellite radio collars were an excellent noninvasive way of monitoring the positions of the cheetahs and tracking their daily movements.



The author using an antenna cabled to a receiver to track signals from the cheetah Zinzi's radio collar—a basic method for tracking wild animals using radio telemetry.

Each of the nine female cheetahs I studied had been wearing a radio collar for a few months up to a few years. This radio collar contained a VHF and GPS signaling device that had been used to locate the cheetah. The GPS sent a latitude/longitude point via satellite to a computer database, where 28,651 total GPS points were collected for the nine female cheetahs spanning from 2008 to 2016. The historical collection of coordinates had been prepared for me via excel spreadsheet prior to my arrival to the CCF.

I used a geographic information system (ArcGIS by Esri) to interpret, analyze, and compare movement patterns and changes in territorial ranges (10). GPS satellite radio telemetry data analyzed by GIS software is valuable in identifying where to target management practices. It also allows researchers to observe territorial overlaps between populations, and to identify and map hot spots (areas of high activity). Identification of the cheetah population's needs is key for the conservation of the species.

I spent most of my time at the CCF filtering the data so that it would be compatible with the GIS software. The data was then entered into ArcGIS so that I could visually assess and analyze the data points that were now displayed as a map. I used Geospatial Modeling Environment (GME), a program for spatial modeling and analysis, to calculate different percentiles of where the cheetahs had spent most of their time. The territory claimed by a cheetah formed a boundary line. The area (km) within this boundary was calculated using the GME tool, producing the area (km) representing the home range size of the cheetah. Finally, I used R 3.2.1, a statistical program, to determine if the home range size and movement patterns of the nine female cheetahs were significantly different from one another during the three different seasons experienced in Namibia (hot/wet, hot/dry, and cold/dry).

Results and Further Study: What Does This Mean for the Cheetah?

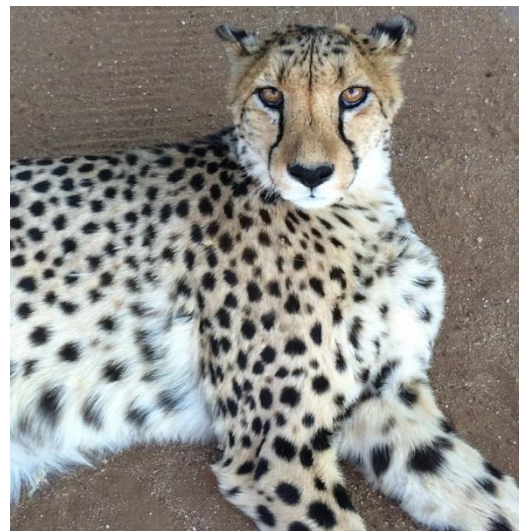
My analysis showed that the home range sizes among the nine female cheetahs shifted, contracted, and expanded in size by season and year. It is important to note that I found no statistical difference in the seasonal home range size exhibited by each of the nine female cheetahs, and no statistical difference in the seasonal daily distances moved by the nine female cheetahs. This shows that the rewilded and wild female cheetahs included in the study showed no differential behavior in claiming territory during the hot/wet, hot/dry, and cold/dry seasons. So what does this mean for the conservation of the cheetah?

The similar home range size and movement patterns observed in the rewilded and wild cheetahs points to a bright outlook for rewilded cheetahs. The CCF's goal is to increase and sustain the population of cheetahs in the wild. One step toward accomplishing this goal is through the reintroduction of once-captive cheetahs into the wild. However, other forms of analysis are needed to assess the ability of rewilded cheetahs to survive in the wild. For example, researchers should further investigate additional factors that may determine a female cheetah's home range size, such as cubs, rainfall, or even moon phases. Future research should also investigate the difference between the rewilded and wild female cheetahs independent of seasonal variation, and research should be conducted with a larger sample size. Understanding the movement and territorial ranges of cheetahs is key in determining the density of the population as well as their behavior, particularly movements through commercial farmlands.

Not Your Average Daily Routine

Beginning work at the CCF was an easy transition from my life at UNH. A diverse group of individuals from all around the globe work and visit there, so it was immensely similar to college. I had a dorm room with two roommates; it took no time at all to make friends and become acquainted with the staff. Being in a secluded facility, everyone got to know each other very well. The staff became more like family to me. They truly wanted my project to be successful.

Outside of my research, I helped care for both the fifteen livestock guarding dogs and the forty captive cheetahs. The Livestock Guarding Dog Program, created by the CCF in 1994, is responsible for breeding Anatolian shepherd and Kangal dogs that are given to local farmers to help protect their herds of cattle, goats, and sheep from predation. Interns fed dog food to the livestock guarding dogs and walked them on a leash daily, often up a trail called Leopard Hill. The residential cheetahs were fed horse and donkey meat and had a much different exercise regimen. Essential minerals were provided by organ meat—liver, heart, and kidneys—as well as a calcium and mineral product



Ron, one of the captive cheetahs at the Cheetah Conservation Fund.

called Predator Power. Exercise consisted of time in a “run pen,” where the cheetahs chased a rag attached to a lure operated by a two-way motor—a game of cat and mouse. The older and wilder cheetahs were trained to chase after the food truck, reaching approximately forty-five miles per hour. You can imagine the thrill of standing in the back of a truck as five cheetahs chase after you, hungry for their awaiting meal.

In addition to my husbandry responsibilities, I gave presentations to the CCF’s visitors, which included travelers from all over the world as well as local Namibians. It was a privilege to educate people about cheetahs, the threats to their population, and CCF’s efforts to conserve the species through habitat restoration, nonlethal predator management techniques for farmers, and long-term research on the wildlife population.

Back to the Bush



The author standing on a truck to track the cheetah Zinzi.

The truck stopped, and we got out of the car. We were tracking Zinzi, one of the rehabilitated female cheetahs the CCF had released into the wild. She had given birth to a litter of four cubs about seven months earlier. Zinzi was less than ten meters away. I was given a stick to carry as protection and as a boundary between myself and the wild cheetah. Cheetahs are built for running, not fighting, so the stick merely was a deterrent for Zinzi.

Zinzi stalked her way from the bush, her golden color blended in amongst the dead grass and acacia bush. Her back was curved in a tight arch and her fur stood erect, making her appear bigger. She walked with caution, her face wrinkled to tell me that she was no cat to be messed with. Her tear marks shaped her round eyes, one amber and one hazy white from an old injury, probably from being scratched while hunting in the thick acacia bush.

She kept her distance, unsure. Her eyes were fixed on the truck, anticipating another meal. I climbed into the bed of the truck and threw the horse leg onto the ground. Zinzi clawed into the leg and dragged it into the shade. Did this really happen? A wild cheetah, and I was only a few meters away?

Chirp, chirp, chirp. My ears perked up to the unfamiliar sound coming from Zinzi. She chirped again, a soft but high-pitched sound that disguised her as a gentle bird. Then, through the tall grass, three of her cubs emerged. I stood in awe, unable to look away. I had dreamt of this moment, and it was finally happening. I stood before four cheetahs feasting on a horse leg at sunset in Namibia, Africa.

My hard work has paid off. My drive to save the cheetah has only grown stronger. My findings are only a stepping-stone to what I wish to accomplish and the impact I wish to make on the remaining

cheetah population. I have been accepted into veterinary schools for fall 2017 and plan to continue my contribution to wildlife conservation. Looking forward, I plan to expand my research project with Dr. Marker. I feel that my IROP project is only the first step toward my goal to help regain and sustain a healthy population of wild cheetahs throughout their natural habitats. I will forever be inspired by the day I met Zinzi and her cubs, the fragile but tenacious cats that need everyone's help for survival.



Tracking Zinzi was a success! Here Zinzi lies beneath the thick acacia bush.

I would like to express my deepest appreciation to my teacher and mentor Dr. Drew Conroy. Thank you for never giving up on me and for pushing me beyond my comfort zone in order to pursue my dream of working with cheetahs in Africa. This was a golden opportunity that I will forever be thankful for, and it would not have been possible without Dr. Laurie Marker. Thank you for your guidance and inspiration. It was truly an honor to work with you. I would like to extend my greatest gratitude to my donors, Mr. Dana Hamel, Mr. Frank and Ms. Patricia Noonan, and Mr. Carlton W. Allen, as well as the staff of the Hamel Center for Undergraduate Research, specifically Georgeann Murphy and Peter Akerman. Lastly, I would like to thank my family and siblings for their utmost support of my dreams and their unconditional love. I could not have done it without you.

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Author and Mentor Bios

Elisabeth Wise, a biomedical science and veterinary sciences major from Eldersburg, Maryland has a passion both for big cats and for wildlife conservation. These passions have led her to seek a career as a wildlife veterinarian, with a specialty in animal ophthalmology. Elisabeth was drawn to her research project in part by her desire to expand her comfort zone and gain a new perspective on field research before applying for veterinary school. She traveled to Namibia with the support of an International Research Opportunities Program (IROP) grant through the Hamel Center at the University of New Hampshire. Elisabeth describes the research as "addicting" and says the "real accomplishment was finding more questions and new ideas on how to further investigate" her topic. One challenge was learning that actual research in the field is always different from expectations during the planning stage. However, with the strong support system that Elisabeth developed in Africa, she had a highly satisfactory experience. "For me," Elisabeth says, "the sky is the limit in what I plan to accomplish in my life."

Andrew Conroy, a professor of applied animal science and integrated agriculture within the Thompson School of Applied Science, is in his twenty-eighth year at the University of New Hampshire (UNH). Professor Conroy's specialty is cattle (including beef, dairy, and working oxen) but he has extensive experience with other livestock and with animal handling and behavior. He has conducted

research in Africa, including research with pastoral people in Tanzania and in Namibia. In 2008, Professor Conroy spent a year in Namibia as a Fulbright Scholar. While there, he investigated various organizations where international students could do internships or supervised research projects. He worked with the Cheetah Conservation Fund (CCF) and recognized that it would be an excellent resource for UNH students. This knowledge allowed him to mentor a variety of students. Including Elisabeth, he has mentored sixteen undergraduate researchers since 2003. Professor Conroy feels that Elisabeth's project was particularly interesting as it "pushed her into a new field, where she became very proficient at using GIS software and [meeting] the challenges involved with tracking cheetahs over time."

Laurie Marker is the founder and executive director of the Cheetah Conservation Fund (CCF) in Otjiwarongo, Namibia, which is dedicated to saving the cheetah in the wild through research-based, integrated programs that include securing the future of the human communities that live alongside the cheetah. She specializes in conservation science, cheetah biology and ecology, human-wildlife conflict, and livestock and wildlife management. Dr. Marker has mentored many student researchers at CCF; for Elisabeth's project, she provided research oversight, project design, and training for the data analysis process. Elisabeth's work under Dr. Marker's mentorship was part of a long-term CCF study looking at spatial movements of cheetahs in north-central Namibia.

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