ECOLOGY OF MAMMALIAN PREDATORS IN THE BIG CHICO CREEK ECOLOGICAL RESERVE

A Thesis

Presented

to the Faculty of

California State University, Chico

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Interdisciplinary Studies: Wildland Management

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by

Summer 2022

ECOLOGY OF MAMMALIAN PREDATORS IN THE

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A Thesis

by

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Summer 2022

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DEDICATION

To my parents Yousef and Maria Haddad, for their love and support,

and to Cora, for keeping me company while sitting on my notes.

ACKNOWLEDGMENTS

This study would not have been possible without the help of my large support system. I would like to thank my thesis committee members – Dr. Tag Engstrom, Dr. Colleen Hatfield, and Eli Goodsell – for their continuous guidance throughout this study. Their collective expertise in ecology, zoology, and the study site was invaluable.

would also like to thank Robin Donatello. She played an integral role in the research data analysis, and for that I'm forever grateful. Without her immense help, this thesis would not have been completed.

Many thanks to Paige Munson for creating all the maps in the results section. Despite her constant busy schedule, she generously offered to create them. This means so much to me and I am incredibly thankful. Additionally, thank you to Cassie Corridoni for analyzing each acre's habitat type and recording a detailed description of them. Her knowledge in plant identification is remarkable and I truly appreciate her offering her time.

I wish to thank the Big Chico Creek Ecological Reserve staff, especially Eli Goodsell, Gary Day, and Rhianna Dutra, for providing nearly all the instruments, vehicles, and other resources necessary to conduct this research. This study would not have been possible without their time and support.

Lastly, I would like to thank Katherine Mai, Paige Munson, Kate Valdez, and Dayna Ramel for helping me check the trail cameras regularly. Their assistance made checking the trail cameras go by faster and more enjoyable. Thank you all for helping me retain my sanity.

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ECOLOGY OF MAMMALIAN PREDATORS IN THE

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Rising global temperatures has led to historic droughts in California. This has caused a decline in plant health and production, reduced water levels, increased wildlife mortality rates, and a surge in destructive megafires. Since mammalian predators play a large role in regulating ecosystem health, supporting their presence in the Big Chico Creek Ecological Reserve, located in Forest Ranch, CA, could help preserve critical habitats for environmental research and education. To investigate the distribution and resource use of American black bears (*Ursus americanus*), mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), and gray foxes (*Urocyon cinereoargenteus*), data was collected from May 18, 2021 to May 18, 2022 via 24 trail cameras throughout the Big Chico Creek Ecological Reserve, east of the Big Chico Creek. The bears and foxes displayed a strong preference in the location of their water source, with the bears favoring a spring and the foxes choosing a horse trough. They both shared the same preference in food source location, near the BCCER office. With a small bobcat and mountain lion sample size, there was not enough data thus no analysis was conducted. However, there

was a trend in mountain lions favoring the Big Chico Creek as a water source, while the bobcats weren't observed drinking water. Further research should be done to investigate the preferred water sources of the two felids. Activity during each season and different time of day categories were also examined. The bears, mountain lions, and foxes were seen most in the fall, while bobcats were most active in the winter. Additionally, the bears, mountain lions, and foxes were mostly nocturnal with some crepuscular activity, while the bobcats displayed the opposite trend – they were mostly diurnal with some nocturnal activity. The results of this study are important in informing the Big Chico Creek Ecological Reserve staff on the ecology of local mammalian predators, educating the public including current donors and potential future donors, as well as influencing wildland management practices to support the populations. In addition to the four study species, the following species in the order Carnivora were also observed: coyote (*Canis latrans*), raccoon (*Procyon lotor*), ringtail (*Bassariscus astutus*), fisher (*Pekania pennanti*), and striped skunk (*Mephitis mephitis*). The observed fisher is an adult male that was detected on three trail cameras. Due to the species' population decline, 40 fishers were reintroduced to the northern Sierra Nevada and Southern Cascade, and they were listed as endangered under the Endangered Species Act in 2020.

CHAPTER I

INTRODUCTION

Background

The health of the forests in the western United States has been negatively affected by global warming in recent decades (Keen et al., 2021). The impact of this trend was especially notable during the 2000 to 2018 megadrought that occurred in southwestern North America. This event should have been a moderate drought; however, it became the "second driest 19-year period since 800 CE" due to anthropogenic warming (Williams et al., 2020). Some of the direct effects of drought include reduced forest productivity, increased fire hazards, reduced water levels, increased wildlife mortality rates, and damage to their habitats (Wilhite et al., 2007). These effects have been prominent in California, with the warming trend and prolonged drought leading to many destructive wildfires (Chen, 2022).

According to Prugh et al. (2018), climate change is transforming ecosystems across the planet, and California is a biodiversity hotspot that is being impacted by prolonged drought. Their study investigated the responses of plants, arthropods, birds, reptiles, and mammals to California's 2012 to 2015 drought. They revealed that vertebrates were most responsive to long-term water deficits, with carnivores being impacted the most by extended drought.

In a study conducted by Gitlin et al. (2006), plant population mortality was examined during a drought in the southwestern United States. They found that prevalent plant species from diverse habitat types, including riparian, chaparral, and forests, showed high mortality rates. This means that the impact of drought is widespread across varying habitat types. The average mortality rate of Fremont Cottonwood (*Populus fremontii*) was 20.7%, manzanita (*Arctostaphylos* spp.) was 14.6%, and ponderosa pine (*Pinus ponderosa*) was 15.9%. These three plant species are especially important to American black bears (*Ursus americanus*) (Graber & White, 1983).

The dramatic changes in plant productivity directly impact all higher levels of the food web. For example, herbage is the largest part of a black bear's diet, with an increased importance in spring and summer (Graber & White, 1983). This category includes grasses, leaves, and stems, such as Fremont cottonwood leaves (Lundgren et al., 2022). Reproductive plant parts, including seeds, nuts, and berries, make up the second largest category of a black bear's diet, with an increased importance during the fall. Manzanitas are one of the major foods within this category (Graber & White, 1983). In terms of other plant-related resource use, the most common (33%) black bear bed site is in mixed conifer forests, while the second most common (22.5%) bed site is in ponderosa pine forests (Bard & Cain, 2020). Bears also favor unburned and unthinned locations, with 48% of bed sites occupying these areas (Bard & Cain, 2020). With the drought and wildfires killing these plants, American black bears are losing some of their main sources of food and will have to alter their behavior to accommodate the changing environment. According to Baruch-Mordo et al. (2014), the availability of natural food for black bears affects their space use and activity patterns. During "poor food years," the bears used urban areas and became more nocturnal. However, during "good food years," they inhabited wildland areas and their survival rate was higher. With an expected increase in natural food failure years due to climate change, American black bear urbanization is expected to increase by 11% across their range (Barush-Mordo et al., 2014).

Another forest-dependent species that is being affected by drought and wildfires in California is the gray fox (*Urocyon cinereoargenteus*) (Green et al., 2022). According to a study conducted on gray fox diet, fruits compose a large portion of their food, especially in the western United States. A total of 70% of the food found in fox scat was fruit, including coffeeberry (*Rhamnus californica*), manzanita (*Arctostaphylos glandulosa*), toyon (*Heteromeles arbutifolia*), and hollyleaf redberry (*Rhamnus illicifolia*) (Wilson, 1998), all important vegetation species in the study area. However, these plants undergo a variety of responses during a drought, including reduced plant growth, reduced leaf size, fewer leaves, and decreased fruit production. Lack of water during the initial phase of plant development could even lead to dehydration and death (Silva et al., 2013). With a reduced fruit yield in the plants that gray foxes consume the most, they will have to adjust their diet during droughts.

Mountain lions (*Puma concolor*) and bobcats (*Lynx rufus*) are carnivores (Shivaraju, 2003; Ciszek, 2002), so they do not rely on vegetation for food, however, precipitation affects their prey abundance. One of the main prey species for mountain lions is the mule deer (*Odocoileus hemionus*) (USDA). According to Bender et al. (2011), drought and lack of quality forage can lead to poor mule deer body condition, causing a decreased survival rate and productivity. A similar trend has been observed with one of the bobcat's main prey species, rodents. A study conducted near Catarina, Texas investigated the responses of five rodent species to a 13-month above average precipitation period after a one-year long drought. They found a 500% increase in the total number of individuals after the drought (Bradley et al., 2006). This decrease in prey populations associated with drought could cause mountain lions and bobcats to search for alternative prey sources (Nordberg & Schwarzkopf, 2019), assuming they aren't also negatively affected by drought.

Predators are important for ecosystem function because they influence the behavior of other species and affect ecosystem processes. Removing apex predators can change the behavior and abundance of prey and other predators, which affects the vegetation community (Glen & Dickman, 2014). American black bears are important in ecosystems because of their effects on insect populations and fruits. They consume large numbers of colonial insects, controlling their population, and aid in the seed dispersal of the plants they eat. They also stir up the soil while foraging which increases species richness and nitrogen availability (Kronk, 2007). Mountain lions are important as top predators in the ecosystem they inhabit because they are instrumental in controlling ungulate populations (Shiravaju, 2003). Although gray foxes have a small role in our ecosystem, it is important. Their feeding habits influence small rodent populations by their steady predator-prey interactions (Vu, 2011). Bobcats are important predators because they control the populations of small mammals and bird species (Ciszek, 2002).

American black bears, mountain lions, gray foxes, and bobcats are the four prominent mammalian predator species found in the Big Chico Creek Ecological Reserve (BCCER), located in Northern California. Although the presence of these species and the effect that drought has on them is known, their distribution throughout the BCCER and their local resource use is unknown. Supporting the populations of these species is important for maintaining prey abundance and promoting ecosystem health. This study was created to influence the BCCER's land management practices in response to drought by providing information on the water and food resources that need to be conserved. This will be accomplished by investigating where each species is observed most frequently, identifying the water sources that each species uses the most, and determining the acres where bears and foxes consume the most plant matter.

Statement of the Problem

This study seeks to determine the distribution and resource use of American black bears (*Ursus americanus*), mountain lions (*Puma concolor*), gray foxes (*Urocyon cinereoargenteus*), and bobcats (*Lynx rufus*) east of the Big Chico Creek in the BCCER. Since the public views these four species as charismatic, they are interested in adopting acres that these species access the most through the Adopt an Acre Campaign. The locations these species visit the most in the BCCER is unknown, making it difficult to determine which acres are best to adopt. Although studies have been conducted on these species' diet and habitat, the BCCER staff doesn't know what location-specific resources they are utilizing. This is especially important for identifying the water sources that the species prefer since Butte County is currently in an extreme drought (National Integrated Drought Information System [NIDIS], 2022). This study's results will help promote public support, including the BCCER's Adopt an Acre Campaign, by advertising areas with high mammalian predator activity, in addition to influence land management practices to protect the resources that the species depend on.

Purpose of the Study

The purpose is to answer the following questions regarding American black bears, mountain lions, bobcats, and gray foxes:

1. What is the distribution of each species in the BCCER east of the Big Chico Creek?
2. Why are these species going to these acres/what resources are they using?
3. What percentage of each species detected are at an acre for a water-related reason? In addition, what acre with a nearby water source and food source do they prefer?

This research aims to investigate where mammalian predators go most frequently in the BCCER and why. Knowing the areas these charismatic species frequent could help promote the Adopt an Acre Campaign, which will provide funding for land stewardship and further research. Additionally, determining the main resources that each study species depends on will help further develop wildland management protocols to ensure that these species and resources are protected. From 2021-2022, Butte County has been in severe to exceptional drought (Figure 1) (NIDIS, 2022). By locating and maintaining vital water sources in the BCCER, these species will be given some support through the drought.

Limitations of the Study

This study is highly dependent on the proper function of twenty-four trail cameras, SD cards, and 144 AA batteries at a time. As with anything relying on technology, there are likely to be malfunctions. This includes trail cameras errors (from damage by bears, the weather, visitors turning them off, etc.), SD cards corrupting or the

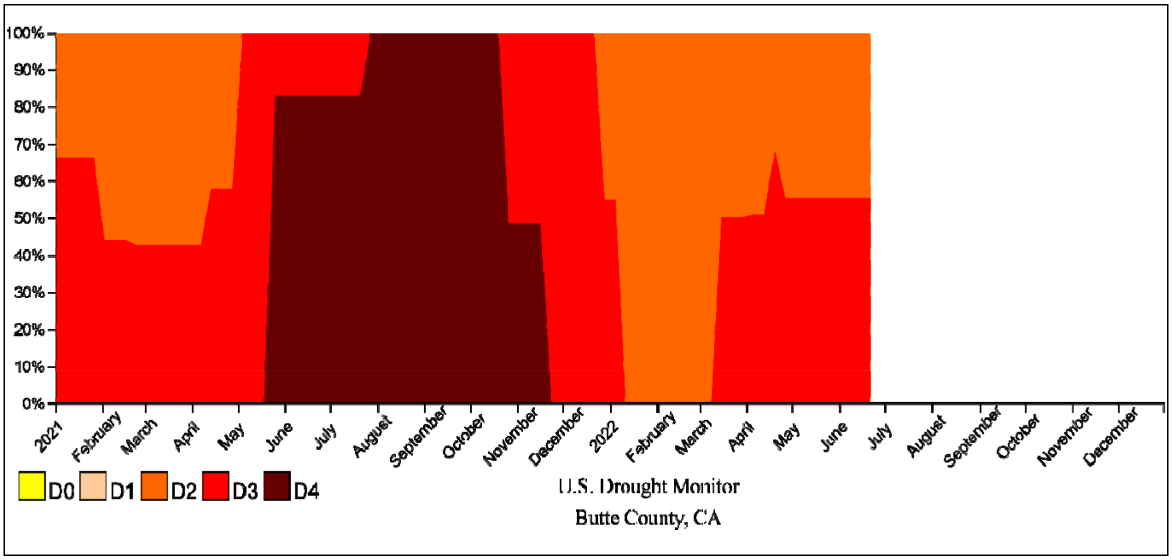

Figure 1. Intensity of Drought in Butte County, 2021-2022. The U.S. Drought Monitor shows the intensity of drought in Butte County by using a five-category system. D0 – abnormally dry, D1 – moderate drought, D2 – severe drought, D3 – extreme drought, D4 – exceptional drought.

storage capacity maxing out, or leaking batteries which could cause the camera to die or break. Table 1 shows the number of days out of the 365-day study period during which cameras on each acre were not working. During this time, there could have been species present, but they were unable to be documented.

This study also included some human constraints, including being incapable of accurately identifying 44 animal observations. This was due to either poor photo quality, only a small portion of the animal was visible, or only the eyeshine was detected. The trail cameras were also not checked every time it was scheduled due to extreme weather (fire and storms), sickness, and the occasional lack of available vehicles to drive to each camera.

At the beginning of this study, one of the goals was to estimate the local bobcat population. The identification of individuals through their unique coat patterns by

Table 1

Number of Days that Each Camera was Functioning or Not Functioning Within 365-Day Study Period

Acre	Number of days working	Number of days not working	Percentage of days working
B61	351	14	96.2%
F61	358	7	98.1%
I64	344	21	94.2%
K63	345	20	94.5%
S57	353	12	96.7%
T58	365	0	100.0%
T57	365	0	100.0%
Z59	320	45	87.7%
AN60	365	0	100.0%
AR70	332	33	91.0%
AS70	340	25	93.2%
AW68	320.5	44.5	87.8%
AX67	306	59	83.8%
AW54	365	0	100.0%
AX75	349	16	95.6%
BF60	342.5	22.5	93.8%
BI49	323	42	88.5%
BU48	305	60	83.6%
BX48	365	0	100.0%
BZ48	365	0	100.0%
CJ55	317	48	86.8%
CK55	333	32	91.2%
CM43	351	14	96.2%
CY42	317	48	86.8%

Note. The trail cameras on acres T58, T57, AN60, AW54, BX48, and BZ 48 were the only ones that remained functional throughout the study and did not miss a day. The cameras that were not functioning every day could have missed species detections.

using trail camera photos proved to be more difficult than anticipated. The bobcats weren't oriented the same way every time they were detected, so isolating and matching coat patterns with other detections was impossible. Since whatever estimate would have been developed would be highly inaccurate, the question was dropped.

Another limitation to this study is that there were very few bobcat and mountain lion detections. This made running statistical tests to analyze questions on these two species difficult, often resulting with a warning message in R Studio stating that the "chi-squared approximation may be incorrect." Because of the small sample size, the trends observed could not be rigorously statistically analyzed and thus conclusions based on these trends should be interpreted cautiously.

An additional factor that played a role in the data collected was the Dixie Fire, the largest non-complex wildfire in California's history (California Department of Forestry and Fire Protection [CAL FIRE], 2022). It originated above the Cresta Dam in Feather River Canyon on July 13, 2021, and burned across five counties: Butte, Plumas, Shasta, Lassen, and Tehama. The fire burned 963,309 acres over the course of 103 days and was reported as 100% contained on October 25, 2021. From August 12 to August 30, Butte Meadows was under evacuation warning (CAL FIRE, 2021). This area is approximately 33.7 kilometers (21 miles) from the BCCER. This likely affected the behavior and movement of the local fauna, which would alter the detection frequency of the study species from summer to early fall. Refer to Appendix A for a map of the Dixie Fire.

Definition of Terms

Exceptional Drought

- Fields are left fallow; orchards are removed; vegetable yields are low; honey harvest is small.
- Fire season is very costly; number of fires and area burned are extensive.
- Fish rescue and relocation begins; pine beetle infestation occurs; forest mortality is high; wetlands dry up; survival of native plants and animals is low; fewer wildflowers bloom; wildlife death is widespread; algae blooms appear. (NIDIS, 2022)

Extreme Drought

- Livestock need expensive supplemental feed; cattle and horses are sold; little pasture remains; fruit trees bud early; producers begin irrigating in the winter.
- Fire season lasts year-round; fires occur in typically wet parts of the state; burn bans are implemented.
- Water is inadequate for agriculture, wildlife, and urban needs; reservoirs are extremely low; hydropower is restricted. (NIDIS, 2022)

Gigabyte (GB)

"A unit of computer memory or data, equal to one billion bytes" (Lexico, n.d.a).

Secure Digital (SD) Card

"A type of memory card typically used in digital cameras and other portable devices" (Lexico, n.d.a).

Severe Drought

- Grazing land is inadequate.
- Fire season is longer, with high burn intensity, dry fuels, and large fire spatial extent.
- Trees are stressed; plants increase reproductive mechanisms; wildlife diseases increase. (NIDIS, 2022)

CHAPTER II

LITERATURE REVIEW

Introduction

Historically, people have viewed large predators as dangerous animals, as well as competitors for prey species (Rockwood, 2006). The numerous fables involving wolves, lions, and tigers have left a distinguishable mark in human culture. Additionally, early species and ecosystem management practices were guided by resource-driven (bottom-up) models. This means that “the system is regulated by energy moving upward, from lower to higher trophic levels,” giving carnivores little ecological value (Miller et al., 2001). Fear of predators, need for farmland, lack of knowledge, and negative public opinion fueled mass predator killings in the United States throughout the twentieth century.

A prominent example of these mass killings occurred on the Kaibab Plateau in northern Arizona from 1906 to 1931. Before 1906, a population of mule deer shared the plateau with cattle, sheep, coyotes, wolves, mountain lions, bears, and bobcats. When President T. Roosevelt made the Kaibab a game refuge as part of the new Grand Canyon National Park, federal agents removed the cattle, sheep, and nearly all the predatory species. At that time, wildlife biologists had a very negative view of predators and agreed with the predator removal policy. From 1906 to 1931, approximately 781 mountain lions, 30 wolves, 4,338 coyotes, and 554 bobcats had been killed on the Kaibab. There were around 4,000 deer in 1906 but due to the dramatic drop in the predator population, they were free from competition and predation, causing their population to skyrocket to nearly

100,000 by 1924. However, due to overgrazing, the deer population crashed to less than 1,906. Although the extirpation of carnivores took place throughout the twentieth century, the perception of large predators began to shift from “vermin” to “charismatic megafauna” among citizens of developed and wealthy countries during that time (Rockwood, 2006).

An alternative theory to the bottom-up model is the top-down model (Miller et al., 2001). This is when herbivores reduce the biomass of plants while carnivores regulate the biomass of herbivores. Carnivores can control prey populations both directly and indirectly. Through predation, carnivores directly reduce numbers of prey, which puts less pressure on plants and allows them to flourish. Indirectly, carnivores can change prey behavior. The prey populations will avoid areas where the predators are, causing them to choose different habitats, food sources, group sizes, time of activity, and reduce grazing time. By reducing the populations of competitively superior prey species and changing prey behavior, carnivores construct ecological boundaries. This protects weaker competitors from competitive exclusion and promotes the biodiversity of both fauna and flora. Predator removal will dissolve the ecological boundaries, causing prey species to compete for resources. This competition will reduce the biodiversity of the ecosystem through the displacement of weaker competitors and overgrazing of dominant prey. In addition to the impact carnivores have on herbivores, they also shape the structure of plant communities, which “influence the distribution, abundance, and competitive interaction within groups of birds, mammals, and insects” (Miller et al., 2001).

Study Site

The effect of predators on ecological communities has been observed globally, including the BCCER. The indigenous Mechoopda Maidu had occupied this area since time immemorial. They stewarded the land and enhanced resource production through prescribed burns and gathering plants for food and fiber. However, by 1850, European colonizers began to settle in the area and traditional land stewardship was no longer maintained. They cut timber for land development, released livestock to graze, and hunted and trapped native wildlife for food, sale, and to prevent predation on their livestock. In the late eighteenth century, timber in the upper watershed of Big Chico Creek was being overexploited. From 1874 to 1910, a flume was operating from Chico Creek headwaters, through the BCCER, to the town of Chico (BCCER, 2020d). The settlers began to see vast changes in the ecosystem. “Much of the timberland was replaced by brush and the perennial native grasses were replaced by exotic annual grasses and weeds” (BCCER, 2020d). The homestead families sold their land to owners of large cattle ranches and left. As pastures deteriorated, ranchers sold their land and left as well.

The BCCER is 31.71 square kilometers of protected land in Forest Ranch, California (Figure 2). It ranges in elevation from 213 meters to 623 meters and includes three major geologic formations - the Tuscan Formation, Lovejoy Basalt, and Chico Formation (BCCER, 2020c). The BCCER also has a trout stream, numerous perennial and intermittent tributaries, springs, seeps, and rock cliffs (BCCER, 2020e). The changing aspects (slope, exposure, elevation, soil moisture, and soil depth) of the BCCER’s microhabitats cause its vegetation to be extremely varied. The vegetation types have been grouped into categories, including grasslands, wet meadows, riparian zones,

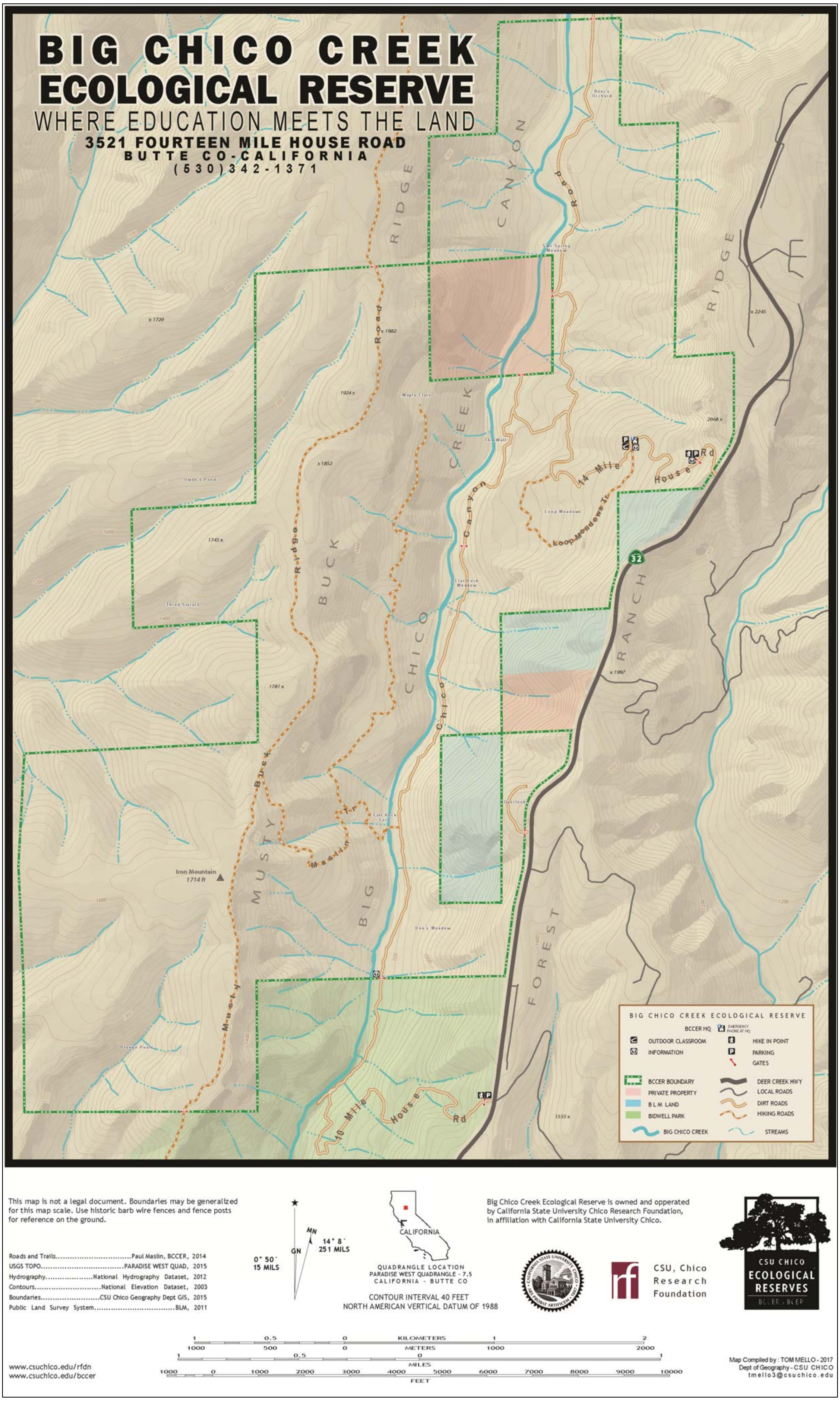

Figure 2. Map of Big Chico Creek Ecological Reserve (BCCER) in Forest Ranch, California.

valley oak woodlands, blue oak savanna/woodland, mixed woodland/forest, chaparral, and chaparral/savanna (BCCER, 2020g). These diverse habitats support over 600 plant species and around 196 wildlife species: 117 birds, 46 mammals, 15 reptiles, and nine amphibians and fish. There are an additional 14 wildlife species - 13 mammals and one amphibian - expected to inhabit the BCCER, but they haven't been observed yet (BCCER, 2020f).

Since 1999, the BCCER is now owned and managed by California State University and Chico State Enterprises. It was established to protect and monitor on-site natural resources, support research and teaching at CSU, Chico, and provide public outreach and education. One of the ways that the BCCER is supporting its goals through the Adopt an Acre Campaign. This program combines public outreach, fundraising, research, and monitoring by inviting members of the public to adopt any of the BCCER's acres. Funds from the Adopt an Acre Program are then used for the BCCER's many projects, including fire mitigation projects, the development of future land managers and environmental stewards, K-12 outdoor education programs, innovative student research, and community workshops. There are currently six levels of support, each at different costs and providing unique benefits. Supporters that adopt an acre for at least $1,000 get a wildlife trail camera set up on their acre, with pictures and an individualized report sent to them annually. Knowing what species are utilizing the BCCER and where they are found most, could help promote the campaign by advertising locations with the most activity. This is especially important for the species more commonly admired by the public, mammalian predators such as American black bears (*Ursus americanus*), mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), and gray foxes (*Urocyon cinereoargenteus*) (BCCER, 2020a).

Study Species Life History

American Black Bear (*Ursus americanus*)

American black bears are typically black, especially those in eastern North America. However, they can also have brown, cinnamon, or blonde coats, which are more commonly found in western populations. Black bears usually have a pale muzzle and can have a white spot on their chest (Kronk, 2007). Adults range from 1.3 to 1.9 meters in length with males weighing between 60 to 300 kilograms and females weighing between 40 to 80 kilograms (International Bear Association [IBA], 2017).

Black bears occupy a wide variety of habitats; however, their populations are most dense in forested areas with a wide variety of intermediate stages characterized by “relatively inaccessible terrain, thick understory vegetation, and abundant sources of food in the form of a shrub or tree-borne soft or hard mast” (Kronk, 2007). The bears are known to use annual grasslands sporadically, although they more commonly utilize montane chaparral and woodlands and mixed conifer forests because they supply food, cover, and water. The valley foothills also provide a seasonally important habitat for the bears (California Department of Fish and Wildlife [CDFW], 2022a).

According to a study conducted in Yosemite National Park, 75% of the black bear diet is plants (Graber and White, 1983). This includes grasses, sedges, herbaceous dicots, nuts, and berries, especially manzanita (*Arctostaphylos* spp.) and oak acorns (*Quercus* spp.). They also eat insects and mule deer (*Odocoileus hemionus*), as well as human food when given the chance (Graber & White, 1983).

Black bears are generally crepuscular, meaning they are active during twilight, however, breeding and feeding could alter this pattern seasonally (Kronk, 2007). According to Garshelis and Pelton (1980), American black bears are more active during the day in summer when berries are ample, and at night in the fall because they're foraging to prepare for hibernation. They are very opportunistic feeders, so if human food or garbage is available, then the bears become "diurnal (on roadsides) or nocturnal (in campgrounds)" (Kronk, 2007). Black bears are usually solitary animals, except for adult females with her cubs, breeding pairs in summer, and at some feeding sites. Where there is an aggregated food source, such as during salmon runs, large numbers of bears congregate and form social hierarchies. Black bears possess a high level of intelligence and curiosity. They communicate with their body and facial expressions, vocalizations, touch, and scent marking (Kronk, 2007).

Mountain Lion (*Puma concolor*)

Mountain lions (*Puma concolor*) has one of the largest ranges of any felid. The species range from Patagonia to Alaska, known by various common names throughout this range including cougars, pumas, and panthers. Mountain lions are North America's largest member of the cat family. They have short, coarse fur with colors ranging from rust, apricot, smoke, and black. Their underside is white, and they have a black-tipped tail. As adults, these large cats can reach 76 centimeters in height at the shoulder (National Parks Service [NPS], 2015). From the head to the base of the tail, males are 1.01 to 1.52 meters in length while females are 0.86 to 1.30 meters, with their long and slender tails making up one-third of their total length (Shivaraju, 2003).

Mountain lions usually weigh between 34 to 80 kilograms. Although they have been documented to weigh over 90 kilograms, it is extremely rare (NPS, 2015).

Mountain lions inhabit a wide variety of habitats, including "montane coniferous forests, lowland tropical forests, grasslands, dry brush country, swamps, and any areas with adequate cover and prey" (Shivaraju, 2003). Their home ranges can cover between 65 to 2,033 square kilometers, with the adult males averaging around 518 square kilometers and adult females averaging around 195 square kilometers (NPS, 2015). Since the BCCER is only 31.71 square kilometers, and mountain lions are territorial, then there is likely only one living in the BCCER.

Mountain lions are carnivores. Their prey base includes a wide variety of smaller animals such as squirrels, muskrats, beavers, raccoons, skunks, coyotes, bobcats, rabbits, birds, and fish but the diet primarily consists of ungulates including moose, elk, deer, and caribou (Shivaraju, 2003). The only native ungulates present in the BCCER are Columbian black-tailed deer (*Odocoileus hemionus columbianus*). These lions are ambush hunters. They wait patiently in dense vegetation for their prey, silently stalking it, then leap onto their backs, breaking their neck with a powerful bite (NPS, 2015). They consume around 860 to 1,300 kilograms of large prey yearly, which is about 48 ungulates per lion per year. When the mountain lions make a large kill, they drag the prey up to 347 meters from the capture site, bury it under leaves, and return to it to feed at night (Shivaraju, 2003).

Mountain lions are typically solitary animals, except during mating season and periods of juvenile dependence (Shivaraju, 2003). Population densities vary from as low as one individual per 83 square kilometers to as high as one individual per 13 square kilometers. These densities depend on prey densities and other resources in the area. Mountain lions mark their territories by spraying urine or depositing feces by trees marked with scrapes (Shivaraju, 2003). They have excellent vision due to their large eyes, and their retinas contain more rods than cones, allowing them to see in the dark. These adaptations have allowed them to be primarily nocturnal animals that hunt at dawn and dusk (NPS, 2015).

According to Allen et al. (2014), mountain lion activity is dependent on factors such as the abundance and vulnerability of prey, which varies across seasons. This means that their feeding ecology will vary based on the availability of prey. So, there isn’t necessarily a season where they are consistently most active. According to the study, the mountain lions had a higher ungulate kill rate during summer and fall which correlated with the increased density of black-tailed deer fawns (*Odocoileus hemionus columbianus*).

Bobcat (*Lynx rufus*)

Bobcats got their name due to their short, bobbed tails (Ciszek, 2002). Their fur varies between buff and brown, with dark brown or black stripes and spots on certain parts of the body. The tip of their tail is black and they have ruffs of hair on the side of their head. They range in length from 0.63 to 1.04 meters, with their tail adding an extra 12 centimeters. Bobcats are also .43 to .56 meters high at the shoulder and weigh between 4 to 15 kilograms (Ciszek, 2002).

Bobcats are found throughout North America, from southern Canada to southern Mexico. Within the national forests of California, male bobcats have an average home range size of 5.2 square kilometers, while female home ranges are much smaller at

2.3 square kilometers (Serieys, 2011). Their home range size depends mostly on resource abundance and secure areas for resting or mating. It is also influenced by the bobcat population density. If the population density is high, then their home ranges decrease (Serieys, 2011). Assuming all 31.71 square kilometers of the BCCER is adequate bobcat habitat, then there are likely 6 to 14 individuals living in the BCCER.

In the United States, their population densities are much higher in the southeast in comparison to the western states. “Bobcats can be found in a variety of habitats, including forests, semi-deserts, mountains, and brushland” (Ciszek, 2002). They sleep in hidden dens, hollow trees, and rocky crevices. Bobcats are territorial, using urine, feces, and anal gland secretions to outline home ranges that are usually up to 8 square kilometers (Ciszek, 2002).

Bobcats are carnivorous animals, preying on rodents, rabbits, small ungulates, birds, and reptiles. They stalk their prey, pounce, and kill it with a lethal bite to the neck. “Like many felids, bobcats are solitary animals” (Ciszek, 2002). Males and females interact almost exclusively during the mating season. Although they rarely vocalize, they often yowl and hiss during this time. Bobcats are essentially nocturnal; however, they are often active at dawn and dusk (Ciszek, 2002).

Since bobcats are small felines, they have proportionately smaller eyes that aren’t as adapted to low light, as seen in other cats (Hansen, 2007). According to Rockhill et al. (2013), their behavior changes based on the “period of day (dark, moon, crepuscular, day), lunar illumination (<10%, 10 - <50%, 50 - <90%, >90%), and moon phase (new, full).” His research showed that the bobcats had high movement rates during crepuscular and day periods, as well as at nighttime with high lunar illumination, such as during a full moon. This behavior is consistent with their prey availability and by their limited nighttime vision (Rockhill et al., 2013).

Gray Fox (*Urocyon cinereoargenteus*)

Adult gray foxes are medium-sized canids with elongated bodies and relatively short legs (Vu, 2011). Their coats are a mix of white, red, black, and gray fur, and they usually weigh between 3 to 5 kilograms. Populations living in high elevation habitats are slightly larger than those living in low elevations. Generally, gray foxes can grow up to 91 centimeters in length. Their tail makes up around one-third of their total body length and it has a dorsal black stripe and black tip (Vu, 2011).

Gray foxes are very territorial animals, with a home range of only 2.6 square kilometers (Vermont Fish & Wildlife Department, 2022). Since the BCCER is 31.71 square kilometers, then there could potentially be approximately 12 individuals living there. Their habitat consists of "deciduous forests interspersed with brushy, woodland areas," in addition to a nearby water source (Vu, 2011). These foxes can live in elevations ranging from one to three kilometers. Their dens are usually found in hollow trees or logs, crevices, and burrows. Gray foxes are the only member of the Canidae family that can climb trees. This allows them to also live in dens in the lower forest canopy, 10 yards above the forest floor (Vu, 2011).

Gray foxes are omnivorous; they feed on small vertebrates, fruits, and invertebrates. During winter, cottontails, mice, woodrats, and cotton rats comprise most of their diet. In spring, fruits become more available and make up 70% of their diet (Vu, 2011). Invertebrates, nuts, and grains also increase in importance during this time. These foxes can also feed on carrion when it is available. When they accumulate an excessive amount of food, they dig a hole with their forepaws, bury it, and mark it with urine or the scent glands on their paws and tail. The scent is used to ward off other animals as well to make it easier to relocate. Gray foxes are solitary animals, however, during winter, they socialize with their mate and offspring after parturition. They are mostly nocturnal but have been seen in the daytime (Vu, 2011).

Terrestrial Vertebrate Fauna
Survey Techniques

There are several survey techniques for detecting fauna. The appropriate method depends on "the expected species or assemblages, the nature of the environment, weather conditions and the purpose of the overall study (Environmental Protection Agency [EPA], 2020). American black bears and mountain lions weigh over 2,500 grams, classifying them as large mammals. Bobcats and gray foxes are considered medium mammals because they fall between the 30 to 2,500 grams category. Since the study species fall into the medium and large mammal categories, the primary survey techniques that are commonly used for those classifications were examined. These techniques have been known to efficiently provide presence and abundance data.

The primary detection techniques for medium mammals include aluminum box traps, cage traps, searching for tracks and other signs, and camera traps. Aluminum box traps are baited and equipped with a trigger plate on the floor of the trap. When the animal enters, the plate triggers a hinged door to close, trapping the animal inside. The sizes of the boxes vary depending on the target species. Cage traps are made of wire mesh and have a treadle and wire link holding the door open. To get the bait, the animal must cross the treadle which releases the trap door and locks the animal inside. These traps range in size and can be rigid or collapsible. Both types are difficult to handle and set out. Searching for tracks and other signs, including "diggings, burrows, nests, scats and pellets, claw marks on tree trunks and other signs require persistence, well-developed observation skills and knowledge of the natural history of the local fauna" (EPA, 2020). This is useful for species that avoid traps, are too large to trap, or are at low densities in the study site. It may be easier to detect species with clumped distributions because large areas can be assessed quickly. Sand is an ideal substrate for detecting tracks, although they will be concealed quickly by wind and rain. The optimal times to search for tracks and other signs are early morning or late afternoon, when the sun is lowest in the sky. This timing created the greatest amount of shadow within tracks, making them easier to detect and interpret. Even though tracks may not last long, diggings and burrows can last for years, indicating the historical usage of the area. Camera traps are digital cameras that capture images or videos by using an infrared sensor to detect the movement of a heat signature. They can be left for several days to months depending on the power source and multimedia storage. The cameras are best placed in areas of activity, including tracks, burrows, or areas with evidence of foraging. They are useful for medium to large, distinctive mammals and they provide information that human observers can't obtain during a field survey. They can also estimate density and abundance for some species. Baits and scent lures can be used to attract wildlife to camera traps while a reference scale can be installed in the detection zone to help identify them (EPA, 2020).

In addition to searching for tracks and other signs, and using camera traps, the primary detection techniques for large mammals include spotlighting and headtorching (taken from the British term for a head lamp), and observation (EPA, 2020). Spotlighting and headtorching are important techniques when studying nocturnal or crepuscular fauna, especially threatened species. Both techniques should be conducted in a way that minimizes disturbance to wildlife. Spotlighting is when a spotlight is illuminated over an area. Some species will freeze, while others flee immediately. This can make it hard to identify some species, so knowing the species that you may encounter beforehand is essential. Spotlighting can be done from a vehicle, enabling a larger distance to be traveled and studied. Portable spotlights can also be used while walking to investigate a smaller study area. Headtorching is more useful than spotlighting for certain species because the light is dimmer and it shines in the same plane as the observer's eyes, improving the detection of reflected eye shine. It is also useful for inspecting distinct features, including termite mounds and caves. Observation through active searching is primarily used for herpetofauna and involves searching microhabitats. This includes digging up burrows, turning over rocks and logs, and raking soil and leaf litter. This method requires knowledge of the species that may be detected and their habitat preferences. If the observer puts in the adequate effort and has a great deal of experience, then more species will be detected. It is also important to conduct these surveys during the right conditions and to minimize the impact on the habitat. Opportunistic observation involves recording the vertebrate fauna detected, and their location, while traveling between sites (EPA, 2020).

Searching for tracks and other signs, and using camera traps are the two primary survey techniques used for both medium and large mammals. Since the BCCER doesn't have an ideal substrate for identifying tracks, and is prone to wet and windy conditions, searching for tracks may not be ideal. Using camera traps would allow for the continuous detection of species, even in the absence of the observer. They will also help with the examination of the resources being utilized by detected species, as well as the individuals' health and size.

Conclusion

California has been in "moderate to extreme drought" since 2012 and it is unknown when, or if, this period will end (NIDIS, 2022). This makes providing and maintaining appropriate water sources to sustain the wildlife, more important than ever. By using the camera trap technique, we can observe the distribution of mammalian predator species in the BCCER and gather data on the resources they are utilizing. This will give the BCCER staff information on the water sources and other resources that should be protected. By preserving these resources, the mammalian predators and other fauna have a greater chance of surviving this drought. Additionally, sustaining healthy predator populations will help prevent prey populations from exploding and disrupting the ecosystem. This study will also give the BCCER staff knowledge on the acres to promote for the Adopt an Acre Campaign. By adopting-out more acres, additional funding for land management and education projects will be provided. This study examined the following hypothesis:

1. American black bears
    a. Will be detected most frequently in acres with water and fruit-bearing trees, as well as in forests, chaparrals, and woodlands
    b. Will be using water and fruit resources the most
2. Mountain lions

a. Will be detected most frequently in acres with abundant deer, as well as in forests, grasslands, and brushlands

b. Will be using water resources the most

3. Bobcats

   a. Will be detected most frequently in forests, chaparrals, and brushlands

   b. Will be using water resources the most

4. Gray foxes

   a. Will be detected most frequently in acres near water, as well as in forests with brush and woodlands

   b. Will be using water and fruit resources the most

CHAPTER III

METHODOLOGY

Mapping Camera Locations and Mounting Them

Equipment and funding for this project are provided in part by the BCCER Adopt an Acre Campaign in which donors can sponsor placement of a camera on a particular acre in the BCCER. As such, choice of camera locations was driven by several, sometimes conflicting needs: 1) donor relations, 2) public education and outreach, and 3) fulfilling research monitoring goals of the BCCER. Prior to the beginning of my study, the BCCER already had eighteen trail cameras mounted for their Adopt an Acre Campaign. Donor preferences resulted in some instances clusters of multiple cameras in close proximity on adjacent acres. In general, cameras or camera clusters, were distributed at approximately 700 – 850 meters (0.43 – 0.53 miles) apart from each other. Existing donor-sponsored cameras were supplemented with six additional cameras placed on acres specifically chosen to create an even distribution. A map of the BCCER was used to find the coordinates for trail camera locations in areas where there weren't any. With these six additional non-donor-sponsored acres, the total number of cameras for this study increased to twenty-four. A map of the trail camera locations can be seen in Figure 3.

After the acres for new camera locations were chosen from the maps, specific camera sites were selected by inspecting the area carefully searching for signs of animal activity – animal trails, tracks, scat, or markings. The cameras were mounted where at

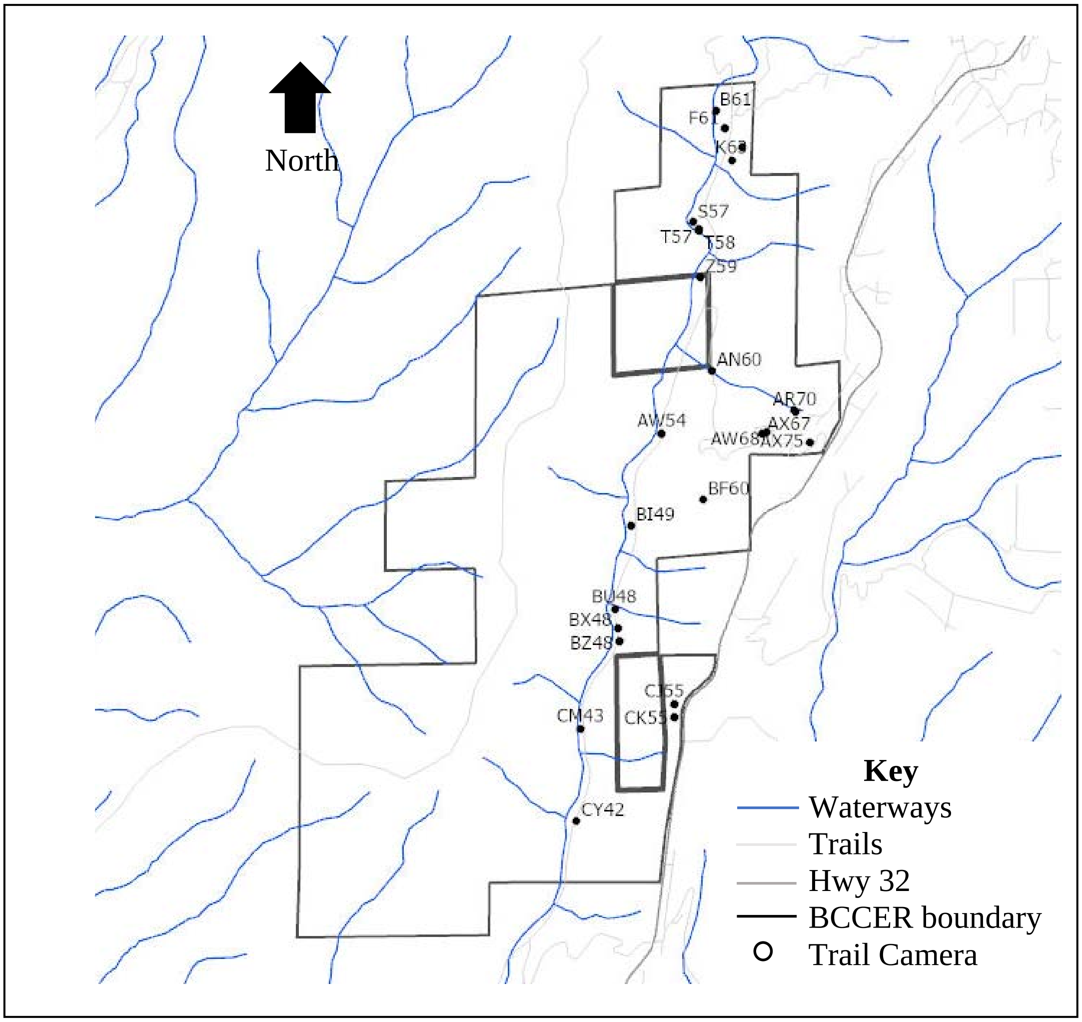

Figure 3. Map of trail camera locations in the BCCER. Acres are labeled alphanumerically with letters in alphabetical order from North to South and numbers ascending from West to East.

least one of those signs of activity were, ensuring that the camera wasn't facing an area with dense vegetation. They were positioned so that they would face trails (almost parallel to it) or at around a 45-degree angle with the trail. When determining the height and angle of the cameras, they were mounted to a tree or T-post, turned on, walked in front of, then the SD card was ejected and inserted into an SD to iPhone adapter to view the pictures. The camera would then be adjusted accordingly. Since the animals being detected are around waist height, the cameras were positioned so that they would at least be able to detect movement from the ground to a person's waist. All the trail cameras for the study were mounted and began collecting data by May 18, 2021.

Programming Trail Cameras

The study began with 20 Browning Dark Ops BTC-6HDX, 2 Browning Recon Force BTC-7A, 1 Moultrie M990i MCG-12634, and 1 Moultrie MCG-12635 trail cameras. Some of these models changed later in the study because the original camera needed to be replaced and the same model was no longer available to order. Table 2 lists the trail camera model at each acre, the date the camera was changed, and the model of the new camera. Although different camera models were used, each one had the same settings programmed. Refer to Appendix B to see the settings that were selected.

Checking the Trail Cameras

The frequency of each time the trail cameras were checked varied from twice a week to once every two weeks. This depended on how quickly the SD cards would fill up, which had a seasonal trend. During summer and fall, animal activity and false detections were higher than winter and spring when both animal activity and foliage-triggered cameras were lower. False detections occurred when the camera was triggered by something other than an animal. This was typically caused by the vegetation becoming so dense that its movement in the breeze triggered the cameras on sunny days. During the summer and fall seasons, the cameras were checked a minimum of once a week, with certain cameras (AX75, AW68, AX67, AS70, AR70, BF60, CK55, and CJ55) being checked twice a week. These cameras were checked more frequently because they tended

Table 2

Each Acre's Trail Camera Information

Acre	Camera Height (Cm)	Camera Type	Prox. To Next Camera - Straight Line (M)	Prox. To Next Camera - On Path (M)	Approx. Dist. To Water (M)
AX75	118.11	Browning Dark Ops BTC-6HDX	to AW68: 397	to AW68: 830	1 km
AW68	160.02	Camera changed from Browning Dark Ops BTC-6HDX to Browning BTC-5HD-MAX on 10-22-21	to AX67: 25.4	to AX67: 25	28 m
AX67	34.29	Browning Dark Ops BTC-6HDX	to BF60: 771	to BF60: 848	3 m
AS70	158.75	Browning Recon Force BTC-7A	to AW68: 303	to AW68: 368	375 m
AR70	134.62	Browning Recon Force BTC-7A	to AS70: 43	to AS70: 60	435 m
BF60	97.79	Browning Dark Ops BTC-6HDX	to AW54: 682	To AW54: 2.12 km	275 m
B61	109.22	Browning Dark Ops BTC-6HDX	to F61: 176 to K63: 453	to F61: 440 to K63: 706	18 m
F61	115.57	Browning Dark Ops BTC-6HDX	to I64: 223	to I64: 360	94 m
I64	119.38	Browning Dark Ops BTC-6HDX	to K63: 147	to K63: 313	2 m
K63	99.06	Camera changed from Browning Dark Ops BTC-6HDX to Browning Dark Ops HD Pro X BTC-6HDPX on 4-15-22	to S57: 637	to S57: 855	315 m
S57	106.68	Browning Dark Ops BTC-6HDX	to T57: 87 to Z59: 483	to T57: 92.8	53 m
T57	129.54	Browning Dark Ops BTC-6HDX	to T58: 6	to T58: 23	5 m
T58	105.41	Browning Dark Ops BTC-6HDX	to Z59: 41	to Z59: 699	28 m
Z59	77.47	Camera changed from Browning Dark Ops BTC-6HDX to Browning Dark Ops HD Pro X BTC-6HDPX on 12-17-21	to AN60: 81	to AN60: 1 km	5 m
AN60	119.38	Browning Dark Ops BTC-6HDX	to AW54: 700	to AW54: 1.13 km	NA
AW54	100.33	Browning Dark Ops BTC-6HDX	to BI49: 847	to BI49: 977	52 m
BI49	161.29	Camera changed from Moultrie MCG-12635 to Browning Strike Force Max HD BTC-5HD-MAX on 9-6-21	to BU48: 743 to BX48: 899	to BU48: 858	28 m
BU48	104.14	Browning Dark Ops BTC-6HDX	to BX48: 151.5	to BX48: 160	70 m
BX48	100.33	Browning Dark Ops BTC-6HDX	to BZ48: 116 to CM43: 927	to BZ48: 140	45 m
BZ48	52.832	Browning Dark Ops BTC-6HDX	to CM43: 826	to CM43: 919	78 m
CM43	111.76	Browning Dark Ops BTC-6HDX	to CY42: 801 to CK55: 832	to CY42: 876	10 m
CY42	113.03	Browning Dark Ops BTC-6HDX			100 m
CK55	67.31	Browning Dark Ops BTC-6HDX	to CJ55: 118	to CJ55: 132	NA
CJ55	97.282	Browning Dark Ops BTC-6HDX			NA

to fill up their SD cards the fastest and they were the most easily accessible cameras. During winter, the cameras were checked once every other week due to a sharp decline in animal activity and lack of false detections. Occasionally, the camera check frequency was extended to once every three weeks due to inclement weather postponing the camera check date. In spring, the cameras were checked once every other week. Refer to Appendix C for the tools taken and steps followed for checking the trail cameras.

Media Upload and Data Organization

After checking the trail cameras, the next steps involve uploading, sorting through, and organizing the media. First, the pictures and videos were transferred from the SD cards to an external hard drive. This clears the SD card so that it can be used in the next camera check and temporarily stores the media in one location to be sorted through. Refer to Appendix D for the detailed steps on transferring the data. Next, is uploading the media from the external hard drive to Box, an online database. This ensures the organized and long-term storage of this data, allowing for more research to be done on the mammals in the BCCER. Refer to Appendix E for the data upload protocol. The last step is sorting through the trail camera folders on the Seagate Expansion Drive and recording the data on Excel whenever a study species was detected. Refer to Appendix F for the steps on sorting through the trail camera folders, uploading media on the study species, and recording the data.

Acre and Camera Information

A description of habitat type and dominant vegetation at each camera site was provided by botanist, Cassie Corridoni and summarized in Table 3 based on surveys

Table 3

Each Acre's Habitat Description and Type

Acre	Habitat Description	Habitat Type
AX75	Black oak, toyon, canyon bay, live oak, grey pine, Douglas' iris, lupine, coffeeberry, bigleaf maple, non-native understory	Oak woodland/mixed conifer
AW68	Directly under olive trees, next to building, bathrooms, fig trees, also near native bunch grasses field	Non-native majority; high traffic area
AX67	Near barn, olive and fig trees near, toyon, water trough present, small low grassy field, overlooking hill	Oak woodland; non-native majority; not-natural, high use area
AS70	Canyon live oak, poison oak, gooseberry, pipevine, Iris, grey pine, big leaf maple, redbud. Heavy canopy, riparian species	Oak woodland/grey pine forest
AR70	Poison oak, CA grape, black oak, redbud, toyon, grey pine, coffeeberry, geranium. Dense canopy	Oak woodland/grey pine forest
BF60	Canyon live oak, bay laurel, valley oak, purple needle grass. Dense tree cover, non-native grasses, non-native hedge parsley	Cam placed in mixed oak woodland, facing annual grassland
B61	Canyon live oak, interior live oak, valley oak, bay laurel, rush, blue dicks, dutchman's pipevine, coffeeberry, poison oak	Mixed oak woodland/riparian forest; next to creek
F61	Redbud, buttercups, poison oak, valley oak, bay laurel, big leaf maple, canyon live oak, blue dicks. Near rock wall, non-native understory (stick straw)	Mixed oak woodland
I64	Big leaf maple, bay laurel, CA rose, near annual grassland, miner's lettuce, ferns. Facing spring	Riparian forest
K63	Interior live oak, coffeeberry, gum plant, sedges, prunes/fruiting tree, Himalayan blackberry, water-loving spp., valley oak	Meadow/riparian forest and shrubs
S57	Poison oak, canyon live oak, Rhus, blue dick, Dutchman's pipevine, interior live oak, bay laurel, oxalis sp., non-native hedge parsley, and grass	Canyon oak woodland with annual grassland understory
T57	CA incense cedar, canyon live oak, poison oak, CA grape, Dutchman's pipevine, buttercup, miner's lettuce	Creekside, mixed oak woodland and conifer forest
T58	Interior live oak, canyon live oak, chaparral honeysuckle, annual grassland understory	Mixed oak woodland
Z59	Clover sp., blue wild rye, sweet pea (non-native), gum plant, lupine sp.	Annual grassland, meadow
AN60	Canyon live oak, toyon, grey pine, poison oak, chaparral honeysuckle, Dutchman's pipevine, non-native hedge parsley, black oak	Mixed conifer oak woodland forest (dense)

Table 3 (continued)

Acre	Habitat Description	Habitat Type
AW54	Grey pine, Douglas fir, bay laurel, poison oak, Rhus, ferns, canyon live oak, toyon, Dutchman's pipevine, non-native understory	Mixed conifer forest
BI49	CA buckeye, canyon live oak, non-native stick straw and grass understory, wildflowers, buttercups, bay laurel, rocks next to creek	Canyon live oak woodland and riparian forest
BU48	Grey pine, blue dicks, buttercup, Douglas' iris, poison oak, tufted poppy, canyon live oak, green leaf manzanita	Oak woodland mixed conifer/chaparral
BX48	Canyon live oak, grey pine, poison oak, green leaf manzanita, toyon, buttercup, fern, pipevine, tufted poppy, holly leaf redberry	Oak woodland mixed conifer forest
BZ48	Grey pine, CA buckeye, toyon, poison oak, tufted poppy, chaparral honeysuckle, ferns, canyon live oak, pipevine	Oak woodland/chaparral
CM43	Douglas fir, ponderosa pine, CA incense cedar, bay laurel, canyon live oak, Oregon Ash, poison oak, soaproot, toyon, white alder, Himalayan blackberry, mugwort, Rhus, Santa Barbara sedges	Riparian mixed conifer forest
CY42	Blue oak, grey pine, CA buckeye, blue dicks, interior live oak, annual grasses, hollyleaf redberry, deergrass, Ithuriel's spear, Rhus	Blue oak woodland
CK55	Mountain mahogany, yerba santa, grey pine, toyon, hollyleaf redberry, manzanita, buckbrush	Chaparral
CJ55	Grey pine, yerba santa, popcorn flowers, hollyleaf redberry, buckbrush, non-native grasses	Chaparral

conducted on March 2, 2022. Table 2 shows each trail camera's height, camera type, proximity to the next camera, and the approximate distance to a water source. The distances between cameras and water source were determined by using Avenza, a mobile map app that uses the phone's GPS. The values in the "proximity to next camera – straight line" column were determined by drawing straight lines from one trail camera to the next on the Avenza map. This means that slopes and possibly uncrossable terrain were not considered. Only the shortest possible distance between the cameras were measured. However, this is not how wildlife travels, they follow trails to get to their next destination. "Proximity to next camera – path" was measured on Avenza by tracking my path while walking to each camera on established wildlife trails. These “path” distances are likely to be similar to what the wildlife travels. The “approximate distance to water” column was also measured by using Avenza to track the paths from the cameras to the nearest known water source. If there is no known water source around, then “NA” was placed in the corresponding cell.

Data Analysis

All data was recorded on a Microsoft Excel file with the images from each detection organized in BOX, a cloud-based archive-system contracted by California State University Chico. Images were cataloged based on the species, acre, and date. Preliminary analysis was performed on Excel to visualize general trends and clean up the data. All formal analysis was produced on R Studio and chi-squared tests were conducted to analyze the data. Chi-squared was chosen because it analyzes differences between observed data and expected results, and it can test if two variables are related or independent from each other. The distribution maps were created on ArcGIS.

Camera Clusters

Since eighteen of the trail cameras used were set up at acres chosen by donors prior to the start of this study, some areas have clusters of two to three cameras. The cameras within these clusters can range from approximately 23 to 160 meters apart from each other. Since some of these cameras are so close together, there is potential for an individual being detected on multiple cameras in a cluster within a short timeframe. This could create a bias in areas with camera clusters because one detection event could be recorded as two or three detection events. To minimize the number of potential duplicate detections, the following factors were taken into consideration: distance between the cameras within clusters, the walking speed and behavior of each species, and the resources around the cameras.

There were five trail camera clusters whose data needed to be filtered through – AS70 to AR70 (60 m); AW68 to AX67 (25 m); S57 to T57 (93 m) to T58 (23 m); BU48 to BX48 (160 m) to BZ48 (140 m); CK55 to CJ55 (132 m). AW68, AX67, S57, T57, T58, CK55 and CJ55 are all in open areas, which gives animals the opportunity to wander around and spend more time in those locations. However, the cameras on AS70, AR70, BU48, BX48, and BZ48 are all facing narrow trails that the animals must follow.

Although there is an abundance of information on the study species' running speeds, there is relatively little information on their walking speeds. According to Elop (2021), American black bears travel throughout their home range walking less than 107 m/min. They are also not territorial animals, with their home range often overlapping with other bears (FWC, 1999). This means that multiple bears could be detected on one trail camera within a short timeframe. Although the bears were most active in the fall, the time between most detections within a cluster of cameras were over 30 minutes apart. This large time gap means that the detections were likely of different bears. However, March and April had the most observations with a smaller time gap between cameras within a cluster. This high detection frequency between cameras within clusters could be due to the bears waking up hungry from their winter torpor in mid-March, and vigorously foraging for plant matter throughout April (Breiter, 2005).

Gray foxes are highly territorial of their small 2.6 square kilometer home ranges (Vermont Fish & Wildlife Department, 2022). This indicates that it is unlikely for multiple foxes to be detected on one trail camera within a short timeframe. Although their walking/trotting speed is not documented, red foxes (*Vulpes vulpes*) can trot at approximately 100 – 217 m/min (iNaturalist, n.d.). This speed will be used to calculate how quickly the gray foxes should be able to travel through areas with multiple trail cameras. Since they are omnivorous and don’t go into torpor, it can be expected for the fox to spend time at acres with their favorite plant matter year-round, especially in the spring.

Mountain lions have a walking pace of approximately 268 m/min (USDA, n.d.), while bobcats will zigzag throughout their territory at 0.15 – 1 m/min (Adams, 2020). Since both felids are carnivorous, they will likely walk through the camera clusters, not stopping to forage like the bears and foxes. No bobcat detections occurred in the same area during the same time of the day, meaning each observation was unique. Therefore, bobcats were not included in the camera cluster analysis.

The trail cameras on the Grandmother Pine Trail (AS70 and AR70) are surrounded by oak trees, gooseberry, redbud, toyon, coffeeberry, and California grape – all producing potential food for bears and foxes. Although all species should be able to walk through this trail within a minute, five minutes were allocated between detections for the bears and foxes due to the abundance of food. Meaning, if a fox or bear was detected on one of those two trail cameras within five minutes after the other, then it would be documented as a duplicate detection of the same individual and removed from the analysis. There were 43 duplicate fox detections and 13 duplicate bear detections that were removed. Mountain lions were listed as a duplicate detection within two minutes of the first observation, with only one duplicate.

The trail cameras near the BCCER office (AW68 and AX67) are near olive trees, fig trees, toyon, grasses, and a horse trough, which are used by the bears and foxes. Although these cameras are only 25 meters apart, they are in an open area with no distinct trails, allowing for animals to roam around. Most gray fox detections that occurred on both cameras had a large time gap, indicating a unique detection event. There were only four fox detections that occurred on one camera within five minutes of a detection on the other. These four observations were listed as duplicates of the same fox. The bears tended to spend more time in this area and were documented as repeat detections if they were observed within 15 minutes on both cameras. This threshold time was extended to 21 minutes for observations occurring in March and April due to their behavior. A total of 21 minutes was determined because the pictures taken within 25 minutes were examined and the bears observed over 21 minutes apart were different individuals. There were 27 bear detections that were listed as duplicates in this area, and no repeat mountain lion observations.

There are three trail cameras in Henning Hole (S57, T57, and T58) which has oak trees, grasses, California grape, and the Big Chico Creek runs near it. There were only three fox detections in this area, all on different days, so they were not included in the camera cluster analysis. Since there aren’t many resources for bears to use, along with the few observations, duplicate detections were documented with observations occurring within five minutes of each other. There were two repeat observations at acres T57 and T58 that occurred one minute apart, one repeat at S57 and T58 at two minutes apart, and one duplicate at T58 in two minutes. Mountain lions were listed as a duplicate observation if they were detected on two of the cameras within two minutes. There were three duplicates at T57 and T57, and one duplicate at all three acres, so there were five detections that were removed from further analysis because they were likely of the same mountain lion.

The cluster of trail cameras on acres BU48, BX48, and BZ48 are farther apart from each other than any other cluster of cameras. However, they all face a trail on a slope which could cause the animals to follow this path and be detected on all the cameras. It should take the foxes and bears around a minute and a half to walk from one camera to the next, but there is dense vegetation in this area that could provide food for them. This includes oak trees, manzanitas, holly leaf redberry, and toyon. The presence of food would likely increase their travel time. There were 48 fox observations in this area, with only one being at acre BZ48, and most of them took place on different days. Since fox detections were listed as duplicates if they occurred within five minutes of each other at cameras that were 60 meters apart on a trail (AS60 and AR60), this same ratio was applied to detections at BU48 and BX48. The distance between BU48 and BX48 is 160 meters, or around 2.7 times more than the distance between AS70 and AR70. Therefore, 2.7 times the five minutes, is 13.5 minutes. This means that fox detections that occurred within 14 minutes on BU48 and BX48 were listed as duplicates, with 3 observations occurring within 12 minutes of each other. There were 44 bear observations on these three trail cameras, most occurring on different days. There was one detection at BX48, with a second at BU48 25 minutes later. After the two detections were analyzed, it was clear that it was the same bear. Therefore, all observations that occurred within 25 minutes on two cameras in this cluster, were documented as duplicate detections, at only three duplicates. There was also one mountain lion that was observed at BX48, eight minutes after being detected at BU48. This was the lion’s only duplicate detection.

The last cluster of trail cameras are on Tuscan Loop (CK55 and CJ55). There were no bear or mountain lions observed here, therefore, only the foxes needed to be analyzed. This area is wide open and has toyon, holly leaf redberry, manzanita, and non-native grasses. Although the foxes should be able to travel from one camera to the next in under two minutes, there are no clear animal trails, so they could spend a large amount of time wandering around. With most detections in this area taking place on different days, there was only one detection that occurred 8 minutes apart, and another that took place 12 minutes apart. These were the only two documented duplicate detections in this area.

Species Distribution Heat Maps

After finalizing the data, a “catch per unit effort” (CPUE) was created of each species’ detection frequency at each acre. The CPUE was used by Paige Munson to create the species distribution heat maps (Figures 4, 6, 8, and 10 in Chapter IV). CPUE rankings of low, moderate, and high were created for each species based on their total number of detections during the study. American black bears and gray foxes had high detection frequencies of 1,411 and 961, respectively. For these species, a “low” CPUE ranking was classified as 1 – 14 detections at a particular acre, “moderate” was 15 – 29 detections, and “high” was 30 + detections. Bobcats and mountain lions had a relatively low total number of detections, at 33 and 29, respectively. For these species, a “low” CPUE ranking was classified as 1 – 2 detections at a particular acre, “moderate” was 3 – 4 detections, and “high” was 5 + detections. Acres with “low” CPUEs are green, “moderate” CPUEs are yellow, and “high” CPUEs are red.

The base layer of the maps is “world hillshade” and the analysis layer is “suitability surface.” The analysis layers were produced by selecting variables for each species that influence their habitat selection. Bears, bobcats, and foxes share the same variables of ruggedness, distance to streams, distance to roads, and land cover. The variables for mountain lions are ruggedness, distance to roads, and land cover. The variables for each species were assigned a classification ranking of 1 (most suitable habitat), 2 (moderately suitable habitat), or 3 (least suitable habitat). Since not all variables share the same value, they were assigned a weight based on how important it is when selecting habitat. The sum of the variable weights for each species equals 1, with larger proportions being more significant to the model. For example, mountain lions prefer habitat away from roads, so habitat 0-1,000 meters away from the road was classified as least suitable (3), 1,000-2,000 meters was moderately suitable (2), and 2,000+ meters was most suitable (1). Considering the low-use roads in the BCCER, the overall weight of distance to roads was weighted at 0.05 in relation to other variables. On the heat maps, most suitable habitats are represented in red, moderately suitable is yellow, least suitable is green. Refer to Appendix G for the analysis layer parameters of each species’ distribution heat maps.

Resources

All resource use/activity was placed into five categories: water related, crossed through/sat/stood there, unknown, food related, other, and both water and food related. “Water related” activity includes species being detected drinking water, getting in a water source, walking to a water source, and walking away from a water source. “Crossed through/sat/stood there” includes species walking, running, sitting, or standing without using any resources (water or food). Detections placed in the "unknown" category means that it is unclear as to what they are doing. This is likely due to low quality photos or only one picture was taken of the species, making it impossible to track their movements and activity. "Food related" includes species being detected at fig or olive trees, at toyon, or engaged in foraging activities such as climbing trees, digging with head in ground, eating things from the ground, hunting, rodent in mouth, and watching rabbit. "Other" involves activities that aren't utilizing resources, such as playing with/checking out the trail camera and defecating. "Water and food related" means that the species detected used both water and food resources in one detection event.

There are nine trail cameras with a water source within 30 meters. These acres have been classified as "acres with water" and are AW68, AX67, B61, I64, T57, T58, Z59, BI49, and CM43. All acres with a trail camera had vegetation that American black bears and gray foxes are known to eat from, such as toyon, oak trees, olive trees, fig trees, gooseberries, California grape, Himalayan blackberry, manzanita, and wild grasses. For the tables and analyses regarding food, only the acres where bears and foxes were detected using a food resource were considered. Mountain lions and bobcats weren't included in this portion because plant matter isn't a common component of their diet. The actions of "hunting," "rodent in mouth," and "watching rabbit" were eliminated from this portion of "food-related" resource use because the only food resource being analyzed is the vegetation. The acres where the bears and foxes were seen using vegetation for food were AW68, AX67, B61, BF60, BI49, CY42, F61, I64, and K63.

Seasons and Time of Day

After recording each detection event's date and time, they were grouped into season and time of day categories for analysis. Seasons were selected for date categories because of the similar weather patterns within each one. Spring is from March 1 to May 31, summer is from June 1 to August 31, fall is from September 1 to November 30, and winter is from December 1 to February 28. Detection times were placed into six four-hour categories. These groups were determined based on activity patterns and time of day categories. During the study period, sunset hours varied from approximately 4:45 to 8:30 PM, creating the dawn time category of 5 – 9 PM. Sunrise occurred from approximately 5:30 to 7:30 AM, creating the dusk 5 – 9 AM time slot. This left hours with no sunlight occurring from approximately 9 PM – 5 AM. This time was divided into 9 PM – 1 AM and 1 – 5 AM. Daylight hours occurred from 9 AM – 5 PM which was broken up to 9 AM – 1 PM and 1 – 5 PM. Daylight savings were accounted for when recording the data. It occurred on November 7, 2021, and March 13, 2022, at 2 AM.

Moon Phase

It has been suggested that bobcats hunt prey during high illumination moon phases at night to compensate for their non-excellent night vision (Rockhill et al., 2013). However, other studies have shown that prey species will change their time of activity during the day to evade their predators (Tambling et al., 2015). This suggests that if the bobcat's prey is no longer active at night as an attempt to avoid them, then the bobcats will also change the time that they hunt. Although investigating whether nighttime bobcat activity correlates to the moon phase isn't a research question, the data to further explore this theory had already been recorded. This could provide more information on the elusive species.

All bobcat detections were filtered to show only observations at night. An online weather database called Visual Crossing was used to determine the cloud cover and visibility at the time of the detection because the lunar illumination won't matter if the moon is covered by clouds. Detections that occurred with approximately 50% cloud cover or more were excluded from analysis. This removed three detections – two first quarter phases and one third quarter phase – leaving only seven viable observations to investigate.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to investigate the distribution and resource use of American black bears (*Ursus americanus*), mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), and gray foxes (*Urocyon cinereoargenteus*) in the BCCER. Camera traps were selected as the survey technique because they can collect continuous data without an observer and reveal animal activity. Table 4 shows a list of all species within the order Carnivora that were observed on the trail cameras during this study. The following is an analysis of the data collected from twenty-four camera traps from May 18, 2021 to May 18, 2022.

Table 4
Species in Order Carnivora Detected During Study

Suborder: Caniformia	
Family: Ursidae	American black bear (*Ursus americanus*)
Family: Canidae	Gray fox (*Urocyon cinereoargenteus*) Coyote (*Canis latrans*)
Family: Procyonidae	Raccoon (*Procyon lotor*) Ringtail (*Bassariscus astutus*)
Family: Mustelidae	Fisher (*Pekania pennanti*)
Family: Mephitidae	Striped skunk (*Mephitis mephitis*)
Suborder: Feliformia	
Family: Felidae	Mountain lion (*Puma concolor*) Bobcat (*Lynx rufus*)

Detection Frequency

American black bears and gray foxes were detected more frequently than mountain lions and bobcats (Figure 4). Over half of the total observations were of bears, at 1,411/2,434 (58.0%) detections, and 961 (39.5%) observations were of foxes. On the other end, bobcats were only observed 33 (1.4%) times, and the fewest observations were of mountain lions, at only 29 (1.2%) detections.

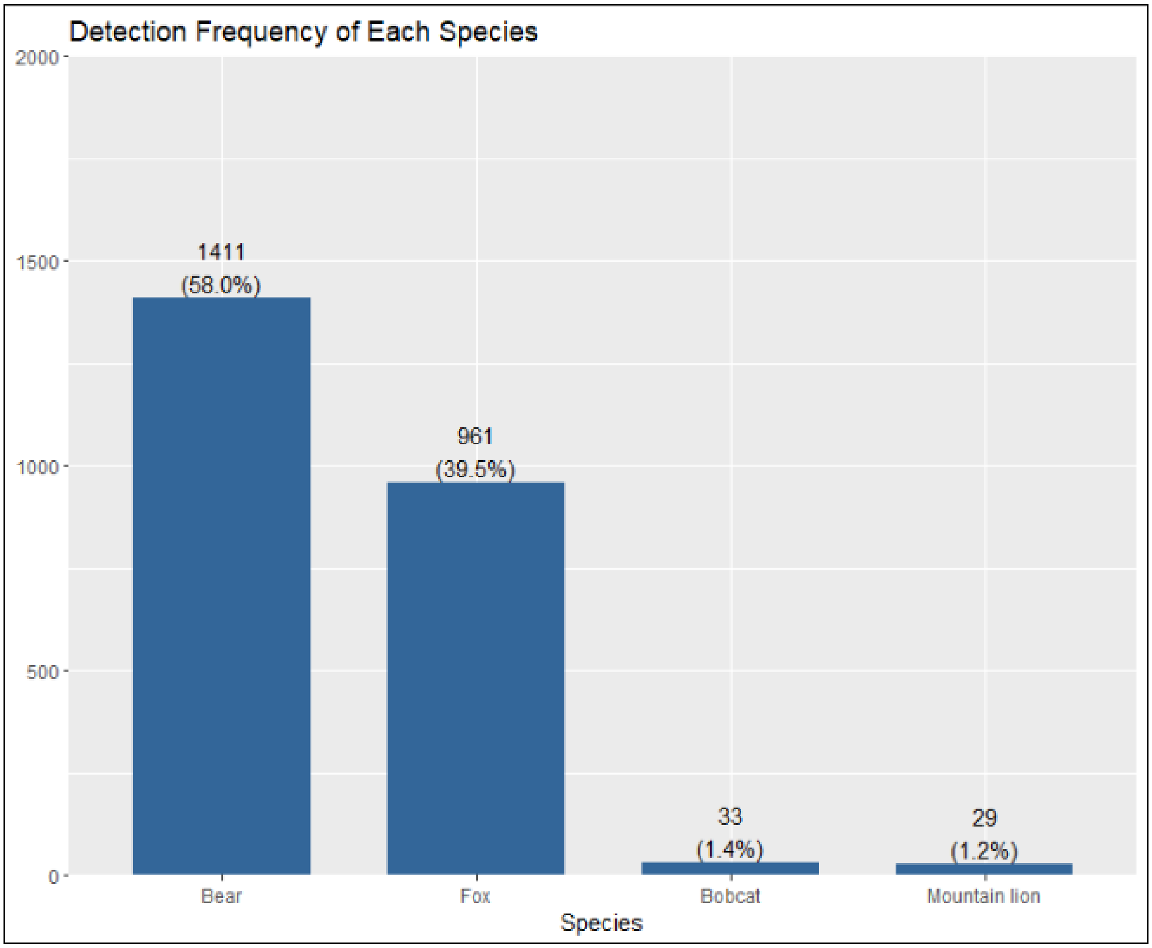

Figure 4. Detection frequency of each species. Bears and foxes were detected the most at 1411 (58.0%) and 961 (39.5%) observations, respectively.

Species Distribution

American Black Bears

American black bears were detected at every acre, except for CK55 and CJ55, the two cameras on Tuscan Loop. However, on May 19, 2022, the day after the study concluded, a bear was detected on CK55. The acre with the most detections was I64 at 699/1,411 (49.5%) observations (Figures 5 and 6). The camera on this acre is in a riparian forest and near annual grassland. The habitat consists of big leaf maple, bay laurel, California rose, miner's lettuce, and ferns. The camera is facing a spring which the bears frequented. The second most frequent detection site of American black bears occurred at acre AX67 with 168/1,411 (11.9%) detections. This camera is next to a barn near the office which receives a lot of human activity during the day. This area is described as an unnatural area with an office building, a porta potty, wooden fences, and other structures. The habitat type is an oak woodland with mostly non-native vegetation, including olive and fig trees, and toyon. The camera faces a horse trough filled with water.

Mountain Lions

Mountain lions were only seen at 10 of the 24 trail cameras, with detections occurring most frequently at acres T58, at 7/29 (24.1%) observations, and CM43, at 6/29 (20.7%) observations (Figures 7 and 8). T58 is part of the Henning Hole camera complex, with the camera being approximately 28 meters away from Big Chico Creek. It is in a mixed oak woodland consisting of interior live oak, canyon live oak, chaparral honeysuckle, and an annual grassland understory. The camera in acre CM43 is facing a road that leads to a creek crossing. It is approximately 10 meters away from Big Chico Creek and is in a riparian mixed conifer forest consisting of Douglas fir, ponderosa pine,

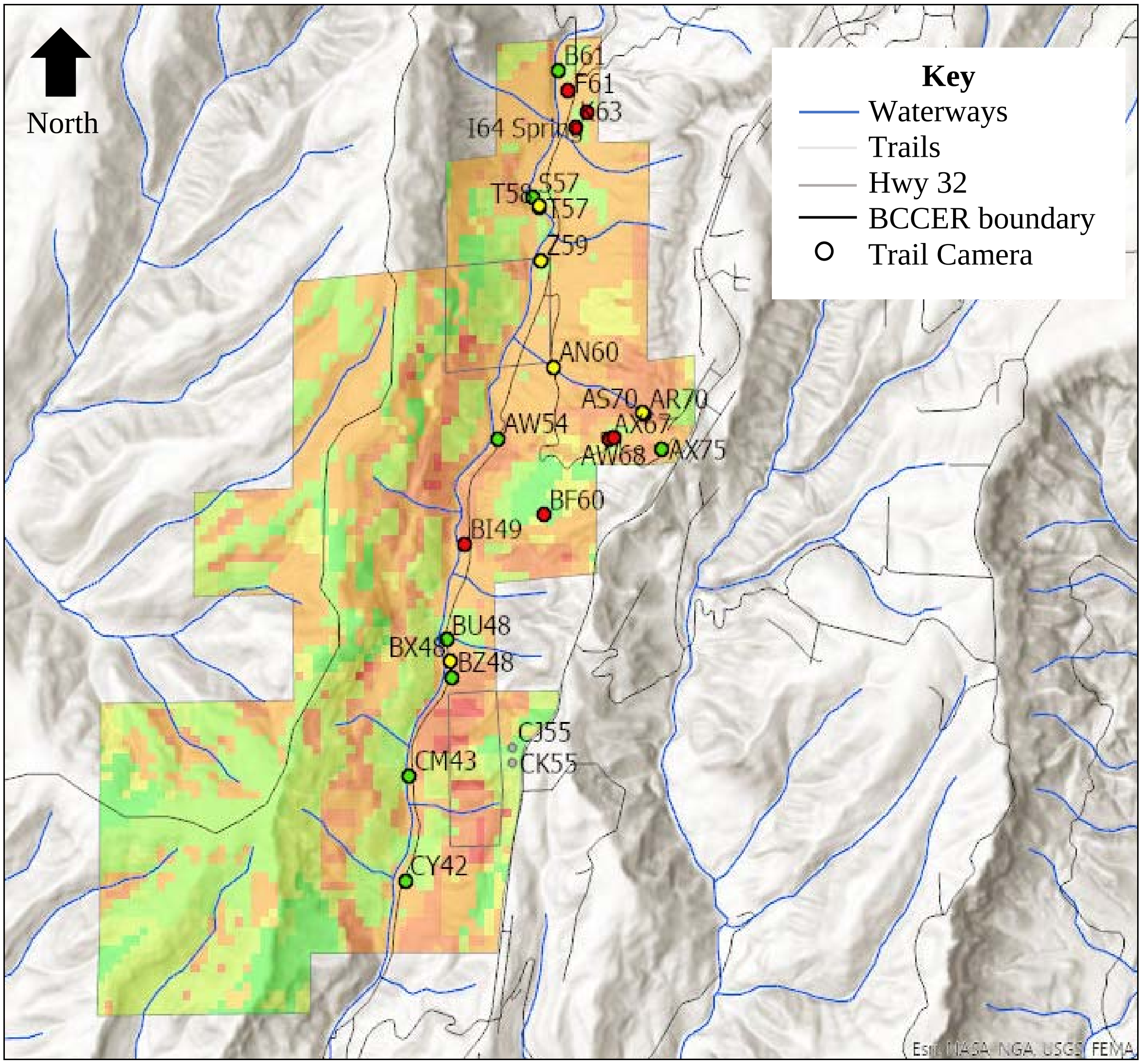

Figure 5. American black bear distribution. Heat map depicting the detection frequency of American black bears per acre in the BCCER, with a world hillshade base map and suitability surface analysis layer. Red trail camera locations indicate a high catch per unit effort (CPUE), yellow indicates a moderate CPUE, green indicated a low CPUE, and gray indicates no detections. Red on the map is indicative of the most suitable habitat, yellow is moderately suitable, and green is least suitable.

California incense cedar, bay laurel, canyon live oak, Oregon Ash, poison oak, soaproot, toyon, white alder, Himalayan blackberry, mugwort, Rhus, and Santa Barbra sedges. Additionally, although there were 3/29 (10.3%) mountain lion observations at acre AR70, there were none at acre AS70, which is only 60 meters away.

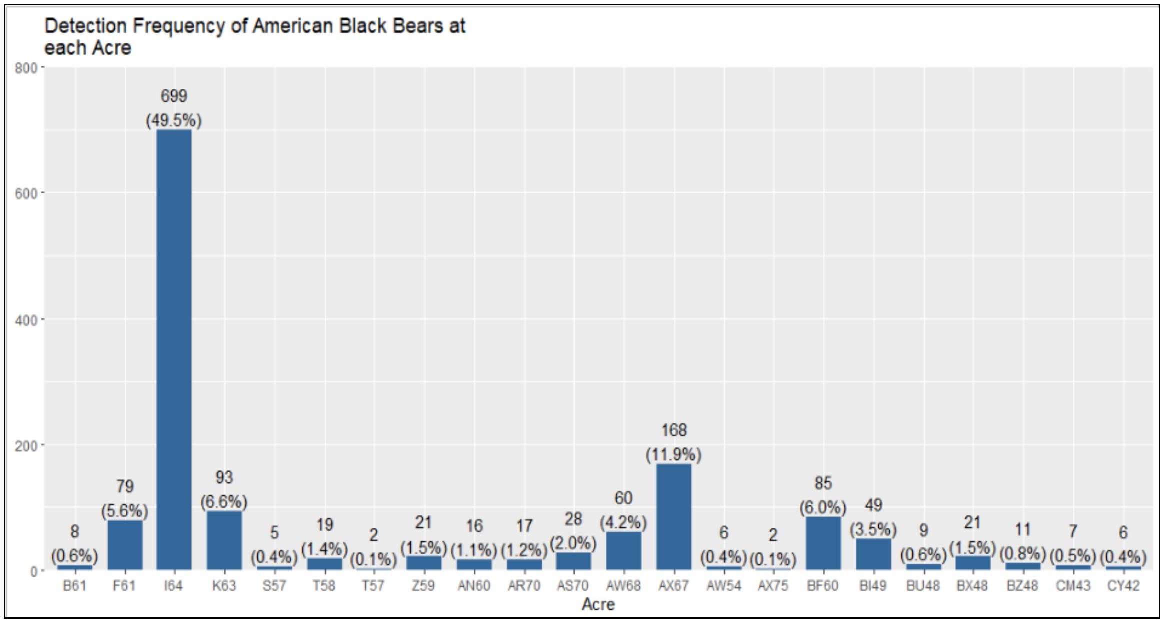

Figure 6. American black bear detection frequency per acre. They were observed most frequently at acres I64 (49.5%) and AX67 (11.9%) and were not detected on CK55 or CJ55. Acres are arranged from northernmost (left) to southernmost (right).

<u>Bobcats</u>

Bobcats were seen on 11 of the 24 trail cameras, with most detections occurring at acres CJ55, at 8/33 (24.2%) detections, and AS70, at 6/33 (18.2%) detections (Figures 9 and 10). CJ55 is part of the Tuscan Loop, which is described as chaparral with grey pine, yerba santa, popcorn flowers, holly leaf redberry, buckbrush, and non-native grasses. There is no known water source within this 23-acre (approximately 93,000 square meters) area of land. AS70 is part of the Grandmother Pine Trail and is described as an oak woodland/grey pine forest with heavy canopy cover. Although bobcats were observed relatively frequently at acre AS70, they were not seen at acre AR70, which is only 60 meters away. This is the opposite pattern that was observed in mountain lions. Some vegetation in this area includes canyon live oak, gooseberry, pipevine, iris, grey pine, big leaf maple, and redbud. Although there was a tributary that flowed through this

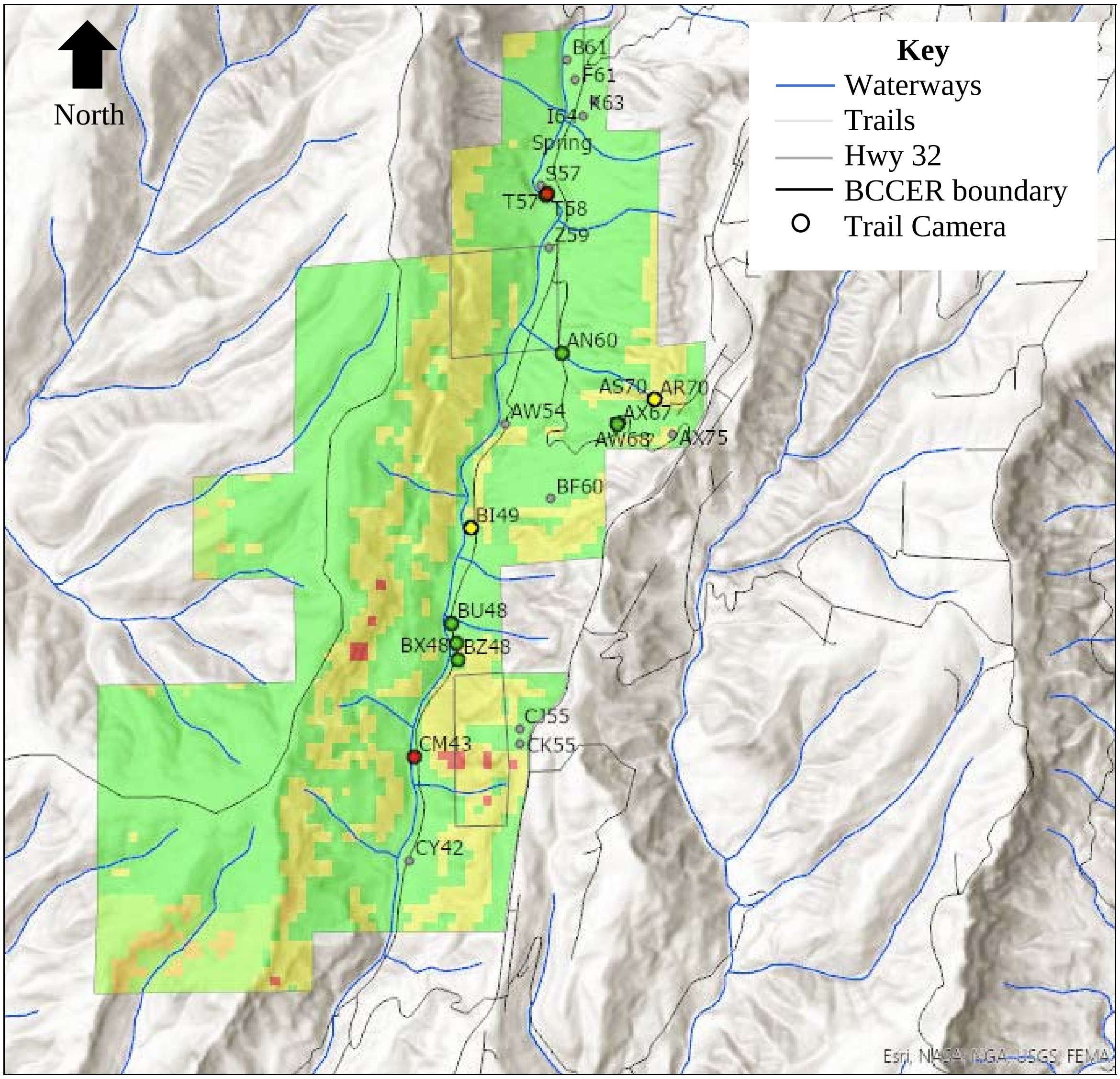

Figure 7. Mountain lion distribution. Heat map depicting the detection frequency of mountain lions per acre in the BCCER, with a world hillshade base map and suitability surface analysis layer. Red trail camera locations indicate a high catch per unit effort (CPUE), yellow indicates a moderate CPUE, green indicated a low CPUE, and gray indicates no detections. Red on the map is indicative of the most suitable habitat, yellow is moderately suitable, and green is least suitable.

area, it has been dry for the duration of this study. The closest known consistent water source is the horse trough at AX67, which is approximately 375 meters away.

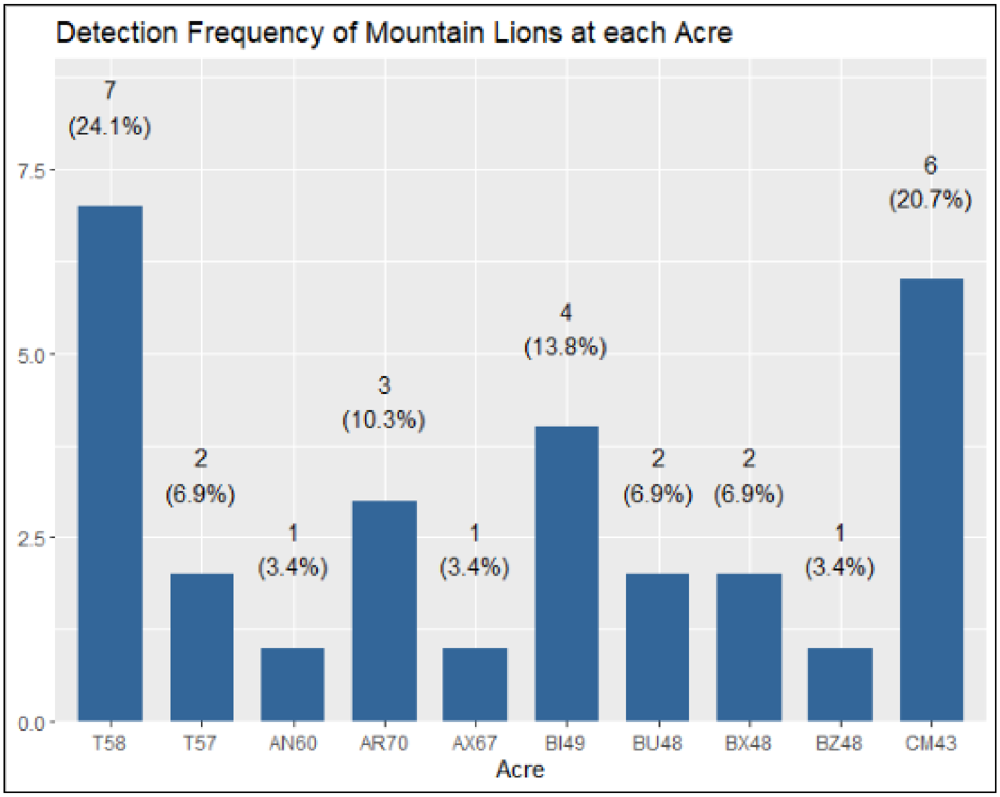

Figure 8. Mountain lion detection frequency per acre. They were seen most at acres T58 (24.2%) and CM43 (20.7%) and were not observed on 14 of the trail cameras. Acres are arranged from northernmost (left) to southernmost (right).

Gray Foxes

Gray foxes were detected at every acre except B61, T58, Z59, and CM42. They were seen most frequently at acres AX67, at 223/961 (23.2%) observations, and AS70, at 206/961 (21.4%) observations (Figures 11 and 12). Acre AX67 was described in the American black bear section and AS70 was described in the bobcat section.

Detections at Acres With Versus Without Water

There are nine trail cameras with a water source within 30 meters. These acres have been classified as "acres with water" and are AW68, AX67, B61, I64, T57, T58,

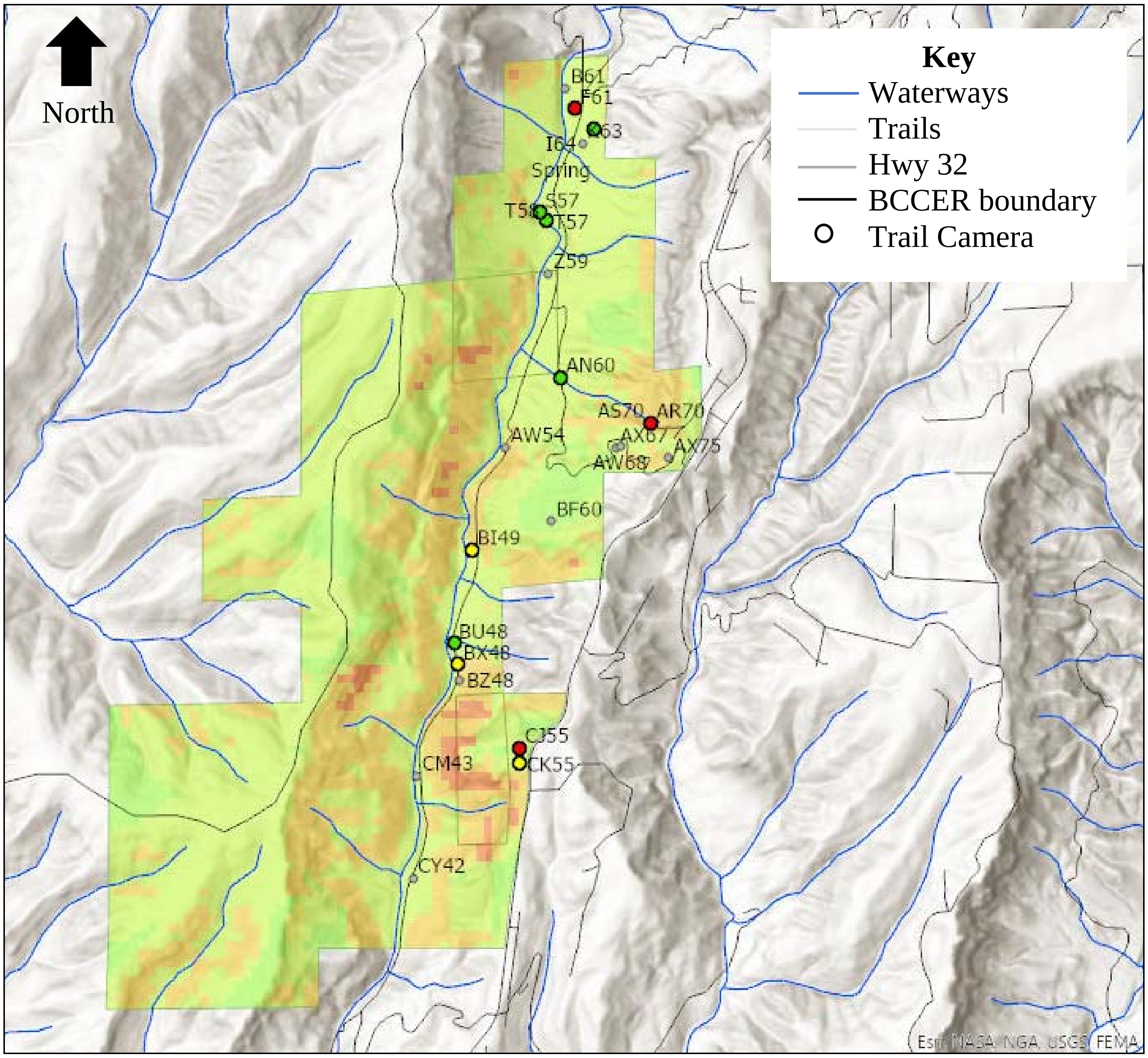

Figure 9. Bobcat distribution. Heat map depicting the detection frequency of bobcats per acre in the BCCER, with a world hillshade base map and suitability surface analysis layer. Red trail camera locations indicate a high catch per unity effort (CPUE), yellow indicates a moderate CPUE, green indicated a low CPUE, and gray indicates no detections. Red on the map is indicative of the most suitable habitat, yellow is moderately suitable, and green is least suitable.

Z59, BI49, and CM43. A total of 74.0% of all species detections that occurred on acres with a known water source nearby, were of American black bears. While gray foxes were detected most often at acres without a known water source, at 60.0% (Table 5). A chi-squared test was conducted to analyze if all four species were detected the same

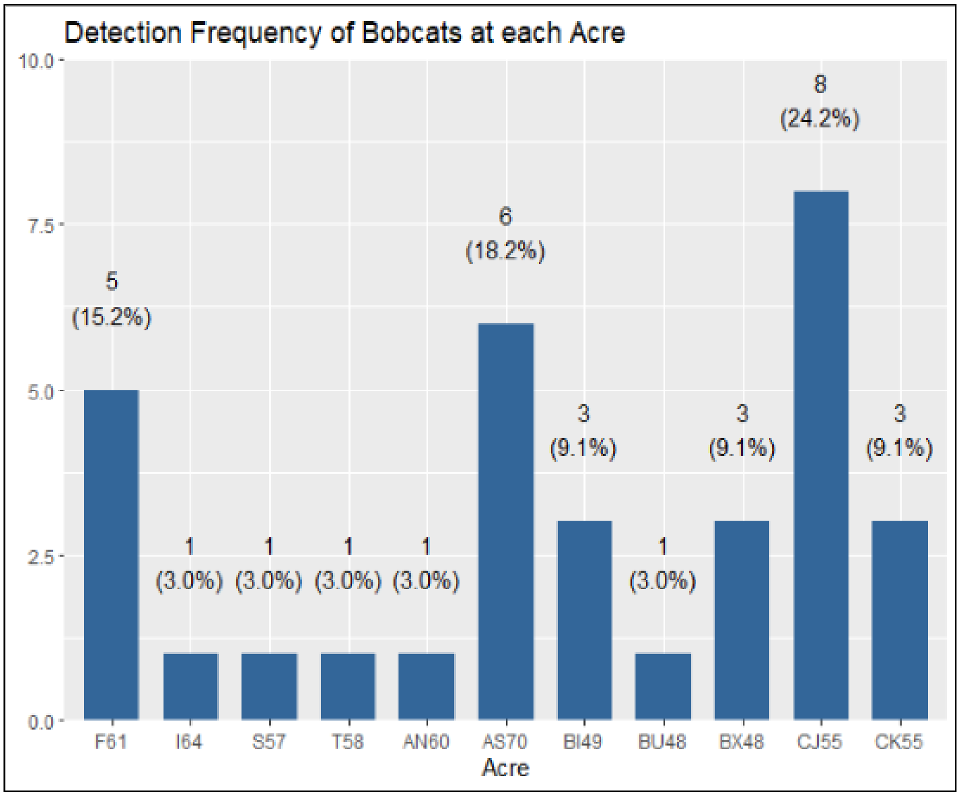

Figure 10. Bobcat detection frequency per acre. They were seen most at acres CJ55 (24.2%) and AS60 (18.2%) and were not observed on 13 of the trail cameras. Acres are arranged from northernmost (left) to southernmost (right).

percentage of times at acres with water. The results indicate that there is a difference between species detections at acres with and without water ($X^2 = 364$, $P < 0.001$).

Table 6 shows the distribution of times that each species was detected at acres with water versus without a water source. Bears and mountain lions were observed more frequently at acres with water, at 1,033 (73.2%) and 20 (69.0%) detections, respectively. On the other hand, bobcats and foxes were seen more at acres without water, at 28 (84.8%) and 623 (64.8%) detections, respectively. This could mean that these two species are going to these acres to travel to another location, for a food source, or another reason.

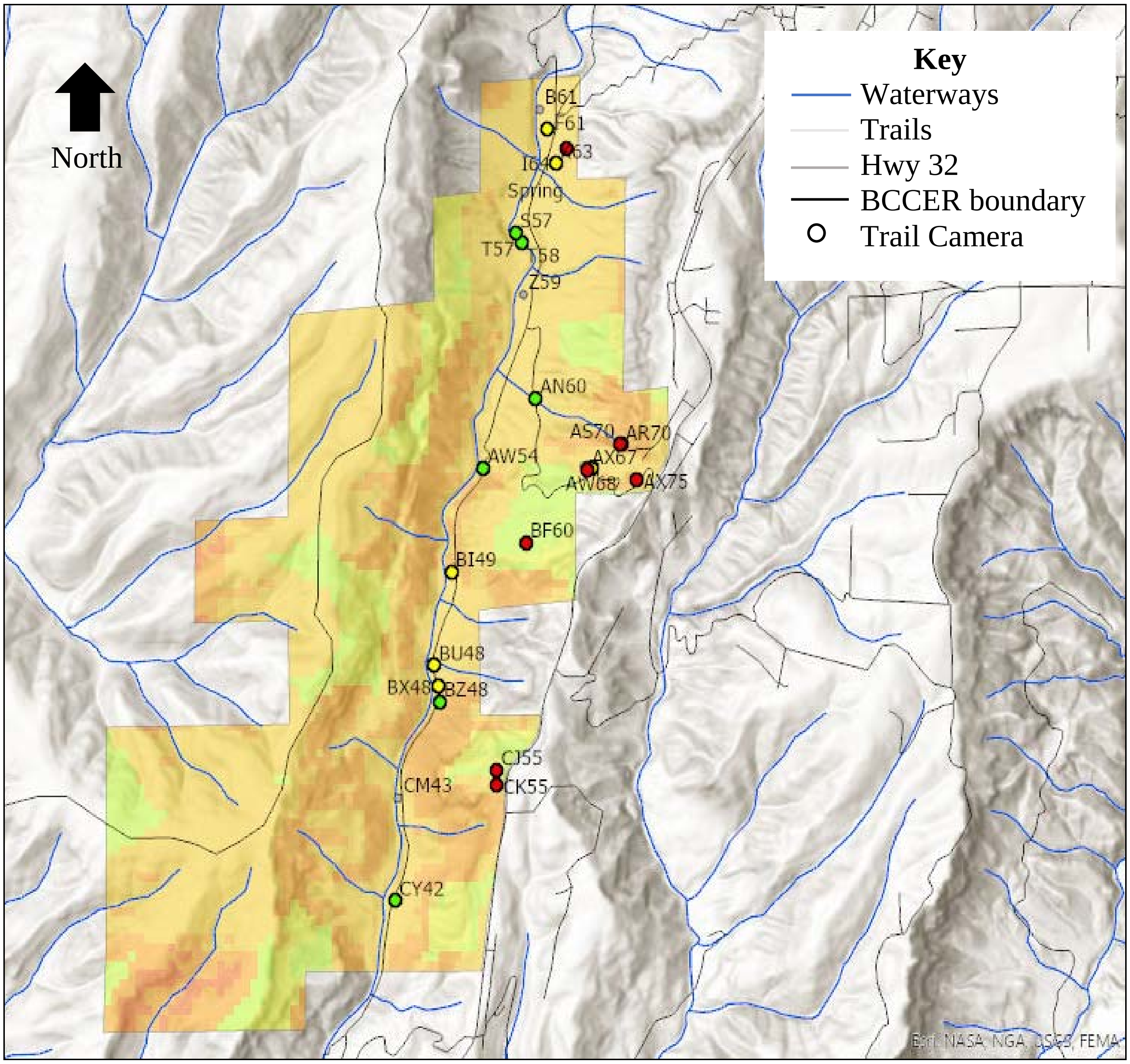

Figure 11. Gray fox distribution. Heat map depicting the detection frequency of gray foxes per acre in the BCCER, with a world hillshade base map and suitability surface analysis layer. Red trail camera locations indicate a high catch per unit effort (CPUE), yellow indicates a moderate CPUE, green indicated a low CPUE, and gray indicates no detections. Red on the map is indicative of the most suitable habitat, yellow is moderately suitable, and green is least suitable.

The results indicate that the study species aren't detected equally across acres with and without water ($X^2 = 364$, $P < 0.001$).

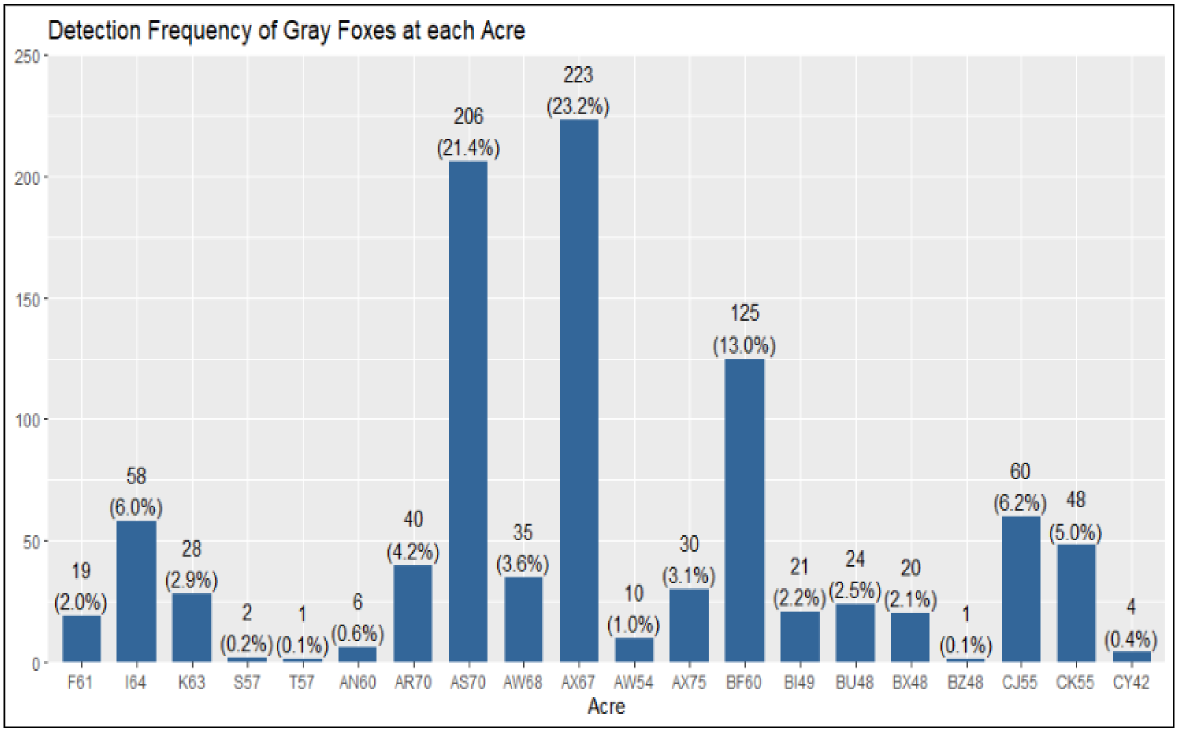

Figure 12. Gray Fox detection frequency per acre. They were seen most at acres AX67 (23.2%) and AS70 (21.4%) and were not observed on 4 of the trail cameras. Acres are arranged from northernmost (left) to southernmost (right).

Table 5

Percentage of Detections at Acres With and Without Water

	9/24 Acres with water	15/24 Acres without water
Bear	1,033 (74.0%)	378 (36.4%)
Bobcat	5 (0.4%)	28 (2.7%)
Fox	338 (24.2%)	623 (60.0%)
Mountain lion	20 (1.4%)	9 (0.9%)
Total	100.0%	100.0%

Note. Bears were seen most at acres with water ($X^2 = 364$, $P < 0.001$)

Table 6

Percentages of Each Species Detected at Acres With and Without Water

	Bear	Bobcat	Fox	Mountain lion
9/24 acres with water	1,033 (73.2%)	5 (15.2%)	338 (35.2%)	20 (69.0%)
15/24 acres without water	378 (26.8%)	28 (84.8%)	623 (64.8%)	9 (31.0%)

Note. Bears and mountain lions were seen more at acres with water while bobcats and foxes were detected most at acres without water ($X^2 = 364$, $P < 0.001$).

Resource Use

Resources Used Across All Acres

All four study species were detected most frequently crossing through an area/sitting/standing there (Table 7). Although they aren't using a specific resource such as water, food, or shelter when they're detected, they are using the trails to safely travel from one area to another. The second most frequent resource used among the bears, foxes, and mountain lions is water, respectively: 605 (42.9%) bear detections, 219 (22.8%) fox detections, and 6 (20.7%) mountain lion detections were observed for a water-related reason. Bobcats were not observed using or traveling to or from any water source.

Table 7

Resource Use/Activity Across All Acres

	Water related	Crossed through/ sat/stood there	Unknown	Food related	Other	Water and food related
Bobcat	0	31 (93.9%)	2 (6.1%)	0	0	0
Bear	605 (42.9%)	589 (41.7%)	0	86(6.1%)	120 (8.5%)	11 (0.8%)
Fox	219 (22.8%)	592 (61.6%)	0	50 (5.2%)	100(10.4%)	0
Mountain lion	6 (20.7%)	22 (75.9%)	1 (3.4%)	0	0	0

Resources Used at Acres With Water

Out of all the species detections at an acre with a water source nearby, 830 (59.5%) of them are there for a water-related reason (Table 8). Among all nine acres with water nearby, 605 (58.6%) bear, 219 (64.8%) fox, and 6 (30.0%) mountain lion detections were of each species utilizing the water source (Table 9). Bobcats and mountain lions were detected crossing through the acre with a water source most frequently, at 4 (80.0%) and 14 (70.0%) observations, respectively. Four chi-squared tests

Table 8

Detections at Acres With Water for a Water-Related Reason

Detections using water	Detections not using water
830 (59.5%)	566 (40.5%)

Table 9

Resource Use Across Acres With a Water Source

	Water related	Crossed through/ sat/stood there	Food related	Other	Water and food related
Bobcat	0	4 (80.0%)	0	1 (20.0%)	0
Bear	605 (58.6%)	288 (27.9%)	73 (7.1%)	56 (5.4%)	11 (1.1%)
Fox	219 (64.8%)	89 (26.3%)	11 (3.3%)	19 (5.6%)	0
Mountain lion	6 (30.0%)	14 (70.0%)	0	0	0

Note. American black bears and gray foxes went to acres with a water source for a water-related reason (bear: $X^2 = 1181.7$, $P < 0.001$; fox: $X^2 = 329.03$, $P < 0.001$). Mountain lions weren't observed doing one activity more frequently than the other ($X^2 = 3.2$, $P = 0.074$). Bobcats were only detected five times at acres with a water source nearby, so an accurate analysis could not be conducted.

were conducted to analyze if each species were doing all activities equally at acres with water. The results indicate that American black bears and gray foxes went to acres with a water source for a water-related reason (bear: $X^2 = 1181.7$, $P < 0.001$; fox: $X^2 = 329.03$, P

< 0.001). However, mountain lions weren't observed doing one activity more frequently than the other (X^2 = 3.2, P = 0.074). Data were insufficient to conduct an accurate analysis for bobcats with only five bobcat detections occurring at acres with a water source nearby.

Preferences in Acres With Water

American Black Bears

American black bears were detected at all nine acres with a nearby water source, with 699 (67.7%) detections at I64. The acre with the second most bear detections was AX67, at 168 (16.3%). An overview of the results can be seen in Table 10. To test if bears were seen more frequently at one acre with water, a chi-squared test was performed. The results show that there is a difference between their detection frequency and acre (X^2 = 11135, P < 0.001).

Table 10

American Black Bear Detections at Acres With a Water Source

Acre	AW68	AX67	B61	BI49	CM43	I64	T57	T58	Z59
Detection frequency	60 (5.8%)	168 (16.3%)	8 (0.8%)	49 (4.7%)	7 (0.7%)	699 (67.7%)	2 (0.2%)	19 (1.8%)	21 (2.0%)

Note. They were observed most frequently at I64 with 699 (67.7%) detections (X^2 = 11135, P < 0.001).

Table 11 shows how frequently the bears detected were using the water source at each acre. I64 still had the most observations with 502 (48.6%) bear detections using the spring, while AX67 saw 94 (9.1%) bear detections using the horse trough to either drink water or cool down. Although the bears were detected at each of the nine acres with a water source, they were not observed using the water during each detection event.

Meaning, even though they went to an area with water, they didn't always take advantage of that available resource. It should be noted that the water sources near the trail cameras on acres AW68, B61, BI49, CM43, and T57 are not visible from the cameras. Even though the bears were not observed using the water source near those cameras, it does not mean that they didn't use them. An overview of the results can be seen in Table 11.

Table 11

American Black Bears Detected Using a Water Source at Each Acre

Acre	AW68	AX67	B61	BI49	CM43	I64	T57	T58	Z59
Not using water	60 (5.8%)	74 (7.2%)	8 (0.8%)	49 (4.7%)	7 (0.7%)	197 (19.1%)	2 (0.2%)	14 (1.4%)	17 (1.6%)
Using water	0	94 (9.1%)	0	0	0	502 (48.6%)	0	5 (0.5%)	4 (0.4%)

Note. The bears were not using the water source every time they were at an acre with the resource available.

Mountain Lions

Mountain lions were detected at five acres with a water source, one being the horse trough and the others being Big Chico Creek. Of these five acres, they were seen most at acres T58 and CM43, at 7 (35.0%) and 6 (30.0%) detections respectively (Table 12). A chi-squared test could not be conducted to test if mountain lions were seen more frequently at one acre with water because the sample size was too small, at only 20 detections.

Table 12

Mountain Lion Detections at Acres with a Water Source

Acre	AX67	BI49	CM43	T57	T58
Detection frequency	1 (5.0%)	4 (20.0%)	6 (30.0%)	2 (10.0%)	7 (35.0%)

Table 13 shows how frequently the mountain lions detected were using the water source at each acre. CM43 had the most observations with 3 (15.0%) mountain lions detected walking to Big Chico Creek, while T58 had 2 (10.0%) detections of the lions walking to the creek. Although the mountain lions were observed at five acres with a water source, they were not detected using them at acres BI49 and T57. As previously stated, the trail cameras on these acres are close to the water but did not face the water source. An overview of the results can be seen in Table 13.

Table 13

Mountain Lions Detected Using a Water Source at Each Acre

Acre	AX67	BI49	CM43	T57	T58
Not using water	0	4 (20.0%)	3 (15.0%)	2 (10.0%)	5 (25.0%)
Using water	1 (5.0%)	0	3 (15.0%)	0	2 (10.0%)

Note. There were only six detection events of the mountain lions using a water source.

Bobcats

Although bobcats weren't observed at an acre for a water related reason, out of all their detections at an acre with a water source, 3 (60%) occurred at BI49 (Table 14). The camera on this acre does not face the water source, Big Chico Creek, so it is possible that the bobcats were going to the creek for water but were not observed doing so. With only five bobcat detections occurring at acres with a water source, a chi-squared analysis could not be conducted due to the inadequate sample size. A table depicting the detection frequency of bobcats using a water source at each acre was not created because they were not observed using the water.

Table 14

Bobcat Detections at Acres With a Water Source

Acre	BI49	I64	T58
Detection frequency	3 (60.0%)	1 (20%)	1 (20%)

Note. Although they weren't seen using a water source, they could have been using the Big Chico Creek that flows near BI49 since that trail camera doesn't face the water.

<u>Gray Foxes</u>

Gray foxes were detected at five acres with a water source nearby, with 223 (66.0%) of these detections occurring at AX67 (Table 15). To test if gray foxes were detected more frequently at acres with water, a chi-squared test was conducted. The results show that they were seen more frequently at one acre with water ($X^2 = 3550.3$, $P < 0.001$).

Table 15

Gray Fox Detections at Acres With a Water Source

Acre	AW68	AX67	BI49	I64	T57
Detection frequency	35 (10.4%)	223 (66.0%)	21 (6.2%)	58 (17.2%)	1 (0.3%)

Note. They were seen the most at acre AX67, with 223 (66.0%) detections ($X^2 = 3550.3$, $P < 0.001$).

Table 16 shows how frequently the gray foxes detected were using the water source at each acre. AX67 still had the most observations with 197 (58.3%) foxes detected using the horse trough, and I64 had 22 (6.5%) detections of the foxes using the spring. Although the foxes were observed at five acres with a water source, they were not detected using the water at acres AW68, BI49, and T57. Since the trail cameras on these acres do not face the water source, they could have still used it.

Table 16

Gray Foxes Detected Using a Water Source at Each Acre

Acre	AW68	AX67	BI49	I64	T57
Not using water	35 (10.4%)	26 (7.7%)	21 (6.2%)	36 (10.7%)	1 (0.3%)
Using water	0	197 (58.3%)	0	22 (6.5%)	0

Note. Most observations were of them using the horse trough at acre AX67.

Preferences in Acres With Food

All acres with a trail camera had vegetation that American black bears and gray foxes are known to eat from. For the following tables and analyses regarding food, only the acres where bears and foxes were detected using a food resource were considered – acres AW68, AX67, B61, BF60, BI49, CY42, F61, I64, and K63. Out of the 1,774 American black bear and gray fox detections at the selected acres with a food resource available, only 102 (5.7%) of them were observed being there for a food-related reason (Table 17).

Table 17

American Black Bears and Gray Foxes Detected at Acres with Food for a Food-Related Reason

Detections using food resource	Detections not using food resource
102 (5.7%)	1672 (94.3%)

Note. American black bears and gray foxes were not seen eating plant 94.3% of the time.

American Black Bears

American black bears were detected at all nine selected acres with a food resource, with 699 (56.1%) of these detections occurring at I64. The acre with the second most bear detections was AX67, at 168 (13.5%). An overview of the results can be seen in Table 18. To test if bears were seen more frequently at one acre with food, a chi-squared test was performed. The results show that there is a difference between their detection frequency and acre ($X^2 = 9243$, $P < 0.001$).

Table 18

American Black Bear Detections at Acres with Food

Acre	AW68	AX67	B61	BF60	BI49	CY42	F61	I64	K63
Detections	60 (4.8%)	168 (13.5%)	8 (0.6%)	85 (6.8%)	49 (3.9%)	6 (0.5%)	79 (6.3%)	699 (56.1%)	93 (7.4%)

Note. They were seen at all nine acres with a food resource, with most detections at acre I64 (56.1%) ($X^2 = 9243$, $P < 0.001$).

Table 19 shows how frequently the bears detected were eating plant matter at each acre. AW68 had the most observations with 47 (3.8%) bear detections using the vegetation, especially the olive trees, for food. AX67 saw 14 (1.1%) bear detections eating the plant matter, including toyon berries, figs, and olives. Both of these areas are near the BCCER office. Although the bears were observed at all nine selected acres with a food resource, they were only detected eating them once at acres CY42, F61, and K63. An overview of the results can be seen in Table 19.

Table 19

American Black Bears Detected Eating at Each Acre

Acre	AW68	AX67	B61	BF60	BI49	CY42	F61	I64	K63
Not eating	13 (1.0%)	154 (12.3%)	3 (0.22%)	76 (6.0%)	47 (3.7%)	5 (0.4%)	78 (6.3%)	694 (55.7%)	92 (7.4%)
Eating	47 (3.8%)	14 (1.1%)	5 (0.4%)	9 (0.7%)	2 (0.2%)	1 (0.1%)	1 (0.1%)	5 (0.4%)	1 (0.1%)

Note. They ate vegetation the most near the BCCER office, with 61 (4.9%) observations.

Gray Foxes

Gray foxes were detected at eight of the selected acres with a food resource, with 223 (43.5%) of these detections occurring at AX67. The acre with the second most fox detections was BF60, at 125 (24.4%) (Table 20). To test if foxes were seen more frequently at one acre with food, a chi-squared test was performed. The results show that there is a difference between their detection frequency and acre ($X^2 = 2834.1$, $P < 0.001$).

Table 20

Gray Fox Detections at Acres With Food

Acre	AW68	AX67	BF60	BI49	CY42	F61	I64	K63
Detections	35 (6.8%)	223 (43.5%)	125 (24.4%)	21 (4.1%)	4 (0.8%)	19 (3.7%)	58 (11.3%)	28 (5.5%)

Note. They were observed at all acres with food except B61. They were seed the most at acre AX67, at 223 (43.5%) detections ($X^2 = 2834.1$, $P < 0.001\%$).

Table 21 shows how frequently the foxes detected were eating plant matter at each acre. AW68 had the most observations with 9 (1.8%) fox detections using the vegetation. BF60 saw only three (0.6%) fox detections eating the plant matter. Although the foxes were observed at eight selected acres with a food resource, they were not detected eating them at acres AX67, CY42, and I64.

Table 21

Gray Foxes Detected Eating at Each Acre

Acre	AW68	AX67	BF60	BI49	CY42	F61	I64	K63
Not eating	26 (5.1%)	223 (43.5%)	122 (23.8%)	19 (3.7%)	4 (0.8%)	18 (3.5%)	58 (11.3%)	26 (5.1%)
Eating	9 (1.8%)	0	3 (0.6%)	2 (0.4%)	0	1 (0.2%)	0	2 (0.4%)

Note. There were only 17 total detections of foxes eating plant matter.

Species Activity by Time of Day
and Season of the Year

Although it wasn't a research question, the data to analyze the frequency of each species' detections occurring during the day and year had been recorded. Figure 13 shows the detection frequency of all species during each season. American black bears, mountain lions, and gray foxes were detected most frequently in the fall, while bobcats were detected most frequently in the winter. Figure 14 shows the detection frequency of all species during different times of the day. American black bears, mountain lions, and gray foxes were detected least frequently from 9 AM – 5 PM, while bobcats were detected most frequently during that time.

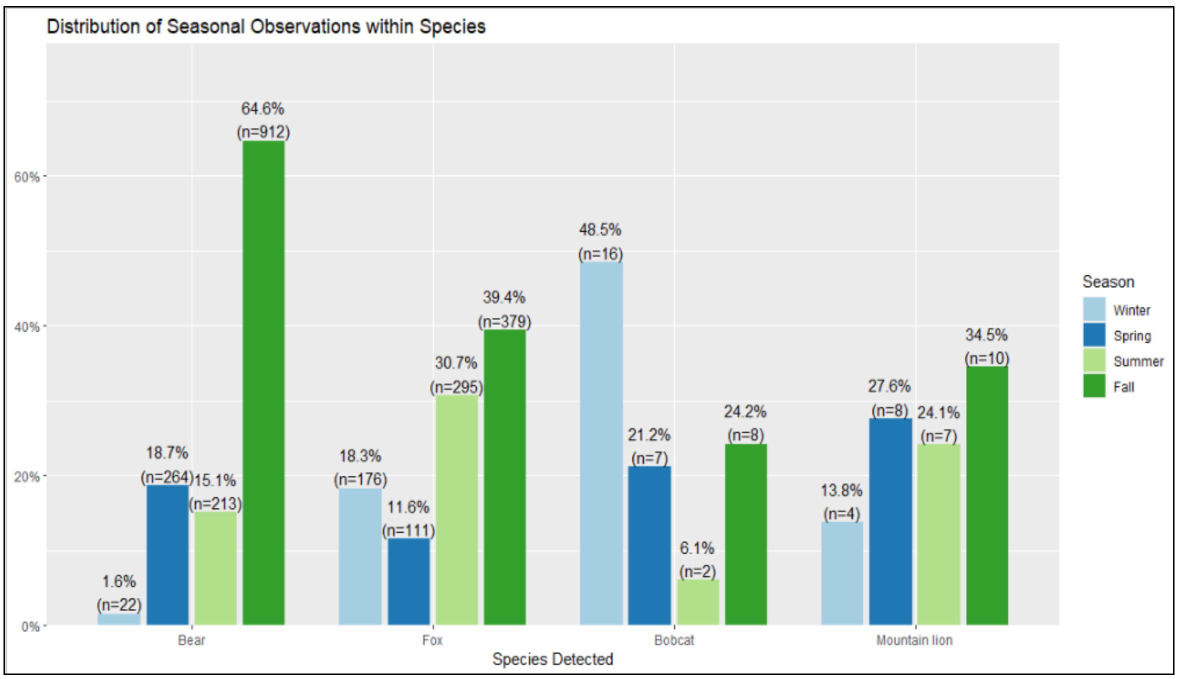

Figure 13. Detection frequency of each species per season. American black bears, mountain lions, and gray foxes were detected most frequently in the fall, while bobcats were detected most frequently in the winter.

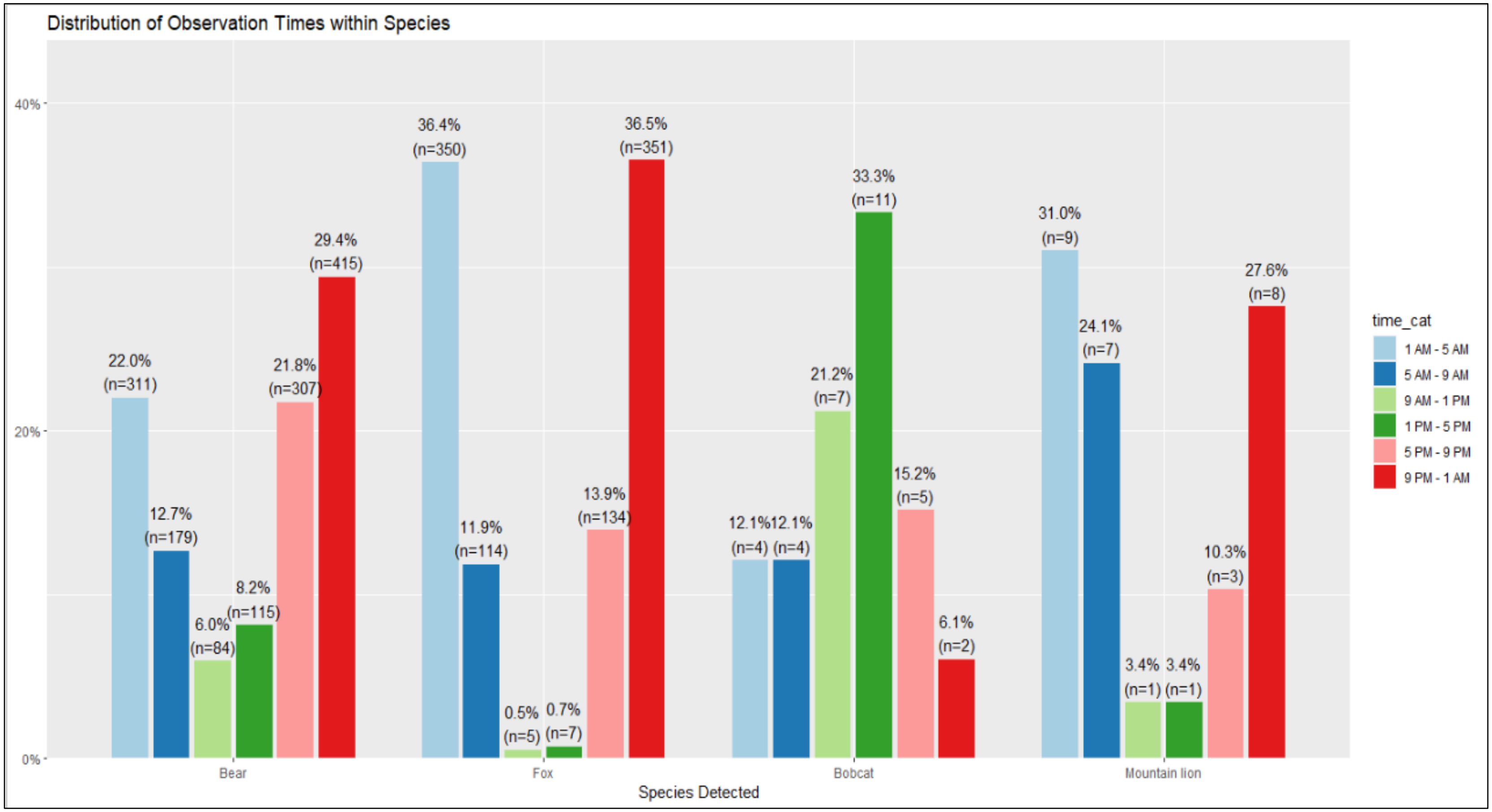

Figure 14. Detection frequency of each species per time of day. American black bears, mountain lions, and gray foxes were detected least frequently during daylight hours from 9 AM – 5 PM, while bobcats were detected most frequently during daylight.

American Black Bear

American black bears were detected most frequently in the fall, with 912/1,411 (64.6%) detections occurring in this period. The least amount of bear activity occurred during winter, at only 22/1,411 (1.6%) of detections (Figure 15). To test if bears were detected more frequently during a particular season, a chi-squared test was conducted. The results indicate that their detection frequency was not equal across all seasons ($X^2 = 1274.5$, $P < 0.001$).

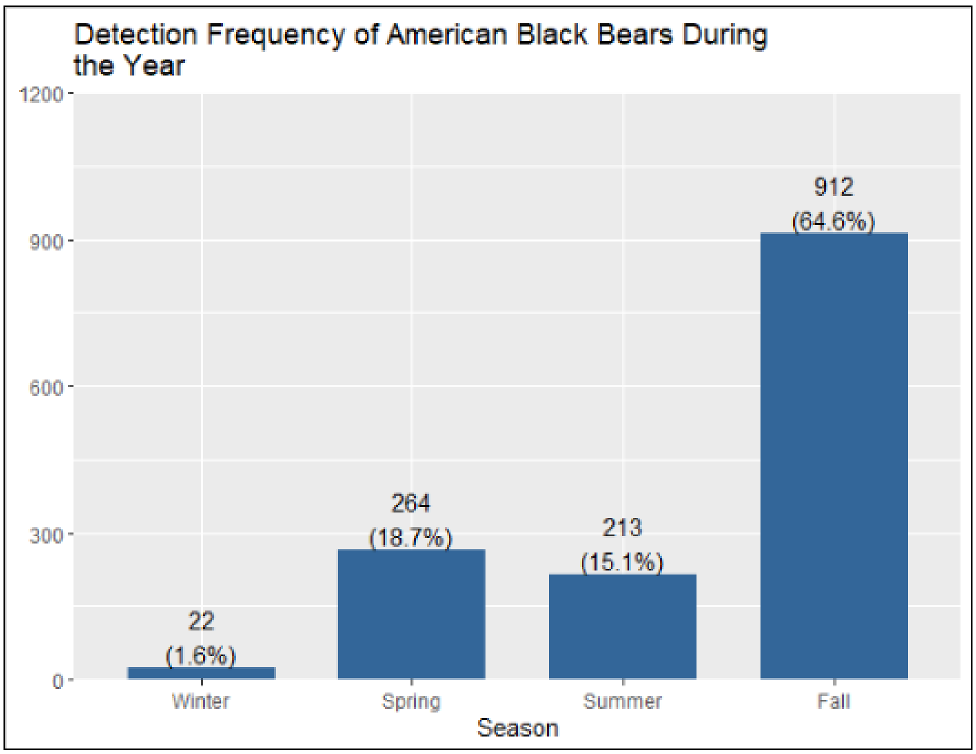

Figure 15. American black bear detection frequency vs. season. They were detected most frequently in the fall, at 912 (64.6%) observations ($X^2 = 1274.5$, $P < 0.001$).

The bears were observed most frequently at 1,033/1,411 (73.2%) detections from 5 PM to 5 AM, with 4151,411 (29.4%) detections occurring from 9 PM – 1 AM specifically (Figure 16). A chi-squared test was conducted to test if bears were detected more frequently during a particular time of the day. The results show that they were not detected equally across all times of the day (X^2 = 355.9, P < 0.001).

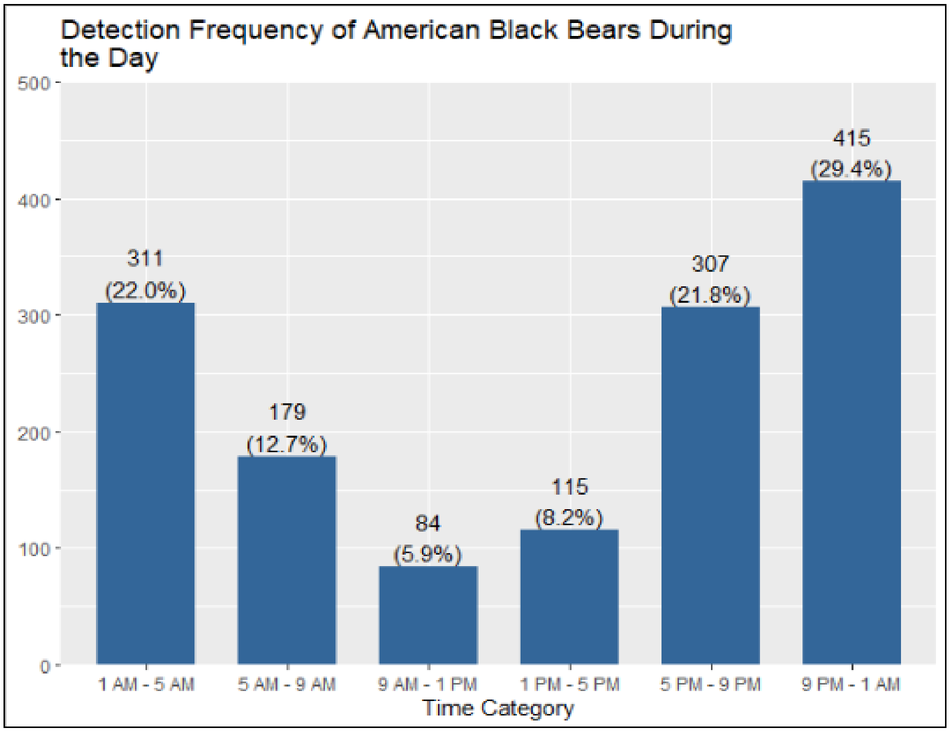

Figure 16. American black bear detection frequency vs. time of day. They were most active from 9 PM to 1 AM, at 415 (29.4%) detections (X^2 = 355.9, P < 0.001).

<u>Mountain Lion</u>

The detection frequency for mountain lions was nearly evenly distributed during the spring, summer, and fall at 8/29 (27.6%), 7/29 (24.1%), and 10/29 (34.5%) respectively. Winter held the fewest mountain lion detections at only 4/29 observations, or 13.8% (Figure 17). To test if mountain lions were observed more frequently during a certain season, a chi-squared test was conducted. The results indicate that there is not a big difference between their detection frequency across seasons (X^2 = 2.59, P = 0.4599).

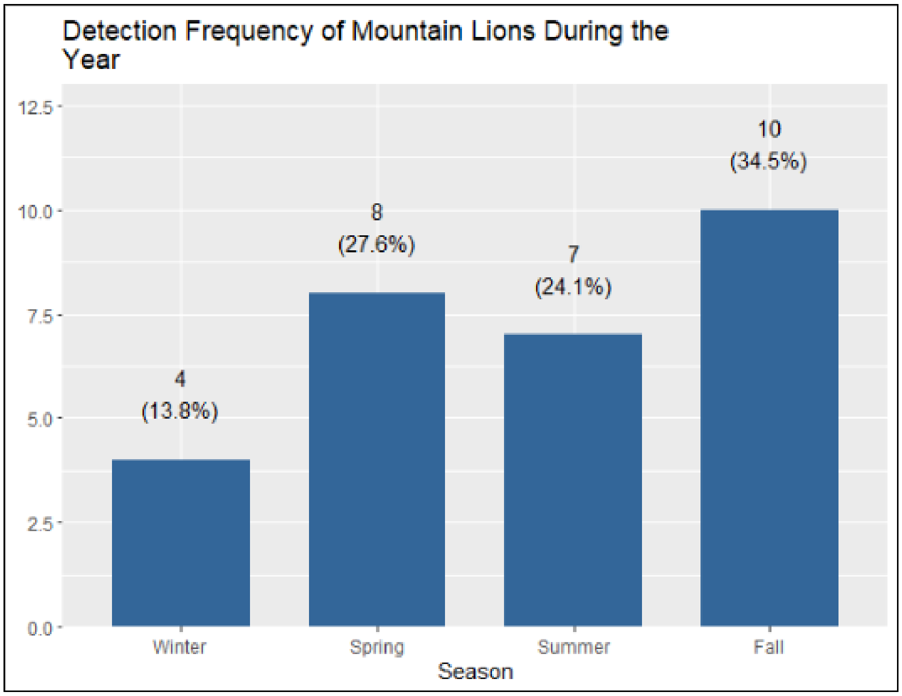

Figure 17. Mountain lion detection frequency vs. season. They were detected evenly across all seasons (X^2 = 2.59, P = 0.4599).

Mountain lions were detected most frequently from 9 PM – 9 AM, with 24/29 (82.7%) detections happening during this time. Detection frequency was almost evenly distributed between the 9 PM – 1 AM, 1 – 5 AM, and 5 – 9 AM time categories at 8/29 (27.6%), 9/29 (31.0%), and 7/29 (24.1%) respectively (Figure 18). A chi-squared test could not be conducted due to the limited sample size.

<u>Bobcat</u>

Bobcats were detected most frequently during the winter months, with 16/33 (48.5%) of detections taking place in this season. They were observed least during the summer, at only 2/33 (6.1%) detections (Figure 19). To test if bobcats were detected more frequently during one season, a chi-squared test was conducted. The results show that their detection frequency was not equal across all seasons (X^2 = 12.21, P = 0.007).

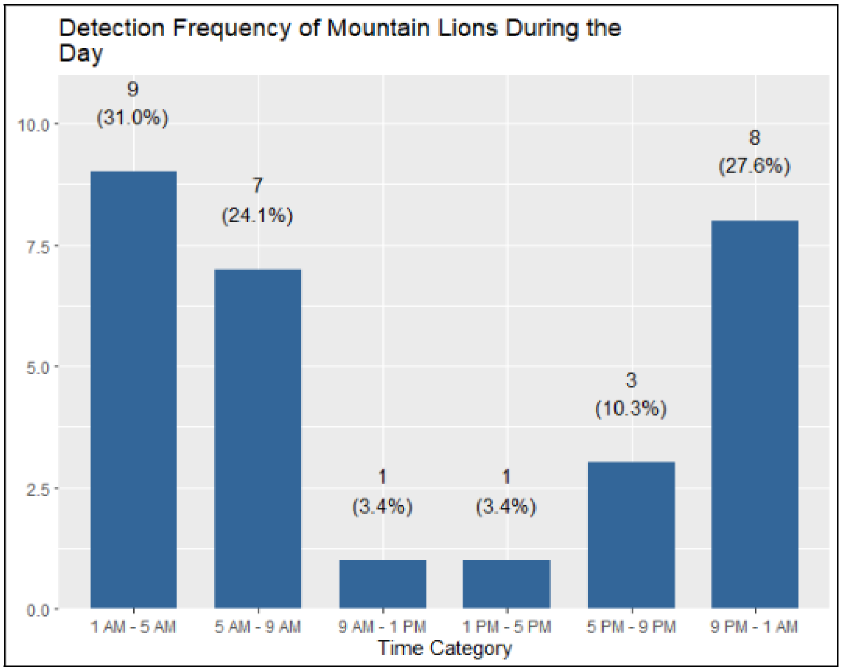

Figure 18. Mountain lion detection frequency vs. time of day. They were detected most frequently from 9 PM – 9 AM, with 24 (82.7%) observations.

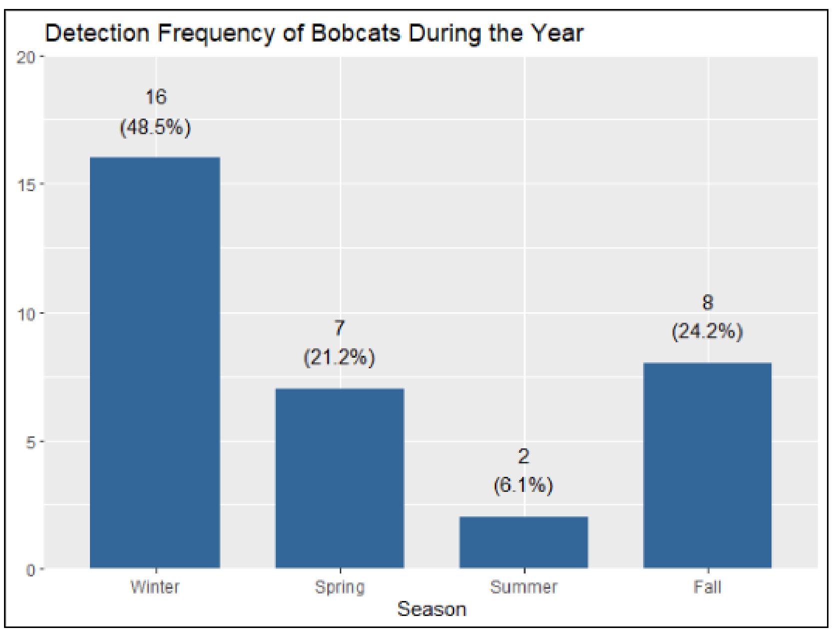

Figure 19. Bobcat detection frequency vs. season. They were seen most in winter, with 16 (48.5%) detections (X^2 = 12.21, P = 0.007).

Bobcats were most active from 9 AM – 5 PM, with most detections 11/33 (33.3%) occurring from 1 – 5 PM (Figure 20). A chi-squared test was conducted to test if bobcats were detected more frequently during a particular time of the day. The results indicate that their detection frequency did not vary enough during different times of the day ($X^2 = 9$, $P = 0.1091$).

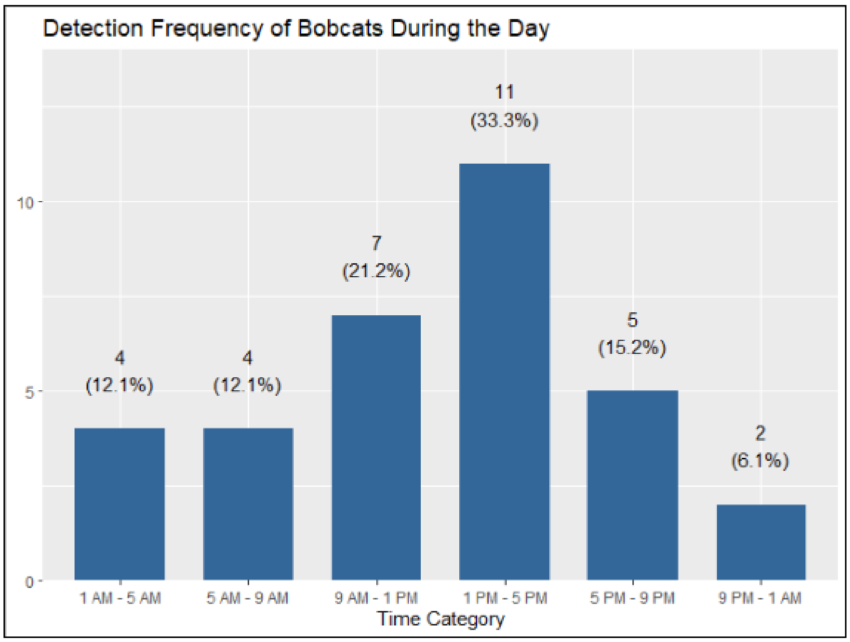

Figure 20. Bobcat detection frequency vs. time of day. They were not detected more frequently during one time of the day ($X^2 = 9$, $P = 0.1091$).

Gray Fox

Gray foxes were active throughout the year but were observed most frequently during the fall, with 379/961 (39.4%) detections. They were least active in the spring, with only 111/961 (11.6%) detections (Figure 21). A chi-squared test was conducted to test if foxes were observed more frequently during a season. The results indicate that their detection frequency was not equal across all seasons ($X^2 = 179.32$, $P < 0.001$).

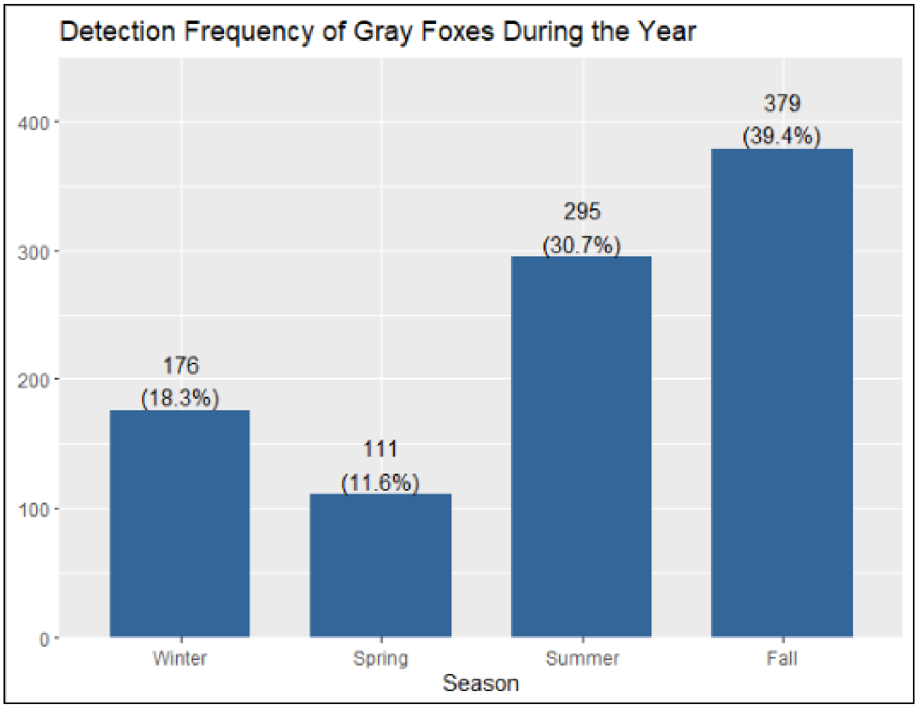

Figure 21. Gray fox detection frequency vs. season. They were most active in the fall, with 379 (39.4%) detections (X^2 = 179.32, P < 0.001).

Foxes were almost exclusively detected from 5 PM – 9 AM, with 949/961 (98.7%) detections occurring. They were observed most frequently from 9PM – 5 AM, at 701/961 (72.9%) detections (Figure 22). To test if foxes were detected more frequently during a particular time of the day, a chi-squared test was conducted. The results show that their detection frequency was not equal across all times of the day (X^2 = 766.74, P < 0.001).

Bobcat Activity and Moon Phase

The relationship between bobcat activity at night and the moon phase was investigated since there is little conclusive information on it. The data presented in the graphs below are of bobcats detected at night with less than 50% cloud cover. Most

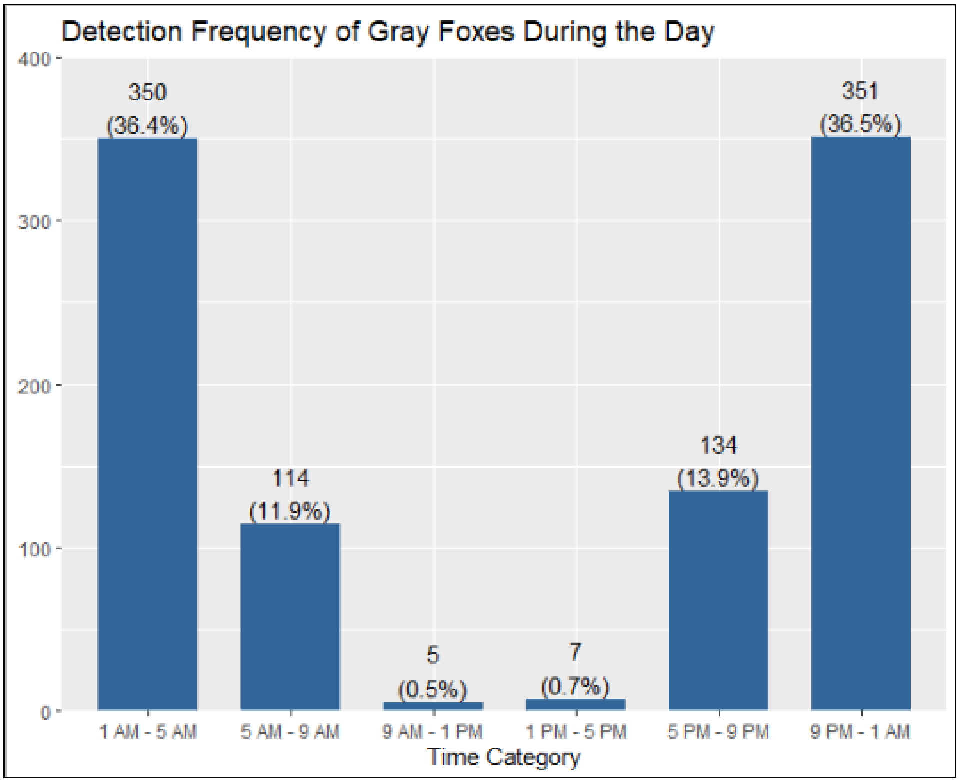

Figure 22. Gray fox detection frequency vs. time of day. Foxes were only detected 12 times from 9 AM – 5 PM, making up 1.2% of detections (X^2 = 766.74, $P < 0.001$).

detections (4) happened during a waxing crescent phase and there were no detections during full moon, waning gibbous, third quarter, and new moon phases (Figure 23). Due to their identical illumination percentages, both crescent phases, gibbous phases, and quarter phases were then combined to observe if there is a correlation between bobcat detection frequency and lunar illumination. Most detections (5) occurred during a crescent phase (Figure 24).

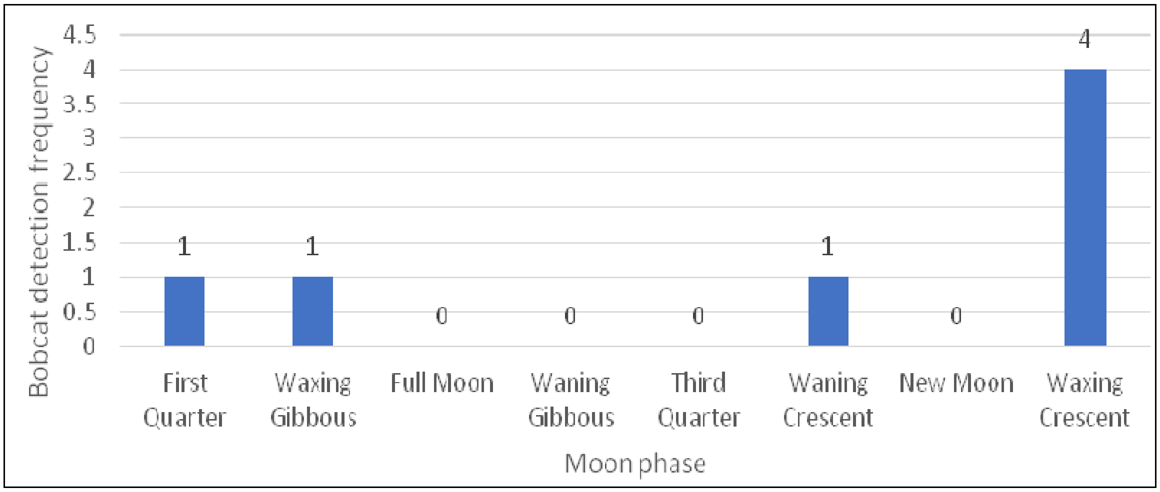

Figure 23. Bobcat detection frequency vs. moon phase. Most detections occurred during a waxing crescent moon phase (4).

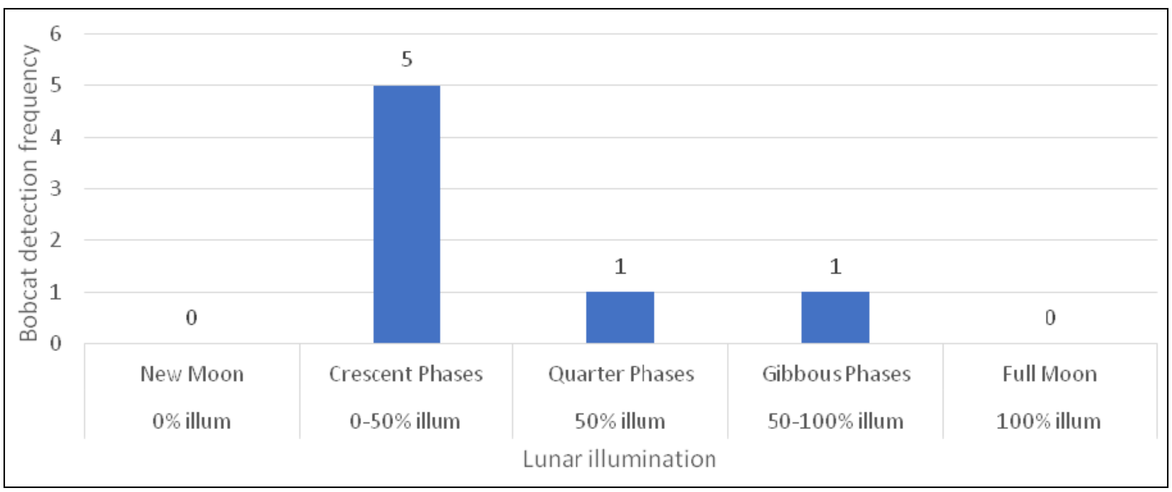

Figure 24. Bobcat detection frequency vs. lunar illumination. Most detections occurred during a crescent moon phase (5) which is 0-50% lunar illumination.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

One of the purposes of this research was to determine habitat use and distribution of American black bears (*Ursus americanus*), mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), and gray foxes (*Urocyon cinereoargenteus*) in the BCCER and to relate distribution patterns to particular resources in the BCCER. These four species were chosen due to the important roles they each play in the ecosystem, the public interest in these charismatic faunae, and because relatively little research has been conducted on these species in this region. Knowledge of areas where these species are known to regularly visit will facilitate fundraising through the Adopt an Acre Campaign. This is a large source of funding for land stewardship, research, and other projects at the BCCER which will further benefit the local wildlife.

Identifying the resources that these four study species depend on will provide important information for developing wildland management practices to further maintain these resources. Knowing the water sources that these species utilize the most is especially important now because of the California-wide drought. According to the National Integrated Drought Information System (NIDIS, 2022), 220,000 (100%) people in Butte County are affected by drought. If everyone in this county is affected, then we can assume that the wildlife is also affected. Finding and preserving vital water sources in the BCCER will help support these species through the drought.

Each species' detection frequency during the times of day and seasons of the year, as well as bobcat activity during different moon phases, were investigated. Effect of moon phase on bobcat activity was investigated because of the findings on predator and prey behavior by Rockhill et al. (2013) and Tambling et al. (2015). Rockhill et al. (2013) suggested that bobcats hunt prey at night during high illumination moon phases to augment for their vision, while Tambling et al. (2015) found that prey species change their time of activity to avoid predators. This could mean that prey species, such as rodents and rabbits, would avoid activity during high illumination moon phases to evade bobcats.

The objectives of this project were accomplished by placing twenty-four trail cameras throughout the section of BCCER located east of Big Chico Creek. Cameras or camera clusters were separated by approximately 800 meters (0.5 mi) away from each other to create an even distribution. Data was collected from May 18, 2021 to May 18, 2022, however not all the cameras were fully functional during the entire study period due to technical issues.

American Black Bears

American black bears were observed on every trail camera, except for the ones on acres CK55 and CJ55, which are part of the Tuscan Loop (chaparral). Out of all the trail cameras, they were seen most at acres I64 (riparian forest), AX67 (oak woodland), and K63 (meadow/riparian forest and shrubland). These are all open areas with plenty of vegetation that provides food for bears, including olive trees, fig trees, toyons, grasses, oak trees, coffeeberries, prunes/fruiting trees, and Himalayan blackberries. The trail cameras on I64 and AX67 are also only 2 and 3 meters away from a water source, respectively. The bears were observed more frequently in the areas north of Meadow Loop (BF60). The bears were detected at every acre with a water source, with 1,033 (73.2%) observations occurring at acres with water, and they were observed using water 605 (58.6%) times. This indicates that when suggesting acres for donors to adopt though the Adopt an Acre Campaign, sites with a water source (especially a spring), plenty of edible vegetation, and in the areas north of BF60 should be taken into consideration. Some potential acres include K61 which is near Bear's Orchard and the Big Chico Creek, or any acres surrounding I64 since there are four trails that lead to the popular spring in that acre.

The bears appeared to heavily favor one specific acre, I64. Out of all the acres with a water source, there were 699 (67.7%) bear detections there. Furthermore, out of all the bear detections at I64, 502 (71.8%) observations were of them using the spring. This includes drinking the water and getting in the spring. Since the bears seem to depend on the spring in acre I64, it should be monitored and maintained by the BCCER staff. This could include making weekly visits to the spring to ensure it is full of water or installing a guzzler nearby so that they have a backup water source in case the spring dries up.

Since black bears are omnivorous, with most of their diet consisting of plant matter, the acres where they were seen eating vegetation was analyzed. Although each acre had several plants that bears are known to eat, only the nine where they were observed utilizing this resource were investigated. Of all the acres with a food resource, the bears were observed eating near the BCCER office the most, with 47 (3.8%) detections at AW68 and 14 (1.1%) detections at AX67. This area has olive trees, fig trees, native bunch grasses, and toyon. Although olives and figs are non-native species, they appear to have become an important part of the local bears' diet. I recommend that the BCCER staff continue to manage the native grasses and toyon. They should also consider keeping the non-native olive and fig trees because they are a frequent food source for the bears. Keeping these plants healthy and abundant could help the bears during this extreme drought.

The bears were highly active during the fall, with 912 (64.6%) detections. Their second most productive season was spring, which saw 294 (18.7%) detections. They were almost completely inactive during the winter, with only 22 (1.6%) observations. The literature (Garshelis & Pelton, 1980) stated that bears were most active during the fall and summer, however, this study showed that they were more active in the fall and spring than in any other season. This is likely because the bears will prepare to go into their winter torpor in the fall and wake up hungry in the spring. The bears were also detected most frequently from 5 PM – 5 AM, with 1,033 (73.2%) observations. They were especially active from 9 PM – 1 AM, with 415 (29.4%) detections. Although the bears were active during the twilight hours, as the literature (Kronk, 2007) suggests, they were detected most frequently during the nighttime.

Mountain Lions

During this study, there were only 29 mountain lion detection events. They were also only observed at 10 out of the 24 trail cameras, with no detections occurring North of Henning Hole or on the Tuscan Loop. Out of all the trail cameras, they were seen most at acres T58 (mixed oak woodland) with 7 (24.1%) observations, CM43 (riparian mixed conifer forest) with 6 (20.7%) observations, and BI49 (canyon live oak woodland and riparian forest) with 4 (13.8%) observations. T58 is an open area in

Henning Hole that is approximately 28 meters away from Big Chico Creek. The trail cameras on CM43 and BI49 both face a trail that leads to the creek and are 10 and 28 meters away from the creek, respectively. Out of all their observations, 20 (69.0%) of them were at acres with a water source nearby. However, out of all their detections with a water source nearby, they were only seen using the water six (30.0%) times – three (15.0%) times at CM43, twice (10.0%) at T58, and once (5.0%) at AX67. Since the sample size was so small, there is not enough data to determine if there was a preference in activity at these acres. This indicates that when suggesting acres for donors to adopt through the Adopt an Acre Campaign, sites leading to the creek should be taken into consideration. Some potential acres include the ones with paths that lead to the creek, such as around Henning Hole (R58), the creek crossing in AT53, and the creek crossing in CM43. Because the camera that was mounted on CM43 for this study wasn't from the Adopt an Acre Campaign, it was removed at the end of my study. Therefore, this would be an ideal acre to suggest to a donor, especially if they are interested in mountain lions.

The mountain lions didn't appear to favor one specific acre with a water source, but they were seen more frequently at acres with the creek nearby, at 19 (95%) observations. Whereas they were only seen once (5%) at acres with a contained water source such as a spring or the horse trough. Since the mountain lions appear to rely on flowing water rather than confined water, the BCCER staff should ensure that the paths that lead to the Big Chico Creek are maintained. This could include clearing encroaching vegetation, removing fallen trees, and creating new paths.

Mountain lion activity was relatively even throughout the seasons, with a slight dip in detection frequency in the winter, with four (13.8%) observations. Because the literature stated that mountain lion activity depends on the abundance and vulnerability of their prey (Allen et al., 2014), then this could mean that their prey was active year-round with a slight decrease in the winter. Although an analysis couldn't be conducted due to the small sample size, the lions were observed more frequently from 9 PM – 9 AM, with 24 (82.7%) detections. They were seen evenly throughout the three 4-hour categories within this period. The literature stated that mountain lions are nocturnal (USDA), which the data from this study agrees with.

<u>Bobcats</u>

There were only 33 bobcat detection events during this study, with detections occurring at 11 out of the 24 trail cameras. The bobcats were not observed south of BX48, except for on Tuscan Loop, or on the cameras near the BCCER office. Out of all the trail cameras, they were seen most on the Tuscan Loop (CJ55 and CK55) with 11 (33.3%) observations, on the Grandmother Pine Trail (AS70) with six (18.2%) observations, and at acre F61 with five (15.2%) observations. The Tuscan Loop is a chaparral habitat, the Grandmother Pine Trail is an oak woodland/grey pine forest, and F61 is described as a mixed oak woodland. None of these areas have a known water source within 30 meters of the trail camera. Out of all their observations, 28 (84.8%) of them were at acres without a water source nearby and they were never detected drinking water. When suggesting acres for donors to adopt through the Adopt an Acre Campaign, habitats such as chaparrals, oak woodlands, and brushlands should be considered. Since the bobcats were seen near the start of the Grandmother Pine Trail (AS70) and not further down the trail (AR70), then a potential acre to be adopted would be AT69 which is at the trailhead. Another potential location would be on the Tuscan Loop, such as acres CF55 or

CJ56. These two acres were selected based on the direction that the bobcats were observed walking through. Lastly, acres around F61, such as F62, E61, or G61, could be suggested for adoption.

Although the bobcats were not observed using any water source, they were seen most at BI49, with three (60.0%) detections. They could have been walking to or from the creek that flows through this area. To further evaluate if they were traveling through this area for the water, then another camera could be placed closer to the creek on the path. Since the bobcats weren't seen drinking water, a water source for the BCCER staff to maintain to help this species cannot be suggested. More trail cameras would need to be placed facing a variety of water sources to investigate where these cats are getting their water from.

The bobcats were most active during the winter, with 16 (48.5%) observations, and were least active during the summer, with only two (6.1%) observations. It is unknown whether bobcats are more active during a particular season, so this trend could be associated with the local bobcat population or the availability of their prey. Although the analysis showed that bobcat activity didn't correlate with different times of the day, they were seen most from 9 AM – 5 PM, with 18 (54.5%) observations. This suggests that they could be diurnal, which does not agree with the literature which states that they are crepuscular (Ciszek, 2002). More data would need to be collected to further evaluate this trend.

Because Rockhill et al. (2013) suggests that bobcats are most active during high illumination moon phases at night, further analysis on this theory was conducted. With a limited sample size of only seven nighttime bobcat observations during a less than

50% cloud cover, no analysis could be done. However, the trend showed that most observations occurred during a crescent phase, with five (71.4%) detections, four (57.1%) during a waxing crescent and one (14.3%) during a waning crescent. There were also no observations during a new moon or full moon, and only one during a quarter phase and gibbous phase. This data does not agree with the literature (Rockhill et al., 2013) since the bobcats appeared to be more active during a moon phase with a lunar illumination of 0-50%. However, more data would need to be collected to further investigate this theory.

Gray Foxes

Gray foxes were common throughout the BCCER and were observed on 20 of the 24 trail cameras, with most detections around the BCCER office (oak woodland), on the Grandmother Pine Trail (oak woodland/grey pine forest), and on Meadow Loop (annual grassland). The two cameras near the BCCER office (AX67 and AW68) are in an open area with olive trees, fig trees, grasses, toyon, and a horse trough. The two cameras on the Grandmother Pine Trail (AS70 and AR70) are under dense canopy cover and face a trail that goes through canyon live oak, black oak, poison oak, gooseberry, pipevine, iris, grey pine, big leaf maple, redbud, coffeeberry, and geranium. The camera on Meadow Loop (BF60) is in a mixed oak woodland with bay laurel and dense canopy cover but faces a trail that goes through a field of purple needle grass. Out of all the trail cameras, the foxes were detected 258 (23.8%) times around the BCCER office, 246 (25.6%) times on the Grandmother Pine Trail, and 125 (13.0%) times on the Meadow Loop. The foxes were detected at eight of the nine acres with a water source, with 338 (35.2%) observations occurring at acres with water, and they were observed using water 219 (64.8%) times. This indicates that when suggesting acres for donors to adopt through the Adopt an Acre Campaign, sites with a water source, fruit bearing plants, and in the areas north of the Meadow Loop should be taken into consideration. A potential area includes other locations on the Grandmother Pine Trail, either further up the trail (AP70), or facing the dried tributary that the foxes were seen using as a trail (AT68 or AR72). Another suggested area would be facing other parts of the Meadow loop (BD58 or BA61).

Of all the acres with a water source, the foxes visited AX67 the most, with 223 (66.0%) detections there. Additionally, out of all the fox detections at this acre, 197 (88.3%) observations were of them drinking water out of the horse trough. Since the foxes appear to rely on this trough for water, it should continue to be regularly filled by the BCCER staff. In addition to filling it up every morning, electrolytes could be mixed inside to replenish their nutrients and fluids.

Since gray foxes are omnivorous, with a large portion of their diet consisting of plant matter, the acres where they were seen eating vegetation was analyzed. Of all the acres with a food resource, foxes were seen the most at acre AX67, with 223 (43.5%) observations. However, they were not seen eating there. Instead, they were detected using the food resources the most at acre AW68, with nine (1.8%) detections. The foxes were seen eating something from the ground by the olive tree which were likely fallen olives, as well as climbing the olive tree. Since this area also had the most observations of bears eating plant matter, the non-native olive tree should not be removed, especially during the drought.

The foxes were detected throughout the entire study period, but were most active during the fall and summer, with 379 (39.4%) and 295 (30.7%) observations, respectively. They were also seen the least in spring, with 111 (11.6%) detections. It is unknown whether foxes are most active during a particular season, so this trend could be associated with the local fox population. The foxes were almost exclusively active from 5 PM – 9 AM, with 949 (98.7%) detections occurring during this period. They were especially active from 9 PM – 5 AM, with 701 (72.9%) observations. There were only 12 (1.2%) detections from 9 AM – 5 PM. The data collected agrees with the literature (Vu, 2011) which stated that gray foxes are nocturnal.

Recommendations

Since this is the first mammalian predator study in the BCCER, there is much room for improvement, as well as further development of additional research questions. If this study were to be replicated and improved upon, the largest SD card size available should be used and solar panel attachments should be installed where it's appropriate. This would lower the chance of the SD card filling up and the batteries dying or leaking. The cameras would likely last longer without being checked.

Another improvement would be setting up pairs of cameras (approximately 20 m apart) facing the same trail at each desired acre. This will create a greater area for possible detections within an acre, and pictures/videos will be captured at two different angles, allowing for easier and more accurate species identifications. This could be extremely beneficial if the goal of the study is to estimate the population sizes of each species via camera trapping by identifying individuals through their unique coat patterns.

Future studies could also replicate this protocol to determine the distribution and resource use of mammalian predators on the West side of Big Chico Creek in the

BCCER. The different aspect of the canyon is reflected in the flora, and therefore could alter the resources that these mammals are using on that side. To further evaluate each species' water usage during this drought, trail cameras could be placed facing different types of water sources – the creek, springs, and guzzlers/man-made water sources – to investigate if there is a preference between them. The results would inform the BCCER staff of the best ways to provide water for the wildlife. Additionally, since gray foxes are nocturnal, further research could be done to test the correlation between their activity at night and the moon phase. Another study could be to investigate whether each species' peak time of activity changes across different seasons.

While going through the trail camera photos for this study, there appeared to be a downward trend in mule deer (*Odocoileus hemionus*) detection frequencies, particularly during the Dixie Fire. Former BCCER director and now full-time volunteer, Paul Maslin, has also noticed a decline in deer observations, especially fawns, in the last couple of years. Future research could be conducted to monitor the BCCER deer population which is important in sustaining the mountain lion population and managing the vegetation.

During this study, an adult male fisher (*Pekania pennanti*) was detected on three trail cameras. This is important because on June 15, 2020, the U.S. Fish and Wildlife Service listed the Southern Sierra Nevada Population Segment (DPS) of fisher as endangered under the Endangered Species Act (Shipwith, 2020). Because of their status, the fisher translocation project began, and from 2009 to 2011, 40 fishers were reintroduced to the northern Sierra Nevada and Southern Cascades (CDFW, 2022b). Further research could be done to attempt to monitor this fisher.

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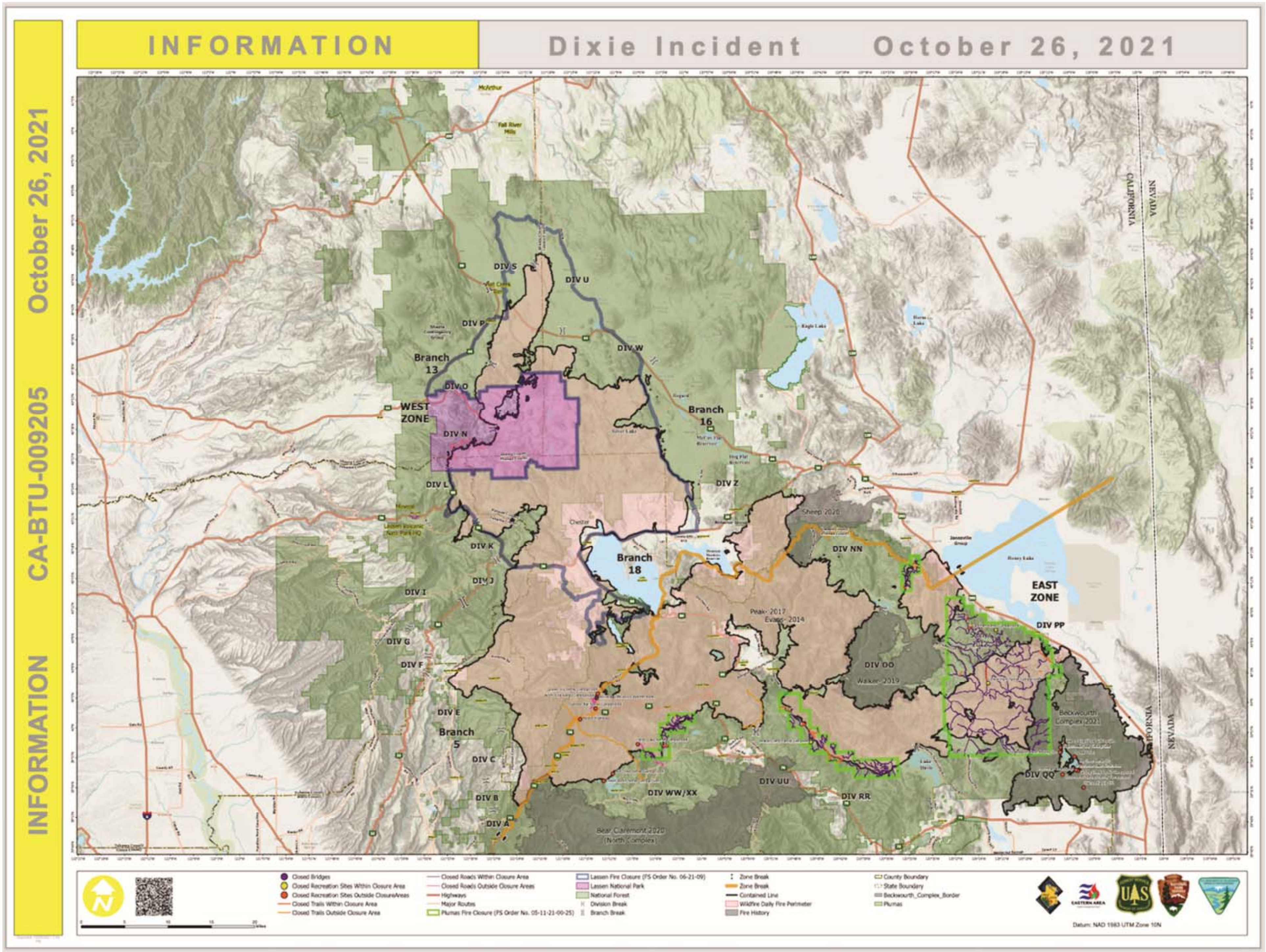
APPENDIX A

Appendix A contain a map of the Dixie Fire burn scar. The fire started above the Cresta Dam in Feather River Canyon on July 13, 2021, and was extinguished on October 25, 2021, after burning 963,309 acres.



APPENDIX B

Appendix B contains the settings that each trail camera was programmed to. Below are the trail camera settings along with what they mean:

- Operation mode: Trail camera (pictures) or video mode. Most of the cameras were on trail camera mode since video mode uses more data on the SD cards.
- Photo/Video Quality: Ultra (16 megapixels)
- Video length: 10-20 seconds
- Delay time: 1-second delay. This is the time between the camera detecting a heat signature and the time that it takes a picture or video.
- Photo burst: 3-shot rapid fire. This is how many pictures the camera takes in a burst when it detects something.
- Temperature units: Fahrenheit
- Camera name: The acre name
- Image data strip: On. This is the strip on the bottom of the picture with all the data (date, time, temp, moon phase, cam name)
- Motion test: Off
- Motion detection: 80 ft range. The distance that the camera will detect something from
- Battery type: Lithium or alkaline, depending on the battery type inserted
- Trigger speed: Fast
- Smart IR Video: Off
    - This allows a daytime video clip to keep recording as long as the camera detects movement during filming. If the camera no longer detects movement, it will end the video.
    - Since this setting is off, then the camera will produce multiple 10-20 second video clips (depending on the video length setting) until it doesn't detect anything.
- SD management: off. If this is on and the SD card is full, then the camera will overwrite the oldest pictures or videos with newer images or videos

APPENDIX C

Appendix C contains the tools taken and steps followed for checking the trail cameras. The following tools were taken when checking the trail cameras:

- Functioning radio
- Approximately 30 AA batteries – either lithium or alkaline
- A box of 16, 32, 64, and 128 GB SD cards
- Kubota or another Utility Terrain Vehicle
- Rite in the Rain notebook and pen
- Extra straps or camera (taken when available)
- Loppers or machete (only needed when clearing vegetation from camera's view)

The trail cameras were checked in the following order:

AX67, AW68, AS70, AR70, BF60, B61, F61, I64, K63, S57, T57, T58, Z59, AN60, AW54, BI49, BU48, BX48, BZ48, CM43, CY42, AX75, CK55, CJ55

Below are the steps for checking the trail cameras:

1. Walk and/or drive to the desired camera
    a. AX67, AW68, AS70, and AR70 are within walking distance from the BCCER office – the Kubota was not required for accessing these cameras
    b. A personal vehicle was driven to acres AX75, CK55, and CJ55 since AX75 is near the BCCER's front gate, and CK55 and CJ55 are on the Tuscan loop which is only accessible from State Route 32.
    c. The Kubota provided by the BCCER was driven to access the rest of the trail cameras
2. Open the camera door and check the battery life. If it's low or dead, then change the batteries, if not then leave them in.
    a. The "threshold" for changing the batteries is camera-dependent and is also influenced by the season. Some trail cameras see much more animal activity then others and will therefore drain their batteries faster. A Rite in the Rain notebook was used to record each camera's battery life every time the cameras were checked. This made it easier to predict when the

batteries needed to be changed because the battery life trends were visualized.

3. Check how many pictures/videos the camera took and remove the SD card. Put in an empty SD card with the size depending on how active the camera has been.
    a. 16 GB: ~2,000 or less photos
    b. 32 GB: ~2-4,000 photos
    c. 64 GB: ~4-8,000 photos
    d. 128 GB: ~8,000 or more photos
4. Click “mode” to check the other settings – make sure date and time are accurate. The time runs fast on these cameras and sometimes they will reset back to January 1, 2017. If the time is wrong, then fix it.
5. Ensure that the camera is positioned correctly, and nothing is obstructing the view. If there’s vegetation in the way, then cut it with the loppers or machete. If the camera was moved, then reposition it.
6. Close the camera door and go to the next camera.

APPENDIX D

Appendix D contains the protocol for transferring the trail camera media from the SD cards to an external hard drive. An external hard drive was used to temporarily store the media in one location while being sorted through. The external hard drive used in this study was a Seagate Expansion Drive.

The steps for moving the media from the SD cards to the Seagate Expansion Drive are below:

1. Plug in the Seagate Expansion Drive and an SD card that was collected from a camera check to a laptop/computer and open the SD card folder.
2. Within the SD card folder, select the “DCIM” folder which is where the media is stored.
3. Open a picture or video to figure out which acre it is from by checking the data strip at the bottom. Select all the media then cut it (“CTRL” + “X”).
4. Within the Seagate Expansion Drive folder, open the “adopt an acre trail cameras” folder. This folder contains subfolders with each acre’s name.
5. Open the folder for the corresponding acre.
6. Create a new folder and name it whatever date the camera was checked (MM-DD-YY).
7. Open the new folder and paste (“CTR” + “V”) the media from the SD card into the new folder.
8. Wait for the media to transfer and double check the DCIM folder to make sure everything transferred.
9. Close the window for the SD card and remove it from the laptop/computer.
10. Insert the next SD card and repeat the steps.

APPENDIX E

Appendix E contains the protocol for uploading the media from the Seagate Expansion Drive to Box. This ensures the organized and long-term storage of this data, allowing for more research to be done on the mammals in the BCCER.

The following steps explain how to accomplish this goal:

1. Plug in the Seagate Expansion Drive to a laptop/computer.
2. Open Box and log on.
3. Open the “Trail Camera Photos” folder on Box.
4. Find and open the folder of the acre that you wish to upload to.
5. Select the “New +” button at the top right corner of the page then select “Folder Upload”.
6. On the expansion drive, open the “adopt an acre trail cameras” folder, then open the corresponding acre.
7. Single click on the folder that you want to upload, then select “Upload” at the bottom right corner of the window. Don’t double click on folder because that will open it.
8. Box will then ask if you wish to upload the folder and select “Upload”.
9. Repeat these steps until all folders from the latest camera check are uploaded.

APPENDIX F

Appendix F contains the steps for sorting through the trail camera folders on the Seagate Expansion Drive and recording the data when a study species is detected.

Below are the steps for achieving this:

1. Plug in the BCCER Seagate Expansion Drive to a laptop/computer.
2. Open the “adopt an acre trail cameras” folder.
3. Open the folder for the acre that you want to sort through.
4. Open the appropriate camera check date folder.
5. Go through all the pictures/videos within the folder.
6. When an American black bear, gray fox, bobcat, or mountain lion is detected, write down the species, image label, detection date and time, moon phase, number of individuals observed in a detection, resource use/activity, and amount of time spent at that location.
7. Once the media has been sorted through and all detections are recorded. The images from each detection will be uploaded on Box. Open Box, select the folder for whatever species you will be uploading the pictures to, create a new folder and name it the date that the detection occurred, and upload the corresponding pictures into it.
8. When you have uploaded all the files you need from the camera check date folder, then you can delete it from the Seagate Expansion Drive (right click on the folder name then select delete).
9. Enter the written species detection data into an Excel document. Also note the number of days each camera has missed potential detection days (full SD card, dead batteries, stolen, etc.) and any other notable information.

APPENDIX G

Appendix G contains the parameters used to create the suitability surface analysis layer for the American black bear, mountain lion, bobcat, and gray fox distribution heat maps. These parameters include habitat variables with a classification ranking and weighted value.

Below are the parameters for the American black bear distribution map:

Variable	Value	Classification
Ruggedness		
	0-50 m	3
	50-100 m	1
	100 + m	1
Distance to Streams		
	0-500	1
	500-1000	2
	1000-1451	3
Distance to Roads		
	0-1000	3
	1000-2000	2
	2000-3107	1
Land Cover		
	Water	2
	Trees	1
	Grass	1
	Flooded Vegetation	2
	Crops	1
	Scrub/Shrub	1
	Built Area	3
	Bare Ground	3
	Snow/Ice	3

Variable	Weight in model
Ruggedness	0.1
Distance to streams	0.3
Distance to roads	0.1
Land cover	0.5

Below are the parameters for the mountain lion distribution map:

Variable	Value	Classification
Ruggedness		
	0-50 m	3
	50-100 m	2
	100 + m	1
Distance to Roads		
	0-1000	3
	1000-2000	2
	2000-3107	1
Land Cover		
	Water	3
	Trees	1
	Grass	1
	Flooded Vegetation	2
	Crops	2
	Scrub/Shrub	1
	Built Area	3
	Bare Ground	3
	Snow/Ice	3

Variable	Weight in model
Land Cover	0.8
Distance to roads	0.05
Ruggedness	0.15

Below are the parameters for the bobcat distribution map:

Variable	Value	Classification
Ruggedness		
	0-50 m	3
	50-100 m	2
	100 + m	1
Distance to Streams		
	0-500	1
	500-1000	2
	1000-1451	3
Distance to Roads		
	0-1000	3
	1000-2000	2
	2000-3107	1
Land Cover		
	Water	3
	Trees	1
	Grass	1
	Flooded Vegetation	2
	Crops	2
	Scrub/Shrub	1
	Built Area	3
	Bare Ground	3
	Snow/Ice	3

Variable	Weight in model
Cover	0.4
Distance to roads	0.1
Ruggedness	0.3
Distance to streams	0.2

Below are the parameters for the gray fox distribution map:

Variable	Value	Classification
Ruggedness		
	0-50 m	3
	50-100 m	1
	100 + m	1
Distance to Streams		
	0-500	1
	500-1000	2
	1000-1451	3
Distance to Roads		
	0-1000	3
	1000-2000	2
	2000-3107	1
Land Cover		
	Water	2
	Trees	1
	Grass	1
	Flooded Vegetation	2
	Crops	1
	Scrub/Shrub	1
	Built Area	3
	Bare Ground	3
	Snow/Ice	3

Variable	Weight in model
Ruggedness	0.1
Distance to streams	0.3
Distance to roads	0.1
Land cover	0.5