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Integrating Camera Trap Data and Occupancy Modeling to Estimate Seasonal Variations in Occurrence, Detection, and Activity Patterns of Mesocarnivores in Southcentral Oklahoma

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Integrating Camera Trap Data and Occupancy Modeling to Estimate Seasonal Variations in Occurrence, Detection, and Activity Patterns of Mesocarnivores in Southcentral Oklahoma

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ABSTRACT OF THESIS

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TITLE OF THESIS: Integrating Camera Trap Data and Occupancy Modeling to Estimate Seasonal Variations in Occurrence, Detection, and Activity Patterns of Mesocarnivores in Southcentral Oklahoma

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ABSTRACT:

Mesocarnivores have important ecological roles as primary predators of food webs who significantly contribute to maintaining the health of the lower trophic levels. Various anthropogenic effects impact the viability of mesocarnivore populations; therefore, conservation is essential to maintain ecosystem integrity. Camera trapping has been increasingly used to monitor different ecological aspects of wildlife, specifically for elusive, large carnivores. Recently, camera-traps have been used to study temporal species interactions, most often for predator-prey relationships in large carnivores. Relatively few studies have been conducted on spatial ecology and temporal activity overlap between mesocarnivore species using camera-traps, and there are no such studies done in the State of Oklahoma. My study was conducted at Oka' Yanahli Preserve (OYP), located in southcentral Oklahoma. The primary goal of this project was to expand the current body of knowledge about mesocarnivore ecology in southcentral Oklahoma, specifically at OYP. Camera traps were used to capture images of mesocarnivores in the preserve over winter (November 2016 to February 2017) and summer (May to August 2017). Six remotely-triggered infra-red cameras were deployed for 4 weeks. After 4 weeks, cameras were moved to different, random locations. Half of the cameras were systematically baited by using canned mackerel. A total of 2778 mesocarnivore pictures from winter and 1455 from summer were taken from 25 camera locations in winter and 18 camera locations in summer. Species richness, detection frequencies, detectability, and occupancy estimates were determined by analyzing pictures. Mesocarnivore species identified from both seasons were coyote (*Canis latrans),* raccoon *(Procyon lotor),* bobcat (*Lynx rufus)*, Virginia opossum (*Didelphis virginiana)*, and striped skunk (*Mephitis mephitis).* Results show the proportion of sites occupied and detection probabilities were higher for all species during winter than in summer (single species occupancy modeling). Overall detection probability was higher with baited camera traps for raccoon, skunk and opossum (not significantly different) obtained from single species occupancy modeling. Baiting had no overall effect on the probability of detection for all species in summer. A possible reason could be the abundance of food resources were higher during summer than winter; therefore, there was less attraction to the bait around camera sites in summer. Temporal activity densities were higher for all species during winter than in summer (Circular Kernel Density Estimates) and all species were mostly nocturnal during winter whereas in summer coyote and raccoon were often active during the day. Bobcat were strictly nocturnal in both seasons. Temporal activities overlapped largely ($\Delta>0.7$) between all species in winter, except for skunk. The summer had moderate activity overlap for all species ($\Delta<0.7$). There was a significant difference in activity overlap within species, between two seasons ($p<0.05$). Contradictory to what I expected, the data show that mesocarnivore species present in this preserve do not necessarily avoid each other, rather they co-exist partitioning their resources. Intraguild competition or avoidance could be less expected in this preserve as supported by my results of large temporal overlap between the species. The data gathered from this research will be useful in future research, long-term monitoring efforts, and restoration of habitats of mesocarnivores in OYP. Establishing baseline knowledge of the abundance and species richness of mesocarnivore species is imperative to gain an understanding of how mesocarnivores react to different management strategies, and could be compared to this baseline inventory. In addition, knowing which species inhabit the area may alert property managers to species of conservation concern.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1. The importance of mammals in wildlife conservation and management

Mammals are a diverse vertebrate group with approximately 5400 known species with divergent ecology. They are an extensive group of animals which supports ecosystem integrity, often acting as keystone species. There are a number of reasons to study mammals, but conservation and management is a priority. Even though recent discoveries yet could unveil new mammalian species, most of known species are on the edge of extinction (Ceballos et al. 2005; Carwardine et al. 2008; Milner-Gulland et al. 2013). Therefore, research is necessary to gain further knowledge that could be used in conservation.

There are challenges to developing mammalian conservation goals due to the diversity of mammalian taxa. Conservation needs and priorities are different from mice to bats, shrews to whales, and elephants (Milner-Gulland et al. 2013). Similar conservation needs are often associated with body size and feeding habits of mammals. Larger bodied mammals are more vulnerable than small mammals for several reasons. Larger mammals, especially carnivores, have larger body sizes, have higher energy demands, higher dispersal and larger home ranges (Bogoni et al. 2017). Some mammals are aesthetically pleasing because they have colorful pelage which makes them vulnerable to hunting by humans (Milner-Gulland et al. 2013; Bogoni et al. 2017). Many mammalian species are threatened with extinction due to low population densities this includes carnivores and mesocarnivores. Human exploitation of fur, skin, teeth, and bone, as well as habitat fragmentation have expedited the extinction process of carnivore and mesocarnivore species (Ceballos et al. 2005; Carwardine et al. 2008; Milner-Gulland et al. 2013). Because carnivores are often charismatic and iconic creatures in ecosystems, conservation and sustainable management could provide more benefits than overexploitation. Therefore, the necessity of carnivore and mesocarnivore conservation cannot be stressed enough.

Carnivores have a profound impact on the ecosystems they inhabit and contribute significantly to ecosystem integrity (Prugh et al. 2009). Although smaller in size than larger carnivores, mesocarnivores have an effect on the ecosystem, especially managing trophic cascades (Prugh et al. 2009; Roemer et al. 2009). Geographic distributions are uncertain for some species and abundance data are also not readily available due to elusiveness of behavior, large spatial requirements, preferred habitats, and low densities of mesocarnivores (Monterroso et al. 2014).

2. Importance of mesocarnivores

Mesocarnivores are small and midsized carnivores (< 20 kg). Mesocarnivores usually exceed carnivores in species richness. They can be more specialized animals with specialized habitat and behaviors like in mink (*Neovison vison*) or could be generalized animals living in close proximities to human like skunks (*Mephitis mephitis*) and coyotes (*Canis latrans*) (Roemer et al. 2009). Mesocarnivores have the ability to survive in different habitats, they have smaller bodies, and mesocarnivore populations are more abundant than large carnivores. Collectively mesocarnivores may perform ecosystems services which large carnivores cannot do, but they have gained relatively little attention.

If there are no carnivores, herbivore population density has been shown to increase that, in turn, increases pressure on primary producers (Bu et al. 2016). Therefore, to balance each trophic level, there should be a carnivore in the system (Crooks and Soulè 1999; Barrett et al. 2012). At an ecosystem level, mesocarnivores are a good replacement for large carnivores (Roemer et al. 2009). Mesocarnivores are increasingly taking on the role of apex predators due to the rapid decline of larger carnivore populations (Crooks and Soulè 1999).

Mesocarnivores can drive community structure in the absence of introduced or native large carnivores (Roemer et al. 2009). The contribution of mesocarnivores to a healthy ecosystem has not been studied well enough and has gained slight attention. Research needs to discover a lot about mesocarnivores expeditiously because their populations have been declining dramatically. For example, bobcat populations in Oklahoma decreased since the 1960s due to excessive hunting for fur (Rolley 1985) and eastern spotted skunk populations have declined dramatically since the 1950s due to fur trapping resulting in an "endangered" conservation status in many states (Gompper and Hackett 2005).

Mesocarnivores can disperse large distances, and their adaptability to new habitats has made them more vulnerable to human exploitation (Roemer et al. 2009). Mesocarnivore association with domestic trash cans and dumpsters, especially raccoons, has been increasing rapidly, and mesocarnivores like coyotes could harm livestock as well (Reiter et al. 1999; Treves and Karanth 2003). Consequently, humans often kill them. Also, a considerable amount of mesocarnivore population decline is due to vehicle collisions on highways. Cortes and Steury (2016) determined that areas close to four lane highways were more detrimental to mesocarnivore populations than areas with vegetative cover. Therefore, mesocarnivore conservation strategies have to be implemented sooner rather than later. Better conservation and management thrives on proper knowledge of ecology of each species. Identifying the species richness, habitat use, activity patterns, and site occupancy of mesocarnivores is prominently important for proper conservation (Bu et al. 2016).

3. Cross Timber-prairie ecoregion in southcentral Oklahoma

The state of Oklahoma is one of the most biodiverse states located in the contiguous United States with variable vegetation, topography, and climatic factors (Blair 1939). The diversity of plant communities throughout the state of Oklahoma is significantly impacted by the variation in climate, soil types, and geography (Blair 1939). Flora and fauna of a particular area are highly related to geography. Therefore, geographical variations are important factors that should be considered when understanding faunal distributions, and species richness in a particular area.

Blair and Hubbell (1938) identified 11 biotic districts in Oklahoma. Biotic districts were later named ecoregions. Ecoregions are areas with similar ecosystems and environmental resources (Hall and Carr 1965). Ecoregions have to be considered as a general frame of reference when conducting environmental research. United States Environmental Protection Agency (USEPA) identified level I, II, III, and IV of ecoregions in the conterminous United States with numerous subdivisions at each level. The conterminous United States has 84 ecoregions at level III (U.S. Environmental Protection Agency 2005). Oklahoma has 12 level III ecoregions. Characteristic features like geology, hydrology, physiography, climate, soil, land use, fish and wildlife are unique to each subdivision of ecoregion within the state (Kasparian et al. 2004). According to phytogeography, Oklahoma is an ecotone between eastern deciduous forests and grasslands. Southcentral Oklahoma is on the edge of the Great Plains grasslands and Cross Timber forests (Gourley and Park 2012).

Climate is highly variable across Oklahoma. Humidity and moisture of the eastern part of the state are higher than the western due to the influence from the Gulf of Mexico. Average yearly precipitation has a gradient from 1400 mm ─ 400 mm, from southeast to northwest (Tyrl et al. 2012). Mean annual temperature ranges from 12 °C ─ 17 °C and length of growing season is 170 ─ 230 days (Oklahoma Climatological Survey, http://climate.ok.gov/ accessed 04/11/2018). Elevation ranges from 1500 m in the panhandle and as low as 90 m in the southeastern region. These climatic features have a significant influence on the distribution of flora and fauna. Oklahoma consists of plains, plateaus, hills, and intermittent mountain ranges (Tyrl et al. 2012). Eastern Oklahoma is mostly covered with forest that includes many species associated with the eastern deciduous forest. Declines in average precipitation from east to west results in a transition from forest to tall grass, mixed grass, and short grass communities. Woodlands mainly consist of post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*). Grasslands comprise switchgrass (*Panicum virgatum*), little bluestem (*Andropogon scoparius*), and Indian grass (*Sorghastrum nutans*) with intermittent bottomland forests consiststing of hardwoods like pecan (*Carya illinoinensis*), black walnut (*Juglans nigra*), and American elm (*Ulmus americana*) (Johnson and Risser 1975). Different soil types are formed from limestone, granite, dolomite, and sandstone (Woods et al. 2005).

The Cross Timber ecoregion is 29th ecoregion of level III ecoregions defined by United States Environmental Protection Agency. This ecoregion is a mixture of woodland, prairie, and savanna on coarse sandy soils (Johnson and Risser 1975; Therrell and Stahle 1998). Woodland portion of the Cross Timber consists of post oak and blackjack oak mainly with some invaded eastern red cedar (*Juniperus virginiana*) which makes a transition between eastern temperate forests and western Great Plains (Therrell and Stahle 1998). Today most of the historic Cross Timber ecoregion was cleared for agriculture (Therrell and Stahle 1998; Woods et al. 2005).

This study was conducted at Oka' Yanahli Preserve (OYP) which is managed by the Nature Conservancy and is located in Johnston County, southcentral Oklahoma (Figure 1 and Figure 2). It is a mixture of Cross Timber, prairie, and old fields. Soil types in Johnston County consist of Alfisols, Mollisols, and Entisols (Woods et al. 2005). OYP is located in Arbuckle Uplift with abundant streams and dominated by spring flow, especially in the summer. Perennial, clear, cool streams are common (Woods et al. 2005). The Blue River runs 1.5 km in the northern and eastern sides of OYP. The Arbuckle Uplift area that includes OYP are largely grasslands, rangelands, and croplands. OYP consists of old fields and abandoned ranches used since European settlement, now managed as wildlife preserve by The Oklahoma Nature Conservancy.

4. Non-invasive trapping techniques and modeling techniques

Mesocarnivores receive a great deal of conservation attention globally, but estimating their population size is difficult because of the smaller population densities compared to other mammals and their elusive behavior (Steenweg et al. 2016). Common carnivore trapping methods are invasive and usually require capture of the animal, immobilization, and handling to collect data (Gompper et al. 2006). This method is time consuming and potentially risky due to the behavior of carnivores, and not effective in gathering data if the research needs are community-level data (Gompper et al. 2006). Therefore, non-invasive methods have become more popular among wildlife biologists. Common methods for detecting carnivores include capture in Tomahawk traps, radio collaring for mark-recapture methods, camera-traps, covered track-plates, scent stations, snow-tracking, and scat surveys. Scat surveys are mostly incorporated into DNA analysis (Gompper et al. 2006). There are advantages and disadvantages of all those methods, but camera trapping can collect a large amount of data with minimal to zero impact on the target species (Steenweg et al. 2016).

Remote camera trapping is a non-invasive method that has been widely used by wildlife biologists, though they were initially used by game hunters (Kelly and Holub 2008; Rovero et al. 2013). Camera traps use an infra-red beam and have the ability to trigger automatically when something moves in front of them. (Figure 3) (Cutler and Swann 1999). There are some technical specifics that should be considered when selecting a camera trap including speed of triggering, detection ability, charge retention of the batteries, and size of memory cards (Cutler and Swann 1999). Also, the camera trap has to withstand various environmental conditions, like rain and freezing temperatures. Batteries should hold a charge for at least a month, and there should be enough space in the memory cards for thousands of pictures (Rovero et al. 2013).

Camera traps can be used with bait or without bait; both methods have been used successfully in research (Randa and Yunger 2006; Ordeñana et al. 2010; Kowalski et al. 2015). Detection probability of animals varies with baiting. Baits can be of different types, such as cat food, animal carcasses, and different types of lure to create scent stations. Detection probability of camera traps with and without baits has not been properly studied (Kelly and Holub 2008). Therefore, the detection probability with random baiting on camera-traps is an interesting factor to consider in mammalian surveys.

Occupancy modeling is a method to predict species occupancy and detection probabilities in a specified habitat (MacKenzie et al. 2002, 2003; Gu and Swihart 2004; MacKenzie and Royle 2005; MacKenzie et al. 2005; Cove et al. 2013). Models of occupancy to predict habitat occurrence are widely used in conservation and management research (MacKenzie et al. 2002; Hines et al. 2010; Cove et al. 2013; Lesmeister et al. 2015). Occupancy modeling is an accurate method because it accounts for imperfect detection of an animal in the field (MacKenzie et al. 2002, 2003; MacKenzie and Royle 2005; MacKenzie et al. 2005). Wildlife species are not detectable at one hundred percent accuracy in the field (Gu and Swihart 2004). If one species could not be detected in a place that does not mean that particular species is not present in that environment. Therefore, detection probability is considered when predicting the habitat use or occupancy of a particular species.

Occupancy models use mathematical calculations that use the history of detection and non-detection of a species in a particular area. Environmental factors like forest cover, disturbances, and habitat type can also be considered that might explain the occurrence of that species (MacKenzie et al. 2002, 2003; MacKenzie and Royle 2005; MacKenzie et al. 2005). This class of mathematical models estimates species occurrence for imperfect detectability (Gu and Swihart 2004). In order to calculate occupancy models for a particular species, data have to be gathered from a habitat repeatedly. The probability of a particular species to occupy a specific habitat (ψ) and its detection probability (p) are calculated based on the number of surveys (MacKenzie et al. 2002, 2003; MacKenzie and Royle 2005; MacKenzie et al. 2005). Akaike's Information Criterion (AIC) with maximized log-likelihood can be used to predict the best model of occupancy (Cove et al. 2013).

Occupancy models enable researchers to use repeated camera survey data to determine presence-absence of species and predict occupancy estimates and detection probabilities (MacKenzie et al. 2003; MacKenzie and Royle 2005; Cove et al. 2013). Detection probability (p) is relevant to the site occupancy of a species. By definition, occupancy (ψ) is the probability that a particular randomly selected area is occupied by a species. If "*x"* is the number of sites occupied by a species and "s" is the total number of sites, then naïve occupancy is $\psi = x / s$. Due to imperfect detectability, "x" cannot be directly used to predict the occupancy of that species. Multiple surveys are considered as a detection history in occupancy modeling, and other factors that could affect occupancy called covariates, are added to the models. Regression analysis using logit link model to predict species occupancy incorporate survey specific or site-specific covariates (MacKenzie et al. 2003; MacKenzie and Royle 2005; Cove et al. 2013). Multiple predicted models are ranked by using Akaike's Information Criterion (AIC) with a log-likelihood function to estimate the best prediction about site occupancy and the probability of detection (Cove et al. 2013). AIC is used to rank a set of models in order of closeness. Models with a minimal number of parameters are considered to be the best models; models with lower ΔAIC values are the best models (MacKenzie et al. 2003; MacKenzie and Royle 2005; Cove et al. 2013).

Occupancy models can be categorized into several different analysis methods, depending on the type of the research. If the focus of the research is about many species with minimal interactions, single season-single species modeling can be used. If there are more interacting species in multiple seasons multiple season-multiple species modeling can be used and vice versa.

5. Monitoring activity patterns of mesocarnivores

Animals need to use their time effectively, dividing it among different behaviors, because most energy has to be spent on foraging and avoiding predators (Rowcliffe et al. 2014). Activity is a major component of an animal's life which could vary according to the environment they inhabit, any environmental stressors, and predation risk (Ni et al. 2017). In wildlife management and conservation, monitoring animal activity is specifically important because it can be used to identify the activity of animals with elusive behavior. Monitoring animal activity patterns helps to identify animal home ranges, their resource use, and energy partitioning throughout their home range. Species interactions are crucial when studying mesocarnivores because they all have similar life histories, their behavior is elusive, and they are most active during the crepuscular period (Rowcliffe et al. 2014; Lesmeister et al. 2015; Ni et al. 2017). Interspecific competition, avoidance, and intraguild mesocarnivore predation could be identified by studying activity patterns. Carnivore and mesocarnivore activity patterns have not been studied as much as circadian rhythms and migratory patterns of birds (Salvatori et al. 1999). Therefore, when applying conservation and management implications for mesocarnivores, assessing their activity patterns can also be appropriate (Salvatori et al. 1999).

Direct observations, radio-telemetry, and Very High Frequency (VHF) collars have been used in wildlife monitoring and identification of activity patterns for a long time. Those methods can gather a large amount of data that can be analyzed using various parametric and non-parametric statistical methods. Attaching collars to animals requires extensive time and field work as well as handling of animals, which is fairly dangerous when it comes to mesocarnivores and carnivores (Salvatori et al. 1999). To limit potential hazards and extensive fieldwork, data obtained from camera traps have been used to study activity patterns. This method provides data that can also use to estimate temporal activity patterns (Ridout and Linkie 2009). Therefore, in this research, I used camera trapping data to analyze activity patterns of mesocarnivores at the same study site and to document their seasonal variations. More information on activity pattern analyses and its importance of conservation are presented in Chapter 3.

Objectives

Mesocarnivore ecology is largely unknown in southcentral Oklahoma specifically at Oka' Yanahli Preserve. The primary goal of this project was to expand the current body of knowledge about mesocarnivore ecology in southcentral Oklahoma. Species that I expected to find were bobcat (*Lynx rufus*), coyote (*Canis latrans*), grey fox (*Urocyon cinereoargenteus*), North American river otter (*Lontra canadensis*), northern raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and striped skunk (*Mephitis mephitis*). I expected to estimate species richness of mesocarnivores in the preserve and their preferable habitats in the preserve or site occupancy. Further, I wanted to identify the activity patterns of mesocarnivores and any seasonal variations in their activity patterns and site occupancy. I wanted to identify the differences and seasonal variations of detection probability with baited camera traps and non-baited camera traps. I had two predictions. The main prediction was that the detection probabilities should be higher during the winter than summer because of the scarcity of food during winter, and they should be higher with baited camera traps than non-baited camera traps. I also predicted that site occupancy and activity densities would be higher during winter than summer.

Chapters 2 and 3 are written in the format accepted by the Journal of Mammalogy. Chapter 2 focuses on occupancy and detection of mesocarnivores in the study area. Chapter 3 focuses on activity patterns of mesocarnivore in this study area during winter and summer seasons.

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Figures

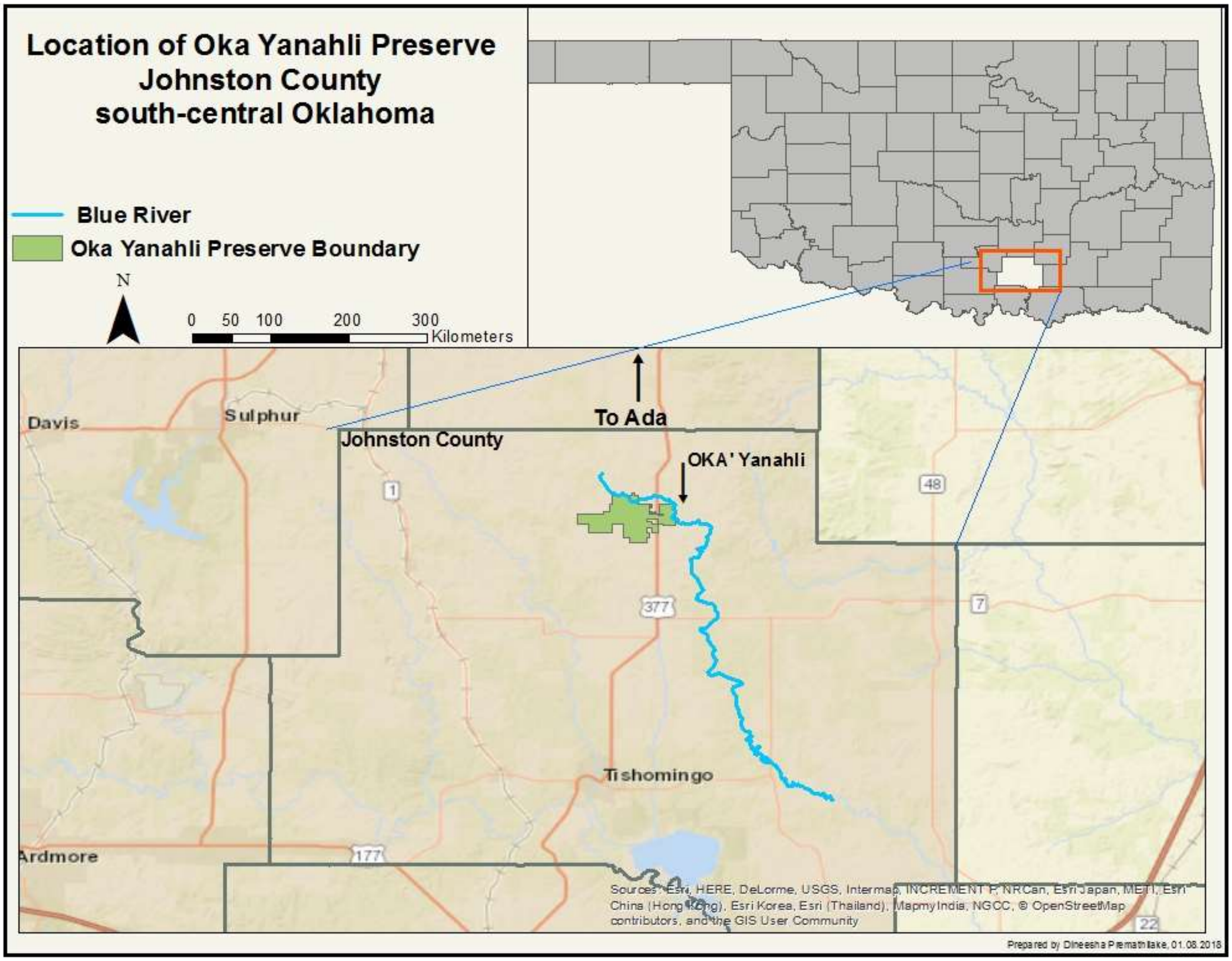

Figure 1: Location of study area, Oka' Yanahli Preserve in Johnston County, southcentral, Oklahoma.

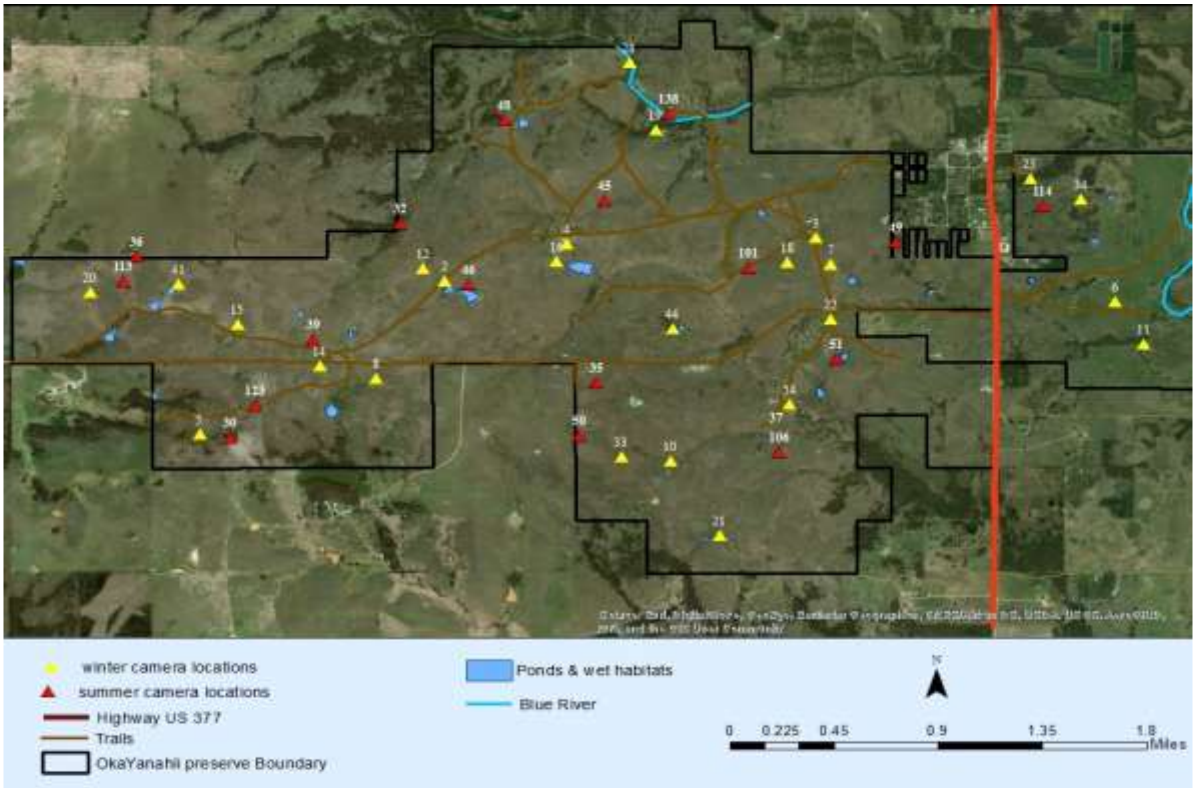

Figure 2. A map of the study site with aerial imagery showing various habitat types, winter 2016-2017 camera-trap locations, and summer 2017 camera-trap locations.

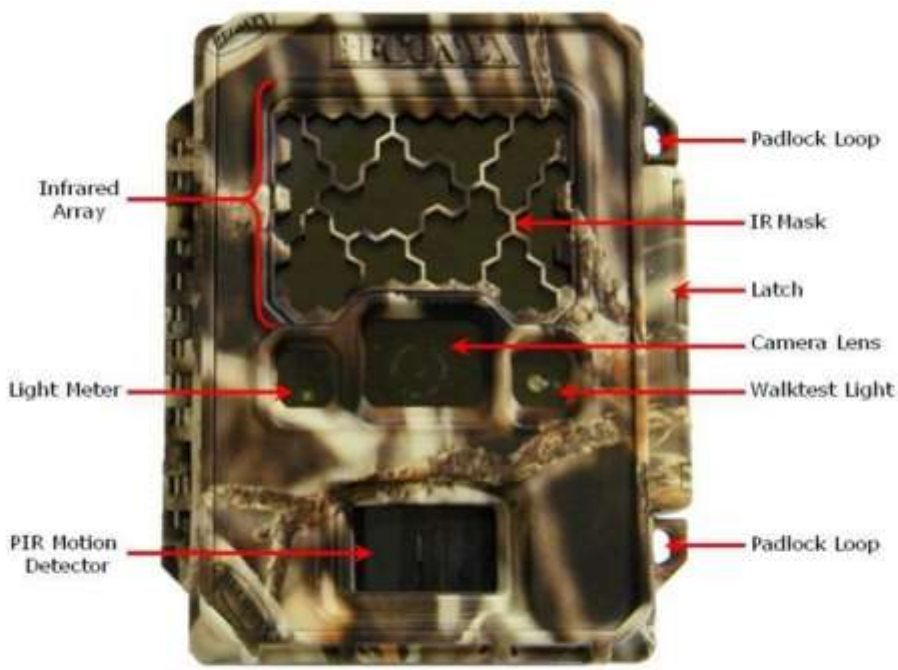

Figure 3. Diagram of a Reconyx HC500 showing the main components of a camera trap (Copyright Reconyx Inc., Rovero et al. 2013).

Chapter 2 is written in the format accepted by the Journal of Mammalogy

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Integrating Camera Trap Data and Occupancy Modeling to Estimate Spatial Ecology of Mesocarnivores in Southcentral Oklahoma

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Mesocarnivores have important ecological roles as primary predators of food webs and contribute significantly to maintaining the health of the lower trophic levels. Various anthropogenic effects impact the viability of mesocarnivore populations; therefore, conservation is essential to maintain ecosystem integrity. My study was conducted at Oka' Yanahli Preserve (OYP), located in southcentral Oklahoma. The primary goal of this project was to expand the current body of knowledge about mesocarnivore ecology in southcentral Oklahoma, specifically at OYP. Camera traps were used to capture images of mesocarnivores in the preserve during winter (November 2016- February 2017) and summer (May – August 2017). Six remotely-triggered infra-red cameras were deployed for 4 weeks. After 4 weeks, cameras were moved to different, random locations. Half of the cameras were systematically baited by using canned mackerel. A total of 2778 mesocarnivore pictures from winter and 1455 from summer were taken from 25 camera locations in winter and 18 camera locations in summer. Species richness, detection frequencies, detectability, and occupancy estimates were determined by analyzing pictures. Mesocarnivore species identified from both seasons were coyote (*Canis latrans)*, raccoon *(Procyon lotor)*, bobcat (*Lynx rufus)*, Virginia opossum (*Didelphis virginiana),* and striped skunk (*Mephitis mephitis).* Results show the proportion of sites occupied and detection probabilities were higher for all species during winter than in summer (single species occupancy modeling). Overall detection probabilities were higher with baited camera traps for raccoon, skunk and opossum (not significantly different) obtained from single species occupancy modeling, in winter. Baiting had no overall effect on the probability of detection for all species in summer. A possible reason could be that the abundance of food resources was higher during summer than winter. Data gathered from this research will be useful in conservation, management, and restoration of habitats of mesocarnivores in OYP.

Keywords: mesocarnivores, occupancy models, camera trapping

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Biodiversity monitoring using non-invasive techniques has been a challenge for wildlife biologists and land managers since early 21st century (O'Connell Jr. et al. 2010). Large-scale monitoring programs focused mostly on species that are considered as an ecological indicator or species that are popular with the public. Programs have been implemented for the conservation of reptiles and birds, such as North American Breeding Bird Survey, Amphibian Monitoring Initiative, Mourning Dove Survey, and Stream Fish Community Survey (Pollock et al. 2002; Newman et al. 2003; O'Connell Jr. et al. 2010). Even though mammals have the same ecological importance monitoring programs have not established, except for a few game species and species of aesthetic value (Pollock et al. 2002; O'Connell Jr. et al. 2010). Mammals, in general, are essential for maintaining ecosystem integrity. Carnivores contribute to regulating prey species in lower trophic levels; thus, they directly influence the trophic cascade and behaviorally mediate an indirect influence. Herbivores directly alter the vegetation structure and plant diversity through grazing (O'Connell Jr.et al. 2010; Haskell et al. 2013). Invasive mammals like nutria (*Myocastor coypus*) and feral hogs (*Sus scrofa*) can ravage the whole ecosystem (O'Connell Jr.et al. 2010; Haskell et al. 2013). Mountain lions (*Puma concolor*), coyotes (*Canis latrans*), and grey wolves (*Canis lupus*) are natural predators of feral hogs (Weeks and Packard 2009). Also, there can be numerous other ecological values of mammals that have not been identified by humans yet.

Implementing large-scale monitoring programs for mammal conservation are relatively difficult because of the elusive nature of many mammals like mountain lion, bobcat (*Lynx rufus*), ferret (*Mustela nigripes*), and mink (*Neovison vison*) (Newman et al. 2003; O'Connell Jr. et al. 2010; Steenweg et al. 2016). Some mammals are nocturnal, have large home ranges, are rare to find, and are difficult to detect using common trapping methods. Therefore, implementing one standard monitoring program for mammals has been laborious and demanding (Noss et al. 1996; Steenweg et al. 2016). This dilemma is particularly applicable to carnivores because they additionally have predator-driven effects and fear-driven effects on other species including humans (Roemer et al. 2009).

Carnivore conservation is challenging, particularly for large carnivores (Noss et al. 1996; Randa and Yunger 2006). Carnivores are often large and can be dangerous to humans. They have large home ranges, which is a major factor for their rapid susceptibility to extinction. Habitat fragmentation has an immense impact on the survival of large carnivores in this century (Noss et al. 1996; Randa and Yunger 2006). Carnivore conservation requires large scale areas, high human labor, and long-term monitoring. That was the reason that Aldo Leopold mentioned that carnivore conservation and management are critical indicators of the commitment of a society to conservation (Noss et al. 1996). Despite immense conservation efforts, and re-introductions, large carnivores are decreasing in population density, to the point where some populations are critically endangered and threatened to extinction (Roemer et al. 2009; Robinson et al. 2014). Usually, large carnivores are the apex predators of the ecosystem and influence lower trophic levels. In a balanced community, several species engage in complex interactions. Removing an apex predator can have severe effects throughout the community (Crooks and Soulé 1999; Russell et al. 2009). During this century, removal of apex predators from ecosystems has rapidly increased globally, specifically due to human impacts like hunting and habitat alteration (Crooks and Soulé 1999; Russell et al. 2009). In some ecosystems, competition between mesocarnivores and apex predators exist. A healthy ecosystem has both apex predators and mesocarnivores which are regulated by apex predators through intraguild predation or competition (Mortensen and Elmhagen 2015). When the apex predator is removed from the system, mesocarnivores become the apex predators of the system. This hypothesis is called the Mesopredator Release Hypothesis (MRH). This hypothesis has not been thoroughly researched, and is controversial, but is often used to emphasize the importance of carnivore conservation (Crooks and Soulé 1999). According to MRH, the top apex predator is replaced by mesocarnivores, which could have negative impacts for lower trophic levels (Crooks and Soulé 1999; Russell et al. 2009; Schuette et al. 2013; Mortensen and Elmhagen 2015;). Human-altered landscape and fragmentation are often beneficial for generalists. Mesocarnivores are often generalists, and are highly adaptable to changing environments resulting in acting as apex predators for all lower trophic levels, which includes endangered species, like some bird species (Soulé et al. 1988; Crooks and Soulé 1999; Schuette et al. 2013). Further, increased mesocarnivore populations have increased contact with humans, which often cause negative impacts that includes acting as reservoir hosts for some pathogens and parasites (Theimer et al. 2017).

Most species that are considered "mesocarnivores" belong to the mammalian order Carnivora, but some species are from different mammalian orders (e.g., Virginia opossum (*Didelphis virginiana*) from order Didelphimorphia) (Roemer et al. 2009; Agha et al. 2017). Mesocarnivores often have small bodies, 90% of terrestrial mesocarnivores weigh <20 kg, and are generalists in behavior (Roemer et al. 2009). Despite habitat fragmentation, mesocarnivores are able to disperse into various ecosystems. Relative to large carnivores, mesocarnivores have higher species richness and are more ubiquitous in their habitat requirements (Roemer et al. 2009; Agha et al. 2017). Mesocarnivores have variable life histories and ecology in which some species are solitary and some are highly social. Some mesocarnivore species live in close contact with humans, some can be elusive. They can be hypercarnivores to omnivores, with high potential for dietary flexibility according to the environment they live. The diet of hypercarnivores consists 70% of meat balanced with fungi, fruits, and plant materials (Gehrt and Clerk 2003; Roemer et al. 2009).

In an ecological context, mesocarnivores are rising as apex predators of most ecosystems. During the last two decades, research emerged mostly on Mesopredators Release Hypothesis, but there are innumerable ecosystems services done by mesocarnivores that have not received considerable attention by the scientific community. With the absence of large carnivores, mesocarnivores were released and intraguild predation was also reduced. Since mesocarnivores prey upon a variety of species, increased density of mesocarnivores increases predation pressure on small prey species. As a result, prey population numbers are gradually declining, including endangered species and species of conservation concern (Jordano et al. 2007; Roemer et al. 2009).

Sometimes mesocarnivores can be omnivorous, eating fruit and dispersing a massive amount of seeds. Usually, birds disperse seeds 250 m whereas mesocarnivores can disperse seeds up to 1 km (Jordano et al. 2007; Roemer et al. 2009). Mesocarnivores usually deposit those seeds in open areas. Tree genetic studies have determined that seeds dispersed by mesocarnivore contribute to the gene flow between plant species (Jordano et al. 2007; Roemer et al. 2009). Therefore, mesocarnivores are significant contributors to the plant diversity in an ecosystem. Also, they could contribute to the plant community structure indirectly by preying on seed predators. When seed predators eat seeds and mesocarnivores eat them, they indirectly disperse more seeds which are trapped in digestive tracts of mice and rats (Jordano et al. 2007; Roemer et al. 2009).

Another important aspect of mesocarnivores is that they act as scavengers and consume carcasses considerably faster than any other source (Yarnell et al. 2013; Allen et al. 2015; Theimer et al. 2017). Whether it is a fragmented landscape, agricultural land, or urban landscape, birds and mesocarnivores are the top scavengers. Usually, birds are diurnal and they can only remove carcasses during the daytime. Mesocarnivores are the top scavengers during the night irrespective of the type of habitat (Roemer et al. 2009; Inger et al. 2016). One negative ecological aspect of mesocarnivores is that they can be a reservoir for various pathogens, especially for rabies viruses and other lyssaviruses (Roemer et al. 2009; Theimer et al. 2017). Due to urbanization and habitat fragmentation, mesocarnivores have proximate contact with humans that could cause a public health risk or spread diseases to other wildlife (Theimer et al. 2017).

Unfortunately, many mesocarnivore species have become vulnerable even before they are well understood. Natural history, autecology, and synecology of some mesocarnivores are yet to be studied in order to implement proper management and conservation plans. Having increased anthropogenic contact due to urbanization, habitat fragmentation, and over-exploitation of fur, can cause populations of mesocarnivores to decline. Increasing numbers of mesocarnivore deaths occur by vehicle collisions on highways and roads (Cortes and Steury 2016). Some mesocarnivores, like raccoons, get acclimated to foraging in garbage dumpsters around urban neighborhoods which make them vulnerable to various toxic products that could kill them (Totton et al. 2002; Prange et al. 2004; Santonastaso et al. 2012). In order to minimize mesocarnivore-human conflicts, proper conservation plans are needed through the collaboration of wildlife researchers and the general public.

Many mammal species, including mesocarnivores, are elusive, nocturnal, and difficult to detect (Newman et al. 2003; Steenweg et al. 2016). Therefore, detection and survey methods are mostly species-specific. When a species is a conservation priority, non-invasive methods should be used whenever possible. Camera-traps have been used in wildlife research for the past two decades and are one of the most useful, non-invasive survey methods that can be used for a myriad of species specifically, mesocarnivores (Kelly and Holub 2008). Camera-trapping is absolutely free of animal capturing and handling and can collect data that can be incorporated into spatial and temporal scale analysis (Kelly and Holub 2008; Cove et al. 2013, 2014). The data can be incorporated into various modeling techniques to predict species-specific spatial ecology and temporal activity patterns.

In this research, I used baited and non-baited cameras to collect photographs of mesocarnivores in winter 2016-2017 and summer 2017 to create detection histories in order to model species occupancy and detection. Very few camera trap surveys have been conducted in Oklahoma and none have been published on mesocarnivores in the state. The primary goal of this project was to expand the current body of knowledge about mesocarnivore ecology in southcentral Oklahoma. I hypothesized that (1) detection probabilities should be higher during the winter than summer due to the scarcity of food during winter: (2) detection probabilities should be higher with baited camera traps than non-baited camera traps: (3) site occupancy and activity patterns should be higher during winter than summer. The main objectives of this research were to: (1) estimate species richness of mesocarnivores at OYP: (2) determine preferable habitats in the preserve by estimating site occupancy: (3) compare activity patterns of mesocarnivores and determine seasonal variations in activity patterns and site occupancy: and (4) compare seasonal variations of detection probability with baited camera traps and non-baited camera traps. Species that I expected to find were, bobcat (*Lynx rufus*), coyote (*Canis latrans*), grey fox (*Urocyon cinereoargenteus*), North American river otter (*Lontra canadensis*), northern raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and striped skunk (*Mephitis mephitis*). These species are not considered as vulnerable or endangered, but they are important furbearers currently harvested legally. Harvest regulations are impacted by changes in population densities and better understanding the demographics of these species can help state agencies and conservation organizations manage them more effectively.

MATERIALS AND METHODS

Study area.—Oka' Yanahli Preserve (OYP) is located in Johnston County, southcentral Oklahoma (34°26'14.7"N 96°38'09.9"W) and is managed by The Nature Conservancy. It is situated about 40 km south of Ada and about 24 km north of Tishomingo, on the Arbuckle Mountain Plains (Fig. 1). The preserve consists of 1457 hectares along 3.2 km of the Blue River. The Blue River is one of only two rivers in the state of Oklahoma that freely flows without any human disturbances or constructions. The Arbuckle-Simpson Aquifer sustains the Blue River and OYP is the main restoration of the aquifer. OYP consists of limestone prairies interspersed with oak mottes, and some bottomland hardwoods and is part of the Cross Timbers ecoregion, which is an intersection between the eastern deciduous forest and the Great Plains (Woods et al. 2005). Tree species like post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), and American elm (*Ulmus americana*) and intermittent eastern red cedar (*Juniperus virginiana*) occur in wooded areas (Kasparian et al. 2004). The prairie is dominated by silver bluestem (*Andropogon saccharoides*), little bluestem (*Andropogon scoparius*), broomsedge bluestem (*Andropogon virginicus*), oldfield threeawn (*Aristida oligantha*), and buffalograss (*Bouteloua dactyloides*). Some other grasses and forbs include prairie dropseed (*Sporobolus hetrolepis*), sideoats grama (*Bouteloua curtipendula*), compass plant (*Silphium laciniatum*), leadplant (*Amorpha canescens*), wild alfalfa/scurf pea

(*Psoralea tenuifolia*), Illinois bundleflower (*Desmanthus illinoensis*), blazing star (*Liatris sp*.), goldenrod (*Solidago sp*.), Indian paintbrush (*Castillega coccinea*), and Maximillian sunflower (*Helianthus maximilliani*) (Diamond and Elliott 2015). The specific habitat types that can be identified within the preserve are wooded areas, aquatic habitats consisting of abandoned ponds, ephemeral pond, and riparian corridors; bottomland forests; and prairie (Appendix C). The area that is presently OYP has been subjected to extensive cultivation since the 19th century, and abandoned old-field and ranches of previous owners can still be seen on the preserve. In winter there was a period that OYP was opened to deer hunting and cattle grazing during summer (Appendix D).

The average annual precipitation of the study area is 99-120 cm and most precipitation occurs from midsummer to fall (Oklahoma Climatological Survey 2017). During winter months there is an average of 2 cm of snow. In summer the temperature is as high as 35 °C, in winter it is as low as -1.6 °C, and the annual average temperature is 17 °C. Average frost-free days are 224-231 and the average growing season is 212 days. Wind speed is on average 12 km/h. and relative humidity ranges from 42% to 96%. Highest humidity is in May and lowest in August. On average there are 45 thunderstorms per year (Oklahoma Climatological Survey 2017).

There are about 40 different soil types in OYP. Among them Kaufman clay Verdigris silty clay loam can be seen near Blue River. All other areas inside OYP consist of Claremore-Rock outcrop, Durant loam, Kiti-Rock outcrop, Lula loam, and Stephenville fine sandy loam in various percentages (The Nature Conservancy unpublished data; USDA Web Soil Survey 2017).

*Camera trapping.—*Camera surveys were conducted in two seasons. Winter season was from November 2016 to February 2017 and summer season was May to August 2017. During a preliminary visit to the study site in Fall 2016, various habitat types were identified. Using ArcGIS 10.4 (Environmental Systems Research Institute, Redlands, CA), a map with 100 random camera trap locations was made to determine the locations of the cameras during both winter and summer seasons. Camera traps were Reconyx HC 500 Hyper Fire Semi-Covert Cameras, which have infra-red, motion trigger function (Reconyx Inc., 3828 Creekside Ln, Site 2, Holmen, WI 54636). Cameras were set to be active 24 hours a day, take 3 pictures per movement, and picture interval was 1 second. The quiet period was 5 minutes. Picture resolution was 1080 pixels. Each camera had a specific identification number. Date, time, and the temperature were recorded on pictures for each movement.

Eight camera traps were established in November 2016. Subsequently, 6 camera traps were set each month in new, random locations. Coordinates (UTM) of the random locations were uploaded to the GPS unit (model-GPSMAP64S, Garmin International Inc. Kansas City, MO). In the field, locations were identified using the GPS. Sometimes there were no trees/posts to attach the cameras, in that exact same location. In that case, they were set up in nearest appropriate locations. New GPS coordinates were recorded with the GPS device and new coordinates were updated into GIS database. Cameras were placed about 0.5─1 m above ground, facing downwards. Usually, cameras were attached to trees, bushes, or fence posts, but when not available wooden posts with stable stands were used (Appendix C).

Cameras were systematically baited by using canned mackerel (Kelly and Holub 2008). The bait was placed 1─2 m away from the camera. The 1st, 3rd, and 5th cameras were baited out of 6 cameras. I did not use heavy animal carcasses as bait because I did not want to attract animals just for the bait if they do not naturally occur in that area. Photographs of the camera location and surrounding habitat type were taken. Cameras were kept on that location for 3─4 weeks (Cove et al. 2013). One to two weeks after initial placement, a field technician checked the cameras, downloaded pictures, and replaced the batteries and memory cards. The technician also re-baited the cameras in the same systematic way. After 3─4 weeks, cameras were picked up from initial placements and moved into different random locations. Winter season had 25 camera locations and summer season had 18 camera locations. Camera malfunctions were very rarely identified and did not affect the survey during either season.

Data analysis.—After winter 2016-2017 and summer 2017 seasons ended, I examined all the pictures from all the locations. For mesocarnivore detection, I recorded the species, number of animals per picture, location, camera ID, the date the camera was set, date detected, time of the first picture, time of the last picture, number of pictures recorded during that detection, and temperature. Then I calculated the duration of activity by using the time difference between the initial detection and final detection. Latency to initial detection (LTD) was the mean number of camera nights required to initially detect a species (Cove et al. 2013). It was calculated using photographic data. Detection frequencies for 1000 trap night were calculated for each species using the total detections at each season separately.

Occupancy and detection.—Naïve occupancy is the ratio of number of sites occupied by a particular species divided by total number of sites. Naïve occupancy was calculated for each species during both seasons. For the occupancy estimates (Ψ) and detection probability (p), I used binary detection histories (MacKenzie et al. 2002, 2003, 2005, 2006; MacKenzie 2006; Cove et al. 2014). If a species was detected it was given a 1 and if that species was not detected it was given a 0. When predicting the occupancy of species with imperfect detections, I had to survey the same location repeatedly (MacKenzie et al. 2002, 2003, 2005, 2006). I combined 3 sampling days as 1 survey block, to get 17 repeated surveys for the winter season and 13 repeated surveys for the summer season.

Site-specific and survey-specific covariates.—Site covariates are those that may impact occupancy, and I assessed 6 site-specific covariates. Survey specific covariates were those that impacted probability of detection, and I assessed 4 survey specific covariates (Mackenzie et al. 2002, 2003, 2005, 2006). Some covariates may have impacted both occupancy and detections. Site covariates were the distance from the camera location to water body, trees, and trails/roads; temperature; month; and cattle status (summer) (Table 1) (Lesmeister et al. 2015). Occupancy and detection has been shown to be dependent upon temperature and precipitation in large carnivores like mountain lion (Pease et al. 2016). Following Pease et al. (2016) and Bischoff-Mattson and Mattson (2009), mean average temperature at each location during the survey period, taken at nearest National Weather Service station, was used during both winter and summer occupancy models. Month in which each camera was set up was also considered as a site-specific covariate during both seasons. Cattle were present at certain locations during summer season only, therefore presence and absence of cattle at certain camera locations were considered as a site-specific covariate during summer occupancy analysis.

Survey specific covariates were bait status during each survey, cattle status, precipitation, and temperature at each survey. Following Thorn et al. (2009), bait status was considered as days since baited. I assumed that bait would last for 3 days (1 survey) from the date first baited. There were surveys without bait until the location was rebaited (Thorn et al. 2009). Presence and absence of bait was a survey-dependent factor, which was considered as a covariate. Cattle status was also similar to bait status as there were some surveys where cattle were present at certain locations. Presence of cattle at a camera location was considered as a site-specific covariate. Temperature and precipitation were highly variable during survey period. They were considered as a survey-specific covariate as well (Thorn et al. 2009; du Preez et al. 2014). The average temperature at sites was obtained from Mesonet past daily retrieval files (https://www.mesonet.org), at the nearest National Weather Service station located at Tishomingo, which is 24 km south of study area. I used daily temperature and precipitation data and they were also combined into 3-day survey blocks.

In order to calculate the distance for site-specific covariates, I entered all camera locations into ArcGIS 10.4 software as a shapefile and measured the distance from each camera location to nearest water body, patch of trees, and trail. Detection histories, site-specific covariates, and survey specific covariates were entered into PRESENCE 12.6 (USGS Patuxent Wildlife Research Center) (Mackenzie et al. 2002, 2003, 2005, 2006; Hines et al. 2010). Single species-single season models were run for each species separately (Table 2). I tested the importance of each covariate (Cov) separately for each mesocarnivore species detected. First, I held probability of detection, p (.), constant and tested variations of Ψ (Cov) with each occupancy covariates shown in Table 1 separately (Bailey et al. 2004). Next, I held proportion of site occupancy, Ψ(.), constant and tested variations of p (Cov) with each detection covariates shown in Table 1 separately (Bailey et al. 2004). I used my constant or null model, Ψ(.)p(.) as a reference. All the models were ranked using Akaike Information Criterion (AIC) calculated by PRESENCE 12.6 software. The best approximate models were selected using relative difference of Akaike Information Criterion (ΔAIC). The lowest ranked Ψ(Cov)p(.) models and Ψ(.)p(Cov) models for each species were selected to identify best covariate that would influence occupancy and detection of each species during each season (Table 2) (Bailey et al. 2004). However, I want to stress that the models selected as the "best" model do not necessarily represent all covariates that could influence occupancy and detection of a species, because I considered one covariate at a time.

Model weights calculated from AIC values give the level of support for each model considered. In addition, model weight indicates how important that particular covariate in terms of resource selection probability. Models with high model weight as a percentage could be considered as the best model for particular resource selection (MacKenzie 2006). I used a spreadsheet software designed by B. Mitchell (www.uvm.edu/%7Ebmitchel/software.html) (Cove et al. 2013) to get the model weights.

RESULTS

I set 25 cameras in winter and 18 cameras in summer (Fig. 2). The winter season had 844 camera nights, while summer had 600 camera nights for a total of 1444 camera nights. I recorded 5 mesocarnivore species (Table 3, Table 4, Appendix A and B), and 5 other mammalian species (Appendix A and B). A grey fox (*Urocyon cinereoargenteus*) was recorded in only 2 pictures and it was not included in occupancy modeling. Mesocarnivore species richness was 5 for both seasons. More than 100,000 pictures were recorded, among them, 4233 pictures were mesocarnivores. A higher number of pictures were taken from winter season (2778) than summer season (1455). The highest number of pictures were obtained for raccoons in both seasons and lowest number of pictures were obtained for bobcat in winter and for opossum in summer (Fig. 3). Species specific total number of pictures was lower in summer than in winter. Seasonal variations were observed in Latency to Initial Detection (LTD) and detection frequency among the species. Raccoons had the highest detection frequency in both winter (141) and summer (51.67) (Table 3, Table 4). Lowest detection frequency was recorded for bobcat (26.07) in winter and opossum (1.67) in summer (Table 3, Table 4). Lowest LTD was recorded for opossum (1.92 ± 0.67) in winter and for skunk (3.38 ± 1.37) in summer (Table 3, Table 4). Lower LTD means less time to get a picture of an animal if it was in front of a camera, the higher the LTD the more time it took to get a picture. Highest LTD was recorded for coyote (7.23 ± 1.32) in winter and for raccoon (9.22 ± 3.88) in summer (Table 3, Table 4).

Occupancy and detection.—Among all species coyote was detected in most number of locations in both seasons. Thus, highest naïve occupancies in winter (0.80) and summer

(0.67) were also for coyote (Table 3, Table 4), meaning coyotes were ubiquitous at OYP. Lowest naïve occupancy had a seasonal variation, where lowest was recorded from bobcat and skunk in winter (0.28), and from opossum in summer (0.06) (Table 3, Table 4).

Single season occupancy models with occupancy and detection covariates and the best models for each species for the winter season are given in Table 5; same parameters for summer are given in Table 6. Due to the ubiquitous nature of coyote best models did not restrict occupancy to specific habitat types. Their detection probabilities were based on rainfall, baited sites and baited surveys (Δ AIC=1.33 baited survey, Δ AIC =1.88 baited sites). Bobcat (Ψ= 0.31 ± 0.12 winter, Ψ= 0.22 ± 0.05 summer), raccoon (Ψ= 0.66 ± 0.09 winter, Ψ= 0.42 ± 0.11 summer), opossum (Ψ= 0.34 ± 0.18 winter, Ψ= 1.0 ± 0.001 summer), and skunk (Ψ= 0.56 ± 0.26 winter, Ψ= 0.34 ± 0.28 summer) had higher habitat occupancies during winter than summer (Table 5 and Table 6). None of the occupancy covariates were in the best models during winter (Table 5), instead detection covariates were the best models for all species. The best detection models were environmental parameters (coyote and bobcat) and bait covariates (opossum, raccoon, and skunk) for winter. Contradictory to winter season, none of detection covariates became the best models for any species in summer (Table 6). Except for coyote, all the other species got best models with occupancy covariates. The best models for bobcat, skunk, and opossum were based on habitat type and environmental parameter for raccoon.

Figs. 4 and 5 show the graphical representation of seasonal variations in habitat occupancy and detection probabilities for all the species derived from Ψ(.)p(.) model, which was my reference model. This model did not include any of the covariates that would affect site occupancy or detection, instead this model was constant for season. Following Bailey et al. (2004), I used probabilities of occupancy and detection of each species using Ψ(.)p(.) model and plotted to show seasonal variations in overall site occupancy and detection assuming that there was no influence from any covariate for occupancy and detection. As shown in Fig. 4, overall site occupancy was higher in winter than summer for all species. Likewise, probability of detection was also higher in winter than summer for all species (Fig. 5).

Detection probabilities of baited and unbaited camera traps were obtained from the model Ψ(.)p(bait_site) of all species in each seasons separately. Detection probability with or without bait within each season for each species were plotted (Figs. 6 and 7). In winter, baited camera traps had highest detection probability for raccoon (0.43 ± 0.041), and lowest for skunk (0.085 ± 0.045). However, detection probability of bobcat with a baited camera (0.18 ± 0.053) was slightly lower than with a non-baited camera (0.33 ± 0.1) (Fig. 5). In summer, detection probabilities of all species did not depend on the presence of bait at camera locations (Fig. 6), because detection probabilities had little deviation between baited and unbaited camera traps.

Probabilities of occupancy among various habitat types for all species obtained from Ψ(habitat)p(.) model in winter and summer for each species, are shown in Figs. 8 and 9 respectively. There were seasonal variations in habitat occupancy in each species between seasons. Habitat occupancies of each mesocarnivore species at various habitat types is shown in Fig. 10 for winter and Fig. 11 for summer. Except for coyote, there were seasonal habitat occupancy shifts for all the other species. Bobcat, opossum, and skunk had higher site occupancy in wooded habitat in winter, but their occupancy was shifted to meadows and proximity to water during summer. Raccoon had the same pattern of habitat occupancy in both seasons with slightly higher occupancy in winter than summer.

Habitat occupancy of all mesocarnivore species with the range from lowest occupancy to highest occupancy at different camera locations in winter and summer are shown in maps (Figs. 12-15). The bubble size represents the value of occupancy for both seasons and bubble color represent season. Bobcat had low occupancies in eastern side and southern side of preserve during both seasons (Fig. 12). Coyote had equal size bubbles during both seasons around all most all camera locations as shown in Fig. 13. That is due to ubiquitous nature of coyote as shown in occupancy results as well. Fig. 14 shows distribution of site occupancies of opossum during winter and summer seasons, which clearly shows opossum occupied habitats close to water during winter. Raccoon occupancy map (Fig. 15) shows raccoons are less common towards southern and eastern sides of OYP. Skunk occupancy distribution map (Fig. 16) shows higher distribution in southern side of OYP than all other areas. Observing all the maps, it can be said that raccoons and opossums have low habitat occupancy in areas where skunk has higher occupancy. However, raccoon and opossum have similar occupancy patterns that overlap each other.

DISCUSSION

My main objective was to identify mesocarnivore species at Oka' Yanahli Preserve in southcentral Oklahoma. Commonly occurring mesocarnivores in the state of Oklahoma could be identified at OYP. They were coyote, bobcat, raccoon, striped skunk, and opossum. Except for just one occurrence of a gray fox, I did not detect any other foxes. One occurrence of a grey fox was not sufficient to include in analyses. Gray fox has higher distribution range in eastern Oklahoma than all other areas. There were few gray fox records from Johnston County in research done in 1978-1979 compared to southeastern counties of Oklahoma (Schnell et al. 1985). Their preferable habitats are wooded areas and swamps, not rolling farmland (Schnell et al. 1985). Gray fox breeding season is late winter and the detection that I had was also during late winter. The detection can be a random movement of gray fox who moved during breeding season, because OYP does not contain preferred habitat types.

I expected to detect river otter at OYP because of the Blue River. There are few county records (Barrett and Leslie Jr 2010) and much unpublished data exist about river otter in Johnston County. According to Barrett and Leslie Jr. (2010), it is unlikely to detect river otter in large densities in southcentral Oklahoma west of the Blue River and east of Wichita Mountain National Wildlife Refuge due to few perennial habitats. OYP is located at that area, due to the presence of fewer persistent aquatic habitats, therefore, I can agree with Barrett and Leslie Jr. (2010) that otter abundance and detection probability would be less expected this area. River otter usually have scent markings, fecal, urine, nasal secretion depositions on discrete sites along riparian areas and visit those sites frequently (Wagnon and Serfass 2016). In order to detect a river otter on a camera trap, it is better to search those specific places on riparian areas before setting camera trap, which I did not do in this study. I did not set camera traps too close to Blue River and I didn't have many cameras locations along Blue River, therefore more research is needed on river otter along Blue River at OYP.

The other mesocarnivore species that I was expected to detect was American mink, a semi-aquatic mesocarnivore having a stable population, and distribution throughout Oklahoma; the riparian area along Blue River is an ideal habitat to detect mink (Payne et al. 2001). However, mink was the most elusive and nocturnal species out of all the species that I expected to detect. Few studies exist on mink distribution in Oklahoma but I could not find any research on mink using camera traps. Bartolommei et al. (2013) suggested to use several other trapping methods simultaneously with camera traps to detect mink. Floating rafts, hair tubes, and scent stations have to be created along with camera traps to successfully detect mink (Bartolommei et al. 2013). In my research I only used camera traps, and I did not have several cameras extensively used along Blue River, probably the same reason for no detections from river otter. Considering the nocturnal, elusive behavior of mink, and low number of camera locations along Blue River, the probability of detecting a mink was lower than other species in my study.

One objective was to identify seasonal variations in site occupancy and detection probabilities of mesocarnivores. I hypothesized that the detection probabilities and site occupancy should be higher during the winter than summer due to the scarcity of food during winter. My results supported this hypothesis, that habitat occupancy of all the species of interests was higher in winter season than the summer season. There is considerable variation in occupancy of bobcat, raccoon, skunk, and opossum between the two seasons. Coyotes are ubiquitous in my study area in both seasons and that was similar to other studies done in Great Plains and Neotropics (Cove et al. 2013; Lesmeister et al. 2015; Jones et al. 2016). Detectability was largely variable between seasons for all other species except coyote. Higher detection probability was recorded for all the species during the winter season, but very low detection probability was recorded during the summer season. Human activities such as electric fence building and cattle moving were associated with the presence of cattle at OYP during summer. These activities may have had some impact for low detections of mesocarnivores during summer season. Cattle occurred in 6 out of 18 summer locations, and may have had an impact on the behavior of mesocarnivores. According to Schuette et al. (2013), mesocarnivore occupancy was negatively related to increased human influences such as distance to human settlements and livestock in Africa.

My next hypothesis was that detection probability should be higher with baited camera traps than non-baited camera traps. Detection probabilities of raccoon, skunk, and opossum were higher with baited camera traps during winter, but there was no effect of bait during the summer season. Coyote detection was slightly higher with bait during winter. Bobcat detection was higher without bait during winter. Bait had no effect on detection during summer for any species, meaning abundant natural resources during summer made all the species less attracted to bait. These results corroborate a previous study that used baited camera traps during summer season where baiting was not a strong predictor of detection of mesocarnivores during summer (Jordan and Lobb-Rabe 2015).

Coyote.—My results on coyote data supported previous research, that they are ubiquitous (Table 5, Figs. 8 and 9) and utilized much of the preserve (Gompper et al. 2006;

Lesmeister et al. 2015). LTD value of coyote was the highest during both seasons and they had second highest detection frequency among all species during both seasons. LTD is used to measure the effectiveness of camera-trap to detect a species (Gompper et al. 2006; Cove et al. 2013). Even though coyote had higher detection frequency, high LTD means that camera-traps were not very efficient in detecting coyote, which is further supported by a similar study done in the northeastern United States (Gompper et al. 2006). According to Gompper et al. (2006), coyote could avoid camera-traps and move without getting captured. Coyotes have been living in fragmented landscapes for a long time and have close contact with humans. Séquin et al. (2003) suggest that coyotes may have learned wariness towards unfamiliar objects adapted through close association with humans. (Séquin et al. 2003).

The probability of occupancy showed that coyotes did not select for any 1 type of habitat over the others during both seasons (Fig. 4). Coyotes are generalists and are successful in urban, rural, or fragmented lands with considerable anthropogenic impacts and that might be the reason for occupancy results. Being the apex predator of the ecosystem in central North America, the coyote movement distance could be as large as 650 ha while a group of coyotes could move around in about 800 ha (Kenaga et al. 2013). Therefore, my results agree with previous research that the occupancy of coyote in this preserve did not depend upon any habitat type. The best models for detection probability of coyote were based on environmental factors like rainfall and temperature during both seasons (Table 5).

Summer coyote detection was also based on temperature and rainfall, but the model based on the presence of cattle at camera locations had 8% model weight (Table

6). This detection model provides considerable support that presence of cattle at camera locations had an impact on detection of coyotes. Further, variable detection probabilities of coyote between winter and summer season could provide strong support to the argument that coyotes avoid the sites where cattle were present. In the trophic cascade, coyote and cattle have a predator-prey relationship, but studies have revealed there is less than 0.1% North American cattle population killed by coyotes (Mitchell et al. 2004). Similar research done in south Texas found that coyote and bobcat did not necessarily avoid cattle ranching areas, in fact they would coexist (Bradley and Fagre 1988). At OYP, my results are inconclusive to provide a better explanation for the low detection of coyotes in summer because there are considerable amount of research showing that coyote would not avoid cattle, thus I had fewer detections of coyote in summer. With the amount of food available during summer, coyote would not necessarily have attracted to bait that I used at camera location. Furthermore, coyote adaptability to a variety of habitats may allow it to feed upon a large range of food sources. That would be a possible reason for fewer detections but the relationship between cattle grazing and fewer detections of coyote in summer needs more research.

Raccoon.—The raccoon had the highest number of detections and highest detection frequency among all mesocarnivore species detected during both seasons (Table 3 and Table 4). LTD was higher during summer than winter which means camera efficiency of detecting a raccoon during summer is lower than winter. Similar studies have found the best methods for raccoon identification was through scat sample analysis rather than camera trapping (Gompper et al. 2006). However, my results show that raccoons could be successfully detected using camera traps given low LTD during the winter season.

Unlike similar studies, I cannot consider raccoons as ubiquitous, because there were some sites in both seasons where raccoons were not present. The best model for habitat occupancy in winter for raccoons was near aquatic areas. During summer the best models did not show any specific habitat preference (Table 6), instead, their occupancy was based on environmental parameters. Raccoons are highly adaptable to fragmented urban environments. They can live in close proximity to humans as well as with other sympatric mesocarnivores (Kasparian et al. 2004; Lesmeister et al. 2015). A number of studies have been conducted on co-occurrences of raccoons with opossum, coyotes, and bobcats; and intraguild predation has not been recorded between raccoons and coyotes or bobcats. That is because raccoons are quite large for coyotes and bobcats to consume as a prey, but they may compete for same food sources (Lesmeister et al. 2015). I had several pictures of raccoons co-occurring with other species such as white-tailed deer (*Odocoileus virginianus*) and opossum, similar to another study that showed raccoons' ability to co-occur (Cove et al. 2017). However, raccoon had a site occupancy shift between seasons. They occupied habitats close to water during winter which ultimately changed during summer, where they utilized all habitat types. Raccoons are generalists and increased anthropogenic activities during summer season would not necessarily affect their occupancy. Abundant resources during summer season would increase movement range of raccoon during summer.

Winter detection probability of raccoons depends on the presence of bait at the camera location. The best detection model was at baited sites, for opossum as well, indicating a possible co-occurrence among mesocarnivore species that is not subject to any kind of intraguild predation, rather competition for prey. Summer detection probability was highly based on surveys where cattle were present rather than bait. In a study conducted in Michigan, raccoons have spatial interactions with livestock, sharing water resources and supplemental food sources, both in large-scale ranches and small pasture lands (Atwood et al. 2009). In my study site, there was no supplementary food given for cattle, therefore the interacting factors of raccoons and cattle would be minimal. Even though both species utilize the same water resources, there are abundant water resources throughout the preserve and raccoons have comparably high home ranges of about 1.51 km^2 (Atwood et al. 2009) that enable them to avoid cattle. Even though summer detection probability of raccoons were lower than winter presence of cattle would not be the reason, because raccoon could co-exist with cattle.

*Opossum***.—**This species had the most seasonal variations in LTD, occupancy, and detection probability among all mesocarnivore species (Table 3 and Table 4). In winter, opossum had third-highest detection frequency after raccoon and coyote. In summer it had lowest detection frequency. Lowest LTD was recorded from opossum during winter, but I couldn’t calculate LTD for summer because there was only one detection of opossum. Similar studies found that opossum could be detected equally well by using camera traps and other methods like scat analysis and track plates (Gompper et al. 2006). Opossum are highly dependent on water. Summer weather in southcentral Oklahoma may have an impact on opossum survival, and it could be the reason for seasonal variation of LTD and detection frequency. My results support similar seasonal variation in opossum LTD that was found in the northeastern United States (O'Connell Jr et al. 2010; Fidino et al. 2016).

The best occupancy model shows that highest site occupancy by opossum during the winter season is in aquatic habitats. Even though the presence of water is crucial for their survival, they can survive and adjust to fragmented landscapes. Studies have shown that they can live in urban landscapes, where access to water is limited (Fidino et al. 2016). Subsequently, in summer their occupancy shifted to wooded habitats (model weight 32%). The second best model in summer was aquatic habitats with 25% model weight which means that they prefer aquatic habitats, even though they slightly prefer tree cover as suggested by my results because at OYP there is no considerable difference between wooded and aquatic habitats. The distribution range of opossum showed that they cannot withstand severe cold temperatures in the northern United States. (Kanda et al. 2005). Occupancy and detection frequency in my results showed that they are more active during winter than summer. Southcentral Oklahoma has mild winters that would favor opossum movement compared to northern regions.

Detection of opossum in winter was influenced by the presence of bait at sites by 98% model weight which supports my hypothesis that bait should have an impact on the detection. Further, detection probability between baited and non-baited camera traps in winter shows high variability for opossum. It supports the argument that in order to detect an opossum in winter bait should be used. In contrast, summer detection was not influenced by the presence of bait. The best detection models do not show any covariate that could affect the detection probability of opossum. In fact, opossum had just one detection in summer which was not enough to provide better estimations. A similar study conducted in northeastern Unites States recorded highest opossum activity during late summer to early fall (O'Connell Jr et al. 2010), but opossum is known to have seasonal variation in habitat selection and activity. Therefore, I can say that further research looking at seasonal variability in opossum detection should be conducted in Oklahoma.

Bobcat.—Bobcats have elusive behavior with fairly large home ranges (Lynch et al. 2008). My results further support the elusiveness of bobcat behavior, because I got lower detection frequencies from bobcat than other species during both seasons. There was no considerable seasonal variation in detection frequency of bobcat in the study area (Table 3 and Table 4). Latency to initial detection of bobcat in winter was the second lowest from all species for both seasons. The results suggest camera traps are more efficient in capturing bobcat than all other species in any season.

Overall bobcat site occupancy in both seasons was smaller than all the other species. Prey abundance, habitat quality, an abundance of den sites, and interactions with other mesocarnivores may affect the occurrence of this species (Lynch et al. 2008; Lesmeister et al. 2015). The study area consisted of more open grasslands than wooded or aquatic habitats, offering limited habitat for den sites. Therefore, low site occupancy of this species is as expected with reference to other studies (Lynch et al. 2008; Lesmeister et al. 2015). The habitat type that bobcats occupied during winter was wooded habitat with 4% model weight. All the other covariates that had an impact on the site occupancy of bobcat were environmental covariates. In summer, wooded habitat occupancy was the best model with 37% model weight, and aquatic habitat model second with 22% model weight. Model weight for wooded habitat occupancy was higher in summer than winter. Summer occupancy results showed that bobcat equally occupied wooded and riparian habitats, and these results agree with previous research that showed both a forest cover and wetland requisite for bobcat occupancy (Long et al. 2011; Clare et al. 2015). The obvious and most reasonable explanation for these results could be the impact of weather. Oklahoma has hot summer seasons that should have an impact on smaller mammals which are prey species to bobcat. Small mammals are abundant in wooded areas during summer, ultimately bobcat also tend to occupy wooded areas searching for prey (Long et al. 2011; Clare et al. 2015).

Detection probability mainly depended upon the environmental factors in winter. When I compared detection probability of baited camera traps vs non-baited camera traps for bobcat, in winter they had higher detection probability when the camera location was not baited. The model with baiting at a camera location had 3% model weight that did not strongly imply the effect of baiting for bobcat detection. A possible reason could be the variability of the baits at the baited sites. When I first baited a camera location, the bait lasted < 3 days at a site because raccoons and coyotes quickly ate the bait. Even though bobcat followed the smell of bait, the bait might have already been eaten by raccoon or coyote. That could be a possible reason that I concluded presence of bait had no affect in the detection of bobcats. The summer season has more food abundance than winter, like all the other species bobcat has no interest in bait during summer. Also, bobcat breeding season falls in January to February and gestation is about 50 days (Johnson et al. 2010). Initial dispersal period of kitten falls in spring, which was in between my sampling seasons. Bobcats were the most elusive species that I detected among all other mesocarnivore species and they are more elusive when they have kittens (Johnson et al. 2010). This would be another reason for low detection of bobcat during summer.

Similar studies have revealed that the bobcat moves around various habitats in order to select the best habitat with best resources to maximize their individual fitness

(Lynch et al. 2008). Since this is a species with lower population densities, I highly doubt that bobcats have established their den sites inside this preserve. According to my results, their preferred habitat type is tree patches and forest areas. That is compatible with similar studies (Lesmeister et al. 2015). Wooded and forest habitat were the least amount of habitat in this preserve. Therefore, the probability of bobcats having den sites inside this preserve is low. On the other hand, it has been suggested that bobcats avoid interactions with other mesocarnivore species, specifically coyotes. Because coyotes were abundant in the preserve, low occupancy of bobcats in the preserve could be expected (Lesmeister et al. 2015).

Striped skunk.—The skunk had the lowest detection frequency during winter and second lowest in summer after opossum. LTD had no seasonal variation and LTD values were comparatively lower than coyote and raccoon (Table 3 and Table 4), indicating that skunks could be detected easily using a camera trap. A few studies found that skunks in the northeastern United States have winter hibernation where they have very low activity during winter (Lariviere and Messier 1997; Gompper et al. 2006; O'Connell Jr et al. 2010). My results were contradictory, I had higher detection frequency during winter than summer. There could be changes in the seasonal activity of skunk depending on the severity of winter. Oklahoma winter temperatures are not as low as the northeastern United States, therefore winter dormancy may not be seen in skunk populations in Oklahoma (Lesmeister et al. 2015), but further research is needed to understand winter behavior of the skunk.

Striped skunks are generalists in habitat occupancy, but prefer dense vegetation cover and heterogeneous landscape for den sites (Bixler and Gittleman 2000). In my study site during winter season best occupancy models revealed that they prefer wooded (model weight 11%) and riparian habitats (model weight 4%). In summer they preferred habitats along trails and roads with the model weight of 54%, and wooded areas 18%. Site occupancy of striped skunk had considerable variation between two seasons. Skunks can live closely with human and human-altered landscapes. Their habitat occupancy is greatly variable across landscapes, and insensitive to habitat fragmentation, because they could survive and adapt to diverse habitats (Bixler and Gittleman 2000; Crooks 2002; Neiswenter and Dowler 2007; Lesmeister et al. 2015). During the summer season, there was some metal trash piled up along the trails of the preserve that might have attracted skunks. Similar studies found higher site occupancy of skunks around man-made structures, as they use those structures as their den and resting sites (Lariviere and Messier 1997; Lesmeister et al. 2015). Skunk breeding season usually occurs in early spring, using man-made structures as den-sites at the study site may have led them to show higher site occupancy near trails and roads. Therefore, my study also supports the same finding that skunks prefer trash pilled up areas specifically after their breeding season. Gestation and parturition of skunk occur late spring through early summer when females do not move like males (Lariviere and Messier 1997). Home ranges of females during breeding season were less than males during parturition, but during mid-summer their home ranges increase when females move around and forage with young (Lariviere and Messier 1997). That would be a possible reason for low detection of skunks during summer, because skunks may have moved away from the preserve.

Detection probability of skunk was highly based on baited surveys with 72% model weight in winter. During summer their detection probability was based on environmental factors. The bait had no considerable effect on detection probability during summer. A possible reason could be abundant food sources like newly emerged insects in late spring which made them less attracted to the bait (Lesmeister et al. 2015). Cattle grazing had no considerable effect on detection or site occupancy of skunks because skunks are generalists in behavior and have the ability to adapt for any environmental condition.

Patterns of occupancy and detection among seasons.—As a group, all the mesocarnivore species that I detected in southcentral Oklahoma had intermediate detection probabilities and one factor did not exceed the others in the detection of any species. Habitat occupancy was correlated with site covariates mostly for bobcat, skunk, and opossum, but not for coyotes (Table 5 and Table 6). Probabilities of habitat occupancy (Figs. 7-10) showed that bobcat and skunk occupancies were higher in wooded habitats and raccoon and opossum occupancies were higher in riparian habitats. Meanwhile, coyote occupied everywhere but had less occupancy in wooded habitat during the winter season. During the summer season similar patterns could be seen for bobcat, skunk, raccoon, and opossum; that all species had higher site occupancy in riparian areas. The warm and dry temperature in southcentral Oklahoma in summer could be the most probable reason.

In this research, I considered large-scale impacts of habitat types and environmental conditions for the occurrences of mesocarnivores. Their localized distribution could be influenced by many more factors other than habitat types and environmental conditions, which are yet to be identified. Very low detection probabilities of all the species in summer have to be considered in future research, because there may be many more factors that could be involved that I could not identify in this research.

This research provides evidence that non-invasive camera trapping could be incorporated broadly in wildlife research; it is eco-friendly, supportive for conservation, and is a high-quality data source that could be analyzed using robust statistical methods.

My results reveal 3 components that could be considered in managing this preserve: (1) more research on mesocarnivores is needed, especially concerning species specific small-scale covariates that could affect their ecological roles; (2) camera–trap surveys incorporated into occupancy modeling could be successfully applied in future research in this preserve, not only for mesocarnivores, but for all the other mammal species like white-tailed deer, beaver (*Castor canadensis*), nine-banded armadillo (*Dasypus novemcinctus*), and rabbit species (*Lepus californicus*, *Sylvilagus floridanus*); and, (3) intensive grazing using cattle may negatively affect all mesocarnivores species. This factor is important because in future there will be a herd of bison introduced into the preserve. My results indicate that coyotes and raccoons sometimes avoided the areas where there were cattle, and I believe a similar situation could be expected with bison. On the other hand, coyotes or raccoons are generalists and species of no conservation concern for now. I urge more conservation efforts need to restore bison in their natural habitats. My ultimate suggestion for management and conservation efforts at this time is to introduce bison in to the preserve. Further research will have to be conducted in order to determine if other mesocarnivore species like gray foxes, red foxes, and river otter occur in this preserve.

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TABLE 1.—Type of variable, description, type of covariate that each of those variables used, and the season; W=winter (November 2016- February 2017), S-summer (May-August 2017), that were used in single-season- single species occupancy modeling. Those survey variables were used to inform detection probability (p), and site occupancy (Ψ) of mesocarnivores at Oka' Yanahli Preserve, southcentral Oklahoma.

Variable	Description	Covariate type	Season
Water	Distance (m) to linear water feature (ponds, river)	Site covariate	W, S
Trees	Distance(m) to nearest tree patch	Site covariate	W, S
Road	Distance (m) to nearest roads or trails	Site covariate	W, S
Temperature	Mean average temperature at each location during the survey period, taken at nearest National Weather Service station	Site covariate	W, S
Month	The month that each camera location belonged	Site covariate	W, S
Baited site	Number of sites that were baited using canned mackerel	Site covariate	W, S
Cattle grazing	Number of sites where cattle were grazing during summer (1=cattle present, 0=cattle absent at the site)	Site covariate	S
Bait survey	Number of baited surveys, one survey was 3 days block	Survey Covariate	W, S
Temperature survey	Mean average temperature (^{0}C) during each 3-day block survey taken from nearest National Weather Service station	Survey Covariate	W, S
Rainfall Survey	Mean average precipitation (cm) during each 3-day block survey taken from nearest National Weather Service station	Survey Covariate	W, S
Cattle survey	Number of the survey where cattle were present near camera locations (1=cattle present, 0=cattle absent during the survey)	Survey Covariate	S

TABLE 2.—Model type and model matrix design of the habitat occupancy and detection models used to predict mesocarnivore detection probability (p), and site occupancy (Ψ) using single species-single season occupancy modeling during winter (November 2016-February 2017) and summer (May- August 2017) at Oka' Yanahli Preserve, southcentral Oklahoma.

Model type	Matrix design
Ψ(.),p(.)	α_0 , β_0
Ψ (road),p(.)	$\alpha_0 + \alpha 1$(road)
Ψ (water),p(.)	$\alpha_0 + \alpha 1$(water)
Ψ (trees),p(.)	$\alpha_0 + \alpha 1$(trees)
Ψ (cattle), p(.)	$\alpha_0 + \alpha 1$(cattle_sites)
Ψ (temp),p(.)	$\alpha_0 + \alpha 1$(aveg_temp)
Ψ (month),p(.)	$\alpha_0 + \alpha 1$(month)
Ψ (.),p(bait_site)	$\beta_0 + \beta_1$ (Bait_site)
Ψ (.),p(bait_survey)	$\beta_0 + \beta_1$ (Bait_sur)
Ψ (.),p(rainfall_survey)	$\beta_0 + \beta_1$ (rain_sur)
Ψ (.),p(temp_survey)	$\beta_0 + \beta_1$ (temp_sur)
Ψ (.),p(cattle_survey)	$\beta_0 + \beta_1$ (cattle_sur)

TABLE 3.—All mesocarnivore species that were detected from camera survey during winter season (November 2016-Februry 2017), with common name, species name, number of detected camera locations out of 25 total sites, total detections at each camera location, latency to first detect a species in trap nights (SE), detection frequency calculated per 1000 trap nights, and naïve occupancy (total number sites species detected/total sites) at Oka' Yanahli Preserve, southcentral Oklahoma.

Common Name	Species Name	No. of locations detected N=25	Tot. detections	LTD (SE)	Detection Frequency /1000 trap nights	Naïve Occupancy
Carnivora						
bobcat	*Lynx rufus*	7	22	2.38 (1.51)	26.07	0.28
coyote	*Canis latrans*	20	78	7.23 (1.32)	92.42	0.80
striped skunk	*Mephitis mephitis*	7	18	3.53 (1.33)	21.33	0.28
northern raccoon	*Procyon lotor*	16	119	4.07 (0.89)	141.00	0.64
Didelphimorphia						
Virginia opossum	*Didelphis virginiana*	8	42	1.92 (0.67)	49.76	0.32

TABLE 4.— All mesocarnivore species that were detected from camera survey during summer season (March – August 2017), with common name, species name, number of detected camera locations out of 18 total sites, total detections at each camera location, latency to first detect a species in trap nights (SE), detection frequency calculated per 1000 trap nights, and naïve occupancy (total number sites species detected/total sites) at Oka' Yanahli Preserve, southcentral Oklahoma.

Common Name	Species Name	No. of locations detected N=18	Total detections	LTD (SE)	Detection Frequency /1000 trap nights	Naïve occupancy
Carnivora						
bobcat	*Lynx rufus*	3	3	3.94 (3.22)	5.00	0.17
coyote	*Canis latrans*	12	24	7.77 (0.82)	40.00	0.67
striped skunk	*Mephitis mephitis*	3	4	3.38 (1.37)	6.67	0.17
northern raccoon	*Procyon lotor*	7	31	9.22 (3.88)	51.67	0.39
Didelphimorphia						
Virginia opossum	*Didelphis virginiana*	1	1	0	1.67	0.06

TABLE 5.—Each mesocarnivore species habitat occupancy and detection probability with baited and non-baited camera traps were analyzed in single species-single season method using PRESENCE software. The table shows the best models obtained with AIC value, Δ AIC, AIC weight, number of parameters (k), and model weight calculated for each species in winter 2016-2017 at Oka' Yanahli Preserve, southcentral Oklahoma. Among all the models, best four models for each mesocarnivore species are presented here.

Species	Best Model	AIC	Δ AIC	AIC weight	k.	Model weight
bobcat	psi(.),p(temp)	113.05	0	0.7949	3	0.79
	psi(trees),p(.)	119.21	6.16	0.0365	3	0.04
	psi(temp),p(.)	119.34	6.29	0.0342	3	0.03
	psi(.),p(bait_survey)	119.63	6.58	0.0296	3	0.03
coyote	psi(.),p(rainfall)	27.4	0	0.5757	3	1
	psi(.),p(.)	283.86	0	0.2575	2	1.24×10^{-55}
	psi(.),p(bait-daily)	285.16	1.3	0.1344	3	1.07×10^{-56}
	psi(.),p(bait_site)	285.74	1.88	0.1006	3	7.98×10^{-57}
opossum	psi(.),p(bait-site)	146.19	0	0.972	3	0.98
	psi(water),p(.)	155.57	9.38	0.0089	3	0.01
	psi(.),p(.)	157.45	11.26	0.0035	2	0.00
	psi(.),p(bait daily)	157.45	11.26	0.0035	2	0.00
raccoon	psi(.),p(bait/site)	254.25	0	0.4841	3	0.48
	psi(.),p(bait_only)	254.25	0	0.4841	3	0.48
	psi(.water),p(.)	265.01	10.76	0.0022	3	0.002
	psi(.),p(rainfall)	265.84	11.59	0.0015	3	0.001
skunk	psi(.),p(bait_survey)	82.25	0	0.7016	3	0.72
	psi(trees),p(.)	86.04	3.79	0.1055	3	0.11
	psi(water),p(.)	88.16	5.91	0.0365	3	0.04
	psi(.),p(.)	88.16	5.91	0.0365	2	0.01

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TABLE 6.— Each mesocarnivore species habitat occupancy and detection probability with baited and non-baited camera traps were analyzed in single species-single season method using PRESENCE software. The table shows the best models obtained with AIC value, Δ AIC, AIC weight, number of parameters (k), and model weight calculated for each species in summer 2017 at Oka' Yanahli Preserve, southcentral Oklahoma. Among all the models, best four models for each mesocarnivore species are presented here.

Species	Best Model	AIC	Δ AIC	AIC weight	k	Model weight
bobcat	psi(trees),p(.)	33.64	0	0	3	0.37
	psi(water),p(.)	34.68	1.04	0	3	0.22
	psi(.),p(bait_site)	34.87	1.23	0	3	0.20
	psi(.),p(.)	35	1.36	0	2	0.07
coyote	psi(.),p(.)	127.69	0	0.1815	2	0.08
	psi(.),p(rainfall_survey)	128.32	0.63	0.1324	3	0.15
	psi(.),p(temp_survey)	128.52	0.83	0.1198	3	0.14
	psi(.),p(cattle_survey)	129.57	1.88	0.0709	3	0.08
opossum	psi(trees),p(.)	13.84	0	0.3002	3	0.32
	psi(water),p(.)	14.31	0.47	0.2374	3	0.25
	psi(.),p(.)	16.54	2.7	0.0778	2	0.03
	psi(road),p(.)	16.9	3.06	0.065	3	0.07
raccoon	psi(temp),p(.)	108.92	0	0.7841	3	0.80
	psi(.),p(.)	115.15	6.23	0.0348	2	0.01
	psi(.),p(cattle_survey)	115.39	6.47	0.0309	3	0.03
	psi(.),p(rainfall_survey)	115.41	6.49	0.0306	3	0.03
skunk	psi(road),p(.)	35.93	0	0.5261	3	0.54
	psi(trees),p(.)	38.11	2.18	0.1769	3	0.18
	psi(.),p(rainfall_survey)	39.39	3.46	0.0933	3	0.09
	psi(.),p(temp_survey)	40.5	4.57	0.0535	3	0.05

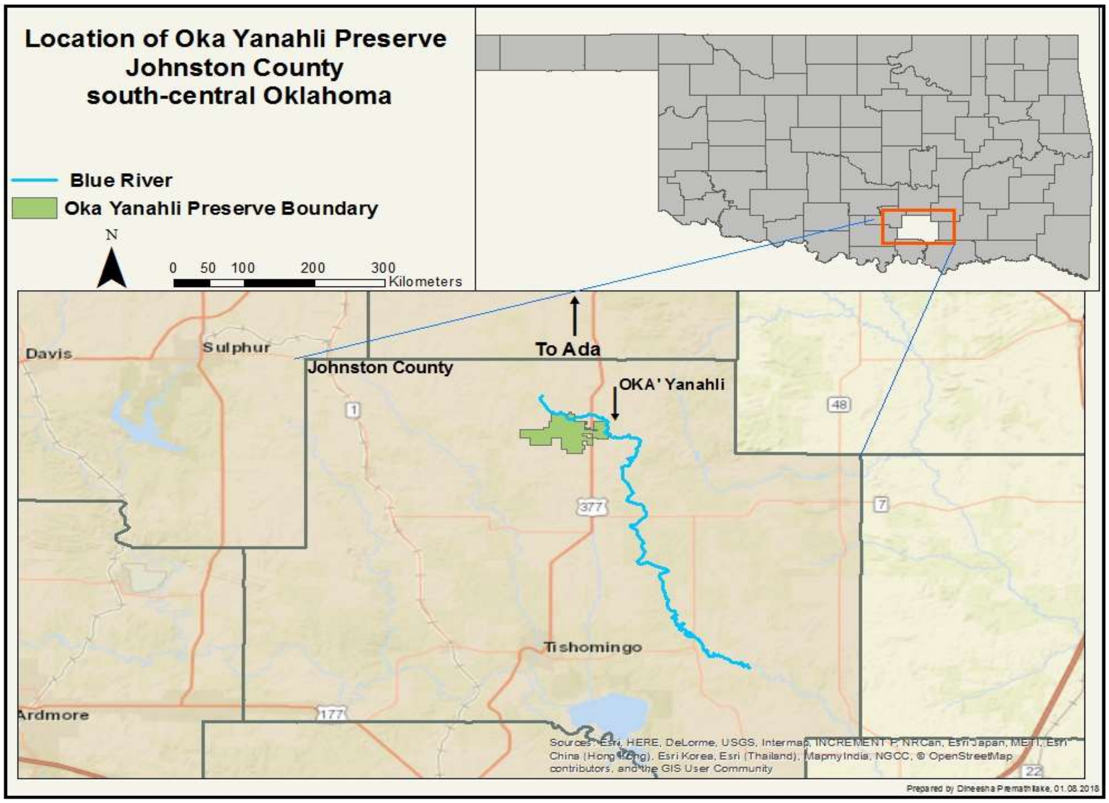

FIG. 1.—Location of study area, Oka' Yanahli Preserve in Arbuckle Mountain Plains, Johnston County, southcentral, Oklahoma.

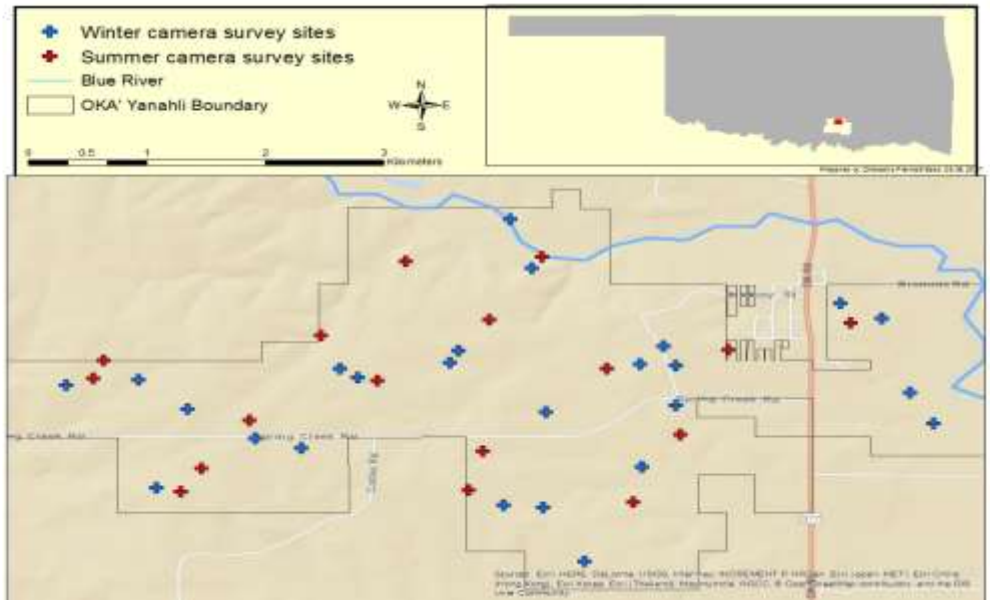

FIG. 2.—Locations during camera survey at Oka' Yanahli Preserve southcentral Oklahoma in winter (November 2016-Februry 2017) (blue dots) and summer (May – August 2017) (red dots).

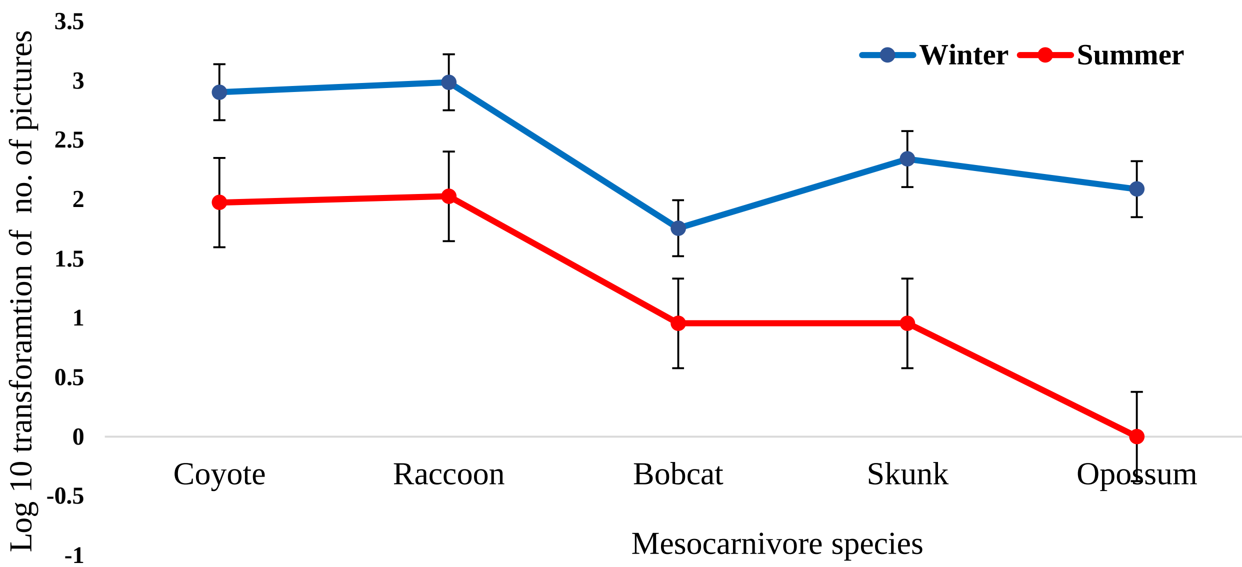

FIG. 3.—Log transformation of total number of pictures recorded from each mesocarnivore species during winter 2016-2017 and summer 2017 at Oka' Yanahli Preserve, southcentral Oklahoma. A total of 1531 mesocarnivore pictures from winter and 1455 from summer were taken from 25 camera locations in winter and 18 camera locations in summer

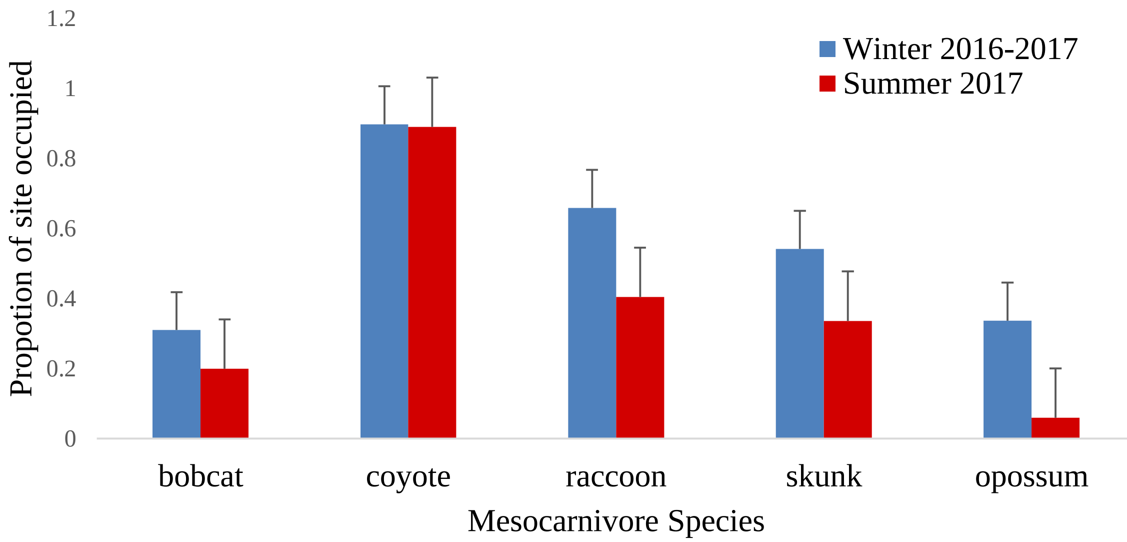

FIG. 4.—Occupancy estimates (mean + 1SE) for the proportion of sites occupied, Ψ (·), for each mesocarnivore species detected during winter 2016-2017 (blue bars) and summer 2017 (red bars) at Oka' Yanahli Preserve, southcentral Oklahoma.

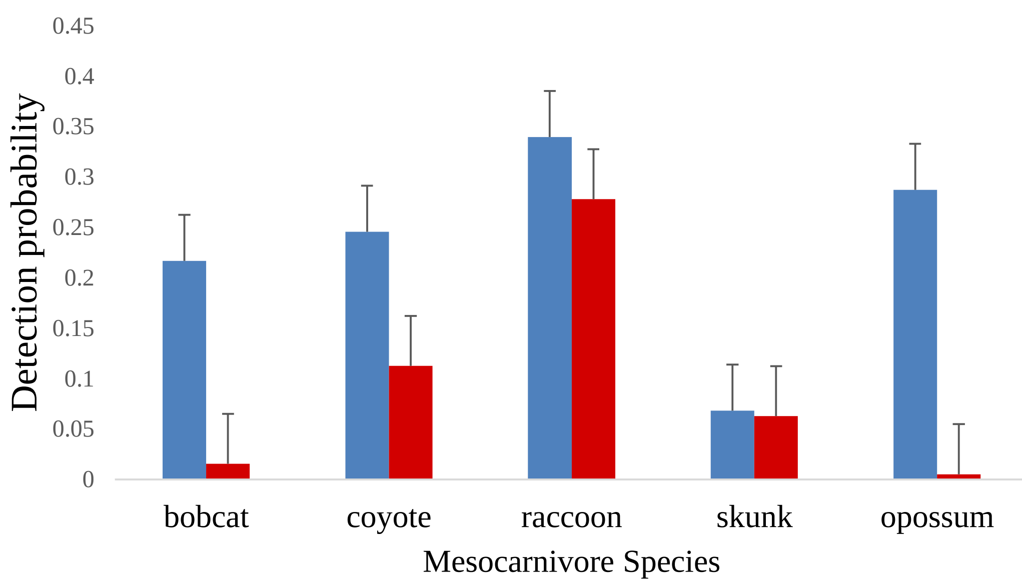

FIG. 5.—Detection probability estimate (mean + 1SE) for the probability of detection p (·), for each mesocarnivore species detected during winter 2016-2017 (blue bars) and summer 2017 (red bars) at Oka' Yanahli Preserve, southcentral Oklahoma.

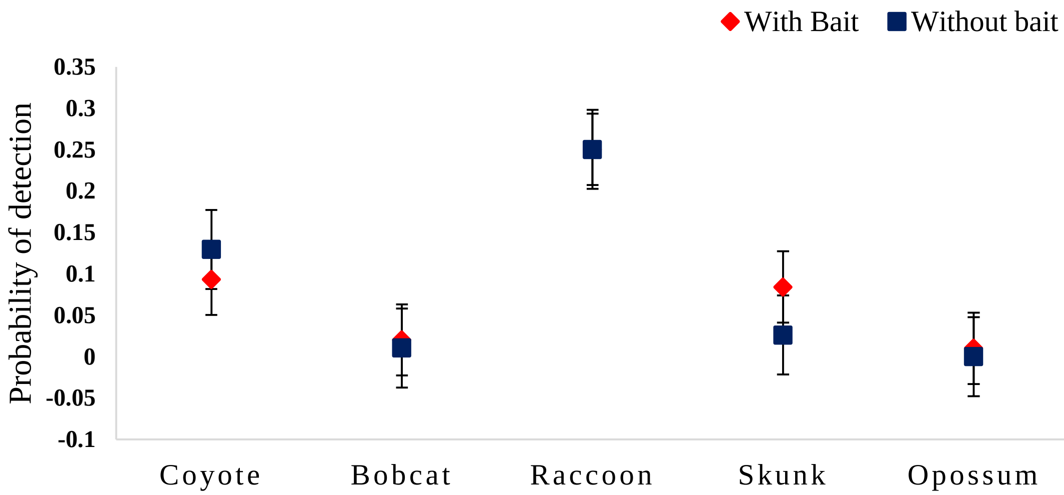

FIG. 6.—Detection probabilities of baited and un-baited camera traps for winter 2016-2017 were obtained from single season-single species occupancy models ran using Presence software version 12.7. The graph shows the probability of detection per baited/ un-baited camera trap sites for all mesocarnivore species, based on Ψ(.)p(bait), and Ψ(.)p (not bait) for winter 2016-2017, at Oka' Yanahli Preserve, southcentral Oklahoma. Error bars are 95% confidence intervals.

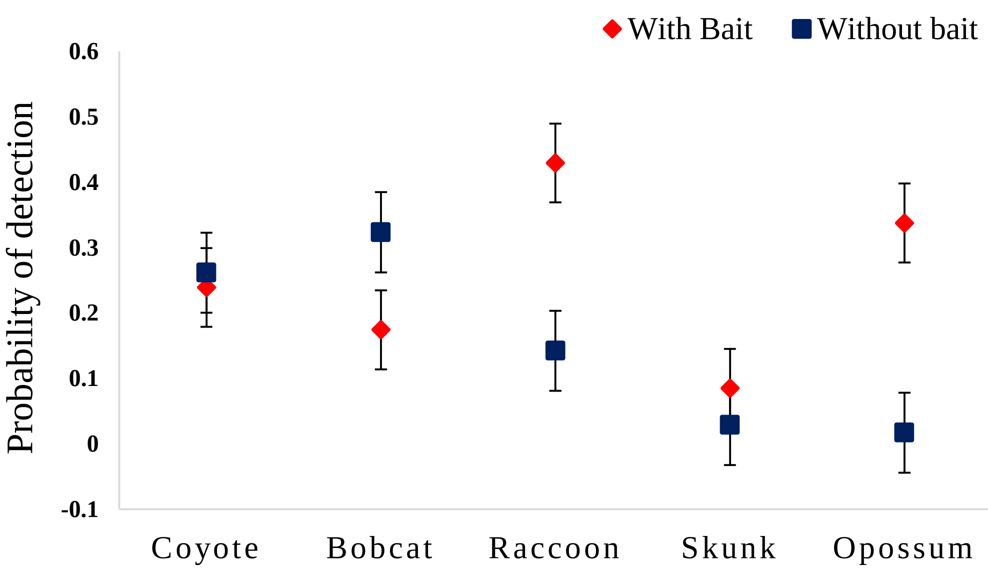

FIG. 7.—Detection probabilities of baited and un-baited camera traps for summer 2017 were obtained from single season-single species occupancy models ran using Presence software version 12.7. The graph shows the probability of detection per baited/ un-baited camera trap sites for all mesocarnivore species, based on Ψ(.)p(bait), and Ψ(.)p (not bait) for summer 2017, at Oka' Yanahli Preserve, southcentral Oklahoma. Error bars are 95% confidence intervals.

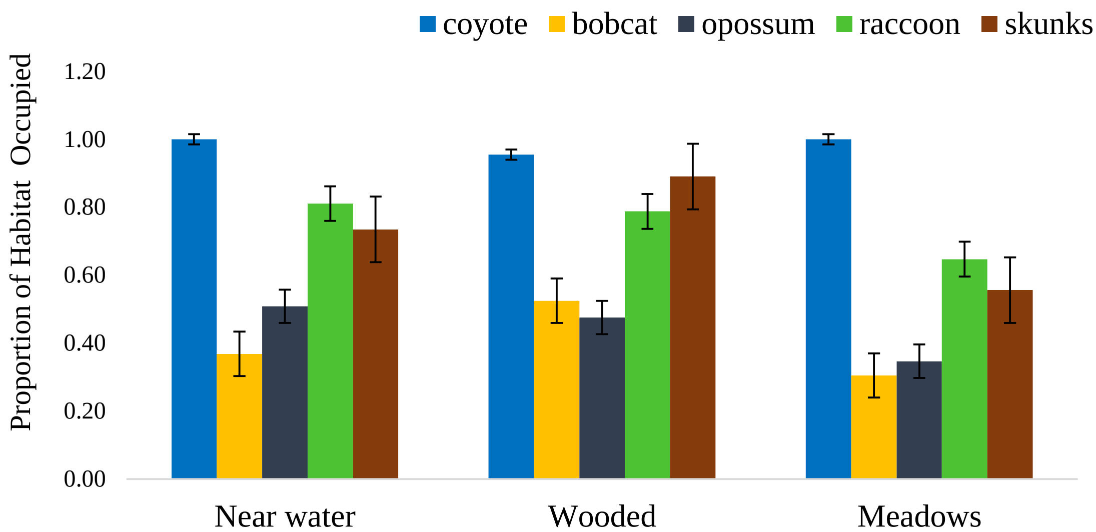

FIG. 8.—Average proportion of sites occupied by each mesocarnivore at each habitat type during winter 2016-2017 at Oka' Yanahli Preserve southcentral Oklahoma. Each site was categorized into three different habitat types; habitat near water, wooded, and meadows. Occupancy estimates for each species were obtained from occupancy modeling at each site.

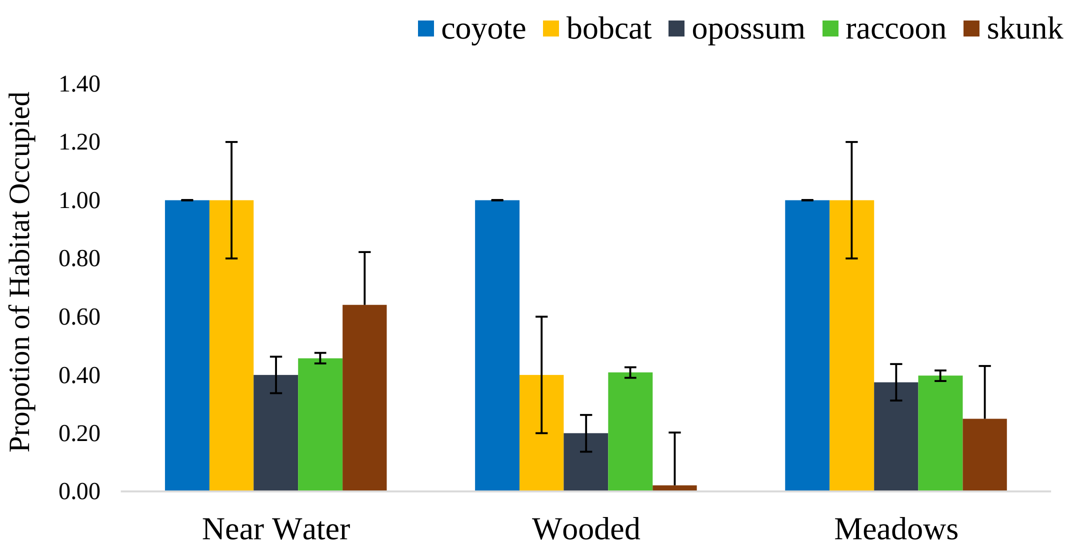

FIG. 9.—Average proportion of sites occupied by each mesocarnivore at each habitat type during summer 2017 at Oka' Yanahli Preserve southcentral Oklahoma. Each site was categorized into three different habitat types; habitat near water, wooded, and meadows. Occupancy estimates for each species were obtained from occupancy modeling at each site.

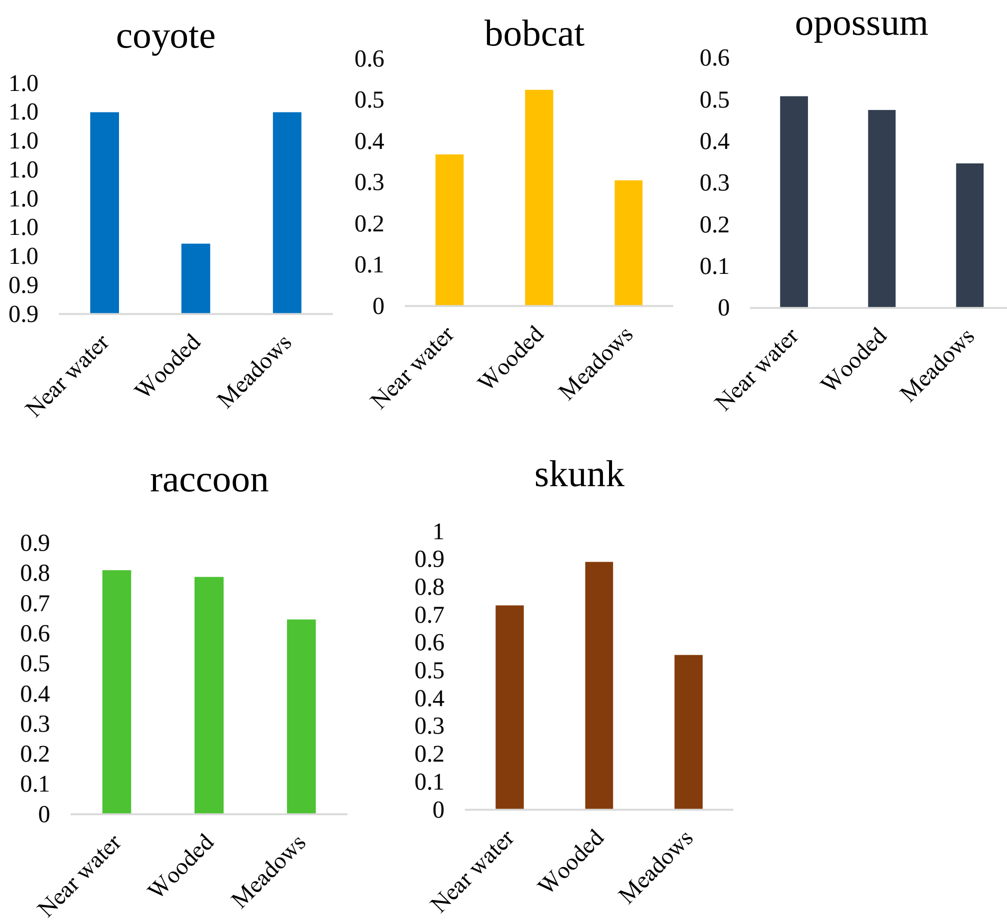

FIG. 10.—Individual species habitat occupancy estimates of coyote, bobcat, opossum, raccoon, and skunk derived from habitat specific occupancy models during winter 2016-2017 at Oka' Yanahli Preserve, southcentral Oklahoma.

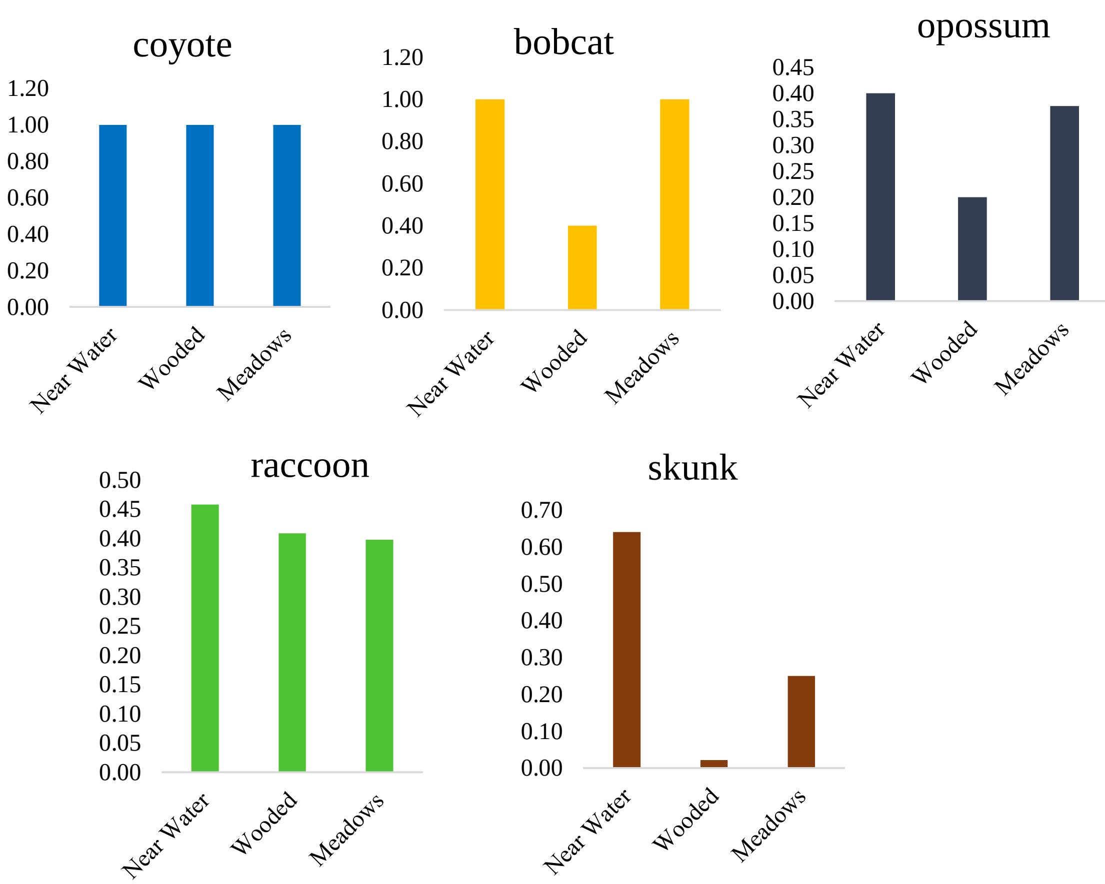

FIG.11.—Individual species habitat occupancy estimates of coyote, bobcat, opossum, raccoon, and skunk derived from habitat specific occupancy models during summer 2017 at Oka' Yanahli Preserve, southcentral Oklahoma.

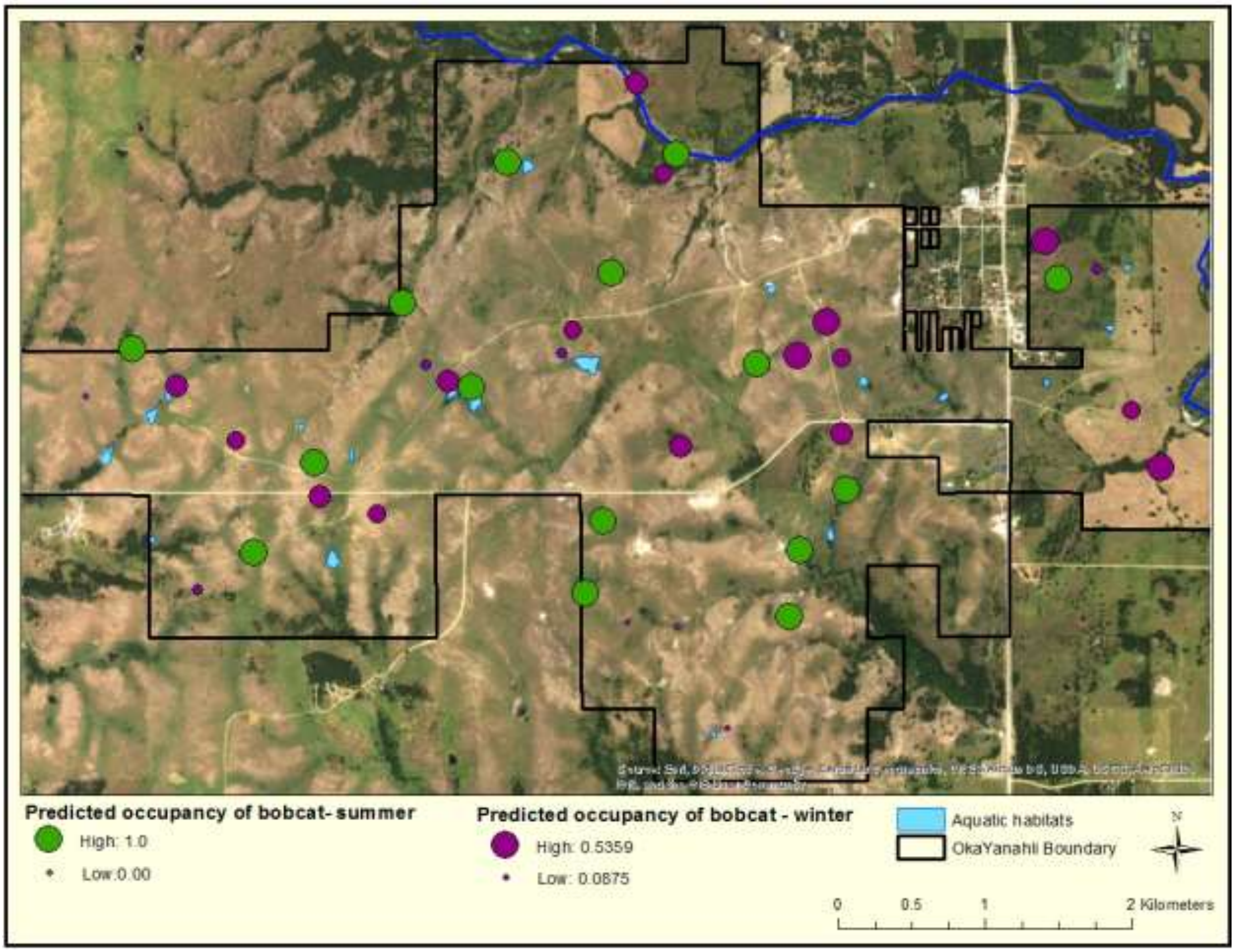

FIG. 12.—Predicted site occupancy of bobcat derived from habitat covariate occupancy models in winter 2016-2017 (range Ψ= 0.088-0.54) and summer 2017 (range Ψ= 0.00-1.00) at Oka' Yanahli Preserve, southcentral Oklahoma. Bubble size indicates the value of the probability of site occupancy.

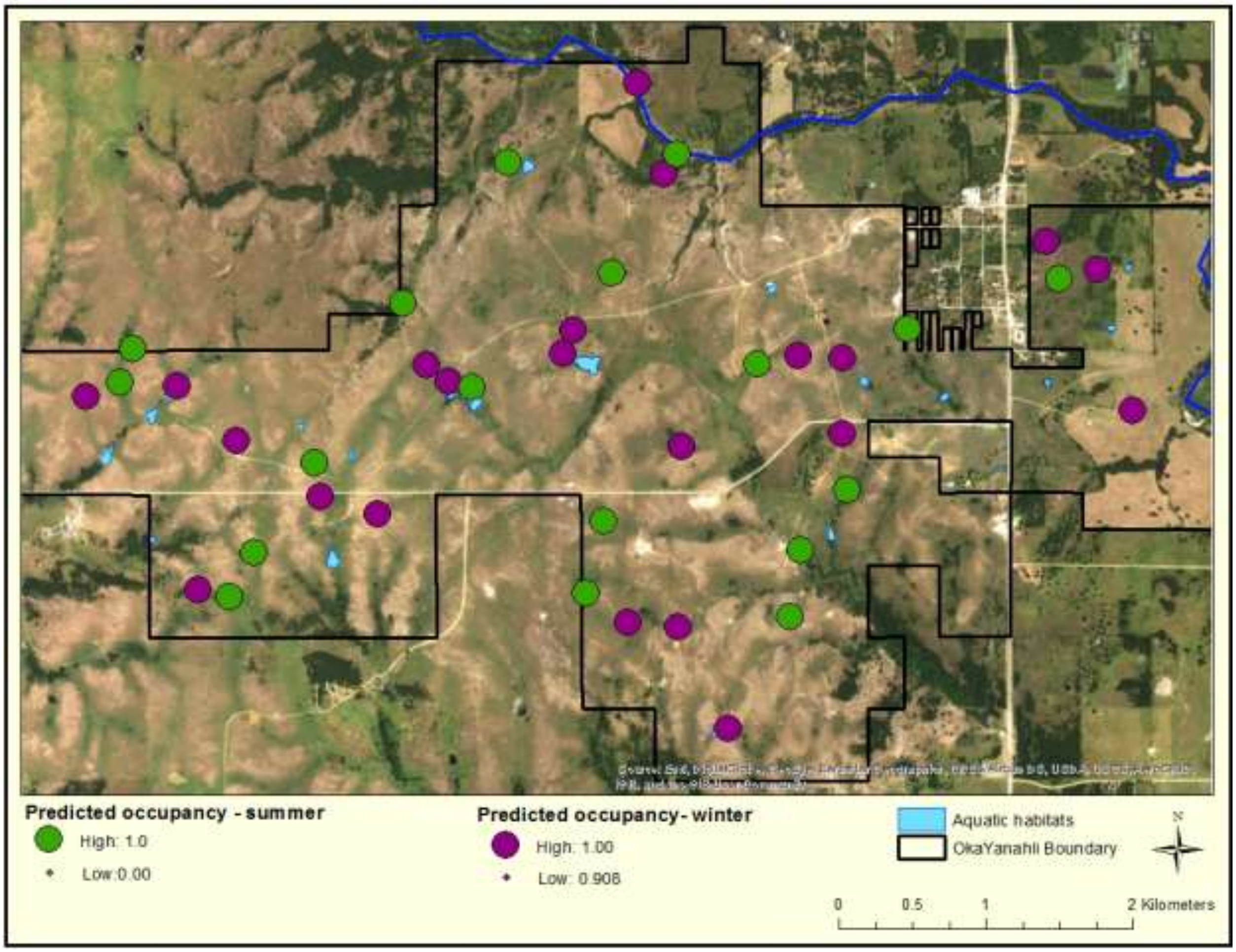

FIG. 13.—Predicted site occupancy of coyote derived from habitat covariate occupancy models in winter 2016-2017 (range Ψ= 0.91-1.0) and summer 2017 (range Ψ= 0.00-1.00) at Oka' Yanahli Preserve, southcentral Oklahoma. Bubble size indicates the value of the probability of site occupancy.

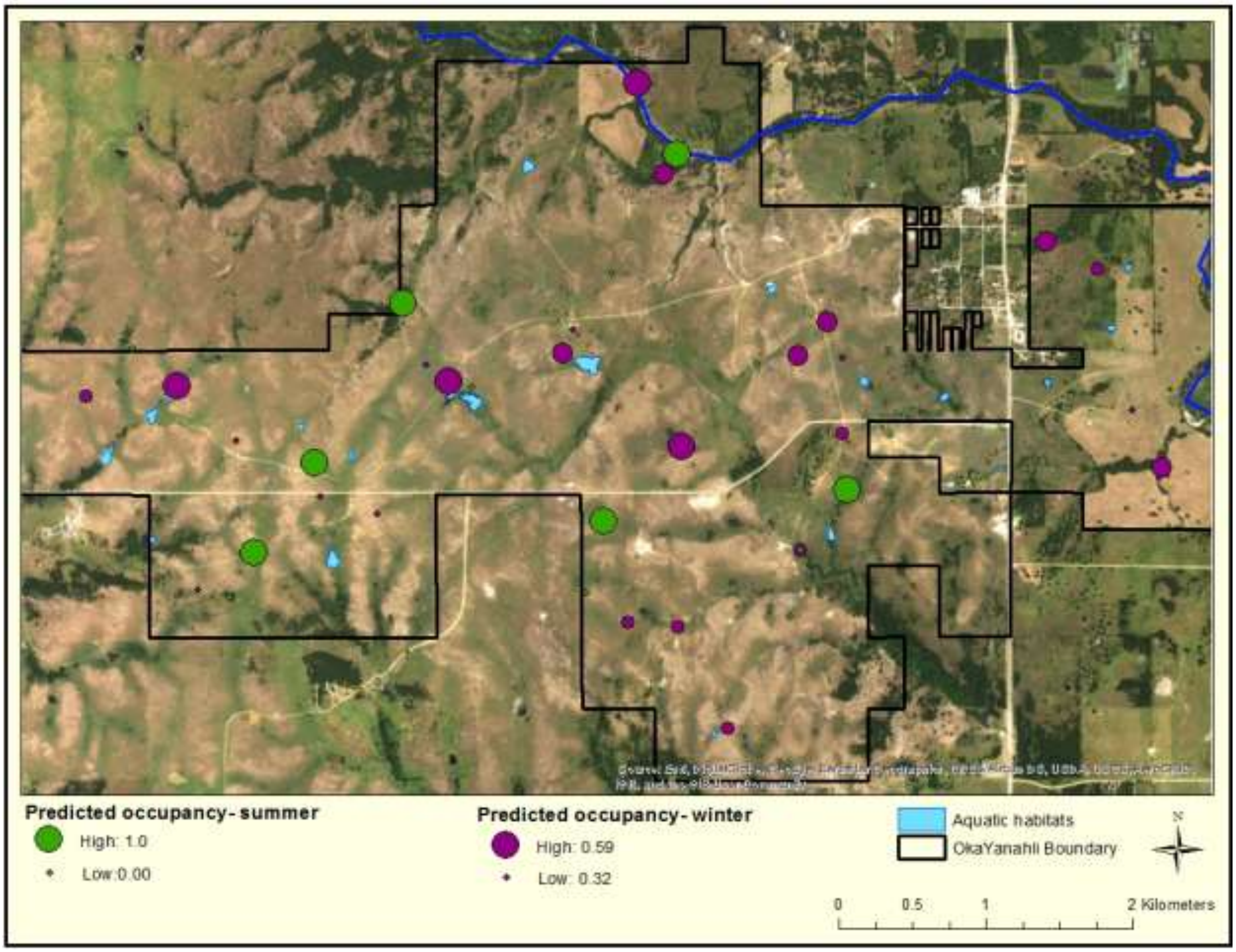

FIG 14.— Predicted site occupancy of opossum derived from habitat covariate occupancy models in winter 2016-2017 (range Ψ= 0.32-0.59) and summer 2017 (range Ψ= 0.00-1.00) at Oka' Yanahli Preserve, southcentral Oklahoma. Bubble size indicates the value of the probability of site occupancy.

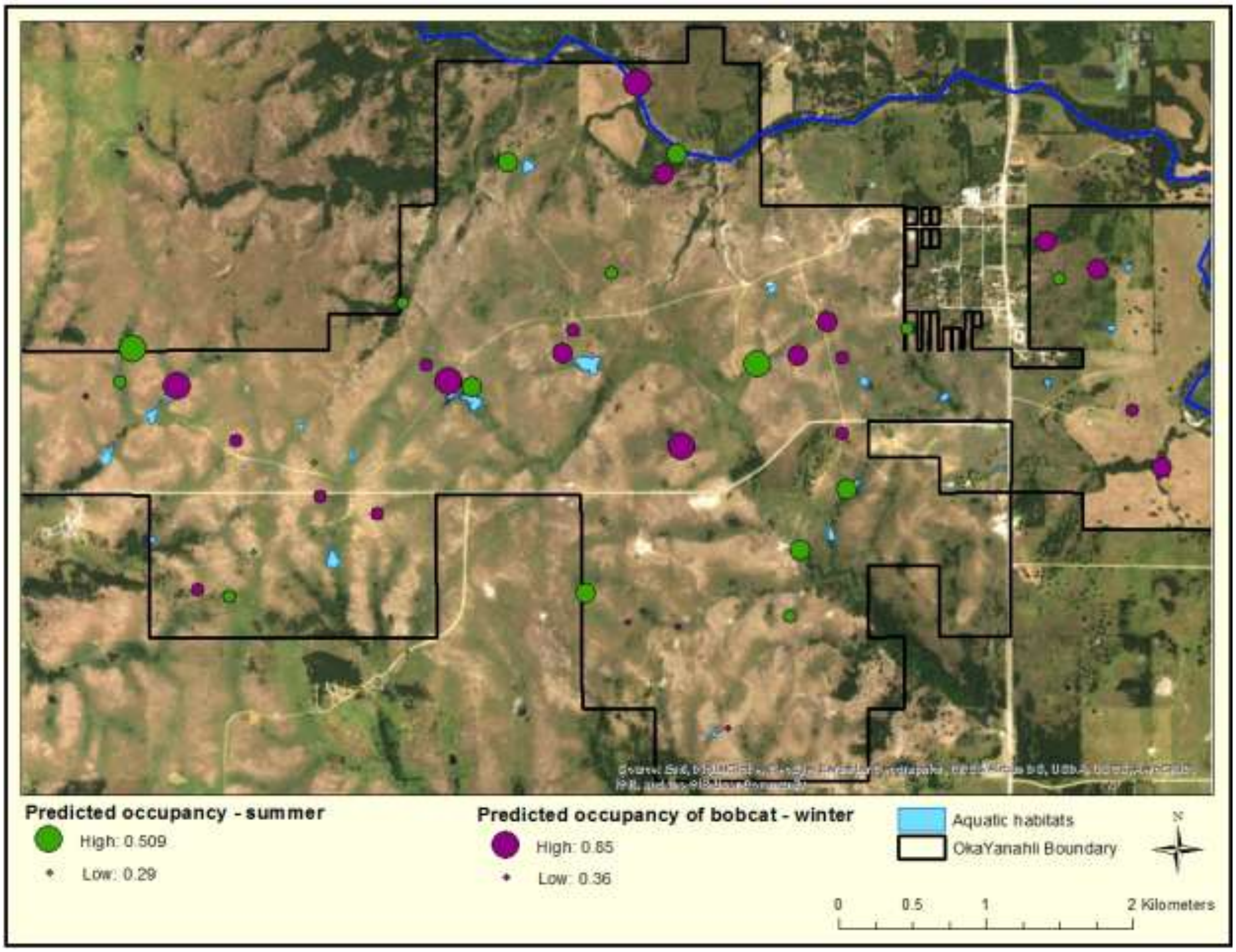

FIG. 15.— Predicted site occupancy of raccoon derived from habitat covariate occupancy models in winter 2016-2017 (range Ψ= 0.36-0.85) and summer 2017 (range Ψ= 0.29-0.51) at Oka' Yanahli Preserve, southcentral Oklahoma. Bubble size indicates the value of the probability of site occupancy

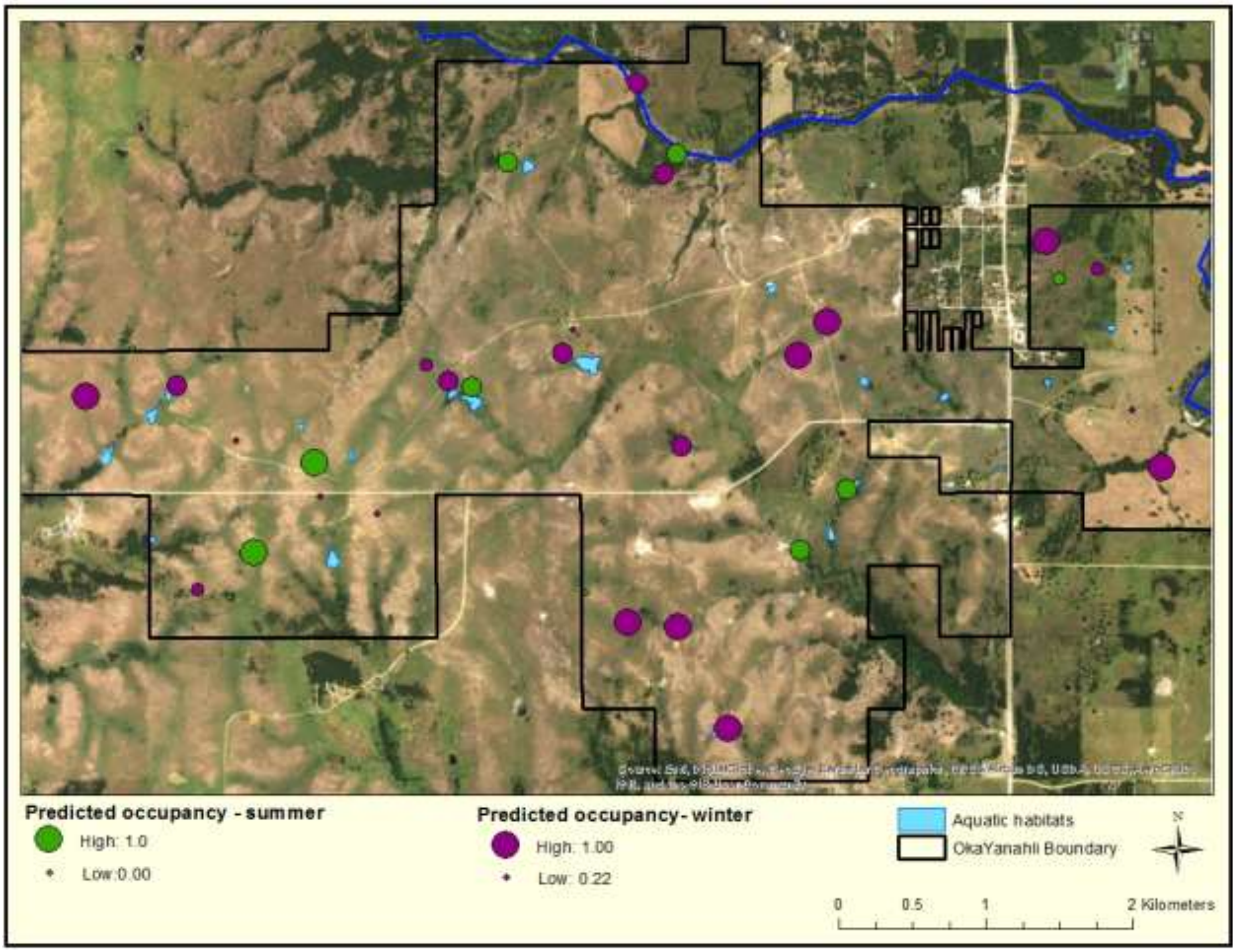

FIG. 16.— Predicted site occupancy of skunk derived from habitat covariate occupancy models in winter 2016-2017 (range Ψ= 0.22-1.0) and summer 2017 (range Ψ= 0.0-1.0) at Oka' Yanahli Preserve, southcentral Oklahoma. Bubble size indicates the value of the probability of site occupancy

Chapter 3 is written in the format accepted by the Journal of Mammalogy

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Does intraguild avoidance occur in mesocarnivores? Temporal activity pattern analysis of mesocarnivores in southcentral Oklahoma.

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Camera trapping has been increasingly used to monitor different ecological aspects of wildlife, specifically for elusive, large carnivores. Recently, camera-traps have been used to study temporal species interactions, most often for predator-prey relationships in large carnivores. Relatively few studies have been conducted on temporal activity overlap between mesocarnivore species using camera-traps, and no such studies have been done in Oklahoma. My study was conducted at Oka' Yanahli Preserve (OYP), located in southcentral Oklahoma. The primary goal of this project was to identify temporal activity patterns of mesocarnivores present in this preserve and identify activity overlap and seasonal variations in their activity overlap. Camera traps were used to collect photographs of mesocarnivores in the preserve during winter (November 2016 – February 2017 and summer (May – August 2017). Six remotely-triggered infra-red cameras were deployed for 4 weeks. After 4 weeks, cameras were moved to different, random locations. Half of the cameras were systematically baited by using canned mackerel. A total of 1531 mesocarnivore pictures from winter and 1455 from summer were taken from 25 camera locations in winter and 18 camera locations in summer. Mesocarnivore species identified from both seasons were coyote (*Canis latrans),* raccoon *(Procyon lotor),* bobcat (*Lynx rufus),* Virginia opossum (*Didelphis virginiana),* and striped skunk (*Mephitis mephitis).* Temporal activity densities were higher for all species during winter than in summer (Circular Kernel Density Estimates) and all species were mostly nocturnal during winter whereas in summer coyote and raccoon were often active during the day. Bobcat were strictly nocturnal in both seasons. Temporal activities overlapped largely ($\Delta > 0.7$) between all species in winter, except for skunk. The summer had moderate activity overlap for all species ($\Delta < 0.7$). There was a significant difference in activity overlap within species, between two seasons ($p < 0.05$). Contradictory to what I expected, the data show that mesocarnivore species present in this preserve do not necessarily avoid each other, rather they co-exist through resource partitioning. Intraguild avoidance could be less expected in this preserve as supported by my results of large temporal overlap between the species.

Keywords: mesocarnivores, camera trapping, circular kernel density estimates

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The activity of any animal can be defined as the time that they spend performing fundamental processes needed for survival. Performing an activity costs more energetically than resting (Bu et al. 2016). For survival, animals have to perform various activities within their habitat (Bu et al. 2016). The activities they perform could expose them to elevated predation risk or thermal stress, thus they need to perform these activities in a way that is as energetically beneficial as possible (Rowcliffe et al. 2014).

The fundamental ecological niche of a species is its physiological range of tolerance for environmental factors in the absence of biotic interactions (Soberón and Arroyo-Peña 2017). Realized niche is the actual set of conditions used by an animal after interacting with other species, which include predation, diseases, and parasitism. However, environmental pressures, habitat fragmentation, and other anthropogenic influences have altered realized the niche of a vast number of species across the globe. In need of survival, animals have to utilize the resources that are available by niche partitioning and most importantly by co-existing with minimal conflicts (Monterroso et al. 2013). Therefore, activity time has been considered as one of the most important axes of niche space after food and habitat. Animals use activity time to segregate from each other to prevent antagonistic encounters (Carothers and Jaksić 1984). However, diel activity patterns and an adaptive routine of performing them according to the environmental structures have been inherited through evolutionary processes and shaped by flexible responses to the actual environment (Carothers and Jaksić 1984; Monterroso et al. 2013). The adaptive significance of diel activity and circadian rhythms are intrinsic and their plasticity for local environmental adaptations are rather restricted (Kavanau and Ramos 1975). For example, nocturnal animals have physical and physiological adaptations that could maximize their energetic expenditures when they behave nocturnally whereas diurnal animals have different types of adaptations. Using all these adaptations, animals try to utilize niche dimensions with low energetic demand while potentially avoiding predation (Brown et al. 1999; Monterroso et al. 2013).

Ecological niche partitioning in spatial and temporal scale is important when studying predator-prey relationships, intraguild predation, and intraguild competition. According to optimal foraging theory, predators have to utilize energy budgets in a way to gain the most energy that could ultimately increase fitness (Porfirio et al. 2016). On the other hand, species should avoid potentially risky areas by either using their behavioral adaptations or some physical characteristics that help them avoid predators. Prey try to minimize activity overlap with predators while predators try to maximize and synchronize their temporal overlap with prey. Therefore, animals are in an arms race when they partition their niches (Brown et al. 1999; Lima 2002; Monterroso et al. 2013).

With the decline of large carnivores, mesopredators have replaced the apex predator in most ecosystems (Roemer et al. 2009). Like all the other species, mesocarnivores divide their time performing several behaviors such as resting, hunting, defending their territories, and minimizing human conflict. Mesocarnivores can feed on a variety of prey species. Simultaneously, mesocarnivores are a very diverse group of mammals that could have intraguild predation or competition. Understanding the time allocation for each activity pattern by mesocarnivores provides useful information that can be used to understand behavioral and ecological aspects of energy expenditure for intraguild predation and species coexistence (Rowcliffe et al. 2014; Porfirio et al. 2016). Intraguild predation, activity overlap, and spatial and temporal avoidance within mesocarnivore guilds have not been the focus of much research in the midwestern United States.

Mesocarnivores are very proficient in altering their niche and dietary requirements according to their environment. Therefore, their realized niches and temporal activities are dynamic. At the same time, these deviations are mostly location specific. Mesocarnivores are a diverse group of mammals; they can be elusive, nocturnal, dietary specialists or sometimes generalists (Roemer et al. 2009). Therefore, monitoring their temporal activity patterns can be challenging. Temporal activity patterns have been traditionally studied through direct observation, radio-telemetry, and using laboratory equipment. Direct observations and radio-telemetry are tedious; sometimes radio collars can be lost during surveys and they do not give enough data on animal performance, physiology, or chronobiology (Shepard et al. 2008; Nathan et al. 2012; Rowcliffe et al. 2014). On the other hand, laboratory equipment could measure physiological performances but they are not helpful for understanding behavioral ecology of activity in the ecosystem (Shepard et al. 2008; Nathan et al. 2012). The use of camera traps is convenient in this situation where a single camera-trap could unveil secretive lives of many mesocarnivores in the wild. Camera-traps exclusively provide a large set of data that can be analyzed by using modern robust analyses. Animal detection times that print on a picture from a camera-trap can be used in various analytical methods. These data can be successfully used to identify species co-existence and niche partitioning. The degree of spatial overlap between sympatric species elucidates intraguild predation or avoidance. In order to extract this species-specific information, times from camera-trap data have to be considered as circular data. Analysis of circular data is specialized but well explained by mathematical equations and specific statistical analyses can be applied to camera trap data (Ridout and Linkie 2009; Linkie and Ridout 2011; Frey et al. 2017).

There are no standard analysis techniques, but many different methods have been proposed to quantify temporal activity from camera trap data. Innovative circular density application to camera-trap data to analyze activity patterns was first described by Ridout and Linkie (2009). Circular density application to camera trap data has been further developed and added to R statistical software as a ‘package’. In this method, temporal activity overlap between two species can be applied to male-female or predator-prey interactions. Observed captured samples are considered as random samples and their probability density functions are calculated in this method. The coefficient of overlap (Δ) is estimated by nonparametric Kernel Density estimates (Ridout and Linkie 2009; Linkie and Ridout 2011; Frey et al. 2017). The key element is that the recorded time of an animal detection within a day is considered as a circular random variable and its underlying density is bimodal. Because time is a circular function within a day and its origin is arbitrary, classical statistical approaches like mean, standard deviation or regression cannot be used (Ridout and Linkie 2009).

In this research I used detection data of mesocarnivores at Oka' Yanahli Preserve in southcentral Oklahoma and fitted them in circular density estimates to identify temporal activity patterns of individual mesocarnivore species in winter and summer seasons. Also, I analyzed temporal activity overlap between sympatric mesocarnivore species to identify any temporal activity relationships. I expected that coyote (*Canis latrans*) and bobcat *(Lynx rufus*) would avoid each other temporally, hence they should have minimal activity overlap. Bobcats are more elusive than coyote and bobcat cubs could be eaten by coyotes (Knick 1990; Koehler and Hornocker 1991; Palomares and Caro 1999). I also predicted that opossum (*Didelphis virginiana*), raccoons (*Procyon lotor*), and skunk (*Mephitis mephitis*) should also avoid coyotes because coyotes are larger in body size and more ubiquitous. (Gehring and Swihart 2003; Prange and Gehrt 2007). I also predicted that there should be a significant difference in coefficient of activity overlap in mesocarnivore guild between winter and summer seasons. Abundant resources in summer may decrease the need for intraguild competition.

MATERIALS AND METHODS

Study area.—Oka' Yanahli Preserve (OYP) is located in Johnston County, south central Oklahoma (34°26'14.7"N 96°38'09.9"W), and is managed by The Nature Conservancy. It is located about 40 km south of Ada and about 24 km north of Tishomingo, on the Arbuckle Mountain Plains (Fig. 1). The preserve consists of 1457 ha along 3.2 km of the Blue River. The Blue River is one of only two rivers in the state of Oklahoma that freely flows without any human disturbances or constructions. The Arbuckle-Simpson Aquifer sustains the Blue River and OYP is the main restoration of the Aquifer. Oka' Yanahli Preserve is a part of Cross Timbers forest-mixed grass prairie ecoregion; which is an ecotone between the eastern deciduous forest and the Great Plains. Tree species like post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), American elm (*Ulmus americana*) and intermittent eastern red cedar (*Juniperus virginiana*) occur in forests in the area (Kasparian et al. 2004). The prairie is dominated by silver bluestem (*Andropogon saccharoides*), little bluestem (*Andropogon scoparius*), broomsedge bluestem (*Andropogon virginicus*), oldfield threeawn (*Aristida oligantha*), and buffalograss (*Bouteloua dactyloides*). Some other grasses and forbes include prairie dropseed (*Sporobolus hetrolepis*), sideoats grama (*Bouteloua curtipendula*), compass plant (*Silphium laciniatum*), leadplant (*Amorpha canescens*), wild alfalfa/scurf pea (*Psoralea tenuifolia*), Illinois bundleflower (*Desmanthus illinoensis*), blazing star (*Liatris sp*.), goldenrod (*Solidago sp*.), Indian paintbrush (*Castillega coccinea*), and Maximillian sunflower (*Helianthus maximilliani*) (Diamond and Elliott 2015).

The specific habitat types that can be identified within the preserve are aquatic habitats consisting of abandoned ponds, ephemeral pools, and riparian corridors;

bottomland forests; and prairie (Appendix C). The area that is presently OYP has been subjected to extensive cultivation since the 19^{th} century, oldfield and ranches of previous owners can still be seen on the preserve. In winter there was a period that OYP was opened to deer hunting and cattle grazing during summer (Appendix D).

The average annual precipitation of the study area is 99-120 cm and most precipitation occurs from midsummer to fall (Oklahoma Climatological Survey 2017). During winter months there is an average of 2 cm of snow. In summer the temperature is as high as 35 $^{\circ}$C, in winter it is as low as -1.6 $^{\circ}$C, and the annual average temperature is 17 $^{\circ}$C. Average frost-free days are 224-231 and the average growing season is 212 days. Wind speed is on average 12 km/h. and relative humidity ranges from 42% to 96%. Highest humidity is in May and lowest in August. On average there are 45 thunderstorms per year (Oklahoma Climatological Survey 2017).

There are about 40 different soil types in OYP. Among them Kaufman clay and Verdigris silty clay loam can be seen near Blue River. All other areas inside OYP consist of Claremore-Rock outcrop, Durant loam, Kiti-Rock outcrop, Lula loam, and Stephenville fine sandy loam in various percentages (The Nature Conservancy unpublished data; USDA Web Soil Survey 2017).

Camera trapping.—Camera surveys were conducted in two seasons. The winter season lasted from November 2016 to February 2017 and summer season was May to August 2017. During a preliminary visit to the study site in Fall 2016, various habitat types were identified. Using ArcGIS 10.4 (Environmental Systems Research Institute, Redlands, CA), a map with 100 random camera trap locations was made to determine the locations for the cameras during both winter and summer seasons. Camera traps were Reconyx HC

500 Hyper Fire Semi-Covert Cameras, which have infra-red, motion trigger function (Reconyx Inc., 3828 Creekside Ln, Site 2, Holmen, WI 54636). Cameras were set to be active 24 hours a day with 3 pictures per movement and picture interval was 1 second. The quiet period was 5 minutes. Picture resolution was 1080 pixels. Each camera had a specific identification number. Date, time, and the temperature were recorded on pictures for each movement.

Eight camera traps were set in November 2016. Subsequently, 6 camera traps were set each month in new, random locations. Coordinates (UTM) of the random locations were uploaded to the GPS unit (model-GPSMAP64S, Garmin International Inc. Kansas City, MO). In the field, locations were identified using the GPS. Sometimes there were no trees/posts to attach the cameras in that exact same location; in that case, they were set up in nearest appropriate locations. Coordinates were updated into the GIS database. Cameras were placed about 0.5─1 m above ground, facing downwards. Usually, cameras were attached to trees, bushes, or fence posts, but when not available wooden posts with stable stands were used (Appendix C).

Cameras were systematically baited by using canned mackerel (Kelly and Holub 2008). The bait was placed 1─2 m away from the camera. The 1st, 3rd, 5th cameras were baited. I did not use heavy animal carcasses as bait because I did not want to attract animals just for the bait if they do not naturally occur in that area. Photographs of the camera location and surrounding habitat type were taken. Cameras remained at that location for 3─4 weeks (Cove et al. 2013). One to 2 weeks after initial placement, a field technician checked the cameras, downloaded pictures, and replaced the batteries and memory cards. The technician also re-baited the cameras in the same systematic way.

After 3–4 weeks, cameras were picked up from initial locations and moved to different random locations. I had 25 camera locations in winter and 18 camera locations in summer. Camera malfunctions were rarely identified and did not affect the survey during either season.

Data analysis.—After winter 2016-2017 and summer 2017 seasons ended, I obtained all the pictures from all locations and looked for possible detections. When there was a mesocarnivore detection, I recorded species, number of animals per picture, location, camera ID, the date the trap was set, date detected, time of the first picture, time of the last picture, number of pictures recorded during that detection, temperature, and bait status. Following Bu et al. (2016), I quantified the relative activity indices (RAI) for each species during winter and summer seasons. RAI is the number of detections per 1000 camera days. It is the ratio of number of detections per species in each month and camera-days in that month multiplied by 1000 camera days. Consecutive pictures of the same species and multiple animals in pictures were considered as a single detection.

Using data from camera traps to calculate temporal activity overlap and partitioning is a relatively new method. Camera-trap data were used in nonparametric circular density functions, and activity analysis was conducted through circular inferential statistics (Ridout and Linkie 2009; Linkie and Ridout 2011; Frey et al. 2017). In this method, time of the day was considered as a continuous variable over the course of 24 hours per day and species detection times were considered random samples from that continuous variable, and used in probability density functions (PDF) (Lashley et al. 2018). I estimated activity pattern of each species during each season using Kernel Density estimation for circular data and activity overlap using the coefficient of overlap

(Δ) (Ridout and Linkie 2009; Porfirio et al. 2016). The coefficient of overlap describes how much 2 activity patterns are similar or their degree of overlap. The coefficient of overlap varies from 0 to 1, where 0 is no overlap and 1 is complete overlap (Penido et al. 2017). According to Ridout and Linkie (2009), Kernel Density estimate considers camera trap pictures as random samples with an underlying continuous distribution. Therefore, they are not categorized into discrete time variables. Ridout and Linkie (2009) described several mathematical formulas to estimate Δ, and out of those I selected the estimator Δ_1 which was recommended for smaller samples where the lowest sample was below 50 records. Confidence intervals of Δ_1 were calculated as a percentile of intervals from 10000 bootstraps (Ridout and Linkie 2009; Linkie and Ridout 2011; Frey et al. 2017). If $\Delta>0.7$, coefficient of activity overlap was considered higher activity overlap and $0.4< \Delta$ was considered as lower activity overlap (Bu et al. 2016). Moderate coefficient of activity overlap was $0.4<\Delta< 0.7$.

To calculate Δ, I obtained detection time of all species from pictures. Animal detections differed between baited camera traps vs unbaited camera traps (Chapter 2). I assumed that presence of bait alone would not be able to drive a mesocarnivore to a camera, but an individual already needed to be active and moving across the landscape in order to encounter bait (Satterfield 2014; Satterfield et al. 2017). Hence, in this analysis all detections were considered as random samples. However, the animals tend to move around baited sites frequently. Pictures having detections less than 2 hours apart from same camera locations were deemed 1 detection, to prevent pseudoreplication. Also, if there was more than one animal in one picture, it was considered as a single detection (Bu et al. 2016). All detections between 0600─1800 hours were considered as diurnal and 1800─0600 hours were considered as nocturnal. All detection times were calculated into a fraction of 24 hours and converted into radians. All statistical analyses were performed using R software (R Software Core team 2018 version 3.4.3) using packages Overlap, Circular, and Boot (Meredith and Ridout 2014). Opossum had a single detection during summer 2017 and therefore was not analyzed. In order to identify if there was a significant difference in the values of coefficient of overlap between winter and summer season of mesocarnivore species pairs, a paired samples t-test was performed using SPSS software (IBM SPSS Statistics version 24).

RESULTS

I had 25 camera locations in winter and 18 camera locations in summer. I recorded 1444 camera nights for both winter and summer seasons, with 844 camera nights in winter and 600 in summer (Table 1). More than 100,000 pictures were recorded. Among them, 4,233 pictures were obtained for mesocarnivores. Winter season had a higher number of pictures (2,778) than summer season (1,455). Mesocarnivore species recorded were coyote, bobcat, opossum, raccoon, and striped skunk. Higher Relative Activity Indices (RAI) were recorded from winter than summer for all species (Fig. 1). All species recorded their highest RAI between December to February. RAI was comparatively low during summer months.

Diel activity patterns and temporal overlap.—Kernel Density Estimates (KDE) for single species during winter season show that all species started their activity around 0600 hours and reduced it by 0600─0700 hours the following day, with few crepuscular activities. The graphs (Fig. 2) show that overall recorded mesocarnivore species were highly nocturnal during the winter season. Coyote, opossum, and raccoon had few activities during the daytime around 1200 hours while bobcat and skunk were not active during the day.

In summer, 4 species had variable KDE peaks (Fig. 3). Skunks followed a similar activity pattern in summer like in winter with an elevated activity peak slightly after 1800 hours that dissolved slightly before 0600 hours (Fig. 3). Bobcats were only active from 1900─2400 hours with high activity peaks, which was different from winter activity. Raccoons were active slightly after 2400 hours until around 0700 hours while coyotes were active throughout the day. Coyote and raccoon activity was different from winter season with more diel activity peaks during summer (Fig. 3).

During the winter season, almost all mesocarnivore pairs had a high coefficient of activity overlap ($\Delta > 0.7$), except for bobcat-skunk and coyote-skunk ($0.4 < \Delta<0.7$), which were moderate (Table 2, Fig. 4). During summer, all mesocarnivore pairs had moderate activity overlap ($0.4 < \Delta < 0.7$), except for raccoon-skunk ($\Delta>0.7$) which was high (Table 3, Fig. 5). However, activity overlap patterns were dissimilar from winter activity patterns. Diel activity overlaps were almost zero and most activity overlaps were nocturnal during 1800─2400 hours (Fig. 5).

Diel activity patterns and temporal overlap during winter and summer seasons for each mesocarnivore species are shown in Fig. 6. Each species shows different seasonal variations. Coyote had higher nocturnal activity during winter, and higher diurnal activity during summer. Bobcat had higher nocturnal activity with very low to no diurnal activity during both seasons. Summer nocturnal activity was higher than winter for bobcat. Raccoon and skunk had similar seasonal activity variations with higher nocturnal activity densities in both seasons compared to diurnal activity densities (Fig. 6). Nocturnal activity in summer was higher than winter for both species. Paired samples t-test performed for the coefficient of overlap values between mesocarnivore pairs between two season resulted in a significant difference ($t = 2.705$, $p = 0.043$) between winter and summer seasons. Therefore, there is a significant difference in activity overlap pattern within mesocarnivore guilds between winter and summer seasons.

DISCUSSION

Camera-trap data provides a large amount of useful data that can be incorporated into various activity pattern analyses. I used the Kernel Density Estimations using circular activity cycles to model temporal activity between mesocarnivore species (Ridout and Linkie 2009; Meredith and Ridout 2014). During the winter season, RAI was higher for all the detected species in the months of December to February, and then activity gradually declined. The lack of available resources, such as food and water, during the winter months is likely to contribute to this increased activity during this time. All mesocarnivore species that I detected consume small mammals, like rats, mice, and rabbits, that they could not easily find during the winter season. The effect of bait that I used at some camera stations would attract mesocarnivores, hence their activity increased. The wind speed of Oklahoma was relatively higher (average wind speed 31 km/h in spring and 26 km/h in summer in Johnston County) than other states that did similar studies (Lashley et al. 2018), and could have possibly spread the smell of bait and attracted mesocarnivores. During summer, there was cattle grazing and more human activities at OYP that may have had an influence on low relative activity. According to previous research, coyotes do not necessarily avoid cattle, but there were some human activities associated with cattle that could led coyotes and other species to avoid the preserve during summer season (Symmank et al. 2014; Wang et al. 2015; Murray and St. Clair 2015)

Temporal activity densities at OYP were higher in winter than summer for all species. Coyotes were ubiquitous in habitat requirements as shown in chapter 2. They were more nocturnal or crepuscular during the winter than summer. Mammals are known to change their daily rhythmic activity according to their thermoregulatory energy requirements (Pavey et al. 2016). In winter, homoeothermic animals could alter their foraging and other related activities in a way that would maximize their foraging activities. Consequently, all detected mesocarnivore species were nocturnal because the potential of finding prey at night is higher in winter than summer (Symmank et al. 2014). This is likely the case for coyotes because they travel significantly higher distances at night in winter when they are not breeding or rearing pups (Andelt and Gipson 1979). Bobcats are more elusive and avoid any human activities, hence they also tend to be nocturnal (Lesmeister et al. 2015). My results agree with other related studies about winter activity patterns of bobcats, primarily that they are active during crepuscular and mostly nocturnal times (Tigasa et al. 2002; Lesmeister et al. 2015). Raccoon and skunk activity patterns were similar to each other, showing high-density peaks from 1800─0600 hours and absolutely no activity during 0600─1800 hours which was daytime. Raccoons are predominantly nocturnal. Raccoon breeding season starts during March, with movement increasing as much as twice regular distance travelled, about 6.1 km for a female and 8.2 km for a male (Greenwood 1982; Newbury and Nelson 2007). In Illinois, Newbury and Nelson (2007) showed raccoons foraged around barns and domestic households during winter and avoided open grassland where there were less food sources like bird nests. OYP contains a lot of meadows, therefore, less activity during daytime in winter could be expected because lack of food sources.

In contrast, summer had slightly different activity patterns than winter. Bobcat activity was recorded between 1800─2400 hours, and skunks also had no diurnal activity recorded. Coyote and raccoon had increased diurnal activities compared to winter. Coyote, bobcat, raccoon, and skunk have their breeding season during spring, therefore they should be active throughout the day while nurturing their pups in summer (Ozoga and Harger 1966). Ozoga and Harger (1966) reported that lactating coyote females tend to travel as far as males during summer. My results of coyote activity pattern during summer supported the results of previous studies (Ozoga and Harger 1966; Lesmeister et al. 2015). Bobcat males and females usually live separately with wider home range separations, but they live in close proximity during the breeding season (Lawhead 1984). Bobcat breeding season is from March to May and during this time they are highly active (Lawhead 1984). I may have detected higher activity during winter than summer because my winter sampling was overlapped with bobcat breeding season. During kitten rearing season, bobcat male and female separation would be maximum and their home ranges are much larger during that time (Lawhead 1984). Usually kitten rearing season falls in the summer (Lawhead 1984) and might be the reason for lower activity and detection at OYP in summer.

Contrary to what I expected, coyote and bobcat activity patterns were largely overlapped during winter. Bobcats have more elusive behavior than coyotes, I expected that they would avoid coyotes during their active periods. However, coyote and bobcat had activity overlap throughout 24-hour period with lower diurnal overlap and higher nocturnal overlap. Similar studies have found that bobcats do not completely avoid coyotes, and on some occasions they do coexist (Fedriani et al. 2000; Lesmeister et al. 2015). Bobcats are solely carnivorous and their diet mainly consists of rodents and lagomorphs. Coyotes are mostly carnivorous but their diet has seasonal variations. Coyote sometimes depend upon deer carcasses, and in some cases invertebrates. These two mesocarnivores could co-exist by separating their resource use. This type of resource partitioning could yield realized niche partitioning due to competition. Coyotes have a larger fundamental niche that overlaps bobcats so they utilize the portion with least overlap to reduce competition (Lesmeister et al. 2015; Neale et al. 2001; Wilson et al. 2010). Evidence from these studies further supports the use of habitat from my occupancy estimate results for each species during the winter season (Chapter 2). Coyotes had higher site occupancy in both riparian and meadows, but low occupancy in wooded habitat. Bobcat, on the other hand, had high site occupancy in wooded habitat. My results strongly support the fact that both species coexist by resource and habitat partitioning that is exhibited by their spatial patterns.

Due to the omnipresence of coyotes, I expected that their activity would overlap with other small mesocarnivores. Raccoon and opossum had a higher coefficient of overlap with coyote while skunk had considerably low activity overlap with coyotes in winter. According to the Mesopredator Release Hypothesis (MRH) (Crooks and Soulè 1999), large mesocarnivores have a profound impact on smaller mesocarnivores. The intensity of the impact may depend upon the defensive mechanisms coupled with the intensity of competition between small mesocarnivores and coyotes (Prange and Gehrt 2007). According to MRH, coyotes have the ability to significantly reduce the population numbers of skunks, opossums, and raccoons. A considerable amount of research around the United States has still failed to identify skunks or raccoons in coyote diet (Prange and Gehrt 2007). Therefore, predation may not be the major reason for avoidance of coyotes by skunk, raccoon, and opossum. In fact, there is evidence that they actually do not temporally avoid coyotes (Crooks and Soulè 1999; Prange and Gehrt 2007; Sovada et al. 2000).

Coyote and bobcats are more carnivorous than raccoons, who are more generalists in their diet. Having a larger body size than all the prey species of coyotes and bobcats, Lesmeister et al. (2015) observed that a raccoon can successfully defend deer carcasses from coyote. Hence, there should be less intraguild predation between coyote, bobcat, and raccoon because all species are physically large that allows them to co-exist and have high temporal activity overlap. These findings could be further strengthened by my findings of activity overlap among these three species. Identical to raccoons, opossums also followed the same activity overlap with both coyote and bobcat. Opossum activity and behavior are strongly associated with aquatic habitat and precipitation. Moreover, an opossum cannot tolerate freezing temperatures, resulting in reduced activity with decreasing temperatures (Troyer et al. 2014). Other research provides evidence that coyote and bobcat are not major predators of opossum (Prange and Gehrt 2007; Cove et al. 2012). High activity overlap of opossum with coyote and bobcat observed in my study strongly support the current findings on mesocarnivore resource partitioning and co-existence. On the other hand, skunk had slightly lower activity overlap with coyote and bobcat compared to raccoon and opossum. Skunk is predominantly nocturnal in winter with zero activity during the daytime. A possible reason would be to avoid sympatric large mesocarnivores. However, other researchers have evidence that skunk and coyote can co-exist with slight interspecific avoidance due to conspicuous coloration in pelage of skunks and their defensive noxiousness (Aleksiuk and Stewart 1977; Prange and Gehrt 2007; Lesmeister et al. 2015).

Significant different coefficients of overlap of mesocarnivore species between winter and summer indicate that there are seasonal variations in activity overlap within the guild. Possible reasons could be the effect of climate in southcentral Oklahoma and human alterations to the landscape during summer. The abundance of natural resources in summer may possibly be another reason. Comparatively, summer had lower detections than in winter; the opossum had only one detection. Lowest temporal activity overlap was recorded between coyote and bobcat in summer. Bobcat was strictly nocturnal during summer and coyote had elevated activity pattern throughout the day. Plowman et al. (2006) determined that bobcats shift their home ranges due to the availability of resources and cover availability in the summer season. There are no adequate references to evaluate the relevancy of this fact specifically to southcentral Oklahoma, but my results with low detections and low activity overlap support similar studies done in other areas (Plowman et al. 2006; Lesmeister et al. 2015; Satterfield 2014).

During the summer, the most influential event that happened at OYP was cattle grazing. Cattle may not have had a significant influence on coyote behavior because they had higher diurnal activities in summer than winter. Coyote are a predator of new born calves, but they occasionally attack cows as well (Gilliland 1995). Similar studies have found that coyote home range overlap with cattle ranches, but they aggregate more around carcasses of cattle rather than live cattle (Danner and Smith 1980; Bradley and Fagre 1988). Therefore, the presence of cattle may not have affected the activity of coyote during summer, as indicated by my results.

Southcentral Oklahoma summer weather could be another possibility for low activity detections. Most species prefer to be near cover and the preserve mostly consists of open grassland with little cover. The highest activity overlap was recorded for raccoon and skunk. Skunk activity tends to increase during late spring to summer with an abundance of insects and other natural resources (Lesmeister et al. 2015). Increased skunk activity could possibly overlap with raccoons rather than coyote and bobcat. However, more research and data are needed to investigate this activity overlap between skunk and raccoon.

There was no seasonal variation in activity patterns of skunk and raccoon because they followed the same pattern in both seasons. Coyote and bobcat had seasonal variations in activity pattern. Coyote summer activity was more diurnal and could be due to rearing, nurturing, and hunting with pups. Bobcats were strictly nocturnal during summer compared to winter because bobcat have sex-specific activity patterns related to parturition (Allen et al. 2015). When female bobcats have neonatal young, they tend to hunt during night. From males' perspective summer nocturnal behavior could relate to territorial behavior (Chamberlain et al. 1998; Allen et al. 2015). Nocturnal activity of bobcat during summer coincides with changes in Lagomorph activity during summer, a primary prey item of bobcat (Chamberlain et al. 1998). Compared to coyote and bobcat, raccoons and skunks are smaller in size. Smaller species have to seek cover even during their foraging. That would be the best reason why I could not identify specific season variation in activity patterns of raccoon and skunk. However specific research is needed to clarify this question.

In conclusion, this study supported the fact that strong intraguild competition may not always happen within carnivore communities. My data suggests species tend to coexist and structure the community in a way that all of them could co-exist. Strong competition may occur between species with very high dietary overlap or foraging strategies. The targeted mesocarnivore species in this research did not have strong dietary overlap or inference competition between each other. Therefore, they could co-exist. Future research is needed to identify how this intraguild co-existence could affect the herbivore community structure, when TNC introduces bison to OYP.

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TABLE 1.—Camera days and numbers of independent detections of each mesocarnivore species coyote (*Canis latrans*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), and skunk (*Mephitis mephitis*) detected during the camera-trap survey in winter (November 2016- February 2017) and summer (May – August 2017) at Oka' Yanahli Preserve, southcentral Oklahoma.

	Winter season	Summer season	Totals
Camera days	844	600	1444
Species Detections			
coyote	80	24	104
bobcat	22	3	25
raccoon	138	31	169
opossum	60	1	61
skunk	19	4	22

TABLE 2.—Estimated activity level overlap of 5 mesocarnivore species coyote (*Canis latrans*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), and skunk (*Mephitis mephitis*) detected during the camera-trap survey in winter (November 2016- February 2017) at Oka' Yanahli Preserve, southcentral Oklahoma. The coefficient of activity overlap obtained from circular density functions, with overlap value, upper, and lower 95% confidence intervals are given in the table.

Species	The coefficient of Overlap (Δ)			95% Confidence intervals	
	Type	Lowest Value	Overlap value	Upper	Lower
coyote-bobcat	Δ_1	22	0.776	0.915	0.620
coyote-raccoon	Δ_4	76	0.799	0.888	0.699
coyote-opossum	Δ_1	42	0.745	0.833	0.644
coyote- skunk	Δ_1	18	0.674	0.835	0.494
bobcat-raccoon	Δ_1	22	0.719	0.910	0.601
bobcat-skunk	Δ_1	18	0.693	0.908	0.550
bobcat-opossum	Δ_1	22	0.759	0.888	0.611
raccoon-opossum	Δ_1	42	0.788	0.879	0.628
raccoon-skunk	Δ_1	18	0.722	0.920	0.572

TABLE 3.—Estimated activity level overlap of 4 mesocarnivore species coyote (*Canis latrans*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), and skunk (*Mephitis mephitis*) detected during the camera-trap survey in summer (May – August 2017) at Oka' Yanahli Preserve, southcentral Oklahoma. The coefficient of activity overlap obtained from circular density functions, with overlap value, upper, and lower 95% confidence intervals are given in the table

Species	The coefficient of overlap (Δ)			95% Confidence intervals	
	Type	Lowest value	Overlap Value	Upper	Lower
coyote-bobcat	Δ_1	3	0.231	0.368	0.074
coyote-raccoon	Δ_1	24	0.532	0.718	0.343
coyote- skunk	Δ_1	4	0.454	0.706	0.203
bobcat-raccoon	Δ_1	3	0.568	0.710	0.402
bobcat-skunk	Δ_1	3	0.477	0.646	0.280
raccoon-skunk	Δ_1	4	0.797	0.827	0.463

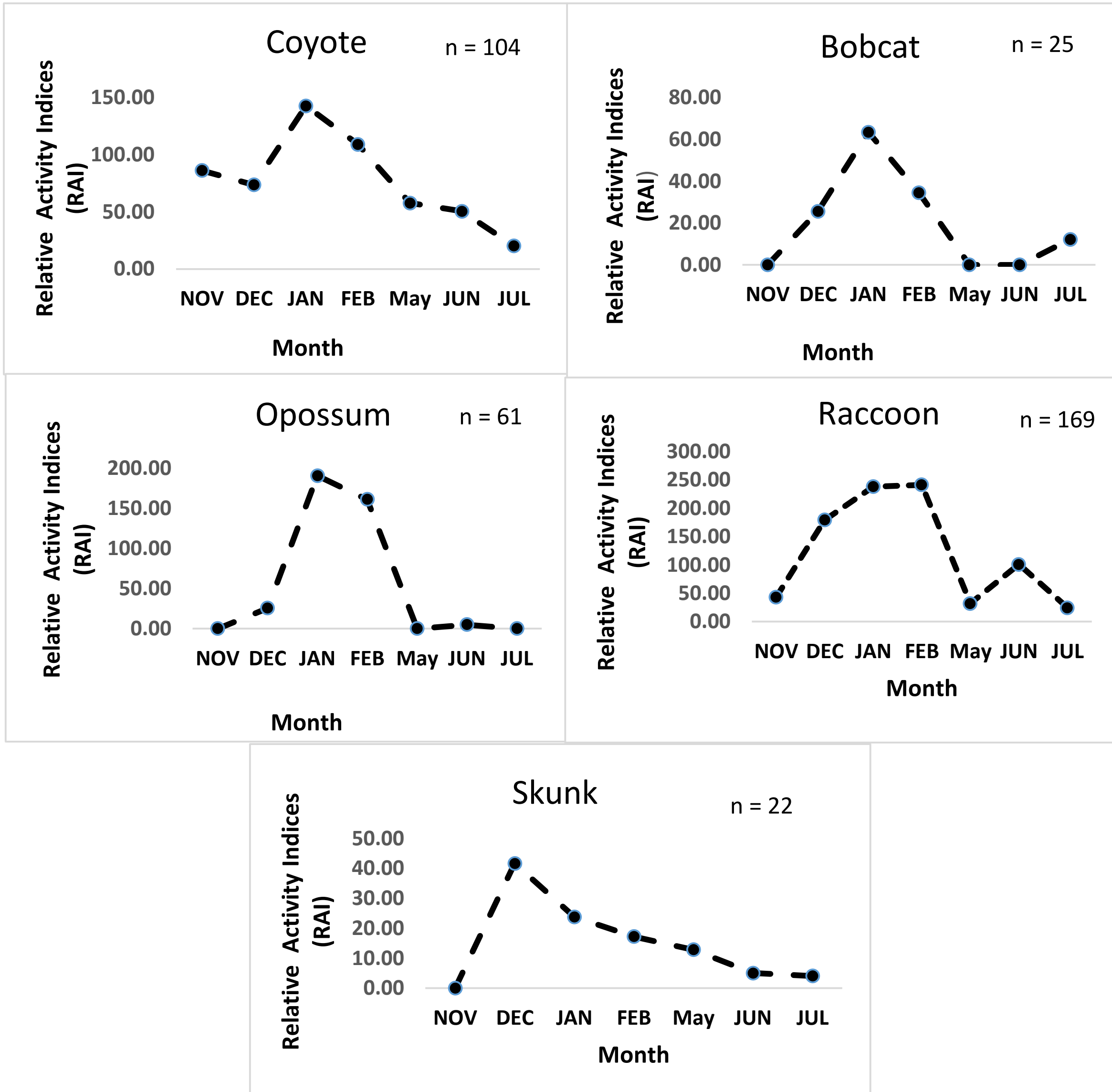

FIG. 1. —Relative activity indices (RAI, number of detections per 1,000 camera-days) in each month of both winter (November 2016 – February 2017) and summer (May – August 2017) seasons and number of total detections (n) for each mesocarnivore species at Oka' Yanahli Preserve southcentral Oklahoma.

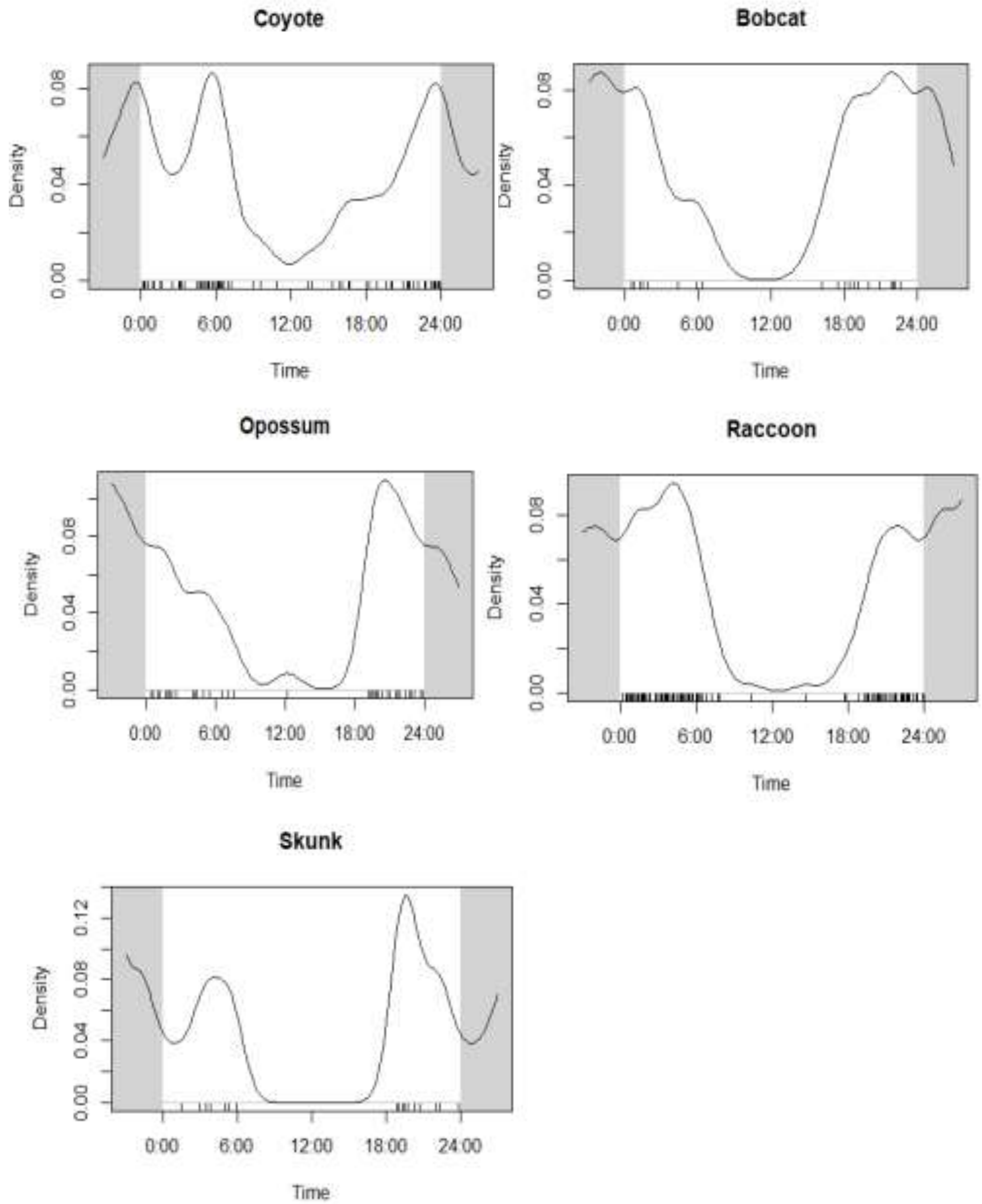

FIG. 2.—Activity patterns of 5 species of mesocarnivores coyote (*Canis latrans*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), and skunk (*Mephitis mephitis*) detected during the camera-trap survey in winter (November 2016-February 2017) at Oka' Yanahli Preserve, southcentral Oklahoma as captured by camera trap records. Solid curves are fitted circular kernel density distributions along with the time of the day. The actual data are shown at the foot of each figure as a `rug'.

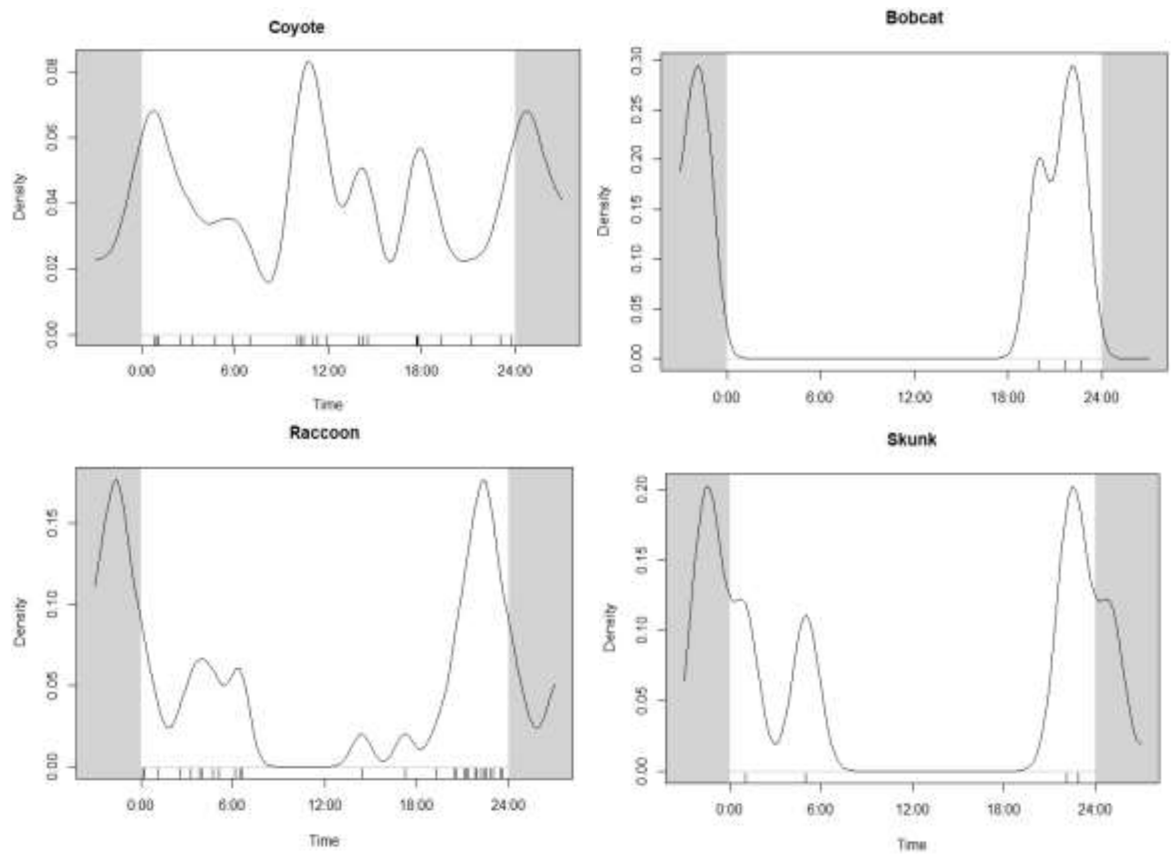

FIG. 3.—Activity patterns of 4 species of mesocarnivores coyote (*Canis latrans*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), and skunk (*Mephitis mephitis*) detected during the camera-trap survey in summer (May- August 2017) at Oka' Yanahli Preserve, southcentral Oklahoma as captured by camera trap records. Solid curves are fitted circular kernel density distributions along with the time of the day. The actual data are shown at the foot of each figure as a `rug'.

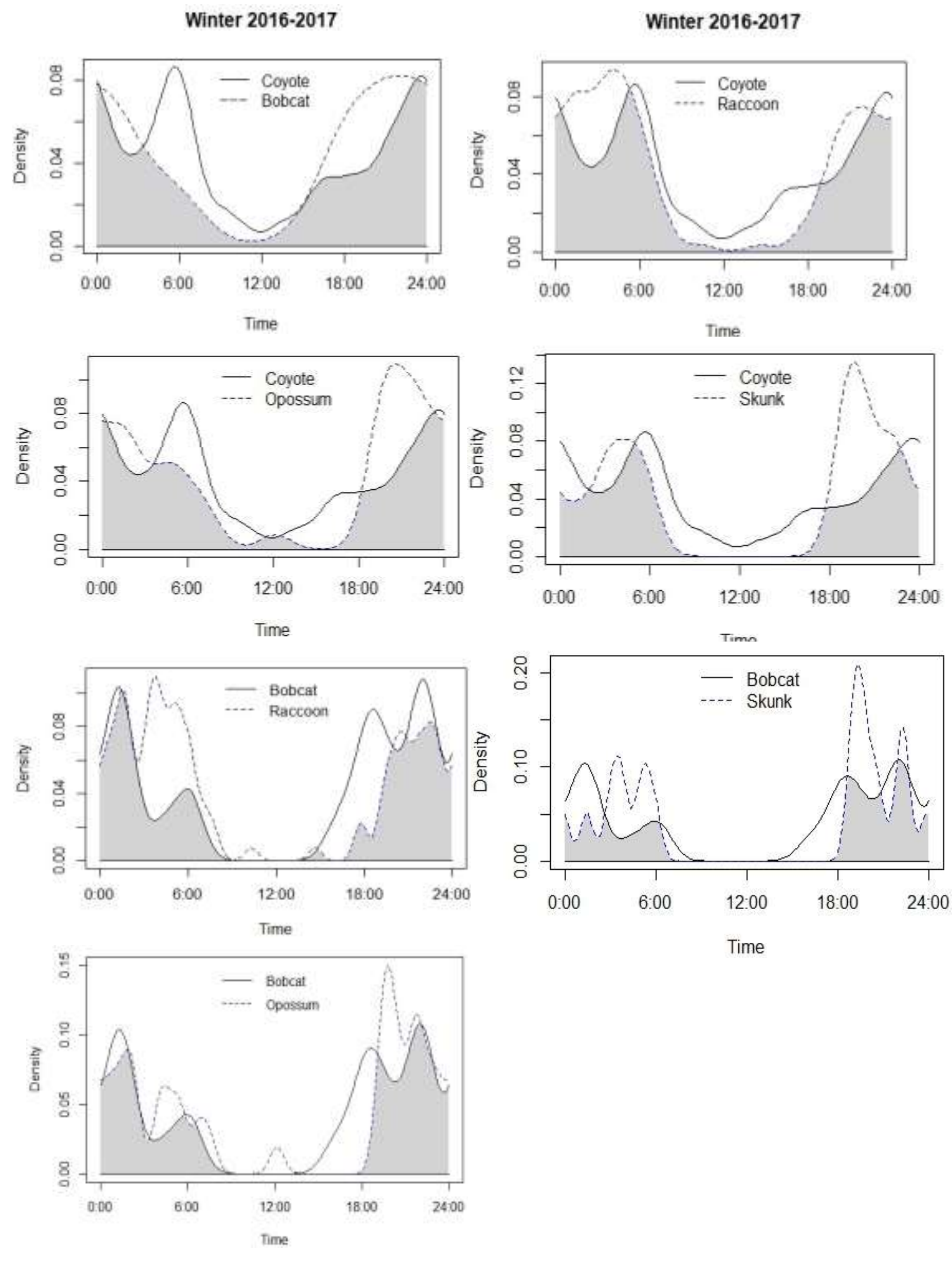

FIG. 4.—Continued to next page

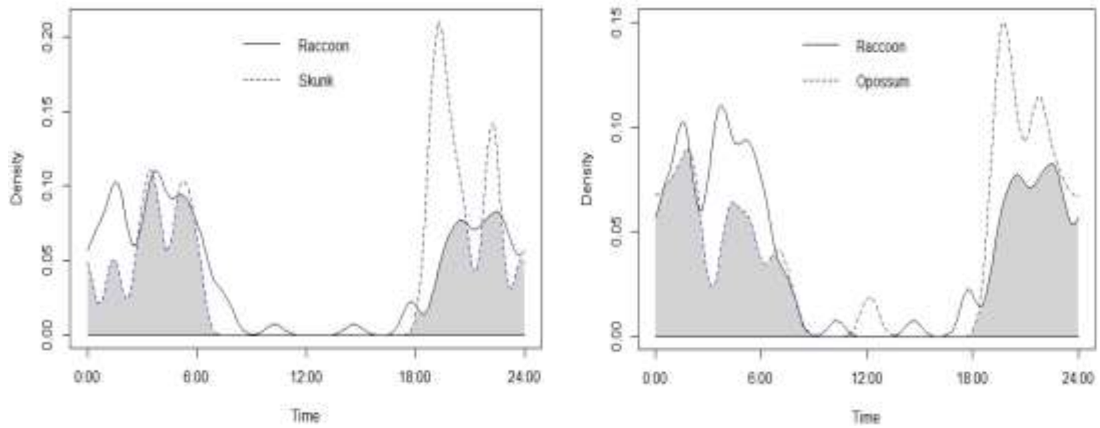

FIG. 4.—Activity patterns and temporal activity overlap between 5 species of mesocarnivores during the winter season (November 2016 to February 2017) in Oka' Yanahli Preserve at southcentral Oklahoma. The y-axis is the Kernel Density Estimates. The overlap area was denoted in grey. Species names are given in the legend of each graph.

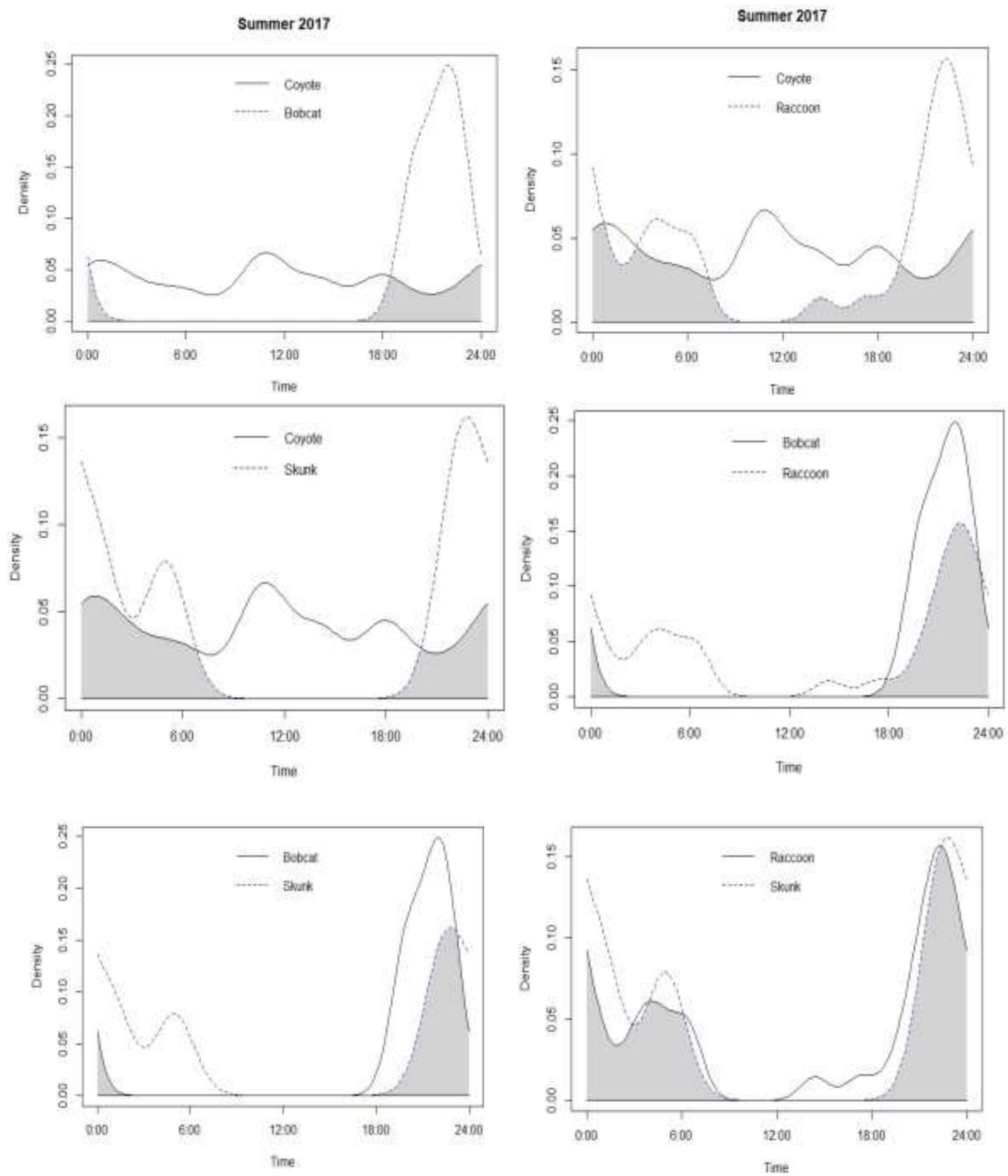

FIG. 5.—Activity patterns and temporal overlap of 4 mesocarnivore species during summer season (May to August 2017) in Oka' Yanahli Preserve southcentral Oklahoma. The y-axis is the Kernel Density Estimates. The overlap area was denoted in grey. Species names are given in the legend of each graph.

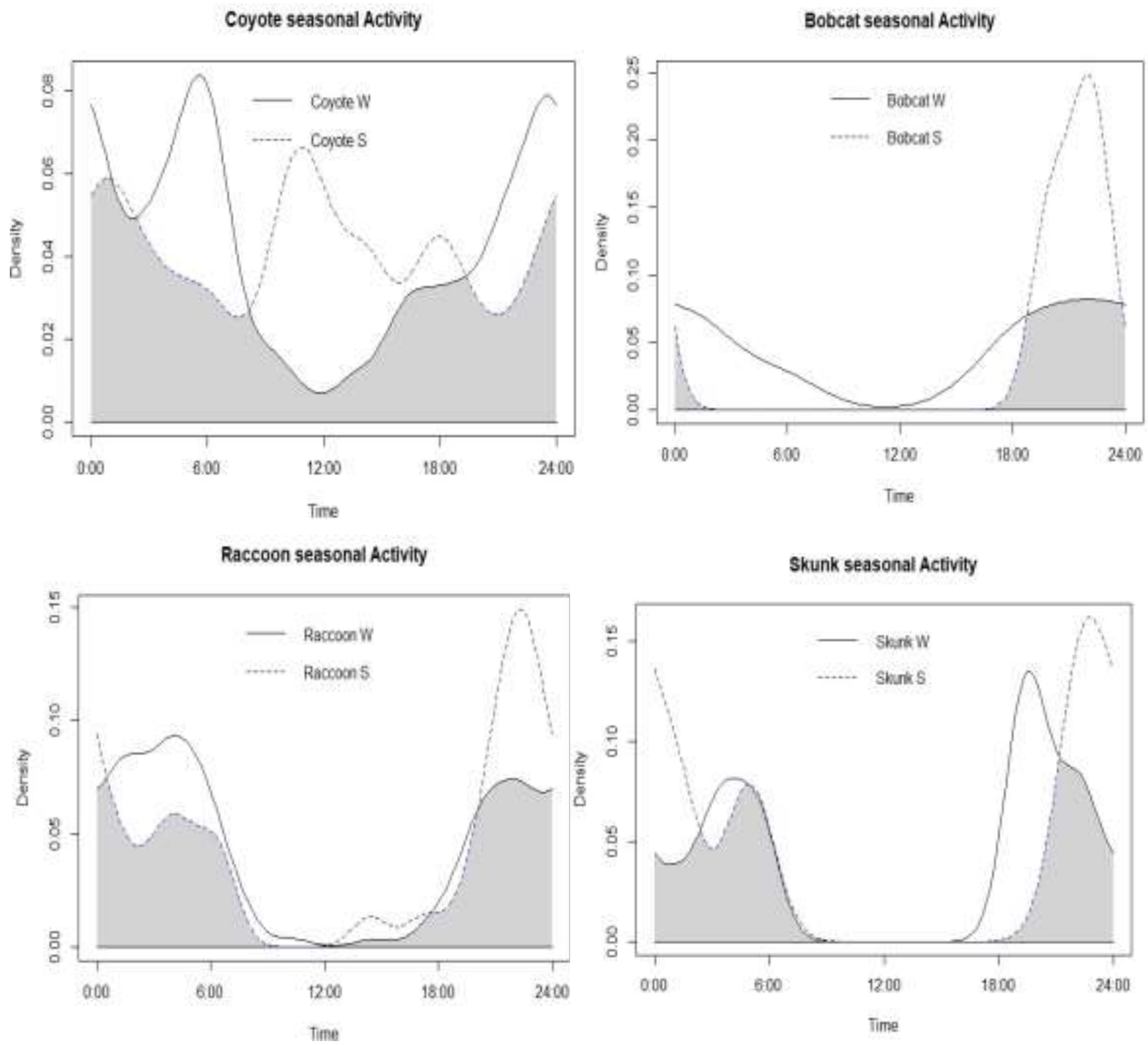

FIG. 6.—Diel activity patterns and temporal overlap in the same species of mesocarnivores during the winter season (November 2016 to February 2017) and summer season (May to August 2017) in Oka' Yanahli Preserve southcentral Oklahoma. The y-axis is the Kernel Density Estimates. The overlap area was denoted in grey. Species names are given in the legend of each graph and the abbreviations W=winter and S=summer.

CHAPTER 4
CONCLUSIONS AND FUTURE DIRECTIONS

In this study I analyzed occupancy estimates and activity patterns of mesocarnivores found in Oka’ Yanahli Preserve at southcentral Oklahoma. Mesocarnivore spatial ecology and activity were largely unknown in this area and my study used non-invasive camera traps to survey mesocarnivores. The data gathered from this survey were incorporated into modern robust analyses like occupancy modeling and temporal activity pattern analysis to describe spatial and temporal ecology of mesocarnivores at the study site. Each chapter of this thesis provides a comprehensive description of importance and application of two different modeling techniques using camera trap data. Even though I could not identify any rare species, camera trap could be used to detect elusive, potentially endangered species.

My results suggested that there was no difference in species richness during both seasons for mesocarnivores. Coyote had highest detections, and detection frequency with low latency to detect. Naïve occupancy was also higher in coyotes than all the other species. The proportion of sites occupied was higher for all species during winter than in summer. The highest occupancy difference between two seasons recorded was for opossum. Detection probability for all species was also higher during winter than in summer. The reason for higher detection in winter could be the scarcity of food resulting in elevated activity and higher probability of being detected. Highest detection probability, as well as total detections was recorded for raccoon. There is a huge variability in detection and occupancy of bobcat and opossum between the two seasons. Warm and dry weather along with increased human activities and cattle grazing on the preserve during the summer could have decreased the detection probabilities.

Overall detection probability is higher with baited camera traps than unbaited camera traps for raccoon, opossum, and skunk, during winter. Detection probability without baits is slightly higher for coyote than with baits. The reason for that could be the coyotes are ubiquitous and occur throughout OYP. The probability of detection for bobcat is not dependant upon the availability of bait in the camera sites, even during winter. There could be several reasons for bobcat anomaly. Either bobcat did not prefer the bait that I used or bobcat were not competitive enough with raccoon and skunk for bait. In summer, detection probabilities have almost no difference in all species except skunk, with or without baited camera traps. A possible reason could be that the abundance of food resources is higher during summer than winter, therefore, there is less attraction to the baits around camera sites in summer.

All species were mostly nocturnal in winter, and summer. Coyotes were exception that they were active during daytime in summer. Temporal activity densities of coyote overlapped with all other species, during both seasons. Lowest activity overlap was recorded between raccoon and opossum in winter. Summer season had significantly low activity overlap between each species, compared to winter. Overall higher activity overlap between species in winter than summer indicate these species could co-exist in a period where natural resources are abundant. In summer low activity overlap indicate that these species had other resources or breeding related activities which prevented them roaming around the same area.

My results reveal 3 components that should be considered in managing this preserve: (1) more research on mesocarnivores is needed, especially concerning species specific factors that could affect their ecological roles; (2) camera-trap surveys incorporated into occupancy modeling could be successfully applied in future research in this preserve, not only for mesocarnivores, but for all the other mammalian species like white-tailed deer, beaver, nine-banded armadillo, and rabbit, (3) intensive cattle grazing could interfere with mesocarnivore data collections, because cattle sometimes graze close to camera-traps both day and night covering field of view of the camera. My results indicate that coyotes and raccoons avoided the areas where cattle were present, and in the future when TNC possibly introduces bison to OYP, I hope bison may have an effect coyotes and raccoons.

Conservation priorities should be given to species that are endangered or need attention. None of the mesocarnivore species that I detected at OYP are species of conservation concern, but all these species are fur bearers and their population demographics are not widely understood in the state of Oklahoma. Providing them places to exist without trapping pressure is important and their presence at Oka' Yanahli is an indication of the health of the ecosystem. Having more predators in an ecosystem indicate that there is higher biodiversity, meaning OYP is a healthy ecosystem. Introduction of bison into a healthy ecosystem would be beneficial for all species. Further research will need to find out whether mesocarnivore species like gray foxes, red foxes, and river otter occur in this preserve and if present, any interactions with bison.

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APPENDIX A. LIST OF ALL DETECTED SPECIES FROM CAMERA TRAP SURVEYS IN OKA' YANAHLI PRESERVE SOUTHCENTRAL OKLAHOMA IN WINTER AND SUMMER 2016-2017

MAMMALIA

Didelphimorphia

Virginia opossum (*Didelphis virginiana*)

Xenarthra

nine-banded armadillo (*Dasypus novemcinctus*)

Rodentia

eastern fox squirrel (*Sciurus niger*)

woodrat (*Neotoma floridana*)

North American beaver (*Castor canadensis*)

Lagomorpha

black-tailed jackrabbit (*Lepus californicus*)

eastern cottontail rabbit (*Sylvilagus floridanus*)

Carnivora

coyote (*Canis latrans*)

bobcat (*Lynx rufus*)

grey fox (*Urocyon cinereoargenteus*)

northern raccoon (*Procyon lotor*)

striped skunk (*Mephitis mephitis*)

dog (*Canis familiaris*)

Artiodactyla

white-tailed deer (*Odocoileus virginianus*)

feral hog (*Sus scrofa*)

AVES

Passeriformes

American crow (*Corvus brachyrhynchos*)

northern cardinal (*Cardinalis cardinalis*)

Accipitriformes

turkey vulture (*Cathartes aura*)

APPENDIX B. SELECTED PHOTOGRAPHS FROM CAMERA TRAP SURVEYS IN OKA' YANAHLI PRESERVE SOUTHCENTRAL OKLAHOMA IN WINTER AND SUMMER 2016-2017

Bobcat picture at meadow habitat at Oka' Yanahli Preserve southcentral Oklahoma.

Coyote picture at meadow habitat at Oka' Yanahli Preserve southcentral Oklahoma.

Grey fox picture at riparian habitat at Oka' Yanahli Preserve southcentral Oklahoma.

Virginia opossum picture at riparian habitat at Oka' Yanahli Preserve southcentral Oklahoma.

Striped skunk picture at wooded habitat at Oka' Yanahli Preserve southcentral Oklahoma.

Northern raccoons picture at wooded habitat at Oka' Yanahli Preserve southcentral Oklahoma.

American beaver picture at Oka' Yanahli Preserve southcentral Oklahoma.

Nine-banded armadillo picture at Oka' Yanahli Preserve southcentral Oklahoma.

White-tailed deer adult male and female at Oka' Yanahli Preserve southcentral Oklahoma.

White-tailed deer fawn at Oka' Yanahli Preserve southcentral Oklahoma.

Eastern fox squirrel at Oka' Yanahli Preserve southcentral Oklahoma.

Woodrat at Oka' Yanahli Preserve southcentral Oklahoma.

Eastern cottontail rabbit at Oka' Yanahli Preserve southcentral Oklahoma.

Black-tailed jackrabbit at Oka' Yanahli Preserve southcentral Oklahoma.

American crow at Oka’ Yanahli Preserve southcentral Oklahoma.

Turkey vulture at Oka’ Yanahli Preserve southcentral Oklahoma.

Northern cardinal at Oka' Yanahli Preserve southcentral Oklahoma.

Domestic dog picture at Oka' Yanahli Preserve southcentral Oklahoma.

APPENDIX C. SELECTED PHOTOGRAPHS FROM DIFFERENT HABITAT TYPES AND CAMERA TRAP LOCATIONS AT OKA' YANAHLI PRESERVE SOUTHCENTRAL OKLAHOMA IN WINTER AND SUMMER 2016-2017

Riparian habitat type at Oka' Yanahli Preserve southcentral Oklahoma.

Wooded habitat type at Oka' Yanahli Preserve southcentral Oklahoma.

Meadow habitat type at Oka' Yanahli Preserve southcentral Oklahoma.

(a) (b) (c)

Pictures showing different locations that camera-traps attached (a) Christmas tree posts (b) trees (c) branches of trees.

APPENDIX D. SELECTED PHOTOGRAPHS OF DIFFERENT ACTIVITIES AT OKA' YANAHLI PRESERVE SOUTHCENTRAL OKLAHOMA IN WINTER AND SUMMER 2016-2017

Cattle grazing during summer 2017 at Oka' Yanahli Preserve southcentral Oklahoma.

Cattle activities close to a camera trap in summer 2017 at Oka' Yanahli Preserve southcentral Oklahoma.

White-tailed deer hunters in winter 2016 at Oka' Yanahli Preserve southcentral Oklahoma.

Different human activities in winter and summer at Oka' Yanahli Preserve southcentral Oklahoma