COMPARISON OF TWO TECHNIQUES THAT DETERMINE HABITAT SELECTION BY BOBCATS AND A DISCUSSION OF HABITATS WITHIN OVERLAPPING AND NON-OVERLAPPING AREAS

by

JASON A. KEENAN

(Under the Direction of Robert J. Warren)

ABSTRACT

Radio-telemetry is an expensive and time-consuming technique for collecting wildlife habitat data. Therefore, we compared bobcat (*Lynx rufus*) habitat selection as determined from radio-telemetry locations versus scent station visitations in Baker County, southwestern Georgia. We compared the proportions of each habitat used as derived from radio-telemetry locations to the proportions of habitats within buffers surrounding scent stations visited by bobcats. Scent stations differed from radio-telemetry ($P<0.0001$, all situations). This suggests that scent stations do not provide an adequate substitute for radio-telemetry.

Habitats not only differ in their composition, but also how they are used. Overlapping and non-overlapping polygons of bobcat home ranges were tested for differences using a MANOVA to test among the eight available habitats. This resulted in finding that males do not differ in the overlapping and non-overlapping areas of their home ranges ($\Lambda=0.3788$, $P=0.3471$). Females did prefer not to share ($\Lambda=0.6234$, $P=0.0325$) the urban/barren areas ($t<0.0876$) as well as the shrub/scrub ($t<0.0696$) and pine regeneration ($t<0.0687$) habitats.

INDEX WORDS: bobcats, carnivores, habitat composition, habitat selection, *Lynx rufus*, overlap, radio-telemetry, scent stations, space use, techniques.

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B.S., Mississippi State University, 2004

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2007

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May 2007

ACKNOWLEDGEMENTS

I could not even begin to acknowledge anyone without thanking my wife, Katie for her continued support. Thank you for putting up with all my delays on getting this finished and for making sure there was no detailed left uncovered and addressed. I will love you always and thank you for everything.

This entire project would not be possible without the help of my co-major advisors Drs. Bob Warren and Mike Conner. Your guidance and assistance is second to none. I could never have asked for a better set of advisors. With that goes my thanks to the University of Georgia and the Joseph W. Jones Ecological Research Center for the extremely valuable resources that were made available to me. Especially, I would like to thank Danielle Temple, Danny Gammons, and Greg Lynch for their help with study design, trapping, paper reviews, study suggestions, and being great friends during my tenure at my field site.

I would like to thank my family for their encouragement to do whatever I wanted with my life. Thank you Mom and Dad for teaching me everything I needed to know to succeed and become great in the eyes of those dearest to me. Thank you Scott and Elizabeth for being great siblings and great friends, may we all get along for many, many years!

Finally, I would like to thank my Mississippi State University professors for instilling a wonderful basis above and beyond normal undergraduate educations. Your teachings have made me able to succeed at what I am doing today, enjoying wildlife to its fullest extent. Namely, I would like to thank Rich Minnis, Dr. Bruce Leopold, Dr. Jeanne Jones, and Dr. Kevin Hunt.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Radio-telemetry is commonly used to obtain information about habitat use, but less time consuming and less expensive alternatives may exist. Visual observations (Loughry and McDonough 1998), call counts (Madden et al. 2000), scat counts (Hernandez et al. 1998) and track plates (Pedlar et al. 1997) have all been used to quantify habitat selection.

Bobcats are generally considered to be solitary animals (Sandell 1989), but may actually share portions of their home range with neighboring individuals of the same gender (Doughty 2004). Studying these areas of home range overlap may provide insight into why individuals share some areas while exclusively defending others.

Currently, the differences between shared and unshared portions of bobcat homeranges have not been studied. In addition, no research has assessed use of scent stations for quantifying habitat use of carnivores. This thesis addresses both of these concepts and is a continuation of a study that began in 2001 to address the ecology of bobcats within a longleaf pine (*Pinus palustris)* ecosystem.

LITERATURE REVIEW

Background

The bobcat is distributed among all 48 of the contiguous United States. New Jersey once had no known bobcat populations, but due to successful reintroduction techniques in the late 70s and early 80s, now has resident populations (Young 1958, Schantz and Valent 2003). Typically, they range from below the 50th parallel to above the 18th parallel and from the Pacific Ocean to the Atlantic Ocean. The bobcat is the only felid that is distributed across such a large area (Anderson 1987). There are twelve recognized subspecies: *Lynx rufus baileyi, L.r. californicus, L.r. fasciatus, L.r. floridanus, L.r. gigas, L.r. oaxacensis, L.r. pallescens, L.r. peninsularis, L.r. rufus, L.r. superiorensis, and L.r. texensis* (Anderson 1987).

In 1978, and again in 1982, the bobcat was listed in Appendix II of the Convention on International Trade in Endangered Species (CITES) due to its similarity to endangered cats. The bobcat is listed as endangered in Indiana, Iowa, New Jersey, and Ohio. Therefore, much emphasis has been placed on bobcat research (Anderson 1987). Population records are now being kept to help protect the bobcat, keep it from being overexploited, and to maintain a sustainable population. Currently, 38 states have open seasons on the bobcat, and ten others have continuous closed seasons. Bobcats are the management responsibility of state wildlife agencies, though the export of the pelts is under the control of the federal government via CITES (McCord and Cardoza 1982).

Home ranges

Bobcat home ranges vary with bobcat sex and age, population density, prey density, and human development. Typically, male bobcats have larger home ranges than females. Males are known to maintain home ranges sizes from 3 km^2 to 73 km^2 (McCord and Cardoza 1982), whereas females tend to have home ranges as small as 1 km^2 to as large as 49 km^2 (Hall and Newsom 1976, Nielson and Woolf 2001). A bobcat's age can also affect its home range size. Older male bobcats, once established, tend to have larger home ranges, possibly for increased opportunities to reproduce (Conner et al. 1999). In contrast, female home ranges tend to decrease with time-in-residence, possibly due to increased awareness of available resources (Conner et al. 1999). Bailey (1981) found that the home range size of bobcats was inversely related to density. Many studies have suggested that prey abundance has the greatest effect on bobcat home range size (Beasom and Moore 1977, Litvaitis et al. 1986, Godbois et al. 2004).

Bobcats also have been found to avoid areas of high human activity and presence. Lovallo and Anderson (1996b) found that bobcats avoided areas that had high vehicular traffic. Bobcats, as well as coyotes, decrease their activity patterns in fragmented habitats created by urban areas in an attempt to avoid humans (Tigas et al. 2002). In contrast, bobcats have been known to reside under residential homes and elevated porches, often without the homeowner's knowledge (Shane Roberts, pers. comm.). Therefore, bobcats can thrive in the presence of human development.

Overlap

Although bobcats are considered to be solitary animals, home range overlap is often observed (Doughty 2004). Some suggest that males and females will have home ranges exclusive of other members of the same gender (Rolley 1985). Lovallo and Anderson (1996a) found males overlapped other males and females, but females tended to hold exclusive territories. Nielsen and Woolf (2001) found high levels of intrasexual overlap in a bobcat population in southern Illinois. Deifenbach et al. (2006) found that overlap occurs commonly among same sexes and between sexes within a reintroduced population of bobcats on Cumberland Island, Georgia. Overlapping areas may occur because of high prey abundance (Miller and Speake 1978), low prey abundance (Knick 1990), high bobcat abundance (Fendley and Buie 1986), or perhaps space sharing by related individuals (Kitchen et al. 2005). Also, overlapping areas could be avoided by successive bobcats due to resource limitations and competition (Rolley and Warde 1985).

Overlapping bobcats also tend to take over vacant home ranges when available (Lovallo and Anderson 1995, Benson et al. 2004).

Habitat

Bobcats can adapt to a variety of habitats, thereby allowing them to have a wide geographical distribution (Anderson and Lovallo 2003). Bobcat habitat use varies throughout their geographical range. In the West, they use desert areas and rocky cliffs; in the North, they use conifer forests; and in the Southeast, bobcats tend to prefer bluffs, brushy fields, and second-growth oak habitats (Anderson 1987). In southwestern Georgia, bobcats preferred mixed pine/hardwood habitats, agriculture, hardwoods and mature pine during the spring and summer, likely because of the availability of resting and hunting areas (Godbois et al. 2003b). In Mississippi, bobcats preferred < 8 year-old and >30 year-old pine habitats (Chamberlain et al. 2003).

When other species are the focal point of management, these management practices can affect the home ranges and habitat selection of bobcats. For example, supplemental feeding of the northern bobwhite (*Colinus virginianus*) can attract prey items like cotton rats, which in turn, can support bobcats (Godbois et al. 2004). Therefore, the management for one species, bobwhite quail, also benefited other bobcat prey.

Diet composition

Bobcats are predators of small animals. Small rodents and rabbits tend to be the most-consumed prey item (McCord and Cardoza 1982, Anderson 1987, Anderson and Lovallo 2003). In the northeastern United States, snowshoe hares (*Lepus americanus*) and white-tailed deer (*Odocoileus virginianus*) can be important food items (McCord and

Cardoza 1982). In the Southeast, rabbits, rodents, and deer tend to be the most consumed prey of the bobcat (Miller and Speake 1978, Fox and Fox 1982), with the main prey item being the cotton rat (*Sigmodon hispidus*) (McCord and Cardoza 1982). On Ichauway, Georgia rodents made up 91% of all scats, and 70% of the rodents were cotton rats (Godbois et al. 2003a). Other rodents consumed by bobcats are woodrats (*Neotoma* spp.), voles (*Microtus* spp.), and mice (*Mus* pp.)(Anderson 1987). When a preferred prey population declines, changes in the bobcat's diet are seen. For example, in the Southeast, bobcat diets diversified when there was a decline in cotton rat populations (Maeher and Brady 1986).

Bobcats are also opportunistic predators. For example, Fox and Fox (1982) and Labisky and Boulay (1998) found that in southern Florida, white-tailed deer are one of the most common prey items, but this may be due to the abundance of carrion during the hunting season (Pollack 1951, Labisky and Boulay 1998). Snakes, birds, bats, and frogs have all been recorded as bobcat prey; however, bats have been only recorded twice as food items (Young 1958, Wroe and Wroe 1982). Reptiles appear to increase in occurrence with a decrease in latitude (Delibes et al. 1997). In some areas, livestock, such as goats, sheep, and chickens are occasionally prey items of the bobcat, but predation on livestock is localized and generally minor (Anderson 1987). Although bobcats are often grouped with other mammalian quail predators, quail typically comprise only 1 – 3% of a bobcat's diet (Miller and Speake 1978, Maehr and Brady 1986, Godbois et al. 2003a). In contrast, bird eggshells have been found in up to 10 % of bobcat scats (Jones and Smith 1979). Finally, bobcats have been video-taped while depredating turkey nests (Michael Juhan, pers. comm.). Dietary overlap between bobcats and other carnivores of comparable size is minimal (Small 1971, Makar 1980, Major 1983). While bobcats share space and use similar habitats as other sympatric carnivores, lack of dietary overlap suggests that little competition is occurring.

Habitat selection techniques

Radio-telemetry is probably the most accepted and widely used method to accrue data sets for habitat selection analysis (Millspaugh and Marzluff 2001). Radio-telemetry reduces bias when tracking an animal in the wild by minimizing disturbance by researchers because locations are obtained from a distance (Kenward 2001). However, other methods of quantifying habitat selection exist (e.g., Potvin et al. 2005). Visual observation can provide data for determining habitat selection of highly visible species such as the African buffalo (*Syntcerus caffer*) (Ryan et al. 2006). Starr and Leung (2006) used fluorescent powder to follow grassland earless dragons (*Tympanocryptis pinguicolla*) and determine habitat use. Mist nets and point counts were used to assess habitat selection in Swainson's Warbler (*Limnothlypis swainsonii*) in southeastern Louisiana (Bassett-Touchell and Stouffer 2006). Mark-recapture methods have been used to infer habitat selection of the salt harvest mouse (*Reithrodontomys raviventris*) (Bias and Morrison 2006). Track plates were used to determine habitat at two different spatial scales in a raccoon population in Canada (Pedlar et al. 1997). Another study used scent stations to correlate visitation rates with environmental variables to determine carnivore use of the urban/wild land interface (Rhanda and Yunger 2006). These alternatives to radio-telemetry could be considered beneficial if they provide results similar to those obtained using radio-telemetry.

JUSTIFICATION

As wild felids become rarer, increased attention is being directed towards their management. After passage of the Endangered Species Conservation Act of 1969, trade of many wild cats became illegal. As a result, the demand for furs from harvestable felid populations in the United States increased. Since 1975, the bobcat has been listed in Appendix II of CITES. This legislation requires that bobcat populations be monitored to ensure that they will not be over-harvested (Anderson 1987). Trapping for pelts or for predator control could cause bobcat populations to decline if these populations are not monitored or managed properly; thus, different techniques to determine population size, habitat use, and habitat selection are needed to provide information for management of this species. While radio-telemetry can help address these needs, telemetry is both expensive and time consuming. Therefore, we tested an alternative method using scent stations to determine habitat selection.

In some cases, shared areas may occur due to a concentration of resources (Rolley and Warde 1985). Alternatively, otherwise territorial animals may share space because resources are lacking, thus providing no reason to defend the area (Knick 1990). Bobcats are sometimes thought to be a major predator of turkey and quail, so they are often harvested under predator control programs. Thus, wildlife managers need to know how bobcat removal may affect the overall bobcat population (Anderson 1987, Rucker et al. 1989). Managers need to be aware of spatial organization because bobcat populations are known to be variable depending on their prey populations (Miller and Speake 1978, Conner et al. 1992, Anderson and Lovallo 2003). Overall, knowledge of how bobcats share space is needed to be able to maximize or minimize carrying capacity of an area depending on management objectives.

OBJECTIVES

1. Determine if radio-telemetry and scent stations provide a similar assessment of bobcat habitat selection.
2. Compare habitat composition within overlapping and non-overlapping areas of bobcat home ranges.

THESIS FORMAT

My thesis is written in a manuscript format. Chapter 1 is the background information on general bobcat history, objectives, and the thesis format. Chapter 2 is a comparison between radio-telemetry and scent stations to determine bobcat habitat selection. Chapter 3 compares habitat composition of overlapping and non-overlapping areas within bobcat home ranges. Chapters 2 and 3 are formatted for submission to the Journal of Wildlife Management.

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CHAPTER 2

COMPARING TWO TECHNIQUES FOR DETERMINING HABITAT SELECTION BY BOBCATS[1]

[1]Keenan, J.A., L.M. Conner, and R.J. Warren. To be submitted to the *Journal of Wildlife Management.*

Abstract: Radio-telemetry is an expensive and time-consuming technique for collecting wildlife habitat data. Using scent stations may provide a more time-efficient and less-costly alternative. However, there are few published data to compare these two techniques. We compared bobcat (*Lynx rufus*) habitat selection determined from radio-telemetry locations to habitat selection determined using scent station visitations on the 11,735-ha Joseph W. Jones Ecological Research Center at Ichauway in Baker County, southwestern Georgia. Our data included habitats associated with 2,900 radio-telemetry locations from 26 bobcats compared to habitat surrounding 78 scent stations ($n = 227$) that had been visited by bobcats during a 3-day sampling session. We compared the proportions of each habitat selected as derived from radio-telemetry locations to the proportions of habitats within buffers surrounding scent stations visited by bobcats. We then determined habitat selection using the two techniques by comparing each technique's estimate of habitat use to proportion of habitats available on the study area. Our results suggest that habitat selection determined using scent stations differed ($F = 20.64$, $P = 0.001$ for 50-m buffer) from habitat selection results obtained using radio-telemetry, suggesting that scent stations do not provide similar results to radio-telemetry. Future work should evaluate efficacy of scent stations for quantifying habitat selection in other species. Additional comparisons of techniques should be conducted on other study sites to determine if our results are similar on other areas.

Key Words: scent stations, radio-telemetry, techniques, habitat use, habitat selection, carnivores.

INTRODUCTION

Radio-telemetry probably is the most commonly used technique to measure wildlife habitat use because this technology allows even secretive animals to be monitored (Johnson 2000). There are problems associated with radio-telemetry, mainly the cost. So the need for an alternative exists. Scent stations have been used to estimate abundance and to determine presence of wildlife species (Linhart and Knowlton 1975, Diefenbach et al. 2006), but they are not widely used to determine habitat selection. However, Gehring and Swihart (2003) used scent stations to determine predator habitat use in Indiana. We explored the possibility of using scent stations to determine habitat selection by bobcats.. Specifically, we attempted to test scent stations to see if they provided similar information regarding habitat selection as did radio-telemetry.

In some cases radio-monitoring of individuals may not be permitted. For example, Institutional Animal Care and Use Committees (IACUC) must often approve all field research with animals, and an organization's IACUC may not approve of the capture of some species. In a 1988 survey, 48% of committees did not have a wildlife expert (Bowman 1989). Without a wildlife expert, committees may not understand or approve capture methods. Similarly, capture of endangered or threatened species may not be permitted due to concerns over injuring the animal.

Radio-telemetry equipment, though decreasing in costs, remains a significant expenditure associated with many habitat studies. However, man-hours, not equipment purchases, generally are the most costly component of a radio-telemetry study. Scent stations may provide a cost-efficient alternative for measuring habitat use. The equipment and man-hour costs of establishing and executing a scent station study are much less that that required for a radio-telemetry study.

Some studies must examine habitat selection to gain supplemental information to be used to explain the primary species or process under study. However, the high cost of radio-telemetry may leave researchers looking for alternatives to provide the supplemental information mentioned above. For example, Erwin et al. (2001) used scent stations to look at predators while simultaneously studying declining tern (*Sterna* spp.) and Black Skimmer (*Rhynchops niger*) populations. The purpose of the research was to assess the decline in the two bird species in question, but predators were monitored as a less emphasized, though still important, component of the research project. Our objective was to determine if habitat use of bobcats could be inferred from scent stations. We evaluated the efficacy of scent stations as a tool for inferring habitat use by comparing results obtained from scent stations to results obtained using radio-telemetry.

STUDY SITE

Our research occurred at the Joseph W. Jones Ecological Research Center at Ichauway in Baker County in southwestern Georgia. Ichauway is comprised of about 11,735 ha encompassing eight different habitats. Those eight habitats include: agriculture, shrub/scrub, hardwood, pine regeneration, mature pines, mixed pine/hardwoods, wetlands, and urban areas. The property is divided by 24 km of the Ichauwaynochaway Creek and bordered on the eastern side by 17 km of the Flint River. Rainfall averages about 132 cm per year with temperatures ranging from 11.1^{0} C to 27.2^{0} C. An extensive road system exists throughout the property, which facilitated scent station placement and monitoring. Roads ran throughout all available habitats.

The property is managed mainly for the longleaf pine (*Pinus palustris)* ecosystem. Sixty percent of the area is managed for wildlife and timber and the remaining areas are managed to restore the longleaf-wiregrass ecosystem (Joseph W. Jones Ecological Research Center 2001). About 4,000 - 4,900 ha are burned each year throughout all seasons for research and educational opportunities, fuel reduction, and more importantly the maintenance of the longleaf-wiregrass ecosystem. Other management practices include maintenance of wildlife food plots and supplemental feeding for bobwhite quail (*Colinus virginiana*). Limited predator removal occurs, though bobcats have not been removed since 2000, except for an experimental removal of individuals in the winter of 2005-2006 (Lynch 2006). The management practices implemented on site provide excellent habitat for bobcats and other carnivores.

METHODS

Bobcats were captured beginning in December 2000 using 1.75 Victor laminated offset and #3 Victor soft-catch foot-hold traps. Each captured bobcat was sedated with ketamine hydrochloride (10mg/kg of body weight; Seal and Kreeger 1987) and body measurements were taken, and since 2003, ear punches were taken for a companion genetic study (Reid 2006). Bobcats received a unique tattoo and mature bobcats were collared with a 180 g telemetry transmitter (Advanced Telemetry Systems, Isanti MN). All animal handling followed the University of Georgia Institutional Animal Care and Use Committee guidelines (IACUC #A990159). Bobcats were monitored for 8 to 24 hours before being released at the capture site.

Though many cats were already collared and monitored prior to study period, only summer of 2006 through spring of 2007 locations were used for this analysis. We radio-tracked bobcats using a Wildlife Materials Inc. receiver, model # TRXC-2000S (Wildlife Materials, Inc., Murphysboro, IL) and a 3-element yagi antenna. For each location, ≥ 2 bearings were taken <15 minutes apart. Bearings were converted to coordinates using LOCATE III (Nams 2006), and those coordinates were incorporated into a GIS. The habitat type associated with each location was determined. We then calculated the percentage of locations falling within each habitat for each bobcat (Rolley and Warde 1985). Finally, we buffered all bobcat telemetry locations at 50-m and 100-m distances, determined habitat percentages within those buffers, and then averaged the percentages for each bobcat.

Scent stations were created beginning in the summer of 2005 and sampled each season through spring of 2006. Stations were established by raking a 1-m^2 plot on the ground and placing a single cotton ball soaked in bobcat urine daily in the center of the plot, similar to methods described in Roughton and Sweeny (1982). There were 227 scent stations across the study site (Figure 2.1). Scent stations were placed at known points along roads and were located at least 0.32 km apart. We monitored half of the stations for 3 days then the other half was checked in the same manner during the following 3 days within the season. All mammal tracks were recorded at each scent station and the station raked clean after recorded. Samples were taken in all four seasons with each station serving as the sample unit. Stations visited multiple times within a season were only counted once for analysis. Locations of stations visited by bobcats were entered into ArcGIS 9 (ERSI 2005) and 50-m and 100-m radius buffers were placed around each visited station. We then calculated the percentage of each habitat within each buffer using Xtools (Data East, LLC 2006).

ANALYSIS

We used compositional analysis (Aebischer et al. 1993) to examine use versus availability of habitats for locations determined by radio-telemetry and scent stations. We calculated log-ratios for each habitat within buffers, buffered radio-telemetry locations, or percent use as determined using telemetry locations using the methodology described by Aebischer et al. (1993). We replaced any habitats that had no value (i.e., zero percent use or available) with a value of 0.001 (Aebischer et al. 1993). We then used the log-ratio differences to determine if the proportion of habitats within buffers surrounding visited scent stations differed from the proportion of habitats as derived from radio-telemetry locations. We also compared habitat use as calculated from buffered scent stations to that as determined from buffered telemetry locations. We did not attempt to rank habitats in order of preference, as our primary objective was to determine if the various techniques provided similar results. Though our data were collected seasonally, we pooled our seasonal data sets into one yearly data set because of low detection rates of bobcats during some seasons. All analyses were conducted using the PROC GLM procedure with a MANOVA option in SAS (SAS Institute 2003). A P-value ≤ 0.10 was considered significant in this analysis.

RESULTS

Scent stations were monitored for 11 days (3, 3-day runs and one 2-day run cut short due to rain). Seventy-eight of 227 stations were visited by bobcats Habitat proportions within the 50-m buffers around visited scent stations were 10.1% ±3.4($\bar{x}$ ±SE) agriculture/food plots , 0.3%±0.6 shrub/scrub, 9.5% ±3.3 hardwoods,, 4% ±2 pine regeneration, 40.9% ±5.6 mature pine, 31.8% ±5.3 mixed pine/hardwoods, 1.5% ±1.3

wetland/water, and 1.8% ±1.5 urban/barren. The 100-m scent station buffers contained 2.6% ±3.8 agriculture/food plots, 1.2% ±1.2 shrub/scrub, 10.2%±3.4 hardwoods, 5.7%±3.6 pine regeneration, 37.4%±5.5 mature pine, 29%±5.1 mixed pine/hardwoods, 2.8%±1.9 wetland/water, and 0.9%±1.1 urban/barren (Figure 2.2).

Our radio-telemetry data set contained 2,900 locations obtained on 26 bobcats. Habitat selection based on visited scent stations differed ($P < 0.0001$) between the 50-m and 100-m buffers. Similarly, habitat selection of 50-m and 100-m buffers differed from the habitat selection results associated with radio-telemetry locations ($P<0.0001$ both cases). When we buffered the individual telemetry locations, calculated habitat selection ratios within each buffer, and then averaged these ratios for each bobcat, the 50-m buffered scent stations differed ($P <0.0001$) from the 50-m buffered telemetry locations and the 100-m buffered scent stations differed ($P<0.0001$) from the 100-m buffered telemetry locations.

DISCUSSION

Our results suggest that scent stations and radio-telemetry data provide different measures of habitat use. Similarly, Nielson and Woolf (2002) used Penrose distance statistics to model the habitat used by bobcats from radio-telemetry and suggested that scent stations are not an adequate substitution. They found that not only did radio-telemetry results differ from scent station results, but that habitat selection statistics differed as a function of the size of the buffer placed around scent stations, providing evidence that buffer size affects habitat selection results when using scent stations.

The most likely explanation for differing habitat selection conclusions between scent stations and radio-telemetry is that each scent station acts as a single observation.

In contrast, radio-telemetry provides multiple locations, which are summarized for each animal to determine habitat use. Perhaps a more appropriate approach to calculating habitat metrics using animal tracks would be to passively (i.e., without attractant) monitor transects instead of individual scent stations. This would allow for more opportunities to observe animal presence and not be limited to the 0.32-km minimum distance between scent stations (Sargeant et al. 2003). Scent stations placed too close together increases the chance that a single individual could visit multiple stations (Hamm et al. 2003). If so, scent station visits may have little to do with habitat composition around the scent station. The result is similar to the non-independence of consecutive radio-telemetry locations from autocorrelation (White and Garrott 1990). Each station visit would be contingent upon the previous visit, and thus the visits would be related more to travel corridors, such as roads, than the visits would be related to habitats surrounding the scent station.

Scent stations are limited to a single point in space; thus, if there are multiple habitats surrounding a given point, we must assume that each of these habitats contributed to an animal's use in proportion to the habitat's availability around a visited scent station. Therefore, if a bobcat visited a scent station because of a single habitat, the importance of other habitats around the point could be overestimated. The overestimation could be solved by placing each scent station in a single habitat. Therefore each visit would have a single habitat variable, thus eliminating the overestimation.

Other studies have used scent stations to determine habitat use (Edwards et al. 2002, Whittington et al. 2005). However, our study questions the validity of using animal sign at specific locations to infer habitat use. Habitat use studies that relied upon habitat attributes around locations that were visited by an animal should be interpreted cautiously. Moreover, future studies should attempt to validate results obtained using scent stations before continuing to collect habitat use data based on animal sign. More comparisons need to be made between radio-telemetry and track-based approaches for estimating habitat. Two examples would be the techniques used by Whittington et al. (2005), who trailed wolf tracks with GPS units, and Alexander and Waters (2000) who used transects along highways. Also, Pedlar et al (1997) used scent stations placed in individual habitats to determine habitat use for raccoons. Placing scent stations within specific habitats without buffering the station may allow more accurate estimation of habitat use metrics because each scent station would provide a single habitat instead of multiple estimations of habitat used. Placing scent stations within a single habitat would reduce errors associated with unused habitats that are present within buffers. However, numbers of scent stations required using this approach would likely be great if sufficient statistical power is obtained (Gehring and Swihart 2003).

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Figure 2.1. Placement of scent stations used to determine habitat selection for comparison of radio-telemetry determined habitat selection throughout the Ichauway property, Joseph W. Jones Ecological Research Center, Newton, Georgia, 2005-2006.

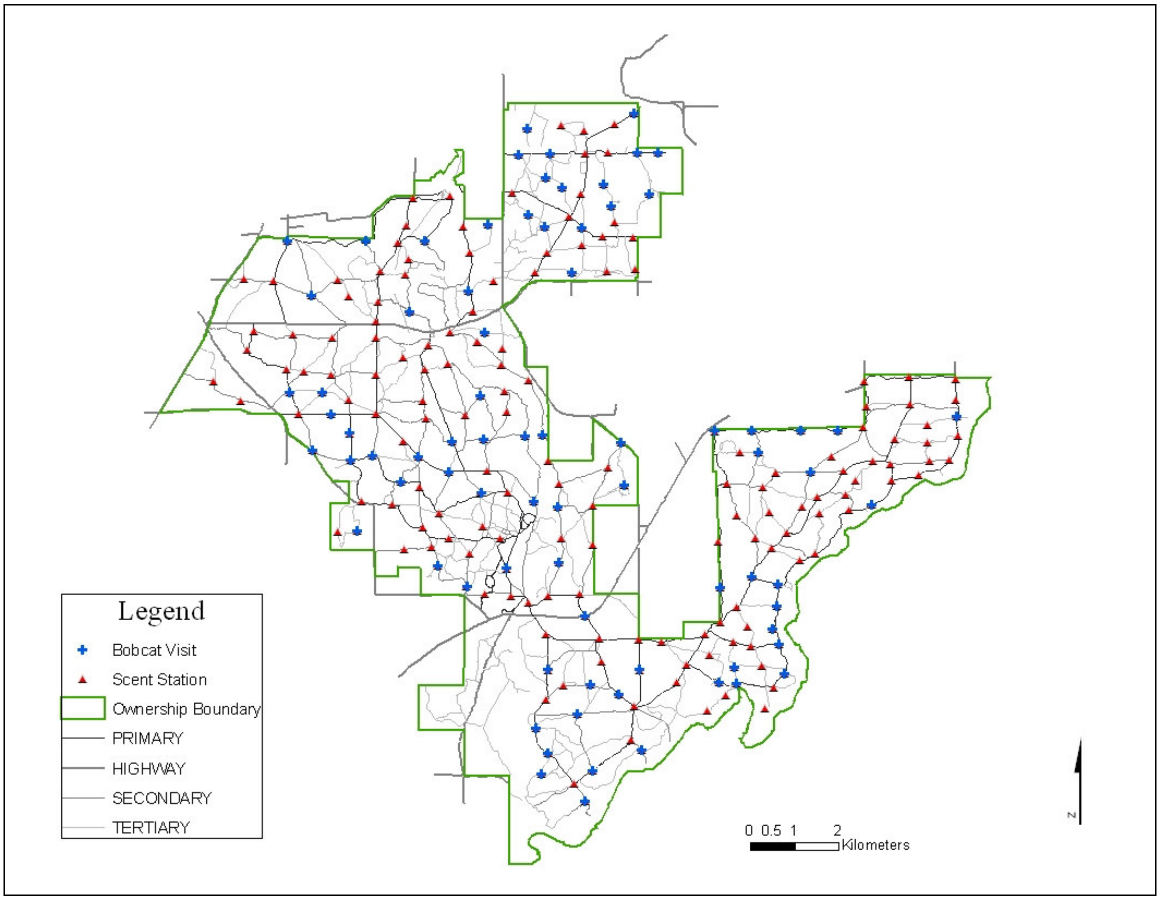
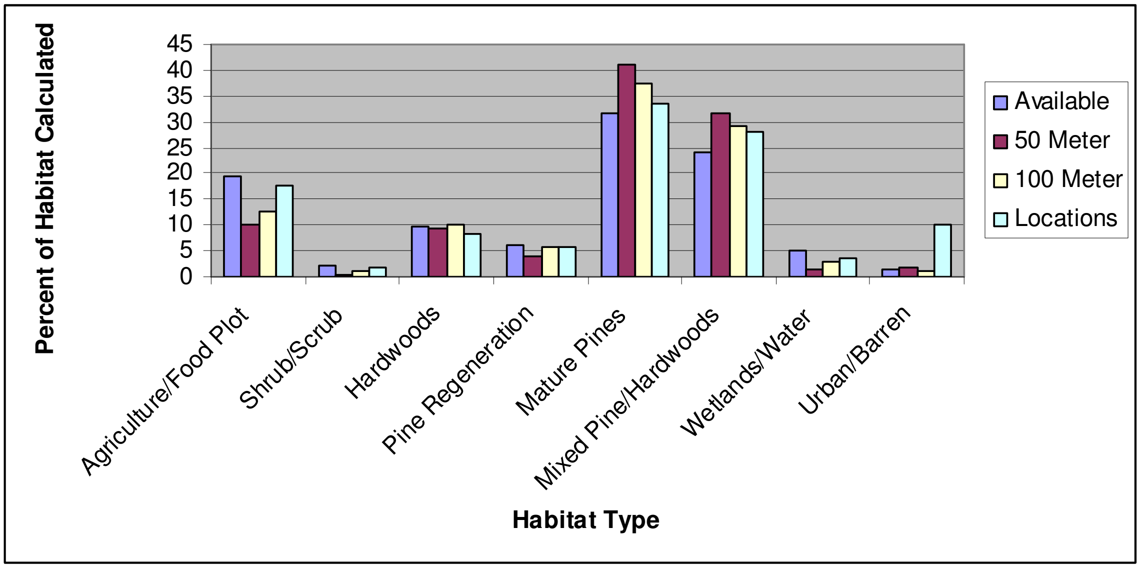

Legend
Bobcat Visit
Scent Station
Ownership Boundary
PRIMARY
HIGHWAY
SECONDARY
TERTIARY
0 0.5 1 2
Kilometers
N

Figure 2.2. Habitat proportions of the eight available habitats, the habitats within 50- and 100-m buffers around scent stations visited by bobcats, and the proportion of habitat used by bobcats as determined using radio telemetry, Joseph W. Jones Ecological Research Center, Newton, Georgia, 2005.


Percent of Habitat Calculated
45
40
35
30
25
20
15
10
5
0
Available
50 Meter
100 Meter
Locations
Agriculture/Food Plot
Shrub/Scrub
Hardwoods
Pine Regeneration
Mature Pines
Mixed Pine/Hardwoods
Wetlands/Water
Urban/Barren
Habitat Type

CHAPTER 3

DIFFERENCES IN HABITATS AMONG OVERLAPPING AND NON-OVERLAPPING AREAS WITHIN BOBCAT HOME RANGES[1]

[1]Keenan, J.A., L.M. Conner, R.J. Warren. To be submitted to *American Midwest Naturalist.*

Abstract: Intraspecific individuals often share habitats, and some share large portions of their home range while others share minimal areas. We determined whether habitat composition within areas shared by bobcats of the same sex differed from habitat composition in areas that were not shared. We used radio-telemetry to derive home ranges for 24 bobcats. Differences in habitat composition of overlapping and non-overlapping portions of home ranges were compared using a variation of compositional analysis. H abitat composition of overlapping and non-overlapping portions of male bobcat home ranges did not differ (Λ=0.3788, P =0.3471). However, shared and non-shared portions of female bobcat home ranges differed (Λ=0.6234, P =0.0325). The proportions of urban/barren ($t<0.0876$), shrub/scrub ($t<0.0696$), and pine regeneration ($t<0.0687$) habitats were greater in non-shared areas than in shared portions of home ranges. Habitats used exclusively by one bobcat could be habitats that provide moderate to high prey abundance within a home range or landscape encompassing poorer prey producing areas. A great abundance of resources at the landscape scale may allow home range overlap. Similar overlap may be observed when resources are lacking at the landscape scale because resource poor home ranges would not be worth the energy expended to defend exclusive areas. Future research should examine the temporal aspect of overlap to determine if overlapping areas are occupied at similar times.

Key Words: Bobcats, habitat composition, home range overlap, *Lynx rufus,* space use.

INTRODUCTION

Bobcats are solitary and often maintain exclusive territories (Miller and Speake 1979, Zezulak and Schwab 1979, Anderson 1987, Thorton et al. 2004). Despite being solitary, bobcat home ranges are known to overlap (Kamler and Gibson 2000). Many studies have examined overlap between bobcats (Neale and Sacks 2001, Nielson and Woolf 2001, Chamberlain and Leopold 2005), but none have examined the habitat composition within overlapping bobcat home ranges. Maintaining exclusive areas within a home range could suggest that there are sufficient resources within the area to warrant defending it against competing neighbors or could simply a function of denning behaviors (Anderson 1987, Cochrane 2003). However, it is also logical that resources within defended areas are sufficiently limited or animals would not expend energy in their defense (Knick 1990). Thus, differences between those overlapping and non-overlapping areas within bobcat home ranges may provide insight into their habitat requirements. Our objective was to determine if habitat composition differed between shared and exclusive areas of bobcat home ranges.

STUDY SITE

Our research occurred at the Joseph W. Jones Ecological Research Center at Ichauway in Baker County in southwestern Georgia. Ichauway is comprised of about 11,735 ha encompassing eight different habitats. Those eight habitats include: agriculture, shrub/scrub, hardwood, pine regeneration, mature pines, mixed pine/hardwoods, wetlands, and urban areas. The property is divided by 24 km of the Ichauwaynochaway Creek and bordered on the eastern side by 17 km of the Flint River. Rainfall averages about 132 cm per year with temperatures ranging from 11.1^{0} C to 27.2^{0} C. An extensive road system exists throughout the property, which facilitated radio-telemetry monitoring.

Sixty percent of the area is managed for wildlife and timber and the remaining areas are managed to restore the longleaf pine (*Pinus palustris*)-wiregrass (*Aristida* spp.) ecosystem (Joseph W. Jones Ecological Research Center 2001). About 4,000 - 4,900 ha are burned each year for research and educational opportunities, fuel reduction, and more importantly, the maintenance of the longleaf-wiregrass ecosystem. Other management practices include maintenance of wildlife food plots and supplemental feeding for bobwhite quail. Some limited predator removal occurs, though bobcats have not been removed since 2000, except for an experimental removal in the winter of 2005-2006 (Lynch 2006). The management practices implemented on site provide excellent habitat for bobcats and other carnivores.

METHODS

Bobcats were captured beginning in December 2000 using 1.75 Victor laminated offset and 3 Victor soft-catch foot-hold traps. Each captured bobcat was sedated with ketamine hydrochloride (10 mg/kg body weight; Seal and Keeger 1987) and body measurements and DNA tissue punches were taken from the ear. Also, each individual was uniquely tattooed and adult bobcats were fitted with a 180 g ATS telemetry transmitter collar (Advanced Telemetry Systems, Isanti, MI). Adults were determined by size: males were >8.5 kg and females were 5.5 – 8.4 kg. Bobcats were monitored for 8 to 24 hours before being released at the capture site. All animal handling followed the University of Georgia Institutional Animal Care and Use Committee guidelines (IACUC #A990159).

Radio monitoring for this study began in summer of 2005 and continued through spring of 2006. Telemetry was conducted using a Wildlife Materials Inc. receiver (model

TRXC-2000S, Wildlife Materials, Inc., Murphysboro, IL.), and a 3-element yagi antenna. For each triangulation, > 2 bearings were taken with <15 minutes between bearings. Bearings were converted to Universal Transverse Mercator (UTM) coordinates using LOCATE III (Nams 2006). Locations were imported into ArcMap (ESRI 2005) and minimum convex polygons were created for each bobcat using the home range tools extension (Rodgers et al. 2005). We then used the clipping tools in ArcGIS (ERSI 2005) to identify overlapping (i.e., areas used by more than one bobcat during the study period) and non-overlapping areas (i.e., areas used by only one bobcat during the study period). Overlays were performed only for bobcats of the same sex because male bobcats have been documented to overlap many females to increase breeding opportunities (Anderson and Lovallo 2003). Each overlapping or non-overlapping polygon was considered an experimental unit. We calculated habitat proportions within each polygon using the Xtools extension (Data East, LLC 2006) for ArcGIS.

Before analysis, we transformed the data to adjust the independence associated with the unit-sum constraint (Aebischer et al. 1993). The habitat percentages for the eight available habitats were transformed by dividing the proportion of each of seven habitats by the proportion of the eighth and then taking the natural log of the ratio. Unlike the typical compositional analysis (Aebischer et al. 1993), we did not calculate log-ratio differences because we were not interested in habitat selection. We used a Multivariate Analysis of Variance (MANOVA) to test for differences in habitat composition between the habitats of the overlapping and non-overlapping areas (Aebischer et al. 1993). Overlapping and non-overlapping areas were considered the class of the variables in the MANOVA procedure. If the null hypothesis was rejected, we used separate t-tests to assess differences between each proportion of each habitat in overlapping and non overlapping areas.

RESULTS

We located 26 bobcats a minimum of 30 times per season, resulting in more than 2900 locations for analysis. Two bobcats were excluded from the analysis because their home ranges did not overlap the home ranges of any other monitored bobcat; therefore 24 cats provided polygons for the analysis. Seven males had 7 overlapping areas and 7 non-overlapping areas. Several females overlapped in such a way that 17 females had 20 overlapping areas and 18 non-overlapping areas. For example there is a possibility that three home ranges could create four overlapping polygons.

Habitat composition of overlapping and non-overlapping male home ranges did not differ (Λ=0.3788, P =0.3471); however, habitat composition of overlapping and non-overlapping female home ranges differed (Λ=0.6234, P =0.0325). Univariate t-tests on the log-ratios of the habitat composition between overlapping and non-overlapping female home ranges suggest that the urban/barren, pine regeneration and shrub/scrub habitats all differed with ($P < 0.10$) with a greater proportion of these habitats occurring in non-overlapping areas (Figure 3.1).

DISCUSSION

We found no differences in habitat composition of overlapping and non-overlapping areas with regard to male bobcats. This lack of a detectable difference is likely due to the low sample size of males. Further, many of the overlapping areas were so small that they did not cover all the habitats that were available on the study area. Thus, the resulting data had a large proportion of zeros for availability of habitat types.

Male bobcats have been found to maintain exclusive home ranges with little to no overlap with other males (Zezulak 1980, Miller and Speake 1979). Our study supports other research in concluding that male bobcats rarely overlap with other males and maintain as exclusive permanent home ranges as possible.

Females bobcats typically maintain smaller home ranges and core areas (Chamberlain et al. 2003). Nielsen and Woolf (2001) found that female core ranges are exclusive of other bobcats. The female bobcats were found to maintain different proportions of habitats in exclusive areas than shared areas. Perhaps areas that bobcats use exclusively, such as pine regeneration and shrub/scrub habitats, provide adequate resources and are easily defended. Other habitats in the surrounding area probably do not provide adequate resources (Anderson and Lovallo 2003), and may not be worth defending, though this is speculation. Doughty (2004) and Cochrane (2003) also found that pine regeneration and shrub/scrub habitats are preferred by bobcats on the same study area. Where these habitats occur within the home range most likely have an effect on whether a bobcat will defend them. For example, habitats on the outer edge of a bobcat's home range would be more difficult to defend. The idea of bobcats maintaining exclusive core areas within their overall home range supports this concept (Nielsen and Woolf 2001). Thus, bobcats likely establish core areas in the best available habitat and defend these areas. Because these areas are smaller, they would be presumably easier to defend, and because they are resource-rich, they are worth defending.

Bobcat habitat preference is most likely a function of prey abundance (Knick 1990). If so, then prey abundance may be the resource that best explains home range overlap in bobcats as well. We found that habitats without large trees, such as regenerating pines and shrub/scrub areas were less likely to be shared. Bobcats may have exclusively maintained these areas because these habitats provide more sunlight to the ground, creating earlier succession habitats which tend to support dense prey populations (Litvaitis 2001).

If prey abundance determines whether or not bobcats share space, then more sharing of space should occur if prey resources are high across the study area (i.e., all patches are prey-rich). Similarly, if prey abundance is low across the landscape, then areas should be shared as home ranges increase (Knick 1990). We suggest that defended areas represent relatively prey-rich areas that are surrounded by areas with less prey. We speculate that as prey becomes more abundant on the landscape, only the habitats with the greatest abundance would be shared and that as prey abundance across the area declines, bobcats will defend areas of lower prey abundance until prey abundance at the landscape scale falls below a threshold below which no patches are worth defending. This concept would be consistent with the breakdown in land tenure observed by Knick (1990) following a prey decline in Idaho. If prey abundance influences home range overlap as we speculate, we would expect the greatest degree of exclusivity of home ranges to occur when prey abundance is at some intermediate, yet spatially uniform, level across the landscape.

In our study, the exclusive areas included more pine regeneration and shrub/scrub habitats. These areas are known to be preferred habitats by bobcats (Godbois 2003, Cochrane 2003). These habitats may have had relatively more prey than surrounding habitats; thus, bobcats may have chosen to defend these habitats to a greater degree than other habitat types. Alternatively, no habitats were more abundant in shared areas than within non-shared areas, possibly because bobcats will defend the same habitats as other individuals, yet share a wider variety of habitats. We found bobcats defended shrub/scrub and pine regeneration habitats, yet wetlands, hardwoods, mature pines, and mixed pines/hardwoods still occur in abundance across the site. Each bobcat could share a different proportion of the other habitats than the neighboring bobcats. For example, two bobcats would share hardwoods, one of those bobcats and another would share the mature pines, and two bobcats would share the wetland areas, yet they all used exclusive areas of shrub/scrub and pine regeneration habitats. Multiple bobcats could share multiple habitats, but defend only a small few. Perhaps this is an explanation of why bobcats would not have habitats in shared areas in greater abundance then exclusive areas.

In summary, bobcats share space that encompasses all available habitat types on our study site. Prey abundance likely dictates where bobcats establish their home range (Laitvaitis et al. 1986), and prey abundance within the home range likely determines the degree to which a bobcat defends portions of the home range. Whether or not a patch is defended is likely due to the abundance of resources (e.g., prey) within the patch, location of the patch relative to other patches of varying resource availability, and general abundance of critical resources across the landscape. Future research should address overlap at a finer temporal scale than examined during this study. While areas overlapped within a season, bobcats could have used these areas at different times to minimize contact with one another. For example, since we pooled our data across seasons, efforts can be concentrated on how bobcats shared habitats within seasons.

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Figure 3.1. Proportions of each habitat within overlapping and non-lapping polygons of female bobcats on Ichauway, Joseph W. Jones Ecological Research Center, Newton, Georgia, 2005-2006.

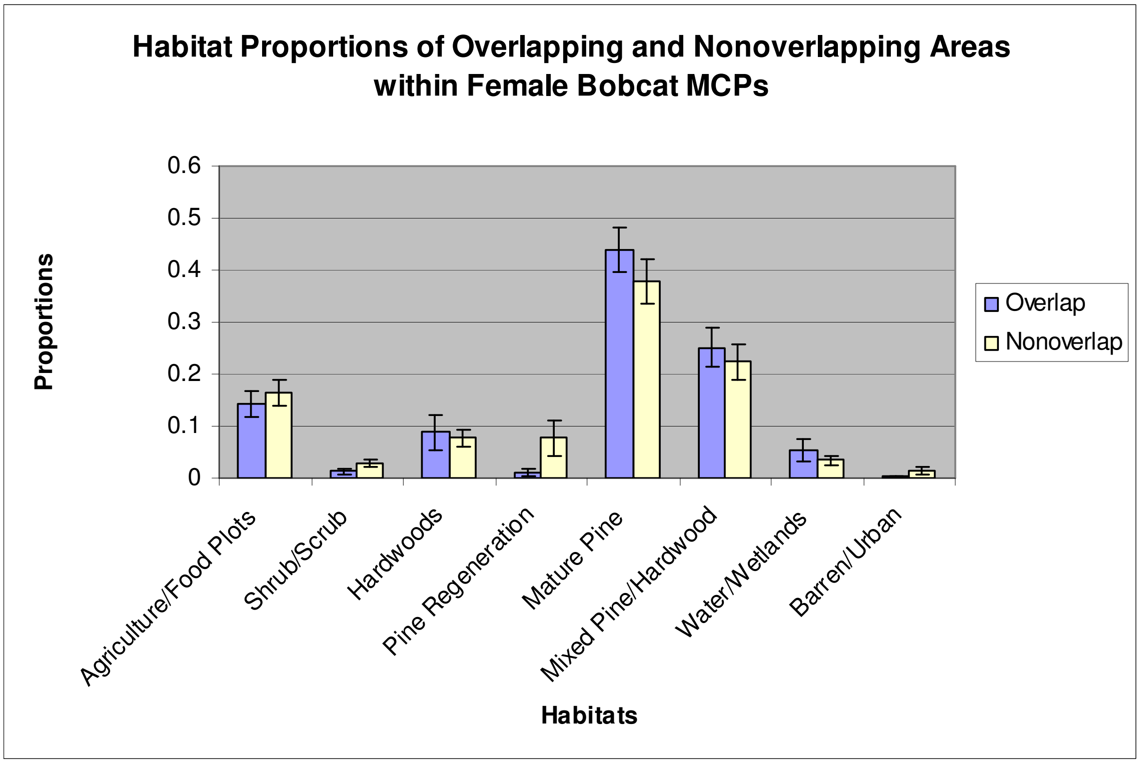
Habitat Proportions of Overlapping and Nonoverlapping Areas within Female Bobcat MCPs
Proportions
0.6
0.5
0.4
0.3
0.2
0.1
0
Overlap
Nonoverlap
Agriculture/Food Plots
Shrub/Scrub
Hardwoods
Pine Regeneration
Mature Pine
Mixed Pine/Hardwood
Water/Wetlands
Barren/Urban
Habitats

Table 3.1. Proportions of habitats in overlapping and non-overlapping areas for female bobcats in Southwestern Georgia, Joseph W. Jones Ecological Research Center, Newton, Georgia, 2005-2006.

Habitats	**Overlap**	**Standard Error**	**Nonoverlap**	**Standard Error**
Agriculture/Food Plots	14.2%	2.5%	16.4%	2.6%
Shrub/Scrub	1.3%	0.4%	2.7%	0.7%
Hardwoods	8.8%	3.3%	7.8%	1.6%
Pine Regeneration	1.1%	0.7%	7.8%	3.4%
Mature Pine	43.8%	4.3%	37.8%	4.3%
Mixed Pine/Hardwood	25.1%	3.8%	22.5%	3.4%
Water/Wetlands	5.5%	2.1%	3.5%	0.8%
Barren/Urban	0.2%	0.2%	1.5%	0.7%

CHAPTER 4

SUMMARY AND CONCLUSIONS

Bobcat ecology in Southwest Georgia has been studied since 2001 at the Joseph W. Jones Ecological Research Center. As a continuation of this project, we studied we looked at finding a more inexpensive alternative to radio-telemetry for habitat selection studies. Also, we looked at habitat composition within overlapping and non-overlapping polygons within bobcat home ranges.

If the home ranges between the two techniques were similar, then there would be definite advantages for scent stations to be an adequate substitute for radio-telemetry, but the results tell us the opposite. Scent stations are not an adequate substitution for radio-telemetry as the technique was implemented similar to our study. The most likely explanation why the techniques do not give us similar results is that each scent station acts as a single observation. Radio-telemetry provides multiple locations, which are summarized by bobcat to determine habitat selection metrics. Perhaps a more appropriate step when using scent stations would be to run transects instead of individual points. Using transects would allow for many more opportunities for an observation and not be limited to the 0.32-km minimum distance of the stations. Scent stations are limited to a single point in space; thus, if there are multiple habitats surrounding a given point, we must assume that each of these habitats contributed to an animal's use in proportion to the habitat's availability around a visited scent station. Therefore, if a bobcat visited a scent station because of a single habitat, the importance of other habitats around the point could be overestimated. The overestimation can be solved by placing each scent station in a single habitat. Therefore each visit would have a single habitat variable, thus eliminating the overestimation.

Other studies have used scent stations to determine habitat use (Edwards et al. 2002, Whittington et al. 2005). However, our study questions the validity of using animal sign at specific locations to develop infer habitat use. Habitat use studies that relied upon habitat attributes around locations that were visited by an animal should be interpreted cautiously. Moreover, future studies should attempt to validate results obtained using scent stations before continuing to collect habitat use data based on animal sign. Pedlar et al (1997) used scent stations placed in individual habitats to determine habitat use for raccoons. Placing scent stations within specific habitats without buffering the station may allow more accurate estimation of habitat use metrics because each scent station would provide a single habitat instead of multiple estimations of habitat used. Having the stations in single habitats would reduce errors associated with unused habitats that are present within buffers. However, numbers of scent stations required using this approach would likely be great if sufficient statistical power is obtained (Gehring and Swihart 2003).

We found no differences in habitat composition of overlapping and non-overlapping areas with regard to male bobcats. The lack of a detectable difference is likely due to the low sample size of radio-monitored male bobcats. Further, many of the overlapping areas were so small that they did not cover all the habitats that were available on the study area. Thus, the resulting data had a large proportion of zeros for availability of habitat types.

Bobcats habitat preference is most likely a function of prey abundance (Knick 1990). Perhaps prey abundance can explain home range overlap in bobcats as well. We found that habitats without large trees, such as regenerating pines and shrub/scrub areas were less likely to be shared by females. Female bobcats may have exclusively maintained these areas because these habitats provide more sunlight to the ground, creating earlier succession habitats which tend to support dense prey populations (Litvaitis 2001). When more resources are available to an individual bobcat than what is needed, the need to defend an area is reduced. Similarly, low food abundance would not be worth the energy spent to defend them when those resources alone cannot sustain the individual bobcat (Knick 1990).

If prey abundance determines whether or not bobcats share space, then more sharing of space should occur if prey resources are high across the study area (i.e., all patches are prey-rich). Similarly, if prey abundance is low across the landscape, then areas should be shared as home ranges increase (Knick 1990). We suggest that defended areas represent relatively prey-rich areas that are surrounded by areas with less prey. We speculate that as prey becomes more abundant on the landscape, only the habitats with the greatest abundance would be shared and that as prey abundance across the area declines, bobcats will defend areas of lower prey abundance until prey abundance at the landscape scale falls below a threshold below which no patches are worth defending. This concept would be consistent with the breakdown in land tenure observed by Knick (1990) following a prey decline in Idaho. If prey abundance influences home range overlap as we speculate, we would expect the greatest degree of exclusivity of home ranges to occur when prey abundance is at some intermediate, yet spatially uniform, level across the landscape.

No habitats were more abundant in shared areas than within non-shared areas. This can occur when bobcats will defend the same habitats, yet share a wider variety of habitats. We found bobcats to defend shrub/scrub and pine regeneration habitats, yet wetlands, hardwoods, mature pines, and mixed pines/hardwoods still occur in abundance across the site. Each bobcat could share a different proportion of the other habitats than the neighboring bobcats. For example, two bobcats would share hardwoods, one of those bobcats and another would share the mature pines, and two bobcats would share the wetland areas, yet they all used exclusive areas of shrub/scrub and pine regeneration habitats. Perhaps this is an explanation of why bobcats would not have habitats in shared areas in greater abundance then exclusive areas. Bobcats overlap all available habitat types across our study site. Mostly, we think that prey abundance across the study site can determine where bobcats prefer to be, and which habitats they will choose to defend.

In summary, we found that scent stations do not provide an adequate substitution for radio-telemetry. We also found that there are only minor differences in overlapping and non-overlapping habitat composition. Perhaps in the future, more research will be done to find a better way whereby scent stations could substitute for radio-telemetry and a reason why differences in the habitats that bobcats share and those they remain exclusive of other bobcats.

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