# **Home Range, Activity Patterns, and Habitat Selection of the Coyote (*Canis latrans*) Along an Urban-Rural Gradient**

by

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Abstract

Throughout the past several decades, coyotes (*Canis latrans*) have become common inhabitants of urban areas in the southeastern United States. Because their southward expansion is recent, there is a lack of information on movements of urban coyotes in the Southeast. I examined seasonal variation in size of home range, activity patterns, and habitat selection along an urban-rural gradient in east-central Alabama during 2007-2009. I created an urban-rural gradient based on percentage of urban land-cover in coyote home ranges. Percentage of urbanization in home ranges was 2-45%. Both composite and breeding season home ranges decreased as percentage of urbanization within the home range increased. However, models indicate that there was no difference in home range size along the gradient during pup-rearing and dispersal seasons. Mixed logistic-regression models indicated that coyotes along the gradient were active at similar times during all seasons. Along the gradient, coyotes avoided areas of high-, medium-, and low-intensity urbanization. As the percentage of urbanization within a home range increased, coyotes selected for hardwoods and for habitats near sources of water, while they selected against natural pine forests. Information presented in this study will allow biologists and resource managers to gain an understanding of movements of coyotes in urban areas and will be helpful in predicting and mitigating potential human-coyote interactions in the Southeast.

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# CHAPTER I: INTRODUCTION

Most ecosystems are dominated by humans (McIntyre et al. 2000). As global expansion of urban areas increases, interest in ecology of wildlife in urban areas is expanding rapidly (DeStefano and DeGraaf 2003). The earliest literature concerning wildlife in urban areas was published in the early 1900s, but the number of studies increased substantially after publication of Leopold's Game Management in 1933 (DeStefano and DeGraaf 2003). As metropolitan areas grow worldwide, it is becoming more important to study impacts of the urban-rural gradient on the changing ecology of landscapes (McDonnell and Pickett 1990). Studying ecological changes along the urban-rural gradient helps us to understand how urbanization is changing ecological patterns and processes (McDonnell and Pickett 1990). As landscapes urbanize, many species are able to adapt to the changes; synurbanization (Andrzejewski et al. 1978, Babiñska-Werka et at. 1979, Luniak 2004) is a term coined to describe the ability of animals to exist in urban areas in their wild state.

The coyote (*Canis latrans*) is able to exist and thrive in urban areas (Gehrt 2004). The coyote has expanded its range naturally, as well as with assistance from humans (Young and Jackson 1951, Bekoff 1977, Hill et al. 1987). The past 200 years have brought large-scale changes to the North American landscape and coyotes are now present in every state in the continental U.S., throughout all but the northernmost parts of Canada, and even in some isolated areas such as Cape Cod and Prince Edward Island (Gompper 2002). Researchers hypothesize that both decline of the red wolf (*C. rufus*) and clearing of forests for timber and agriculture (Gibson 1974) supported expansion of the geographic range of coyotes. The Southeast was among the last places for natural and artificial expansion of the range. In 1924, hunters, trying to replace the depleted stock of foxes (*Urocyon cinereoargenteus*, *Vulpes vulpes*), released coyote pups in Barbour County, Alabama. By 1929, there were reports of damage by coyotes in surrounding areas (Young and Jackson 1951). Populations are likely to continue to expand due to concentrated sources of food (Gipson and Sealander 1972, Gipson 1974), as well as changes in use of land.

The coyote is adaptive. Throughout recorded history, coyotes have been persecuted; the only immunity was from the early Navajo's and other aboriginal tribes who considered the coyote to be a deity (Young and Jackson 1951). Just a few years after American explorers first saw the coyote in the early 1800s, a bounty was placed on the species (Young and Jackson 1951). One of the most intensive campaigns to kill gray wolves (*C. lupus*) and coyotes for their pelts occurred during 1860-1885 when hundreds of thousands of coyotes were killed in the western United States (Grinnell 1914, Young and Jackson 1951). Although coyotes were persecuted similar to that of gray and red (*C. rufus*) wolves, they survived and flourished while populations of the gray wolf were decimated and the red wolf was nearly extirpated (Riley and McBride 1972, Peterson et al. 1998). In most states, there is still an open season that allows for year-round hunting of coyotes. Finkel (1999) estimates that 400,000 coyotes are killed every year throughout the United States; yet populations continue to thrive. Stanley Young (1951:11) provided a hypothesis:

> …"It is my feeling that the great and constant pressure exerted upon the coyote by man has been a real factor in its spread through the centuries. Even among the human races

> may be found cases where persecution has encouraged the constant seeking of newer and greener pastures in the attempt at survival. The sum-total of the causes behind this urge to spread on the part of the coyotes is a field yet to be thoroughly explored for final answers. They are one of the few animals that have been able to extend its range within historic times."

Habituation of coyotes is not something new; there are many historical accounts of coyotes and their adaptability. One account from the book The Clever Coyote (Young and Jackson 1951), tells how coyotes associated campfires as signs of food in the 1880s. In 1947, Yellowstone National Park reported that coyotes caused many traffic jams after joining bears in looking for food from visitors (Young and Jackson 1951).

Because coyotes are top predators in most urban areas they inhabit, they have become extremely controversial in these landscapes (Gehrt 2007). Recently, attacks by coyotes have received attention from the public. In urban areas, coyotes have injured and killed domestic cats, small dogs, (Grubbs and Krausman 2009), and occasionally, people (Timm et al. 2004). During 1960-2006, 142 attacks on humans were reported from 4 Canadian provinces and 14 states; 70% of these were either on, or immediately adjacent to the victim's residence (Gehrt and White 2009). Although these statistics may cause the coyote to sound like a threatening predator, in comparison, from 1979-1996 more than 300 people were killed from dog bite-related incidences (Sacks et al. 2000).

In the 19th and 20th centuries, many top predators were removed from the United States. Shifts in the carnivore community can result in trophic cascades (Terborgh et al. 2001). Because coyotes dispersed across the landscape, they may now be playing an important role as apex predators by controlling populations of raccoons (*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*), which are two species that also are prevalent in urban areas (Kamler and Gipson 2004). Coyotes also may be helpful in controlling populations of feral cats (Grubbs and Krausman 2009), white-tailed deer (*Odocoileus virginianus*; Howze et al. 2009, VanGilder et al. 2009), and Canada geese (*Branta canadensis*; Brown 2007). An increase in mid-sized predators can have an effect on populations of songbirds, waterfowl, and other game birds (Crooks and Soulé 1999). Areas with coyotes have increased reproductive success of waterfowl and ground-nesting birds because coyotes reduce populations of foxes (Sovada et al. 1995; Rogers and Caro 1998).

Recent studies have investigated behavior of coyotes in cities across the United States (Quinn 1997, Grinder and Krausman 2001, Riley et al. 2003, Way et al. 2004, Gehrt et al. 2009), but no study has been conducted in urban areas of the southeastern United States. Studies have been conducted on behavior (Sumner et al. 1984, Holzman et al. 1992, Chamberlain and Leopold 2000, Constible et al. 2006, Schrecengost et al. 2009) and expansion of geographic range in the Southeast (Hill et al. 1987), but none investigated the influence of urban environments on behavior.

LITERATURE CITED

Andrzejewski, R., J. Babiñska-Werka, J. Gliwicz, and J. Goszczyñski. 1978. Synurbanization processes in an urban population of *Apodemus agrarius*. I. Characteristics of population in an urbanization gradient. Acta Theriologica 23:341-358.

Babiñska-Werka, J., J. Gliwicz, and J. Goszczyñski. 1979. Synurbization processes in an urban population of *Apodemus agrarius*. II. Habitats of the striped field mouse in town. Acta Theriologica 26:405-415.

Bekoff, M. 1977. *Canis latrans*. Mammalian Species 79:1-9.

Brown, J. L. 2007. The influence of coyotes on an urban Canada goose population in the Chicago metropolitan area. M.S. thesis, Ohio State University, Columbus.

Chamberlain, M. J., C. D. Lovell, and B. D. Leopold. 2000. Spatial-use patterns, movements, and interaction among adult coyotes in central Mississippi. Canadian Journal of Zoology 78:2087-2095.

Constible, J. M., M. J. Chamberlain, and B. D. Leopold. 2006. Relationships between landscape pattern and space use of three mammalian carnivores in central Mississippi. American Midland Naturalist 155:352–362

Crooks, K. R., and M. E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400:563-566.

Destefano, S., and R. M. Degraff. 2003. Exploring the ecology of suburban wildlife. Frontiers in Ecology and Environment 1:95–101.

Finkel, M. 1999. The ultimate survivor. Audubon 101:52-59.

Gehrt, S. 2007. Ecology of coyotes in urban landscapes. Proceedings of the Wildlife Damage Management Conference 12:303-311.

Gehrt, S. D. 2004. Ecology and management of striped skunks, raccoons, and coyotes in urban landcscapes. Pages 81-104 in Predators and people: from conflict to conservation (N. Fascione, A. Delach, and M. Smith, eds.). Island Press, Washington, D.C.

Gehrt, S. D., and L. A. White. 2009. Coyote attacks on humans in the United States and Canada. Human Dimensions of Wildlife 14:419-432.

Gehrt, S. D., C. Anchor, and L. A. White. 2009. Home range and landscape use of coyotes in a metropolitan landscape: conflict or coexistence? Journal of Mammalogy 90:1045-1057.

Gipson, P. S. 1974. Food habits of coyotes in Arkansas. Journal of Wildlife Management 38:848–853.

Gipson, P. S., and J. A. Sealander. 1972. Home range and activity of the coyote (*Canis latrans frustror*) in Arkansas. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish 26:82–95.

Gompper, T. 2002. Top carnivores in the suburbs? Ecological and conservation issues raised by colonization of northeastern North America by coyotes. BioScience 521:185–190.

Grinder, M. I., and P. R. Krausman. 2001. Home range, habitat use, and nocturnal activity of coyotes in an urban environment. Journal of Wildlife Management 65:887-898.

Grinnell, G. B. 1914. The wolf hunters. Grosset and Dunlap Publishers, New York.

Grubbs, S. E., and P. R. Krausman. 2009. Observations of coyote-cat interactions. Journal of Wildlife Management 73:683-685.

Hill, E. P., P. W. Sumner, and J. B. Wooding. 1987. Human influences on range expansion of coyotes in the Southeast. Wildlife Society Bulletin 15:521-524.

Holzman, S., M. Conroy, and J. Pickering. 1992. Home range, movements and habitat use of coyote in south-central Georgia. Journal of Wildlife Management 56:139-146.

Howze, B. M., L. M. Conner, R. J. Warren, and K. V. Miller. Predator removal and white-tailed deer recruitment in southwestern Georgia. Proceedings of the Annual Southeastern Association of Fish and Wildlife Agencies 63:17-20.

Kamler, J. F. and P. S. Gipson. 2004. Survival and cause-specific mortality among furbearers in a protected area. American Midland Naturalist 151:27-34.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York.

Luniak, M. 2004. Synurbization adaption of animal wildlife to urban development. Pages 50-55 in Proceedings of the 4th international symposium on urban wildlife conservation (W. W. Shaw, L. K. Harris, and L. Vandruff, eds.). University of Arizona, Tucson.

McDonnell, M. J. and S. T. A. Pickett. 1990. Ecosystem structure and function along urban-rural gradient: an unexploited opportunity for ecology. Ecology 71:1232-1237.

McIntyre, N. E., K. Knowles-Yánez, and D. Hope. 2000. Urban ecology as an interdisciplinary field: differences in the use of "urban" between the social and natural sciences. Urban Ecosystems 4:5-24.

Peterson, R., N. J. Thomas, J. M. Thurber, J. A. Vucetich, and T. A. Waite. 1998. Population limitation and the wolves of Isle Royale. Journal ofMammalogy 79:828–841.

Quinn, T. 1997. Coyote (*Canis latrans*) habitat selection in urban areas of western Washington via analysis of routine movements. Northwest Science 71:289-297.

Riley, G. A., and R. T. McBride. 1972. A survey of the red wolf (*Canis rufus*). Pages 263–277 in The wild canids: their systematics, behavioral ecology and evolution (M. W. Fox, ed.). Van Nostrand Reinhold, New York.

Riley, S. T., R. M. Sauvajot, T. K. Fuller, E. C. York, D. A. Kamradt, C. Bromely, and R. K. Wayne. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. Conservation Biology 17:566-576.

Rogers, C. M., and M. J. Caro. 1998. Song sparrows, top carnivores and nest predation: a test of the mesopredator release hypothesis. Oecologia (Berlin) 116:227-233.

Sacks, J. J., L. Sinclair, J. Gilchrist, G.C. Golab, and R. Lockwood. 2000. Breeds of dogs involved in fatal human attacks in the United States between 1979 and 1998. Journal of the American Veterinary Medical Association 217:836–840.

Schrecengost, J. D. 2009. Home range, habitat use, and survival of coyotes in western South Carolina. American Midland Naturalist. 162:346-355.

Sovada, M. A., A. B. Sargeant, and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. Journal of Wildlife Management 59:1–9.

Sumner, P. W., E. P. Hill, and J. B. Wooding. 1984. Activity and movements of coyotes in Mississippi and Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38:174-181.

Terborgh, J., P. Nuñez, M. Rao, G. Shahabuddin, G. Orihuela, M. Riveros, R. Ascanio, G. H. Adler, T. D. Lambert, and L. Balbas. 2001. Ecological meltdown in predator-free forest fragments. Ecology 294:1923-1926.

Timm, R. M., R. O. Baker, J. R. Bennett, and C. C. Coolahan. 2004. Coyote attacks: an increasing suburban problem. Transactions of the North American Wildlife and Natural Resources Conference 69:67-88.

VanGilder, C. L., G. R. Woods, and K. V. Miller. Effects of an intensive predator removal on white-tailed deer recruitment. Proceedings of the Annual Southeastern Association of Fish and Wildlife Agencies 63:11-16.

Way, J. G., I. M. Ortega, and E. G. Strauss. 2004. Movement and activity patterns of eastern coyotes in a coastal, suburban environment. Northeastern Naturalist 11:237-254.

Young, S. P., and H. H. T. Jackson. 1951. The clever coyote. Stackpole Company and Wildlife Management Institute, Washington, D.C.

## CHAPTER II: HOME RANGE, ACTIVITY PATTERNS, AND HABITAT SELECTION BY THE COYOTE (*CANIS LATRANS*) ALONG AN URBAN-RURAL GRADIENT IN EAST-CENTRAL ALABAMA


### ABSTRACT

As populations of humans in the southern United States continue to grow, distinct urban- rural gradients are forming throughout the landscape. Wildlife in these areas may have different behavioral patterns due to interactions with the increasing populations of humans and ever-changing habitat. I examined composite size of home range of the coyote (*Canis latrans*), seasonal size of home range, activity patterns, and selection of habitat along an urban-rural gradient in east-central Alabama during 2007-2009. I created an urban-rural gradient based on amount of urban land-cover in individual home ranges. Percentage of urbanization in individual home ranges was 2-45% and population density was 4-780 humans/km$^2$. Both composite and breeding season home ranges decreased as percentage of urbanization within the home range increased. However, models indicate that there was no difference in home range size along the gradient during pup-rearing and dispersal seasons. Mixed logistic-regression models indicated that coyotes along the gradient were active at similar times during all seasons. Along the gradient, coyotes avoided areas of high-, medium-, and low-intensity urbanization. As the percentage of urbanization within a home range increased, coyotes selected for hardwoods and for habitats near sources of water, while they selected against natural pine forests.

Information presented in this study will allow biologists and resource managers to gain an understanding of movements of coyotes in urban areas and will be helpful in predicting and mitigating potential human-coyote interactions in the Southeast.

## INTRODUCTION

The population of the world is >6.8 billion people, with the United States at almost 310 million (U.S. Census Bureau 2010). The exponential growth in populations of humans is causing rapid development of undeveloped areas and further development of already developed areas. As cities become more densely populated, residents are moving away from the centers and into suburban, exurban, and rural areas. This movement causes gradients in urbanization (Marzluff et al. 2001) that become more complex as use of land changes and outlying areas become more urbanized (Alberti et al. 2001). Although most of the world is undergoing urbanization, little is known about wildlife in urban areas because scientists often focus on pristine environments (Cairns 1988). Synurbanization (Andrzejewski et al. 1978, Babiñska-Werka et al. 1979, Luniak 2004) is a term used to describe ability of animals to exist in urban areas in their wild state in response to global expansion of urban areas (Luniak 2004). Adaptation to these areas requires species-specific behavioral changes (Luniak 2004), and as a mesocarnivore known to inhabit urban areas (Gehrt 2004), behaviors of coyotes (*Canis latrans*) in these areas deserves investigation.

Despite persecution in the early 20th century, both alteration of habitat and reduction of apex predators have allowed the coyote to expand its range to colonize nearly all of North America (Moore and Parker 1992, Dennis 2010; Fig. 2.1). Harvesting timber for revenue and agricultural practices along with decreases and eliminations of populations of gray (*Canis rufus*) and red (*C. lupus*) wolves have allowed coyotes to occupy new habitats with little competition or harassment (Gipson 1974). The Southeast was one of the last places for natural and human-induced expansion of the geographic range to occur (Bekoff 1977, Hill et al. 1987, Moore and Parker 1992), as populations were not reported east of the Mississippi River until the 1920s (Young and Jackson 1951). Most recently, coyotes have become common inhabitants of many urban areas in the United States and Canada, including the southeastern United States (Gehrt 2004, 2007). Coyotes are able to exist in the most developed landscapes while usually avoiding interactions with humans (Gehrt et al. 2009). The unyielding adaptability of coyotes, as well as their transition from undeveloped land to developed agricultural and human-dominated areas, is a good indication that populations will continue to expand throughout the Southeast (Holzman et al. 1992).

Attacks on humans by coyotes, although once rare, have increased during the past decade (Timm et al. 2004). Coyotes may not fear entry into suburban areas because of nearby wildlands and activities by humans that serve as sources of food (Timm et al. 2004). Similar to parts of California, the Auburn-Opelika metropolitan statistical area (MSA) is a growing metropolitan area with many attractive landscapes for potential prey. As human-coyote interactions increase, there is a greater need for information on behavioral adaptations of coyotes so appropriate management plans can be developed (McClennen et al. 2001).

Although research has been conducted on impacts of urbanization on behavior of coyotes in other parts of the country (e.g., Quinn 1997, Grinder and Krausman 2001, Riley et al. 2003, Way et al. 2004, Gehrt et al. 2009), there has been much variability in quantification of the urban gradient (Theobald 2004, Gehrt 2007). Because results have varied geographically (Andelt and Mahan 1980, Atkinson and Shakleton 1991, Grinder and Krausman 2001, Quinn 1991, Way et al. 2004) and there is no published information available on spatial and temporal effects of urbanization on coyotes in the Southeast, this study is vital to our understanding of coyotes in the southeastern United States.

Size of home range is influenced by the individual, sex, biological season, efficacy of movement, distribution of resources, density of populations, habitats, and other factors (Schoener 1971, Laundré and Keller 1984, Gese et al. 1988, Shargo 1988). These factors cause size of home ranges to vary, not only in different regions of North America, but also among individuals in a population (Holzman et al. 1992). Small home ranges can be indicators of large populations (Andelt 1985, Fedriani et al. 2001), which may increase likelihood of diseases, aggression between coyotes, and human-coyote encounters (Atwood et al. 2004). However, small home ranges can also be indicators of abundant, evenly dispersed resources (Clutton-Brock and Harvey 1978). Data compiled from previous studies demonstrate that size of home range varies with amount of urbanization inside of the home range (Gehrt 2007). Although data from across the country indicate that home ranges of coyotes are smaller in urban areas, this is not always true. Studies in Chicago (Gehrt et al. 2009) and Los Angeles (Riley et al. 2003) revealed that size of home range increases with increasing fragmentation of habitat; however, size of home range also can vary with proximity of resources and activities of humans (Gehrt 2009).

Because movements of coyotes vary among localities, knowledge of general patterns of movements is vital to understanding needs and responses of coyotes in urbanized areas (Grinder and Krausman 2001). Previous research demonstrated that coyotes that were subjected to little or no hunting pressure, tended to be more active during diurnal and crepuscular hours (Gipson and Sealander 1972, Andelt 1985) than those that were hunted intensively (Andelt and Gipson 1979). Daytime and crepuscular activity directly correlates with hours when the visual system functions most efficiently (Kavanau and Ramos 1975). In urban areas, researchers have reported that nocturnal activity increases with amount of development or activity by humans (Grinder and Krausman 2001, McClennen et al. 2001, Tigas et al. 2002, Riley et al. 2003, Morey 2004). This increase in activity of coyotes may be due to decrease in vehicular traffic and lowered likelihood of human-coyote interactions during the night (Gehrt 2007). Because activity patterns of coyotes are consistent in urban areas studied across the United States, an understanding of activity patterns in the Southeast would serve as a predictor of habituation and help improve management techniques to reduce the risk of human-coyote conflict (Way et al. 2004).

Managing and conserving animals requires an understanding of habitats that they use (Levin 1992). Studying preferences for habitats attempts to quantify inherent needs of animals in the environment where they live (Johnson 1980). Urban areas present a new challenge for studies of use of habitats. The process of urbanization changes a habitat from one that was unfragmented or barely fragmented, to a highly fragmented or patchy area. Fragments, or patches, make up urban landscapes with the largest amounts of natural vegetation typically present in parks and reserves (Quinn 1997). Although urbanized areas usually are disjunct, availability of subsidized resources from humans and elimination of apex predators have led to high densities of coyotes in urban areas (Crooks and Soulé 1999, Grinder and Krausman 2001).

Although other studies have examined habitats selected by coyotes along urban-rural gradients (Atwood et al. 2004, Randa and Yunger 2006), these studies were not performed in the Southeast. It is unknown how coyotes use urban areas in the southeastern United States because expansion of geographical range into this area was recent. Inferences from the western United States about the ecology of coyotes are not relevant to the Southeast due to variability in spatial patterns (Holzman et al. 1992, Schrecengost et al. 2009) and habitat types. Holzman et al. (1992) suggested that coyotes had adapted and would continue to thrive in the Southeast.

I examined effect of urbanized land on size of home range, activity patterns, and habitats occupied along an urban-rural gradient. The objectives of my study were to: 1) quantify a repeatable urban-rural gradient within Lee County, Alabama; 2) determine the effect of varying levels of urbanization on composite and seasonal size of home range; 3) determine how seasonal and diel activity patterns are affected by varying levels of urbanization; and 4) determine how selection of habitat is affected by varying levels of urbanization. I predicted that as urbanization increased, size of home ranges would be smaller and less variable throughout biological seasons. I expected coyotes in areas with greater percentages of urbanization to be more active during nocturnal hours; thereby, avoiding interaction with humans, whereas coyotes in areas with lesser percentages of urbanization would be most active during dawn and dusk. I predicted that as urbanization increased, coyotes would be more likely to select urbanized patches and less likely to select natural landscapes. Information from this study will allow biologists, planners, and managers to gain an understanding of behavior of coyotes in southeastern urban, exurban, and rural areas, and will be helpful in determining how the coyote has adapted to urban areas.

## MATERIALS AND METHODS

### *Study Area*

Lee County is in east-central Alabama and includes the Auburn-Opelika Metropolitan Statistical Area (MSA); MSAs are defined by the U.S. Census Bureau as urbanized areas with ≥50,000 inhabitants. The population of the Auburn-Opelika MSA has increased 18.1% during 2000-2009, from 115,094 to 135,883 people (U.S. Census Bureau 2010). Lee County has extensive biotic diversity and a pronounced urban-rural gradient with almost equal amounts of urban and rural areas. Of the 2,966 census blocks in the county, 56% are rural and 44% are urban (Fig. 2.2).

East-central Alabama has a subtropical climate with an average high temperature of 32ºC in July and an average low of 1ºC in January; average precipitation is 1,337 mm. Lee County contains 1,595 $km^2$ of land, 18 $km^2$ of surface water (U. S. Census Bureau 2000), and is in the southeastern Mixed Forest Province (Bailey 1980). There is an abundance of biotic variation in Lee County because it is at a physiographic fall line, the southern one-half is in the East Gulf Coastal Plain and the northern one-half is in the southern Piedmont Upland region. Forests consist of a variety of broadleaf deciduous trees mixed with pines and bottomland hardwoods (Appendix 1).

The Auburn-Opelika MSA is composed of urban and suburban features within a patchwork of natural areas. The populated core of the county is comprised of schools, single-family homes, condominiums, apartments, shopping centers, operating and abandoned factories, and recreational areas. Outskirts of the MSA are both exurban and rural landscapes and contain natural areas, agricultural lands, fallow fields, clear cuts, managed hunting areas, pastures, pine plantations, recreational areas, single-family homes, schools, scattered small businesses, and roadside markets.

*Live Captures*

Fieldwork was conducted during July 2007-July 2009 in Lee County, Alabama (Fig. 2.2) during all biological seasons as defined by Holzman et al. (1992): breeding (1 January–30 April), pup-rearing (1 May–31 August), and dispersal (1 September–31 December). To maximize trapping success and ensure an even sample across the study area, I placed 5 motion-sensing cameras (DV-5, Leaf River Outdoor Products, Taylorsville, Mississippi) in areas of suspected activity throughout the county during June-September 2007. Cameras were placed at 10 sites, both university and private lands, for ≥7 nights. I used dirt-hole sets in conjunction with a long-range canid lure (Carmen's Canine Call, Russ Carmen, New Milford, Pennsylvania) and a meso-carnivore bait (Caven's Hiawatha Valley, Minnesota Trapline Products, Pennock, Minnesota) to attract coyotes to camera sites. Sites where coyotes were photographed were used for trapping.

I used number 3 Victor Soft-Catch foothold traps (Woodstream Corporation, Lititz, Pennsylvania) modified with crunch-proof swivels (Minnesota Trapline Products, Pennock, Minnosota) to capture coyotes. I set traps during September 2007-May 2008 and November-December 2008. Trapping was discontinued during pup-rearing (1 May-31 August) due to high temperatures and to minimize risk of capturing lactating females or pups. I placed traps in areas that were part of the camera study, as well as in areas with reported activity. Traps were set at forks in roads in fields and forests, in game trails, and in other areas easily accessible by coyotes; I did not set traps close to water or fruiting trees to reduce accidental capture of non-target species.

Caven's Hiawatha Valley (Minnesota Trapline Products, Pennock, Minnesota) and Kozy Kitten cat food (Promark International, Boise, Idaho) were alternated as baits, and Carmen's Canine Call (Russ Carmen, New Milford, Pennsylvania), urine of coyotes, and urine of red foxes (*Vulpes vulpes*) were alternated as lures. I deployed traps in mid-afternoon and checked them after sunrise and before sunset. Non-target captures were released immediately and traps were removed from the area. I photographed and described each captured coyote. Coyotes were pinned to the ground with a snare pole, their muzzles and legs were bound with electrical tape, and each coyote was weighed using a hanging spring scale. Sex, approximate age (by tooth wear), and reproductive status were determined. Measurements (cm) included total length, length of body, length of right hind foot, and length of ear. All injuries were recorded. VHF collars (160 g) with mortality sensors (Advanced Telemetry Systems, Isanti, Minnesota) were attached to coyotes weighing ≥3.2 kg as described by White and Garrott (1990). I released coyotes at the point of capture.

Capture and handling followed guidelines of the American Society of Mammalogists (Animal Care and Use Committee 1998). This research was approved by

Auburn University Institutional Animal Care and Use Committee (protocol 2007-1244) and by the Alabama Department of Conservation and Natural Resources (permit 4311).

*Radiotelemetry*

After initial capture, I waited 2 weeks before tracking to allow time for coyotes to adjust to radiocollars (White and Garrott 1990). Coyotes were located initially by using an Omni antenna fixed to a moving vehicle. Once a signal was received, I used a portable, hand-held, 3-element Yagi antenna (Wildlife Materials, Carbondale, Illinois) and a R2000 Scientific Receiver (Advanced Telemetry Systems, Isanti, Minnesota) to triangulate locations. Sequential locations were taken a minimum of 2 times/week during: breeding (1 January–30 April), pup-rearing (1 May–31 August), and dispersal (1 September–31 December) seasons. I tracked coyotes during 8-hour intervals, randomly across the 24-hour day. Each coyote was located ≥2 times during a session. Three bearings were taken within ≤20 minutes and ≥0.5 km apart as suggested by Arjo and Pletscher (2004) with an intersecting angle >20 and <160º (Gese et al. 1988). For each coyote, ≥3 bearings were taken; more were taken if the signal was weak. I waited ≥2 hours between locations to avoid temporal autocorrelation of data. I used a Garmin Ique 3600 with a Garmin GPS antenna kit (Garmin International, Inc., Olathe, Kansas), to input bearings and GPS locations into the program LOCATE III (Nams 2006) while in the field. Error was measured by testing radiocollars in a blind study following techniques of White and Garrott (1990). For each of the two tests, approximately 100 locations were taken. Precision was 7.5° and was entered into Locate III (Nams 2006) to estimate locations with maximum-likelihood estimation. Locations with an error ≥1 $km^2$ were not used in calculations of size of home range.

*Estimation of Size of Home Range*

I estimated overall (composite) and seasonal (breeding, pup-rearing, dispersal) size of home ranges (95% contours) and core areas (50% contours) with the adaptive-density-kernel method (ADK; Worton 1989) in the program Home Range Tools for ArcGIS 9.3.1 (Rodgers et al. 2005). The ADK method was chosen because it accurately represented the fragmented home ranges of urban coyotes (Grinder and Krausman 2001, Atwood et al. 2004). Bandwidth was estimated by least-squares cross-validation. I used a linear model to determine overall seasonal variation in home range size.

*Estimation of Activity Patterns*

I gathered data on activity by using signal-attenuation techniques during all hours of the day and during all seasons following recommendations of Patterson et al. (1999) and Riley et al. (2003). I held the antenna stationary and animals were recorded as active or inactive depending on changes in attenuation over a 30-second period following Patterson et al. (1999). To determine variation in diel activity, I divided data into nocturnal (1931-0430 hour), crepuscular (0431-0730 and 1631-1930 hours), and diurnal (0731-1630 hour) based on average yearly length of day using the technique described by McClennen et al. (2001). Percentage of activity was number of active signals divided by total amount of active and inactive signals for each individual. I used a logistic regression model to determine differences in activity patterns for all coyotes during all seasons and diel periods. Although the signal-modulation method has been criticized (White and Garrott 1990), other researchers consider it legitimate for determining times of activity (Patterson et al. 1999, Riley et al. 2003, Way et al. 2004).

*Urban-Rural Gradient*

Urban gradients are difficult to quantify; each place may have a variety of factors affecting the gradient. Via Mcintyre et al. (2000), I created a working definition of urban, one that described the Auburn-Opelika MSA with the least redundancy as suggested by Hahs and McDonnell (2006). I used ArcMap (Version 9.3.1, Environmental Systems Research Institute, Redlands, California) with TIGER/Line edge and census block data (U.S. Census Bureau 2007), and a digital map from the Alabama Gap Analysis Project (AL-GAP; Silvano et al. 2010) to quantify the urban gradient. Associated tables of attributes for county census blocks (U.S. Census Bureau 2000) were joined to the census-block layer. Maps were projected on North American Datum 83 (NAD 83). I reclassified the AL-GAP digital map to reduce land-use types from 23 to 11 following Riley et al. (2003) and Way et al. (2004; Table 2.1). I also reclassified edge files into three categories for roads as specified by Atwood et al. (2004; Table 2.2).

I estimated density of populations of humans in each home range by determining average number of humans/$km^2$ in each census block, then calculating amount of each census block in individual home ranges of coyotes. I used the same technique to determine types of roads in each home range. Because Lee County has grown markedly in the past 10 years, analyses required more recent data on land-cover than were available from AL-GAP. To correct this problem, I used the Geospatial Modeling Environment

(GME) in ArcMap to generate 200 random 30 x 30-m blocks (AL-GAP imagery pixel size) in each home range and compared their AL-GAP-land-cover classifications to 2006 digital-orthophoto-quarter quadrangles (DOQQ) produced by the Alabama State Water Program. Using the same classification criteria as the AL-GAP, I updated all points so the land-cover classification was consistent with the DOQQ. This method was less laborious than reclassifying the entire study area. I used ground truthing to validate areas where the classification had changed.

I calculated land-use association as the percentage of the 11 classes of land in each home range following Riley et al. (2003; Appendix 2). Employing data on use of land, I summed amounts of low, medium, and high urbanization in each home range to create an urbanization variable (Atwood et al. 2004). Urbanization was measured by the percentage of each home range consisting of urbanized land (Riley et al. 2003).

I examined relationships between amount of urbanization and size of home range using linear-regression models following Gehrt et al. (2009). I tested for non-linearities in data using polynomial regression. Urbanization models were generated using five independent variables: percentage urban area in each home range, proportion of low-intensity roads in each home range ($km^2$), proportion of medium-intensity roads in each home range ($km^2$), proportion of high-intensity roads in each home range ($km^2$), and population density of humans in each home range (Table 2.3). Because there were five variables of urbanization, I used principal-components analysis (PCA) in the statistical package R (R Development Core Team, R Foundation for Statistical Computing, Vienna, Austria) to uncover potential trends in the data.

I used linear-regression models, in the statistical package R, to determine effects of urbanization on seasonal size of home range. Dependent variables were seasonal size of home ranges and independent variables were percentage urban area in each home range, proportion of low-intensity roads in each home range ($km^2$), proportion of medium-intensity roads in each home range ($km^2$), proportion of high-intensity roads in each home range ($km^2$), and population density of humans in each home range.

A mixed-effects, logistic-regression model (lme4 library in R; R Development Core Team, R Foundation for Statistical Computing, Vienna, Austria) was used to describe effects of diel period, season, and urbanization on activity patterns. I used mixed-effects logistic regression because data on activity was in binary form and each coyote was considered an individual. Active was coded as 1 and inactive as 0.

*Estimation of Habitat Selection*

Following Manly's (2002) type III design, I assessed availability of habitat and habitat selection by coyotes along an urban-rural gradient. To determine selected habitat, I used all locations for each coyote. To determine available habitat, I used the GME to obtain 200 random-sampling points in each home range. I used maps from AL-GAP (Silvano et al. 2010) to determine classifications of land and updated each point using 2006 DOQQ's produced by the Alabama State Water Program. Using the same classification criteria as the AL-GAP, I updated all points so the land-cover classification was consistent with the DOQQ. I used ground truthing to validate my new classifications. For each point that was used or available, I used the GME to determine distance to nearest road and distance to nearest body of water from each point. Distance to road and distance to body of water were used with the land-classification variables to create the model for habitats occupied.

To determine overall habitat selection, I used a logistic regression model to create a Resource Selection Function (RSF) based on a use and availability following Manly et al. (2002). To determine habitat selection along the gradient, I used a mixed-effects logistic-regression model in R (lme4; R Development Core Team, R Foundation for Statistical Computing, Vienna, Austria) to create a RSF. Individuals were used as a random intercept to prevent correlation between coyotes. Based on results of the RSF model, I created a global-logistic-regression model for all coyotes using all variables of habitat (Table 2.1), as well as distances to roads and water. I generated RSF models for each coyote during each season, each diel period, and for the entire year.

I used coefficient estimates from individual logistic regressions to form simple-linear-regression models for each habitat along the urban-rural gradient. Due to the low sample size, I was not able to model seasonal or diel habitat selection along the gradient.

## RESULTS

I captured and radiocollared 20 coyotes (3 males, 17 females). Of these 20, 14 (2 males, 12 females) survived long enough to be included in analyses of home range and activity. During May 2008 - August 2009, I acquired 2,382 locations on 14 collared coyotes throughout Lee County, Alabama (Appendices 3 and 4). As of 8 May 2011, 9 of the original 20 coyotes had died. Of the 9 mortalities, 4 females and 1 male dispersed prior to their death. Dispersal distances ranged from 40-402 $km^2$ from the trap site. Survival and dispersal information is located in Appendix 5.

*Overall Size of Home Ranges*

Mean size of composite home range for all coyotes was 10.61 $km^2$ ($n$ = 14; range = 3.72-18.82 $km^2$). Mean sizes of seasonal home ranges were 9.15 $km^2$ ($n$ = 13; range = 6.67-12.50 $km^2$) during breeding, 9.41 $km^2$ ($n$ = 13; range = 2.6-23.0 $km^2$) during pup-rearing, and 7.43 $km^2$ ($n$ = 13; range = 0.50-23.0 $km^2$) during dispersal. I detected no differences in seasonal sizes of home range (Table 2.4).

*Urban-Rural Gradient and Composite Home Ranges*

Percentage of urbanization in individual home ranges was 2-45%. Results of a PCA, including all five variables of urbanization (Table 2.5), revealed that the first principal component, density of the population of humans, explained 99.9% of variation among variables of urbanization. In the first regression model (Table 2.6), density of the population of humans did not have an effect on size of home range ($F_{1,12}$ = 3.31, $P$ = 0.09); however, the coefficient estimate indicated that home ranges in the most-populated areas were 7.9 $km^2$ (-1.55-15.50 $km^2$) smaller than those in the least-populated areas (Fig. 2.4). In the second model, percentage of urbanization within a home range had a negative effect on size of home range ($F_{1,12}$ = 8.80, $P$ = 0.01), with the most-urbanized home ranges 9.6 $km^2$ (2.60-16.70 $km^2$) smaller than home ranges with the least urbanization (Fig. 2.5). In the fourth model, medium-intensity roads were an indicator of size of home range ($F_{1,12}$ = 5.94, $P$ = 0.03); home ranges with the most medium-intensity roads were 9.2 $km^2$ (1.14-17.00 $km^2$) smaller than home ranges with the lowest density of medium-intensity roads (Fig. 2.6). Proportions of low- and high-intensity roads did not affect sizes of home range along the gradient.

*Seasonal Size of Home Ranges Along the Urban-Rural Gradient*

During the breeding season, home ranges decreased in size as urbanization increased; however, home range size did not differ during the pup-rearing and dispersal seasons (breeding, $F_{1,11} = 6.56$, $P = 0.03$; pup-rearing, $F_{1,11} = 1.50$, $P = 0.24$; dispersal, $F_{1,11} = 4.20$, $P = 0.07$; Table 2.7). During the breeding season, coyotes in areas with the most urbanization had home ranges that were 5.52 $km^2$ (0.80-10.30 $km^2$) smaller than those in areas with the least urbanization (Fig. 2.8). Although the coefficient estimates show that size of home range decreases with increasing urbanization during the pup-rearing and dispersal seasons, the results of the regression were not significant (Figs. 2.9 & 2.10).

*Overall Activity Patterns*

When all coyotes were grouped together, 381 (53%) locations in the breeding season, 207 (39%) in the dispersal season, and 404 (47%) in the pup-rearing season were classified as active (Fig. 2.11). I classified 317 (65%) of crepuscular locations, 364 (36%) of diurnal locations, and 390 (63%) of nocturnal locations as active (Fig. 2.12). Coyotes were least active during dispersal season (z = -2.8; $P < 0.01$) and most active during breeding season (z = 2.5; $P < 0.01$; Table 2.8). Coyotes were most active during nocturnal hours (z = 0.60; $P < 0.01$) and least active during diurnal hours (z = -0.52; $P < 0.01$; Table 2.9)

*Activity Patterns along the Urban-Rural Gradient*

Coyotes along the gradient had similar levels of activity during all biological seasons and diel periods (Table 2.10).

*Overall Habitat Selection*

Overall, coyotes avoided open developed areas (z = -5.54; $P < 0.01$), low-intensity development (z = -4.07; $P < 0.01$), medium-intensity development (z = -4.43; $P < 0.01$), high-intensity development (z = -5.61; $P < 0.01$) and mixed forests (z = -2.75; $P = 0.01$). No other habitat type was selected for or against (Table 2.11).

*Habitat Selection along the Urban-Rural Gradient*

As the percentage of urbanization within a home range increased, coyotes used habitats near water greater than their availability within the home range ($F_{1,12} = 15.10$, $P = 0.002$; Table 2.12). For each 10% increase in urbanization, the odds ratio for effect of distance to water increased by 0.04. For the coyote in the area with the lowest percentage of urbanization, the regression equation predicted that for each 1-km increase in distance to water, a coyote was 25% more likely to select a habitat while the coyote in the area with the highest percentage of urbanization was 68% less likely to select a habitat ($R^2 = 0.56$; Fig. 2.14).

Coyotes in areas with greater percentages of urbanization were just as likely as coyotes with lesser percentages of urbanization to select for low-intensity development ($F_{1,8} = 0.01$, $P = 0.90$), medium-intensity development ($F_{1,3} = 0.60$, $P = 0.48$), and high-intensity development ($F_{1,2} = 0.31$, $P = 0.60$; Table 2.12). However, as the percentage of urbanization within a home range increased, coyotes selected against open-developed lands ($F_{1,12}$ = 5.40, $P$ = 0.04) such as parks and golf courses.

As the percentage of urbanization within a home range increased, coyote selection for hardwood habitats was greater than availability within a home range ($F_{1,11}$ = 5.40, $P$ = 0.04; Table 2.12). For each 10% increase in urbanization within the home range, the odds ratio that a coyote would select hardwood versus successional areas increased 1.4 times. For example, the coyote in the area with the lowest percentage of urbanization was 24% less likely to select a hardwood habitat, while the coyote in the area with the highest percentage of urbanization was 238% more likely to select hardwood habitat ($R^2$ = 0.34; Fig. 2.19).

Overall, coyotes in areas with greater percentages of urbanization within their home range were as likely as coyotes in areas with lesser percentages to select for pine plantations ($F_{1,11}$ = 1.80, $P$ = 0.20). However, coyotes in areas with greater percentages of urbanization within their home range were more likely than coyotes in areas with lesser percentages to select for natural pine forests ($F_{1,3}$ = 10.40, $P$ = 0.05; Table 2.12). For each 10% increase in urbanization within the home range, the odds ratio that a coyote would select natural pine forest versus successional areas decreased 0.5 times. For example, the coyote in the area with the lowest percentage of urbanization was 2.2% more likely to select natural pine forest than successional areas, while the coyote in the area with the greatest percentage of urbanization was 73% less likely to select natural pine forest than successional areas ($R^2$ = 0.78; Fig. 2.22).

Coyotes in areas with greater percentages of urbanization were just as likely as coyotes with lesser percentages of urbanization to select for pasture and agricultural lands ($F_{1,11}$ = 0.60, $P$ = 0.50).

## DISCUSSION

### *Home Ranges and Activity Patterns along the Gradient*

Composite home ranges in Lee County, Alabama, were similar to those in rural areas of south-central Georgia (10 $km^2$; Holzman et al. 1992), but smaller than those in Florida (25 $km^2$; Thornton et al. 2004) and west-central South Carolina (30 $km^2$; Schrecengost et al. 2009). Compared to composite home ranges in other urban areas, home ranges were similar to those in Tucson (12.6 $km^2$; Grinder and Krausman 2001) and Chicago (8 $km^2$; Gehrt 2007).

I found that home ranges in east-central Alabama did not vary by season. Other urban studies that estimated seasonal variation in size of home range detected no variation among seasons (Grinder and Krausman 2001, Atwood et al. 2004, Gehrt et al. 2009). Because availability of food, cover, and water has an influence on use of space, coyotes in east-central Alabama may have their needs met year-round. The lack of seasonal variability in home range size may also be due to availability of space in the study area. If the population density of coyotes is high, there may be a lack of available habitat in the area, causing coyotes to maintain similar home ranges throughout the year. Out of the 5 coyotes that dispersed during my study, 4 were trapped near the center of the city. The male dispersed 64 $km^2$, while the 3 females dispersed 40-402 $km^2$. This high urban dispersal rate may be another indication that population densities in the area are high.

Although dispersal home ranges are usually largest, I was not able to monitor coyotes after they had dispersed. All home ranges in this study consist of resident coyotes, which affects the size of home ranges. Dispersal occurs during autumn, a time when natural food sources, like persimmons (*Diospyros virginiana*), are abundant. These, along with anthropogenic foods, may have allowed coyotes to live in smaller areas. A study of food habits in western Alabama and central Mississippi determined that coyotes were dependent on persimmons and seasonal fruits during autumn (Wooding 1984). In addition, because many yearling coyotes disperse during this time, the population density may have been greater than usual causing the sizes of individual home ranges to decrease (Andelt 1985). These smaller home ranges may have been sufficient because females were no longer lactating and there were no pups to feed.

Results of the PCA suggested that density of populations of humans best described variation in variables for urbanization; however, the regression model suggested that size of home range did not vary with density of populations of humans (Fig. 2.4). Because data for density of populations of humans were outdated (from the 2000 census) and because the population in Lee County had increased 18.1% (U.S. Census Bureau 2010), I removed that variable. I was able to update land-cover data by using randomized points and ground truthing. This combination of factors led me to use land-cover data as the urban-rural gradient. Other studies of urban coyotes have used similar methods to define urbanization (Riley et al. 2003, Atwood et al. 2004); however, variation in urbanization gradients, in both definition and perspective, has brought about the need for researchers to define the gradient as a quantifiable, repeatable measurement. The gradient created for my study was a simple, repeatable, measurement that quantified the urbanization gradient without up-to-date GIS data.

Although composite and breeding home range size decreased with increasing urbanization, there was no difference in home range size during pup-rearing and dispersal seasons along the gradient. Results from a study of coyotes along a suburban-rural gradient in west-central Indiana (Atwood et al. 2004) also show that composite home ranges decreased as urbanization within the home range increased; however, seasonal results were not presented. Perhaps breeding season home ranges were smaller in urban areas due to an increased coyote density. An increase in the coyote population would allow coyotes to maintain normal home ranges without having to travel far to find a suitable mate. In addition, use of anthropogenic resources during this season may play a role. Breeding season is in the middle of winter, a time when coyote populations typically experience the highest mortality rates (Windberg et al. 1985). Since coyotes living in areas with greater amounts of urbanization are able to maintain smaller home ranges during the most resource-limited time of the year, this may be an indicator of behavioral change.

In Chicago, Gehrt et al. (2009) reported that urban coyotes had smaller annual home ranges than those in rural Illinois (Gosselink et al. 2003), but detected an increase in size of home range as urbanization increased. This difference may have been due to geographical locations of studies, contrasting levels of urbanization in study areas, quantification of the gradient, and low sample sizes. It is possible that coyotes are able to subsist efficiently in small urban fragments until an upper limit of urbanization or fragmentation is reached, at which point, size of home ranges will increase. Coyotes also may be using urban areas as sources of food, but may be less likely to have dens in these areas, causing their home ranges to be larger as they travel across fragmented habitats (Gehrt et al. 2009). Since home range sizes along the gradient are similar during pup-rearing and dispersal seasons, it may be an indication that the coyotes along the gradient are living similarly. As the Auburn-Opelika area becomes more populated with both humans and coyotes, the same phenomenon eventually may be present there.

Activity patterns are difficult to compare among studies. Researchers study activity of coyotes in a variety of ways, including successive locations, modulation of signals, and activity sensors on radiocollars (McClennen et al. 2001). These varying techniques, along with inherent differences among populations, limit comparisons (McClennen et al. 2001). However, in suburban and urban areas, activity patterns provide important insight into how much coyotes in the area have become habituated to humans.

Coyotes had the highest percentage of active locations during nocturnal hours in breeding (70% of points active) and pup-rearing (64% of points active) seasons and the lowest percentage of activity in diurnal hours during dispersal (29% of points active) and pup-rearing (32% of points active; Fig. 2.11). Activity was lowest in diurnal hours during dispersal and greatest in diurnal hours during breeding season. This variation may be due to weather. Breeding season occurs during the coldest season of the year and coyotes may be more energetically capable of handling cool weather rather than hot weather. Laundré and Keller (1984) suggested that coyotes in some parts of the country may be nocturnal due to heat in daylight hours and stress associated with thermoregulation and osmoregulation; however, Shargo (1988) believed that disturbance by humans may be a more important factor influencing activity. Shargo (1988) reported that two coyotes in Los Angeles, one of which demonstrated no fear towards humans, foraged primarily during diurnal hours. All other coyotes in his study were most active at night and they demonstrated fear and avoidance toward humans. He also detected no seasonal variation in activity. If this was caused by physiological reasons alone, there should have been some seasonal change in activity. Similarly, a study by Kitchen et al. (2000) suggested that coyotes subjected to persecution by humans were more active at night and less active during diurnal times. When persecution ended, 8 years later, coyotes increased diurnal activity (Kitchen et al. 2000).

Along the urban-rural gradient in Lee County, Alabama, there were no differences in coyote activity. Coyotes were mostly nocturnal in other urban areas (Tigas et al. 2002, Riley et al. 2003, Atwood et al. 2004, Morey 2004, Way et al. 2004), but they were more active in rural areas during diurnal hours (Andelt 1985, Patterson et al. 1999, Kitchen et al. 2000). Nocturnal activity is beneficial to urban coyotes, as they are able to avoid people and cross roads at times when vehicular traffic is least (Gehrt 2007). Coyotes were least active during diurnal hours. This may have been due to an increase in vehicular traffic at these times; however, it also may have been due to availability of prey. To increase foraging efficiency, activity patterns likely are dependent on activity patterns of prey (Laundré and Keller 1984, Morton 1988, Shargo 1988, Patterson et al. 1999, McClennen et al. 2001).

The only difference I found in size of home range along the gradient was during breeding season; activity patterns were similar along the gradient during all seasons and diel periods. Although activity patterns along the gradient are not what I predicted, they showed that coyotes with more urbanization within their home ranges are behaving similarly to their rural counterparts. The highest activity levels occur during nocturnal hours, which may demonstrate that coyotes in this area are avoiding human activity. At this point, results do not indicate that urban coyotes in Lee County, Alabama have changed their behavior to cope with increasing urbanization. Perhaps this is the outcome of a small sample size, or maybe the area is not yet urbanized enough to necessitate a behavioral change.

Further studies with larger samples over longer periods in other areas of the Southeast are needed. Baker and Timm (1998) pointed out that coyotes are most habituated in areas where they have been for several generations. It is hypothesized that young coyotes learn new behaviors from parents and pass these behaviors to pups. If true, we need to continue to monitor these areas to determine rate of habituation. Studies investigating the effect urbanization has on activity of prey and the importance of persimmons in the diet are important as well. The urbanization gradient should be standardized so that use of habitat by coyotes can be compared among areas.

*Habitats Occupied along the Gradient*

Data from the AL-GAP was from 2000 and since that time, the population of humans in Lee County has increased from 115,124 to 135,883 in 2008 (U.S. Census Bureau 2010). Along with growth in population, the land-cover also has changed dramatically. Fortunately, I was able to update data on land-cover by ground-truthing a sample of randomized points. Other researchers have used similar methods to define urbanization (Atwood et al. 2004; Riley et al. 2003); however, variation in urban gradients, in both definition and perspective, has brought about the need to define the gradient as a quantifiable, repeatable measurement. The gradient created for this study was a simple, replicable measurement that quantified the index of urbanization in absence of current data.

Coyotes in areas with greater percentages of urbanization selected for habitats near water and for hardwood forests. Because a network of storm drains carries rainwater in cities away, the increase in area of impervious surface decreases the volume of standing water in cities and may be causing coyotes in urban areas to seek other sources of water. In addition, many of the streams running through Lee County are located in hardwood riparian areas. It is possible that coyotes in town are selecting for bottomland hardwood forests and, as a result, are closer to sources of water. In rural areas of south-central Georgia, coyotes selected for bottomland hardwoods during daytime hours, most likely due to increased cover in these areas (Holzman et al. 1992). Schrecongost et al. (2009) reported that coyotes in South Carolina selected areas with early successional vegetation over hardwoods; they believed that this was associated with use of soft-mass species (Schrecengost et al. 2008). Foraging for fruits may require less energy than searching for prey (MacArthur and Pianka 1966). Since urban coyotes in east-central Alabama were consuming more vegetation than rural coyotes (Santana 2010), perhaps coyotes living within Lee County are using successional areas at night.

As urbanization within a home range increased, coyotes were more likely to avoid open developed habitat; all coyotes avoided areas of low-, medium-, and high-intensity development. Although I expected coyotes living in areas with greater percentages of urbanization to have selected for these areas, it is reasonable that they would also avoid these areas. In larger cities, other researchers reported that coyotes selected mostly natural patches of land within the city (Quinn 1997; Tigas et al. 2002; Riley et al. 2003) and that coyotes select less-developed sections of large metropolitan areas (Riley et al. 2003; Randa and Yunger 2006). Since Lee County is not a major metropolitan area, coyotes may have sufficient forested habitat on the outskirts of developed areas to meet their daily needs and to sustain their populations. Coyote populations should continue to be monitored as behavioral changes may occur as both human and coyote populations increase.

Pine forests and plantations are important habitats to investigate because loblolly pines (*Pinus taeda*) are the most common species of tree in the southern United States (Schultz 1997). Other studies in the Southeast have determined that coyotes in rural areas select pine habitats (Holzman et al. 1992, Chamberlain and Leopold 2000, Schrecengost et al. 2009). In my study, coyotes in areas with a greater percentage of urbanization avoided natural pine habitats, while those in areas with a lower percentage selected for them. In rural areas, pine habitats most likely help coyotes meet life-history requirements (Chamberlain and Leopold 2000) and are probably important to coyotes living in managed forests. Pine habitats also may provide important denning sites (Chamberlain et al 2000). In urban areas, few pine habitats exist, and those that do exist are on small patches of land. It may not be energetically economical for a coyote in an urban environment to select these areas because of their small size and limited availability of prey.

## MANAGEMENT IMPLICATIONS

After assessing the results of my study, I believe that a local effort to educate citizens on the biology of coyotes, as well as to cultivate awareness of this urban resident, may be the most effective plan of action for Lee County, Alabama. As the coyote population in Lee County increases, citizens must learn to take appropriate actions to correct behavior of coyotes before feeding patterns are established or they become habituated. Proper disposal of garbage, keeping pet foods indoors, and using scare devices and hazing techniques should help prevent coyote habituation. Citizens should be watchful around sources of water (streams, lakes), as coyotes living within the urban matrix are more likely to be near water. If a coyote becomes a problem in an urban area, the problem individual should be removed. Trapped coyotes should not be relocated. Relocation enables potential transmission of diseases and usually is unsuccessful among canids. Most relocated coyotes are killed after release, by cars or hunters, while trying to get back to their original home range (Gehrt 2006).

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LITERATURE CITED

Alberti, M., E. Botsford, and A. Cohen. 2001. Quantifying the urban gradient: linking urban planning and ecology. Pages 89-115 in Avian ecology and conservation in an urbanizing world (J. M. Marzluff, R. Bowman, and R. Donnelly, eds.). Kluwer Academic, Norwell, Massachussetts.

Andelt, W. F., and P. S. Gipson. 1979. Home range, activity, and daily movements of coyotes. Journal of Wildlife Management 43:944-951.

Andelt, W. F. 1985. Behavioral ecology of coyotes in South Texas. Wildlife Monographs 94:1-45.

Andelt, W. F., and B. R. Mahan. 1980. Behavior of an urban coyote. American Midland Naturalist 103:399-400.

Andrzejewski, R., J. Babiñska-Werka, J. Gliwicz, and J. Goszczyñski. 1978. Synurbanization processes in an urban population of *Apodemus agrarius*. I. Characteristics of population in an urbanization gradient. Acta Theriologica 23:341-358.

Animal Care and Use Committee. 1998. Guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists. Journal of Mammalogy 79:1416-1431.

Arjo, W. M., and D. H. Pletscher. 2004. Coyote and wolf habitat use in northwestern Montana. Northwest Science 78:24–32.

Atkinson, K. T., and D. M. Shackleton. 1991. Coyote, *Canis latrans,* ecology in a rural-suburban environment. Canadian Field-Naturalist 105:49-54.

Atwood, T. C., H. P. Weeks, and T. Gehring. 2004. Spatial ecology of coyotes along a suburban-to-rural gradient. Journal of Wildlife Management 68:1000-1009.

Babiñska-Werka, J., J. Gliwicz, and J. Goszczyñski. 1979. Synurbization processes in an urban population of *Apodemus agrarius*. II. Habitats of the striped field mouse in town. Acta Theriologica 26:405-415.

Bailey, R. G. 1980. Descriptions of the ecoregions of the United States. United States Department of Agriculture Miscellaneous Publications 1391:1–77.

Baker, R. O., and R. M. Timm. 1998. Management of conflicts between urban coyotes and humans in southern California. Proceedings of the Vertebrate Pest Conference 18:299-312.

Bekoff, M., 1977. *Canis latrans*. Mammalian Species 79:1-9.

Cairns, J. 1988. Restoration ecology: the new frontier. Pages 2-11 in Rehabilitating damaged ecosystems (J. Cairns, eds.). CRC Press, Boca Raton, Florida.

Chamberlain, M. J., and B. D. Leopold. 2000. Spatial-use patterns, movements, and interactions among adult coyotes in central Mississippi. Canadian Journal of Zoology 78:2087-2095.

Clutton-Brock, T. H. and P. H. Harvey. 1978. Mammals, resources and reproductive strategies. Nature 273: 191-195.

Crooks, K. R., and M. E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400:563-566.

Dennis, D. 2010. Genetic Analysis of Dispersal and Population Dynamics of the Southeastern Coyote (*Canis latrans*). M.S. thesis, Auburn University, Alabama.

Environmental Systems Research Institute, Inc. 2009. ArcGIS 9.3.1. Environmental Systems Research Institute, Inc., Redlands, California.

Fedriani, J. M., T. K. Fuller, and R. M. Sauvajot. 2001. Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in Southern California. Ecography 24*:* 325–331.

Gehrt, S. D. 2004. Ecology and management of striped skunks, raccoons, and coyotes in urban landcscapes. Pages 81-104 in Predators and people: from conflict to conservation (N. Fascione, A. Delach, and M. Smith, eds.). Island Press, Washington, D.C.

Gehrt, S. D. 2006. Urban coyote ecology and management. The Cook County, Illinois coyote project. Ohio State UniversityExtension Bulletin 929:1–32.

Gehrt, S. D. 2007. Ecology of coyotes in urban landscapes. Proceedings of the Wildlife Damage Management Conference, 12:303-311.

Gehrt, S. D., C. Anchor, and L. A. White. 2009. Home range and landscape use of coyotes in a metropolitan landscape: conflict or coexistence? Journal of Mammalogy 90:1045-1057.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1988. Home range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management 52:640–646.

Gipson, P. S., and J. A. Sealander. 1972. Home range and activity of the coyote **(***Canis latrans frustror*) in Arkansas. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish 26:82–95.

Gipson, P. S. 1974. Food habits of coyotes in Arkansas. Journal of Wildlife Management 38:848–853.

Gosselink, T. E., T. R. Van Deelen, R. E. Warner, and M. G. Joselyn. 2003. Temporal habitat partitioning and spatial use of coyotes and red foxes in east-central Illinois. Journal of Wildlife Management 67:90–103.

Grinder, M. I., and P. R. Krausman. 2001. Home range, habitat use, and nocturnal activity of coyotes in an urban environment. Journal of Wildlife Management 65:887-898.

Hahs, A. K., and M. J. McDonnell. 2006. Selecting independent measures to quantify Melbourne's urban–rural gradient. Landscape and Urban Planning 78:435–448.

Hill, E. P., P. W. Sumner, and J. B. Wooding. 1987. Human influences on range expansion of coyotes in the Southeast. Wildlife Society Bulletin 15:521-524.

Holzman, S., M. Conroy, and J. Pickering. 1992. Home range, movements and habitat use of coyote in south-central Georgia. Journal of Wildlife Management 56:139-146.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Kavanau, J. L., and J. Ramos. 1975. Influences of light and phasing on carnivores. American Naturalist 109:391-418.

Kitchen, A. M., E. M. Gese, and E. R. Schauster. 2000. Changes in coyote activity patterns due to reduced exposure to human persecution. Canadian Journal of Zoology 78:853–857.

Laundré, J. W., and B. L. Keller. 1984. Home-range size of coyotes: a critical review. Journal of Wildlife Management 48:127-139.

Levin, S. A. 1992. The problem of pattern and scale in ecology. Ecology 73:1943-67

Luniak, M. 2004. Synurbization adaption of animal wildlife to urban development. Pages 50-55 in Proceedings of the 4th international symposium on urban wildlife conservation (W. W. Shaw, L. K. Harris, and L. Vandruff, eds.). University of Arizona, Tucson.

MacArthur, R. H., and E. R. Pianka. 1966. On optimal use of a patchy environment. American Naturalist 100:603-609.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P.Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Wolters Kluwer Publishing, New York, New York.

Marzluff, J. M., R. Bowman, and R. Donnelly. 2001. A historical perspective on urban bird research: trends, terms, and approaches. Pages 1-17 in Avian ecology and conservation in an urbanizing world (J. M. Marzluff, R. Bowman, and R. E. Donnelly, eds.). Kluwer Academic, Norwell, Massachusetts.

McClennen, N., R. R. Wigglesworth, S. H. Anderson, and D. G. Wachob. 2001. The effect of suburban and agricultural development on the activity patterns of coyotes (*Canis latrans*). American Midland Naturalist 146:27-36.

McIntyre, N. E., K. Knowles-Yánez, and D. Hope. 2000. Urban ecology as an interdisciplinary field: differences in the use of “urban” between the social and natural sciences. Urban Ecosystems 4:5-24.

Moore, G. C., and G. R. Parker. 1992. Colonization by the eastern coyote (*Canis latrans*). Pages 23-37 in Ecology and management of the eastern coyote (A. Boer, ed.). Wildlife Research Unit, University of New Brunswick, Fredericton, New Brunswick, Canada.

Morey, P. S. 2004. Landscape use and diet of coyotes, *Canis latrans*, in the Chicago metropolitan area. M.S. thesis, Utah State University, Logan.

Morton, L. D. 1988. Winter ecology of the eastern coyote **(***Canis latrans*) in Fundy National Park. M.S. thesis, University of New Brunswick, Fredericton, New Brunswick, Canada.

Nams, V. O. 2006. Locate III user's guide. Pacer Computer Software, Tatamagouche, Nova Scotia, Canada.

Patterson, B. R., S. Bondrup-Nielsen, and F. Messier. 1999. Activity patterns and daily movements of the eastern coyote, *Canis latrans*, in Nova Scotia. Canadian Field-Naturalist 113:251-257.

Quinn, T. 1991. Distribution and habitat associations of coyotes in Seattle, Washington. Wildlife Conservation in Metropolitan Environments Symposium Series 2:48–51.

Quinn, T. 1997. Coyote (*Canis latrans*) habitat selection in urban areas of western Washington via analysis of routine movements. Northwest Science 71:289-297.

R Development Core Team. 2010. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Randa, L. A., and J. A. Yunger. 2006. Carnivore occurrence across an urban-rural gradient: a landscape-level analysis. Journal of Mammalogy 87:1154-1164.

Riley, S. T., R. M. Sauvajot, T. K. Fuller, E. C. York, D. A. Kamradt, C. Bromely, and R. K. Wayne. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. Conservation Biology 17:566-576.

Rodgers, A. R., A. P. Carr, L. Smith, and J. G. Kie. 2005. HRT: home range tools for ArcGIS. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario, Canada.

Santana, E. 2010. Food habits and anthropogenic supplementation in the diet of coyotes **(***Canis latrans*) along an urban-rural gradient. M.S. thesis, Auburn University, Alabama.

Schoener, T. W. 1971. Theory of feeding strategies. Annual Review of Ecology and Systematics 2:369-404.

Schrecengost, J. D., J. C. Kilgo, D. Mallard, H. S. Ray, and K. V. Miller. 2008. Seasonal food habits of the coyote in the South Carolina coastal plain. Southeastern Naturalist 7:135–144.

Schrecengost, J. D., J. C. Kilgo, H. S. Ray, and K. V. Miller. 2009. Home range, habitat use and survival of coyotes in western South Carolina. American Midland Naturalist 162:346-355.

Schultz, R. P. 1997. Loblolly Pine: The ecology and culture of loblolly pine **(***Pinus taeda* L.). United States Department of Agriciulture Forest Service, Agriculture Handbook 713:1-493.

Shargo, E. M. 1988. Home range, movements, and activity patterns of coyotes **(***Canis latrans*) in Los Angeles suburbs. Ph.D. dissertation, University of California at Los Angeles, Los Angeles.

Silvano, A. L., K. J. Kleiner, J. A. Grand, M. D. Mackenzie, M. S. Mitchell, and E. R. Irwin. 2010. Alabama gap analysis project. Gap Analysis Bulletin 17:40-46.

Theobald, D. M. 2004. Placing exurban land use change in a human modification framework. Frontiers in Ecology and Environment 2:139–144.

Thornton, D. H., M. E. Sunquist, and M. B. Main. 2004. Ecological separation within newly sympatric populations of coyotes and bobcats in south-central Florida. Journal of Mammalogy 85:973–982.

Tigas, L. A., D. H. Van Vuren, and R. M. Sauvajot. 2002. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. Biological Conservation 108:299-306.

Timm, R. M., R. O. Baker, J. R. Bennett, and C. C. Coolahan. 2004. Coyote attacks: an increasing suburban problem. Proceedings of the Vertebrate Pest Conference 21:47–57.

Way, J. G., I. M. Ortega, and E. G. Strauss. 2004. Movement and activity patterns of eastern coyotes in a coastal, suburban environment. Northeastern Naturalist 11:237-254.

White, C. G., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, New York.

Windberg, L. A., H. L. Anderson, and R. M. Engeman. Survival of coyotes in southern Texas. Journal of Wildlife Management 49(2):301-307.

Wooding, J. B. 1984. Coyote food habits and the spatial relationship of coyotes and foxes in Mississippi and Alabama. M.S. thesis, Mississippi State University, Starkville.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

Young, S. P., and H. H. T. Jackson. 1951. The clever coyote. Stackpole Company and Wildlife Management Institute, Washington, D.C.

Table 2.1. Classifications of habitats in Lee County, Alabama.

| Class | Description |
|---|---|
| Water | Open water, fresh |
| Developed open space | Primarily vegetation in the form of lawns; impervious surfaces account for <20% of total cover |
| Low- intensity development | Single-family housing units, parks, golf courses, and planted vegetation; impervious surfaces account for 20-49% of total cover |
| Medium- intensity development | Primarily single-family housing units; impervious surfaces account for 50-79% of the total cover |
| High- intensity development | Apartment complexes, row houses and commercial-industrial areas; impervious surfaces account for 80-100% of the total cover |
| Pine forest | Longleaf pine woodlands |
| Hardwood forest | Mesic hardwood, dry oak, small stream, floodplain, and riparian forests |
| Mixed forest | Longleaf, loblolly, and shortleaf pine woodlands intermixed with hardwoods |
| Successional | Clear cuts, utility swaths, scrub, and herbaceous |
| Agriculture | Pasture, hay, and row crops |
| Pine plantations | Managed evergreen plantations |

Table 2.2. Classifications of roads in Lee County, Alabama.

| Classification | Description |
|---|---|
| High-intensity | Primary roads, airport runways, highway ramps, parking lots |
| Medium-intensity | Secondary roads |
| Low-intensity | Neighborhood streets, rural roads, vehicular trails, private roads |

Table 2.3. Variables used in principal-components analysis and regression models to determine the urban-rural gradient for 14 coyotes in Lee County, Alabama, 2007-2009.

| Variable | Description |
|---|---|
| Urbanization | Percentage of urban area in each home range |
| High-intensity roads | Proportion of high-traffic roads in each home range ($km^2$) |
| Medium-intensity roads | Proportion of medium-traffic roads in each home range ($km^2$) |
| Low-intensity roads | Proportion of low-traffic roads in each home range ($km^2$) |
| Population density | Population density of each home range |

Table 2.4. Linear model determining seasonal differences in home range size for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Season[a] | Coefficient estimate | Standard error | P-value |
|---|---|---|---|
| Dispersal | -0.11 | 0.22 | 0.64 |
| Breeding | 1.2 | 0.61 | 0.09 |

[a]Y variable is pup-rearing season

Table 2.5. Relative contributions of variables to principal-components analysis used to determining the urban-rural gradient for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Component statistics | Density of population of humans | Low-intensity roads, medium-intensity roads, high-intensity roads | Percentage of urbanization, low-intensity roads, medium-intensity roads | Percentage of urbanization, low-intensity roads, high-intensity roads | Density of population of humans, percentage urbanization |
|---|---|---|---|---|---|
| Standard deviation | 198.00 | 0.45 | 0.41 | 0.09 | 0.02 |
| Proportion of variance | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cumulative proportion | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Table 2.6. Importance of regression variables in determining the urban-rural gradient for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Equation[a] | Variable[b] | Coefficient estimate | Standard error | P-value | Adjusted $R^2$ |
|---|---|---|---|---|---|
| 1 | Population/ $km^2$ | -0.01 | 0.01 | 0.09 | 0.15 |
| 2 | Percentage urbanization | -22.39 | 7.55 | 0.01 | 0.38 |
| 3 | Proportion of low-intensity roads | -2.28 | 2.02 | 0.29 | 0.36 |
| 3 | Proportion of medium- intensity roads | -6.12 | 2.40 | 0.03 | 0.36 |
| 3 | Proportion of high-intensity roads | 0.28 | 11.50 | 0.98 | 0.36 |

[a]Number of the urban-rural gradient equation
[b]Variables used in the equation

Table 2.7. Linear regression determining seasonal differences in size of home range along the urban-rural gradient for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Season[a] | Coefficient estimate | Standard error | P-value | Adjusted $R^2$ |
|---|---|---|---|---|
| Breeding | -12.84 | 5.02 | 0.03 | 0.32 |
| Pup-rearing | -18.37 | 14.78 | 0.24 | 0.04 |
| Dispersal | -39.45 | 19.29 | 0.07 | 0.21 |

[a]Breeding (1 January–30 April), pup-rearing (1 May–31 August), and dispersal (1 September–31 December).

Table 2.8. Seasonal logistic-regression-activity model for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Season [a] | Coefficient estimate[b] | Standard error | P-value |
|---|---|---|---|
| Breeding | 0.26 | 0.10 | 0.01 |
| Dispersal | -0.32 | 0.11 | < 0.01 |

[a] Reference is pup-rearing season

[b]A positive estimate means coyotes in areas with more urbanization are more likely to be active during a specific season than coyotes in areas with less urbanization, and a negative estimate means that coyotes in areas with more urbanization are less likely to be active during a specific season than are coyotes in areas with less urbanization.

Table 2.9. Temporal logistic-regression-activity model for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Time[a] | Coefficient estimate[b] | Standard error | P-value |
|---|---|---|---|
| Crepuscular | -0.59 | 0.12 | < 0.01 |
| Diurnal | -1.11 | 0.11 | < 0.01 |

[a] Reference is nocturnal hours

[b]A positive estimate means coyotes in areas with more urbanization are more likely to be active during a specific time than coyotes in areas with less urbanization, and a negative estimate means that coyotes in areas with more urbanization are less likely to be active during a specific time than are coyotes in areas with less urbanization

Table 2.10. Log odds of activity during all times and seasons for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Season[a] | Diel period[b] | Odds ratio | Standard error | P-value | 95% | CI[c] |
|---|---|---|---|---|---|---|
| Breeding | Diurnal | 0.50 | 1.01 | 0.5 | (0.07, | 3.6) |
| | Crepuscular | 0.27 | 1.90 | 0.5 | (0.01, | 11.41) |
| | Nocturnal | 0.62 | 1.39 | 0.7 | (0.04, | 9.4) |
| Pup-rearing | Diurnal | 0.47 | 1.33 | 0.6 | (0.04, | 6.35) |
| | Crepuscular | 0.21 | 1.69 | 0.4 | (0.01, | 5.8) |
| | Nocturnal | 2.17 | 1.49 | 0.6 | (0.12, | 40.03) |
| Dispersal | Diurnal | 0.00 | 1.69 | 0 | (0.0, | 0.12) |
| | Crepuscular | 0.90 | 1.51 | 0.9 | (0.05, | 17.2) |
| | Nocturnal | 1.36 | 1.46 | 0.8 | (0.08, | 23.7) |

[a] Breeding (1 January–30 April), pup-rearing (1 May–31 August), and dispersal (1 September–31 December).

[b] Diurnal (0731-1630 h), crepuscular (0431-0730 h, 1631-1930 h) and nocturnal (1931-0430 h).

[c] 95% Confidence interval on the odds ratio

Table 2.11. Logistic-regression-habitat model for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Habitat [a] | Coefficient estimate [b] | Standard error | P-value |
|---|---|---|---|
| Distance to roads | 0.15 | 0.15 | 0.30 |
| Distance to water | 0.05 | 0.04 | 0.24 |
| Hardwood forest | -0.07 | 0.15 | 0.62 |
| High-intensity development | -1.20 | 0.21 | < 0.01 |
| Low-intensity development | -0.81 | 0.20 | < 0.01 |
| Medium-intensity development | -0.98 | 0.22 | < 0.01 |
| Mixed forest | -0.23 | 0.10 | 0.01 |
| Natural pine forest | -0.15 | 0.14 | 0.29 |
| Open-developed area | -0.86 | 0.16 | < 0.01 |
| Pasture | 0.08 | 0.11 | 0.45 |
| Pine plantation | -0.09 | 0.12 | 0.44 |

[a] Reference is successional land

[b] A positive estimate means coyotes in areas with more urbanization are more likely to select a specific habitat than coyotes in areas with less urbanization, and a negative estimate means that coyotes in areas with more urbanization are less likely to select a specific habitat than are coyotes in areas with less urbanization.

Table 2.12. Mixed-regression-habitat model for 14 coyotes (*Canis latrans*) along an urban-rural gradient in Lee County, Alabama, 2007-2009.

| Habitat [a] | Coefficient estimate [b] | Standard error | P-value |
|---|---|---|---|
| Distance to roads | -1.18 | 4.18 | 0.78 |
| Distance to water | -3.22 | 0.83 | 0.01 |
| Hardwood forest | 3.49 | 1.50 | 0.04 |
| High-intensity development | 3.55 | 6.37 | 0.63 |
| Low-intensity development | -0.27 | 2.24 | 0.91 |
| Medium-intensity development | -0.62 | 0.77 | 0.48 |
| Mixed forest | -2.66 | 1.38 | 0.08 |
| Natural pine forest | -6.66 | 2.07 | 0.05 |
| Open-developed area | -3.12 | 1.35 | 0.04 |
| Pasture | -1.35 | 1.77 | 0.46 |
| Pine plantation | -2.40 | 1.78 | 0.20 |

[a] Reference is successional land
[b]A positive estimate means coyotes in areas with more urbanization are more likely to select a specific habitat than coyotes in areas with less urbanization, and a negative estimate means that coyotes in areas with more urbanization are less likely to select a specific habitat than are coyotes in areas with less urbanization.

Figure 2.1. Theorized historical pattern of dispersal of coyotes (*Canis latrans*) outward from their original geographical range: 1) western; 2) northeastern; and 3) southeastern (Dennis 2010; adapted from Parker 1995).

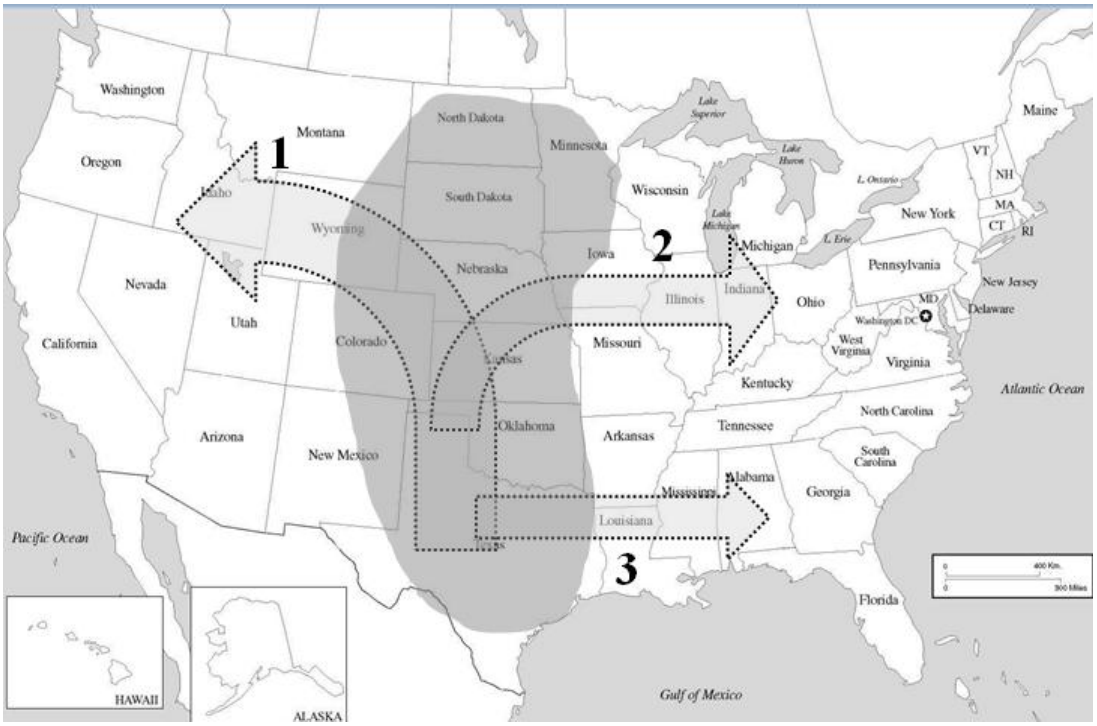


Figure 2.2. Location of Lee County within Alabama and urban and rural areas as defined by the U.S. Census Bureau (2000).

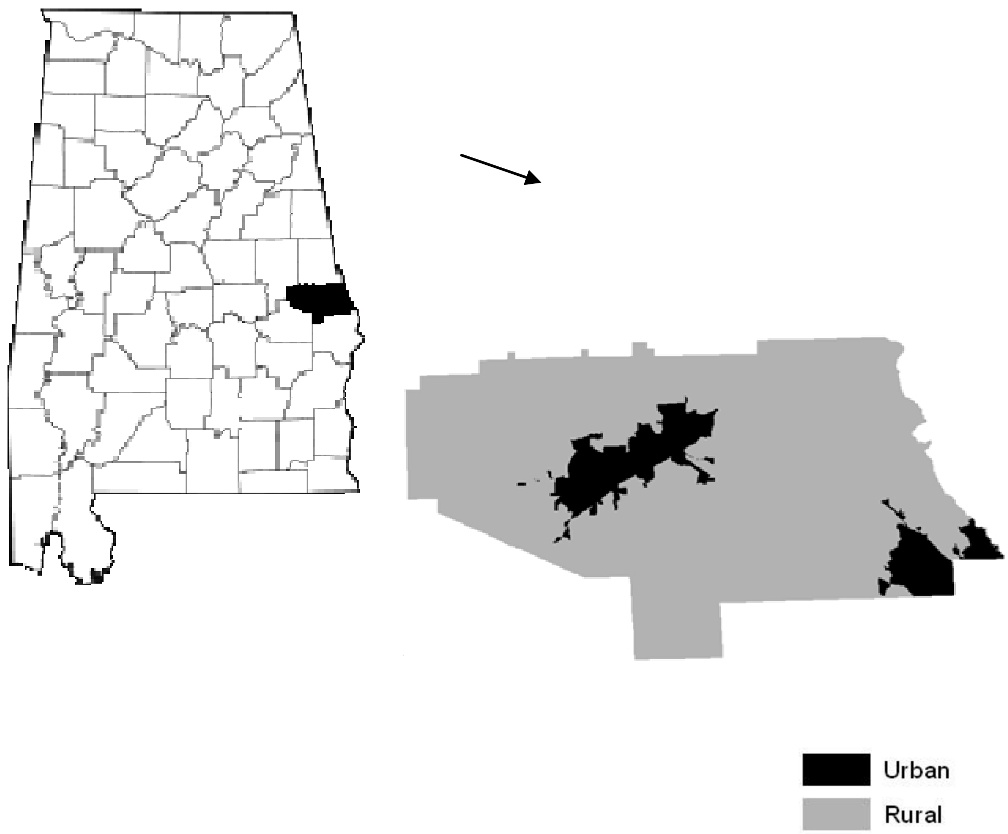


Figure 2.3. Isopleths of home ranges (95%-adaptive-density-kernel method), spatially referenced, for 14 coyotes (*Canis latrans*) in Lee County, Alabama, during 2007-2009. Dashed lines differentiate overlapping home ranges.

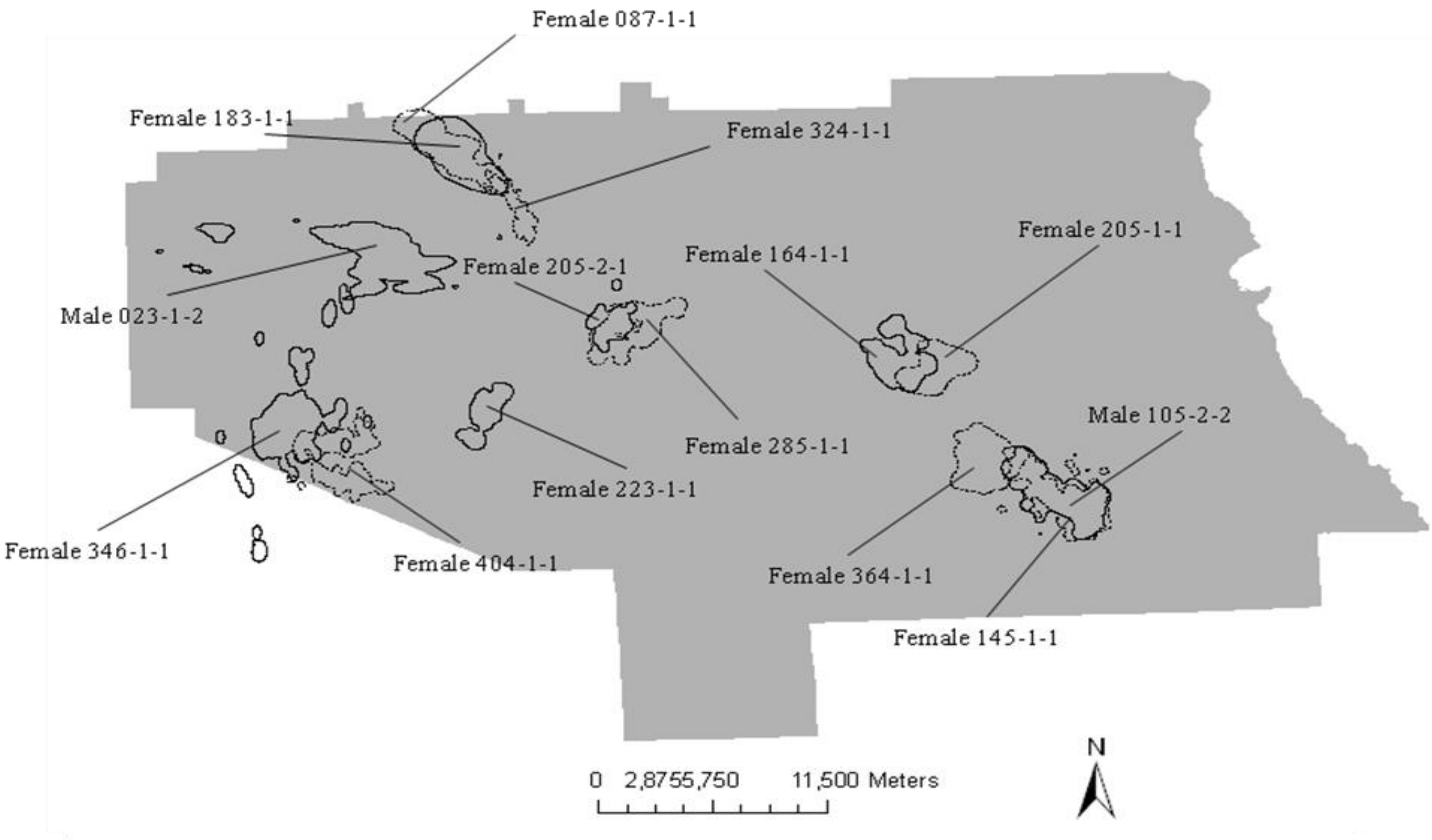


Figure 2.4. Gradient of urbanization generated from regressing density of population of humans on composite size of home range (95%-adaptive-density-kernel method) of 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

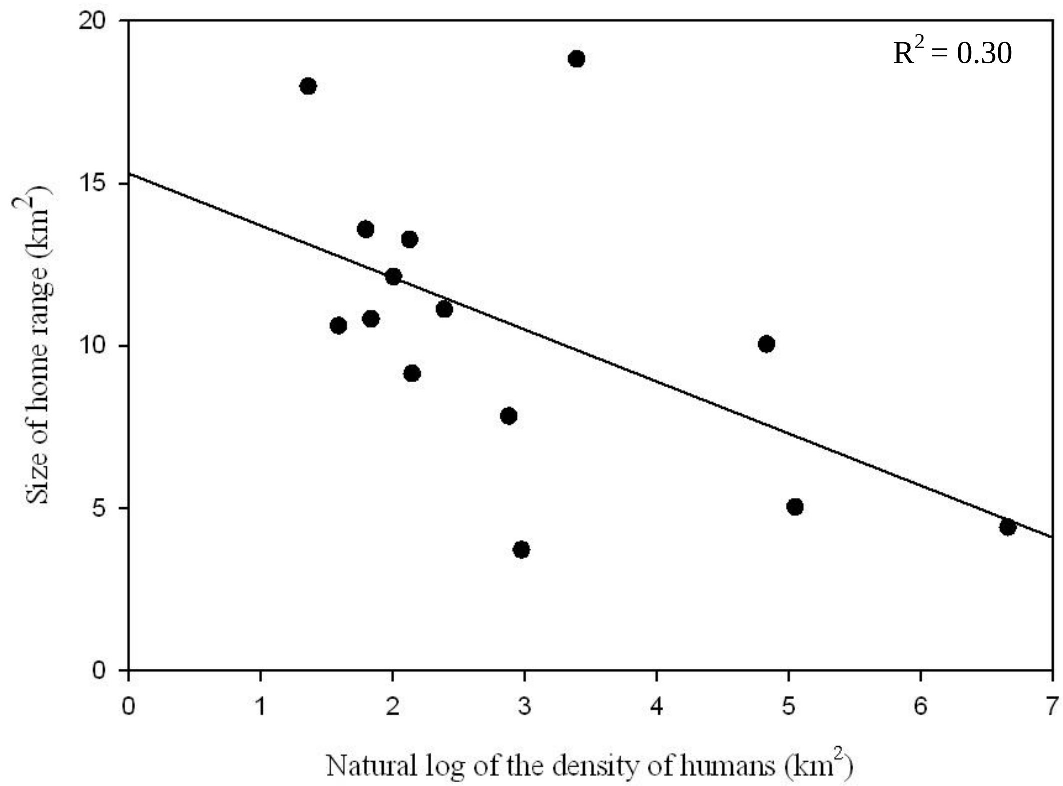


Figure 2.5. Gradient of urbanization generated from regressing size of home range (95%-adaptive-density-kernel method) of 14 coyotes (*Canis latrans*) on percentage of urbanization in Lee County, Alabama, 2007-2009.

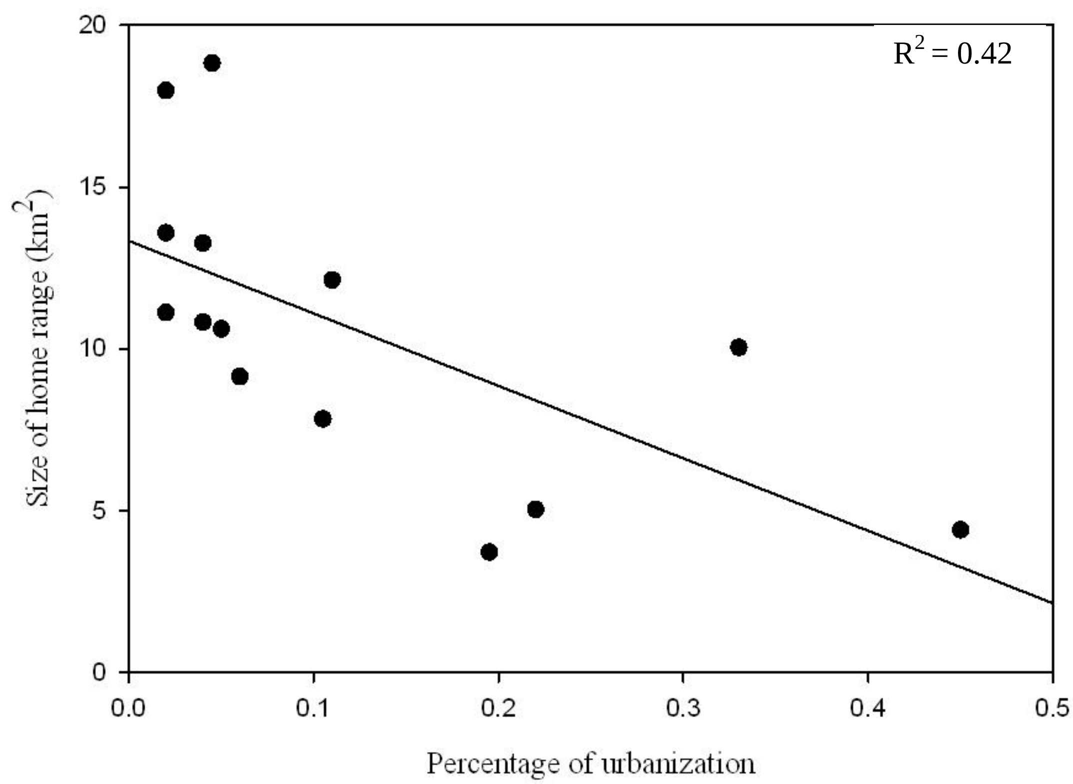


Figure 2.6. Gradient of urbanization generated from regressing composite size of home range (95%-adaptive-density-kernel method) of 14 coyotes (*Canis latrans*) on proportion of medium-intensity roads in Lee County, Alabama, 2007-2009.

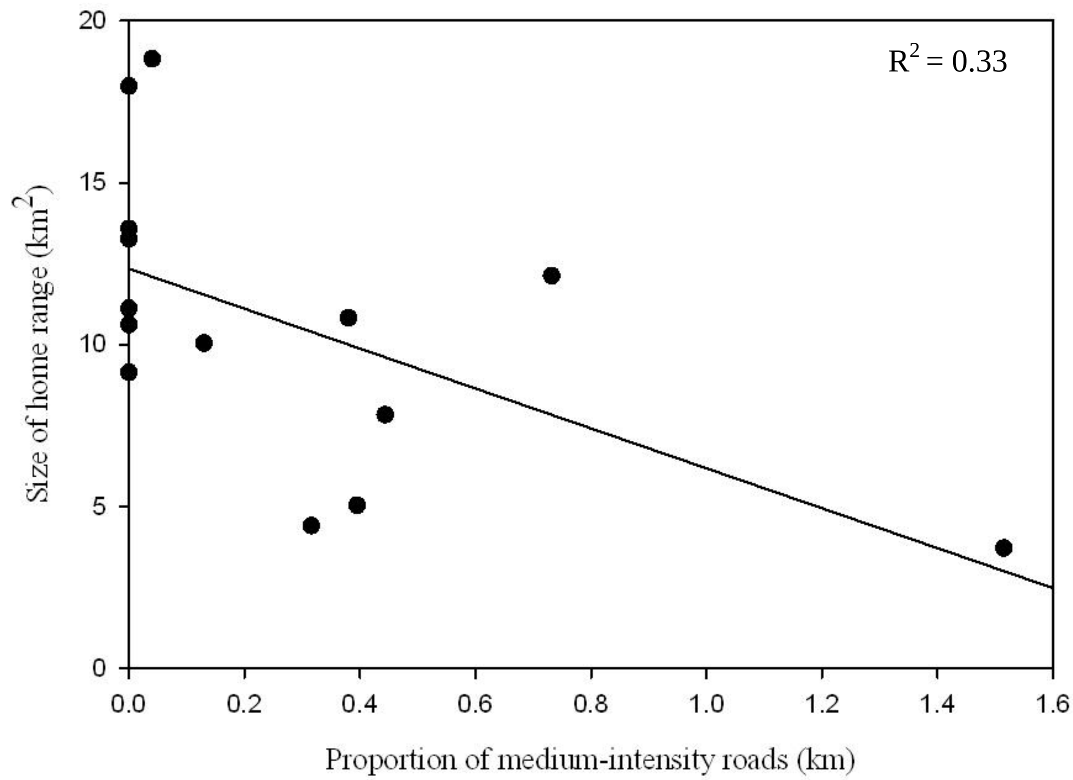


Figure 2.7. Gradient of urbanization generated from regressing composite size of home range (95%-adaptive-density-kernel method) of 14 coyotes (*Canis latrans*) on proportion of low-intensity roads in Lee County, Alabama, 2007-2009.

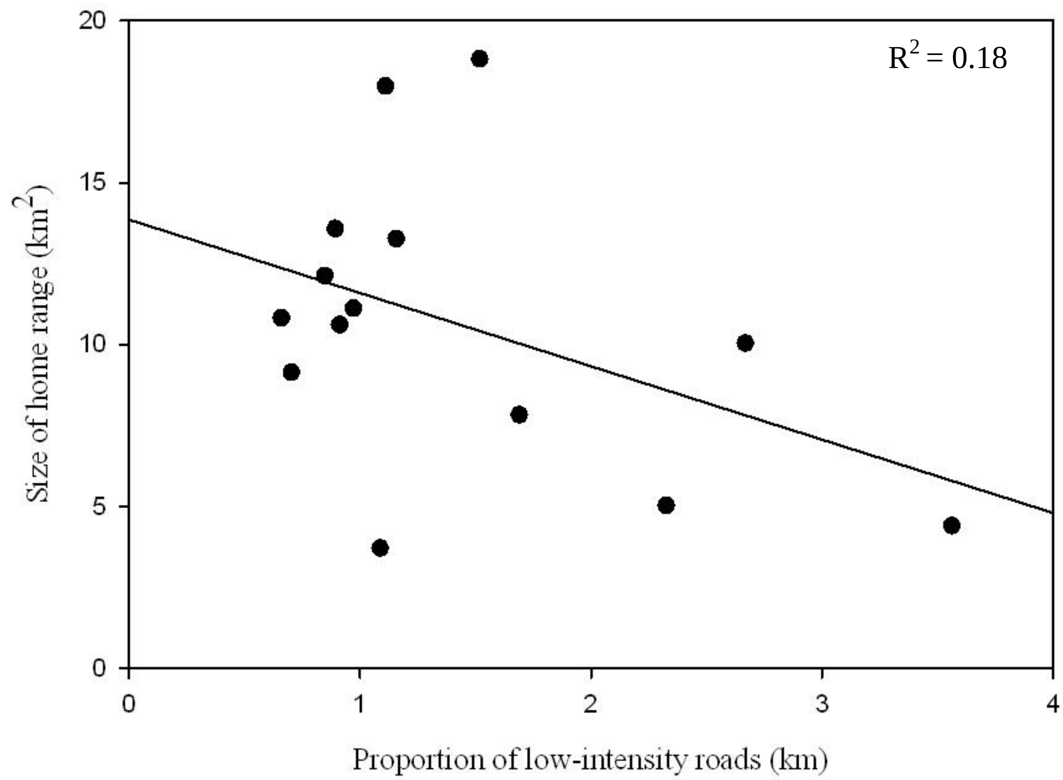


Figure 2.8. Gradient of urbanization generated from regressing size of home range (95%-adaptive-density-kernel method) of 14 coyotes (*Canis latrans*) during breeding (1 January-30 April) on percentage of urbanization in Lee County, Alabama, 2007-2009.

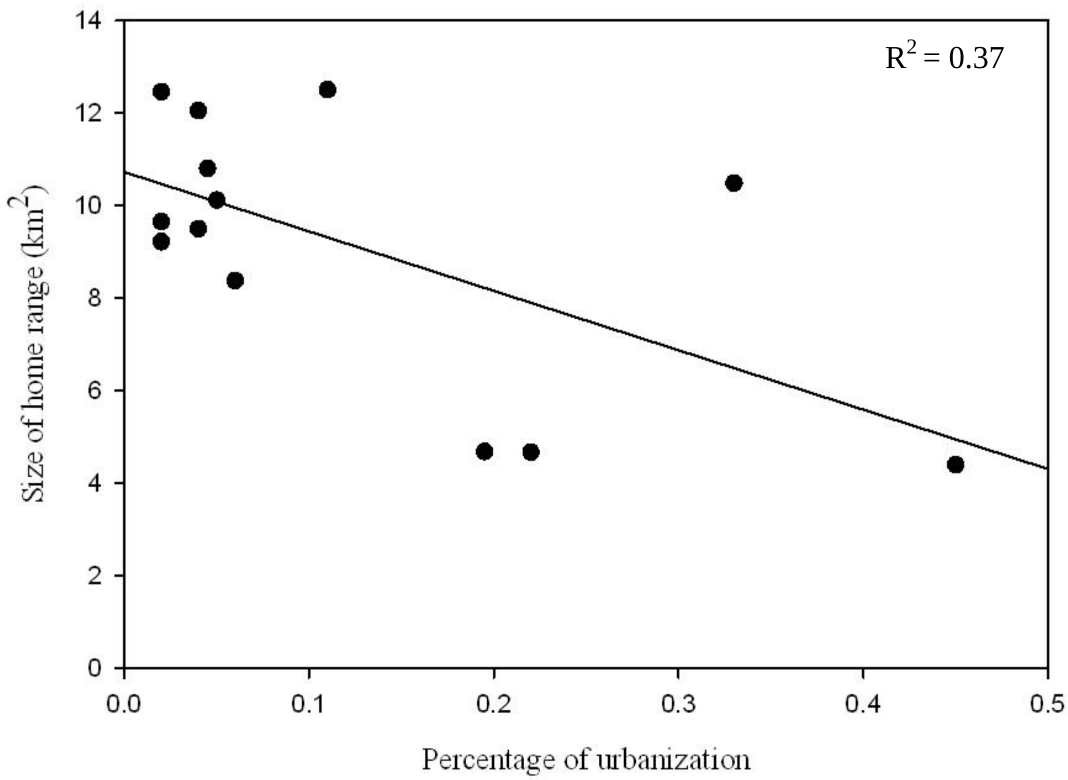


Figure 2.9. Gradient of urbanization generated from regressing size of home range (95%-adaptive-density-kernel) of 12 coyotes (*Canis latrans*) during pup-rearing (1 May-31 August) on percentage of urbanization in Lee County, Alabama, 2007-2009.

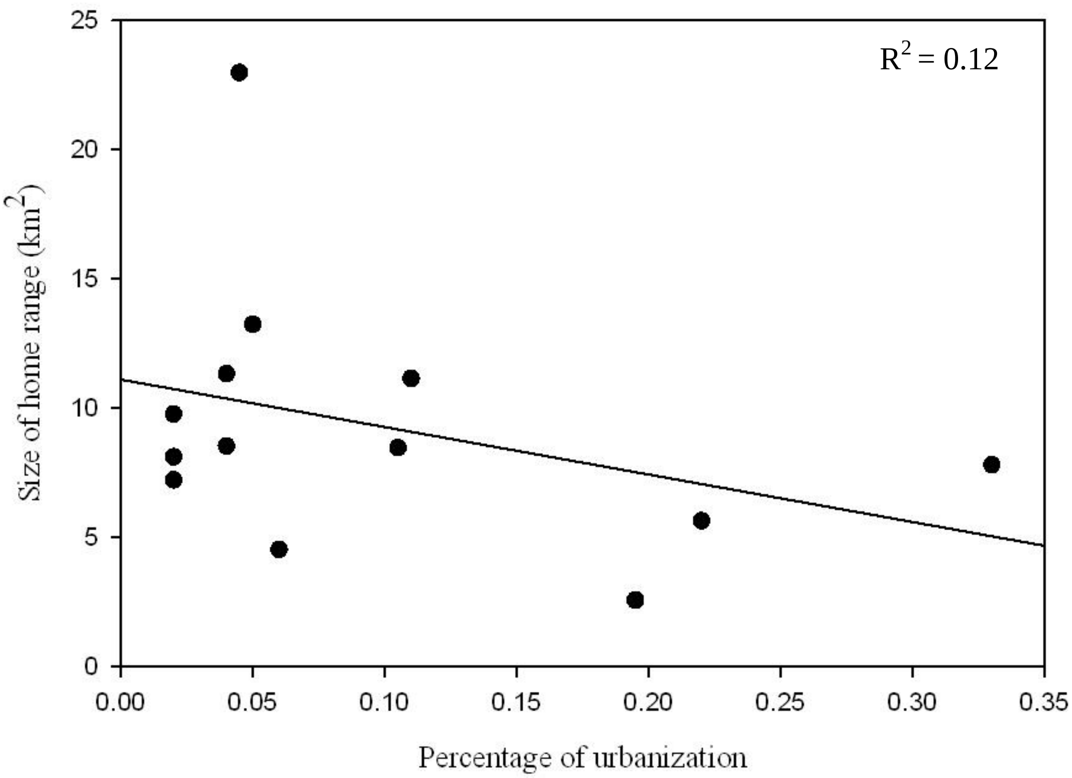


Figure 2.10. Gradient of urbanization generated from regressing size of home range size (95%-adaptive-density-kernel method) of 13 coyotes (*Canis latrans*) during dispersal (1 September-31 December) on percentage of urbanization in Lee County, Alabama, 2007-2009.

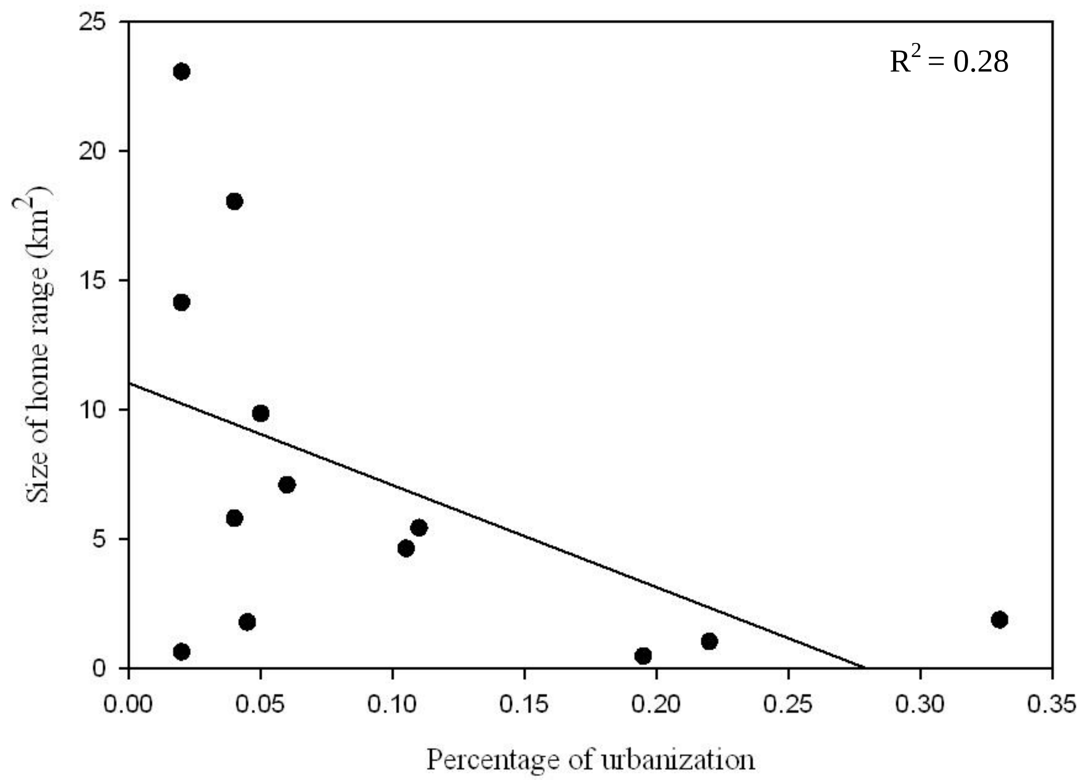


Figure 2.11. Percentage of active locations for 14 coyotes (*Canis latrans*) in Lee County, Alabama, during breeding (1 January-30 April), dispersal (1 September-31 December), and pup-rearing (1 May-31August) seasons, 2007-2009.

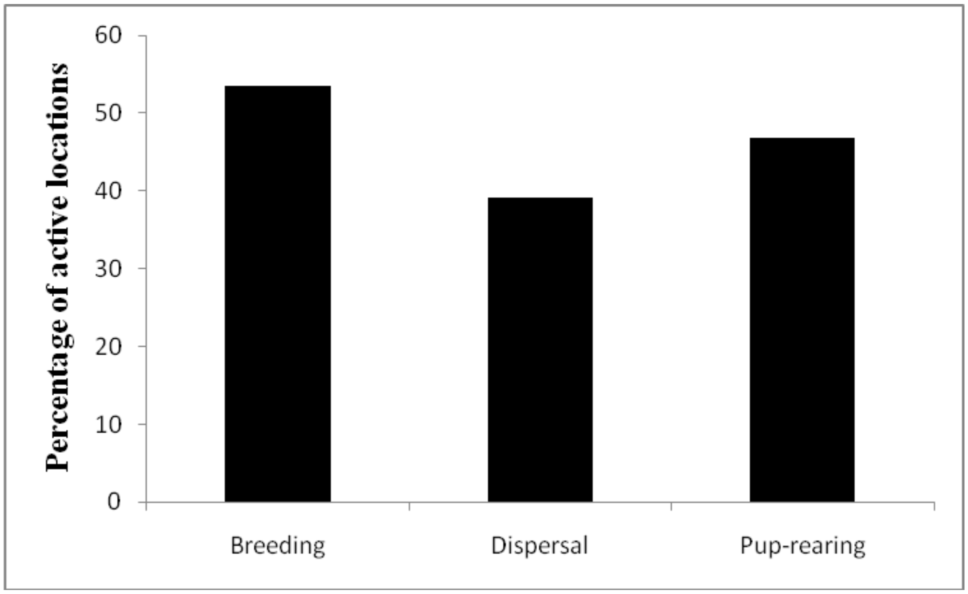


Figure 2.12. Percentage of active locations for 14 coyotes (*Canis latrans*) in Lee County, Alabama, during the 24-hour day, 2007-2009.

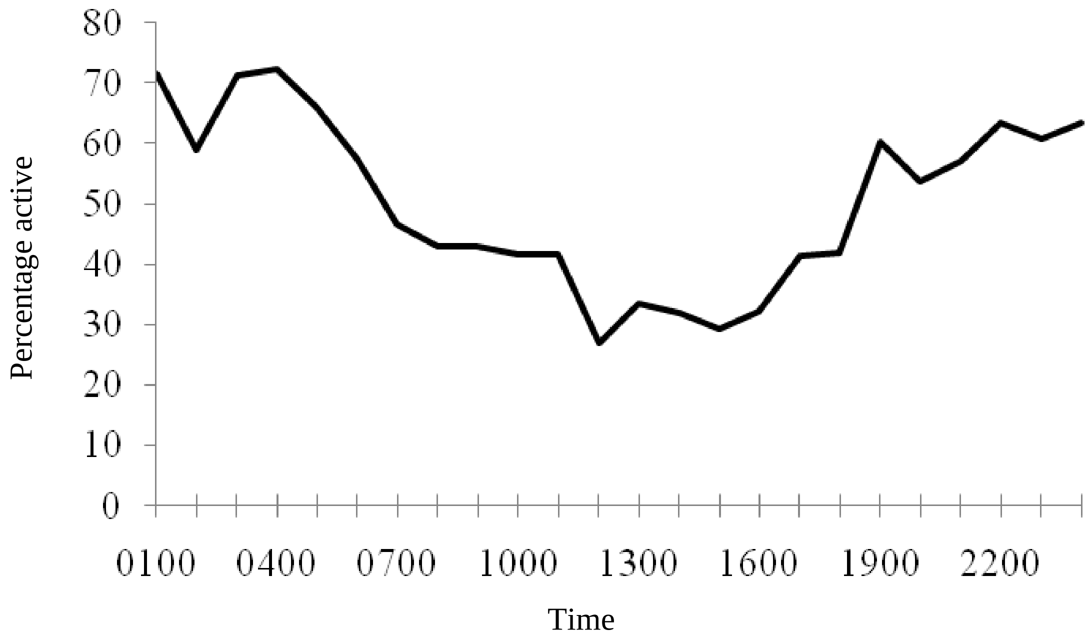


Figure 2.13. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for distance to roads (km) on percentage of urbanization for 13 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

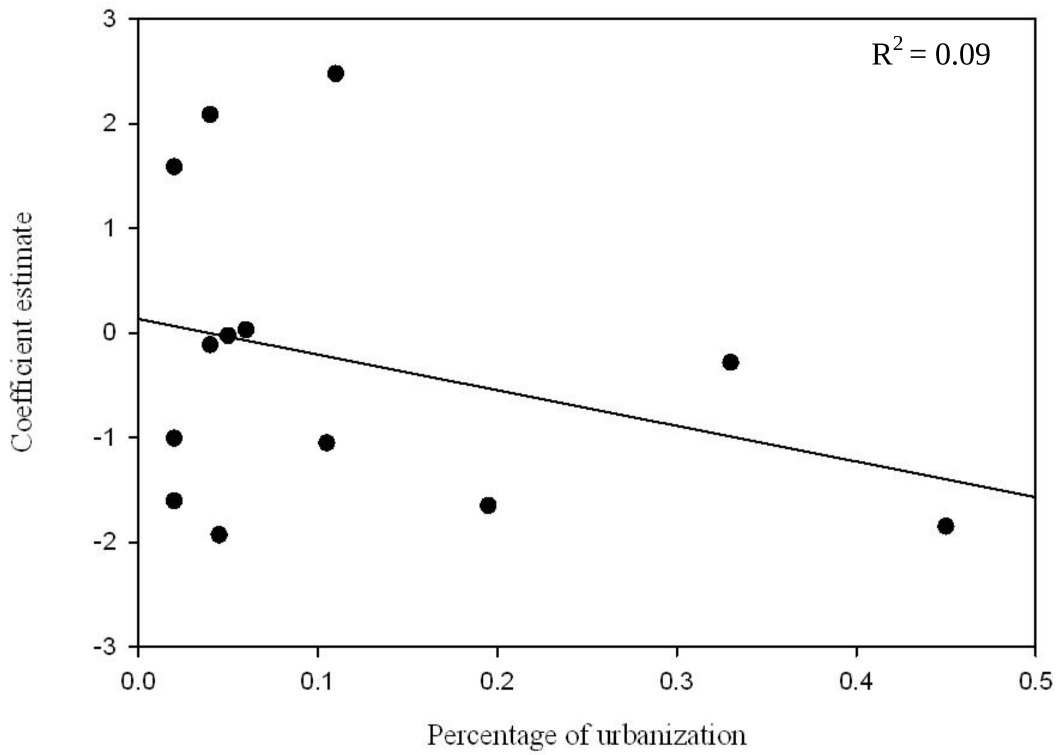


Figure 2.14. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for distance to water (km) on percentage of urbanization for 14 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

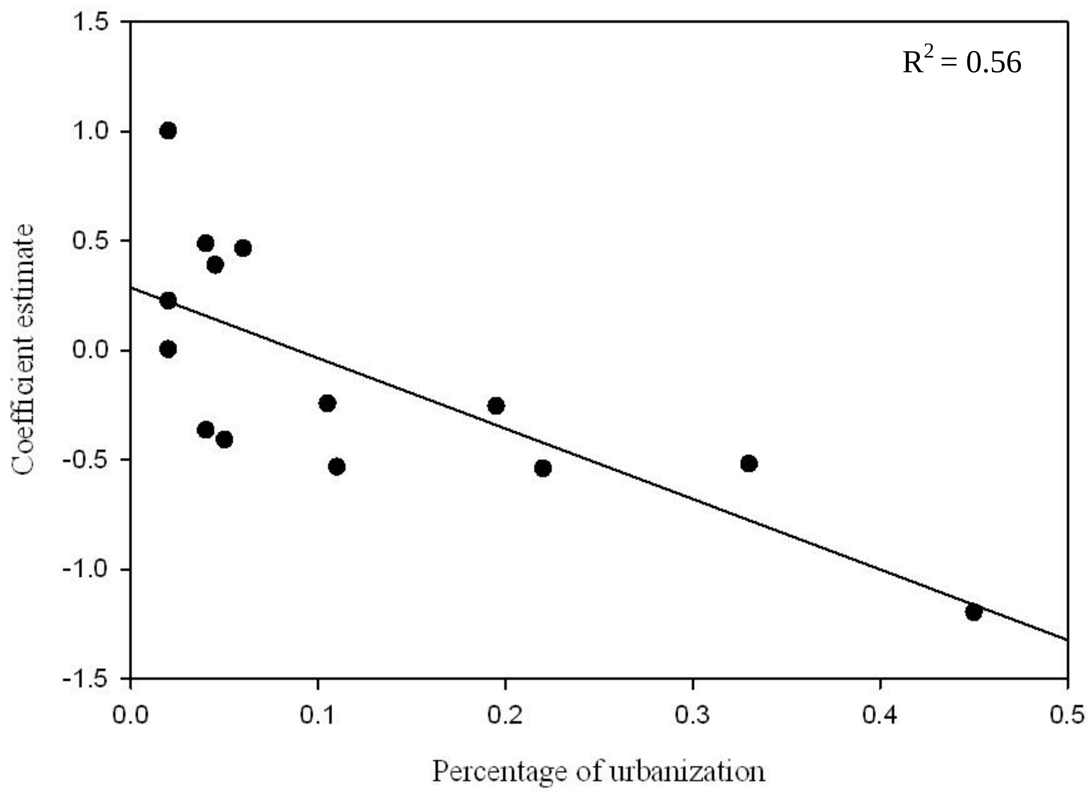


Figure 2.15. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for open developed area on percentage of urbanization for 3 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

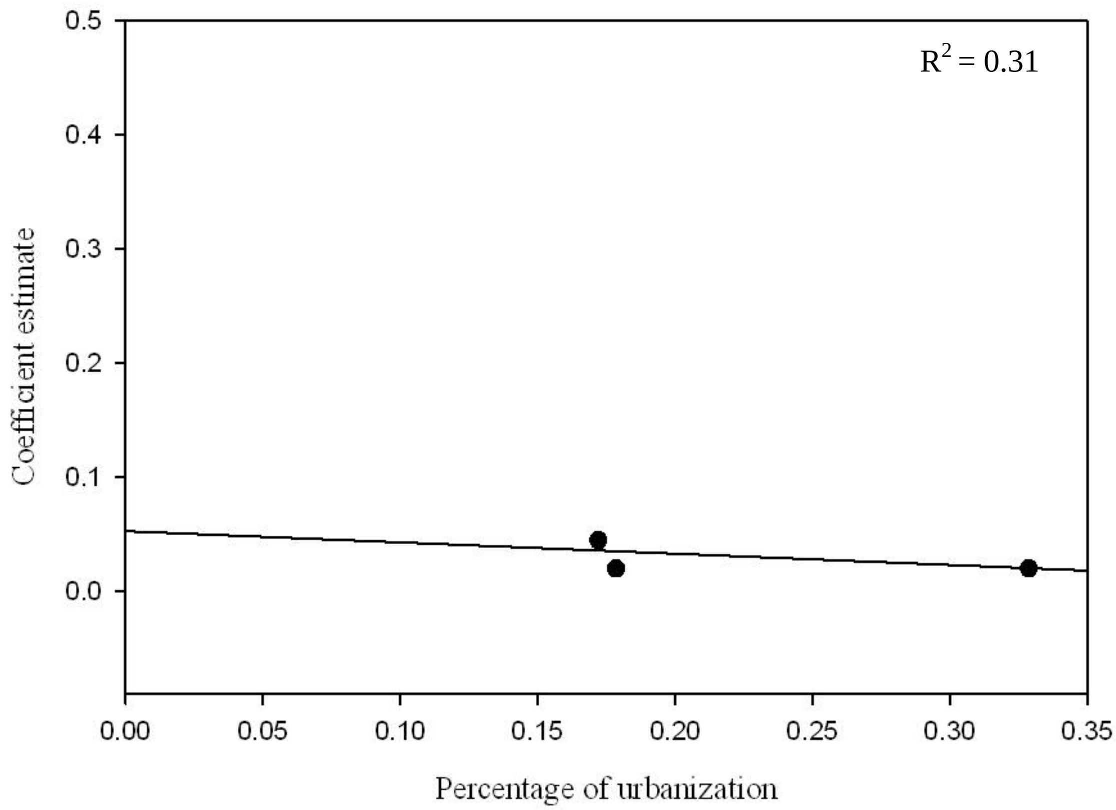


Figure 2.16. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for low-intensity development on percentage of urbanization for 10 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

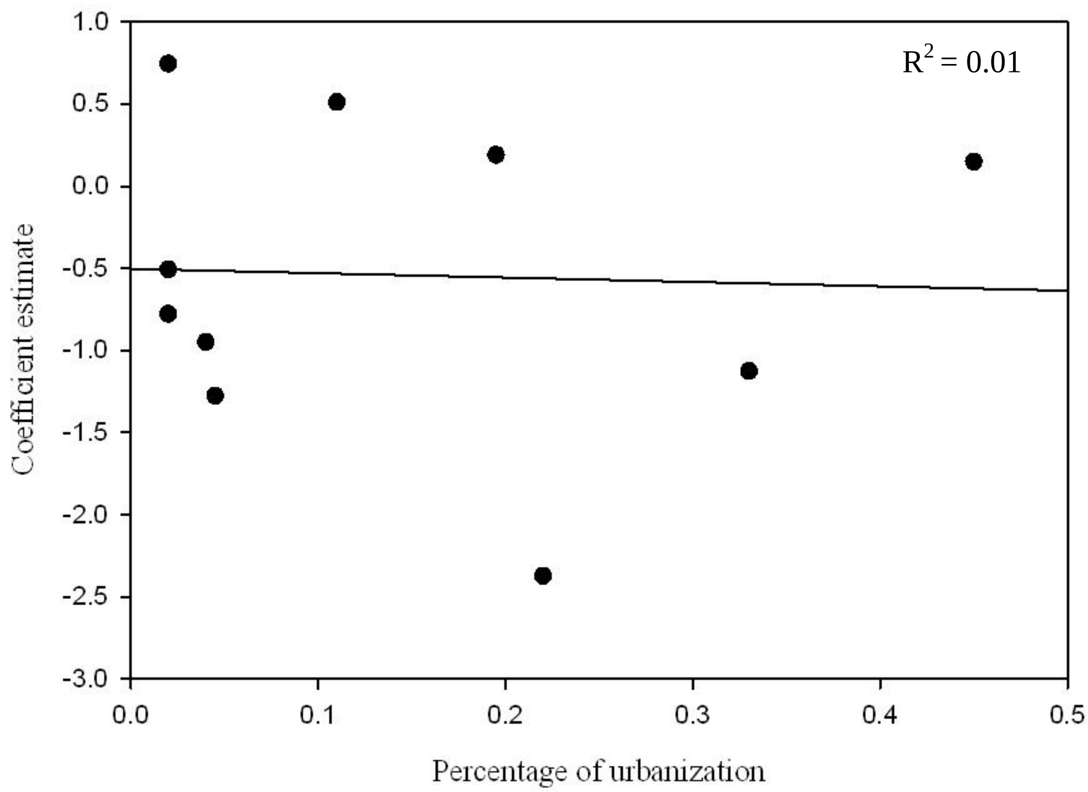


Figure 2.17. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for medium-intensity development on percentage of urbanization for 5 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

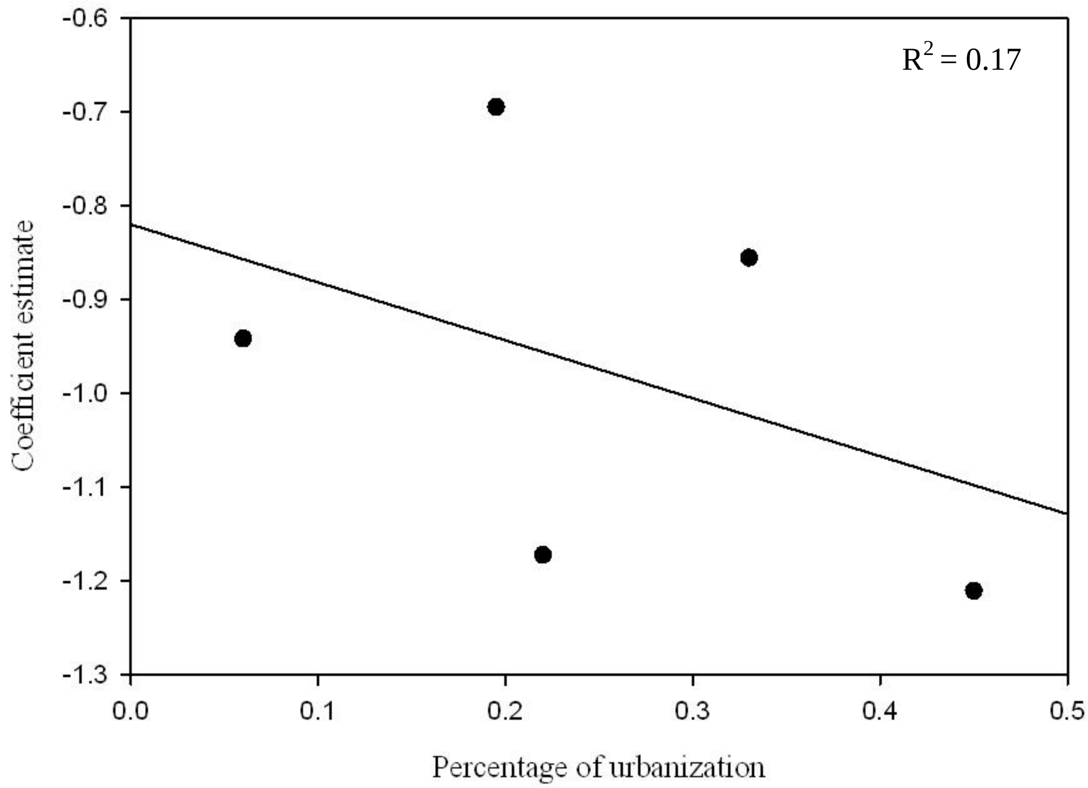


Figure 2.18. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for high-intensity development on percentage of urbanization for 4 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

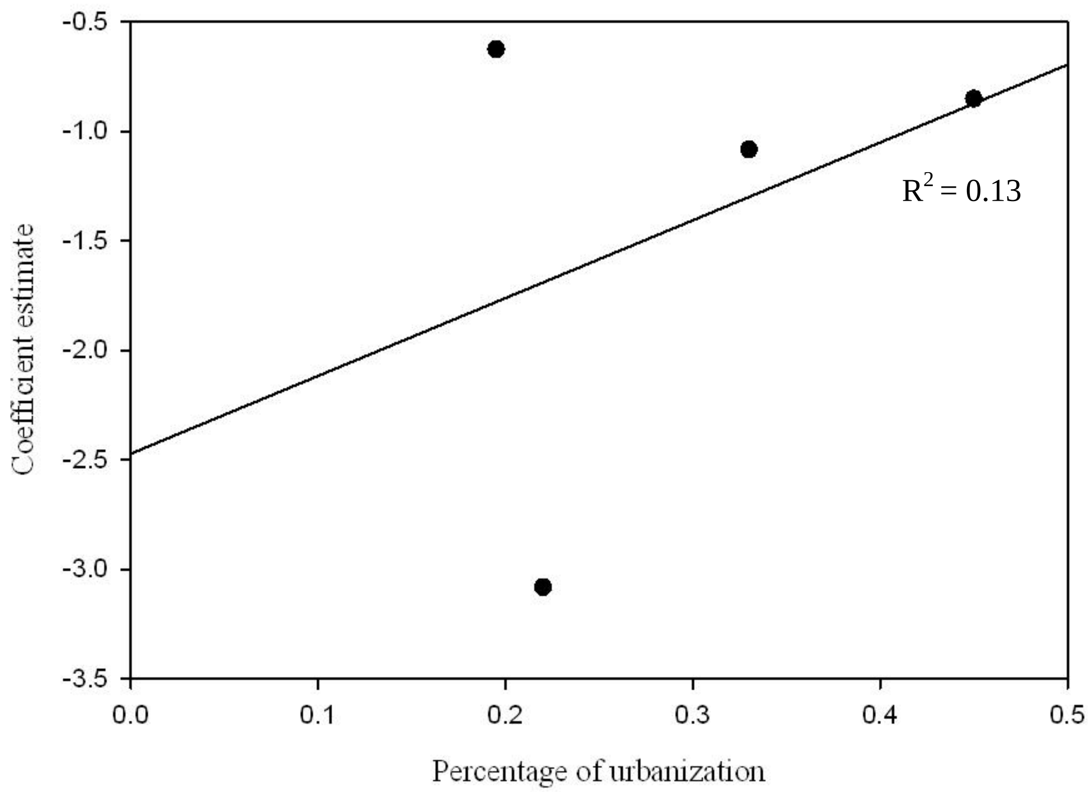


Figure 2.19. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for hardwood forests on percentage of urbanization for 12 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

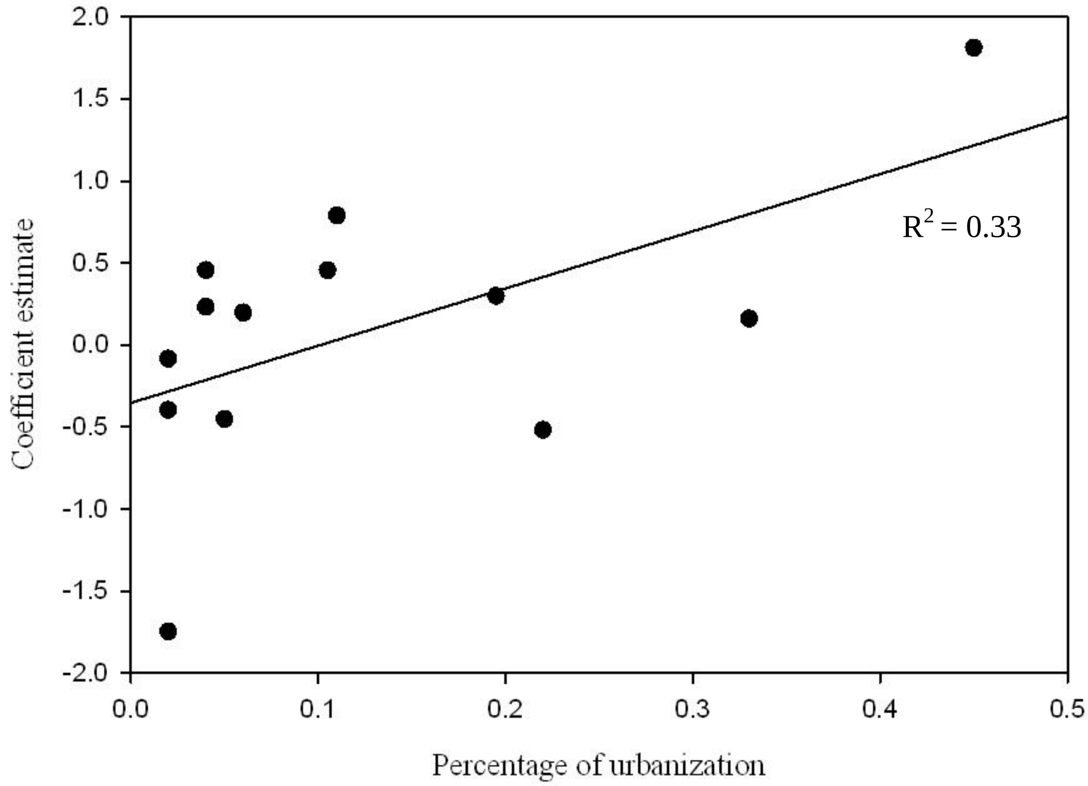


Figure 2.20. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for mixed forests on percentage of urbanization for 14 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

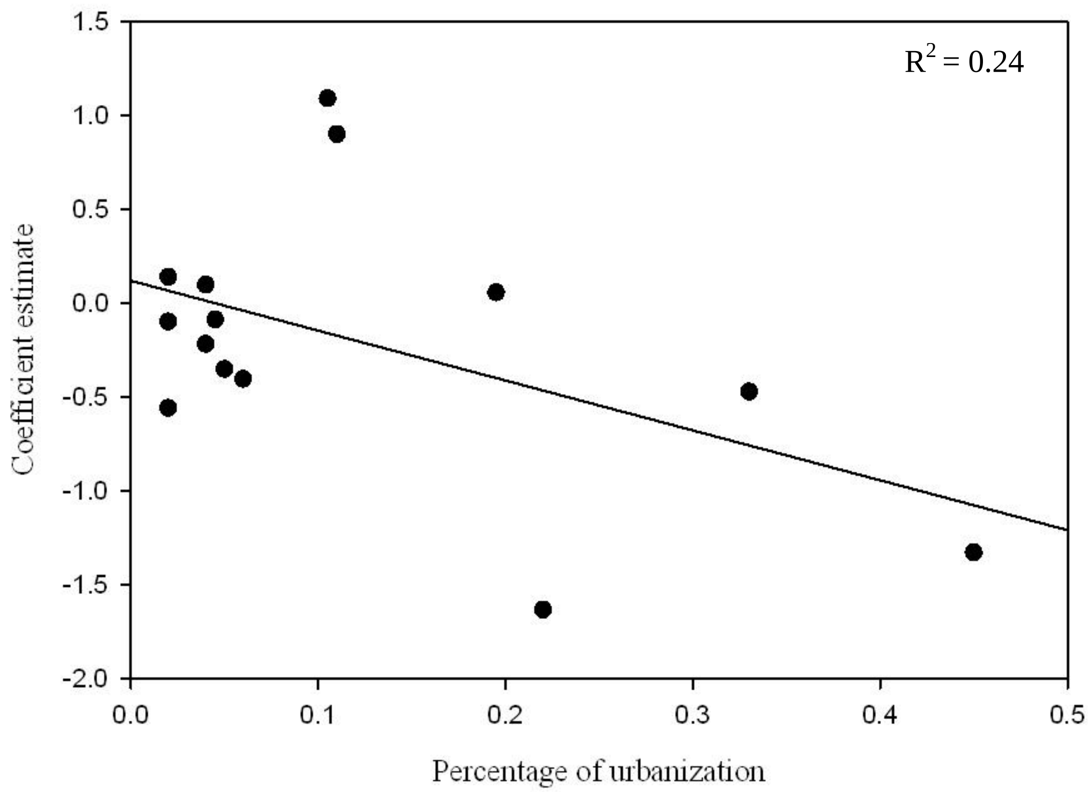


Figure 2.21. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for pine plantations on percentage of urbanization for 13 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

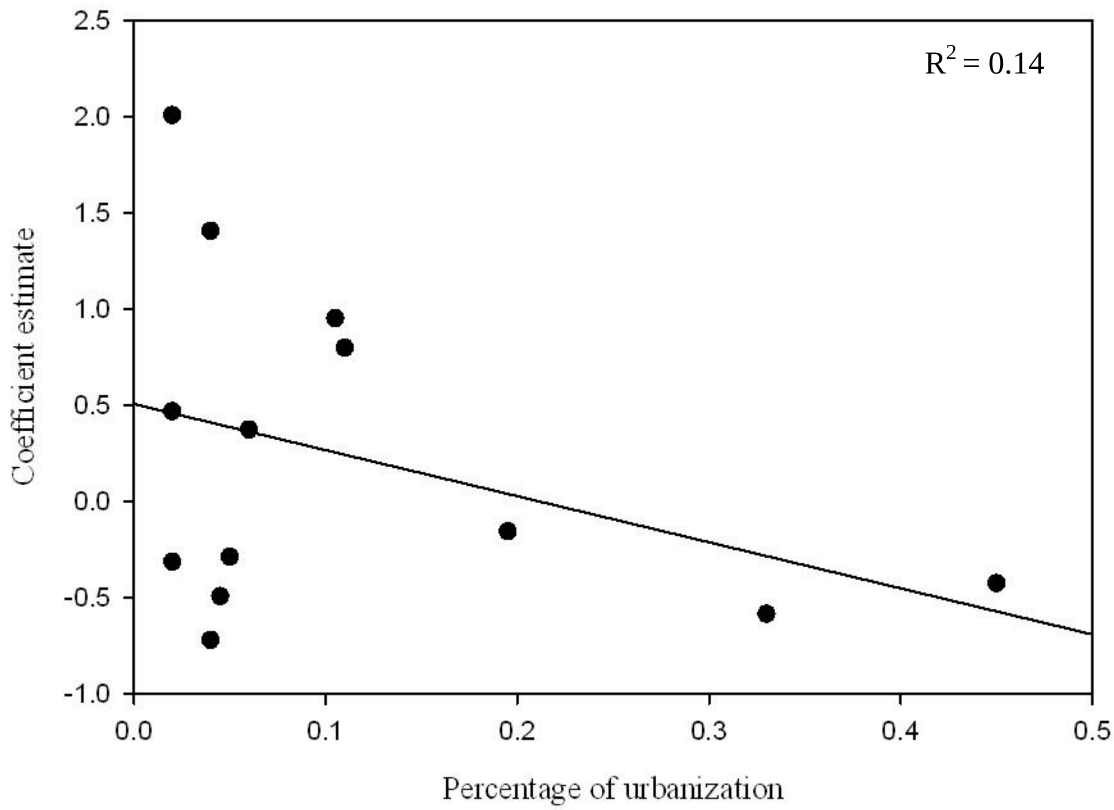


Figure 2.22. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for natural pine forests on percentage of urbanization for 5 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.

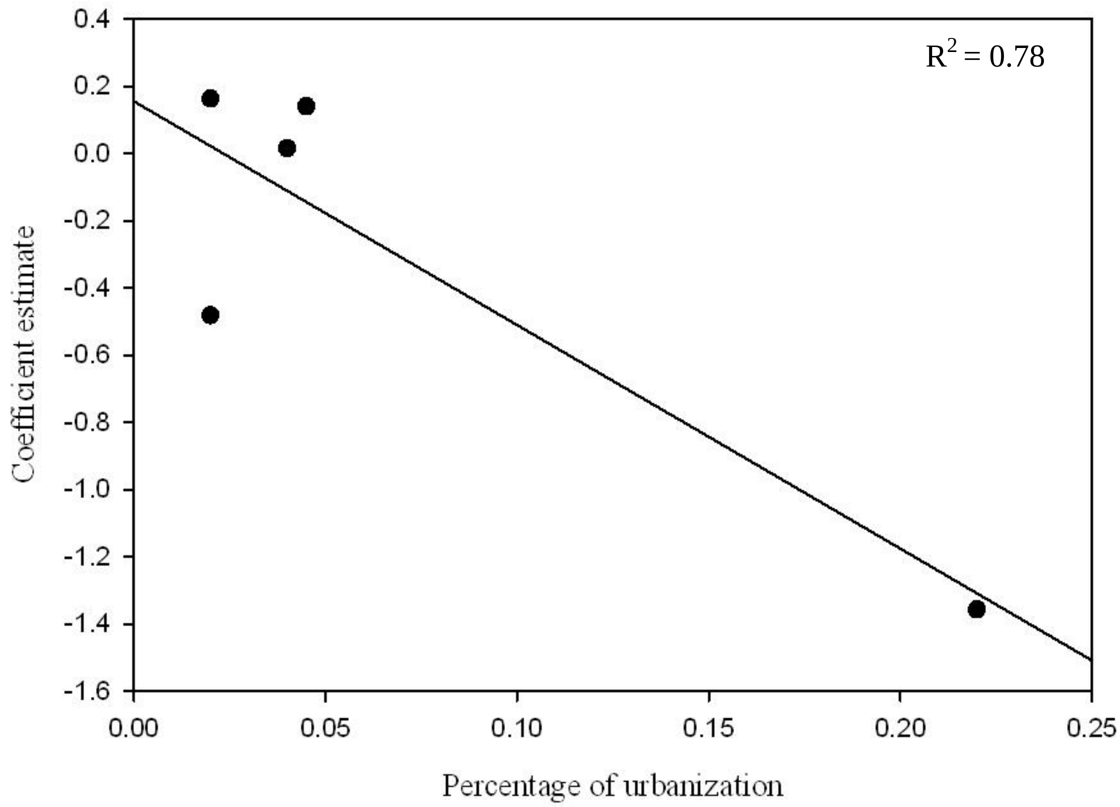
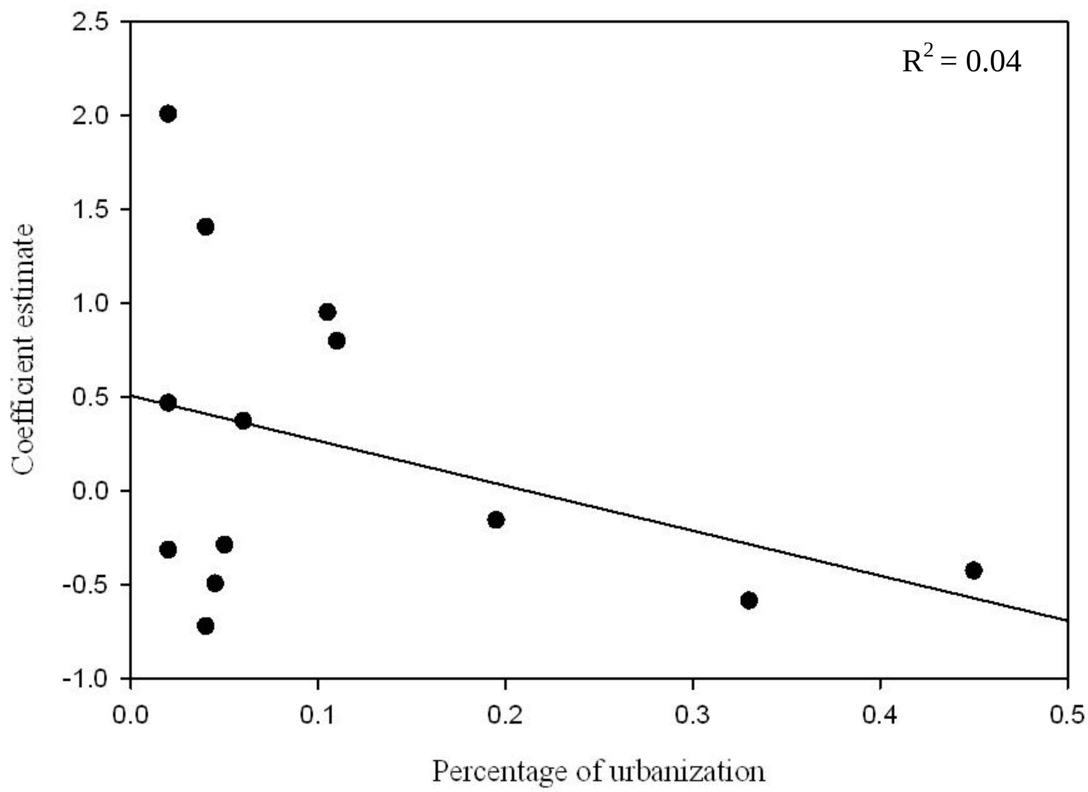


Figure 2.23. Selection of habitat along a gradient of urbanization generated from regressing resource selection coefficients for agricultural land on percentage of urbanization for 13 coyotes *(Canis latrans)* in Lee County, Alabama, 2007-2009.



Appendix 1. Common species of trees in Lee County, Alabama.

| Scientific name | Common name |
|---|---|
| *Acer rubrum* | Red maple |
| *Carya comentosa* | Mockernut hickory |
| *Carya ovalis* | Red hickory |
| *Carya ovate* | Shagbark hickory |
| *Carya texana* | Black hickory |
| *Diospyros virginiana* | Persimmon |
| *Fagus grandifolia* | American beech |
| *Liquidambar styraciflua* | Sweetgum |
| *Liriodendron tulipifera* | Tulip poplar |
| *Magnolia grandiflora* | Southern magnolia |
| *Nyssa sylvatica* | Black gum |
| *Pinus echinata* | Short leaf pine |
| *Pinus elliotii* | Slash pine |
| *Pinus palustris* | Long leaf pine |
| *Pinus taeda* | Loblolly pine |
| *Platanus occidentalis* | Sycamore |
| *Prunus serotina* | Cherry |
| *Quercus alba* | White oak |
| *Quercus falcate* | Southern red oak |
| *Quercus marilandica Münchh* | Black jack oak |
| *Quercus nigra* | Water oak |
| *Sassafras albidum* | Sasifras |

Appendix 2. Percentage of habitats in home ranges of coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Animal | Water | Developed open space | Low-intensity development | Medium-intensity development | High-intensity development | Succession | Agriculture | Pine plantation | Mixed forest | Hardwood forest | Pine forest |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 324-1-1 | 0 | 9 | 2.5 | 7.5 | 9.5 | 11 | 10.5 | 13.5 | 23 | 13.5 | 0 |
| 205-2-1 | 1.5 | 25 | 11 | 13.5 | 20.5 | 2 | 2.5 | 6.5 | 12.5 | 5 | 0 |
| 223-1-1 | 1.5 | 16.5 | 5 | 7.5 | 9.5 | 2 | 7 | 0.01 | 0 | 10.5 | 40.5 |
| 205-1-1 | 0.5 | 8 | 1.5 | 6 | 3 | 18 | 5.5 | 18 | 34 | 5.5 | 0 |
| 164-1-1 | 0 | 4.5 | 1.5 | 4.5 | 0 | 8 | 1.5 | 26.5 | 44.5 | 9 | 0 |
| 285-1-1 | 0.5 | 31 | 10 | 8 | 15 | 2 | 3.5 | 10.5 | 13 | 6.5 | 0 |
| 364-1-1 | 0 | 6 | 4.5 | 0.5 | 0 | 13.5 | 7 | 25.5 | 29 | 13 | 1 |
| 087-1-1 | 2 | 5 | 1 | 0.5 | 2.5 | 10 | 34.5 | 18.5 | 19.5 | 6.5 | 0 |
| 404-1-1 | 1.5 | 3.5 | 1.5 | 0.5 | 0 | 4.5 | 41 | 0.5 | 0 | 12 | 35 |
| 183-1-1 | 0.5 | 8.5 | 2 | 5.5 | 3.5 | 6.5 | 37.5 | 13 | 12.5 | 10.5 | 0 |
| 145-1-1 | 0 | 11.5 | 2.5 | 1.5 | 0 | 15.5 | 9 | 9 | 10 | 17 | 24 |
| 105-2-2 | 0 | 13 | 1 | 1 | 0 | 11.5 | 8.5 | 12.5 | 9 | 15.5 | 28 |
| 023-1-2 | 1 | 4 | 1 | 1 | 0 | 9.5 | 10.5 | 24 | 39 | 10 | 0 |
| 346-1-1 | 1 | 9 | 4 | 0.5 | 0 | 7.5 | 20 | 5.5 | 6 | 4.5 | 42 |

Appendix 3. Data for captures and measurements for 21 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2008.

| Animal | Sex | Date captured | Weight (kg) | Length of body (cm) | Length of tail (cm) | Length of right hind foot (cm) | Length of ear (cm) |
|---|---|---|---|---|---|---|---|
| 023-1-2 | M | 25 April 2008 | 12 | 132 | 42 | 21 | 11 |
| 046-1-1 | F | 17 November 2008 | 10 | 113 | 35 | 17 | 11 |
| 066-1-1 | F | 18 January 2008 | 11 | 116 | 33 | 18 | 10 |
| 087-1-1 | F | 12 November 2007 | 10 | 121 | 41 | 19 | 9 |
| 105-1-2 | M | 11 April 2008 | 16 | 134 | 38 | 20 | 13 |
| 124-1-1 | F | 6 November 2008 | 12 | 118 | 37 | 19 | 11 |
| 145-1-1 | F | 10 April 2008 | 15 | 135 | 41 | 19 | 11 |
| 164-1-1 | F | 15 March 2008 | 13 | 115 | 32 | 19 | 10 |
| 183-1-1 | F | 4 April 2008 | 14 | 133 | 39 | 18 | 10 |
| 205-1-1 | F | 16 March 2008 | 10 | 135 | 35 | 22 | 10 |
| 205-2-1 | F | 18 November 2008 | 12 | 128 | 37 | 17 | 10 |
| 205-2-1 | F | 18 November 2008 | 12 | 128 | 37 | 17 | 10 |
| 223-1-1 | F | 27 March 2008 | 14 | 130 | 41 | 19 | 10 |
| 245-1-1 | F | 21 December 2007 | 12 | 132 | 38 | 19 | 11 |
| 264-1-2 | M | 30 January 2008 | 9 | 122 | 40 | 19 | 12 |
| 285-1-1 | F | 21 January 2008 | 11 | 116 | 33 | 18 | 10 |
| 324-1-1 | F | January 16 2008 | 14 | 131 | 44 | 19 | 13 |
| 346-1-1 | F | 12 March 2008 | 14 | 127 | 33 | 18 | 12 |
| 364-1-1 | F | 11 April 2008 | 14 | 130 | 41 | 19 | 10 |
| 383-1-1 | F | 12 November 2007 | 12 | 130 | 43 | 20 | 10 |
| 404-1-1 | F | 11 March 2008 | 15 | 124 | 40 | 20 | 10 |

Appendix 4. Monitoring information and seasonal size of home ranges calculated using the 95%-adaptive-density-kernel method and seasonal size of core areas determined by the 50%-adaptive-density-kernel method for 14 coyotes (*Canis latrans*) in Lee County, Alabama, 2007-2009.

| Animal | Season[a] | Sex | Monitoring period | Size of home range ($km^2$) | Size of core area ($km^2$) |
|---|---|---|---|---|---|
| 023-1-2 | Breeding | M | 6 May 2008-22 July 2009 | 12.46 | 1.98 |
| | Pup-rearing | | | 9.77 | 0.74 |
| | Dispersal | | | 23.08 | 5.56 |
| 087-1-1 | Breeding | F | 18 April 2008-22 July 2009 | 12.05 | 1.35 |
| | Pup-rearing | | | 8.54 | 1.37 |
| | Dispersal | | | 5.81 | 0.94 |
| 105-2-2 | Breeding | M | 7 May 2008-23 July 2009 | 9.66 | 0.76 |
| | Pup-rearing | | | 8.12 | 0.91 |
| | Dispersal | | | 14.16 | 3.11 |
| 145-1-1 | Breeding | F | 7 May 2008-23 July 2009 | 9.50 | 0.85 |
| | Pup-rearing | | | 11.33 | 1.11 |
| | Dispersal | | | 18.06 | 3.01 |
| 164-1-1 | Breeding | F | 24 April 2008-23 July 2009 | 8.38 | 1.26 |
| | Pup-rearing | | | 4.54 | 0.69 |
| | Dispersal | | | 7.11 | 0.81 |
| 183-1-1 | Breeding | F | 6 May 2008-22 July 2009 | 12.50 | 1.70 |
| | Pup-rearing | | | 11.15 | 2.28 |
| | Dispersal | | | 5.45 | 0.93 |
| 205-1-1 | Breeding | F | 23 April 2008-19 September 2009 | N/A | N/A |
| | Pup-rearing | | | 8.47 | 0.88 |
| | Dispersal | | | 4.64 | 0.87 |
| 205-2-1 | Breeding | F | 1 December 2008-5 March 2009 | 4.40 | 0.61 |

| | | | | | |
|---|---|---|---|---|---|
| | Pup-rearing | | | N/A | N/A |
| | Dispersal | | | N/A | N/A |
| 223-1-1 | Breeding | F | 23 April 2008-July 22 2009 | 4.67 | 0.51 |
| | Pup-rearing | | | 5.65 | 0.73 |
| | Dispersal | | | 1.05 | 0.16 |
| 285-1-1 | Breeding | F | 6 May 2008-14 January 2009 | 10.49 | 2.31 |
| | Pup-rearing | | | 7.81 | 1.18 |
| | Dispersal | | | 1.88 | 0.37 |
| 324-1-1 | Breeding | F | 7 May 2008-24 June 2009 | 4.69 | 0.85 |
| | Pup-rearing | | | 2.58 | 0.23 |
| | Dispersal | | | 0.48 | 0.08 |
| 346-1-1 | Breeding | F | 23 April 2008-22 July 2009 | 10.80 | 1.16 |
| | Pup-rearing | | | 22.98 | 3.21 |
| | Dispersal | | | 1.80 | 0.14 |
| 364-1-1 | Breeding | F | 7 May 2008-23July 2009 | 10.12 | 2.17 |
| | Pup-rearing | | | 13.25 | 3.12 |
| | Dispersal | | | 9.86 | 1.56 |
| 404-1-1 | Breeding | F | 23 April 2008-22 May 2009 | 9.22 | 1.53 |
| | Pup-rearing | | | 7.22 | 0.74 |
| | Dispersal | | | 0.64 | 0.09 |

[a] Breeding (1 January-30 April), pup-rearing (1 May-31 August), dispersal (1 September-31 December).

Appendix 5. Dispersal and mortality data for 21 coyotes (*Canis latrans*) captured in Lee County, Alabama, 2007-2008.

| Animal | Sex | Trap date | Date of last location | Status | Dispersed? | Distance from trap site (km) |
|---|---|---|---|---|---|---|
| 023-1-2 | M | 25 April 2008 | 1 September 2009 | live | | |
| 046-1-1 | F | 17 November 2008 | 20 November 2008 | dead | Yes | 402 |
| 066-1-1 | F | 18 January 2008 | 22 September 2008 | dead | Yes | 145 |
| 087-1-1 | F | 12 November 2007 | 1 September 2009 | live | | |
| 105-1-2 | M | 11 April 2008 | 1 September 2009 | live | | |
| 124-1-1 | F | 6 November 2008 | 29 December 2008 | unknown | | |
| 145-1-1 | F | 10 April 2008 | 1 September 2009 | live | | |
| 164-1-1 | F | 15 March 2008 | 1 September 2009 | live | | |
| 183-1-1 | F | 4 April 2008 | 1 September 2009 | live | | |
| 205-1-1 | F | 16 March 2008 | 19 September 2008 | dead | No | 0.8 |
| 205-2-1 | F | 18 November 2008 | 5 March 2009 | dead | Yes | 241 |
| 223-1-1 | F | 18 November 2008 | 1 September 2009 | live | | |
| 245-1-1 | F | 27 March 2008 | 23 April 2008 | dead | Yes | 40 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 264-1-2 | M | 21 December 2007 | 10 December 2010 | dead | Yes | 64 |
| 285-1-1 | F | 30 January 2008 | 14 January 2009 | unknown | | |
| 324-1-1 | F | 21 January 2008 | 29 December 2008 | dead | No | 0.8 |
| 346-1-1 | F | January 16 2008 | 1 September 2009 | live | | |
| 364-1-1 | F | 12 March 2008 | 1 September 2009 | live | | |
| 383-1-1 | F | 11 April 2008 | 23 November 2007 | dead | No | 0.8 |
| 404-1-1 | F | 12 November 2007 | 24 April 2009 | dead | No | 0.8 |