HOME RANGE AND FOOD HABITS OF THE COYOTE (*CANIS LATRANS*) AT THE SAVANNAH RIVER SITE, SOUTH CAROLINA

by

JOSHUA DAVID SCHRECENGOST

(Under the Direction of Karl V. Miller)

ABSTRACT

Coyote food habits were assessed by fecal analysis of 415 scats collected from May 2005 through July 2006 on the Savannah River Site, South Carolina. Seasonally available soft mast was the most common food item in 12 of the 15 months sampled. Adult white-tailed deer occurred most frequently in December and March, and fawn remains were common during May and June. Thirty-three adult coyotes were radio collared between April and October 2005 and monitored through September 2006. Radio telemetry locations were used to assess home range size and habitat selection was assessed by compositional analysis. Coyote home ranges averaged 31.8 km^2 using the fixed Kernel method (30.5 km^2 Minimum Convex Polygon) and contained more early successional habitat than was available on the landscape. Data from this study suggest that coyotes are heavily dependant on soft mast, may be affecting local white-tailed deer populations, and have larger home ranges with more intraspecific overlap than previously reported in the Southeast.

INDEX WORDS: *Canis latrans*, compositional analysis, coyote, fecal analysis, food habits, home range, radio telemetry, Savannah River Site, South Carolina, white-tailed deer

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DEDICATION

For Mindy and Madeline; you inspired me to begin and finish this endeavor.

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I like to believe that people become part of, or pass through our lives for good reason. Sometimes it is so we may learn; sometimes it is so we may teach. I have been blessed with many teachers and hope there are a few who have learned from me.

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INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Coyotes (*Canis latrans*) are historically associated with open habitats and grasslands of western North America (Bekoff 1977). Fossil evidence suggests that a coyote-like canid periodically inhabited western North America during the Pleistocene era (Gipson 1978), but no coyote populations existed in the east at the time of European colonization (Nowak 1978). However, coyote distribution is expanding and now includes most of the United States and Canada. Recent expansion into the southeastern U.S. has been aided largely by humans (Hill et al. 1987). Hill et al. (1987) cites 20 releases in southeastern states between 1925 and 1981, many for sport hunting of coyotes with dogs. Several of these releases established local populations of coyotes. These local populations merged with populations of coyotes expanding from their western ranges and expedited colonization of the southeastern United States.

Throughout most of the United States, state wildlife agencies treat coyotes more like vermin than game animals. Despite year round hunting and generally no bag limits, coyotes continue to survive and thrive. Coyote fur has little value in the Southeast. However, live coyotes can be sold for as much as $125 to fox pens for the sport of running coyotes with hounds. Although this practice is controversial, it is tolerated by some states. Hunters often blame coyotes for limiting the abundance of popular game animals such as white-tailed deer, bobwhite quail, and wild turkeys. Studies across North America have yielded mixed results regarding coyote impacts on game populations.

Coyote ecology has been explored in detail throughout much of their historical range (Bekoff 1977, Gier 1968, Murie 1945, Young et al. 2006). However, because coyotes exhibit temporal and spatial variability in food item use (Bekoff 1977, Cypher et al. 1994) and home range (Holzman et al. 1992), the findings of these studies may have diminished value in the Southeast.

Several studies have investigated coyote ecology in southeastern states, but no published record exists in South Carolina.

Coyote ecology studies typically focus on food habits or spatial ecology. Food habit studies are used to define the diet of coyotes by analysis of coyote scat or stomach contents. They are useful in determining the plant and animal species that coyotes are directly influencing through predation. Spatial ecology studies are conducted by fitting coyotes with radio transmitters and remotely tracking their movements. In open habitats, coyote movements have also been documented through direct observation. The resulting location data is useful in assessing the size and habitat types of a coyote's home range. In addition, radio collared coyotes can be monitored for mortality, which provides survivorship information. Population density studies can consist of scat deposition rate indices, scent stations, and howling surveys. A measure of coyote presence, such as scat counts, track counts, or vocalization counts, serves as an index of coyote abundance.

Food Habit Studies

In the southeastern United States, food habits of coyotes have been documented by fecal and stomach content analysis in Alabama (Blanton 1988, Hoerath 1990, Wagner 1993, Wooding 1984), Arkansas (Gipson 1974, Wagner 1993), Florida (Thornton et al. 2004, Wagner 1993), Kentucky (Blanton 1988), Louisiana (Hall 1979, Michaelson 1975, Wilson 1967), Mississippi (Blanton 1988, Wagner 1993, Wooding 1984), and Tennessee (Blanton 1988, Lee 1986, Smith and Kennedy 1983). Nearly all of these studies list small mammals and/or rabbits as the most common mammalian food item for coyotes. Interestingly, use of white-tailed deer (*Odocoileus virginianus*) and fruit seem to be extremely variable in the diet of southeastern coyotes. In seven southeastern study areas, Blanton and Hill (1989) reported 31% average occurrence of deer in the summer coyote diet. This is similar to findings in Mississippi and Alabama (Wooding 1984) and in Louisiana (Hall 1979). Blanton and Hill (1989) observed a decreased use in other food items as fawns became available in areas of high deer density, suggesting that coyotes may select fawns over less profitable food items. Changing forestry practices, resulting in different suites of mast producing species, and expanding deer populations across the southeast, limit the application of past studies in describing the food habits of unstudied coyote populations.

Spatial Ecology Studies

Spatial ecology of coyotes has been studied extensively in western ecosystems. However, most coyote habitat in the west consists of open, arid environments. These differences in habitat and prey availability likely alter the density of coyotes. However, even among southeastern studies, much variation is evident. Holzman (1992) found that coyotes in Georgia have average 95% minimum convex polygon home ranges of 10.1 km^2 based on the telemetry locations of 12 coyotes. Wooding (1984) tracked six coyotes in Alabama and two coyotes in Mississippi and reported an average home range size of 27.0 km^2. In another study in Mississippi and Alabama, adult coyotes were found to have an average home range of 33.4 km^2 based on 7 coyotes (Sumner 1984). Thornton et al. (2004) found coyotes to have average 95% Fixed-Kernel home range of 24.8 km^2 based on the telemetry locations of 7 coyotes. Chamberlain et al. (2000) found coyotes to have average home ranges of 14.8 km^2 based on the locations of 18 adult coyotes. The variable home range sizes reported by these studies and the small sample sizes reinforce the need for further investigation into coyote spatial ecology in the Southeast.

Population Density Studies

Use of an artificially produced howl to elicit a howling response from coyotes was first reported by Alcorn (1946). Elicited coyote howling surveys have been used as a census technique in western and northern states, but has seen limited use in the Southeast. The technique has been used in Tennessee and Kentucky (Sharp 1981), as well as Arkansas, Mississippi, and Alabama (Blanton 1988). Primarily, howling surveys are useful as an index of abundance (Wenger and Cringan 1978), but with careful site-specific considerations this technique can serve as an estimate of coyote density (Blanton 1988).

THESIS OBJECTIVE AND FORMAT

The primary objective of this research was to document coyote ecology on the Savannah River Site, SC in order to establish baseline data to assist United States Department of Agriculture Forest Service biologists in managing the coyote population as well as other wildlife populations. Because coyotes are recent invaders of the southeastern United States, data does not exist for some regions. Therefore, a second objective was to provide data on coyote ecology in the South Carolina Upper Coastal Plain region for comparison with ecological data on coyotes in other regions of the Southeast.

This thesis is presented in manuscript form. Chapters 2 and 3 are separate manuscripts for submission to peer-reviewed scientific journals. Chapter 2, titled “Seasonal food habit of the coyote in the South Carolina Coastal Plain” presents coyote food habits as determined by fecal analysis. Chapter 3, titled “Home range, habitat use, and survival of the coyote in western South Carolina” presents data on home range size, intraspecific overlap, habitat selection, and cause specific mortality. Chapter 4 presents a summary of results and management implications for this research.

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CHAPTER 2

SEASONAL FOOD HABITS OF THE COYOTE IN THE SOUTH CAROLINA COASTAL PLAIN[1]

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[1] Joshua D. Schrecengost, John C. Kilgo, David Mallard, H. Scott Ray, Karl V. Miller. Submitted to the *Southeastern Naturalist,* 4/21/2007.

***Abstract*:** Spatial and temporal plasticity in coyote (*Canis latrans*) diets require regional studies to understand the ecological role of this predator. Because coyotes have recently become established in South Carolina, we investigated their food habits by collecting 415 coyote scats on the Savannah River Site in western South Carolina. Seasonally available soft mast was the most common food item in 12 of the 15 months we sampled. White-tailed deer (*Odocoileus virginianus*) was the most common food item during December (40%) and March (37%). During May-June, wild plums (*Prunus* spp.) and blackberries (*Rubus* spp.) were the most commonly occurring food items. Fawns were the most common mammalian food item during May and June of both years despite low deer density.

Keywords: *Canis latrans*, diet, fawn, fecal analysis, predation, scat, soft mast, white-tailed deer

INTRODUCTION

The coyote (*Canis latrans*, Say) is historically associated with western North America. However, during the last 50 years, they have expanded their range into the southeastern U.S., aided largely by humans (Hill et al. 1987). Coyote food habits have been explored in detail throughout much of their historical range (Andelt et al. 1987, Bekoff 1977, Murie 1951, Murie 1945). However, because coyotes exhibit temporal and spatial variability in food item use (Bekoff 1977, Cypher et al. 1994), the findings of these studies have limited value in the Southeast. Coyote food habits have been documented in several areas of the Southeast (Blanton and Hill 1989, Gipson 1974, Hall 1979, Hoerath 1990, Lee 1986, Michaelson 1975, Smith and Kennedy 1983, Thornton et al. 2004, Wagner 1993, Wilson 1967, Wooding 1984) but no published record exists for South Carolina or adjacent states. Although there is considerable overlap in the types of food items documented in these studies, the importance of particular food items in the coyote diet differs geographically among study areas and temporally among seasons due to changes in food item availability. Coyote food habits can also be affected by changes in land use practices (Gipson and Sealander 1976) and successional changes in vegetation (Andelt et al. 1987).

The effect of coyote predation on game animal populations has been of interest for decades. In the Southeast, only two studies have focused on specific game animals. Wagner (1993) studied coyote diet during the wild turkey (*Meleagris gallopavo*, L.) reproductive season in Arkansas, Mississippi, Alabama, and Florida and reported wild turkey occurred in <2% of scats collected during the spring reproductive season. Blanton and Hill (1989) compared diets of coyotes in areas of high and low white-tailed deer (*Odocoileus virginianus*, Zimmerman) densities during the fawning period in Alabama, Kentucky, Mississippi, and Tennessee.

Occurrence of deer in coyote scats and stomachs ranged from 9% in low density areas to 74% in high density areas during the fawning period. This wide variation in occurrence is consistent with the findings of other Southeastern studies. Michaelson (1975) and Wilson (1967) both reported annual deer occurrences <5%, whereas Wooding (1984) reported deer occurrences of 71% during August.

Variability in food habits, even among similar habitats, limits the use of prior studies in determining site-specific ecological impact of coyotes. Detailed data describing coyote use of intensely managed populations such as white-tailed deer are of particular interest. Therefore, our objectives were to determine the breadth of coyote food habits and identify seasonal trends in the coyote diet on Savannah River Site in South Carolina.

Study Area

Our research was conducted on the 80,000 ha Savannah River Site (SRS) in Aiken, Barnwell, and Allendale counties, South Carolina. The SRS is a U.S. Department of Energy National Environmental Research Park located in the Upper Coastal Plain physiographic province along the Savannah River (Imm and McLeod 2005). Coyotes were first reported on the SRS in 1986 (Mayer et al. 2005). Since that time, the population has expanded dramatically (Mayer et al. 2005) and coyotes are now observed frequently. Topography of the SRS is gently rolling to flat and elevation ranges from 20-130m. Once used for agriculture, SRS is now predominately forested (97%). Longleaf (*Pinus palustris*, P.Mill.) and loblolly (*P. taeda*, L.) pines dominate the overstory canopy (68%). Other major vegetative types include swamps and bottomland hardwood (22%) and upland hardwood (7%) forests (Imm and McLeod 2005). Approximately 12% of the total forest stands are <10 years of age (Blake and Bonar 2005). The SRS is intersected by over 2,600 km of roads, logging trails, and railroads (Blake et al. 2005).

The white-tailed deer population on the SRS is managed to limit deer-vehicle collisions and deer impact on the environment. Controlled dog hunting is used to maintain a target population of 4,000 deer (Johns and Kilgo 2005). Currently, deer population density is estimated at 1/20 hectares (Ray and Kilgo, unpubl. data). Hunts during the course of this study occurred in October through December 2005. Recent evidence from harvest data suggests that white-tailed deer recruitment is declining at SRS, coincident with increasing coyote abundance.

The wild hog (*Sus scrofa*, L.) population on SRS was estimated at 900 animals in 2003 (Mayer 2005). Wild hogs are hunted and trapped year round to minimize impact on the environment and vehicle collisions. From May 2005 through June 2006, 172 hogs were killed on SRS. Most wild hog carcasses are disposed of on site which provides an incidental source of carrion for coyotes.

METHODS

We collected coyote scats opportunistically along roads and rights-of-way throughout SRS from May 2005 through July 2006. Scats were evaluated in the field for relative moisture content and decomposition in an attempt to collect samples < 5 days old. Scats were placed in plastic bags labeled with date and location of collection and stored frozen to minimize decomposition. For analysis, scats were oven dried at 65° C for 72-96 hours and food items were separated manually. We identified food items macroscopically from tooth, claw, and hoof fragments, as well as plant residues. Dorsal guard hairs were identified microscopically when necessary using the pigment patterns of the medulla and the morphology of cuticular scales and compared to reference slides prepared from the University of Georgia mammalian collection. Plant residues, primarily seeds, were compared to reference manuals and collections of known specimens. We recorded the occurrence for each food item in each scat.

Previous studies have used several terms interchangeably to describe the frequency of occurrence of food items in the diet of coyotes (Wagner 1993). We chose to define “percent of scats” as the percent of a sample of scats in which a prey item occurs, and “percent of occurrence” as the number of times a prey item occurs as a percent of total number of occurrences for all prey items (Kelly 1991, Wagner 1993). Percent of scats and percent of occurrence were calculated for each food item. We grouped some food items due to difficulties in differentiating among species and combined items occurring at low frequencies into a miscellaneous category.

RESULTS

We analyzed 415 scats to evaluate coyote food habits between May 2005 and July 2006. No single food item occurred in all 15 months sampled. White-tailed deer, rabbits (*Sylvilagus* spp., Gray), and insects, primarily Orthoptera, occurred in 14 months each and small mammals occurred in 13 months. (Table 2.1) A single food item made up greater than 90% of the scat in 227 samples.

The coyote diet was dominated by plant matter from May 2005 through November 2005 as well as June and July 2006 (Fig. 2.1a) and the occurrence of individual plant food items consumed varied with availability (Fig. 2.1b). Wild plums (*Prunus* spp., L.) occurred in 85% of scats in May 2005 and 54% of scats in May 2006. Blackberries (*Rubus* spp., L.) occurred in 64% of scats in June 2005, 58% of scats in June 2006, and 89% of scats in July 2006. Black cherry (*Prunus serotina*, Ehrh.) occurred in 59% of scats during July 2005. Pokeberry (*Phytolacca americana*, L.) occurred in 51% of scats during August 2005 and 62% of scats during November 2005. Persimmon (*Diospyros virginiana*, L.) occurred in 78% of scats during September 2005 and 81% of scats during October 2005.

During December through April the coyote diet was dominated by animal food items (Fig. 2.1a), although percent occurrence of individual mammalian food items varied throughout the year (Fig. 2.1c). White-tailed deer occurred in 40% of scats during December and 37% of scats during March. Conception dates of white-tailed deer at SRS (H.S. Ray, unpublished data) and a 200 day gestation period (Haugen 1959, Verme 1965) place parturition primarily in the months of May and June. During 2005, fawns were present in scat collected in May (31%), June (15%), July (18%), and August (2%). During 2006 fawns were present is scat collected in May (38%) and June (23%). Wild hogs and rabbits (*Sylvilagus* spp.) each occurred in 31% of scats during February. Orthoptera occurred in 31% of scats during April (Table 2.1).

DISCUSSION

From spring through late fall coyotes fed on soft mast when it was available. However, from December through March, when vegetative food items were less abundant, coyotes relied heavily on mammalian food items. Small and medium sized mammals may also be more vulnerable at this time of year due to a decrease in herbaceous cover. Orthopterans, primarily grasshoppers, were common in scats throughout the year; however, they rarely comprised a significant portion of the volume of the scats. Other studies have reported high occurrences of lagamorphs (Bartel and Knowlton 2005, Blanton and Hill 1989, Thornton et al. 2004) and small mammals (Bartel and Knowlton 2005, Bowyer et al. 1983, Hall 1979, Smith and Kennedy 1983, Wilson 1967) in the diets of coyotes. Although both of these groups were present in the diet of coyotes at SRS throughout most of the year, their importance was limited and occurrence was greatest during winter and early spring. In Louisiana, Wilson (1967) found the highest use of rodents and lagamorphs during summer and fall.

Occurrence of wild hog in scats was greatest during February, corresponding with the peak of hog control (January through March) during which 69 hog carcasses were disposed of on SRS. Although small hog hooves were occasionally found in scats, most hog occurrence was large, coarse hairs, suggesting that coyotes fed on adult hogs as well as piglets. It is unclear if coyotes kill adult hogs though they undoubtedly scavenge carrion. Similarly, Wagner (1993) found hog remains in 17-25% of scats in Bolivar County, Mississippi and reported peak occurrence with peak sport hunting of hogs.

Fruit use by coyotes has been documented by numerous studies (Andelt et al. 1987, Blanton and Hill 1989, Murie 1951, Thornton et al. 2004, Wooding 1984). However, the timing of fruit availability and species use is variable. Wooding (1984) reported persimmons in 67% of scats and stomachs during fall in Mississippi and Alabama, similar to the findings of this study. Blackberry and pokeberry have also been reported at significant levels in several southeastern states (Blanton 1988). However, occurrence of wild plums, comparable to the findings of this study, has not been previously reported. These differences in occurrence of soft mast further emphasize the need for locally specific coyote food habit studies.

White-tailed deer were consumed in every month except October. Road-killed deer carcasses are available to coyotes in limited quantities throughout the year. During 2005, 72 road killed deer were recovered on SRS (P. Johns, unpubl. data) and most were deposited on site. This may explain a portion of the deer remains encountered in coyote scats. The absence of white-tailed deer in October is likely due to the increase in seasonal soft mast consumption due to availability of persimmon and pokeberry fruits. Increased use of white-tailed deer during November and December corresponded with the timing of controlled hunts on SRS. Apparently coyotes consumed deer crippled or un-recovered during hunts or perhaps hunting pressure made deer more susceptible to predation. However, D'Angelo et al. (2003) found that female white-tailed deer on SRS quickly resumed normal movement patterns after hunt-associated disturbances, indicating that risk of coyote predation likely would not be increased by hunting activity. White-tailed deer remains also occurred in a large proportion of scats during March (Table 2.1). Increased coyote use of deer during late winter has been associated with increased deer vulnerability due to winter severity and deep snows (Patterson et al. 1998). However, this is certainly not a factor in South Carolina. Deer-vehicle collision data from the SRS suggests there was not a significant increase in available carrion at this time. Although coyotes may have been killing adult deer, it is more likely that coyotes were returning more often and from greater distances to the available carrion and consuming even the deer hides. This could account for the increased occurrence of deer remains in scats during March. White-tailed deer fawns were an important component of the diet during May through July, coincident with the timing of parturition and fawn rearing. During this time fawns comprised the largest proportion of mammalian food items encountered, although blackberries and wild plums were the most frequently encountered items in scats overall. In seven southeastern study areas, Blanton and Hill (1989) reported 31% average occurrence of deer in the summer coyote diet. This is similar to the findings of this study as well as in Mississippi, Alabama (Wooding 1984), and in Louisiana (Hall 1979). Blanton and Hill (1989) observed a decreased use in other food items as fawns became available in areas of high deer density, suggesting that coyotes may select fawns over less profitable food items. On SRS, fawns may be more profitable than alternative food sources despite low deer density (1/20ha). Fawn mortality, recruitment, and population trend data from SRS (Kilgo and Ray, unpubl. data), along with the high occurrence of fawns in coyote scats reported in this study suggest that coyotes may be impacting deer recruitment at the SRS. In addition, the increased use of mammalian food items when soft mast availability is limited, suggests that a spring soft mast failure could result in increased predation of white-tailed deer fawns (Andelt et al. 1987). Our data presents further evidence in support of this theory because mammalian food item use increases were correlated with decreases in soft mast availability. Because coyotes have established populations throughout the Southeast, biologists may need to consider coyote use of fawns, as well as the availability of alternate food sources, when recommending white-tailed deer harvest levels.

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Table 2.1. Percent of scats containing common coyote food items at the Savannah River Site, SC by month from May 2005 through July 2006.

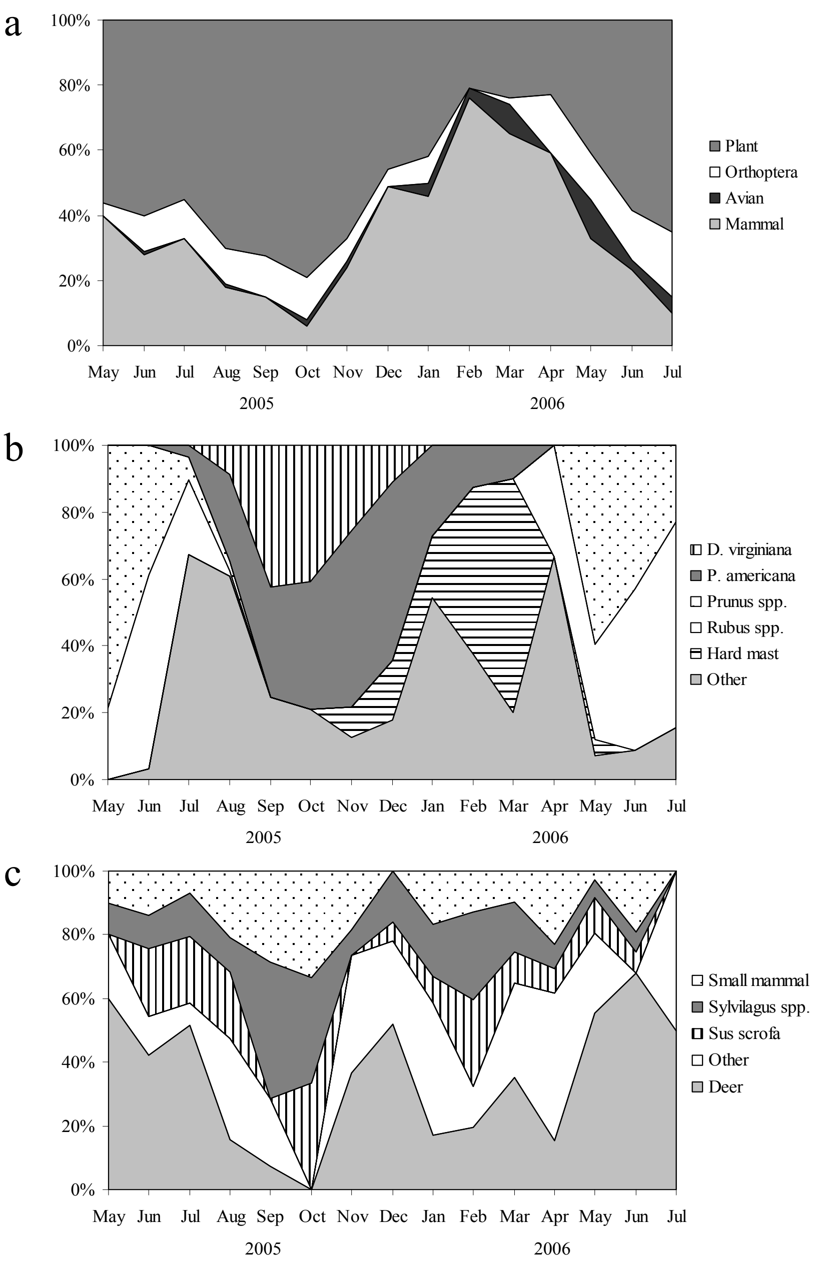
	2005								2006						
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
Food Item	(13)	(53)	(22)	(51)	(32)	(26)	(26)	(25)	(18)	(27)	(30)	(13)	(39)	(31)	(9)
Plants															
Arachis hypogaea						4			17	4	3	8	3		
Carya spp. (nuts)							8	4		15	13		3		
Crataegus spp.				25	13	15	4	8	6						
Diospyros virginiana				18	78	81	31	8							
Phytolacca americana			5	51	59	77	62	36	17	4	3				
Poaceae (leaves)				4	6		4				3	8	3	10	
Prunus serotina		4	59	10					6	4					22
Prunus spp.	85	43	9	6									54	52	33
Quercus spp. (acorns)							4	8	11		7				
Rubus spp.	23	64	27	2								8	26	58	89
Vaccinium spp.			18	37		4		4	6						
Vitis spp.				30	25	12									
Other*			5	6		4	8								
Animals															
Aves		2		2		4	4		6	4	10		18	6	11
Castor canadensis				2					6		3				11
Dasypus novemcinctus			5	4				4		4		8	5		
Neotoma floridana		2							11		3	23	5		
Odocoileus virginianus (adult)	15	8	14	6	3		15	40	11	23	37	15	5	10	11
Odocoileus virginianus (fawn)	31	15	18	2									38	23	
Orthoptera	8	21	27	31	31	31	12	8	11		3	31	31	32	44
Procyon lotor				6	3		4			4	7	8	3		
Sciurus spp.	15	3		6	3	4	4	8	6	4	10	8			
Small mammal	8	8	5	10	9	4	8		11	15	10	23	3	10	
Sus scrofa		11	14	10		4		4	6	31	10	8	8	3	
Sylvilagus spp.	8	6	9	6	16	4	4	12	11	31	17	8	5	3	
Other**					3		8	8	6	4	7		8		

Note: Numbers in parentheses are sample sizes.

* includes *Ilex decidua* , *Ostrya virginiana* , *Passiflora incarnata* , and *Pyrus* sp.

** includes *Canis latrans* , *Didelphis virginiana* , *Lynx rufus* , *Ondatra zibethicus, Urocyon cinereoargenteus* , and egg fragments.

Figure 2.1. Monthly occurrence of food items in coyote scats collected on the Savannah River Site, SC, May 2005 through July 2006; a) Percent occurrence of 4 major food item groups; b) Percent occurrence of plant food items; c) Percent occurrence of mammalian food items


a
100%
80%
60%
40%
20%
0%
May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
2005
2006
Plant
Orthoptera
Avian
Mammal
b
100%
80%
60%
40%
20%
0%
May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
2005
2006
D. virginiana
P. americana
Prunus spp.
Rubus spp.
Hard mast
Other
c
100%
80%
60%
40%
20%
0%
May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
2005
2006
Small mammal
Sylvilagus spp.
Sus scrofa
Other
Deer

CHAPTER 3

HOME RANGE, HABITAT USE, AND SURVIVAL OF THE COYOTE IN WESTERN SOUTH CAROLINA[2]

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[2] Joshua D. Schrecengost, John C. Kilgo, H. Scott Ray, Karl V. Miller. To be submitted to the *Canadian Journal of Zoology.*

Abstract**:** Home range size, habitat use, and survival of the coyote is variable throughout its range. Because coyotes have recently become established in South Carolina, we investigated their spacing, habitat use, and mortality on the Savannah River Site (SRS) in western South Carolina. Annual survival for adult coyotes on the SRS was 0.658. Off-site trapping and shooting accounted for 60% of mortality. Home ranges averaged 30.5 km^2 and 31.85 km^2 by the 95% minimum convex polygon and 95% fixed kernel methods, respectively. We detected no difference in home ranges size between males and females. Intraspecific home range overlap averaged 22.4%, excluding mated pair interactions, with 87.5% of coyotes sharing their home range with one or more individuals. Coyotes selected home ranges and core areas containing higher proportions of early successional habitat than was available on the landscape.

Keywords: *Canis latrans*, compositional analysis, mortality, radio telemetry, Savannah River Site, territory.

INTRODUCTION

The coyote (*Canis latrans*) is historically associated with western North America. However, during the last 50 years, it has expanded its range into the southeastern United States, aided largely by humans (Hill et al. 1987). Coyote ecology has been intensively studied throughout much of its North American range, and this research has indicated a high degree of behavioral plasticity (Bekoff 1977, Holzman et al. 1992) which has been related to prey characteristics (Bowen 1981) and habitat variables (Gese et al. 1988). Because the coyote is a novel predator Southeastern ecosystems, additional study is necessary to understand their ecological impacts on native fauna, and the efficacy of potential management actions.

Coyote harvests have increased dramatically in South Carolina and Georgia in recent years (GADNR, SCDNR unpublished data). Little is known of how trapping and shooting impact local coyote populations in the southeastern states, although these activities are promoted by some livestock producers and land managers. Highly fragmented land ownership patterns in the Southeast results in a mosaic of degrees at which coyotes are controlled. In order to further understand coyote impact and management implications on southeastern ecosystems, we studied survivorship, home range size, and habitat use on the Savannah River Site in west central South Carolina. Our objectives were to determine the factors affecting coyote mortality, document the size and amount of intraspecific overlap in coyote home ranges, and to assess coyote habitat selection.

MATERIALS AND METHODS

Study Site

Our research was conducted on the 78,000 ha Savannah River Site (SRS) in Aiken, Barnwell, and Allendale counties, South Carolina, USA. The SRS is a U.S. Department of

Energy National Environmental Research Park located in the Upper Coastal Plain physiographic province along the Savannah River (Imm and McLeod 2005). Topography of the SRS is flat to gently rolling and elevation ranges from 20-130m above sea level. Used primarily for agriculture until 1950, SRS is now predominately forested (97%). Longleaf (*Pinus palustris*, P.Mill.) and loblolly (*P. taeda*, L.) pines dominate the forest canopy (68%). Other major vegetative suites include swamps and bottomland hardwood (22%) and upland hardwood (7%) forests (Imm and McLeod 2005). Approximately 12% of the total forest stands are <10 years of age (Blake and Bonar 2005). The SRS is intersected by over 2,600 km of roads, logging trails, and railroads (Blake et al. 2005).

Coyotes were first reported on the SRS in 1986 (Mayer et al. 2005). Since that time, the population has expanded dramatically (Mayer et al. 2005) and coyotes are now observed frequently, even during daylight hours. Although coyotes are trapped during January and February and shot on adjacent private properties, they were not subject to persecution on SRS during the course of this study.

Capture and Radio Telemetry

We captured coyotes with offset jawed #1.75 leghold traps (Woodstream Corp., Lititz, PA). Coyotes were anesthetized with medetomidine (Domitor®, Novartis Animal Health Canada Inc., Mississauga, Ontario) at labeled doses delivered intramuscularly via a jab stick. Each animal was blindfolded, muzzled, and evaluated for indications of age (Gier 1968) and reproductive status. Animals estimated to be ≥ 1 year of age were ear tagged and fitted with a motion-sensitive radio-collar (200 g, 3.2-year battery life, ATS Telemetry, Inc., Isanti, MN) equipped with a mortality switch. Vital signs (heart rate, body temperature) were monitored during handling, blood and tissue samples collected, animals were weighed, and standard mammalian measurements were recorded. Chemical immobilization was reversed using atipamezole (Antisedan®, Novartis Animal Health Canada Inc., Mississauga, Ontario) at labeled doses. Capture and handling procedures were approved by the University of Georgia Institutional Animal Care and Use Committee.

Radio tracking was conducted with point locations from June 2005 through July 2006. Radio monitoring for survival continued through September 2006. We estimated locations of coyotes via biangulation and triangulation from 2-5 telemetry bearings using handheld Yagi antennas. Only bearings taken within a 20 minute interval were used for the estimation of locations to decrease error associated with animal movements. In the case of biangulations, we limited the inter-bearing angle to >50° and <130° to minimize error. Average (± SE) location error distance (Zimmerman and Powell 1995) estimated from 24 test collars located 126-1281 m away was 124 m (± 21.3), with an average angular error of 11±1.3°. Locations were estimated using the Andrews-M estimator in the computer program L.O.A.S. (Ecological Software Solutions, Inc., Sacramento, CA). Triangulations resulting in an error ellipse area ≥4 ha were discarded. We attempted to locate each individual 1-2 times a week and distributed tracking events throughout the diel period. Successive locations were separated by a minimum of 12 hours and assumed to be independent (Reynolds and Laundre 1990).

Survival

We used the known-fate model in the program MARK (Version 4.3) to estimate survival of radio marked individuals. The known fate procedure allowed for staggered entry of coyotes throughout the capture period. We assumed that our sample was representative of the population, capture and marking had no effect on survival, and time of capture was independent of survival. We constructed models based on sex, month, season, and year to determine factors affecting coyote survival (Table 3.1). Akaike's Information Criteria (AIC, Akaike 1973, Burnham and Anderson 2002) was used to select the best-fit model. In two of the survival models we grouped months into the following 2-month seasons corresponding with biological and anthropogenic factors likely to affect coyote survival: Jan-Feb, breeding and trapping season; Mar-April, gestation; May-June, nursing; July-Aug, weaning; Sept-Oct, pup independence; Nov-Dec, pre-breeding and SRS deer hunts. We also present annual survival estimates using the Kaplan-Meier approach adjusted for staggered entry (Pollock et al. 1989).

Home Range

We estimated individual annual home ranges for coyotes with ≥ 30 telemetry locations (Seaman et al. 1999) with 95% fixed kernel (FK, Worton 1989) and 50% FK isopleths using Home Range Tools (Rodgers et al. 2005) for ArcGIS 9 (Environmental Systems Research Institute, Inc., Redlands, CA). We used least squares cross-validation (LSCVh) to select the kernel smoothing factor (Seaman et al. 1999).

We also report 95% minimum convex polygon (MCP) home ranges using Home Range Tools (Rodgers et al. 2005) for ArcGIS 9 (Environmental Systems Research Institute, Inc., Redlands, CA) because this method has been used most consistently in previous studies (Holzman et al. 1992). To determine the minimum number of locations needed to estimate MCP home ranges, we used the Animal Movements Extension 2.1 (Hooge and Eichenlaub 2000) in ArcView 3.2 (Environmental Systems Research Institute, Inc., Redlands, Calif.) to calculate 100 bootstrap estimates of MCP home range area using 10-all randomly selected locations for all coyotes. We plotted the mean MCP area by the number of locations (area-observation curve) used in the bootstrap re-sampling and used the number of locations at which the area increased by <1% with the inclusion of an additional location as the minimum number of locations needed to calculate 95% MCP home range (Odum and Kuenzler 1955). We compared home range estimates between males and females using Student's *t* test (PROC TTEST, SAS).

We calculated the percent of home range overlap for coyotes with adjacent home ranges at both the 95% FK and 50% FK levels. We used ArcGIS 9 (Environmental Systems Research Institute, Inc., Redlands, CA) to overlay coyote home range projections and calculate the area of overlap. The percent overlap was calculated by dividing the area of overlap by the total area of the coyote's home range or core area. Interactions between mated pairs were considered separately. We present the mean overlap for individuals sharing part of their home range with more than one other coyote. In overlap calculation, we excluded transient individuals and individuals not surviving for >10 months of the study.

Habitat Selection

We developed a GIS-based habitat map for the SRS based on the U.S. Forest Service FSVEG database and stands coverage (U.S. Forest Service, unpublished data) using ArcGIS 9 (Environmental Systems Research Institute, Inc., Redlands, CA). We delineated six habitats based on forest stand species composition and age (Table 3.2) and calculated the proportions of each habitat within each coyote's 95% FK and 50% FK overlap.

We defined habitat selection on two levels according to Johnson (1980). Second order selection refers to habitats available within the home range versus general availability across the study area. Third order selection refers to habitat use within the core area versus habitat availability within a home range. We defined study area, home range, and core area as the entire SRS, the 95% FK isopleth, and the 50% FK isopleth for each animal, respectively.

We used compositional analysis (Aebischer et al. 1993) to examine habitat selection. Habitat use and availability proportions were compared using multivariate analysis of variance

(MANOVA) with BYCOMP.SAS (Ott and Hovey 1997) for both orders of selection. Habitat use and availability proportions for coyotes believed to be mated pairs (based on observations of male/female interactions and shared home ranges) were combined to avoid pseudoreplication (Thornton et al. 2004). BYCOMP.SAS generates a Wilks' Lambda statistic and associated F-value for overall use versus availability. In addition, matrices of *t* tests were constructed to examine preferences between each pair of habitat types (Aebischer et al. 1993).

RESULTS

Between April and October 2005 we captured 33 adult (14 female, 19 male) and 7 juvenile (<1 year old) coyotes. Adult males (13.53 ± 0.51 kg) weighed more (t=-2.49, P=0.017) than adult females (11.67 ± 0.53 kg). We recorded 1603 locations between June 2005 and July 2006 from radio telemetry (75% biangulations) and an additional 36 locations from visual sightings. Locations were dispersed throughout the diel period as follows: 2400-0800, 20%; 0800-1600, 42%; 1600-2400, 38%. We lost contact or had only sporadic contact with five of the 33 coyotes we collared, suggesting that these animals were transients or had made an atypical excursion onto our study area at the time of capture.

Survival

We used 33 adult coyotes (14 female, 19 male) monitored from April 2005 through September 2006 to estimate survival. Of the 10 known coyote mortalities, 4 animals were trapped outside of the study area, 2 were shot on adjacent properties, 2 deaths were associated with heartworm infestation, and 2 were of unknown causes. In both unknown cases, the coyote was in an advanced stage of decomposition at time of recovery. Five animals were censored following the last day of radio contact. We recovered only the radio collar of one animal which was also censored.

Annual survival for adult coyotes on the SRS was 0.658 (CI = 0.480-0.836; Figure 3.1). Of the six survival models, the model "Seasonal, constant" received 0.958 of the AIC_c weight, which was >23 times more than the second best model "Seasonal, annual" (Table 3.3).

Home Range

Based on bootstrap estimates, 18 coyotes (8 female, 10 male) had sufficient locations ($\bar{x}$ =35, range 30-62) to calculate 95% MCP home ranges. MCP home ranges averaged 30.5 (±8.6) km² (range 3.7-137.0 km²; Table 3.4). We also calculated 95% MCP home ranges with the removal of 1 male and 1 female that could be considered transients due to home ranges of 82 km^2 and 137 km^2, respectively. MCP home range with removal of transients averaged 20.61 (±5.4) km^2 and we detected no difference (t_{14} = -0.76, P = 0.46) between the sexes.

Sufficient locations (>30) were collected to calculate FK home ranges for 22 coyotes (10 female, 12 male). Overall 95% FK isopleths averaged 31.85 (±8.3) km² (range 4.2-147.9 km²) and 50% FK isopleths averaged 6.73 (±1.7) km² (range 0.62-33.6 km²; Table 3.4). With the removal of transients, 95% FK and 50% FK home ranges averaged 24.25 (±4.7) and 5.42 (±1.1) km², respectively. We detected no difference in 95% FK (t_{18} = -1.35, P = 0.192) and 50% FK (t_{18} = -1.52, P = 0.145) home ranges between the sexes.

Of the 22 coyotes for which FK home ranges were calculated, 16 met our criteria for home range overlap analysis. Fourteen of these coyotes (87.5%) had 95% FK home ranges that overlapped with the 95% FK home ranges of one or more other individuals. Excluding mated pair interactions, 95% FK overlap averaged 22.4% (±6.7). Six coyotes (3 male, 3 female) were believed to be mated pairs based on telemetry locations and observations. Mated pair overlaps averaged 72.9% (±5.6) for 95% FK home ranges and 75.9% (±6.7) for 50% FK core areas. Five coyotes (2 female, 3 male) that were not part of a known mated pair had overlaps of the 50% FK core area with one or more other individuals that averaged 18.5% (±8.8) (Table 3.4). We detected no difference in the average percent overlap between unmated males and females at the 95% FK home range ($t_{14} = 0.31$, $P = 0.760$) or the 50% FK core area ($t_8 = -0.06$, $P = 0.955$).

Habitat Selection

Compositional analysis showed that habitat use differed from availability at both the second order ($F_{[5, 14]} = 15.51$, $P = 0.0001$) and third order ($F_{[5,14]} = 3.89$, $P = 0.019$) level for coyotes on the SRS. Coyotes selected home ranges (second order) with early successional habitat over mature pine stands ($t_{18} = 2.54$, $P = 0.019$), hardwood stands ($t_{18} = 2.72$, $P = 0.013$), young pines ($t_{18} = 1.93$, $P = 0.078$), and middle-aged pines ($t_{18} = 1.97$, $P = 0.062$). Coyotes selected core areas (third order) with early successional habitat over young pines ($t_{18} = -2.05$, $P = 0.008$) and mature pines over young pines ($t_{18} = -1.66$, $P = 0.088$). Simplified ranks based on observed *t* statistics and randomized *p*-values are presented in table 3.2.

DISCUSSION

Throughout much of the coyote's range, anthropogenic factors account for the majority of mortality (Andelt 1985, Chamberlain and Leopold 2001, Roy and Dorrance 1985, Tzilkowski 1980). Our results confirm this for southeastern coyotes with 60% of mortality attributable to shooting (n=2) and trapping (n=4) despite these activities not occurring within the boundary of the SRS. In addition, the best-fit survival model grouped January and February (trapping season) which accounted for 40% of the total mortality. Chamberlain and Leopold (2001) reported slightly higher survival (*S*= 0.733 during 1993-1997) for adult coyotes in their study area in Mississippi than on SRS. They concluded that harvest by sport hunters was the primary mortality factor affecting southeastern coyote populations and that trapping was having little effect due to low fur prices. Like the SRS, no trapping occurred on their study area, but sport hunting was permitted.

Trappers that captured our study animals reported they planned to sell the animals live to fox pens. Fox pens are large enclosures in which foxes (or coyotes) are pursued with hounds for sport. Based on this study, trapping may impact local southeastern coyote populations, particularly in states that tolerate the live sale of coyotes.

Variation in coyote home range size is evident across North America (Andelt and Gipson 1979, Gese et al. 1989, Gipson and Sealander 1972, Holzman et al. 1992) and is influenced by habitat composition (Gese et al. 1988). Based on this, coyote home ranges should be comparable within the same geographic region given similar habitats. Coyotes on SRS had larger home ranges than those reported for Mississippi (14.8 km^2, Chamberlain et al. 2000), Georgia (10.1 km^2, Holzman et al. 1992), and Florida (24.8 km^2, Thornton et al. 2004). Wooding (1984) and Sumner (1984) each reported home ranges of 27.0 km^2 and 33.4 km^2, respectively, for coyotes in Alabama and Mississippi. These two studies present home range sizes most similar to our findings, but they are based on sample sizes of 6 (Wooding 1984) and 7 (Sumner 1984) coyotes. Thornton et al. (2004) based their home range estimation on 7 coyotes. In addition to the possible bias associated with small sample size, there is difficulty in comparing home range sizes of coyotes among studies due to differences in sampling methods (Laundre and Keller 1984) and different home range estimators (Woodruff and Keller 1982). Based on our data, the inclusion or exclusion of transients, and the means at which transients are defined can also impact the average home range size of coyotes. If we include 2 animals that could be defined as transients, our results present the largest documented home ranges of coyotes in the Southeast. Exclusion of these two animals still produces home range estimates larger than those from Georgia and

Mississippi. Holzman et al. (1992) speculated that coyote home ranges may increase in size with an increasing proportion of forested habitat. Given the forested composition of the SRS, our data support this suggestion.

Holzman et al. (1992) and Chamberlain et al. (2000) reported larger home ranges for adult female coyotes than males. We detected no differences in home range size between the sexes. Our findings are in agreement with those of Laundre and Keller (1984) who standardized and compared the results of several studies and found no evidence of differential home range size between males and females.

Previous southeastern studies have found little overlap in home range and core areas between neighboring coyotes with the exception of mated pair interactions (Thornton et al. 2004, Chamberlain et al. 2000). However, our data suggests that there is wide variation in the amount of intraspecific overlap at both the home range and core area level. In fact, our data should be considered minimum overlap because non-collared coyotes were seen in the home ranges of marked animals. Camenzind (1978) proposed that 4 social organizational classes of coyotes existed on the National Elk Refuge in Jackson, WY ranging from single nomad coyotes to packs. Coyote social group size may be correlated with prey size (Bowen 1981). Coyotes on SRS do not often prey on large mammals (Schrecengost et al. In Review), so there is little need for pack formation. However, we believe a gradient of social organization exists in southeastern coyote populations evident by the wide range of home range overlap.

The broad geographic range of the coyote throughout North America is evidence of the coyote's ability to adapt and thrive in different habitats. However, within a suite of habitats coyotes may exhibit preference for certain types (Gese et al. 1988). Although habitats on the SRS are fragmented, coyotes consistently chose home ranges and core areas with higher proportions of early successional habitat than were available on the landscape. Coyotes have been shown to prefer habitats with high prey abundance (Litvaitis and Shaw 1980, Gese et al. 1988, Chamberlain et al. 2000) and coyotes in Georgia regularly used early successional habitats for nocturnal foraging areas (Holzman et al. 1992). The preference of early successional habitats on SRS is likely associated with coyote dietary dependence on soft mast species such as *Prunus* spp., *Rubus* spp., and *Phytolacca* sp. (Schrecengost et al. In Review). Holzman et al. (1992) proposed that coyotes may select mature pine stands due to availability of den sites, consistent with our data because mature pines ranked second in preference at the core area level.

This study presents further evidence of the variability associated with coyote spatial patterns and emphasizes the limitations of a single or few local studies for drawing conclusions about coyote behavior on a regional level. However, when combined with previous research, reasonable expectations can be formed pertaining to coyote populations throughout the southeastern United States. Coyotes on the Savannah River Site had larger home ranges with more intraspecific overlap than has been reported elsewhere in the southeastern United States. The high amount of overlap may indicate that the coyote population on the SRS is saturated and is functioning as a source population. Despite no exploitation of coyotes on the SRS, anthropogenic causes accounted for most mortality. Although we did not directly assess lethal control of coyotes, some conclusions can be drawn on its efficacy based on our data. The efficacy of lethal coyote control has been associated with the presence of transient individuals (Windberg and Knowlton 1988, Holzman et al. 1992). In south-central Georgia, Holzman et al. (1992) classified two of 17 coyotes as transients and suggested that local coyote control may be effective. Although we had a similar proportion of transients in our South Carolina sample, our findings suggest that the long-term effect of lethal coyote control would be limited, especially on small properties, due to large home range size and the high degree of home range overlap among resident coyotes.

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Table 3.1. Name, number of parameters (*K*), and description of AIC_c models used in estimation of coyote survival on the Savannah River Site, SC.

Model	*K*	Description
Constant	1	Overall survival with no effect of sex or time
Sex	2	Differential male and female survival
Seasonal, constant	6	Time grouped by 2 month seasons (Jan + Feb, Mar + Apr, etc)
Seasonal, year effect	10	Time grouped by 2 month seasons, but considers 2005 separately from 2006
Month	18	18 months considered individually
Sex X Month	36	18 months considered individually with differential male and female survival

Table 3.2. Habitat types of the Savannah River Site, SC used in compositional analysis and simplified rankings of habitat selections by coyotes from June 2005 - July 2006 based on Johnson's (1980) selection orders, higher numbers indicate selection.

			Rank	
Habitat	Area (ha)	Description	Second order	Third order
Water	1735	Open water, lakes, ponds, rivers	1	2
Young Pine	6218	Pine stands 5-15 years old	4	1
Middle Pine	10397	Pine stands 16-30 years old	5	3
Mature Pine	30109	Pine stands >30 years old	3	5
Hardwood	24342	Hardwood and mixed forests stands >15 years old	2	4
Early Successional	7539	Grass, brush, hardwood stands <10, pine stands <5	6	6

Table 3.3. Candidate models, number of parameters (*K*), Akaike's Information Criterion with the small-sample bias adjustment, Δ AICc, and Akaike weights for predicting coyote survival on the Savannah River Site, SC, April 2005-September 2006.

Model	*K*	AIC_c	Δ AIC_c	AIC_c Weights
Seasonal, constant	6	125.71	0.000	0.958
Seasonal, year effect	10	131.99	6.284	0.041
Constant	1	142.04	16.332	0.000
Sex	2	144.02	18.315	0.000
Month	18	144.54	18.827	0.000
Sex X Month	36	179.97	54.258	0.000

Table 3.4. Sex, number of radio locations (n), home range sizes, and percent overlap of home ranges and core areas of adult coyotes on the Savannah River Site, SC from June 2005-July 2006.

			95% Fixed Kernel				50% Fixed Kernel		
Sex	n	MCP (ha)	home range (ha)	overlap[a]	overlaps with[a]	mated pair overlap	core area (ha)	overlap	overlaps with
Female	83	876	1371	96.2%	1 M		333	69.7%	M
Female[c]	77	374	425	34.0%	2 F, 2 M	75.5%	62	92.9%	Male[c]
Female	76	520	811	21.1%	1 F, 3 M		179	1.7%	M
Female	91	1418	1419	17.0%	2 F,5 M		164	0.0%	none
Female[b]	92	5218	3198	5.9%	2 F, 2 M	78.6%	609	77.3%	Male[b]
Female[d]	58	1612	2167	0.0%	none	90.5%	461	88.0%	Male[d]
Female	58[e]	1598	2159	0.0%	none		515	0.0%	none
Female[g]	49	1147	1801				402		
Female[f]	51	13709	14793				3365		
Female[g]	45[e]	1266	2340				572		
Male	85	1346	2193	60.2%	1 F		652	35.6%	F
Male[c]	86	496	468	44.3%	1 F, 2 M	68.6%	71	81.0%	Female[c]
Male	95	758	1042	42.9%	1 F, 1 M		238	65.1%	M
Male	86	1191	1634	13.8%	4 F, 3 M		354	0.0%	none
Male	63	1296	2187	8.2%	3 F, 3 M		668	0.0%	none
Male	75	4577	5361	6.2%	2 F, 2 M		1172	13.2%, 0.3%	M, F
Male[d]	74	3120	2622	4.0%	2 M	74.8%	585	69.4%	Female[d]
Male[b]	57	8086	5118	3.6%	2 M	49.1%	1001	47.0%	Female[b]
Male	89	954	1502	1.4%	1 M		353	0.0%	none
Male[g]	31[e]	5865	9378				2196		
Male[f]	62	8207	10246				1608		
Male[g]	30[e]	690	1317				254		

[a] Excludes mated pair overlap.

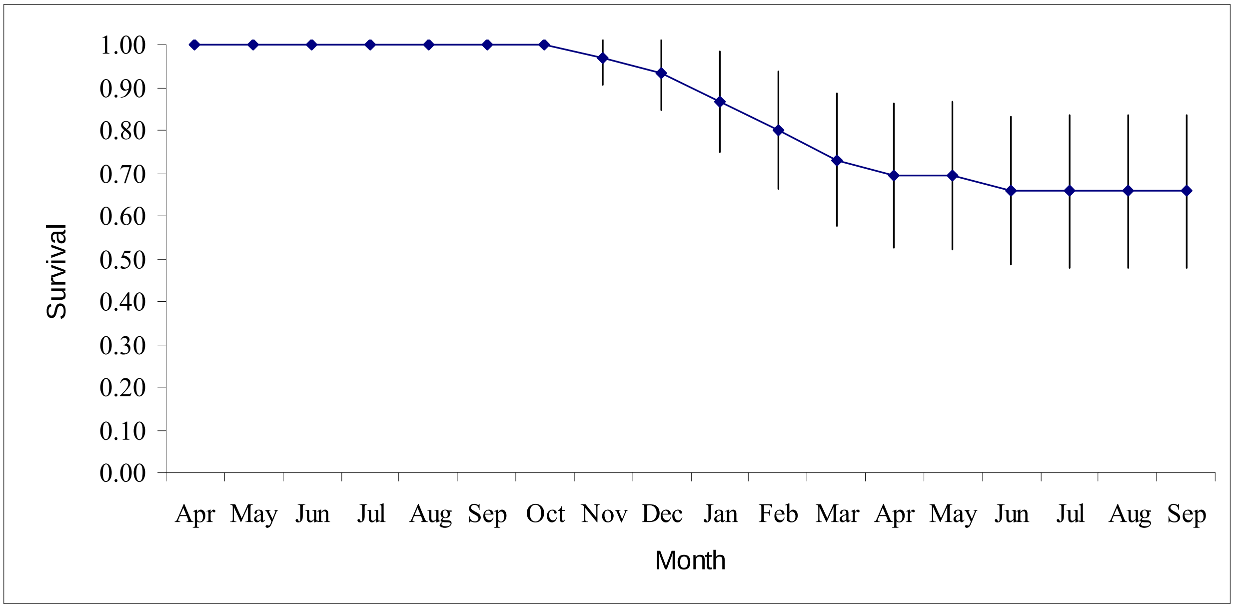
[b,c,d] Letters correspond with mated pairs.

[e] Bootstrap resampling indicates insufficient locations for 95% MCP.

[f] Transient excluded from overlap due to overlap with ≥10 individuals.

[g] Excluded from overlap due to mortality.

Figure 3.1. Survival of adult coyotes on the Savannah River Site, SC by month from April 2005 through September 2006.


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Survival
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month

CHAPTER 4

CONCLUSIONS

SUMMARY

Coyotes on the Savannah River Site consumed a wide variety of plant and animal food items that differed based on availability. Previous food habit studies have reported occurrence of many of the same food items as this study, but frequency and proportions differ. Most notably, many studies have reported small mammals and lagomorphs as the most common or most important food item in coyote diets (Blanton and Hill 1989, Hall 1979, Smith and Kennedy 1983, Thornton et al. 2004, Wilson 1967). Although both lagomorphs and small mammals occurred in the SRS coyote diet, they did not appear to be staple foods. Nearly all coyote diet studies report some occurrence of regionally available soft mast (Andelt et al. 1987, Murie 1951, Thornton et al. 2004). However, coyotes at the SRS appear more dependant on fruit than coyotes in other regions. In fact, seasonally available soft mast occurred in more scats that any other food item in 12 of the 15 months sampled. Occurrence of white-tailed deer in the diet of coyotes also seems to be linked to availability. Peaks in deer occurrence corresponded with fawn vulnerability and deer hunting season. Although there was considerable occurrence of deer in the scats of coyotes during late winter, we believe it unlikely that coyotes prey on adult deer in appreciable numbers. Coyotes probably make repeated visits to deer carrion in late winter due to decreased availability of alternative food sources, thus inflating the perceived number of deer occurring in scat. In addition, carrion lasts longer this time of year due to lower air temperatures and decreased invertebrate activity. White-tailed deer fawns were the most common mammalian food item during the months of May and June despite relatively low deer densities on the SRS (1/20 hectares). Previous research has suggested that coyote predation of fawns may be associated with deer density (Blanton and Hill 1989).

Coyotes on the SRS had larger home ranges than most reported in other regions of the Southeast. In fact, our data is likely best interpreted as minimum home range size due to low numbers of locations per animal. Although there is no evidence to suggest formation of packs, 87.5% of radio collared coyotes had home ranges that overlapped those of other radio collared coyotes. This number excludes interactions between suspected mated pairs and must be regarded as minimum overlap because non-collared coyotes were regularly observed within the home ranges of collared coyotes. Three pairs of coyotes that were routinely located together were assumed to be mated. Although many of the other coyotes with overlapping home ranges were located simultaneously, they were never perceived to be interacting. Coyotes selected home ranges and core areas with more early successional habitat than was available on the landscape. Annual survival for coyotes on the SRS was 66%. Although trapping and shooting did not occur within the boundaries of the SRS, these activities accounted for 60% of mortality.

MANAGEMENT IMPLICATIONS

Coyotes are a permanent addition to Southeastern ecosystems. Increasing harvest numbers in recent years suggest that the coyote population is growing (GADNR, SCDNR unpublished data). Based on food habit studies and evidence of coyote population increase, this novel predator has the potential to greatly impact prey populations. Because of economic and recreational interests, most land owners and managers are principally concerned with the coyote’s potential to influence white-tailed deer recruitment. Our data suggest that although coyotes prey on fawns in appreciable numbers, the coyote impact on deer recruitment may be buffered by early soft mast such as wild plums and blackberries. Land owners and managers can likely affect the impact of coyotes on white-tailed deer by manipulating habitats to produce buffering soft mast and harbor alternative prey species such as small mammals and lagomorphs. On areas with high deer densities, coyote predation may positively affect the environment by reducing browsing impact. On areas of low deer density, the degree of coyote predation must be considered to prevent over harvesting by hunters.

Previous research has suggested that local lethal control of coyotes may be effective in the Southeast (Holzman 1990). Although we concede that coyote ecology is highly variable, even on a regional level, our data suggests that the efficacy of lethal control may be limited. Due to the high degree of home range overlap and large home range size, local coyote control would be unlikely to have any long-term effect unless it is conducted on very large properties for extended periods of time. Coyotes are not actively trapped or hunted on the SRS. It is possible that this affects resident coyote behavior, even though shooting and trapping were the most common causes of mortality. However, fragmented land ownership throughout the southeastern United States likely results in areas of refuge for coyotes. This mosaic of areas of persecution and sanctuary is likely to further confound any efforts of lethal coyote control. If coyote impact on game populations, particularly white-tailed deer, is judged to be detrimental, intensive coyote removal just prior to the fawning period may temporarily reduce fawn depredation. Lethal control of coyotes requires further study to understand its impact on both coyote and prey populations.

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APPENDICIES

APPENDIX A

COYOTE VOCALIZATION SURVEYS ON THE SAVANNAH RIVER SITE, SC

INTRODUCTION

Since the coyote was first documented on the Savannah River Site in 1986 (Mayer et al. 2005), sightings have increased in frequency, suggesting that the population is growing. However, there has been no formal population monitoring and no information on coyote density or abundance exists for SRS. We chose to use elicited vocalizations surveys to establish a baseline index of coyote abundance and to estimate coyote density.

Use of an artificially produced howl to elicit a howling response from coyotes was first reported by Alcorn (1946). Elicited coyote howling surveys have been used as a census technique in western and northern states, but has seen limited use in the Southeast. The technique has been used in Tennessee and Kentucky (Sharp 1981), as well as Arkansas, Mississippi, and Alabama (Blanton 1988). Primarily, howling surveys are useful as an index of abundance (Wenger and Cringan 1978), but with careful site-specific considerations this technique can produce an estimate of coyote density (Blanton 1988).

Previous studies have found coyotes may become habituated to sirens and fail to respond after repeated exposure (Wenger and Cringan 1978). In addition, temporal variation in howling behavior affects coyote response rate (Laundre 1981). Although these factors may influence the results of vocalization surveys, their effect can be controlled through proper design. We believe this is the best available method for monitoring coyote abundance on SRS because of the repeatability of survey methods and the minimal equipment and maintenance needs.

METHODS

We first tested elicited howling methods on SRS during December of 2005 using a standard wail siren. Twelve trials, each on a different collared coyote, only elicited 2 responses. We felt this would result in too large a correction factor for use in estimating the population.

Therefore we attempted to elicit howling responses with a recorded coyote howl. This stimulus sound was more efficient and elicited 5 vocal responses during 15 attempts during December and 12 responses during 23 attempts during January and February.

Survey Protocol

Vocalization (howling) surveys were conducted between one half hour after sunset and midnight, from 1 January through 28 February 2006. Surveys were only conducted on nights with no precipitation and wind speeds <16 km/h (Okoniewski and Chambers 1984, Wenger and Cringan 1978). We used a Johnny Stewart Game Calls call box and a coyote group yip-howl recording to elicit coyote vocal response. Forty-five listening sites (LS) were established along secondary roads at a minimum of 3.2 km intervals throughout SRS. These LS's were grouped as three survey routes with 15 LS's each. Each survey route was run no more than once per week to minimize coyote acclimation to the recorded howls.

Two persons were present to conduct each survey. One person acted as the call box operator while the other was the observer and listened for any coyote response. Upon arrival at the LS, the speaker was placed on the roof of the vehicle, facing upward. The call box operator and observer both put on hearing protection. The call box operator played the recorded howl for twenty seconds. At the conclusion of the 20 second play period, a two minute listening period ensued. During this time, the observer recorded the direction, approximate distance, number of coyotes in any group, and type of any coyote vocalization heard. The call box operator again played the recorded howl for 20 seconds, followed by a second two minute listening period. At the conclusion, the call box operator and the observer agreed upon the number and direction of all coyote howls observed. When all data was recorded, the team moved to the next LS and repeated the process.

Determining Response Rate

In order to establish response rate, coyotes were located by radio telemetry and their locations plotted using LOAS 3.02 (Ecological Software Solutions, Inc., Sacramento, CA). Upon location of a coyote, a recorded group howl was played using the howling survey methods listed above. We assumed any response from the direction and distance of the radio location was from the telemetered coyote. We repeated this process on multiple coyotes on multiple nights prior to conducting howling surveys. In addition, during the course of the surveys, any radio collared coyote in the proximity of a listening station was monitored for response. Average response rate was established from these attempts.

Determination of Area Sampled

All observers were subjected to a coyote howl hearing test. This test took place under the same conditions as the vocalization surveys. Several locations were selected throughout SRS in which common habitat types were well represented. Following the condition protocol of the vocalization surveys we tested the detectability of a recorded coyote howl at varying distances. We played a recorded coyote howl through a Johnny Stewart call box with the volume set at 100 decibels as determined by a decibel meter to approximate the intensity of an actual coyote howl (H. Scott Ray, personal communication). We positioned observers at a pre-determined location while another individual moved around their location and played the recorded howl at varying distances. We recorded the location of the call box and the location of the observers via GPS and measured the distance of separation. These distances were used to estimate the area sampled at each listening station during howling surveys.

Density Estimate

The total number of responses during each survey was used to establish a baseline index of abundance for coyotes on SRS. The number of coyotes along the route was estimated by correcting the number of responses using the pre-determined response rate. Density was estimated by dividing by the total area surveyed, as determined by the detection distance.

RESULTS

In total we conducted 230 playback events at 45 listening stations and elicited vocal responses from 277 coyotes. Data from these playback events is presented in table A.1. The average number of coyotes responding per listening station was 1.204. This number should serve for a baseline index of coyote abundance on SRS.

Dividing the average coyotes/listening station by the response rate during January and February (0.522) gives us a reasonable estimate of the number of coyotes at each listening station. However, in order to estimate the coyote population on SRS we need a reasonable estimate of the area sampled at each listening station. We calculated this with several distances based on the results of detection distance testing (Figure A.1). The maximum distance at which all observers always detected the coyote howl was 708 meters. This number was used to calculate the number of coyotes per unit area, then expanded to estimate the number of coyotes on the 80,000 ha SRS. Using 708 meters as a detection distance results in a coyote population estimate for the SRS of 1177. However, on most occasions all observers detected the howl at further distances, meaning that we usually were sampling a larger radius than 708 meters. Using the maximum distance (1621 meters) at which the coyote howl was ever detected results in an similarly biased population estimate of 224 coyotes. We also calculated a population estimate using 1000 meters for a detection distance which resulted in a population of 590 coyotes on the

SRS. We believe this is the most reasonable estimate of the coyote population size. However, more reliable estimates can likely be reached using distance sampling techniques that account for decreasing detectability with increasing distance from the observer.

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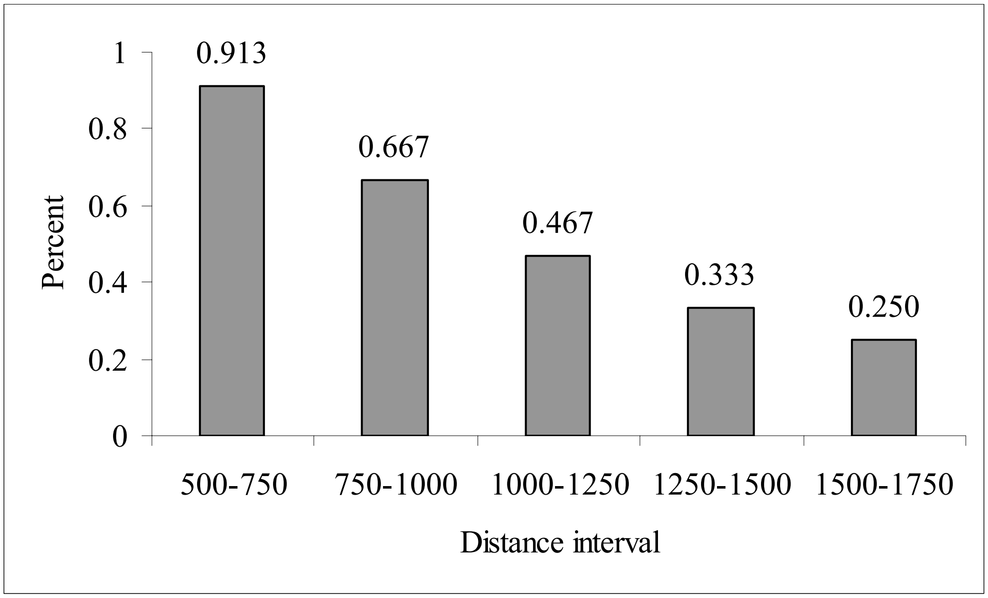
Table A.1. Results of coyote howling surveys on the Savannah River Site during January and February 2006. Includes date of survey for each route, number of coyotes responding at each station, and total coyotes responding on each route.

	Survey Route 1						Survey Route 2							Survey Route 3				
Station #	9-Jan	26-Jan	1-Feb	9-Feb	21-Feb	Station #	5-Jan	19-Jan	31-Jan	8-Feb	15-Feb	23-Feb	Station #	3-Jan	12-Jan	27-Jan	3-Feb	13-Feb
1	2	1	1	4	0	16	0	0	0	0		0	31	2	3	0	0	0
2	2	0	2	0	0	17	2	0	4	2		0	32	0	0	2	0	0
3	0	0	0	0	0	18	2	censored due to traffic noise					33	0	3	0	2	2
4	5	3	3	4	0	19	0	0	0	0		0	34	0	0	6	4	1
5	0	0	2	1	0	20	2	0	0	0		0	35	0	4	0	2	1
6	0	0	0	0	0	21	1	2	0	7		3	36	2	0	1	0	0
7	0	0	5	0	1	22	0	2	0	0		2	37	0	0	0	0	2
8	3	0	6	9	4	23	0	0	0	3		0	38	0	0	0	0	1
9	2	0	9	12	7	24	0	0	0	0	0	0	39	0	3	0	0	0
10	0	10	4	3	2	25	0	0	1	2	2	1	40	1	0	0	0	0
11	0	0	3	3	0	26	5	0	0	2	0	0	41	0	0	0	0	2
12	5	0	2	0	8	27	1	0	1	1	1	0	42	0	1	0	2	0
13	0	0	1	4	6	28	0	0	5	3	0	0	43	0	0	0	3	3
14	2	0	0	0	2	29	0	0	3	0		1	44	0	0	0	2	0
15	0	0	0	2	0	30	0	0	4	1		0	45	4	2	2	3	0
Total	21	14	38	42	30		13	4	18	21	3	7		9	16	11	18	12

Figure A.1. Percent of recorded coyote howls detected by human observers at varying distance intervals on the Savannah River Site, SC during winter of 2006.


1
0.8
0.6
0.4
0.2
0
Percent
0.913
0.667
0.467
0.333
0.250
500-750
750-1000
1000-1250
1250-1500
1500-1750
Distance interval

APPENDIX B

COYOTE CAPTURE DATA

Table B.1. Biological data collected from captured coyotes on the Savannah River Site, SC from May-October 2005.

Sex	Weight (kg)	Total Length (cm)	Tail Length (cm)	Standing Height (cm)	Hind foot length (cm)	Ear Length (cm)	Girth (cm)	Lactation (Y/N)	Neck Girth
Male	9.98	116.0	31.0	53.0	17.0	10.0	43.0		28.5
Male	10.49	118.0	41.0	55.0	19.0	12.0	43.5		28.5
Male	10.89	119.0	31.0	54.5	17.5	11.0	45.0		28.0
Male	10.95	128.5	39.0	57.0	20.6	11.0	45.5		
Male	12.65	121.0	31.0	57.0	18.0	10.5	49.0		
Male	12.70	120.5	39.3	56.0	19.5	10.8	47.0		
Male	12.70	137.0	35.0	57.0	19.0	11.0	47.0		
Male	12.85	123.5	38.5	51.0	21.3	11.2	50.0		
Male	13.02	125.0	42.0	60.0	20.5	10.5	50.0		32.0
Male	13.16	128.8	41.5	47.3	20.0	10.5	51.0		
Male	13.75	130.0	38.0	57.0	20.0	11.0	48.0		30.0
Male	13.81	128.0	41.0	58.0	20.0	11.0	51.0		30.0
Male	14.07	121.0	37.0	54.5	21.0	11.3	47.5		
Male	14.66		42.5	58.5	20.9	12.0	53.0		
Male	14.97	138.0	37.0	60.0	19.5	10.5	51.0		30.5
Male	15.31	127.0	34.0	57.0	20.5	11.5	53.0		
Male	15.45	137.0	38.0	56.0	19.0	11.4	53.0		29.0
Male	16.79	138.0	38.0	60.0	19.5	11.0	53.0		32.0
Male	18.80	137.0	37.0	61.0	22.0	12.0	54.0		34.0
Female	7.26	109.0	32.0	47.0	17.5	10.0	38.0	N	23.0
Female	8.96	112.0	29.0	51.0	16.5	9.5	40.0	N	25.0
Female	10.52	117.0	33.0	57.0	18.5	10.5	44.0	N	26.0
Female	10.89	111.0	33.0	46.0	18.5	11.5	47.0	Y	
Female	11.26	121.0	36.0	59.0	18.5	10.0	46.0	N	28.5
Female	11.34	119.0	32.0	56.0	18.0	10.0	44.5	N	26.0
Female	11.48	117.0	41.0	55.0	18.5	11.4	46.0	filling	
Female	11.48	117.0	28.0	52.0	18.0	12.0	50.0	N	
Female	11.88	124.0	42.5	55.5	19.0	10.8	47.5	Y	
Female	12.73	122.0	31.0	58.0	19.5	10.5	49.5	Y	30.0
Female	13.16	127.0	35.0	57.0	19.0	10.5	47.0	N	
Female	13.33	122.0	36.0	57.0	20.0	10.5	53.5	Y	
Female	14.07	125.0	32.5	59.0	18.5	10.0	49.0	N	28.5
Female	14.97	124.0	40.6	56.7	20.0	10.6	50.0	N	30.0