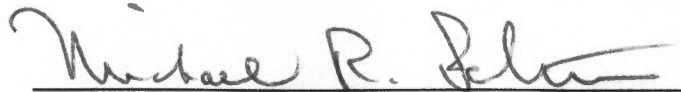
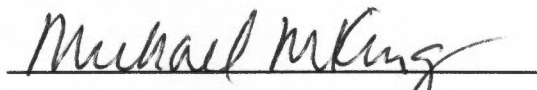
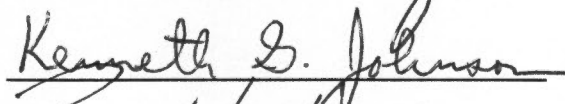
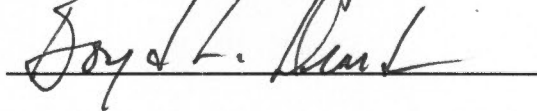


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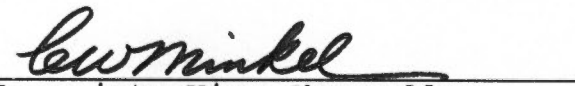
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COYOTES IN GREAT SMOKY MOUNTAINS NATIONAL PARK:
EVALUATION OF METHODS TO MONITOR RELATIVE ABUNDANCE,
MOVEMENT ECOLOGY, AND HABITAT USE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Barron Allen Crawford

August 1992

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Funding for this project was provided by the U. S. Fish and Wildlife Service, Red Wolf Recovery Program through the Great Smoky Mountains National Park.

ABSTRACT

Scent stations, passive hair-snaggers and howl surveys were evaluated as possible survey methods for monitoring relative abundance of coyotes (Canis latrans) in Great Smoky Mountains National Park (GSMNP) from January 1990 to April 1991. Scent stations (n = 198), passive hair-snaggers (n = 70), and howl surveys (n = 197) produced one (0.5%), zero (0.0%), and 35 (17.8%) coyote responses, respectively. Scent stations and hair-snaggers proved ineffective for monitoring coyotes at current population levels. Howl surveys elicited responses from approximately 21 coyotes at 12 locations indicating the feasibility of designing and implementing a standardized survey to monitor the relative abundance of coyotes over time or from area to area. Howl surveys indicated that Cades Cove has about twice the density of coyotes as other areas surveyed in GSMNP. Preliminary estimates from three indices of relative abundance ranged from 1 coyote/12.9 km² to 1 coyote/39.7 km². Wildlife managers and researchers must accept a wide margin of error if surveys of relative abundance are used for coyotes and other wide ranging carnivores in the southern Appalachians.

Six coyotes were captured, radio-collared and monitored by radio telemetry in GSMNP from March 1990 to March 1991 to determine seasonal and composite movement ecology.

A year of movement data was collected for 3 subadult male coyotes. Average annual home range for coyotes ($n = 3$) with more than 100 locations was 122.9 km^2 (range 25.4 km^2 to 230 km^2) using the modified minimum area polygon method of analysis. Largest seasonal movements (56.1 km^2 and 152.44 km^2) were during the pup rearing season. However, these two yearling males were unmated and probably ranged more than mated males during this season. Greatest dispersal distance recorded was 46.7 km and greatest recorded distance moved in 24 hours was 33.5 km .

A chi-square test indicated that two coyotes apparently more frequently selected open areas, mixed hardwood, oak/pine, and pine cover types when active. However, one coyote did not appear to select one cover type when active or inactive. Most coyote locations were in pine (38.9%), xeric oak (24.5%), and treeless (16.1%) areas. Chi-square tests indicated that no seasonal preference was detected for two coyotes. However, one coyote apparently more frequently selected mixed hardwood cover type during the breeding season and oak/pine and pine forest types during the gestation period. Coyotes 2 and 3 were active and located more times than expected in flat areas and resting on

northern, southern, and western aspects. Coyote 4 used all aspects equally when active and inactive. A high percentage of locations (95%, 89%, and 83%) for coyotes 2, 3 and 4, respectively, were below 700 m. The high percentages of locations in lower elevations may be attributed to the cove landscapes surrounding GSMNP and the selection of these coves by coyotes 2 and 4 outside of GSMNP.

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PART I

INTRODUCTION

In North America, coyotes (Canis latrans) are the most primitive members of the genus Canis and are believed to have evolved from the ancestral coyote (C. leophagus) (Nowak 1978). During the late Pleistocene period, coyotes were found throughout North America. However, until the 1900's the range of modern coyotes only extended as far east as Wisconsin and south to central Texas (Nowak 1978). It appears that wolf populations were the major factor limiting coyotes in Eastern North America (Nowak 1978, Parker 1988).

Coyotes are adaptable carnivores that have survived human persecution and expanded their range while other carnivores have diminished. The extermination of wolves and disruption of the environment enabled coyotes to expand into Eastern North America. Logging and farming, which have created open pastures, and along with large poultry farms have created ideal habitat for coyotes in the Southeast (Korschgen 1957, Gipson 1974, Hill et al. 1987). Today, coyotes have been reported in all of the continental United States (Gipson 1978).

Concerns about depredation and impacts on game animals by coyotes in the Western United States resulted in numerous long term studies (Bekoff 1982, Linhart and Knowlton 1975, Nellis and Keith 1976, Roughton and Sweeny 1982). These

same concerns dictate a need for coyote studies in the Southeast where coyotes are a newcomer to a variety of habitats. To date studies of coyote biology and ecology have been conducted in west Tennessee, Mississippi, and Alabama (Babb and Kennedy 1989, Blanton 1988, Gipson 1978, Hill et al. 1987, Sumner et al. 1984). However, no coyote studies have been conducted in east Tennessee.

Great Smoky Mountains National Park (GSMNP) offered the opportunity to study the colonization of coyotes in east Tennessee where they were relatively free from human persecution. The objectives of this study were to provide base line information about methods for monitoring relative abundance, movement patterns, and habitat use of coyotes in GSMNP. Methods to monitor relative abundance are needed to evaluate trends in coyote abundance for future red wolf (C. rufus) releases in GSMNP. Movement patterns and habitat use by coyotes may provide useful information about how red wolves might respond to the same habitats and reveal similarities or differences in natural history and ecology of the two species.

The body of this thesis was written as two separate papers. These papers were written in style appropriate for the Proceedings of the Southeastern Association of Fish and Wildlife Agencies and will be submitted for publication.

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PART II

EVALUATION OF TECHNIQUES TO MONITOR RELATIVE ABUNDANCE OF COYOTES IN GREAT SMOKY MOUNTAINS NATIONAL PARK

ABSTRACT

Scent stations, passive hair-snaggers and howl surveys were evaluated as possible survey methods for monitoring relative abundance of coyotes (Canis latrans) in Great Smoky Mountains National Park (GSMNP) from January 1990 to April 1991. Scent stations (n = 198), passive hair-snaggers (n = 70), and howl surveys (n = 197) produced one (0.5%), zero (0.0%), and 35 (17.8%) coyote responses, respectively. Scent stations and hair-snaggers proved ineffective for monitoring coyotes at current population levels. Howl surveys elicited responses from approximately 21 coyotes at 12 locations indicating the feasibility of designing and implementing a standardized survey to monitor the relative abundance of coyotes over time or from area to area. Responses were elicited from coyotes at 14 station soundings (14/197 x 100%) for a response index of 7.1%; domestic dogs (C. familiaris) responded at 12 station soundings (12/197 x 100%) for a response index of 6.1%. Responses were elicited from 27 coyotes in Cades Cove for a coyote index (27/118 x 100%) of 22.9% and 8 coyotes outside Cades Cove for a coyote index (8/79 x 100%) of 10.1%. Howl surveys indicated that

Cades Cove has about twice the relative abundance of coyotes as other areas surveyed in GSMNP. Preliminary estimates from three indices of relative abundance ranged from 1 coyote/12.9 km² to 1 coyote/39.7 km². Wildlife managers and researchers must accept a wide margin of error if surveys of relative abundance are used for coyotes and other wide ranging carnivores in the southern Appalachians.

INTRODUCTION

Concerns about depredation by coyotes (Canis latrans) in the Western United States have resulted in numerous publications of long term studies (Bekoff 1982, Linhart and Knowlton 1975, Roughton and Sweeny 1982). Coyotes have expanded their range into eastern North America because of human induced manipulation of habitats and extermination of gray wolves (C. lupus) and red wolves (C. rufus) (Gipson 1978, Nowak 1978, Parker 1988). Logging and farming, which have created open pastures, and along with large poultry farms have created ideal habitat for coyotes in the Southeast (Korschgen 1957, Gipson 1974, Hill et al. 1987). Coyotes moved into the Southeast in the last 30 years (Gipson 1978, Kennedy et al. 1986) and Great Smoky Mountains National Park (GSMNP) in 1985 (Delozier per. comm. 1990).

Concerns about potential coyote problems in the Southeast dictate a need for determining relative abundance or trends in coyote populations. Determining the current status of coyotes in GSMNP may help clarify if future red wolf reintroductions are successful and whether red wolves displace resident coyotes from their home ranges.

Methods developed for estimating carnivore populations are crude and often produce estimates with broad confidence intervals (Pelton and Marcum 1975). The problems associated with censusing most carnivores are compounded with coyotes in the Southeast due to low population densities (Linhart and Knowlton 1975, Sharp 1981). Linhart and Knowlton (1975) grouped canid survey methods into five categories: (1) direct counts or mark and recapture, (2) counts of dens, tracks or scats, (3) questionnaires and bounties, (4) catch per unit effort, and (5) elicited responses. Due to limited resources and the inability to thoroughly sample large areas, direct counts are impossible in GSMNP. An index of relative abundance often is the only alternative. However, indices are subject to the same limitations as direct counts such as nonrandom distributions, varying seasonal movements and behavioral patterns, and the influence of topography and habitat (Linhart and Knowlton 1975). The researcher must accept these limitations and select a method unbiased by these variables and expect some variation in coyote responses (Linhart and Knowlton 1975).

Linhart and Knowlton (1975) suggested elicited responses, particularly scent stations and howl surveys, as having the greatest potential for development of a reliable index. Scent station surveys have been used on numerous furbearer populations throughout the United States (Linhart and Knowlton 1975, Johnson and Pelton 1981, Morrison et al. 1981, Nottingham et al. 1989, Roughton and Sweeny 1982, Wood 1959). The siren elicited howl survey, first described by Alcorn (1946), has been limited to surveying canids (McCarley and Carley 1979, Pyrah 1984, Okoniewski and Chambers 1984, Russell and Shaw 1971, Sharp 1981, Wenger and Cringan 1978). Both of these methods have certain advantages and disadvantages. The advantages of scent stations are (1) easy to standardize, and (2) not biased by trap shy animals. The disadvantages of scent stations are (1) inclement weather washing away stations, (2) other species masking earlier visits, (3) and labor intensive in certain areas. The advantages of the howl survey method are (1) less labor intensive, (2) not influenced by inclement weather, and (3) responses not influenced by other carnivores responding to stimulus. However, human howling is difficult to standardize among researchers.

The objectives of this study were to evaluate techniques to determine relative abundance of coyotes in GSMNP and test for differences in response rates among survey techniques for coyotes in GSMNP.

STUDY AREA AND METHODS

This study was conducted in the western portion of Great Smoky Mountains National Park (GSMNP) in eastern Tennessee between January 1990 and March 1991. The topography is steep and elevations range from 266 to 2024 m. Mean annual precipitation ranges from 127 to 152 cm per year in low elevations to 230 cm per year above 1829 m (Shanks 1954). The wettest seasons are in late winter-early spring and July with September and October the driest (Stephens 1969).

GSMNP offers a diversity of plants which may be attributed to changes in climate due to elevational changes. King and Stupka (1950) identified approximately 1,300 species of flowering plants and over 2,400 nonflowering plants. Within the study area is Cades Cove, a valley with 748 ha of fescue pastures for cattle and horse grazing and 230 ha of woodlots.

In contrast to the floral diversity, GSMNP does not support a rich variety of mammals. Linzey and Linzey (1971) list 59 species of mammals found in GSMNP and six species are probably extirpated. This list does not include coyotes which migrated into GSMNP around 1985.

Park records containing the locations of reported coyote sightings from 1989 ($n = 7$) were reviewed before initiating field work. These areas were checked for current coyote activity by walking the areas and noting fresh sign (ie. tracks, scats and hair snagged in fences). Seven areas, which covered a linear total of 54 km, were hiked and activity was found only in Cades Cove.

Scent stations were operated to assess the possibility of determining the relative abundance and activity of coyotes in the study area. Scent stations were operated following the procedures suggested by Linhart and Knowlton (1975) and Roughton and Sweeny (1982); these authors suggested spacing stations at 0.2 to 0.3 km intervals. To avoid possible interference from visitors and livestock, scent stations were randomly placed in likely coyote travel corridors and spaced to avoid high visitor use areas. The above resulted in stations spaced at approximately 0.5 km intervals in Cades Cove. Scent stations were placed along the road or trail edge approximately 0.5 to 1.5 km apart outside of Cades Cove depending on the topography, slope, and trail condition. All scent stations were operated for one night to minimize the effects of inclement weather.

Scent stations consisted of a one meter diameter circle of sifted soil or lime. Lime was only used for one route in Cades Cove due to problems identifying tracks. Attractants used included a long distance lure (Russ Carmans Canine Call), coyote urine, sardine oil, and artificial raspberry. Attractants were randomly chosen until each had been used then the procedure was repeated until completion of the route. All attractants were saturated into a plaster disk approximately 2.5 cm³ and placed in the center of the substrate. The plaster disk was cheap to prepare, easy to handle in the field, and provided a way to deliver a consistent amount of attractant. Also, the disk probably served as a visual attractant.

Scent stations were checked the following morning and tracks were identified with A Field Guide to Animal Tracks (Murie 1974). Data recorded included scent station route, number of stations, weather conditions in the past 24 hours, date stations were established and checked, location of station, scent used, and species visiting.

A total of 198 scent stations were established throughout the western portion of GSMNP (Figure II-1). Scent stations (n = 58) were established from 23 January 1990 to 20 February 1990 in Cades Cove, Forge Creek Road, Parsons Branch Road, Turkey Pen Ridge Trail, and Schoolhouse Gap Trail. Also, from 13 June 1990 to 6 July 1990, scent stations (n = 52) were operated on Anthony Creek Trail, Lead

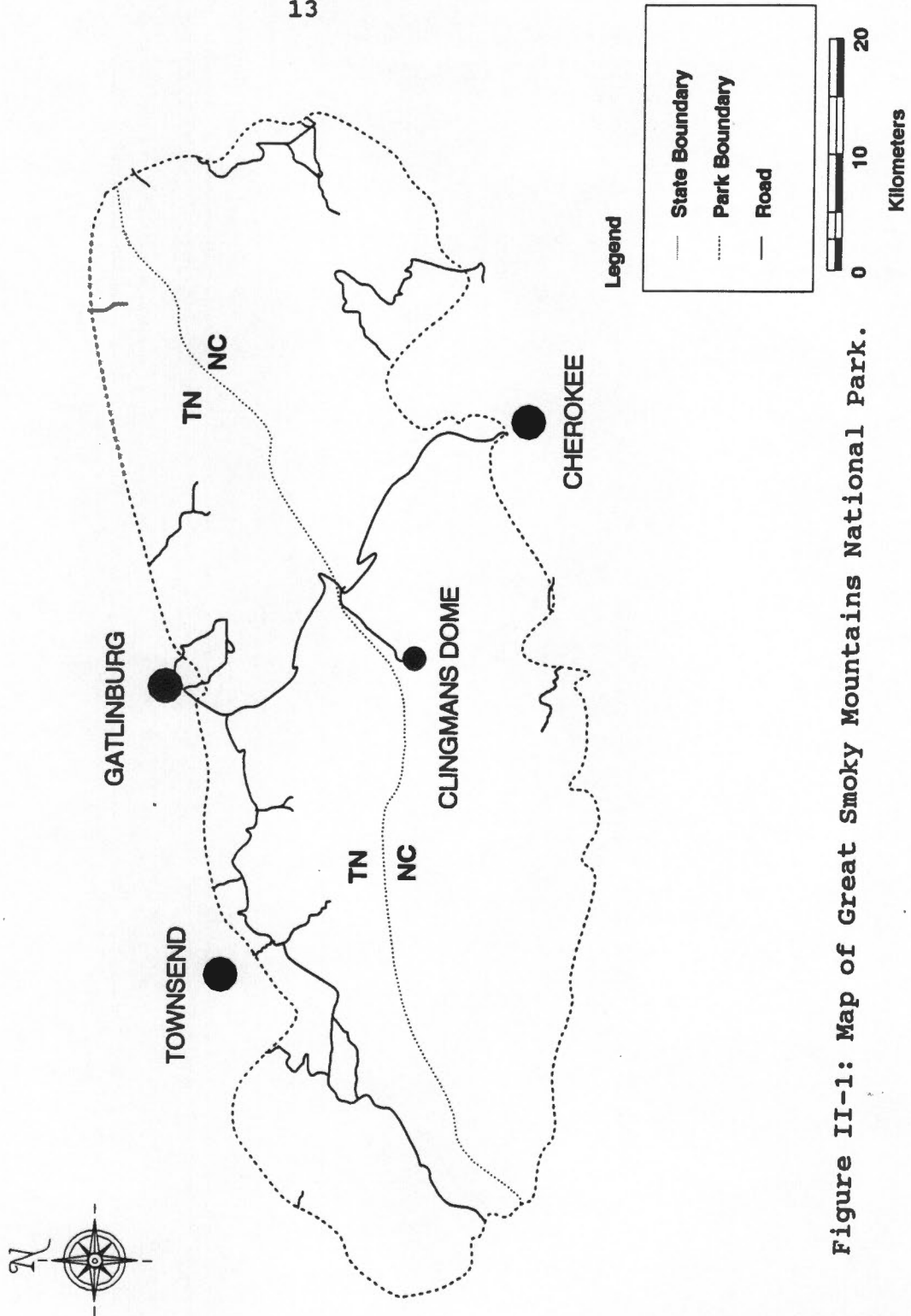


Figure II-1: Map of Great Smoky Mountains National Park.

Cove Trail, Bote Mountain Road, Meigs Creek Trail, Meigs Mountain Trail, Curry Mountain Trail, Sugarlands Mountain Trail, and Hannah Mountain Trail to Gregory Bald. From 04 August 1990 to 25 August 1990, all scent station routes were repeated. This effort covered approximately 278.0 km of roads and trails. Of the 198 scent stations, Russ Carmans Canine Call and coyote urine were the scents used at 66 stations each, sardine oil was used at 37 stations, and artificial raspberry was used at 29 stations. Sardine oil was used as a possible attractant due to the lack of success with lure and urine. Artificial raspberry was used from June to August, when berry crops were present.

In conjunction with scent stations, passive hair-snaggers ($n = 70$) were placed approximately 30 cm off the ground approximately every kilometer along well traveled game trails. Hair-snaggers were placed approximately 50 m from main trails. Hair-snaggers consisted of 12 gauge barbed wire cut into appropriate lengths to reach across the game trail. Hair-snaggers were left in place for five nights then collected and examined. From 13 June 1990 to 23 June 1990, 7 hair-snaggers were placed along Bote Mountain Trail and Meigs Mountain Trail for 5 days each.

Also, howling surveys were conducted to assess the possibility of determining the relative abundance and presence of coyotes in the western portion of GSMNP. Howling surveys were conducted following the procedures

suggested by Wenger and Cringan (1978), Sharp (1981), and Okoniewski and Chambers (1984). Sharp (1981) spaced eight to fourteen stations 1.6 to 2.4 km apart depending on topography, and proximity to moving water. Wenger and Cringan (1978) and Okoniewski and Chambers (1984) drove from 0.2 km to 4.8 km away from collared coyotes to determine distance coyote response was audible. In GSMNP howling surveys were conducted during mostly clear nights and winds less than 15 km/hour. Surveys started one hour after sunset and were completed two to four hours later. Approximately 15 minutes elapsed between station soundings (Okoniewski and Chambers 1984, Sharp 1981, Wenger and Cringan 1978).

Howling stations were located from 1.6 to 4.8 km apart depending on topography, vegetation, and distance from moving water. The same stations were used for each survey. The amount of area covered by each station sounding was determined by how far a response from coyotes could be heard. The average distance a response could be heard in Cades Cove was 3.0 km and approximately 1.6 km outside Cades Cove. Stimuli used were a Smith and Wesson Mark IV siren and human howling.

The siren was mounted on top of the vehicle and directed vertically for omni directional travel of sound. The siren was sounded for two complete cycles, approximately 20 seconds, followed by a two minute listening period. The siren was sounded again for two cycles followed

by a one minute listening period. Operators wore ear protection; this was removed immediately after each sounding.

Human howls were used to test responses from coyotes. Five to six seconds of human howls followed by two barks and five to six seconds of more howls were used per station. A two minute listening period followed the howling. The procedure was repeated followed by a one minute listening period.

At each survey, the date, route, station number or location, time, type of stimulus, type of canid responding, number, estimated distance and azimuth were recorded. Before each survey, the weather conditions and moon phase were noted. Also, radio-collared coyotes were located to determine if the collared animals responded.

If the exact number of animals responding could not be determined, a conservative figure was recorded. Prior to conducting the surveys, taped coyote, domestic dog, and red wolf vocalizations recorded by John Carley (U. S. Fish and Wildlife Service) were reviewed both indoors and outdoors at various distances. Surveys were limited to less than two surveys a month to minimize habituation of coyotes.

Howling surveys were conducted from 5 March 1990 to 14 April 1991 along six routes. Survey routes included Cades Cove, Clingmans Dome Road, Foothills Parkway, Parsons Branch Road, Rich Mountain Road, and Roaring Fork Motor trail.

A total of 197 stations, covering 364.0 km of roads, were surveyed.

Response indices and coyote indices were calculated for Cades Cove and outside of Cades Cove to compare the two areas using the following formulas:

$$\text{Response Index} = \frac{\text{Number of stations with response}}{\text{total number of stations}}$$

$$\text{Coyote Index} = \frac{\text{Number of coyotes responding}}{\text{total number of stations}}$$

Indices of relative abundance were calculated for GSMNP using two formula's used by Sharp (1981).

$$\text{Sharp Index 1} = \frac{\text{Number of coyote responses} \times (2)}{\text{estimated area surveyed}}$$

$$\text{Sharp Index 2} = \frac{\text{Est. \# coyotes responding} \times (2)}{\text{estimated area surveyed}}$$

An alternative index (Index 3) was determined based on the estimated known minimum number of coyotes in a known area surveyed to calculate a density estimate for potential calibration for GSMNP.

$$\text{Index 3} = \frac{\text{Minimum known \# coyotes to respond}}{\text{estimated area surveyed}}$$

Surveys in which no responses were elicited were eliminated. This index does not use a correction factor for coyotes that may not have responded therefore, reducing the amount of possible error. This index can be standardized for Cades Cove and then compared to number of responses/km² outside of Cades Cove.

Because Cades Cove is a valley with one road making a loop along the base of the valley, all survey stations overlapped considerably. This produced a large denominator (estimated area surveyed) in the indices for Cades Cove and reduced density estimates. Therefore, approximate area surveyed was determined by eliminating the overlap between stations.

Statistical analyses were performed using the Statistical Analysis System (SAS Institute Inc. 1985). Chi-square tests for independence were performed to test differences in response rates for coyotes to sirens and human howls and responses to human howls in Cades Cove and outside Cades Cove.

RESULTS AND DISCUSSION

Only one coyote visit was recorded in 198 scent station nights. Other species included 36 (18.2%) black bears (Ursus americanus), 24 (12.1%) white-tailed deer (Odocoileus virginianus), 10 (5.1%) raccoons (Procyon lotor), 9 (4.5%) bobcats (Lynx rufus), and 6 (3.0%) domestic dogs (Table II-1). Scent stations appear to have limited potential as an index for coyotes in GSMNP.

Possible explanations for the low coyote response rates to scent are: (1) Low density of coyotes in GSMNP; (2) Early coyote visits were masked by other species; (3) Poor weather

Table II-1: Mammals recorded visiting scent stations in GSMNP
from January 1990 to August 1990.

<u>Species Recorded</u>	<u>Number (%)</u>	<u>Visits</u>
Black bear	(<u>Ursus americanus</u>)	36 (18.2)
White-tailed deer	(<u>Odocoileus virginianus</u>)	24 (12.1)
Raccoon	(<u>Procyon lotor</u>)	10 (5.1)
Bobcat	(<u>Lynx rufus</u>)	9 (4.5)
Dog	(<u>Canis familiaris</u>)	6 (3.0)
Red fox	(<u>Vulpes vulpes</u>)	3 (1.5)
Wild boar	(<u>Sus scrofa</u>)	3 (1.5)
Skunk	(<u>Mephitis spp.</u>)	2 (1.0)
Gray fox	(<u>Urocyon cinereoargenteus</u>)	2 (1.0)
Cottontail rabbit	(<u>Sylvilagus floridanus</u>)	1 (0.5)
Coyote	(<u>Canis latrans</u>)	1 (0.5)
Unknown		24 (12.1)

conditions washed out responses; (4) High human and horse traffic on trails; and (5) Scents used for stations were also used for trapping. Andelt et al. (1985) noticed coyotes that were trapped were less likely to respond to scent stations than nontrapped coyotes. Andelt et al. (1985) believed that trapping caused a negative experience thus decreasing response rates.

Only hair samples from black bears ($n = 10$) were collected on the hair-snaggers. Due to the lack of human resources, time constraints and no success, this method was abandoned after two trails.

Thirty-five howl responses (17.8%) were recorded from approximately 21 coyotes at 12 different stations and a total of 20 (10.2%) responses were elicited from domestic dogs at eight different stations (Table II-2). Radio-collared coyotes were close enough to respond to the stimulus during 15 of 23 surveys. Six (3.0%) responses from radio-collared coyotes were elicited during five surveys from five different stations. One radio-collared animal responded twice during the same night from different locations. Fourteen (7.0%) of the 20 domestic dog responses were from private property adjacent to the Foothills Parkway.

Responses were elicited from coyotes at 14 station soundings ($14/197 \times 100\%$) for a response index of 7.1%; domestic dogs responded at 12 station soundings

Table II-2: Responses elicited from howl surveys in GSMNP
from March 1990 to April 1991.

Month & year	# of stations	Length in km	# Responses		est. # coyotes resp.	
			dog	coyote	uncollared	collared
Mar 90	09	17.6	--	--	--	--
Apr 90	45	43.2	--	--	--	--
May 90	09	17.6	--	--	--	--
Jun 90	09	17.6	--	06	05	01
Jul 90	17	28.8	--	--	--	--
Aug 90	09	17.6	--	--	--	--
Sep 90	07	17.6	--	--	--	--
Oct 90	09	17.6	--	08	03	01
Nov 90	09	17.6	--	11	03	01
Dec 90	09	17.6	--	--	--	--
Jan 91	--	----	--	--	--	--
Feb 91	17	30.4	05	05	04	01
Mar 91	25	64.0	07	02	02	--
Apr 91	23	57.6	08	03	02	01
Total	197	364.8	20	35	19	05

($12/197 \times 100\%$) for a response index of 6.1%. Coyote responses were greatest in October (22%), November (33%), and February (29%) (Figure II-2). Twenty-seven coyote responses were elicited in Cades Cove for a coyote index ($27/118 \times 100\%$) of 22.9% and 8 coyote responses were elicited for a coyote index ($8/79 \times 100\%$) of 10.1%. The coyote index indicates that densities of coyotes in Cades Cove may be twice as high as areas outside Cades Cove.

Sharp (1981) reported a response rate of 0.95% to 7.4% and Blanton (1988) reported response rates of 12.5% to 33.3% on wildlife management areas in Mississippi and Alabama. The 7.1% response rate is probably high for GSMNP due to the large number of samples taken in a small area (Cades Cove). The higher response rates for October and November correspond with other studies conducted by Sharp (1981) and by Knowlton (1972) in which coyote numbers were highest in summer through the fall and declined in late fall through winter. The decline was likely due to dispersal of animals. Surveys in the fall should provide an estimate during the highest point in the coyote population cycle. Social behavior may play an important role in responses. If coyotes transmit information for social behavior by howling, the seasonal need for information would influence the amount of howls elicited throughout the year (Laundre 1981).

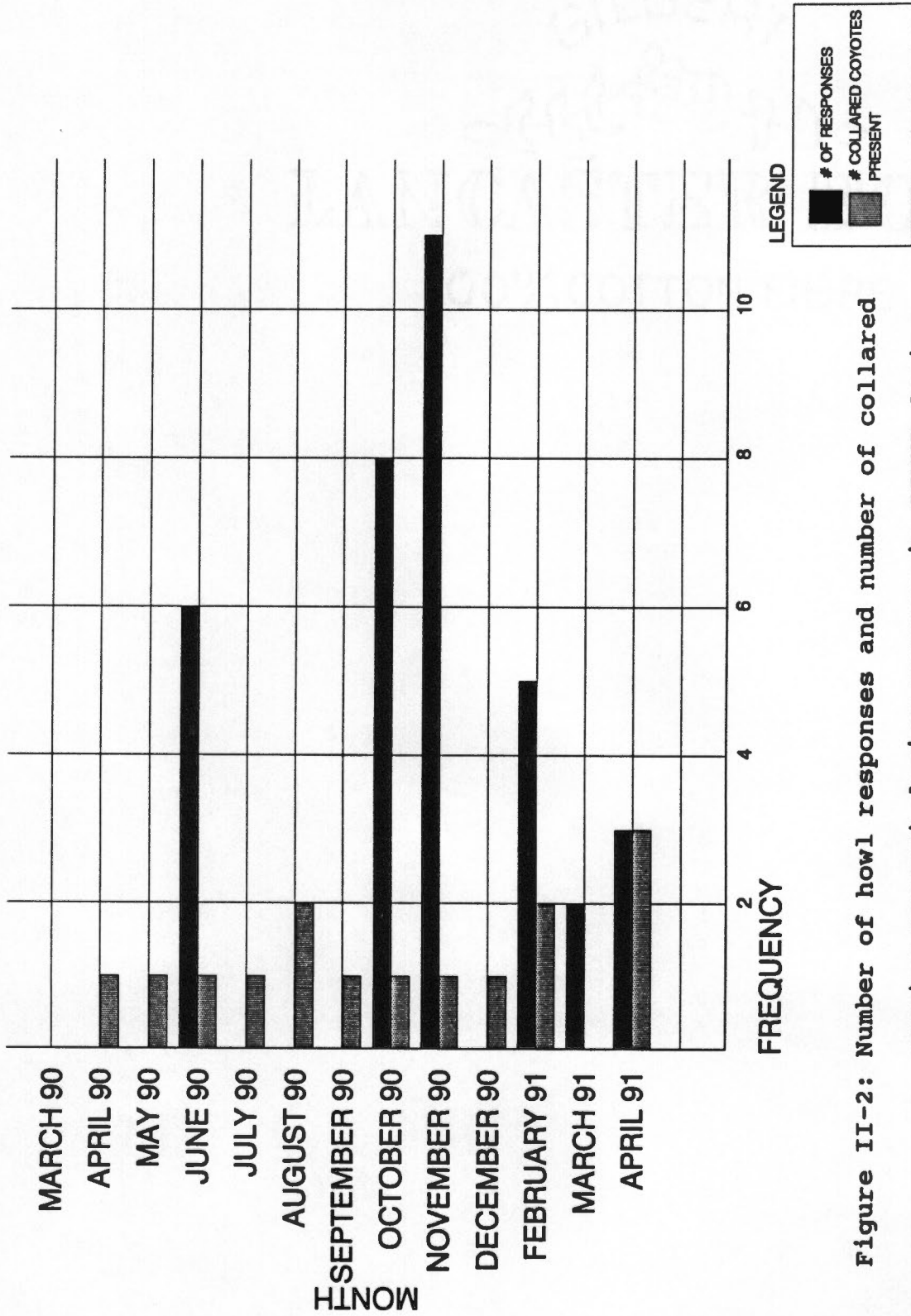


Figure II-2: Number of howl responses and number of collared coyotes present during surveys in GSMNP during 1990 and 1991.

Indices of relative abundance were calculated using the methods described by Sharp (1981) and an independent index using known numbers of coyotes responding. Index 1 produced relative abundance of 1 coyote/13.2 km² (0.0755 individuals/km²) in Cades Cove and 1 coyote/39.7 km² (0.0252 individuals/km²) outside Cades Cove. Index 2 produced relative abundances of 1 coyote/21.0 km² (0.0476 individuals/km²) in Cades Cove and 1 coyote/39.7 km² (0.0252 individuals/km²) outside of Cades Cove (Table II-3). However, these indices may produce too much inherent error due to the correction factor.

An alternative index was calculated using known information such as minimum known number of coyotes responding. Index 3 produced relative abundance of 1 coyote/12.9 km² (0.0773 individuals/km²) in Cades Cove and 1 coyote/20.0 km² (0.0498 individuals/km²) outside of Cades Cove (Table II-3). Based on number of howl responses, observations of collared and uncollared animals and trapping information, it appears only one family group occupies Cades Cove. Therefore, density estimates based on Index 1 and Index 3 are feasible for Cades Cove.

Surveys in Cades Cove were intensive and the entire area was covered during each survey. Therefore, every coyote in Cades Cove had numerous opportunities to respond. On 10 occasions, radio-collared coyotes were close enough to respond to the stimulus but never did. Outside of Cades

Table II-3: Relative abundance estimates for coyotes derived from three indices in GSMNP from 1990 to 1991.

Relative abundance 1 coyote/___km ²			
<u>Area</u>	<u>Index 1</u>	<u>Index 2</u>	<u>Index 3</u>
Cades Cove	13.2	21.0	12.9
Outside Cades Cove	39.7	39.7	20.0

Cove, only a small area was surveyed. Also not all areas overlapped due to topography and moving water and this hampered hearing responses. The response index, coyote index and all relative abundance estimates were higher in Cades Cove than outside the Cove which suggests the Cove has higher densities; this is expected due to the open habitats and available prey in Cades Cove.

If these indices are extrapolated to the number of coyotes in GSMNP, the density of the GSMNP would range from 52 to 160 coyotes/2072 km². This range is considered possible due to the recent colonization of GSMNP in the last six years and the number of reported sightings of coyotes by park employees in past years.

The response rate of coyotes to siren and human howls is not independent ($X^2 = 19.8$; $P < 0.0001$; $df = 1$) (Appendix table A-1). It appears that coyotes respond more to human howls than an electronic siren because howls of experienced humans resemble coyote howls more than sirens. McCarley (1975) and Okoniewski and Chambers (1984) felt that human howling was an alternative to the siren because of a closer resemblance to coyote howls and less likely to elicit responses from animals at distant stations.

The response rate of coyotes in Cades Cove compared to the rest of the GSMNP with human howls as the method is independent ($X^2 = 1.8$; $P = 0.178$; $df = 1$) (Appendix table A-2).

This supports the idea that there are likely more coyotes/km² in Cades Cove than outside of the Cove.

Fifty-four percent of the responses were group-howls involving four or more coyotes. It is difficult to determine the exact number of coyotes howling in a group and direction of all animals responding. The aid of a tape recorder and sound spectrograph analysis may help produce a better estimate of the total number of animals responding. It is recommended that two or more people be used to locate and determine the number of individuals responding. Two or more people were available to determine number and location of coyotes responding during 7 of 8 surveys.

Coyote responses to various surveys are difficult to compare among areas because of differences in methods, individual researchers, interpretations of the data, and the individuality of the animals to respond to the stimulus. Variables such as topography, vegetation, moving water, and weather may affect the researchers ability to elicit or record coyote responses.

Future use of scent stations in GSMNP appears limited but may be improved if stations were established along major roads and surveys were conducted in fall of the year with scents that were not used for trapping. However, due to the amount of labor, time, and problems with visitors and inclement weather, I suggest scent stations not be used for measuring relative abundances of coyotes in GSMNP.

Although these results are limited and preliminary, the howl survey appears to have more potential as a coyote index in GSMNP. Comparing the howl survey method (197 stations covering 364.8 km of road) to scent stations (198 stations covering 278.4 km of road and trails), the howl survey elicited 35 coyote responses and scent stations recorded only one coyote response. Also, howl surveys were less labor intensive, easier to distinguish coyote and domestic dog howls than coyote and dog tracks, were not influenced by inclement weather, masking of tracks, human interference, and the use of lures which might bias some animals that were exposed to traps. Howl surveys also may be useful after red wolves are released in GSMNP. Howl surveys may be used to calibrate response rates of coyotes with known red wolf densities after reintroduction. In the future, howl surveys may be used to compare relative densities among areas as well as an annual indices, provided that experiments are designed carefully to assess the relationship between measured densities and response rates and are consistent between years.

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LITERATURE CITED

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PART III

MOVEMENT ECOLOGY AND HABITAT USE OF COYOTES IN EAST TENNESSEE

ABSTRACT

Six coyotes were captured and radio-collared in Great Smoky Mountains National Park (GSMNP) to determine movements and habitat use. A year of movement data was collected for 3 subadult male coyotes. Average annual home range for coyotes ($n = 3$) with more than 100 locations was 122.9 km^2 (range 25.4 km^2 to 230 km^2) using the modified minimum area polygon method. Largest seasonal movements (56.1 km^2 and 152.44 km^2) were during the pup rearing season. These two yearling males were unmated and probably ranged more than mated males during this season. Greatest dispersal distance recorded was 46.7 km and greatest recorded distance moved in 24 hours was 33.5 km.

Chi-square analyses indicated that two coyotes apparently frequently selected open areas, mixed hardwood, oak/pine, and pine cover types when active. However, one coyote did not appear to select a specific cover type when active or inactive.

Most coyote locations were in pine (38.9%), xeric oak (24.5%), and treeless (16.1%) areas. Chi-square tests indicated that no seasonal preference was detected for two

coyotes. However one coyote apparently appeared to frequently select mixed hardwood forest type during the breeding season and oak pine and pine forest types during the gestation period.

Coyotes 2 and 3 were active and located more times than expected in flat areas and resting on northern, southern, and western aspects. Coyote 4 used all aspects equally when active and inactive. A high percentage of locations (95%, 89%, and 83%) for coyotes 2, 3 and 4, respectively, were below 700 m. The high percentages of locations in lower elevations may be attributed to the cove landscapes surrounding GSMNP and the selection of these coves by coyotes 2 and 4 outside of GSMNP. The effects of steep slopes, elevation, and vegetation may influence the movements of coyotes in GSMNP. A more detailed study of a colonizing population of coyotes in GSMNP should look at how coyote movements are affected by landscape patterns in and around GSMNP throughout the year.

INTRODUCTION

Coyotes (Canis latrans) are adaptable and highly mobile carnivores that have survived and expanded their range while other carnivores have diminished this century. Until the early 1900's, the range of coyotes extended only as far east as northern Wisconsin to central Texas (Nowak 1978). The

major factor limiting the range of coyotes appeared to be gray wolves (C. lupus) and red wolves (C. rufus) (Nowak 1978, Parker 1988). However, human extirpation of wolves and habitat modification permitted coyotes to move gradually into eastern North America.

Along with natural migrations, coyotes also were released by humans for various reasons. Most of the releases were by fox hunters introducing coyote pups they thought were red foxes (Vulpes vulpes) and adult coyotes for training hounds. Hill et al. (1987) reported five releases of coyotes in Florida and Georgia, three releases in Alabama and Tennessee, two releases in Mississippi, and one release in Virginia and North Carolina.

Numerous home range, movement, and dispersal studies have been conducted on coyotes throughout North America and have produced a wide variety of estimates (Babb 1988, Bowen 1982, Litvaitis and Shaw 1980, Nellis and Keith 1976, Roy and Dorrance 1985, Springer 1982, Sumner et al. 1984). However, no coyote studies have been conducted in the southern Appalachian mountains.

The objective of this study was to provide baseline data on the seasonal movement patterns and seasonal habitat use of coyotes in east Tennessee.

STUDY AREA AND METHODS

This study was conducted in the western portion of Great Smoky Mountains National Park (GSMNP) in eastern Tennessee between January 1990 to March 1991 (Figure III-1). The topography is steep and elevations range from 266 to 2024 m. Mean annual precipitation ranges from 127 to 152 cm per year in low elevations to 230 cm per year above 1829 m (Shanks 1954). The wettest times of year are in late winter-early spring and July with September and October the driest (Stephens 1969).

A diversity of plants occur in GSMNP which can be attributed to the changes in climate associated with elevational changes. King and Stupka (1950) identified approximately 1,300 species of flowering plants and over 2,400 nonflowering plants. Within the study area is Cades Cove, a valley with 748 ha of fescue pastures for cattle and horse grazing and 230 ha of woodlots.

In contrast to the flora diversity, GSMNP does not support a rich variety of mammals. Linzey and Linzey (1971) list 59 species of mammals found in GSMNP and six species are probably extirpated. This list does not include coyotes which migrated into GSMNP around 1985.

Coyotes were trapped using number 3 Victor soft-catch leg-hold traps using dirt hole sets, scent post sets, and carcasses. Traps were secured using a butterfly swivel and

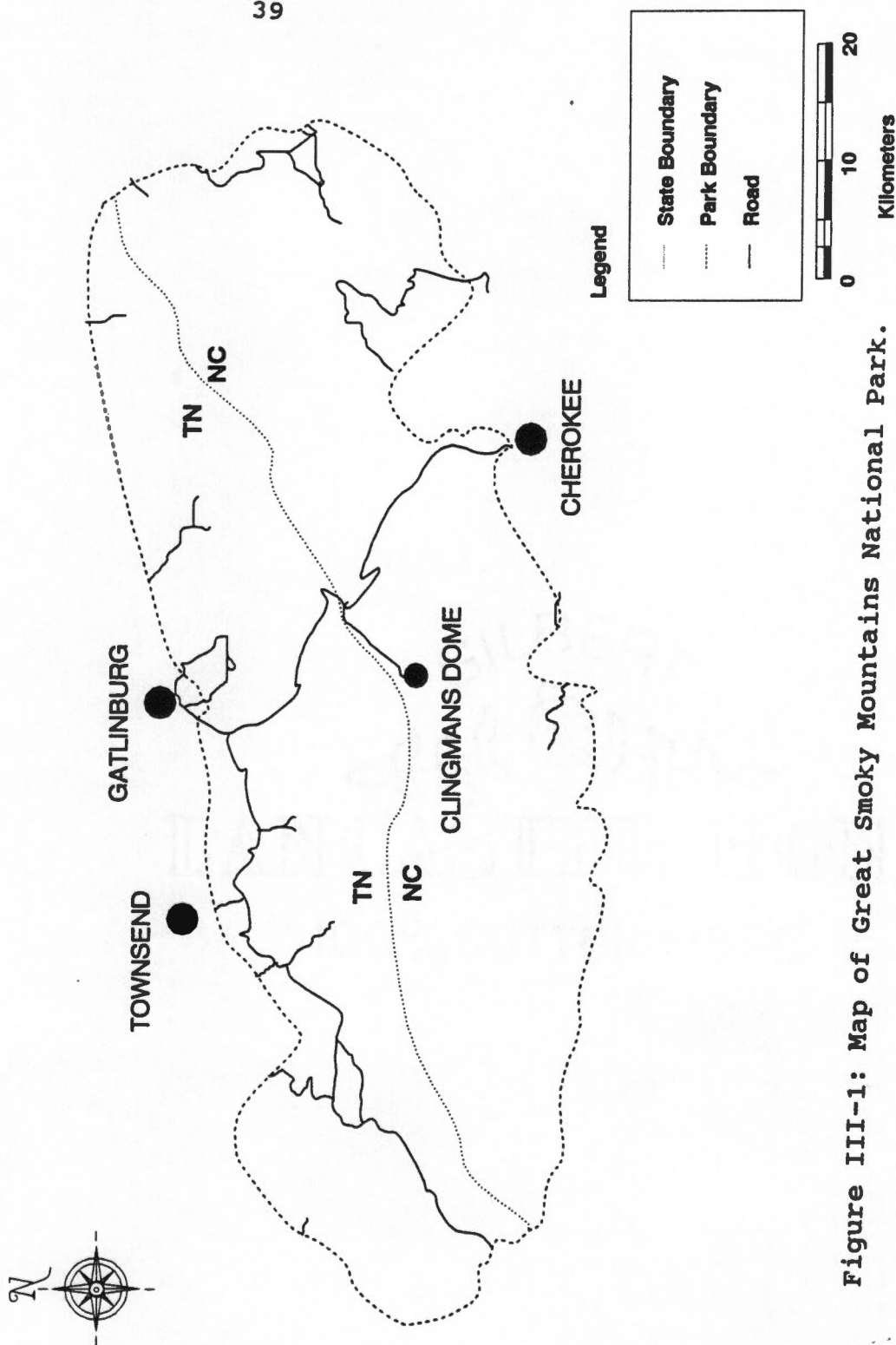


Figure III-1: Map of Great Smoky Mountains National Park.

two 75 cm by 1.25 cm rebar stakes. Attractants included coyote urine, long distant lures, deer, boar, and cow carcasses.

Trapping was concentrated in Cades Cove, however, traps also were set along Parsons Branch Road, Hannah Mountain Trail, Turkey Pen Trail, Clingmans Dome Road, and Sugarlands Mountain Trail. In agreement with National Park Service officials and to avoid possible visitor conflicts, traps were placed at least 100 m off hiking trails, out of sight from main roads, and away from possible visitor use areas in the open fields. Instead of obvious coyote travel routes, trap locations were chosen to minimize visitor contact. Traps were checked in morning hours and covered or tripped during the day during high months of visitor use. This effort probably contributed to the low capture success.

At first coyotes were immobilized with 2.0 ml Ketamine hydrochloride (Springer 1982). However, due to submissive behavior of coyotes, captured animals were subdued by a catch pole then restrained with a muzzle and physical force. All coyotes were fitted with a Telonics radio-collar with a motion sensitive activity monitor in the 150.040 to 150.590 MHz range.

All captured coyotes were aged (juvenile, yearling, or adult) according to Nellis et al. (1978) sexed, physical condition noted and inspected for injuries. Standard morphological measurements taken included weight, total

length, tail length, front and hind pad length, neck circumference and ear length. Blood samples were collected and sent to Dr. Robert Wayne (University of California, Berkley) for genetics testing. All animals were released at capture sites.

Radio-collared coyotes were monitored from 27 March 1990 to 30 March 1991 using a Telonics TR-2 receiver with a handheld H antenna, five element vehicle mounted antenna or fixed wing-aircraft. Azimuths were determined using the loudest signal method of Springer (1979). Coyotes were located daily when possible and four to five nights of sequential locations were collected to determine seasonal home range size. Composite and seasonal home range sizes were determined following the suggestions of Laundre and Keller (1984) and Smith et al. (1981). Laundre and Keller (1984) reported that to adequately delineate seasonal home ranges of coyotes, four to five nights of sequential locations were needed for the pup rearing season and probably the other seasons as well. Seasons were broken down according to Smith et al. (1981): breeding (01 January to 15 March); gestation (16 March to 30 April); pup rearing (01 May to 31 August); and dispersal (01 September to 31 December). Also, Laundre and Keller (1984) suggested that at least 100 locations were needed to delineate yearly home ranges.

Coyotes were monitored throughout GSMNP and the surrounding areas of Blount and Sevier counties Tennessee. The habitat of areas surrounding GSMNP is predominantly open pastures and pine/hardwood forests common to east Tennessee.

Locations were determined with the use of XYLOG 6 (Dodge and Steiner 1986) and Telem 88 (Coleman and Jones 1988) computer programs on a IBM personnel computer and were plotted on a 1:24,000 USGS topographic map. Size of home ranges were calculated using angles between 40 and 120 degrees apart and collected within 30 minutes when the coyote was at rest and within 5 minutes when the coyote was active. Home range size was determined using the modified minimum area polygon method (concave polygon) described by Harvey and Barbour (1965) with the Telem 88 computer program.

Locations were entered into GIS and vegetation types were determined for locations inside GSMNP and aspect, elevation and slope were determined for locations in GSMNP and surrounding areas. Statistical analyses were performed using the Statistical Analysis System (SAS Institute Inc. 1985). Chi-square tests were performed to test for changes in activity patterns during the year and different forest types, seasonal changes in forest cover types, and seasonal and activity changes in aspect, elevation and slope.

RESULTS AND DISCUSSION

From 27 February 1990 to 22 January 1991, six coyotes were captured during 1977 trap nights (Table III-1). One adult male, three yearling males, one juvenile male and one juvenile female were captured in Cades Cove (Table III-2). The low capture success and the capture of only one female coyote may indicate a colonizing population (Moore and Millar 1984). Coyote number 1, an adult male, was captured on 07 March 1990 but escaped by pulling the trap from the ground. This animal was recaptured on 17 March 1990 with the previous trap still on the left paw. The left paw was cut to the bone on all sides and severely infected. This coyote was radio-collared and released and on 19 March 1990 was found dead approximately 400 m from the capture site. The cause of death was probably a result of the infected paw and weakened condition.

On 17 March 1990, another trap was pulled from the ground. On 27 March 1990 a yearling male coyote (number 2) was captured with the missing trap attached to the right front paw. The paw was cut to the bone on the anterior side. This animal was processed, radio-collared and released. On 09 April 1990, coyote number 2 was recaptured and had lost the right front paw. The stub appeared completely healed with no signs of infection.

Table III-1: Daily coyote trapping log in GSMNP from 1990 to 1991.

Area trapped	Dates	# of sets	# trap nights	Species captured	# bear visits
Forge Creek	02/27/90 to 03/05/90	08	36	1 raccoon	0
Parsons Branch	02/27/90 to 03/05/90	08	54	1 bobcat	3
Cades Cove	03/06/90 to 04/27/90	39	700	4 coyotes 7 raccoons 3 vultures 2 bobcats	0
Turkey Pen	03/13/90 to 03/17/90	06	24	1 domestic dog	0
Sams Gap to Gregory Bald	05/14/90 to 05/18/90 and	10	50	0	26
	05/28/90 to 06/11/90	07	119	0	82
Cades Cove	06/18/90 to 07/06/90	17	182	0	53
Sugarlands Mountain	07/23/90 to 08/06/90	18	188	1 bobcat	13
Cades Cove	09/10/90 to 10/01/90	10	148	0	07
	10/20/90 to 11/25/90	20	311	1 coyote 1 opossum 1 gray fox 5 bobcats 18 raccoons	0
	12/10/90 to 01/22/91	11	165	1 coyote 3 raccoons 1 opossum 1 bobcat	1
Total			1977		185

Table III-2. Biological measurements of coyotes captured in
GSMNP 1990 to 1991.

Date of capture	#	Sex	Approx. Age	Weight in kg	Total lgt.	Tail lgt.	Neck circ.	Foot Front
03/17/90	1	M	< 2 yr	18.0	131cm	31cm	32cm	8.5cm
03/27/90	2	M	1 yr	13.0	130cm	38cm	29cm	8.5cm
04/11/90	3	M	1 yr	13.5	126cm	33cm	31cm	8.0cm
04/13/90	4	M	1 yr	11.0	120cm	32cm	27cm	7.0cm
11/07/90	5	M	> 1 yr	8.1	111cm	33cm	----	6.6cm
01/09/91	6	F	> 1 yr	13.4	123cm	28cm	30cm	6.8cm

Young and Jackson (1951) summarized three accounts of double peg-legged coyotes that travelled extensively and were in excellent condition when killed. Young and Jackson (1951) stated "the coyote seemingly possesses an anatomy that can withstand much in the way of shock and pain as shown by its ability to overcome severe physical disability to the point of complete recovery." This survival instinct of coyotes may help explain why coyotes have persisted and expanded their range in spite of human persecution (Young and Jackson 1951).

Prior to these instances, traps were secured to the ground by a single rebar stake. After these instances, all traps were secured with a butterfly swivel and two rebar stakes. The remaining coyotes were captured without injuries.

Of the six collared coyotes, three were monitored until completion of the study. Coyote number 6 was captured on 09 January 1991 and left Cades Cove on 12 January 1991 and could not be located with fixed-wing aircraft. On 19 March 1991, coyote number 6 was located outside of GSMNP boundaries in Happy Valley and has not been located since.

The number of locations varied from 16 to 231 locations. A year of movement data was collected for coyotes number 2, 3 and 4. Greatest dispersal distance recorded was 46.7 km to the east by coyote number 5 (Table III-3). Greatest recorded distance moved in a 24 hour

Table III-3. Maximum distance moved between any two locations
in km for coyotes in GSMNP, 1990 to 1991.

Coyote number	Season				
	Breeding	Dispersal	Gestation	Pup-rear	Yearly
1	----	----	----	----	----
2	25.46	27.95	23.41	33.54	33.54
3	10.50	8.03	4.99	6.01	10.95
4	12.34	29.89	27.72	30.34	33.72
5	----	----	----	----	46.66
6	----	----	----	----	----

period was 33.5 km by coyote number 2 (Table III-3). Average annual home range for coyotes with more than 100 locations was 122.9 km² (range 25.4 km² to 230 km²) using the concave method of analysis. Largest seasonal movements were during the pup rearing season for coyote number 2 and number 4 (56.1 km² and 152.44 km²) respectively (Table III-4) (Figures III-2, III-3, III-4). However, these two yearling males were unmated and probably ranged more than mated males during this season. Smallest seasonal movements were by coyote number 3, also a yearling male, during the gestation period (1.70 km²) and pup rearing season (9.65 km²) (Table III-5) (Appendix Figures A-1 to A-8).

Various results were obtained depending on method used for home range analysis. The convex polygon method (Mohr 1947) produced area estimates considerably larger than the modified minimum area method. After developing histograms and overlapping home range boundaries calculated by convex polygon method and modified minimum area method, the modified minimum area method appeared to produce better estimates of range. Previous coyote home range studies have produced varied results depending on geographical location, habitat, age, sex, densities of coyotes, densities of prey, and social order (Babb and Kennedy 1989, Bekoff 1977, Bowen 1982, Gese et al. 1989, Holzman et al. 1992, Litvaitis and Shaw 1980, Nellis and Keith 1976, Person and Hirth 1991,

Table III-4. Variation in estimates of home range size between the modified minimum area and convex polygon methods and percentage of locations used for coyotes in GSMNP.

Method of analysis and percentage of data points				
Coyote Number	Modified Min. area 100%	Modified Min. area 100%	Convex 100%	Convex 95%
2	112.4 km ²	109.6 km ²	450.0 km ²	437.8 km ²
3	25.4 km ²	16.8 km ²	44.9 km ²	18.2 km ²
4	230.9 km ²	180.1 km ²	343.9 km ²	314.4 km ²

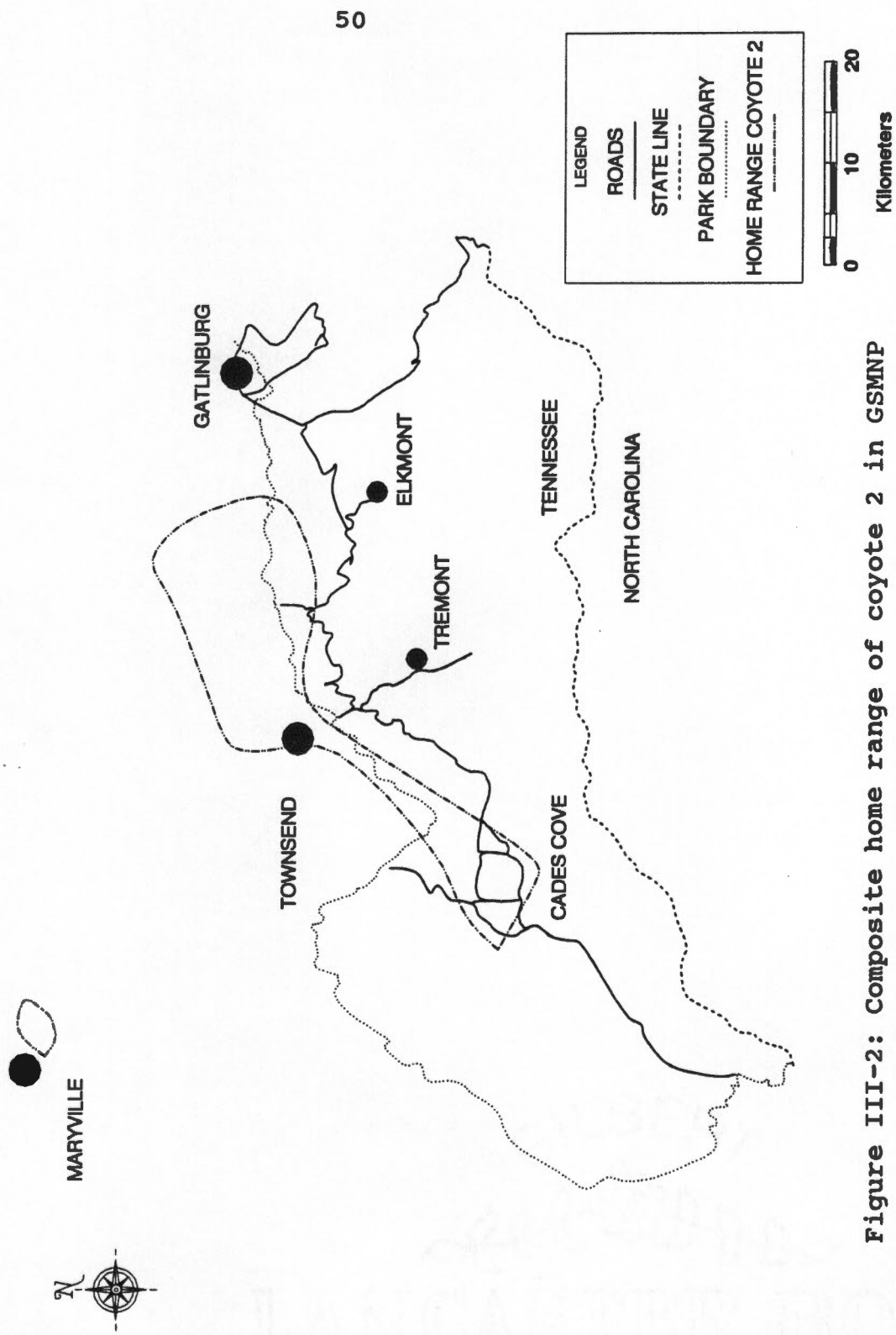


Figure III-2: Composite home range of coyote 2 in GSMNP from 1990 to 1991.

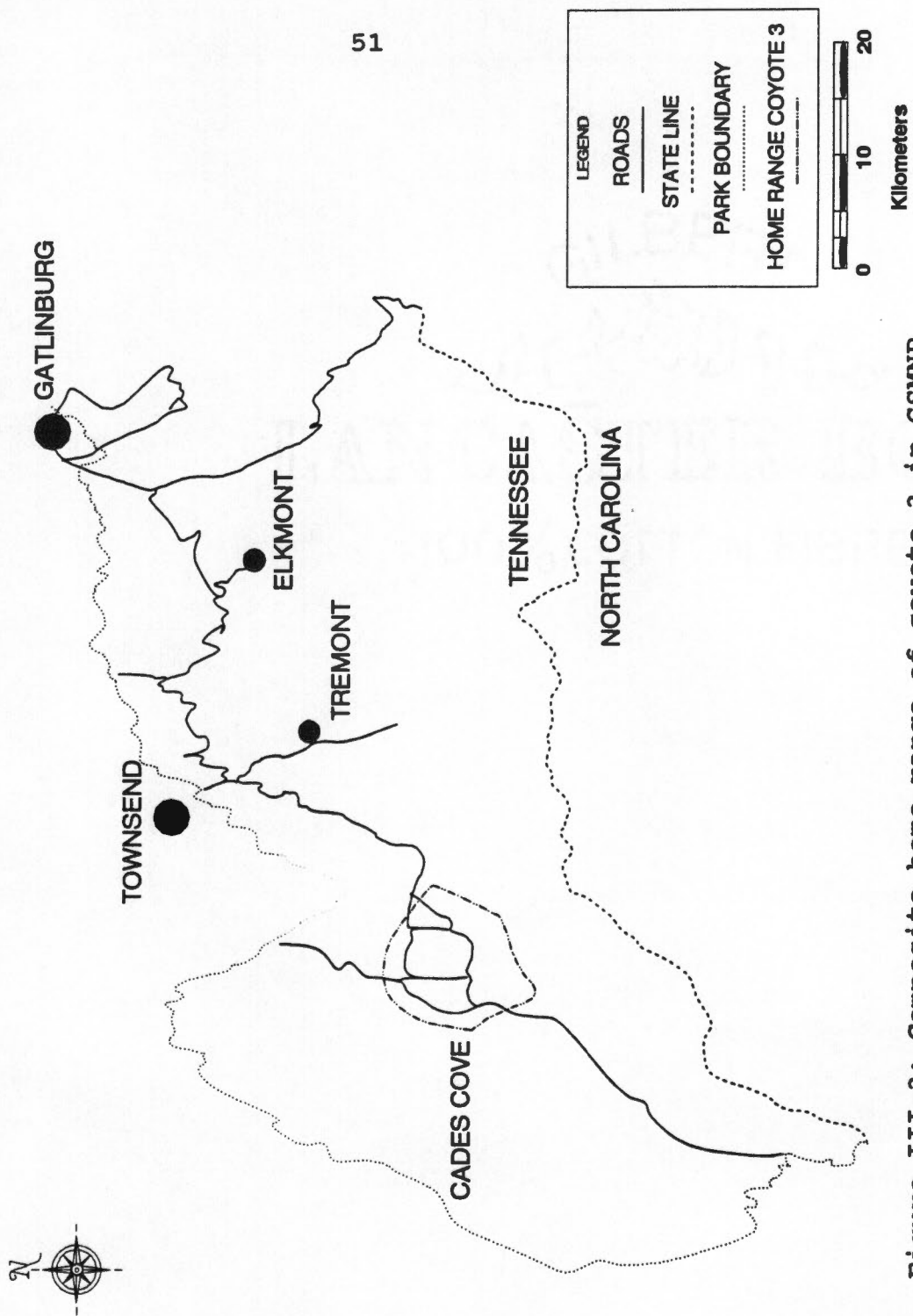


Figure III-3: Composite home range of coyote 3 in GSMNP from 1990 to 1991.

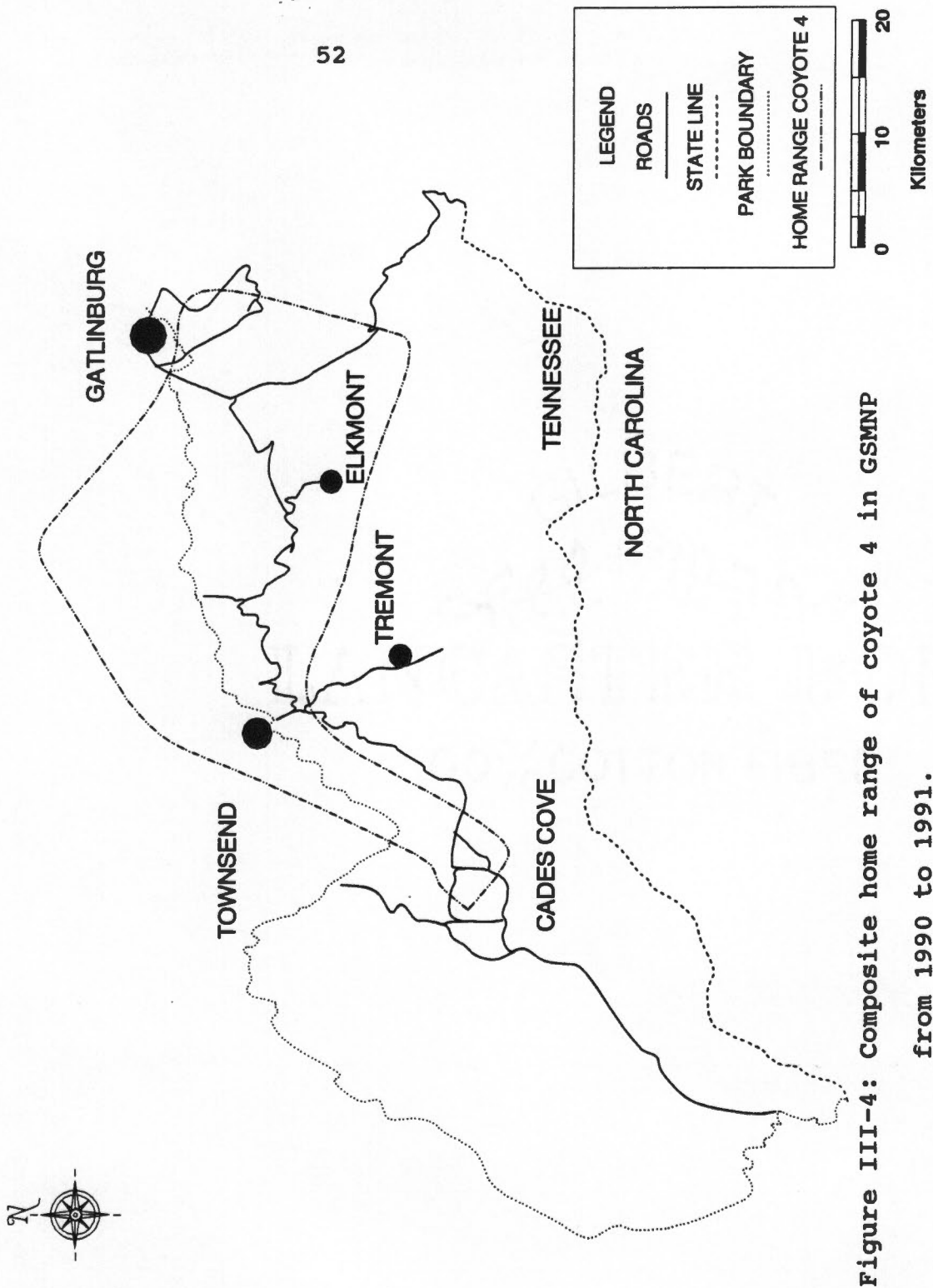


Table III-5. Seasonal and overall home range sizes calculated with the modified minimum area (concave method) for coyotes in GSMNP.

Coyote Number	Season				
	Breeding (km ²)	Dispersal (km ²)	Gestation (km ²)	Pup-rearing (km ²)	Composite (km ²)
2	17.46	51.67	13.42	56.10	112.44
3	17.63	15.21	1.70	9.65	25.39
4	16.40	71.58	24.27	152.44	230.92

Springer 1982, Sumner et al. 1984). However, Laundre and Keller (1984) contend that this variation between studies may be described by a lack of consistency in sampling design and method of data analysis. Laundre and Keller (1984) standardized four coyote home range studies and found that home range size did not differ statistically among four geographic areas, four distinct habitat types, and social order. However, generalizations are tentative due to the limited number of comparable data sets (Laundre and Keller 1984).

Large home ranges of coyotes in GSMNP may be attributed to the forested habitat and prey densities. Also, coyotes number 2 and 4 were probably dispersing yearlings. Wide ranging movements probably reflect exploratory movements of coyotes searching for mates and suitable home ranges. Coyote number 3 never dispersed and exhibited signs of being mated and occupying a territory. Another year of telemetry data might have revealed a decrease in movements of coyotes number 2 and 4.

Seasonal movements of coyotes 2 and 4 show two to three centers of activity; this suggesting a nomadic behavior instead of occupying a definite home range. Travel corridors between centers of activity apparent when seasonal movements were mapped. However, more data points during these seasons may have masked these travel routes (Appendix Figures A-1 to A-8).

Movements of these coyotes may provide insight to movement patterns of released red wolves into GSMNP. Dispersal directions and distances travelled by these coyotes may help to project patterns of dispersal of red wolves in GSMNP. Travel corridors may have been identified by coyotes and scent trails from these and other coyotes might be followed by red wolves from Cades Cove to other parts of GSMNP.

Coyotes were located in various forest types including northern hardwood (n = 1), cove hardwood (n = 11), mixed mesic hardwood (n = 35), mesic oak (n = 1), tulip poplar (n = 28), xeric oaks (n = 105), pine/oak (n = 12), pine forests (n = 166), and treeless areas (n = 69) (Table III-6, III-7, III-8). To facilitate statistical comparisons, hardwood and tulip poplar were pooled, pine/oak and pine forests were pooled and xeric oaks were pooled with pine/oak and pine forest types for one test.

Also a chi-square test for activity patterns and vegetation types indicated that coyote 2 appeared to use open areas and mixed hardwood forest type when active ($\chi^2 = 19.7$, $P = 0.0001$ $df = 2$) (Table III-6). Coyote 3 apparently used mixed hardwood, pine/oak and pine, and xeric forest types when inactive and open areas when active ($\chi^2 = 19.4$, $P = 0.0001$ $df = 3$) (Table III-7). No use of one forest type was noted when coyote 2 was inactive. However,

Table III-6: Frequency table of activity and forest cover type data for coyote 2 in GSMNP from 1990 to 1991.

Activity	Forest Type			Total
	Pine/Oak & Pine	Xeric Oak	Open	
Active	10	18	19	47
Not active	18	15	0	33
Total	28	33	19	80

Table III-7: Frequency table of activity and forest cover type data for coyote 3 in GSMNP from 1990 to 1991.

Activity	Forest Type				Total
	Mixed Hardwood	Pine/Oak & Pine	Xeric Oak	Open	
Active	7	45	23	36	111
Not active	17	60	32	12	121
Total	24	105	55	48	232

Table III-8: Frequency table of activity and forest cover type data for coyote 4 in GSMNP from 1990 to 1991.

Activity	Forest Type		Total
	Mixed Hardwood	Pine/Oak & Pine	
Active	32	26	58
<u>Not Active</u>	<u>36</u>	<u>20</u>	<u>56</u>
Total	68	46	114

coyote 4 was independent for activity and habitat type ($\chi^2 = 1.0$, $P = 0.321$ $df = 1$) and apparently used each cover type equally when active or inactive (Table III-8).

Tests for independence for coyote 2 indicated that season and vegetation were not independent ($\chi^2 = 16.7$, $P = 0.010$ $df = 6$). It appeared that coyote 2 was located more frequently in mixed hardwood during the breeding season and pine/oak and pine during the gestation period. No obvious patterns were noted for other seasons (Table III-9). Coyote 3 and coyote 4 showed no obvious selection for forest types within seasons ($\chi^2 = 15.2$, $P = 0.086$ $df = 9$ coyote 3; $\chi^2 = 2.7$, $P = 0.440$ $df = 3$ coyote 4) and although not statistically significant, the majority of locations were in pine/oak and pine forest types (Tables III-10 and III-11). The lack of clear seasonal selection may be attributed to the individual behavior of the animals, small sample sizes, movement patterns of the animals going from forested area to more mixed landscapes, and the omnivorous diet of coyotes.

Coyote 3 was recorded inactive 12 times in open pastures. Coyotes 2 and 4 spent approximately 56% and 28%, respectively, of their time outside GSMNP and were never recorded inactive in open pastures. Coyote 3 was in the protected confines of GSMNP and this may explain why coyote 3 rested in open pastures. Person and Hirth (1991) observed coyotes resting less than expected in open areas of Vermont.

Table III-9: Frequency table of season and forest cover type data for coyote 2 in GSMNP from 1990 to 1991.

Season	Forest Type			Total
	Pine/Oak & Pine	Xeric Oak	Open	
Breeding	1	11	8	20
Gestation	16	6	6	28
Pup-rearing	6	9	2	17
<u>Dispersal</u>	<u>5</u>	<u>7</u>	<u>3</u>	<u>15</u>
Total	28	33	19	80

Table III-10: Frequency table of season and forest cover type data for coyote 3 in GSMNP from 1990 to 1991.

Season	Forest Type				Total
	Mixed Hardwood	Pine/Oak & Pine	Treeless (Open)	Xeric Oak	
Breeding	6	14	12	8	40
Gestation	4	18	3	6	31
Pup-rearing	7	38	26	22	93
Dispersal	7	35	7	19	68
Total	24	105	48	55	232

Table III-11: Frequency table of season and forest cover type data for coyote 4 in GSMNP from 1990 to 1991.

Season	Forest Type		
	Mixed Hardwood	Pine/Oak & Pine	Total
Breeding	16	10	26
Gestation	9	4	13
Pup-rearing	15	16	31
<u>Dispersal</u>	<u>28</u>	<u>15</u>	<u>43</u>
Total	68	45	113

Roy and Dorrance (1985) found that coyotes also used forested areas over open areas especially during the day.

Coyotes 2 and 3 were active and located more times than expected in flat areas and resting on northern, southern and western aspects than expected ($X^2 = 10.0$, $P = 0.04$ $df = 4$ coyote 2; and $X^2 = 11.9$, $P = 0.018$ $df = 4$ coyote 3) (Tables III-12 and III-13). Coyote 4 was independent ($X^2 = 2.6$, $P = 0.631$ $df = 4$) and apparently used all aspects equally when active or inactive (Table III-14). Due to some cells having expected counts below 5, these statistical tests may not be valid, however, 52% of locations for coyote 2 were on southern aspects during the winter months. In the spring and summer, 56% and 46%, respectively, of locations were on northern aspects. For coyote 3, 70% and 45% of locations were on northern aspects during the spring and summer, respectively (Appendix Table A-3). It appears that these coyotes may take advantage of the warmer and cooler air of the southern and northern aspects during the winter and summer.

Approximately 89% of locations of coyote 3 were in elevations below 700 m. Although not statistically significant, a large percentage (83%) of locations of coyote 4 were below 700 m. Although not a valid test due to a low number of observations in some cells, coyote 2 had a large percentage (95%) of locations below 700 m (Table A-3). The high percentages of locations in lower elevations may be

Table III-12: Frequency table of aspect and activity
data for coyote 2 in GSMNP from 1990 to
1991.

Activity	Aspect					Total
	North	East	South	West	Flat	
Active	30	8	27	17	18	100
Not Active	31	8	24	9	3	75
Total	61	16	51	26	21	175

Table III-13: Frequency table of aspect and activity
data for coyote 3 in GSMNP from 1990 to
1991.

Activity	Aspect					Total
	North	East	South	West	Flat	
Active	51	1	6	16	35	109
Not Active	60	3	10	28	17	118
Total	111	4	16	44	52	227

Table III-14: Frequency table of aspect and activity
data for coyote 4 in GSMNP from 1990 to
1991.

Activity	Aspect					Total
	North	East	South	West	Flat	
Active	25	8	13	27	10	83
Not Active	25	4	11	33	7	80
Total	50	12	24	60	17	163

attributed to the landscape patterns surrounding GSMNP and the selection of these coves outside of GSMNP by coyotes 2 and 4.

Although not statistically significant (coyote 2 = $\chi^2 = 2.64$, $P = 0.104$ $df = 1$; coyote 3 = $\chi^2 = 1.54$, $P = 0.215$ $df = 1$; and coyote 4 = $\chi^2 = 0.04$, $P = 0.845$ $df = 1$), 80%, 85% and 76% of locations for coyotes 2, 3 and 4, respectively, were on less than 13% slope (Table A-3). Coyotes in GSMNP may use gentle slopes when foraging and resting.

The landscape patterns, areas of high human occupation and activity, and the drastic changes in elevation and habitat in and around GSMNP offered a unique setting for studying a colonizing population of coyotes. Much research needs to be conducted to understand the relationship of these variables on coyote densities and movements.

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LITERATURE CITED

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APPENDIX

Appendix table A-1: Frequency table of responses
by coyotes to siren and human howls in
GSMNP from 1990 to 1991.

Area	Stimulus		
	Siren	Human Howls	Total
Cades Cove	3	5	8
Outside Cades Cove	0	6	6
Total	3	11	14

Appendix table A-2: Frequency table of responses elicited
from coyotes using human howls
in GSMNP from 1990 to 1991.

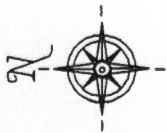
Area	Responses		
	Yes	No	Total
Cades Cove	8	110	118
Outside Cades Cove	6	73	79
Total	14	183	197

Appendix Table A-3: Frequency of locations for aspect,
elevation and slope for coyotes in GSMNP
from 1990 to 1991.

ID	Status	Aspect					Elevation		Slope	
		N	E	S	W	F	High	Low	High	Low
2	active	30	8	27	17	18	2	94	15	81
2	inactive	31	8	24	9	3	7	67	19	55
3	active	51	1	6	16	35	5	105	13	97
3	inactive	60	3	10	28	17	20	99	21	98
4	active	25	8	13	27	10	11	71	20	62
4	inactive	25	4	11	33	7	17	61	18	60

D

MARYVILLE



GATLINBURG

TOWNSEND

CADES COVE

TENNESSEE

NORTH CAROLINA

LEGEND

ROADS

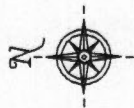
STATE LINE

PARK BOUNDARY

HOME RANGE COYOTE 2

0 10 20
Kilometers

Appendix figure A-1: Movements of coyote 2 during breeding season in GSMNP.



GATLINBURG

TOWNSEND

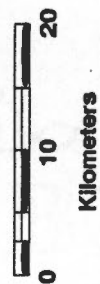
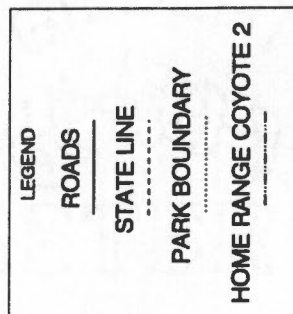
ELKMONT

TREMONT

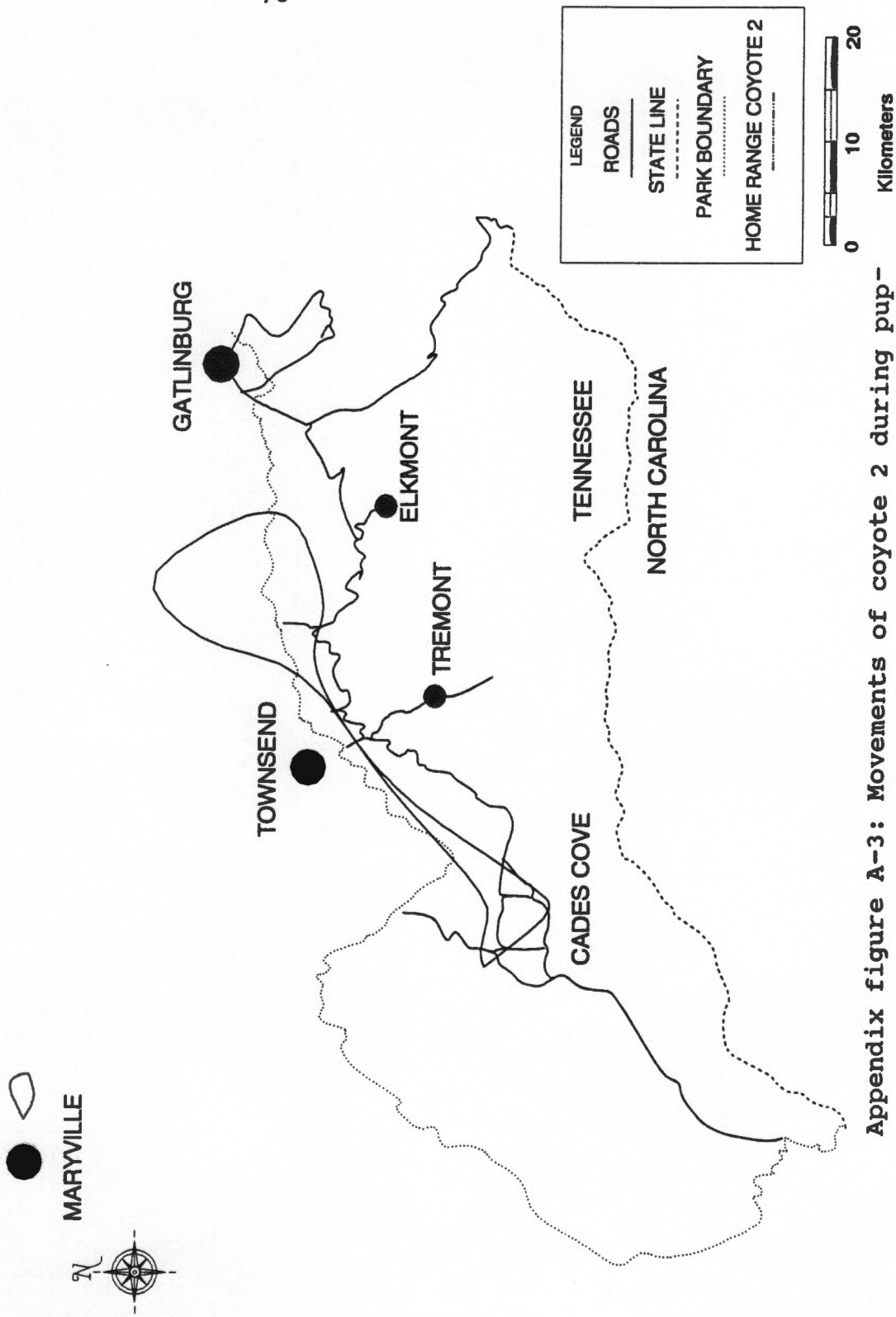
CADES COVE

TENNESSEE

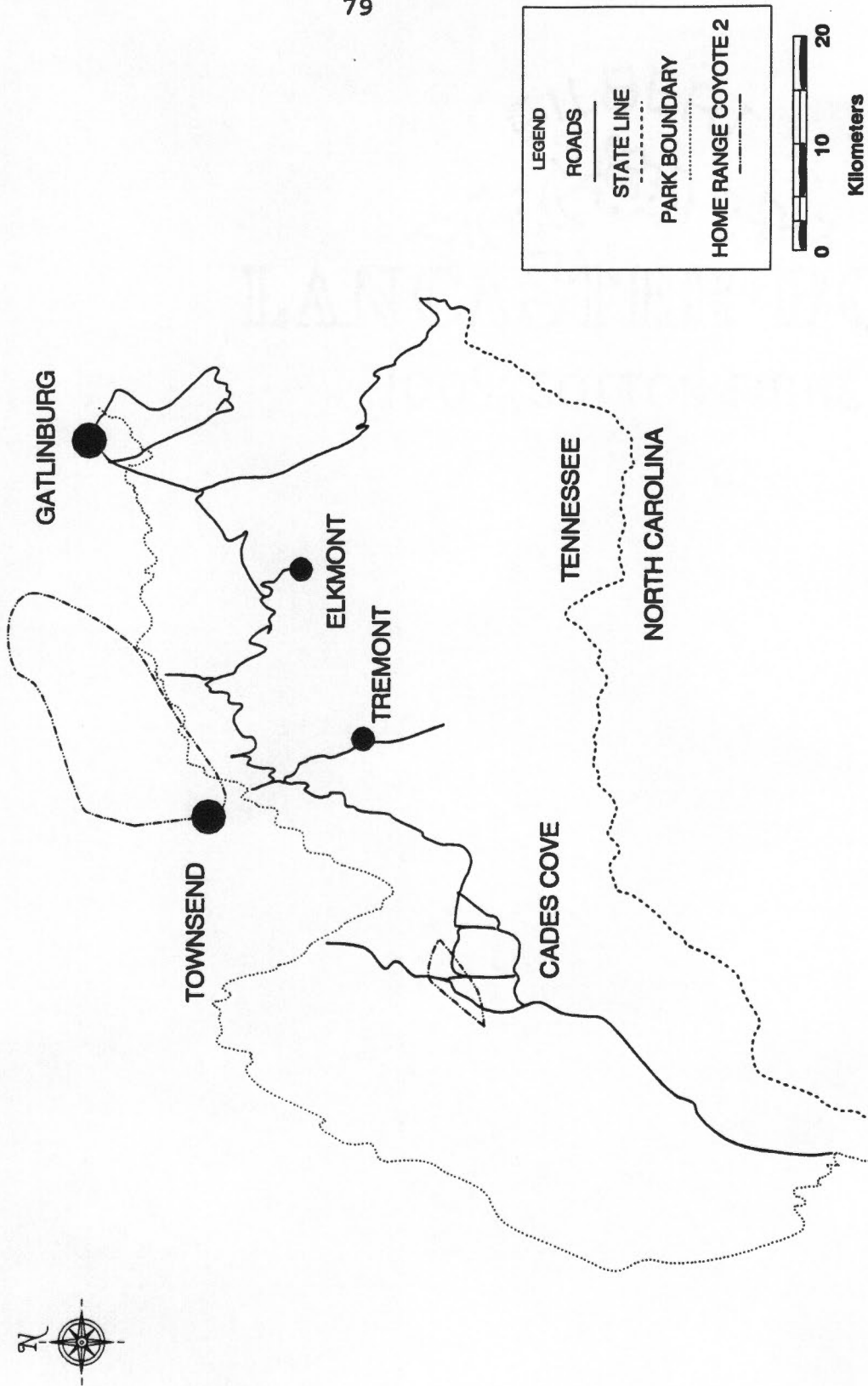
NORTH CAROLINA



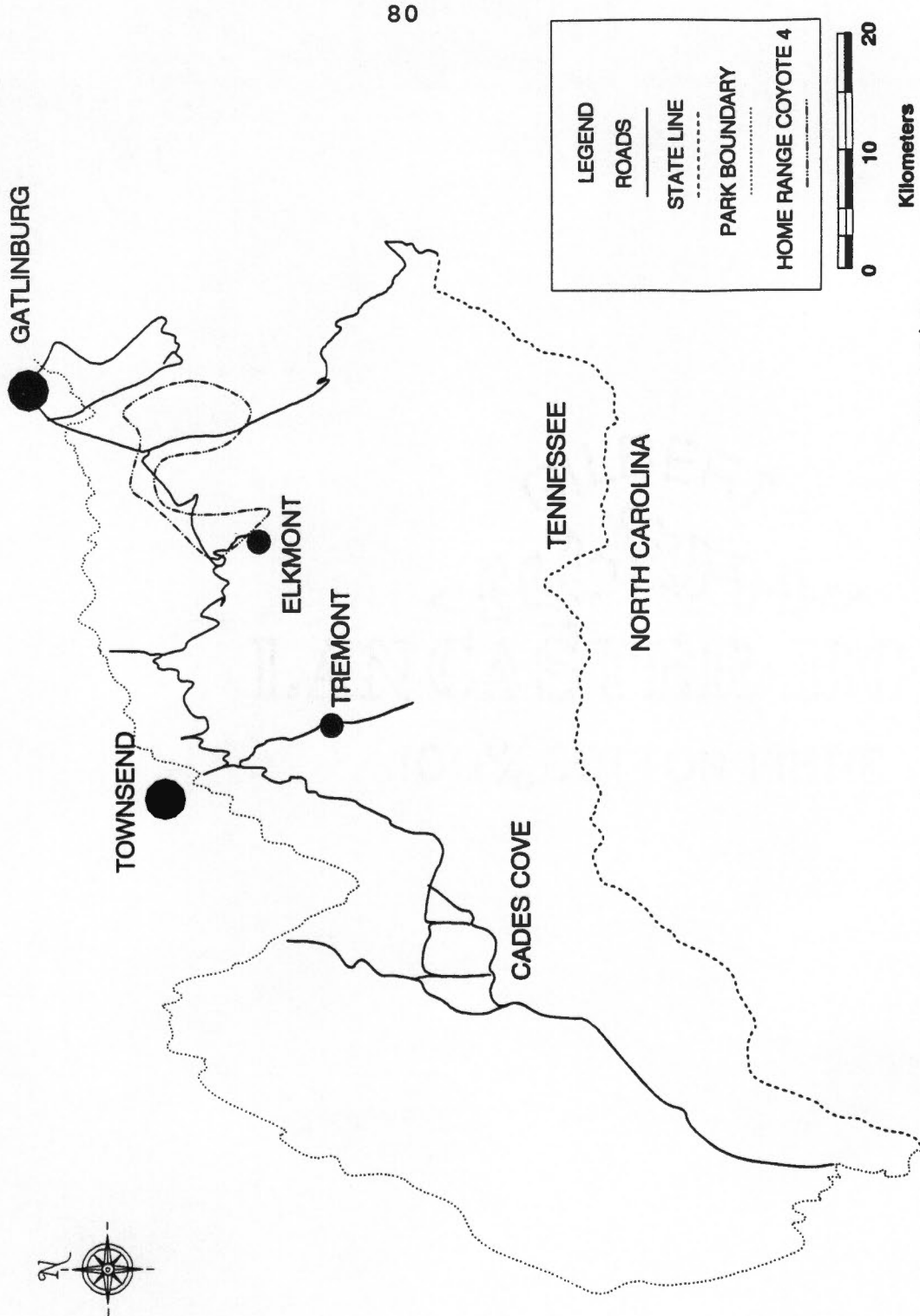
Appendix figure A-2: Movements of coyote during gestation period in GSMNP



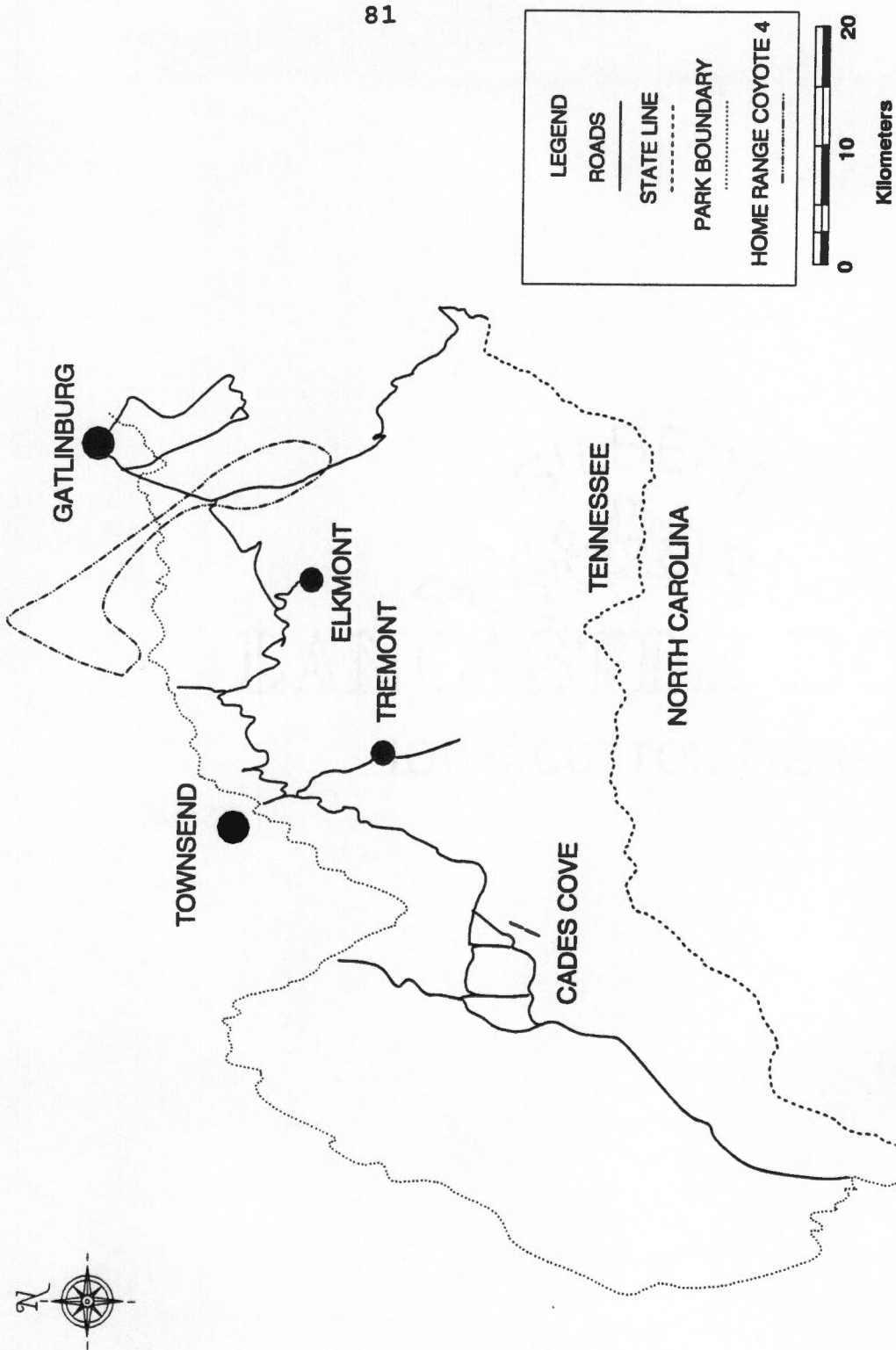
Appendix figure A-3: Movements of coyote 2 during pup-rearing season in GSMNP.



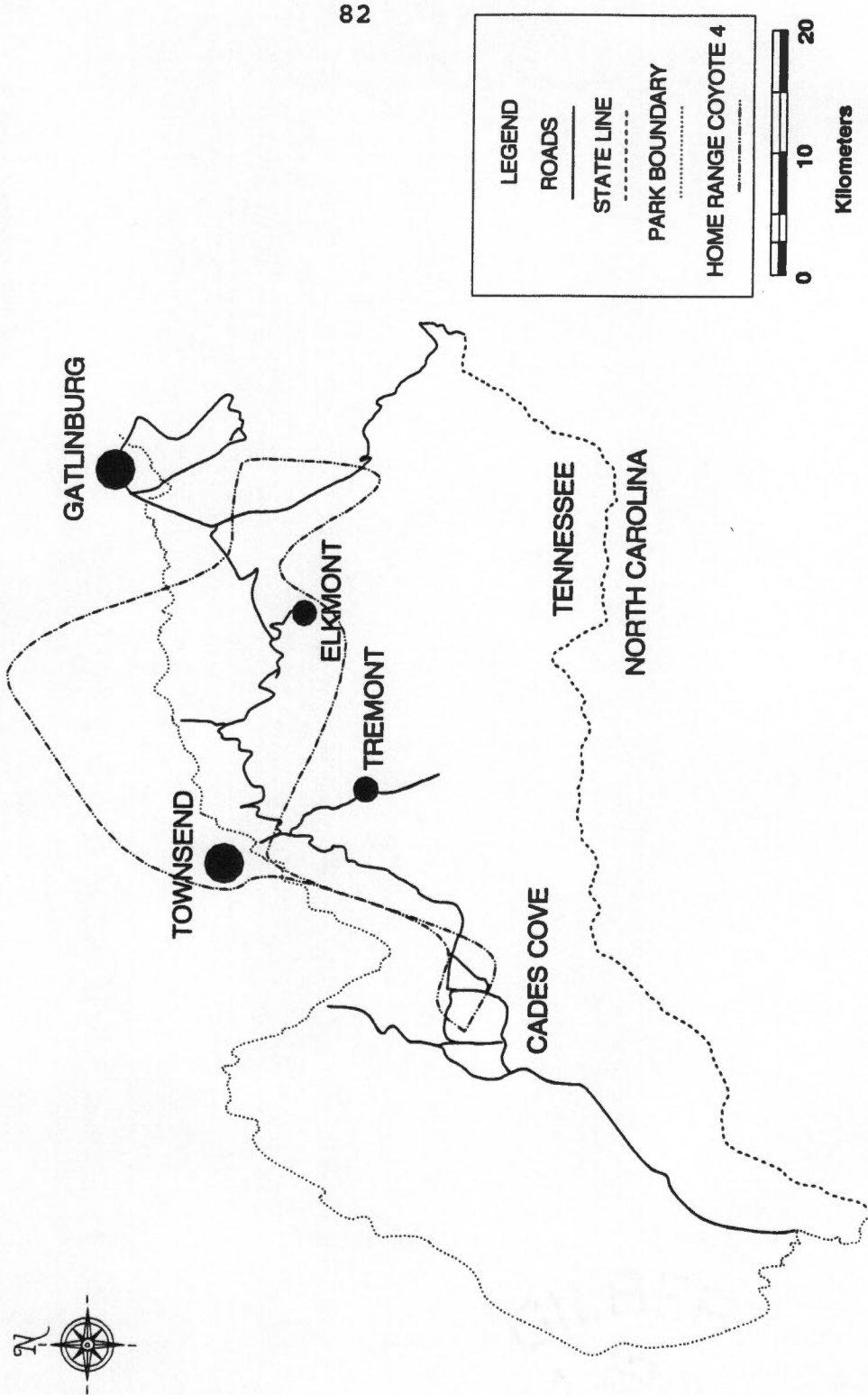
Appendix figure A-4: Movements of coyote 2 during dispersal season in GSMNP.



Appendix figure A-5: Movements of coyote 4 during breeding season in GSMNP.

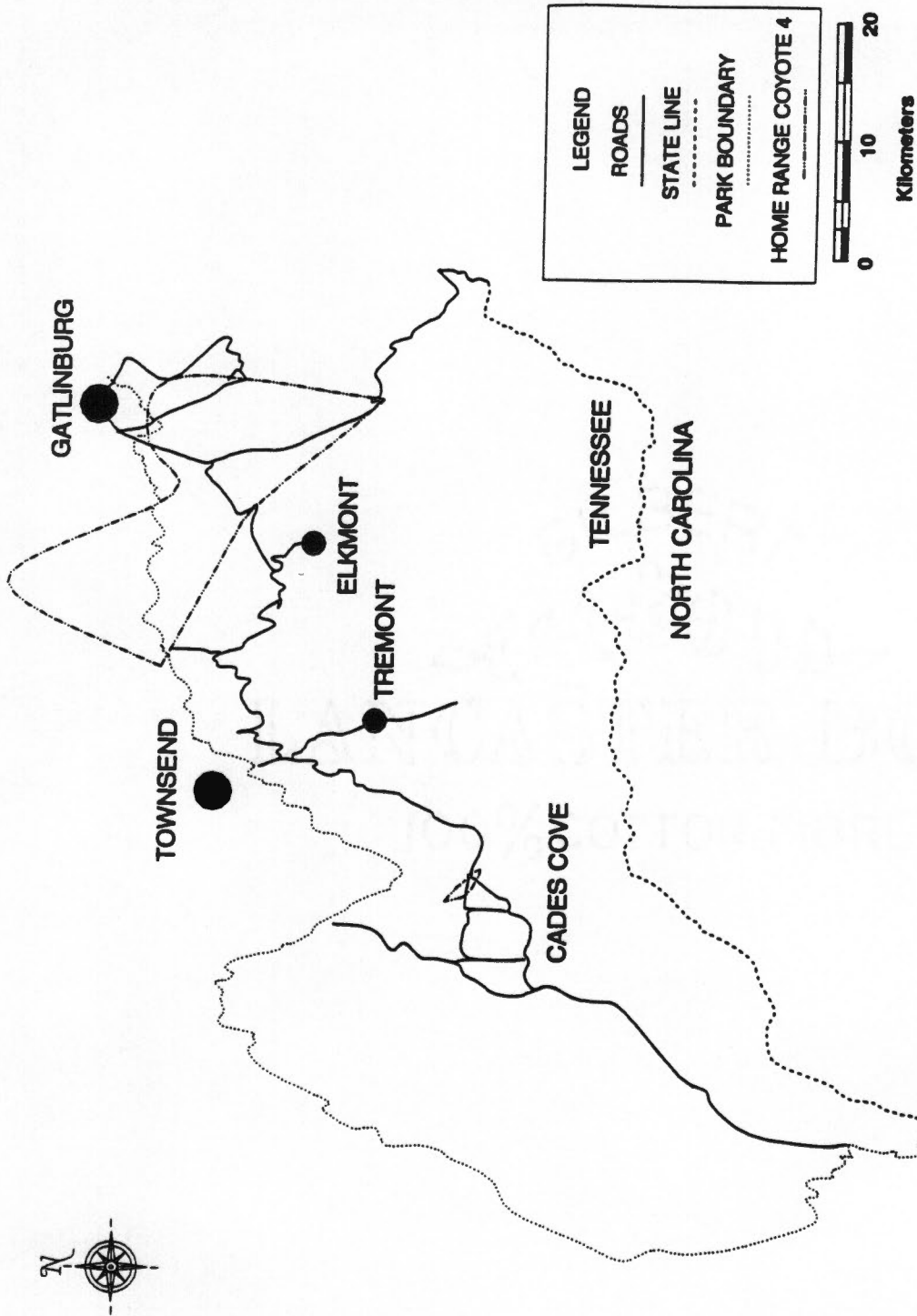


Appendix figure A-6: Movements of coyote 4 during gestation period in GSMNP.



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Appendix figure A-7: Movements of coyote 4 during pup - rearing season in GSMNP.



Appendix figure A-8: Movements of coyote 4 during dispersal season in GSMNP.

VITA

Barron Allen Crawford was born in Los Angeles, California on 18 May 1965. He grew up in Estill Springs, Tennessee. He attended Franklin County High School in Winchester, Tennessee and graduated in 1983. He entered The University of Tennessee, Knoxville's Department of Forestry, Wildlife, and Fisheries in 1985. He graduated in 1988 with a Bachelor of Science degree in Wildlife and Fisheries. In August 1988 he began a study towards a Master of Science degree in Wildlife and Fisheries at The University of Tennessee, Knoxville. He is currently working for Great Smoky Mountains National Park as the National Park Service Red Wolf Biological Technician.