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I am submitting herewith a thesis written by Jeffrey James Beringer entitled "Habitat Use and Response to Roads by Black Bears in Harmon Den, Pisgah National Forest, North Carolina." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

  
Michael R. Pelton, Major Professor

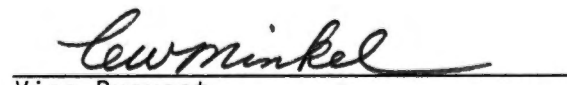
We have read this thesis  
and recommend its acceptance:







Accepted for the Council:

  
Vice Provost  
and Dean of The Graduate School

HABITAT USE AND RESPONSE TO ROADS BY BLACK BEARS IN HARMON DEN,  
PISGAH NATIONAL FOREST, NORTH CAROLINA

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

Jeffrey James Beringer

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Thesis  
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To the  
"Northwoods Boys"

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## ABSTRACT

Twenty black bears (Ursus americanus) were captured 22 times in Harmon Den Study Area, Pisgah National Forest, North Carolina, during 1984 and 1985. A total of 1735 radio locations was obtained on these animals. However, only 1312 (76%) of these were used in habitat analysis. Other locations did not meet predetermined selection criteria.

Male home ranges averaged 15 km<sup>2</sup> during summer and 36 km<sup>2</sup> during fall. Female home ranges averaged 10 km<sup>2</sup> during summer and 11 km<sup>2</sup> during fall. Male home ranges were significantly larger ( $P < 0.05$ ) than female ranges during summer, fall, and annually.

The method of harmonic means was used to calculate centers of activity. Activity centers did not vary significantly between seasons or on a yearly basis.

All mortality was human caused; 7 of 18 (39%) study animals were legally harvested (6) or poached (1) during the study. Annual mortality was 54% in 1984 and 8% in 1985.

Habitat use was determined using U.S. Forest Service Continuous Inventory of Stand Condition (CISC) maps and animal relocations from ground and aerial locations and transmitter drops. Chi-square analysis using ground radio-tracking data indicated that bears preferred pine stands and avoided yellow poplar stands during summer and selected for yellow poplar-white oak-northern red oak stands in fall. Stands

with site indices of less than 40 (forest openings) were preferred during summer and fall. Stands with site indices of greater than 81 were selected for during the fall. Bears preferred stands aged between 30 and 49 years and those older than 90 years during summer. They avoided stands aged 50 to 69 years during summer. During fall, females were indifferent to all stand ages and males avoided stands between 10 and 29 years old and those 70 to 89 years old.

Habitat use determined from transmitter drops was a more accurate method than ground or aerial tracking. Using this method bears were found to avoid nonforest, pine, mixed pine/hardwood, and yellow poplar stands and to select for yellow poplar-white oak-northern red oak stands. Preferences for the yellow poplar-oak cover type likely reflect the productive nature of these stands; most had site indices of greater than 80.

Forest cover types determined from ground sampling were different ( $P < 0.001$ ) from those available from CISC cover type maps. Perceived differences were likely a function of stand classification methods.

The reactions of bears to roads were examined by relating the number of road crosses by a bear to the road density in its home range, and to the traffic volume associated with these roads. Bear movements were not restricted by roads with traffic volumes of less than 100 vehicles per day regardless of road density. However, they seldom crossed ( $n=12$ ) Interstate 40, the western boundary of the study area.

Harmon Den appears to be serving its purpose as a bear sanctuary; however, illegal hunting within its perimeters is still common.

The current timber harvest rotation should continue to provide bears with adequate mast producing stands. However, caution must be observed to ensure proper oak regeneration, especially in the yellow poplar-oak stands. Clear-cutting timber in these stands will not regenerate an oak component equal to that which was present before timber harvest. Mistakes made in stand manipulation may take centuries to reverse.

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## CHAPTER I

### INTRODUCTION

Black bears (Ursus americanus) have inhabited the Southern Appalachians since before the arrival of white settlers. Their wide-spread range was undoubtedly a result of their adaptability and the fact that most of the area was forested. Bears were important in fulfilling the cultural and physical needs of Indian tribes and were used for food by early settlers. Since the early 1800's habitat loss has diminished the black bear's range throughout the United States and especially in the Southeast (Southern Appalachians). Bears today are limited to the few remaining tracts of large forested areas; these lands are chiefly government owned and most support stable bear populations.

As the geographic distribution of black bears has diminished, the remaining suitable habitats became increasingly important to the species. There will likely be no substantial range expansion of the species in the Southern Appalachians. Habitat encroachment from human activity is eliminating any remaining lands which are not federally owned. Bears forced to subsist in remaining isolated or marginal habitats are vulnerable to human caused mortality. The above underscores the need to properly manage the existing habitats to meet the needs of remaining populations.

In order to properly manage bear habitat, requirements for the self maintenance of bears must be understood. Bears have been extensively studied in Great Smoky Mountains National Park (GSMNP) to determine food habits (Beeman and Pelton 1980, Eagle and Pelton 1983), home range size and movements (Garshelis and Pelton 1981, Quigley 1982, Carr 1983), reproductive and denning biology (Eiler 1981, Wathen 1983), and habitat utilization (Quigley 1982, Carr 1983).

Park bears were found to be omnivorous with plant materials composing 80% of their diet; spring foods were primarily herbaceous, summer foods included various fruits, and hard mast (when available) composed the majority of utilized fall foods (Beeman and Pelton 1980, Eagle and Pelton 1983). Home ranges were larger for males ( $\bar{X}$  = 1110 ha) than for females ( $\bar{X}$  = 681 ha) (Pelton 1976). The average litter size of park bears was approximately 2, and they first produced offspring at 5 years (Eiler 1981, Wathen 1983). Habitat use was influenced by seasonal food availability (Quigley 1982, Carr 1983).

The above results are not representative of those found in areas subject to forest management. Disturbances caused by timber management on Forest Service lands are absent in GSMNP. Additionally many of these areas are open to hunting. National forest lands have higher road densities, hunting seasons, and timber compositions which are constantly changing because of timber harvest activities. High road densities promote hunter access and human disturbance. Hunting may change age structures and sex ratios (Jonkel and Cowan 1971, Lindzey and Meslow 1977, Modafferi 1982). Even aged management creates

a diversity of stand ages and compositions. However, old growth timber, important as producers of mast and den trees, is noticeably absent from those areas. Also much of the forest is managed for the species best suited for the site, not necessarily that which is present. Regeneration following clearcuts often favors intolerant species such as yellow poplar (Liriodendron tulipifera), red maple (Acer sachrum), and black locust (Robinia pseudo-acacia), not those originally present.

In order to determine reactions of black bears to the aforementioned disturbances caused by forest management, studies were initiated in nearby national forests. Studies have already been completed in Citico Creek, Cherokee National Forest (CNF), Tennessee (Garris, 1983, Clevenger 1986). This study is the second in a series of research projects in Harmon Den, a portion of Pisgah National Forest, North Carolina. The study was initiated by the United States Forest Service and is designed to document bear use of habitat and reactions to roads and/or disturbances associated with roads. It is hoped that these findings can be incorporated into forest management decisions and that further management will favor black bears. Specific objectives of this study were to describe:

- (1) Black bear utilization of available habitats in Harmon Den, Pisgah National Forest.
- (2) The effects of forest management on seasonal movements and habitat utilization.
- (3) The effects of roads and their associated disturbances on bear movements.

## CHAPTER II

### STUDY AREA

#### Location

The Harmon Den Study Area is in the French Broad Ranger District of Pisgah National Forest, Haywood County, North Carolina (Figure 1). The study focused on a 5740 ha area of the forest. Originally the study area extended to portions of the 12 Mile Strip, an area west of Interstate 40 (Brody 1984a). This area was abandoned for 3 reasons: (1) Most bears found in the 12 Mile Strip are actually residents of adjoining GSMNP or are dispersing males. (2) The 12 Mile Strip receives extremely heavy hunting pressure while Harmon Den is a bear sanctuary. (3) Restricted budgets and manpower made a trapping/telemetry study over the entire area impossible.

Harmon Den, referred to as "Harmon's Den" by local residents, was named after a Civil War evader who lived in a rock outcrop on what is now Harmon Den Mountain (Letha Hicks, pers. comm.). The study area is bounded on the north by the North Carolina-Tennessee State line, on the south by private lands, on the east by Interstate 40, and on the west by Madison County, North Carolina. Major cities in the surrounding area include Newport, Tennessee, 42 km to the west, and Waynesville, North Carolina, 48 km to the south. The Pigeon River drains the area; its major tributaries include Hurricane, Cold Springs and Ground Hog Creeks.

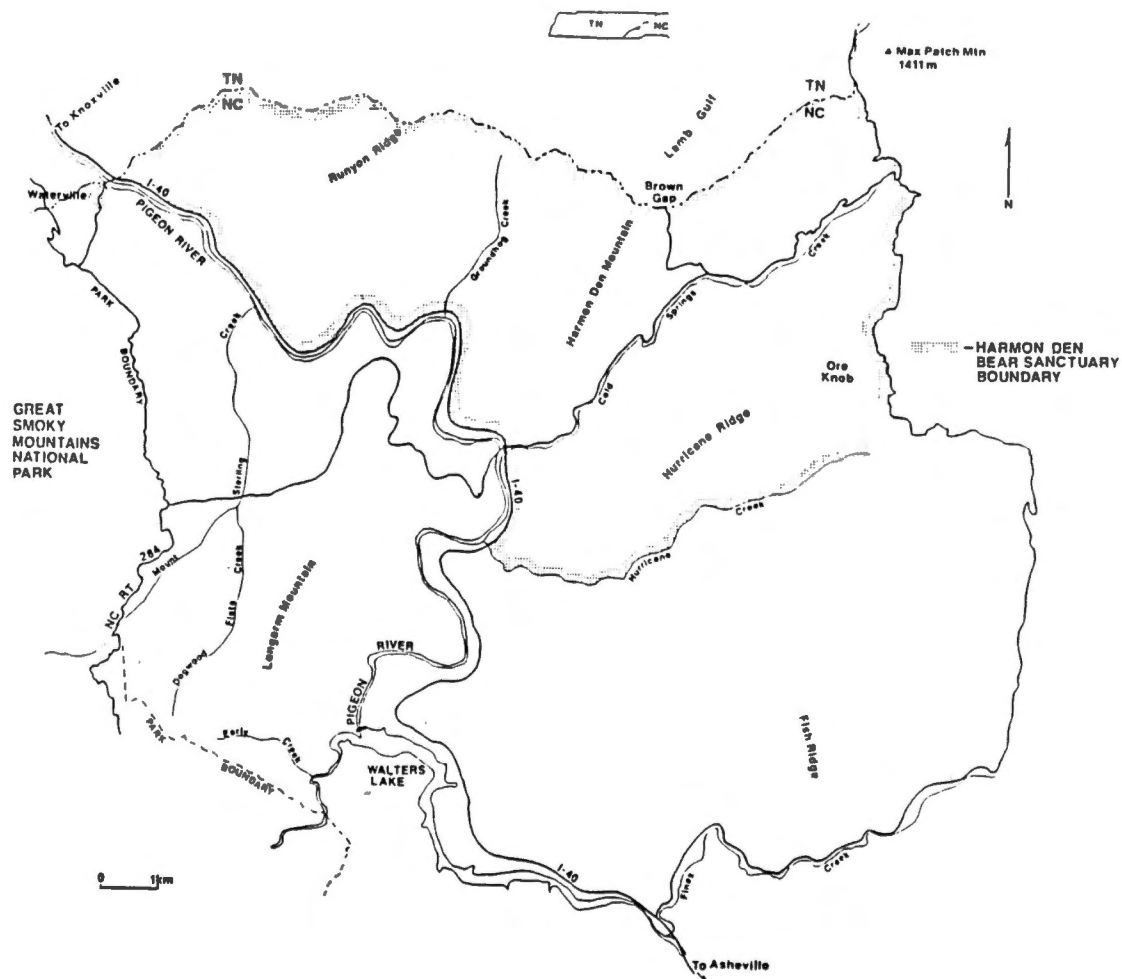


Figure 1. The Harmon Den Study Area in Pisgah National Forest, North Carolina.

### Physiography

Harmon Den lies in the unglaciated portion of the east-central United States. It is part of the Blue Ridge Physiographic Province and lies within the Bald Mountains Range of the Unaka Chain (Fenneman 1938). The mountains are sharply dissected and the terrain is steep. The drainage pattern is coarse (Fenneman 1938). Mountain peaks are as high as 1800 m (USFS 1982b). Locally, elevations of 1260-1320 m are common; slopes average over 30% (Finlayson 1957).

Soil parent materials for the area include granites, gneisses, and schists on the more productive sites. Soils of poorer quality are from sedimentary and meta sedimentary rocks (USFS 1982b). However, site quality is more directly related to elevation, slope and aspect than to soil parent material.

### Biota

The dissected terrain and varying slopes and aspects create microhabitats for a variety of plant species. At least 1,885 plant species have been documented on U.S. Forest Service lands (USFS 1982b). Vegetation descriptions by King and Stupka (1950) in the nearby Great Smoky Mountains National Park, showed that there were 131 different tree species. Barrett (1980) called the forests mixed oak. The Society of American Foresters (1926) classified the forests as: (1) the northern forest; (2) moist slope and cove forest; (3) dry slope and ridge forest. The northern forest group occurs at the highest elevations and is essentially a spruce-fir cover type. It is

all but absent in Harmon Den. However, moist slope cove forest and dry slope ridge forest groups are well represented. These 2 forest groups are subdivided into 4 major forest cover types by the U.S. Forest Service (USFS 1981).

The 4 types are:

1. Pine types--70% of the crowns in dominant and codominant positions are softwoods.
2. Pine-hardwood types--51-69% of the crowns in dominant and codominant positions are softwoods.
3. Hardwood Pine types--51-69% of the crowns in dominant and codominant positions are hardwood species.
4. Hardwood types--70% or more of the crowns in dominant or codominant positions are hardwoods.

The majority (88%) of Harmon Den is in hardwood cover types. These stands are most important as producers of mast and den trees. Five cover types are prevalent:

1. White Oak-Red Oak-Hickory. This type covers 45% of the Harmon Den study area. It occurs on dry to moist sites and at elevations between 150 and 1,220 m. It may become the climax type on dry sites. Common understory shrubs include dogwood (Cornus florida), sassafras (Sassafras albidum), sourwood (Oxydendrum arboreum), and serviceberry (Amelanchier spp.). Herbaceous species common in this type are poverty oat grass (Avena fatua), Solomon's seal (Polygonatum biflorum), may apple (Podophyllum peltatum), and trillium (Trillium grandiflorum).

2. Yellow Poplar-White Oak-Northern Red Oak. This cover type covers approximately 26% of the area. It is found on good sites with good soil depth and moisture, and occurs at elevations between 150 and 1500 m. The climax species for this type is upland oak, barring no disturbances. Understory species commonly associated with this forest cover type are sugar (Acer saccharum) and red maple (Acer rubrum), oaks (Quercus spp.), hickories (Carya spp.), and spicebush (Lindera benzoin). Herbaceous cover includes Christmas fern (Polystichum acrostichoides), maidenhair fern (Adiantum podatum), cinnamon fern (Osmunda cinnamomea), and spring beauty (Claytonia virginica).

3. Yellow Poplar. This forest cover type represents approximately 10% of the Harmon Den study area. This stocking is commonly associated with other species requiring moist sites. It is found on the best sites. Site index values are often over 100 (30 m at base age 50 years). Elevations supporting this type range to 1000 m. Soils are deep, moist, and well drained. Aspects are north or northeast. Yellow poplar (Liriodendron tulipifera) is not a climax species and is usually replaced by more shade tolerant species. Maples, oaks, hickories, greenbrier (Smilax spp.), and dogwood are common understory species found in yellow poplar cover types. Aster (Aster spp.), Jack-in-the-pulpit (Arisaema triphyllum), and Christmas and cinnamon ferns are common herbaceous species.

4. Scarlet Oak. Scarlet oak (Quercus coccinea) represents 5% of the Harmon Den area. Found on poor sites, this species is

common on shallow soils and gravelly sites. Aspects are usually south to southwest, ridge tops are also common. Scarlet oak is often found with pitch (Pinus rigida), table mountain (Pinus pungens), and Virginia pines (Pinus virginiana). It is more tolerant than the pines and may become the climax species. Shrub associates are mountain laurel (Kalmia latifolia), greenbriar, and huckleberry (Gaylussacia spp.). Common ground cover is wintergreen (Gaultheria procumbens), partridge berry (Gaultheria hispidula), and hobblebush (Viburnum alnifolium).

5. Chestnut Oak. This type covers approximately 3% of the Harmon Den area; it is primarily a ridge top cover type and grows at elevations up to 1400 m. Dry sites with thin soils and southern aspects are favored by this species. Shrub species found in this cover type are blueberries (Vaccinium spp.), huckleberries, mountain laurel, and flame azalea (Rhododendron calendulaceum). Wintergreen, Indian pipe (Monotropa uniflora), and partridge berry are often found in the sparse herbaceous layer.

### Climate

Thornthwaite (1948) described the climate as a warm-temperature rain forest. Precipitation and temperature vary greatly with elevation and aspect; average precipitation is 152 cm per year (NOAA 1980). Higher elevations tend to receive more precipitation and have lower temperatures. July receives the most precipitation and November the least, 14.4 and 9.2 cm, respectively. Temperatures reach their

peak during July ( $\bar{X}$  = 22.6°C) and are lowest during January ( $\bar{X}$  = 3.3°C). Warm humid summers with afternoon showers are normal. Snowfall occurs from November to March; showers of up to 40 cm were observed during the study. However, most snow does not remain over 1 week. Precipitation exceeds evapotranspiration in all seasons (NOAA 1972).

### Fauna

Harmon Den and the surrounding area support a diversity of wildlife. While not all present within this study area, Linzey and Linzey (1971) found 59 species of mammals in Great Smoky Mountains National Park. Big game species observed during the study include black bear, white-tailed deer (Odocoileus virginianus), and turkey (Meleagris gallopavo). Small game animals observed were ruffed grouse (Bonasa umbellus), gray squirrel (Sciurus carolinensis), red squirrel (Tamiasciurus hudsonicus), raccoon (Procyon lotor), gray fox (Urocyon cinereoargenteus), cottontail rabbit (Sylvilagus floridanus), bobcat (Lynx rufus), opossum (Didelphis virginiana), and woodchuck (Marmota monax).

There is a variety of nongame animals inhabiting the area. King and Stupka (1950) listed over 200 species of birds inhabiting the Southern Appalachians. Warbler migrations were noted each year of the study. Raptor populations are good. Raptors observed during the study were the red-tailed hawk (Buteo jamaicensis), Coopers hawk (Accipiter cooperii), sharp-shinned hawk (Accipiter striatus), great

horned owl (Bubo virginianus), and saw whet owl (Aegolius acadicus). Attempts to reintroduce golden eagles (Aquila chrysaetos) through hacking were carried out on Max Patch during each year of study.

#### Designation As A Bear Sanctuary

Harmon Den was designated as a bear sanctuary by the North Carolina Wildlife Resources Commission in 1971. Sanctuaries are intended to protect a core population of breeding females and provide a surplus of animals for the hunted surrounding areas. Harmon Den is open to small game (excluding raccoon) and deer hunting. Areas adjacent to Harmon Den receive heavy bear hunting pressure. Bear hunting is a local tradition in the area and is by far the most popular recreational activity among hunters. During this study, the bear season lasted 9 weeks, opening in mid-October. There was a 3 week period in November and December during which it was closed to allow for the deer season. Many bear hunters hunted every day of the bear season. All hunters used dogs. Baiting (on private lands) was outlawed in 1985; however, several bait piles were observed each year. Hunters harvest sanctuary bears each year through perimeter hunting. Illegal hunting within the sanctuary occurs frequently (Brody 1984a, pers. observ.). Other recreational activities in Harmon Den include ginseng (Panax quinquefolius) gathering, horseback riding, trout fishing, and car camping.

### History and Land Use

Before lands in Harmon Den were purchased and/or condemned by the U.S. Forest Service, they supported several families. The first white inhabitants were subsistence farmers. Hogs and cattle ran wild in the forests and were gathered each fall. Balds and other openings were used for crop farming. Logging began in the late 1800's; tram roads are still visible throughout the area. Most logging was completed by 1920. Today 75% of the forest is between 60 and 80 years old (USFS 1982b). Logging is still occurring but on a reduced scale compared to the earlier days. However, farming and logging are still the major forms of employment for many residents. Recently, the area has become a popular spot for retirement homes. Most of the retirees are from out of state, the majority coming from Florida. Rural areas are growing more rapidly than nearby incorporated towns (USFS 1982b).

## CHAPTER III

### MATERIALS AND METHODS

#### Trapping and Handling

Trapping was performed intermittently between the months of June and September each year. Prebaiting (Johnson and Pelton 1980) was used in 1985. Trapsites were selected along ridge tops, areas showing fresh bear sign, or game trails. During 1984, traplines were run on Hurricane Ridge and Harmon Den Mountain. A series of traps was also placed along the forest service road to Hurricane Gap. In 1986, Hickory Ridge also was trapped. Ridge top traps were checked by foot, and road traps by vehicle each day. Personnel from the North Carolina Wildlife Resources Commission assisted for 14 days in June each year. This extra manpower enabled us to trap almost the entire core area. Trapping for the rest of the year was on a limited basis.

Bears were trapped with Aldrich foot snares using the methods of Johnson and Pelton (1980). Captured bears were immobilized with intramuscular injections of a mixture of Ketaset (Ketamine hydrochloride, Bristol Laboratories, Syracuse, NY), Rompun (Xylazine, Haver-Lockhart, Inc., Shawnee, KS), and Carbocaine V (Mepivacine hydrochloride, Winthrop Laboratories, New York, NY). Drug ratios in the mixture were 2:1:0.2, respectively. Ketaset and Rompun are

general anesthetics and carbocaine is a local anesthetic. The drug was administered using a dart fired from a CO<sub>2</sub> powered pistol (CAPCHUR, Palmer Chemical Company, Douglasville, GA), a jab stick, or a syringe. The method used depended on the individual bear and capture circumstances. Dosages were 200 mg/100 mg/20 mg per 45 kg body weight.

Following sedation, bears were weighed, measured, and examined for external parasites. Blood and hair samples were taken and a premolar was extracted for aging purposes. Ages were determined by counting cementum annuli using the techniques of Willey (1974) and Eagle and Pelton (1978). Initial captures were marked with numbered ear tags and tattoos. During 1984, two types of ear tags were used; a yellow tag was placed in the right ear of females and a silver tag in the left. The opposite ears were tagged as mentioned for males. During 1985, only metal tags were used because of the ease and consistency of application. Tattoos were placed in the lip or the inner groin. Selected individuals were fitted with radio collars operating in the 150-152 Mhz range (Telonics, Mesa, AZ). Breakaway collars, designed to fall off after 18 months, were used; electrical tape was wrapped around the breakaway portion of each collar to ensure that they did not fall off before this time. Bears were given liquamycin (Phizer Laboratories, New York, NY) intramuscularly and spray antibiotics locally to prevent infection from trap injury or handling. Lactating females were given oxytocin (Burns Veterinary Supply Oakland, CA) to stimulate milk let down because Ketaset inhibits it.

The dens of surviving study animals were visited each winter. Den sites were located aerially. Ground homing techniques (Mech 1983) were used to find each site on the ground. After finding the den, bears were immobilized and processed as previously described. During these visits radio collars were replaced if necessary, cub production was recorded, and the general condition of the animal was noted. Physical characteristics, such as den type (ground nest, tree den, rock crevice), aspect, and surrounding habitat were also recorded. The dens of females with cubs were visited again, after they had left, to document cub mortality.

#### Radio Telemetry

Radio-tagged animals were monitored using ground triangulation and aerial homing techniques (Springer 1979, Mech 1983). A TR-2 receiver (Telonics, Mesa, AZ) and TDP-2 digital signal processor, (Telonics) equipped with a 2 element H antenna, were used to track the animals. The TDP-2 helped differentiate between similar signal strengths. Whip antennas were used when attempting to locate lost animals.

Ground triangulation was the primary method used for locating collared animals. Ridge tops, gaps, and other places which were identifiable on topographic maps and provided an unobstructed view were used as sites from which to radio-track. Most tracking was done from roads. There were 46 tracking sites that were used regularly. In most instances 5-7 azimuths were taken for each animal during

each tracking period. Rough locations were plotted in the field to determine which azimuths were accurate. Often 1 or 2 azimuths would be much different from the rest; these were discarded. Only 2 azimuths were used to delineate the animal's position. These 2 azimuths were selected using the following criteria: (1) the angle between the 2 azimuths was between  $60^\circ$  and  $120^\circ$ , (2) the time interval between azimuths was less than 30 minutes, (3) the signal integrity was good, (4) the distance between the receiver and animal in question was closest using the selected azimuths, and (5) judging from topography, there were no ridges or obstructions between the receiver and radio-tagged animal.

Directional accuracy of the telemetry equipment (and user) was tested using preplaced transmitters at known locations. The transmitters were placed at various elevations and distances. One hundred azimuths were taken on these preplaced transmitters. Azimuths were taken from the same tracking points used most often when tracking collared bears. As with bear locations, only signals with good integrity were used. Mean deviation from the actual azimuth was measured and a 95% confidence area was calculated. This confidence area was used to construct error polygons (Springer 1979).

Error polygons were used to circumvent the poor telemetry accuracy caused from signal deflection. Selected azimuths were entered into the computer program PLOTEQ (Brody 1984b). PLOTEQ calculates error polygons using the predetermined confidence area. Output from this program was then run through the program NEWPLO

(Brody 1984b). NEWPLO, when used with a Calcomp flatbed plotter, draws the error polygons to a scale of 1:24000. Error polygons were then overlaid on cover type maps of the same scale; habitat use then was tallied. Error polygons were discarded if they were larger than 50 hectares or encompassed more than 5 cover types.

### Sampling Schedule

Bears were located every 20 hours; this sampling schedule was used because it resulted in locations at all hours and the locations were independent (Dunn and Gipson 1977, Lindzey and Meslow 1977, Smith et al. 1981, Garshelis 1983). Samuel and Garton (1985) indicated the importance of independent locations and stated that "animal locations should be representative of the proportion of time an animal spends in a given area." Using these techniques the bias of time of day on habitat use should be eliminated. When collared bears could not be found by ground tracking, and weather permitted, they were located aerially. A Cessna 172 fixed wing aircraft with H antennas mounted on each wing was used for this method. Aerial tracking techniques used in this study are described by Quigley (1982) and Carr (1983). Aerial locations were estimated to be within a 300 m diameter circle by Quigley (1982). This degree of accuracy was determined by using preplaced transmitters. Accuracy checks in Harmon Den yielded similar results. However, the accuracy of individual bear locations probably varied with flying conditions.

### Transmitter Drops

Habitat studies using cover type maps require accurate locations to successfully place a bear in a particular habitat. Telemetry in mountainous terrain often results in deflected signals, large error polygons, and long time intervals between consecutive readings, thus biasing perceived habitat utilization. Aerial locations eliminate telemetry problems associated with ground tracking.

Cover type maps used in this study were sometimes inaccurate (Brody 1984a, pers. observ.) or lacked the desired detail. Stand composition and boundaries for the area were recorded by USFS personnel and private contractors, and were somewhat subjective. To overcome the problems of telemetric and map inaccuracies, a transmitter drop technique was devised to locate a bear at a given time and, through vegetative sampling and sign interpretation, determine bear activities. Habitat preferences using this method were compared to those found using traditional ground tracking and to those found when using only aerial tracking.

Equipment used for the transmitter drops were refurbished raccoon transmitters, operating in the 150-152 Mhz range (Wildlife Materials, Inc., Carbondale, IL), wrapped in foam rubber 15-20 cm thick, Telonics TR-2 receivers, and 2 element yagi antennas.

Collared bears were located aurally. After a good location was obtained, aircraft speed was reduced to 70-80 knots (129-148 km/hr) and above ground altitude reduced to 40-150 m; this varied depending on wind speed and topographic location of the collared

bear. As the desired spot was approached, the passenger held a transmitter package out the window and, at the pilot's command, dropped the package. Transmitters were dropped approximately 2 seconds per 40 m altitude ahead of the desired spot. The path of the dropped transmitter could be observed and recorded about 50% of the time.

The dropped transmitters were retrieved within 2-3 days. Ground homing techniques were used to find the transmitter packages. After finding the package, steep sites were examined for skid marks to see if the package had rolled. A systematic search of the area was conducted for evidence of bear use. Vegetation was sampled using a modified stratum rank method (Lindsey et al. 1961). Other data routinely collected included stand age, mast abundance, slope, and aspect. The site position was checked with topographic features before leaving. A data sheet is included in the Appendix.

#### Vehicular Traffic Volume

Pneumatic traffic counters were used to determine the traffic volume of study area roads. A counter was already in place on Cold Springs Road. Counters were installed on the roads to Brown and Hurricane Gaps. Volume was checked daily until the counters were stolen or vandalized. Roads were classified based on their traffic volumes.

#### Data Analysis

For the purposes of analysis, bears were grouped by sex and age. Bears were considered adults if they were 3 years or older

because they are sexually mature (Collins 1973); otherwise they were considered subadults.

Habitat use was examined on a seasonal basis because it may vary with seasonal foods (Jonkel and Cowen 1971, Amstrup and Beecham 1976, Beeman and Pelton 1980, Eagle and Pelton 1983). Seasons were classified based on observations of available foods and the number of animal locations. The 2 seasons were: (1) Summer--den emergence to September 14. Most bear sign observed during this period indicated bears were using soft mast through August. Eagle and Pelton (1983) found bears had similar nutrition levels through early fall. (2) Fall--15 September to den entrance. During this period, bears in GSMNP fed on acorns more than other foods when they were available (Eagle and Pelton 1983). Strickland (1972) found hard mast production was greatest during this period.

#### Home Range

Home ranges were calculated for those animals with at least 15 locations. Ranges were calculated for individual bears on a seasonal basis. The convex polygon method (Hayne 1949) was used to compare home range size among bears. The convex polygon method defines the minimum spatial use of an area during an animal's normal activities (Beeman 1975, Young and Ruff 1982). It has been used in many previous studies in the Southern Appalachians (Beeman 1975, Garshelis and Pelton 1981, Quigley 1982, Villarrubia 1982, Carr 1983, Garris 1983, Brody 1984a, Clevenger 1986, Warburton and Powell 1986) and could therefore be used for comparison with other studies.

The computer program TELEM (Koeln 1980) was used to construct home ranges. The program was modified so that output data from PLOTEQ could be used directly. Convex polygon home ranges generally represent the minimum perimeter of a home range (Voigt and Tinline 1980).

Ranges were produced on tracing paper at a scale of 1:24000; the same scale as study and cover type maps. In 2 instances, a single outlier location caused the home range to be disproportionately large. There were no transit locations between the outlier and the majority of locations to indicate an exploratory venture. Other studies (Quigley 1982, Carr, 1983, Smith 1985) have circumvented the effects of outlier locations by constructing a corridor between the outlier and the polygon. The 1 km wide corridor was added to the home range determined without the outlier. In this study, I felt the 2 outliers were likely the result of telemetry or recorder error and they were discarded.

Comparisons of home range size were made seasonally and between sex and age groups. Comparisons were made using nonparametric tests with SAS (SAS Institute 1982), using Rank and General Linear Model (GLM) procedures.

"Home ranges" also were calculated based on the methods of Dixon and Chapman (1980). This method calculates a utilization distribution based on the reciprocal mean location distance between each location and a superimposed grid. Areas enclosing predetermined percentages of the animal's locations were drawn. The computer program HARMON (Brody 1984b) was used to calculate and draw these utilization

distributions to a scale of 1:24000. The utilization distributions were used to determine which habitat types were available to bears within their home ranges.

HARMON was also used to calculate centers of activity for each bear on a seasonal basis. Dixon and Chapman (1980) used this term to define "the geographical location within the home range of the point of greatest activity." This method of calculating activity centers was used because (1) it is insensitive to movements within the animal's home range and (2) it is located within the home range (Dixon and Chapman 1980). These characteristics are not consistent when using arithmetic centers of activity. Other disadvantages of arithmetic activity centers are discussed by Neft (1966).

Harmonic centers of activity were used to measure seasonal movements and stability of seasonal home ranges. Distances between activity centers were calculated by:

- (1) Determining the difference between the northerly UTM (Universal Transverse Mercator Grid System) coordinates for each activity center and squaring it.
- (2) Determining the difference between the easterly UTM coordinates for each activity center and squaring it.
- (3) Adding and taking the square root of these differences.

Activity centers were compared between the 2 female age classes. Shifts of activity centers were compared on a seasonal basis for each year (intra-yearly) and between years (inter-yearly). Fall home range data were limited to a single male bear, hence comparisons between sexes were not made.

### Habitat Utilization

U.S. Forest Service continuous inventory of stand condition (CISC) data and my vegetation inventories were used to classify cover types. CISC data are based on the stand; a stand is the smallest unit managed by the Forest Service and its conditions are continually updated. Stands are further grouped into compartments consisting of from 6 to 40 stands. Available from CISC data are a variety of habitat measurements. Those used in this analysis included cover type, age, and site index. Table 1 lists habitat components that were selected for analysis of bear use. Stand types were grouped in order to generate a sample size large enough to "assure a reasonable approximation to the Chi-square distribution" (Byers et al. 1984:1050; Roscoe and Byars 1971). Stand age groupings follow those used by Brody (1984a) and Clevenger (1986). Site indices are difficult to compare among tree species but the grouping used in this analysis approximate site classifications used by Carmean (1968).

### Determining Available Habitat

The first step in analyzing utilization-availability data is determining what habitat is available to the animals in question. Studies in the Southern Appalachians have used various methods to determine availability. Quigley (1982) used an area "which encompassed most bear locations" as that which was available to all bears; Garris (1983) used a similar procedure. Brody (1984a) calculated a utilization distribution using all bear locations and this was

used as the boundary of available habitat. In another region Smith (1985) used his study area core as representing the area available to all bears. Habitat availability as determined using the aforementioned methods assumes that a given area is available to all bears regardless of age or social status. Granted, bears are mobile enough to theoretically reach and use a huge area (Garshelis 1983), and male bears do use large areas, but I feel there are shortcomings in using such a large area to represent availability. Garshelis and Pelton (1981) found males excluded females from preferred mast areas during fall foraging. Carr (1983) and Clevenger (1986) calculated separate availability proportions for male and female bears. Clevenger (1986) used the cumulative home ranges for each bear to tally available habitat. Availability data were summed among sex and age groups. The same areas were assumed available each season. This method circumvents the problems associated with grouping sexes when determining available habitat.

The methods used to determine available habitat for this study most closely approximate those of Clevenger (1986). However, in this study available habitat was calculated for each bear using seasonal rather than cumulative utilization distributions. Contours encompassing 90 and 95% of the total locations for males and females, respectively, were used as boundaries in tallying available habitat. Areas of each habitat component used for analysis were totaled for each bear by season. Inadequate sample sizes precluded analysis of individual bears (Roscoe and Byars 1971) so they were grouped

by sex. Comparisons were based on available habitat for a particular sex and season.

### Habitat Use

Habitat use for each bear was calculated on a seasonal basis. Error polygons were used because telemetry accuracy was generally poor. Error polygons vary with the distance from transmitter to receiver and the angle between the azimuths. This technique eliminates biases created by using a predetermined area for every location. Error polygons were overlaid with U.S. Forest Service cover type maps. The compartment and stand of each location were recorded; if an error polygon covered more than one stand the percentage of each stand covered was recorded. Error polygons were discarded if they were larger than 50 ha or covered more than 5 stands. Because each location had a stand and compartment number they could be merged with the CISC data (SAS Institute 1982). Habitat variables (Table 1) were totaled for each bear by season, thereby giving a percentage of use. These utilization data were compared with availability data using the methods of Neu et al. (1974) and Byers et al. (1984).

Habitat use also was calculated using data gathered for the transmitter drops. Habitat availability data used were those which were calculated for females. Use data were determined from vegetation surveys at drop sites; each site was considered a location. Vegetation was classified into the same groups used in CISC so that comparisons could be made. Cover types determined using this method were

Table 1. Habitat variables selected for analysis of bear use in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Habitat Variable                                  | Divisions                                                                                                                                                                 |
|---------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Forest cover type                                 | Nonforest<br>Softwood<br>Mixed Hardwood Softwood<br>Yellow Poplar<br>Chestnut Oak<br>White Oak-Red Oak-Hickory<br>Scarlet Oak<br>Yellow Poplar-White Oak-Northern Red Oak |
| Stand Age (years)                                 | > 9<br>10-29<br>30-49<br>50-69<br>70-89<br>90+                                                                                                                            |
| Site Index (height of dominant trees at 50 years) | 0-49<br>41-60<br>61-80<br>80+                                                                                                                                             |

compared to CISC stand maps. Forest cover types were considered equal if 2 of the 3 major tree species observed were listed in the U.S. Forest Service cover type or if the tree species considered most abundant was the same using both methods.

#### Determining Response to Roads

Roads and vehicular disturbance have been shown to influence movements of turkey (Wright and Speake 1975), white-tailed deer (Dorrance et al. 1975), and mule deer (Rost and Bailey 1979), among others. Bears' reactions to roads have been documented but with contrasting results. Studies reporting bear avoidance of roads include those of Miller (1975) and Brown (1980) in West Virginia, Hamilton (1978) in Eastern North Carolina, Quigley (1982) in GSMNP, Villarrubia (1982) in Cherokee National Forest, Tennessee, and Brody (1984a) in western North Carolina. Hugie (1982) noted that bears crossed small roads and secondary highways when the roads crossed bear travel routes. Carr (1983) found that bears crossed roads regularly and that they used habitat near roads as often as that which was away from roads. Whether bears are reported to react negatively to roads or vehicular traffic may depend on the method of analysis (Brody 1984a), the characteristics of the habitat around a particular road (Quigley 1982), the learned avoidance of an individual or subpopulation or whether or not the population is hunted (Geist 1971, Dorrance et al. 1975). The road analysis used in this study parallels that of Brody (1984a). Road crossing index (RCI) was plotted (defined

as the number of times an animal crossed a road divided by the total locations for that animal) against road density (km of road divided by area in home range) and road class (determined by traffic volume) to determine if bears crossed roads in proportion to their availability, or avoided roads with greater traffic volumes. Variables used in this analysis are listed in Table 2.

If bears cross roads in a direct relationship to their availability, the best fit line for these plots would be a straight line with a positive slope (Figure 2). Plots of road density versus RCI were compared to this theoretical plot to determine if bears were in fact indifferent to roads.

An additional variable used in this study was road avoidance index (RAI), defined as the number of times a collared bear moved parallel to or away from a road, yet moved far enough to potentially cross the road, divided by the total locations for that animal. If bears are not indifferent to roads there should be a direct relationship between road density and road avoidance; as road density increases road avoidance also increases. Plots of road avoidance index against road density were fitted with regression lines (when appropriate) and relationships were noted.

Road crossing and avoidance indices were calculated for bears seasonally. Most (66%) animals used in the analysis had a 79% or better tracking success rate. For the rest, road crosses were tabulated only during periods of successful daily tracking.

Traffic counters were used to determine vehicular volume. Roads were classified according to the mean number of vehicles per

Table 2. Variables used in analysis of the effects of roads on bear movements in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Variable                      | Explanation Definition                                                                                                                                                                                                                                                     |
|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Road Class 1, 2, 3            | Broken into 3 classes as determined by traffic volume.<br><br>Road Class I = $\bar{X}$ traffic volume > 1000 vehicles per day<br><br>Road Class II = $\bar{X}$ traffic volume = 75 vehicles per day<br><br>Road Class III = $\bar{X}$ traffic volume = 15 vehicles per day |
| Road Crossing Index (RCI)     | Determined by dividing total road crosses (by Road Class) by total locations for a seasonal home range.                                                                                                                                                                    |
| Modified Road Crossing Index  | Same as road crossing index but divided by km of each road class.                                                                                                                                                                                                          |
| Road Avoidance Index (RAI)    | Determined by counting the number of potential road crosses (bear moved parallel to or away from road without crossing it yet moved far enough to potentially cross it) and dividing by total locations.                                                                   |
| Modified Road Avoidance Index | Same as road avoidance Index but divided by km of each road class.                                                                                                                                                                                                         |
| Road Density                  | Km's of each Road Class divided by km <sup>2</sup> s of area in a bear's seasonal home range.                                                                                                                                                                              |
| Season                        | Summer or Fall                                                                                                                                                                                                                                                             |
| Year                          | 1984 or 1985                                                                                                                                                                                                                                                               |

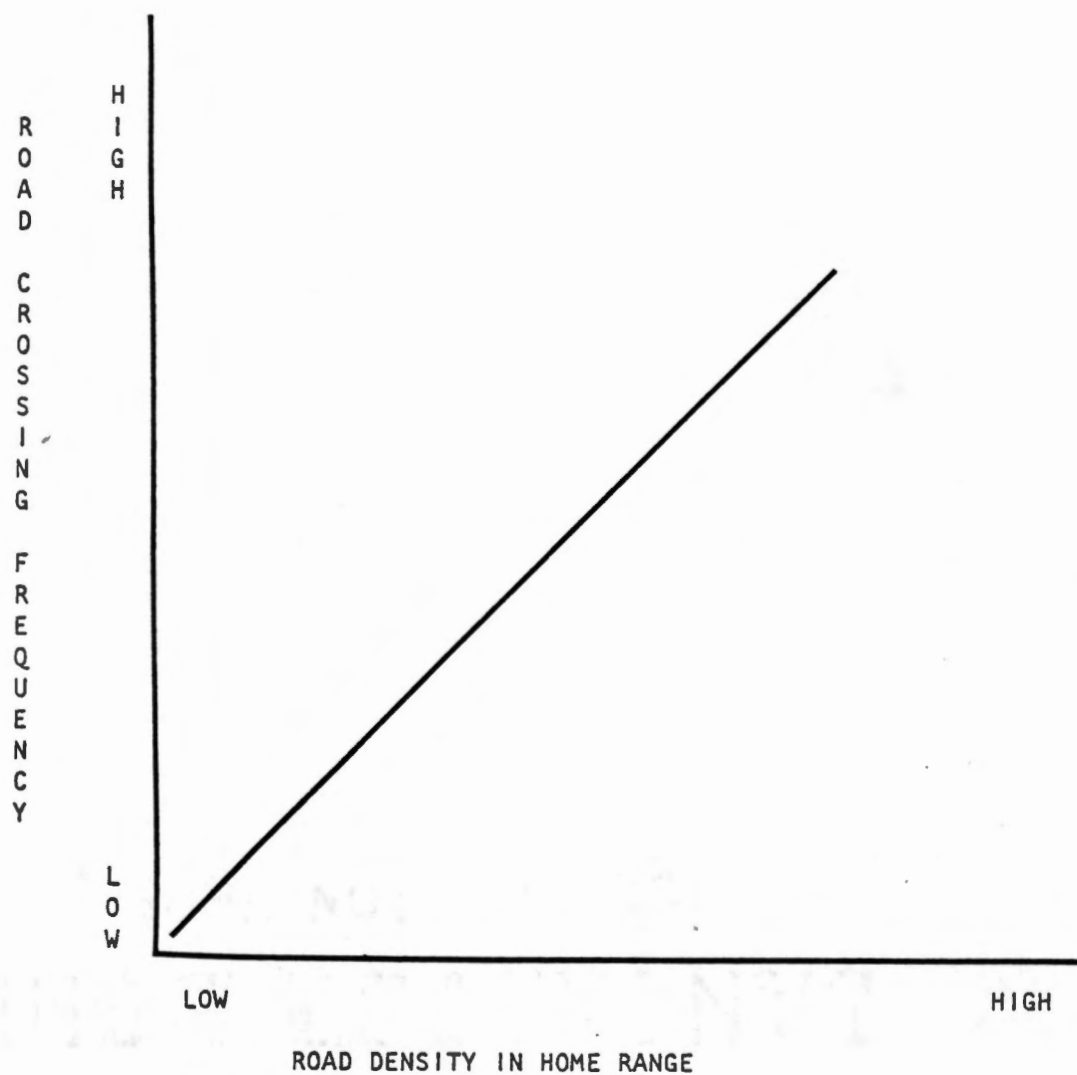


Figure 2. Relationship between road crossing frequency and kilometers of roads in a bear's home range if bears are indifferent to roads. (From Brody 1980a.)

day. Class I roads had 1000+ vehicles per day, Class II roads had 50-100 vehicles per day, and Class III roads had 5-20 vehicles per day.

Initial analysis consisted of plotting the dependent variable (Road Crossing Index or Road Avoidance Index) against each of the predictor variables. Road density, road class, year, and season were used as predictor variables. If the plots indicated anything other than a random distribution, the analysis was continued. Tests for interactions among predictor variables were accomplished by using separate symbols for each variable in the plots. If the individual symbols were clumped or a nonrandom distribution was evident, tests of correlation were run. Highly correlated variables were combined and/or one of them was removed or both.

Variable selection procedures (SAS Institute 1979) were used to find the best predictor variables. A variable was removed if not significant at  $P < 0.05$ . Finally, a regression analysis was run to fit a line to each of the plots. A nonrandom relationship was accepted if the best fit equation was significant at  $P < 0.05$ .

A nonrandom relationship could be linear or curvilinear. To test for a curvilinear relationship the predictor variable was squared and added to the model. If the new variable was significant, this would indicate a possible curvilinear relationship. Additionally, plots of the dependent variable versus the residuals (the difference between the observed and fitted values of RCI or RAI) and this new variable were made. If a curvilinear relationship existed

it would be evident in these plots; otherwise a linear relationship was assumed. The best fit equation was compared to the theoretical relationships proposed by Brody (1984a) and this study.

Road crossing index was plotted against road class to determine if roads with varying degrees of traffic volume were crossed with equal intensity. For this portion of the analysis, roads were weighted; the road crossing index for each bear was divided by the road length (km) for that particular class. The resulting modified crossing index was compared among road classes.

To test if road crossing frequency varied among the 3 road classes, an analysis of variance was performed. Contrast statements were used to make comparisons among the 3 road classes (SAS Institute 1979).

Bears may avoid roads because of the human disturbance associated with them. One such disturbance is vehicular traffic. If bears avoid roads because of traffic, it could be hypothesized that they will cross roads with low intensities of use more than roads with high intensities of use. A plot of RCI against road class should show a direct, positive slope. To test this, plots were made and means among the road classes were compared.

## CHAPTER IV

### RESULTS AND DISCUSSION

#### Trapping and Handling

A total of 20 bears were captured 22 times in 1,012 trapnights during 2 years of trapping in Harmon Den. Overall trapping efficiency was 46 trapnights per capture; 4 were from the previous study on the area. Two of the initial captures were cubs which were released untagged. Physical data for captured bears are summarized in Table 3.

Hurricane Ridge was the most productive trapline in 1984 (7 captures) and 1985 (6 captures). Harmon Den Mountain trapline had a better trapnights per capture ratio: 23.7 versus 60 for Hurricane Ridge (Table 4).

More male than female bears were captured; the ratios of males to females was 13:9. Five of 9 female captures were recaptures. The high occurrence of female recaptures likely reflects their smaller home range, and site fidelity (Rogers 1977, Lecomte 1980). Additionally, the high male hunting mortality (60%), and the fact that one male removed its collar, left only 1 male to be recaptured in 1985. Sex ratios in un hunted populations tend to favor males (Beeman 1975, Smith 1985), while those in heavily hunted populations favor females (Rogers 1977, Lindzey and Meslow 1977, Modafferi 1982, Beecham 1983).

Table 3. Capture, marking, and physical data for bears captured in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Ear Tag # | Transmitter Frequency | Capture Date | Capture Site | Sex | Age (Yrs.) | Weight (lbs.) | Comments                                       |
|-----------|-----------------------|--------------|--------------|-----|------------|---------------|------------------------------------------------|
| 901       | 150.061               | 8 June 84    | HR           | M   | 4 1/2      | 102.2 (225)   | Pulled collar off after 2 weeks of tracking    |
| 902       | 151.710               | 8 June 84    | HD           | F   | 1 1/2      | 23.6 (52)     | Located with bear #532 through aerial tracking |
| 904       | 151.160               | 9 June 84    | HR           | M   | 6 1/2      | 90.9 (200)    | Puncture wounds on neck                        |
| 905       | 151.180               | 12 June 84   | HD           | M   | 2 1/2      | 49.5 (109)    |                                                |
| 906       | 151.400               | 12 June 84   | HR           | M   | 2 1/2      | 56.8 (125)    | Excellent condition                            |
| 907       | 151.050               | 13 June 84   | HD           | M   | 2 1/2      | 49.1 (108)    |                                                |
| 531*      | 151.620               | 14 June 84   | HR           | F   | 4 1/2      | 38.2 (84)     | Lactating, no cubs observed                    |
| 531*      | 151.620               | 7 Sept. 84   | HR           | F   | 4 1/2      | 45.9 (101)    |                                                |
| 521*      | 151.061               | 5 Sept. 84   | HR           | F   | 4 1/2      | 61.4 (135)    | Dropped previous collar 28 Aug. 84             |
| -         | -                     | 10 June 84   | HD           | M   | Cub        | 45.5 (10)     | No collared females nearby                     |
| -         | -                     | 9 Aug. 84    | HR           | M   | Cub        | 6.8 (15)      | Female 531 within 50 yards                     |
| 428*      | 151.570               | 17 June 85   | HR           | F   | 7 1/2      | 56.8 (125)    | Swollen vulva                                  |
| 532*      | 151.800               | 21 June 85   | HD           | F   | 9 1/2      | 64.1 (141)    | Vulva slightly swollen                         |
| 902*      | 151.810               | 19 June 85   | HR           | F   | 2 1/2      | 38.6 (85)     | Vulva slightly swollen                         |
| 910       | -                     | 16 June 85   | HR           | M   | 8 1/2      | 181.8 (400)   | Teeth worn                                     |

Table 3 (Continued)

| Ear Tag # | Transmitter Frequency | Capture Date | Capture Site | Sex | Age (Yrs.) | Weight kg | Weight (lbs.) | Comments                |
|-----------|-----------------------|--------------|--------------|-----|------------|-----------|---------------|-------------------------|
| 911       | 151.750               | 23 June 85   | HR           | M   | 2 1/2      | 34.5      | (76)          |                         |
| 913       | 151.690               | 21 June 85   | HR           | F   | 1 1/2      | 23.6      | (52)          |                         |
| 917       | 151.930               | 24 June 85   | HRD          | M   | 3 1/2      | 113.6     | (250)         | Fighting wounds on face |
| 920       | 151.091               | 1 July 85    | HD           | F   | 1 1/2      | 22.7      | (50)          | Fair-Poor condition     |
| 921       | 151.020               | 26 July 85   | HR           | M   | 1 1/2      | 20.0      | (44)          | Poor condition          |
| 923       | 151.387               | 25 July 85   | HRD          | M   | 6 1/2      | 136.4     | (300)         | Heavy tooth wear        |
| 925       | -                     | 27 July 85   | HR           | M   | 2 1/2      | 36.4      | (80)          |                         |

\*These bears were recaptures.

HR = Hurricane Ridge.

HD = Harmon Den Mountain.

HRD = Hickory Ridge.

Table 4. Trap success by month and trapline in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Trap Line Location       | Dates Operated        | Trap Nights (Captures) | Trap Nights/Capture |
|--------------------------|-----------------------|------------------------|---------------------|
| Hurricane Ridge          | 4 June - 19 June 84   | 177 (4)                | 44.25               |
|                          | 7 July - 23 July 84   | 170 (0)                | -                   |
|                          | 8 Aug. - 16 Aug. 84   | 44 (1)                 | 44                  |
|                          | 5 Sept. - 10 Sept. 84 | 80 (2)                 | 40                  |
|                          | 18 June - 1 July 85   | 198 (4)                | 49.5                |
|                          | 15 July - 27 July 85  | 84 (2)                 | 42                  |
|                          | 7 Aug. - 15 Aug. 85   | 36 (0)                 | -                   |
| Hurricane Ridge Subtotal |                       | 798 (13)               | 60.69               |
| Harmon Den Mtn.          | 4 June - 19 June 84   | 54 (4)                 | 13.5                |
|                          | 8 Aug. - 16 Aug. 84   | 16 (0)                 | -                   |
|                          | 5 Sept. - 10 Sept. 84 | 10 (0)                 | -                   |
|                          | 14 June - 28 June 85  | 86 (3)                 | 28.6                |
| Harmon Den Mtn. Subtotal |                       | 166 (7)                | 23.7                |
| Hickory Ridge            | 24 June - 1 July 85   | 60 (2)                 | 30                  |
| Total                    |                       | 1012 (22)              | 46                  |

Adult to subadult age ratios were nearly equal (10:12). Ratios in heavily hunted populations favor subadults (McIllroy 1972, Kemp 1976). The average age of captured females was slightly greater than that of males, 3.6:2.9, respectively. Other studies have reported catching older females more than males (Poelker and Hartwell 1973, Hugie 1982, Carr 1983). Besides the smaller home range and trap shyness of adult females, the increased mobility of males and especially subadults, make males more vulnerable to trapping. Captures of 2 male cubs and 5 subadult males also skewed the age structure of captured males.

#### Winter Den Visits

The dens of 8 surviving females were visited during February and March of 1985 and 1986 (Table 5). One bear was denned in a tree, 2 were found at ground level under slash piles in clearcuts, 1 was in a rock crevice, 3 were in exposed, bowl shaped ground nests, and 1 den was not observed. Dens were on slopes facing at least partially north in 6 instances; the other 2 were on south facing slopes. All observed dens and nests had grass for nesting material. Two adult females had 3 cubs and the third had 4.

Researchers have documented bears in a variety of den structures. This variability in den sites may indicate that den selection is not a limiting factor to bear survival. However, in at least 1 instance bears were killed while denning (Rogers and Mech 1981). Dens should provide protection because while denning parturition

Table 5. Den characteristics and physical data of eight radio-tagged bears in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Ear Tag | Year | Sex | Age | Den Location             |      | Den Description                         | Observed Cover Type                      | Stand Age | Aspect | Comments                                                                |
|---------|------|-----|-----|--------------------------|------|-----------------------------------------|------------------------------------------|-----------|--------|-------------------------------------------------------------------------|
|         |      |     |     | UTM                      |      |                                         |                                          |           |        |                                                                         |
| 902     | 1985 | F   | 2   | Hurricane Ridge<br>1880  |      | Rock Crevice                            | Scarlet oak                              | 68        | N      | Within 20 feet of creek. Bear moved after den visit.                    |
| 532     | 1985 | F   | 10  | Harmon Den Mtn.<br>1942  | 5900 | Ground den under slash pile in clearcut | Red maple-Locust                         | 2         | S      | With 3 cubs--2 male and 1 female.                                       |
| 521     | 1985 | F   | 5   | Little Bear Mtn.<br>2000 | 5932 | Ground nest in Laurel thicket           | Scarlet oak-brush                        | 50        | S      | With 3 male cubs.                                                       |
| 919     | 1986 | F   | 2   | Cherry Creek<br>2280     | 6170 | Tree den- Chestnut oak                  | Sugar maple-beech-<br>Yellow-birch       | 48-90     | NE     | Den tree Dbh = 48 in., near creek.                                      |
| 913     | 1986 | F   | 2   | ORE Knob<br>2110         | 5700 | Ground den under slash pile in clearcut | Red maple-Locust                         | 9         | NE     | Bear left den as I approached; it appeared very healthy.                |
| 521     | 1986 | F   | 6   | Hurricane Gap<br>2030    | 5630 | Ground nest in Laurel thicket           | Hemlock                                  | 60        | N      | Observed with 1 yearling; both left as I approached nest.               |
| 902     | 1986 | F   | 3   | Hurricane Ridge<br>1890  | 5680 | Not observed                            | Yellow poplar-White oak-Northern red oak | 60        | NW     | Bear left before I could see it.                                        |
| 428     | 1986 | F   | 8   | Hurricane Ridge<br>1890  | 5580 | Ground nest in Rhododendron             | White oak-Red oak-Hickory                | 73        | NW     | With 4 cubs rototags:<br>521 male<br>522 female<br>523 male<br>524 male |

takes place (Folk et al. 1980). The ground nests of 2 of the females with cubs (nos. 428 and 521) were totally exposed and afforded little or no protection from predators (probably feral dogs or bobcats in Harmon Den). When I observed the den of 521 the following winter, she was with only 1 yearling. Besides providing protection from harassment, tree dens may provide energy savings of 15% (Johnson et al. 1978). However, energy conservation did not affect productivity of bears in exposed dens in Wisconsin (Massopust 1984). Tree dens are not as plentiful in Harmon Den as they are in GSMNP, but they do exist (pers. observ.).

The denning habits of bears may be a learned response. The single bear that I was able to visit in 2 consecutive winters had ground nests both years. Also, a 2 year old offspring of female no. 531 denned in the same clearcut that her mother did 2 years earlier. Wathen (1983) found that bears born in tree dens tended to use tree dens more often than offspring born in ground dens. Tree dens protect bears from harassment and provide insulation. Whether bears utilize available tree dens in Harmon Den cannot be verified with such small sample sizes. However, because of the protection afforded females and newborn cubs, large trees (90+ cm dbh) should be preserved.

#### Radio Telemetry

Telemetry accuracy in Harmon Den was poor. Accuracy tests on preplaced transmitters resulted in a 95% confidence area of

$\pm 8.1^\circ$ . This margin of error was used in calculating error polygons. For this study the average error polygon size used in analysis was 15.8 ha. Stands averaged 21.8 ha, thus most error polygons covered more than one stand. Previous telemetry studies in the Southern Appalachians have cited ground telemetry accuracies of  $\pm 300$  m using masts and hand-held H antennas (Garshelis 1978, Quigley 1982, Carr 1983, Garris 1983). Recent habitat studies have incorporated confidence limits on telemetry azimuths; these vary the size and shape of error polygons depending on the angle between readings and the distance from the receiver to the animal (Brody 1984a, Clevenger 1986). In mountainous terrain, animals can be tracked from ridge tops; this greatly enhances receiving distances. However, the accuracy of readings in which the animal and receiver are many kilometers apart must be questioned. I found error polygons often were over 100 ha when tracking from these distances.

The time interval between azimuths was another problem when tracking in Harmon Den. Logging traffic and rough roads often resulted in large time intervals between consecutive azimuths. Only azimuths within 30 minutes of one another were used for analysis. Using this and other previously mentioned telemetry selection criteria 1312 of 1735 locations were used for habitat analysis. Ninety-four of these locations were obtained aurally.

Seventeen radio collars were deployed in 2 years of radio tracking in Harmon Den; 12 of these were used for initial captures; 3 were used to recollar previously tagged bears (Brody 1984a) and

2 were used to recollar bears at den sites. Eight females provided the bulk of the relocations (78%). Tracking success (Garshelis and Pelton 1981) for females averaged over 80% but averaged only 56% for males (Table 6). The low tracking success for male bears stems from their large home ranges and subadult dispersals. Limited travel funds prevented extensive searches for bears outside of the study area.

### Hunting Mortality

All observed mortality to radio-tagged bears was human caused. Seven of 18 (39%) study animals (4 male and 3 female) were legally harvested or poached during the study. Minimum annual mortality rates were 54% and 8% during 1984 and 1985, respectively. Six study animals were taken by hunters in 1984 when there were extensive movements by bears searching for food. Hard mast was rated as a medium crop (6.03 of possible 10) by the North Carolina Wildlife Resources Commission, but my observations on the study area showed a poor crop.

All harvested bears were killed within 10 km of Harmon Den (Table 7). I was able to observe 4 of the harvested animals; all were in good condition. One female was killed near Hurricane Mountain while she was accompanied by 2 cubs. Harvest figures for Haywood County were high for 1984 (66 animals). During 1985, 1 study animal was poached during the dog training season. Poachers released dogs on Cold Springs Road, and the bear was chased across Hurricane Ridge and killed as it crossed Hurricane Creek road.

Table 6. Summary of tracking success and fate of bears radio-tagged in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Bear # | Age   | Sex | Date First Collared | Total Locations | Ground Tracking Success % | Fate                                                                                            |
|--------|-------|-----|---------------------|-----------------|---------------------------|-------------------------------------------------------------------------------------------------|
| 428    | 7 1/2 | F   | 17 June 85          | 132             | 95                        | Dropped collar at den site, attempt to immobilize was unsuccessful.                             |
| 521*   | 4 1/2 | F   | 13 June 83          | 268             | 81                        | Dropped collar 28 Aug. 84, recaptured and collared 5 Sept. 84, still alive.                     |
| 524*   | 8 1/2 | F   | 8 Sept. 83          | 60              | 41                        | Legal hunter kill near Spring Creek, North Carolina, 16 Nov. 84, dressed weight was 300 pounds. |
| 531*   | 1 1/2 | F   | 20 July 82          | 112             | 79                        | Killed 14 Nov. 84 near Hurricane Mountain. Observed with 2 cubs on harvest date, illegal kill.  |
| 532*   | 7 1/2 | F   | 20 July 82          | 229             | 79                        | Dropped collar Sept. 1985.                                                                      |
| 901    | 4 1/2 | M   | 8 June 84           | 10              | 71                        | Pulled collar off 22 June 84.                                                                   |
| 902    | 1 1/2 | F   | 8 June 84           | 255             | 82                        | Still alive with transmitter.                                                                   |
| 904    | 6 1/2 | M   | 9 June 84           | 27              | 16                        | Dispersed across Interstate 40.                                                                 |
| 905    | 2 1/2 | M   | 12 June 84          | 54              | 39                        | Legal kill 9 November 1984, near Fines Creek, North Carolina. Estimated weight 200 pounds.      |

Table 6 (Continued)

| Bear # | Age   | Sex | Date First Collared | Total Locations | Ground Tracking Success % | Fate                                                         |
|--------|-------|-----|---------------------|-----------------|---------------------------|--------------------------------------------------------------|
| 906    | 2 1/2 | M   | 12 June 84          | 59              | 44                        | Legal kill November 1984 near Spring Creek, North Carolina.  |
| 907    | 2 1/2 | M   | 13 June 84          | 90              | 64                        | Legal kill November 1984 near Wilkins Creek, North Carolina. |
| 911    | 2 1/2 | M   | 23 June 85          | 8               | <1                        | Dispersed South of Fines Creek, presently unaccounted for.   |
| 913    | 1 1/2 | M   | 21 June 85          | 129             | 93                        | Still alive with transmitter.                                |
| 917    | 3 1/2 | M   | 24 June 85          | 52              | 65                        | Pulled collar off Sept. 1984.                                |
| 920    | 1 1/2 | F   | 1 July 85           | 100             | 93                        | Still alive with transmitter.                                |
| 921    | 1 1/2 | M   | 26 July 85          | 58              | 98                        | Poached in sanctuary 1985.                                   |
| 923    | 6 1/2 | M   | 25 July 85          | 2               | 100                       | Pulled collar off after 2 days.                              |

Table 7. Summary of hunting mortality of tagged study animals in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Ear Tag # | Approximate Kill Date | Location        | Sex | Approximate Distance from Trap Site | Estimated Weight Kg | Estimated Weight (lbs.) | Condition |
|-----------|-----------------------|-----------------|-----|-------------------------------------|---------------------|-------------------------|-----------|
| 906       | 23 Oct. 84            | Spring Creek    | M   | 6 km                                | 68.2                | (150)                   | good      |
| 905       | 9 Nov. 84             | Fines Creek     | M   | 7 km                                | 90.9                | (200)                   | good      |
| 531       | 14 Nov. 84            | Hurricane Mtn.  | F   | 5 km                                | 54.5                | (120)                   | fair      |
| 524       | 16 Nov. 84            | Spring Creek    | F   | 4 km                                | 136.4               | (300)                   | excellent |
| 628       | 16 Nov. 84            | Spring Creek    | F   | 4 km                                | 5.5                 | (120)                   | fair      |
| 907       | Nov. 84               | Wilkins Creek   | M   | 6 km                                | 90.9                | (200)                   | good      |
| 921       | Sept.* 85             | Hurricane Creek | M   | 4 km                                | -                   | -                       | -         |

\*Poached.

Brody (1984a) reported an overall mortality rate of between 47% and 56% in a previous study in this area. All 5 of his study animals which were residents of areas open to hunting were killed. Mortality rates for bears in Harmon Den are higher than those reported in other studies. In Maine, Hugie (1982) reported annual mortality rates of 8 and 12% for males and 2 and 6% for females. Reported rates in Virginia were 33% (Stickley 1961) and 24% (Raybourne 1976). In Washington, Poelker and Hartwell (1973) observed a 15-18% annual mortality, and in Montana, Jonkel (1967) found yearly mortality rates of 3 and 13%.

The high mortality rates observed in and around Harmon Den are likely the result of long hunting seasons, extreme hunting pressures, increased road densities, and periodic mast failures. The bear season opened in mid-October and was open through December each year of the study. It was closed for 3 weeks during November and December; hunters could legally hunt 52 days. Hunting pressure is extreme during the first weeks of the season. I observed upwards of 50 hunting vehicles per day on the 12 Mile Strip, an area of approximately 5,660 ha. The area is also dissected with ungated roads, allowing hunters to harvest nearly every bear in the area. There are likely few resident bears in these hunted areas. Instead, bears from GSMNP and Harmon Den are drawn to these areas in search of mast. During years of mast failure, bears travel widely and are vulnerable to hunting.

### Home Range Comparisons

Twenty-eight seasonal home ranges were constructed for 14 bears. Home ranges were constructed for animals with at least 15 locations over a season (Table 8). Male home ranges were larger ( $P < 0.05$ ) than female home ranges during summer ( $15 \text{ km}^2 \pm 1.56 \text{ km}^2$  versus  $10 \text{ km}^2 \pm 1.1 \text{ km}^2$ ), fall ( $36 \text{ km}^2 \pm 3.81 \text{ km}^2$  versus  $11.3 \text{ km}^2 \pm 1.20 \text{ km}^2$ ), and annually ( $61.4 \text{ km}^2 \pm 3.81 \text{ km}^2$  versus  $14.8 \text{ km}^2 \pm 1.15 \text{ km}^2$ ) for male and female bears, respectively (Table 9). Home range size was not significantly different ( $P > 0.0005$ ) between adults and subadults, but in all cases annual ranges for individual bears were larger ( $P < 0.05$ ) than summer or fall ranges. Seasonally, among the same sex, home range size was significantly different only among males,  $14.7 \text{ km}^2 \pm 1.56 \text{ km}^2$  and  $36.2 \text{ km}^2 \pm 3.81 \text{ km}^2$  for summer and fall home ranges, respectively.

Home ranges in this study most closely approximate those found in Cherokee National Forest (CNF) (Clevenger 1986) and the previous study in Pisgah National Forest (PNF) (Brody 1984a). They are larger than home ranges determined for bears in GSMNP (Beeman 1975, Garshelis 1978, Quigley 1982).

Annual home range size for females may be directly correlated to habitat quality (Alt et al. 1976, Amstrup and Beecham 1976, Lindzey and Meslow 1977, Massopust 1984). It seems likely that sizes of female home ranges from different areas, but similar in habitat quality, would be roughly the same. Young and Ruff (1982) state that "home range size of female bears estimated by the same method

Table 8. Individual, seasonal, and annual home ranges (km<sup>2</sup>) for radio-tagged bears in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Ear Tag | Sex | Age   | Year | Summer (n) | Fall (n)  | Annual (n) | Comments                    |
|---------|-----|-------|------|------------|-----------|------------|-----------------------------|
| 902     | F   | 1 1/2 | 84   | 9.9 (65)   | 6.6 (31)  | 11.5 (96)  |                             |
| 902     | F   | 2 1/2 | 85   | 13.6 (101) | 10.0 (50) | 14.8 (151) |                             |
| 904     | M   | 6 1/2 | 84   | 15.6 (20)  | -         | -          |                             |
| 905     | M   | 2 1/2 | 84   | 19.6 (40)  | -         | -          |                             |
| 906     | M   | 2 1/2 | 84   | 13.6 (43)  | -         | -          |                             |
| 907     | M   | 2 1/4 | 84   | 17.8 (56)  | 36.1 (21) | 61.4 (77)  |                             |
| 524     | F   | 8 1/2 | 84   | 6.2 (21)   | 8.6 (25)  | 9.7 (46)   |                             |
| 531     | F   | 4 1/2 | 84   | 7.0 (56)   | 12.2 (34) | 13.0 (90)  |                             |
| 521     | F   | 4 1/2 | 84   | 12.1 (55)  | 14.3 (59) | 17.2 (111) | With at least 2 cubs.       |
| 521     | F   | 5 1/2 | 85   | 14.8 (98)  | 13.7 (46) | 18.3 (144) | Pregnant without yearlings. |
| 428     | F   | 7 1/2 | 85   | 10.9 (82)  | 7.0 (51)  | 11.8 (131) | With 3 cubs.                |
| 532     | F   | 8 1/2 | 84   | 9.9 (58)   | 14.4 (32) | 20.0 (90)  | Pregnant without yearlings. |
| 532     | F   | 9 1/2 | 85   | 10.3 (87)  | 3.1 (20)  | 10.7 (107) | Pregnant without yearlings. |
| 913     | F   | 1 1/2 | 85   | 11.3 (81)  | 19.0 (46) | 23.0 (127) | With 3 cubs.                |
| 917     | M   | 3 1/2 | 85   | 14.9 (46)  | -         | -          |                             |
| 920     | F   | 1 1/2 | 85   | 9.3 (58)   | 8.3 (51)  | 12.8 (109) |                             |
| 921     | M   | 1 1/2 | 85   | 6.8 (47)   | -         | -          |                             |

Table 9. Seasonal and annual convex polygon home range averages ( $\text{km}^2$ ) for radio-tagged bears by sex and age in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Age Class     | Sex    | Mean Size<br>( $\text{km}^2$ ) | N | Range |
|---------------|--------|--------------------------------|---|-------|
| <u>SUMMER</u> |        |                                |   |       |
| Adult         | Female | 10                             | 7 | 6-14  |
| Subadult      | Female | 11                             | 4 | 9-14  |
| Adult         | Male   | 15                             | 2 | 15-16 |
| Subadult      | Male   | 14                             | 4 | 6-20  |
| <u>FALL</u>   |        |                                |   |       |
| Adult         | Female | 12                             | 6 | 7-14  |
| Subadult      | Female | 11                             | 4 | 7-19  |
| Subadult      | Male   | 36                             | 1 | -     |
| <u>ANNUAL</u> |        |                                |   |       |
| Subadult      | Female | 15                             | 4 | 11-23 |
| Adult         | Female | 14                             | 7 | 10-20 |
| Subadult      | Male   | 61                             | 1 | -     |

for different areas could provide a means of comparing the quality of black bear habitat between areas." Thus, Cherokee and Pisgah National Forests likely offer bears similar quality habitat, and these home ranges reflect the habitat quantity necessary for bears' self maintenance (Amstrup and Beecham 1976).

The smaller home range of bears in GSMNP likely reflects a higher population of bears rather than a habitat superior to that found in Harmon Den. Young and Ruff (1982) found females were sensitive to crowding and that their home range size may decrease when population densities increase.

General home range sizes of male bears are undoubtedly larger than those determined for this study. During this study, males often moved to areas beyond the range of ground telemetry but returned before they could be found using aircraft. Young and Ruff (1982) noted a direct relationship between the number of tracking days and the size of a male bear's home range. Males in this study were usually harvested or dispersed before an accurate home range could be determined. However, male home ranges in this study ( $n = 8$ ) were still larger than female ranges. This relationship seems to occur throughout the range of black bears. The reasons for this difference stem from the larger male body size (Harestad and Bunnell 1979), breeding habits (Rogers 1977, Herrero and Hamer 1977), and the general site fidelity exhibited by females. Males require more energy to maintain their larger body size. Harestad and Bunnell (1979) noted a correlation between body weight and home range size for omnivores.

Breeding is probably most responsible for the increased male home range size. Males increase their chance of reproduction by overlapping 1 or more female home ranges and by traveling widely during the breeding season.

Significant changes in home range size between summer and fall were evident for only males. Brody (1984a) noted larger fall home ranges for Harmon Den bears of both sexes. However, he also reported that 3 female bears exhibited summer to fall reductions and that the increased use of aerial tracking in fall increased the success of tracking for far ranging animals. Other studies reporting larger fall home ranges for both sexes in the Southern Appalachians include those of Clevenger (1986) and Garris (1983) in CNF, and Carr (1983) in GSMNP.

Seasonal home range size is probably most influenced by fall mast availability. Carr (1983) and Garris (1983) reported larger fall home ranges for both sexes during a year when mast crops were poor and reported no significant seasonal changes during a normal mast year. Warburton and Powell (1986) noted no intra-year difference in home range size among adult bears during normal mast years in western North Carolina as did Garshelis and Pelton (1981) and Quigley (1982) in GSMNP. Clevenger (1986) thought that hunting pressure might play a role in the increased fall home ranges of male bears. However, Massopust and Anderson (1984) and Allen (1984) found that bears chased by dogs rarely left their home ranges, and if they did, they returned shortly thereafter.

Home range overlap was observed within and between sexes of all bears. Male home range overlap (Figure 3) is common, and I found no reports of studies which did not observe overlap among males. Apparently this is a universal characteristic and males do not attempt to defend their entire ranges. Certain studies report that male home range overlap was minimal (Poelker and Hartwell 1973) or male movements were restricted by territorial pressures. That is, males used the same areas but at different times.

Home range overlap among female bears was also extensive (Figures 4 and 5). Others have observed this behavior in Washington (Lindzey and Meslow 1977), Idaho (Amstrup and Beecham 1976), Alaska (Modafferi 1982), and the Southern Appalachians (Garshelis and Pelton 1981, Villarrubia 1982, Brody 1984a). Related females tend to have home ranges that show extensive overlap (Rogers 1977, Garshelis and Pelton 1981); yearling females often establish home ranges within their mother's range, but young males usually disperse and establish home ranges elsewhere. It is likely that a portion of the radio-tagged females in Harmon Den are related; the area has been protected from hunting since 1971. The female ranges are small, in the center of the sanctuary, and are not as susceptible to perimeter hunting.

#### Seasonal Movements

Harmonic centers of activity (Dixon and Chapman 1980) did not vary significantly between seasons on an annual basis ( $P>0.05$ ) (Table 10). Movements of activity centers between years were greater

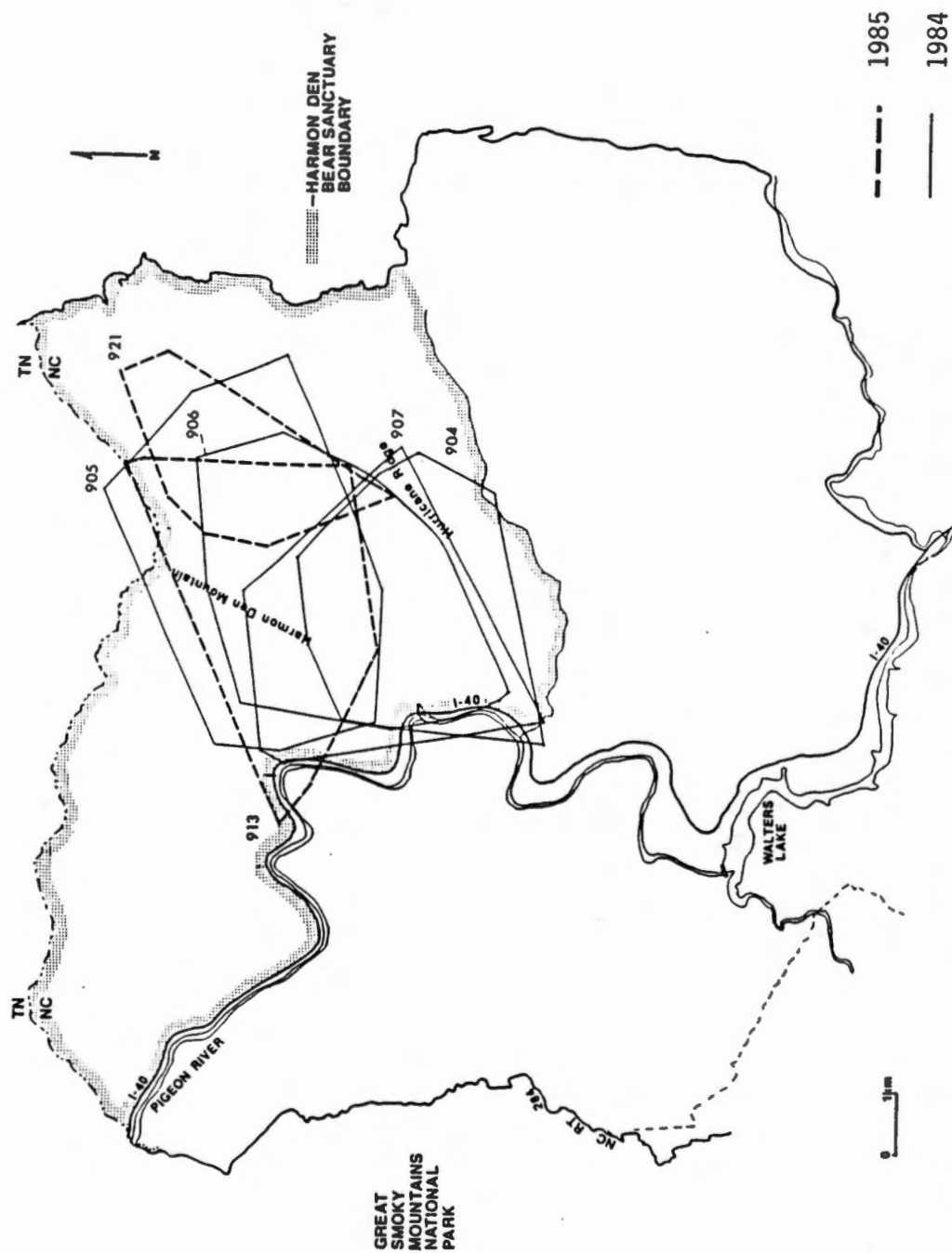


Figure 3. Seasonal home range overlap of male bears in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984.

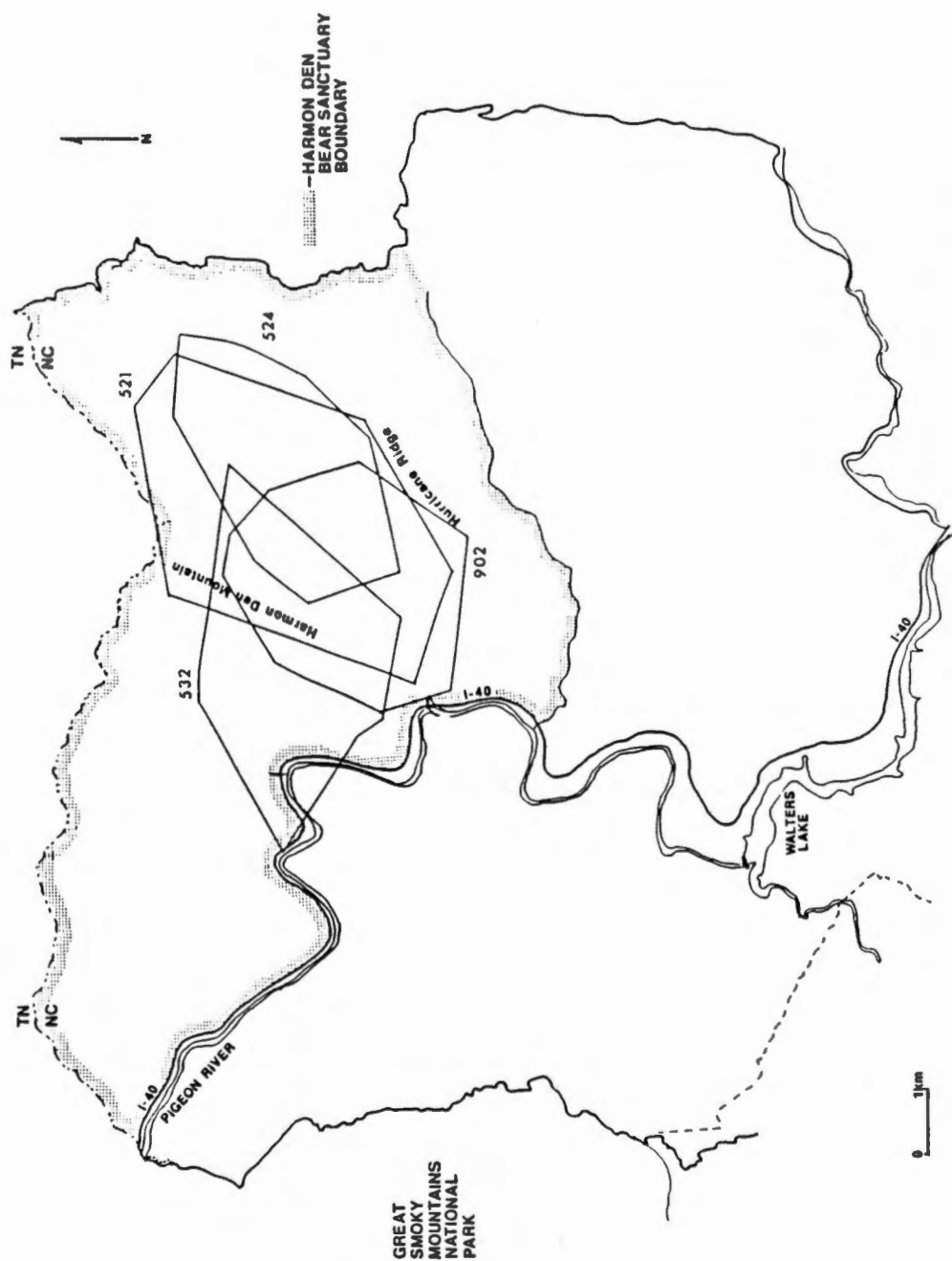


Figure 4. Annual home range overlap of female bears in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984.

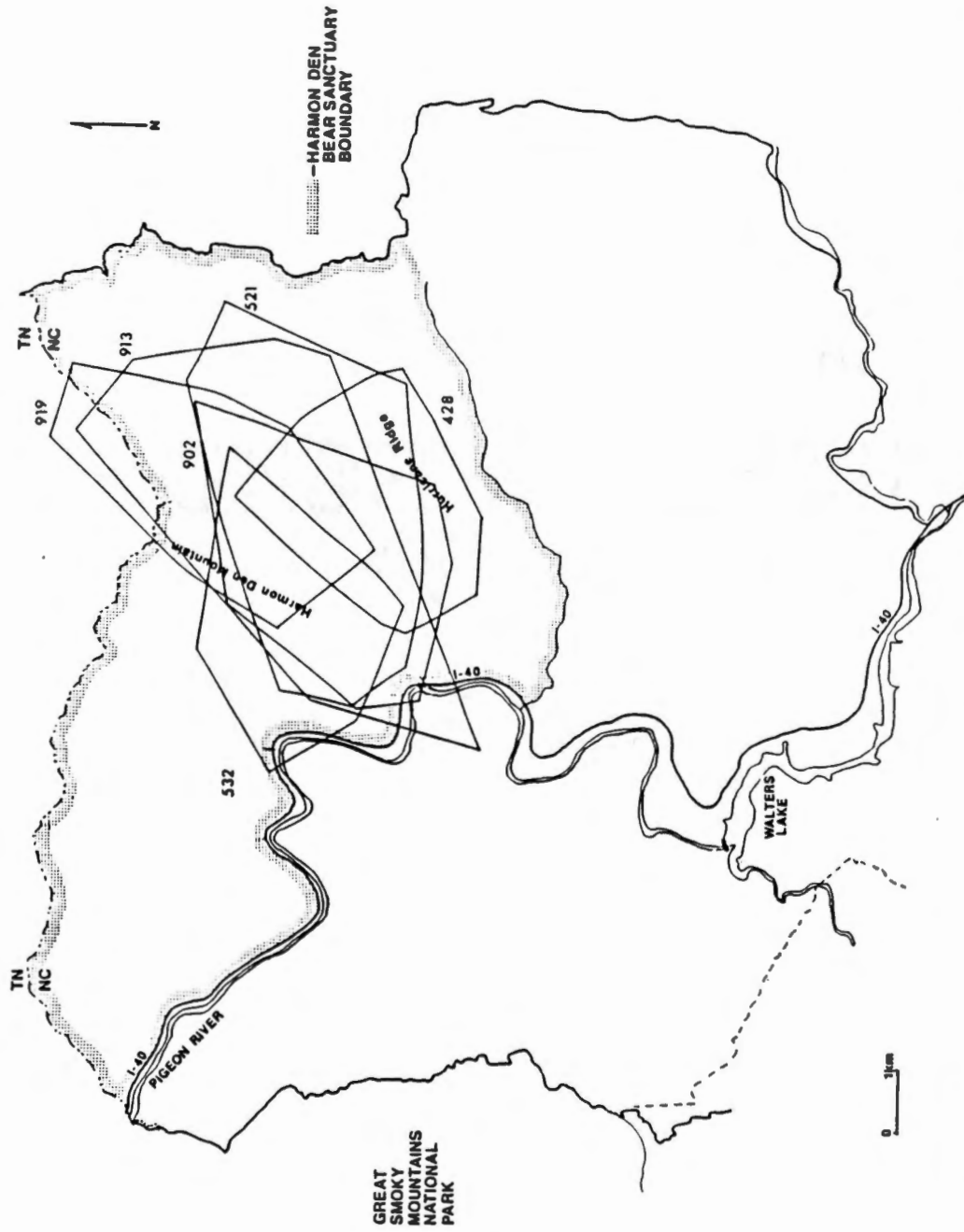


Figure 5. Annual home range overlap of female bears in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1985.

Table 10. Distances<sup>a</sup> between seasonal activity centers for bears in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Sex/Age Class    | Season Category           | Mean<br>(10 <sup>2</sup> m) | STD<br>(10 <sup>2</sup> m) | n |
|------------------|---------------------------|-----------------------------|----------------------------|---|
| All Females      | Summer 1984 - Fall 1984   | 11.9                        | 5.2                        | 6 |
|                  | Summer 1985 - Fall 1985   | 9.1                         | 6.6                        | 6 |
|                  | Summer 1984 - Summer 1985 | 3.6                         | 3.1                        | 3 |
|                  | Fall 1984 - Fall 1985     | 12.1                        | 6.9                        | 3 |
| Adult Females    | Summer 1984 - Fall 1984   | 11.2                        | 5.4                        | 5 |
|                  | Summer 1985 - Fall 1985   | 10.1                        | 8.2                        | 4 |
|                  | Summer 1984 - Summer 1985 | 4.9                         | 3.1                        | 2 |
|                  | Fall 1984 - Fall 1985     | 14.6                        | 7.6                        | 2 |
| Subadult Females | Summer 1984 - Fall 1984   | 8.0                         | -                          | 1 |
|                  | Summer 1985 - Fall 1985   | 10.1                        | 5.7                        | 3 |
|                  | Summer 1984 - Summer 1985 | 1.0                         | -                          | 1 |
|                  | Fall 1984 - Fall 1985     | 7.1                         | -                          | 1 |
| Subadult Males   | Summer 1984 - Fall 1984   | 15.6                        | -                          | 1 |

<sup>a</sup>Distances given in hundreds of meters.

during 1984 than they were during 1985 for those bears with 2 years of telemetry data, probably because mast was more abundant in 1985 (pers. observ.). Adult females had slightly greater shifts in activity centers than subadult females both intra- and inter-yearly. The only male that was tracked through the fall had an intra-year shift of 1.5 km. Hunting mortality, slipped collars, and dispersal precluded fall tracking for most male bears.

Brody (1984a) also found no significant shifts in activity centers for bears in the same area. Warburton and Powell (1986) found no significant shifts in another portion of Pisgah National Forest.

Studies that reported prominent shifts in centers of activity (Reynolds and Beecham 1980, Garshelis and Pelton 1981, Carr 1983, Garriss 1983, Clevenger 1986) attributed the shifts to seasonally abundant foods. In the Southern Appalachians, seasonal shifts to areas of mast abundance are common. Harmon Den has a diversity of oak species at various elevations. In fact over 75% of the area is in an oak associated cover type. This almost continuous overstory of oak species allows bears to meet their nutritional requirements within their established home ranges. Daily tracking indicated that bears displayed minor shifts within their home ranges. Ground truthing revealed these areas had abundant white oak mast.

#### Habitat Use

Bear habitat use of forest cover type, stand age, and site index was determined using the methods of Neu et al. (1974) and Byers

et al. (1984). Only 1312 of 1735 radio locations (76%) were used in the habitat analysis; 423 locations were dropped because they did not meet the predetermined criteria of error polygon size, and/or they overlapped more than 5 forest stands. This analysis used 0.10 levels of significance, and bears were grouped using all bears, and by sex. Table 11 describes bear use of the selected habitat parameters.

#### Cover Type

During summer all bears used softwood cover types disproportionately. They tended to avoid stands of pure yellow poplar and used other cover types in proportion to their availability. Female bears showed no preference for any cover type during the summer. Male bears used pine stands disproportionately and avoided yellow poplar stands. Other cover types were used in proportion to their availability.

Bears in GSMNP consumed primarily herbaceous materials during the summer months (Beeman and Pelton 1980, Eagle and Pelton 1983). Squawroot is probably the major spring and early summer food, and source of nutrition for bears in Harmon Den (Eagle and Pelton 1983). Scats containing almost exclusively squawroot were observed both summers. Squawroot is saprophytic and grows on oak roots (Beeman 1971). The large proportion of oak cover types in Harmon Den would make this food available almost everywhere. Indeed squawroot was extremely abundant throughout the study area. The preponderance of squawroot may be responsible for the lack of forest preferences

Table 11. Black bear habitat use by forest cover type, site index, and age in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Category                 | Expected Proportion of<br>Radio Locations (%) |      | Actual Proportion<br>Radio Locations (%) |      | Significance <sup>a</sup> |      |
|--------------------------|-----------------------------------------------|------|------------------------------------------|------|---------------------------|------|
|                          | SUMMER                                        | FALL | SUMMER                                   | FALL | SUMMER                    | FALL |
| <u>ALL BEARS</u>         |                                               |      |                                          |      |                           |      |
| <u>Forest Cover Type</u> |                                               |      |                                          |      |                           |      |
| Nonforest                | 1.6                                           | 1.0  | 1.2                                      | 0.6  | 0                         | 0    |
| Softwood (pine)          | 5.0                                           | 6.4  | 8.0                                      | 6.2  | +                         | 0    |
| Mixed softwood/hardwood  | 3.7                                           | 3.2  | 3.2                                      | 3.2  | 0                         | 0    |
| Yellow poplar            | 10.6                                          | 9.0  | 8.0                                      | 9.8  | -                         | 0    |
| Chestnut oak             | 2.6                                           | 2.6  | 3.0                                      | 2.5  | 0                         | 0    |
| White oak-Red oak        | 44.0                                          | 46.0 | 43.8                                     | 44.8 | 0                         | 0    |
| Hickory                  | -                                             | -    | -                                        | -    | -                         | -    |
| Yellow poplar-White      | 27.5                                          | 25.0 | 26.0                                     | 28.0 | 0                         | 0    |
| Oak-Northern red oak     | -                                             | -    | -                                        | -    | -                         | -    |
| Scarlet oak              | 5.0                                           | 5.8  | 6.8                                      | 5.8  | 0                         | 0    |
| <u>Site Index</u>        |                                               |      |                                          |      |                           |      |
| 0-40                     | 1.7                                           | 1.1  | 6.4                                      | 4.6  | +                         | +    |
| 41-60                    | 1.5                                           | 1.7  | 1.4                                      | 1.1  | 0                         | 0    |
| 61-80                    | 24.7                                          | 29.4 | 25.0                                     | 24.8 | 0                         | 0    |
| 81+                      | 72.1                                          | 67.8 | 67.2                                     | 69.5 | -                         | 0    |
| <u>Age (Years)</u>       |                                               |      |                                          |      |                           |      |
| ≤ 9                      | 1.3                                           | 1.4  | 3.1                                      | 1.4  | 0                         | 0    |
| 10-29                    | 1.5                                           | 2.3  | 1.3                                      | 1.3  | 0                         | 0    |
| 30-49                    | 1.8                                           | 2.6  | 3.4                                      | 1.5  | +                         | 0    |
| 50-69                    | 73.5                                          | 73.6 | 65.2                                     | 72.8 | -                         | 0    |
| 70-89                    | 14.7                                          | 14.1 | 15.8                                     | 13.0 | 0                         | 0    |
| 90+                      | 7.2                                           | 6.3  | 11.2                                     | 10.1 | +                         | +    |

Table 11 (Continued)

| Category                 | Expected Proportion of<br>Radio Locations (%) |      | Actual Proportion<br>Radio Locations (%) |      | Significance <sup>a</sup> |      |
|--------------------------|-----------------------------------------------|------|------------------------------------------|------|---------------------------|------|
|                          | SUMMER                                        | FALL | SUMMER                                   | FALL | SUMMER                    | FALL |
| <u>ALL FEMALE BEARS</u>  |                                               |      |                                          |      |                           |      |
| <u>Forest Cover Type</u> |                                               |      |                                          |      |                           |      |
| Nonforest                | 1.2                                           | 1.1  | 0.5                                      | 0.9  | 0                         | 0    |
| Softwood (pine)          | 5.0                                           | 6.0  | 4.8                                      | 4.0  | 0                         | 0    |
| Mixed softwood/hardwood  | 4.1                                           | 3.5  | 4.5                                      | 3.0  | 0                         | 0    |
| Yellow poplar            | 11.1                                          | 9.8  | 10.9                                     | 10.0 | 0                         | 0    |
| Chestnut oak             | 2.6                                           | 2.5  | 3.6                                      | 2.6  | 0                         | 0    |
| White oak-Red oak        | 42.8                                          | 46.0 | 41.8                                     | 42.0 | 0                         | C    |
| Hickory                  | -                                             | -    | -                                        | -    | -                         | -    |
| Yellow poplar-White      | 27.2                                          | 25.1 | 26.1                                     | 30.6 | 0                         | +    |
| Oak-Northern red oak     | -                                             | -    | -                                        | -    | -                         | -    |
| Scarlet oak              | 6.0                                           | 6.0  | 7.8                                      | 6.9  | 0                         | 0    |
| <u>Site Index</u>        |                                               |      |                                          |      |                           |      |
| 0-40                     | 1.3                                           | 1.6  | 4.1                                      | 2.3  | +                         | 0    |
| 41-60                    | 1.7                                           | 2.4  | 2.2                                      | 1.5  | 0                         | 0    |
| 61-80                    | 25.6                                          | 27.0 | 23.3                                     | 23.7 | 0                         | 0    |
| 81+                      | 71.4                                          | 69.0 | 70.4                                     | 9.0  | +                         | 0    |
| <u>Age (Years)</u>       |                                               |      |                                          |      |                           |      |
| ≤ 9                      | 1.5                                           | 1.3  | 3.0                                      | 1.0  | 0                         | 0    |
| 10-29                    | 2.0                                           | 2.1  | 1.2                                      | 1.6  | 0                         | 0    |
| 30-49                    | 2.1                                           | 2.6  | 2.9                                      | 1.7  | +                         | 0    |
| 50-69                    | 72.1                                          | 73.0 | 64.0                                     | 70.0 | -                         | 0    |
| 70-89                    | 16.2                                          | 14.0 | 18.5                                     | 16.7 | 0                         | 0    |
| +90                      | 6.1                                           | 7.0  | 10.4                                     | 9.0  | +                         | 0    |

Table 11 (Continued)

| Category                | Expected Proportion of<br>Radio Locations (%) |      | Actual Proportion<br>Radio Locations (%) |      | Significance <sup>a</sup> |      |
|-------------------------|-----------------------------------------------|------|------------------------------------------|------|---------------------------|------|
|                         | SUMMER                                        | FALL | SUMMER                                   | FALL | SUMMER                    | FALL |
| ALL MALE BEARS          |                                               |      |                                          |      |                           |      |
| Forest Cover Type       |                                               |      |                                          |      |                           |      |
| Nonforest               | 2.4                                           | *    | 2.1                                      | *    | 0                         | *    |
| Softwood (pine)         | 6.3                                           | 11.8 | 12.5                                     | 14.6 | +                         | 0    |
| Mixed softwood/hardwood | 3.2                                           | *    | 1.9                                      | *    | 0                         | *    |
| Yellow poplar           | 10.0                                          | *    | 4.7                                      | *    | -                         | *    |
| Chestnut oak            | 1.9                                           | 5.0  | 2.2                                      | 1.0  | 0                         | -    |
| White oak-Red oak       | 44.6                                          | 53.0 | 44.9                                     | 54.9 | 0                         | 0    |
| Hickory                 | -                                             | -    | -                                        | -    | -                         | -    |
| Yellow poplar-White     | 27.2                                          | 22.1 | 26.3                                     | 27.0 | 0                         | 0    |
| Oak-Northern red oak    | -                                             | -    | -                                        | -    | -                         | -    |
| Scarlet oak             | 4.4                                           | 8.1  | 5.4                                      | 2.5  | 0                         | 0    |
| Site Index              |                                               |      |                                          |      |                           |      |
| 0-40                    | 2.4                                           | 0.4  | 9.0                                      | 10.3 | +                         | +    |
| 41-60                   | 1.2                                           | 1.3  | 0.4                                      | 0.3  | 0                         | 0    |
| 61-80                   | 23.1                                          | 52.8 | 25.6                                     | 27.6 | 0                         | -    |
| 81+                     | 73.3                                          | 45.5 | 65.0                                     | 61.8 | 0                         | +    |
| Age (Years)             |                                               |      |                                          |      |                           |      |
| 5-9                     | 0.9                                           | 2.4  | 3.0                                      | 2.5  | 0                         | 0    |
| 10-29                   | 1.1                                           | 4.5  | 1.0                                      | 0.6  | 0                         | -    |
| 30-49                   | 1.2                                           | 3.8  | 3.9                                      | 1.0  | +                         | 0    |
| 50-69                   | 76.0                                          | 69.3 | 67.1                                     | 81.3 | -                         | 0    |
| 70-89                   | 13.1                                          | 15.0 | 12.7                                     | 4.4  | 0                         | -    |
| +90                     | 7.6                                           | 5.0  | 12.3                                     | 10.2 | +                         | 0    |

<sup>a</sup>0 = used in proportion to availability,  $p \leq .10$ ; + = used in greater proportion than available,  $p \leq .10$ ; - = used in less proportion than available,  $p \leq .10$ ; \* due to limited male locations, the forest types were not tested.

displayed by some bears in the summer. Yellow poplar stands, which do not produce squawroot, were avoided by male bears. Other foods bears used in summer in Harmon Den were jewelweed (Impatiens capensis), stinging nettle (Urtica dioica), fruit, and insects (pers. observ.)

The preference of pine cover types is likely a reflection of the cover type classification. Some of the area that is classified as pine contains young, clumped stands of white pine interspersed with Rubus spp., apple, and Prunus spp.; some of these were formerly classified as shrub species and was preferred by bears in the summer in a previous study (Brody 1984a). Bears also preferred yellow poplar-oak stands during the summer in Brody's study. Clevenger (1986) observed bear preferences of oak-hickory stands in CNF, but Villarrubia (1982) found they selected for pine types in the same area.

All tagged bears combined, during the fall, used all cover types in proportion to their availability. Females selected for yellow poplar-white oak-northern red oak stands. Males showed no stand preferences but avoided chestnut oak (Quercus prinus) and scarlet oak stands.

The large proportion of oak species in Harmon Den may be part of the reason bears seemed impartial to these cover types. A yellow poplar-oak preference and white oak-red oak-hickory indifference was also noted by Brody (1984a). The poplar-oak preference likely results from the productive nature of these stands. This cover type tends to occur on moist, well drained, sites with good soils (SAF 1980). Intuitively, mast production should be better on these good

sites. Additionally, Golden (1981) reported black cherry (Prunus serotina) and serviceberry are more abundant in this cover type. Mast is undoubtedly available in white oak-red oak-hickory stands and the indifference to these stands was not expected. However, because of the large proportion of white oak-red oak-hickory cover types (one stand of 259 ha) only pronounced preferences were indicated using the utilization availability tests of Neu et al. (1974). The high expected proportion of use, and telemetry inaccuracies weaken the power of the Chi-squared tests used in this analysis (White and Garrott 1986).

The avoidance of scarlet and chestnut oak stands by male bears cannot be explained. However, Warburton and Powell (1986) found bears avoided scarlet oak types in another portion of PNF. They attributed the avoidance to mast shortages in this cover type. I did not observe distinct shortages of scarlet or chestnut oak acorns during this 2 year study and believe the avoidance was the result of the small sample size. Only 1 male bear was tracked through the fall.

Regardless, bears used hard mast in the fall in Harmon Den. Fall scats and stomachs from harvested bears that were examined contained almost exclusively acorns. Bear use of oak associated cover types was also documented by Garshelis and Pelton (1981), Quigley (1982), Villarubia (1982), Carr (1983), Garris (1983), Clevenger (1986), and Warburton and Powell (1986) in the Southern Appalachian.

### Site Index

During the summer months, all bears combined selected for stands with site indices less than 40 and avoided stands with site indices greater than 81. Female bears preferred stands with poor site indices and used the rest in proportion to their availability. Male bears showed the same utilization of site indices.

Site index is not a good parameter to compare among different tree species; however, it was the best readily available parameter. In Harmon Den, stands with site indices of less than 40 were those in brush species or grassy openings (USFS 1982a). Grassy openings offer bears herbaceous plants, many of which are important as spring food. Brush cover types contain Rubus spp., Vaccinium spp., and Prunus spp. species which are staple summer and early fall foods (Beeman and Pelton 1980, Eagle and Pelton 1983).

During the fall all bears continued to select for stands with low site indices. However, females also preferred stands with site indices of greater than 81. They used others in proportion to their availability. Males preferred stands in the 81+ site index category as well as those less than 40. They avoided stands with site indices from 61 to 80 and used stands with site indices of 41 to 60 in proportion to their availability. Brody (1984a) also found that bears preferred stands with site indices greater than 80. Most yellow-poplar-white oak-northern red oak stands (which were a preferred cover type) have a site index of greater than 81 (USFS 1982a).

### Stand Age

Bears of both sexes selected for stands aged between 30 and 49 years, and those older than 90 years during the summer. They avoided stands that were 50 to 69 years old and were indifferent to all other stands. Stands greater than 90 years old characteristically consist of a closed canopy with little understory and a dense herbaceous layer, often containing Vaccinium spp. Perhaps the 30-49 year old stands were used as bedding or loafing areas or were in some way related to breeding. Clevenger (1986) also found males preferred this age class during the summer.

The indifference bears showed towards young age classes contrasts with the findings of Brody (1984a). Bears did not prefer clear-cut areas ( $\leq$  9 years or between 10 and 29 years) at any time of the year during this study. Bears were also indifferent to young stands (0-29 years) in CNF (Clevenger 1986).

Recent clearcuts offer bears soft mast for only a few years. Apparently, Harmon Den bears used other areas for soft mast foraging. During 1985 there was a blackberry crop failure; this may have affected bear use of clearcuts during that year. Huckleberries are another food source that bears could utilize in clearcut areas. However, I observed several older aged stands which contained dense understories of huckleberries.

The soft mast in young clearcuts, in contrast to that found in mature stands, is a new and short-lived food source (plant succession). Bears must discover it before they can use it. However,

berry crops in stands of mature timber are consistent food sources, thus learned behavior may determine foraging areas. Rogers (1977) found that offspring of female bears sometimes visited the same foraging areas of their mothers.

### Transmitter Drops

Before reporting habitat use data obtained from transmitter drops, a few factors concerning radio telemetry in mountainous terrain need to be related. Determining habitat use from ground tracking in the Southern Appalachians is hampered by periodic variability in telemetry accuracy and the generation of large error polygons. Precision of telemetry accuracy is a major factor influencing the power of Chi-square tests when determining habitat selection; in fact the power "decreases by a factor of 2.5 as the bearing deviation doubles" (White and Garrott 1986). Large error polygons, when overlaid with cover type maps, often enclose several cover types. The problem is compounded by the patchy habitats found in Harmon Den. The bear is only using one of these at a time, however, and while the inaccuracies associated with telemetric bounce are partially compensated for, the large error polygons make correct habitat use determination difficult. Studies which do not use error polygons, or use a fixed radius for locations bias their habitat data. The mapped location of their point may or may not be accurate.

Accurate telemetry is especially important when studying the use of complex habitats by large, mobile, and secretive mammals.

The altitudinal gradient and mosaic of diverse and complex vegetation patterns through much of the range of black bears, and specifically in the Southern Appalachians, limits radio telemetry. White and Garrott (1986) reported low powers of habitat selection using Chi-square tests when performing simulation tests in patchy habitats. They assumed no bounce in the simulation, and thought the power would be even less in mountainous terrain. Additionally, radio signals probably interact with habitat structure (Hupp and Ratti 1983).

Cover type maps lacking sufficient detail to focus on small habitats (i.e., small berry patches or openings in mature timber) compound the problem of describing exact habitat utilization. Cover type data for this study area included USGS topographic maps, aerial photographs, and timber stand maps (USFS 1982a). USGS maps delineate only forest and non-forest areas. Aerial photographs allow timber canopy detection but, since the composition is changing through timber harvest, several flights would be needed. Additionally, accurate understory composition detection is impossible. Timber stand maps offer the most detailed descriptions of forest cover types. However, stand composition and boundaries for the maps are recorded by USFS personnel and private contractors whose interpretation is somewhat subjective. Also, small areas within a stand may not be the same as the stand composition classification; this was tested for and the results are presented later.

Fifty-seven transmitter packages were dropped and 56 were successfully retrieved; 1 package failed to transmit after being

dropped. The foam rubber was sufficient protection to withstand the impact. The high percentage of fresh bear sign (55%) observed at the site of the dropped transmitters was believed to be substantiating evidence that the technique was accurate. Feeding sign was observed at 17 sites (30%). The dropped transmitter was within 50 m of a wildlife trail 11 times (20%); scats were found 7 times (13%), and tracks were observed 7 times (13%). The transmitter was near a drainage in 5 instances (9%).

Sign interpretation yielded an interesting account of bear activities through the fall. During July, bears frequented oak and yellow-poplar-oak cover types, stand ages were usually old (80+), but some use of younger stands was noticed. While in these cover types bears fed on squaw root and on grubs in rotted logs. On 10 July 1985, I retrieved a transmitter in a yellow-poplar-oak cover type. The transmitter was near a rock outcrop heavy with ripe blueberries. Bear sign was heavy; she (and her cubs?) had been feeding on the blueberries. This was my first observation of ripe blueberries in the study area. On 15 July, my assistant and I found a 1 m<sup>2</sup> pile of doughnuts near a dropped transmitter; bear no. 428 had been feeding at the illegal bait pile for some time. Telemetry locations indicate she revisited this bait pile several times through the summer. On another occasion I found a day bed on a northwest slope in a laurel thicket. The bear obviously had spent days here judging from the number of scats observed.

Bears continued to favor oak and yellow-poplar-oak stands through October. During August, bears visited at least 4 abandoned

apple orchards. In one instance, there were fresh claw marks on 17 of 21 apple trees at Hurricane Gap. Scats were everywhere indicating the bear (or bears) had spent considerable time there. Other August drop sites were characterized by extremely dense understories of mountain laurel and greenbriar. Bears often dug yellow jacket nests in these habitats. The incidence of dug nests continued through September. On 1 September, I observed the first signs of mast foraging; bear no. 524 had climbed a chestnut oak, broken some of its branches, and fed on the acorns. The only use of a clearcut occurred during September. The retrieved transmitters (2) were 12 and 15 m from a horse trail and logging road, respectively. This suggests the bears may have been feeding along the roads, although no sign was found. Later fall drops were retrieved from oak ridges where acorns were abundant. Bears used all oak associated cover types, but most scats containing acorns were in stands containing white oaks.

#### Verification of Drop Sites

The point placed on the topographic map during the flight and the location of the dropped transmitter were verified in all cases but one; in this instance the transmitter was 200 m into a wooded area instead of on the edge of the woodline where it should have been. In another instance, a transmitter was dropped at the site of a collar that had been dropped by a bear; the dropped transmitter and collar were less than 40 m apart. The only time the located bear was observed from the air, the transmitter package was

dropped on the same outcrop where the bear was spotted. Additionally, when attempts were made to drop the packages at known sites (i.e., apple orchards, balds, road intersections, etc.), they were on target. The accuracy of the drop procedure is as much of an art as a technique, and the accuracy should be credited to the pilot's knowledge of the terrain and airplane.

#### Cover Type Use

Habitat use for the 6 bears that provided transmitter drop data was determined using the Chi-squared procedure and the methods of Neu et al. (1974). The results obtained from the transmitter drops were compared to those found using ground and aerial tracking. The same bears and tracking periods were used in each case. Results of both methods are presented in Table 12.

Habitat use as determined by the 3 tracking methods varied. All bears used all cover types in proportion to their availability when using traditional ground tracking data. They avoided yellow poplar stands and were indifferent to all other cover types when habitat use was calculated using only aerial locations. However, data from the transmitter drops gave another picture of habitat selection. Bears avoided non-forest, pine, mixed hardwood, and yellow-poplar stands. The avoidance was strong; not one location was found in any of these habitats. Bears strongly preferred ( $P < 0.05$ ) stands of yellow-poplar-white oak-northern red oak. This type represents 25% of the area, but bears were found using it 43% of the time. Slight preferences ( $P > 0.05$ ) were noted for chestnut and scarlet oak stands.

Table 12. Black bear habitat use for selected individuals as determined by ground tracking aerial locations and transmitter drops in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

| Forest Cover Type       | Expected Proportion of Radio Locations (%) |  | Actual Proportion Radio Locations (%) |                   |                 |  | Significance <sup>a</sup> |                   |
|-------------------------|--------------------------------------------|--|---------------------------------------|-------------------|-----------------|--|---------------------------|-------------------|
|                         | All Methods                                |  | Aerial Tracking                       | Transmitter Drops | Ground Tracking |  | Aerial Tracking           | Transmitter Drops |
| Nonforest               | 1.4                                        |  | 2.0                                   | 0                 | 0.5             |  | 0                         | -                 |
| Softwood (pine)         | 5.6                                        |  | 5.6                                   | 0                 | 4.5             |  | 0                         | -                 |
| Mixed softwood/hardwood | 3.9                                        |  | 3.7                                   | 0                 | 4.5             |  | 0                         | -                 |
| Yellow poplar           | 9.3                                        |  | 2.0                                   | 0                 | 9.9             |  | -                         | -                 |
| Chestnut oak            | 2.5                                        |  | 2.0                                   | 3.7               | 3.2             |  | 0                         | 0                 |
| White oak-Red oak       | 46.2                                       |  | 5.1                                   | 44.4              | 43.7            |  | 0                         | 0                 |
| Hickory                 | -                                          |  | -                                     | -                 | -               |  | -                         | -                 |
| Yellow poplar-White     | 25.3                                       |  | 2.8                                   | 42.6              | 25.8            |  | 0                         | +                 |
| Oak-Northern red oak    | -                                          |  | -                                     | -                 | -               |  | -                         | -                 |
| Scarlet oak             | 5.8                                        |  | 7.5                                   | 9.3               | 7.9             |  | 0                         | 0                 |

<sup>a</sup>0 = used in proportion to availability,  $p \leq 0.10$ ; + = used in greater proportion than available,  $p \leq 0.10$ ; - = used in less proportion than available,  $p \leq 0.10$ .

### Ground Truthing CISC Data

Forest cover types determined using transmitter drops were different ( $P < 0.001$ ) from the assigned CISC cover types. The Society of American Foresters recognized the problem of variant and transitional areas when they classified forest cover types. Some of the discrepancies encountered were the result of gradual changes in cover type and others were habitats too small to be classified separately. Many discrepancies occurred in compartment 56 where an area of 259 ha was classified using a single cover type, site index, and age. Recent clearcut areas often were typed according to their stand composition before cutting; 10 year old white oak-red oak-hickory stands are nonexistent in Harmon Den. Generally, however, my observations agreed with the CISC stand maps and the perceived differences were a function of classification schemes.

### Transmitter Drops As A Habitat Analysis Method

Using transmitter drops to collect habitat use data appears to be a more accurate technique than traditional ground and aerial tracking. For general home range purposes, and given enough data points collected in a systematic fashion, ground tracking in the Southern Appalachians may be satisfactory. However, more accurate findings regarding habitat use and analysis required more detailed information. Ground tracking emphasizes cover types not actually used by bears and the power of statistical tests is severely limited by telemetry inaccuracies. The lack of apparent habitat selection in this study is likely a reflection of the poor telemetry accuracy

(White and Garrott 1986). In addition, there is no way this method could ever be used to evaluate micro-habitat use--the telemetry errors are just too large.

Location of bears by aerial searches is a more accurate method but this technique is limited by the inaccuracies or inadequacies of cover type maps. Ground truthing telemetry locations will eliminate cover type map inaccuracies. Ground truthing aerial locations without transmitter drops in Harmon Den would be difficult. The complex topography makes exact ground locations difficult to determine. Dropped transmitters assure the researcher that they are in the correct spot. Drawbacks of this method are that night drops are impossible and the technique is limited by weather. The accuracy of the technique is probably highly related to the pilot's interest and experience (Hoskinson 1976).

In Harmon Den, black bears are very difficult to observe. Virtually none have ever been seen while ground tracking, and less than 1% of the aerial tracking sessions have ever resulted in visual observations. In addition, the complex overstory/understory vegetation types make visual classifications of habitats from aerial observations very subjective. The above, coupled by inaccurate or ambiguous maps likely results in significant errors when interpreting habitat use by black bears. This technique also enhances the closeness of the researcher to his subject matter and may provide valuable insights into social habits, food and cover utilization, and other useful observations not possible with conventional telemetry methods.

### Response to Roads

In determining the reaction of black bears to roads, I looked for relationships between road density and/or traffic volume and bear crossings. What follows is a summary of my findings and the logic used to arrive at them. Variables that were used in the analysis are listed in Table 1, page 26.

There was no relationship between year or season and RCI (road crossing index) or RAI (road avoidance index). Plots using these variables showed only random scatter. Additionally, year and season were not significant using variable selection procedures (SAS Institute 1982). The variable road density was significant, and it was highly correlated with RCI ( $r = 0.45$ ). Analysis was performed separately on each of the 3 road classes because road class and road density were correlated and were interacting.

#### Class I Roads

Traffic appears to inhibit bear movements when volumes are high. Bears crossed the Class I road less and avoided it more than other roads in the study area; Interstate 40 was the only Class 1 road in the study area. Telemetry locations indicate a total of 12 crosses in the 2 year study. The small number of crosses resulted in extremely low RCI's; plots of RCI versus road density gave a small cluster of points (Figure 6). To fit an equation to this would have been meaningless. Interstate 40 (Class I road) seems to act as a partial barrier to bear movements. On several occasions bears were

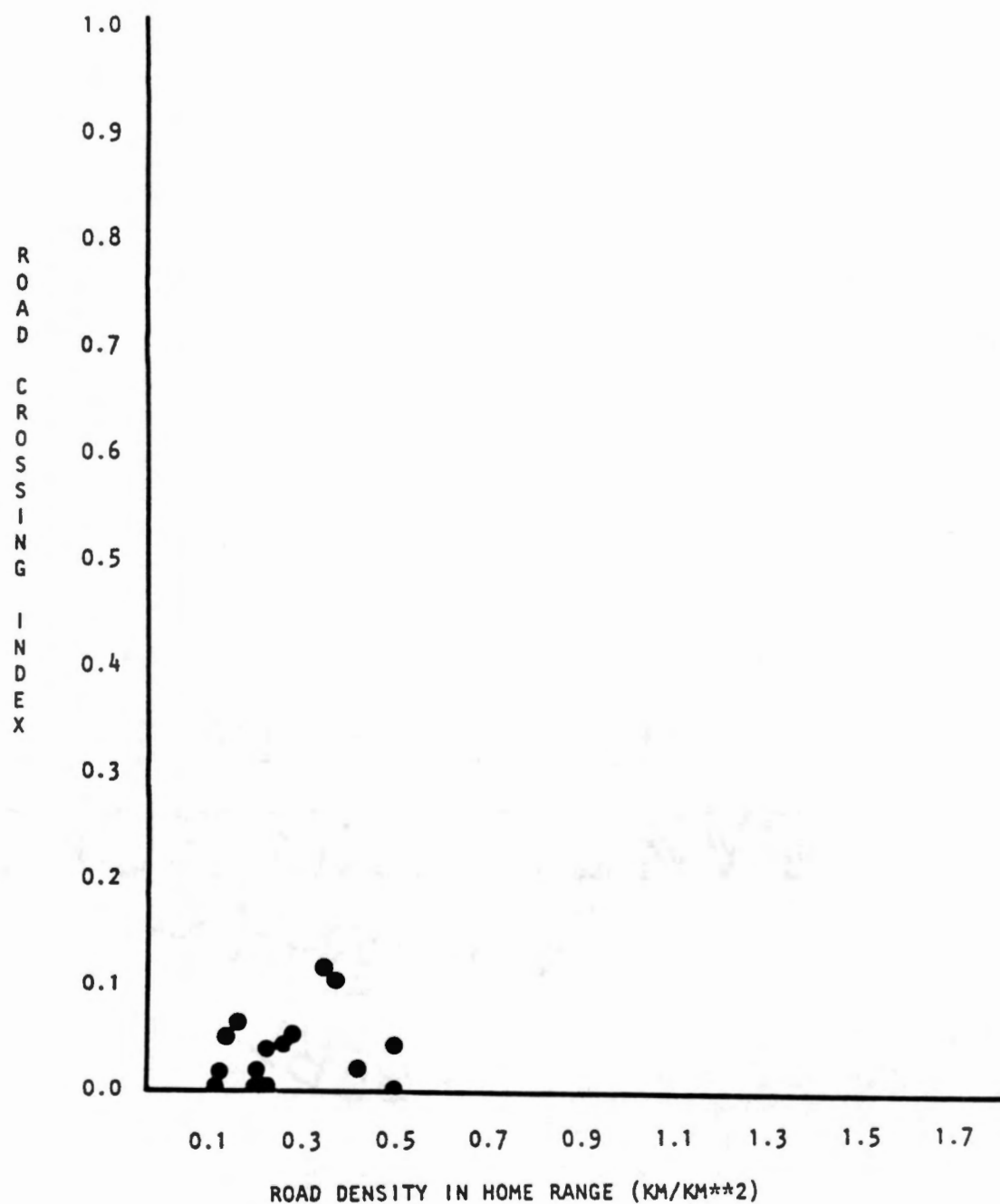


Figure 6. Plot of road crossing frequency by bears and Class I road density in their home range in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

located near the interstate but they seldom crossed it. If bears did cross, it was usually at or near a tunnel which provided a small corridor between the 12 Mile Strip on one side of I-40 and Harmon Den on the other side (Brody 1984a, pers. observ.).

Plots of RAI and road density for this class of road also indicate that bear movements are restricted by them (Figure 7). There is a direct linear relationship between road length in a bear's home range (utilization distribution) and the number of times it avoided the road. Bears with greater densities of Class 1 roads had proportionately higher RAI's than those with lower densities. Bears often approached and then moved parallel to or away from the interstate.

#### Class II Roads

Data concerning bear reactions to Class 2 roads were not conclusive. The plot of RCI and road density (Figure 8) shows a large amount of scatter. Logically the next step in determining the aptness of a model is to plot the residual (the difference between the observed RCI value and the corresponding fitted value, often referred to as the observed error) values against the X values (road density). This plot also showed no relationship existed. Bears did not appear to cross these roads with any relationship to road density in their home range. Neither did they avoid these roads with any regularity. Plots of RAI and road density showed no relationship (Figure 9). When tallying road crosses, I noticed certain bears crossed and recrossed Class II roads numerous times while others seldom crossed.

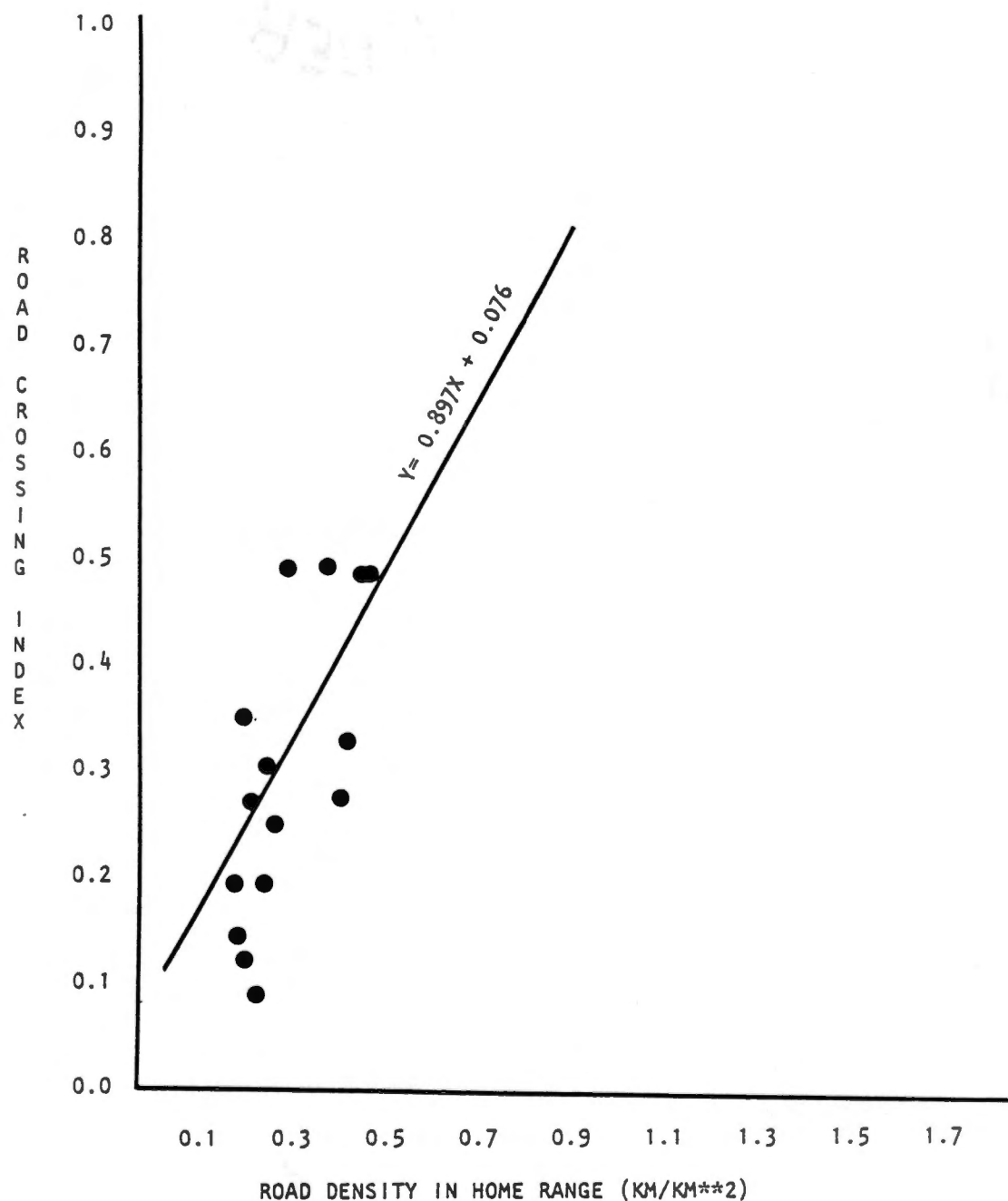


Figure 7. Relationship between road avoidance by bears and Class I road density in their home range in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

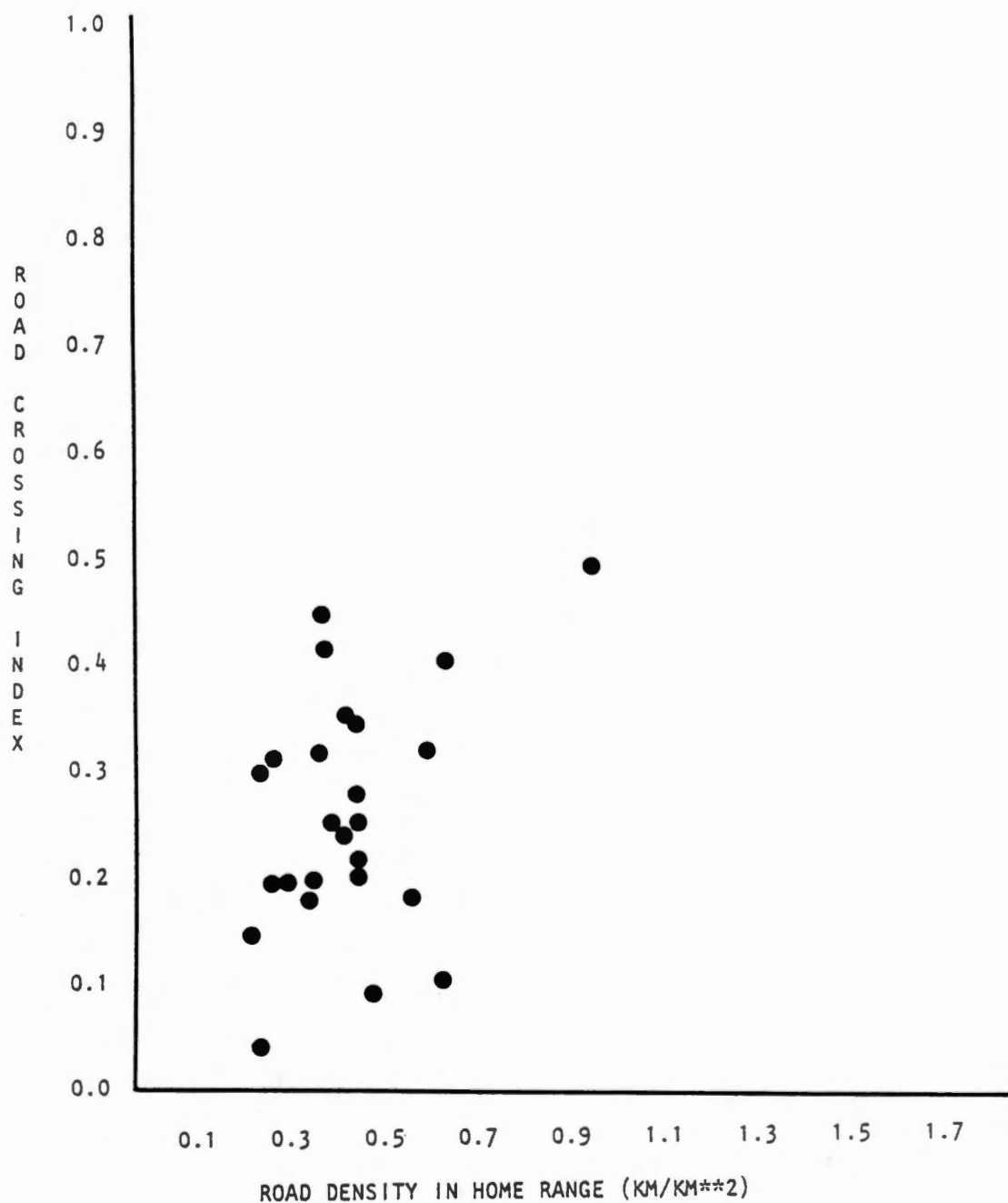


Figure 8. Plot of road crossing frequency by bears and Class II road density in their home range in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

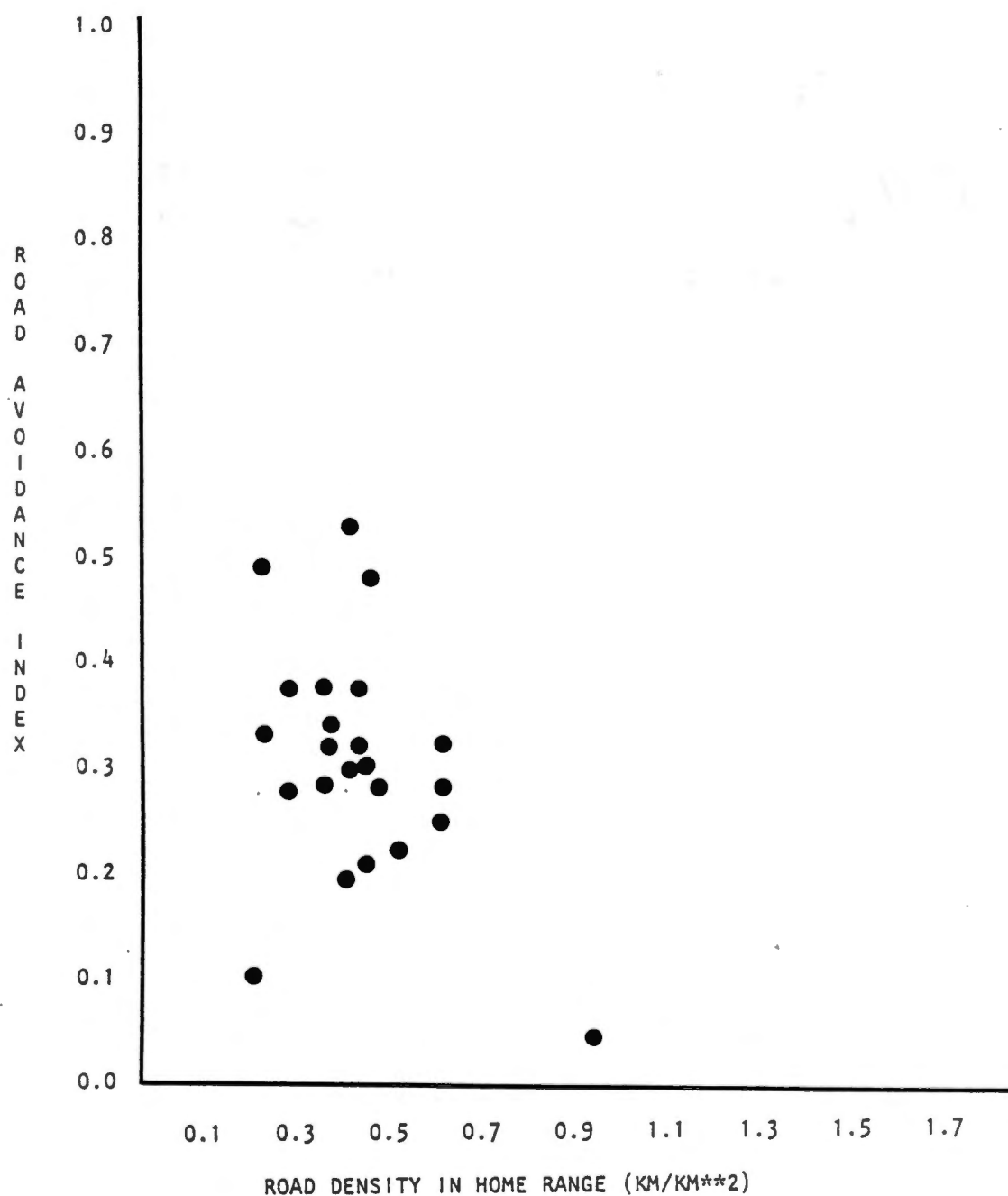


Figure 9. Plot of road avoidance by bears and Class II road density in their home range in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

Crossing roads may be related to learned experience or to the juxtaposition of roads and habitat in a bear's home range. However, there appears to be a direct relationship between RCI and the density of Class III roads in a bear's home range.

#### Class III Roads

The plot of RCI and road density indicates the relationship is positive and linear (Figure 10); tests for a curvilinear relationship showed that none existed. Bears tended to cross roads more often as the road density increased. This supports the hypothesis that at least Class III roads do not seem to inhibit bear movements. Intuitively, if RCI and road density are directly related, RAI and road density should not be. Indeed, there was no relationship between RAI and road density (Figure 11).

#### The Effects of Traffic Volume on RCI

RCI varied significantly among the 3 road classes ( $P < 0.05$ ). The plot of RCI versus road class is depicted in Figure 12. The plot indicates a difference in RCI between Class I roads and Class II and III roads. Bears crossed Class I roads significantly less than Class II and Class III roads. They crossed Class II and III roads with almost equal intensity; mean modified RCI's (RCI/km's of road in home range) were 0.0654 and 0.0663, respectively. A mean difference of approximately 60 vehicles per day did not inhibit bears from crossing Class II roads any differently than Class III roads. The fact that bears crossed these 2 road classes with equal frequency

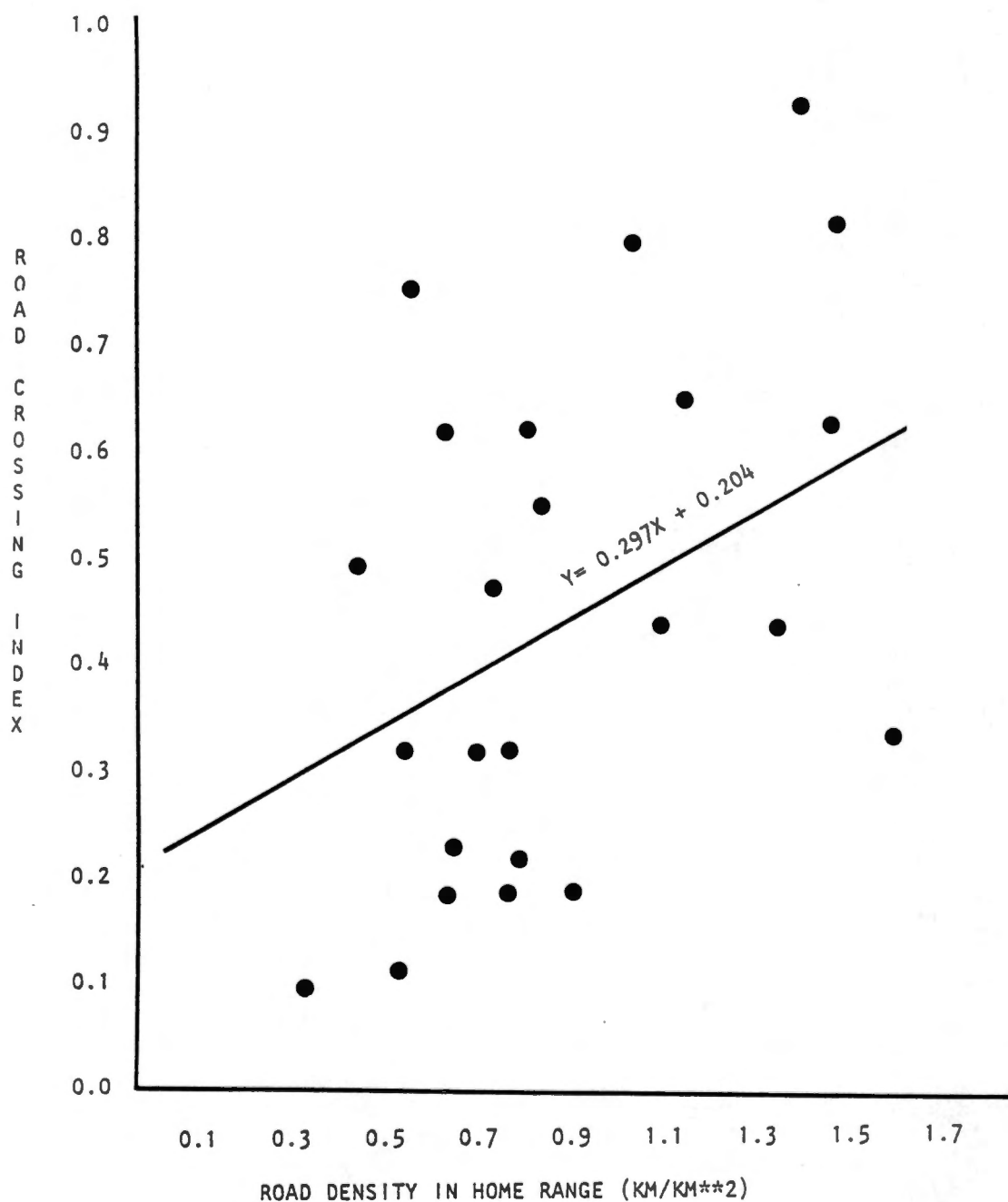


Figure 10. Relationship between road crossing frequency by bears and Class III road density in their home range in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

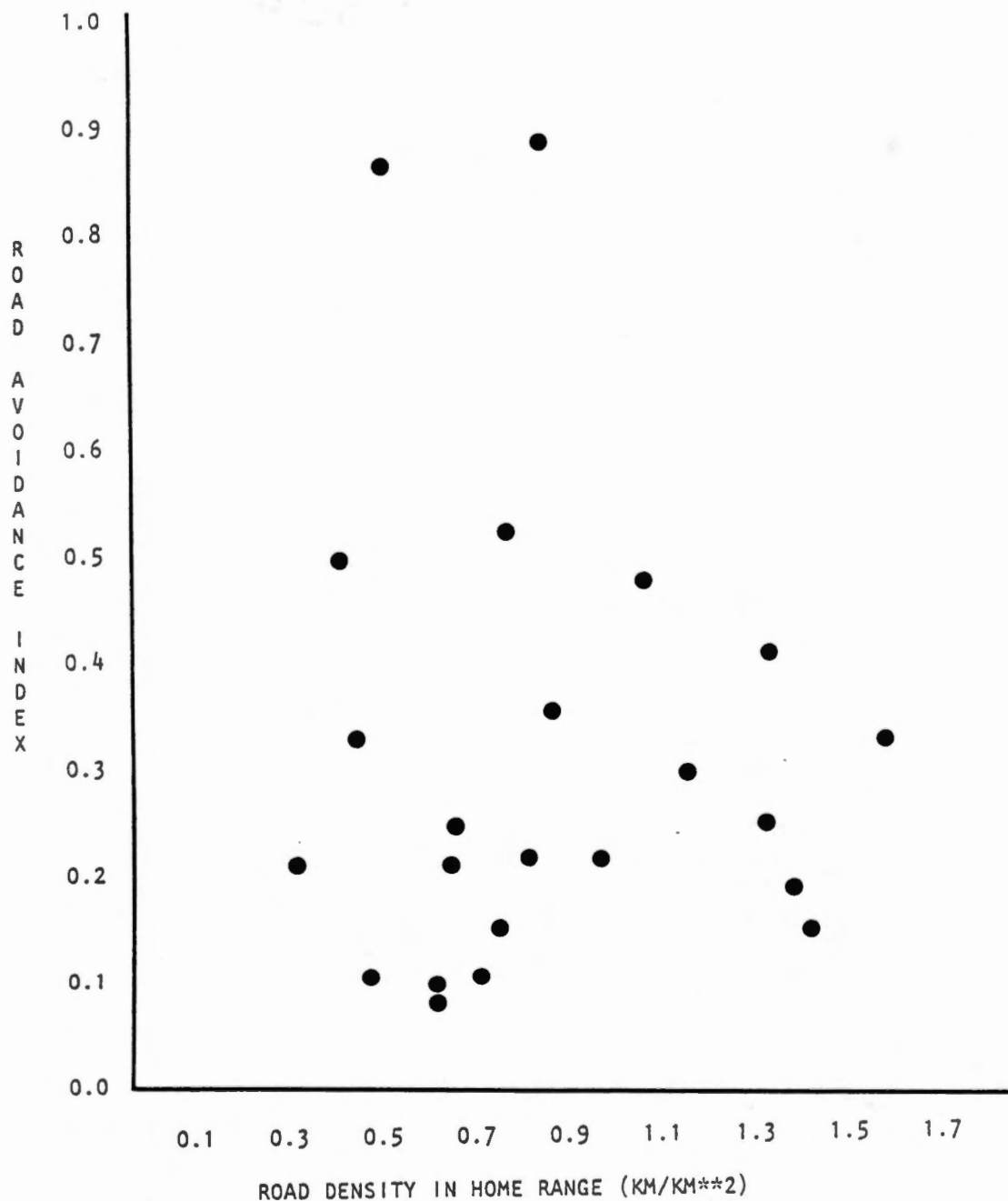


Figure 11. Plot of road avoidance by bears and Class III road density in their home range in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

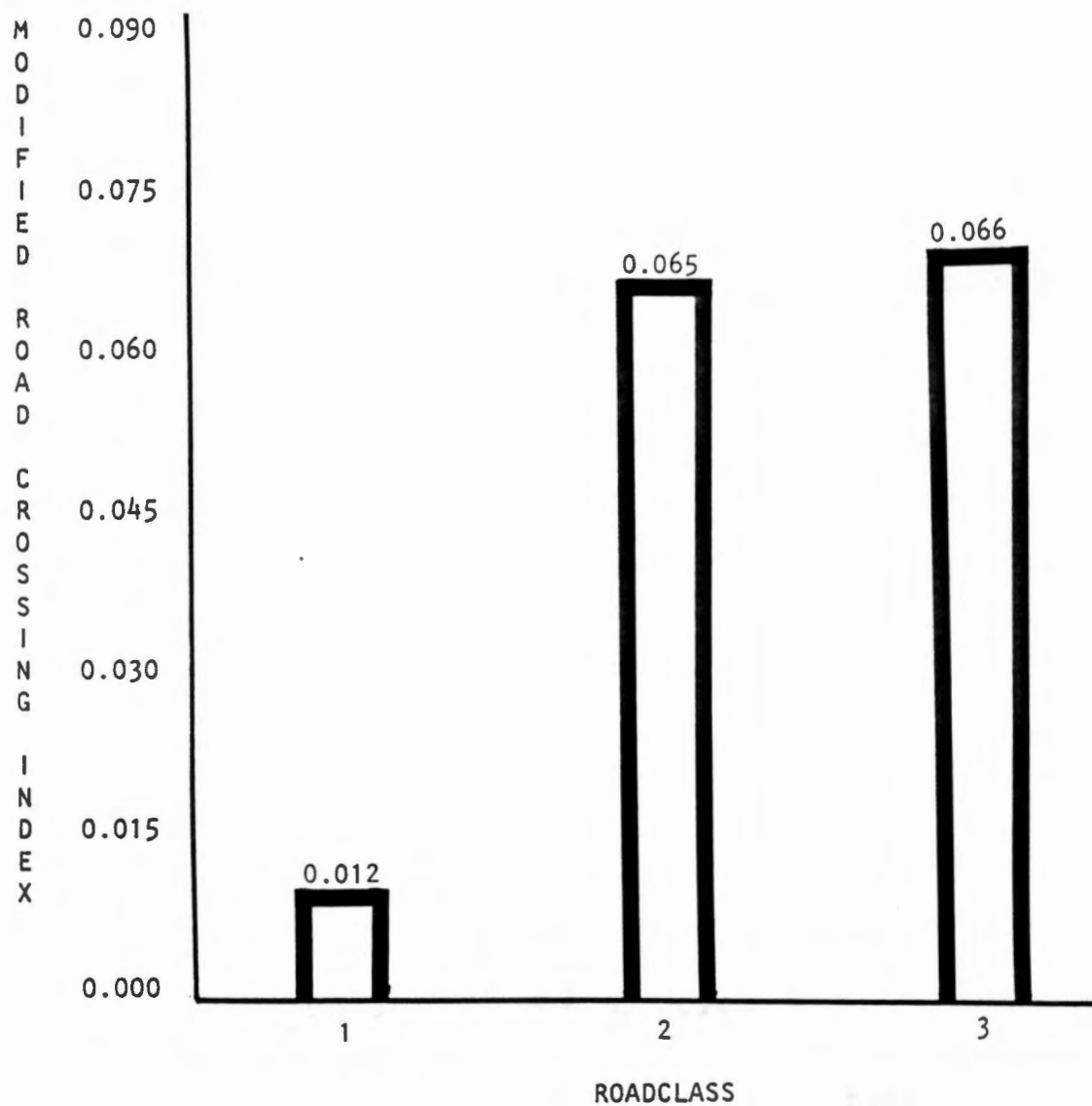


Figure 12. Relationship between road crossing frequency and traffic volume for bears in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

indicates their movements were not inhibited; this is logical because Class III roads were crossed in proportion to their availability.

Whether bear movements are partially restricted by certain road densities or traffic volumes probably has little effect on their livelihood. If bear movements were inhibited by roads their adaptability would enable them to survive anyway. Class II and III roads do not appear to detract from bear habitat and may improve habitats lacking sufficient spring and summer foods. Bear sign was abundant along secondary roads in Harmon Den. Bear dens within 50 m of heavily traveled, paved roads, have been observed in GSMNP (pers. observ.) and Wisconsin (pers. observ.).

Bears cross roads with mean traffic volumes of 75 and 15 vehicles per day with almost equal intensity. Bears crossed Class II and III roads an average of 14 (range = 4 - 40) and 20 (range = 3 - 52) times, respectively, per season. The higher road densities of Class III roads are responsible for the greater number of crossings.

It is when bears cross roads that they become susceptible to hunting mortality. Bear hunting in western North Carolina is done almost exclusively from roads. Hunters drive backroads with strike dogs poised on the hoods of their vehicles. These dogs can smell bear crossings that are hours old. Bear hunters without strike dogs scan the road bank for bear sign. Dogs are released when a place that a bear has crossed the road is found. Hunters monitor the chase with CB radios and the radio collars many of their dogs carry. Many bears are shot and killed as they recross roads in front

of hunters. Most are shot within 1.9 km of a road and 23% are killed within 70 m of a road (Collins 1983).

Using methods previously described, I found that bears avoided the interstate but did not avoid secondary roads. Because bears cross roads, they become more vulnerable to hunting pressures. If bears avoid roads, it is due to disturbances associated with them. Most roads that are used by bear hunters are not heavily traveled (except during bear season) and the advanced tools and hunting techniques of the modern bear hunter leave bears few opportunities to learn to avoid them. With increased road densities, bears cross roads more often. The high road densities in the 12 Mile Strip, west of Harmon Den, enable hunters to harvest nearly every bear in the area (Brody 1984a, pers. observ.). Gated roads hinder hunter access, but vehicles behind "locked" gates were not uncommon during the bear season. If new roads are constructed, they should be gated and the locks should be changed periodically.

#### Future Considerations

Harmon Den appears to be serving its intended purpose as a bear sanctuary; that is, providing a surplus of bears for the hunted surrounding areas. There is a good population of breeding females in Harmon Den. These females appear to be breeding and producing young at rates higher than those observed in surrounding areas. Telemetry indicates subadult males are dispersing to areas outside of the sanctuary, but their mortality rates are high. Females in

Harmon Den are protected, but perimeter hunting and poaching took 3 adult females during the 2 year study.

Hunting mortality for sanctuary bears was higher than rates reported in many hunted populations; rates for bears spending all their time in hunted areas are even higher (Brody 1984a). Bears would likely be nonexistent in areas surrounding Harmon Den without sanctuaries like it and GSMNP. Gated roads and proper enforcement are essential in protecting the usefulness of Harmon Den as a sanctuary. Observations of vehicles and loose dogs behind locked gates were not uncommon. At least 8 bears (excluding study animals) were taken illegally during the 2 year study.

Of equal importance to harvest management in Harmon Den is habitat management. Bears need a proper diversity of habitats to ensure against natural food shortages. Spring and summer food requirements can be found in a variety of habitats but fall foods center around oak stands. Brody (1984a) expressed concern over changing age structures and their mast producing capabilities. In this study, bears used stands aged 30-49 and 90+, which will be plentiful over the next decades.

Of greater concern is timber stand composition. Northern red oak and white oak are the most consistent and bountiful mast producers (Beck 1977) available to bears in Harmon Den. Both species are well represented, but current problems with oak regeneration indicate this may change.

Oak regeneration has recently gained a lot of attention, and it appears that no one knows the best way to regenerate oaks in this

region. Clearcutting does not facilitate oak regeneration on good sites or on sites in which yellow poplar is a component (Beck 1970, McGee and Hooper 1970, 1975; Loftis 1982, 1985). This is even true for oak dominated stands (McGee 1975). Successful oak regeneration is consistent only when there is large advance oak regeneration (Sander 1972) or the site is a poor and/or a dry one.

Oak species cannot compete with faster growing yellow poplar, red maple (Acer rubrum) and other intolerant species. Oaks require large stems of advance regeneration to compete (Loftis 1983); seedlings will be outcompeted when the overstory is removed. Clark (1970) found that only when oak stems had large root systems and were well established did they become a major component of the new stand.

Oaks must be "reproduced before the harvest" (Clark 1970). Methods that favor the crucial advance regeneration include the use of fire (McGee 1979, Clark 1970). Although traditional shelterwood cuts do not benefit oaks in the Southern uplands, modified shelterwood methods (spread over 10-20 years) that provide enough light to favor oaks, but not enough for yellow poplar and other intolerants, may prove effective in oak regeneration (Loftis 1983). Intensive understory control using herbicides (Loftis 1985) offers further alternatives. Bears preferred yellow poplar-white oak-northern red oak stands in this and the previous study. However, if these stands are harvested using traditional even-aged management much of the oak component will likely be lost. Perhaps given enough time, oaks will again become a major component of these stands eventually

replacing the subclimax yellow poplar. However, the present rotation is too short for this. If oaks are to remain a major component of these productive stands, special considerations (perhaps site specific) will be required to facilitate their regeneration. Caution must be taken when manipulating habitat composition; if left to chance, the oak component of many stands could be lost and recovery may take centuries.

## CHAPTER V

### SUMMARY AND CONCLUSIONS

1. Research was conducted in Harmon Den, a portion of Pisgah National Forest, North Carolina.

2. A total of 20 bears were captured 22 times in 1,012 trap-nights. Trapping efficiency was 46 trapnights per capture.

3. A total of 17 radio collars were deployed; 12 were for initial captures; 3 were used to recollar previously tagged bears and 2 were used to recollar bears at den sites.

4. A total of 1735 radio relocations were obtained on these animals during the study.

5. The dens of 8 female bears were visited during the study.

6. Cub production for adult females was 3 in 2 cases and 4 in the third.

7. Bears denned under slash pines, in exposed ground nests, in rock dens, and in a tree. Tree dens offer protection to female bears with cubs and should be preserved.

8. Seven of 18 study animals (39%) were legally harvested or poached; minimum mortality rates were 54% and 8% during 1984 and 1985, respectively. Hunting was the most significant human activity affecting bear populations.

9. Twenty-eight seasonal home ranges were constructed for 14 bears.

10. Male home ranges averaged 15, 13, and 61 km<sup>2</sup> during summer, fall and annually, respectively. They were significantly  $P < 0.05$  larger than female ranges over each time period.

11. Female home ranges averaged 10, 11, and 14.8 during summer, fall and annually, respectively.

12. Home range size was not significantly different between adults and subadults. Seasonally, home range size varied significantly ( $P < 0.05$ ) only among males.

13. Home range sizes determined for bears in Harmon Den were similar in size to those found in Cherokee National Forest.

14. Home range overlap was extensive and occurred within and between sexes of all bears.

15. Seasonal and annual shifts of activity centers were measured using the method of harmonic means. Harmonic centers of activity did not vary significantly between seasons or annually. Shifts were likely not prominent because of the almost continuous overstory of oak species in Harmon Den.

16. Bear use of forest cover type, stand age, and site index was determined using the methods of Neu et al. (1974).

17. Cover type preferences using ground tracking indicated that bears selected for pine stands, and males avoided chestnut and scarlet oak stands; all other cover types were used in proportion to their availability.

18. Bears selected for stands with site indices of less than 40 (primarily forest openings) both seasons. Females preferred stands

with site indices of less than 40 during summer and those greater than 81 during fall. Males selected for forest openings (site index < 40) both seasons and for stands with > 81 site indices during fall; they avoided stands with site indices between 61 and 80 during fall.

19. Both sexes selected for stands that were between 30 and 49 years and greater than 90 years and avoided stands aged between 50 and 69 years during summer. No preferences were noted for females during fall, but males avoided stands aged between 10 and 29 years and those between 70 and 89 years.

20. Forest cover type use by 6 female bears was compared using 3 different methods of data collection: ground tracking, aerial tracking, and transmitter drops.

21. Transmitter drops were a much more accurate and sensitive method of determining cover type preferences. Using this method, bears were found to avoid non-forest, pine, mixed pine/hardwood, and yellow poplar stands; they preferred yellow poplar-white oak-northern red oak stands.

22. Using aerial tracking bears were found to avoid yellow poplar stands, and using ground tracking no preferences or avoidances were noted.

23. Transmitter drop data also gave important insights to microhabitat use and bear activities in certain cover types.

24. Forest cover types determined using transmitter drops were significantly different ( $P < 0.001$ ) from assigned CISC cover types. Perceived differences were a function of classification schemes.

25. Bear reactions to roads and their associated disturbances were measured.

26. Bear movements were not inhibited by roads with traffic volumes less than 100 vehicles per day. Bears seldom crossed Interstate 40 and this road seemed to act as a partial barrier to their movements.

27. Gating roads and maintaining an abundance of mast producing oak species is essential to maintaining the feasibility of Harmon Den as a bear sanctuary. Site specific harvest considerations should be taken to ensure that there is large advance oak regeneration before overstory removal; mistakes made in cover type manipulation may take centuries to reverse.

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APPENDIX

Observer \_\_\_\_\_

Date \_\_\_\_\_

Temperature \_\_\_\_\_

Rain \_\_\_\_\_

Bear No. \_\_\_\_\_

UTM \_\_\_\_\_

Transmitter Drop Time \_\_\_\_\_

Date \_\_\_\_\_

Slope \_\_\_\_\_

Aspect \_\_\_\_\_

| <u>Dominant overstory</u>    | <u>Species</u> | <u>Age class</u> | <u>% of stand</u> |
|------------------------------|----------------|------------------|-------------------|
|                              | 1              |                  |                   |
|                              | 2              |                  |                   |
|                              | 3              |                  |                   |
|                              | 4              |                  |                   |
|                              | 4              |                  |                   |
| <u>Dominant understory</u>   | 1              |                  |                   |
|                              | 2              |                  |                   |
|                              | 3              |                  |                   |
|                              | 4              |                  |                   |
|                              | 5              |                  |                   |
| <u>Herbaceous vegetation</u> | 1              |                  |                   |
|                              | 2              |                  |                   |
|                              | 3              |                  |                   |
|                              | 4              |                  |                   |
|                              | 5              |                  |                   |

CISC Classification —

Comments; bear sign activities—

Figure 13. Data collection sheet used for transmitter drops in Harmon Den Study Area, Pisgah National Forest, North Carolina, 1984-1985.

## VITA

Jeffrey James Beringer, son of James and Donna Beringer, was born in Neenah, Wisconsin, on 16 September 1961. He attended S. F. Shattuck and Armstrong High Schools in Neenah, and graduated in 1980. He then attended the University of Wisconsin-Stevens Point from 1980 to 1984 and graduated with honors with a Bachelor of Science degree in Wildlife Management. In June 1984, he began work in the Department of Forestry, Wildlife and Fisheries at The University of Tennessee, Knoxville. He accepted a position with the Missouri Department of Conservation in September 1986, and graduated with a Master of Science degree in Wildlife and Fisheries Science from The University of Tennessee, Knoxville, in December 1986.