Incidence of Road Crossing by Black Bears on Pisgah National Forest, North Carolina

Author(s): Jeffrey J. Beringer, Steven G. Seibert, Michael R. Pelton
Source: *Bears: Their Biology and Management*, Vol. 8, A Selection of Papers from the Eighth International Conference on Bear Research and Management, Victoria, British Columbia, Canada, February 1989 (1990), pp. 85-92
Published by: International Association of Bear Research and Management
Stable URL: http://www.jstor.org/stable/3872906
Accessed: 02/01/2009 16:27

INCIDENCE OF ROAD CROSSING BY BLACK BEARS ON PISGAH NATIONAL FOREST, NORTH CAROLINA

JEFFREY J. BERINGER,[1] Department of Forestry, Wildlife, and Fisheries, University of Tennessee, Knoxville, TN 37901
STEVEN G. SEIBERT,[2] Department of Forestry, Wildlife, and Fisheries, University of Tennessee, Knoxville, TN 37901
MICHAEL R. PELTON, Department of Forestry, Wildlife, and Fisheries, University of Tennessee, Knoxville, TN 37901

Abstract: We examined the reactions of 24 radio-tagged black bears (*Ursus americanus*) to roads on the Harmon Den area of Pisgah National Forest, North Carolina, during 1984 to 1987. The number of times roads were crossed by bears was related to the road density within their home range, and to the traffic volume associated with these roads. Roads were classified according to the mean number of vehicles using that road per day. Class I roads had 10,000+ vehicles per day, Class II had 50-100 vehicles per day, and Class III roads had 5-20 vehicles per day. Bears crossed Class I roads significantly less ($P < 0.0001$) than Class II and Class III roads. Class II and III roads were crossed with almost equal frequency. A mean difference of 60 vehicles per day between the 2 classes did not affect the crossing frequency by bears. Bears strongly avoided ($P < 0.0001$) Class I roads as the density of these roads in their home range increased. Bear crossings of Class III roads increased as road density increased. Bears were found to cross roads with greater frequency during daylight hours than at night. The potential adverse effects of human activities such as timber management and hunting are discussed in relation to different types and uses of roads.

Int. Conf. Bear Res. and Manage. 8:85–92

Numerous studies have documented avoidance of roads by many wildlife species including: turkey (*Meleagris gallopavo*) (Wright and Speake 1975), white-tailed deer (*Odocoileus virginianus*) (Dorrance et al. 1975), mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) (Rost and Bailey 1979), mountain lions (*Felis concolor*) (Van Dyke et al. 1986), and grizzly bears (*Ursus arctos*) (Archibald et al. 1987). Studies also have documented relationships between black bears and roads, often with conflicting results. Bears were reported to avoid roads in eastern (Hamilton 1978) and western North Carolina (Brody 1984), Great Smoky Mountains National Park (GSMNP) (Quigley 1982), Cherokee National Forest (Villarrubia 1982), and West Virginia (Miller 1975, Brown 1980). However, Carr (1983) reported bears did not avoid roads on his study area in GSMNP. Bears were reported to avoid some roads but not others in Maine (Hugie 1982), Michigan (Manville 1983), Great Dismal Swamp National Wildlife Refuge (Hellgren 1988), and western North Carolina (Beringer 1986, Seibert 1989). Brody and Pelton (1989) suggested bears establish home ranges so as to keep road density or traffic volume below threshold levels. Many variables are associated with bears and their reactions to roads. Juxtaposition of habitat components, road density, traffic volume, learned behavior of individual bears, whether or not the population is hunted (Geist 1971, Dorrance et al. 1975), and even method of analysis (Brody 1984) affect interpretation of bear interactions with roads.

Road densities and bears' reactions to roads are significant in the southern Appalachians where hunting bears with the aid of dogs is traditional and very popular. The bear season in western North Carolina opened in mid-October and remained open through December each year of the study. It was closed for 3 weeks during November and December; hunters could legally hunt 52 days. When bears cross roads they become vulnerable to hunting. Ninety percent of the bears killed in western North Carolina are killed with the aid of hounds (Collins 1983). Hunters drive roads with "strike" dogs on the hoods of vehicles; some dogs apparently can smell bear crossings that are several hours old. Dogs are released at locations where a bear has recently crossed a road. Hunters monitor the chase by listening to the dogs' voices, with CB radios, and with radio collars on their dogs. The road network enables them to follow most chases with vehicles and many bears are shot and killed as they recross roads in front of hunters. Seventy-three percent of the kills occur within 1.6 km (1 mi) of a road; 23% within 70 m of a road (Collins 1983). Greater access also increases the potential for illegal hunting. Thus, extensive road systems may be a critical factor for hunter success and bear survivability. With this in mind we tried to determine if bears avoided roads or the disturbances associated with roads.

This study was an extension of previous work by Brody and Pelton (1989). They provided the conceptual framework and initial testing of a proposed model to determine the effects of roads on black bear movements in western North Carolina.

This research was funded by the United States Forest Service (USFS) and the University of Tennessee Agricultural Experimental Station, Department of Forestry, Wildlife, and Fisheries. We thank the North Carolina Wildlife Resources Commission (NCWRC) for assistance in trapping. Special thanks are due to J. Collins

[1] Present address: Missouri Department of Conservation, RR 3, Box 50, Montgomery City, MO 63361.

[2] Present address: School of Forest Resources, University of Georgia, Athens, GA 30602.

(NCWRC) and L. Hillman (USFS). We thank A. Brody for reviewing this manuscript and greatly improving early versions.

STUDY AREA

The study was conducted on the Harmon Den bear sanctuary, a 5,740-ha section of Pisgah National Forest (PNF), North Carolina. The mountains are sharply dissected and the terrain is steep. Elevations range from 439-1,411 m, slopes average over 30% (Finlayson 1957). Climate is described as a warm-temperate rain forest (Thornwaite 1948). Vegetation is diverse and changes dramatically with aspect, elevation, soil, and drainage (Finlayson 1959). Roads on the study area included 23 km of interstate highway, 10 km of 2-lane gravel roads, and 21 km of 1-lane gravel roads. The 2-lane gravel roads were maintained by the county and were through roads. The single lane roads were usually gated, dead-end logging roads. Most travel on these roads was related to logging activities. Many of these roads followed mountain contours and travel was necessarily slow.

METHODS

Bears were captured with Aldrich foot snares using methods described by Johnson and Pelton (1980). Selected individuals were fitted with radio collars operating in the 150-152 MHz range (Telonics, Mesa, AZ).

Bears were located once every 20 hours during 1984-1986. During 1987, bears were located twice daily at 6-hour intervals on alternating days. The tracking period started 4 hours earlier each tracking day to simulate the tracking periods of the previous years. Ground triangulation was done from ridge tops, gaps, and other sites identifiable on topographic maps. Bears also were located from a Cessna 172 aircraft with H antennas mounted on each wing strut.

Bear locations obtained from telemetry were used to construct seasonal home ranges using the convex polygon method (Hayne 1949). Seasons were defined as summer (den emergence to 15 September), and fall (16 September to den entrance) (Beringer 1986, Seibert 1989).

We used pneumatic counters to measure traffic volumes on each of the gravel roads. Traffic volume for Interstate 40 (I-40) was obtained from the North Carolina Department of Transportation. Counters for each gravel road were read prior to radio tracking each day. Vehicles per day (VPD) for each road were tallied and a mean and range were calculated for each. We used these numbers to classify the various roads because their means were significantly different and the breakdown correlated well with the surface and access classifications of Brody and Pelton (1989). Roads that averaged 10,000+ VPD were classed as Class I roads, those with 50-100 VPD Class II roads, and those with 5-20 VPD Class III roads.

The density of each road class in each seasonal home range was determined by overlaying the convex polygon on a topographic map and measuring the length of roads inside the home range.

We also formulated a road crossing index (RCI) for each road class in each seasonal home range. The RCI was calculated by dividing the number of times a bear crossed each road class by the number of locations used to construct the home range:

$$I_{ijr} = X_{ijr} / N_{ij} \quad (1)$$

where I_{ijr} is the road crossing index for bear i in season j of road class r, X_{ijr} is the minimum number of times bear i crossed road class r in season j, and N_{ij} is the number of telemetry locations of bear i in season j. In addition, a road avoidance index (RAI) was calculated. The RAI was the number of times a bear moved parallel to or away from a road, yet moved far enough to potentially cross the road, divided by the number of locations used to construct the seasonal home range:

$$A_{ijr} = X_{ijr} / N_{ij} \quad (2)$$

where A_{ijr} is the road avoidance index for bear i in season j of road class r, X_{ijr} is the minimum number of times bear i avoided road class r in season j, and N_{ij} is the number of telemetry locations of bear i in season j.

Analysis was based on the assumption that if roads do not affect bear movements and bears travel randomly through their home ranges, they cross roads in direct proportion to road density within their home ranges (Brody and Pelton 1989). Plots of RCI and RAI versus density (km of road divided by area in home range) of each road type were constructed to determine if bears were in fact indifferent to roads. Only bears that were located regularly during tracking sessions were used in the analysis. This excluded many adult males because of poor tracking success and long time intervals between consecutive locations.

Initial analysis consisted of plotting the dependent variable (RCI or RAI) against each of the predictor variables: road density, bear, year, and season (Table 1). Nonparametric analysis of variance and Pearson correlation coefficients were used to determine significance of the predictor variables.

An additional variable, time of crossing or avoidance, was analyzed for the 1987 data. Daytime crosses occurred between 0600-2000 hours; nighttime crosses occurred between 2000-0600 hours. Contrast statements (SAS 1985) were used to detect differences of RCI and

Table 1. Variables used in analysis of the effects of roads on bear movements on Harmon Den, Pisgah National Forest, North Carolina, 1984-1987.

Variable	Explanation definition
Road class I, II, III	Broken into 3 classes as determined by traffic volume. Road Class I = X traffic volume >10,000 vehicles per day. Road Class II = X traffic volume = 75 vehicles per day. Road Class III = 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 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 of each Road Class divided by km^2 of area in a bear's seasonal home range.
Bear	Individual bears
Season	Summer or Fall
Year	1984 to 1987
Time of day	Day (0600-2000 hours) Night (2000-0600 hours)

RAI for the 2 time periods.

The RCI for each bear was divided by the road length (km) in its home range 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 1985).

RESULTS AND DISCUSSION

Forty bears were captured during the study, 35 were fitted with radio collars, and 24 of these (16 females, 8 males) were tracked frequently enough to yield 51 seasonal home ranges (Table 2). Nine of the 24 were killed by hunters during the study: 7 legally and 2 illegally. Both illegally killed bears were killed inside the sanctuary, 1 before the hunting season and the other in a den. Three additional collared bears that were not tracked frequently enough to be included in the analysis and 3 tagged bears that were not collared also were legally killed.

Road density was correlated with RCI ($R^2 = 0.50$, $P < 0.0001$) over all road classes. Subsequent analysis was performed separately on each of the 3 road classes. The variables season and year were only significant for the period from 1986-1987. There was no difference in RCI or RAI among individual bears.

The validity of RAI may be of concern. Telemetry inaccuracies and our sampling schedule may have, at times, allowed a bear to cross then recross a road before we obtained another triangulation. Also, a bear could approach a road, travel on it for some distance then move away. Both times, these movements would have been tallied as an avoidance. We acknowledge these drawbacks. However, we believe that since our data were collected in a random fashion and because we obtained a large number of locations, these possible errors have not biased our findings. In addition, the road avoidance results seem to support the road crossing data, particularly the data from Class I roads.

Table 2. Number of telemetry locations (*N*), road densities, road crossing indices, and road avoidance indices for 24 bears on Harmon Den, Pisgah National Forest, North Carolina, 1984-1987. Means with standard errors in parentheses.

		Class I roads			Class II roads			Class III roads		
	N	RD[a]	RCI[b]	RAI[c]	RD	RCI	RAI	RD	RCI	RAI
Summer: (28 ranges)	1,705	0.18 (0.15)	0.03 (0.03)	0.23 (0.18)	0.33 (0.15)	0.22 (0.14)	0.25 (0.15)	0.75 (0.31)	0.41 (0.23)	0.29 (0.17)
Fall: (23 ranges)	1,069	0.19 (0.16)	0.03 (0.04)	0.20 (0.16)	0.41 (0.14)	0.19 (0.12)	0.21 (0.17)	0.76 (0.42)	0.33 (0.17)	0.25 (0.18)

[a] RD = Road density (km/km^2)
[b] RCI = Road crossing index
[c] RAI = Road avoidance index (see text).

Class I Roads

Traffic appears to inhibit bear movements when volumes are high. Bears crossed I-40 (the only Class I road in the study area) significantly less than Class II and Class III roads ($P < 0.0001$) (Fig. 1). We detected only 14 crossings by 9 bears in 4 years. One bear was killed by a vehicle while crossing I-40. Plots of RCI versus road density for Class I roads resulted in a small cluster of points (Fig. 2a). The plot of RAI for Class I roads further illustrates that bear movements are restricted by high traffic volumes (Fig. 3a). There was a linear relationship between road length in a bear's home range and the RAI. Bears with a greater density of I-40 in their home range had proportionately higher RAI's than those with lower densities.

Class I road density in a bear's home range may be an artifact of the convex polygon method because the intersections with I-40 occurred near the edges of the home range (Brody and Pelton 1989). Interstate 40 seems to act as a partial barrier to bear movements. On several occasions bears were located near I-40, but they seldom crossed it, often approaching the interstate and then moving parallel to or away from the road. If bears did cross, it was usually above a tunnel that allowed crossing of I-40 without having to contend with traffic (Brody 1984, Beringer 1986, Brody and Pelton 1989).

Class II Roads

Data concerning bear reactions to Class II roads were not conclusive. The only significant variable was year. Bears had a greater ($P < 0.0169$) RCI during 1984-1986 than 1987. The plots of RCI and RAI versus road density of Class II roads (Figs. 2b and 3b, respectively) did not show any relationship. Bears crossed Class II and III roads with almost equal intensity; mean modified RCI's (RCI/km of road in home range) were 0.0563 and 0.0617, respectively (Fig. 1).

When tallying road crosses, we noticed certain bears crossed and recrossed Class II roads numerous times whereas others seldom crossed. The movements of only 2 female bears explained the difference in RCI between 1986-1987. Bear 529 repeatedly crossed Class II roads in 1986. However, she dropped her collar in December 1986 and was not captured in 1987. Also, bear 951

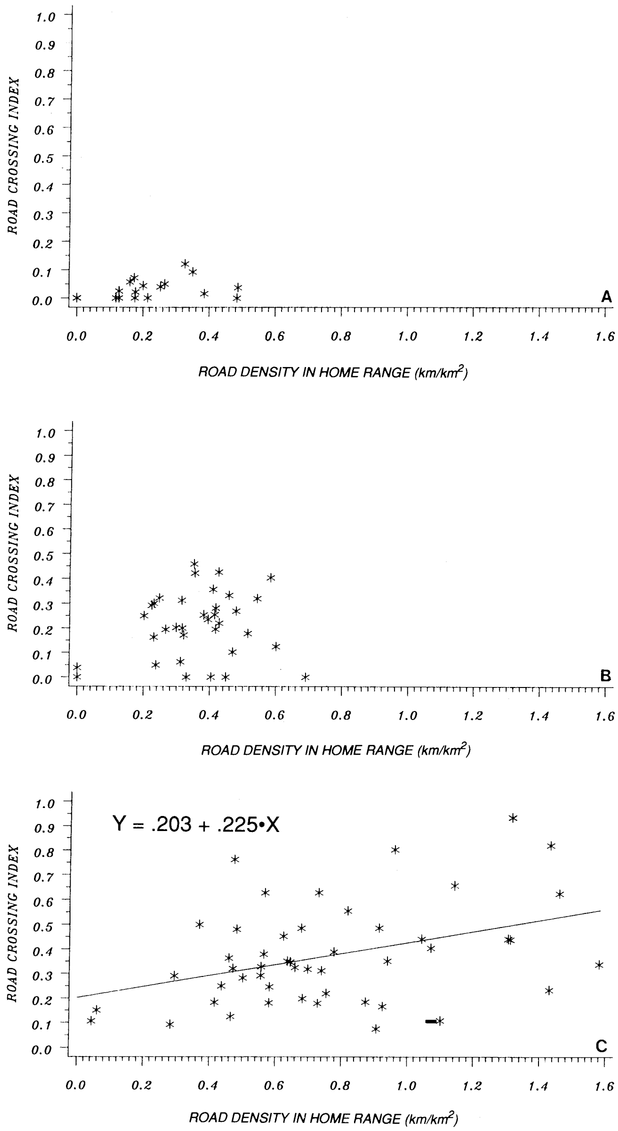

Fig. 2. Road crossing frequency by bears and road density in their home range on Harmon Den, Pisgah National Forest, North Carolina, 1984-1987. A) Class I, B) Class II, C) Class III.

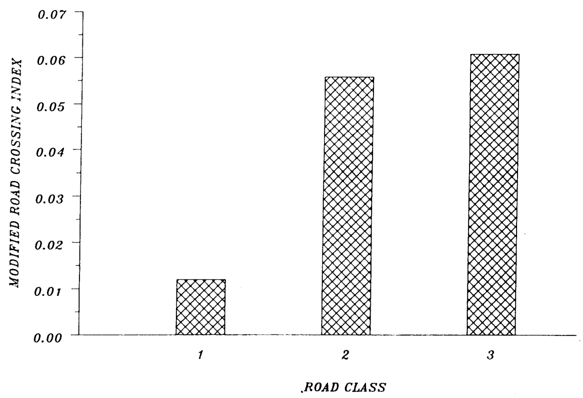

Fig. 1. Road crossing frequency by levels of traffic volume for bears on Harmon Den, Pisgah National Forest, North Carolina, 1984-1987.

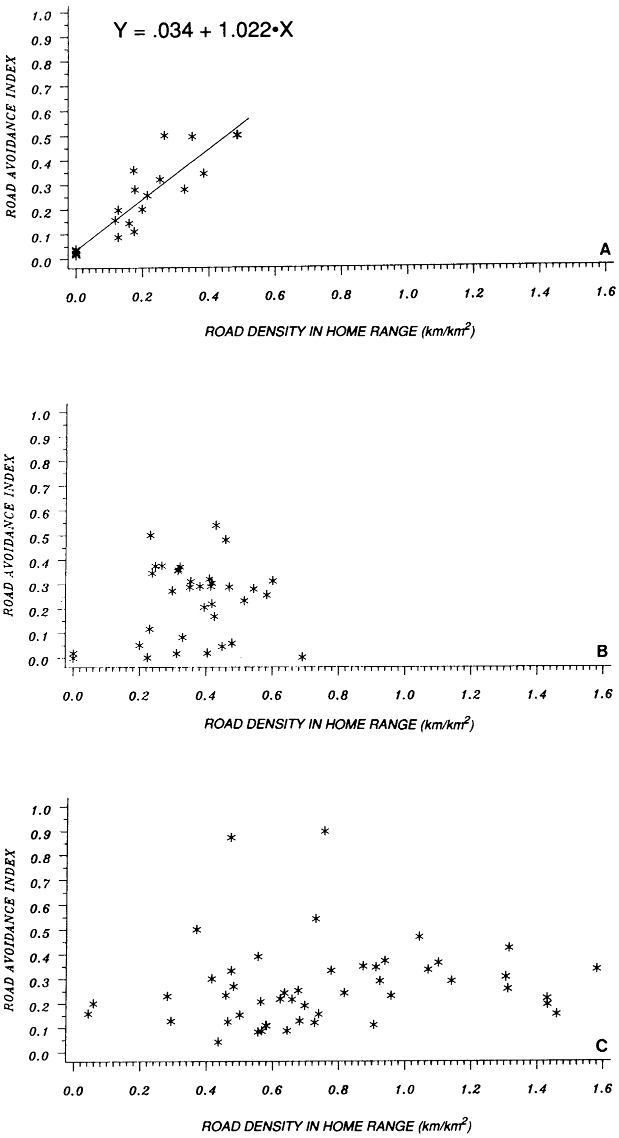

Fig. 3. Road avoidance by bears and road density in their home ranges on Harmon Den, Pisgah National Forest, North Carolina, 1984-1987. A) Class I, B) Class II, C) Class III.

crossed Class II roads in 1986 but did not cross these roads in 1987, even though her home range, road density, and traffic volume within it were similar in both years. Learning, and/or the juxtaposition of roads and specific habitats in a bear's home range may affect road crossing behavior.

Class III Roads

The plot of RCI against road density indicates the relationship is positive and linear for Class III roads (Fig. 2c). Bears crossed roads more frequently as road density increased. 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 (Fig. 3c).

Class II and III roads do not seem to inhibit bear movements. A difference of approximately 60 vehicles per day did not inhibit bears from crossing Class II roads compared to Class III roads. The fact that bears crossed these 2 road classes with equal frequency indicates their movements were not inhibited by traffic volumes ≤100 VPD.

Analysis of variance indicated that the Class III RCI for summer was greater ($P = 0.0541$) than the RCI for fall (Fig. 4) during 1986-1987. Time of day of road crossing was examined only in 1987 ($n = 8$ bears, 887 locations). Only 2 bears had Class II roads in their home ranges, the roads occurred along the perimeter of the ranges and no crossings of these roads occurred, therefore only Class III roads were used in this analysis. Bears had greater RCI's during the day than at night ($P = 0.0029$) (Fig. 5). However, RAI was not significantly different for the 2 time periods.

RCI for summer may be greater for numerous reasons. First, breeding occurs during the summer, and males may travel great distances in search of mates (Alt et al. 1980, Eiler 1981, Rogers 1987). Maximum daily movements of breeding females also may occur during the breeding season (Alt et al. 1980). Also, the abundance of soft mast

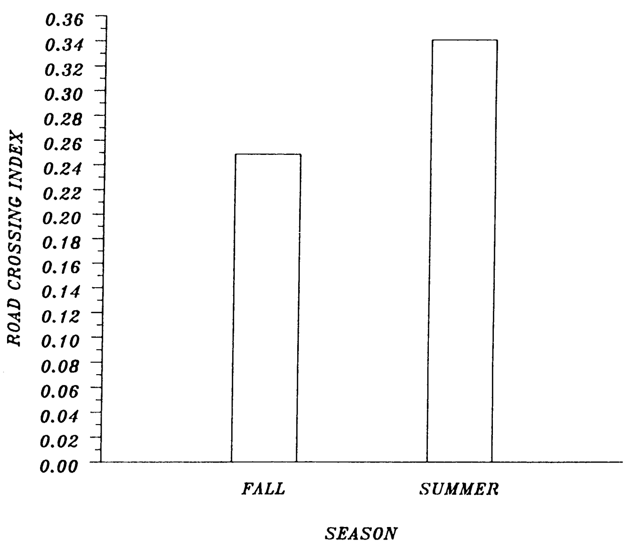

Fig. 4. Road crossing frequency by season for bears on Harmon Den, Pisgah National Forest, North Carolina, 1986-1987.

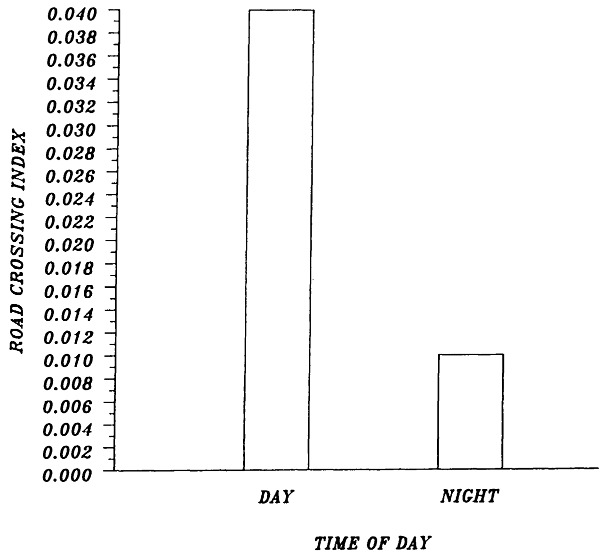

Fig. 5. Road crossing frequency by time of day for bears on Harmon Den, Pisgah National Forest, North Carolina, 1987.

along road openings may draw bears to roads during summer (Carr and Pelton 1984, Hellgren 1988, Brody and Pelton 1989). We observed numerous bears crossing or feeding along Class III roads during summer. Pokeberry (*Phytolacca americana*) and blackberry (*Rubus* spp.) were abundant along roadways on the study area. During 1 week in late summer 1987, we counted 9 fresh scats containing pokeberry along a 2.7-km section of a Class III road. Because Harmon Den is dominated by oak cover types, bears can feed extensively on acorns during fall without making long distance movements.

Size of home ranges did not vary between seasons. This is in contrast to other areas in the southern Appalachians (Beeman 1975, Garshelis and Pelton 1981, Quigley 1982, Carr 1983), and may result in a low RCI for fall. Additionally, increased traffic volumes in the sanctuary during deer and small game hunting seasons may help to lower the RCI during fall. Bears also may use roads with low traffic volumes as travel lanes (Hellgren 1988, Seibert 1989), because travel along these routes provide relief from the steep terrain and may maximize foraging and movement efficiency. Also, bears on Harmon Den may not have to learn avoidance of these roads because most are gated and occur within the sanctuary.

Studies of bear activity patterns indicate bears are often diurnal during summer. Garshelis and Pelton (1981), Hugie (1982), Quigley (1982), Villarrubia (1982), and Garris (1983) reported more activity during diurnal hours than nocturnal hours during summer. In fall, bears are just as likely to be active at night as during the day (Quigley 1982, Villarrubia 1982, Garris 1983).

Roads and Hunting

Although Harmon Den is a bear sanctuary, 15 tagged bears were killed during the study. Hunters often release dogs on bears in the sanctuary and kill them when they are treed outside the sanctuary. Perimeter roads on Harmon Den are heavily hunted. Many bears that spend most of their lives inside the sanctuary are killed on the perimeter or just outside the borders. Illegal bait piles are often used to entice bears to leave the area or are used as a place to start tracking bears. Clearly roads enhance exploitation of certain bear populations.

The efficiency of hunters using CB radios, 4-wheel drive vehicles, and radio collars on hounds may not allow bears to associate roads with negative experiences. In GSMNP, Quigley (1982) suggested that older bears may have a learned avoidance of roads from negative experiences caused by increased traffic volumes at certain times of the year. However, bears in highly accessible and heavily hunted areas may not learn road avoidance and may suffer near 100% mortality each hunting season (Brody 1984, Beringer 1986). Thus it may be difficult for bears to associate people, dogs, and the hunting experience with roads. Many chases begin when the bear is some distance from the road it previously crossed, ending when the bear is shot as it crosses a road. Consequently, bears will continue to cross lightly travelled roads in proportion to their availability and be killed by hunters that use these same roads. Bears' survival may be directly related to road density.

MANAGEMENT IMPLICATIONS

High traffic volumes (10,000+ VPD) impede bear movements but do not totally restrict them. The accessibility that roads provide to hunters can be detrimental to local bear populations as hunting mortality is the most important factor limiting bear populations on parts of PNF (Brody and Stone 1987).

Impact on the local bear population (particularly breeding females) should be considered before constructing new roads into bear habitat. All new roads constructed during our study were for timber harvest. We suggest conservative road management for these and other logging roads. Unused roads should be closed permanently to reduce hunter access and illegal hunting. All new roads, and those being used, should be gated and locked. Also, locks should be changed periodically. In our study area, loggers were allowed to put their own locks on gates and thus controlled access. Many times gates were left unlocked or their keys were "passed around". Clearly a better defined and enforced gate policy would prevent much unauthorized travel. Roads, by themselves, do not adversely affect bears but increased access does.

It is difficult to monitor the effects of roads on bear movements accurately. Traffic volumes often vary with the time of year. Although not quantified, traffic volumes are much greater during hunting seasons than any other time on Harmon Den. Also, our study was unable to measure impacts of roads with traffic volumes between 100 and 10,000+ VPD. Bear movements on Harmon Den are not affected by traffic volumes of 100 VPD but, are inhibited by roads with traffic volumes of 10,000+ VPD. Many roads in the southern Appalachian area receive traffic volumes in the 100 to 10,000 VPD range. We speculate that, with increased volumes above 100 VPD, the RCI will decrease and the RAI will increase as volumes approach 10,000 VPD. We suggest further research in occupied bear range where traffic volumes exceed 100 VPD.

LITERATURE CITED

ALT, G.L., G.J. MATULA, F.W. ALT, AND J.S. LINDZEY. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. Int. Conf. Bear Res. and Manage. 4:131-136.

ARCHIBALD, W.R., R. ELLIS, AND A.N. HAMILTON. 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River Valley, British Columbia. Int. Conf. Bear Res. and Manage. 7:251-257.

BEEMAN, L.E. 1975. Population characteristics, movements, and activities of the black bears (*Ursus americanus*) in the Great Smoky Mountains National Park. Ph.D. Thesis. Univ. of Tenn., Knoxville. 232pp.

BERINGER, J.J. 1986. Habitat use and response to roads by black bears in Harmon Den, Pisgah National Forest, North Carolina. M.S. Thesis. Univ. of Tenn., Knoxville. 103pp.

BRODY, A.J. 1984. Habitat use by black bears in relation to forest management in Pisgah National Forest, North Carolina. M.S. Thesis. Univ. of Tenn., Knoxville. 123pp.

_____, AND J.N. STONE. 1987. Timber harvest and black bear population dynamics in a southern Appalachian forest. Int. Conf. Bear Res. and Manage. 7:243-250.

_____, AND M.R. PELTON. 1989. The effects of roads on black bear movements in western North Carolina. Wildl. Soc. Bull. 17:5-10.

BROWN, W.S. 1980. Black bear movements and activities in Pocahontas and Randolph counties, West Virginia. M.S. Thesis. W. Va. Univ., Morgantown. 91pp.

CARR, P.C. 1983. Habitat utilization and seasonal movements of black bears in the Great Smoky Mountains National Park. M.S. Thesis. Univ. of Tenn., Knoxville. 95pp.

_____, AND M.R. PELTON. 1984. Proximity of adult female black bears to limited access roads. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 38:70-77.

COLLINS, J.M. 1983. North Carolina bear kill statistics. Pages 213-238 *in* Tri-state bear study. Tenn. Wildl. Resour. Agency, Nashville.

DORRANCE, M.J., P.J. SAVAGE, AND D.E. HUFF. 1975. Effects of snowmobiles on white-tailed deer. J. Wildl. Manage. 39:563-569.

EILER, J.H. 1981. Reproductive biology of black bears in the Smoky Mountains of Tennessee. M.S. Thesis. Univ. of Tenn., Knoxville. 83pp.

FINLAYSON, C.P. 1957. The geology of the Max Patch Mountain area, Lemon Gap Quadrangle, Tennessee-North Carolina. M.S. Thesis. Univ. of Tenn., Knoxville. 41pp.

GARRIS, R.S. 1983. Habitat utilization and movement ecology of black bears in Cherokee National Forest. M.S. Thesis. Univ. of Tenn., Knoxville. 99pp.

GARSHELIS, D.L., AND M.R. PELTON. 1981. Movements of black bears in the Great Smoky Mountains National Park. J. Wildl. Manage. 45:912-945.

GEIST, V. 1971. Bighorn sheep biology. Wildl. Soc. News 136:61.

HAMILTON, R.J. 1978. Ecology of the black bear in southeastern North Carolina. M.S. Thesis. Univ. of Ga., Athens. 214pp.

HAYNE, D.W. 1949. Calculation of size of home range. J. Mammal. 30:1-18.

HELLGREN, E.C. 1988. Ecology and physiology of a black bear (*Ursus americanus*) population in Great Dismal Swamp and reproductive physiology in the captive female black bear. Ph.D. Thesis. Va. Polytechnic Inst. and State Univ., Blacksburg. 231pp.

HUGIE, R.D. 1982. Black bear ecology and management in the northern conifer-deciduous forests of Maine. Ph.D. Thesis. Univ. of Mont., Missoula. 203pp.

JOHNSON, K.G., AND M.R. PELTON. 1980. Prebaiting and snaring techniques for black bears. Wildl. Soc. Bull. 8:46-54.

MANVILLE, A.M. 1983. Human impact on the black bear in Michigan's lower peninsula. Int. Conf. Bear Res. and Manage. 5:20-33.

MILLER, T.O. 1975. Factors influencing black bear habitat selection on Cheat Mountain, West Virginia. M. S. Thesis. W. Va. Univ., Morgantown. 61pp.

QUIGLEY, H.B. 1982. Activity patterns, movement ecology, and habitat utilization of black bears in the Great Smoky Mountains National Park, Tennessee. M.S. Thesis. Univ. of Tenn., Knoxville. 140pp.

ROGERS, L.L. 1987. Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. Wildl. Monogr. 97. 72pp.

ROST, G.R., AND J.A. BAILEY. 1979. Distribution of mule deer and elk in relation to roads. J. Wildl. Manage. 43:634-641.

SEIBERT, S.G. 1989. Black bear habitat use and response to roads on Pisgah National Forest, North Carolina. M.S. Thesis. Univ. of Tenn., Knoxville. 144pp.

STATISTICAL ANALYSIS SYSTEM INSTITUTE, INC. 1985. SAS user guide: statistics. Cary, N.C. 956pp.

THORNWAITE, C.W. 1948. An approach toward a rational classification of climate. Geogr. Rev. 38:55-94.

VAN DYKE, F.G., R.H. BROCKE, AND H.G. SHAW. 1986. Use of road track counts as indices of mountain lion presence. J. Wildl. Manage. 50:102-109.

VILLARRUBIA, C.R. 1982. Movement ecology and habitat utilization of black bears in Cherokee National Forest, Tennessee. M.S. Thesis. Univ. of Tenn., Knoxville. 159pp.

WRIGHT, G.A., AND D.W. SPEAKE. 1975. Compatibility of the eastern wild turkey with recreational activities at Land Between the Lakes, Kentucky. Proc. Southeast. Assoc. Game and Fish Comm. 29:578-584.