

HOME RANGE, HABITAT USE, AND MORTALITY OF BLACK BEARS IN NORTH-CENTRAL FLORIDA

JOHN B. WOODING, Florida Game and Fresh Water Fish Commission, 4005 S. Main Street, Gainesville, FL 32601
THOMAS S. HARDISKY,¹ Florida Game and Fresh Water Fish Commission, 4005 S. Main Street, Gainesville, FL 32601

Abstract: Thirty-three black bears (*Ursus americanus*) were captured and 27 (11 F: 16 M) were radiocollared from 1983 to 1988 on 2 study areas in north-central Florida to study home-range characteristics, habitat use, and mortality. A total of 2,146 locations were recorded. Home-range sizes, calculated by the convex polygon method, averaged 170 ± 26 (SE) km² for adult males ($n = 12$) and 28 ± 5 km² for adult females ($n = 8$). Home-range sizes were smallest during winter and spring and largest during summer and fall for all bears. Home ranges of bears from all sex and age classes overlapped. Habitat preference of bears on the Ocala study area shifted from pine flatwoods in winter and spring to sand pine scrub in summer and fall. Bears on the Osceola study area preferred hardwood swamps throughout the year. Annual mortality rates were 0.16 for females and 0.12 for males. Major causes of death for tagged bears were hunting and collisions with motor vehicles.

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Until the late 1800s, black bears occurred throughout the Florida mainland (Brady and Maehr 1985). The replacement of native forests with agricultural and urban development has resulted in forest fragmentation and bear populations that are geographically isolated. Bear populations in Florida are largely restricted to the expansive, undeveloped woodlands concentrated in and around Apalachicola, Osceola, and Ocala National Forests, and Big Cypress National Preserve. The black bear is listed by the State of Florida as a threatened species, except in 2 areas in northern Florida where it retains game status.

Wise management of Florida's black bears requires information on the biological needs of the species. The gathering of this information was begun in the 1950s (Harlow 1961), but little else was done until the mid-1970s. Information has since been collected on distribution (Williams 1978, Brady and Maehr 1985), food habits (Maehr and Brady 1984), parasites (Conti et al. 1983), beeyard depredation and control (Maehr and Brady 1982, Wooding et al. 1988), roadkill mortality (Wooding and Brady 1987), home range (Mykytko and Pelton 1989, 1990), and winter denning (Wooding and Hardisky 1992).

The purpose of this study was to investigate black bear home-range characteristics and habitat use in north-central Florida. In the process, we also gained some insight into mortality, density, and dispersal. This information is also reported here.

J. Brady initiated this study in 1983 and, with D. Maehr's assistance, conducted the fieldwork through 1985. We thank J. Brady, P. Moler, and an anonymous reviewer for their helpful comments on earlier drafts of this manuscript.

STUDY AREAS

Fieldwork was conducted in Osceola National Forest and surrounding private land from 1983 to 1985; the study was moved to Ocala National Forest in 1985 and concluded there in 1988. The Ocala study area contained an extensive network of roads and human development. Bear hunting has been prohibited within Ocala N.F. since 1961. The Osceola study area, in contrast, was sparsely populated by humans and had a less extensive road system than Ocala. Bears were legally hunted during the fall in the Osceola study area.

The Ocala study area contained 4 major plant communities (Snedaker and Lugo 1972), including the world's largest continuous community of sand pine (*Pinus clausa*). This xeric community, called sand pine scrub or scrub, was characterized by an overstory of sand pine and a dense midstory of dwarf evergreen oaks (*Quercus* spp.). Within the scrub were xeric, open, park-like "islands" of longleaf pine (*P. palustris*) and turkey oak (*Quercus laevis*). Pine flatwoods, the third major community, occurred on poorly-drained soils; the predominant vegetation included an overstory of slash pine (*Pinus elliotii*) and an understory of saw palmetto (*Serenoa repens*), gallberry (*Ilex coriacea*), and loblolly bay (*Gordonia lasianthus*). The fourth major plant community in Ocala National Forest, mixed hardwood swamps, occurred primarily as narrow bands along rivers and consisted predominately of bald cypress (*Taxodium distichum*), red maple (*Acer rubrum*), and swamp ash (*Fraxinus caroliniana*).

The vegetative communities of the Osceola study area were an interspersed of pine flatwoods and extensive hardwood swamps (Avers and Bracy 1973). Either cypress and blackgum (*Nyssa* spp.) or fetterbush

¹ Present Address: Pennsylvania Game Commission, 2001 Elmerton Avenue, Harrisburg, PA 17110-9797.

(*Lyonia lucida*) predominated in the largest swamps. Slash pine, saw palmetto, and gallberry predominated in flatwoods communities. Small cypress swamps and bayheads were scattered throughout the pine flatwoods.

The climate of north-central Florida is characterized by hot, humid summers and mild winters. Mean annual rainfall in north-central Florida ranges from 127 to 140 cm (Winsberg 1990), and the temperature rises above 32°C for more than 100 days during the year. Freezing temperatures occasionally occur, but the duration of cold spells is brief, and the temperature rarely falls below -7°C.

METHODS

Black bears were captured in Aldrich spring-snares, barrel traps (Kohn 1982), or culvert traps and immobilized with injections of ketamine hydrochloride and xylazine hydrochloride. Ages of captured bears were estimated from first premolars using cementum annuli techniques. Three age classes of bears were recognized: cubs (<1 years old); subadults (1-2 years old and 3-year-old females that had not reproduced); and adults (≥ 3 years old).

Thirty-three bears were captured: 26 in Ocala National Forest (13 F:13 M) and 7 in Osceola National Forest (2 F:5 M). Twenty-seven (11 F:16 M) of these bears were radiomonitored and 2,146 locations recorded. The six bears not monitored were cubs that were not collared ($n = 4$) or bears that slipped their collars within 24 hours after handling ($n = 2$). The collars used on most males and young females were equipped with a break-away mechanism using either surgical tubing or leather.

Attempts were made to locate bears weekly from an airplane. Beginning in December 1986, bears also were located twice per week from the ground. Locations were plotted and coordinates recorded to the nearest 10 m.

Home ranges were calculated using the minimum area (convex polygon) method (Mohr 1947). All telemetry and home-range data were analyzed with the computer package TELEM (Coleman and Jones 1986). We recognized the following seasons: winter (Jan-Mar), spring (Apr-May), summer (Jun-Aug), and fall (Sep-Dec). Comparisons of home-range sizes by season, sex, and study area were made using the Wilcoxon rank sum test. Differences were considered significant at $\alpha = 0.05$.

Annual home ranges were calculated for 15 male and 10 female bears. One female and 2 males were monitored during their subadult and adult years; a

separate home range was calculated for each age classification. A home range was not calculated for a radio-collared female cub that was always in the company of her radio-collared mother. Three males were captured, radiocollared, and monitored prior to or during dispersal. After these bears established their new home ranges, dispersal locations were identified and excluded from home-range calculations. The number of months of monitoring for each of the annual home ranges ranged from 3 to 28 (mean 11 ± 1.2 SE); the number of locations ranged from 13 to 225 (mean 73 ± 12 SE).

Habitat use was assessed during flights by recording the bear's location and classifying it by predominant cover type. Aerial photographs were used to determine habitat use obtained from ground locations. Other habitat evaluations were made by walking in on radio-collared bears.

Habitat preference was determined by comparing ranks of habitat selection with ranks of habitat availability (Johnson 1980). Available habitat was defined as the area within each bear's total home range. Habitat and home-range boundaries were plotted, and the total area of each habitat within each home range was measured using a digitizer. Habitat use represented the number of times each bear was located within each habitat type. Statistical comparisons of use versus availability were made using Hotelling's T^2 (Johnson 1980).

Annual mortality rates were estimated with the program MICROMORT, version 1.2 (Heisey and Fuller 1985). We assumed daily mortality rates were constant for each area throughout the period of radiomonitored. Comparisons of estimated annual mortality rates by age and sex classes were made using a Z-statistic.

RESULTS AND DISCUSSION

Annual Home Range

Adult male home-range sizes were significantly larger than those of adult females, subadult females, and subadult males (Table 1). Subadult male and subadult female home-range sizes were not significantly different, nor were the home-range sizes of adult females and subadult females.

The home-range size of Osceola adult males (215 ± 43 km²) was not significantly different from the home-range size of Ocala adult males (135 ± 33 km²). Mykytka and Pelton (1989), using the minimum area method, reported a mean home-range size for 3 adult

Table 1. Home-range sizes (mean km² ± standard error) for black bears radiomonitored in north-central Florida, 1983-88.

Study area	Adult male	Adult female	Subadult male	Subadult female
Ocala	135 ± 33 (n = 7)	25 ± 4 (n = 7)	60 ± 14 (n = 4)	32 ± 16 (n = 3)
Osceola	215 ± 43 (n = 4)	52 (n = 1)	69 (n = 1)	--- (n = 0)
Both areas ^a	170 ± 26 (n = 12)	28 ± 5 (n = 8)	62 ± 11 (n = 5)	32 ± 16 (n = 3)

^a Includes the home range of 1 adult male that dispersed from the Ocala study area.

males monitored in Osceola from 1976 to 1978 of 156 ± 16 km², which falls within the range we observed in this study. A second comparison of the adult male home-range sizes for the 2 study areas was made by combining our data on Osceola with that collected by Mykytka and Pelton (1989). The mean adult male home-range size for Osceola males from the 2 studies (190 ± 36 km², n = 7) did not significantly differ from the mean home-range size for Ocala adult males.

The 1 adult female monitored in the Osceola study area had a home range of 52.5 km². In Mykytka and Pelton's (1989) Osceola telemetry study, 2 adult females had home ranges of 39.4 and 93.4 km² (minimum area method). Combining data from the 2 studies, the mean home-range size for Osceola adult female bears (61.7 ± 16 km², n = 3) was significantly larger than the mean home-range size for the adult females monitored in Ocala (25 ± 4 km², n = 7). Because female home-range size is thought to reflect habitat quality (Amstrup and Beecham 1976, Lindzey and Meslow 1977, Young and Ruff 1982), the adult female home-range sizes suggest that habitat quality is better in Ocala than in Osceola. In other studies that determined home-range size by the minimum area method, the mean adult female home-range size ranged from 8 to 49 km² (Table 2). In comparison to other areas in North America, Osceola appears to have poor quality black bear habitat and Ocala moderate quality habitat.

Seasonal Home Ranges

Adult male home-range sizes were significantly larger than those of adult females in summer, fall, and winter, but the data failed to show a significant difference in spring home-range sizes. Seasonal comparisons of subadult home ranges were not made because of small sample sizes. Male and female home-range sizes followed similar trends among seasons

Table 2. Comparison of black bear home ranges calculated by the minimum area method.

Reference	Location	n Male:Female	Home-range size (km ²)	
			Male	Female
This study and Mykytka and Pelton 1989 ^a	Florida (Osceola)	7:3	190	62
Amstrup and Beechum 1976	Idaho	2:7	112	49
Hugie 1982	Maine	5:9	1,721	43
Elowe 1984	Massachusetts	3:8	318	28
This study	Florida (Ocala)	7:7	135	25
Warburton and Powell 1985	North Carolina	2:2	79	18
Smith and Pelton 1990	Arkansas	6:6	116	12
Hamilton 1978	North Carolina	3:3	91	8
Garshelis and Pelton 1981	Tennessee	10:14	21	8

^a Home-range data collected in Osceola in this study was combined with that collected in Osceola by Mykytka and Pelton 1989.

(Fig. 1). The smallest average home-range sizes were observed in the winter, but ranges became progressively larger during the year, peaking in the fall. The trends in home-range sizes are consistent with the black bear's circannual rhythm (Johnson and Pelton 1980), with little or no movement in the winter and progressively increased activity peaking during the fall, when foraging is intensive.

Spatial Distribution

Home-range overlap existed among all age and sex classes on both study areas. Overlap was most pronounced for a portion of the Ocala area where trapping was heavily concentrated and least pronounced for portions of the study areas where trapping was less intensive. The lack of home-range overlap in the lightly trapped portions of the study areas is believed a result of low trapping effort and capture success rather than a reflection of the true spatial distribution of bears in the study areas.

Territoriality was suggested by the breeding season movements of 3 adult males captured in the heavily trapped portion of the Ocala study area. These 3 male

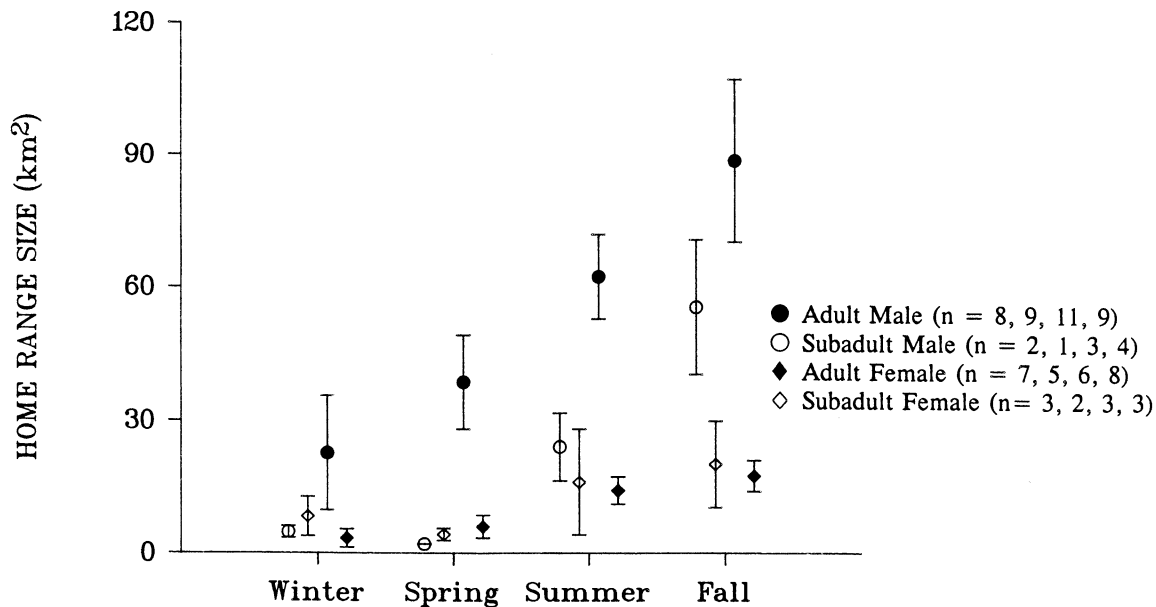


Fig. 1. Mean seasonal home ranges by sex and age class for black bears radiomonitored in north-central Florida, 1983-88. Bars represent \pm standard error of the mean.

bears had extensively overlapping, nonbreeding season home ranges, but they established nearly exclusive breeding-season home ranges. After the mating season, all 3 bears returned to their nonbreeding season home ranges. In contrast to the repositioning of these 3 male bears in the breeding season, the home ranges of 2 breeding females from the heavily trapped location in Ocala showed similar overlap in all seasons.

Habitat Use

Habitat use on both study areas was disproportional ($P = 0.001$) to habitat availability (Table 3), and appeared a response to seasonal food availability and cover. Habitat use was not proportional to habitat available during any season: (Winter, $P = 0.01$; Spring, $P = 0.04$; Summer, $P = 0.03$; or Fall, $P = 0.0002$).

In the Ocala study area, bears occurred most frequently in pine flatwoods and sand pine scrub (Table 3). Pine flatwoods provide dense cover for winter den sites; 10 of the 11 dens we located in Ocala were in pine flatwoods (Wooding and Hardisky 1992). The flatwoods also contain a variety of food-producing plants, including gallberry, blueberry (*Vaccinium* spp.), and saw palmetto. Bear use of scrub, the second most important habitat type for Ocala bears, gradually increased throughout the year, peaking in the fall (Table 3). The shift in habitat use from pine flatwoods

to sand pine scrub during late summer and fall corresponded to the availability of acorns produced by the abundant dwarf oaks in the scrub. Bear use of the longleaf pine community was minimal. This habitat type is open and provides little concealment cover. A similar avoidance of open, pine communities was observed in Arizona (Mollohan 1987).

In the Osceola study area, bears used cypress/blackgum swamps in greater proportion than their availability during all seasons ($P = 0.001$). These swamps received the greatest use during the fall and winter, a period when they provide food, such as blackgum berries, denning cover, and refuge from hunters. The 3 dens located in Osceola were all in flooded cypress swamps (Wooding and Hardisky 1992). Flatwoods received the greatest use in the summer, a period which corresponds to the availability of soft mast produced in this community.

Most (96%) of the telemetry locations in Osceola were either in pine flatwoods or cypress/blackgum swamps. Mykytka and Pelton (1990) also reported that black bears in Osceola showed a preference for these 2 habitat types. Although the radio-collared bears did not show a preference for fetterbush swamps, these swamps appear to provide excellent cover.

There may be several reasons for the differences observed in bear use of flatwoods and swamps on the 2 study areas. In the Ocala study area, the swamps occurred as narrow, stream and river riparian zones, in

Table 3. Habitat availability and seasonal use by radio-collared black bears in north-central Florida, 1983-88.

Study area	Habitat type	Percentage available	Percentage use				
			Spring ^a	Summer	Fall	Winter	Annual
Osceola	Flatwoods	69	26	40	17	13	24
	Cypress/Gum	18	65	51	80	80	72
	Fetterbush	12	9	9	3	7	4
Ocala	Scrub	60	28	45	61	27	52
	Longleaf Pine	17	2	1	1	0	2
	Flatwoods	16	62	44	31	64	39
	Swamp	7	8	10	7	9	7

^a Sample sizes of monitored black bears by season: Osceola, *n* = 6 for all seasons; Ocala - Spring (*n* = 11), Summer (*n* = 15), Fall (*n* = 18), Winter (*n* = 12).

contrast to the expansive, amorphous swamps on the Osceola study area. The configuration of the swamps in Ocala may have modified their attractiveness to bears as a refuge for denning and escape cover. The species composition of the swamps on the 2 areas also differed, particularly in the abundance of blackgum, a species common in Osceola but rare in Ocala. The rarity of this important fall food species in Ocala may also have reduced the attractiveness of the swamps to the Ocala bears. However, given the abundance of acorns available to Ocala bears in scrub habitat, it is possible that even if the Ocala swamps contained abundant blackgum that the bears would have shown a preference in the fall for scrub over blackgum swamps. The heavy seasonal dependence that Ocala bears demonstrated for flatwoods may have been in part due to the lack of large swamps such as those available in Osceola—we suspect that if the Ocala study area had large swamps that the bears would have used them for cover, particularly for denning. We also suspect that we may have underestimated the importance of flatwoods to bears on the Osceola study area because of the telemetry tracking schedule. For example, 30% of the bear locations in Osceola that we classified as swamp were on the edge of swamps that bordered flatwoods. Perhaps with more frequent locations of the Osceola bears we would have detected greater bear use of the flatwoods.

Dispersal

The age of dispersal reported in other studies ranged from 1 to 4 years (Alt 1978, Rogers 1987, Schwartz and Franzmann 1992). In our observations, 4 males dispersed when they were 1 (*n* = 2) or 2 (*n* = 2) years old. Based on recapture, radiotelemetry, or mortality data, dispersal distances were 35 and 56 km for the 2 yearlings and 22 and 56 km for the 2-year-olds.

Mortality

Mortality rates were not calculated for the Osceola study area because no deaths occurred during the period the 7 radio-collared bears were monitored. However, 3 of these bears were killed by hunters the year after fieldwork was concluded. Estimates of annual mortality rates for the Ocala study area are presented in Table 4. In Ocala, 3 radio-monitored bears died (1 adult female by a poacher [suspected], 1 subadult male by a vehicle, and 1 subadult female by another bear [suspected]). Other studies have found male mortality rates to be consistently higher than those of females (Bunnell and Tait 1981, Schwartz and Franzmann 1992), but the Ocala data failed to show a significant (*P* = 0.14) difference in the annual mortality rates of adult males

Table 4. Estimated annual mortality rates (Heisey and Fuller 1985) for black bears radiomonitored in the Ocala study area, 1985-88.

Age/sex	<i>n</i>	Bear days	Deaths	Annual mortality rate (95% C.I.)
Subadult female	3	988	1	0.31 (0.00-0.66)
Adult female	7	3,153	1	0.11 (0.00-0.21)
Total female	10	4,141	2	0.16 (0.00-0.34)
Subadult male	4	528	1	0.50 (0.00-0.87)
Adult male	8	2,251	0	0.00
Total male	12	2,779	1	0.12 (0.00-0.32)
Total subadult	7	1,516	2	0.38 (0.00-0.68)
Total adult	15	5,404	1	0.06 (0.00-0.18)
Total	22	6,920	3	0.15 (0.00- 0.29)

and adult females, in the annual mortality rates of subadult males and subadult females ($P = 0.33$), or in the annual mortality rates of males and females from both age groups ($P = 0.40$). Also unlike other studies, our data failed to show a significant ($P = 0.08$) difference in the annual mortality rates of adults and subadults.

We suspect that the similarity in the mortality rates observed between the age and sex classes was in part due to small sample sizes. However, the major difference between the rates we observed and those in other studies was in the low mortality rate for males; rates for females were comparable to those found elsewhere (Bunnell and Tait 1981, Hellgren and Vaughan 1989). The low mortality rate for Ocala males was probably due to the absence of human-related mortality factors. There was no legal bear hunting in the Ocala study area, no males were killed by poachers, and only 1 male was killed by a vehicle. These 3 mortality factors have been recognized as the major causes of death for male bears >1 year old (Bunnell and Tait 1981, Hellgren and Vaughan 1989). The absence of these factors in the Ocala study area during the period of monitoring, and the resulting similarity in mortality rates between males and females, suggests that mortality rates of adult male and female black bears would be comparable without human-caused deaths.

After radiomonitoring in Ocala ended, 3 bears (1F:2M) monitored during the study were killed by vehicles. A fourth bear (M), tagged in the study but not radiocollared, was also killed by a vehicle. Thus, of the 10 marked bears whose deaths were documented during and after the monitoring ended, 9 were killed by humans (5 by vehicles, 3 by hunters, and 1 by a poacher).

Density

Three years of fieldwork in the Ocala study area were concentrated in the northeastern portion of Ocala National Forest. In summer 1987, when trapping and radiotracking were most intensive, we knew of 8 resident bears. All were tagged and 7 were radiocollared. Most of their movements were restricted to a 100 km² area. We were not aware of other resident bears in this area, based on trapping, radiotracking, and observations of tracks on the numerous sandy roads in the area, but we recognize that a few bears may have been overlooked. Therefore, a density of 8 bears/100 km² (1 bear/12.5 km²) is offered as a minimum density estimate for the Ocala study area. An estimate of density was not made for

Osceola because of the small sample size of marked bears. Our impression, however, based primarily on capture success, was that the density of bears was lower in Osceola than in Ocala.

MANAGEMENT IMPLICATIONS

"Black bears are inhabitants of the forest. They evolved as forest dwellers and have remained dependent on the forest for their survival" (Kolenosky and Strathearn 1987:445). Large amounts of forested land are needed by individuals, and although the land requirements necessary to sustain a viable population are less clear, the implication of the home-range sizes and low population density is that vast acreages are necessary. Clearly, the continued survival of black bears in Florida, as elsewhere, is dependent on preserving large forested areas.

In some cases in Florida, habitat loss has already resulted in small, isolated populations where the amount of forested land may be insufficient to support viable populations. In these small, isolated forests inhabited by bears, the threat of extirpation could be reduced by managing the forests specifically for bears. These management practices would include protection of mast-producing trees, a burning program that favors fruit production from the soft mast-producing species, and maintenance of densely vegetated areas needed for year-round cover and winter denning.

These same habitat management practices would also be valuable in the larger areas inhabited by bears in Florida. The implication of the home-range size of females and the density estimate for Ocala is that Florida bear habitat is of poor to marginal quality. The quality could be improved by management that favors food production and cover. Large areas could be managed by focusing on habitat blocks of similar size to the average size of the female home range, such that within each 28 km² area, a manager would strive to maintain a diversity of upland and wetland community types managed specifically to provide for the bear's annual needs.

Mortality factors identified in this study were primarily associated with humans. Hunting mortality can be regulated and controlled so that harvests are within limits that populations can sustain. On the other hand, roadkill mortality is much harder to regulate. In Ocala, most of the radio-collared bears periodically crossed highways. With the extensive highway system in the Ocala area and the large home-range sizes of black bears, we believe that most, if not all, Ocala bears will attempt to cross highways during their

lifetime and be at risk of being hit by a vehicle. Although roadkill mortality was not a significant mortality factor in the northeastern portion of Ocala National Forest where we conducted most of our fieldwork, in other areas of the state where traffic levels are higher and the highway network more dense, we believe that roadkill mortality may be a much more significant mortality factor. Highways also can act as barriers to movement (Brody and Pelton 1989), leading to further habitat fragmentation and population isolation. Techniques that may be of value to mitigate the impacts of highways include underpasses, which allow bears to safely cross under the highway, and warning signs, which alert motorists to identified bear-crossing areas (Wooding and Brady 1987).

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