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Author(s): Anthony P. Clevenger and Michael R. Pelton

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PRE AND POST BREAKUP MOVEMENTS AND SPACE USE OF BLACK BEAR FAMILY GROUPS IN CHEROKEE NATIONAL FOREST, TENNESSEE

ANTHONY P. CLEVINGER,¹ Department of Forestry, Wildlife, and Fisheries, The University of Tennessee, Box 1071, Knoxville, TN 37901-1071
MICHAEL R. PELTON, Department of Forestry, Wildlife, and Fisheries, The University of Tennessee, Box 1071, Knoxville, TN 37901-1071

Abstract: The movements and space use of 7 yearling black bears (*Ursus americanus*) (3 males, 4 females) from 3 family groups were intensively monitored concurrently with 13 adults (6 males, 7 females) in the Cherokee National Forest, Tennessee from February 1983 until December 1983. The timing of family breakup occurred in 2 families between 29 May-5 June, and 22-25 June, respectively. The third family dissolved after the accidental death of the mother during immobilization at the den; the subsequent movements of the orphaned young were recorded. Reassociations between mother and offspring, and between siblings did occur after breakup. The mean summer home ranges of yearlings ($n = 6$) averaged 4 km² while those of adult bears ($n = 8$) measured 11 km². Fall ranges for yearlings were 20 km² and for adults 77 km². The intra-year seasonal ranges of yearlings increased significantly ($P < 0.01$) from summer to fall while the adult ranges did not ($P > 0.10$). Yearlings after separation from their mothers became progressively independent of their mothers' range. Mean distances between mothers and offspring, and between siblings after breakup, increased each month as family bonds began to weaken and exploratory movements took place. Six of 7 yearlings survived until the following winter although 1 shed his collar before denning and his fate was unknown; all other yearlings returned and located dens in their respective maternal home ranges.

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The movements, space use, and survival rates of subadult black bears from time of family breakup until adult age have been scarcely documented in North America (Rogers 1977, 1987; Alt 1978), and even less-so in the Southern Appalachian Mountains (Clevenger 1986). Subadult bears, particularly males, are typically the least settled and often require several years before establishing home ranges. In doing so, they may travel over large areas and move far from the home range of their mother. This information, if applied to areas where bears are exploited, may provide insight as to the degree of hunting pressure (legal and illegal), the survival rates of the subadult class, and utility of bear refuges/sanctuaries. The objectives of the study were to determine the timing of family breakup and duration of kinship bonds, and the post-breakup patterns of space use among adult and yearling bears in the Cherokee National Forest (CNF), Tennessee.

Financial support for this study came from the Tennessee Wildlife Resources Agency (TWRA), the Agricultural Experiment Station and Department of Forestry, Wildlife, and Fisheries, The University of Tennessee, Knoxville, the United States Forest Service, and the National Rifle Association. Much of the work could not have been carried out without the assistance of TWRA technicians, J. Morris and L. Hunt. Invaluable aerial support came from pilots B. Kindy and D. Stark.

STUDY AREA

The CNF is located in Tennessee and totals 4,905 km², forming a narrow strip 24 km wide along the North

Carolina state line. It is made up of 2 sections separated by the Great Smoky Mountains National Park (GSMNP), abutting it on the Park's north and south sides. The study area is located on the Tellico Ranger District in the southern section (including the 124 km² Tellico Bear Refuge) bordering the North Carolina boundary and included the newly created Citico Creek Wilderness Area (Fig. 1).

The study area is part of the Blue Ridge Province and is in the northern Unicoi Mountains. The Unicoi Ridge is situated in a north-south direction and delineates much of the Tennessee-North Carolina state line. Elevations range from 450 m to 1,550 m. The terrain is rugged, characterized by steep mountains and perennial, fast-flowing streams and rivers.

Mean annual precipitation for the area is approximately 170 cm. Snowfall averages 63 cm/year (<3% annual precipitation). March is the wettest month; October the driest. Summer temperatures rarely exceed 32 C except on exposed ridges. Winter temperatures remain below freezing for extended periods with lows between -23 C and -18 C common.

Forests cover about 99% of the study area consisting of second growth mixed hardwood or pine stands mostly in the 50-69 year age class (U.S. Dep. Agric., For. Serv. 1982). Five major forest types are present: Cove Hardwood - occurs between 170-1,330 m on lower northerly slopes, coves, ravines, and moist flats; Oak Hickory - in coves, mountain slopes, high valleys, and flat ridge tops; Pine - predominantly on old fields, relatively infertile ridges, dry flats and slopes, and is found mostly below 1,000 m; Mesic Hemlock - occurs above 500 m in cool locations, moist coves and ravines and northern slopes; Northern Hardwood - located mostly above 1,200 m on sites with adequate moisture and relatively high fertility.

¹Present address: Departamento de Biología Animal, Universidad de León, 24071 León, Spain.

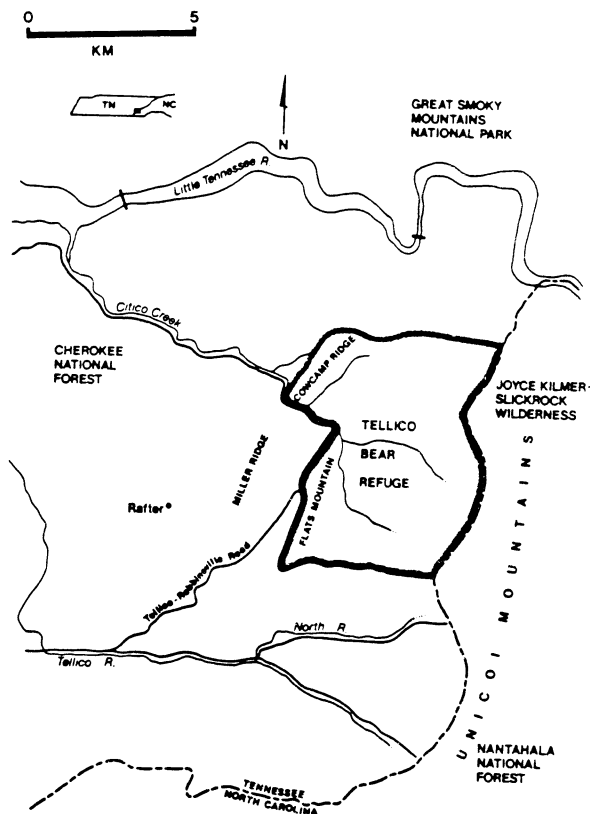


Fig. 1. Cherokee National Forest Study Area, Tennessee.

METHODS

Field work for the study began in July 1982 and was terminated in December 1983. In summer, bears were captured by modified Aldrich foot snares (Johnson and Pelton 1980), baited with sardines and checked daily. Once captured, bears were immobilized with an intramuscular injection of Etorphine hydrochloride (D-M Pharmaceuticals, Rockville, MD) at a dose of 1 mg per 45 kg estimated body weight. After processing, bears were revived with Diprenophrine hydrochloride (D-M Pharmaceuticals, Rockville, MD) at a dosage of 2 mg per 45 kg body weight. All standard body measurements were recorded, blood samples were collected, and a tooth was extracted for age estimation (Willey 1974). Bears were fitted with radio transmitters equipped with motion sensors, operating at the 150-152 MHz frequency range (Telonics Inc., Mesa, AZ). All bears >3.5-years-old were considered adults; yearlings were between 1 and 2 years of age.

During January 1983, winter dens of radio-collared adult females with yearlings were visited. Females were

immobilized by jabstick with a 2:1 mixture of Ketamine hydrochloride (Bristol Laboratories, Syracuse, NY) and Xylazine (Haver-Lockhart, Inc., Shawnee, KS) at a concentration of 200 mg/ml. Once the mother became completely anesthetized, each yearling in the litter was immobilized by the same method. Yearlings were sexed, ear tagged, weighed, and fitted with breakaway radio collars (Telonics Inc., Mesa, AZ). Collars were fastened with 5-cm strips of surgical tubing, wrapped lightly with electric tape and designed to break away from the animal after 1-2 years. A Telonics TR-2 receiver was used with a hand-held 2-element directional antenna to obtain radiolocations of the bears.

Before collecting radio telemetry data, directional accuracy was tested in the study area. Four transmitters were placed in known locations and approximately 100 readings were taken to construct error polygons (Springer 1979) with 95% confidence limits. Tests resulted in an 8.8 error arc and a mean error polygon size of 16.7 ha. Error polygon centers were used in analysis of movements. Aerial tracking was conducted whenever transmitted bears could not be located and regularly during fall when bear movements were erratic and wide-ranging.

Seasons were defined as the following: Spring - 1 April to 15 June; Summer - 16 June to 15 September; and Fall - 16 September to 15 December.

Home ranges were estimated by the minimum convex polygon method (Hayne 1949) using the TELEM computer program (Koeln 1980). The Mann-Whitney U-test was used to analyze seasonal and annual differences in the home range size between adults and yearlings (Sokal and Rohlf 1981).

RESULTS AND DISCUSSION

Previous field studies (Garris 1983) left transmitters operating on 8 radio-tagged bears (2 adult males, 5 adult females, and 1 subadult female). Additional radio transmitters were placed on 13 bears (7 males, 6 females).

Family Units

Among the 8 radio-marked bears at the commencement of the study, 4 were adult females with cubs of the year (G. Wathen, pers. commun.), which enabled us to study the pre and post family breakup movements and space use and possibly juvenile dispersal.

At least 7 yearlings could be accounted for from the 4 families (Table 1). Yearlings were present in numbers of 3 (2 females, 1 male), 3 (2 females, 1 male) and 1 (male) in the first 3 families, respectively. The sexes of all

Table 1. Family units of radio-collared females in Cherokee National Forest, Tennessee.

Mother	Yearling (Sex)	Comments
305	511 (F)	All members of family remained in radio contact for duration of study
	512 (M)	
	513 (F)	
306	514 (F)	Bear 306 died during winter immobilization; yearling 545 died of unknown causes; other yearlings monitored until end of study
	545 (M)	
	546 (F)	
326	510 (M)	Bear 326 remained in radio contact throughout the study; yearling 510 removed radio collar, November 1983
349	Number ?	Unable to immobilize and radio tag yearlings of 349 due to inaccessible den location

7 yearlings had been determined and all were ear tagged as newborn cubs during the previous winter as part of a reproduction and denning study (Wathen 1983). Female 349 was inaccessible during the previous winter denning work and her litter size was not determined.

During the winter of 1983, we tried to place radio collars on all yearlings of the 4 families. Ten bears from 3 families were immobilized in winter dens during January and February 1983; 7 yearlings were equipped with radio collars. The den of the fourth family (349) was inaccessible as in the previous winter.

A total of 1,635 radio locations were collected on 21 bears over the course of the study. The minimum and maximum number of locations recorded for individual bears were 17 and 169, respectively.

The mean monitoring period for adult males was 165 days ($n = 6$) and adult females 407 days ($n = 7$); yearling males 133 days ($n = 3$) and yearling females 240 days ($n = 4$). Combining the sex and age classes of the bears, all bears were monitored for an average of 260 days ($n = 20$). The minimum and maximum radio-tracking periods for individual bears were 30 and 490 days, respectively, the latter being the duration of the study.

There was 1 mortality during the winter immobilizations. The mother of 1 litter of 3 (bear 306) died while the entire family was immobilized at the den.

A second mortality was yearling male 545 of the orphaned group. After the death of the mother, the 3 yearlings remained at the den. By March 6, the 3 yearlings had abandoned the tree den. Two of the yearlings, male 545 and female 514, had moved to another tree den approximately 75 m from the original den. They were located at the new den throughout March until 24 April.

Between 24 April and 5 May, male 545 left the den and was found dead approximately 400 m away with no sign of predation or human-related mortality.

When food is scarce, either during years of mast and/or berry crop failures, or in spring when little food is available, yearlings and even older-aged bears can be affected, occasionally dying from starvation (Jonkel and Cowan 1971). Rogers (1977) reported the successive deaths of 3 yearlings while in association with the mother during spring after a fall season of scarce food. In GSMNP, yearling bears in undernourished condition have been observed wandering aimlessly, and without apparent fear, into areas of human habitation (M. Pelton, pers. observ.).

Intra-specific predation among black bears is known to occur although difficult to document. In 9 years of intensive monitoring of bear social relationships and movements, Rogers (1977) felt that predation by males was rare or non-existent. Others have reported bears killing trapped bears (Erickson 1957, Jonkel and Cowan 1971, LeCount 1982, D. Graber pers. commun.). Adult males have usually been implicated, although females are capable of cannibalism also (Troyer and Hensel 1962, Lindzey and Meslow 1977).

The orphaned yearling 545 was in excellent condition (14.0 kg) and the heaviest of the 3 littermates when immobilized during the winter. Emerging from his winter den without his mother and faced with the regular paucity of food in the spring may have led to deteriorating nutrition, lower body weight, and possibly starvation. Another possible cause of mortality might have resulted from intra-specific predation. Adult males may exclude subadults from their home ranges by overt aggression. Although there was no evidence of predation in the form of broken bones, scats, etc., bears may kill younger bears with quick, forceful swats, without incurring bone damage, but causing hemorrhaging and eventual death. This method of killing was employed by black bears in 5 instances on caribou (*Rangifer tarandus*) calves in Denali National Park, Alaska, during May 1984 (pers. observ.).

The radio-collared families of 305 and 326 including 4 yearlings and the remaining 2 orphaned yearlings were monitored from den emergence through the family breakup period and the subsequent 6 months of the study.

Family Separation

Black bear families remain together for 1 1/2 to 2 1/2 years before separation occurs and the offspring begin a solitary existence (Jonkel and Cowan 1971). The timing of separation normally occurs during early summer, approximately the time when breeding activity begins.

The family of bear 305 was last located together on 29 May 1983 and on 5 June the family had separated. All of the yearlings were separated as well, none being further than 1 km apart. Bear 326 and her lone offspring, male 510, were last located together on 22 June 1983 and by 25 June they had separated.

Rogers (1977) discovered that, in 26 of 28 cases, families had separated between 1 June and 3 July. While monitoring 4 families in Idaho, Reynolds and Beecham (1980) noted that families separated between 25 May and 4 June. In Pennsylvania (Alt 1978), 5 females separated from their offspring in May and 1 in June. Jonkel and Cowan (1971) observed 2 females with yearlings on 20 June and 1 with yearlings on 23 June. Subsequent observations in early July found the first 2 females without yearlings. The dates of family breakup in this study agree with the few studies where data are available, indicating that family breakup primarily occurs in June but occasionally may take place in late May or early July.

The reasons why some families separate early while others late is not clear. Separation generally is thought to be caused by the mother's sudden intolerance of her yearlings (Rogers 1977, Murie 1981) or by adult males during the breeding season (Egbert and Luque 1975, Herrero and Hamer 1977). The onset of breeding in Minnesota (Rogers 1977) and Tennessee (Eiler 1981, Wathen 1983, Eiler et al. 1989) occurs after the earliest records of family breakup from these 2 areas (Rogers 1977, this study, respectively), which indicates that separation may possibly be induced by the mother in these 2 areas.

Several characteristics of the mother may influence the timing of family breakup. These may include age, social status, nutritional condition, number of prior litters, and the current number of yearlings. Age and reproductive history of the 2 mothers 305 and 326 in the study were disparate. The first to separate from her family was female 305. She was 11-years-old and was with her third, possibly fourth litter. The last to separate was female 326, a 5-year-old with her first litter.

In GSMNP and the CNF, 2 different periods of estrous were noted by Wathen (1983): 1) 22 June to 12 July, and 2) 5 August to 18 August. The mean age of females in estrous during the first period was 4.6 years ($n = 5$) whereas the mean for the second was 2.3 years ($n = 3$). Eiler et al. (1989) also observed that the majority of females in estrous during August were 2-year-olds.

Since bears are believed to be induced ovulators (Wimsatt 1963, Erickson and Nellor 1964), it may be advantageous for an adult female to separate from her offspring early, come into estrous and breed early. A

mother that separates from her yearlings in late June or early July will enter estrous later than most females and may risk losing the opportunity to breed. In the spruce-fir forest of Montana, Jonkel and Cowan (1971) noted that it may be disadvantageous for females to come into estrous late in the breeding season as many males may have moved higher into the mountains.

Reassociations

Mother and offspring of both families did reassociate after separation. On 7 June 1983, at least 2 and not more than 8 days after the breakup, the entire family of bear 305 was radiolocated together. The following day, on 8 June, 2 of the yearlings had separated again while yearling male 512 was still with the mother. The family of bear 326 did not reassociate as quickly after breakup as did the family of bear 305. On 31 July and 14 September 1983, both mother and offspring were radiolocated together.

Sibling reassociations were detected twice (7 June and 8 September 1983) and involved the 2 orphaned yearlings (female 546 and female 514).

Reynolds and Beecham (1980) noted "there were occasional reassociations between the female and one or both yearlings and also between the yearlings," though the exact number was not reported. Rogers (1977) observed only one reassociation, between a mother and 2 yearlings, 1 month after the initial family breakup. This family then rejoined for an additional 11 months before separating permanently in June of the following year. Reassociations between siblings were not reported by Rogers (1977).

Home Range

Adult summer ranges were significantly larger than yearling summer ranges ($P = 0.10$) but not significantly larger than the fall and annual ranges ($P > 0.10$) (Table 2).

Table 2. Annual and seasonal home range sizes (km²) for black bears in Cherokee National Forest, Tennessee.

Category	Mean	Range	<i>n</i>	Signif.
Summer 1983				
Adult	11	2 - 41	8	$P = 0.10$
Yearling	4	3 - 6	6	
Fall 1983				
Adult	77	2 - 315	8	$P > 0.10$
Yearling	20	3 - 56	6	
Annual 1983				
Adult	53	5 - 342	8	$P > 0.10$
Yearling	30	4 - 66	6	

The mean summer and fall home range size was not significantly different ($P > 0.10$) for adults; however, it was for the yearlings ($P < 0.10$) (Table 3).

The summer ranges of adult bears were significantly larger than yearlings' primarily because the younger bears restricted their movements to an area within their mothers' range and rarely utilized the entire area during this season. During the fall, however, several yearlings (male 510, female 511, and male 512) increased their home range and roamed far from their mothers' ranges. These ranges were larger than any of the adult females for this season and approximated those of adult males.

Several studies have reported seasonal and/or annual home ranges of yearlings following family breakup (Rogers 1977, Reynolds and Beecham 1980, Carr 1983, Garris 1983). Only 2 had sample sizes greater than this study; Rogers (1977) found yearlings of both sexes ($n = 24$) to have annual ranges of 1 to 7 km² while Reynolds and Beecham (1980) discovered yearlings ($n = 10$) in Idaho with ranges of 5 to 9 km². The 6 yearlings monitored during this study had a mean annual home range of 30 km² (Table 2); the 3 yearlings exhibiting long range fall movements away from their mothers' range influenced this mean greatly as their annual home ranges were 58, 33, and 66 km², respectively. The 2 aforementioned studies did not record movements this wide-ranging for male or female yearlings and reported a much smaller mean annual home range size.

The fall home ranges were large for 3 of the yearlings monitored. In Idaho (Reynolds and Beecham 1980), yearling black bears remained within their mothers' home range and did not increase their range size from summer to fall. Rogers (1977) noted that 5 of 24 yearlings (3 males, 2 females) in Minnesota increased their home range size from summer to fall as did the yearlings in this study. These seasonal increases in range size among yearlings may be a result of their exploratory or pre-dispersal movements during the fall, which generally culminate in their return to their mothers' range to den for the winter.

Table 3. Changes in home range sizes (km²) for black bears in Cherokee National Forest, Tennessee.

Age (Seasons 1-2)	Means (1-2)	n_1-n_2	Signif.
Adults			
Summer 83 - Fall 83	11 - 77	8 - 8	$P > 0.10$
Yearlings			
Summer 83 - Fall 83	4 - 20	6 - 6	$P < 0.10$

Patterns of Space Use

The spatial relationships between bears 305 and 326 and their yearlings after family breakup were analyzed in addition to the orphaned yearlings with their mother's vacated home range.

During summer 1983, bear 305 and bear 326 each shared ranges with their yearlings after breakup. The ranges of the yearlings of bear 305 were nearly enclosed within the range of their mother, all sharing an average of 81% of their ranges with her. Bear 326 and her yearling 510 exhibited the same spatial relations with 43 of 46 (93%) radio locations of the yearling within the mother's home range.

In contrast, the fall ranges of yearlings increased in size greatly. Bear 305 centered her activities in the western edge of her home range while her yearlings used the northeastern corner and areas beyond. The fall range of 2 of her yearlings (female 511 and male 512) increased dramatically in size as they moved southeast into North Carolina. Female 511 was located twice approximately 9 km from her summer range before returning. Her sibling 512 was located 12 times at a distance of up to 15 km from his summer range before returning on 2 December 1983. Nearly identical patterns of movement occurred with yearling male 510. His range increased during the fall as he also traveled up to 15 km in a southeast direction and was located 13 times before shedding his radio collar on 8 November 1983.

The spatial relations between mothers and offspring after family breakup have been discussed by several authors. Reynolds and Beecham (1980) found that 9 of 10 yearlings (6 male, 3 female) remained in the mother's home range through the fall while 1 male moved 20 km away from the study area and eventually denned there. In Minnesota, 24 yearlings (10 male, 14 female) settled in areas of the mother's home range after breakup and concentrated their activities there for at least a year (Rogers 1977). In a pattern much like that in the CNF, 5 of the 24 yearlings (3 males, 2 females) left the mother's home range for up to 6 weeks during late summer or early fall and all but 1 returned there to den.

The initial space use patterns of the 2 orphaned yearlings after den emergence in spring 1983 were in the area of the vacated 1982 home range of their mother. They shared more than 50% of their spring ranges within her old range, but the use of the mother's area differed. Yearling 514 was located 8 of 17 times and yearling 546, 5 of 27 (19%) times inside the range of 306. These figures also may be misleading as bear 306 was radiolocated only 39 times between August and December 1982, and no location data from spring and early summer 1982 were

collected. The vacant home range of bear 306 may be larger than the data indicate. During the summer, yearling 514 concentrated nearly all her activity within the home range of her mother, while yearling 546 concentrated her activity near, but outside the mother's home range. During the fall, yearling 514 moved far outside the mother's range but not as far as yearlings 510, 511, and 512. Her sibling, bear 546, continued to use the same size area but shifted her activity to within her mother's range. The movements and space use patterns shown here are not markedly different from the other yearlings.

Spatial relations and dissolution of family bond were examined by analyzing the mean distance between radio locations of mothers and their respective yearlings from the time of family breakup until denning (Table 4). The first month after family breakup (June), the mean distance between all mothers ($n = 2$) and yearlings ($n = 4$) was 0.8 km. In July, the mean distance increased significantly to 1.2 km ($P = 0.10$) and continued to increase monthly until it reached a maximum of 4.2 km in October. In November the measure decreased to 2.9 km.

Of the yearlings, males ($n = 2$) and females ($n = 3$) both were located at nearly the same distance from their mothers from June (males = 0.8 km; females = 0.8 km) until August (males = 1.3 km; females = 1.4 km) (Table 4). Beginning in September, males increased the mean distance to 4.3 km and in October to 8.5 km while the females were located at a mean distance of 1.4 km and 2.8 km, respectively. The November distance decreased for both sexes. The mean distance between siblings after family breakup was also measured (Table 4). As with the spatial relations between mothers and yearlings, siblings reflected the same pattern; beginning at 0.7 km in June and increasing the mean distance each month, reaching a maximum in October of 4.0 km and decreasing in November to 1.3 km.

Reynolds and Beecham (1980) also discovered that the mean distance between locations of mothers and yearlings and between siblings became greater as the season progressed (data only recorded through October). In Minnesota, yearlings in late summer or fall made long forays away from their mothers' ranges but eventually returned to den (Rogers 1977). Although mother and offspring and siblings may be able to recognize each other after breakup and reassociations occur, the family bond appears to become progressively weaker over time. Rogers (1977) found adult females sharing their home ranges with their offspring although avoiding them, giving nearly exclusive use of those areas to the young bears, resulting in reduced competition for food between mothers and yearlings.

Subadult dispersal seldom occurs before 1.5 years (Jonkel and Cowan 1971) and often later (Rogers 1977). On Long Island, Washington (Lindzey and Meslow 1977), 5 yearlings (3 males, 2 females) remained within their mothers' range the first 7 months after breakup, enlarged their seasonal home ranges at 2 years of age, and dispersed from the island at 4 years. In the White River National Wildlife Refuge, Arkansas, Smith (1985) did not observe long range dispersal among young males (1-, 2-, or 3-years-old) because of the lack of dispersal corridors and the juxtaposition of forested and agricultural areas in the White River basin. Dispersing males, therefore, had to establish ranges within or nearby their mothers' ranges.

Five of the 7 radio-tagged yearlings are known to have survived until the following winter. However, we recovered male 510's radio collar in NNF before winter and his fate was unknown. Of the monitored juveniles in CNF, none dispersed from their mothers' home area establishing their own ranges during the first year. All remained within or near their mothers' range; several pre-dispersal

Table 4. Mean distance \pm SD (km) between radio locations of female and yearling black bears and between siblings after family breakup, Cherokee National Forest, Tennessee, 1983. Number of paired radio locations are in parentheses.

Month	Females and yearlings-combined	Females and yearlings		
		Males	Females	Siblings
June	0.8 \pm 0.02 (52)	0.8 \pm 0.4 (22)	0.8 \pm 0.5 (30)	0.7 \pm 0.2 (49)
July	1.2 \pm 0.1 (84)	1.1 \pm 0.8 (44)	1.4 \pm 0.8 (40)	0.8 \pm 0.2 (56)
August	1.3 \pm 0.01 (53)	1.3 \pm 1.4 (24)	1.4 \pm 0.6 (29)	0.9 \pm 0.3 (46)
September	2.7 \pm 2.1 (66)	4.3 \pm 4.8 (28)	1.4 \pm 0.7 (38)	2.3 \pm 1.6 (47)
October	4.2 \pm 18.8 (45)	8.5 \pm 4.5 (11)	2.8 \pm 2.1 (34)	4.0 \pm 1.2 (25)
November	2.9 \pm 19.2 (57)	4.0 \pm 3.2 (20)	2.3 \pm 1.1 (37)	1.3 \pm 0.1 (49)

forays were made during the fall, and all returned and denned within their mothers' range.

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