

DIEL MOVEMENTS OF BLACK BEARS IN THE SOUTHERN APPALACHIANS

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Abstract: Hourly movements of radio-collared black bears (*Ursus americanus*) were monitored periodically from May through December 1976–1979 in the Great Smoky Mountains National Park and Cherokee National Forest in eastern Tennessee. Diel movements were affected by habitat, food supply, time of year, time of day, sex, age, presence of cubs, and social interactions. Bears were relatively sedentary where food was easily obtained but foraged over larger areas when high-energy foods were dispersed. Nocturnal movements were most affected by food supply. Daily movements changed seasonally and from year to year in response to seasonal and year-to-year changes in food supply. Adult males generally traveled more per day than adult females, and young bears traveled further than adult bears. Females with cubs limited their movements, especially during the spring. All bears utilized only a small portion of their seasonal range in the course of a day, often traveling in a zig-zag or circular pattern. Circuitous travel routes were particularly evident where bear densities were high.

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Radio-telemetry has enabled biologists to track movements of secluded species such as the black bear. Studies of black bear movements using radio-telemetry have described home range size, seasonal movements, and dispersal patterns (Poelker and Hartwell 1973, Beeman 1975, Piekielek and Burton 1975, Alt et al. 1977, 1980, Amstrup and Beecham 1976, Lindzey and Meslow 1977, Reynolds and Beecham 1980, Garshelis and Pelton 1981). Few studies have attempted to examine diel (24-hour) movements. Analysis of such movements requires short sampling intervals (Heezen and Tester 1967), which are often difficult to achieve (Beeman 1975) or simply not practical in black bear studies. Some recent studies, however, were successful in obtaining hourly radio-locations on black bears continuously for 1–16 days (Rieffenberger 1974, Rogers 1977:68, R. Hamilton, Univ. Ga., pers. commun.).

Diel movement patterns may be particularly important in evaluating social behavior and habitat utilization of black bears. Examination of social behavior through analysis of diel movements requires a large number of radio-marked individuals in a particular area, and determination of habitat utilization demands a high degree of accuracy of radio-locations. Due to dispersion of radio-marked bears, we generally were unable to

observe social interactions directly using diel movement data. Similarly, because most tracking stations in our study areas were accessible only by foot trails, we usually were restricted to tracking from 2 fixed stations, which reduced the accuracy of radio-locations and limited our ability to decipher detailed habitat utilization from diel movement patterns. We were able to quantify daily movement parameters, however, with respect to travel rates, distances moved, and routes taken. These data were used to evaluate the influence of time of year, time of day, sex, and age status, as well as infer social and habitat influences on black bear movements.

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STUDY AREA

Data were collected from 3 separate study areas in the southern Appalachian Mountains of eastern Tennessee: 2 areas within the Great Smoky Mountains National Park (GSMNP or Park) and 1 within the Tellico Wildlife Management Area (TWMA) in the southern portion of the Cherokee National Forest. The GSMNP is

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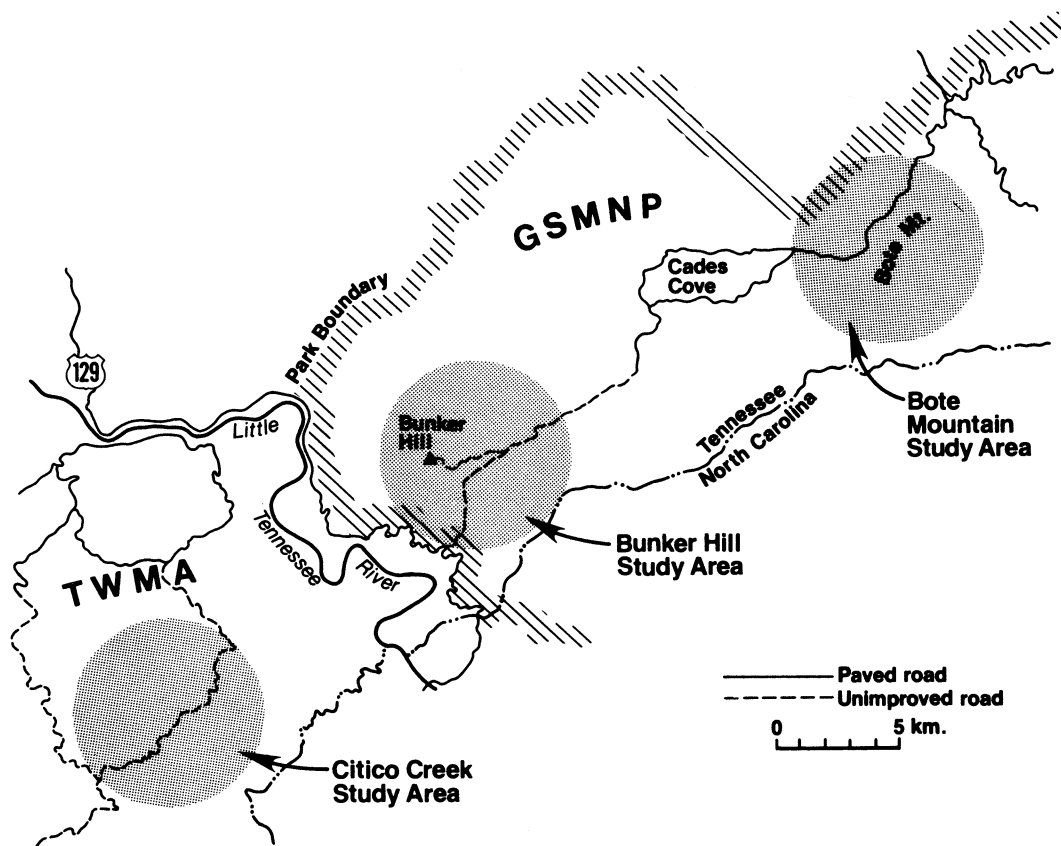


Fig. 1. Location of 3 study areas in the southern Appalachians. Two are within the Great Smoky Mountains National Park and 1 is within the Tellico Wildlife Management Area in the Cherokee National Forest.

adjacent to and northeast of the TWMA; the Little Tennessee River and a paved highway separate the 2 areas (Fig. 1).

One of the 2 study areas within the Park extended from Cades Cove to the Little Tennessee River on the western border of the Park. This study area is designated as the Bunker Hill area (Fig. 1) in reference to a prominent fire tower used extensively during the study. Elevations in the Bunker Hill area range from 271 m to 1,509 m. The overstory vegetation in this area is predominantly mixed oak (*Quercus* spp.) and pine (*Pinus* spp.); mountain laurel (*Kalmia latifolia*), huckleberry (*Gaylussacia baccata*), and blueberry (*Vaccinium* spp.) form most of the understory.

The other study area in the GSMNP was east of Cades Cove. Most trapping and radio-tracking in this area was conducted on Bote Mountain;

thus, this area is referred to as the Bote Mountain area (Fig. 1). Elevations are higher in this area than in the Bunker Hill area, ranging from about 365 m to 1,685 m, and mountain slopes are generally steeper. Vegetation in the higher elevations is characterized as a cove hardwood association (Whittaker 1956) whereas lower elevations are dominated by several species of oaks and pines.

The third study area was located within the Citico Creek watershed of the TWMA and hence is termed the Citico Creek area (Fig. 1). Elevations in this area range from 290 m to 1,341 m. The vegetation is similar to that in the Bunker Hill area.

The climate in all 3 study areas is similar. Mean annual temperature ranges from 8 C to 14 C depending on elevation. Precipitation averages

about 140 cm a year at low elevations but ranges to over 200 cm at the highest elevations. Maximum precipitation usually occurs in July, whereas the minimum is in September or October (Shanks 1954, Tanner 1963, U.S. Department of Commerce 1972).

Legal hunting of bears is not permitted in any of the study areas. Poaching does occur, but data from recovered radio-collars indicate that mortality from this cause does not exceed 10% annually.

METHODS AND MATERIALS

Bears were captured in either Aldrich foot snares or barrel traps, immobilized with intramuscular injections of M-99 (etorphine) at 0.013 mg/kg body weight, or Sernylan (phencyclidine hydrochloride) at 1.5 mg/kg body weight, and instrumented with radio-collars in the frequency range 150–152 mHz (Wildlife Materials, Inc., Carbondale, IL 62901, and Telonics, Inc., Mesa, AZ 85203). Seventy-two bears were radio-collared, although data from diel tracking were obtained for only 38 of these animals, including 18 in the Bote Mountain area, 12 in the Bunker Hill area, and 8 in the Citico Creek area; the other radio-collared animals were not within the range of our tracking stations. Diel data were collected from May through December 1976–1977 in the Bote Mountain area, and from May through November 1978–1979 in the Bunker Hill and Citico Creek areas.

Radio-locations were determined by triangulation of simultaneously obtained bearings from 2 tracking stations, each equipped with an 8-element antenna mounted to a mast. Attempts were made to locate all animals within range of the tracking stations once an hour for periods of up to 25, or occasionally 48 hours. As many as 15 animals were monitored from a single tracking station during the course of an hourly tracking sequence, but usable radio-locations were obtained on only some of these individuals, and consecutive locations over a period of 12 or more hours were obtained infrequently. We rejected radio-locations if they appeared anomalous with respect to prior or subsequent locations, or if the signal quality received at a tracking station was inadequate to determine an accurate azimuth on the animal. Tests with reference transmitters indicated that radio-locations were rarely in error by more than 100 m in any direction. However,

we found it generally impractical to use error polygons in our treatment of diel movements as suggested by Springer (1979) because the analysis became overly difficult to interpret. Instead, locations were plotted as points, and distances were measured between points representing sequential hourly locations.

Diel movements were analyzed with respect to daily range length (maximum distance between radio-locations in a 24-hour period) and its relationship to seasonal home range length (maximum distance between 2 points in the seasonal home range), total daily movement (sum of distances between 24 consecutive hourly locations), net daily movement (distance between locations obtained 24 hours apart, i.e., distance between beginning and end point in a 24-hour sequence of locations), and circuitry of the travel route. Circuitry was calculated by dividing net movement over a period of 12 or more hours by the total distance traveled in that period. A value of 1 indicated straight-line movement, whereas a value of 0 indicated that the animal returned to the original location. Relatively stationary animals were deleted from the analysis of circuitry.

Hourly rates of travel were computed by dividing total movement measured between consecutive hourly locations by the number of recorded hourly locations. Rates of travel during daylight hours were determined only for diel data including 8 or more hourly movements; nocturnal rates of travel were tabulated for diel data including at least 4 consecutive hourly movements. We defined diurnal movements as occurring between 0600 and 2000, and nocturnal movements as occurring between 2000 and 0600. These divisions were based on the activity patterns observed for bears instrumented with motion-sensitive radio-collars in the GSMNP (Garshelis and Pelton 1980). Activity interpreted from motion-sensitive radio-collars was found to be highly correlated with diel movements (Garshelis 1978:71–74).

Seasonal divisions used in diel movement analysis also were based on patterns of activity. However, whereas Garshelis and Pelton (1980) recognized 3 seasons, March–May, June–September, and October–December, we had insufficient diel data in March and April to consider spring a separate season. Thus, we considered spring and summer a single season lasting from May through September.

Table 1. Mean rates of travel (km/hr), grouped by study area, time of day, season, and sex, of black bears in the southern Appalachians, 1976–1979. Black bear sample sizes are shown in parentheses.

	Diurnal rate			Nocturnal rate		
	Bote Mountain	Bunker Hill	Citico Creek	Bote Mountain	Bunker Hill	Citico Creek
Spring/summer						
Females	0.22(8)	0.46(11)	0.37(4)	0.03(5)	0.27(7)	0.26(4)
Males	0.16(2)	0.46(11)	0.50(6)	0.00(1)	0.21(10)	0.21(6)
Total	0.21(10)	0.46(22)	0.44(10)	0.03(6)	0.23(17)	0.23(10)
Fall						
Females	0.21(15)	0.43(15)	0.37(3)	0.16(18)	0.27(6)	0.23(3)
Males	0.35(12)	0.25(2)	0.34(1)	0.33(11)	0.14(2)	0.32(1)
Total	0.27(27)	0.37(7)	0.36(4)	0.23(28)	0.24(8)	0.25(4)

The *t*-test, or when necessary, the approximate *t*-test (Sokal and Rohlf 1969:376), was used to determine statistical significance in all comparisons between means.

RESULTS

Comparisons Among Study Areas

Comparing the Bunker Hill and Citico Creek areas, we found no significant differences in total daily movements, net movements, circuitry of travel routes, daily range lengths, or hourly rates of travel, considering both males and females, and spring/summer, fall, diurnal, and nocturnal movements (Tables 1–5). Therefore, data for the Bunker Hill and Citico Creek areas were combined for this analysis.

Diel movements in the Bote Mountain area differed appreciably from movements in the Bunker Hill and Citico Creek areas, especially during the spring/summer season. During this season, diurnal and nocturnal hourly rates of travel were significantly higher ($P < 0.05$) in the Bunker Hill and Citico Creek areas for both males and females (Table 1); consequently, total daily movements were also greater ($P < 0.05$) for

both sexes in the Bunker Hill and Citico Creek areas (Table 2). However, spring/summer travel routes in the Bunker Hill and Citico Creek areas were more circuitous than in the Bote Mountain area (values of circuitry closer to zero, Table 3) ($P < 0.01$), resulting in net movements over a 24-hour period that were similar among all study areas (Table 4). Spring/summer daily range lengths were not significantly different between areas for either sex alone, but with both sexes combined, daily range lengths were somewhat larger ($P < 0.05$) in the Bunker Hill and Citico Creek areas (Table 5).

In contrast to the movements in the spring/summer season, movements during the fall were similar among all study areas. Total daily movements, net daily movements, circuitry, daily range lengths, and nocturnal travel rates were not significantly different between Bote Mountain and Bunker Hill–Citico Creek (Tables 1–5). Diurnal travel rates in the fall were somewhat higher ($P < 0.01$) for females in the Bunker Hill and Citico Creek areas, but these higher diurnal travel rates occurred only in 1978; comparison of the 1979 Bunker Hill–Citico Creek data with Bote

Table 2. Mean total daily movements (km), grouped by study area, season, and sex, of black bears in the southern Appalachians, 1976–1979. Black bear sample sizes are shown in parentheses.

	Bote Mountain	Bunker Hill	Citico Creek
Spring/summer			
Females	3.2(6)	9.6(8)	6.1(2)
Males	1.7(1)	8.8(9)	8.4(6)
Total	3.0(7)	9.2(17)	7.8(8)
Fall			
Females	4.9(23)	7.8(5)	4.5(2)
Males	6.7(17)	5.0(2)	8.0(1)
Total	5.7(40)	7.0(7)	5.4(3)

Table 3. Mean circuitry of travel routes (net movement/total movement), grouped by study area, season, and sex, of black bears in the southern Appalachians, 1976–1979. Values can range from 0.0 through 1.0; values closer to 0.0 represent more circuitous travel routes. Sample sizes are shown in parentheses.

	Bote Mountain	Bunker Hill	Citico Creek
Spring/summer			
Females	0.4(6)	0.1(7)	0.1(2)
Males	0.6(1)	0.2(9)	0.2(5)
Total	0.4(7)	0.2(16)	0.2(7)
Fall			
Females	0.3(22)	0.1(5)	0.3(2)
Males	0.2(16)	0.1(2)	0.2(1)
Total	0.3(38)	0.1(7)	0.3(3)

Table 4. Mean net daily movements (km), grouped by study area, season, and sex, of black bears in the southern Appalachians, 1976–1979. Sample sizes are shown in parentheses.

	Bote Mountain	Bunker Hill	Citico Creek
Spring/summer			
Females	1.3(6)	0.8(7)	0.6(2)
Males	1.0(1)	1.4(8)	1.3(5)
Total	1.3(7)	1.1(15)	1.1(7)
Fall			
Females	0.8(9)	0.8(1)	1.6(1)
Males	1.6(7)	0.6(2)	
Total	1.2(16)	0.7(3)	1.6(1)

Mountain yielded no significant differences in fall movements. Indeed, diurnal rates of travel were found to be significantly higher ($P < 0.01$) in 1978 than in 1979 in the Bunker Hill and Citico Creek areas. However, even using only 1979 data from Bunker Hill and Citico Creek, spring/summer movements, as discussed above, were found to be significantly greater than in the Bote Mountain area.

Seasonal Comparisons

Seasonal differences in diel movements were apparent only within the Bote Mountain area. In this area, bears of both sexes traveled greater distances ($P < 0.05$) per day during the fall than during the spring/summer (Table 2). Whereas diurnal travel rates were similar in spring/summer and fall, nocturnal travel rates were considerably greater ($P < 0.05$) in the fall (Table 1). Travel routes also were more circuitous ($P < 0.05$) in the Bote Mountain area during the fall (Table 3), but the difference was significant only for males. In the Bunker Hill and Citico Creek areas, total daily movements, rates of travel, and circuitry of travel routes did not change seasonally (Tables 1–3). Net daily movements did not vary seasonally in any area (Table 4). Net daily movements averaged 1.1 km, which compares closely with the findings of Amstrup and Beecham (1976) of 1.3 km for black bears in Idaho. Maximum net movement in our study was 4.9 km. Alt (1977:56) observed net movements of translocated bears in Pennsylvania ranging between 1.5 and 10.8 km.

Day/Night Comparisons

In all study areas, diurnal rates of travel exceeded ($P < 0.01$) nocturnal rates of travel during spring/summer (Table 1). Fall diurnal and

Table 5. Mean daily range lengths (km), grouped by study area, season, and sex, of black bears in the southern Appalachians, 1976–1979. Sample sizes are shown in parentheses.

	Bote Mountain	Bunker Hill	Citico Creek
Spring/summer			
Females	1.6(6)	2.1(7)	2.0(4)
Males	1.0(1)	2.1(11)	2.5(6)
Total	1.5(7)	2.1(18)	2.3(10)
Fall			
Females	1.5(23)	1.4(5)	1.6(3)
Males	2.1(17)	0.9(2)	1.9(1)
Total	1.8(40)	1.2(7)	1.7(4)

nocturnal rates of travel were similar in the Bote Mountain area for the 2 sexes. In the Bunker Hill and Citico Creek areas, fall diurnal rates of travel for females were slightly greater ($P < 0.05$) than nocturnal rates, but these 2 rates were similar for males. During both seasons, maximum hourly movements recorded in each study area occurred diurnally (Table 6); the maximum hourly diurnal movement was 2.3 km, whereas the maximum nocturnal movement was only 1.3 km. Rogers (1977:69) observed maximum movements of 1.6–2.7 km/hr. Maximum total daily movement in our study was over 14 km.

Comparisons Among Sex and Age Groups

Male and female movements differed most dramatically in the Bote Mountain area. During the fall, males traveled further per hour ($P < 0.05$) than females, both diurnally and nocturnally (Table 1); thus, total daily movement also was greater ($P < 0.05$) for males than females (Table 2). A valid spring/summer sex comparison could not be made in the Bote Mountain area because of a small sample size for male bears. In the Bunker Hill and Citico Creek areas, there were no significant differences in diel movements between males and females in either season (Tables

Table 6. Maximum hourly movements (km) recorded, by study area, season, and time of day, for black bears in the southern Appalachians, 1976–1979. Sex of bear is shown in parentheses.

	Bote Mountain	Bunker Hill	Citico Creek
Spring/summer			
Diurnal	1.1(F)	2.3(M)	2.0(M)
Nocturnal	0.8(F)	1.2(F)	0.9(F)
Fall			
Diurnal	1.6(M)	1.5(F)	1.6(F)
Nocturnal	1.3(M)	1.1(F)	1.2(F)

1 and 2), except that females' travel routes were slightly more circuitous ($P < 0.05$) than males' in the spring/summer (Table 3). Differences in circuitry between male and female travel routes were not noticed in the Bote Mountain area; thus, greater total daily movements by males in this area during the fall resulted in daily ranges that were longer ($P < 0.05$) than the daily ranges of females (Table 5). However, because female home ranges were smaller than those of males in both length and area (Garshelis and Pelton 1981), the proportion of the seasonal home range covered in the course of a day was similar for the 2 sexes. Generally, daily range lengths were 1/3 to 2/3 (mean 0.5) the length of the seasonal home range, although some very circuitous daily ranges were less than 10% of the seasonal home range length, and in 1 case a daily travel route spanned the entire length of the home range (Fig. 2).

Few differences were observed in diel movement patterns which could be related directly to differences in age or presence of cubs. Some of the differences between movements in the Bote Mountain area and Bunker Hill–Citico Creek areas may have occurred as a result of differences in the age of bears being radio-tracked; radio-collared bears were significantly older ($P < 0.05$) in the Bote Mountain area than in the Bunker Hill and Citico Creek areas. Within each study area, no differences were observed during the fall in hourly travel rates, total and net daily movements, or circuitry between adult and immature bears of the same sex. In the spring/summer, immature females traveled greater distances per hour ($P < 0.05$) during the day in the Bunker Hill and Citico Creek areas than did adult females from these areas. It is difficult to determine whether increased movement by the subadult bears was due to their young age or the fact that all of the adult females being radio-tracked were traveling with cubs. Alt et al. (1977) and Rogers (1977:75) observed limited movements for females with cubs in the spring.

DISCUSSION

Differences in diel movement patterns observed for black bears in the Bote Mountain area and the Bunker Hill–Citico Creek areas (Table 7) may have been due in part to the younger age

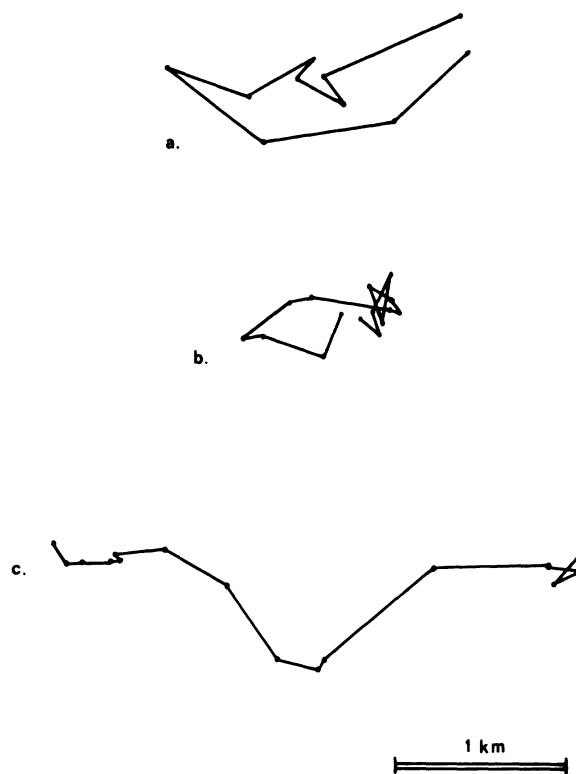


Fig. 2. Maximum and minimum circuitry of diel travel routes observed for black bears in the southern Appalachians of eastern Tennessee, 1976–1979. (a) = circular travel route of a subadult male, circuitry = 0.05. (b) = zig-zag travel route of an adult female, circuitry = 0.04. (c) = linear travel route spanning entire length of home range of a subadult female, circuitry = 0.74.

structure of the radio-collared bears in the latter areas, as suggested above. Not only were the instrumented bears in the Bunker Hill–Citico Creek areas younger than instrumented bears in the Bote Mountain area, but apparently the population age structure in general was weighted more heavily toward younger age classes in Bunker Hill and Citico Creek, presumably because of heavy poaching pressure in these areas. (Data from trapping records, 1975–1979, indicated that the mean age of bears in Bunker Hill and Citico Creek was significantly less [$P < 0.01$] than that of bears in Bote Mountain.) Greater diel movements by younger bears probably reflected their attempts to establish home ranges, their inexperience in locating food sources within their home range, and their avoidance of more dominant bears feeding within their home range. Garshelis

Table 7. Characteristics of the study areas in the southern Appalachians and their effects on diel movements of black bears, 1976–1979.

Study areas	Characteristics of the habitat	Effects on food habits and age structure	Effects on diel movements
Bote Mountain	1. High topographic relief; late ripening foods in spring/summer home ranges 2. Inaccessible location; low poaching	1. Bears forage heavily on grasses until mid-summer, acorns in fall 2. Old age structure; many females with cubs	1. Short, linear, diurnal movements in spring/summer; long, circuitous, diurnal and nocturnal movements in fall 2. Males' movements greater than females'
Bunker Hill–Citico Creek	1. Low topographic relief; early ripening foods in spring/summer home ranges 2. Accessible to humans; high poaching	1. Bears forage on squawroot and berries in spring/summer, acorns in fall 2. Young age structure; many females without cubs	1. Long, circuitous, diurnal and nocturnal movements in both spring/summer and fall 2. Movements not different for males and females

and Pelton (1981) observed highly overlapping home ranges during all seasons for bears in the GSMNP, and mutual avoidance between bears with home ranges that overlapped.

Because differences in diel movements of bears in the Bote Mountain and Bunker Hill–Citico Creek areas were evident only in the spring/summer (Table 7), we suspect that age differences did not account entirely for the greater movements by bears in Bunker Hill and Citico Creek (otherwise we should have observed differences in fall movements as well). The nature of the habitat, especially food availability in late spring and early summer, was similar between Bunker Hill and Citico Creek, but different between these areas and the Bote Mountain area. Therefore, we believe that differences in food availability contributed to the differences observed in diel movements between the Bote Mountain and Bunker Hill–Citico Creek areas. Eagle (1979:36) found that during May–July 1977, the only year for which spring/summer diel movements were observed in the Bote Mountain area, herbaceous material made up 1/3 of the diet of bears in this area. In contrast, herbaceous material was not found in the scats of bears in the Bunker Hill area (= the Hannah Mountain area of Eagle 1979). Bears in the Bunker Hill area were apparently able to find sufficient quantities of squawroot (*Conopholis americana*) and huckleberry during this period, as these 2 items together composed almost 85% of the diet. Herbaceous material probably was more abundant and consumed more quickly than small, dispersed food items like squawroot and huckleberry. In

addition, herbaceous material was digested less completely and provided less energy than squawroot and huckleberry (Eagle 1979:54, 62). Thus, bears that fed largely on herbaceous material in the Bote Mountain area likely became satiated more quickly, and also were more energetically restricted, than bears that fed on dispersed, nutritious food items in the Bunker Hill and Citico Creek areas; daily movements of bears in the Bote Mountain area therefore were more limited than movements of bears in the Bunker Hill and Citico Creek areas during the spring/summer. The availability of fall foods, chiefly acorns, was similar among all areas (Eagle 1979:45); thus, fall movement patterns were similar.

Differences in diel movement patterns between years also may be attributed to differences in food supply. Bears moved greater distances in both spring/summer and fall of 1978 than in the spring/summer and fall of 1979. Observations by 2 of us (Quigley and Villarrubia) and a deer range survey (Tenn. Wildl. Resour. Agency, Pittman-Robertson Proj. Rep. 110–046, TWRA tech. rep. 77–11, Nashville, Tenn., 1977) indicated that spring/summer and fall foods (i.e., both berries and acorns) were less abundant in 1978 than in 1979; thus, in 1978 bears were forced to forage over larger areas. Garshelis and Pelton (1981) indicated that bears in the GSMNP made greater fall movements in years when acorns were scarce than when they were abundant. The high nutritive value of berries and acorns (Eagle 1979; 62, 68) evidently prompted bears to search widely for these items when they were in short supply.

Differences between spring/summer and fall movements were not evident in either 1978 or 1979 in the Bunker Hill and Citico Creek areas (Table 7). We assume from this that bears were able to use similar foraging strategies throughout the year in these 2 study areas, although the food consumed changed from squawroot to berries to acorns. In both seasons, foraging was somewhat more common during the day than during the night, but nocturnal foraging was apparently necessary, especially during the fall when bears increased their body weight prior to winter.

Seasonal differences in movements were more apparent in the Bote Mountain area, probably corresponding to greater seasonal differences in food quality, abundance, and distribution (Table 7). Bears feeding on herbaceous material in the spring/summer were more sedentary, especially during the night, than when feeding on acorns during the fall.

Sex related differences in diel movement patterns were observed only in the Bote Mountain area (Table 7). Males moved greater distances than females in this area, but the movements of the 2 sexes were in proportion to the sizes of their respective home ranges. In contrast, male and female diel movements were similar in both the Bunker Hill area and the Citico Creek area. We offer 2 explanations for this: (1) Sexual differences in movement patterns were less distinct for subadult than adult bears. Garshelis and Pelton (1980) showed that differences in activity related to sex were more pronounced for adult bears, especially because many adult females were with cubs or yearlings. Thus, because most bears radio-tracked in the Bunker Hill and Citico Creek areas were subadults, sexual differences in diel movements were not evident. (2) Many of the male bears in the Bunker Hill and Citico Creek areas that appeared to move the most, frequently moved out of range of our tracking stations; therefore, diel movement data on these individuals were often lacking.

Many of the diel movements we observed were probably influenced by social interactions. However, because we were never able to radio-collar all bears in a given area at one time, it was difficult to witness directly the effects of social interactions on movement patterns. Instead, social interactions had to be inferred from diel

movement parameters, especially circuitry. Very circuitous travel routes indicated confined movements (Fig. 2). Bears may have confined their movements because of physical limitations imposed by the habitat, their preference to remain within a small area of concentrated food, or their avoidance of other bears. Our observations of diel travel routes, as well as physical signs of bears, including scats and mark trees, indicated that bears often traveled along trails, stream drainages, and ridgetops. Prominent ridge systems marked home range boundaries (Garshelis and Pelton 1981), but smaller ridges within the home range were crossed frequently during daily travels. Apparently, physical barriers did not greatly influence the circuitry of travel routes of bears in the southern Appalachians. Thus, we assume that circuitry of travel routes was affected primarily by the distribution and abundance of food, and social interactions. In the Bote Mountain area, bears may have traveled more circuitously during the fall than during the spring/summer (Table 7) because densities of bear in fall feeding areas were greater than densities in the area of spring/summer home ranges (Garshelis and Pelton 1981). The more circuitous travel routes of bears in the Bunker Hill and Citico Creek areas than in the Bote Mountain area during the spring/summer may reflect a more patchy distribution of food and/or greater density of bears in Bunker Hill and Citico Creek. It is also possible that the social organization of bears in Bunker Hill and Citico Creek differed somewhat from that of bears in the Bote Mountain area because of differing age structures. For example, mutual avoidance may have been greater between subadult bears than between adults and subadults, causing more circuitous travel routes where encounter rates between subadults were higher (as expected in the Bunker Hill and Citico Creek areas). Rogers (1977:121–126) noted greater tolerance between females and their offspring after family breakup than between subadult siblings.

It is apparent that movements of black bears in the southern Appalachians were affected by habitat, food supply, time of year, time of day, sex, age, and social interactions. Although we were unable to relate daily movement parameters to weather conditions, we believe, considering its

effects on activity (Garshelis and Pelton 1980), that weather also represents an important factor influencing the diel movements of black bears.

LITERATURE CITED

- ALT, G.L. 1977. Home range, annual activity patterns, and movements of black bears in northeastern Pennsylvania. M.S. Thesis. Pennsylvania State Univ., University Park. 67pp.
- , F.W. ALT, AND J.S. LINDZEY. 1977. Home range and activity patterns of black bears in northeastern Pennsylvania. *Trans. Northeast Sect. Wildl. Soc.* 33:45–56.
- , 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.
- AMSTRUP, S.C., AND J. BEECHAM. 1976. Activity patterns of radio-collared black bears in Idaho. *J. Wildl. Manage.* 40:340–348.
- BEEMAN, L.E. 1975. Population characteristics, movements and activities of the black bear (*Ursus americanus*) in the Great Smoky Mountains National Park. Ph.D. Thesis. Univ. Tennessee, Knoxville. 232pp.
- EAGLE, T.C. 1979. Foods of black bears in the Great Smoky Mountains National park. M.S. Thesis. Univ. Tennessee, Knoxville. 104pp.
- GARSHELIS, D.L. 1978. Movement ecology and activity behavior of black bears in the Great Smoky Mountains National Park. M.S. Thesis. Univ. Tennessee, Knoxville. 117pp.
- , AND M.R. PELTON. 1980. Activity of black bears in the Great Smoky Mountains National Park. *J. Mammal.* 61:8–19.
- , AND ———. 1981. Movements of black bears in the Great Smoky Mountains National Park. *J. Wildl. Manage.* 45:912–915.
- HEEZEN, K.L., AND J.R. TESTER. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. *J. Wildl. Manage.* 31:124–141.
- LINDZEY, F.G., AND E.C. MESLOW. 1977. Home range and habitat use by black bears in southwestern Washington. *J. Wildl. Manage.* 41:413–425.
- PIEKIELEK, W., AND T.S. BURTON. 1975. A black bear population study in northern California. *Calif. Fish and Game* 61:4–25.
- POELKER, R.J., AND H.D. HARTWELL. 1973. Black bear of Washington. *Washington State Game Dep. Biol. Bull.* 14. 180pp.
- REYNOLDS, D.G., AND J.J. BEECHAM. 1980. Home range activities and reproduction of black bears in west-central Idaho. *Int. Conf. Bear Res. and Manage.* 4:181–190.
- RIEFFENBERGER, J.C. 1974. Range and movements of West Virginia black bear during summer and autumn, 1973. *Proc. East. Workshop Black Bear Manage. and Res.* 2:139–142.
- ROGERS, L.L. 1977. Social relationships, movements, and population dynamics of black bears in northeastern Minnesota. Ph.D. Thesis. Univ. Minnesota, Minneapolis. 203pp.
- SHANKS, R.E. 1954. Climates of the Great Smoky Mountains. *Ecology* 35:354–361.
- SOKAL, R.R., AND F.J. ROHLF. 1969. *Biometry*. W.H. Freeman and Co., San Francisco, Calif. 776pp.
- SPRINGER, J.T. 1979. Some sources of bias and sampling error in radio triangulation. *J. Wildl. Manage.* 43:926–935.
- TANNER, J.T. 1963. Mountain temperatures in the southeastern and southwestern United States during late spring and early summer. *J. Appl. Meteorol.* 2:473–483.
- U.S. DEPARTMENT OF COMMERCE. 1972. *Climatology of the United States*. No. 20–40.
- WHITTAKER, R.H. 1956. Vegetation of the Great Smoky Mountains. *Ecol. Monogr.* 26:1–80.