DENNING BEHAVIOR OF BLACK BEARS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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Abstract: Denning behavior of black bears (*Ursus americanus*) in the Great Smoky Mountains National Park was studied using motion sensitive radio-collars. All radio-instrumented bears (n = 29) entered dens and exhibited periods of decreased activity in the predenning and postdenning periods (n = 20). Denning behavior was characterized by a reduction in sensitivity, with females being more lethargic than males. Female bears departed fall ranges earlier ($P<.010$), traveled shorter distances to their dens ($P<.050$), began to depress activities earlier, and were less active ($P<.005$) in the predenning period than males. These activity patterns suggest that late hunting seasons in the Southern Appalachians may aid in reducing the harvest of females. Mast availability also influenced denning behavior and should be an important parameter in determining hunting seasons.

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Winter denning by black bears has long been a topic of interest among naturalists, physiologists, and biologists. This unique behavioral adaptation allows bears to circumvent severe weather conditions and food shortages. Aldous (1937) and Morse (1937) observed that dormant black bears in northern Minnesota were in a "deep slumber" or "partial stupor" from which arousal was possible. They further documented birth of cubs in winter dens and found that yearling cubs (1 year old) accompanied their mother in the den. Rogers (1977) later demonstrated the value of recapturing radio-instrumented bears in winter dens to monitor reproduction, survival, and social relationships.

Jonkel and Cowan (1971) reported dormant bears in Montana were easily aroused but only 2 of 40 bears observed in winter dens exhibited agonistic behavior. Reduced sensitivity of bears in winter dens results in greater vulnerability once discovered by hunters; about 37% of the November bear harvest in Michigan consisted of bears in winter dens (Erickson 1964:94). Denning bears are also more vulnerable to attack by predators such as wolves (*Canis lupus*) (L.L. Rogers, personal communication) and other bears (Lindzey and Meslow 1976a, Rogers 1977:161). Bears in regions of less severe climate apparently differ in this respect since they will frequently abandon dens as a result of disturbances (Poelker and Hartwell 1973:74, Hardy 1974:93, Lindzey and Meslow 1976b, Johnson 1978:29-32). Lundberg et al. (1976) reported that frequent disturbances interrupt the transition into hibernation and may result in bears dying of starvation and urea poisoning. Studies are needed to determine the extent of this problem in the wild.

Decreased activity during the predenning and postdenning periods was observed by Jonkel and Cowan (1971), Rogers (1974), Lindzey and Meslow (1976b), and Hamilton and Marchinton (1977). Rogers (1974) postulated the postdenning inactivity was related to tender footedness due to shedding of foot pads during denning. Lindzey and Meslow (1976b) correlated predenning and postdenning inactivity with daily weather, principally maximum daily temperature and precipitation.

Reports on the denning behavior and associated periods of inactivity for black bears in southern regions are sparse. Casual observations resulted in the common belief that bears in southern regions do not hibernate (Mathies 1972:30). The advent of radiotelemetry has provided objective means to investigate denning behavior of bears. An

understanding of denning behavior and associated periods of inactivity is important, since these behaviors govern the availability of bears to hunters and may bias sex and age data based on hunter kills (Lindzey and Meslow 1976b). Adult females generally enter dens first and are followed by subadults and adult males (Erickson 1964:95, Jonkel and Cowan 1971, Lindzey and Meslow 1976b, and Johnson 1978:35). Manipulation of hunting seasons in relation to differences in denning behavior and periods of inactivity among the sex and age groups may facilitate protection of the breeding segment of the population. Our objective is to report on observations of denning behavior and predenning and postdenning activity patterns of black bears in the Great Smoky Mountains National Park.

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STUDY AREA

The Great Smoky Mountains National Park (GSMNP or Park) comprises 2074 km^2 in eastern Tennessee and western North Carolina. This study was conducted primarily in a 428 km^2 quadrant on the Tennessee side of the Park (Fig. 1). The Smokies are part of the Unaka Mountains of the Blue Ridge Province in the southern division of the Appalachian Highlands (Fenneman 1938:173-174). The topography is extremely steep and complex with more than 90% of the surface area having a slope of greater than 10% (Message from the President 1902:21). Most of the study area is accessible only by foot trails. Elevations range from 270 m to 2024 m.

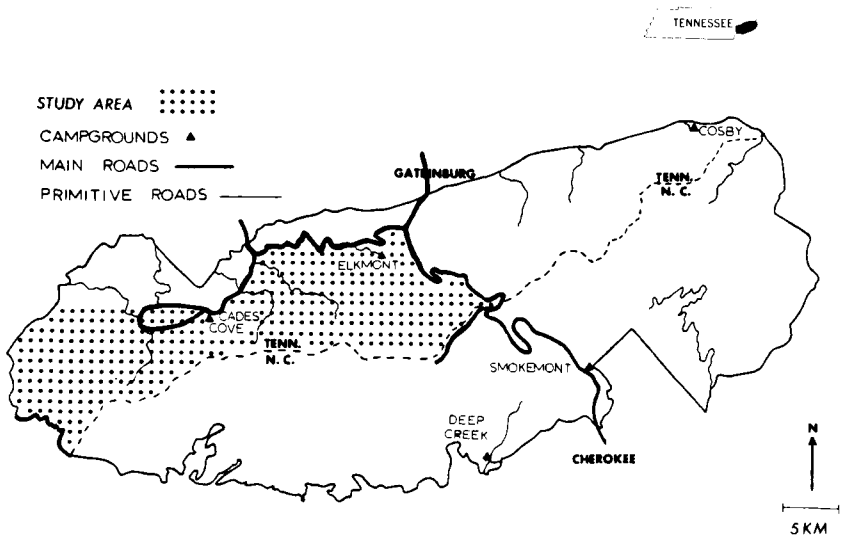

Fig. 1. Location of the study area within the northwest portion of the GSMNP, Tennessee.

The climate of the Smokies exhibits much variation due primarily to a large range in elevation. Average annual temperature ranges from about 14 C at elevations below 450 m to 8 C at elevations above 1900 m. Precipitation, principally rain, averages 140 cm a year at lower elevations to over 230 cm at the highest elevations. Precipitation maxima occur in late winter to early spring and in July or August (Shanks 1954a, Dickson 1960, U.S. Dept. Commerce 1972).

The vegetation of the Smokies is dense, diverse, and well interspersed. Major forest types include spruce-fir, northern hardwood, cove hardwood, hemlock, closed oak, and open oak-pine (Shanks 1954b). Logging dominated the land use until establishment of the Park in 1934 (Lambert 1958).

METHODS

Bears were captured in Aldrich foot snares, immobilized with intramuscular injections of Etorphine or Phencyclidine hydrochloride, and instrumented with radio-collars equipped with a motion-sensitive activity monitor (Wildlife Materials, Inc., Carbondale, IL). Only 20 of the 29 radio-instrumented bears had functioning activity monitors. Triangulation from known points on the ground was used to determine subsequent locations. Bears were located every 2 to 3 days to obtain den entry and emergence dates and to monitor activity patterns. If the pulse rate of the activity monitor changed at least 2 times over a period of 3 or more minutes, or at least 4 times during any 1-minute period, the bear was classified as active. If changes in pulse rate occurred but were less frequent, the bear was assumed to be inactive and a note was made of the probable head movement (Garshelis and Pelton 1978). Den sites were located after bears entered dens; behavioral observations were made concurrently. Age determination was made by the cementum-annuli technique (Willey 1974). Statistical comparisons of numeric data and data that only classify observations were made with the t-test and Chi-squared distribution, respectively.

RESULTS AND DISCUSSION

Denning Behavior

All radio-instrumented bears (n = 29) entered dens and exhibited periods of decreased activity in the predenning and postdenning periods (n = 20) (Fig 2.). Denning behavior

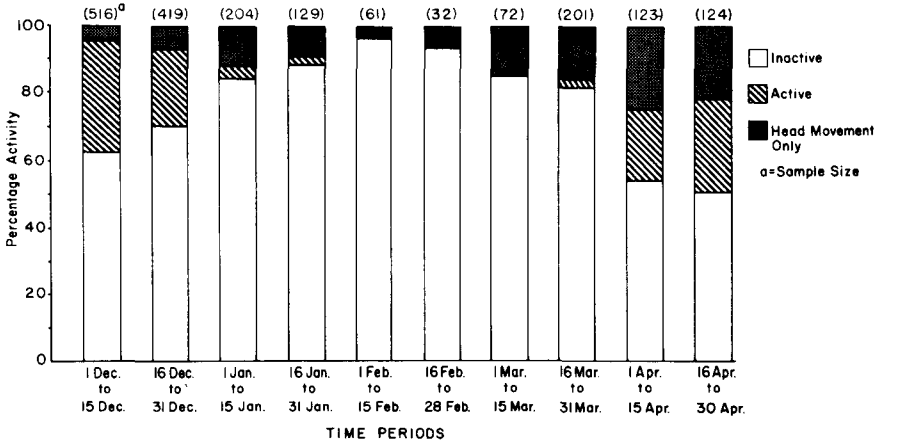

Fig. 2. Predenning and postdenning activity patterns of black bears in the GSMNP, 1976-1978.

was characterized by a reduction in sensitivity; females were more lethargic than males. Disturbances made in our attempts to locate dens caused male bears to abandon dens more readily than females ($P<.005$). However, this difference was also related to the more frequent selection of tree dens high above ground ($\bar{x}=11.2$m) by females (Johnson 1978:67). Ground dens, the most common den type for males, offered less seclusion than tree dens and were readily abandoned. When a den was approached, most bears (14,70%) were aroused enough to raise their heads; however, 4 bears denning in tree cavities apparently did not detect our presence. The activity monitor showed that bears in tree cavities were less likely to be aroused ($p<.050$) than bears in ground dens.

Seclusion of bears in ground dens due to heavy snow cover in northern regions reduces the chance of arousal and abandonment and may account for some of the apparent differences in the degree of lethargy and den abandonment between regions of severe and mild climates. Differences in the degree of lethargy may be more associated with den selection and climate (snow cover and temperature) than to actual differences in denning behavior. No observations were made of bears intermittently leaving or returning to dens. The degree of lethargy of bears in the GSMNP did not appear to differ substantially from northern regions since all radio-instrumented bears entered dens, undisturbed bears exhibited a strong adherence to dens, and den emergence dates were fairly consistent among regions (Johnson 1978:38,33). Observations of the degree of winter dormancy in southern regions have been biased due to variation in den selection and the degree of lethargy among the sex and age groups of a population (Johnson 1978:67,40), a small incidence (2, 6%) of bears changing dens in winter due to heavy rainfall (Johnson 1978:38), and unusually late den entry by a few individuals (3, 9%) (Johnson 1978:29-31), LeCount (1977), Hamilton and Marchinton (1977), and Mykytka (personal communication) recently provided telemetry data from other southern regions (Arizona, North Carolina, and Florida, respectively), which document that winter dormancy appears to be common behavior throughout the range of black bears in North America.

Arousal of bears was accompanied by shivering (n=4), slow movement of the head from side to side (n=2), and extremely slow body movements (n=5). Shivering, also observed by Jonkel and Cowan (1971), indicates that arousal alters the heat balance causing bears to expend more energy in the rewarming process (Kayser 1961:287). Bears did not appear to focus their eyes effectively and appeared timid and docile when observed in dens. Dormant bears appear to present no danger to persons happening upon winter dens. Jonkel and Cowan (1971) reported 2 cases of midwinter agonistic behavior of 2 pregnant female black bears. Only 1 incidence of agonistic behavior was observed in the present study. A closer than normal approach (approximately 0.6 m) to a cavity believed empty evoked a "woof" and rush to the entrance by a female bear. She did not have cubs and this disturbance did not cause abandonment.

Bears apparently sleep in a curled position with the forehead pressed to the floor of the den and the extremities underneath the body (n=4). Posterior and anterior extremities of 1 bear could not be differentiated; she was curled in a very tight ball which appeared almost symmetrical. Folk et al. (1972) reported that captive bears sleep in a similar position and move very little during the entire dormancy period. Changes in the signal pulse between periodic checks and a small incidence of head movements throughout the winter indicated bears do move and may change positions in dens. The frequency of such movements was undetermined. The curled posture of bears is similar to the posture of smaller mammalian hibernators. This posture facilitates more efficient energy conservation since heat loss through the foot pads, head, and respiration is minimized.

Winter mortality due to disturbances during the transition into hibernation (Lundberg et al. 1976) was not observed in the present study. The majority of bears (14, 70%) were aroused enough to raise their heads and 7 bears (19%) abandoned dens upon

our approach. Four bears that abandoned dens were known to have survived since they were subsequently recaptured. No contacts were made with the other 3 bears that abandoned dens. Bears were approached once and only after den entry; consequently, this disturbance may not have occurred at a critical time in the transition into hibernation.

Predenning and Postdenning Activity Patterns

The onset of denning behavior and lethargy was noted prior to den entry (Fig. 2, Table 1). The majority of bears (14, 82%) entered dens between 25 December and 7 January

TABLE 1. Predenning activity patterns of black bears in the GSMNP, 1976-1978.

	No. inactive (%)	No. inactive with head movement (%)	No. active (%)
November 15-30			
Adult males	35(50.7)	5(7.3)	29(42.0)
Subadult males	22(52.4)	1(2.4)	19(45.2)
Adult females	53(47.7)	7(6.3)	51(46.0)
Subadult females	17(56.7)	2(6.7)	11(36.7)
Subtotal males	57(51.4)	6(5.4)	48(43.2)
Subtotal females	70(49.6)	9(.6.4)	62(44.0)
December 1-15			
Adult males	85(52.8)	8(5.0)	68(42.2)
Subadult males	52(54.2)	4(4.2)	40(41.6)
Adult females	140(70.0)	10(5.0)	51(25.0)
Subadult females	48(77.4)	4(6.5)	10(16.1)
Subtotal males	137(53.3)	12(4.7)	108(42.0)
Subtotal females	188(71.5)	14(5.3)	61(23.2)
December 16-31			
Adult males	82(58.6)	14(10.0)	44(31.4)
Subadult males	25(64.1)	3(7.7)	11(28.2)
Adult females	94(71.8)	14(10.7)	23(17.6)
Subadult females	77(84.6)	5(5.5)	9(9.9)
Subtotal males	107(59.8)	17(9.5)	55(30.7)
Subtotal females	171(77.0)	19(8.6)	32(14.4)
Total males	301(55.0)	35(6.4)	211(38.6)
Total females	429(68.5)	42(6.7)	155(24.8)

(Johnson 1978:28) but bears began to gradually decrease activity as much as 1 month prior to denning. Dates of den entry were later than traditional hunting seasons in the Southern Appalachians; this would apparently have little effect on the availability of bears to hunting. The predenning movements and activity patterns appear more important than dates of den entry in the differential vulnerability of bears to hunting.

Female bears departed fall ranges earlier ($P<.010$) and traveled shorter distances to their dens ($P<.050$) than males (Table 2). Three adult females did not move from their spring-summer ranges during the fall; this also likely reduced their vulnerability to

TABLE 2. Predenning movements and dates of departure from fall ranges by black bears in the GSMNP, 1976-1978.

Bear no.	Departure from fall range	Distance traveled to den (km)
	ADULT MALES	
B12	after 27 Dec. 1977	10.5
65	24-27 Dec. 1976	6.0
A26	24-27 Dec. 1976	5.6
A50	20-23 Dec. 1977	5.6
A52	5-7 Jan. 1978	6.2
A42	20-23 Jan. 1978	2.4
Sub-average	30 Dec.	6.1
	SUBADULT MALES	
A30	24 Nov.-4 Dec. 1976	19.9
A47	11-16 Dec. 1977	7.5
A53	23-30 Dec. 1977	6.8
Sub-average	9 Dec.	11.4
Average (all males)	23 Dec.	7.8
	ADULT FEMALES	
A28	16-23 Dec. 1977	3.4
A44	20-23 Dec. 1977	4.5
D2	9-12 Dec. 1976	a
H1	1-3 Dec. 1977	4.7
89	4-9 Dec. 1976	3.9
B10	23-29 Oct. 1977	4.5
F5	b	0
E7	b	0
A45	b	0
Sub-average	2 Dec.	2.6
	SUBADULT FEMALES	
A9	12-15 Dec. 1976	13.1
A9	9-16 Dec. 1977	3.8
A29	5-10 Nov. 1976	3.9
B18	10-15 Nov. 1977	3.8
Sub-average	24 Nov.	6.2
Average (all females)	29 Nov.	3.8

[a]Transmitter failed prior to den location.
[b]No movement from spring-summer range.

mortality. Movements by females in the fall were often within the same watershed but males frequently travesed several different watersheds (Garshelis 1978). Subadults did not depart fall ranges earlier ($.20<P<.10$) than adults but they traveled greater distances to their dens ($P<.050$). Subadults and males also extended winter activity longer than

females; 1 adult male did not enter a den until 12-15 February (Johnson 1978:31). Hamilton and Marchinton (1977) also observed extended winter activity in the coastal plain of North Carolina by subadults and believed they were more vulnerable to harvest late in the hunting season.

Upon return to the spring and summer home ranges prior to denning,(Beeman 1975, Garshelis 1978) movements and activities gradually decreased and were centered around the denning areas. Activities declined significantly ($P<.005$) between 1-15 December and 16-31 December (Fig. 2). Activities again declined ($P<.005$) between 16-31 December and 1-16 January. No other significant differences in activities were found until they began to increase ($P<.005$) between 16-31 March and 1-15 April. Inactivity was still predominant in the postdenning period until activity gradually increased ($P<.025$) between 1-15 April and 15-30 April. There was no significant difference detected between years in the predenning and postdenning activity patterns. The gradual changes in activity and the nature of the metabolic and excretory alterations of hibernation (Nelson et al. 1973, Folk et al. 1976) suggest that this predenning and postdenning behavior may be a physiological transition period. Postdenning inactivity may also represent a more efficient energy regime since spring is a time of consistent scarcity of nutritious foods across most of the black bear's range (Jonkel and Cowan 1971, Rogers 1976, and Beeman and Pelton 1977).

Males significantly reduced activity ($P<.025$) betwen 1-15 December and 16-31 December while females began to depress activity ($P<.005$) between 15-30 November and 1-15 December (Table 1). Males were more ($P<.005$) active than females during the predenning period but this difference was reflected only in December since no differences in activity between males and females occurred from 15-30 November (Table 1).

The frequency of head movements increased significantly ($P<.005$) prior to den emergence indicating movements within dens and probable readjustment to normal behavior (Fig. 2). Jonkel and Cowan (1971) noted 2 denned bears that rushed the observer late in the spring and concluded that a marked behavioral change occurs before bears leave their dens.

Females returned to denning areas earlier, over shorter distances, and began to restrict activities before males indicating that later hunting seasons would be beneficial in reducing the harvest of females in the population. Harvest, radio-tracking, and track count data from the coastal plain of North Carolina suggest a decreasing vulnerability of adult bears, particularly females, from October though December (Hamilton 1978:109). A 2-week delay in the hunting season in the coastal plain and a 1-week delay in the season in the mountain region reduced the North Carolina statewide harvest of females from 47% in 1975 to 37% in 1976 (Collins 1978). Delaying the hunting season in Virginia from the second Monday to the fourth Monday in November reduced the harvest of females from 50% to an average of 41% during 1973-1977 (Raybourne 1978). A late season (15-27 December) in West Virginia during 1975 resulted in a 32.6% female harvest while the early season (3-8 November) resulted in a 52.4% female harvest (Rieffenberger 1976:60). The sex and age differences in the predenning activity patterns and movements of bears observed in the GSMNP partly explain these harvest trends in the Southeast.

In areas such as the Southeastern United States where the status of black bear populations is often poorly known (Pelton and Nichols 1972), December hunting seasons would appear to aid in protection of the breeding segment of the population. However, later seasons are unpopular among mountain hunters and may be difficult to implement (Collins 1978). During years with fair to poor mast yield bears entered dens between 1-15 December and in years of good mast yield they entered dens between 25 December and 7 January (Johnson 1978:37). With corresponding decreases in predenning activity in years with fair to poor mast yields, hunting seasons in late November may also facilitate protection of females. However, during years of good mast yield, December seasons would be preferable.

Den Site Preparation

All dens contained bedding material, but ground dens contained a greater volume than tree dens ($P<.065$). This likely reflected the availability of material as well as the less protected nature of ground dens. An adult female was the only bear observed to carry bedding material (7 hemlock boughs) from the ground into a tree den. She later gave birth, but 3 other females known to produce cubs showed no unusual behavior in den preparation. Three bears (2 subadult males and 1 adult female with 1 year old cubs) lined tree cavities with twigs and branches broken from the den tree or trees adjacent to the den entrance. The clawing of the inside walls of tree dens may enlarge the cavity but more importantly it provided bedding material in the form of punky wood. Clawing activities occurred in all tree dens and was a valuable aid in identification of active dens for availability and utilization studies. No attempt was made to block den entrances as is common for smaller mammalian hibernators.

An adult male collected an estimated 192 liters of rhododendron (*Rhododendron maximum*) and doghobble (*Leucothoe editorium*) branches and leaves; this material was woven into an intricate "nest" by breaking several large rhododendron branches into the rather open ground den to serve as the framework. A 19.8 m^2 area in front of the den was cleared of vegetation. The elaborate structure provided a level bed on the steep slope (32°) and aided in insulation and protection against ground moisture. This observation supports speculation by Erickson (1964:101) that adult males in Michigan gathered less bedding material than adult females and subadults since they entered dens later when vegetation was less abundant.

Fecal Plugs

Four fecal plugs located near dens of radio-instrumented bears are described in Table 3. Searches at other dens yielded no additonal fecal plugs indicating that most bears retain

TABLE 3. Description of fecal plugs located in the GSMNP.

Bear number	Plug wgt. (g)	Length (cm)	Diameter (cm)	Volume (ml, water displacement)	Contents
A30	182.0	22.8	3.9	192	Bear hair, wood chips, twigs
E7	156.5	20.5	4.1	145	Bear hair, clay chips, and fine roots, small rocks, and leaf fragments
A44 and yearling cubs	153.0	19.5	3.7	155	Bear hair, wood chips, twigs and buds
A44 and yearling cubs	76.0	9.4	3.6	80	Bear hair, twigs and wood chips

the plugs and may not feed for some time after emergence. The low incidence of scats on index routes during spring (Pelton 1972) and a high level of inactivity in the postdenning period (Fig. 2) further indicated suppressed feeding activities. Plug formation and other digestive and excretory alterations (Matson 1946, Lundberg et al. 1976) raise doubts if it is physiologically possible for dormant bears to forage intermittently in winter during favorable weather conditions as postulated by Lindzey and Meslow (1976b). No evidence

of bears intermittently leaving and returning to dens was observed in the present study but 3 bears extended winter activity during years of abundant mast crops (Johnson 1978:37).

The fecal plugs were densely compressed with bear hair mixed throughout serving as the framework of the plug. The contents may have been the result of grooming in the den and ingestion of debris adhering to damp fur since bears often entered dens during periods of precipitation (Johnson 1978:37). Also some debris may have been ingested during collection of bedding material. A dark green mucous coated the outside of all plugs.

Three other scats of very loose consistency were located in the vicinity of dens. They consisted entirely of a greenish-yellow, jelly-like substance which may have been an internal secretion defecated just prior to plug formation. Craighead (1972:136) reported passage of a "very dark watery stool" by grizzly bears (*Ursus arctos*) and postulated it "to be a scouring of the digestive tract in preparation for hibernation."

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