

BEHAVIORAL RESPONSES OF BLACK BEARS TO GYPSY MOTH INFESTATION IN SHENANDOAH NATIONAL PARK, VIRGINIA

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Abstract: During 1986-89 nearly 27,000 ha of Shenandoah National Park (SNP) were defoliated by the gypsy moth (*Lymantria dispar*), inflicting wide-spread habitat alteration, overstory cover loss, and hard mast failure. Gypsy moth primary hosts were the oaks (*Quercus* spp.), which comprised 55% of the study area. We examined aspects of black bear (*Ursus americanus*) habitat use during years (1987-89) of extensive defoliation and compared the results to predefoliation years (Garner 1986). In all seasons, relative habitat use differed between the time periods. Females used cove hardwood and black locust more, especially in late summer and early fall, because of cherry abundance. Bears did not avoid defoliated habitat in summer during peak defoliation, nor did they increase use of gypsy moth nonhost stands (e.g., yellow poplar [*Liriodendron tulipifera*]). In fall, bears avoided defoliation and preferred chestnut oak (*Quercus prinus*) only in October, corresponding with fall excursions made by 21 of 50 females. Although oak habitats were preferred in fall prior to defoliation for acorn consumption, most bears in this study did not move away from defoliation to areas of abundant hard mast.

Int. Conf. Bear Res. and Manage. 9(1):461-470

Since the accidental introduction of the gypsy moth in 1869 in Medford, Massachusetts, it has become one of the most destructive and economically important forest insects known in the eastern United States. It slowly spread throughout all portions of New England, sections of southern Quebec, south to Delaware and Maryland and west through New York, Pennsylvania, northern Virginia, and northeastern West Virginia, where it has defoliated nearly 25 million hectares of forest since 1924 (U.S. Department of Agriculture 1989). In recent years the gypsy moth is continuing to spread into the predominantly oak-hickory climax forest of the southern Appalachians.

Defoliation is known to cause an immediate loss of overstory cover from early June to late July and can result in permanent forest species composition changes through large scale mortality of host species. Chestnut oak (*Quercus prinus*) is the most preferred host species (Gansner and Herrick 1985), followed by northern red oak (*Q. rubra*), white oak (*Q. alba*), scarlet oak (*Q. coccinea*), and black oak (*Q. velutina*). Detailed lists of host species are given by Crow and Grafton (1984) and Houston and Valentine (1979). In addition, there is an almost complete failure of hard mast crops in defoliated areas (Fedde 1964, Liscinsky 1984, McConnell 1988). Defoliated oaks can be expected to abort acorn production in early summer in the year of defoliation (McConnell 1988) and may not regain predefoliation production for 10 years (Campbell and

Sloan 1977). Thus, extensive defoliation has the potential to significantly alter wildlife habitats and food supplies both in the short and long term.

Nevertheless, the effects of this severe environmental perturbation on wildlife populations and habitats is virtually unknown. With the exception of a few studies concerning songbirds (DeGraaf and Holland 1978, Smith and Lautenschlager 1981, Smith 1985, Cooper et al. 1987, DeGraaf 1987) no one has documented the response of wildlife, especially mammals, to large-scale gypsy moth defoliation.

The influence of gypsy moth infestations on southeastern bear populations may be substantial. Summer overstory cover reduction may induce bears to abandon defoliated areas and seek nondefoliated stands. Loss of acorns, an important and preferred fall bear food in the southeast (Eagle 1979, Beeman and Pelton 1980, Carlock et al. 1983, Garner 1986), will necessitate bear utilization of alternative foods and may result in changes in habitat use and movement patterns. Many studies have shown that bears will shift their ranges to oak forest types during the fall in order to take advantage of areas with abundant hard mast (Beeman 1975, Garshelis and Pelton 1981, Carlock et al. 1983, Garner 1986).

This study was undertaken to determine the response of black bears to gypsy moth infestation in Shenandoah National Park, Virginia. In this paper we discuss aspects of bear habitat use during years of extensive

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defoliation (1987-89) and compare the results with predefoliation years, 1982-85 (Garner 1986). Specifically, we examined 2 hypotheses: (1) bears used defoliated habitat less than its availability, especially in summer and fall because of overstory cover loss and defoliation induced acorn failure, respectively, and (2) bear habitat preferences differed between years with heavy defoliation and years prior to gypsy moth infestation. The effects of defoliation on bear habitat, reproduction and survival, food habits and nutrition, movements and home-range dynamics, denning ecology, and hunter harvest and bear nuisance behavior will be presented elsewhere.

We thank N.P. Garner for use of his data, A. Teetor for GIS help, and our pilot R. Roberts. We also acknowledge B. Greenewalt, R. Hughes, L.A. Kasbohm, and the many SNP employees who provided field assistance. Funding for this study was provided by the National Park Service, the U.S. Fish and Wildlife Service, Virginia Cooperative Fish and Wildlife Unit, the Virginia Department of Game and Inland Fisheries, and the Department of Fisheries and Wildlife Sciences, VPI & SU.

STUDY AREA

The 522 km² study area was the North and Central Districts of Shenandoah National Park, located in the Blue Ridge Mountains of northcentral Virginia, approximately 120 km southwest of Washington, D.C. The park has a narrow, irregular shape, 21 km at its widest point, oriented in a northeast to southwest direction. Bisecting the study area was Skyline Drive, on which were located scenic overlooks, picnic areas, and campgrounds. Throughout the park were numerous foot trails and fire roads. Visitor traffic was often heavy in both the front and back country of the park. Hunting was prohibited in SNP, but was allowed in all surrounding counties.

The park was characterized by mountainous, rocky terrain, varying in elevation from 270 to 1,200 m. The primary vegetation was indicative of an oak-hickory forest and was very susceptible to gypsy moth infestation. The dominant overstory species associations were chestnut oak (41% of the study area); red oak (14%); yellow poplar (*Liriodendron tulipifera*) (20%); black locust (*Robinia pseudoacacia*)/black cherry (*Prunus serotina*) (4%); cove hardwoods (16%) including American basswood (*Tilia americana*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), black birch (*Betula lenta*), yellow poplar, and mixed oaks; pines (3%) such as white pine (*Pinus strobus*),

pitch pine (*P. rigida*), table-mountain pine (*P. pungens*), and Virginia pine (*P. virginiana*); and eastern hemlock (*Tsuga canadensis*) (1%). Understory species common in SNP were flowering dogwood (*Cornus florida*), striped maple (*A. pennsylvanicum*), mountain laurel (*Kalmia latifolia*), spicebush (*Lindera benzoin*), and witch hazel (*Hamamelis virginiana*). Other important species were apple (*Malus pumila*), sweet cherry (*Prunus avium*), blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), huckleberry (*Gaylussacia* spp.), grape (*Vitis* spp.), and greenbrier (*Smilax* spp.).

The gypsy moth was first discovered in SNP in 1984. Each year it continued to spread southward, devastating the extremely susceptible oak-dominated forest. Acreage of defoliation increased dramatically during the course of the study from almost none in 1985, to 546 ha in 1986 (1% of the study area), 2,304 ha in 1987 (4%), 6,227 ha in 1988 (12%), and 17,736 ha in 1989 (34%). Prior to 1989, defoliation was restricted primarily to the North District. In both 1988 and 1989, approximately 28% of the North District was completely stripped of overstory foliage. Chestnut oak and red oak habitat types received the heaviest defoliation; 60% and 45% of these habitat types suffered greater than 60% overstory canopy loss during the study in the North and Central Districts, respectively.

Defoliation occurred in SNP as a patchwork of heavily defoliated (>60% overstory canopy loss) stands mixed with areas with lesser levels of defoliation (<60%), and stands relatively untouched by the moth (Fig. 1). Nondefoliated areas tended to occur in drainages, primarily along stream beds, where nongypsy moth host trees were in greater abundance. Additional areas not defoliated included sections of the park sprayed with insecticides. These were restricted to high visitor-use areas (e.g., campgrounds and picnic areas) and along the Skyline Drive.

The timing of defoliation was consistent between years. Caterpillars hatched from egg masses of 100 to 1,000 eggs in mid-May, corresponding with bud break of most forest hardwoods. By early June defoliation became noticeable and by early July caterpillars began to pupate as nearly all edible foliage had been consumed. In most heavily affected areas of the study area, canopy loss was near 100% for primary host trees (e.g., the oaks). Beginning in mid-July trees with canopy defoliation greater than about 60% refoliated—i.e., produced a new crown of foliage. Refoliated leaves tended to be smaller than those produced in the spring and, hence, the canopy in defoliated areas remained incomplete for the remainder

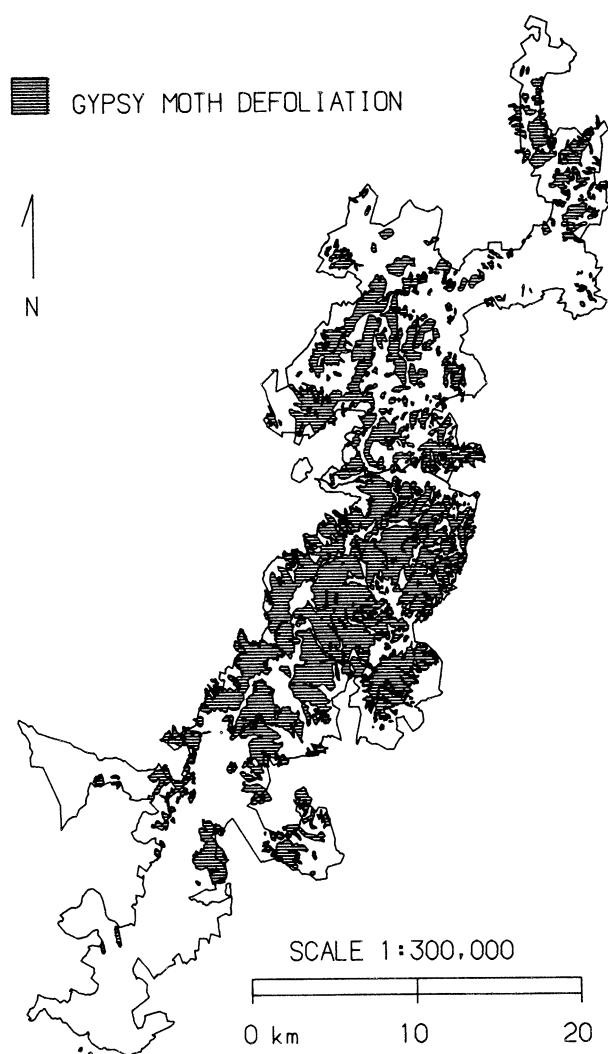


Fig. 1. Gypsy moth defoliation in the North and Central Districts of Shenandoah National Park, Virginia in 1989. Cross-hatched areas received greater than 60% overstory canopy defoliation and represented 17,736 ha.

of the year.

Surrounding SNP to the east and west were the Piedmont and Shenandoah valley, respectively. Privately owned agricultural lands containing corn fields, apple orchards, and small livestock farms dominated nonpark land. Limited bear habitat remains in the Shenandoah valley. However, a mosaic of fragmented, forested "islands" provided additional bear habitat in the Piedmont.

Annual precipitation averages about 130 cm of rain, with an additional 120 cm of snow. Average temperatures range from -3°C in the winter to 19°C in the summer. Higher elevations tend to be $5\text{--}10^{\circ}\text{C}$

cooler than the surrounding lowlands (Heatwole 1978).

METHODS

This study began in December 1985 and continued intermittently until fall 1986. Full-time fieldwork was initiated in July 1987 and ended in early 1990. No field-work was conducted from January-June 1987. Bears were captured from May to late fall each year using Aldrich foot snares and culvert traps. Trapping was conducted in all defoliated sections of SNP. This included the entire North District and the northern half of the Central District. Captured bears were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride (Rompun) at 300 mg/ml with a dose of 1 cc per 45 kg (100 lbs) of estimated body weight. Drug was administered by a jab pole or Capchur pistol. Immobilized bears were weighed, ear tagged with numbered plastic tags color-coded for each sex, and given a lip tattoo identification number. A premolar was extracted for aging using cementum annuli (Willey 1974).

Adult bears and selected subadult females were fitted with 164-165 Mhz radio-transmitter collars (Telonics, Inc., Mesa, Ariz.). Because of the small number of male bears radiocollared in this study only data collected for females were analyzed. Data from all female age classes were examined together. Bears were located from fixed-wing aircraft with directional yagi antennas mounted under each wing and by ground triangulation with hand-held yagi antennas. Triangulations were formed with at least 3 bearings taken within a 20-minute time limit. However, close (<200 m), 2-bearing triangulations were obtained occasionally; long range 2- (>200 m) or 3- (>2 km) bearing locations were considered only general locations. Locations were plotted on USGS 1:24,000 topographic maps and assigned Universal Transverse Mercator System (UTM) coordinates. Annual convex polygon home ranges were estimated using program Telem (Koeln 1980). No long-range locations were used to investigate habitat and defoliation use. All telemetry locations were used in home-range calculations.

The accuracy of telemetry locations was determined by estimating the location of radio collars placed at known sites throughout the study area, from collared bears in their winter dens, and from collar-drop recoveries. Den sites and collar drops were considered the most useful accuracy checks because they represented actual bear locations and, hence, they could not be biased by transmitter placement. All test

locations were representative of the locations and distances encountered during day-to-day radiotracking.

Prior to July 1987 capturing and radiocollaring bears was of primary importance. Hence, obtaining radio-telemetry locations was restricted to aerial locations, supplemented by ground triangulations on an irregular basis. In 1988 attempts began to locate all collared bears every 10 days from the air with at least 2 ground triangulations between aerial locations.

Seasons were based on Garner (1986) and were defined by changes in plant phenology and bear denning chronology: spring (den emergence-15 Jun), summer (16 Jun-31 Aug), early fall (1 Sep-15 Oct), and late fall (16 Oct-den entry or 1 Mar). No winter season was used because most bears were denned by 1 January.

Forest habitat mapping of SNP was performed from 1983 to 1987 by the Resource Management Office of SNP (Teetor 1988). Habitat in SNP was classified into 7 different habitat types based on dominant overstory tree species, identifiable from aerial color infrared (CIR) photography (Teetor 1988). These were chestnut oak, red oak, yellow poplar, black locust, cove hardwoods, pine, and eastern hemlock. Stands greater than 1-2 ha were identified and their perimeters digitized into the park's geographic information system. Accuracy of the resultant map was then tested using a discrete multivariate analysis technique developed by Congalton et al. (1983) and averaged 70% (Teetor 1988).

Annual gypsy moth defoliation maps of SNP classifying habitat into defoliated (>60% overstory canopy defoliation) and nondefoliated (<60%) areas also were created by Resource Management personnel using CIR photographs taken during the peak defoliation period each year (late Jun to early Jul). Perimeter coordinates of defoliated polygons visualized on the photographs were transferred to USGS 1:24,000 topographic maps and then digitized. Both defoliation and habitat maps were created only for areas inside the park boundary. No data were available for areas surrounding SNP.

Habitat and defoliation maps, home-range polygons, and telemetry locations were installed on ARC/INFO, a geographic information system, to create a series of map layers (coverages). Seasonal and monthly habitat use and availability were determined by overlaying telemetry locations and annual home-range polygons, respectively, on habitat and defoliation coverages. Availability of defoliation was calculated on a yearly basis. Habitat availability remained constant throughout the course of the study. Percent use and availability of each habitat or defoliation type were then calculated for

each bear per time period. Only locations and portions of home ranges that fell inside park boundaries were used in the analyses. Pine and hemlock habitat types were combined to form 1 type (pine-hemlock) for analyses. Use minus availability (D) was then calculated for each season or month for all females whose home ranges included defoliated areas. Bears who were located less than 10 times in the season of interest were discarded in that season's calculations. Similarly, 5 or more locations per month were required. Hence, only locations obtained in 1988 and 1989 were used in these calculations. T -tests were used to determine the validity of the null hypothesis that the mean difference between use and availability (\bar{D}) was equal to 0 for a designated time period. Under the null hypothesis, habitat use is proportional to availability. Use was compared to availability of defoliation types calculated for the year of use as well as for 1 and 2 years prior to the year of use to examine lag effects. Seasonal habitat use was examined for all data combined. Defoliation use was examined monthly and seasonally for combined data and for 1988 and 1989 separately.

Results of this study were statistically compared with Chi-square contingency table analyses to predefoliation, seasonal habitat use of black bears in SNP in a study conducted by Garner (1986) from 1982 to 1985. Direct comparison to Garner (1986) necessitated pooling locations from all bears and years (1987-89) by season. To fully allow comparison and also to be complete, in addition to t -tests, differences in habitat use versus availability in defoliated areas also were examined using Chi-square goodness-of-fit tests (Beyers et al. 1984). For Chi-square tests habitat availability was defined as the relative area of each habitat type in the North and Central Districts combined. Because Chi-square tests used data pooled across all bears, individual variability in behavior was not accounted for, making t -test habitat-use comparisons more desirable. Hence, except for comparison to Garner (1986), habitat-use data is discussed in terms of t -test results.

To examine possible differences in defoliation use because of reproductive status, bears were classified into those that had cubs-of-the-year and those without. Presence of cubs was determined by visits to dens and by periodic visual observations of family groups. Each family group was observed at least once in spring and again in fall. Use-availability was compared between groups using 2 sample t -tests.

Bears also were classified into groups based on whether they made fall excursions. Bears were considered to have made fall moves if they left their

traditional spring-summer ranges from September to December for at least 4 weeks. *T*-tests were used to compare \bar{D} between groups.

RESULTS

From 1985 to 1989, 126 bears were captured 158 times. Forty-three females were radio-collared long enough to provide useful data concerning habitat use. Of the 3,193 locations on females, 2,303 were considered accurate enough for habitat-use analyses, with the remainder being only general locations. Aerial and ground triangulation test locations were achieved with accuracies of $146 \text{ m} \pm 23.8 \text{ SE}$ ($n = 30$) and $137 \text{ m} \pm 11.9 \text{ SE}$ ($n = 89$), respectively. In 1987-89, the number of female bears monitored ranged from 24 to 34 per season, with up to 76 locations per individual per year.

Defoliation Use

Use minus availability *t*-tests by season revealed no evidence that female black bears in SNP consistently preferred or avoided habitat defoliated (>60% overstory canopy loss) in the year of use. Although some bears spent considerably more (or less) time in defoliation, in all seasons mean use-availability (\bar{D}) was not significantly different from 0 (Table 1). Analysis of 1988 and 1989 data separately supported overall results, indicating equal use and availability in all seasons.

Monthly examination of combined 1988-89 location data provided evidence that $\bar{D} \neq 0$ during some months (Table 1). Defoliated habitat was used more than available during June. However, June preference for defoliation was not significant for either year when examined separately (1988: $\bar{D} = 18.6 \pm 8.9 \text{ SE}$, $n = 2$, $P = 0.207$; 1989: $\bar{D} = 8.3 \pm 5.1 \text{ SE}$, $n = 16$, $P = 0.127$). In October females avoided areas that had been defoliated the previous June-July. On a yearly basis, October avoidance of defoliation was highly significant in 1988 ($\bar{D} = -14.3 \pm 3.4 \text{ SE}$, $n = 11$, $P = 0.002$), but not significant in 1989 ($\bar{D} = -5.3 \pm 5.0 \text{ SE}$, $n = 24$, $P = 0.297$). In November 1988 females spent more time in defoliation ($\bar{D} = 20.0 \pm 8.6 \text{ SE}$, $n = 7$, $P = 0.063$). Time spent in defoliated or nondefoliated habitat were equal in all other months.

Seasonal and monthly use of habitat defoliated 1 and 2 years prior to the year of use were also examined. *T*-tests indicated proportional use in all months and seasons except August and spring, respectively. Habitat defoliated the previous year was avoided ($\bar{D} = -8.6 \pm 4.6 \text{ SE}$, $n = 11$, $P = 0.089$) in the spring and in

Table 1. Mean defoliation percent use - percent availability (\bar{D}) for female black bears during gypsy moth infestation in Shenandoah National Park, Virginia, 1988-89.

Season/month	\bar{D}	SE	n^a	P^b
Spring	4.6	3.6	19	0.211
Summer	2.3	3.7	35	0.549
Early fall	-3.5	3.8	21	0.374
Late fall	0.7	3.3	35	0.844
May	4.5	3.4	26	0.225
Jun	9.5	4.7	18	0.058
Jul	0.8	5.5	29	0.893
Aug	1.9	5.0	33	0.707
Sep	0.4	3.3	36	0.915
Oct	-8.1	3.6	35	0.031
Nov	-0.6	4.3	30	0.892
Dec	0.1	9.3	14	0.999

^a n = number of bears monitored.

^b Probability that $H_0: \bar{D} = 0$, is true.

August ($\bar{D} = -5.7 \pm 3.0 \text{ SE}$, $n = 26$, $P = 0.065$).

Seasonal Habitat Use

T-tests revealed few significant differences between seasonal use and availability of the 6 habitat types (Table 2). Pine-hemlock was avoided in all seasons except late fall ($P = 0.082$, 0.0004, and 0.052 for spring, summer, and early fall, respectively). Bears spent more time than expected in red oak in summer ($P = 0.047$) and less in black locust in late fall ($P < 0.001$). All other use of habitats by season were not significantly different than availability.

Analysis by month gave similar results (Table 2). Chestnut oak was avoided in July ($P = 0.049$) and August ($P = 0.076$) and preferred in October ($P = 0.028$). Red oak was used greater than its availability in July ($P = 0.036$). In August and October, \bar{D} for cove hardwood was significantly greater ($P = 0.027$) and less ($P = 0.024$) than 0, respectively. Both yellow poplar ($P = 0.008$) and black locust ($P = 0.0005$) were avoided in December. Black locust also was avoided in November ($P = 0.0005$), but was used more in August ($P = 0.105$). Pine-hemlock was used less than expected ($P < 0.006$) except from September-November when it was used in proportion to its availability.

Direct comparisons of location data collected during

Table 2. Mean habitat percent use - percent availability (\bar{D}) for female black bears during gypsy moth infestation in Shenandoah National Park, Virginia, 1988-89.

Season/month	Habitat type																	
	Chestnut oak			Red oak			Cove hardwood			Yellow poplar			Black locust			Pine-hemlock		
	\bar{D}	SE	n^a	\bar{D}	SE	n	\bar{D}	SE	n	\bar{D}	SE	n	\bar{D}	SE	n	\bar{D}	SE	n
Spring	0.1	3.8	19	-1.2	3.2	18	5.2	4.2	19	-1.4	4.5	17	-0.7	1.5	18	-2.1 ^b	1.1	18
Summer	-3.3	2.5	38	3.9 ^c	1.9	38	1.3	1.9	38	-1.0	2.2	35	1.2	1.2	35	-2.2 ^c	0.6	37
Early fall	0.7	3.7	25	2.4	4.2	25	-1.6	2.8	25	-2.9	3.2	25	0.2	1.5	23	-0.8 ^c	0.4	22
Late fall	4.9	3.1	37	0.9	2.5	36	-1.3	2.1	37	-0.3	1.9	34	-4.0 ^c	0.9	35	-0.2	0.8	31
May	4.9	4.2	27	-2.8	3.1	26	4.2	4.0	27	-1.5	2.9	24	-2.4	1.7	26	-2.7 ^c	0.9	23
Jun	0.4	4.4	19	4.5	3.6	19	-1.5	4.0	19	-2.3	4.3	17	1.6	2.5	18	-2.6 ^c	0.5	19
Jul	-7.9 ^c	3.9	31	9.0 ^c	4.1	31	1.3	3.1	31	0.2	3.1	29	0.1	1.3	29	-2.6 ^c	0.8	31
Aug	-6.3 ^b	3.5	33	-2.0	2.1	33	7.2 ^c	3.1	33	-0.4	3.2	31	4.5 ^b	2.7	30	-2.5 ^c	0.7	31
Sep	1.8	3.8	39	3.4	3.6	39	-1.9	2.8	39	-3.4	3.0	37	-0.5	1.3	36	-0.5	0.9	32
Oct	7.9 ^c	3.5	37	-2.8	3.0	37	-5.0 ^c	2.1	37	-1.0	2.1	35	-1.5	1.3	35	0.5	1.3	31
Nov	3.3	4.4	31	-0.3	3.5	31	1.9	3.2	31	-0.6	2.6	28	-4.2 ^c	1.1	29	-0.1	1.2	26
Dec	6.0	6.9	16	9.6	5.6	15	0.7	5.7	16	-7.9 ^c	2.6	16	-6.6 ^c	1.5	15	-1.8 ^c	0.3	12

^a n = number of bears monitored.

^b Use is significantly different than availability ($P < 0.10$), $H_0: \bar{D} = 0$.

^c Use is significantly different than availability ($P < 0.05$), $H_0: \bar{D} = 0$.

this study in years of heavy defoliation and predefoliation years from Garner (1986) demonstrate changes in habitat use between the time periods (Table 3). Relative location frequencies in each habitat between predefoliation and heavy defoliation years were significantly different for spring ($\chi^2 = 35.83$, $df = 5$, $P < 0.001$), summer ($\chi^2 = 70.01$, $df = 5$, $P < 0.001$), and early fall ($\chi^2 = 29.95$, $df = 5$, $P < 0.001$). Late fall comparisons revealed only moderate evidence of a difference in use ($\chi^2 = 9.06$, $df = 5$, $P = 0.107$). Chi-square goodness-of-fit tests on data collected during defoliation (1987-89) indicated overall habitat use was significantly different than availability in all seasons ($P < 0.05$, Table 3). In the years prior to gypsy moth infestation (1982-84), Garner (1986) reported proportional use of all habitat types by females in the spring. During defoliation in spring, bears used cove hardwood more than expected, and yellow poplar and pine-hemlock less. Yellow poplar was used more than its availability in summer before infestation (Garner 1986), but less during defoliation. Bears were located in red oak, cove hardwood, and black locust significantly more in summer in 1987-89. From 1982 to 1984 in early fall, chestnut oak was used

significantly less and red oak was used significantly more (Garner 1986). Garner (1986) also documented a significantly high amount of time spent in chestnut oak in late fall. Oak habitat types were used in proportion to their availabilities throughout the fall during defoliation. Yellow poplar and pine-hemlock were avoided in both early and late fall during defoliation, but only in late fall before gypsy moth infestation (Garner 1986). Black locust and cove hardwood habitat types were used more than expected during defoliation years in early and late fall, respectively.

Fall Movements, Reproductive Status, and Defoliation Use

In 1988 and 1989, 10 of 20 and 11 of 30 females monitored in defoliated areas, respectively, made fall movements from their spring-summer ranges. Moves were initiated from early September to November. All but 3 individuals returned to their spring-summer ranges by mid-December. The remainder of females did not make detectable moves and used spring-summer ranges throughout the fall.

Use of defoliated habitat differed between those

Table 3. Availability and seasonal habitat use by female black bears before^a and during^b gypsy moth infestation in Shenandoah National Park, Virginia.

Habitat type	Availability (%)	Use (%)							
		Spring ^c		Summer ^d		Early fall ^e		Late fall ^f	
		Before	During	Before	During	Before	During	Before	During
Chestnut oak	41	42	38	38	38	24*	42	52*	46
Red oak	14	13	17	15	19*	30*	18	19	15
Cove hardwood	16	13	26*	10	22*	18	19	16	21*
Yellow poplar	20	26	13*	29*	13*	17	11*	9*	13*
Black locust	4	2	5	4	7*	6	8*	2	4
Pine-hemlock	4	4	1*	4	1*	5	2*	1*	2*

* Use is significantly different than availability ($P < 0.05$) by Chi-square analysis (Beyers et al. 1984).

^a Data from Garner (1986), collected 1982-85.

^b Data collected 1987-89.

^c Before and during habitat use overall $\chi^2 = 35.83$, $df = 5$, $P < 0.001$, $n_{\text{Before}} = 215$ locations, $n_{\text{During}} = 375$ locations.

^d Before and during habitat use overall $\chi^2 = 70.01$, $df = 5$, $P < 0.001$, $n_{\text{Before}} = 369$ locations, $n_{\text{During}} = 719$ locations.

^e Before and during habitat use overall $\chi^2 = 29.95$, $df = 5$, $P < 0.001$, $n_{\text{Before}} = 199$ locations, $n_{\text{During}} = 523$ locations.

^f Before and during habitat use overall $\chi^2 = 9.06$, $df = 5$, $P = 0.107$, $n_{\text{Before}} = 201$ locations, $n_{\text{During}} = 686$ locations.

females that made fall movements and those that did not, both on a seasonal and monthly basis (Table 4). In summer, bears that moved used defoliation significantly

Table 4. Mean defoliation percent use - percent availability (\bar{D}) for female black bears that made fall moves and those that did not, in Shenandoah National Park, Virginia, 1988-89.

Season/month	Moved			Did not move			P^b
	\bar{D}	SE	n^a	\bar{D}	SE	n	
Spring	5.7	5.0	7	3.6	5.9	7	0.789
Summer	19.6	4.2	14	-7.0	3.1	17	0.001
Early fall	-16.3	6.4	4	-0.5	4.2	17	0.106
Late fall	-0.8	7.8	12	1.4	3.1	23	0.797
May	0.9	9.1	8	7.5	4.1	12	0.471
Jun	18.5	5.0	8	7.1	4.5	7	0.120
Jul	12.6	6.7	15	-10.8	7.5	10	0.031
Aug	23.6	8.3	13	-11.2	4.5	17	0.001
Sep	7.0	5.6	12	-3.0	4.0	24	0.156
Oct	-16.8	3.7	12	-3.6	5.0	23	0.041
Nov	0.3	8.8	11	-1.1	4.6	19	0.877
Dec	-1.6	16.0	7	1.6	11.0	7	0.870

^a n = number of bears monitored.

^b Significance level of 2-sample t -test comparing \bar{D} of females that moved with those that did not.

more than those females that did not move ($P = 0.001$). This difference held up in both July and August. During the actual period of movement to fall range areas, defoliation use was different for both groups. Bears that moved avoided defoliation to a greater extent in early fall ($P = 0.106$) and October ($P = 0.041$). No significant difference in use could be detected in any other season or month.

Twenty-three litters were born and raised in 1988 and 1989 in which at least 1 cub survived until denning. Little evidence could be found to indicate a difference in use of defoliation by females with cubs-of-the-year and those without. No difference was found in any season. In August, the only month with a significant difference in use ($P = 0.064$), females with cubs used defoliation less than those without cubs. However, \bar{D} was not significantly different than 0 for either group, indicating proportional use of defoliation.

DISCUSSION

Gypsy moth infestation over the course of the study resulted in a reduction in overstory cover available to the SNP bear population. In mid-summer, bears experienced 100% overstory canopy loss in up to 84% of their home range. Such temporary loss is not comparable to any other type of disturbance, either natural or human induced. During peak defoliation periods, i.e., the summer months, defoliated areas became hotter and drier relative to areas not affected

by the gypsy moth, because of increased light penetration and wind circulation (McConnell 1988). Thermometers placed 0.5 m above the ground in adjacent defoliated and nondefoliated stands indicated defoliated sites averaged 4.8°C hotter (Kasbohm 1994). Nevertheless, monitored bears did not respond with dramatic behavioral alterations with respect to habitat use or movement patterns.

During summer, defoliation was not avoided, nor did bears seek stands of yellow poplar or pine-hemlock (nongypsy moth hosts) for cover. In fact, females decreased their use of yellow poplar and pine-hemlock throughout the year relative to predefoliation years. Yellow poplar is one of the most unpalatable tree species to the gypsy moth and is rarely defoliated (Houston and Valentine 1979, Crow and Grafton 1984). Hence, poplar habitat should have provided bears the opportunity for refuge from defoliated oak habitat during peak defoliation. Increased overstory cover opportunities did not entice bears into poplar.

Chi-square analyses indicated cove hardwood and black locust were used more than that shown by Garner (1986). *T*-tests revealed August use of these habitats was greater than availability. Summer and early fall use of black locust and cove hardwood may have been related to abundance of cherry (*Prunus* spp.) trees in these stands. In SNP cherry is found in association with black locust, and to a lesser extent, cove hardwood (Teetor 1988). In 1988 and 1989 both sweet cherry and black cherry produced excellent crops throughout the study area and were used as food in late spring to early fall. Gypsy moth infestation, and thus, increased sunlight penetration to the understory likely enhanced cherry (and other soft mast) production (Twery 1991). Congruously, bears preferred defoliated habitat in June, as sweet cherries were ripening, and used black locust and cove hardwoods less in fall months after the cherry crop had diminished. Bennett et al. (1943), Eagle (1979), Beeman and Pelton (1980), and Garner (1986) all noted heavy use of black cherry in late summer and early fall by bears in the Appalachians. Garshelis and Pelton (1981) found cherry trees in greater abundance in areas used by bears in these seasons.

Summer oak habitat use was unexpected. Red oak habitat was used more than available in summer, specifically in July. Conversely, chestnut oak was avoided in both July and August. Garner (1986) showed proportional use of these habitats in summer. Because both of these forest types were extensively defoliated, no explanation for this behavior was apparent. Perhaps understory components in red oak stands provided a more suitable environment for bears

in terms of cover availability and food abundance. Refoliation of these habitats was complete in mid-July and may have influenced bear behavior.

Avoidance in spring of habitat defoliated in previous years was likely related to alterations in woody and herbaceous vegetation. Stands with prior infestation histories, especially those experiencing significant overstory mortality, generally exhibited increased densities of understory woody vegetation (Kasbohm 1994). Pioneer species such as blackberry (*Rubus* spp.) can dramatically expand in density with the local area becoming nearly impenetrable (Ehrenfeld 1980). In the spring, bears in SNP fed primarily on herbaceous forbs including jack-in-the-pulpit (*Arisaema* spp.) and sweet cicely (*Osmorhiza* spp.) (Garner 1986, this study). These food plants may have been reduced in density in previously defoliated stands because of increased competition with woody vegetation responding to canopy opening. Hence, bears may have been required to forage in other areas to secure an adequate spring diet.

Like many bear studies, Garner (1986) found bears used oak habitat types in greater proportion than their availabilities in the fall, presumably to take advantage of abundant hard mast, specifically acorns. Seasonal Chi-square and *t*-test results during defoliation, however, indicated no preference for oak in either early or late fall. Similarly, defoliated habitat was used in proportion to availability in these seasons. This was not surprising because oaks in defoliated areas of SNP, in all years of the study, produced essentially no acorns. Acorns that were produced were available only in nondefoliated areas on the fringes of the study area. These areas were not used by most collared bears. McConnell (1988) demonstrated that heavily defoliated oak stands in Maryland and Virginia in 1985 produced only 2.44 kg/ha of acorns versus 464.96 kg/ha in nondefoliated stands.

Closer examination of habitat and defoliation use on a monthly basis, however, indicated avoidance of defoliation in October. This short time period of defoliation avoidance corresponded with a disproportionately high use of chestnut oak. In addition, those bears that made fall excursions were usually away from their spring-summer ranges during this month. Monitored females had larger fall ranges and made significantly longer distance summer-to-early fall moves during defoliation (1987-89) than prior to defoliation (1982-84) (Kasbohm 1994). Individuals that moved also avoided defoliation in early fall and October to a greater extent than those that did not move, indicating that a lack of acorns may have stimulated

bears to initiate fall moves in search of food resources in other areas. Garner (1986) found that bears made fall excursions to areas of hard mast abundance. However, of the 21 fall moves exhibited by monitored bears (20 in 1988 and 30 in 1989) only 8 were to areas of known acorn abundance. Five of these were made in 1988 to a small area in the southwest portion of the North District that escaped defoliation in that year. Although fall moves were generally away from defoliated areas, they were not necessarily associated with increased oak use or increased acorn consumption. Carr (1983) reported that bears in Great Smoky Mountains National Park (GSMNP) preferred oak habitat in fall regardless of acorn availability. No difference in use of oak habitat types by bears that moved and those that did not could be demonstrated.

The majority of radio-collared bears in heavily defoliated areas in this study did not make significant fall excursions and, thus, these females had virtually no oak mast available as a fall food source. Logically, alternative foods substituted during this period and their distribution and abundance influenced bear habitat use. Bears in GSMNP (Eiler 1981) and North Carolina (Warburton 1984) fed on grapes in the fall during mast failures. Scats collected in our study area also revealed a heavy dependence on soft mast to offset the impacts of gypsy moth induced acorn loss. Bears apparently used most habitats in proportion to their availability throughout the fall in search of soft mast such as grape, spicebush, and pokeweed (*Phytolacca americana*). Unfortunately, the relative occurrence of these species in the various habitats of SNP is not known.

LITERATURE CITED

- BEEAMAN, 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. 218pp.
- _____, AND M.R. PELTON. 1980. Seasonal food habits and feeding ecology of black bears in the Smoky Mountains. Int. Conf. Bear Res. and Manage. 4:141-147.
- BENNETT, L.J., P.F. ENGLISH, AND R.L. WATTS. 1943. The food habits of the black bear in Pennsylvania. J. Mammal. 24:25-31.
- BEYERS, C.R., R.K. STEINHORST, AND P.R. KRAUSMAN. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.
- CAMPBELL, R.W., AND R.J. SLOAN. 1977. Forest stand responses to defoliation by the gypsy moth. For. Sci. Monogr. 19:1-34.
- CARLOCK, D.M., R.H. CONLEY, J.H. COLLINS, P.E. HALE, K.G. JOHNSON, AND M.R. PELTON. 1983. The tri-state black bear study. Tech. Rep. 83-9. Univ. Tennessee, Knoxville. 286pp.
- CARR, P.C. 1983. Habitat utilization and seasonal movements of black bears in the Great Smoky Mountains National Park. M.S. Thesis, Univ. Tennessee, Knoxville. 95pp.
- COOPER, R.J., K.M. DODGE, P.J. MARINAT, P.M. SMITH, AND R.C. WHITMORE. 1987. Impacts of the gypsy moth on nongame bird populations. Pages 48-58 in Proc. Coping with the gypsy moth in the new frontier. West Virginia Univ., Morgantown.
- CONGALTON, R., R. ODERWALD, AND R. MEAD. 1983. Assessing Landsat classification accuracy using discrete multivariate analysis statistical techniques. Photogrammetric Eng. and Remote Sensing. 49:1671-1678.
- CROW, J., AND W.N. GRAFTON. 1984. The gypsy moth: landscape trees and shrubs for gypsy moth areas. Coop. Extension Serv., West Virginia Univ., Morgantown. 4pp.
- DEGRAAF, R.M. 1987. Breeding birds and gypsy moth defoliation: short-term responses of species and guilds. Wildl. Soc. Bull. 15:217-221.
- _____, AND D.G. HOLLAND. 1978. Response of breeding birds to gypsy moth defoliation of an upland oak habitat. Trans. N.E. Fish Wildl. Conf. 35:105-119.
- EAGLE, T.C. 1979. Foods of black bears in the Great Smoky Mountains National Park. M. S. Thesis, Univ. Tennessee, Knoxville. 104pp.
- EHRENFELD, J.G. 1980. Understory response to canopy gaps of varying size in a mature oak forest. Bull. Torrey Bot. Club. 107:29-41.
- EILER, J.H. 1981. Reproductive biology of black bears in the Smoky Mountains of Tennessee. M.S. Thesis, Univ. Tennessee, Knoxville. 128pp.
- FEDDE, G.E. 1964. Elm Spanworm, a pest of hardwood forests in the Southern Appalachians. J. For. 62:102-107.
- GANSNER, D.A., AND O.W. HERRICK. 1985. Host preferences of gypsy moth on a new frontier of infestation. U.S. Dep. of Agric. For. Serv. Res. Note NE-330. 3pp.
- GARNER, N.P. 1986. Seasonal movements, habitat selection, and food habits of black bears (*Ursus americanus*) in Shenandoah National Park, Virginia. M.S. Thesis, Virginia Polytech. Inst. and State Univ., Blacksburg. 104pp.
- GARSHELIS, D.L., AND M.R. PELTON. 1981. Movements of black bears in the Great Smoky Mountains National Park. J. Wildl. Manage. 45:912-925.
- HEATWOLE, H. 1978. Guide to Skyline Drive. Good printers, Harrisonburg, Va. 226pp.
- HOUSTON, D.R., AND H.T. VALENTINE. 1979. Classifying forest susceptibility to gypsy moth defoliation. U.S. Dep.

- of Agric. Handb. No. 542.
- KASBOHM, J.W. 1994. Response of black bears to gypsy moth infestation in Shenandoah National Park, Virginia. Ph.D. Diss., Virginia Polytechnic Institute and State University, Blacksburg. 219pp.
- KOELN, G.T. 1980. A computer technique for analyzing radio-telemetry data. *Proc. Natl. Wild Turkey Symposium* 4:262-271.
- LISCINSKY, S. 1984. Tree seed production. *Pa. Game News*. 5:23-25.
- MCCONNELL, S.P. 1988. Effects of gypsy moth defoliation on acorn production and viability, litterfall, and litter layer depth and biomass in Northcentral Virginia and western Maryland. M.S. Thesis, Virginia Polytech. Inst. and State Univ., Blacksburg. 124pp.
- SMITH, H.R. 1985. Wildlife and the gypsy moth. *Wildl. Soc. Bull.* 13:166-174.
- SMITH, H.R., AND R.A. LAUTENSCHLAGER. 1981. Gypsy moth predators. Pages 96-124 *in* *The gypsy moth: research towards integrated pest management*. U.S. Dep. of Agric. Tech. Bull. 1594.
- TEETOR, A. 1988. Identification and mapping of vegetation communities in Shenandoah National Park, Virginia. U.S. Natl. Park Serv. Res. Resour. Manage. Rep. Mar-34. 62pp.
- TWERY, M.J. 1991. Effects of defoliation by gypsy moth. Pages 27-39 *in* K.W. Gottschalk, M.J. Twery, and S.I. Smith, eds. *Proc. U.S. Dep. of Agric. Interagency gypsy moth res. review 1990*. Gen. Tech. Rep. NE-146.
- U.S. DEPARTMENT OF AGRICULTURE. 1989. Final environmental impact statement for Appalachian integrated pest management (AIPM) gypsy moth demonstration project. U.S. Dep. of Agric. For. Serv., Southern Region.
- WARBURTON, G.S. 1984. An analysis of a black bear sanctuary in western North Carolina. M.S. Thesis, N.C. State Univ., Raleigh. 121pp.
- WILLEY, C.H. 1974. Aging black bears from first premolar tooth sections. *J. Wildl. Manage.* 38:97-100.