Population Characteristics and Female Denning of Black Bears in a Managed South Carolina Forest

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Abstract: We captured 54 black bears (*Ursus americanus*) 91 times and equipped adult females with radio-transmitters in a managed forest in the mountains of South Carolina during the summers of 1991–1993 to determine population dynamics and female denning ecology. Ages of captured bears ranged from 1 to 10 years, averaging 3.3 ± 0.3 (± 1 SE) for males and 3.7 ± 0.3 years for females. Litter size ($N = 7, \bar{x} = 2.3$), lactation rate (42.3 %), suspecting mean age at primiparity (4 years), and interbirth interval (2.2 years) were representative of a productive population and good-quality habitat. Eight female dens were visited and consisted of 3 ground nests, 2 root systems, 1 tree den, 1 brush pile, and 1 hollow log. Most dens ($N = 5$) were associated with early successional communities. Estimated population density for the 192-km^2 study area was 0.31–0.34 bears/km^2.

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Black bears are the most common and widely distributed of the 3 ursids found in North America; however, their status and density vary tremendously within this existing range. Although black bears were once abundant throughout South Carolina (Logan 1859), the state now supports only 2 small populations: 1 in the mountains and 1 in the coastal plain.

Black bears have been studied intensively in the southern Appalachian Mountains (Collins 1973, Pelton et al. 1980, Lentz et al. 1983, Carney 1985, Eiler et al. 1989); however, South Carolina's population has been overlooked in the past. In South Carolina, bears inhabit lower elevations than other bears in the southern Appalachian Mountains and subsequently experience milder climates. Also, the population

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is relatively small (Fendley et al. 1989) and possibly isolated from other populations. In addition, the study area differed from many other southeastern bear study areas in that it was privately owned and managed intensely for timber. The result was a fragmented oak-hickory and mixed-mesophytic hardwood forest interspersed with many clearcuts and selection cuts. The effects of such forest management on black bear reproduction and denning in the southern Appalachian Mountains is not well documented.

The black bear is the largest mammal remaining in South Carolina and has important economic, aesthetic, recreational, social, and scientific value. Of great importance is the future contribution that South Carolina bears could make toward assuring the genetic viability of the southeastern black bear metapopulation. This study provides needed information about South Carolina's black bear population, and fills a major information gap for the southern Appalachian black bear population as a whole. The primary objectives of the study were to determine population dynamics of black bears and to describe denning ecology of female black bears in the mountains of South Carolina.

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Methods

This study was conducted in the northwest corner of South Carolina within the southern Appalachian Mountains. The Horsepasture study area encompassed 120 km^2 in Pickens County, and was generally bordered to the north by the North Carolina/South Carolina state line, to the east by Highway 178, to the south by Highway 11, and to the west by Lake Jocassee. This area was dominated by holdings of Crescent Resources, Inc. (a subsidiary of Duke Power Co.), was closed to public vehicular access except during the legal hunting season (10 Sep–1 May), and was included in the SCDNR's Wildlife Management Area System.

The study area was along the southern aspect of the Appalachian Mountains and was part of the Blue Ridge Mountain Physiographic Region of the Blue Ridge Prov-

ince (Myers et al. 1986). This region consisted of steep, mountainous topography divided by branching streams forming narrow floodplains and valleys. Slopes ranged from 10% to 80% (Myers et al. 1986), and elevations ranged from 305 to 945 m (Soil Conserv. Serv. 1972). Mean annual temperature for the region is 12.5 C. Annual rainfall averages 205 cm, with March and June being the wettest months (Natl. Oceanic and Atmos. Admin. 1982).

Dry ridges and upper south slopes were dominated by Virginia (*Pinus virginiana*) and shortleaf pines (*P. echinata*) and chestnut (*Quercus prinus*) and scarlet (*Q. coccinea*) oaks. Moist, cool, north slopes and coves typically had mixed mesophytic hardwoods, white pine (*P. strobus*), and eastern hemlock (*Tsuga canadensis*) overstories often with thick understories of rhododendron (*Rhododendron maximum*) and mountain laurel (*Kalmia latifolia*). Oak-pine mixed forest dominated the intermediate moist slopes (Myers et al. 1986). Other common understory species found throughout the study area included dogwood (*Cornus* spp.), blueberry (*Vaccinium* spp.), and huckleberry (*Gaylussacia* spp.).

The forest within the study area was managed by Crescent Resources, Inc., which used clearcutting as its primary means of forest regeneration. This network of clearcuts provided excellent summer habitat for black bears in the form of cover and soft mast food sources. Some of the most important components for bears found in these early successional areas included blackberry (*Rubus* spp.), pokeberry (*Phytolacca americana*), black cherry (*Prunus serotina*), and wild grapes (*Vitis* spp.) (SCDNR, unpubl. data).

Black bears were captured with Aldrich (Clallam Bay, Wash.) and Fremont (Candle Lake, Saskatchewan. Can.) foot-snares using trapping techniques described by Johnson and Pelton (1980*a*). Captured black bears were immobilized with a 2:1 mixture of ketamine hydrochloride (100 mg/cc) (Aveco Co., Inc., Fort Dodge, Iowa) and xylazine hydrochloride (100 mg/cc) (Haver Lockhart, Inc., Shawnee, Kan.) administered via a 2.4-m jab stick or occasionally with a dart pistol.

We recorded sex of the bear and checked females for reproductive status and teat length. Each bear was equipped with a metal, numbered ear tag and a corresponding tattoo on the upper lip and inner thigh. The first upper or lower premolar was extracted for age estimation via cementum annuli analysis (Willey 1974). Selected adult female bears were fitted with radio-collars (Wild. Materials, Carbondale, Ill.).

An unbiased Lincoln-Petersen estimator used for small sample size, $N_1 = [(n_1 + 1)(n_2 + 1)/(m_2 + 1)] - 1$, was used to estimate population size at onset of trapping in 1991 and 1992 (Pollock et al. 1990). The Lincoln-Petersen estimate is used with closed populations and has the following assumptions: no births, deaths, immigration, or emigration; equal probability of capture between marked and unmarked individuals; and identification marks are not lost. Assumptions of no emigration and no deaths can be relaxed by assuming that the probability is equal for both marked and unmarked individuals. Bears known to have died between the 2 sampling periods were included in the analysis, because their removal would violate this assumption. The model then gives an estimate at the time of the first sampling. To remove the effect of births, yearlings captured during the second sampling period were excluded from the analy-

sis. Immigration was assumed to be negligible. The assumption of equal catchability was lessened by diligent trapping efforts throughout the entire study area each year.

Density estimates are often based on arbitrary and politically defined boundaries. To determine biologically sound boundaries for the study area and to strengthen the assumption of closure, a boundary strip of 3.75 km, which is equal to one-half the diameter of the average home range of adult male bears (Butfiloski 1996), was added to the trapping grid as suggested by Dice (1938, 1941), further described by Caughley (1977:140) and Otis et al. (1978), and used in a similar study by Clark (1991). The resulting area was 192 km^2. All locations (N = 741) of radio-collared females (N = 12) were located within the 192-km^2 study area (Butfiloski 1996), further supporting closure within the population. In addition, since 1991, 6 ear-tagged male bears had been harvested. Five of the 6 were harvested within the 192-km^2 study area. The other bear was harvested near Cashiers, North Carolina, which is located approximately 25 km from the Horsepasture study area.

Based on teat length and lactation, female bears were classified as either having nursed a litter in the past (nipples > 10 mm), as currently nursing a litter (lactating), or as having never nursed a litter (nipples < 10 mm). This nipple length criteria was used by Doan-Crider and Hellgren (1996) to determine nulliparity and previous parity in black bears in Mexico. Estimates on minimum reproductive age were made using this information and observation of radio-collared females in dens. Minimum litter sizes were estimated from observation of offspring at capture and den sites of radio-collared females. Den sites of female radio-collared bears were located in February and March 1992 and 1993 to determine reproductive status. Females were classified as having no offspring, having cubs, or having yearlings.

As the denning period approached, female bears equipped with radio-transmitters were located periodically to determine the date of den entry. Den entry dates were defined as the midpoint between the date of the last recorded movement and the first of a series of stationary signals (Hellgren and Vaughan 1989*a*). As the period of den emergence approached, bears were again located periodically to determine activity status. Den emergence dates were determined as the midpoint between the date of the last recording of a stationary signal and the date of the first location away from the den site (Hellgren and Vaughan 1989*a*).

Data analysis was performed using the Statistical Analysis System (SAS Inst. 1987). Kruskal-Wallis and Kolmogorov-Smirnov tests were used to test for differences between sexes in median age scores and age distribution shape, respectively. Chi-square was used to determine whether sex ratios of captured bears differed from 1:1. We assumed a Type 1 error rate of 5% to infer statistical significance.

Results

Population Size and Density

We captured 54 different bears 91 times in 4,235 trapnights during the summers of 1991–1993, yielding an average of 1 bear capture/46.5 trapnights. Lincoln-Petersen

estimates of the Horsepasture bear population size were estimated to be 59 ± 9 (0.31/km^2) and 66 ± 12 (0.34/km^2) bears for 1991 and 1992, respectively (Table 1).

Age Structure and Sex Ratios

Ages of captured bears ranged from 1 to 10 years ($N = 53$, $\bar{x} = 3.5 \pm 0.2$). Mean ages for males and females were 3.3 ± 0.3 and 3.7 ± 0.3 years, respectively. No difference was detected in median age scores ($\chi^2 = 2.32$, 1 df, $P = 0.13$) or age class distribution between sexes (KSa = 0.69, $P = 0.72$). Seventy-two percent of captured bears were classified as adults (≥3 years).

The sex ratio of initial captures (31M:23F) did not differ from 1:1 ($\chi^2 = 1.19$, 1 df, $P = 0.28$). The sex ratio of adult bears (≥3 yr) was even (19M:19F); however, the sex ratio of subadults (<3 years) (12M:4F) revealed that males outnumbered females significantly ($\chi^2 = 4.00$, 1 df, $P = 0.046$) in the sample.

Reproduction

Three of 8 3-year-old females and 2 of 5 4-year-old females were lactating during the 3 summers of capture. Teat examinations and observations of offspring at capture sites and den sites indicated that all females ≥5 years of age had produced cubs. Only 1 of 5 reproductively active females monitored for ≥2 years was known to have skipped a year in the typical 2-year reproductive cycle of black bears.

Offspring were observed with females on 7 occasions, either at winter den sites or at summer trap sites. Four observations involved females with cubs, with a mean litter size of 2.5. The other 3 occurrences involved females with yearlings, with a mean number of young of 2.0.

Denning

In 1991, due to problems incurred with telemetry, exact dates of den entry were not determined; however, 2 female bears initiated denning sometime before 19 December, and a third female denned sometime before 13 December. In 1992, den chronology data were determined for 5 radio-collared females. These bears entered dens from 6 to 10 December ($\bar{x}$ = 8 December) and emerged from 3 to 13 April

Table 1. Lincoln-Peterson (Pollock et al. 1990) population estimates and statistics for black bears in the Horsepasture Study Area, Pickens County, South Carolina, 1991 and 1992.

Year	n_1[a]	n_2[b]	m_2[c]	N_1[d]	SE	95% Confidence interval
1991	24	28	11	59	9	41–77
1992[e]	28	22	9	66	12	42–90

[a]n_1 = total number captured on first trapping occasion.

[b]n_2 = total number captured on second trapping occasion.

[c]m_2 = total number of marked animals captured on second trapping occasion.

[d]N_1 = estimated population size at onset of first trapping occasion.

[e]Bears captured and marked in 1991 and recaptured in 1993 but not in 1992 were considered unmarked in 1992 estimates.

($\bar{x}$ = 7 April). Length of the denning period ranged from 114 days to 128 days ($\bar{x}$ = 120 days).

We found 8 dens during this study. These consisted of 3 ground nests, 2 root systems, 1 brush pile, 1 tree den, and 1 hollow log. Five of 8 dens occurred in early successional communities associated with recent clearcut and selection cuts.

Discussion

Population Size and Density

Despite the associated problems with existing techniques for estimating population sizes and densities (Hellgren and Vaughan 1989*b*), we feel that assumptions were adequately met and are confident of the estimates provided by the Lincoln-Petersen estimator. The resulting densities were similar to other studies reported across North America, especially those in the southeast (Table 2). Given our estimates, the present harvest levels within the Horsepasture study area (4%) were below the maximum sustainable yield for black bears (Miller 1990). Due to the relatively low numbers of bears within this population, we caution against extension of the present 2-week season because of the potential for over-exploitation.

Age Structure and Sex Ratio

The age structure of bears in the mountains of South Carolina was indicative of a slightly exploited population (Hellgren and Vaughan 1989*b*, McLean 1991). Beecham (1980) compared 2 black bear populations (Council and Lowell) in Idaho subjected to different degrees of hunting pressure. Adults constituted only 53% of the bear population in the Council study area (high accessibility and heavy hunting pressure); whereas, in the Lowell study area (poor accessibility and light hunting pressure), adults made up 71% of the population. Beecham (1980) concluded that the high proportion of nonbreeding bears and the low incidence of adult males supported the theory that the Council population was heavily exploited. The resulting age structure for our study was not surprising given the low average annual harvest of 2.6

Table 2. Estimates of black bear densities in North America (adapted from Clark 1991).

Location	Density estimate (bears/km^2)	Reference
Arkansas	0.08–0.09	Clark 1991
Massachusetts	0.13	Elowe 1987
Minnesota	0.19	Garshelis 1988
North Carolina	0.16–0.23	Warburton 1984
Arkansas (Delta)	0.18–0.42	Smith 1985
Tennessee	0.27	Eagar 1977
South Carolina	0.31–0.34	This Study
Montana	0.23–0.48	Jonkel and Cowan 1971
Great Smoky Mts. NP	0.37	Marcum 1974
Great Dismal Swamp NWR	0.53–0.67	Hellgren and Vaughan 1989
Shenandoah NP	0.71–1.04	Carney 1985

bears (1981–1994) within the study area, a low occurrence of bear/vehicle collisions (1–2/year in Pickens County), and a suspected low occurrence of poaching within the poorly accessible study area and adjacent properties (S. Stokes, SCDNR, pers. commun.). Major causes of mortality in most black bear populations are hunting, poaching, and vehicle/bear collisions (Carney 1985, Hellgren and Vaughan 1989*b*, Clark 1991).

Sex ratios of black bear cubs usually do not differ from 1:1 (Jonkel and Cowan 1971, Hellgren and Vaughan 1989*b*); however, many black bear studies have reported sex ratios that are skewed toward males, especially in the subadult age classes (Jonkel and Cowan 1971, McLean 1991). Similar results were reported for subadult bears in this study (12M:4F). Male black bears typically have larger home ranges (Warburton and Powell 1985, Hellgren and Vaughan 1990) and disperse farther than females (Jonkel and Cowan 1971). Greater movements and inexperience of subadult males increases their chance of encountering a trap and probably explains some of the difference observed in the sex ratio of subadults.

Reproduction

Reproductive parameters reported for females in the mountains of South Carolina was indicative of a productive population and was similar to parameters reported for other southeastern black bear populations (Eiler et al. 1989, Hellgren and Vaughan 1989*b*, Clark 1991, Kasbohm et al. 1996). The 37.5% of 2-year-olds breeding was high compared to other studies (Collins 1973, Elowe and Dodge 1989, Hellgren and Vaughan 1989*b*) with the exception of Pennsylvania (38%) (Kordek and Lindzey 1980) and the Interior Highlands of Arkansas (66%) (Clark 1991). Breeding of female black bears at 2 years of age is considered to be reflective of a high plane of nutrition (Rogers 1976, Kasbohm et al. 1996).

The Horsepasture study area is managed by Crescent Resources for a wide array of natural resources, including timber. Clearcutting and selection cutting were used extensively within the study area (L. Bloomer, Crescent Resour., Inc., pers. commun.). The resulting openings provided a tremendous amount of soft mast, which bears used heavily during summer months (Butfiloski 1996). The correlation of hard mast production in the fall to black bear reproduction is well documented in the literature (Jonkel and Cowan 1971, Rogers 1976, Elowe and Dodge 1989, Eiler et al. 1989); however, abundant and diverse soft mast may help to reduce the negative impacts of hard mast failures on black bear reproduction (Kasbohm et al. 1995, 1996). Despite the almost complete hard mast failure of 1992 (R. D. Willey, unpubl. data), 2 of 3 monitored females that should have produced cubs not only did so, but produced 3 cubs each. The other female represented the only skip in the normal 2-year reproductive cycle for black bears during the study.

Denning

Den entry, den emergence, and length of denning for female black bears in the mountains of South Carolina were similar to other southeastern black bear populations (Hamilton and Marchinton 1980, Johnson and Pelton 1980*b*, Hellgren and Vaughan

1989*a*). According to early explorers, tree dens were once common in upstate South Carolina (Logan 1859:43). However, only 1 tree den was recorded during our study. Even though the availability of den trees within our study area was not quantified, they appeared to be lacking due to past and present forest management practices. Use of tree dens also has been reported in the mountainous regions of Montana (Jonkel and Cowan 1971), Tennessee (Pelton et al. 1980), Georgia (Lentz et al. 1983), and Virginia (Carney 1985), the bottomland hardwoods of Arkansas (Smith 1985), and the coastal plain of North Carolina and Virginia (Hamilton and Marchinton 1980, Hellgren and Vaughan 1989*a*). Pelton et al. (1980) and Smith (1985) stressed that tree dens add to the survival value of bears, especially females with cubs, due to added protection from precipitation, cold temperatures, and human activities. However, other studies reported conflicting results, concluding that tree dens were not crucial for successful denning and reproduction of black bears and that dense cover, microelevational relief, and inaccessibility to humans allow bears to successfully use ground dens (Hamilton and Marchinton 1980, Hellgren and Vaughan 1989*a*). In our study, pregnant females took advantage of the numerous brush piles and blow-downs left after logging operations to den and raise offspring.

Our study suggests that black bears can thrive in a managed, fragmented forest. The managed forest, interspersed with clearcuts, selection cuts, and adequate stands of mature hardwoods, provided a more diverse and reliable food supply than an old growth forest, especially during years of hard mast failure. In addition, this patchwork of clearcuts and associated debris provided escape cover for all bears and protective cover for denning bears, including females with cubs. We found no detrimental effect of timber management as practiced on the Horsepasture study area on black bear reproduction or denning. Black bear management should consider nutritional and cover requirements for all seasons. The greater the diversity of resources afforded to the opportunistic and adaptive female black bear, the greater the probability of successful recruitment of her offspring.

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