POPULATION RESPONSES OF BLACK BEARS FOLLOWING OAK MORTALITY INDUCED BY GYPSY MOTHS

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Abstract: During 1990–93, we measured demographic responses of black bears (*Ursus americanus*) in Shenandoah National Park, Virginia, to oak (*Quercus* spp.) mortality induced by infestations of gypsy moths (*Lymantria dispar*). We hypothesized that a reduction in the park's oak component and the subsequent acorn crop would negatively affect bear reproduction and survival. We compared the results to data collected in SNP from 1982 to 1985, before the gypsy moth infestation. Survival of all bears fitted with radiotransmitters (n = 36) was 100%, indicating that at least the female survival rate did not decline from a high pre-infestation survival rate of 95%. Minimum annual mortality (n = 61), based on eartag returns, was 4% (SE = 0.007). Mean litter size (n = 12) was 2.25 cubs (SE = 0.31) and did not differ (P = 0.49) from a pre-infestation mean of 2.0 cubs (n = 21 litters, SE = 0.17).

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Key words: black bears, gypsy moths, *Lymantria dispar*, oak mortality, populations, radio-telemetry, Shenandoah National Park, *Ursus americanus*.

In 1984 the gypsy moth, a European native, reached Shenandoah National Park (SNP) in northern Virginia after arriving in North America through Massachusetts in 1869 (Evans 1985, Kasbohm et al. 1996). The area of canopy defoliation in SNP due to foraging gypsy moth larvae was insignificant in 1985 but quickly increased to 546 ha in 1986, 2,304 ha in 1987, 6,277 ha in 1988, and 17,736 ha in 1989 (Kasbohm et al. 1996). Although at epidemic levels gypsy moth larvae defoliate much of the canopy of eastern hardwood forests, oaks are one of the preferred host species of the caterpillars (Gansner et al. 1987, Twery 1990), and oak mortality can occur after only 1 defoliation (Campbell and Sloan 1977).

Gypsy moth larvae emerge from their egg masses in late April and early May, climb into the canopy, and begin feeding. The larvae discontinue feeding in late June and enter the pupal stage. At this time severely defoliated trees draw energy reserves from the root system and attempt to grow a second leaf crop leaving little energy for acorn production (Campbell and Sloan 1977, Parker 1981, McConnell 1988). After 2 weeks as pupae, the adult moths emerge and mate. The adult moths then die, and the eggs overwinter to hatch the following year (Fosbroke and Reardon 1990). Gypsy moth defoliation does not kill a tree directly. Rather, it stresses the tree, thus making it more susceptible to invasion by secondary organisms such as the two-lined chestnut borer (*Agrilus bilineatus*) or shoestring root rot (*Armallaria mellea*), which may ultimately kill it.

Defoliation and oak mortality are of special concern for managers of wildlife species that use oak forests or include acorn mast in their fall diets. The high fat and carbohydrate content of acorns (Landers et al. 1979) provides energy necessary for winter survival. Defoliation and subsequent oak mortality reduce the oak composition of existing stands as well as future stands if oaks do not regenerate (Campbell and Sloan 1977, Allen and Bowersox 1989, Hix et al. 1991, Tigner 1992). Therefore, changes in forest composition may reduce the value of these stands to wildlife species such as black bears, which include acorns in their diets. Despite the gypsy moth's long residence in North America and its ability to alter forest environments, relatively little research has been conducted to determine how gypsy moth-induced oak mortality may affect wildlife species.

From 1982 to 1985, 2 studies were conducted in SNP on the population dynamics, food habits, home ranges, and habitat selection of black bears (Carney 1985, Garner 1986). These studies predated the first significant defoliation and subsequent oak mortality induced by the gypsy moth and provided a baseline black bear response to this ecological disruption that could be studied. Kasbohm et al. (1996) investigated the immediate effects of the initial defoliation (1986–89) on reproduction and survival of SNP's black bears. We focus on black bear population dynamics from 1990–93 in response to the oak mortality created by the gypsy moth following the initial period of defoliation.

Prior to the arrival of the gypsy moth, oaks comprised >50% of SNP's canopy. During 1985–90, 60% of the study area (>23,000 ha) was defoliated (>60% canopy loss) 1–3 times (Kasbohm et al. 1996). Subsequent oak

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mortality patterns varied depending on the number of times a stand was defoliated and drought conditions during a defoliation event. Oak mortality was estimated as 1% on 11,300 ha, 11% on 4,800 ha, 14% on 5,800 ha, and ≥48% on 1,100 ha (Schrage 1994). A minimum of 10% of the oaks across the study area were estimated to have died following the initial gypsy moth outbreak.

Carney (1985) estimated SNP's black bear population density as among the highest recorded in North America at 1 bear/0.96 km^2–1.49 km^2. Reproductive rates were high; females bred for the first time at the comparatively young age of 3.5 years and averaged 2 cubs every other year. Garner (1986) reported that acorns comprised 19–66% of the fall diet of SNP's black bears. Because of their nutritional value and abundance in good years (Landers et al. 1979, Beeman and Pelton 1980, Eagle and Pelton 1983), acorns likely contributed a great deal to the ability of SNP's bear population to maintain itself at such a high density. We expected that gypsy moth-induced oak mortality in SNP would reduce the availability of acorns and that a decline in reproductive and survival rates of SNP's bear population would follow.

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STUDY AREA

Field work was conducted from June 1990 to November 1993 in the 777 km^2 Shenandoah National Park. The park is located in the Blue Ridge Mountains between Front Royal and Waynesboro, Virginia, approximately 120 km southwest of Washington, D.C. (Fig. 1).

Within SNP, the study area consisted of the North Administrative District and the northern one-half of the Central Administrative District. This irregularly shaped area was <1–13 km wide and contained approximately 38,300 ha. On Skyline Drive, which bisected SNP north to south, the study area extended south from the Front Royal Entrance Station (milepost 0), to milepost 51 (82 km) and the Big Meadows Lodge. Most of the gypsy moth-induced oak mortality within SNP at the time of this study occurred in this area.

Both districts were characterized by steep ridges and narrow valley bottoms. Elevations ranged from 200 to 1,250 m. SNP was bounded by the Piedmont region to the east and the Shenandoah Valley to the west. These adjoining regions were primarily devoted to corn production, apple orchards, and small livestock operations. A fall bear hunting season took place annually outside SNP, but hunting was prohibited inside the park.

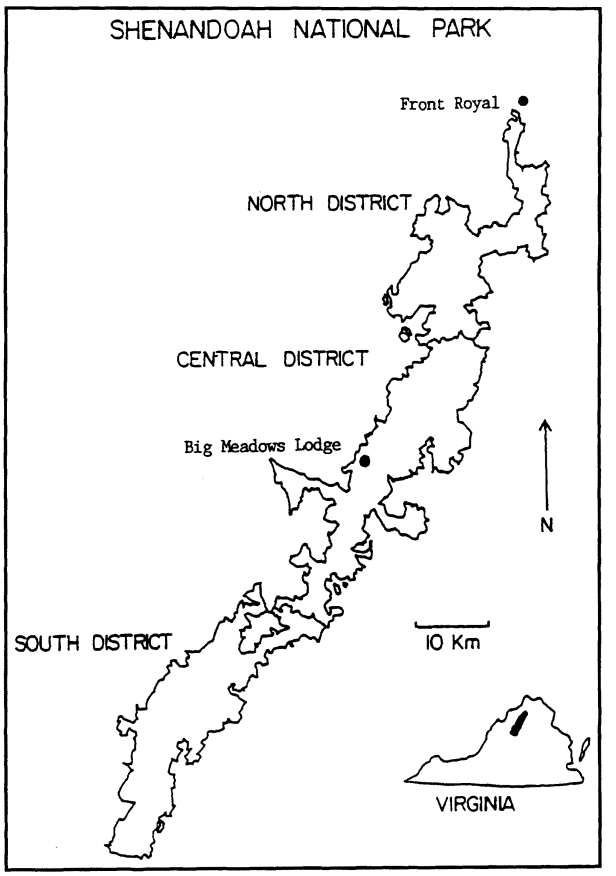

Fig. 1. Study area in Shenandoah National Park (SNP), Virginia, 1990–93.

SNP was heavily forested with vegetation characteristic of an oak–hickory (*Carya* spp.) forest. Many stands were even-aged and growing on poor sites, making them highly susceptible to the gypsy moth (Kegg 1973). Second-growth timber (<70 years old) predominated due to logging and agricultural practices prior to the formation of SNP in 1936 (Mazzeo 1979).

Annual precipitation averaged 94–130 cm of rain and 79–122 cm of snow, depending on elevation (Conners 1988). Temperatures averaged -3 C in January and 19 C during July. Temperatures averaged 5–10 C cooler at higher elevations than in surrounding lowlands (Heatwole 1978).

MATERIAL AND METHODS

We captured bears with foot snares and culvert traps between June and August 1990–92, capturing 58 bears 61 times. We immobilized captured bears with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride at a mixture concentration of 300 mg/ml at dosages of 1.2 ml/45.4 kg of body weight. In 1992, yohimbine hydrochloride was administered at dosages of 0.11 mg/kg body weight to return bears to consciousness after processing was completed.

Primary candidates for radiocollaring were adult females (≥3 years old) identified in the field as weighing ≥45.4 kg. We targeted adult females to maximize the sample sizes for estimating reproductive parameters. Suitable female bears were fitted with radiocollars (Telonics, Inc., Mesa, Ariz.). Collars were equipped with a breakaway cotton spacer to prevent permanent collaring of the animal and to permit retrieval of collars prior to battery failure (Hellgren et al. 1988).

Accessible adult females were immobilized in their dens during early March to determine litter sizes. Litter sizes of inaccessible adult females were determined by visual observation as soon as possible following den emergence. We compared litter sizes to those before gypsy moth infestation (Carney 1985) using the Wilcoxon Rank Sum procedure.

Routine monitoring of radiocollared bears was used to calculate survival rates (Trent and Rongstad 1974). In addition, minimum adult mortality rates for bears that were eartagged only were estimated based on tag returns to the Virginia Department of Game and Inland Fisheries (VDGIF) and at hunter check stations. Cub survival estimates were determined by checking dens following emergence for any evidence of mortality and by repeated visual observations of family groups until the following denning period.

RESULTS

Reproduction

Litter size of radiocollared female bears from 1991 to 1993 averaged 2.25 cubs/litter (n = 12, SE = 0.031), which did not differ (Z = 0.69, P = 0.49) from the average litter size of 2.0 cubs (n = 21, SE = 0.17) prior to the gypsy moth invasion (Carney 1985). Four litters of 1 cub, 2 litters of 2 cubs, 5 litters of 3 cubs, and 1 litter of 4 cubs were produced.

Two of 4 female bears monitored for >2 consecutive years in this study produced litters in consecutive years when they lost their original litter by midsummer. One of these 2 bears produced 4 consecutive litters totaling 14 cubs. The remaining 2 bears successfully produced and raised litters in alternate years. Age at first breeding was not documented in this study.

Cub Survival

The minimum cub survival rate to 1 year of age was 64.7% (n = 17 cubs from 7 litters). We assumed that cubs not observed with their mothers at 12 months of age had died. One litter of 2 cubs suffered partial loss following emergence from their natal den; 1 litter of 1 cub and 1 litter of 4 cubs were entirely lost. The remaining 4 litters suffered no losses. The cause and timing of cub disappearance in this study was not known. Carney (1985) reported entire loss of 3 of 10 litters (30%), but not individual cub survival rates.

Adult Survival

Of 28 adult females radiotracked for 11,071 radio days ($\bar{x}$ = 395 days/bear, range = 8–1,004 days) and 8 males (1 subadult and 7 adults) tracked for 2,513 radio days ($\bar{x}$ = 314 days/bear, range = 8–540 days), none died during this study. One adult female died in her den from an apparent reaction to the immobilizing drug; however, her death was not factored into survival calculations. No recovered collars bore any evidence that they were removed by hunters or poachers, nor were any carcasses, blood, or other indications of a dead bear located near a dropped collar. Some radiotransmitters failed before the cotton spacer parted, but in each case it coincided with the expected end of the transmitter's battery life. Several bears wearing failed transmitters were seen or captured later. Therefore, the maximum survival rate of male and female bears in this study was 100%.

At least 7 of 61 eartagged bears (n = 61, including 3 male cubs tagged in their natal den) died between June 1990 and January 1993. An automobile struck and killed 1 subadult male outside SNP's northern boundary. Hunters legally harvested the remaining 6 outside of the park (2 adult males, 3 adult females, and 1 subadult male). Minimum average annual mortality was 4% (SE = 0.007) over the 3 years of the study.

DISCUSSION

We predicted that gypsy moth-induced oak mortality would decrease reproduction and survival of SNP's bear population. A decline in the hard-mast crop, due to extensive oak mortality, was expected to lead to decreases in bear reproduction and survival. These changes were expected to occur as the predicted hard-mast shortage led

to nutritional stress, resulting in smaller litter sizes and decreased cub survival. Adult survival also was expected to decline as resident SNP bears sought sufficient forage outside SNP in agricultural areas, where they would be vulnerable to hunting or possibly cause property damage.

One of the most anticipated effects of the gypsy moth infestation and subsequent oak mortality was a reduction in litter size or a total failure to produce litters as reported elsewhere following a decline in the fall forage base (Jonkel and Cowan [1971] in Montana, LeCount [1982] in Arizona, Eiler et al. [1989] in Tennessee, Elowe and Dodge [1989] in Massachusetts, McLaughlin et al. [1994] in Maine). The average litter size of 2.25 cubs in this study, however, did not differ from the 2.0 average reported by Carney (1985) prior to the gypsy moth's arrival in SNP. Kasbohm et al. (1996) reported an average litter size of 2.3 cubs during the initial gypsy moth defoliation of SNP's canopy.

Rogers (1976) and Eiler et al. (1989) believed cub survival was connected with mast availability, although LeCount (1982) and Elowe and Dodge (1989) found no such correlation. Cub survival to 1 year of age in this study was 64.7%. Elowe and Dodge (1989) recorded cub survival rates of 59% in Massachusetts, and Eiler et al. (1989) observed survival rates of 62% in Tennessee. In Arkansas, Clark (1991) reported a 31% survival rate on 1 study area and 90% on another. In SNP, Kasbohm et al. (1996) recorded 91% cub survival during the initial gypsy moth outbreak. Therefore, the survival rate of cubs in this study appears to be in the mid-range of other reported rates.

Mortality of eartagged and radiocollared adult and subadult bears was likely underestimated in this study for several reasons. Prior to the 1991 hunting season, reporting requirements for hunter-killed bears in Virginia were less stringent than in 1991 and afterwards. Some eartags from legally harvested bears may not have been recovered by the investigators. Natural mortality of eartagged bears was not known. Also, home ranges of SNP adult females were small (Garner 1986, Schrage 1994) and much of the trapping for this study took place in the interior of the park. Therefore, radiocollared females in this study were probably less vulnerable to hunters or poachers than those with home ranges near or overlapping the park boundary. Although no radiocollared bears were lost to poachers during this study, poaching does occur in SNP. Carney (1985) and Kasbohm et al. (1996) reported that 11% and 5% respectively of radiocollared bears were poached during their studies of SNP's bear population. Lastly, males, the most vulnerable segment of the population, were not well represented in the sample of radiocollared animals in this study. Only 8 males were collared, 1 of whom shed his collar after only 8 days. In contrast to this study, maximum annual survival rates for SNP males were only 60% for Carney (1985) and 36% for Kasbohm et al. (1996).

The 100% survival rate of radiocollared adult females in this study is consistent, however, with high (≥90%) adult female survival rates reported for SNP in pre-infestation data (Carney 1985) and during the initial gypsy moth outbreak (Kasbohm et al. 1996). Schrage (1994) found that gypsy moth-induced mortality of oaks did not appear to have sufficiently depleted SNP's overall food resources from pre-infestation data (Garner 1986) to force adult females out of SNP to obtain adequate forage. Increased movements likely would cause them to spend more time outside SNP where they would be vulnerable to hunting mortality. Rogers (1976), Beeman and Pelton (1980), and J. Blank (VDGIF, Harrisonburg, pers. commun., 1995) reported that contact between bears and people—contact usually detrimental to the bear—increased during years of mast failures as bears entered areas, frequently agricultural, that they usually avoided. The survival rates reported in this study do not suggest an increase in legal hunting mortality correlated with oak mortality, and no radiocollared bears were removed by the VDGIF outside SNP for property damage in spite of an active response to bear damage complaints. No reports of bear damage to property inside SNP were reported to the authors by SNP personnel during this study. In addition, the frequency of occurrence of agricultural crops in the fall diet of SNP's black bears did not change following the increase in gypsy moth-related oak mortality (Schrage 1994).

Diet analysis by Schrage (1994) suggests that omnivorous black bears switched to available soft mast food without any appreciable effects on their population dynamics. The gypsy moth may have actually increased the size and diversity of the forage base for black bears in SNP by creating openings in an otherwise continuous forest canopy and thereby stimulating soft mast production. Some of this soft mast, such as grape (*Vitis* spp.) and pokeweed (*Phytolacca americana*), is available in the fall. In addition, oak mortality induced by the gypsy moth may be concentrated in weakened or subdominant individuals, which are not the primary mast producers (Campbell and Sloan 1977, Gottschalk 1990). Although the importance of acorns in the fall diet declined in this study as compared to Garner (1986), they were still the most important food item by volume (Schrage 1994).

Of future concern, however, will be additional oak mortality caused by further defoliations and the species composition of overstory regeneration in the forest openings. The gypsy moth is likely to be a permanent resident of SNP. Oak regeneration is not well understood and fails under certain conditions (McGee and Loftis 1993). Therefore, oaks lost to the gypsy moth or other causes may not replace themselves, and new species may not provide the same food value to bears as oak mast. If no management practices are instituted to maintain the current forest openings, much of the soft mast production will decline as a new overstory regenerates. Therefore, the continued long-term effects of the gypsy moth on SNP's black bear population remain uncertain.

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