

INFLUENCE OF GYPSY MOTH INDUCED OAK MORTALITY
ON A BLACK BEAR POPULATION

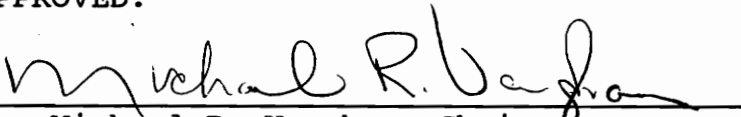
by

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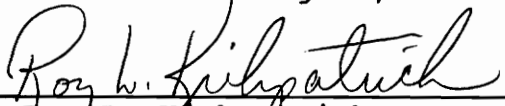
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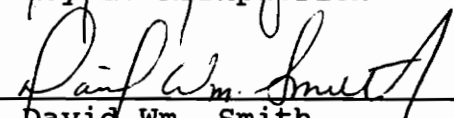
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**Influence of Gypsy Moth Induced Oak Mortality
on a Black Bear Population**

by

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Fisheries and Wildlife Sciences

(ABSTRACT)

During June 1990 - November 1993 I measured the responses of black bears (Ursus americanus) in Shenandoah National Park (SNP), Virginia to gypsy moth (Lymantria dispar) induced oak (Quercus spp.) mortality. Oak species composed >50% of the forest canopy of SNP, and oak mortality rates ranged from 1- \geq 48%. I compared black bear population dynamics, food habits, movements and habitat use to preinfestation data collected in SNP from 1982 - 1985.

Scat analysis indicated that the current diet of SNP's black bear population includes proportionally more soft mast in the fall and more soft mast and ants (Formicidae spp., $P < 0.0001$) in the summer than did the preinfestation diet. Fewer acorns (Quercus spp. mast, $P = 0.03$) and squawroot (Conopholis americana, $P = 0.01$) were consumed in the fall and summer respectively. No decline in the physical condition of adult females ($P = 0.91$), subadult males ($P = 0.34$) or subadult females ($P = 0.94$) was evident. Adult male physical condition declined ($P = 0.03$) for unknown reasons.

The mean age of neither female ($P=0.99$) nor male bears ($P=0.54$) was different from preinfestation data. Mean litter size - 2.25 cubs - did not differ ($P=0.49$) from a preinfestation mean of 2.0 cubs. Survival of radio-collared female bears was 100%, indicating that the female survival rate has not declined from a high preinfestation survival rate. Minimum cub survival rate to 1 year was 64.7%.

Fall and annual home ranges of female bears were smaller ($P=0.001$ and $P=0.002$, respectively) than during preinfestation years. Use of forest cover types differed from availability during the summer ($P<0.01$), early fall ($P<0.0001$) and late fall ($P<0.001$) and when compared to preinfestation data. Use of stands with different levels of oak mortality was not different from availability during the summer ($P=0.1$) but was different during the early fall ($P<0.005$) and late fall ($P<0.001$).

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Last of all I would like to thank Elizabeth, who waited patiently until I could catch up.

One [Confederate] detachment lost its sleep, on a night of especially heavy rain, when a bear blundered into camp and set the men caroming into one another in the dripping blackness.

Bruce Catton - The Terrible Swift Sword

Introduction and Justification

The gypsy moth, (Lymantria dispar) was imported to Medford, Massachusetts in 1869 in an attempt to aid the silk industry. By 1879 it had escaped captivity and had begun to reproduce naturally (Evans 1985). By 1984 the moth had spread southward to Shenandoah National Park in northern Virginia. Defoliation in the Park was insignificant in 1985, but quickly grew to 546 ha in 1986, 2,304 ha in 1987, 6,277 ha in 1988, and 17,736 ha in 1989 (Kasbohm 1994).

Oaks (Quercus spp.) are one of the most preferred host species of gypsy moth larvae, although at epidemic levels the caterpillars will defoliate much of the canopy of eastern hardwood forests (Gansner et al. 1987, Twery 1990). Tree mortality can occur after one defoliation, and oak trees may require as many as 10 years to recover from the impact of a single heavy defoliation (Campbell and Sloan 1977).

Defoliation and oak mortality are of special concern for managers of wildlife species that include hard mast crops 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 reduces the percentage of oak in existing

stands, and in future stands as well, if oaks do not regenerate (Campbell and Sloan 1977, Allen and Bowersox 1989, Hix et al. 1991, Tigner 1992). Oak regeneration is not well understood and fails under certain conditions (McGee and Loftis 1993). Therefore, changes in forest composition may reduce the value of these stands to wildlife species, such as wild turkeys (Meleagris gallopavo), gray squirrels (Sciurus carolinensis), white-tailed deer (Odocoileus virginianus), and black bears (Ursus americanus), which include acorns in their diets. However, in spite of its 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 impacts wildlife species.

From 1982 - 1985 2 studies were conducted in Shenandoah National Park (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 event and subsequent tree mortality induced by the gypsy moth within SNP. As such, the opportunity existed to investigate how the Park's bear population responded to the ecological disruption wrought by the gypsy moth. During 1985 - 1990 a study was conducted to examine how bears responded to the initial defoliation of SNP's forests (Kasbohm 1994). In 1990 this study was

initiated to investigate how oak mortality resulting from the initial and subsequent defoliation events, would impact the bear population of SNP.

The black bear is an important wildlife species of SNP and surrounding state, federal and private lands. Carney (1985) estimated a stable population of 500-800 individuals in the 777 km² Park. A survey by Baptiste (1977) found that over 90% of visitors to SNP wanted to see bears. The Park also makes a large contribution to the total black bear population and hunter harvest in Virginia. Although hunting is not allowed within the boundaries of SNP, approximately 50% of the State's bear harvest comes from the 8 counties that contain the borders of SNP (Virginia Department Game and Inland Fisheries 1992). Black bears also are important in Virginia because of the property damage they cause on agricultural lands surrounding SNP and to visitors of SNP itself (Vaughan et al. 1990).

Carney (1985) found SNP's black bear population existed at one of the highest densities recorded in North America. Reproductive rates were high, with females breeding for the first time at the comparatively young age of 3.5 years and producing an average of 2 cubs every other year. Garner (1986) reported that acorns composed 19-66% of the fall diet of SNP's 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 contribute a great deal to the ability of SNP's bear population to maintain itself at present levels. Alterations in this diet, due to wide-spread gypsy moth induced mortality of oaks, may lead to changes in the ecology and structure of SNP's bear population. Therefore, the objectives of this study were to investigate changes in the bear population of SNP related to gypsy moth induced oak mortality. These changes were expected to include changes in diet, reproduction, survival, sex ratios, age structure, home range size, physical condition and habitat use. Information from this study should assist managers of black bears in predicting how populations may respond to widespread habitat alterations as the gypsy moth continues to expand its range south and west of SNP. In addition, managers of other wildlife species, that utilize acorn crops and oak forests, may benefit from the results of this study.

Study Area

Field work was conducted from June 1990 to November 1993 in the 777 km² Shenandoah National Park (SNP). 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). In 1992, >1.85 million people visited the Park and >45,000 permits for backcountry camping were issued (Donna Knight SNP Interpretive Division, pers. commun.). Hunting is prohibited in SNP.

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

Both districts are characterized by mountainous terrain of steep ridges and narrow valley bottoms between 213 and

SHENANDOAH NATIONAL PARK

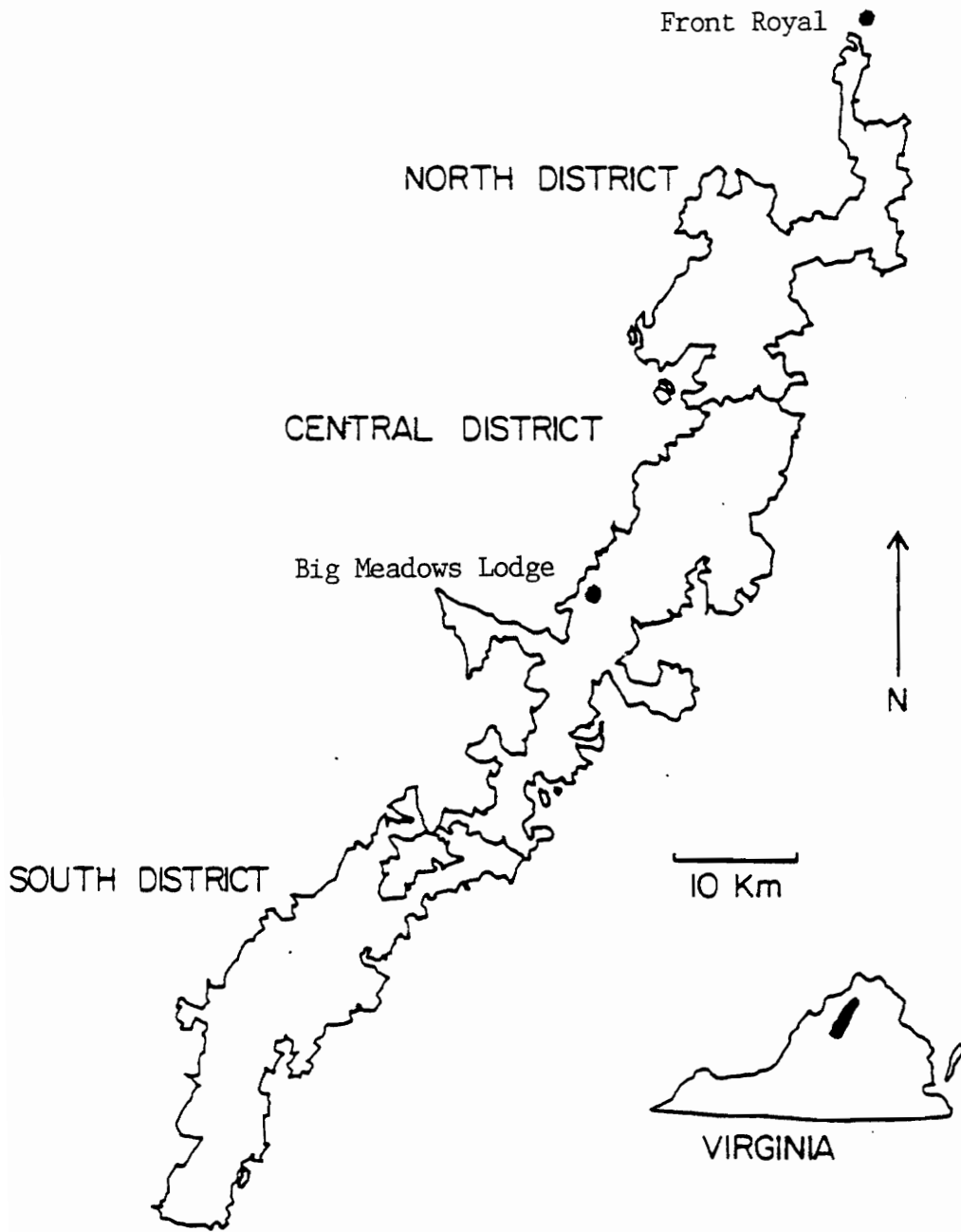


Figure 1. Study area in Shenandoah National Park, Virginia.

1,234m in elevation. The Park is bounded by the Piedmont region to the east and the Shenandoah Valley to the west. Where they adjoin SNP, these regions are primarily agricultural land, much of which is devoted to corn or orchard production and small livestock operations.

The Park is heavily forested with vegetation characteristic of an oak/hickory forest. Many stands are even-aged and growing on poor sites. Thus, the study area is dominated by hardwood forests that are highly susceptible to the gypsy moth (Kegg 1973). Second-growth timber (<70 years old) predominates due to the logging and agricultural practices of settlers who inhabited SNP prior to its formation in 1936 (Mazzeo 1979). Major forest cover types of SNP are northern red oak (Quercus rubra), chestnut oak (Q. prinus), yellow poplar (Liriodendron tulipifera), black locust (Robinia pseudoacacia), eastern hemlock (Tsuga canadensis), pine species such as pitch pine (Pinus rigida) and Virginia pine (P. virginiana) and cove hardwoods such as American basswood (Tilia americana), white ash (Fraxinus americana), red maple (Acer rubrum), sugar maple (A. saccharum), black birch (Betula lenta), yellow poplar and various oak species (Teetor 1988).

Annual precipitation averages 94-130 cm of rain and 79-122 cm of snow, depending on elevation (Connors 1988). Temperatures average -3°C in January and 19°C during July.

Temperatures average 5-10°C cooler in the higher elevations than the surrounding lowlands (Heatwole 1978).

Chapter 1: Literature Review

INTRODUCTION

Gypsy moth larvae emerge from their egg masses in late April and early May, climb into the canopy and begin feeding. Larvae pass through several stages or instars (5 for males and 6 for females). At each progressive stage a greater variety of plant species can serve as forage (Fosbroke and Reardon 1990), and at peak population levels large areas of forest can be defoliated [e.g. in 1989 17,736 ha in the study area (46%) suffered $\geq 60\%$ canopy loss (Kasbohm 1994)]. In June the larvae discontinue feeding and enter the pupal stage. At this time defoliated trees will draw upon energy reserves in the root system and attempt to grow a second leaf crop (Campbell and Sloan 1977 and Parker 1981). After 2 weeks as pupae, the adult moths emerge and mate. Cases of 100-1,000 eggs are laid by each female in a protected place such as the underside of tree limbs. The moths die and the eggs overwinter to hatch the following year (Fosbroke and Reardon 1990). Gypsy moth defoliation does not kill a tree by itself. Rather, it leaves the tree in a stressed condition wherein it is more susceptible to invasion by a secondary organism, such as the two-lined chestnut borer (*Agrilus bilineatus*) or shoestring root rot

(Amallaria mellea), that ultimately kills it.

The effects of gypsy moth outbreaks on tree mortality and corresponding forest stand responses have been documented by Kegg (1973) in New Jersey, Campbell and Sloan (1977) and Gansner and Herrick (1987) in New England, Quimby (1987), Allen and Bowersox (1989) and Gottschalk (1990b) in Pennsylvania, Hix et al. (1991) and Fosbroke et al. (1991) in Pennsylvania and Maryland, and Tigner (1992) in Virginia. Gypsy moth impacts on wildlife, however, have received little attention, and except for Kasbohm (1994), black bear/gypsy moth interactions have received none at all. Most of the available literature concerns the impacts of wildlife predation on gypsy moth populations or the responses of nongame birds to defoliation. Much of the remaining literature, such as Gottschalk (1990a) and Twery (1990), is limited to speculation. To date, good information on large mammal responses appears almost nonexistent.

FACTORS AFFECTING TREE MORTALITY

Tree mortality rates following gypsy moth infestation of a stand depend on a range of factors. Presence of preferred host species, defoliation intensity, number of defoliation episodes, individual crown class and health, site conditions, previous harvest methods, and drought can

all affect tree mortality levels.

Gypsy moth larvae feed on at least 500 species of plants. However, the susceptibility of each of these 500 species to defoliation varies with the presence or absence of more preferred host species and the larval stage of the caterpillar involved (McManus 1980). Gansner et al. (1987) lists gypsy moth feeding preferences for some common eastern forest species (Table 1). Campbell and Sloan (1977) in New England, Hicks and Fosbroke (1987) in the central Appalachians and Kegg (1973) in New Jersey concluded that species favored as food by gypsy moth larvae were more likely to be defoliated than neighboring species. Fosbroke et al. (1991) found the proportion of oak in a stand to be one of the strongest predictors of tree mortality. Kegg (1971) believed that the percentage of oaks killed in New Jersey would have been much higher without the moderating effect of a high number of individuals from less preferred species. Gottschalk (1989) recommended decreasing the number of individuals of a preferred host species as a means of reducing a stand's susceptibility to defoliation and subsequent mortality. Campbell and Sloan (1977) calculated defoliation potentials for stands with varying proportions of oak. Stands with a $>2/3$ oak component were 38% more likely to have suffered defoliation than stands with a $<1/3$ oak component. Stands wherein $<20\%$ of the stand was

Table 1. Gypsy moth feeding preference list from Gansner et al. (1987)

Common name	Scientific name
Species preferred at all larval stages:	
Alder	<u>Alnus</u> spp.
American mountain-ash	<u>Sorbus americana</u>
Apple	<u>Malus</u> spp.
American basswood	<u>Tilia americana</u>
Bigtooth aspen	<u>Populus grandidentata</u>
Boxelder maple	<u>Acer negundo</u>
Eastern hophornbeam	<u>Ostrya virginiana</u>
Gray birch	<u>Betula populifolia</u>
Hawthorn	<u>Crataegus</u> spp.
Hazelnut	<u>Corylus</u> spp.
Larch	<u>Larix laricina</u>
Lombardy poplar	<u>Populus nigra</u>
Oaks	<u>Quercus</u> spp.
Paper birch	<u>Betula papyrifera</u>
Quaking aspen	<u>Populus tremuloides</u>
River birch	<u>Betula nigra</u>
Serviceberry	<u>Amelanchier</u> spp.
Sumac	<u>Rhus</u> spp.
Sweetgum	<u>Liquidambar styraciflua</u>
Willow	<u>Salix</u> spp.
Witch hazel	<u>Hamamelis virginiana</u>
Species preferred by older larval stages:	
American chestnut	<u>Castanea dentata</u>
Eastern hemlock	<u>Tsuga canadensis</u>
Pine	<u>Pinus</u> spp.
Spruce	<u>Picea</u> spp.
Less preferred species eaten only during older larval stages:	
American beech	<u>Fagus grandifolia</u>
American elm	<u>Ulmus americana</u>
American hornbeam	<u>Carpinus caroliniana</u>
Black birch	<u>Betula lenta</u>
Black cherry	<u>Prunus serotina</u>
Black walnut	<u>Juglans nigra</u>
Blackgum	<u>Nyssa sylvatica</u>
Blueberries	<u>Vaccinium</u> spp.
Butternut	<u>Juglans cinera</u>
Choke cherry	<u>Prunus virginiana</u>

Table 1. continued

Common name	Scientific name
Cucumbertree	<u>Magnolia acuminata</u>
Eastern cottonwood	<u>Populus deltoides</u>
Hackberry	<u>Celtis occidentalis</u>
Hickory	<u>Carya</u> spp.
Norway maple	<u>Acer platanoides</u>
Ohio buckeye	<u>Aesculus glabra</u>
Paw paw	<u>Asimina triloba</u>
Pear	<u>Pyrus communis</u>
Persimmon	<u>Diospyrus virginiana</u>
Pin cherry	<u>Prunus pennsylvanica</u>
Red maple	<u>Acer rubra</u>
Redbud	<u>Cercis canadensis</u>
Sassafras	<u>Sassafras albidum</u>
Silver poplar	<u>Populus alba</u>
Slippery elm	<u>Ulmus rubra</u>
Sourwood	<u>Oxydendrum arboreum</u>
Sugar maple	<u>Acer saccharum</u>
Sweetfern	<u>Comptonia peregrina</u>
Yellow birch	<u>Betula alleghaniensis</u>
Yellow buckeye	<u>Aesculus octandra</u>
Species rarely eaten by gypsy moth larvae:	
American holly	<u>Ilex opaca</u>
Ash	<u>Fraxinus</u> spp.
Azalea	<u>Azalea</u> spp.
Baldcypress	<u>Taxodium distichum</u>
Balsam fir	<u>Abies balsamea</u>
Black locust	<u>Robinia psuedoacacia</u>
Dogwood	<u>Cornus</u> spp.
Eastern redcedar	<u>Juniperus virginiana</u>
Elderberry	<u>Sambucus</u> spp.
Fraser fir	<u>Abies fraseri</u>
Grape	<u>Vitis</u> spp.
Greenbriar	<u>Smilax</u> spp.
Honey locust	<u>Gleditsia triacanthos</u>
Horsechestnut	<u>Aesculus hippocastanum</u>
Juniper	<u>Juniperus communis</u>
Kentucky coffeetree	<u>Gymnocladus dioica</u>
Mountain maple	<u>Acer spicatum</u>
Mountain laurel	<u>Kalmia latifolia</u>
Mulberry	<u>Morus rubra</u>
Northern catalpa	<u>Catalpa speciosa</u>
Rhododendron	<u>Rhododendron</u> spp.
Raspberry	<u>Rubus</u> spp.

Table 1. continued

<u>Common name</u>	<u>Scientific name</u>
Sarsparilla	<u>Aralia hispida</u>
Sheep laurel	<u>Kalmia angustifolia</u>
Spicebush	<u>Lindera benzoin</u>
Striped maple	<u>Acer pennsylvanicum</u>
Sycamore	<u>Platanus occidentalis</u>
Yellow poplar	<u>Liriodendron tulipifera</u>
Viburnum	<u>Viburnum spp.</u>

composed of preferred host species had a defoliation potential 58% less than that of stands with a >2/3 oak component.

Host species that are most susceptible to defoliation may not necessarily be the most susceptible to mortality. Huston and Valentine (1977) reported that some oaks can survive repeated defoliations, whereas eastern hemlock, described as a host of a more intermediate preference (Gansner et al. 1987), seldom survives 1 defoliation (Stephens 1988). Hemlock stores its energy in its needles and thus has no energy reserves to draw on following defoliation. Campbell and Sloan (1977) found that host species of intermediate preferences had higher mortality rates following a single heavy defoliation than did oak species.

Gansner and Herrick (1987) found total mortality rates for all tree species varied with the intensity of defoliation in the stand. Plots that averaged $\leq 10\%$ defoliation levels over 3 years suffered 13% mortality, while plots with a 3-year average of $\geq 40\%$ defoliation suffered 28% mortality. Over a 5-year period where the average defoliation was $\leq 20\%$, basal area losses were $< 20\%$ (Fosbroke et al. 1991). During this same period, where defoliation averages exceeded 25%, basal area losses were 29%. Where average defoliation rates were $\geq 40\%$, at least

56% of the basal area died.

Tree mortality also increases with the number of defoliation episodes. Quimby (1987) found oak mortality rates increased from 18% after one year of heavy defoliation, to 98% following 3 years of heavy defoliation in a 10-year period. For oaks rated in good condition, mortality rates were 7% following one heavy defoliation. However, after 2 consecutive defoliations, mortality rates for oaks in good condition climbed to 22% (Campbell and Sloan 1977). In New Jersey, oak mortality increased from 14.3% after one year's defoliation to 38% following 2 years of defoliation (Kegg 1973). Fosbroke et al. (1991) showed stand mortality to increase from 24% following one defoliation to 34, 45 and 77% following 2, 3 and 4 defoliations, respectively. Tigner (1992) showed general trends in increased mortality for 5 oak species as the number of defoliations increased from 0 to 3.

Kasbohm (1994) found that oak species in SNP suffered a mortality rate of 4.7%/year with 1 year of defoliation. Oak mortality averaged 17.6%/year on sites defoliated 2-3 times. One site suffered 85% oak mortality after 3 consecutive defoliations. Using Geographic Information Survey overlays to identify areas of multiple defoliations, >50% oak mortality was predicted over at least 20% of the oak habitat types in SNP following 3 years of defoliation in his study.

Another SNP study (Watson, SNP unpubl. data) found that total gypsy moth induced tree mortality, averaged over 32 species, ranged from 0 in nondefoliated stands to 10% following 1 defoliation in an average or below average moisture year, 7% following 2 years of defoliation and $\geq 42\%$ in stands defoliated 3 times. Oak mortality rates were 14%, 11% and $\geq 48\%$, respectively, for the same defoliation classes.

The crown class of an individual tree also can be an indicator of its susceptibility to mortality. Campbell and Sloan (1977) found that dominant trees were less likely than subdominant trees to die following defoliation. Indeed, defoliation and subsequent mortality was described as being similar in effect to a "thinning from below." Gansner and Herrick (1987) reported that many of the trees killed following defoliation "were small and of low grade." Gottschalk (1989, 1990b) recommended the removal of trees with intermediate and suppressed crowns to improve the vigor of dominant and codominant trees in advance of the gypsy moth. Dominant and codominant crown classes were more likely to survive defoliation events (Gottschalk 1990b). This has additional significance to wildlife as most of the most producing individuals are in the dominant and codominant crown classes (Gottschalk 1990b).

Tree health, as measured by crown condition, also

affects susceptibility to mortality following defoliation. Campbell and Sloan (1977), in eastern New England, found oak mortality rates differed within a crown class based on the health of the tree. For dominant oaks rated in good condition prior to a single heavy defoliation, mortality rates were 3% 5 years after the defoliation episode. Conversely, 22% of dominant oaks rated in poor condition were dead after 5 years. Subdominant oak mortality rates were 12 and 41% for individuals rated in good and poor conditions, respectively, 5 years after the defoliation episode. Tigner (1992), in Virginia, also found substantially higher mortality rates for stressed versus healthy trees following defoliation. Trees rated as stressed on one study site suffered 65% mortality rates following defoliation, whereas healthy trees suffered 18% mortality. Another study site yielded mortality rates of 83 and 7% for stressed and healthy trees, respectively.

The significance of site condition as an indicator of mortality also has been discussed in the literature. Kegg (1973) attributed higher oak mortality on one study site as compared to another to less favorable (shallow, poorly drained and low fertility soils) site conditions. Tigner (1992) found that most of the areas examined in the state of Virginia with extensive mortality were poor sites with steep rocky slopes. Fosbroke et al. (1991) found conflicting

results between site quality and mortality levels. They proposed that species composition may have driven mortality rates instead. Hicks and Fosbroke (1987) and Quimby (1987), however, found increased mortality rates on those sites with higher site index values. These authors hypothesized that trees on poor sites would tend to develop larger root systems and thus would have a better ability to rebound from defoliation stress. In addition, it was proposed that better site conditions provided better habitat for shoestring root rot. This fungus is one of the secondary organisms that can invade stressed oaks and ultimately cause mortality following defoliation.

Quimby (1987) identified previous harvest methods as predisposing a stand to mortality and found the most severe mortality to be present in stands subjected to intermediate or improvement cuts in the previous 5 to 6 years. He suggested that increases in root compaction, stress from exposure, and increased reservoirs of shoestring root rot and two-lined chestnut borer due to logging, may have predisposed the stands to mortality.

Drought conditions place an additional stress on trees and may predispose them to mortality following defoliation. Quimby (1987) and Tigner (1992) believed that drought conditions prior to and during defoliation episodes served to increase mortality rates. In SNP (Watson, SNP unpubl.

data) gypsy moth induced oak mortality in stands defoliated once during a wet year (above normal precipitation) was only 1%, while stands defoliated once during a dry year (normal or below normal precipitation) suffered 14% oak mortality.

GYPSY MOTH EFFECTS ON REGENERATION

An important future consideration for wildlife and wildlife managers will be the regeneration underneath stands that have suffered mortality due to the gypsy moth. Regeneration will determine the short and long-term value of a stand to wildlife depending on what species are regenerated and their value to wildlife as food and cover. If the primary concern for wildlife managers is the loss of a stand's oak component and a subsequent reduction in hard mast production, then the regeneration of oak seedlings or alternate mast producing species is an important consideration. In addition, although some plant species may respond well in the short-term to increased sunlight and reduced root competition, these species may be replaced by still other species over time.

The impact of gypsy moth defoliation and subsequent overstory removal on regeneration is poorly understood (Allen and Bowersox 1989, Hix et al. 1991). Most studies that have been done on this subject tend to focus on regeneration from a timber production standpoint. However,

the value of regenerated species most likely will be different for the resident wildlife species than it will be for the forest industry.

Ehrenfeld (1980), in New Jersey, Hix et al. (1991), in Pennsylvania and Maryland, and Tigner (1992), in Virginia, determined that current oak seedling regeneration was inadequate to replace losses in the overstory. Although oak was likely to remain a component of future stands, it would be at a reduced level. Allen and Bowersox (1989), in Pennsylvania, concluded that oak seedling establishment and growth would depend on their ability to compete with red maple (Acer rubrum), birch (Betula spp.) and other species which were termed "non-commercial." Hix et al. (1991) did not feel that enough existing oak stems had reached sufficient height to successfully compete with faster growing species such as red maple, black birch (Betula lenta), and black cherry (Prunus serotina) and regenerate a stand with a 30% oak stocking level.

Ehrenfeld (1980) and Hix et al. (1991) determined that understory regeneration in response to tree mortality resulted from species already present. No significant recruitment of new species was noted. In New Jersey, red maple was the most important overstory species regenerating under large canopy gaps, whereas American beech (Fagus grandifolia) was the most important overstory species under

small gaps (Ehrenfeld 1980). The principle beneficiary among understory species was dogwood (Cornus florida).

Allen and Bowersox (1989) found that red maple dominated regeneration (stems/acre) in both the Ridge and Valley and the Allegheny Mountains physiographic provinces of Pennsylvania following gypsy moth defoliation and subsequent mortality. Red maple accounted for 49 and 90%, respectively, of the stems for all commercial species in the 2 regions. The next most common commercial species in both regions was birch. The seedling component of red and white oaks was only 4% of the total commercial species component in the Allegheny Mountains, but was 16% in the Ridge and Valley. Abundance values for the stems of commercial species were higher than for noncommercial species. The most important noncommercial species were striped maple (Acer pennsylvanicum), sassafras (Sassafras albidum), and witch-hazel (Hamamelis virginiana). The combined stem count of these 3 species was higher than the combined stem count for northern red oak (Quercus rubra) and white oak (Q. alba) in the Allegheny Mountains, but not in the Ridge and Valley. Ferns dominated surface area coverage in the Allegheny Mountains (38%), but not in the Ridge and Valley (6%). Blueberry (Vaccinium spp.) and huckleberry (Gaylussacia spp.) dominated surface area coverage in the Ridge and Valley (21%) and were the second most abundant group in the

Allegheny Mountains (14%).

Hix et al. (1991) measured regeneration under forest stands before and after gypsy moth defoliation in the Appalachian Plateau and Ridge and Valley physiographic provinces of Pennsylvania and Maryland. The number of all woody stems increased by >49,000 stems/ha in both provinces following defoliation. The number of red maple stems more than doubled in both study areas, and red maple was the most common commercial species in both provinces following defoliation. In the Appalachian Plateau there were significant ($P < 0.1$) increases for blueberry, greenbriar (Smilax spp.), raspberry (Rubus spp.), witch-hazel, and serviceberry (Amelanchier spp.). In the Ridge and Valley province blueberry, raspberry, and serviceberry increased ($P < 0.1$). Blueberry and raspberry stems alone increased on average from 86,000 to 160,000 stems/ha following defoliation in the Appalachian Plateau and from 37,000 to 57,000 stems/ha in the Ridge and Valley. In both provinces dogwood declined ($P < 0.1$); however, this may have been due to the lethal disease dogwood anthracnose.

In the Appalachian Plateau, chestnut oak (Q. prinus), northern red oak and white oak stems declined ($P < 0.01$). White oak stems also declined ($P < 0.01$) in the Ridge and Valley; however, northern red oak ($P < 0.05$) and chestnut oak ($P < 0.01$) stems increased. The authors felt that the

existing advanced oak regeneration was responding to defoliation by increasing in height. They were uncertain, however, how well the small oak seedlings (0-0.3 meters) would survive and grow due to the influx of competing species (e.g. red maple, blueberry, and raspberry). Ehrenfeld (1980) suggested that if understory vegetation persisted for as long as 10 to 20 years it could profoundly affect the eventual canopy composition.

Kasbohm (1994) found that, on average, soft mast producing trees such as black cherry, and soft mast producing shrubs, especially Rubus spp., tended to increase in density with increasing episodes of defoliation. Soft mast shrubs in 3 of 5 plots increased by 6,380 to 51,111 stems/ha following 2-3 years of defoliation. The remaining 2 plots did not change from predefoliation stem densities. Oak regeneration tended to decrease with increased defoliation, but this may have been due to higher initial oak densities on sites defoliated 2-3 times. Regeneration responses, due to defoliation, were not noted for nonpreferred host species such as black locust or mountain laurel (Kalmia latifolia).

GYPSY MOTH EFFECTS ON WILDLIFE

Information on gypsy moth effects on wildlife is lacking (Cooper et al. 1987, Gottschalk 1990a and 1990b).

Conditions created by the gypsy moth may benefit some species and yet be detrimental to others. Potential habitat changes mentioned by Gottschalk (1990a) include more woody debris on the forest floor, less hard mast production, more soft mast production, more snags for nesting and foraging, changes in microclimate, increased patchiness, greater insect availability, increased understory, and increased vertical stratification. Additionally, widespread changes in tree species composition, due to mortality of preferred host species, may elicit changes in the wildlife community (Cooper et al. 1987).

Smith (1985) and Cooper et al. (1987) found a number of bird species that fed on gypsy moth larvae. Cooper et al. (1987), however, believed that only the yellow-billed cuckoo (Coccyzus americanus) fed preferentially on gypsy moth larvae. The remaining species appeared to take larvae only incidentally, or responded in an opportunistic manner to outbreaks. Observations by Whelan et al. (1989) showed that passerine birds fed preferentially on hairless larvae of other species when offered an alternative to hairy gypsy moth larvae. Smith (1985) and Yahner and Smith (1991) suggested that several species of small mammals could be important predators of gypsy moth pupae and larvae; however, densities of these predators were lowest on stands most susceptible to defoliation. In addition, availability of

alternative foods, such as blueberry, reduced small mammal predation on pupae (Yahner and Smith 1991).

DeGraaf (1987) stated that "A completely defoliated forest looks devastated, but the breeding bird community as a whole is largely unaffected." Cooper et al. (1987) observed little foraging of deep forest bird species in defoliated areas; however, individuals remained in the area if pockets of undefoliated trees still existed. DeGraaf (1987) found similar numbers of bird species (25 species) in control versus defoliated stands (26 species) and observed that no species was restricted to either foliated or defoliated stands during the study.

Thurber (1992) investigated the effects of gypsy moth induced tree mortality on bird populations. Of the 42 species studied, 5 declined, 19 increased and 18 showed no significant change within 5 years of the initial defoliation episode. On highly impacted sites, flycatchers (Empidonox spp.), which require an open understory for foraging, declined in abundance. Tree nesting and canopy foraging guilds also declined in abundance. On these same sites, low nesting, cavity nesting and bark foraging guilds increased in abundance. On moderately impacted sites, forest edge and forest generalist species increased as more canopy openings were created and habitat heterogeneity increased. Forest interior birds showed no net change regardless of impact

class. The author believed that these species also benefitted from the level of increase in habitat heterogeneity. Thurber (1992) concluded that moderate defoliation by the gypsy moth led to sufficient retention of habitat important to canopy foraging and nesting species while improving habitat for bark, shrub and ground foragers and cavity, ground and shrub nesters.

Tomblin (1994) investigated the effects of gypsy moth defoliation and subsequent tree mortality on small mammal communities in chestnut oak stands in Virginia. Differences occurred in the characteristics of small mammal populations between impacted (defoliation in progress or stands already suffering overstory mortality) and nonimpacted sites. Defoliated sites had the highest species diversity of small mammals during the summer and fall. Sites with tree mortality present due to past defoliation episodes were intermediate in diversity followed by nonimpacted sites. Defoliation and subsequent mortality created a more complex habitat structure and thus more niches for the coexistence of a greater number of species.

Kasbohm (1994) investigated the response of black bears in SNP to gypsy moth defoliation. Defoliation had no significant effect on bear nutrition, physical condition, reproduction, or survival despite a near total acorn failure in defoliated areas. Bears switched fall feeding strategies

from predominantly acorns to soft mast fruits such as black cherry, pokeweed (Phytolacca americana), spicebush (Lindera benzoin), and grape (Vitis spp.). Bears did not avoid areas undergoing defoliation during the summer, but stands defoliated during the summer were avoided the following fall. Fall range areas were significantly greater during defoliated years than during preinfestation years implying that acorn loss stimulated increased movements. Increased movements may have led to increased hunter harvest outside SNP.

Chapter 2: Food Habits and Physical Condition

INTRODUCTION

Food habits of black bears in the central and southern Appalachians have been intensively studied (Cottam et al. 1939, Bennett et al. 1943, Beeman and Pelton 1980, Carlock et al. 1983, Eagle and Pelton 1983, Garner 1986). These studies illustrated the black bear's omnivorous eating habits as well as the seasonal importance of certain foods in their diet. Spring appears to be a period of poor forage quality, as bears exist on a diet of generally undigestible plant material (Jonkel and Cowan 1971, Eagle and Pelton 1983). Summer is a time of increasing weight gain, while the fall diet is high in fats and carbohydrates enabling bears to store sufficient energy to survive their period of winter dormancy (Beeman 1975, Eagle and Pelton 1983).

Garner (1986) recorded the food habits of black bears in Shenandoah National Park (SNP) and pointed out the importance of oak mast in the fall diet. Oak mast provided 19-66% of the fall diet before the gypsy moth infestation began. In 1985 the gypsy moth began to defoliate trees in the northernmost regions of SNP. By 1990 60% of the study

area had been defoliated ($\geq 60\%$ canopy loss) from 1-3 times. Oak tree (Quercus spp.) mortality rates in defoliated stands ranged from 1 to $\geq 48\%$ (Watson, SNP unpubl. data). A subsequent reduction in future acorn crops was expected to follow. Mast crop failures have negatively affected black bear survival, reproduction, and physical condition in Montana (Jonkel and Cowan 1971), Minnesota (Rogers 1976), Arizona (LeCount 1982), Tennessee (Eiler et al. 1989), Massachusetts (Elowe and Dodge 1989), and Maine (McLaughlin et al. in press). Bear movements increased during years of mast failures in Tennessee (Garshelis and Pelton 1981). In addition, mast failures led to increases in nuisance complaints in Minnesota (Rogers 1976).

Kasbohm (1994) investigated the effects of the initial gypsy moth defoliation events on the diet and physical condition of SNP's bear population. Data from that study indicated a switch to a diet high in soft mast during the fall period, as acorns were almost nonexistent in defoliated areas. Similarly, in the southern Appalachians, Carlock et al. (1983) found an increase in consumption of soft mast foods, primarily grape (Vitis spp.), during a poor acorn year.

The objectives of this portion of the study were to investigate changes in diet and physical condition of the bear population related to gypsy moth induced oak mortality.

Acorns were expected to have a less important role in the fall diet as a result of oak mortality. Acorns, easily available in good years, are high in fats and carbohydrates (Landers et al. 1979). Physical condition of the bears was therefore expected to decline with the reduction of available acorns.

MATERIALS AND METHODS

Food habits were determined through the collection and analysis of scats. Scats were collected incidental to other field activities such as trapping or radio-tracking. Constraints on field work limited the collection of scat to the summer (June 16 - August 31) and fall (September 1 - December 20) seasons. Seasons were based on changes in weather patterns and plant phenology. Only scats that could be accurately dated to season were collected. Dating was a subjective judgement based on moisture content, mold, decay or breakdown of the scat. Scats were placed in labeled plastic bags and frozen for later analysis of contents. The entire scat was collected.

Scats were thawed, and then washed through a series of sieves with mesh openings of 3.36mm, 2mm, 0.6mm and 0.25mm to separate the contents. The total volume of each scat's contents was measured by water displacement. A subsample of the contents was examined until all the food items were

identified to the lowest possible taxa. The frequency of occurrence for all food items was recorded and the percent volume of each food item in a scat was ocularly estimated. Each food item was assigned a midpoint value based on its estimated percent volume in the scat: 0=absent; 0.5=trace; 12.5=1-25 percent; 37.5=26-50 percent; 62.5=51-75 percent and 87.5=76-100 percent. Estimated percent volume in the diet was calculated using the following equation.

$$\text{Estimated Percent Volume} = \frac{\text{Sum of midpoint values for each food item across all scats}}{\text{Total number of scats}}$$

The frequency of occurrence of food items, which composed $\geq 5\%$ of a season's diet by volume in either this study or Garner (1986), was compared between studies using the Z-test for Proportions. I assumed that items which composed $\geq 5\%$ of the diet by volume were either more available as food to the bears or were actively sought. A p-value ≤ 0.05 was considered significant. Due to the relatively small sample size of fall-season scats in this study, however, the early and late fall seasons described by Garner (1986) for SNP were combined into a single fall season.

Correction factors developed by Hewitt (1989), which relate the residual volume in a scat to the dry matter ingested, were used in an attempt to better understand the

actual importance of food items in the diet. The methods used by Garner (1986) and this study would tend to underestimate the importance of highly digestible foods and overestimate the importance of foods that were not readily digestible. However, these correction factors were developed for grizzly bear food items from the western United States. Consequently only a few specific food items were common to both Hewitt (1989) and this study, and hence only the correction factors for those food items common to both studies could be directly transferred to this study. Remaining food items in this study were given correction factors based on general recommendations for food groups (e.g. nuts, vegetation, etc.) by Hewitt (1989, Appendix Table 1). Because in many cases correction factors likely are not entirely accurate for the food items used by bears in this study, corrected volumes are provided only as an indication of potential bias in this and other food habits analyses which fail to account for digestibility (Appendix Table 2).

An index to physical condition during the summer (June 16 - August 31) season was established using a physical condition ratio (PCR) described by Schroeder (1987): $PCR = [\text{body weight (kg)} / \text{total body length (cm)}] \times 10$. Higher index values indicate relatively better physical condition. Only the value from a bear's initial capture is reported.

Bears were placed in 1 of 4 classes according to sex and age [male or female adult (≥ 3 years) and male or female subadult]. Total length and body weight data provided by Carney and Kasbohm (unpubl. capture data) were used to calculate PCRs for each class prior to gypsy moth defoliation and subsequent tree mortality (1982 - 1988). These data were compared by class with postmortality data (1990 - 1992) from this study using the Wilcoxon Rank Sum procedure.

RESULTS

Data from 74 scats collected during the summer seasons of 1990 - 1992 and 72 scats from the fall seasons of 1990 - 1993 were used to analyze food habits (Table 2). In the summer, forbs and grasses composed 26% of the diet followed in importance by squawroot (19% - Conopholis americana), invertebrates (19%), tree fruits (19%) shrub and vine fruits (11%), and mammals (2%). The remaining 3% was composed of debris such as rocks, twigs and leaves. Fall diets contained tree fruits (48%), shrub and vine fruits (20%), forbs and graminoids (12%), corn (5%), invertebrates (5%), squawroot (2%), and mammals (2%). Debris made up the remaining 3%.

Animal matter, primarily ants (16% - Formicidae), comprised 21% of summer scat volumes. Beetles (Coleoptera),

Table 2. Frequency of occurrence and mean percent volume of food items identified in 146 scats collected in Shenandoah National Park, Virginia between 1990 and 1993 following gypsy moth induced oak mortality.

Food Item	Summer		Fall	
	n=74		n=72	
	Freq.	Vol.	Freq.	Vol.
Forbs and Graminoids				
<u>Arisaema</u> spp.	6	4 ^a		
Graminae	6	4	4	2
<u>Phytolacca americana</u>	4	2	27	10
<u>Rubus</u> spp.	27	13		
unidentified spp.	7	3	1	T ^b
Squawroot				
<u>Conopholis americana</u>	28	21	2	2
Tree Fruit				
<u>Amelanchier</u> spp.	1	T		
<u>Carya</u> spp.			13	7
<u>Celtis</u> spp.			1	T
<u>Ilex montana</u>	1	T		
<u>Juglans nigra</u>			1	1
<u>Malus</u> spp.	10	7	13	6
<u>Nyssa sylvatica</u>			2	T
<u>Prunus avium</u>	2	T		
<u>Prunus serotina</u>	12	7	8	5
<u>Quercus</u> spp.	4	4	27	28
<u>Sassafras albidum</u>	5	1	1	T
Shrub & Vine Fruit				
<u>Elaeagnus umbellata</u>			4	1
<u>Gaylussacia</u> spp.	3	1		
<u>Lindera benzoin</u>	5	1	15	6
<u>Ribes</u> spp.	2	1		
<u>Vaccinium</u> spp.	16	8		
<u>Vitis</u> spp.			19	13
Corn			5	5

Table 2. continued

Food Items	Summer		Fall	
	n=74		n=72	
	Freq.	Vol.	Freq.	Vol.
Invertebrates				
Cambridae			1	T
Coleoptera	10	1	3	1
Formicidae	51	16	6	T
Orthoptera	1	T		
Vespidae	8	1	4	2
unidentified spp.	10	1	10	1
Mammals				
<u>Odocoileus virginianus</u>	3	2	3	1
unidentified spp.	2	T	3	1
Debris & Garbage				
Debris	30	3	25	3
Garbage			1	T

^a Percentage values are rounded to the nearest whole number.

^b T indicates a trace amount (< 0.5%).

bees (Vespidae), unidentified insects, white-tailed deer (Odocoileus virginianus) and unidentified mammal made up the remainder. Black bear hair was noted in several scats, but never in quantities to suggest it came from anything other than grooming activities.

Fruits of several trees, shrubs, and forbs were an important part of the summer diet. Blueberry (Vaccinium) and blackberry/raspberry (Rubus spp.) appeared to be abundant throughout the course of the study and bears consumed them in large quantities (8% and 13% of scat volume, respectively). As the summer progressed, fruits of black cherry (7% - Prunus serotina) and apple trees (7% - Malus spp.) appeared in larger quantities.

Jack-in-the-pulpit (4% - Arisaema spp.) and other unidentified plant material were important in the early summer. Squawroot was the single most important food item by volume (21%) throughout the summer and small quantities even appeared into the fall season.

Ants, blackberry/raspberry, and blueberry were consumed more often ($Z=-4.29$, $P<0.0001$, $Z=-6.3$, $P<0.0001$, and $Z=-10.58$, $P<0.0001$ respectively) in the summer diet during this study than prior to the gypsy moth's arrival (Table 3). No changes were noted in the frequency of vegetation ($Z=0.31$, $P=0.76$), black cherry ($Z=-0.88$, $P=0.38$), sweet cherry (Prunus avium - $Z=1.84$, $P=0.07$) or apples ($Z=0.61$, $P=0.54$)

Table 3. Comparison of the frequency of occurrence of major black bear food items^a before (Garner 1986) and after gypsy moth induced oak mortality.

Food Item	Garner (1986) Freq. ^b	This study Freq. ^c	Increased or Decreased ^d	P-value ^e
Summer				
<u>Conopholis americana</u>	124	28	Decreased	P=0.011
<u>Vaccinium</u> spp.	9	16	Increased	P<0.0001
Formicidae	97	51	Increased	P<0.0001
<u>Malus</u> spp.	39	10	No change	P=0.54
<u>Prunus serotina</u>	28	12	No change	P=0.38
<u>Prunus avium</u>	24	2	No change	P=0.07
<u>Rubus</u> spp.	17	27	Increased	P<0.0001
Vegetation	64	19	No change	P=0.76
Fall				
<u>Carya</u> spp.	49	13	No change	P=0.09
Corn	17	5	No change	P=0.23
<u>Quercus</u> spp.	229	27	Decreased	P=0.03
<u>Lindera benzoin</u>	26	15	Increased	P<0.0001
<u>Malus</u> spp.	90	13	No change	P=0.7
<u>Phytolacca americana</u>	44	27	Increased	P<0.0001
<u>Prunus serotina</u>	181	8	Decreased	P<0.0001
<u>Vitis</u> spp.	38	19	Increased	P<0.0001

^a Items which comprise $\geq 5\%$ of the scat volume in 1 or both time periods.

^b Out of 231 scats in the summer and 444 in the fall.

^c Out of 74 scats in the summer and 72 in the fall.

^d Level of Significance set at $P \leq 0.05$.

^e Z-test for Proportions

consumed. Based on frequency of occurrence, fewer squawroot stalks ($Z=2.54$, $P=0.01$) were consumed in this study than in Garner (1986).

Fall diets were characterized by increased reliance on hard and soft mast crops. Acorn crops in SNP appeared to be fair but spotty in 1990, abundant in 1991, and fair in 1992 and 1993 (pers. obs.). In spite of gypsy moth induced oak mortality, hard mast fruits such as acorns (28%) and hickory (7% - Carya spp.) were still the most important food items by volume. Soft mast fruits such as grape (13%), pokeweed (10% - Phytolacca americana), and spicebush (6% - Lindera benzoin) also were important. Animal foods were primarily insects (4%), with unidentified mammals (1%) and white-tailed deer (1%) composing the remainder. Corn (5%) was available in surrounding agricultural lands and apples (6%) were available in orchards outside SNP and at old homesites within SNP.

The frequency of acorns and black cherry in the fall diet of this study was less ($Z=2.19$, $P=0.03$ and $Z=4.91$, $P<0.0001$ respectively) than in Garner (1986, Table 3). There was no change in the frequency of hickory ($Z=1.71$, $P=0.09$) in the diet between studies, nor were there significant changes in the frequency of apples ($Z=.39$, $P=0.7$) or corn ($Z=-1.2$, $P=0.23$) consumed. The soft mast species of spicebush ($Z=-4.41$, $P<0.0001$), pokeweed ($Z=-6.36$,

$P < 0.0001$), and grape ($Z = -4.25$, $P < 0.0001$) became more important in the fall diet after the gypsy moth's arrival.

Summer physical condition ratios of adult females were not different ($Z = 0.11$, $P = 0.91$) for pre and postinfestation periods (Table 4). Subadult male ($Z = -0.96$, $P = 0.34$) and subadult female ($Z = 0.08$, $P = 0.94$) PCR's also were not different for pre and postinfestation periods although the sample size of subadult females was small. Adult male PCR's were lower in this study relative to preinfestation data ($Z = 2.23$, $P = 0.03$, Table 4).

DISCUSSION

Across much of its western and northern range the black bear subsists on a diet containing little or no acorn mast. Even in areas where oaks are common in the forest canopy, such as the southeastern United States, acorn crops fluctuate yearly, and failures are not unusual. The omnivorous dietary habits of the black bear allow it to readily switch to an alternative food source if one is available. Bears also are capable of moving long distances to areas where food is available when necessary (Garshelis and Pelton 1981, Carlock et al. 1983, Garner 1986, Hellgren and Vaughan 1990, Rogers and Lindquist 1991, Kasbohm 1994). Acorns are, however, an important part of the black bear's fall diet when and where they are available, such as

Table 4. Physical condition ratios (PCRs) of black bears captured in Shenandoah National Park, Virginia from June 16 - August 31 before and after gypsy moth induced oak mortality.

Mortality Period and Class	n	PCR (kg/cm x 10)		P-value ^a
		Mean	SE	
Adult Males				
Before ^b	15	6.4	0.4	P=0.03
After ^c	17	5.2	0.3	
Adult Females				
Before	17	4.2	0.2	P=0.91
After	19	4.2	0.2	
Subadult Males				
Before	13	3.5	0.2	P=0.34
After	12	3.2	0.2	
Subadult Females				
Before	4	2.9	0.3	P=0.94
After	9	2.7	0.2	

^a Wilcoxon Rank Sum Procedure

^b Carney and Kasbohm (unpubl. capture records) 1982 - 1988. Kasbohm's records are from nondefoliated areas.

^c This study 1990 - 1992.

in Pennsylvania (Bennett et al. 1943), California (Piekielek and Burton 1975), North Carolina, Tennessee, and Georgia (Carlock et al 1983), Florida (Maehr and Brady 1984), Arkansas (Smith 1985), Virginia (Garner 1986), Massachusetts (Elowe and Dodge 1989), and Maine (McLaughlin et al. in press).

When acorns become scarce in habitats where they are normally available, bears are forced to find alternate food sources. Rogers (1976) reported increases in damage to farm crops, beehives, and livestock in Wisconsin during blueberry and acorn failures. Elowe and Dodge (1989), in Massachusetts, reported that bears switched to agricultural crops when fall mast crops failed. Carlock et al. (1983), in the southern Appalachians, reported an increase in the use of grape during an acorn mast failure. Kasbohm (1994) found large increases in the consumption of many of the same species of soft mast (e.g. grape, pokeweed, and spicebush) following defoliation and subsequent acorn failure due to the gypsy moth, as did this study. The loss of acorns, however, did not appear to reduce the nutritional quality of the bears' diet. The primarily soft mast diet consumed during the acorn failure contained higher levels of crude fat and crude protein than the diet consumed in preinfestation years (Kasbohm 1994). Despite the decline of acorns in the diet, data from this study (Chapter 3) and

Kasbohm (1994) showed no significant effects on survival or reproductive rates.

Summer diets in this study were characterized by an increase in the frequency of ants, blackberry/raspberry, and blueberry and a decrease in the frequency of squawroot than Garner (1986) reported prior to oak mortality induced by the gypsy moth. The increase in the frequency of ants in the diet is probably due to an increase in their habitat. The large amounts of standing and fallen dead timber created by gypsy moth defoliation and subsequent tree mortality likely have proven beneficial to insect species. Increases in soft mast species such as blueberry and blackberry/raspberry are probably due to the increased amount of sunlight reaching the forest floor in stands where tree mortality is common. Hix et al. (1991), in Pennsylvania and Maryland, and Kasbohm (1994), in SNP found large increases in blackberry/raspberry and blueberry stems following gypsy moth infestations. Squawroot grows parasitically on the roots of oak trees (Wofford 1989) thus a reduction in live oaks might create a decline in the amount of available squawroot habitat and therefore a decline in its availability to bears. Alternatively, bears may simply prefer to eat other species, such as blackberries or raspberries, which may have increased in abundance since the arrival of the gypsy moth.

Relative to the preinfestation period (Garner 1986) the

postinfestation fall diet was characterized by a reduction in the frequency of acorns and an increase in the frequency of soft mast especially pokeweed, grape, and spicebush. The soft mast species likely increased with the increase in sunlight on the forest floor. Pokeweed especially was noted in areas that had suffered extensive canopy mortality.

Garner (1986) and Kasbohm (1994) reported that black cherry fruit was an important part of the early fall diet of SNP's bear population. Although no significant decline was noted in the frequency of black cherry in the summer diet, the frequency of black cherry was significantly less in the fall diet of this study than in the preinfestation diet (Garner 1986). Significant mortality of black cherry trees was not noted in data collected by Watson (SNP unpubl. data) in SNP following gypsy moth defoliation. The decline of black cherry in the fall diet during this study may be related to at least one poor cherry year (1991 - pers. obs.) and a small number of fall season scats collected in years with a good cherry crop (1990 and 1992 - pers. obs.)

The reduction of acorns in the bear diet may in part have been due to lingering effects on the surviving oak overstory from the initial gypsy moth defoliation and not just subsequent oak mortality, increased soft mast consumption, or a general acorn crop failure. McConnell (1988) found a reduced acorn crop in oak stands 1 year after

defoliation, and Campbell and Sloan (1977) reported that trees required up to 10 years to completely recover from a single heavy defoliation. Defoliation in the study area began in 1985 and lasted through 1990 with many stands receiving more than 1 defoliation. Acorn crops for the state of Virginia were described as fair but spotty in 1990, good in 1991, and fair in 1992 and 1993 (Denny Martin, Virginia Dept. Game & Inland Fisheries pers. commun.)

It is unclear what effect gypsy moth induced oak mortality has had on SNP's acorn crop. Watson (SNP unpubl. data) sampled stands in SNP with different defoliation histories and found gypsy moth induced oak mortality rates to range from 1% in stands defoliated once in a year with above average rainfall to $\geq 48\%$ in stands defoliated in 3 consecutive years. However, rigorous park-wide estimates of the extent of oak mortality in SNP have not been developed. Gottschalk (1990b) reported that $>60\%$ of an oak stand's basal area must be lost before effects on that stand's acorn production are noted. This conclusion was based on evidence that the intermediate and suppressed crown classes - which normally do not contribute significantly to a stand's acorn production - frequently bear the brunt of the mortality. This thinning effect may even serve to stimulate future mast production in residual trees. It would appear, however, that based on the reduced frequency of acorns in the fall

diet of SNP's bear population, acorns, for whatever reasons, were not as important to the bear population as they were prior to the invasion of the gypsy moth and subsequent oak mortality.

Of further interest is the lack of significant change in the frequency of agricultural crops, specifically corn and apples, in the diet. Both crops are easily accessible outside of SNP in the fall, and it was hypothesized at the start of this investigation that a decrease in the acorn crop, following the gypsy moth induced oak mortality, would lead to an increase in the amount of agricultural crops consumed. Evidently, the increase in the soft mast crops compensated for any reduction in the acorn crop.

PCR values also did not indicate a decline in the nutritional condition of SNP bears. Although the sample size for subadult females may be too small to draw conclusions from, results from the analysis of adult female and subadult male cohorts do not indicate that any change in their physical condition occurred. Results of the adult male PCR comparison were unexpected. Garshelis and Pelton (1981), in Tennessee, reported that adult males occupied the best feeding areas, and Young and Ruff (1982), in Alberta, concluded that adult males regulated the numbers of subadult males. Adult males have also been known to prey upon smaller bears on occasion (Hellgren and Vaughan 1989).

Therefore it would seem unlikely that adult males would suffer nutritionally before adult females or subadult males.

The mean age of adult males in both samples was 5 years, so it is unlikely that the difference in physical condition is due to a difference in age between the 2 adult male cohorts used in this comparison. Carney (1985), Kasbohm (1994), and this study found the age structure of the male cohort to be indicative of an exploited population (Chapter 3). The bear harvest in Virginia has increased almost continually since Carney (1985), and approximately 50% of the yearly harvest comes from the 8 counties that contain SNP (Virginia Department Game and Inland Fisheries 1992). Perhaps larger males are selected for by hound hunters, a common harvest method in Virginia and are no longer as common as in previous years.

The addition of the gypsy moth to SNP has probably benefitted the bear population in the short-term by increasing the diversity of food items available to the bears. SNP bears may be less susceptible to hard mast failures for the immediate future given the apparent increase in soft mast foods. However, the diet of SNP bears probably will be subject to additional change over the next 10 - 20 years. The gypsy moth is still present in the study area, and further defoliation and tree mortality will occur in the future. In addition, regeneration of a new overstory

canopy may eventually shade out many of the soft mast producing plants. This regeneration, however, may not be oak species. Literature reviewed in Chapter 1 indicates that regeneration may be dominated by maple (Acer spp.) or birch (Betula spp.), which do not provide forage for bears. In addition, it is unknown how many bears and individuals of other acorn-consuming species can be supported by SNP's current acorn-production capacity. The loss of even a relatively small percentage of current acorn production may affect the park's long-term carrying capacity. Mattson et al. (1991) recommended long-term studies to adequately document bear food habits in environments where the diet can vary seasonally and annually with changes in the availability of mast crops. Eastern hardwood forests vary in their annual hard and soft mast crop production even under "normal" conditions. The addition of the gypsy moth and subsequent changes in the forest flora will increase this variation. Further study of changes in bear diets due to the influence of the gypsy moth are warranted.

Chapter 3: Population Dynamics

INTRODUCTION

Garner (1986) reported 19-66% of the fall diet of black bears in Shenandoah National Park (SNP), prior to the arrival of the gypsy moth, was acorns. Fall is a critical time for bears. Feeding activity and movements to areas of greater food availability increases as bears put on weight to provide adequate reserves for their winter dormancy and, for females, parturition and nourishment of cubs (Garshelis and Pelton 1980, 1981 and Rogers 1976, 1983). In addition, bears forced to travel greater distances during years when the food supply fails are more vulnerable to mortality from either hunting or damage control activities. These forms of mortality usually take a higher proportion of males (Rogers 1976, Beeman and Pelton 1980, Garshelis and Pelton 1981, and Pelton 1989).

Gypsy moth induced oak mortality in SNP was expected to impact reproduction, survival, the sex ratio, and age structure of the black bear population. A decline in the percentage of oaks in the forest canopy and in the subsequent acorn crop was expected to increase competition among wildlife species dependent on hard mast and individuals within populations for the remaining crop. A

decline in reproduction and survival rates and changes in the sex ratio, and age structure of SNP's bear population was expected to follow.

The effects of nutrition on the population dynamics of various wildlife species have been extensively documented. Matschke (1964) found European wild hogs (Sus scrofa) in an anestrus condition following an acorn failure in Tennessee. The following year, when acorn mast was again available, sows were in an estrous condition. Verme (1967, 1969) found that white-tailed does on a higher nutritional plane produced more fawns and that a higher proportion of yearlings produced fawns. A number of authors have reported that squirrel (Sciurus spp.) numbers, litter sizes, and survival increase with increasing hard mast crops (Christisen and Korschgen 1955, Barkalow et al. 1970, and Nixon et al. 1975). Hoefs (1984) found correlations between forage production on the winter range and lamb production and survival in Dall's sheep (Ovis dalli). Festa-Bianchet (1988) suggested that inadequate nutrition led to higher lamb mortality in bighorn sheep (Ovis canadensis). Cow elk (Cervus elaphus) placed on restricted diets gave birth to smaller calves, which suffered higher mortality than calves born to cows kept on a higher nutritional plane (Thorne et al. 1976).

Adequate nutrition also plays a role in the population

dynamics of black bears. Jonkel and Cowan (1971) found a correlation between the size of the huckleberry crop and black bear reproductive rates in Montana. They felt that suboptimal nutritional conditions on their study area led to a greater age at primiparity, smaller litter sizes and a reduced frequency of litters. LeCount (1982) in Arizona and Elowe and Dodge (1989) in Massachusetts believed that fall forage levels affected the number of cubs born the following year. Schwartz and Franzmann (1991) compared 2 black bear populations in Alaska. The population with the highest growth and reproductive rates inhabited the area of greatest moose abundance. Their findings demonstrated a relationship between moose (Alces alces) calf consumption and black bear population demographics. Rogers (1983) presented evidence from Minnesota that decreased food supplies negatively affected survival of all age classes, age at first reproduction, litter sizes and intervals between litters.

The objectives of this portion of the study were to investigate changes in the reproduction, survival, sex ratio, and age structure of SNP's black bear population related to gypsy moth induced oak mortality.

MATERIAL AND METHODS

Trapping and Handling:

Bears were trapped between June and August during 1990

- 1992 with foot snares and culvert traps. Captured bears were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride at a mixture concentration of 300 mg/ml at dosages of 1.2cc/45.4kg of body weight. The drug was administered by a jab stick or CO₂ pistol.

Immobilized bears were weighed, given numbered color-coded plastic eartags (blue for males and orange for females) and corresponding lip tatoos. Measurements for total length, neck girth, chest girth, zygomatic circumference, hind paw width and length, and front paw width and length also were taken. The first premolar was extracted from the upper jaw for ageing using cementum annuli (Willey 1974). Initial age determination was done by Matson's Laboratory (Milltown, MT), and I confirmed this by rereading each tooth section. In 1992 Yohimbine was administered at dosages of .11 mg/kg to return bears to consciousness after processing was completed.

Primary candidates for radio-collaring were adult females (≥ 3 years old) identified in the field as female bears weighing ≥ 45.4 kg (100 lbs). Collaring full grown adults minimized chances for collars to become ingrown in the bear's neck due to growth. Adult females were targeted to maximize the sample of reproductive parameters.

Suitable female bears were fitted with 164-165 MHz radio transmitter collars (Telonics, Inc., Mesa AZ). A breakaway cotton spacer was placed on the collar to prevent permanent collaring of the animal and to permit retrieval of the collar prior to battery failure (Hellgren et al. 1988).

Reproduction, Survival, Sex Ratio, and Age Structure

In early March, adult females were located in their dens and all accessible females were immobilized to determine their litter size. Accessible females were, with one exception, all in ground-level dens. Only one den tree had a den chamber that was accessible by researchers for the purpose of determining the litter size. Litter sizes of inaccessible adult females were determined by visual observation as soon as possible following den emergence. Litter sizes were compared to preinfestation data (Carney 1985) with the Wilcoxon Rank Sum procedure. Den types were recorded on site.

Survival of radio-collared bears was used to calculate survival rates (Trent and Rongstad 1974). Adult mortality figures reported here are calculated based on tag returns at hunter check stations from captured bears that were eartagged, but not radio-collared. Adult mortality rates were compared to preinfestation data (Carney 1985) with the Z-test for proportions. 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.

Sex ratios and age structure were determined from initial captures. The Z-test for proportions was used to determine differences in capture probabilities of sex and age groups. Differences in ages between sexes and between this study and preinfestation data (Carney 1985) were compared with the Wilcoxon Rank Sum procedure.

RESULTS

Sex Ratio and Age Structure:

Fifty-eight bears were captured 61 times. Although approximately 75% of the trapping effort was with snares, most bears (n=34) were caught in culvert traps. Twenty-four of 34 bears (71%) captured in culvert traps, but only 8 of 27 (30%) captured in snares were males.

The overall sex ratio of initial captures was not different from 1:1 (1.1M:1F, $Z=0.3$, $P=0.76$). The sex ratio of the adult (≥ 3 years of age, n=37) and subadult (< 3 years of age, n=21) classes also were not different from 1:1 (.95M:1F, $Z=-0.12$, $P=0.9$ and 1.3M:1F, $Z=0.65$, $P=0.52$ respectively). The overall and adult sex ratios determined by Carney (1985) (2.03M:1F, n=115 and 1.3M:1F, n=64, respectively) were not different ($Z=1.78$, $P=0.08$ and $Z=0.78$,

$P=0.44$, respectively) from ratios in this study, however; the preinfestation subadult sex ratio favored males more than this study (3.8M:1F, $n=48$, $Z=2.56$, $P=0.01$).

At initial capture female bears averaged 4.9 years of age ($n=28$), while male bears averaged 3.6 years of age ($n=30$). The age range for both sexes was 1 to 14 years (Fig. 2); however, female bears were on average older than male bears ($Z=2$, $P=0.05$). Although male bears captured in this study averaged 0.4 years older than those captured by Carney (1985, $\bar{x}=3.2$, $n=76$) this difference was not significant ($Z=0.61$, $P=0.54$). In addition, ages of female bears captured in this study were not different from those captured prior to the gypsy moth infestation of Shenandoah National Park ($\bar{x}=5.1$, $n=36$, $Z=-0.007$, $P=0.99$, Carney 1985).

Reproduction:

Litter size of radio-collared female bears from 1991 - 1993 averaged 2.25 cubs per litter ($n=12$), which was not different ($Z=0.69$, $P=0.49$) from the average litter size of 2.0 ($n=21$) reported by Carney (1985) prior to gypsy moth induced oak mortality in SNP. Four litters of 1 cub, 2 litters of 2 cubs, 5 litters of 3 cubs and 1 litter of 4 cubs were produced. The sex ratio of cubs in the natal den was 1.4M:1F. This was not different from 1:1 ($n=22$, $Z=0.84$, $P=0.4$). However, the ratio of male to female cubs in this

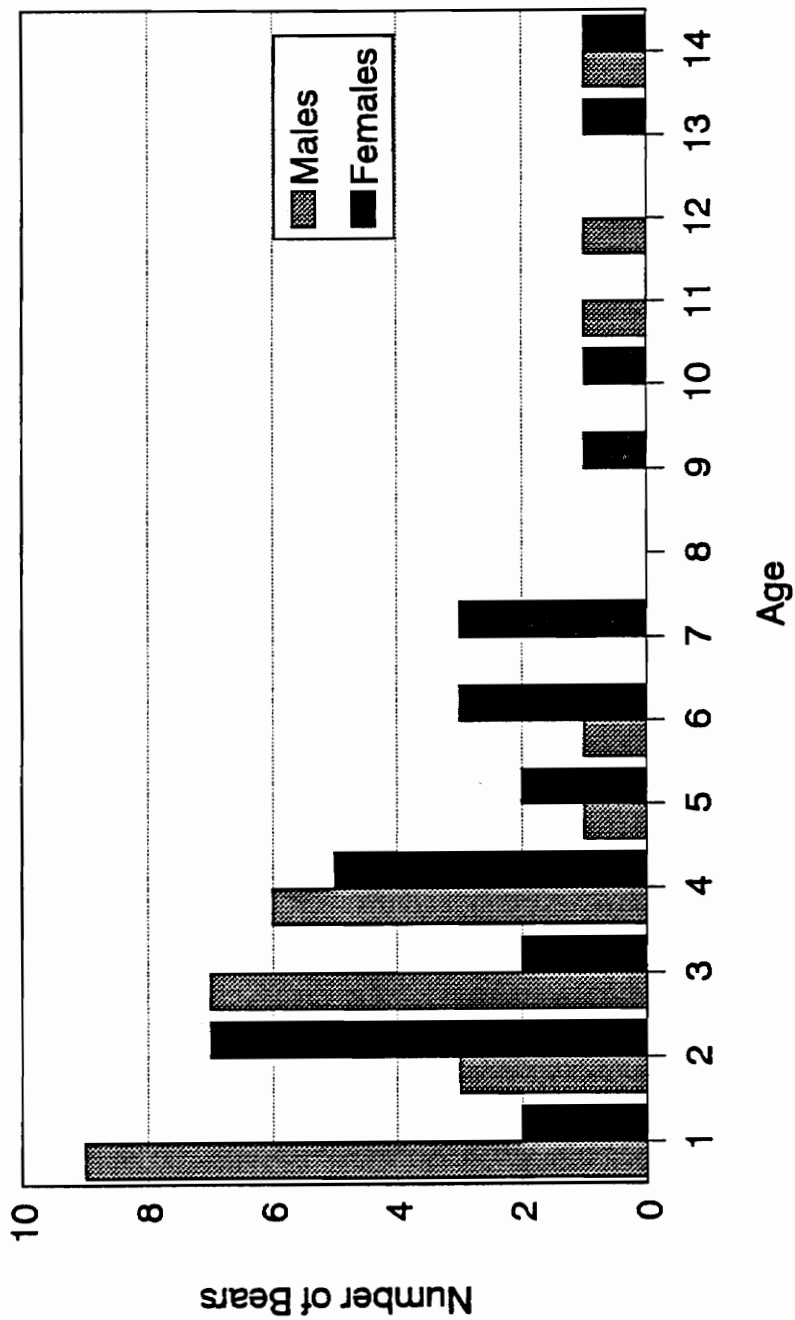


Figure 2. Age frequencies of black bear captures in Shenandoah National Park, Virginia 1990 - 1992.

study was greater than during preinfestation data (0.85M:1F n=24 $Z=-3.71$, $P<0.0001$, Carney 1985).

Four female bears were monitored for >2 consecutive years in this study. Two bears produced litters in consecutive years when they lost their original litter by midsummer. One of these 2 bears, dating back to March 1990 (Kasbohm 1994), 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. One 4-year-old female was captured accompanied by a single young-of-the-year cub. This would indicate that she had bred at least once by 3.5 years of age. None of the remaining 4 year old females (n=4) showed evidence of breeding at the time of their July capture dates. The reproductive history of 2 of these remaining 4-year-olds is unknown. One of the other 2 was bred the summer she was captured (and aged) and produced cubs that winter. The remaining bear bred at 5.5 years of age. I could not determine if these were the first litters produced by these 2 females.

None of the 2- or 3-year-old females captured during this study showed evidence of having bred previously (e.g. lactating or accompanied by cubs). However, no 2- or 3-year-old female met the minimum size requirement of 45.4kg

(100 lbs) to be fitted with a radio collar. Therefore it was possible that 2- and 3-year-old females were bred prior to or after capture and subsequently produced and raised cubs.

On 5 occasions adult female bears did not den during this study. Their reproductive status was either unknown or they were solitary (Table 5). Twenty-six different dens were used on 29 other occasions by radio-collared adult female bears. Den reuse occurred on 3 occasions by 3 different bears; twice in trees and once on the open ground. Forty-seven percent of dens were in above-ground tree cavities (Table 5).

Cub Survival:

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

Table 5. Den types selected by adult female black bears for the winters of 1990/91 - 1992/93 in Shenandoah National Park, Virginia.

Den Type	Pregnant		With yearlings		Reproductive Status					
	n	% ^a	n	%	Solitary	Unknown	Total	Total		
			n	%	n	%	n	%		
Tree cavity ^b	4	11.8	2	5.9	2	5.9	8	23.5	16	47.1
Rock cavity	6	17.6	1	2.9					7	20.6
Root excavation	1	2.9							1	2.9
Open ground den	3	8.8	2	5.9					5	14.7
No den					2	5.9	3	8.8	5	14.7
Total	14	41.2	5	14.7	4	11.8	11	32.4	34	100.0

^a Percent of 34 denning incidents.

^b All tree cavities were in living trees at the time of denning.

Adult Survival:

Twenty-eight adult females were radio tracked for 11,071 radio days (\bar{x} =395 days/bear, range =8-1004 days). One subadult and seven adult males were tracked for 2,513 radio days (\bar{x} =314 days/bear, range =8-540 days). No radio-collared bears were known or suspected to have died during this period. One adult female died in her den, but her death appeared to be a reaction to the immobilizing drug, and her death was not factored into survival calculations. No recovered collars bore any evidence of having been cut off by hunters or poachers, nor were any carcasses, blood etc. ever located in the vicinity of a dropped collar. A number of radio transmitters did fail before the cotton spacer parted; however, in each case it was coincidental with the expected end of the battery life in the transmitter. Several bears wearing failed transmitters were seen or captured later. Therefore maximum survival rates of male and female bears in this study were 100%. Carney (1985) calculated maximum annual survival rates of 60% and 95% for male and female bears, respectively.

At least 7 of 61 eartagged bears (n=61 includes 3 male cubs tagged in their natal den) died between June 1990 and January 1993. One subadult male was struck by an automobile north of the park. The remaining 6 were legally taken by hunters outside of park boundaries. The 6 hunting

mortalities consisted of 2 adult males, 3 adult females and 1 subadult male. Minimum average annual mortality was 3.8% over this time period. Carney (1985) calculated a minimum average annual mortality rate of 6.1% for eartagged bears over a similar length of time (1982-1985) prior to the gypsy moth's arrival in SNP. These figures were not different ($Z=-1.17$, $P=0.24$).

Five additional and unmarked bears were known to have died in the study area during the course of this study. Two subadult males were electrocuted by power lines and a subadult female apparently suffocated in an irrigation pipe. The carcasses of an adult female and a bear of unknown age and sex were recovered by SNP personnel under circumstances believed to have involved poachers.

DISCUSSION

Age data collected in this study indicated that the bear population of Shenandoah National Park exhibits some of the characteristics of an exploited population. This is consistent with data collected by Carney (1985) and Kasbohm (1994) from SNP. Studies of relatively unexploited black bear populations by Beecham (1980), LeCount (1982), Young and Ruff (1982) and Hellgren and Vaughan (1989) averaged 73% adults in the capture data with a mean age >4 years. Conversely more exploited black bear populations have a more

even ratio of adults and subadults and a mean age of <4 years (Jonkel and Cowan 1971, Beecham 1980, and Young and Ruff 1982). In this study 64% of the animals trapped were adults, midrange between the exploited and unexploited ratios from other studies. The percentage of adults in this study is higher than the 50% adult ratio reported by Kasbohm (1994), but lower than the 69% and 67% adult ratios reported by Raybourne (1976) and Carney (1985) respectively, for SNP, as well as the 71% adult percentage reported by Stickley (1957) for the mountains of Virginia outside of SNP.

Mean age of all adults in this study was 4.2 years. The lower mean age of males versus females obtained in this study (3.6 versus 4.9) probably reflects their greater vulnerability to hunting. This general trend towards lower age structures and lower adult:subadult ratios may reflect population changes due to hunting. Bear harvests in Virginia grew from 230 in 1976 to 781 in 1993. The long and narrow shape of SNP does not serve to entirely insulate resident bears, especially the more wide-ranging male cohort, from hunting pressure just beyond its borders. It is a general tenet of bear ecology that male bears are more susceptible to trapping, as well as hunting, than are female bears (Bunnell and Tait 1981). Capture records of relatively unexploited black bear populations usually show a preponderance of male bears (Beecham 1980, LeCount 1982, and

Hellgren and Vaughan 1989). The nearly equal sex ratios obtained in this study reflect similar results and conclusions reached by Kasbohm (1994). The population is likely skewed towards females: possibly a further result of increased hunting pressure on males. Further evidence supporting this conclusion is that only 1 of 30 captured males bore evident scars from fighting although virtually all trapping was done during, or just after, the peak of the breeding season.

Reasons for the sex bias in the trapping methods are unclear. Female bears have smaller home ranges than males in SNP (Garner 1986 and Kasbohm 1994), and therefore may be more likely to encounter a snare within their home range than male bears. Males may be less cautious than females about entering culvert traps even though they may not encounter them as frequently. It is unclear why culvert traps were generally more effective at capturing bears than were snares. A possible hypothesis is that culvert traps had to be placed along roadsides due to the logistics of their transport. These were unpaved secondary roads in SNP where most traffic is limited to hikers. Perhaps the abundance of soft mast, such as Rubus spp., along these secondary roads served as an attraction for foraging bears.

Changes in the age and sex structure of SNP's bear population are, for the immediate future, more likely to be

driven by hunting pressure outside SNP than by the gypsy moth infestation within SNP. Neither the mean ages of the male or female cohorts, nor the adult:subadult and male:female ratios were significantly different from preinfestation data collected by Carney (1985). The one exception - the decline in the ratio of subadult males - may reflect increased hunting pressure and greater vulnerability of young, dispersing male bears.

Documented mortality of SNP bears appears to be almost entirely due to direct or indirect human causes. None of the 13 bears known to have died during this study was attributed to natural causes. The one research-related fatality, however, may have been aggravated by the bear's poor physical condition. The only aggressive action between bears that was witnessed by the investigators involved a nonlethal conflict between an adult sow and two subadults (one female and one of unknown sex) over a deer carcass. As with Carney (1985) and Kasbohm (1994) hunting was the leading cause of bear deaths in the SNP ecosystem.

Mortality of eartagged and radio-collared bears, however, was likely underestimated in this study for several reasons. Prior to the 1991 hunting season, reporting requirements for hunter-killed bears in Virginia were not as stringent as they were in 1991 and afterwards. It is likely that some eartags from legally harvested bears were not

recovered by the investigators. Natural mortality of eartagged bears was not known. Road access and logistic constraints in SNP also limited much of the trapping to SNP's interior. The small home ranges of resident adult females reported in this study (Chapter 4) and by Garner (1986) probably meant that radio-collared females did not spend as much time over SNP's boundaries, where they would be vulnerable to hunters, as might resident females in areas closer to or overlapping SNP's perimeter. Although no radio-collared bears were lost to poachers in this study, poaching does occur in SNP (pers. obs.). Carney (1985) and Kasbohm (1994) reported that 11% and 5% respectively of radio-collared bears were poached in their studies of SNP's bear population. Poaching of tagged bears not wearing radio collars likely would never be discovered. Lastly, the most vulnerable segment of the population, males, were not as well represented in the sample of radio-collared animals in this study. Only 8 males were collared, and one of these shed his collar after only 8 days. However, both Carney (1985) and Kasbohm (1994) reported high maximum annual survival rates, of $\geq 90\%$ for females in SNP. Maximum annual survival rates for males, by contrast, were only 60% for Carney (1985) and 36% for Kasbohm (1994).

The 100% survival rate of radio-collared adult females in this study is still consistent with high female survival

rates reported in preinfestation data (Carney 1985). Gypsy moth induced mortality of oaks appears not to have diminished SNP's food base sufficiently (Chapter 2) to force females to increase their movements 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 (Virginia Department of Game and Inland Fisheries pers. commun.) 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.

Given the promiscuous breeding habits of bears, the most important cohort to the future of SNP's bear population is the adult females. Even if hunting pressure outside SNP has reduced the number of males in the population, sufficient males still appear to be present to breed all receptive females. The home ranges of male bears are substantially larger than female bears and there is usually considerable range overlap between and among both sexes (Lindzey and Meslow 1977, Reynolds and Beecham 1980, Garner 1986, and Powell 1987). This arrangement probably aids in putting most receptive females in contact with 1 or more males. In Washington, Barber and Lindzey (1986) found females in estrous to associate with up to 4 different

males. In this study, 1 receptive female was observed with 2 large males and another trapwise, and evidently receptive, female appeared to have attracted 4 different males to a trapsite she was visiting over a period of 2 weeks.

Reproduction and cub survival to 1 year of age did not appear to be adversely affected by gypsy moth induced oak mortality. The results of this study were similar to results obtained by Kasbohm (1994) during the initial defoliation events wrought by the gypsy moth and to preinfestation data gathered by Carney (1985).

Rogers (1976) and Eiler et al. (1989) believed cub survival was connected with mast availability; however, 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. Therefore the survival rates of cubs in this study appear to be in the mid-range of other reported rates.

Litter size in black bears has been correlated with the previous fall's mast supply (Jonkel and Cowan 1971, Rogers 1976, LeCount 1982, Eiler et al. 1989, and Elowe and Dodge 1989). Other factors involved in reproduction, age at first breeding and frequency of litters, also have been tied to

diet quality (Jonkel and Cowan 1971, Rogers 1976, Bunnell and Tait 1981, and McLaughlin et al. in press). Although the evidence in this study is not strong, indications are that age at first breeding and the frequency of litters are at least still consistent with data provided prior to gypsy moth induced oak mortality in Virginia (Stickley 1957, Raybourne 1976, and Carney 1985). These studies indicated alternate-year litter production and evidence for 2- and 3-year-old females breeding. Eastern black bear populations generally have a lower age of first breeding than do western populations and usually produce litters in alternate years due to the rich and various mast crops of eastern hardwood forests (Jonkel and Cowan 1971, Bunnell and Tait 1981, Alt 1989, Eiler et al. 1989, and Elowe and Dodge 1989).

One of the most anticipated effects of the gypsy moth infestation was a decline in litter size due to a decline in the available oak mast. Jonkel and Cowan (1971), in Montana, LeCount (1982), in Arizona, Eiler et al. (1989), in Tennessee, Elowe and Dodge (1989), in Massachusetts, and McLaughlin (in press), in Maine, reported a decline in average litter size or general failure to produce litters following a decline in the fall food supply. The average litter size of 2.25 cubs in this study, however, is not significantly different than the 2.0 average reported by Carney (1985) prior to the gypsy moth's arrival in SNP.

With access to a larger and more varied hard and soft mast crop, eastern black bear populations tend to have larger litter sizes ($\bar{x}=2.4$) than western populations ($\bar{x}=1.7$) (Bunnell and Tait 1981). Data from this study (Chapter 2) indicate that bears in SNP were able to successfully exploit soft mast following the arrival of the gypsy moth and a decline in overstory oak numbers, without suffering a decline in litter size or a general failure to produce litters.

Gypsy moth induced oak mortality was originally predicted to impact the reproduction, survival, and sex ratio, and age structure of SNP's bear population. A decline in the hard mast crop, due to extensive oak mortality was expected to decrease reproduction and survival and lead to changes in the sex ratio and age structure. These changes were expected to occur as a hard mast shortage forced resident SNP bears to increase their movements to obtain sufficient forage, likely taking them outside SNP and into agricultural areas where they would be vulnerable to hunting and could cause property damage. These hypotheses were not borne out for the present time with the available evidence. Litter size, cub and adult survival, age structure, and sex ratios remained relatively unaffected by gypsy moth induced tree mortality. Evidence provided by diet analysis (Chapter 2) suggests that the omnivorous

dietary habits of black bears allowed them to switch to available soft mast species without any appreciable impacts on their population dynamics. Literature reviewed in Chapter 1 suggests that these soft mast species would be more readily available to bears as the overstory mortality would allow more sunlight to reach the forest floor, thus stimulating their growth.

Chapter 4: Home Range and

Habitat Use

INTRODUCTION

Gypsy moths have had substantial effects on the forests of Shenandoah National Park (Kasbohm 1994, Watson, SNP unpubl. data). During 1985 - 1990 60% of the study area (over 23,000 ha) was defoliated (>60% canopy loss) 1-3 times. This study was initiated to determine the impacts of oak mortality induced by defoliation, on Shenandoah National Park's (SNP) black bear population. Oak species, which compose >50% of the forest canopy in SNP, are a preferred food for the larval stages of the gypsy moth (Gansner et al. 1987).

Gypsy moth induced tree mortality and resulting habitat alterations may have a significant long-term impact on the bear population. Regeneration underneath stands of dead trees may result in changes in the future overstory composition and an increase in soft mast in the understory (Chapter 1). Oak mortality may result in a reduction in the acorn crop, an important bear food in the southeastern hardwood forest (Eagle 1979, Beeman and Pelton 1980, Carlock et al. 1983) and SNP (Garner 1986). A decline in the acorn

resource will require bears to find alternative food sources (Chapter 2) and may result in changes in habitat use and range sizes.

The objectives of this portion of the study were to investigate black bear use of stands containing different levels of gypsy moth induced oak mortality. In addition, I sought to identify changes in movements, home range size and use of forest cover types related to gypsy moth induced oak mortality. Results were compared with preinfestation data compiled for SNP's bear population (Garner 1986).

MATERIALS AND METHODS

Trapping and Handling

Bears were trapped between June and August during 1990 - 1992 with foot snares and culvert traps. Captured bears were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride at a mixture concentration of 300 mg/ml at dosages of 1.2cc/45.4kg of body weight. The drug was administered by a jab stick or CO₂ pistol.

Immobilized bears were weighed, given numbered color-coded plastic eartags (blue for males and orange for females) and corresponding lip tatoos. Measurements for total length, neck girth, chest girth, zygomatic

circumference, hind paw width and length, and front paw width and length also were taken. The first premolar was extracted from the upper jaw for ageing using cementum annuli (Willey 1974). Initial age determination was done by Matson's Laboratory (Milltown, MT), and I confirmed this by rereading each tooth section. In 1992 Yohimbine was administered at dosages of .11 mg/kg to return bears to consciousness after processing was completed.

Primary candidates for radio-collaring were adult females (≥ 3 years old) identified in the field as female bears weighing ≥ 45.4 kg (100 lbs). Collaring full grown adults minimized chances for collars to become ingrown in the bear's neck due to growth. Adult females were targeted in order to maximize the sample of reproductive parameters. Suitable female bears were fitted with 164-165 MHz radio transmitter collars (Telonics, Inc., Mesa AZ). A breakaway cotton spacer was placed on the collar to prevent permanent collaring of the animal and to permit retrieval of the collar prior to battery failure (Hellgren et al. 1988).

Home Range and Habitat Use

Home range size and habitat use data were obtained by ground triangulation and aerial location of radio-collared animals from June 1990 through December 1991. Although some bears remained collared until 1993, location data collected

after December 1991 were not used due to the infrequency of relocations. Locations were obtained during daylight hours between 0700 and 2000. Quigley (1982) in the Great Smokey Mountains National Park of Tennessee and North Carolina reported bears to be most active between 0600 and 2100. Elowe (1984) reported only limited nocturnal activity in Massachusetts, and then only during the breeding seasons. Telemetry data from SNP indicated bears had a similar activity pattern. Bears were located as often as possible, but no more often than once in a 24-hour period. White and Garrott (1990:147) suggest that locations could be considered independent if sufficient time had elapsed for an animal to move from one end of its home range to the other. The size and mobility of black bears and the relatively small size of the ranges calculated for SNP in this study, Garner (1984) and Kasbohm (1994), suggests that locations taken 24 hours apart likely were independent in this study.

Ground triangulations were made with hand-held, directional, H-antennas. Compass bearings were taken in the direction of the strongest signal and plotted on United States Geological Survey 1:24,000 topographic maps. Compass bearings were taken from at least 3 points that could be accurately located on the map and were accessible within a 30 minute time frame. This procedure helped to minimize bias due to animal movement. Locations were assigned

Universal Transverse Mercator (UTM) coordinates. Only ground locations with ≥ 3 bearings, or in which the bear was sighted or heard were used for further analysis.

Aerial locations were taken from fixed-wing aircraft with directional H-antennas mounted under each wing. Originally, aerial locations were determined using the LORAN-C system; however, the accuracy of this system was judged to be insufficient, and its use was discontinued when locations were found to be off by as much as 1600m. All aerial locations used for data analysis were plotted by circling the strongest signal at altitudes of ≤ 240 meters and recording the location on a topographic map. In many instances, following leaf drop in the fall, it was possible to visually locate bears from the air.

Location accuracy was estimated using test collars placed in a location unknown to the radio-tracker. Aerial locations were accurate within a mean of 119m (range 50 - 200m, n=8) from the transmitter's actual location and ground locations within a mean of 154m (range 50 - 400m, n=12). Mean bearing error associated with ground triangulation was 6.6° (range $0^\circ - 28^\circ$ n=40).

Home range size was estimated using the combined ground and aerial locations for an animal. Home range boundaries were plotted using 100% convex polygons and program TELEM (Koeln 1980). Because fieldwork did not commence before May

and because radio-tracking efforts were limited during the summer (June 16 - August 31) season, due to trapping efforts, only the fall (September 1 - December 20) season was used for the determination of seasonal home range. However, it was felt that enough locations were obtained over the combined spring (March 20 - June 15) summer, and fall seasons to calculate annual home range. Garner (1986) believed that tracking female bears for ≥ 6 months was sufficient to determine annual range size in SNP. Program HOMERANG was used to determine the relationship between number of locations and range size for each individual in this study (Raphael and Brink 1988). Only those individuals whose range size was not a function of the number of locations were retained for further analysis.

Differences in range size before and after gypsy moth induced oak mortality were analyzed using the Wilcoxon Rank Sum procedure. Preinfestation data were obtained for 1982 - 1984 from Garner (1986) and post-mortality data for 1990 and 1991 from this study. All data were pooled within a mortality period (i.e., 1982 - 1984 and 1990 - 1991) because of small yearly sample sizes. Female bears were not separated by reproductive class because neither Kasbohm (1994) nor Garner (1986) demonstrated consistent differences in fall or annual home range size between solitary females and females accompanied by cubs in SNP.

Use of oak mortality areas and forest cover types was determined using the location of all collars located after their breakaway cotton spacer rotted through, all aerial locations, and ground locations where the bear was seen or heard in an undisturbed state. Additional ground triangulations were used when 3 bearings were separated by a minimum of 30° each, when at least 90° separated 2 of the 3 bearings, and if the polygon formed by the 3 (or sometimes more) bearings could be enclosed within a circle with a radius of 100m. These locations were thought to be the best of the ground locations and likely had an average error of less than the 154m determined by the test collars for all ground locations. Also, these locations likely were less affected by signal bounce or bearing error than the remaining ground locations, which were used only for home range analysis.

Habitat location coordinates were entered into the ATLAS Geographic Information System (GIS) used by the Natural Resources Office at SNP to map use of the various forest cover types. Habitat location coordinates also were entered into Geographic Resource Analysis Support System (GRASS) GIS to determine use of stands by defoliation history. Defoliation history was determined by the Resource Management Office of SNP using aerial color infra-red photographs taken during peak defoliation of each year (late

June - early July, Keith Watson, SNP entomologist pers. commun.). Defoliated stands were classified as stands suffering >60% canopy loss (Fig. 3). Defoliation histories were digitized into GRASS GIS using 30 x 30m pixels. Oak mortality rates based on defoliation history were determined from transect counts conducted by the Natural Resources Office of SNP (Watson, SNP unpubl. data, Fig. 4). Therefore, use of a stand with a given rate of oak mortality is actually use of a stand with a known defoliation history, which has an expected level of gypsy moth induced oak mortality as determined by Watson (SNP, unpubl. data). Oak mortality data were gathered in the fall of 1990 (Watson SNP unpubl. data). As relatively little defoliation occurred in the study area in 1990 and 1991, and 1991 rainfall patterns were described as above average (Watson, SNP unpubl. data), the extent of oak mortality was assumed to have remained relatively constant during the radio-telemetry period. Although 42 species of hardwoods and conifers were sampled, oaks comprised 86-94% of gypsy moth induced mortality (Watson, SNP unpubl. data).

Forest cover types were mapped by the Resource Management Office of SNP using color infra-red photography (Teetor 1988). Forest cover types were classified into 6 different habitat types based on the dominant overstory tree species (Table 6). These cover types were chestnut oak

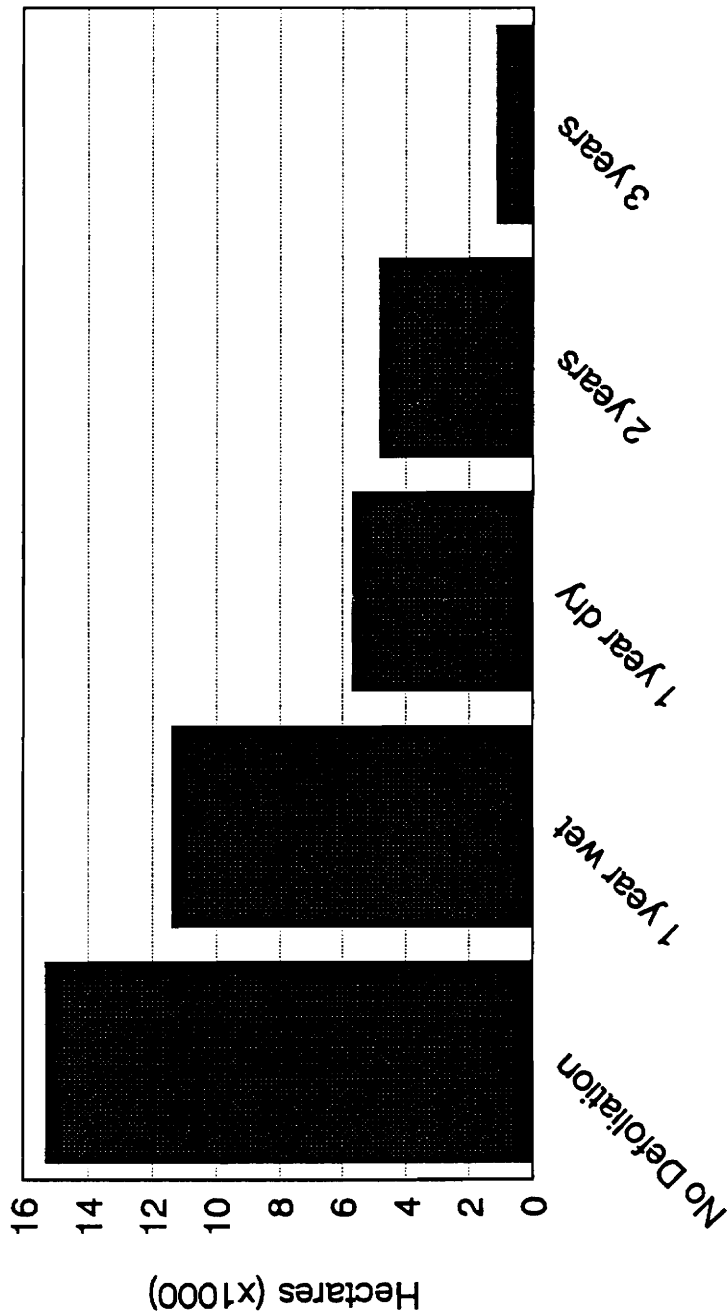
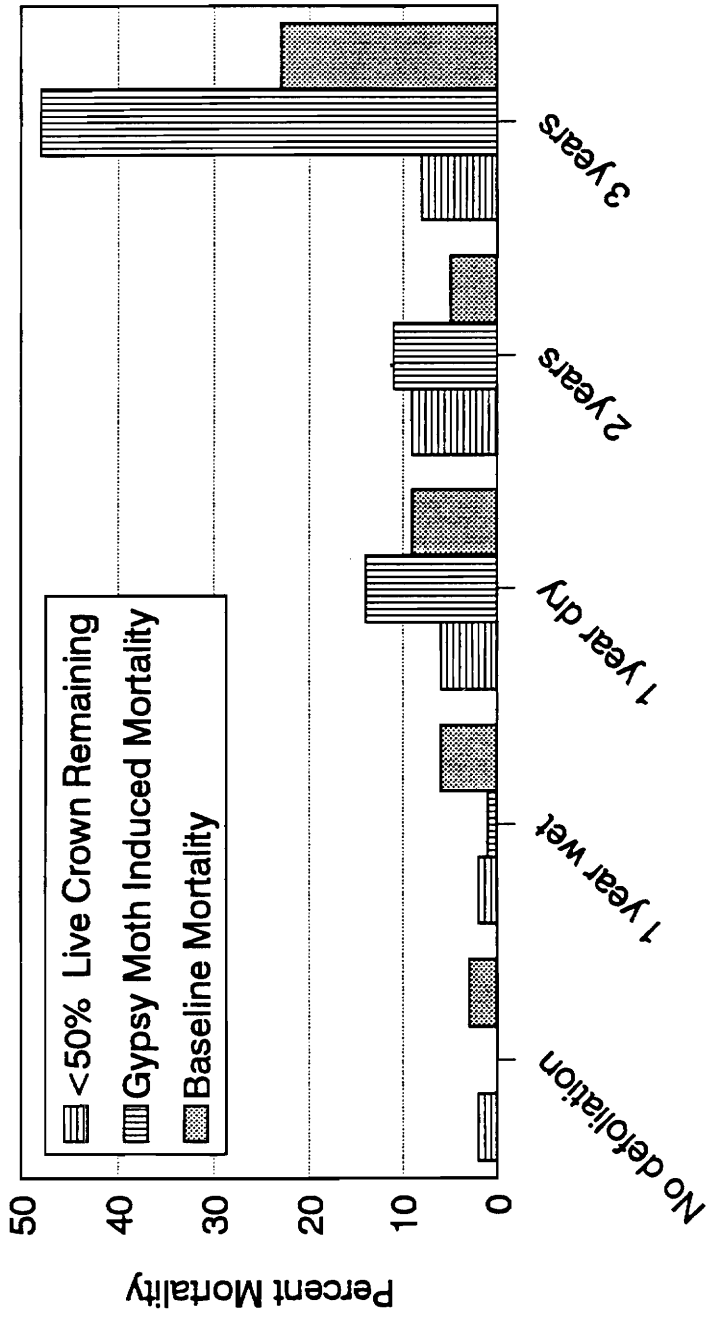


Figure 3. Defoliation classes (1986 - 1990) for the study area in Shenandoah National Park, Virginia. Classes are defined as follows: No defoliation - never defoliated, 1 year wet - defoliated once in a year with above average rainfall, 1 year dry - defoliated once in a year with average or below average rainfall, 2 years - defoliated in 2 consecutive years, and 3 years - defoliated in 3 consecutive years.



Defoliation Class

Figure 4. Percentage of oak mortality by defoliation class in Shenandoah National Park, Virginia as of 1990. Baseline (existing, preinfestation) mortality after 3 years consecutive defoliation may be difficult to separate from gypsy moth induced mortality (Watson, SNP unpubl. data). Trees with <50% of a living crown intact were not expected to significantly contribute to mast production. Classes are defined as follows: No defoliation - never defoliated, 1 year wet - defoliated once in a year with above average rainfall, 1 year dry - defoliated once in a year with average or below average rainfall, 2 years - defoliated in 2 consecutive years, and 3 years - defoliated in 3 consecutive years.

Table 6. Descriptions and accuracy values for the 7 major forest cover types within the study area of Shenandoah National Park, Virginia.

Name ^a	Description ^b Size and Accuracy ^c
Chestnut Oak:	Found on the dryer and poorer sites of SNP with steep slopes and shallow soils. Commonly associated overstory species include northern red oak, hickory (<u>Carya</u> spp.), scarlet oak (<u>Quercus coccinea</u>), black oak (<u>Q. velutina</u>), red maple (<u>Acer rubra</u>), black locust pitch pine (<u>Pinus rigida</u>) and Virginia pine (<u>P. virginiana</u>). 15,651 ha. k=.66
Yellow Poplar:	Productive type found on cool moist sites with moderate to deep, fertile and well-drained soils. Commonly associated overstory species include northern red oak and white oak (<u>Q. alba</u>), eastern hemlock, eastern white pine (<u>P. strobus</u>), sugar maple (<u>Acer saccharum</u>), white ash (<u>Fraxinus americana</u>), American beech (<u>Fagus grandifolia</u>), basswood (<u>Tilia americana</u>), black locust, red maple and black birch (<u>Betula lenta</u>). 7,857 ha. k=.70
N. Red Oak:	Generally cool sites with good moisture conditions. Commonly associated overstory species include other oak species, hickory species white ash, black birch and yellow poplar. 5,029 ha. k=.69
Cove Hardwood:	Cool moist sites in protected coves. Common overstory species include sugar maple (<u>A. saccharum</u>), American beech, black birch, red maple, hickory species eastern hemlock, black locust, yellow poplar and chestnut oak. 6,983 ha. k=.66
Black Locust:	An early succession forest type dominated by black locust in pure stands during the first years of secondary succession. Due to the wide range of site conditions on which this type is found, associated overstory species may include almost any native SNP species. 1,681 ha. k=.76
Pine/Hemlock:	Stands of pitch pine (<u>P. rigida</u>), Virginia pine, and eastern hemlock growing in pure stands or in association with oaks, yellow birch (<u>B. alleghaniensis</u>), Table Mountain pine (<u>P. pungens</u>), eastern white pine or with each other. 1,117 ha. k=.67

^a Forest cover type name represents dominant tree species (>60% canopy coverage) in the overstory.

^b Ravlin et al. (1990) provides a more complete description of forest cover types and their associated species in SNP.

^c Accuracy values are defined for the study area using data from Teetor (1988). One represents 100% accuracy.

(Quercus prinus), northern red oak (Q. Rubra), yellow poplar (Liriodendron tulipifera), black locust (Robinia pseudoacacia), pine/eastern hemlock (Pinus spp. and Tsuga canadensis) and cove hardwoods. Accuracy of the resultant map was tested using a discrete multivariate analysis technique developed by Congalton et al. (1983). In the absence of large-scale perturbations other than gypsy moth defoliation in the forests of SNP, the availability of forest cover types was believed to be unchanged during the study.

Use versus availability for different levels of oak mortality and forest cover types were compared using chi-square goodness-of-fit tests (Neu et al. 1974 and Byers et al. 1984). Bonferonni-z confidence intervals (Byers et al. 1984) were then used to test for disproportionate use of cover types and stands of oak mortality. Data were pooled within a season among bears and between years. White and Garrott (1990:191) believed pooling data was appropriate when relatively few locations were obtained for many animals. Habitat use was analyzed by season; summer (June 16 - August 31), early fall (September 1 - October 15) and late fall (October 16 - December 20). Spring (April 1 - June 15) and winter (December 21 - March 31) seasons were not analyzed for habitat use patterns because intensive radio-telemetry efforts were not sustained during those

seasons. Use versus availability of forest cover types was compared between this study and preinfestation data (Garner 1986) with chi-square contingency table analysis.

Locations used to analyze use of forest cover types and areas of tree mortality also were utilized to determine the proportion of time that adult females were outside of SNP. Garner (1986) described 3 zones of use for SNP and its surrounding environs. Zone A was located within the boundaries of SNP. Zone B was outside of SNP, but within 2-3 km of the boundary line, and Zone C was >2-3 km from the boundary line. The Z-test for proportions was used to analyze differences between this study and Garner (1986).

RESULTS

Home Range

Female fall ranges ($\bar{x}=10.2$ km² in 1990 and $\bar{x}=4.7$ km² in 1991; $Z=1.64$, $P=0.1$) and annual ranges ($\bar{x}=12.3$ km² in 1990 and $\bar{x}=7$ km² in 1991; $Z=-1.97$, $P=0.12$) did not differ between years (Table 7). However, fall ranges ($\bar{x}=7.1$ km² postinfestation and $\bar{x}=14.2$ km² preinfestation; $Z=-3.24$, $P=0.001$) and annual ranges ($\bar{x}=9.4$ km² postinfestation and $\bar{x}=23.0$ km² preinfestation; $Z=-3.06$, $P=0.002$) of female bears were smaller in this study than prior to the gypsy moth's arrival (Table 7).

Table 7. Black bear range sizes (km²) before^a and after^b gypsy moth induced oak mortality in Shenandoah National Park, Virginia.

Sample	N	Mean ^c	SD	Range
Female Fall Ranges				
Fall 1990	10	10.2	7.8	2.0 - 20.8
Fall 1991	13	4.7	3.6	1.1 - 12.5
Female Annual Ranges				
Annual 1990	7	12.3	7.6	4.3 - 21.1
Annual 1991	8	7.0	5.0	2.5 - 16.4
Female Fall Ranges				
Before Mortality	42	14.2	13.0	3.0 - 70.2
After Mortality	23	7.1	6.3	1.1 - 20.8
Female Annual Ranges				
Before Mortality	23	23.0	18.1	6.5 - 85.4
After Mortality	15	9.4	6.7	2.5 - 21.1

^a 1982 - 1984 Garner (1986).

^b 1990 -1991 this study.

^c 100% convex polygons.

Adult female bears in this study were never located >2-3 km outside the boundary of SNP. Adult females were located outside of SNP, but within 2-3 km of the boundary 5% of the time during the summer, 4% in the early fall and 1% in the late fall (Table 8). This was less ($Z=-3.69$, $P<0.001$, $Z=-3$, $P<0.01$, and $Z=-4.12$, $P<0.001$ respectively) time spent outside of SNP than reported by Garner (1986).

Habitat Use

Data from 28 adult female bears were used for analysis of use of forest cover types and areas of oak mortality. Each individual bear contributed an average of 3.6% of the data points (range = 0.2-9%) used for the analysis.

Use of forest cover types differed from availability in all 3 seasons; summer ($\chi^2=15.61$, 5=df, $P<0.01$), early fall ($\chi^2=32.45$, 5=df, $P<0.001$) and late fall ($\chi^2=26.4$, 5=df, $P<0.001$). Yellow poplar stands were used less than expected in all seasons ($P<0.05$). Red oak was used more than expected in the early fall, and cove hardwood was used more than expected in the late fall ($P<0.05$, Fig. 5). Chestnut oak, black locust and pine/hemlock cover type use was not different from availability in any season.

Direct comparisons between this study and preinfestation data from Garner (1986) exhibit differences

Table 8. Seasonal distribution of adult female black bears inside and outside Shenandoah National Park, Virginia before^a and after^b gypsy moth induced oak mortality.

Season	N	Percent of Locations		
		Zone A ^c	Zone B ^d	Zone C ^e
Summer				
Before Mortality	361	79	19	2
After Mortality	100	95	5	0
Early Fall				
Before Mortality	176	84	14	2
After Mortality	102	96	4	0
Late Fall				
Before Mortality	183	92	8	0
After Mortality	265	99	1	0

^a 1982 - 1984 Garner (1986).

^b 1990 - 1991 this study.

^c Inside SNP boundaries.

^d <2-3 km outside SNP boundaries.

^e >2-3 km outside SNP boundaries.

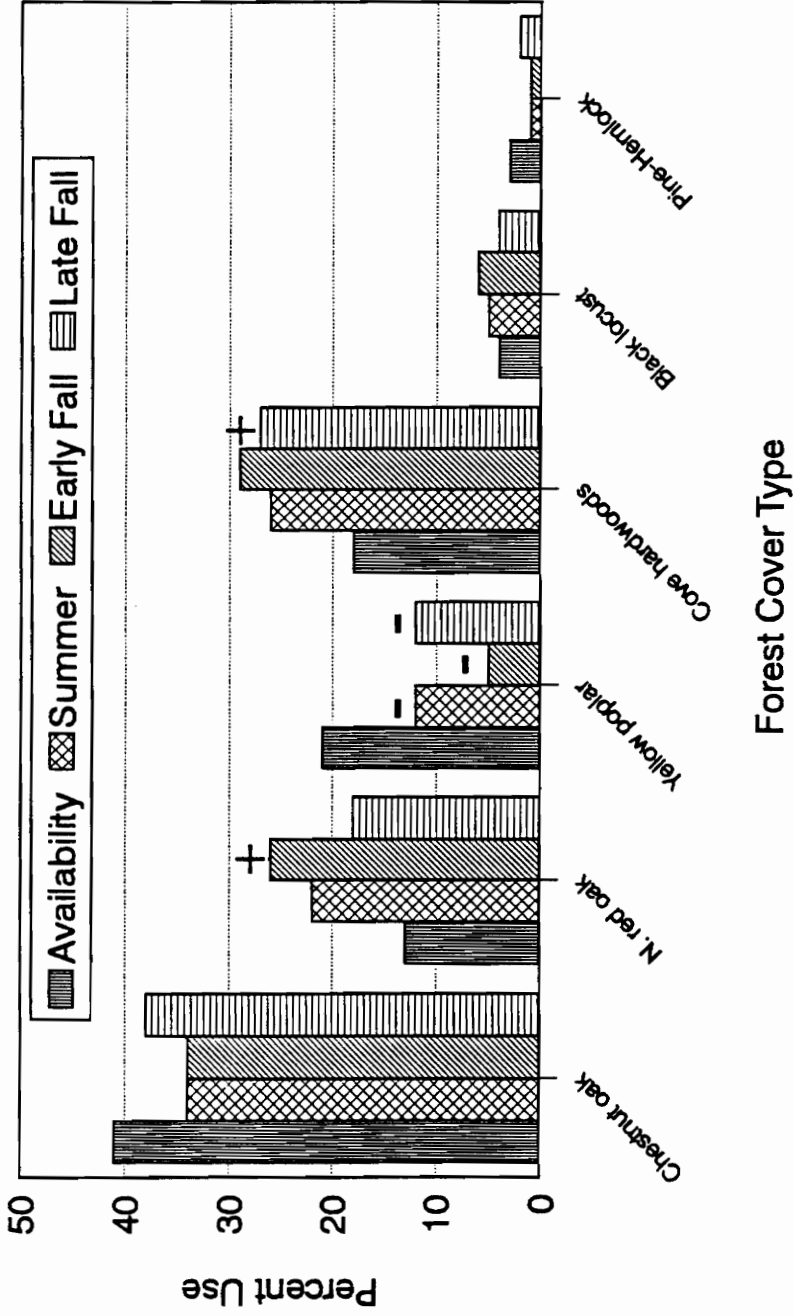


Figure 5. Use versus availability by female black bears of forest cover types following gypsy moth induced oak mortality in Shenandoah National Park, Virginia.

in use of forest cover types in all 3 seasons (Table 9); summer ($\chi^2=23.01$, 5=df, $P<0.001$), early fall ($\chi^2=16.15$, 5=df, $P<0.01$) and late fall ($\chi^2=13.36$, 5=df, $P<0.025$).

Use of stands with different levels of oak mortality was not different from availability during the summer ($\chi^2=6.63$, 4=df, $P=0.1$), but was different during the early fall ($\chi^2=16.69$, 4=df, $P<0.005$) and late fall ($\chi^2=25.1$, 4=df, $P<0.001$). Stands with no defoliation history (and thus no gypsy moth induced oak mortality) were used less than expected in the early fall ($P<0.05$), whereas in the late fall stands defoliated once in a wet year (1% gypsy moth induced oak mortality) were used less than expected ($P<0.05$) and stands defoliated in 2 consecutive years (11% gypsy moth induced oak mortality) were used more than expected ($P<0.05$, Fig. 6). Use was not significantly different from availability in all seasons for stands defoliated once in a dry year and in 3 consecutive years (14% and 48%+ gypsy moth induced oak mortality respectively).

DISCUSSION

The decline in oaks in SNP due to gypsy moth induced mortality was expected to decrease the amount of available acorns during the critical fall foraging period. Bears in SNP were expected to increase their fall range size to

Table 9. Availability and use of forest cover types before^a and after^b gypsy moth induced oak mortality in Shenandoah National Park, Virginia.

Cover type	% Use							
	% Availability ^c		Summer ^d		Early Fall ^e		Late Fall ^f	
	Before	After	Before	After	Before	After	Before	After
Chestnut oak	39	41	39	34	23 ^{-*}	34	52 ⁺	38
Red oak	17	13	15	22	30 ⁺	26 ⁺	19	18
Yellow poplar	22	21	29 ⁺	12 ⁻	17	5 ⁻	10 ⁻	12 ⁻
Cove hardwood	14	18	11	26	18	29	16	27 ⁺
Black locust	3	4	4	5	6	6	2	4
Pine-hemlock	5	3	3	1	4	1	2	2

* Use is greater (+) or less (-) than availability (P<0.05) by chi-square analysis (Byers et al. 1984).

^a Data from Garner (1986) collected 1982 - 1984.

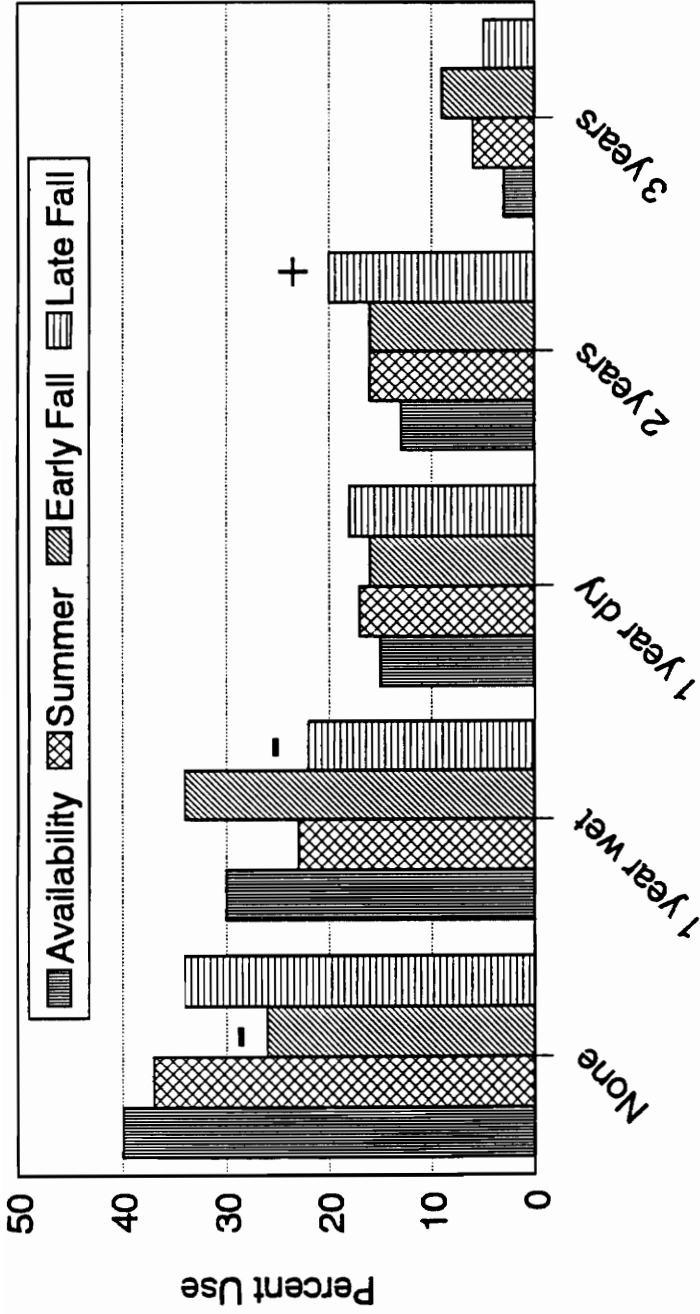
^b Data from this study 1990 - 1991.

^c Availability differs between studies due to different study areas within Shenandoah National Park.

^d Before (369 locations) and after (98 locations) habitat use overall ($\chi^2=15.61$, 5=df, p<0.01).

^e Before (199 locations) and after (98 locations) habitat use overall ($\chi^2=32.45$, 5=df, p<0.001).

^f Before (201 locations) and after (262 locations) habitat use overall ($\chi^2=26.4$, 5=df, p<0.001).



Defoliation Class

Figure 6. Use versus availability by female black bears of stands suffering defoliation and subsequent oak mortality by gypsy moths in Shenandoah National Park, Virginia. Gypsy moth induced oak mortality equals 0 in stands not defoliated, 1% in stands defoliated once in a wet year, 14% in stands defoliated once in a dry year, 11% for stands defoliated in 2 consecutive years and $\geq 48\%$ in stands defoliated in 3 consecutive years.

acquire adequate nutrition prior to denning and parturition. Beeman (1975) and Pelton (1989) noted increased movements of Tennessee bears during poor acorn years, and Kasbohm (1994) reported larger annual and fall ranges for female bears in SNP in areas experiencing fall acorn failures due to gypsy moth defoliation the preceding summer.

In spite of gypsy moth induced mortality of oaks, female black bear annual home ranges remained within the 5-22 km² range reported for the neighboring southern Appalachian states of North Carolina and Tennessee, where the gypsy moth has not arrived (Beeman 1975, Quigley 1982, Villarrubia 1982, Carr 1983, Garris 1983, Brody 1984 and Warburton 1984). Fall ranges of female bears also fell within the range reported for these states (3-17 km² Quigley 1982, Villarrubia 1982, Carr 1983, Garris 1983 and Brody 1984). However, female annual and fall home ranges were significantly smaller in this study than in preinfestation ranges for SNP, and movements by adult female bears to areas outside SNP declined from preinfestation data (Garner (1986). Smaller ranges and fewer movements outside of SNP seem to indicate that oak mortality inside SNP did not force the resident bear population to increase their movements in search of forage, or invade surrounding agricultural lands where corn and orchard crops are readily available.

An increase in available soft mast underneath overstory mortality may explain the lack of increase in movements, especially during the critical fall period, following gypsy moth induced oak mortality. Soft mast may be abundant and yet localized to stands suffering overstory mortality. Although soft mast availability and production was not measured, visual observation of stands of mortality indicated large amounts of blackberry/raspberry (Rubus spp.), grape (Vitis spp.) and pokeweed (Phytolacca americana). Trends in diet (Chapter 2) point towards an increasing frequency of soft mast in the summer and fall diets of SNP bears. Nutrition work by Kasbohm (1994) and physical condition data from this study (Chapter 2) and Kasbohm (1994) indicate that a diet high in soft mast did not affect either nutritional quality of the diet nor physical condition of the bears.

Gottschalk (1990b) reported that significant losses in acorn production occurred only when mortality exceeded 60% of the basal area of a stand. Below that level mortality tended to be concentrated in the intermediate and suppressed crown classes, which do not contribute significantly to a stand's total acorn production. Only stands defoliated in 3 consecutive years likely had oak mortality levels that would have approached this level of mortality during this study (Fig. 4), and those stands were limited to 3% (1,130 ha) of

the study area. Fall diet trends in this study (Chapter 2) indicate that although the frequency of acorns decreased significantly from the preinfestation fall diet reported by Garner (1986), acorns are still available and still constitute a relatively large part of the fall diet.

Use of yellow poplar stands by adult female black bears was less than their availability in all seasons. This finding was different from that of Garner (1986), where female bears used yellow poplar less than its availability only during the late fall season. Yellow poplar is not a preferred gypsy moth forage (Gansner et al. 1987), so stands dominated by yellow poplar likely received little defoliation and subsequent overstory mortality. Female black bears may forage in stands where overstory mortality has increased the availability of insects and soft mast species (Chapters 1 and 2).

The northern red oak cover type was used more than its availability in the early fall. Increased use of red oak stands in the early fall was reported by Garner (1986) as well. Red oaks are commonly associated with white oaks in SNP (Teetor 1988) and black bears may feed preferentially on white oak acorns due to their lower tannin content (Baumgras 1944 and Short and Epps 1976).

Use of the cove hardwood cover type was greater than availability only during the late fall at the $P < 0.05$ level

of significance. However, larger sample sizes during the early fall and summer seasons likely would have shown use to be greater than availability in all 3 seasons. The trend towards greater use of cove hardwoods is evident in both this study and Garner (1986). Cove hardwoods in SNP provide a variety of soft mast species in the understory (Teetor 1988), and the presence of many species besides oak in the overstory may have helped to dampen the severity of defoliation and subsequent oak mortality. Female bears may seek out cove hardwood stands as a source of acorns and soft mast forage. The decline in the use of chestnut oak stands in the late fall from Garner's (1986) study (Table 8) may be related to oak mortality and a subsequent decline in acorn production in this cover type. Given the relatively short duration of both this study and Garner (1986), however, a decline in the use of chestnut oak cover types may be related to yearly variations in the quantity of the chestnut oak acorn crop.

Stands that never were defoliated and thus escaped gypsy moth induced mortality were used significantly less than their availability only in the early fall. However, summer and late fall trends also were in that direction, although the differences were not significant at the $P < 0.05$ level. Stands that were not defoliated likely were composed primarily of less preferred gypsy moth forage species. In

SNP these stands would have been dominated by yellow poplar, black locust or pine/eastern hemlock (Gansner et al. 1987). These cover types were either used less than their availability or at a rate not different from availability (Fig. 5).

Use of stands defoliated once in a wet year (1% gypsy moth induced oak mortality) was less than expected during the late fall. Stands in this defoliation class, however, were defoliated in 1989 and therefore acorn production may have been limited in these stands especially in 1990. McConnell (1988) found that oaks still had lower acorn production in the year following defoliation. For stands defoliated once in a dry year (14% gypsy moth induced oak mortality), twice in consecutive years (11% gypsy moth induced oak mortality), or in 3 consecutive years (48%+ gypsy moth induced oak mortality), only late fall use of stands defoliated in 2 consecutive years was greater than expected at the $P < 0.05$ level of significance. The trend in all 3 of these defoliation classes, however, was consistently for greater than expected use during the summer, early and late fall periods (Fig. 6). Female black bears may use these stands because of increased availability of soft mast species and insects due to overstory mortality. Summer and fall dietary trends (Chapter 2) lend support to this hypothesis.

The gypsy moth is now a permanent part of the ecosystem in Shenandoah National Park. Future defoliation episodes and subsequent mortality of overstory species are certain to occur. The percentage of oak in the forest canopy may continue to decline or it may eventually stabilize when those individuals most susceptible to mortality are lost and only the most vigorous individuals remain. The long-term success of oak regeneration may be important once a new overstory shades out the soft mast species, which may have responded to the increase in sunlight during the initial mortality. Oak regeneration is poorly understood and consistent natural regeneration is difficult to achieve (Smith 1993). National Park Service mandates will limit oak management options. If species such as birch (Betula spp.) or maple (Acer spp., Chapter 1) replace oaks in the canopy and shade out soft mast species in the understory, then the forage base for black bears and other mast-dependent species in SNP likely will decline. Future changes in the forage base may result in changes in range dynamics and habitat use by the black bear population.

In the 8 counties that contain SNP, the human population has increased by 16% since 1980 and now numbers over 260,000 (Virginia Statistical Abstracts 1994). Concurrently, over 4,000 ha of forestland have been lost since 1986 in the same region (Virginia Statistical

Abstracts 1987 and 1994). A continuation of these trends may increase the importance of SNP as a forested reserve, but also may limit potential bear habitat and management options. Further study of the extent of tree mortality, subsequent regeneration and responses in black bear range dynamics and habitat use is warranted.

Literature Cited

- ALLEN, D. AND T. BOWERSOX. 1989. Regeneration in oak stands following gypsy moth defoliations. Pages 67-73 in L.H. McCormick and K.W. Gottschalk ed. Proc. 7th Central Hardwood Forestry Conf. U.S. For. Serv. Gen. Tech. Rep. NC-132.
- ALT, G. L. 1989. Reproductive biology of female black bears and early growth and development of cubs in northeastern Pennsylvania. Ph.D. Thesis. West Virginia University, Morgantown. 116pp.
- BAPTISTE, M. E. 1977. A survey of visitor knowledge, attitude, and judgement concerning black bears at Shenandoah National Park. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 92pp.
- BARBER, K. R. AND F. G. LINDZEY. 1986. Breeding behavior of black bears. Int. Conf. Bear Res. and Manage. 6:129-136.
- BARKALOW, F.S., R.B. HAMILTON, AND R.F. SOORS, Jr. 1970. The vital statistics of an unexploited gray squirrel population. J. Wildl. Manage. 34:489-500.
- BAUMGRAS, P. 1944. Experimental feeding of captive fox squirrels. J. Wildl. Manage. 8:296-300.
- BEECHAM, J. 1980. Some population characteristics of two black bear populations in Idaho. Int. Conf. Bear Res. and Manage. 4:201-204.
- BEEMAN, L. E. 1975. Population characteristics, movements and activities of the black bear (Ursus americanus) in the Great Smoky Mountains National Park. Ph.D. Thesis. Univ. Tennessee, Knoxville. 218pp.
- AND M.R. PELTON. 1980. Seasonal foods 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.

- BRODY, A. J. 1984. Habitat use by black bears in relation to forest management in Pisgah National Forest, North Carolina. M.S. Thesis. Univ. Tennessee, Knoxville. 123pp.
- BUNNELL, F. L. AND D. E. N. TAIT. 1981. Population dynamics of bears - implications. Pages 78-98 in T. D. Smith and C. Fowler eds. Dynamics of large mammal populations. John Wiley and Sons, Inc. New York.
- BYERS, 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. 34pp.
- CARLOCK, D. M., R. H. CONLEY, J. M. COLLINS, D. E. HALE, K. G. JOHNSON, A. S. JOHNSON, AND M. R. PELTON. 1983. The tri-state black bear study. Tech. Rep. 83-9. Univ. Tennessee, Knoxville. 286pp.
- CARNEY, D. W. 1985. Population dynamics and denning ecology of black bears in Shenandoah National Park, Virginia. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 84pp.
- 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.
- CHRISTISEN, D.M. AND L.J. KORSCHGEN. 1955. Acorn yields and wildlife usage in Missouri. Trans. N. Am. Wildl. Conf. 20:337-356.
- CLARK, J. D. 1991. Ecology of two black bear (Ursus americanus) populations in the interior highlands of Arkansas. Ph.D. Thesis. University of Arkansas, Fayetteville. 228pp.
- CONGALTON, R. G., R. G. ODERWALD, AND R. A. MEAD. 1983. Assessing landsat classification accuracy using discrete multivariate analysis statistical techniques. Photogrammetric Engineering and Remote Sensing. 49:1671-1678.
- CONNERS, J. A. 1988. Shenandoah National Park: An

Interpretive Guide. McDonald and Woodward Publishing Company. Blacksburg, VA 214pp.

- COOPER, R. J., K. M. DODGE, P. J. MARTINAT, H. R. SMITH AND R. C. WHITMORE. 1987. Impacts of the gypsy moth on nongame bird populations. Pages 48-58 in D. E. Fosbroke and R. R. Hicks Jr. ed. Coping with the gypsy moth in the new frontier. West Virginia University Books. 153pp.
- COTTAM, C., A. L. NELSON, AND T. E. CLARKE. 1939. Notes on early winter food habits of the black bear in the George Washington National Forest. J. Mammal. 20:310-314.
- DEGRAAF, R. M. 1987. Breeding birds and gypsy moth defoliation: short-term responses of species and guilds. Wildl. Soc. Bull. 15:217-221.
- EAGLE, T. C. 1979. Foods of black bears in the Great Smoky Mountains National Park. M.S. Thesis. Univ. Tennessee, Knoxville. 104pp.
- AND M. R. PELTON. 1983. Seasonal nutrition of black bears in the Great Smoky Mountain National Park. Int. Conf. Bear Res. and Manage. 5:94-101.
- EILER, J. H., W. G. WATHEN, AND M. R. PELTON. 1989. Reproduction in black bears in the southern Appalachian Mountains. J. Wildl. Manage. 53:353-360.
- ELOWE, K. D. 1984. Home range movements and habitat preferences of black bear (Ursus americanus) in western Massachusetts. M.S. Thesis. Univ. of Massachusetts, Amherst. 104pp.
- AND W. E. DODGE. 1989. Factors affecting black bear reproductive success and cub survival. J. Wildl. Manage. 53:962-968.
- EVANS, H. E. 1985. The gypsy moth. Pages 68-81 in The pleasures of entomology: portraits of insects and the people who study them. Smithsonian Institution Press, Washington, D.C.
- FESTA-BIANCHET, M. 1988. Birthdate and survival in bighorn lambs (Ovis canadensis). Zool. Lond. 214:653-661.
- FOSBROKE, D. E., R. R. HICKS Jr., AND K. W. GOTTSCHALK.

1991. Predicting tree mortality following gypsy moth defoliation. Pages 583-585 in L. H. McCormick and K. W. Gottschalk eds. Proc. 8th Central Hardwood Forestry Conf. University Park, PA 605pp.

FOSBROKE, S. AND R. C. REARDON. 1990. AIPM: managing gypsy moths in the Appalachians. U.S. For. Serv. NA-GR 23. 6pp.

GANSNER, D. A. AND O. W. HERRICK. 1987. Impact of gypsy moth on the timber resource. Pages 11-20 in S. Fosbroke and R. R. Hicks Jr. eds. Coping with the gypsy moth in the new frontier. West Virginia University Books 153pp.

-----, O. W. HERRICK, G. N. MASON AND K. W. GOTTSCHALK. 1987. Coping with the gypsy moth on new frontiers of infestation. Southern J. of App. For. 11:201-209.

GARNER, N. P. 1986. Seasonal movements, habitat selection and food habits of black bear (Ursus americanus) in Shenandoah National Park, Virginia. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 104pp.

GARRIS, R. S. 1983. Habitat utilization and movement ecology of black bears in Cherokee National Forest, Tennessee. M.S. Thesis. Univ. Tennessee, Knoxville. 98pp.

GARSHELIS, D. L. AND M. R. PELTON. 1980. Activity of black bears in the Great Smoky Mountains National Park. J. Mammal. 61:8-19.

----- AND ----- . 1981. Movements of black bears in the Great Smoky Mountains National Park. J. Wildl. Manage. 45:92-925.

GOTTSCHALK, K. W. 1989. Using silviculture to minimize gypsy moth impacts. Pages 6.14-6.14-4 in F. B. Clark and J. G. Hutchinson ed. Central Hardwood Notes. Washington, D.C.

----- . 1990a. Economic evaluation of gypsy moth damage in the United States. Pages 235-246 in International Union of Forest Research Organizations. Proc. XIX World Congress. Montreal, Canada.

----- . 1990b. Gypsy moth effects on mast production. Pages 42-50 in C. E. McGee ed. Proc of the Workshop, Southern Appalachian Mast Management. Univ. of Tenn., Knoxville.

85pp.

- HEATWOLE, H. 1978. Guide to Skyline Drive. GOOD Printers. Harrisonburg, VA. 226pp.
- HELLGREN, E. C. AND M. R. VAUGHAN. 1989. Demographic analysis of a black bear population in the Great Dismal Swamp. J. Wildl. Manage. 53:969-977.
- AND ----- . 1990. Range dynamics of black bears in the Great Dismal Swamp, Virginia - North Carolina. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies. 44:268-278.
- , D. W. CARNEY, N. P. GARNER, AND M. R. VAUGHAN. 1988. Use of breakaway cotton spacers on radio collars. Wildl. Soc. Bull. 16:216-218.
- HEWITT, D. G. 1989. Correcting grizzly bear fecal analysis to observed food habits. M.S. Thesis, Washington State Univ., Pullman, WA 20pp.
- HICKS Jr., R. R. AND D. E. FOSBROKE. 1987. Mortality following gypsy moth defoliation in the Central Appalachians. Pages 423-426 in R. L. Hay, F. W. Woods and H. DeSelm eds. Proc. 6th Central Hardwood Forestry Conf. Knoxville, TN 526pp.
- HIX, D. M., D. E. FOSBROKE, R. R. HICKS Jr., AND K. W. GOTTSCHALK. 1991. Development of regeneration following gypsy moth defoliation of Appalachian Plateau and Ridge & Valley hardwood stands. Pages 347-359 in L. H. McCormick and K. W. Gottschalk ed. Proc. 8th Central Hardwood Forestry Conf. University Park, PA 605pp.
- HOEFS, M. 1984. Productivity and carrying capacity of a subarctic sheep winter range. Arctic. 37:141-147.
- JONKEL, C.J. AND I. McT. COWAN. 1971. The black bear in the spruce-fir forest. Wildl. Monogr. 27. 57pp.
- KASBOHM, J. W. 1994. Response of black bears to gypsy moth infestation in Shenandoah National Park, Virginia. Ph.D. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 219pp.
- KEGG, J. D. 1971. The impact of the gypsy moth: repeated defoliation of oak in New Jersey. J. of For. 69:852-854.

- . 1973. Oak mortality caused by repeated gypsy moth defoliations in New Jersey. *J. Econ. Ent.* 66:639-641.
- KOELN, G. T. 1980. A computer technique for analyzing radio-telemetry data. *Proc. Natl. Wild Turkey Symp.* 4:262-271.
- LANDERS, J. L., R. J. HAMILTON, A. S. JOHNSON, AND R. L. MARCHINTON. 1979. Foods and habitat of black bears in southeastern North Carolina. *J. Wildl. Manage.* 43:143-153.
- LECOUNT, A.L. 1982. Characteristics of a central Arizona black bear population. *J. Wildl. Manage.* 46:861-868.
- LINDZEY, F. G. AND E. C. MESLOW. 1977. Home range and habitat use by black bears in southwestern Washington. *J. Wildl. Manage.* 41:413-425.
- MAEHR, D. S. AND J. R. BRADY. 1984. Food habits of Florida black bears. *J. Wildl. Manage.* 48:230-235.
- MATSCHKE, G.H. 1964. The influence of oak mast on European wild hog reproduction. *Proc. Southeastern Assoc. Game and Fish Comm. Conf.* 18:35-39.
- MATTSON, D. J., B. M. BLANCHARD, AND R. R. KNIGHT. 1991. Food habits of the Yellowstone grizzly bears. *Can J. Zool.* 69:1619-1629
- MAZZEO, P. M. 1979. *Trees of Shenandoah National Park.* Shenandoah Natural History Association, Inc. Luray, VA. 76pp.
- McCONNELL, S. P. 1988. Effects of gypsy moth defoliation on acorn production and viability, litterfall, and litter layer depth and biomass in north-central Virginia and western Maryland. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 124pp.
- McGEE, C. E. AND D. L. LOFTIS. 1993. Oak regeneration: a summary. *in* D.L. Loftis and C.E. McGee eds. *Oak regeneration: serious problems, practical recommendations.* USDA Forest Service, Southeastern For. Exp. Stat. Ge. Tech. Rep. SE-84. 319pp.
- McLAUGHLIN, C. R., G. J. MATULA Jr., AND R. J. O'CONNOR. 1992. Synchronous reproduction by Maine black bears.

Int. Conf. Bear Res. and Manage. 9:In Press.

- McMANUS, M. L. 1980. The gypsy moth. Forest Insect and Disease Leaflet 162. U.S. For. Ser. 10pp.
- NEU, C. W., C. R. BYERS AND J. M. PEEK. 1974. A technique for analysis of utilization - availability data. J. Wildl. Manage. 38:541-545.
- NIXON, C.M., M.W. McCLAIN, AND R.W. DONOHOE. 1975. Effects of hunting and mast crops on a squirrel population. J. Wildl. Manage. 39:1-25.
- PARKER, J. 1981. Individual tree relationships: effects of defoliation on oak chemistry. pp. 219-225 in The Gypsy Moth: Research Towards Integrated Pest Management. U.S. For. Serv. Tech. Bull. 1584.
- PELTON, M.R. 1989. The impacts of oak mast on black bears in the southern Appalachians. Pages 7-11 in C.E. McGee ed. Proc. of the Workshop, Southern Appalachian Mast Management. Univ. Tenn. Knoxville.
- PIEKIELEK, W. AND T. S. BURTON. 1975. A black bear population study in northern California. California Fish and Game J. 61:4-25.
- POWELL, R. A. 1987. Black bear home range overlap in North Carolina and the concept of home range applied to black bears. Int. Conf. Bear Res. and Manage. 7:235-242.
- QUIGLEY, H. B. 1982. Activity patterns, movement ecology and habitat utilization of black bears in the Great Smoky Mountains National Park, Tennessee. M.S. Thesis. Univ. Tennessee, Knoxville. 140pp.
- QUIMBY, J. W. 1987. Impact of gypsy moth defoliation on forest stands. Pages 21-27 in S. Fosbroke and R. R. Hicks Jr. ed. Coping with the gypsy moth in the new frontier. West Virginia University Books. 153 pp.
- RAPHAEL, M. G. AND G. E. BRINK. 1988. Bootstrap estimation of home range area: user's guide to program Homerang. USDA For. Serv. Gen. Tech. Rep. RM-165. Rocky Mt. For. and Range Exp. Stat. Fort Collins, Colorado.
- RAVLIN, F. W., J. R. VOSHELL Jr, D. Wm. SMITH, S. L. RUTHERFORD, S. W. HINER AND D. A. HASKELL. 1990

Shenandoah National Park long-term ecological monitoring system. Nat. Park Serv. NPS/NRSHEN/NRTR-90/02.

- RAYBOURNE, J. W. 1976. A study of black bear populations in Virginia. Trans. Northeast Fish and Wildl. Conf. 33:71-81.
- REYNOLDS, D. G. AND J. J. BEECHAM. 1980. Home range activities and reproduction of black bears in west-central Idaho. Int. Conf. Bear Res. and Manage. 4:181-190.
- ROGERS, L.L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. Trans. N. Am. Wildl. and Nat. Res. Conf. 41:431-438.
- . 1983. Effects of food supply, predation, cannibalism, parasites, and other health problems on black bear populations. Pages 194-211 in F.L. Bunnell, D.S. Eastman, and J.M. Peek eds. Symposium on Natural Regulation of Wildlife Populations. Moscow, Idaho.
- AND E. L. LINDQUIST. 1991. Black bears and the oak resource in northeastern Minnesota. pp. 107-114 in S.B. Laursen and J.F. DeBoe eds. The Oak Resource in the Upper Midwest: Implications for management. Univ. Minnesota, St. Paul.
- SCHROEDER, M. T. 1987. Blood chemistry, hematology and condition evaluation of black bears in northcoastal California. Int. Conf. Bear Res. and Manage. 7:333-349.
- SCHWARTZ, C.C. AND A.W. FRANZMANN. 1991. Interrelationships of black bears to moose and forest succession in the northern coniferous forest. Wildl. Monogr. 113. 58pp.
- SHORT, H. L. AND E. A. EPPS. 1976. Nutrient quality and digestibility of seeds and fruits from southern forests. J. Wildl. Manage. 40:283-289.
- SMITH, D. Wm. 1993. Oak regeneration: The scope of the problem. pp 40-52 in D.L. Loftis and C.E. McGee eds. Oak regeneration: Serious problems and practical recommendations. USDA Forest Service. Southeastern For. Exp. Stat. Gen. Tech. Rep. SE-84. 319pp.
- SMITH, H. R. 1985. Wildlife and the gypsy moth. Wildl. Soc.

Bull. 13:166-174.

- SMITH, T. R. 1985. Ecology of black bears in a bottomland hardwood forest in Arkansas. Ph.D. Thesis. Univ. Tennessee, Knoxville. 209pp.
- STEPHENS, G. R. 1988. Mortality, dieback and growth of defoliated hemlock and white pine. Northern J. of App. For. 5:93-96.
- STICKLEY, A. R. 1957. The status and characteristics of the black bear in Virginia. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 102pp.
- TEETOR, A. 1988. Identification and mapping of vegetation communities in Shenandoah National Park, Virginia. MAR-34. 62pp.
- THORNE, E.T. R.E. DEAN, AND W.G. HEPWORTH. 1976. Nutrition during gestation in relation to successful reproduction in elk. J. Wildl. Manage. 40:330-335.
- THURBER, D. K. 1992. Impacts of a gypsy moth outbreak on bird habitats and population. Ph.D. Thesis. West Virginia University. Morgantown, WV. 302pp.
- TIGNER, T. 1992. Gypsy moth impact on Virginia's hardwood forests and forest industry. Virginia Dept. of Forestry. Charlottesville, Va. 35pp.
- TOMBLIN, D. C. 1994. Ecological niche responses of small mammals to gypsy moth disturbance. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 190pp.
- TRENT, T. T. AND O. J. RONGSTAD. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. J. Wildl. Manage. 38:459-472.
- TWERY, M. J. 1990. Effects of defoliation by gypsy moth. Pages 27-39 in K. W. Gottschalk, M. J. Twery, and S. I. Smith eds. U. S. Dept. of Agriculture interagency gypsy moth research review. Gen. Tech. Rep. NE-146.
- VAUGHAN, M. R., P. F. SCANLON, S. E. P. MERSMANN, AND D. D. MARTIN. 1990. Pages 147-154. Proc. 4th Eastern Wildl. Damage Control Conf. 258pp.

- VILLARRUBIA, C. R. 1982. Movement ecology and habitat utilization of black bears in Cherokee National Forest, Tennessee. M.S. Thesis. Univ. of Tennessee, Knoxville. 159pp.
- VIRGINIA DEPARTMENT GAME AND INLAND FISHERIES. 1992. Virginia Wildl. Investigations. Annual Rep. 483pp.
- VIRGINIA STATISTICAL ABSTRACTS. 1987. Univ. of Virginia, Charlottesville. 735pp.
- VIRGINIA STATISTICAL ABSTRACTS. 1994. Univ. of Virginia, Charlottesville. 899pp.
- WARBURTON, G. S. 1984. An analysis of a black bear sanctuary in western North Carolina. M. S. Thesis. Univ. Tennessee, Knoxville. 123pp.
- WHELAN, C. J., R. I. HOLMES AND H. R. SMITH. 1989. Bird predation on gypsy moth (Lepidoptera: Lymantriidae) larvae: An aviary study. Environ. Ent. 18:43-45.
- WHITE, G. C. AND R. A. GARROTT. 1990. Analysis of wildlife radio-tracking data. Academic Press Inc. San Diego, California. 383pp.
- WILLEY, C. H. 1974. Aging black bears from first premolar tooth sections. J. Wildl. Manage 38:97-100.
- WOFFORD, B. E. 1989. Guide to the Vascular Plants of the Blue Ridge. Univ. of Georgia Press, Athens. 384pp.
- YAHNER, R. H. AND H. R. SMITH. 1991. Small mammal abundance and habitat relationships on deciduous forested sites with different susceptibility to gypsy moth defoliation. Environ. Manage. 15:113-120.
- YOUNG, B. F. AND R. L. RUFF. 1982. Population dynamics and movements of black bears in east central Alberta. J. Wildl. Manage. 46:845-860.

Appendix

Appendix Table 1. Diet correction factors developed by Hewitt (1989).

<u>Food Item or Group</u>	<u>Recommended Correction Factor</u>
Apple	0.51
Blueberry	0.54
<u>Rubus</u> spp.	0.87
Deer	4.00
Small mammals	4.00
Mast & nuts	1.50
Insects	1.10
Roots, bulbs, berries & fruits	0.93
Vegetation	0.26

Appendix Table 2. Correction factors and corrected volumes based on recommendations by Hewitt (1989).

Food Item	Uncorrected Volume	Correction Factor	Corrected Volume
SUMMER DIET			
Forbs and Graminoids			
<u>Arisaema</u> spp.	4 ^a	0.26	1
Graminae	3	0.26	1
<u>Phytolacca americana</u>	2	0.93	2
<u>Rubus</u> spp.	13	0.87	12
unidentified spp.	4	0.26	1
Squawroot			
<u>Conopholis americana</u>	19	0.93	20
Tree Fruit			
<u>Amelanchier</u> spp.	T ^b	0.93	T
<u>Ilex montana</u>	T	0.93	T
<u>Malus</u> spp.	7	0.51	4
<u>Prunus avium</u>	T	0.93	T
<u>Prunus serotina</u>	7	0.93	4
<u>Quercus</u> spp.	4	1.50	6
<u>Sassafras albidum</u>	1	0.93	1
Shrub & Vine Fruit			
<u>Gaylussacia</u> spp.	1	0.54	1
<u>Lindera benzoin</u>	1	0.93	1
<u>Ribes</u> spp.	1	0.93	1
<u>Vaccinium</u> spp.	8	0.54	8
Invertebrates			
Coleoptera	2	1.10	2
Formicidae	16	1.10	18
Orthoptera	T	1.10	1
Vespidae	2	1.10	2
unidentified spp.	1	1.10	1
Mammals			
<u>Odocoileus virginianus</u>	2	4.00	8
unidentified spp.	T	4.00	2

Appendix Table 2. continued.

Food Item	Uncorrected Volume	Correction Factor	Corrected Volume
Debris	5	1.00	5
FALL DIET			
Forbs and Graminoids			
Graminae	2	0.26	T
<u>Phytolacca americana</u>	10	0.93	8
unidentified spp.	T	0.26	T
Squawroot			
<u>Conopholis americana</u>	2	0.26	2
Tree Fruit			
<u>Carya</u> spp.	7	1.50	9
<u>Celtis</u> spp.	T	0.93	T
<u>Juglans nigra</u>	1	1.50	1
<u>Malus</u> spp.	6	0.51	3
<u>Nyssa sylvatica</u>	T	1.50	1
<u>Prunus serotina</u>	5	0.93	4
<u>Quercus</u> spp.	28	1.50	38
<u>Sassafras albidum</u>	T	0.93	T
Shrub & Vine Fruit			
<u>Elaeagnus umbellata</u>	1	0.93	1
<u>Lindera benzoin</u>	6	0.93	5
<u>Vitis</u> spp.	13	0.93	11
Corn	5	0.51	2
Invertebrates			
Cambridae	T	1.10	T
Coleoptera	1	1.10	1
Formicidae	T	1.10	T
Vespidae	2	1.10	2
unidentified spp.	1	1.10	1
Mammals			
<u>Odocoileus virginianus</u>	1	4.00	4
unidentified spp.	1	4.00	4

Appendix Table 2. continued

<u>Food Item</u>	<u>Uncorrected Volume</u>	<u>Correction Factor</u>	<u>Corrected Volume</u>
Debris & Garbage			
Debris	3	1.00	3
Garbage	T	1.00	T

^a Percent values are rounded to the nearest whole number.

^b T indicates a trace amount (<0.5%).

Vita

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