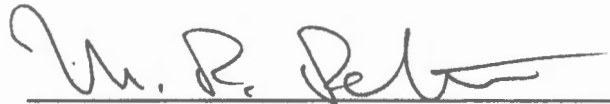


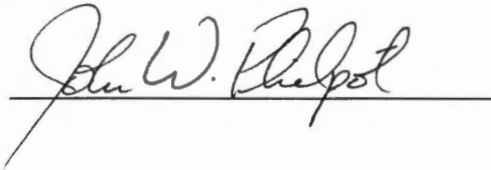
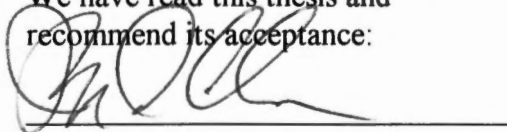
To the Graduate Council:

I am submitting herewith a thesis written by Donald Alfonso Martorello entitled "Ecology of black bears in coastal North Carolina." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.



Michael R. Pelton, Major Professor

We have read this thesis and
recommend its acceptance:



Accepted for the council:



Associate Vice Chancellor
and Dean of the Graduate School

ECOLOGY OF BLACK BEARS IN COASTAL NORTH CAROLINA

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Donald Alfonso Martorello

August 1998

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DEDICATION

I dedicate this thesis to my wife, Holli Martorello, for her love and support, and to my father, Don Martorello, for introducing me to the outdoors.

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ABSTRACT

In eastern North Carolina, forested lands have changed in composition and been reduced in area. Agriculture and timber industries dominate the landscape and understanding the impacts of these industries on black bear ecology is key for managing bears in eastern North Carolina.

I investigated population size, adult survival, movements, and denning ecology of black bears (*Ursus americanus*) on the Neuse-Pamlico Peninsula (NPP) in eastern North Carolina, 1994-1996. Most of the NPP was privately owned and managed for agriculture and forest products. To represent the peninsula, I established 2 study areas, the Big Pocosin and Gum Swamp. The Gum Swamp contained a portion of a black bear sanctuary.

During the study, project personnel captured 77 bears 93 times in the Big Pocosin and 136 bears 200 times in the Gum Swamp. I estimated population size using a variety of capture-recapture and capture-resight models. At the end of the study, population density in the Big Pocosin and Gum Swamp was 0.53 and 1.35 bears/km², respectively.

I estimated adult survival for female bears using the Kaplan-Meier Staggered entry procedure. Annual survival of adult females in the Big Pocosin and Gum Swamp was 1.00 (95% CI* = 0.88-1.00) (D. Sylwester, Univ. of Tenn., pers. commun. via J. Philpot) and 0.83 (95% CI = 0.70-0.96), respectively. Female survival was greater at Big Pocosin compared to Gum Swamp ($P = 0.02636$). Hunting reduced the survival rate of females in the Gum Swamp from 0.94 to 0.83 and accounted for 5 of 8 of the mortalities. Combining study areas, annual survival of adult females was 0.90 (95% CI = 0.82-0.98).

To evaluate bear movement parameters, I calculated total movement, rate of travel, net movement, and range length from diel locations of bears on the NPP. Mean total movement and net movement was 3,611.4 m (SE = 228.2) and 871.0 m (SE = 133.5), respectively. Mean range length was 1,537.5 m (SE = 133.1) and mean rate of travel was 164.9 m/h (SE = 10.0). I found no difference ($P = 0.5899$) when comparing movement parameters between the Big Pocosin and Gum Swamp. However, I detected a difference ($P = 0.0021$) in movement parameters between summer and fall seasons, but the differences may have been an artifact of telemetry error ($P = 0.6445$).

To determine if bears moved randomly across the landscape or if they selected specific macrohabitat characteristics for movements, I compared 7 landscape characteristics between actual and random movement trajectories. I found a difference between actual and random trajectories ($P = 0.0032$); actual movement trajectories ($\bar{x} = 257.8$ m, SE = 7.7, $n = 123$) were farther from roads ($P = 0.0011$) than random trajectories ($\bar{x} = 226.0$ m, SE = 7.5, $n = 123$).

I investigated 20 nest dens, 2 excavated ground dens, and 1 tree den. I measured 6 microhabitat characteristics around nest dens and random sites. I compared the variables between pairs of nest and random sites. An overall difference was detected between nest and random sites ($P = 0.0006$). Shrub height was greater ($P = 0.0022$) at nest sites ($\bar{x} = 74.3$, SE = 3.8, $n = 16$) than random sites ($\bar{x} = 47.6$, SE = 5.3, $n = 16$). Similarly, stem density was greater ($P = 0.0057$) at nest sites ($\bar{x} = 18.2$, SE = 2.8, $n = 16$) than random sites ($\bar{x} = 7.5$, SE = 1.3, $n = 16$) and cover density was greater ($P = 0.0001$) at nest sites ($\bar{x} = 71.7$, SE = 3.8, $n = 16$) compared with random sites ($\bar{x} = 40.8$, SE = 2.2, $n = 16$).

The Big Pocosin and Gum Swamp study areas may represent both ends of the spectrum in terms of bear densities on the NPP. The population size found in the Gum Swamp exceeded previous estimates from other Southeastern coastal bear populations. Female survival rates on the NPP were similar to other bear populations, and the number of bears harvested and the spatial distribution of those harvested bears relative to local bear densities seems to be the best tools for managing mortality. Higher mortality of female bears residing near the border of the Gum Swamp sanctuary suggests that hunting effort or hunter success may not be constant across the NPP. Given the restricted movements and relatively small home ranges (Jones 1996) of bears on the peninsula, bear management units (BMU) and hunt clubs may provide a substantial area of refugia. In addition, roads may reduce the area of suitable habitat for bear movements. Thus, restricting road access may increase the amount of suitable bear habitat, particularly in areas with high road densities.

Thick understory cover may be a prerequisite for nest dens on the NPP. If management goals include maintaining suitable nest den habitat, areas with thick understory habitat may need to be retained across the landscape and human disturbance in those areas may need to be restricted during winter.

I hypothesize that the combination of agricultural food sources surrounded by relatively large blocks of forest, the patches of thick cover, the presence of sanctuaries and refugia, and a conservative harvest provide suitable conditions for black bear populations in intensively managed regions such as coastal North Carolina.

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CHAPTER I

INTRODUCTION

General Problem Statement

When European settlers arrived in North Carolina, black bears were found throughout the state. Around 1928, the first formal bear season was established. With the rapid increase of human encroachment and a liberal bear hunting season, black bear numbers and range were reduced greatly by the late 1960's. In 1969, wildlife managers became concerned with the decrease in bear numbers and, in 1975, the state placed the black bear in the category of special concern (Collins 1984). Consequently, the North Carolina Wildlife Resources Commission (NCWRC) initiated strategies to conserve black bears; bear management included a mandatory tagging and kill reporting system coupled with 28 existing bear sanctuaries totaling approximately 365,000 ha. Regulated bear hunting seasons continued in the western mountains and eastern coastal regions of North Carolina. From 1976-85, 12 coastal counties had hunting seasons. Hunting seasons were established in an additional 11 coastal counties between 1986-91 (Warburton et al. 1993). Black bears are now found in 24 western and 28 eastern counties, but are absent from the piedmont (Jones et al. 1995) (Fig. 1.1).

In eastern North Carolina, forested lands have changed in composition and been reduced in area, primarily from the conversion of native forests to managed forests and agricultural lands. Of special concern is the reduction of pocosin, a thick, shrub habitat that may be an important source of cover for bears in coastal environments (Lombardo



Figure 1.1. Black bear range in North Carolina, 1991 (Jones et al. 1995).

1993, Brandenburg 1996, Jones 1996). In 1962, natural pocosins covered approximately 16% (908,319 ha) of the total land area in the 41 eastern counties of North Carolina (Richardson et al. 1981). By 1980, only 31% of these natural pocosins remained unaltered. In addition, approximately 25% of the total land area now is in agriculture (J. Hughes, Weyerhaeuser Company, pers. commun.). Thus, the remaining pocosins, swamps, and blocks of managed forested lands provide the last stronghold for coastal bear populations (Monschein 1981).

Concern for the future of black bears in North Carolina led to the initiation of several research studies on the ecology of coastal black bear populations. Studies in eastern North Carolina were conducted in Dare county (Hardy 1974; Allen, unpubl. data; Folta 1998), Bladen county (Hamilton 1978), the Great Dismal Swamp of Virginia-North Carolina (Camden, Paquotank, and Gates counties) (Hellgren 1988), and Onslow county (Lombardo 1993; Brandenburg 1996; Studer, unpubl. data) (Fig 1.2).

These studies took place on public lands and, prior to this study, no research has been conducted in the southeastern coastal plain where black bears occur on private lands intensively managed for forestry and agriculture. Little information is known about the abundance of bears in regions dominated by agriculture and timber industries. Moreover, with the increase in the number of bears harvested in recent years, managers are concerned about the effects of hunting on bear populations. An estimate of the number of bears is indispensable for managing coastal populations. Also, given the fragmentation of the coastal plain, understanding the characteristics that influence habitat use and movements are important for maintaining suitable bear habitat and connective corridors between

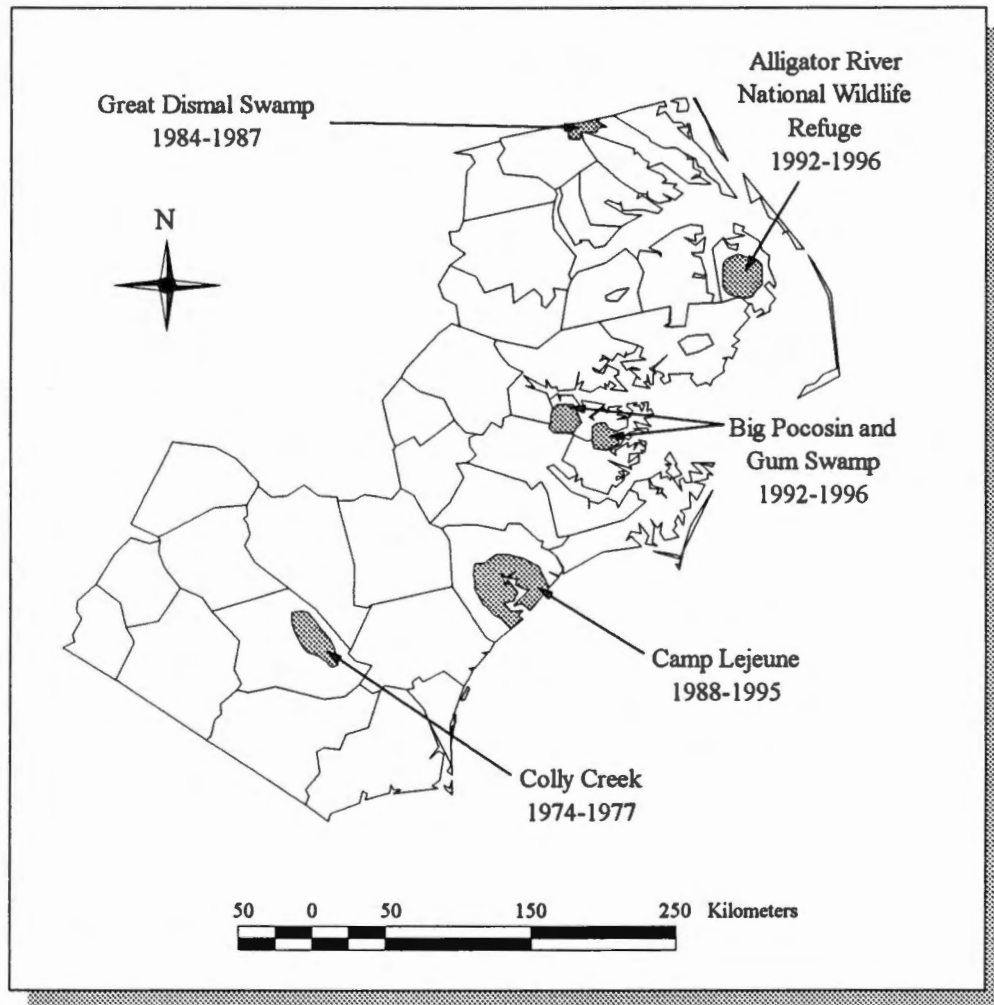


Figure 1.2. Locations of black bear research projects in eastern North Carolina.

populations. As human encroachment continues and lands are altered, management options that facilitate movements and use are essential. Finally, with the intensive forestry practices in coastal North Carolina, maintaining suitable denning habitat may be important. Furthermore, given the relatively high level of disturbance in the forest by the timber industries, identifying areas of suitable denning habitat may help minimize the disturbance to denning bears.

Toward that end, a series of black bear studies were initiated on the Neuse-Pamlico Peninsula (NPP) in coastal North Carolina in 1992. From May 1992 to April 1994, Jones (1996) investigated home range characteristics, habitat use, and den site macrohabitat. During the same time period, Maddrey (1995) investigated morphology, reproduction, food habits, crop depredation, and mortality of black bears on the NPP. I investigated population dynamics, movements, and den site characteristics of black bears on the NPP from May 1994 to August 1996.

Objectives of this study were to: (1) estimate black bear density, (2) estimate annual survival of adult black bears, (3) determine the effects of hunting on survival rates, (4) determine if black bear movement characteristics (total movement, travel rate, net movement, and range length) differ between sexes, seasons, study areas, or years, (5) determine if black bears select specific landscape features for movements, and (6) determine if black bears select specific microhabitat characteristics for den sites. I investigated objectives (3)-(6) by testing the following null hypotheses:

(3a) Hunting does not reduce adult survival rates.

(3b) Adult survival rate in a hunted area does not differ from an unhunted area.

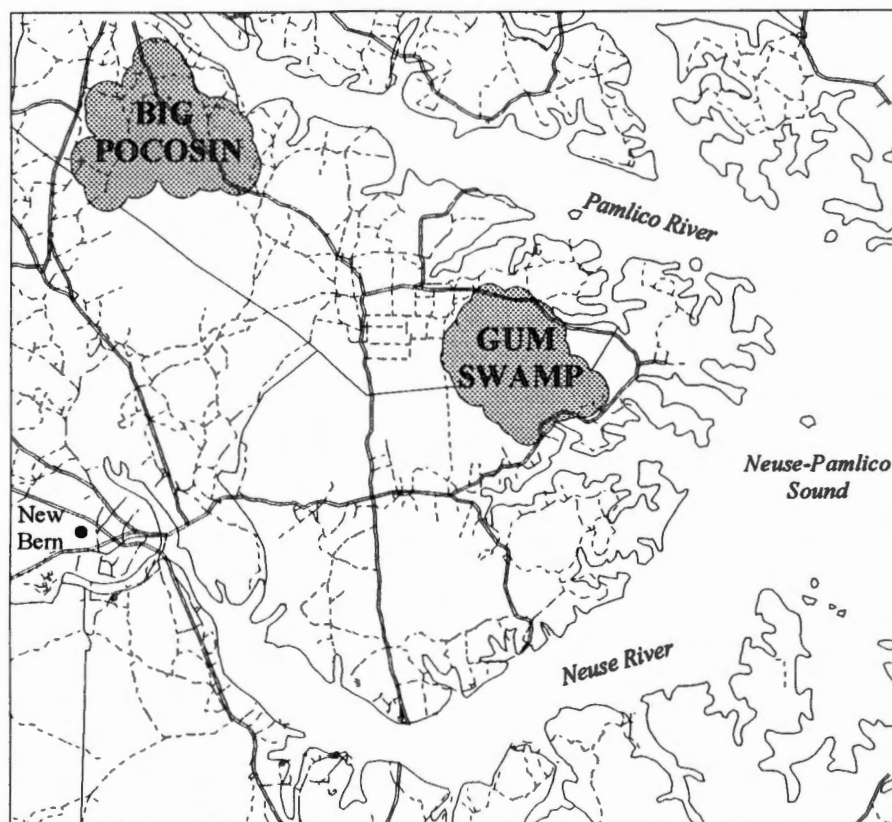
- (4a) Movement characteristics do not differ between sexes.
- (4b) Movement characteristics do not differ between seasons.
- (4c) Movement characteristics do not differ between study areas.
- (4d) Movement characteristics do not differ between years.
- (5) Bears move randomly across the landscape with respect to macrohabitat characteristics.
- (6) Bears do not select den sites based on microhabitat characteristics.

CHAPTER II

STUDY AREA

General

The NPP is a 150,000-ha area in eastern North Carolina (Fig. 2.1) and is bordered by the Pamlico River to the north, the Neuse River to the south, and the Pamlico Sound to the east. The peninsula contains parts of Beaufort and Craven counties, and all of Pamlico county. The peninsula is comprised of a mosaic of human developments, agricultural lands, and forested lands, including managed pine forests, hardwoods, mixed pine-hardwoods, and swamp-marshes (Fig. 2.2). Forestry and agriculture are the dominant land uses on the peninsula; the NPP is comprised of about 70% forested lands and 27% agricultural lands (Hughes 1990, unpubl. data). Weyerhaeuser Forest Products Company is the largest landowner on the NPP, owning about 65,000 of 105,000 ha of forested lands (J. Hughes, Weyerhaeuser Company, pers. commun.). The remaining 40,000 ha of forested lands are owned by PCS Phosphate Company, Champion International, Federal Paperboard, Bates Lumber Company, Taylor Land and Timber Company, and several smaller landowners. Public ownership accounts for less than 1% of the NPP; Goose Creek Game Lands are the largest blocks of public lands and are owned by NCWRC. Agricultural lands are scattered throughout the peninsula and comprise approximately 40,000 ha (Maddrey 1995). Major crops are corn, wheat, soybeans, tobacco, and cotton. Urban-suburban areas comprise approximately 5,000 ha of the NPP, with human dwellings scattered across the landscape.



Legend

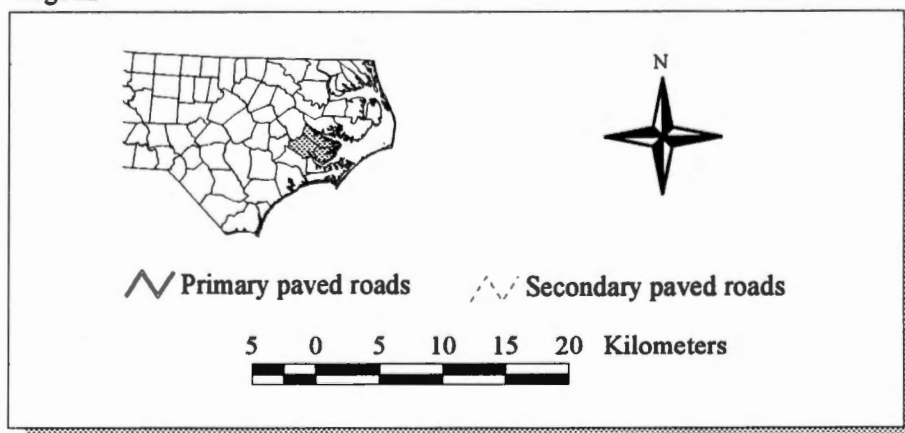
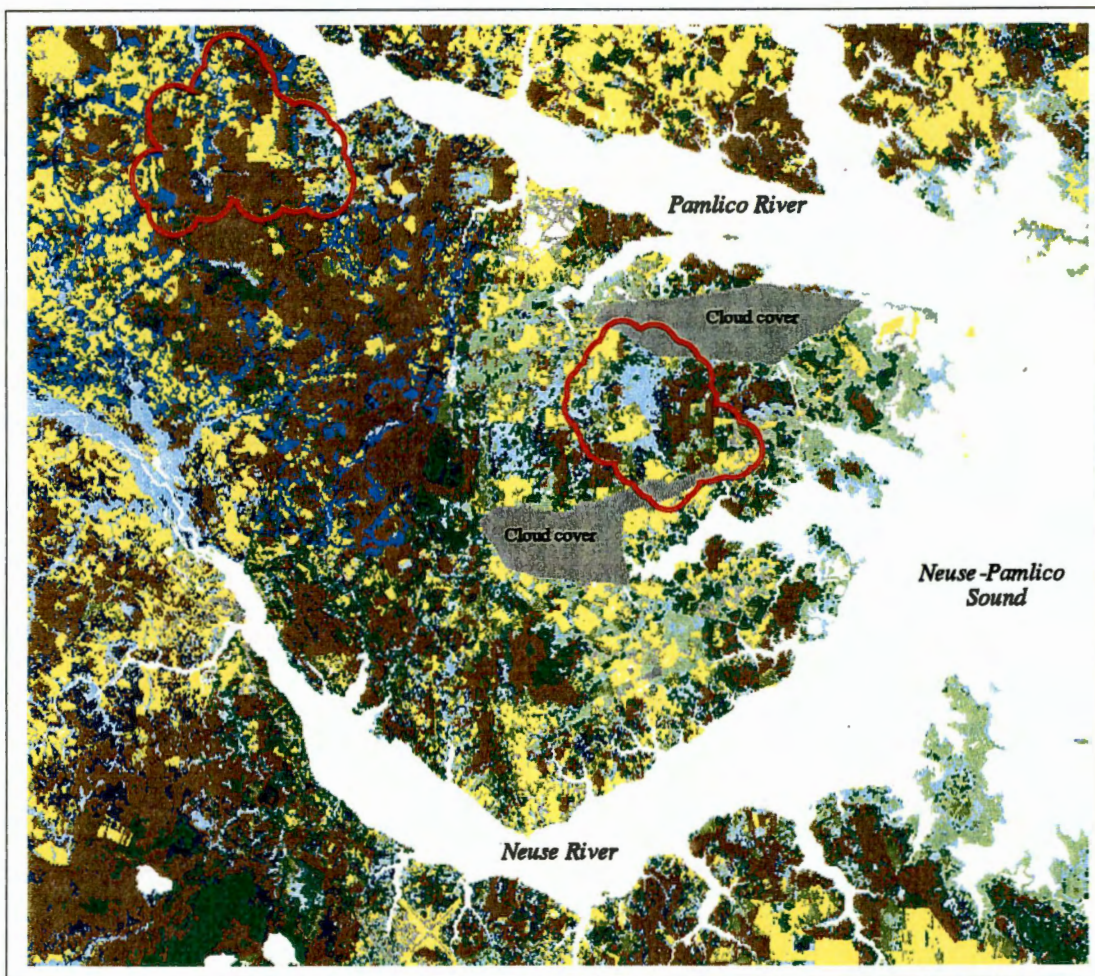


Figure 2.1. Big Pocosin and Gum Swamp study areas, Neuse-Pamlico peninsula, North Carolina, 1992-1996.



Legend

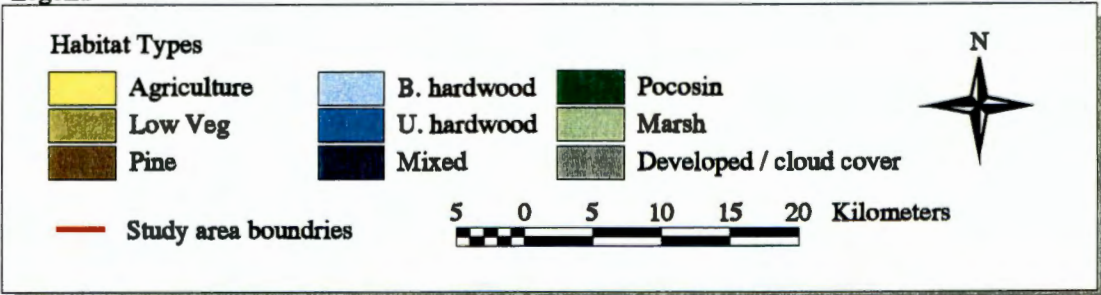


Figure 2.2. Habitat types on the NPP, North Carolina, 1988 (Khorram et al. 1992).

The peninsula includes portions of US Highway 17, NC Highways 33, 43, 304, 306, and 307. East of US Highway 17, the NPP encompasses the towns of Chocowinity, Vanceboro, Ernul, Bridgeton, Aurora, Bayboro, Mesic, Grantsboro, Oriental, Vandemere, and 20 other smaller towns.

I established 2 study areas within the NPP (Fig. 2.1) (see **Methods**). The Gum Swamp study area encompassed 119 km² and was located on the eastern half of the peninsula, within Pamlico and Beaufort counties. The Big Pocosin study area encompassed 149 km² and was located on the western half of the peninsula, within Pamlico, Beaufort, and Craven counties.

Climate and Elevation

The NPP had a mild subtropical climate. Summers were characterized as hot and humid and winters as cool with an occasional freeze. Average summer and winter temperatures were 24.4°C and 7.2°C, respectively. Annual average precipitation was 142 cm with the highest in July (20.3 cm) and lowest in November (6.7 cm), and predominantly consisted of rain with an occasional snow flurry. Elevations ranged from 0-19 m (United States Geological Survey 1985).

Flora

I used the habitat type classification provided by land use/land cover data generated from LandSat Thematic Mapper images from LandSat 5 (1988) (Khorram et al. 1992). I excluded 5 habitat categories because they were nearly absent from the study

areas. The remaining 13 habitat categories were grouped in 9 habitat types (Table 2.1 and Fig. 2.2). Pine habitat was predominantly loblolly plantations that were managed in short-rotations for pulp products. Pocosin and bottomland hardwood forests typically were found near swamps and stream edges and were periodically flooded.

Fauna

The NPP includes a rich array of animal species; including 45 mammal species, 221 bird species, 37 reptile species, and 25 amphibian species. Approximately 13 animal species are federally listed as endangered or threatened. Big game species include black bears and white-tailed deer (*Odocoileus virginianus*). Small game species include marsh rabbits (*Sylvilagus palustris*), cottontail rabbits (*Sylvilagus floridanus*), fox squirrels (*Sciurus niger*), and gray squirrels (*Sciurus carolinensis*). Other common mammals include bobcats (*Lynx rufus*), river otters (*Lutra canadensis*), mink (*Mustela vison*), gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), muskrats (*Ondatra zibethicus*), and Virginia opossums (*Didelphis virginiana*). Common upland game birds are bobwhite quail (*Colinus virginianus*), American woodcock (*Philohela minor*), mourning dove (*Zenaidura macroura*), and the eastern wild turkey (*Meleagris gallopavo*). In addition, several species of waterfowl are hunted on the NPP, including species found year-round on the peninsula and migratory species.

Table 2.1. Dominant habitat types on the NPP, North Carolina (modified from Jones [1996]).

Habitat type / description	Dominant species
Agriculture	<i>Triticum aestivum</i> (winter wheat) <i>Zea mays</i> (field corn)
Cropland, pasture, bare soils, grassy soils, bare fields, and clear-cuts.	<i>Glycine max</i> (soybean) <i>Nicotiana tabacum</i> (tobacco) <i>Gossypium hirsutum</i> (cotton)
Low vegetation	<i>Pinus taeda</i> (loblolly pine) <i>Rubus</i> spp. (blackberry)
Fallow fields and early successional stage clear-cuts.	<i>Phytolacca americana</i> (pokeweed) <i>Smilax laurifolia</i> (greenbriar)
Pine	<i>Pinus taeda</i> <i>Pinus serotina</i> (pond pine)
Medium and high density conifer stands (> 50% crown closure).	<i>Persea borbonia</i> (red bay) <i>Acer rubrum</i> (red maple)
Bottomland hardwood	<i>Quercus laurifolia</i> (swamp laurel oak) <i>Quercus lyrata</i> (overcup oak) <i>Quercus phellos</i> (willow oak) <i>Quercus nigra</i> (water oak) <i>Chamaecyparis thyoides</i> (Atl. white cedar) <i>Liquidambar styraciflua</i> (sweet gum) <i>Nyssa sylvatica</i> (black gum) <i>Nyssa biflora</i> (swamp tupelo) <i>Taxodium distichum</i> (bald cypress)
Upland hardwood	<i>Fagus grandifolia</i> (beech) <i>Liriodendron tulipifera</i> (yellow poplar)
Hardwood stands in upland areas.	<i>Acer floridanum</i> (sugar maple) <i>Quercus michauxii</i> (swamp chestnut oak) <i>Quercus alba</i> (white oak) <i>Quercus rubra</i> (red oak) <i>Liquidambar styraciflua</i> <i>Acer rubrum</i>

Table 2.1. (Cont.)

Habitat type / description	Dominant species
Mixed pine and hardwood	<i>Pinus taeda</i> <i>Pinus serotina</i>
Stands of mixed conifer and deciduous hardwood. Neither comprising > 75% of crown density.	<i>Liriodendron tulipifera</i> <i>Liquidambar styraciflua</i> <i>Acer rubrum</i>
Pocosin	<i>Lyonia lucida</i> (fetterbush) <i>Cyrilla racemiflora</i> (ti ti) <i>Zenobia pulverulenta</i> (zenobia) <i>Smilax laurifolia</i> <i>Pinus serotina</i> <i>Persea palustris</i> (swamp red bay) <i>Gordonia lasianthus</i> (loblolly bay) <i>Magnolia virginiana</i> (sweetbay) <i>Arundinaria gigantea</i> (switchcane)
Marsh	<i>Taxodium distichum</i> <i>Nyssa aquatica</i> (water tupelo) <i>Nyssa biflora</i> <i>Acer rubrum</i> <i>Persea palustris</i> <i>Cyrilla racemiflora</i> <i>Scirpus</i> spp. (bulrushes) <i>Carex</i> spp. (sedges) <i>Juncus</i> spp. (rushes) <i>Typha latifolia</i> (common cattail)

History of Land Use

Many of the NPP residents work in the agriculture or forest industry, or provide goods and services to these industries (Jones 1996). Agricultural farms range in size from >10 km² to small private fields. The majority of the rural residents either farm or lease land to other farmers.

Prior to the 1900's, the original virgin forest on the NPP included stands of longleaf and other southern pines, upland and bottomland hardwoods, and cypress and white cedar (Hughes, unpubl. data). By the 1930's most of the virgin forest was depleted by logging. By the 1950's the second-growth forest regenerated. This second-growth forest is gradually being replaced by the third-growth forest. On the NPP, the third-growth forest can be considered the loblolly pine plantations. On lands not actively managed for pine, these forests regenerate as hardwood or mixed pine-hardwood.

Weyerhaeuser Company began forest management on the NPP in 1936 (Hughes, unpubl. data) and intensively manage their lands for loblolly pine. Weyerhaeuser Company owns about 55% of the Big Pocosin study area and about 50% of the Gum Swamp study area. Most of Weyerhaeuser's tracts are consolidated into nearly continuous land holdings. A complete cycle for harvest, regeneration, and re-harvest typically includes clearcutting the stand, preparing a seedbed, planting seedlings in windrows, 2 commercial thinnings, and fertilizing. These tracts are managed on a 30- to 50-year rotation (Hughes, unpubl. data).

Excluding agricultural and forestry uses, hunting probably is the most common use of the rural landscape. The NPP is divided into several hunt clubs. Most of the hunt club

lands are leased to clubs by Weyerhaeuser Company. Bear hunting season takes place 1 week during mid-November. In 1996, an additional hunting season was incorporated in early December for 3 days.

The NPP contains 1 black bear sanctuary where hunting is illegal. The purpose of the sanctuary is to protect a nucleus of breeding females from hunting while providing surplus bears to surrounding areas for hunting (Collins 1990). The 90 km² sanctuary is in the eastern portion of the peninsula and approximately 75% of the sanctuary is within the Gum Swamp study area.

CHAPTER III

METHODS AND MATERIALS

Capturing and Handling

Project personnel used Aldrich spring-activated foot snares to capture black bears (Johnson and Pelton 1980). Black bears were then immobilized with an intramuscular injection of ketamine hydrochloride (Ketaset, Burns Veterinary Supply, Inc., Farmers Branch, Texas) (200 mg/ml), xylazine hydrochloride (Rompun, Haver-Lockhart, Inc., Shawnee, Kansas) (100 mg/ml), and mepivacaine hydrochloride (Carbocaine V, Winthrop Lab., New York, N.Y.) (20 mg/ml) at a dosage of 1 ml/25 kg body weight. After immobilization, a wetting agent (Artificial Tears, Maurry Biol. Co., Los Angeles, Calif.) was applied to the bear's eyes to prevent desiccation. Each bear was eartagged with a unique number and given a lip tattoo of the same number. For the purpose of using a mark-resight technique to estimate population size, bears captured during 1995-96 were marked with a radio- or cloth-collar so they could later be identified as marked bears in the resight photographs. In addition, all bears captured in 1995 were fitted with orange and white ear streamers, whereas those captured during 1996 were uniquely marked with colored ear streamers. As a result, bears captured in 1995 were only identified as marked or unmarked in the resight sample, whereas those captured in 1996 were identified individually in the resight sample. An upper premolar was extracted for aging by cementum annuli analysis (Willey 1974). Oxytocin (Burns Veterinary Supply, Farmers Branch, Texas) was administered to lactating females (1 ml) to stimulate lactation. An

antibiotic, liquamycin (LA-200, Pfizer Animal Health, New York, N.Y.), was administered to all captured bears (1 ml/5 kg body weight). Yohimbine, (Lloyd laboratories, Shenandoah, Iowa) an antagonist for xylazine, was administered through the medial saphenous vein or in the sublingual vein in the tongue (1 ml/25 kg body weight).

Resight

Following the 1995 and 1996 trapping seasons, remote camera stations were used to collect resight data for estimating population size. Camera stations were used in the Gum Swamp in 1995 and in the Big Pocosin in 1996. Camera stations were placed systematically throughout the study areas, but were not placed at trap sites. The stations used cameras that required manual film advance, therefore only one photograph could be taken after each camera was set. Camera stations were checked once every 1-14 days. Stations were baited with the same bait used at trap sites. A photograph of the back and head region of a bear was taken when a bear pulled on the bait.

Population Size

A robust capture-recapture design incorporates multiple tiers of sampling (Pollock et al. 1990). Following this design, I used both closed and open capture-recapture models (Fig 3.1). Seber (1982) defines a closed population as a population where no births or deaths occur (demographically closed) and no immigration or emigration occur (geographically closed) during a given time period. In contrast, he defines an open population as a population where births and deaths can occur (demographically open) but

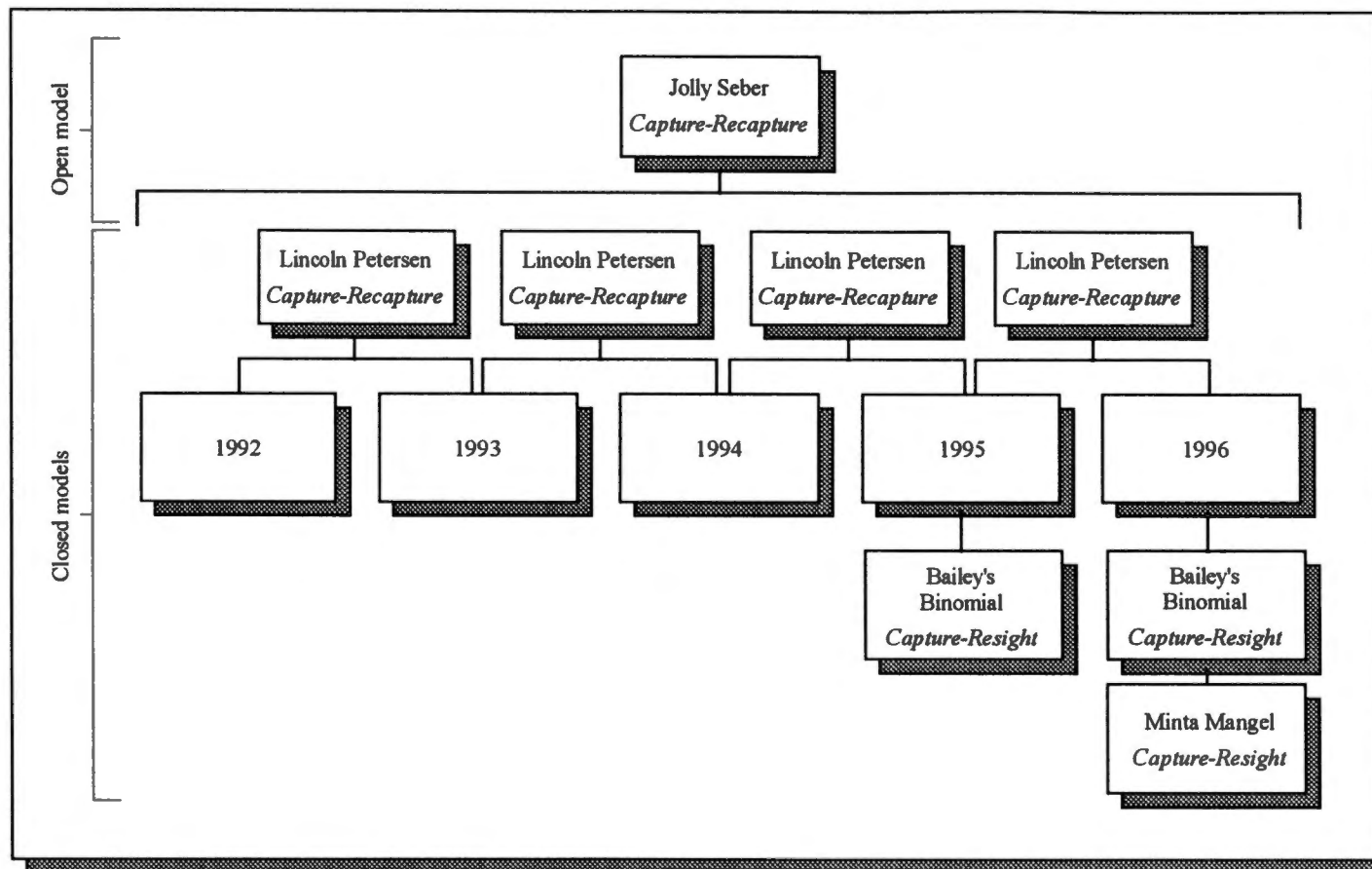


Figure 3.1. Capture-recapture models and the periods each model was used in the Gum Swamp and Big Pocosin study areas, North Carolina, 1992-1996.

no immigration or emigration occur (geographically closed) during a given time period. For open models I did not assume the population was geographically closed. Therefore, in the open model I could not separate births from immigration or deaths from emigration. As a result, I defined an open population as a population where additions and deletions occur during a given time period.

I used 3 closed models, the modified Lincoln-Petersen model (Pollock et al. 1990), Bailey's Binomial model (Seber 1982), and the Minta-Mangel model (Minta and Mangel 1989). The modified Lincoln-Petersen model was used to estimate population size between consecutive capture seasons in the Big Pocosin and Gum Swamp study areas. Bailey's Binomial model was used to estimate population size from capture-resight seasons in the Gum Swamp in 1995 and Big Pocosin in 1996. Also, the Minta-Mangel model was used to estimate population size from capture-resight seasons in the Big Pocosin in 1996. I used the Jolly-Seber model (Jolly 1965, Seber 1965, Pollock et al. 1990), an open model, across capture seasons in both the Big Pocosin and Gum Swamp for 1992-1996.

Modified Lincoln-Petersen Model. The modified Lincoln-Petersen model is appropriate for single mark release with 1 recapture period. All animals must be uniquely marked, so during the recapture period individuals are counted only once (Seber 1982). This model estimates population size as:

$$\hat{N}_c = \left[\frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} \right] - 1,$$

where n_1 is the number of animals captured in the first sample, n_2 is the total number of animals captured in the second sample, m_2 is the number of marked animals captured in the second sample, and $\hat{N}_c$ is the estimated population size. If $m_2 < 7$, bias in $\hat{N}_c$ can be large (Robson and Regier 1964), however the bias of $\hat{N}_c$ is negligible if the number of recaptures is ≥ 7 .

An approximate unbiased estimate of variance (Seber 1982) is

$$\text{var}(\hat{N}_c) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)}.$$

The modified Lincoln-Petersen model assumes: 1) the population is demographically and geographically closed, 2) all animals have the same capture probability, 3) marking does not affect the catchability of the animal, 4) the second sample is a random sample, 5) animals do not lose their marks between samples, and 6) all marks in the second sample are observed (Pollock et al. 1990). If emigration or mortality occurs, the model is robust if the probability is equal for marked and unmarked bears.

The capture periods for the modified Lincoln-Petersen model were from mid-May to mid-August during 1992-96. To lessen the effects of violating closure between summers (births and deaths), I did not include yearlings captured during the second capture period or known mortalities between the first and second capture periods. I added untagged yearlings and cubs captured in the second capture period to the final estimate.

Bailey's Binomial Model. Bailey's binomial model is appropriate for capture-recapture with replacement, capture-resight with replacement, and capture-recapture without replacement when the 4th assumption of the modified Lincoln-Petersen model is

false and the second sample is systematic rather than random (holding all other assumptions constant) (Seber 1982). Population size is estimated by

$$\hat{N}_b = \frac{n_1(n_2 + 1)}{m_2 + 1},$$

where n_1 is the number of animals captured in the first sample, n_2 is the total number of animals captured or sighted in the second sample, m_2 is the number of marked animals captured or sighted in the second sample, and $\hat{N}_b$ is the estimated population size.

An approximate unbiased estimate of variance (Seber 1982) is

$$\text{var}(\hat{N}_b) = \frac{n_1(n_2 + 1)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)}.$$

Bailey's Binomial model assumes: 1) the population is demographically and geographically closed, 2) marked animals have the same resight probability as unmarked animals, 3) marking does not affect the sightability of an animal, 4) the second sample is systematic, 5) animals do not lose their marks between samples, and 6) all marks in the second sample are observed (Seber 1982). For Bailey's Binomial model the capture periods were from mid-May to mid-August and the resight periods were from mid-August to mid-September.

Minta-Mangel Model. I used the Minta-Mangel model, provided in program NOREMARK (Gary White, Dept. Fisheries and Wildlife, Colorado State Univ.), to estimate population size in the Big Pocosin during 1996. The model requires that animals can be individually identified during the resight period. Therefore, I was unable to use the Minta-Mangel model in the Gum Swamp because bears were not uniquely marked with

ear streamers as they were in the Big Pocosin. The Minta-Mangel model uses a Monte Carlo method to generate a maximum likelihood estimate of population size and an asymmetric confidence interval around that estimate (Minta and Mangel 1989). For simplicity, consider that there are 2 types of animals, (e.g., type 1 = males and type 2 = females). Population size is calculated by

$$E\{\hat{N}_m\} = \sum_{m_1} \sum_{m_2} \Pr\{n_1 = m_1, n_2 = m_2\} \\ \left[B(m_1, m_2) + m_1 + m_2 \right],$$

where $\Pr\{n_1 = m_1, n_2 = m_2\}$ is the product of 2 binomial expressions and

$$B(m_1, m_2) = \frac{[(N_1 - m_1)t_1 + (N_2 - m_2)t_2](m_1 + m_2)}{m_1 t_1 + m_2 t_2},$$

where n_1 is the number of marked animals of type 1, n_2 is the number of marked animals of type 2, m_1 is the number of marked animals sighted of type 1, m_2 is the number of marked animals sighted of type 2, t_1 is the number of pictures from animals of type 1, t_2 is the number of pictures from animals of type 2, N_1 is the number of type 1 animals in the population, N_2 is the number of type 2 animals in the population, and $\hat{N}_m$ is the estimated population size.

Assumptions of the Minta-Mangel model are: 1) animals are captured, marked, and randomly or systematically resighted, 2) the population is geographically and demographically closed, 3) tags are not lost and are properly recorded, 4) the initial captures are a random sample of the population, and 5) sampling events are independent

(Minta and Mangel 1989). For the Minta-Mangel model, the capture period was mid-May to mid-August and the resight period was from mid-August to mid-October.

Jolly-Seber Model. I used an open model, the Jolly-Seber estimator provided with program JOLLY (Pollock et al. 1990). Program JOLLY provides 5 models: model A, A', B, D, and 2. Model A is the general model and allows capture and survival probabilities to vary. Model A' is for cases where deletions to the population are allowed but additions are not. Model B is the constant survival model, which assumes survival probabilities are constant over the entire study. Model D is the constant survival and capture model, which assumes both the survival and capture probabilities are constant over the entire study. Model 2 assumes that the survival rate immediately following the first capture is equal to the survival rate of an unmarked or previously marked animal. Population size is estimated by:

$$\hat{N}_i = \frac{n_i M_i}{m_i}$$

and,

$$M_i = \frac{z_i n_i}{r_i + m_i} \quad \text{or} \quad M_i = \frac{z_i R_i}{r_i + m_i} \quad \text{if } R_i < n_i,$$

where n_i is the number of animals caught in the i^{th} sample, m_i is the number of marked animals caught in the i^{th} sample, R_i is the number of animals released with marks from the i^{th} sample, r_i is the number of animals released from the i^{th} sample that are subsequently recaptured, z_i is the number of animals caught before the i^{th} sample that are not caught in the i^{th} sample but are caught subsequently, $\hat{N}_i$ represents the total number of animals in

the population just before the i^{th} sample, and M_i represents the total number of marked animals in the population just before the i^{th} sample (Pollock et al. 1990).

Assumptions of the Jolly-Seber model are: 1) the population is demographically and geographically open, 2) every animal has equal capture probability in the i^{th} sample, 3) every animal has equal survival probability from the i^{th} to the $i^{\text{th}}+1$ sample, 4) marks are not lost and all marks are noted and recorded, and 5) all samples are instantaneous (demographically closed during sample) (Pollock et al. 1990). The capture periods for the Jolly-Seber model were identical to the capture periods defined for the modified Lincoln-Petersen model.

Program JOLLY uses chi-square tests to test for trap heterogeneity and trap response. However, the power in the chi-square tests may be low if sample sizes, capture probabilities, or survival rates are low (Pollock et al. 1990). As an alternative for testing for trap response, I compared capture frequencies to a zero-truncated Poisson distribution (Caughley 1977, Clark 1991). I pooled capture frequencies between study areas and years (Clark 1991), and only included bears that were available for capture during all 5 years of the study (assuming geographic closure).

Telemetry

During the 1992-1996 capture seasons, selected bears were fitted with radio collars equipped with an activity switch (Telonics, Mesa, Ariz.). Project personnel located radio-collared bears using a Telonics receiver (Telonics, Mesa, Ariz.) and a 2-element, hand-held antenna or a 5-element, roof-mounted antenna on a truck. (Wildlife Materials,

Canbondale, IL). Bear locations were obtained using the loudest signal method (Springer 1979, Mech 1983). I used azimuths from 2 station points to calculate bear locations. I used azimuths that were between 45-120 degrees apart and collected ≤ 15 minutes apart for analysis. For each bearing, the observer Universal Transverse Mercator (UTM) coordinates, azimuth, time, and date were recorded (Strahler 1969).

Project personnel determined telemetry station coordinates using a Global Positioning System (GPS). I used program TELEM (Koeln 1980) to calculate bear locations from station coordinates and azimuths.

Survival

Project personnel monitored radio-collared bears 1-4 times/week to estimate survival. After 3 consecutive locations in the same area, project personnel visually located bears to determine fate (mortality or alive), except just prior to and during denning. I recorded the first date monitored, last date monitored, fate, sex, and age for all radio-collared bears. I estimated the mortality date (or censored date) as the median between the last recorded bear movement or change in activity date and the first date of the series of static signals (O'Pezio et al. 1983).

I estimated annual adult (≥ 3 years) (Maddrey 1995) survival for individual sexes and combined sexes using the staggered entry Kaplan-Meier procedure (Pollock et al. 1989). Survival was estimated by

$$\hat{S}(t) = \prod \left(\frac{1 - d_j}{r_j} \right) ,$$

$$\frac{j}{a_j} < t$$

where $\hat{S}$ is estimated survival, d_j is the number that died at time a_j , r_j is the number at risk at time a_j , a_j is a particular death time, and t is the time interval. An estimate of variance (var) is:

$$\text{var}[\hat{S}(t)] = \frac{[S(t)]^2[1 - S(t)]}{r(t)}.$$

Assumptions of the Kaplan-Meier procedure are: 1) bears monitored for survival were sampled randomly, 2) survival times were independent for different bears, 3) capturing or radio marking did not influence survival, 4) censoring mechanisms were random, and 5) newly radio-collared bears had the same survival function as previously radio-collared bears.

I used the Log-rank test (Pollock et al. 1989) to compare survival functions between sex and study area classes. To determine mortality rate through time, I calculated the discrete hazard function for pooled years as $1 - \hat{S}(t)$. To estimate the effects of hunting on adult survival, I recalculated survival treating harvested bears as censored (K. Pollock, N.C. State Univ., pers. commun.). I used the log-rank test to compare survival functions between hunted and non-hunted scenarios. I considered all tests significant at $P \leq 0.05$.

Movements

Movement Parameters. Project personnel located radio-collared bears every 1-3 hours for periods lasting 4-24 hours in duration (diel). These diels were collected on selected bears 1-2 times/month during the summer and fall of 1993-1994. I used diel locations to estimate daily movement (sum of consecutive movements), net movement (distance between first and last location), and range length (maximum distance between any 2 locations). Also, I calculated a mean travel rate (hourly) for each diel by dividing the time interval between consecutive locations into the distance traveled during the same time interval. I did not include bears that were stationary during the entire diel in the analyses (Garshelis et al. 1983). Because the estimates of movement parameters were calculated from assuming a straight line between consecutive locations, the estimates are $\leq$ the actual movement parameters.

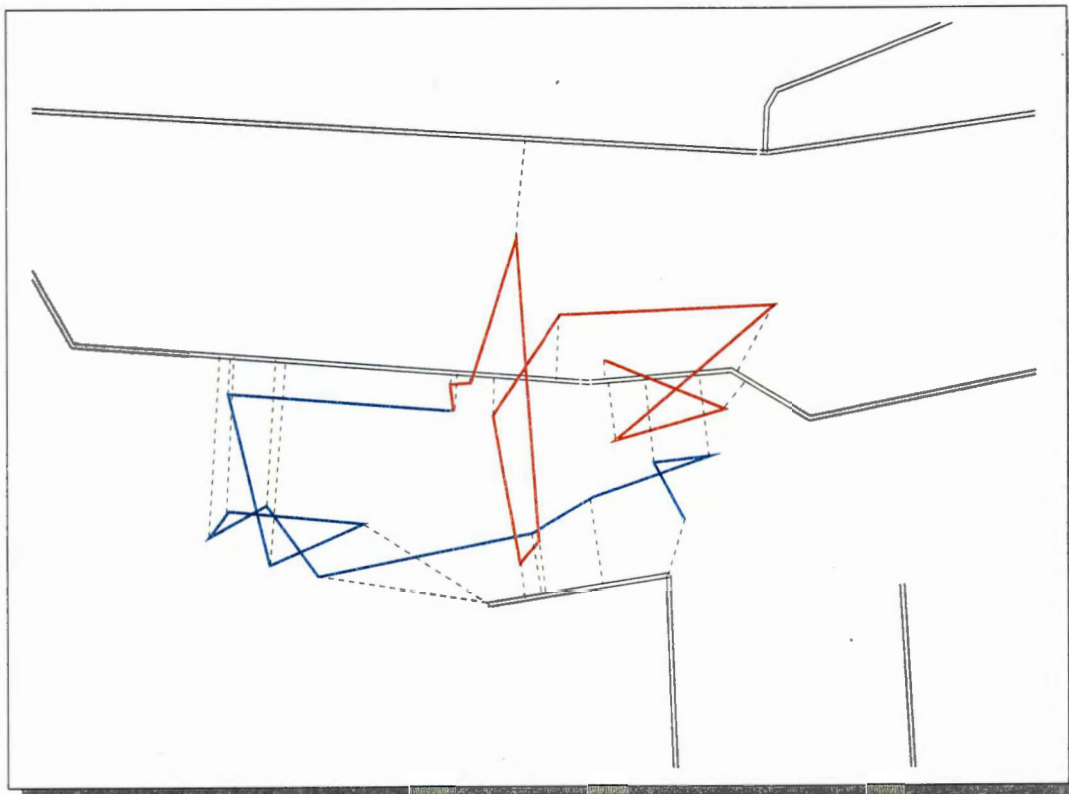
I compared movement parameters between sex, season (I defined summer as 1 April to 31 August and fall as 1 September to 31 December), study area, and year classes using a multivariate analysis of variance test (MANOVA) (SAS Institute, Inc. 1988). To minimize variation because of differences in sampling, I used diels that were between 20-24 hours long and with an average time between locations of 1.5 to 2.5 hours. Because multiple diels were collected for individual bears, an individual bear effect may exist. To account for possible individual bear effects, when calculating Wilks' Lambda F statistic I substituted the error bear (*class*) matrix for the error sum-of-squared cross product matrix. I also tested for individual bear effects by use of a MANOVA test. I compared

overall tests to $\alpha_I = 0.05$. If an overall test resulted in rejecting H_0 , I compared subtests to $\alpha_s = \alpha_I / p$, where p equals the number of subtests.

Movement Trajectories. To determine if bears move randomly across the landscape or if they select specific landscape features for movements, I compared actual movement trajectories to random movement trajectories. For actual trajectories, I used all diels with ≥ 4 locations. I created random trajectories by generating new locations, each in a random direction from the prior location, but at a distance based on the distribution of known movement distances. Actual and random trajectories shared the same initial location and, as such, were paired (Fig. 3.2).

Many methods which use bear locations to investigate habitat use are restricted to locations that are not serially correlated. In addition, habitat use methods tend to restrict the analyses to cover types only and fail to incorporate other landscape features which may influence bear use. I selected landscape variables that may contribute to the variability in bear movements from a biological standpoint, and that were available at an appropriate spatial scale and resolution (Table 3.1).

For every location, I calculated the distance to the nearest road, agricultural field, body of water, habitat edge, and human development site (Fig. 3.2). For each variable, I averaged the distances for all of the locations within each trajectory to generate a mean distance for every trajectory (actual and random). The road coverage was provided by U. S. Geological Survey - Earth Science Information Center (ESIC) (1990). The coverage identified primary (paved), secondary (paved), and tertiary (dirt) roads. Since 1990, many



Legend

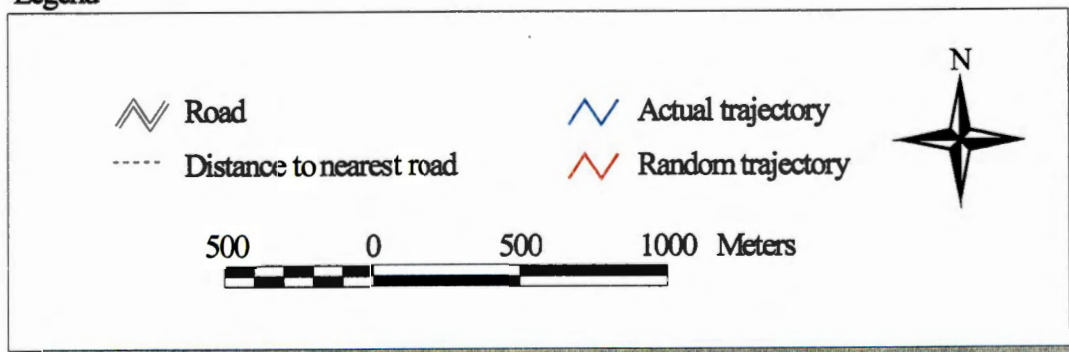


Figure 3.2. Example of distance to nearest road for actual and random trajectories in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Table 3.1. Variables used for analysis of black bear movements, North Carolina, 1994-1996.

Variable	Units/Data type	Description
Distance to road	Meters	Mean distance of trajectory to road
Distance to agriculture	Meters	Mean distance of trajectory to agricultural field
Distance to water	Meters	Mean distance of trajectory to permanent body of water, stream, or river
Distance to habitat edge	Meters	Mean distance of trajectory to habitat edge
Distance to development	Meters	Mean distance of trajectory to human development site
Habitat rank	Scale 1-7	Mean habitat rank for trajectory
Habitat richness	Scale 1-11	Mean habitat richness for trajectory
Patch area	Hectares	Mean patch area for trajectory
30 Agriculture corridor	Percentage	Proportion of locations in trajectory in agriculture habitat
Low vegetation corridor	Percentage	Proportion of locations in trajectory in low vegetation habitat
Pine corridor	Percentage	Proportion of locations in trajectory in pine habitat
Bottomland hardwood corridor	Percentage	Proportion of locations in trajectory in bottomland hardwood habitat
Upland hardwood corridor	Percentage	Proportion of locations in trajectory in upland hardwood habitat
Mixed pine/hardwood corridor	Percentage	Proportion of locations in trajectory in mixed pine/hardwood habitat
Pocosin corridor	Percentage	Proportion of locations in trajectory in pocosin habitat
Marsh corridor	Percentage	Proportion of locations in trajectory in marsh habitat

tertiary roads have been converted to secondary roads; therefore, I combined all road types into 1 coverage.

Habitat type typically is used in habitat use models and may explain some of the variability in bear movements. To determine if bears used certain habitat types for movement corridors, I compared the proportion of locations in a given habitat type between actual and random trajectories (Fig. 3.3). I also used habitat rank as a variable relating habitat type to movements. Habitat rank is a measure of relative habitat use by black bears and was determined by Jones (1996) in the Big Pocosin and Gum Swamp (scores ranging from 1 to 7 with 1 being the most used) using bear locations that were not serially correlated. I calculated mean habitat rank for each trajectory by averaging the rank values for all locations within each trajectory. Using the same procedure, I calculated the mean habitat richness for each trajectory. Habitat richness for any given pixel (30 x 30 m) equaled the number of different habitat types within a 90 m radius around that pixel. Richness values ranged from 1 to 11 with 11 being the highest. I generated a habitat richness coverage of the NPP using methods described by van Manen (1994). Similar to calculating the mean habitat rank and richness, I calculated mean habitat patch area for each trajectory. Patch area was calculated for each polygon of a homogeneous habitat type. The habitat type coverage used to create the habitat richness, rank, and patch area coverages were generated from LandSat Thematic Mapper images from LandSat 5 (1988) and had a 73% correct classification rate (Khorram et al. 1992).

I used univariate logistic regression to reduce the number of variables prior to analysis (Hosmer and Lemeshow 1989). Using logistic regression, I discarded variables

that resulted in an α -level ≥ 0.25 (Mickey and Greenland 1989). Because actual and random trajectories were paired, I calculated difference scores for each variable. I used the multivariate analysis of variance Hotelling's T^2 statistic (SAS Institute, Inc. 1988) to determine if bears selected specific landscape variables more than expected if use were random. I compared the overall test to $\alpha_1 = 0.05$. If the overall test resulted in rejecting H_0 , I compared subtests to $\alpha_s = \alpha_1 / p$, where p equals the number of subtests.

Telemetry Error

Sixty-one "test" radio collars were placed at known locations in both study areas where bears typically were located. Every person locating bears also located test collars. The distance from the estimated location and the actual location (obtained with a GPS) was recorded for each test collar (Clark 1991), and a distribution of error distances was calculated (mode = 100.0, $n = 61$). To determine the effects of telemetry error on the movement analyses, I repeated the movement analyses including telemetry error for the original diel data. I created the diels by generating new locations in a uniform random direction from the original locations, but at a distance based on the distribution of error distances.

Den Characteristics

I collected microhabitat characteristics at den sites of radio-collared bears and random sites during 1995 and 1996. Random sites were defined as sites in a random direction from the den but within the same habitat type as the den. This criterion was

chosen to keep overstory characteristics constant between paired sites. I used 7 vegetation types to characterize den sites: loblolly pine plantation, hardwood forest, mixed pine/hardwood forest, swamp, pocosin, low vegetation, and agriculture. I classified vegetation types according to the tree species dominating the overstory ($\geq 70\%$ of the canopy cover). I considered sites to be mixed pine/hardwood when 1 type (pine or hardwood) did not dominate the canopy. I classified non-forested vegetation types according to the plant forms that occupied $\geq 70\%$ of the vegetation.

I measured vegetative characteristics within a 0.04-ha circular plot (11.25 m radius) centered at the den site or random point (Schmutz et al. 1989). I sampled den site characteristics in the overstory (>2.5 m) and shrub (≤ 2.5 m) layers (Table 3.2).

Overstory characteristics included canopy cover, diameter-at-breast-height (DBH), tree number, and tree height. I calculated basal area for each plot from tree height. Shrub layer characteristics included cover density (horizontal and vertical cover), sapling frequency, shrub height, stem density, and stem diameter. I assumed that the dependent random sites were not used as den sites.

Several bears denned until mid April; consequently, I had to sample those den and random sites within a short window of time. As a result, den sites from the 1994 winter were sampled the following winter, when the herbaceous material was absent. Therefore, the results may be biased because those plots sampled 1 year after the bears denned at the sites may not reflect the vegetation that was present when the bears selected the sites. To determine if the variables I sampled differed by the effects of 1 years growth, I used a Student's t-Test to compare nest sites that were sampled in the same year they were

Table 3.2. Habitat characteristics measured within black bear den site and dependent random site plots, North Carolina, 1992-1996.

Characteristic	Units	Sampling Technique
Overstory (> 3 m)		
Canopy cover	%	Spherical densiometer (Strickler 1959)
DBH	m	DBH tape measure
Tree number	#	Direct count
Nest to tree distance	m	Tape measure
Tree height	m	Clinometer
Basal area	m ²	Calculated from tree height
Shrub (≤ 3 m)		
Cover density	%	Nudds cover board (Nudds 1977)
Sapling number	#	Direct count
Shrub height	cm	Centimeter stick
Shrub stem density	#/m ²	Daubenmire frame (Daubenmire 1959)
Shrub stem diameter	mm	Calipers/Daubenmire frame

occupied to nest sites that were sampled the winter after they were occupied. I found that nest characteristics did not differ due to 1 years growth; therefore, I pooled all nest sites (Appendix D.2.).

I used univariate logistic regression and correlation coefficients to reduce the number of variables prior to the analysis (Hosmer and Lemeshow 1989). Using logistic regression, I discarded variables that resulted in an α -level ≥ 0.25 (Mickey and Greenland 1989). Because use and non-use plots were paired, I calculated difference scores for each variable. I discarded variables (difference scores) that had a correlation coefficient ≥ 0.70 .

I used the multivariate analysis of variance Hotelling's T^2 statistic (SAS Institute, Inc. 1988) to determine if microhabitat characteristics differed between use and non-use sites. I compared the overall test to $\alpha_I = 0.05$. If the overall test resulted in rejecting H_0 , I compared the subtests to $\alpha_s = \alpha_I / p$, where p equals the number of subtests.

CHAPTER IV

RESULTS

Study Area Delineation

Male and female seasonal home ranges did not differ in the Big Pocosin, and only differed in fall 1992 and summer 1993 in the Gum Swamp (Jones 1996). Therefore, I buffered each trap site with the average radius of combined male and female home ranges for each respective study area. Mean radii for males and females in the Gum Swamp were 1,795 and 1,373 m, respectively (Jones 1996). I buffered each trap site in the Gum Swamp with the average radius of 1,584 m. In the Big Pocosin, mean radii for males and females were 1,901 m and 1,896 m, respectively (Jones 1996). I buffered each trap site in the Big Pocosin with the average radius of 1,899 m. During the first 2 years of the study some areas were trapped to examine bear damage to agriculture fields; as such, the objective was not to focus the trapping effort in a particular area. During the last 3 years of the study, the objectives of the study changed and trap sites were focused in 2 areas. To include capture data from the first 2 years of the study, I delineated the areas sampled by overlaying the buffered trap sites for each year. For the purpose of estimating population size, I excluded buffer regions that were not sampled each year. The Gum Swamp study area was 119 km² and the Big Pocosin study area was 149 km² in size (Fig. 4.1).

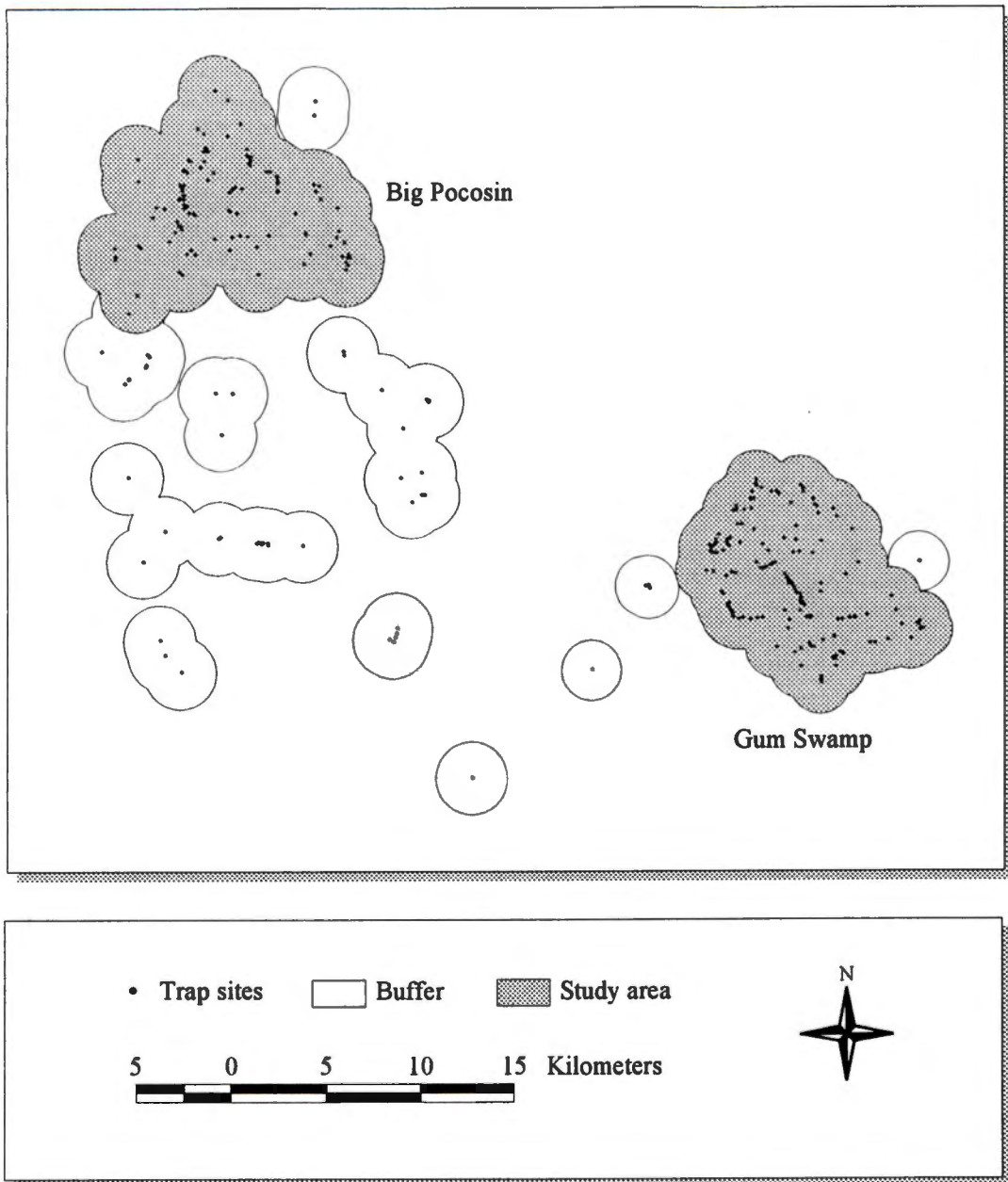


Figure 4.1. Delineation of the Big Pocosin and Gum Swamp study areas from areas trapped each summer of the study, North Carolina, 1992-1996.

Trapping

Overall, project personnel captured 213 bears 293 times (Table 4.1). In the Gum Swamp, 1,685 trap nights resulted in 200 captures of 136 bears and in the Big Pocosin 1,585 trap nights resulted in 93 captures of 77 bears. Eighty bears were recaptured; of these, 56 were recaptures from prior trapping seasons. Average trap success was 5.9 and 11.9% in the Big Pocosin and Gum Swamp study areas, respectively. Overall, trap success was 9.0%, averaging 11.2 trap nights/capture. Trap success was consistently greater in the Gum Swamp compared with the Big Pocosin.

Of the 213 individual bears captured, 114 were males and 99 were females. In the Gum Swamp 73 males and 63 females were captured, whereas in the Big Pocosin 41 males and 36 females were captured. The sex ratio did not differ from 1:1 within each study area ($\chi^2_{0.5} = 0.036$, 1 df, $P = 0.850$) or overall ($Z = -1.0278$, $P > 0.05$). The age of captured bears ranged from 7 months to 13 years ($\bar{x} = 4.2$, $SE = 0.22$, $n = 123$).

Resight

During the 1995 trapping season, project personnel marked 42 bears in the Gum Swamp with cloth collars and colored ear streamers. From 1 October to 27 October, 117 camera nights resulted in 35 photographed bears, yielding a 29.9% success rate.

Similarly, during the 1996 trapping season, project personnel uniquely marked 29 bears in the Big Pocosin with numbered collars and colored ear streamers. From 17 August to 18 October 1996, 246 possible photographs produced 29 bear pictures. Although the 20 camera stations totaled 994 camera nights, I checked the cameras

Table 4.1. Trapping results for the Neuse-Pamlico Peninsula black bear study, North Carolina, 1992-1996.

Year	Area	Trap nights	Total captures	Initial captures	Previous year recaptures	Within year recaptures	Trap nights per 1 capture	Trap success
1992	Big Pocosin	421	22	22	0	0	19.1	5.2%
1993	Big Pocosin	201	17	16	0	1	11.8	8.5%
1994	Big Pocosin	240	9	9	0	0	26.7	3.8%
1995	Big Pocosin	225	14	12	1	1	16.1	6.2%
1996	Big Pocosin	498	31	18	11	2	16.1	6.2%
Total	Big Pocosin	1,585	93	77	12	4	17.0	5.9%
40 1992	Gum Swamp	193	20	20	0	0	9.7	10.4%
1993	Gum Swamp	240	43	31	5	7	5.6	17.9%
1994	Gum Swamp	247	39	30	8	1	6.3	15.8%
1995	Gum Swamp	576	46	27	15	4	12.5	8.0%
1996	Gum Swamp	429	52	28	17	7	8.3	12.1%
Total	Gum Swamp	1,685	200	136	45	19	8.4	11.9%
TOTAL		3,270	293	213	57	23	11.2	9.0%

approximately once every 12 days, thus 246 photographs were possible. Photograph success (bear pictures/possible pictures) was 11.0% (27/246) for bears.

Population Size

The equal catchability test described by Caughley (1977) indicated that the observed capture frequency did not differ from a zero-truncated poisson distribution ($\chi^2_{0.5} = 4.121$, 2 df, $P = 0.1274$). Similarly, the goodness-of-fit tests provided with program JOLLY failed to detect capture bias due to heterogeneity in any of the models (model A: $\chi^2_{0.5} = 2.4130$, 3 df, $P = 0.4912$; model A': $\chi^2_{0.5} = 5.5152$, 5 df, $P = 0.3563$; model B: $\chi^2_{0.5} = 6.5865$, 4df, $P = 0.1594$; model D: $\chi^2_{0.5} = 5.7430$, 7 df, $P = 0.5701$) (Gum Swamp only, see *Jolly-Seber Model* below). Therefore, I assumed that trap response and heterogeneity did not significantly bias population size estimates.

Modified Lincoln-Petersen Model. Estimated population size was 55.7 bears (95% CI = 22.0-89.4) in the Big Pocosin during 1996, or 0.37 bears/km² (95% CI = 0.14-0.60) (Table 4.2). Due to the paucity of recaptures, I was unable to estimate population size in the Big Pocosin from 1992-1995. Population size estimates ranged from 84.6 to 204.0 bears in the Gum Swamp. Mean population size in the Gum Swamp was 140.3 bears (95% CI = 61.2-219.4), or 1.18 bears/km² (95% CI = 0.52-1.84).

Bailey's Binomial Model. Of the 29 bear photographs in the Big Pocosin during 1996, I censored 2 photographs because I was unable to determine if the sighted bear was marked. Eight bears were marked in the remaining 27 photographs. Estimated population

Table 4.2. Estimated black bear population size from the Lincoln-Petersen model in the Big Pocosin (BP) and Gum Swamp (GS) study areas, North Carolina, 1992-1996.

Study area	Year	n ₁	n ₂	m ₂	N _{LP}	95% CI	Cubs and yearlings	Mortality	Population estimate	Bears/km ² _a
BP	1992-93	12	11	0	---	---	---	---	---	---
BP	1993-94	11	8	0	---	---	---	---	---	---
BP	1994-95	8	13	0	---	---	---	---	---	---
BP	1995-96	13	28	5	66.7	(33.0-100.4)	1	12	55.7	0.37
BP	Mean				66.7	(33.0-100.4)			55.7	0.37
42 GS	1992-93	13	31	4	88.6	(35.8-141.4)	4	8	84.6	0.71
GS	1993-94	32	34	8	127.3	(68.8-185.8)	4	16	115.3	0.97
GS	1994-95	34	35	5	209.0	(79.7-338.3)	6	11	204.0	1.71
GS	1995-96	38	36	8	159.3	(83.5-235.1)	8	10	157.3	1.32
GS	Mean				146.1	(67.0-225.2)			140.3	1.18
BP+GS	Total				212.8	(100.0-325.6)			196.0	0.73

n₁ = Number marked in first sample

n₂ = Number captured in second sample

m₂ = Number of recaptures in second sample

N_{LP} = Estimated population size

_a Big Pocosin = 149 km², Gum Swamp = 119 km²

size using Bailey's binomial model was 90.2 bears (95% CI = 44.1-136.3), or 0.61 bears/km² (95% CI = 0.31-0.91).

Of the 35 bear photographs in the Gum Swamp during 1995, I censored 12 photographs because I was unable to determine if the sighted bears were marked. In the remaining 23 photos, 6 bears were marked. Estimated population size using Bailey's Binomial model was 144.0 bears (95% CI = 60-228), or 1.21 bears/km² (95% CI = 0.50-1.92).

Minta-Mangel Model. Of the 8 marked bears sighted in the Big Pocosin in 1996, bear M206 was sighted twice, bear F213 was sighted 3 times, and bears F210 and M216 were sighted once each. I censored 1 marked bear photograph because I was unable to uniquely identify the bear. Estimated population size using the Minta-Mangel model was 89 bears (95% CI = 64-145), or 0.60 bears/km² (95% CI = 0.43-0.97).

Jolly-Seber Model. In the Big Pocosin only models A and A' provided estimates. In addition, only model A' provided a confidence interval, and no chi-square tests were provided at all. Based on the poor performance of the Jolly-Seber models in the Big Pocosin, the results were probably not robust to model violations. Therefore, I discarded Jolly-Seber estimates for the Big Pocosin.

In the Gum Swamp, models A, A', D and B calculated population size. Estimates from model A' were consistently higher than the other models; ranging from 197.1 to 345.7 bears ($\bar{x}$ = 248.8, 95% CI = 173.1-324.5) (Table 4.3 and Fig. 4.2). Estimates from models A, D and B provided similar results, mean estimates were 114.0 (95% CI = 58.9-169.1), 140.9 (95% CI = 30.3-251.5), and 138.9 (95% CI = 13.6-264.3) bears,

Table 4.3. Estimated black bear population size from the Jolly-Seber models in the Gum Swamp (GS) study area, North Carolina, 1992-1996.

Study area	Year	Model A _a		Model A' _b		Model B _c		Model D _d	
		N	(95% CI)	N	(95% CI)	N	(95% CI)	N	(95% CI)
GS	1992	---	---	345.7	(101.1-590.3)	---	---	---	---
GS	1993	43.6	(20.6-66.6)	197.1	(137.1-257.1)	98.7	(16.6-180.8)	123.1	(65.0-181.2)
GS	1994	172.3	(37.9-306.7)	242.6	(131.1-354.1)	155.3	(69.4-241.2)	136.4	(78.8-194.0)
GS	1995	128.1	(35.0-220.4)	210.0	(92.1-327.9)	134.5	(67.0-202.0)	146.9	(84.0-209.8)
GS	1996	---	---	---	---	167.3	(64.4-270.2)	157.2	(84.4-230.0)
44 GS	Mean	114.7	(59.6-169.8)	248.8	(173.1-324.5)	138.9	(13.6-264.2)	140.9	(30.3-251.5)

_a Model A allows for survival and capture probabilities to vary

_b Model A' is for cases where death is allowed but immigration is not

_c Model B assumes survival is constant over the entire study

_d Model D assumes both survival and capture probabilities are constant over the entire study

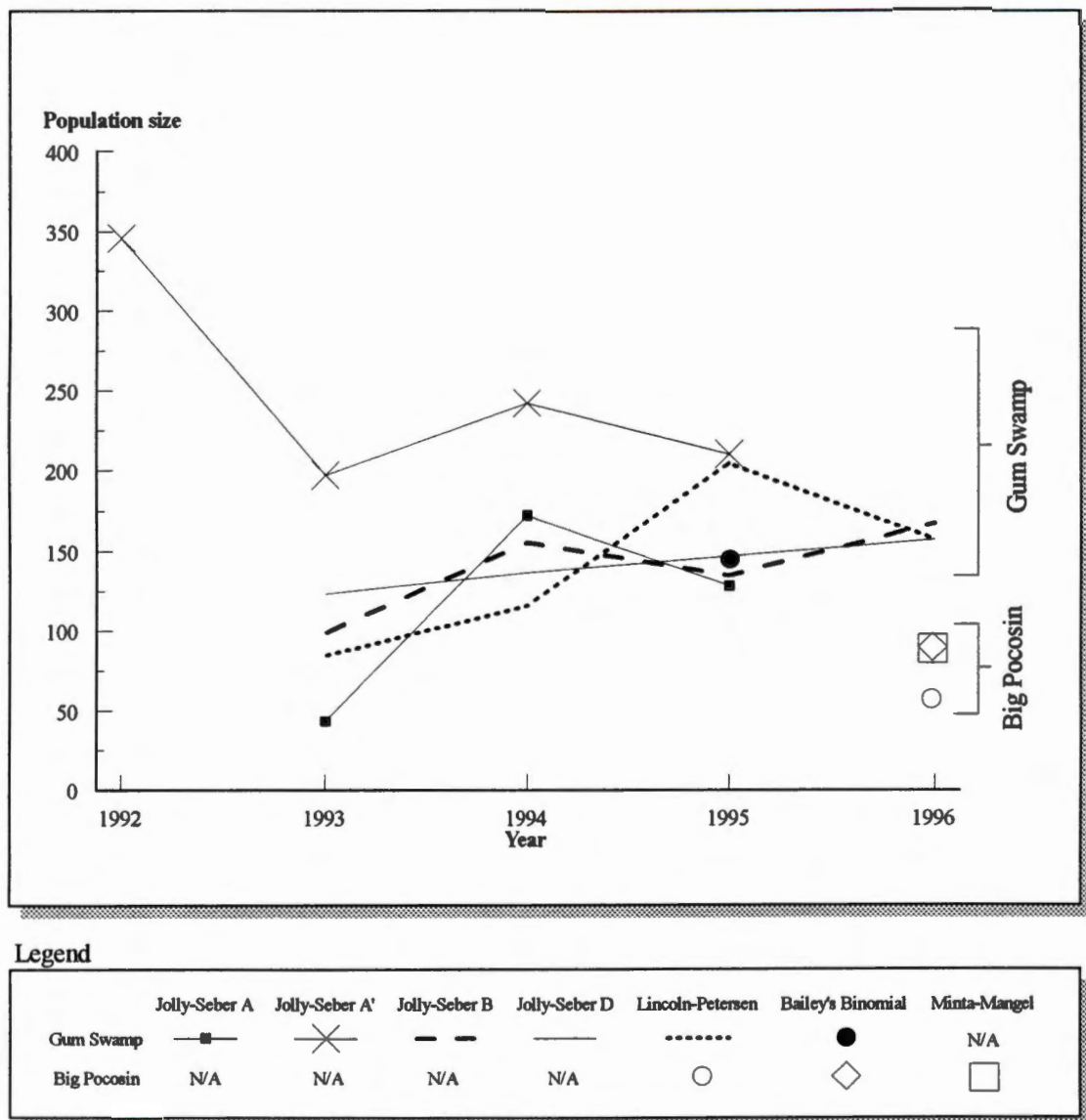


Figure 4.2. Estimated population size of black bears, using Jolly-Seber (models A, A', B, and D), Lincoln-Petersen, Bailey's Binomial, and Minta-Mangel models, in the Big Pocosin and Gum Swamp, North Carolina, 1992-1996.

respectively. Mean population size calculated from models A, A', D, and B was 160.8 bears (95% CI = 69.1-252.5), or 1.35 bears/km² (95% CI = 0.58-2.12).

Survival

Combining years, project personnel monitored 77 bears (a total of 82 bear units were monitored because 5 individuals were monitored during 2 different time spans) for survival analysis. Bears were monitored from May 1992 to August 1996. Of the 27 radio-collared males, 19 dropped their collars (including 1 collar that was removed), 2 were harvested (1 bear was harvested outside the study areas, therefore I censored it from the analysis), 1 was found dead, and 5 had unknown status (Table 4.4). Of the 55 radio-collared females, 33 dropped their collars (including 2 collars that were removed), 4 were harvested, 2 were found dead, 6 had unknown status, and 10 active bears were censored at the end of the study.

Combining years, the mean number of female sampling units monitored in the Big Pocosin and Gum Swamp was 25.9 (SE = 0.6) and 31.0 (SE = 1.4), respectively (Appendix B). Similarly, the mean number of male sampling units monitored in the Big Pocosin and Gum Swamp was 5.5 (SE = 0.7) and 7.4 (SE = 1.1), respectively. I did not estimate survival for males because the mean sample size for males was < 20 (Pollock et al. 1989). Combining years and study areas, the mean number of female sampling units monitored was 56.4 (SE = 1.9).

Nine mortalities of radio-collared bears were documented: 6 harvested bears, 2 suspected natural mortalities, and 1 suspected poaching mortality. Due to the uncertainty

Table 4.4. Fate of radio-collared black bears in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Study area	Sex	Active	Drop	Harvest	Dead ^a	Unknown	Total
BP	F	6	17	0	0	0	23
GS	F	10	13	4	2	0	29
BP	M	1	7	1	0	2	11
GS	M	1	10	1 ^b	1	3	16
BP+GS	F	16	30	4	2	0	52
BP+GS	M	2	17	2 ^b	1	5	27

^a Cause of death was undetermined

^b One bear was harvested off the study areas and was censored from the analysis

of death, I reclassified suspected natural and poaching mortalities as unknown mortalities. Of the 6 harvested bears, 1 male was harvested off the study areas. Within the study areas, hunting accounted for 5 of 8 radio-collared bear mortalities and unknown causes accounted for the remaining mortalities.

Annual survival for females in the Big Pocosin and Gum Swamp was 1.00 (95% CI* = 0.88-1.00) (D. Sylwester, Univ. of Tenn., pers. commun. via J. Philpot) (see Appendix D.3) and 0.83 (95% CI = 0.70-0.96), respectively (Fig. 4.3) and differed ($\chi^2_{0.5} = 4.932$, 1 df, $P = 0.02636$) between study areas. Combining study areas, annual survival for females was 0.90 (95% CI = 0.82-0.98).

Of the 6 female bear mortalities in the Gum Swamp, 2 died from unknown causes and 4 were harvested. Treating harvested bears as censored, the annual survival rate for females increased from 0.83 (95% CI = 0.70-0.96) (with hunting) to 0.94 (95% CI = 0.86-1.00) (without hunting). No females were harvested in the Big Pocosin.

Mortality Rate. The discrete hazard function provided instantaneous mortality rates throughout the year (Fig. 4.3). Mortality from unknown causes occurred in January, April, and October, whereas mortality from harvest occurred in November. The annual mortality rate from unknown causes was 0.06 ($n = 65$) for females in the Gum Swamp. Similarly, the annual mortality rate from harvest was 0.12 ($n = 34$) for females in the Gum Swamp. In the Big Pocosin, no bear mortalities were documented from unknown causes. Combining study areas, the annual mortality rate for females was 0.03 ($n = 116$) due to unknown causes and 0.07 ($n = 61$) due to harvest.

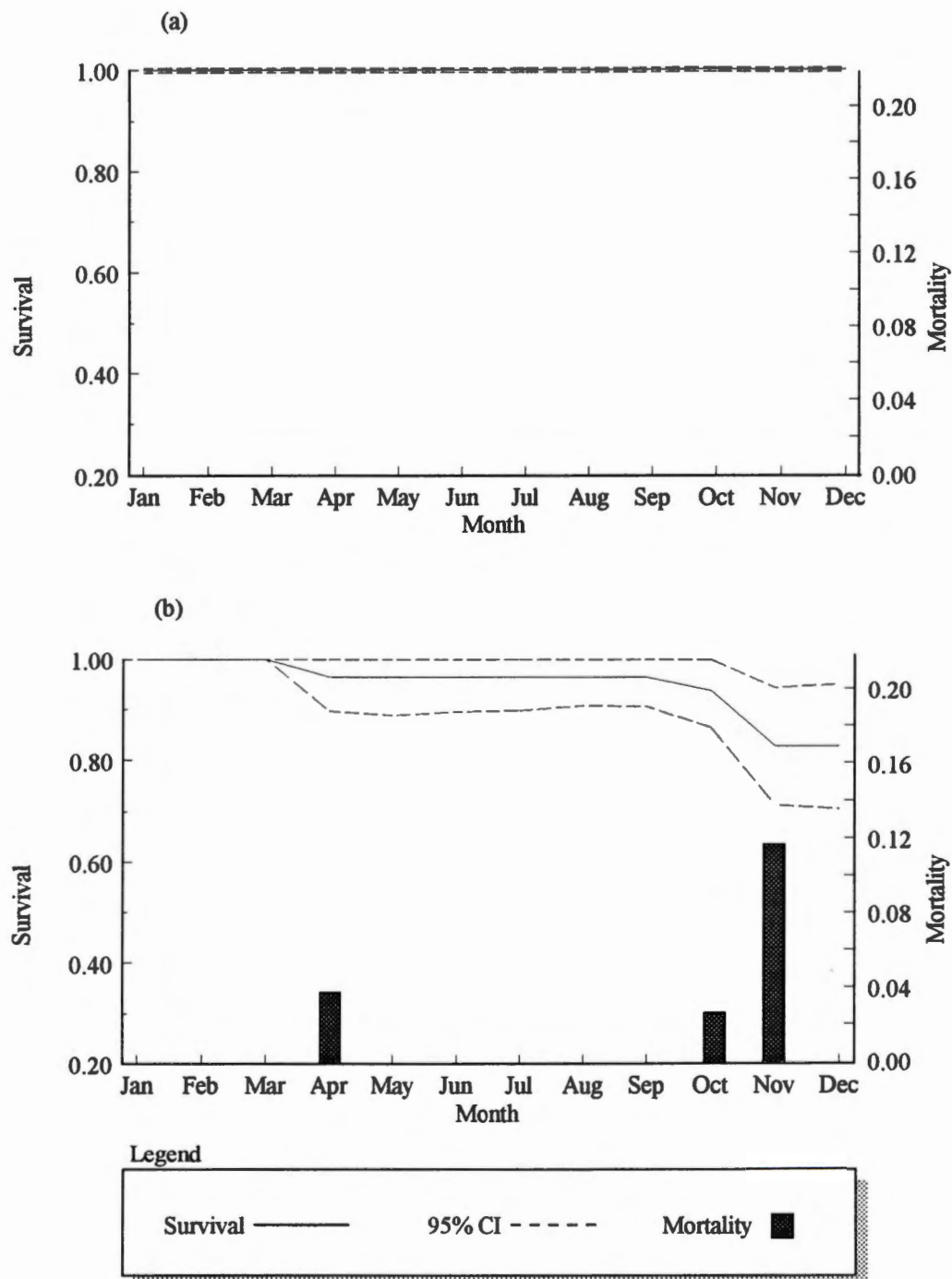


Figure 4.3. Annual black bear survival curve (95% CI) and mortality rates for (a) Big Pocosin and (b) Gum Swamp females, North Carolina, 1992-1996.

Movements

Movement Parameters. Project personnel collected 1,288 bear locations from April 1993 through December 1994. Twenty-seven bears were radiotracked during 130 diels (Figures 4.4 and 4.5).

Combining sex, season, study area, and year classes, mean total movement was 3,611.4 m (SE = 228.2, $n = 50$, range = 847.9-8,631.2 m), mean travel rate was 164.9 m/h (SE = 10.0, $n = 50$, range = 38.4-389.9 m/h), mean net movement was 871.0 m (SE = 133.5, $n = 50$, range = 33.6-5,337.8 m), and mean range length and was 1,537.5 m (SE = 133.1, $n = 50$, range = 418.7-5,193.0 m).

I was unable to compare movement parameters among sex or year classes because of low sample sizes. I found no differences in movements between study areas ($F = 0.73304$; 4, 10 df, $P = 0.5899$) (Table 4.5). However, I detected an overall difference in movements between seasons ($F = 6.45621$; 4, 18 df, $P = 0.0021$) (Table 4.6), although the differences were not evident at any of the individual subtests. Therefore, the overall significance was due to a combination of some or all of the variables. Based on the comparisons of means, movement parameters were greater in the summer than the fall. I did not detect any bear effect when comparing movements between seasons ($F = 0.86783$; 84, 97 df, $P = 0.7468$).

Telemetry Error. I analyzed the movement parameters substituting the diels including telemetry error for the original diels. These analyses indicated that telemetry error did not affect the original results comparing movements between study areas ($P_{original} = 0.5899$ and $P_{error} = 0.5209$). However, when comparing movements between seasons,

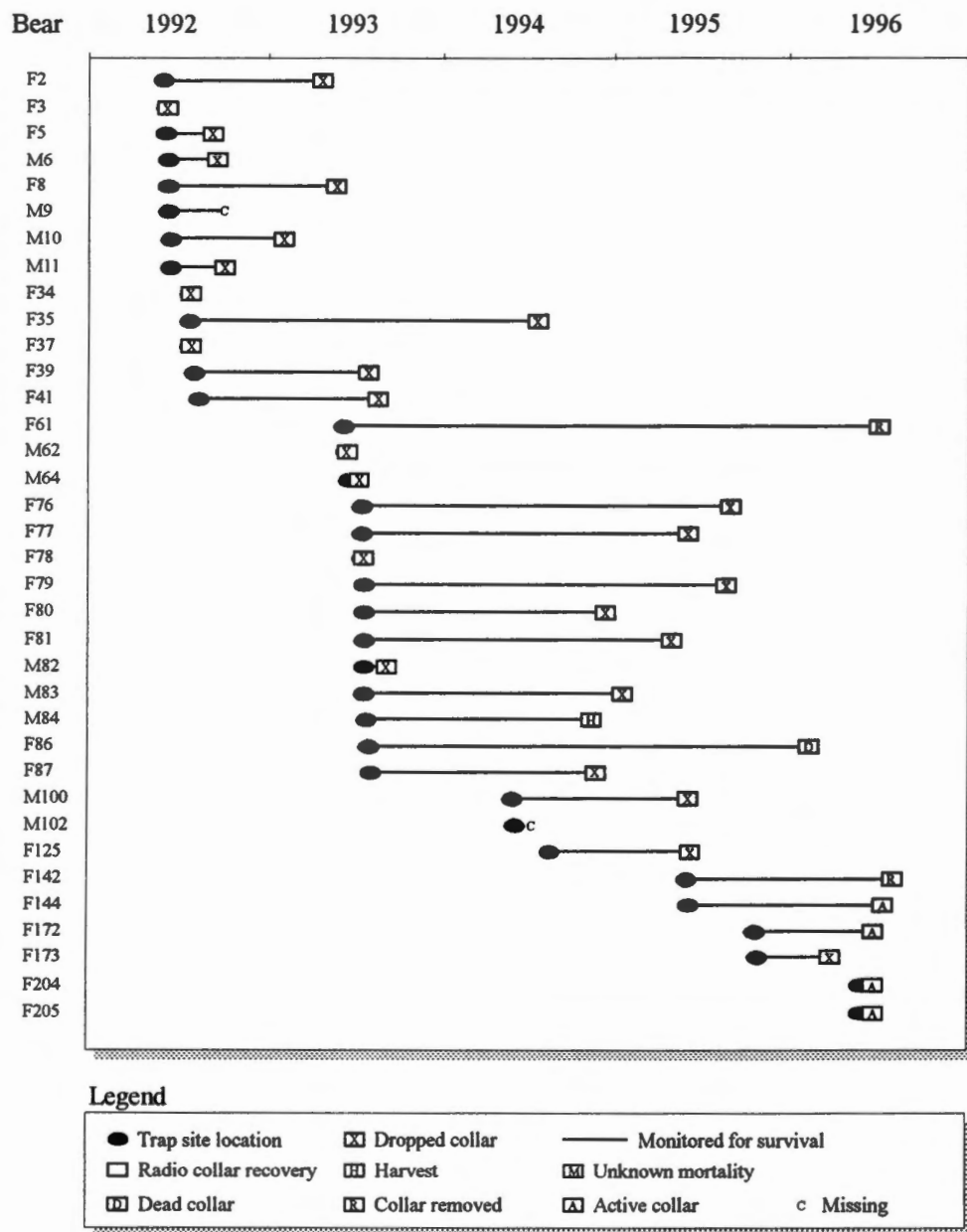


Figure 4.4. Tracking history of black bears in the Big Pocosin, North Carolina, 1992-1996.

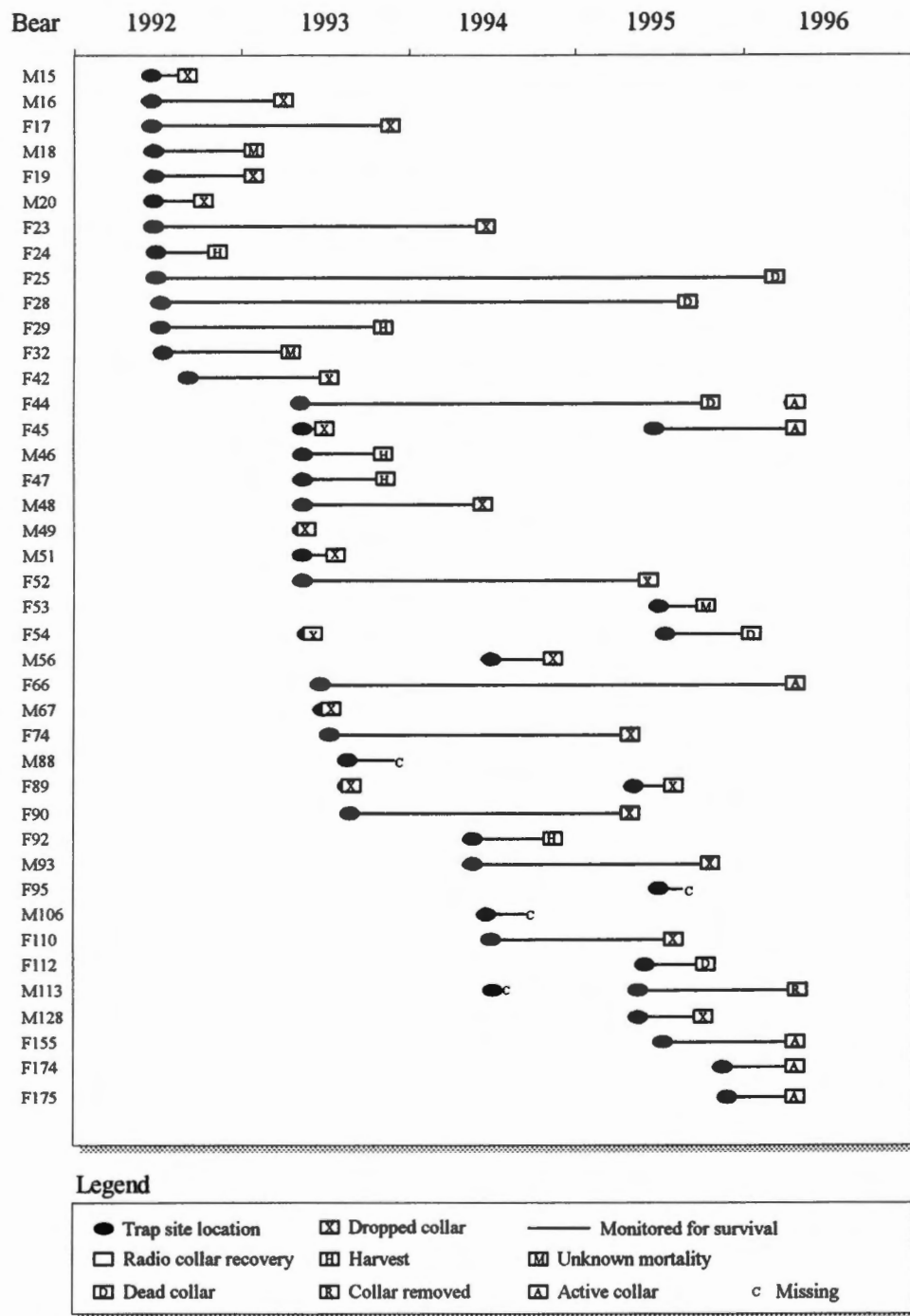


Figure 4.5. Tracking history of black bears in the Gum Swamp, North Carolina, 1992-1996.

Table 4.5. Comparison of black bear movements between the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Variable	Study area	Mean	Standard error	<i>n</i>	Range	df	<i>F</i> ^a	<i>P</i> ^b
Total movement (m)	BP	3,767.3	363.6	25	841.9-8,631.2			
	GS	3,455.6	280.1	25	1,849.6-7,558.4			
Rate of travel (m/h)	BP	169.2	16.0	25	38.4-389.9			
	GS	160.6	12.2	25	88.2-308.8			
53 Net movement (m)	BP	1,025.5	236.1	25	105.5-5,337.8			
	GS	716.5	122.8	25	33.6-2,729.6			
Daily range length (m)	BP	1,679.4	212.2	25	418.7-5,193.0			
	GS	1,395.6	160.0	25	502.5-3,374.3			
Bear effects						52,126	1.35803	0.0858
Overall						4,10	0.73304	0.5899

^a F statistic for subtests not shown unless the overall test was significant

^b P-values for subtests not shown unless the overall test was significant

Table 4.6. Comparison of black bear movements by season in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Variable	Season	Mean	Standard error	<i>n</i>	Range	df	<i>F</i>	<i>P</i>
Total movement (m)	Summer	3,885.8	343.4	24	1,889.0-8,631.2	22,27	0.93	0.5655
	Fall	3,358.2	301.4	26	841.9-6,792.0			
Rate of travel (m/h)	Summer	174.2	14.6	24	88.2-389.9	22,27	0.98	0.5148
	Fall	156.3	13.7	26	38.4-289.4			
54 Net movement (m)	Summer	952.8	160.7	24	46.1-3,101.6	22,27	0.85	0.6497
	Fall	795.4	211.7	26	33.6-5,337.8			
Daily range length (m)	Summer	1,587.8	178.1	24	502.2-3,374.3	22,27	0.68	0.8210
	Fall	1,491.1	199.0	26	418.7-5,193.0			
Bear effects						84,97	0.86783	0.7468
Overall						4,18	6.45621	0.0021

the analysis of the original and error diels differed ($P_{original} = 0.0021$ and $P_{error} = 0.6445$); the error analysis resulted in failure to reject the null hypothesis. Therefore, the difference detected in movements between seasons may have been an artifact of telemetry error. Thus, I cannot be certain that there were differences in movements between summer and fall seasons (Appendix C.3.).

Movement Trajectories. To increase the sample size and improve the power of the statistical tests, I combined sex, study area, season, and year classes in the movement trajectory analysis. Because the results from the movement parameter analyses failed to detect any differences in movements between study area and season classes, I assumed that pooling these classes had no affect on the movement trajectory analysis. I was unable to make the same movement comparisons between sex or year classes. Therefore, by pooling sex and year classes, I assumed that pooling sex and year classes had a minor effect on the movement trajectory analysis (Table 4.7).

I detected an overall difference between actual and random movement trajectories ($F = 3.2892$; 7, 116 df; $P = 0.0032$) (Table 4.8 and Fig. 4.6). The mean distance to roads was greater ($F = 11.11$; 1, 122 df; $P = 0.0011$) in actual diels ($\bar{x} = 257.8$, $SE = 7.7$, $n = 123$) than random diels ($\bar{x} = 226.0$, $SE = 7.5$, $n = 123$). In the remaining subtests, no differences were detected (Table 4.8).

Telemetry Error. In the same analysis as the actual diels, I reanalyzed the movement trajectories incorporating telemetry error in the actual diels. The analyses indicated that telemetry error did not affect the original analysis comparing actual trajectories to random trajectories ($P_{original} = 0.0032$ and $P_{error} = 0.0133$) (Appendix C.5.).

Table 4.7. Movement trajectory statistics of black bears in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Variable	Mean	Standard error	<i>n</i>	Range
Distance to road (m)	257.8	7.7	123	59.2-450.2
Distance to agriculture (m)	534.6	33.6	123	8.0-1,431.8
Distance to water (m)	2,571.8	66.0	123	1,070.1-4,863.0
Distance to habitat edge (m)	75.0	5.5	123	12.9-433.4
Distance to development (m)	1,617.6	48.1	123	566.6-3,431.7
Habitat rank	4.9	0.07	123	1.8-6.5
Habitat richness	2.1	0.04	123	1.0-3.2
Patch area (ha)	668.6	84.8	123	4.8-5,848.0
Agriculture corridor (%)	8.3	1.3	123	0.0-75.0
Low vegetation corridor (%)	3.6	0.8	123	0.0-66.7
Pine corridor (%)	21.9	2.2	123	0.0-100
Bottomland hardwood corridor (%)	28.0	2.5	123	0.0-100
Upland hardwood corridor (%)	7.8	1.4	123	0.0-70.0
Mixed pine/hardwood corridor (%)	10.4	1.4	123	0.0-80.0
Pocosin corridor (%)	14.5	1.9	123	0.0-100
Marsh corridor (%)	5.5	1.0	123	0.0-58.3

Table 4.8. Comparison of actual to random movement trajectories of black bears in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Variable	Diel	Mean	Standard error	<i>n</i>	Range	df	<i>F</i>	<i>P</i>
Distance to road (m)	Actual	257.8	7.7	123	59.2-450.2	1, 122	11.11	0.0011
	Random	226.0	7.5	123	85.4-470.3			
Distance to agriculture (m)	Actual	534.6	33.6	123	8.0-1,431.8	1, 122	1.61	0.2064
	Random	564.1	34.4	123	21.9-1,318.0			
Distance to habitat edge (m)	Actual	74.9	5.5	123	12.9-433.4	1, 122	1.22	0.2710
	Random	83.3	6.2	123	8.7-487.0			
Distance to development (m)	Actual	1,617.6	48.1	123	566.6-3,431.7	1, 122	0.32	0.5738
	Random	1,643.0	51.7	123	88.2-3,248.7			
Habitat richness	Actual	2.1	0.04	123	1.0-3.2	1, 122	2.84	0.0945
	Random	2.0	0.04	123	1.0-3.7			
Pocosin corridor (%)	Actual	14.5	1.9	123	0.0-100	1, 122	6.94	0.0095
	Random	9.3	1.1	123	0.0-58.3			
Marsh corridor (%)	Actual	5.5	1.0	123	0.0-58.3	1, 122	3.95	0.0491
	Random	8.3	1.3	123	0.0-66.7			
Overall						7, 116	3.2892	0.0032

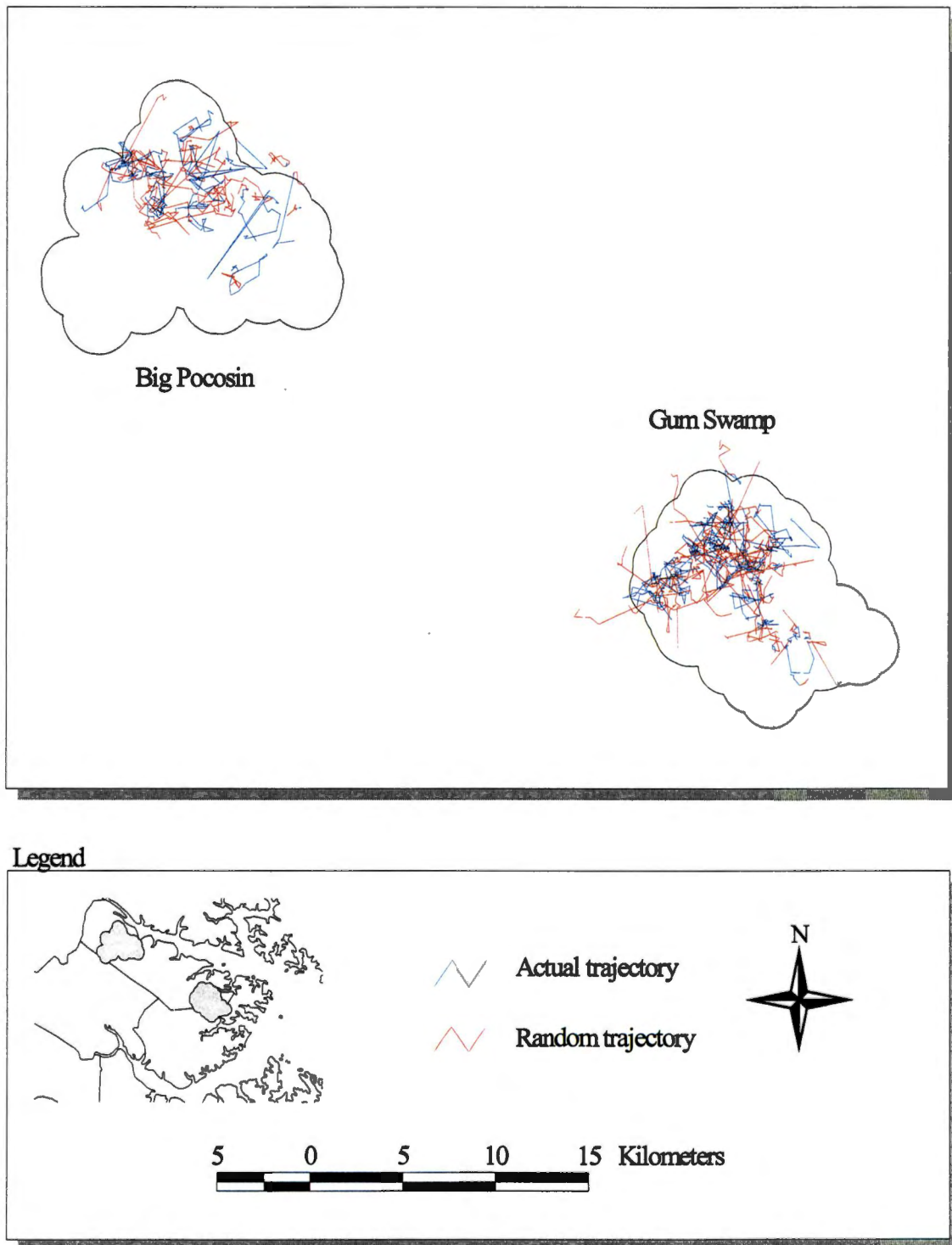


Figure 4.6. Actual and random movement trajectories of black bears in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Denning

Den Type and Date. Twenty-eight of the 31 bears I investigated denned during winter. Of these, 5 re-denned: 3 moved to a new den site after the researcher investigation and 2 moved to new sites for unknown reasons. Average den entrance ($n = 14$) and emergence ($n = 4$) dates were 3 January and 14 April during the 1994-95 winter, respectively. Similarly, average den entrance ($n = 13$) and emergence ($n = 8$) dates were 24 December and 8 April during the 1995-96 winter, respectively.

I visually confirmed den type on 23 dens, resulting in 20 nest dens, 2 excavated ground dens and 1 tree den. I was unable to locate 2 den sites. Nests typically were oval-shaped bowls constructed of leaves, pine needles, and small woody stems. Nest bowls ($n = 14$) averaged 71.8- x 93.3-cm and 5.6 cm above the ground. One ground den was in a mature pine stand, excavated at the base of a pine tree. The den was caved in when I revisited the site after the bear emerged. The second ground den was in a 2-year-old pine stand, where the bear burrowed into a wind-row. The tree den was in a 272 cm DBH bald cypress. The entrance hole was 13.3 m above the ground and the cavity was 2.7 m beneath the entrance.

Microhabitat Characteristics. I collected microhabitat data on 16 nest sites and 16 dependent random sites (Table 4.9). Of the 16 nests, 10 were in pine, 3 were in mixed pine/hardwood, 2 were in shrub, and 1 was in hardwood. Based on logistic regression, I excluded canopy cover from the analysis ($\chi^2_{0.5} = 0.275$, 1 df, $P = 0.5999$). I excluded basal area ($r = -0.7763$, $P = 0.0004$) and stem diameter ($r = 0.6987$, $P = 0.0026$) based on their high correlation with cover density and shrub height, respectively.

Table 4.9. Microhabitat statistics of black bear den sites in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Variable	Mean	Standard error	<i>n</i>	Range
Canopy cover (%)	73.73	6.11	16	0.00-93.20
Basal area (m ²)	0.79	0.12	16	0.00-1.53
Shrub height (cm)	74.32	3.78	16	37.75-91.94
Shrub stem density (m ²)	18.16	2.84	16	7.26-52.26
Shrub stem diameter (mm)	0.64	0.05	16	0.36-0.99
Cover density (%)	71.74	3.78	16	44.50-97.80

I detected an overall difference between nest and random sites ($F = 11.5534$; 3, 13 df; $P = 0.0006$) (Table 4.10). Shrub height was greater ($F = 13.60$; 1, 15 df; $P = 0.0022$) at nest sites ($\bar{x} = 74.3$, SE = 3.8, $n = 16$) than random sites ($\bar{x} = 47.6$, SE = 5.3, $n = 16$). Similarly, stem density was greater ($F = 10.40$; 1, 15 df; $P = 0.0057$) at nest sites ($\bar{x} = 18.2$, SE = 2.8, $n = 16$) than random sites ($\bar{x} = 7.5$, SE = 1.3, $n = 16$) and cover density was greater ($F = 38.92$; 1, 15 df; $P = 0.0001$) at nest sites ($\bar{x} = 71.7$, SE = 3.8, $n = 16$) than random sites ($\bar{x} = 40.8$, SE = 2.2, $n = 16$).

Table 4.10. Microhabitat characteristics of black bear den sites and dependent random sites, Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Variable	Site	Mean	Standard error	<i>n</i>	Range	df	<i>F</i>	<i>P</i>
Shrub height (cm)	use	74.32	3.78	16	37.75-91.94	1,15	13.6000	0.0022
	random	47.58	5.35	16	6.38-80.13			
Shrub stem density (m ²)	use	18.16	2.84	16	7.26-52.26	1,15	10.4000	0.0057
	random	7.50	1.26	16	1.26-20.00			
Cover density (%)	use	71.74	3.78	16	44.50-97.80	1,15	38.9200	0.0001
	random	40.82	2.23	16	24.50-57.50			
Overall						3,13	11.5534	0.0006

CHAPTER V

DISCUSSION

Population density

There are numerous problems associated with estimating densities of black bears. Black bears have large home ranges ($>100 \text{ km}^2$) and can disperse over long distances in a relatively short time period (Carr 1983, Garris 1983, Elowe 1984, Hellgren and Vaughan 1990). Therefore, to estimate bear densities large study areas are necessary which limits the ability to sample an area effectively. Black bears are secretive animals and, particularly in areas where bears live in close proximity to humans, have retreated to inaccessible areas with thick cover. These conditions substantially hamper studies of black bear population dynamics.

In addition to the biological and behavioral characteristics that make estimating bear numbers difficult, there are study design and statistical considerations. When estimating population size of animals using capture-recapture experiments, it is important to minimize model violations to reduce bias (Pollock et al. 1990). Pollock et al. (1990) suggested that model violations should be considered in 3 stages: 1) during the design of the study, 2) during data analyses, where specific tests of assumptions should be used to determine which model is most appropriate for the data, and 3) during interpretation; if specific assumptions have been violated, information on the effects of the violation should be used to interpret the estimates.

Following the first stage, I identified 2 potential assumption violations and reduced their effect with changes in the study design. First, a violation of closure in the modified Lincoln-Petersen model because of the long time span between the first and second capture periods. When conducting capture-recapture experiments on bears, summers are typically deemed capture periods. However, the modified Lincoln-Petersen model is a closed model and, thus, assumes there are no additions or deletions to the population from the start to the end of the experiment. Therefore, with capture periods defined as successive summers, the model assumes closure for about 15 months, which is a difficult assumption to meet. To minimize the magnitude of violating closure, I incorporated a capture-resight design that reduced the assumption of closure from 15 months to 4 months. The second change in study design was related to differences in capture probabilities as a result of temporary trap response. Coley (1995) found that the average time between initial capture and recaptures for individual bears in GSMNP was 5 years, suggesting that the Jolly-Seber models may be more effective for capture-recapture experiments that are ≥ 5 years in duration. Based on Coley's (1995) results, the study on the NPP was extended to 5 years.

The second stage of addressing model violations involves the use of generalized and specific tests for determining whether model assumptions are met. When estimating population size of animals, a typical source of model bias results from unequal capture probabilities of animals (Pollock et al. 1990). Most notably are the differences in capture probabilities due to heterogeneity and trap response, where heterogeneity refers to some measurable characteristic of individual animals (e.g., sex, age, social status) and trap

response refers to animals becoming “trap happy” or “trap shy” after being captured (Garshelis 1993). The design of this study helped to minimize problems associated with heterogeneity by incorporating different methods of capturing bears (i.e., capture versus resight) (Pollock et al. 1990). However, heterogeneity is difficult to eliminate and likely occurred in this study. If heterogeneity in capture probabilities is known to exist and is constant throughout the study, a simple solution is to stratify the data into groups with homogenous capture probabilities and estimate population size for each group. In this study sex ratios from the capture and harvest samples were nearly equal and home range sizes were similar between sexes, therefore I chose to pool sex classes to increase sample size. In many cases, the increase in sample size results in higher capture probabilities, which, in turn, makes capture-recapture models more robust to model violations (Pollock et al. 1990). Therefore, a trade-off exists between reducing possible heterogeneity by segregating the data or pooling capture data (Seber 1982).

Trap response bias likely occurred during this study. I used 3 techniques to reduce the effects of trap response. First, I conducted intensive trapping during the duration of the study with numerous traps in any given bears home range to increase the probability of a bear encountering a trap. Second, I changed the physical appearance of the traps and baited some but not others. Therefore, bears that associated bait with a trap site may not detect an unbaited trap. Similarly, bears that returned to a particular site frequently were faced with a new trap type. Lastly, I added a capture-resight experiment to counteract the differences in capture probabilities. In this study, the Lincoln-Petersen and Jolly-Seber models were based on the same capture method. Therefore, if trap response occurred,

bears that were “trap shy” had a lower capture probability than bears that were not “trap shy” and “trap happy” bears had greater capture probabilities than bears that were not “trap happy” (based on capture histories, the “trap happy” response probably was not a factor in this study). Therefore, the capture-recapture technique may not have adequately re-sampled trap shy bears and, consequently, resulted in a biased high population estimate. The capture-resight models changed the sampling technique between the first and second samples. Again, bears were initially sampled with snares, however bears were re-sampled with a remote camera. Ideally, the probability of resight was independent of an individual’s capture probability. However, because bears were attracted to the remote cameras with bait, the re-sample may not have been independent from the first sample. If most of the bears that detected the bait took the bait, and unequal capture probabilities mainly resulted from some individuals being able to take bait without being captured, then the remote camera stations likely reduced model bias. In contrast, if some bears took the bait while others did not, then the remote camera stations were not independent from the capture sample and may not have reduced model bias. Although both of these scenarios likely occurred during this study, the later was probably less frequent. I tested for unequal capture probabilities in the capture data with the chi-square tests provided by program JOLLY and as described by Caughley (1977): both failed to detect unequal capture probabilities. Therefore, in terms of trap response, all the models are equally appropriate.

The third stage of assessing model assumptions involves determining the effects of the assumption violation on the population estimate. In the Big Pocosin, the lack of

recaptures in early years hindered estimating population size using the modified Lincoln-Petersen or the Jolly-Seber models, and the resight models were not used. However, the modified Lincoln-Petersen, Bailey's Binomial, and Minta-Mangel models produced estimates in the final year of the study. The population estimate provided by the Lincoln-Petersen model may be biased, because the number of recaptures in the second sample was < 7 (Robson and Regier 1964). Therefore, Bailey's Binomial and Minta-Mangel models were more appropriate because the number of resights were > 7 and the reduced time span between the sampling periods. In addition, the 2 resight models also used different sampling techniques for the 2 samples (capture-resight versus capture-recapture), which further reduced the likelihood of trap response and the effects of heterogeneity (Seber 1982). The modified Lincoln-Petersen model produced a lower estimate compared to the resight models, which is what one might expect if trap heterogeneity occurred.

Program JOLLY provided a chi-square goodness-of-fit test to aid in the selection of the most appropriate model. Unfortunately, the tests failed to identify the most appropriate model for this study. However, Pollock et al. (1990) stated that as capture probability increases, a model becomes more robust to violations and precision increases. In terms of capture probabilities, model A was the most appropriate in this study, as it yielded the highest capture probability. However, all the Jolly-Seber models resulted in capture probabilities below 0.50, thus serious bias may have resulted from model violations (Gilbert 1973, Pollock et al. 1990). All of the Jolly-Seber models resulted in estimates that had a similar rate of change over time, with the exception of Jolly-Seber model A'. Moreover, despite the violation to closure in the modified Lincoln-Petersen

model, the Lincoln-Petersen model produced similar estimates of population size as the Jolly-Seber models in the last year of the study. Thus, there is no clear conclusion identifying the most appropriate model. The Jolly-Seber model A' behaved erratically and consistently produced higher estimates compared with the other models. Based on this behavior and the low capture probability from model A', I discarded it from calculating density in the Gum Swamp. Fortunately, with regard to the population size at the end of the study, selecting of the most appropriate model became less critical because all the models produced estimates within 10 bears of each other.

Reported black bear densities in the southeastern Coastal Plain range from 0.5 to 68 bears/100 km² (Table 5.1). The black bear population density in the Big Pocosin was within this range, however, the Gum Swamp density exceeded previous estimates. The density of black bears in the Gum Swamp was higher than many densities reported in the southeastern United States (Garshelis 1994). However, comparisons of population densities between 2 areas may not be appropriate because of differences in the models used, the spatial extent, and the relative sample sizes. I found that the Gum Swamp had twice the density of bears compared to the Big Pocosin. I caution extrapolating density estimates from either study area to the entire NPP. The peninsula is comprised of a mosaic of habitat types, human disturbance levels, connective corridors, and other factors that may affect bear densities. If the 2 study areas represent both ends of the spectrum in terms of density and the NPP is comprised equally of lower density areas and higher density areas, then the average between the Big Pocosin and Gum Swamp densities may provide a rough estimate of the number of bears on the NPP. The average density of the

Table 5.1. Population densities and female survival rates of southeastern black bear populations (modified from Brandenburg [1996]).

Locality	Bears/100 km ²	Female Survival ^a	Reference
Gum Swamp, North Carolina	135	0.83	This study
Great Dismal Swamp, North Carolina - Virginia	47-68	0.84 (0.73-0.98)	Hellgren and Vaughan 1989
Big Pocosin, North Carolina	53	1.00	This study
Southeastern, Georgia	26-42		Abler 1985
☉ White River NWR, Arkansas	17-42	0.95 ^b	Smith 1985
Camp Lejeune, North Carolina	18-24	0.69 (0.52-0.74)	Lombardo 1993
Bladen County, North Carolina	11.5		Hamilton 1978
Tensas River Basin, Louisiana	6.6-10		Weaver et al. 1991
Dare County, North Carolina	6.3		Hardy 1974
Camp Lejeune MCB, North Carolina	0.5-3.3	0.71 (0.56-0.87)	Brandenburg 1996

^a Adult annual survival rate

^b Male and female survival rate

two study areas was 0.94 bears/km² and the peninsula is approximately 1,500 km², thus corresponding to approximately 1,400 bears on the NPP. The estimate probably is biased high, because portions of the NPP were not occupied by bears. I suspect that the difference in density between the 2 areas was influenced by habitat quality and quantity, human disturbance, and past mortality rates and densities. Natural habitat types and agricultural lands were more important to black bears than pine lands in the Big Pocosin and Gum Swamp (Jones 1996). Natural habitat types and agricultural lands occupied more land area in the Gum Swamp compared to the Big Pocosin. However, habitat use, or the ranking of habitats in relation to their use, may not infer density. Additionally, the Gum Swamp had fewer permanent human settlements and paved roads compared to the Big Pocosin. Dwellings and roads with higher traffic volumes generally occurred on the periphery of the Gum Swamp area, whereas they were more uniformly distributed in the Big Pocosin.

Survival

Survival of adult females in this study ranged from 83% in the Gum Swamp to 100% in the Big Pocosin and was similar to other southeastern coastal bear populations (Table 5.1). Given these estimates, the Gum Swamp represents a moderately exploited female bear population (Bunnell and Tait 1985). Survival in the Big Pocosin was higher than other coastal populations. The actual survival rate for the entire population of bears was lower than 100%, because there were several bears harvested in the study area during study. Hunting was the primary cause of death for radio-collared bears on the NPP. The

mortality rate from hunting was 7%. Adult females in the Big Pocosin had a higher survival rate compared with adult females in the Gum Swamp. Moreover, hunting had no impact on adult female survival rate in the Big Pocosin. Given the lower densities found in the Big Pocosin compared to the Gum Swamp, I speculate that bear hunting effort was not consistent between the areas. It seems reasonable to assume that hunters congregated in areas known or believed to have more bears.

Harvest management strategies on the NPP seemed to have an effect on bear survival. The peninsula was divided into Bear Management Units (BMU), each of which were composed of between 7 to 27 hunt clubs. Being the largest land owner on the peninsula, Weyerhaeuser Company regulated the majority of hunt club lands; they regulated bear hunting on their lands beyond state and local laws by restricting take methods, the number of permits issued, and implementing a “sanctuary-like” system. On Weyerhaeuser Company lands only still hunting was legal, 0-3 bear permits were issued annually per hunt club, and only 2/3 of any BMU were hunted within a 3-year period. Therefore, 1/3 of all BMU’s functioned as a “revolving sanctuary.” Survival likely was influenced as a result of the “revolving sanctuary” effect and may have contributed to the differences in survival between the study areas. The influence of the “revolving sanctuary” on survival likely depended on the size and shape of the sanctuary. The larger the sanctuary and the more the individual sanctuaries formed a continuous block, the greater the probability of survival. The joint management of bears on the peninsula by NCWRC and Weyerhaeuser Company resulted in a more conservative harvest, and ultimately higher survival rates for portions of the NPP bear population. The number of bear permits a hunt

club was issued was based on the perceived bear density, nuisance activity, and crop damage by bears. In addition, hunt clubs that only were issued 1 permit often forfeited their permits. This study only lasted 5 years; perhaps some portions of the Big Pocosin were not hunted during that time. However, in a 10- or 20-year period, the effects of the “revolving sanctuary” may cancel out when comparing the 2 areas. Nonetheless, from May 1992 to August 1996, survival of adult females was significantly greater in the Big Pocosin and hunting did not affect survival rates for adult females in the Big Pocosin, as it did in the Gum Swamp.

The Gum Swamp sanctuary had a mixed effect on bear survival. Ideally, the sanctuary protects a core of breeding females from hunting. Thus, mortality because of hunting should be zero for bears that resided entirely within the boundary of the sanctuary. Many bear home ranges overlapped areas outside on the boundary of the sanctuary, so those individuals were susceptible to harvest. If harvest pressure was constant across the landscape, the mortality rate because of harvest should be lower for bears that overlap the boundary of the sanctuary compared to those that occurred entirely outside the sanctuary. Most of the bears I monitored for survival had home ranges that were bisected by the boundary of the sanctuary, therefore survival should be higher compared to bears in the Big Pocosin, assuming other mortality factors remained constant. However, in spite of the partial protection provided by the sanctuary, survival rates were significantly lower for bears that occurred on the boundary of the sanctuary compared to those that occurred entirely out of the sanctuary (Big Pocosin). Again, I believe this relates to higher hunting pressure near the boundary of the sanctuary. Hellgren and Vaughan (1994) found a

similar situation near the boundary of the Great Dismal Swamp, where hunter success was greater in areas where agricultural fields were adjacent to the sanctuary.

The effectiveness of the sanctuary also relates to its size and shape. The Gum Swamp sanctuary was approximately 90 km² and the average home range size for females in the Gum Swamp was 1,373 meters (Jones 1996). Therefore, a minimum of approximately 70 females could reside within the sanctuary (assuming no home range overlap). As the size of the sanctuary increases, so does the potential number of bears it encompasses. However, an increase in size doesn't necessarily infer complete protection to more bears. The shape of the sanctuary also is important. The more circular the sanctuary, the greater the probability that the sanctuary encompasses entire home ranges of bears and not just portions of a bears home range. It is unknown how many bears reside within the Gum Swamp sanctuary. However, the shape of the sanctuary seems adequate for encompassing numerous bear home ranges.

The Kaplan-Meier model incorporated some assumptions that were difficult to evaluate in this study. Violating the assumption that the censoring mechanism is random can introduce bias. For example, if bears that were censored (i.e., missing or dropped collar) were actually hunting mortalities (legal or illegal) whereby the hunter destroyed the radio-collar or left it in an attempt to simulate a dropped collar, estimates of survival would be biased high. Pollock et al. (1989) offered 2 methods for evaluating this possibility; estimate minimum survival by assuming all censored animals were really mortalities and estimate maximum survival by assuming all censored animals really

survived until the end of the study. In this study, the option of estimating minimum and maximum survival was not realistic, as there were 32 censored bears.

Movements

Bear movements on this study were more restricted compared with those of other bear populations (Garshelis 1978, Quigley 1982, Carr 1983, Garriss 1983, van Manen 1994, Brandenburg 1996). Jones (1996) also found that home ranges of bears on the NPP were smaller than those in other regions. These restricted movements in combination with the “revolving sanctuary” discussed previously likely resulted in an increase in bear survival over time. For example, if a particular hunt club was not issued any permits in 1994, bears that reside on the land of that club are “protected” from harvest if their movements remain within that club’s land.

When comparing bear movements between seasons and study areas, I found that movements were similar. In contrast, many studies have documented differences in movements, particularly when comparing movements between seasons (Garshelis and Pelton 1980, van Manen 1994, Brandenburg 1996). In GSMNP, bear movements differed between spring, summer, and fall seasons (Garshelis and Pelton 1980). Garshelis and Pelton (1980) speculated that seasonal movements differed because of differences in food abundance, distribution, and caloric value. They hypothesized that spring movements were restricted because food quantity and quality were low, compared to greater summer and fall movements as a result of an increase in food quantity and quality. This hypothesis, in part, is supported by the seasonal shifts in food abundance and caloric value

and the corresponding seasonal bear activities in GSMNP (Inman 1997). In this study, extensive agriculture may be related to the lack of differences in movements between seasons and the restricted nature of the movements. Maddrey (1995) documented the dominance of agricultural food in bear diets on the NPP during spring, summer, and fall. In spring, when bears emerged from dens, winter wheat was a primary food item. On many occasions, bears were observed congregating and foraging in wheat fields. This phenomenon resembles the congregation of grizzly bears to salmon runs in Alaska, where bears, which are generally solitary animals, tolerate the close proximity of other bears because of the high food quantity and quality. In summer, food became even more plentiful as corn ripened. By fall, wheat and corn were harvested and bears shifted to soybeans, which lasted until early winter. In addition to the agricultural food items, natural foods also were available. Bears foraged on blackberries during the time period when wheat was harvested and corn was still ripening. In late fall, when agricultural foods were less abundant, bears foraged on pokeberry, which was widely available and abundant on disturbed lands such as clear-cuts. I hypothesize that these continuous, predictable, and widely distributed food sources contributed to the uniformity of bear movements and the restricted nature of the movements.

I investigated the spatial relationship between bear movements and several landscape-scale features and found that bear movements were farther from roads than expected if movements were random. On the NPP, bear movements averaged 258 m from roads. Brody and Pelton (1989) also found that bears avoided roads in Pisgah National Forest and attributed the behavior to different levels of vehicle traffic and the risk of

mortality to bears. In eastern North Carolina, Brandenburg (1996) found similar results to Brody and Pelton (1989) and suggested that bears avoided areas 100-200 m from roads. Grizzly bears, a species considered even more sensitive to human disturbance, also were found to avoid roads in the Interior Columbia Basin ecosystem of Idaho and Montana (Walker and Craighead, in press). The reason why bears tend to avoid roads cannot be made with any certainty and likely involves a combination of factors rather than any single factor. However, the human disturbances that are commonly associated with roads likely account for the majority of the negative effect on bear use. With the high road densities and the spatial relationship between bear movements and roads on the NPP, many blocks of forested land, which seemed to be suitable bear habitat from a habitat ranking standpoint, may actually receive lower use because of the close proximity to roads. Therefore, road densities may substantially reduce the amount of suitable bear habitat in the Big Pocosin and Gum Swamp study areas (Fig. 5.1).

Other habitat features may not have contributed to the differences between actual and random trajectories because of the scarcity of the habitat feature in the study areas and the lack of interaction between bear movements and the feature. For example, proximity to water was $>2,500$ m for both actual and random trajectories. Because the average distance to water was so large, bears may not respond to it for daily movements. A similar situation may have occurred with proximity to human disturbance sites, where the average distance was $>1,600$ m for actual and random trajectories.

The lack of differences in habitat richness between actual and random trajectories may be explained, in part, by patch characteristics. The study areas were largely

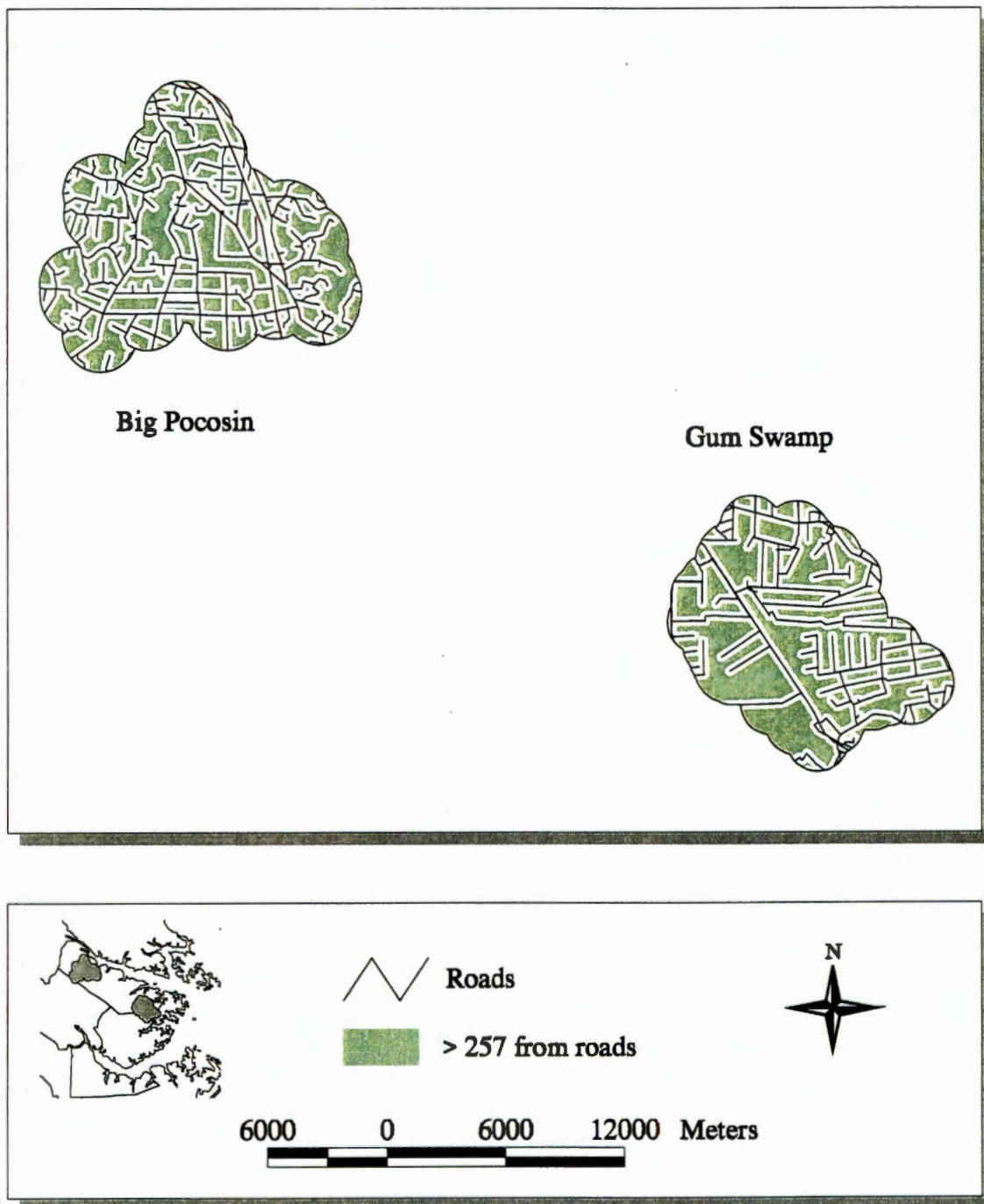


Figure 5.1. Areas > 257 m from roads in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

comprised of blocks of monocultures; loblolly pine, clear-cuts, and agricultural fields.

From a habitat richness standpoint a block of loblolly pine was equivalent to the same size block of corn, however the influence those blocks had on bear movements likely was different.

I also found that bears did not select specific habitat types for movement corridors. The use of pocosin and marsh habitats as corridors appeared moderately important, however statistical significance was not detected. In a study investigating bears movements between isolated woodlots on Tensas River Basin (TRB) of Louisiana, Anderson (1997) found that bears tended to use forested riparian areas as corridors. The security of forested cover may be the primary prerequisite for corridors. As such, the lack of an identifiable corridor on the NPP may be because approximately 70% of the peninsula was forested.

Den Site Characteristics

Black bears have been documented using a variety of den types, including ground cavities, caves, tree bases, tree hollows, brush piles, nests, and, in some cases, human structures (Jonkel and Cowan 1971, Lindzey and Meslow 1976, Johnson 1978, Smith 1985, Hellgren 1988). Along the southeastern Coastal Plain excavated ground dens are uncommon because of the low elevation and periodic flooding during winter months, whereas caves are rare because of the geological processes that formed the region (Hellgren 1988). Although researchers have documented the use of large hollow trees as dens in the southeastern Coastal Plain (Hamilton 1978, Hellgren 1988, Folta, unpubl.

data), few suitable den trees remain because of the intense land use practices common throughout the region. Nest dens were the primary den type on this study and were reported in several other southeastern coastal bear studies (Hamilton and Marchinton 1980, Hellgren 1988, Lombardo 1993, Brandenburg 1996, Folta, unpul. data). Therefore, in the absence of more secure den types, understanding the characteristics of nest dens is important for maintaining nest den habitat across the landscape. Lombardo (1993) first quantified nest dens by comparing cover density at nest and random sites. However, no studies have intensively quantified microhabitat characteristics and made recommendations for suitable nest den habitat. I found that, within a macrohabitat type, bears selected for greater shrub height ($\bar{x} = 74.32$ cm, range = 37.75-91.94), shrub stem density ($\bar{x} = 18.16$ m², range = 7.26-52.26), and cover density ($\bar{x} = 71.74\%$, range = 44.5-97.80) than if selection were random. I would consider habitat with these characteristics to be suitable or high probability denning areas. Lombardo (1993) found a similar relationship at Camp Lejeune, where nest sites had greater vegetative cover compared to random sites. These variables contribute to the overall thickness or density of the vegetation. In this study, nest den habitat can be described as thick, almost impenetrable habitat.

The thick cover associated with nest sites probably functioned as a protective barrier between the denning bear and human or animal disturbances (i.e., hunters, loggers, dogs, deer, and bears) (Hamilton 1978, Lombardo 1993). Not only did the thick vegetation probably discourage people and animals from traveling through it, it also may have allowed denning bears to quickly detect intruders (Hamilton 1978, Lombardo 1993). During most den investigations, the denning bear detected my presence (i.e., the activity

switch would change or cubs would cry) while I was 15-20 m away. Only once did I see a denning bear without the bear ever detecting my presence. Bears that were not accompanied by cubs often abandoned the nest without being detected by sight or sound. Occasionally, the bear would return to the nest moments after I left. Females with cubs typically did not leave the nest site and I pinpointed the nest location by the sound of the cubs. Lombardo (1993) also found that females with cubs had a high site fidelity to the nest when disturbed. Only on 1 occasion did a female with cubs leave the nest. During the den investigation she moved her cubs to a new site about 150 m away.

I encountered a few problems in determining if bears selected specific habitat characteristics for nest dens, most of which related to the amount of time it took to sample the dens in relation to the window of time between bear emergence and spring green-up. Locating denning bears also was a problem. The vegetation was usually so thick, that unless I could get within 10 m of the bear, I would never find the site when I returned after the bear emerged. Therefore, some dens were never sampled. If these sites were all nest dens, my analysis on nest sites may be biased, because I only sampled dens that I could find. If these dens were nests, my results probably are conservative.

Management Implications

The Big Pocosin and Gum Swamp may represent both ends of the spectrum in terms of population density and survival. Areas like the Big Pocosin have lower bear densities and may be less resilient to habitat fragmentation and exploitation (Warburton et al. 1993). These areas should be carefully managed with special concern for minimizing

fragmentation and monitoring mortality relative to the population size. Areas like the Gum Swamp have higher bear densities and may require different management strategies. With these higher densities managers may need to address the “cultural carrying capacity” (Warburton et al., in press) rather than the “bear carrying capacity.” Managing bear populations in relation to landowner concerns is critical in areas such as the NPP where bears occur on intensively managed private lands. If bear populations exceed this cultural carrying capacity, landowners may be less tolerant to crop damage and nuisance activity, which would likely result in greater exploitation. I recommend an adaptive management strategy that is easily and quickly molded to meet new demands and conditions. NCWRC and Weyerhaeuser Company already have taken the lead in developing a management plan that involves the wildlife agency, timber companies, hunting organizations, and small land owners. Together they have developed the framework to monitor bear hunting pressure, disperse bear harvest at a relatively fine spatial grain, create new areas of refugia as needed, and conserve areas of preferred habitat.

Given the results from this study, the role of the Gum Swamp sanctuary may need to be further evaluated, particularly with regard to hunter efficiency immediately adjacent to the sanctuary border. If protection is a primary objective of the sanctuary system, then managers may consider further restrictions on hunting or including adjacent agricultural lands into the sanctuary. Additionally, managers may also want to evaluate the effectiveness of current BMU and hunt club areas in relation to bear management objectives. Given the variations in bear density on the NPP, harvest management may need to be tailored to each area. Within each BMU, hunt clubs provide a mechanism to

disperse the harvest across the landscape and to create areas of refugia on a temporal scale.

If management objectives include maximizing suitable bear habitat, then road access may need to be restricted and the construction of new roads reduced. In cases where roads are only needed for a limited period of time, road access can be restricted and allowed to regenerate.

Although a den tree was used on this study and den trees offer more security to bears, I believe timber harvest of potential den trees would not seriously impact denning behavior because the NPP bear population demonstrated that bears can be and are successful denning on nests. However, maintaining mature trees that could serve as future dens may provide bears, especially females with cubs, an alternative that could increase survival and production (Hellgren 1988). If maintaining nest den habitat is a management objective then areas of suitable denning habitat should be retained across the NPP and human activity in the forest should be minimized. If winter silvicultural practices are planned, denning chronology (Jones 1996) and high probability denning areas should be considered.

SUMMARY

1. I studied several aspects of black bear ecology in the Big Pocosin and Gum Swamp study areas, Neuse-Pamlico Peninsula, North Carolina, 1994-1996. I also compiled data from 2 prior studies (1992-1994) on the Neuse-Pamlico Peninsula (Maddrey 1995, Jones 1996). My objectives were to estimate density, estimate adult survival, evaluate movements, and evaluate den site characteristics of black bears in the Big Pocosin and Gum Swamp.
2. Project personnel captured 213 bears 293 times. In the Gum Swamp 136 bears were captured 200 times and in the Big Pocosin 77 bears were captured 93 times.
3. Project personnel radio-collared and monitored 77 bears for survival analysis. Twenty-seven of these bears were radiotracked during 130 diels, totaling 1,288 locations.
4. Thirty-one bears were monitored for denning activity. Of these, I visited 20 nest dens, 2 excavated ground dens, and 1 tree den.
5. I estimated population size using Jolly-Seber, Modified Lincoln-Petersen, Bailey's Binomial, and Minta-Mangel models. Mean population density in 1996 in the Big Pocosin and Gum Swamp were 53 and 135 bears/100 km², respectively. Population density in the Gum Swamp exceeded previous estimates from other Southeastern coastal plain bear populations.

6. Capture-resight models (Bailey's Binomial and Minta-Mangel models) produced population size estimates similar to the other models and had similar confidence intervals. Moreover, capture-resight models produced the estimate in about 4 months compared to 15 months for capture-recapture models.
7. Of the radio-collared bears, 52 dropped their collars, 11 disappeared, and 9 died.
8. I estimated annual adult survival using the Kaplan-Meier staggered entry procedure. Female adult survival in the Big Pocosin and Gum Swamp were 1.00 and 0.83, respectively.
9. Overall, hunting was the primary mortality factor of radio-collared bears. I estimated that hunting mortality reduced survival of females in the Gum Swamp from 0.94 to 0.83. In contrast, hunting mortality did not affect survival of females in the Big Pocosin.
10. Female survival was lower immediately adjacent to a black bear sanctuary (Gum Swamp) compared to 35 km² away from the sanctuary (Big Pocosin).
11. I estimated movement parameters from sequential bear locations. Total movement of bears averaged 3,611.4 m (SE = 228.2) with an average range length of 1,537.5 m (SE = 133.1). Mean net movement was 871.0 m (SE = 133.5) and mean rate of travel was 164.9 m/h (SE = 10.0).

12. I used multivariate analysis of variance to determine if movements differed between seasons or study areas. I found no difference in movements between study areas. I detected an overall difference in movements between summer and fall seasons, however the differences may have been an artifact of telemetry error.
13. I evaluated the spatial relationship between bear movements and several landscape-scale features. I used multivariate analysis of variance to determine if actual bear movement trajectories differed from random trajectories. I found an overall significant difference between actual and random trajectories, which was primarily related to bears being farther from roads compared with random trajectories. These results suggest that bears avoided a 258 m zone around roads.
14. I sampled microhabitat vegetative characteristics at 16 nest and 16 dependent random sites.
15. I used multivariate analysis of variance to determine if microhabitat variables differed between nest and random sites. I found an overall significant difference between nest and random sites. Shrub height, stem density, and cover density were greater at nest sites compared with random sites.
16. The spatial distribution of harvested bears and the number of harvested bears seemed to offer the best tools for managing bear mortality and relative population densities on the NPP.
17. If management goals include increasing the amount of suitable habitat for bears or facilitating bear movements, access to roads may need to be limited.

18. If management goals include maintaining suitable nest den habitat, areas with thick understory habitat may need to be retained across the landscape. Additionally, during winter months, access and human disturbance in suitable or high probability denning areas may need to be restricted.

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APPENDICES

Appendix A. Summary of program JOLLY parameters.

Table A.1. Black bear population parameters in the Gum Swamp derived from program JOLLY, model A, North Carolina, 1992-1996.

Year	N ^a	SE	95% CI	M ^b	SE	95% CI	B ^c	SE	95% CI	PHI ^d	SE	95%CI	p ^e	SE	95% CI
1992										0.37	0.15	0.08 - 0.66			
1993	43.6	11.8	20.6 -66.7	5.9	1.4	3.2 - 8.6	124.0	63.9	-1.2 - 249.2	1.13	0.33	0.49 - 1.78	0.68	0.25	0.20 - 1.16
1994	172.3	68.6	37.9 - 306.7	41.9	12.2	17.9 - 65.9	14.0	39.8	-64.0 - 92.1	0.66	0.25	0.17 - 1.15	0.19	0.08	0.03 - 0.35
1995	128.1	47.1	35.8 - 220.4	47.7	15.6	17.2 - 78.2							0.31	0.12	0.08 - 0.55
1996															
Mean	114.7	28.1	59.6 - 169.8	31.8	6.6	18.9 - 44.8	69.0	42.5	-14.3 - 152.3	0.72	0.11	0.51 - 0.94	0.39	0.14	0.03 - 0.60

- ^a Population estimate.
- ^b The estimated number of marked bears in the population.
- ^c The estimated number of animals added to the population since the previous year.
- ^d Annual survival rate for bears > 1 year old.
- ^e The probability that a marked bear alive in the i^{th} interval is captured in the i^{th} interval.

Table A.2. Black bear population parameters in the Gum Swamp derived from program JOLLY, model A', North Carolina, 1992-1996.

Year	N ^a	SE	95% CI	M ^b	SE	95% CI	B ^c	SE	95% CI	PHI ^d	SE	95%CI	p ^e	SE	95% CI
1992	345.7	124.8	101.1 - 590.3							0.51	0.20	0.12 - 0.90			
1993	197.1	30.6	137.1 - 257.0							1.21	0.33	0.56 - 1.86	0.18	0.04	0.10 - 0.25
1994	242.6	56.9	131.1 - 354.1							0.82	0.30	0.23 - 1.41	0.14	0.04	0.06 - 0.22
1995	210.0	60.1	92.2 - 327.9										0.19	0.06	0.07 - 0.30
1996															
Mean	248.8	38.6	173.1 - 324.5							0.85	0.11	0.64 - 1.06	0.17	0.03	0.12 - 0.22

^a Population estimate.

^b The estimated number of marked bears in the population.

^c The estimated number of animals added to the population since the previous year.

^d Annual survival rate for bears > 1 year old.

^e The probability that a marked bear alive in the i^{th} interval is captured in the i^{th} interval.

Table A.3. Black bear population parameters in the Gum Swamp derived from program JOLLY, model D, North Carolina, 1992-1996.

Year	N ^a	SE	95% CI	M ^b	SE	95% CI	B ^c	SE	95% CI	PHI ^d	SE	95%CI	p ^e	SE	95% CI
1992															
1993	123.1	29.7	64.9 - 181.2	8.8	2.5	3.8 - 13.7	36.4	21.8	-6.3 - 79.1						
1994	136.4	29.4	78.7 - 194.0	36.4	6.3	24.1 - 48.7	40.8	20.7	0.2 - 81.4						
1995	146.9	32.1	84.1 - 209.8	50.5	10.4	30.2 - 70.8	49.9	21.0	8.8 - 91.1						
1996	157.2	37.2	84.3 - 230.0	53.6	15.5	23.3 - 83.9									
Mean	140.9	56.4	30.3 - 251.4	37.3	14.3	9.3 - 65.3	42.4	14.6	13.7 - 71.1	0.77	0.08	0.61 - 0.94	0.28	0.06	0.17 - 0.39

^a Population estimate.

^b The estimated number of marked bears in the population.

^c The estimated number of animals added to the population since the previous year.

^d Annual survival rate for bears > 1 year old.

^e The probability that a marked bear alive in the i^{th} interval is captured in the i^{th} interval.

Table A.4. Black bear population parameters in the Gum Swamp derived from program JOLLY, model B, North Carolina, 1992-1996.

Year	N^a	SE	95% CI	M^b	SE	95% CI	B^c	SE	95% CI	Φ^d	SE	95%CI	p^e	SE	95% CI
1992															
1993	98.7	41.9	16.5 - 180.8	8.3	2.2	4.0 - 12.5	72.5	52.1	-29.5 - 174.6				0.35	0.16	0.04 - 0.67
1994	155.3	43.9	69.4 - 241.2	37.6	6.2	25.5 - 49.7	16.7	40.3	-62.3 - 95.7				0.24	0.08	0.08 - 0.40
1995	134.5	34.4	67.0 - 202.0	48.5	10.9	27.1 - 70.0	64.6	37.1	-8.0 - 137.3				0.31	0.09	0.13 - 0.50
1996	167.3	52.5	64.4 - 270.1	57.0	16.1	25.5 - 88.5							0.26	0.09	0.08 - 0.45
Mean	138.9	63.9	13.6 - 264.2	37.9	16.3	5.8 - 69.9	51.3	26.8	-1.2 - 103.7	0.77	0.11	0.57 - 0.98	0.29	0.11	0.07 - 0.51

^a Population estimate.

^b The estimated number of marked bears in the population.

^c The estimated number of animals added to the population since the previous year.

^d Annual survival rate for bears > 1 year old.

^e The probability that a marked bear alive in the i^{th} interval is captured in the i^{th} interval.

Appendix B. Survival statistics.

Table B.1. Survival calculations for adult female black bears in the Big Pocosin, North Carolina, 1992-1996.

Year	Month	No. at risk (r_j)	No. added	No. censored	No. deaths (d_j)	Survival	Mortality	Variance (survival)	95% CI Lower	95% CI Upper	$E(d_j)^a$	Contingency Table $Var_1(d_j)^b$	$Var_2(d_j)^c$
1992	Jan	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Feb	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Mar	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Apr	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	May	0	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Jun	1	3	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Jul	3	3	2	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Aug	4	2	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Sep	6	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Oct	5	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Nov	5	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Dec	5	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
Total		29	9	4	0						0.000	0.000	0.000
Mean		2	1	0	0						Chi-square	-	-
1993	Jan	5	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Feb	5	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Mar	5	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Apr	5	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	May	4	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jun	3	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jul	4	6	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Aug	9	2	2	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Sep	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Oct	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Nov	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Dec	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
Total		76	9	5	0						0.000	0.000	0.000
Mean		6	1	0	0						Chi-square	-	-

Table B.1. (Cont.).

Year	Month	No. at risk (r_i)	No. added	No. censored	No. deaths (d_i)	Survival	Mortality	Variance (survival)	95% CI	Upper	$E(d_i)^a$	Contingency Table $Var_1(d_i)^b$	$Var_2(d_i)^c$
1994	Jan	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Feb	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Mar	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Apr	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	May	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jun	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jul	9	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Aug	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Sep	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Oct	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Nov	8	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Dec	7	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
Total		102	0	3	0						0.000	0.000	0.000
Mean		9	0	0	0						Chl-square	#DIV/0!	#DIV/0!
Year	Month	No. at risk (r_i)	No. added	No. censored	No. deaths (d_i)	Survival	Mortality	Variance (survival)	95% CI	Upper	$E(d_i)^a$	Contingency Table $Var_1(d_i)^b$	$Var_2(d_i)^c$
1995	Jan	6	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Feb	6	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Mar	6	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Apr	6	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	May	6	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jun	5	2	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jul	6	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Aug	6	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Sep	5	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Oct	4	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Nov	5	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Dec	6	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
Total		67	4	4	0						0.000	0.000	0.000
Mean		6	0	0	0						Chl-square	#DIV/0!	#DIV/0!

[illegible]

Table B.1. (Cont.).

$$^a E(d_{ij}) = d_j r_{ij} / r_j \text{ (Pollock et al. 1989)}$$

$$^b \text{var}_1(d_{ij}) = d_j r_{0i} (r_j - d_j) / r_j^2 (r_j - 1), \text{ (Pollock et al. 1989)}$$

$$^c \text{var}_2(d_{ij}) = r_{0i} r_{ij} d_j / r_j^2, \text{ (Pollock et al. 1989)}$$

Table B.2. Survival calculations for adult female black bears in the Gum Swamp, North Carolina, 1992-1996.

Year	Month	No. at risk (r _j)	No. added	No. censored	No. deaths (d _j)	Survival	Mortality	Variance (survival)		95% CI		Contingency Table		
										Lower	Upper	E(d _j) ^a	Var ₁ (d _j) ^b	Var ₂ (d _j) ^c
1992	Jan	0	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Feb	0	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Mar	0	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Apr	0	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	May	0	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Jun	0	2	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Jul	2	6	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Aug	8	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Sep	8	1	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Oct	9	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	-	-	-
	Nov	9	0	0	1	0.8889	0.1111	0.0098	0.0953	1.0825	1.0825	-	-	-
	Dec	8	0	0	0	0.8889	0.0000	0.0110	0.6836	1.0942	1.0942	-	-	-
Total		44	9	0	1							0.000	0.000	0.000
Mean		4	1	0	0							Chi-square	-	-
Year	Month	No. at risk (r _j)	No. added	No. censored	No. deaths (d _j)	Survival	Mortality	Variance (survival)		95% CI		Contingency Table		
										Lower	Upper	E(d _j) ^a	Var ₁ (d _j) ^b	Var ₂ (d _j) ^c
1993	Jan	8	0	1	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Feb	7	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Mar	7	0	0	0	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Apr	7	0	0	1	0.8571	0.1429	0.0150	0.6171	1.0971	1.0971	1.000	0.000	0.000
	May	6	5	0	0	0.8571	0.0000	0.0175	0.5979	1.1164	1.1164	0.000	0.000	0.000
	Jun	11	1	1	0	0.8571	0.0000	0.0095	0.6657	1.0486	1.0486	0.000	0.000	0.000
	Jul	11	1	2	0	0.8571	0.0000	0.0095	0.6657	1.0486	1.0486	0.000	0.000	0.000
	Aug	10	1	0	0	0.8571	0.0000	0.0105	0.6563	1.0579	1.0579	0.000	0.000	0.000
	Sep	11	1	1	0	0.8571	0.0000	0.0095	0.6657	1.0486	1.0486	0.000	0.000	0.000
	Oct	11	0	0	0	0.8571	0.0000	0.0095	0.6657	1.0486	1.0486	0.000	0.000	0.000
	Nov	11	0	1	2	0.7013	0.1818	0.0134	0.4748	0.9278	0.9278	1.650	0.000	0.664
	Dec	8	0	0	0	0.7013	0.0000	0.0184	0.4357	0.9669	0.9669	0.000	0.000	0.000
Total		108	9	6	3							2.650	0.743	0.664
Mean		9	1	1	0							Chi-square	0.165	0.184

Table B.2. (Cont.).

Year	Month	No. at risk (r)	No. added	No. censored	No. deaths (d)	Survival	Mortality	Variance (survival)	95% CI	Upper	E(d) ^a	Contingency Table Var.(d) ^b	Var ₂ (d) ^c
1994	Jan	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Feb	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Mar	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Apr	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	May	8	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jun	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jul	8	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Aug	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Sep	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Oct	9	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Nov	9	0	0	0	0.8889	0.1111	0.0098	0.6836	1.0825	1.350	0.743	0.664
	Dec	8	0	0	0	0.8889	0.0000	0.0110	0.6836	1.0942	0.000	0.000	0.000
Total		101	2	0	1						1.883	0.991	0.913
Mean		8									Chl-square	0.787	0.854
1995	Jan	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Feb	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Mar	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Apr	8	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	May	8	1	2	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jun	7	2	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jul	8	4	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Aug	12	0	3	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Sep	9	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Oct	8	0	2	1	0.8750	0.1250	0.0120	0.6606	1.0894	0.471	0.249	0.230
	Nov	5	1	0	0	0.8750	0.0000	0.0191	0.6038	1.1462	0.357	0.230	0.230
	Dec	6	1	0	0	0.8750	0.0000	0.0160	0.6275	1.1225	0.000	0.000	0.000
Total		95	9	9	1						0.828	0.479	0.479
Mean		8									Chl-square	0.062	0.062

Year	Month	No. at risk (r _j)	No. added	No. censored	No. deaths (d _j)	Survival	Mortality	Variance (survival)	95% CI	Upper	E(d _j) ^a	Contingency Table Var ₁ (d _j) ^b	Var ₂ (d _j) ^c
1996	Jan	7	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Feb	6	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Mar	6	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Apr	5	1	6	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	May	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jun	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Jul	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Aug	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Sep	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Oct	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Nov	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
	Dec	0	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000
1992-96	Jan	31	0	2	0	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	-	-
	Feb	29	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	-	-
	Mar	29	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	-	-
	Apr	28	1	6	1	0.9643	0.0357	0.0012	0.8968	1.0318	1.0318	-	-
	May	22	7	2	0	0.9643	0.0000	0.0015	0.8881	1.0404	1.0404	-	-
	Jun	27	5	3	0	0.9643	0.0000	0.0012	0.8955	1.0330	1.0330	-	-
	Jul	29	12	2	0	0.9643	0.0000	0.0011	0.8980	1.0306	1.0306	-	-
	Aug	39	1	3	0	0.9643	0.0000	0.0009	0.9071	1.0215	1.0215	-	-
	Sep	37	2	2	0	0.9643	0.0000	0.0009	0.9056	1.0230	1.0230	-	-
	Oct	37	0	2	1	0.9382	0.0270	0.0015	0.8631	1.0134	1.0134	-	-
	Nov	34	1	1	4	0.8278	0.1176	0.0035	0.7124	0.9433	0.9433	-	-
	Dec	30	1	0	0	0.8278	0.0000	0.0039	0.7049	0.9508	0.9508	-	-

Table B.2. (Cont.).

^a $E(d_{ij}) = d_j r_{ij} / r_j$ (Pollock et al. 1989)

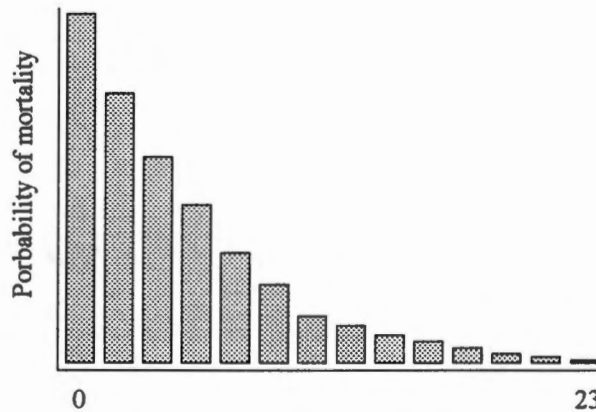
^b $\text{var}_1(d_{ij}) = d_j r_{0i} (r_j - d_j) / r_j^2 (r_j - 1)$, (Pollock et al. 1989)

^c $\text{var}_2(d_{ij}) = r_{0i} r_{ij} d_j / r_j^2$, (Pollock et al. 1989)

Table B.3. Survival calculations for cases when no black bear mortalities were documented, North Carolina, 1992-1996.

In the Big Pocosin study area there were no recorded mortalities of radio collared females. Therefore, the annual survival estimate was 1.00 or 100%. Because no mortalities were documented, an estimate of variance (and 95% confidence interval) could not be calculated. The estimated survival of 100% is misleading without an associated variance because female bears in the population were known to die during the study. Despite the inability to calculate variance given the formula provided by Pollock et al. (1989), Sylwester (Univ. of Tennessee, pers. commun. via J. Philpot) recommends an alternate method.

Consider the distribution of the number of bears that die annually, where the probability of a bear dying at time x equals P_x ($x, 0 - 23$) ($n = 23$ bears).



Therefore, the probability of 0 bears dying equals $P_{(x=0)}$. By setting $\alpha = 0.05$, we have

$$P_{(x=0)} = P_L^{23} = 0.05,$$

where P_L^{23} equals the probability that 23 bears live. Solving for P_L as:

$$23 \ln P_L = \ln 0.05$$

$$\ln P_L = (\ln 0.05)/23$$

$$P_L = 0.88.$$

Appendix C. Diel movement statistics.

Table C.1. Movement parameters of black bears in the Big Pocosin (BP) and Gum Swamp (GS), North Carolina, 1992-1996.

Diel	Bear	No. of locations	Study area	Sex	Year	Season	Total movement (m)	Travel rate (m/h)	Net movement (m)	Daily range length (m)
1	100	12	BP	M	94	Fall	1,258.0	118.8	352.0	355.0
2	100	11	BP	M	94	Fall	6,576.5	595.6	0.0	2,913.7
3	125	11	BP	F	94	Fall	3,790.3	305.5	765.0	2,016.9
4	125	10	BP	F	94	Fall	3,241.1	320.6	2,118.9	2,229.1
5	39	11	BP	F	93	Summer	8,631.2	389.9	167.5	2,846.2 †
6	39	10	BP	F	93	Summer	5,039.2	208.9	1,078.3	2,500.2 †
7	61	11	BP	F	93	Summer	2,973.4	131.4	166.3	1,313.3 †
8	61	11	BP	F	93	Summer	3,936.1	166.5	1499	1,659.2 †
9	61	9	BP	F	93	Summer	2,720.0	142.1	399.6	12,522.3
10	61	11	BP	F	93	Fall	4,131.2	191.5	1,379.5	1,734.6 †
11	61	11	BP	F	93	Fall	2,868.2	128.8	264.6	1,265.6 †
12	61	11	BP	F	93	Fall	2,226.2	101.3	105.5	751.0 †
13	61	11	BP	F	93	Fall	2,176.6	94.6	198.8	967.4 †
14	61	8	BP	F	94	Summer	2,935.3	207.2	1,143.9	1,167.7
15	76	11	BP	F	93	Summer	2,614.6	120.2	945.6	1,189.0 †
16	76	11	BP	F	93	Summer	4,362.7	200.0	1,676.4	1,676.4 †
17	76	11	BP	F	93	Fall	2,955.5	135.0	988.5	1,113.6 †
18	76	11	BP	F	93	Fall	2,453.5	111.3	129.6	1,012.9 †
19	76	11	BP	F	93	Fall	841.9	38.5	170.8	450.5 †
20	76	11	BP	F	93	Fall	1,002.3	48.1	162.7	418.7 †
21	77	11	BP	F	93	Summer	3,365.0	146.4	449.4	1,526.1 †
22	77	9	BP	F	93	Summer	5,336.1	211.2	3,101.6	3,220.3 †
23	77	11	BP	F	93	Fall	2,392.5	109.1	1,375.3	1,603.2 †
24	77	10	BP	F	93	Fall	6,792.0	289.4	5,337.8	5,193.0 †
25	77	10	BP	F	93	Fall	3,189.2	149.5	532.6	1,092.6 †
26	77	11	BP	F	94	Summer	2,636.2	123.2	393.3	583.8 †
27	79	8	BP	F	93	Summer	4,399.0	253.9	2,062.1	2,271.1
28	79	7	BP	F	94	Summer	12,746.2	1,033.7	759.5	5,785.0
29	79	10	BP	F	94	Fall	3,770.8	351.7	2,808.7	2,808.8
30	79	11	BP	F	94	Fall	439.9	41.8	220.6	269.9
31	80	11	BP	F	94	Fall	1,585.8	147.3	399.7	540.8
32	80	11	BP	F	94	Fall	5,646.6	485.6	1,732.7	2,612.3
33	81	11	BP	F	93	Fall	5,704.3	279.8	758.4	2,281.4 †
34	81	7	BP	F	93	Fall	5,688.8	407.3	3,441.0	4,164.3
35	81	10	BP	F	94	Fall	554.1	121.7	139.5	232.6
36	81	8	BP	F	94	Fall	14.4	2.7	14.1	14.1
37	82	11	BP	M	93	Summer	4,854.5	209.8	178.8	1,561.0

Table C.1. (Cont.).

Diel	Bear	No. of locations	Study area	Sex	Year	Season	Total movement (m)	Travel rate (m/h)	Net movement (m)	Daily range length (m)
38	86	11	BP	F	93	Summer	3,867.4	184.3	1,132.7	1,491.2 †
39	86	11	BP	F	93	Fall	6399.1	284.2	2,441.9	3,216.2 †
40	86	11	BP	F	93	Fall	3433.4	177.8	1,002.1	1,318.2 †
41	86	6	BP	F	93	Fall	1939.0	164.6	389.2	761.9
42	86	8	BP	F	94	Summer	13902.0	704.0	950.3	3,317.8
43	86	10	BP	F	94	Fall	2941.0	183.8	2,222.9	2,285.4
44	86	12	BP	F	94	Fall	2642.8	565.8	783.0	1,076.5
45	.	.	.	.	.	.	.	.	.	.
46	86	14	BP	F	94	Fall	2545.3	304.3	793.5	1,326.3
47	87	11	BP	F	94	Fall	3855.5	351.1	1,436.6	1,741.5
48	87	11	BP	F	94	Fall	2196.5	199.6	1,358.8	1,406.2
49	110	9	GS	F	94	Summer	3417.3	171.3	330.5	1,199.1
50	17	3	GS	F	93	Summer	294.0	52.1	246.5	249.1
51	17	3	GS	F	93	Summer	335.0	56.8	159.5	184.6
52	17	2	GS	F	93	Summer	467.3	98.8	11.1	238.3
53	23	3	GS	F	93	Summer	510.6	84.6	7.2	256.5
54	23	3	GS	F	93	Summer	555.0	92.5	239.2	370.8
55	23	3	GS	F	93	Summer	310.3	53.7	244.2	243.8
56	23	10	GS	F	94	Summer	3490.5	175.2	46.1	900.0 †
57	23	11	GS	F	94	Fall	2045.6	188.5	270.7	447.4
58	23	2	GS	F	94	Fall	398.2	261.9	269.0	333.2
59	25	3	GS	F	93	Summer	854.7	151.7	783.6	783.7
60	25	3	GS	F	93	Summer	361.5	60.8	114.3	186.3
61	25	2	GS	F	93	Summer	410.8	105.8	361.2	361.4
62	25	8	GS	F	94	Fall	4658.1	452.9	1,155.3	1,754.2
63	25	11	GS	F	94	Fall	3017.0	292.7	630.6	936.2
64	28	5	GS	F	93	Summer	1810.5	364.7	281.0	604.5
65	28	7	GS	F	93	Summer	3500.2	511.4	272.4	1,304.9
66	28	8	GS	F	93	Summer	395.5	50.5	44.5	212.0
67	28	8	GS	F	93	Summer	6698.2	353.7	759.5	2,105.2
68	28	4	GS	F	93	Summer	1044.2	134.9	694.3	782.4
69	28	9	GS	F	93	Summer	2735.9	158.2	1,483.8	1,509.8
70	28	8	GS	F	93	Fall	4222.0	202.3	317.1	1,702.5
71	28	10	GS	F	93	Fall	3922.7	169.9	744.3	2,092.8 †
72	28	11	GS	F	93	Fall	4969.9	238.2	1,377.9	2,603.1 †
73	28	10	GS	F	93	Fall	2371.4	107.1	33.6	694.2 †
74	28	7	GS	F	94	Summer	1886.8	133.7	1,334.1	1,334.1
75	28	2	GS	F	94	Summer	2617.0	442.1	1,391.2	1,685.7

Table C.1. (Cont.).

Diel	Bear	No. of locations	Study area	Sex	Year	Season	Total movement (m)	Travel rate (m/h)	Net movement (m)	Daily range length (m)
76	29	5	GS	F	93	Summer	739.9	149.3	82.6	366.3
77	29	8	GS	F	93	Summer	2,460.2	329.4	366.2	824.0
78	29	8	GS	F	93	Summer	546.2	67.3	100.2	246.0
79	29	11	GS	F	93	Summer	2,861.1	133.3	1,315.2	1,465.5 †
80	29	9	GS	F	93	Summer	3,057.7	142.5	1,012.4	1,029.0 †
81	29	10	GS	F	93	Fall	5,598.1	277.8	1,385.5	2,051.2
82	29	5	GS	F	93	Fall	3,196.3	306.9	1,946.4	2,060.3
83	42	5	GS	F	93	Summer	1,355.2	278.5	238.9	563.9
84	42	8	GS	F	93	Summer	1,811.1	220.0	1,193.9	1,246.3
85	42	8	GS	F	93	Summer	3,993.2	500.0	549.9	1,153.2
86	42	11	GS	F	93	Summer	2,912.5	132.4	485.5	606.9 †
87	42	8	GS	F	93	Summer	1,644.1	80.6	168.3	531.3
88	44	11	GS	F	93	Summer	3,567.7	163.4	801.0	1,689.1 †
89	44	8	GS	F	93	Summer	1,677.8	99.3	465.2	547.4
90	44	4	GS	F	93	Summer	838.4	114.5	338.3	338.1
91	44	11	GS	F	93	Summer	4,709.2	203.4	1,651.9	2,493.1 †
92	44	11	GS	F	93	Fall	1,849.6	90.4	728.1	797.3 †
93	44	11	GS	F	93	Fall	3,965.7	196.3	168.2	1,196.1 †
94	44	11	GS	F	93	Fall	3,895.9	179.3	206.7	1,571.3 †
95	44	9	GS	F	93	Fall	6,861.7	323.1	604.3	2,445.6
96	44	11	GS	F	94	Summer	1,889.0	88.2	420.1	502.5 †
97	44	5	GS	F	94	Summer	1,331.0	136.9	205.7	450.4
98	44	11	GS	F	94	Fall	2,258.6	235.7	609.3	730.3
99	44	11	GS	F	94	Fall	3,695.5	326.8	579.1	1,220.8
100	47	11	GS	F	93	Summer	5,826.6	284.8	2,729.6	2,919.1 †
101	47	6	GS	F	93	Summer	5,814.5	346.6	3,467.0	3,537.0
102	47	4	GS	F	93	Summer	1,914.8	255.3	1,189.4	1,506.2
103	47	11	GS	F	93	Summer	2,645.9	109.8	1,256.6	1,477.2 †
104	47	10	GS	F	93	Fall	4,227.8	201.7	2,035.7	2,291.9
105	47	10	GS	F	93	Fall	4,535.6	216.5	369.0	1,559.5 †
106	51	5	GS	M	93	Summer	2,915.1	108.1	2,021.1	2,033.9
107	51	2	GS	M	93	Summer	145.9	33.7	140.0	140.0
108	52	11	GS	F	93	Summer	7,558.4	308.8	1,103.6	3,374.3 †
109	52	11	GS	F	93	Fall	4,321.2	202.2	557.1	1,874.7 †
110	52	10	GS	F	93	Fall	1,883.2	94.5	180.9	506.1 †
111	52	10	GS	F	94	Summer	2,917.3	140.6	104.7	660.9 †
112	52	10	GS	F	94	Summer	2,125.1	99.5	826.6	826.6 †
113	52	11	GS	F	94	Fall	6,312.7	660.8	1,877.2	2,907.5

Table C.1. (Cont.).

Diel	Bear	No. of locations	Study area	Sex	Year	Season	Total movement (m)	Travel rate (m/h)	Net movement (m)	Daily range length (m)
114	52	10	GS	F	94	Fall	5,133.9	437.6	1,998.7	2,804.1
115	56	10	GS	M	94	Fall	8,570.2	778.6	1693	2,304.8
116	66	11	GS	F	93	Fall	4,447.1	213.6	343.6	1,369.7 †
117	66	11	GS	F	93	Fall	2,731.9	127.1	622.2	1,459.3 †
118	66	10	GS	F	93	Fall	1,852.6	90.5	501.9	624.4 †
119	66	10	GS	F	94	Summer	2,081.1	106.1	324.6	596.3 †
120	66	5	GS	F	94	Summer	1,200.2	112.5	763.8	820.1
121	66	11	GS	F	94	Fall	3,358.7	334.2	568.8	1,076.2
122	66	8	GS	F	94	Fall	2,764.3	324.1	232.8	735.3
123	66	11	GS	F	94	Fall	3,134.4	306.8	693.1	885.0
124	66	10	GS	F	94	Fall	3,469.3	322.4	2,931.4	2,931.6
125	92	8	GS	F	94	Summer	1,942.2	94.4	306.6	480.5
126	92	11	GS	F	94	Fall	4,162.3	387.3	2,327.7	2,327.7
127	92	11	GS	F	94	Fall	3,094.5	249.0	1,017.7	1611
128	93	5	GS	M	94	Summer	2,535.6	235.8	732.2	1332
129	93	11	GS	M	94	Fall	1,051.8	92.0	167.6	352.2
130	93	11	GS	M	94	Fall	3,639.5	306.7	460.3	1,106.5

† Diels selected for movement parameter analysis.

Table C.2. Comparison in mean movement statistics between original and dependent random locations of black bears, North Carolina, 1992-1996.

Variable	Analysis	<i>n</i>	Mean	SE	Range
Total movement (m)	Original	50	3,611.4	228.2	841.9-8,631.2
	Error	51	5,217.3	310.2	2,307.9-16,687.0
Rate of travel (m/h)	Original	50	164.9	10.0	38.4-389.9
	Error	51	244.4	15.3	109.3-861.8
Net movement (m)	Original	50	871.0	133.5	33.6-5,337.8
	Error	51	1,109.4	272.0	33.6-13,030.3
Daily range length (m)	Original	50	1,537.5	133.1	418.7-5,193.0
	Error	51	1,943.2	254.7	623.5-13,056.8

Table C.3. Comparison in telemetry error and original movement analysis of black bears by season, North Carolina, 1992-1996.

Variable	Season	Original Locations				Error Locations			
		LS Mean	LS SE	<i>n</i>	<i>P</i>	LS Mean	LS SE	<i>n</i>	<i>P</i>
Total movement (m)	Summer	3,811.4	351.2			5,491.7	435.6	25	
	Fall	3,704.9	344.3		0.5655	4,912.7	431.3	26	
Rate of travel (m/h)	Summer	172.8	15.8			251.2	21.5	25	
	Fall	174.1	15.5		0.5148	233.3	21.2	26	
Net movement (m)	Summer	849.4	205.0			1,162.1	370.3	25	
	Fall	805.9	201.0		0.6497	805.9	366.6	26	
Daily range length (m)	Summer	1,473.2	191.7			1,954.2	352.5	25	
	Fall	1,599.3	187.9		0.8210	1,757.8	349.0	26	
Bear effects					0.7468	0.1244			
Overall					0.0021	0.6445			

Table C.4. Comparison in telemetry error and original movement analysis of black bears by study area, North Carolina, 1992-1996.

Variable	Study area	Original Locations			<i>P</i>	Error Locations			<i>P</i>
		LS Mean	LS SE	<i>n</i>		LS Mean	LS SE	<i>n</i>	
Total movement (m)	BP	4,476.6	493.0	25		5,916.0	499.7	26	
	GS	3,413.1	459.5	25		4,866.2	467.5	25	
Rate of travel (m/h)	BP	202.9	22.2	25		274.7	24.1	26	
	GS	159.7	20.7	25		230.6	22.5	25	
Net movement (m)	BP	890.3	238.3	25		1,143.9	297.5	26	
	GS	691.4	222.1	25		691.2	278.3	25	
Daily range length (m)	BP	1,855.1	242.9	25		2,226.6	310.7	26	
	GS	1,296.5	226.4	25		1,533.1	290.7	25	
Bear effects					0.0858	0.2552			
Overall					0.5899	0.5209			

Table C.5. Comparison between movement trajectories of black bears adjusted for telemetry error and random movement trajectories, North Carolina, 1992-1996.

Variable	Diel	Original Locations				Error Locations			
		Mean	SE	<i>n</i>	<i>P</i>	Mean	SE	<i>n</i>	<i>P</i>
Distance to road (m)	Use	257.8	7.7	123		253.5	8.0	123	
	Random	226.0	7.5	123	0.0011	226.0	7.5	123	0.0057
Distance to agriculture (m)	Use	534.6	33.6	123		526.2	31.2	123	
	Random	564.1	34.4	123	0.2064	564.1	34.4	123	0.0860
Distance to habitat edge (m)	Use	75.0	5.5	123		75.7	4.8	123	
	Random	83.3	6.2	123	0.2710	83.3	6.2	123	0.2865
Distance to development (m)	Use	1,617.6	48.1	123		1,611.2	48.1	123	
	Random	1,643.0	51.7	123	0.5738	1,643.0	51.7	123	0.4676
Habitat richness	Use	2.1	0.04	123		2.1	0.04	123	
	Random	2.0	0.04	123	0.0945	2.0	0.04	123	0.0945
Pocosin/evergreen corridor (%)	Use	14.5	1.9	123		12.3	1.5	123	
	Random	9.3	1.1	123	0.0095	9.3	1.1	123	0.0949
Marsh corridor (%)	Use	5.5	1.0	123		5.4	1.0	123	
	Random	8.3	1.3	123	0.0491	8.3	1.3	123	0.0486
Overall					0.0032				0.0133

Table C.6. Movement trajectory characteristics of black bears in the Big Pocosin and Gum Swamp study areas, North Carolina, 1992-1996.

Diel Bear	Distance to										Corridor									
	road	agri.	water	water	edge	edge	devel.	rank	rich	Habitat	Patch	agri.	low veg.	pine	B. hard	U. hard	mixed	pocosin	marsh	
	(m)	(m)	(m)	(m)	(m)	(m)	(m)				(ha)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
1	123.3	653.3	2,048.6	58.3	3,332.3	4.9	1.8	482.2	0	85	0	0	0	8	8	0	0	15	0	0
2	100	237.9	37.0	30.5	2,746.6	5.2	2.0	80.3	33	8	0	0	0	8	8	8	50	0	0	0
3	125	179.2	8.0	37.3	1,605.1	6.1	1.7	114.3	75	0	0	0	0	0	0	17	8	0	0	0
4	125	339.4	124.5	2,015.3	70.9	2,196.2	4.9	2.1	489.9	9	9	0	0	64	9	9	9	0	0	0
5	39	368.1	277.9	2,111.5	25.4	1,920.5	4.7	2.2	78.5	8	8	0	0	25	8	17	0	33	0	0
6	39	364.4	235.9	2,580.6	89.7	1,909.1	4.5	2.2	150.7	9	0	0	0	45	0	0	0	45	0	0
7	61	343.8	119.1	2,772.0	30.4	1,819.2	5.5	2.3	11.7	0	0	0	0	0	8	8	8	75	0	0
8	61	319.3	159.3	2,764.4	35.6	1,935.9	5.3	1.8	138.7	8	0	0	0	33	17	17	25	0	0	0
9	61	336.5	57.5	2,971.4	42.1	2,046.3	5.9	2.2	80.6	30	0	0	0	10	0	0	60	0	0	0
10	61	268.6	162.2	2,732.6	103.2	1,785.4	5.5	1.8	343.1	25	0	0	0	58	0	0	17	0	0	0
11	61	154.1	289.1	1,882.0	187.2	1,843.0	5.5	1.3	367.2	8	0	0	0	67	0	8	17	0	0	0
12	61	133.4	292.5	1,839.3	197.0	1,553.8	4.9	2.5	549.7	0	0	0	0	92	0	0	0	8	0	0
13	61	249.5	108.0	2,901.4	60.0	1,719.4	4.3	2.3	348.3	25	0	0	0	67	0	0	0	8	0	0
14	61	206.7	131.6	2,924.9	60.8	1,633.6	4.3	2.2	159.5	22	0	0	0	44	0	0	33	0	0	0
15	76	103.3	89.0	3,124.1	48.6	1,513.3	3.7	2.3	352.2	25	0	0	0	50	0	0	25	0	0	0
16	76	205.9	108.3	2,772.0	56.2	1,623.3	5.9	2.4	183.3	25	0	0	0	42	0	0	17	17	0	0
17	76	191.8	99.8	3,014.6	35.0	1,938.9	2.9	2.3	44.3	17	0	0	0	25	8	0	33	17	0	0
18	76	290.6	116.4	3,045.0	33.9	2,166.6	5.1	2.3	57.6	17	0	0	0	25	0	0	42	17	0	0
19	76	264.4	167.4	2,792.7	35.5	1,732.7	6.3	1.9	107.0	17	0	0	0	50	0	0	25	0	0	0
20	76	260.7	102.8	3,171.6	47.0	2,049.7	5.8	2.3	81.0	0	0	0	0	33	8	0	58	0	0	0
21	77	262.5	108.0	2,932.7	33.0	1,436.0	3.6	2.6	72.1	0	0	0	0	17	17	0	58	0	0	0
22	77	206.5	110.4	3,377.4	48.7	1,230.9	5.6	2.9	116.0	10	0	0	0	20	0	0	70	0	0	0
23	77	188.8	99.3	3,512.1	54.8	1,446.6	2.7	2.8	83.4	8	0	0	0	25	8	8	50	0	0	0

Table C.6. (Cont.).

Diel	Bear	Distance to					Habitat		Patch area (ha)	Corridor								
		road (m)	agri. (m)	water (m)	edge (m)	devel. (m)	rank	rich		agri. (%)	low veg. (%)	pine (%)	B. hard. (%)	U. hard. (%)	mixed (%)	pocosin (%)	marsh (%)	
119	24	77	131.3	230.5	3,496.4	80.0	1,164.0	5.7	2.6	184.8	9	0	27	0	55	9	0	0
	25	77	198.5	233.0	4,073.8	82.7	1,176.4	5.4	2.1	2,369.7	36	0	36	0	18	9	0	0
	26	77	126.7	123.3	3,127.6	82.6	1,260.7	5.0	2.0	245.1	33	0	58	0	8	0	0	0
	27	79	188.2	134.9	4,214.2	66.7	1,647.9	5.3	2.6	735.4	0	0	33	0	67	0	0	0
	28	79	205.6	184.5	3,273.8	106.2	1,233.0	4.9	2.1	977.5	13	0	38	0	38	13	0	0
	29	79	168.1	247.7	3,882.1	140.7	1,339.7	5.5	1.7	3,498.8	0	0	73	9	18	0	0	0
	30	79	239.5	272.3	4,608.7	64.5	1,360.8	3.5	1.8	2,198.0	17	0	50	8	0	0	25	0
	31	80	215.6	308.7	2,141.8	23.5	2,215.9	5.0	2.0	719.5	17	0	8	58	17	0	0	0
	32	80	213.0	448.0	2,947.7	37.6	1,910.3	4.2	1.7	1,198.1	8	0	17	50	8	17	0	0
	33	81	366.8	546.7	4,459.1	52.9	1,361.5	5.3	2.5	1,073.3	8	17	17	33	8	17	0	0
	34	81	227.4	521.3	4,294.2	70.7	1,576.7	4.0	1.9	3,204.2	13	0	50	13	13	13	0	0
	35	81	379.6	598.8	4,317.0	72.5	1,712.5	5.0	1.1	4,117.2	0	0	82	9	9	0	0	0
	36	81	290.3	259.7	4,863.0	79.4	1,858.5	5.0	1.0	2,339.2	44	11	33	11	0	0	0	0
	37	82	262.5	106.3	3,216.4	79.6	1,722.9	6.7	1.6	929.8	33	0	50	8	0	8	0	0
	38	86	153.1	104.2	1,809.0	70.8	1,177.0	5.8	1.7	1,657.5	8	8	25	0	42	8	0	0
	39	86	377.8	170.2	3,072.0	96.2	711.8	5.2	2.0	5,848.0	0	0	92	0	0	0	8	0
	40	86	137.4	881.0	2,537.9	433.4	2,233.0	4.7	2.9	4,028.8	0	0	100	0	0	0	0	0
	41	86	258.8	539.7	1,427.5	153.7	2,066.5	5.0	2.4	257.5	29	14	29	29	0	0	0	0
	42	86	102.3	677.1	1,458.5	12.9	2,076.1	4.3	3.1	8.6	0	11	22	0	22	11	33	0
	43	86	371.7	534.0	1,596.6	30.0	1,966.6	5.5	1.6	780.5	0	0	27	0	36	27	9	0
	46	86	351.4	459.2	1,461.4	37.4	1,400.9	5.1	2.5	750.6	7	0	33	13	13	27	7	0
	47	87	292.0	679.2	2,670.2	39.9	1,986.8	4.6	1.5	942.3	0	0	42	0	8	25	25	0
	48	87	399.2	644.3	2,675.5	79.0	881.4	3.1	2.3	2,708.1	0	0	50	0	38	13	0	0

Table C.6. (Cont.).

Diel	Bear	Distance to				Habitat		Patch	Corridor								
		road	agri.	water	edge	devel.	rank	rich	area	agri.	low veg.	pine	B. hard.	U. hard.	mixed	pocosin	marsh
		(m)	(m)	(m)	(m)	(m)			(ha)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
49	110	328.1	216.8	2,841.6	147.2	1,305.1	5.0	2.8	2,705.2	0	14	57	0	0	14	0	14
50	17	398.1	229.5	2,312.1	76.0	1,763.7	5.3	2.3	33.5	0	0	25	25	0	50	0	0
51	17	336.1	512.3	3,093.5	373.7	1,646.5	6.5	1.3	2,688.0	0	0	0	100	0	0	0	0
53	23	343.8	309.6	2,605.2	78.7	2,089.6	4.3	1.8	54.4	0	0	0	100	0	0	0	0
54	23	271.7	450.5	2,478.3	78.6	1,576.1	6.0	2.0	1,366.0	0	0	33	33	0	0	33	0
55	23	282.8	372.4	2,656.0	72.7	1,997.1	3.8	2.0	45.4	0	0	0	75	0	0	25	0
56	23	143.2	164.5	2,622.7	57.3	1,578.6	5.3	1.8	500.0	60	10	0	20	0	0	10	0
57	23	228.0	200.9	2,812.0	52.4	1,383.1	5.7	2.2	920.1	50	0	0	0	0	0	50	0
59	25	195.5	286.1	2,700.9	50.9	1,533.1	5.7	2.3	71.4	0	0	25	25	0	0	75	0
60	25	120.5	545.6	3,243.9	34.0	1,371.9	4.5	2.8	24.7	0	0	25	40	0	25	0	50
62	25	258.2	326.3	2,559.4	54.3	1,390.8	3.6	2.8	2,389.5	0	0	0	0	0	0	20	40
63	25	243.1	376.4	2,788.7	33.7	1,411.4	5.9	2.3	927.0	20	10	0	10	0	0	40	20
64	28	225.1	419.1	2,993.2	44.8	1,352.0	5.3	1.5	40.7	17	0	0	50	0	0	33	0
65	28	299.4	275.8	2,751.7	27.7	1,000.9	4.4	2.4	27.2	13	38	0	38	0	0	13	0
66	28	250.8	510.8	3,036.1	30.6	1,454.8	4.7	2.4	59.1	11	0	0	11	0	0	67	11
67	28	375.3	419.9	2,938.1	46.7	1,247.6	5.2	2.8	72.0	0	0	0	20	0	0	100	0
68	28	354.1	614.2	3,164.6	18.7	1,411.4	5.4	2.0	44.5	0	0	0	20	0	0	80	0
69	28	299.6	569.1	3,170.1	42.0	1,171.6	4.6	2.2	505.3	0	10	0	50	0	0	20	20
70	28	450.2	298.1	2,963.4	66.9	566.6	4.4	2.9	349.3	33	11	0	44	0	0	11	0
71	28	367.3	560.8	2,729.3	47.8	833.7	5.3	2.4	278.3	0	0	0	27	0	18	36	18
72	28	183.1	880.1	2,754.0	119.5	1,217.3	5.1	1.8	584.4	0	0	8	83	0	0	8	0
73	28	228.1	947.6	2,815.9	94.6	1,137.8	5.5	1.7	542.1	0	0	9	73	0	0	9	9
74	28	388.0	876.8	2,733.6	64.6	945.6	5.5	2.1	372.5	0	0	0	38	0	0	25	38

Table C.6. (Cont.).

Diel	Bear	Distance to					Habitat			Patch	Corridor								
		road	agri.	water	edge	devel.	rank	rich	area		agri.	low veg.	pine	B. hard.	U. hard.	mixed	pocosin	marsh	
		(m)	(m)	(m)	(m)	(m)			(ha)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)		
76	29	292.7	1,012.1	2,748.4	112.9	1,150.8	6.0	2.2	498.6	0	0	0	50	0	17	0	33		
77	29	309.5	1,132.7	2,511.7	49.0	1,478.0	3.8	2.0	335.8	0	0	0	33	0	11	44	11		
78	29	320.1	1,259.2	2,593.9	95.0	1,463.2	4.9	2.1	664.9	0	0	0	67	0	0	11	22		
79	29	315.8	868.1	2,668.3	61.1	1,076.7	4.6	2.0	336.7	0	0	0	42	0	17	17	25		
80	29	295.9	1,284.0	2,558.2	57.3	1,586.0	5.3	1.9	302.1	0	0	0	40	0	0	50	10		
81	29	169.5	1,168.0	2,267.1	100.8	1,556.9	4.0	2.4	666.8	0	0	9	55	0	9	18	9		
82	29	283.4	1,159.9	2,531.5	84.2	1,372.0	3.7	2.3	173.0	0	0	0	17	0	17	50	17		
83	42	248.4	1,368.8	2,548.2	44.4	1,615.1	5.8	1.7	337.4	0	0	0	33	0	0	50	17		
84	42	282.0	1,273.8	2,645.9	88.8	1,458.7	5.0	1.8	664.7	0	0	0	67	0	0	11	22		
85	42	280.0	989.5	2,662.1	45.5	1,190.8	3.2	2.3	645.1	0	0	33	22	0	0	22	22		
86	42	256.4	737.9	2,403.9	42.2	1,216.1	4.5	3.2	513.1	0	0	17	42	0	0	17	25		
87	42	285.5	698.4	2,231.7	39.7	1,176.8	2.6	3.1	663.3	0	0	44	33	0	0	11	11		
88	44	169.9	658.8	2,209.0	53.4	1,142.2	3.3	1.9	479.1	0	0	8	83	0	8	0	0		
89	44	132.4	611.2	1,999.0	73.1	1,103.4	2.6	2.3	132.4	0	0	11	11	0	78	0	0		
90	44	59.2	1,421.1	2,561.8	172.6	1,724.9	6.0	1.0	679.3	0	0	20	40	0	40	0	0		
91	44	185.6	1,050.1	2,276.8	170.7	1,616.4	4.0	2.3	697.6	0	0	0	83	0	17	0	0		
92	44	157.4	1,431.8	2,368.0	188.9	1,873.6	3.0	2.3	663.4	0	0	0	67	0	0	0	33		
93	44	158.7	961.0	2,169.4	119.1	1,418.6	5.6	1.5	325.1	8	0	25	42	0	8	0	17		
94	44	242.3	1,079.7	2,662.6	50.4	1,325.7	3.2	2.0	490.2	0	0	8	67	0	0	8	17		
95	44	237.1	1,093.9	2,266.8	61.3	1,442.6	4.0	2.5	554.0	0	0	10	50	0	30	10	0		
96	44	300.0	982.2	2,221.8	148.1	1,378.5	5.1	1.6	793.5	0	0	42	50	0	0	8	0		
97	44	380.0	1,334.3	2,272.2	292.0	2,162.4	4.5	2.3	989.2	0	0	0	100	0	0	0	0		
98	44	321.9	1,428.2	2,444.5	138.8	1,760.1	6.0	1.0	881.5	0	0	33	50	0	17	0	0		

Table C.6. (Cont.).

Diel	Bear	Distance to					Habitat		Patch area (ha)	Corridor							
		road (m)	agri. (m)	water (m)	edge (m)	devel. (m)	rank	rich		agri. (%)	low veg. (%)	pine (%)	B. hard. (%)	U. hard. (%)	mixed (%)	pocosin (%)	marsh (%)
99	44	262.0	1,027.5	2,166.4	125.9	1,673.4	5.4	1.7	714.6	0	0	8	92	0	0	0	0
100	47	193.6	1,049.2	2,057.4	148.0	1,860.1	4.9	1.9	757.3	0	0	8	75	0	17	0	0
101	47	194.7	1,304.2	2,459.7	107.8	1,841.7	5.7	2.4	650.2	0	0	0	71	0	29	0	0
102	47	177.2	782.9	2,017.4	36.7	947.8	5.2	1.4	121.9	0	0	0	20	0	80	0	0
103	47	136.3	826.1	2,066.4	27.4	1,261.5	4.9	2.8	266.5	0	0	0	42	0	58	0	0
104	47	113.3	680.2	1,842.0	65.1	1,005.9	5.0	1.9	423.8	0	9	9	55	0	27	0	0
105	47	296.9	436.7	1,905.1	59.3	695.6	5.7	1.7	254.0	0	9	0	55	0	18	18	0
106	51	193.9	549.0	1,879.7	102.5	1,300.1	4.3	2.7	413.1	0	0	0	50	0	33	17	0
108	52	324.7	379.4	1,806.3	105.2	893.4	5.7	1.8	344.9	0	0	0	50	0	0	50	0
109	52	306.0	540.0	1,912.2	107.7	1,203.5	5.3	1.8	258.1	0	17	0	33	0	17	33	0
110	52	318.5	584.5	1,930.2	63.8	930.9	6.7	1.9	155.5	0	9	0	18	0	9	55	9
111	52	229.5	590.2	1,917.9	42.2	1,187.5	6.2	1.5	77.1	0	0	0	36	0	27	18	18
112	52	182.6	413.6	1,486.0	51.2	1,650.3	5.0	3.1	245.8	18	18	0	45	0	9	0	9
113	52	202.1	306.8	1,226.3	33.7	1,231.7	5.3	1.8	266.4	25	17	0	50	0	8	0	0
114	52	216.8	368.0	1,070.1	40.4	1,775.3	5.6	2.6	336.2	45	9	0	27	0	18	0	0
115	56	229.5	611.8	1,443.4	29.9	1,182.3	4.9	1.9	343.9	0	0	9	91	0	0	0	0
116	66	419.4	594.9	1,153.7	37.7	1,234.3	5.7	1.2	69.5	0	17	0	50	0	8	25	0
117	66	415.6	644.6	1,350.7	42.9	1,511.8	4.8	1.6	170.6	0	8	8	42	0	25	8	8
118	66	425.5	539.9	1,180.2	46.1	1,237.3	5.7	1.8	124.7	0	9	0	64	0	27	0	0
119	66	438.5	452.4	1,798.1	54.0	2,622.5	4.6	2.7	551.0	0	9	9	64	0	18	0	0
120	66	316.5	289.3	1,874.3	46.1	2,189.7	4.8	2.2	384.5	17	33	0	50	0	0	0	0
121	66	339.8	405.7	1,535.0	55.9	2,324.1	6.0	1.3	203.7	8	17	0	42	0	17	8	8
122	66	384.7	199.3	2,039.0	21.9	3,137.0	4.4	1.6	300.9	44	11	0	11	0	33	0	0

Table C.6. (Cont.).

Diel Bear	Distance to					Habitat		Patch	Corridor							
	road	agri.	water	edge	devel.	rank	rich	area	agri.	low veg.	pine	B. hard.	U. hard.	mixed	pocosin	marsh
(m)	(m)	(m)	(m)	(m)	(m)			(ha)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
123	66	187.8	818.5	3,055.8	34.8	3,431.7	4.7	2.6	624.5	0	42	8	0	25	17	8
124	66	222.9	829.0	3,250.9	37.2	3,411.3	5.5	1.7	600.2	0	45	0	0	9	45	0
125	92	308.0	839.1	3,237.7	61.6	3,145.3	4.4	2.4	581.7	0	44	0	0	22	33	0
126	92	140.5	333.3	3,094.2	35.9	2,221.6	4.9	1.9	31.6	0	42	8	0	0	50	0
127	92	219.2	249.5	2,816.5	66.6	1,715.4	5.0	1.7	11.6	0	75	8	0	0	0	17
128	93	189.7	306.2	2,921.1	21.1	2,157.3	5.7	2.3	4.8	0	17	0	0	0	0	17
129	93	305.5	506.5	2,980.2	56.5	2,409.7	5.6	2.3	27.9	0	8	0	0	0	33	58
130	93	313.5	367.3	1,987.1	41.6	1,668.3	5.1	2.0	567.5	0	27	9	0	0	55	9

Appendix D. Den site and dependent random site microhabitat characteristics.

Table D.1. Nest den characteristics of black bears in the Big Pocosin and Gum Swamp study areas, North Carolina, 1994-1996.

Bear	Plot ^a	Habitat type ^b	Average tree height (m)	Total canopy cover (%)	Number of pine trees	Basal area pine (m ²)	Number of hardwood trees
81	1	1	11.54	87.3	46	0.8787	9
81	2	1	13.54	84.9	117	1.5861	13
172	1	1	21.16	83.5	10	0.8641	4
172	2	1	19.73	84.3	7	0.9820	8
113	1	3	13.64	84.1	0	0.0000	8
113	2	3	15.05	63.8	2	0.2500	25
77	2	1	15.55	77.3	14	1.0375	42
77	1	1	8.01	84.7	64	0.4995	13
90	1	4	17.75	33.8	1	0.2290	0
90	2	4	16.49	51.4	1	0.2706	0
86	1	1	18.21	90.3	23	0.9788	18
86	2	1	17.19	85.1	23	1.0645	10
100	1	1	19.04	82.2	28	0.9136	10
100	2	1	19.74	82.3	22	0.8110	7
155	1	3	9.58	82.0	10	1.0088	29
155	2	3	9.28	87.0	6	0.5497	47
66	1	3	11.64	80.3	3	0.2138	39
66	2	3	17.03	40.1	4	0.4469	32
100	1	1	14.20	93.2	63	1.2517	4
100	2	1	11.11	87.2	83	1.4582	3
45	1	2	13.51	72.6	0	0.0000	16
45	2	2	16.61	54.7	0	0.0000	31
61	1	1	15.02	78.5	45	1.1746	27
61	2	1	15.33	76.5	52	1.4683	14
174	1	1	7.16	74.2	28	0.4940	1
174	2	1	16.09	68.0	20	0.8828	5
144	1	1	6.25	60.0	42	0.3519	1
144	2	1	8.88	85.3	94	0.8914	0
86	1	1	14.17	82.6	74	1.4308	0
66	1	4	.	0.0	0	0.0000	0
66	2	4	.	0.0	0	0.0000	0
173	1	1	16.60	93.1	53	1.4236	9
173	2	1	13.90	82.7	59	1.2333	8

Table D.1. (Cont.).

Bear	Plot	Basal area hardwood (m ²)	Total number of trees	Total basal area (m ²)	Number of trees < 2.5 m	Total shrub height (cm)
81	1	0.0933	55	0.9720	33	213.4
81	2	0.0753	130	1.6613	4	16.2
172	1	0.0264	14	0.8905	136	201.9
172	2	0.1434	15	1.1254	82	172.1
113	1	0.3032	8	0.3032	24	227.3
113	2	0.9128	27	1.1628	65	87.0
77	2	0.5389	56	1.5765	22	148.1
77	1	0.0555	77	0.5550	117	233.5
90	1	0.0000	1	0.2290	37	135.6
90	2	0.0000	1	0.2706	3	203.5
86	1	0.0709	41	1.0497	5	166.4
86	2	0.0758	33	1.1403	4	178.1
100	1	0.0658	38	0.9794	6	152.9
100	2	0.0442	29	0.8552	8	162.3
155	1	0.3730	39	1.3818	78	167.3
155	2	0.6324	53	1.1820	54	202.6
66	1	0.3710	42	0.5848	17	224.2
66	2	0.9204	36	1.3672	25	63.8
100	1	0.0247	67	1.2764	41	197.2
100	2	0.0227	86	1.4809	12	101.0
45	1	0.7107	16	0.7107	32	205.4
45	2	1.3030	31	1.3030	20	128.3
61	1	0.1999	72	1.3745	72	210.8
61	2	0.1176	66	1.5859	26	78.1
174	1	0.0053	29	0.4992	5	186.4
174	2	0.1064	25	0.9892	8	104.1
144	1	0.0047	43	0.3566	44	230.2
144	2	0.0000	94	0.8914	8	121.6
86	1	0.0000	74	1.4308	6	152.4
66	1	0.0000	0	0.0000	49	95.9
66	2	0.0000	0	0.0000	84	54.3
173	1	0.1089	62	1.5326	15	171.8
173	2	0.1139	67	1.3472	4	112.4

Table D.1. (Cont.).

Bear	Plot	Total stem density (0.5 m ²)	Total stem diameter (cm)	Total cover density (%)
81	1	5.38	0.96	71.0
81	2	0.88	0.85	40.8
172	1	7.00	0.58	72.5
172	2	5.75	0.45	48.0
113	1	5.00	0.99	70.5
113	2	4.88	0.31	35.3
77	2	3.75	0.46	29.0
77	1	16.13	0.52	89.8
90	1	6.25	0.50	63.8
90	2	10.00	0.85	50.0
86	1	3.63	0.75	59.8
86	2	4.25	0.68	57.5
100	1	10.50	0.60	68.5
100	2	4.88	0.51	48.8
155	1	6.13	0.55	44.5
155	2	3.88	1.00	46.0
66	1	7.50	0.84	79.3
66	2	0.88	0.60	27.0
100	1	13.88	0.46	86.3
100	2	3.38	0.32	41.8
45	1	6.88	0.85	89.3
45	2	4.13	0.59	41.5
61	1	4.38	0.59	67.5
61	2	1.88	0.36	39.0
174	1	9.63	0.81	80.3
174	2	0.63	0.53	24.5
144	1	26.13	0.44	97.8
144	2	1.50	0.23	46.8
86	1	5.13	0.47	69.3
66	1	10.13	0.36	45.5
66	2	7.25	0.46	40.3
173	1	6.75	0.36	61.5
173	2	2.00	0.36	36.8

^a 1 = nest site, 2 = dependent random site

^b 1 = pine, 2 = hardwood, 3 = mixed pine/hardwood, 4 = shrub

Table D.2. Univariate comparison of nest site characteristics between black bear nest sites sampled the same year they were occupied and nest sites sampled 1 year after they were occupied, Big Pocosin and Gum Swamp study areas, North Carolina, 1994-1996.

Year	Variable	<i>n</i>	Mean	Standard error	<i>T</i>	<i>P</i>
1994	Tree height	7	14.4	1.4		
1995	(m)	8	12.6	2.0	0.7859	0.4460
1994	Canopy cover	8	78.8	6.7		
1995	(%)	8	68.7	10.4	0.8172	0.4275
1994	No. trees	8	49.1	8.7		
1995	(#)	8	26.4	7.3	2.0040	0.0648
1994	Basal area	8	0.9	0.1		
1995	(m ²)	8	0.7	0.2	0.7193	0.4838
1994	Regeneration	8	41.0	13.3		
1995	(#)	8	47.9	14.9	-0.3442	0.7358
1994	Shrub height	8	191.8	12.7		
1995	(cm)	8	185.7	15.2	0.3007	0.7681
1994	Shrub stem density	8	8.5	1.6		
1995	(m ²)	8	9.7	2.4	-0.4285	0.6748
1994	Shrub stem diameter	8	0.7	0.1		
1995	(cm)	8	0.6	0.1	0.3316	0.7451
1994	Cover density	8	73.3	3.8		
1995	(%)	8	70.2	6.8	0.3871	0.7045

VITA

Donald Alfonso Martorello was born on December 4, 1968 in Los Gatos, California. He graduated from Meridian High School in Meridian, Idaho in 1987. He attended Boise State University from January 1988 to May 1992 as a biology student. While at BSU, Donny decided to pursue a degree in wildlife and transferred to the University of Idaho in May, 1992, where he received a Bachelor of Science degree in Wildlife Resources in May, 1994. Also in May of 1994, Donny began his Master's research on black bears at the University of Tennessee, Knoxville, in the Department of Forestry, Wildlife, and Fisheries. He received his Master's of Science degree in Wildlife and Fisheries Science in May, 1998. Donny is married to Holli Elizabeth Martorello and they reside in Knoxville, Tennessee.

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