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Ecology and Physiology of a Black Bear (Ursus americanus) Population in Great Dismal Swamp and Reproductive Physiology in the Captive Female Black Bear

by

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(ABSTRACT)

Ecology and physiology of black bears in Great Dismal Swamp (GDS) National Wildlife Refuge and surrounding area, a forested wetland in eastern Virginia and northeastern North Carolina, were studied from April 1984 to March 1987. A total of 101 bears (71M, 30F) were captured 120 times. Males dominated the capture sample ($P < 0.001$), but age did not differ between sexes ($P = 0.74$). Mean ($\pm$SE) age was 4.2 ± 0.3 years. Litter size ($\bar{x} = 2.1$; $N = 12$), modal age at primiparity (4 years), and interbirth interval (slightly greater than 2 years) were indicative of good-quality habitat. Estimated annual adult survival rates were 0.84 for females and 0.58 for males. Causes of mortality included legal (outside the Refuge) and illegal harvest, vehicle collisions, depredation permit kills, research, and predation. Population density for the study area was estimated by 6 techniques at 0.47-0.68 bears/km^2, corresponding to 262-377 bears for the 555 km^2 study area. Demographic data suggested a stable and productive population.

Three major levels of diet quality were observed in terms of crude fiber, fat, and protein. Spring diets were high in protein but moderate in crude fiber, while fall diets were low in crude protein and high in ether extract. Condition indices and several blood characteristics (e.g. total protein, albumin, HCT, hemoglobin, and RBC) were at peaks in spring and late fall and at a low during summer. Serum creatinine concentrations also varied seasonally ($P < 0.001$), with a peak during denning and high levels in spring and late fall, perhaps resulting from transition from and to hibernation. A urea/creatinine (U/C) ratio ≤ 10 was not a good indicator of the hibernating state, as 39 of 120 (32.5%) trapped, active bears had U/C ratios ≤ 10. Creatinine and total protein were the best indicators of the hibernating state. Albumin, HCT, hemoglobin, and RBC were the best indicators of condition during active stages, as indicated by significant ($P < 0.1$) correlations of

condition indices and blood variables. Nine blood variables varied with age ($P < 0.1$). Multivariate analysis of variance and discriminant function analysis using blood variables failed to reject the hypothesis that bears cycled through 4 metabolic stages throughout the year. Results showed that metabolic shifts were tied to concomitant seasonal changes in diet quality, diet composition, and body condition, but also may have an endogenous component.

Habitat and range use dynamics were described by radiotracking of 24 female and 22 male bears. Median annual range size estimates were 79.1 km^2 for males ($N = 10$), 33.1 km^2 for subadult females ($N = 7$), and 21.4 km^2 for adult females ($N = 11$). Preferred ($P < 0.05$) habitats on an annual basis were pocosins and mesic areas for females and gum-cypress and maple-coniferous stands for males. Seasonally, pocosin, gum-cypress, mesic, and disturbed areas were important for females. Bear distribution analysis indicated that roads were preferred ($P < 0.05$) during all seasons except early fall, when bears made fall excursions to feeding areas far from Swamp roads and close to the study area boundary. Range overlap was extensive for both sexes, although it appeared that females maintained exclusive ranges during spring and early summer.

Denning ecology was described by monitoring 35 bears (26F, 9M). Five bears (2M, 3F) remained active throughout the winter. Den types included 14 elaborate ground nests, 11 excavated ground cavities, 2 ground-level tree cavities, 1 above-ground-level tree cavity, and 1 den in a stump. Females with cubs denned earlier, ($P < 0.02$) emerged later ($P < 0.001$), and denned longer ($P < 0.001$; 119 ± 4 days vs. 78 ± 4 days) than all other bear groups. Dry den sites did not appear to be limited.

Present population management (protection from hunting and no public vehicular access) should be continued in the Refuge. The small effective population size ($N = 66$) in GDS indicated the need for study of dispersal and genetics in the GDS and other southeastern wetland populations to determine the degree of isolation and extent of genetic variability. Maintenance and enhancement of pocosins, mature gum, oak, and disturbed habitats would benefit black bears in southeastern wetlands by providing a wide variety of natural foods throughout the year. Large den trees may not be necessary for successful denning and reproduction in certain southeastern wetlands

because bears can use dense cover and microelevational factors to overwinter. Black bear conservation strategies in the Southeast are a critical need due to increasing habitat fragmentation.

Six adult female black bears were maintained in captivity in Virginia from August 1987 to April 1988. Serum samples, as well as data on body weight and rectal temperatures, were collected from each bear at approximately 10-day intervals from 25 September to 30 March. Four of the six bears hibernated, not feeding for periods of 56 to 121 days ($\bar{x} = 94$ d). Rectal temperature declined in both active and hibernating bears during winter, but to a greater extent ($P = 0.013$) in hibernators. Average weight loss during hibernation represented 27.9% of peak body weight. Mean serum urea/creatinine (U/C) ratios were similar between physiological groups during the prehibernation phase. However, U/C ratios differed ($\underline{P} < 0.025$) after the onset of hibernation. Concentrations of total serum protein, serum urea nitrogen, and serum creatinine were similarly affected by significant time-group interactions ($\underline{P} < 0.01$). Alkaline phosphatase, phosphorus, sodium, and chloride changed significantly ($\underline{P} < 0.05$) during the course of the experiment, without regard to physiological group. U/C ratio was a good indicator of the hibernating state, but the sensitivity of serum urea levels to diet suggests careful use of U/C ratio as a field index. Serum progesterone (P) concentrations slowly increased from 2 to 5 ng/ml during October and November, then increased 2-2.5 fold 58 ± 5 days before parturition in 2 bears that produced cubs. After the implantation peak, P declined, reaching undetectable levels 1-2 days postpartum. Similar P profiles were observed in 3 of 4 bears that did not produce any observed cubs. P also was assayed in 38 active wild black bears to relate to reproductive status in the den. Changes in serum estradiol-17β concentrations during gestation also were profiled. The occurrence of pseudopregnancy or early embryonic mortality in bears with elevated serum progesterone concentrations is discussed.

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INTRODUCTION

The ecology of the black bear (Ursus americanus) in the Atlantic Coastal Plain in general and the Great Dismal Swamp (GDS) in particular has been the subject of limited study. The GDS, a 850-km^2 forested wetland on the Virginia-North Carolina border (Fig. 1), supports the last breeding population of black bears in eastern Virginia and extreme northeastern North Carolina. The 1973 establishment of the 440-km^2 GDS National Wildlife Refuge (NWR), which occupies the core of the Swamp, placed management responsibility for the bear population on the U. S. Fish and Wildlife Service. The need for population estimates and evaluation of habitat suitability for proper bear management in GDSNWR has been identified (Bureau of Sport Fisheries and Wildlife 1974), yet bear-related research has not met this need. Management of refuge bears is currently limited to protection from hunting.

The potential of the unhunted Refuge population to act as a reservoir for black bear reproduction and dispersal in the Atlantic Coastal Plain is unknown. In recent years, clearing of privately-owned GDS land for agricultural or residential development has accelerated, making GDSNWR vital as a sanctuary for the bear population. Population characteristics are unknown. Past population estimates (30-200) have been based on little (hunter harvest) or no data. Information such as sex and age distribution, age at primiparity, birth rate, and survival rate of the GDS bear population is necessary to predict results of bear-related management actions.

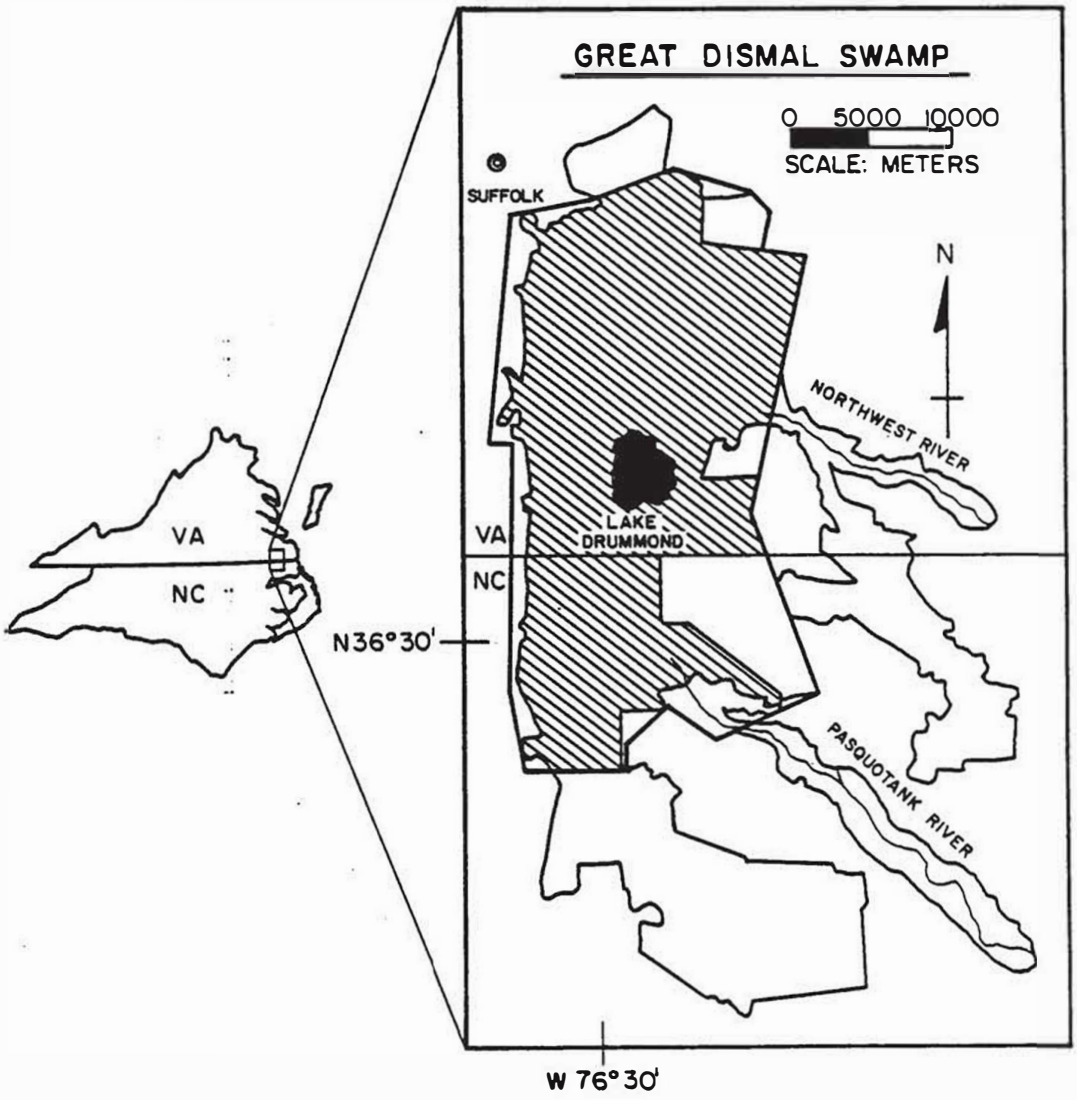

Figure 1. Location of Great Dismal Swamp (GDS) in Virginia and North Carolina. Study area (555 km^2) is outlined by heavy border. GDS National Wildlife Refuge is hatched portion.

Many of the above-mentioned demographic values of black bear populations are influenced by nutrition. Reproductive rate in North American bears is apparently density-independent and nutritionally regulated (Bunnell and Tait 1981). However, little research has been directed toward basic values of bear nutrition, such as protein and energy requirements, digestive abilities, or assessment of bear nutritional condition. Food habits have been studied in several populations, yet only Bunnell (1983) and Eagle and Pelton (1983) have evaluated nutritional quality of composite seasonal diets. Assessment of seasonal changes in diet quality and bear nutritional condition in conjunction with reproductive rate data would provide insight into the relationship between bear population dynamics and nutrition, as well as valuable management information for the Refuge.

Seasonal movements and habitat preferences of GDS bears were unknown. Available data and anecdotal information are too limited to predict bear behavioral responses to management actions. For example, the short-term and long-term effects of management activities such as hunting, surface water manipulation, timber harvest, burning, roller-chopping and public use management on bear movements, distribution, and habitat use can not be assessed with available data. Denning ecology of the GDS bear population is another unknown. Areas of GDS are flooded during the winter denning period. Availability of dry den sites may play a role in limiting productivity (Alt 1984). Data on denning chronology and site requirements in the GDS are necessary to aid in management decisions, particularly those that may directly affect den site availability, such as surface water manipulation and timber harvest.

Basic research on black bear reproductive physiology has been very limited and handling bears during the course of the study provided an opportunity to gain baseline data on this aspect of black bear biology. It has been speculated that female bears may somehow assess body fat stores and prevent implantation when deposits are too low to meet the metabolic demands of gestation and lactation during the denning period (Rogers 1976, Bunnell and Tait 1981). Such a resorption strategy would likely be under hormonal control. Endocrine events associated with bear gestation and lactation are not well understood (Foresman and Daniel 1983). Data on female reproductive endocrinology in association with den monitoring to determine presence or absence of cubs would provide information on the occurrence of blastocyst resorption.

This study was designed to provide information on demographics and ecology of the black bear population in GDSNWR for the purpose of improving bear management. Specific objectives for the study are:

1. To characterize dynamics of the GDSNWR black bear population.

2. To identify seasonal habitat uses of bears in GDSNWR and relate these to habitat availability.

3. To determine home range, movement patterns, distribution, and food habits of black bears in GDSNWR.

4. To determine the relationship between nutritional quality of seasonal black bear diets and physiological indices of condition.

5. To describe winter ecology and denning behavior of black bears in GDSNWR.

6. To characterize the relationships between circulating levels of progesterone, estradiol-17B and reproductive status in wild and captive female black bears.

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STUDY AREA

Work was conducted from April 1984 to August 1986 primarily on the 440 km^2 Great Dismal Swamp National Wildlife Refuge (GDSNWR), as well as 57.5 km^2 North Carolina Dismal Swamp State Park and adjacent privately-owned land. The entire study area was 555 km^2 (Fig. 1). GDS is a forested wetland located on the Virginia-North Carolina border on the mid-Atlantic Coastal Plain. Lake Drummond, about 4 km in diameter, is centrally located within the Swamp. An east-west gradient of approximately 19 cm/km characterizes the generally flat Swamp (Gammon and Carter 1979). Mean temperatures for January and July are 5.1 C and 26.0 C, respectively (Lichtler and Walker 1979). Annual precipitation averages 120 cm, with snow being light and irregular (U. S. Dept. of Commerce 1984-1985).

The vegetation of GDS includes numerous herbaceous plants, evergreen and deciduous shrubs, vines, and deciduous and evergreen, broad-leaved or needle-leaved tree species (Gammon and Carter 1979). Virtually the entire GDS was harvested for timber beginning in the late 1700's. Besides timber harvest, the vegetative community has been disturbed by fire, ditching, drainage, and road-building. In general, the water table has dropped and the GDS has become drier since colonial times due to extensive ditching (Lichtler and Walker 1979). The ditches have modified natural water flow patterns, allowing surface water to be shunted rapidly through the Swamp instead of remaining for several months (Carter et al. 1977). As

a result, the areal extent of flooding in GDS is probably much less than historical levels. Organic soils, or peats, dominate the study area, with mineral soils restricted to the western periphery of the Swamp and the outflow areas of the Northwest and Pasquotank Rivers (Fig. 1)(U. S. Fish and Wildlife Service 1986: pp. E-7-E-11). Approximately 250 km of sand or peat roads crisscross the study area. Roads generally have been built with spoil from ditch construction and consequently are adjacent to ditches (Fig. 2).

Scientific nomenclature for plant species follows Radford et al. (1968) and vegetation information was gleaned from Musselmann (1977), Gammon and Carter (1979), and U. S. Fish and Wildlife Service (1986). The major forest cover type is the red maple (Acer rubrum)-black gum (Nyssa sylvatica) association. Other tree species found with this association are sweetgum (Liquidambar styraciflua), redbay (Persea borbonia), sweetbay (Magnolia virginiana), and yellow poplar (Liriodendron tulipifera). This cover type is expanding with the drying trend in the Swamp. Cypress-gum forests are adapted to surface inundation and hydric soil conditions for part of the growing season. Major tree species in this type are black gum, water gum (N. aquatica), and bald cypress (Taxodium distichum). Major understory shrubs for both cypress-gum and maple-gum forests include sweet pepperbush (Clethra alnifolia), blueberry (Vaccinium spp.), fetterbush (Lyonia lucida), leucothoe (Leucothoe spp.), and hollies (Ilex spp.).

Loblolly pine (Pinus taeda) occurs in pure stands or mixed with red maple or maple-gum. Atlantic white cedar (Chamacyparis thyoides) occurs in pure, even-aged stands or mixed with red maple, black gum, sweetbay or redbay. It is considered a subclimax community and is slowly succeeding to hardwood forest types, particularly maple-gum. Evergreen shrub pocosins, with a sparse pond pine (P. serotina) canopy and a dense evergreen shrub understory, cover about 3.5% of the study area. Dominant shrubs in this community include inkberry (Ilex glabra), sweet gallberry (I. coriacea), fetterbush, leucothoe, sweet pepperbush, and myrtle (Myrica cerifrea). Much of this community is being invaded by maple and pine. Mesic hardwood stands containing oak-beech (Quercus-Fagus spp) associations occur as islands within GDS (on sand ridges) and also along the western

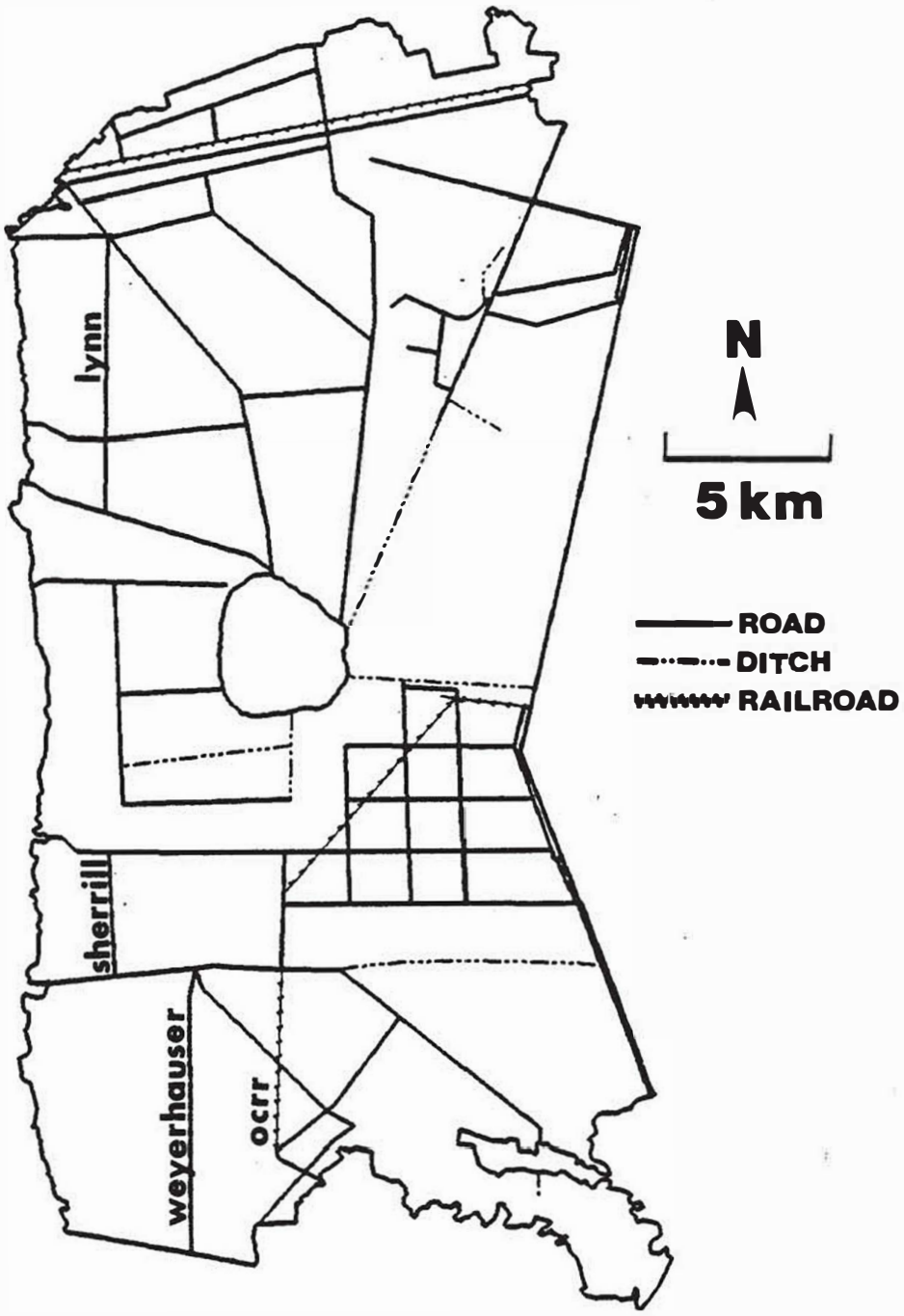

Figure 2. Distribution of roads, ditches, and railroads in Great Dismal Swamp (GDS),Virginia-North Carolina.

periphery. They occur at higher elevations and with well-drained, mineral soils. Other species commonly found with these stands include loblolly pine, American holly (I. opaca), and sweetbay. Approximately 10 species of greenbriar (Smilax spp.) occur throughout GDS. Other major vine species include wild grape (Vitis spp.), Japanese honeysuckle (Lonicera japonica), and gessamine (Gelsemium sempervirens). The dominant herbaceous plant is switchcane (Arundinaria gigantea).

A mixture of woodlots, agricultural areas, and urban areas surround the study area. The western boundary of the study area is the Suffolk Scarp, an escarpment that is oriented almost due north-south and runs for > 200 km from southeastern Virginia into North Carolina. West of the Scarp, the study area is bordered by a mosaic of peanut, soybean, and corn fields mixed with small woodlots. The north edge is bordered by the cities of Suffolk and Portsmouth and a six-lane highway (U.S. 58-460). Approximately 4000 ha of Swamp occurs north of the highway and south of the James River. To the east, the study area is bordered by Dismal Swamp Canal and U.S. Highway 17. Little swampland occurs east of Dismal Swamp Canal, as agricultural and residential development has cleared most of the forest. The south edge of the study is bordered by Highway 158 and agricultural fields. South of the highway is a large tract of privately-held swamp, which in turn is bordered to the south by U.S. Highway 17 and Albemarle Sound.

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CHAPTER 1: POPULATION DYNAMICS

The ecology of the black bear (Ursus americanus) in southeastern wetlands has been the subject of limited study (Hamilton 1978, Smith 1985). Islands of wetland habitats, primarily swamps and pocosins (Sharitz and Gibbons 1982), provide the last remaining refuges for the black bear on the Atlantic Coastal Plain (Monschein 1981, Zeveloff 1983). Large hardwood swamps and pocosins provide excellent denning habitat (Hamilton and Marchinton 1980, Hellgren and Vaughan 1987), diverse food supplies, and protection from disturbance (Hamilton 1978, Monschein 1981). However, dynamics of wetland populations remain poorly understood.

The Great Dismal Swamp (GDS), a 850-km^2 forested wetland on the Virginia-North Carolina border, supports the last breeding population of black bears in eastern Virginia and extreme northeastern North Carolina. The 1973 establishment of the now 440-km^2 GDS National Wildlife Refuge (NWR), which occupies the core of the Swamp, placed management responsibility for the bear population on the U. S. Fish and Wildlife Service. The need for population estimates for proper bear management in GDSNWR has been identified (Bureau of Sport Fisheries and Wildlife 1974), yet bear-related research has not met this need. Management for refuge bears is currently limited to protection from hunting. The GDS population, although afforded sanctuary in the 440 km^2 Refuge and unhunted in North

Carolina since the early 1970's, is exploited on private Swamp land adjacent to the Refuge in Virginia. Legal hunter harvests averaged 13.4 bears/year between establishment of big game check stations in 1947 and refuge establishment in 1973. Harvests have dropped to 9.4 bears/year since refuge establishment (Carpenter 1973, Anon. 1984). Other human-related causes of bear mortality documented for the GDS population are vehicle collision, poaching, train kills, and harvest due to crop or apiary depredation (Settle 1979).

The potential of the unhunted Refuge population to act as a reservoir for black bear reproduction and dispersal in the Atlantic Coastal Plain is unknown. In recent years, clearing of privately-owned GDS land for agricultural or residential development has accelerated, making GDSNWR vital as a sanctuary for the bear population. Population characteristics were unknown. Past population estimates (30-200) have been based on little (hunter harvest) or no data. Information such as sex and age distribution, age at primiparity, birth rate, survival and density of the GDS bear population is necessary to predict results of bear-related management actions. The objective of this study was to characterize dynamics of the Great Dismal Swamp black bear population.

MATERIALS AND METHODS

Trapping and Handling

Bears were captured using Aldrich spring-activated cable snares. Trapped bears were immobilized with a 2:1 mixture of ketamine hydrochloride (Ketaset) and xylazine hydrochloride (Rompun) at a concentration of 300 mg/ml. Initial dosage rate was 6.6 mg/kg

estimated body weight and drugs were administered by blow-gun dart syringe (Lochmiller and Grant 1983), jabstick, or dart rifle.

All bears were sexed and weighed to the nearest kg. The first premolar was extracted for aging by cementum annuli analysis (Willey 1974). Numbered plastic ear tags were placed in the ears of each bear. In addition, an identification number was tattooed inside each bear's upper lip for permanent identification. Selected bears were equipped with radio-transmitter collars (Telonics,Inc., Mesa, Ariz.) in the 164-165 MHz range with a 5-minute delay motion sensor. All females (except 2 subadults) were radio-collared. Selected males were collared to provide a wide distribution of age and weight classes. A breakaway cotton spacer was inserted in each collar (Hellgren et al. 1988) to minimize injuries caused by rubbing or chafing of the collar and to prevent collared bears from retaining collars throughout their lives.

Bear premolars were aged to year class independently by three separate individuals. If disagreements occurred with regard to age determination, teeth were reexamined until a consensus was reached.

Data Analysis

Differences in capture probabilities between sex and age classes were examined with the z-test for comparing binomial proportions. Differences in age between sexes were determined with the Wilcoxon Rank Sum Test. Reproductive characteristics (litter size, age at primiparity, and interbirth interval) were estimated using the female capture sample and by monitoring radio-collared females. Litter size was determined by den observation of family groups and by examination of female reproductive tracts from harvested and road-killed females for corpora lutea. Survival of radio-telemetered bears was used to calculate maximum and minimum survival rates (Trent and Rongstad 1974). Confirmed mortalities were used to calculate maximum survival estimates. Confirmed mortalities and radioed bears whose

signals were lost due to unknown causes were used to calculate minimum survival rates. A composite life table also was constructed from the capture data and age frequencies smoothed by a log-polynomial curve (Caughley 1977) to estimate survival of bears from 6 months to 2 years of age.

Several methods were used to estimate population size and density. The single mark-recapture or Petersen method was used to estimate bear numbers in the entire study area and both north and south of Lake Drummond for 1984 and 1985. Although male bears occasionally moved from one end of the Swamp to the other, the north and south halves of the study area represented fairly distinct entities. The closure assumption was relaxed by assuming an equal probability of loss between marked and unmarked individuals (Seber 1973). The assumption of equal probability of capture was not met for males and females (see below). Other assumptions were believed met. Mortalities due to handling, mortalities of marked bears between sampling periods and bears recruited to the population between sampling periods were removed from calculations. These animals were added to estimates after calculation. Population numbers also were estimated using the Schnabel Method, the Jolly-Seber Method (Seber 1973), and Program Capture (Otis et al. 1978). For these analyses, each year's trapping results constituted a trapping interval or occasion and recaptures within an interval were ignored. Finally, an independent, minimum estimate of density was obtained by intensive trapping of a 64.5 km^2 region within the main study area. This area was southeast of Lake Drummond and contained a grid of 55 km of roads (Fig. 2). It was believed that virtually all resident bears within this area were captured. Nine resident female bears were monitored for 8-24 months within this region. The area of intensive trapping was determined by planimetry of the trapped area bounded by a 1 km buffer strip or by peripheral points of the above female home ranges, whichever was larger (fall excursions were ignored).

RESULTS

Sex Ratio and Age Structure

A total of 120 captures of 101 bears (71M: 30F) was made between June 1984 and July 1986. Trapping effort was divided approximately equally between the area north of Lake Drummond (1639 trapnights/47 captures = 2.9% success) and area south of Lake Drummond (1793 trapnights/73 captures = 4.1% success). Overall trapping success was 3.5 %.

Sex ratio of initial captures was 237M: 100F (N = 101) and differed from 1: 1 ($\underline{P} < 0.001$). Among years, sex ratios of capture samples varied considerably. In 1984 (400M: 100 F; N = 35) and 1986 (1900M: 100F; N = 20), ratios differed significantly from 1: 1 ($\underline{P} < 0.001$); while in 1985, the ratio was almost even (110M: 100F; N = 46). Sex ratio of adults (> 3 years of age) (255M: 100F; N = 71) also was different from an even ratio ($\underline{P} < 0.001$),as was the subadult ratio (200M: 100F; N = 30; $\underline{P} = 0.07$). However, the sex ratio of 16 cubs from 7 litters did not differ from an even ratio (60M: 100F, $\underline{P} = 0.32$).

Ages of captured bears ranged from 1.5 to 16 years ($\bar{x} \pm$ SE = 4.2 ± 0.3; N = 100)(Fig. 3). Ages of females (4.0 ± 0.5; N = 30) and males (4.3 ± 0.3; N = 70) were not significantly different (W = 1470, $\underline{P} = 0.73$). Five captured males but no females were over 9 years of age.

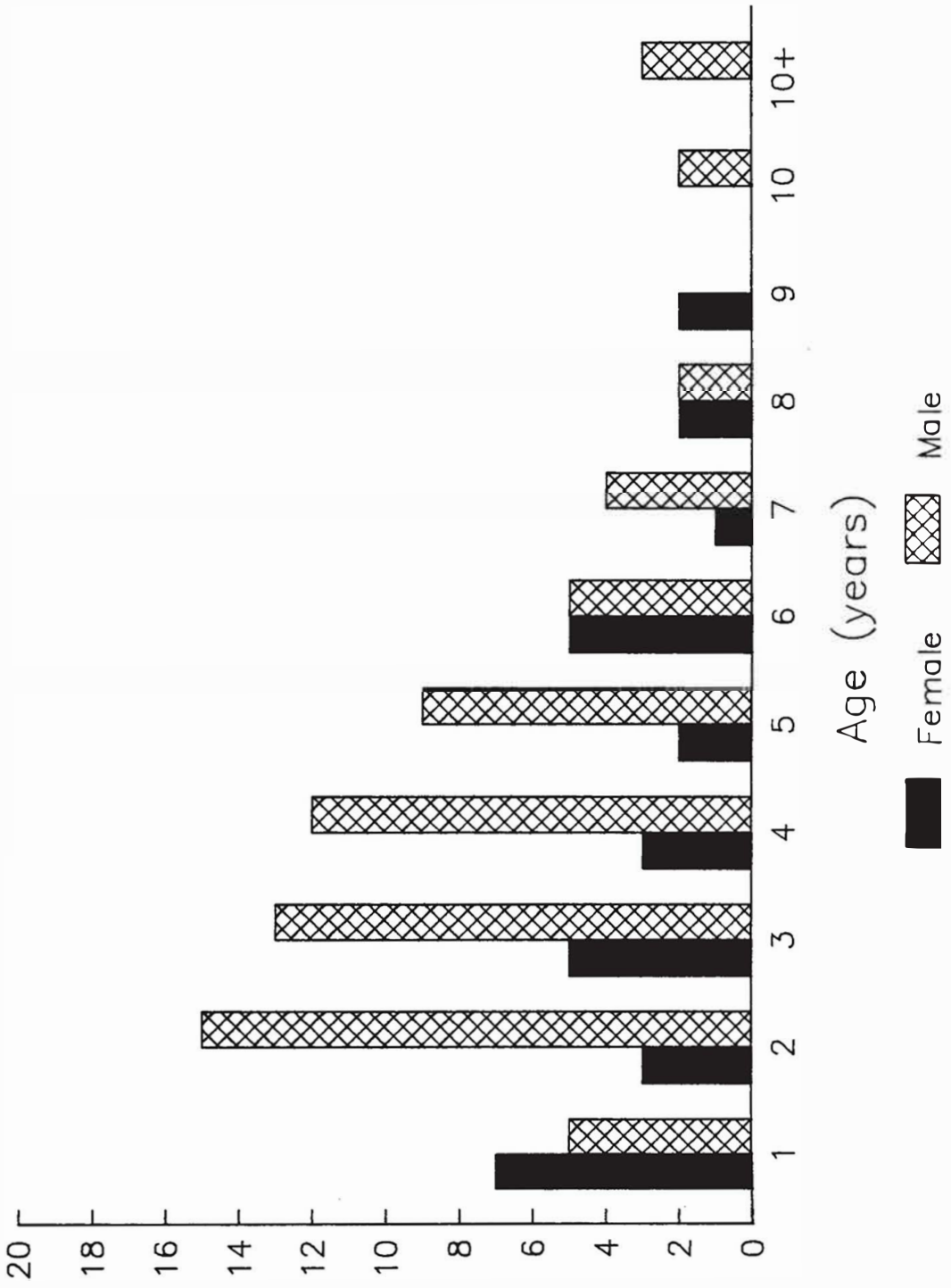

Figure 3. Age-frequency distribution (by sex) of black bears captured in Great Dismal Swamp, Virginia-North Carolina during 1984-1986.

Reproduction

Five of 10 reproductive tracts from road-killed or harvested females had corpora lutea and contained an average of 1.8 (Table 1). Litter size determined from den observations of 7 litters was 2.3 (Table 1). Remains of a cub were found in the den of an adult female immediately following emergence. Although her spring movements were similar to those of other females with cubs (Hellgren and Vaughan, Chapter 3), she was not sighted during spring or summer to determine whether she had another cub(s) traveling with her. This datum was not included in litter size calculations. Mean litter size determined by both methods (corpora lutea and den observations) combined was 2.1 (N = 12).

Youngest observed age of breeding from reproductive tracts or den observations was 3 years. Five 3 year-old females were captured during the study. Of 3 captured in July, one was in estrus (based on vulval appearance) but was killed and eaten near her den the following February by a large bear before den observations could be made; one was seen traveling with cubs (indicating breeding at 2 years of age); and radio contact was lost from the third in December. The other 3 year-olds were captured in August and September, respectively. The first did not produce cubs overwinter and the second had 1 corpus luteum, based on ovary examination following harvest. Three 4 year-olds were captured during the study. Teat development and expression of milk indicated that 2 of these sows had produced cubs and thus had bred at age 3. Finally, a female monitored through 3 winters gave birth for the first time at age 5. All captured bears > 5 years of age were pregnant, lactating, or had teat development indicating previous parturition (Appendix Table 1). These limited data suggest a modal age of first breeding at age 3 and primiparity at age 4.

Table 1. Litter size of black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

	Determination Method.			
	Corpora Lutea		Den Observations	
Age	N	$\bar{x}$	N	$\bar{x}$
3	1	1.0	-	-
4	1	2.0	-	-
5	2	2.0	1	2.0
6	1	2.0	1	2.0
7	-	-	1	2.0
8	-	-	1	2.0
9	-	-	1	2.0
10	-	-	2	3.0
Total	5	1.8	7	2.3

Little data on litter frequency were collected due to frequent loss of radio contact with females after approximately one year. Three other females were monitored through 2 winters. One denned with yearlings at age 7 and gave birth at age 9 (she was not monitored at age 8). Another denned alone at age 9 and produced cubs at age 10. A third did not den at age 7 (suspected to be with yearlings, Hellgren and Vaughan 1988) and gave birth at age 8. These data are not sufficient to determine whether young were produced every 2 or every 3 years. Of 19 adult (> 3 years) females monitored from capture until denning, 9 were pregnant. Five of ten reproductive tracts of harvested adult females contained corpora lutea. Thus, 14 of 29 (48%) adult females were pregnant, which suggests that the mean interbirth interval is slightly more than 2 years.

Survival Rates and Mortality Factors

Fifty-one of 101 captured bears were equipped with radio transmitters during the course of the study. Thirteen radioed bears (6M, 7F) and 8 other tagged bears (7M, 1F) were reported killed. Three radio-collared individuals were research-related mortalities due to heat stress (1M, 1F) and complications resulting from the compound fracture of a foreleg (1F). Two other radioed females died approximately 10 days after handling from unknown causes. Handling of these two bears was uneventful, but death may have resulted from capture myopathy, pneumonia, or bacterial infection introduced during drugging or other handling procedures. Carcasses of these individuals were too badly decomposed upon discovery to determine cause of death. The above 5 deaths were attributed to research activities and were removed from survival calculations. The 46 radio-collared bears that survived at least 2 weeks were monitored for 12,768 radio-days for calculation of survival rates (Table 2).

Mortalities of marked bears were attributed to 6 causes: legal kill, cannibalism, vehicle collision, poaching (suspected), damage complaint kills, and handling (discussed above). Six

Table 2. Annual survival rates of black bears in Great Dismal Swamp, Virginia-North Carolina as estimated by radiotelemetry (Trent and Rongstad 1974).

Sex	Age	N	Radio-days Monitored	Mortalities	Maximum annual survival rate[1]	Minimum annual survival rate[2]	Average annual survival rate (95% CI)
Male	> 2.5 years	22	3638	5	0.61	0.55	0.58(0.37-0.84)
Female	> 1.5 years	24	9130	3	0.89	0.79	0.84(0.73-0.98)
Total		46	12768	8	0.80	0.69	0.74(0.66-0.90)

[1] Determined using only known mortalities

[2] Determined using known mortalities and disappearances

(4M, 2F) of 35 bears legally harvested in the Virginia portion of GDS during 1984-1986 were tagged. A 4 year-old female was cannibalized during the winter of 1986 by another bear. She entered a den in late December, 1985 and her den was located on 29 January, 1986 under a live red maple tree root system. The den was found destroyed on 13 February during a visit to listen for cub sounds. The carcass was found 75m south of the den. Eight bear scats containing bear hair, flesh, and bone fragments were found in the immediate vicinity of the carcass. The zygomatic arches of the skull and the coronoid processes of the mandible were crushed. Distances between tooth marks on the skull were similar to canine breadths of adult males. Vehicle collision killed 8 bears (3 tagged males, 3 untagged males, and 2 untagged females) Seven of these deaths occurred on the major highways in Virginia and North Carolina that bound the study area. Four tagged bears (3 male, 1 female) likely were poached; two of these 4 occurred within GDSNWR. Two tagged males were legally shot for damaging crops near GDS in Virginia.

Subadult (< 3 years) survival rates could not be estimated reliably by radiotelemetry due to small samples (Seven subadult females were monitored 1784 radio-days and 4 subadult males were monitored 470 days without a mortality). Thus, mortality rates of subadults were estimated by life table analysis (Caughley 1977)(Appendix Table 2). Overall mortality (or disappearance) rates for both sexes were 0.31 from 6 months to 2 years of age and 0.14 for 2 years to 3 years of age. Cub mortality, as estimated from reduction in mean litter size from birth (Table 1) to 6-12 months postpartum (determined by observations: N = 14) was 0.246. No family groups were monitored closely enough to determine cub mortality. Determination of cub mortality from observations and reduction in litter size is fraught with problems. Losses of entire litters are not noted and observations of family groups may not be complete. For example, between 3 July and 15 August 1986, a radioed female with 3 cubs was observed 7 times. Average litter size from these observations was 1.7 (range: 0-3). The last sighting involved 3 young.

Population Size and Stability

Several estimates of population size were made for the study area bear population (Appendix Table 3). Petersen estimates (± SE) for 1984 and 1985 were 261 ± 87 and 311 ± 123, respectively, or a mean estimate of 286. This represents a density of 0.52 bears/km^2. Total population estimates (± SE) made using the Jolly-Seber Method, and Program Capture (Model M(O)) were 134 ± 65 (0.24 bears/km^2) and 366 ± 133 (0.66 bears/km^2), respectively. The Schnabel estimate was 253 animals (0.46/km^2). A minimum density estimate of 0.45 bears/km^2 was derived from intensive trapping of a 64.5 km^2, highly accessible region southeast of Lake Drummond. Extrapolated to the entire study area, this estimate represents a population of 250 bears. Our estimate of the GDS bear population density using all the trapping data is 0.47 bears/km^2, which is an average of the above estimates and corresponds to 262 bears within the study area.

Estimates of population numbers north and south of Lake Drummond averaged 86 (density = 0.28 bears/km^2; range 0.14-0.45) for the north area and 166 (density = 0.68 bears/km^2; range 0.42-0.94) for the south area. Although trapping effort in terms of trapnights was equal between these two areas, I am not confident that this density difference is real. Road access in the south part of GDS is greater (0.48 km road/km^2 to 0.43 km road/km^2), especially in the heavily trapped areas (Fig. 2). Bears in the south end were thus more likely to cross roads and ditches, which is where most traps were located. More roads also enhanced the ability to trap within small home ranges, as evidenced by capture of 21 females in the south section versus only 9 in the north section. Therefore, extrapolating the south estimate (0.68 /km^2) to the entire study area, I calculated a population size of 377 bears.

Because males are more likely to be captured because of behavioral reasons, the assumption of equal capture probabilities among all animals was violated. Therefore, an independent estimate of the male bear population was made (the female sample was too small to obtain estimates). Petersen estimates for 1984 and 1985 were 173 ± 64 and 199 ± 93,

respectively. The mean estimate for the 2 years was 186 males (0.34 males/km^2). Assuming a 1: 1 sex ratio, I derived a population estimate of 372 bears (0.67 bears/km^2). Based on the above data, I believe that the density of the GDS bear population lies between 0.47 and 0.68 bears/km^2, which corresponds to 262-377 bears.

The equation $\sum l_x e^{-rx} m_x = 1$, where l_x = proportion of individuals surviving to age x, m_x = number of female offspring produced per female at age x, and e is the natural log, was solved for r, the exponential rate of increase, to determine the population growth rate. Estimated survival rates presented above were used to determine the l_x schedule. Subadult survival rates were determined by life table analysis and thus their use in the calculation of r is tautological (Caughley 1977). However, cub and adult survival rates were estimated independently. Adult females were assumed to produce one female offspring per litter every 2.1 years (i.e., 48% of the females produced cubs in any given year) between the ages of 4 and 18 years. These assumptions resulted in an estimate of r = 0.0032 ($\lambda = 1.003$), indicating that bear numbers are virtually stable in GDS.

DISCUSSION

Most previous black bear population studies have been done in upland or mountainous areas. Reproductive and population characteristics of bear populations using southeastern wetland habitats are less well-documented (Table 3). The data of Smith (1985) indicated that productivity in the White River bottomland hardwood forest in Arkansas was comparable to other eastern populations. Reproductive characteristics (litter size, interbirth interval, and age at primiparity) of the GDS population are similar to those of the White River population (Table 3). Smith (1985) suggested that the relatively low age of sexual maturity and high reproductive success (including a mean interbirth interval of 2.4 years) of female bears in his

Table 3. Demographic characteristics of southeastern wetland black bear populations.

Locality	Litter Size	N	Litter Size Method	Sex Ratio (M:F)	N	Age at Primiparity (yrs)	Estimated Density (bears/100 km^2)	Adult (>1 year) Mortality Rate	Reference
Dismal Swamp	2.1	12	CL[1], den	237:100[2]	101	4	47-68	0.42 male 0.16 female[3]	This study
Arkansas	2.3	10	den obs.	156:100[2]	51	4	17-42	0.05 [3]	Smith 1985
Southeastern Georgia	2.0	5	CL	72:100[4]	43	-[5]	26-40	0.18 male[6] 0.32 female[6]	Abler 1985
Southeastern North Carolina	2.4	11	CL, PS[7]	194:100[4]	66	-[5]	11.5	0.28 Male[6] 0.16 female[6]	Hamilton 1978
Northeastern North Carolina	-	-	-	-	-	-	6.3	-	Hardy 1974
Florida	2.2	10	field count	139:100[4]	-	-	-	-	Harlow 1961

[1] Corpora lutea

[2] Determined from trapping data

[3] Based on survival of radio-collared bears

[4] Determined from trapping and harvest data

[5] CL observed in reproductive tracts of 2.5 year females

[6] Apparent annual mortality rate calculated according to Bunnell and Tait (1983)

[7] Placental scars

study area denoted high quality habitat, an interpretation supported by rapid growth rate of individuals (Smith 1985:70-72) and small home ranges (Amstrup and Beecham 1976, Smith 1985:136-141). Mean litter size for all wetland litters (2.1, N = 48) was slightly less than the mean litter size of 2.42 (N = 421) for eastern populations reviewed by Bunnell and Tait (1981)(Only the data of Harlow [1961] is common to these two averages).

Sex ratios reported for cub black bears usually do not differ from 1: 1 (Jonkel and Cowan 1971, Kemp 1972, Alt 1982, Carney 1985). However, numerous studies of black bear populations, including wetland populations (Harlow 1961, Hamilton 1978, Smith 1985) have reported sex ratios of capture samples skewed toward males. It is generally believed that the extensive travel behavior and large home ranges characteristic of male black bears increase their vulnerability to hunting and trapping, thus inflating estimates of male numbers relative to females. The present trapping data indicate similar biases. Legal harvest from the Dismal Swamp region in Virginia from 1972 to 1986 (Settle 1979, D. J. Schwab, Virginia Dept. Game and Inland Fish., pers. commun.) has been 67 females and 65 males, a nearly even sex ratio. Bunnell and Tait (1985) suggested that an equal sex ratio in a large kill indicates heavy hunting pressure and that hunting represents the major population mortality factor. Because legal harvest has averaged only 9.4 bears/year in the GDS region since NWR establishment in 1973 and accounted for only 6 of 16 mortalities among tagged bears, neither of these statements apply to the GDS population. Privately-owned land adjacent to GDSNWR is primarily mesic swamp habitat and bears congregate in these areas during the October-November bear hunting season to feed on oak acorns and black gum mast (Chapters 2 and 3). The likely result is equal vulnerability by sex to hunting, which is generally done coincident to hunting of white-tailed deer (Odocoileus virginianus). The Virginia harvest data may thus provide a better estimate of the GDS black bear sex ratio than my trapped sample. The assumed equal vulnerability to hunting also may be responsible for the similarity in mean age between sexes in my capture sample. We conclude that until a less biased collection technique is developed, the true sex ratio of black bear populations will be virtually impossible to determine.

The mean age of GDS bears and the age structure indicated a lightly exploited population. In unexploited populations, bears are generally older and percent adults higher than in exploited populations. For example, among wetland populations, the unexploited White River area in Arkansas contains approximately 70% adults (> 3 years of age) and many bears over 10 years of age (Smith 1985). Age structures of other unexploited populations are similar (Alberta- Young and Ruff 1982, Arizona- LeCount 1982, Idaho- Beecham 1980, Great Smoky Mountains National Park- Carlock et al. 1983). Heavily exploited populations typically have mean ages below 4 years and < 55% adults (Maine- Hugie 1982, Idaho- Beecham 1980, Pennsylvania- Lindzey et al. 1983, North Carolina- Carlock et al. 1983). Age characteristics of 2 exploited wetland populations follow these patterns (Hamilton 1978, Abler 1985). The GDS population had a mean age of 4.2 years and contained 57% adults (assuming 19% cubs from family group data), intermediate on the exploited-unexploited continuum.

Little information is available on natural causes of bear mortality (Rogers 1983). Human-related mortality, especially hunting, is considered the major form of mortality in black bears over one year of age. In a review of several exploited North American populations, Bunnell and Tait (1985) reported that apparent annual mortality rates (calculated from harvest data) for black bears > 1 year of age averaged 0.17 ± 0.002(SE) and 0.26 ± 0.004 for females and males, respectively. The average female survival rate in GDS of 0.84 (Table 2), or conversely a mortality rate of 0.16, is similar to average female rates described by Bunnell and Tait (1985), as well as the mortality rates of females in the wetland population studied by Hamilton (1978)(Table 3). The male mortality rate of 0.42 (Table 2; 1 - 0.58) is greater than the female rate, a usual condition among bear populations (Bunnell and Tait 1985). However, this rate was substantially higher than other North American, including wetland, populations (Hamilton 1978, Smith 1985)(Table 3). Although the overall survival rate, 0.74, is indicative of a heavily exploited population, the harvest data and age structure indicate that the population is lightly exploited. This light exploitation is because of protection from hunting within the Refuge.

It is probable that the sexes are equally vulnerable to sport hunting in GDS, as discussed above. The high male and overall mortality rate are due to other factors, notably depredation permit kills and vehicle collisions, which accounted for 7 of 16 (44%) tagged bear mortalities. Behavioral traits of male bears, such as dispersal and large home ranges may be responsible for greater vulnerability to these mortality factors. For example, all vehicle-caused deaths were on highways bounding or outside the study area, which represents the core of bear habitat. Although I did not detect permanent dispersal from GDS (this study was not designed to assess dispersal), 3 tagged males (aged 3, 4, and 6 years, respectively) were road-killed on the study area periphery. This situation is somewhat analogous to the Shenandoah National Park (SNP) bear population (Carney 1985). There, the female segment was essentially unexploited (survival = 0.935) while the male segment was heavily exploited (survival = 0.585). Carney (1985) attributed this difference to male movements outside the Park boundary, thus increasing their vulnerabilty to human-related mortality.

Published information on cub mortality is limited, due to difficulty in obtaining evidence on mortality factors. Cub mortality rates have been estimated by comparing changes in mean litter sizes between cubs of the year and yearlings (Bunnell and Tait 1985) or reduction in mean litter size from birth to 9-12 months post-partum (Smith 1985). These estimates are likely underestimates of cub mortality due to failure to include total litter loss. Our estimate of cub mortality, 0.246, is no exception, although it is similar to cub mortality rate estimates in other North American black bear populations, which have ranged from 0.13 to 0.38 (Jonkel and Cowan 1971, Rogers 1977, Alt 1982, Wathan 1983, Smith 1985). Smith (1985) reported a 0.32 cub mortality rate in a bottomland hardwood forest. Radiotracking of cubs has provided higher estimates of mortality than previously reported, 0.41 in Massachusetts (Elowe and Dodge 1986) and 0.48 in Arizona (LeCount 1986). Causes of mortality in these areas were determined to be cannibalism, predation, den abandonment, maternal death, disease, and hunting (Elowe and Dodge 1986, LeCount 1986). We found 3 scats containing cub claws, bones, and hair, suggesting that intraspecific predation may be one mortality factor acting on cubs in GDS. Flooding of natal dens, a potential problem in

wetland black bear habitats, did not occur in GDS during the winters of this study (Hellgren and Vaughan 1987), although it has been described as a major cause of cub mortality in Pennsylvania (Alt 1984). Cub survival also has been related to maternal nutritional condition and food supply (Rogers 1976, 1983, LeCount 1982, Wathan 1983).

Estimating population densities of black bears is made difficult by such factors as low densities, use of inaccessible habitats, capture difficulties, and inadequacies of existing population estimation techniques (Pelton and Marcum 1975). The wide variety of methodologies used to generate black bear density estimates across North America makes comparison of these estimates of limited value except within wide bounds. In addition, the available estimators are often unreliable. McCullogh and Hirth (1988) found that Petersen estimates were frequently inaccurate and skewed toward overestimation in counts of marked white-tailed deer, while Bartmann et al. (1987) reported underestimation of mule deer (Odocoileus hemionus) numbers using the same estimator. The major problem appeared to be violation of the assumption of equal catchability/observability. Bartmann et al. (1987) suggested that a large proportion of the population (> 45%) should be marked before reliable estimates and confidence intervals can be obtained. In the present study, 32%-39% of the population were marked, based on the marking of 101 animals and Petersen estimates of 261 and 311 animals (see Results). Pollock (1982) showed that under cases of heterogeneity of capture, the Jolly-Seber estimate was negatively biased. In the present study, the Jolly-Seber estimate was the lowest. Nevertheless, given the data, the estimators used in this study were the best available. The density estimate for the GDS population was higher than density estimates in other southeastern wetlands, which range from 6.3 to 42 bears/100 km^2(Table 3). However, it is intermediate on the density scale among North American black bear populations (see Carney 1985 for a review).

It has been estimated that 750 to 1000 bears remain in the pocosins and other habitats of the Coastal Plain of eastern North Carolina (Monschein 1981). Black bear numbers and demographics in GDS attest to the quality of this habitat. My density estimate is 4-6 times larger than previous estimates for Coastal Plain populations (Table 3) and indicates that bear

numbers in eastern North Carolina may be greater than previously believed. I believe that previous studies underestimated densities. Data used to arrive at the estimate of Hardy (1974) were limited to capture of 4 adult male bears (no recaptures), a single observation of a female with cubs, and track counts. No estimation technique was described. Hamilton's estimate also may be low, as he apparently trapped at traditional "bait stations where bear sign commonly was seen"(Hamilton 1978: 12). This strategy may have led to bait-fed, traphappy bears and a high rate of recapture.

Although black bear numbers in southeastern wetlands may be greater than previously believed, the species remains in precarious status in the Atlantic Coastal Plain due to the fragmented nature of populations. Habitat destruction for phosphate or peat mining, forestry, and agriculture is accelerating this fragmentation. For example, between 1962 and 1979, 33% (3000 km^2) of the pocosins in eastern North Carolina were totally developed (drained, ditched, natural vegetation removed, and soils prepared for agriculture, forestry, or industry)(Richardson 1981). Recent agricultural conversion of Carolina bays (densely vegetated wetlands) has resulted in large losses in bear habitat and increased bear vulnerability in Bladen County, North Carolina, among other areas (Earley 1985). Active conservation is needed to slow this habitat loss.

The island nature of black bear populations in the Southeast also renders them susceptible to loss of genetic variability. It should be emphasized here that research on subadult dispersal needs to be done to determine if these populations are indeed "islands". Gene flow between the GDS population and bear populations to the south of GDS may be occurring at a slow rate by movements of subadult dispersers through a mosaic of farmland and woodlots. Using the model of Reed et al. (1986) for calculating effective population size for species with overlapping generations, I calculated an effective population size of 66 in GDS (assuming a 1: 1 sex ratio, 25% of 3 year-old and 50% of 4 year-old males breeding, all females over 4 years-old producing litters of 2 in alternate years, and the survival rates determined above). This effective population size is only slightly above the recommended size of 50 for short-term population survival and well below the 500 recommended for

preservation of genetic variability and long-term population survival (Franklin 1980). Growing evidence among animal populations (reviewed by Soule 1980 and Allendorf and Leary 1986) indicates that individual genetic variation is positively correlated with fitness components such as survival, growth, and disease resistance. Conversely, loss of genetic variability due to inbreeding and genetic drift in small populations can lead to decreased natality and survival. The result is an increase in the probability of population extinction (Gilpin and Soule 1986).

Several other southeastern wetland black bear populations approximate the size, at least geographically, of the GDS population. Examples include > 900 km^2 Okefenokee Swamp in southern Georgia, 527 km^2 Alligator River NWR in northeastern North Carolina, and 457 km^2 White River NWR in Arkansas (Smith 1985). The effective size of the White River population is estimated to be between 53 and 92 (Smith 1985). Genetic and biochemical study of these populations could provide data on the degree of genetic isolation of these island bear populations. The use of genetic markers could provide a technique to deal with the problem of determining gene flow (i. e. dispersal) among black bear populations (Manlove et al. 1980). In addition, genetic study could describe the extent of genetic variability in these small effective population sizes. Previous work on black bear genetics has been done on the Great Smoky Mountains National Park population, which has a large effective size (Wathan et al. 1985), or on poorly defined populations (Manlove et al. 1980).

This study generated demographic and reproductive information to aid in black bear management in Great Dismal Swamp NWR. Currently, the GDS population is productive and numbers are stable, providing a source of bears for colonisation of suitable habitat directly adjacent to the Swamp. Protection from hunting and lack of public vehicular access should be continued within GDSNWR. This study also emphasized the need for development of black bear conservation strategies in the Atlantic Coastal Plain and other southeastern wetlands. Theoretical considerations suggest that the long-term fitness of these populations is low (Smith 1985) and efforts need to be made to maintain or enhance effective population sizes in these areas. Future research needs include study of dispersal, especially

by subadult males, to determine the role of GDS as a bear reservoir for the central Atlantic Coastal Plain. The extent of gene flow between the fragmented bear populations in the Southeast also could be examined by study of dispersal and population genetics.

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CHAPTER 2: SEASONAL PATTERNS IN NUTRITION AND PHYSIOLOGY

Black bears undergo dramatic seasonal changes in nutritional condition and physiology that are tied to annual food cycles. Seasonal fluctuations in fat deposits (Poelker and Hartwell 1974), body weight (Franzmann and Schwartz 1988), and metabolism (Nelson et al. 1983a) track seasonal changes in diet composition and quality (Eagle and Pelton 1983). These observations led Nelson et al. (1983a) to hypothesize that black bears annually cycle through 4 metabolic stages: hibernation, walking hibernation, normal activity, and hyperphagia. The latter 3 stages of this cycle correspond roughly to changing levels of black bear diet quality (Eagle and Pelton 1983) and nutritional condition.

The use of metabolic and endocrine indicators, such as serum characteristics, hematologic values, and thyroid hormones, to assess nutritional condition has shown potential in several wild ungulate species (Franzmann and LeResche 1978, Seal and Hoskinson 1978, Seal et al. 1978, Warren 1979, Lochmiller 1984). LeResche et al. (1974) outlined a 3-step procedure to determine relationships between nutritional condition and blood characteristics. Study of these indicators in ursids has been limited primarily to the first 2 steps, namely obtaining baseline values and detecting major sources of variation, such as

age, sex, and season, for blood characteristics in black bears (Youatt and Erickson 1958, Erickson and Youatt 1961, Eubanks et al. 1976, Matula et al. 1980, Bush et al. 1980, Beeman 1981) and brown bears (Halloran and Pearson 1972, Pearson and Halloran 1972, Brannon 1985a, 1985b). The next step in establishing nutrition-blood value relationships is to tie changes in blood biochemistry to shifts in diet quality and animal condition.

The use of discriminant analysis to classify animals into broad nutritional groups is well-suited to analysis of blood data, which typically include many variables (Hawley 1987). Multivariate analyses may aid in the use of animal metabolic profiles as indicators of habitat quality or population condition. For instance, Franzmann and Schwartz (1988) recently used discriminant analysis to select blood variables useful for condition evaluation in black bears in Alaska. Hematocrit (HCT) and hemoglobin (Hb) were selected as the most sensitive values to bear condition, which was assessed by body weight changes. Schroeder (1987), who used univariate and correlation techniques, also found HCT and Hb, among other variables, to be potentially useful as indices of nutritional status in black bear populations. In addition, he suggested that blood variables that are correlated with physical condition ratios (PCR) may be useful nutritional indicators.

The main interest of this chapter was to describe seasonal variation in food habits, diet quality, condition indices, and blood characteristics in a single black bear population. Identification of blood indicators of bear metabolism and condition, using the 4 physiological stages proposed and defined by Nelson et al. (1983a) as a basis for grouping, was also desired. Specifically, objectives were (1) to describe food habits of black bears; (2) to determine nutritional value of bear diets by season; (3) to test for age and seasonal differences in blood characteristics and condition (PCR) indices of black bears ; and (4) to test Nelson et al.'s (1983a) hypothesis of bear metabolic states by classifying bears into nutritional and metabolic status categories using blood characteristics. The black bear population in Great Dismal Swamp (GDS), an 850 km^2 forested wetland in eastern Virginia and North Carolina, served as the model for this research.

MATERIALS AND METHODS

Trapping and Handling

Bears were captured using Aldrich spring-activated cable snares. Trapping was continuous from April to December during the years of the study. Trapped bears were immobilized with a 2:1 mixture of ketamine hydrochloride (Ketaset) and xylazine hydrochloride (Rompun) at a concentration of 300 mg/ml. Initial dosage rate was 6.6 mg/kg estimated body weight and drugs were administered by blow-gun dart syringe (Lochmiller and Grant 1983), jabstick, or dart rifle.

All bears were sexed and weighed to the nearest kg. Head and total length were measured to the nearest 5mm using a cloth tape. The first premolar was extracted for aging by cementum annuli analysis (Willey 1974). Blood samples were collected in Vacutainers from a femoral vein as soon as possible following immobilization. Subsequent samples were obtained at 15-30 min intervals following initial samples. Each sample consisted of at least two 10-ml clot tubes for serum analyses and one 7-ml tube containing ethylenediamine tetraacetate (EDTA) anticoagulant for hematological analyses. At the conclusion of handling procedures, each bear received an intramuscular injection of Combiotic (Pfizer, New York, NY 10017), a prophylactic antibiotic.

Blood samples were placed in an ice chest immediately after collection. Upon return to the laboratory, EDTA tubes were refrigerated and clot tubes were centrifuged at 2500 rpm (796-1450 RCF) for 15-20 minutes. Serum was harvested and, during the first year of the study, frozen at -20 C for later analysis. During the second and third years of the study, serum samples were refrigerated. Whole blood and serum samples were sent by courier *either the*

day of capture or the day following capture to Pathologist's Service Professional Associates (PSPA), Inc. (Atlanta, Ga) for serum chemistry and whole blood analysis.

Food Habits and Blood Analysis

Bear food habits were determined from analysis of 553 scats collected incidentally to other research activities. Scats found in groups, such as around daybeds, were considered to be one independent scat. Scats were placed in labelled plastic bags and frozen for later analysis. In the laboratory, samples were thawed and washed through a series of sieves (sieve openings = 3.36 mm, 2 mm, and 0.6mm) to separate equal-sized particles. Contents were identified to species or lowest taxa possible. Frequency of occurrence and a visual estimate of percent volume of individual food items were determined for scats.

Each food item was assigned an index value based on percent volume in each scat: 0 = 0%, 1 = 0-1% 2 = 1-5%, 3 = 6-25%, 4 = 26-50%, 5 = 51-75%, 6 = 76-95%, and 7 = > 95%. Relative amounts (aggregate percent, Martin et al. 1946) of each food item in annual and seasonal diets were determined by assigning each index value the percent corresponding to the midpoint of its particular interval. Aggregate percent values for each food item then were summed, multiplied by 100, and divided by the sum of all percent values of all food items. Daubenmire (1968) discussed the precision and use of unequal-sized classes to estimate canopy coverage with large numbers of sample plots, a analogous situation to using index classes in this study.

Seasons were determined by changes in plant phenology and shifts in bear food habits: spring - 1 April to June 15; early summer - 16 June to 31 July; late summer - 1 August to 15 September; early fall - 16 September to 15 November; late fall - 16 November to 15 January; winter - 16 January to 31 March. Literature values for crude protein (CP), crude fiber (CF) and crude fat (CFT) content of major food items (> 1% aggregate percent in any

season) were reviewed (Appendix Tables 5-10). Food items for which nutritive values could not be found in the literature were collected in GDS and analyzed by the Forage Testing Lab at Virginia Polytechnic Institute and State University. Nutritional values of composite seasonal diets then were calculated by multiplying aggregate percent of individual food items in a seasonal diet by proportion of CP, CF or CFT in each item (Eagle and Pelton 1983) (Appendix Tables 5-10).

Physical Condition Ratios (PCR) were developed from weight/somatic measurement ratios: PCR-A = (body weight/total length)X100 and PCR-B = (body weight/head length)X100 (Schroeder 1987). Sexes were analyzed separately due to sample size and seasonal distribution differences. PCR and weight data were analyzed by an analysis of variance model using the General Linear Model (GLM) procedure of SAS (SAS Institute Inc. 1982) including the main effects of age and season and the age X season interaction. Differences ($\underline{P} < 0.05$) among seasons and ages were isolated using Fisher's Least Significant Difference test.

Blood samples were analyzed by PSPA. Serum chemistry analyses were performed using a Technicon autoanalyzer SMAC-2 using procedures specified by the manufacturer. Serum values measured were total protein, albumin, total bilirubin, alkaline phosphatase, aspartate aminotransferase (SGOT), alanine aminotranferase (SGPT), lactate dehydrogenase (LDH), total cholesterol, triglycerides, glucose, urea nitrogen (SUN), creatinine, uric acid, calcium, phosphorus, sodium, potassium, chloride, gamma-glutamyl transferase (GGT), iron, and globulin. Urea/creatinine ratio (U/C) was calculated from urea nitrogen and creatinine concentration (Nelson et al. 1984). Whole blood analyses were performed using the Coulter Counter S-Plus III. Values for red blood cell count (RBC), hemoglobin concentration (Hb), mean corpuscular volume (MCV), hematocrit (HCT), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were determined. Overall white blood cell counts (WBC), differentials, and platelet counts also were performed. Level of hemolysis was determined by ocular estimation (Frank et al. 1978). Samples with hemolysis of greater than +2 (using criteria of Frank et al.) were discarded from future

analyses due to the effect of hemolysis on serum constituents. Only first capture data were used from bears captured twice during a particular season to maintain independence. All blood data were tested for a normal distribution (PROC UNIVARIATE; SAS Institute Inc. 1982). Nonnormal variables were log-transformed and retested for normality. Later analyses were run on transformed data if they were closer to normality than the raw data. Blood data were analyzed using the same two-way analysis of variance model (age and season) as described above for the PCR data (Appendix Tables 11-18). Variables not analyzed for age and season differences due to sensitivity to trapping stress were serum enzymes (SGOT, SGPT, LDH, GGT), glucose, differential counts, and platelet counts (Appendix Table 19). Serum chemistry data from initial blood samples (i. e., first sample taken during a handling session) only were used in the ANOVA analysis. The influence of capture stress and handling procedures on blood values was assessed separately using data from multiple samples collected during a single handling session. These data were analyzed by a paired t-test or an Anova model for repeated measures (Appendix Table 20).

Simple Pearson correlation analysis (Sas Institute Inc. 1982) was used to examine relationships between condition indices and blood characteristics. Because of the dependence between weight (or PCR-A) and age, we attempted to minimize the age effect on condition-blood value correlations by grouping females into 2 age categories (1-3 years and > 3 years) and males into 3 age categories (1-2 years, 3-4 years, and 5+ years). Pearson correlation analysis was then performed for each age-sex cohort to determine significant relationships between condition indices and blood variables within a given age group (Appendix Tables 21-22).

We used the metabolic stage scheme of Nelson et al. (1983a) and major dietary shifts to group bears into physiological status categories. Stepwise discriminant analysis (SAS Institute Inc. 1982) was used to select blood variables for each sex that provided adequate ($P < 0.1$) separation among groups. A discriminant function analysis using a jacknife procedure (Dixon 1983) then was used to determine classification accuracy among groups. Canonical discriminant analysis was performed to further determine relationships among

metabolic groups within each sex. Sample size constraints limited analysis to 3 groupings for each sex: spring, summer, fall for males and summer, fall, hibernation for females (early and late summer and fall were combined for these analyses).

RESULTS AND DISCUSSION

Food Habits and Diet Quality

The seasonal pattern of diet composition paralleled shifts observed in previous studies of black bear food habits in the southeastern United States (Hardy 1974, Landers et al. 1979, Eagle and Pelton 1983, Maehr and Brady 1984, Smith 1985, Garner 1986) (Table 4, Figure 4, Appendix Table 4). Spring diets (emergence to 15 Jun) were dominated (72%) by succulent new growth of woody plants, primarily stems and leaves of greenbriar (Smilax sp.) and sweetbay (Magnolia virginiana)(Table 4). This is the first report of intensive black bear use of sweetbay. Sweetbay leaf samples collected on 19 May in GDS contained 25.8% crude protein, 21.1% acid-detergent fiber (about 15% crude fiber), and 5.7% ether extract. Grasses, particularly switchcane (Arundinaria gigantea), and ferns also were important. These results parallel those seen in other southeastern wetland populations (Hardy 1974, Landers et al. 1979, Maehr and Brady 1984). Debris (e.g. soil, wood slivers) made up 7% of spring scats. Hardy (1974) and Smith (1985) also reported a high frequency of bark and wood slivers in spring scats. Hardy (1974) suggested that these items were accidentally ingested while extracting insects from logs and stumps. However, during April and May in our study, we found numerous Atlantic white cedar trees which had been debarked and scratched up to

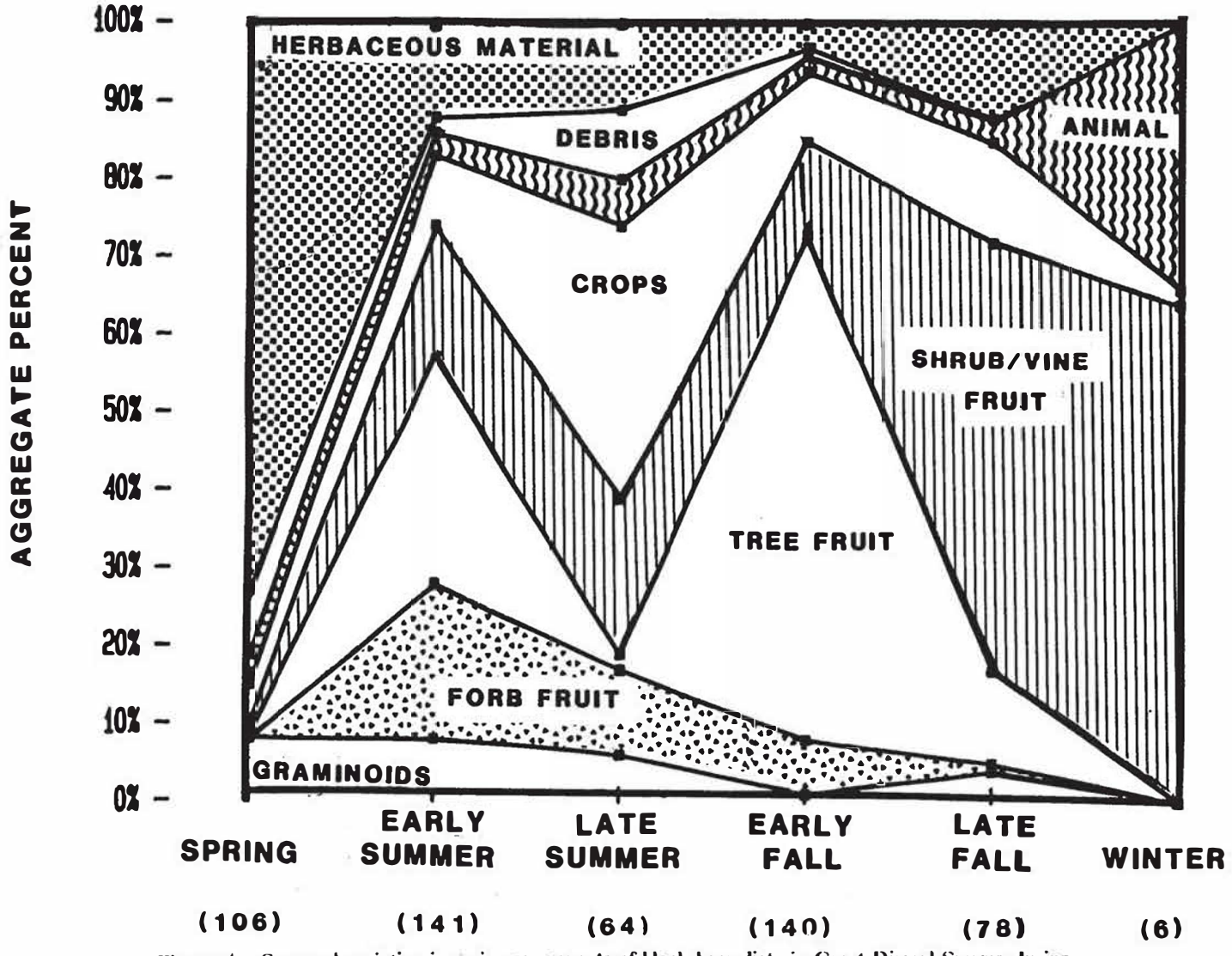

Figure 4. Seasonal variation in major components of black bear diets in Great Dismal Swamp during 1984-1986.

Table 4. Percent frequency of occurrence and aggregate percentage of items identified in 533 black bear scats collected within Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

	Spring (*N* = 106)		Early Summer (*N* = 141)		Late Summer (*N* = 64)		Early Fall (*N* = 140)		Late Fall (*N* = 78)		Winter (*N* = 6)		Entire Year (*N* = 533)	
Food Item	% Freq.	Agg. %	% Freq.	Agg. %	% Freq.	Agg. %	% Freq.	Agg. %	% Freq.	Agg. %	% Freq.	Agg. %	% Freq.	Agg. %
Graminae	21[a]	8	22	8	25	6	15	1	15	4			19	5
Forbs														
Aralia spinosa (f)[b]							16	4	3	1			5	1
Phytolacca americana (f)					17	9	7	2	13	T[c]			6	2
Rubus spp. (f)			29	18									8	5
Others			10	T	8	1	2	T					1	T
Ferns	19	2	17	2	11	1	11	1					12	1
Moss			1	T	2	T							T	T
Algae			1	T			1	1					T	T
Tree Fruit														
Nyssa sylvatica			1	T	22	2	61	33	6	3			20	9
Prunus serotina			37	29	2	T							10	8
Quercus spp.							34	32	10	9			10	10
Others	5	T			4	T	5	T	1	T			1	T
Shrub Fruit														
Ilex coriacea					20	7	5	1					4	1
Ilex glabra							2	1	41	30			7	5
Ilex verticillata							2	1	21	11			4	2
Vaccinium spp.	7	2	26	16									8	5
Others			1	T			2	1	11	T	17	T	2	T

Table 4 (continued).

Vine Fruit														
Lonicera japonica									3	1			T	T
Smilax spp.	8	T	1	T	5	T	11	1	40	13	66	63	12	3
Vitis spp.			4	1	27	13	16	8					8	4
Crops														
Corn (f)	2	1	9	8	37	29	9	6	8	5	17	2	11	8
Corn (h)			3	1	23	6	5	1					5	1
Peanuts					1	T	2	2	9	8			2	2
Others	5	4	3	1	23	6	5	1					6	2
Tree, Shrub and Vine Herbaceous Matter														
Magnolia virginiana[d]	43	31	6	2					3	T			11	7
Smilax spp.	38	21	14	5	9	5	4	1	21	7	50	1	17	7
Others	3	T	19	T	17	T	11	T	37	2			17	T
Animal Matter														
Hymenoptera	43	2	41	1	48	5	5	T			17	T	27	1
Coleoptera	11	T	15	T	31	1	20	T	4	T			16	T
Odocoileus virginanus	2	1	6	T	3	T	2	1	12	3			5	1
Ursus americanus[e]	6	T	9	1	19	T	4	T	3	T	33	35	8	T
Unknown	2	T					1	T					1	T
Others	3	T	5	1	4	T	4	1	4	T			4	T
Debris (bark, leaf, soil, etc.)	44	8	33	2	57	9	12	T	13	T	17	T	30	3
Unidentified vegetation	39	20	26	5	11	4	11	T	20	3	17	T	22	6

[a] Percentage values are rounded to the nearest whole number.
[b] f = fruit, h = herbaceous material (stems, leaves).
[c] Indicates trace amount (< 0.5 %).
[d] Spring aggregate percent estimates for *Magnolia virginiana* and *Smilax* spp. are minimum estimates. If identifiable leaf parts were found, these were included in frequency data. However, if scat contents were too finely ground to estimate individual species volumes, contents were considered unidentifiable ground vegetation.
[e] Four scats contained evidence of cannibalism (claws, bone, tissue). The remainder were associated with grooming activities.

heights of 2m. Although we could never positively identify white cedar slivers in scats, it is possible that bears were feeding on new sapwood in the spring, as reported by Poelker and Harwell (1973) in western Washington.

Soft mast became the staple of the diet in early summer (16 Jun to 31 Jul). Blackberry (Rubus sp.) and wild black cherry (Prunus serotina), associated with roadsides and disturbed areas, and blueberry (Vaccinium sp.) were the major fruits used (Table 4). Vegetative plant parts decreased in dietary importance as fruits ripened. As availability of the above 3 fruits waned in late summer (1 Aug to 15 Sep), other soft mast, such as pokeberry (Phytolaca americana), wild grape (Vitis sp.), and sweet gallberry (Ilex coriacea), ripened (Table 4). The wide variety of soft mast consumed during summer has been reported for other southeastern populations (Hardy 1974, Landers et al. 1979, Maehr and Brady 1984, Smith 1985). In southeastern North Carolina, sweet gallberry was 48% and 64% of the diet, volumetrically, during August and September, respectively (Landers et al. 1979). Use of this fruit in GDS may have been underestimated. Eight radio-collared females used an Ilex-dominated pocosin in August 1985 (Hellgren and Vaughan, unpubl. data) and were believed to be feeding on sweet gallberry. Very few scats were collected from this area because of its dense vegetation. Use of agricultural crops was heaviest during late summer, as corn fruit, leaves, and stalks composed 35% of the late summer diet (Table 4, Figure 4). Landers et al. (1979) noted similar bear use of corn fields in coastal North Carolina during summer.

Mast from black gum and oaks made up 65% of the early fall (16 Sep to 15 Nov) diet (Table 4, Figure 4). Bear feeding sign indicated that swamp chestnut oak (Q. michauxii), a white oak species, was used heavily. The importance of these 2 mast types as fall food for several southeastern wetland populations has been well-documented (Harlow 1961, Hardy 1974, Landers et al. 1979, Maehr and Brady 1982, 1984, Smith 1985). Black gum constituted only 5% of the fall bear diet in GDS north of Lake Drummond in a previous study (Daniel 1978). Daniel (1978) found wild grape, persimmon (Diospyros virginianus) and paw-paw (Asimina triloba) to be primary fall foods. However, black gum is very abundant in GDS, forming with red maple the most prevalent community type in the study area (Levy and

Walker 1979). The paucity of black gum seeds in Daniel's (1978) scat sample may have been due to his small sample (N = 42) and sampling area or to gum mast failure in his sampling area during the fall of his study. Grapes, devil's walking-stick (Aralia spinosa), pokeberry and corn also were eaten during early fall (Table 4).

Late fall (16 Nov to 16 Jan) and winter (16 Jan to emergence) diets were dominated by shrub and vine mast, primarily Ilex sp. and greenbriar fruits (55% and 63%, respectively; Table 4, Figure 4). Black gum and oak mast still were eaten where available. Domestic crops comprised 13% of the late fall diet, as bears fed on peanuts laying in fields postharvest and on corn.

Animal matter was a small but consistent part of the diet, forming about 3% of the annual diet (Table 4, Figure 4). Colonial hymenopterans, especially ants (Formicidae), and coleopterans were eaten with high frequency during spring and summer. Extensive spring sign of bears foraging for insects in decaying stumps and logs corroborated the abundance of insects in scats. Large amounts of soil commonly were found in scats containing ants. Similar results have been seen in other studies of wetland populations (Hardy 1974, Landers et al. 1979, Maehr and Brady 1984, Smith 1985). During fall, scavenging of hunter-killed deer (Odocoileus virginanus) became important (Table 4). Smith (1985) reported a similar result. Other vertebrates identified in bear scats were trace amounts of eastern cottontail (Sylvilagus floridanus), opossum (Didelphis virginianus), and black bear. Black bear hair was found in 41 scats and generally represented grooming activities. However, 4 scats contained evidence of cannibalism (claws, bone, tissue). Three of these scats, collected in April, June, and July, respectively, contained cub parts. The fourth scat contained parts of a radio-collared adult female that had been cannibalized. No fish remains were found in any scats.

Nutritional values of seasonal diets indicated 3 distinct levels of nutrition (Table 5), as observed by Eagle and Pelton (1983) (Appendix Tables 5-10). Spring diets were high in crude protein but, surprisingly, crude fiber content was similar to that of other seasonal diets (Table 5). Spring is generally considered a "negative foraging period" (Poelker and Hartwell 1973) for black bears, as individuals lose weight and condition on a high fiber, indigestible diet

Table 5. Nutritive quality of composite seasonal diets of black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Season	N^1	% Crude Protein	% Crude Fiber	% Crude Fat
Spring (1 Apr.-15 June)	106	22.2	15.4	6.2
Early Summer (16 June-31 July)	141	9.0	18.5	5.2
Late Summer (1 Aug.-15 Sep.)	64	10.7	13.5	6.7
Early Fall (16 Sep.-15 Nov.)	140	7.1	17.3	10.2
Late Fall (16 Nov.-15 Jan.)	78	9.3	15.5	9.0
Winter (16 Jan.-31 Mar.)	6	6.8	16.7	6.3
Captive diet (ZuPreme)	-	20.0	6.0	4.0

[1] Number of scats used to calculate composite diet quality.

References used to calculate diet quality:
Beck and Beck 1955; Bonner 1971; Bonner 1974; Bonner 1975; Eagle and Pelton 1983; Elowe 1987; King 1940; King and McClure 1944; Landers et al. 1979; Lay 1957; Leung 1968; McCullogh and Ullrey 1983; Mealey 1980; National Academy of Sciences 1971; Redford and Doria 1984; Servello and Kirkpatrick 1987; Servello and Kirkpatrick 1988; Short and Epps 1976; Short and Epps 1977; Short et al. 1975; Smart et al. 1960; Smith et al. 1956; Spinner and Bishop 1950; Treichler et al. 1946; U.S.D.A. 1963; Wainio and Forbes 1941.

See Appendix Tables 5-10 for a complete listing of foods and nutrient values.

(Eagle and Pelton 1983). Our data (see below) on seasonal weight dynamics, condition, and blood characteristics indicate that spring was a negative foraging period in GDS. However, diet indigestibility may not have been the cause. Work with grizzly bears (Ursus arctos) shows that this species feeds on plant foods high in soluble nutrients and low in fiber throughout the year (Mealey 1980, Hamer and Herrero 1988). Literature review of the chemical composition of southeastern browses during the spring growing season indicated that these foods also are high in protein and low in fiber (Smith et al. 1956, Short et al. 1975, Landers et al. 1979). Spring hypophagia (Nelson et al. 1983a) and problems associated with forage acquisition and processing may contribute to the weight losses observed in black bears in spring. As mentioned by Landers et al. (1979), succulent spring vegetation is largely water and large volumes would be necessary to meet energy requirements. The digestive tract of the black bear may not be able to process enough leaves and stems to meet energy needs. Quantitative data on food intake and digestibility during spring is needed to address this question of bear nutrition.

Summer diets (early and late) were characterized by low crude protein and moderate levels of crude fiber and crude fat (Table 5) Most foods were soft fruits of shrubs and trees. Fall diets also were low in protein but high in crude fat (Table 5), suggesting a high energy diet. Similarly, fall black bear diets high in fats and digestible carbohydrates were reported by Landers et al. (1979) and Eagle and Pelton (1983). Bunnell (1983), in a study of food habits of 12 grizzly bear populations, suggested that bears select for fat and energy in the fall. Eagle and Pelton (1983) stated that this high-energy diet, coupled with fall hyperphagia (Nelson et al. 1983a), leads to rapid weight gain in the form of fat. The coupling of hyperphagic behavior with the availability of high-energy foods to maximize energy storage prior to denning and lactation (for pregnant females) has obvious adaptive value.

Condition Indices

Effects of season and age on condition indices were consistent for both sexes (Tables 6 and 7). All 3 indices increased with age ($P < 0.001$) for both sexes, presumably due to overall growth in size. PCR-A and PCR-B cycled throughout the year, with a predenning peak in late fall, a decline from spring to late summer, and improvement in condition through the fall (Tables 6 and 7). Weight varied seasonally in females ($P = 0.031$). Seasonal variation was weak in males ($P = 0.113$). A closer examination of the female data, supported by an age-season interaction ($P = 0.061$), indicated that most of the seasonal weight variation was among subadult females. Small samples may have prevented seasonal weight trends from being more apparent. These results indicate that the seasonal rhythm in body condition and weight dynamics among black bears in GDS, a southeastern wetland, was similar to cycling observed in more northerly black bear populations (Jonkel and Cowan 1971, Poelker and Hartwell 1973, Rogers 1977, Hugie 1982, Schroeder 1987, Franzmann and Schwartz 1988). The amplitude of the rhythm may not be as great in GDS bears as in northern bears, owing to the longer period of food availability and shorter period of denning (Hellgren and Vaughan 1987) in the Swamp.

Serum Chemistry and Hematology

Handling effects

Two blood samples were collected from each of 59 bears (at 15-30 minute intervals) and 3 samples each from an additional 31 bears (Appendix Table 20). Mean (±SE) times of

Table 6. Weight and physical condition ratios (PCR)(mean ± SE) of male black bears in Great Dismal Swamp, Virginia-North Carolina (1984-1986), as affected by age and season.

	Weight (kg)			PCR-A[1]			PCR-B[2]		
Season and Age	N	X	SE	N	X	SE	N	X	SE
Spring									
1-2 years	3	59.3	6.7	1	3.6		1	16.6	
3-4 years	7	91.4	9.6	5	5.2	0.6	6	25.6	2.4
≥ 5 years	12	136.3	6.3	12	7.2	0.3	12	35.6	1.5
Early Summer									
1-2 years	8	59.1	8.7	5	4.1	0.7	6	18.2	3.2
3-4 years	11	73.9	5.0	6	4.1	0.2	6	20.7	1.0
≥ 5 years	8	122.9	13.8	4	5.3	0.5	5	27.9	2.6
Late Summer									
1-2 years	2	51.0	10.0	2	3.7	0.5	2	16.2	2.6
3-4 years	7	79.0	4.6	6	4.8	0.3	7	23.5	1.0
≥ 5 years	3	110.7	14.5	2	6.4	1.4	2	30.3	5.9
Early Fall									
1-2 years	5	50.6	8.9	3	4.0	0.5	5	16.4	2.0
3-4 years	3	89.3	7.4	2	5.1	0.4	3	25.6	1.6
≥ 5 years	3	131.3	12.2	2	7.0	0.8	3	33.5	1.7
Late Fall									
1-2 years	1	86.0		1	5.0		1	24.2	
3-4 years	1	104.0		1	6.0		2	28.5	
≥ 5 years	2	145.5	20.5	2	7.8	1.2	2	38.5	5.5
Anova F-value (*P*)									
Age	60.47(< 0.001)			31.35(< 0.001)			47.18(< 0.001)		
Season	1.95			3.09(0.027)			3.08(0.025)		
Age*Season	0.34			0.60			0.59		

[1] (Weight/Total Length) X 100

[2] (Weight/Head Length) X 100

Table 7. Weight and physical condition ratios (PCR)(mean ± SE) of female black bears in Great Dismal Swamp, Virginia-North Carolina (1984-1986), as affected by age and season.

Season and Age	Weight (kg)			PCR-A[1]			PCR-B[2]		
	N	X	SE	N	X	SE	N	X	SE
Spring									
adult (> 3 years)	2	60.5	5.5	2	4.3	0.4	2	18.7	1.3
Early Summer									
subadult	6	37.5	2.5	6	2.8	0.1	6	13.0	0.6
adult	5	61.6	4.0	1	3.4		1	16.1	
Late Summer									
subadult	4	30.8	3.6	4	2.5	0.2	4	11.2	0.9
adult	6	54.5	3.1	6	3.6	0.2	6	17.4	1.0
Early Fall									
subadult	3	59.3	13.5	2	3.8	1.2	3	19.8	4.2
adult	4	60.3	3.4	3	4.1	0.3	4	19.1	1.1
Late Fall									
subadult	3	50.7	3.5	2	3.4	0.1	2	16.5	0.7
adult	2	61.5	4.5	1	4.7		2	20.5	0.5
Denning									
adult	4	64.3	4.5	2	4.5	0.9	2	20.9	2.5
Anova F-value (*P*)									
Age	32.33(< 0.001)			19.86(< 0.001)			17.60(< 0.001)		
Season	2.88(0.031)			2.35(0.080)			3.15(0.027)		
Age*Season	2.75(0.061)			0.64			1.95		

[1] (Weight/Total Length) X 100

[2] (Weight/Head Length) X 100

sample collection were 12 ± 8 minutes, 35 ± 9 minutes, and 49 ± 12 minutes post-immobilization for first, second, and third samples, respectively. The six serum variables and 4 hematologic variables in Table 8 showed significant ($\underline{P} < 0.05$) changes during the handling procedure. These variables showed the same effect whether 2 or 3 samples were collected. Brannon (1985a) reported significant decreases in RBC, HB, HCT, and MCV over time in blood samples taken an hour apart in brown bears immobilized with phencyclidine hydrochloride (PCP). The bears in this study were sampled after being pursued by helicopters for long distances. He attributed these changes to splenic contraction in response to stress and physical exertion, resulting in the release of red blood cells into the circulation and a temporary elevation of hematologic values. By the second sample, osmotic equilibrium had returned RBC values to normal levels. A similar explanation was put forth by Wesson et al. (1979) to explain time-related hematologic changes in white-tailed deer. I believe that similar mechanisms were at work in our study. Brannon (1985a) attributed increases in brown bear WBC counts during handling to neutrophilia caused by muscle damage resulting from darting and muscle sampling extraction. The stress of long helicopter chases also may have affected WBC counts.

It is likely that adrenergic responses to trapping stress resulted in initial glucose concentrations above normal and a continuing rise after anesthetization (Table 8). Ketamine and xylazine (Gibson 1980) anesthesia has been associated with induction of hyperglycemia, possibly mediated by impaired insulin activity or decreased hepatic metabolism of glucose (Hsu and Hembrough 1982). It may be difficult to obtain baseline concentrations of serum glucose because of stressors. Albumin decreased ($\underline{P} = 0.006$) between the first and second samples (Table 8). Similar short-term changes, perhaps also due to osmotic fluctuations as discussed above, were observed for total plasma protein in xylazine-immobilized white-tailed deer (Gibson 1980). Brannon (1985b) reported no changes in serum protein constituents between samples in PCP-immobilized brown bears. Inorganic phosphorus increased ($\underline{P} < 0.001$) throughout the handling procedure (Table 8). Elevated phosphorus concentrations following immobilization with xylazine (Drevemo and Karstad 1974) and

Table 8. Blood characteristics (mean ± SE) affected ($P < 0.05$) by time during handling of black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

		Sample 1		Sample 2		Sample 3		Anova	
Characteristic (unit)	N	X	SE	X	SE	X	SE	F-value	*P*
Albumin (g/dl)	59	3.8	0.0	3.7	0.0			8.18	0.006
Albumin/Globulin Ratio	31	1.16	0.0	1.16	0.0	1.20	0.0	4.48	0.015
Glucose (mg/dl)	59	153	6	179	7			46.65	< 0.001
	31	150	7	171	11	179	12	15.46	< 0.001
Uric acid (mg/dl)	59	1.79	0.1	1.68	0.1			9.00	0.004
	31	1.93	0.1	1.86	0.1	1.79	0.1	3.50	0.037
Phosphorus (mg/dl)	59	3.0	0.2	3.7	0.2			133.12	< 0.001
	31	3.5	0.2	4.1	0.3	4.7	0.3	79.70	< 0.001
Potassium (meq/l)	59	4.1	0.1	4.3	0.1			18.31	< 0.001
	31	4.2	0.1	4.4	0.1	4.4	0.1	4.34	0.017
WBC ($x10^3$/ml)	56	19.0	0.8	20.2	0.8			14.29	< 0.001
	30	19.3	0.9	20.3	1.0	21.9	0.9	21.51	< 0.001
RBC ($x10^6$/ml)	56	8.0	0.1	7.8	0.1			30.54	< 0.001
	30	8.3	0.2	8.1	0.2	8.1	0.2	8.48	< 0.001
Hemoglobin (g/dl)	56	16.1	0.2	15.7	0.2			48.35	< 0.001
	30	16.6	0.3	16.5	0.4	16.4	0.3	26.93	< 0.001
HCT (%)	56	46.0	0.6	44.7	0.7			42.48	< 0.001
	30	47.3	1.0	46.4	1.0	46.5	1.0	8.40	< 0.001

ketamine (Hellgren et al. 1985) have been observed in impala (Aepyceros melampus) and collared peccaries (Tayassu tajacu), respectively. Brannon (1985b) showed a decrease in phosphorus in PCP-immobilized brown bears. He also reported increases in serum chloride, CO_2, and cortisol concentrations and decreases in SUN, creatinine, and uric acid during handling.

Blood samples collected for condition evaluation should be obtained at a standardized point after immobilization to permit objective comparison of values. Although amount of time spent in the trap prior to handling can not be controlled, standardizing the point after immobilization would remove one source of variation from the analysis. This protocol is particularly important for the analysis of RBC, Hb, and HCT, variables shown to be good indicators of bear nutritional status (Franzmann and Schwartz 1988, Schroeder 1987). We could not examine effect of drug dosage on blood variables.

Age effects

Age differences ($P < 0.1$) among blood characteristics of GDS bears confirm and extend previous reports on bear blood chemistries. Nine blood variables and one ratio differed ($P < 0.01$) between ages (Table 9). Higher levels ($P < 0.001$) of alkaline phosphatase and phosphorus in subadults of both sexes can be attributed to greater osteoblastic activity in young bears (Brannon 1985b). Other ursid studies have reported similar differences (Lee et al. 1977, Beeman 1981, Brannon 1985b, Schroeder 1987). Creatinine levels were higher ($P < 0.001$) in adults of both sexes, with an age-season interaction in females ($P = 0.033$). Blood creatinine concentration is proportional to muscle mass (McGilvery 1983: 630), and thus would tend to be higher in larger adults. The age-season interaction among females is due to a rise in serum creatinine in denning samples, which were collected only from adult females. Age differences in total protein, albumin, and MCH concentrations were similar to those in Alaskan brown bears (Ursus arctos)(Brannon 1985a, 1985b) and Pennsylvania black

Table 9. Blood characteristics (mean ± SE) of black bears in Great Dismal Swamp, Virginia-North Carolina (1984-1986), affected by age ($P < 0.1$). See text for explanation of abbreviations.

		Subadult (1-3 years)			Adult (> 3 years)			Anova	
Characteristic	Sex	N	X	SE	N	X	SE	F-value	*P*(age)
Total Protein (g/dl)									
	Male	33	7.1	0.1	45	7.4	0.1	6.66	0.012
	Female	15	6.4	0.1	25	6.8	0.1	3.56	0.0692
Albumin (g/dl)									
	Male	33	3.6	0.1	45	3.9	0.1	9.78	0.003
Alkaline Phosphatase (U/l)[1]									
	Male	33	46.0	4.1	45	29.3	3.2	26.03	< 0.001
	Female	15	51.7	8.2	25	23.0	2.5	14.28	< 0.001
Creatinine (mg/dl)[1]									
	Male	33	1.4	0.1	45	1.9	0.1	28.11	< 0.001
	Female	15	1.2	0.1	25	1.9	0.2	37.42	< 0.001[2]
Phosphorus (mg/dl)[1]									
	Male	33	4.2	0.2	45	3.0	0.2	15.90	< 0.001
	Female	15	4.0	0.6	25	2.3	0.2	12.41	0.001
Chloride (meq/l)									
	Female	15	109	1.7	25	105	1.5	8.20	0.008
Iron (ug/dl)[1]									
	Male	33	113	13	45	146	13	3.85	0.054
Urea/Crea (ratio)									
	Female	15	26.1	4.7	25	13.6	1.7	6.45	0.017
WBC ($x10^3$/ml)									
	Female	15	19.6	1.6	25	16.4	1.2	4.90	0.035
MCH (pg)									
	Male	33	19.8	0.2	41	20.2	0.1	4.25	0.044
	Female	15	19.6	0.3	25	20.2	0.2	3.73	0.063

[1] Analysis performed on log-transformed data.
[2] Significant Age*Season interaction, $P < 0.05$.

bears (Matula et al. 1980). These effects may be due to differences in nutritional status between age groups. Matula et al. (1980) suggested that young bears may have hypochromic microcytic anemia relative to adults, perhaps due to an iron deficiency resulting from growth demands. An age difference was observed ($\underline{P} = 0.054$) in serum iron among males (Table 9).

Seasonal effects

Seasonal changes among serum chemical and hematological values for GDS black bears also confirmed and extended previous bear physiological research (Table 10). All serum protein constituents (total protein, albumin, globulin, and albumin/globulin ratio) varied ($\underline{P} < 0.1$) on a seasonal basis (Table 10). Highest levels were recorded during denning (females) and spring and late fall (males). A similar seasonal shift was seen for black bears in Alaska (Franzmann and Schwartz 1988) and California (Schroeder 1987).

Serum urea nitrogen (SUN)($\underline{P} = 0.022$) and urea/creatinine (U/C) ($\underline{P} = 0.051$) varied seasonally in males (Table 10). The seasonal variation was due to high late fall SUN levels. Other bear blood studies have reported seasonal changes in SUN (or BUN) and U/C ratio (Halloran and Pearson 1972, Nelson et al. 1983a, 1983b, Nelson et al. 1984, Ensrud et al. 1986, Franzmann and Schwartz 1988), leading Nelson et al. (1984) to postulate a U/C ratio of ≤ 10 as a biological indicator of hibernation. Serum samples were collected from 4 denned bears in GDS and 1 bear in Shenandoah National Park (Carney 1985, Garner 1986) and all of these bears had U/C ratios $\leq$ 10 (mean = 5.6; range: 3.9-9.0). I agree with the hypothesis of Nelson et al. (1984) that denned bears have U/C ratios ≤ 10. However, I feel that use of this ratio as an indicator of hibernation may be too simplistic, because not all bears with U/C ratios ≤ 10 are hibernating. In this study, 32.5% (39 of 120) of all bears sampled had U/C ratios ≤ 10. Low ratios occurred in all months except October. Although *Nelson et* al. (1984) stated that bears undergo a gradual transition into the hibernating state, thus explaining ratios

Table 10. Blood characteristics (mean ± SE) of black bears in Great Dismal Swamp, Virginia-North Carolina (1984-1986) as affected by season ($P < 0.1$). See text for explanation of abbreviations.

Characteristic	Spring (N = 24,2)[1]		Early Summer (N = 26,11)		Late Summer (N = 13,10)		Early Fall (N = 11,7)		Late Fall (N = 4,5)		Denning (N = 0,4)		Anova	
Sex	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	F-value	*P*
Total Protein (g/dl)														
Male	7.5	0.1(a)[2]	7.2	0.1(b)	7.2	0.2(ab)	6.9	0.2(b)	7.5	0.4(ab)			2.29	0.069
Female	7.0	0.1(ab)	6.6	0.2(b)	6.8	0.1(b)	6.0	0.2(c)	6.6	0.2(b)	7.6	0.3(a)	5.52	0.001
Albumin (g/dl)														
Male	4.1	0.1(a)	3.5	0.1(c)	3.8	0.1(bc)	3.6	0.1(c)	4.1	0.2(ab)			8.99	< 0.001
Female	3.9	0.1(ab)	3.3	0.1(bc)	3.6	0.1(ab)	3.2	0.1(c)	3.5	0.2(bc)	4.0	0.1(a)	3.94	0.008
Globulin (g/dl)														
Female	3.1	0.0	3.3	0.2	3.2	0.1	2.8	0.2	3.1	0.1	3.6	0.1	2.21	0.082[3]
Alpha/Globulin (ratio)														
Male	1.3	0.1(a)	1.0	0.0(c)	1.1	0.0(c)	1.1	0.0(abc)	1.2	0.1(ab)			4.93	0.002
Alk. Phos. (U/l)[4]														
Male	27.0	2.6(b)	29.9	3.3(b)	48.0	8.8(a)	56.5	9.7(a)	41.5	10.3(ab)			4.54	0.003
Cholesterol (mg/dl)														
Male	253	9(a)	217	9(b)	226	14(ab)	216	15(b)	240	28(ab)			2.75	0.035
Female	256	26(ab)	201	14(c)	237	11(b)	198	16(c)	247	11(b)	315	23(a)	8.62	< 0.001[3]
Triglycerides (mg/dl)														
Male	293	25	254	13	252	18	213	15	201	31			2.15	0.084
Urea Nitrogen (mg/dl)														
Male	14.0	1.5(ab)	10.8	0.9(b)	10.1	1.1(b)	10.0	2.4(b)	19.5	4.7(a)			3.07	0.022
Creatinine (mg/dl)[4]														
Male	2.1	0.1(a)	1.6	0.1(b)	1.5	0.1(bc)	1.3	0.1(c)	1.6	0.2(bc)			5.74	< 0.001
Female	1.7	0.3(b)	1.3	0.1(b)	1.5	0.1(b)	1.2	0.1(b)	1.7	0.4(b)	3.8	0.4(a)	14.59	< 0.001[3]
Urea/Crea (ratio)														
Male	15.8	1.8	14.8	1.3	14.9	1.6	17.2	4.7	29.8	8.8			2.50	0.051[3]

Table 10 (continued).

Calcium (mg/dl)																
Male	8.7	0.1(a)	8.4	0.1(ab)	8.2	0.1(b)	8.1	0.2(b)	8.5	0.2(ab)					2.72	0.037
Potassium (meq/l)[4]																
Male	4.1	0.1(b)	4.2	0.1(b)	4.8	0.2(a)	4.2	0.1(b)	4.5	0.2(ab)					5.13	0.001
Chloride (meq/l)																
Male	107	1.0(b)	111	1.0(a)	111	1.7(a)	108	1.7(ab)	113	3.9(ab)					2.58	0.045
Female	109	0.5(ab)	109	1.7(ab)	110	1.9(a)	107	2.6(abc)	101	4.4(c)	96	0.3(c)			4.41	0.004
Iron (ug/dl)[4]																
Female	56	1(c)	157	27(ab)	84	13(c)	174	27(a)	182	103(abc)	195	16(a)			3.23	0.020
RBC ($x10^6$/ml)																
Male	8.4	0.2(b)	7.7	0.2(c)	7.6	0.1(c)	8.1	0.2(bc)	9.6	0.3(a)					6.50	< 0.001
Female	8.7	0.3(a)	7.2	0.2(c)	7.4	0.2(bc)	8.1	0.2(a)	8.9	0.3(a)	8.7	0.2(a)			6.83	< 0.001
Hemoglobin (g/dl)																
Male	17.2	0.4(ab)	15.3	0.4(c)	15.5	0.3(c)	16.3	0.4(bc)	18.5	0.3(a)					5.41	< 0.001
Female	17.6	0.9(a)	14.5	0.5(c)	15.2	0.4(bc)	16.3	0.6(ab)	16.8	0.2(a)	16.9	0.5(a)			4.10	0.006
MCV (um^3)																
Female	55.2	1.4(ab)	57.4	0.7(a)	58.7	0.9(a)	57.9	1.0(a)	53.2	1.1(b)	54.9	0.2(b)			4.57	0.003
Hematocrit (%)																
Male	48.7	1.3(ab)	44.2	1.2(c)	44.4	0.8(c)	46.3	0.9(bc)	53.8	0.8(a)					4.55	0.003
Female	47.8	0.7(a)	41.4	1.5(b)	43.2	0.8(ab)	46.6	1.8(a)	47.2	0.8(a)	48.0	1.4(a)			3.10	0.023
MCH (pg)																
Female	20.2	0.2(ab)	20.1	0.3(ab)	20.6	0.2(A)	20.2	0.4(ab)	18.9	0.5(c)	19.3	0.1(ab)			4.55	0.004[3]
WBC ($x10^3$/ml)																
Female	16.0	1.9(ab)	18.5	1.3(a)	18.8	1.5(a)	20.2	3.0(a)	20.5	2.0(a)	7.1	1.0(b)			3.33	0.017

[1] Represents N male, N female.
[2] Different letters in the same row represent seasonal differences ($P < 0.05$).
[3] Significant Age*Season interaction, $P < 0.05$.
[4] Analysis performed on log-transformed data.

≤10 in Colorado bears 8-9 weeks prior to denning, I find it unlikely that bears captured in July that had U/C ratios ≤10 (29%; 9 of 31) were entering hibernation. I propose two possible explanations for the low U/C ratios throughout the year in this study. First, SUN levels are closely tied to dietary protein levels in monogastrics under conditions of adequate energy intake (Atinmo et al. 1974, Lochmiller 1984, Corn and Warren 1985). GDS bear diets from early summer onward are low in protein (Table 5). Thus, individuals with low SUN levels from low dietary protein but normal creatinine levels would have low U/C ratios. Secondly, bears are commonly trapped using meat or meat scraps as bait. The above studies do not describe baiting techniques. In the present study, meat was rarely used; instead, traps were baited with stale pastries and doughnuts or used unbaited trail sets. Trapped bears feeding on meat bait would have elevated SUN levels, due to the high concentration of digestible protein in meat (Bunnell and Hamilton 1983). The result would be artificially elevated U/C ratios in trapped bears versus denned bears in previous studies (Nelson et al. 1984, Ensrud 1986, Franzmann and Schwartz 1988, Schroeder 1987). The work of Nelson and colleagues (Nelson et al. 1973, Nelson et al. 1975, Lundberg et al. 1976, Nelson et al. 1983a, Nelson et al. 1984) has shown conclusively that serum creatinine rises and urea concentration declines during hibernation. However, the variation of bear diets in the wild makes a single ratio of these two variables too simplistic to use as an indicator of hibernation.

Strong seasonal effects ($\underline{P} < 0.001$) were found for serum creatinine levels in both sexes (Table 10). Among denned females, creatinine levels were more than double levels seen in any other season. Among males, spring concentrations were highest. Similar seasonal trends have been observed in brown bears (Halloran and Pearson 1972, Brannon 1985b), wild black bears (Nelson et al. 1984, Schroeder 1987, Franzmann and Schwartz 1988), and captive black bears (Brown et al. 1971, Nelson et al. 1973). Reduced renal function during hibernation (Brown et al. 1971) is probably responsible for elevated creatinine at this time. High levels during late fall and spring (Table 10) may result from the biochemical transition to and from hibernation (Halloran and Pearson 1972, Nelson et al. 1979, Nelson et al. 1983a).

Serum lipids also varied ($P < 0.1$) on a seasonal basis (Table 10). In females, cholesterol was highest for denned bears and lowest during early summer and early fall. In males, cholesterol and triglycerides were highest during the postdenning spring period. Cholesterol concentrations in denned bears in Alaska were higher than in summer and fall bears; spring cholesterol values were not reported (Franzmann and Schwartz 1988). Nelson et al. (1973) and Ahlquist et al. (1984) reported increases in serum lipids, including cholesterol and triglycerides, during hibernation. Matula et al. (1980) and Schroeder (1987) found no seasonal variation in lipid constituents.

Pronounced seasonal hematologic changes occurred in both sexes (Table 10). RBC, Hb, and HCT cycled throughout the year, decreasing from denning to summer and increasing from summer to denning. This cyclic pattern has been reported consistently in the bear literature (Erickson and Youatt 1961, Pearson and Halloran 1972, Matula et al. 1980, Franzmann and Schwartz 1988) and is believed to be the result of seasonal changes in body condition (Franzmann and Schwartz 1988). The influence of inherent circannual metabolic rhythms (Moen 1978, Seal and Mech 1983) on this hematologic cycle is unknown.

Seasonal shifts in female RBC indices (MCV, MCH)(Table 10) suggested replacement of the denning/spring RBC population with larger, less numerous cells containing more hemoglobin during the summer. Such a shift has been proposed in brown bears (Pearson and Halloran 1972) and captive black bears (Erickson and Youatt 1961, Seal et al. 1967). On the other hand, Matula et al. (1980) reported higher MCV values for predenning samples compared to postdenning samples in black bear. However, they realized the need for adequate midsummer and midwinter samples to provide a better understanding of seasonal changes. A shift in the RBC population to smaller mean cell size during denning may be adaptive by increasing erythrocyte surface area relative to mass, thus increasing gas exchange efficiency (Matula et al. 1980). It should be noted that MCV values presented for this study are smaller than those reported for other wild black bear populations.

Correlation of Blood Characteristics with Condition Indices

Low but significant correlations ($P < 0.1$) between weight, PCR-A, and age-affected blood variables, such as alkaline phosphatase, phosphorus, and creatinine, were generally seen among subadult bears (Tables 11 and 12). Age changes in these characteristics were attributed to osteoblastic activity and increases in muscle mass (see above). Thus, it is not surprising to see such correlations in younger, actively-growing age groups that encompass a 2-3 year age range. Significant correlations ($P < 0.1$) between condition indices and RBC, hemoglobin, and HCT were found in all cohorts except subadult females (Tables 11 and 12). Also, serum albumin was correlated ($P < 0.01$) to condition indices in all male age groups. These variables show parallel cyclic shifts in seasonal levels (Table 6, Table 7, Table 10). Albumin and the hematologic characteristics have been reported to be the most sensitive indicators of bear nutritional condition (Schroeder 1987, Franzmann and Schwartz 1988). Within-season correlation analysis is necessary to completely corroborate these reports. Sample sizes were too small in the present study to perform within-season correlations for each age and sex group. The association of hematologic values to animal condition was first observed by Rosen and Bischoff (1952) and has been reported commonly in ungulates (Franzmann and LeResche 1978, Seal and Hoskinson 1978, Lochmiller 1984).

Test of Metabolic Stage Hypothesis

Four physiological status categories were developed to test the hypothesis of Nelson et al. (1983a) that black bears annually cycle through 4 metabolic states. I used major dietary shifts in composition (Table 4, Figure 4) and quality (Table 5) of foods, as well as changes in condition of bears (Tables 6 and 7), to produce these groupings. Categories were Stage I (hibernation), Stage II (spring,walking hibernation) -emergence to 15 June, Stage *III*

Table 11. Significant ($P < 0.1$) Pearson's correlation coefficients (r) between blood characteristics, body weight (kg), and condition index among age groups for female black bears from Great Dismal Swamp. See text for explanation of abbreviations.

	Subadult (1-3 yrs)		Adult (> 3 yrs)	
Blood Characteristic	PCR-A (N = 12)	Weight N = 14)	PCR-A (N = 16)	Weight (N = 24)
Albumin/Globulin	0.51*	--	--	--
Triglycerides (mg/dl)	-0.69*	--	--	--
Creatinine (mg/dl)	--	--	0.43*	--
Uric acid (mg/dl)	--	-0.54*	--	--
Phosphorus (mg/dl)	-0.77**	-0.57*	--	--
Sodium (mEq/l)	--	--	--	0.37*
RBC ($x10^6$/ml)	--	--	0.48*	--
Hemoglobin (g/dl)	--	--	0.48*	--
MCV (um^3)	-0.71**	--	--	--
HCT (%)	--	--	0.43*	--

* $P < 0.1$.

** $P < 0.01$.

Table 12. Significant ($P < 0.1$) Pearson's correlation coefficients (r) between blood characteristics, body weight (kg), and condition index among age groups for male black bears from Great Dismal Swamp. See text for explanation of abbreviations.

	Subadult (1-2 yrs)		Adult (3-4 yrs)		Adult (> 4 yrs)	
Blood Characteristic	PCR-A (N = 14)	Weight (N = 19)	PCR-A (N = 29)	Weight (N = 38)	PCR-A (N = 20)	Weight (N = 25)
Total Protein (g/dl)	--	0.44*	--	--	--	--
Albumin (g/dl)	0.74**	0.66**	0.50**	0.58**	0.67**	0.48*
Albumin/Globulin	0.67**	0.52*	--	--	0.40*	--
Alkaline Phosphatase (IU/l)	-0.47*	0.50*	--	--	--	--
Creatinine (mg/dl)	0.70**	0.71**	--	0.40*	--	--
Phosphorus (mg/dl)	-0.56*	--	--	--	--	--
Chloride (mEq/l)	--	--	-0.42*	-0.41*	--	--
Iron (ug/dl)	--	--	0.41*	0.37*	--	--
WBC ($x10^3$/ml)	0.47*	0.56*	--	--	--	--
RBC ($x10^6$/ml)	0.58*	0.57*	0.48*	0.49**	0.48*	--
Hemoglobin (g/dl)	0.70**	0.66**	0.49**	0.51**	0.45*	0.39*
HCT (%)	0.62*	0.57*	0.51**	0.54**	0.40*	--
MCHC (%)	--	--	--	--	--	0.39*
Platelet Count ($x10^3$/ml)	0.62*	--	--	--	--	--

* $P < 0.1$.

** $P < 0.01$.

(summer,normal activity) -16 June-15 September, Stage IV (fall,hyperphagia) -16 September to 15 December.

Stepwise discriminant analysis selected 8 male blood variables (albumin, alkaline phosphatase, cholesterol, creatinine, sodium, potassium, Hb, HCT) and 5 female variables (total protein, creatinine, potassium, RBC, MCH) that provided significant ($\underline{P} < 0.1$) separation among stages. To maintain at least 10 samples/discriminating variable (Magnusson 1983), sodium was dropped from further male analyses and potassium and MCH from further female analyses. These characteristics had the lowest $\underline{P}$-values among the selected variables. Multivariate analysis of variance indicated strong differences among group means for females (Wilks' $\lambda = 0.149$, d.f. = 6,64, $\underline{P} < 0.001$) and males (Wilks' $\lambda = 0.254$, d.f. = 14,128, $\underline{P} < 0.001$). Discriminant functions then were developed to classify individual blood profiles into metabolic status groups (Table 13). Using a jackknife procedure, 84% (31 of 37) and 75% (53 of 71) of cases were classified correctly for females and males, respectively.

Following classification, canonical discriminant analysis was used to further define relationships among metabolic groups. Canonical variates (CV)(Figure 5) are composites of the discriminating variables. On the basis of correlations between discriminating variables and CV, it appeared that the first canonical function for females represented a gradient of decreasing creatinine and total protein (Table 14, Fig. 5). Stage I (hibernation) bears had higher serum concentrations of these 2 variables and were separated from other groups along CV1 (Fig. 5). The second canonical function was defined as a gradient of increasing total protein and decreasing RBC (Table 5). The CV2 axis separated Stage III (summer) and Stage IV (fall) bears (Fig. 5). One misclassified case was an individual captured on 29 November that was classified as hibernating. The lethargic activity of this individual at the trapsite, an elevated creatinine concentration (3.2 mg/dl), and her den entry by 30 December suggested that she was in transition to hibernation mode (Nelson et al. 1984) at the time of capture. Among males, the first canonical function represented an increasing gradient of albumin, creatinine, and Hb (Table 14, Fig. 5). Stage II (spring) bears had higher levels of these 3 variables than other groups, and were thus separated from other groups along the first

Table 13. Classification functions[1] to separate metabolic stages among black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Characteristic	Stage I[2] Hibernation	Stage II Spring	Stage III Summer	Stage IV Fall
Female				
Total Protein	25.086		25.041	22.017
Creatinine	6.177		-2.771	-2.108
RBC	12.362		10.009	12.738
Constant	-161.450		-119.272	-122.078
Male				
Albumin		18.973	14.682	14.415
Alkaline Phos.		0.157	0.173	0.219
Cholesterol		0.218	0.174	0.165
Creatinine		7.325	2.859	0.929
Potassium		7.027	10.039	9.114
Hemoglobin		-1.536	-0.554	-0.577
HCT		7.703	5.031	6.144
Constant		-120.828	-100.983	-110.126

[1] Used with original measurements. Add products of blood characteristic measurement X function coefficient to constant to get the probability of the sample coming from each stage. Classify depending on which results in the highest probability for its classification function.

[2] Stages: I- denned bears; II- emergence to 15 June; III- 16 June to 15 September; IV- 16 September to 15 December.

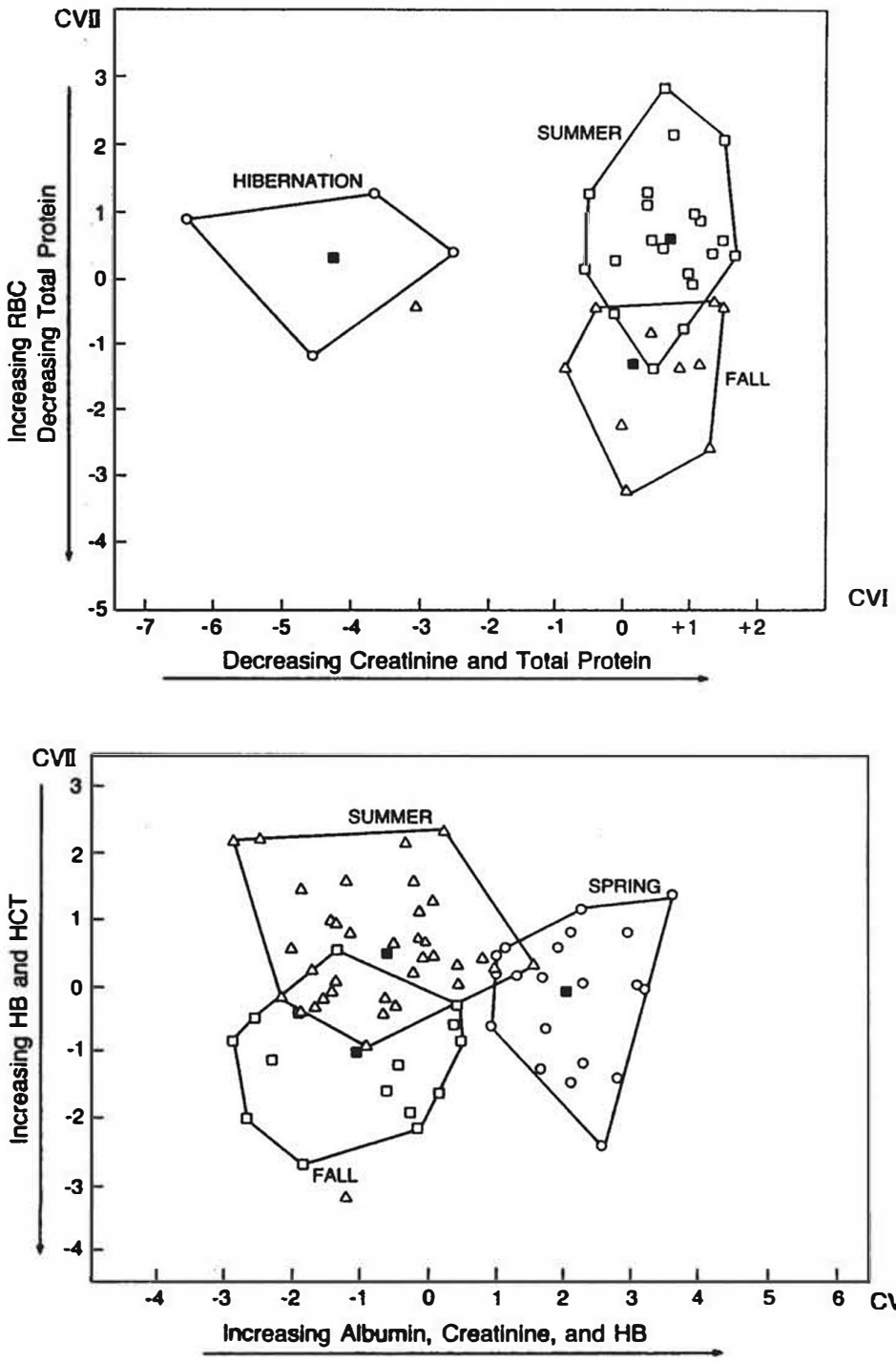

Figure 5. Canonical variates from discriminant function analysis grouping female (top) and male (bottom) metabolic state using blood characteristics. Each symbol represents one individual.

canonical axis (Fig. 5). All spring captures ($N = 20$) were classified correctly. Separation of Stage III and Stage IV animals was via the second canonical function, which was a gradient of decreasing HCT and Hb (Table 14, Fig. 5). Pairwise comparisons using Mahanolobis Distance indicated that all female groups were significantly different ($P < 0.006$) from each other in canonical space. Among males, Stage II was significantly ($P < 0.001$) different from the other 2 groups in canonical space. Between Stage III and Stage IV, this separation was not as strong ($P = 0.16$). However, if one Stage III summer outlier was removed from the data set (due to abnormally high levels of alkaline phosphatase)(Fig. 5), then separation between Stage III and Stage IV groups became significant ($P = 0.028$).

The discriminant analysis of blood characteristics supported the hypothesis of Nelson et al. (1983a). I distinguished hibernating bears from other bears by elevated creatinine (an index of reduced renal function) and elevated total protein (a consequence of hibernation metabolism [Nelson et al. 1983b]). Nelson et al. (1983a) defined Stage II as the 2-3 weeks following den emergence constituting a transition between hibernation and normal activity. It is characterized by hypophagia and low urine volumes (Nelson et al. 1979). We extended this period to include the entire "negative foraging period" (Poelker and Hartwell 1973) of spring when bears are feeding primarily on herbaceous diets (Table 5, Eagle and Pelton 1983) and losing weight and condition (Tables 7 and 8). Biochemically, Stage II bears could be distinguished by relatively high serum creatinine and cholesterol concentrations (Table 10). These alterations have been reported previously in bears (Halloran and Pearson 1972) and may have been due to reduced excretion and defecation associated with hypophagia (Nelson et al. 1983a). High HCT, Hb, and albumin levels also were characteristic of Stage II bears.

Bears in Stage III, normal activity, fed on readily digestible soft mast (Tables 4 and 5, Figure 4). Condition was poorest during this time, reflected in low values for condition indices (Tables 6 and 7) and hematological constituents (Table 10). Stage III and Stage IV (hyperphagia) could be distinguished by improving condition (Table 6, Table 7) and increasing concentrations of HCT, Hb, and albumin (Table 10). Bear foods had shifted in Stage IV to a high-fat diet of tree mast (Tables 4 and 5). As discussed above, the fall diet

Table 14. Correlations of blood variables with the 2 canonical functions derived from classifying black bears into metabolic status groups.

Sex	Variable	Canonical Function I	Canonical Function II
Female	Total Protein	-0.58	0.56
	Creatinine	-0.98	0.14
	RBC	-0.51	-0.72
Cumulative % Variance Accounted for		72.1	100.0
Significance of Canonical Function		< 0.001	< 0.001
Male	Albumin	0.62	-0.33
	Alkaline Phos.	-0.39	-0.38
	Cholesterol	0.35	-0.01
	Creatinine	0.70	0.14
	Potassium	-0.30	0.23
	HCT	0.31	-0.57
	Hemoglobin	0.39	-0.63
Cumulative % Variance Accounted for		81.0	100.0
Significance of Canonical Function		< 0.001	< 0.001

offered a high-energy source used by bears to store fat and gain weight rapidly in preparation for denning.

Franzmann and Schwartz (1988) used blood variables (e.g. HCT, Hb, albumin/globulin ratio, globulin) to classify Alaskan black bears into poor condition (summer) and good condition (fall) categories. These variables also were good for nutritional assessment in GDS bears. Franzmann and Schwartz (1988) correctly classified 90 (70 of 78) and 89% (50 of 55) of cases for females and males, respectively. This level of accuracy was higher than in my study. I believe that this may be due to the less severe environment in GDS. Nutritional and physiological differences between Alaskan bears in summer and fall are magnified by the severe environmental demands that compress annual bear activity into a 6-month period (Schwartz et al. 1988). In GDS, denning periods are short (60-120 days) and some bears (up to 33%) actively forage throughout the winter (Hellgren and Vaughan 1987). Long transitional periods between metabolic stages may result. Misclassifications in this study commonly occurred for bears that were sampled near the dates designated as cutoffs between stages and thus may have been in transition between stages.

Ecological and Management Implications

It previously has been established that bears undergo an annual cycle in body condition tied to food availability. The present study showed relationships between seasonal variation in bear blood biochemistry and observed shifts in diet and body condition in a single population. These data support the hypothesis of Nelson et al. (1983a) that bears have an annual metabolic rhythm that can be divided into 4 seasonal stages. Similar metabolic rhythms have been demonstrated in white-tailed deer (Moen 1978) and gray wolves (Canis lupus)(Seal and Mech 1983). I also have identified blood indicators of bear metabolism and

condition. In the study animals, the hibernating state was better identified by changes in serum creatinine and total protein concentrations than by the U/C ratio (Nelson et al. 1984, Ensrud et al. 1986). The relationship of urea (and SUN) to dietary protein places uncertainty in the U/C ratio as a hibernation index.

This study also supports the findings of Franzmann and Schwartz (1988), who recommended the use of HCT and Hb for nutritional assessment in black bears. Nutrition has been implicated as a major influence on several demographic parameters of black bear populations, such as age at primiparity, litter size, breeding interval, and cub survival (Rogers 1976, 1983, Bunnell and Tait 1981). Assessment of nutritional status thus may be particularly important in predicting bear population productivity. This study was not designed to examine relationships between nutrition, condition, and female reproductive success. However, Rogers (1976) found a relationship between fall body weight and winter cub production in Minnesota black bears. Similarly, Elowe (1987) reported strong positive relationships among fall energy intake, female winter nutritional condition, and productivity. He found no relationship among winter serum values, nutritional condition, and fall diets. However, the metabolic changes involved with hibernation may mask any relationship between winter serum chemistry and fall body condition. Fall blood values would be a more sensitive indicator of nutritional status. Use of a discriminant function to classify bears into broad condition categories based on blood characteristics (Franzmann and Schwartz 1988) may provide an excellent index to overall population condition.

The seasonal pattern observed in physiology and condition was associated with changes in diet composition and quality. However, the role of an endogenous rhythm in effecting these seasonal changes in black bears is unknown. Endogenous circannual rhythms linking animal physiology and behavior to annual plant cycles have been demonstrated in many species of mammals (Pengelley and Asmundson 1974, Gwinner 1981). These rhythms include annual cycles in body weight, food and water consumption, reproduction, and metabolic rate (Pengelley and Asmundson 1974). An endogenous rhythm has been proposed by Johnson and Pelton (1980) to explain bear hibernation under a wide range of environmental and

ecological conditions. Future bear research in this area should include work with captive bears with ad libitum nutrition to determine whether the physiologic patterns we observed are due solely to diet variation or if an endogenous component exists. Annual cycles in hematologic values and serum thyroxine have been observed in captive gray wolves under conditions of ad libitum food and ambient temperature and light (Seal and Mech 1983). Replication of this work throughout black bear range would provide stronger evidence for existence of bear seasonal metabolic rhythms. The comparable nature of these results and the work of Franzmann and Schwartz (1988) in black bear populations at extremes of the species' geographic range argues for such an adaptation.

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CHAPTER 3: HOME RANGE DYNAMICS AND HABITAT USE

The ecology of the black bear (Ursus americanus) in the Atlantic Coastal Plain has been the subject of limited study. The work of Hamilton (1978) and colleagues (Landers et al. 1979, Hamilton and Marchinton 1980) remains the only extensive study of bear ecology in this region. Black bears inhabiting southeastern wetland environments require a complex of habitats to fulfill foraging, denning, and cover needs. Habitat use is strongly tied to food availability and phenological development of plant foods (Smith 1985). Spatial and temporal distribution of food also affects range dynamics, including seasonal movements, range overlap, and range size. Other factors, such as age, sex, reproductive status, and social interactions, also affect spatial use by black bears. The Great Dismal Swamp (GDS), a 850-km^2 forested wetland on the Virginia-North Carolina border, supports the last breeding population of black bears in eastern Virginia and extreme northeastern North Carolina. The 1973 establishment of the 440-km^2 GDS National Wildlife Refuge (NWR), which occupies the core of the Swamp, placed management responsibility for the bear population on the U. S. Fish and Wildlife Service. The need for population estimates and evaluation of habitat suitability for proper bear management in GDSNWR has been identified (Bureau of Sport

Fisheries and Wildlife 1974), yet bear-related research has not met this need. Management of refuge bears is currently limited to protection from hunting.

Seasonal movements and habitat preferences of GDS bears are unknown. Available data (food habits: Daniel 1978) and anecdotal information are too limited to predict bear behavioral responses to management actions. For example, the short-term and long-term effects of wildlife management (i.e. hunting), vegetation management (e.g. surface water manipulation, timber harvest, burning, roller-chopping) and public use management on bear movements, distribution, and habitat use cannot be assessed with available data. The objectives of this study were to determine seasonal habitat preferences of black bears in GDS, to elucidate patterns of bear range dynamics in GDS, and to provide recommendations for black bear management in GDSNWR applicable to other Atlantic Coastal Plain populations.

MATERIALS AND METHODS

Trapping and Handling

Bears were captured using Aldrich spring-activated cable snares. Trapping was continuous from April to December during the years of the study. Trapped bears were immobilized with a 2:1 mixture of ketamine hydrochloride (Ketaset) and xylazine hydrochloride (Rompun) at a concentration of 300 mg/ml. Initial dosage rate was 6.6 mg/kg estimated body weight and drugs were administered by blow-gun dart syringe (Lochmiller and Grant 1983), jabstick, or dart rifle.

All bears were sexed and weighed to the nearest kg. The first premolar was extracted for aging by cementum annuli analysis (Willey 1974). Numbered plastic ear tags were placed

in the ears of each bear. In addition, an identification number was tattooed inside each bear's upper lip for permanent identification. Selected bears were equipped with radio-transmitter collars (Telonics,Inc., Mesa, Az) in the 164-165 MHz range with a 5-minute delay motion sensor. All females (except 2 subadults) were radio-collared. Males were collared to provide a wide distribution of age and weight classes. A breakaway cotton spacer was inserted in each collar (Hellgren et al. 1988) to minimize chafing and rubbing of the collar and to prevent bears from retaining the collars throughout their lives. Blood samples were collected in Vacutainers from a femoral vein as soon as possible following immobilization. At the conclusion of handling procedures, each bear received an intramuscular injection of 2-5 cc Combiotic (Pfizer, New York, NY 10017) as a prophylactic antibiotic.

Telemetry Data Collection and Analysis

Locations of radioequipped bears were made 1 to 7 times weekly by triangulation with handheld receiving equipment from at least 3 points on refuge or state roads. Locations were made primarily (99%) between 0700 and 2100 hours. Nighttime tracking was sporadic. To supplement ground locations, flights were conducted 2 to 4 times monthly to locate bears using aircraft-mounted receiving equipment. Locations were plotted on USGS 1:24000 topographic maps and assigned grid coordinates (to the nearest 50m) based on the Universal Transverse Mercator (UTM) system. Telemetry data were processed by Telem (Koeln 1980) and home range determined by the convex polygon method.

Females monitored for $\geq$ 8 months ($\underline{N} = 18$)(Appendix Table 23) and males monitored for $\geq$ 6 months ($\underline{N} = 10$) (Appendix Table 24) were used to estimate total home range size. Four females monitored for > 12 months provided annual home range size estimates. Seasonal home ranges were calculated for bears that were monitored for > 50% of a given season and were relocated on average at least once per week during that season. Seasons were

based on changes in plant phenology and shifts in bear food habits: spring (emergence to 15 June), early summer (16 June to 31 July), late summer (1 August to 15 September), early fall (16 September to 15 November), and late fall (16 November to den entry or 15 January). Dates for the early fall season varied slightly for individual bears depending on when the fall shuffle, which are long excursions made by bears to take advantage of mast concentrations outside their normal ranges, occurred. Early fall range size estimates were based on radiolocations after bears had moved to their fall feeding areas.

Seasonal and annual home range areas were tested for differences between age and sex groups using nonparametric one-way layout tests (Kruskal-Wallis tests) with a protected ($P < 0.05$) LSD procedure to make median comparisons. Data were pooled between years because of small sample sizes and similar movement patterns between years. Male data were not divided by age, as all collared males were > 3 years of age except two 2.5 year-olds.

Coordinates for radiolocations were merged with a digitized version of the vegetation cover map prepared by Gammon and Carter (1979) to determine patterns of habitat utilization by collared bears. Large-scale habitat changes, such as timber harvest and burns, that have occurred since original digitizing of the cover map, were redigitized on the cover map. The 243 specific vegetative communities distinguished by Gammon and Carter (1979) were grouped into 12 habitats (Table 15) for analysis of bear habitat preferences. These habitats were based on dominant canopy classes. The smallest habitat stand digitized was 9 ha. Few radiolocations were collected in forested and agricultural lands outside the study area boundary and they were not used to compare habitat use to availability. Habitat preference analysis was at three scales. Relative availability of habitats over the entire study area was determined and compared to relative use of those habitats by bears using radiolocations. This comparison was used to assess habitat selection by males and females at a macro scale (Appendix Tables 25-26). As female home ranges did not cover the entire study area (Fig. 6), a composite range determined by union of the home ranges of the 18 individuals for which total home ranges were calculated was considered available habitat. Habitats intersected by radiolocations of these 18 females were considered habitats used. A second analysis

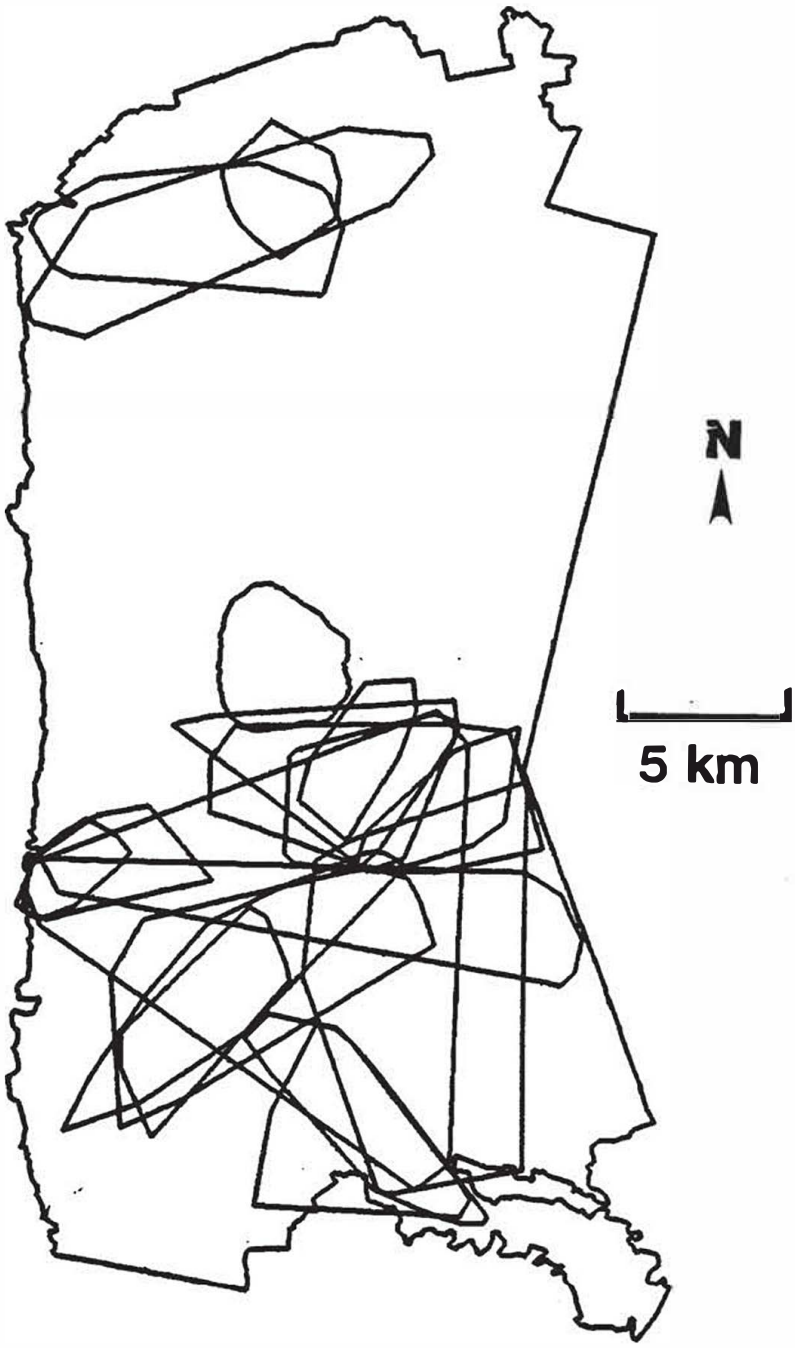

Figure 6. Convex polygon home ranges for 18 females monitored for ≥8 months in Great Dismal Swamp, Virginia-North Carolina during 1984-1986.

Table 15. Habitat categories developed from vegetation cover map of Great Dismal Swamp, Virginia-North Carolina (Gammon and Carter 1979) for black bear habitat use/availability analysis.

Category	Area (ha)	Percent	Description
Pine	5122	9.2	Dominated by *Pinus* sp.
Pine-Maple	3408	6.1	Pine-dominated with red maple (*Acer rubrum*) subdominant
Maple	5891	10.6	Dominated by red maple
Maple-Coniferous	9895	17.8	Red maple mixed with pine and/or white cedar (*Chamaecyparis thyoides*)
Maple-Gum	16197	29.2	Red maple - Black gum (*Nyssa sylvatica*) dominated
White cedar	3232	5.8	Dominated by Atlantic white cedar
Gum-Cypress	6577	11.8	Bald cypress (*Taxodium distichum*) and gum (*Nyssa* sp.) dominated
Pocosin	1951	3.5	Shrub and small tree communities dominated by evergreen bays and hollies
Grass	428	0.8	Canebrakes, especially switchcane (*Arundinaria gigantea*)
Mesic	1650	3.0	Upland hardwoods (e.g. *Quercus* sp.) and pine
Disturbed-old	1010	1.8	Burned or harvested between 1964 and 1974.
Disturbed-new	167	0.3	Burned or harvested between 1974 and 1984.
Lake Drummond	1294	--	Open water; not considered available habitat

comparing habitat availability to habitat use then was performed. A third analysis was performed at the scale of individual home ranges. Proportions of available habitat within individual home ranges were determined for females that were located > 125 times ($\underline{N} = 6$). Habitat use throughout the year for individuals (based on radiolocations) was then compared to habitat available within that individual's home range. Years were pooled because of small sample sizes during the first 9 months of the study. Preference or avoidance of individual habitats was determined by the method of Neu et al. (1974) using χ^2 analysis and Bonferronni Z-statistics (programmed using Sas Institute Inc. 1982). If habitats were used proportionately more or less ($\underline{P} < 0.05$) than available, they were considered preferred or avoided, respectively. A χ^2 goodness-of-fit test also was performed to test the null hypothesis that the proportions of habitats within the composite female home range were similar to proportions within the entire study area.

Radiolocations used for habitat preference analysis met the following criteria: ≤ 150m from observer or if > 150m from observer, then the triangulated location was used if at least 3 bearings were collected within 30 minutes and were separated by at least 45°. In addition, I used only locations that I had collected, except for visual or aural (bear was heard moving) observations by other personnel. The standard deviation of bearing error associated with handheld equipment averaged ± 5.1° ($\underline{N} = 25$). Size of error polygons increases as observer-transmitter distance increases. Because virtually all radiotracking was done from roads, distance to roads is essentially equal to distance to observer. A total of 32% of female radiolocations was collected < 200m from roads, 23% were 200-400m from roads and 29% were 400-800m from roads (see Appendix Table 33). Developing error arcs from average standard deviation of error estimates, 95% error arc widths of radiotelemetry bearings were 70m, 145m, and 290m for these distance categories, respectively. Mean (± SE) distance of triangulated locations of hidden transmitters ($\underline{N} = 7$; observer distance to transmitters averaged 1229m) from true locations was 201 ± 40m.

Distances of female bear radiolocations to GDS roads and the study area boundary were compared among seasons and to random points to describe and define shifts in bear

distribution. All radiolocation data that met the above bearing and time criteria were used for this analysis, regardless of observer. Mean distance to road and mean distance to study area boundary were determined for each bear for each season. Paired t-tests were performed using the differences between mean distances for each pair of seasons and for each season relative to random distances (Sas Institute Inc. 1982). The null hypothesis was that the mean difference between mean distances was 0. Because 15 comparisons were made for each feature, α was set at 0.005. Distances also were categorized into 5 categories for roads (< 100m, 100-200m, 200-400m, 400-800m and > 800m) and 6 categories for the boundary (< 1000m, 1000-2000m, 2000-3000m, 3000-4000m, 4000-6000m, and > 6000m). Comparisons of the distribution of radiolocation and random distances from roads and the boundary then were performed using χ^2 and Bonferroni Z-statistics (programmed using Sas Institute Inc. 1982). Male data were not used in these analyses due to small seasonal sample sizes and biases associated with difficulty in locating radiocollared males.

Seasonal shifts in overlap of female ranges were examined by determination of the percent of each female seasonal convex polygon range that was nonoverlapping in the same year with other females. Only range data from females monitored south of Lake Drummond, which ranged in number from 12 to 17 for any given season, were used in this analysis because of an inadequate sample north of the Lake. Paired t-tests were used as described above to test for differences in percent nonoverlapping range among seasons (Sas Institute Inc. 1982.)

RESULTS

Home Range Size

Total home range size was different ($\underline{P} = 0.004$) among groups (Table 16). Male total ranges were larger than either subadult ($\underline{P} = 0.003$) or adult ($\underline{P} = 0.001$) female ranges. Annual ranges, which were calculated on a 12-month basis starting with the date of capture, were determined for 4 females. Annual range size estimates were 14.3, 32.7, 20.6, and 94.3 km^2, for solitary females (the former 2 estimates are annual ranges for 1984-85 and 1985-86 for a single female) and 14.5 km^2 for a female with cubs. Extensive early fall movements, or the fall shuffle, greatly inflated home range estimates. Spring-summer and early fall ranges were commonly disjunct. When convex polygons were drawn around all locations, large unused areas between spring-summer ranges and fall feeding areas were included in the total home range polygon. Removing early fall locations from convex polygon analysis reduced median home range size to 10.4 km^2 for adult females ($\underline{N} = 11$) and 9.7 km^2 for subadult females ($\underline{N} = 7$).

Male ranges were larger ($\underline{P} < 0.05$) than ranges of subadult females, solitary adult females, or females with cubs during all seasons of the study with the exception of early summer (Table 16). In this season, range size of males and females with cubs were not different ($\underline{P} = 0.23$). During spring, solitary adult females had larger ranges than either subadults ($\underline{P} = 0.01$) or females with cubs ($\underline{P} = 0.008$)(Table 16). In early summer, solitary adult female ranges also were larger than subadults ($\underline{P} = 0.009$). Subadult females, however, had larger ($\underline{P} < 0.05$) ranges than other female groups during early fall, as well as larger ($\underline{P} = 0.043$) ranges than females with cubs during late fall (Table 16).

Home range size did not differ among seasons for males ($H = 6.95$, 4 df, $\underline{P} > 0.1$) or for solitary adult females ($H = 2.62$, 4 df, $\underline{P} > 0.1$). Seasonal range sizes were different for subadult

Table 16. Total and seasonal home range size (km^2) of solitary adult females, females with cubs, subadult females, and male black bears in Great Dismal Swamp, Virginia-North Carolina in 1984-1986.

Sample[1]	*N*	Median[2]	Mean	SE	Range	Locations per bear
Spring (emergence to 15 June)						
Solitary Adults	10	5.3b[3]	6.0	1.0	2.2-14.4	25-61
Subadult Females[4]	4	2.1c	2.7	0.8	1.6-4.9	25-29
Females with Cubs	5	3.4c	3.3	0.5	1.6-4.7	22-41
Males	9	22.5a	34.7	17.1	2.6-169.6	11-33
Early Summer (16 June to 31 July)						
Solitary Adults	11	4.5b	4.9	0.6	1.1-7.2	13-21
Subadult Females	4	3.0c	2.7	0.4	1.5-3.4	13-30
Females with Cubs	3	5.8abc	6.9	3.2	2.1-12.9	12-29
Males	5	6.7a	10.7	3.9	5.5-26.2	6-20
Late Summer (1 August to 15 September)						
Solitary Adults	9	4.7b	5.8	1.1	2.6-13.3	11-24
Subadult Females	4	2.7b	3.1	0.9	1.4-5.4	13-23
Females with Cubs	1	4.6	4.6	--	--	22
Males	5	14.5a	16.2	3.9	5.9-30.0	7-17
Early Fall (16 September to 15 November)[5]						
Solitary Adults	14	5.9c	7.3	1.7	1.0-24.1	7-37
Subadult Females	5	11.9b	15.7	5.8	5.1-37.7	9-39
Females with Cubs	3	2.7c	2.8	1.1	1.0-4.7	19-23
Males	8	52.8a	53.0	14.0	7.5-113.4	6-24
Late Fall (16 November to 15 January or den entry)						
Solitary Adults	12	3.7bc	4.8	1.5	0.5-18.2	9-32
Subadult Females	7	3.0b	3.9	1.3	0.2-9.0	8-38
Females with Cubs	3	1.0c	1.0	0.0	1.0-1.1	21-33
Males	8	22.6a	42.4	15.1	3.4-130.6	10-23
Total Range Size (≥8 months for females and ≥6 months for males)						
Adult Females	11	21.4b	27.0	8.2	8.9-105.4	48-298
Subadult Females[4]	7	33.1b	29.0	7.5	5.5-62.4	65-353
Males	10	79.0a	111.7	36.9	16.8-427.6	28-142

[1] Only bears monitored at least 50% of the season and with at least one location per week are included in samples.

[2] 100% Convex polygon method used to calculate seasonal and total home range.

[3] Medians within the same column and season that share the same letter are not different ($P > 0.05$) according to protected LSD.

[4] < 3 years old when captured.

[5] These dates varied slightly for individual bears depending on when fall shuffle occurred.

females ($H = 9.37$, 4 df, $P < 0.1$) and females with cubs ($H = 6.67$, 3 df, $P < 0.1$). For subadults, early fall ranges were larger ($P < 0.014$) than during all other seasons. Among females with cubs, late fall range size was smaller than during spring ($P = 0.012$) and early summer ($P = 0.023$).

Home Range Overlap

Total home range overlap was extensive for females (Fig. 6) and males (Fig. 7). Seasonal overlap, as measured by percent of nonoverlapping range, did not differ ($P > 0.10$) between seasons for females. Percent nonoverlapping range was highest during spring (70.3 ± 9.0 %; $N = 13$) and early summer (70.8 ± 9.5 %, $N = 12$) and least during late summer (54.0 ± 8.6 %, $N = 14$) and early fall (48.1 ± 7.4 %, $N = 17$)(Fig. 8-12).

Seasonal Habitat Use

Totals of 1717 radiolocations from 25 females and 530 radiolocations from 22 males met habitat use criteria and were used in the habitat use vs. availability analysis. As male ranges covered the entire study area (Fig. 6), the entire study area was considered available habitat (Appendix Table 26). To meet sample size requirements for χ^2 expected values, old and new disturbed areas were pooled into one category.

For radiocollared females, proportions of available habitat within the entire study area were different ($\chi^2 = 54.1$, df = 10, $P < 0.005$) from the proportions within the area enclosed by a composite home range of long-term radioed bears. The area within the composite range contained proportionately more ($P < 0.05$) pine and maple-coniferous habitats and proportionately less ($P < 0.05$) gum-cypress and maple-gum habitats than the study area as a

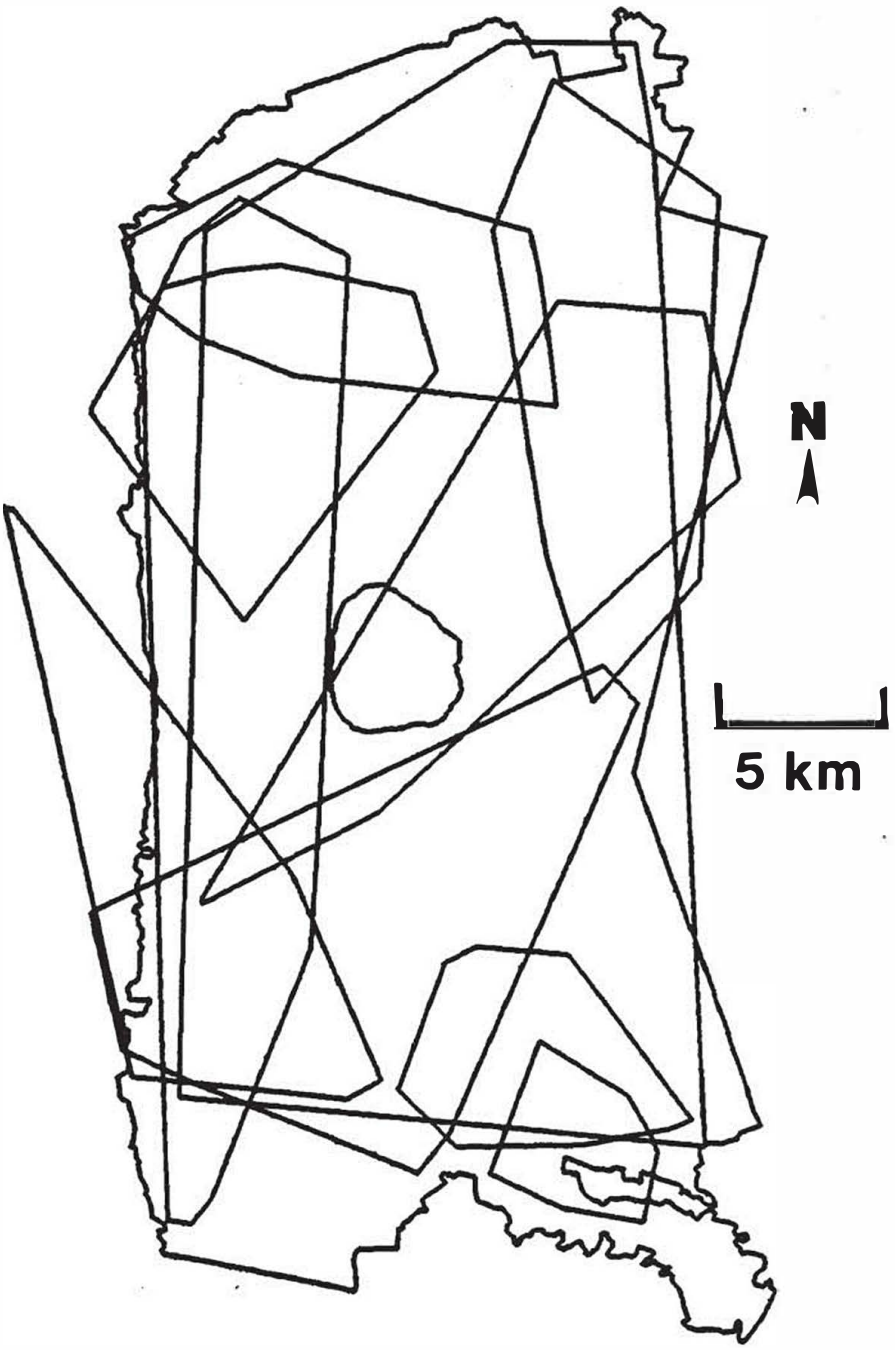

Figure 7. Convex polygon home ranges for 10 males monitored for ≥6 months in Great Dismal Swamp, Virginia-North Carolina during 1984-1986.

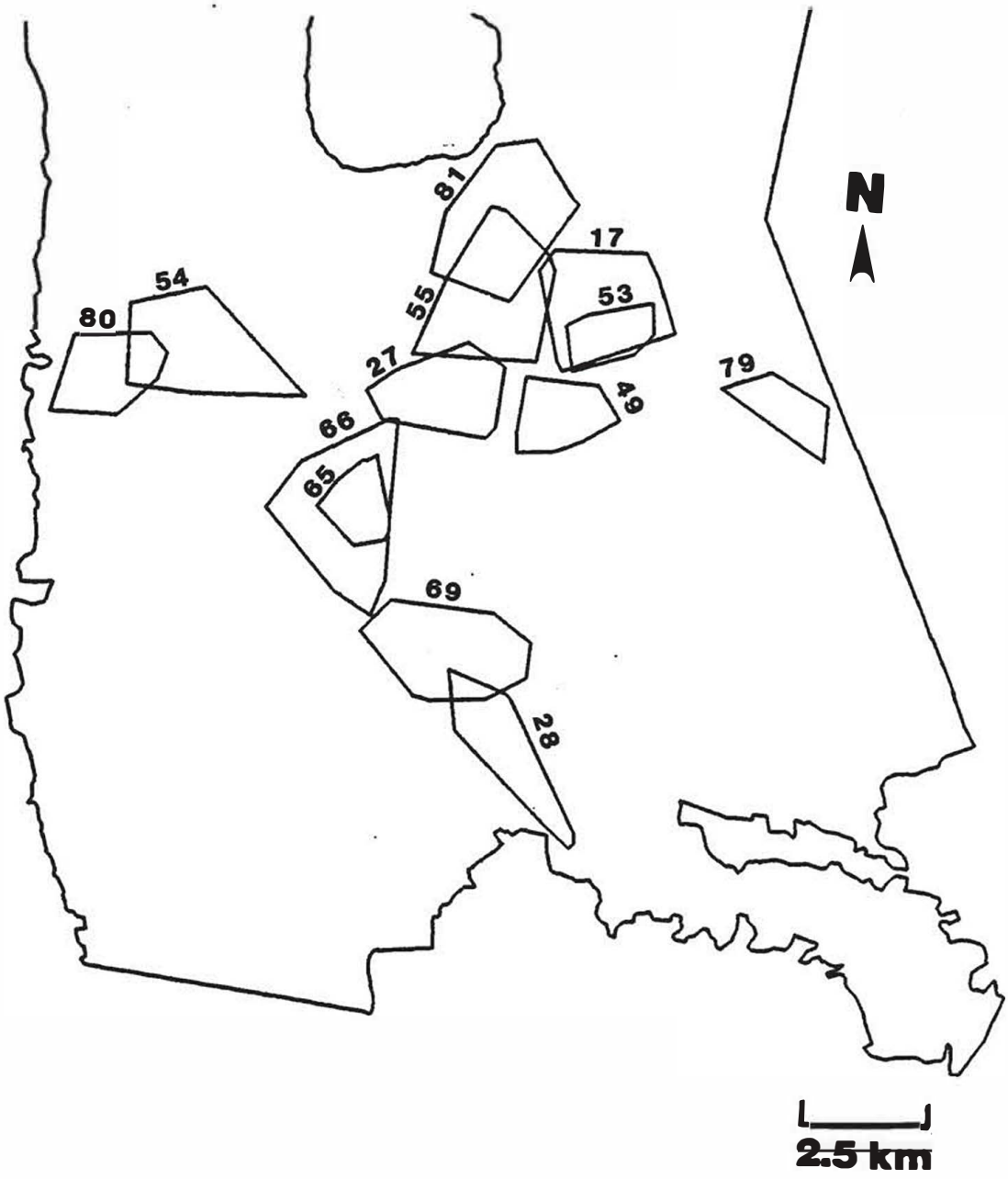

Figure 8. Convex polygon home ranges for females monitored during spring (emergence to 15 June) in Great Dismal Swamp, Va-NC during 1985-1986. Mean % nonoverlapping range = 70.3%.

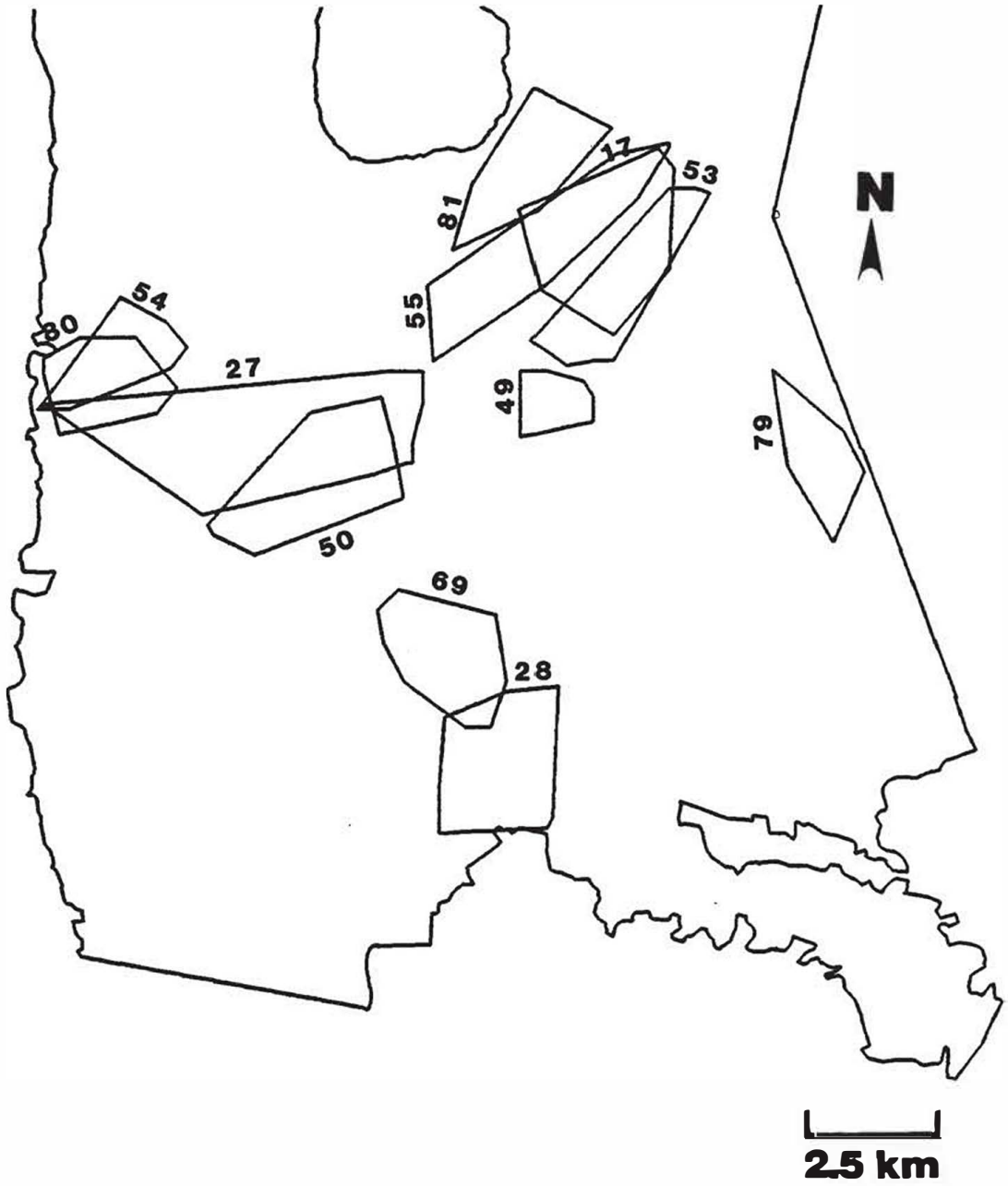

Figure 9. Convex polygon home ranges for females monitored during early summer (16 June to 31 July) in Great Dismal Swamp, Va-NC during 1984-1986. Mean % nonoverlapping range = 70.8%.

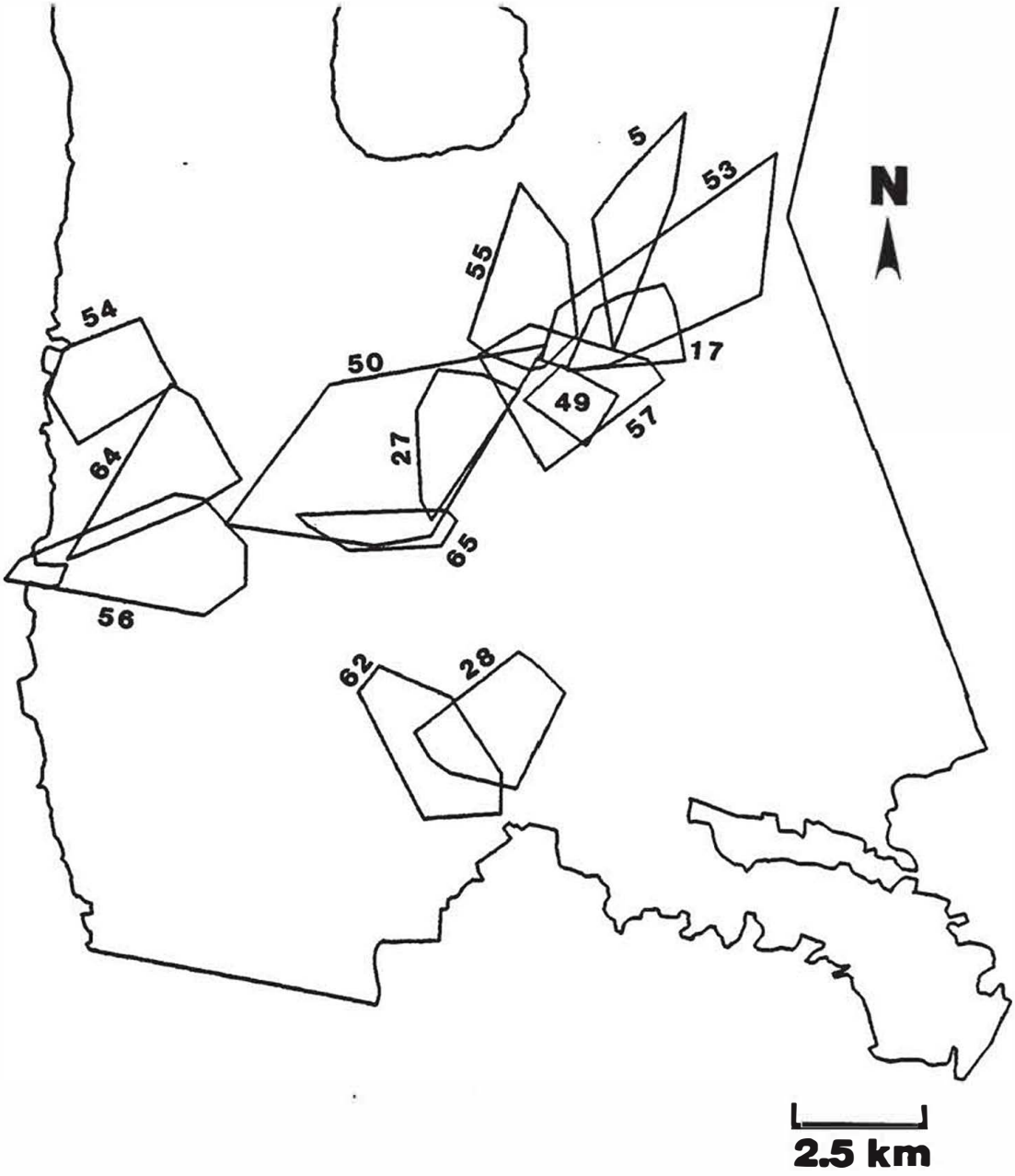

Figure 10. Convex polygon home ranges for females monitored during late summer (1 Aug to 15 Sept) in Great Dismal Swamp, Va-NC during 1984-1986. Mean % nonoverlapping range = 54.0%.

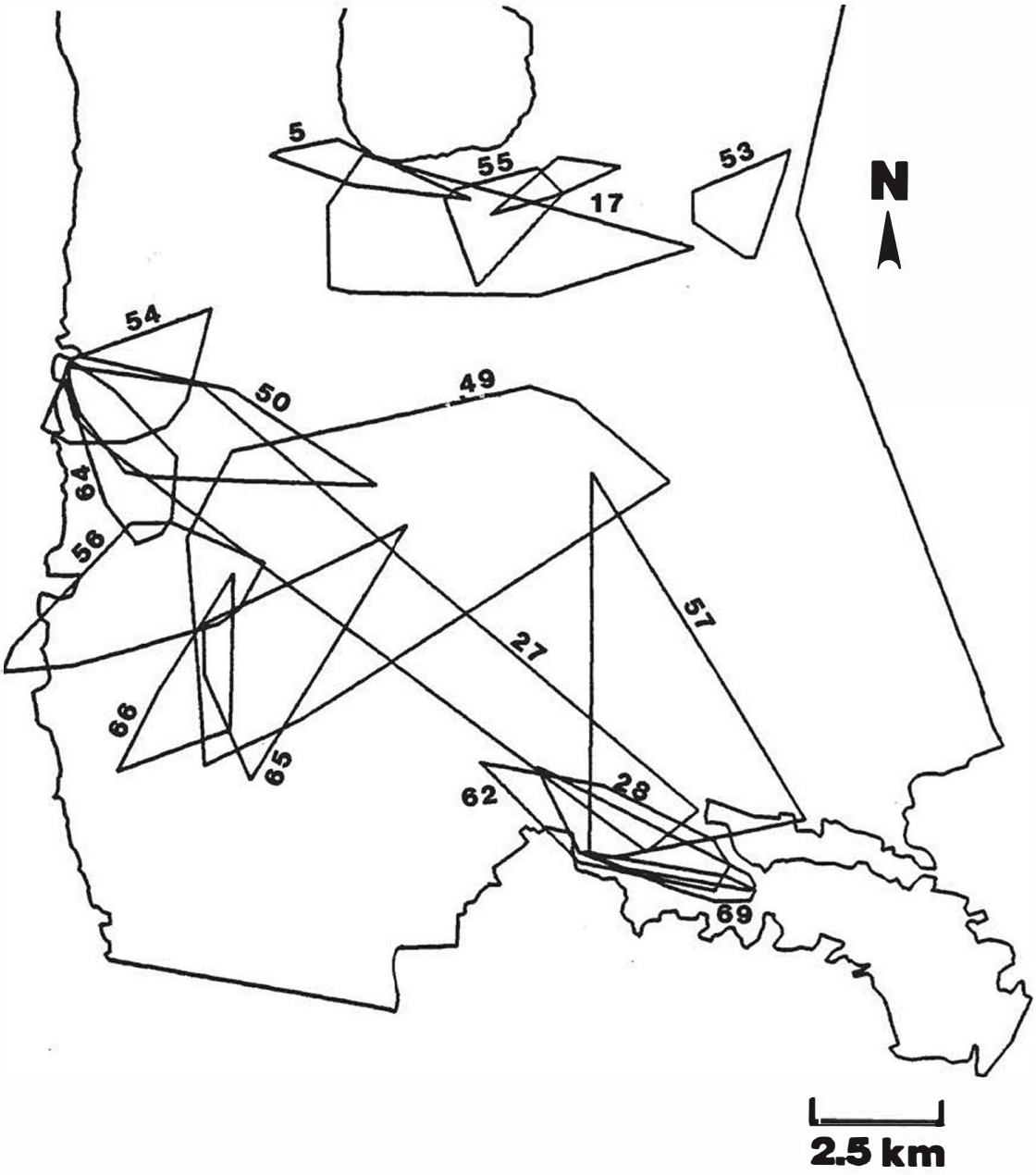

Figure 11. Convex polygon home ranges for females monitored during early fall (16 Sept to 15 Nov) in Great Dismal Swamp, Va-NC during 1984-1986. Mean % nonoverlapping range = 48.1%.

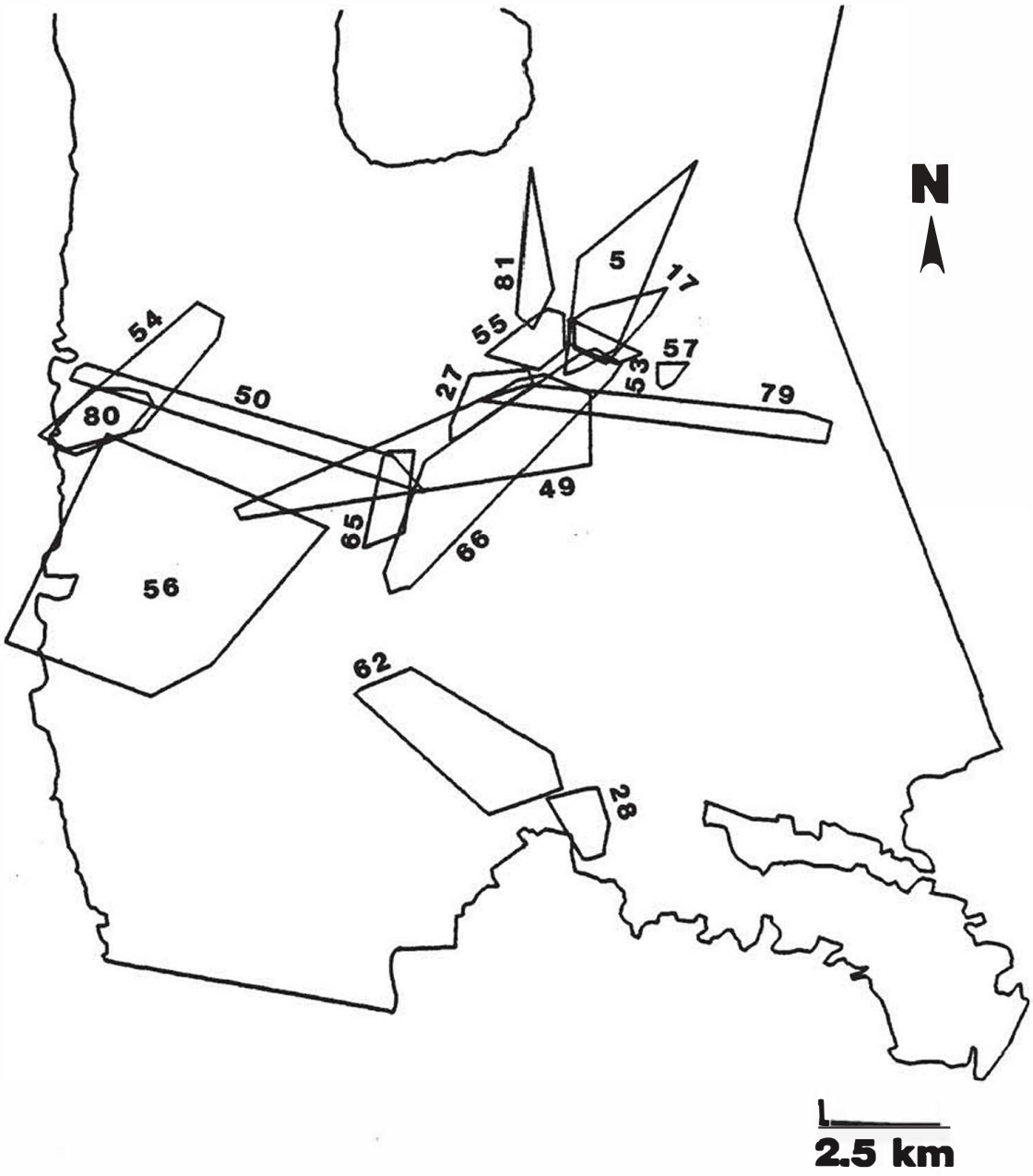

Figure 12. Convex polygon home ranges for females monitored during late fall (16 Nov to 15 Jan) in Great Dismal Swamp, Va-NC during 1984-1986. Mean % nonoverlapping range = 65.1%.

whole. The resulting differences led to different results in habitat use vs. availability analyses. For example, using the entire study area as available, females preferred ($\underline{P} < 0.05$) mesic, old disturbed areas, new disturbed areas, pine, and pocosin habitats, while avoiding ($\underline{P} < 0.05$) gum-cypress, maple-gum, maple, and pine-maple habitats on a year-round basis. Also, no radiolocations were recorded in grass-canebrake habitat (Appendix Table 25). When available habitats were reduced to that area contained within a composite female home range, only mesic and pocosin habitats were preferred ($\underline{P} < 0.05$) and cedar, maple-coniferous, maple-gum, and pine-maple habitats were avoided ($\underline{P} < 0.05$) on a year-round basis (Table 17). With the entire study area as available, use significantly ($\underline{P} < 0.05$) different from availability could occur merely because the areas covered by marked females were not equivalent to total area available. Thus, only results from the composite home range use vs. availability analysis will be presented and discussed for females.

Spring

Females preferred ($\underline{P} < 0.05$) pine and pocosin habitats during spring, while using mesic, gum-cypress and maple-gum habitats proportionately less ($\underline{P} < 0.05$) than their availability (Table 17). With the exception of late fall, spring was the only season that white cedar habitat was used in proportion to its availability. Throughout the other seasons, it was avoided ($\underline{P} < 0.05$). As mentioned in Chapter 2, bear feeding sign was seen on white cedar boles during the spring. Four visual observations of radio-collared females on roads were made during spring. Among males, maple-coniferous habitats were preferred ($\underline{P} < 0.05$), while maple-gum, pine, pine-maple, and pocosin habitats were avoided ($\underline{P} < 0.05$) (Table 17).

Table 17. Seasonal habitat use vs. habitat availability for black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

		All Year		Spring		E. Summer[1]		L. Summer		Early Fall		Late Fall	
Habitat Type	% Available	% Used	Pref.[2]	% Used	Pref.	% Used	Pref.	% Used	Pref.	% Used	Pref.	% Used	Pref.
FEMALES													
Cedar	8.6	6.8	-	10.8	0	4.9	-	3.0	-	3.9	-	8.2	0
Gumcyp	5.7	6.9	0	2.8	-	3.1	0	3.0	0	16.8	+	9.5	0
Mapcon	26.9	16.7	-	26.1	0	12.0	-	15.1	-	15.3	-	9.5	-
Mapgum	16.8	12.8	-	8.0	-	13.9	0	10.8	-	23.4	0	9.5	-
Maple	9.6	8.3	0	8.0	0	8.6	0	14.7	0	7.8	0	4.3	-
Mesic	1.7	5.2	+	0.0	-	2.2	0	3.4	0	17.7	+	4.6	0
Newcut	0.6	1.1	0	0.2	0	0.3	0	4.3	0	1.2	0	0.9	0
Oldcut	3.8	5.2	0	3.4	0	12.0	+	5.2	0	1.5	-	5.2	0
Pine	17.6	16.1	0	26.7	+	20.1	0	8.6	-	5.4	-	12.2	-
Pinmap	4.5	3.2	-	2.6	0	4.6	0	3.9	0	1.5	-	4.0	0
Pocosin	4.1	17.8	+	11.4	+	18.2	+	28.0	+	5.7	0	32.3	+
N locations		1717		499		324		232		334		328	
MALES													
Cedar	5.8	5.1	0	5.3	0	2.4	0			0.0	-	14.2	0
Grass	0.8	0.9	0	0.5	0	3.2	0			0.0	-	0.0	-
Gumcyp	11.8	17.9	+	19.7	0	14.5	0			16.7	0	20.4	0
Mapcon	17.8	33.2	+	37.2	+	25.8	0			41.7	+	24.5	0
Mapgum	29.2	13.8	-	12.2	-	4.8	-			23.3	0	16.3	-
Maple	10.6	9.1	0	9.6	0	12.9	0			7.5	0	5.1	0
Mesic	3.0	2.1	0	2.7	0	1.6	0			3.3	0	0.0	-
Cut	2.1	3.6	0	6.4	0	4.0	0			1.7	0	0.0	-
Pine	9.2	6.4	0	3.7	-	16.9	0			2.5	-	3.1	-
Pinmap	6.1	3.4	-	1.6	-	2.4	0			2.5	0	9.2	0
Pocosin	3.5	4.5	0	1.1	-	11.2	0			0.8	-	7.1	0
N locations		530		188		124				120		98	

[1] Early and late summer male data pooled because of small sample size.
[2] + = used more than available, - = used less than available, 0 = used proportional to availability ($P < 0.05$).

Summer

Use of habitat types by females was not proportional to availability during early summer ($\chi^2 = 252.3$, df = 10, $\underline{P} < 0.005$) or late summer ($\chi^2 = 424.4$, df = 10, $\underline{P} < .005$). During early summer, females used cedar and maple-coniferous habitats proportionately less ($\underline{P} < 0.05$) than their availability and used old disturbed areas and pocosins more ($\underline{P} < 0.05$) than their availability (Table 17). Road use was heavy, with 16 visual observations of radio-collared bears on roadsides. The use of roadsides and other disturbed areas is consistent with food habits data (Chapter 2, Table 4), which show that 47% of the early summer diet is blackberry and wild black cherry soft mast. These fruits are found almost exclusively on road margins and other disturbed areas in GDS. Pocosin was the only habitat preferred ($\underline{P} < 0.05$) during late summer, with 28.0% of the radiolocations occurring within 4.1% of the available habitat area (Table 17). Road margins continued to be used heavily by bears, as 18 observations of radioed females were made during this season. Cedar, maple-coniferous, maple-gum, and pine habitats were avoided ($\underline{P} < 0.05$) by females (Table 17). Food habits data again support these results, as pokeberry and sweet gallberry, found on roadsides and in pocosins, respectively, were 2 of the major natural foods consumed by bears during late summer (Chapter 2, Table 4).

Male data for the summer months were pooled into one season to meet sample size requirements for χ^2 expected values. All habitats were used according to availability except maple-gum habitat, which was avoided ($\underline{P} < 0.05$) (Table 17).

Early Fall

Use of habitat types by females was not proportional to availability during early fall ($\chi^2 = 660.1$, df = 10, $\underline{P} < 0.005$). Stands of gum-cypress and mesic habitats were preferred ($\underline{P} < 0.05$), while cedar, maple-gum, old disturbed areas, and 2 pine-dominated habitats were

avoided ($\underline{P} < 0.05$) (Table 17). Only 2 road observations were made during this period. These results are once again consistent with food habits data, as 65% of early fall diets were either black gum or oak mast and few roadside fruits were consumed. Among males, cedar, grass, pine, and pocosin types were avoided ($\underline{P} < 0.05$), while maple-coniferous habitats were used more ($\underline{P} < 0.05$) than their availability (Table 17). One particular stand classified as maple-coniferous contained small patches of productive gum trees and was used heavily by 4 radio-collared adult male bears during the fall of 1984.

Late Fall

During late fall, use of habitat types by females was not proportional to availability ($\chi^2 = 722.4$, df = 10, $\underline{P} < 0.005$). Females used the 3 maple-dominated types, as well as pine habitat, proportionately less ($\underline{P} < 0.05$) than their availability (Table 17). Pocosin type was used proportionately more ($\underline{P} < 0.05$) than its availability by females, with 32.3% of late fall radiolocations occurring within 4.1% of the available habitat (Table 17). Six sightings of radiocollared females on roads were made during late fall. Males used grass, maple-gum, mesic, disturbed, and pine habitats proportionately less ($\underline{P} < 0.05$) than their availability. No habitats were preferred ($\underline{P} < 0.05$), although cedar, pine-maple, gum-cypress, and pocosin habitats were used more ($\underline{P} > 0.05$) than their availability (Table 17).

Habitat Use of Individual Bears

Habitat use analysis at the individual bear level revealed the same trends observed at the composite range level (Table 18). All 3 individuals that had pocosin habitat in their home range showed a strong preference ($\underline{P} < 0.05$) for that habitat (Table 18). Gum-cypress and mesic habitats also were preferred ($\underline{P} < 0.05$) when they occurred within an animal's range. At least 2 bears avoided all maple-dominated habitats and cedar habitat (Table 18).

Maple-coniferous, maple-gum, and cedar habitats also were avoided on a year-round basis by female bears (Table 17).

Bear Distribution

Relative to Roads

Paired t-tests indicated that early fall radiolocations of female bears were significantly ($\underline{P} < 0.005$) farther from roads than during spring, late summer and late fall. Early summer locations tended to be closer ($\underline{P} = 0.009$) to roads than during early fall (Table 19). In addition, female bears were located significantly ($\underline{P} < 0.005$) closer to roads than random locations during all seasons except early fall (Table 19). Since most radiocollared females were captured south of Lake Drummond and because the southern half of the study area had a slightly higher road density (0.48 km roads/km^2 vs. 0.43 km/km^2) and a different road distribution (Fig. 2) than the northern half, a separate analysis was performed using only female radiolocations from and random locations generated in the area south of Lake Drummond. A similar pattern was observed (Table 20). Forty-seven observations of radiocollared females were made on GDS roads, primarily during early and late summer (see above habitat use results). These data (distance to road = 0m) were not included in this analysis to make the test more conservative. Of a total of 97 visual observations of individual bears or bear family groups that I made during the course of the study, 88 (91%) of them were made on Swamp roads. This result is not surprising because of the good visibility on roads relative to the forest.

A χ^2 analysis indicated that areas $\leq$100m, 100-200m, 200-400m, and 400-800m from roads were used by females more ($\underline{P} < 0.05$) than expected throughout the year (Appendix Table 33). Areas $\geq$800m from roads were used less ($\underline{P} < 0.05$) than expected. A seasonal

Garshelis and Pelton 1981). In coastal North Carolina, Hamilton (1978) reported that adult females showed the least overlap of any age-sex group. However, his study suffered from a common problem among bear studies examining spatial organization, namely the monitoring of a small percentage of resident bears. In such cases, measures of overlap are minimal and must be interpreted with caution. In other wetland areas, Abler (1985) and Smith (1985) found considerable female range overlap and attributed this to utilization of aggregated food sources and kinship.

I cannot address kinship because I do not know familial relationships among females in GDS. However, I believe that spatial and temporal distribution of food most strongly affected female range dynamics in the GDS study area. Territory defensibility theory hypothesizes that resources are worth defending if they are economically defensible in terms of reproductive fitness (Wittenberger 1981: p. 300). Two major factors would contribute to female bear territoriality in spring and early summer in GDS (and many other bear populations as well). First, food resources (primarily succulent leaves and stems, Table 4) are evenly distributed and predictable, a favorable situation for territorial behavior (Wittenberger 1981: p. 286-287). Second, territoriality may increase feeding efficiency of resident females and their offspring (Rogers 1987) by intimate knowledge of food sources in a small area, as well as increase survival of young cubs. These benefits may outweigh the costs of territorial defense. Continued territorial defense by females without cubs would be adaptive to maintain land tenure for times when it is necessary. In late summer and early fall, bear foods in GDS become localized in small patches of productive habitat, such as pocosins and oak and gum stands. Cubs are more mobile and less susceptible to predators, such as adult male bears and felids (Elowe 1986, LeCount 1987). During these seasons, the benefits of resource defense are decreasing and the costs are increasing, because more competitors are likely to intrude on a productive food patch. Defensibility theory argues that as resource aggregation and unpredictability increases, territoriality eventually will break down as the resources become indefensible (Wittenberger 1981: p. 287). The result for GDS female bears would be extensive range overlap in productive habitat patches, which was observed. Factors

Table 18. Yearly habitat use of 6 female black bears with > 125 radiolocations compared to habitat availability within their convex polygon home range, Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

	Bear 17		Bear 24		Bear 27		Bear 28		Bear 54		Bear 55	
Habitat	% Avail.	% Used	% Avail.	% Used	% Avail.	% Used	% Avail.	% Used	% Avail.	% Used	% Avail.	% Used
Cedar	13.8	2.5(-)[1]	0.0	0.0	15.5	14.3	0.4	1.4	6.3	1.4(-)	11.1	5.5(-)
Gum-Cypress	0.0	0.0	0.0	0.0	4.6	3.4	0.0	0.0	28.3	45.9(+)	0.0	0.0
Maple-Coniferous	11.8	0.9(-)	52.3	33.6(-)	29.4	22.6	55.4	52.3	1.0	0.0	18.8	16.6
Maple-Gum	12.5	5.3(-)	0.0	0.0	11.9	4.2(-)	31.3	38.6	0.0	0.0	11.3	11.7
Maple	6.5	2.2(-)	0.0	0.0	10.2	4.9(-)	2.5	0.9	48.7	33.6(-)	7.6	3.4
Mesic	0.0	0.0	0.0	0.0	0.9	6.0(+)	0.0	0.0	9.5	19.2(+)	0.0	0.0
Disturbed (0-10 years)	0.0	0.0	0.0	0.0	0.4	2.3	4.5	3.6	0.0	0.0	0.0	0.0
Disturbed (10-20 years)	3.3	2.5	0.0	0.0	6.5	18.9(+)	2.1	2.3	6.1	0.0(-)	8.7	9.0
Pine	21.4	40.6(+)	47.7	66.4(+)	7.2	0.0(-)	1.6	0.9	0.0	0.0	2.1	0.7
Pine-Maple	18.0	13.8	0.0	0.0	7.0	0.0	2.1	0.0	0.0	0.0	21.9	11.0(-)
Pocosin	12.5	32.1(+)	0.0	0.0	6.5	23.4(+)	0.0	0.0	0.0	0.0	18.6	42.1(+)
N locations	318		146		265		220		146		145	
χ^2	238.72		20.60		338.63		16.22		53.19		651.08	
d.f.	7		1		10		7		6		7	
P-value	< 0.005		< 0.005		< 0.005		< 0.05		< 0.005		< 0.005	

[1] + = used more ($P < 0.05$) than available, - = used less ($P < 0.05$) than available.

Table 19. Mean distances of female black bears from the study area boundary and roads in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Season (dates)	Number of Females N	Number of Locations N	Distance from Road (m) $\bar{x}$	SE	Distance from Boundary(m) $\bar{x}$	SE
Spring (emergence to 15 June)	19	668	421	12	4180	75
Early Summer (16 June to 31 July)	18	320	390	19	3368	103
Late Summer (1 August to 15 September)	14	254	320	17	4099	128
Early Fall (16 September to 15 November)	21	466	840	32	2050	86
Late Fall (16 November to denning)	22	495	453	19	3793	102
All Seasons	24	2203	501	10	3515	46
Random Points	---	952	974	31	3083	68

Table 20. Mean distances of female black bears captured south of Lake Drummond from the study area boundary and roads in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Season (dates)	Number of Females N	Number of Locations N	Distance from Road (m) $\bar{x}$	SE	Distance from Boundary(m) $\bar{x}$	SE
Spring (emergence to 15 June)	16	553	406	13	4208	88
Early Summer (16 June to 31 July)	15	276	396	21	3349	118
Late Summer (1 August to 15 September)	14	254	320	17	4099	128
Early Fall (16 September to 15 November)	17	340	918	40	2174	110
Late Fall (16 November to denning)	19	443	459	21	3953	109
All Seasons	20	1866	499	11	3635	52
Random Points	---	1084	861	24	2964	59

breakdown revealed that zones < 200m from roads were used more ($P < 0.05$) than expected during each season except early fall (Appendix Table 33). Thirty-two percent of all locations ($N = 2203$) were within 200m of a Swamp road. During early fall, areas 400-800m from roads were used more ($P < 0.05$) than expected.

Relative to Study Area Boundary

Paired t-tests indicated that mean distances of female radiolocations inside the study area boundary did not differ ($P > 0.005$) among seasons or from random points (Table 19). Early fall distances tended to be less than during spring ($P = 0.022$) and late summer ($P = 0.034$). Early summer distances also tended to be less than during spring ($P = 0.029$) and late summer ($P = 0.049$). A similar relationship held for data from females monitored south of Lake Drummond (Table 20). When the distribution of radiolocation distances was compared to the random point distribution, seasonal shifts were evident (Appendix Table 33). Throughout the year, females used areas > 4000m from the study area boundary more ($P < 0.05$) than expected, while using areas < 3000m from the boundary less ($P < 0.05$) than expected (Appendix Table 33). During all seasons except early fall, zones < 2000m from the boundary were used less ($P < 0.05$) than expected. These zones were preferred ($P < 0.05$) during early fall, when 67% of all female locations ($N = 2203$) were < 2000m from the GDS boundary. All distance zones > 2000m from the boundary also were used less ($P < 0.05$) than expected during early fall. Similar shifts were observed with only female data from south of Lake Drummond (Appendix Table 34).

Relative to Surrounding Agricultural Areas

Only 15 of 2218 (< 1%) female radiolocations were made outside the study area boundary. They were distributed relatively evenly among early summer ($N = 5$), late summer

(N = 3), early fall (N = 4), and late fall (N = 3). Females rarely were located near agricultural fields, except for animals with home ranges adjacent to the study area boundary. On the other hand, all radiocollared males were monitored in or adjacent to agricultural areas outside of the study area at some time of the year. Thirty-three of 806 male radiolocations (4.1%) were outside the study area, with summer (N = 15) and late fall (N = 13) being the major periods of bear egress. These were also the 2 major periods of bear use of crops as food (Table 4). Predominantly male use of agricultural areas also was evidenced by corn depredation complaints. In response to complaints, a limited number of traps were set to catch depredating bears in the summer of 1984. Six bears (5M, 1F) were captured on the edge of cornfields. In addition, the only 2 bears killed on crop depredation permits in Virginia near GDS during the study were males.

DISCUSSION

Habitat use and range dynamics of black bears in GDS were tied strongly to the spatial and temporal distribution of food. Other factors, such as sex, age, and reproductive status, adjusted bear spatial use, but phenological development and availability of plant foods appeared to be the driving force behind bear range use. Other studies of black bear ecology in southeastern wetlands have reported similar results (Lander et al. 1979, Smith 1985).

Analysis of female habitat use at the composite home range level and the individual home range level indicated the importance of pocosin habitat throughout the year. Pocosins were preferred on a yearly basis, as well as during each season except early fall (Table 17). Heaviest pocosin use was during late summer and late fall. For example, a single 600 ha pocosin was used by 8 of 15 (56%) radiocollared females during August 1985 and by 7 of 20 (35%) females during November-December 1985 (Fig. 10, Fig. 12). This pocosin also was used by 2 of 4 radioed females during the same periods in 1984. These seasons coincided with

ripening and heavy consumption by bears of fruits of Ilex sp. shrubs and Smilax vines (Table 4). Pocosins also provided good denning habitat (see Chapter 4). Male habitat use data did not show as strong a preference for pocosins, although pocosin use was heaviest by males during summer and late fall (Table 17).

Pocosins are freshwater forested wetlands in the southeastern United States characterized by a sparse pond pine canopy, a dense broadleaved evergreen shrub understory, organic soils, and poor drainage (Sharitz and Gibbons 1982, Zeveloff 1983). They provide the last large blocks of suitable habitat for black bears in the Atlantic Coastal Plain (Monschein 1981). This study provides the first specific evidence on the habitat value of pocosins to black bears. The study of Hardy (1974) hints at the value of pocosins to black bears in Dare County, North Carolina (site of Alligator River NWR); but its scope is too limited to provide information on how pocosins are used by bears. Carolina bays in southeastern North Carolina (Landers et al. 1979) are vegetatively and structurally similar to GDS pocosins. Carolina bays received the greatest amount of use by bears and contributed the greatest amount of food to the annual diet of any habitat studied (Landers et al. 1979). These features often have similar soil types and floral and faunal species composition as pocosins, but they are of different (but unknown) geological formation and present geomorphometry (Sharitz and Gibbons 1982). Nevertheless, the data presented in the present study, combined with the work of Landers et al. (1979), make a strong case for the importance of pocosin habitat to black bears in the southeast.

Another critical habitat component for black bears in GDS are productive stands of mast-bearing trees in the fall. As in other southeastern wetlands (Hardy 1974, Landers et al. 1979, Smith 1985), bear habitat selection in GDS in fall was closely tied to soft and hard mast availability (Table 17). In coastal North Carolina, bears selected hardwood swamps during a year of high gum fruit availability (Hardy 1974, Landers et al. 1979) but used scrub oak (short, stunted oaks) ridges when acorns were available (Landers et al. 1979). In an Arkansas bottomland hardwood, bears used either homogeneous stands of low forest (overcup oak, Q. lyrata, flats) or heterogeneous areas of high forest containing red oaks and sweet pecan

(Carya illinoiensis), depending on which habitat contained abundant mast. Overcup oak flats were preferred (Smith 1985). Large contiguous hardwood swamps with dense vegetation and expanses of water also appear to be critical for escape cover during the fall hunting season and for foraging and denning habitat during winter (Landers et al. 1979).

The shift in female bear distribution relative to the study area boundary also was tied to the presence of fall mast. Long fall excursions by bears to take advantage of mast concentrations outside their normal ranges, which have been observed throughout black bear range, including wetland populations (Hardy 1974, Smith 1985), have been termed the "fall shuffle." Except during early fall, radio-collared females were distributed close to randomly relative to the study area boundary, even using zones >4000m from the boundary to a greater extent ($P < 0.05$) than expected. However, the fall shuffle (ranging from 3 to 12 km) led females to feeding areas in mature (60-100 years) gum-cypress and oak stands. These preferred habitats are located primarily along the western edge of GDS and in the Pasquotank River drainage due to the present soil and hydrologic characteristics. For example, local areas of noted heavy bear use of gum mast during both 1984 and 1985 included areas west of Lynn Road, Sherrill Road, and Weyerhauser Road, as well as the Pasquotank River bottomland hardwoods and mature stands of black gum around Lake Drummond (Figs. 1-2). Except for the latter area, all these stands are located along the periphery of GDS. Feeding on oak acorns was heavy along the Suffolk Scarp, the escarpment that forms the western boundary of the study area. The resulting range shifts meant that most female bears were located <2000m from the study area boundary. Because these feeding areas also occur in the largest roadless areas in GDS, a significant shift in female bear distribution relative to roads also was observed during this season (Tables 19, 20). Although male locations were not analyzed statistically (see Methods), a similar shift in distribution occurred for males that were radio-collared. Implications of this distributional shift will be discussed below (See Management Overview).

The importance of disturbed areas to black bears in the completely forested Swamp was evidenced by habitat use, food habits (Chapter 2), and distributional data. Disturbed

areas in GDS include road margins, burns, and regenerating clearcuts. Old clearcuts and burns (10-20 years old) were preferred by females in early summer. These habitats are good producers of soft mast, such as fruits of blueberry (Vaccinium sp.), black cherry (Prunus serotina), and blackberry (Rubus sp.). These 3 fruits composed 63% of the early summer diet by volume (Table 4). One 283 ha, 20 year-old burn north of Persimmon Ditch was used heavily by 7 radiocollared bears during July 1985 and July 1986. Feeding was primarily on black cherry and blackberry fruit. Disturbed areas also accounted for 9.5% of female locations during late summer, with pokeberry (Phytolacca americana) the major food consumed.

Roads and road margins are a specific type of disturbed area that appeared to be an important habitat component to bears in GDS. Roads were not avoided, as radiocollared females were located closer to roads than random locations during all seasons except early fall (Table 19, 20). Since public vehicular access to GDSNWR is prohibited, foods available on roadsides made roads attractive to bears. Major bear foods found on road margins included wild black cherry, blackberry, pokeberry, devil's walking stick (Aralia spinosa), switchcane, and greenbriar (Smilax sp.). The attractiveness of roads to bears has been noted in other unharvested and protected populations. Carr and Pelton (1984) found that responses to seasonally abundant food supplies seemed to determine road use among bears in Great Smoky Mountains National Park. During summer in White River NWR in Arkansas, a bottomland hardwood, bears showed an affinity to edges, particularly roads and areas of high forest diversity, where soft mast may be abundant (Smith 1985). Garner (1986) found that female bears in Shenandoah National Park preferred fire roads during summer and early fall, using wild black cherry mast found on those roads. Both sexes avoided heavier traveled roads, probably due to human activity. Road avoidance by bears generally is observed in harvested areas with unrestricted road use (Hamilton 1978, Carr and Pelton 1984).

Roads also were used as travel corridors, perhaps to facilitate travel through the dense vegetation of GDS. Although some bear sightings were merely road crossings, the majority were observations of feeding or traveling bears. Single sets of bear tracks on roads could at times be followed for > 1 km. Track counts have been used in other southeastern wetlands

as indices of bear activity (Hardy 1974, Hamilton 1978). Mark trees, primarily loblolly pine, were observed commonly on road margins. Abandoned logging roads and railroads, especially Old Cedar Railroad (OCRR), also were used as bear travel corridors. These features often had longtime bear trails, with deep, permanent footprints in the substrate and numerous mark trees. OCRR runs throughout the southern half of the study area and 12 bears were captured at its 13 intersection points with Swamp roads.

A potential bias in the distribution data of radiocollared females is that trapping was conducted within 100m of roads. It could be argued that the radiomarked sample was "road-happy". However, ranges of radiocollared females covered almost the entire study area south of Lake Drummond (Fig. 5). When locations from these females were compared to random points generated in the southern region, females clearly preferred roads except during early fall (Table 20), when excursions were made. In addition, some females were captured en route to fall feeding areas. After returning to their spring-summer ranges, they did not cross roads.

Sex differences in habitat use were apparent, although habitat use was not statistically compared. Maple-gum and pine-maple habitats were avoided by both sexes throughout the year (Table 17). However, females preferred pocosin and mesic stands while also avoiding maple-coniferous stands, which males preferred. The gross differences in use of pocosins were particularly striking. In 4 of 5 seasons, > 15% of female locations were in pocosin habitat, yet male use of pocosins never exceeded 11% (Table 17). Reasons for these differences include an inadequate sample of radiocollared males, inaccurate habitat descriptions, or avoidance. The predominantly male use of agricultural areas may be due to the extensive travel behavior and large home ranges characteristic of male black bears.

Annual and seasonal range use of black bears in GDS were affected by several factors other than food, namely sex, age, reproductive status, and social interactions. Comparisons of home range estimates between studies are difficult to make because of different methods of defining areas (Garshelis and Pelton 1981) and use of different methodologies, particularly

sampling regimes (Smith 1985). Despite these difficulties, a general pattern of bear spatial use has emerged and the GDS population appears to follow this pattern.

Males used larger areas than females on both an annual and seasonal basis. Mean annual home range estimates in this study were comparable to convex polygon home range estimates made in other southeastern wetlands (Taylor 1971, Hardy 1974, Hamilton 1978, Abler 1985, Smith 1985). It has been hypothesized that adult males can increase their reproductive fitness by using areas that encompass the ranges of several adult females. The mating benefits of these ranges thus leads to the use of large areas that can not be defended as territories (Amstrup and Beecham 1976, Rogers 1977).

Female ranges, on the other hand, may be directly related to habitat quality and should be large enough to supply adequate resources for successful reproduction (Amstrup and Beecham 1976). Smaller home ranges may indicate intense use of high quality habitats (Lindzey and Meslow 1977, Modafferi 1982, Garner 1986). In Arkansas, Smith (1985) found evidence of a relationship between home range size and habitat quality. Ranges were smaller for both sexes east of the White River, which bisected his study area. The eastern portion of the area was characterized by greater habitat diversity, more food production (measured qualitatively), and less human disturbance. This study was not designed to examine the relationship between habitat quality, range size, and reproductive fitness. Home ranges were generally small throughout the study area, but some range sizes were inflated due to bears that had extensive fall movements. Population characteristics are indicative of good-quality bear habitat (Chapter 1, Table 3).

Age did affect home range dynamics, particularly seasonal range use, among females. Overall range size of subadult and adult females was similar but varied among seasons (Table 17). Females with cubs of the year generally have small spring ranges due to limited cub mobility (Smith 1985). I cannot explain the small ranges of females with cubs during late fall. Subadult female ranges were larger than those of adult females during early fall. It appeared that adult females that made fall excursions to mast-producing stands did so rapidly and directly, usually within 1-2 days, whereas subadults wandered more extensively. Rogers (1987)

suggested that cubs may remember as adults the food-rich sites they visited with their mothers. If a subadult returns to such an area and the area is not productive, it may need to wander to find a productive area. Smith (1985) reported no age difference in female fall range size. The question of how bears find fall feeding areas far from their normal home ranges remains unanswered.

The degree of overlap between black bear ranges varies due to several factors. Male ranges in GDS overlapped extensively. Most studies of bear populations, including wetland populations, have reported similar behavior. For example, Smith (1985) found considerable overlap among male ranges in a bottomland hardwood forest, despite monitoring only a small percentage of resident bears. Hamilton (1978) found that males had overlapping ranges in coastal North Carolina. Both authors found that male ranges overlapped several female ranges, especially during the breeding season.

Home range overlap among females has been the subject of much discussion. Some studies have reported exclusive female ranges (Rogers 1977, LeCount 1980, Young and Ruff 1982), whereas others have noted considerable spatial overlap (Lindzey and Meslow 1977, Reynolds and Beecham 1980, Garshelis and Pelton 1981, Garner 1986). In the present study, it appeared that radiocollared females maintained exclusive ranges during spring and early summer (Fig. 7, 8). An average of > 70% of each of these seasonal ranges was non-overlapping with other females, compared to 48-54% during late summer and early fall (Fig. 9, 10). Although these differences were not significant and only a small percentage of resident bears were monitored, site fidelity during spring and early summer was very high and actual spatiotemporal overlap was minimal. Further analyses using the distribution of radiolocations rather than convex polygon ranges may better define female territories.

Several ideas have been put forth to explain overlapping of female ranges. Among these ideas are kinship and social tolerance (Jonkel and Cowan 1971, Rogers 1977, Lindzey and Meslow 1977)(adequately demonstrated only by Rogers 1977), spatial and temporal distribution of food (Reynolds and Beecham 1980, Garner 1986, Rogers 1987), and temporal separation of areas of common use (Lindzey and Meslow 1977, Reynolds and Beecham 1980,

affecting degree of overlap and how they affect efficiency of resource utilization need further study.

Management Implications

As discussed by Landers et al. (1979), a variety of habitat types are needed to fulfill bear needs throughout the year. Management plans for Coastal Plain bear populations should include guidelines to maintain and enhance stands of mature gum and oaks, pocosins, and forest openings (e.g. roadside margins, burns). Provision of a number of alternate natural foods may minimize bear use of agricultural fields during failures of major fruit-producing species. Prescribed burns, small (< 5 ha) permanent clearings, and 10m-wide roadside strips are planned in GDSNWR (U.S. Fish and Wildlife Service 1986). Maintenance and enhancement of shrub pocosins and cypress-gum communities also are planned. These management activities should benefit black bears by providing food-producing habitats. Similar management activities are suggested for other large Coastal Plain tracts of public land containing bear populations, such as Croatan National Forest and Alligator River National Wildlife Refuge.

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CHAPTER 4: DENNING ECOLOGY

Denning behavior of American black bears in southeastern wetland environments is not clearly understood, though the importance of denning habitat to bears, particularly females rearing cubs, has been recognized by bear biologists. Potential den sites in southeastern wetlands may be limited due to periodic flooding. For example, in a seasonally flooded bottomland in Arkansas, Smith (1985) reported that all females used above-ground tree cavities. Males used either tree cavities or elaborate ground nests located in forest gaps. Availability of dry den sites may play a role in limiting female productivity in wetlands. Alt (1984) noted that partial or total litter loss due to flooding of natal dens reduced productivity in northeastern Pennsylvania.

The impact of management actions, such as timber harvest, prescribed burning, and surface water manipulation on den site availability and bear productivity in southeastern wetlands cannot be assessed with available data. The objectives of this chapter were to determine denning chronology and requirements of black bears in the Great Dismal Swamp (GDS), a 850-km^2 forested wetland on the Virginia-North Carolina border. Information from this project will be used to aid in planning management actions which may impact the bear population in GDS National Wildlife Refuge, a 440-km^2 tract of the GDS.

MATERIALS AND METHODS

Trapping and Handling

Bears were captured using Aldrich spring-activated cable snares. Trapped bears were immobilized with a 2:1 mixture of ketamine hydrochloride (Ketaset) and xylazine hydrochloride (Rompun) at a concentration of 300 mg/ml. Initial dosage rate was 6.6 mg/kg estimated body weight and drugs were administered by blow-gun dart syringe (Lochmiller and Grant 1983), jabstick, or dart rifle.

All bears were sexed and weighed to the nearest kg. The first premolar was extracted for aging by cementum annuli analysis (Willey 1974). Numbered plastic ear tags were placed in the ears of each bear. In addition, an identification number was tattooed inside each bear's upper lip for permanent identification. Selected bears were equipped with radio-transmitter collars (Telonics,Inc., Mesa, Az) in the 164-165 MHz range with a 5-minute delay motion sensor. All females (except 2 subadults) were radio-collared. Males were collared to provide a wide distribution of age and weight classes. A breakaway cotton spacer was inserted in each collar (Hellgren et al. 1988) to minimize chafing and rubbing of the collar and to prevent bears from retaining the collars throughout their lives.

Denning and Winter Activity

Bears were radio-tracked to dens in winter. Bears that denned or failed to den (winter-active bears) were relocated 1 to 7 times weekly by ground or aerial tracking (Hellgren

and Vaughan 1987). Den entry dates were defined as the midpoint between the last recorded movement and the first of a series of stationary signals. Den emergence dates were defined as the midpoint between the last denning location and the first location away from the den (O'Pezio et al. 1983). In our study, changes in radio signal strength and clarity from radioed bears combined with close radio-tracking (< 50 m) indicated that females with cubs often (at least 4 of 6 instances) emerged from dens 10 to 12 days before vacating the immediate den site. We used abandonment of the den site as the emergence date due to the difficulty of determining when mothers actually "emerged" from dens only to rest 5 m from the den. Chronology data were pooled across years. Seventeen of 23 denning chronologies were measured during the winter of 1985-86 and 6 during the winter of 1984-85. Den chronology data were analyzed by two-way analysis of variance with age and sex as main effects to examine for differences between cohorts with respect to length of denning. Data from all age-sex cohorts except females with newborn cubs were pooled and reanalyzed by a Student's t-test with cubs vs. no cubs as the main effect. Statistical analyses were performed using SAS (Sas Institute Inc. 1982) procedures.

Dens of adult females known to be without yearlings at the beginning of the denning period were visited in late March or early April. Attempts were made to immobilize mothers and weigh and sex cubs. Because bears abandoned dens readily during the first year of the study, later dens were located remotely by radiotracking within 50-100 m, then obtaining a series of bearings around the site (Smith 1985). After bear emergence, we visited and measured dens. Den values measured, depending on den type - nest, ground cavity, tree cavity - included den entrance width, entrance height, cavity height, cavity width, bed length, bed width, bed material thickness, height of tree cavity above ground, height of den floor above ground, den cavity length, and entrance aspect. Scats collected at den sites were analyzed as described in Chapter 2. A digitized version of the vegetation cover map prepared by Gammon and Carter (1979) was used to compare habitat availability to habitat used for den sites. Large-scale habitat changes, such as timber harvest and burns, that have occurred since original digitizing of the cover map, were redigitized on the cover map. Sample sizes were too

small to perform a Chi-Square analysis to determine if specific habitats were used for den sites in proportion to availability.

RESULTS

Thirty-five bears (26F, 9M) were radio-monitored in the winters of 1984-85, 1985-86, and 1986-87. Five bears (14 %) remained active throughout the winter. Four bears (2M, 2F) were active during the winter of 1984-85 (Hellgren and Vaughan 1987) and 1 female was active during 1985-86. Twenty-nine dens of 28 bears were located and denning chronology data were collected for 23 animals. Collar failure occurred on one male bear during February 1985 before its den could be located and the den of one female could not be located.

Denning periods varied from 53 to 131 days. Maximum error for den entry or emergence dates was ± 5 days. Pregnant females (Table 21) entered dens 19 days earlier ($P < 0.02$) than all other bears ($N = 17$, 3 Jan ± 4 days) and emerged 23 days later ($P < 0.001$) than all other groups (23 Mar ± 2 days). Their denning period was thus longer (119 days, $P < 0.001$) than other age-sex groups (78 ± 4 days). Other bear cohorts showed great similarity in denning chronology (Table 21).

A total of 14 disturbances were recorded. Four of these were den immobilizations of females with offspring. In each of these cases, females remained in the den after handling and emerged 4-32 days later. In 10 cases, bears abandoned dens because of observer disturbance. In 3 of these incidents (3 F), bears returned to their original dens. In 4 incidents (3F, 1M), new dens were constructed and used for 16-118 days before spring emergence. In the final 3 incidents (1F, 2M), bears did not re-den. Data from these latter individuals were therefore not used in denning chronology analysis. Den emergence dates of 5 of the 7 disturbed individuals that re-denned were either equal to or later than the mean emergence date for their particular age-sex group.

Dens were found in several habitats. Among deciduous types, 6 (21%) were found in maple-gum cover type (the most common type found in GDS - 29.8%)(Levy and Walker 1979), 2 (7%) were located in maple habitat, and 1 (3%) was found in a gum-cypress stand.

Table 21. Denning chronology of black bears in Great Dismal Swamp, Virginia and North Carolina during 1984-1986.

Age-sex group	N	Mean entry date	Mean emergence date	Denning period	Range
Pregnant females	6	15 Dec ± 6 d[1]	14 Apr ± 3 d	119 ± 4 d	106-131 d
Solitary females	9	2 Jan ± 5 d	21 Mar ± 2 d	74 ± 6 d	53-105 d
Females with yearlings	4	2 Jan ± 8 d	25 Mar ± 4 d	82 ± 11 d	61-114 d
Males	4	5 Jan ± 10 d	27 Mar ± 3 d	82 ± 10 d	71-111 d

[1] mean ± se .

Dens selected in evergreen types included 9 (31%) in pine or pine-maple types and 3 (10%) in Atlantic white cedar forest. Eight (28%) dens were located in evergreen shrub pocosins or regenerating clearcuts 6-15 years old. This last group of habitats is characterized by a sparse canopy and extremely dense stands of ericaceous shrubs, particularly Ilex sp. and fetterbush (Lyonia lucida). Although these habitat types make up a small percentage of the available area (6.7%), they provide important denning sites. The cover value of these stands was illustrated during one den location attempt in a pocosin thicket. Two observers approached within 2 m of the denned bear and went around the den on 3 sides without seeing sign of the den. The den was found when the bear emerged.

Twenty-eight of 29 located dens of radiocollared bears were measured (some measurements were not applicable for certain dens - see Methods). Measurements were not taken for an above ground tree cavity and bed dimensions were not determined for 2 ground-level tree cavity dens. Den types were ground nests, excavated ground cavities, ground-level tree cavities, an above ground tree cavity, and a den in a stump. Fourteen bears (10F [including 3 with newborn cubs], 4M) used ground nests constructed of debris raked from around the site. Common items used in nest construction were red bay (Persea borbonia) and fetterbush leaves, greenbriar (Smilax sp.) vines, switchcane (Arundinaria gigantea) leaves and stems, loblolly pine needles, and twigs. Four of the nests were at the base of large red maple or loblolly pine trees and 2 were on small hummocks in inundated areas. Several nest dens ($N = 12$) had secondary nests associated with them. One pregnant adult female built a nest den above water level in a rotting stump of a bald cypress in an inundated area.

Excavated ground cavities were used as hibernacula by 10 females (11 dens). These cavities were either dug into small hummocks of soil surrounding old stumps or rotting logs, or were under root systems of red maple trees. Beds in cavity dens were constructed of material similar to the nest dens. Only 1 cavity, abandoned by an adult female due to disturbance by investigators, contained water during the winter.

Only 3 bears used tree dens. Two adult males used ground-level cavities in black gum trees of 65 cm and 107 cm dbh. Both trees had large butt swells 117 cm and 196 cm in diameter. One adult female denned with yearlings in a large bald cypress.

Den bed size varied among age-sex groups (Table 22). Males and females with newborn cubs constructed larger ($P < 0.05$) beds than other reproductive classes of females. Den dimensions did not vary among groups, although male dens tended to be wider ($P = 0.054$) than dens of solitary females and females with yearlings (Table 22). Entrances of cavity dens had north ($N = 7$), south ($N = 3$), east ($N = 2$), and west ($N = 2$) aspects.

Scats collected at den sites ($N = 20$) seemed to be of 2 types. One type was clearly remains of food consumed before hibernation, while the other type consisted of fecal plugs. Fruits of Ilex glabra and Smilax sp. made up 9.8% and 9.4%, respectively, of the volume of den scats. A slimy, mucous substance (probably sloughed intestinal tissue and bile) composed 42.7% of the volume and occurred in 80% (16 of 20) of den scats. Fecal plugs consisted primarily of this material. Other major items observed in scats by volume were Smilax leaves (14.4%), switchcane leaves and stems (9.7%), and red maple leaves (4.5%).

DISCUSSION

We did not expect to observe such a predominant use of ground dens in GDS. Twenty-eight of 29 dens were at or just above ground level, with 22 of 23 female bears using ground dens. In a bottomland hardwood forest in Arkansas, females used above-ground tree cavities exclusively ($N = 34$) although dry ridges and second bottom terraces were available to bears within or near their home ranges; male bears used ground nest dens ($N = 15$) and tree dens ($N = 13$) with nearly equal frequency (Smith 1985). Smith (1985) hypothesized that tree cavities were crucial to reproductive fitness in bottomland hardwood forests. Data are scarce on bear denning behavior in other southeastern wetland environments. Hamilton and Marchinton (1980) described a ground nest den in a Carolina bay and suggested that most dens in Carolina bay habitat probably were ground nests surrounded by dense cover. Limited

Table 22. Characteristics of ground dens used by black bears in the Great Dismal Swamp, Virginia and North Carolina during 1984-1986 (mean ± se).

		Bed Dimensions (cm)					Den Dimensions (cm)				
Group	*N*	Length	Width	Depth	Volume(m^3)	*N*	Entrance height	Entrance width	Den height	Den length	Den width
Solitary females	10	65 ± 4a[1]	56 ± 4	22 ± 2	0.09 ± 0.01	6-9	38 ± 5	48 ± 5	54 ± 7	123 ± 13	95 ± 10
Females with Cubs	8	83 ± 5bc	75 ± 7	21 ± 5	0.14 ± 0.05	4-5	43 ± 4	50 ± 2	58 ± 3	139 ± 12	109 ± 11
Females with yrlgs	3	66 ± 7ab	57 ± 4	24 ± 6	0.11 ± 0.05	2	28 ± 9	53 ± 0	55 ± 5	137 ± 17	90 ± 3
Males	5	88 ± 7c	73 ± 7	26 ± 5	0.18 ± 0.06	5	---	---	---	143 ± 14	140 ± 14
F-ratio		4.79	2.78	0.27	1.41		0.54	0.26	0.12	0.53	3.11
p-value		0.01	0.06	0.84	0.27		0.59	0.85	0.88	0.66	0.054

[1]Values with different letters within a column differ ($p < 0.05$).

information indicates that bears use ground nests in the Okefenokee Swamp in Georgia (Abler 1985) and in northern Florida (D. Maehr, pers. commun.).

The nearly exclusive use of ground dens in GDS may have been due to a number of factors. The entire GDS has been harvested for timber over the past 200 years. However, approximately 25% of the study area is classified as 'mature' (50-100 years old) or 'old-growth' (> 100 years old) forest (U. S. Fish and Wildlife Service 1986) and certain areas of the GDS, such as around Lake Drummond, along the western periphery, and along the Pasquotank River, appear to contain potential tree den sites. In addition, large, hollow, cull gum and cypress trees occur throughout GDS. Tree den availability has not been estimated. Of the 29 bears tracked to dens, 8 had stands of mature forest in their home ranges and only 1 denned in a tree. The other 2 instances of tree denning occurred in hollow gum trees in intermediate age (30-50 years), second-growth forest. We believe that although timber harvest would reduce tree den availability, it would not seriously impact bear denning behavior.

Dense cover and microelevational changes also allow bears to use ground dens. Three ground nests were located in areas of flooding, but were positioned on hummocks of soil and vegetation 10-30 cm above mean ground level. Other dens were in areas with a water table sufficiently below the soil surface that the dens did not become flooded. In general, the water table has dropped and the GDS has become drier since colonial times due to extensive ditching (Lichtler and Walker 1979). The ditches have modified natural water flow patterns, allowing surface water to be shunted rapidly through the Swamp instead of remaining for several months (Carter et al. 1977). As a result, the areal extent of flooding in GDS probably is much less than historical levels.

The extremely dense vegetation found throughout the GDS provides excellent cover for denning bears as well. For example, 28% of dens we found were in evergreen shrub-dominated habitats or regenerating clearcuts (6-15 years old), which cover only 5.6% of the study area. These habitats are characterized by a sparse canopy and extremely dense stands of ericaceous shrubs, particularly Ilex sp. and fetterbush (Lyonia lucida). Shrub

ground cover commonly exceeds 100% in these habitats and number of shrub stems/ha can be > 20,000/ha (Sharitz and Gibbons 1982).

Bears should be under considerable selective pressure to choose secure dens that enhance productivity (Johnson et al. 1978). A model developed by Johnson et al. (1978) suggested that energy savings from choosing tree cavities would enhance survival and reproduction, because parturition and lactation occur in winter dens. In GDS, excavated ground dens were generally dry and secure. Flat topography and dense cover likely minimize heat loss due to wind convection. Ground cavities are thus probably similar to tree dens in terms of heat retention characteristics. Johnson et al.'s (1978) hypothesis would predict that productivity and survival will be greater in ground cavities than in ground nests. We obtained no data on cub survival, although cub remains (claws, fur) were found in a nest den 2 days following maternal emergence. Alt (1984) found that cub mortality was greatest in cavities because of flooding. In the present study, there was no difference in mean litter size of cavity-users ($\bar{x}$ = 2.25; $\underline{N}$ = 4) and ground nesters ($\bar{x}$ = 2.0; $\underline{N}$ = 4). There also were no differences in cub weights, as median weights of newborn cubs measured in mid March-early April were 2.6 kg ($\underline{N}$ = 7) in cavities and 1.7 kg ($\underline{N}$ = 7) in nests (Wilcoxon Rank Sum W = 49, $\underline{P}$ > 0.1). Statistical power of these tests was low due to small sample sizes. However, Rogers (1987) reported a similar lack of differences in reproductive success between bears using different den types.

Productivity differences between den types may not be immediately evident and the effect of maternal nutritional condition on cub production (Rogers 1976, Elowe 1987) may override the effect of den type. Long-term study is needed to determine if lifetime productivity is compromised by ground nesting, e.g., is length of time between litters greater in ground nesting bears due to the extra energy demands of nesting in the open? Such study would need to be supplemented with nutritional (e.g., body weight) and age data on females to appropriately test this hypothesis. Flooding and human disturbance may be stronger forces affecting den site selection than solely energetics (Rogers 1987), particularly in southeastern

wetlands such as GDS, that have very mild winter climates (Hamilton and Marchinton 1980, Smith 1985, Hellgren and Vaughan 1987).

Sizes of ground dens (nests and cavities) were similar to den dimensions reported in other wetland environments (Hamilton and Marchinton 1980, Abler 1985, Smith 1985). Nest dens were also similar in size and shape to temporary winter beds located in Great Smoky Mountains National Park (Johnson and Pelton 1983). The oval shape of den nests and winter beds reflects the energy-conserving, curled position of sleeping, denned bears (Johnson and Pelton 1979). It appeared that ground dens, particularly cavities, were just large enough to accomodate the bear. This characteristic of bear dens has been observed in several other studies (Tietje and Ruff 1980, Novick et al. 1981, Beecham et al. 1983). No tunnels were seen leading into den chambers in GDS, although tunnels are common in other areas (Tietje and Ruff 1980, Beecham et al. 1983).

Denning chronology of GDS bears was similar to bears denning in other southeastern wetlands. Smith (1985) reported that females with cubs denned for an average of 134 days in an Arkansas bottomland compared to 119 days in the present study. However, mean entry date was identical for each study (15 Dec). The later emergence dates in Arkansas may have been due to the limited ability of cubs to traverse flooded areas, thus stranding family groups in den trees until floodwaters receded (Smith 1985). Females with yearlings and adult males denned for an average of 81 days and 76 days, respectively, in Arkansas (Smith 1985) compared to 82 days for both in GDS. In Carolina bay habitat in southeastern North Carolina, 250 km south of GDS, Hamilton and Marchinton (1980) reported that denning periods averaged 102 days (ranging from 85 to 113) for 4 females and 1 male. Bear denning periods in GDS were, on the average, 11-48 days shorter than denning periods in other regions with mild winter climates, such as coastal Washington (Lindzey and Meslow 1976), southern California (Novick et al. 1981), Tennessee (Johnson and Pelton 1980), and Arizona (LeCount 1983). Since disturbed bears that re-denned did not emerge earlier than undisturbed bears (see above), we feel that our research activities did not affect denning chronology.

Females that gave birth in the den were the first cohort to enter dens and the last to emerge from dens (Table 21). Several studies have demonstrated that adult females as a group enter earlier and emerge later than other bear cohorts (Erickson et al. 1964, Lindzey and Meslow 1976, Novick et al. 1976, Johnson and Pelton 1980, Tietje and Ruff 1980, LeCount 1980, Beecham et al. 1983, O'Pezio et al. 1983, Smith 1985, Schwartz et al. 1987, Kolenosky and Strathearn 1987). The implications of this strategy to bear population management have been recognized (i. e. a late autumn hunting season affords an increased probability of protection to the early denning, reproductive female cohort [O'Pezio et al. 1983]). Limited cub mobility has been cited as the reason for the extremely late emergence dates of females with newborn cubs (Lindzey and Meslow 1976, LeCount 1983, Smith 1985), although physiological state of the female also may play a role. In our study, changes in radio signal strength and clarity from radioed bears combined with close radiotracking (< 50m) indicated that females with cubs often (at least 4 of 6 instances) emerged from dens 10 to 12 days before vacating the immediate den site. We used abandonment of the den site as the emergence date due to the difficulty of determining when mothers actually "emerged" from dens only to rest 5m from the den. Similar behavior has been reported for females with cubs in coastal Washington (Lindzey and Meslow 1976), Alberta (Tietje and Ruff 1980), Arizona (LeCount 1980), and New York (O'Pezio et al. 1983).

Reasons for the early den entry dates among adult females remain speculative. Johnson and Pelton (1980) expanded upon Pengelley and Asmundsen's (1972) hypothesis of mammalian hibernation and suggested that bears have evolved a flexible, endogenous circannual rhythm tied to annual plant cycles as the ultimate denning mechanism. Physiological readiness and the general timing of dormancy are controlled by the endogenous rhythm, with integration of a number of proximate factors cueing the final stimulus to den. Suggested proximate den entry and den emergence cues include photoperiod, food availability, bear nutritional condition, and weather effects. Perhaps adult females, and pregnant females in particular, are more sensitive to these cues or have a lower threshold to den than other bear cohorts. Long-term captive studies of black bear under controlled

conditions of temperature and photoperiod with concomitant physiological sampling are necessary to test for an endogenous circannual rhythm.

Management Implications

Results from this study indicate that in some southeastern wetlands, elevated cavities in large trees are not necessary for successful denning and reproduction of black bears. The presence of dense cover and microelevational relief, along with the absence of human disturbance, enables bears in GDS to use ground dens. It is likely that bears in other Atlantic Coastal Plain populations, which occur in primarily pocosin and Carolina bay habitats (Monschein 1981), use similar dens. Den trees may be crucial to female reproductive fitness in habitats with relatively deep (> 1m) winter flooding, such as bottomland hardwoods (Smith 1985). We believe that den availability is not a problem in southeastern wetlands if bears are provided with habitat patches large enough to offer seclusion from human disturbance.

Planned management activities on GDSNWR include timber harvest, surface water manipulation. and burning (U. S. Fish and Wildlife Service 1986). If winter burns are planned, denning chronology of adult females with newborn cubs (mid-December to mid-April) should be considered. Surface water manipulation, which is planned to enhance and maintain the Swamp's wetland character, should not induce winter flooding to depths (perhaps > 1.5m) that would completely inundate all potential denning hummocks. Timber harvest would not seriously affect tree den availability due to the lack of extant den trees. However, hollow trees with diameters in excess of 1m should be left standing.

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CHAPTER 5: MANAGEMENT OVERVIEW

Ecology of black bears in the Atlantic Coastal Plain has been the subject of limited study (Hardy 1974, Hamilton 1978). The justification for this study was to collect information on demographics and ecology of black bears in Great Dismal Swamp National Wildlife Refuge (GDSNWR) to enhance bear management in the Refuge. The data generated in the study are relevant not only for formulating management recommendations for black bear in GDSNWR, but for other Atlantic Coastal Plain populations as well. Management implications of much of the data have been discussed in previous chapters. In this chapter, I would like to make some specific recommendations for black bear management in GDSNWR.

Management strategies affecting black bears can be grouped into 3 categories: population management, public use management, and habitat management. The existence and perpetuation of GDSNWR, which was created by Public Law 92-478, is of paramount importance to the continued existence of a breeding bear population. As discussed in Chapter 1, current population management occurs in the form of hunting outside the Refuge. Exploitation is light, but will increase in the future. The 3 counties in North Carolina that contain Swamp forest (Pasquotank, Gates, and Camden) will have bear hunting seasons by 1989 (J. Collins, pers. commun.). The combination of a bear distribution shift in early fall

to mesic and gum-cypress stands close to the Swamp boundary and the fact that privately-owned Swamp lands are primarily mesic stands means that bears move into the most vulnerable areas at the most vulnerable time. For these reasons, I would not recommend a bear season in GDSNWR, unless as a highly controlled (perhaps by lottery) and limited hunt. Delaying the opening of the public hunting season (currently 1 October in Virginia) to 15 November or later would allow most bears to return to spring-summer ranges far from the Swamp boundary. A later season also would decrease the proportion of females in the harvest. Continued land acquisition for GDSNWR, particularly along the oak-rich Suffolk Scarp, can only benefit the GDSNWR bear population by increasing the protected area.

This study was not designed to develop a population monitoring index. However, possibilities include track counts, mark tree activity, and bait stations. Discussions on bait station surveys can be found elsewhere (e. g. Proc. 7th Eastern Black Bear Workshop 1984) and will not be discussed here. Monitoring the incidence of fresh marks on trees may be a useful index of population changes (Burst and Pelton 1983), especially of the adult male and estrous female segments of the population. In GDSNWR, however, track counts may be the most useful index because of the high use of sandy roads by bears. A track count route would need to be designed, preferably using roads with soft sand for good track impressions. Route roads could be dragged smooth and track counts performed on subsequent days. As discussed by Hamilton (1978: p.55), index results could be expressed in tracks/track-night/km of road to give a view of changes in bear activity from year to year. Biases of such a technique as a population index do exist, such as the effect of yearly differences in food availability on use of roads by bears, but it would provide data that could be used with other information.

Curent public use management in GDSNWR is beneficial to black bears. Prohibition of overnight camping and motorized vehicular travel by the public (except by special permit or conducted tours) protects bears from disturbance within the bounds of the 440 km^2 Refuge. I believe that the heavy use of roads and roadside foods by bears that I observed is a function of this lack of disturbance. The special white-tailed deer hunt held annually in the Refuge is a disturbance and may produce a poaching problem as it increases in scope (A

radiocollared female was believed to be shot within GDSNWR during the October 1986 deer hunt after I left the study area. Her decomposed carcass was found in January 1987 less than 50m from an abandoned logging road south of Corapeake Ditch). However, many bears are in large roadless areas during the early fall hunt, far from most hunters. Also, the hunt produces carrion in the form of crippled deer.

The proposed alternative from the GDSNWR Master Plan (U. S. Fish and Wildlife Service 1986) recommends an increase in public use in the Refuge, but maintains the current policy of no vehicular access and overnight activities, except via special permit or tours. I do not believe this alternative will significantly affect bears directly, but will increase public awareness, understanding, and appreciation of GDS and black bears.

Habitat management can provide the most direct benefits to black bears in GDSNWR. Maintenance and enhancement of stands of mature gum, oaks, pocosin, and forest openings would be beneficial to black bears by providing food-producing habitats. The proposed GDSNWR alternative plans these activities, not only for wildlife management, but to maintain the unique wetland character of GDS. Increasing the amount of area in oak habitat is unlikely, as soil conditions favorable to oaks are limited within GDS. However, maintenance of the present upland areas with hard mast-producing species will be sufficient to supplement the soft mast production of gum stands. As mentioned above, continued land acquisition along the Suffolk Scarp would increase the hectares of oak forest under GDSNWR protection.

Maple-dominated stands, which cover approximately 60% of the study area and, if left unmanaged, are predicted to almost wholly dominate the GDS in the form of maple-gum habitat within 100 years (U. S. Fish and Wildlife Service 1986), are generally avoided by bears throughout the year. Because they are poor bear habitat, succession to maple stands constitutes a detriment to GDS as a bear range. Stands of maple-gum that contain mature (50-100 years old) black gum, such as those adjacent to Lake Drummond and in the Pasquotank River swamp, however, were used heavily by bears during early fall. Gum-cypress stands were preferred by males on a year-round basis and by females in early fall. Surface

water manipulations using water control structures are planned in GDSNWR to produce site conditions conducive to gum-cypress forest, but are not believed to be able to redirect current successional trends from maple-gum (U. S. Fish and Wildlife Service 1986: p. xiii). Retardation of red maple is a major management goal in GDSNWR and will be beneficial to black bears. Perhaps development of new chemical or biological control agents specific for red maple will be used in the future. Presently, it is not economically feasible to control red maple with forest management techniques over a broad scale.

Evidence from this study strongly suggests that pocosins are highly preferred habitats in GDS by bears for feeding and denning. It also supports the proposed management goal in GDSNWR of maintaining evergreen shrub communities as valuable bear habitat (U. S. Fish and Wildlife Service 1986: p. 10). Unfortunately, invasion and shading-out of pocosins by red maple already has occurred and is occurring in GDSNWR. Thus, management steps need to be taken to prevent loss of pocosin habitat, although impact of human alterations on pocosins still need to be researched fully. For example, the short- and long-term effects of fire on pocosin vegetation composition are poorly understood though periodic burning is considered a pocosin characteristic (Sharitz and Gibbons 1982). GDSNWR would be an excellent site for such research. I suggest the experimental use of drum-chopping and prescribed burns to retard red maple invasion and maintain pocosin habitat. In April 1988, a 250-ha block of pine and pocosin habitat was burned in GDSNWR. Experimental 5- and 10-ha clearings also have been made. Regeneration of these sites should be monitored closely. If successful, these techniques could be used to enhance the evergreen shrub areas of GDS.

The importance of forest openings, specifically road margins and regenerating burns and clearcuts, to bears in GDS is obvious. Management of 10m-wide road margin strips for blackberries and other roadside food plants by 3-4 year rotation mowing has begun in GDSNWR. Monitoring of these strips should be made to ensure that this rotation is adequate for berry production. Prescribed burning and timber harvest are planned for approximately 200 ha/yr in GDSNWR (U. S. Fish and Wildlife Service 1986: p. x). If bears are to be a featured, managed species in GDSNWR, then these management activities are necessary to

replace natural processes, such as fires, windthrow, and treefall that historically provided openings for production of bear foods. The attractiveness of roads to bears has been noted in several protected and unharvested populations (Carr and Pelton 1984, Smith 1985, Garner 1986). In harvested populations with unrestricted public road use, managers would need to consider the effects of roadside management on bear vulnerability. If out-of-season poaching is not a problem, it may be beneficial to manage for fruits that ripen during summer, but not for fall fruits that ripen concomitant with the hunting season. Management is not recommended for margins of heavily traveled roads.

Strategies to deal with the problem of bears damaging agricultural crops, particularly corn, include maintenance of the status quo and planting of buffer crops within GDSNWR. The present policy allows landowners to obtain permits from the Virginia or North Carolina state agencies to kill depredating bears. It is believed that this policy has little deleterious affect on the bear population at present, as only 1-5 bears/year are harvested on depredation permits. Planting of buffer crops in GDSNWR may reduce crop depredation outside the Refuge, but may not be compatible with other Refuge objectives, such as maintaining the wetland character of GDS.

The above discussions are relevant to black bear management in the Atlantic Coastal Plain. Several large blocks of publicly-managed lands that contain bear populations occur in this region. Examples include Alligator River NWR, Croatan National Forest, Okefenokee NWR, Hofmann State Forest (NC), Holly Shelter Game Management Area (NC), and Camp LeJeune Marine Base. These areas have different vegetative compositions than GDSNWR, but similar bear food plants and plant phenology. The above-mentioned areas, with the exception of Okefenokee NWR, also have substantial amounts of pocosin habitat. The value of pocosins to bears previously was unclear, as bears primarily are restricted to pocosins in the Coastal Plain because they are the last remaining large blocks of suitable habitat of any kind. This study has shown their ecological value to black bears, especially when in close juxtaposition with mast-producing species. Population and public use management in other

southeastern wetland bear populations varies. However, data from the present study should provide a base from which to manage.

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CHAPTER 6: PHYSIOLOGY OF GESTATION AND HIBERNATION

The American black bear is one of several mammalian species that undergoes obligate delayed implantation. Following conception in May-July, the fertilized egg(s) arrests development at the blastocyst stage (about 300 cells). The unimplanted blastocyst remains dormant in the uterus until implantation sometime in late November or early December (Wimsatt 1963, Foresman and Daniel 1983). Parturition usually occurs in January and February (Alt 1983), about 60 days after implantation (Foresman and Daniel 1983, Tsubota et al. 1987).

Hormonal events associated with delayed implantation have been fairly well-studied in several species, such as mustelids (see Ogle 1984 for a review in the mink, Mustela vison). However, these events are poorly understood in the bear. Studies by Foresman and Daniel (1983) in the black bear and Tsubota et al. (1987) in Hokkaido brown bears (Ursus arctos yesoensis) on serum progesterone profiles during pregnancy constitute current knowledge on this aspect of bear reproductive physiology. Foresman and Daniel (1983) noted elevated basal progesterone levels during the delay phase. Both studies reported a sharp increase in progesterone about 60 days prepartum, apparently associated with implantation. This

hormonal elevation is concomitant with a marked alteration in corpora luteal morphology and a 2-4.5 fold increase in luteal volume (Wimsatt 1963). Data from Tsubota et al. (1987) indicated that progesterone remained elevated until parturition, at which time basal concentrations returned.

Nonpregnant, anestrous black bears had uniformly low concentrations of progesterone throughout September-December (Foresman and Daniel 1983) while an unmated brown bear had a progesterone profile similar to that of pregnant individuals (Tsubota et al. 1987). It is unknown if this brown bear spontaneously ovulated and formed corpora lutea. Black bears are considered induced ovulators on the basis of the presence of large atretic follicles in unbred bears during the breeding season (Wimsatt 1963, Erickson et al. 1964).

Basic research on reproductive physiology in female black bears is necessary to test Rogers' (1976) hypothesis of blastocyst abortion [sic]. Rogers (1976) speculated that females may somehow assess body fat stores and prevent implantation when reserves are too low to meet the metabolic demands of gestation and lactation during the denning period. A strategy of blastocyst resorption, or other early embryonic mortality, near the time of implantation would be highly adaptive, as body condition in bears during the June-July breeding season often has no relationship to condition during the time of implantation in late November (see Chapter 2). The delay phase allows females to postpone a decision on reproduction until late fall, when fat reserves are sufficient to support lactation through the spring. If fat stores are inadequate, the resorption hypothesis predicts that implantation will not occur or that mortality will occur early in the postimplantation period (Bunnell and Tait 1981). If such a strategy exists and is nutritionally related (Rogers 1976), then fall nutritional condition of solitary females would be a major factor in bear population dynamics. This chapter reports on the first step in testing this hypothesis. The main objectives were to profile serum concentrations of progesterone and estradiol-17β from October to April in captive pregnant and nonpregnant black bears and to determine the feasibility of using serum progesterone concentrations as an indicator of pregnancy.

Physiological study of captive male bears by Ralph Nelson and colleagues (Nelson et al. 1973, Nelson et al. 1975, Lundberg et al. 1976) has provided data on many aspects of protein and fat metabolism during black bear hibernation. This work, combined with field studies (Nelson et al. 1984, Franzmann and Schwartz 1988) indicates that concentrations of most serum chemistries remain stable during hibernation. Notable exceptions are serum urea, serum creatinine, total protein, and several lipid components (Nelson et al. 1975, Ahlquist et al. 1984, Nelson et al. 1984, Franzmann and Schwartz 1988, Storm et al. 1988). However, these studies sampled only 1-3 times during both active and hibernating phases. Secondary to the objectives relating to endocrine function, I wanted to collect serial data on serum chemistry in the adult female black bear to examine time-related changes in physiology during hibernation. Data on rectal temperature and body weight dynamics also were collected to better characterize hibernation in the female black bear.

MATERIALS AND METHODS

Maintenance and Handling

Female bears, either captive-born (N = 2, Bears 1 and 2) or wild-caught (N = 4, Bears 3, 4, 6 and 7) after 1 August, were maintained in captivity at Center Woods Research Facility at Virginia Polytechnic Institute and State University (VPISU). Bears were held separately in circular holding pens (Behlen Manufacturing Company, Columbus, NE 68601) in an unheated, covered, open pole barn. Pens were 5m in diameter and 3m in height and were constructed of 0.5cm steel bars in a grid pattern. Pens were in 2 rows of 3, anchored to an asphalt floor, and separated by wooden planks and chain-link fencing. Pen centers were 12m

apart. Dens and nesting material (straw) were provided. A pilot study using the 2 captive-born bears was conducted from December 1986 to March 1987 to determine the feasibility of immobilizing individuals every 10 days. No difficulties were observed. Thus, the present study (during the fall and winter of 1987-1988) was conducted.

The captive-born bears were held at Maymount Zoological Park in Richmond Virginia prior to arrival at VPISU. They were exposed to a fertile male from mid-May to late September. However, keepers reported no breeding activity during this period. All wild-caught females were not lactating and had access to males until capture in August or September. Breeding activity could not be monitored.

Food (ZuPreem omnivore chow, Hill's Foods, Topeka, KS 66601, 20% crude protein, 6% crude fiber, 4% crude fat) and water were provided until onset of denning behavior. All bears were fed 1.0 kg of chow daily until 30 September. From 1 October to 7 December, 2.0 kg of food was provided daily to increase weight. Daily rations were reduced to 1.0 kg/day on 7 December, 0.75 kg/day on 14 December, 0.50 kg/day on 21 December, and 0.25 kg/day on 5 January in an attempt to simulate field conditions. Feeding frequency also was reduced to every two days to reduce disturbance. If bears did not consume all offered food on 2 separate occasions, food was no longer provided. Food was not provided to hibernators once food intake ceased until body weights returned to pre-experimental (late summer) levels. Water was provided throughout the experiment. Constant freezing and thawing made it difficult to monitor water intake. However, water was consumed on occasion by hibernating bears, e.g., Bear 2 was observed drinking and urinating on 24 February and on 5 March.

During 29 September 1987 to 30 March 1988, captives were immobilized between 0800 and 1200 hours at approximately 10 day intervals with a 2: 1 mixture of ketamine hydrochloride and xylazine hydrochloride at a concentration of 300 mg/ml. Initial dosage rate was 6.6 mg/kg estimated body weight and was administered by jabstick or Cap-Chur gun. Sampling periods consisted of sampling 3 bears on each of 2 consecutive days. Each bear was immobilized 18 times during the experiment. Food was last provided 24 hours before immobilization. Weights were determined to the nearest kg with a hanging spring scale and

rectal temperature was determined to the nearest 0.5 C. Blood samples were collected from a femoral vein using a vacuum tube assembly as soon as possible following immobilization. Each sample consisted of three 10-ml clot tubes and one 7-ml tube containing heparin. Blood tubes were centrifuged at 1450 RCF for 15-20 minutes within 2 hours after collection. Serum was harvested and stored frozen at -20 C for later analysis.

Ultrasound analysis was performed on all bears during the January 13-14 sampling period using an Aloka Model 210 (Corometrics Medical Systems, Inc., 61 Barns Park Road North, Wallingford, CT 06492) with a linear array and 5 mHz probe. Bears were shaved on their lower abdomen and scanning was done transabdominally.

Cubs of captive females were weighed to the nearest g using a triple beam balance or a Mettler P11N analytical balance. Total length and head length were measured with a cloth tape to the nearest mm. Ear length was measured with dial calipers.

Blood samples also were collected from female bears trapped from June 1984 to August 1986 on the 440 km^2 Great Dismal Swamp National Wildlife Refuge (GDSNWR), part of the 850 km^2 Great Dismal Swamp (GDS). GDS is a forested wetland located on the Virginia-North Carolina border on the mid-Atlantic Coastal Plain. A description of the study area and trapping and handling techniques can be found in Hellgren and Vaughan (1987).

Trapped females were assessed for reproductive status (estrus, nonestrus, lactating). The estrous or nonestrous condition was evaluated by degree of vulval swelling. Teat length and width was measured to distinguish between nulliparous and parous individuals. In solitary adult females, reproductive status (pregnant, nonpregnant) at time of sampling was determined by den monitoring in winter.

Serum Analyses

Frozen serum samples from captive animals were sent as a batch to SmithKline Veterinary Laboratory (Tucker, GA 30084) at the end of sample collections in March. Serum chemistry analyses were performed using a Technicon autoanalyzer SMAC-2 using procedures specified by the manufacturer. Serum values measured were total protein, albumin, globulin, total bilirubin, alkaline phosphatase, aspartate aminotransferase (SGOT), alanine aminotranferase (SGPT), total cholesterol, glucose, urea nitrogen (SUN) creatinine, calcium, phosphorus, sodium, potassium, and chloride. Urea/Creatinine (U/C) ratio was determined as SUN/0.466/creatinine (Nelson et al. 1984). Level of hemolysis was determined by ocular estimation (Frank et al. 1978). Samples with hemolysis of greater than + 2 (using the criteria of Frank et al.) were discarded from analyses due to the effect of hemolysis on serum constituents.

Serum concentrations of progesterone in both captive and wild females were determined by radioimmunoassay of 100 μl aliquots in duplicate without an extraction step using a kit provided by Diagnostic Products (Los Angeles, CA 90045). This procedure was modified for use with black bear serum by comparing standard curves obtained from progesterone standards prepared in male bear serum with the human standards supplied with the kit. These curves were parallel between progesterone concentrations of 0.1 ng/ml and 20 ng/ml (Fig. 13).

Validity of this method for assaying progesterone in bear serum was demonstrated by adding known amounts of nonradioactive hormone to aliquots of serum and assaying. Values obtained were compared between the standard curves prepared in male bear serum and human serum. Standards prepared in bear serum were used for the assays, as human prepared standards generally overestimated added progesterone (Table 23). Progesterone concentrations reported are relative to male bear serum. Displacement of bound progesterone by increasing volumes (50 μl, 75 μl, 100 μl) of a bear serum pool also was parallel to the standard curve. Mean ($\pm$ SE) concentrations of P in the serum pool for these volumes were

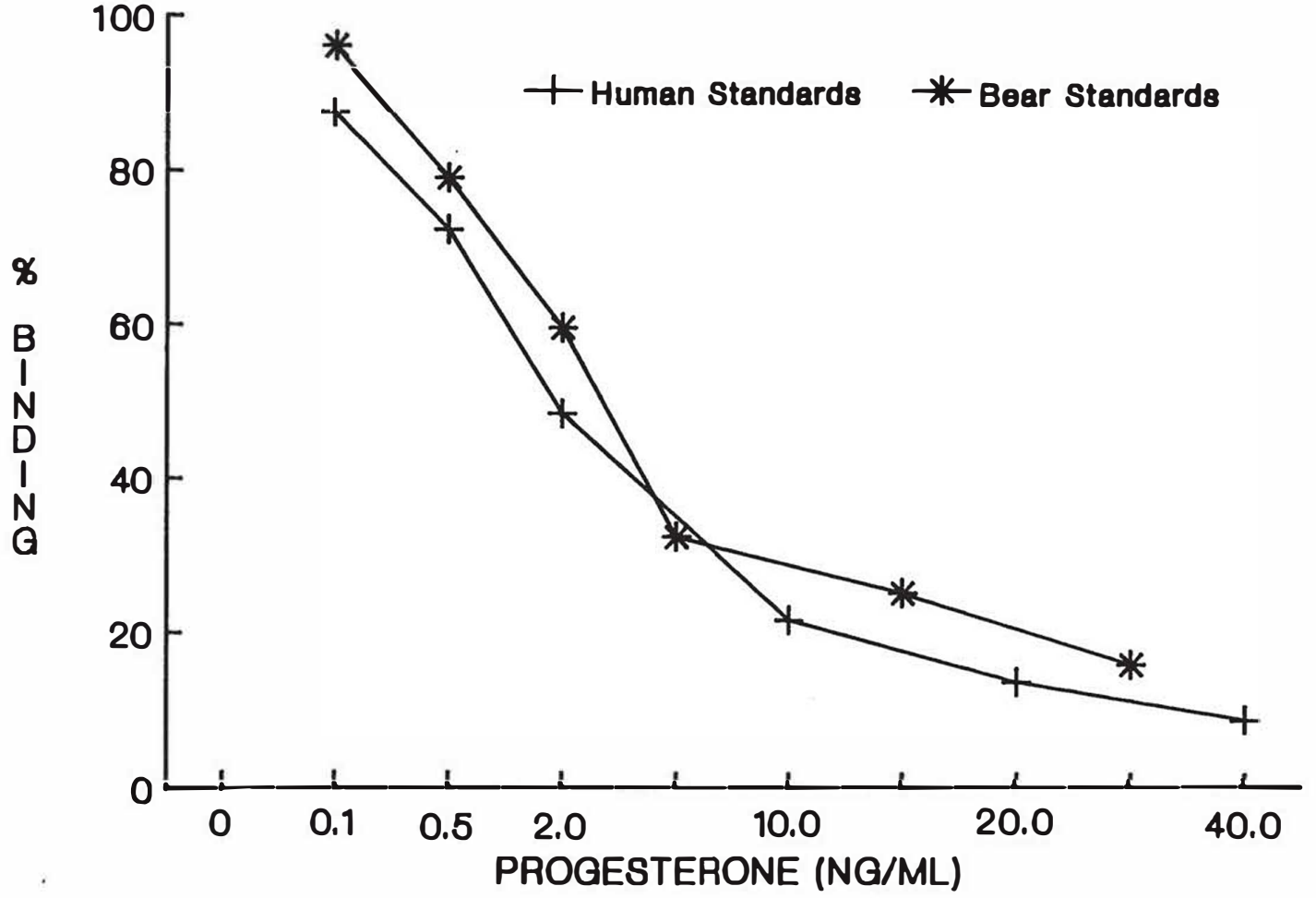

Figure 13. Relationship of % progesterone-antibody binding to progesterone concentration in standards prepared in human serum and bear serum.

Table 23. Recovery of added unlabeled progesterone from male black bear serum assayed against human serum prepared standards.

Progesterone added (pg)	Progesterone Measured (pg)			
	Human Serum ($N=3$)		Bear Serum ($N=2$)	
	Mean	SE	Mean	SE
10	7.3	3.9	9	--
50	76.5	0.5	56	3.0
200	221.3	16.0	188	14.0
750	904.7	117.4	855	14.5
1250	1416.7	134.0	1204	16.0
2500	2940.7	256.9	2354	121.0

8.12 ± 0.26 ng/ml, 7.66 ± 0.44 ng/ml, and 7.36 ± 0.12 ng/ml, respectively. Assay sensitivity, defined as the least amount of hormone that could be detected from 0, was 0.1 ng/ml or 10 pg per tube. Intraassay and interassay coefficents of variation for the progesterone assays were 6.1% and 11.2%, respectively.

Serum concentrations of estradiol-17β (E_2) in both captive and wild females were determined by radioimmunoassay of 500 μl aliquots in duplicate without an extraction step using a kit provided by Diagnostic Products (Los Angeles, CA 90045). This procedure was modified for use with black bear serum by comparing standard curves obtained from E_2 standards male bear serum with the human standards supplied with the kit. These curves were parallel between E_2 concentrations of 50 pg/ml and 1000 pg/ml (Fig. 14).

Validity of this method for assaying E_2 in bear serum was demonstrated by adding known amounts of nonradioactive hormone to aliquots of serum and assaying. Values obtained were compared between the standard curves prepared in male bear serum and human serum. Standards prepared in bear serum were used for the assays, as human prepared standards generally underestimated added E_2 (Table 24). Displacement of bound E_2 by increasing volumes (500 μl, 750 μl, 1000 μl) of a bear serum pool also was parallel to the standard curve. Mean concentrations of E_2 in the serum pool for these volumes were 15.36 ± 0.36 pg/ml., 18.95 ± 1.12 pg/ml, and 19.48 ± 0.24 pg/ml, respectively. Assay sensitivity, defined as the least amount of hormone that could be detected from 0, was 10 pg/ml, or 5 pg per tube. Intraassay and interassay coefficients of variation for the E_2 assays ($\underline{N} = 3$) were 7.2% and 14.6%, respectively.

Statistical Analysis

Bears were divided into 2 groups: hibernating ($\underline{N} = 4$) and nonhibernating (or active) ($\underline{N} = 2$) for statistical analysis of serum chemistry, body weight, and rectal temperature. As

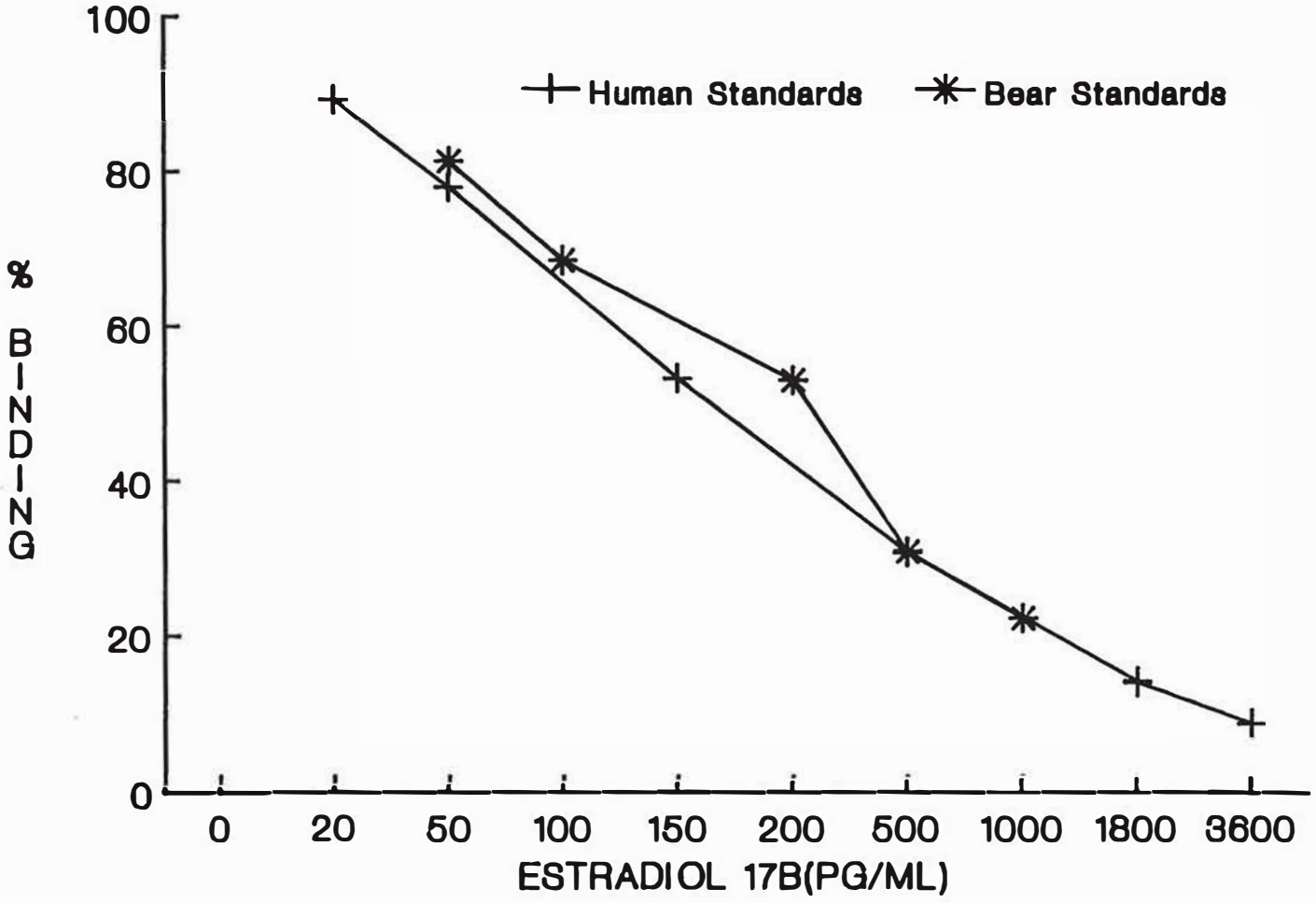

Figure 14. Relationship of % estradiol-17β-antibody binding to estradiol-17β concentration in standards prepared in human serum and bear serum.

Table 24. Recovery of added unlabeled estradiol-17β from male black bear serum assayed against human serum prepared standards.

Estradiol-17β added (pg)	Estradiol-17β Measured (pg)			
	Human Serum ($N=3$)		Bear Serum ($N=4$)	
	Mean	SE	Mean	SE
5	0.5	0.2	4.9	0.3
10	6.4	0.5	10.7	0.5
20	17.4	2.5	20.9	0.9
50	49.5	10.7	50.1	1.6
100	77.6[1]	--	95.7[2]	2.0

[1] $N=1$.

[2] $N=2$.

individuals stopped feeding on dates ranging from 4 December to 10 January, sampling periods were calibrated to interval before and interval after cessation of eating. The mean date of cessation of food intake was used to calibrate sampling interval of active bears. Fifteen sampling periods were used, as at least 5 bears were sampled 7 times before (prehibernation or fall phase) and 8 times after (hibernation or winter phase) food intake ceased. Serum chemistry data were tested for normality (PROC UNIVARIATE, Sas Institute Inc. 1982) using model residuals prior to analysis of variance. Non-normal variables were log-transformed and retested for normality. Data were analyzed by an analysis of variance model for repeated measures with group as the main effect, sampling interval as the repeated measures effect, and the group-sample interaction (PROC GLM, Sas Institute Inc. 1982). Progesterone and E_2 data in adult wild bears were analyzed by analysis of variance with reproductive group (e.g., pregnant, lactating, etc.) as the main effect. Means were separated ($\underline{P} < 0.05$) using Tukey's studentized range procedure (Sas Institute Inc. 1982).

RESULTS

Two bears continued to eat throughout the experimental period and were placed on a 1.0 kg/day diet on 15 January for the remainder of the study. Four bears entered hibernation (Table 25). Onset of hibernation, which was considered the cessation of food intake, ranged from 4 December to 10 January (Table 25). Three of these animals, 2, 4 and 6, constructed nests within the provided nest boxes. The fourth hibernator, 7, constructed a large, well-built nest outside the den box but often was observed pacing in the cage during winter. Hibernating animals generally were alert during feedings of the active, nonhibernating bears (1 and 3). The active animals did not nest and often paced in their cages during winter. Length of hibernation averaged 94 d (Table 25).

Table 25. Characteristics of adult female black bears held in captivity at Virginia Polytechnic Institute and State University, September 1987 to April 1988

Bear ID	Source[1]	Initial Weight[2] (kg)	Peak Weight (kg)	Date of Parturition	Cubs Produced	Onset of Denning Behavior	Cessation of Food Intake	Beginning of Feeding	Days Hibernated	Daily Weight Loss (kg/day)
1	zoo	123	132	---	---	---	---	---	---	---
2	zoo	148	150	---	---	28 Nov	4 Dec	30 Mar[3]	117	0.225
3	wild	54	77	---	---	---	---	---	---	---
4	wild	70	100	2 Feb	2	12 Dec	12 Dec	12 Apr	121	0.271
6	wild	72	93	1 Feb	2	5 Jan	10 Jan	1 Apr	81	0.277
7	wild	57	80	---	---	---[4]	2 Jan	27 Feb	56	0.312

[1] Zoo bears obtained from Richmond Maymount Zoological Park. Wild-caught bears were captured in the Shenandoah Mountains area.

[2] On 30 September.

[3] Still hibernating when returned to zoo on 30 March.

[4] Did not use den box. Nested outside.

Rectal temperatures did not vary by physiological group ($P = 0.60$), but did vary by sampling period ($P < 0.001$)(Fig.15). There was also a significant ($P = 0.013$) sample-group interaction. Temperatures declined in both groups during winter, but to a greater extent in the hibernating animals. Mean ± SE temperature was 38.0 ± 0.1 ($N = 41$) during the fall feeding phase and 36.8 ± 0.1 ($N = 41$) during the winter dormant period (Bears 1 and 3 were fed maintenance rations during this time). Minimum recorded rectal temperature in hibernating bears was 35.5 C ($N = 3$).

Body weight varied according to sampling interval ($P < 0.001$) (Fig. 16), increasing during the fall period and declining during winter hibernation. Weights of hibernating bears 6 and 7 declined prior to the onset of hibernation because of food reductions (see Materials and Methods). Average daily weight gain of the 4 wild bears for the fall period was 393 g/d , with total weight gains averaging 38.7%. Weight gains of captive-born bears were not calculated, as they began the experiment 2-3 times heavier than wild-caught bears. Average weight loss for hibernating individuals was 271 g/d ($N = 4$)(Table 25) and total weight loss was 27.9% of peak body weight. Daily weight loss was least for the hibernating captive-born bear, intermediate for the females with newborn cubs, and highest for bear 7, which was the most 'active' of the hibernating group (Table 25).

Four cubs (2M, 2F) were born to 2 females. Weights at < 3 days postpartum were 262(F), 282(M), 328(M), and 332(F)g. The male cub of Bear 6 disappeared between 3 and 14 days postpartum. Ten days after the disappearance was noted, a large scat was collected from the pen of Bear 6. Although it is suspected that the female ate the neonate, fecal analysis was inconclusive. Cub growth rates were linear until mothers were placed back on Omnivore chow in April, at which time growth rates became exponential (Fig. 17) (Appendix Table 27). Eyes opened for 2 of the 3 cubs between 33 and 44 days of age, with the third cub opening her eyes between 44 and 54 days.

Four serum characteristics, total protein, SUN, creatinine,and U/C ratio, were affected ($P \leq 0.025$) by a sample-group interaction (Table 26). In general, these characteristics were similar between groups during the prehibernation phase, but differed after the onset of

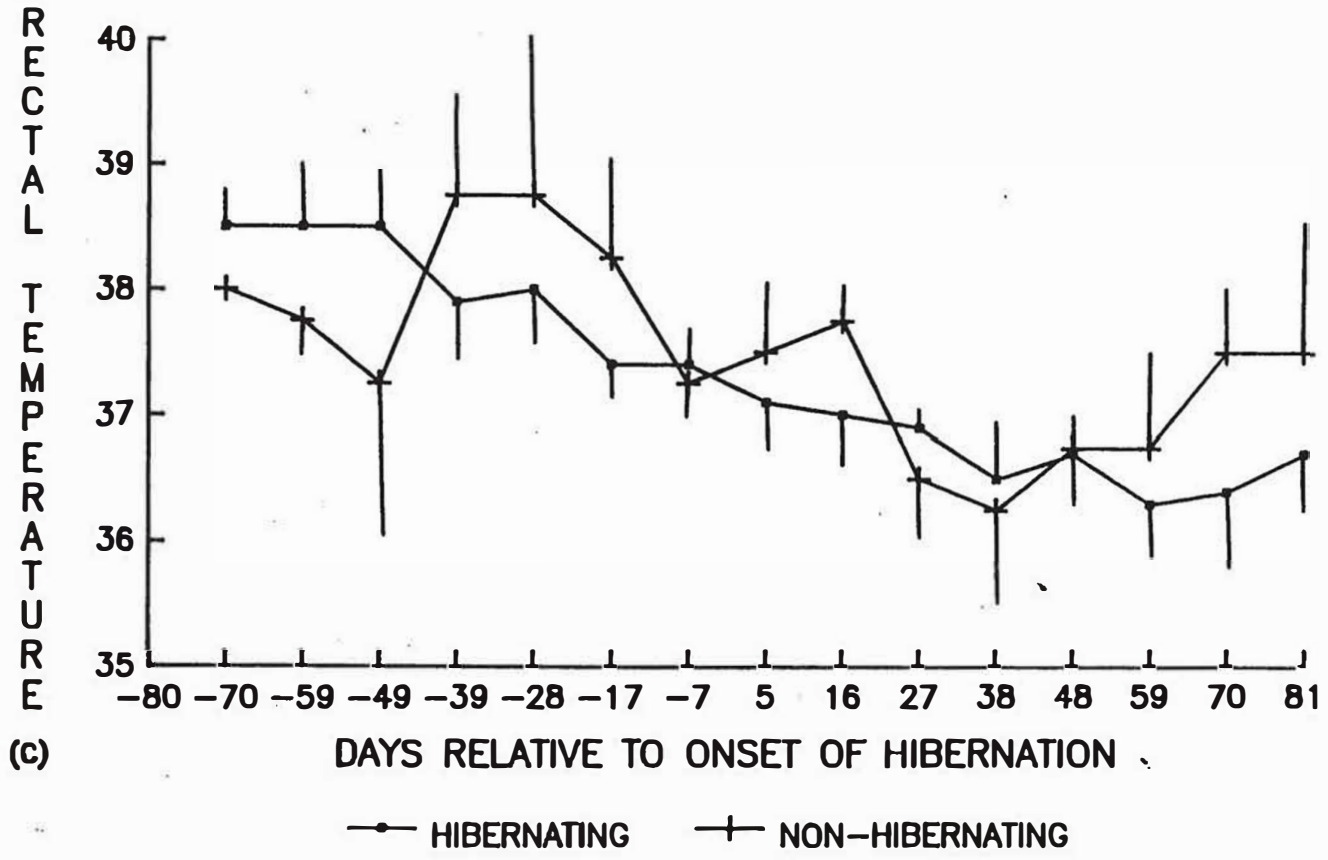

Figure 15. Changes in rectal temperature in active (N = 2) and hibernating (N = 4) captive female black bears from September 1987 to March 1988.: Vertical bars represent standard error. Days on X-axis represent midpoint of 10-day interval.

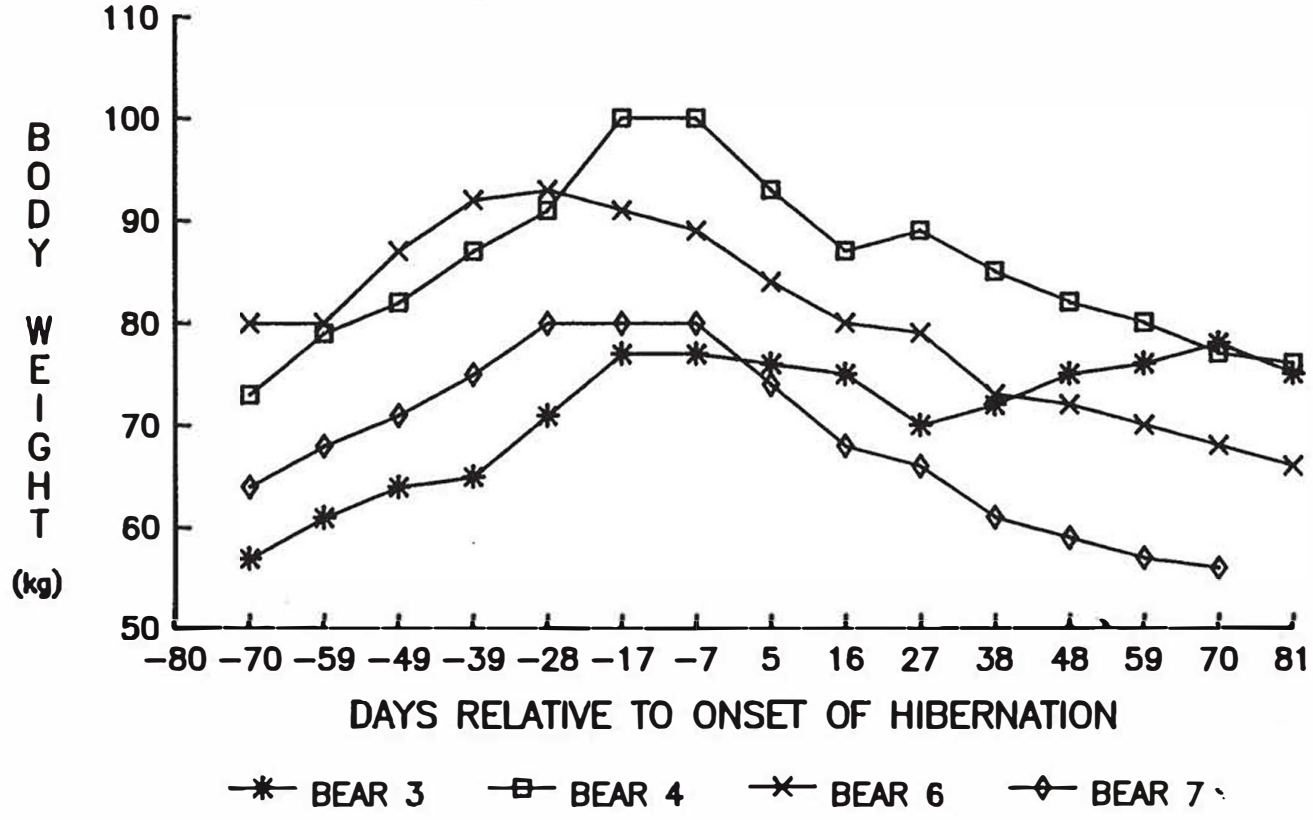

Figure 16. Changes in body weight (kg) in wild-trapped, captive female black bears from September 1987 to March 1988.: Bear 3 was fed throughout the experimental period. Days on X-axis represent midpoint of 10-day interval.

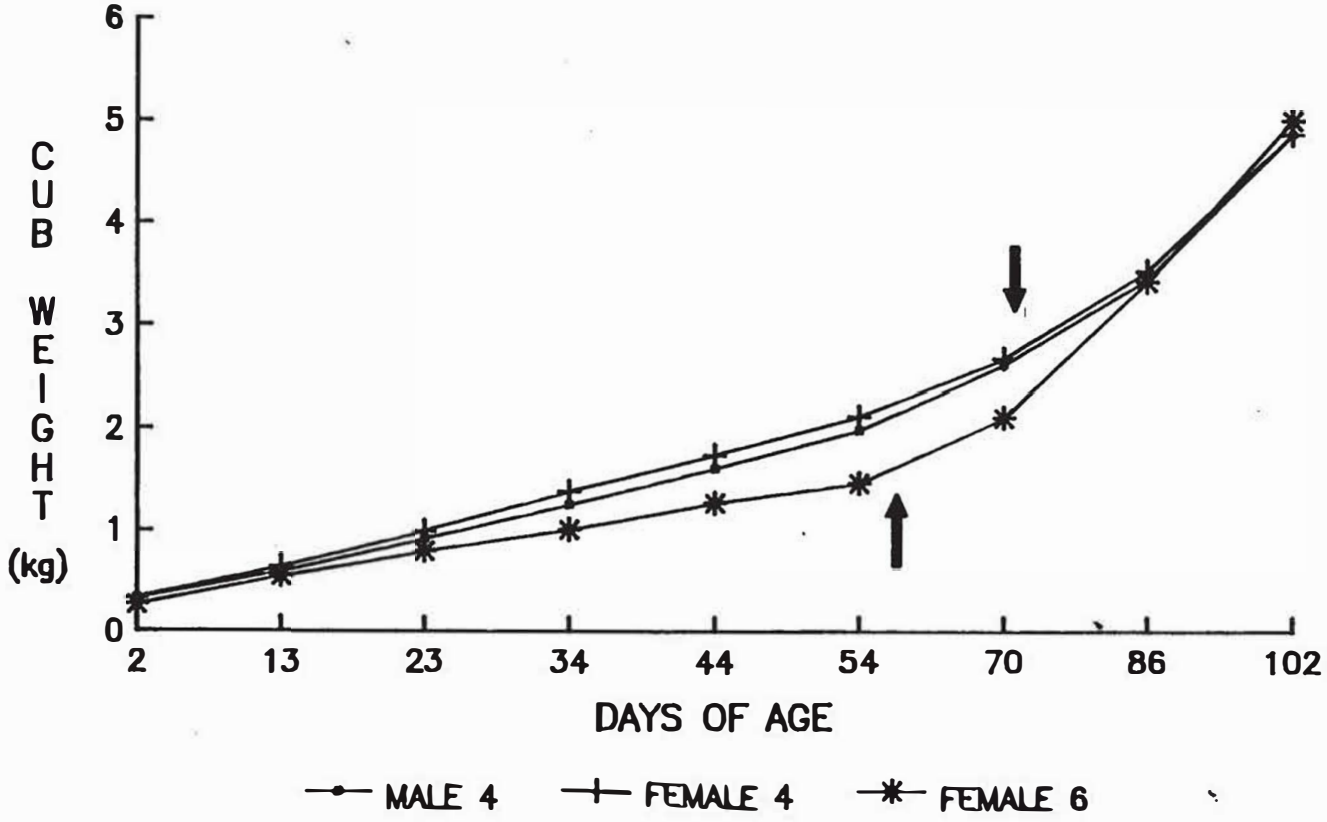

Figure 17. Changes in body weight (kg) of 3 black bear cubs from birth to 102 days of age. Arrows represent time when mother bears were refed 1 kg chow/day.

Table 26. Mean (SE) concentrations of serum chemistries from September to March for hibernating ($N = 4$) and active ($N = 2$) adult female black bears significantly ($P < 0.1$) affected by time.

Days Relative to Hibernation Group	Total Protein (g/dl) $\bar{x}$	Total Protein (g/dl) SE	Albumin (g/dl) $\bar{x}$	Albumin (g/dl) SE	SUN (mg/dl) $\bar{x}$	SUN (mg/dl) SE	Creatinine (mg/dl) $\bar{x}$	Creatinine (mg/dl) SE	Urea/Crea[2] Ratio $\bar{x}$	Urea/Crea[2] Ratio SE
Days pre onset										
64-76										
Hibernating	7.0	0.3	4.2	0.2	25.0	3.0	1.7	0.1	31.8	2.2
Active	7.1	0.1	4.1	0.2	19.0	2.0	1.6	0.3	26.9	7.7
54-64										
Hibernating	6.8	0.2	4.0	0.1	24.3	3.1	1.7	0.1	30.5	2.7
Active	7.1	0.3	4.0	0.3	24.0	1.0	1.5	0.2	35.7	2.2
44-54										
Hibernating	6.9	0.2	4.1	0.2	24.0	2.0	1.6	0.2	34.2	3.4
Active	7.0	0.3	4.1	0.2	25.5	3.5	2.0	0.6	31.7	12.8
34-44										
Hibernating	6.8	0.3	4.2	0.1	23.5	2.7	1.5	0.2	33.9	2.3
Active	6.9	0.2	4.1	0.3	25.0	2.0	1.7	0.4	32.8	5.2
24-32										
Hibernating	6.8	0.2	4.2	0.1	23.8	2.1	1.8	0.1	28.5	2.6
Active	6.8	0.1	4.2	0.3	25.5	3.5	1.8	0.3	32.5	8.9
11-22										
Hibernating	6.9	0.1	4.1	0.1	22.5	1.5	2.1	0.2	24.1	2.8
Active	6.6	0.3	4.0	0.3	15.0	8.0	1.6	0.8	20.1	1.3
1-12										
Hibernating	7.3	0.3	4.2	0.2	17.0	3.6	2.0	0.3	21.7	7.7
Active	7.2	0.1	4.3	0.2	21.5	3.5	2.0	0.2	23.7	6.1
Days post onset										
2-9										
Hibernating	7.4	0.3	4.4	0.2	14.3	2.5	2.5	0.1	12.6	2.3
Active	7.0	0.0	4.3	0.1	19.0	1.0	2.4	0.2	17.2	2.3
12-21										
Hibernating	7.4	0.2	4.3	0.1	13.5	2.2	3.1	0.1	9.4	1.6
Active	6.9	0.2	4.3	0.1	24.5	0.5	2.3	0.1	22.9	1.5
23-32										
Hibernating	7.7	0.2	4.5	0.2	12.3	2.2	2.9	0.1	9.3	1.8
Active	7.2	0.1	4.6	0.1	15.5	2.5	2.7	0.1	12.3	1.5
33-43										
Hibernating	7.5	0.3	4.4	0.2	13.5	1.8	3.1	0.1	9.5	1.4
Active	6.9	0.1	4.3	0.3	15.0	3.5	2.1	0.2	15.2	1.6
43-53										
Hibernating	7.4	0.3	4.5	0.2	11.5	1.8	3.1	0.3	7.9	1.2
Active	6.7	0.2	4.2	0.4	16.5	5.5	2.3	0.3	15.0	3.2
54-64										
Hibernating	7.3	0.3	4.4	0.1	12.5	3.0	3.3	0.2	8.0	1.8
Active	6.6	0.2	4.1	0.3	21.5	0.5	1.9	0.2	24.6	3.2
65-74										
Hibernating[1]	7.5	0.5	4.3	0.2	9.0	1.7	3.1	0.2	6.1	0.9
Active	6.4	0.4	4.1	0.1	24.5	2.5	2.1	0.3	25.7	0.5
77-85										
Hibernating[1]	7.3	0.4	4.0	0.1	8.3	1.3	3.0	0.5	6.1	0.9
Active	6.7	0.4	4.3	0.1	21.5	3.5	2.2	0.3	21.3	1.0
Anova F-value (P)										
Group	0.77	0.43	0.14	0.73	1.46	0.29	5.42	0.08	5.20	0.08
Sample	2.57	< 0.01	1.64	0.10	7.50	< 0.01	9.64	< 0.01	13.79	< 0.01
Group*Sample	2.64	< 0.01	0.44	0.95	4.15	< 0.01	3.03	< 0.01	4.68	< 0.01

[1] $N = 3$
[2] log-transformed.

Table 26. (continued)

Days Relative to Hibernation Group	Phosphorus (mg/dl) $\bar{x}$	SE	Alkaline Phosphatase[2] (IU/l) $\bar{x}$	SE	Chloride (meq/l) $\bar{x}$	SE
Days pre onset						
64-76						
Hibernating	4.3	0.2	12.5	4.4	106	1
Active	5.3	0.1	11.0	2.0	104	1
54-64						
Hibernating	4.8	0.3	10.3	2.2	104	0
Active	5.4	0.5	9.5	0.5	103	3
44-54						
Hibernating	4.6	0.4	9.0	1.5	105	1
Active	4.4	0.6	12.0	2.0	102	4
34-44						
Hibernating	4.0	0.3	28.0	19.5	105	1
Active	4.8	0.2	12.0	2.0	103	1
24-32						
Hibernating	4.9	0.3	10.0	1.2	104	1
Active	4.9	0.9	10.0	3.0	104	3
11-22						
Hibernating	4.8	0.1	7.3	2.7	102	0
Active	4.6	0.7	84.5	70.0	103	2
1-12						
Hibernating	4.8	0.5	28.8	23.4	96	3
Active	5.6	0.4	11.0	1.0	102	1
Days post onset						
2-9						
Hibernating	5.0	0.4	4.3	0.7	102	1
Active	5.7	0.6	8.5	3.5	101	2
12-21						
Hibernating	5.1	0.3	6.0	0.9	99	1
Active	5.8	0.3	5.5	0.5	104	2
23-32						
Hibernating	5.6	0.3	4.3	0.9	100	2
Active	4.7	0.5	7.5	3.5	100	0
33-43						
Hibernating	5.2	0.3	5.8	1.1	100	1
Active	5.3	0.1	8.0	4.0	101	1
43-53						
Hibernating	5.3	0.2	4.3	0.9	101	2
Active	5.4	0.2	8.0	4.0	103	3
54-64						
Hibernating	5.0	0.3	4.5	0.6	104	1
Active	5.6	0.1	8.0	3.0	103	1
65-74						
Hibernating	5.4	0.1	5.3	0.7	101	2
Active	5.3	0.1	10.0	2.0	102	2
77-85						
Hibernating	5.5	0.6	5.0	0.6	102	2
Active	5.2	0.4	9.5	2.5	102	5
Anova F-value (*P*)						
Group	0.70	0.45	4.27	0.11	0.05	0.84
Sample	1.93	0.04	1.75	0.07	1.92	0.04
Group*Sample	1.25	0.27	0.96	0.50	1.04	0.43

hibernation in December and January (Table 26, Fig. 18, Appendix Table 28). Mean U/C ratios were 29.3 ± 1.5 ($\underline{N}$ = 28) for hibernators and 29.1 ± 2.5 ($\underline{N}$ = 14) for nonhibernators during fall. About 30 days before food intake ceased, U/C ratios began to decline (Table 26, Fig. 18). After the onset of hibernation, U/C ratios declined below 10 for all hibernating bears ($\bar{x}$ ± SE = 8.8 ± 0.6; $\underline{N}$ = 30)(Fig. 18). U/C ratios also declined in active bears during this period, but remained above 10 ($\bar{x}$ ± SE = 19.3 ± 1.3; $\underline{N}$ = 16)(Fig. 18). Concentrations of SUN and creatinine, the 2 variables that produce the U/C ratio, had similar, but opposite, sample-group interaction effects ($P < 0.002$). SUN decreased and creatinine increased in hibernating bears during winter, while changing only slightly in active bears (Table 26). Total protein concentrations also had a strong sample-group interaction ($\underline{P} = 0.005$), increasing during the hibernating phase only in the hibernating group (Table 26, Fig. 19). Mean total protein concentrations in the hibernation group increased from 6.9 ± 0.1 g/dl ($\underline{N}$ = 28) during prehibernation to 7.4 ± 0.1 g/dl ($\underline{N}$ = 30) during hibernation.

Six serum chemistries and one ratio were affected ($\underline{P} < 0.05$) by sampling interval during the experiment (Table 26, Appendix Table 28). Effect of sampling interval on total protein, SUN, creatinine, and U/C ratio were discussed above with reference to the sample-group interaction. Phosphorus, chloride and alkaline phosphatase concentrations changed ($\underline{P} < 0.05$) during the course of the experiment (Table 26). Alkaline phosphatase and chloride showed a general decrease during winter, while phosphorus showed an increasing trend (Table 26). No group differences existed between these variables. Eight other serum chemistries and one ratio remained fairly stable over time and physiological state (Table 27, Appendix Table 28).

Serum progesterone concentrations in 2 bears (4 and 6) that produced cubs showed a slight rise during the delay (pre-implantation) phase, ranging from 1.76 to 5.31 ng/ml (Fig. 20). Progesterone concentrations increased 2-3 fold, to 18.72 and 9.90 ng/ml, 58 ± 5 days prepartum, apparently associated with implantation. Progesterone levels then declined during the post-implantation phase, reaching undetectable levels (< 0.1 ng/ml) 1 and 2 days postpartum (Fig. 20). In 3 of the 4 bears that did not produce observed cubs, progesterone

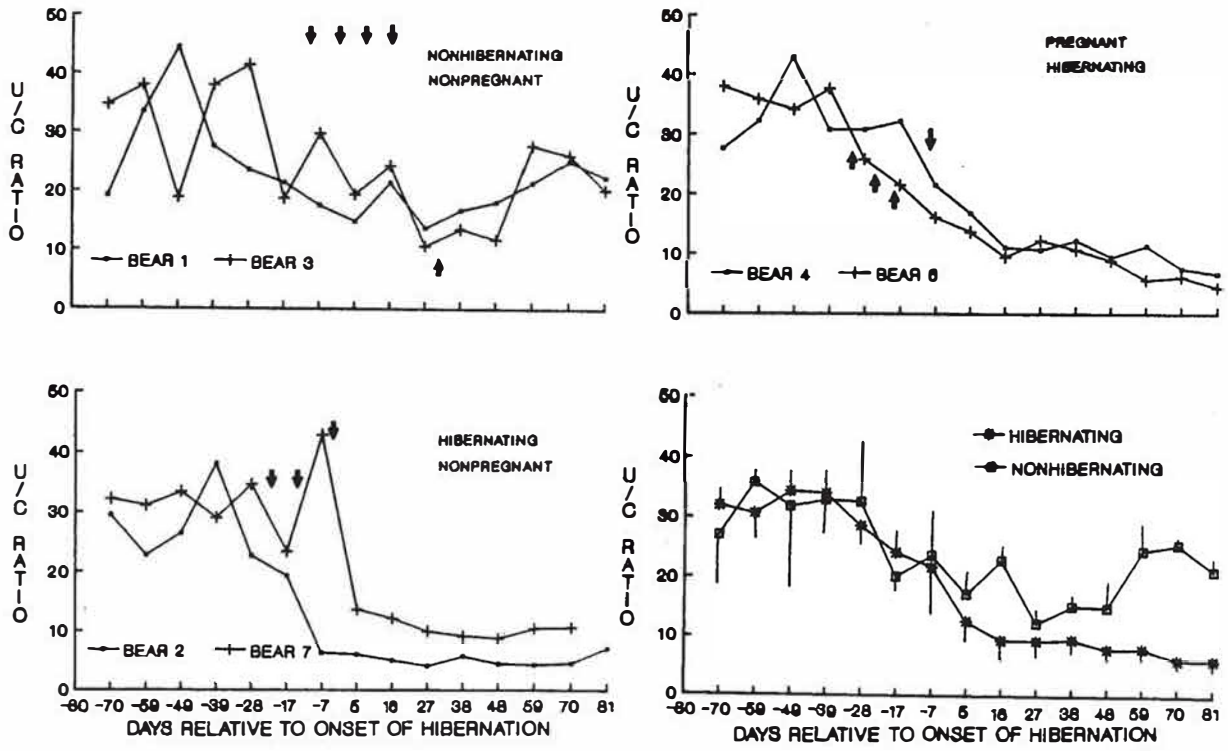

Figure 18. Urea/creatinine (U/C) ratio in 6 captive female black bears from September 1987 to March 1988. Day 0 represents cessation of food intake. Arrows represent times of food reduction.: Lower righthand figure is mean &PLM. S.E. for physiological group. Days on X-axis represent midpoint of 10-day interval. Mean date of hibernation was used to calibrate samples of nonhibernating bears.

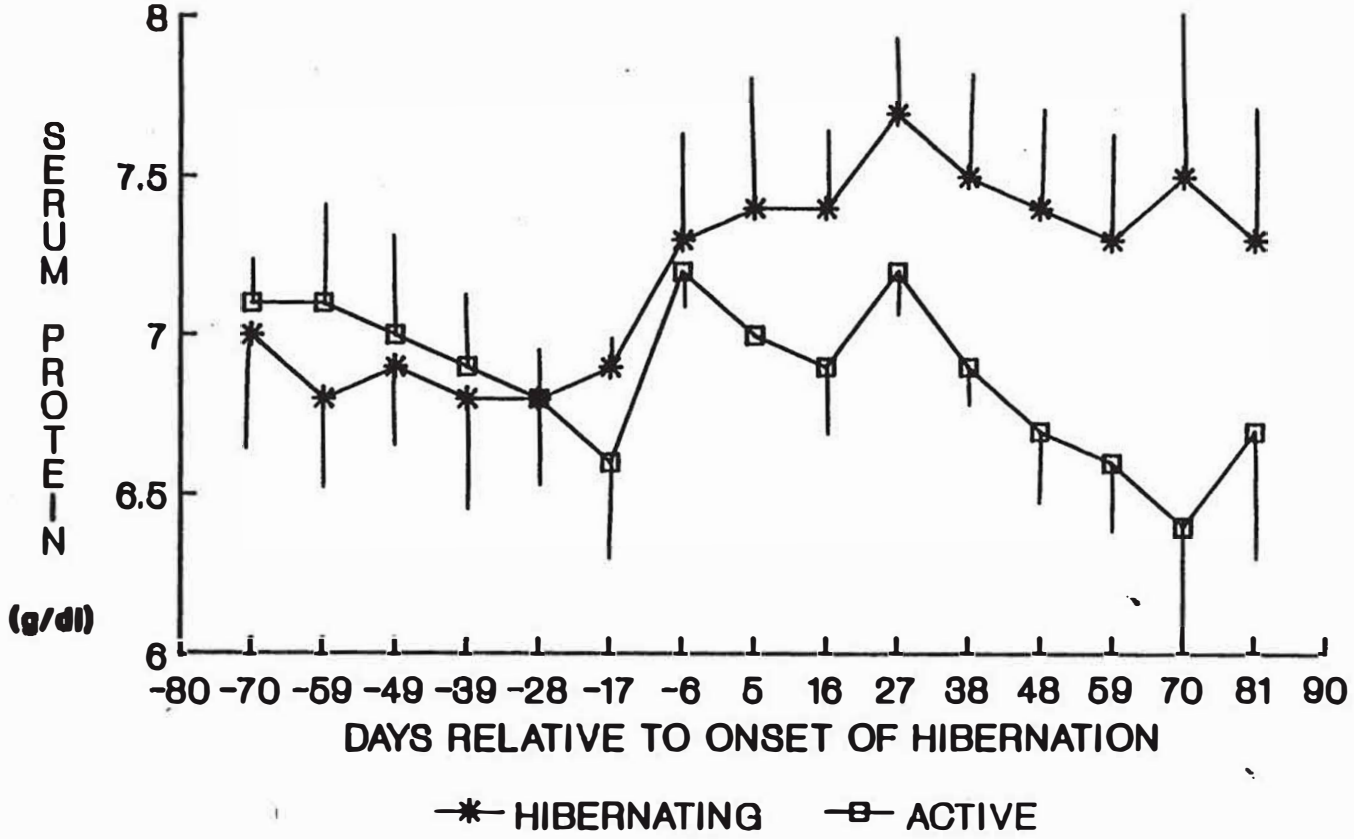

Figure 19. Mean serum protein (g/dl) concentration in hibernating and nonhibernating captive female black bears from September 1987 to March 1988. Day 0 represents cessation of food intake.: Vertical bars represent standard errors. Days on X-axis represent midpoint of 10-day interval. Mean date of hibernation was used to calibrate samples of nonhibernating bears.

Table 27. Mean concentrations of serum characteristics not affected by physiological state or sampling interval in 6 adult female black bears held in captivity at Virginia Polytechnic Institute and State University, September 1987 - March 1988.

Characteristic	PreHibernation Phase[1]			Hibernation Phase[2]		
	N	$\bar{x}$	SE	N	$\bar{x}$	SE
Globulin (g/dl)	42	2.8	0.1	46	2.9	0.1
Albumin/Globulin ratio	42	1.5	0.04	46	1.5	0.04
SGOT (IU/l)	42	55	3	46	50	3
SGPT (IU/l)	42	30	3	46	23	1
Cholesterol (mg/dl)	42	258	7	46	270	7
Glucose (mg/dl)	42	118	6	46	107	5
Calcium (mg/dl)	42	8.5	0.1	46	8.6	0.1
Sodium (meQ/l)	42	137	0.6	46	135	0.4
Potassium (mEq/l)	42	4.5	0.1	46	4.5	0.1

[1] PreHibernation Phase represents 7 samples collected from each bear from 29 September to 4 January.

[2] Hibernation phase represents 8 samples collected from each bear from 10 December to 30 March (one individual was sampled 6 times).

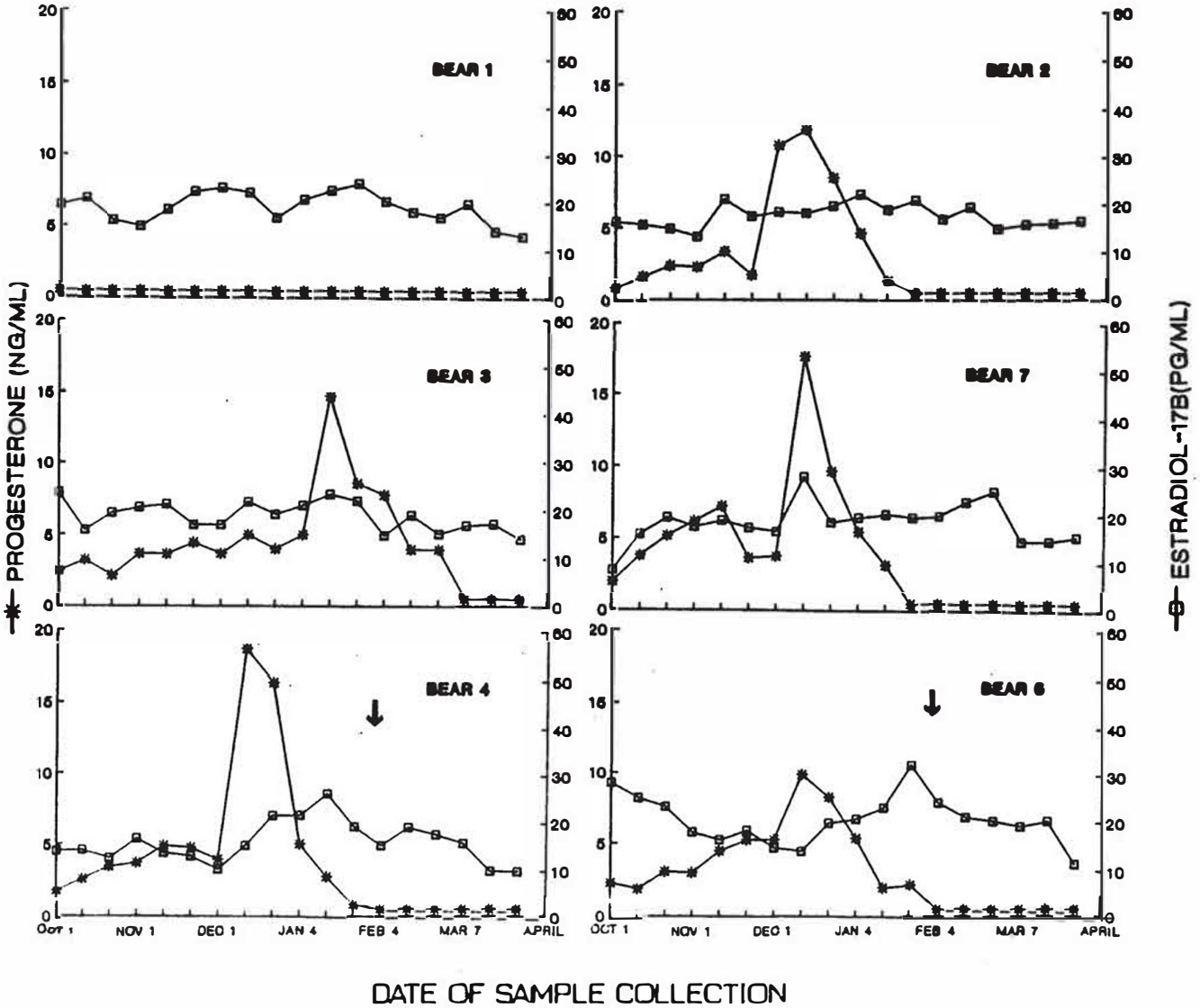

Figure 20. Serum progesterone and estradiol-17β concentrations in captive female black bears from 29 September 1987 to 30 March 1988. Arrows represent time of parturition for bears 4 and 6.: Bears 1 and 3 did not hibernate.

profiles were very similar to the above profiles (Fig. 20). In 2 of these animals (2 and 7), a 2-3 fold increase occurred at a similar time as the 2 bears that produced cubs. Declines to baseline levels occurred 45 to 65 days after the peak (Fig. 20). Bear 3 had the same pattern of progesterone changes as the 2 bears that gave birth, but the progesterone peak occurred 30 days later (Fig. 20). The fourth bear that did not produce observed cubs, Bear 1, had undetectable progesterone levels throughout the experiment (Fig. 20).

Fetal heartbeats were observed during ultrasound analysis on January 13-14 in Bears 4, 6 and 7. Bears 4 and 6 produced cubs, but Bear 7 did not. Serum progesterone concentrations in Bear 7 declined to basal concentrations by the next sampling period (January 25)(Fig. 20). No followup ultrasound analysis was performed.

Progesterone levels in wild-caught bears were low (< 0.2 ng/ml) or undetectable in yearlings, with the exception of one heat-stressed animal that died soon after handling (Table 28). Prebreeding, estrus, and lactating adults also had low or undetectable progesterone concentrations, regardless of time of year. Only one bear from these groups, a 6-year old female with captured in December with 2 cubs, had a progesterone concentration > 0.2 ng/ml. Serum progesterone concentrations in pregnant bears (verified by winter den observations) had low variance and all were > 0.35 ng/ml (Included in this group was a female which was sampled on 23 September and subsequently harvested on October 19. The reproductive tract of this animal contained 1 corpora luteum.). Nonproductive bears (solitary adults that did not produce observed cubs in winter) and bears of unknown status had progesterone levels greater ($P < 0.05$) than all other groups of adult females except pregnant individuals (Table 28).

Serum E_2 concentrations ranged from 8.3 to 27.9 pg/ml for captive bears that did not produce cubs and from 9.0 to 32.0 pg.ml for known pregnant captive bears (Fig. 19). It appeared that E_2 concentrations decreased prior to implantation, doubled during the time between implantation and parturition in Bears 4 and 6, then decreased to about 10 pg/ml during early lactation (Fig. 19). No surges of E_2 were observed at implantation or within 10 days prepartum. Except for a sharp increase in E_2 concentration in Bear 7 concomitant with

Table 28. Mean serum concentrations of progesterone (ng/ml) and estradiol-17β (pg/ml) in wild female black bears from Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

		Progesterone			Estradiol-17β			
Female Group	N	$\bar{x}$	SE	Range	$\bar{x}$	SE	Range	Range of Dates
Yearlings	8	0.27	0.17	0.10-1.48	17.8	1.4	12.8-24.5	9 Jul - 26 Nov
2.5 Years	4	0.70	0.42	0.10-1.89	19.8	1.4	17.0-23.6	4 Feb - 14 Aug
Adult - Prebreeding	2	0.10b[2]	0.0	---	17.7	3.9	13.8-21.6	23 May - 4 Jun
Adult - Estrus	2	0.10b	0.0	---	21.1	5.3	13.7-31.4	3 Jul - 4 Jul
Adult - Lactating	7	0.12b	0.02	0.10-0.24	17.5	2.1	9.3-26.9	19 Mar - 14 Dec
Adult - Pregnant[1]	6	0.72ab	0.15	0.35-1.37	17.0	1.4	12.7-20.5	9 Jul - 23 Sep
Adult - Nonproductive[1]	3	1.88a	0.70	0.58-3.02	17.5	1.1	15.4-19.1	10 Aug - 14 Oct
Adult - Unknown	4	1.35a	0.48	0.51-2.72	14.8	2.8	7.5-20.2	12 Jul - 26 Oct

[1] Pregnant and Nonproductive categories were determined by monitoring bears in dens.

[2] Means that share the same letter are not different ($P < 0.05$) according to Tukey's studentized range procedure.

an increase in progesterone (Fig. 19), E_2 concentrations were very stable in individuals not producing cubs. No differences ($P < 0.05$) were observed in serum E_2 concentrations among groups of wild adult females (Table 28). Serum E_2 concentrations of wild-caught bears ranged from 7.5 to 31.4 pg/ml (Table 28). A 3.5 year old female classified as being in estrus had the highest observed serum E_2 concentration (31.4 pg/ml) pg/ml) among wild-trapped animals.

DISCUSSION

The number of bear blood studies using the U/C ratio as an indicator of the hibernating state is rapidly increasing (Nelson et al. 1983, Nelson et al. 1984, Ramsay et al. 1985, Ensrud et al. 1986, Franzmann and Schwartz 1988, Storm et al. 1988). The present data support the hypothesis of Nelson et al. (1984) that hibernating bears have serum U/C ratios of ≤ 10. As reported by Nelson et al. (1984), the decrease in U/C ratios was due to a simultaneous decrease in urea and increase in creatinine concentrations. I have documented that this ratio is achieved soon after the cessation of food intake and is constant throughout the hibernation period. I also have shown a transition period of approximately 30 days before hibernation during which time the U/C ratio gradually declines to its hibernation level (Fig. 18).

Use of this ratio as an indicator of hibernation needs to be conservative, however. Although hibernating bears have been shown conclusively to have U/C ratios ≤ 10, it can not be said that all bears with ratios ≤ 10 are hibernating. In a field study in Great Dismal Swamp (GDS), Virginia-North Carolina (see Chapter 2), 32.5% (39 of 120) of all bears sampled had U/C ratios ≤ 10. Low ratios occurred in all months except October. Nelson et al. (1984) stated that bears undergo a gradual transition into the hibernating state, thus explaining ratios ≤ 10 in Colorado bears 8-9 weeks prior to denning. I believe that because of the strong positive

relationship between blood (or serum) urea nitrogen and dietary protein intake in monogastrics under conditions of adequate energy intake (Atinmo et al. 1974, Lochmiller 1984, Corn and Warren 1985), low U/C ratios in wild bears in late summer and fall may be dietary-related and thus not indicative of transition into hibernation. Fall foods of bears, such as oak (Quercus sp.) acorns and (Nyssa sylvatica) berries, are high in fats and carbohydrates, but low in protein (Short et al. 1976, Landers et al. 1979, Servello and Kirkpatrick 1987, Chapter 2). In GDS, several bears captured in September while feeding on these low-protein foods had U/C ratios $\leq$10. Serum creatinine levels in these individuals were normal (1.0-1.5 mg/dl), suggesting normal renal function, but urea nitrogen concentrations were very low (0-5 mg/dl). Two adult females in this group did not den for 11-13 weeks after capture and were known to be feeding until late November. U/C ratios also declined in active bears in the present study and this decline was associated with reductions in food and thus protein intake (Fig. 18). More work is necessary to elucidate the relationships between dietary protein intake, U/C ratio, and the hibernating state. Feeding diets of low protein levels (4-8%) during summer and measuring U/C ratios would be one way to address this question, as Nelson et al. (1975) have shown that starving black bears in the summer can not duplicate hibernation responses.

Increases observed in total serum protein ($P < 0.01$) and serum albumin ($P = 0.10$) concentrations have been predicted to occur based on changes in protein metabolism in hibernation (Lundberg et al. 1976, Nelson et al. 1983). However, the literature is somewhat inconsistent regarding hibernation changes in nitrogenous serum components. Although Lundberg et al. (1976) found that protein turnover, as measured by the disappearance of labeled albumin from serum and incorporation of labeled leucine into plasma protein, increased 3 to 5-fold during hibernation, they found no significant difference in albumin concentrations between active and hibernating states. Nelson et al. (1973) also reported no change in total protein concentrations during hibernation. A closer examination of these papers revealed that an increase in mean total protein of 0.5 g/dl occurred during hibernation (no significance level was reported) in Nelson et al. (1973). In Lundberg et al. (1976), albumin

levels were higher in 2 of 3 bears during hibernation, although sample sizes, standard errors, and significance levels were not reported. Subsequent reports in both captive (Ahlquist et al. 1984) and wild (Franzmann and Schwartz 1988, Chapter 2 this study) situations indicate that increases in total serum protein concentrations do occur during hibernation. Incorporation of nitrogen into plasma proteins apparently occurs at a faster rate than entry into the urea cycle and protein degradation, leading to decreases in blood urea and increases in serum protein (Table 26) (Nelson et al. 1983). Nelson et al. (1983) calculated an increase of 21g of plasma protein in a male bear containing approximately 70 liters of total body water. Assuming a blood volume of 5 liters and a hematocrit of 50%, the increase in total plasma protein would be 21g/5 l x 0.50 = 8.4 g/l or 0.84 g/dl. In the present study, serum protein increased 0.5 g/dl during hibernation.

Decreases in serum alkaline phosphatase concentrations during hibernation have been observed in both subadult and adult denning black bears in Alaska (Franzmann and Schwartz 1988). In the present study, both hibernating and active bears showed decreases in alkaline phosphatase concentrations from fall to winter. As alkaline phosphatase is involved with bone mineralization (Ferguson 1985: p. 166) I speculate that this decrease may be associated with reduced bone metabolism during winter.

Observed weight losses and rectal temperatures in hibernating bears were comparable to those in other studies, although disturbances (sampling, feedings) were numerous and ambient temperatures were warmer relative to previous studies. Body temperatures of hibernating bears have ranged from 31 to 36 C (Hock 1957, Erickson and Youatt 1961, Rausch 1961, Folk 1967, Craighead et al. 1976, Watts et al. 1981). Bears in this study were on the high end of this scale. Decreases in rectal temperature in active bears during winter (Fig. 14) suggest that a seasonal rhythm in metabolism may be involved (Moen 1978). Rectal temperatures in captive bears during fall activity (38.0 C) were similar to previously published observations (Hock 1957, Brown et al. 1971, Craighead et al. 1976).

Disturbance due to sampling may have played a role in large weight losses (27.9%) in hibernating individuals (Table 25, Fig. 15) by increasing energy use due to arousal, increased

heart rates, and activity. Weight losses have ranged from 15 to 27% of predenning body weight in captive bears (Hock 1957, Erickson and Youatt 1961, Nelson et al. 1973, Craighead et al. 1976, Folk et al. 1976) and 16 to 37% in wild bears (Tietje and Ruff 1980). Tietje and Ruff (1980) reported that weight loss was 56% greater for bears that abandoned dens due to disturbance than for undisturbed bears. Daily weight losses in the present study (Table 25) were 2-3 times greater than previously reported losses, which have ranged from 0.07 to 0.10 kg/day (Craighead et al. 1976, Tietje and Ruff 1980).

This study is the first to document serial changes in serum progesterone concentrations from pre-implantation to post-partum in the black bear. A previous study (Foresman and Daniel 1983) stopped sampling in mid-December after observing an abrupt increase in serum progesterone concentrations, apparently associated with implantation (the stoppage was due to logistical reasons). The progesterone profile in the black bear is very similar to that observed in the Hokkaido brown bear in Japan (Tsubota et al. 1987), with luteal activity (2-5 ng/ml) throughout the pre-implantation phase, an implantation-associated rise in progesterone about 2 months pre-partum, and a decline in progesterone concentrations to undetectable levels within 1-3 days post-partum. Data on pregnant polar bears (Ursus maritimus) shows similar trends in serum progesterone concentrations during pre-implantation and at implantation (Palmer et al. 1988).

Progesterone profiles similar to that of the black bear have been observed in other species with delayed implantation, such as mustelids (Mead 1981) and roe deer (Hoffman et al. 1978). An increase in serum progesterone concentrations associated with implantation is common among carnivores (Rowlands and Weir 1984). Progesterone is not believed to be the cause of implantation, as administration of exogenous progesterone does not shorten the delay phase nor induce implantation in mink, weasels, or western spotted skunks (Spilogale putorius)(Mead 1981, Mead et al. 1981). Daylength and changes in prolactin concentrations have been implicated in the termination of diapause in European badgers (Meles meles)(Canivenc and Bonnin 1981) and mink (Martinet et al. 1981), respectively.

The similarity of progesterone profiles in 3 of the 4 captive females that did not produce observed cubs to profiles of the 2 known pregnant bears is difficult to interpret (Fig. 20). Previous work in black bears has shown that females in lactational anestrus during the summer breeding season had low, baseline progesterone concentrations from September to December (Foresman and Daniel 1983). I propose 3 alternative explanations for the luteal activity in bears not producing cubs: (1) pseudopregnancy, (2) normal implantation followed by early embryonic mortality, or (3) normal pregnancy followed by infanticide. The latter possibility would be due to the stress of captivity, but is unlikely at least in the case of the female born in captivity that had evidence of luteal activity (Bear 2). This bear had successfully raised 2 litters in captivity. It may have occurred with Bear 7, which was diagnosed with a fetal heartbeat but never observed with cubs.

Pseudopregnancy is common among carnivores and also occurs in species that exhibit delayed implantation (Rowlands and Weir 1984). In this nonpregnant state, the ovaries and uterus function as though fertilization occurred after ovulation. The adaptive value of pseudopregnancy may be as a mechanism for pregnancy protection in species in which the blastocyst can not assure its own security prior to implantation (Schams et al. 1980). If the uterus can not detect the blastocyst due to its slowed metabolic activity, the response may be to provide the proper uterine environment in case the blastocyst does exist. Among felids, pseudopregnancy lasts about two-thirds the length of a normal pregnancy. During the pseudopregnancy, serum concentrations of progesterone and estradiol-17β are similar to those of pregnancy (Verhage et al. 1976, Bonney et al. 1981). Among canids (dog: Smith and McDonald 1974, Concannon et al. 1975, 1977; wolf (Canis lupus): Seal et al. 1979; red fox (Vulpes vulpes): Bonnin et al. 1978b) and some mustelids that exhibit delayed implantation (ferret (Mustela putorius): Heap and Hammond 1974; European badger: Bonnin et al. 1978a), pseudopregnancy, as measured by luteal activity and serum progesterone concentrations, lasts as long as normal pregnancy. However, serum progesterone concentrations and length of pseudopregnancy often are more variable than during pregnancy (Smith and McDonald 1974, Bonnin et al. 1978a).

Progesterone profiles of bears that produced cubs and bears that did not produce cubs were similar in the present study, but the time sequence of progesterone changes was more variable among the nonproducing bears (Fig. 20). Declines to baseline levels after the peak ranged from 45 to 65 days and one profile was offset 30 days from the other profiles (see Results). Besides this comparative evidence, pseudopregnancy has been documented in a captive Hokkaido brown bear (Tsubota et al. 1987). This brown bear was isolated from male bears throughout the year, yet exhibited changes in progesterone concentrations virtually identical to 4 pregnant individuals and may have spontaneously ovulated and formed corpora lutea. The incidence of pseudopregnancy among black bears could be easily documented with a vasectomized male and laparoscopic examination of bred females. Captive work also could document whether bears are induced ovulators. Histological evidence indicates that ovulation is induced in wild black bears (Wimsatt 1963, Erickson et al. 1964). However, no controlled, captive study has been performed to substantiate this phenomena.

Normal implantation followed by early embryonic mortality may have occurred in one or more of the captive bears. Nutritional or captivity stress may have caused resorption or abortion. Bears 3 and 7, which did not produce cubs but had evidence of luteal activity and, in the case of Bear 7, a fetal heartbeat, had the lowest body weights of the experimental animals (Fig. 16), reaching only 80 kg by late November. Rogers (1976) hypothesized that bears may somehow assess body fat stores and prevent implantation when reserves are considered inadequate to meet energetic demands of gestation and lactation. He found that nonlactating females weighing less than 67 kg on 1 October (N = 16) produced no cubs, whereas females weighing greater than 80 kg on that date produced cubs in 28 of 30 cases. Females weighing 67 to 80 kg (N = 8) had variable reproductive success. Virtually all of these animals had been observed with males and/or in estrus during the previous summer. Similarly, Elowe (1987) reported strong positive relationships between female fall energy intake, winter nutritional condition, and cub production. It is possible that Bears 3 and 7 had insufficient fat to maintain the pregnancy. They also may have terminated the pregnancy due to endocrine changes resulting from the stress of captivity.

Progesterone data from wild bears is equally difficult to interpret. Females captured prior to the breeding season, during estrus, or during lactation had uniformly low progesterone concentrations. A recent paper reported low progesterone concentrations throughout the year in a sample of 85 lactating or nonpregnant female black bears (Palmer et al. 1988). All known pregnant wild bears in the present study had elevated serum progesterone concentrations from late July to September. However, 3 solitary females captured between 10 August and 14 October that had elevated progesterone concentrations (Table 24) did not produce observed cubs in the den. The 3 explanations offered above for lack of production in the captive animals (pseudopregnancy, early embryonic mortality, cannibalism) also can be offered for these wild animals.

Changes in serum E_2 concentrations provided some information regarding reproductive status in the black bear. A decrease in E_2 concentrations prior to implantation (as defined by progesterone concentrations) and an increase between implantation and parturition occurred in the 2 pregnant captives. Similar changes did not occur in the 4 captives not producing cubs (Fig. 20). To my knowledge, there are no existing data on serum E_2 concentrations in pregnant black bears. Palmer et al. (1988) reported no differences in E_2 concentrations between months in wild-caught, lactating or nonpregnant black bears throughout the year. They reported concentrations ranging between 20 and 40 pg/ml (Palmer et al. 1988), similar to the concentrations reported in the present study. Pregnant and nonpregnant polar bears had elevated E_2 concentrations in August, 2 months before implantation and 3-4 months after the breeding season (Palmer et al. 1988).

More data are necessary to verify that the changes observed in E_2 concentrations are of biological significance. Ravindra and Mead (1984) found that estrogen concentrations decreased and stabilized prior to implantation in the western spotted skunk. They speculated that low estrogen concentrations at this time may promote an uterine environment conducive to implantation and embryonic development (Ravindra and Mead 1984). Sampling frequency may have been inadequate to define an implantation surge of E_2, as seen in the Alaskan fur seal (Callorhinus ursinus)(Daniel 1974) and the red fox (Bonnin et al. 1978b),

or a prepartum rise in E_2. The domestic dog (Concannon et al. 1975), the domestic cat (Verhage et al. 1976), the western spotted skunk (Ravindra and Mead 1984) and the puma (Felis concolor) Bonney et al. 1981) exhibit approximately twofold prepartum increases in E_2. Other carnivores, such as the mink (Pilbeam et al. 1979) and the red fox (Bonnin et al. 1978b), do not show a prepartum E_2 rise. A larger sample and more frequent sampling during the gestative phase may reveal differences in E_2 profiles between pregnant and pseudopregnant bears, as well as between successful and unsuccessful pregnancies.

New techniques are needed to test the blastocyst resorption hypothesis (Rogers 1976). The data reported in this study indicate that progesterone concentrations are elevated above basal levels as early as July in known pregnant animals. It also indicates that progesterone concentrations in lactating or estrous females are virtually undetectable. However, some bears with elevated progesterone concentrations during the delay phase or even the gestative phase may not produce observed cubs (Table 28, Fig. 20). These individuals may have been examples of blastocyst resorption or embryonic mortality, or merely pseudopregnant. Obviously, an independent method of pregnancy detection is necessary to completely test the resorption hypothesis. A combination of E_2 and progesterone data may provide the necessary information, but more research is needed. Flushing reproductive tracts of females for blastocysts would provide data on pregnancy, but also would forego testing the blastocyst hypothesis. Foresman and Gagnon (1986) reported detection of a pregnancy-specific protein produced at the time of implantation in black bears. Female testing for this protein might be the technique needed. Attempts to replicate this work with the present experimental animals have been unsuccessful (Barry Williams, unpubl. data), however.

Future work examining the effect of nutrition on female black bear reproductive physiology should include studying the effects of different levels of fall energy intake on cub production. Until the question of pregnancy detection is answered, adult female black bears used in this research should have evidence of luteal activity (via progesterone concentrations or laparoscopy). Dietary restrictions should be caloric (dietary protein appears to be less important during the hyperphagic fall period). Treatment levels should be based on feeding

different amounts of food during the fall or maintenance of specified body weight levels (e.g. 80 kg, 100 kg, 120 kg) at the time of hibernation. If different feeding levels are used, they should include an ad libitum-fed group. Another group(s) should be percentages of ad lib (e.g., 50%, 75%). Amount of food consumed/(kg body weight)$^{0.75}$ should be monitored daily in the ad lib group and restricted groups fed accordingly on the next day.

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APPENDICES

Appendix Table 1. Reproductive information on female black bears at first capture in Great Dismal Swamp, 1984-1986.

ID	Age	Weight (kg)	Teat Measurements(mm)[1] Width	Length	Was or Had Lactated	Status
15	1	30	4	-	no	-
25	1	34	-	-	no	-
54	1	34	3.5	2	no	-
65	1	25	4	3	no	-
68	1	27	5	4	no	-
79	1	57	5.5	4.5	no	-
80	1	45	4	2	no	-
17	2	41	6	6	no	-
49	2	39	5.5	6	no	-
57	2	27	4	4	no	-
50	3	43	5.5	8	no	estrus
55	3	43	6.5	9.5	yes	cubs of year
56	3	39	5	6.5	no	-
62	3	-	7.5	6	no	-
78	3	64	5.5	7	no	1 corpora lutea
64	4	55	7	23	yes	no cubs seen
70	4	50	7	6	no	-
73	4	52	11.5	15	yes	no cubs seen
5	5	61	7	12	yes	estrus
66	5	55	9.5	10	yes	-
24	6	57	8.5	13	yes	cubs of year
28	6	55	13	12	yes	-
44	6	55	9	12	yes	-
53	6	75	-	-	yes	pregnant
81	6	57	15	15	yes	cubs of year
99	7	61	8	15	yes	-
27	8	70	8	12	yes	-
69	8	47	9	12.5	yes	cub of year
75	9	-	8	13	yes	pregnant
77	9	59	11	9	yes	pregnant

[1] second thoracic teat

Appendix Table 2. Life table information for captured black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Age	f_x	F_x[1]	l_x	d_x	q_x	m_x
0	24[2]	24.0	1.00	0.21	0.21	0.00
1	12	19.0	0.79	0.10	0.13	0.00
2	18	16.6	0.69	0.10	0.14	0.00
3	18	14.1	0.59	0.09	0.15	0.00
4	15	11.6	0.48	0.09	0.19	0.48
5	11	9.4	0.39	0.09	0.23	0.48
6	10	7.3	0.30	0.07	0.23	0.48
7	5	5.6	0.23	0.06	0.26	0.48
8	4	4.2	0.17	0.04	0.24	0.48
9	2	3.0	0.13	0.04	0.31	0.48
10	2	2.1	0.09	0.03	0.33	0.48
11	1	1.5	0.06	0.02	0.33	0.48
12	1	1.0	0.04	0.01	0.25	0.48
12+	1	0.6	0.03	-	-	

[1] Fitted by log polynomial log (f_x) = 1.33 - 0.043 (Age) - 0.0057 (Age)^2 from age 1 onward (Caughley 1977).

[2] Determined by fecundity (cubs of lactating and pregnant trapped bears.)

Appendix Table 3. Black bear population estimates (± se) for Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Area	Estimation method	Date of Estimation	Population Estimate	Density bears/km^2
Total area (545 km^2)	Petersen	1984	261 ± 87	0.47 ± 0.16
	Petersen	1985	311 ± 123	0.56 ± 0.23
	Schnabel	1984	253 ± --	0.46 ±
	Jolly-Seber	1985	134 ± 65	0.24 ± 0.12
	Program Capture	1985	366 ± 133	0.66 ± 0.24
	Trapped Area[1]	1984	250	0.45
	Average		262	0.47
North Section (306 km^2)	Petersen	1984	75 ± 29	0.24 ± 0.09
	Petersen	1985	87.5 ± 40	0.28 ± 0.13
	Program Capture	1985	140 ± 87	0.45 ± 0.28
	Jolly-Seber	1985	43 ± 27	0.14 ± 0.11
	Average		86	0.28
South Section (239 km^2)	Petersen	1984	143 ± 52	0.59 ± 0.22
	Petersen	1985	187 ± 81	0.77 ± 0.34
	Program Capture	1985	230 ± 102	0.94 ± 0.43
	Jolly-Seber	1985	103 ± 80	0.42 ± 0.33
	Average		166	0.68

[1] Trapped area represents a 64.5 km^2 area in GDS which was intensively trapped and virtually all resident bears were believed captured.

Appendix Table 4. Frequency and aggregate percentage of all food items identified in 533 black bear scats collected within and surrounding Great Dismal Swamp National Wildlife Refuge, Virginia-North Carolina, 1984-1986.

	Spring (N = 106)		Early Summer (N = 141)		Late Summer (N = 64)		Early Fall (N = 140)		Late Fall (N = 78)		Winter (N = 6)		Entire Year (N = 533)	
Food Item	Freq.	Agg. %	Freq.	Agg. %	Freq.	Agg. %	Freq.	Agg. %	Freq.	Agg. %	Freq.	Agg. %	Freq.	Agg. %
Graminae		**8**		**8**		**6**		**1**		**4**				**5**
Arundinaria gigantea	9[1]	4	18	8	23	6	15	1	12	4			15	4
Other	12	4	4	T[2]	2	T			3	T			4	1
Forbs				**18**		**10**		**6**		**1**				**9**
Aralia spinosa (f)[3]							16	4	3	1			5	1
Lespedeza spp. (h)[3]			1	T									T	T
Phytolaca americana (f)					17	9	7	2	13	T			6	2
Phytolaca americana (h)					6	1	1	T					1	T
Rubus spp. (f)			29	18									8	5
Rubus spp. (h)			9	T									T	T
Silphium perfoliatum (f)					2	T	1	T					T	T
Ferns	19	2	17	2	11	1	11	1					12	1
Moss			1	T	2	T							T	T
Algae			1	T			1	1					T	T
Tree Fruit		T		**29**		**2**		**65**		**12**				**27**
Pinus					2	T							T	T
Acer rubrum	5	T					1	T					1	T
Asimina triloba					2	T							T	T
Diospyros virginia							1	T					T	T
Liriodendron tulipera							1	T					T	T
Nyssa aquatica							1	T	1	T			T	T
Nyssa sylvatica			1	T	22	2	61	33	6	3			20	9
Prunus serotina			37	29	2	T							10	8
Quercus spp.							34	32	10	9			10	10
Symplocos tinctoria							1	T					T	T
Shrub Fruit		**2**		**16**		**7**		**3**		**41**		**1**		**13**
Ilex coriacea					20	7	5	1					4	1
Ilex glabra							2	1	41	30			7	5
Ilex opaca							1	T	5	T	17	T	1	T
Ilex verticillata							2	1	21	11			4	2
Persea borbonia									6	T			1	T
Gaylussacia spp.			1	T									T	T
Vaccinium spp.	7	2	26	16									8	5
Vine Fruit		T		**1**		**13**		**9**		**14**		**63**		**7**
Lonicera japonica									3	1			T	T
Smilax spp.	8	T	1	T	5	T	11	1	40	13	66	63	12	3
Vitis spp.			4	1	27	13	16	8					8	4

Appendix Table 4 (continued).

Food Item	Spring		Early Summer		Late Summer		Early Fall		Late Fall		Winter		Entire Year	
	Freq.	Agg. Vol.	Freq.	Agg. Vol.	Freq.	Agg. Vol.	Freq.	Agg. Vol.	Freq.	Agg. Vol.	Freq.	Agg. Vol.	Freq.	Agg. Vol.
Crops		**5**		**9**		**35**		**9**		**13**		**2**		**12**
Corn (f)	2	1	9	8	37	29	9	6	8	5	17	2	11	8
Corn (h)			3	1	23	6	5	1					5	1
Oats	1	1											T	T
Wheat	4	3											1	1
Peanuts					1	T	2	2	9	8			2	2
Tree, Shrub and Vine Vegetable Matter		**52**		**7**		**6**		**3**		**9**		**T**		**14**
Magnolia virginiana[4]	43	31	6	2					3	T			11	7
Smilax spp.[4]	38	21	14	5	9	5	4	1	21	7	50	1	17	7
Chamaecyparis thyoides	1	T			2	T	1	T	5	T			1	T
Acer rubrum			1	T			1	T					1	T
Nyssa sylvatica	1	T			2	T	4	T					2	T
Prunus serotina			9	T									2	T
Quercus spp.							1	T	1	T			1	T
Ilex coriacea					8	T	2	T	1	T			2	T
Ilex glabra	1	T	1	T			1	T	29	2			5	T
Ilex opaca			1	T									T	T
Ilex verticillata					2	T			1	T			T	T
Vaccinium spp.			7	T									2	T
Vitis spp.					3	T	1	T					1	T
Animal Matter		**3**		**3**		**6**		**2**		**3**		**35**		**3**
Hymenoptera														
Formicidae	42	2	40	1	37	4	4	T					25	1
Vespidae	1	T	1	T	11	1	1	T			17	T	2	T
Coleoptera	11	T	15	T	31	1	20	T	4	T			16	T
Isoptera	2	T											T	T
Endoparasites			1	T					4	T			1	T
Sylvilagus floridanus	1	T			2	T	1	T					1	T
Didelphis virginanus					2	T							T	T
Odocoileus virginanus	2	1	6	T	3	T	2	1	12	3			5	1
Ursus americanus[5]	6	T	9	1	19	T	4	T	3	T	33	35	8	T
Bait scraps	2	T	4	1			2	1					2	T
Unknown	2	T					1	T					1	T
Debris		**8**		**2**		**9**		**1**		**T**		**T**		**3**
Soil	12	5	9	1	16	7	1	1					7	2
Other(bark,leaf, etc)	32	3	24	1	41	2	11	T	13	T	17	T	23	1
Unidentified		**20**		**5**		**4**		**T**		**3**		**T**		**6**
Ground vegetation[4]	30	18	23	3	8	3	7	T	5	1	17	T	14	5
Other(fruit,leaf,etc)	9	2	3	2	3	1	4	T	15	2			8	1

[1] Percentage values are rounded to the nearest whole number
[2] Indicates trace amount (< 0.5 %)
[3] f = fruit, h = herbaceous material (stems, leaves)
[4] Spring aggregate volume estimates for Magnolia virginiana and Smilax spp. are minimum estimates. If identifiable leaf parts were found, these were included in frequency data. However, if scat contents were too finely ground to estimate individual species volumes, contents were considered unidentifiable ground vegetation.
[5] Remains of Ursus americanus occurred in 41 scats. Four scats contained evidence of cannibalism (claws, bone, tissue). The remainder were associated with grooming activities.

Appendix Table 5. Nutrient composition of spring food items of black bears in Great Dismal Swamp.

Food Item	Part	% Diet	% Crude Protein	% Crude Fiber	%ADF	% Ether Extract	Ref.
Arundinaria gigantea	stem, leaf	4	15.3	26.3		2.8	21
Graminae		4	20.3	25.6		3.7	
	preflowering		24.3			3.7	13
	leaf		16.3	25.6			6
Ferns	leaf	2	10.3	18.3		4.8	24
Vaccinium sp.	whole fruit	2	5.7	14.1		7.0	
V. sp.			4.2	9.7		3.8	26
V. *corymbosum*			9.0	11.7		7.2	23
V. *stamineum*			5.8	14.1		4.9	9
V. *arboreum*			3.9	20.3	25.0	12.2	18
Corn	fruit	1	10.3	2.3		4.1	
			10.8	2.4		3.3	6
			10.3				25
			9.3	2.1		4.2	7
			10.9	2.4		4.7	14
Winter Wheat	aerial	1	16.0	22.9		3.3	10
Peanuts	whole fruit	3	23.6	21.1		37.9	10
Magnolia virginiana	leaf	31	25.8		21.1	5.7	this study
Smilax sp.	leaf, stem	21	24.2	13.4		1.7	
S. *glauca*			25.7	12.5		1.4	9
S. *rotundifolia* - S. *bona-nox*			30.9	9.7	13.6		20
S. *laurifolia*			16.1	18.1		2.1	22
Formicidae	bodies	2	16.4			13.5	11
Odocoileus virginianus	flesh	1	47.4	0.0		41.3	12
Unidentified ground vegetation		20	19		33		13
	6 species		12.9	21.6		3.7	22
	20 species		22	13			20
Composite of Diet (8% debris)		72	22.2	15.4		6.2	

Appendix Table 6. Nutrient composition of early summer food items of black bears in Great Dismal Swamp.

Food Item	Part	% Diet	% Crude Protein	% Crude Fiber	%ADF	% Ether Extract	Ref.
Arundinaria gigantea	stem, leaf	8	12.9	25.3		5.2	21
Rubus sp.	fruit	18	9.4	22.2		7.1	
R. sp.			10.0		30		5
R. *cuneifolius*			13.1	24.7		8.0	9
R. *alleghiensis*			7.9	20.5		7.2	23
R. *occidentalis*			8.2	21.4		7.6	26
R. sp.			7.8	22.3		5.4	6
Fern	leaf	2	10.3	18.3		4.8	24
Prunus serotina	fruit	18	8.3	21.2		4.7	
			7.0	20.0		3.7	23
			13.9	32.7		7.0	8
			4.4	10.8		3.3	6
			7.8			4.9	4
Vaccinium sp.	whole fruit	16	5.7	14.1		7.0	
V. sp.			4.2	9.7		3.8	26
V. *corymbosum*			9.0	11.7		7.2	23
V. *stamineum*			5.8	14.1		4.9	9
V. *arboreum*			3.9	20.3	25.0	12.2	18
Vitis sp.	fruit	1	7.4	21.3		10.9	
V. *rotundifolia*			6.0	19.9		1.8[sic]	9
V. sp.	pulp		8.7				16
V. sp(4 sp.)			7.6	22.6	33.6	10.9	19
Corn	fruit	1	10.3	2.3		4.1	
			10.8	2.4		3.3	6
			10.3				25
			9.3	2.1		4.2	7
			10.9	2.4		4.7	14
Corn	leaf	1					
	stem, stalk		7.5	31.7		2.3	14
Magnolia virginiana	leaf	2	10.7				10
Smilax sp.	leaf, stem	5	9.7	27.4	-	2.6	
S. *glauca*			8.4				9
S. *rotundifolia* - S. *bona-nox*			11.7	27.6	34.1		20
S. *laurifolia*			9.1	27.2		2.6	22
Formicidae	bodies	1	16.4			13.5	11
Ursus americanus	flesh	1	-	-	-	-	
Unidentified ground vegetation	20 species	5	10.3	17.8			20
Composite of Diet (Debris 2%)		98	9.0	18.5		5.2	

Appendix Table 7. Nutrient composition of late summer food items of black bears in Great Dismal Swamp.

Food Item	Part	% Diet	% Crude Protein	% Crude Fiber	%ADF	% Ether Extract	Ref.
Arundinaria gigantea	stem, leaf	6	12.9	25.3		5.2	21
Phytolaca americana	fruit	9	12.3	7.5	-	8.9	
			11.4	8.8	24.6	8.9	19
			13.2	6.2		9.0	6
Phytolaca americana	leaf	1					
Fern	leaf	1	10.3	18.3		4.8	24
Nyssa sylvatica	fruit	2	4.7	17.3		13.3	
			4.8	8.2		15.2	23
			6.4	35.8	38.2	14.4	19
	(pulp)		4.1	8.0		1.5[sic]	9
			3.5			10.4	2
Ilex coriacea	fruit	7	3.4	19.3		10.8	9
Vitis sp.	fruit	13	7.4	21.3		10.9	
V. *rotundifolia*			6.0	19.9		1.8[sic]	9
V. sp.	pulp		8.7				16
V. sp.(4 sp.)			7.6	22.6	33.6	10.9	19
Corn	fruit	1	10.3	2.3		4.1	
			10.8	2.4		3.3	6
			10.3				25
			9.3	2.1		4.2	7
			10.9	2.4		4.7	14
Corn	leaf	6					
	stem, stalk		7.5	31.7		2.3	14
Smilax sp.	leaf, stem	5	9.7	27.4	-	4.1	
S. *glauca*			8.4				9
S. *rotundifolia* - S. *bona-nox*			11.7	27.6	34.1		20
S. *laurifolia*			9.1	27.2		2.6	22
Formicidae	bodies	4	16.4			13.5	11
Vespidae	bodies	1	79.4			12.0	15
Coleoptera	bodies	1	40.7	22.0			1
	May beetles		65			16.0	15
Unidentified ground vegetation		4	9.3	21.6	-	5.3	
	20 species		10.3	17.8			20
	7 species		8.4	25.4		5.3	22
Composite of Diet (Debris 9%)		90	10.7	13.5		6.7	

Appendix Table 8. Nutrient composition of early fall food items of black bears in Great Dismal Swamp.

Food Item	Part	% Diet	% Crude Protein	% Crude Fiber	%ADF	% Ether Extract	Ref.
Arundinaria gigantea	stem, leaf	1	12.7	24.9		5.2	22
Phytolaca americana	fruit	2	12.3	7.5	-	8.9	
			11.4	8.8	24.6	8.9	20
			13.2	6.2		9.0	6
Aralia spinosa	fruit	4	7.8	22.2	26.6	16.9	19
Fern	leaf	1	10.3	18.3		4.8	25
Nyssa sylvatica	fruit	33	4.7	17.3	-	13.3	
			4.8	8.2		15.2	24
			6.4	35.8	38.2	14.4	20
	(pulp)		4.1	8.0		1.5[sic]	9
			3.5			10.4	2
Quercus sp.	acorn	32	6.0	18.7	23.8	5.5	
Q. *alba*			5.9	18.7	23.8	4.3	18
Q. sp.			8.0				16
Q. *michauxii*			4.1			3.3	3
Q. *prinus*			5.9			8.8	17
Ilex coriacea	fruit	1	3.4	19.3		10.8	9
Ilex glabra	fruit	1	4.9	12.8		3.4	9
Ilex verticillata	fruit	1	6.1	15.6		5.1	26
Smilax sp.	fruit	1	6.6	17.1	-	6.3	
S. sp.			7.7				16
S. sp.			2.8	13.6	-	1.3[sic]	9
5 species			9.4	20.6	30.3	6.3	19
Vitis sp.	fruit	8	7.4	21.3	-	10.9	
V. *rotundifolia*			6.0	19.9		1.8[sic]	9
V. sp.	pulp		8.7				16
V. sp.(4 sp.)			7.6	22.6	33.6	10.9	19
Corn	fruit	1	10.3	2.3		4.1	
			10.8	2.4		3.3	6
			10.3				25
			9.3	2.1		4.2	7
			10.9	2.4		4.7	14
Corn	leaf	1					
	stem, stalk		7.5	31.7		2.3	14
Peanuts	whole fruit	2	23.6	21.1		37.9	14
Smilax sp.	leaf, stem	1	10.9	20.4		10.4	
S. sp.			11.1	25.2	30.3		20
S. *glauca*			10.8	15.6		10.4	24
Odocoileus virginanus	flesh	1	47.4	0	0	41.3	12
Composite of Diet (Debris 4%)		96%	7.1	17.3		10.2	

Appendix Table 9. Nutrient composition of late fall food items of black bears in Great Dismal Swamp.

Food Item	Part	% Diet	% Crude Protein	% Crude Fiber	%ADF	% Ether Extract	Ref.
Arundinaria gigantea	stem, leaf	4	12.7	24.9		5.2	22
Aralia spinosa	fruit	1	7.8	22.2	26.6	16.9	19
Nyssa sylvatica	fruit	3	4.7	17.3	-	13.3	
			4.8	8.2		15.2	24
			6.4	35.8	38.2	14.4	20
	(pulp)		4.1	8.0		1.5[sic]	9
			3.5			10.4	2
Quercus sp.	acorn	9	6.0	18.7	23.8	5.5	
Q. *alba*			5.9	18.7	23.8	4.3	18
Q. sp.			8.0				16
Q. *michauxii*			4.1			3.3	3
Q. *prinus*			5.9			8.8	17
Ilex glabra	fruit	30	4.9	12.8		3.4	9
Ilex verticillata	fruit	11	6.1	15.6		5.1	26
Lonicera japonica	fruit	1	6.2	9.3	16.3	3.8	19
Smilax sp.	fruit	13	6.6	17.1	-	6.3	
S. sp.			7.7				16
S. sp.			2.8	13.6	-	1.3[sic]	9
5 species			9.4	20.6	30.3	6.3	19
Corn	fruit	1	10.3	2.3		4.1	
			10.8	2.4		3.3	6
			10.3				25
			9.3	2.1		4.2	7
			10.9	2.4		4.7	14
Peanuts	whole fruit	8	23.6	21.1		37.9	14
Smilax sp.	leaf, stem	7	11.1	22.4		6.7	
S. sp.			11.1	25.2	30.3		20
S. *glauca*			10.8	15.6		10.4	24
S. sp.			13.1				16
S. *laurifolia*			9.4	26.5		3.1	22
Ilex glabra	leaf	2	6.1	11.9		7.7	22
Odocoileus virginanus	flesh	3	47.4	0	0	41.3	12
Unidentified ground vegetation		3	9.1	18.5		6.3	
	20 species		10.1	17.0			20
	5 species		8.1	19.9		6.3	22
Composite of Diet		100%	9.3	15.5		9.0	

Appendix Table 10. Nutrient composition of winter food items of black bears in Great Dismal Swamp.

Food Item	Part	% Diet	% Crude Protein	% Crude Fiber	%ADF	% Ether Extract	Ref.
Smilax sp.	fruit	63	6.6	17.1	-	6.3	
S. sp.			7.7				16
S. sp.			2.8	13.6	-	1.3[sic]	9
5 species			9.4	20.6	30.3	6.3	19
Corn	fruit	1	10.3	2.3		4.1	
			10.8	2.4		3.3	6
			10.3				25
			9.3	2.1		4.2	7
			10.9	2.4		4.7	14
Smilax sp.	leaf, stem	7	11.2	19.5	-	7.6	
S. sp.			12.3	23.3	26.8		20
S. *glauca*			10.8	15.6		10.4	24
S. sp.			13.1				16
S. sp.			8.5	19.5		4.9	22
Ursus americanus	flesh	35	-	-	-	-	
Composite of Diet		66	6.8	16.7		6.3	

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Appendix Table 11. Serum electrolyte and mineral concentrations (mean ± SE) of female black bears in Great Dismal Swamp as affected by age and season.

Season and Age	N	Calcium (mg/dl) X	SE	Phosphorus[1] (mg/dl) X	SE	Sodium (meq/l) X	SE	Potassium[1] (meq/l) X	SE	Chloride (meq/l) X	SE	Iron[1] (ug/dl) X	SE
Spring													
subadult													
adult	2	7.6	0.5	2.4	0.6	147	2.5	4.0	0.3	109	0.5	56	1
Early Summer													
subadult	5	8.4	0.3	4.2	1.2	143	2.7	4.4	0.3	109	2.5	150	36
adult	6	8.6	0.5	2.0	0.4	144	1.8	4.6	0.4	108	2.4	163	42
Late Summer													
subadult	4	8.3	0.2	5.0	0.8	149	3.7	4.4	0.4	114	4.0	97	30
adult	6	7.9	0.1	2.2	0.3	143	1.3	4.0	0.2	108	1.5	75	12
Early Fall													
subadult	2	8.0	0.2	5.7	0.8	146	3.0	4.3	0.0	109	3.0	191	5
adult	5	7.4	0.2	2.4	0.3	144	5.6	3.9	0.1	106	3.5	168	39
Late Fall													
subadult	3	8.1	0.5	2.2	0.5	141	2.5	3.7	0.3	107	1.7	263	164
adult	2	6.9	0.0	2.1	0.2	139	2.5	3.5	0.4	93	7.5	60	16
Denning													
subadult													
adult	4	8.1	0.2	3.2	0.4	137	1.3	4.3	0.2	96	0.3	195	16
Anova F-value (*P*)													
Age		2.35(0.136)		12.41(0.001)		1.34(0.257)		0.31(0.580)		8.20(0.008)		0.89(0.354)	
Season		2.05(0.100)		1.78(0.148)		1.47(0.229)		1.83(0.138)		4.41(0.004)		3.23(0.020)	
Age*Season		1.32(0.288)		1.13(0.355)		0.52(0.671)		0.41(0.746)		1.55(0.223)		1.23(0.315)	

[1] Analysis performed on log-transformed data.

Appendix Table 12. Serum electrolyte and mineral concentrations (mean ± SE) of male black bears in Great Dismal Swamp as affected by age and season.

Season and Age	N	Calcium (mg/dl) X	SE	Phosphorus[1] (mg/dl) X	SE	Sodium (meq/l) X	SE	Potassium[1] (meq/l) X	SE	Chloride (meq/l) X	SE	Iron[1] (ug/dl) X	SE
Spring													
subadult	7	8.7	0.1	3.4	0.5	143	2.0	3.9	0.1	106	1.8	160	33
adult	17	8.7	0.1	2.8	0.2	144	1.2	4.1	0.1	108	1.2	151	23
Early Summer													
subadult	11	8.4	0.1	4.2	0.5	146	2.1	4.1	0.1	113	2.0	71	13
adult	15	8.4	0.1	3.2	0.4	146	1.0	4.3	0.1	110	1.0	128	24
Late Summer													
subadult	7	8.3	0.2	4.6	0.5	146	3.0	4.6	0.2	112	3.0	108	20
adult	6	8.1	0.2	3.3	0.6	144	2.0	5.1	0.3	111	1.6	159	27
Early Fall													
subadult	6	8.1	0.2	4.5	0.4	145	2.7	4.2	0.2	109	2.2	145	36
adult	5	8.2	0.5	3.3	0.5	143	5.5	4.2	0.2	107	2.9	167	49
Late Fall													
subadult	2	8.9	0.3	4.5	0.3	155	5.5	4.6	0.1	119	3.0	97	44
adult	2	8.2	0.1	2.4	0.0	144	0.5	4.4	0.5	107	1.5	152	7
Anova F-value (*P*)													
Age		0.00(0.968)		15.90(< 0.001)		0.41(0.524)		0.73(0.395)		2.31(0.133)		3.85(0.054)	
Season		2.72(0.037)		0.97(0.430)		0.91(0.462)		5.13(0.001)		2.58(0.045)		1.93(0.116)	
Age*Season		0.39(0.812)		0.31(0.873)		0.95(0.443)		0.57(0.683)		1.62(0.179)		0.95(0.440)	

[1] Analysis performed on log-transformed data.

Appendix Table 13. Selected serum chemistries (mean ± SE) of female black bears in Great Dismal Swamp as affected by age and season.

Season and Age	N	Uric Acid (mg/dl) X	SE	Total Bilirubin (mg/dl) X	SE	Alkaline Phosphatase[1] (U/l) X	SE	Cholesterol (mg/dl) X	SE	Triglycerides (mg/dl) X	SE	Glucose (mg/dl) X	SE
Spring													
subadult													
adult	2	2.3	0.4	0.2	0.1	23.5	11.5	256	26	204	25	160	5
Early Summer													
subadult	5	2.1	0.2	0.1	0.0	59.2	18.9	237	15	216	18	112	16
adult	6	1.8	0.2	0.1	0.0	26.7	4.1	171	12	169	20	171	14
Late Summer													
subadult	4	1.7	0.2	0.1	0.0	64.5	16.4	220	11	203	7	186	14
adult	6	2.0	0.3	0.1	0.0	24.2	7.3	249	16	247	21	135	14
Early Fall													
subadult	2	1.7	0.3	0.1	0.0	40.5	15.5	235	28	168	29	186	45
adult	5	1.8	0.1	0.1	0.0	28.8	5.2	183	16	164	19	167	18
Late Fall													
subadult	3	1.5	0.1	0.1	0.0	41.7	8.3	248	6	148	45	137	12
adult	2	1.3	0.2	0.1	0.0	11.5	0.5	247	33	258	69	196	61
Denning													
subadult													
adult	4	1.5	0.1	0.2	0.0	14.3	3.1	315	23	232	34	120	46
Anova F-value (*P*)													
Age		0.00(0.988)		0.02(0.884)		14.28(< 0.001)		0.28(0.602)		0.81(0.375)		0.12(0.736)	
Season		1.80(0.144)		1.93(0.120)		0.68(0.644)		8.62(< 0.001)		1.64(0.182)		0.82(0.548)	
Age*Season		0.73(0.542)		1.13(0.352)		0.77(0.519)		3.61(0.025)		2.96(0.049)		2.97(0.048)	

[1] Analysis performed on log-transformed data.

Appendix Table 14. Selected serum chemistries (mean ± SE) of male black bears in Great Dismal Swamp as affected by age and season.

Season and Age	N	Uric Acid (mg/dl) X	SE	Total Bilirubin (mg/dl) X	SE	Alkaline Phosphatase[1] (U/l) X	SE	Cholesterol (mg/dl) X	SE	Triglycerides (mg/dl) X	SE	Glucose (mg/dl) X	SE
Spring													
subadult	7	1.8	0.2	0.1	0.0	33.4	6.2	244	21	292	34	169	23
adult	17	2.0	0.1	0.1	0.0	24.3	2.4	257	10	294	33	172	13
Early Summer													
subadult	11	1.6	0.1	0.1	0.0	43.5	4.9	240	13	270	21	167	14
adult	15	1.7	0.2	0.1	0.0	19.9	2.0	200	11	242	17	177	15
Late Summer													
subadult	7	2.0	0.2	0.1	0.0	59.9	14.2	241	12	264	32	160	17
adult	6	1.7	0.2	0.1	0.0	34.2	6.7	208	26	237	16	179	24
Early Fall													
subadult	6	1.7	0.1	0.1	0.0	51.3	9.1	229	25	210	20	147	11
adult	5	1.7	0.2	0.1	0.0	62.6	19.4	200	14	216	25	116	7
Late Fall													
subadult	2	1.4	0.3	0.1	0.0	39.0	0.0	235	69	177	7	173	57
adult	2	1.9	0.3	0.1	0.0	44.0	25.0	246	10	226	69	162	31
Anova F-value (*P*)													
Age		0.34(0.561)		0.01(0.906)		26.03(< 0.001)		1.74(0.191)		0.00(0.994)		0.20(0.653)	
Season		1.51(0.210)		1.42(0.237)		5.56(< 0.001)		2.75(0.035)		2.15(0.084)		1.33(0.269)	
Age*Season		0.99(0.418)		0.07(0.990)		2.42(0.057)		1.16(0.335)		0.25(0.908)		0.43(0.788)	

[1] Analysis performed on log-transformed data.

Appendix Table 15. Red blood cell characteristics (mean ± SE) of female black bears in Great Dismal Swamp as affected by age and season. See text for explanation of abbreviations.

Season and Age	N	WBC ($x10^3$/ml) X	SE	RBC ($x10^6$/ml) X	SE	Hemoglobin (mg/dl) X	SE	MCV (um^3) X	SE	Hematocrit (%) X	SE	MCH (pg) X	SE	MCHC (%) X	SE
Spring															
subadult															
adult	2	16.0	1.9	8.7	0.3	17.6	0.9	55.2	1.4	47.8	0.7	20.2	0.2	36.7	1.4
Early Summer															
subadult	5	17.9	2.0	7.4	0.5	15.0	0.7	57.4	1.4	42.2	2.6	20.4	0.4	35.7	0.7
adult	6	19.0	1.9	7.1	0.3	14.1	0.7	57.3	0.8	40.7	1.9	19.8	0.3	34.6	0.6
Late Summer															
subadult	4	19.9	2.5	7.4	0.1	14.9	0.4	58.5	1.3	43.4	0.2	20.0	0.2	34.3	0.9
adult	6	18.0	2.0	7.3	0.3	15.4	0.6	58.9	1.3	43.1	1.4	21.0	0.2	35.7	0.6
Early Fall															
subadult	2	25.2	8.9	8.0	0.4	15.4	0.2	55.8	2.6	44.3	0.5	19.3	1.3	34.6	0.7
adult	5	18.3	2.8	8.1	0.3	16.7	0.7	58.7	0.9	47.6	2.5	20.6	0.1	35.1	0.5
Late Fall															
subadult	3	21.6	2.1	9.1	0.4	16.7	0.4	51.7	1.0	46.8	1.4	18.4	0.5	35.7	0.2
adult	2	18.7	4.6	8.6	0.3	16.9	0.3	55.4	1.1	47.7	0.6	19.6	1.0	35.4	1.1
Denning															
subadult															
adult	4	7.1	1.0	8.7	0.2	16.9	0.5	54.9	0.2	48.0	1.4	19.3	0.1	35.2	0.2
Anova F-value (*P*)															
Age		4.90(0.035)		0.01(0.919)		1.15(0.292)		1.48(0.233)		0.70(0.233)		3.73(0.063)		0.13(0.726)	
Season		3.33(0.017)		6.83(< 0.001)		4.10(0.006)		4.57(0.003)		3.10(0.023)		4.55(0.004)		0.54(0.742)	
Age*Season		0.75(0.529)		0.18(0.909)		1.06(0.381)		1.02(0.399)		0.47(0.706)		3.42(0.030)		1.60(0.210)	

Appendix Table 16. Red blood cell characteristics (mean ± SE) of male black bears in Great Dismal Swamp as affected by age and season. See text for explanation of abbreviations.

Season and Age	N	WBC ($x10^3$/ml) X	SE	RBC ($x10^6$/ml) X	SE	Hemoglobin (mg/dl) X	SE	MCV (ucm^3) X	SE	Hematocrit (%) X	SE	MCH (pg) X	SE	MCHC (%) X	SE
Spring															
subadult	4	18.5	3.6	8.0	0.5	16.8	1.2	58.7	0.6	46.9	2.8	20.9	0.3	35.7	0.5
adult	16	20.6	1.6	8.6	0.2	17.3	0.5	57.5	0.7	49.2	1.5	20.2	0.2	35.2	0.3
Early Summer															
subadult	11	21.1	1.0	7.6	0.3	14.8		56.7	0.5	43.3	1.7	19.4	0.3	34.2	0.4
adult	12	19.2	1.2	7.8	0.3	15.7		58.0	0.6	45.1	1.8	20.2	0.3	34.8	0.5
Late Summer															
subadult	7	19.7	1.8	7.7	0.1	15.6	0.4	58.3	0.8	45.0	0.5	20.1	0.3	34.6	0.6
adult	6	17.3	1.8	7.5	0.3	15.4	0.6	58.6	1.4	43.8	1.6	20.5	0.2	35.2	0.7
Early Fall															
subadult	6	19.4	1.6	8.0	0.3	16.1	0.6	57.2	0.5	45.9	1.4	19.9	0.2	34.8	0.3
adult	5	21.3	3.1	8.1	0.2	16.6	0.5	57.9	1.0	46.7	1.1	20.5	0.3	35.4	0.3
Late Fall															
subadult	2	24.2	1.2	10.0	0.5	19.0	0.1	55.6	1.9	55.1	0.8	19.2	0.8	34.7	0.2
adult	2	19.7	0.3	9.2	0.1	18.1	0.3	57.4	1.2	52.6	0.8	19.7	0.3	34.4	1.2
Anova F-value (*P*)															
Age		0.20(0.655)		1.05(0.310)		3.11(0.083)		0.77(0.383)		1.67(0.201)		4.25(0.044)		1.53(0.222)	
Season		0.43(0.787)		6.50(< 0.001)		5.41(< 0.001)		0.76(0.558)		4.55(0.003)		2.00(0.105)		0.72(0.579)	
Age*Season		0.76(0.558)		0.68(0.606)		0.34(0.853)		0.68(0.608)		0.35(0.844)		1.81(0.139)		0.49(0.744)	

Appendix Table 17. Nitrogenous serum characteristics (mean ± SE) of female black bears in Great Dismal Swamp as affected by age and season. See text for explanation of abbreviations.

Season and Age	N	Total Protein (g/dl) X	SE	Albumin (g/dl) X	SE	Globulin (g/dl) X	SE	SUN (mg/dl) X	SE	Creatinine[1] (mg/dl) X	SE	Albumin/Globulin Ratio X	SE	SUN/C Ratio X	SE
Spring															
subadult															
adult	2	7.0	0.1	3.9	0.1	3.1	0.0	15.5	4.5	1.7	0.3	1.3	0.1	10.1	4.3
Early Summer															
subadult	5	6.4	0.2	3.5	0.2	2.9	0.1	11.2	2.1	1.3	0.1	1.2	0.1	9.0	1.7
adult	6	6.7	0.2	3.1	0.1	3.6	0.2	8.2	1.2	1.4	0.1	0.9	0.1	6.2	1.1
Late Summer															
subadult	4	6.7	0.1	3.5	0.3	3.2	0.2	17.0	6.8	1.2	0.1	1.1	0.1	13.5	4.5
adult	6	6.9	0.2	3.7	0.1	3.2	0.1	13.5	3.0	1.7	0.1	1.2	0.0	8.3	1.6
Early Fall															
subadult	2	6.3	0.1	3.2	0.1	3.1	0.2	8.0	7.0	1.0	0.1	1.1	0.1	8.9	7.9
adult	5	5.9	0.3	3.3	0.2	2.7	0.3	9.4	2.9	1.3	0.1	1.3	0.2	7.0	2.1
Late Fall															
subadult	3	6.5	0.3	3.5	0.3	3.1	0.2	12.7	4.4	1.1	0.0	1.2	0.1	11.3	4.1
adult	2	6.7	0.1	3.6	0.1	3.1	0.1	7.5	5.5	2.6	0.7	1.2	0.1	2.6	1.5
Denning															
subadult															
adult	4	7.6	0.3	4.0	0.1	3.6	0.1	10.5	2.2	3.8	0.4	1.1	0.0	2.8	0.5
Anova F-value (*P*)															
Age		3.56(0.069)		0.43(0.518)		2.81(0.105)		0.78(0.384)		37.42(< 0.001)		0.53(0.474)		6.46(0.017)	
Season		5.52(0.001)		3.94(0.008)		2.21(0.080)		1.00(0.435)		14.59(< 0.001)		0.95(0.463)		1.08(0.394)	
Age*Season		0.72(0.550)		1.34(0.280)		2.96(0.049)		0.22(0.885)		3.34(0.033)		3.24(0.036)		0.50(0.682)	

[1] Analysis performed on log-transformed data.

Appendix Table 18. Nitrogenous serum characteristics (mean ± SE) of male black bears in Great Dismal Swamp as affected by age and season. See text for explanation of abbreviations.

Season and Age	N	Total Protein (g/dl) X	SE	Albumin (g/dl) X	SE	Globulin (g/dl) X	SE	SUN (mg/dl) X	SE	Creatinine[1] (mg/dl) X	SE	Albumin/Globulin Ratio X	SE	SUN/C Ratio X	SE
Spring															
subadult	7	7.4	0.2	4.0	0.1	3.4	0.2	15.7	2.9	1.8	0.2	1.2	0.1	9.2	1.8
adult	17	7.5	0.1	4.1	0.1	3.3	0.1	13.4	1.7	2.2	0.1	1.3	0.1	6.6	0.9
Early Summer															
subadult	11	6.9	0.2	3.3	0.1	3.6	0.1	9.5	1.8	1.4	0.1	0.9	0.0	7.0	1.1
adult	15	7.3	0.1	3.7	0.1	3.7	0.1	11.8	1.0	1.8	0.1	1.1	0.1	6.8	0.7
Late Summer															
subadult	7	7.0	0.2	3.7	0.1	3.2	0.2	8.9	1.3	1.4	0.1	1.2	0.1	6.6	1.0
adult	6	7.4	0.3	3.8	0.1	3.6	0.2	11.5	1.7	1.6	0.1	1.1	0.1	7.4	1.3
Early Fall															
subadult	6	6.7	0.2	3.6	0.2	3.2	0.1	10.7	3.8	1.1	0.1	1.1	0.1	10.1	3.7
adult	5	7.1	0.2	3.7	0.2	3.4	0.1	9.2	3.1	1.6	0.2	1.1	0.1	5.5	1.5
Late Fall															
subadult	2	7.8	0.6	4.1	0.4	3.7	0.2	26.5	1.5	1.3	0.0	1.2	0.1	20.4	1.2
adult	2	7.2	0.5	4.1	0.2	3.1	0.3	12.5	5.5	1.8	0.2	1.3	0.1	7.4	3.9
Anova F-value (*P*)															
Age		6.66(0.012)		9.78(0.003)		0.31(0.581)		0.02(0.898)		28.1(< 0.001)		1.72(0.194)		4.63(0.035)	
Season		2.29(0.069)		8.99(< 0.001)		2.05(0.098)		3.07(0.022)		5.74(< 0.001)		4.93(0.002)		2.49(0.051)	
Age*Season		1.21(0.313)		0.89(0.476)		1.22(0.310)		1.92(0.118)		0.48(0.751)		0.94(0.449)		2.67(0.039)	

Appendix Table 19. Concentrations of serum chemical and hematologic characteristics in black bears from Great Dismal Swamp not tested for age and season variation.

Characteristic	Male			Female		
	N	X	SE	N	X	SE
SGOT (IU/l)	64	633	95	32	467	93
SGPT (IU/l)	77	113	11	38	100	17
Lactate Dehydrogenase (IU/l)	50	3044	363	30	2123	230
Gamma-Glutamyl Transferase (IU/l)	78	8.1	0.7	39	10.1	1.0
Glucose (mg/dl)	79	165	6	40	152	8
Platelet count ($x10^3$/ml)	69	466	16	39	551	19
Neutrophils (%)	65	85.3	1.0	39	82.8	1.8
Banded Neutrophils (%)	65	2.5	0.4	39	2.5	0.4
Lymphocytes (%)	65	8.9	1.0	39	11.3	1.6
Monocytes (%)	65	2.7	0.2	39	2.6	0.3
Eosinophils (%)	65	0.5	0.2	39	0.8	0.2

Appendix Table 20. Blood characteristics (mean ± SE) as influenced by time during handling of black bears in Great Dismal Swamp.

		Sample 1		Sample 2		Sample 3		Anova	
Characteristic (unit)	N	X	SE	X	SE	X	SE	F-value	*P*
Total Protein (g/dl)	59	7.1	0.1	7.0	0.1			1.10	0.298
	31	7.1	0.1	7.0	0.1	7.0	0.1	2.04	0.139
Albumin (g/dl)	59	3.8	0.0	3.7	0.0			8.18	0.006
	31	3.8	0.1	3.7	0.1	3.8	0.1	1.60	0.210
Albumin/Globulin	59	1.16	0.0	1.15	0.1			2.42	0.126
Ratio	31	1.16	0.0	1.16	0.0	1.20	0.0	4.48	0.015
Globulin (g/dl)	59	3.3	0.1	3.3	0.1			0.05	0.820
	31	3.3	0.1	3.3	0.1	3.3	0.1	2.54	0.087
Alkaline Phos.	59	36.6	3.8	36.2	3.6			1.35	0.2511
(U/l)	31	33.0	3.0	32.8	3.0	32.6	2.9	0.34	0.712
SGPT (U/l)	57	98	12	106	14			1.45	0.234
	31	147	23	146	23	142	22	1.87	0.163
SGOT (U/l)	51	466	72	650	141			1.75	0.193
	24	879	199	997	217	867	194	0.32	0.731
LDH (U/l)	50	2274	218	2742	353			1.03	0.315
	17	4419	836	4761	886	4676	863	0.21	0.814
GGT (U/l)	59	8.8	0.7	8.6	0.7			0.34	0.561
	31	7.7	0.8	8.0	0.8	7.6	0.7	0.22	0.805
Cholesterol	59	225	6	223	6			2.38	0.129
(mg/dl)	31	249	9	246	9	252	10	2.20	0.120
Triglycerides	59	230	9	231	10			0.01	0.943
(mg/dl)	31	262	22	249	16	260	21	2.16	0.124

Appendix Table 20(continued).

Glucose (mg/dl)	59	153	6	179	7		46.65	< 0.001
	31	150	8	171	11	179 12	15.46	< 0.001
Urea nitrogen	59	12.3	1.2	12.1	1.2		1.57	0.216
(mg/dl)	31	12.8	1.0	12.8	1.0	12.7 1.0	0.17	0.85
Creatinine (mg/dl)	59	1.7	0.1	1.7	0.1		1.97	0.166
	31	1.7	0.1	1.7	0.1	1.7 0.1	1.27	0.287
Uric acid (mg/dl)	59	1.79	0.1	1.68	0.1		9.00	0.004
	31	1.93	0.1	1.86	0.1	1.79 0.1	3.50	0.037
Calcium (mg/dl)	59	8.2	0.1	8.3	0.1		1.14	0.290
	31	8.2	0.1	8.2	0.1	8.2 0.1	0.27	.0764
Phosphorus (mg/dl)	59	3.0	0.2	3.7	0.2		133.12	< 0.001
	31	3.5	0.2	4.1	0.3	4.7 0.3	79.70	< 0.001
Sodium (meq/l)	59	143	1	143	1		0.45	0.505
	31	147	1	148	1	147 1	0.62	0.541
Potassium (meq/l)	59	4.1	0.1	4.3	0.1		18.31	< 0.001
	31	4.2	0.1	4.4	0.1	4.4 0.1	4.34	0.017
Chloride (meq/l)	59	107	1	108	1		0.84	0.3624
	31	111	1	111	1	111 1	0.13	0.878
Iron (ug/dl)	59	141	13	139	14		0.69	0.410
	31	118	13	114	13	113 13	2.26	0.114
UN/Crea Ratio	59	8.0	0.9	8.4	1.0		1.00	0.323
	31	8.2	0.9	8.4	0.9	8.3 0.8	0.41	0.665

Appendix Table 20(continued).

WBC ($x10^3$/ml)	56	19.0	0.8	20.2	0.8			14.29	< 0.001
	30	19.3	0.9	20.3	1.0	21.9	0.9	21.51	< 0.001
RBC ($x10^6$/ml)	56	8.0	0.1	7.8	0.1			30.54	< 0.001
	30	8.3	0.2	8.1	0.2	8.1	0.2	8.48	< 0.001
Hemoglobin (g/dl)	56	16.1	0.2	15.7	0.2			48.35	< 0.001
	30	16.6	0.3	16.5	0.4	16.4	0.3	26.93	< 0.001
MCV (um^3)	56	57.5	0.4	57.2	0.4			0.00	0.976
	30	57.5	0.5	57.4	0.5	57.4	0.5	0.71	0.495
HCT (%)	56	46.0	0.6	44.7	0.7			42.48	< 0.001
	30	47.3	1.0	46.4	1.0	46.5	1.0	8.40	< 0.001
MCH (pg)	56	20.0	0.1	20.0	0.1			0.18	0.670
	30	20.1	0.2	20.3	0.2	20.1	0.1	0.51	0.605
MCHC (%)	56	34.9	0.2	35.1	0.2			0.04	0.834
	30	35.0	0.3	35.4	0.4	35.2	0.2	0.52	0.597
Neutrophils (%)	54	85	1	86	1			2.31	0.136
	27	86	1	86	1	87	1	0.03	0.97
Banded neutrophils (%)	54	2.2	0.5	2.5	0.3			0.04	0.837
	27	2.2	0.4	3.1	0.7	3.0	0.6	2.03	0.142
Lymphocytes (%)	54	9.3	1.3	8.6	1.0			1.49	0.228
	27	8.4	1.2	8.0	1.2	6.5	1.3	0.93	0.402
Monocytes (%)	54	2.7	0.2	2.4	0.2			1.37	0.248
	27	2.6	0.4	2.4	0.3	3.1	0.4	0.79	0.458
Eosinophils (%)	54	0.5	0.2	0.5	0.2				
	27	0.6	0.4	0.3	0.1	0.4	0.1	0.47	0.630
Platelets ($x10^3$)	55	486	16	491	14				
	29	533	21	511	22	530	17	1.41	0.255

Appendix Table 21. Correlation coefficients (r) between blood characteristics, body weight, and condition indices in black bears from Great Dismal Swamp. See text for explanation of abbreviations.

	Female			Male		
Blood Characteristic	PCR-A ($N=28$)	PCR-B ($N=31$)	Weight (kg) ($N=38$)	PCR-A ($N=53$)	PCR-B ($N=61$)	Weight (kg) (N=72)
Total Protein (g/dl)	0.316(0.101)[1]	0.165(0.376)	0.245(0.139)	0.417(0.002)	(0.436) < 0.001)	0.475(< 0.001)
Albumin (g/dl)	0.346(0.071)	0.265(0.149)	0.166(0.318)	0.651(< 0.001)	0.610(< 0.001)	0.574(< 0.001)
Alkaline Phosphatase (IU/l)	-0.408(0.031)	-0.510(0.003)	-0.537(< 0.001)	-0.152(0.276)	-0.213(0.100)	-0.253(0.032)
Total bilirubin (mg/dl)	0.065(0.742)	-0.028(0.879)	-0.093(0.579)	0.091(0.517)	0.104(0.424)	0.067(0.575)
Cholesterol (mg/dl)	0.201(0.305)	0.140(0.454)	0.059(0.725)	-0.187(0.181)	-0.193(0.137)	-0.235(0.047)
Triglycerides (mg/dl)	0.184(0.349)	0.090(0.629)	0.078(0.644)	-0.196(0.159)	-0.138(0.290)	-0.133(0.265)
Glucose (mg/dl)	-0.134(0.495)	0.121(0.517)	0.077(0.648)	0.207(0.137)	0.163(0.209)	0.148(0.214)
Urea Nitrogen (mg/dl)	-0.089(0.652)	-0.197(0.288)	-0.238(0.150)	0.067(0.631)	0.123(0.344)	0.107(0.372)
Creatinine (mg/dl)	0.561(0.002)	0.469(0.008)	0.421(0.009)	0.567(< 0.001)	0.574(< 0.001)	0.586(< 0.001)
Uric acid (mg/dl)	-0.047(0.811)	-0.180(0.333)	-0.105(0.529)	0.091(0.518)	0.093(0.476)	0.043(0.723)
Calcium (mg/dl)	-0.245(0.209)	-0.309(0.091)	-0.093(0.580)	0.093(0.509)	0.043(0.742)	0.072(0.550)
Phosphorus (mg/dl)	-0.549(0.003)	-0.580(< 0.001)	-0.563(< 0.001)	-0.427(0.001)	-0.468(< 0.001)	-0.278(0.018)
Sodium (mEq/l)	-0.388(0.042)	-0.479(0.006)	-0.407(0.011)	-0.159(0.254)	-0.179(0.167)	-0.127(0.288)
Potassium (mEq/l)	-0.239(0.221)	-0.280(0.127)	-0.146(0.381)	0.067(0.635)	0.034(0.796)	0.137(0.252)
Chloride (mEq/l)	-0.420(0.026)	-0.509(0.004)	-0.413(0.010)	-0.224(0.107)	-0.250(0.052)	-0.261(0.027)
Iron (ug/dl)	-0.063(0.750)	-0.008(0.968)	0.170(0.309)	0.481(< 0.001)	0.372(0.003)	0.298(0.011)

Appendix Table 21 (continued).

Globulin (g/dl)	0.145(0.463)	0.007(0.968)	0.187(0.261)	-0.138(0.326)	-0.046(0.727)	0.056(0.641)
Albumin/Globulin	0.096(0.628)	0.138(0.461)	-0.057(0.732)	0.445(< 0.001)	0.367(0.004)	0.302(0.010)
Urea Nitrogen/Creatinine	-0.268(0.169)	-0.346(0.057)	-0.373(0.021)	-0.158(0.257)	-0.115(0.377)	-0.144(0.228)
WBC ($x10^3$/ml)	-0.236(0.227)	-0.222(0.230)	-0.290(0.078)	0.221(0.119)	0.246(0.063)	0.250(0.042)
RBC ($x10^6$/ml)	0.323(0.094)	0.285(0.120)	0.104(0.534)	0.481(< 0.001)	0.492(< 0.001)	0.411(< 0.001)
Hemoglobin (g/dl)	0.475(0.011)	0.416(0.020)	0.197(0.237)	0.562(< 0.001)	0.560(< 0.001)	0.540(< 0.001)
MCV (um^3)	-0.063(0.751)	-0.106(0.569)	-0.062(0.711)	0.130(0.363)	0.084(0.530)	0.167(0.176)
HCT (%)	0.367(0.056)	0.295(0.107)	0.106(0.525)	0.529(< 0.001)	0.523(< 0.001)	0.463(< 0.001)
MCH (pg)	0.158(0.421)	0.126(0.501)	0.139(0.404)	0.291(0.038)	0.246(0.063)	0.386(< 0.001)
MCHC (%)	0.265(0.173)	0.290(0.113)	0.236(0.154)	0.173(0.226)	0.186(0.162)	0.257(0.036)
Platelet Count ($x10^3$/ml)	0.003(0.989)	-0.002(0.992)	-0.117(0.485)	-0.436(0.002)	-0.359(0.007)	-0.253(0.044)

[1] *P*-value associated with correlation coefficient.

Appendix Table 22. Correlation coefficients (r) between blood characteristics, body weight (kg), and condition index among sex and age groups in black bears from Great Dismal Swamp. See text for explanation of abbreviations.

	Female				Male					
	Subadult (1-3 yrs)		Adult (> 3 yrs)		Subadult (1-2 yrs)		Adult (3-4 yrs)		Adult (> 4 yrs)	
Blood Characteristic	PCR-A (N = 12)	Weight N = 14)	PCR-A (N = 16)	Weight (N = 24)	PCR-A (N = 14)	Weight (N = 19)	PCR-A (N = 29)	Weight (N = 38)	PCR-A (N = 20)	Weight (N = 25)
Total Protein (g/dl)	0.14	-0.14	0.18	0.13	0.41	0.44*	0.27	0.30	0.28	0.27
Albumin (g/dl)	0.46	0.07	0.32	0.15	0.74**	0.66**	0.50**	0.58**	0.67**	0.48*
Globulin (g/dl)	-0.32	-0.24	0.00	0.06	-0.28	-0.09	-0.08	-0.13	-0.25	-0.10
Albumin/Globulin	0.51*	0.17	0.31	0.09	0.67**	0.52*	0.25	0.37	0.40*	0.29
Alkaline Phosphatase (IU/l)	-0.29	-0.43	0.06	-0.00	-0.47*	-0.50*	0.25	0.14	0.24	0.11
Total bilirubin (mg/dl)	-0.07	0.22	0.29	0.18	-0.06	0.00	0.06	0.09	0.05	0.05
Cholesterol (mg/dl)	-0.08	0.15	0.14	0.00	-0.38	-0.27	0.25	0.14	-0.09	-0.09
Triglycerides (mg/dl)	-0.69*	-0.42	0.26	0.14	-0.32	-0.28	0.04	-0.01	-0.29	-0.20
Glucose (mg/dl)	-0.17	0.27	-0.31	-0.12	0.25	0.24	0.06	0.02	0.31	0.26
Urea Nitrogen (mg/dl)	0.07	-0.19	0.15	0.02	0.19	0.24	0.22	0.12	-0.15	-0.10
Creatinine (mg/dl)	0.23	-0.03	0.43*	0.29	0.70**	0.71**	0.30	0.40*	0.10	0.07
Uric acid (mg/dl)	-0.38	-0.54*	-0.02	0.00	-0.35	-0.13	0.09	0.11	-0.14	-0.18
Calcium (mg/dl)	0.15	-0.17	0.00	0.13	0.19	0.19	-0.02	0.11	-0.02	0.08
Phosphorus (mg/dl)	-0.77**	-0.57*	-0.02	0.04	-0.56*	-0.39	-0.08	0.03	-0.04	0.26

Appendix Table 22 (continued).

Sodium (mEq/l)	-0.27	-0.42	-0.41	-0.37*	0.10	0.14	-0.31	-0.19	-0.37	-0.20
Potassium (mEq/l)	-0.39	-0.40	-0.23	-0.10	0.12	0.09	-0.07	-0.02	-0.16	-0.10
Chloride (mEq/l)	-0.19	-0.33	-0.41	-0.27	0.15	0.16	-0.42*	-0.41*	-0.21	-0.24
Iron (ug/dl)	-0.04	0.42	0.29	0.44	0.29	0.04	0.41*	0.37*	0.33	0.19
Urea Nitrogen/Creatinine	0.08	-0.22	0.04	0.01	0.02	0.06	0.05	-0.07	-0.12	-0.08
WBC ($x10^3$/ml)	0.08	-0.10	-0.31	-0.28	0.47*	0.56*	0.20	0.25	0.38	0.32
RBC ($x10^6$/ml)	0.44	0.20	0.48*	0.20	0.58*	0.57*	0.48*	0.49**	0.48*	0.29
Hemoglobin (g/dl)	0.34	0.22	0.48*	0.19	0.70**	0.66**	0.49**	0.51**	0.45*	0.39*
MCV (um^3)	-0.71**	0.40	-0.19	-0.19	0.26	0.07	0.08	0.02	-0.17	-0.13
HCT (%)	0.10	0.00	0.43*	0.15	0.62*	0.57*	0.51**	0.54**	0.40*	0.23
MCH (pg)	-0.41	-0.10	0.00	-0.04	0.39	0.28	0.03	0.03	-0.00	0.29
MCHC (%)	0.49	0.47	0.20	0.16	0.35	0.34	0.06	-0.01	0.17	0.39*
Platelet Count ($x10^3$/ml)	-0.29	-0.17	-0.07	-0.26	-0.62*	-0.37	-0.19	-0.01	-0.21	-0.15

* $P < 0.1$.

** $P < 0.01$.

Appendix Table 23. Monitoring periods and location samples for female black bears in Great Dismal Swamp, Virginia-North Carolina in 1984-1986.

ID	Age at Capture	Monitoring Period	Days	Number of Locations	Notes
5	5	07/03/84 - 04/27/85	298	39	Died - unknown
17	2	08/14/84 - 10/25/87	1168	330	Collar failed
24	6	09/30/84 - 07/26/85			
		05/23/86 - 10/24/87	1147	153	Collar failed
27	8	10/14/84 - 08/15/86	670	290	Believed poached
28	6	10/26/84 - 08/11/86	654	219	Spacer broke
44	6	06/04/85 - 06/15/85	11	9	Died - unknown
49	2	07/02/85 - 06/07/86	340	117	Spacer broke
50	3	07/06/85 - 02/13/86	224	89	Cannibalized
53	6	07/09/85 - 06/24/86	350	116	Spacer broke
54	1	07/09/85 - 06/11/86	337	155	Spacer broke
55	3	07/10/85 - 08/13/86	399	157	Missing
56	3	07/12/85 - 12/25/85	166	73	Missing
57	2	07/13/85 - 03/28/86	258	63	Pulled collar off
62	3	08/10/85 - 03/06/86	208	56	Spacer broke
64	4	08/13/85 - 11/26/85	105	61	Missing
65	1	08/14/85 - 07/05/86	325	93	Spacer broke
66	5	08/23/85 - 06/24/86	304	93	Spacer broke
69	8	08/30/85 - 08/11/86	347	86	Spacer broke
70	4	09/05/85 - 09/12/85	7	--	Died - broken leg
73	4	09/13/85 - 03/28/86	196	56	Spacer broke
75	9	09/18/85 - 08/12/86	329	81	Spacer broke
77	9	09/23/85 - 06/24/86	273	83	Spacer broke
78	3	09/23/85 - 10/19/85	26	16	Hunter harvest
79	1	11/23/85 - 08/08/86	260	59	Spacer broke
80	1	11/26/85 - 08/07/86	254	84	Spacer broke
81	6	12/14/85 - 03/22/87	463	63	Spacer broke
99	6	07/12/86 - 08/08/86	27	--	Missing
Total			9130	2632	

Appendix Table 24. Monitoring periods and location samples for male black bears in Great Dismal Swamp, Virginia-North Carolina in 1984-1986.

ID	Age at Capture	Monitoring Period	Days	Number of Locations	Notes
1	2	06/06/84 - 09/01/84	87	8	Spacer broke
2	2	06/13/84 - 09/12/84	91	8	Spacer broke
3	4	06/24/84 - 10/06/84	104	6	Spacer broke
6	8	07/10/84 - 10/02/84	83	22	Hunter harvest
7	3	07/15/84 - 10/12/84	89	5	Spacer broke
8	4	07/17/84 - 10/26/84	100	31	Died - roadkill
10	2	07/24/84 - 03/10/85	228	93	Spacer broke
12	7	07/28/84 - 02/28/85	217	23	Collar failure
13	4	07/30/84 - 11/17/84	111	19	Hunter harvest
14	7	08/07/84 - 03/28/85	232	75	Spacer broke
19	3	09/01/84 - 07/09/85	312	143	Spacer broke
29	7	10/30/84 - 06/02/85	215	67	Died - poaching?
31	3	11/15/84 - 08/01/85	258	64	Spacer broke
32	5	11/26/84 - 07/13/85	229	28	Died - roadkill
33	3	11/29/84 - 01/14/85	45	12	Pulled collar off
37	3	04/25/85 - 11/22/85	211	62	Spacer broke
38	4	05/13/85 - 10/20/85	160	26	Spacer broke
39	16	05/17/85 - 05/26/86	374	39	Spacer broke
42	4	05/27/85 - 03/17/86	294	30	Spacer broke
48	2	06/29/85 - 10/16/85	110	18	Missing
82	4	04/30/86 - 08/07/86	99	20	Spacer broke
86	4	05/23/86 - 08/12/86	81	7	Spacer broke
Total			3638	806	

Appendix Table 25. Habitat use vs. habitat availability for female black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Habitat Type	Composite Home Range[1]				Overall Study Area[2]			
	Proportion Used	95% CI	Proportion Available	Preference	Proportion Used	95% CI	Proportion Available	Preference
				YEAR-ROUND HABITAT USE (N = 1717, 1794)				
Cedar	0.068	0.051-0.086	0.086	-	0.065	0.048-0.082	0.058	0
Gumcyp	0.069	0.051-0.086	0.057	0	0.088	0.069-0.107	0.118	-
Mapcon	0.167	0.141-0.192	0.269	-	0.162	0.137-0.187	0.178	0
Mapgum	0.128	0.104-0.151	0.168	-	0.125	0.102-0.147	0.292	-
Maple	0.083	0.064-0.102	0.096	0	0.079	0.061-0.098	0.106	-
Mesic	0.052	0.036-0.067	0.017	+	0.060	0.044-0.076	0.030	+
Newcut	0.011	0.004-0.018	0.006	0	0.011	0.004-0.018	0.003	+
Oldcut	0.052	0.037-0.068	0.038	0	0.052	0.037-0.067	0.018	+
Pine	0.161	0.135-0.186	0.176	0	0.157	0.132-0.181	0.092	+
Pinmap	0.032	0.020-0.044	0.045	-	0.031	0.019-0.043	0.061	-
Pocosin	0.178	0.152-0.205	0.041	+	0.171	0.145-0.196	0.035	+
				SPRING (N = 499, 499)[3]				
Cedar	0.108	0.068-0.148	0.086	0	0.108	0.068-0.148	0.058	+
Gumcyp	0.028	0.007-0.049	0.057	-	0.028	0.007-0.049	0.118	-
Mapcon	0.261	0.204-0.317	0.269	0	0.261	0.204-0.317	0.178	+
Mapgum	0.080	0.045-0.115	0.168	-	0.080	0.045-0.115	0.292	-
Maple	0.080	0.045-0.115	0.096	0	0.080	0.045-0.115	0.106	0
Mesic	0.000	0.000-0.000	0.017	-	0.000	0.000-0.000	0.030	-
Newcut	0.002	0.000-0.008	0.006	0	0.002	0.000-0.008	0.003	0
Oldcut	0.034	0.011-0.057	0.038	0	0.034	0.011-0.057	0.018	0
Pine	0.267	0.210-0.324	0.176	+	0.267	0.210-0.324	0.092	+
Pinmap	0.026	0.006-0.047	0.045	0	0.026	0.006-0.045	0.061	-
Pocosin	0.114	0.073-0.155	0.041	+	0.114	0.073-0.155	0.035	+

[1] Habitat available represents habitats within a composite home range determined by total home ranges of 18 females radio-monitored ≥8 months.

[2] Habitat available represents habitats within the entire study area.

[3] Represents number of locations used in each analysis.

Appendix Table 25.(continued)

Habitat Type	Composite Home Range[1] Proportion Used	95% CI	Proportion Available	Preference	Overall Study Area[2] Proportion Used	95% CI	Proportion Available	Preference
			EARLY SUMMER (N = 324, 325)					
Cedar	0.049	0.015-0.084	0.086	-	0.049	0.015-0.084	0.058	0
Gumcyp	0.031	0.003-0.059	0.057	0	0.034	0.005-0.063	0.118	-
Mapcon	0.120	0.068-0.172	0.269	-	0.120	0.068-0.172	0.178	-
Mapgum	0.139	0.084-0.194	0.168	0	0.138	0.083-0.194	0.292	-
Maple	0.086	0.041-0.131	0.096	0	0.086	0.041-0.131	0.106	0
Mesic	0.022	0.000-0.045	0.017	0	0.022	0.000-0.045	0.030	0
Newcut	0.003	0.000-0.012	0.006	0	0.003	0.000-0.012	0.003	0
Oldcut	0.120	0.068-0.172	0.038	+	0.120	0.068-0.172	0.018	+
Pine	0.201	0.137-0.265	0.176	0	0.200	0.136-0.264	0.092	+
Pinmap	0.046	0.013-0.080	0.045	0	0.046	0.013-0.080	0.061	0
Pocosin	0.182	0.120-0.244	0.041	+	0.182	0.120-0.243	0.035	+
			LATE SUMMER (N = 232, 242)					
Cedar	0.030	0.000-0.063	0.086	-	0.029	0.000-0.060	0.058	0
Gumcyp	0.030	0.000-0.063	0.057	0	0.037	0.002-0.072	0.118	-
Mapcon	0.151	0.083-0.219	0.269	-	0.153	0.086-0.220	0.178	0
Mapgum	0.108	0.049-0.166	0.168	-	0.120	0.060-0.180	0.292	-
Maple	0.147	0.080-0.213	0.096	0	0.140	0.076-0.205	0.106	0
Mesic	0.034	0.000-0.069	0.017	0	0.037	0.002-0.072	0.030	0
Newcut	0.043	0.005-0.082	0.006	0	0.041	0.004-0.078	0.003	+
Oldcut	0.052	0.010-0.094	0.038	0	0.050	0.009-0.090	0.018	0
Pine	0.086	0.033-0.139	0.176	-	0.083	0.032-0.134	0.092	0
Pinmap	0.039	0.002-0.075	0.045	0	0.041	0.004-0.078	0.061	0
Pocosin	0.280	0.195-0.365	0.041	+	0.269	0.187-0.351	0.035	+

Appendix Table 25.(continued)

Habitat Type	Composite Home Range[1] Proportion Used	95% CI	Proportion Available	Preference	Overall Study Area[2] Proportion Used	95% CI	Proportion Available	Preference
			EARLY FALL (N = 334, 381)					
Cedar	0.039	0.008-0.069	0.086	-	0.034	0.007-0.061	0.058	0
Gumcyp	0.168	0.109-0.227	0.057	+	0.220	0.159-0.282	0.118	+
Mapcon	0.153	0.096-0.209	0.269	-	0.136	0.086-0.187	0.178	0
Mapgum	0.234	0.167-0.300	0.168	0	0.205	0.145-0.264	0.292	-
Maple	0.078	0.036-0.120	0.096	0	0.068	0.031-0.105	0.106	-
Mesic	0.177	0.117-0.237	0.017	+	0.189	0.131-0.247	0.030	+
Newcut	0.012	0.000-0.029	0.006	0	0.010	0.000-0.026	0.003	0
Oldcut	0.015	0.000-0.034	0.038	-	0.016	0.000-0.034	0.018	0
Pine	0.054	0.018-0.089	0.176	-	0.058	0.023-0.092	0.092	0
Pinmap	0.015	0.000-0.034	0.045	-	0.013	0.000-0.030	0.061	-
Pocosin	0.057	0.020-0.093	0.041	0	0.050	0.018-0.082	0.035	0
			LATE FALL (N=328, 347)					
Cedar	0.082	0.039-0.126	0.086	0	0.078	0.036-0.119	0.058	0
Gumcyp	0.095	0.048-0.141	0.057	0	0.115	0.066-0.165	0.118	0
Mapcon	0.095	0.048-0.141	0.269	-	0.092	0.047-0.137	0.178	-
Mapgum	0.095	0.048-0.141	0.168	-	0.092	0.047-0.137	0.292	-
Maple	0.043	0.011-0.075	0.096	-	0.040	0.010-0.071	0.106	-
Mesic	0.046	0.013-0.079	0.017	0	0.058	0.022-0.094	0.030	0
Newcut	0.009	0.000-0.024	0.006	0	0.009	0.000-0.023	0.003	0
Oldcut	0.052	0.017-0.087	0.038	0	0.055	0.020-0.090	0.018	+
Pine	0.122	0.070-0.174	0.176	-	0.118	0.068-0.168	0.092	0
Pinmap	0.040	0.009-0.071	0.045	0	0.037	0.008-0.067	0.061	0
Pocosin	0.323	0.249-0.398	0.041	+	0.305	0.234-0.377	0.035	+

Appendix Table 26. Habitat use vs. habitat availability for male black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Habitat Type	Overall Study Area[2] Proportion Used	95% CI	Proportion Available[1]	Preference
		YEAR-ROUND HABITAT USE (N = 530)[2]		
Cedar	0.051	0.023-0.078	0.058	0
Grass	0.009	0.000-0.022	0.008	0
Gumcyp	0.179	0.131-0.227	0.118	+
Mapcon	0.332	0.273-0.391	0.178	+
Mapgum	0.138	0.095-0.181	0.292	-
Maple	0.091	0.055-0.126	0.106	0
Mesic	0.021	0.003-0.039	0.030	0
Cut	0.036	0.013-0.059	0.021	0
Pine	0.064	0.033-0.095	0.092	0
Pinmap	0.034	0.011-0.057	0.061	-
Pocosin	0.045	0.019-0.071	0.035	0
		SPRING (N = 188)		
Cedar	0.053	0.006-0.100	0.058	0
Grass	0.005	0.000-0.020	0.008	0
Gumcyp	0.197	0.113-0.280	0.118	0
Mapcon	0.372	0.271-0.474	0.178	+
Mapgum	0.122	0.054-0.191	0.292	-
Maple	0.096	0.034-0.158	0.106	0
Mesic	0.027	0.000-0.060	0.030	0
Cut	0.064	0.012-0.115	0.021	0
Pine	0.037	0.000-0.077	0.092	-
Pinmap	0.016	0.000-0.042	0.061	-
Pocosin	0.011	0.000-0.032	0.035	-

[1] Habitat available represents habitats within the entire study area.

[2] Represents number of locations used in each analysis.

Appendix Table 26.(continued)

Habitat Type	Overall Study Area: Proportion Used	95% CI	Proportion Available	Preference
		SUMMER (N = 124)		
Cedar	0.024	0.000-0.064	0.058	0
Grass	0.032	0.000-0.078	0.008	0
Gumcyp	0.145	0.054-0.236	0.118	0
Mapcon	0.258	0.145-0.371	0.178	0
Mapgum	0.048	0.000-0.104	0.292	-
Maple	0.129	0.042-0.216	0.106	0
Mesic	0.016	0.000-0.049	0.030	0
Cut	0.040	0.000-0.091	0.021	0
Pine	0.169	0.072-0.266	0.092	0
Pinmap	0.024	0.000-0.064	0.061	0
Pocosin	0.112	0.031-0.195	0.035	0
		EARLY FALL (N = 120)		
Cedar	0.000	0.000-0.000	0.058	-
Grass	0.000	0.000-0.000	0.008	-
Gumcyp	0.167	0.069-0.265	0.118	0
Mapcon	0.417	0.287-0.546	0.178	+
Mapgum	0.233	0.122-0.345	0.292	0
Maple	0.075	0.006-0.144	0.106	0
Mesic	0.033	0.014-0.081	0.030	0
Cut	0.017	0.000-0.050	0.021	0
Pine	0.025	0.000-0.066	0.092	-
Pinmap	0.025	0.000-0.066	0.061	0
Pocosin	0.008	0.000-0.032	0.035	-
		LATE FALL (N = 98)		
Cedar	0.142	0.041-0.245	0.058	0
Grass	0.000	0.000-0.000	0.008	-
Gumcyp	0.204	0.087-0.321	0.118	0
Mapcon	0.245	0.120-0.370	0.178	0
Mapgum	0.163	0.056-0.271	0.292	-
Maple	0.051	0.000-0.115	0.106	0
Mesic	0.000	0.000-0.000	0.030	-
Cut	0.000	0.000-0.000	0.021	-
Pine	0.031	0.000-0.081	0.092	-
Pinmap	0.092	0.008-0.176	0.061	0
Pocosin	0.071	0.000-0.146	0.035	0

Appendix Table 27. Growth of black bear cubs born in captivity at Virginia Polytechnic Institute and State University, February 1988

Character	Cub ID	Days of Age								
		1-3	12-14	22-24	33-35	43-45	54-55	70-71[1]	86-87[1]	102-103
Weight (g)										
	4M	328	593	910	1245	1598	1971	2602	3440	4860
	4F	332	637	986	1373	1728	2105	2662	3521	4860
	6F	262	542	788	999	1260	1454	2093	3414	5000
Total Length (mm)										
	4M	232	278	315	365	410	455	515	630	
	4F	236	272	315	398	440	485	520	630	
	6F	222	243	282	337	395	430	490		
Ear Length (mm)										
	4M		13.9	17.1	22.4	29.2	37.5	37.1	43.3	
	4F		15.8	19.0	28.2	25.5	32.0	45.0	45.5	
	6F		15.5	14.4	21.8	25.0	21.5	37.8	38.8	
Head Length (mm)										
	4M				130	155	165	190	200	
	4F				130	150	165	200	200	
	6F				125	140	150	180	180	

[1] Mother of cub 6F was refed when cub when was 71 days old. Mother of cubs 4M and 4F was refed when cubs were 86 days of age.

Appendix Table 28. Mean (SE) concentrations of serum chemistries during fall and winter for hibernating ($N = 4$) and active ($N = 2$) adult female black bears. Sampling intervals were 10-12 days apart.

	Sampling interval relative to cessation of feeding														
Characteristic	-7	-6	-5	-4	-3	-2	-1	1	2	3	4	5	6	7	8
Total Protein (g/dl)															
Hibernating	7.0(0.3)	6.8(0.2)	6.9(0.2)	6.8(0.3)	6.8(0.2)	6.9(0.1)	7.3(0.3)	7.4(0.3)	7.4(0.2)	7.7(0.2)	7.5(0.3)	7.4(0.3)	7.3(0.3)	7.5(0.5)[1]	7.3(0.4)[1]
Active	7.1(0.1)	7.1(0.3)	7.0(0.3)	6.9(0.2)	6.8(0.1)	6.6(0.3)	7.2(0.1)	7.0(0.0)	6.9(0.2)	7.2(0.1)	6.9(0.1)	6.7(0.2)	6.6(0.2)	6.4(0.4)	6.7(0.4)
Albumin (g/dl)															
Hibernating	4.2(0.2)	4.0(0.1)	4.1(0.2)	4.2(0.1)	4.2(0.1)	4.1(0.1)	4.2(0.2)	4.4(0.2)	4.3(0.1)	4.5(0.2)	4.4(0.2)	4.5(0.2)	4.4(0.1)	4.3(0.2)	4.0(0.1)
Active	4.1(0.2)	4.0(0.3)	4.1(0.2)	4.1(0.3)	4.2(0.3)	4.0(0.3)	4.3(0.2)	4.3(0.1)	4.3(0.1)	4.6(0.1)	4.3(0.3)	4.2(0.4)	4.1(0.3)	4.1(0.1)	4.3(0.1)
Globulin (g/dl)															
Hibernating	2.8(0.2)	2.8(0.3)	2.8(0.1)	2.7(0.2)	2.6(0.2)	2.9(0.1)	3.1(0.2)	3.1(0.1)	3.0(0.1)	3.2(0.1)	3.1(0.2)	3.0(0.2)	2.9(0.3)	3.2(0.3)	3.3(0.4)
Active	3.0(0.2)	3.1(0.5)	3.0(0.5)	2.8(0.1)	2.6(0.3)	2.7(0.1)	2.9(0.2)	2.8(0.1)	2.6(0.1)	2.6(0.1)	2.6(0.4)	2.6(0.6)	2.5(0.5)	2.3(0.5)	2.5(0.5)
A/G Ratio															
Hibernating	1.5(0.1)	1.5(0.2)	1.5(0.1)	1.6(0.1)	1.6(0.2)	1.4(0.1)	1.4(0.1)	1.4(0.1)	1.4(0.0)	1.4(0.0)	1.5(0.1)	1.5(0.1)	1.6(0.2)	1.3(0.1)	1.2(0.1)
Active	1.4(0.1)	1.3(0.3)	1.4(0.3)	1.5(0.2)	1.6(0.3)	1.5(0.1)	1.5(0.2)	1.5(0.1)	1.7(0.0)	1.8(0.1)	1.7(0.4)	1.7(0.5)	1.8(0.4)	1.9(0.4)	1.8(0.4)
Total Bilirubin (mg/dl)															
Hibernating	0.1(0.0)	0.1(0.1)	0.1(0.0)	0.2(0.1)	0.2(0.1)	0.1(0.0)	0.2(0.1)	0.1(0.0)	0.2(0.1)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)	0.1(0.0)
Active	0.1(0.0)	0.1(0.0)	0.1(0.1)	0.1(0.0)	0.1(0.0)	0.3(0.2)	0.1(0.0)	0.1(0.0)	0.1(0.1)	0.1(0.0)	0.1(0.0)	0.1(0.1)	0.1(0.1)	0.1(0.1)	0.1(0.1)
Alkaline Phosphatase (U/l)															
Hibernating	12.5(4.4)	10.3(2.2)	9.0(1.5)	28.0(19.8)	10.0(1.2)	7.3(2.7)	28.8(23.4)	4.3(0.7)	6.0(0.9)	4.3(0.9)	5.8(1.1)	4.3(0.9)	4.5(0.6)	5.3(0.7)	5.0(0.6)
Active	11.0(2.0)	9.5(0.5)	12.0(2.0)	12.0(2.0)	10.0(3.0)	84.5(70.0)	11.0(1.0)	8.5(3.5)	5.5(0.5)	7.5(3.5)	8.0(4.0)	8.0(4.0)	8.0(3.0)	10.0(2.0)	9.5(2.5)
Cholesterol (mg/dl)															
Hibernating	241(19)	249(20)	261(18)	219(21)	242(32)	285(26)	285(47)	307(29)	308(29)	295(35)	271(32)	267(23)	272(27)	261(35)	235(57)
Active	260(7)	248(3)	250(24)	267(8)	283(28)	279(35)	279(9)	254(6)	248(6)	268(6)	245(1)	249(10)	252(4)	244(13)	274(20)
Glucose															
Hibernating	108(11)	98(9)	110(17)	128(21)	133(27)	131(4)	164(39)	148(13)	137(8)	122(26)	114(16)	115(27)	87(13)	84(12)	84(21)
Active	141(60)	102(33)	115(16)	94(7)	87(11)	118(14)	89(7)	95(36)	80(2)	105(17)	108(15)	115(8)	96(30)	95(17)	81(17)
Urea Nitrogen (mg/dl)															
Hibernating	25.0(3.0)	24.3(3.1)	24.0(2.0)	23.5(2.7)	23.8(2.1)	22.5(1.5)	17.0(3.6)	14.3(2.5)	13.5(2.2)	12.3(2.2)	13.5(1.8)	11.5(2.1)	12.5(3.0)	9.0(1.7)	8.3(1.3)
Active	19.0(2.0)	24.0(1.0)	25.5(3.5)	25.0(2.0)	25.5(3.5)	15.0(8.0)	21.5(3.5)	19.0(1.0)	24.5(0.5)	15.5(2.5)	15.0(3.0)	16.5(5.5)	21.5(0.5)	24.5(2.5)	21.5(3.5)
Creatinine (mg/dl)															
Hibernating	1.7(0.1)	1.7(0.1)	1.6(0.2)	1.5(0.2)	1.8(0.1)	2.1(0.2)	2.0(0.3)	2.5(0.1)	3.1(0.1)	2.9(0.1)	3.1(0.1)	3.1(0.3)	3.3(0.2)	3.1(0.2)	3.0(0.5)
Active	1.6(0.3)	1.5(0.2)	2.0(0.6)	1.7(0.4)	1.8(0.3)	1.6(0.8)	2.0(0.2)	2.4(0.2)	2.3(0.1)	2.7(0.1)	2.1(0.2)	2.3(0.3)	1.9(0.2)	2.1(0.3)	2.2(0.3)
Urea/Crea (ratio)															
Hibernating	31.8(2.2)	30.5(2.7)	34.2(3.4)	33.9(2.3)	28.5(2.6)	24.1(2.8)	21.7(7.7)	12.6(2.3)	9.4(1.6)	9.3(1.8)	9.5(1.4)	7.9(1.2)	8.0(1.8)	6.1(0.9)	6.1(0.9)
Active	26.9(7.7)	35.7(2.2)	31.7(12.8)	32.8(5.2)	32.5(8.9)	20.1(1.3)	23.7(6.1)	17.2(2.3)	22.9(1.5)	12.3(1.5)	15.2(1.6)	15.0(3.2)	24.6(3.2)	25.7(0.5)	21.3(1.0)

Appendix Table 28 (continued)

Calcium (mg/dl)															
Hibernating	8.6(0.2)	8.4(0.2)	8.4(0.2)	8.6(0.4)	8.5(0.2)	8.3(0.1)	8.8(0.3)	8.8(0.2)	8.6(0.2)	8.8(0.1)	8.8(0.2)	8.7(0.2)	8.7(0.3)	8.8(0.2)	8.6(0.1)
Active	8.8(0.2)	8.5(0.2)	8.1(0.5)	8.3(0.0)	8.1(0.3)	8.7(0.3)	8.4(0.2)	8.4(0.1)	8.5(0.3)	8.3(0.2)	8.2(0.4)	8.4(0.3)	8.5(0.2)	8.4(0.3)	8.7(0.3)
Phosphorus (mg/dl)[1]															
Hibernating	4.3(0.2)	4.8(0.3)	4.6(0.4)	4.0(0.3)	4.9(0.3)	4.8(0.1)	4.8(0.5)	5.0(0.4)	5.1(0.3)	5.6(0.3)	5.2(0.3)	5.3(0.2)	5.0(0.3)	5.4(0.1)	5.5(0.6)
Active	5.3(0.1)	5.4(0.5)	4.4(0.6)	4.8(0.2)	4.9(0.9)	4.6(0.7)	5.6(0.4)	5.7(0.6)	5.8(0.3)	4.7(0.5)	5.3(0.1)	5.4(0.2)	5.6(0.1)	5.3(0.1)	5.2(0.4)
Sodium (meq/l)															
Hibernating	140(3)	140(2)	137(2)	140(2)	139(1)	139(2)	135(1)	134(1)	136(1)	132(1)	137(3)	135(2)	137(1)	136(2)	136(2)
Active	137(4)	136(5)	134(0)	136(3)	137(5)	135(2)	136(3)	135(1)	135(2)	134(0)	135(2)	135(1)	135(1)	135(2)	134(1)
Potassium (meq/l)															
Hibernating	4.4(0.1)	4.6(0.1)	4.4(0.1)	4.4(0.2)	4.6(0.1)	4.6(0.2)	4.6(0.3)	4.7(0.3)	4.6(0.1)	4.5(0.2)	4.3(0.1)	4.3(0.3)	4.2(0.1)	4.2(0.3)	4.1(0.2)
Active	4.3(0.3)	4.6(0.2)	4.6(0.7)	4.2(0.2)	4.6(0.1)	4.8(0.3)	4.9(0.1)	4.6(0.1)	5.1(0.2)	4.5(0.0)	4.7(0.2)	4.4(0.1)	4.9(0.1)	4.7(0.2)	4.6(0.1)
Chloride (meq/l)															
Hibernating	106(1)	104(0)	105(1)	105(1)	104(1)	102(0)	96(3)	102(1)	99(1)	100(2)	100(1)	101(2)	104(1)	101(2)	102(2)
Active	104(1)	103(3)	102(4)	103(1)	104(3)	103(2)	102(1)	101(2)	104(2)	100(0)	101(1)	103(3)	103(1)	102(2)	102(5)
SGOT (U/l)															
Hibernating	76(21)	52(1)	52(5)	42(8)	55(4)	60(3)	61(6)	70(20)	45(4)	49(4)	50(6)	48(4)	53(7)	73(26)	44(1)
Active	37(7)	42(8)	39(2)	50(2)	47(6)	89(27)	54(2)	45(1)	45(4)	45(1)	46(5)	44(7)	40(8)	48(16)	46(3)
SGPT (U/l)															
Hibernating	45(20)	29(2)	27(1)	24(2)	28(2)	29(1)	29(3)	27(5)	24(2)	22(1)	21(2)	21(2)	22(2)	21(3)	17(1)
Active	25(4)	23(2)	22(2)	24(4)	23(3)	72(40)	31(2)	27(1)	25(3)	27(2)	27(6)	26(7)	23(7)	25(8)	27(5)

[1] $N = 3$.

Appendix Table 29. Morphometric characteristics of male black bears in Great Dismal Swamp, Virginia-North Carolina. Numbers in parentheses represent sample size. Values in mm unless otherwise noted.

	Age (years)													
	1		2		3		4		5		6		7+	
Characteristic	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE
Weight(kg)	40.4	7.7(5)	63.6	4.8(14)	82.0	6.0(14)	82.0	3.9(15)	111.5	9.4(10)	127.3	5.3(6)	146.6	7.4(11)
Tail Length	66.3	2.4(4)	76.3	5.7(12)	70.0	4.0(12)	75.5	3.8(12)	76.5	5.2(10)	82.0	7.2(6)	62.6	5.1(12)
Ear Length	111	6(4)	121	2(11)	119	2(12)	118	1(12)	121	2(10)	120	3(6)	117	2(12)
Total Length	1227	119(3)	1553	56(9)	1673	30(11)	1679	36(9)	1814	29(10)	1896	29(5)	1880	30(9)
Head Length	278	18(4)	331	8(12)	346	7(12)	340	6(11)	368	5(10)	383	7(6)	383	6(12)
Neck Girth	405	44(4)	544	22(11)	589	17(12)	572	14(12)	687	27(10)	731	23(6)	764	12(12)
Chest Girth	626	58(4)	821	31(12)	900	28(11)	863	17(12)	1007	42(10)	1074	29(6)	1153	19(12)
Wrist Girth	206	15(4)	250	6(11)	276	17(12)	257	6(12)	284	7(10)	286	7(6)	296	5(12)
Elbow Girth	290	26(4)	363	11(11)	369	11(12)	385	11(12)	427	13(10)	450	12(6)	465	13(12)
Zygomatic Circ	446	32(4)	567	18(11)	599	15(12)	592	10(12)	664	18(10)	713	15(6)	745	15(12)
Forepaw Width	88	5(4)	101	3(11)	106	2(12)	104	2(12)	111	2(10)	119	2(6)	116	2(12)
Forepaw Length (pads)	86	3(4)	96	2(11)	98	2(12)	96	2(12)	106	2(10)	107	3(6)	105	2(11)
Forepaw Length (claws)	112	5(4)	123	3(11)	127	2(12)	125	2(12)	135	2(10)	134	4(6)	132	2(11)
Hindpaw Width	79	6(4)	92	2(11)	96	2(12)	97	2(12)	104	2(10)	108	2(6)	108	2(12)
Hindpaw Length (pads)	155	12(4)	174	3(11)	178	3(12)	179	2(12)	187	3(10)	190	3(6)	189	3(12)
Hindpaw Length (claws)	172	9(4)	191	3(11)	194	3(12)	199	2(12)	206	3(10)	211	4(6)	211	4(12)

Appendix Table 30. Morphometric characteristics of female black bears in Great Dismal Swamp, Virginia-North Carolina. Numbers in parentheses represent sample size. Values in mm unless otherwise noted.

	Age 97mms)													
	1		2		3		4		5		6		7+	
Characteristic	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE
Weight(kg)	37.8	4.1(8)	35.7	4.4(3)	52.8	6.5(6)	51.8	1.2(4)	57.5	3.5(2)	60.2	3.7(5)	62.8	2.2(12)
Tail Length	78.4	3.4(8)	82.3	13.9(3)	70.4	6.5(7)	77.5	10.1(4)	70.0	(1)	78.3	4.4(3)	67.1	4.8(11)
Ear Length	113	2(8)	112	2(3)	114	3(7)	118	3(4)	105		104	4(4)	113	2(11)
Total Length	1271	33(7)	1297	87(3)	1466	40(5)	1500	20(4)	1510		1487	41(3)	1454	18(7)
Head Length	274	4(7)	285	9(3)	302	2(7)	309	3(4)	305		305	7(4)	321	2(9)
Neck Girth	390	15(7)	413	22(3)	455	14(7)	450	7(4)	480		496	7(4)	506	10(9)
Chest Girth	640	37(5)	640	44(3)	724	23(7)	704	3(4)	740		765	13(4)	804	20(9)
Wrist Girth	195	7(7)	198	11(3)	212	4(7)	219	6(4)	210		215	12(4)	223	4(9)
Elbow Girth	274	8(7)	280	10(3)	316	14(7)	310	5(4)	320		314	14(4)	328	5(9)
Zygomatic Circ	441	11(7)	462	15(3)	507	14(7)	499	8(4)	515		521	9(4)	538	7(9)
Forepaw Width	82	2(8)	78	2(3)	84	3(7)	84	3(4)	87		84	1(4)	86	1(11)
Forepaw Length (pads)	82	2(8)	83	2(3)	85	2(7)	86	3(4)	90		86	4(4)	90	2(11)
Forepaw Length (claws)	106	2(8)	110	3(3)	112	3(7)	114	4(4)	117		112	5(4)	117	2(11)
Hindpaw Width	77	2(8)	77	1(3)	81	1(7)	82	2(4)	82		77	2(4)	79	2(11)
Hindpaw Length (pads)	144	2(8)	144	3(3)	150	3(7)	152	3(4)	148		141	10(4)	150	2(11)
Hindpaw Length (claws)	161	2(8)	158	3(3)	168	3(7)	171	4(4)	165		171	2(4)	168	2(11)

Appendix Table 31. Canine characteristics (mm) of male black bears in Great Dismal Swamp, Virginia-North Carolina. Numbers in parentheses represent sample size.

	Age (years)													
	1		2		3		4		5		6		7+	
Characteristic	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE
Canine Length (upper)	22.9	2.7(4)	27.5	0.6(12)	29.1	0.4(11)	29.3	0.4(12)	30.5	0.8(10)	31.4	0.7(4)	32.1	0.6(11)
Canine Length (lower)	22.5	2.6(4)	26.6	0.5(12)	27.4	0.3(12)	27.7	0.2(12)	28.1	0.6(10)	29.5	0.5(4)	27.1	0.6(10)
Canine ant-post (upper)	13.7	1.5(4)	17.3	0.4(12)	21.0	2.8(12)	17.9	0.4(12)	19.2	0.6(10)	19.2	0.6(5)	19.8	0.5(12)
Canine ant-post (lower)	13.9	1.5(4)	17.5	0.6(12)	20.8	2.4(12)	18.0	0.4(12)	19.1	0.6(10)	19.3	0.7(5)	19.5	0.4(12)
Canine lin-lab (lower)	8.8	0.6(4)	10.0	0.2(11)	9.9	0.3(12)	10.4	0.2(12)	11.1	0.3(10)	11.8	0.6(5)	11.1	0.3(12)
Canine Breadth (upper)	49.0	1.6(4)	52.3	1.0(11)	53.9	0.9(11)	52.7	0.7(11)	57.6	0.9(10)	60.0	2.4(4)	60.2	0.9(12)
Canine Breadth (lower)	42.0	2.5(4)	46.4	0.9(11)	48.5	0.8(11)	48.3	0.5(12)	50.8	0.8(10)	54.4	1.2(3)	52.6	0.8(10)

Appendix Table 32. Canine characteristics (mm) of female black bears in Great Dismal Swamp, Virginia-North Carolina. Numbers in parentheses represent sample size.

	Age (years)													
	1		2		3		4		5		6		7+	
Characteristic	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE
Canine Length (upper)	21.4	0.8(8)	23.9	1.6(3)	25.8	0.7(7)	26.0	0.9(4)	24.9		26.0	0.4(4)	26.2	0.6(10)
Canine Length (lower)	21.6	0.8(8)	22.8	0.8(3)	23.6	0.4(7)	23.6	0.4(4)	22.0		23.6	0.5(4)	24.0	0.3(10)
Canine ant-post (upper)	11.5	0.5(7)	13.6	1.3(3)	15.3	0.4(7)	16.0	0.5(4)	16.0		16.6	0.2(4)	16.3	0.4(10)
Canine ant-post (lower)	12.1	0.7(7)	15.0	0.9(3)	14.7	0.4(7)	16.4	0.7(4)	15.5		17.1	0.7(4)	15.8	0.6(10)
Canine lin-lab (lower)	7.7	0.3(7)	8.8	0.6(3)	8.7	0.3(7)	8.7	0.1(4)	8.7		9.0	0.2(4)	9.2	0.2(10)
Canine Breadth (upper)	44.0	0.8(7)	47.1	2.4(3)	47.8	0.5(7)	48.8	0.4(4)	46.8		50.3	2.1(3)	49.7	0.4(10)
Canine Breadth (lower)	40.6	0.7(7)	41.5	1.1(3)	42.9	0.7(7)	43.9	0.2(4)	42.7		44.1	0.8(4)	43.7	0.4(9)

Appendix Table 33. Distribution of female black bear radiolocations to distribution of random points for distance to roads and distance to the study area, Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

Distance (m)	% Random	Spring % Used	Spring Pref.[1]	Early Summer % Used	Early Summer Pref.	Late Summer % Used	Late Summer Pref.	Early Fall % Used	Early Fall Pref.	Late Fall % Used	Late Fall Pref.	All Year % Used	All Year Pref.
TO NEAREST ROAD													
≤100	10.7	15.3	+	21.9	+	22.8	+	5.2	-	22.0	+	16.5	+
100-200	8.0	15.4	+	19.1	+	20.1	+	9.0	0	17.0	+	15.5	+
200-400	14.8	27.4	+	22.2	+	28.0	+	17.0	0	20.4	0	22.9	+
400-800	23.7	30.2	+	24.4	0	25.6	0	33.7	+	26.1	0	28.6	+
≥800	42.8	11.7	-	12.5	-	3.5	-	35.2	-	14.5	-	16.5	-
TO STUDY AREA BOUNDARY													
≤1000	20.9	7.2	-	11.3	-	5.9	-	39.3	+	19.0	0	17.1	0
1000-2000	15.9	7.9	-	9.7	-	9.7	0	27.9	+	10.1	-	13.4	-
2000-3000	16.5	14.4	0	26.9	+	18.5	0	7.7	-	7.3	-	13.7	-
3000-4000	13.4	19.3	+	17.8	0	10.6	0	4.5	-	9.5	0	12.8	0
4000-6000	21.8	27.1	0	24.4	0	29.1	0	16.1	-	34.3	+	26.2	+
≥6000	11.4	24.1	+	10.0	0	23.6	+	4.5	-	19.8	+	16.9	+
N	952	668		330		254		466		495		2203	

[1] Preference: + = used more ($P < 0.05$) than available, - = used less ($P < 0.05$) than available, 0 = used proportional to availability.

Appendix Table 34. Distribution of radiolocations of female black bears captured south of Lake Drummond compared to distribution of random points for distance to roads and distance to the study area, Great Dismal Swamp, Virginia-North Carolina,1 984-1986.

Distance (m)	% Random	Spring % Used	Spring Pref.[1]	Early Summer % Used	Early Summer Pref.	Late Summer % Used	Late Summer Pref.	Early Fall % Used	Early Fall Pref.	Late Fall % Used	Late Fall Pref.	All Year % Used	All Year Pref.
TO NEAREST ROAD													
≤100	9.1	16.5	+	21.4	+	22.8	+	4.4	-	22.6	+	17.3	+
100-200	9.7	16.3	+	18.8	+	20.1	+	9.1	0	16.9	+	16.0	+
200-400	16.6	29.5	+	23.6	+	28.0	+	14.4	0	20.8	0	23.6	+
400-800	23.9	27.3	0	23.2	0	25.6	0	31.8	+	24.2	0	26.5	0
≥800	40.7	10.7	-	13.0	-	3.5	-	40.3	0	15.6	-	16.6	-
TO STUDY AREA BOUNDARY													
≤1000	18.6	8.7	-	13.0	0	5.9	-	40.6	+	17.8	0	16.9	0
1000-2000	17.9	9.2	-	11.2	-	9.7	0	24.3	+	10.4	-	12.9	-
2000-3000	18.5	13.9	-	27.2	+	18.5	0	7.1	-	5.4	-	13.2	-
3000-4000	15.3	17.4	0	12.7	0	10.6	0	4.4	-	7.5	-	11.0	-
4000-6000	20.6	22.6	0	24.3	0	29.1	0	17.6	0	36.8	+	26.2	+
≥6000	9.0	28.2	+	11.6	0	23.6	+	6.2	0	22.1	+	19.7	+
N	1084		553		276		254		340		443		1866

[1] Preference: + = used more ($P < 0.05$) than available, - = used less ($P < 0.05$) than available, 0 = used proportional to availability.

Appendix Table 35. Rectal temperatures (mean ± SE) of black bears in Great Dismal Swamp, Virginia-North Carolina, 1984-1986.

	Spring			Early Summer			Late Summer			Early Fall			Late Fall			Denning		
Sex	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
Male	23	40.1	0.3	18	39.5	0.2	8	40.1	0.4	10	40.1	0.3	4	38.5	0.6	--	---	---
Female	2	39.2	0.7	10	39.6	0.3	9	39.6	0.4	6	39.7	0.3	5	37.8	0.7	4	37.4	0.7

VITA

Eric Charles Hellgren was born in Bethpage, New York on April 25, 1960. His family settled in Fort Lauderdale, Florida in 1966, where he was graduated from Fort Lauderdale High School in 1978. From 1978 to 1982, he attended Colorado State University in Fort Collins, Colorado and received a B.S. degree in Wildlife Biology. Following graduation, he worked for a summer at Idaho National Engineering Laboratory as a technician on a variety of wildlife research projects. From August 1982 to August 1984, he attended Texas A&M University in College Station, Texas, completing a M.S. degree in wildlife science on a study of reproductive physiology of the collared peccary. From August 1984 to August 1988, he has attended Virginia Polytechnic Institute and State University, studying black bear ecology and physiology in the Great Dismal Swamp in eastern Virginia and in captivity. He married Katherine Grace Timothy on June 4, 1988. In August 1988 he completed the requirements for a Doctor of Philosophy degree in Wildlife Science.