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To the Graduate Council:

I am submitting herewith a thesis written by David M. Brandenburg entitled "Effects of Roads on Behavior and Survival of Black Bears in Coastal North Carolina." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Joe Clark, David Buehler

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
and Dean of The Graduate School

EFFECTS OF ROADS ON BEHAVIOR AND SURVIVAL OF BLACK BEARS IN COASTAL NORTH CAROLINA

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

David Michael Brandenburg

August 1996

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ABSTRACT

I studied the effects of roads on the behavior and survival of black bears (*Ursus americanus*) at Marine Corps Base Camp Lejeune in Coastal North Carolina from May 1990 to December 1992. I used mark-recapture methods, radiotelemetry, and a Geographic Information System (GIS) for the study.

I estimated there were 16 bears on the study area in 1990. By 1992, the population likely was reduced to ≤ 6 bears (3.3 bears/100 km^2), primarily from vehicle-kills. Since 1988, vehicle-kills accounted for 20 of 28 (71%) of the total known mortality. The annual female survival rate was 71% for female bears on Camp Lejeune. This is the lowest estimate of survival reported for females in a southeastern black bear population.

Telemetry revealed that movement and activity patterns of bears on Camp Lejeune are complex and dynamic. I hypothesize that the spatiotemporal orientation of preferred fall foods has resulted in increased bear movements. Furthermore, the separation of preferred foraging and bedding areas by high-speed highways may have attributed to vehicle-kills. Eighteen of 20 (90%) vehicle-kills occurred between August and December.

I determined the seasonal and annual diet of bears on Camp Lejeune from examination of 421 scats. Artificial foods comprised 5% of the annual diet by volume but may have been underestimated. In 90 of 553 (16.3%) times I monitored radio-collared bears, they were <100 m from artificial food sources (landfill, dumpsters, and troop activity).

I determined the distribution of bears to secondary and primary roads with a

GIS using chi-square analysis. In 62 of 82 (76%) seasonal tests, bears used habitats adjacent to secondary and primary road zones disproportionately ($P < 0.05$). Using Bonferroni Z-statistics, I determined the selection of individual road zones. Most noticeably, the <100 m road zone was avoided the majority of the time and in all cases annually for both secondary and primary roads ($P < 0.05$).

Using a repeated measures analysis, I detected season and biological period effects in travel rates, as well as the frequency of secondary and primary road crossings ($P < 0.05$). Furthermore, bears did not cross secondary or primary roads randomly ($P < 0.05$).

The response/reaction behavior of bears to primary roads was more pronounced compared to secondary roads (i.e, nonpaved roads). I documented only 2 primary road crossings between 1100 and sunset. Bears crossed primary roads less frequently compared to secondary roads ($P = 0.06$). Primary road crossings occurred 44% less frequently than simulated random primary road crossings. In contrast to primary roads, some bears used secondary roads as convenient travel corridors. Secondary road crossings only occurred 20% less frequently than simulated secondary road crossings.

I measured the distance to roads immediately before and after bears crossed. Bears were located further ($\bar{x}$ = 216 m, SE = 96, n = 45, P = 0.017) from primary roads after crossing compared to distances before crossing. Furthermore, bears were located further from primary roads ($\bar{x}$ = 719 m, SE = 68, n = 45) compared to secondary roads ($\bar{x}$ = 446 m, SE = 20, n = 308) after crossing ($P < 0.001$).

Correlation analysis suggests that bears preferred to cross primary roads during low traffic volumes. Weekday traffic volume and the mean frequency of

primary road crossings were inversely correlated annually ($r = -0.39$, $n = 60$, $P = 0.002$) and in spring ($r = -0.60$, $n = 12$, $P = 0.038$). Furthermore, correlation analysis also suggested that bears were less discriminating in crossing primary roads in early and late fall. Early and late fall travel rates were more strongly correlated with the frequency of primary road crossings ($r = 0.79$, $P = 0.002$; and $r = 0.65$, $P = 0.02$, respectively) compared to the frequency of secondary road crossings ($r = 0.59$, $P = 0.044$; and $r = 0.62$, $P = 0.03$, respectively). Furthermore, the frequency of secondary and primary road crossings were strongly correlated in all seasons except early fall ($P = 0.117$).

I used a GIS, chi-square analysis, and Bonferroni Z-statistics to determine that radio-collared black bears selected habitats for crossing primary roads ($\chi^2 = 211.72$, 6 df, $P < 0.001$). Bears preferred pocosins, drainages, and pure hardwoods and avoided habitat openings for crossing primary roads ($P < 0.05$).

Camp Lejeune may represent a worst-case scenario of habitat fragmentation and impediment to movements for a southeastern black bear population. Not only is Camp Lejeune highly isolated from other bear populations, but its interior is fragmented by high-speed highways. Due to the high density of roads on Camp Lejeune, bears were unable to shift home ranges to avoid high-speed highways. As a result, vehicle-kill mortality has not only caused the number of bears to decline on Camp Lejeune but is threatening to extirpate this population. To recover this population, I discuss strategies to reduce bear movements across high-speed highways and thus reduce vehicle-kills on Camp Lejeune.

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CHAPTER I

INTRODUCTION

Habitat loss and fragmentation by human disturbance has greatly diminished the range of the American black bear (*Ursus americanus*) which formerly covered contiguous forested habitats over most of North America. In the Southeast, 90 to 95% of the former range of black bears has been lost (Hall 1981, Pelton 1982, Maehr 1984). There are at least 30 disjunct or relatively disjunct populations in 13 southeastern states (Pelton 1990) (Fig. 1). The Southeast Coastal Plain harbors the majority of these isolated bear populations. Loss of genetic variability may be a limiting factor for the future of bear populations in the Southeast Coastal Plain. Road mortality is an immediate risk to many small and isolated black bear populations of this region.

Studies of Southeast Coastal Plain bears clearly demonstrate the importance of pocosin habitat to this species (Hardy 1974, Hamilton 1978, Hellgren 1988, Lombardo 1993). Their limited economic value, nearly impenetrable nature, and waterlogged-peaty (muck) soils have successfully repelled ecologists and entrepreneurs for years. Until recently, pocosins have received little commercial (agriculture and forestry) or scientific interest.

The Russian grain deal and the world-wide weather problems in the mid-70's increased the demand for America's crops. To meet this demand, pocosins were targeted because of their price and their potentially productive soil properties. In addition, tax incentives for farmers made the purchase of pocosin land profitable.

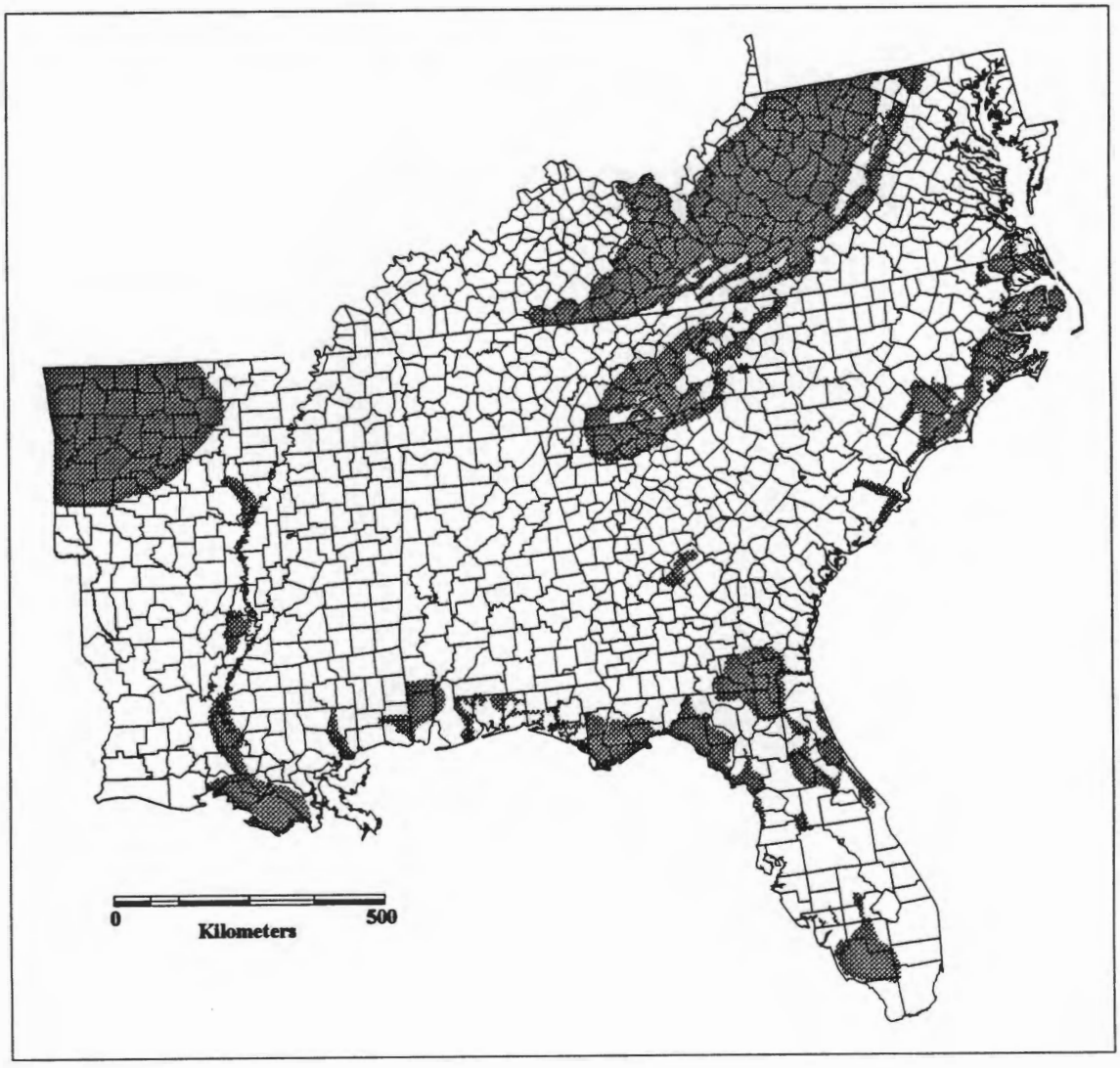


Figure 1. Present distribution of the American black bear in the southeastern United States. From Pelton and van Manen (in press).

Large agricultural corporations control approximately 21% of North Carolina's pocosins (Richardson 1981). From 1962 to 1980, 2810 km^2 (33%) of preferred black bear habitat (pocosins and hardwood swamps) have been ditched and/or drained for agriculture and forestry development (Richardson 1981). Thirty-six percent of pocosins are under partial or potential development status, and 31% remain in the natural state (Richardson 1981). Only 5% of pocosins are protected from development by federal and state agencies (Richardson 1981).

The value of pocosins for industrial forestry development also has changed. The Coastal Plain of North Carolina is strategically located near the largest timber market in the world. The flat topography of the Coastal Plain is well-suited to the intensive site preparation that is impractical in the piedmont and mountain areas (Campbell and Hughes 1981). However, poorly drained soils and phosphate deficiencies of pocosins make the growth of planted pines (*Pinus* spp.) marginal at best. To meet the "pocosin challenge," Weyerhaeuser Company invested 120 man-years in research from 1969 to 1981 (Campbell and Hughes 1981). Research programs have led to the development of water management techniques, proper site preparations, and fertilization treatments for pocosins resulting in an increase in wood production 2 to 3 times compared to natural stands in this region (Campbell and Hughes 1981). With technological advances and the increasing demand for timber, pocosin loss to conversion to monoculture pine plantations will continue. Major timber companies now control 44% of North Carolina's pocosins (Richardson 1981).

Conservation efforts to link "corridors" to fragmented key habitats was originally proposed by Wilson and Willis (1975) based on the classic work, *The Theory of Island Biogeography* (MacArthur and Wilson 1967). Corridors for

conservation have received considerable attention over the last decade. However, there is a paucity of empirical data illustrating how corridors are used (Simberloff and Cox 1987, Hobbs and Hopkins 1991, Nicholls and Margules 1991, Saunders and Hobbs 1991). The rationale for movement corridors is to lower extinction rates, lessen demographic stochasticity, curb inbreeding depression, and to provide habitats for safe travel (Simberloff *et al.* 1992). However, these justifications for corridors are speculative. Effective population management of bears will require a detailed understanding of their ecological niche rather than their discrete use of habitat types (Schoen 1990).

Harris (1985) contended that corridors are essential for the survival of wide-ranging mammals. For black bears, desired habitat types for corridors have not been identified but only suggested. It is of paramount interest to identify these parameters so critical areas can be identified and management can be directed toward protecting, and/or enhancing these key habitats.

Secondary and primary roads are 2 major fragmenting forces on black bear habitat in the Southeast (Hellgren and Maehr 1992). Secondary roads provide access to habitats and increase the vulnerability of bears to anthropogenic forms of mortality. Primary roads not only interrupt contiguous forest habitats but also expose bears to vehicular mortality. The success of dispersing bears may be limited by the number of intervening high-speed highways. Growth of small, isolated bear populations may be limited by road mortality.

Bear avoidance of roads appears related to the extent of human activity. Bears were reported to avoid roads in several studies (Rieffenberger 1974, Miller 1975, Hamilton 1978, Brown 1980, Quigley 1982, Villarrubia 1982). However, Carr and

Pelton (1984) reported that female bears did not avoid closed National Park Service roads in their study. Bears avoided some roads but not others in several other studies (Hugie 1982, Manville 1983, Beringer 1986, Hellgren 1988, Brody and Pelton 1989, Seibert 1989).

Despite our extensive knowledge of bear relationships to roads, only a few studies have measured the actual frequency of road crossings by bears. Carr and Pelton (1984) reported the actual frequency of seasonal road crossings by female bears for roads used by < 100 vehicles per day. Beringer *et al.* (1990) studied road crossings in western North Carolina, but they were unable to radiotrack bears intensively enough to determine the actual frequency of road crossings. They reported a "road crossing index" and a "road avoidance index" for roads used by < 100 and > 10,000 vehicles per day. No empirical data exist of bear relationships to roads used by 100 to 10,000 vehicles per day.

Coastal Plain black bear populations in North Carolina have grown moderately over the last decade (Fig. 2) (Warburton 1992). With the opening of bear hunting season in 10 eastern North Carolina counties, the harvest has rapidly increased (Warburton 1992). Unfortunately, the number of vehicle-kills in eastern North Carolina also has increased dramatically over the last 10 years (Warburton 1992).

Twenty-eight bear sanctuaries were established in North Carolina by North Carolina Wildlife Resources Commission to protect a core population of breeding females and to provide a surplus of dispersing animals (Sanders 1978). Marine Corps Base Camp Lejeune, Onslow County, North Carolina became part of this sanctuary system in 1971. By 1984, bear-troop encounters increased to undesirable levels coincident with an increase of bear sightings at dumpsters (A. Henry, Environmental

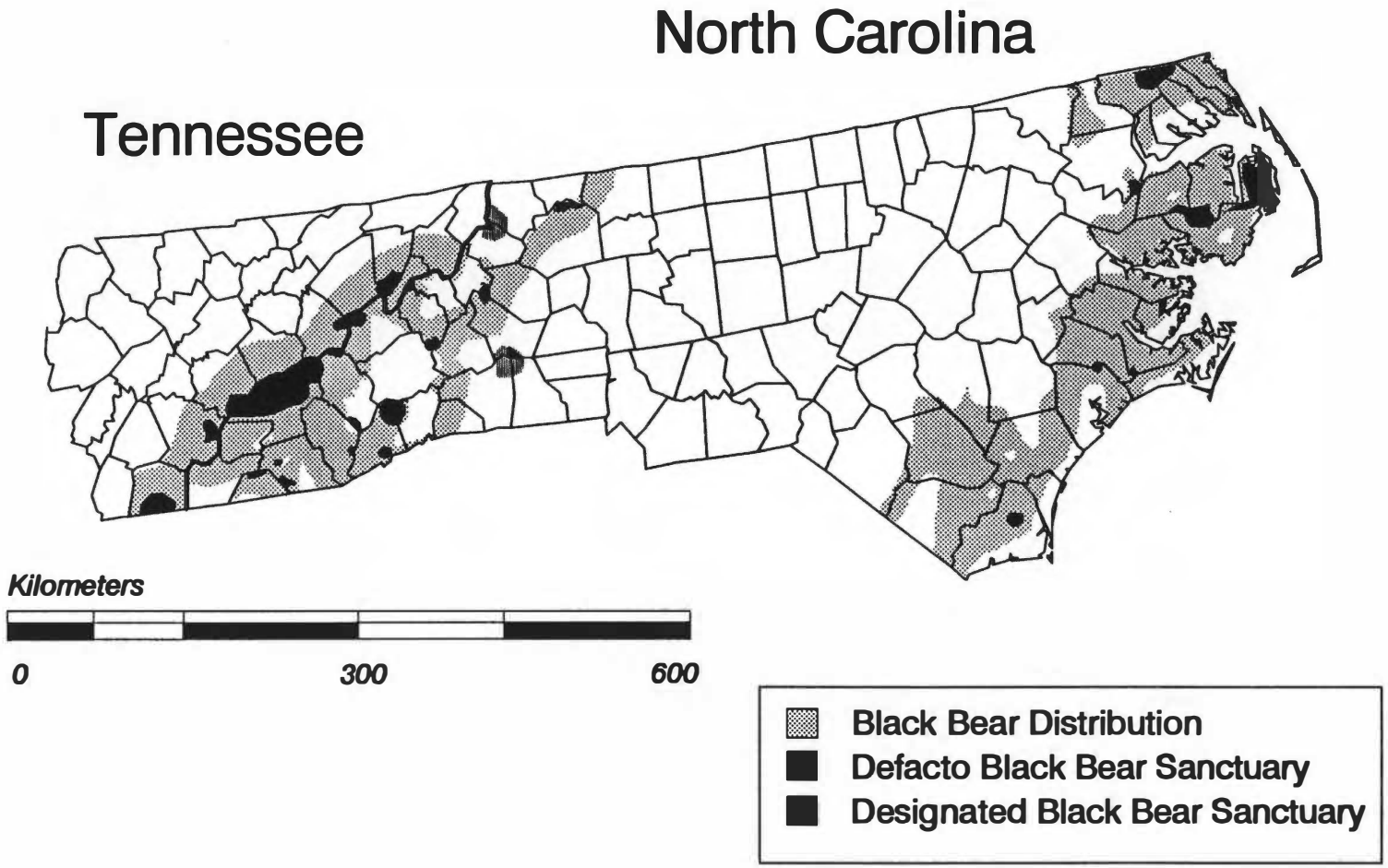


Figure 2. Distribution of black bears in North Carolina.

Management Division [EMD], pers. commun.). With this information, EMD opened the Base bear season in 1984 to alleviate those problems. Reported harvest levels for pre-and post-sanctuary periods on Camp Lejeune were low (≤ 6) (Lombardo 1993). But the unreported harvest of bears on Camp Lejeune from 1984 to 1987 may have been extremely high (anonymous 1989). EMD closed the bear hunting season in 1988 based on rumors of an unreported high number of bears harvested, an increase in vehicle-killed females, and a decrease of bear sightings at dumpsters. The bear hunting season will remain closed until we can answer fundamental questions about the survival of bears on Camp Lejeune.

My research is part of a long-term project including the ecology of black bears on Mainside Camp Lejeune (Lombardo 1993) and the recently purchased Sandy Run Pocosin (Studer in progress). I evaluated bear-road relationships using mark-recapture methods, radiotelemetry, and GIS for this study. Specific objectives were

- to obtain population and density estimates of bears on the study area,
- to determine mortality factors,
- to determine the seasonal and annual diet of bears on Camp Lejeune,
- to describe bear movement and activity patterns,
- to determine bear behavior in relation to roads,
- to determine desired habitat types used for corridors to cross primary roads.

CHAPTER II

STUDY AREA

Location

Camp Lejeune is an 82,000-ha military Marine Corps Base located in Onslow County in southeastern North Carolina (Fig. 3). Camp Lejeune is approximately 80 km from Moorehead City, Wilmington, and New Bern. The city of Jacksonville (population 135,000) borders Camp Lejeune on the northwest. The townships of Piney Green, Hubert, Queens Creek, Sneads Ferry, and Verona border Camp Lejeune on the north, northeast, east, southwest, and west, respectively (Fig. 4). Twenty-two km of shoreline on the Base border the Atlantic Ocean.

Four major highways (primary roads) form the boundaries of Camp Lejeune. US Route 210, US Route 17, and NC 24 comprise the southwestern, western, and northern boundaries, respectively. The northern section of Highway 172 forms the western boundary of Camp Lejeune and transects the southern to southeastern part of the Base. These 4 major highways and secondary roads (i.e., nonpaved roads) traverse approximately 150 and 500 km of Base property, respectively (Fig. 5).

Mainside, the eastern 25,000 ha section of Camp Lejeune, was selected as the study area (Fig. 5). Lack of bear sign found on the western section of the base by Lombardo (1993) precluded this area from the investigation.

Physiography, Geology, Soils, and Tributaries

Camp Lejeune lies on the eastern edge of the Coastal Plain Physiographic

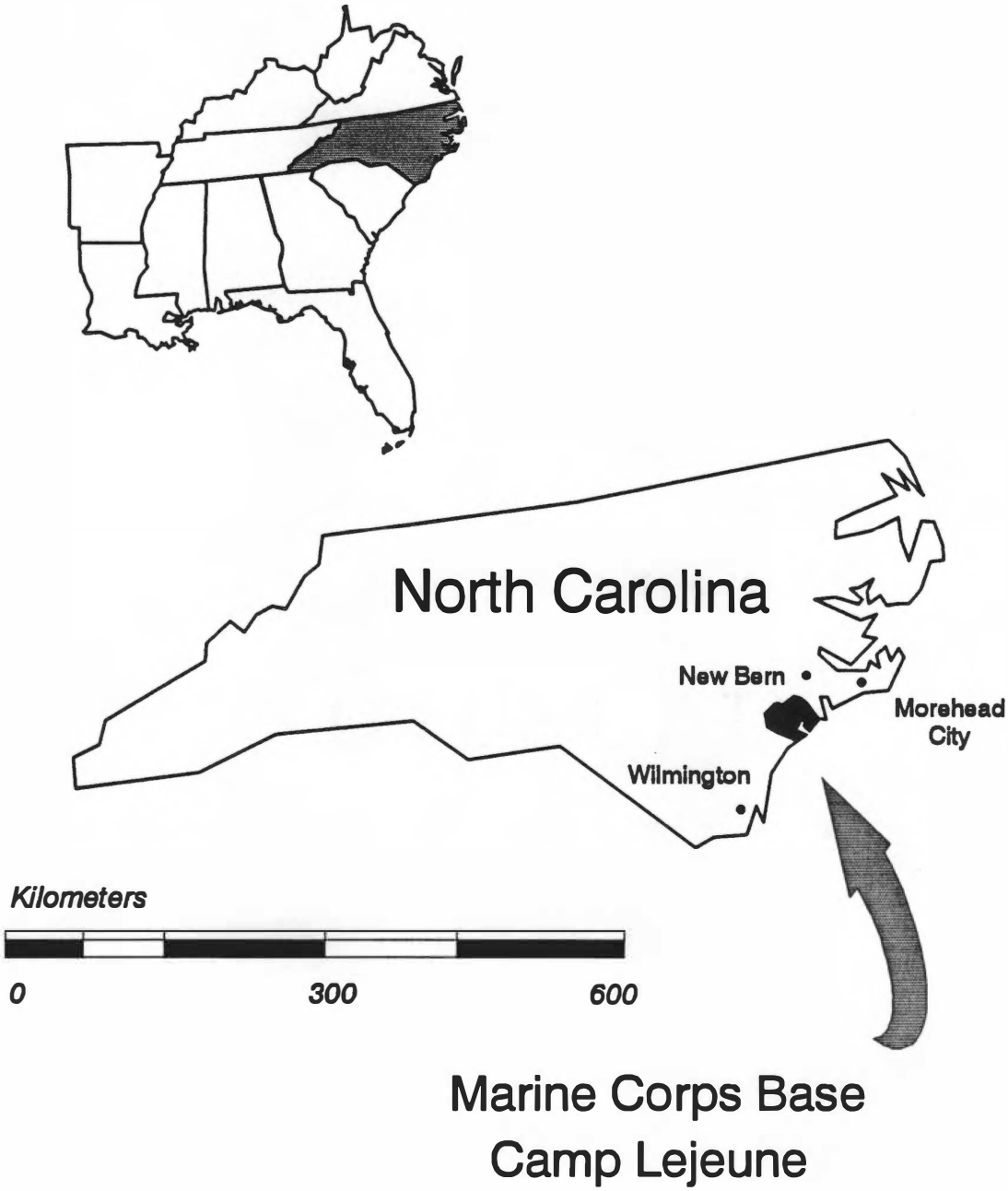


Figure 3. Geographic location of United States Marine Corps Base, Camp Lejeune, Onslow County, North Carolina.

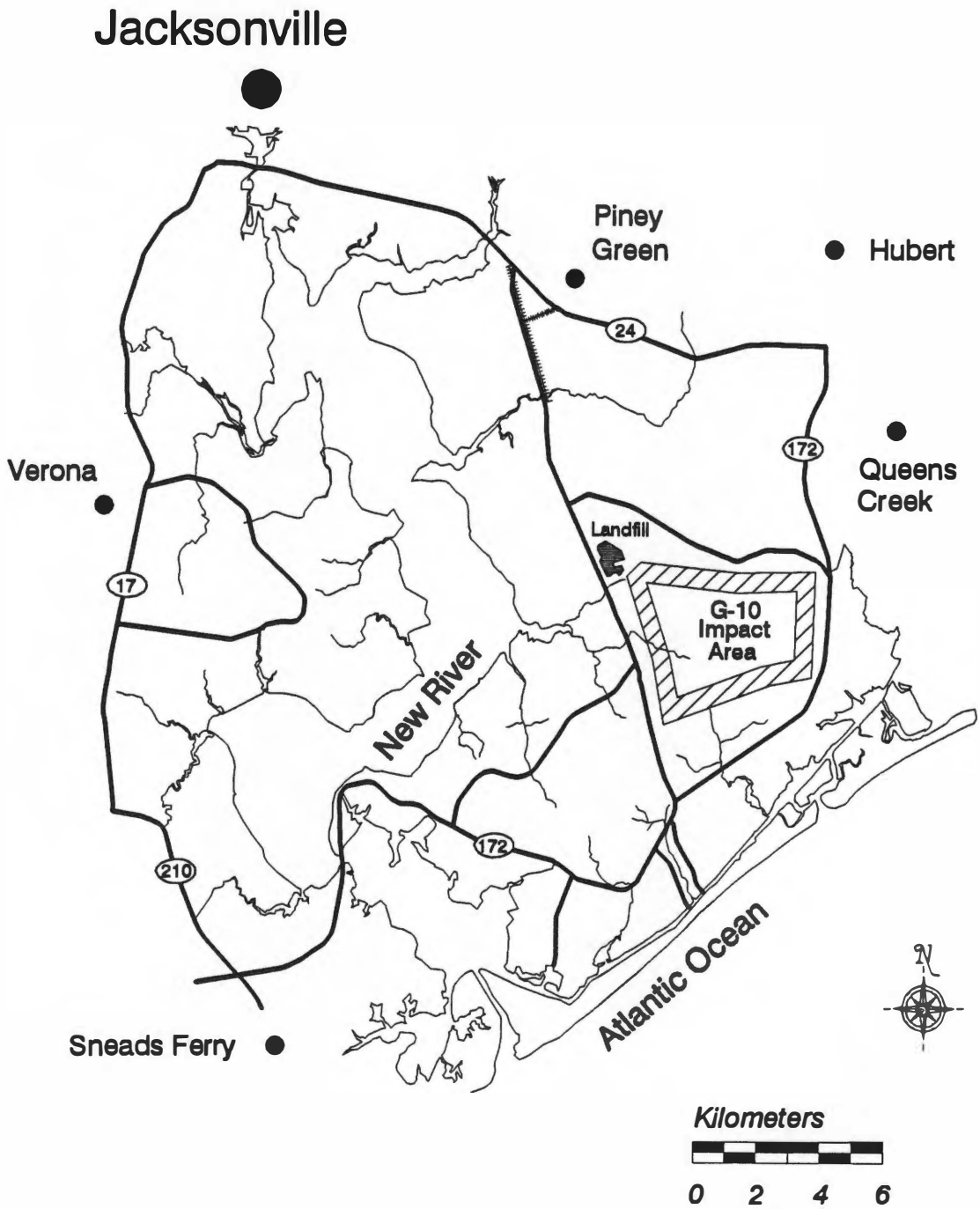


Figure 4. Locality map for Camp Lejeune, North Carolina.

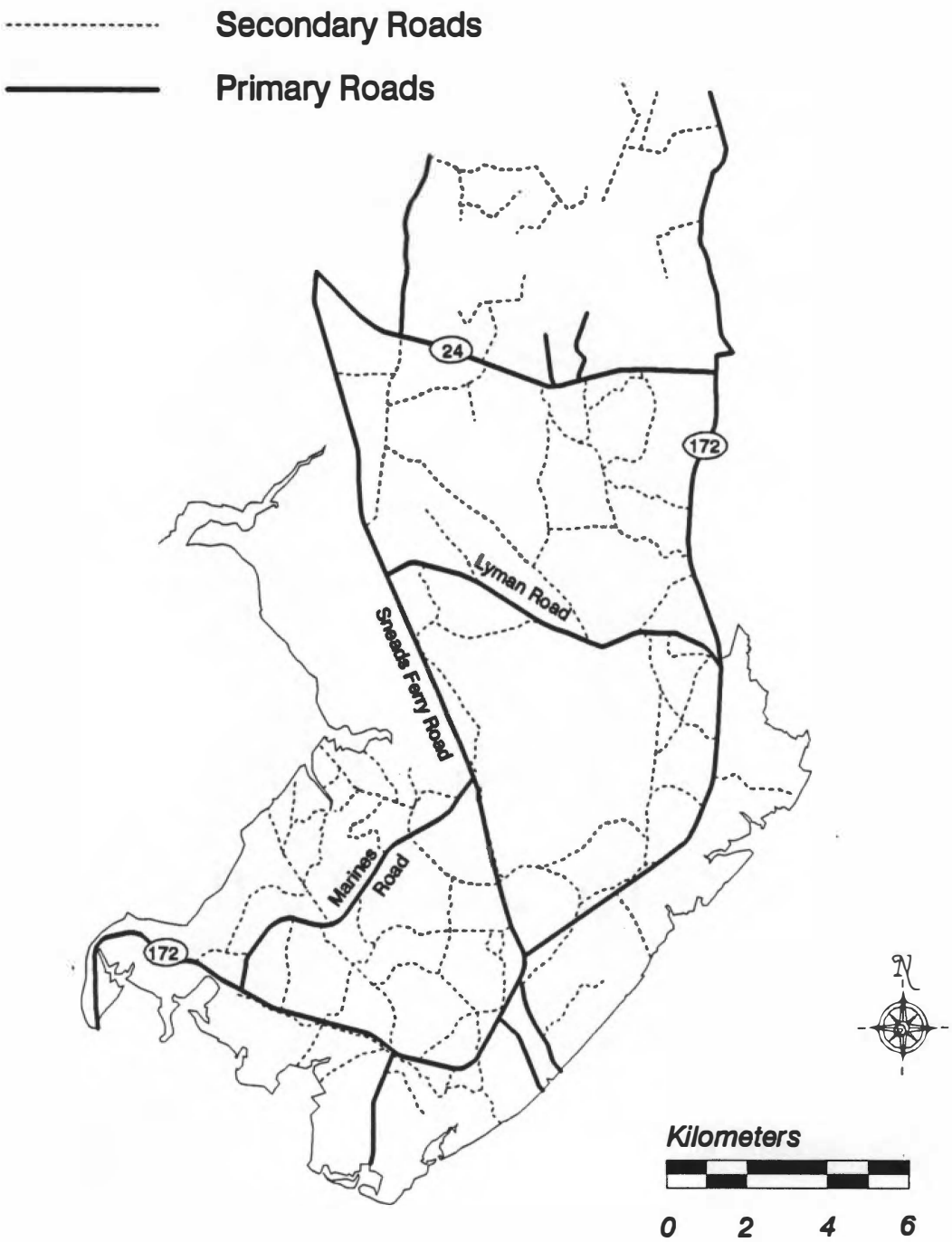


Figure 5. Distribution of secondary and primary roads on Mainside study area on Camp Lejeune, North Carolina.

Province. Camp Lejeune is part of a beach deposit that forms the Coastal Sand Ridge that approximately parallels the present Atlantic Coast. The alternating emergence and submergence of continental and marine sediments due to glacial fluctuations and/or slight crustal movements caused the formation of the Coastal Sand Ridge (Dolan and Vincent 1970).

Camp Lejeune contains parts of 3 geomorphic surfaces. Each surface represents a period of geologically recent land emergence (Barnhill 1984). The Pamlico surface lies at elevations of 0 to 7.6 m above sea level in a 3.2-km-wide strip near the coast and narrower areas along New River and other streams (Daniels *et al.* 1978). The Talbot surface comprises most of Camp Lejeune and lies at elevations of 7.6 to 13.7 m above sea level. A few western areas of the Base are represented by the Wicomico surface that lies at elevations of 13.7 to 22.9 m above sea level.

Most of Camp Lejeune consists of nearly level, undissected divides with minimal relief. This results in slow water movement, causing soils to range from somewhat poorly- to very poorly-drained (Barnhill 1984). The major soils of these areas are Torhunta, Murville, Woodington, Leon, Rains, and Stallings (Barnhill 1984). Croatan soils exist in the few oval depressions (i.e., Carolina Bays) that have developed on Camp Lejeune. The well-drained Baymeade and the moderately well-drained Marvyn soils are on side slopes near drainageways (Barnhill 1984).

Main streams that drain Camp Lejeune are tributaries of the New River. These streams are the Northeast Creek, Wallace Creek, Stones Creek, Everett Creek, Southwest Creek, Mill Creek, French's Creek, Bell Swamp, Duck Creek, Cowhead Creek, and Lewis Creek. Other important streams that drain Camp Lejeune are tributaries of the Intracoastal Waterway. These are Holover Creek, Gillets Creek,

Freeman's Creek, and Bear Creek. These coastal streams are characterized by wide estuarial flood plains with brackish water as much as 1.6 to 5 km inland (Barnhill 1984).

Climate

Camp Lejeune has a mild subtropical climate, with hot humid summers and cool winters with some subfreezing cold spells. The average summer temperature is 24.4°C and the average daily maximum is 31.1°C in summer. The average winter temperature is 7.2°C and the average daily minimum is 0°C in winter. Snowfall is rare; however a record 38 cm accumulation occurred in December 1989. The average annual temperature is 23.1°C. The average annual precipitation is 142 cm with the greatest concentration occurring in July ($\bar{x}$ = 20.3 cm) and the least during November ($\bar{x}$ = 6.7 cm).

Fauna

Camp Lejeune supports a variety of wildlife species. A representative list of vertebrate species on Camp Lejeune includes 87 fish, 21 reptilian, 14 amphibian, 165 avian, and 48 mammalian species (Marine Corps Base Camp Lejeune *et al.* 1987). Small game species found on Base include cottontail rabbit (*Sylvilagus floridanus*), fox squirrel (*Sciurus niger*), gray squirrel (*Sciurus carolinensis*), long-tailed weasel (*Mustela frenata*), marsh rabbit (*Sylvilagus palustris*), mink (*Mustela vison*), opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), and river otter (*Lutra canadensis*). Big game species include black bear and white-tailed deer (*Odocoileus virginianus*). Upland game bird species include the eastern wild turkey (*Meleagris gallopavo*),

northern bobwhite (*Colinus virginianus*), and American woodcock (*Philohela minor*).

Flora

Plant communities are diverse and range from longleaf pine (*P. palustris*) savannas and pure hardwood stands to beach communities and wetland habitats. Dune communities are located inland and parallel beach areas. Dune communities are essentially waves of drifting sands whose physical characteristics are determined by wind direction and intensity. Typical species of dune communities are salt-tolerant bitter panic grass (*Panicum amarum*), salt-meadow cordgrass (*Spartina patens*), sea oats (*Uniola paniculata*), and broomsedges (*Andropogon* spp.).

Maritime shrub thickets (i.e., salt-spray shrub communities) replace salt-tolerant grasses landward. These communities are characterized by dense growth of shrubs entangled with vines. Typical inhabitants of maritime shrub thickets are wax myrtle (*Myrica cerifera*), yaupon (*Ilex vomitoria*), red cedar (*Juniperus virginiana*), Virginia creeper (*Parthenocissus quinquefolia*), poison ivy (*Rhus radicans*), greenbriers (*Smilax* spp.), and wild grapes (*Vitis* spp.). Due to the shading effect of dense evergreen shrubs, few herbaceous species are present in the understory of maritime shrub thickets.

Maritime shrub thickets extend landward into tidal marshes or blend into maritime forest. Maritime forests are dominated by live oak (*Quercus virginiana*). Common tree associates of maritime forest are sweetgum (*Liquidambar styraciflua*) and water oak (*Q. nigra*). Few shrubs or herbaceous plants occur beneath the tree canopy in the maritime forest.

Seventy-six percent of Camp Lejeune is predominated by pine cover types.

Loblolly pine (*P. taeda*) occurs on approximately 30% of the land area, while longleaf pine comprises approximately 11% of Base property.

Pure hardwood stands approximate 17% of Base land area. On upland sites, white oak (*Q. alba*), black oak (*Q. velutina*), and northern red oak (*Q. rubra*) comprise the majority of the stocking. Scarlet oak (*Q. coccinea*), turkey oak (*Q. laevis*), and post oak (*Q. stellata*) are common associates on sand ridges. Common hardwoods found on lowland sites are black gum (*Nyssa sylvatica* var.) and red maple (*Acer rubrum*).

Pocosin habitat on Camp Lejeune comprises approximately 1500 ha or about 9% of total land area on Camp Lejeune. The word "pocosin" is an Algonquin Indian term that means "swamp-on-a-hill" (Tooker 1899). The term "pocosin" has been viewed and defined differently by scientists in various fields (e.g., geologists, botanists, soil scientists, and forest and wildlife biologists). Common synonyms for pocosins include bay, bayland, xeric shrub bog, and evergreen shrub bog. Pocosins are important, not only as refugia for animal species, but also for plant communities, some of which are threatened or endangered.

Geologically, pocosins are endemic to the southeastern Coastal Plain, occurring in broad or shallow basins, in drainage basin heads, and on broad, flat uplands (Wells 1928, Woodwell 1958, Kologiski 1977). Fire, hydroperiod, and peat depth are the predominant environmental forces that control the evolution and maintenance of pocosins (Otte 1981).

Pocosins typically have long hydroperiods during the cool seasons. Due to impermeable subsurface layers and water holding capacity of peat soils, pocosins buffer against flooding by discharging water as slow surface runoff. During warm

seasons, the water table drops in pocosins and water discharge occurs as evapotranspiration.

Pocosins often are characterized by their nearly impenetrable understory comprised of a variety deciduous and evergreen shrubs tangled with greenbriers, and canopied by a sparse overstory. The most common evergreen shrubs species found in pocosins include ti ti (*Cyrilla racemiflora*), fetterbush (*Lyonia lucida*), gallberries (*Ilex* spp.), wax myrtle, and greenbriers. Staggerbush (*L. mariana*), zenobia (*Zenobia pulverulenta*), and sweet pepperbush (*Clethra alnifolia*) are common deciduous shrubs found in pocosins. Common tree associates of pocosins are pond pine (*P. serotina*), red maple, sweet bay (*Magnolia virginiana*), red bay (*Persea borbonia*), and loblolly bay (*Gordonia lasianthus*).

Bogs, characterized by semi-floating mat or cushion-like vegetation, are frequently interspersed among pocosin communities. Insectivorous plants, particularly pitcher plants (*Sarracenia* spp.), and sundews (*Drosera* spp.), are often found scattered in these bogs.

History and Land Use

Camp Lejeune was established in 1941 with amphibious military training as the major function. Jacksonville was a relatively small community prior to the start of World War II in 1940. This coastal Carolina site was selected as a Marine Corps Base due to its proximity to Jacksonville for supplies and 22 km of coastline. Today, Camp Lejeune is the world's largest amphibious training area. The evolution of new weapon systems since World War II has resulted in the inland areas of Camp Lejeune (and the accompanying airspaces) being filled with new training ranges and facilities.

From the initial days of development (and through the projected future), training programs have always considered the underlying concept of "keep training and the environment in balance" (Marine Corps Base Camp Lejeune *et al*. 1987).

The main objective of EMD is to promote the enhancement and utilization of natural resources within constraints of the military mission. This objective can be met through implementation of the "multiple-use concept" of land use management (Marine Corps Base Camp Lejeune *et al*. 1987). The Range Control military division coordinates all natural resource activities (e.g., timber harvesting, hunting, and fishing activities) to avoid conflicts with military missions, which receive first priority. Some areas on Base (e.g., G-10 Impact Area) are restricted to military use only.

Major highways usually remain open for public use. Highway 172 is subject to partial closure for military training. Major highways experience heavy traffic volumes when Base personnel go to and from work in the early morning and late evening. Secondary roads are restricted to authorized personnel (e.g., military, EMD, and research personnel) and receive relative low traffic volumes compared to major highways. Hunters, fishermen, and outdoor recreationists must obtain a pass before entering secondary roads.

Camp Lejeune's hunting and fishing regulations closely resemble the state-mandated game regulations with few exceptions (e.g., season lengths, type of weapon, and type of ammunition). The EMD Wildlife Branch is responsible for monitoring populations, regulating harvest of game animals, and enforcing game laws. Due to the high density of deer on Camp Lejeune, organized deer hunts are scheduled to maintain deer populations at manageable levels. Organized hunts are conducted on a

unit by unit basis within the constraints of military missions. The harvest of black bears is prohibited on Base.

CHAPTER III

MATERIALS AND METHODS

Trapping

I trapped black bears from June through December in 1990 and from May through August in 1991 using Aldrich spring-activated foot snares (Aldrich Animal Trap Co., Clallam Bay, WA), 2 cage traps, and a culvert trap. Thickly-vegetated pocosins and restricted areas (such as the G-10 impact area) precluded random placement of traps. Trapsites were primarily established according to habitat type (i.e., areas juxtaposed to creek drainages and hardwood forests), known bear travel routes, and bear sign. I intensively trapped (10-18 traps were checked and maintained daily) the study area to achieve complete coverage of the Base.

Trail and modified cubby trapsets were used to capture bears in forested areas. I used Artificial Raspberry Flavoring (Medallion International Inc., North Haledon, NJ) to lure bears to trapsites, and bakery products (e.g., sweet rolls and donuts) were used to attract bears to trapsets in forested areas.

I used dirt-hole and drain-pipe trapsets to capture bears in nonforested areas. Visual attractants (e.g., garbage and Meals Ready to Eat [MRE's]) were used to attract bears to these trapsets. Blind sets (trapsets without bait) were employed where patterns in bear movements were observed (such as the habitual routes to the landfill).

I employed mobile home anchors (122 cm long with a 10-cm auger) to secure snared bears in nonforested areas. Drag logs (i.e., telephone poles approximately 1.5 m in length and 68 kg in weight) were substituted when mobile home anchors could

not be screwed into substrates.

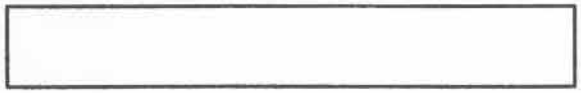
I usually checked trapsets in forested areas by 1100. Trapsets without the cover of shade or located in areas of human activity were checked by 0800. I deactivated trapsets during the day to prevent bears being captured in full sun or in view of the public.

I modified trapsets to capture bears on sand substrates with snares (see Fig. 6 for details). Simple modifications of trapsets and the use of mobile home anchors allowed me to capture bears in poor substrates and nonforested areas.

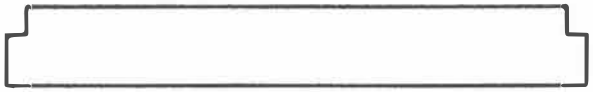
Handling

I immobilized captured bears with a 2:1 mixture of ketamine hydrochloride (Ketaset, Bristol Lab., Syracuse, NY) and xylazine hydrochloride (Rompun, Haver-Lockhart, Inc., Shawnee, KS). Ketamine hydochloride and xylazine hydrochloride was freeze-dried and reconstituted with a local anesthetic, Carbocaine V (Mepivacaine Hydrochloride, Winthrop Lab., New York, NY), at a 200/100/20 mg/ml concentration, respectively. I initially administered the mixed drug with a jab stick at a dosage of 4.4 mg/kg ketamine hydrochloride, 2.2 mg/kg xylazine hydrochloride, and 0.4 mg/kg mepivacaine hydrochloride i.e., 1 ml per 45.4 kg (100 lbs) of estimated body weight. After adequate immobilization, bears were sexed, checked for injuries, and examined for abnormalities. Body temperatures were monitored. I applied a wetting solution (Akwa Tears, Akorn Inc., Abita Springs, LA) to the eyes of bears to keep them moist during the handling process. To minimize stress, the face of the animal was covered with a bandana. I gave lactating females 1 ml of Oxytocin (Burns Veterinary Supply, Oakland, CA) to counteract the milk-inhibiting

Step 1:
Cut a 80.6 cm long piece from 7.6 cm wide x 3.2 mm thick flat metal.

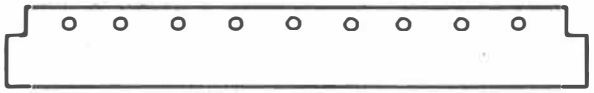


Step 2:
Cut a 1.9 deep x 1.4 wide cm notch on both sends of the metal piece.

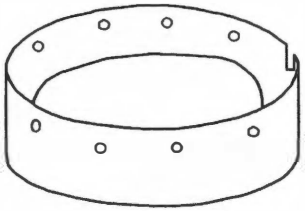


Step 3:
Drill a 1.2 cm hole 3.2 cm from the top edge of the metal piece, centered between the ends (i.e., 40.3 cm from the end of the metal piece).

Step 4:
Drill 4 1.2 cm holes, 3.2 cm from the top edge of the metal piece as above on each side of the first drilled hole. These holes should be spaced 7.6 cm apart.



Step 5:
Bend metal into a circle and weld the ends together below the notch to complete the ring structure.



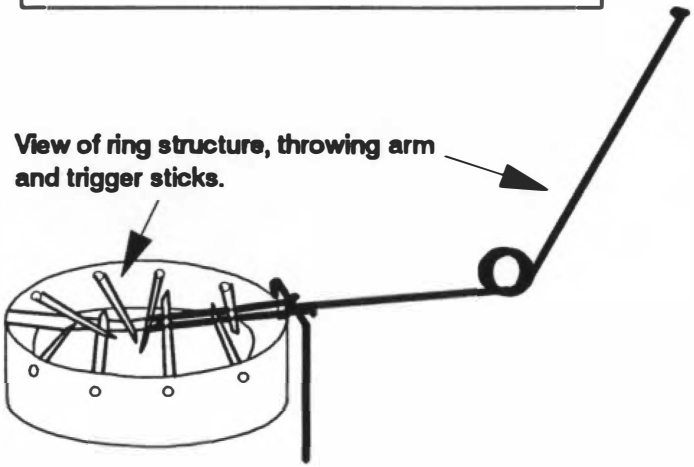


Figure 6. Instructions for trapset modifications.

properties of ketaset. A long-lasting antibiotic (Liquamycin LA-200, Pfizer Animal Health, New York, NY), concentrated at 200 mg/ml, was given to some bears which had sustained minor injuries. I used a dosage of 19.8 mg/kg (i.e., 4.5 ml per 45 kg but not to exceed 10 ml per bear).

Upon initial capture, I ear tagged and tattooed each bear. I extracted first premolars and sectioned and stained these teeth (Eagle and Pelton 1978) for age identification by cementum annuli counts (Willey 1974). I weighed bears to the nearest 2.2 kgs with a portable hanging scale (Iron Clad Straight Scale, Chatillon Co., New York, NY). I measured a number of morphological characteristics and recorded descriptive information on captured bears.

Radio Telemetry

I monitored radio-collared bears from 1 September 1990 until den entry and again from den emergence until 15 August 1991. Radio-collared bears were primarily located from roads using a receiver (TR-2, Telonics Inc., Mesa, AZ) and a 5-element, vehicular roof-mounted antennae (Wildlife Materials, Carbondale, IL). I obtained sequential locations every 2 hrs during diurnal tracking periods (0700-2200) and nocturnal tracking periods (1 hr before sunset until 1000 the next morning). Radio-collared bears were located 6 to 10 times during each tracking period. I simultaneously monitored 5 to 7 radio-collared bears during each tracking period. Each radio-collared bear was monitored 2 to 4 times weekly.

I fitted motion-sensitive radio-collars (Mod-500, Telonics Inc., Mesa, AZ) to all captured bears. Transmitters emitted 90 to 120 pulses per minute (PPM) when bears were moving and 60 to 90 PPM when bears were motionless for >3 minutes.

I assumed radio-collared bears were resting when transmitters emitted a slow pulse rate. I used a leather spacer to attach radio-collars to bears; this allowed the collar to remain on the animal for 12 to 18 months.

I positioned telemetry stations (i.e., receiver stations or known reference points) adjacent to identifiable features on maps such as road intersections, bends in roads, and habitat boundaries, and <400 m apart on all roads within home ranges of radio-collared bears. Telemetry stations were given an identification (ID) number, plotted, and Universal Transverse Mercator (UTM) coordinates obtained to the nearest 10 m on 1:24,000 maps compiled from 1983 National High Altitude Photography.

I used 4 tracking criteria to locate radio-collared bears. First, I obtained 2 azimuths by the "loudest signal method" described by Springer (1979). The loudest signal was obtained from "in phase" radio waves (Kenwood 1987:115). Second, bears were located from the nearest roads. Third, I located active bears (i.e., collected 2 azimuths) in ≤ 6 minutes. Finally, I obtained 3 azimuths from radio-collared bears when angles between azimuths were $<30°$ and radio-collared bears were relatively far from telemetry stations (i.e., roads). Additionally, I obtained 3 azimuths when time permitted, regardless of the situation.

I entered the telemetry data into the software program XYLOG (Dodge and Steiner 1986) after each tracking period and visually checked data for errors (i.e., erroneous azimuths). Generated output included bear ID, date, time, and UTM coordinates.

Triangulation Error Analysis

I placed a radio-collar on a 35-kg dog restrained in areas in which bears were typically located. This closely simulated actual bear activity, locations, and emitted radio waves. I located this test collar using methods described above. I determined the distance in meters (i.e., error) from the true location to the estimated location. Because virtually all radiotracking was done from roads, distance to roads is essentially equal to distance to observer. Therefore, I categorized error distances based on test collar distances to the nearest roads: <100 m ($\bar{x}$ = 18.9 m SE = 3.4, n = 21), 100-200 m ($\bar{x}$ = 35.3 m SE = 5.0, n = 16), 200-400 m ($\bar{x}$ = 49.7 m SE = 6.4, n = 24), 400-800 m ($\bar{x}$ = 80.5 m SE = 10.4, n = 17), and >800 m ($\bar{x}$ = 115 m SE = 14.8, n = 15).

I generated simulated locations based on a uniform distribution of random azimuths, mean error distances, and the road distance category of original locations. Simulated locations were used to determine the effect of triangulation error on habitat use analysis (see **Bear Distribution in Relation to Roads**).

Population Dynamics

I estimated the number of bears on Camp Lejeune with intensive trapping, telemetry, track examinations, and observations. The validity of this estimate is strengthened by the small number of bears inhabiting a relatively small area. For comparative purposes, I used a modified version of the Petersen Estimate as a second estimate of population size (Chapman 1951) with an approximately unbiased estimate of variance (Seber 1982:60).

The Petersen model assumes the population is closed to additions (births or

immigrants) and deletions (deaths or emigrants), equal catchability for all animals, and marks are not lost or overlooked by the observer. The closure assumption can be relaxed if emigration occurs equally among marked and unmarked animals resulting in a unbiased estimate at the time of first sampling (Seber 1982). Known deaths occurring between the 2 sampling periods were deleted from analysis. Unmarked yearlings (immigrants) captured during the second sampling period were not included in the model and were added to the estimate. Only the initial capture of individuals within the same sampling period were included in the analysis. An unknown bear was vehicle-killed and illegally taken from the highway in December 1992. For population estimation purposes, I identified this individual as adult female 08 based on the vicinity of the vehicle-kill. Finally, I determined a density estimate by dividing the composite 95% convex polygon annual home ranges of radio-collared bears by the derived population estimate.

I determined seasonal and annual survival rates for adult females using a modified Kaplan-Meier product limit method (Pollock *et al.* 1989). Seasons were determined by shifts in bear food habitats (see **Food Habits Analysis**). For radio-collared bears whose signals were lost due to unknown causes, the monitoring period ended the last day of positive contact. Small sample sizes precluded the estimation of survival rates for adult and subadult males.

Food Habits Analysis

I collected scats at trap sites, dumpsters, and the landfill. Radio telemetry aided in finding scats in foraging and bedding areas and den sites. Seasons were determined by shifts in bear food habits (Hellgren and Vaughan 1988): winter - 16

January to 31 March, spring - 1 April 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 15 January.

I washed scats through a series of sieves with openings of 7, 2, and 0.15 mm to separate food particles of equal size. I identified individual food items to the lowest possible taxon. I determined frequency of occurrence and volume percent both seasonally and annually for each food item. Volume percent was visually estimated for individual food items in each scat. I estimated the annual diet by averaging seasonal volume percent values, excluding winter data due to a small sample (n = 11).

I grouped food items into 7 categories. These are tree fruit, shrub/vine fruit, animal matter, vegetation, grasses (Graminae), garbage, and debris. Food habitats analysis was repeated for each food category.

Home Range Estimation

I used the percent convex polygon (Michener 1979, Bowen 1982, Bekoff and Mech 1984) to estimate seasonal, annual, and composite home range perimeters of bears. The convex polygon is a non-statistical method not restricted by assumptions of distribution and independent observations. Because convex polygons are severely affected by outliers and may include areas never observed to be used by animals (MacDonald *et al.* 1980), I used 95% convex polygons for the analysis.

I used the HOME RANGE (Ackerman *et al.* 1990) software program to estimate home range perimeters of the bears. Bears monitored $\geq$8 months (n = 8) were used to estimate annual and composite home range perimeters. For some bears,

I pooled early fall seasons with small samples to either late summer or late fall.

Bear Distribution in Relation to Roads

Clark and van Manen (1993) state that black bears are excellent candidates for habitat analysis using geographic information systems (GIS) because of their generalized habitat requirements, the appropriateness of landscape scaling for use analysis, and because most readily available data layers (e.g., roads and forest cover types) are often significant to black bear ecology. I investigated bear-road relationships on Camp Lejeune using Arc/Info (Environmental Systems Research, Inc., Redlands, CA). Arc/Info is a vector-based GIS that performs 2 primary functions. It stores and performs all operations on coordinate data and attributes (i.e., descriptive non-coordinate data). A "coverage" is the basic unit of storage in Arc/Info. It is a digital version of a single map sheet layer that contains both the location data and the attributes that describe that location. In a coverage, map features are stored as points (e.g., bear locations), arcs (e.g., roads), or polygons (e.g., habitat types).

Roads were digitized from 1:24,000 USGS quadrangles by EMD Forestry Branch and uploaded to Arc/Info. Using this information, I generated secondary (unpaved) and primary (paved) road coverages in Arc/Info. The secondary road coverage contained all tank trails and unpaved roads and excluded roads that intersected habitat openings (i.e., Tactical Landing Zones and clearcuts).

For both secondary and primary roads, I created road zone coverages using an overlay procedure (BUFFER in Arc/Info). Coverages contained areas (i.e., road zones) of <100, 100-200, 200-400, 400-800, and >800 m from the roads.

I developed a bear location coverage in Arc/Info using the UTM bear locations. To determine the seasonal and annual use of road zones for radio-collared bears, I superimposed the bear location coverage on the road zone coverages using an overlay procedure (IDENTITY in Arc/Info).

I developed seasonal and annual home range coverages in Arc/Info using the home range perimeters of radio-collared bears. I determined the proportion of road zones within seasonal and annual home ranges of radio-collared bears by superimposing home ranges on road zone coverages with an overlay procedure (CLIP in Arc/Info).

To test the null hypothesis that bears use secondary and primary road zones in proportion to their availability, I compared the observed frequency of bear use of road zones with the proportion of road zones occurring within home ranges using chi-square goodness-of-fit tests. For a valid test there must be at least 1 expected observation in each category, no more than 20% of all categories contain less than 5 expected observations (Dixon and Massey 1969), and study animals must have access to and the opportunity to be observed in various categories (Neu *et al.* 1974, Byers *et al.* 1984). To meet these criteria, road zones not containing 5 expected observations were pooled with other categories.

When road zone selection was detected, I determined confidence intervals for the observed frequencies using Bonferroni Z-statistics (Neu *et al.* 1974, Byers *et al.* 1984). If the observed frequencies were outside confidence intervals, then I considered those road zones preferred or avoided. The terms "preferred" or "avoided" were first used by Neu *et al.* (1974) and are used here for convenience to describe greater or less use than expected. Clark (1991) cautions that a behavioral

response to habitat parameters is not necessarily implied with these terms.

Radiotracking by triangulation provides only an estimate of the animal's location. The quality of the estimate locations as determined by triangulation is a function of the telemetry station location, the animal's location relative to telemetry station, and the precision of the bearings from telemetry stations to the animal (White 1985). The power of the chi-square goodness-of-fit tests to detect habitat selection is a balance between (1) fineness of habitat classification, (2) accuracy of the estimate of habitat use, and (3) the number of locations used to estimate habitat use (White and Garrot 1986).

To determine the power of statistical tests for various road zones, the above analysis was repeated on a set of simulated locations (see **Triangulation Error Analysis**). New chi-square values and percentages that differed from original chi-square values were calculated. Misclassification rate was calculated by totalling the difference in the error-generated locations (those classed differently from the original set of locations) and dividing by the total number of observations used for the chi-square analysis. These values are given to show the relative effects that telemetry error, habitat structure, or sample size may have on the analysis.

Weak statistical power is indication of large telemetry errors relative to habitat composition. This results in large deviations of chi-square values from the original chi-square values and a high percentage of misclassifications (Clark 1991). If habitat selection is detected when statistical power is weak, this is an indication that strong habitat selection forces are operating (White and Garrot 1986).

Road Density

I determined the densities (km/km^2) of roads occurring within the seasonal and annual home ranges of bears. For this analysis, I superimposed home range perimeters of radio-collared bears on the secondary and primary road coverages using an overlay procedure (CLIP in Arc/Info).

Bear Movements and Activity

I documented bear movements by sequentially radio-monitoring bears. Assuming a straight line of travel, travel rate (kmph) was determined by dividing the distance between location i (x_i, y_i) and the next location (x_{i+1}, y_{i+1}) by the time elapsed (et_i) between sequential locations. I determined the distance (d_i) between sequential locations using the formula

$$d_i = \sqrt{(x_{i+1}-x_i)^2 + (y_{i+1}-y_i)^2}.$$

To account for the seasonal differences in sunrise and sunset times, and the length of day, I categorized travel rates into more meaningful biological periods:

- sunrise, 1 hr before sunrise to 2 hrs after sunrise,
- morning, 2 hrs after sunrise to noon,
- afternoon, noon to 1 hr before sunset,
- sunset, 1 hr before sunset to 2 hrs after sunset, and
- night, 2 hrs after sunset to 1 hr before sunrise.

Sunrise and sunset are defined as when the sun is 6° below the horizon. I examined travel rates for season, biological period, and season-by-biological period effects. I compared travel rates with a 2-way and 1-way analysis of variance using a repeated

measures analysis (GLMM 1990).

Bear Behavior in Relation to Crossing Roads

I documented secondary and primary road crossings by sequentially monitoring radio-collared bears and determining if a road was located between consecutive bear locations. Short time intervals (approximately 2 hrs) between sequential locations minimized the chance of bears crossing and recrossing the same road undetected.

Road crossing time was determined using Arc/Info and Statistical Analysis System (SAS Institute, Inc., Cary, NC) software (SAS Institute, Inc., 1990). Assuming a straight line and a constant rate of travel, road crossing time (rct_i) was determined using the following formula

$$rct_i = (r_i/d_i/)(et_i) + (t_i)$$

where (r_i) is the distance from the road to the location occurring before the bear crossed a road, d_i is the distance between sequential locations, et_i is the time elapsed between sequential locations, and t_i is the time of the location before the bear crossed a road.

I categorized road crossings into 5 biological periods (see **Bear Movements and Activity**). The frequency of secondary and primary road crossings were examined for season, biological period, and season-by-biological period effects and compared with a 2-way and 1-way analysis of variance using a repeated measures analysis (GLMM 1990).

To address the question of whether bears cross secondary and primary roads with the same frequency, I compared the frequency of secondary road crossings and

adjusted primary road crossings. Primary road crossing frequency was adjusted by multiplying the frequency of primary road crossings by the proportion of secondary roads to primary roads within seasonal home ranges of bears. This adjustment was necessary because the density of secondary and primary roads was unequal. I made the comparison using the nonparametric Wilcoxon's signed-rank test (Siegel 1956).

I tested the hypothesis that bears cross secondary and primary roads randomly by comparing the frequency of road crossings with simulated random road crossings. Simulated locations were generated based on the distance bears moved between the original sequential locations and uniform random azimuths. I simulated road crossings by superimposing simulated locations on the road coverage in Arc/Info and determined if sequential locations were bisected by a road. I compared the differences between the original and simulated road crossing frequencies within seasons using Wilcoxon's signed-rank test (Siegel 1956).

I tested several hypothesis concerning the response of bears to roads characterized by having low volumes of traffic to those that are heavily traveled, high-speed highways. I also examined the relationship between traffic volume and the mean frequency of primary road crossings. For all correlation analysis, I classified road crossings and travel rates into twelve 2-hr time intervals: from 0000-0200, 0200-0400, 0400-0600, 0600-0800, 0800-1000, 1000-1200, 1200-1400, 1400-1600, 1600-1800, 1800-2000, 2000-2200, and 2200-0000 hrs.

First, I examined the relationships between travel rates and the mean frequency of seasonal road crossings using Pearson correlation analysis. Road crossings are undoubtedly a function of bear movements and therefore are strongly

correlated with travel rates. I hypothesize that lower correlations with the frequency of primary road crossings compared to secondary road crossings are a reflection of bear behavior to the additional factor associated with primary roads, traffic. Therefore, higher correlations with the frequency of primary road crossings compared to the correlations with secondary road crossings will be indicative that bears were less discriminatory in crossing primary roads on Camp Lejeune.

In a second analysis, I tested for differences between the distances that bears were radio-located from roads before crossing compared to distances after crossing. I used Arc/Info to determine the distance that bears were from roads and assumed a straight line travel between these locations. Furthermore, I assumed that location time both before and after crossing roads were random. I made comparisons within seasons and biological periods using Wilcoxon's signed-rank test (Siegel 1956). Additionally, I compared these distances between road types. For valid comparisons, observations that included multiple road crossings between sequential locations were deleted from the analysis.

Thirdly, I examined the relationships between mean weekday traffic volume and the mean frequency of primary road crossings again using Pearson correlation analysis. To do this, I collected traffic volume data on major highways frequently crossed by bears: Lyman Road, Old Sneads Ferry Road, Marines Road, and highway 172 (Fig. 5). From September to December 1990, I sampled traffic volume in 2-hr intervals during each tracking period using Impulse traffic counters (K-Hill Signal Co. Inc., Uhrichsville, OH). Because of small sample sizes, I pooled weekend and weekday day traffic volumes for all roads.

Corridor Use Analysis

I tested the hypothesis that bears prefer and/or avoid specific habitat types for crossing primary roads. For this analysis, I compared the observed frequency of road crossings at habitats adjacent to primary roads to the proportion of habitats adjacent to primary roads within composite home ranges using the chi-square goodness-of-fit test. As before, when habitat selection was detected, I determined confidence intervals for the observed frequencies and if outside the confidence intervals, I considered those habitats preferred or avoided.

To test the above hypothesis, I created a corridor coverage by buffering (BUFFER in Arc/Info) primary roads to 50 m and superimposing this coverage on a habitat coverage using an overlay procedure (CLIP in Arc/Info). I determined the available habitat (ha) adjacent to primary roads for the habitat selection analysis.

The habitat coverage was created by EMD by digitizing forest stand types from aerial photographs. There are 56 specific stand types that average 23 ha (Lombardo 1993). Stand types were grouped into 7 habitat types: (1) pure pine, (2) pine/hardwoods, (3) habitat openings, (4) pure hardwoods, (5) pocosins, (6) narrow drainages, and (7) major drainages. Major drainages were identified by the intersection of creeks and associated habitat with primary roads. Narrow drainages were identified by fingers of pocosins or pocosin-like vegetation <75 m in width at road margins that intersected primary roads.

I determined the use of habitats for crossing primary roads by simulating bear movements in Arc/Info. Assuming a straight line of travel, line segments connecting "before" and "after" road crossing bear locations were superimposed on the corridor

coverage. I identified habitats used for crossing primary roads by the intersection of these lines and habitats adjacent to roads. I recorded the observed frequency of road crossings at habitats adjacent to primary roads for both sides of the road. This was necessary because some habitats on the study area were different from those occurring directly across the road.

Telemetry error, time elapsed between sequential locations, nonlinear bear movements, and fineness of habitat classification are 4 factors that can bias this analysis. Telemetry accuracy was good for this study, ranging from 18.9 to 115 m. Therefore, I consider the effects of telemetry error insignificant for this analysis. The effects of the duration between sequential locations ($\bar{x}$ = 2.3 hrs, SE = 0.08) will be significant only if time span is large and bear movements are nonlinear.

CHAPTER IV

RESULTS

735 16
42 7

Population Dynamics

Trapping

I captured 16 bears (4M and 12F) 23 times during the study (Table 1). Only 2 adult bears (female 31 and male 24) were initially captured during my study. I captured all bears from the previous study except for 3 adult males. One of these was a radio-collared adult male (bear 11) that died in early fall in 1990.

In 1990, 735 trap nights produced 16 captures of 13 different bears for a trap success of 1 capture per 48 trap nights. In 1991, 42 trap nights produced 7 captures from 5 different bears for a trap success of 1 capture per 6 trap nights. The age of captured bears ranged from 8 months to 21.5 years ($\bar{x}$ = 5.7, SE = 1.45, n = 15). The average age of females was $\bar{x}$ = 5.9, (SE = 1.17, n = 10). I captured three 1.5-year-old males and a 21.5-year-old male.

In 1990, I captured 2 adult females with 2 cubs each. I observed an untagged female with a cub in 1990; she was subsequently captured in 1991. The average litter size in 1991 was 2.5 (SE = 0.29, n = 4)

Population Size and Density

There were 16 bears known (excluding 5 known cubs) on the study area in

Table 1. Black bear captures on Camp Lejeune, North Carolina, 1990-1991.

Date	ID#	Sex	Weight (kg)	Age in Years
15 Jun 90	20	M	20.5	1.5
16 Jun 90	06	F	88.5	12.5
23 Jun 90	21	M	20.5	1.5
26 Jun 90	22	F	38.5	2.5
27 Jun 90	16	F	43.2	3.5
12 Jul 90	01	F	56.8	6.5
13 Jul 90	23	M	15.5	1.5
13 Jul 90	08	F	59.1	6.5
30 Jul 90	24	M	156.8	20.5
04 Aug 90	16	F	43.2	3.5
05 Aug 90	24	M	156.8	20.5
07 Aug 90	04	F	56.8	5.5
27 Sep 90	06	F	127.3	12.7
12 Nov 90	24	M	181.8	20.7
07 Dec 90	09	F	62.7	11.7
08 Dec 90	26	F	29.5	0.7
02 Jun 91	28	M	31.8	1.5
25 Jun 91	09	F	50.0	12.5
28 Jun 91	28	M	31.8	1.5
06 Jul 91	30	F	22.7	2.5
09 Jul 91	31	F	63.6	6.5
22 Jul 91	28	M	34.0	1.5
25 Jul 91	16	F	45.4	4.5

1990. This included 7 adult females, 4 adult males, 3 yearling males, and 2 yearlings of unknown sex. I believe all bears on the study area were radio-collared except for 2 adult males captured in the previous study, and 2 yearlings of unknown sex. This is evidenced by the high proportion of recaptures occurring compared to the few number of initially captured bears. Additionally, only 4 of 96 bear sightings were of bears not wearing a radio-collar. The Peterson model underestimated the number of bears within the study area in 1990 (13.6 bears, 95% CI's = 11.8 to 15.4, var N = 0.83).

The population was likely reduced to $\leq$6 bears (i.e., 1 adult female, 2 adult males, 2 subadult females, and 1 subadult of undetermined sex [excluding 3 known cubs]) or $\leq$3.3 bears/100 km^2 between September 1990 and December 1992. Eleven of 16 radio-collared bears died between this period. I lost radio-contact with 3 female bears and suspect that 2 of these were vehicle-killed. Female 06 accompanied by 2 cubs was the only radio-collared bear known on Mainside in December 1992.

Mortality Factors

Twenty-eight mortalities have been recorded since the initiation of black bear research on Camp Lejeune in 1988. Human related deaths accounted for 27 of 28 (96%) total mortalities on Camp Lejeune (Fig. 7). Vehicle-kills accounted for 20 (71%) mortalities and 6 of 7 (86%) known cub deaths. Sixteen of 22 radio-collared bears died since 1988. Between 10 August and 6 December, 24 mortalities occurred; 18 of them were vehicle-kills. Ten vehicle-kills occurred in early fall.

Legal harvest accounted for 3 mortalities. Adult male 17 was killed in a corn

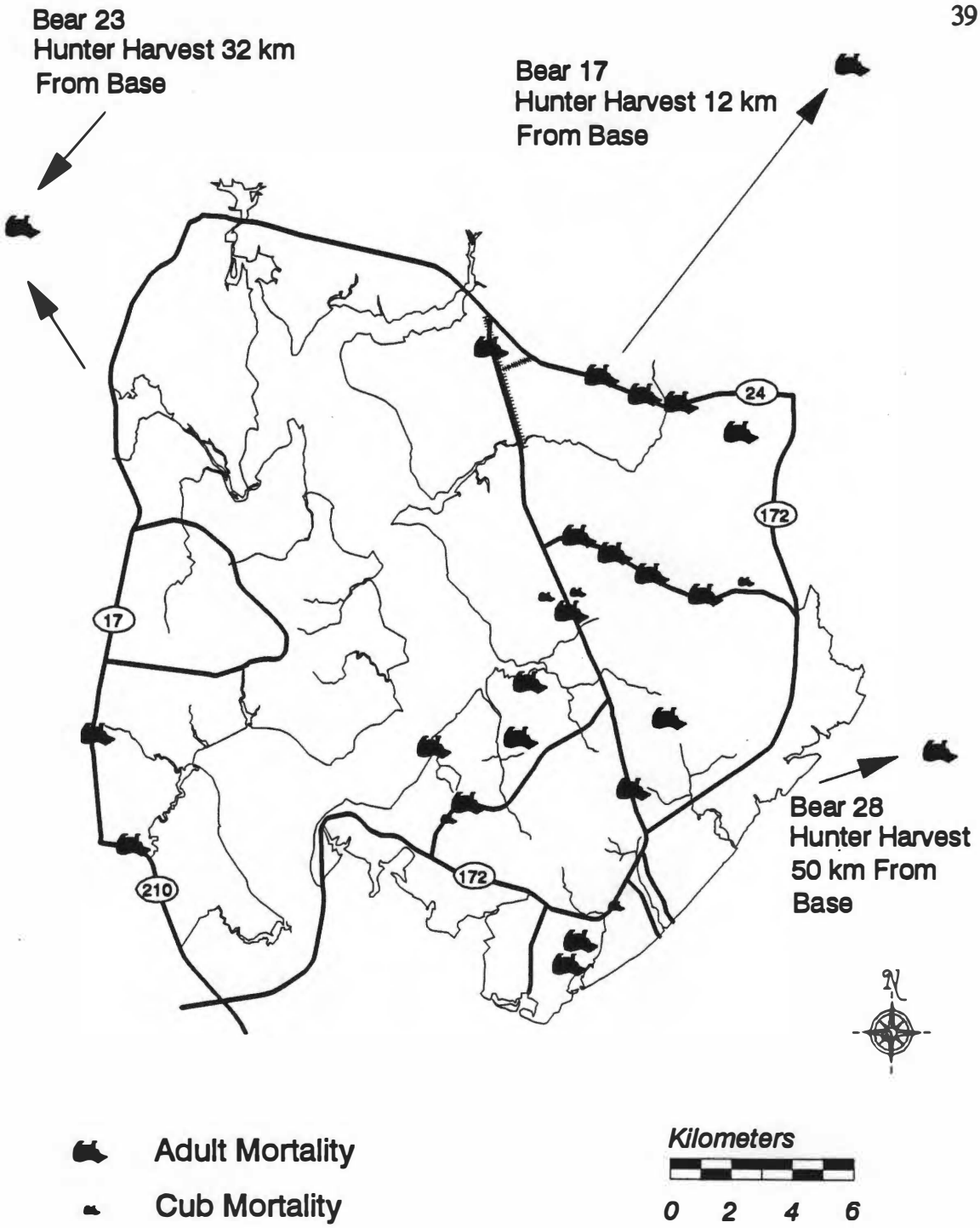


Figure 7. Mortality location of 28 black bears on Camp Lejeune, North Carolina, 1988-1992.

field approximately 8 km off Base and 12 km from his capture location. Subadult male 23 dispersed from the study area and was harvested approximately 30 km northwest of Base. Subadult male 28 dispersed from the study area and was harvested approximately 50 km east of Base.

Three radio-collared bears were illegally killed on Base. Yearling male 20 was found floating in French's Creek with his skin, head, and feet missing. Skeletal remains of adult female 01 were discovered 200 m from a secondary road also with her skull and feet missing. Adult female 31 was killed illegally during the deer hunting season. Adult female 15 and adult female 04 were vehicle-killed and illegally taken from the scene. Bear 15 was later recovered in the Marine barracks. Bear 04 was never recovered.

Natural causes accounted for 1 mortality on Camp Lejeune. On 25 June 1991, I recaptured adult female 09 in poor condition. She weighed 50 kg; this was 25 kg less than her initial capture weight in 1989. The reason for her poor condition is unknown. I intensively monitored her the last days of her life. On 26 June, she moved from French's Creek to the Traps Bay area and then to an area east of Plexiglass Road. During this excursion, bear 09 crossed 3 primary and 9 secondary roads. Bear 09 also made contact with adult male 24 for a brief period of time. On 1 July she was located with adult male 24. They remained together and in the same area until 1800 the next day when bear 24 departed. Bear 09 was found dead on 3 July. I speculate that her poor physical condition coupled with possible rough breeding activity from bear 24 contributed to her death.

The annual survival rate for females was 71% (95% CI's = 0.56 - 0.87).

Seasonal survival rates for early summer, early fall, and late fall ranged from 0.87 to 0.92 (95% CI's range = 0.76 - 1.00). No females died or were censored during winter, spring, and late summer.

Feeding Ecology

Between May 1988 and August 1991, 421 scats were collected to determine the major food items in the diet of bears on Camp Lejeune. I determined 20 separate food items in scats. Eighty percent of the diet of bears was of plant origin.

Spring diets of Camp Lejeune bears were dominated by ants (Formicidae) which occurred in 61% of the spring scats and accounted for 29% of the diet by volume (Table 2, Fig. 8). Ant eggs and larvae probably were ingested also, but they left no trace in scats. Bessie bug beetles (*Odontotaenius disjunctus*) occurred in almost half of the spring scats, but they only accounted for 7% of the volume. Debris (e.g., unidentified material, soil, and wood particles) accounted for 24% of the spring diet by volume. These items were probably accidentally ingested while foraging for insects. Vegetation (unidentified leaves) accounted for 19% of the spring diet by volume.

The early summer diet was volumetrically dominated by soft mast (tree and shrub fruit). Black cherry (*Prunus serotina*) accounted for 36% of the early summer diet by volume. Huckleberry (*Gaylussacia* spp.) occurred in two thirds of the scats examined and comprised 38% of the early summer diet by volume.

The late summer diet was dominated by sweet gallberry and black gum. Sweet gallberry accounted for almost half the late summer diet by volume. Black

Table 2. Frequency of occurrence (%) and volume percent of items identified in 421 black bear scats collected on Camp Lejeune, North Carolina, 1988 to 1991.

	% Frequency of Occurrence / % Volume						
Food Item	**Spring (*n*= 56) F V**	**Early Summer (*n*= 35) F V**	**Late Summer (*n*= 17) F V**	**Early Fall (*n*= 53) F V**	**Late Fall (*n*= 249) F V**	**Winter (*n*= 11) F V**	**Entire Year (*n*= 421) F V**
Tree Fruit							
Nyssa sylvatica var.	2 / T		41 / 32	87 / 78	2 / T		14 / 22
Quercus spp.				6 / 3	30 / 28		18 / 6
Persea borbonia	2 / 1				63 / 60	64 / 7	39 / 12
Prunus serotina		46 / 36					4 / 7
Ilex opaca		3 / T			4 / T		3 / T
Symplocos tinctoria			6 / T	2 / 2			T / 2
Shrub and Vine Fruit							
Ilex coriacea		6 / 1	59 / 48	26 / 9			6 / 12
Ilex glabra			6 / T		7 / 2		5 / 3
Gaylussacia spp.		66 / 38	6 / 3				6 / 8
Vaccinium spp.	11 / 7	17 / 6	12 / 3				3 / 3
Smilax spp.	2 / 2			8 / T	28 / 3	55 / 18	19 / 2
Vitis rotundifolia			12 / T	2 / T			1 / T

Table 2. (continued)

Food Item	Spring (*n*= 56) F / V	Early Summer (*n*= 35) F / V	Late Summer (*n*= 17) F / V	Early Fall (*n*= 53) F / V	Late Fall (*n*= 249) F / V	Winter (*n*= 11) F / V	Entire Year (*n*= 421) F / V
	% Frequency of Occurrence / % Volume						
Animal Matter							
Ursus americanus	38 / T	29 / T	35 / T	9 / T	5 / T	64 / T	15 / T
Odocoileus virginianus	9 / 2	3 / 1			10 / T	9 / T	8 / T
Colaptes auratus	2 / T		6 / T				T / T
Formicidae	61 / 29	14 / 7		2 / 1		9 / 8	10 / 7
Coleoptera	46 / 7	34 / 1	35 / 4	34 / 2	4 / T	9 / 1	18 / 3
Hymenoptera		3 / T	6 / 2	2 / T			1 / T
Vegetation	20 / 19	6 / 2		6 / 1		82 / 65	6 / 4
Graminae	27 / 2	20 / 1		8 / 3	2 / T	9 / 1	8 / 2
Garbage	27 / 8	14 / 2	12 / 3	2 / T	9 / 6		11 / 4
Debris	68 / 24	46 / 7	47 / 4	55 / 2	2 / T	9 / 1	23 / 7

F = Frequency of occurrence.
V = Volume percent.
T = Trace amount (<1%).

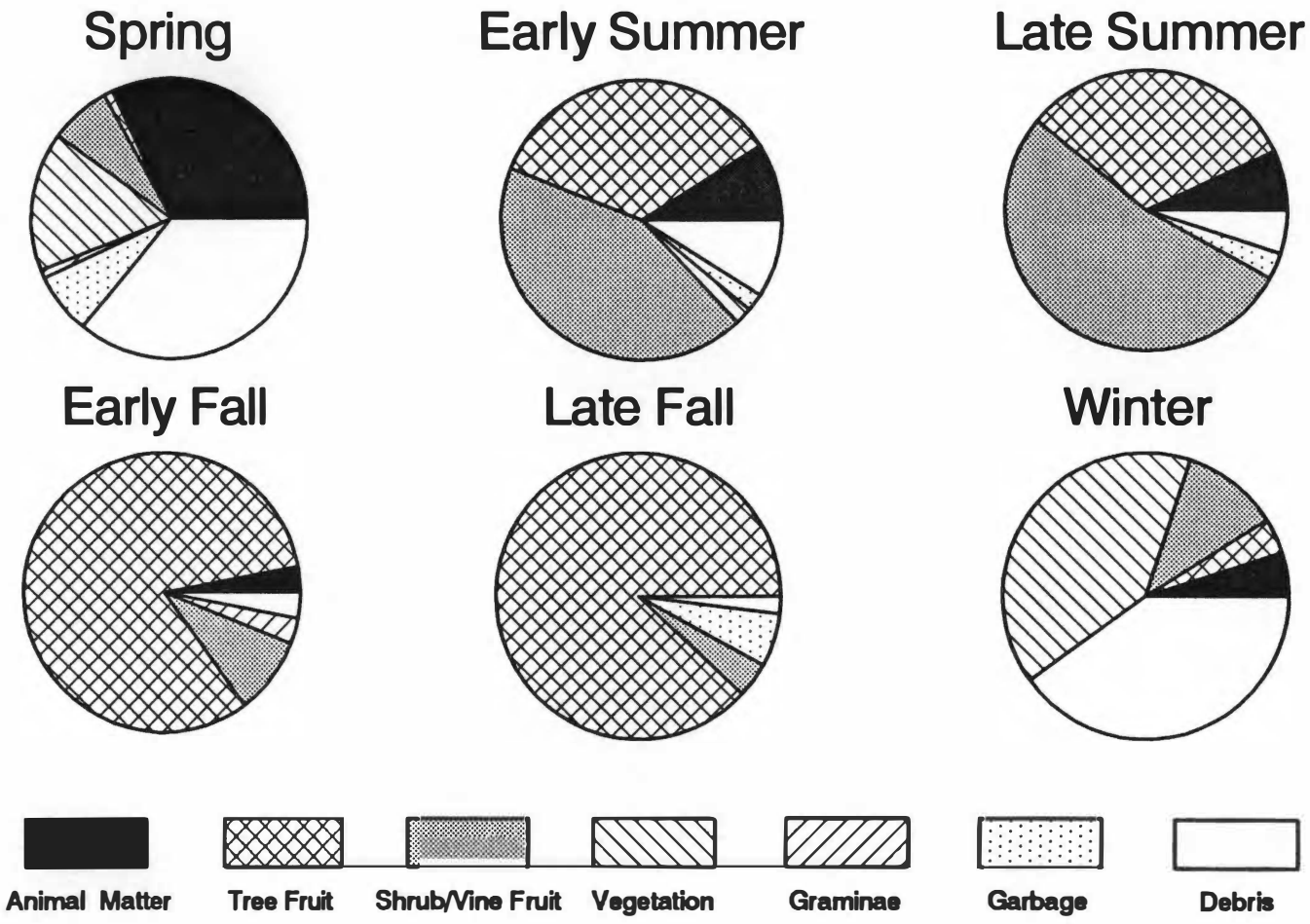


Figure 8. Seasonal diet (% volume) of black bears on Camp Lejeune, North Carolina, 1988-1991.

bears shifted from sweet gallberry to black gum in mid-September, the latter accounting for nearly a third of the late summer diet by volume.

During early fall, black gum comprised approximately three fourths of the diet by volume. Bessie bug beetles occurred in 34% of the early fall scats.

The late fall diet of bears on Camp Lejeune was dominated by red bay fruit. Red bay fruit accounted for 60% of the late fall diet by volume and occurred in 63% of the scats examined. Oak mast accounted for 28% of the late fall diet by volume. Deer hair occurred in 10% (n = 26) of the late fall scats, but represented only trace amounts of the diet by volume.

The annual volume of bear foods consumed on Camp Lejeune was dominated volumetrically (64%) by tree fruit (Fig. 9). Shrub/vine fruit, debris, animal matter, vegetation, and Graminae comprised 11, 9, 7, 4, and <1%, respectively, of the annual diet by volume.

Artificial foods (discarded human foods) only made up 5% of the annual diet by volume but occurred in 11% of the scats examined. Except for accidental ingestion of nonfood items, garbage is highly digestible and it is likely that the actual volume of garbage was underrepresented in the diet of bears. Therefore, indirect measures for estimating garbage consumption in the diets of bears may be more reliable. For example, I located radio-collared bears <100 m from artificial food sources in 90 of 553 (16.3%) instances that I monitored them (Fig. 10). Additionally, in 24 of 96 (25%) bear sightings, they were <100 m from artificial food sources.

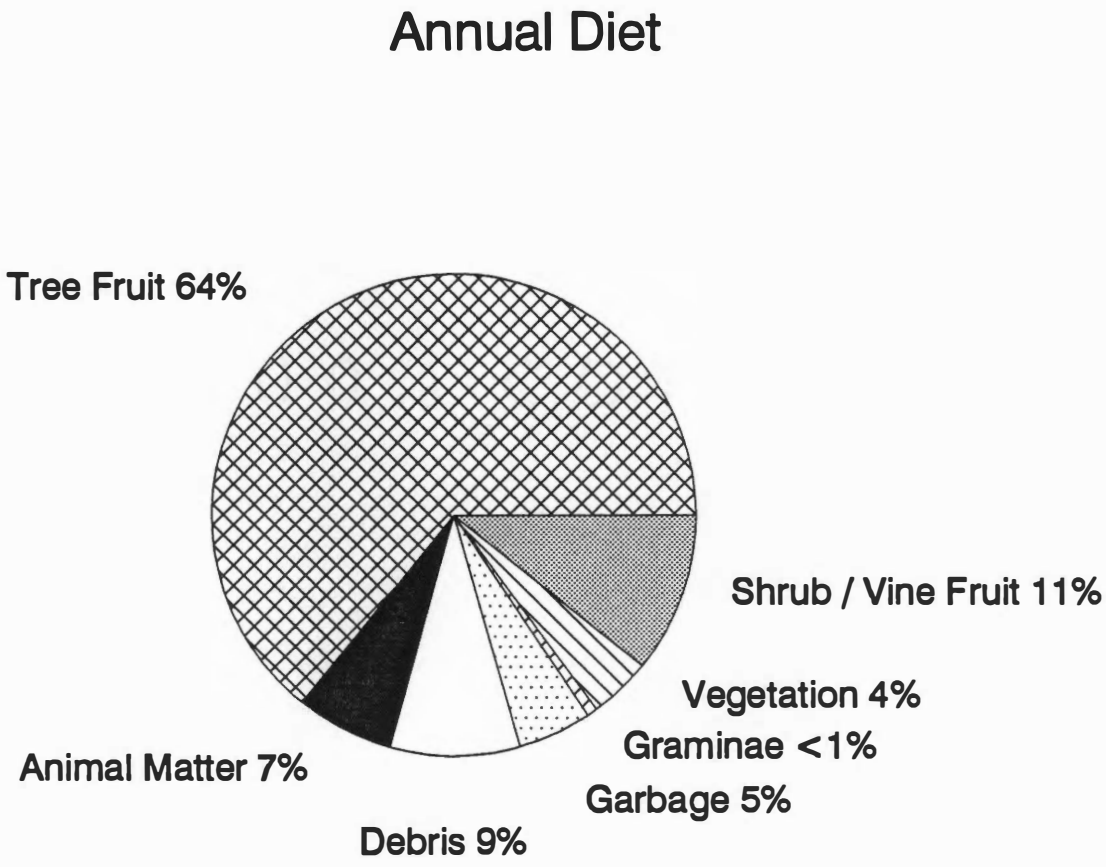


Figure 9. Annual diet (% volume) of black bears on Camp Lejeune, North Carolina, 1988-1991.

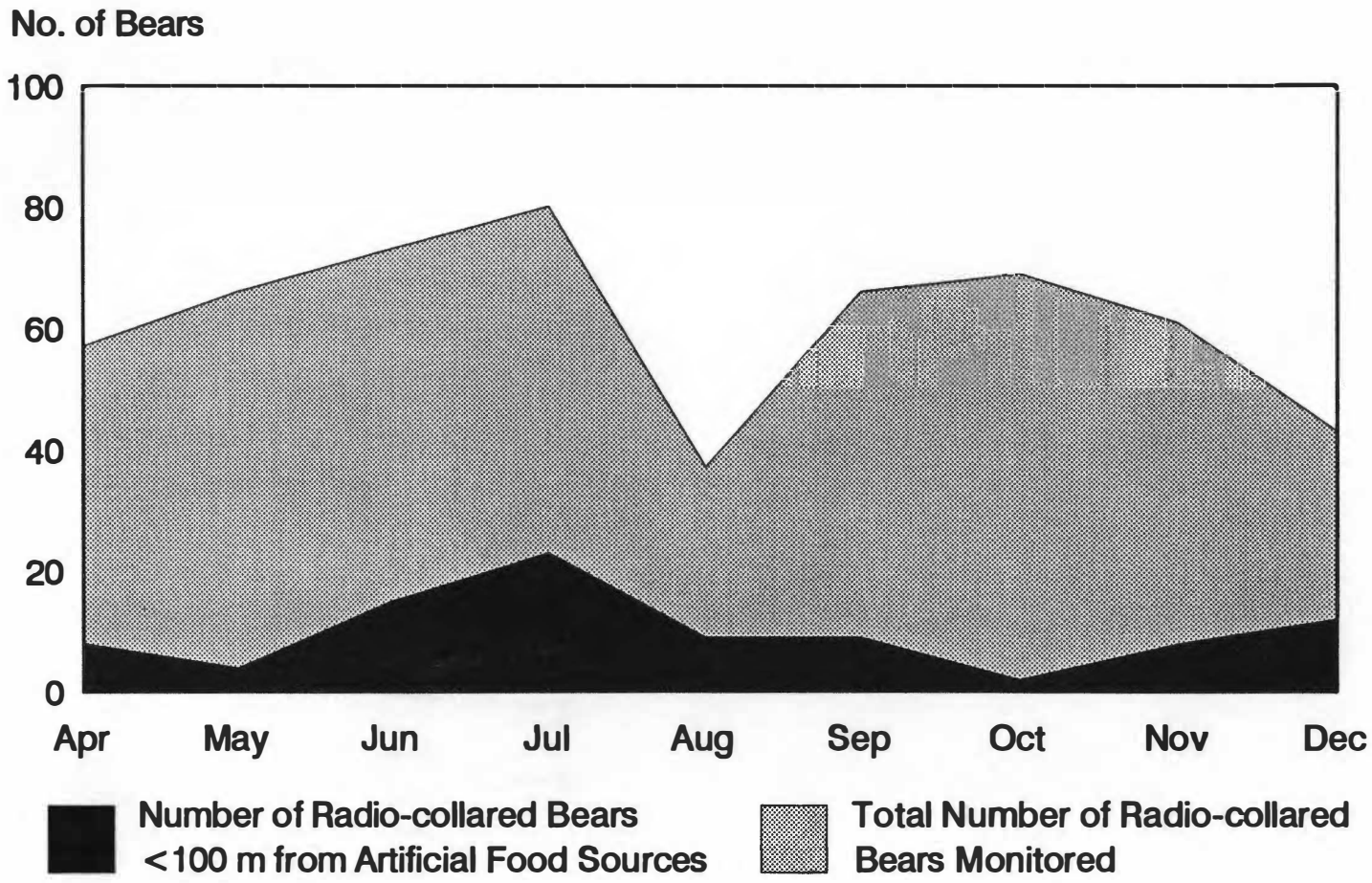


Figure 10. Frequency of radio-collared black bears < 100 m from artificial food sources (landfill, dumpsters, and troop activity) during tracking periods on Camp Lejeune, North Carolina, 1990-1991.

Bear Distribution in Relation to Roads

Bears used secondary and primary road zones disproportionately ($P < 0.05$) to their availability in 28 of 41 (68%) and 34 of 41 (83%) seasonal tests (62 of 82, 76%) for secondary and primary roads, respectively (Tables A-1 and A-2). In all annual cases ($n = 8$), bears used secondary and primary road zones disproportionate ($P < 0.05$) to their availability.

Five of 62 seasonal tests (8%) that detected road zone selection had simulated chi-square values that were not significant (Tables A-1 and A-2) indicating weak statistical power for those test. Misclassification rates for road zone tests ranged from 0 to 28.9% (Tables A-1 and A-2).

Except for the early summer >800 m primary road area, the <100 m road zone was the most avoided area for all seasons and annually for both secondary and primary roads (Tables 3, A-3, and A-4). This zone was avoided 22 of 31 (72%) and 18 of 23 (78%) cases for secondary and primary roads, respectively, for all seasons ($P < 0.05$).

Each km of road avoided to 100 m on Camp Lejeune results in 20 ha of habitat being used less than expected by bears. This corresponded to an average of 31% (range 2 - 46%, SE = 0.014, $n = 41$) of the seasonal home ranges of radio-collared bears. Similarly, bears avoided an average of 32% of their annual home range (range = 25 - 39%, SE = 0.016, $n = 8$).

The avoidance of habitats 100-200 m from roads by bears was more evident for primary roads than secondary roads on Camp Lejeune. The 100-200 m secondary road zone was avoided in only 5 of 27 cases (18%) for all seasons and was used

Table 3. Black bear use of secondary and primary road zones on Camp Lejeune, North Carolina, 1990-1991.

	Number of Bears Used					
	Secondary Roads			Primary Roads		
Road Zone	<Available	Equal	>Available	<Available	Equal	>Available
Spring						
<100	7	1	0	4	1	0
100-200	1	7	0	2	3	0
200-400	0	4	4	1	3	2
400-800	0	6	2	0	4	2
>800	1	0	0	3	1	2
Early Summer						
<100	5	2	0	4	5	0
100-200	1	6	0	3	6	0
200-400	0	4	3	0	9	1
400-800	1	5	1	0	5	5
>800	2	0	0	5	4	1
Late Summer						
<100	2	0	0	0	0	0
100-200	0	2	0	2	0	0
200-400	0	2	0	0	2	2
400-800	0	1	1	0	2	0
>800	0	0	0	0	0	2
Early Fall						
<100	3	3	0	7	1	0
100-200	1	5	0	6	5	0
200-400	1	3	2	3	6	2
400-800	1	4	1	1	7	3
>800	1	1	0	3	5	3
Late Fall						
<100	4	0	0	2	0	0
100-200	1	0	0	2	1	1
200-400	0	2	2	1	3	0
400-800	0	1	3	3	1	0
>800	0	0	0	0	2	2

Table 3. (continued)

	Number of Bears Used					
	Secondary Roads			Primary Roads		
Road Zone	<Available	Equal	>Available	<Available	Equal	>Available
All Seasons						
<100	22	0	6	18	7	0
100-200	0	23	5	16	15	0
200-400	1	16	11	5	24	5
400-800	2	17	9	5	19	10
>800	5	1	0	11	12	11
Annual						
<100	7	1	0	7	1	0
100-200	0	8	0	4	4	0
200-400	1	4	3	1	6	1
400-800	0	3	5	1	4	3
>800	4	1	0	1	4	3

equally by all bears (n = 8) annually. In contrast, the 100-200 m primary road zone was avoided 16 of 31 cases (52%) for all seasons and avoided by 4 of 8 bears annually.

Road Density

The density (km/km^2) of secondary roads occurring within the seasonal home ranges of bears ranged from 0.2 to 1.6 ($\bar{x}$ = 1.19, SE = 0.052, n = 41) on Camp Lejeune (Table 4). The density of primary roads occurring within the seasonal home ranges of bears ranged from 0 to 0.9 ($\bar{x}$ = 0.33, SE = 0.031, n = 41) on Camp Lejeune. The density of roads occurring within annual home ranges of bears ranged 1 to 1.6 and from 0.2 to 0.6 for secondary and primary roads, respectively, on Camp Lejeune.

Bear Movements and Activity

I investigated factors related to bear movements with intensive radio-telemetry, frequent "walk-ins" to foraging and bedding areas, observations, and food habits analysis. Bear movements were often related to the spatiotemporal orientation of food sources. Military training, reproductive condition, and behavior of individual animals also attributed to bear movements.

I located 15 radio-collared bears on 3,825 occasions from 1 September 1990 to 15 August 1991. During 93 nocturnal and 16 diurnal sequential tracking periods, I radiotracked bears on 553 occasions. Bears were radiotracked an average of 13.8 hrs (SE = 0.011) and located an average of 6.7 times (SE = 0.054) during each

Table 4. Road lengths and densities within home ranges of radio-collared black bears on Camp Lejeune, North Carolina, 1990-1991.

Bear ID	Length of Roads (km)			Density of Roads (km/km^2)		
	Secondary	Primary	Total	Secondary	Primary	Total
Winter						
24	4.0	1.4	5.4	1.1	0.4	1.5
Spring						
01	33.3	6.0	39.3	1.5	0.3	1.7
06	16.7	2.7	19.4	0.9	0.2	1.1
08	20.5	8.8	29.3	1.4	0.6	2.1
09	40.8	8.2	49.0	1.4	0.3	1.7
16	9.7	0.0	9.7	1.2	0.0	1.2
21	94.5	34.8	129.3	1.1	0.4	1.5
23	17.2	6.0	23.2	1.5	0.5	2.0
24	103.3	29.5	132.8	1.2	0.3	1.5
Early Summer						
01	35.8	8.8	44.6	1.4	0.3	1.8
06	24.2	5.4	29.6	1.0	0.2	1.2
08	23.3	10.5	33.8	1.5	0.7	2.2
09	17.5	4.3	21.8	1.3	0.3	1.6
16	27.9	6.7	34.6	1.3	0.3	1.6
21	19.3	1.7	21.0	1.0	0.1	1.1
24	75.1	21.8	96.9	1.2	0.3	1.5
26	2.8	1.8	4.6	0.2	0.1	0.4
28	38.6	9.2	47.8	1.4	0.3	1.8
30	9.2	2.1	11.3	1.5	0.3	1.8
31	46.3	15.2	61.5	1.2	0.4	1.6
Late Summer						
01	12.9	3.1	16.0	1.0	0.3	1.3
08	12.8	5.5	18.3	1.6	0.7	2.3
09	8.0	3.1	11.1	1.1	0.4	1.6
16	9.2	2.7	11.9	1.3	0.4	1.7

Table 4. (continued)

Bear ID	Length of Roads (km)			Density of Roads (km/km²)		
	Secondary	Primary	Total	Secondary	Primary	Total
Early Fall						
01	21.0	4.4	25.4	1.5	0.3	1.8
04	24.0	7.9	31.9	1.2	0.4	1.6
06	26.9	4.0	30.9	1.1	0.2	1.3
08	15.8	9.6	25.4	1.4	0.9	2.3
09	30.0	5.0	35.0	1.5	0.3	1.8
16	13.3	4.4	17.7	1.2	0.4	1.6
20	18.4	5.8	24.2	1.4	0.5	1.9
21	22.8	8.4	31.2	1.6	0.6	2.1
22	29.2	17.1	46.3	0.8	0.5	1.3
23	8.2	1.5	9.7	1.3	0.2	1.6
24	3.9	1.9	5.8	0.1	0.0	0.1
Late Fall						
01	3.3	1.1	4.4	1.1	0.4	1.5
08	1.8	0.3	2.1	0.8	0.1	0.9
09	38.1	7.2	45.3	1.5	0.3	1.8
21	32.5	10.4	42.9	1.4	0.4	1.8
23	10.3	0.0	10.3	1.3	0.0	1.3
24	1.5	0.0	1.5	0.6	0.0	0.6
Annual						
01	37.5	6.2	43.7	1.4	0.2	1.7
06	32.8	5.9	38.7	1.1	0.2	1.3
08	26.0	13.0	39.0	1.3	0.6	1.9
09	43.0	8.0	51.0	1.4	0.3	1.7
16	27.1	6.5	33.6	1.3	0.3	1.6
21	127.9	48.0	175.9	1.0	0.4	1.4
23	20.5	4.4	24.9	1.6	0.3	1.9
24	147.3	59.8	207.1	1.0	0.4	1.5

tracking period. The average time elapsed between sequential locations was 2.3 hrs (SE = 0.008).

Season (F = 4.12; 4,23 df; P = 0.012) and biological period (F = 6.97; 4,141 df; P < 0.001) effects were detected in travel rates. Early Summer travel rates were greater than spring and late fall (Table 5). Early fall travel rates were greater than late fall. Sunset travel rates were greater than sunrise, morning, afternoon, and night.

The least bear movement occurred in spring, late summer, and late fall. I attributed the reduction in spring movement to bears recovering from the period of winter. In late summer, most radio-collared bears concentrated their activities in pocosins and foraged on the abundant and concentrated sweet gallberry. Bears foraging on sweet gallberry exhibited few movements outside of pocosins. I radio-located 1 adult female in the same 0.50 ha area for 3 weeks. Similarly in late summer, I located 3 other radio-collared bears foraging for long periods in *Ilex*-dominated pocosins. In late fall, bears responded to the abundant and concentrated ripening red bay fruit found in pocosins in the same way they did to sweet gallberry. After 7 December 1990, 3 radio-collared bears foraged on red bay fruit for a month. During 9 tracking periods in December, I did not document bears leaving these red bay-dominated pocosins.

During early fall, bear movements were often erratic and resulted in increased highway crossings. All adult males radio-collared in this and the previous study moved north, off of Base property, and crossed a 4-lane highway to forage on corn (*Zea mays*) in early fall. Three radio-collared males were killed on this highway.

Table 5. Season and biological period results of travel rates (kmph) of radio-collared black bears on Camp Lejeune, North Carolina, 1990-1991.

	Mean[a]	SE	*n*	Prob.[b]
Season				
Spring	0.163	0.024	44	ab
Early Summer	0.263	0.022	55	cd
Late Summer	0.214	0.038	18	abc
Early Fall	0.225	0.023	51	ad
Late Fall	0.156	0.027	35	b
Biological Period				
Sunrise	0.206	0.024	42	a
Morning	0.170	0.024	42	ab
Afternoon	0.128	0.021	36	b
Sunset	0.289	0.024	41	c
Night	0.228	0.024	42	a

[a] Generalized Least Squared Means.

[b] Means with the same letter are not significantly different ($P > 0.05$).

Another tagged adult male was harvested while foraging in a corn field. Furthermore, in early fall, I frequently located a radio-collared female foraging north of Base property on corn. Shortly thereafter, I lost radio-contact with her and suspect she was vehicle-killed while returning to Base.

The orientation of productive ripe black gum and oak stands to pocosins also resulted in increased bear movements. During 14 tracking periods in September and October 1990, 2 subadult males crossed 17 primary roads traveling to and from black gum stands and pocosins. In this and the previous study, 5 radio-collared bears frequently crossed Marines Road traveling to and from oak stands and pocosins. In November 1990, a subadult male crossed Marines Road 11 times during 7 tracking periods traveling to and from oak stands and pocosins. In late fall 1991, a radio-collared adult female was vehicle-killed on Marines Road where she frequently crossed traveling to and from foraging and bedding areas. Similarly in 1989, Lombardo (pers. commun.) documented a radio-collared adult female crossing Lyman Road, foraging all night in an oak stand, recrossing Lyman Road, and returning to her bedding area. The next night she was vehicle-killed on Lyman Road; apparently she was returning to forage in the same area as she did the previous night.

For opportunistic animals (garbage-prone bears), movements were related to the unpredictable availability of artificial foods in dumpsters and permanent bivouacs. Garbage and MRE's offer opportunistic bears a high-energy food during periods of low food availability and/or periods of nutritional stress. In 49 of 177 times (28%) I monitored 4 females with cubs, they were < 100 m from artificial food sources. In the winter of 1992, a radio-collared female with 2 cubs remained active and foraged

frequently in the landfill. I located a lone adult female in bivouacs 7 of the 13 (53%) times I monitored her. In the previous study, adult female 04 had a home range boundary conforming to the location of 6 dumpsters (Lombardo 1993). In her search for garbage, not only would she regularly visit dumpsters and the landfill, but she would go to the industrial area on Camp Lejeune. Search patterns like this often led garbage-prone bears across high-speed highways. Bear 04 and her 2 cubs were vehicle-killed <1 km from the landfill. Evidently, they were going to the landfill. Another 2 untagged bears were vehicle-killed <200 m from dumpsters.

Bear Behavior in Relation to Crossing Roads

Secondary roads were crossed on 741 occasions by radio-collared bears during 109 sequential tracking periods. Multiple secondary road crossings occurring between sequential locations accounted for 36.3% (n = 269) of the total. Two, 3, and 4 secondary road crossings between sequential locations occurred on 109, 13, and 3 occasions, respectively.

Radio-collared bears crossed 179 primary roads during 109 sequential tracking periods. Multiple primary road crossings occurring between sequential locations occurred 17 times. Two and 3 primary road crossings between sequential locations occurred on 7 and 1 occasions, respectively.

The number of secondary and primary road crossings varied among individual bears. The total number of secondary roads crossed by individual bears ranged from 10 (subadult female 30) to 118 (adult female 09). The total number of primary roads crossed ranged from 2 (subadult female 30) to 39 (yearling male 21) for individual

bears.

The greatest number of roads crossed during a tracking period was 12 (9 secondary and 3 primary roads) by adult female 09 on 25-26 June 1991. The greatest number of primary roads crossed during a tracking period was 4 by yearling male 21 on 16-17 May 1991. Interestingly, 2 females with cubs did not cross a primary road from den emergence (mid April) until 15 June even though they regularly crossed primary roads as lone bears.

Secondary roads did not appear to inhibit bear movement. Some bears used secondary roads as convenient nocturnal travel corridors. Telemetry and observations indicated that adult male 24 tracked potential mates on secondary roads during the breeding season. Apparently, bear 24 optimized his breeding opportunities by using secondary roads to find mates quickly and efficiently.

In contrast to secondary roads, primary roads appeared to inhibit bear movement. Bears preferred to cross primary roads camouflaged by darkness. I documented only 2 primary road crossings between 1100 and sunset.

The frequency of secondary and primary road crossings peaked at night in all seasons except early summer where secondary road crossings peaked at sunset (Fig. 11). A second peak in primary road crossings was noticeable in early fall during the morning.

I detected season (F = 5.39; 4,23 df; P = 0.003) and biological period (F = 7.42; 4,145 df; P < 0.001) effects in the frequency of secondary road crossings. Similar to travel rates, bears crossed secondary roads more frequently in early summer compared to spring and late fall (Table 6, Fig 11). Sunset and night

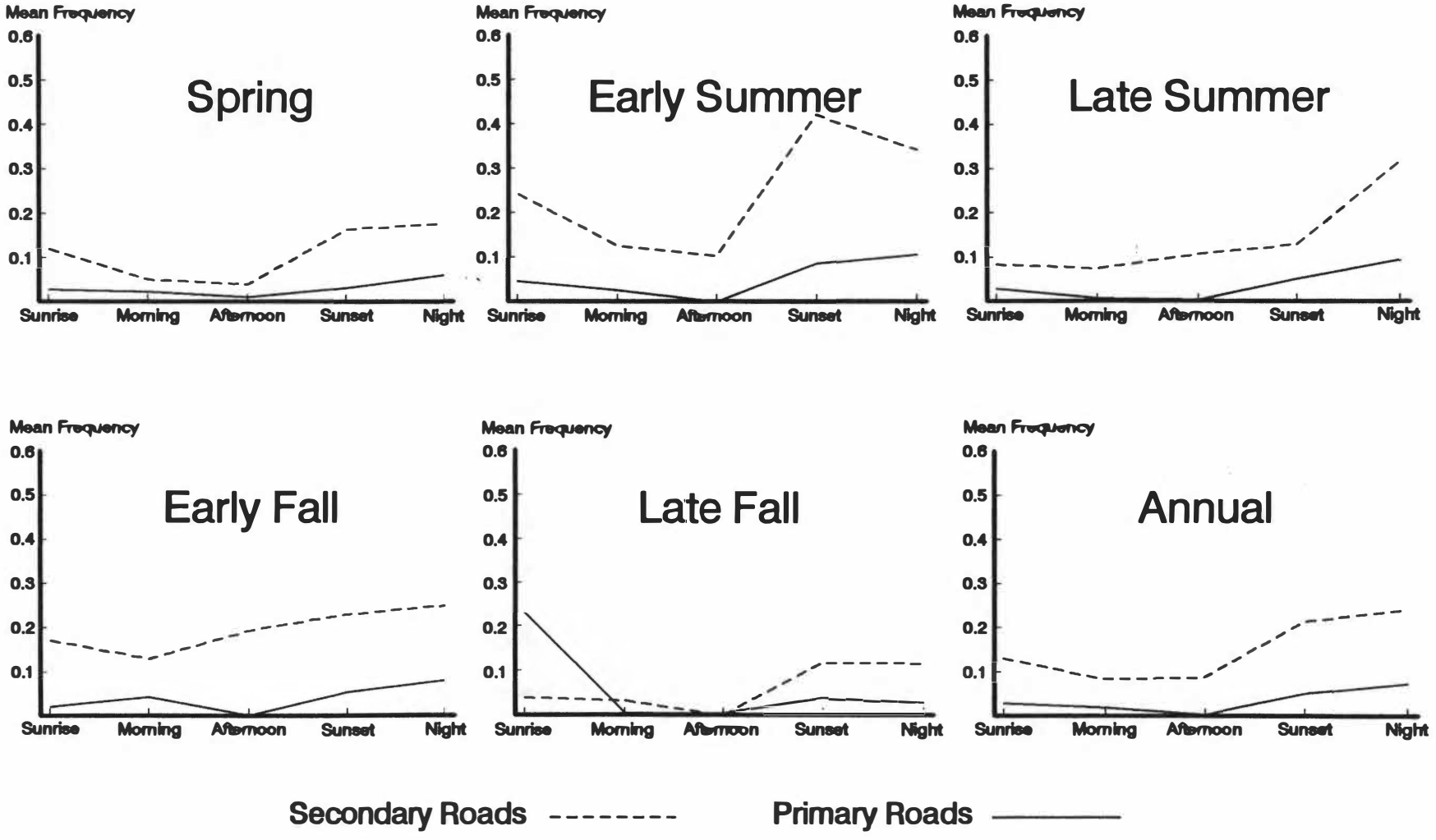


Figure 11. Mean frequency of secondary and primary road crossings during biological periods on Camp Lejeune, North Carolina, 1990-1991.

Table 6. Season and biological period results of the frequency of secondary and primary road crossings of radio-collared black bears on Camp Lejeune, North Carolina, 1990-1991.

	Secondary Roads				Primary Roads			
	Mean[a]	SE	*n*	Prob.[b]	Mean[a]	SE	*n*	Prob.[b]
Season								
Spring	0.109	0.033	44	ab	0.031	0.013	44	a
Early Summer	0.247	0.030	55	cd	0.052	0.012	55	a
Late Summer	0.142	0.049	19	abc	0.037	0.016	19	a
Early Fall	0.193	0.030	54	ad	0.039	0.012	54	a
Late Fall	0.062	0.037	35	b	0.019	0.013	35	a
Biological Period								
Sunrise	0.130	0.031	42	a	0.029	0.013	42	ab
Morning	0.082	0.030	42	a	0.020	0.013	42	ac
Afternoon	0.088	0.032	39	a	0.004	0.014	39	c
Sunset	0.213	0.031	42	b	0.052	0.013	42	bd
Night	0.239	0.031	42	b	0.073	0.013	42	d

[a] General Least Squared Means.

[b] Means with the same letter are not significantly different ($P > 0.05$).

secondary road crossings occurred more frequently than sunrise, morning, and afternoon secondary road crossings (Table 6).

A biological period effect (F = 10.26; 4,145 df; P < 0.001) also was detected in the frequency of primary road crossings. Bears crossed primary roads more frequently during night than sunrise, morning, and afternoon (Table 6). No differences were detected in the frequency of primary road crossings between seasons (F = 2.07; 4,23 df; P = 0.117) or between season-by-biological period (F = 0.81; 16,145 df; P = 0.666).

I rejected the null hypothesis that secondary and primary roads are crossed with the same frequency ($\bar{x}$ = -1.8, SE = 1.2, n = 41, P = 0.06). Bears crossed primary roads 75 times less frequently than secondary roads.

I found strong evidence that bears cross secondary and primary roads considerably less frequently than they would if their movements were random (Table 7). Secondary road crossings (n = 741) occurred 20% less frequently than simulated random secondary road crossings (n = 931). In contrast, primary road crossings (n = 179) occurred 44.6% less frequently than simulated random primary road crossings (n = 323).

I found considerable evidence that bears responded differently to primary roads compared to secondary roads. Interestingly, the mean travel rates were more strongly correlated with the frequency of primary road crossings than secondary road crossings in early and late fall (Table 8). Additionally, secondary and primary road crossings were not correlated in early fall (r = 0.477, P = 0.117).

I detected overall differences in the behavior of bears before crossing primary

Table 7. Mean differences between road crossings and simulated random road crossings of radio-collared black bears on Camp Lejeune, North Carolina, 1990-1991.

Season	Frequency of Road Crossings		Mean[a]	SE	*n*	Prob.
	Secondary	vs Random				
Spring	167	200	-0.223	0.112	148	0.044
Early summer	261	311	-0.331	0.152	151	0.019
Late Summer	39	63	-0.888	0.421	27	0.049
Early Fall	223	284	-0.401	0.136	152	0.002
Late Fall	51	73	-0.293	0.156	75	0.052
Total	741	931				
	Primary	vs Random				
Spring	38	73	-0.236	0.069	148	<0.001
Early Summer	63	102	-0.258	0.088	151	0.003
Late Summer	9	21	-0.444	0.240	27	0.075
Early Fall	54	112	-0.382	0.089	152	<0.001
Late Fall	15	15	0.0	0.066	75	1.000
Total	179	323				

[a] Mean differences.

Table 8. Correlation coefficients (r) between the mean travel rates (kmph) and the mean frequencies of secondary and primary road crossings, between the mean frequency of primary road crossings and the mean traffic volume, and between the mean frequencies of secondary and primary road crossings, on Camp Lejeune, North Carolina, 1990-1991.

	Spring	Early Summer	Late Summer	Early Fall	Late Fall
		Secondary Roads (n = 12)			
Travel Rates	0.86[a]	0.79[a]	0.66[a]	0.59[a]	0.62[a]
		Primary Roads (n = 12)			
Travel Rates	0.63[a]	0.69[a]	0.58[a]	0.79[a]	0.66[a]
		Primary Roads (n = 12)			
Traffic Volume	-0.60[a]	-0.48	-0.45	-0.36	-0.19
		Secondary Roads (n = 12)			
Primary Roads	0.85[a]	0.83[a]	0.66[a]	0.48	0.92[a]

[a] Significant correlations ($P < 0.05$).

roads compared to after crossing roads. Bears averaged 216 m (SE = 96, n = 45, P = 0.017) further from primary roads after crossing them than before crossing. In early fall and night, radio-collared bears were located further from primary roads after crossing than before crossing ($\bar{x}$ = 707 m, SE = 159, n = 10, P = 0.002; $\bar{x}$ = 276 m, SE = 134, n = 27, P = 0.016, respectively).

In contrast to primary roads, no overall differences were detected in distances from secondary roads to locations occurring before compared to after bears crossed roads ($\bar{x}$ = -35 m, SE = 29, n = 308, P = 0.355). Additionally, I detected no seasonal differences in distances that radio-collared bears were from secondary roads before compared to after crossing. However, radio-collared bears were located further from secondary roads during sunrise ($\bar{x}$ = 124 m SE = 54, n = 59, P = 0.023) after crossing compared to before crossing. At night, radio-collared bears were located closer to secondary roads ($\bar{x}$ = -110, SE = 48, n = 132, P = 0.037) before crossing compared to after crossing.

I detected differences in distances that bears were from primary roads compared to secondary roads after road crossings occurred (Table 9). In all cases of behavioral differences, bears were further from primary roads compared to secondary roads after road crossings occurred.

I found a relationship between primary road crossings and traffic volume on Camp Lejeune. The weekday traffic volume and the frequency of primary road crossings (Table A-5) were negatively correlated annually (r = -0.389, n = 60, P = 0.002), and in spring (r = -0.604, n = 12, P = 0.037) (Table 8). The weekday traffic was not correlated with primary road crossings during all other seasons.

Table 9. Mean differences between the distances (m) that radio-collared black bears were from primary roads compared to secondary roads after crossing roads on Camp Lejeune, North Carolina, 1990-1991.

	Secondary Roads			Primary Roads			
	Mean	SE	*n*	Mean	SE	*n*	Prob.
Season							
Spring	436.2	37.3	74	495.7	91.9	9	0.408
Early Summer	448.2	42.1	98	504.6	89.5	17	0.419
Late Summer	428.2	44.7	45	971.7	211.3	6	0.013
Early Fall	444.5	36.1	74	1057.3	128.7	10	<0.001
Late Fall	534.5	71.2	17	984.3	313.7	3	0.204
Annually	446.3	19.7	308	719.9	68.1	45	<0.001
Biological Period							
Sunrise	523.5	46.5	59	387.4	132.4	5	0.409
Morning	416.5	51.9	38	855.1	70.0	7	<0.001
Afternoon	-						
Sunset	466.3	43.4	64	663.2	232.9	6	0.431
Night	407.9	30.7	132	759.1	94.3	27	<0.001

My data suggest that bears avoid crossing primary roads during high traffic levels. Weekday traffic volume peaks occurred at 0600-0800 and 1600-1800 (Tables A-6, A-7, A-8, and A-9, Fig. 12). The personnel of Camp Lejeune go to and from work during these time intervals. The average daily weekday traffic volume was 3,123.

Corridor Use

Radio-collared black bears used certain habitats for crossing primary roads more than others ($\chi^2 = 211.72$, 6 df, $P < 0.001$) (Table 10). Bears preferred pocosins, major and minor drainages, and pure hardwoods as corridors to cross primary roads. Ten major drainages used for crossing primary roads are illustrated on the locality map for Camp Lejeune (Fig. 4) where creeks intersect major highways. Habitat openings were avoided by bears for crossing primary roads. No habitat selection was detected for pure pine and pine/hardwood forest cover types.

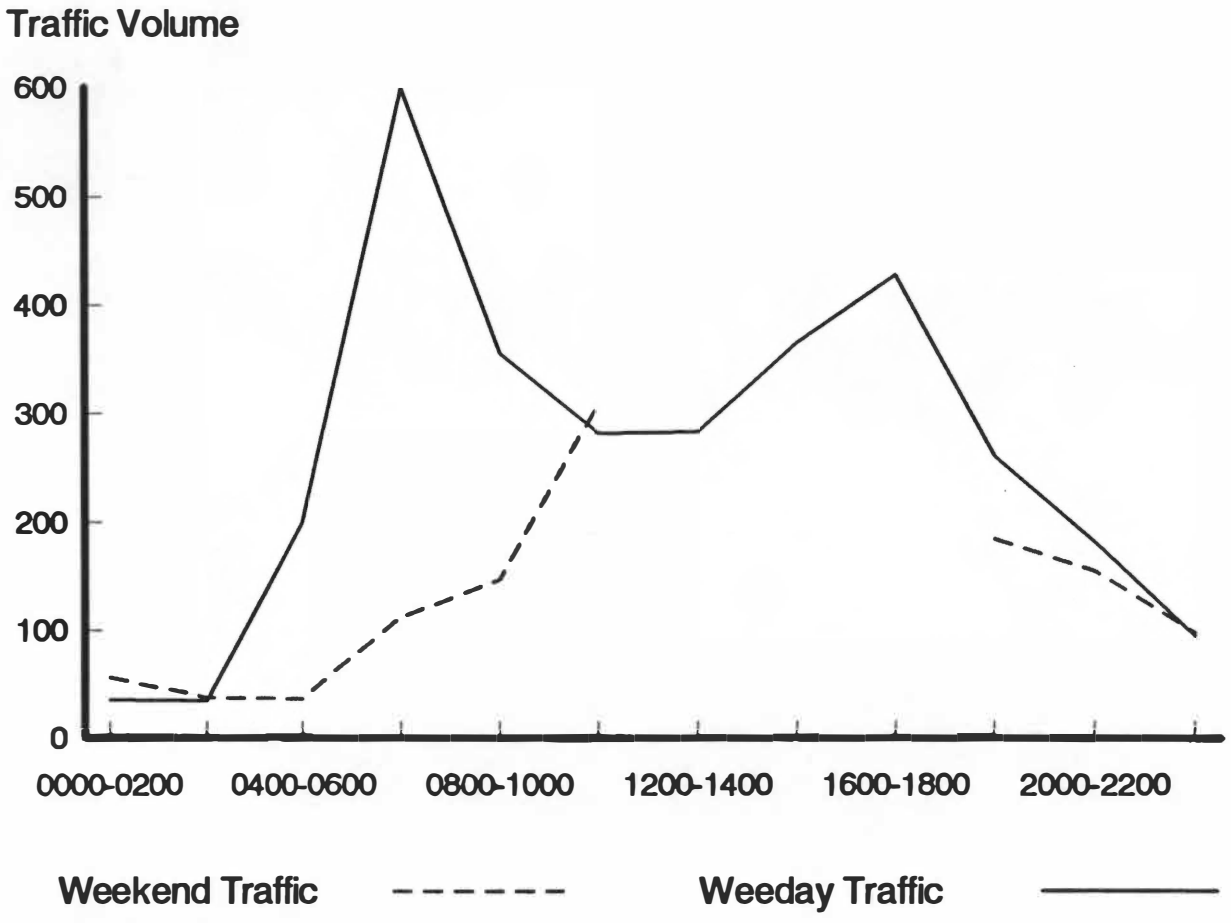


Figure 12. Mean weekend and weekday traffic volume of primary roads on Camp Lejeune, North Carolina, September-December 1990.

Table 10. Habitat selection for crossing primary roads by radio-collared black bears on Camp Lejeune, North Carolina, 1990-1991.

Habitat Type	Ha	Ha %	Observed %	Observed	Expected	95% CI
Pure Pine	264.449	0.409	0.356	122	140	0.286 - 0.426
Pine/Hardwoods	155.808	0.241	0.195	67	83	0.137 - 0.253
Openings[a]	117.984	0.183	0.076	26	63	0.038 - 0.114
Pure Hardwoods[a]	30.036	0.047	0.023	8	16	0.001 - 0.045
Pocosins[a]	43.627	0.068	0.160	55	23	0.107 - 0.213
Minor Drainages[a]	10.309	0.016	0.073	25	5	0.035 - 0.111
Major Drainages[a]	23.642	0.037	0.117	40	13	0.070 - 0.164

[a] Significant differences between use and availability ($P < 0.05$).

CHAPTER V

DISCUSSION

Population Dynamics

Research on Camp Lejeune may have uncovered a worst-case scenario of habitat fragmentation and impediments to movements for a southeastern black bear population. Not only is Camp Lejeune highly isolated from other bear populations, its interior is also fragmented by high-speed highways. Twenty-seven (96%) black bear deaths on Camp Lejeune were human related with vehicle-kills accounting for 71% (n = 20) of the total mortality. My data indicate the number of bears on Camp Lejeune is declining. The estimated density of $\leq$3.3 bears/100 km^2 ($\leq$6 bears) on Camp Lejeune is extremely low relative to other estimates of black bear density in North America (Table 11). Except for Camp Lejeune, harvest and vehicle-kill data indicate a stable to increasing bear population in eastern North Carolina (Warburton *et al.* 1993). Hellgren and Vaughan (1989) believed that previous Coastal Plain studies underestimated bear densities.

Camp Lejeune has the highest vehicle-kill mortality rate ever reported for a black bear population. The majority of vehicle-kills occurred during early and late fall. Unfortunately, black bear vehicle-kills in eastern North Carolina have steadily increased from 1970 to 1990 (Warburton *et al.* 1993). Vehicle-kills not only peaked in summer in both eastern North Carolina and Florida but again in fall (Warburton *et al.* 1993, Wooding and Brady 1987).

Table 11. Population densities of Southeast black bear populations.

Locality	Bears/100 km^2	Reference
Great Dismal Swamp, Virginia	47-68	Hellgren and Vaughan 1989
Southeastern Georgia	26-42	Abler 1985
White River NWR, Arkansas	17-42	Smith 1985
Smoky Mountain NP, Tennessee	29	McLean and Pelton 1994
Camp Lejeune, North Carolina	18-24	Lombardo 1993
Bladden County, North Carolina	11.5	Hamilton 1978
Dry Creek, Arkansas	9	Clark 1991
White Rock, Arkansas	8	Clark 1991
Tensas Basin, Louisiana	6.6-10	Weaver *et al.* 1991
Dare County, North Carolina	6.3	Hardy 1974
Camp Lejeune, North Carolina	0.5-3.3	This study

Since 1988, I know of only 1 of 14 radio-collared females to be alive on Mainside. The high number of vehicle-kills on Camp Lejeune has resulted in a low survival for females (71%). This estimate is substantially lower than reported for other southeastern bear populations (Hamilton 1978, Abler 1985, Smith 1985, Hellgren and Vaughan 1989, Clark 1991, Weaver pers. commun.). In a review of several exploited North American populations, Bunnell and Tait (1985) report that the average annual survival rate for female black bears > 1-year old was 83%.

The future of Camp Lejeune's Mainside bear population is precarious due to its isolated nature and the limited number of females that remain there. Great Sandy Run Pocosin, Hoffmann Forest, Croatan National Forest, Holly Shelter Swamp, and Angola Swamp are nearby bear populations that range from approximately 15 to 50 km from the Mainside study area (Fig. 13). These populations are well within dispersing distances for males. However, the recruitment of immigrant females to Camp Lejeune is unlikely because females are not prone to disperse. Furthermore, the number of high-speed highways and urban developments fragmenting the Base from other bear populations makes immigration difficult, if not impossible for females. In northeastern Minnesota, only 3 of 31 females whose birth places were known, dispersed (Rogers 1987). Similarly, only 1 of 30 females in southeastern Alaska dispersed from their birth place (Schwartz and Franzmann 1992).

The male cohort does not appear to be a limiting factor for Camp Lejeune's bear population. The dispersal abilities, extensive movements, and large home ranges of males should provide ample breeding opportunities for females on Camp Lejeune. For long-term considerations, immigrating bears can provide gene flow between

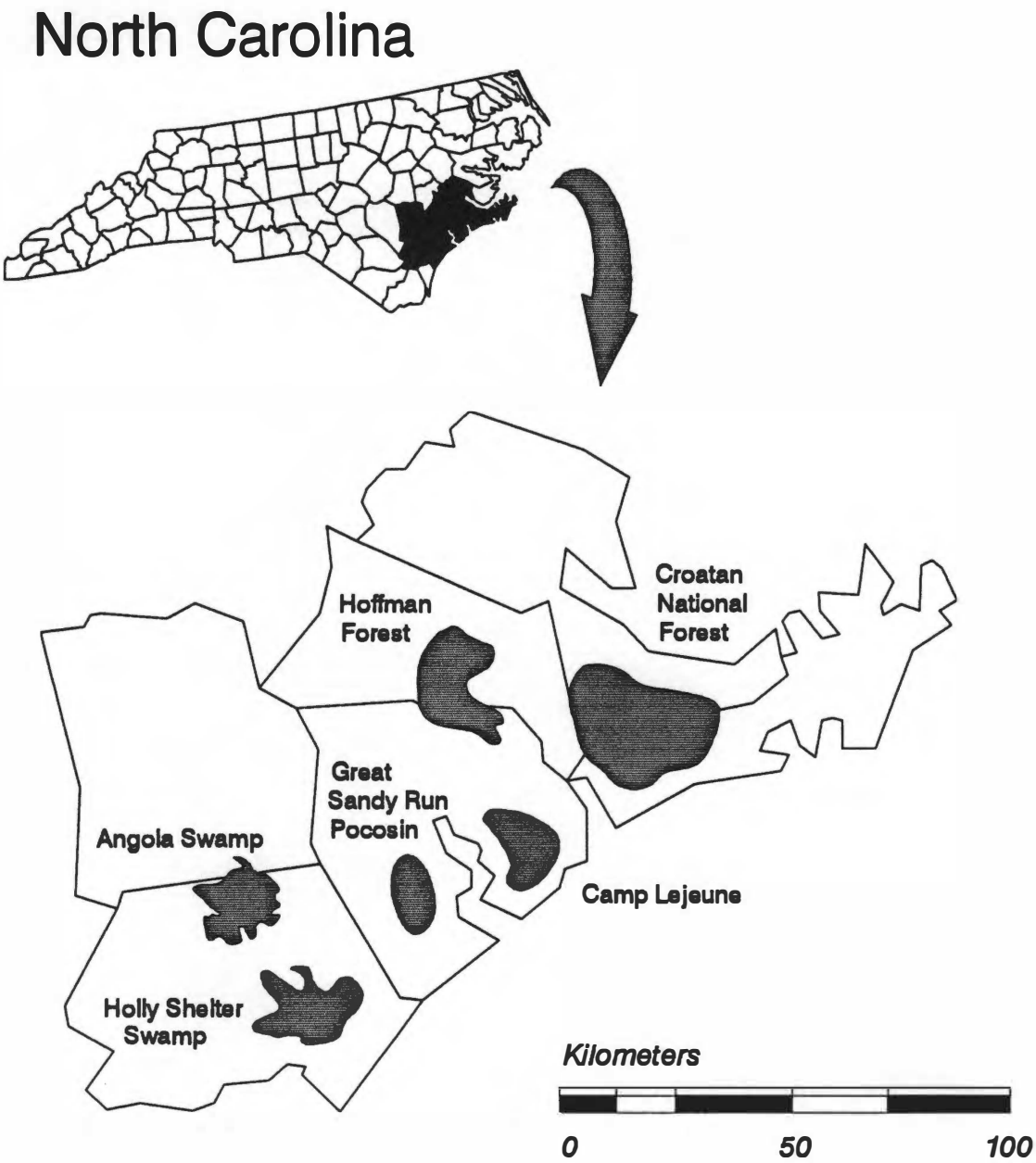


Figure 13. Black bear populations near Mainside study area, Camp Lejeune, North Carolina.

populations. However, Camp Lejeune will likely serve as a mortality source for most immigrant males due to high-speed highways on Base.

Laurance (1991) listed 7 life history characteristics to predict a species response to fragmentation including population size prior to fragmentation, dispersal ability, ecological specialization, tolerance to edge conditions, level of population stability, longevity, and intrinsic rate of population growth. Of these characteristics, Camp Lejeune not only has a very low density of bears, but the population is declining with little likelihood of female immigration. Bear populations that are reduced to lower levels than desired may require years to recover because of low reproductive rates and delayed maturation (Miller 1990).

Fifty bears are recommended as an effective population size for short-term population survival and 500 bears for preservation of genetic variability and long-term population survival (Franklin 1980). Smith (1985) estimated the effective population size of 53 to 90 bears at White River study area in Arkansas. Hellgren and Vaughan (1989) estimated the effective population size of Great Dismal Swamp (GDS) to be 56 bears. Thirty to 40 bears may have inhabited Camp Lejeune prior to the opening of bear hunting in the early 1980's (Lombardo pers. commun.). This corresponded to a density estimate of 54-72 bears/100 km^2 on Base and is similar to the 52-66 bears/100 km^2 estimated for GDS (Hellgren and Vaughan 1989). Considering the relative small size of the study area, high road densities, and fragmented habitat on Camp Lejeune, the recommended population size of 50 bears for short-term survival is more than the Base could support. However, I believe 30 to 40 bears would be a realistic and obtainable recovery goal for Camp Lejeune. Recovery should be targeted at restoring

the "habitat island" of 20 to 25 females on Camp Lejeune.

To recover this population, short term conservation efforts should focus on the mitigation of female mortality on Camp Lejeune (see **MANAGEMENT IMPLICATIONS**). Once recovery objectives are met, then management strategies should focus on the long-term survival of bears on Camp Lejeune. Research is needed to determine "source" populations that supply immigrant bears to Camp Lejeune. Desired parameters of habitat corridors need further investigation. Key habitats linking Camp Lejeune to "source" populations should be identified. Acquisition and restoration of key habitats connecting important bear populations to Camp Lejeune may be necessary. Interfragment migration promotes population survival by genetic and demographic contributions of immigrants (Laurance 1991). Restoring historic corridors may increase the frequency of female dispersal and the success of female immigrants reaching Camp Lejeune. The monitoring of female survivorship and reproductive success should be fundamental to any long-term monitoring of small isolated bear populations.

Bear Movements in Relation to Foods

Black bear movement and the activity patterns are both dynamic and complex behaviors. Similar to Camp Lejeune, seasonal movements by black bears in other studies were mainly governed by distribution, phenology, and abundance of preferred foods (Garshelis and Pelton 1981, Pelchat and Ruff 1986, Rogers 1987, Hellgren and Vaughan 1991, Schooley *et al.* 1994).

Seasonal and time period differences in bear movement were evident on Camp

Lejeune and often were attributed to food availability and abundance, military training, reproductive condition, and behavior of individual animals. In general, lone adult bears were nocturnal in their habits during all seasons. The least movement and activities occurred during the afternoon. Lone adult bears were primarily nocturnal likely to avoid military activity and/or mid-day heat in summer. Peak bear movements occurred at sunset and were a clear reflection of bears traveling to foraging areas.

I hypothesize that the spatiotemporal orientation of preferred fall foods resulted in increased bear movements. Furthermore, I hypothesize that the separation of preferred foraging and bedding areas by high-speed highways has attributed to the majority of vehicle-kills, thereby causing Camp Lejeune's bear population to decline. Ninety percent of vehicle-kills occurred between early August and early December.

The largely herbivorous diet of black bears on Camp Lejeune reflected distinctive seasonal shifts to ripening and preferred foods. Due to the differential phenologies of huckleberry, blueberry, sweet gallberry, black gum, corn, oak, and red bay, and the unpredictable availability of garbage, there were distinct periods of diminishing preferred food sources coinciding with periods of ripening foods. Telemetry, food habits, and observation data all indicate that bears responded to diminishing food sources by increasing their movements to find other productive foraging areas.

For garbage-prone bears, movements were directly related to the unpredictable availability of artificial foods in dumpsters and permanent bivouacs. These movements often led garbage-prone bears across high-speed highways on Camp

Lejeune. Five vehicle-kills were likely related to artificial food sources on Camp Lejeune.

Telemetry and observation data indicate that bears traveled further in early fall compared to late summer and late fall. The majority of the late summer and late fall diets of bears were comprised of pocosin foods (i.e., sweet gallberry and red bay fruit). Bears traveled less during those periods because they were able to forage and/or escape in the same habitats. In contrast, non-pocosin foods (i.e., black gum) comprised the majority of the early fall diet. Bears foraging on black gum traveled out of pocosins thereby increasing their movements. Additionally, 3 vehicle-kills on the northern boundary of Camp Lejeune may have been the result of bears moving to corn fields to forage.

Effects of Roads on Bears

Road densities on Camp Lejeune were the highest reported for a black bear study. Only 10 to 15% of bear habitat was >800 m from roads. The avoidance of areas near roads significantly reduces the amount of bear habitat on Camp Lejeune. For example, for each 200 m-wide strip along roads that are avoided, 20 ha of habitat per km is also avoided. This corresponds to an average of 31% of each bear's home range on Camp Lejeune.

I hypothesize that the contrasting patterns of habitat use between secondary and primary road zones on Camp Lejeune was related to the type of human activity on roads. The avoidance of habitats 100-200 m from roads by bears was more evident for primary roads than secondary roads on Camp Lejeune. Secondary roads

receive moderate to heavy foot traffic during military training exercises on Camp Lejeune. In contrast to secondary roads, primary roads receive moderate to heavy vehicular traffic (approximately 3,100 vehicles per week day) on Camp Lejeune.

Bear distribution to roads is well documented but often with conflicting results. These conflicting accounts are probably related to different research methodologies, different road classification between studies, and the relative use of roads by people (Carr and Pelton 1984). In other studies, the extent of bear avoidance to roads depended on traffic volume (Carr and Pelton 1984, Rogers and Allen 1987, Brody and Pelton 1989, Beringer *et al.* 1990, Clark 1991, Lombardo 1993), roadside cover (Hugie 1982, Rogers and Allen 1987, Seibert 1989, Lombardo 1993), sex of the bear (Brown 1980, Young and Beecham 1986), season (Hellgren 1988, Kasworm and Manley 1990, Clark 1991), food abundance along the road (Hardy 1974, Garner 1986, Hellgren 1988, Clark 1991), time of day (McLellan and Shackleton 1988), and human activity along roads (Hamilton 1978, Gardner 1986, Seibert 1989, Reagan 1991).

Roads can negatively influence bears in at least 5 ways: vehicular mortality, displacement of bears from quality habitat, reduction of bear use of altered habitats, social disruption of bears away from roads, and elevation of illegal harvest (McLellan 1990). Vehicular mortality was undoubtedly the most apparent of these negative influences on Camp Lejeune.

Harris and Gallagher (1989) state that vehicle-kills are the major known source of mortality for most of Florida's remaining large mammals. Over 50% of known deaths of the endangered Florida panther (*Felis concolor*) since 1981 have been

vehicle-kills. Based on historical observations in Wisconsin, wolves did not survive when road densities exceeded 0.93 km/km^2 (Thiel 1985). When road density reached 0.73 km/km^2 in Minnesota, more than 50% of the wolf mortality was caused by humans (Mech *et al.* 1988).

Roads can have positive influences on black bears in unexploited populations. Black bears show an affinity to edges, such as roads, where soft mast is abundant (Carr and Pelton 1984, Smith 1985, Garner 1986, Hellgren and Vaughan 1988, Clark 1991). In addition, bears use roads as travel corridors (Hardy 1974, Garner 1986, Seibert 1989, Lombardo 1993). However, productive natural bear foods were absent on Camp Lejeune's road-side margins. Nevertheless, some bears used secondary roads as travel corridors as an alternative to moving through nearly impenetrable habitats on Camp Lejeune.

Brody and Pelton (1989) found a linear relationship between the road crossing frequency and road densities within the ranges of black bears in western North Carolina. They speculated that bears altered their movement patterns to minimize the risk associated with traffic as long as road densities remain low. They suggested that when road densities reached certain threshold levels, bears shift home ranges to areas of low road density. Mech (1989) suggested low density wolf populations may be supported at greater road densities when adjacent areas have either no roads or low road densities. On Camp Lejeune, there were no roadless areas suitable and large enough to support bears given their current home range size (Fig. 14). Therefore, bears had no other alternative but to live in this high-speed highway environment.

The threshold level of roads within bear ranges is unknown. However, this

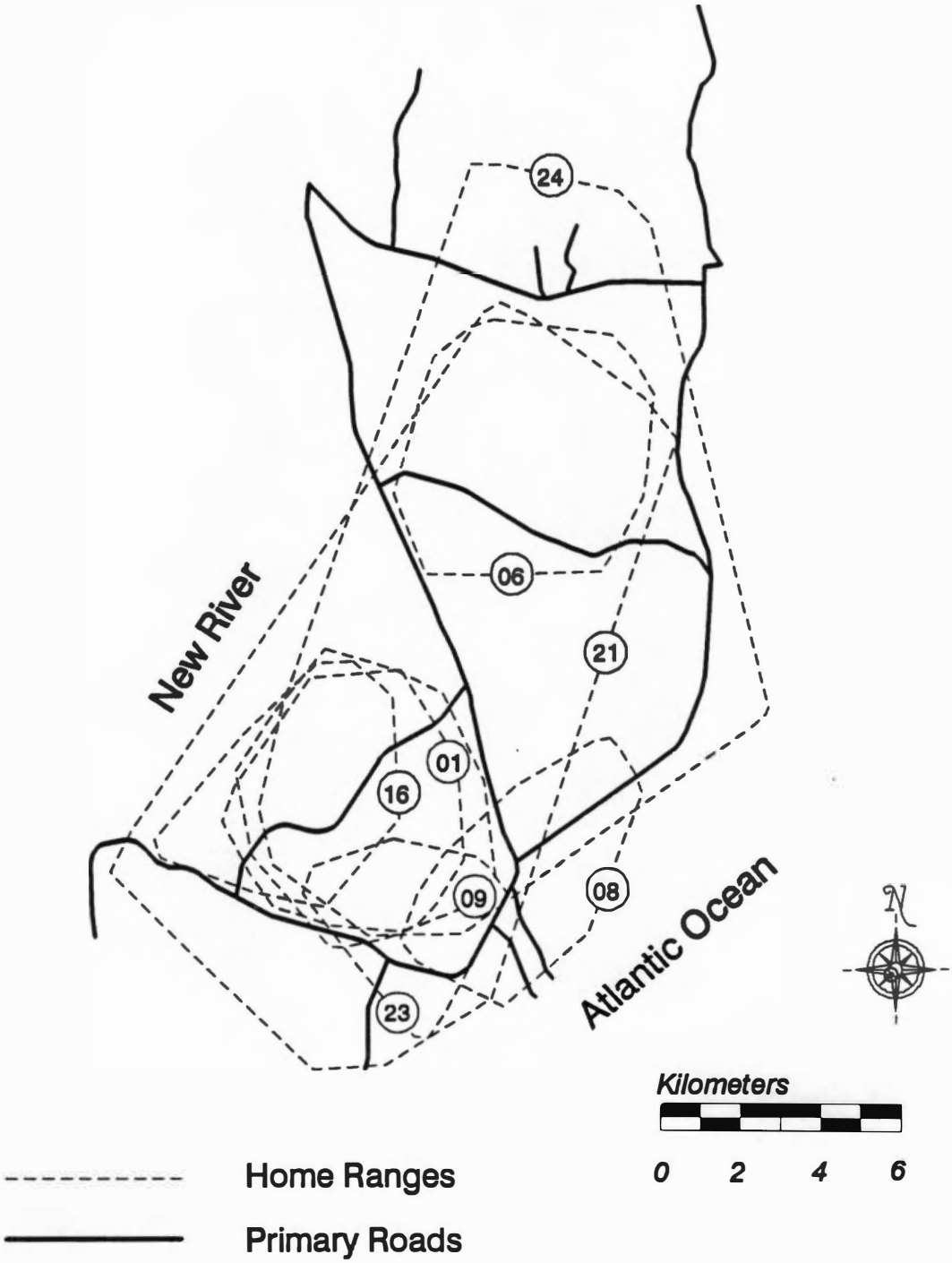


Figure 14. Annual home ranges of black bears and primary roads on Camp Lejeune, North Carolina, 1990-1991.

study has shown that high-speed highway densities averaging 0.33 km/km^2 in a small isolated black bear population can potentially result in extirpation. The fragmenting effects of roads on black bear habitats and populations appear to be exacerbated by the level of vehicle traffic. Brody (1984) suggested that roads on Pisgah National Forest began to interfere with bear use of habitat when the densities reached 1.25 km/km^2 for open roads and 0.5 km/km^2 for logging roads. Hillman and Yow (1986) recommend the density of roads not to exceed 0.20 to 0.25 km/km^2 within bear ranges. However, this is a biological guess regarding limiting human access in black bear habitats to reduce illegal hunting of bears. Their recommendations does not consider high-speed highways and the vehicular mortality of bears.

Little has been done to reduce black bear vehicle-kills or habitat fragmentation caused by highways (Wooding and Maddrey 1994). Most research has been aimed at reducing the number of white-tailed deer killed in the United States. Management techniques that have been tried to reduce deer vehicle-kills are highway fencing to prevent access to the highway, box culverts that allow animals to pass under roads, one-way gates to direct deer out of the road, roadside reflectors, intercept feeding programs, and warning signs (Bellis and Graves 1971, 1978; Reed *et al.* 1974, Pojar *et al.* 1975, Reed *et al.* 1975, Reed and Woodward 1981, Ward 1982, Schafer and Penland 1985, Wood and Wolfe 1988). Highway fencing is the most successful measure to reduce deer vehicle-kills, whereas lighting and illumination signs were not effective. Coulson (1982) reported that warning signs to motorists were not effective in reducing the number of kangaroos killed in Australia. Ward (1982) found the combination of fencing and underpasses greatly reduced mule deer (*O. hemionus*)

vehicle-kills in Wyoming where their migration trail crossed a highway. The effectiveness of these techniques for reducing black bear vehicle-kills is speculative. In Florida, highway underpasses combined with fencing has been constructed to reduce black bear vehicle-kills (Gilbert and Wooding 1994). However, the expense of highway underpasses may limit their employment in other areas.

The fragmenting effects of high-speed highways on black bears may be irreversible in most populations including Camp Lejeune. Because roads (especially major highways) have significant impacts on wildlife, the behavioral responses of wildlife to roads should be considered and incorporated into the planning process (Bennett 1991). Before road construction begins, research needs to identify species that are vulnerable to vehicular mortality and, where significant impacts are likely to occur, to develop strategies that protect crossing points so animals can safely cross roads (Bennett 1991). The least costly and the most obvious strategy to reduce vehicle kills, is to reduce traffic speeds in areas prone to vehicle mortality (see discussion on **Corridor Use**). More costly strategies include building tunnels rather than deep cuttings; building longer elevated road bridges over streams and rivers to allow continuity of a broad swathe of riparian vegetation; elevating the highways in selected areas to create broad underpasses; and bridging over deep cuttings. For existing abandoned and remote roads, controlling human access is probably the most important management scheme for exploited or hunted bear populations (Hillman and Yow 1986).

Bear Behavior in Relation to Roads

This is the first study to examine the effects of roads on black bears with traffic volumes between 100 and 10,000 vehicles per day. My data suggest that bears prefer to cross primary roads at night and/or during times of low traffic volume. I documented only 2 primary road crossings between 1100 and sunset.

Because travel rates were strongly correlated with both the mean frequency of primary and secondary road crossings, many of the same factors that influence bear movements and activity patterns likely influence the frequency of road crossings. Additionally, the effects of season and time of day on both travel rates and the frequency of road crossings were similar. For example, travel rates and the frequency of road crossings both peaked in early summer and early fall for bears on Camp Lejeune.

The avoidance behavior of bears to primary roads was more pronounced than their behavior to secondary roads on Camp Lejeune. The data on road crossing and bear distribution to roads strongly supports the hypothesis that bears have a higher tolerance to secondary roads compared to primary roads. The behavior of bears in response to roads is probably learned and is linked to costs and benefits experienced and perceived by individual bears (Brody and Pelton 1989). Bears were unable to avoid roads on Camp Lejeune, given their current home range size. However, by crossing primary roads at night, bears were able to temporally avoid high traffic volumes on Camp Lejeune; this illustrates a significant amount of behavioral plasticity by black bears on Camp Lejeune.

The relationship between primary roads, bear behavior, and vehicle mortality

on Camp Lejeune is a puzzling one. If bears temporally avoid crossing roads during high traffic volumes, then why are bears being vehicle-killed on Camp Lejeune? Furthermore, why did the majority of bear vehicle-kills occur in early fall even though peak movements and primary road crossings occurred in early summer?

The coat color of bears makes them extremely difficult to see at night. Furthermore, night traffic speeds often exceed 65 mph on Camp Lejeune (pers. obser.). These 2 factors are deadly combinations and probably expose bears to a higher risk to vehicular mortality at night, even though traffic levels are lower.

The disproportionate number of vehicle-kills during early fall is likely influenced by a number of interrelated factors. First, I hypothesize that bear movements and vehicle-kills were related to the spatiotemporal orientation of preferred fall foods and the separation of preferred foraging and bedding areas. Secondly, in early and late fall, travel rates were more strongly correlated with the frequency of primary road crossings than secondary road crossings. This evidence suggests that bears were less discriminating towards primary road traffic during those periods; this may have resulted in bear vehicle-kills. Thirdly, as day length decreased in fall, bears crossed primary roads earlier compared to summer. This shift in movements to earlier time periods resulted in bears crossing primary roads during higher traffic volumes in fall compared to summer.

Corridor Use

This is the first study to demonstrate that black bears prefer and avoid specific habitats for crossing roads. Bears preferred pocosins, drainages, and pure hardwoods

as corridors for crossing primary roads. Bears avoided habitat openings for crossing primary roads.

The selection of preferred habitats or corridors for crossing primary roads may be stronger than indicated by the statistical test because some road crossings may have been missclassified. Bear movements were <200 m from preferred habitats or corridors in 69% of the road crossings classified as occurring at habitat openings. Furthermore, in two thirds and nearly half of the primary road crossings classified as occurring in pure pine and pine/hardwood habitats, respectively, bear movements were <200 m from preferred habitats or corridors.

Habitat use for crossing primary roads does not appear to be different from overall habitat use for bears on Camp Lejeune. In a previous study, Lombardo (1993) found that pocosin and hardwood habitats were used more than expected ($P < 0.05$) and pure pine and habitat openings were used less than expected ($P < 0.10$) on a year around basis. Additionally, pine/hardwood were used in proportion to their availability.

This study and others (Hamilton 1978, Hellgren 1988, Lombardo 1993) have clearly shown the preference for pocosins by bears. I hypothesize that bears prefer to cross primary roads at pocosins and drainages because of their thick vegetative understories. Thick vegetative understories allow bears to move undetected. Interestingly, bears selected thickly-vegetated narrow drainages that were <75 m in width to cross primary roads. In addition, bears often traveled 2 to 3 times further through thick vegetative corridors to cross primary roads rather than traveling shorter distances through more open habitats.

Habitat corridors for black bear road crossings need further investigation, especially in isolated populations. On Camp Lejeune, I speculate the use of drainages for crossing primary roads is greater than overall habitat use of drainages. Radio-collared bears were located only 14 and 9 times in drainages before and after crossing primary roads, respectively. However, bears used drainages on 65 occasions for crossing primary roads.

In eastern North Carolina, bear vehicle-kills continue to increase (Warburton *et al.* 1993). GIS technology and known locations of bear vehicle-kills could be used to further test if bears prefer specific habitats for crossing primary roads in other areas. This knowledge would be valuable for formulating management strategies to reduce vehicle-kills and in the planning process of building future roads.

To reduce the number of vehicular mortalities on Camp Lejeune, night traffic and/or night traffic speeds through corridors could be reduced. Some primary roads could be closed to civilian traffic at night. Furthermore, wide corridors could be landscaped or narrowed at primary road margins. Corridors that are relatively close to other corridors could be cut or eliminated. By landscaping or eliminating certain corridors bears could be funnelled or forced to cross roads at specific points. Night traffic speeds could be reduced at specific points with the use of flashing caution lights.

CHAPTER VI

MANAGEMENT IMPLICATIONS

Preservation of the remaining large contiguous forest tracts with minimal human disturbance is recommended for conserving southeastern black bear populations (Hellgren and Vaughan 1995). Another popular strategy includes linking isolated bear populations by "corridors" (Harris 1988). However, these strategies do not address the small bear populations that are severely fragmented from human disturbances (e.g., agricultural, residential, urban, governmental, recreational, and forestry development). The future of these bear populations is uncertain.

I recommend several immediate strategies to reduce bear movements across high-speed highways and thus mitigate bear mortality on Camp Lejeune. Management for bears on Camp Lejeune should consider military training, forestry management practices, and management of other wildlife species.

I recommend dividing the base into 6 Bear Management Units (BMU's) (Fig. 15). BMU's are defined by occupied bear habitat, entirely bounded by major waterways (New River and the Atlantic Ocean) and/or major highways. Each unit should be evaluated and managed to contain adequate food resources and cover to restrict bear movements within BMU's and on Camp Lejeune. This can be accomplished through supplemental plantings of agriculture crops, proper management of artificial foods, and continued management of natural foods and key habitats.

I recommend planting 2 to 3 corn and/or soybean (*Glycine max*) food plots in

Figure 15. Proposed Bear Management Units (BMU's) on Camp Lejeune, North Carolina.

each BMU. I recommend the use of corn because this study and others (Landers *et al.* 1979, Hellgren and Vaughan 1988, Maddrey 1995) have shown the high preference of corn by bears. Each food plot should be 1 to 2 ha in size. Correct positioning of the food plots will be critical to the success of reducing bear movements. Food plots should be juxtaposed to preferred resting/escape habitats (pocosins). Corn/soybean food plots should be located ≥ 1 km from major highways and not visible from high-use secondary roads. To lessen the frequency of bears traveling to and from corn/soybean food plots fragmented by roads, ≥ 4 km should separate food plots divided by major highways.

I recommend experimentally using soybean food plots in conjunction with corn plots. This will increase the probability that at least 1 crop is available to bears in the fall if weather, insects, and/or diseases destroy the other. Some of the existing rye grass food plots on Camp Lejeune can easily be converted to corn/soybean food plots. Corn/soybean food plots should contain a quantity of food able to withstand foraging from bears and other species and persist to at least December.

I recommend the elimination of roll-off dumpsters within bear ranges on Camp Lejeune for 2 reasons. First, roll-off dumpsters are dangerous to bears. A low level of garbage in roll-off dumpsters prevents bears from escaping from these dumpsters. Undetected bears trapped in roll-off dumpsters are subject to severe heat stress and possibly death. Second, roll-off dumpsters have no lid and therefore cannot be bear-proofed.

I believe temporary garbage storage for large military training exercises is the only real necessity for dumpsters within bear ranges on Camp Lejeune. Therefore,

dumpsters used for other purposes within bear ranges should be eliminated. For large military training exercises, dumpster sites should be designated by coordinating efforts of the EMD and the military. Dumpsters should be conveniently located to military training exercises, accessible to garbage disposal trucks, and ≥1 km from major highways.

Dumpsters should be bear-proofed. To lock dumpster doors, a hasp and a snap connected to a chain should be welded on dumpsters. A sign briefly explaining proper garbage disposal should be attached to dumpsters. Dumpsters should be emptied regularly and removed immediately after the military exercises are completed.

Permanent and temporary bivouacs should be located ≥1 km from major highways. Permanent bivouacs not meeting this criterion should be relocated. Garbage should not accumulate in bivouacs. Garbage left for pick up at vacated bivouacs should be disposed of the same day, especially before night. Garbage at remote bivouacs should be carried out and properly disposed of and not be buried.

I consider Camp Lejeune's forestry practices (i.e., partial clear cuts, seed tree cuts, selective thinning, and prescribed burns) favorable for soft mast production. I recommend that 3- to 5-year burning cycles be continued in pine stands for optimum fruit production. Some areas should be spared for more than 5 years to favor late maturing species (Johnson and Landers 1978). I believe the accidental burning of pocosins due to military training is adequate to maintain the diversity and productivity of soft mast species in these areas.

High quality mature oak and black gum stands are key habitat components

important to the welfare of black bear populations of the Southeast Coastal Plain (Landers *et al.* 1979, Hellgren and Vaughan 1988). Hardwood forests should be managed to promote high yields of mast and to produce a mosaic of successional vegetative stages to provide all life needs for black bears. Camp Lejeune's hardwood management schemes (100-120 year rotation) are also compatible with bear management recommendations for southeastern habitats (Pelton 1985, Hillman and Yow 1986, Brody and Stone 1987, Weaver *et al.* 1990). Conversion of mature mast-producing stands (oak or black gum) to pine plantations reduces mast potential. To insure each BMU has key natural foods for fall, I recommend regenerating 2 to 3 areas in each BMU to high quality mast producing species. Regenerated stands should be juxtaposed to preferred cover and be 1 to 2 ha in size.

Long-term strategies for North Carolina Coastal Plain bear populations should focus on conserving the remaining pocosins and hardwood swamps. This study and others (Hamilton 1978, Hellgren 1988, Lombardo 1993) have clearly demonstrated the importance of pocosins. Pocosins provide critical escape, resting, and denning habitats, and produce important bear foods (e.g., sweet gallberry and red bay fruits) for black bears.

It is inevitable that more southeastern black bear populations will face varying degrees of fragmentation in the future. If these small, fragmented bear populations are to be preserved, then it is vital to determine their limiting factors and develop management strategies. The development and implementation of intuitive active management techniques will certainly be necessary to recover and/or protect severely fragmented black bear populations in the Southeast. Camp Lejeune's recovery efforts

can provide a model for other severely fragmented southeastern populations.

CHAPTER VII

SUMMARY AND CONCLUSIONS

1. I estimated there were 16 bears within the study area in 1990. My data indicates the population is declining and likely was reduced to ≤ 6 bears by December 1992. This corresponded to a density estimate of $\leq 3.3/100$ km^2 and is extremely low relative to other estimates of black bear density in North America.

2. Twenty-eight mortalities have been recorded since initiation of black bear research on Camp Lejeune in 1988. Twenty-seven (96%) bear mortalities on Camp Lejeune were human-related. Vehicle-kills accounted for 20 (71%) mortalities and 6 of 7 (86%) known cub deaths. Twenty-four of 28 (86%) mortalities occurred between 10 August and 6 December and 18 of these mortalities were vehicle-kills.

3. The annual survival rate for females was 71% on Camp Lejeune. This is the lowest reported survival rate for females in a southeastern black bear population.

4. I hypothesized the spatiotemporal orientation of preferred fall foods and the separation of preferred foraging and bedding areas by high-speed highways has resulted in increased bear movements and attributed to the majority of vehicle-kills. Bears moved less when foraging in bedding habitats (i.e., pocosins) and therefore were less vulnerable to vehicle mortality.

I determined the seasonal and annual diet of black bears on Camp Lejeune from 421 scats. Artificial foods comprised 5% of the annual diet of bears although radio-collared bears were <100 m from artificial food sources in 90 of 553 (16%)

instances that I monitored them.

5. Road densities within seasonal home ranges of bears on Camp Lejeune are the highest reported for a bear study. Densities ranged from 0.20 to 1.6 and 0 to 0.9 km/km^2 for secondary and primary roads, respectively. This study has shown that these densities of high-speed highways are extremely detrimental. In addition, habitats >800 m from roads only comprised 10 to 15% of the total habitat available to bears on Camp Lejeune.

6. The avoidance of habitats <100 m from roads was the most distinctive pattern of bear use of both secondary and primary roads on Camp Lejeune. This corresponded to nearly a third of each bear's home range being used less than expected.

7. Movement and activity patterns of radio-collared bears on Camp Lejeune varied by sex, age, and reproductive class. Seasonal and time period differences often were attributed to food availability and abundance, military training, and behavior of individual animals. In general, lone adult bears were nocturnal in their habits during all seasons. Peak bear movements occurred at sunrise and were a clear reflection of bears traveling to foraging areas.

8. I found the behavior of bears to primary roads more pronounced compared to secondary roads. Bears crossed primary roads less frequently than secondary roads. Primary roads appeared to temporally inhibit bear movements while secondary roads did not. My data suggest that bears preferred to cross roads during night and/or during low traffic volumes. Some bears used secondary roads as convenient travel corridors. Bears crossed primary roads 44% less frequently than simulated

random primary road crossings. In contrast, secondary road crossings occurred 20% less frequently than simulated secondary road crossings. Additionally, the avoidance of habitats 100-200 m from roads by bears was more evident for primary roads compared to secondary roads.

Bears were located further from primary roads after crossing roads compared to before crossing. Conversely, no differences were detected in distances from secondary roads between locations occurring before or after crossing. In addition, bears were located further from primary roads compared to secondary roads after crossing.

In early and late fall, my data suggest bears were less discriminating towards primary roads. During those periods, travel rates were more strongly correlated with primary compared to secondary road crossings. This behavior may have attributed to vehicle-kills. Furthermore, secondary and primary road crossings were strongly correlated in all seasons except early and late fall.

9. This is the first study to demonstrate that bears prefer and avoid specific habitats for crossing roads. I detected significant habitat selection from 171 primary road crossings by radio-collared bears ($\chi^2 = 211.72$, 6 df, $P < 0.001$). Bears preferred pocosins, drainages, and pure hardwoods as corridors to cross primary roads. Bears avoided habitat openings for crossing primary roads.

10. Research on Camp Lejeune may have uncovered a worst-case scenario of habitat fragmentation and impediments to movements for a southeastern black bear population. Not only is Camp Lejeune highly isolated from other bear populations, but its interior is fragmented by high-speed highways. Due to the high density of

roads on Camp Lejeune, bears were unable to shift home ranges to avoid high-speed highways. As a result, vehicle-kill mortality has caused a decline in the number of bears on Camp Lejeune.

11. To recover this population, I recommend strategies to reduce bear movements across high-speed highways and thus reduce vehicle-kills on Camp Lejeune. Management strategies include dividing the Base into bear management units, planting corn/soybean food plots to decrease bear movement across major highways, proper disposal of and minimization of the availability of artificial foods, and habitat management. Other management strategies to reduce vehicle-kills on Camp Lejeune include reducing the night traffic and/or traffic speeds through movement corridors on Camp Lejeune. Furthermore, wide corridors could be landscaped (narrowed) at road margins to funnel bears to specific points where traffic speeds can be controlled.

LITERATURE CITED

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Abler, W. A. 1985. Bear population dynamics on a study area in southeastern Georgia. Georgia. Georgia Dept. Nat. Resources, Atlanta. Final Rep. 91pp.

Ackerman, B. B., F. A. Leban, M. D. Samuel, and E. O. Garton. 1990. User's manual for program HOME RANGE. Second Edition. Tech. Rep. No. 15. For., Wildl. and Range Expt. Sta., Univ. Idaho, Moscow. 79pp.

Barnhill, W. L. 1984. Soil Survey of Camp Lejeune, North Carolina. National Cooperative Soil Survey Series, USDA. 227pp.

Bekoff, M., and L. D. Mech. 1984. Simulation analyses of space use: home range estimates, variability, and sample size. Beh. Res. Meth., Instr., and Comp. 16:32-37.

Bellis, E. D., and H. B. Graves. 1971. Deer mortality on a Pennsylvania interstate highway. J. Wild. Manage. 35:232-237.

____, and ____. 1978. Highway fences as deterrents to vehicle-deer collisions. Trans. Res. Rec. 674:53-58.

Bennett, A. F. 1991. Roads, roadsides, and wildlife conservation: a review. Pages 99-118 *in* Saunders and R. J. Hobbs, eds. The role of corridors. Surrey Beatty, Chipping Norton, New South Wales, Australia.

Beringer, J. J. 1986. Habitat use and response to roads by black bears in Harmon Den, Pisgah National Forest, North Carolina. M. S. Thesis, Univ. Tenn., Knoxville. 103pp.

____, S. G. Seibert, and M. R. Pelton. 1990. Incidence of road crossings by bears on Pisgah National Forest, North Carolina. Int. Conf. Bear Res. and Manage. 8:85-92.

Bowen, W. D. 1982. Home range and spatial organization of coyotes in Jasper National Park, Alberta. J. Wildl. Manage. 46:201-216.

Brody, A. J. 1984. Habitat use by black bears in relation to forest management in Pisgah National Forest, North Carolina. M. S. Thesis, Univ. Tenn., Knoxville. 123pp.

___, and J. N. Stone. 1987. Timber harvest and black bear population dynamics in a southern Appalachian forest. Proc. Int. Conf. Bear Res. and Manage. 4:141-147.

___, and M. R. Pelton. 1989. The effects of roads on black bear movements in western North Carolina. Wildl. Soc. Bull. 17:5-10.

Brown, W. S. 1980. Black bear movements and activities in Pocahontas and Randolph counties, West Virginia. M. S. Thesis. W. Va. Univ., Morgantown. 91pp.

Bunnell, F. L., and D. E. N. Tait. 1985. Mortality rates of North American bears. Arctic. 38:316-323.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wild. Manage. 48:1050-1053.

Campbell, R. G., and J. H. Hughes. 1981. Forest management systems in North Carolina pocosins: Weyerhaeuser. Pages 199- 213 *in* C. J. Richardson, ed. Pocosin wetlands, an integrated analysis of Coastal Plain freshwater bogs in North Carolina. Hutchinson Ross Publ., Stroudsburg, PA.

Carr, P. C., and M. R. Pelton. 1984. Proximity of adult female black bears to limited access roads. Southeast. Assoc. Fish Wildl. Agencies 38:70-77.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. Univ. Cal. Publ. Stat. 1:131-160.

Clark, J. D. 1991. Ecology of two black bear populations (*Ursus americanus*) in the Interior Highlands of Arkansas. Ph. D. Dissertation, Univ. Ark., Fayetteville. 228pp.

___, and F. T. van Manen. 1993. Geographic information systems and black bear habitat analyses. Eastern Workshop Bear Res. and Manage. 11:137-153.

Coulson, G. 1982. Road-kills of macropods on a section of highway in central Victoria. Aust. Wildl. Res. 9:21-26.

Daniels, R. B., E. E. Gamble, W. H. Wheeler, J. W. Gilliam, E. H. Wiser, and C. W. Welby. 1978. Water movement in surficial coastal plain sediments, inferred from sediment morphology. N.C. Ag. Expt. Sta. Tech. Bull. No. 243, 31pp.

Dixon, W. J., and F. J. Massey. 1969. Introduction to statistical analysis. McGraw-Hill, New York, N.Y. 638pp.

Dodge, W. E., and A. J. Steiner. 1986. XYLOG: a computer program for field processing locations of radio-tagged wildlife, Tech. Rep. 4. U. S. Fish and Wildl. Serv., Washington, D. C. 22pp.

Doulan, R., and L. Vincent. 1970. Shoreline changes along the Outer Banks of North Carolina. U.S. Department of the Interior, Technical Report 70-5.

Eagle, T. C., and M. R. Pelton 1978. A tooth sectioning simplified technique for aging black bears in the Southeast. Proc. Eastern Workshop on Black Bear Manage. and Res. 4:92-98.

Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135-150 *in* M. E. Soul'e and B. A. Wilcox, eds. Conservation biology: an evolutionary-ecological perspective. Sinauer Assoc., Sunderland, Mass.

Garner, N. P. 1986. Seasonal movements, habitat selection, and food habits of black bears (*Ursus americanus*) in Shenandoah National Park, Virginia. M. S. Thesis, Va. Polytech. Inst. and State Univ., Blacksburg. 104pp.

Garshelis, D. L, and M. R. Pelton. 1981. Movements of black bears in the Great Smoky Mountains National Park. J. Wildl. Manage. 45:912-925.

Gilbert, T., and J. Wooding. 1994. Chronic roadkill problem areas for black bears in Florida. Florida Game and Fresh Water Fish Commission, 620 S. Meridian St., Tallahassee, FL 32399-1600. 24pp.

GLMM. 1990. Department of Experimental Statistics, Louisiana Agriculture Experiment Station, LSU.

Hall, E. R. 1981. The mammals of North America. Vol. 2. 2nd ed. John Wiley and Sons, New York. 1181pp.

Hamilton, R. J. 1978. Ecology of the black bear in southeastern North Carolina. M. S. Thesis, Univ. Georgia, Athens. 214pp.

Hardy, D. M. 1974. Habitat requirements of the black bear in Dare County, North Carolina. M. S. Thesis, Virginia Polytech. Inst. and State Univ., Blacksburg. 121pp.

Harris, L. D. 1985. Conservation corridors: a highway system for wildlife. ENFO Report 85-5. Environmental Information Center of the Florida Conservation Foundation, Inc. Winter Park, Florida.

___. 1988. Landscape linkages: The dispersal corridor approach to wildlife conservation. Transactions of the North American Wildlife and Natural Resources Conference. 53:595-607.

___, and P. B. Gallagher. 1989. New initiatives for wildlife conservation: the need for movement corridors. Pages 11-34 *in* G. Mackintosh, editor. Preserving communities and corridors. Defenders of Wildlife, Washington, D.C.

Hellgren, E. C. 1988. Ecology and physiology of a black bear (*Ursus americanus*) population in Great Dismal Swamp and reproductive physiology in the captive female black bear. Ph. D. Dissertation, Va. Polytech. Inst. and State Univ., Blacksburg. 231pp.

___, and D. S. Maehr. 1992. Habitat fragmentation, human disturbance, and black bears in the eastern United States. East. Workshop Black Bear Res. and Manage. 11:154-165.

___, and M. R. Vaughan. 1988. Seasonal foods habits of black bears in Great Dismal Swamp, Virginia-North Carolina. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 42:295-305.

___, and ___. 1989. Demographic analysis of a black bear population in a southeastern wetland. J. Wildl. Manage. 53:969-977.

___, and ___. 1991. Macrohabitat use by black bears in a southeastern wetland. J. Wildl. Manage. 55:442-448.

___, and ___. 1995. Management of isolated black bear populations in the southeastern Coastal Plain of the United States: views from Great Dismal Swamp. Int. Conf. Bear Res. and Manage. 10:In prep.

Hillman, L. L., and D. L. Yow. 1986. Timber management for black bears. Proc. East. Workshop Black Bear Res. and Manage. 8:125-136.

Hobbs, R. J., and J. M. Hopkins. 1991. The role of conservation corridors in a changing climate. Pages 281-290 *in* D. A. Saunders and R. J. Hobbs, eds. The role of corridors. Chipping Norton, Surrey Beatty, New South Wales, Australia.

Hugie, R. D. 1982. Black bear ecology and management in the northern conifer-deciduous forest of Maine. Ph. D. Dissertation, Univ. Mont., Missoula. 203pp.

Johnson, A. S., and J. L. Landers. 1978. Fruit production in slash pine plantations in Georgia. J. Wildl. Mange. 42:606-613.

Kasworm, W. F., and T. L. Manley. 1990. Road and trail influences on grizzly bears and black bears in Northwest Montana. Int. Conf. Bear Res. and Manage. 8:79-84.

Kenwood, R. 1987. Wildlife Radio Tagging. Academic Press, San Diego, CA. 222pp.

Kologiski, R. L. 1977. The phytosociology of the Green Swamp, North Carolina. Tech. Bull. No. 250, N.C. Agric. Exp. Sta., Raleigh, N.C. 101pp.

Landers, J. L., R. J. Hamilton, A. S. Johnson, and R. L. Marchinton. 1979. Foods and habitat of black bears in southeastern North Carolina. J. Wildl. Manage. 43:143-153.

Laurance, W. F. 1991. Ecological correlates of extinction proneness in Australian tropical rain forest mammals. Conserv. Biol. 5:79-89.

Lombardo, C. A. 1993. Population ecology of black bears on Camp Lejeune, North Carolina. M. S. Thesis, Univ. Tenn., Knoxville. 155pp.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey.

MacDonald, D. W., F. G. Ball, and N. G. Hough. 1980. The evaluation of home range size and configuration using radio tracking data. Pages 405-424 *in* C. J. Amlaner and D. W. MacDonald, eds. A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford, UK.

Maddrey, R. C. 1995. Morphology, reproduction, food habits, crop depredation, and mortality of black bears on the Neuse-Pamlico Peninsula, North Carolina. M. S. Thesis, Univ. Tenn., Knoxville. 146pp.

Maehr, D. S. 1984. Distribution of black bears in eastern North America. Page 74 *in* D. S. Maehr and J. R. Brady, eds. Proc. 7th eastern workshop on black bear management and research. Florida Game and Fresh Water Fish Comm., Gainesville, FL.

Manville, A. M. 1983. Human impact on the black bear in Michigan's lower peninsula. Int. Conf. Bear Res. and Manage. 5:20-33.

Marine Corps Base Camp Lejeune, USDA-Soil Conservation Service, and Onslow Soil and Water Conserv. District. 1987. Multiple-Use Natural Resources Management Plan - Camp Lejeune, North Carolina. USDA-SCS, Publ. 253pp.

McLean, P. K., and M. R. Pelton. 1994. Estimates of population and density and growth of black bears in the Smoky Mountains. Int. Conf. Bear Res. and Manage. 9:253-261.

McLellan, B. N. 1990. Relationships between human industrial activity and grizzly bears. Int. Conf. Bear Res. and Manage. 8:57-64.

___, and D. M. Shackleton. 1988. Grizzly bears and resource extraction industries: effects of roads on behavior, habitat use, and demography. J. Applied Ecol. 25:451-460.

Mech, L. D. 1989. Wolf population survival in an area of high road density. Am. Midl. Nat. 121:387-389.

___, S. H. Fritts, G. L. Radde, and W. J. Paul. 1988. Wolf distribution and road density in Minnesota. Wildl. Soc. Bull. 16:85-87.

Michener, G. R. 1979. Spatial relationships and social organization of adult Richardson's ground squirrels. Can J. Zool. 57:125-139.

Miller, T. O. 1975. Factors influencing black bear habitat selection on Cheat Mountain, West Virginia. M. S. Thesis, W. Va. Univ., Morgantown. 61pp.

Miller, S. D. 1990. Population management of bears in North America. Int. Conf. Bear Res. Manage. 8:357:373.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Nicholls A. O., and C. R. Margules. 1991. The design of studies to demonstrate the biological importance of corridors. Pages 49-61 *in* D. A. Saunders and R. J. Hobbs, eds. The role of corridors. Surrey Beatty, Chipping Norton, New South Wales, Australia.

Otte, L. J. 1981. Origin, development and maintenance of the pocosin wetlands of North Carolina. N. C. Dep. Nat. Resour. and Comm. Dev., Nat. Heritage Program. Raleigh, NC.

Pelchat, B. O., and R. L. Ruff. 1986. Habitat and spatial relationships of black bears in boreal mixedwood forest of Alberta. Int. Conf. Bear Res. and Manage. 6:81-92.

Pelton, M. R. 1982. Black bear. Pages 504-514 *in* J. A. Chapman and G. A. Feldhamer, eds. Wild mammals of North America: biology, management, and economics. John Hopkins University Press, Baltimore, MD.

___. 1985. Habitat needs of black bears in the East. Pages 49-53 *in* D. L. Kulhavy and R. N. Conner, eds. Wilderness and natural areas in the eastern United States: a management challenge. Center for Appl. Studies, Stephen F. Austin State Univ., Nacogdoches, Texas.

___. 1990. Black bears in the Southeast: To list or not to list. East Workshop Black Bear Res. and Manage. 10:155-161.

___, and F. T. van Manen. In press. Distribution of black bears in North America. Proc. East. Black Bear Workshop 12.

Pojar, T. M., R. A. Prosence, D. F. Reed, and T. N Woodward. 1975. Effectiveness of a lighted, animated deer crossing sign. J. Wildl. Manage. 39:87-91.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. J. Wildl. Manage. 53:7-15.

Quigley, H. B. 1982. Activity patterns, movement ecology, and habitat utilization of black bears in the Great Smoky Mountains National Park. M. S. Thesis, Univ. Tenn., Knoxville. 140pp.

Reagan, S. R. 1991. Habitat use by female black bears in a southern Appalachian bear sanctuary. M. S. Thesis, Univ. Tenn., Knoxville. 110pp.

Reed, D. F., and T. N. Woodward. 1981. Effectiveness of highway lighting in reducing deer-vehicle accidents. J. Wildl. Manage. 45:721-726.

___, T. M. Pojar, and T. N. Woodward. 1974. Use of one-way gates by mule deer. J. Wildl. Manage. 38:9-15.

___, T. N. Woodward, and T. M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. J. Wildl. Mange. 39:361-367.

Richardson, C. J. Evans, and D. Carr. 1981. Pocosins: an ecosystem in transition. Pages 3-19 *in* C. J. Richardson, ed. Pocosin wetlands, an integrated analysis of Coastal Plain freshwater bogs in North Carolina. Hutchinson Ross Publ., Stroudsburg, Pa.

Rieffenberger, J. C. 1974. Range and movements of West Virginia Black bear during summer and autumn, 1973. Proc. East. Workshop on Black Bear Manage. and Res. 2:139-142.

Rogers, L. L. 1987. Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. Wildl. Monogr. 97. 72pp.

___, and A. W. Allen. 1987. Habitat suitability index models: black bear, Upper Great Lakes region. U. S. Fish and Wildlife Service, Washington, D. C. Biological Report 82 (10.144). 54pp.

Sanders, O. T. 1978. An evaluation of black bear sanctuaries. Proc. East. Black Bear Workshop. 4:278-297.

SAS Institute, Inc. 1990. SAS/STAT User's Guide, Version 6, 4th edition, Volumes 1 and 2. SAS Institute Inc., Cary, NC.

Saunders, D. A., and R. J. Hobbs. 1991. The role of corridors in conservation: what do we know and where doe we go? Pages 421-427 *in* Saunders and R. J. Hobbs, editors. The role of corridors. Surrey Beatty, Chipping Norton, New South Wales, Australia.

Schafer, J. A., and S. T. Penland. 1985. Effectiveness of Swareflex reflectors in reducing deer-vehicle accidents. J. Wildl. Manage. 49:774-776.

Schoen, J. W. 1990. Bear habitat management: a review and future perspective. Int. Conf. Bear Res. and Manage. 8:143-154.

Schooley R. L., C. R. McLaughin, W. B. Krohn, and G. J. Matula. 1994. Spatiotemporal patterns of macrohabitat use by females black bears during fall. Int. Conf. Bear Res. and Manage. 9:339-348.

Schwartz, C. C., and A. W. Franzmann. 1992. Dispersal and survival of subadult black bears from the Kenai Peninsula, Alaska. J. Wildl. Manage. 56:426-431.

Seber, G. A. 1982. Estimation of animal abundance and related parameters, 2nd ed., 654pp.

Seibert, S. G. 1989. Black bear habitat use and response to roads on Pisgah National Forest, North Carolina. M. S. Thesis, Univ. Tenn., Knoxville. 144pp.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Publ. Co., New York. 312pp.

Simberloff, D., and J. Cox. 1987. Consequences and cost of conservation corridors. Conservation Biology. 1:63-71.

___, ___, and D. W. Mehlman. 1992. Movement corridors: Conservation bargains or poor investments. Conservation biology. 6:493-504.

Smith, T. R. 1985. Ecology of black bears in the bottomland hardwood forest in Arkansas. Ph. D. Dissertation, Univ. Tenn., Knoxville. 209pp.

Springer, J. T. 1979. Some sources of bias and sampling error in radio triangulation. J. Wildl. Manage. 43:926-935.

Thiel, R. P. 1985. Relationships between road densities and wolf habitat suitability in Wisconsin. Am. Midl. Nat. 113:404-407.

Tooker, W. W. 1899. The adapted Algonquin term "Pocosin." Am. Anthropol. Jan.: 162-170.

Villarrubia, C. R. 1982. Movement ecology and habitat utilization of black bears in Cherokee National Forest, Tennessee. M. S. Thesis, Univ. Tenn., Knoxville. 159pp.

Warburton, G. S. 1992. North Carolina status report. Proc. East. Workshop Black Bear Res. and Manage. 11:64-68.

___, R. C. Maddrey, and D. W. Rowe. 1993. Characteristics of black bear mortality on the Coastal Plain of North Carolina. Proc Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:276-286.

Ward, A. L. 1982. Mule deer behavior in relation in fencing and underpasses on Interstate 80 in Wyoming. Transp. Res. Rec. 859:8-13.

Weaver, K. M., and J. C. Posey, and M. D. Esters. 1991. Louisiana black bear status report. Proc. East Workshop Black Bear Res. and Manage. 10:23-29.

___, D. K. Tabberer, L. U. Moore, G. A. Chandler, J. C. Posey, and M. R. Pelton. 1990. Bottomland hardwood management for black bears in Louisiana. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 44:342-350.

Wells, B. W. 1928. Plant communities of the Coastal Plain of North Carolina and their successional relations. Ecology 9:230-242.

White, G. C. 1985. Optimum locations of towers for triangulation studies using biotelemetry. J. Wildl. Manage. 49:190-196.

___, and R. A. Garrot. 1986. Effects of biotelemetry triangulation error on detecting habitat selection. J. Wildl. Manage. 50:509-513.

Willey, C. H. 1974. Aging black bears from first premolar tooth sections. J. Wildl. Manage. 38:97-100.

Wilson, E. O., and E. O. Willis. 1975. Applied biogeography. Pages 523-534 *in* M. L. Cody and J. M. Diamond, eds. Ecology and evolution of communities. Harvard University Press, Cambridge, Massachusetts.

Wood, P. G., and M. L. Wolfe. 1988. Intercept feeding as a means of reducing deer-vehicle collisions. Wildl. Soc. Bull. 16:376-380.

Wooding, J. B., and J. R. Brady. 1987. Black bear roadkills in Florida. Proc. Southeast. Assoc. Fish. and Wildl. Agencies 41:438-442.

___, and R. C. Maddrey. 1994. Impacts of roads on black bears. Proc. East. Workshop Bear Res. Manage. 12:In Press.

Woodwell, G. M. 1958. Factors controlling growth of pond pine seedlings in organic soils of the Carolinas. Ecol. Monogr. 28:219-236.

Young, D. D., and J. J. Beecham. 1986. Black bear habitat use at Priest Lake, Idaho. Int. Conf. Bear Res. and Manage. 6:73-80.

APPENDICES

Table A-1. Probabilities that black bears use secondary road zones in proportion to their availability and associated classification error rates, on Camp Lejeune, North Carolina, 1990-1991.

Bear ID	CHI-Square Value	df	Prob.	Simulated CHI-Square Value	*n*	Number in Error	%
Winter							
24	18.11	4	0.001	18.11	21	0	0
Spring							
01	46.05	3	<0.001	39.23	163	6	3.7
06	10.48	3	0.015	9.45	101	8	7.9
08	22.12	3	<0.001	19.00	99	15	15.2
09	7.63	3	0.054	8.76	179	8	4.5
16	27.25	3	<0.001	27.25	113	14	12.4
21	50.87	4	<0.001	48.45	145	15	10.3
23	15.79	3	0.001	11.93	76	4	5.3
24	63.96	4	<0.001	61.78	130	3	2.3
Early Summer							
01	10.09	3	0.018	10.74	79	6	7.6
06	3.56	3	0.313	4.10	110	4	3.6
08	10.18	3	0.017	8.65	80	7	8.8
09	1.94	3	0.585	2.66	38	4	10.5
16	4.74	3	0.192	5.62	73	10	13.7
21	14.86	3	0.002	7.89	79	7	8.9
24	13.27	4	0.010	3.98[a]	87	14	16.1
26	37.03	3	<0.001	34.29	112	12	10.7
28	2.66	3	0.447	2.39	107	15	14.0
30	23.06	3	<0.001	21.46	80	4	5.0
31	24.85	4	<0.001	24.23	77	2	2.6
Late Summer							
01	12.65	3	0.005	8.11	51	5	9.8
08	8.27	4	0.082	5.48	38	6	15.8
09	0.38	4	0.984	0.38	34	0	0
16	10.57	4	0.032	8.63[a]	51	6	11.8

Table A-1. (continued)

Bear ID	CHI-Square Value	df	Prob.	Simulated CHI-Square Value	*n*	Number in Error	%
Early Fall							
01	6.72	3	0.081	2.83	85	13	15.3
04	12.30	4	0.015	11.61	61	6	9.8
06	11.24	3	0.011	10.52	111	7	6.3
08	38.36	3	<0.001	34.08	99	8	8.1
09	6.50	3	0.090	4.12	89	6	6.7
16	28.08	3	<0.001	20.84	104	10	9.6
20	5.21	3	0.157	6.16	67	4	6.0
21	31.75	3	<0.001	28.25	114	13	11.4
22	20.30	4	<0.001	39.19	73	16	21.9
23	4.52	3	0.211	1.56	130	16	12.3
24	7.18	4	0.127	5.79	90	16	17.8
Late Fall							
01	3.90	3	0.272	0.63	38	9	23.7
08	1.86	3	0.602	3.13	34	8	23.5
09	42.63	3	<0.001	31.77	111	26	23.4
21	45.98	3	<0.001	42.48	94	2	2.1
23	42.97	3	<0.001	31.20	126	16	12.7
24	14.61	3	0.002	11.66	60	10	16.7
Annual							
01	61.64	3	<0.001	47.16	418	28	6.7
06	20.25	4	<0.001	17.92	337	16	4.7
08	61.08	4	<0.001	55.38	353	13	3.7
09	33.17	3	<0.001	25.78	453	20	4.4
16	64.73	4	<0.001	40.67	339	98	28.9
21	171.26	4	<0.001	145.11	437	26	5.9
23	63.10	4	<0.001	46.69	331	20	6.0
24	92.61	4	<0.001	75.34	390	39	10.0

[a] χ^2 tests for simulated points differed from original points.

Table A-2. Probabilities that black bears use primary road zones in proportion to their availability and associated classification error rates on Camp Lejeune, North Carolina, 1990-1991.

Bear ID	CHI-Square Value	df	Prob.	Simulated CHI-Square Value	*n*	Number in Error	%
Winter							
24	18.86	4	<0.001	18.86	21	0	0
Spring							
01	35.78	4	<0.001	27.96	163	8	4.9
06	4.98	4	0.289	4.90	101	2	2.0
08	43.86	4	<0.001	39.90	99	6	6.1
09	19.28	4	<0.001	24.87	179	9	5.0
06	126.09	2	<0.001	95.34	103	3	2.9
21	5.32	4	0.256	5.46	145	2	1.4
23	14.70	4	0.005	15.29	76	4	5.3
24	23.81	4	<0.001	22.95	130	3	2.3
Early Summer							
01	15.81	4	0.003	17.24	79	8	10.1
06	24.70	4	<0.001	24.03	110	4	3.6
08	16.79	4	0.002	15.85	80	5	6.3
09	11.96	2	0.002	6.16	37	7	18.9
16	12.73	4	0.013	12.16	73	4	5.5
21	0.46	1	0.498	1.07	64	2	3.1
24	17.84	4	0.001	16.76	87	4	4.6
26	19.60	4	<0.001	20.11	112	8	7.1
28	13.22	4	0.010	13.78	107	4	3.7
30	48.12	4	<0.001	44.02	80	2	2.5
31	40.12	4	<0.001	37.19	77	2	2.6
Late Summer							
01	7.14	3	0.068	6.61	51	3	5.9
08	4.80	4	0.308	2.55	38	2	5.3
09	9.29	3	0.026	12.35	34	5	14.7
16	11.19	3	0.011	9.56	51	4	7.8

Table A-2. (continued)

Bear ID	CHI-Square Value	df	Prob.	Simulated CHI-Square Value	*n*	Number in Error	%
Early Fall							
01	38.37	4	<0.001	35.00	85	4	4.7
04	13.61	4	0.009	13.61	61	0	0
06	30.97	3	<0.001	25.79	111	4	3.6
08	83.74	4	<0.001	80.98	99	3	3.0
09	12.57	3	0.006	12.85	89	5	5.6
16	33.54	4	<0.001	31.61	104	3	2.9
20	13.73	4	0.008	3.29[a]	67	12	17.9
21	33.01	4	<0.001	26.90	114	8	7.0
22	47.98	3	<0.001	33.02	73	8	11.0
23	32.02	4	<0.001	30.62	130	6	4.6
24	24.99	4	<0.001	24.26	90	4	4.4
Late Fall							
01	7.01	3	0.072	7.76	38	4	10.5
08	2.03	2	0.362	3.31	34	4	11.8
09	28.71	4	<0.001	31.67	111	4	3.6
21	79.99	4	<0.001	80.36	94	3	3.2
23	21.96	3	<0.001	17.21	126	10	7.9
24	12.95	3	0.005	8.29	60	2	3.3
Annual							
01	36.30	4	<0.001	41.98	418	22	5.3
06	18.54	4	<0.001	18.02	337	4	1.2
08	85.05	4	<0.001	81.05	353	9	2.5
09	26.33	4	<0.001	28.94	453	15	3.3
16	54.38	4	<0.001	49.36	339	6	1.8
21	17.98	4	0.001	15.24	437	11	2.5
23	24.90	4	<0.001	33.05	331	14	4.2
24	48.54	4	<0.001	47.17	390	7	1.8

[a] χ^2 tests for simulated points differed from original points.

Table A-3. Black bear use of secondary road zones on Camp Lejeune, North Carolina, 1990-1991.

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
Winter								
24	<100	66.48	0.184	0.048	1	4	-0.072- 0.168	-
24	100-200	58.75	0.163	0.000	0	3	0.000- 0.000	-
24	200-400	112.26	0.312	0.190	4	7	-0.031- 0.411	
24	400-800	122.85	0.341	0.762	16	7	0.523- 1.001	+
Spring								
01	<100	624.33	0.273	0.067	11	44	0.018- 0.116	-
01	100-200	536.40	0.235	0.209	34	38	0.130- 0.288	
01	200-400	714.40	0.313	0.417	68	51	0.321- 0.513	
01	400-800	408.86	0.179	0.307	50	29	0.217- 0.397	+
06	<100	327.96	0.182	0.069	7	18	0.006- 0.132	-
06	100-200	317.06	0.176	0.188	19	18	0.091- 0.285	
06	200-400	585.88	0.326	0.436	44	33	0.313- 0.559	
06	400-800	567.28	0.315	0.307	31	32	0.192- 0.422	
08	<100	373.57	0.264	0.091	9	26	0.019- 0.163	-
08	100-200	304.54	0.215	0.172	17	21	0.077- 0.267	
08	200-400	435.70	0.308	0.465	46	30	0.340- 0.590	+
08	400-800	301.63	0.213	0.273	27	21	0.161- 0.385	
09	<100	765.35	0.269	0.179	32	48	0.108- 0.250	-
09	100-200	656.86	0.231	0.240	43	41	0.160- 0.320	
09	200-400	884.58	0.311	0.358	64	56	0.269- 0.447	
09	400-800	536.48	0.189	0.223	40	34	0.145- 0.301	
16	<100	185.56	0.237	0.044	5	27	-0.004- 0.092	-
16	100-200	167.25	0.214	0.204	23	24	0.109- 0.299	
16	200-400	236.70	0.303	0.442	50	34	0.325- 0.559	+
16	400-800	192.66	0.246	0.310	35	28	0.201- 0.419	
21	<100	1772.08	0.199	0.110	16	29	0.043- 0.177	-
21	100-200	1558.20	0.175	0.221	32	25	0.132- 0.310	
21	200-400	2412.48	0.271	0.483	70	39	0.376- 0.590	+
21	400-800	2109.55	0.237	0.186	27	34	0.103- 0.269	
21	>800	1040.87	0.117	0.000	0	17	0.000- 0.000	-
23	<100	333.28	0.289	0.184	14	22	0.073- 0.295	
23	100-200	291.05	0.252	0.132	10	19	0.035- 0.229	-
23	200-400	369.07	0.320	0.447	34	24	0.305- 0.589	
23	400-800	161.23	0.140	0.237	18	11	0.115- 0.359	
24	<100	1897.25	0.216	0.077	10	28	0.017- 0.137	-
24	100-200	1587.66	0.181	0.169	22	24	0.084- 0.254	
24	200-400	2248.91	0.256	0.238	31	33	0.142- 0.334	
24	400-800	2006.74	0.228	0.500	65	30	0.387- 0.613	+
24	>800	1041.78	0.119	0.015	2	15	-0.012- 0.042	-

Table A-3. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
Early Summer								
01	<100	682.75	0.271	0.127	10	21	0.034- 0.220	-
01	100-200	586.59	0.233	0.215	17	18	0.100- 0.330	
01	200-400	788.18	0.313	0.380	30	25	0.244- 0.516	
01	400-800	462.86	0.184	0.278	22	15	0.152- 0.404	
06	<100	471.44	0.193	0.182	20	21	0.090- 0.274	
06	100-200	435.66	0.179	0.245	27	20	0.143- 0.347	
06	200-400	770.74	0.316	0.318	35	35	0.207- 0.429	
06	400-800	760.31	0.312	0.255	28	34	0.151- 0.359	
08	<100	425.98	0.272	0.125	10	22	0.033- 0.217	-
08	100-200	347.48	0.222	0.225	18	18	0.109- 0.341	
08	200-400	491.32	0.314	0.413	33	25	0.276- 0.550	
08	400-800	302.32	0.193	0.238	19	15	0.119- 0.357	
09	<100	333.03	0.243	0.263	10	9	0.085- 0.441	
09	100-200	291.73	0.213	0.158	6	8	0.010- 0.306	
09	200-400	423.92	0.310	0.263	10	12	0.085- 0.441	
09	400-800	319.01	0.233	0.316	12	9	0.128- 0.504	
16	<100	532.58	0.252	0.192	14	18	0.077- 0.307	
16	100-200	481.43	0.228	0.233	17	17	0.110- 0.356	
16	200-400	677.98	0.321	0.425	31	23	0.281- 0.569	
16	400-800	423.05	0.200	0.151	11	15	0.046- 0.256	
21	<100	409.11	0.208	0.089	7	16	0.009- 0.169	-
21	100-200	374.68	0.191	0.177	14	15	0.070- 0.284	
21	200-400	630.11	0.321	0.506	40	25	0.366- 0.646	+
21	400-800	549.87	0.280	0.228	18	22	0.110- 0.346	
24	<100	1381.97	0.215	0.218	19	19	0.104- 0.332	
24	100-200	1157.35	0.180	0.276	24	16	0.153- 0.399	
24	200-400	1654.62	0.257	0.276	24	22	0.153- 0.399	
24	400-800	1410.87	0.219	0.218	19	19	0.104- 0.332	
24	>800	830.82	0.129	0.011	1	11	-0.018- 0.040	-
26	<100	326.50	0.254	0.080	9	28	0.016- 0.144	-
26	100-200	284.28	0.221	0.107	12	25	0.034- 0.180	-
26	200-400	389.85	0.303	0.473	53	34	0.355- 0.591	+
26	400-800	285.07	0.222	0.339	38	25	0.227- 0.451	+
28	<100	735.01	0.271	0.252	27	29	0.147- 0.357	
28	100-200	636.10	0.235	0.299	32	25	0.189- 0.409	
28	200-400	803.95	0.297	0.280	30	32	0.172- 0.388	
28	400-800	535.72	0.198	0.168	18	21	0.078- 0.258	
30	<100	168.60	0.271	0.150	12	22	0.050- 0.250	-
30	100-200	138.28	0.222	0.213	17	18	0.099- 0.327	
30	200-400	204.26	0.328	0.563	45	26	0.425- 0.701	+
30	400-800	111.01	0.178	0.075	6	14	0.002- 0.148	-

Table A-3. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
31	<100	815.93	0.214	0.221	17	16	0.099- 0.343	
31	100-200	623.00	0.163	0.221	17	13	0.099- 0.343	
31	200-400	803.37	0.211	0.351	27	16	0.211- 0.491	
31	400-800	772.65	0.203	0.208	16	16	0.089- 0.327	
31	>800	798.23	0.209	0.000	0	16	0.000- 0.000	-
Late Summer								
01	<100	253.18	0.204	0.039	2	10	-0.029- 0.107	-
01	100-200	237.13	0.191	0.157	8	10	0.030- 0.284	
01	200-400	410.00	0.331	0.353	18	17	0.186- 0.520	
01	400-800	338.55	0.273	0.451	23	14	0.277- 0.625	+
08	<100	232.86	0.293	0.132	5	11	-0.009- 0.273	
08	100-200	181.40	0.228	0.395	15	9	0.191- 0.599	
08	200-400	253.58	0.319	0.368	14	12	0.166- 0.570	
08	400-800	127.56	0.160	0.105	4	6	-0.023- 0.233	
09	<100	155.27	0.220	0.235	8	7	0.048- 0.422	
09	100-200	149.95	0.213	0.176	6	7	0.008- 0.344	
09	200-400	214.07	0.303	0.324	11	10	0.117- 0.531	
09	400-800	186.26	0.264	0.265	9	9	0.070- 0.460	
16	<100	174.98	0.246	0.098	5	13	-0.009- 0.205	-
16	100-200	167.42	0.235	0.176	9	12	0.039- 0.313	
16	200-400	239.54	0.336	0.451	23	17	0.272- 0.630	
16	400-800	130.36	0.183	0.275	14	9	0.114- 0.436	
Early Fall								
01	<100	393.71	0.278	0.259	22	24	0.140- 0.378	
01	100-200	349.67	0.247	0.341	29	21	0.213- 0.469	
01	200-400	442.74	0.313	0.318	27	27	0.192- 0.444	
01	400-800	230.14	0.162	0.082	7	14	0.008- 0.156	
04	<100	441.92	0.226	0.164	10	14	0.042- 0.286	
04	100-200	357.45	0.182	0.230	14	11	0.091- 0.369	
04	200-400	492.15	0.251	0.377	23	15	0.217- 0.537	
04	400-800	481.56	0.246	0.230	14	15	0.091- 0.369	
04	>800	186.32	0.095	0.000	0	6	0.000- 0.000	-
06	<100	497.58	0.213	0.189	21	24	0.096- 0.282	
06	100-200	457.31	0.196	0.261	29	22	0.157- 0.365	
06	200-400	737.03	0.316	0.396	44	35	0.280- 0.512	
06	400-800	643.61	0.276	0.153	17	31	0.068- 0.238	-
08	<100	289.58	0.258	0.061	6	26	0.001- 0.121	-
08	100-200	227.46	0.203	0.232	23	20	0.126- 0.338	
08	200-400	320.75	0.286	0.525	52	28	0.400- 0.650	+
08	400-800	282.56	0.252	0.182	18	25	0.085- 0.279	

Table A-3. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
09	<100	565.96	0.284	0.180	16	25	0.078- 0.282	
09	100-200	485.84	0.244	0.225	20	22	0.115- 0.335	
09	200-400	629.94	0.316	0.382	34	28	0.254- 0.510	
09	400-800	312.52	0.157	0.213	19	14	0.105- 0.321	
16	<100	257.75	0.233	0.115	12	24	0.037- 0.193	-
16	100-200	236.36	0.214	0.096	10	22	0.024- 0.168	-
16	200-400	363.40	0.329	0.394	41	34	0.274- 0.514	
16	400-800	248.52	0.225	0.394	41	23	0.274- 0.514	+
20	<100	355.06	0.280	0.209	14	19	0.085- 0.333	
20	100-200	306.00	0.241	0.313	21	16	0.172- 0.454	
20	200-400	414.55	0.327	0.388	26	22	0.239- 0.537	
20	400-800	191.86	0.151	0.090	6	10	0.003- 0.177	
21	<100	430.57	0.293	0.105	12	33	0.033- 0.177	-
21	100-200	373.42	0.254	0.193	22	29	0.101- 0.285	
21	200-400	470.65	0.320	0.482	55	36	0.365- 0.599	+
21	400-800	196.18	0.133	0.219	25	15	0.122- 0.316	
22	<100	575.50	0.167	0.110	8	12	0.016- 0.204	
22	100-200	566.59	0.164	0.123	9	12	0.024- 0.222	
22	200-400	1019.38	0.295	0.151	11	22	0.043- 0.259	-
22	400-800	1026.49	0.297	0.438	32	22	0.288- 0.588	
22	>800	267.92	0.078	0.178	13	6	0.063- 0.293	
23	<100	159.18	0.257	0.177	23	33	0.093- 0.261	
23	100-200	140.36	0.226	0.269	35	29	0.172- 0.366	
23	200-400	202.75	0.327	0.354	46	43	0.249- 0.459	
23	400-800	117.70	0.190	0.200	26	25	0.112- 0.288	
24	<100	824.32	0.175	0.111	10	16	0.026- 0.196	
24	100-200	768.42	0.163	0.233	21	15	0.118- 0.348	
24	200-400	1281.67	0.272	0.222	20	24	0.109- 0.335	
24	400-800	1469.28	0.311	0.378	34	28	0.246- 0.510	
24	>800	373.44	0.079	0.056	5	7	-0.006- 0.118	
01	<100	62.29	0.216	0.132	5	8	-0.005- 0.269	
01	100-200	54.93	0.190	0.211	8	7	0.046- 0.376	
01	200-400	86.05	0.298	0.237	9	11	0.065- 0.409	
01	400-800	85.57	0.296	0.421	16	11	0.221- 0.621	
08	<100	35.71	0.157	0.147	5	5	-0.005- 0.299	
08	100-200	44.07	0.194	0.294	10	7	0.099- 0.489	
08	200-400	90.90	0.400	0.382	13	14	0.174- 0.590	
08	400-800	56.34	0.248	0.176	6	8	0.013- 0.339	
09	<100	711.14	0.278	0.117	13	31	0.041- 0.193	-
09	100-200	603.55	0.236	0.153	17	26	0.068- 0.238	
09	200-400	792.44	0.310	0.333	37	34	0.221- 0.445	
09	400-800	449.02	0.176	0.396	44	20	0.280- 0.512	+

Table A-3. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
Late Fall								
21	<100	627.15	0.268	0.021	2	25	-0.016- 0.058	-
21	100-200	553.62	0.237	0.160	15	22	0.066- 0.254	
21	200-400	749.56	0.320	0.489	46	30	0.360- 0.618	+
21	400-800	410.16	0.175	0.330	31	16	0.209- 0.451	+
23	<100	189.85	0.243	0.048	6	31	0.000- 0.096	-
23	100-200	168.79	0.216	0.175	22	27	0.091- 0.259	
23	200-400	270.09	0.346	0.595	75	44	0.486- 0.704	+
23	400-800	151.12	0.194	0.183	23	24	0.097- 0.269	
24	<100	31.82	0.135	0.017	1	8	-0.025- 0.059	-
24	100-200	36.44	0.155	0.067	4	9	-0.014- 0.148	-
24	200-400	79.11	0.336	0.367	22	20	0.212- 0.522	
24	400-800	87.73	0.373	0.550	33	22	0.390- 0.710	+
Annual								
01	<100	706.61	0.270	0.117	49	113	0.078- 0.156	-
01	100-200	610.44	0.233	0.230	96	97	0.179- 0.281	
01	200-400	831.01	0.317	0.376	157	133	0.317- 0.435	
01	400-800	473.59	0.181	0.278	116	76	0.223- 0.333	+
06	<100	610.50	0.200	0.172	58	67	0.119- 0.225	
06	100-200	561.09	0.184	0.240	81	62	0.180- 0.300	
06	200-400	978.01	0.321	0.365	123	108	0.297- 0.433	
06	400-800	831.42	0.273	0.223	75	92	0.165- 0.281	
06	>800	69.98	0.023	0.000	0	8	0.000- 0.000	-
08	<100	478.56	0.239	0.102	36	84	0.061- 0.143	-
08	100-200	398.23	0.199	0.238	84	70	0.180- 0.296	
08	200-400	596.20	0.297	0.445	157	105	0.377- 0.513	+
08	400-800	488.37	0.243	0.207	73	86	0.151- 0.263	
08	>800	43.85	0.022	0.008	3	8	-0.004- 0.020	-
09	<100	810.24	0.264	0.174	79	120	0.130- 0.218	-
09	100-200	703.07	0.229	0.201	91	104	0.154- 0.248	
09	200-400	967.72	0.315	0.351	159	143	0.295- 0.407	
09	400-800	591.05	0.192	0.274	124	87	0.222- 0.326	+
16	<100	515.62	0.244	0.112	38	83	0.068- 0.156	-
16	100-200	465.83	0.221	0.183	62	75	0.129- 0.237	
16	200-400	702.60	0.333	0.183	62	113	0.129- 0.237	-
16	400-800	400.69	0.190	0.277	94	64	0.214- 0.340	+
16	>800	27.81	0.013	0.006	2	4	-0.005- 0.017	
21	<100	2405.40	0.190	0.082	36	83	0.048- 0.116	-
21	100-200	2132.49	0.168	0.197	86	73	0.148- 0.246	
21	200-400	3275.72	0.259	0.483	211	113	0.421- 0.545	+
21	400-800	2968.19	0.235	0.229	100	103	0.177- 0.281	

Table A-3. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
21	>800	1874.44	0.148	0.009	4	65	-0.003- 0.021	-
23	<100	387.24	0.292	0.136	45	97	0.087- 0.185	-
23	100-200	338.08	0.255	0.202	67	84	0.145- 0.259	
23	200-400	422.74	0.319	0.471	156	106	0.400- 0.542	+
23	400-800	175.97	0.133	0.190	63	44	0.134- 0.246	+
24	<100	2751.42	0.196	0.095	37	76	0.057- 0.133	-
24	100-200	2388.81	0.170	0.182	71	66	0.132- 0.232	
24	200-400	3617.91	0.257	0.262	102	100	0.205- 0.319	
24	400-800	3532.35	0.251	0.426	166	98	0.362- 0.490	+
24	>800	1771.62	0.126	0.036	14	49	0.012- 0.060	-

+ Road zone used more than available.
- Road zone used less than available.

Table A-4. Black bear use of primary road zones on Camp Lejeune, North Carolina 1990-1991.

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
Winter								
24	<100	27.23	0.076	0.000	0	2	0.000- 0.000	-
24	100-200	28.44	0.079	0.000	0	2	-0.000- 0.000	-
24	200-400	62.69	0.174	0.095	2	4	-0.070- 0.260	
24	400-800	127.05	0.353	0.143	3	7	-0.054- 0.340	-
24	>800	114.93	0.319	0.762	16	7	0.523- 1.001	+
Spring								
01	<100	120.15	0.053	0.006	1	9	-0.010- 0.022	-
01	100-200	119.98	0.053	0.055	9	9	0.009- 0.101	
01	200-400	236.05	0.103	0.202	33	17	0.121- 0.283	+
01	400-800	537.37	0.235	0.331	54	38	0.236- 0.426	+
01	>800	1270.46	0.556	0.405	66	91	0.306- 0.504	-
06	<100	54.19	0.030	0.000	0	3	0.000- 0.000	
06	100-200	54.59	0.030	0.030	3	3	-0.014- 0.074	
06	200-400	106.06	0.059	0.030	3	6	-0.014- 0.074	
06	400-800	250.87	0.140	0.139	14	14	0.050- 0.228	
06	>800	1332.46	0.741	0.802	81	75	0.700- 0.904	
08	<100	166.09	0.117	0.030	3	12	-0.014- 0.074	-
08	100-200	153.75	0.109	0.030	3	11	-0.014- 0.074	-
08	200-400	251.29	0.178	0.020	2	18	-0.016- 0.056	-
08	400-800	407.40	0.288	0.404	40	29	0.277- 0.531	
08	>800	436.91	0.309	0.515	51	31	0.386- 0.644	+
09	<100	162.76	0.057	0.028	5	10	-0.004- 0.060	
09	100-200	161.31	0.057	0.061	11	10	0.015- 0.107	
09	200-400	316.39	0.111	0.179	32	20	0.105- 0.253	
09	400-800	624.87	0.220	0.296	53	39	0.208- 0.384	
09	>800	1577.93	0.555	0.436	78	99	0.341- 0.531	-
16	200-400	31.23	0.040	0.252	26	4	0.150- 0.354	+
16	400-800	138.91	0.180	0.126	13	19	0.048- 0.204	
16	>800	603.35	0.780	0.621	64	80	0.506- 0.736	-
21	<100	667.91	0.075	0.076	11	11	0.019- 0.133	
21	100-200	623.99	0.070	0.028	4	10	-0.007- 0.063	
21	200-400	1160.15	0.130	0.152	22	19	0.075- 0.229	
21	400-800	1984.73	0.223	0.262	38	32	0.168- 0.356	
21	>800	4456.40	0.501	0.483	70	73	0.376- 0.590	
23	<100	123.11	0.107	0.026	2	8	-0.021- 0.073	-
23	100-200	121.12	0.105	0.079	6	8	-0.001- 0.159	
23	200-400	225.09	0.195	0.105	8	15	0.014- 0.196	
23	400-800	363.72	0.315	0.474	36	24	0.326- 0.622	+
23	>800	321.59	0.279	0.316	24	21	0.179- 0.453	

Table A-4. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
24	<100	580.65	0.066	0.000	0	9	0.000- 0.000	-
24	100-200	564.83	0.064	0.008	1	8	-0.012- 0.028	-
24	200-400	1067.33	0.122	0.077	10	16	0.017- 0.137	
24	400-800	1911.20	0.218	0.223	29	28	0.129- 0.317	
24	>800	4658.34	0.530	0.692	90	69	0.588- 0.796	+
Early Summer								
01	<100	175.55	0.070	0.000	0	6	0.000- 0.000	-
01	100-200	175.54	0.070	0.038	3	6	-0.017- 0.093	
01	200-400	350.32	0.139	0.089	7	11	0.006- 0.172	
01	400-800	666.05	0.264	0.418	33	21	0.275- 0.561	+
01	>800	1152.89	0.457	0.456	36	36	0.312- 0.600	
06	<100	119.55	0.049	0.091	10	5	0.020- 0.162	
06	100-200	118.19	0.048	0.073	8	5	0.009- 0.137	
06	200-400	221.42	0.091	0.118	13	10	0.039- 0.197	
06	400-800	411.90	0.169	0.291	32	19	0.179- 0.403	+
06	>800	1567.06	0.643	0.427	47	71	0.306- 0.548	-
08	<100	199.17	0.127	0.025	2	10	-0.020- 0.070	-
08	100-200	182.52	0.116	0.025	2	9	-0.020- 0.070	-
08	200-400	290.58	0.185	0.188	15	15	0.075- 0.301	
08	400-800	431.48	0.275	0.375	30	22	0.236- 0.514	
08	>800	463.32	0.296	0.388	31	24	0.248- 0.528	
09	200-400	193.61	0.162	0.189	7	6	0.035- 0.343	
09	400-800	415.95	0.348	0.595	22	13	0.402- 0.788	+
09	>800	585.76	0.490	0.216	8	18	0.054- 0.378	-
16	<100	132.74	0.063	0.027	2	5	-0.022- 0.076	
16	100-200	133.77	0.063	0.014	1	5	-0.021- 0.049	-
16	200-400	278.48	0.132	0.096	7	10	0.007- 0.185	
16	400-800	522.58	0.247	0.178	13	18	0.063- 0.293	
16	>800	1047.45	0.495	0.685	50	36	0.545- 0.825	+
21	400-800	267.09	0.144	0.109	7	9	0.022- 0.196	
21	>800	1583.82	0.856	0.875	56	55	0.782- 0.968	
24	<100	423.95	0.066	0.034	3	6	-0.016- 0.084	
24	100-200	412.75	0.064	0.023	2	6	-0.018- 0.064	
24	200-400	805.16	0.125	0.195	17	11	0.086- 0.304	
24	400-800	1473.09	0.229	0.368	32	20	0.235- 0.501	+
24	>800	3320.68	0.516	0.379	33	45	0.245- 0.513	-
26	<100	78.25	0.061	0.000	0	7	0.000- 0.000	-
26	100-200	78.07	0.061	0.000	0	7	0.000- 0.000	-
26	200-400	157.04	0.122	0.080	9	14	0.014- 0.146	
26	400-800	307.85	0.239	0.295	33	27	0.184- 0.406	
26	>800	664.52	0.517	0.625	70	58	0.507- 0.743	

Table A-4. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
28	<100	181.32	0.067	0.000	0	7	0.000- 0.000	-
28	100-200	177.20	0.065	0.028	3	7	-0.013- 0.069	
28	200-400	343.26	0.127	0.093	10	14	0.021- 0.165	
28	400-800	646.53	0.239	0.308	33	26	0.193- 0.423	
28	>800	1362.46	0.503	0.570	61	54	0.447- 0.693	
30	<100	39.26	0.063	0.100	8	5	0.014- 0.186	
30	100-200	38.07	0.061	0.038	3	5	-0.017- 0.093	
30	200-400	80.54	0.129	0.350	28	10	0.213- 0.487	+
30	400-800	201.48	0.324	0.350	28	26	0.213- 0.487	
30	>800	262.81	0.422	0.163	13	34	0.057- 0.269	-
31	<100	294.97	0.077	0.091	7	6	0.007- 0.175	
31	100-200	285.17	0.075	0.091	7	6	0.007- 0.175	
31	200-400	522.59	0.137	0.260	20	11	0.131- 0.389	
31	400-800	824.71	0.216	0.416	32	17	0.271- 0.561	+
31	>800	1885.72	0.495	0.143	11	38	0.040- 0.246	-
Late Summer								
01	100-200	123.26	0.099	0.039	2	5	-0.029- 0.107	
01	200-400	127.15	0.103	0.039	2	5	-0.029- 0.107	
01	400-800	336.75	0.272	0.412	21	14	0.240- 0.584	
01	>800	651.69	0.526	0.510	26	27	0.335- 0.685	
08	<100	100.44	0.126	0.211	8	5	0.041- 0.381	
08	100-200	89.88	0.113	0.026	1	4	-0.040- 0.092	
08	200-400	136.90	0.172	0.132	5	7	-0.009- 0.273	
08	400-800	214.17	0.269	0.289	11	10	0.100- 0.478	
08	>800	254.02	0.319	0.342	13	12	0.144- 0.540	
09	100-200	123.76	0.175	0.029	1	6	-0.043- 0.101	-
09	200-400	124.62	0.177	0.118	4	6	-0.020- 0.256	
09	400-800	236.22	0.335	0.324	11	11	0.124- 0.524	
09	>800	220.96	0.313	0.529	18	11	0.315- 0.743	+
16	100-200	108.12	0.152	0.020	1	8	-0.029- 0.069	-
16	200-400	106.21	0.149	0.176	9	8	0.043- 0.309	
16	400-800	207.99	0.292	0.216	11	15	0.072- 0.360	
16	>800	289.99	0.407	0.588	30	21	0.416- 0.760	+
Early Fall								
01	<100	87.47	0.062	0.000	0	5	0.000- 0.000	-
01	100-200	87.31	0.062	0.000	0	5	0.000- 0.000	-
01	200-400	172.95	0.122	0.000	0	10	0.000- 0.000	-
01	400-800	336.41	0.238	0.165	14	20	0.061- 0.269	
01	>800	732.15	0.517	0.835	71	44	0.731- 0.939	+
04	<100	153.09	0.078	0.016	1	5	-0.025- 0.057	-

Table A-4. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
04	100-200	145.80	0.074	0.049	3	5	-0.022- 0.120	
04	200-400	271.67	0.139	0.033	2	8	-0.026- 0.092	-
04	400-800	539.44	0.275	0.426	26	17	0.263- 0.589	
04	>800	849.44	0.434	0.475	29	26	0.310- 0.640	
06	100-200	160.10	0.069	0.099	11	8	0.028- 0.170	
06	200-400	178.53	0.076	0.180	20	8	0.089- 0.271	+
06	400-800	393.95	0.169	0.252	28	19	0.149- 0.355	
06	>800	1602.95	0.686	0.468	52	76	0.350- 0.586	-
08	<100	181.85	0.162	0.040	4	16	-0.011- 0.091	-
08	100-200	168.94	0.151	0.010	1	15	-0.016- 0.036	-
08	200-400	264.38	0.236	0.040	4	23	-0.011- 0.091	-
08	400-800	357.57	0.319	0.616	61	32	0.490- 0.742	+
08	>800	147.65	0.132	0.293	29	13	0.175- 0.411	+
09	100-200	200.79	0.101	0.022	2	9	-0.017- 0.061	-
09	200-400	198.11	0.099	0.191	17	9	0.087- 0.295	
09	400-800	403.42	0.202	0.202	18	18	0.096- 0.308	
09	>800	1191.96	0.598	0.584	52	53	0.454- 0.714	
16	<100	86.83	0.079	0.000	0	8	0.000- 0.000	-
16	100-200	86.68	0.078	0.038	4	8	-0.010- 0.086	
16	200-400	168.13	0.152	0.163	17	16	0.070- 0.256	
16	400-800	304.26	0.275	0.135	14	29	0.049- 0.221	-
16	>800	460.13	0.416	0.663	69	43	0.544- 0.782	+
20	<100	116.89	0.092	0.015	1	6	-0.023- 0.053	-
20	100-200	120.09	0.095	0.194	13	6	0.070- 0.318	
20	200-400	221.38	0.175	0.134	9	12	0.027- 0.241	
20	400-800	362.83	0.286	0.328	22	19	0.180- 0.476	
20	>800	446.30	0.352	0.328	22	24	0.180- 0.476	
21	<100	166.70	0.113	0.009	1	13	-0.014- 0.032	-
21	100-200	161.16	0.110	0.044	5	13	-0.005- 0.093	-
21	200-400	290.65	0.198	0.123	14	23	0.044- 0.202	
21	400-800	456.34	0.310	0.482	55	35	0.361- 0.603	+
21	>800	396.01	0.269	0.342	39	31	0.228- 0.456	
22	100-200	415.99	0.120	0.041	3	9	-0.017- 0.099	-
22	200-400	331.31	0.096	0.329	24	7	0.192- 0.466	+
22	400-800	554.73	0.161	0.164	12	12	0.056- 0.272	
22	>800	2153.86	0.623	0.466	34	45	0.320- 0.612	-
23	<100	40.35	0.065	0.077	10	8	0.017- 0.137	
23	100-200	50.24	0.081	0.031	4	11	-0.008- 0.070	-
23	200-400	95.45	0.154	0.131	17	20	0.055- 0.207	
23	400-800	153.90	0.248	0.446	58	32	0.334- 0.558	+
23	>800	280.04	0.452	0.315	41	59	0.210- 0.420	-
24	<100	308.21	0.065	0.000	0	6	0.000- 0.000	-

Table A-4. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
24	100-200	276.35	0.059	0.022	2	5	-0.018- 0.062	
24	200-400	530.90	0.113	0.211	19	10	0.100- 0.322	
24	400-800	925.55	0.196	0.322	29	18	0.195- 0.449	
24	>800	2676.12	0.567	0.444	40	51	0.309- 0.579	
Late Fall								
01	100-200	42.91	0.149	0.000	0	6	0.000- 0.000	
01	200-400	46.57	0.161	0.211	8	6	0.046- 0.376	
01	400-800	118.34	0.410	0.474	18	16	0.272- 0.676	
01	>800	81.01	0.280	0.316	12	11	0.128- 0.504	
08	200-400	44.68	0.208	0.235	8	7	0.061- 0.409	
08	400-800	114.68	0.533	0.412	14	18	0.210- 0.614	
08	>800	55.82	0.259	0.353	12	9	0.157- 0.549	
09	<100	143.17	0.056	0.009	1	6	-0.014- 0.032	-
09	100-200	141.18	0.055	0.000	0	6	0.000- 0.000	-
09	200-400	273.44	0.107	0.099	11	12	0.026- 0.172	
09	400-800	643.97	0.252	0.126	14	28	0.045- 0.207	-
09	>800	1354.37	0.530	0.766	85	59	0.662- 0.870	+
21	<100	204.89	0.088	0.011	1	8	-0.017- 0.039	-
21	100-200	201.14	0.086	0.011	1	8	-0.017- 0.039	-
21	200-400	388.76	0.166	0.021	2	16	-0.017- 0.059	-
21	400-800	705.85	0.302	0.160	15	28	0.063- 0.257	-
21	>800	839.87	0.359	0.798	75	34	0.691- 0.905	+
23	100-200	3.16	0.004	0.040	5	1	-0.004- 0.084	
23	200-400	43.84	0.056	0.087	11	7	0.024- 0.150	
23	400-800	211.37	0.271	0.183	23	34	0.097- 0.269	-
23	>800	521.47	0.669	0.690	87	84	0.587- 0.793	
24	200-400	9.64	0.041	0.117	7	2	0.013- 0.221	
24	400-800	69.38	0.295	0.267	16	18	0.125- 0.409	
24	>800	156.06	0.664	0.617	37	40	0.460- 0.774	
Annual								
01	<100	123.89	0.047	0.005	2	20	-0.004- 0.014	-
01	100-200	135.56	0.052	0.031	13	22	0.009- 0.053	
01	200-400	301.16	0.115	0.120	50	48	0.079- 0.161	
01	400-800	619.56	0.236	0.330	138	99	0.271- 0.389	+
01	>800	1441.48	0.550	0.514	215	230	0.451- 0.577	
06	<100	117.65	0.039	0.027	9	13	0.004- 0.050	
06	100-200	117.68	0.039	0.065	22	13	0.030- 0.100	
06	200-400	254.29	0.083	0.107	36	28	0.064- 0.150	
06	400-800	552.00	0.181	0.231	78	61	0.172- 0.290	
06	>800	2009.42	0.659	0.570	192	222	0.501- 0.639	-

Table A-4. (continued)

Bear ID	Road Zone	Total Ha	Ha %	Observed %	Observed	Expected	95% CI	
08	<100	243.34	0.121	0.057	20	43	0.025- 0.089	-
08	100-200	227.23	0.113	0.025	9	40	0.004- 0.046	-
08	200-400	374.98	0.187	0.102	36	66	0.061- 0.143	-
08	400-800	576.93	0.288	0.431	152	102	0.363- 0.499	+
08	>800	583.12	0.291	0.385	136	103	0.318- 0.452	+
09	<100	160.24	0.052	0.018	8	24	0.002- 0.034	-
09	100-200	158.66	0.052	0.031	14	24	0.010- 0.052	
09	200-400	336.14	0.109	0.159	72	49	0.115- 0.203	+
09	400-800	741.84	0.241	0.258	117	109	0.205- 0.311	
09	>800	1675.22	0.545	0.534	242	247	0.474- 0.594	
16	<100	129.31	0.061	0.012	4	21	-0.003- 0.027	-
16	100-200	131.53	0.062	0.027	9	21	0.004- 0.050	-
16	200-400	266.16	0.126	0.168	57	43	0.116- 0.220	
16	400-800	532.99	0.252	0.147	50	85	0.097- 0.197	-
16	>800	1052.55	0.498	0.646	219	169	0.579- 0.713	+
21	<100	909.08	0.072	0.041	18	31	0.017- 0.065	-
21	100-200	841.42	0.066	0.039	17	29	0.015- 0.063	-
21	200-400	1548.88	0.122	0.098	43	53	0.061- 0.135	
21	400-800	2715.90	0.215	0.263	115	94	0.209- 0.317	
21	>800	6640.99	0.525	0.558	244	229	0.497- 0.619	
23	<100	94.91	0.072	0.036	12	24	0.010- 0.062	-
23	100-200	97.13	0.073	0.048	16	24	0.018- 0.078	
23	200-400	179.20	0.135	0.109	36	45	0.065- 0.153	
23	400-800	326.14	0.246	0.347	115	81	0.280- 0.414	+
23	>800	626.64	0.473	0.459	152	157	0.388- 0.530	
24	<100	1051.54	0.075	0.008	3	29	-0.004- 0.020	-
24	100-200	975.55	0.069	0.013	5	27	-0.002- 0.028	-
24	200-400	1839.71	0.131	0.141	55	51	0.096- 0.186	
24	400-800	3236.12	0.230	0.274	107	90	0.216- 0.332	
24	>800	6959.11	0.495	0.564	220	193	0.499- 0.629	+

+ Road zone used more than available.
- Road zone used less than available.

Table A-5. Mean road crossing frequencies and travel rates (kmph) of radio-collared black bears on Camp Lejeune, North Carolina, 1990-1991.

Time Interval	Secondary Roads			Primary Roads			Kmph		
	Mean[a]	SE	*n*	Mean[a]	SE	*n*	Mean[a]	SE	*n*
Spring									
0000-0200	0.172	0.070	9	0.049	0.024	9	0.167	0.052	9
0200-0400	0.133	0.070	9	0.047	0.024	9	0.161	0.052	9
0400-0600	0.156	0.070	9	0.027	0.024	9	0.178	0.052	9
0600-0800	0.104	0.070	9	0.023	0.024	9	0.207	0.052	9
0800-1000	0.076	0.070	9	0.027	0.024	9	0.140	0.052	8
1000-1200	0.039	0.070	9	0.013	0.024	9	0.106	0.055	8
1200-1400	0.059	0.074	8	0.003	0.025	8	0.093	0.055	8
1400-1600	0.024	0.074	8	0.003	0.025	8	0.072	0.055	8
1600-1800	0.039	0.074	8	0.021	0.025	8	0.100	0.055	8
1800-2000	0.089	0.074	8	0.003	0.025	8	0.166	0.055	8
2000-2200	0.216	0.070	9	0.038	0.024	9	0.248	0.052	9
2200-0000	0.251	0.070	9	0.073	0.024	9	0.209	0.052	9
Early Summer									
0000-0200	0.375	0.063	11	0.078	0.022	11	0.266	0.047	11
0200-0400	0.267	0.063	11	0.035	0.022	11	0.163	0.047	11
0400-0600	0.280	0.063	11	0.050	0.022	11	0.215	0.047	11
0600-0800	0.218	0.063	11	0.041	0.022	11	0.244	0.047	11
0800-1000	0.169	0.063	11	0.032	0.022	11	0.254	0.047	11
1000-1200	0.078	0.063	11	0.012	0.022	11	0.137	0.047	11
1200-1400	0.057	0.063	11	0.000	0.022	11	0.092	0.047	11
1400-1600	0.057	0.063	11	0.000	0.022	11	0.115	0.047	11
1600-1800	0.163	0.063	11	0.000	0.022	11	0.153	0.047	11
1800-2000	0.117	0.063	11	0.000	0.022	11	0.299	0.050	10
2000-2200	0.451	0.063	11	0.094	0.022	11	0.466	0.047	11
2200-0000	0.413	0.063	11	0.205	0.022	11	0.361	0.047	11

Table A-5. (continued)

Time Interval	Secondary Roads			Primary Roads			Kmph		
	Mean[a]	SE	*n*	Mean[a]	SE	*n*	Mean[a]	SE	*n*
Late Summer									
0000-0200	0.333	0.103	4	0.040	0.035	4	0.316	0.078	4
0200-0400	0.127	0.103	4	0.067	0.035	4	0.199	0.078	4
0400-0600	0.033	0.103	4	0.005	0.035	4	0.145	0.078	4
0600-0800	0.147	0.103	4	0.046	0.035	4	0.232	0.078	4
0800-1000	0.110	0.103	4	0.005	0.035	4	0.181	0.078	4
1000-1200	0.037	0.103	4	0.005	0.035	4	0.075	0.089	3
1200-1400	-0.006	0.118	3	0.001	0.040	3	0.059	0.109	2
1400-1600	-0.034	0.144	2	-0.001	0.049	2	0.071	0.109	2
1600-1800	0.327	0.118	3	0.001	0.040	3	0.204	0.109	2
1800-2000	0.127	0.103	3	0.005	0.035	4	0.451	0.089	3
0000-2200	0.516	0.103	4	0.109	0.035	4	0.326	0.078	4
2200-0000	0.323	0.103	4	0.161	0.035	4	0.406	0.078	4
Early Fall									
0000-0200	0.255	0.063	11	0.032	0.022	11	0.210	0.047	11
0200-0400	0.128	0.063	11	0.067	0.022	11	0.194	0.047	11
0400-0600	0.154	0.063	11	0.018	0.022	11	0.166	0.047	11
0600-0800	0.173	0.063	11	0.020	0.022	11	0.207	0.047	11
0800-1000	0.158	0.063	11	0.060	0.022	11	0.285	0.047	11
1000-1200	0.081	0.063	11	0.013	0.022	11	0.171	0.047	11
1200-1400	0.139	0.066	10	0.000	0.023	10	0.133	0.055	8
1400-1600	0.170	0.074	8	-0.006	0.025	8	0.209	0.055	8
1600-1800	0.300	0.074	8	-0.006	0.025	8	0.200	0.055	8
1800-2000	0.212	0.063	11	0.063	0.022	11	0.316	0.050	10
2000-2200	0.343	0.063	11	0.163	0.022	11	0.342	0.047	11
2200-0000	0.244	0.063	11	0.045	0.022	11	0.253	0.047	11

Table A-5. (continued)

Time Interval	Secondary Roads			Primary Roads			Kmph		
	Mean[a]	SE	*n*	Mean[a]	SE	*n*	Mean[a]	SE	*n*
Late Fall									
0000-0200	0.100	0.079	7	0.022	0.027	7	0.083	0.059	7
0200-0400	0.068	0.079	7	0.013	0.027	7	0.094	0.059	7
0400-0600	0.061	0.079	7	0.024	0.027	7	0.111	0.059	7
0600-0800	0.019	0.079	7	0.013	0.027	7	0.258	0.059	7
0800-1000	0.057	0.079	7	0.001	0.027	7	0.099	0.059	7
1000-1200	0.003	0.079	7	0.001	0.027	7	0.122	0.059	7
1200-1400	0.003	0.079	7	0.001	0.027	7	0.108	0.059	7
1400-1600	0.003	0.079	7	0.001	0.027	7	0.110	0.059	7
1600-1800	0.139	0.079	7	0.037	0.027	7	0.298	0.059	7
1800-2000	0.117	0.079	7	0.037	0.027	7	0.146	0.059	7
2000-2200	0.233	0.079	7	0.048	0.027	7	0.349	0.059	7
2200-0000	0.104	0.079	7	0.023	0.027	7	0.130	0.059	7

[a] Generalized Least Squared Means.

Table A-6. Mean traffic volume of highway 172 on Camp Lejeune, North Carolina, 14 September - 19 December 1990.

Time Interval	Mean	SE	*n*	Range
Weekday Traffic				
0000-0200	18.9	1.3	14	11- 28
0200-0400	15.7	1.4	13	7- 24
0400-0600	56.0	4.4	12	30- 86
0600-0800	193.3	14.0	12	96- 253
0800-1000	208.9	8.2	16	162- 276
1000-1200	215.8	11.4	6	163- 241
1200-1400	203.0	6.9	5	178- 220
1400-1600	264.2	22.7	5	195- 303
1600-1800	309.0	25.2	5	247- 363
1800-2000	155.9	11.4	16	111- 282
2000-2200	103.5	12.7	15	49- 208
2200-0000	55.8	6.0	15	32- 113
Weekend Traffic				
0000-0200	36.3	2.6	6	29- 44
0200-0400	22.2	1.3	6	17- 26
0400-0600	31.5	4.4	6	18- 43
0600-0800	79.2	12.5	6	41- 122
0800-1000	158.0	22.1	6	91- 226
1000-1200	331.0		1	
1200-1400	-			
1400-1600	-			
1600-1800	-			
1800-2000	155.3	3.2	3	149- 159
2000-2200	102.4	8.1	5	89- 134
2200-0000	66.2	11.9	5	44- 108

Table A-7. Mean traffic volume of Lyman Road on Camp Lejeune, North Carolina, 12 September - 29 November 1990.

Time Interval	Mean	SE	*n*	Range
Weekday Traffic				
0000-0200	16.6	1.6	8	10- 23
0200-0400	20.8	3.4	8	15- 44
0400-0600	226.3	20.6	8	127- 303
0600-0800	619.0	87.6	8	343- 1024
0800-1000	288.4	29.6	9	173- 481
1000-1200	257.0		1	
1200-1400	364.0		1	
1400-1600	403.0		1	
1600-1800	442.0		1	
1800-2000	200.4	18.9	7	128- 285
2000-2200	126.7	15.1	9	85- 233
2200-0000	68.0	8.8	8	46- 119
Weekend Traffic				
0000-0200	31.5	2.7	4	24- 37
0200-0400	15.0	1.5	4	12- 19
0400-0600	22.5	4.8	4	15- 35
0600-0800	109.7	21.2	4	67- 157
0800-1000	92.3	13.4	3	71- 117
1000-1200	-			
1200-1400	-			
1400-1600	-			
1600-1800	-			
1800-2000	80.0	14.0	2	66- 94
2000-2200	61.0	11.0	3	43- 81
2200-0000	43.7	6.0	3	32- 52

Table A-8. Mean traffic volume of Marines Road on Camp Lejeune, North Carolina, 10 September - 19 December 1990.

Time Interval	Mean	SE	*n*	Range
Weekday Traffic				
0000-0200	33.9	3.2	17	11- 57
0200-0400	37.0	6.0	16	12- 93
0400-0600	156.6	13.4	14	43- 211
0600-0800	530.2	44.8	13	203- 741
0800-1000	312.8	13.0	19	197- 407
1000-1200	344.0	28.8	7	216- 438
1200-1400	337.8	37.0	6	208- 483
1400-1600	443.8	46.8	6	270- 581
1600-1800	523.2	74.5	6	224- 750
1800-2000	274.9	27.5	18	57- 536
2000-2200	172.2	18.0	17	80- 347
2200-0000	92.3	7.9	18	41- 176
Weekend Traffic				
0000-0200	64.2	15.5	6	17- 130
0200-0400	43.8	8.8	6	19- 81
0400-0600	40.2	12.1	6	10- 96
0600-0800	121.8	45.7	5	44- 300
0800-1000	128.8	31.2	5	55- 238
1000-1200	287.0		1	
1200-1400	-			
1400-1600	-			
1600-1800	-			
1800-2000	179.3	33.7	4	119- 276
2000-2200	149.2	16.7	5	113- 201
2200-0000	82.7	4.7	4	73- 93

Table A-9. Mean traffic volume of Sneads Ferry Road on Camp Lejeune, North Carolina, 24 September - 29 November 1990.

Time Interval	Mean	SE	*n*	Range
Weekday Traffic				
0000-0200	116.0	12.8	6	86- 161
0200-0400	102.0	21.6	6	63- 201
0400-0600	578.8	108.7	6	104- 784
0600-0800	1607.5	63.2	6	1363- 1790
0800-1000	1014.2	21.3	6	958- 1104
1000-1200	-			
1200-1400	-			
1400-1600	-			
1600-1800	-			
1800-2000	715.7	69.3	4	526- 846
2000-2200	520.3	37.2	6	397- 665
2200-0000	253.8	28.5	6	123- 321
Weekend Traffic				
0000-0200	157.5	29.5	2	128- 187
0200-0400	128.0	7.0	2	121- 135
0400-0600	82.0	14.0	2	68- 96
0600-0800	214.0	65.0	2	149- 279
0800-1000	227.0	47.0	2	180- 274
1000-1200	-			
1200-1400	-			
1400-1600	-			
1600-1800	-			
1800-2000	505.0		1	
2000-2200	440.0	13.0	2	427- 453
2200-0000	294.5	21.5	2	273- 316

VITA

David Michael Brandenburg, son of Bill and Ann Brandenburg, was born in Pineville, North Carolina on 23 March 1962. He graduated from Morristown West High School in Morristown, Tennessee in 1980. He attended Walters State Community College in 1981, 1985, and 1986. He transferred to the University of Tennessee, Knoxville in 1986 and graduated with a Bachelor of Science Degree in Wildlife and Fisheries Science and minors in Zoology and Ornamental Horticulture and Landscape Design in 1989. He entered the graduate program in the Department of Forestry, Wildlife, and Fisheries at the University of Tennessee, Knoxville, in May 1990 and received a Master of Science degree in Wildlife and Fisheries in August 1996.