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Resource selection by black bears on U.S. Marine Corps Base Camp Lejeune

David J. Telesco
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by David J. Telesco entitled "Resource selection by black bears on U.S. Marine Corps Base Camp Lejeune." 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.

Frank T. van Manen, Major Professor

We have read this thesis and recommend its acceptance:

David A. Buehler, Sammy L. King, Shih-Lung Shaw

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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Dr. Shih-Lung Shaw

Accepted for the Council:

Vice Provost and Dean of Graduate Studies

RESOURCE SELECTION BY BLACK BEARS ON U.S. MARINE CORPS BASE CAMP LEJEUNE

A Thesis

Presented for the

Master of Science Degree

The University of Tennessee

David J. Telesco

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ABSTRACT

In 1992, U.S. Marine Corps Base Camp Lejeune (Camp Lejeune) purchased the 16,691-ha Greater Sandy Run Acquisition (GSRA) in Onslow County, North Carolina. Development and use of the GSRA for live-weapons firing and other military training has steadily increased since the land purchase. Resource managers at Camp Lejeune are interested in assessing the combined effects of military activities, forest management, roads, and the importance of natural vegetation types on black bear habitat use. My objectives were to determine black bear home range and habitat use in relation to those factors, and then synthesize spatial use patterns into a geographic information system-based habitat model. Between 2000–2001, field personnel captured 26 bears and collected 2,119 locations on 20 radio-collared bears (10 M:10 F). Based on the 95% probability fixed kernel method, the mean annual home range was 37.2 km^2 for males ($n = 11$) and 27.8 km^2 for females ($n = 12$). I used 1,934 telemetry locations collected from 17 bears (7 M: 10 F) to assess habitat use with the multinomial logit form of discrete choice analysis. I compared the resource attributes of selected habitats (telemetry locations) with those available (random locations) within a spatially and temporally defined circle (i.e., "choice set"). I investigated habitat use at a daily movements scale (7-km^2 choice sets) and at a more local scale (1-km^2 choice sets). The analysis was based on 5 primary habitat variables (land-cover type, forest management, burn history, paved road density, and land-cover diversity) and 5 interaction terms (year, season, sex, age, and firing range activity). I used Akaike's information criterion to select the best model and used the parameter estimates to create a map of bear habitat utility values for the study area. The resource selection models performed well at both analysis scales based on model testing with independent data. Both models were robust to the effects of telemetry error. Resource selection varied depending on the spatial analysis scale. Although the importance of variables was relatively consistent for both models, parameters were more significant in the 7-km^2 model. Bears selected areas with greater diversity of land-cover types only in the 7-km^2 model. Land-cover was the most influential variable in both habitat models. Bottomland hardwoods exerted the greatest positive influence on bear habitat selection, followed closely by pocosin. Current levels of firing range activity did not have a measurable effect on black bear habitat selection, however, bears seemed to avoid the open land-cover type associated with the firing ranges. The density of paved roads and areas burned within 5 years had a strong negative influence on black bear habitat use at both spatial scales. I was unable to analyze the effects of forest management on black bear habitat selection because most forest stands available to bears were in the same age class. Conservation and management of pocosin and bottomland hardwoods is crucial to maintain the black bear population on the GSRA. Infrastructure development, increases in traffic volumes, and development in surrounding areas are likely to affect bear habitat use in the future; careful land-use planning and consideration of these factors will be critical for bear management on the GSRA. Although current levels of firing range activity did not influence black bear habitat use, substantial increases in the number of firing ranges and subsequent firing activities would require further examination to determine the effects on bear habitat use.

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CHAPTER I

INTRODUCTION

Historically, wetland habitats were the dominant vegetation type throughout the southeastern Coastal Plain. However, paludal wetlands (e.g., rain or ground water-fed marshes) have declined substantially throughout the region, and <50% of remaining wetlands are now considered intact, functioning ecosystems (Christensen 2000). Wetland habitats in the region often are highly fragmented and are interspersed primarily with industrial forests and agriculture (Monschein 1981). Since the 1940s, for example, >67% of the estimated 1.4 million ha of shrub bog (pocosin) wetlands have been at least partially developed (Wilson 1962, Richardson et al. 1981, Richardson and Gibbons 1993). Recent developments along coastal areas threaten to further fragment wetland habitats.

In the southeastern Coastal Plain, wetland habitats have been crucial in maintaining viable black bear populations (Monschein 1981, Pelton 1982, Hellgren et al. 1991, Hellgren and Vaughn 1994, Wooding et al. 1994). Despite the loss and fragmentation of these forested wetland types in the southeastern United States, occupied bear habitat has increased in some areas. In eastern North Carolina, for example, bear range has increased from 667,000 ha in 1971 to 2.2 million ha in 1991 (Jones et al. 1998). That range expansion likely was due to the combined effects of improved black bear management over the last 3 decades, a landscape with relatively low human density, large extents of industrial forests, agricultural crops that provide high-quality black bear foods, and a network of public land reserves (Fig. 1). That remarkable recovery may not have

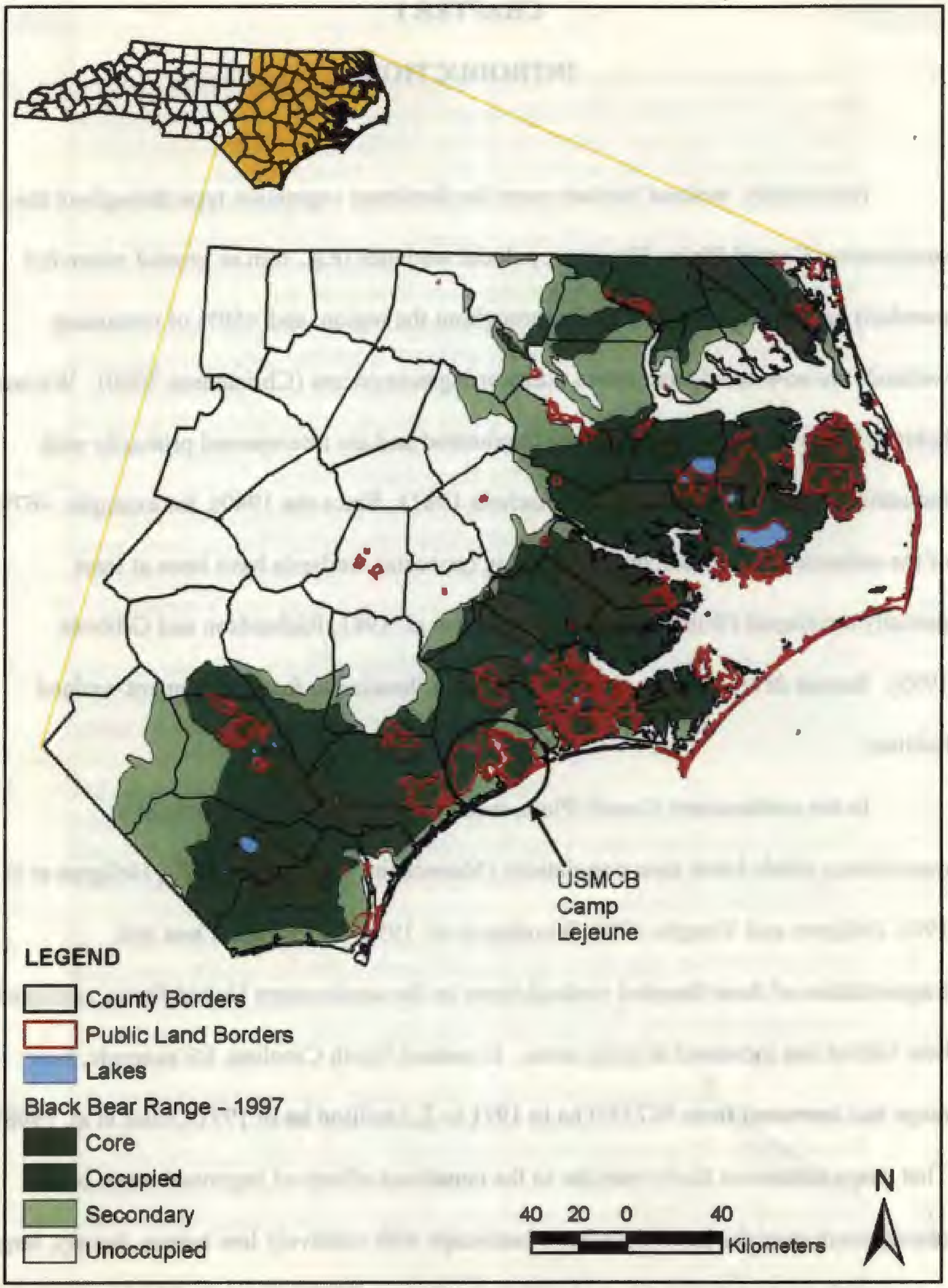

Figure 1. Black bear range and public lands in eastern North Carolina (based on 1997 data from the North Carolina Wildlife Resources Commission, Raleigh, North Carolina, unpublished report).

been possible, however, without the existence of large forested wetlands. Such areas may have served as de facto sanctuaries by protecting bears by virtue of their relative inaccessibility. Once the effect of overexploitation gradually was reversed during the latter half of the twentieth century, the persistence of such core populations may have been crucial for recovery of the species.

Despite the recent range expansion, black bear populations remain vulnerable in coastal areas because of increasing habitat fragmentation due to human development. The response of wildlife populations to fragmentation of habitat may not become evident until a threshold level has been reached. Below this critical threshold, further reduction in suitable habitats may cause populations to decline sharply (Schoen 1990, Andrén 1994, Wiens et al. 1997, Summerville and Crist 2001). In west-central Florida, for example, fragmentation caused by human development near Tampa has isolated black bear habitats, resulting in a population of <20 individuals whose future viability is uncertain (Eason 2001). Such instances indicate the importance of science-based decision tools to guide land-use planning and habitat management.

Justification

U.S. Marine Corps Base Camp Lejeune (hereafter Camp Lejeune) is the largest Marine Corps Base in the world. The 61,600-ha military base provides extensive wildlife habitat in an increasingly developed area of southeastern North Carolina (Fig. 1). Because of its large size and coastal location, Camp Lejeune offers some of the greatest floral and faunal diversity in the southeastern United States (LeBlond 1997). The Camp Lejeune Environmental Management Division (EMD) is responsible for the conservation of natural resources in support of the military mission. EMD game species management closely parallels North Carolina Wildlife Resources Commission seasons and regulations, with some access restrictions because of military activity. The North Carolina Wildlife Resources Commission selected Camp Lejeune to be part of a state-wide bear sanctuary system in 1971 (Collins 1980, Lombardo 1993). The sanctuary status was lifted in 1984, when the EMD resumed bear hunting to mitigate increased nuisance problems; <7 bears were harvested annually on Camp Lejeune between 1984 and 1988 (Lombardo 1993). A high proportion of females in the harvest and lack of data on local black bear ecology prompted the EMD to close the bear hunting season in 1988. Black bear research was initiated for the eastern portion of Camp Lejeune (Mainside), focusing on population ecology and habitat use (Lombardo 1993) and food habits and effects of roads on bear behavior and survival (Brandenburg 1996).

In 1992, Camp Lejeune purchased the 16,691-ha Greater Sandy Run Acquisition (GSRA) from the International Paper Company and several private landowners. That property is adjacent to Mainside Camp Lejeune and contains a black bear population within relatively contiguous tracts of forest and wetland habitats. Development and use of the GSRA has been steadily increasing since the land purchase. By 1999, 2 live-weapons firing ranges were in use with a third range under construction. In addition, the Camp Lejeune Forestry Section continued timber management operations, harvesting over 2.9 million cu ft of timber in 1999 (U.S. Marine Corps Base Camp Lejeune 2000). Camp Lejeune recognizes the potential impacts of development, military activities, and timber management on the black bear population on the GSRA. At the local scale, EMD managers consider monitoring of pocosin habitat as vital for the management of bears on

Camp Lejeune (U.S. Marine Corps Base Camp Lejeune 2000). Regionally, the GSRA could provide an important link among public lands containing core bear range in eastern North Carolina (Fig. 1; Zeveloff 1983).

Although Lombardo (1993) reported that black bears on Mainside Camp Lejeune seemed adaptable to fluctuating levels of military activities, he did observe changes in feeding and movement patterns in response to large training exercises. However, no studies have been able to quantify the effects of military activity on black bear habitat use. Habitat selection may also be influenced by timber harvest and prescribed burning practices commonly used on the GSRA. These management practices may influence black bear habitat use by changing the composition and structure of forests, which may affect the quantity and quality of food and cover (van Manen and Pelton 1997). Black bears may further respond to other management activities and landscape characteristics, such as land-cover diversity, use of wetlands, and response to roads (Lombardo 1993, Brandenburg 1996). The impacts of all these factors are difficult to assess individually because selection for one resource likely is affected by the availability of other resources. Consequently, resource managers at Camp Lejeune are interested in assessing the combined effects of military activities, forest management, roads, and the importance of natural vegetation types on black bear habitat use. Moreover, managers need a spatial decision tool to map black bear habitat use and forecast the effects of habitat alterations on habitat quality. Therefore, the primary objectives of my study were to: 1) determine black bear activities, movements, and home ranges on the GSRA, 2) determine black bear habitat use in relation to forest management, roads, military activities, and wetlands, and 3) synthesize spatial use patterns into a GIS-based habitat model.

CHAPTER II

STUDY AREA

Location

Camp Lejeune is located within Onslow County, North Carolina and is bordered by the city of Jacksonville to the north, the Atlantic Ocean to the southeast, and a mosaic of farmland and commercial timber land to the west and south (Fig. 2). Camp Lejeune consists of three main areas, Mainside and Verona (hereafter, Mainside; 34,800 ha of land and 10,400 ha of open water) and the GSRA (16,691 ha). Because bears did not restrict their movements to the GSRA, I incorporated some adjacent areas into the study area. The study area borders included a 1,500-m area beyond State Route 53 to the north, U.S. Highway 17 to the east, the Onslow County border to the west, and the intersection of U.S. Highway 17 and State Route 50 to the south (Fig. 3). The study area included the entire GSRA, portions of Stone Bay (western Mainside Camp Lejeune), and over 5,000 privately-owned land parcels (P. C. Pike, Onslow County Geographic Information Service, personal communication).

Geology and Soils

The study area is located in the Atlantic Coastal Flatlands Section of the Outer Coastal Plains Mixed Province Ecoregion (Bailey 1995). Stratified marine deposits and deep, medium textured Ultisol and Spodosol soils characterize the region. There is little topographic relief (12–23 m), and 75–80% of the soils are classified as hydric (U.S. Marine Corps Base Camp Lejeune 2000). The majority of the area is on the Wicomico

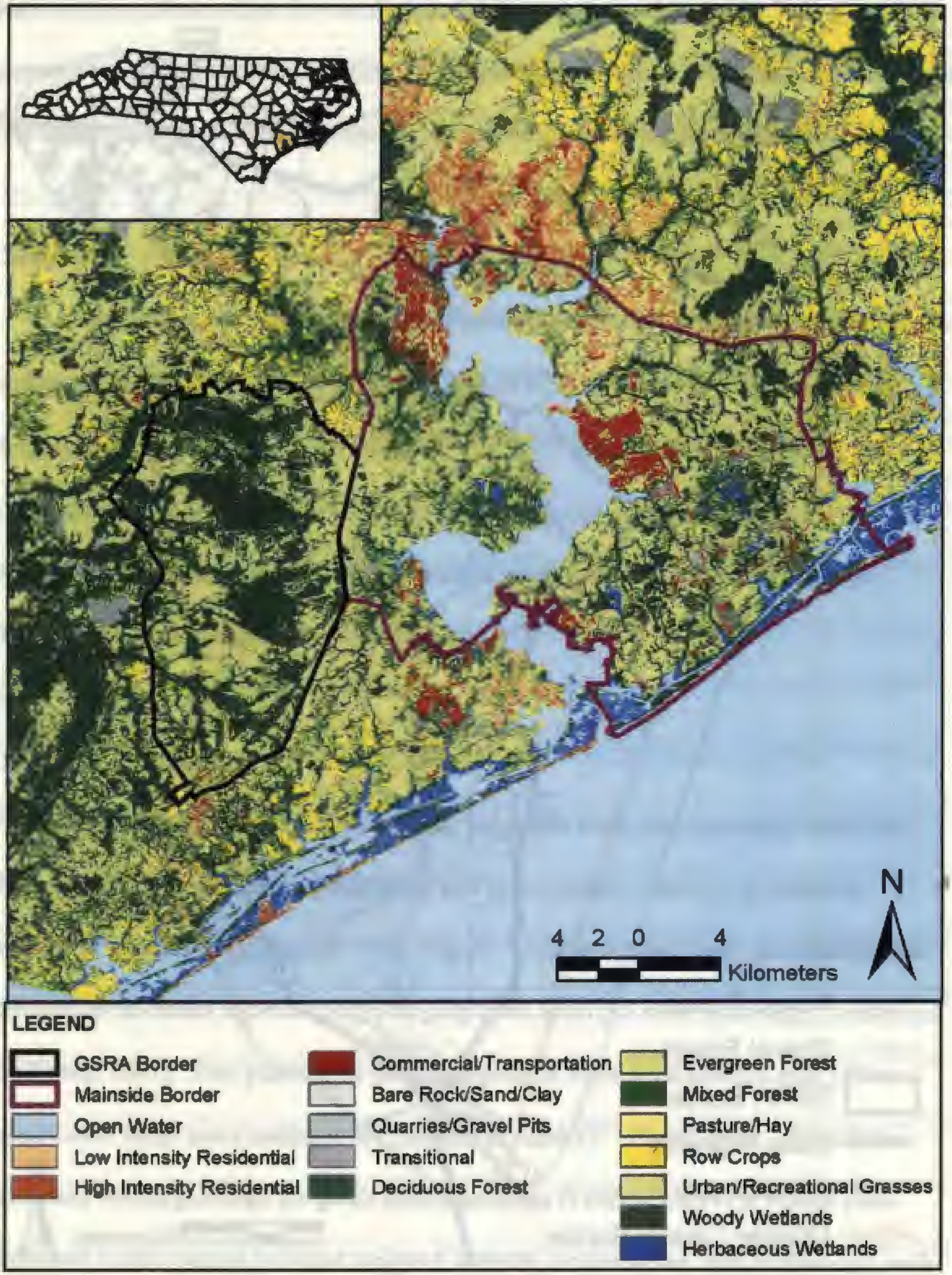

Figure 2. (A) Onslow County, North Carolina. (B) The Greater Sandy Run Acquisition (GSRA) and Mainside sections of U.S. Marine Corps Base Camp Lejeune, North Carolina.

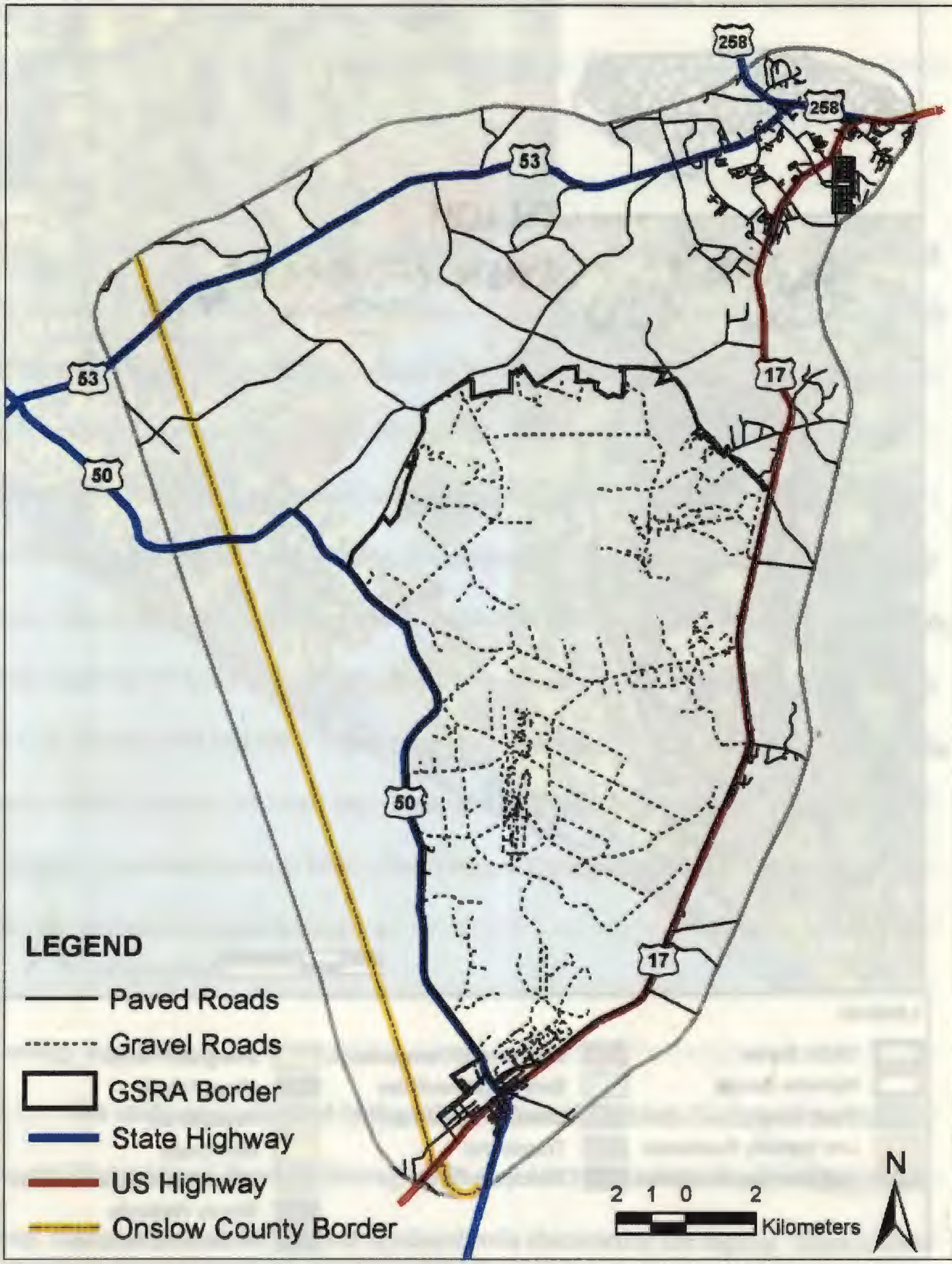

Figure 3. Black bear study area centered on the Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

geomorphic surface with a few small areas in the eastern portion on the Talbot geomorphic surface (Barnhill 1992). The majority of the study area was within the Cape Fear River watershed, with only the easternmost section draining into the New River.

Climate

The climate was temperate, with long humid, summers and short, relatively mild winters. The average annual temperature was 23 C°, with average daily mean temperatures ranging from 13 C° in January to 32 C° in July (National Oceanic and Atmospheric Administration 2001). The average annual precipitation was 1,373 mm, with monthly averages ranging from 78 mm in April to 180 mm in July (National Oceanic and Atmospheric Administration 2001).

Flora

The study area was characterized as temperate rainforest, primarily with pine (*Pinus* spp.) communities in upland areas and gum (*Nyssa sylvatica, N. aquatica*) swamps in lowland areas (Bailey 1995; Fig. 2). Longleaf pine (*Pinus palustrus*) forests occurred as savannas and flatwoods, ranging from hydric to xeric hydrologic conditions (LeBlonde 1997). Pine plantations primarily were in even-aged loblolly pine (*Pinus taeda*), with some areas managed for longleaf or slash (*P. elliottii*) pine. Mixed pine-hardwood forests occurred on mesic drainage slopes (LeBlonde 1997). Mixed pine-hardwood forest species included longleaf, loblolly, or slash pine, and hardwoods, such as maple (*Acer* spp.) and sweetgum (*Liquidambar styraciflua*). Pure hardwood forests were found in upland areas, and consisted of maple, sweetgum, oak (*Quercus* spp.), or a combination of several hardwood species that dominated the canopy as a group (hereafter, miscellaneous hardwoods; Appendix A; U.S. Marine Corps Base Camp Lejeune 2000). Bottomland hardwoods existed as narrow swamps along watercourses. The historical logging of bald cypress (*Taxodium distichum*) allowed gum, sweetgum, maple, and miscellaneous hardwood species to dominate the canopies of bottomland hardwoods in the area. Pocosin wetland community types on the GSRA include low pocosin, high pocosin, and pond pine woodland (Weakley and Schafale 1991). Pocosins are peatlands with a low (1–4 m) but extremely dense evergreen shrub layer occasionally interspersed with pond pine (*Pinus serotina*; LeBlonde 1997). Foresters for Camp Lejeune classified all areas into stand-level management units ranging from 0.09 to 553.4 ha in size (mean = 21.0 ha). Fifty-six forest stand types were classified based on the dominant primary and secondary vegetative canopy species (Appendix B).

Fauna

The variety of habitat types found on the study area supported a diverse array of animal species. Approximately 165 species of birds used the area for breeding or feeding purposes (U.S. Marine Corps Base Camp Lejeune 2000). Avian game species included eastern wild turkey (*Meleagris gallopavo*), northern bobwhite (*Colinus virginianus*), mourning dove (*Zenaida macroura*), and wood duck (*Aix sponsa*). The area supported 48 mammalian species (U.S. Marine Corps Base Camp Lejeune 2000), including game species such as eastern cottontail (*Sylvilagus floridanus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), gray squirrel (*Sciurus carolinensis*), raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), river otter (*Lutra canadensis*), striped skunk (*Mephitis*

mephitis), and white-tailed deer (*Odocoileus virginianus*). Camp Lejeune also listed the occurrence of 21 reptile, 14 amphibian, and 87 fish species on base property (U.S. Marine Corps Base Camp Lejeune 2000).

Land Use

Camp Lejeune originally was established as Marine Barracks, New River in 1941 to provide amphibious and ground training facilities for the First Marine Division (U.S. Marine Corps Base Camp Lejeune 2000). During World War II, the installation was expanded to serve as a training school for Marine replacements and specialists, and renamed in honor of General John A. Lejeune. The U.S. Marine Corps Air Station New River was established in 1951, and the GSRA was acquired in 1992 (U.S. Marine Corps Base Camp Lejeune 2000).

Camp Lejeune provides integrated air, ground, amphibious, and support training facilities for Fleet Marine Forces in support of its mission to "maintain combat-ready units for expeditionary deployment" (U.S. Marine Corps Base Camp Lejeune 2000). During my study, Camp Lejeune supported approximately 36,000 active duty Marines, with many thousands more traveling to the base to participate in short-term training activities each year (U.S. Marine Corps Base Camp Lejeune 2000). Camp Lejeune consisted of 1 Naval Command, the Naval Hospital, and 2 Marine Corps Commands, the Marine Corps Base and the II Marine Expeditionary Force. The Marine Corps Base operated 3 schools; the School of Infantry (for infantry and Marine combat training), the Marine Corps Combat Service Support School (for training in administration and logistical support), and the Field Medical Service School (for medical and ministry training). Training facilities on Mainside included 55 firing ranges, 87 maneuver areas, 17 tactical landing zones, 4 special combat areas, 3 high impact zones, and several amphibious training sites along the New River and Onslow Beach (U.S. Marine Corps Base Camp Lejeune 2000). Training facilities on the GSRA during my study included 3 firing ranges, 2 maneuver areas, and 8 tactical landing zones.

Publicly-owned land and 6 municipalities controlled 42% of Onslow County (U.S. Marine Corps Base Camp Lejeune 2000). Of the remaining 58% regulated by the County, 3% was water, 9% was developed, 17% was in agriculture, and 71% was managed forest. Wetlands comprised 50% of the land controlled by Onslow County. Approximately 43% of county-regulated land was considered suitable for future development (U.S. Marine Corps Base Camp Lejeune 2000).

The 2000 population estimate for Onslow County was 150,355, a 0.3% increase from 1990 (U.S. Census Bureau 2002). In 2000, approximately 113,000 people residing in Onslow County were supported by Camp Lejeune as active duty Marines, dependents, retired military, or civilian employees. Camp Lejeune generates an estimated 2 billion dollars annually for the local economy (U.S. Marine Corps Base Camp Lejeune 2000).

CHAPTER III

METHODS

Military Considerations

Military training areas on the GSRA posed a potential safety hazard to field researchers and limited access to certain areas. I collaborated with the Range Control Office to generate conditional access maps for the GSRA. These maps were derived from the surface area danger fans that corresponded with each live-weapons firing range based on the type of weaponry used and firing positions. The maps delineated areas open to researchers according to firing range activity on the GSRA (Appendix C). Research personnel contacted the Range Control Office to receive daily and monthly schedules for military and firing range activities on the GSRA and to report their daily positions.

Trapping

Black bears were captured on the GSRA during the summers of 2000 and 2001. Bears were captured using modified Aldrich spring-activated snares (Aldrich Animal Trap Company, Clallam Bay, Washington, USA; Johnson and Pelton 1980*a*). I established trapsites within 500 m of roads or trails to increase trapping efficiency. I recorded trap site coordinates using a hand-held global positioning system (GPS) receiver (GPS 12XL; Garmin International, Olathe, Kansas, USA). Snares were anchored to trees or mobile home anchor pins (1.2-m length). Traps were baited with bakery products (Merita Thrift Shop, Jacksonville, North Carolina, USA) and scented with artificial raspberry flavoring (Mother Murphy's Laboratories, Greensboro, North Carolina, USA).

Capture sites were checked daily. Environmental conditions in areas associated with high bear use required preventive methods to minimize heat exposure to a captured bear. On days with an expected high temperature near 32 C°, traps were closed daily from 1100 to 1600 (Brandenburg 1996). The maximum amount of time between when a trap was set and checked was 24 hours.

All bears were handled according to the University of Tennessee Protocol for Use of Live Vertebrates (IACUC #1019). Bears were immobilized with a mixture of ketamine hydrochloride (Ketaset®; Fort Dodge Laboratories, Iowa, USA) and xylazine hydrochloride (Rompum®; Bayer Corporation, Shawnee Mission, Kansas, USA) at a concentration of 200 mg/ml and 100 mg/ml, respectively (Addison and Kolenosky 1979). The immobilization agent was administered intramuscularly with a pole syringe at a dosage of 1 ml/25 kg estimated body weight. After immobilization, the bears' eyes were wet with a topical solution (Akwa Tears, Akorn Incorporated, Abita Springs, Louisiana, USA) and covered with a cloth to prevent desiccation and reduce stress. Body temperature, respiration rate, and pulse were monitored regularly.

All bears were marked with a unique number using metal ear tags and a tattoo on the inside of the upper lip (Nasco, Fort Atkinson, Wisconsin, USA; Johnson and Pelton 1980*b*). A small (<0.5 cm^2) tissue sample from an ear tip was collected from each animal for genetic identification. A premolar tooth was extracted for age estimation using cementum annuli analysis (Matson's Laboratory, Milltown, Montana, USA; Willey 1974). Morphological measurements and body mass were recorded. Bears were given an antibiotic intramuscularly (liquamycin at 1 ml/25 kg body mass; Phizer Laboratories, New York, New York, USA) and topically (triple antibiotic ointment; Burns Veterinary

Supply, Farmers Branch, Texas, USA) if recent injuries were observed. Females known to have cubs were given 1 ml of oxytocin (Burns Veterinary Supply) intramuscularly to reduce any lactation complications caused by the immobilization agent.

All females and selected males were fitted with radio-collar transmitters equipped with motion and mortality monitors (Telonics Inc., Mesa, Arizona, USA or Advanced Telemetry Systems, Isanti, Minnesota, USA). A strip of untreated leather (0.476 x 5 x 10 cm) was used to secure each radio-collar, similar in design to the cotton spacer described by Hellgren et al. (1988). The leather spacer was designed to rot in 1–2 years, ensuring that radio-collars would drop off the animals near the end of the study period (D. A. Martorello, Washington Department of Natural Resources, personal communication). Upon completion of data collection, an antagonist to xylazine hydrochloride was administered intravenously at 1 ml/25 kg estimated body weight 60 minutes after the initial immobilization (yohimbine hydrochloride at 5 mg/ml; Lloyd Laboratories, Shenandoah, Iowa, USA). All bears were released at the site of capture.

Radiotelemetry

Radio-collared bears were located by ground triangulation with hand-held, 5-element, yagi antennas (Wildlife Materials, Carbondale, Illinois, USA). The telemetry schedule for spring, summer, and fall was based on 4-hour periods. Field personnel attempted to locate bears once per day during 1 of the 6 daily periods. Tracking times varied weekly to ensure that bears were located up to 6 times a week during various activity periods. That sampling scheme allowed intensive monitoring of habitat use, while reducing the bias associated with animals choosing different habitats for certain activities (Cooper and Millspaugh 2001). That telemetry schedule also permitted collection of an equivalent number of locations during active and inactive firing range times. Bears were located only monthly during the winter denning season (January–mid-March). A concerted effort was made to collect location information with equal intensity for all bears.

Bear locations were estimated using azimuths collected from 3 telemetry stations based on the loudest signal method (Springer 1979). All telemetry station coordinates were recorded and mapped with a GPS receiver. Azimuths were considered for analysis when angles were between 30° and 120° apart and were collected within a 30-minute period. Telemetry data were prepared with SAS® statistical software (SAS Institute, Cary, North Carolina, USA) before locations were estimated by triangulation with program Telem88© (Coleman and Jones 1986).

Bear activity data were recorded in conjunction with the collection of all azimuths. Mercury tip switches in radio-collars changed signal frequency when the transmitter changed position, indicating the bear was changing its head position (Horner and Powell 1990). An active location was recorded when signal volume was variable or signal frequency changed for at least 1 azimuth. An inactive location was recorded when signal volume was steady and signal frequency remained constant for all 3 azimuths.

Telemetry error was measured by having each observer locate 30 test transmitters placed at locations unknown to that observer. The distance between a triangulated test location and the test transmitter's actual location was measured for an estimate of telemetry error (Schmutz and White 1990, Clark et al. 1993).

Home Range Estimation

Biologically independent locations provide unbiased estimates of home range and habitat use even under circumstances where locations may not be statistically independent (Lindzey and Meslow 1977, Lair 1987, Arthur et al. 1996). For biological independence, the time elapsed between locations must be long enough to allow animals to move throughout their home ranges. Time periods used to maintain biological independence for black bear locations vary from 4 hours (Clark et al. 1993) to 24 hours (Hellgren et al. 1991), depending on home range sizes and movement rates. For black bears on Mainside Camp Lejeune, the average annual female home range size was 20.4 km^2 (Lombardo 1993) and overall average hourly movement rate was 204 m (Brandenburg 1996). Based on these findings, I maintained a minimum of 11 hours between sequential locations to ensure biological independence among observations.

I estimated seasonal and annual home ranges based on the fixed kernel method (Worton 1987) with the Animal Movement extension (Hooge and Eichenlaub 2000) to ArcView® GIS (Environmental Systems Research Institute [ESRI], Redlands, California, USA). Because precision of the fixed kernel estimator depends on a relatively large number of locations (Worton 1989), seasonal home ranges were not estimated for bears with <15 locations per season. Annual home ranges were estimated for bears with >37 total locations collected in >1 season. Seasons were determined based on food habits of bears on the GSRA (D. J. Telesco, University of Tennessee, unpublished data) and in eastern North Carolina (Landers et al. 1979, Maddrey 1995, Brandenburg 1996, Allen 1999). Seasonal home ranges were estimated for spring (16 March–15 June), summer (16 June–15 September), and fall (16 September–15 December).

Habitat Variables

When selecting variables for a multivariate habitat analysis, the goal is to explain as much variation in resource selection with the least number of variables (Burnham and Anderson 1992). I chose habitat variables based on important bear management issues on the GSRA (i.e., forest management, military activity, development) and additional variables based on an extensive literature review. I considered the following variables: land-cover type, forest management, burn history, firing range activity, land-cover diversity, and paved road density (Table 1). Because of the large number of private tracts beyond the GSRA boundaries, it was not feasible to seek information from all private landowners for specific habitat information. However, 39% of all telemetry locations on private lands were on property owned by Great Eastern Timber Company (GETCO). I obtained habitat information for the 4,519 ha of land owned by GETCO in the study area.

Land-cover types were delineated based on initial classifications from the National Land Cover Data (NLCD; Vogelmann et al. 2001), with modifications based on the Camp Lejeune Forestry Section and GETCO data (Table 2). The NLCD was based on 1992 Landsat Thematic Mapper imagery depicting 23 land cover classes at a 30-m pixel resolution (Vogelmann et al. 2001). I pooled the 23 land-cover classes into 9 different cover types.

I identified 4 non-forest land-cover types: agriculture, developed, firing range, and open area. Agricultural cover represented crops, such as corn, which provide abundant and predictable foods for bears in eastern North Carolina (Brandenburg 1996, Jones 1996, Allen 1999). Areas were classified as developed if the predominant land use was associated with human activities (Vogelmann et al. 2001; Table 2). The 3 active

Table 1. Variables used in the analysis of black bear habitat use, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina.

Categorical variables	**Class**
Land-cover type[a]	Pine forest Pine-hardwood mixed forest Hardwood forest Bottomland hardwood forest Pocosin Agriculture Developed Firing ranges Open areas
Forest management[b]	Regeneration (<10 years old) Growth (10–40 years old) Mature (>40 years old) Unmanaged
Burn history	Burned ≤1 year Burned 2–5 years Burned >5 years
Firing range noise zones	I (<60 decibels) II (60–70 decibels) III (>70 decibels)
Continuous variables	**Measurement scales**
Paved road density	km/km^2
Land-cover diversity[c]	Proportion

[a] Land cover classifications derived from National Land Cover Data (Vogelmann et al. 2001).
[b] Regeneration = seedling/ sapling trees <13 cm dbh; growth = poletimber trees 13–30 cm dbh; mature = sawtimber trees >30 cm dbh.
[c] Land-cover diversity was based on Simpson's diversity index, as modified by McGarigal et al. (2002).

Table 2. Land-cover types with corresponding National Land Cover Data (NLCD) classes, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina.

Class	Description	NLCD class description
Pine	Primary species: loblolly, longleaf, or slash pine	Evergreen forest
Pine-hardwood mix	Primary species: loblolly, longleaf, or slash pine or maple, poplar, red oak, sweetgum, or miscellaneous hardwoods	Mixed forest
Hardwood	Primary species: beech, maple, poplar, red oak, sweetgum, white oak, or miscellaneous hardwoods	Deciduous forest
Bottomland hardwood	Primary species: bald cypress, blackgum, sweetgum, maple, or miscellaneous hardwoods	Woody wetlands[a]
Pocosin	Primary species: pocosin, pond pine, maple, or miscellaneous hardwoods	Woody wetlands[a]
Agriculture	Food plots	Row crops
Developed	Old home sites, parking areas, runways, cemeteries, barracks, highway bypass,	Low and high intensity residential, commercial/ industrial/transportation
Firing ranges	Firing ranges	Urban/recreational grasses
Open areas	Wildlife openings, powerline cuts, tactical landing zones, heliponds, wetland mitigation bank, borrow pits	Pasture/hay, urban/recreational grass, open water, bare rock /sand/clay, quarries/strip mine /gravel pit transitional, emergent herbaceous wetland

[a] Woody wetlands were considered bottomland hardwoods unless soil types were indicative of pocosin.

live-weapons firing ranges on the GSRA were maintained as low-vegetation fields surrounded by clearings and identified as firing range cover. Open areas included all remaining non-forest land-cover types (Table 2).

Forest land-cover types were categorized based on vegetative species designations of the NLCD, Camp Lejeune Forestry Section, or GETCO data. Pine cover was identified at sites where the dominant canopy species was loblolly, longleaf, or slash pine. Mixed pine-hardwood had a combination of pine and hardwood species as the dominant primary and secondary canopy species. I used vegetative species and soil classifications established by LeBlonde (1997; Table 2) to distinguish among the hardwood, bottomland hardwood, and pocosin land-cover types. Areas were classified as pocosin when the primary species was pond pine or hardwood and when the majority of the soils were Croatan muck, Murville fine sand, Panteg mucky loam, or Torhunta fine sandy loam (Weakley and Schafale 1991, LeBlonde 1997). Sites were classified as bottomland hardwoods when the canopy was dominated by a hardwood species and the majority of the soil types were Muckalee loam or Dorovan muck (LeBlonde 1997). The hardwood cover type primarily occurred on upland soil types and was dominated by a hardwood species.

As forests grow and develop, changes occur in the quantity and quality of food and cover for bears. The forest management variable represented the structure and composition of forests at different growth stages. I classified managed timber stands into regeneration, growth, and mature classes to represent seedling-sapling, poletimber, and sawtimber stand conditions, respectively (Fig. 4; D. B. Marshburn, Camp Lejeune Forestry Section, and T. W. Tabak, Great Eastern Timber Company, personal

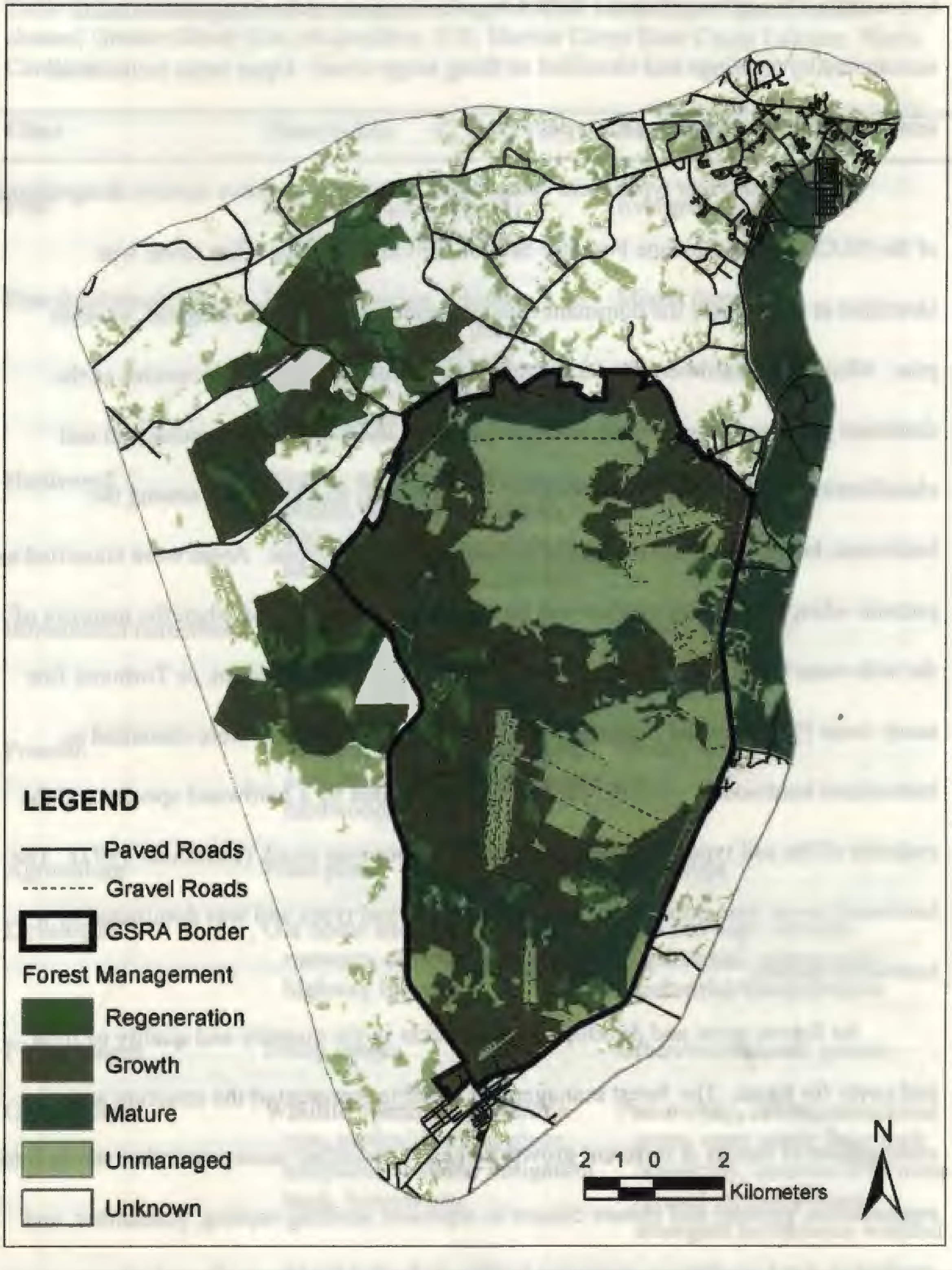

Figure 4. Forest management classes, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

communications). Stands <10 years old that were in regeneration or had seedling or sapling growth (trees <13 cm dbh) were classified as regeneration stands. Growth class stands were 10–40 years old and primarily consisted of poletimber (13–30 cm dbh), and some small sawtimber (25–36 cm dbh). Mature class stands were >40 years old and in sawtimber (≥38 cm dbh). The regeneration, growth, and mature classes closely resemble the stand initiation, stem exclusion, and understory reinitiation stages, respectively, as described by Oliver and Larson (1990). All non-forest cover types and pocosin areas were classified as unmanaged because they were not under timber.

Fire influences production of wildlife food by changing the successional stage of vegetation. I classified burn history to examine the effects of fire on bear habitat use. The Camp Lejeune Forestry Section burns primarily on a 5-year cycle, with shorter cycles for training areas or to meet endangered species requirements (U.S. Marine Corps Base Camp Lejeune 2000). Based on current burning practices on Camp Lejeune and the effects of fire on wildlife food production (Johnson and Landers 1978, Hamilton 1981), I created 3 categories: burned within 1 year, burned within 2–5 years, and burned >5 years ago (Fig. 5). The most recent wildfire and prescribed burn information reported by Camp Lejeune Forestry Section and GETCO was used to map burn history. After consulting with professional foresters in the area, a consensus was reached that privately-owned forests rarely were burned within the study area (R. L. Adkins, North Carolina Division of Forest Resources, D. B. Marshburn, Camp Lejeune Forestry Section, and T. W. Tabak, Great Easter Timber Company, personal communications). Consequently, privately-owned lands were designated as burned >5 years ago.

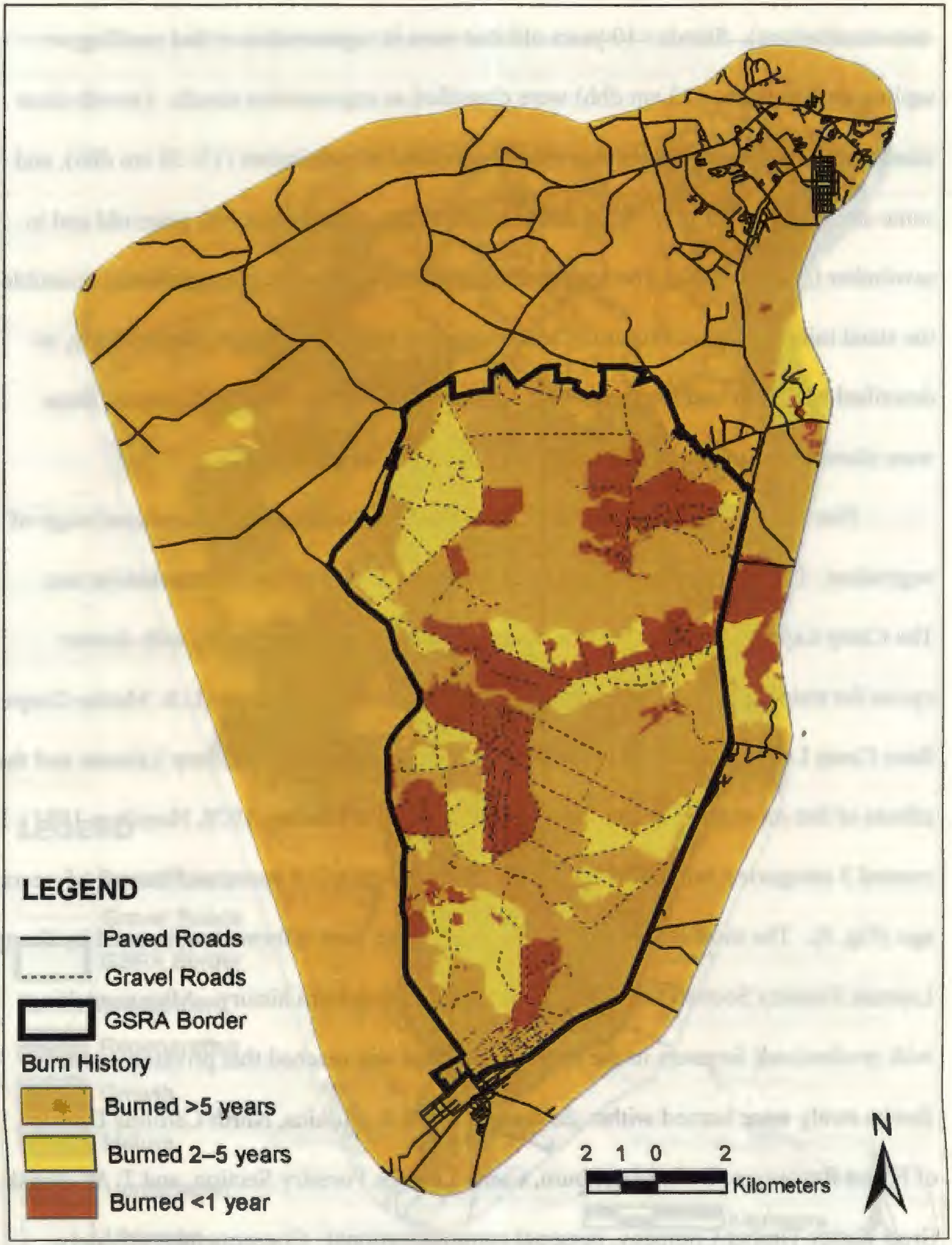

Figure 5. Burn history, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

Military training exercises may influence bear movements and habitat use through temporary displacement. Therefore, I examined whether military activity on the 3 live-weapons firing ranges affected bear habitat selection. Because explosive ordinance is not used on the GSRA, the disturbance to bears was assumed to be noise- related and localized near the firing positions on each firing range. The Onyx Group (2002) developed spatial contours of human auditory disturbance levels around each firing range based on the high-energy, low-frequency impulse noise generated from weapons firing activities. Estimated human disturbance was based on decibel (dB) levels that would 'disturb' a certain percentage of individuals in a typical population. Using those noise contours, 3 primary noise zones were established for each range based on daily decibel averages during the month with the greatest firing activity (Fig. 6). Daily average noise was measured from the time Camp Lejeune Range Control cleared a range for firing to when military personnel on the range called Range Control to close activity. Military activities on an active firing range included vehicle and troop maneuvers as well as actual weapons firing. Noise zone 3 experienced the most noise (>70 dB) which would cause the greatest human disturbance (>39%), followed by zone 2, with 15–39% disturbance, and zone 1, with <15% disturbance (Onyx Group 2002). For each bear location, I determined which noise zone it was located and whether that firing range was active. I also determined the proximity of the bear to active firing positions.

Bear habitat use can be influenced by the diversity of natural cover types (Lindzey and Meslow 1977, Clark et al. 1993, van Manen and Pelton 1997). I determined land-cover diversity with program FragStats 3.3 using a modification of

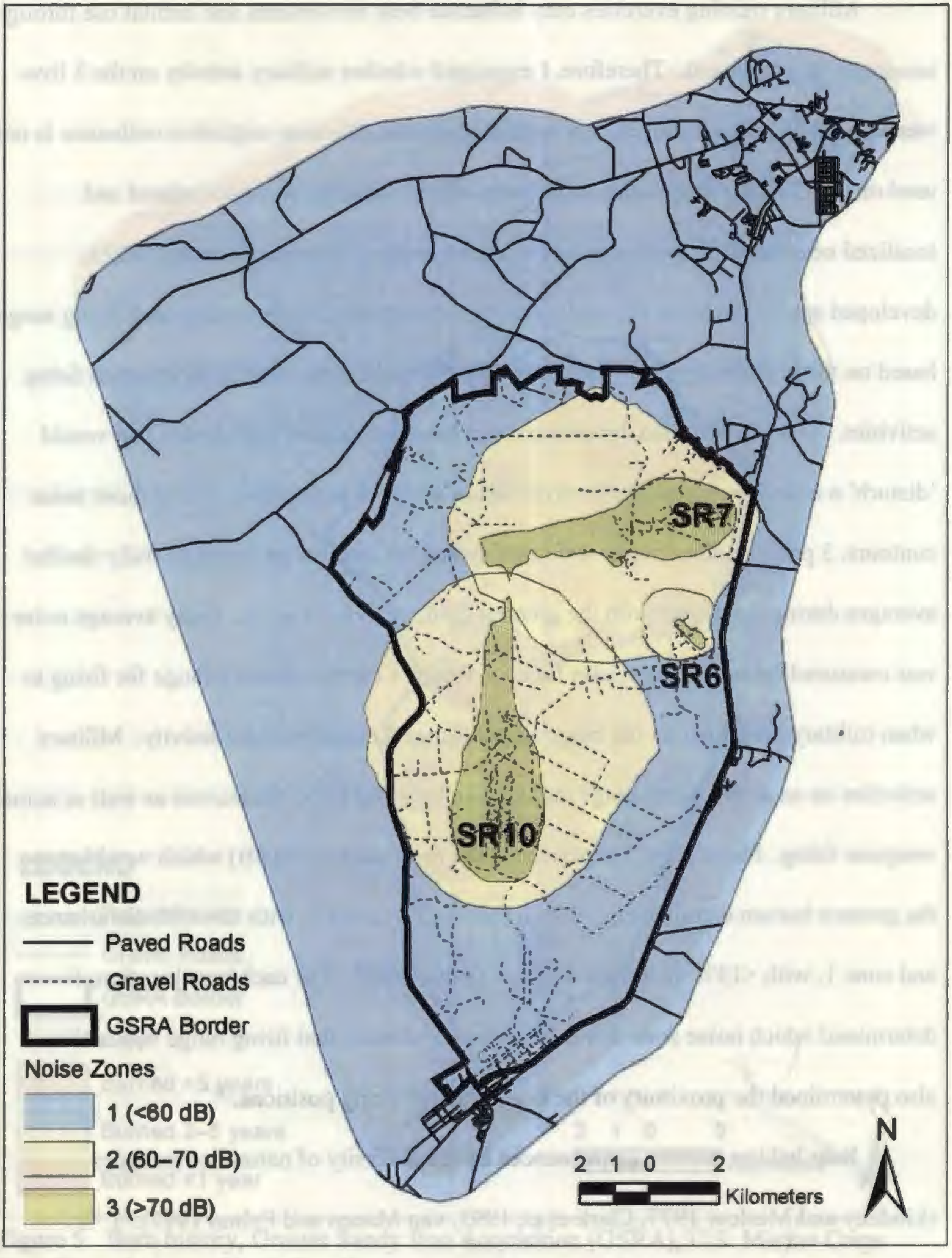

Figure 6. Noise zones for the SR6, SR7, and SR10 firing ranges, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

Simpson's diversity index (McGarigal et al. 2002):

$$1 - \sum_{i=1}^{m} P_i^2 ,$$

where P is the proportion of land cover types occupied by type i and m is the number of cover types. I only calculated land-cover diversity for the 5 land-cover types that were compatible with bear habitat use; developed, firing range, and open areas were combined and included as a background layer. I calculated diversity with a circular window of 1.0 km^2 (570-m radius) with neighborhood analysis in ArcView® GIS (Fig. 7). The average size of land-cover stands on GSRA was 21.0 ha. Therefore, that window size was large enough to measure land-cover diversity but small enough to reduce the averaging effects of the window analysis.

Roads may influence bear movements and habitat use, although responses vary depending on road type, traffic volume, and landscape context (Carr and Pelton 1984, Brody and Pelton 1989, Beringer et al. 1990, Brandenburg 1996). Secondary roads with low traffic, for example, do not necessarily affect bear habitat use (Carr and Pelton 1984, Weaver et al. 1990, Hellgren et al. 1991, Lombardo 1993, Brandenburg 1996); therefore I only included paved roads to calculate road density. I reclassified the ESRI Streets Database (ESRI, Redlands, California, USA; Volume 4 South: North Carolina) into paved or unimproved road types. I calculated paved road density (km/km^2) based on a neighborhood analysis in ArcView® GIS using a 570-m radius circular window (1.0 km^2 area; Fig. 8). Previous studies suggested that bears avoid 100–260-m areas adjacent to paved roads (Brody and Pelton 1989, Brandenburg 1996, Martorello 1998), therefore I chose a 570-m radius as a realistic distance where roads could influence habitat use.

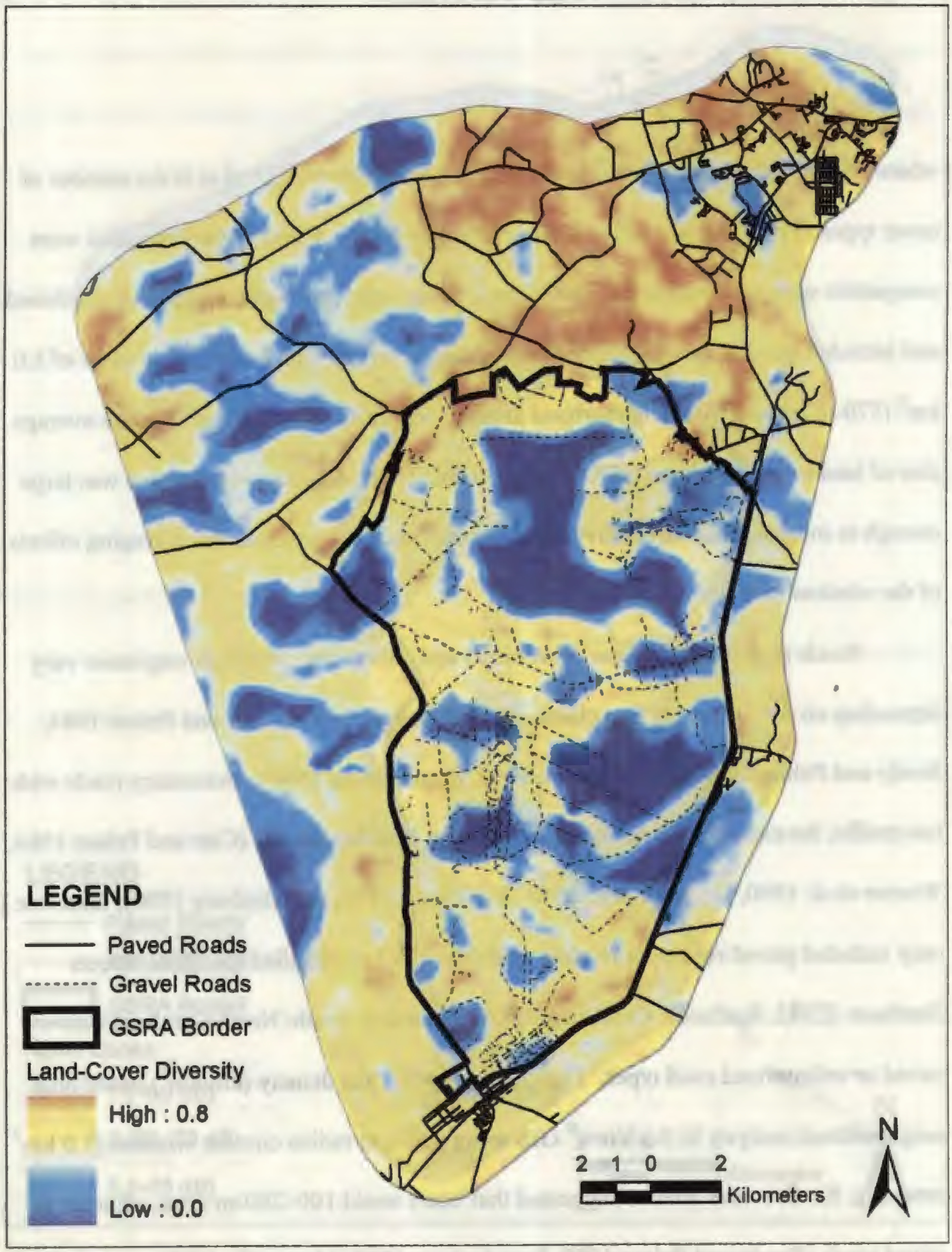

Figure 7. Land-cover diversity, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

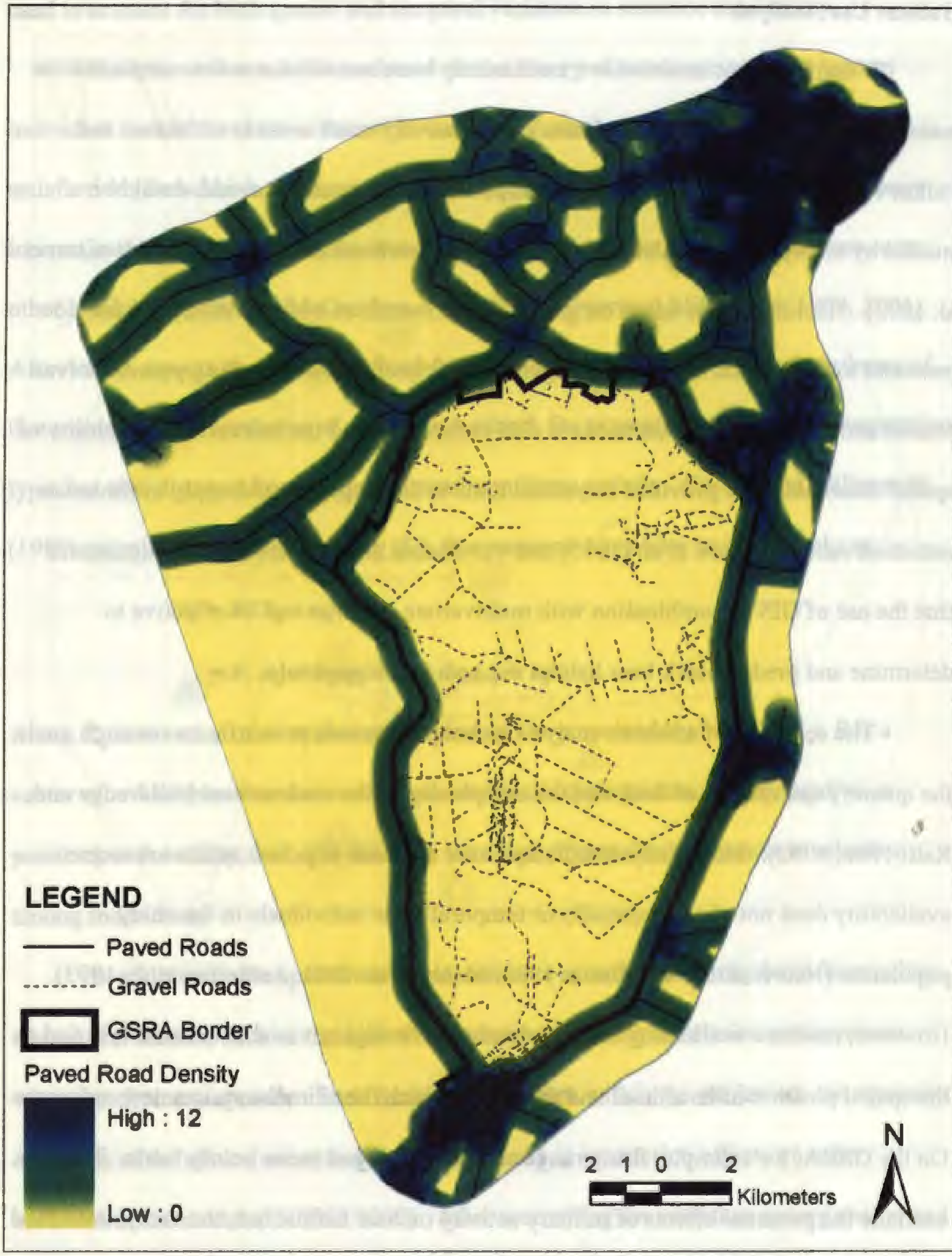

Figure 8. Paved road density (km/km^2), Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

Habitat Use Analysis

Wildlife-habitat models have traditionally been restricted to a few simple habitat measures (e.g., broad vegetation classes) and relatively small areas (van Manen and Pelton 1997). However, habitat relationships are multi-dimensional and should be studied by incorporating the many attributes that contribute to habitat value (Morrison et al. 1992). Habitat models based on geographic information systems (GIS) can provide powerful tools to assist resource managers in variety of decision-making processes (van Manen and Pelton 1997). Advances in GIS technology and the increasing availability of spatial databases have provided important tools to develop, test, and apply multivariate statistical models. Clark et al. (1993) and van Manen and Pelton (1997) demonstrated that the use of GIS in combination with multivariate statistics can be effective to determine and predict black bear habitat use on a landscape scale.

The selection of a habitat analysis technique depends primarily on research goals, the quantity and quality of data, and the complexity of the environment (Alldredge and Ratti 1986, 1992). Most analysis techniques for resource selection assume resource availability does not change spatially or temporally for individuals in the study population (Neu et al. 1974, Johnson 1980, Manly et al. 1993, Aebischer et al. 1993). However, resource availability on a fine scale can be highly variable because it is tied to the spatial position of an animal and the rate at which the animal acquires new resources. On the GSRA, for example, firing range activities changed on an hourly basis. Thus, to examine the potential effects of military activity on bear habitat use, the analysis method would have to account for that short-term temporal variation. The multinomial logit form of discrete choice analysis (Ben-Akiva and Lerman 1985) is one technique that can be used to account for both spatial and temporal variation in resource availability.

Discrete choice models are based on the theory of economic value, where an individual makes the choices that will result in the maximum level of customer satisfaction (Ben-Akiva and Lerman 1985). For resource selection studies, the primary interest is to define attributes of a resource that result in selection of that resource over other available resources (McCracken et al. 1998; Cooper and Millspaugh 1999, 2001). All relevant aspects that can be defined for a resource would be considered attributes of that resource. The attributes of a pocosin wetland, for example, would include vegetation type, but also distance from roads and nearby military activity. Cooper and Millspaugh (1999) calculate the value, or utility (U), that resource i provides to individual j as:

$$U_{ij} = B'X_{ij} + \epsilon_{ij}$$

$$= b_1 x_{1j} + b_2 x_{2j} + \ldots, + b_m x_{mj} + \epsilon_{ij} ,$$

where X_{ij} is a vector of m attributes of resource i as perceived by individual j, B is a vector of m variables that determine each attribute's contribution (either negative or positive) to the utility, and ϵ_{ij} is the error term that adjusts for differences in selection among individuals.

In addition to the spatial attributes, resource selection also may be influenced by non-spatial factors, such as the age of the individual making the choice or the season when the choice was made. Such factors are constant within the choice set, but represent attributes of the choice event and can be examined as interaction effects on other variables in the model (Kuhfeld 2002). After accounting for variation among spatial and choice event attributes, differences may still exist among individuals that are not detectable. However, the error term accounts for those individual differences by transforming the utility function into a utility probability (Manski 1981). Thus, habitat utility can be defined as the probability of individual j choosing resource A from the group of i resources available within a specified spatial and temporal context:

$$P_j(A) = Pr\,(B'X_{Aj} - B'X_{ij} > \epsilon_{ij} - \epsilon_{Aj}\ \forall i),$$

For each resource selection, the error term ($\epsilon_{ij} - \epsilon_{Aj}\ \forall i$) is assumed to be distributed as a logistic random variable; consequently the formula can be treated as a probabilistic, rather than a deterministic, equation (Cooper and Millspaugh 2001). Given that assumption, the probability of resource selection can be examined using maximum likelihood estimates (Ben-Akiva and Lerman 1985). The probability that resource A will be selected instead of any of the other available i resources by individual j can be expressed as:

$$P_j(A) = \frac{\exp(B'X_{Aj})}{\sum_{\forall i} \exp(B'X_{ij})}.$$

There are 2 primary assumptions for the multinomial logit form of discrete choice analysis. Resource attributes are assumed to be uncorrelated, a common assumption for most resource selection analysis techniques (Alldredge and Ratti 1986, 1992). The second assumption is independence of irrelevant alternatives (Luce 1959). Given a choice between resources A and B, for example, the independence of irrelevant alternatives assumption requires that the probability ratio of A being chosen over B remains constant with the addition of a third choice, resource C (McCracken et al. 1998).

I measured habitat use and availability within a defined time and area, which is referred to as a "choice set" (Fig. 9; Cooper and Millspaugh 1999). A choice set considers all habitat patches found within a spatially and temporally defined circle to

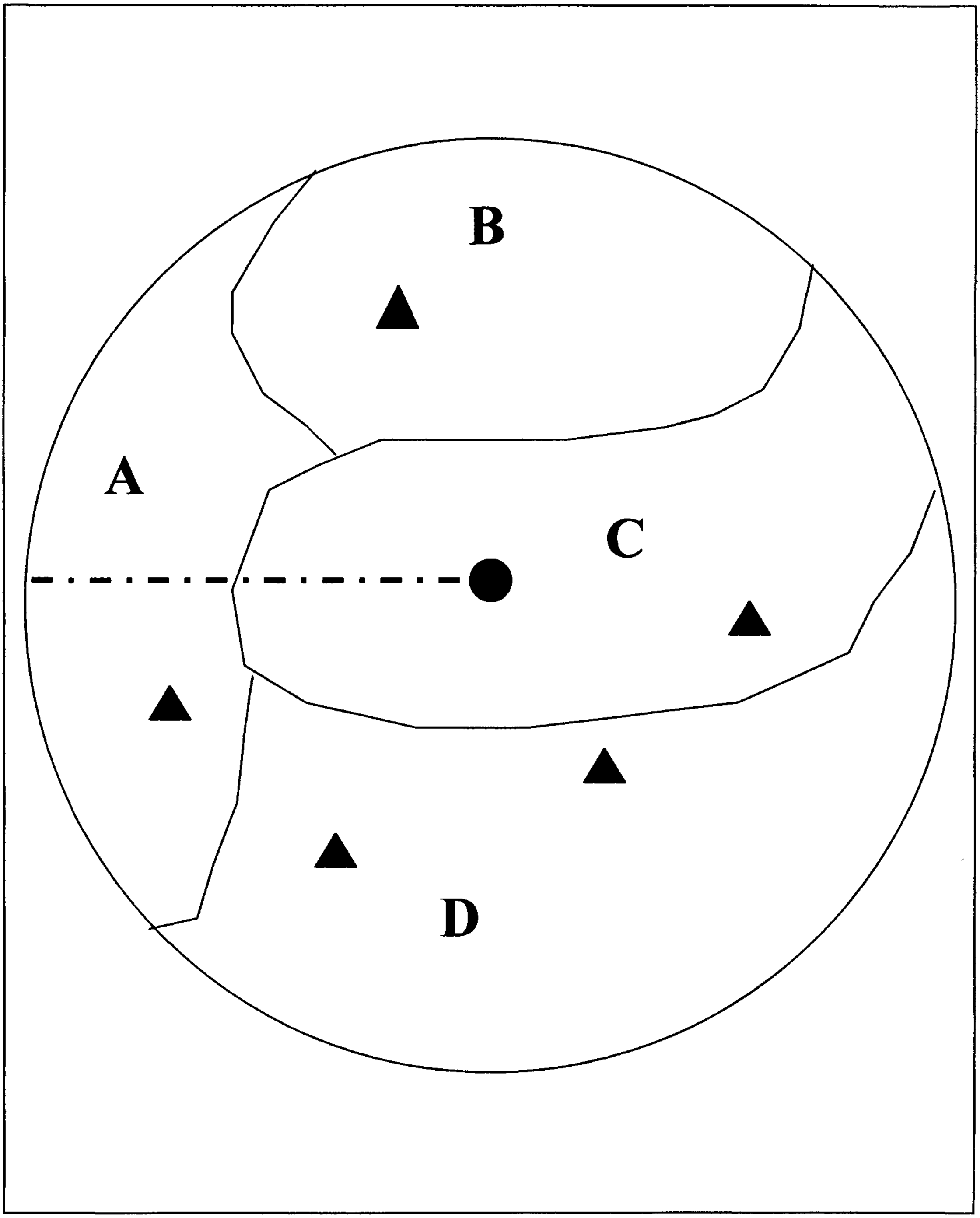

Figure 9. A circular choice set with 4 covertypes (A, B, C, D) is centered on a telemetry location (solid circle) with radius length (dotted line) based on the distance an individual can move during a specific time period. Random locations (solid triangles) are paired with each telemetry location within each choice set to measure available resources.

delineate available habitat. Assuming each animal can evaluate all attributes of the resource, the circle is centered on an animal's location with a radius equal to the distance the animal could travel from that location during a set amount of time (Cooper and Millspaugh 1999, Arthur et al. 1996).

Because resource selection can occur at different scales, I investigated habitat use at 2 spatial scales representing the concepts of Johnson's (1980) orders of selection. I examined habitat use within the home range based on a circular choice set with a 1,500-m radius (approximately 7 km^2). The radius of this choice set represented the mean daily movement distance of bears on the GSRA. Because the power to detect resource selection is influenced by the accuracy of telemetry locations (White and Garrott 1986), I set the choice set for selection at the local scale to a 500-m radius circle (approximately 1 km^2). Given the error distances of telemetry locations on my study (median = 236 m), 1 km^2 seemed reasonable to ensure that locations were actually within the choice set. Each choice set is considered a separate selection event, so sample size is equal to the total number of locations. I only included bears with >18 total locations in the habitat use analysis. Moreover, given the objectives of my study, I only included bears in the analysis if >75% of their locations were on the GSRA.

Similar to other habitat analysis techniques, discrete choice analysis compares the resource attributes of selected sites (telemetry locations) with those of unused sites (random locations; Alldredge and Ratti 1986, 1992). With most resource selection analysis techniques, the assumption that random locations represent unused habitats may not be valid (Clark et al. 1993). That assumption is less likely to be violated with discrete choice analysis because non-chosen and chosen sites are paired spatially and temporally, and thus are mutually exclusive.

Uniformly distributed random locations were generated within each choice set with the Random Points extension (Jeness 2001) to ArcView® GIS. Based on McFadden (1978), 4 random locations would produce an adequate sample when 6 or more alternatives are available; fewer points would be needed in choice sets with lower heterogeneity. I examined habitat patch heterogeneity within the 1-km^2 and 7-km^2 choice sets to determine the appropriate number of sampled alternatives for each model. I measured patch heterogeneity by estimating the average number of habitat patches within each choice set. Habitat patches were created by combining all habitat layers into a single GIS layer (Cooper and Millspaugh 1999). Continuous variables (e.g., road density) were categorized into 3 classes. The combination of all GIS habitat layers resulted in 647 unique combinations of habitat variable values (habitat patches) and 41,427 habitat patches (Fig. 10). The average patch size was 1.2 ha (range = 0.1–1,672.0 ha, variance = 138.7). The 1-km^2 choice sets had an average of 11 patches (median = 10, range = 1–39), whereas the 7-km^2 choice sets averaged 57 patches (median = 54, range = 10–126). I generated 4 random locations per telemetry location for the 1-km^2 choice sets (McFadden 1978). However, I generated 5 random locations per telemetry location to account for the greater patch heterogeneity of the 7-km^2 choice sets.

I estimated parameters for the multinomial logit model using a maximum likelihood approach with the proportional hazards regression (PHREG) procedure (SAS® Institute 2000, Kuhfeld 2002). The variance of the parameters was estimated using the Fisher information matrix (Ben-Akiva and Lerman 1985). I first performed univariate

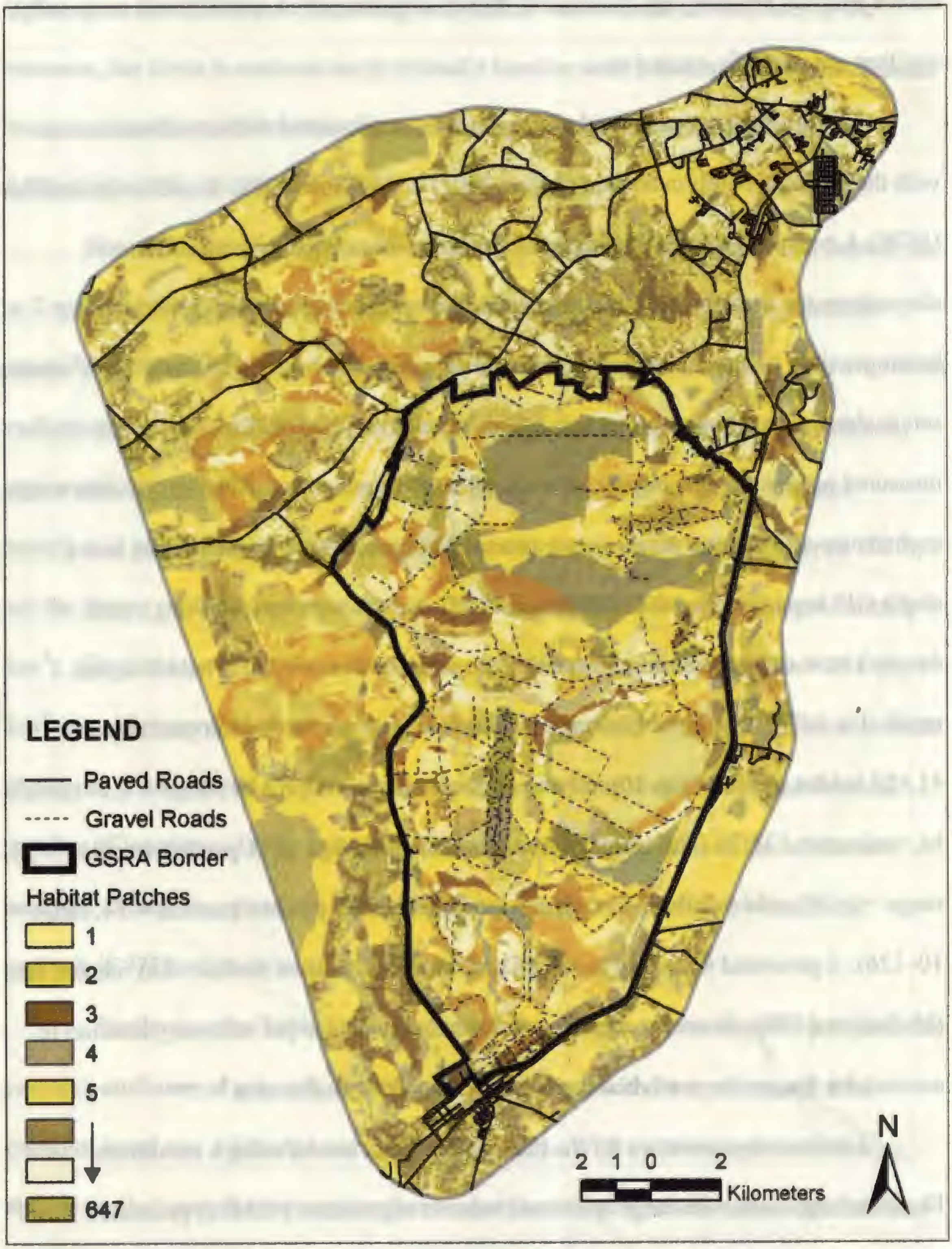

Figure 10. Unique habitat patches, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

analyses on all habitat variables. For categorical variables, I also tested for differences among variable classes with the TEST statement in PHREG to determine whether some classes may be pooled. I pooled classes if no differences ($P > 0.05$) in bear use were observed and if classes represented similar ecological attributes.

Habitat variables that did not show at least a moderate relationship with bear use in the univariate analysis ($P > 0.20$) were excluded from further consideration (Hosmer and Lemeshow 1989). I used backward elimination and forward and stepwise selection procedures (SAS® Institute, Cary, North Carolina, USA) with the remaining variables to identify initial discrete choice models. From those results, I selected the best model for each scale based on Akaike's information criterion (AIC; Burnham and Anderson 1992). AIC is based on the principle of parsimony; the best model has the fewest number of parameters that explain the most variation in the model (Burnham and Anderson 1992).

I selected the discrete choice analysis utility equation (U) rather than the probability equation to map black bear habitat values. In discrete choice analyses, probabilities are calculated for each alternative in a choice set, where alternatives represent unique combinations of variables (Kuhfeld 2002). Because I examined several variables with multiple classes, the number of alternatives ($n = 647$; Fig 10) was too high to allow for meaningful interpretation of a probability map for the GSRA. Therefore, I used the parameter estimates to create a map of bear habitat utility for the study area based on the discrete choice analysis utility equation (Spatial Analyst extension [ESRI 2000] to ArcView® GIS). I transformed those values to a 0–1 scale with a linear transformation for ease of interpretation (Spatial Analyst extension [ESRI 2000] to ArcView® GIS).

I examined the effects of triangulation error on the habitat analysis by incorporating the error distance based on the test locations. For each bear location, I generated a location within a random distance from the telemetry location based on a normal distribution of the approximated error distance of all observers (Random Points extension [Jeness 2001] to ArcView® GIS). That set of error locations was used to repeat the habitat analysis. I compared those analysis results with the original model to determine the degree to which telemetry error resulted in bias. The effects of telemetry error were considered acceptable if parameter estimates for the analysis based on error locations were within the 95% confidence intervals of corresponding parameter estimates in the original model.

Based on those final models, I examined various interaction effects for additional interpretation of the data. Although models including interaction effects assist with interpretation, it would be impractical to apply those model results in a management setting. For example, pocosin would not be managed for a certain season or for bears of a certain sex or age group. I included binary interaction effects in the analysis to determine if habitat use varied by sex (M, F), age (adult [≥4 years], subadult [<4 years]), season (spring/summer, fall), year (2000, 2001), or firing range activity (active, inactive). Interaction effects were added to the model only when sample sizes for habitat categories were sufficient and when they were biologically meaningful. Only significant ($P < 0.05$) interaction terms were retained during model selection procedures.

Model Calibration and Testing

The most robust method for evaluating model performance is to compare model results with independent data collected by different methods than those used to create the model (Johnson 2001). When different data are used, potential biases associated with data used for model development will not be repeated in model testing (Power 1993). The independent data I used for model testing were collected during the same study to estimate population abundance on the GSRA.

I established 53 barbed-wire enclosures to collect DNA from black bear hair roots. I used these DNA samples to identify individuals for mark-recapture population estimates (Woods et al. 1999, Mowat and Strobeck 2000). Hair-sampling sites were chosen randomly within forested areas (Fig. 11). Because frequent military activity restricted access, sites were placed within 250 m from roads and trails. On average, 1–3 sampling sites were available within a typical female bear home range (Lombardo 1993, Boersen 2001). Enclosures were checked every 6–7 days to collect hair samples and re-apply scent and bait. Hair was collected during an 8-week sampling period in fall 2000 and a 12-week sampling period in summer 2001. Presence or absence of bear hair was recorded at each site for each sampling period.

Using ArcView® GIS, I calculated the mean habitat utility value for all pixels in a 1-km^2 and 7-km^2 circular area around each hair-sampling site. I used linear regression to test whether the frequency of bear visits to hair-sampling sites increased with the mean habitat utility values for areas surrounding each site (NCSS® statistical software; Hintze 2001, Neter et al. 1996). I tested for the assumption of normality based on skewness and kurtosis tests, and for equal variances using a modified Levene's test.

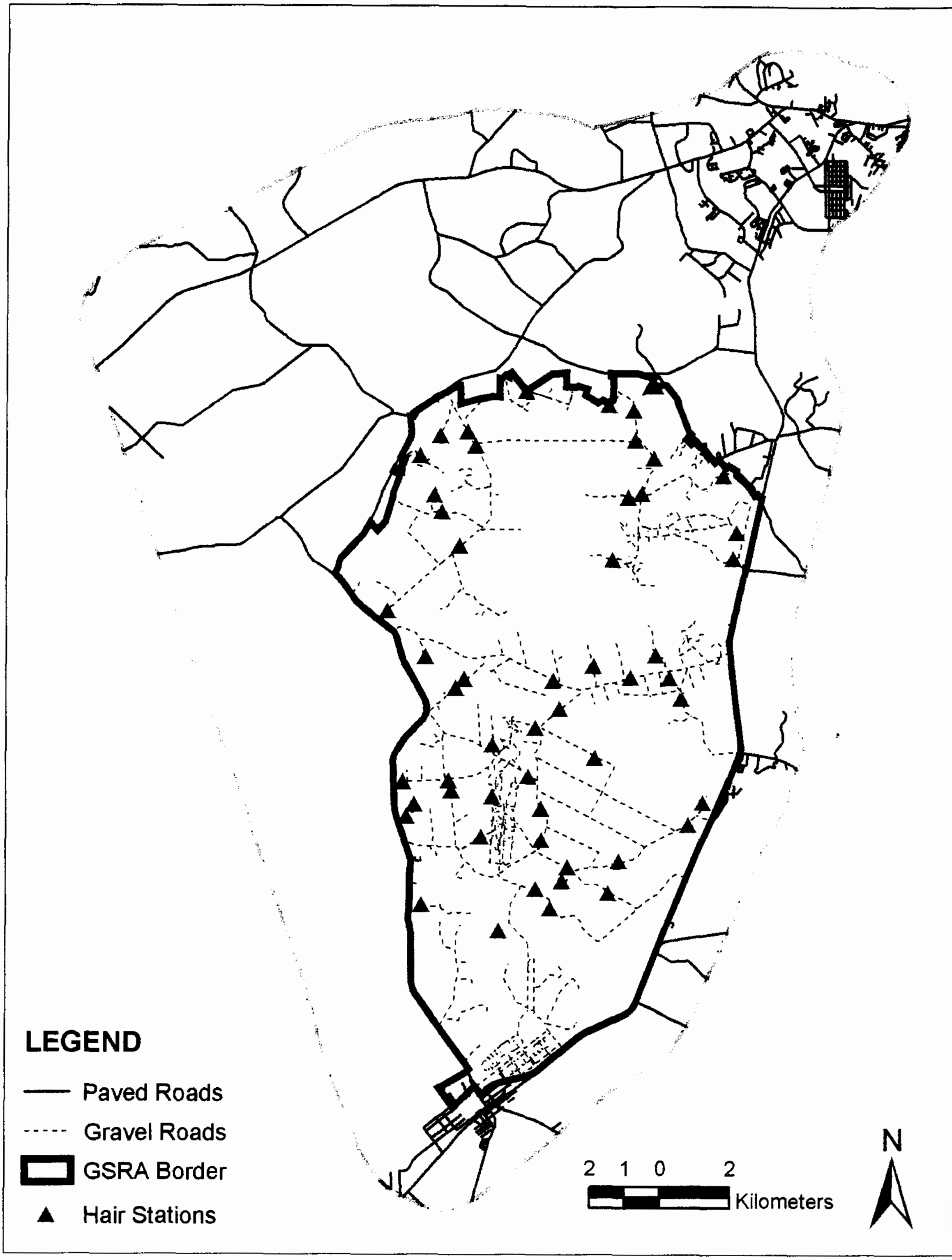

Figure 11. Black bear hair-sampling sites ($n = 53$), Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

CHAPTER IV

RESULTS

Trapping

Bears were captured from 21 May to 7 September 2000 and 11 June to 12 August 2001. A total of 26 bears were captured 35 times during this study. The sex ratio of captured bears was 1.4:1 (15 M:11 F) and the average age was 5 years (range = 1–12; Appendix D). Overall, 39 captures occurred during 710 trap nights, resulting in a 5.5% success rate (18 trap nights per capture). Field personnel attached radio-collars to 12 bears (9 M:3 F) in 2000 and 7 additional bears (1 M:6 F) in 2001 (Appendix D).

Radiotelemetry

Between 06 June 2000 and 16 December 2001, I collected 2,119 locations on 20 radio-collared bears (10 M:10 F; Appendix E). Twelve radio-collared bears (9 M:3 F) were tracked during 2000, resulting in 616 locations. Three male bears (Bears 03, 05, and 16) had <15 total locations and were excluded from home range and habitat use analyses. During 2001, locations were collected from 16 radio-collared bears (n = 1,503; 6 M:10 F). Female bear 22 was excluded from the habitat use analysis because only 22% of her locations were on the GSRA. Three of the leather spacers on radio-collared bears captured in 2000 rotted through, causing transmitters to drop off in 2001 (Appendix D).

Five observers collected telemetry locations on the project. The median distance between the test locations and the test transmitters was 236 m for all observers in both years (Table 3). Collectively, 80% of the triangulated locations for all 5 observers were <417 m from the test transmitters (median = 236 m, range 28–1,780 m; Table 3).

Home Range Analysis

Annual and seasonal home ranges were estimated for 8 bears (5 M:3 F) in 2000 and 16 bears (6 M:10 F) in 2001 (Appendix E). For both years combined, the mean annual home range was 37.2 km^2 for males (n = 11; Fig. 12) and 27.8 km^2 for females (n = 12; Fig. 13; Table 4). The mean size of seasonal home ranges for males was 56.7 km^2 in spring (n = 5), 33.3 km^2 in summer (n = 7), and 18.1 km^2 in fall (n = 9). For females, seasonal home ranges were 6.7 km^2 in spring (n = 3), 11.0 km^2 in summer (n = 12), and 32.6 km^2 in fall (n = 10).

Habitat Use Analysis

Bears showed no difference in use among agricultural, developed, firing range, and open area land-cover classes for the 2 spatial scales I examined. Therefore, I combined those 4 classes into 1 (open areas), resulting in a total of 6 classes for the land-cover variable (Fig. 14).

Although the majority of telemetry locations (87%) were in areas where forest management information was available, I could not adequately model the effects of forest management on black bear habitat use. The majority of both telemetry and random locations tended to be in 1 of the 3 management classes for each forest type, with only a small number of locations for the remaining classes (Table 5). For example, of all forest cover types in the 7-km^2 choice set analysis, pine had the most locations across the

Table 3. Telemetry locations collected and telemetry error distance (m) for each of 5 observers, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Observer	Locations collected	Average error	Median error	80% below	90% below	Error range
Year 2000						
DJT	439	247	184	399	477	58–692
RLT	105	237	234	335	491	32–535
Overall	544	242	212	389	531	32–692
Year 2001						
CJW	648	413	415	568	685	33–903
DJT	126	247[a]	184[a]	399[a]	477[a]	58–692[a]
KMA	563	199	175	282	345	66–413
TLS	145	312	238	424	556	28–1,780
Overall	1,482	293	238	444	650	28–1,780
2000-2001						
Overall	2,026	284	236	417	535	28–1,780

[a] Results based on telemetry error tests in 2000.

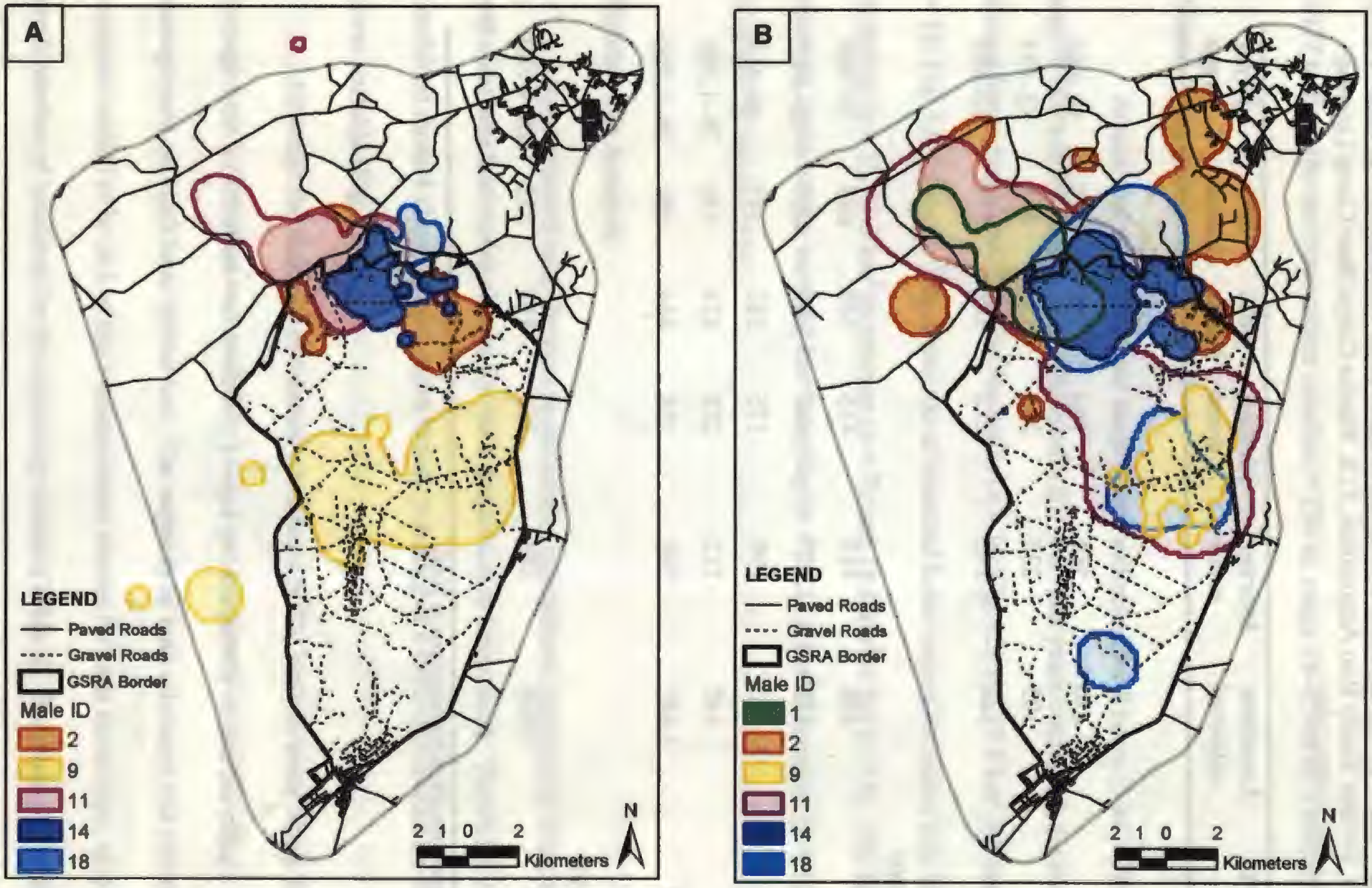

Figure 12. Annual home range estimates (95% probability fixed kernel method) for male black bears in 2000 (A) and 2001 (B), Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

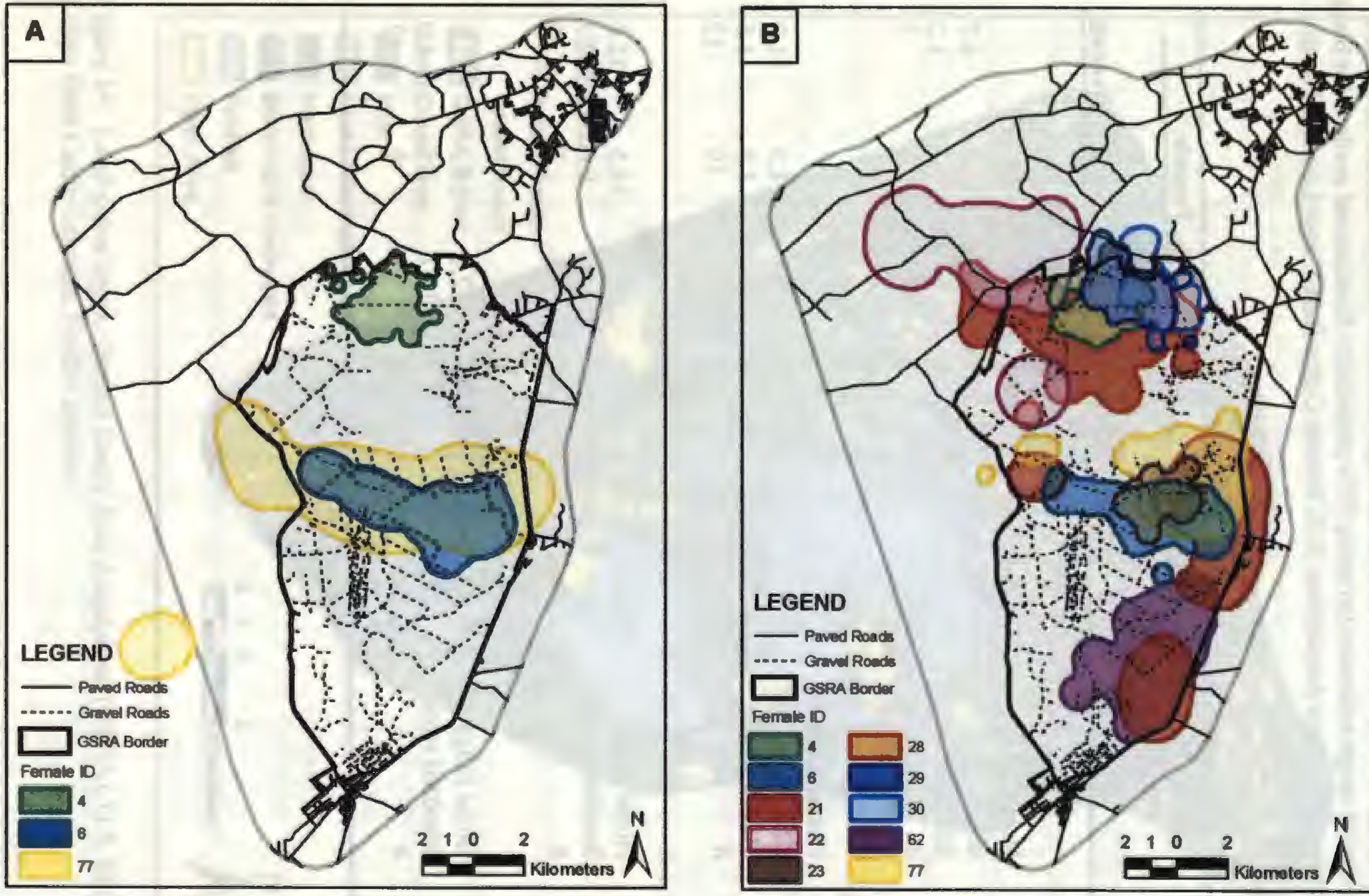

Figure 13. Annual home range estimates (95% probability fixed kernel method) for female black bears in 2000 (A) and 2001 (B), Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

Table 4. Average seasonal and annual home range estimates (km^2), standard errors, and number of home range estimates (*n*) using 95% probability fixed kernel method for black bears, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

		Male			Female		
Season		**2000**	**2001**	**Overall**	**2000**	**2001**	**Overall**
Spring							
	Home range size	-	56.7	56.7	-	6.7	6.7
	Standard error	-	23.9	23.9	-	1.2	1.2
	n	-	5	5	-	3	3
Summer							
	Home range size	36.8	31.9	33.3	9.8	11.3	11.0
	Standard error	6.8	11.7	8.3	0.5	1.8	1.5
	n	2	5	7	2	10	12
Fall							
	Home range	19.6	16.2	18.1	28.1	34.5	32.6
	Standard error	5.8	5.5	3.8	14.9	9.6	7.7
	n	5	4	9	3	7	10
Annual							
	Home range	24.4	47.9	37.2	27.1	21.3	22.8
	Standard error	7.1	14.8	8.7	13.1	3.8	4.0
	n	5	6	12	3	9	12

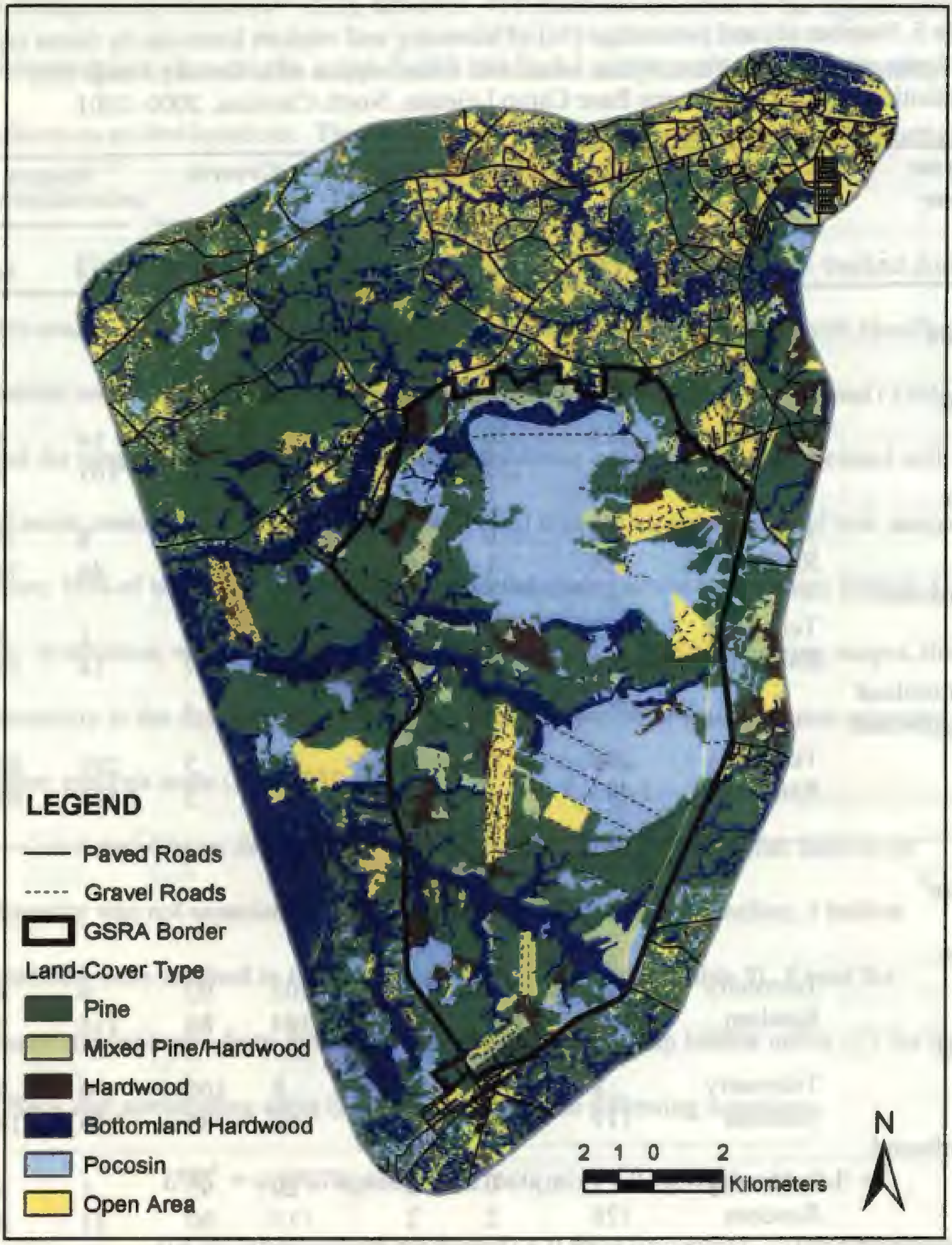

Figure 14. Land-cover types, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

Table 5. Number (n) and percentage (%) of telemetry and random locations by forest type and forest management class within 1-km^2 and 7-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Forest cover	Location type	Total	Regeneration		Growth		Mature	
		n	*n*	%	*n*	%	*n*	%
1-km^2								
Pine								
	Telemetry	319	20	6	284	89	14	5
	Random	1,684	167	10	1,412	84	101	6
Mix								
	Telemetry	54	0	0	46	85	8	15
	Random	314	1	0	269	86	44	14
Hardwood								
	Telemetry	22	0	0	21	95	1	5
	Random	116	1	1	101	87	14	12
Bottomland hardwood								
	Telemetry	308	0	0	15	5	293	95
	Random	1,483	1	0	71	5	1,411	95
7-km^2								
Pine								
	Telemetry	222	8	4	205	92	9	4
	Random	1,569	109	7	1,344	86	116	7
Mix								
	Telemetry	8	0	0	8	100	0	0
	Random	117	3	3	98	84	16	14
Hardwood								
	Telemetry	21	0	0	20	95	1	5
	Random	128	2	2	115	90	11	8
Bottomland hardwood								
	Telemetry	140	0	0	0	0	140	100
	Random	610	1	0	7	1	602	99

3 management classes ($n = 222$); however, <10 locations occurred in the regeneration and mature classes. It would be inappropriate to base an analysis of forest management effects on so few locations. Therefore, forest management was excluded from further consideration.

Firing ranges were active on 47% of the 317 days that bears were tracked during this study. The current level of firing range activity was not associated with black bear habitat use. Univariate discrete choice analyses on all firing ranges combined (Table 6) and for ranges analyzed individually indicated firing activity was not associated with use of noise zones ($P = 0.106$ to 0.919). That result was not a consequence of low sample sizes; 56% of telemetry locations were collected during active firing range periods (Table 7). In addition, when bears were within noise zones 2 or 3 of active firing ranges, their proximity to the firing positions was not different from what was randomly expected at either analysis scale ($P = 0.232$ to 0.785).

1-km² Choice Set Analysis. -- Univariate analysis indicated that land-cover diversity was not associated with bear habitat use (Table 8). Therefore, 3 habitat variables were retained in the final 1-km² choice set model (Table 9). I used the parameter estimates from the discrete choice analysis to map habitat utility (U) for the GSRA and surrounding areas (Fig. 15), based on the following equation:

$$U^{1km^2} = 0.37678(\text{pine}) + 0.21660(\text{mix}) + 0.08574(\text{hardwood}) + 0.42053(\text{bottomland hardwood}) + 0.45541(\text{pocosin}) - 0.08650(\text{burned} \leq 1 \text{ year}) - 0.29916(\text{burned 2–5 years}) - 0.37627(\text{paved road density}).$$

Table 6. Univariate discrete choice analysis of black bear use of firing range noise zones with firing activity interaction effects based on 1-km^2 and 7-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	**Parameter estimate**	**Standard error**	**Chi square**	***P*-value**
1-km^2				
FIRING RANGE NOISE ZONE				
Zone 3	-0.173	0.365	0.23	0.636
Zone 2	0.082	0.148	0.30	0.581
Zone 1 [a]	0	-	-	-
FIRING ACTIVITY INTERACTION *(Active relative to inactive)*				
Zone 3	0.530	0.755	0.49	0.482
Zone 2	-0.134	0.239	0.31	0.576
7-km^2				
FIRING RANGE NOISE ZONE				
Zone 3	-0.414	0.232	3.18	0.075
Zone 2	0.044	0.088	0.25	0.621
Zone 1 [a]	0	-	-	-
FIRING ACTIVITY INTERACTION *(Active relative to inactive)*				
Zone 3	-0.271	0.474	0.33	0.567
Zone 2	-0.079	0.150	0.28	0.599

[a] Class parameter estimates are relative to this reference class.

Table 7. The number (*n*) and percentage (%) of telemetry locations in firing range noise zones and by firing range activity, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Noise Zone	**Total**	**Inactive**		**Active**	
	n	***n***	**%**	***n***	**%**
3	45	33	73	12	27
2	868	627	72	241	28
1	1,021	198	19	823	81
Total	1,934	858	44	1,076	56

Table 8. Univariate discrete choice analysis of black bear habitat use based on 1-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	**Parameter estimate**	**Standard error**	**Chi square**	***P*-value**
LANDCOVER				
Pine	0.395	0.155	6.51	0.011
Mix	0.259	0.180	2.07	0.150
Hardwood	0.068	0.226	0.09	0.762
Bottomland hardwood	0.485	0.161	9.06	0.003
Pocosin	0.535	0.169	10.00	0.002
Open[a]	0	-	-	-
BURN HISTORY				
Burned ≤1 year	-0.177	0.133	1.78	0.182
Burned 2–5 years	-0.334	0.140	5.67	0.017
Burned >5 years[a]	0	-	-	-
PAVED ROAD DENSITY	-0.407	0.128	10.06	0.002
LAND COVER DIVERSITY	0.171	0.241	0.50	0.479

[a] Class parameter estimates are relative to this reference class.

Table 9. Multivariate discrete choice analysis of black bear habitat use based on 1-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	**Parameter estimate**	**Standard error**	**Chi square**	***P*-value**
LANDCOVER				
Pine	0.377	0.156	5.81	0.016
Mix	0.217	0.182	1.43	0.233
Hardwood	0.086	0.227	0.14	0.706
Bottomland hardwood	0.421	0.164	6.58	0.010
Pocosin	0.455	0.173	6.96	0.008
Open[a]	0	-	-	-
BURN HISTORY				
Burned ≤1 year	-0.087	0.141	0.38	0.538
Burned 2–5 years	-0.299	0.146	4.19	0.041
Burned >5 years[a]	0	-	-	-
ROAD DENSITY	-0.376	0.129	8.48	0.004

[a] Class parameter estimates are relative to this reference class.

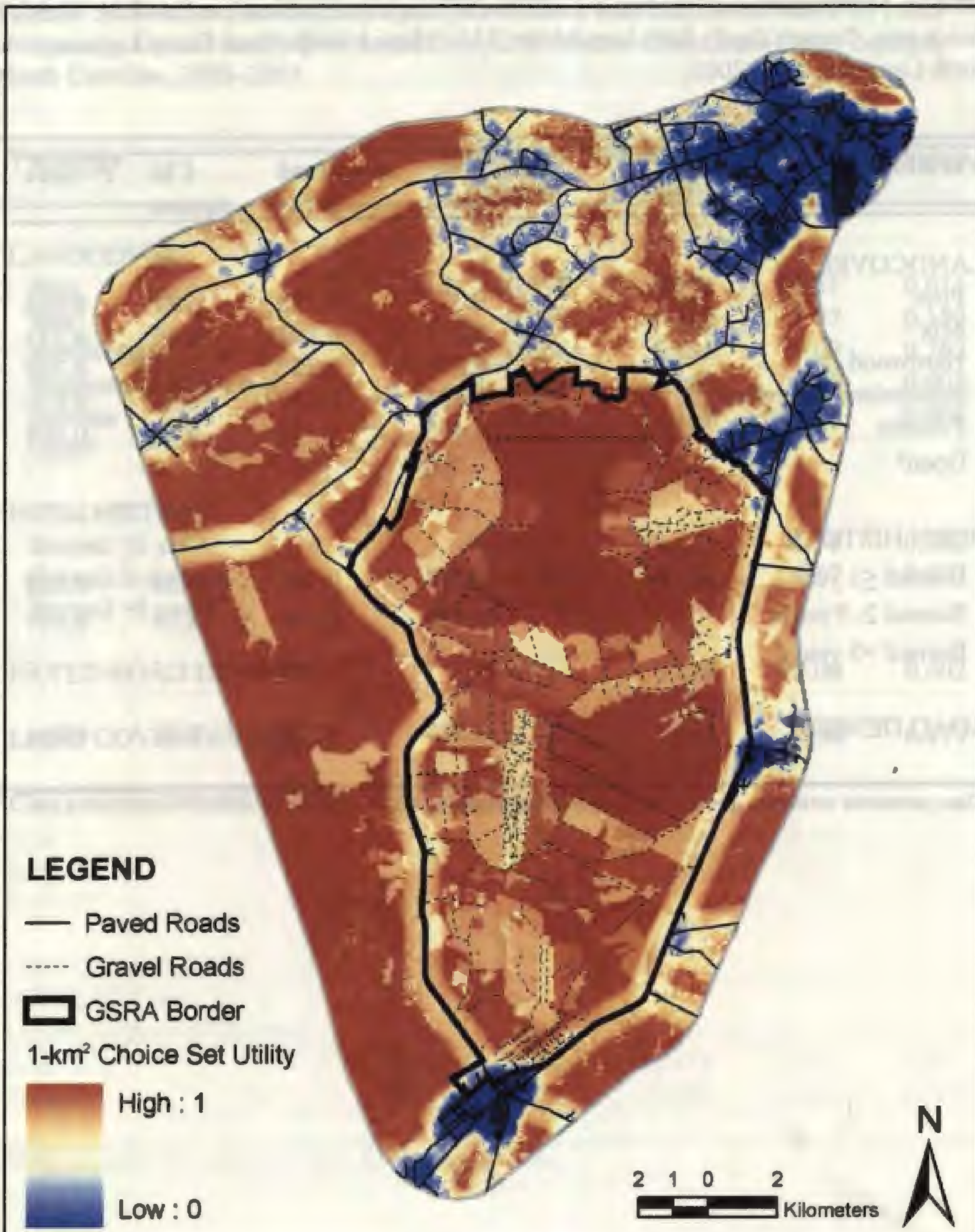

Figure 15. Habitat utility based on discrete choice analysis of black bear habitat use within 1-km^2 choice sets, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

I examined 9 binary interaction effects with model selection procedures. One interaction term and the 3 habitat variables were retained for the 1-km^2 choice set model (Table 10).

7-km^2 Choice Set Analysis. -- Based on univariate analysis, 4 habitat variables were associated with bear habitat use (Table 11). All 4 habitat variables were retained in the final 7-km^2 choice set model (Table 12). I used the following equation to calculate and map habitat utility for the 7-km^2 choice set model (Fig. 16):

$$U^{7km^2} = 0.53125(\text{pine}) + 0.16035(\text{mix}) - 0.02878(\text{hardwood}) + 0.73365(\text{bottomland hardwood}) + 0.66549(\text{pocosin}) - 0.12687(\text{burned} \leq 1 \text{ year}) - 0.61686(\text{burned 2–5 years}) - 0.73348(\text{paved road density}) + 0.93317(\text{land-cover diversity}).$$

I examined 14 interaction terms with model selection procedures. The model based on both forward and stepwise selection included 5 interaction terms (2 seasonal effects, 2 sex effects, and 1 age effect; AIC = 6,673.8). Based on backward elimination, however, the final model included 3 interaction terms, including 1 seasonal effect, 1 sex effect, and 1 age effect (Table 13; AIC = 6,677.0). AIC values for the 2 models differed only slightly and both models included the same 2 interaction terms. I selected the latter model because biological explanations were more reasonable.

When telemetry error was incorporated into the habitat analysis, results were consistent for both spatial scales. All error-based parameter estimates were within 95% confidence intervals of the telemetry-based parameter estimates, with one exception for (Tables 14 and 15). In the 7-km^2 choice set analysis, the error-based parameter estimate

Table 10. Multivariate discrete choice analysis, including interaction terms, of black bear habitat use based on 1-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	**Parameter estimate**	**Standard error**	**Chi square**	***P*-value**
LANDCOVER				
Pine	0.385	0.156	6.07	0.014
Mix	0.226	0.181	1.55	0.213
Hardwood	0.092	0.227	0.16	0.686
Bottomland hardwood	0.696	0.185	14.12	<0.001
Pocosin	0.498	0.173	8.25	0.004
Open[a]	0	-	-	-
BURN HISTORY				
Burned ≤1 year	-0.039	0.141	0.08	0.784
Burned 2–5 years	-0.246	0.147	2.80	0.094
Burned >5 years[a]	0	-	-	-
ROAD DENSITY	-0.377	0.129	8.49	0.004
SEX INTERACTION *(Male relative to female)*				
Bottomland hardwood	-0.477	0.150	10.12	0.002

[a] Class parameter estimates are relative to this reference class.

Table 11. Univariate discrete choice analysis of black bear habitat use based on 7-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	**Parameter estimate**	**Standard error**	**Chi square**	***P*-value**
LANDCOVER				
Pine	0.584	0.131	19.82	<0.001
Mix	0.447	0.157	8.09	0.004
Hardwood	0.013	0.208	0.00	0.951
Bottomland hardwood	1.041	0.137	57.73	<0.001
Pocosin	0.796	0.139	32.96	<0.001
Open[a]	0	-	-	-
BURN HISTORY				
Burned ≤1 year	-0.253	0.100	6.45	0.011
Burned 2–5 years	-0.599	0.107	31.52	<0.001
Burned >5 years[a]	0	-	-	-
PAVED ROAD DENSITY	-0.757	0.080	89.34	<0.001
LAND-COVER DIVERSITY	0.527	0.133	15.64	<0.001

[a] Class parameter estimates are relative to this reference class.

Table 12. Multivariate discrete choice analysis of black bear habitat use based on 7-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	**Parameter estimate**	**Standard error**	**Chi square**	***P*-value**
LANDCOVER				
Pine	0.531	0.135	15.53	<0.001
Mix	0.160	0.162	0.98	0.323
Hardwood	-0.029	0.210	0.02	0.891
Bottomland hardwood	0.734	0.144	26.09	<0.001
Pocosin	0.666	0.149	19.87	<0.001
Open[a]	0	-	-	-
BURN HISTORY				
Burned ≤1 year	-0.127	0.107	1.40	0.236
Burned 2–5 years	-0.617	0.115	28.92	<0.001
Burned >5 years[a]	0	-	-	-
PAVED ROAD DENSITY	-0.734	0.083	78.16	<0.001
LAND-COVER DIVERSITY	0.933	0.154	36.94	<0.001

[a] Class parameter estimates are relative to this reference class.

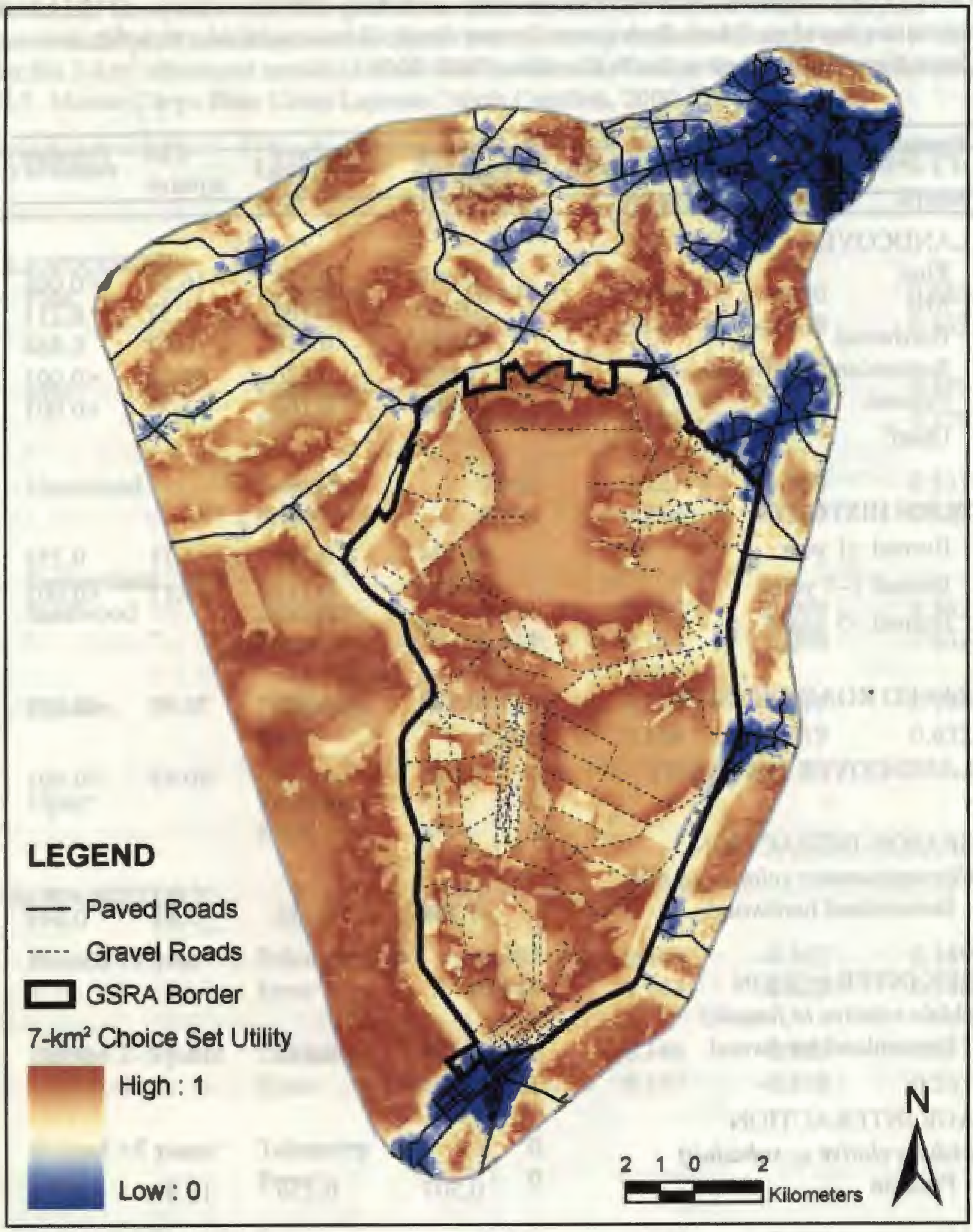

Figure 16. Habitat utility based on discrete choice analysis of black bear habitat use within 7-km^2 choice sets, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Table 13. Multivariate discrete choice analysis, including interaction terms, of black bear habitat use based on 7-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	**Parameter estimate**	**Standard error**	**Chi square**	***P*-value**
LANDCOVER				
Pine	0.549	0.135	16.57	<0.001
Mix	0.204	0.163	1.57	0.211
Hardwood	-0.036	0.210	0.03	0.864
Bottomland hardwood	1.103	0.170	42.32	<0.001
Pocosin	0.982	0.168	34.23	<0.001
Open[a]	0	-	-	-
BURN HISTORY				
Burned ≤1 year	-0.124	0.109	1.31	0.253
Burned 2–5 years	-0.630	0.117	29.17	<0.001
Burned >5 years[a]	0	-	-	-
PAVED ROAD DENSITY	-0.728	0.083	76.90	<0.001
LAND-COVER DIVERSITY	0.985	0.155	40.49	<0.001
SEASON INERACTION *(Spring/summer relative to fall)*				
Bottomland hardwood	-0.268	0.136	3.88	0.049
SEX INTERACTION *(Male relative to female)*				
Bottomland hardwood	-0.450	0.135	11.19	<0.001
AGE INTERACTION *(Adult relative to subadult)*				
Pocosin	0.507	0.136	13.89	<0.001

[a] Class parameter estimates are relative to this reference class.

Table 14. Comparison of 95% confidence intervals (CI) for discrete choice analyses based on telemetry locations and locations incorporating random telemetry error (417 m) for the 1-km^2 choice set model of black bear habitat use, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	Location type	Parameter estimate	Standard error	95% CI: Lower	95% CI: Upper
LANDCOVER					
Pine	Telemetry	0.377	0.156	0.070	0.683
	Error	0.147	0.145	-0.138	0.432
Mix	Telemetry	0.217	0.181	-0.139	0.572
	Error	0.040	0.173	-0.299	0.379
Hardwood	Telemetry	0.086	0.227	-0.360	0.531
	Error	0.103	0.216	-0.321	0.527
Bottomland hardwood	Telemetry	0.421	0.164	0.099	0.742
	Error	0.331	0.154	0.030	0.632
Pocosin	Telemetry	0.455	0.173	0.117	0.794
	Error	0.306	0.166	-0.019	0.632
Open[a]	Telemetry	0	-	-	-
	Error	0	-	-	-
BURN HISTORY					
Burned <1 year	Telemetry	-0.087	0.140	-0.362	0.189
	Error	-0.143	0.143	-0.423	0.138
Burned 2–5 years	Telemetry	-0.299	0.146	-0.585	-0.013
	Error	-0.021	0.147	-0.310	0.267
Burned >5 years[a]	Telemetry	0	-	-	-
	Error	0	-	-	-
ROAD DENSITY	Telemetry	-0.376	0.129	-0.629	-0.123
	Error	-0.346	0.131	-0.604	-0.089

[a] Class parameter estimates are relative to this reference class.

Table 15. Comparison of 95% confidence intervals (CI) for discrete choice analyses based on telemetry locations and locations incorporating random telemetry error (417 m) for the 7-km^2 choice set model of black bear habitat use, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Variables	Location type	Parameter estimate	Standard error	95% CI: Lower	95% CI: Upper
LANDCOVER					
Pine	Telemetry	0.531	0.135	0.267	0.795
	Error	0.377	0.127	0.128	0.626
Mix	Telemetry	0.160	0.162	-0.158	0.479
	Error	0.175	0.153	-0.125	0.476
Hardwood	Telemetry	-0.029	0.210	-0.440	0.383
	Error	-0.012	0.199	-0.402	0.378
Bottomland hardwood	Telemetry	0.734	0.144	0.452	1.015
	Error	0.573	0.136	0.307	0.839
Pocosin	Telemetry	0.665	0.149	0.373	0.958
	Error	0.553	0.142	0.276	0.831
Open	Telemetry	0	-	-	-
	Error	0	-	-	-
BURN HISTORY					
Burned <1 year	Telemetry	-0.127	0.107	-0.337	0.083
	Error	-0.116	0.106	-0.323	0.091
Burned 2–5 years	Telemetry	-0.617	0.115	-0.842	-0.392
	Error	-0.344	0.107	-0.554	-0.134
Burned >5 years	Telemetry	0	-	-	-
	Error	0	-	-	-
ROAD DENSITY	Telemetry	-0.733	0.083	-0.896	-0.571
	Error	-0.570	0.077	-0.720	-0.420
LAND-COVER DIVERSITY	Telemetry	0.933	0.154	0.632	1.234
	Error	0.687	0.152	0.389	0.985

[a] Class parameter estimates are relative to this reference class.

for areas burned within 2 to 5 years was outside of the interval. However, confidence intervals from the error- and telemetry-based analyses for that parameter estimate overlapped, indicating some similarity in the range of values for both estimates.

Model Calibration and Testing

I calibrated the model results based on habitat utility values associated with telemetry locations (n = 1,934) for both analysis scales. Values for the telemetry locations used to create the 1-km^2 choice set model ranged from 0.71 to 1.00 (mean = 0.97, SD = 0.044), with 95% of values >0.87. For the 7-km^2 choice set model, telemetry location values ranged from 0.69 to 1.00 (mean = 0.93, SD = 0.042), with 95% of values >0.85. Values for unused choice set locations ranged from 0.59 to 1.00 for both model scales

The frequency of bear visits to hair-sampling sites during the 20 weeks of sampling ranged from 0 to 20. Mean habitat utility values for areas around hair-sampling sites ranged from 0.86–1.00 and 0.82–0.94 for the 1-km^2 (Fig. 17) and 7-km^2 (Fig. 18) choice set models, respectively. There was a positive relationship between the frequency of bear visits and the mean habitat utility values for both models (Figs. 19 and 20). The assumption of normality and equal variances were met for both regressions.

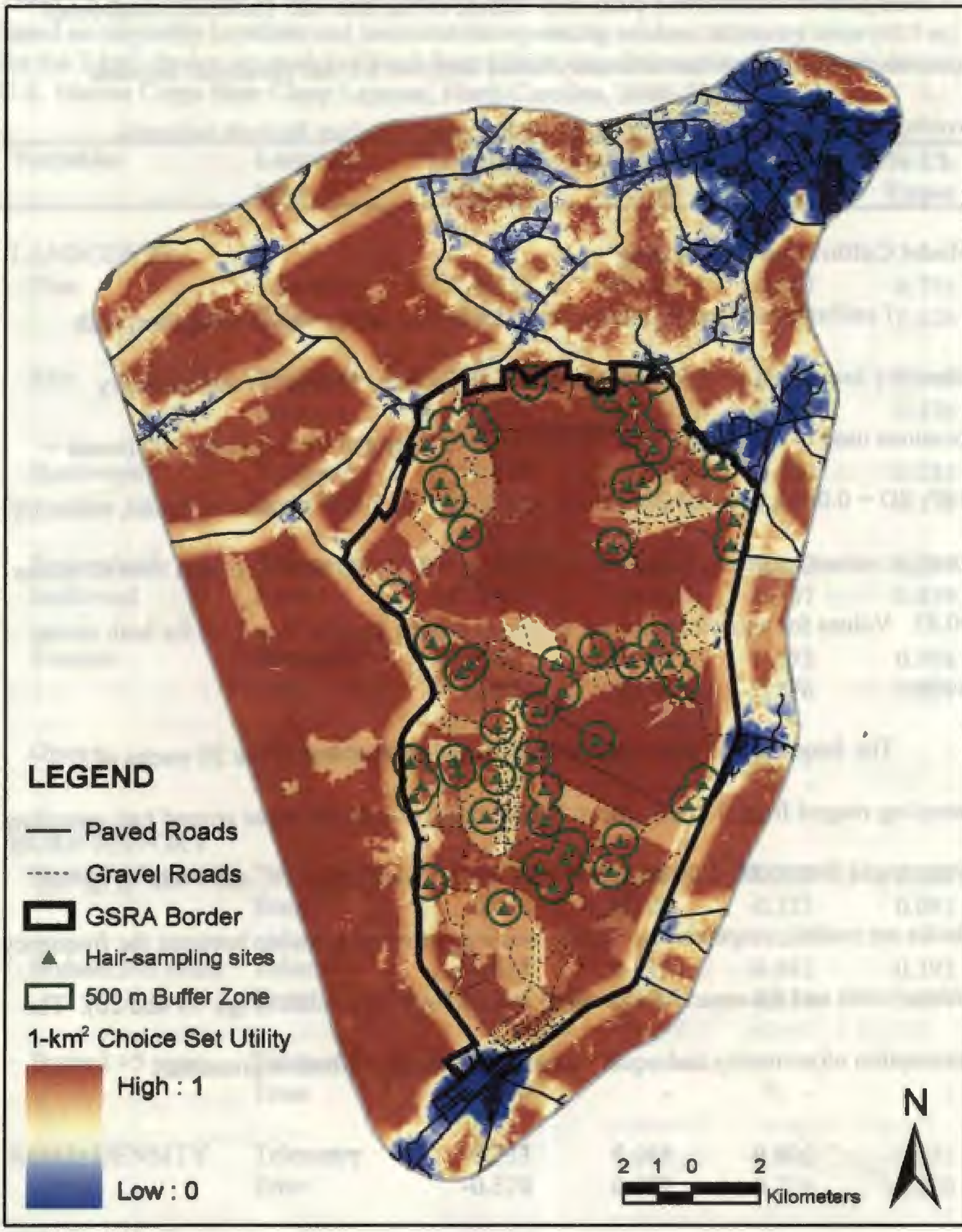

Figure 17. Hair-sampling sites with 500-m buffer zones encompassing average habitat utility values based on discrete choice analysis of black bear habitat use within 1-km^2 choice sets, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina 2000–2001.

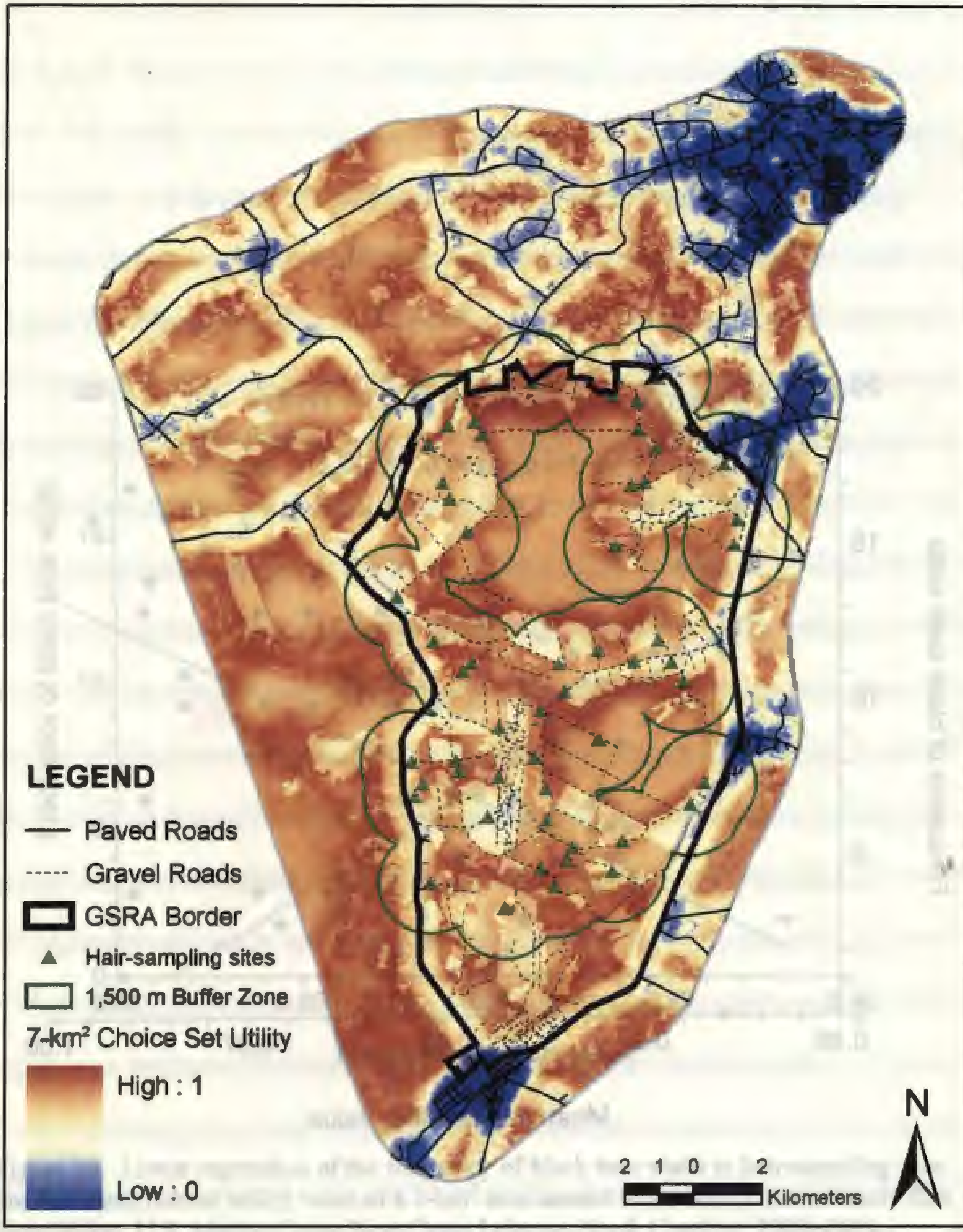

Figure 18. Hair-sampling sites with 1,500-m buffer zones encompassing average habitat utility values based on discrete choice analysis of black bear habitat use within 7-km^2 choice sets, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina 2000–2001.

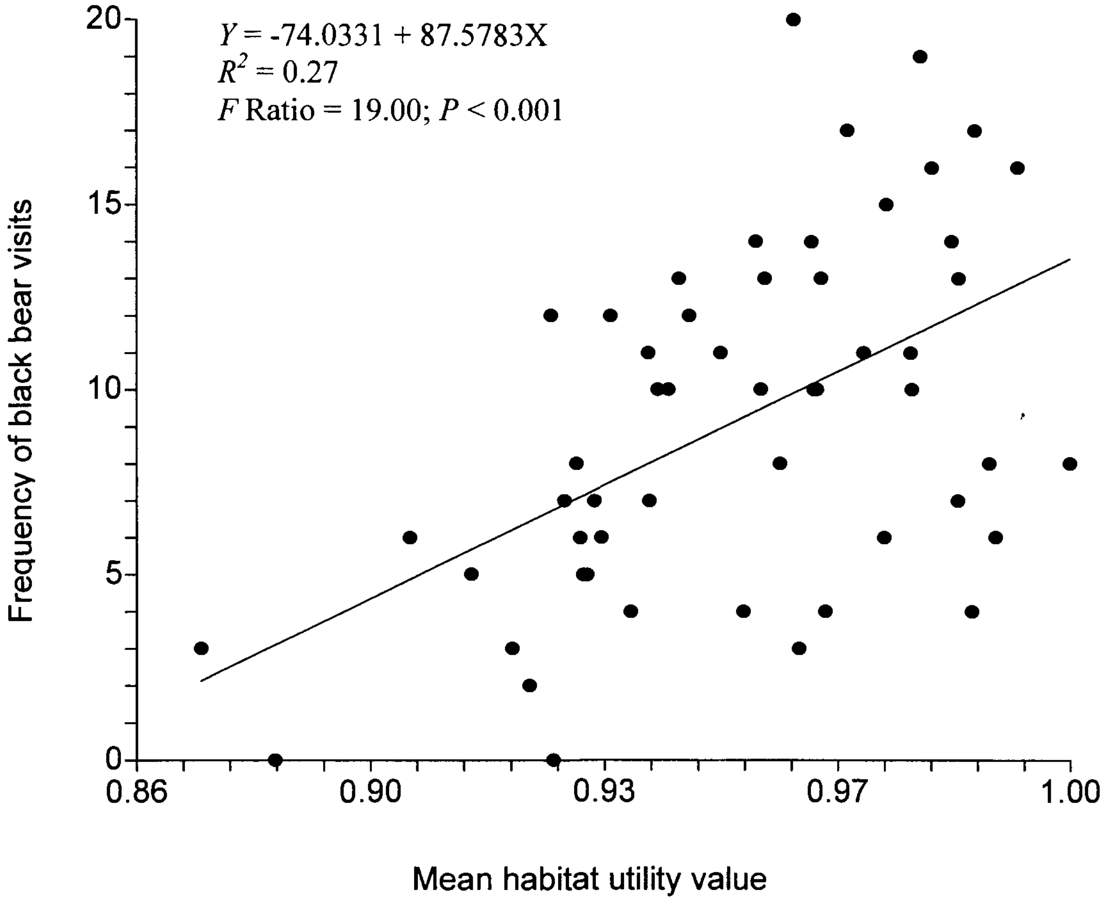

Figure 19. Linear regression of the frequency of black bear visits to hair-sampling sites and the mean habitat utility value of a 1-km^2 area around those sites, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

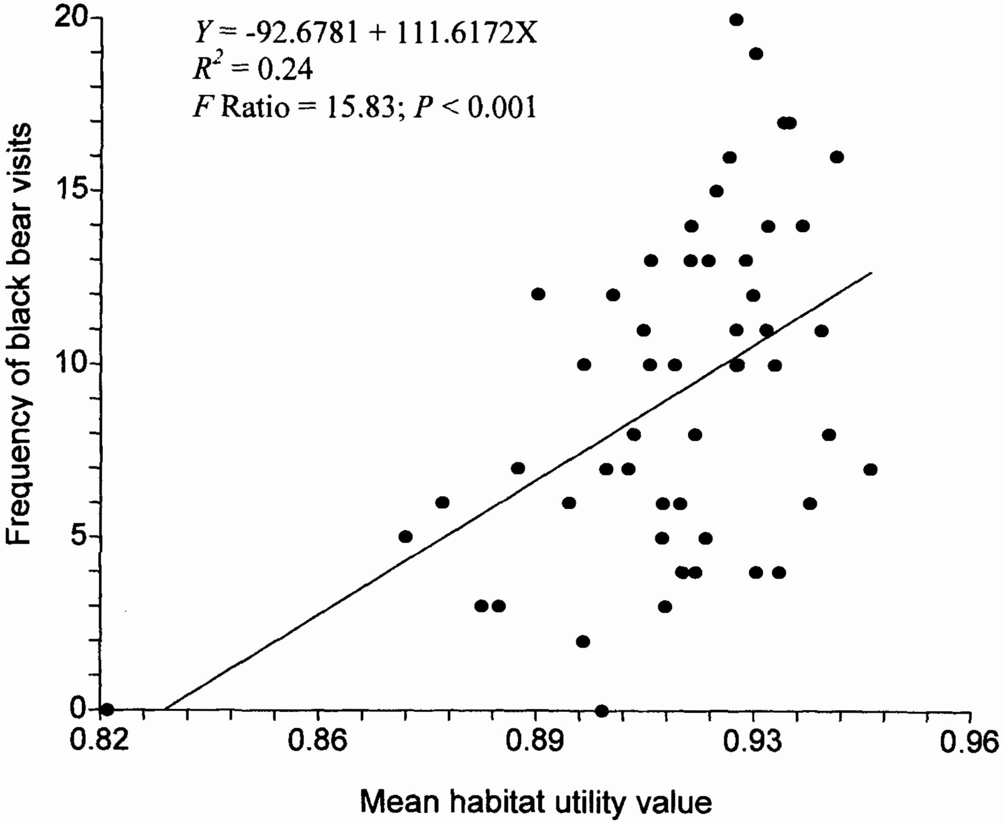

Figure 20. Linear regression of the frequency of black bear visits to hair-sampling sites and the mean habitat utility value of a 7-km^2 area around those sites, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

CHAPTER V

DISCUSSION

The seasonal and annual home range estimates for bears on the GSRA were consistent with estimates for bears in other portions of the southeastern Coastal Plain (Lombardo 1993, Brandenburg 1996, Jones 1996). Home ranges of bears in this region are relatively small compared with those in other portions of the species range and several authors have suggested this is a direct function of access to abundant agricultural food resources. Agricultural crops are considered a key food resource in eastern North Carolina (Maddrey 1995, Jones 1996, Martorello 1998, Allen 1999, Thompson 2003). Based on field examination of scats, bears in the northern portion of the GSRA commonly consumed corn and milo, primarily during summer and early fall (D. J. Telesco, University of Tennessee, unpublished data). The use of these highly nutritious and abundant resources likely explains why overlap among home ranges was particularly extensive in the northern portion of the study area. Given such abundant food sources, normally solitary black bears may form dominance hierarchies (Rogers 1987), which allow a greater number of bears to take advantage of the food source with limited intra-specific aggression. Indeed, I often located adult males within 200 m of each other near agricultural areas. As many as 15 bears have been observed feeding together in small (approximately 9 ha) wheat fields in Craven, Pamlico, and Dare counties in coastal North Carolina (Allen 1999; M. D. Jones, North Carolina Wildlife Resources Commission, personal communication).

The larger home ranges of males compared with females has been documented for black bears throughout their range (Pelton 1982). Black bear males have a larger body mass than females and require greater food intake. In addition, adult males during the mating season maintain an area that encompasses the home ranges of several female bears, likely to increase mating opportunities and enhance their reproductive fitness (Amstrup and Beecham 1976, Rogers 1987). In contrast, female mobility is seasonally restricted while they care for their young. The presence of young also may explain why female home range sizes tended to increase from spring to fall. As the young become more mobile, females can gradually use larger areas.

I designed my analysis of black bear habitat use to address specific issues associated with bear management on the GSRA. Selection of the proper statistical technique was crucial to address those management issues in an integrated manner. Discrete choice analysis provided a relatively new approach to investigate the complex habitat relationships of black bears. Although discrete choice analysis has not been applied in many wildlife studies (McCracken et al. 1998; Cooper and Millspaugh 1999, 2001), the scientific basis was established for applications in business, economics, and marketing fields (Ben-Akiva and Lerman 1985). As such, extensive reference information and applications in existing statistical software were readily available (e.g., Kuhfeld 2002). The primary advantage of discrete choice analysis lies with the concept of a choice set (Cooper and Millspaugh 1999, Arthur et al. 1996). The choice set essentially represents available habitat defined based on temporal criteria. Thus, the effects of specific temporal and spatial conditions on habitat selection can be examined simultaneously. In addition, attributes of the choice set can be incorporated. Cooper and

Millspaugh (2001), for example, examined elk habitat use by behavior within a nested logit form of discrete choice analysis. The choice set also reduces biases associated with the assumption that random locations represent unused resources in typical use-availability analyses. By defining a choice set for a specific time (i.e., the time that a telemetry location was collected), associated random locations within the choice set would represent unused habitats for that sample time. Depending on the area of the choice set, different spatial and temporal scales can be defined to examine ecological concepts of selection hierarchy (Johnson 1980).

The assumption of independence of irrelevant alternatives is critical in assessing the validity of discrete choice analysis. Violations of the assumption occur when the decision maker (i.e., bears in my study) cannot clearly differentiate among alternatives. Consequently, a large number of choices and choices that are similar or irrelevant to the decision (e.g., separating upland pine vegetation into 3 land-cover types) would be more likely to result in biases. I reduced the likelihood of violating that assumption by reclassifying the number of categorical variables into fewer and more distinct classes. A second consideration with discrete choice analysis is sample size. The choice set based on the telemetry location and associated random locations represents the sampling unit. Although variation in habitat selection among different bears is accounted for by the error term in discrete choice analysis, it is important to sample each individual with approximately equal intensity. Moreover, given that only a certain number of telemetry locations can be collected, Cooper and Millspaugh (2001) suggested that it is better to have more individuals with fewer locations rather than many locations for only a few individuals. The number of bears included in the habitat analysis ($n = 17$) represented the largest number of bears for which data could be collected given the logistical constraints of my study. Furthermore, I attempted to equalize the number of locations collected per bear by using a consistent tracking effort; an average of 13 locations were collected per month for each bear (range = 6–18, standard error = 0.7).

When studying wide-ranging species such as bears, obtaining current and accurate data across large spatial extents is an important consideration. Information on land cover and paved road density was readily available over the entire study area, but forest management and burn history was current and field-validated only for the GSRA and GETCO lands. Although burn history was not digitally available for areas outside of the GSRA and GETCO, I was still able to examine the influence of this variable by supplementing the available databases with estimates based on a consensus of local forestry experts. In addition, I was able to update the 1992 NLCD to 2000 land-cover status for GSRA and GETCO lands based on the Camp Lejeune Forestry Section and GETCO databases.

The resource selection models performed well at both analysis scales. Tests with independent data indicated that the frequency of bear use at hair-sampling sites was associated with habitat utility based on the predictive equation derived from the discrete choice models. Because all values of unused locations in choice sets ranged from 0.59 to 1.00, model predictions are only appropriate for this range of habitat values. Considering that model testing was based on hair-sampling sites that were placed mostly in suitable bear habitat, the habitat models performed exceptionally well. Apparently, model power was large enough to detect relationships even within the upper range of habitat utility values (0.8–1.0). Therefore, I conclude that the 2 models were effective in predicting black bear habitat use at their respective scales. Furthermore, the telemetry error analyses indicated that the models were robust with regard to the effects of telemetry error. Although telemetry error was relatively large, the 95% confidence intervals of parameter estimates overlapped substantially for all variables.

As with logistic regression, parameter estimates for categorical variables indicate the contribution of a variable class on habitat selection (relative to a reference group), with positive parameters indicating selection of resources, whereas negative parameters represent resources that were selected less than expected (van Manen and Pelton 1996). Parameter estimates for continuous variables represent the effect of a unit change in the measurement scale (e.g., a 1-km change in road density). I incorporated several choice set attributes (season, year, sex, and age) in the analysis as interaction terms. Because all interaction effects were binary, parameter estimates are easily interpreted. For example, in the 1-km^2 model, the parameter estimate for male use of bottomland hardwoods was -0.477; the interaction term indicated that males used bottomland hardwoods less than females, reducing the original parameter estimate by 0.477. When calculating the model equation for females, the original parameter estimate applies because the interaction term would be 0.

Resource selection varied depending on the spatial analysis scale. Although the importance of variables was relatively consistent for both models, parameters were more significant ($P < 0.001$) in the 7-km^2 model. In addition, bears selected areas with greater diversity of land-cover types only at the larger scale. Selection for land-cover diversity may have been difficult to detect at the smaller scale because of the existence of large homogeneous areas that often were >1 km^2 (Fig. 14).

My results on land-cover diversity agree with those reported by Lindzey and Meslow (1977), who found that smaller black bear home ranges were associated with greater habitat richness in Washington. Studies in Arkansas (Clark et al. 1993) and Tennessee (van Manen and Pelton 1997) also indicated the importance of land-cover diversity for black bear habitat selection. In some Coastal Plain areas, bear densities are extremely high and home ranges are relatively small in part because of high land-cover diversity associated with the interspersion of bottomland hardwoods, managed pine forests, and agriculture (Martorello 1998, Beausoleil 1999, Thompson 2003).

Although all variables affected habitat utility estimates, land-cover was the most influential variable in both habitat models. The low use of open land cover types is consistent with findings from other studies: such areas provide limited or no vertical structure and typically have little value for black bears (Schooley et al. 1994, Stratman 1998). Although agriculture was included in open areas, the edges of agricultural fields were used by bears to feed on corn or milo. I recorded few locations in agricultural cover probably because bears spent only enough time in crop fields to forage before returning to the security cover of nearby forests (Marchinton 1995, Allen 1999).

Allen (1999) suggested that bear use of pine forests surrounding crop fields likely inflates the importance of pine in a habitat analysis. However, most pine stands in my study area were not adjacent to agricultural crops. Therefore, pine use likely was due in part to the abundance of this cover type in the study area (45%) and food resources associated with pine. For example, galberry bushes often occurred in pine understory. Based on scat contents, galberry fruits were frequently consumed by bears during summer and fall.

Unlike other areas in the Southeast, hard mast was not a primary food source for bears on the GSRA; out of 200 scats I examined, only 1 contained hard mast remains. Vegetation types with hard-mast producing trees were rare on the study area (hardwoods = 5% and mixed forests = 7%) and bears did not exhibit any selection for those vegetation types at either analysis scale.

Bottomland hardwoods exerted the greatest positive influence on bear habitat selection, followed closely by pocosin. Bottomland hardwoods provide abundant spring and fall food sources. In spring, bears forage for grasses and forbs in these forested wetlands (Hamilton and Marchinton 1980). In late summer and fall, bears on the GSRA relied heavily on fruits of black gum. Black gum mast is an important food source for bears in the Coastal Plain. Brandenburg (1996) reported that fall movements on Mainside Camp Lejeune seemed to be driven by use of areas with abundant black gum mast. Bottomland hardwoods also provide security and travel cover for bears. Bears use riparian corridors as narrow as 10 m for traveling through suboptimal habitats (Stratman 1998, Beausoleil 1999). Bottomland hardwoods connect the GSRA with several adjacent areas. During the fall of 2000, male 09 and female 77 used bottomland hardwood corridors to travel into the eastern portion of Holly Shelter Game Lands, west of the GSRA. Although bottomland hardwoods likely are important as travel corridors for both females and males, female selection for this vegetation type was greater possibly because it also provides excellent security cover. Females may increase reproductive fitness by ensuring their survival and that of their offspring, which requires more emphasis on security cover. In contrast, males may increase reproductive fitness by increasing mating opportunities, resulting in a lower dependence on security cover.

Bears use pocosin for denning, security cover, and food resources (Landers et al. 1979, Hellgren et al. 1991, Lombardo 1993, Brandenburg 1996, Jones 1996, Martorello 1998, Allen 1999). Landers et al. (1979) found that pocosin provided various food items from June through September, which coincided with periods of high use of this vegetation type on the GSRA. In summer, the majority of bear scats on the GSRA contained galberry fruits. Large galberry (*Ilex coriacea*) and greenbrier fruits were prevalent in pocosin areas and road margins through pocosins had abundant blackberry (*Rubus allegheniensis*) and pokeberry (*Phytolacca americana*) production during late summer. Pocosin also provides spring foods in the form of sweetbay (*Magnolia virginiana*) and greenbrier (*Smilax* spp.) stems and leaves (Hellgren and Vaughn 1988); I observed several scats along pocosin roads with greenbrier leaves and berries.

Pocosin habitats are preferred for den sites throughout the southeastern Coastal Plain (Hamilton and Marchinton 1980, Hellgren et al. 1991, Folta 1998, Martorello 1998), including Camp Lejeune (Lombardo 1993). The low, dense canopy in pocosin habitats provides important security and thermal cover for ground-denning females. Although I did not investigate den sites during my study, all bears that were sedentary during the winter months were located in pocosin habitats.

The GSRA contains relatively large areas of contiguous pocosin habitat compared with most areas in eastern North Carolina. The habitat utility map based on the 7-km^2 choice-set model indicated that the interior of the large pocosin tracts had lower habitat utility values than the peripheral areas. Although large pocosin tracts were relatively inaccessible for trapping and telemetry, bears were located in the interior pocosin (Fig. 12–13), therefore, no location bias was evident. I speculate that the lower utility value of the interior pocosin was a result of the lower land-cover diversity associated with those areas. Bears using interior pocosin likely would also need adjacent habitats to acquire additional resources. Further evidence for this explanation is provided by the analysis of interaction effects. Subadults may use pocosins more than adults because they may be more dependent on security cover afforded by pocosin habitats. In addition, adult use of the prime habitats with greater land-cover diversity relegates subadults into habitats of somewhat lower quality and habitats that afford better security cover, such as the 2 large pocosin tracts on the GSRA (Fig. 14).

Prior to my study, a quantitative analysis of black bear responses to military activity had not been conducted. Most inference of such responses was based on largely anecdotal information (Lombardo 1993, Brandenburg 1996, Stratman 1998). Based on the results of my study, bears seemed to avoid areas near firing ranges, but that avoidance was a consequence of the open land-cover type associated with the firing ranges rather than firing range activity. Thus, I conclude that firing range activities per se did not have a measurable effect on black bear habitat selection. Bears are extremely adaptable animals and may quickly learn based on experience that the noise associated with weapons firing has no consequence. In fact, I often observed bears near active firing ranges with radiotelemetry signals that indicated no bear movement, suggesting that they were undisturbed by the military activity. These findings are consistent with those reported by Stratman (1998), who suggested that bears at Eglin Air Force Base were used to daily low-level flight training. Lombardo (1993) also indicated bears did not respond to daily military training operations on Mainside Camp Lejeune. However, Lombardo (1993) did suggest that bears react to major training operations that involved large numbers of troops. One large-scale operation was conducted on the GSRA during this study, consisting of air, amphibious, and ground training exercises for approximately 5,000 military personnel. Camp Lejeune Range Control restricted all non-military access to the GSRA during the 11-day operation, so I was not able to measure the influence of that exercise on bear movements. Because such large-scale operations occur infrequently, the effects on habitat selection may only be localized and temporary.

Burn history had a significant effect on bear habitat selection. Areas burned ≤1 year and within 2 to 5 years reduced habitat utility for bears on the GSRA, whereas bears selected for areas burned >5 years ago. Areas burned ≤1 year received low bear use in Florida, likely because of low food production (Stratman 1998). Prescribed burning on GSRA was conducted primarily in pine stands, and may affect galberry fruit production in the understory of these stands. Johnson and Landers (1978) found that galberry fruit production was high in stands were fire occurred on a cycle of 3 years or more. In addition, Lewis and Harshbarger (1976) did not find a significant difference in the average crown size of galberry between unburned control stands and stands burned periodically in summer. These 2 studies indicate that galberry can be productive in stands with burn cycles close to 5 years or more. Thus, selection of older burn areas may be a function of food availability.

I was unable to analyze the effects of forest management on black bear habitat selection. Pine and bottomland hardwoods were the most abundant forest cover types in the study area. Pine was the predominant managed forest type; however, the majority (72%) of all pines were in the growth class (Appendix F). Almost all bottomland hardwoods (>88%) were in the mature class (Appendix F). Thus, the majority of both telemetry and random locations tended to be in 1 management class for each forest type because of a lack of availability of multiple forest management classes within the choice sets. As such, use comparisons among the 3 classes were not appropriate.

The density of paved roads had a strong influence on black bear habitat use at both spatial scales. On Mainside Camp Lejeuene, bears crossed paved roads and used areas near these roads less than randomly expected, thereby reducing available habitat (Brandenburg 1996). In the southern Appalachian mountains, paved road densities >0.5 km/km^2 begin to cause bears to shift their home ranges to avoid these roads (Brody 1984). Habitat values in my study area were lowest in areas where paved road densities were above this threshold. On Mainside Camp Lejeune, bear mortality due to vehicle collisions accounted for approximately 70% of overall mortality (Lombardo 1993, Brandenburg 1996). Density of paved roads on GSRA is much lower than on Mainside Camp Lejeune. However, mortality due to vehicle collisions is still relatively high because of busy highways bordering the GSRA. Of the 14 documented bear mortalities in and around GSRA that were documented during my study, 5 were attributed to vehicle collisions along those border roads. In a situation similar to GSRA, Hellgren and Vaughan (1989) reported no vehicle-related bear mortality on Great Dismal Swamp National Wildlife Refuge, but several bears were killed on surrounding highways.

Large areas of high-utility habitats are available to the GSRA black bear population. Federal ownership of the large tracts of bottomland hardwoods and pocosin habitats offer a de facto sanctuary for bears in an increasingly developed landscape. However, black bears tracked in this study used surrounding areas as well as the GSRA, indicating that bear management on the GSRA is partially dependent on land use and management practices outside the GSRA. The maintenance of bottomland hardwoods, for example, would be critical to provide secure corridors for movement between the GSRA and adjacent areas. While development of training areas on the GSRA could be planned to minimize disturbance of bottomland hardwoods, cooperative partnerships between private landowners could be necessary to secure these critical habitats.

CHAPTER VI

MANAGEMENT IMPLICATIONS

The results of my analysis indicate that live-weapons firing can be compatible with management of habitats that are highly selected by black bears. Although the level of firing range activity did not influence bear habitat use, placement of firing ranges on the landscape can affect habitat quality because bears generally avoided these open areas. If maintenance of bear habitat is a management goal for the GSRA, the placement of additional training areas should be considered; for example, placement in upland habitat types (i.e., pine or mixed forest) would have a lower impact on bears than placement in bottomland hardwoods. A second consideration is related to the management of firing range buffer zones. Buffer zones around firing ranges are maintained to reduce the risk of wildfire spreading into the large pocosin tracts or other surrounding areas. The altered hydrology and fire suppression in pocosin areas on the GSRA has created the potential of elevated wildfire danger (LeBlonde 1997). Current ditches in pocosin could be filled to restore the water table and allow pocosin to return to a more natural state. Once water saturation levels are restored, prescribed burns could be initiated to promote natural disturbance regimes (T. A. Jenkins, Pocosin Lakes National Wildlife Refuge, personal communication). Such actions would lower the wildfire potential without the need for additional clearings around training areas.

I could not analyze the effects of forest management on bear habitat use. However, in general, current forest management policy on Camp Lejeune seems to be beneficial for bear habitat. Silvicultural treatments, such as seed tree and shelterwood cuts, open the forest canopy to allow for increased soft mast production (Hillman and Yow 1986, Lombardo 1993, Brandenburg 1996, U.S. Marine Corps Base Camp Lejeune 2000). Timber harvest in bottomland hardwoods currently is prohibited to protect fragile soils, so the majority of bottomland hardwoods are in a mature stage, producing important bear foods (e.g., black gum fruits). Management for greater land-cover diversity could be accomplished by increasing the amount of hardwood and mixed forests in uplands where homogeneous pine stands currently exist. Increasing the amount of hardwoods on Camp Lejeune would also increase hard mast production, which is currently lacking on the GSRA. Because selection for land-cover diversity occurred at a relatively large scale (7 km^2), the optimum management of land-cover diversity would be at the timber compartment (mean area = 4 km^2), rather than timber stand (mean area = 0.2 km^2) scale.

As a relatively easy integration into the current prescribed burning schedule, pine stands on the GSRA could be extended from the current 1–5 year burn cycle to a 1–7 year burn cycle. That longer interval would better simulate natural disturbance regimes (LeBlonde 1997), while providing longer period between burns to favor galberry and better protect hard mast producing trees (Hamilton 1981). In addition, the size of prescribed burn may be reduced to limit large expanses of lower-utility habitats. Bottomland hardwoods are not fire-adapted ecosystems, therefore prescribed burns should be excluded from these areas (LeBlonde 1997).

I selected paved roads for my analyses because they receive greater traffic volume than unimproved roads. Although paved roads adjacent to the GSRA affect bear habitat use, the current level of traffic on the GSRA is minimal and likely does not affect habitat quality. However, if traffic on gravel roads on the GSRA increases substantially because of changing military activities, black bear habitat use may change in response.

During my study, little military training activity occurred outside of the firing ranges in the eastern and central portions of the GSRA (Appendix C), leaving large areas of the GSRA relatively undisturbed. Therefore, the placement of additional firing ranges on the landscape could change the quality and distribution of bear habitats on the GSRA. For example, a new firing range has been proposed within 1 km west of the SR6 firing range. The impacts of this new range on black bear habitat would be minimal. The location is in upland forest in an area with high burn frequency. In addition, the close proximity of the SR6 range would minimize the area of increased vehicle traffic and the interspersion of open land-cover types. The habitat selection models can be used to examine the potential effects of such land use changes on black bear habitat values. I simulated 3 changes to conditions existing on the GSRA during my study (simulation areas 1–3, Fig. 21). I examined the changes that could occur with the addition of a firing range along the western border of the GSRA in simulation area 2. I changed 73.7 ha of pine, 20.2 ha of bottomland hardwood, and 7.0 ha of open areas to 101.0 ha of open cover to simulate the effect of a new firing range on the landscape. I also assumed this new firing range would cause an increase in vehicle traffic along the gravel road through the center of the GSRA. Therefore, I changed this road from gravel to paved in the model (simulation area 3). I also changed 193.3 ha in the northwestern corner of the GSRA (simulation area 1) from a burn frequency between 2 to 5 years to a longer (>5 year) interval.

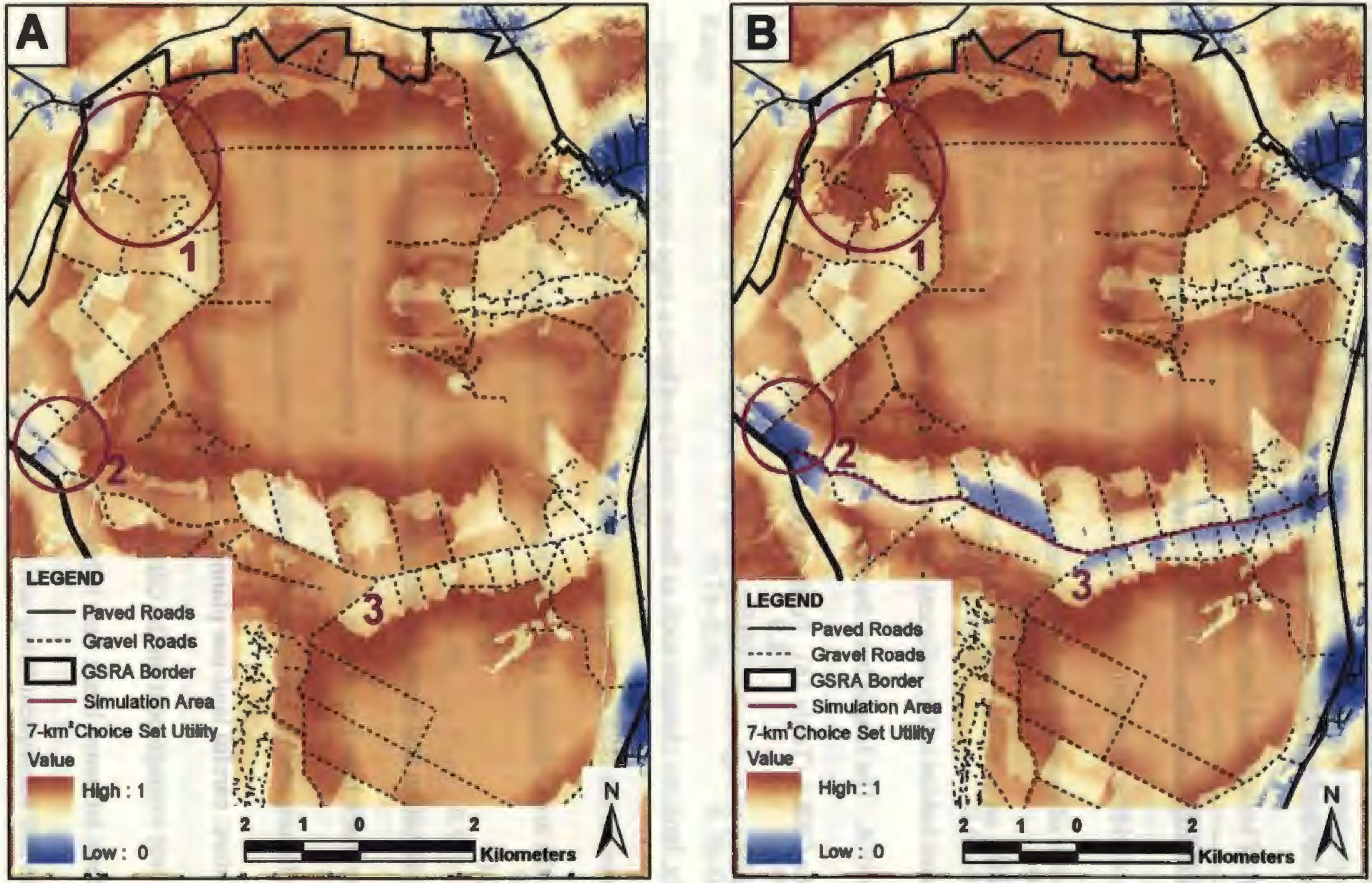

Figure 21. Habitat utility values for habitat conditions during this study (A) and with 3 simulated land use changes (B) based on discrete choice analysis of black bear habitat use in 7-km²choice sets, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000-2001.

The location of the simulated firing range decreased the habitat values among high-utility bottomland hardwood habitats. The firing range could also disrupt the use of this section of bottomland hardwoods as a travel corridor for movements into adjacent areas. The change in traffic volume decreased habitat values across the central portion of the GSRA, dividing high-utility habitats north and south of the road (Table 16). Because of the position of those habitats with greater utility, road crossings would frequently occur, creating an increased risk of vehicle-related mortality. In addition, the road links areas of lower habitat utility adjacent to the GSRA, effectively separating northern and southern GSRA. The longer burn frequency increased habitat values in the northeastern corner of the GSRA (Table 16). Furthermore, this change in values extended the contiguous area of high-utility habitat along the northern border of the GSRA. Individually, land use changes such as these would not have a large impact on overall habitat values on the GSRA. However, as habitat changes occur more frequently throughout the area, changes in habitat values would begin to influence the black bear population.

Conservation and management of pocosin and bottomland hardwoods is crucial to maintain the black bear population on the GSRA. Infrastructure development, increases in traffic volumes, and development in surrounding areas are likely to affect bear habitat use in the future; careful land-use planning and consideration of these factors will be critical for bear management on the GSRA. Although current levels of firing range activity did not influence black bear habitat use, substantial increases in the number of firing ranges and subsequent firing activities would require further examination to determine the effects on bear habitat use.

Table 16. Habitat utility values for habitat conditions during this study (current) compared with 3 simulated land use changes based on discrete choice analysis of black bear habitat use in 7-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Simulation	Current	Simulation
Paved road (260 m buffer)		
Area = 559.2 ha		
Mean	0.89	0.81
Standard Error	<0.001	<0.001
Range	0.74–0.98	0.67–0.92
Firing range		
Area = 100.8 ha		
Mean	0.85	0.76
Standard Error	<0.001	<0.001
Range	0.74–0.94	0.70–0.88
Burn frequency		
Area = 193.3 ha		
Mean	0.92	0.98
Standard Error	<0.001	<0.001
Range	0.85–1.00	0.91–1.00

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APPENDICES

Appendix A. Tree species identified by the Camp Lejeune Forestry Section, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina (from U.S. Marine Corps Base Camp Lejeune 2000).

Table A.1. Tree species identified by the Camp Lejeune Forestry Section, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina (from U.S. Marine Corps Base Camp Lejeune 2000).

Hardwoods **Common name**	**Scientific name**
Black cherry	*Prunus serotina*
Black gum	*Nyssa sylvatica*
Elm	*Ulmus spp.*
Red maple	*Acer rubrum*
Sweet gum	*Liquidambar styraciflua*
Sycamore	*Platanus occidentalis*
Water tupelo	*Nyssa aquatica*
Yellow poplar	*Liriodendron tulipifera*
Ash	*Fraxinus spp.*
Birch	*Betula spp.*
Hickory	*Carya spp.*
Black oak	*Quercus velutina*
Laurel oak	*Quercus laurifolia*
Northern red oak	*Quercus rubra*
Scarlet oak	*Quercus coccinea*
Southern red oak	*Quercus falcata*
Shumard oak	*Quercus shumardii*
Water oak	*Quercus nigra*
White oak	*Quercus alba*
Willow oak	*Quercus phellos*

Softwoods **Common name**	**Scientific name**
Loblolly pine	*Pinus taeda*
Longleaf pine	*Pinus palustrus*
Pond pine	*Pinus serotina*
Shortleaf pine	*Pinus echinata*
Slash pine	*Pinus elliottii*
Atlantic white cedar	*Thuja occidentalis*
Bald cypress	*Taxodium distichum*
Pond cypress	*Taxodium distichum nutans*
Red cedar	*Juniperus* spp.

Appendix B. Stand types identified by Great Eastern Timber Company or the Camp Lejeune Forestry Section, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, Onslow County, North Carolina.

Table B.1. Stand types identified by Great Eastern Timber Company or the Camp Lejeune Forestry Section, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, Onslow County, North Carolina.

Species code	Description	Number of Stands	Hectares
0000	Misc-Misc [a]	120	1,582.66
0100	Longleaf-Filler	89	1,078.71
0103	Longleaf-Loblolly	12	110.47
0104	Longleaf-Pond	14	201.48
0117	Longleaf-Maple	1	4.27
0200	Slash-Filler	27	529.53
0203	Slash-Loblolly	6	59.15
0204	Slash-Pond	1	33.27
0217	Slash-Maple	2	14.98
0300	Loblolly-Filler	348	5,712.74
0301	Loblolly-Longleaf	8	193.09
0302	Loblolly-Slash	6	77.76
0304	Loblolly-Pond	11	139.92
0311	Loblolly-Poplar	2	5.55
0312	Loblolly-Sweetgum	5	54.70
0314	Loblolly-Red oak	5	86.53
0317	Loblolly-Maple	8	92.92
0319	Loblolly-Misc [b]	35	541.15
0400	Pond-Filler	37	803.51
0401	Pond-Longleaf	4	48.98
0402	Pond-Slash	2	77.40
0403	Pond-Loblolly	8	117.04
0417	Pond-Maple	3	28.04
0419	Pond-Misc [b]	27	1,058.20
0619	Cypress-Misc [b]	1	2.47
1119	Poplar-Misc [b]	1	14.70
1217	Sweetgum-Maple	3	44.11
1319	White oak-Misc [b]	6	53.84
1403	Red oak-Loblolly	1	0.61
1413	Red oak-White oak	1	27.76
1419	Red oak-Misc [b]	10	182.50
1619	Beech-Misc [b]	1	69.40
1700	Maple-Filler	13	280.93
1701	Maple-Longleaf	4	63.53
1703	Maple-Loblolly	6	269.46

Table B.1 (Continued).

Species code	Description	Number of Stands	Hectares
1704	Maple-Pond	1	1.92
1712	Maple-Sweetgum	4	26.43
1718	Maple-Blackgum	1	72.97
1719	Maple-Misc [b]	56	2,909.84
1800	Blackgum-Filler	3	125.19
1812	Blackgum-Sweetgum	2	6.54
1817	Blackgum-Maple	18	884.64
1819	Blackgum-Misc [b]	22	547.53
1900	Misc [b]-Filler	24	879.34
1903	Misc [b]-Loblolly	11	184.37
1904	Misc [b]-Pond	4	70.00
1912	Misc [b]-Sweetgum	1	51.35
1913	Misc [b]-White oak	1	2.01
1914	Misc [b]-Red oak	1	21.35
1917	Misc [b]-Maple	1	0.37
1918	Misc [b]-Blackgum	3	79.68
GETCO 1	Loblolly pine	143	3,624.49
GETCO 2	Slash pine	13	266.28
GETCO 3	Pond pine	1	8.90
GETCO 4	Soft hardwoods[c]	15	626.45
GETCO 5	Hard hardwoods[d]	1	9.31
	Total	1,150	24,231.00

[a] The Misc-Misc category represents all non-forested stands.
[b] A single Misc in the species code indicates that a combination of several hardwood species dominate either the primary or secondary canopy as a group.
[c] i.e., sweetgum and red maple.
[d] i.e., oak and hickory.

Appendix C. Limits of advance maps for research access when live-weapons firing ranges were active, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina.

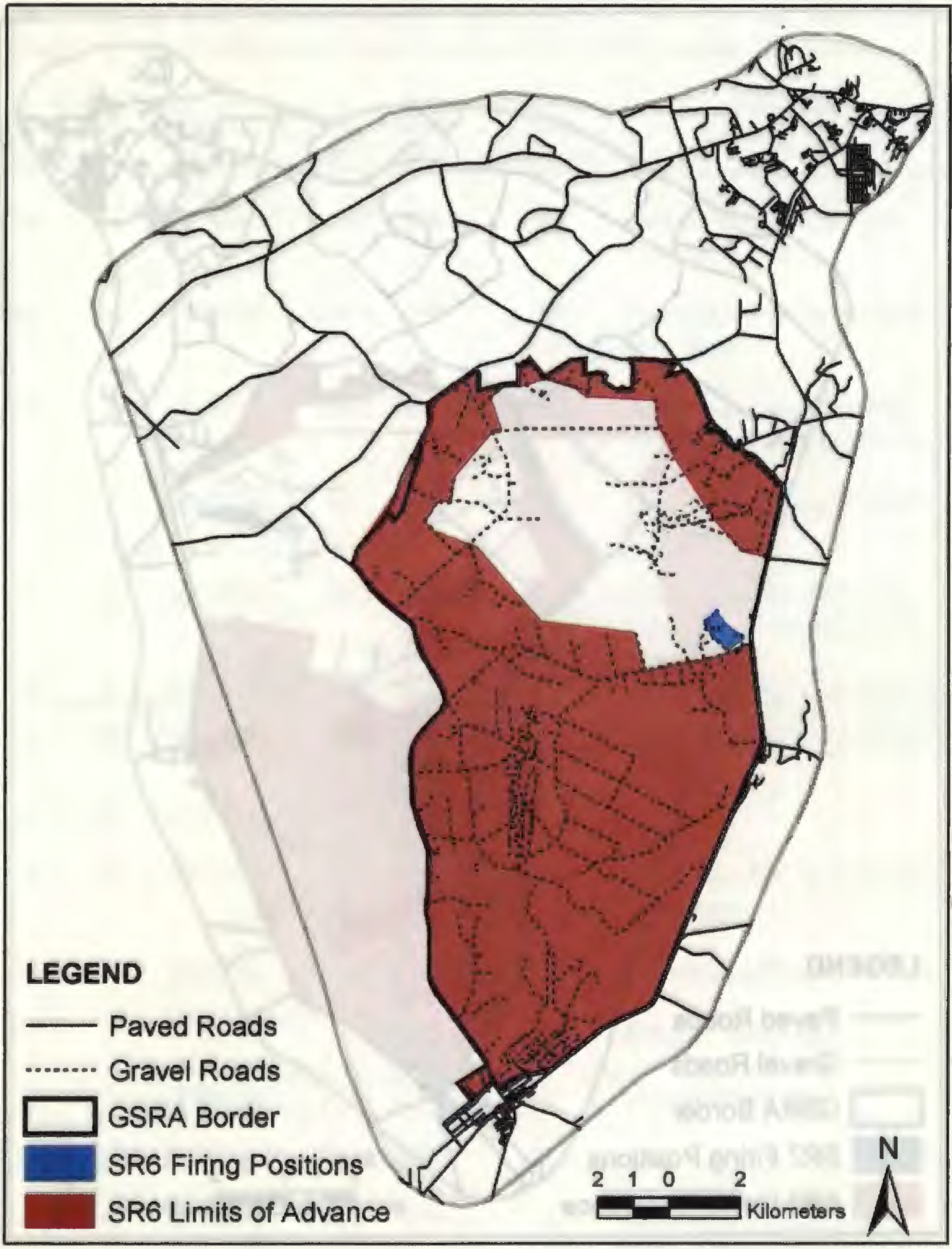

Figure C.1. Limits of advance map for research access when SR-6 live-weapons firing range was active, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

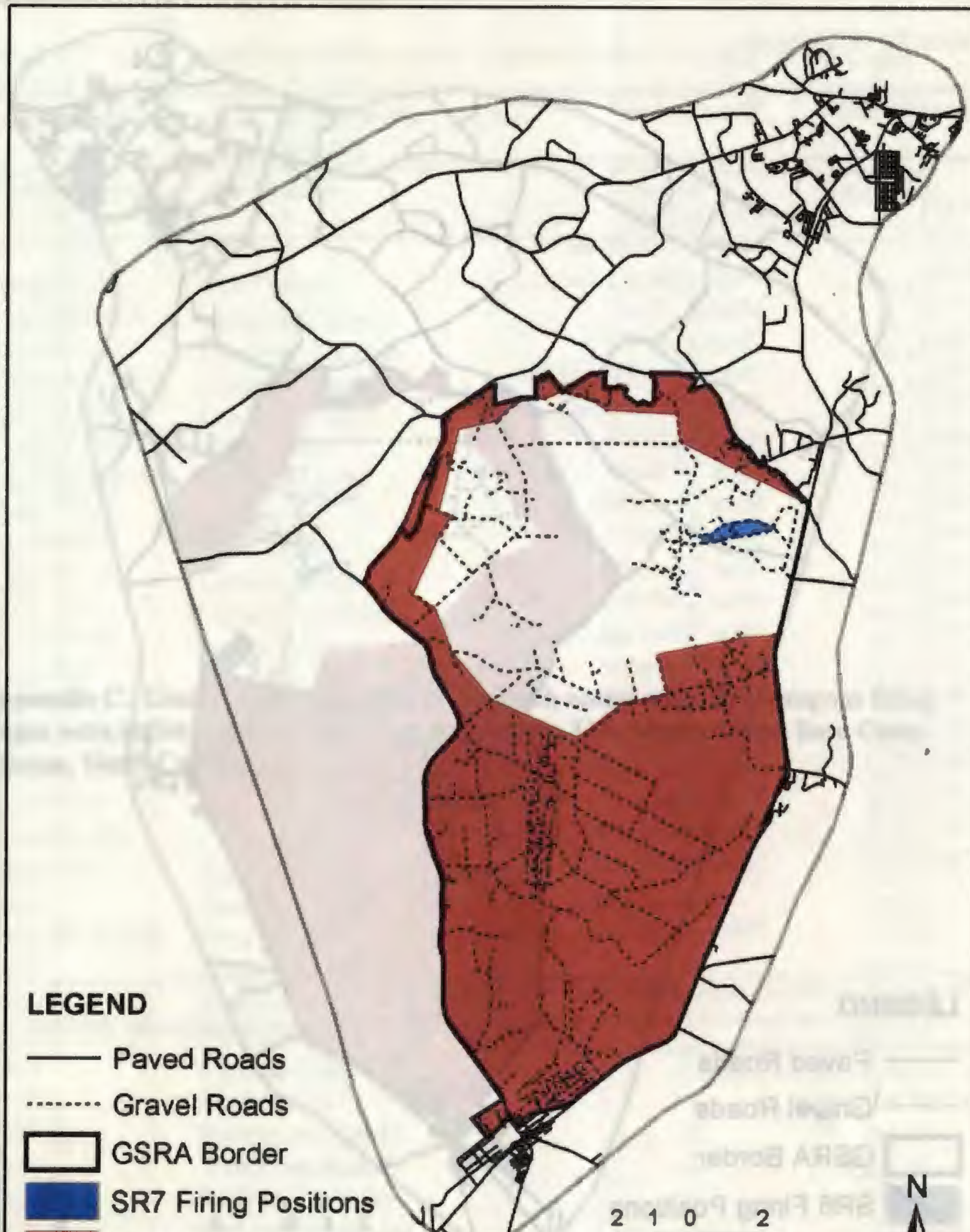

Figure C.2. Limits of advance map for research access when SR-7 live-weapons firing range was active, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

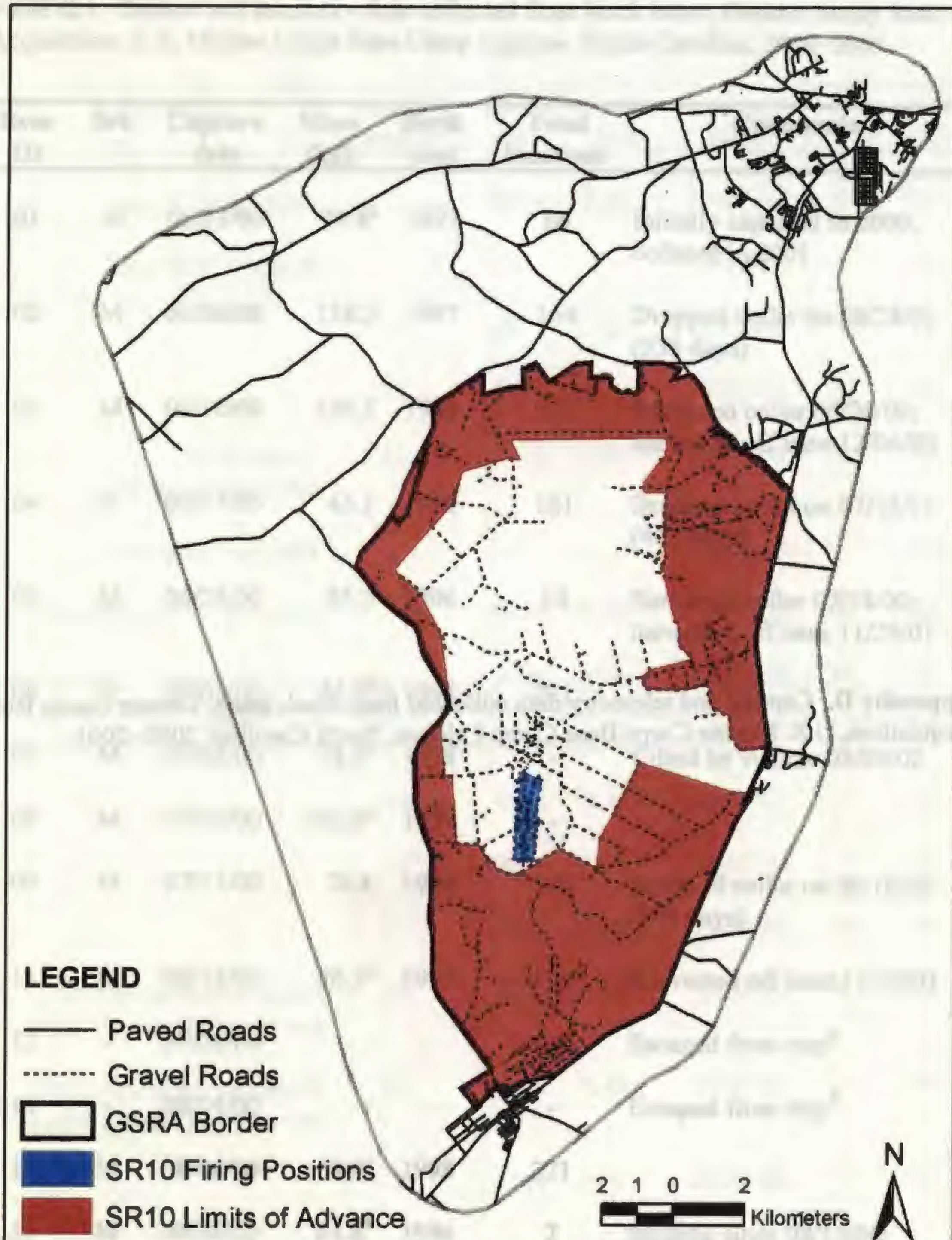

Figure C.3. Limits of advance map for research access when SR-10 live-weapons firing range was active, Greater Sandy Run Acquisition (GSRA), U.S. Marine Corps Base Camp Lejeune, North Carolina.

Appendix D. Capture and telemetry data collected from black bears, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Table D.1. Capture and telemetry data collected from black bears, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Bear ID	Sex	Capture date	Mass (kg)	Birth year	Total locations	Comments
01	M	06/03/00	79.4[a]	1997	86	Initially captured in 2000, collared in 2001
02	M	06/06/00	138.3	1997	164	Dropped collar on 08/28/01 (335 days)
03	M	06/10/00	120.2	1995	12	Removed collar 06/20/00; harvested off base 12/06/00
04	F	06/17/00	43.1	1998	161	Dropped collar on 07/16/01 (442 days)
05	M	06/25/00	95.3	1996	14	Removed collar 07/18/00; harvested off base 11/29/01
06	F	07/05/00	57.2[a]	1994	221	
07	M	07/05/00	78.5[a]	1998	-	Killed by vehicle 08/09/02
08	M	07/07/00	106.6[a]	1997	-	
09	M	07/15/00	74.8	1996	104	Dropped collar on 06/16/01 (394 days)
11	M	08/13/00	86.2[a]	1995	196	Harvested off base 11/30/01
12	-	07/20/00	-	-	-	Escaped from trap[b]
13	-	08/04/00	-	-	-	Escaped from trap[b]
14	M	08/06/00	68.0[c]	1998	221	
16	M	08/08/00	84.8[a]	1996	2	Missing since 08/15/00; collar found 08/05/02
18	M	08/16/00	113.4[a]	1995	203	

Table D.1 (Continued).

Bear ID	Sex	Capture Date	Mass (kg)	Birth Year	Total Locations	Comments
19	F	06/20/01	40.8[c]	1996	-	Found dead in trap
20	-	06/21/01	-	-	-	Escaped from trap[b]
21	F	06/25/01	43.1	1996	97	
22	F	06/29/01	47.6	1999	92	
23	F	07/02/01	43.1	1995	21	Found dead; last location 08/22/01
24	-	07/05/01	-	-	-	Escaped from trap[b]
25	M	07/06/01	53.5[a]	1999	-	Killed by vehicle 08/04/01
26	M	07/24/01	47.6	2000	-	
27	M	07/28/01	93.0	1997	-	
28	F	07/30/01	53.5[a]	1993	80	
29	F	07/31/01	52.2	1998	92	
30	F	08/05/01	68.0[a]	1997	78	
62	F	07/02/01	65.8	1989	38	Removed collar 09/17/01; harvested off base 11/12/01
64	M	08/06/00	149.2[a]	1993	20	Removed collar 10/12/00; harvested off base 11/21/01
77	F	08/16/00	49.9	1993	197	

[a] Calculated with mass equation (T. Eason and F. van Manen, University of Tennessee, unpublished data)
[b] Evidence at trap site indicated bear was captured but escaped before researchers arrived.
[c] Estimated by field observers; weighing and measurements not possible due to injury.

Appendix E. Seasonal and annual home range estimates (km^2; 95% probability fixed kernel) and sample sizes of locations (*n*) for black bears, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000–2001.

Table E.1. Seasonal and annual home range estimates (km^2; 95% probability fixed kernel) and sample sizes of locations (n) for black bears, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2000.

Bear ID	Sex	Spring		Summer		Fall		Annual	
		Home range	*n*	Home range	*n*	Home range	*n*	Home range	*n*
02	M	-	8	30.0	34	17.7	54	32.1	99
04	F	-	0	10.3	38	6.9	54	8.6	92
06	F	-	0	9.3	20	20.6	54	20.2	74
09	M	-	0	43.6	16	37.7	37	46.3	53
11	M	-	0	-	9	27.3	51	25.6	60
14	M	-	0	-	9	7.8	52	8.2	61
18	M	-	0	-	7	7.7	54	9.6	61
77	F	-	0	-	8	56.8	49	52.4	57
Avg	M	-	8	36.8	25	19.6	43	24.4	59
Avg	F	-	-	9.8	22	28.1	52	27.1	74

Table E.2. Seasonal and annual home range estimates (km^2; 95% probability fixed kernel) and sample sizes of locations (*n*) for black bears, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejeune, North Carolina, 2001.

Bear ID	Sex	Spring		Summer		Fall		Annual	
		Home range	*n*	Home range	n	Home range	*n*	Home range	*n*
01	M	-	0	18.0	26	27.3	60	20.9	86
02	M	71.3	38	76.9	24	-	0	79.1	64
04	F	8.7	52	3.4	15	-	0	10.1	69
06	F	6.7	48	14.0	37	19.8	60	16.1	147
09	M	14.3	48	-	0	-	0	15.1	51
11	M	24.5	46	32.2	36	23.7	52	101.9	136
14	M	29.4	47	12.4	33	7.7	72	18.5	154
18	M	144.0	48	20.1	31	5.9	61	51.8	142
21	F	-	0	12.5	38	52.3	60	34.5	97
22	F	-	0	12.3	37	40.5	55	35.9	92
23	F	-	0	6.9	21	-	0	-	21
28	F	-	0	13.2	21	34.9	60	34.5	81
29	F	-	0	8.9	23	7.6	69	9.6	92
30	F	-	0	7.1	20	8.4	58	7.8	78
62	F	-	0	24.0	36	-	2	23.0	38
77	F	4.6	49	10.6	36	77.9	53	20.4	140
Avg	M	56.7	45	31.9	30	16.2	61	47.9	106
Avg	F	6.7	50	11.3	28	34.5	61	21.3	86

Appendix F. Availability of forest land-cover types with corresponding forest management classes in the 1-km^2 and 7-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejuene, North Carolina.

Table F.1. Availability of forest land-cover types with corresponding forest management classes in the 1-km^2 and 7-km^2 choice sets, Greater Sandy Run Acquisition, U.S. Marine Corps Base Camp Lejuene, North Carolina.

Variable	Regeneration		Growth		Mature	
	ha	%	ha	%	ha	%
1-km^2						
Pine	870.4	17	3,712.4	72	592.2	11
Pine-hardwood mix	13.5	2	418.2	70	164.3	28
Hardwood	24.4	7	286.2	78	56.5	15
Bottomland hardwood	12.4	1	175.3	10	1,577.3	89
7-km^2						
Pine	1,596.8	18	6,453.1	72	973.1	10
Pine-hardwood mix	69.9	7	648.8	63	313.9	30
Hardwood	42.7	5	530.9	66	225.8	29
Bottomland hardwood	12.4	<1	240.5	10	2,242.5	90

VITA

David Joseph Telesco was born in Succasunna, New Jersey in 1973. He graduated from Roxbury High School in Succasunna in 1992. He graduated with a Bachelor of Science degree in Forestry and Wildlife Resources with a minor in Biology from Virginia Tech University in Blacksburg, Virginia in 1996. After graduation, David worked for 4 years as a technician on different wildlife management and research projects before attending graduate school in 2000. He graduated with a Master of Science degree in Wildlife and Fisheries Science at The University of Tennessee in Knoxville, Tennessee in August 2003. David is married to Rebecca Lyn Telesco, and they reside in Louisville, Tennessee.