BALANCING WHITE-TAILED DEER ECOLOGY WITH MICHIGAN NATIONAL GUARD TRAINING AT FORT CUSTER TRAINING CENTER IN AUGUSTA, MI

By

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ABSTRACT

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The Michigan Department of Military and Veteran Affairs (MDMVA) manage an array of natural resources at Ft. Custer Training Center (FCTC) in Augusta, Michigan, and their Integrated Natural Resources Management Plan (INRMP) promulgates management goals of ecosystem restoration and rehabilitation. White-tailed deer (*Odocoileus virginianus*) herbivory can influence the forest structure and composition. The hunter harvest period of white-tailed deer of approximately 75 days (the length of the season is subject to some minor annual variations) cannot take place since the FCTC functions as a military installation and its' needs dictate limited access to hunters, confounding the MDMVA's ability to meet their management goals. I evaluated the effectiveness of the current 5-day hunter harvest period by quantifying deer herbivory effects on structure and composition of forest types, and developed a suite of deer population indices. I captured, aged, ear-tagged and radio-collared 66 deer during winter from 2004 to 2008, and 14 neonatal fawns during spring in 2006 and 2007. The annual survival rate varied among the groups (adult females = 0.756, adult males = 0.493, yearling females = 0.443, yearling males = 0.379, fawns = 0.289). The short hunter harvest period is an effective and integral component of the ecosystem restoration and rehabilitation efforts of FCTC.

In memory of my loving father,

Robert Earl Humphries

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CEQ	Council for environmental quality
CFR	Code of federal regulations
FCRA	Fort Custer Recreation Area
FCTC	Fort Custer Training Center
INRMP	Integrated natural resources management plan
MNFI	Michigan National Features Inventory
MDMVA	Michigan Department of Military and Veteran’s Affairs
MDNR	Michigan Department of Natural Resources
NEPA	National Environmental Policy Act
RDD	Relative deer density
USC	United States code
UXO	Unexploded ordinance

CHAPTER 1: INTRODUCTION

The Michigan Army National Guard base, Fort Custer Training Center (FCTC), in southwest Michigan functions as a training site for the Michigan National Guard, and other reserve components of the armed forces (Figure 1.1). Training exercises at FCTC include a variety of small arms, land navigation, light armor, and urban assault procedures, and an assortment of other tasks related to military preparedness. The Michigan Department of Military and Veterans Affairs (MDMVA) under license from the United States Army Corps of Engineers (USACE) is responsible for management of natural resources at FCTC which sits on 3,064 hectares. In accordance with a wide array of environmental laws and regulations, MDMVA has implemented the Integrated Natural Resources Management Plan and Environmental Assessment (INRMP) at FCTC. INRMP allows the Michigan National Guard (MING) to achieve the training standards set to ascertain the highest levels of military preparedness. Although it is not explicitly outlined in the INRMP, the white-tailed deer (*Odocoileus virginianus*) herd must be managed to allow the MDMVA to reach goals put forth in the INRMP.

Brief History and Site Description of Ft. Custer

Settlement of the land around FCTC began in the 1830's, converting the landscape to an agricultural landscape from oak-hickory (*Quercus spp.* and *Carya spp.*) hardwood forests, and prairie communities (Comer et al. 1995). With the onset of direct U.S. involvement in WWI the American government sought the establishment of an area suitable for training large numbers of soldiers. The U.S. government secured 3,359 hectares from private land holders to found FCTC and trained 36,000 "doughboys" (INRMP 2001). In 1940 the U.S. government expanded the FCTC to 5,827 hectares. After WWII the role of FCTC diminished, and in the late 1960's and 1970's portions of land were sold, decreasing its size to 3,064 hectares (INRMP 2001). However, the conversion from small farm homesteads to a military installation allowed large portions of the landscape to proceed through successional stages.

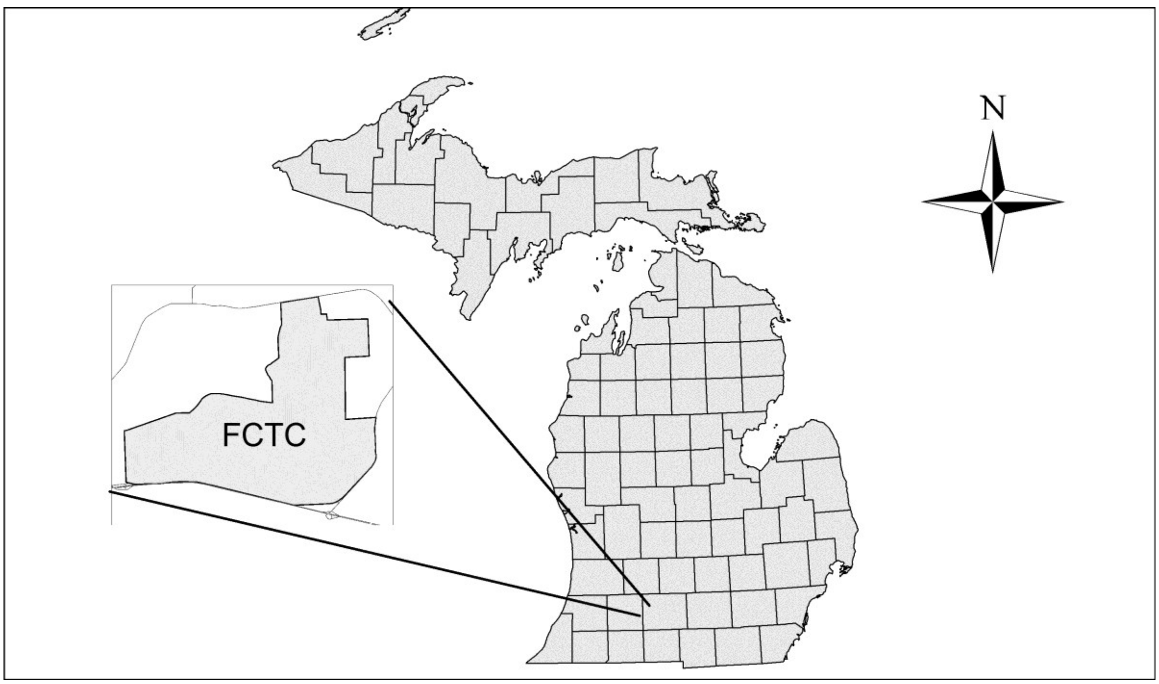

Figure 1.1. Location of Ft. Custer Training Center in southwest Michigan.

As of a 1998/1999 forest inventory at FCTC, 77% of the land occurs in some seral stage in one of the following forest types: mixed hardwoods, oak hardwoods, and mixed oak community (INRMP 2001). An additional 15% of the area at FCTC has been classified as wetlands and aquatic communities (Legge et al. 1995). The Michigan Natural Features Inventory (MNFI) conducted an intensive investigation of FCTC's flora and fauna. That resulted in the identification of 815 species of plants, which is roughly a third of the species found in Michigan (Herman et al. 1996). A total of 13 state listed or special concern plants were collected, and an additional 5 state listed or special concern plants were deemed likely to occur at FCTC (Legge et al. 1995). Interspersed across FCTC are 15 natural plant community types, 7 of which are identified by the MNFI as high quality rare communities because there is strong evidence of a high degree of native species richness and diversity (Legge et al. 1995). These high quality areas have been determined to also play a crucial role in preserving biotic diversity at regional and local scales, and four of the communities are considered rare globally (INRMP 2001).

For training purposes, FCTC has been subdivided into 9 sequentially numbered training areas (Figure 1.2). An additional 32-hectare cantonment area lies in the northern portion of the installation and contains the majority of the buildings. Areas 8 and 9 (combined = 1,059 hectares) are used for firing live rounds of ammunition of various small caliber weapons on fourteen different ranges. Areas 8 and 9 are also referred to as the *impact area* because live ammunition is fired in those areas. Area 9 is distinct from other areas because of the potential for UXO (unexploded ordinance), which limits access by FCTC personnel and members of the public. Area 6 has a clear-cut of 95 hectares referred to as the tank range that provides a place to conduct M1-A1 Abrams tank and other mechanized infantry training maneuvers (Figure 1.2). Natural resource management goals for the tank range include planting a variety of native prairie grasses and forbs that includes big bluestem (*Andropogon gerardii*) and switchgrass (*Panicum virgatum*). The north section of area 3 has several small clearings utilized as landing zones for helicopters. The remaining areas are used primarily by foot soldiers for other assorted operations, and bivouacking (INRMP, 2001).

The areas surrounding FCTC vary in landscape composition, but a large portion offers suitable habitat for white-tailed deer. The Fort Custer Recreation Area (FCRA) managed by the Michigan Department of Natural Resources and Environment (MDNRE) lies on FCTC's northwest perimeter, and was originally a part of FCTC until it was deeded to the State of Michigan in 1971. The 1,227 hectares of land that makes up FCRA is similar to FCTC with large contiguous tracts of closed canopy forests consisting of oak-hickory hardwoods, mixed hardwoods, and remnant prairie communities. On FCTC's eastern perimeter is the Ft. Custer Industrial Park, also once a part of FCTC. The industrial park encompasses 1,190 hectares of land that varies in levels of development. Approximately 243 hectares of the industrial park serves as a buffer to FCTC. It will not be developed, and has a combination of oak forest types, wetlands and aquatic areas. The remainder of the industrial park has a mixture of light

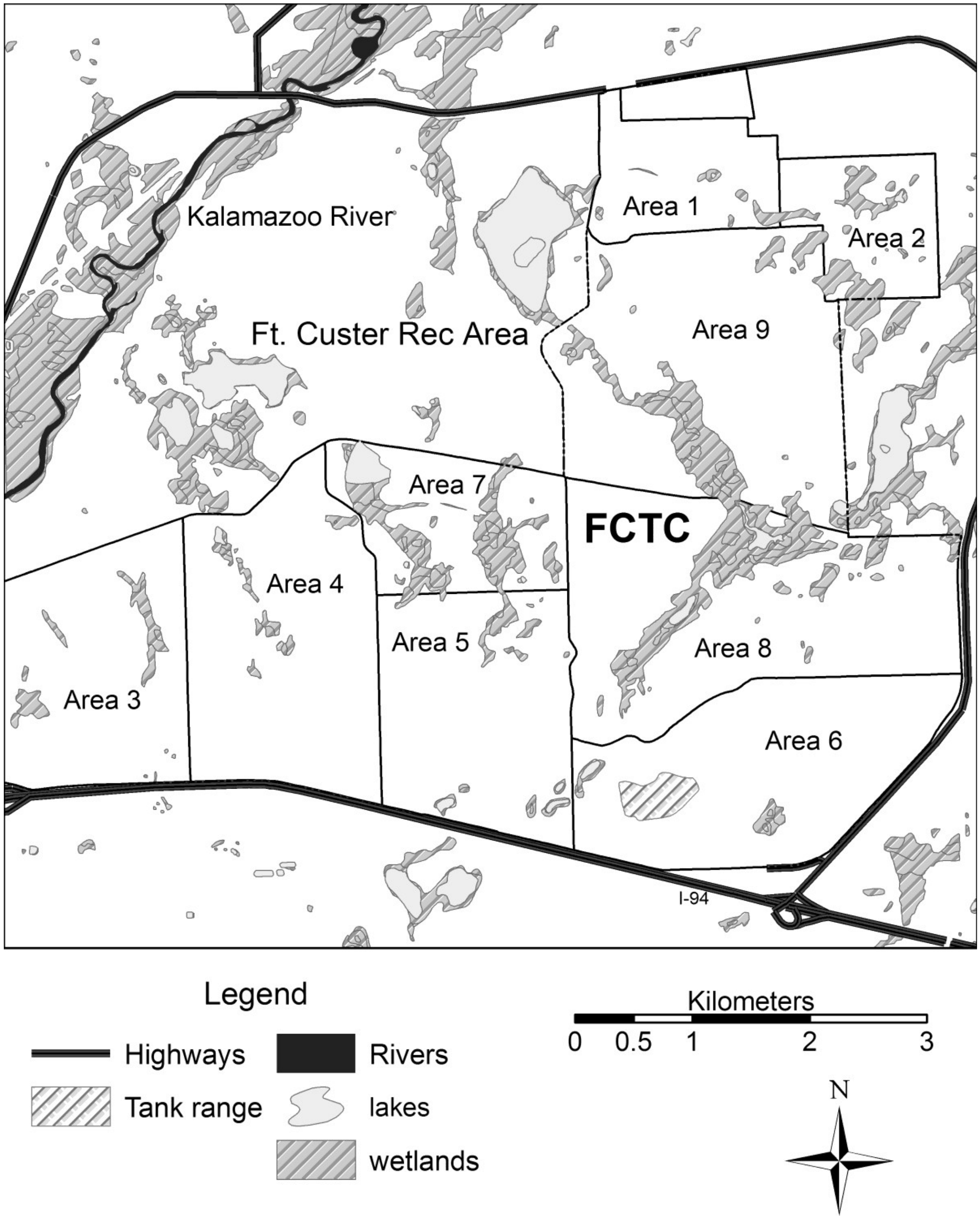

Figure 1.2. Layout of the 9 training areas at FCTC. The majority of buildings are shown in the cantonment zone north of area 1. Area 9 is off limits to the general public and hunting at all times because of the potential for UXO.

Industrial sites, wooded areas, oak openings, and wetlands. The south end of FCTC is bounded by I-94 and agricultural fields. The west border consists of a fragmented landscape with a low density residential area, small scale agricultural fields, small patches of woods, and the Kalamazoo River which has a corridor of lowland habitat. Immediately to the north of FCTC is the 253 hectares Fort Custer National Cemetery and Veterans Administration complex, which has a mixture of small patches of oak hardwoods (*Quercus spp.*) and large manicured grass openings. Battle Creek is the nearest developed city with its boundary 1.1 miles to the northeast of FCTC and a population of 53,364 (2000 U.S. Census). The Kalamazoo-Portage area has a population of 143,717 and lies 12 miles to the west of FCTC.

Historical Look at the FCTC Deer Herd

Deer hunting ceased in the early 1970s when FCTC implemented a limited public access policy for security. With no public access and no deer hunting on the grounds of FCTC, the deer herd reached or exceeded carrying capacity by the mid 1980s according to biologists with the Michigan Department of Natural Resources (in January 2010 the MDNR became the MDNRE). During a wetland survey in the mid 1980s at neighboring FCRA, numerous over-winter deaths of deer were observed around the area of Eagle Lake (Figure 1.2). Biologists with the MDNR concluded that the deer herd at FCTC was overabundant, and the over-winter deaths were a spillover effect. A hunt for National Guard service members was established in 1985 at FCTC in which field dressed half-year-old deer frequently weighed less than 50 pounds. This prompted the MDNR to further assess the situation. MDNR biologist John Lerg and several others noted an observable browse line in the hardwoods understory, deer trails that were rutted from a very high level of use and a dense population of deer. Lerg also observed a large number of emaciated deer at FCTC. These factors, along with pellet group counts led to an estimate of 60 deer per square mile on the grounds of FCTC (Lerg personal communication).

To address the issue of overabundance in the deer herd a public hunt was established in 1986 as a means to manage the herd. However, the number of days the public could access FCTC, since it is a military installation, was limited to five days. With the resumption of hunting the MDNR felt is was necessary to document the reduced weight in the young-of-the-year deer, and other body indices that are considered reliable indicators for the health of a deer herd (Lerg personal communication). All deer harvested at FCTC were subject to a mandatory deer check in which body weight, and hind leg length were recorded, in addition to the typical age, sex, beam diameter, and total points biodata gathered by the MDNR.

Antler characteristics such as beam diameter and number of points are correlated with the physical condition of a deer population (McCullough 1982, Severinghaus and Moen 1983, Rasmussen 1985). I compared the historical biodata from (1987-2004, the year prior to the onset the study) from FCTC and the counties that surround it (Kalamazoo and Calhoun), and other nearby counties with large amounts of closed canopy forest with similar cover types

(Barry and Allegan) to test for significant differences in indices of herd condition between FCTC and these four areas. I focused on the yearling age class to examine indices of herd condition because of the correlation of antler development and the added burden of body growth that requires sufficient food intake and nutrition (Moen and Severinghaus 1981, Harder and Kirkpatrick 1993). If resources are limited, this will be reflected in antler development and is especially apparent in yearlings (Severinghaus et al. 1950, Riney 1955, Rasmussen 1985). Yearlings with relatively large antler characteristics are indicative of a deer in good physical condition with resources readily available. The results of the deer biodata analysis prior to the onset of this study indicate the physical characteristics of yearlings at FCTC are significantly poorer than in the aforementioned areas. A summary of the results is provided in Appendix A.

The Impetus for Natural Management at FCTC

The foundation of the INRMP stems primarily from The Natural Resources Management Lands Act, Title 16 of the United States Code Section 670, commonly referred to as the Sikes Act; The National Environmental Policy Act of 1969 (NEPA) (42 U.S.C 4321 et seq.); and Natural Resource Management, Army Regulation 200-3. The Sikes Act dictates that military installations must initiate management plans to conserve and rehabilitate natural resources on military installations. The INRMP adheres to the regulations set forth in NEPA, in which the Council on Environmental Quality (CEQ) has established the key requirements in the Code of Federal Regulations (40 CFR, Parts 1500-1508).

The goal of NEPA is to ensure the restoration or enhancement of the environment through well informed decisions and lays out the basic principles to protect the countries' environment. As a result of being in line with NEPA and the Sikes Act, the INRMP natural resource objectives include rehabilitation and restorations of ecosystems to a state that would have been observed before Euro-American settlement and agriculture practices that altered the landscape.

Southwest Michigan's vegetation prior to Euro-American settlement in the 1800s differed considerably from the land-use matrix of cities and farmland prevalent today. Accounts of early European settlers depict forests dominated by large contiguous stands of oak and hickory, oak savanna, and prairie (Kenoyer 1930, Brewer 1984, Comer 1998). After Euro-American settlement FCTC's landscape was used for farming, except for hillsides with a slope greater than 40% (Stoynoff 1983). The establishment of FCTC resulted in the cessation of agricultural practices, and the landscape shifted from agriculture fields to a majority of closed canopy forest (Chapman 1984). FCTC offers a rare opportunity for restoration of the ecosystems that once dominated the landscape of Southwest Michigan and is relatively rare in terms of size, species richness, and species diversity. FCTC is one of three places in southwest Michigan with large amounts of contiguous closed canopy forest (Michigan Natural Features Inventory, Lansing, Michigan, USA)

INRMP goals include management for ecosystem restoration and rehabilitation. However, the effects of deer herbivory can drastically change the structure and composition of a forest ecosystem (Alverson 1988, Tilghman 1989, Stomayer and Warren 1997, Strole 1988, Potvin et al. 2003). Strole and Anderson (1992) concluded that deer had a browse preference for white oak (*Quercus rubra*) and shagbark hickory (*Carya ovata*) and this preferential browse will cause greater scarcity in the overall abundance of oaks and hickorys in an ecosystem. Healy (1997), conducted a study in contiguous oak forest in central Massachusetts and when deer density in a refuge area exceeded 10 deer/km^2 he found few saplings and no oak seedlings >100cm tall. When deer densities range from 3 to 6 deer/km^2 he noted many small trees and seedlings distributed throughout his study site. Deer affect recruitment of tree species into the canopy and they can induce major changes in the forest understory plant communities (Strole 1988, Putnam et al. 1989, Waller and Alverson 1997). The deer herd will have a propensity to act as a confounding factor for the MDMVA in achieving their INRMP goals.

Traditional deer herd management practices involving hunter harvest are difficult to implement at FCTC while maintaining base security. Hunting is limited with respect to time when compared to other areas in Michigan with only 5-6 days to hunt annually. In the 5 to 6 days the public is allotted to hunt FCTC, military operations come to a halt. FCTC's purpose is to provide training to the Michigan Army National Guard (MIANG) and other components of the armed forces; FCTC plays a critical role in national defense, both abroad and at home. Countless numbers of troops have performed training exercises before being deployed to both Iraq and Afghanistan. After hurricane Katrina, evacuees from the south called FCTC home temporarily. Figure 1.3. chronologically summarizes the events that molded FCTC into it's present state.

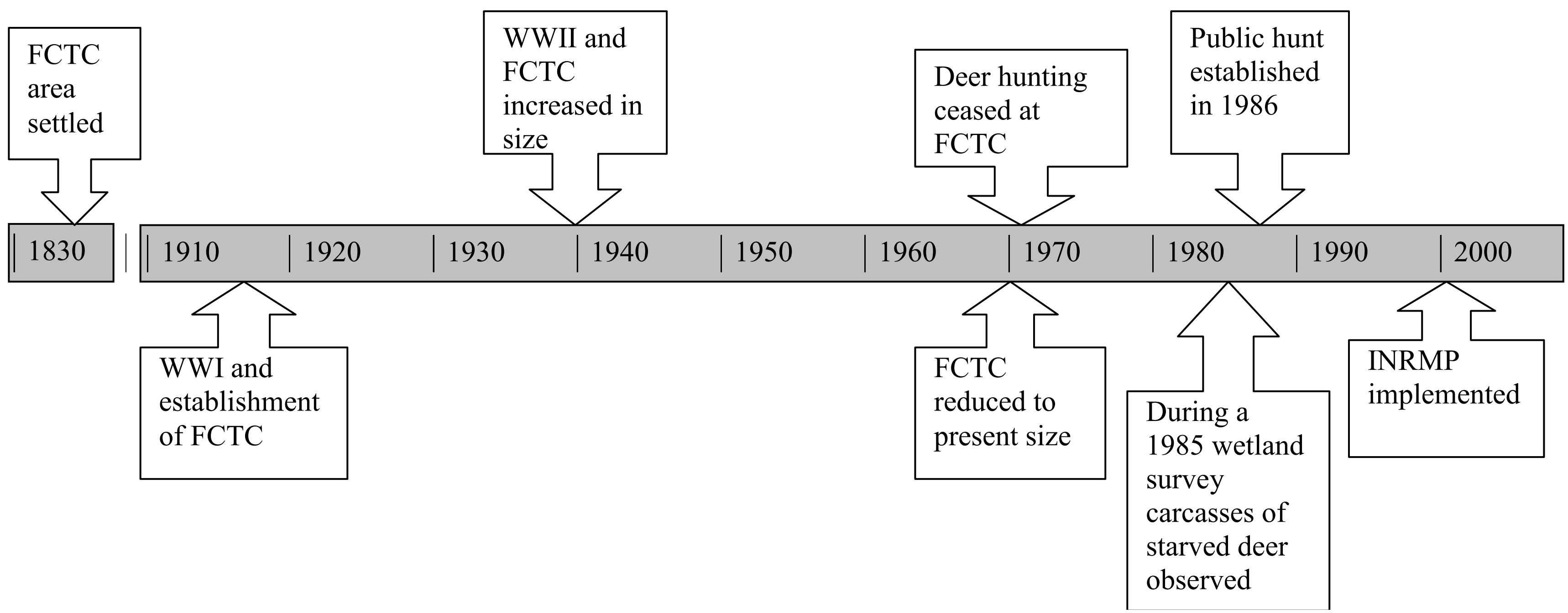

Figure 1.3. A chronological summary of events that shaped FCTC.

To assist the MDMVA in meeting the requirements of their INRMP and for the MIANG to achieve their military objectives, methodology needs to be developed to analyze the deer herd population and its impact on the landscape of Ft. Custer. The historical biodata from FCTC provides evidence that the deer herd's physical condition is poor when compared to the rest of the surrounding areas, and areas with similar forest communities. For the MDMVA to make informed and effective management decisions they will need a better understanding of the effect of the deer herd on forest dynamics, the population parameters of the deer herd, and the impact of the hunter harvest on the population parameters of the deer herd.

Objectives

This study was designed to assist the MDMVA in achieving their INRMP goals in conjunction with FCTC's ability to fulfill their primary objective of military preparedness, with respect to the deer herd's impact on the landscape, overall health, and the ability to conduct military training operations. The objectives will provide the MDMVA personnel the knowledge and means to assess the deer herd's overall health, size, and effects on forest regeneration and composition. The objectives are:

1. Develop survey methodologies that will provide an accurate estimation of deer population parameters (e.g. population size, sex ratio, fawn-to-doe ratio, survival, and sources of mortality).
2. Examine deer movement patterns to determine the annual pattern of area/habitat use on FCTC and the season specific level of movement between FCTC and the surrounding area, with particular emphasis on fall movements into areas that cannot be hunted.
3. Quantify the effects of deer herbivory on forest regeneration, with respect to species composition and density.
4. Provide training to MDMVA/FCTC personnel so that they can continue the monitoring/research efforts beyond the completion date of this project
5. Provide management recommendations to MDMVA/FCTC personnel that are in compliance with the INRMP.

CHAPTER 2: METHODOLOGY

Spring Capture

Preliminary results suggested there was a need to study fawn survival, movement, and sources of mortality to account for a low sighting rate of fawns during the spotlight survey; so, the original protocol of the project was amended to include a spring capture period of neonatal fawns. I captured neonatal fawns during the spring of 2006 with assistance of MDMVA personnel and qualified volunteers. In 2007, three field assistants aided in the capture of neonatal fawns. My field assistants and I performed capture of neonatal fawns in accordance with Michigan State University's (MSU) Institutional Animal Care and Use Committee guidelines (Application No. 01/04-006-00) and protocols detailed in the scientific collectors permit number SC 816 issued by the MDNR. All captured neonatal fawns were weighed, ear tagged, aged, and fitted with expandable VHF M-2110 radio-collars manufactured by Advance Telemetry Systems, (Ishanti, Minnesota, USA).

The spring capture period began in the second week of May in 2006 and 2007. I anticipated a peak period around June 1 based on other research that entailed the capture of neonatal fawns in southern Michigan (Pusateri et al. 2006, Hiller 2007). Fawns were located and captured based on several techniques: behavioral clues from does, grid searching, and searching established home ranges of radio-collared does combined with grid searching (Downing and McGinnes 1969, Lund 1975, Bartush and Lewis 1978, Huegel et al. 1985, Ballard et al. 1999). A fishing net was used to assist in the capture of fawns if they were flushed.

Captured fawns were aged based on the condition of the umbilical cord (Haugen and Speake 1958), the amount of new hoof growth (Haugen and Speake 1958), and behavior (Haugen and Speake 1958, Downing and McGinnes 1969, White et al. 1972). Captured fawns were manually restrained, and blindfolded to subdue the animal and lessen capture related stress. If the cover was disturbed where the fawn was captured, it was moved to an area no more than several meters away where it remained concealed from predators.

All positions of captured fawns were recorded using a hand held global positioning system (GPS) unit (Model GPS V; GARMIN International, Incorporated, Olathe, Kansas, USA). At each capture location, I recorded the vegetation characteristics, handling duration of the fawn, time of day, and weather conditions.

Winter Capture

I captured, radio-collared, and ear tagged deer from 2005 to 2008 from December to late March each year except the first capture season that began in February. I conducted trapping and baiting in accordance with protocols detailed in the scientific collectors permit number SC 816 issued by the MDNR and with Michigan State University's (MSU) animal care and use forms (Application No. 01/04-006-00). Deer were captured using clover traps (Clover 1954, Clover 1956, McCullough 1975) when the weather conditions (e.g. cold temperatures and snow cover) increased the likelihood of capture. In April of 2005, drop-nets (Ramsey 1968) were used in addition to clover traps because only three deer were caught with clover traps during that trapping season. Drop-nets were not the ideal trapping method for two reasons: at least 8-10 people are needed because several deer can be captured at once, and increased capture related stress and trauma placed on the captured deer increases trap related mortality rates (Beringer et al. 1996, Haulton et al. 2001). In addition, FCTC lacks multiple drop-netting sites, since it is mostly closed canopy forest. Deer captured would have come from the same area, so, that would have been a poor sample of the deer herd.

Clover traps were distributed throughout FCTC, with half placed in the interior and the other half along the exterior (Figure 2.1). Traps were not set during inclement weather if the predicted ambient air temperature was below -12.2 C°, or if the predicted wind chill factor was below -17.8 C°. Under those conditions traps were tied open with the area around the trap baited. I discovered through trial and error that traps would not work correctly if it rained and the nighttime temperatures fell below freezing. The netting on the trap would freeze and prevent the door closing properly, and on several occasions, I observed deer sign inside the trap, but a hung door where the deer escaped. To avoid a negative trap response from a deer, I tied the trap doors open when the netting of the traps were saturated with moisture and nighttime temperatures fell below freezing.

Traps were checked once or twice each day. Each deer caught was manually restrained, blindfolded, sexed, and aged as an adult or juvenile based on tooth wear and replacement (Severinghaus 1949). To reduce the amount of stress on a deer, processing time, noise and movement were kept to a minimum.

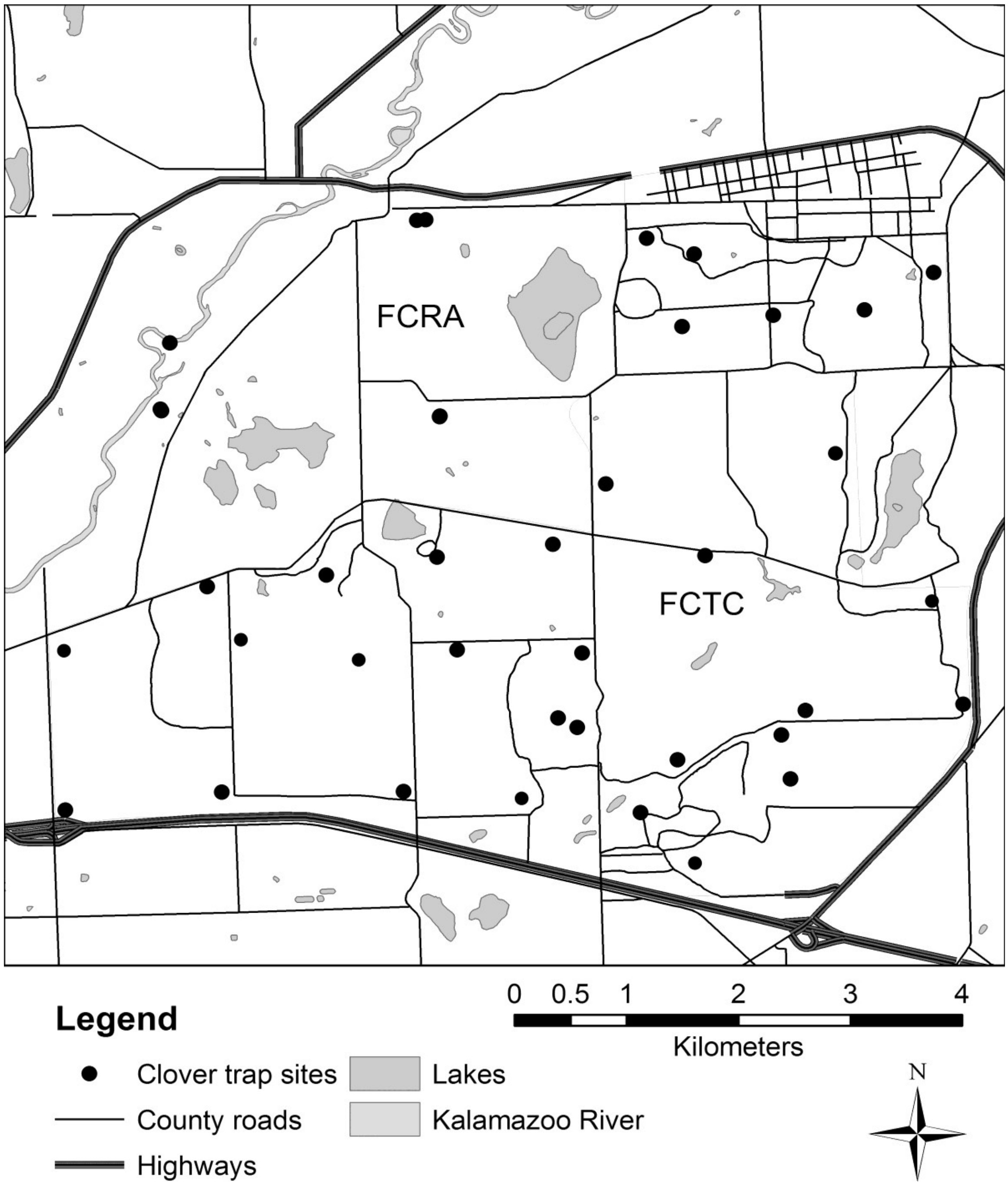

Figure 2.1. Clover trap distribution during winter capture seasons.

All abrasions and lacerations were treated with Furall™ (4% furazolidone) an aerosol topical antibiotic.

All captured deer were fitted with color-coded area-specific ear tags with unique values used to identify individuals. Ear tags were placed in the right ear for males, and the left for females. All captured deer were fitted with hermetically sealed VHF MOD-500 radio-collars manufactured by Telonics, Inc. (Mesa, AZ, USA) with a minimum battery life of 3 years and a motion sensitive mortality sensor. Juvenile males were the exception to the rule; they were collared on a case-by-case basis since male deer have such a large variation in neck size from 6 months old to the latter adult stages. I would determine if it was possible to fit a juvenile male with a collar that has a foam insert that will not be overly constrictive when the deer attains full body size and when the neck swells during the rut. The foam insert in radio-collars wears out over time, which aids in fitting juvenile deer with radio-collars. Juvenile females were typically fitted with a foam insert collar, but do not have a similar amount of variation in neck size throughout their life.

I used a different style collar on the juvenile deer during the last year of winter capture (2008), since I had M-2110 expandable fawn collars manufactured by Advanced Telemetry Systems (Ishanti, Minnesota, USA) leftover from the spring capture period. Any deer less than 1.5 years old that was captured and fitted with a radio-collar in 2007-2008 had a fawn collar to lessen the chance of a slipped collar or a collar that would not fit properly as the deer grew. All deer were ear tagged in the same manner as previous years.

Monitoring Radio-Collared Deer

I monitored radio-collared deer for alive or dead status daily for 30 days after capture as recommended by Haulton et al. (2001) because of the possibility of capture related myopathy. Deer were monitored at least once per week throughout the duration of the project for alive or dead status to determine survival rates. All mortality signals were promptly investigated, and all mortalities transported to the MDNR wildlife disease lab to have a necropsy performed to determine the cause of death. I classified mortalities into 7 categories: hunter harvest, trauma, deer vehicle collisions, coyote (*Canis latrans*) predation, dehydration, abandoned and malnutrition, and unknown. The location of mortality sites were recorded with a global positioning system (GPS) unit (Model GPS IV; GARMIN International, Incorporated, Olathe, Kansas, USA) and thoroughly investigated to find any clues to help determine the cause of death. I provided any pertinent information and details relevant to the mortality to the pathologist to assist in determining the cause of the mortality.

During periods associated with high activity, deer were monitored for alive or dead status, and located 2 or 3 times a week. Periods of high activity include the fawning period in the spring and the fall rut and hunting season (Nelson and Mech 1992). It is not uncommon for deer to disperse from their natal ranges, or migrate from their seasonal ranges in spring or fall (Nelson 1998). Typically, yearling males are the most likely to exhibit such behavior (Nelson 1993, Purdue et al. 2000). During the spring the doe-fawn interaction is the driver for dispersal events, while in the fall male-male interactions are the predominant force in causing changes in white-tailed deer movement patterns (Holzenbien and Marchinton 1992, Ozoga and Verme 1985, Rossenburry et al. 2001).

Radio-collared deer were located at a minimum of once a week during other periods of the year. I used hand held yagi triple beam antennas with R-1000 telemetry receivers manufactured by Communication Specialists, Inc. (Orange, California, USA) to locate deer. I triangulated the location of radio-collared deer by inputting the data into the computer program Locate III (Pacer, Truro, Nova Scotia, Canada) which calculates point locations and 95% confidence area ellipses based on maximum likelihood estimate (Lenth 1981) as recommended by White and Garrot (1990) and Nams and Boutin (1991). Distances to a radio-collared deer were kept minimal because bearings were measured at multiple telemetry stations at different times; it is possible that the radio-collared deer moved between bearing readings. Reducing the distance to the transmitter shortened the amount of time to travel from one telemetry station to the next, decreasing the distance the radio-collared deer may move. Greater distance to a transmitter also increases the weight of bearing error (Hupp and Ratti 1983, Saltz and Alkon 1985, Nams 1989). My field assistants and I also recorded all visual locations with GPS, along with the deer's behavior, physical condition, what type of cover it was in, antler characteristics if applicable, and if one or more fawns accompanied a radio-collared doe.

I estimated home ranges with the GIS software packages ArcView V3.2 (Environmental System Research Institute, Redland California, USA) with the Spatial Analyst and Animal Movement Extensions using fixed kernel estimates with least cross squares validation (LCSV). Fixed kernel methods provide more accurate home range estimates than do minimum convex polygons and harmonic mean methods (Worton 1995, Seaman and Powell 1996, Swihart and Slade 1997). Kernel methods produce a utilitarian distribution (UD) which is a three dimensional estimate of home range (Worton 1989). The third dimension is associated with time, and the likelihood of the animal being in that region of its home range. Seaman et al. (1999) reported that sample size is critical when estimating a home range, and recommended that a minimum of 30 observations be required to calculate a home range.

When examining home range habitat use and preference, analyses were restricted to radio-collared deer that had a minimum of 30 observations to avoid overestimation of the home range size (Seaman et al. 1999). There were occasions when a deer slipped a radio-collar, died, or suffered some other fate before the minimum number of observations was met for an accurate estimate of home range. If the criteria for the minimum number of observations were not meet then results were treated on a case by case basis, and the findings were reported, but not treated with the same weight.

Habitat Use and Resource Selection

I performed compositional analysis as outlined by Aebischer et al. (1993) to assess habitat use of radio-collared deer. MDMVA personnel provided spatial vegetation data layers from a 2001 vegetation sampling of FCTC conducted by Michigan Natural Features Inventory (MNFI). I used ArcView v3.2 to reclassify the vegetation cover types into seven categories: oak hardwoods (*quercus spp.*), mixed hardwoods, fields, pines (*pinus spp.*), brush, locust (*robinia spp.*), and wetlands. The core home ranges of radio-collared deer were used in the compositional analysis with the software Resource Selection for Windows (Fred Leban, University of Idaho).

Compositional analysis compares the composition of the seven categories of vegetation cover that is available within FCTC to the composition of the vegetation cover types within each radio-collared deer's core home range. The Resource Selection for Windows (RSW) software program performs a log ratio test between the habitat used and the habitat available by radio-collared deer. Vegetation cover types were ranked by strongest preference to the weakest.

I performed compositional analysis by gender and age (neonatal fawns, mature fawns, yearlings, and adults). I considered fawns less than 6 months old as neonatal, while fawn less than a year old, but older than 6 months were classified as mature fawns. The multiple age classification of fawns was due to capture during two distinctly different time periods, spring and winter, where new individuals would be added to a pool at approximately 6 months old. It is reasonable to assume the home range fidelity of a mature fawn may not be the same as that of a neonatal fawn, since home range size typically increases as a fawn matures, in addition to seasonal differences in the home range of the white-tailed deer.

Estimation of Population Parameters

I pooled deer by gender and age for survival analysis. There were three general pools: adults, yearlings, and fawns. The fawn pool also had two time subcategories, for a couple of reasons. Fawns were captured at two distinctly different periods, spring and winter capture periods. Neonatal fawn survival during the first several months may vary over the first several months, so I examined survival of neonatal fawns over their first 30 and 60 days. Fawns captured during winter were in a distinct category from neonatal fawns captured during spring. Radio-collared neonatal fawns that survived up too, and past the winter capture period were then subsequently categorized in the same category as winter captured fawns. The data structure dictated grouping fawns into two classes for survival analysis, since capture could have occurred in either spring or winter capture periods. In the survival analysis of fawns, I will refer to spring capture fawns as neonatal fawns, while referring to mature fawns for any fawn captured during the winter capture season. Any neonatal fawn surviving past 6 months of age became classified as mature fawn for survival analysis purposes.

I grouped survival data together over the entire duration of the study because of the relatively small sample size. I used the Mayfield Method to estimate the survival of radio-collared deer (Mayfield 1961, 1975). The variances were calculated using the MICROMORT software. Survival analysis included staggered entry since not all deer were radio-collared at the same time (Pollack et al. 1989). I used a seven day acclimation period to the radio-collars. Captured deer may experience capture related stress which could result in mortality; data indicated that capture stress was no longer attributable at seven days, so the acclimation period was defined to be over.

The Mayfield Method was used to determine survival. In recent years a preponderance of the journal articles published have used the Kaplan-Meier method, one reason being that it does not assume constant survival. But, the Kaplan-Meier method typically requires a minimum of 50 animals per treatment period for accurate survival estimates and the Mayfield Method should be used with sample sizes smaller than 50 animals (Winterstein et al. 2001). Since survival is assumed constant for the duration of the study with the Mayfield Method, survival was assessed over different time intervals that have constant survival and overall survival was calculated as the product of the estimates from the different time intervals (Johnson 1979, Bart and Robson 1982, Heisey and Fuller 1985). To test the assumption that constant survival holds for the shorter time intervals the hazard function was examined as suggested by Winterstein et al. (2001).

Population Size Estimate

I utilized the sex-age-kill (SAK) model as an estimator of the population size at FCTC. I calculated the variance estimates of the SAK model as described by Skalski and Millspaugh (2002) and Millspaugh et al. (2009). The generic equation I used is as follows:

$$\hat{N}_T = \frac{\hat{H}}{\hat{M}_T \hat{B}}[1 + \hat{R}_{F/M} + \hat{R}_{F/M} * \hat{R}_{J/F}] \qquad \text{equation (2.1)}$$

where

$\hat{N}_T$ = estimate of total abundance;

$\hat{H}$ = estimated adult male harvest in year *i*;

$\hat{M}_T$ = total annual mortality rate of adult males;

$\hat{B}$ = proportion of total male mortality due to harvest (male recovery rate);

$\hat{R}_{F/M}$ = estimated ratio of adult females to adult males in the population;

$\hat{R}_{J/F}$ = estimated ratio of juveniles to adult females in the population.

I used survival data of radio-collared deer to estimate $\hat{M}_T$ and $\hat{B}$. To estimate the adult female, adult male and juvenile segments of the population I used the SAK model outlined by Skalski and Millspaugh (2002).

Forward Looking Infrared

On two occasions, Vision Air Research Incorporated surveyed FCTC, FCRA, and the Hart's Lake area using forward looking infrared (FLIR) to estimate the size of the white-tailed deer herd. One FLIR survey took place on March 24, 2007, while the other FLIR survey occurred on November 13 and 14, 2007. Both FLIR surveys began after sunset for improved detectability of white-tailed deer. Fog interrupted the November survey on the 13th, which resumed the morning of the November 14.

Vision Air Research used a PolyTech Kelvin 350 II (Sweden) mounted on the left wing of a Cessna 206 “Stationair”. The sensor gimbal allows 330 ^{o} of azimuth and 90 ^{o} of elevation allowing us to look in all directions except directly behind the airplane. The infrared sensor installed in the gimbal is the high resolution Agema Thermovision 1000, which is a long wave system (8-12 micron). It has 800 by 400 pixels providing good resolution with the ability to determine animals by their morphology or body shape. The thermal delta is less than 1 ^{o}C, which means it can detect objects with less than 1 ^{o}C different than the background. There are 2 fields of view (FOV): wide (20 ^{o}) and narrow (5 ^{o}). At 305 m. above ground level looking straight down using the wide FOV the footprint or area covered by the sensor is 110 m. x 71 m. while the narrow FOV provides a footprint 27 m. x 18 m.

Transects were spaced 213 m. apart and running north – south. The sensor look angle was approximately 45 ^{o} elevation or down look angle. The pilot used a Garmin 496 which provided the transect locations and flight track covered. Flight altitude was 305 m. above ground level of the highest point along the transect flown and the adjacent transect for flight safety.

The portion of the flight within the study area was recorded on videotape. The pilot and sensor operator communicated to verify the location of the boundaries to turn the tape off and on. The sensor operator turned the tape off at the transect end and commenced recording at the start of the transect. The tapes were reviewed by playing the tape backward and forward and in slow motion and frame by frame as needed to identify deer groups, count individuals within the group, and map group location. Deer were located by observing their level of emitted infrared energy versus background levels. Vision Air has the ability to switch fields of view to zoom in and confirm subject as needed. Duplicates or repeat groups were identified. For each hour of tape time it took 3 – 4 hours to review the tape and map the group location and run a tally of groups and total count. Groups were mapped at their observed position not the position of the airplane. Vision Air performed an additional check of the data through sampling the videotape for detection verification, and checking for duplicate groups.

White-Tailed Deer Exclosures

As part of the white-tailed deer ecology study conducted by Michigan State University, eight 20m x 20m deer proof exclosures were constructed to quantify the effects of deer herbivory on forest regeneration, composition and structure. This portion of the study is intended to continue after MSU personnel ceased conducting research, with the procedures for vegetation sampling outlined for Ft. Custer Training Center (FCTC) personnel. Continued monitoring of the exclosures is needed to ascertain if deer herbivory at FCTC is significantly affecting forest regeneration and composition in such a manner that will make it difficult to meet the objectives outlined in the Integrated Natural Resources Management Plan (INRMP).

Site selection included 4 areas with mixed hardwoods and 4 areas with oak hardwoods with canopy cover greater than 85%. No sites were selected in training area 9 because of the potential for UXO (unexploded ordinance) existing in that area, and no suitable sites were located in the training areas 1 and 2. Figure 2.2 displays the distribution of exclosures and paired control sites. Since FCTC incorporates prescribed burns into their land management practices, 2 mixed hardwoods sites and 2 oak hardwoods sites underwent prescribed burns. There appeared to be similar initial conditions between the exclosure and paired controlled site in terms of ground cover, midstory, and canopy species composition and the amount of cover. Data were collected upon completion of the exclosures to determine any significant statistical difference between the exclosure and paired control site before deer herbivory could be a factor. Areas selected did not have large variation in terms of elevation to avoid heterogeneity in soil characteristics (e.g. moisture content and soil type). Similarity in initial abiotic and biotic conditions within each site was based on visual observation.

A large degree of variation in soil characteristics could preclude a species from occurring throughout the site area. In the scope of this design soil characteristics should not be a limiting factor to make within site comparisons between the exclosure and the paired controlled site. This could also lead to false positives or false negatives when making such comparisons between the paired control site and exclosure. Any differences in species composition and density will be assumed to be a result of deer herbivory, and not because of soil characteristics.

The paired controlled site and exclosure each measures 20 x 20 m on the perimeter while their nearest point lies approximately 20 m from each other. The distance between the exclosure and paired control site acts as a buffer between the effects caused by deer encountering the exclosure impeding their travel. Over time such behavior will produce edge effects around the exclosure as deer wander around the edge of the exclosure. The height of each exclosure is 2.4m. Each exclosure was constructed with galvanized steel farm fence that has a 9 gauge top and bottom wire, and 11 gauge filler wire with 6 inch vertical stays. The fencing material is mounted on 16 posts spaced 5 meters apart. The posts consist of a variety of materials ranging from treated yellow pine 4x4's 12 feet long, black locusts posts 12 feet long with diameters from 4 to 6 inches, and galvanized steel street sign posts salvaged from the Michigan Department of Transportation (MDOT).

Each of the 8 herbivory study areas has an exclosure and a paired control site (Figure 2.2). Each control site is an unfenced 20m x 20m area in close proximity (~20m) to the exclosure. Paired control and exclosure site were selected to have similar vegetation characteristics, along with similar soil types, drainage and moisture characteristics so that any differences that may occur as time progresses are from deer herbivory, and not some other exogenous factor. In this study I considered the exclosure, the fenced in area, as the experimental unit, and the area vulnerable to browse the control. The location and forest type for each exclosure and paired control site are listed in Appendix B. The coordinates provided correspond to the northwest corner of the control site and the exclosure, which also is the location of the access point for every exclosure. The access point has had the wire fencing cut, and patched to function as a gate.

I used 3 vegetation metrics (frequency of occurrence, density, and vertical cover) to quantify and monitor changes in the plant community. Monitoring and analyzing changes in these vegetation characteristics will allow FCTC personnel to evaluate the effectiveness of their management policies. Frequency of occurrence is the proportion of sample units in which a species occurs (Bonham 1989), and describes the distribution of plants within a community (Mueller-Dombois and Ellenberg 1974). Absolute frequency is the number of times a species occurs in each plot. Vertical cover, the vertical projection of a stem or leaf onto the surface of the ground, determines the dominance of a species within a community (Higgins et al 2005). Density provides an added description of a plant community when coupled with the frequency of occurrence of a species (Higgins et al 2005).

Vegetation sampling began in June and was completed by mid to late August. In this study the understory is from 0.0m > 0.5m high, the midstory ranges from 0.5m ≥ 2.0m, the overstory is > 2.0m. To avoid including any changes in the plant community associated with the disturbance from the construction of the exclosure sampling took place > 1 meter inside the perimeter of each of the exclosure and paired control sites.

General Overview of Vegetation Sampling

The line intercept method (Canfield 1941) estimates the amount of cover in the understory, midstory, and overstory. The line intercept method consists of placing a tape measure between two points (an 18 meter long transect), and having an observer measure the amount of vegetation touching the tape or any vertical projections. Each site was sampled with 5 transects, each 18m long. The distribution of transects is determined by placing the initial transect parallel to the perimeter's edge at a random interval 1 to 4 m from the fence. The second transect was placed randomly 3 to 4 m away and parallel to the initial transect; the next three transects were spaced 3 m apart. The amount of cover was measured in centimeters and expressed as a percentage. Appendix B contains a data sheet for recording data while measuring vertical cover and stem density. A database will also be passed on to FCTC personnel of the data collected to date.

Three 1x2m nested plots were randomly placed off each of the line intercept transects to sample species density and frequency of occurrence in the understory. Sampling included both woody and herbaceous species. The plots were marked with flagging to allow me to return to the same plot if needed throughout the sampling period to correctly identify all species. A prolonged sampling period may have occurred when some species were indistinguishable from other species since they were not in bloom at that time; so, I returned to a plot at a latter period when species were in bloom.   The species composition sampling methods were the same in the midstory, but have three 1x5m nested plots instead of 1x2m nested plots. The plots were marked with flagging, and sampled as needed throughout the spring and summer to identify all the vegetation that occurs in the nested plots of the midstory. Sampling of species composition in the overstory was accomplished by counting and identifying all the species in each paired control site and exclosure. There are two categories for overstory species: diameter at breast height (DBH) ≥ 10.16 cm or a DBH < 10.16 cm, based on measurements with a Biltmore stick. A theoretical layout for sampling a exclosure or paired control site is in Figure (2.3).

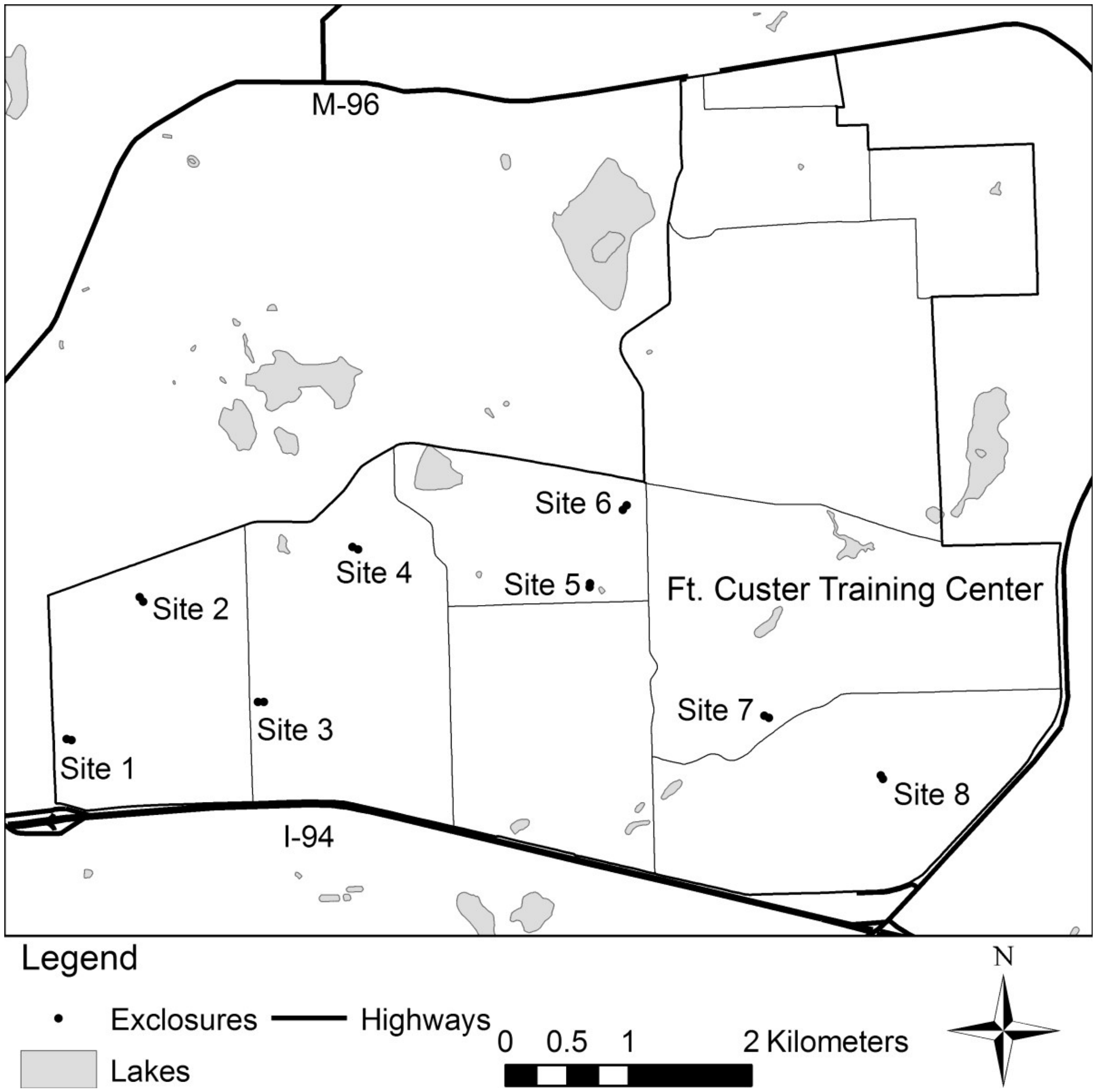

Figure 2.2. A map of the exclosure site locations at FCTC.

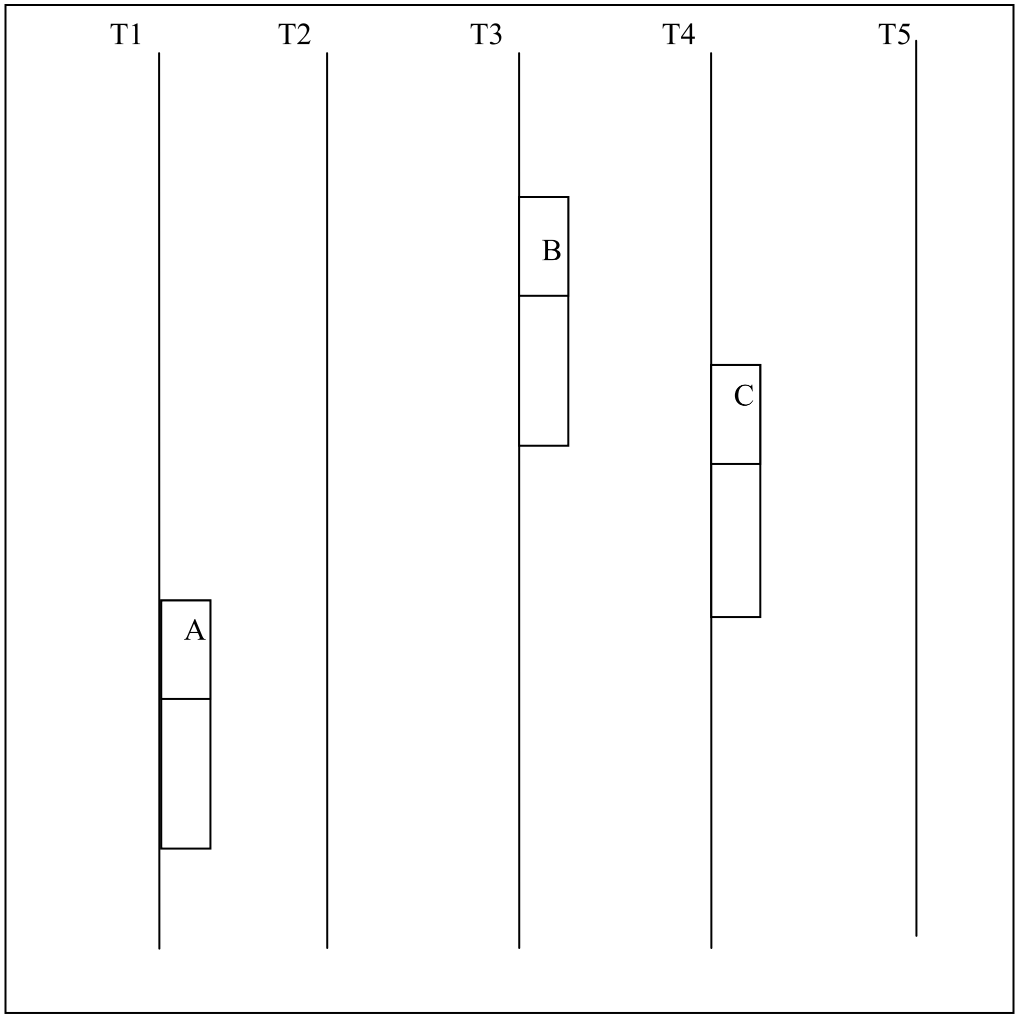

Figure 2.3. A schematic layout of either an exclosure or a paired control site for vegetation sampling. There are five transect lines marked as T1, T2 … T5 to use for the vegetation density in the understory, midstory, and overstory. The rectangles marked A, B, and C are the nested plots that estimate species composition and frequency in the understory and midstory. The midstory nested plot is 1m x 5m, while the understory plot is a subplot of the midstory and measures 1m x 2m.

CHAPTER 3: RESULTS

Winter Capture

I captured 62 deer using clover traps from 2004-2008, and four more deer were captured with drop nets in 2004 (Table 3.1). Thirty-eight of the deer captured were females, all of which were radio-collared. Twenty-four of the twenty-eight males captured were fitted with a radio-collar. I captured 24 female adult deer, 14 juvenile female deer, 13 adult male deer, and 15 juvenile male deer (Table 3.1).

I had a success rate, the total number of deer captured per the total number of trap days, for the winter capture that varied from 4.6% in 2005, and 0.51% in 2006 (Table 3.2.). The success rate was 2.38% in 2004, 1.41% in 2007, and 3.19% in 2008 (Table 3.2.). A mild winter attributed to the extremely low success rate for trapping during the 2006 season. During the capture season from December 28, 2005 to March 5, 2006 FCTC lacked snow cover (personal observation) and unseasonably warm temperatures coupled with an unusual amount of other forage decreased the effectiveness of baited traps. In the month of January 2006 the daily mean temperature was 1.1 °C, while the daily high averaged 3.9 °C, and the low averaged -1.6 °C (Midwestern Regional Climate Center, Champaign, Illinois, USA). Annually the daily high averages -1.1 °C and the average daily low is -8.8 °C, which yields a daily mean of -4.9 °C (Midwestern Regional Climate Center, Champaign, Illinois, USA). In January 2006 it snowed 13 cm, compared to an average of 38 cm (Midwestern Regional Climate Center, Champaign, Illinois, USA). In January 2006 there were only 4 days with snow cover on the ground, with an average depth of 2.5 cm during that time frame (Midwestern Regional Climate Center, Champaign, Illinois, USA). The month of February in 2006 had 16 cm of snow compared to the average 23 cm (Midwestern Regional Climate Center, Champaign, Illinois, USA).

Competition for bait amongst by-catch species lowered success rates when these species ate the available bait and tripped the traps. Additionally, several deer exhibited a trap-happy response, where once captured they were recaptured multiple times. I captured a male fawn on 14 different occasions at 2 different trap sites, which were a kilometer away from each other during winter of 2007. This caused me to remove the traps from both sites since the likelihood of capturing another deer was low and I wanted to avoid unnecessary stress on this particular deer.

Table 3.1. The number of deer captured at FCTC during the winters of 2004 to 2008.

	Female		Male		
Year	Adults	Yearlings	Adults	Yearlings	Total
2004	6	3	0	0	9
2005	7	10	3	11	31
2006	2	0	1	0	3
2007	5	0	4	1	10
2008	4	1	5	3	13
Total	24	14	13	15	66

Table 3.2. Capture success rate of winter captured deer at FCTC based on number of trap days and total number of captures.

Year	Total Captures	Recapture events	Total Number of Trap Days	Success Rate
2004	9	2	378	2.38%
2005	31	22	674	4.60%
2006	3	0	593	0.51%
2007	10	19	709	1.41%
2008	13	7	408	3.19%
Total	66	50	2762	2.39%

Spring Capture

During the two spring capture seasons, I captured 14 neonatal fawns, all of which were radio-collared, weighed, ear-tagged, and aged. I captured two males and two females in 2006. The following year 10 neonatal fawns were captured, six of which were females and four were males (Table 3.3).

Table 3.3. The average age and weights of spring captured neonatal fawns at FCTC in 2006 and 2007.

Year	Average Age (days)	SE	Average Weight (Kg)	SE
2006	2.20	0.41	2.97	0.11
2007	7.93	2.09	5.67	0.69
Total	6.29	1.64	4.90	0.59

Table 3.4. Capture success based on neonates observed and number of personnel hours per capture during the spring capture at FCTC.

Year	Observed	Captured	Percentage of Observed Captured	Hours averaged per capture
2006	9	4	44.4%	58.5
2007	17	10	58.8%	34.2
Total	26	14	53.8%	46.4

A neonatal fawn carcass was discovered in addition to the 10 fawns captured in 2007. A necropsy performed by the MDNR at the Wildlife Disease Lab indicated that the male fawn was a stillborn. Since the deer was never alive, it has not been included in any analysis, or counted as captured.

On average, fawns weighed 4.90 ± 0.59 Kg for both spring capture seasons. However, in 2006 fawns on average weighed 2.97 ± 0.11, while fawns weighed 5.67 ±0.69 kg in 2007; but this shift in weight is explained by the change in the average age at capture. Fawns typically were 2.20 ±0.41 days old and 7.93 ±2.09 days old respectively in 2006 and 2007 when captured. The overall average age of capture was 6.29 ±1.64 days old.

The age at capture differed between the two seasons due to my field assistants' and my own experience catching and observing neonatal fawns. After flushing several neonatal fawns we noticed that if the fawn had its' ears upright versus laid back on its head, it would flush. Thereafter, when we noticed that behavior, my field assistants and I would slowly back away from the fawn. At that point, we would enlist assistance from several personnel of the MDMVA environmental staff to capture the fawn. Anticipating the flush of the fawn personnel would surround the deer, and slowly encircle it in a concerted team effort. Once captured, it took on average 4.6 ±0.46 minutes to process the animal (i.e. age, weigh, ear-tag, radio-collar, and determine its' gender).

Survival

Spring Captured Neonatal Fawns

The data structure dictated grouping fawns into two classes for survival analysis, since capture could have occurred in either spring or winter capture periods. In the survival analysis of fawns, I will refer to spring capture fawns as neonatal fawns, while referring to mature fawns for any fawn captured during the winter capture season. Any neonatal fawn surviving past 6 months of age became classified as a mature fawn for survival analysis purposes.

I grouped survival data together over the entire duration of the study because of the relatively small sample size. Neonatal fawns (n=14) experienced a period survival rate of 0.493 for their first six months; males and females included in the same group for fawns because there are minimal differences at a young age (Ozoga and Verme 1986). Neonatal fawns had 5 different sources of mortalities: probable coyote (*Canis latrans*) predation (n=3), hunter harvest (n=2), deer vehicle collision (n=1), abandoned/malnourishment (n=1), and dehydration (n=1) (Table 3.5). Collars remained on the deer for an average of 244 days (SE=68.2) for deer that were censored due to collar deterioration or being alive at the end of data collection. On one occasion a collar prematurely expanded, and came off the fawn after only 16 days. The next shortest duration a collar remained on a fawn was for 79 days, while another fawn retained a collar for 442 days.

Table 3.5. Fate of neonatal captured fawns at FCTC from 2006 to 2007.

Fate	Female	Male	Total	Percent
Possible coyote predation	1	2	3	21.43%
Hunter Harvest	2	0	2	14.29%
Abandoned/malnutrition	0	1	1	7.14%
Dehydration	1	0	1	7.14%
Deer vehicle collision	0	1	1	7.14%
Slipped collar	1	1	2	14.29%
Censored	3	1	4	28.57%

Winter Captured Deer

I categorized deer by gender and age for survival analysis since differences are likely based on those categories. Survival data were pooled together across years because each year's sample size was relatively small. I also included all neonatal deer that survived to 1 December, and reclassified them as mature fawns from that point forward. Deer that survived past June 1 were grouped into the next age group (i.e. mature fawns became yearlings, and yearlings became adults) for survival estimates.

The daily survival rate for mature fawns (n=22) was 0.997. Yielding a period (6 months) survival rate of 0.581. The annual survival rate for all fawns equaled 0.289 when combining the neonatal rate with the mature fawn rate. Adult does (n=26) experienced the highest daily and annual survival rates, 0.999 and 0.756 respectively. A yearling doe (n=10) had a 0.998 daily survival rate, or a 0.443 annual survival rate. The daily and annual rates for adult bucks (n=14) were 0.998 and 0.493, respectively. Yearling bucks (n=9) survived at a 0.997 daily rate and a 0.379 annual rate. The survival rates of deer are listed with their variances in Table 3.6.

Other than the hunter harvested radio-collared deer, the cause specific mortality was determined by field observations, the history of the animal, and a necropsy of the carcass performed by a wildlife pathologist at the MDNR Wildlife Disease Laboratory in East Lansing, MI. Winter captured deer died from the following sources of mortality: hunter harvest (n=21), possible canid predation by coyotes (*Canis latrans*) (n=6), stress and trauma (n=3), accident and starvation (n=1), unknown mortality source (n=1), and deer vehicle collisions (n=1). A complete listing by age and gender of the fate of winter captured radio-collared deer is contained in Tables (3.7 and 3.8). In addition to the mortalities suffered by the radio-collared deer, 19 were alive at the conclusion of the study, and 11 more deer slipped their radio-collars. The relatively high number of slipped collars was attributed to age class of the deer radio-collared, and I tried to avoid collaring the animals too tightly. A total of four fawns, four yearlings, and three does slipped their respective radio-collars (Table 3.7 and 3.8).

The deer, an adult doe, which died from an accident and starvation, was located underground in the tunnel system at FCTC that is associated with the live firing ranges. The doe fell into the tunnel, and apparently could not escape, and then died from starvation. In the cases involving predation, I found carcasses mutilated by coyotes (*Canis latrans*) and scavenged with the radio-collar forcibly removed from the deer with clear indications of bite marks from canines. In the instance of the unknown mortality source, I did not discover the carcass in time to have a necropsy performed with a conclusive cause of death. I found the carcass of this ten-month-old doe heavily scavenged by turkey vultures

(*Cathartes aura*) and other scavengers, and I suspected that the mortality sensor did not activate upon its' death due to the scavenging.

Table 3.6. Annual and daily survival rate estimates of radio-collared deer at FCTC based on the Mayfield Method.

Gender	Age	Sample Size	Daily Survival	Variance	Period Survival (One Year)	Period Variance	Lower 95% CI of period survival	Upper 95% CI of period survival
Female and Male	Neonatal Fawns[1]	14	0.996	2.11E-06	0.493	0.017	0.230	0.755
Female and Male	Mature Fawns[1]	22	0.997	1.46E-06	0.581	0.017	0.324	0.838
Female	Yearling	9	0.998	1.24E-06	0.443	0.032	0.083	0.803
Female	Adult	26	0.999	4.88E-08	0.756	0.004	0.634	0.878
Male	Yearling	10	0.997	1.75E-06	0.379	0.034	0.012	0.746
Male	Adult	14	0.998	5.32E-07	0.493	0.017	0.230	0.757
Female and Male	Fawn[2]	14,22	n/a	n/a	0.289	0.010	0.147	0.568

1. The period survival is for 6 months.
2. The fawn age class survival rate is a combination of the neonatal and mature fawn age class, and no daily survival rate can be calculated. The period survival rate estimate for fawn is a multiple of the neonatal and mature fawn

Table 3.7. Fate of female winter captured radio-collared deer at FCTC.

Fate	Fawns	Yearlings	Adults	Total	Percent
Hunter harvest	0	2	8	10	20.00%
Possible coyote predation	2	0	3	5	10.00%
Stress/trauma	1	1	0	2	4.00%
Deer vehicle collision	0	1	0	1	2.00%
Accident/starvation	0	0	1	1	2.00%
Slipped collar	3	1	3	7	14.00%
Unknown mortality source	1	0	0	1	2.00%
Alive[1]	0	2	9	11	22.00%
Collar malfunction[2]	0	0	1	1	2.00%
Censored[3]	6	5	0	11	22.00%

1. The radio-collared deer survived to the end of the study June 1, 2008.
2. The radio-collared deer was sighted and identified by the unique ear tag associated with the individual, but no radio signal was detected. Detection of the radio signal of the collared deer had been sporadic after four months of capture.
3. Censored radio-collared deer survived long enough to be reclassified into the next older age category (i.e. fawns became yearlings, and yearlings became adults on June 1 each year).

Table 3.8. Fate of male winter captured radio-collared deer at FCTC.

Fate	Fawns	Yearlings	Adults	Total	Percent
Hunter harvest	1	4	6	11	34.38%
Possible coyote predation	1	0	0	1	3.13%
Stress/trauma	0	0	1	1	3.13%
Slipped collar	1	3	0	4	12.50%
Alive[1]	0	2	6	8	25.00%
Censored[2]	6	1	0	7	21.88%

1. The radio-collared deer survived to the end of the study June 1, 2008.
2. Censored radio-collared deer survived long enough to be reclassified into the next older age category (i.e. fawns became yearlings, and yearlings became adults on June 1each year).

Home Range Estimates

I compiled location data from visual locations recorded with gps and telemetry location data to estimate home ranges of deer. I calculated home ranges for deer for which I had a minimum of 30 locations (Seaman et al. 1999, Kernohan et al. 2001). I made an exception for one male fawn (n=28). The smaller sample size of this individual did not seem to greatly affect the home range estimate, for several reasons: there is a degree of arbitrariness for a minimum sample size n=30 and this individual had the fifth smallest home range area. Other than the exception to the sample size rule, my sample sizes for number of locations ranged from n=31 to n=259. Forty-four radio-collared deer fulfilled the criteria for a fixed kernel home range estimate and were used to estimate home range size.

Fawns exhibited the smallest home range size amongst all age classes, fawns, yearlings, and adult (Table 3.9 and Table 3.10). Male yearlings (n=2) had the largest home ranges, averaging 112.98 hectares (ha) (SE=107.75) for a core home range while the 95% probability overall home range was $\bar{X}$=847.59 ha (SE=812.89). All radio-collared deer home range estimates and locations are depicted in Appendix C.

Table 3.9. The mean core home range size of radio-collared deer in hectares by age and gender.

Gender	Age	n	Mean	Std Error	LCL	UCL
female	adult	19	18.31	3.03	11.95	24.67
female	fawn	4	7.63	2.56	0.00	15.78
female	yearling	6	58.01	26.37	0.00	125.78
male	adult	9	43.36	6.21	29.03	57.68
male	fawn	3	11.58	2.83	0.00	23.75
male	yearling	2	112.98	107.75	0.00	1482.12

Table 3.10. The mean overall home range size of radio-collared deer in hectares by age and gender. The overall home range represents the area where radio-collared deer have 95% chance of ranging.

Gender	Age Class	n	Mean	Std Error	LCL	UCL
female	adult	19	132.22	16.05	98.49	165.95
female	fawn	4	73.22	23.27	0.00	147.29
female	yearling	6	266.41	114.24	0.00	560.08
male	adult	9	324.82	37.69	237.90	411.74
male	fawn	3	52.99	6.02	27.07	78.91
male	yearling	2	847.59	812.89	0.00	11176.38

Habitat Use

Forty-four deer were used to calculate core home-ranges to perform compositional analysis as outlined by Aebischer et al. (1993) to test for random habitat use and rank the habitats according to resource utilization. I categorized deer into data subsets based on gender and age to test for differences in those categories with respect to resource utilization and random habitat use. The groups are: adults n=26, bucks n=9, does n=19, yearlings n=8, and fawns n=7. The yearling group contains six females and two males, while there were three male fawns and four female fawns.

Results of compositional analysis indicate each group of deer had nonrandom habitat use (Table 3.11). The oak hardwoods (*quercus spp.*) were the preferred vegetation type for all groups, except for fawns that were most commonly in the open fields of FCTC. Fawns selected the oak hardwood (*quercus spp.*) habitat as their second highest preference, while maple hardwoods (*acer spp.*) were selected second for habitat among yearlings, both male and female, bucks and does.

Table 3.11. Rankings of the preferred vegetation types used by radio-collared deer at FCTC.

Deer classification	Vegetation Classification						
	Oak Hardwoods	Mixed Hardwoods	Fields	Conifers	Brush	Wetlands	Locust
All radio-collared deer	1	3	2	4	6	5	7
Radio-collared bucks	1	2	3	4	6	5	7
Radio-collared does	1	2	3	4	7	5	6
Radio-collared fawns	2	3	1	4	7	6	7
Radio-collared adults	1	2	3	4	6	5	7

Population Estimates

Spotlight Survey

From 8/30/2004 to 9/10/2004 a spotlight survey was conducted at dusk eight times to estimate adult sex ratio, and fawn-to-doe ratio. The survey took approximately an hour and 45 minutes each night. In the design of the spot-light route areas 3 and 4 were omitted from the survey because there was no feasible way to include them. Areas 3 and 4 do not contain enough suitable sites to conduct a survey in a timeframe of around an hour and 45 minutes and sample an adequate number of sites. A total of 593 deer were observed, 218 does, 154 bucks, 148 fawns, and 73 unknowns, yielding, about 68 fawns for every 100 does and 1.42 does for every buck. The survey results led researchers to believe that the survey should be conducted one to two weeks earlier because of a lower than expected number of fawn observations; fawns may have been mistaken for does.

The 2005 spotlight mark-resight survey yielded a population estimate of 397 adult deer with the Lincoln-Petersen estimator:

$$\hat{N} = \frac{n_1 n_2}{m_2}$$

The number of deer sighted during a given night is n_1, the total number of radio-collared deer on FCTC is denoted by n_2, and m_2 is the number of radio-collared deer sighted on a given night. Since no fawns were marked during the spotlight survey they were not included in the population estimate. In 2005 there were 3.41 does for every buck and 0.344 fawns per doe.

Sex-Age-Kill Model

The Sex-Age-Kill model (SAK) indicated that the deer population has decreased at FCTC over the last several years (Figure 3.1.). I used two versions of the model, which varied with the parameter estimating male mortality (M_t) and the ratio of 1.5-year-old male deer as a percentage of the male population (P_{ym}) (Skalski and Millspaugh 2002, Millspaugh et. al. 2009). Survival analysis based on the Mayfield Method of radio-collared deer yielded an estimate of (M_t) = 0.51. The hunt data yielded an estimate of P_{ym} = 0.703 with a variance of 0.000878 (Table 3.12).

The two models produced similar results, but the P_{ym} model population estimates were lower than the M_t model estimates (Table 3.12). The M_t model only produced estimates for the entire population while the P_{ym} model estimated the number of adult does, adult bucks, and juvenile deer. The deer population has declined steadily from 2004 to 2009 in both of the SAK models; the M_t model has estimated the population at 712 deer in 2004 and 496, 488, 352, 328, and 320 deer in the subsequent years. The deer population estimate went from 516 deer in 2004 to 360 deer in 2005, 354 deer in 2006, 255 deer in 2007, 238 in 2008, and 232 deer in 2009 in the SAK P_{ym} model (Table 3.12). In terms of density, the deer population for 2009 is estimated at 19.62 deer per mi^2 by the SAK P_{ym} model, or 27.04 deer per mi^2 by the SAK M_t model (Table 3.14).

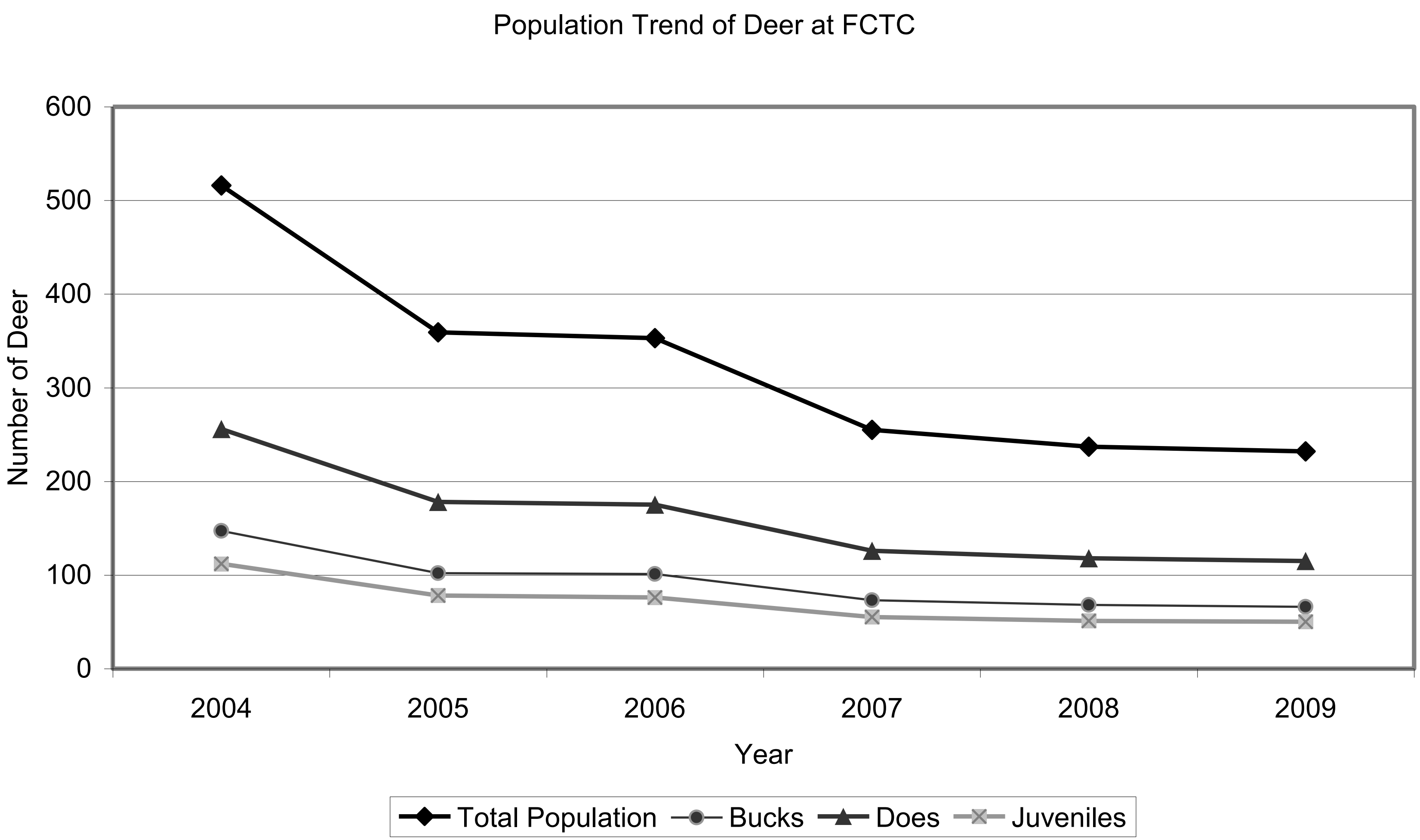

Figure 3.1. the population trend of deer from the SAK P_{ym} model.

Table 3.12. SAK model population estimates.

Year	Model Pym[1]	Mt[2]
2004	516	712
2005	360	496
2006	354	488
2007	255	352
2008	238	328
2009	232	320

1. Pym is the proportion of 1.5 year old males harvested versus the entire male population harvested.

2. Mt is estimated from the annual survival rate of radio-collared

Table 3.13. SAK Pym model annual populations estimates of age classes by gender with variance.

Gender	Age Class	Year	Number of deer	Variance
Bucks	Adult	2004	148	39
Bucks	Adult	2005	103	19
Bucks	Adult	2006	101	18
Bucks	Adult	2007	73	9
Bucks	Adult	2008	68	8
Bucks	Adult	2009	66	8
Does	Adult	2004	256	1455970
Does	Adult	2005	179	706571
Does	Adult	2006	176	683962
Does	Adult	2007	127	355859
Does	Adult	2008	127	309261
Does	Adult	2009	118	294359
Bucks and Does	Juvenile	2004	113	n/a
Bucks and Does	Juvenile	2005	79	n/a
Bucks and Does	Juvenile	2006	77	n/a
Bucks and Does	Juvenile	2007	56	n/a
Bucks and Does	Juvenile	2008	51	n/a
Bucks and Does	Juvenile	2009	50	n/a

Table 3.14. The number of deer per square mile and kilometer with the SAK model.

	P_{ym}		M_t	
Year	Deer/mi^2	Deer/km^2	Deer/mi^2	Deer/km^2
2004	43.65	16.86	60.17	23.24
2005	30.41	11.74	41.91	16.19
2006	29.92	11.55	41.24	15.93
2007	21.58	8.33	29.75	11.49
2008	20.11	7.77	27.72	10.71
2009	19.62	7.58	27.04	10.44

Forward Looking Infrared

During the night of March 27, 2007, Vision Air Research, Inc. conducted a forward-looking infrared (FLIR) flight over FCTC, FCRA, and the Heart Lake area. 285 deer in 92 different groups were observed with detection rate ranging from 70-100% (Table 3.15). The largest group size observed was 16, while several groups of one were observed. Vision Air Research, Inc. claimed an 82 – 87% detection rate in deciduous forest types, 100% in open meadows and agricultural fields, and 30-60% in conifer cover types. The deer that were sighted during the FLIR were concentrated in several areas (Figure 3.2).

On 13 November 2007, Vision Air Research, Inc. flew another FLIR flight, but midway through the flight dense fog caused safety concerns preempting completion of the survey. The following morning of 14 November 2007 the fog no longer posed a safety issue to the flight that allowed the completion of the FLIR survey. The 13 November flight had 198 deer in 102 groups; during the following morning flight, 113 deer were observed in 66 groups (Table 3.16). Vision Air Research Inc. again claimed the same detection rates: 70-100% overall, 82-87% in deciduous forest cover types, 100% in open meadows and agricultural fields, and 30-60% in conifer cover types. The Vision Air detection rates were estimates from their past studies in similar vegetation types. Their report indicated there were a number of leaves lingering on trees, but the leaves were relatively dry and not undergoing photosynthesis, which did not change detection rates. Deer sighted during the November FLIR were distributed throughout the survey area (Figure 3.3).

The deer density from the March FLIR survey yielded estimates of 6.04 deer per km^2 at FCTC and 6.64 deer per km^2 over the entire survey area that included FCRA and Hearts Lake (Table 3.17). The November FLIR survey estimated 6.30 deer per km^2 and 7.25 deer per km^2 respectively over the same areas (Table 3.17).

To account for the detection rate under 100% in the various cover types, I examined each data point from the FLIR surveys for the cover classification and group size for those particular points. I then adjusted the number of deer in the group based on the detection rates for the associated cover types. The detection rates had a range for each cover type, so I used both the high and low end of the range for these calculations, that led to a high and low adjustment of deer sighted for the two FLIR surveys. The detection rate adjusted values of deer density during the March flight ranged from 7.35 to 7.72 deer per km^2, the deer density ranged from 8.22 to 8.67 deer per km^2 in the November survey (Table 3.18).

Table 3.15. The number of deer sighted during the March 2007 FLIR survey.

	Total Deer	Number of Deer	Mean Deer Group Size	Max Deer Group Size	Min Deer Group Size
FCTC	185	62	2.98	10	1
IR Survey Area	285	92	3.09	16	1

Table 3.16. The number of deer sighted from the November 2007 FLIR survey.

	Total Deer	Number of Deer Groups	Mean Group Size	Max Group Size	Min Group Size
FCTC[1]	193	120	1.6	5	1
IR Survey Area[1]	311	181	1.69	5	1

1. The IR survey was delayed for approximately eight hours due to weather and the survey area was split in half, which led to the possibility of deer being either omitted or counted twice during the survey. Further analysis of the IR data indicates that 8 deer could have been counted twice reducing the number to 185 deer sighted on FCTC and 303 deer for the entire survey area.

Table 3.17. The deer density at FCTC and FCRA based on both FLIR surveys.

	FCTC		FCTC and FCRA	
Survey Period	Deer/mi^2	Deer/km^2	Deer/mi^2	Deer/km^2
March 2007	15.64	6.04	17.21	6.64
November 2007	16.31	6.30	18.78	7.25

Table 3.18. The deer density estimate from the two forward looking infrared surveys conducted in 2007. There are low and high adjustments in the deer density to account for a slightly diminished detection rate associated with FLIR in deciduous cover types.

	Deer/mi^2		Deer/km^2	
	Low Adjustment	High Adjustment	Low Adjustment	High Adjustment
March 2007 FLIR	19.06	20.01	7.35	7.72
November 2007 FLIR	21.29	22.46	8.22	8.67

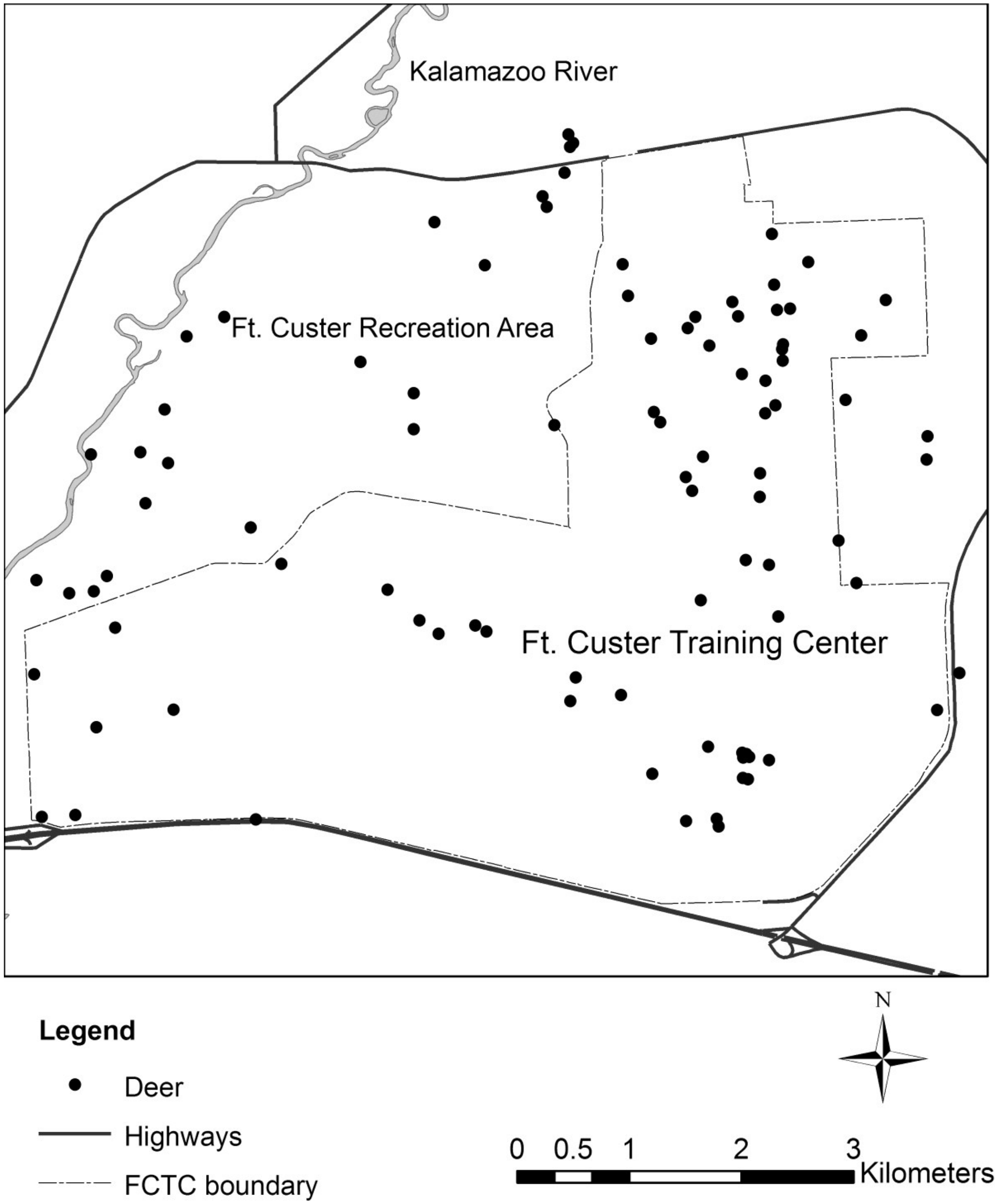

Figure 3.2 The locations of deer from the March 2007 forward looking infrared flight.

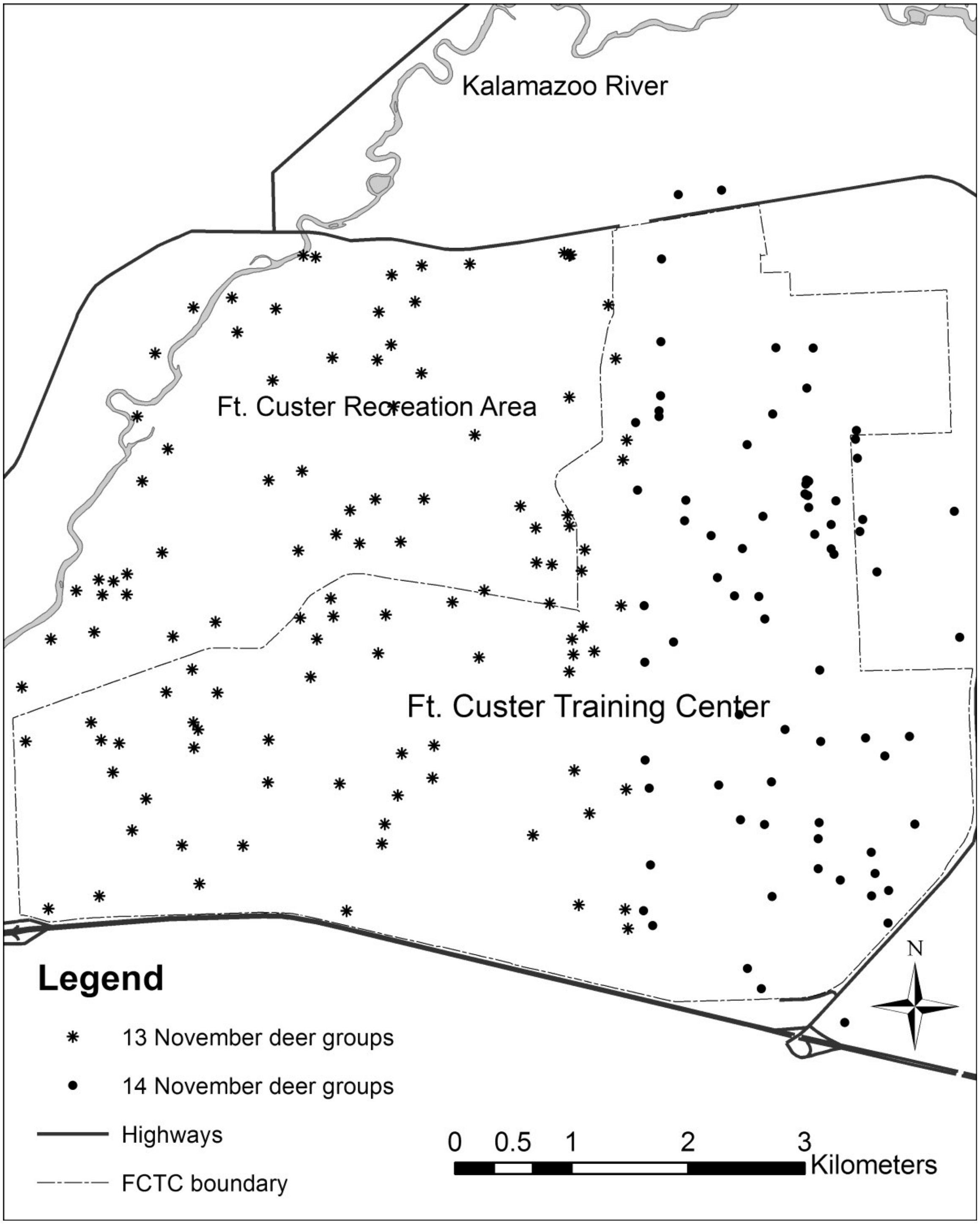

Figure 3.3 Locations of deer groups from the forward looking infrared survey on the evening of 13 November and morning of 14 November 2007. An asterisk indicates the locations from the 13th, while the locations from the 14th are indicated by a dot. Fog interrupted the flight after completion of approximately half of the survey.

Hunt Biodata

The beam diameter of year old male antlers did not change from 2004 to 2009 significantly according to an ANOVA ($F_{5,\ 199}$ = 0.83, P=0.53). The average number of antler points did show significant differences during the same time span ($F_{5,\ 162}$ = 3.61, P=0.0041). The number of antler points for year old males fluctuated somewhat from 2004 to 2008. In 2004, year old males averaged 4.74 (SE ± 0.31) pts, rising to 5.6 (SE ± 0.33) pts in 2006, then decreasing the following year to 4.11 (SE ± 0.33) pts , 2008 averaged 4.74 (SE ± 0.38) pts, while 2009 averaged 3.45 (SE ± 0.41) pts (Figure 3.3). Beam diameters of year old males increased incrementally each year from 19.4 (SE ± 0.65) mm in 2004 to 21.36 (SE ± 0.75) mm in 2009 (Figure 3.4). The sample sizes of year old males from 2004 to 2009 were (n=55, n=47, n=48, n=30, n=27, and n=11) respectively.

Two year old males average beam diameter did not show significant changes from 2004 to 2009 ($F_{5,\ 35}$ = 1.06, P=0.40), and neither did the average number of antler points ($F_{5,\ 31}$ = 0.37, P=0.86). The average beam diameter, and the number of antler points fluctuated from 2004 to 2009 (Figures 3.3 and 3.4). The sample sizes of two year old males from 2004 to 2009 were (n=16, n=6, n=3, n=5, n=6, and n=7) respectively. Beam diameter size of two year olds ranged from an average of 20.8 (SE ± 1.70) mm in 2005 to 27.0 (SE ± 1.00) mm in 2006. The number of antler points ranged from 6.40 (SE ± 1.16) pts in 2005 to 8.00 (SE ± 1.00) pts in 2006.

The beam diameter size did not show any statistically significant changes from 2004 to 2009 for three year olds ($F_{5,\ 30}$ = 1.42, P=0.24). The number of antler points was relatively consistent ($F_{5, 29}$ = 0.76, P=0.58). From 2004 to 2007 (no four year old deer were harvested after 2007) beam diameter size in four year olds changed significantly ($F_{3, 12}$ = 5.46, P=0.013), while the number of antler point have not show signs of significant statistical changes ($F_{3, 10}$ = 1.45, P=0.29)

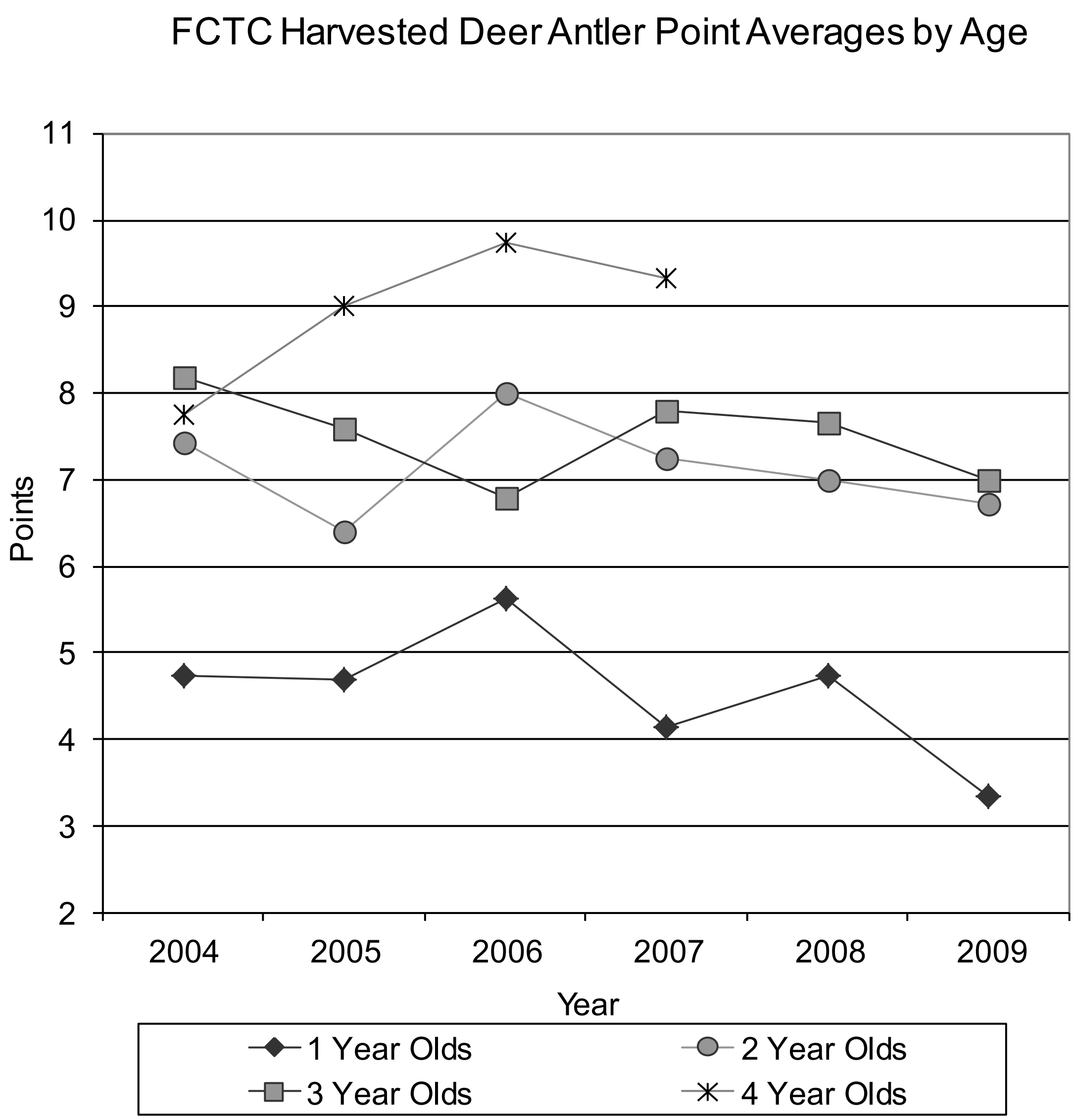

Figure 3.4. The annual trend in hunt biodata of the mean antler point counts by age.

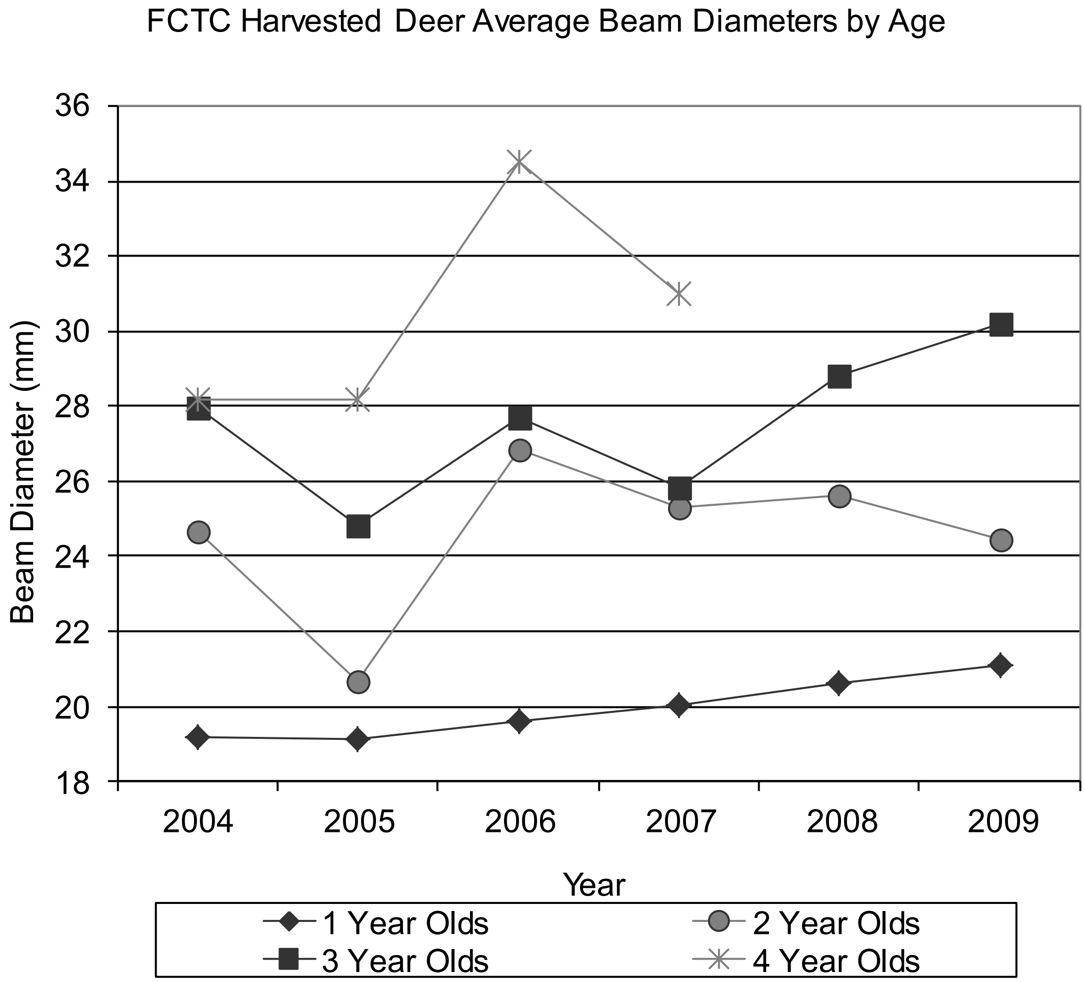

Figure 3.5. The annual trend of means with respect to beam diameter by age. No four-year-old deer were harvested in 2008 or 2009.

Vegetation Sampling

Typically, the amount of vertical cover in the understory did not differ between the exclosure and the paired control site. Site 1, consisting of mixed hardwoods, was the only site that had a significant difference in vertical cover measurements. The differences occurred in the understory in 2004 and 2007 (P=0.025, df=8) and (P=0.014, df=8), respectively. Site 1's exclosure understory averaged 180 (SE ± 28.11) and 339 (SE ± 77.35) cm per 1800 cm transect in

2004 and 2007 respectively. The paired control sites averaged 94 cm (SE ± 14.28) and 87 cm (SE ± 22.40) cm per 1800 cm transect in 2004 and 2007 (Tables 3.19-3.42).

The vegetation in the midstory in terms of vertical cover did not show major differences between the exclosures and paired control sites, except in one instance. In 2006 the midstory at the oak hardwood site 6, the exclosure had more vertical cover than the paired control, averaging 63 (SE ± 14.63) and 6 (SE ± 6.00) cm per 1800 cm transect respectively. Results from a t-test indicated a significant difference between the means (P=0.0069, df=8) (Tables 3.19-3.42).

The overstory did not have any instances of significant differences between the exclosure and paired control site. However, the 2005 overstory vertical cover at site 6, an oak hardwood site, yielded a t-test on the fringe of having a significant difference. The exclosure averaged 1690 (SE ± 29.32) cm per 1800 cm transect, while the paired control mean equaled 1558 (SE ± 50.34) cm per 1800 cm transect (P=0.053, df=8) (Tables 3.19-3.42).

On one occasion from 2004 to 2008, the stem density in the understory of the exclosure and the paired control were statistically significantly different. The exclosure at site 2 in 2006 averaged more stems per plot than the paired control (P=0.02, df=4) in 2006. At site 2, in 2006, on average 21.33 (SE ± 1.45) stems per 2 m^2 plot were sampled in the exclosure, and the paired control averaged 7.00 (SE ± 3.21) stems per 2 m^2 plot. The following year 9.00 (SE ± 4.16) stems per 2 m^2 plot were sampled in the paired control, while the exclosure had 29.67 (SE ± 7.42) stems per 2 m^2 plot.

Stem density did not differ significantly between the exclosure and paired control sites in the midstory. The mixed hardwood, site 3, in 2007 was the closest to having a significant difference ($P=0.09$, $df=4$). In that instance, 26.33 (SE ± 6.67) stems per 5 m^2 plot were sampled in the paired control compared to 10.67 (SE ± 2.19) stems per 5 m^2 plot in the exclosure.

The stem density of the understory tended to increase at each site from 2004 to 2007, while in 2008 the stem density tended to decrease from the 2007 means. This pattern occurred in both the exclosure and the paired control. The pattern was most pronounced at sites 4 and 5. Site 4 was composed of oak hardwoods, while site 5 consisted of mixed hardwoods. The understory of site 4 in the exclosure averaged 14.67 (SE ± 2.91), 32.67 (SE ± 7.26), 48.67 (SE ± 7.17), 100.67 (SE ± 23.95), and 51.00(SE ± 10.21) stems per 2 m^2 plot from 2004 to 2008, while the paired control averaged 20.33 (SE ± 1.67), 48.67 (SE ± 8.69), 83.00 (SE ± 13.23), 179.00 (SE ± 44.02), and 78.67(SE ± 9.21) stems per 2 m^2 plot (Tables 3.49-3.59). The understory stem density at site 5 followed a similar trend, where the exclosure averaged 6.33 (SE ± 0.67), 22.67 (SE ± 2.85), 85.00 (SE ± 17.62), 247.33 (SE ± 33.95), and 87.33(SE ± 11.29) stems per 2 m^2 plot from 2004 to 2008. This trend was not unique to the exclosure at site 5, the paired control mimicked the exclosure's pattern with an average of 8.00 (SE ± 1.15), 28.67 (SE ± 6.33), 98.33 (SE ± 7.17), 259.33 (SE ± 12.78), and 97.67 (SE ± 3.38) stem per 2 m^2 plot during the same time span. The pattern was not strongly pronounced, or did not occur at sites 1 and 2. The stem density in the paired control at site 2 was relatively flat, it averaged 10.00 (SE ± 2.08), 6.33 (SE

± 1.45), 7.00 (SE ± 3.21), 9.00 (SE ± 4.16) stem per 2 m^2 plot, and 14.33 (SE ± 7.88) from 2004 to 2008. The exclosure at site 2 averaged 11.67 (SE ± 2.19), 13.00 (SE ± 3.21), 21.33(SE ± 1.45), 29.67(SE ± 7.42), and 18.67 (SE ± 2.40) stems per 2 m^2 plot. The complete results of the stem density sampling of the units are found in Tables (3.43-3.59).

Table 3.19. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the understory. A standard t-test was used to test for differences between the two means.

Site 1 Mixed Hardwoods Understory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	180	28.11	94	14.28	8	0.025	Yes
2005	259	113.12	73	9.95	8	0.14	No
2006	222	45.90	165	40.81	8	0.38	No
2007	339	77.35	87	22.40	8	0.014	Yes
2008	256	58.16	163	43.88	8	0.23	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.20. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the midstory. A standard t-test was used to test for differences between the two means.

Site 1 Mixed Hardwoods Midstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	181	41.11	261	26.2	8	0.17	No
2005	108	48.34	91	17.9	8	0.75	No
2006	270	47.03	126	48.0	8	0.068	No
2007	264	95.47	67	28.8	8	0.084	No
2008	136	35.37	136	21.7	8	0.13	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.21. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the overstory. A standard t-test was used to test for differences between the two means.

Site 1 Mixed Hardwoods Overstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	1784	16.00	1717	45.43	8	0.20	No
2005	1732	22.23	1780	20.00	8	0.15	No
2006	1762	16.25	1757	13.93	8	0.82	No
2007	1691	16.85	1751	11.14	8	0.061	No
2008	1754	5.31	1759	8.42	8	0.63	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.22. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the understory. A standard t-test was used to test for differences between the two means.

Site 2 Mixed Hardwoods Understory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	240	47.86	253	32.35	8	0.83	No
2005	293	24.37	231	32.76	8	0.17	No
2006	263	43.29	224	38.79	8	0.53	No
2007	268	34.59	160	40.20	8	0.075	No
2008	266	24.54	217	10.54	8	0.10	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.23. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the midstory. A standard t-test was used to test for differences between the two means.

Site 2 Mixed Hardwoods Midstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	52	12.80	38	14.16	8	0.48	No
2005	20	12.40	14	40.36	8	0.66	No
2006	34	18.53	49	21.00	8	0.61	No
2007	110	21.37	101	21.64	8	0.76	No
2008	54	4.73	50	10.96	8	0.77	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.24. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the overstory. A standard t-test was used to test for differences between the two

Site 2 Mixed Hardwoods Overstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	1784	16.00	1790	10.00	8	0.76	No
2005	1786	8.72	1782	13.56	8	0.81	No
2006	1782	11.14	1787	8.31	8	0.73	No
2007	1792	8.00	1784	9.80	8	0.54	No
2008	1786	7.07	1778	2.61	8	0.95	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.25. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the understory. A standard t-test was used to test for differences between the two means.

Site 3 Mixed Hardwoods Understory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	929	57.59	1000	37.02	8	0.32	No
2005	958	111.99	827	58.02	8	0.33	No
2006	906	81.82	852	128.96	8	0.73	No
2007	787	52.41	830	31.02	8	0.50	No
2008	718	63.77	817	21.78	8	0.80	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.26. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the midstory. A standard t-test was used to test for differences between the two means.

Site 3 Mixed Hardwoods Midstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	498	36.53	389	41.95	8	0.087	No
2005	287	50.34	348	70.21	8	0.49	No
2006	359	49.05	443	54.55	8	0.29	No
2007	393	76.21	416	24.22	8	0.82	No
2008	406	47.48	396	27.14	8	0.86	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.27. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the overstory. A standard t-test was used to test for differences between the two means.

Site 3 Mixed Hardwoods Overstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	1788	12.00	1782	11.14	8	0.72	No
2005	1772	19.60	1764	22.27	8	0.79	No
2006	1758	13.56	1757	13.92	8	0.96	No
2007	1774	16.61	1791	5.56	8	0.36	No
2008	1770	5.40	1783	9.34	8	0.25	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.28. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the understory. A standard t-test was used to test for differences between the two means.

Site 4 Oak Hardwoods Understory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	732	70.52	849	67.68	8	0.27	No
2005	721	51.17	837	183.40	8	0.56	No
2006	701	90.88	731	129.08	8	0.85	No
2007	699	71.58	794	64.87	8	0.36	No
2008	703	34.20	799	104.33	8	0.40	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.29. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the midstory. A standard t-test was used to test for differences between the two means.

Site 4 Oak Hardwoods Midstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	418	61.02	347	46.16	8	0.38	No
2005	164	37.20	176	31.08	8	0.81	No
2006	148	20.04	183	44.99	8	0.50	No
2007	174	22.90	131	17.63	8	0.16	No
2008	230	27.53	205	20.74	8	0.49	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.30. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the overstory. A standard t-test was used to test for differences between the two means.

Site 4 Oak Hardwoods Overstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	1735	21.79	1686	20.15	8	0.14	No
2005	1658	9.69	1670	34.29	8	0.66	No
2006	1685	18.03	1660	15.25	8	0.32	No
2007	1663	18.95	1648	28.88	8	0.68	No
2008	1694	8.62	1678	12.15	8	0.30	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.31. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the understory. A standard t-test was used to test for differences between the two means.

Site 5 Mixed Hardwoods Understory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	1449	51.34	1533	50.09	8	0.27	No
2005	1425	65.13	1564	42.70	8	0.11	No
2006	1476	87.62	1375	87.62	8	0.37	No
2007	1262	183.81	1377	60.35	8	0.57	No
2008	1384	57.24	1465	35.57	8	0.26	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.32. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the midstory. A standard t-test was used to test for differences between the two means.

Site 5 Mixed Hardwoods Midstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	49	19.39	34	10.41	8	0.51	No
2005	77	27.21	50	28.42	8	0.50	No
2006	40	18.91	51	18.80	8	0.69	No
2007	79	12.08	73	27.18	8	0.85	No
2008	53	17.72	62	23.05	8	0.78	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.33. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the overstory. A standard t-test was used to test for differences between the two means.

Site 5 Mixed Hardwoods Overstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	1766	18.33	1766	16.00	8	1.00	No
2005	1740	31.47	1726	28.74	8	0.75	No
2006	1765	15.65	1759	13.45	8	0.78	No
2007	1764	16.39	1752	15.29	8	0.61	No
2008	1778	13.89	1750	17.02	8	0.22	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.34. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the understory. A standard t-test was used to test for differences between the two means.

Site 6 Oak Hardwoods Understory							
	Exclosure		Paired control				significant
Year	Mean[1]	SE	Mean[1]	SE	df	p value	difference
2004	343	48.57	344.8	45.85	8	0.98	No
2005	698	94.85	786	111.50	8	0.56	No
2006	299	52.50	249	52.09	8	0.52	No
2007	382	123.37	442	44.77	8	0.66	No
2008	428	57.67	456	40.37	8	0.70	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.35. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the midstory. A standard t-test was used to test for differences between the two means.

Site 6 Oak Hardwoods Midstory							
	Exclosure		Paired control				significant
Year	Mean[1]	SE	Mean[1]	SE	df	p value	difference
2004	42	29.39	19	9.27	8	0.47	No
2005	63	14.63	6	6.00	8	0.0069	Yes
2006	44	17.42	33	10.56	8	0.60	No
2007	37	8.75	17	7.35	8	0.12	No
2008	55	14.99	25	7.21	8	0.11	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.36. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the overstory. A standard t-test was used to test for differences between the two means.

Site 6 Oak Hardwoods Overstory							
	Exclosure		Paired control				significant
Year	Mean[1]	SE	Mean[1]	SE	df	p value	difference
2004	1550	53.01	1584	41.55	8	0.63	No
2005	1690	29.32	1558	50.34	8	0.053	No
2006	1658	24.58	1665	38.18	8	0.88	No
2007	1661	25.42	1666	23.15	8	0.89	No
2008	1646	16.21	1616	23.72	8	0.32	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.37. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the understory. A standard t-test was used to test for differences between the two means.

Site 7 Oak Hardwoods Understory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	175	15.19	211	29.55	8	0.31	No
2005	434	91.68	434	36.67	8	0.27	No
2006	485	93.90	518	125.24	8	0.84	No
2007	413	38.42	579	118.68	8	0.22	No
2008	375	39.83	414	36.19	8	0.48	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.38. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the midstory. A standard t-test was used to test for differences between the two means.

Site 7 Oak Hardwoods Midstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	32	11.20	75	24.25	8	0.14	No
2005	61	3.67	47	9.95	8	0.22	No
2006	51	21.93	56	17.73	8	0.85	No
2007	76	13.55	117	25.28	8	0.19	No
2008	63	3.76	73	16.14	8	0.55	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.39. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the overstory. A standard t-test was used to test for differences between the two means.

Site 7 Oak Hardwoods Overstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	1675	30.25	1734	20.88	8	0.15	No
2005	1666	24.21	1632	39.17	8	0.48	No
2006	1629	32.11	1619	36.99	8	0.84	No
2007	1626	20.88	1663	26.27	8	0.31	No
2008	1674	11.98	1663	13.16	8	0.57	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.40. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the understory. A standard t-test was used to test for differences between the two means.

Site 8 Oak Hardwoods Understory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	713	60.86	815	110.49	8	0.44	No
2005	1226	110.11	881	67.55	8	0.028	Yes
2006	1044	91.58	1029	133.56	8	0.93	No
2007	1030	85.49	1027	68.22	8	0.98	No
2008	1006	42.67	939	47.58	8	0.32	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.41. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the midstory. A standard t-test was used to test for differences between the two means.

Site 8 Oak Hardwoods Midstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	290	34.56	378	30.03	8	0.093	No
2005	199	59.72	268	48.18	8	0.39	No
2006	292	59.38	323	48.95	8	0.70	No
2007	303	49.76	263	39.33	8	0.54	No
2008	273	33.87	309	18.53	8	0.38	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.42. Comparison of means between the paired control unit and the exclosure from the line intercept method measuring vertical cover in the overstory. A standard t-test was used to test for differences between the two means.

Site 8 Oak Hardwoods Overstory							
	Exclosure		Paired control				
Year	Mean[1]	SE	Mean[1]	SE	df	p value	significant difference
2004	1725	27.39	1756	19.66	8	0.38	No
2005	1772	19.60	1756	19.13	8	0.57	No
2006	1768	13.19	1748	15.94	8	0.36	No
2007	1716	29.76	1720	10.49	8	0.90	No
2008	1758	5.80	1747	14.42	8	0.49	No

1. The mean is estimated from a transect 1800 cm long.

Table 3.43. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 1 Mixed Hardwoods Understory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	13.00	3.61	12.33	1.76	4	0.88	No
2005	13.33	6.06	18.00	7.00	4	0.64	No
2006	18.00	7.51	12.33	2.96	4	0.52	No
2007	36.33	14.68	8.67	1.20	4	0.13	No
2008	19.67	6.33	16.00	2.31	4	0.62	No

1. The mean is estimated from the number of stems sampled in a 2 m^2 plot

Table 3.44. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 2 Mixed Hardwood Understory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	11.67	2.19	10.00	2.08	4	0.61	No
2005	13.00	3.21	6.33	1.45	4	0.13	No
2006	21.33	1.45	7.00	3.21	4	0.02	Yes
2007	29.67	7.42	9.00	4.16	4	0.07	No
2008	18.67	2.40	14.33	7.88	4	0.63	No

1. The mean is estimated from the number of stems sampled in a 2 m^2 plot

Table 3.45. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 3 Mixed Hardwoods Understory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	13.00	1.15	14.33	5.24	4	0.82	No
2005	39.67	23.21	32.33	6.01	4	0.78	No
2006	43.00	16.92	48.33	1.76	4	0.77	No
2007	82.00	28.36	96.00	17.24	4	0.69	No
2008	41.33	10.97	46.67	3.38	4	0.67	No

1. The mean is estimated from the number of stems sampled in a 2 m^2 plot

Table 3.46. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 4 Mixed Hardwoods Understory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	14.67	2.91	20.33	1.67	4	0.17	No
2005	32.67	7.26	48.67	8.69	4	0.23	No
2006	48.67	7.17	83.00	13.23	4	0.08	No
2007	100.67	23.95	179.00	44.02	4	0.19	No
2008	51.00	10.21	78.67	9.21	4	0.11	No

1. The mean is estimated from the number of stems sampled in a 2 m^2 plot

Table 3.47. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 5 Mixed Hardwoods Understory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	6.33	0.67	8.00	1.15	4	0.28	No
2005	22.67	2.85	28.67	6.33	4	0.44	No
2006	85.00	17.62	98.33	7.17	4	0.52	No
2007	247.33	37.95	259.33	12.78	4	0.78	No
2008	87.33	11.29	97.67	3.38	4	0.43	No

1. The mean is estimated from the number of stems sampled in a 2 m^2 plot

Table 3.48. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 6 Mixed Hardwoods Understory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	6.33	3.18	18.00	5.20	4	0.13	No
2005	24.33	6.84	17.67	7.67	4	0.55	No
2006	23.00	6.43	27.67	2.40	4	0.53	No
2007	44.00	16.04	50.33	13.30	4	0.78	No
2008	23.67	7.80	28.00	2.52	4	0.62	No

1. The mean is estimated from the number of stems sampled in a 2 m^2 plot

Table 3.49. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 7 Mixed Hardwoods Understory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	7.33	2.33	8.00	1.15	4	0.81	No
2005	9.33	2.03	8.67	3.28	4	0.87	No
2006	23.33	2.91	39.33	13.38	4	0.31	No
2007	53.00	10.69	98.00	33.18	4	0.27	No
2008	23.00	2.31	43.67	14.19	4	0.22	No

1. The mean is estimated from the number of stems sampled in a 2 m^2 plot

Table 3.50. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 8 Mixed Hardwoods Understory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	12.00	5.86	13.67	2.03	4	0.80	No
2005	52.00	7.21	44.00	2.65	4	0.36	No
2006	57.00	4.62	68.33	19.10	4	0.60	No
2007	108.67	20.09	143.33	52.72	4	0.57	No
2008	55.67	5.84	65.33	16.34	4	0.61	No

1. The mean is estimated from the number of stems sampled in a 2 m^2 plot

Table 3.51. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 1 Mixed Hardwoods Midstory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	2.33	1.20	2.33	0.33	4	1.00	No
2005	2.67	0.88	0.67	0.67	4	0.14	No
2006	5.33	1.33	3.67	1.20	4	0.41	No
2007	2.00	1.53	1.33	0.33	4	0.69	No
2008	3.00	1.00	1.33	0.88	4	0.28	No

1. The mean is estimated from the number of stems sampled in a 5 m^2 plot

Table 3.52. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 2 Mixed Hardwoods Midstory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	0.67	0.67	1.33	0.88	4	0.58	No
2005	1.00	0.58	0.33	0.33	4	0.37	No
2006	2.33	0.88	2.33	0.33	4	1.00	No
2007	1.33	1.33	1.33	0.88	4	1.00	No
2008	1.33	0.88	1.00	0.58	4	0.77	No

1. The mean is estimated from the number of stems sampled in a 5 m^2 plot

Table 3.53. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 3 Mixed Hardwoods Midstory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	5.33	2.33	2.00	0.58	4	0.24	No
2005	4.00	1.53	4.33	1.33	4	0.88	No
2006	9.33	2.03	11.00	1.53	4	0.55	No
2007	10.67	2.19	26.33	6.67	4	0.09	No
2008	6.33	1.45	8.33	1.86	4	0.44	No

1. The mean is estimated from the number of stems sampled in a 5 m^2 plot

Table 3.54. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 4 Oak Hardwoods Midstory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	3.67	1.67	5.67	2.91	4	0.58	No
2005	5.67	1.76	3.67	1.20	4	0.40	No
2006	13.67	2.03	16.00	3.79	4	0.62	No
2007	16.67	1.86	24.00	4.58	4	0.21	No
2008	8.67	1.76	11.33	1.76	4	0.35	No

1. The mean is estimated from the number of stems sampled in a 5 m^2 plot

Table 3.56. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 5 Mixed Hardwoods Midstory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	1.67	0.88	1.67	1.67	4	1.00	No
2005	0.67	0.67	0.33	0.33	4	0.68	No
2006	5.33	1.86	4.33	2.85	4	0.78	No
2007	9.00	5.57	8.00	4.04	4	0.89	No
2008	3.67	2.19	3.67	2.19	4	1.00	No

1. The mean is estimated from the number of stems sampled in a 5 m^2 plot

Table 3.57. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 6 Oak Hardwoods Midstory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	1.00	1.00	1.00	1.00	4	1.00	No
2005	1.00	1.00	0.33	0.33	4	0.56	No
2006	2.67	2.19	1.67	0.88	4	0.69	No
2007	2.00	1.15	1.67	0.88	4	0.83	No
2008	2.00	1.15	1.00	0.58	4	0.48	No

1. The mean is estimated from the number of stems sampled in a 5 m^2 plot

Table 3.58. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 7 Oak Hardwoods Midstory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	3.00	0.58	3.33	0.33	4	0.64	No
2005	0.58	1.00	2.33	1.20	4	0.64	No
2006	8.67	1.67	10.00	1.00	4	0.53	No
2007	10.33	3.71	13.00	5.29	4	0.70	No
2008	5.67	1.20	6.67	0.88	4	0.54	No

1. The mean is estimated from the number of stems sampled in a 5 m^2 plot

Table 3.59. The annual mean of stem density, with a standard t-test to compare differences between the exclosure and its paired control site.

Site 8 Oak Hardwoods Midstory							
	Exclosures		Paired Control				
Year	Mean[1]	SE	Mean[1]	SE	df	P-Value	Signficant difference
2004	2.33	1.33	5.00	1.00	4	0.18	No
2005	8.67	1.33	7.33	2.60	4	0.67	No
2006	17.33	3.53	19.00	4.16	4	0.78	No
2007	20.00	4.51	22.00	3.61	4	0.75	No
2008	11.00	3.06	13.33	2.85	4	0.61	No

1. The mean is estimated from the number of stems sampled in a 5 m^2 plot

CHAPTER 4: DISCUSSION

It is common for natural resource managers to face challenges in their quest to conserve resources; however, the specific challenges that the MDMVA faces at FCTC are unique. The primary mission of FCTC is to function as a military base; coincidently the base encompasses 7,560 acres of diverse flora and fauna. The INRMP dictates a secondary objective at FCTC of ecosystem restoration and rehabilitation. It is implicit in the INRMP that management of the deer herd at FCTC plays an integral role in meeting the criteria promulgated within the INRMP. To manage the deer herd the MDMVA needs to mitigate deer effects on the ecosystem at FCTC and serve as an intermediary between stakeholders wanting different outcomes with the deer herd (e.g. population size).

To provide assistance managing the deer herd at FCTC, I examined and developed a management policy for the MDMVA addressing the deer herd based on the outcome of the research conducted from 2004-2008. I have accounted for the nuances at FCTC that differ from other deer management areas and policies.

Winter and Spring Capture

Success of the winter capture period depended on the severity of winter weather. I attribute the lack of overall success during the winter capture period in 2005-2006, where only 3 deer were captured, to an extremely mild winter. Ironically, that year clover traps were placed in the field earlier than in any other year, but FCTC lacked snow cover for nearly the entire trapping period. Snow cover limits deer access to forage, while cold temperatures increase the caloric and nutritional requirements for the survival of deer. Therefore, a mild winter reduced the allure of bait piles in and around the trap site. Other factors that decreased capture success included capturing other species (e.g. turkeys [*Meleagris gallopavo*], fox squirrels [*Sqiurus niger*], cottontail rabbits [*Sylvilagus floridanus*], opossums [*Didelphis virginiana*], raccons [*Procyon lotor*], and various passerines) and having the trap tripped inadvertently for numerous reasons.

Successful capture of deer relied on snow cover, cold temperatures, and knowledge of movement patterns of deer at FCTC. The distribution of traps was relatively homogenous throughout FCTC and FCRA, and every trap site had a considerable amount of deer sign. Areas 5 and 7 proved problematic, since I did not capture any deer in these areas during any of the winter capture seasons (a map of FCTC is contained in Figure 1.2 on page 5). In part, this difficulty arose from a probable lower density of deer and bad luck (traps with false trips, high amount of raccoon and turkey activity).

Capturing neonatal fawns in the spring proved more time intensive than anticipated. Other studies that captured neonatal fawns did not require the personnel hours that this study required capturing individuals. Pusateri (2003) averaged 7.5 and 10 personnel hours per fawn capture, respectively, for two spring capture periods of neonatal fawns. Over a three-year period, Hiller (2007) averaged 25 hours per neonatal fawn capture, while it improved each succeeding year with 39.2, 30.8, and 12.3 hours per neonatal fawn capture respectively. I averaged 46.4 hours per neonatal fawn capture, in which the first year took 58.5 hours per neonatal fawn and 34.2 hours per neonatal fawn in 2007.

The large decrease year-to-year required to capture a neonatal is indicative of the subtleties necessary to determine an ideal location to search for neonatal fawns, which search techniques to use, and observers refining their search image of fawns. My field team's ability to capture older neonatal fawns changed during the second season, and that led to an increase in the number captured (see spring capture in Methods for more detail).

A combination of techniques in all likelihood led to the greatest chance for capture of neonatal fawns. Locating solitary does that are in habitat conducive to fawning and exhibiting behavior indicative of having a fawn nearby led to the highest capture success. Closely monitoring radio-collared does during the fawning season contributed to several captures of neonatal fawns. I theorized that when does with radio-collars displayed an extremely high degree of a fidelity to a certain site; they most likely had recently given birth. The area was then grid searched, and on several occasions, neonatal fawns were either captured or observed.

Survival and Fate Assessment

The greatest source of mortality was that of hunter harvest, where hunter harvest accounted for 64% of all mortalities followed by predation at 18% and stress and trauma related mortalities at 9% in winter captured deer. Hunter harvest accounted for 85% of the mortalities for adult female deer in Hiller's

(2007) south central Michigan deer study. Hiller (2007) did not radio-collar any adult males, so no comparisons could be made with respect to adult male deer. Hunter harvest was the greatest source of mortality (65%) with deer vehicle collisions second (27%) in a study in the southwestern lower peninsula of Michigan in adult female deer (Pusateri 2003). The preponderance of hunter harvest as the leading cause of mortality clearly illustrates the integral role hunting plays in managing the size of the southern Michigan deer herd.

Predation of adult and yearling radio-collared deer occurred during the winter months when snow depths and conditions disadvantage deer to coyotes (*Canis latrans*) the majority of the time (Patterson and Messier 2000). The conditions during my study were similar to that of the Patterson and Messier (2000) study in terms of daily mean temperature in January where both sites averaged approximately -5 °C and snow depths were not different, they both did not exceed 30 cm (Midwestern Regional Climate Center, Champaign, Illinois, USA). During the one notable relatively mild winter in 2006, no predation of radio-collared deer occurred. The rate of predation may vary with the severity of winter and density of the deer herd.

Spring captured neonatal fawns did not have a statistically significant single source of mortality. Possible coyote predation occurred 3 times, and accounted for 37.5% of mortalities; while hunter harvest accounted for 2 additional mortalities at 25%. On two occasions where coyote predation was the likely source of mortality, the head of the fawn was discovered buried underground and no body was recovered. The necropsy results of the examination of both fawn heads indicated canine bites that commonly occur with coyote predation.

The survival of fawns over their first 180 days was 0.49 (95% CL = 0.23 – 0.75), and the annual survival was estimated at 0.29 (95% CL = 0.15-0.57) which differed significantly from the 0.75 (95% CL = 0.59–0.91; Kaplan-Meier method) estimate for southwestern Lower Michigan (Pusateri-Burroughs et al. 2006), and Hiller's (2007) estimate of 0.51 (95% CL = 0.37–0.66). A smaller sample size, and thus an increased sensitivity to stochastic effects, may account for some of the lower survival rates observed in my study (n=14); compared to Pusateri (2003) (n=75) and Hiller (2007) (n=34). Differences in human density and land use among the study sites may also affect the mortality sources. It is possible that FCTC has a higher coyote density than that of the other study sites where people may harvest coyotes thus reducing the density in those areas.

SAK Model

Many state agencies use the SAK model to estimate the abundance of deer. The application of the SAK model typically occurs at a relatively broad geographic scale, and model fitness for precise estimates occurs with populations over 10,000 animals (Millspaugh et al. 2009). Model precision, as evaluated by Millspaugh et al. (2009) is dependent on the accuracy of harvest data that forms the model. The SAK model typically used by agencies utilizes harvest data to estimate the proportion of mortality in male deer caused by hunting. The SAK M_t model I derived depended on data from radio-collared deer to estimate the amount of male deer mortality from hunter harvest. In addition to the parameter estimates derived from radio-collared deer data to increase precision, the hunter harvest data at FCTC is for every individual deer and this avoids the possibility of bias from hunters' selectively deciding what deer to check or not to check. The harvest data is not biased on other factors that are problematic with voluntary check stations, such as distance to the check station, gender, size, and other intangible factors that may or may not make the hunter feel inclined to check the deer.

The SAK models show a desirable population trend from a management standpoint with the population decreasing. A significant reduction in the size of the deer herd has been the overarching goal since the establishment of the public hunt in 1986.

Forward Looking Infrared (*FLIR*)

The FLIR conducted in March of 2007 was flown under better conditions (i.e. snow cover, colder temperatures, and lack of residual leaf cover on trees obscuring thermal images) than was the November 2007 survey. The March results were in line with expectations based on SAK model estimates and my personal observations of the deer herd at FCTC. Results from the November survey were slightly lower than the anticipated size of the deer herd. The November survey took place when trees still had some residual leaf cover and no snow cover, which could lower detection rates. Additionally, the March survey had a greater proportion of deer in open fields where detection rates are at or near 100%, where the November survey had fewer deer and a smaller proportion of deer in open fields. The majority of deer in the November survey were detected in deciduous forests where there is a detection rate ranging from 82%-87%. The cover deer were typically located in during the November survey, weather, and leaf cover may have affected the results slightly.

The spatial distributions of deer from the FLIR surveys detected were different. The March flight depicted a heterogeneous distribution, while the distribution of deer in November was more homogeneous. The larger group sizes and distribution of deer from the March flight is attributed to seasonal variability in resource selection and behavioral differences. I attribute the small group sizes in mid November to behavior associated with the rut and breeding cycle of deer. The March flight results are representative of deer selecting cover and forage at FCTC in addition to being in their typical social units.

I would recommend that the MDMVA have a FLIR performed every 5 years to verify the abundance of the deer herd relative to the other indices (the SAK model, vegetation sampling, and hunt biodata). The SAK model and hunt biodata coupled with the vegetation sampling will indicate if the size of the deer herd is increasing significantly. A significant increase in the abundance of deer at FCTC will affect the MDMVA long term management goals. The ideal time to conduct a FLIR is during the winter with an absence of leaf cover obscuring thermal images. In addition, the likelihood of misidentifying thermal signatures as a deer is minimal, while deer are more distinguishable.

Spotlight Survey

In 2004 and 2005 the spotlight survey was performed and its' effectiveness was greatly limited by lack of suitable terrain. A spotlight survey requires terrain that has numerous areas where deer can be observed from a distance. In the case of FCTC, areas offering observers a reasonable chance to spot deer is limited. Training areas 1, 2, and the northern edge of 9 offer the greatest likelihood. Originally, it was believed that training areas 3, 4, and six might also offer areas with relatively good chance at observing deer. However, the few open areas in training area 3 and 4 had a variety of grass and shrub species that are tall enough to obscure deer from an observer's view. FCTC's size and landscape composition limited the effectiveness of the spotlight survey.

Hunt Biodata

Since the inception of the public hunt at FCTC, the biodata gathered has indicated an improvement in the quality of forage available, implying a decrease in deer density. Biometric indices measuring the physical characteristics of deer have steadily improved. The mean deer weight for fawns harvested has increased significantly from 1986 to 2009. In 1986, female fawns averaged 42.2 (S.E. ± 1.1) lbs versus a mean weight of 63.7 (S.E. ± 3.9) lbs in 2008 (only one female fawn was harvested in 2009 and it weighed 59 lbs). Male fawns averaged 44.5 (S.E. ± 1.0) lbs, and 69.5 (S.E. ± 3.9) in 1986 and 2008 respectively. The mean beam diameter has increased across the board in year old bucks with statistical significance. In 1986 bucks averaged 18.8 (S.E. ± 0.51) mm, while in 2009 the mean beam diameter was 21.1 (S.E. ± 0.76) mm. The average number of antler points in 1986 was 4.17 (S.E. ± 0.23) points while in 2009 the mean was 4.7 (S.E. ± 0.38) points. A decreasing deer density from 1986 to 2009 has allowed the quality of forage to improve, which accounts for an increase in mean beam diameter, number of antler points, and the weight of fawns in the hunt biodata.

Beam diameter of yearling males is indicative of the quality of the forage during summer months (Severinghaus and Moen 1983, Schmidt et al. 2001). The high deer densities that cause the quality of forage to degrade does not happen immediately; so, changes in the physical characteristics of deer correlated with the quality of forage subsequently lags behind an increase in deer density (Patterson and Power 2002). Such a lag between deer density and range quality has the potential to encourage pronounced fluctuations in deer populations if managers base decisions solely on biodata (May 1981; Messier et al. 1988; Fryxell et al. 1991). Despite being a useful tool, biodata alone is inadequate in detecting changes in range conditions and approximating deer densities. The time lag inherent with biodata being correlated with changes associated with range conditions can prevent a managerial change before the deer density increases to a point where the herd may negatively impact their range. To assess changes in the abundance of the deer herd the biodata should be used in conjunction with continued collection of data from the exclosures and SAK model estimates.

Resource Utilization and Habitat use

The results from the compositional analysis indicate that deer at FCTC have a strong selection preference for the two vegetation types that the MDMVA is trying to preserve and restore (oak hardwoods and prairies ‘fields’). Adult deer heavily relied on both types of hardwoods and fields. While fawns were also reliant on the oak and mixed hardwood, their most highly selected vegetation type was fields. The hardwoods preference of adults most likely stems from the fact they provide good mast crops that have high nutritional value. Fawns selected habitat that provided cover over habitat that provided forage because their mother fulfilled a significant portion of their nutritional needs. Until their first autumn fawns will continue to nurse, but by 10 weeks the have become functionally weaned (Marchinton and Hirth1984). This selection of habitat use by deer complicates the MDMVA’s ability to achieve their management goals because deer act as keystone herbivores and can influence the composition of a landscape.

The influence that deer have on a landscape’s composition is density dependent. Alverson et al. (1988) suggested that deer densities should not exceed 4 deer/km^2 (10.4 deer/mi^2). Since the deer herd is selecting the oak hardwoods and prairie resources, they are also more likely to have a detrimental impact on the very landscape the MDMVA is trying to preserve. The oak hardwoods and prairies provide deer with mast crops and cover for fawns, so it is not unexpected to observe these trends of resource utilization at FCTC. If the

MDMVA is going to achieve their natural resources management objectives, it's essential to manage the size of the deer herd.

In 2009, when the MDMVA had assumed responsibility to monitor the exclosures, *Liparis liliifolia*, a species listed as special concern, was found inside the exclosure at Site 3. Two individuals of *L. liliifolia* were observed during the annual vegetation survey of the exclosures. The occurrence of this orchid is rare throughout its range, and the prevalence of *L. liliifolia* leads to a relatively low probability of detection. There is not sufficient data at the current time to conclude that deer herbivory has limited the abundance of *L. liliifolia*. *L. liliifolia* is found in a variety of habitats; it is usually found in areas that have been disturbed, and prescribed burns are beneficial for the species (Michigan Natural Species Inventory, Lansing, Michigan, USA).

The contiguous closed canopy forest at FCTC differed from the landscape composition of two other deer studies in the southern Lower Peninsula of Michigan conducted by Pusateri Burroughs et al. (2006), and Hiller (2007) where 34% and 20% of their study area was composed of agricultural fields respectively. Differences in the study areas' landscape composition did not seem to influence home range size.

The sizes of home ranges of deer amongst the three studies in southern Michigan were similar. The mean home range size for fawns in southwestern Michigan was 75.36 ha (SE ± 4.47) with values ranging from 38.38 ha to 118.5 ha (Pusateri 2003). Comparatively, my annual home range size for fawns was 73.22 (SE ± 23.27) ha. My average home range size for adult females was

132.22 (SE ± 16.05) ha, which is inline with home range estimates from south central Michigan at 140.4 ha during the growing season, and 157.7 ha for deer > 6 months and non-dispersers in southwestern Michigan (Hiller 2007, Pusateri 2003, respectively). I did not use deer with less than 30 locations for comparisons because a small sample size may result in an underestimate of the size of fixed kernel home range estimates leading to poor bandwidth selection and any outliers have greater weight (Seaman et al. 1999).

I did not observe dispersal in any adult deer, male or female. Adult deer demonstrated a high degree of fidelity to their capture areas. Yearling males were the only deer that dispersed in my study. I adopted Kenward et al. (2001, 2002) definition of dispersal; a white-tailed deer permanently emigrated from a natal range to a distinct adult range, such that predispersal locations did not overlap postdispersal locations. Despite being a fenced in area, the deer herd at FCTC can move on and off the base. The fence is rather porous in terms of constraining a deer's movement. Male deer dispersal from their natal range is a common behavior; Ozoga and Verme (1985) suggested that yearling males disperse from their natal ranges due to domination by older female relatives and a basic drive for fraternal membership to establish their dominance. Holzenbien and Marchinton (1992) demonstrated that maternal domination did serve as a mechanism to promote yearling male dispersal, and they theorized that their dispersal reduced inbreeding and increased the inclusive fitness of their mothers.

Vegetation Sampling

In 2004, when I selected the 8 exclosure and paired control sites I attempted to find similar type sites in a broad spectrum of two basic cover types, oak hardwoods and mixed hardwoods. I selected sites that were homogenous and relatively identical in regards to the exclosure and paired control site. Upon completion of the vegetation sampling in 2008 of the exclosures and paired control sites, there is no evidence that deer are significantly affecting their range at FCTC.

Data from exclosures and the paired control sites indicate the current deer densities produce minimal impacts regarding changes in the structure and composition of forest types. The results from the vegetation analysis indicate that the deer herd has not fundamentally changed the species composition and vegetation structure at FCTC.

The tolerance to deer herbivory by the plant community varies from one geographic region to another with varying biotic and abiotic components (Horsley et al. 2003, Côté et al. 2004). The effect on forest resources of a given deer density is dependent on the surrounding landscape and available forage (deCalesta and Stout 1997). DeCalesta and Stout (1997) assessed studies by Tilghman (1989), deCalesta (1992), and Palmer et al. (1997) concluding that those studies indicated that the impact of deer on a landscape needed to be scaled to the specific area where they occur.

Kittredge and Ashton (1995) claimed diverse forest regeneration of New England forests was incompatible with deer densities in excess of 23 deer per square mile. The precise density of deer that could roam FCTC without causing significant changes to the forest structure and composition is difficult to estimate. At the same time, managing the size of the deer herd to a level that precise is an impossible task. The density levels would fluctuate year to year with different weather patterns and food availability, especially in the case of FCTC where oak mast may be highly variable one year to the next. However, the range of the deer densities over the duration of this study, in which few changes occurred in structure and composition of forest types, would be a reasonable range in the deer density.

Relative Deer Density

Studies concerning the sustainability of oak and hickory forests in the Lower Peninsula of Michigan with respect to a specific deer density are nonexistent at the current time. However, the concept of relative deer density (RDD) is applicable to FCTC. RDD, a concept proposed by deCalsta and Stout (1997) incorporates theories by McCullough (1984) and Marquis et al (1992) and is consistent with the theory of managing the effects of deer relative to their occurrence. McCullough (1984) defined carrying capacity (K) as the residual population productivity declining to zero. Carrying capacity is further defined as the maximum number of animals an environment will support on a sustained basis. DeCalsta and Stout (1997) combined McCullough's concept of K carrying capacity and his population recruitment curve (McCullough 1979) as backdrop for defining RDD relating to sustaining ecosystem components and deer harvests where RDD is the proportion of deer density at K, carrying capacity (Figure 4.1). It allows stakeholders to prioritize their management decisions based on specific needs at local or regional levels. It should be noted that deCalasta and Stout (1997) predicted that a RDD that would sustain biodiversity is < 1/3 the maximum sustained yield of deer for hunter harvest. The RDD that would allow the maximum number of resources maintained in an ecosystem, is considered sustaining biodiversity by deCalsta and Stout (1997), and is annotated as RDD_s (Figure 4.1)

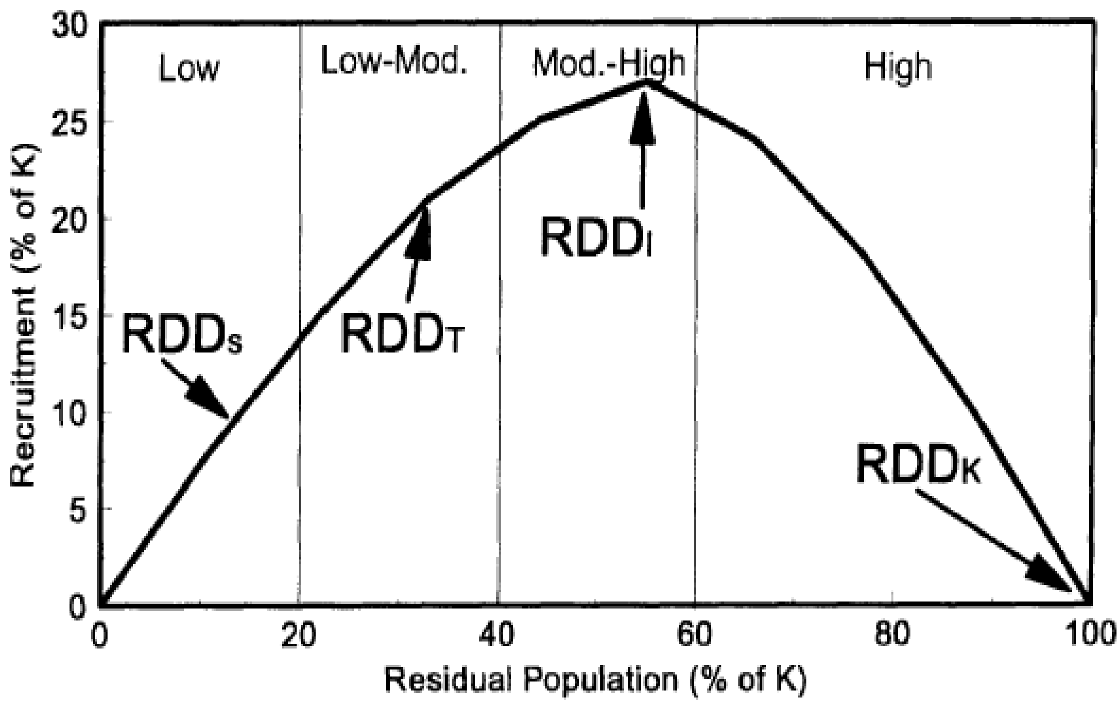

Figure 4.1. Relative deer density (RDD) displayed on McCullough's (1984) graph. DeCalasta and Stout (1997) approximated the location of RDD_S, the level associated with sustaining biodiversity, RDD_T, the level at which timber productivity is sustained, and RDD_I, the level associated with maximum sustained yield of deer numbers for harvest.

Marquis et al. (1992) work on a deer impact index is integrated with McCullough's concepts to form the idea of a RDD. Marquis et al. (1992) postulated at any given deer density, the amount of forage available in a landscape determines the impact of deer herbivory on forest regeneration. This suggests that deer at even low densities can significantly affect a landscape.

The protocol and management recommendations I have outlined herein factor in the theory of RDD. The continued monitoring and analysis of the data from the deer exclosures will indicate if the deer herd has reached a size where they are significantly altering their range. Those significant changes in vegetation are indicative of a higher density deer herd. The biodata gathered during the public hunt is sensitive to changes in deer density, as the density increases, quality forage decreases, and as quality forage decreases physical characteristics of deer change (e.g. beam diameters, point counts, and weight all decrease). The change in these physical characteristics is most notable in one-year-old males. The FLIR and SAK model estimates provide population estimates with a level of precision that will allow managers at FCTC to make sound decisions. The population estimates used in conjunction with the deer density indices constitutes a RDD for FCTC. In addition to the aforementioned methodology contributing to a RDD at FCTC, it would behoove the MDMVA to routinely walk and inspect FCTC for deer browse lines, overwinter deaths, and other deer sign every spring to further validate the RDD.

The concept of RDD is applicable to the type of management done at FCTC. Proper management of the deer herd and estimation of the deer density rely on several types of qualitative and quantitative methods estimating the approximate density of deer. The MDMVA needs to incorporate the host of indices estimating deer density and browse effects on the forest composition and structure. In addition to incorporating the various methods, managers should not overreact to a single set of data that may change in one-year's time, yet managers should be aware that those changes might be indicative of a change in the RDD. Significant changes in biodata may occur over a single year due to the variability of weather and other stochastic effects. If the data from one index or population estimate indicates a significant change, the MDMVA should assess the other indices, and consider the possibility of revising the current management protocol if appropriate. The managerial scenarios and recommendations are discussed later on in this document.

Hunter Participation

Hunter participation is a critical aspect in managing the deer herd at FCTC. Over the last few years a trend has developed where the number of hunters participating the public hunt has declined significantly (Figure 4.2). An insufficient amount of hunter participation may decrease the number of deer harvested to a point where the deer population will begin to increase. Despite the significant decrease in the number of hunters and hunter days, the hunting efficiency in terms of number of hunter days per deer harvested has remained rather static (Figure 4.3).

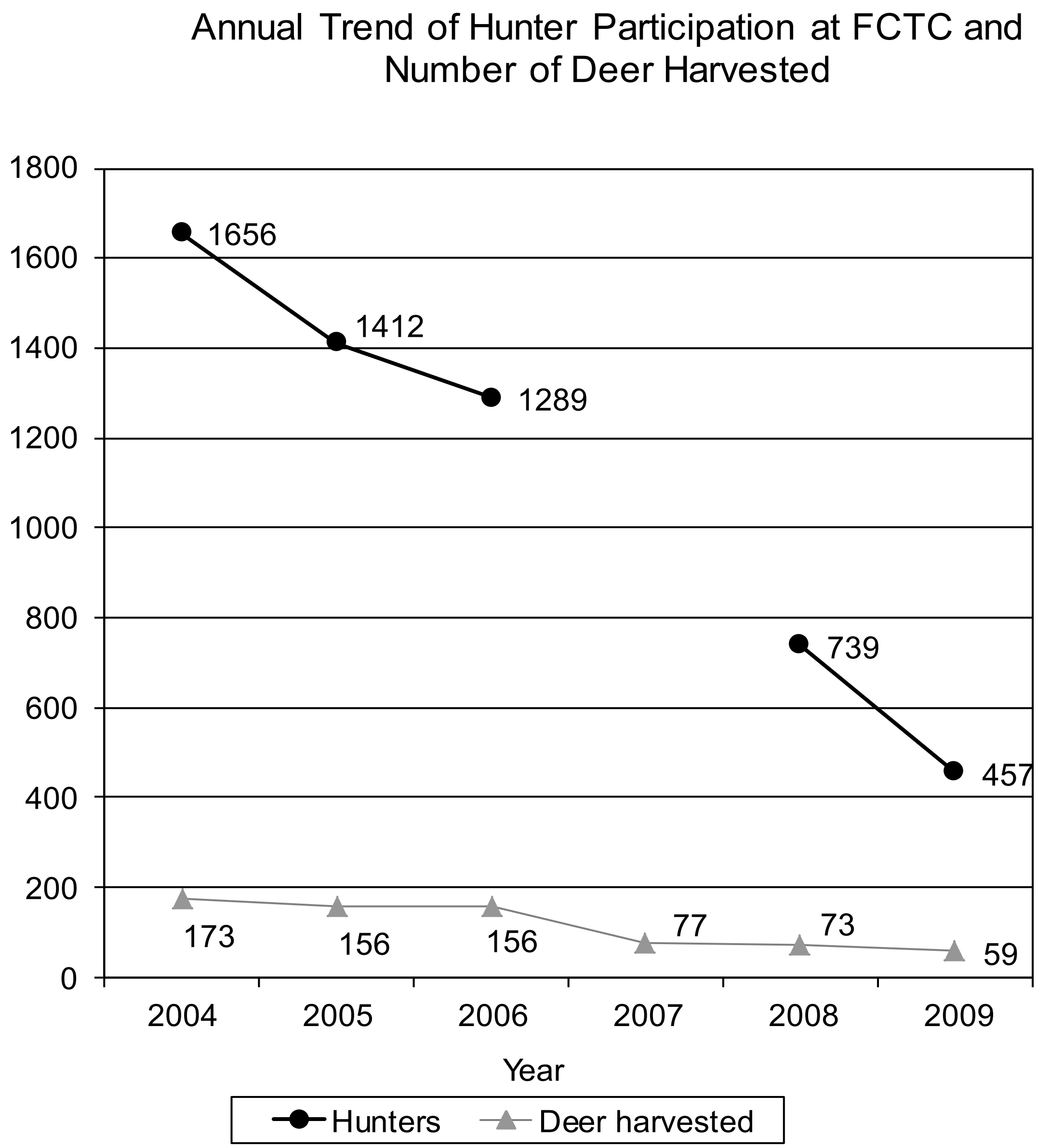

Figure 4.2. The annual trend of total hunter days in the public hunt at FCTC and number of deer harvested (from data provided by the MDMVA).

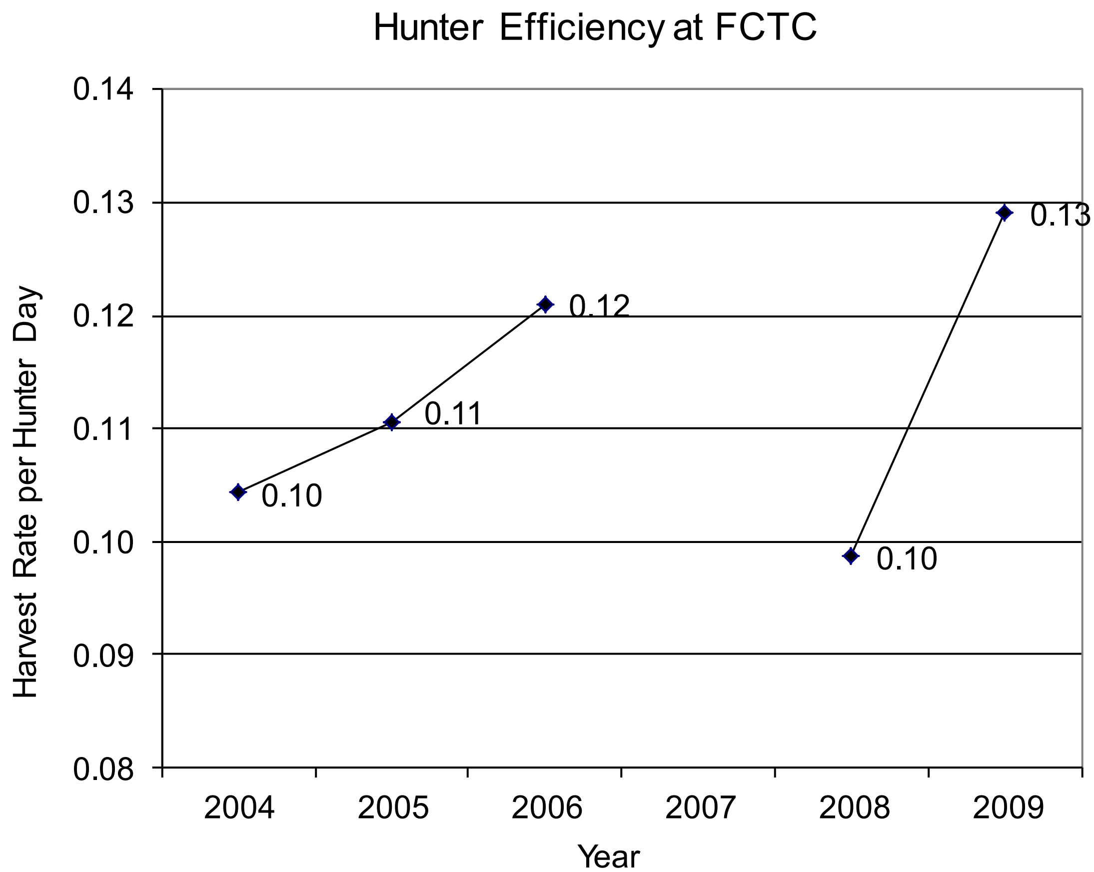

Figure 4.3. The hunter efficiency at FCTC based on the total number of hunter days and deer harvested. No hunter efficiency estimate is available for 2007 because the total number of hunter days is unknown.

Management Implications

The public hunt has played an integral part in managing the deer herd, reducing the population below maximum carrying capacity and within levels such that the deer herd does not significantly affect their range. With the current size of the deer herd at FCTC, deer should not negatively influence the MDMVA ecosystem restoration and rehabilitation goals. It has taken approximately 30 years to achieve the primary goal in significantly reducing the size of the deer herd at FCTC. Continuation of the public hunt is critical in maintaining the deer herds' current abundance. However, the public hunt does not guarantee that the deer herd will not increase in size.

The reduction in the size of the deer herd consequently reduced the number of individuals hunting annually at FCTC. Hunter participation may continue to decline, thus reducing the number of deer harvested at FCTC that will in turn lead to growth in the size of the deer herd. Lacking a significant harvest of deer over several years the deer population may then grow exponentially. The reproductive potential of deer coupled with less hunter participation poses a great risk to the MDMVA long-term management goals. For these reasons, it is essential that the MDMVA use indices (SAK models, FLIR, monitor exclosures and paired control sites, maintain biodata collection from the public hunt) to monitor changes in the population.

The cost of a FLIR will vary to a degree. Vision Air charges by flight time, a per diem expense, and the rates may change over time. The costs of the two flights were $7,900 and $9,170, with the November 2007 flight costing more because of the weather delay and rate change from $700 per hour to $725 per hour.

There are alternatives to holding an annual public hunt to manage the deer herd. Though undesirable because of expense and a likely tarnished reputation to FCTC, an annual cull could act as a substitute or in addition to a public hunt to harvest deer. Additionally, an annual cull does not fulfill the obligations outlined by the Sikes Act, whereas the public hunt is within the spirit of the legislation. The public hunt should be considered as a success in attaining the goal of reducing the size of the deer herd, and to drastically change the role of the public hunt is not justifiable under the present set of circumstances. Drastic changes could permanently alienate the hunter stakeholder group and hunter participation could drop below a threshold that harvests a sufficient number of deer.

To maintain interest in the public hunt the MDMVA needs to focus on the public relations with outreach programs. The MDMVA must continue the annual After Action Report (AAR) that summarizes the past years' deer hunt at FCTC and has multiple stakeholders in attendance ranging from the public, the MDNRE, and base personnel. This annual meeting allows communication amongst various stakeholders and raises involvement in hunters while fostering ideals integral for the continued success of the public hunt.

It is important to remember that the primary stakeholder in this case is the MIANG and the base's function is to serve as a training facility for military operations. The deer hunter group plays a critical role by assisting the MDMVA in management of the deer herd. Other stakeholders at FCTC include the MDNRE, MNFI, Kalamazoo Nature Center, and Native Connections where their interests are related to deer density dependent effects on the ecology of FCTC. The MDMVA should consider engaging communication among all stakeholders to raise the awareness levels of the various interests and outcomes desired by all parties involved. This objective could be achieved with a meeting or a newsletter with articles representative of the various positions.

For the stakeholders to accept the management policy at FCTC they will need not only to be in agreement with the recommended outcomes, but also believe that the prescribed course of action will achieve those goals (Enck et al. 2006). Therefore, the management policy at FCTC needs to engage the various stakeholder groups in the process of managing the deer herd (Lancia et al. 1996, Riley et al. 2002). Lischka et al. (2008) stated that the traditional management practices solely focused on the size of wildlife populations might be insufficient in achieving the desired outcomes. The acceptance capacity of the deer is influenced by perceptions of the effects of interactions (Lischka et al. 2008). At varying levels of abundance, in terms of both social carrying and biological carrying capacity, deer have differing effects on a social and ecological level (Figure 4.4). Hunter perception of deer abundance may confound the MDMVA's ability to manage the population.

Deer Hunter Satisfaction	Deer Density: Low	Deer Density: High
High	Lower deer harvest rates, but "trophy bucks harvested Limited negative deer browse effects Deer pose problems to day to day operations at FCTC Deer seen with regularity Larger deer	Significant negative deer impacts on landscape Hunter harvest rates high, but less "trophy bucks" Deer affect daily operations at FCTC Deer starvation during winter Deer vehicle collisions occur, but not considered problematic
Low	Limited deer impact on landscape Low number of deer harvest annually Decreased satisfaction among deer hunters Deer seldom seen	Small deer are harvested No "trophy bucks" Significant deer browse effects on range Deer vehicle collisions occur, but not considered problematic Deer starvation during winter

Figure 4.4. The ecological and perceived impacts of deer on stakeholders at high and low abundance levels with respect to stakeholder satisfaction and deer density. The stakeholder satisfaction is relative to the perception that individuals or groups of individuals might have about the deer herd (e.g. too few deer, too many deer because they are causing damage to the ecosystem). Whereas the relative deer density is in terms of biological levels being low or high with respect to resource availability acting as a constraint on population growth. Other stakeholders may have different views than those expressed by the deer hunters.

Van Deelen and Etter (2003) stressed the importance of integrating the understanding of the functional response of deer hunters to declining deer densities into management practices. Data indicates that as deer densities decline the relationship to deer hunter effort required to harvest a deer is a curvilinear function, and an asymptotic relationship exists with the effort to harvest or see a deer in Midwestern habitat when deer density decreases below 15 deer per km^2 (~39 deer per mi^2) (Figures 4.5 and 4.6) (Van Deelen and Etter 2003).

Van Deelen and Etter (2003) used five data sets to create Figures 4.5 and 4.6, with each data set resulting from an independent study. The study sites in the Midwest ranged from central Wisconsin to northern Michigan to Ontario (Van Deelen and Etter 2003). The results of the metadata produce identical relationships, though the rates varied site to site, which yielded 5 independent functions (Figure 4.5 and 4.6). It is reasonable to assume that FCTC hunters are experiencing a similar relationship to these other studies. Given the current density of deer at FCTC hunters may experience significant increases in the amount of time needed to either harvest or see a deer.

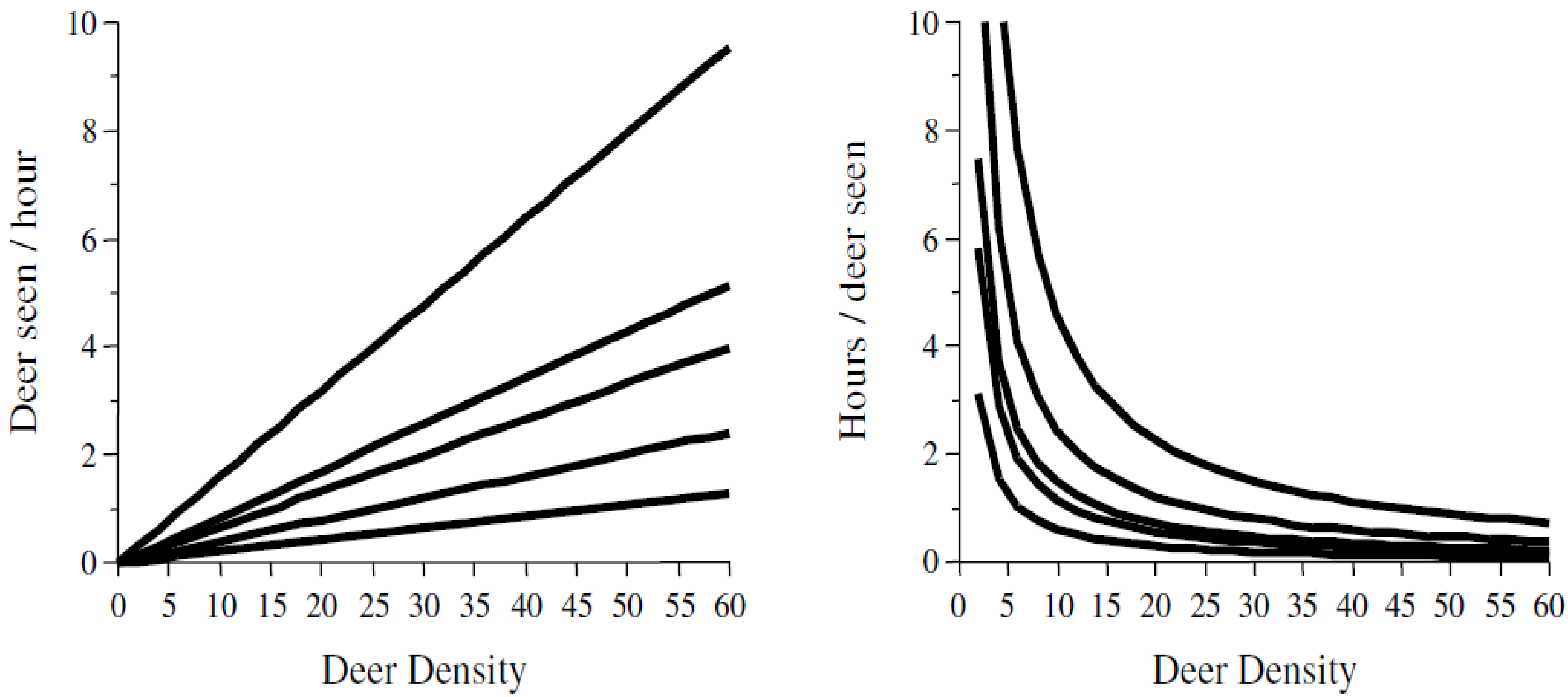

Figure 4.5. Deer seen as a function of deer density in five Midwestern data sets; the figure is a reproduction from Van Deelen and Etter (2003).

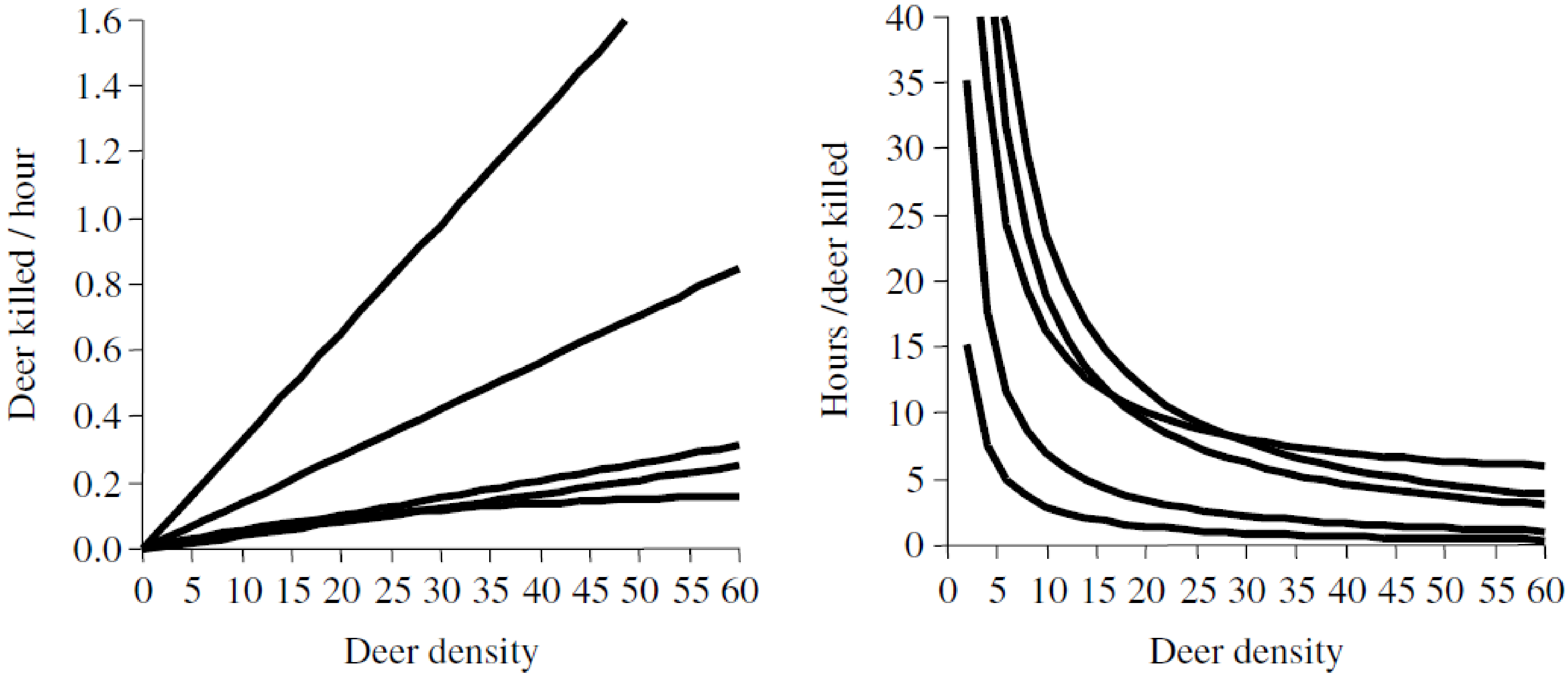

Figure 4.6. Deer killed as a function of deer density in five Midwestern data sets; the figure is a reproduction from Van Deelen and Etter (2003).

The significance of the relationship of deer density to that of hunter effort being curvilinear is twofold. One, hunters may become discouraged when deer densities require an exponential increase in effort to harvest or see a deer, and secondly the perceived density of deer by hunters at levels less than approximately 15 deer km^2 may be significantly less than the true density yielding a perception gap between the true density and perceived density (Figure 4.7).

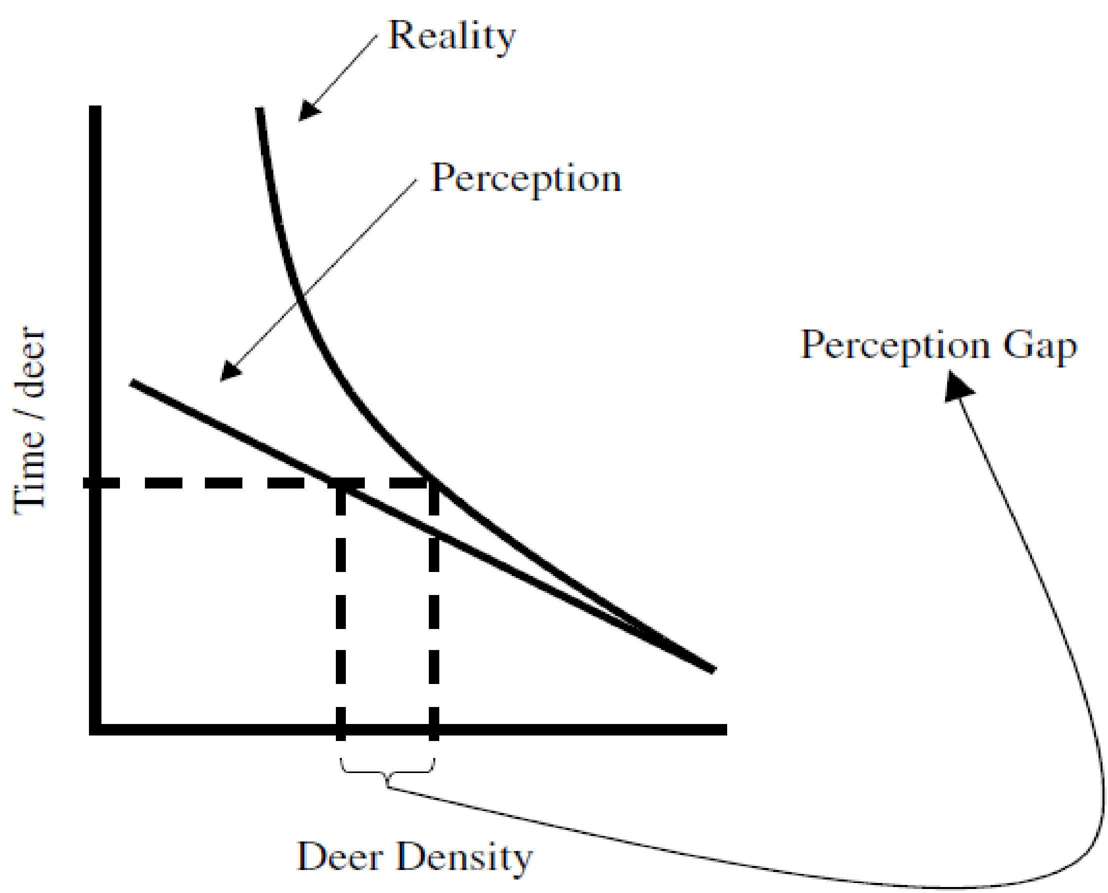

Figure 4.7. Hypothetical relationship between hunter effort, perceptions, and deer density. If hunter perception of deer density is based on an assumed linear relationship but is in reality hyperbolic, then for any given level of effort hunters will perceive fewer deer than there actually are. Moreover, this bias will accelerate as deer density decreases. The figure is a reproduction from Van Deelen and Etter (2003).

The danger of this perception gap of deer density may lead to a further decline in hunter participation at FCTC. A decrease in hunter participation potentially could result in a hunter harvest that is insufficient to maintain the current size of the deer herd at FCTC. As a result, the deer population at FCTC will increase in all likelihood. One scenario is that over a relatively short time of 2 to 3 years the deer population grows exponentially and the deer densities are again at or near the biological carrying capacity. Another possibility is, as the deer population increases the number of hunters increase, which should yield higher harvests. The later scenario may create a situation where the population would increase, then decrease as hunter participation would increase, and then subsequently decrease as the deer population changed periodically.

A hunter survey conducted by the MDMVA could be insightful into the perception gap associated with hunter effort and deer density. The hunter survey serves multiple purposes ranging from being a part of public relations, it weighs public opinion, and it assesses support for or against an action. If a hunter survey were performed every 3-5 years, or before changes were made to the current hunt policy, it could potentially predict an increase or decrease in hunter participation.

To maintain steady interest in the public hunt, the MDMVA is in a unique situation to draw hunters with special hunt periods. The MDMVA already hosts a special hunt in September to Purple Heart recipients. The MDMVA could consider several different special hunts to bolster hunter participation and raise the awareness of hunters in Kalamazoo and Calhoun counties with a crossbow hunt, a youth hunt, or a second opener. In doing so, the MDMVA should consider engaging their core-hunting base of group leaders, and or the numerous military base personnel that hunt. Alienation of these two groups would be detrimental in the long-term continued success at FCTC of deer herd management. An additional option to arouse public interest in the deer hunt at FCTC is publishing articles in local newspapers touting FCTC's relative uniqueness in the immediate area of large contagious forested tracts of land offering a quality deer hunt.

Management Recommendations

- Continue to collect and analyze public hunt biodata.
    - If biodata indicates a significant decrease in physical characteristics of the deer herd, a change in management of the herd may be necessary.
- Maintain interest in the public hunt by continuing and developing an outreach program.
- It is imperative that the MDMVA assess the FCTC area each spring for deer browse lines, and dead deer because these qualitative assessments provide insight into the state of the ecological well being of the deer herd and ecosystem at FCTC.
- Continue to monitor and maintain exclosures and paired control sites, and test for significant statistical differences every two years.
- Use SAK model to estimate size of deer herd.
- Contract a FLIR survey every 5 years in January, or when multiple population indices indicate a significant change in the deer density to validate changes in the indices.
- Conduct a hunter survey every 3 to 5 years
- Contact an outreach specialist in 5 to 8 years to learn what resonates with the public at the current time with respect to deer hunting management.

These management recommendations are based on the current state of FCTC; however, management of a deer herd is a dynamic endeavor. The set of circumstances might change in the near future, or the long-term future. I have tried to anticipate various scenarios and incorporate the management techniques applicable for those situations. The MDMVA needs to continually assess, and decide the appropriate course of action under a given set of circumstances with the methodology prescribed in estimating the size, and quantifying effects of the deer on their range.

APPENDICES

APPENDIX A

Historical Biodata of the deer herd at FCTC

ANOVA and a Tukey's studentized range test were conducted to examine if FCTC was significantly different from Allegan, Barry, Calhoun, and Kalamazoo counties with respect to beam diameters and antler points. Multiple-comparisons were restricted to 2001-present because FCTC biodata is a subset of both Calhoun and Kalamazoo counties and there is no logistically feasible way to separate the biodata until 2001. There has been unique biodata kept for FCTC, but it is also incorporated into the biodatabase of Calhoun and Kalamazoo counties maintained by the MDNR.

The results from ANOVA with respect to total points show a statistically significant difference among the five areas from 2001-2004 ($F_{4,\ 3497}$=9.33; P<0.0001). The Tukey studentized range test indicated that the mean number of total points for FCTC was significantly less than for Allegan, Barry, Calhoun, and Kalamazoo Counties (Table A.1), while other areas had no significant difference. Looking at the trend of consecutive years from 2001-2004 ANOVA indicated a statistically significant difference in beam diameters with ($F_{4,\ 3681}$=8.64; P<0.0001) among the five areas. The Tukey studentized range test showed that the mean beam diameter for FCTC was significantly less than that for Allegan, Calhoun, Barry, and Kalamazoo Counties, while there was no significant difference among the other areas (Table A.2). Figures A.1 and A.2 display a graphical representation of the trends for the five areas from 1987 to 2004, they compare the annual means of number of points and beam diameter over time. The results indicate that even with reintroduction of hunting to FCTC addressing issues of overabundance there is evidence that the deer herd’s condition is still below standards of the surrounding areas, and areas with similar habitat.

Table A.1. The results from a Tukey studentized range test comparison of yearling bucks total point counts between FCTC and surrounding counties from 2001-2004 showing the difference of the means between areas with a 95% confidence intervals. FCTC was significantly less than the four other areas.

Area of Comparison	Difference between Means	Simultaneous 95% Confidence Limits	
		Lower	Upper
FCTC and Allegan	-0.75199	-1.14	-0.36
FCTC and Barry	-0.43028	-0.83	-0.03
FCTC and Calhoun	-0.71068	-1.19	-0.23
FCTC and Kalamazoo	-0.54442	-0.97	-0.11

Table A.2. The results from a Tukey studentized range test comparison of yearling bucks mean beam diameters between FCTC and surrounding counties from 2001-2004 showing the difference of the means between areas with a 95% confidence intervals. FCTC was significantly less than the four other areas.

Area of Comparison	Difference between Means	Simultaneous 95% Confidence Limits	
		Lower	Upper
FCTC and Allegan	-1.2683	-1.89	-0.65
FCTC and Barry	-1.2604	-1.89	-0.63
FCTC and Calhoun	-1.4274	-1.86	-0.47
FCTC and Kalamazoo	-1.1668	-2.03	-0.65

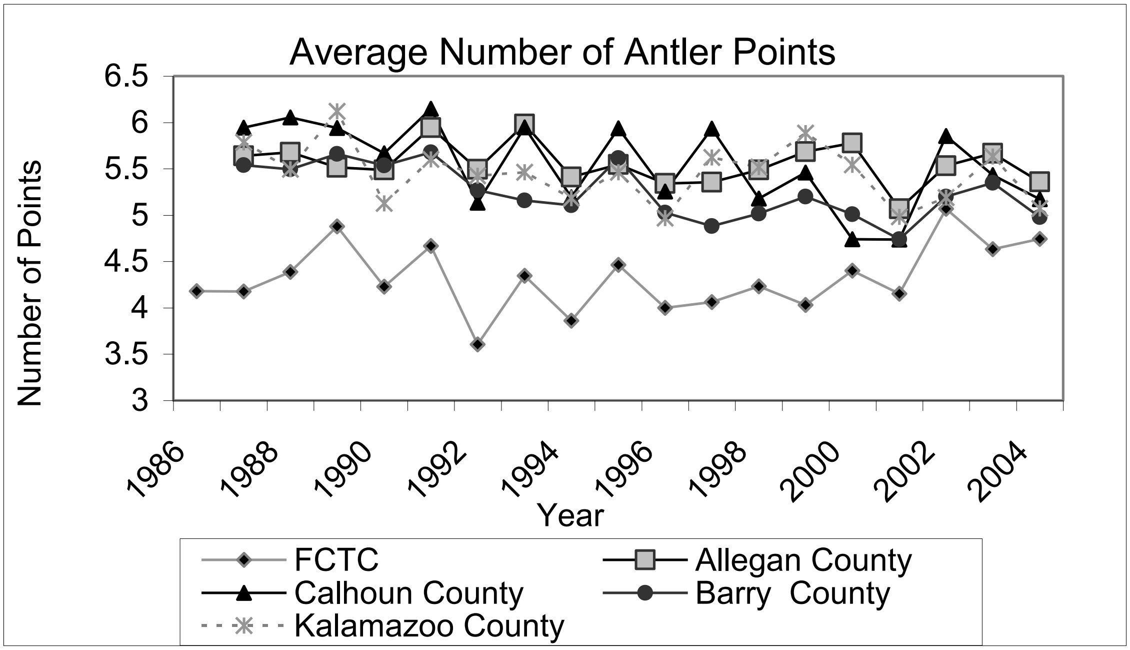

Figure A.1. The temporal trend among the five areas of interest in regards to average number of points for bucks age = 1.5 years.

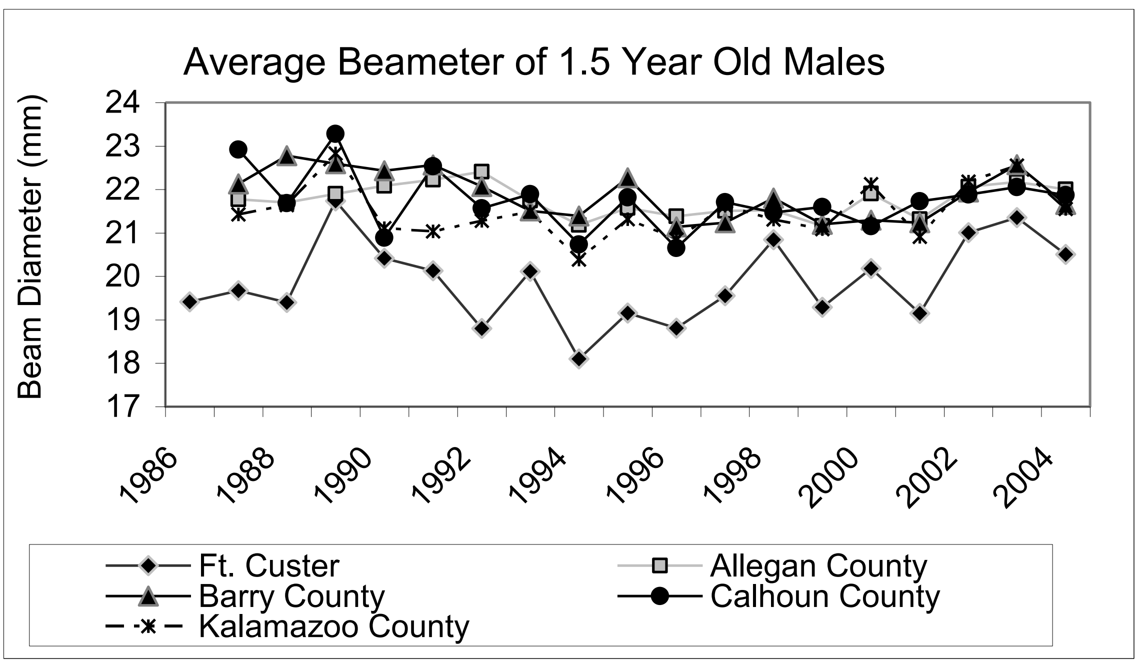

Figure A.2. The temporal trend of average beam diameter among the five areas of interest for bucks age=1.5 years.

APPENDIX B

Coordinates of the exclosure sites and paired control units and vegetation sampling data sheets

Table B.1. Locations and forest type of each exclosure and paired control site. The locations listed are based on the NAD 83 datum and projected in UTM 16T. Each site's forest type is listed as a mixed hardwood or as oak hardwood.

Site	Forest type	X coordinate[1]	Y coordinate[1]
Exclosure 1	mixed hardwoods	633991.39	4682991.95
Paired control 1	mixed hardwoods	634033.12	4682984.41
Exclosure 2	mixed hardwoods	634586.05	4684144.44
Paired control 2	mixed hardwoods	634615.08	4684106.86
Exclosure 3	mixed hardwoods	635548.73	4683292.98
Paired control 3	mixed hardwoods	635595.60	4683294.48
Exclosure 4	oak hardwoods	636316.63	4684553.25
Paired control 4	oak hardwoods	636362.63	4684530.91
Exclosure 5	mixed hardwoods	638245.82	4684257.31
Paired control 5	mixed hardwoods	638244.22	4684226.29
Exclosure 6	oak hardwoods	638512.32	4684852.50
Paired control 6	oak hardwoods	638545.65	4684889.51
Exclosure 7	oak hardwoods	639662.48	4683182.36
Paired control 7	oak hardwoods	639700.91	4683163.46
Exclosure 8	oak hardwoods	640625.81	4682668.86
Paired control 8	oak hardwoods	640610.66	4682696.57

[1]The coordinates for the sites are for the northwest corners.

Vertical Cover Percentage

Forest type:____________________ Site:__________________
Observers:________________________ Date:__________
Burn treatment: yes / no Line intercept length: 18m

Exclosure Height Strata*

Strata Height	0.0m-0.5m	0.5m-2.0m	>2m
Transect 1	__________	__________	______
Transect 2	__________	__________	______
Transect 3	__________	__________	______
Transect 4	__________	__________	______
Transect 5	__________	__________	______
mean (cm)	__________	__________	______
mean % covered	__________	__________	______

Paired Control Height Strata*

Strata Height	0.0m-0.5m	0.5m-2.0m	>2m
Transect 1	__________	__________	______
Transect 2	__________	__________	______
Transect 3	__________	__________	______
Transect 4	__________	__________	______
Transect 5	__________	__________	______
mean (cm)	__________	__________	______
mean % covered	__________	__________	______

*measured in centimeters

Figure B.1. The vertical cover data sheet used during vegetation sampling.

Exclosure Species Composition

Forest type:_______________________ Burn treatment: yes / no
Observers:_________________________ Date:_______________
Site type:__________________________ Site #:_____

Understory (0.0m-0.5m) plot size:1x2m

Species:	Plot A	Plot B	Plot C
Total number of species			

Figure B. 2. The understory stem density data sheet.

Exclosure Species Composition

Forest type:______________________ Burn treatment: yes / no
Observers:______________________ Date:______________
Site type:______________________ Site #:_____

Midstory (0.5m-2m) plot size: 1x5m

Species:	Plot A	Plot B	Plot C
Total number of species			

Overstory (>2m and DBH <4in)

plot size:20x20m

Species:	Plot A
Total number of species	

Figure B.3. The stem density data sheets for the midstory and overstory.

APPENDIX C

Home Range Estimates and Locations of Radio-Collared Deer

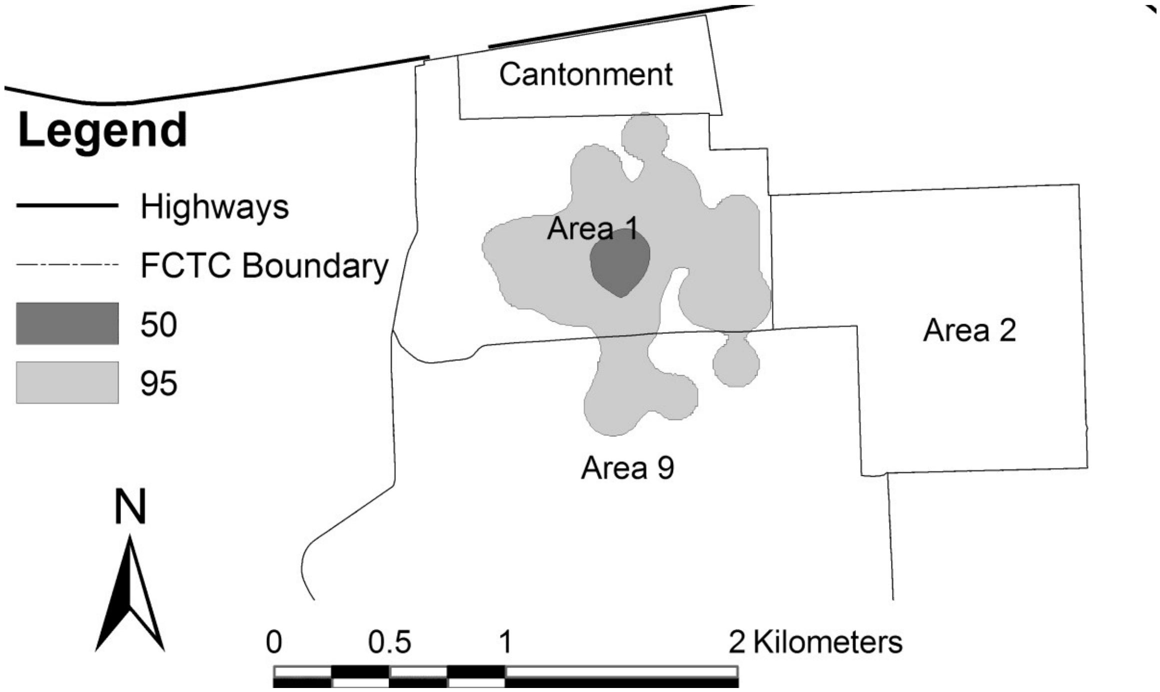

Figure C.1. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.004.

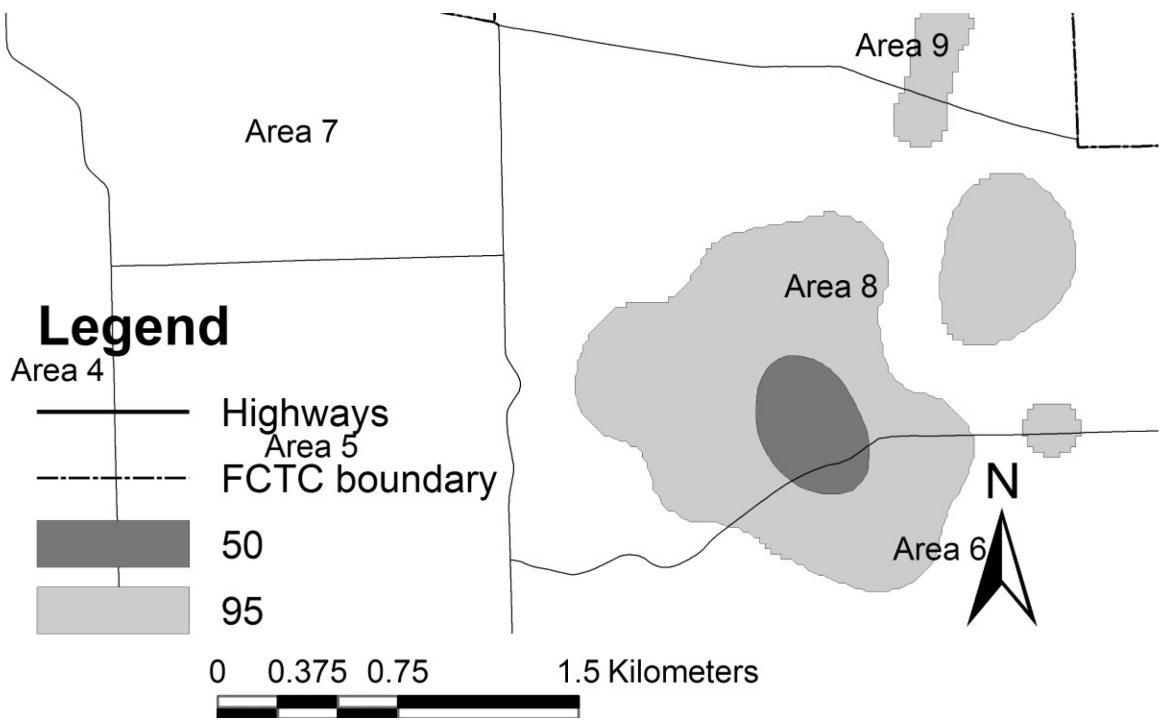

Figure C.2. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.010.

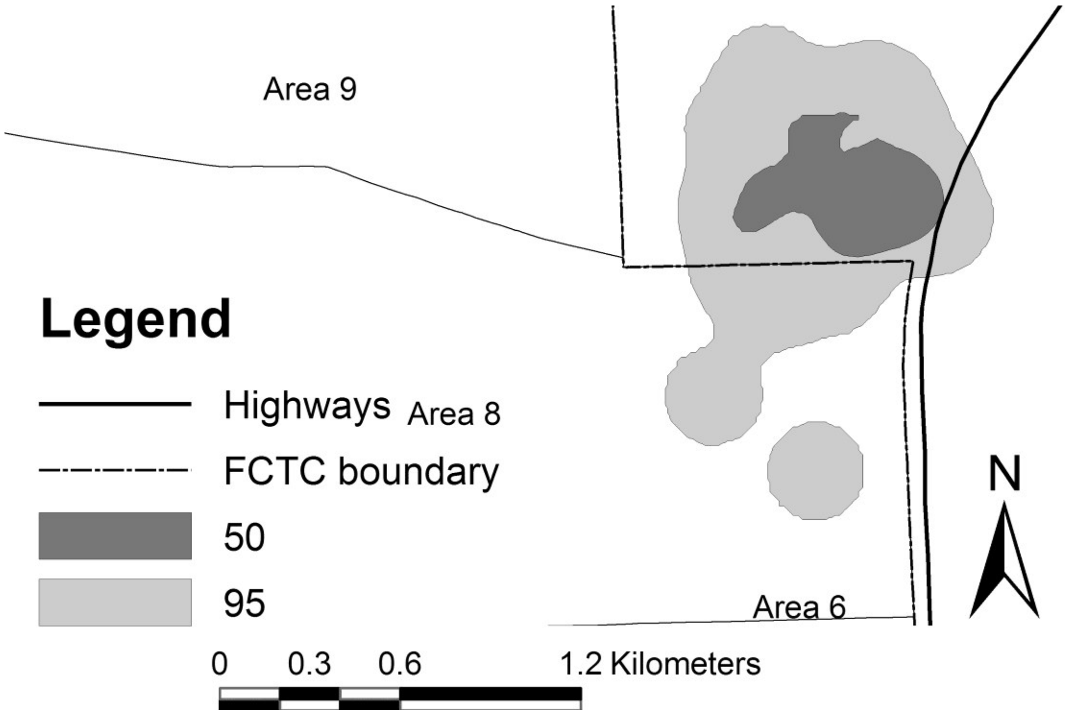

Figure C.3. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.020.

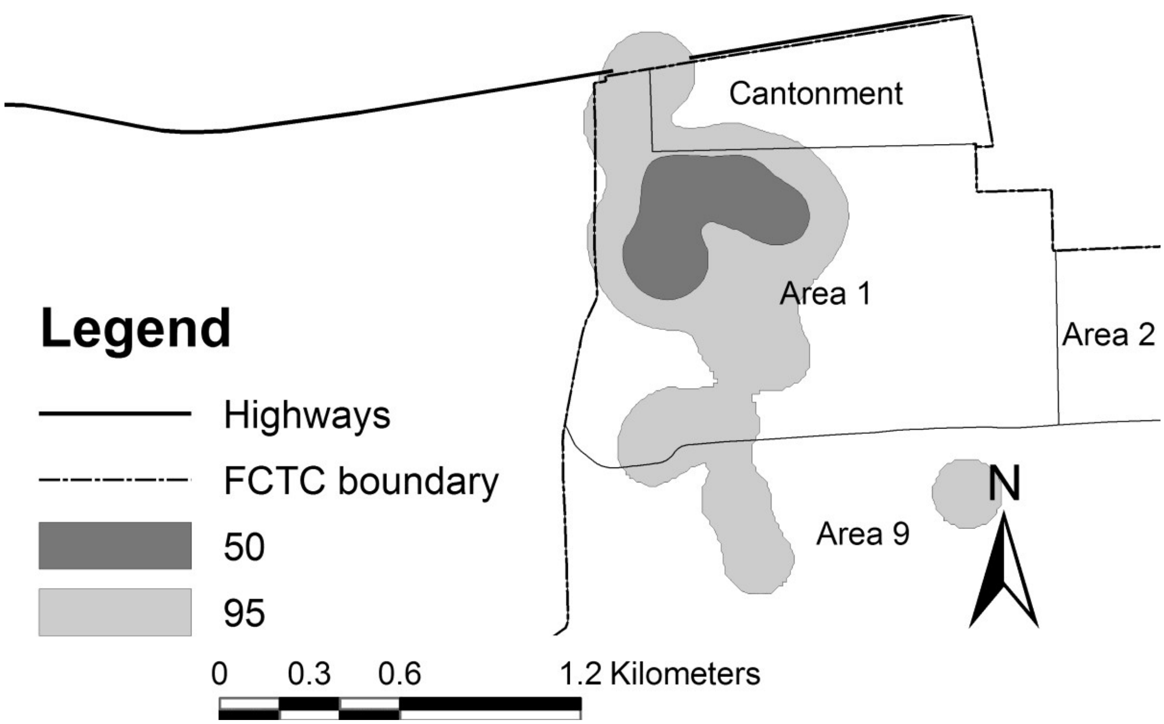

Figure C.4. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.029.

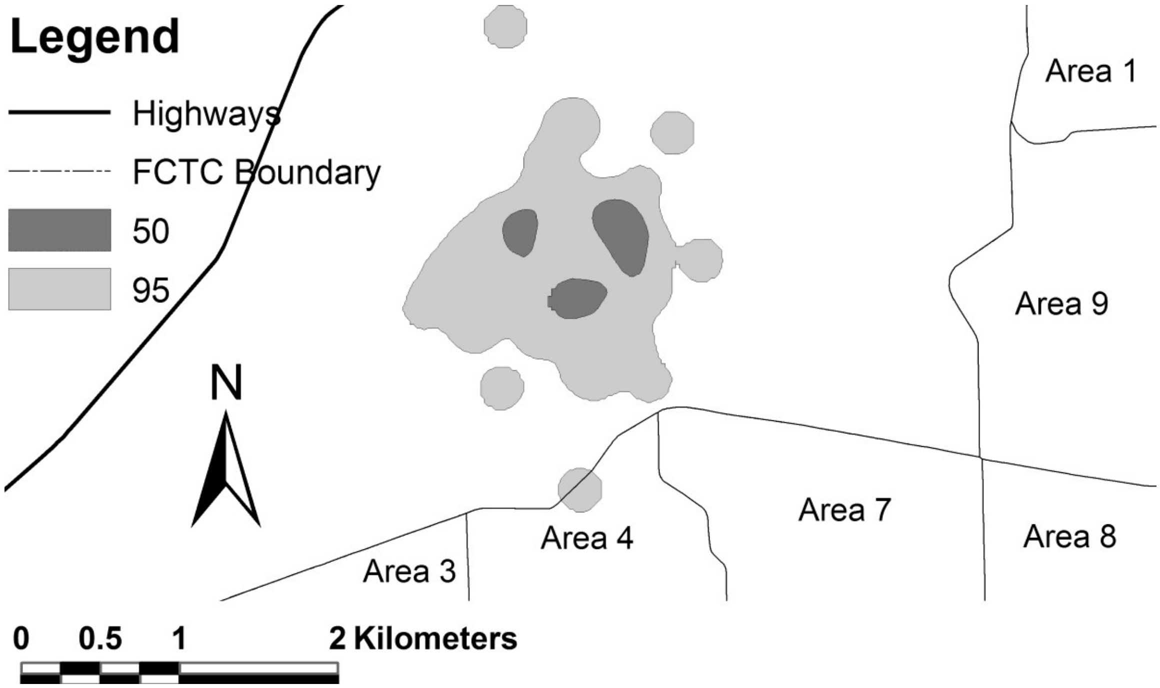

Figure C.5. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.039.

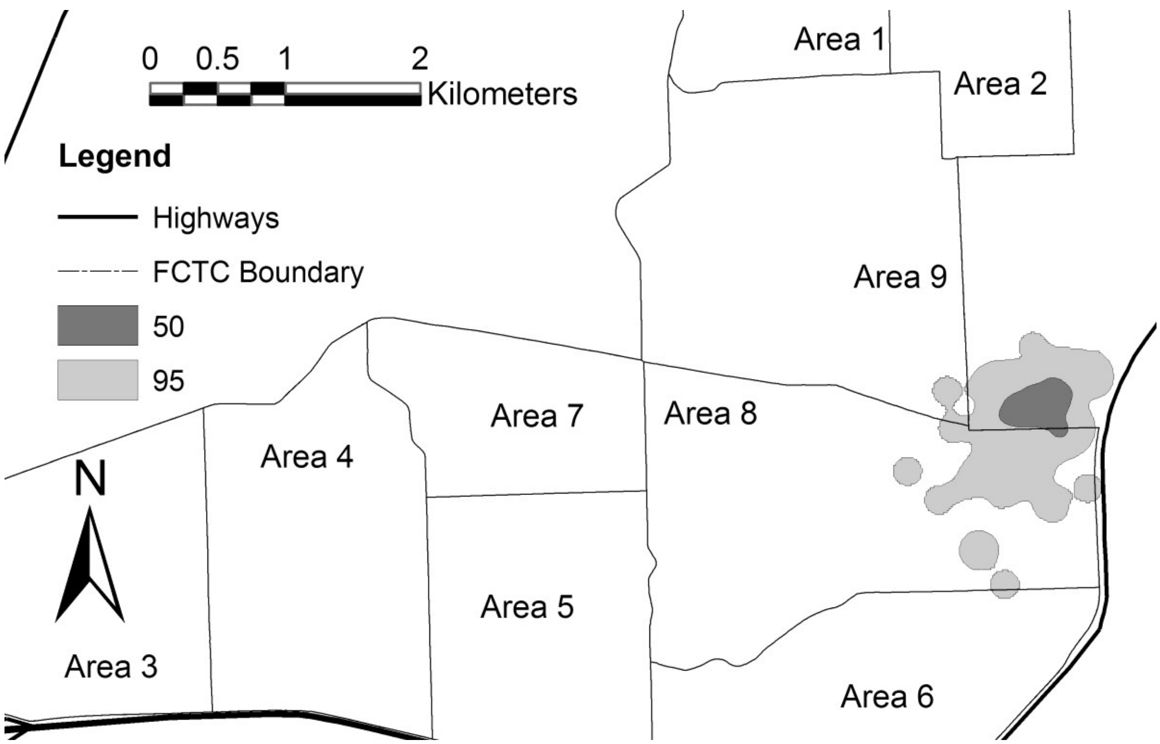

Figure C.6. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.049.

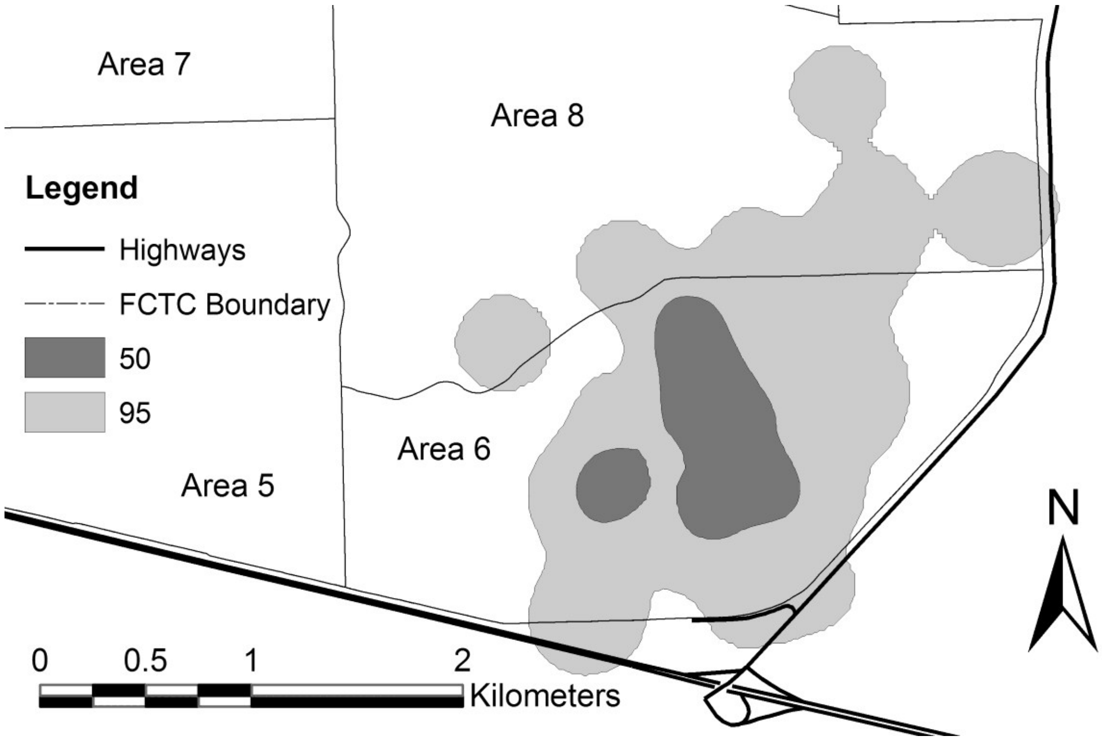

Figure C.7. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.060.

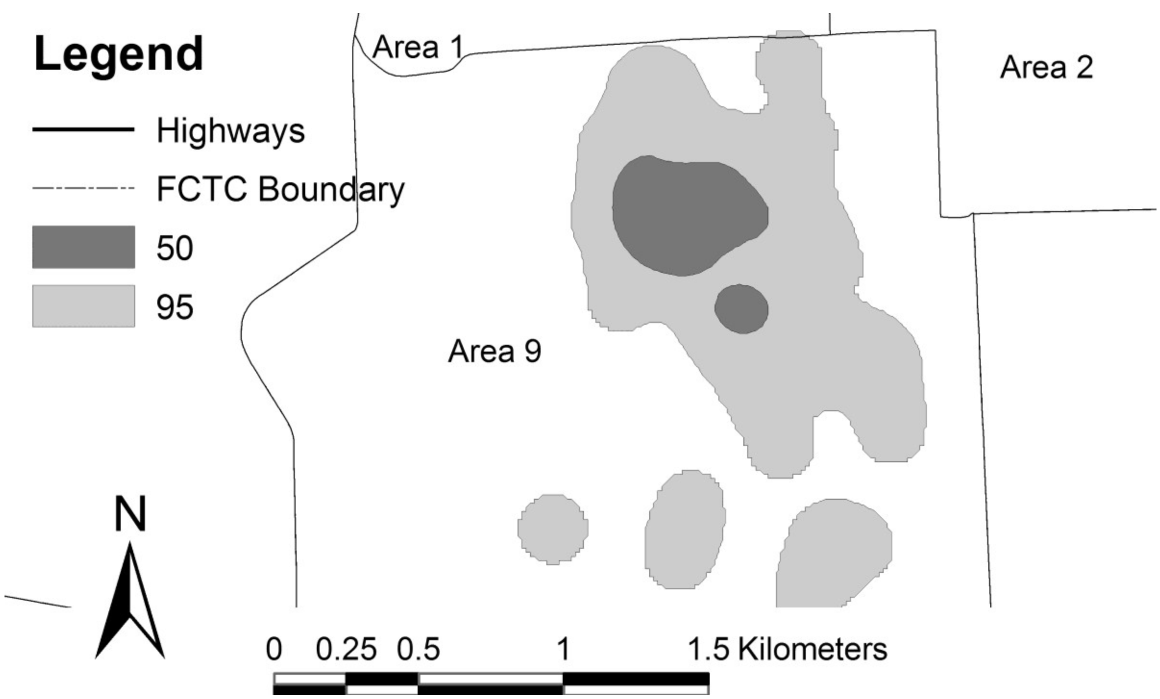

Figure C.8. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.069.

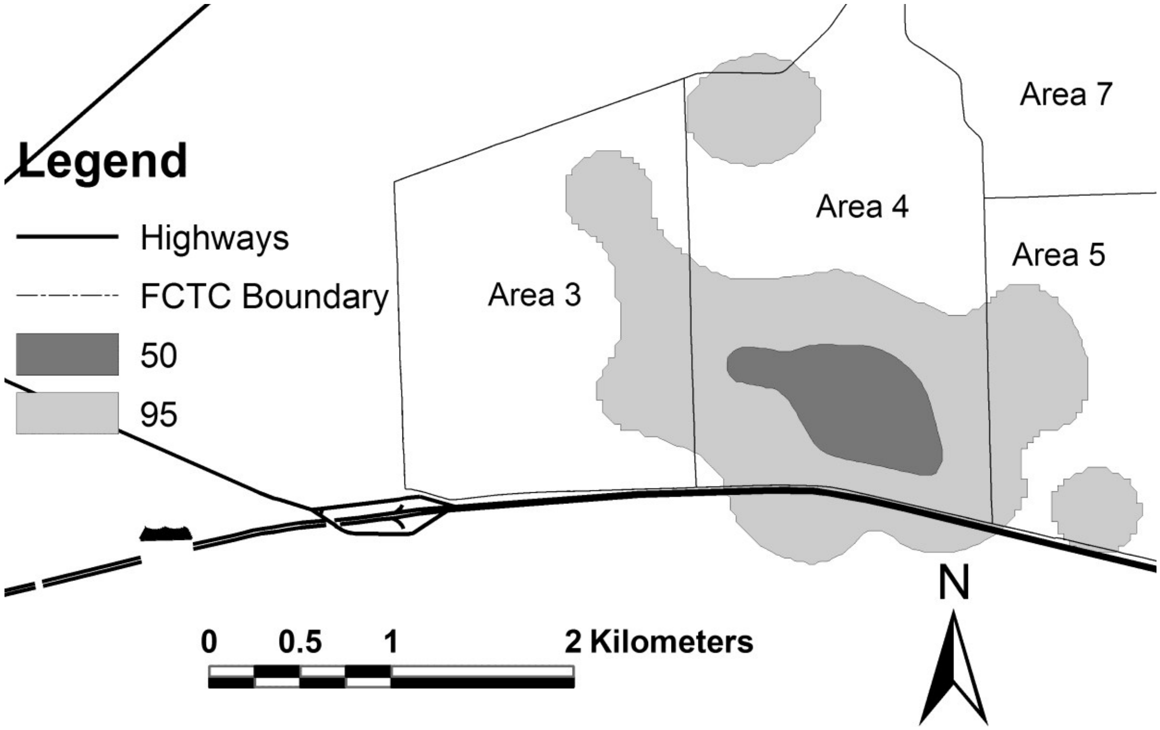

Figure C.9. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.090.

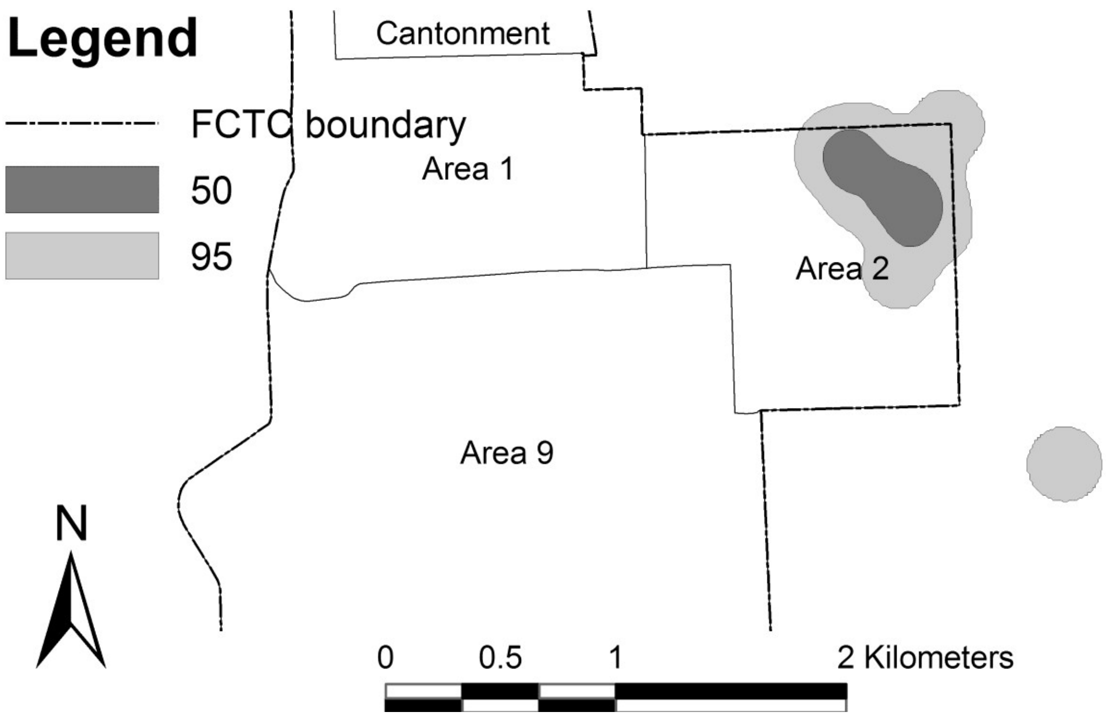

Figure C.10. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.173.

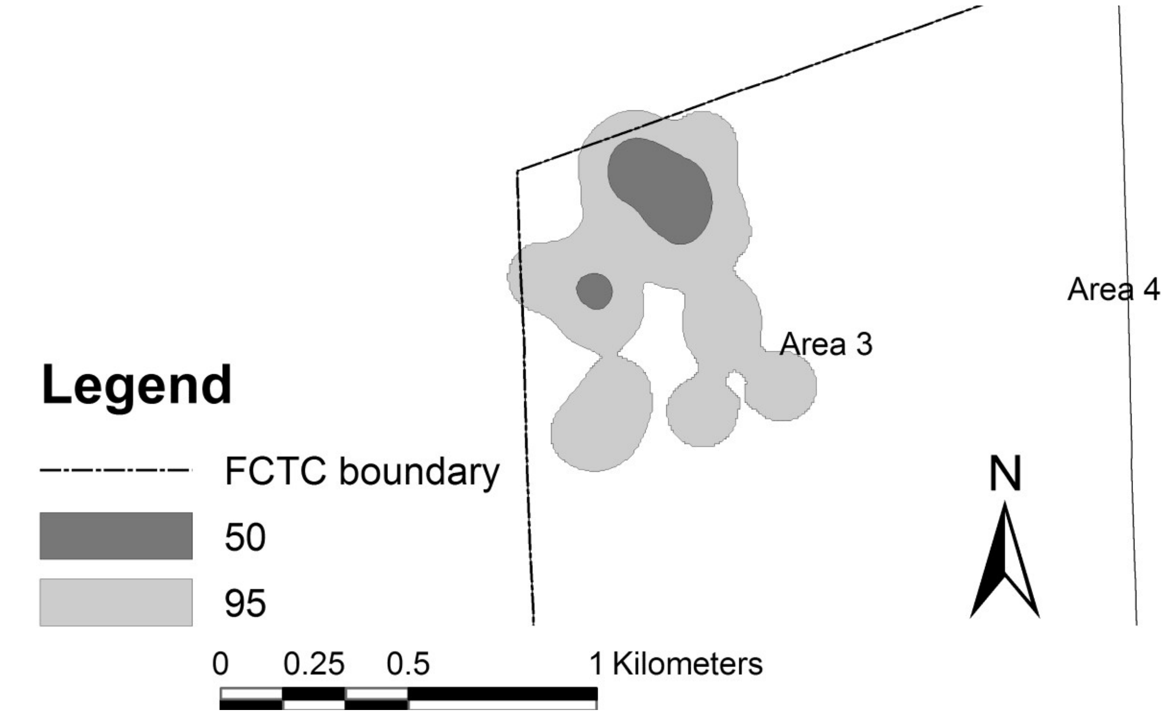

Figure C.11. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.273.

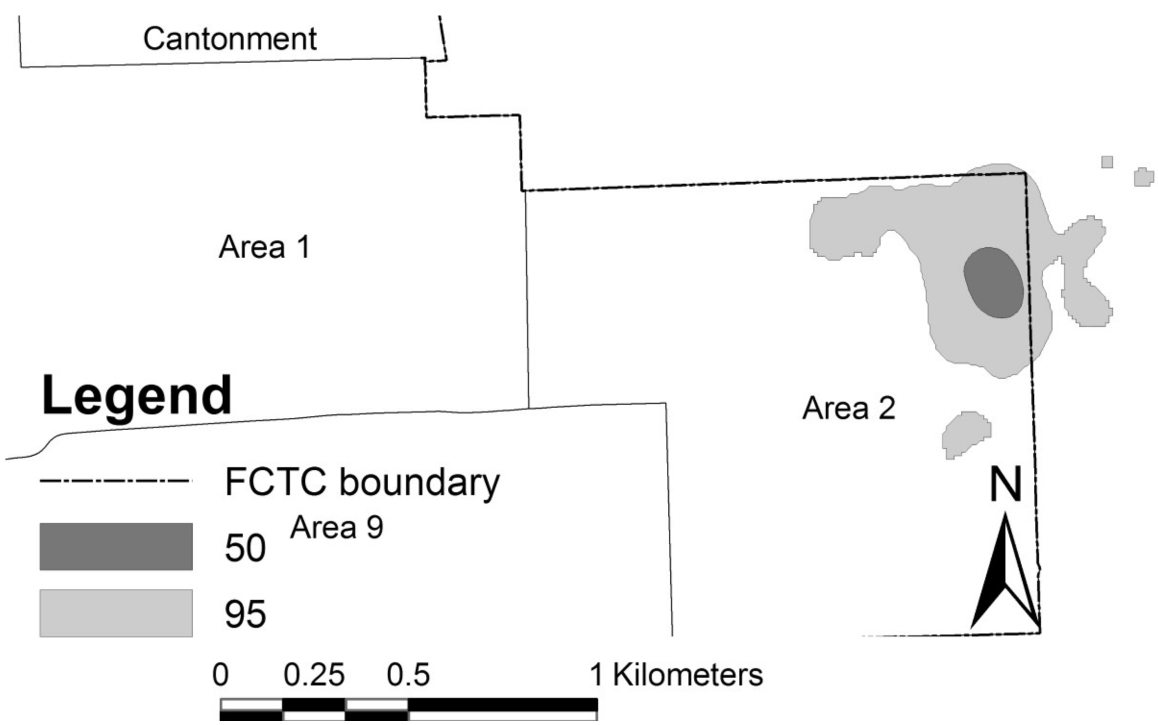

Figure C.12. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.280.

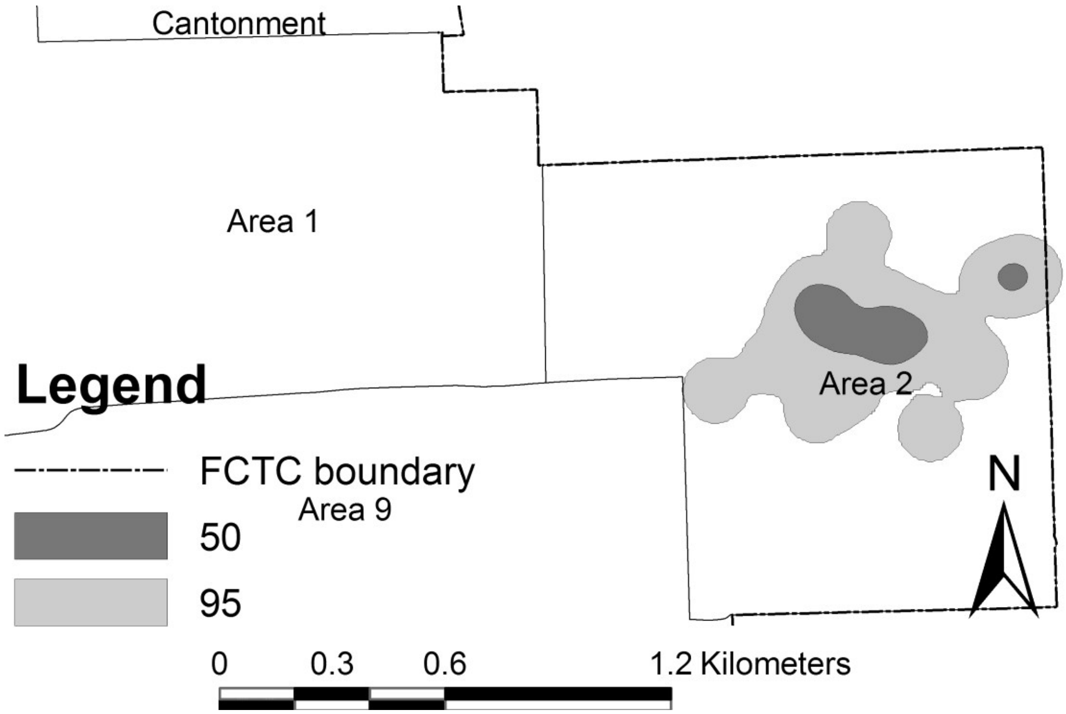

Figure C.13. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.290-1.

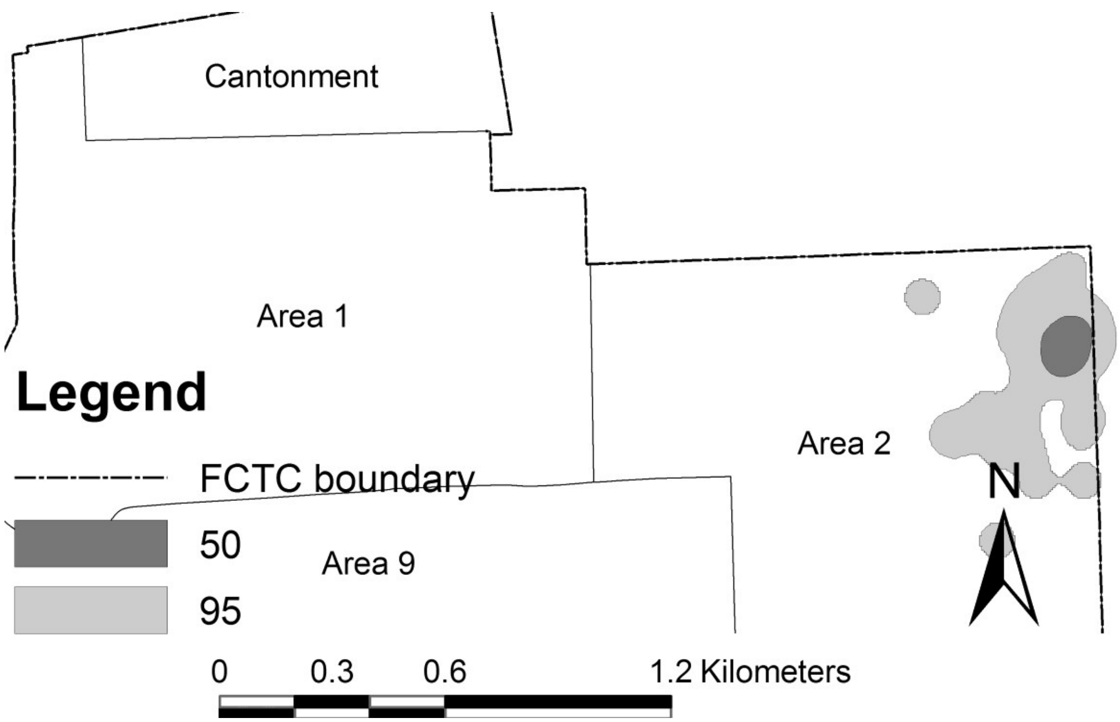

Figure C.14. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.300.

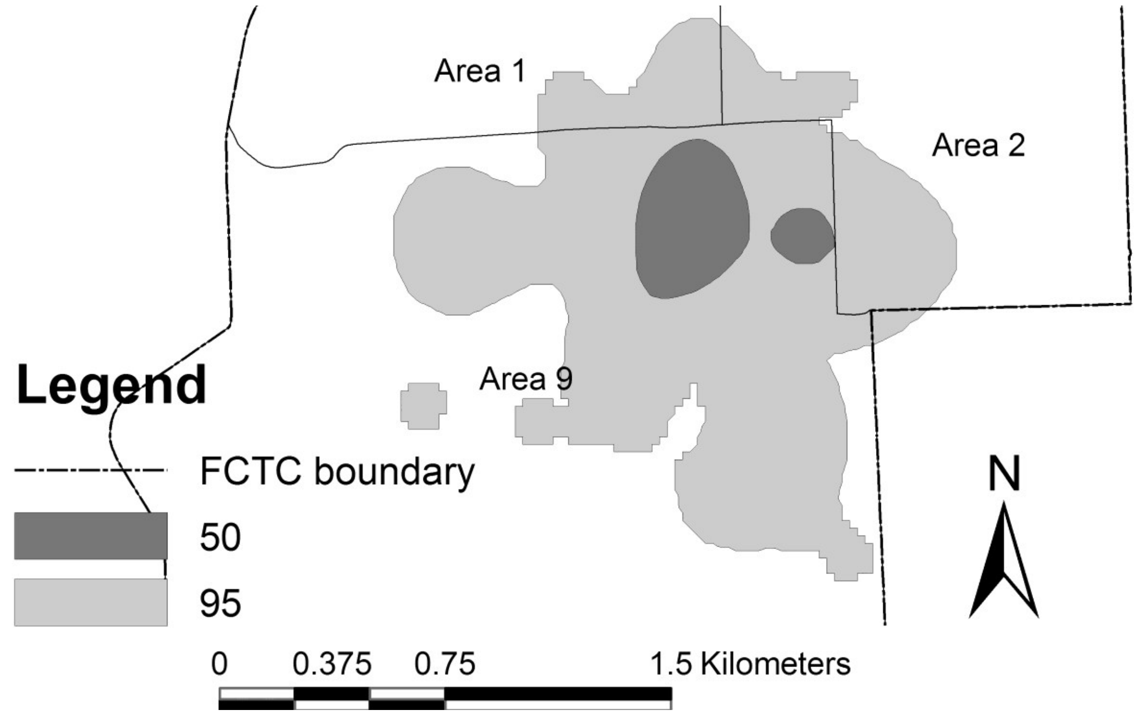

Figure C.15. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.310.

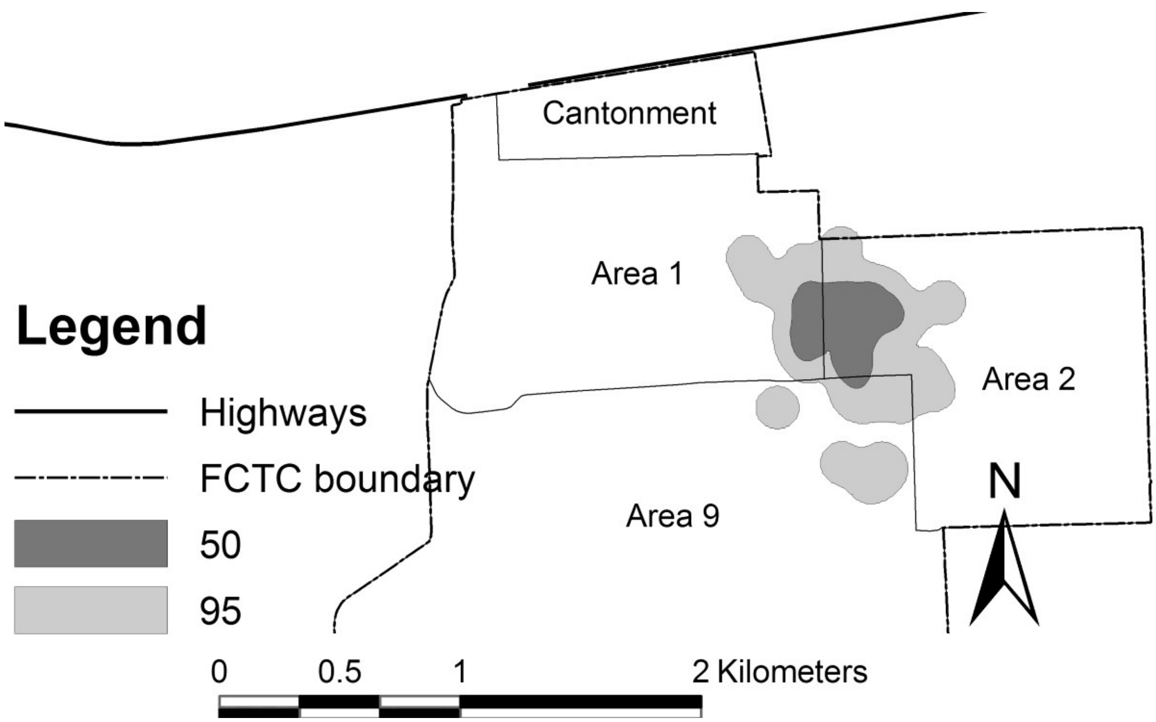

Figure C.16. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.315.

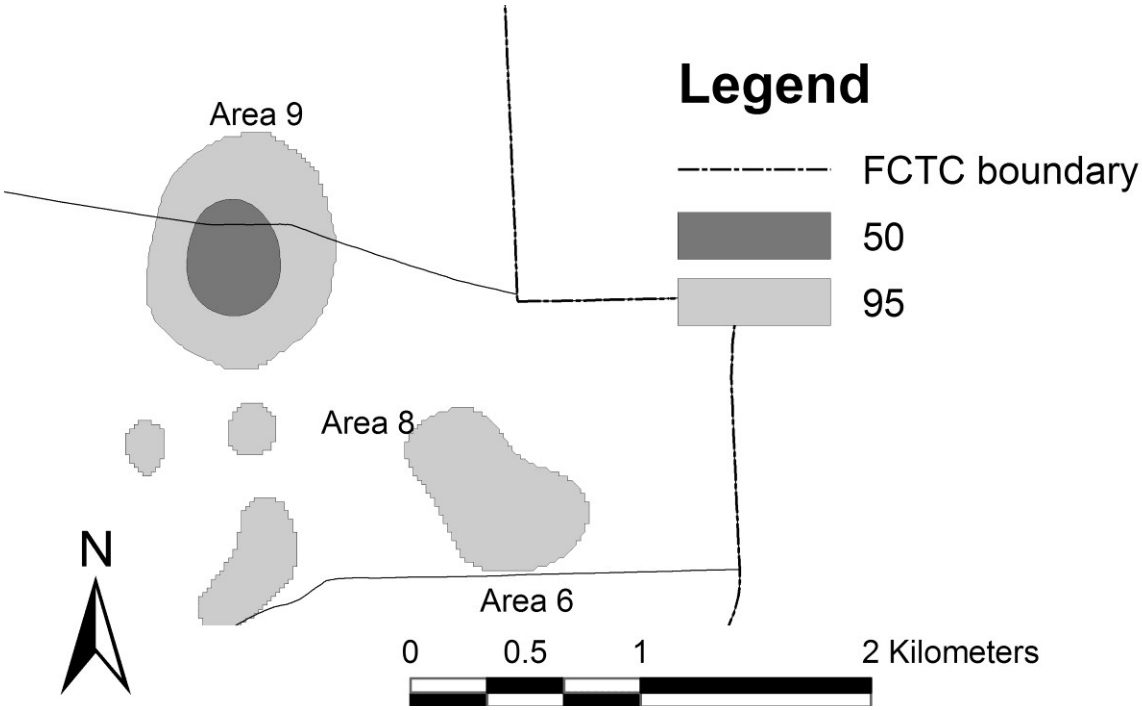

Figure C.17. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.330.

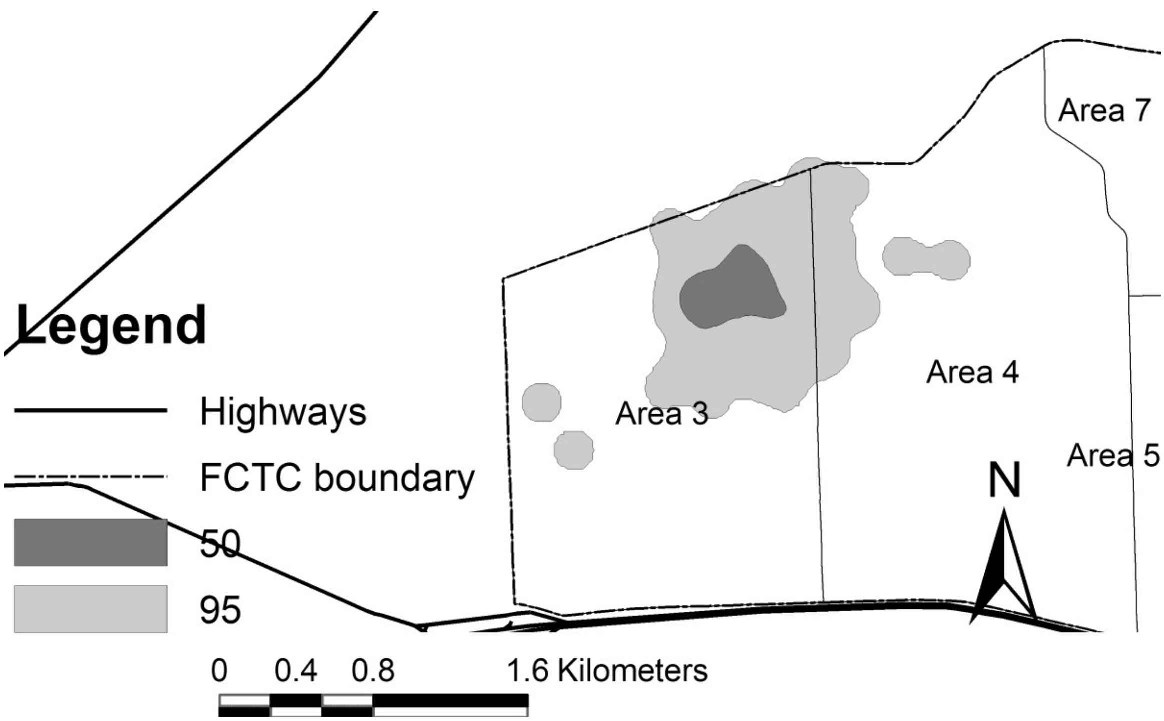

Figure C.18. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.334.

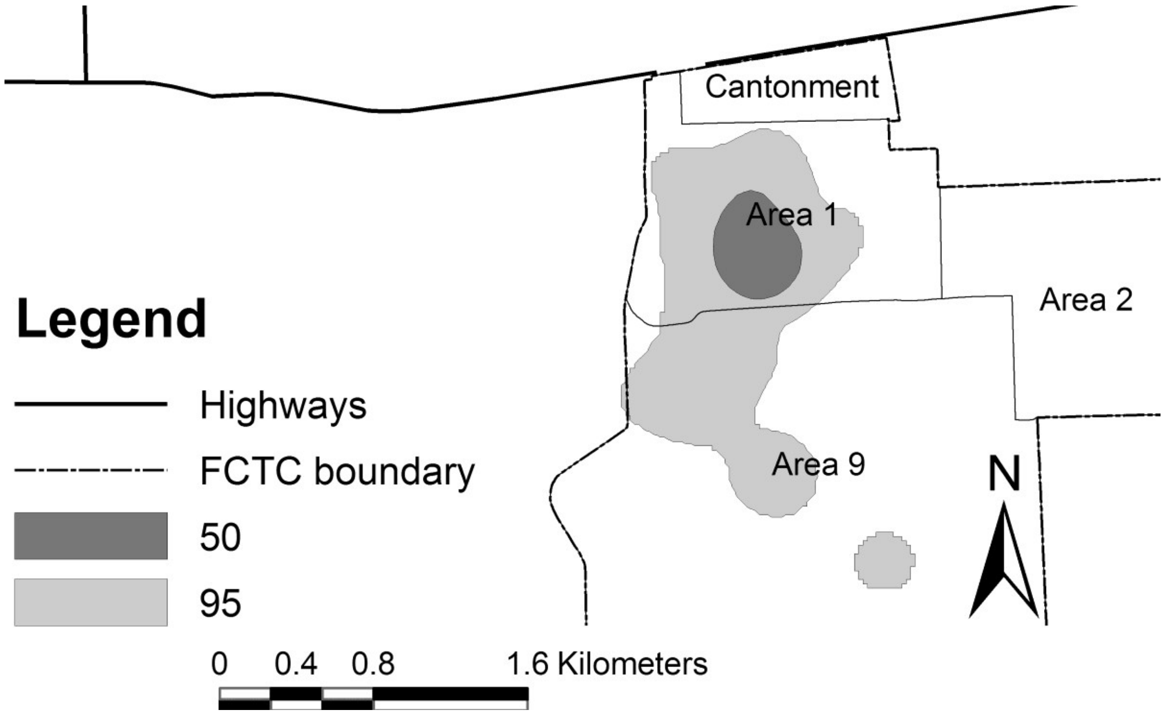

Figure C.19. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.340.

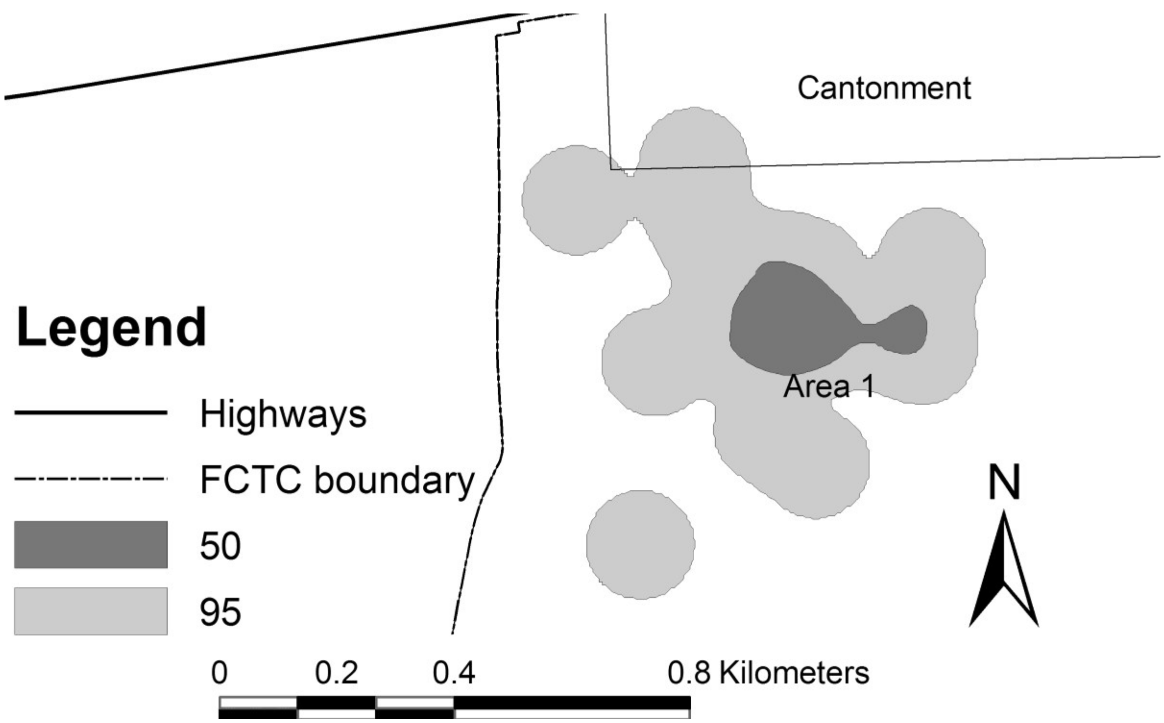

Figure C.20. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.353.

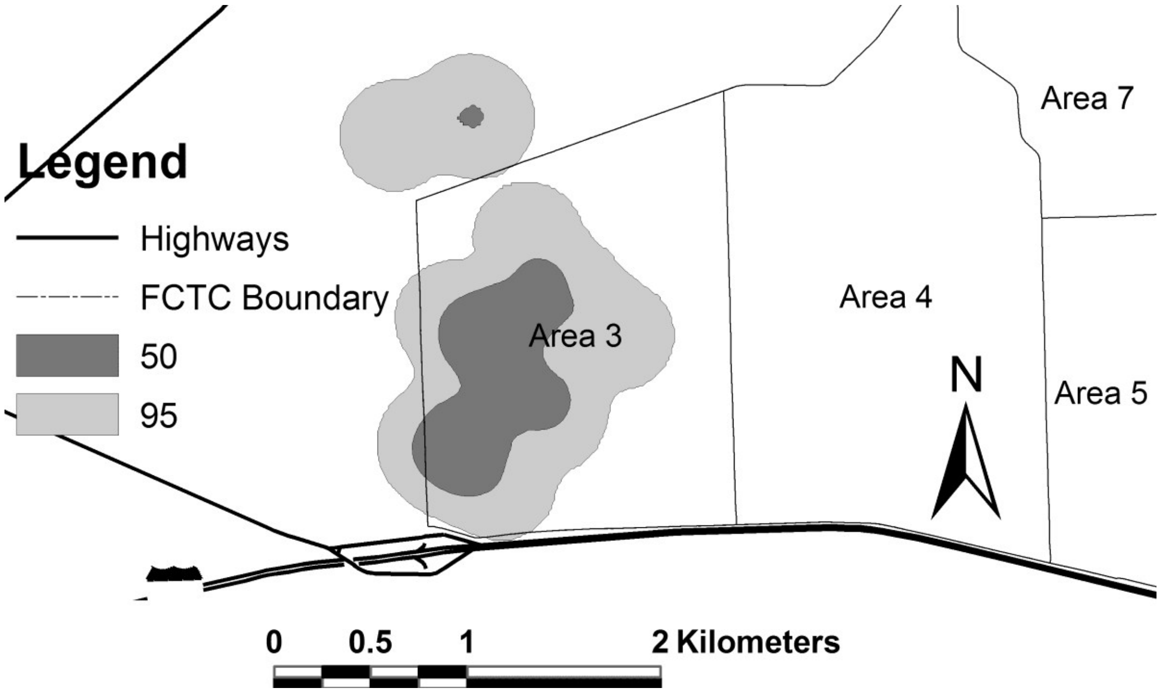

Figure C.21. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.370.

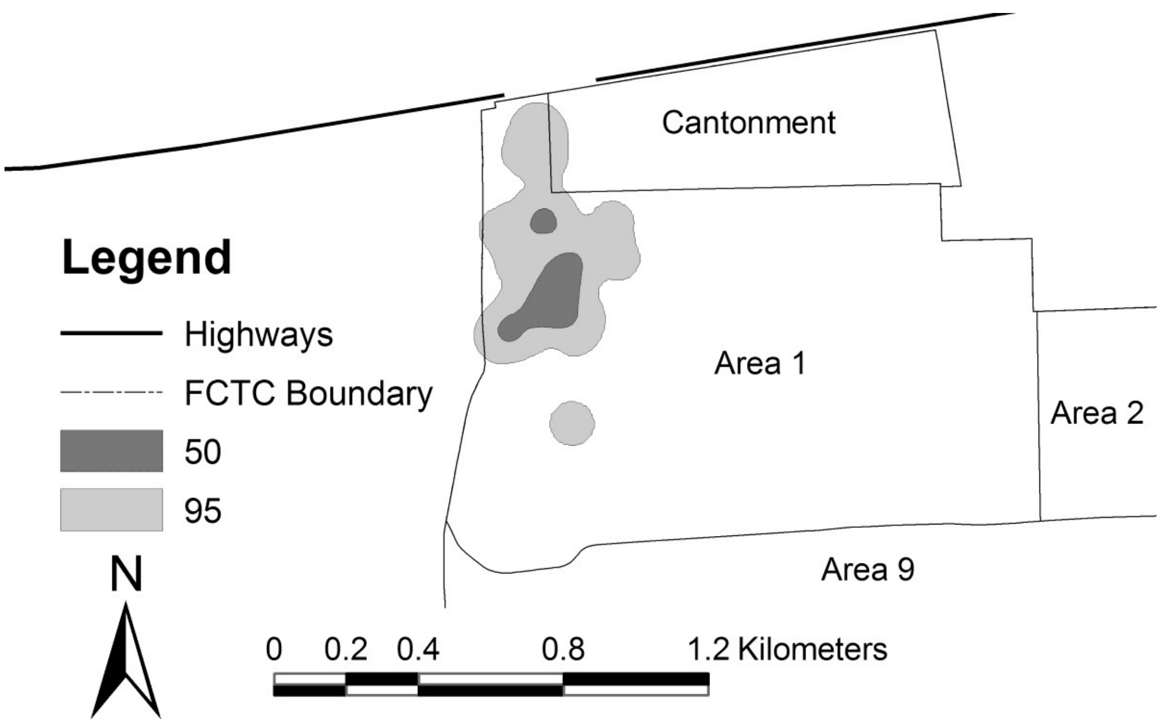

Figure C.22. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.380.

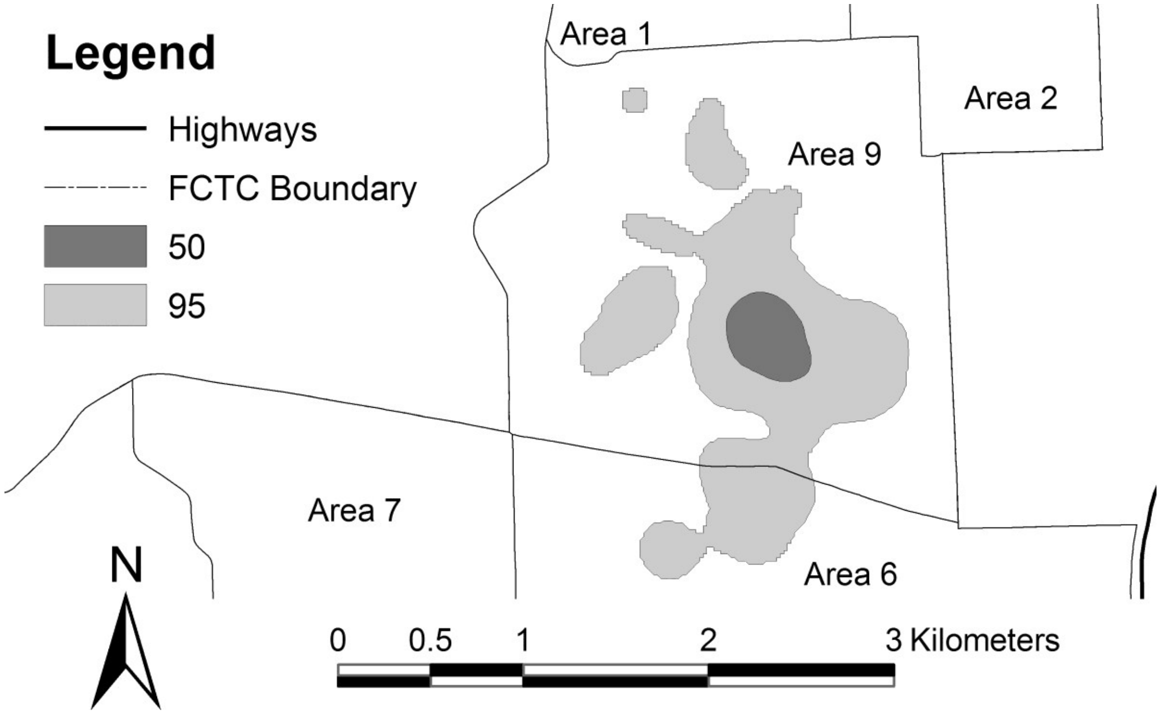

Figure C.23. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.390.

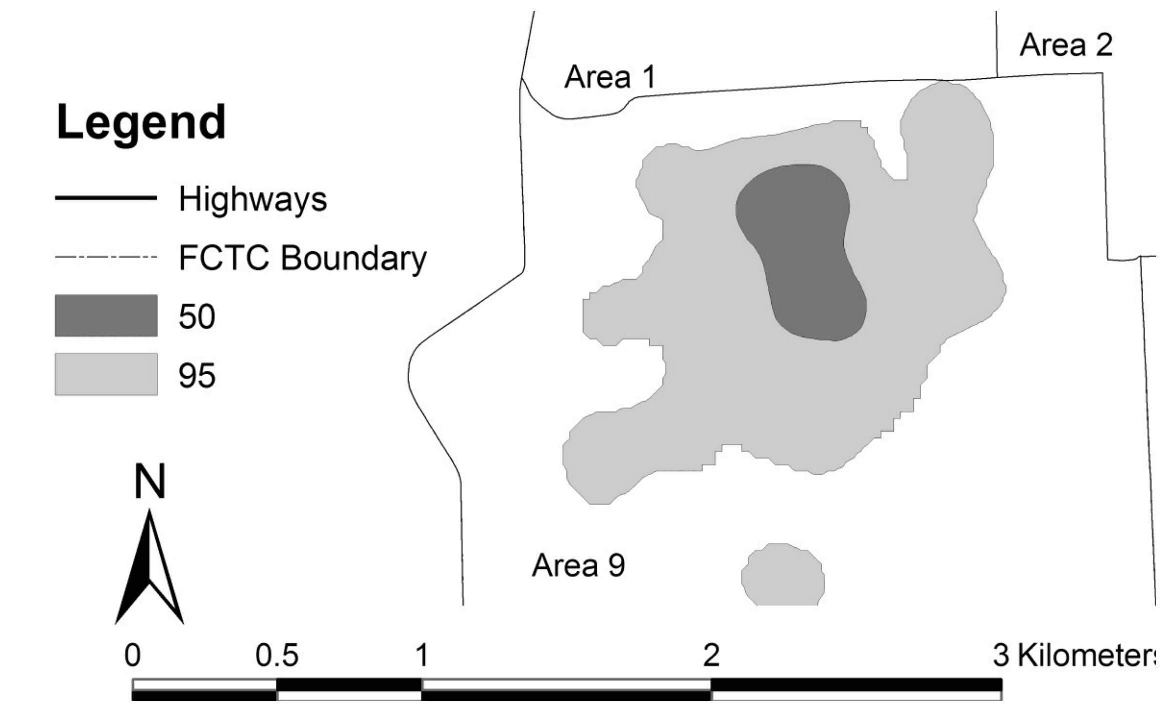

Figure C.24. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.400.

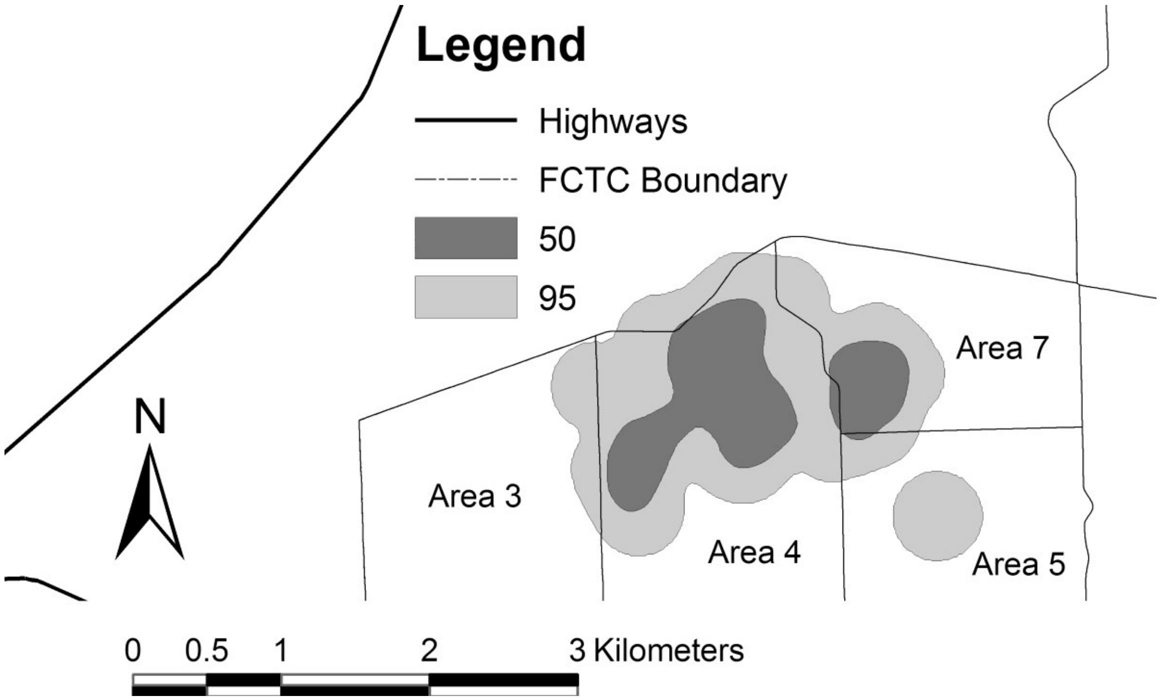

Figure C.25. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.420-2.

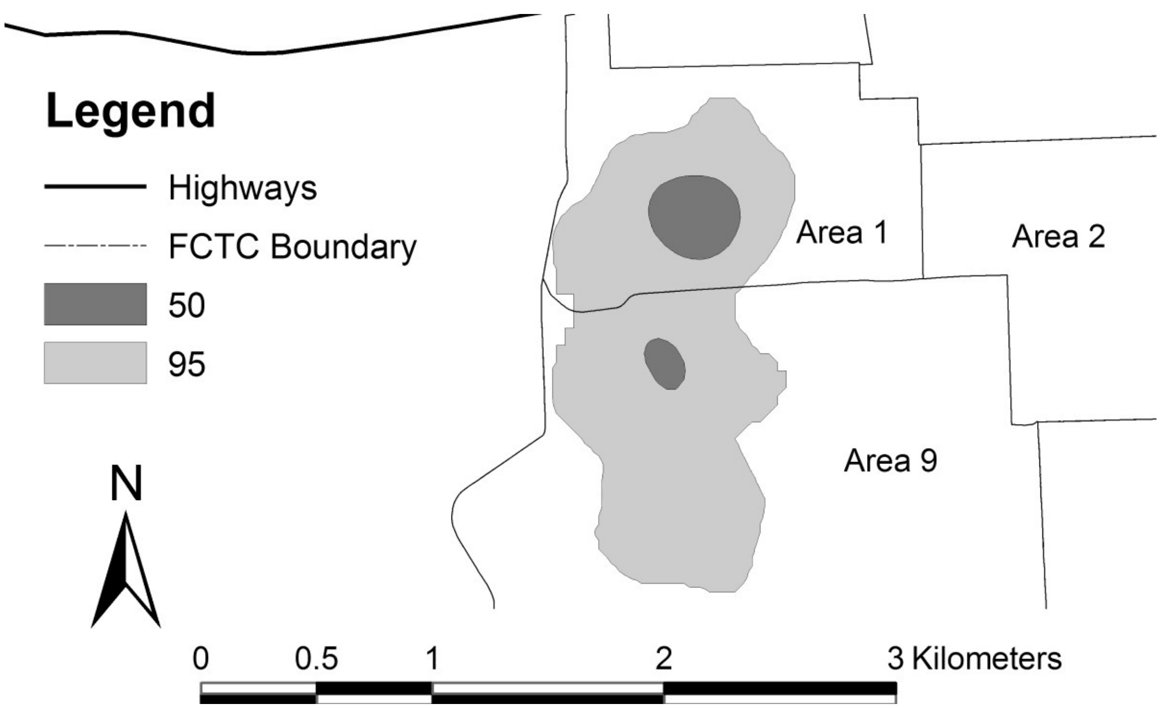

Figure C.26. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.430.

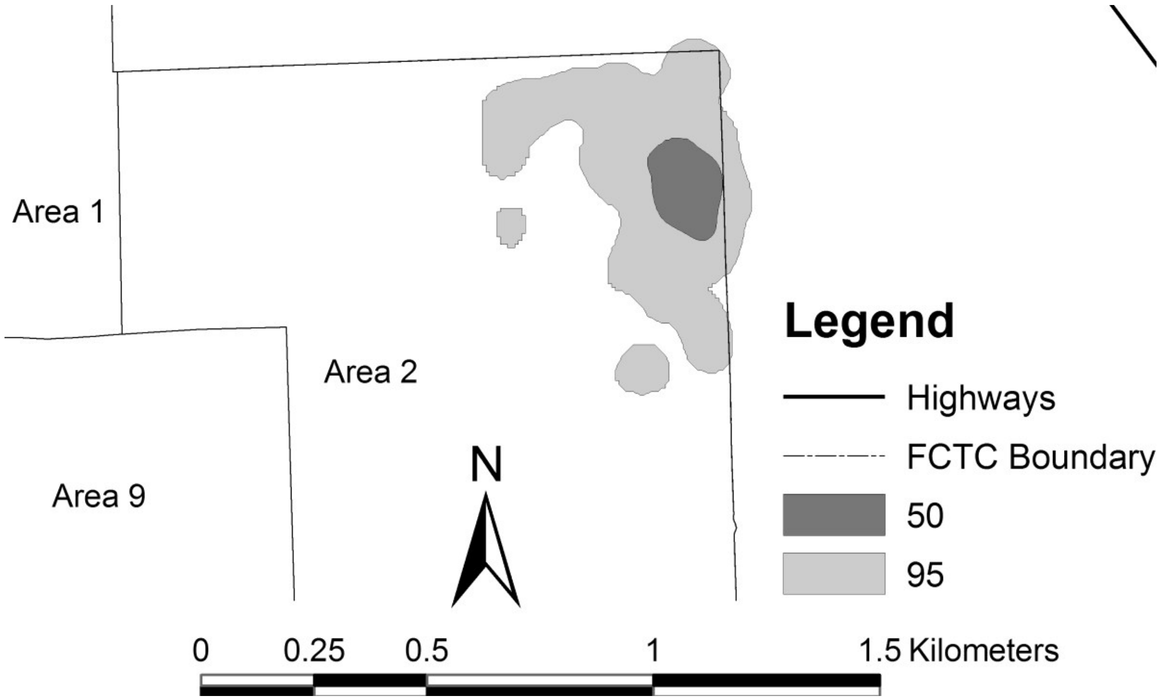

Figure C.27. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.440.

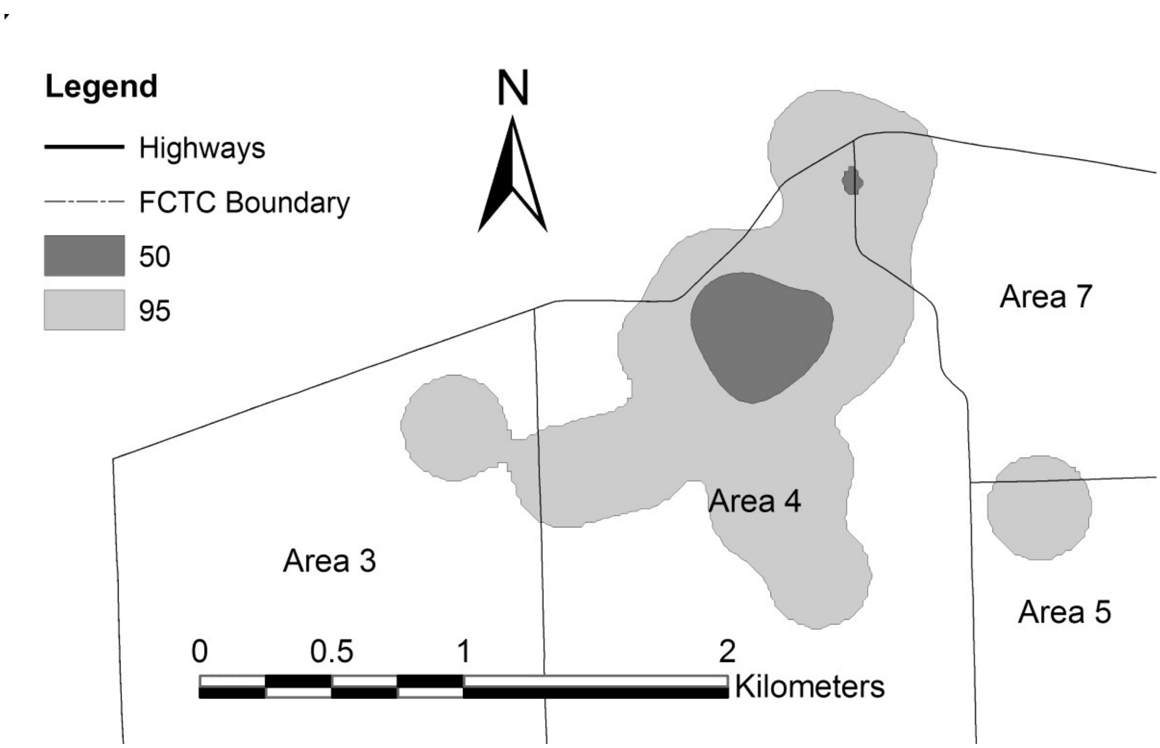

Figure C.28. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.470.

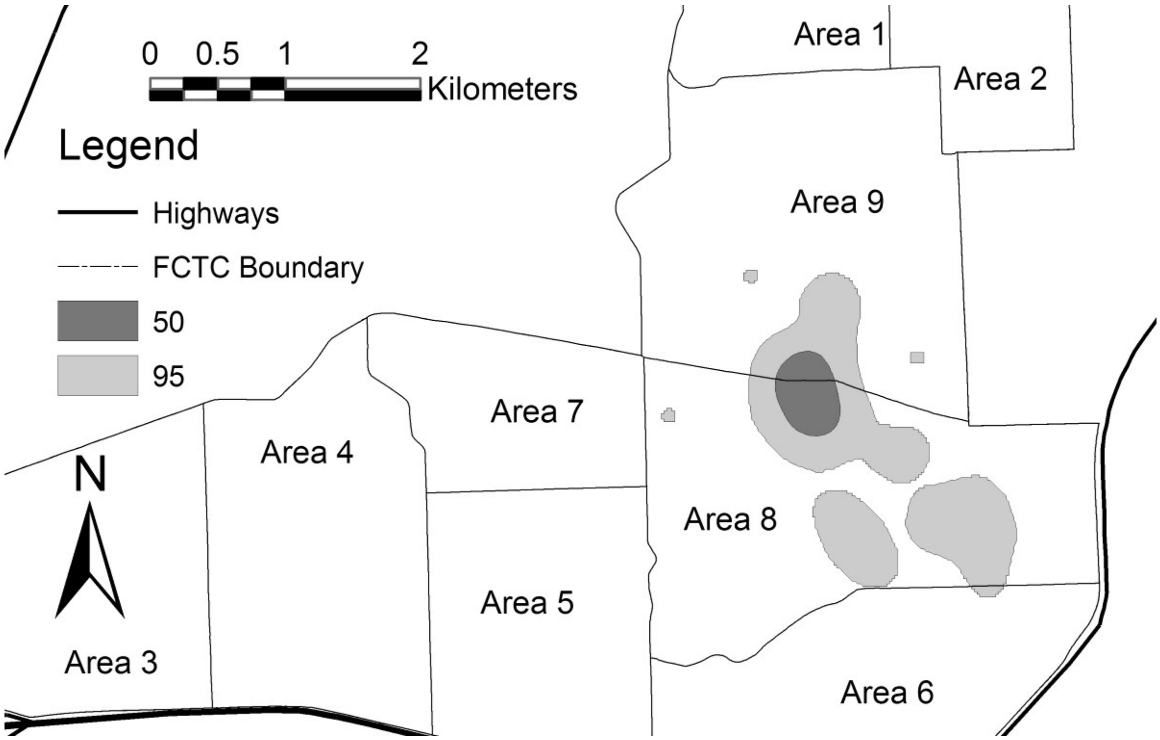

Figure C.29. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.480-1.

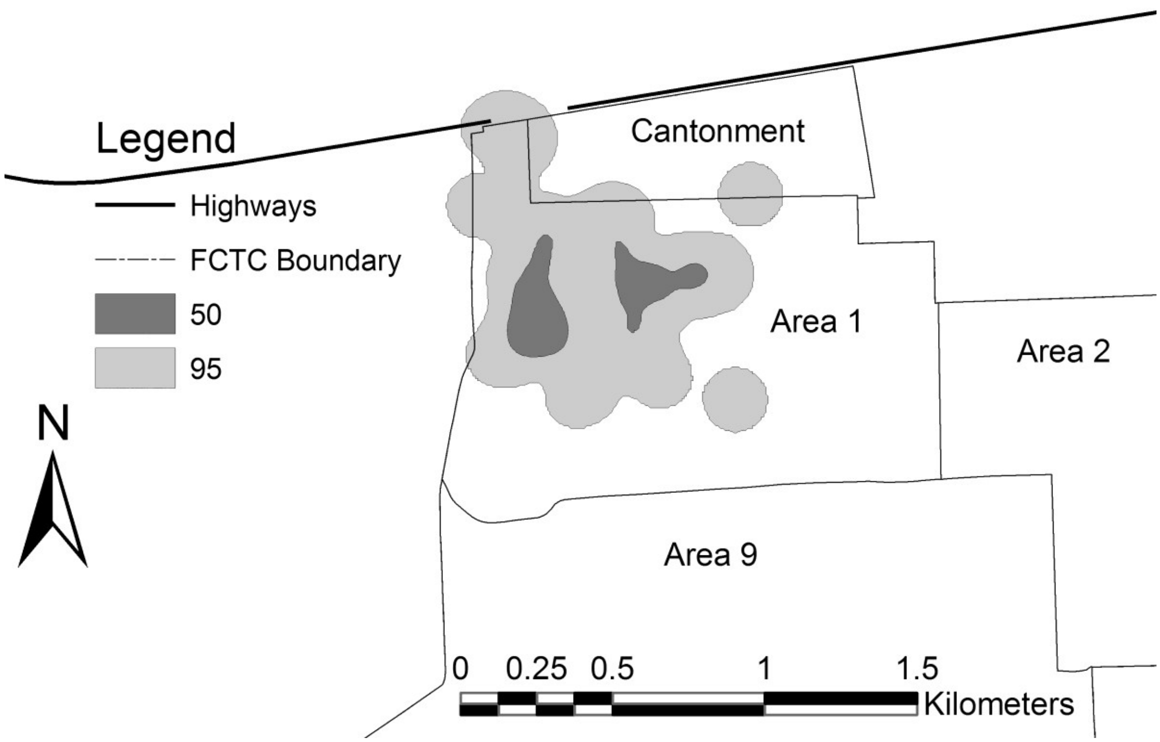

Figure C.30. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.480-2.

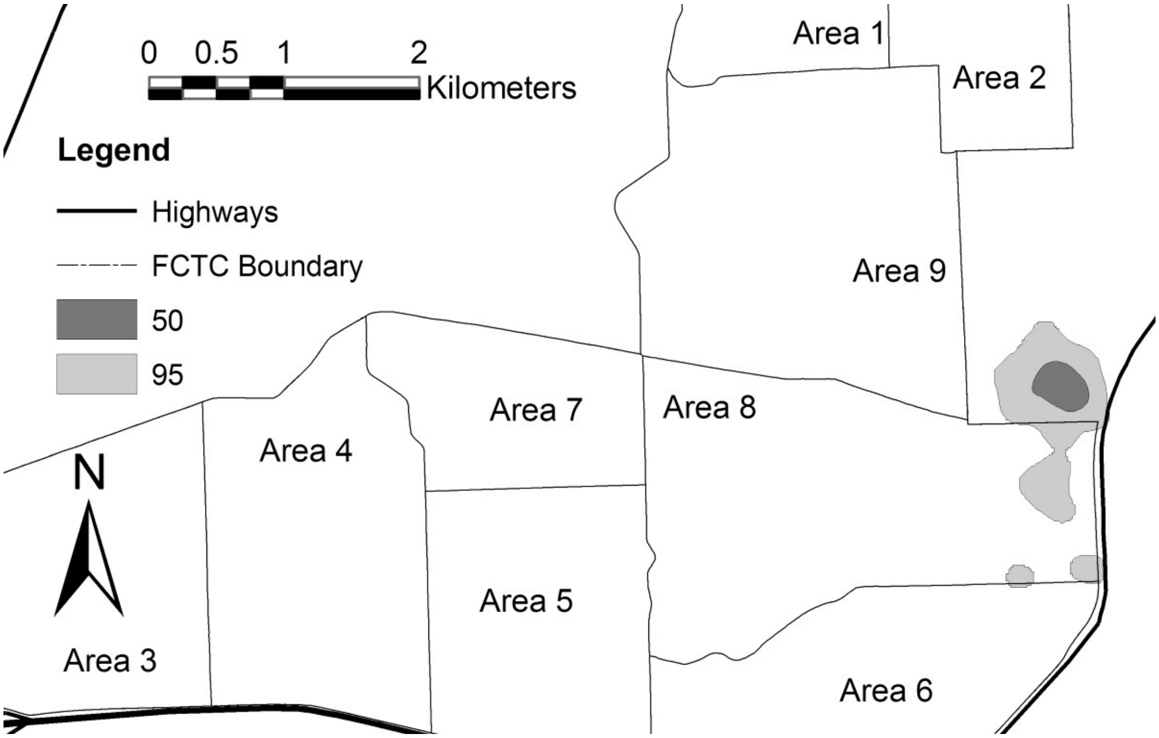

Figure C.31. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.490.

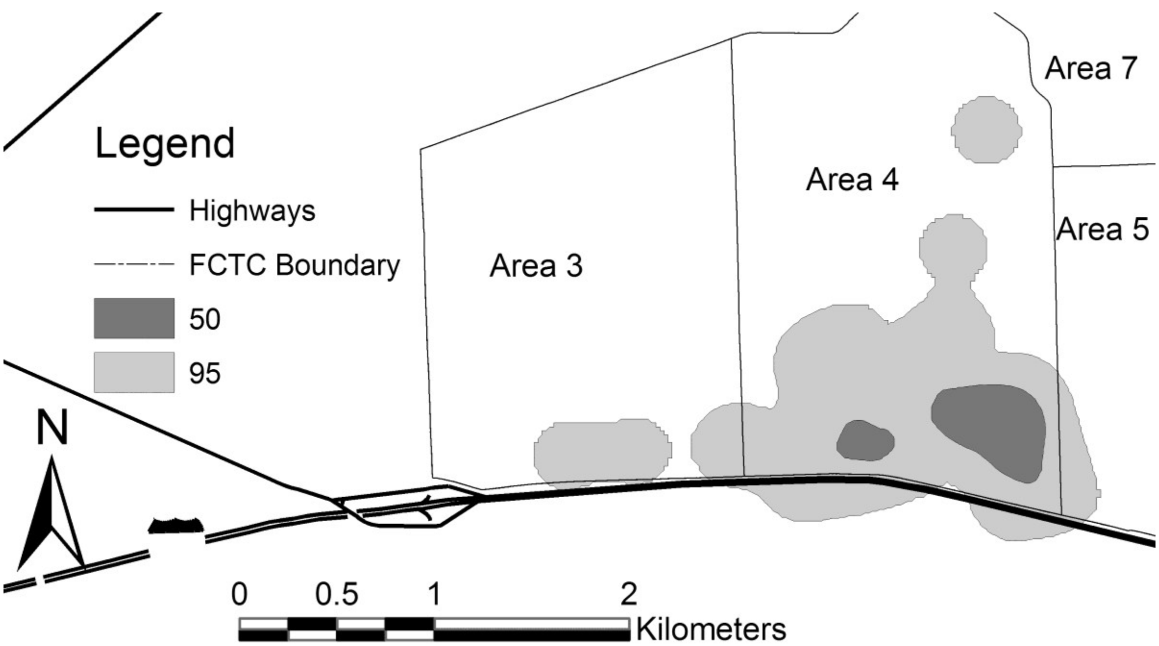

Figure C.32. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.519.

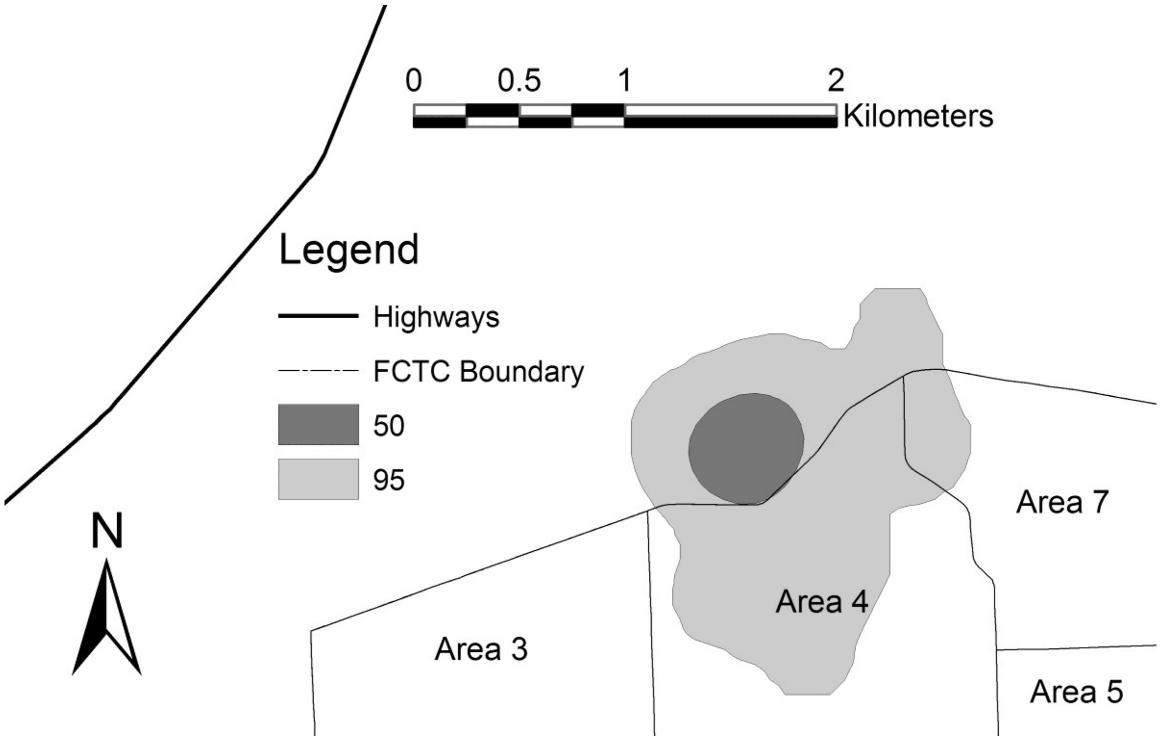

Figure C.33. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.530.

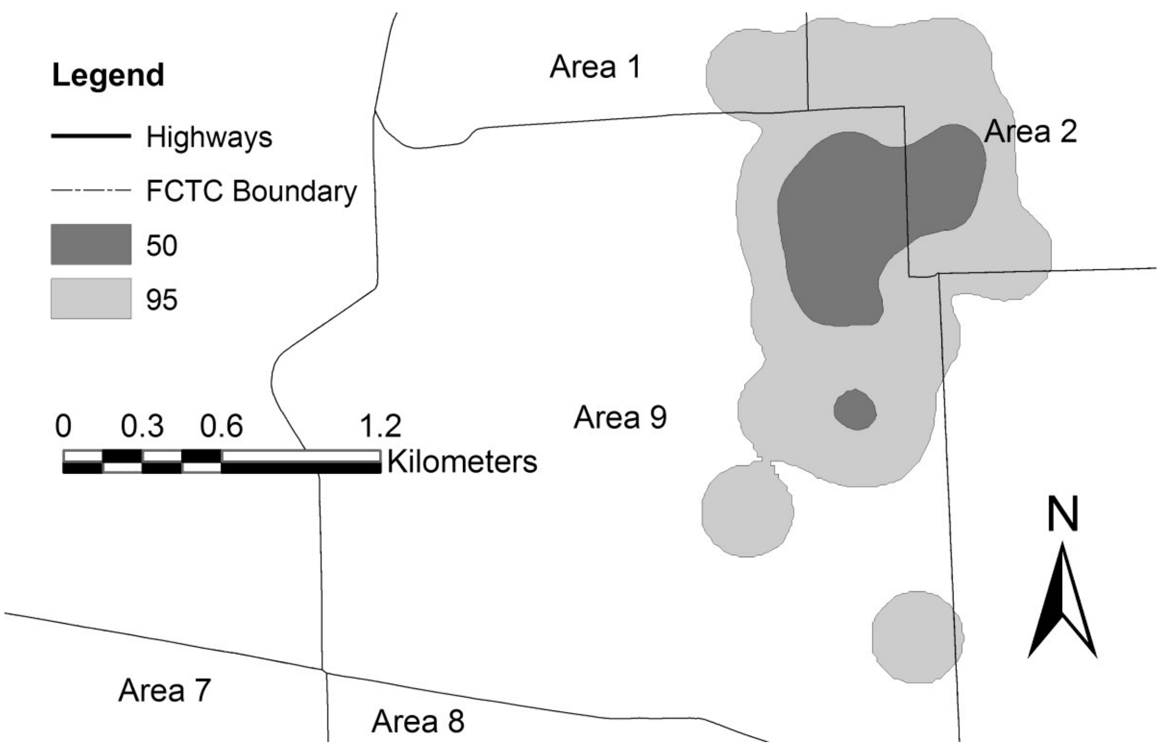

Figure C.34. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.540.

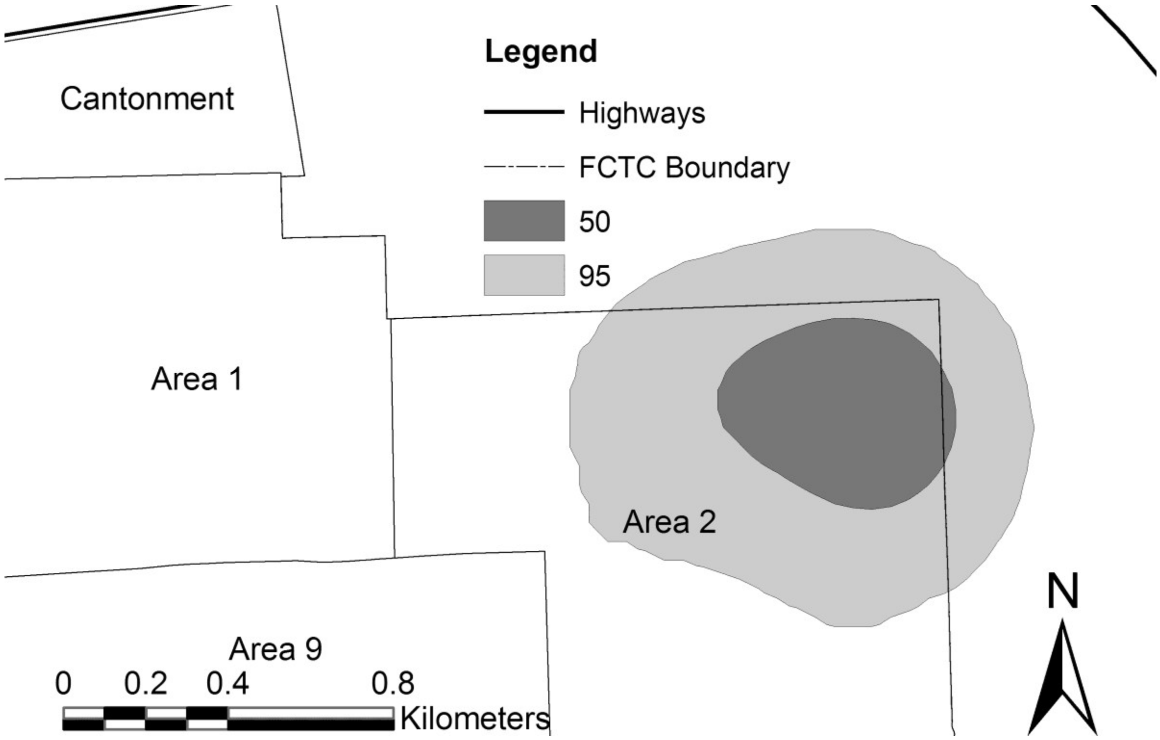

Figure C.35. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.560.

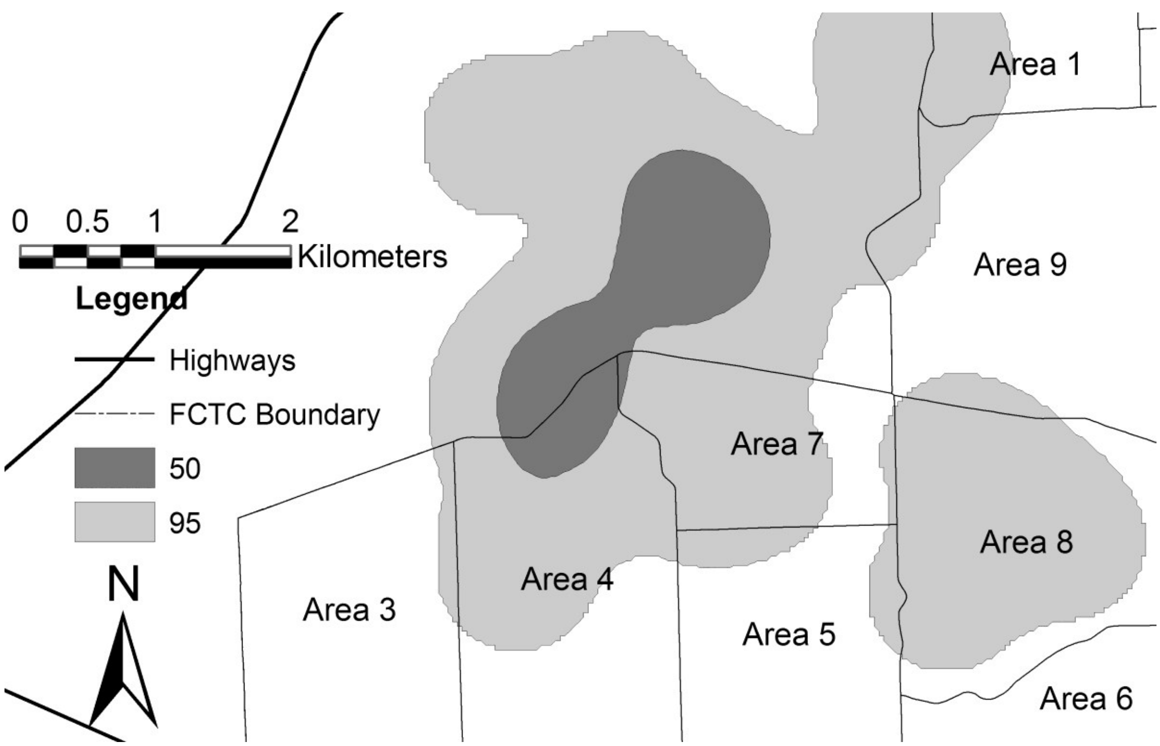

Figure C.36. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.580-1.

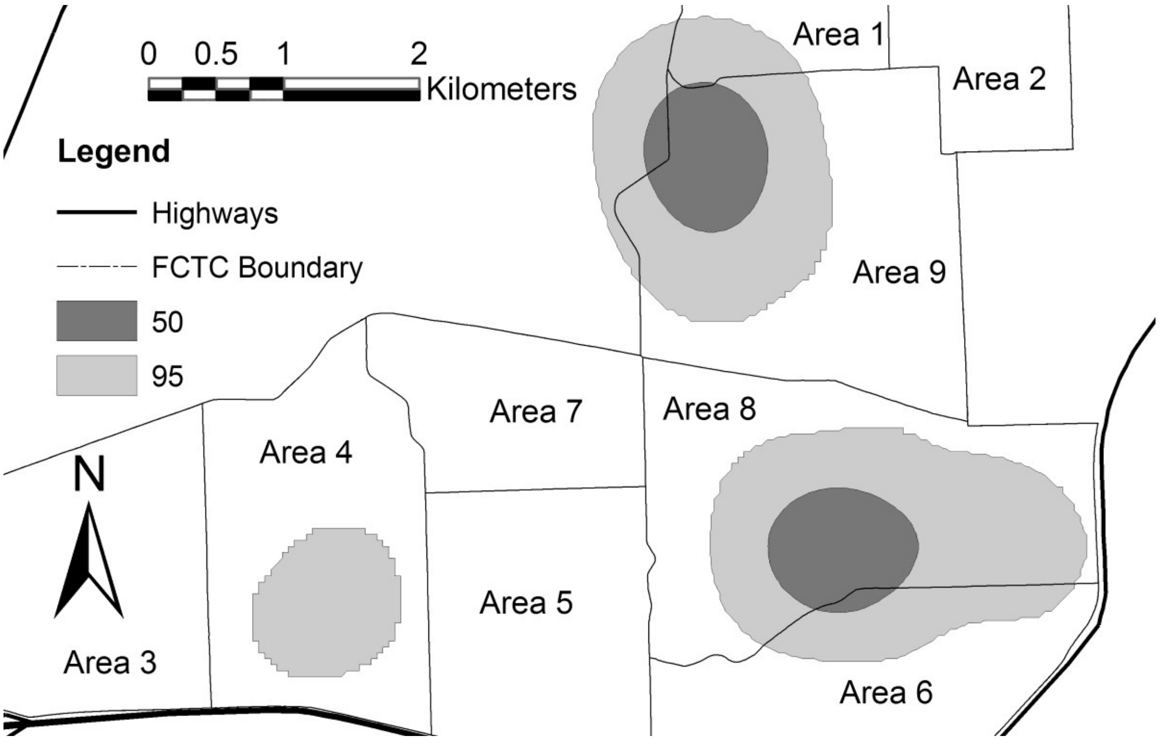

Figure C.37. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.580-2.

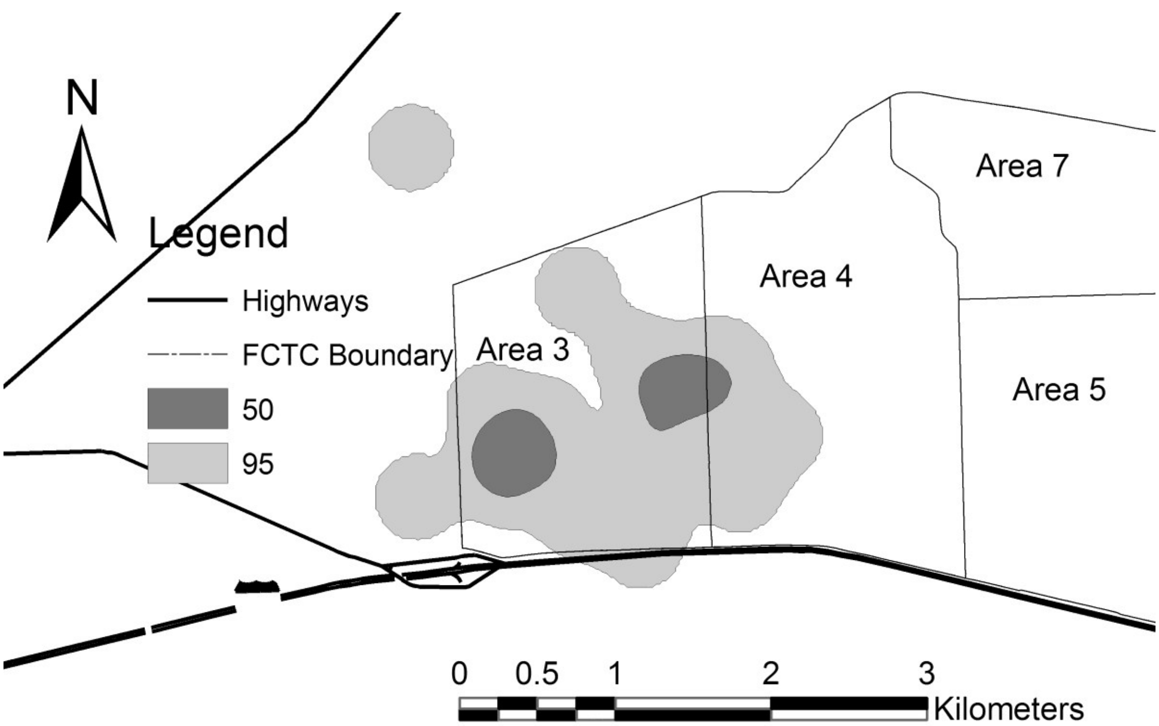

Figure C.38. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.590-2.

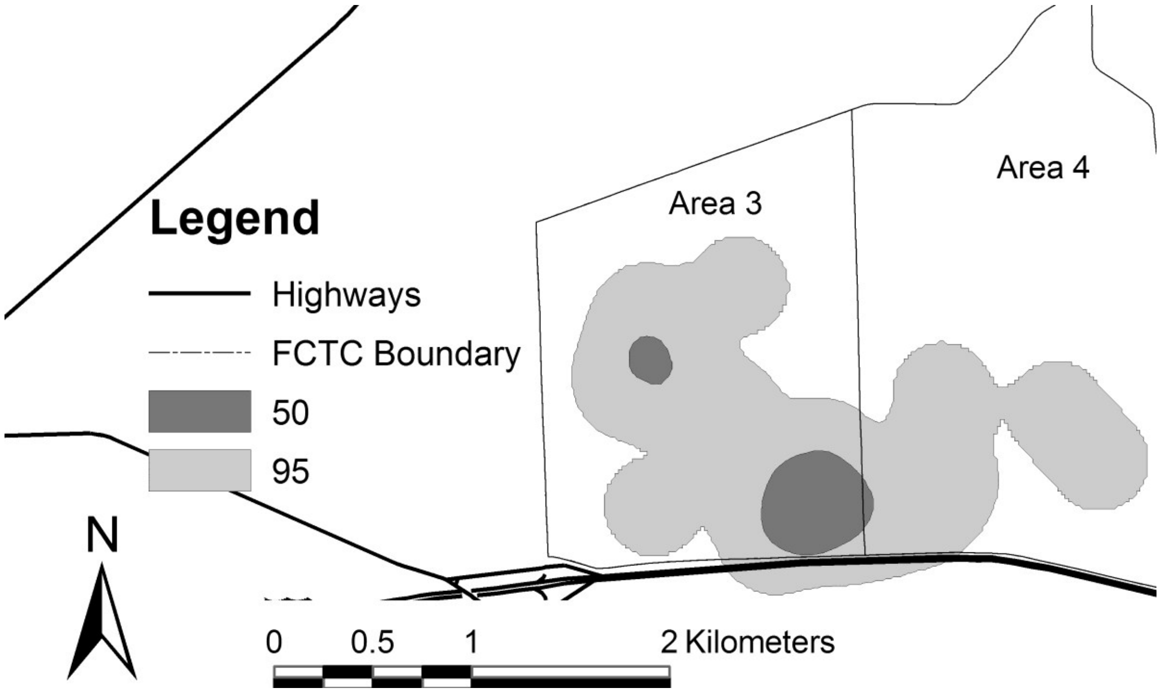

Figure C.39. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.630.

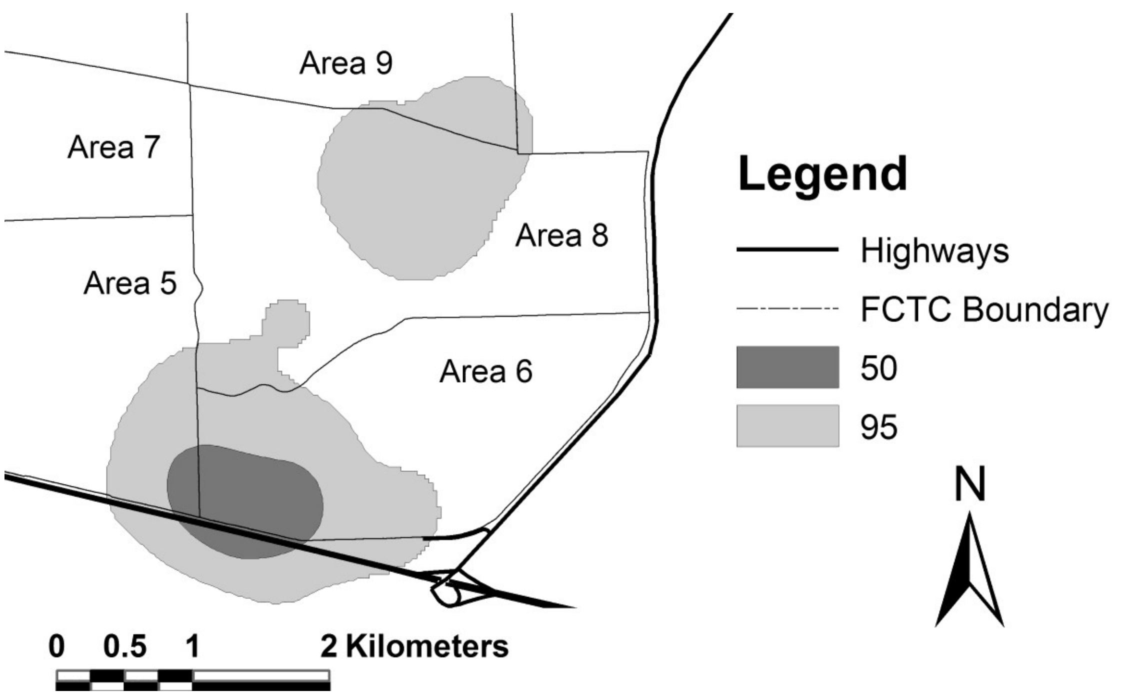

Figure C.40. The fixed kernel home range estimate with the 95% and 50% probability of occupancy for radio frequency 150.710.

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