ESTIMATING DENSITY OF FLORIDA KEY DEER

A Thesis

by

CLAY WALTON ROBERTS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2005

Major Subject: Wildlife and Fisheries Sciences

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Approved as to style and content by:

Roel R. Lopez (Chair of Committee)	Nova J. Silvy (Member)
Steven G. Whisenant (Member)	Robert D. Brown (Head of Department)

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ABSTRACT

Estimating Density of Florida Key Deer.

(May 2005)

Clay Walton Roberts, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Roel Lopez

Florida Key deer (*Odocoileus virginianus clavium*) were listed as endangered by the U.S. Fish and Wildlife Service (USFWS) in 1967. A variety of survey methods have been used in estimating deer density and/or changes in population trends for this species since 1968; however, a need to evaluate the precision of existing and alternative survey methods (i.e., road counts, mark-recapture, infrared-triggered cameras [ITC]) was desired by USFWS.

I evaluated density estimates from unbaited ITCs and road surveys. Road surveys (n = 253) were conducted along a standardized 4-km route each week between January 1999–December 2000 (total deer observed, n = 4,078). During this same period, 11 ITC stations (1 camera/42 ha) collected 5,511 deer exposures. Study results found a difference (P < 0.001) between methods with road survey estimates lower (76 deer) than ITC estimates (166 deer). Comparing the proportion of marked deer, I observed a higher (P < 0.001) proportion from road surveys (0.266) than from ITC estimates (0.146). Lower road survey estimates are attributed to (1) urban deer behavior resulting in a high proportion of marked deer observations, and (2) inadequate sample area coverage. I suggest that ITC estimates are a reliable and precise alternative to road surveys for estimating Key deer densities on outer islands.

I also evaluated density estimates from 3 road survey methods. Road survey methods (n = 100) were conducted along a standardized 31-km route where mark-resight, strip-transect, and distance sampling data were collected between June 2003–May 2004. I found mark-resight estimates to be lower ($\bar{x}$ = 384, 95% CI = 346–421) than strip-transect estimates ($\bar{x}$ = 854, 95% CI = 806–902) and distance estimates ($\bar{x}$ = 523, 95% CI = 488–557). I attribute low mark-resight estimates to urban deer behavior resulting in a higher proportion of marked deer observations along roadways. High strip-transect estimates also are attributed to urban deer behavior and a reduced effective strip width due to dense vegetation. I propose that estimates using distance sampling eliminate some of these biases, and recommend their use in the future.

DEDICATION

I dedicate this to my Mom and Dad who taught me that the journey is more important than the destination; and, to my Grandmother and Stepmother who always have time to share a cup of coffee. Also, to my Brother who shares my passion for the outdoors and history.

ACKNOWLEDGMENTS

I would like to thank the members of my committee, Roel Lopez and Nova Silvy, for their guidance through my graduate school experience. The lessons I learned from them, many of which had nothing to do with scholastic improvement or Key deer biology, will not soon be forgotten. They understand the value and concepts of working hard, having fun, and promoting positive energy with colleagues. Additionally, I would also like to thank Professors M. Peterson, S. Davis, and S. Whisenant who helped drag me kicking and screaming up to a higher standard of understanding of various aspects of ecology and research.

Secondly, I would like to express my appreciation to my fellow graduate students in the Department of Wildlife and Fisheries Sciences (WFSC) at Texas A&M University, colleagues at the National Key Deer Refuge, The Nature Conservancy, Mosquito Control, and Mote Marine Institute, many of whom are friends, hunting buddies, spear fishing buddies, rum drinking buddies, co-authors and co-conspirators; all of whom made my experience at A&M and in the Keys unforgettable. Special thanks have to be extended to the TAMU student interns, Americorps volunteers, and other volunteers who assisted in the collection of field data.

Funding was provided by TAMU System, Rob and Bessie Welder Wildlife Foundation, Florida Fish and Wildlife Conservation Commission, and USFWS (Special Use Permit No. 97-14). Special thanks are extended to the staff of the National Key Deer Refuge, Monroe County, Florida. Last, but certainly not least, thank you to the ladies in the WFSC office that kept me in line all those years.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE | Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

The endangered Florida Key deer, the smallest subspecies of white-tailed deer in the United States, are endemic to the Lower Florida Keys (Hardin et al. 1984). Key deer occupy 20-25 islands within the boundaries of the National Key Deer Refuge (NKDR) with the majority of the population (≈75%) found on Big Pine (BPK) and No Name (NNK; Fig. 1.1; Lopez 2001) keys. The most recent population estimate indicates approximately 500 Key deer on BPK and NNK (Lopez 2001), an increase from the estimated 30–50 deer in the late 1940s.

The need for wildlife managers to obtain reliable population estimates is paramount in the field of wildlife ecology. Managers need practical, field-tested techniques that are repeatable and can be used by a variety of field personnel (Koenen et al. 2002). Estimating abundance or density of an animal population is important for developing proper conservation policy and management protocols (Gelatt and Siniff 1999, Swann et al. 2002), particularly with threatened or endangered species like the Florida Key deer. Annual population monitoring is mandated in the current Key Deer Recovery Plan (U. S. Fish and Wildlife Service [USFWS] 1999).

Traditional methodologies such as drive, strip, aerial, thermal/infrared counts, and mark-capture techniques can be expensive, labor intensive, or limited to habitats with high visibility and lack of dense cover (Lancia et al. 1994, Jacobson et al. 1997, Jachmann 2002). Since 1968, spotlight counts have been conducted on the Florida Key

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deer (Silvy 1975, Lopez 2001) to monitor population trends (index). Efforts to estimate population density (deer/unit area), however, have been limited to mark-resight efforts conducted in 1968-1972 and 1998-2001 (Silvy 1975, Lopez 2004). Use of mark-resight methodologies are labor intensive and expensive, and may be impractical in the annual monitoring of Key deer by USFWS biologists. A need to evaluate alternative methods of estimating Key deer density is necessary, particularly methods that are easy to implement, precise, and economical. Furthermore, methods that provide USFWS biologists with annual density estimates rather than population trends (e.g., index from spotlight counts) would be preferred.

OBJECTIVES

The objective of my thesis was to evaluate 2 alternative methods to estimate population density for the endangered Florida Key deer. First, I evaluated the use of infrared-triggered cameras (ITC) in estimating deer numbers (Kucera et al. 1995, Jacobson et al. 1997, Koerth and Kroll 2000) compared to traditional mark-resight methods to assess the applicability of ITCs in estimating Key deer densities on outer islands. Alternative methods of estimating Key deer densities on outer keys where the lack of roads precludes traditional road counts are needed. Second, I compared distance sampling (Buckland et al. 1993, Corn and Conroy 1998, Tomas et al. 2001, Forcardi et al. 2002*a*, Koenen et al. 2002, Swann et al. 2002, Ransom and Pinchak 2003), strip-transect (Burnham and Anderson 1984, Johnson and Rutledge 1985, Hiby and Krishna 2001), and mark-resight methodologies to evaluate the usefulness of these methods in future monitoring efforts with Key deer. My thesis is divided into 3 chapters:

1. Use of infrared-triggered cameras in estimating Key deer (Chapter II).
2. Comparison of distance sampling, strip-transects, and mark-resight methods in estimating Key deer (Chapter III).
3. Final recommendations for estimating Key deer (Chapter IV).

STUDY AREA

The Florida Keys extend 200 km from the southern tip of peninsular Florida (Fig. 1.1). Soils vary from marl deposits to bare rock of the oolitic limestone formation (Dickson 1955). Typically, island areas near sea level (maritime zones) are comprised of red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erecta*) forests. With increasing elevation, maritime zones transition into hardwood (e.g., gumbo limbo [*Bursera simaruba*], Jamaican dogwood [*Piscidia piscipula*]) and pineland (e.g., slash pine [*Pinus elliottii*], saw palmetto [*Serenoa repens*]) upland forests with vegetation intolerant of salt water (Dickson 1955, Folk 1991). Two islands, BPK (2,548 ha) and NNK (461 ha), were selected in my study because (1) the majority of the Key deer population (≈ 75%, Lopez 2001, Lopez 2004) reside on these 2 islands, and (2) long-term population survey data have been collected on these 2 islands (Silvy 1975, Lopez 2004).

Figure 1.1. Range of the endangered Florida Key deer, Monroe County, Florida.

CHAPTER II

COMPARISON OF CAMERA AND ROAD SURVEY ESTIMATES FOR WHITE-TAILED DEER

SYNOPSIS

Wildlife managers require reliable, cost effective, and accurate methods for conducting population surveys in making wildlife management decisions. Traditional methods such as spotlight counts, drive counts, strip counts (aerial, thermal, infrared) and mark-recapture techniques can be expensive, labor intensive, or limited to habitats with high visibility. Convenience sampling designs are often used to circumvent these problems, creating the potential for unknown bias in survey results. Infrared-triggered cameras (ITCs) are a rapidly developing technology that may provide a viable alternative to wildlife managers, as they can be economically used within a random sampling design. I evaluated population density estimates from unbaited ITCs and road surveys for the endangered Florida Key deer on No Name Key, Florida (461-ha island). Road surveys (n = 253) were conducted along a standardized 4-km route each week at sunrise (n = 90), sunset (n = 93), and nighttime (n = 70) between January 1999–December 2000 (total deer observed, n = 4,078). During this same period, 11 ITC stations (1 camera/42 ha) collected 8,625 exposures, of which 5,511 registered deer (64% of photographs). Study results found a difference ($P < 0.001$) between methods with road survey population estimates lower (76 deer) than from ITC estimates (166 deer). In comparing the proportion of marked deer between the 2 methods, I observed a higher ($P < 0.001$) proportion from road surveys (0.266) than from ITC estimates

(0.146). Spatial analysis of deer observations also revealed the sample area coverage to be incongruent between the 2 methods; approximately 79% of all deer observations were on urban roads which comprised 63% of the survey route. Lower road survey estimates are attributed to (1) urban deer behavior resulting in a high proportion of marked deer observations, and (2) inadequate sample area coverage. I suggest that ITC estimates are a reliable and precise alternative to road surveys for estimating white-tailed deer densities, and may alleviate sample bias generated by convenience sampling, particularly on small, outer islands where habitat and/or lack of infrastructure (i.e., roads) precludes the use of other methods.

INTRODUCTION

Reliable population estimates are paramount in the field of wildlife ecology (Jenkins and Marchinton 1969) because assessment of "the stock on hand" is a prerequisite for many wildlife management endeavors (Leopold 1933). Population density estimates are important for implementing harvest strategies or in developing proper conservation policy and management protocols (Gelatt and Siniff 1999, Koenen et al. 2002, Swann et al. 2002). Since white-tailed deer (*O. virginianus*) are the most economically important big game mammal in North America (Beechinor 1986, Schaefer and Main 2001), obtaining reliable population estimates is both a necessary and worthwhile component of white-tailed deer management. Reliable population estimates are even more important with threatened or endangered species, like the Florida Key deer whose recovery efforts require annual population monitoring (U. S. Fish and Wildlife Service [USFWS] 1999).

Traditional methodologies such as drive counts, strip counts (aerial, thermal, infrared), and mark-recapture techniques can be expensive, labor intensive, or limited to habitats with high visibility (Lancia et al. 1994, Jacobson et al. 1997). As a result, sampling designs often are altered to obtain estimates in a non-random fashion, which lowers the cost and/or effort required to obtain the estimate. Convenience sampling of this sort has been criticized widely within the literature due to the probability of bias that is inherent to this type of sample design (Anderson 2001, Mackenzie and Kendall 2002, Thompson 2002, Anderson 2003, Ellingson and Lukacs 2003). Of greater concern is the lack of evidence to either validate the assumption that the sample is not biased by convenience sampling or to determine the amount and/or direction of bias resulting from the non-random sampling design.

Infrared-triggered cameras (ITCs) are a rapidly developing technology that may provide a viable alternative to wildlife managers as they can be economically used within a random or systematic sampling design. Due to their relatively small size, automated function, and robust sampling duration, ITCs can be used to conduct population surveys (Mace et al. 1994, Jacobson et al. 1997) and to study animal behavior and movements (Savidge and Seibert 1988, Carthew and Slater 1991, Mason et al. 1993, Foster and Humphrey 1995, Karanth 1995, Karanth and Nichols 1998). While previous research (Kucera et al. 1995, Jacobson et al. 1997, Koerth and Kroll 2000) suggests that ITCs are a useful means for estimating population densities, these studies were conducted using baited camera sites which may introduce unwanted bias in the estimates. A basic assumption of mark-resight methods is that all animals have "equal catchability" (Krebs 1999), which may not be the case when using bait to draw animals into the sample area. Information on the utility of estimating white-tailed deer numbers with randomly placed, unbaited, ITCs is needed. Furthermore, mark-resight estimates from traditional road surveys and ITCs should be evaluated, including similarities in animal sightability between methods (i.e., "equal catchability").

I compared estimates from traditional road surveys and ITCs for a marked island population of white-tailed deer. Florida Key deer are an endangered subspecies of white-tailed deer endemic to the Lower Florida Keys (Hardin et al. 1984). The Key deer population on No Name Key (461 ha) provided me with a unique opportunity to (1) compare estimates from unbaited ITCs to road surveys and (2) to evaluate the proportion of marked deer between the 2 methods. Comparable results would provide a precedent for using ITCs to estimate deer densities on the outer islands where a lack of roads precludes the use of traditional road surveys.

METHODS

Trapping and Marking

Deer were captured and marked on No Name Key between January 1999–December 2000 using portable drive nets (Silvy et al. 1975), drop nets (Lopez et al. 1998), and hand capture (Silvy 1975, Lopez 2001). Deer were physically restrained after capture with an average holding time of 10–15 minutes (no drugs were used). Sex, age, capture location, body weight, radio frequency (if applicable), and body condition were recorded for each deer prior to release (Lopez et al. 2003*b*). Captured deer were marked with plastic neck collars (8-cm wide) for adult and yearling females, leather antler collars (0.25-cm wide) for yearling and adult males and elastic expandable neck collars for (3-cm wide) for fawns (Lopez et al. 2004*a*). Neck collars were equipped with plastic ear tags for easy identification at a distance; 67–75% of the marked deer were equipped with radio transmitters (Lopez et al. 2004*a*). Captured deer also were given an ear tattoo that served as a permanent marker (Silvy 1975).

Road Surveys

Weekly road counts were conducted along a standardized 4-km route on No Name Key at sunrise, sunset, and nighttime from January 1999–December 2000 (Fig. 2.1, Lopez et al. 2004*a*). Start and finish points were the same for each survey route. Sunrise surveys started 30 minutes before sunrise. Sunset surveys started 1.5 hours before sunset, and night surveys were conducted about 1 hour after sunset. Two observers in a vehicle traveled along the survey route (average travel speed 16–24 km/hr) and recorded the observed number (marked/unmarked), location, sex, and age (fawn, yearling, adult) on a map of the survey route (Lopez et al. 2004*a*). Deer were not counted on the backtrack portions of the road to alleviate the problem of double counting. Survey data were entered into an Access database and Arcview GIS for further analysis (Lopez 2001).

Camera Surveys

Eleven TrailMaster 1500 Active Infrared Trail Monitors (TrailMaster, Goodson and Associates, Inc., Lenexa, KS, USA) consisting of a transmitter, receiver, and a 35-mm camera were placed following a systematic design (Fig. 2.1). First, I restricted camera placement to upland Key deer habitats (Lopez et al. 2004*b*), avoiding

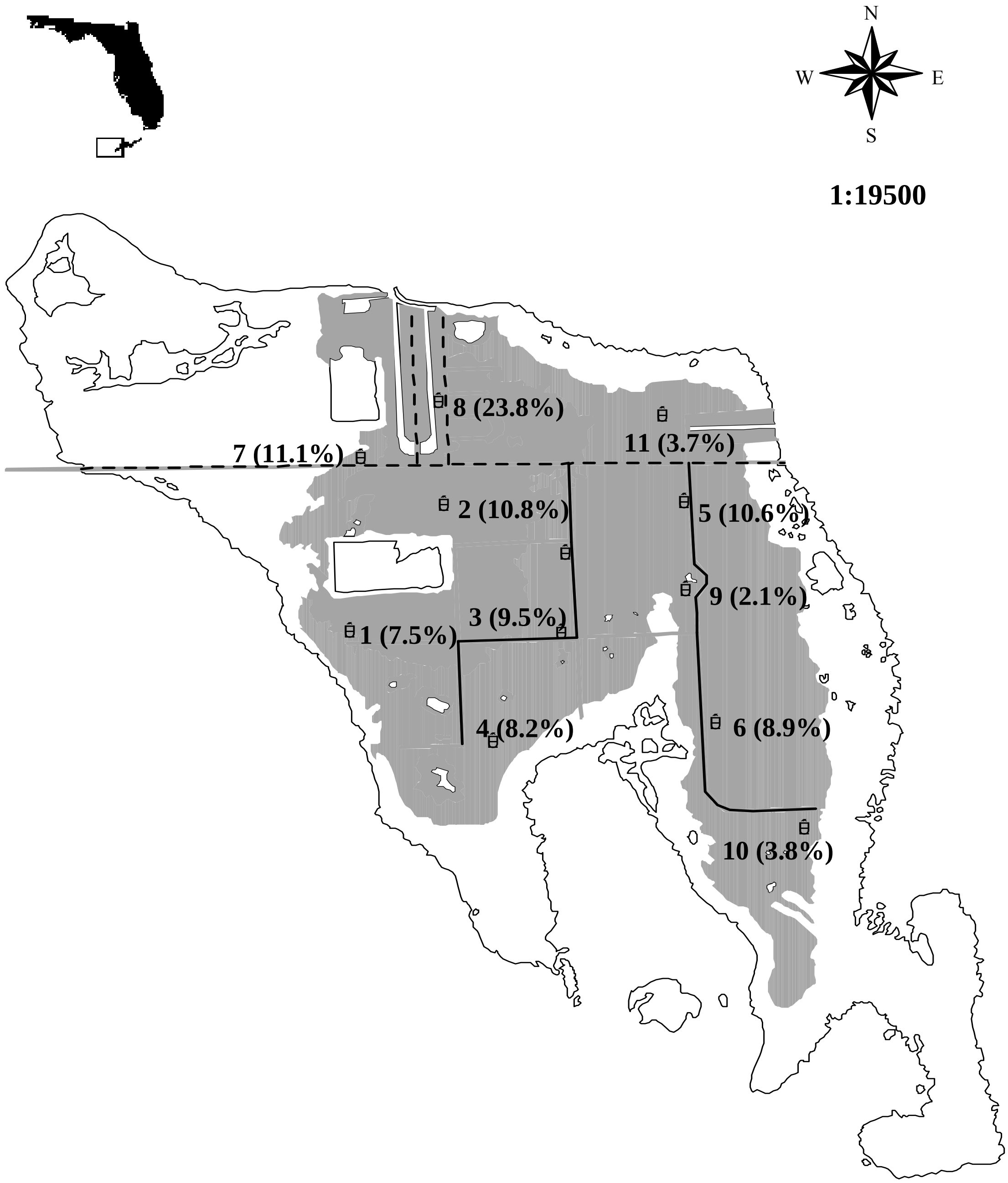

Figure 2.1. Road survey route (4-km) and 11 infrared-triggered camera (ITC) stations used to estimate Key deer densities on No Name Key (461-ha), Monroe County, Florida, January 1999-December 2000. Road survey is divided into urban (dashed line, 2.5-km) and rural roads (solid line, 1.5-km). Approximately 79% of total deer observations (n = 3,222) were observed on urban roads compared to 21% for rural roads. The percent of Key deer observations (n = 5,511) by camera station are in parentheses, the star symbol indicates approximate camera station placement. Gray shading represents areas inhabited by deer (upland areas).

mangrove and buttonwood areas that are influenced by tides and not used by deer. I then divided inhabited areas into approximately 42-ha blocks (slightly higher camera density suggested by Jacobson et al. 1997); each block was then searched until a suitable (e.g., well used deer trail, waterhole) camera location was found. Camera stations collected data from January 1999–December 2000. Cameras were set to take pictures throughout the day (0001–2400 hours) with a delay between pictures of 30 minutes. The number of marked and unmarked animals including the animal's ear tag number, sex, age, and location were recorded and entered into an Access database.

Data Analysis

I determined weekly population estimates using a using Lincoln-Petersen (Seber's modification) estimator for road surveys (White et al. 1982, Krebs 1999, Lopez et al. 2004*a*) and ITC data (Lincoln-Petersen, Seber's modification estimator, Krebs 1999). Population data (road surveys and photographs) met the requirements for this estimate because (1) the population was closed (i.e., study area is an island, with limited dispersal between islands and small population growth, Lopez et al. 2004*a*), and (2) a segment of the population was marked for individual identification during the study. The marked population (approximately 67–75% of marked population included radio transmitter) allowed us to readjust the number of available marked deer each week from telemetry data or survey data observations. Deer observations from ITC stations were pooled to determine a weekly population estimate.

Weekly estimates were randomly selected from both methods to generate a balanced design which maximized the number of surveys within each season x method x year treatment combination. I applied the Lilliefors significance modification to the Kolmogorov-Smirnov test to determine if the data were normally distributed. Levene's test for equal variance among treatment groups, followed by a spread versus level diagnostic regression (modified Box-Cox algorithm; SPSS 2001), was used to determine if a variance stabilizing transformation would be needed. Results indicated that a log(Y+1) transformation was required to meet assumptions of a parametric ANOVA.

I tested for differences in population estimates between methods (road, ITC), seasons (spring, summer, fall, winter), and years (1999, 2000) using a 1 within-subjects factor, 2 between-subjects factor, split-plot (repeated measures) ANOVA (SPSS 2001). Seasons were defined as winter (January–March [pre-fawning season]), spring (April–June [fawning season]), summer (July–September [pre-breeding season]), and fall (October–December [breeding season], Lopez et al. 2004*a*). Repeated-measures ANOVA designs account for lack of independence when repeated observations are obtained from the same experimental units (Tzilkowski and Storm 1993, Zar 1996, Lomax 2001, von Ende 2001). Because there were only 2 levels for the within-subjects factor (year), compound symmetry was assured (i.e., only 1 covariance). As such, adjusted *F*-test (Geisser and Greenhouse 1958, Huynh and Feldt 1976) and MANOVA techniques (no compound symmetry assumption) were not required for the evaluation of these data. Results for each method were plotted separately for each year using the estimated marginal means for all 4 seasonal categories (SPSS 2001). For each weekly estimate, I compared the proportion of marked deer (number marked/total deer observed) between methods using an independent Student's *t*-test (SPSS 2001). All statistical comparisons were conducted at $\alpha = 0.05$.

I compared the "sightability" of individually marked Florida Key deer between road and camera surveys using Simpson's index of evenness (Krebs 1999). The Simpson's index of evenness (E_D) describes the evenness of observations for an individual among all observations (E_D assumes a value between 0–1, with 1 being completely even). I restricted my analysis to animals marked with neck collars (only neck collars could be used to identify individual deer) and animals monitored for 12 months. I standardized the sampling period to avoid biases in the calculation of the index due to differences in sampling effort.

RESULTS

Density Estimates

Road and ITC surveys were conducted from January 1999–December 2000 except September 1999 due to the landing of Hurricane Irene (Lopez et al. 2003*a*). A weekly average of 22 deer (with a range between 18 and 35) were maintained in my marked herd. A total of 253 road surveys were conducted (sunrise $n = 90$, sunset $n = 93$, nighttime $n = 70$) with 4,078 deer observations (male $n = 1{,}411$, female $n = 2{,}246$, unknown $n = 421$). Eleven camera stations collected 8,625 exposures during the same time period, with 5,511 of those photographs registering deer (64% of the total photographs). Other camera exposures included mammalian ($n = 172$, 2%), deer unknown ($n = 670$, 8%), misfires ($n = 1{,}969$, 23%), and other ($n = 303$, 4%).

After transformation, I obtained a non-significant result ($P = 0.125$) for Levene's Test of equal variance among treatment groups. The Kolmogorov-Smirnov test with Lilliefors significance modification, revealed 2 of 16 treatment combinations to be non-normal (camera × winter × 1999 [$P = 0.23$], road × fall × 1999 [$P = 0.040$]). As ANOVA is deemed robust to minor departures from normality, these treatments were included in the analysis.

I found road survey estimates to be lower ($\bar{x} = 76$, SE = 6.45) compared to ITC estimates ($\bar{x} = 166$, SE = 14.92). The repeated-measures ANOVA results for between-subject effects (i.e., method) revealed a significant difference between the 2 methods ($P < 0.001$) but not between seasons ($P = 0.439$), and there were no method x season interactions ($P = 0.963$) (Fig. 2.2). The within-subject effects results indicated there were differences ($P = 0.046$) in density estimates between years and no year x method interaction ($P = 0.919$); however, I found a significant ($P = 0.004$) interaction between year x season. As a result, the estimates between seasons depend upon the year of the survey. Finally, there was no year x method x season interaction ($P = 0.159$).

In comparing the proportion of marked deer between the 2 methods, I observed a higher ($P < 0.001$) proportion from road surveys ($\bar{x} = 0.266$, SE = 0.010) than from ITC estimates ($\bar{x} = 0.146$, SE = 0.009). Unlike the ITC estimates which offered a more uniform sample of the island (Fig. 2.1), deer observations collected on the road survey also were biased towards urban roads. Approximately 79% of all deer observations were observed on urban roads which comprised 63% of the survey route (Fig. 2.1).

A total of 19 individually marked Key deer (n = 12 females, n = 7 males) met my criteria (total camera observations = 377, total road survey observations = 389). I found the E_D estimates from camera surveys (male E_D = 0.566, female E_D = 0.677, total E_D = 0.615, Fig. 2.3) were higher than road surveys (male E_D = 0.333, female E_D = 0.599, total E_D = 0.509, Fig. 2.3) from individually marked Florida Key deer.

DISCUSSION

Road surveys have been the preferred method to estimate Key deer densities and/or monitor population trends by NKDR biologists for the last 30 years. All previous population data have been collected using road surveys due to their ease of application and the limited time and man-power available to conduct these surveys (Lopez et al. 2004*a*). In comparing road survey estimates to ITC estimates, however, my study revealed a significant difference between the 2 methods for all seasons and years. ITC estimates were nearly 2 times those of road survey estimates (Fig. 2.2). While my study did reveal the anticipated results, it does demonstrate that convenience sampling can easily bias survey results. I attribute differences in density estimates to biases in (1) the effective area sampled between methods, and (2) the proportion of marked animals observed between methods.

Sampling Area

Spatial analysis of survey results found 79% of road survey observations occurred on urban roads (63% of the survey route); whereas ITC estimates were more uniformly distributed (Fig. 2.1). I propose the systematic sampling design (i.e., more uniform coverage) and use of non-baited sites for the ITC surveys captured a larger

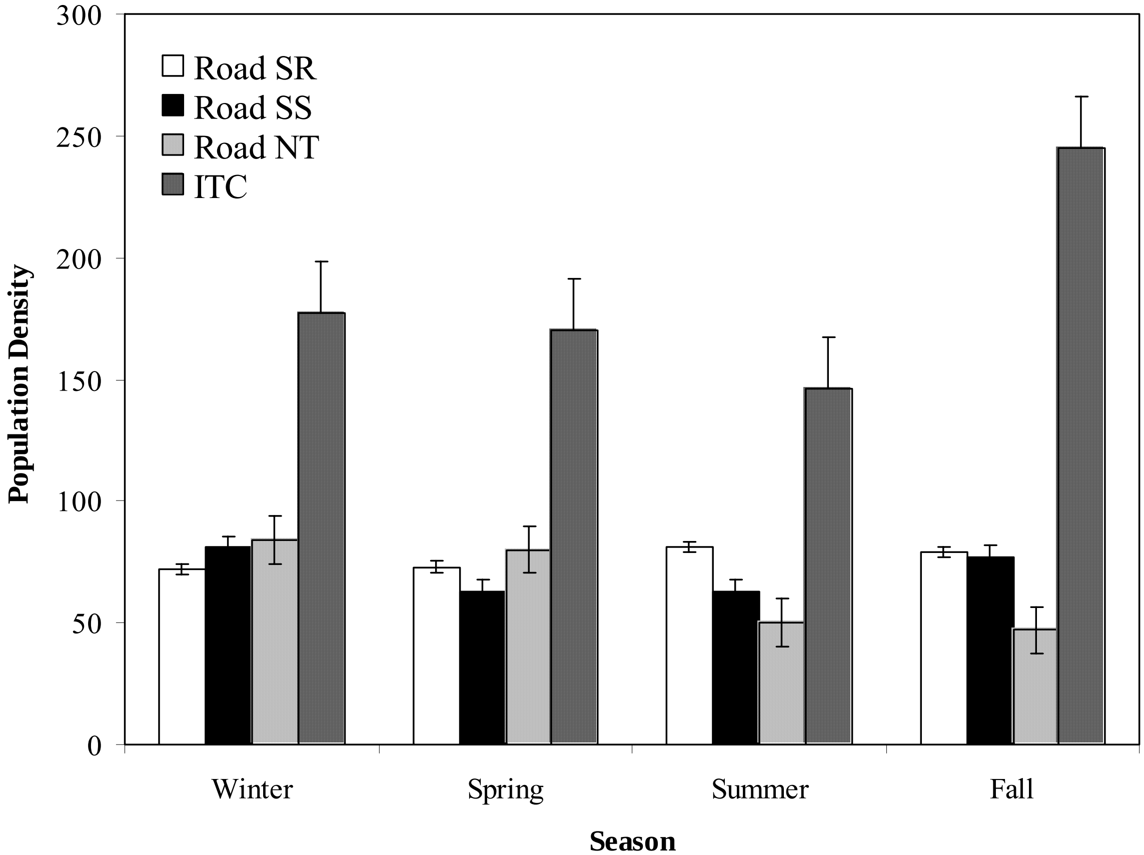

Figure 2.2. Florida Key deer density estimates (mean, SE) by season, time of day (sunrise=SR, sunset=SS, nighttime=NT), and method (road survey, infrared-triggered camera estimates [ITC]) for No Name Key (461-ha), Monroe County, Florida, January 1999-December 2000.

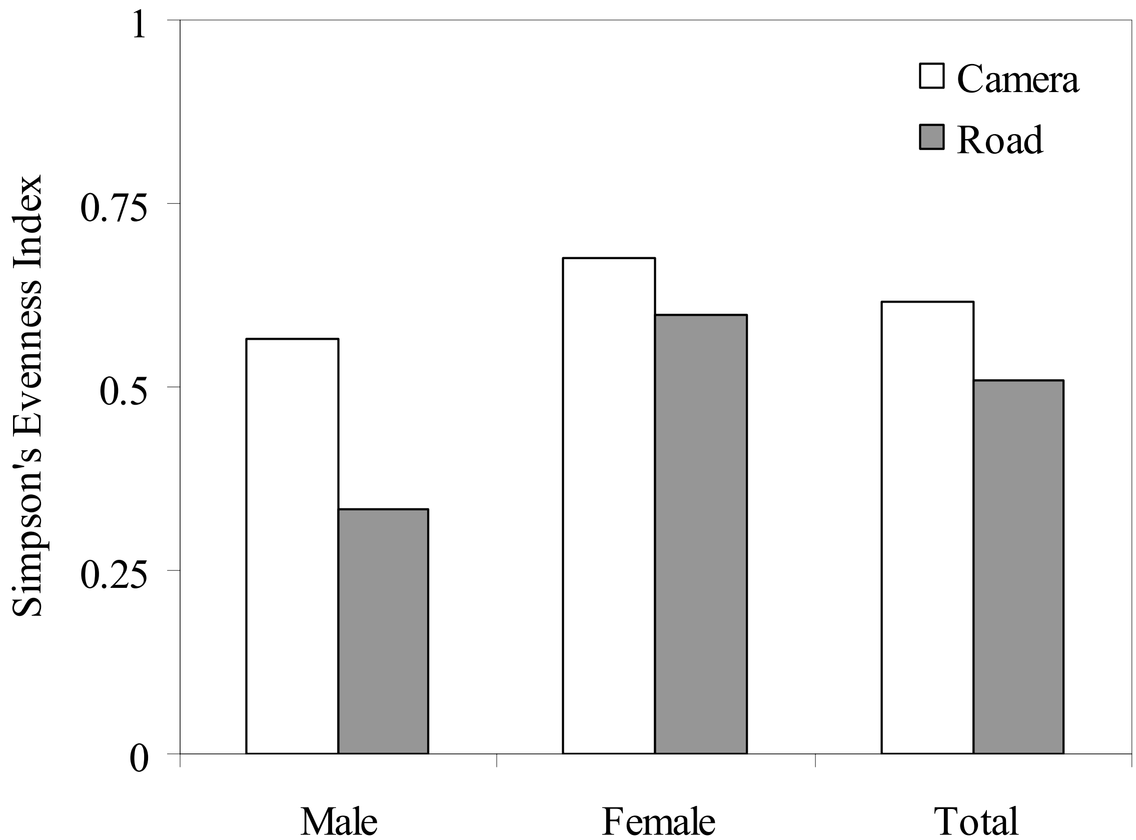

Figure 2.3. Simpson's index of evenness for observations from individually marked Florida Key deer (*n* = 19, *n* = 12 females, *n* = 7 males) by method for No Name Key, Monroe County, Florida, January 1999-December 2000.

portion of the spatial variability and was not biased by the road network, which is highly correlated with urban development. Furthermore, urban roads in the northern area of island (Fig. 2.1) were improved, 2-lane, paved roads frequently driven by tourists and residents. Human-deer interactions were greatest along these roadways (e.g., urban deer feed by tourists by roadways). Conversely, the rural roads in the southern area of island (Fig. 2.1) were unimproved, single-lane, roads on bare limestone cap rock. Key deer were rarely observed along these roadways because animals were less domesticated (i.e., “wild” deer) and typically fled into the brush when a vehicle approached. Access into these areas is limited (rural roads provide access to NKDR lands). Use of road surveys would require that deer observations be obtained over a wider percentage of the island. The road survey sampling design used in my study, however, was dictated by roadway infrastructure that was biased towards urban areas. The difference in the “effective” sampling area is a classic example of bias which often results from convenience sampling.

Proportion Marked

Another difference observed in my study was the proportion of marked animals observed between the 2 sampling methods. I found the proportion of marked animals observed on road surveys was nearly double those obtained from ITC data. As a result, density estimates from road survey data were biased low (Krebs 1999). I attribute this difference to trapping methods used and deer behavior. First, many animals were trapped and collared in areas that were large enough for trapping procedures to take place (i.e., use of drop nets, Lopez et al. 1998), and as a result were often located in close proximity to the survey route. Likewise, in recent years Key deer have become urbanized in response to the abundance of food and fresh water in and around housing areas (Lopez et al. 2004*b*). In particular, Key deer have been observed to remain near roads due to the propensity of visiting tourists that feed deer from their vehicles (R. Lopez, Texas A&M University, personal observation). I propose that both of these variables have resulted in a biased road survey sample due to an unequal distribution of marked deer. The bias in sightability of individual marked deer (camera surveys, E_D = 0.615; road surveys, E_D = 0.509, Fig. 2.3) supports this idea. Collectively, I propose the bias in sampling area and differences in sightability of marked deer between both methods accounts for population estimate differences observed in my study.

MANAGEMENT IMPLICATIONS

My study demonstrates that ITC surveys can be used to carry out precise population estimates without the limitations inherent to road surveys. Road survey estimates remain a viable method to estimate population numbers; however, biologists should be aware of potential biases. The use of ITC in estimating population numbers also should be applied with caution. Previous research with ITCs (Kucera et al. 1995, Jacobson et al. 1997, Koerth and Kroll 2000) were conducted using baited camera sites which also may introduce unwanted bias in the estimates similar to my road surveys (i.e., “trap-happy” deer). In comparing E_D values between methods, though road observations were higher (road surveys, E_D = 0.509, Fig. 3), an E_D value < 1 for camera observations of marked deer also suggests that ITC estimates were influenced by roadway biases. Furthermore, the use of ITCs to monitor large areas may become costprohibitive or logistically impractical. For example, the costs in collecting road survey data was approximately $50/week (2 people, does not include vehicle, fuel, spotlights) compared to $85/week for ITC surveys (1 person, 11 cameras; does not include vehicle, fuel, and ITC equipment, latter is a significant cost). Though the ITC surveys are more expensive, I suggest that ITC surveys can be cost-effective in the monitoring of the endangered Key deer on small, outer islands and in other areas where habitat and/or lack of infrastructure precludes the use of other methods. In addition, ITC surveys reduce potential biases associated with convenience sampling, and can be used in areas where road infrastructure does not exist. I also recommend that natural markers (i.e., antler patterns, physical deformities/injuries) can be used in place of maintaining a marked deer herd for outer islands (Jacobson et al. 1997, Karanth and Nichols 1998, Koerth and Kroll 2000, Heilbrun et al. 2002).

CHAPTER III

COMPARISON OF 3 METHODS IN ESTIMATING WHITE-TAILED DEER DENSITY

SYNOPSIS

Wildlife managers need practical, field-tested survey techniques that are accurate and precise, and can be easily obtained by field personnel when estimating deer populations. Reliable population estimates for the white-tailed deer (*Odocoileus virginianus*) are useful in establishing harvest schedules, setting harvest limits, or in implementing other conservation policies. In my study of the endangered Florida Key deer (*O. v. clavium*), evaluating density estimation procedures was needed in the management of this endangered deer herd and required in the recovery plan. I compared 3 methods of estimating white-tailed deer density in my study: mark-resight, strip-transect, and distance sampling. Road surveys (n = 100) were conducted along a standardized 31-km route where mark-resight, strip-transect, and distance sampling data were collected between July 2003–May 2004. I found mark-resight estimates to be lower ($\bar{x}$ = 384, 95% CI = 346–421) than strip-transect estimates ($\bar{x}$ = 854, 95% CI = 806–902) and distance estimates ($\bar{x}$ = 523, 95% CI = 488–557). I attribute low mark-resight estimates to urban deer behavior resulting in a higher proportion of marked deer observations along roadways. High strip-transect estimates also were attributed to urban deer behavior and a reduced effective strip width due to dense vegetation. I propose that estimates derived from distance sampling were less affected by these biases and were more accurate of the grand mean ($\bar{x}$ = 587, 95% CI = 555–619), assuming the sum of all

3 method estimates captured the true population mean. I suggest that distance sampling estimates are a reliable alternative to labor intensive and costly mark-resight estimates historically used by refuge biologists and recommend their use in the future.

INTRODUCTION

The need for wildlife managers to obtain reliable population estimates is paramount in the field of wildlife ecology. Ideally, wildlife managers need practical, field-tested techniques that are accurate and precise and can be easily obtained by field personnel (Koenen et al. 2002). The white-tailed deer (*Odocoileus virginianus*) is the most economically important big game mammal in North America. Reliable population estimates for the white-tailed deer are useful in establishing deer harvest schedules and in setting harvest limits. Furthermore, estimating abundance or density of an animal population is important for developing proper conservation policy and management protocols (Gelatt and Siniff 1999, Swann et al. 2002), particularly with a threatened or endangered species like Florida Key deer (*O. v. clavium*). Conducting annual Key deer counts are important in the recovery of the sub-species and are required in the South Florida Multi-species Recovery Plan (United States Fish and Wildlife Service [USFWS] 1999).

Traditional methodologies used in estimating deer densities include spotlight counts (McCullough 1982, Cypher 1991, Whipple et al. 1994, Lopez et al 2004*a*, strip-transects (Hirst 1969, Lancia et al. 1994, Rakestraw et al. 1998, Pierce and Baccus 1999, Pierce 2000, Focardi et al 2002*a*), aerial counts (Bear et al. 1989, Potvin et al. 2002, Bender et al. 2003), mark-recapture techniques (Strandgaard 1967, McCullough 1979, Staines and Ratcliffe 1987), and distance sampling (Tomas et al. 2001, Focardi et al. 2002*b*, Koenen et al. 2002). Limitations to some methods (i.e., mark-recapture, aerial surveys) include cost, time requirements, and the need for specialized equipment. The use of distance sampling may overcome some of these limitations (Buckland et al. 1993, Tomas et al. 2001, Forcardi et al. 2002*b*, Koenen et al. 2002); however, few studies (Langdon et al. 2001) have evaluated their utility on white-tailed deer populations.

Distance sampling, a specialized transect method (Anderson et al. 1979), is a technique used to generate population estimates. Three major assumptions are made when using distance sampling for deer: deer located on the transect are always detected, deer do not move in response to the observer's presence, and accurate measurements are taken (Buckland et al. 1993, Langdon et al. 2001, Tomas et al. 2001, Forcardi et al. 2002*b*, Koenen et al. 2002). Distance sampling estimates density by fitting a function through observed perpendicular distances and evaluating that function at distance zero (Anderson et al. 1979, Buckland et al. 1993, Langdon et al. 2001). By avoiding the need to ensure that all animals within a predetermined area are found, distance methods are usually more efficient than conventional methods (Burnham et al. 1985, Buckland et al. 1993, Gill et al. 1997).

Previous efforts in estimating Key deer density have been limited to mark-resight estimates conducted in 1970–1972 and 1998–2000 (Lopez et al. 2004*a*) along a 71-km standardized route on Big Pine Key (BPK; Fig. 3.1). These estimates, however, are limited in their annual application due to the need to mark and maintain marked animals and the associated trapping and marking costs. As a result, alternative methods in

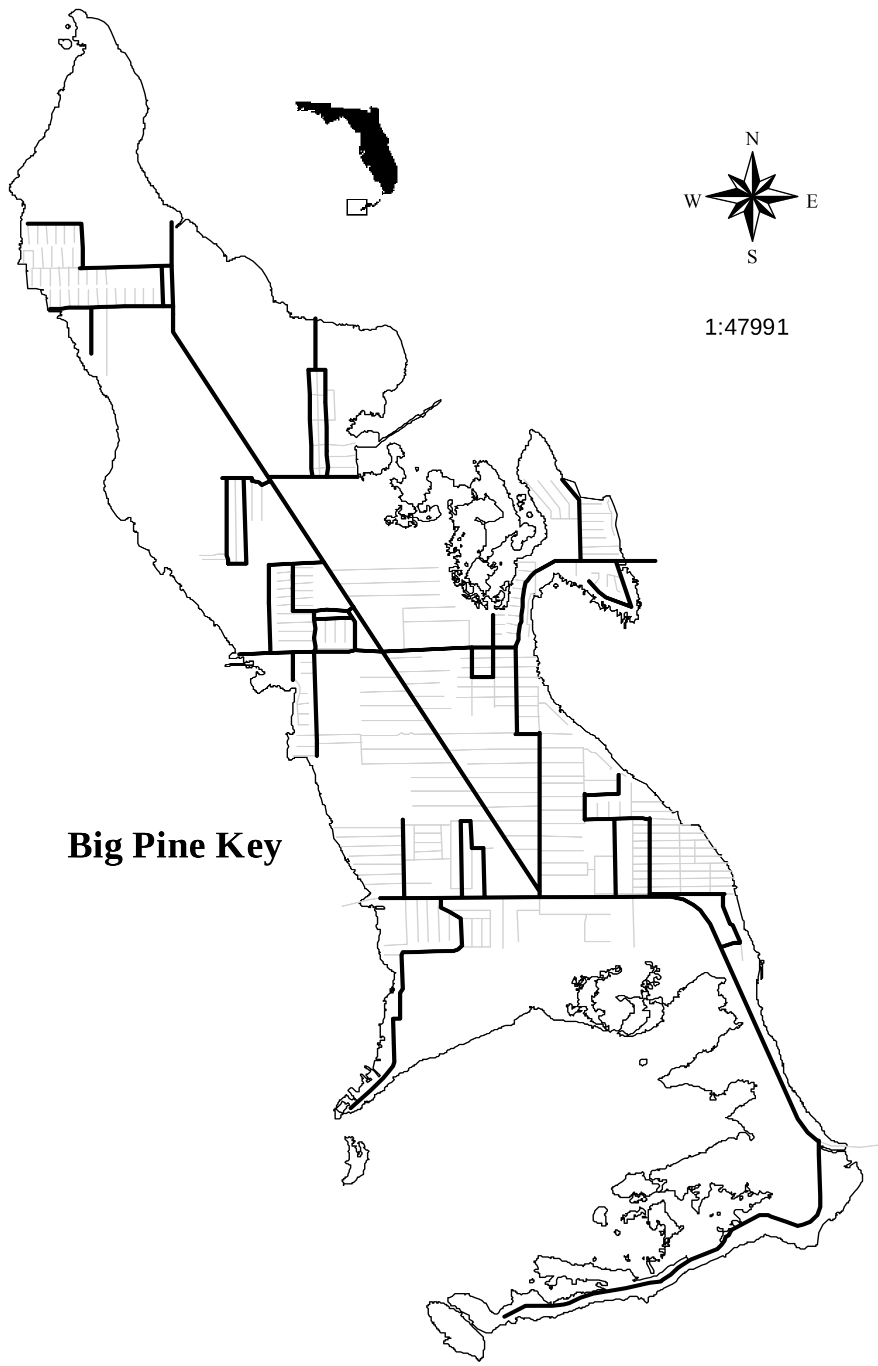

Figure 3.1. Official U. S. Fish and Wildlife Service 71-km survey route used in estimating Key deer density on Big Pine Key, Monroe County, Florida, (Silvy [1975], Lopez [2001]).

estimating Key deer densities annually are desired. In 1975, the original survey route was reduced to a 31-km standardized route on BPK (Fig. 3.2) by USFWS biologists to collect population trend data (i.e., number of deer observed, Lopez et al. 2004*a*). Modifications to data collected along this route (e.g., distance estimates) could yield population density estimates that would be beneficial in monitoring the Key deer population (Burnham and Anderson 1984); however, such changes require evaluation of alternative methods to estimate Key deer densities. The objective of my study was to compare 3 methods of estimating Florida Key deer density, namely mark-resight, strip-transect, and distance sampling.

METHODS

Trapping and Marking

Key deer were trapped and marked on BPK from January 2003–May 2004. Deer were captured using portable drive nets (Silvy et al. 1975), drop nets (Lopez et al. 1998), and hand capture (Silvy 1975, Lopez 2001). Deer were physically restrained after capture with an average holding time of 10–15 minutes (no drugs were used). Sex, age, capture location, body weight, radio frequency (if applicable), and body condition were recorded for each deer prior to release (Lopez et al. 2004*a*). Captured deer were marked with plastic numbered neck collars (8-cm wide) for adult and yearling females, and elastic expandable neck collars for (5-cm wide) for yearling and adult males (Lopez et al. 2004*a*). Neck collars were equipped with plastic ear tags for easy identification at a distance. Captured deer also were given an ear tattoo that served as a permanent marker (Silvy 1975).

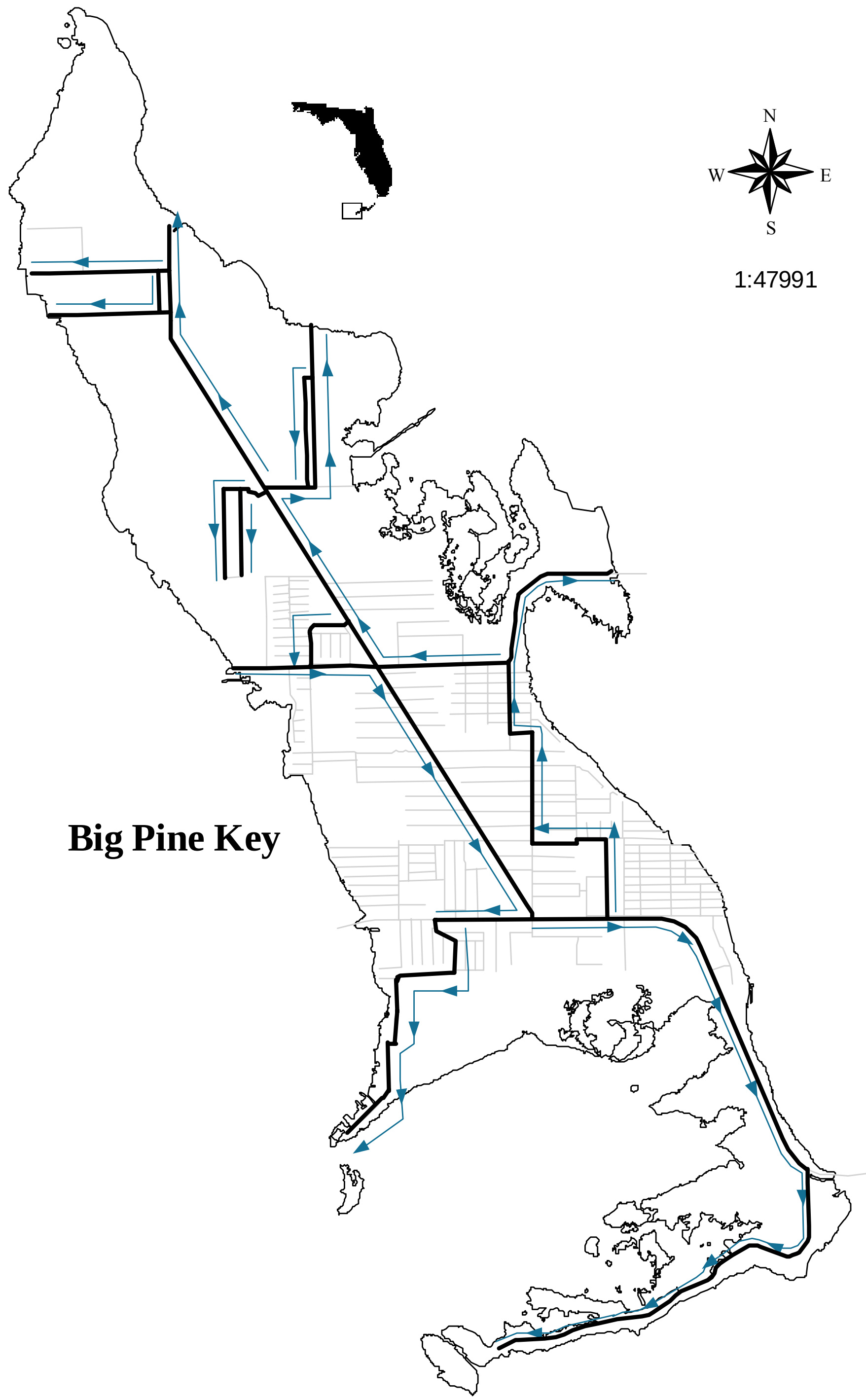

Figure 3.2. Survey route (31-km) used by U. S. Fish and Wildlife Service in monitoring Key deer population trends (1975-present) on Big Pine Key, Monroe County, Florida. Arrows indicate the direction of travel (no double counting).

Road Surveys

Road surveys on BPK were conducted on average 2 times/week along a standardized 31-km route from July 2003–May 2004 (Fig. 3.2). Start and finish points were the same for each survey which began 1.5 hours before sunset. Two observers in a vehicle traveled along the survey route (average travel speed 25–40 km/hr) and recorded the number of deer observed (marked/unmarked), location, sex, and age (fawn, yearling, adult) and distance. Seasons were defined as winter (January–March [pre-fawning season]), spring (April–June [fawning season]), summer (July–September [pre-breeding season]), and fall (October–December [breeding season], Lopez et al. 2004*a*). Perpendicular distance estimates were obtained using a laser rangefinder (Model CLR800, Bushnell ® Corporation, Overland Park, Kansas, USA) from the centerline of the survey route.

Data Analysis

I determined a weekly population estimate for each survey using a Lincoln-Petersen estimate (Seber's modification) (Lopez et al. 2004*a*). Use of this estimator was appropriate because (1) the population surveyed was "closed" due to the study area being an island and the short time interval between estimates, and (2) a portion of population was marked for individual identification during the study (Krebs 1999). Prior to generating a weekly estimate, the number of marked animals was adjusted from telemetry/mortality data and observations from survey data (Lopez et al. 2004*a*). For the strip-transect estimate, I estimated the average transect width from monthly maximum sighting distances (Burnham and Anderson 1984) every 0.16 km along the entire survey route with the aid of a laser rangefinder. Density was estimated as the number of deer observed within the sampling area, which was extrapolated to the entire island (Burnham and Anderson 1984). Finally, distance estimates for each survey were calculated using Program DISTANCE as described by Buckland et al. (1993) and Focardi et al. (2002*b*).

I compared weekly survey estimates by method using a 2 way, factorial, ANOVA with method (mark-resight, strip-transect, and distance) and season (pre-fawning, fawning, pre-breeding, and breeding) as factors. The study design was balanced in terms of method but unbalanced in terms of season. Survey data were transformed using Log 10(Y+1) and tested for normality using the Kolmogorov-Smirnov test and Lilliefors significance correction to meet the normality assumptions. Of the 12 method × season treatment categories, only mark-resight × fawning (P = 0.045) and mark-resight × pre-breeding (P = 0.026) were found to have significant deviations from normality. Because ANOVA is deemed robust to minor deviations from normality (Zar 1996), these treatment factors were included in the analysis. Levene's test (P = 0.052) indicated there were no significant differences in error variance among treatment categories. Testing of the transformed variables indicated the data met the assumptions of normality and homoscedasticity required by the ANOVA design.

RESULTS

Density Estimates

I conducted 100 road surveys where data for mark-resight population estimates, strip-transect densities, and distance sampling estimates were collected. I recorded 5,534 Key deer observations with a mean of 55 (range = 16–89) for each survey conducted (female mean = 44, range = 14–75; male mean = 11, range = 2–22). A mean of 7 collared deer (range = 1–15) were observed for each survey event. Throughout the study period, I maintained a marked subset of the population averaging 43 deer (range = 37–46).

I found mark-resight estimates were lower ($\bar{x}$ = 384, 95% CI = 346–421) than strip-transect estimates ($\bar{x}$ = 854, 95% CI = 806–902) and distance estimates ($\bar{x}$ = 523, 95% CI = 488–557, Fig. 3.4). In combining all 3 method estimates, overall population mean ($\bar{x}$ = 587, 95% CI = 555–619) was similar to the distance estimates. The ANOVA results for between-subject effects (i.e., method) revealed a significant difference between the 3 methods ($P < 0.001$), and significant method × season interactions ($P < 0.001$) (Fig. 3.3). Post-hoc tests indicated that all methods were significantly different, and that estimates from the spring (fawning) season were significantly different from the winter (pre-fawning season, Fig. 3.4). The best model (by AIC selection; AIC = 8,335) for estimating Key deer density with Program DISTANCE was the hazard model with no adjustment terms obtained as a global detection function using data from all strata (i.e., surveys, n = 100).

For my study, encounter rate, cluster size, and density were estimated by stratum, with a pooled estimate of density made from stratum estimates treated as replicates. This facilitated my intent to compare point estimates between methods while accounting for the behavioral changes that occur seasonally. Assessing the validity of the 3 underlying assumptions was not as difficult in my study: (1) transect was a well traveled road with good visibility on the adjacent right of way on either side, ensuring

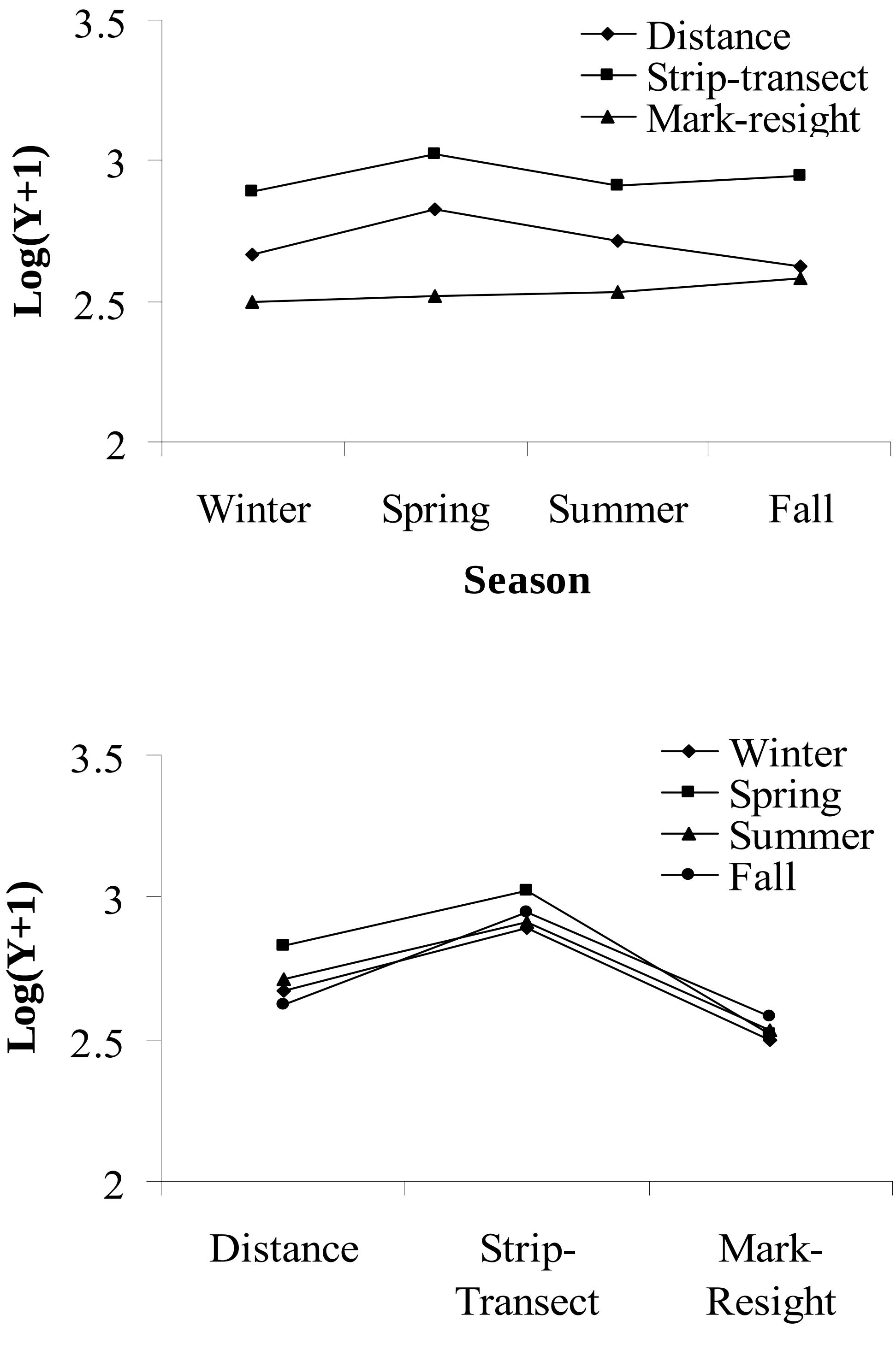

Figure 3.3. Estimated marginal means (Log[Y+1] transformed) by method and season for Florida Key deer, July 2003-May 2004.

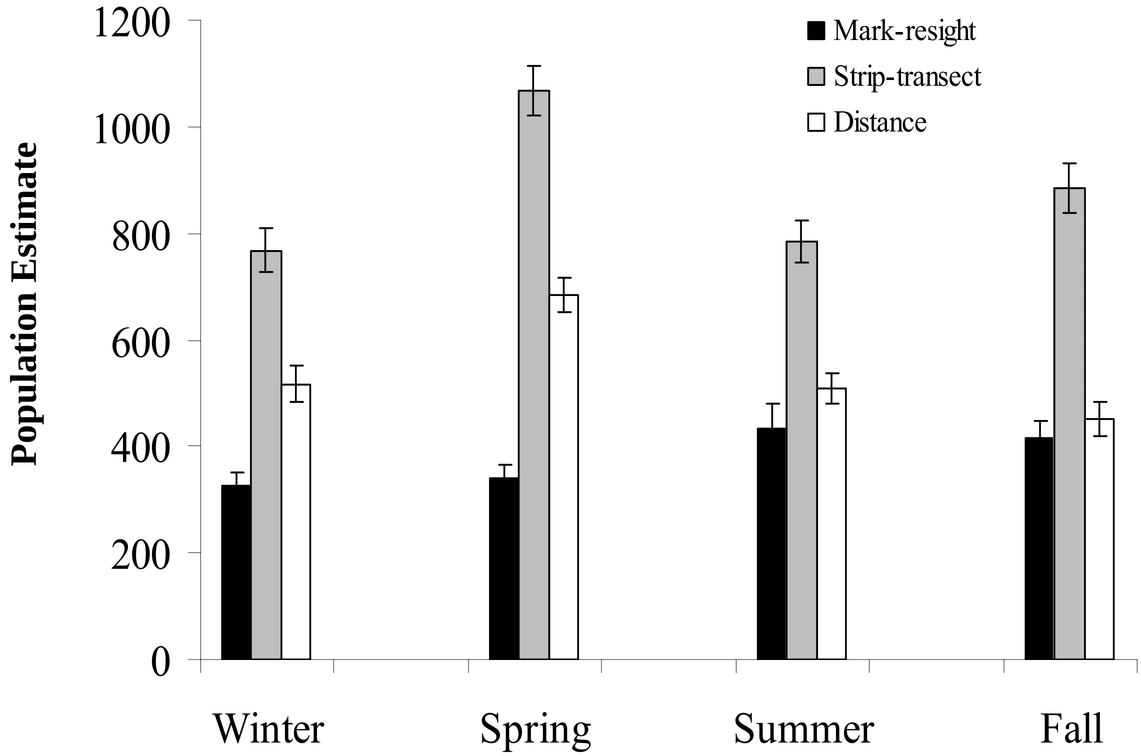

Figure 3.4. Florida Key deer density estimates ($\overline{x}$, 1 SE) by season and method (mark-resight, strip-transect, and distance) for Big Pine Key, Monroe County, Florida, July 2003

that all Key deer on or near the transect line were observed, (2) given the habituated nature of BPK Key deer to human activities (Lopez et al. 2003), I do not believe that animals were moving in response to my presence prior to detection; the detection function had the required "shoulder" at $f(0)$, suggesting that observer induced movement was not occurring (Buckland et al. 1993), and (3) because the transect line was predominately straight, perpendicular distances were measured exactly with a laser rangefinder.

DISCUSSION

I found that mean estimates from mark-resight, strip-transect, and distance sampling differed across all seasons. I attribute low mark-resight estimates to urban deer behavior resulting in a higher proportion of marked deer (bias down) along roadways. In the last 30 years, Key deer have become more habituated to the presence of humans with increasing urban development and increased human-deer interactions (Lopez et al. 2003, Lopez et al. 2004*b*). I suspect the use of drive nets and drop nets that typically were used in urban areas (Lopez et al. 1998) resulted in a greater proportion of marked deer in urban areas, and therefore, more marked deer being seen because of (1) increase visibility in urban areas (less vegetation, more open space), and (2) increased likelihood of seeing "urban deer" (less movement away from urban areas) that were previously marked. For these reasons, I propose mark-resight estimates may be conservative or biased low due to an increase of "trap-happy" deer observed along the survey route.

Key deer population estimates using strip-transects were higher compared to mark-resight and distance sampling. I also attribute high strip-transect estimates to urban deer behavior along roadways, and in addition, a reduced effective strip width (ESW) along the survey route. First, the strip-transect estimate may be biased high because surveys were conducted along roadways where Key deer are easily seen or tend to frequent (Lopez et al. 2003), resulting in a likely overestimation (Thompson et al. 1998, Pierce and Baccus 1999, Pierce 2000). A second factor may be the dense vegetation on BPK. The semi-deciduous vegetation in the Lower Florida Keys is primarily of West Indian origin with limited visibility (Folk 1991). I suspect the perceived ESW from monthly maximum sighting distances for the strip-transects ($\bar{x}$ = 27 m) was underestimated, whereas use of actual animal sighting distances from distance sampling (ESW $\bar{x}$ = 38 m) was larger resulting in a larger area sampled. For these reasons, I suspect use of strip-transects in my study inflated the overall Key deer population estimate. Burnham et al. (1985) found similar results in their study of efficiency and bias in transect sampling.

Assuming the combined sum of all 3 methods captures the true population mean ($\bar{x}$ = 587, 95% CI = 555–619), I propose that distance sampling may be a more accurate and reliable means of estimating Key deer density. In addition to my distance estimate being similar to the overall grand mean (523 versus 534), this estimate also is similar to the estimate reported by Lopez et al. (2004*a*, 523 versus 406). One advantage of distance sampling is the previously mentioned biases for the other methods (i.e., urban deer behavior of marked deer, vegetation density, etc.) may not have a strong influence in the distance estimate. For example, the spatial distribution of the target animals along the survey does not have to be uniform in order to obtain a reliable population estimate from distance methods (Buckland et al. 1993, Tomas et al. 2001, Forcardi et al. 2002*b*, Koenen et al. 2002), which is problematic with mark-resight and strip-transect estimates. Vegetation characteristics also influence the ESW in obtaining density estimates, particularly with strip-transect estimates (Burnham et al. 1985). As previously mentioned, these biases are likely reduced in distance sampling.

MANAGEMENT IMPLICATIONS

I recommend the use of distance sampling for future monitoring of the Key deer population on BPK. Since 1968, USFWS biologists have collected population trend data for Key deer (Lopez et al. 2004*a*); I proposed modifications to data collected along this route could yield population density estimates that would be beneficial in the monitoring of this endangered population. Study results suggest that density estimates were accurate, precise, easily obtained by field personnel, and therefore, more cost-effective. Similar modifications to survey methods commonly used by white-tailed deer managers could afford better estimates that are accurate and precise at a low cost.

CHAPTER IV

SUMMARY AND SURVEY RECOMMENDATIONS FOR ESTIMATING KEY DEER DENSITY

The purpose of this chapter is to summarize methods used to estimate Florida Key deer densities within the National Key Deer Refuge. This chapter also will provide official recommendations and guidelines to U. S. Fish and Wildlife Service (USFWS) biologists in future efforts to monitor population numbers for the endangered Key deer. The chapter is divided into 2 parts: (1) a review of past efforts to estimate Key deer density or monitor population trends, and (2) recommendations and guidelines for future monitoring of the Key deer population. These recommendations will be based on findings in previous chapters (Chapters II-III).

HISTORICAL SURVEYS

Reliable population estimates are paramount in the field of wildlife ecology (Jenkins and Marchinton 1969) because assessment of "the stock on hand" is a prerequisite for many wildlife management endeavors (Leopold 1933). In the case of the Key deer, population density/trend estimates are important for developing proper conservation policy and management protocols (Gelatt and Siniff 1999, Koenen et al. 2002, Swann et al. 2002), and is mandated in the current Key Deer Recovery Plan (U. S. Fish and Wildlife Service [USFWS] 1999). As a point of departure, I will define 2 terms that often are used interchangeably in wildlife population estimation but that differ in meaning. *Population density* refers to the number of animals per unit area, and answers the question "how many?" (Krebs 1999). Conversely, *population trends* or *trend* *estimates* refers to a *relative index* to population density (Krebs 1999). Trend data simply shows variation in the population between sampling periods (e.g., year-to-year spotlight counts). For example, the average number of deer seen on a spotlight count is not an estimate of deer density because it is unlikely that all deer were counted. The usefulness of trend estimates is tracking changes in population density, assuming methods used between sampling periods are identical (Krebs 1999). For management purposes, trend estimates are often useful indices in comparison to population density estimates due to their ease in implementation.

In reviewing population counts for Key deer, both population density and trend estimates have been collected since 1968 (Lopez et al. 2004*a*). Population density estimates have been conducted on Big Pine (BPK) and No Name (NNK) keys using mark-resight procedures (Silvy 1975, Lopez 2001) and distance sampling techniques (Chapter III). The first density estimate was obtained in 1971-1972 for BPK (167 deer) and NNK (34 deer, Silvy 1975). A more recent density estimate (BPK=406, NNK=76) was obtained in 1998-2001 (Lopez 2001) using methods identical to Silvy (1975). Silvy (1975) and Lopez (2001) used the same survey route on BPK (hereafter known as the BPK 44-mile, BPK 10-mile, Fig. 4.1) in obtaining their estimates (Table 4). Survey estimates were conducted at sunrise and 1.5 hours before sunset (Lopez 2001).

Since 1975, USFWS biologists have collected population trend data for the Key deer population via night spotlight counts on a modified version of the original BPK 44-mile route (Silvy 1975, Lopez 2001). The USFWS route (also known as the FWS Fall route) is approximately 22 miles or ½ the length of the original BPK 44-mile route (Fig. 4.2). Monthly trend data (USFWS route) and more intense weekly data (FWS Fall route,

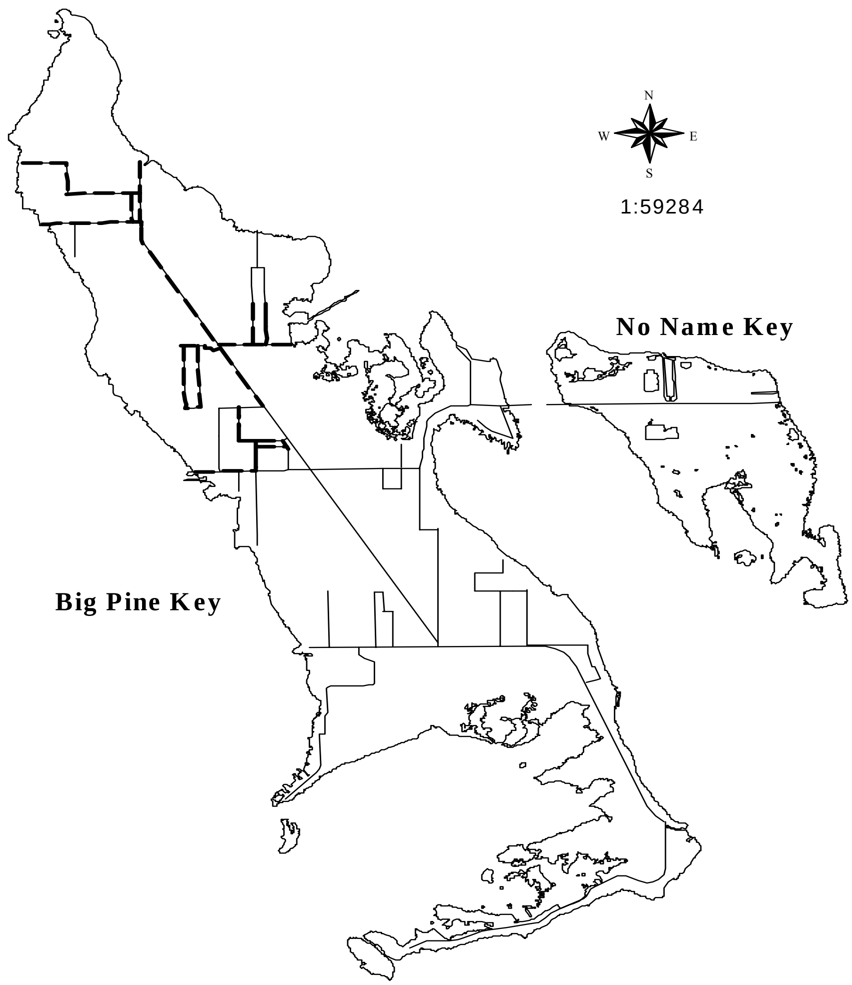

Figure 4.1. Original survey routes (BPK 44-mile, solid and dotted lines; BPK 10-mile, dotted line only; NNK [1998-2001]) used in estimating Key deer density on Big Pine (BPK) and No Name (NNK) keys, 1968-1972 (Silvy 1975), 1998-2001 (Lopez 2001).

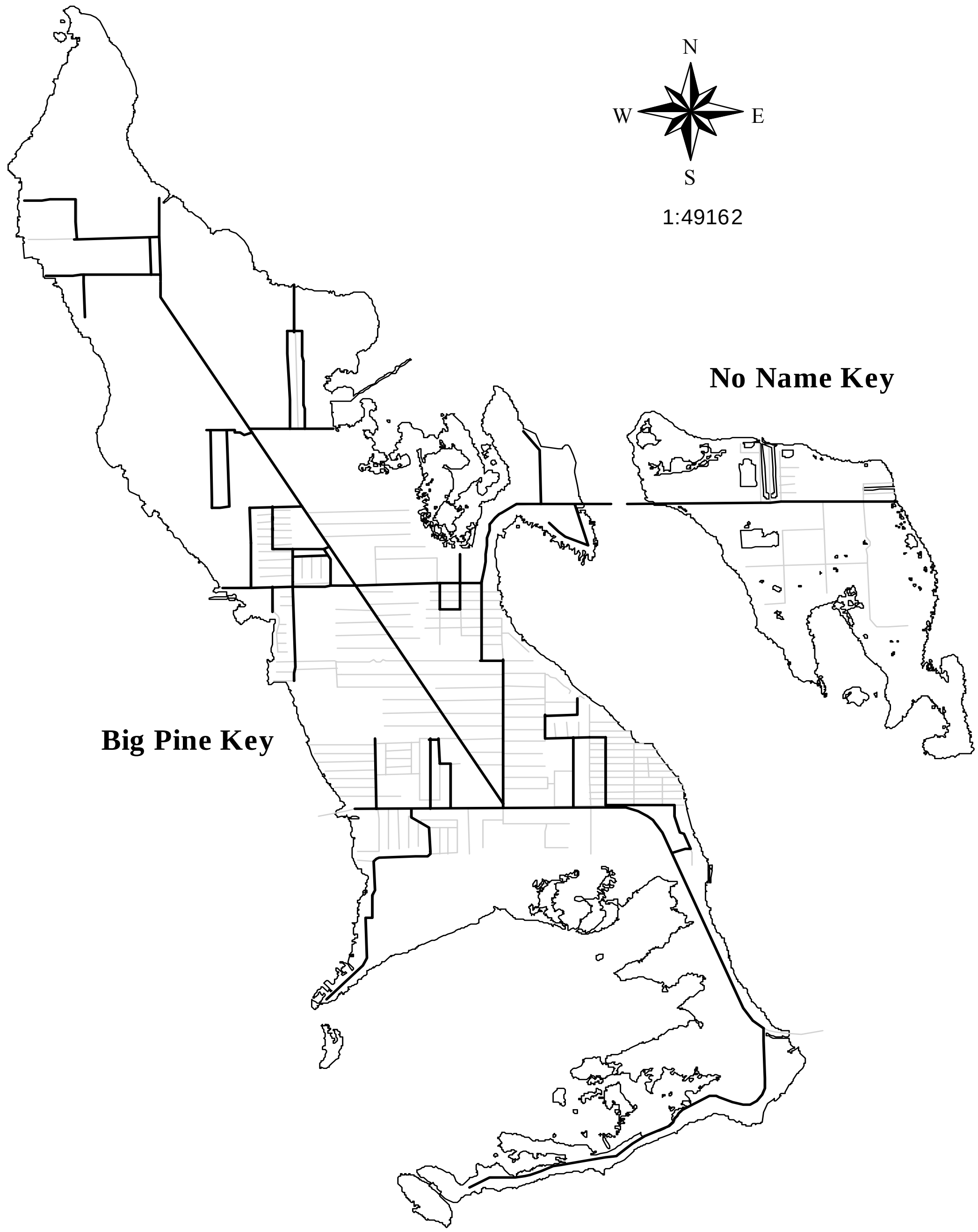

Figure 4.2. Official U. S. Fish and Wildlife Service (USFWS) survey route used in monitoring Key deer population trends on Big Pine (BPK) and No Name (NNK) keys, 1975-present.

5-7 times/week, first week of October) have been collected by USFWS biologists between 1975-present during evening hours (Fig. 4.2, Table 4.1, Lopez 2001). The FWS Fall surveys were initiated in 1988 to collect reproductive data (e.g., fawns/doe). In 2002, the USFWS route was slightly modified to include roads from both survey routes where frequent deer observations were recorded (hereafter TAMU/FWS route, Fig. 4.3). Mark-resight and distance sampling procedures were used in estimating Key deer densities using this modified route (Chapter III). Using this modified route, 508 deer were estimated on BPK using distance methods (Chapter III).

Previous efforts to estimate deer densities on outer islands (defined here as islands in Key deer range excluding BPK and NNK) have been restricted due to accessibility issues and/or low deer densities. In most cases, traditional road survey techniques cannot be implemented for the majority of the islands due to the absence of roads (only 40% [9/20] of islands occupied by Key deer have roads). Future research evaluating reliable methods to estimate Key deer densities on outer keys is needed. In comparing the application of infrared-triggered camera (ITC) estimates to road counts, similar results suggest ITC estimates can be useful in this effort (Chapter II).

SURVEY RECOMMENDATIONS

Based on my review of previous methods to survey Key deer density/trends, I would recommend (1) continued monitoring of Key deer population trends via monthly spotlight surveys, (2) estimating population density for BPK and NNK using a distance sampling twice a year (October and April, 5-7 surveys 1st week of month), and (3)

Table 4.1. Average Key deer observed by survey route and year, Big Pine and No Name keys, 1969-2001.

Year	Route*	*N*	Deer Observed (mean)	SD
1969	BPK 10m	52	12	5
1970	BPK 10m	54	15	6
1971	BPK 10m	50	24	10
1972	BPK 10m	22	16	7
1998	BPK 10m	70	41	19
1999	BPK 10m	96	32	19
2000	BPK 10m	63	41	20
2001	BPK 10m	14	42	24
1971	BPK 44m	53	24	12
1972	BPK 44m	1	8	--
1998	BPK 44m	72	78	25
1999	BPK 44m	96	79	31
2000	BPK 44m	65	94	26
2001	BPK 44m	14	106	62
1988	FWS Fall	12	54	12
1990	FWS Fall	7	55	10

Table 4.1. Continued.

Year	Route*	*N*	Deer Observed (mean)	SD
1991	FWS Fall	7	80	24
1992	FWS Fall	6	113	41
1993	FWS Fall	7	101	10
1994	FWS Fall	7	83	8
1995	FWS Fall	7	72	14
1996	FWS Fall	7	132	13
1997	FWS Fall	7	133	49
1998	FWS Fall	7	138	11
1998	NNK	72	26	14
1999	NNK	139	22	16
2000	NNK	94	23	13
2001	NNK	17	18	8
1975	USFWS	3	24	8
1976	USFWS	11	57	22
1977	USFWS	10	78	15
1978	USFWS	12	66	25
1979	USFWS	12	87	18

Table 4.1. Continued.

Year	Route*	*N*	Deer Observed (mean)	SD
1980	USFWS	8	43	10
1981	USFWS	11	26	12
1982	USFWS	11	33	17
1983	USFWS	11	20	11
1984	USFWS	13	34	12
1985	USFWS	12	33	11
1986	USFWS	10	33	12
1987	USFWS	12	44	14
1988	USFWS	11	48	16
1989	USFWS	12	55	14
1990	USFWS	12	58	18
1991	USFWS	12	57	22
1992	USFWS	13	77	24
1993	USFWS	11	74	19
1994	USFWS	12	92	20
1995	USFWS	13	83	15
1996	USFWS	8	85	21
1997	USFWS	6	110	24
1998	USFWS	9	93	31

Table 4.1. Continued.

Year	Route*	*N*	Deer Observed (mean)	SD
1999	USFWS	11	81	31
2003	TAMU/FWS	57	52	15
2004	TAMU/FWS	43	60	16

*BPK 10m = Big Pine Key 10 mile route, BPK 44m = Big Pine Key 44 mile route, FWS Fall = Fish and Wildlife Service Fall route, NNK = No Name Key route, USFWS = United States Fish and Wildlife Service Route, TAMU/FWS = Texas A&M University/ Fish and Wildlife Service route.

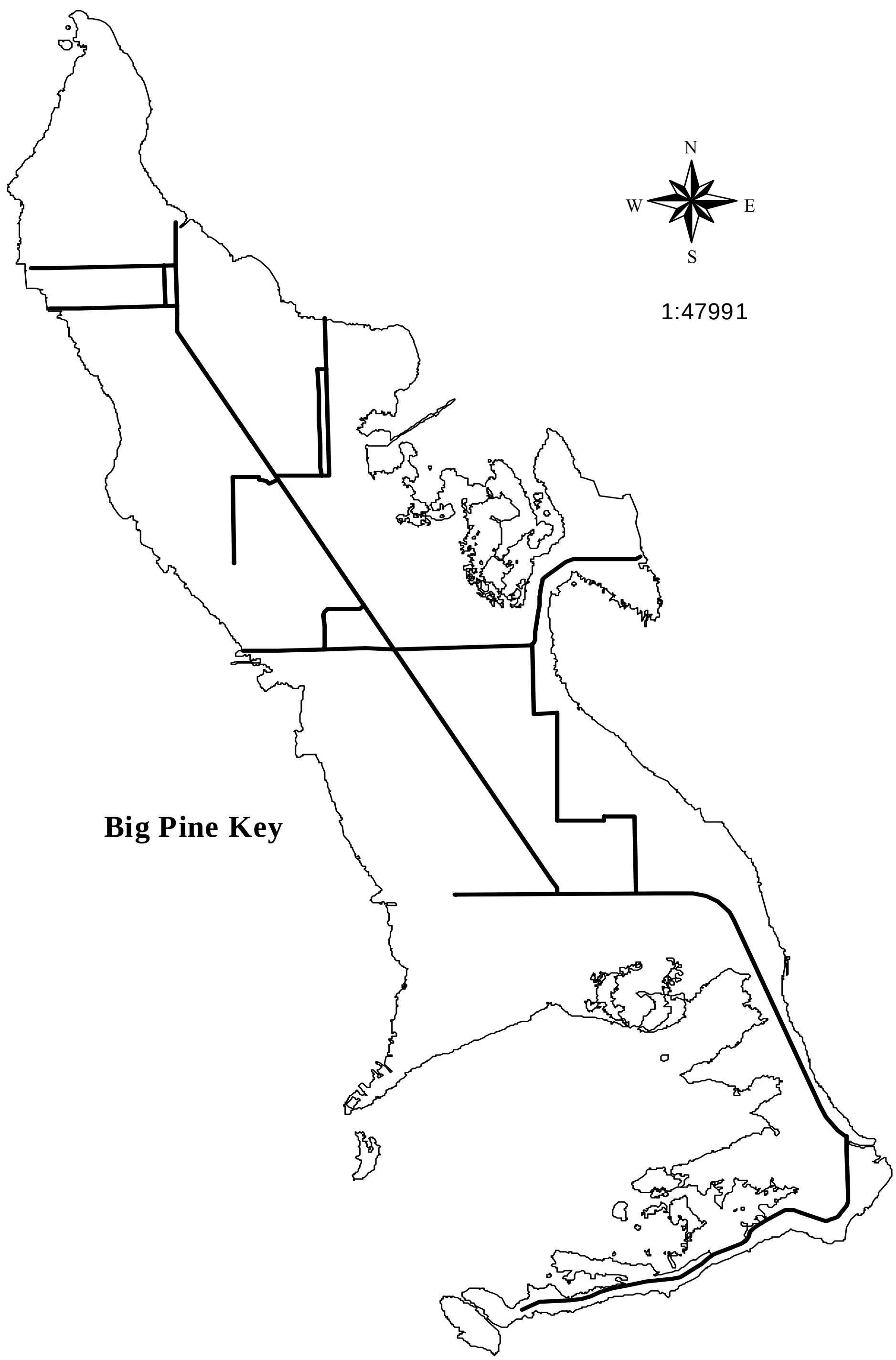

Figure 4.3. The TAMU/FWS 19-mile route used in estimating Key deer density on Big Pine (BPK), 2003-2004.

outlining a future protocol in estimating Key deer densities on outer islands using ITC technology. I would recommend using the modified USFWS route (Fig. 4.4). Prior to the discussion of each of these recommendations, a brief review on the proper sexing and aging procedures will be provided.

Sexing and Aging

Sexing and aging of Key deer "on the hoof" can be difficult to the untrained eye. Here I provided some simple guidelines that can be used classify Key deer observed during surveys. In collecting age data for Key deer, 4 categories are used: fawn, yearling, adult, and unknown. In collecting sex data, 3 categories are used: male, female, and unknown. When marking and recording deer observations (Appendix A), age classification should be followed by sex classification. For example, an adult male would be recorded on the survey form as "1 AM" (Appendix A). Below is a sample of the proper acronyms that should be used on the survey form:

1. AM = Adult male
2. AF = Adult female
3. AU = Adult unknown
4. YM = Yearling male
5. YF = Yearling female
6. YU = Yearling unknown
7. FM = Fawn male
8. FF = Fawn female
9. FU = Fawn unknown

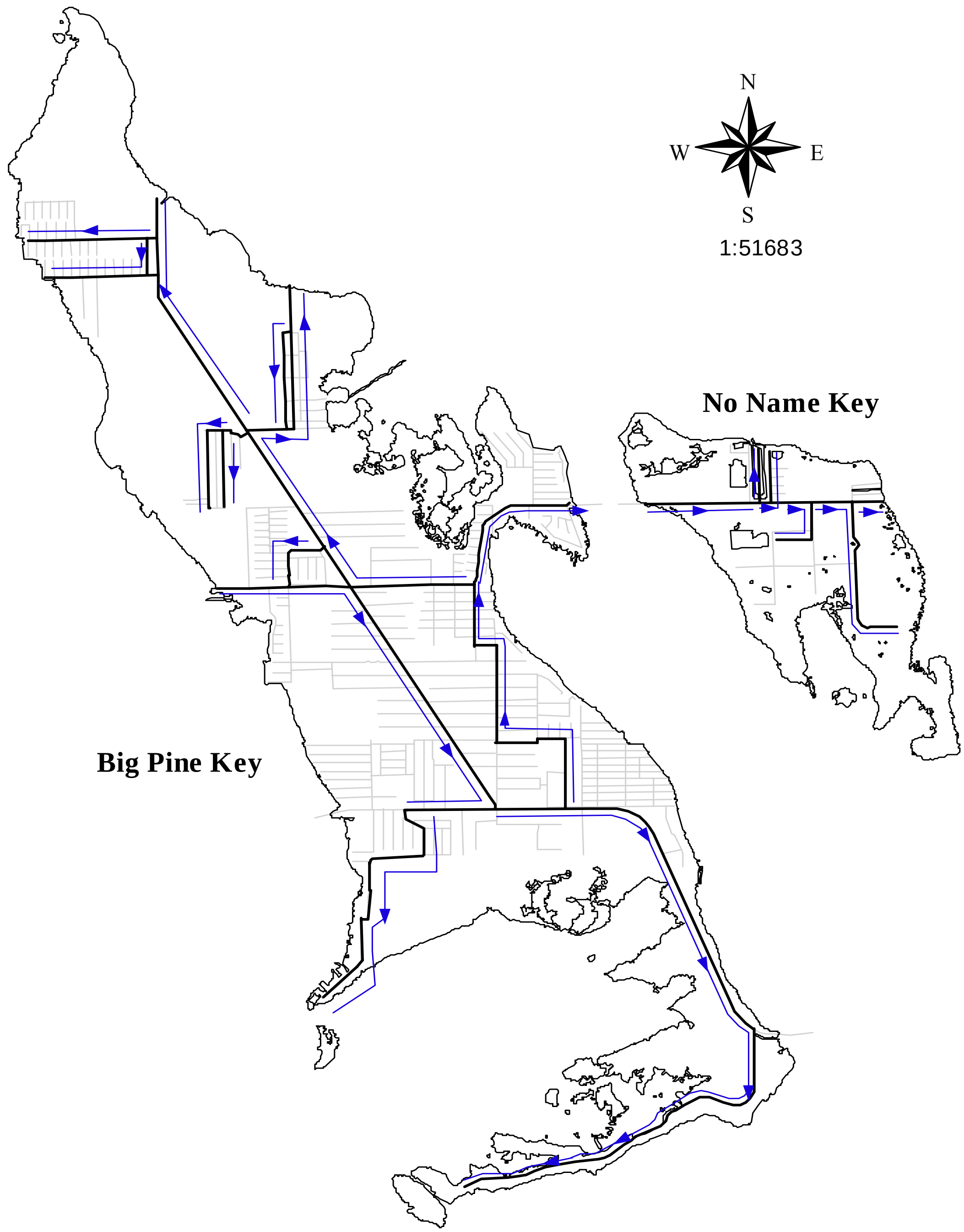

Figure 4.4. Proposed survey route for future Key deer monitoring by the U. S. Fish and Wildlife Service (USFWS). Survey route is slightly modified from the official USFWS route (Figure 4.2), accounting for recent road closures and high density developments. Arrows indicate the direction of travel (no double counting).

10. UM = Unknown male

11. UF = Unknown female

12. UU = Unknown Unknown

It is important to record age followed by sex, otherwise misclassifications can occur. For example, a "FU" could be "female unknown" if sex and age are reversed (a simple mnemonic is "*Remember your ASS*" – **A**ge, **S**ex, **S**tupid).

Sexing.—Sexing Key deer becomes easier with increasing age. For the majority of the year, males have antlers which quickly serve to separate them from females (Figs. 4.5-4.7). When male Key deer have dropped their antlers, their heads tend to be flat or blocking as compared to the rounded head of females (Fig. 4.7). Male heads can be considered to be like Frankenstein versus females which resemble the Pope's round skullcap (i.e., zucchetto) (Fig. 4.7). Correctly classifying the sex of observed Key deer becomes more difficult in younger age classes. For spotted fawns (< 6 months of age), sex determination is difficult in the field and should be avoid. Instead, spotted fawns should be classified as "fawn unknown".

Aging.—Body size and head shape are 2 common traits that can be used in determining the age class of Key deer. Fawns and yearlings tend to have "square" or "blocked" body sizes whereas adults tend to be more rectangular and elongated (Fig. 4.5). For males, "buttons" or "spikes" are typically younger age-classes (Fig. 4.5). Head shape between adults, yearlings, and fawns can be compared to the relative size of egg plants, papayas, and mangos, respectively (Fig. 4.8).

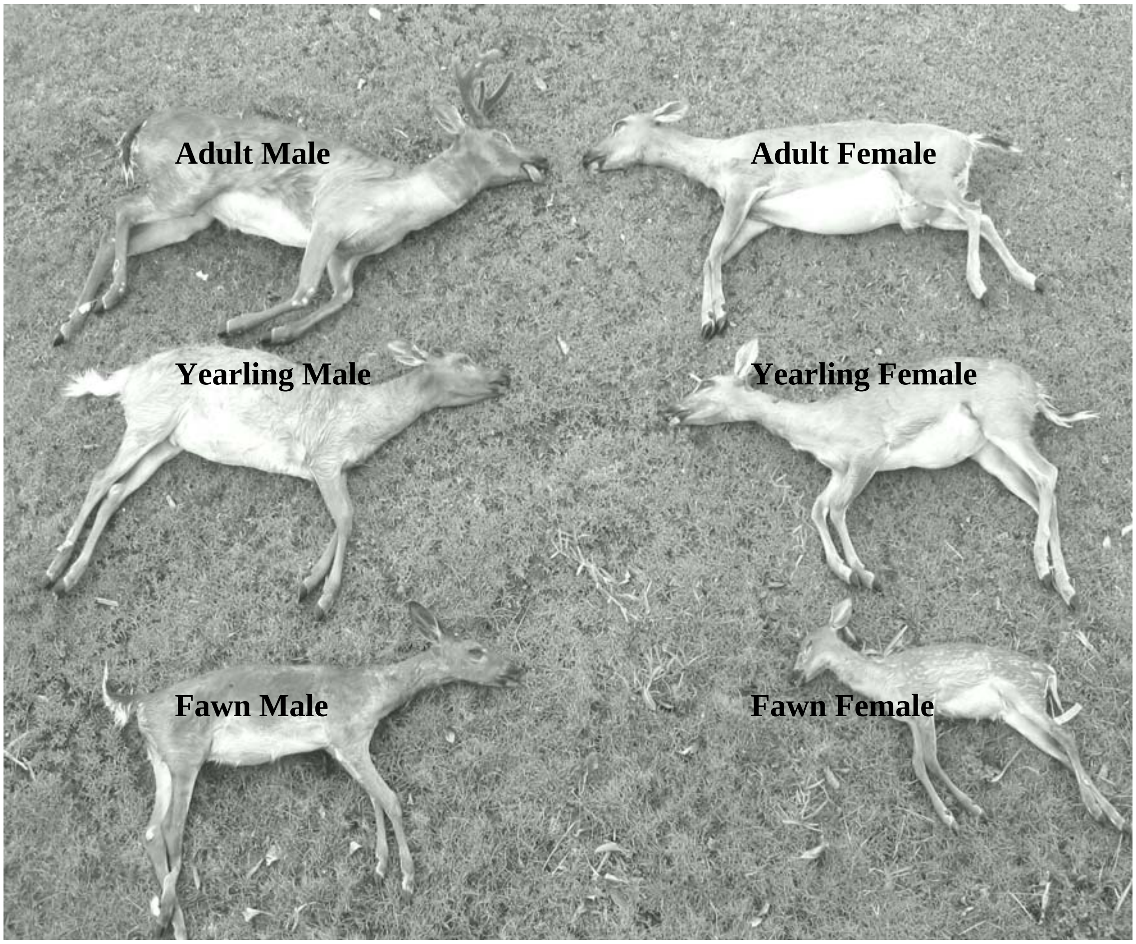

Figure 4.5. Relative size comparison of Florida Key deer by sex and age. Head shapes vary between adults (size of egg plant), yearlings (size of papaya), and fawns (size of mango).

Figure 4.6. Body comparison of adult female (top) and male (bottom) Florida Key deer. Note elongated head, rectangular bodies, and, in the case of the males, hardened antlers and swollen neck.

Figure 4.7. Head comparison of adult female (left) and male (right) Florida Key deer. Note male head shape after dropping antlers.

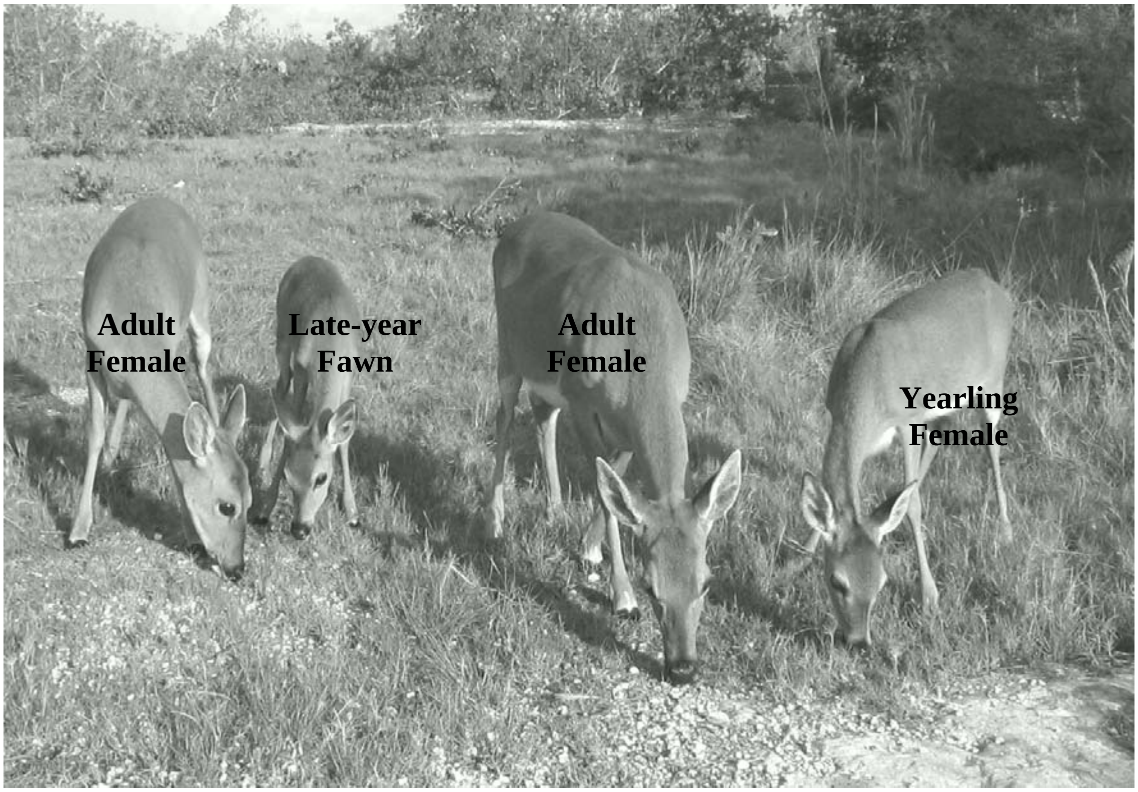

Figure 4.8. Comparison of body size and head shape for 3 age-classes of female Key deer.

Population Trends (Monthly Surveys)

Key deer population trend data have been collected by USFWS personnel since 1975. The continuation of monthly Key deer spotlight counts is recommended in maintaining this long-term data set. At the beginning of each month, the new proposed USFWS route (Fig. 4.4) should be driven with 2 observers recording the sex, age, location, and marker number (if animal is marked with collar). The survey route should be conducted 1 hour after official sunset in a vehicle traveling 10–15 mph (16–24 km/h). Two hand-held spotlights (approximately 100,000 candlepower) and the appropriate forms (Appendix A) should be used in recording Key deer observations. Key deer should not be counted on portions of the survey route that have been previously driven (no double counting). The expected drive time for the survey route is approximately 2.5–3 hours. All data should be summarized and entered into the Access database.

Population Density (Biannual Surveys)

Key deer population density estimates were conducted in 1968-1972 (Silvy 1975), 1998-2001 (Lopez 2001), and 2003-2004 (Chapter III). Distance sampling surveys should be conducted 2 times annually the first week of April (spring survey during fawning season) and October (fall survey during breeding season) using the new proposed USFWS route (Fig. 4.4). Similar to the trend surveys, the route should be driven with 2 observers recording the sex, age, location, marker number (if animal is marked with collar), and deer distance from vehicle (Appendix A). Distance should be obtained using laser range finders (Chapter III). The survey route should be conducted 1.5 hours prior to official sunset in a vehicle traveling 16–37 mph (25–60 km/h).

Observed Key deer should not be double counted on portions of the survey route that have been previously driven. The expected drive time for the survey route is approximately 2–2.5 hours. All data should be summarized and entered in Access database and Arcview GIS for further analysis (Lopez 2001). Distance data can be analyzed using Program DISTANCE (Buckland et al. 1993, Focardi et al. 2002*a*).

Outer Key Estimates

Use of ITC in estimating Key deer density is promising for outer island estimates (Chapter II). Infrared-triggered cameras can provide wildlife managers with density estimates and information on herd composition (Mace et al. 1994, Jacobson et al. 1997). The use of ITC may not be practical for large areas; however, their use may be cost-effective, particularly in areas where habitat and/or lack of infrastructure (i.e., roads) preclude the use of other methods. Continued research with ITC use is needed.

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APPENDIX A

USFWS Key Deer Survey Form BPK North

Observers: C. ROBERTS, A. BRADEN Date: 15 MARCH 2004

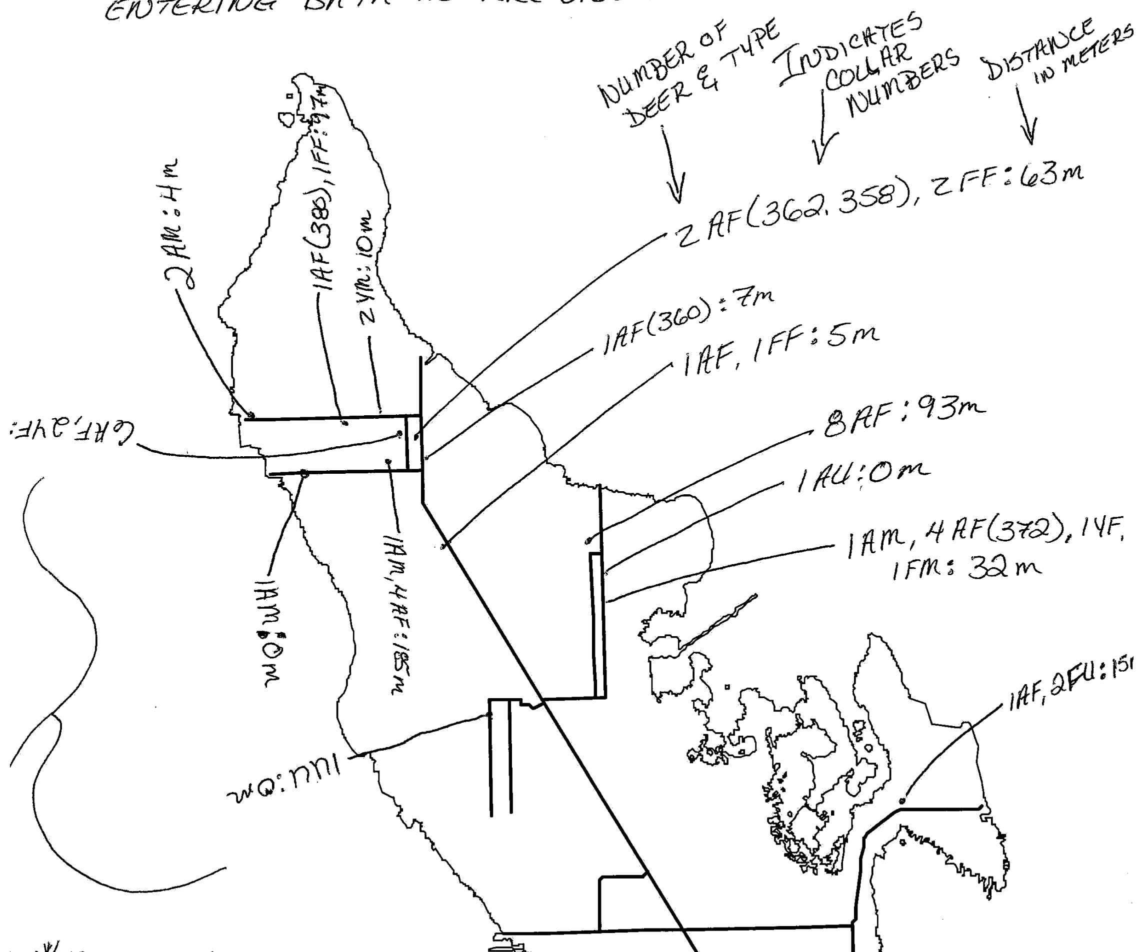
Time(Start): 1736 Time (End): 1919

Sunset: 1906 Number Marked Deer Available: 44

Weather(Circle One):
Sunny
Rainy
Variable (Comments): PARTLY CLOUDY & BREEZY

Example of correct form completion

* AS A RULE OF THUMB WRITE OFF TO THE RIGHT OF DIRECTION OF TRAVEL (MAY HAVE TO TURN MAP TO FACILITATE THIS). CUTS DOWN ON CONFUSION WHEN ENTERING DATA IN ARC VIEW.



*NOTE: MAP TURNED TO FOLLOW DIRECTION OF TRAVEL; OBSERVATIONS ON RIGHT SIDE OF MAP.

Example of survey form completed after survey, includes number of animals seen, type of animals seen, collar numbers of animals, and distance to animals.

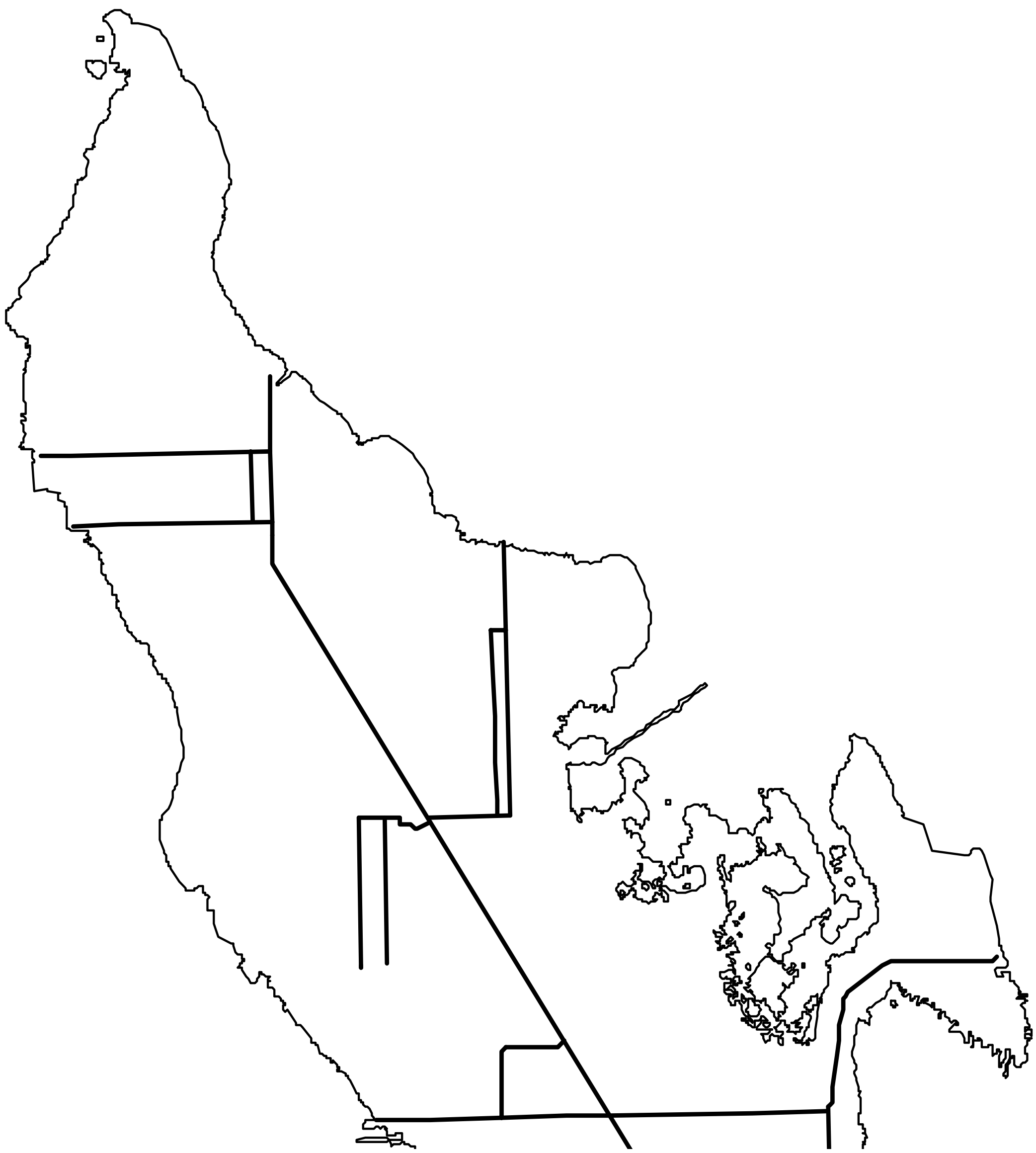
USFWS Key Deer Survey Form BPK North

Observers:_________________________________ Date:______________

Time(Start):________________ Time (End):______________________ Weather(Circle One):

Sunset:___________________ Number Marked Deer Available:_____

Sunny
Rainy
Variable (Comments):_______
____
____



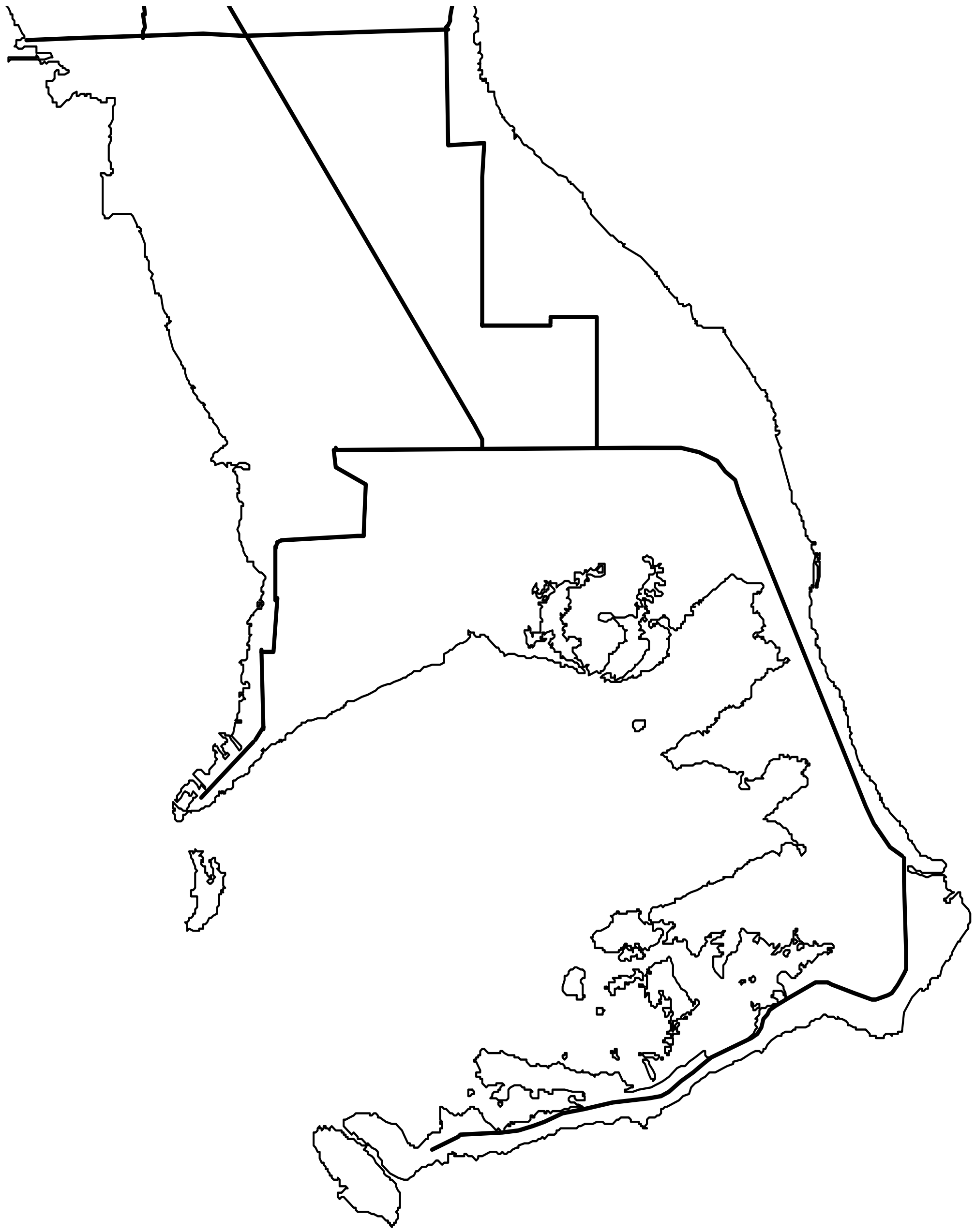
USFWS Key Deer Survey Form BPK South

Observers:_________________________________ Date:______________

Time(Start):_______________ Time (End):______________________ Weather(Circle One):

Sunset:___________________ Number Marked Deer Available:_____

Sunny
Rainy
Variable (Comments):_______
____
____



USFWS Key Deer Survey Form NNK

Observers:_________________________________ Date:______________

Time(Start):_______________ Time (End):______________________ Weather(Circle One):

Sunny

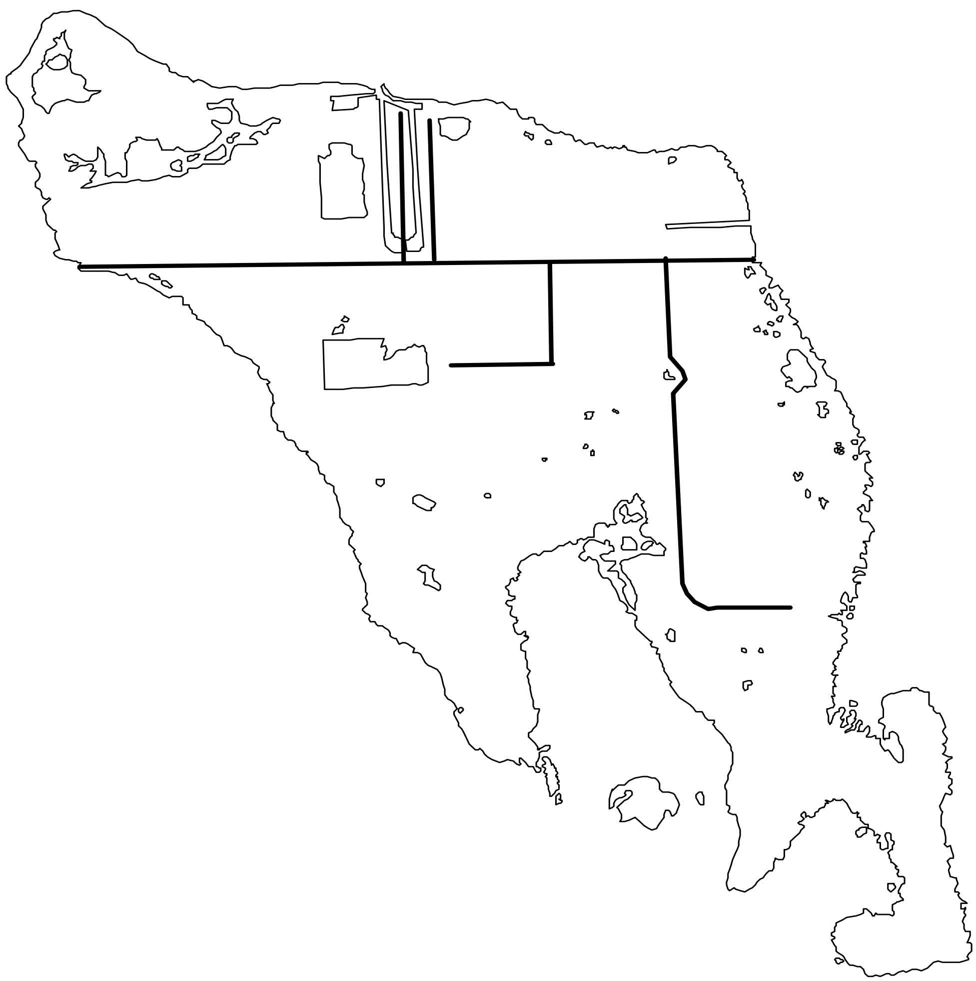
Sunset:___________________ Number Marked Deer Available:_____

Rainy

Variable (Comments):_______

____

____



USFWS Key Deer Summary Tabulation Form

Observers:_________________________________ Date:______________

Time(Start):_______________ Time (End):______________________ Weather(Circle One):

Sunset:___________________ Number Marked Deer Available:_____

Sunny
Rainy
Variable (Comments):_______
____
____

Location	AM	AF	AU	YM	YF	YU	FM	FF	FU	UM	UF	UU
HQ/ Eden Pines												
Key Deer Blvd. South												
US 1 Business												
Palm Villa /Newfound Harbor												
US 1 Undeveloped												
Long Beach Rd.												
County Rd/Avenue B												
Tropical Bay												
No Name Key												
Key Deer Blvd. North												
Koehn’s												
Port Pine Heights												
Blue Hole/ Pine Heights												

VITA

Clay Walton Roberts

BACKGROUND

Parents: Nicky and Bill Roberts

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Born: 11 August 1973, Austin, Texas

EDUCATION

Master of Science, Wildlife and Fisheries Sciences, Texas A&M University, 2005.

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Teaching Assistant, Department of Wildlife and Fisheries Sciences, Texas A&M University, 2002 and 2004.

Engineering Technician, Ducks Unlimited, Inc.**,** Texas Field Office, Richmond, Texas 2002.

Airborne Infantryman, United States Army, Fort Bragg, North Carolina 1999 – 2002.

Biological Technician, Texas Prairie Wetlands Project, Ducks Unlimited, Inc., Rosenberg, Texas 1997- 1999.