ASSESSMENT OF INFRARED-TRIGGERED CAMERA SURVEYS FOR ESTIMATING WHITE-TAILED DEER POPULATIONS IN CENTRAL TEXAS

THESIS

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Matthew L. Cooksey, B.S.

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ABSTRACT

ASSESSMENT OF INFRARED-TRIGGERED CAMERA SURVEYS FOR ESTIMATING WHITE-TAILED DEER POPULATIONS IN CENTRAL TEXAS

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SUPERVISING PROFESSOR: JOHN T. BACCUS

Remote sensing of animal populations using infrared-triggered cameras is a new and innovative technology in monitoring wildlife populations. I compared estimates of white-tailed deer (*Odocoileus virginianus*) density using infrared-triggered cameras with results from mobile line and spotlight surveys in the same areas. Study areas consisted of one wildlife area and two park areas approximately 65 ha each in size at the U.S. Army Corps of Engineers-Lake Georgetown Project, Texas. An infrared-triggered camera was placed in the center of each study area and monitored for 14 days. One week after removal of cameras, four replicates of mobile line and spotlight line counts were completed to provide a basis for comparison. The fawn population was underestimated

by the camera survey technique. The camera survey produced buck:doe ratios and buck population estimates consistent with mobile line and spotlight line counts and minimum number of known fork-antlered bucks in each area. Mobile line and spotlight line surveys underestimated the number of bucks compared to the known number of individually identified bucks with cameras. A new formula I derived for estimating the population only worked when there were no fork-antlered bucks in photographs. Mark-recapture methods produced unreliable results for the camera survey method. Finally, population estimates stabilized after 11 days of camera surveys, which is three fewer days than recommended. Even though statistical test for accuracy could not be conducted on the data, this new technology seems to be a promising method for landowners with small properties and limited survey visibilities for monitoring their deer herd, with the added benefit of a picture of each buck using an area.

I. INTRODUCTION

Wildlife biologists must understand certain aspects of a population or community before implementing a management strategy. Wildlife biologists are often responsible for conserving a particular resource and the ecological information and assessment methodologies needed to accomplish this task depend on the organism (Scalet et al. 1996). In the past, several different methods have been used for monitoring white-tailed deer (*Odocoileus virginianus*) populations. Management of white-tailed deer and other large ungulates is often hindered by a lack of reliable, cost effective, and accurate population census techniques (Jenkins and Marchinton 1969). Infrared triggered cameras and monitors are the latest technology used in studying animal behavior and censusing populations (Mace et al. 1994, Kucera 1995). Infrared triggered video cameras have also been used to study the utilization of areas, movements, and activities of white-tailed deer (Alexy et al. 2001, Main and Richardson 2002). Infrared cameras are valuable because the technology uses temperature differences between an animal, ambient air temperature, and the environment, therefore, increasing the detectability of white-tailed deer (Kreilich and Wiggers 1995). Additionally, the capability for 24-hour, unmanned observations of an animal population greatly increases our ability to evaluate their actions. Although a clear and consistent pattern of avoiding human recreation by deer, the use of infrared cameras showed the probability of detecting deer during the day was lower with increasing levels of human recreation (George and Crooks 2006).

The use of infrared monitors in assessing white-tailed deer populations has not been widely studied. Infrared cameras were used to photograph Radio-collared deer in Mississippi to evaluate deer response to baiting within their home range (Darrow 1993). This technique was also used at the Milan Army Ammunition Plant in Tennessee in 2002 and 2003 (Johnson et al. 2004). Jacobson et al. (1997) derived formulas for calculating demographic statistics using camera census techniques in a free ranging herd with a known number of marked deer. Population estimates derived by cameras provide easy and accurate estimates of buck populations and possibly the entire white-tailed deer population (Walock et al. 1997). Camera surveys produce similar population estimates as traditional survey methods such as helicopter surveys (Koerth et al. 1997). Supplemental feeding of white-tailed deer has been an increasingly popular management activity for landowners (Cooper and Ginnett 2000). Supplemental feeding areas serve as a camera site for population surveying. Corn is the best attractant of baits to use for infrared camera monitoring sites to survey deer populations (Koerth and Kroll 2000). Infrared cameras have also been used in conjunction with other attractants like soybeans to determine consumption and usage by white-tailed deer (Kearley and Causey 2001). Camera surveys were shown to be a safer and less disturbing methodology for monitoring white-tailed deer than mark-recapture methods and provided a greater ability to observe deer without having to physically handle them (Langdon 2001). This would give a truer depiction of white-tailed deer numbers without introducing capture bias. Mark-recapture and pre-season and post-season estimates of white-tailed deer have also been evaluated (Moore 1995). Pre-season and post-season assessments of the camera survey method for white-tailed deer have been conducted with varying and negative results (McDonald

2004). Infrared triggered camera surveys can accurately depict population estimates in white-tailed deer herds (Demaris et al. 2000). It is also suggested that infrared triggered camera estimates may provide an 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 (Roberts et al. 2006).

The objectives of my study were to compare (1) conventional methods of assessing white-tailed deer populations (mobile and spotlight lines) with an infrared-triggered camera system in monitoring a free ranging white-tailed deer population in central Texas, (2) a new formula I derived for estimating population size from photos with a formula derived by Jacobson et al. (1997), and (3) compare population estimates by three mark-recapture methods, Schnabel (Krebs 1999), Joly-Seber (Seber 1982), and Noremark (White 1996), with the camera method. In addition to this, the minimum number of days needed to conduct a camera survey to obtain similar population estimates as the mobile and spotlight methods for the same study areas was determined.

II. METHODS

My study was conducted on the U.S. Army Corps of Engineers property associated with Lake Georgetown. Built and managed by the U.S. Army Corps of Engineers in 1978, Lake Georgetown is a 530-ha reservoir surrounded by 1628 ha of U.S. Army Corps of Engineers Property in the Texas Hill Country. The area is located about 2 km west of U.S. Interstate 35 in Williamson County, Texas at the northern most edge of the Texas Hill Country, coordinates are E621642 x N3394070 (UTM Nad 27, Zone 14N). The area has been continuously managed for a diverse plant and animal community and multiple uses by the general public. A complete ban on public feeding of wildlife to prevent habituation of "park deer" along with controlled harvest are tools used in the reduction and control of an abnormally high white-tailed deer population.

Three 65-ha sites were selected for their size and slight geographic isolation to assess deer survey techniques (Fig. 1). They were Jim Hogg Park and Cedar Breaks Park, two park areas with high human traffic and development, and the Dam Wildlife Area, an area with little or no human traffic and no development the first year. One trial consisting of camera, mobile, and spotlight surveys was completed prior to the annual deer harvest in each area for three years. One post-season set of data collection in 2000 was conducted in Jim Hogg Park and the Dam Wildlife Area for post-harvest comparisons. Post-season surveys were not continued in the subsequent years due to funding and manpower availability. An additional survey area (Cedar Breaks Park) was added the second and third years for additional data.

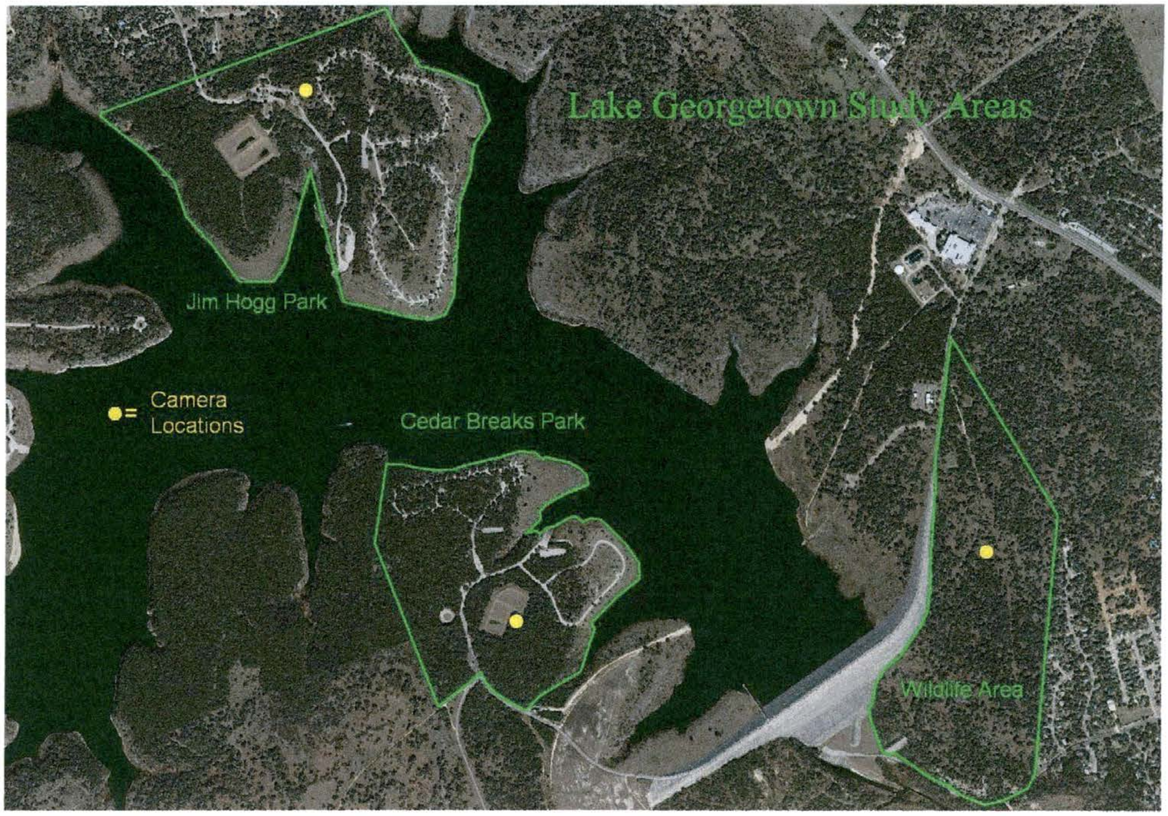

Figure 1. Study areas and camera placement locations at U.S. Army Corp of Engineers Lake Georgetown, Texas from 2000-2002.

I baited camera sites in each study area daily with 10-15 kg of corn for five days before the start of each camera survey. I dispensed corn directly onto the ground between the infrared sensors of cameras to habituate deer to an area prior to camera activation and to attract as many deer as possible to the camera site. I replenished bait daily.

I placed one camera in the center of each 65-ha study site (Jacobson et al. 1997). I used one Trail Master (Model TM1500, Goodson and Associates Inc, Lenexa, KS) active infrared transmitter combined with one Olympus 35 mm camera. I placed sensors and cameras on trunks of straight trees 60-70 cm above the ground and monitored them daily to change film. The cameras were operative continuously for 14 days, 45 days before the start of deer harvest. Photos were developed daily at a local one hour photo shop to ensure that cameras were fully operational each day. I analyzed photographs according Jacobson et al. (1997). I also used a variation of Jacobson's formula and three mark-recapture methods: Schnabel (Krebs 1999), Joly-Seber (Seber 1982) and Noremark (White 1997) to calculate a population density estimate for each 65-ha area.

Two weeks after completing camera surveys for each area, I conducted mobile line and spotlight line surveys of areas where cameras were located. I did not conduct the survey lines during camera operation because of the likelihood of biasing the camera data by disturbances to deer caused by vehicle traffic. I conducted four mobile surveys. I drove designated survey lines about 45-60 minutes before sunset and counted all visible deer. I categorized each deer as fawn, doe or buck. Bucks were further defined as spike or fork-antlered. I used historic survey lines in all areas. I estimated visibility every 161 m along survey lines to determine the total area surveyed. I estimated buck, doe, and fawn abundance for each area from data and extrapolated abundance to 65 ha for comparison with camera survey data. I conducted spotlight surveys on the same day along mobile survey routes. I used two Q-Beam Max Million spotlights to spot deer. Surveys started 15-30 minutes after official sunset and continued until completion of each line. I estimated visibility every 161 m along each survey line. I estimated buck, doe, and fawn abundance for each area from data and extrapolated abundance to 65 ha for comparison with camera survey data.

I analyzed photographs with my new method that determined individually identifiable spike-antlered bucks as well as individually identified fork-antlered bucks, assuming that all bucks utilizing a 65 ha area were photographed during a 14-day camera survey. I assumed an observer could individually identify fork-antlered and spike-antlered bucks. All antlered bucks individually identified in photographs were used to estimate the minimum buck population (Eb) for each area. Spike-buck fawns were excluded from these estimates but were accounted for in fawn population estimates. This accounted for all deer equally. The estimated buck population was calculated by the following formula:

$$E_b = B + B_{sa}$$

Where:

E_b = estimated total buck population

B = number of individually identified fork-antlered bucks

B_{sa} = number of individually identified spike-antlered bucks

I also calculated population estimates using the standard formula (Jacobson et al. 1997), assuming all bucks utilizing a 65 ha area would be photographed in a 14-day camera survey and that spike-antlered bucks were difficult to distinguish individually; therefore, spike:fork-antlered ratios were determined and the estimated total buck population was calculated using:

$$P_s = N_{sa}/N_{ba}$$

Where:

P_s = ratio of spike:fork-antlered bucks

N_{sa} = total number of spike-antlered deer occurrences in photographs

N_{ba} = total number of fork-antlered deer occurrences in photographs

And

$$E_b = (B * P_s) + B$$

Where:

E_b = estimated total buck population

B = number of individually identified fork-antlered bucks

The estimated doe population was calculated using the estimated buck population and the buck:doe ratio calculated from photographs; i.e.,

$$P_d = N_d/N_b$$

Where:

P_d = ratio of does:bucks

N_d = total number of adult antlerless deer occurrences in photographs

N_b = total number of adult antlered deer occurrences in photographs

And

$$E_d = E_b * P_d$$

Where:

E_d = estimated total doe population

The fawn population was calculated in the same manner,

$$P_f = N_f/N_d$$

Where:

P_f = ratio of fawns:doe

N_f = total number of fawn occurrences in photographs

And

$$E_f = E_d * P_f$$

Where:

E_f = estimated total fawn population

For these calculations to be reliable, the observer of photographs must distinguish minute differences in antler configurations of individual bucks. Also, photographs were only used when all deer in photos were completely identifiable as a known or new buck, a doe, or a fawn. Photos with unidentifiable deer were not used to minimize bias and to increase the repeatability of analyzing population attributes needed for calculations. All deer in photos were treated as the current population in an area and not distinguished as resident or transient animals. For estimates of each of the preceding formulas to hold true one has to assume that all deer have the same ability to be photographed during the 14-day period and one segment of the population is not favored over the other. You also have to assume that there is a closed population throughout the duration of the survey.

I used day-to-day data of the total number of individually identified bucks from photographs, plus all other identified bucks seen in the study area to calculate the total minimum number of bucks in the areas during the study. With these comparisons, I constructed a day-to-day chart to assess the minimum number of days needed to conduct the camera survey without compromising the results.

III. RESULTS

Based on photograph verifications, I estimated that the number of individually identified bucks in 2000, 2001, and 2002 was the minimum buck population for an area for each year (Jim Hogg 5-6-4 bucks, Wildlife Area 8-5-9 bucks, Cedar Breaks na-5-10 bucks, respectfully). The estimated buck population obtained by the camera survey method was the most consistent among the three survey methods because the population estimates were the closest to the minimum number of identified bucks. Buck:doe ratios were also consistent for the camera survey in all trials with estimated ratios similar to the spotlight and mobile counts. Doe population estimates remained consistent among all three methods for all trials. Fawn number was underestimated by the camera survey in the park area and was more comparable to mobile and spotlight surveys. Fawn:doe ratios and acres per deer estimates were also compared, but because they were calculated from other population indices, the results parallel those for the individual herd segments. Population estimates rely on the buck population estimate and the buck:doe ratio estimate as a basis for estimating all other population indices, so when plotted on a graph, the curves vary equally from the buck and buck:doe ratio estimate. Therefore, there is no method or need for comparison of the remaining indices.

The new formula for calculating the population estimates from the camera surveys resulted in population estimates that were extremely exaggerated and unreliable. The new formula did, however, work well for the Jim Hogg study area in 2002 because there were no individually identified fork-antlered deer and only four identified spikes.Schnabel (Krebs 1999) and Joly-Seber (Seber 1982) mark-recapture population estimates were only conducted on the buck population and did not produce reliable results. Population estimates of bucks by these methods were less than half of the known fork-antlered deer of the area. Noremark (White 1997) population estimates were also conducted on an assumed closed buck population and produced estimates identical to the number of known marked animals, which was deemed redundant since there was no change among known bucks and the output of the formula. Tables 1, 2, and 3 show the population estimates calculated for all methods. Tables 4, 5, 6, and 7 show the individual buck occurrence by day during the camera surveys used in the mark-recapture calculations for population estimates. An apparent repeatability of results was observed with the camera surveys in the 2000 pre-season and 2001 post-season survey data sets. After a known number of animals were removed from the population by harvest, however, the number of removed animals was low and the true repeatability could not completely be assessed (Tables 8, 9, and 10).

I found that the results for all trials in the areas were similar within less than one deer for the buck population whether cameras were run for 11 days or 14 days as recommended by Jacobson et al. (1997) (Fig. 2). Buck:doe ratios were also plotted and did not change dramatically after 6 days of taking photographs (Fig. 3)

Table 1. White-tailed deer population attributes for all calculation methods at the Dam Wildlife Area, Lake Georgetown, Texas in 2000-2002.

	2000							2001							2002						
Calculation Method	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	Total[f]	Deer/Acre	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	Total[f]	Deer/Acre	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	Total[f]	Deer/Acre
Jacobson	9.0	20.2	2.6	2.2	0.13	31.8	5.0	11.6	71.6	35.1	6.2	0.49	118.3	1.4	8.3	16.6	11.9	2.0	0.72	36.8	4.3
Mobile	4.5	27.0	4.3	6.0	0.16	35.8	4.5	17.1	20.0	12.8	1.2	0.64	49.9	3.2	8.6	48.5	22.8	5.6	0.47	79.9	2.0
Spotlight	1.5	18.5	6.0	12.3	0.32	26.0	6.2	8.6	17.1	15.7	2.0	0.92	41.4	3.9	7.1	22.8	11.4	3.2	0.50	41.3	3.9
New formula	10.3	23.1	3.0	2.2	0.13	36.4	4.4	19.4	119.4	58.4	6.2	0.49	197.2	0.8	10.7	21.4	15.3	2.0	0.71	47.4	3.4
Noremark Closed	8.0	17.6	2.3	2.2	0.13	27.9	5.7	5.0	31.0	15.2	6.2	0.49	51.2	3.1	9.0	18.0	12.8	2.0	0.71	39.8	4.0
Schnabel M/R	2.0	4.4	0.6	2.2	0.14	7.0	22.9	4.8	29.8	14.6	6.2	0.49	49.2	3.3	5.0	10.0	7.1	2.0	0.71	22.1	7.2
Jolly-Seber	4.3	9.5	1.2	2.2	0.13	15.0	10.7	5.3	32.9	16.1	6.2	0.49	54.3	2.9	3.8	7.6	5.4	2.0	0.71	16.8	9.5

Eb[a] = Estimated Bucks, Ed[b] = Estimated Doe, Ef[c] = Estimated Fawns, B/D[d] = Doe per 1 Buck, F/D[e] = % Fawns per doe, Total[f] = Total deer population

Table 2. White-tailed deer population attributes for all calculation methods, Jim Hogg Park, Lake Georgetown, Texas in 2000-2002.

	2000							2001							2002						
Calculation Method	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	Total[f]	Deer/ Acre	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	Total[f]	Deer/ Acre	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	Total[f]	Deer/ Acre
Jacobson	7.5	33.2	7.5	4.4	0.23	48.2	3.3	5.3	21.8	11.2	4.1	0.51	38.3	4.2	0.0	0.0	0.0	5.2	0.44	0.0	0.0
Mobile	8.8	36.0	34.8	4.1	0.97	79.6	2.0	11.4	51.6	44.6	4.5	0.86	107.6	1.5	14.1	53.8	19.4	3.8	0.36	87.3	1.8
Spotlight	9.0	48.8	42.5	5.4	0.87	100.3	1.6	15.8	63.0	49.9	4.0	0.79	128.7	1.2	12.3	43.1	37.0	3.5	0.86	92.4	1.7
New Camera	18.7	82.9	23.7	4.4	0.29	125.3	1.3	7.9	32.7	16.8	4.1	0.51	57.4	2.8	4.0	20.8	9.2	5.2	0.44	34.0	4.7
Noremark Closed	5.0	22.0	6.4	4.4	0.29	33.4	4.8	6.0	24.6	12.5	4.1	0.51	43.1	3.7	4.0	20.8	9.2	5.2	0.44	34.0	4.7
Schnabel M/R	6.0	26.4	7.7	4.4	0.29	40.1	4.0	3.0	12.3	6.3	4.1	0.51	21.6	7.4	6.5	33.8	14.9	5.2	0.44	55.2	2.9
Jolly-Seber	6.3	27.7	8.0	4.4	0.29	42.0	3.8	2.7	11.1	5.6	4.1	0.50	19.4	8.2	8.7	45.2	19.9	5.2	0.44	73.8	2.2

Eb[a] = Estimated Bucks, Ed[b] = Estimated Doe, Ef[c] = Estimated Fawns, B/D[d] = Doe per 1 Buck, F/D[e] = % Fawns per doe, Total[f] = Total deer population

Table 3. White-tailed deer population attributes for all calculation methods, Cedar Breaks Park, Lake Georgetown, Texas in 2001-2002.

Calculation Method	2001							2002						
	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	Total[f]	Deer/ Acre	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	Total[f]	Deer/ Acre
Jacobson	4.5	13.7	7.3	3.0	0.53	25.5	6.3	11.2	18.1	7.3	1.6	0.40	36.6	4.4
Mobile	8.1	32.4	20.3	4.0	0.63	60.8	2.6	9.9	45.6	25.9	4.6	0.57	81.4	2.0
Spotlight	5.4	33.8	20.3	6.3	0.60	59.5	2.7	7.9	35.3	17.7	4.5	0.50	60.9	2.6
New Camera	7.5	22.9	12.2	3.1	0.53	42.6	3.8	16.1	25.8	10.4	1.6	0.40	52.3	3.1
Noremark Closed	5.0	15.0	8.0	3.0	0.53	28.0	5.7	10.0	16.0	6.4	1.6	0.40	32.4	4.9
Schnabel M/R	2.2	6.6	3.5	3.0	0.53	12.3	13.0	5.3	8.5	3.4	1.6	0.40	17.2	9.3
Jolly-Seber	2.4	7.2	3.8	3.0	0.53	13.4	11.9	6.1	9.8	3.9	1.6	0.40	19.8	8.1

Eb[a] = Estimated Bucks, Ed[b] = Estimated Doe, Ef[c] = Estimated Fawns, B/D[d] = Doe per 1 Buck, F/D[e] = % Fawns per doe, Total[f] = Total deer population

Table 4. Daily individually identified white-tailed deer buck occurrence in camera survey photographs at the Dam Area and Jim Hogg Park, Lake Georgetown, Texas in August 2000.

Dam Wildlife Area															Jim Hogg Park														
Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	#	14	Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	13	14
8 pt 1		X		X			X			X	X	X	X	X	Spike 1	X	X		X	X	X	X	X	X	X	X	X	X	X
Spike 1			X	X	X	X		X	X	X	X	X			4 pt 1	X		X	X	X	X	X		X		X		X	X
6 pt 1			X		X	X		X	X	X					Spike 2		X												
8 pt 2				X	X		X	X	X	X	X	X	X	X	Spike 3		X	X	X	X	X		X	X	X	X			
8 pt 3							X	X						X	10 pt 1												X		
Broken											X	X	X	X															
8 pt 4												X	X	X															
8 pt 5												X		X															

Table 5. Daily individually identified white-tailed deer bucks in post-hunting season 14-day camera survey photographs at Dam Wildlife Area and Jim Hogg Park, Lake Georgetown, Texas in January 2001.

	Dam Wildlife Area														Jim Hogg Park														
Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	#	14	Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	13	14
8 pt 1		X			X		X		X						Spike 1		X	X				X					X	X	
8 pt 2		X					X	X							7 pt 1		X		X	X			X						
Broken			X	X	X			X				X			Spike 2			X							X				
Spike 1			X		X			X							8 pt 1				X										
8 pt 3				X	X										4 pt 1					X			X		X			X	
Spike 2							X	X							4 pt 2					X			X		X			X	
															4 pt 3								X		X		X		
															Spike 3								X		X		X	X	
															3 pt 1								X						
															7 pt 2												X		

Table 6. Daily individually identified white-tailed deer buck occurrence in 14-day camera survey photographs at Dam Wildlife Area, Jim Hogg Park and Cedar Breaks Park, Lake Georgetown, Texas in August 2001.

Dam Wildlife Area

Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	#	14
Spike 1	X	X			X	X	X		X				X	X
Spike 2		X							X			X	X	X
9 pt						X					X		X	X
4 pt						X								
5 pt														X

Jim Hogg Park

Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Spike 1	X	X			X	X	X		X				X	X
5 pt		X	X	X	X		X					X	X	X
4 pt			X	X	X	X	X	X			X	X	X	X
6 pt				X		X		X	X	X	X	X	X	X
8 pt									X					
Spike 2													X	

Cedar Breaks Park

Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Spike 1	X	X	X	X	X	X		X	X	X	X	X	X	X
8 pt 1		X				X	X	X	X	X	X	X	X	X
5 pt 1		X				X	X		X	X		X	X	X
8 pt 2							X		X	X		X	X	X
5 pt 2												X		X

Table 7. Daily individually identified white-tailed deer buck occurrence in 14-day camera survey photographs at Dam Wildlife Area, Jim Hogg Park, Cedar Breaks Park, Lake Georgetown, Texas in August 2002.

Dam Wildlife Area

Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	#	14
3 pt	X	X	X	X	X	X	X	X		X				
4 pt	X													
6 pt		X	X	X	X	X	X	X	X	X	X	X	X	
8 pt			X	X	X	X	X	X	X	X	X	X	X	X
3 pt 2			X	X	X	X		X	X	X	X			X
Big 4			X	X	X	X	X		X					X
Non Typ					X	X		X	X		X		X	X
Spike 1						X		X				X	X	X
Spike 2								X						

Jim Hogg Park

Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Spike 1	X	X	X					X						X
Spike 2			X	X	X	X	X		X	X	X	X	X	X
Spike 3			X	X		X		X	X	X	X	X	X	
Spike 4					X		X							

Cedar Breaks Park

Buck ID's	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Spike 1	X			X		X	X		X	X	X	X	X	X
Spike 2	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spike 3	X					X	X							
6 pt		X		X	X	X	X		X	X	X			X
Non Typ		X		X	X	X		X	X	X			X	X
6 pt 2		X	X		X	X	X	X		X	X		X	X
4 pt		X	X	X	X	X	X	X	X		X	X	X	
3 pt			X	X		X	X		X	X	X	X	X	X
Spike 4							X	X	X	X		X	X	
Spike 5							X							

Table 8. Pre-hunting and post-hunting season Jacobson Formula camera population estimates of white-tailed deer at Dam Wildlife Area and Jim Hogg Park, Lake Georgetown, Texas in August 2000 and January 2001.

	Dam Wildlife Area					Jim Hogg Park				
Trial	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]
Pre-season (Aug 00)	8.8	18.8	2.4	2.1	0.13	7.5	26.2	7.5	3.5	0.29
Post-season (Jan 01)	5.7	20.2	5.1	3.5	0.25	8.9	22.2	20.4	2.5	0.92
# Lethally removed	3	1	1	na	na	0	4	0	na	na
Post-season adjusted	8.7	21.2	6.1	2.4	0.29	8.9	26.2	20.4	2.9	0.78

Eb[a] = Estimated Bucks, Ed[b] = Estimated Doe, Ef[c] = Estimated Fawns, B/D[d] = Doe per 1 Buck, F/D[e] = % Fawns per doe.

Table 9. Pre-hunting and post-hunting season mobile surveys comparisons of white-tailed deer at Dam Wildlife Area Lake Georgetown, Texas sites in August 2000 and January 2001.

	Dam Wildlife Area					Jim Hogg Park				
Trial	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]
Pre-season (Aug 00)	4.5	27	4.3	6	0.16	8.8	36	34.8	4.1	0.97
Post-season (Jan 01)	1.4	27.1	2.9	19.4	0.11	1	21	37.1	21	1.77
# Lethally removed	3	1	1	na	na	0	4	0	na	na
Post-season adjusted	4.4	28.1	3.9	6.4	0.14	1	25	37.1	25	1.48

Eb[a] = Estimated Bucks, Ed[b] = Estimated Doe, Ef[c] = Estimated Fawns, B/D[d] = Doe per 1 Buck, F/D[e] = % Fawns per doe.

Table 10. Pre-hunting and post-hunting seasons spotlight surveys comparisons of white-tailed deer at two Lake Georgetown, Texas, sites in August 2000 and January 2001.

	Dam Wildlife Area					Jim Hogg Park				
Trial	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]	EB[a]	ED[b]	EF[c]	B/D[d]	F/D[e]
Pre-season	1.5	18.5	6	12.3	0.32	9	48.8	42.5	5.4	0.87
Post-season	0	1.4	1.4	0	1	3.2	29.8	44.4	9.3	1.49
# Lethally removed	3	1	1	na	na	0	4	0	na	na
Post-season adjusted	3	2.4	2.4	0.8	1	3.2	33.8	44.4	10.6	1.31

Eb[a] = Estimated Bucks, Ed[b] = Estimated Doe, Ef[c] = Estimated Fawns, B/D[d] = Doe per 1 Buck, F/D[e] = % Fawns per doe.

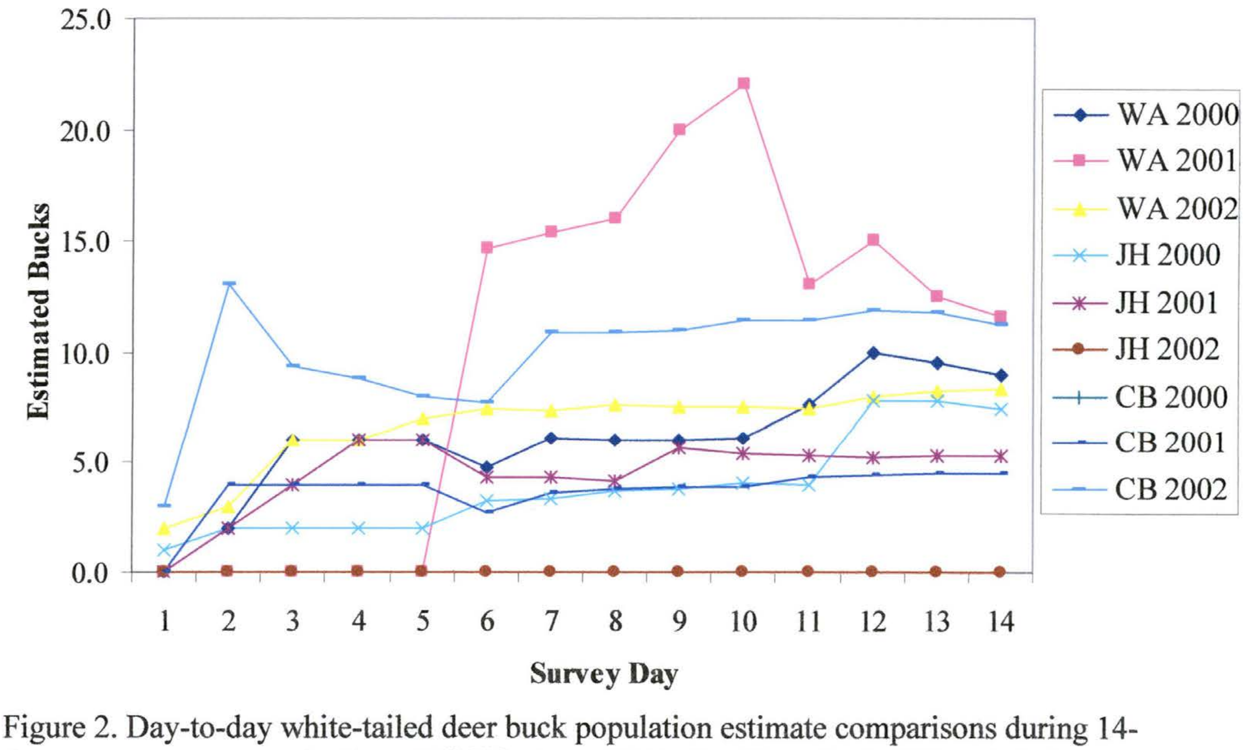

Figure 2. Day-to-day white-tailed deer buck population estimate comparisons during 14-day camera surveys at the Dam Wildlife Area (WA), Jim Hogg Park (JH) and Cedar Break Park (CB) at Lake Georgetown, Texas from 2000-2002.

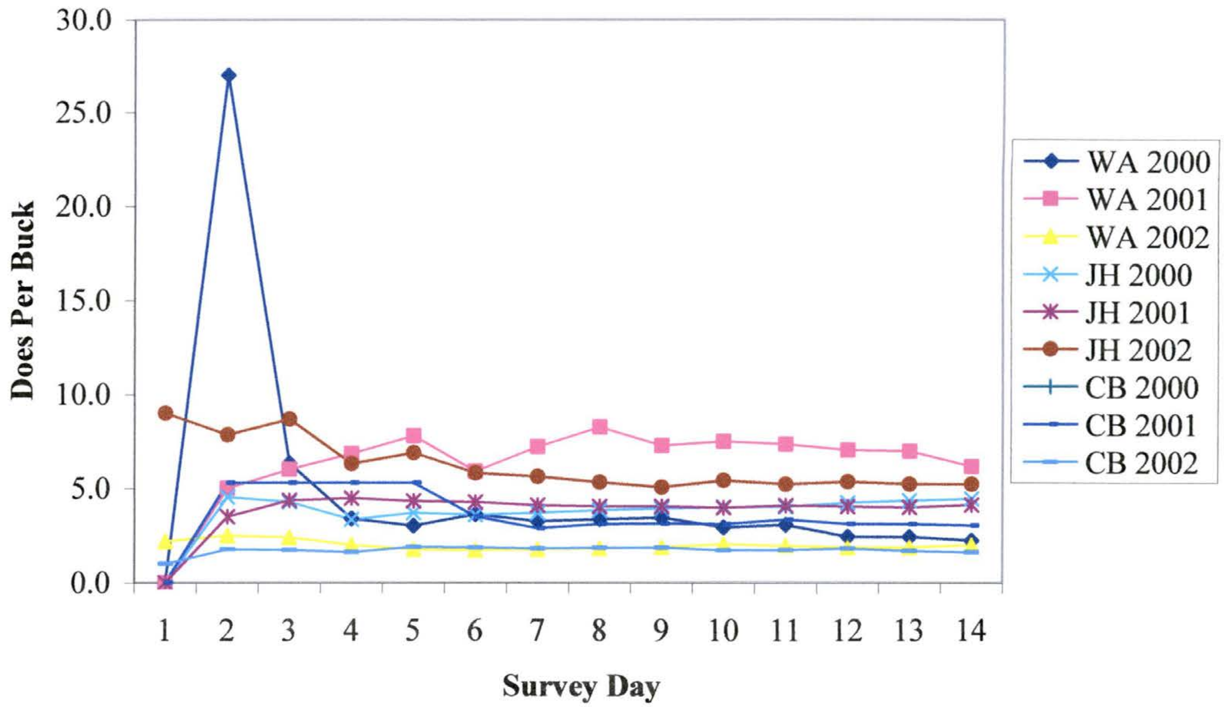

Figure 3: Day-to-day white-tailed deer buck:doe ratio estimate comparisons during 14-day camera surveys at Dam Wildlife Area (WA), Jim Hogg Park (JH) and Cedar Break Park (CB) at Lake Georgetown, Texas from 2000-2002.

IV. DISCUSSION

Useful research hinges on the use of the best experimental design possible for each study. This project had a flaw that limited the use of data in descriptive and visual comparisons without the benefit of the use of statistics. This flaw was introduced by conducting the mobile and spotlight surveys two weeks after the completion of each camera survey, thus making it where direct statistical comparison of the data could not be used. The research data does show comparability and some conclusions can be stated but without definite statistical backing. I do feel that the results are directly comparable and accurate given the short time frame between surveys and my experience with the deer herds of each area. However individual conclusions should be used in reference to this data. For future research, all methods should be done in each area each day so the results are directly comparable. Also the ability to mark more animals than just fork-antlered bucks would greatly increase the strength of a camera survey.

Overall the camera survey technique produced the most consistent and believable representation of the deer population, as well as a visual representation of the white-tailed deer population using an area. From the results of the buck population estimate and buck:doe ratio estimate, all the necessary data can be calculated to successfully manage a deer population in Central Texas. The spotlight and mobile survey methods may be better adapted to larger areas with higher visibilities, instead of a small area with dense vegetation such as occurred in the study area.

Undercounting the fawn population with the camera method was attributed to the fact that during the survey, fawns were not old enough to eat corn and were still under the protection of the doe. Even when eating corn fawns were still undercounted by the cameras due to the height of the sensor, however, the sensor should not be lowered because smaller non-target animals would increase film usage.

The new formula did not accurately represent the population because the results from the addition of identified spikes to the identified fork-antlered deer were altered to a state that was completely unrealistic for the area. It did prove useful in the 2002 survey of Jim Hogg Park where only spike bucks were observed in photographs. It is recommended that in this situation to individually identify the spike-antlered deer in photographs and use those numbers in place of fork-antlered deer in population calculations. The Jacobson Formula provided a more realistic population estimate because it takes into account the variability of spike-antlered and fork-antlered deer within a deer herd. For the entire buck segment of a population to be spike or fork exclusively is a rare occurrence. While it did occur in photographs in 2002, it was not an accurate depiction because fork-antlered deer were seen in the study area during the camera survey. The ratio calculation of the Jacobson formula better accounts for this variation but was not reliable when all deer in photographs were spike-antlered or fork-antlered exclusively. If this occurs the evaluator must then use my new formula taking the total number of all individually identified buck deer during that survey to use as the buck population estimate to complete the remaining calculations for doe, fawns, and sex ratios.

The mark-recapture methods of Schnabel and Joly-Seber provided unreliable population estimates. The recapture occurrences of individually identified deer were too low and the time period was too short to calculate a realistic population estimate. The Noremark (White 1997) method provided reliable population estimates but was exactly the same as the number of marked animals in all cases. This would render the use of this method useless because you could just use the number of marked fork-antlered deer as the population estimate instead of inputting it into the Noremark Program (White 1997).

Evaluation of the length of the camera survey showed that the cameras could be operative for three days less than recommended by Jacobson et al. (1997), thus reducing survey cost without sacrificing results. Because camera surveys are costly, this savings is important. The potential for a shorter survey is feasible, but would need to be based on historic camera surveys for the same area where comparison of population trends could be taken into account. All calculations derived from photographs are based on two population attributes, buck population estimate and the buck:doe ratio, all other indices hinge on these two attributes being accurate.

V. MANAGEMENT IMPLICATIONS

This study indicates that infrared-triggered cameras are a viable population monitoring tool that should be used extensively by landowners. High variability in deer behavior should be considered when implementing deer-management activities that require all deer to use bait sites, such as infrared-triggered camera surveys (Campbell et al. 2006). The benefits of a picture in hand of almost all bucks within the 65 ha survey area makes several management options possible. A more controlled harvest can be achieved in meeting management goals. Also with the rapid expansion of technology, cameras will become cheaper, smaller, and more efficient. Calculating population estimates is easy and the minimum number of days necessary to run the camera system can be easily determined. Camera survey costs can be reduced with the use of generic brand film and next-day photo developing or completely digital systems. Overall, I concluded that wildlife biologists and ranch managers should embrace this new technology. Increased hunting pressure on smaller areas requires more accurate methods of population surveying and more controlled harvest, the camera survey fulfills these needs.

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VITA

Matthew Lucas Cooksey was born in Austin, Texas, on February 28, 1979, the son of Judy Beth Cooksey and David Loftin Cooksey. After completing his work at Liberty Hill High School, Liberty Hill, Texas, he entered Texas A&M University-Kingsville. He received the degree of Bachelor of Science in Agriculture, Range and Wildlife Management from Texas A&M University-Kingsville in May 2002. During the years of 1999-2004 he was employed as a Park Ranger with the U.S. Army Corps of Engineers-Lake Georgetown in Georgetown, Texas. Then he was employed as the Installation Wildlife Biologist beginning in 2005 for Fort Sam Houston & Camp Bullis in San Antonio, Texas under a contract to Essex Corporation of Columbia, Maryland. In September 2002, he entered the Graduate College of Texas State University-San Marcos.

Permanent Address: 591 Avenue A

New Braunfels, Texas 78130

This thesis was typed by Matthew L. Cooksey.