Evaluation of Population Estimates of White-tailed Deer from Camera Survey

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Abstract: Use of trail cameras to make population estimates of white-tailed deer (*Odocoileus virginianus*) has increased since an estimator was developed by Jacobson et al. (1997). We evaluated the accuracy of the camera estimator in six 81-ha enclosures with varying densities of deer replicated on two study areas. Baited camera surveys were conducted for 14 days in autumn and winter. We also tested the finding from previous studies that the probability of sighting bucks and does in photographs was equal. Finally, we conducted an open range test by comparing a camera survey to a helicopter survey. The camera estimator underestimated known populations of marked deer in the enclosures by a mean of 32.2%. The underestimates were the result of photos/marked buck being 1.9 times greater than photos/marked doe. However, cameras captured >90% of marked bucks and >84% of marked does. Deer density and season did not affect population estimate bias but photos/deer were 1.8 times greater during winter versus autumn. On the open range test, number of unique bucks identified during camera survey was double the number of bucks sighted during a 67% coverage helicopter survey of 2,299 ha that included the 607-ha camera survey site. Estimates of doe:buck and fawn:doe ratios were 280% and 31% higher from helicopter survey than camera survey, respectively. Population estimates from baited camera surveys based on the Jacobson et al. (1997) method, though conservative, are simple to conduct and calculate and, on average, estimate a relatively high (68%) portion of the adult population.

Key words: Odocoileus virginianus, white-tailed deer, population estimation, camera survey, ungulate

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Interest in using remotely triggered trail cameras to inventory white-tailed deer (*Odocoileus virginianus*) has increased since Jacobson et al. (1997) and Koerth et al. (1997) first published on the technique (Koerth and Kroll 2000, McKinley et al. 2006, Roberts et al. 2006, Watts et al. 2008, McCoy et al. 2011). The Jacobson et al. (1997) approach involved estimating the buck population by identifying individuals in photos using unique antler characteristics. Then, they assumed that does and fawns are equally as susceptible to camera capture as bucks, and that sightability (photos/deer) was equal among deer classes as well. Using ratios of the number of photos of each deer class, a population estimate was calculated. Jacobson et al. (1997) and Koerth and Kroll (2000) speculated that the assumption of equal susceptibility and sightability of deer classes to camera capture could be flawed. In evaluations of the equal sightability hypothesis, McKinley et al. (2006) and Watts et al. (2008) found no bias in sightability by sex. McKinley et al. (2006) surveyed over bait whereas Watts et al. (2008) conducted unbaited surveys. McCoy et al. (2011) found that adult males were less susceptible to capture at feed sites versus random unfed sites during the rut. However, they found that sex ratio estimates were similar between fed and unfed sites in fall but inaccurate at other times, possibly due to different movement rates among deer classes.

We were provided the opportunity to test the equal susceptibility to camera capture and sightability on camera hypotheses and investigate other factors affecting the Jacobson et al. (1997) technique while conducting a large-scale, replicated field experiment (Timmons et al. 2010). Our specific objectives were to: (1) evaluate accuracy of the Jacobson et al. (1997) estimator by comparing against known marked enclosure populations at three deer densities and during two seasons, (2) test the equal sightability hypothesis by comparing the rate at which marked adult bucks versus marked does occurred in photos from baited camera sites, and (3) compare estimates of population parameters from cameras with estimates from helicopter survey on open range.

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Study Areas

Our research was replicated on the Comanche Ranch (28.28 N, 100.09 W) and Faith Ranch (28.28 N, 100.00 W) in Dimmit County, Texas. Topography of this region was relatively flat with low areas associated with ephemeral streams. Landscape overstory was dominated by honey mesquite (*Prosopis glandulosa*), blackbrush acacia (*Acacia rigidula*), guajillo (*Acacia berlandieri*), spiny hackberry (*Celtis ehrenbergiana*), and guayacan (*Guaiacum angustifolium*) (Timmons et al. 2010). The herbaceous understory was diverse and greatly affected by variable annual rainfall ranging from 40.6 cm in drought years to 81.3 cm in wet periods.

Methods

We conducted our study in six enclosures (three/ranch) of 81 ha each. The enclosures were constructed in late 2003 and surrounded by 2.5 m high net-wire fencing. A water trough with a float control was centrally located in each enclosure. No supplemental feed was present in the six study enclosures. Each ranch had an enclosure with a goal of high (40 deer), medium (25 deer), and low (10 deer) density. Some deer were enclosed in each enclosure when fencing was erected. In March 2004, additional deer were added, as needed, after net gun capture (DeYoung 1988) near the enclosure on each respective ranch. Captured deer were marked with colored and numbered cattle ear tags (Allflex USA, Inc., Dallas, Texas), and immediately transported to an enclosure and released (Texas A&M University-Kingsville Institutional Animal Care and Use Committee approvals 2004-2-9 and 2009-11-5A).

Each subsequent year until our study began in January 2007, combination camera and mark-recapture population estimates (described below) were calculated and deer were ear-tagged and added after net-gun capture outside enclosures or removed after drop-net capture (Ramsey 1968) or harvested by firearm to approximate each enclosure's population goal. We also captured, ear-tagged, and released resident enclosure deer each year to add to marked populations. Marked deer populations contained individuals ranging from yearling to old (lower molars dished) deer.

We performed the evaluation of the Jacobson et al. (1997) method by using the known number of marked deer in enclosures (described later). To determine if there were density dependent behavioral factors, such as movement rates (Jacobson et al. 1997, McCoy et al. 2011), affecting the Jacobson et al. (1997) estimates of marked deer, we also estimated the total deer populations (marked and unmarked) of enclosures and used these estimates to evaluate the effect of deer density on Jacobson et al.(1997) estimates. Total deer populations (marked and unmarked) for the three density treatments were estimated from photos by first determining the absolute number of bucks present in each enclosure using a combination of ear tags and unique antler configurations. We then estimated doe populations by Lincoln-Peterson formula (Williams et al. 2002:291). We estimated fawns by dividing the estimated number of does into the number of doe photos and then dividing the result into number of fawn photos. Finally, we summed number of bucks plus estimated does and fawns for a total enclosure population.

For the evaluation of the Jacobson et al. (1997) estimator, we used marked individuals in each enclosure as the known population against which to compare estimates of the marked population derived using the methods of Jacobson et al. (1997), with slight modification (described below). Because some marked deer died through time, and previous camera studies have not sampled 100% of a marked population (Jacobson et al. 1997, McKinley et al. 2006), we set unbaited cameras (four/enclosure) on trails and water troughs for four weeks during each field season to aid in inventorying the marked population in each enclosure. Then, a baited two-week camera survey was conducted during winter 2007 (February), autumn 2007 (September–October), and winter 2008 (January–February). Four cameras/enclosure were utilized for a camera density of 1/20.3 ha. For each survey, 2.3 kg of shelled corn was placed at each of four cameras set on deer trails on the first day of the survey and replenished as necessary during daily inspections (Jacobson et al. 1997). To be included in a marked population for one of the survey periods, a deer had to be identified by tag number or unique tag color combination during the six weeks (four unbaited, two baited) that cameras were deployed during the same season or a subsequent season.

We used Cuddeback Expert Digital Game Cameras (Non Typical, Inc., Park Falls, Wisconsin) with photographs stored on compact flash cards. Cameras were programmed for a four-minute delay between photos to reduce multiple photos of the same individual. Cameras were attached to two adjacent metal posts at a height of 1 m. Another metal post painted bright yellow was placed 10 m in front of the camera. To avoid miss-identifications, only marked deer between the yellow post and the camera were tallied. Camera cards and batteries were replaced after each two-week period. Photographs were analyzed using Microsoft Office Picture Manager 2003 (Microsoft Software Corp., Redmond, Washington).

Once photograph analysis was completed, appropriate segments of the formula described by Jacobson et al. (1997) were applied to the data obtained on marked adults to estimate the marked adult population. Jacobson et al. (1997) estimated the adult buck population by summing the number of branch-antlered bucks with the number of spike-antlered bucks determined by a spike:branch-antlered ratio. We did not use the spike ratio because there were few spikes in our samples and we could separate those that occurred by ear tags. We did not consider fawns in the marked population estimates to evaluate the camera estimator in enclosures because there frequently were no tagged fawns present.

The marked adult population was estimated after each two-week baited survey as follows:

E_b = number of individual marked bucks indentified by ear tag
$P_d = N_d / N_b$,
Where
P_d = ratio of marked does:marked bucks,
N_d = total number of marked doe occurrences in photographs,
N_b = total number of marked buck occurrences in photographs
$E_d = E_b \times P_d$
Where
E_d = estimated marked doe population
$E_a = E_b + E_d$
Where
E_a = estimated marked adult population

We evaluated the accuracy of the Jacobson et al. (1997) estimates (Objective 1) by calculating percent bias as: Bias = $((E_a - M_a)/M_a)*100$; where M_a = marked adult population and E_a is as defined above. We tested the equal sightability to photo capture of sexes by calculating separately for each sex the number of photos/marked deer (Objective 2). We used a repeated measures analysis of variance (ANOVA) in PROC MIXED (SAS, Inc., Cary, North Carolina) to assess the effect of season, deer density category, and their interaction on bias of Jacobson et al. (1997) estimates. A similar repeated measures ANOVA with all possible interactions was used to assess the effect of sex, season, and deer density category on the number of photos/marked deer.

For the open range test, a single 14-day baited camera census was conducted on 607 ha near the Comanche Ranch enclosures beginning 29 September 2007. A 20.3-ha grid was overlaid on the test area, resulting in 30 sections. Camera stations were placed near the center of each section in a location where deer activity (tracks and feces) was present. All camera procedures were the same as applied in the baited census in the enclosures except that we used antler characteristics to identify bucks instead of ear tags. We recorded the first day each unique buck occurred in photos and total number of unique bucks occurring in photos each day. A survey of deer over 2,288 ha of open deer range, which included the 607 ha camera area, was conducted by helicopter on 24 October 2007, using procedures described by DeYoung (1985). Three observers plus the pilot observed deer from an Astar model B3 helicopter. The coverage area of the helicopter survey was calculated by taking the km of transect flown recorded with a GPS unit and multiplying by an assumed 200 m counting strip. The helicopter survey covered 67% of the 2,288 ha area, or 1,533 ha. We compared bucks counted, sex ratios, and fawn:doe ratios for the camera versus helicopter techniques.

Results

Enclosures. Photos (4,307 total for three seasons) for the four-week unbaited period preceding each baited survey in the enclosures were the main source (79%) for initial identification of marked individuals. The remaining deer to form the marked adult populations were identified during two-week baited surveys. Eight different marked deer (2.8%) were not photographed during the six weeks cameras were deployed one season, but appeared in photos the following season. The three baited camera surveys produced 22,042 photos with deer present on which there were 16,597 occurrences of marked deer. For the baited surveys across all enclosures, 93% of marked bucks and 94% of marked does were identified during winter 2007, 83% of marked bucks and 81% of marked does during autumn 2007, and 94% of marked bucks and 87% of marked does during winter 2008 (Table 1). A population estimate could not be calculated for the

Table 1. Results of baited two-week trail camera surveys of marked white-tailed deer in 81-ha enclosures replicated on two ranches at three deer densities and two seasons near Carrizo Springs, Texas.

Ranch	Density	Parameter	Winter 2007	Autumn 2007	Winter 2008
Comanche	Low	Marked bucks identified/available	4/4	3/3	3/3
		Marked does identified/available	1/1	3/4	3/4
		Marked population	5	7	7
		Jacobson estimate[a]	4.6	5.1	4.8
	Medium	Marked bucks identified/available	3/3	5/6	4/5
		Marked does identified/available	4/6	5/7	5/7
		Marked population	9	13	12
		Jacobson estimate	4.9	8.3	8.0
	High	Marked bucks identified/available	5/7	11/11	15/16
		Marked does identified/available	6/6	9/10	13/20
		Marked population	13	21	36
		Jacobson estimate	9.4	19.2	25
Faith	Low	Marked bucks identified/available	na[b]	3/4	3/3
		Marked does identified/available	na	1/1	3/3
		Marked population	na	5	6
		Jacobson estimate	na	4.1	4.8
	Medium	Marked bucks identified/available	10/10	10/11	11/11
		Marked does identified/available	11/12	12/14	13/13
		Marked population	22	25	24
		Jacobson estimate	15.0	17.0	15.3
	High	Marked bucks identified/available	5/9	12/12	14/16
		Marked does identified/available	9/12	14/16	15/15
		Marked population	21	28	31
		Jacobson estimate	8.4	16.4	20.1

a. Estimator described by Jacobson et al. (1997).
b. No marked deer present in enclosure.

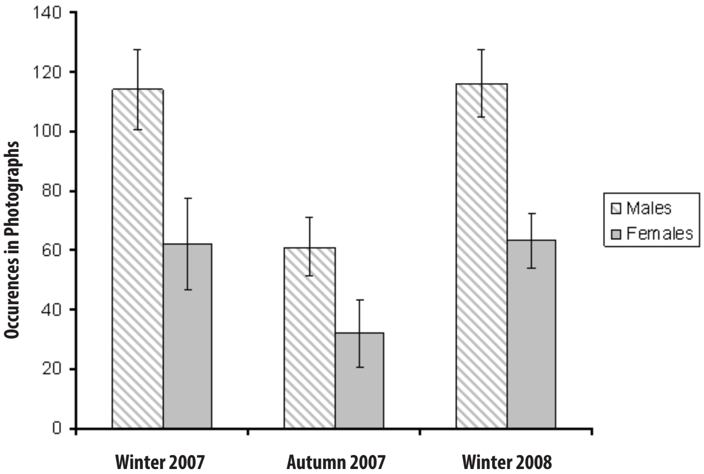

Figure 1. Mean occurrence of individual marked male and marked female white-tailed deer in photographs averaged across deer densities by survey date from baited camera surveys on two ranches near Carrizo Springs, Texas. Standard error is displayed by error bars.

Faith Ranch low-density enclosure during the winter 2007 baited survey because no marked deer were present.

Mean total deer populations (marked and unmarked) across the three periods and two replicates were 10.6 (1.4 SE), 22.3 (2.3), and 42.3 (4.9) for low, medium, and high density treatments, respectively. Marked deer populations were generally correlated with the total population density treatments across replicate ranches (Table 1). Mean size of marked populations was 6 (0.45 SE) (low density), 17.5 (2.84) (medium density), and 25 (3.38) (high density) deer.

Camera survey estimates by the Jacobson et al. (1997) method were, on average, 32.2% ± 4.6 SE lower than known marked populations and were not affected ($F_{1-2,\,3} \leq 0.12$, $P \geq 0.891$) by season of survey or deer density treatments. Number of photos/marked deer was 1.8 times more for males than females (males = 78 ± 7.7; females = 42 ± 10.2; $F_{1,\,3} = 9.06$, $P = 0.057$) and 1.9 times greater during winter than autumn (winter = 71 ± 9.1; autumn = 40 ± 8.6; $F_{1,\,3} = 8.08$, $P = 0.066$; Figure 1).

Open Range. For the open deer range test, one camera malfunctioned during the baited camera survey. The remaining 29 cameras produced 4,399 photographs in which 3,038 bucks, 1,189 does, 534 fawns, and 157 unidentified deer were classified. Number of unique bucks identified during the 14-day baited camera survey was double the number of bucks sighted during the helicopter survey (Table 2). Doe:buck ratio and fawn:doe ratio were higher (280% and 31%, respectively) for the helicopter survey (Table 2). Number of bucks identified each day during the camera survey ranged from a low of 6 on day 1 to 55 on day 14 (Figure 2). The number of unique bucks identified for the first time ranged from a high of 15 on day 2 to zero on days 13–15 (Figure 3).

Table 2. Comparison of estimated total bucks, sex ratios, and fawn ratios obtained from a baited camera survey using methods described by Jacobson et al. (1997) conducted September 29 – October 13, 2007, and a partial helicopter count using methods of DeYoung (1985) conducted October 24, 2007 near Carrizo Springs, Texas, USA.

	Camera estimate[a]	Helicopter estimate
Estimated total bucks	75	33
Does:bucks ratio	0.39:1	1.48:1
Fawns:does ratio	0.45:1	0.59:1

a. Jacobson et al. (1997).

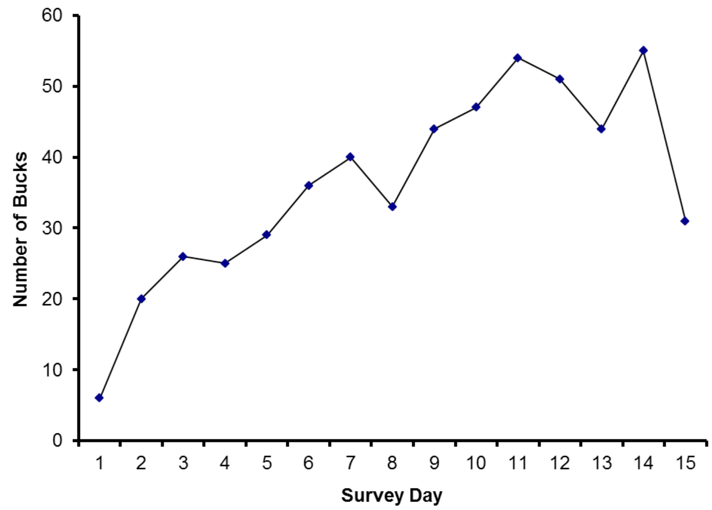

Figure 2. Number of bucks identified each day from photographs obtained during a baited camera survey conducted 29 September – 13 October 2007 near Carrizo Springs, Texas.

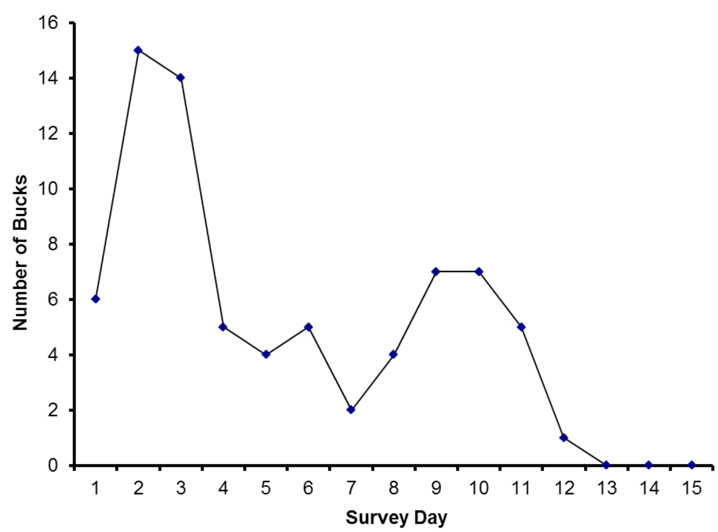

Figure 3. Number of unique bucks identified for the first time each day from photographs obtained during a baited camera survey conducted 29 September – 13 October 2007 near Carrizo Springs, Texas.

Discussion

The values we used for "known" marked populations in the enclosures, used as a benchmark to evaluate the Jacobson et al. (1997) estimator, were very close to the real number of marked deer present. There were three ways marked populations could have error. First, marked deer could have been present but gone unobserved. Only 2.8% (eight different individuals) of marked deer were not observed in one season and identified in the next. And, in all cases, we were able to add them to the previous season's total. There were no cases of marked individuals unobserved for two seasons. We interpret this as indicating we were efficient in identifying the marked deer during the six weeks cameras were deployed each season. A second possible source of error in the marked populations was the possibility of a marked deer being identified during the four weeks of unbaited survey then dying before the start of, or during, the baited survey. Third was the possibility of marked deer losing ear tags. We recaptured many marked deer during the study period and no cases of marked deer losing tags were observed.

We obtained consistent underestimates using the estimator of Jacobson et al. (1997) and the cause was higher sightability for bucks versus does. Susceptability to camera capture during our surveys was similar for marked bucks (90.3) and marked does (84.1). Susceptability to capture was similar to previous studies in forested areas in Mississippi, but our camera density (1/20.3 ha) was greater than for Jacobson et al (1997) (1/65 ha) and McKinley et al. (2006)(1/41 and 1/81 ha). Percentage of marked deer identified was much lower in Oklahoma at 22 for bucks and 35 for does (1/61 ha camera density, McKinley et al. 2006).

McKinley et al. (2006) conducted baited camera surveys as per Jacobson et al. (1997) and found no difference in number of photos for bucks versus does. Jacobson et al. (1997) reported higher capture rates for bucks versus does as camera density decreased. They attributed the difference to larger home range size of bucks and suggested further research at camera densities >1/65 ha. Our camera density of 1/20.3 ha showed a bias toward bucks in photos/deer but it is unlikely that home range size differed appreciably in 81-ha enclosures. Roberts et al. (2006) and Watts et al. (2008) conducted unbaited camera surveys on Florida Key deer (*O. v. clavium*) and found no bias in captures rates of bucks versus does. Watts et al. (2008) speculated that trap-happy individuals would bias baited surveys. We found this to be the case for bucks in south Texas. However, we question whether unbaited surveys would be useful in our situation because we obtained a low number of photos during unbaited surveys used to identify marked populations. During the unbaited surveys, we obtained 45% of photos from cameras at water troughs, a situation that would not normally be available. Despite this, when the four-week unbaited surveys were divided into two-week periods to compare with baited surveys of the same length, 14% of the unbaited Jacobson et al. (1997) marked population estimates were zero, despite marked deer being present.

One way deer density could affect baited camera results would be through behavioral interactions over bait as density increases (Donohue et al. 2013). This could possibly result in lower sightability and susceptibility to capture if some deer are excluded from bait by aggressive behavior. Although mean total (marked + unmarked) enclosure populations ranged from 10.6 to 42.3 deer/81 ha, deer density did not affect camera estimates. This suggests behavioral interactions did not affect camera surveys such as we conducted.

Season of camera survey did make a difference in camera survey results, with lower susceptibility to capture in autumn versus winter. Perhaps this was due to less nutritious food available in winter, causing deer to be more attracted to bait. Most managers would find autumn surveys more useful, particularly since they will potentially aid in harvest decisions before the hunting season.

We did not evaluate our assumption that the usual camera survey practice of identifying individual bucks by antler characteristics was equivalent to our identification of tagged bucks in the enclosure photos. From our experience, there are two potential sources of bias in antler identification. First, two bucks with similar antlers could be identified as a single buck, and second, one buck could be identified as two because different camera angles make antlers appear different. These potential biases should be investigated but were beyond the scope of our study. Our use of numbered ear tags instead of antler characteristics in the enclosure portion of the study avoided these potential biases.

The open range portion of our study also produced higher apparent sightability in favor of bucks in baited trail camera photos. Leon et al. (1987) reported that adult bucks and does were encountered at random during helicopter surveys, although there was high variability across repeated surveys. However, bias was unlikely to be 280% in favor of buck sightings, when comparing our camera estimate versus helicopter results. This added credence that our enclosure results, which did not support the equal sightablity hypotheses, were not influenced by some artifact of the enclosures.

We did not evaluate fawn estimates in the enclosure portion of our study because we did not consistently have marked fawns in the enclosures to form a marked population. However, the open-range camera survey provided some insight versus helicopter surveys. Sullivan et al. (1990) reported fawns were underestimated by as much as 30% versus adult deer in helicopter surveys. Because the camera survey produced a fawn:doe ratio 31% less than the helicopter survey, even allowing for variability in both surveys, it is likely the camera survey on open range underestimated fawns.

A 14-day baited survey period appeared adequate in length because no new bucks were identified in the open range baited survey after 13 days. The helicopter survey resulted in 46.5 ha/buck whereas the camera survey yielded 8.1 ha/buck. Number of bucks identified was 127% (33 versus 75) higher for the camera survey versus the helicopter survey, even though the helicopter survey covered 153% more (1,533 ha versus 607 ha). Helicopter surveys conducted during autumn have been thoroughly researched in south Texas and commonly result in an average count of about 36% of the deer population, with significant count-to-count variation (DeYoung 1985, Beasom et al. 1986, DeYoung et al. 1989). DeYoung (1985) found that 7%–15% of deer were counted twice in helicopter surveys with adjacent 200-m wide transects. This problem was probably minimal in our helicopter data because transects were spaced at wider intervals.

Population estimates from baited camera sites using the methods of Jacobson et al. (1997) underestimated deer population levels by 32.2% under our conditions. However, camera estimates such as we employed result in counting a higher portion of deer populations than helicopter surveys (DeYoung 1985, Beasom et al. 1986), and probably spotlight surveys (Fafarman and DeYoung 1986, Collier et al. 2007, Collier et al. 2013). Population estimates from camera survey also work well in urban, suburban, and exurban habitats (Roberts et al. 2006, Watts et al. 2008), as well as those with heavy woody cover, unlike other common deer survey techniques. The negative bias in population estimates by camera could be reduced by substituting less biased sex ratio data from another survey technique in the Jacobson et al. (1997) estimator. For example, adult sex ratio data from helicopter surveys of deer are less biased (Leon et al. 1987).

Camera surveys did not produce accurate estimates of adult sex ratio because bucks were sighted at a higher rate than does. However, accuracy of adult sex ratio from camera survey may be region-specific as other researchers (McKinley et al. 2006, Watts et al. 2008) have reported camera surveys are not biased by sex.

Susceptability to camera capture was high in our study (bucks >90% and does >84%). However, sightability of bucks was 1.8 times greater than does, resulting in underestimates using the Jacobson et al. (1997) method. Baited camera surveys such as we conducted could be useful to managers so long as shortcomings are recognized.

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Literature Cited

Beasom, S. L., F. G. Leon, III, and D. R. Synatzske. 1986. Accuracy and precision of counting white-tailed deer with helicopters at different sampling intensities. Wildlife Society Bulletin 14:364–368.

Collier, B. A., S. S. Ditchkoff, J. B. Raglin, and J. M. Smith. 2007. Detection probability and sources of variation in white-tailed deer spotlight counts. Journal of Wildlife Management 71:277–281.

______, _____, C. R. Ruth, and J. B. Raglin. 2013. Spotlight surveys for white-tailed deer: Monitoring panacea or exercise in futility? Journal of Wildlife Management 77:165–171.

DeYoung, C. A. 1985. Accuracy of helicopter surveys of deer in south Texas. Wildlife Society Bulletin 13:146–149.

_____. 1988. Comparison of net-gun and drive-net capture for white-tailed deer. Wildlife Society Bulletin 16:318–320.

_____, F. S. Guthery, S. L. Beasom, S. P. Coughlin, and J. R. Heffelfinger. 1989. Improving estimates of white-tailed deer abundance from helicopter surveys. Wildlife Society Bulletin 17:275–279.

Donohue, R. N., D. G. Hewitt, T. E. Fulbright, C. A. DeYoung, A R. Litt, and D. A. Draeger. 2013. Aggressive behavior of white-tailed deer at concentrated food sites as affected by population density. Journal of Wildlife Management 77:1401–1408.

Fafarman, K. R. and C. A. DeYoung. 1986. Evaluation of spotlight counts of deer in south Texas. Wildlife Society Bulletin 14:180–185.

Jacobson, H. A., J. C. Kroll, R. W. Browning, B. H. Koerth, and M. H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. Wildlife Society Bulletin 25:547–556.

Koerth, B. H. and J. C. Kroll. 2000. Bait type and timing for deer counts using cameras triggered by infrared monitors. Wildlife Society Bulletin 25:557–562.

_____, C. D. McKown, and J. C. Kroll. 1997. Infrared-triggered camera versus helicopter counts of white-tailed deer. Wildlife Society Bulletin 28:630–635.

Leon, F. G., III, C. A. DeYoung, and S. L. Beasom. 1987. Bias in age and sex composition of white-tailed deer observed from helicopters. Wildlife Society Bulletin 15:426–429.

McCoy, J.C., S.S. Ditchkoff, and T.D. Steury. 2011. Bias associated with baited camera sites for assessing population characteristics of deer. Journal of Wildlife Management 75:472–477.

McKinley, W. T., S. Demarais, K. L. Gee, and H. A. Jacobson. 2006. Accuracy of the camera technique for estimating white-tailed deer population characteristics. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 60:83–88.

Ramsey, C. W. 1968. A drop-net deer trap. Journal of Wildlife Management 32:187–190.

Roberts, C. A., B. L. Pierce, A. W. Braden, R. R. Lopez, N. J. Silvy, P. A. Frank, and D. Ransom. 2006. Comparison of camera and road survey estimates for white-tailed deer. Journal of Wildlife Management 70:263–267.

Sullivan, J. B., C.A. DeYoung, S. L. Beasom, J. R. Heffelfinger, S. P. Coughlin, and M. W. Hellickson. 1990. Evaluation of bias in the proportion of white-tailed deer fawns sighted from helicopters. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 44:202–205.

Timmons, G.R., D. G. Hewitt, C.A. DeYoung, T.E. Fulbright, and D.A. Draeger. 2010. Does supplemental feed increase selective foraging in a browsing ungulate? Journal of Wildlife Management 74:995–1002.

Watts, D. E., I. D. Parker, R. R. Lopez, N. J. Silvey, and D. S. Davis. 2008. Distribution and abundance of endangered Florida key deer on outer islands. Journal of Wildlife Management 72:360–366.

Williams, B. K., J. D. Nichols, and M. T. Conroy. 2002. Analysis and management of animal populations. Academic Press, San Diego, California.