Temporal and Sex-related Differences in use of Baited Sites by White-tailed Deer

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Abstract: Many of the methods used to estimate white-tailed deer population parameters from camera images are reliant upon the assumption that rates of detectability are similar between both sexes and all age groups of deer. The assumption of equal detectability may not be valid when bait is used to attract deer to survey sites due to physical and behavioral differences between deer groups. We placed trail cameras set at 1-minute time-lapse intervals at randomly selected sites baited with corn inside the Auburn University Deer Research Facility, a 175-ha enclosure containing a captive population of marked white-tailed deer, to investigate temporal and sex-related differences in deer use of baited sites. Surveys were conducted during three 10-day periods (prerut, rut, and postrut) in 2013–2014 to quantify deer use of baited sites (i.e. total number of individual adult deer visiting sites, number of visits by individuals, and duration of visits by individuals to baited sites). We found evidence that both sexes exhibited seasonal differences in use of baited sites, and these differences were more pronounced in male deer. Male deer visited sites more frequently and made longer visits during prerut than during rut and postrut; however, more (~70%) individual male deer were viewed at baited sites during rut and postrut than during prerut. We also observed differences between sexes in use of baited sites that varied in relation to the breeding season. Males spent more time than females at baited sites during prerut and postrut visits; however, females spent more time than males during rut. Deer use of baited sites was most similar between adult male and female deer during postrut, and we suggest that baited surveys conducted during postrut may provide the best opportunity to obtain unbiased adult sex ratio and abundance estimates. However, individuals utilizing camera surveys for deer should consider local factors that may contribute to sex-related differences in use of baited sites when selecting survey periods and camera settings.

Key words: white-tailed deer, camera, survey, abundance, bias

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Trail cameras are a popular tool among wildlife professionals that have been used to remotely gather information from a multitude of game and non-game species (Stokeld et al. 2015, Conner et al. 2016, Martinig and Bélanger-Smith 2016, Rowcliffe et al. 2016). Cameras have been used extensively in surveys of white-tailed deer (*Odocoileus virginianus*) since Jacobson et al. (1997) developed a technique for estimating sex ratio, recruitment, and deer density from camera images (Jacobson et al. 1997, McKinley et al. 2006, Curtis et al. 2009). The method presented by Jacobson et al. (1997; hereafter IBAM method) used camera capture rates of individual branch-antlered males visiting baited camera sites and an extrapolation factor related to survey duration to estimate deer population parameters (Weckel et al. 2011). The assumption of equal detectability among sexes and age classes associated with some camera survey methods that typically utilize bait, including the IBAM method, has been of concern to researchers (Koerth et al. 1997, Cutler and Swann 1999, Larrucea et al. 2007, McCoy et al. 2011). Multiple studies have demonstrated that deer use of baited sites varied between sexes and age classes, and the variation in use between groups can result in bias in survey results (McCoy et al. 2011, Moore et al. 2013). McCoy et al. (2011), for example, demonstrated that cameras placed at feeding stations yielded different sex ratio and recruitment estimates than those placed at random locations or on deer trails. Weckel et al. (2011) presented a modification of the IBAM method that could control for baiting bias using independent probabilities of being photographed (i.e., trap success) to standardize raw images; however, trap success can be challenging to estimate, and its utility may be constrained by assumptions of linear modeling in some data sets. Other emerging methods of estimating deer population parameters from images, such as N-mixture models, may provide advancements on some fronts since they do not rely on identification of specific individuals; however, these methods remain subject to assumptions of equal detectability and the potential resulting bias when bait is used to attract deer (Royle 2004, Dail and Madsen 2011, Zipkin et al. 2014). Further, consecutive images are treated as independent counts by N-mixture methods, and bias could be introduced if camera delay intervals are not selected in a manner that considers deer behavior at baited sites (Royle 2004).

The importance of camera surveys as a management tool for white-tailed deer and the widespread use of bait in surveys necessitates a clear understanding of the influence of bait on deer behavior. We used time-lapse photography to monitor a largely-known captive population of marked deer in an effort to investigate adult (≥1.5 years of age) deer use of baited sites, in terms of counts of unique individuals, number of visits by individuals, and duration of visits by individuals. Camera surveys are often conducted during phases of the deer reproductive season (prerut, rut, and postrut), and we conducted our study during these periods in an effort to reflect realistic survey timing and capture temporal variations in deer use of baited sites. Our objective was to determine specific characteristics of deer use of baited sites by phase of breeding season to aid in selection of survey periods and camera delay intervals.

Study Area

We conducted this study at Auburn University's Deer Research Facility which is located in the Piedmont region of east-central Alabama. The facility was constructed in October 2007 and consists of 174 ha enclosed by 2.6-m steel fence designed to inhibit deer movements. The enclosed population is comprised of wild animals captured during construction and their descendants. White-tailed deer at the facility breed during mid-December to mid-February, with peak conception at approximately January 18 (Neuman et al. 2016).

Vegetation within the enclosure was approximately 40% open fields maintained for hay production, 13% bottomland hardwoods (various oak [*Quercus* spp.]), 26% mature, naturally regenerated mixed hardwoods (various oak and hickory [*Carya* spp.]) and loblolly pine (*Pinus taeda*), 11% early regenerated thicket areas consisting primarily of *Rubus* spp., sweetgum (*Liquidambar styraciflua*), eastern red cedar (*Juniperus virginina*), and Chinese privet (*Ligustrun sinense*), and 10% 10- to 15-year-old loblolly pine. A 2nd order creek bisected the property and provided a stable source of water year-round. Three feeders provided a 16%–18% extruded protein feed (Record Rack, Nutrena Feeds) available ad libitum. Four timed feeders each provided deer approximately 2 kg day^{-1} of corn during periods when we were actively capturing deer each year. Two 0.8-ha fenced plots were planted annually in various warm and cool season forages as part of other ongoing research projects. Deer were allowed to rotationally graze fenced forage plots at regular intervals throughout much of each year.

Methods

We chemically immobilized and captured adult (≥6 months) deer over 7 trapping seasons (~ 1 October–1 July) from 2008–2014 as part of additional research objectives. All methods were approved by the Auburn University Institutional Animal Care and Use Committee (2008-1417, 2008-1421, 2010-1785, 2011-1971, and 2013-2372), and followed the American Society of Mammalogists' guidelines (Sikes and Gannon 2011). Deer were immobilized using a combined intramuscular injection of Telazol (Fort Dodge Animal Health, Fort Dodge, Iowa; 100 mg ml^{-1} given at a rate of 4.5 mg kg^{-1}) and xylazine (Lloyd Laboratories, Shenandoah, Iowa; 100 mg ml^{-1} given at a rate of 2.2 mg kg^{-1}) followed by reversal with the antagonist Tolazine (Lloyd Laboratories, Shenandoah, Iowa; 100 mg ml^{-1} given at a rate of 6.6 mg kg^{-1}) (Miller et al. 2004). Chemical immobilization was primarily delivered using cartridge fired dart guns (Pneu-Dart, Inc., Williamsport, Pennsylvania) equipped with night vision scopes and transmitter darts at feeders (Saalfeld and Ditchkoff 2007). At initial capture, sex was recorded and animals were aged using tooth wear and replacement (Severinghaus 1949). Animals were given a unique three-digit identification number corresponding with age and capture order which was displayed on highly visible ear tags and freeze brands on the front shoulder and hind quarter.

We placed infrared-triggered cameras ($n = 6$) at feeders and random sites baited with corn during ~ 26 February–12 March 2008–2014, and used the collected images of marked and unmarked deer to estimate annual deer abundance using mark-recapture methods. These data were used in conjunction with field observations and capture and mortality records to determine final population demographic estimates. Marked animals were not fitted with devices indicating mortalities, and we considered marked individuals not observed for two years to be dead.

We conducted this study during three 10-day test periods corresponding with phases of the deer breeding season (prerut, 18–28 November 2013; rut, 15–25 January 2014; postrut, 27 February–8 March 2014). We randomly selected bait sites ($n = 3$) for each test period. We placed an infrared-triggered camera (Reconyx PC 800) set to capture images at 1-minute time-lapse intervals 3.66 m from the center of bait pile at each site. We placed three wooden stakes 4.57 m from cameras in a radial manner in the viewed area to provide a distance reference. Sites were pre-baited with corn for five days prior to test periods, and bait was replenished daily as needed to ensure corn was continuously available during each test period. In an effort to standardize data collection and ensure the integrity of our data, we only used images of deer that were within the area bounded by stakes and could be positively identified by unique ID numbers. A visit, according to our criteria, began when the identifiable deer entered the staked area and ended when the individual left the area; however, the individual had to be absent from images for >10 minutes in order for a consecutive image to be considered a new visit. We assumed that visiting individuals not present in consecutive images for brief (<10-minute) periods before returning remained in the immediate area; therefore, the total time the individual was in the area, including time present in images and time not in images but assumed in immediate area, was recorded as the visit duration. We used generalized mixed-effects regression with Poisson distribution in Program R (R core development team, version 3.0.2 accessed 1 January 2016) to examine influence of sex and survey period on number of visits and duration of visits made by deer to baited sites. Random effects terms for site and animal identification number were included in all models to account for variation associated with these effects. We present model estimates using odds ratios in accordance with standard reporting methods of Poisson distributions.

Results

Population monitoring efforts indicated that <90% of adult (≥1.5 years) deer present in the facility were marked at the time of our study, with the marked adult population estimated to be 104 individuals (Table 1). The adult sex ratio was estimated to be nearly balanced, and a wide range of age classes were represented in the population.

Trail cameras captured 10,931 images of 98 marked individual deer (48 males, 50 females) visiting baited sites during the three observation periods (Table 2). We observed the fewest marked individual deer at baited sites during prerut but obtained the greatest number of images during this period. We observed the greatest number of marked males during rut; however, we obtained the fewest images of male deer during this period. We observed the greatest number of marked male and female deer during postrut.

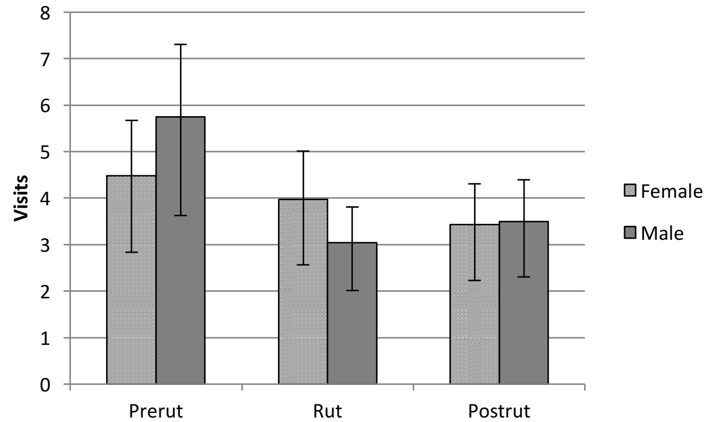

Figure 1. Mean (95% CL) number of visits made by individually-marked white-tailed deer to baited sites during 10-day sampling periods corresponding with prerut (18–28 November 2013), rut (15–25 January 2014), and postrut (27 February–9 March 2014), Auburn University Captive Deer Research Facility, Alabama.

Table 1. Estimated abundances of marked white-tailed deer in breeding populations by sex and age, Auburn University Captive Deer Research Facility, Alabama, 15 March 2014.

	Age (years)										
	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	Total
Male	13	7	8	9	4	6	3	1	1	NA	54
Female	10	11	5	5	3	6	5	3	1	1	50

Table 2. Summary of time lapse (1 minute) trail camera data of white-tailed deer collected during three 10-day periods corresponding with prerut (18–28 November 2013), rut (15–25 January 2014), and postrut (27 February–9 March 2014), Auburn University Captive Deer Research Facility, Alabama.

		Individuals		Images	
Period	Site	Male	Female	Male	Female
Prerut	1	9	5	980	375
	2	10	14	613	500
	3	4	8	420	969
	All	23	28	2013	1844
Rut	1	23	16	555	679
	2	21	12	467	472
	3	18	9	482	692
	All	39	31	1504	1843
Postrut	1	22	18	930	342
	2	21	15	634	543
	3	11	11	548	730
	All	38	41	2112	1615

Males made 1.89 (95% CL = 1.50 to 2.39; $P < 0.001$) times as many visits to baited sites during prerut than rut, and 1.64 (95% CL = 1.30 to 2.08; $P < 0.001$) times as many visits during prerut than postrut (Figure 1). Males made similar number of visits to baited sites during rut and postrut ($\text{Exp}(\beta) = 1.15$; 95% CL = 0.93 to 1.42; $P = 0.19$). Females made similar number of visits to baited sites during prerut and rut ($\text{Exp}(\beta) = 1.12$; 95% CL = 0.89 to 1.43; $P = 0.30$) and rut and postrut ($\text{Exp}(\beta) = 1.16$; 95% CL = 0.92 to 1.45; $P = 0.20$); however, we observed that females made 1.30 (95% CL = 1.03 to 1.66; $P = 0.02$) times as many visits to baited sites during the prerut than postrut. We found no evidence of differences between male and female deer in numbers of visits to baited sites during prerut ($\text{Exp}\ (\beta) = 1.28$; 95% CL = 0.94 to 1.75; $P = 0.11$) and postrut ($\text{Exp}\ (\beta) = 1.02$; 95% CL = 0.77 to 1.34; $P = 0.90$); however, we detected a marginally significant difference between number of visits made by males and females during rut, with females making 1.30 (95% CL = 0.98 to 1.73; $P = 0.06$) times as many visits as males.

Duration of visits by male deer to baited sites during prerut was longer than those occurring in rut ($\text{Exp}\ (\beta) = 1.85$; 95% CL = 1.71 to 2.00; $P < 0.001$) and postrut ($\text{Exp}\ (\beta) = 1.35$; 95% CL = 1.25 to 1.45; $P < 0.001$; Figure 2). Male visits during postrut were also longer ($\text{Exp}\ (\beta) = 1.36$; 95% CL = 1.27 to 1.47; $P < 0.001$) than those occurring during rut. Duration of visits by female deer to sites during prerut was longer than those occurring in rut ($\text{Exp}\ (\beta) = 1.08$; 95% CL = 1.00 to 1.16; $P = 0.04$) and postrut ($\text{Exp}\ (\beta) = 1.32$; 95%

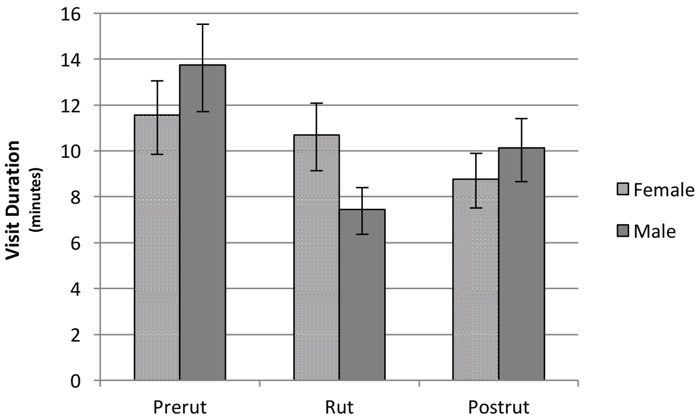

Figure 2. Mean (95% CL) duration (minutes) of visits made by individually-marked white-tailed deer to baited sites during 10-day sampling periods corresponding with phases of the breeding season prerut (1–28 November 2013), rut (15–25 January 2014), and postrut (27 February–9 March 2014), Auburn University Captive Deer Research Facility, Alabama.

CL = 1.23 to 1.43; $P < 0.001$), and female visits were longer during rut than postrut (Exp (β) = 1.21; 95% CI = 1.12 to 1.32; $P < 0.001$). We observed that male deer spent more time at baited sites during visits than females during prerut (Exp (β) = 1.19; 95% CL = 1.02 to 1.38; $P = 0.02$) and postrut (Exp (β) = 1.15; 95% CI = 1.00 to 1.34; $P = 0.05$); however, duration of female visits was longer than male visits during rut (Exp (β) = 1.44; 95% CL = 1.24 to 1.67; $P < 0.001$).

Discussion

Camera survey methods that estimate population parameters using non-standardized counts of deer and inferred detectability between categorical groups are subject to inaccuracies when deer groups do not use survey sites in a similar manner (Larrucea et al. 2007, Weckel et al. 2011). The use of bait may contribute to these errors as the attractiveness of bait can vary between sexes and age classes of deer in relation to resource availability, nutritional needs, and other behavioral factors (McCoy et al. 2011). The number of deer images collected during a survey (i.e., deer use) is a function of the total number of individuals visiting sites, the number of visits made by individuals, and the duration of visits by individuals. We observed that adult deer use of baited sites, in these terms, varied across the breeding season according to sex, and our findings have important implications for individuals utilizing camera surveys for deer.

The increased use of bait sites, in terms of number of visits and visit duration, by both sexes during the prerut period indicated that bait may have been highly attractive to deer that encountered baited sites during this period. Female deer are in the process of weaning fawns or recovering from the nutritional stresses of lactation and male deer are building fat reserves for upcoming breeding efforts during prerut, and these nutritional demands likely contributed to increased use of baited sites (Therrien et al. 2008). The detection of fewer individuals at baited sites during prerut may have been due in part to decreased space use by males during this period. Male deer have been known to greatly expand home ranges during reproductive periods, and our monitoring efforts during prerut may have occurred prior to seasonal increases in male home range size (Beier and McCullough 1990, Holtfreter 2008).

The decrease in number of visits and duration of visits by male deer to baited sites from prerut to rut may have been attributed to behavioral changes associated with breeding efforts. These results are not surprising as male ungulates are known to greatly reduce feeding activities during the rut in an effort to maximize reproductive related activities (e.g., fighting, mate guarding) (Geist 1998). It was interesting, however, that reductions in these facets of deer use occurred concordantly with a 70% increase in detection of individual males and an increase in use of multiple survey sites by males. These increases are likely associated with the previously described expansion of male home range sizes and increased overall movements during rut; however, males may also be using bait sites as a method for mate acquisition (Foley et al. 2015). Male ungulates have been known to utilize resource defense as a reproductive strategy when valuable food resources are available (Carranza et al. 1995). Male deer in our study may have been utilizing baited sites as a means for locating receptive females in addition to nutritional resources, which may have accounted for increased detection of individual males at baited sites during rut.

In terms of sex ratio and numbers of visiting individuals, we found that the most accurate representation of the population occurred during the postrut. The postrut occurs during a period of low forage availability and peak nutritional demand in our study area as it coincides with the end of winter prior to spring green-up, the end of breeding activities, and the beginning stages of pregnancy in female deer. Movement rates have also been shown to remain high for many deer groups following the breeding season in areas where winter temperatures are relatively warm (Holtfreter 2008, Sullivan 2016). High energy resources were likely very attractive and deer movement rates were likely high resulting in high detectability and visitation rates of adult deer at our baited sites during postrut. The density of adult deer in our enclosure (56 adult deer/km^2) was higher than most wild populations, placing additional pressure on nutritional resources. Protein feed was provided ad libitum to supplement the nutritional needs of our herd; however, the increased forage demands associated with high deer density may have contributed to the attractiveness of baited sites during postrut despite the continuous availability of supplemental feed.

Recent technological advancements have increased power efficiency, available user settings, and data storage capacity of cameras, and these advancements have vastly increased the amount of data that can be collected during camera surveys. Although the ability to collect more data can be viewed positively in many ways, it is important to maintain an understanding of how these advancements can influence survey results. Previous research efforts have investigated the influence of various technical aspects of camera survey methods, such as camera performance by brand, camera density, and survey duration, on population estimates (McKinley et al. 2006, Wellington et al. 2014). Surprisingly, very little attention has been given to camera delay interval. Survey methods that are subject to sex-related bias when bait is used may reduce potential bias by selecting delay intervals that more closely consider animal behavior. For example, potential bias associated with the increased duration of female visits to baited sites during rut could potentially have been mitigated by selecting a 10-minute delay interval, as relatively equal pictures of each sex would be gathered, in theory, despite the differences in site use. In this case, decreasing the delay interval in an effort to collect more data would in fact increase the probability of capturing more images of females relative to males, thereby contributing to sex-related bias.

N-mixture models are emerging as an alternative method of estimating deer population parameters from camera images (Royle 2004, Dail and Madsen 2011, Zipkin et al. 2014). These methods may provide advancements over traditional survey methods since they do not rely on identification of individuals to generate abundance estimates; however, these methods remain subject to assumptions of equal detectability and potential inaccuracies when bait is used to attract deer. Traditional N-mixture methods assume that individuals do not visit more than one survey site and deer in consecutive images are different individuals (Royle 2004). We observed variations across phases of the breeding season in the numbers of baited survey sites used by individual deer, and these differences should be considered by users of these methods when selecting camera density. Our camera density (1/60 ha) was largely sufficient in meeting assumptions of independence during prerut as only one female deer was viewed at multiple sites, but was insufficient during other survey periods. Camera delay intervals for surveys using N-mixture models should be selected in a manner that considers the described seasonal trends in visit duration to ensure independence among deer counts.

Management Recommendations

Individuals using camera surveys for deer should carefully consider survey timing and camera delay settings when bait is used in order to minimize unwanted bias. Identification of specific survey goals will aid in the selection process. We observed that male and female deer used baited sites in the most similar manner during postrut, and these findings support the use of postrut surveys to estimate adult sex-ratio. Surveys conducted during postrut may also provide the most representative abundance estimates, as we observed the greatest number of individual deer during this period. The detection of fewer individuals at higher rates during prerut than postrut will result in greater precision in abundance output when using N-mixture models; however, abundance estimates generated using postrut data may provide a greater level of accuracy due to greater detection of individuals. Surveys conducted during rut will be subject to the greatest level sex-related bias and consequently should be conducted with caution. Selecting camera delay intervals of lengths that reflect the maximum average duration of visit of all deer groups (e.g., 10 minutes in our study) may help reduce sex-related bias.

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