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Note

Bias Associated With Baited Camera Sites for Assessing Population Characteristics of Deer

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ABSTRACT Camera surveys often involve placing bait in front of the camera to capture animals more frequently, which could introduce biases in parameter estimates. From September 2008 to March 2009, we monitored cameras placed at random, along game trails, and at feed stations to determine if camera placement influenced measures of population demographics in a herd of white-tailed deer (*Odocoileus virginianus*). There was no time period in which cameras placed at feed stations provided sex ratio and recruitment estimates similar to those acquired from randomly placed cameras. Trail-based camera surveys provided population estimates similar to those from random sites and may provide a feasible alternative to using baited camera stations. © 2011 The Wildlife Society.

KEY WORDS bait, bias, camera, *Odocoileus virginianus*, population monitoring, random sampling, trail camera, white-tailed deer.

The use of remote photography in wildlife science has become increasingly popular in recent years, especially since the development of infrared-triggered camera systems. Cameras have proved useful in answering a variety of wildlife questions related to nest predation (Hunt and Ogden 1991), feeding ecology (Hanula and Franzreb 1995, Pradsad et al. 2009), activity patterns (van Schaik and Griffiths 1996, Larrucea and Brussard 2009), species presence and abundance (Kelley and Holub 2008, Sarmento et al. 2009, Pettorelli et al. 2010, Treves et al. 2010), and habitat use (Main and Richardson 2002, Harmsen et al. 2010). Camera systems are less invasive and more cost efficient than most observation methods (Cutler and Swann 1999). In addition, cameras are less labor intensive, provide permanent documentation of captured animals, and provide the opportunity to gather data during otherwise difficult times (e.g., inclement weather, at night; Seydack 1984, Bull et al. 1992).

Remote photography has also been used to estimate population parameters among a variety of species (Karanth et al. 2004, Varma et al. 2006, Gerber et al. 2010, Harihar et al. 2010), including white-tailed deer (*Odocoileus virginianus*; Jacobson et al. 1997, Roberts et al. 2006). Because of the importance of white-tailed deer as a game species, reliable estimates of population parameters are critical to making management and harvest decisions. Numerous methodologies have been employed to estimate population parameters of white-tailed deer populations but most have drawbacks. Aerial surveys, by way of helicopter counts, are costly and are not practical in most regions of the white-tailed deer range (Koerth et al. 1997). Line transects involving pellet group and track counts (Mooty and Karns 1984) are labor intensive and do not provide information regarding age structure or sex ratios. Historically, spotlight surveys were the most commonly used method of estimating population parameters, but spotlight surveys have low and highly variable detection probabilities (Collier et al. 2007). Thermal imaging equipment has also been used to detect animals, but equipment costs are high (Collier et al. 2007).

Remote photography, because of its ease of use and cost efficiency, seems to be increasing in popularity as a tool for scientists and wildlife biologists, and is even a popular technique for managing deer populations among landowners outside the scientific community. Jacobson et al. (1997) developed a technique to estimate population density of deer in Mississippi using infrared-triggered cameras. Jacobson et al. (1997) identified individual males based on antler configurations and used ratios of all animals photographed to determine population size and sex ratios. However, camera surveys as a census technique involves placing bait (usually shelled corn) in front of the camera to capture animals more frequently (Jacobson et al. 1997, Koerth et al. 1997). Jacobson et al. (1997) cautioned that individual deer may not use bait equally, and, as a result, the possibility exists for biased estimates. Unequal detectability (Larrucea et al. 2007) among sexes or age classes would bias parameter estimates and could ultimately lead to misinformed management decisions.

We had a unique opportunity in a fenced, high-density population to monitor random camera sites, which should provide the least biased approximation of population structure. Our objective was to compare proportions of animals captured at feed stations and along game trails to those captured at random sites to determine if animals captured

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at baited sites and along trails differed from those captured at random locations. We also examined seasonal fluctuations in feeder use, with a specific emphasis on determining the best time of year to conduct a camera survey that yields the least biased population parameters.

STUDY AREA

We conducted our research on the property of the Three Notch Wildlife Research Foundation (hereafter Three Notch), located in east-central Alabama, approximately 10 km east of Union Springs in Bullock County. The study area encompassed 258.2 ha and had been enclosed by 3-m deer-proof fencing since 1997. Food plots and supplemental feeding provided the deer herd with a high quality diet throughout the year. A high protein commercial deer feed (20% protein; Purina Antlermax, St. Louis, MO) was provided ad libitum in 12 permanent feed troughs uniformly distributed across the property. Approximately 20% of the available habitat (48 ha) was farmed to provide deer with an array of food sources. Warm-season food plots generally consisted of iron and clay peas, corn, and various clovers, whereas cool-season plots were usually made up of winter rye and white clover.

Forest cover on the site varied from open, mature stands of loblolly pine (*Pinus taeda*) in upland areas, to dense overstories of oaks (*Quercus* spp.) in creek drainages. Ridges were primarily dominated by loblolly pine or food plots, and lowland areas were planted in clover. Prescribed fire was used each year in upland areas to facilitate searches for shed antlers as well as to provide natural browse for deer. Water sources on the site included the headwaters of the Pea River and a large centrally located pond (approx. 20 ha) that provided the deer herd with an abundant year-round water source.

Hunting on the property was non-commercial and generally limited only to the landowner and family members. Archery was the primary method of harvest, with approximately 40 deer harvested per year (approx. 30–40% males). Harvest was limited to mature males ($\geq$5 yr old) and females of any age class. Due to limited hunting success (archery equipment only), the selective nature of the landowner, and an abundance of food sources, population control within the enclosure was a challenge. These factors combined to create a high density population with a skewed sex ratio favoring males. A prestudy camera survey using the methodology of Jacobson et al. (1997) estimated density at $\geq$1 deer per 1.7 ha, which is >3 times the density normally found in this region. Analysis of the prestudy survey also indicated that the adult sex ratio favored males, at approximately a 2:1 (M:F) ratio.

METHODS

We used 8 commercially available PixController DigitalEye 7.2 MP trail cameras (PixController, Inc., Export, PA), which each consisted of a 7.2-megapixel digital camera attached to a passive infrared (PIR) motion sensor, all encased within a weather-resistant shell. We used the integrated Trail Mode setting for cameras set randomly and along well-used trails. The Trail Mode feature kept the digital camera powered up for 30 s after taking a photo so that all animals passing by at a given time could be photographed. Each additional time the PIR sensor was triggered, the 30-s window was extended. Previous research found that deer feed at trough feeders for a mean of 2.6–10 min (Zaiglin and DeYoung 1989, Kozicky 1997), so we used a time interval of 5 min for cameras placed at feed stations to reduce replicate pictures of the same individuals (Koerth and Kroll 2000).

We monitored cameras placed at random, along heavily used game trails, and at feed stations from 11 September 2008–5 March 2009. Each sampling period consisted of 1 week, for a total of 19 sampling periods. During each sampling period we randomly generated 3 Global Positioning System (GPS) locations for random treatments and 3 locations for trail treatments, and we randomly selected 2 of the 12 feed stations to place our cameras. To standardize our random sites, we oriented all random cameras facing north, so as to minimize observer bias in placement as well as to avoid glare from the rising or setting sun. When placing cameras on trails, we navigated to the randomly generated GPS location and then searched for the closest, heavily used game trail. At feed stations, which were generally located in open fields, we attached cameras to a T-post driven into the ground approximately 3 m away from the feed trough. We oriented cameras at these feed stations at an approximately 45° angle to the feed trough to attain maximum coverage of the feeding area.

We designed our study to simulate an actual camera survey that one would conduct to estimate population demographics. Because we could not differentiate all individual deer, cameras placed at feeders quantify frequency of utilization rather than population structure. As such, our goal was to determine if the frequency of utilization at feeders was similar to an approximation of population structure, which was provided by the random camera sites.

We recorded the number of fawns, females, and males in each photograph. We categorized males into 3 age classes based on antler and body characteristics: yearling (1.5 yr), adult (2.5–3.5 yr), and mature ($\geq$3.5 yr). In our analysis, we only included photographs where we could positively identify age and sex of the deer. To further improve our ability to correctly identify animals, we only used photographs of deer that were within approximately 10 m of the camera. At random and trail sites where we set cameras to take photographs without delay, some deer were photographed multiple times on the same occasion. In these instances, we only counted individuals once. We did not have a reliable method of differentiating individual deer, so we assumed that each individual was equally likely to be detected multiple times throughout the study period. We used 4 seasons to determine any seasonal effects: fall (11 Sep–31 Oct), prerut (1 Nov–26 Dec), rut (6 Jan–7 Feb), and postrut (8 Feb–5 Mar).

We modeled the data using R (R Version 2.11.1, www.r-project.org, accessed 17 Oct 2009). Specifically, we used the function "lmer" within the package "lme4" to run a mixed-effects Poisson regression. We used the number of fawns, females, and yearling or adult males in each picture as our dependent variable and the total number of deer in each photograph as an offset. The model consisted of all main effects of season, treatment (random, trail, or feeder placement), and animal class, all associated interactions, and camera site as a random effect. Upon initial examination, we detected no differences between adult and mature males, so on the basis of parsimony, we combined these into one variable and re-ran the model. We ran a negative binomial (quasipoisson) to test for overdispersion and determined that the mixed-effects Poisson model was adequate. We used female as the reference class, random as the reference treatment, and fall as the reference season. When making comparisons, we calculated 95% confidence intervals of effect sizes of each parameter to determine if they differed from zero.

RESULTS

We counted 5,311 deer in 3,972 distinct photographs. Not surprisingly, we photographed more deer at feed stations ($n = 4,003$; 75.37%) than at random ($n = 461$; 8.68%) or trail ($n = 847$; 15.95%) sites. At feed stations, specifically, we photographed more deer during fall ($n = 2,729$; 68.17%) than during prerut ($n = 467$; 11.67%), rut ($n = 360$; 8.99%), or postrut ($n = 447$; 11.17%) periods. At both random and trail sites, we photographed similar numbers of deer during each season. At random sites, we photographed 131 (28.42%) deer during fall, 135 (29.28%) in the prerut, 126 (27.33%) in the rut, and 69 (14.97%) in the postrut period. We photographed 231 (27.27%) deer at trail sites during fall, 198 (23.38%) in the prerut, 229 (27.04%) in the rut, and 189 (22.31%) in the postrut.

Female use of feeders was similar to random sites during all seasons, but there were differences in the use of feeders compared to random sites among fawns, yearling males, and adult males (Table 1 and Fig. 1). During fall, the proportion of fawns captured at random was 3.10 times greater than those captured at feed stations (95% CL = 1.63–5.75), and yearling buck proportions were 1.86 times greater at feeders than at random sites (95% CL = 1.05–3.29). During the prerut, proportions of yearling and adult bucks photographed at random were 1.77 (95% CL = 1.03–3.04) and 1.53 (95% CL = 1.06–2.20) times greater than those at feed stations, respectively. Likewise, during the rut, proportions of yearling and adult bucks photographed at random were 2.41 (95% CL = 1.23–4.71) and 4.85 (95% CL = 3.35–7.03) times greater than those at feed stations, respectively. Proportions of fawns captured with cameras at feed stations were 1.67 (95% CL = 1.14–2.44), 5.47 (95% CL = 3.19–4.39), and 2.61 (95% CL = 1.28–5.31) times greater than those captured at random sites during the prerut, rut, and postrut periods, respectively. Trail-based cameras provided estimates similar to those from random cameras in all but 2 cases. Proportions of adult bucks photo-captured at random sites during fall and postrut were 1.37 (95% CL = 1.02–1.86) and 1.51 (95% CL = 1.04–2.18) times greater than those from trail-based cameras, respectively. The proportion of adult males caught at random during fall, rut, and postrut was ≥1.87 (95% CL = 1.28–2.74) times greater than those caught during the prerut; as a result, we observed greater proportions of females and fawns at random and trail sites during the prerut.

DISCUSSION

Because important management decisions are based on sex ratios and recruitment rates gleaned from photographic data, verifying that these parameters are accurately assessed with use of bait is critical. We found that feed stations did not provide assessments of population structure similar to those generated using random cameras during any single time period. Koerth and Kroll (2000), in a similar study, hypothesized that baited camera sites did not provide accurate estimates of sex and age structure during any single time period, although those authors did not have a baseline estimate of population structure to compare. Camera surveys conducted at feed stations during both the fall (preseason) and postrut periods provided estimates of adult population structure similar to those generated by random cameras but

Table 1. Counts, proportions (Prop.), and associated confidence limits (CL) of fawns, does, yearling bucks, and adult bucks captured with infrared-triggered cameras during the fall (11 Sep–31 Oct), prerut (1 Nov–26 Dec), rut (6 Jan–7 Feb), and postrut (8 Feb–5 Mar) at Three Notch in east-central Alabama, USA, 2008–2009.

	Fawns			F			Yearling M			Ad M		
Season	**Feeder**	**Random**	**Trail**	**Feeder**	**Random**	**Trail**	**Feeder**	**Random**	**Trail**	**Feeder**	**Random**	**Trail**
Fall												
Count	73	11	21	769	33	74	455	12	39	1,432	75	97
Prop.	0.03	0.08	0.09	0.28	0.25	0.32	0.17	0.09	0.17	0.52	0.57	0.42
CL	0.02–0.03	0.05–0.14	0.06–0.14	0.27–0.30	0.19–0.33	0.26–0.38	0.15–0.18	0.05–0.15	0.13–0.22	0.51–0.54	0.49–0.65	0.36–0.48
Prerut												
Count	178	31	40	157	43	81	39	20	20	93	41	57
Prop.	0.38	0.23	0.20	0.34	0.32	0.41	0.08	0.15	0.10	0.20	0.30	0.29
CL	0.34–0.43	0.17–0.31	0.15–0.26	0.29–0.38	0.25–0.40	0.34–0.48	0.06–0.11	0.10–0.22	0.07–0.15	0.17–0.24	0.23–0.39	0.23–0.35
Rut												
Count	219	14	25	77	19	41	19	16	41	45	77	122
Prop.	0.61	0.11	0.11	0.21	0.15	0.18	0.05	0.13	0.18	0.13	0.61	0.53
CL	0.56–0.66	0.07–0.18	0.08–0.16	0.17–0.26	0.10–0.22	0.13–0.23	0.03–0.08	0.08–0.20	0.13–0.23	0.09–0.16	0.52–0.69	0.47–0.60
Postrut												
Count	135	8	31	66	10	52	24	8	28	222	43	78
Prop.	0.30	0.12	0.16	0.15	0.14	0.28	0.05	0.12	0.15	0.50	0.62	0.41
CL	0.26–0.35	0.06–0.21	0.12–0.22	0.12–0.18	0.08–0.25	0.22–0.34	0.04–0.08	0.06–0.21	0.10–0.21	0.45–0.54	0.51–0.73	0.34–0.48

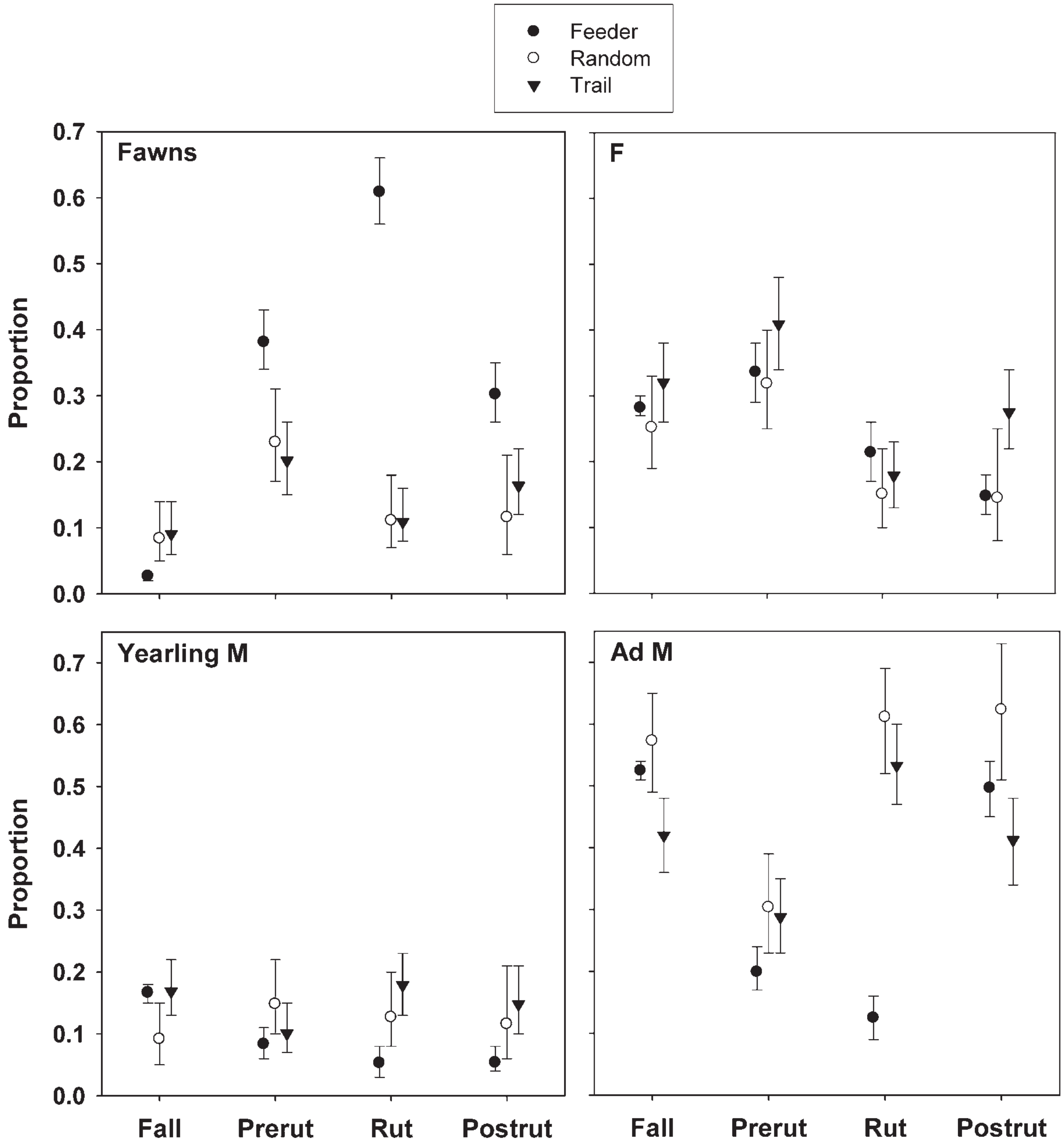

Figure 1. Proportions of fawns, females, yearling males, and adult male white-tailed deer captured at feed stations, random, and trail sites during fall (11 Sep–31 Oct), prerut (1 Nov–26 Dec), rut (6 Jan–7 Feb), and postrut (8 Feb–5 Mar) at Three Notch in east-central Alabama, USA, 2008–2009.

did not provide reliable estimates for fawns. In populations that breed in November and give birth in spring, a fall camera survey may provide more accurate data on fawn abundance than we observed. Fawns in our study area are born during August and were not yet very mobile at the time of the fall survey (Causey 1990, J. C. McCoy, Auburn University, unpublished data). As a result, in most parts of Alabama and other areas where breeding occurs in January, preseason camera surveys are likely to underestimate recruitment because fawns are not active during this period. In populations where most breeding occurs in January, multiple-season camera surveys may be necessary to accurately estimate all population parameters.

The lack of feeder use by males and heavy use by fawns during the prerut and rut periods suggests that interpretation of population structure during these periods may be biased. Adult males were underrepresented at feed stations during the rut, which is not surprising, as male ungulates reduce feeding effort during the breeding season due to the conflicting time constraints of finding food and participating in rutting activities (e.g., fighting, dominance displays, chasing; Espmark 1964, Coblentz 1976, Lincoln and Short 1980, Geist 1982). Similarly, fawns do not actively participate in rutting activities and may be more inclined to visit feed stations in the absence of older individuals that are involved in breeding.

Estimating sex ratio is an integral part of deer management as well as a key aspect of estimating population density (Jacobson et al. 1997). Sex ratio estimates from camera surveys at feed stations may be inaccurate during any time period other than fall. For example, our predicted sex ratio using random sites during the fall survey was 2.64 (M:F). Using photographs from feed stations during this same period yielded a sex ratio estimate of 2.45, similar to the random estimate. However, our data from feed stations yielded sex ratios that were not consistent with those generated from photographs collected at random sites throughout the remainder of the study. Sex ratio estimates at feed stations during the prerut, rut, and postrut periods were 0.84, 0.83, and 3.73, respectively, while estimates generated with data from random sites during the same periods were 1.42, 4.89, and 5.10, respectively.

We hypothesize that the extreme sex ratio estimates garnered from the random sites during the rut and postrut were due to the extreme harvest pressure on females, thus the proportion of females in the population dropped considerably by the end of the study. At Three Notch, according to previous population estimates, there were approximately 35–40 females in the population before hunting season (approx. 25% of the population), so harvest of females during our study would have substantially reduced their proportion. Specifically, 13 females were harvested during fall and prerut periods, which would have dropped the proportion of females in the population from 25% to 14–18%, which is close to estimates we acquired from our random cameras during the rut and postrut periods.

Recruitment estimates (fawns per F) are also important for deer managers and provide critical information regarding reproductive health of the herd. During fall, we infrequently captured fawns in photographs at all 3 camera treatments, most likely because fawns in our study area are born during August and were not yet very mobile (Causey 1990, J. C. McCoy, unpublished data). In contrast, we found that estimates of recruitment would be grossly overestimated at feed stations during the remainder of the study period. Our estimates of recruitment using random sites were similar throughout the study: 0.72, 0.74, and 0.80 for the prerut, rut, and postrut periods, respectively. However, during those same periods we estimated recruitment at 1.13, 2.84, and 2.05, respectively, at feed stations. Feed stations are thus apparently not suitable locations for estimating recruitment.

Our results suggest that trails provide population estimates similar to those from randomly placed cameras during most seasons and thus may provide an alternative and less biased means for conducting camera surveys. Because we recorded almost twice as many photographs at trail sites than at random sites, trail-based camera surveys could also be more efficient and provide larger sample sizes than could randomly placed cameras. Studies designed to collect biological samples for white-tailed deer (e.g., hair, urine, feces) might benefit from a similar sampling scheme. Sampling studies are often hampered by an insufficient sample size from random sampling (e.g., line transects). Because trails may offer an unbiased estimation of population structure, researchers may be able to collect unbiased samples more efficiently by concentrating sample collection in areas of substantial animal use, such as game trails (Ditchkoff and Servello 2002, Beier et al. 2005, J. C. McCoy, unpublished data).

Accuracy of random and trail-based camera sites hinges on an assumption that movement rates are the same for all classes of animals during each time period. For example, fawns are not very active for the first few weeks after birth (Jackson et al. 1972, Schwede et al. 1994), so fawns are likely underrepresented in fall surveys. Additionally, our data suggest that adult males may have suppressed activity levels during the prerut (as they were underrepresented at all camera sites during this time), possibly in anticipation of the excessive energy demands associated with the rut. Holtfreter (2008) reported that movement rates of mature bucks increased 27% from the prerut to the rut and remained elevated during the postrut. Several other studies documented increased movement rates of male white-tailed deer from prerut to rut (Kammermeyer and Marchinton 1976, Beier and McCullough 1990, Tomberlin 2007).

Another important factor to consider when using baited camera sites is individual variation in behavior and preference. Our study is based on overall proportions of animals captured at each treatment, but we were not able to consider possible variability in individual behavior and tendencies. Campbell et al. (2006) found that radio-collared females in West Virginia displayed high variability in response to bait sites, where some deer did not use bait sites at all and others used as many as 4 sites within a 2 weeks. If baited sites are to be used, one may need to consider this variability among individuals, but variability in individual behavior may be similar across all sex and age classes, thus not compromising sex ratio and recruitment estimates.

MANAGEMENT IMPLICATIONS

We were able to photograph 461 deer at random locations throughout a 6-month long survey conducted in a high-fence enclosure. Aside from possible variability in seasonal movement patterns, randomly placed cameras should provide the least biased approximation of population structure. However, in other, less dense free-ranging populations fewer deer would likely be photographed at random locations. Additionally, surveys on trails may have lower sample sizes than we found. Sampling schemes designed to assess population structure using random or trail-based cameras need to consider how population density may influence sample size. The number of cameras used, or the amount of time that cameras are deployed, may need to be increased. Use of bait or other attractants to increase activity around cameras, as has been done historically, does not provide population estimates similar to those generated by random or trail-based cameras except for certain periods during the year. We note that the periods during which bait sites may allow for accurate population estimates will vary regionally, or even statewide, as the timing of the breeding season and its effects on deer activity patterns varies.

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