Feral Pig Detectability with Game Cameras

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Abstract: The use of game cameras for surveying and estimating populations of large mammals has become increasingly popular over the past two decades; however, few studies have examined logistics or patterns of animal detection using cameras. We monitored feral pigs (*Sus scrofa*) for seven consecutive 24-hour periods at 73 pre-baited camera sites on Fort Benning, Georgia, to determine the minimum length of time cameras must be deployed to attain sufficient detection probabilities for three classes of pigs (adult sows, adult boars, and juveniles). We sought to broaden this objective by examining the impact on predicted detection probabilities associated with nocturnal versus diurnal sampling. Predicted detection probabilities for each class exceeded 0.5 following the third day of camera deployment. Results suggest estimation of feral pig abundance may be improved by minimizing sampling periods to three 24-hour periods per monitoring station following a uniform pre-baiting schedule. Sampling may be reduced to nocturnal periods for adult pigs without greatly impacting their detection probabilities; however, detection of juveniles may be slightly diminished. Minimizing monitoring periods as suggested will reduce costs associated with maintaining baited monitoring stations and decrease potential negative influences of human scent at bait sites. Limiting sampling periods will also reduce temporal heterogeneity in abundance estimates, while minimizing potential increases in survival/productivity associated with prolonged baiting.

Key words: baiting, camera surveying, density estimation, feral hogs, *Sus scrofa*

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Use of game cameras for surveying and estimating populations of large mammals has become increasingly popular (Seydack 1984, Jacobson et al. 1997, Larrucea et al. 2007). Cameras are often used to document, record, and estimate population parameters of uncommon or wary species, including large felids (Karanth 1995, Jackson et al. 2006, Soisalo and Cavalcanti 2006), canids (Larrucea et al. 2007), and other mammals (Bull et al. 1992, Martorello et al. 2001), as well as common game species such as white-tailed deer (Jacobson et al. 1997). Observation of animals via remote cameras facilitates collection of data during all hours of the day and under all weather conditions (Larrucea et al. 2007). Additionally, data collection using cameras often is less intrusive than methods that might otherwise rely on capture and handling of animals (Franzreb and Hanula 1995, Larrucea et al. 2007).

The combination of photographic technology with advanced computer modeling applications now allows researchers to use camera-collected data to examine population parameters (e.g., occupancy, density, sex ratio, recruitment) of selected species (Jacobson et al. 1997, Karanth and Nichols 1998, Sweitzer et al. 2000, Hanson 2006) in a cost-effective and logistically efficient manner. These data theoretically may be less affected by biases than traditional data collection methods; however, few studies (except, for example, Cutler and Swann 1999, Sweitzer et al. 2000, Larrucea et al. 2007) have examined logistics or patterns of animal detection using cameras. As the popularity of these techniques increases, researchers must strive to maximize efficiency in data collection via this technique, thereby reducing temporal heterogeneity as well as the amount of time cameras are deployed in the field and the costs associated with maintaining baited camera sites.

Limiting the amount of bait provided to an opportunistic, invasive, pulse-resource-driven species such as feral pigs (*Sus scrofa;* Ostfeld and Keesing 2000) is also attractive. Feral pigs are considered an invasive exotic due to their rapid expansion into 40 of the 50 states in the United States and parts of Canada (Ditchkoff and West 2007). Providing large quantities of bait over protracted periods of time may enhance pig survival, at least locally, and potentially lead to greater densities of the species (Ostfeld and Keesing 2000). By determining the necessary length of time cameras must be deployed to achieve adequate detection probabilities, the amount of bait that is used could be minimized, subsequently reducing the potential to enhance feral pig survival and productivity.

To this end, we monitored feral pigs for seven consecutive 24-hour sampling periods at multiple pre-baited camera sites on Fort Benning, Georgia. Our objective was to estimate detection probabilities for each 24-hour period following camera deployment to determine the point at which adequate detection probabilities were reached. In parts of south Georgia, feral pigs exhibit territorial behavior at the sounder level as well as a high degree of spatial fidelity at the individual level within sounders (Sparklin et al. 2009). Additionally, sounders in this area are relatively small in relation to other regions of their distribution, and do not include sub-groups (Hanson 2006, Sparklin et al. 2009). Consequently, we hypothesized the majority of uniquely identified individuals detected at pre-baited sites would be present throughout the seven, 24-hour sampling periods, with fewer previously unidentified individuals detected with each subsequent 24-hour period. We accordingly predicted adequate detection probabilities would be reached within the first few 24-hour periods. Feral pigs are generally more active during nocturnal periods than during the day (Russo et al. 1997). In that regard, we sought to broaden our objective by determining if detection probabilities would be greatly impacted by limiting sampling to nocturnal periods.

Study Site

This study was conducted on the Fort Benning Army Infantry Training installation located in west-central Georgia and east-central Alabama [3221 N, 8458 W]. Fort Benning was characterized by rolling hills and bottomlands typical of the Fall Line Sandhill area of the East Gulf Coastal Plain (Dilustro et al. 2002). Vegetation on the hills and slopes was dominated by plantations of multi-aged longleaf pine (*Pinus palustris*) interspersed with loblolly (*P. taeda*) and shortleaf pine (*P. echinata*; King et al. 1998). These stands were maintained using a 2- to 4-year prescribed burning rotation to preserve and enhance mature longleaf habitat required by the endangered red-cockaded woodpecker (*Picoides borealis*; King et al. 1998, Dilustro et al. 2002). Oak (*Quercus spp.*) and hickory (*Carya spp.*) were the dominant canopy species in the bottomlands (King et al. 1998); other plant species common throughout Fort Benning included sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandifolia*), flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*), blackberry (*Rubus spp.*), American beautyberry (*Callicarpa americana*), gallberry (*Ilex spp*.), and wax myrtle (*Myrica cerifera*; King et al. 1998). Hanson (2006) and Jolley (2007) provide further landscape descriptions of Fort Benning.

Our study was conducted on two, ~35-km^2 tracts of land previously delineated for research by managers at the Fort Benning Natural Resources Branch. Each area was representative of the forested portions of Fort Benning; however, the northern study site was dominated by upland pine habitat while the southern study site was dominated by bottomland hardwood habitat. Feral pig hunting was allowed during the study; however, hunters were not allowed to trap or hunt over artificial bait in either study area. Trapping and use of bait was allowed outside of the study areas following the end of the Georgia deer season on 1 January 2008. Feral hog density at Fort Benning was estimated prior to the study at 1.15 pigs/km^2 (R.W. Holtfreter, Auburn University, Alabama, unpublished data).

Methods

We deployed RECONYX Silent Image Professional Model PM35, 1.3-megapixel (1280 x 1024), monochrome cameras (Reconyx, Inc., Holman, Wisconsin) for seven consecutive 24-hour periods on camera sites from 10 Oct 2007 through 27 Feb 2008 to assess activity of feral pigs. Cameras were set to take one photograph every three minutes for the duration of each sampling period. Camera sites were pre-baited with 22 kg of whole-kernel corn five days prior to camera placement. Pre-baiting five days prior to camera placement was likely adequate as estimates from (n = 11) camera sites indicated sites were first contacted by feral pigs on average 3.5 ± 0.625 SE days after initial baiting (B.L.Williams, Auburn University, Alabama, unpublished data). Corn was refreshed, as needed, two days prior to camera placement, at camera placement, and two and five days following camera placement. We selected sites by overlaying a 1-km^2 grid over the study area and randomly selecting cells throughout the grid for camera placement. Within each cell, we chose camera sites based on evidence of feral pig activity, typically near creek bottoms within 100 meters of unpaved roads.

In each image where feral pigs were present, individuals were identified using physical characteristics such as sex, approximate weight, pelage markings, and coloration (light or dark) as well as group association (Sweitzer et al. 2000). Where available, pigs were identified by ear-tag number, having been captured during a previous study between 2004 and 2006 (Hanson 2006). Where difficulties arose in distinguishing between solid colored pigs of similar size and sex, we used additional pelage traits (ridgeback, woolly hair) and a unique characteristic such as ear shape or scars to identify individuals.

We recorded the date and time individual pigs were first identified and, from that point forward, those pigs were considered removed from the population for the remainder of that seven-day camera session. We summed removals by class (juveniles, adult sows, and adult boars) for each diurnal period, nocturnal period, and 24-hour period. To estimate mean site abundance, we fit the cumulative total of mean removals per class and period to a two-parameter, exponential rise to max equation, $y{=}a(1{-}b^x)$, using SigmaPlot (2000), where the asymptote (a) predicted the abundance of pigs after (x) 24-hour sampling periods (Borchers et al. 2002). We plotted detection probabilities for each 24-hour period as the cumulative mean number of removals per site divided by the predicted abundance for each class. To determine if predicted detection probabilities would be impacted by limiting sampling to nocturnal periods, we compared the fit of the cumulative mean number of removals during diurnal periods and nocturnal periods by examining for differences among the separate total sum of squares and the total sum of squares when data were pooled (Motulsky and Ransnas 1987). We analyzed differences in the mean number of individuals in each class removed during diurnal versus nocturnal periods using paired *t*-tests, $P < 0.05$ (SAS 2003).

Results

Throughout the study, a total of 240,962 images were gathered from 73 sites, including 10,479 images of feral pigs. A total of 348 feral pigs were uniquely identified. A small proportion (5%; 13/255) of adult pigs observed could not be sexed and were subsequently removed from analysis. Results from nonlinear regression analysis projected a mean site abundance of 2.56 ± 0.126 SE ($F_{1,6} = 898.83$; $r^2 = 0.99$; $P < 0.001$) adult boars detected following 45 24-hour sampling periods (Figure 1). A mean site abundance of 1.34 ± 0.04 SE ($F_{1,6} = 715.03$; $r^2 = 0.99$; $P < 0.001$) was projected for adult sows detected after 43 24-hour sampling periods, and a mean site abundance of 1.56 ± 0.14 SE ($F_{1,6} = 151.94$; $r^2 = 0.97$; $P < 0.001$) was projected for juvenile pigs detected after 35 24-hour sampling periods. Predicted detection probabilities (p) did not reach 1 until each of these points (>35 24-hour sampling periods); however, for each class, p exceeded 0.5 by the third 24-hour sampling period (Figure 1).

The mean number of adult sows ($\bar{x} = 0.14 \pm 0.03$ SE) and boars ($\bar{x} = 0.27 \pm 0.02$ SE) detected per site during nocturnal periods was greater (sows; $t_{510} = -3.57$; $P < 0.001$, boars; $t_{510} = -9.80$; $P < 0.001$) than the mean number removed during diurnal periods (sows; $\bar{x} = 0.03 \pm 0.01$ SE, boars; $\bar{x} = 0.03 \pm 0.01$ SE) throughout the seven 24-hour periods. Across diurnal periods, the cumulative

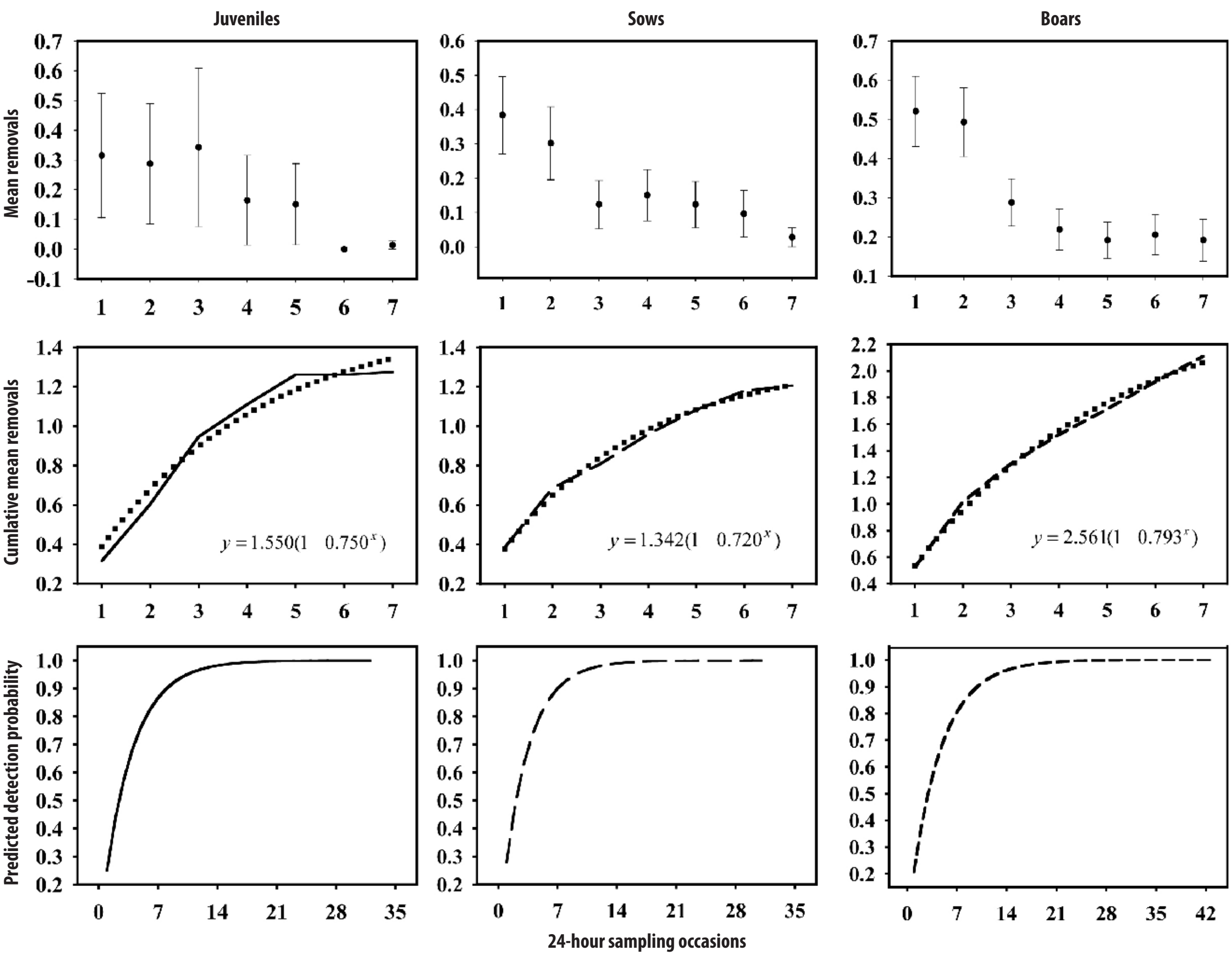

Figure 1. Mean number of removals (unique identification and removal from sampling), cumulative mean removals, and predicted detection probabilities for three classes of feral pigs (*Sus scrofa*) on Fort Benning, Georgia. Dotted lines show the fit of the data to the model.

removal of adult sows ($F_{1,6}$ = 68.78; r^2 = 0.93; P = 0.004) and adult boars ($F_{1,6}$ = 41.99; r^2 = 0.89; P = 0.001) did not fit the model as closely as cumulative removals during nocturnal periods for sows ($F_{1,6}$ = 209.00; r^2 = 0.98; P = 0.001) or boars ($F_{1,6}$ = 1154.94; r^2 = 0.99; P < 0.001). These differences were weakly supported by comparison of the separate versus pooled fit of the data (sows; $F_{1,12}$ = 2.94; P = 0.112, boars; $F_{1,12}$ = 3.11; P = 0.103).

Juvenile pigs showed a similar trend to adult pigs with cumulative diurnal removals fitting the model to a lesser degree ($F_{1,6}$ = 22.47; r^2 = 0.82; P = 0.005) than cumulative nocturnal removals ($F_{1,6}$ = 110.81; r^2 = 0.94; P = 0.001). Juvenile pigs differed from adult pigs, however, in that the mean number of diurnal removals ($\bar{x}$ = 0.06 ± 0.04 SE) did not differ (t_{510} = –0.97; P = 0.335) from the mean number of nocturnal removals ($\bar{x}$ = 0.12 ± 0.04 SE), and, when pooled, diurnal and nocturnal period data showed a better fit ($F_{1,12}$ = 0.33; P = 0.545) than when separated.

Discussion

Detection probabilities in excess of 0.3 are adequate where multiple sites are sampled on more than one occasion, which is necessary to properly obtain capture histories (MacKenzie et al. 2002). Results indicate monitoring feral pig activity via game cameras may be reduced to three 24-hour periods following camera placement at uniformly pre-baited sites because predicted detection probabilities were in excess of 0.5 for adult and juvenile pigs following the third 24-hour sampling period. Our results also indicate that sampling could theoretically be limited to nocturnal periods for adult pigs; however, because juvenile pigs were equally likely to be detected during diurnal periods, elimination of diurnal sampling periods for juveniles likely would reduce their detection probabilities (Table 1).

Population density estimates, derived via camera methods, are frequently based on an assumption that animals observed during such surveys are local to the area or occupy the area within a given radius (often based on home range characteristics) of each camera site. Minimizing sampling periods to three 24-hour periods following initial camera deployment would allow a set number of cameras to be frequently relocated to a greater number of monitoring stations, thereby increasing the precision of abundance estimates. This would also limit temporal heterogeneity in abundance estimates while decreasing the likelihood of attracting distant animals (thus biasing area-based estimates) to cameras sites.

Decreasing sampling period length at each camera site will reduce bait costs, image storage requirements, processing time, and exposure of expensive equipment to the elements. Fewer visits to field sites will also reduce any influence human visitation may have upon the observed species (Franzreb and Hanula 1995, Larrucea et al. 2007). Finally, bait reduction should limit the potential increase in productivity associated with prolonged food availability common to pulse-resource adapted species like feral pigs (Ostfeld and Keesing 2000, Bieber and Ruf 2005).

Table 1. Predicted detection probabilities for juvenile, adult sow, and adult boar feral pigs (*Sus scrofa*) on Fort Benning, Georgia, when monitored for 24-hour periods versus nocturnal periods only.

	Juveniles		Sows		Boars	
Periods	24-hour	Nocturnal	24-hour	Nocturnal	24-hour	Nocturnal
1	0.20	0.08	0.29	0.25	0.20	0.17
2	0.39	0.27	0.51	0.43	0.40	0.34
3	0.61	0.33	0.60	0.49	0.51	0.44
4	0.72	0.43	0.72	0.55	0.59	0.52
5	0.81	0.52	0.81	0.64	0.67	0.59
6	0.81	0.52	0.88	0.72	0.75	0.66
7	0.82	0.53	0.90	0.74	0.82	0.73

Our study should be replicated in other habitat types and at differing population densities to yield comparative estimates of the mean amount of time necessary for camera deployment to maximize feral pig detection and to examine the potential adverse effects of prolonged baiting at camera sites. Additionally, pigs on our study site exhibited territoriality (Sparklin et al. 2009), which could potentially influence results. Additional studies examining these issues will help improve camera surveying techniques for feral pigs and other species with similar life history characteristics.

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