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Reliability and precision of pellet-group counts for estimating landscape-level deer density

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Abstract: This study provides hitherto unavailable methodology for reliably and precisely estimating deer density within forested landscapes, enabling quantitative rather than qualitative deer management. Reliability and precision of the deer pellet-group technique were evaluated in 1 small and 2 large forested landscapes. Density estimates, adjusted to reflect deer harvest and overwinter mortality, were compared with a drive count on the small landscape and with aerial counts using forward-looking infrared videography (FLIR) on the large landscapes. Estimates by 2 expert and 2 novice counters (range = 17.6 to 18.6 deer/km^2) on the small landscape were not different from each other and three of the four were not different from the drive count (17.4 deer/km^2). FLIR density estimates were approximately 30% lower than pellet-group estimates on the large landscapes ($P < 0.04$), an expected result. Precision on the small landscape was high; 95% confidence intervals for individual counters were <7.5% of mean estimates of density, and coefficients of variability were <10%. Precision on the larger landscapes was acceptable: 95% confidence intervals were 18.4 to 30.4% of mean estimates and coefficients of variability were <25%. The pellet-group technique produces reliable and precise estimates of deer density, is inexpensive, requires little training to implement, and is best suited to northern hardwood forests where snow and cold result in minimal deterioration of pellet groups. Unless corrected for hunter harvest and overwinter mortality, pellet-group counts represent average overwinter density and overestimate spring density.

Key words: density estimates, human–wildlife conflicts, *Odocoileus virginianus,* pellet-group technique, white-tailed deer

Overabundant white-tailed deer (*Odocoileus virginianus*) negatively impact forest ecosystems in the northeastern United States (Tilghman 1989, deCalesta 1994, McShea et al. 1997, Horsley et al. 2003). Managing these impacts has involved hunting to reduce densities to levels associated with acceptable impact and desirable herd health. Data on deer density and distribution are required for determining when and where to reduce deer density, by how much, and whether desired reductions are achieved (Rutberg and Naugle 2008, Curtis et al. 2009). Managers need a technique that provides reliable, precise, and economical estimates of deer density. The high cost of direct counts (i. e., aerial surveys, deer drives, and spotlight surveys) and questions over reliability and applicability of indirect counts (e.g., pellet-group counts, track counts, mark-recapture, and population reconstruction from harvest data) are valid concerns (Curtis et al. 2009).

Using infrared-triggered trail cameras (IRCs), Curtis et al. (2009) developed an accurate and precise methodology for estimating deer density within 2 small (263 ha and 458 ha) suburban landscapes. They also determined that 1 camera per 33 ha was effective, at a cost of $14/ha. Extrapolating these numbers to larger forestlands of thousands of ha, however, produces intimidating figures; a 5,000-ha forest would require 150 cameras at a cost of $70,000. Cheaper than this is the cost of estimating deer density using forward-looking infrared (FLIR) cameras mounted on fixed-wing aircraft and flying transects (M. Benner, Pennsylvania Bureau of Forestry, personal communication). But at $1.24/ha, the FLIR technique still is expensive; for a 5,000-ha landscape, the cost would be $6,200. Persons managing deer and deer impacts within large and small landscapes need less expensive technology without sacrificing reliability or precision.

The pellet-group count could be an inexpensive and potentially reliable and precise method for estimating deer density over large and small landscapes. The technique involves counting deer pellet-groups along transects in spring after snow cover has melted and before leaf-out of ground vegetation (McCain 1948).

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The technique is easily learned and requires minimal equipment and training. Defecation rate and length of time from fall leaf-off (when leaves from overstory trees have fallen and will not cover deer pellets deposited over winter) until time of data collection are requisite parameters.

The technique has been disparaged as too inaccurate and imprecise to provide useful estimates or trends of deer density over time (Fuller 1991). Conversely, McCain (1948) stated that the pellet-group technique produced estimates of deer abundance that closely agreed with estimates derived from roadside counts and counts of deer during annual migrations. Eberhardt and Van Etten (1956) compared estimates of deer density derived from pellet-group counts with counts of deer within fenced enclosures (262 ha and 485 ha) in Michigan and concluded that observer, or natural cause, error could be controlled to provide a reliable method for estimating deer density.

This study evaluated the reliability and precision of deer pellet-group counts for estimating deer density over small and large forested landscapes. Reliability and precision of the technique were evaluated within a small landscape by comparing density estimated from pellet-group counts with density obtained from a deer drive. Reliability and precision were evaluated within 2 large landscapes by comparing density estimated from pellet-group counts with density obtained by aerial census with FLIR. Effect of observer experience on reliability and precision was evaluated within the small landscape.

Conceptual framework for calculating deer density

Deer are not randomly distributed across landscapes. Rather, some areas (e.g., foraging, bedding, thermal, and hiding cover) receive disproportionately high use, and less attractive areas receive disproportionately low use. Deriving estimates of deer density within such landscapes requires a sampling framework that randomly locates sample points across the entire landscape, ensuring that points are located in all areas of deer use, high and low. Deer are managed as populations within unique landscapes: estimates of deer density should represent the entire population within entire landscapes. Because habitats are not uniform, deer density estimated from a single point within a landscape is representative of the particular habitat within the landscape it was drawn from, but is not representative of the entire landscape. Deer densities derived from a collection of sample points located randomly across entire landscapes are required to provide estimates of landscape deer density. Combining deer density data from individual sample points across the entire landscape into a single sample yields a single representative estimate of landscape deer density. Additionally, different collections of such sample points must be obtained from the landscape to produce additional estimates of density. These multiple samples may then be used to produce estimates of mean density and variability required to construct confidence intervals (CIs) about the means.

Study areas

Small landscape

The small landscape was the rectangular 445-ha Glendorn Estate (hereafter, Estate), 8 km southwest of Bradford in northwestern Pennsylvania. The Estate was enclosed by a 3-meter-tall deer fence inspected and maintained at regular intervals. The fence was built of heavy-duty, woven-wire livestock fencing with openings between horizontal and vertical stays small enough to prevent deer from crawling through. Six weeks prior to the drive, the fence line was inspected, and places where deer potentially could enter and exit were repaired. Because forested landscapes and levels of timber harvest (and deer forage) were similar inside and outside the Estate, there was little incentive for deer to enter or leave the Estate.

Large landscapes

The 2 large landscapes (5,734 ha and 7,122 ha) were within the 30,000-ha Kinzua Quality Deer Cooperative (KQDC) that surrounded the Estate on the north, west, and south in northwestern Pennsylvania. The Pennsylvania Bureau of Forestry (BOF) contracted with Vision Air Research (VAR) of Boise, Idaho, in 2006 to census deer in these 2 landscapes to address allegations by disgruntled hunters that deer density was lower than the landowners

Figure 1. Line-up of counters along fence line prior to deer drive on the small landscape.

claimed. Lands within the small and large landscapes represented a mix of age classes of northern hardwood forest. These forests typically are dominated by shade-tolerant tree species, such as American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and eastern hemlock (*Tsuga canadensis*). The forests are characterized by an uneven age structure, with major disturbance factors being windthrow and ice storms, and are managed for sustainable production of timber by even-aged forest management techniques.

Methods

Small landscape

Deer drive. I conducted the drive on April 12, 2001, using methodology from an earlier drive on the Estate (deCalesta and Witmer 1990). Ten teams of 9 observers were arrayed along the 1,615-m western edge of the Estate at a spacing of 19 m between observers (Figure 1). Leaders were located in the middle of each team; the leader followed a flagged route through the Estate on a 90° compass bearing; team members aligned themselves with the leader.

Drivers recorded deer that passed between themselves and the driver to their right as the drive line moved from the western end to the eastern end. Observers were placed along the eastern end of the fence to count any deer that might escape through or under the fence, and 2 additional observers walked along the north and south fence lines approximately 150 m ahead of the drive-line and looking backward in the direction of the drive line to count any deer exiting the fence ahead of the drive-line. Drivers also counted dead deer observed along the drive. The drive ended when all drivers reached the fence on the eastern border of the Estate.

Pellet-group counts. I conducted pellet-group counts the week following the deer drive (April 19 to 23, 2001) along 8 transects, 305 m apart, that traversed the Estate from northern to southern boundaries. I counted pellet-groups within circular plots (1.2 m radius) at 30.5-m intervals along transects. I located the first transect a random distance (within 33 to 99 m) of the west end of the property. A lead person laid out transects by following compass bearings of 0° and 180° across the Estate. A piece of surveyor flagging was placed at the center of each plot. Two expert and 2 novice observers followed the lead person and counted pellet groups observed within plots centered on the surveyor flagging. Each observer examined every plot for pellet-groups. Expert observers had ≥10 years of experience with the pellet-group technique; novices received a 1-day training session on the technique prior to collecting data on the Estate.

Observers maintained a 30-m spacing between each other along transects. To avoid observer bias, observers never counted pellet-groups from the same plot simultaneously. Observers might note the number of pellet groups counted by another observer and tally the same number themselves. The order of observers advanced by one every time they changed transects; the former lead counter went to the end of the line, and the former who was second in line became the lead counter, and so on. Pellet groups were tallied if there were ≥10 pellets in a group and at least half of the pellets in a group lay within the plot boundary.

Large landscapes

FLIR counts. Vision Air Research (VAR; Boise, Idaho) laid out 2 separate blocks of forestland within the KQDC for FLIR data collection; 1 rectangle comprised of 5,735 ha in a north–south orientation and a second one of 7,121 ha oriented south–west to north–east. Vision Air Research established protocols for data collection and analysis; it flew the 2 areas on April 7, 2006, at night and analyzed film from the FLIR flights to count deer and to produce estimates of deer density.

Pellet-group counts. I laid a grid of numbered points 1,610 m apart in north–south and east–west orientation over the KQDC and selected 26 of these points randomly for use in estimating deer density across the entire area. At each of the selected points, I placed a smaller grid of 5 transects, each 1,610 m long and spaced 300 m apart, such that the selected point formed the mid-point of the middle transect. I laid out all transects on a compass bearing of 0^o (true north, corrected for declination of 12^o NW). I used the protocols for size and location of plots and counting pellet-groups that I used on the Estate. Nine 5-transect grids fell within each of the 2 landscapes VAR censused within the KQDC. Pellet-group counts were collected April 2 to May 3, 2006.

Calculation of deer density from pellet-group counts

I calculated deer density (deer/km^2) for the Estate and each of 2 landscapes within the KQDC by the formula:

> Deer/km^2=∑number of pellet-groups counted/ (pellet-group deposit rate × deposition period × ∑ plot area in m^2/1,000,000 m^2). (1)

Leaf-off in the area, including the small and large landscapes, generally occurred the first week in November, and pellet groups were counted on the small and large landscapes in April. Rogers (1987) averaged deposition rate from 7 adult does in Minnesota from January to April to be 22.3 pellet groups/day and 52 groups/day in fall (September to December). Deer (adult bucks, does, and fawns) likely consumed much more forage daily and excreted more pellet groups in early fall (September to October) to pack on fat before the rut (November to December) when they spend less time eating and, presumably, defecate at a lower rate; pellet-group deposition rate, hence, is likely closer to 50 in September and October and much less in November and December. Sawyer et al. (1990) recorded daily deposition rate in Georgia from 3 adult does of 27 pellet groups between September and February. I averaged these 2 rates at 24.7 pellet groups per day and rounded up to use Roger's recommended rate of 25 pellet groups per day as the deposition rate for the November to April period between leaf-off and date of data collection. The sum of plot areas was the area of individual plots (1.49m^2) multiplied by the number of plots.

Density estimates produced by the formula above include pellet groups deposited by deer that are harvested or in other ways perish between leaf-off and the time pellet-groups are counted; such estimates represent average overwinter deer density. To estimate density of deer surviving over winter (spring deer density) to the day the pellet groups are counted requires an adjustment to account for pellet groups deposited by deer that died between leaf-off and the day of data collection. Because the deer drive and FLIR counts were conducted in April and counted deer that survived winter, I had to adjust density estimates from pellet group counts to remove the bias introduced by pellet groups deposited and counted for deer that died before the drive count in the small landscape and the FLIR counts in the large landscapes. I made this adjustment by subtracting pellet groups produced by deer that were harvested or to otherwise perished before spring from an estimate of all pellet groups (not just those counted from plots) deposited by harvested deer plus deer surviving to spring and dividing the remainder by daily deposition rate multiplied by the number of days between leaf-off and spring pellet-group counts multiplied by the area of landscape in km^2.

I calculated the number of pellet groups produced by deer that were harvested in the Estate before the deer drive by multiplying the number of harvested deer by daily deposition rate multiplied by the days between leaf-off and mean harvest date. I calculated the number of pellet groups produced by deer that died of starvation or predation by multiplying the number of counted dead on the drive by the daily defecation rate by the estimated number of days between deer-death and leaf-off.

I estimated the total landscape pellet groups by multiplying uncorrected estimate of density (∑ number of pellet groups counted/[i.e., pellet-group deposit rate x deposition period x ∑ plot area in m^2/1,000,000 m^2]) by area of landscape in km^2 by deposition rate by the number of days since leaf-off. I calculated the adjusted deer density by subtracting pellet groups deposited by harvested or winter-killed deer from the estimate of total landscape pellet groups and dividing this number by the product of daily deposition rate multiplied by the number of days between leaf-off and the date that groups were counted multiplied by the area of landscape in km^2.

For the small landscape, I knew that 27 deer had been harvested from the estate an average of 18 days after leaf-off (during the 11-day deer hunting season). Nine winter-killed deer were counted on the small landscape during the drive, and I assumed a mean death date of March 1. These deer likely starved to death, as fall density prior to harvest and winter-kill was 25.8 deer/km^2 (75 live deer + 27 harvested + 9 winter-killed in the 4.3km^2 Estate), which is the threshold density (25.0 deer/km^2) associated with deer winter starvation death in northeast Pennsylvania (deCalesta and Stout 1997). I assumed negligible overwinter deer mortality from predation by coyotes (*Canis latrans*), bobcats (*Felis rufus*), and bears (*Ursus americanus*), which take mostly fawns in summer and rarely prey on adult deer (Matthews and Porter 1988, Labisky and Boulay 1998, Ricca et al. 2002).

For the large landscapes, I estimated the number of deer harvested within each large landscape by dividing the number of deer harvested within each landscape and brought to check stations by the reporting rate. Reporting rates from 2005 were 7.3% in the northern landscape and 9.5% in the southern landscape. The Pennsylvania Game Commission requires that all hunters harvesting deer with Deer Management Assistance Program (DMAP) licenses report results both of deer harvested with these licenses and unfilled licenses. I obtained reporting rates by dividing the number of deer harvested with DMAP licenses and brought to check stations by the actual number harvested. Adjusted deer density on the 2 larger landscapes (i.e., 4.9 and 5.6 deer/km^2; see below) was well below the density associated with starvation mortality.

Reliability

Small landscapes. I compared adjusted estimates of deer density for each observer with the estimate from the deer drive using a simple τ-test (SYSTAT, 2007; Systat Software Inc., Chicago, Illinois).

Large landscapes. I compared density estimates produced by FLIR in each of the 2 landscapes with adjusted spring deer density estimates from pellet-group counts using a simple τ-test.

Precision

I constructed 95% confidence intervals (CIs) and calculated coefficients of variation (CVs; SYSTAT, 2007; Systat Software Inc., Chicago, Illinois) for adjusted density estimates from the small and large landscapes.

Small landscapes. Calculating estimates of precision requires replicate samples so that mean and variance values can be calculated and a confidence interval can be constructed about the mean value. I combined data from the 8 transects on the Estate to produce 1 landscape estimate of deer density, but there was no room to place an additional 8 transects on the Estate to generate a second estimate or more independent samples. Thus, I could not estimate a mean value for multiple density estimates, nor could I calculate variance or a *CI* about a mean. Instead, I used the jackknifing procedure (Schreuder et al. 1987) to produce 8 pseudo-replicates of density on the Estate. Jackknifing is a procedure used to create pseudo-replicates from a set of data points drawn from a sample area wherein there are no replicates; the original data points constitute a single sample because they are drawn from an entire landscape. To create additional samples, all data points, save one, are selected to create an individual sample of *n*-1 data points. In subsequent samples additional, single, and different data points are withheld from the next sample drawn from data points. In this way, *n* samples may be drawn from a collection on *n* data points. For this study, individual transect lines constituted single data points. Each pseudo-replicate consisted of density calculated from 7 of the 8 transects; the first replicate consisted of transects 1 to 7, the second transect consisted of transects 1 and 3 to 8, omitting transect 2, and so on, until 8 replicates of 8 different combinations comprised of 7 transects were constructed. Jackknifing produced 8 landscape estimates of deer density that were used to construct a mean density value and a *CI* about the mean, using the standard *CI* formula:

$$CI = \hat{y} \pm t_{\alpha/2}\sqrt{s^2/n}, \qquad (2)$$

where $\hat{y}$ = mean deer density, $t_{\alpha/2}$ = t value for selected significance level ÷ 2 (2-tailed test), s^2 = sample variance, n = number of transects. Selected significance level was 95%.

Variance was calculated by the standard formula,

$$s^2 = \textstyle\sum_{1..i}(y_i - \hat{y})^2 \div n\ , \qquad (3)$$

where y_i = density estimates of replicate samples; and $\hat{y}$ = mean of all y_i values.

Larger landscapes. Calculating mean estimates and CIs for deer density within the 2 large landscapes did not require jackknifing. Rather, I drew 5 replicate samples from each landscape by assigning each transect within each of the 9 grids of 5 transects a number 1 to 5, randomly. Replicate 1 was comprised of all transects assigned the number 1 from the 9 grids; replicate 2 was comprised of all transects assigned the number 2 from the 9 grids, and so on until 5 replicates of 9 transects each were identified. I then constructed mean deer density estimates and associated variance and *CI* values from the 5 replicates for each landscape.

Expert versus novice observers

I compared jackknifed estimates of deer density among observers with analysis of variance (SYSTAT, 2007; Systat Software Inc., Chicago, Illinois) to test for differences among observers.

Results

Small landscapes

I conducted the drive April 16, 2001, on a clear day with excellent visibility and ambient temperature of approximately 16° C. Understory vegetation was negligible; herbaceous vegetation had not yet emerged, and the high density deer herd had nearly eliminated vegetation in the shrub layer (0.6 to 3 m above ground). Drivers and watchers counted 75 live deer, for a density of 17.4 deer/km^2.

Adjusted density estimates (Table 1) derived from pellet-group counts were not different among observers ($F_{3,28}$ = 1.78; P = 0.53) and ranged from 17.6 deer/km^2 to 18.6 deer/km^2. Adjusted density estimates were different from unadjusted estimates (t_8 > 2.0; P < 0.001), averaging 12.7% higher. All unadjusted density estimates were higher than the drive count estimate (t_8 > 4.40; P < 0.004). Three of the adjusted density estimates for individual observers were not different from that derived from the drive (t_8 < 0.70; P > 0.50); the fourth estimate (by a novice counter) was different (t_8 = 2.05; P = 0.08) but the difference (1.2 deer/km^2) was small: the pellet-group technique produced reliable estimates of deer density, when adjusted for deer harvest and overwinter losses.

*CI*s (95%), standard deviations, and coefficients of variation (Table 1) for expert and novice observers were small, resulting in a high precision of density estimates derived from the pellet-group technique on the Estate when pseudo-replicates are produced by jackknifing. The experience level of observers was a minimal factor in reliability but not precision of estimates, probably because even novice observers are not likely to miss pellet-groups in small plots of the size used in this study.

Large landscapes

Snow cover was gone by the time of the FLIR counts. More deer were counted by FLIR on the southern landscape (4.0 deer/km^2) than on the northern landscape (3.3 deer/km^2). Adjusted and unadjusted density estimates derived from the pellet-group technique were higher than FLIR

Table 1. Mean adjusted deer density (per km^2), 95% confidence intervals (*CI*), and coefficients of variation (*CV*) among observers from the Glendorn Estate (drive count was 17.4 deer/km^2), Pennsylvania.

Observer	Unadjusted density	Adjusted density	95% *CI*	*CV*
Expert #1	20.0	17.7	1.1	7.5%
Expert #2	20.0	17.8	1.3	8.9%
Novice #1	19.9	17.6	1.3	8.9%
Novice #2	20.9	18.6	1.4	9.1%

estimates (t_4 = 4.9; P < 0.005, northern landscape: t_4 = 2.6, P < 0.04 southern landscape). Unadjusted density estimates exceeded spring density derived from pellet-group counts by 6.1% for the northern landscape and 3.8% for the southern landscape. FLIR estimates were 57.6% and 67.3% as high for unadjusted and adjusted pellet-group density estimates, respectively, in the northern landscape and 69.0% and 71.4% as high for unadjusted and adjusted pellet-group density estimates, respectively, in the southern landscape. The BOF states that FLIR surveys detect 70 to 90% of deer within landscapes with primarily hardwood tree cover (M. Benner, Pennsylvania Bureau of Forestry, personal communication), the condition on the larger landscapes, and FLIR counts as a percentage of adjusted pellet-group estimates were at the lower boundary of that detection interval.

Although density estimates obtained from FLIR and pellet-group counts were higher on the southern landscape, the pellet-group estimates were not significantly different (t_5 = 1.0; P = 0.34) between landscapes. Comparison of density estimates generated by pellet-group counts with those obtained by the FLIR technique provides additional evidence of the reliability of the pellet-group count technique to estimate deer density.

Confidence intervals (95%), standard deviations, and coefficients of variation (Table 2) for density estimates derived from the pellet-group technique on the large landscapes were acceptably small but were larger than for the small landscape. The 2 larger landscapes were 13 to 16 times larger than the small landscape and presumably possessed a higher degree of habitat variability; deer-use and pellet-group deposition were likely more variable over the larger landscapes.

Table 2. Mean deer density (per km^2), 95% confidence intervals (CI), and coefficients of variation (CV) for large landscapes.

	Unadjusted density			Adjusted density		
Landscape	$\bar{y}$	95% *CI*	*CV*	$\bar{y}$	95% *CI*	*CV*
North	5.2	1.0	14.3%	4.9	0.9	15.1%
South	5.8	1.7	23.5%	5.6	1.7	24.3%

Adjustments to density estimates derived from pellet-group counts

Unadjusted density estimates from pellet-group counts were higher (P < 0.001) than estimates adjusted for deer harvest and other overwinter mortality (Tables 1 and 2) on small and large landscapes. If reliable estimates of deer harvest and overwinter mortality are available, they should be utilized to provide estimates of spring deer density. Otherwise, density estimates from pellet-group counts will represent average overwinter density and will overestimate spring densities by amounts influenced by magnitude of hunter harvest and other overwinter mortality factors.

Discussion

Application of the pellet-group technique

The pellet-group technique is an inexpensive and rapid way of reliably and precisely estimating deer density; minimal training is required for mastery of the technique, and minimal equipment is needed (a map, a compass, a data sheet and pencil, and boots and clothing suitable for navigating forested terrain). One person can collect data for about 8,000 m of transect per day. The technique is well-suited to smaller landscapes; 1 person could easily collect pellet-group data from an area the size of the Estate in 2 days. On the 30,000-ha Kinzua Demonstration Area, it takes 5 to 6 2-person crews about a week to collect pellet-group data from the 26 grids.

Properties smaller than the typical white-tailed deer home range in northern climates (177 ha; Larson et al. 1978) are too small to sample for estimating deer density (deer from adjacent properties are part of the population utilizing the small property) unless a surrounding landscape of at least 250 ha can be sampled for deer density. Within landscapes too small (<1,000 ha) to collect pellet-group data with replicate transects, jackknifing, such as conducted by this study, will permit managers to estimate the precision of their estimates of deer density. Larger landscapes can lay out ≥2 grids of ≥5 transects to produce replicates.

Cost

Cost for the pellet-group technique is lower than for the infrared-triggered IRC technique

(Curtis et al. 2009; $14/ha) and FLIR counts (M. Benner, Pennsylvania Bureau of Forestry, personal communication; $1.24/ha). A 2-person crew would have cost $0.85/ha to collect pellet-group data on the Estate where sampling was more intensive than on the larger landscapes where costs were $0.22/ha on the northern landscape and $0.25/ha on the southern landscape (derived from $25/hour salary and $0.30/km cost driving to and from sites).

Applications and limitations

The technique works best in landscapes with a primarily deciduous tree canopy; falling leaves cover pellet-groups from previous years, so that observers record only pellet-groups deposited on top of leaves in winter and spring of the current year. The technique is less suited to grasslands or other areas relatively devoid of trees, as pellet-groups from previous years are not covered up by leaves. In such areas, pellet-groups from previous years may be removed from plots or spray-painted, entailing repeated visits and greater expenditures of time and resources.

The technique works well in cold climates with snowy winters; frozen pellet-groups do not deteriorate as rapidly as in warmer areas with rain rather than snow in winter. Also, cold climates delay breakdown of pellet groups by insects and bacteria. There is a fairly narrow period when pellet groups may be counted, i.e., after snow-melt and before green-up in spring when emerging herbaceous plants cover the ground and make observing pellet-groups impossible. I was able to use defecation rates reported in the literature without adjusting them to account for deterioration. It may be necessary to perform field tests to measure weathering and insect deterioration in areas with milder winters and to adjust daily defecation rates downward to compensate for pellet-groups lost to deterioration.

Because the technique counts pellet groups deposited over the fall–spring continuum, it includes the range of habitats utilized by deer for the entire period, making them relatively insensitive to vicissitudes of weather that may greatly bias density estimates drawn from a sampling period of a limited number of days, such as the case with data from FLIR and IRCs.

Management implications

The pellet-group count technique provides managers having limited funding, personnel, or equipment with the means to monitor deer density quantitatively and annually and over long time periods, within small and large landscapes, and with a high degree of confidence in the reliability and precision of the estimates. Quantitative estimates of deer density produced by the pellet-group technique can be compared with estimates of deer impact to produce quantitative, defensible estimates of herd reductions needed to achieve management objectives for resources impacted by deer. Managers, armed with the information of how much deer herds need to be reduced, quantitatively, can then request assistance from state deer-managing agencies in the form of numbers of additional licenses required to achieve desired reductions in local deer herds.

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