

Cost-benefit analysis of managed shotgun hunts for suburban white-tailed deer

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Abstract: Deer managers often utilize managed hunts to curtail burgeoning white-tailed deer (*Odocoileus virginianus*) populations in suburban areas. Although several studies have used population modeling to focus management, these efforts generally provide only harvest numbers, without considering the spatial placement of hunters on the landscape. Further, few studies have modeled management effort as deer density changes during the hunt. We modeled 2 types of managed shotgun hunts, a replacement hunt, where the stand of each successful hunter would be filled the following day, thus, ensuring the same number of hunters would be present each day of the hunt, and a non-replacement hunt, for Southern Illinois University–Carbondale. We modeled population growth of deer and numerical response to harvest to 25%, 50%, and 75% reduction levels. We used a GIS to determine potential hunter numbers and their placement on the landscape. We then used data from the literature to model optimal season length and to estimate the costs and benefits of the 2 managed shotgun hunt types. The non-replacement hunt was less expensive overall and had a lower cost per day, but the replacement hunt was more cost-efficient in terms of deer harvested and could meet higher population reduction goals. Our study illustrates the importance of considering cost, hunter placement, and effort prior to conducting a managed shotgun hunt for suburban deer.

Key words: cost-benefit analysis, human–wildlife conflicts, hunter placement, managed shotgun hunt, *Odocoileus virginianus*, southern Illinois, suburban, white-tailed deer

MANAGEMENT OF SUBURBAN white-tailed deer (*Odocoileus virginianus*) populations has been a challenge for wildlife managers over the last 2 decades. Elevated suburban deer populations frequently cause human–wildlife conflicts, such as deer–vehicle collisions (Finder et al. 1999, Nielsen et al. 2003, Ng et al. 2008), ornamental plant damage (Kilpatrick and Walter 1997, Russel et al. 2001), and concerns about zoonotic diseases (Conover 1995, Deblinger and Rimmer 1995, Schauber and Woolf 2003). Alternatively, community residents often enjoy seeing deer and consider them to be a valuable resource (Cornicelli et al. 1993, Conover 1997), or are opposed to lethal management techniques (Decker and Gavin 1987, Cornicelli et al. 1993, Rutberg 1997). Therefore, local governments often are pressured to develop a balanced deer management solution that will minimize human–wildlife conflict while appeasing stakeholders who are opposed to deer reductions.

Managers have utilized hunts to control deer numbers in suburban areas and park settings (Deblinger et al. 1995, Hansen and Beringer 1997, Kilpatrick et al. 2002). Several case studies have documented the challenges of managing deer in developed settings. For example, Kilpatrick

and Walter (1999) reported that archery hunting was an effective and safe method to control deer populations, but antlerless harvest needed to be emphasized to meet management goals (Kilpatrick et al. 2004).

Given the widespread importance of managed hunts as a tool for population control of suburban deer, biologists require information to support management programs. Population modeling is commonly used to set goals for suburban deer management (Swihart et al. 1995, Seagle and Close 1996, Nielsen et al. 1997, Rudolph et al. 2000). However, such modeling efforts generally provide numbers of deer to harvest or treat with contraceptives with no consideration of how management is to be achieved spatially on the landscape. Several deer studies have addressed aspects of management feasibility or relationships between population abundance and management efficiency (Roseberry et al. 1969, Kilpatrick et al. 1997, Nielsen et al. 1997, Doerr et al. 2001, VanDeelen and Etter 2003). However, no studies have modeled management effort as deer density changes during the management action or cost associated with conducting the action for a specific number of days. By understanding this relationship, managers can determine *a priori*

the duration of the management action to meet harvest goals and predict the costs and returns as the action progresses.

Many deer–human conflicts have been documented at Southern Illinois University–Carbondale (SIUC), such as deer–vehicle accidents, native vegetation and crop depredation, and deer attacks on humans (Hubbard and Nielsen 2009). These issues have prompted SIUC administration to consider a managed shotgun hunt to reduce the deer population. Our objectives were to: (1) model deer population growth at varying reduction levels; (2) model the locations and efficiency of shotgun hunters; and (3) conduct a cost-benefit analysis for 2 types of managed shotgun hunts. Our goals were to provide SIUC administration with a cost-benefit analysis of a managed shotgun hunt as part of a deer management plan (Hubbard 2008) and to illustrate the broader importance of these considerations for suburban deer management.

Study area

Southern Illinois University–Carbondale is located in southwest suburban Carbondale, Illinois (population 20,681 without students present; U.S. Census Bureau 2007). Southern Illinois University–Carbondale employed >4,000 workers and had a student enrollment of >20,000 (K. Blackwell, SIUC Department of Human Resources, personal communication). The university owned 1,394 ha of land in suburban Carbondale, including the main campus (493 ha, of which 101 ha were forested and where most buildings and humans were located), agricultural research fields (551 ha), and surrounding forested property (350 ha).

Dominant woody species included *Acer saccharum*, *Asimina triloba*, *Carya* spp., *Liquidambar styraciflua*, and *Quercus* spp., which were typical of southern Illinois. As part of the SIUC agricultural research program, fields of corn, soybeans, and wheat were located <1 km west of the main campus. The combination of woody cover, manicured lawns, and agricultural land use resulted in high-quality deer habitat throughout SIUC property. Deer freely traveled from the agricultural areas to the interior of campus using forested corridors (Cornicelli et al. 1996). Deer hunting was prohibited on SIUC property during our study.

Methods

Deer demographics

Sex and age distribution. We collected age and sex data for the SIUC deer population using 3 spotlight surveys conducted during November 8 to 13, 2006. Surveys were run on representative roads and habitats throughout the study area from 1900 to 2130 hours. Deer were spotlighted from a truck that was driven at 15 to 25 km/h, and each deer was recorded as fawn (<1 year of age), adult doe, or adult buck. Data were pooled for all nights to quantify numbers of fawns, does, and bucks, fawn:doe ratio, and doe:buck ratio.

Density and abundance estimation. Deer density and abundance on SIUC campus was estimated using road-based distance sampling (LaRue et al. 2007) in March 2007. Three researchers (1 driver and 2 spotters) traveled roads on SIUC property beginning about 1 hour after sunset. The vehicle was driven <25 km/hour, and spotlights were used to locate deer. When a deer cluster (i.e., discrete group of ≥ 1 deer) was spotted, the distance and angle to the center of the cluster were determined using a laser range-finder and angle board. Cluster size was determined using the nearest-neighbor criterion and by observing behavior and proximity of individuals (LaGory 1986). Routes were surveyed for 3 consecutive nights until >60 deer clusters were recorded (Buckland et al. 1993).

We used program DISTANCE 4.0 (Thomas et al. 2002) to estimate deer density. We followed data analysis protocol suggested by Buckland et al. (1993) for line transect data: (1) arbitrarily truncating data then plotting initial histograms for fitting a preliminary model; (2) selecting >1 candidate data sets and choosing the best-fit model; (3) pooling sighting data and choosing appropriate truncation points to improve fit for several models; and (4) assessing evidence of cluster-size bias. We then selected a single, best-fit model based on Akaike's Information Criterion (AIC) and assessed by a goodness-of-fit test. We multiplied the density estimate by the area of SIUC (15 km²) to estimate deer abundance.

Modeling harvest

General approach. Our goal was to model harvest, optimal season length, and hunter placement before a managed hunt to allow for

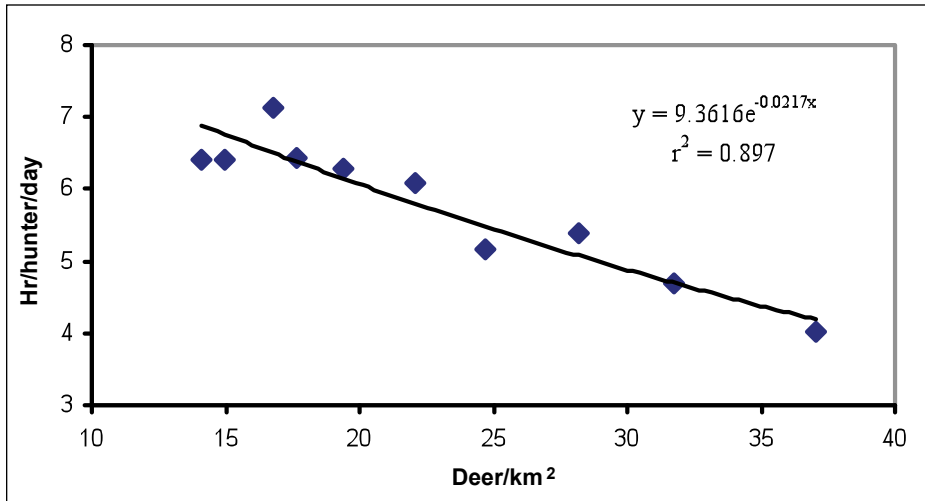


Figure 1. Relationship between deer density and daily hunt duration from a managed shotgun hunt at Crab Orchard National Wildlife Refuge in southern Illinois (Roseberry et al. 1969). This relationship was used to model optimal season length for a proposed managed shotgun hunt at Southern Illinois University–Carbon-dale, fall 2008.

the calculation of costs and benefits. We used the age and sex information, abundance estimate, and published demographic values to build a population model for deer. Then, we used a GIS to model potential hunter placement on the landscape, with safety as a priority, to estimate the number of shotgun hunters SIUC property could support. Finally, we used data from a previous managed shotgun hunt in southern Illinois to model optimal season length and to estimate the costs and benefits of 2 managed shotgun hunt types.

Numerical population modeling. We developed an accounting-based model (Nielsen et al. 1997, Grund and Woolf 2004) in Microsoft Excel to forecast deer population growth from March 2007 until the potential shotgun hunt in fall 2008. Population growth was modeled according to the following equation:

$$N_{t+1} = [N_t + \text{Recruitment}(N_t \text{ does})] - [\text{Adult Loss}(N_t \text{ adults})] \quad (1)$$

The model timeline began in March 2007 with the estimate of deer population abundance (N_t) from distance sampling surveys. N_t consisted of adult bucks and does as proportionately observed in the November 2006 spotlight surveys. Recruitment was added to the population in November 2007, assuming the fawn:doe ratio observed during the November 2006 spotlight surveys. Adult loss (i.e., non-

harvest mortality and net migration) was estimated from published sustained yield tables at 80 to 100% carrying capacity and from local studies in southern Illinois (Storm et al. 2007). We used the midpoint of the range for male adult loss (0.15 to 0.24 [McCullough 1979, Downing and Guynn 1985, Nielsen et al. 1997, Rudolph et al. 2000]) and female adult loss (0.09 to 0.13 [Storm et al. 2007]) in the model. N_{t+1} was the predicted deer abundance in year $t+1$ (in this case, March 2008). The model then predicted deer numbers potentially subject to shotgun harvest in fall 2008 and it determined harvest levels to result in 25, 50, and 75% population reduction levels by 2009.

Modeling hunter placement. We hand-digitized Illinois Digital Orthoquadrangles of SIUC property in ArcMap 9.1 (Environmental Systems Research Institute [ESRI], Redlands, Calif.) to create a land-cover map. We then modeled the placement of hunters (via stand locations) on the landscape using Hawth's Tools in ArcMap according to land-cover type, competing land uses, and safety requirements. Stand locations were restricted to wooded areas to reduce hunter visibility to the public. Available hunting areas were limited on non-forested portions of SIUC property because of livestock production and agricultural study plots. Stand locations were not allowed <0.50 km from the main campus because of human activity (T. Sigler, SIUC Department of Public

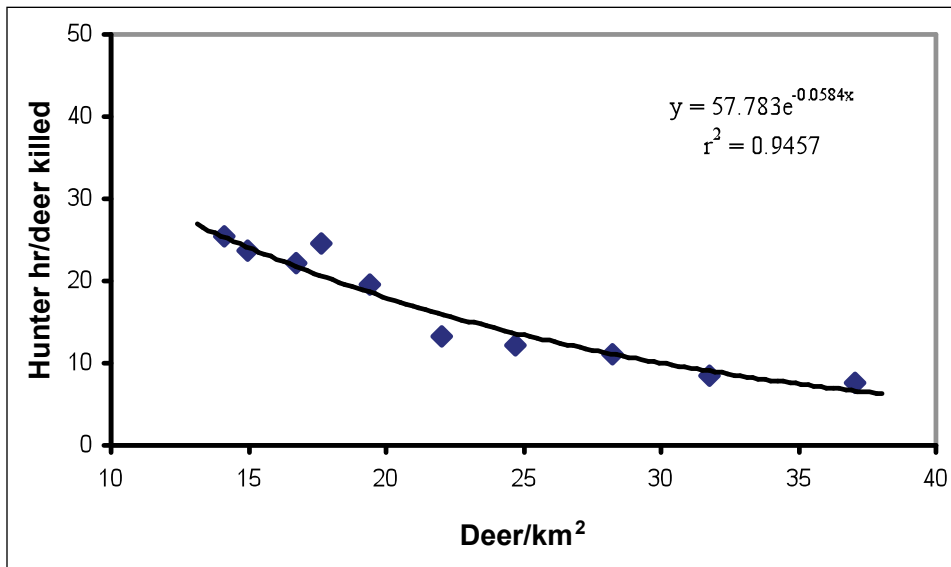


Figure 2. Relationship between deer density and hunter effort from a managed shotgun hunt at Crab Orchard National Wildlife Refuge in southern Illinois (Roseberry and Klimstra 1974). This relationship was used to model optimal season length for a proposed managed shotgun hunt at Southern Illinois University–Carbondale, fall 2008.

Safety, personal communication). Further, to ensure maximum safety, we did not allow stands <100 m from roads and <200 m from buildings and between hunters.

Optimal hunting season length modeling. Given reduction levels of 25, 50, and 75%, the number of stand locations possible, and a bag limit of 1 deer per hunter, we quantified the optimal season length, with a maximum season length of 10 days, for 2 hunt types that had differing levels of hunter participation. We modeled a replacement shotgun hunt, where the stand of each successful hunter would be filled the following day; thus, the same number of hunters would be present each day of the hunt. We also modeled a non-replacement shotgun hunt, where a successful hunter's stand would be idle on subsequent days of the hunt; therefore, the number of hunters on the landscape would decline over time. Daily hunt duration (hours/hunter/day) and hunter effort (hours hunted/deer harvested) increased as deer density decreased (Van Deelen and Etter 2003). We used data from a managed shotgun hunt at Crab Orchard National Wildlife Refuge (Roseberry et al. 1969, Roseberry and Klimstra 1974), located 10 km from SIUC, to model the relationship between deer density and daily hunt duration (Figure 1) and deer density and hunter effort (Figure 2). Because SIUC deer

density was already known, we predicted harvest for each day of the hunt using the following equation:

$$H_x = S_x \times (9.36 \times 2.73^{-0.02 \times D_x}) \div 57.78 \times 2.78^{-0.06 \times D_x} \quad (2)$$

where H_x was the harvest on day x , S_x was the number of shotgun hunters on day x , D_x was the deer density (deer/km²) on day x , $9.36 \times 2.73^{-0.02 \times D_x}$ referred to daily hunt duration given D_x , and $57.78 \times 2.78^{-0.06 \times D_x}$ was hunter effort, given D_x .

We then conducted a cost-benefit analysis for each hunt type by considering managed hunt-related activities reported in the literature (Doerr et al. 2001, Kilpatrick et al. 2002), such as announcement, applicant review per contact, proficiency test per applicant selection, stand placement, hunter orientation, and police patrol to be conducted by the SIUC Field Operations Division (Table 1). We assumed a \$15/hour cost for all labor except police patrol, which cost \$37 per patrol hour (T. Sigler, SIUC Department of Public Safety, personal communication). A corresponding number of police was required per hunter. Costs were evaluated in 2 ways: overall cost and cost-efficiency. Overall cost was cost of each managed hunt type and cost per day to conduct the managed hunt. Cost-

Table 1. Cost considerations (\$15/hour labor, \$37/patrol-hour) for a proposed managed shotgun deer hunt at Southern Illinois University–Carbondale, fall 2008.

Cost type	Hours of effort	Associated cost (\$)
Hunt announcement	4	60
Application review or contact	40	600
Proficiency test	16	240
Applicant selection	10	150
Maps or tree marking	40	600
Hunter orientation	3	45
Patrol	Depends on hunt type ¹	37/hour

¹Nonreplacement of successful hunters requires fewer patrol officers after day 3 of the hunt.

efficiency was calculated as cost per deer and cost per deer per day.

Results

The spring 2007 abundance estimate was 271 + 26 (SE throughout) deer (18 + 2 deer/km²; CV = 12.5%). The half-normal cosine model had the lowest AIC value (AIC = 798.70) and was chosen as the best model. We used a 50-m left truncation

and 25-m intervals on the distance sampling data. The effective strip width was 131 m, and cluster-size bias was not evident in the data.

The November 2006 spotlight survey indicated a doe:buck ratio of 3.6:1 and a fawn:doe ratio of 0.57:1, resulting in a deer population consisting of 31% fawns, 54% does, and 15% bucks. We applied these percentages to the abundance estimate, giving a herd structure of 146 adult females, 43 fawn females, 41 adult males,

and 43 fawn males (assuming a 50:50 fawn sex ratio). The population model predicted a fall 2007 abundance of 324 deer, and a fall 2008 abundance of 381 deer. To meet population reduction goals by 2009 following a fall 2008 hunt, 95 deer would need to be removed for a 25% reduction, 191 for a 50% reduction, and 286 for a 75% reduction.

Based on the criteria we considered, 88

Table 2. Cost (\$) and cost-efficiency estimates for replacement and nonreplacement managed shotgun hunts proposed for Southern Illinois University–Carbondale (SIUC), fall 2008.

Day of hunt	Replacement shotgun hunt ¹			Non-replacement shotgun hunt ²		
	Accumulated cost	Cost/deer harvested ³	Cost/deer/day ⁴	Accumulated cost	Cost/deer harvested	Cost/deer/day
1	2583	65	65	2583	65	65
2	3471	46	25	3471	58	44
3	4359	40	27	4359	61	81
4	5247	38	30	4803	68	74
5	6135	37	32	5247	76	111
6	7023	36	34	5691	85	222
7	7911	36	37	6135	93	222
8	8799	37	40	6579	102	444
9	9687	37	42	7023	111	444
10	10575	38	44	7467	122	444

¹Stand of each successful hunter would be filled the following day; thus, the same number of hunters would occupy SIUC each day of the hunt.

²Stand of each successful hunter would be idle on subsequent days of the hunt; therefore, the number of hunters at SIUC would decline with deer harvest.

³Cost/deer harvested was estimated by dividing the accumulated cost by number of deer harvested through day x.

⁴Cost/deer/day was estimated by dividing the cost to conduct the hunt on day x by the number of deer harvested on that day.



Figure 3. Potential placement of deer hunters at Southern Illinois University–Carbondale (SIUC) for a proposed managed shotgun hunt, fall 2008. Circles represent the location of hunters; lines are the SIUC property boundary. Main campus (east) and agricultural research farms (west) are bisected by McLafferty Road (center).

hunters could safely occupy SIUC at a given time, with most hunters restricted to wooded areas west and southwest of the main campus (Figure 3). The average distance of hunters to the edge of main campus, where many deer–human conflicts occur, was $1,486 \pm 58$ m. Hunter density was 0.25 hunters/ha.

For the replacement hunt, hunter hours/deer harvested ranged from 11.3 on day one to 34.4 by day ten. On day one, the non-replacement hunt required 11.3 hunter hours/deer harvested (i.e., hunter density was the same on day one for both hunt types), but only 16.4 hunter hours per deer harvested by day 10 (i.e., fewer hours than for the replacement hunt) because higher deer numbers remained on the landscape.

After day three of the hunt, replacement of successful hunters cost more than non-replacement (Table 2). Total cost for a 10-day hunt was \$10,575 for the replacement hunt and \$7,467 for the non-replacement hunt. Also, cost per day after day three for the non-replacement hunt declined by \$444 by day relative to the replacement hunt because several hunters had harvested deer. Therefore, fewer patrol officers were needed (Table 2).

Cost per deer per day of the non-replacement hunt was higher than for the replacement hunt for all days except day one when harvest was the same (Table 2). The greatest difference in cost per deer per day between hunt types occurred on day nine, when the non-replacement hunt was almost 10-fold more expensive than the replacement hunt (\$40 versus \$444, respectively). The replacement hunt could meet most management goals because of a higher deer harvest (Figure 4); a 25% reduction was achieved on day three, a 50% reduction on day six, and a maximum reduction of 73% by day ten. The non-replacement hunt reached a maximum reduction of 23% by day seven because most hunters had already harvested deer.

Discussion

Managed gun hunts are effective deer management tools in suburban and exurban landscapes in the United States (<www.dnr.state.md.us/wildlife> February 6, 2008, unpublished data; <www.mdc.mo.gov/hun/hunting-trapping/deer> February 4, 2008,

unpublished data). The Missouri Department of Conservation uses hunting whenever possible to manage deer populations in urban areas (Hansen and Beringer 1997). Deblinger et al. (1995) concluded that controlled, limited hunting was highly effective and efficient for reducing deer populations in Massachusetts. In Connecticut, local herd densities were reduced by 92% in 6 days using a shotgun and archery deer hunts (Kilpatrick et al. 2002).

Our research provides a case study regarding the integration of important variables to model hunter placement and optimal season length so that managed shotgun hunts can be conducted as efficiently as possible, while providing multiple options for management. We were somewhat limited in our analyses, given the specific desires of university officials; thus, we were not able to incorporate archery hunts or sharpshooting methods to manage the deer population. University officials also wished for us to vary police presence based on the number of hunters afield and not on the assumption of constant police presence. However, we believe that these limitations do not limit the wide-scale applicability of our results to other settings. Future researchers may wish to assess multiple harvest techniques, varying hunter densities, hunt durations, and different criteria for stand placement when modeling harvest management for deer in developed areas.

Hunter placement

Planning locations of hunters prior to a managed shotgun hunt can maximize safety and may proportionately distribute deer harvest. Roseberry et al. (1969) predetermined arrangement of 428 ground blinds for shotgun hunters before the hunt at Crab Orchard National Wildlife Refuge (CONWR), but did not suggest a minimum distance to meet potential safety requirements. Additionally, no other competing land uses existed at CONWR where the managed hunt occurred. Managed

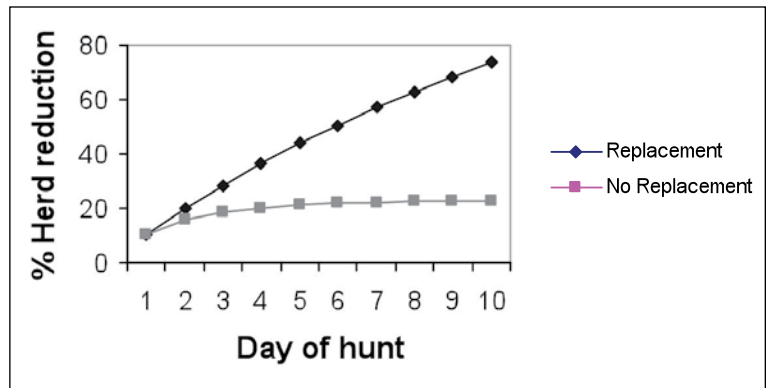


Figure 4. Relationship between managed shotgun hunt day and accumulated percentage deer reduction for 2 hunt types at Southern Illinois University–Carbondale, fall 2008.

hunts in suburban areas may require more deliberate planning than hunts in other areas. We found that 88 hunters can safely occupy SIUC at a given time by being placed 100 m from roads, 200 m from buildings, and an adequate distance from each other.

Although many deer–human conflicts, such as deer attacks, have occurred on the SIUC main campus east of McLafferty Road (Hubbard and Nielsen 2009), hunters would not have access to that segment of the SIUC deer population (Figure 3). Shotgun hunting may be sufficient to reduce depredation on agricultural research plots at SIUC, but may not decrease deer–human conflicts on campus without implementation of other management techniques (e.g., sharpshooting; Nielsen et al. 1997, DeNicola et al. 2008).

A GIS is commonly used to aid in management decisions for deer (Roseberry and Woolf 1998, Nielsen et al. 2003, Felix et al. 2007). A simple GIS analysis of potential hunter density and placement before hunt implementation provides managers with information for decision-making regarding the spatial arrangement of hunters. By spatially modeling hunter locations using a GIS, managers can determine the maximum number of hunters allowable on the managed area to avoid safety hazards or hunter conflicts over a stand site. Use of a GIS also will allow managers to track harvest spatially as hunters check harvested deer. Further, areas of high and low deer density on the landscape can be depicted via GIS, and harvest pressure can be adjusted accordingly.

Deer density, hunter efficiency, and optimal season length

Hunt duration, hunter effort, and other factors affect harvest numbers during a managed hunt. Hunter effort (hours hunted/deer harvested) increased exponentially as deer density was reduced to <15 deer/km² (Van Deelen and Etter 2003). We included this relationship of hunter effort to deer harvested in our model because the initial deer density ($18 + 2$ deer/km²) was near 15 deer/km², and deer density during the replacement and non-replacement hunt would fall to <15 deer/km² after days three and four, respectively. We modeled the change in hunter effort as deer density was reduced during the managed hunt based on a managed shotgun hunt at nearby CONWR (Roseberry et al. 1969, Roseberry and Klimstra 1974), which demonstrated this curvilinear response of hunter effort to deer density. If deer density were >15 deer/km² and management goals did not reduce deer numbers to this level, this change in hunter effort could potentially be ignored.

Wildlife managers must consider how deer harvest will vary with hunt type because some harvest goals may not be achievable by some hunt types. Hansen and Beringer (1997) suggested that firearm hunts longer than 2 days are not cost-effective because hunter participation declines sharply after the second day of the hunt. However, Hansen and Beringer (1997) suggested that if a new cohort of hunters is added after day 2 (i.e., a partial replacement hunt), then, participation and thus harvest, would remain relatively high. We observed a similar trend when modeling the potential harvest when refilling stands of successful hunters at SIUC. Optimal season length, given population reduction goals of 25, 50, and 75%, was different for each hunt type. Our model indicated that a replacement shotgun hunt could achieve our management objectives within 10 days. However, for the non-replacement hunt, hunters who successfully harvested a deer early in the season would be unavailable to hunt on additional days, preventing harvest from reaching higher levels.

Cost of a managed shotgun hunt

The increase in hunt duration as deer density decreases affects the cost of a managed shotgun

hunt. Hunters must spend more time to harvest an animal at lower deer densities (Van Deelen and Etter 2003). When population goals are set at ≤ 15 deer/km² (Van Deelen and Etter 2003), managers must be diligent about incorporating the costs and benefits of harvesting deer to levels below this density. Additionally, the hunt type impacts the costs and overall harvest. Overall cost to conduct the replacement hunt at SIUC was estimated to be greater than for the non-replacement hunt. During the replacement hunt, police patrol levels would be constant because the number of hunters would be 88 for all days, but during the non-replacement hunt, patrol would be reduced after day three because many hunters already would have harvested a deer. Also, the cost per day to conduct the non-replacement hunt would decrease because less salary would be paid daily for police patrol. Although the non-replacement hunt would cost less overall, it would not be as cost-efficient. More deer would be harvested during the replacement hunt, which would drive the overall cost/deer and the cost/deer/day lower than a non-replacement hunt. Analyses such as ours can allow entities considering managed hunts to determine whether management objectives are cost-oriented or goal-oriented.

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