An Integrated Approach for Managing White-Tailed Deer in Suburban Environments:

The Cornell University Study

Jason R. Boulanger, Paul D. Curtis and Bernd Blossey

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Cornell University
Department of Natural Resources
Cornell Cooperative Extension

NORTHEAST WDM COOPERATIVE

Jason R. Boulanger* and Paul D. Curtis
Cornell University Cooperative Extension
Department of Natural Resources
Fernow Hall
Ithaca, NY 14853-3001

Bernd Blossey
Cornell University
Department of Natural Resources
Fernow Hall
Ithaca, NY 14853-3001

Cornell University

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Photo credits:

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*University of North Dakota, Department of Biology, 10 Cornell Street, Stop 9019, Grand Forks, ND 58202

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Executive Summary

Based on decades of growing deer impacts on local biodiversity, agricultural damage, and deer-vehicle collisions, in 2007 we implemented an increasingly aggressive suburban deer research and management program on Cornell University lands in the Town of Ithaca, New York. We also coordinated a bowhunting program in the nearby Village of Lansing (VOL). Our experiences and recommendations will benefit other communities challenged with deer-related impacts. We also describe an experimental approach for planting red oak (*Quercus rubra*) sentinel seedlings to assess the intensity of deer damage to vegetation.

Cornell's Integrated Deer Research and Management (IDRM) Program strived to reduce deer numbers and associated impacts through use of surgical sterilization (tubal ligation and ovariectomy) on core campus (an unhuntable area), and an Earn-a-Buck (EAB) hunting program on surrounding lands, designed to increase the harvest of female deer. We chose to complement these approaches with assessments of deer abundance, monitoring of deer behavior, assessment of ecological outcomes, and a science-support program using harvested deer to enhance other Cornell research. Despite our efforts during the first five years of this study, it became clear that we could not reduce deer numbers on Cornell lands to a level that alleviated negative impacts, such as deer-vehicle collisions and overbrowsing. By winter of 2013, we stabilized the campus deer herd to approximately 100 animals (57 deer/mi^2), a density much higher than project goals (75% reduction =~14 deer/mi^2). Despite these numbers, we did see a decrease in does and fawns appearing in photographs on campus during the five-year study period. This decrease was offset by an increase of bucks that appeared on camera during our population study. Bucks from outside the core campus sterilization zone may have been attracted to the does that received tubal ligation surgery and continued estrus cycling through February or March. Also, we did provide protection for some bucks in the early years as a result of our EAB program focusing on doe harvest. In the last two years of the Cornell study, we implemented use of deer damage permits (DDP) with participants using archery equipment over bait. Concurrent with these activities, we removed additional deer using collapsible Clover traps and deer euthanasia with a penetrating captive bolt. Our efforts demonstrated that these methods can be safely and effectively conducted in densely populated areas with high public use. In concert with sterilization and hunting, the expanded use of DDPs and deer capture resulted in a herd reduction of approximately 45% in just one year on core campus. Based on our experiences, we discontinued use of surgical sterilization and EAB hunting on Cornell lands in 2014. On core campus, we will continue use of deer damage permits given a new statewide law that relaxes archery discharge limits to 150 feet. On adjacent lands, we will continue use of a controlled, public hunting program without EAB restrictions.

We also describe our experiences implementing and expanding a suburban bowhunting program in the VOL. Although hunters safely harvested several hundred deer over a period of seven years, browsing of red oak sentinel seedlings indicates that ecological damage still occurs on these lands. More aggressive deer removal will be needed to reach management goals of reduced plant damage.

Finally, we describe current deer management options and present recommendations for agencies, communities, landowners, and policy-makers to better manage deer impacts. Moreover, we review fertility control, and argue that attempting to manage a suburban deer herd using this method alone will likely not be successful in areas with free-ranging deer. Even with 90% or more of female deer sterilized, the best we could do was stabilize herd growth on core campus lands. Some form of lethal deer management (e.g., hunting, sharp-shooting, capture and euthanization) will be needed to reduce deer numbers in an acceptable time frame (<5 years).

Cornell Integrated Deer Research and Management Program Mission Statement

To improve the health and safety of Cornellians and residents in surrounding communities by reducing threats of deer vehicle collisions (DVCs) and tick-borne diseases; to preserve teaching and research lands by improving tree regeneration and biodiversity for the perpetuity of University lands as outdoor classrooms; and to reduce the burden of economic impacts. As a leader in the field of deer damage mitigation, we carry out this mission through a strong foundation of science, partnership, field demonstration, and novel techniques to reduce deer impacts on University lands and nearby properties.

Introduction

New York's most popular game animal, the white-tailed deer (*Odocoileus virginianus*), is found throughout the eastern U.S., and as a valuable resource, generates over $650 million each year in hunting revenue in the state (Fig. 1). Deer also provide enjoyment for nature watchers, photographers, and residents throughout their range. In recent years, however, the increase in white-tailed deer and their impact on forests, other wildlife, agriculture, and human health, have resulted in increasing conflicts with humans, costing approximately $2 billion per year in the U.S.

This publication provides a summary of deer management on Cornell University and surrounding lands, and highlights current options for mitigating overabundant deer populations. We anticipate that wildlife agency staff, community leaders, and other stakeholders can learn from our experiences, saving valuable time and money.

The white-tailed deer is a keystone herbivore of forest ecosystems. At high population densities, deer can have disproportionately large impacts on biodiversity and forest dynamics. Their feeding, on a wide variety of plants, can prevent forest regeneration, endanger native plants, and facilitate non-native plant invasions. Furthermore, deer impacts cascade through food webs and impact other native wildlife, including small mammals, birds and amphibians. In addition, white-tailed deer may damage crops, resulting in substantial financial loss. At high abundance, deer are often associated with negative impacts in suburban landscapes, where deer find ideal habitat, ample food sources, limited or no hunting, and few wild predators. Deer-human conflicts such as deer-vehicle collisions (DVCs) and tick-borne diseases pose safety and health concerns.

Although the effect of deer on Lyme disease incidence is debated in the scientific literature, recent work suggests a correlation between deer densities, tick abundance, and resident-reported cases of Lyme disease.

Figure 1. An Earn-a-Buck hunter with a deer harvested on Cornell University lands. *Photo – J. Boulanger.*

Sustainability of the white-tailed deer resource has always been a goal of regulated utilization in the U.S. since early game law implementation. However, limitations on hunting and the behavior of hunters, the primary method used by wildlife managers to affect deer populations in rural areas, pose challenges for suburban deer management.

Hunting may be impractical in some communities due to the density of residential neighborhoods and buildings, and legal, safety, or social concerns. Moreover, data from suburban landscapes where regulated hunting was the sole method used to affect deer populations suggest that hunting was insufficient to reduce deer densities to <44 deer/mi^2, well above common management objectives (<8 deer/km^2 or <20 deer/mi^2). To restore biodiversity in areas that have been overbrowsed, or reduce tick populations and associated Lyme disease risk, deer densities may need to be <4 deer/km^2 (<10 deer/mi^2). However, hunting may be sufficient to reduce DVCs depending on community needs or means. We caution the reader that no single density estimate translates to deer impacts in all cases. Throughout this publication we stress the importance of local deer impact reduction vs. arbitrary number reduction goals.

Alternative options for managing deer abundance in areas where hunting is impractical may include sharpshooting, or capture and euthanasia. In most states, deer fertility control (surgical sterilization or immunocontraception) is experimental, requiring research permits from state wildlife agencies. Moreover, there is no peer-reviewed, published evidence to suggest that use of non-lethal methods alone can reduce deer populations to target levels. Deer translocation is not recommended because it is hazardous to managers; expensive; deer may not survive the process; may further spread disease; and many areas are already well above acceptable deer densities. Sharpshooting deer over bait can be very effective in quickly reducing populations in suburban areas. However, this technique is controversial in some communities. Landowners and municipalities are often unprepared for vehement opposition from residents with safety concerns (some justified, some misconstrued), activists opposed to killing animals, or from hunters who either oppose deer herd reduction or believe all deer reduction should be done through hunting. The ensuing controversy often results in lawsuits, extended public debates, and inaction, allowing deer-related problems to persist or worsen.

The last decade has seen an upsurge in local deer management proposals and actions due to the frequency of deer-related conflicts that now increasingly exceed tolerance levels of ecologists, conservationists, and suburban communities. The most important factors that drive communities to embrace more aggressive management efforts often include: 1) rapid rise of tick-borne diseases; 2) DVCs; and 3) unacceptable levels of plant damage (e.g., landscape ornamentals, crops, tree regeneration, or sensitive plant communities and resulting effects on local biodiversity).

In Ithaca, New York, after decades of increasing deer impacts on local biodiversity and agricultural damage, Cornell faculty and staff, community leaders, and stakeholders, developed **Cornell's Integrated Deer Research and Management (IDRM) Program** in 2007. The university responded to the articulated need to reduce deer-human conflicts and evaluate management options on campus. Objectives for similar programs often include reducing deer numbers, but it is more important to consider deer-related impacts when setting management objectives.

> The key to the Cornell program is that it integrates lethal and nonlethal techniques to manage deer populations, paired with assessments of deer abundance, and development of new assessment tools to survey the extent and potential reductions in ecological damage due to deer browsing.

As such, this program is unique in the country. However, this program also exceeds the capabilities of most communities due to the level of funding and scientific expertise it requires.

Study Area

We conducted the IDRM study on the Cornell University central campus, surrounding residential communities, agricultural land, natural areas, and woodlots in the Towns of Dryden, Ithaca, and Lansing, Tompkins County, New York (Fig. 2). Within this area, we identified: 1) a sterilization zone (~1,100 acres) containing core campus areas where building density, human activity, and unsafe shooting zones precluded hunting as a management tool, and 2) a hunting zone (~4,000 acres) containing Cornell-owned agricultural and natural areas adjacent to core campus that had been open to hunting for decades. Within the hunting zone, we identified 20 disjunct hunting areas ranging in size from 14 to 190 acres. Approximately 63% of these lands, those adjacent to suburban communities, are restricted to bowhunting (Fig. 3).

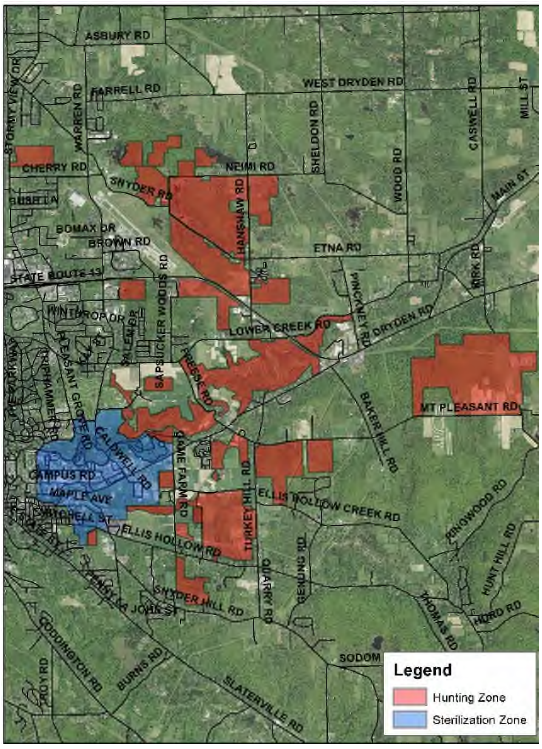

Figure 2. Cornell University properties included in sterilization and hunting zones within the IDRM Program.

In addition to IDRM, we assisted the Village of Lansing (VOL; Lansing, New York) with the implementation of a deer management program using bowhunting. The VOL is not immediately adjacent to Cornell campus, but a number of Cornell properties are located within VOL boundaries. We hunted on small private properties (often less than 5 acres), and landowner participation has increased from one to >40 properties over a period of seven years.

Due to continued concerns and complaints in surrounding communities, and with assistance of staff and faculty, the New York Department of Environmental Conservation (DEC) established a 60,000-acre Deer Management Focus Area (DMFA) in 2012 centered on Cornell campus, but including many outlying areas. Almost all Cornell lands in the study area, and properties in the VOL, are contained within the DMFA. In the DMFA, DEC liberalized antlerless bag limits (two antlerless deer per hunter per day) and created additional hunting opportunity (three-week season for antlerless deer in January).

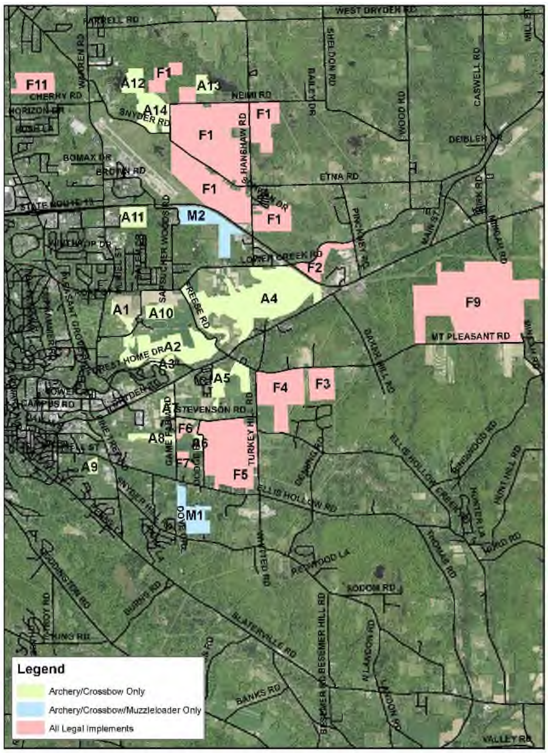

Figure 3. Cornell University hunting properties included in the IDRM Program and permitted use of bows, crossbows, and firearms by property.

IDRM Core Components

Various theoretical studies suggest that sterilization may reduce deer numbers, but in practice this method has resulted in inconclusive results or failed in open deer populations in suburban landscapes. Other studies suggest that sterilization will be more effective if combined with some form of lethal control. We chose an integrated approach with various components focusing on increased harvest of female deer. We anticipated that this integrated approach would help accelerate a decrease of deer numbers and impacts on campus, along with adjacent natural areas, agricultural lands, and suburban neighborhoods. We chose to complement implementation of deer reduction approaches with assessments of deer abundance, monitoring of deer behavior, assessment of ecological outcomes, and a science support program using harvested deer to enhance other Cornell research.

Deer Capture and Sterilization

The number of students and staff, building density, and expressed safety concerns precluded hunting as a tool in the core campus area. We instead chose deer sterilization (using tubal ligation and ovariectomy) for core campus because of the nearby convenience of Cornell University's Hospital for Animals (CUHA), and because this method only requires handling a deer once. Deer treated with immunocontraceptive vaccines require annual booster shots. To assess the impact of capture and surgical procedures on deer behavior and survival, we captured and collared additional females, but without sterilizing them (control group).

The initial goal of the sterilization program was a reduction in deer numbers and associated impacts on core campus by 75% in five years.

Earn-a-Buck Hunting

The total area of University-owned land involved in the hunting program was approximately 4,000 acres of non-contiguous parcels (Fig. 3). Although hunting has been allowed on Cornell lands for decades, it did little to curb increasing deer populations and conflicts. For safety reasons, we restricted hunting zones close to Cornell campus or nearby suburban neighborhoods to archery equipment, but allowed firearms and/or muzzleloaders further away (Fig. 3). Deer hunting occurred during New York State's Southern Zone archery, regular firearms, and muzzleloader/late archery seasons. We implemented an Earn-a-Buck (EAB) deer hunting program (Fig. 4) designed to increase female harvest by requiring hunters to take two females before they were able to take a buck. In 2012, EAB rules were relaxed, requiring hunters to take one antlerless deer before being able to take a buck. Beginning in 2012, DMFA regulations allowed for a three-week season in January for antlerless deer only.

The initial goal of the controlled hunting program was a reduction in deer numbers and associated impacts in hunted areas by 50% in five years.

Population Monitoring

The IDRM Program included monitoring of deer fitted with radio collars to track movements, birthing rates, and survivorship. We also used infrared-triggered cameras to estimate herd size and density.

Figure 4. Adult male deer on Cornell lands exceeding 200 pounds, measured after harvest. *Photo – IDRM Program.*

Ecological Assessments

Traditionally, articulated deer management needs concern lessening deer impacts, yet the debate has centered on the number of deer per square mile or kilometer that would be acceptable or desirable. There is no reliable translation of deer abundance to deer impacts, and the often articulated goal of <20 deer/mi^2 assumes greatly reduced deer impacts based on questionable historical deer abundance at time of European settlement of the continent. We chose an experimental approach, the planting of red oak (*Quercus rubra*) sentinel seedlings to assess deer browse intensity. We chose this method for ease of implementation for researchers and landowners, concerns over oak regeneration failure throughout the Northeast, and the intermediate browse preference of deer for red oak. Most existing woodlots on and near the Cornell campus, and in the region, have been over-browsed by deer for many years (Fig. 5).

Basic Suburban Deer Biology

- White-tailed deer are named for their characteristic white tail that is held erect when alarmed. They have grey-brown coats in winter that turn red-brown in summer. Males (bucks) begin to grow antlers in the spring that are complete in the fall; antlers are used for fighting and establishing rank among other males. In New York, weights average about 100 pounds for females (does) and 150 pounds for males (bucks), and height averages 36 inches at the shoulder (Fig. 4).
- Deer perceive a different color spectrum than humans and have a supreme ability to see movement. They also use excellent scent cues and hearing to navigate through their habitats and daily routines. When frightened, deer can attain speeds of 36 miles per hour over short distances and jump over an 8-foot-high obstacle.
- White-tailed deer can thrive in suburban areas. A combination of increased safety from some predators (including hunters), ample high-quality foods in gardens, ornamental plantings and parks, and feeding by residents (although illegal in New York) maintains their fertility and reduces their mortality.
- Under ideal conditions, adult deer commonly produce twin fawns and sometimes triplets. Deer that can survive suburban traffic may live to be well over 12 years (we have records of tagged suburban deer reaching at least 13 years of age in the southern tier of New York).
- Young deer, particularly males, will disperse from their birth areas to establish home ranges sufficient to fulfill requirements for food, water, shelter and reproduction. Suburban white-tailed deer generally have smaller home ranges than their rural counterparts. Female home ranges (averaging ~140 acres in suburban areas) are generally smaller than those of males.
- Hunter harvest is the primary cause of white-tailed deer mortality in rural landscapes, while deer in suburban landscapes are more likely to die in deer-vehicle collisions.

Deer Damage Permits

After the first five years of the experimental IDRM Program, an internal, university-formed Deer Management Committee (DMC) reviewed program goals, achievements, and methods, and decided to increase effectiveness of our IDRM Program through use of DEC deer damage permits (DDPs). After an initial successful test in March 2013, a small group of trained and proficient bowhunters with suburban deer hunting experience (see VOL below) continued to harvest deer over bait, at night with supplemental light during winter 2013/2014.

Science Support Program

Throughout the Cornell and VOL programs, hunters collected scientific samples from harvested deer (blood, liver, hair, bladder, and kidneys) aiding other Cornell researchers at the College of Veterinary Medicine (CVM) and the Department of Ecology and Evolutionary Biology.

Figure 5. Overbrowsed forest in our region (top) with no herbaceous vegetation or tree seedling recruitment, compared to a healthy forest with multiple layers of herbs, shrubs, and trees of different heights and ages (bottom). *Photos – B. Blossey.*

Concurrent with the February 2014 DDP archery activities, we applied for and received a DEC permit for additional collection of deer to augment management efforts and scientific sampling using collapsible Clover traps and euthanasia via penetrating captive bolt (Fig. 6). This technique is approved by the U.S. Food and Drug Administration, the American Veterinary Medical Association and by Cornell's Institutional Animal Care and Use Committee (Protocol No. 2007-0102). This humane population management technique works well in developed areas where other forms of lethal control, such as sharpshooting, may be inappropriate. In contrast to fertility control, capture and euthanasia yields immediate reduction of the deer population and associated impacts.

Figure 6. Collapsible clover traps used to live-capture deer. Door open ready to release a deer (top), and collapsed with captured deer (bottom). *Photos – P. Curtis.*

Village of Lansing

Although the VOL program is separate from the Cornell IDRM Program, we include it here given shared property boundaries, the experiences are informative within the context of this publication, and because two of us (Blossey and Boulanger) have coordinated efforts in the VOL as volunteers. Furthermore, a number of suburban archery hunters participated in both programs, and the experience hunters gained in the VOL helped inform the aforementioned Cornell DDP deer activities in 2013 and 2014.

The VOL, approximately three-square miles, represents a transition zone from suburban to rural landscape. The VOL deer management program has continued to expand as more landowners open their properties to this program, and VOL trustees sanction new properties annually. Hunting occurs from fixed treestand locations during regular hunting seasons, and equipment is restricted to vertical bows (e.g., no crossbows).

IDRM Implementation

Over the past seven years, we have attempted integrated approaches, but have also revised this program based on annual estimates of deer populations, performance of biological and ecological indicators, deer-vehicle collisions on campus, deer reduction goals, and availability of funding. The following is a more detailed summary of our approaches and experiences. Because we are located in New York, we fall under the rules and obligations governing wildlife management in the state. Regulations and approaches may be quite different from state to state, and we caution the reader not to assume that regulations are similar elsewhere. Furthermore, state regulations are in flux. Two examples include the establishment of the DMFA (unique to the Cornell area in New York), and the recent reduction of bow discharge distance in New York from 500' to 150' in spring 2014, a change that will greatly facilitate access to deer in suburban neighborhoods. The experiences we detail here are based on the 500' discharge distance, yet we will update this publication as we gain more experience with recent discharge changes.

Deer Capture and Sterilization

We obtained a DEC-issued License to Collect or Possess (LCP) and captured deer using modified Clover traps (named after its inventor; Fig. 6), drop nets, or with dart rifles, during late summer or winter from October 2007 through September

2013 in the core campus sterilization zone (~1,100 acres). Using dart rifles, we captured deer using blinds and bait, or opportunistically while patrolling campus lands. We established Clover traps in undisturbed woodlots on private property or Cornell lands, and habituated deer to the traps with daily baiting. All traps were set at dusk, when surgery time was available the following morning to prevent deer from being inside traps for extended periods. In addition to deer slated to be sterilized, we captured control female deer just outside the border of the core campus sterilization zone from 2008–2010 to compare fawning rates between groups. These control deer were captured and anaesthetized using the aforementioned techniques. We fitted all captured deer with numbered livestock ear tags, and all control does (n=26) and a proportion of sterilized does (n=69) with VHF radio collars to estimate deer populations, home range, mortality and fawning rates (Fig. 7). We captured, ear-tagged, and released most bucks without sedation.

Figure 7. Radio collared and ear-tagged white-tailed deer on Cornell lands. *Photo – P. Curtis.*

Upon capture, we anesthetized and hobbled the deer, fitted it with a blindfold and then transported it to the CUHA for surgery (Fig. 8). Most pregnant deer received tubal ligation surgery resulting in does giving birth in the spring, but with no further pregnancies thereafter. Unlike surgical procedures that remove ovaries (ovariectomy), veterinary surgeons preferred tubal ligation because it was less invasive. Tubal ligation also maintains normal hormone function, but results in repeated estrus cycling of females through February or March during subsequent years. Typically, most female deer are pregnant by the end of December and stop estrus cycling.

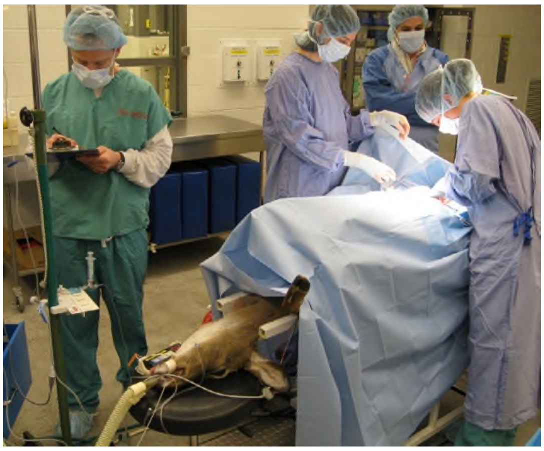

Figure 8. Sterilization surgery on a female white-tailed deer at Cornell University's Hospital for Animals. *Photo – J. Boulanger.*

From 2009–2012, we observed increased immigration of male deer into the sterilization zone, likely due to the prolonged cycling of estrus does on campus. Thereafter, in 2012 and 2013, we discontinued tubal ligations and performed ovariectomies on all females captured prior to becoming pregnant (Table 1). All trapping and surgery procedures conformed to the requirements of Cornell University's Institutional Animal Care and Use Committee (Protocol No. 2007-0102).

Following surgery and marking, we transported does back to the capture site, reversed sedation, and monitored individuals until recovery. Using radio telemetry and sightings, we evaluated deer movements and health during the first 48 hours after release. As required by the DEC LCP, we wrote the date at which the deer would be safe for human consumption on the back of the ear tag with indelible ink. Aggressive trapping efforts continued through 2010, until we had sterilized approximately 90% or more of the female deer in the core campus sterilization zone (based on camera monitoring, see below). In subsequent years, we targeted only the few deer (i.e., ~6 individuals) that immigrated onto campus annually.

As of summer 2014, we captured 167 deer; of these, 45 were male, 96 were females that received sterilization surgery, and 26 were control females (Table 1). Seventy-seven does received tubal ligations, and 19 received ovariectomy surgery, preventing births in 96% and 100% of these deer, respectively (Table 2). Of 29 radio-collared control deer captured and fitted with radio collars, three were recaptured and sterilized. Of the 26 remaining control deer, all (100%) displayed a swollen udder and/or had fawns present, indicating successful births. Based on examination of recaptured deer, the 4% of failed tubal ligation surgeries occurred because tissue regrew post-surgery, reconnecting the fallopian tubes, or other ovarian anomalies. These deer were subsequently re-sterilized.

Table 1. Number of surgery, control, and male deer captured during IDRM from 2007–2013.

Deer Captured by Category				
Year	Tubal ligation	Ovari-ectomy	Control deer	Male deer
2007/2008	20	11	0	17
2008/2009	27	0	10	21
2009/2010	19	0	7	7
Fall 2010	5	1	8	0
2011/2012	6	0	1	0
Fall 2012	0	4	0	0
Fall 2013	0	3	0	0
Totals	**77**	**19**	**26**	**45**

Table 2. Fawning comparison for sterilized and control deer.

Fawning	Tubal ligation	Ovari-ectomy	Control
Gave birth	3	0	26
Did not give birth	74	19	0
Totals	**77**	**19**	**26**

Earn-a-Buck Hunting

Prior to EAB, hunting on Cornell lands was a recreational, decades-long tradition, but permission was limited to a select few individuals at the discretion of various Cornell land managers. These few hunters had excellent hunting opportunities, but did little to reduce deer numbers. We consolidated Cornell hunting lands under a public, first-come, first-served, EAB hunting program designed to increase the harvest of female deer. Previous studies in Wisconsin and New Jersey demonstrated that EAB programs could increase harvest of antlerless deer, and since implementation of EAB at Cornell's Arnot Teaching and Research Forest (~4,000 acres) in 1999, managers observed an increase in maple (*Acer* spp.) and oak (*Quercus* spp.) regeneration (i.e., seedling and sapling survival) in some areas.

The EAB program was free, although prospective hunters had to apply for a Cornell hunting permit and submit to a Cornell Police (CUPD) background check. Approved hunters received a permit, vehicle dash tag for parking, and a pin-on identification tag that attached to an outer garment while hunting. We included the EAB website (now discontinued) on each hunting permit to provide hunters with information and rules. Approved hunters attended non-mandatory hunter orientation meetings where we stressed rules and good neighbor relations. We encouraged hunters to donate deer to a statewide venison donation coalition.

The EAB program established cooperative relationships with the DEC and local landowners. Each year until the establishment of the DMFA, we applied for and received DEC Deer Management Assistance Program Permits (DMAPs) for distribution to hunters to encourage additional harvest of antlerless deer. In 2012, we discontinued use of DMAPs due to the establishment of the DMFA.

To participate in the Cornell EAB program during the hunting season, approved hunters first had to sign in to specific hunting zones, and the number of hunters allowed in each zone was limited to prevent crowding. We required successful hunters to bring harvested deer to a nearby, 24-hour check-in station for biological data collection. We required hunters to fill out a harvest report form and record the number, sex and age of deer, if known, seen while afield. We required hunters to document the harvest of two female deer before qualifying to take a buck. After taking a buck, hunters started over, and again were required to harvest two female deer. Hunter harvest records were cumulative from season to season, allowing successful hunters to stockpile buck eligibility (e.g., 2- or 3-buck eligibility). By 2012, we determined that the success rate of our two female deer per buck EAB rule was not sufficient to achieve our stated reduction goals, and may have discouraged overall hunting effort. To encourage increased deer harvests, we relaxed EAB rules, requiring hunters to take one antlerless deer per buck.

The Cornell program proved to be very popular, with hundreds of hunter registrations prior to each season. However, only about half of those who registered actually signed in to hunt for an average of approximately 30 hours/year (Table 3).

As of 31 January 2014, Cornell EAB hunters harvested 606 white-tailed deer on lands outside the core campus sterilization zone, ranging from 69 during the pilot season in 2008, to 165 during 2012/2013, the first DMFA season (Fig. 9), but the reported sex ratio did not change appreciably over the course of our program (Table 3). We allowed harvest of radio-collared does beginning in 2009 to accelerate reduction of deer numbers on campus. Since the pilot EAB hunting program began in 2008, land available for hunting (including Cornell, state and private lands), on average, has increased (Table 3). Deer removed from the six zones closest to campus, which most directly decreased immigration into the core campus, ranged from 22–38% of the overall harvest. It took hunters 49–88 hours to harvest a deer, and hunter success rate was below 30% after the pilot year. With the establishment of the DMFA in 2012, we saw an appreciable increase in deer harvest. We did not directly estimate deer population numbers on EAB lands given the challenges associated with the size of the study area and terrain. Instead, we assessed population trends based on the average hours hunted per harvest and the number of deer observations and deer harvest per hunter day (Table 3). Changes in these estimates across years suggest fewer deer on the landscape, but not likely a reduction that approaches our goal of 50% in five years.

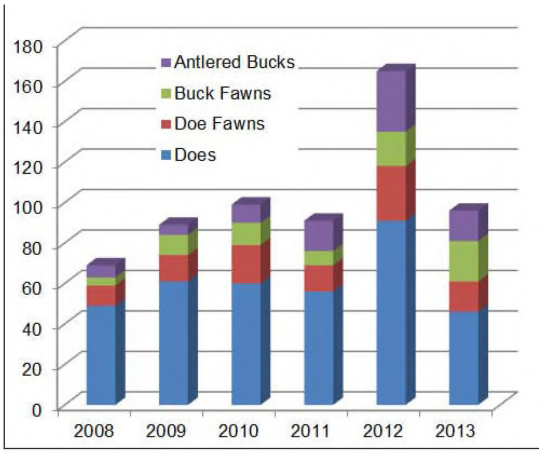

Figure 9. Number of antlered bucks, buck fawns, doe fawns, and does harvested by EAB hunters from 2008–2013.

We promoted self-policing and most of our tips on violations came from EAB hunters. With the help of DEC Conservation Officers and CUPD, we handled infractions every year, including 22 cases of trespassing by participants and nonparticipants, 11 stolen treestands, three cases of illegal baiting, one complaint regarding firearms discharge within 500’ of a home, and three incidences of hunters taking small bucks before they were buck eligible. EAB hunters reported six unmarked treestands and 13 unrecovered deer, including a large buck found with its antlers sawed off. We permanently removed five hunters from the EAB program due to violations.

Ecological Assessments

Determining contributions of deer to deterioration of local habitat conditions is challenging because of methodological difficulties, disagreement about best methods, and disputes from those opposed to lethal deer management who contest available methods. Even determining the appropriate deer density for an area is problematic because impacts are not solely a function of deer abundance, but are associated with productivity of habitats, and legacy effects (e.g., land use history, age of forest, and previous deer feeding pressure). Furthermore, most communities will not have the scientific or monetary resources to estimate local abundance, as we were able to do in this program. In addition, the number of deer that may be acceptable in one community may exceed socially- or ecologically-acceptable levels elsewhere.

Table 3. Comparison of EAB hunter effort and deer harvest results, 2008–2013.

	2008	2009	2010	2011	2012**	2013**
Acres available for hunting	1,438	1,577	1,784	1,929	3,865	3,865
Registrations	161	435	507	286	1,147	803
Active hunters	97	187	198	195	538	405
Average hours hunted	35	33	26	30	26	21
Average hours hunted per harvest	49	61	51	64	85	88
# deer observed per hunter day	0.7	1.3	1	0.9	0.4	0.3
Deer harvest per hunter day	0.07	0.04	0.07	0.05	0.04	0.04
Observed buck:doe ratio	1:2.1	1:2.5	1:3.2	1:2.3	1:2.4	1:1.5
Total deer harvested	69	89	99	91	165	96
Adult bucks harvested	6	5	9	15	30	15
Proportion of successful hunters*	0.38	0.25	0.27	0.28	0.20	0.19

*Success of harvesting at least one deer **Includes January DMFA season

A better method is the assessment of feeding pressure, and researchers have proposed many different plants as indicator species. The most widespread and accepted method is a woody-browse index where investigators focus on removal of branch tips.

Notable problems with many of these browse indices is that woody browse is only one portion of a deer's diet, and the frequency and biomass loss is difficult to determine (i.e., branches could be browsed multiple times which would indicate a much different feeding pressure compared to a single incidence). Moreover, regrowth and removal of regrowth are difficult to evaluate. This method ignores feeding on herbaceous plants, and may not be useful for determining browse pressure in heavily impacted areas, such as typical suburban landscapes (Fig. 5).

How many deer an area can support without severe negative consequences for native vegetation requires reliable information about deer impacts on local vegetation, irrespective of the estimation of deer abundance. We have developed a simple approach using oak sentinel seedlings (Fig. 10) to replace deer abundance estimates, or complicated woody-browse surveys. This method allows individual landowners and communities to assess whether local deer populations are in line with conservation-based management targets, without the need to hire a botanist or wildlife professional.

Although we continue to experiment with additional species to assess their validity and ease of application, here we focus on red oak, a common species throughout Eastern and Midwestern North America, which we grew from locally collected acorns. In our study area, this species is intermediate in browse preference (i.e., not highly preferred, but also not the last to be browsed). Our acorns were stored over winter in refrigerated conditions and planted into Cone-tainers™ in late winter (Fig. 11). We grew germinating oaks in the greenhouse for several weeks until they were about a foot tall and had their first set of four to eight full leaves. Then we hardened them outside, before planting them at forested locations in the study area. We planted oaks in late spring, slightly later than oak seedlings would emerge from overwintering acorns in the field using a hand-held, 2-inch-diameter drill bit.

Figure 10. Red oak (*Quercus rubra*) seedlings ready for transplanting. *Photo – B. Blossey.*

Using this technique, we had extremely high survival rates, even in dry summers. We planted 40 individually marked oak seedlings at each forested site, and protected half of them with a metal or plastic mesh cage to prevent deer browsing (Fig. 12). This allowed us to assess whether the locations were suitable for oak growth, and all were. Consequently, we eliminated cages in later years.

To assess deer-browsing intensity, we regularly visited our planting locations to record browsing by deer and other species (e.g., rodents and insects) during the growing season, and again once in the following spring. The most typical sign of deer browsing was the removal of some or all leaves, or parts of leaves from a seedling (Fig. 12). Deer usually pulled at plants, creating a rough or fibrous appearance where leaves or stems were ripped off. A second sign of deer herbivory was the complete removal of a seedling, and this usually occurred soon after planting, before seedlings had developed deep root systems. Deer tugged on the leaves and pulled out the entire seedling, often found on the ground next to the planting hole.

Figure 11. Northern red oak seedling in Cone-tainer™ grown for 2–3 months and ready for transplanting. *Photo – B. Blossey.*

An individual oak seedling may need 10–20 years to grow out of reach of a deer under a forest canopy, and even longer to get into the canopy. In many instances, seedlings/saplings need to spend extended periods in the understory waiting for their chance to grow should the overstory be damaged (or harvested). Considering this early life history, more than an occasional browsing event on oak sentinels (damage to >3 of 20 seedlings) in any given year would indicate deer populations in the area are too high to achieve forest regeneration.

Yet we routinely saw browse on 10–15 of the 20 deer-accessible individuals in our study area, and most browsing occurred in early summer, indicating that seedlings were discovered rapidly (Fig. 13). Protected seedlings continued to grow, albeit slowly due to reduced light conditions in a forested area.

Figure 12. Red oak seedling growing within a wire cage (left) protected from deer herbivory, and a partially browsed seedling of the same age at the same site (right). *Photos – B. Blossey.*

We saw no difference in survival rates of oak sentinel seedlings between deer sterilization, control, and hunting zones. We also assessed deer browsing pressure in >40 forest locations throughout Tompkins County. While browsing pressure was not as high as in our study area, given current deer abundance, red oak recruitment will continue to fail throughout the county, putting the continued existence of diverse forests in long-term jeopardy.

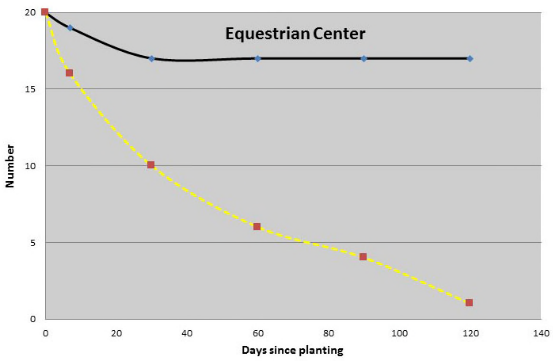

Figure 13. Survival of protected (solid line) and deer accessible (dashed line) oak seedlings planted at the Cornell Equestrian Center over a 3 month period (June–September).

We continue our assessment of red oaks as a monitoring tool to assess deer impacts, and we will be expanding the list of species that communities or landowners may use in a forthcoming publication. What we can say, at this point, is that more preferred and browse-sensitive species, such as red and white trilliums (*Trillium erectum* and *Trillium grandiflorum*, respectively; Fig. 14), are severely browsed even in places where we see good survival of oak seedlings.

Figure 14. Abundant white trillium (*Trillium grandiflorum*) display in May (top) and feeding damage by deer (bottom). Each of the one hundred flags represents a flowering white trillium that was browsed by deer. *Photos – B. Blossey.*

Additional Impact Assessments

We also collected DVC data from CUPD on Cornell and adjacent lands to ascertain annual changes in these incidents, and to date, these accidents appear to be increasing (Fig. 15).

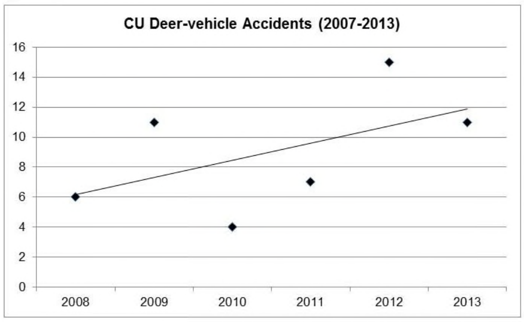

Figure 15. Number of deer-vehicle accidents reported to Cornell University Police from 2007–2013.

Similarly, information from the Tompkins County Health Department depicts a rapidly increasing number of human Lyme disease cases in the county, increasing 1,089% from nine in 2007, to 107 in 2011. However, increased awareness and improved reporting may have contributed to this increase. We continue our research to develop additional assessments that include other browse-sensitive indicator species, assessments of tick populations (Fig. 16), and social acceptance, given the controversies surrounding deer management.

Figure 16. Deer with an infestation of ticks on its ears. *Photo – P. Priolo.*

Deer Damage Permits

In 2012, we formed a second university Deer Management Committee (DMC) to review program goals and methods, and propose new management options. At that point, our annual population estimates indicated that despite our best efforts, we were unable to reduce deer numbers to acceptable levels during the first five years. We opted for use of DEC deer damage permits to supplement sterilization and EAB hunting, beginning in March 2013. In New York, use of deer damage permits is permitted primarily outside of regulated hunting seasons, but these permits may allow baiting, use of lights, and extended activity periods after dark (until 11 PM). We targeted areas previously inaccessible by EAB hunters on Cornell lands sandwiched between sterilization and EAB hunting zones.

A Deer Permit Coordination Group, a subset of the DMC, selected a small group of trained and proficient bowhunters with previous suburban deer hunting experience in the VOL program, who all passed a CUPD background check. We maintained a database of participants and used a website to manage logistics, treestand use, harvest reporting, and deer sightings. Participants conducted nuisance activities from elevated treestands with bait placed 20 yards away (Fig. 17), and reported the fate of every arrow shot. To maximize harvest, we began pre-baiting nuisance sites with corn several days before deer removal commenced. Recognizing that the efficacy of baiting is debated in the scientific literature, and that deer can avoid treestands and bait after hunter disturbance, we temporarily closed locations for 72 hours after two uses within 48 hours, to prevent overuse.

Figure 17. Baiting with corn to attract deer to a nuisance treestand site for deer removal with a NYDEC deer damage permit. *Photo – IDRM Program.*

Participants were not allowed to field dress deer on Cornell property in the DDP program, and removed deer using concealment (e.g., covered sleds) in sensitive locations with other recreational users. Efforts were made to be discrete and to not affect other recreational activities.

Participants conducted activities over a nine-day period beginning 16 March 2013, harvesting 11 deer. Given the success of the pilot activity, the number of available days, treestand sites, and harvest increased the following DDP season from 18 December 2013 to 10 January 2014, and again from 1 February to 31 March 2014. Treestand sites almost doubled from seven to 13, and participants removed 34 deer.

Concurrent with the February 2014 DDP activities, we modified our DEC research license to remove additional deer using collapsible Clover traps and euthanasia with a penetrating captive bolt. The U.S. Food and Drug Administration, the American Veterinary Medical Association, and Cornell's Institutional Animal Care and Use Committee approve this method. The captive-bolt technique provides for instantaneous euthanization of restrained deer, while allowing human consumption of the meat. Clover traps at DDP deer sites were sandwiched between the sterilization and EAB hunting zones, with a focus on sites unavailable for DDP archery activities due to state discharge restrictions (500' for archery).

We set traps at dusk and checked them for deer the following morning before sunrise. If deer were in a trap, we would collapse it to restrain the deer, allowing for safe and efficient euthanization. The time from determining a deer was in the trap to euthanasia was approximately 30 seconds. We conducted these activities from 5 March to 27 March, 2014, and collected scientific samples from eight deer using this method. The meat was donated for human consumption. We are in the process of using our oak sentinel approach to assess whether deer reductions through our DDP activities resulted in an appreciable reduction in deer browsing pressure.

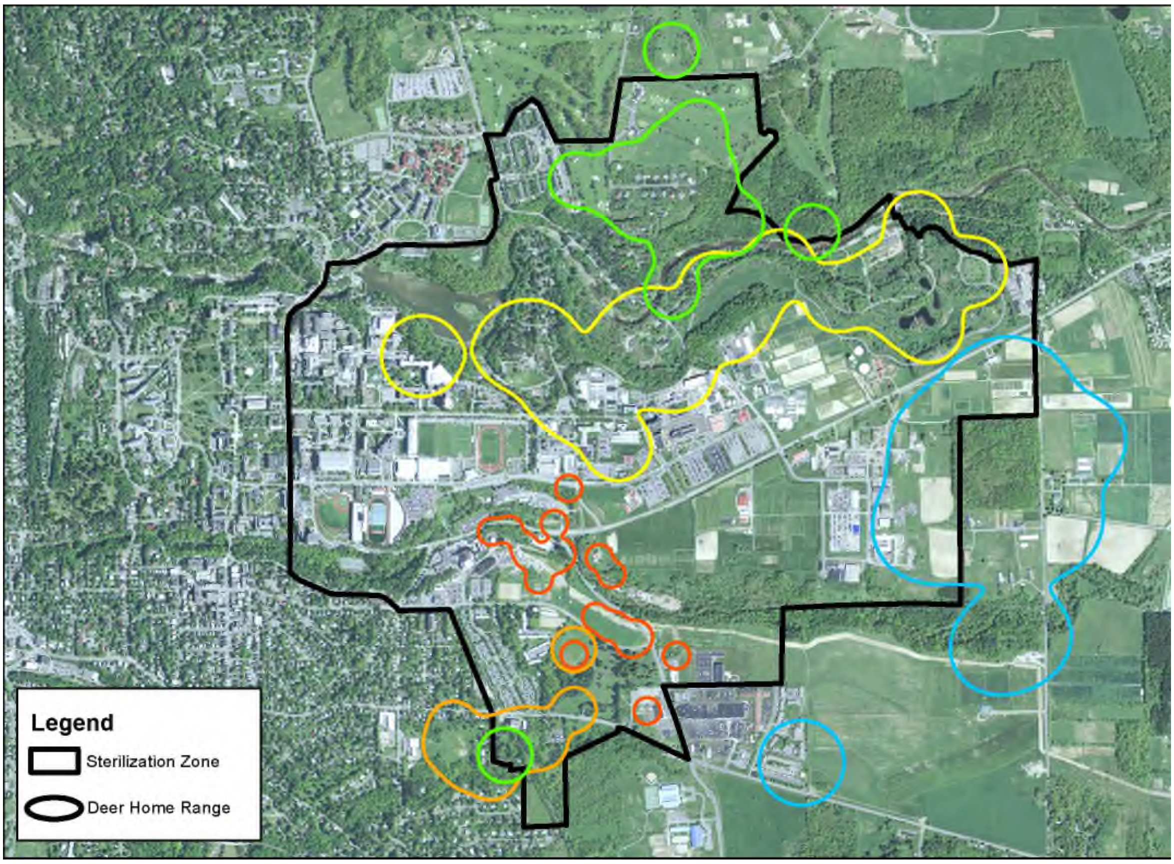

Figure 18. A sample of variation in shape and size of 95% adaptive kernel home range estimates for radio-collared adult female deer using the sterilization zone on Cornell campus.

Deer Home Range and Abundance Estimation

We began radio-tracking collared deer with telemetry equipment in September 2007 to track movements, birthing rates, and survivorship, and these efforts continue. We used triangulation, homing, or combinations of these methods to plot each deer's location. We logged and compiled the date, time, and field notes, and took dead deer to the CVM for necropsy to determine the cause of death. Using telemetry data, we used Geographic Information System (GIS) software and kernel density estimation to estimate home ranges - where deer spend 95% of their time - for each radio-collared deer (Fig. 18). Using locations from tagged, adult female deer in and near the core campus sterilization zone, we estimated the average home range size to be 142 acres. Suburban deer, such as those in our study, tend to have smaller home ranges than their rural counterparts, which benefits managers attempting to reduce negative impacts. Smaller home range size of female deer is related to dispersal distance (i.e., how quickly the next generation may immigrate into a deer mitigation zone).

Figure 19. Sterilization of female deer resulted in a noticeable drop of adult does and fawns, and an increase in the number of antlered bucks. *Photo – IDRM Program.*

To estimate deer abundance, we conducted an annual camera census (mark-recapture study) in the core campus sterilization zone each spring using 12 digital infrared-triggered cameras that took pictures at bait piles continuously for five days (Fig. 19). Cameras were placed in a grid system comprised of 100-acre blocks and calibrated to take a photograph every four minutes, if deer were present at bait piles. We tallied photographs and modeled deer abundance using NOREMARK population modeling software (now phased out). Communities interested in estimating populations may use MARK (http://warnercnr.colostate.edu/~gwhite/mark/mark.htm). Data collected from 2009 to 2013 suggest that the deer population in the sterilization zone on Cornell campus was stable or slightly increasing at almost 100 deer, or 57 deer/mi^2, until we implemented additional DDP removal in 2014 (Fig. 20). Given these densities, we clearly did not meet our desired reduction of 75% (~14 deer/mi^2). But for the first time since inception of the program, we did see a significant drop in the overall deer population in the core campus area, almost directly corresponding to the number of deer taken by archery and Clover traps during the 2013/2014 DDP removal period.

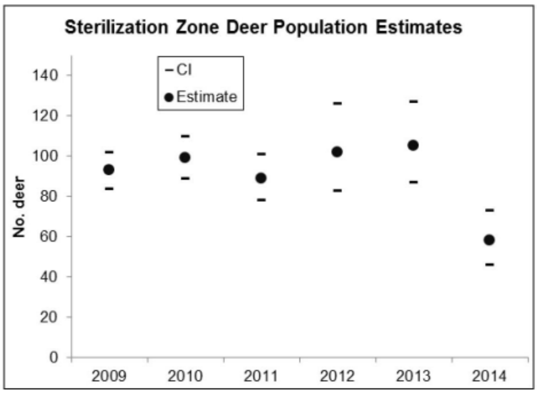

Figure 20. Estimates of deer abundance using infrared-triggered cameras in the IDRM sterilization zone (core campus) during 2009 to 2014 (CI indicates confidence interval of the estimate).

Despite a relatively stable deer population within the core campus sterilization zone from 2008 to 2013 (Fig. 20), we observed a decrease in does and fawns. To explore this further, we randomly sampled approximately 500 pictures from the camera survey to ascertain the relative visitation by bucks, does, and fawns in each year. We totaled the number of deer by sex and age visible in photographs, and determined a decrease in the number of does and fawns concurrent with an increase in the number of bucks. When comparing data from 2009 to 2012, for example, we noted a 38% and 79% decrease of does and fawns visible in photographs, respectively. By comparison, we noted a 90% increase in bucks visible in photographs between these years (Fig. 19 and 21).

Figure 21. Two mature bucks congregating in November at a bait station. This is unusual behavior at the peak of the rut (note swollen necks). *Photo – IDRM Program.*

Mortality

As of spring 2014, 84 out of 120 (70%) marked female deer had died due to DVCs (*n*=32), EAB hunter harvest (*n*=31), DDP activities using archery (*n*=5), Clover traps and captive bolt (*n*=4), capture-related mortality (*n*=4), and undeterminable or other mortality causes (*n*=8). A slightly higher proportion of sterilized female deer (*n*=27, or 29% of surgery deer) were killed by vehicles than control deer (*n*=6, or 23% of control deer), but this difference was not statistically significant.

While sterilization surgery is safe for most deer, some deer have conditions that increase their chances of mortality during capture or surgery. For example, surgeons euthanized one doe on the surgery table because of a hole found in the small intestine with no other evidence of injury. Another doe that died on the surgery table had lesions on the heart and parasites that put her at increased risk of anesthetic death. Another deer expired due to a congenital heart defect.

What continues to surprise us is the high rate of DVCs among sterilized deer in the core campus area, ranking slightly higher than hunter harvest as a mortality factor for the duration of the program. Considering that each DVC has an economic impact of approximately $2,600 or more, as reported in the literature, our radio-collared deer may have been responsible for >$80,000 worth of property damage on personal vehicles alone. However, when accounting for human injuries or fatalities, scene attendance or investigation, and carcass removal, costs per DVC may double, but emotional costs are unmeasurable. Interestingly, research suggests that about 50% or more of DVCs go unreported. Here we note the contradiction of sterilization as a humane alternative to hunting or culling, given that managers must rely on DVCs to reduce deer numbers.

Village of Lansing

Typical of many communities in the U.S., the VOL faced increasing DVCs and deer browse impacts considered unacceptable by residents. On behalf of the Board of Trustees, we implemented and coordinated a bowhunting program in 2007 using approved hunting plans, including voluntary landowners and bowhunters.

Most of the VOL landowners were happy to accommodate our efforts, knowing that we were exclusively using archery equipment to remove deer, and that the meat would be consumed. These were two very important considerations for residents. A spotless safety record, and increasing knowledge, allowed us to grow the program from a single property in 2007 to >30 properties in 2014.

We interviewed and vetted new bowhunting participants before allowing them into the program, and not everyone was accepted. Annual hunter meetings informed participants of regulation changes, and each hunter received a Code of Conduct document that we developed to standardize guidelines and techniques. In addition to excellent bowhunting skills, sensitivities and temperaments among our hunters were crucially important for our continued success. On occasion, our hunters encountered local opposition and illegal activity (e.g., unsanctioned, trespassing hunters), and had to handle themselves accordingly. In addition to these activities, we coordinated 20–30 bowhunters per year using a secure website which allowed hunters to optimize communication, treestand use, and harvest reporting. It took substantial volunteer time to coordinate these activities.

In our experience, having a few dedicated hunters willing to take multiple deer was far more valuable than having large numbers of hunters. Each year, a few hunters were responsible for the majority of the deer harvested. These few individuals were generally the most vested in the program and spent more time hunting. Two of our participants owned and utilized blood-tracking dogs, which helped limit loss of wounded deer that ventured off properties (Fig. 22).

Figure 22. The availability of blood-tracking dogs among some of our participants helped in locating shot deer that were difficult to track. *Photo – B. Blossey.*

We conducted hunting in the VOL from fixed treestand locations based on close cooperation and communication with landowners and neighbors. Where discharge distances fell within 500’, we obtained written permission from adjacent landowners. Each year we noted overuse of treestands with high deer traffic, or sightings of large bucks. Quick success created high shooting pressure in certain locations, and we experimented with temporary closings. However, surviving deer also became savvier, passing treestand locations just outside shooting range.

Initially, the VOL used DEC-issued DMAPs, but hunter harvests were constrained by lack of property access, lack of ability to harvest more than two deer per hunter per year using DMAPs, and changes in deer behavior due to hunting pressure. The establishment of the DMFA allowed a longer season and more liberal antlerless deer harvests, but discharge distances set by New York State (previously 500’) limited use of certain areas. With changes in discharge distances to 150’ approved for the 2014 season, we expect an expansion of access and more ease in determining and shifting treestand locations.

After safely harvesting several hundred deer from VOL lands, our observations and anecdotal reports from VOL residents and officials suggested a substantially reduced deer population, fewer DVCs (Figs. 23 and 24), and a return of some native plants not seen in previous years. However, complete data from VOL is lacking, which precludes statistical testing. Moreover, our aforementioned ecological assessments using red oak sentinels indicated that deer reductions have not sufficiently reduced negative impacts after seven years of coordinated bowhunting. Consequently, we are contemplating changes, including use of bait and DDPs to achieve management goals.

Figure 23. White-tailed doe after a fatal collision with a vehicle. *Photo – B. Blossey.*

Overall, our experiences, along with those of the participating landowners and hunters, have been positive. Landowners who initially participated in the deer management program continue to participate, and we have never lost access to a property due to our activities. We experienced no problems with safety, and no infractions of rules by approved participants. Despite our success in managing a safe and organized deer management plan in VOL, we recognize that goals have not been fully achieved. Further deer reductions will be necessary.

Lessons Learned

We describe an increasingly aggressive deer management program in a suburban landscape for the benefit of other communities challenged with white-tailed deer impacts. Despite our use of surgical sterilization, EAB hunting, and DMFA liberalization of antlerless deer harvest during the first five years of this study, it became clear that we only stabilized the deer population, and did not reduce numbers to a level that alleviated negative impacts. By winter of 2013, we stabilized the campus deer herd to approximately 100 animals (57 deer/ mi^2), a density much higher than project goals (75% reduction =~14 deer/mi^2). Despite these numbers, we did see a decrease in campus does and fawns appearing in photographs during the five-year study period, a decrease offset by an increase of bucks.

Bucks from outside the core campus sterilization zone may have been attracted to the does that received tubal ligation surgery. These females continued estrus cycling each month through February or March, as they did not become pregnant during the normal breeding season. Moreover, EAB program rules required the harvest of two female deer before becoming buck eligible, resulting in few bucks harvested and higher survival rates. For these reasons, we replaced tubal ligation with ovariectomy surgery, and relaxed the EAB rule to one antlerless deer per buck, to increase buck harvests. These changes occurred during the last two years of this study. In 2014, however, we discontinued use of surgical sterilization and EAB rules.

Results from theoretical studies and the Cornell experience do not bode well for the feasibility of surgical sterilization as the sole tool for reducing high-density, open deer populations. We recognize that local housing densities and lack of open space present real challenges for managing deer in suburban and urban areas, and social pressures against lethal control may direct communities toward sterilization or other fertility control programs. Due to the high cost, this will only be feasible in affluent communities, or with help of donors. Nonetheless, communities considering, or being forced into a deer sterilization program by opponents of deer removal, should be prepared to only achieve small reductions in deer numbers. In this scenario, a high proportion of females would need to be treated, and deer mortality from DVCs should offset births and immigration. However, they may not see long-term success, even over 10 years or more, unless immigration can be controlled, or deer mortality rates can be increased. Even under those circumstances, whether ecologically-articulated goals, such as oak recruitment, can be achieved remains questionable. We see little hope for long-term viability of this strategy. Those communities that started with sterilization only, have subsequently either embraced lethal deer management, or allowed deer populations to persist at undesirable levels.

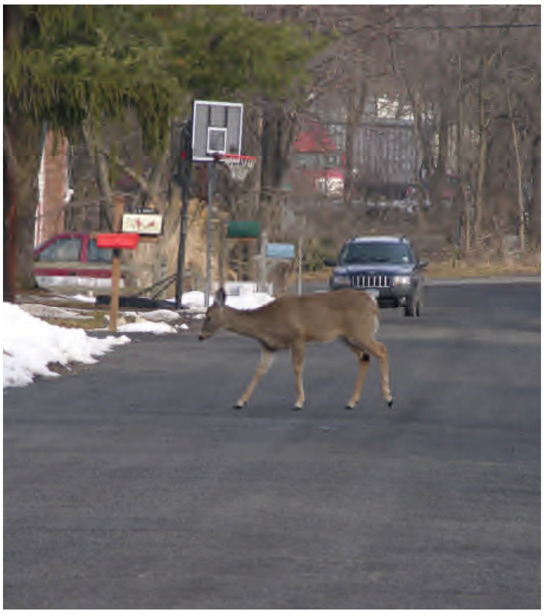

Figure 24. White-tailed deer crossing the road in front of an oncoming vehicle. *Photo – P. Curtis.*

Recommendations for Agencies

- Create suburban deer management zones to reduce deer numbers and associated impacts (similar to DEC's DMFA).
- Expand deer hunting seasons (September to January or beyond) to increase hunting times and avoid changes in deer behavior in response to elevated hunting pressure.
- Expand the ability to use dedicated permits to reduce deer populations and make sure that qualification for use of such tags include conservation goals.
- Consider changing the name of nuisance deer tags (Deer Damage Permits, DDP, in New York State) to Deer Conservation Permits (DCP) to reflect management goals.
- Allow unlimited take of deer for hunters using DCPs.
- Ensure that DCP policies are flexible to allow take of antlered and antlerless deer as needed to meet management objectives.
- Articulate (and assess) management goals using conservation concerns, not only hunter satisfaction and deer numbers. This will receive more support in communities – but maybe less support from hunters.
- Incorporate ecological goal-setting in hunter education programs by initially updating hunter education instructors, and then revamping hunter curricula.
- Consider regulatory structures and management policies that could integrate regulated commercial hunting as a tool to achieve ecological carrying capacity at reduced deer densities.
- Explore incentive programs or financial match grants to stimulate community deer management programs.
- Assess program success using ecological indicators paired with social science work.

Though we strongly advise against implementing sterilization or other fertility control programs without also integrating lethal control, where pursued, we recommend that >90%, and preferably 95% of female deer be targeted for sterilization surgery due to high survival and reproductive rates in suburban landscapes. If a community cannot afford these high costs (e.g., approximately $1,000/deer or more), then sterilization should not be implemented. Sterilization effectiveness may increase for smaller-scale, gated communities that can prevent deer immigration. Other communities are trying immunocontraceptive vaccines. However, these vaccines have proven less effective than sterilization, and our own experience suggests that culling is the most cost-effective management option.

Liberal antlerless deer take through the DMFA allowed for additional deer harvest on EAB lands. The DMFA permits harvest of two antlerless deer per day during open seasons, but survey research indicates that hunters might not wish to harvest more than 2–3 deer per season. In a survey of EAB hunters at Cornell's Arnot Forest, for example, hunters were willing to harvest an average of only 2.5 antlerless deer per season. Should this hold true on Campus EAB lands, more registered hunters would be necessary to offset these limitations. Interestingly, many hunters registered with EAB but never participated, suggesting that these hunters may view these lands as a "backup" place to hunt, or that hunters simply did not have time to participate.

As seen in other EAB studies, we demonstrated that a majority of deer harvested on CU lands across years were adult does, followed by fawns. However, data collected at the deer check station suggest that we have not achieved a 50% reduction in deer numbers. More importantly, increases in antlerless harvest have not yet resulted in demonstrative reductions in rates of oak browsing in the EAB study area. Daily hunting pressure may affect deer behavior by pushing deer into adjacent "no hunting" lands, or creating nocturnal deer. Retaining hunter interest while reducing deer populations remains a paradox, because as deer become sparse or savvy, hunting participation may wane. The question remains as to whether we can retain sufficient hunter interest while decreasing the number of deer in the future.

Permits issued by DEC allowed for a significant increase in deer taken near campus via archery equipment and captive bolt, and these additional methods should help decrease deer numbers and impacts in the core campus sterilization zone (Fig. 25). However, use of a captive bolt was controversial, and its use on Campus lands precipitated national petition efforts by groups opposed to killing of deer. Communities that choose to use lethal control may be subjected to intense controversy and need to be prepared. It takes strong local leadership to weather potential intense negative media campaigns.

We cannot stress enough the issue of safety during this integrated approach to deer management. Our efforts demonstrated that lethal control through hunting and sharpshooting can be safely and effectively conducted in areas with dense human populations and high public use. We also demonstrated that deer can be safely and humanely captured and euthanized with a penetrating captive bolt in areas where firearms or bows could not be discharged. With the discontinuation of deer sterilization on core campus, we will continue using lethal methods into the future.

Figure 25. DDP deer harvests. *Photo – B. Blossey.*

We remain optimistic that continued reduction in deer numbers will lessen negative impacts as this study continues, particularly given recent changes to the IDRM Program.

To review, IDRM changes included:

1) discontinuation of surgical sterilization;
2) discontinuation of EAB rules (hunters may self-select deer harvested based on state laws);
3) the DMFA program which allows harvesting two antlerless deer per day during open hunting seasons; and
4) use of DDPs to allow deer taken outside of regular hunting seasons (Fig. 26).

Figure 26. A sterilized doe (recognizable by the ear tag) feeding in bright daylight on remaining corn at a nuisance bait site. *Photo – IDRM Program.*

Cayuga Heights, a dense suburban village between Cornell University and VOL, has implemented deer sterilization via an independent contractor, but is also contemplating lethal control. These efforts may help reduce deer immigration into neighboring areas. We also remain hopeful that we can educate hunters about benefits of balancing recreation with clearly-articulated goals for ecological restoration and conservation. The expanded use of DDPs and use of Clover traps with penetrating captive bolt in 2014 (sixth year of study) helped reduce the campus deer herd by 45% in just one year. Continuing efforts to reduce deer numbers and impacts are aided by the fact that we are working with a sterilized population with low recruitment.

Overabundant suburban deer populations continue to challenge natural resource agencies and local communities. Although Cornell University as a single landowner is able to combine lethal and nonlethal deer management techniques with wildlife agency and cross-campus support, communities will need broad-based support and the political will to implement lethal deer control. Moreover, communities will need credible and professional wildlife agency staff able to balance both the biological and social dimensions of mitigating negative deer impacts.

Recommendations for Communities and Landowners

- Assess conditions using deer impact and ecological indicators, not deer numbers.
- Articulate desirable deer management goals, not in terms of deer numbers alone, but in concert with ecological and other indicators. Make sure that these assessments continue so management approaches implemented can be validated for their effectiveness and changed if unsuccessful.
- The most successful approach is using sharpshooters over bait (with rifles, bows, or crossbows).
- Avoid, where possible, nonlethal methods as they have not shown promise in areas where deer can move freely on the landscape. Where sharpshooting over bait is not a possibility, we recommend a multi-pronged approach given that archery and fertility control by themselves have not reduced deer populations to tolerable levels. The inclusion of lethal methods can result in a protracted fight with those opposed to killing of deer. Having articulated, measurable deer impacts, and goals to reduce them, will go a long way in winning public support, but may not avoid legal challenges. Local leaders should be patient and have endurance. Professional management advice will be essential.
- Develop local expertise (or contract this out) on deer management. Not every hunter will have the background and information needed to effectively coordinate or implement approaches that differ markedly from traditional hunting.
- Organize hunter/participant education and training. Learn techniques and approaches to enable safe and more successful deer removal. This is particularly important for what we consider the best approaches: bait and shoot at night with volunteer rifle (where permitted), bow or crossbow hunters, or use of contract professionals. Despite the excellent safety records for such programs, people opposed to such approaches will launch scare campaigns. Be prepared.
- Fewer, trained hunters/participants are better than open access. Properly managed access and stand use will increase success rates.
- Continue to assess conditions and report to residents. Support for the program will be essential, because once started, deer management must be maintained.
- Fence high-value plantings (ornamental or native) because deer population reduction may take many years, leaving these plants vulnerable during the interim. We need to protect seed sources and genotypes.
- Begin managing deer populations before impacts become excessive. If deer are in your community now, there will likely be many more in a few years. Save expense and prevent negative impacts by managing proactively rather than reactively.
- Suburban deer management requires community involvement and municipal support. State agencies cannot force management action on private or municipal public lands. If community deer impacts are excessive, inaction by local policy-makers is socially and ecologically irresponsible.

Recommendations for Communities and Landowners *continued*

- Involve legal counsel in the planning process to ensure appropriate compliance with State Environmental Quality Review laws and minimize potential legal challenges by opponents of deer management.
- Identify constraints to effective deer management within municipal codes and ordinances and modify as needed.
- Work with state agencies to identify constraints within state statutes that limit effective deer management within communities, and advocate for amendments granting greater flexibility and regulatory authority to state agencies.
- Consider capture and euthanasia as an effective and humane technique for deer population management in developed areas where other forms of lethal control may be inappropriate. In contrast to fertility control, capture and euthanasia yields immediate reduction of the deer population and associated impacts.

Figure 27. Deer feeding close to occupied buildings such as this house may preclude use of firearms or cartridge-fired dart rifles. *Photo – P. Curtis.*

Recommendations for Policy-makers

- Although deer populations have always been managed for sustainability, recognize that game management laws were developed in a time of deer scarcity. Game law changes since the early years of management have made progress, but they have not adequately evolved to address current deer management challenges in all areas. Push for continued adaptation and progression of laws and regulations.
- Work with management agencies to remove statutory prohibitions that limit management tools and effectiveness in rural and suburban environments (e.g., discharge setbacks [Fig. 27], prohibitions of specific tools except in research contexts, constraints on hunting season length, bag limits, and implements).
- Authorize managing agencies to establish regulations for the limited and controlled use of bait to increase hunter efficacy where needed.
- Authorize managing agencies to establish a regulatory structure specifically for community-based deer management that incorporates nontraditional techniques for recreational hunting (e.g., longer hunting hours, use of lights, sound suppression on firearms, and incentives).
- Streamline the permitting processes for sharpshooting, deer culling, deer capture and euthanasia, and fertility control.
- Expand the toolbox for agency or professional sharpshooters (e.g., use of sound suppression on firearms, discharge from vehicles).

A Deer Manager's Toolbox – Lethal Control

Translocation

Research conducted on the capture and translocation of deer suggests that animals are stressed during the process, and experience high mortality after release, which is why we choose to place this method in with other lethal controls. Translocation is cost prohibitive, may increase the spread of disease, and few places would accept these animals. Many wildlife management agencies prohibit this technique.

Predator Reintroduction

Deer predators such as wolves and mountain lions were extirpated over much of their range, and recent work has shown that coyote predation does not control overabundant deer populations, with the exception of very special circumstances. At this time, wildlife management agencies are unlikely to advocate for release of mountain lions or wolves in our region due to biological constraints in suburban landscapes, and stakeholder concerns over resource use and safety. It is also questionable whether large predators would have the ability to control abundant deer populations given the ratio of predator to prey. In Wisconsin's remaining wolf range, for example, there are likely more than 1,000 deer for every wolf, a clear indication that wolves by themselves, while certainly feeding on deer, will not be able to control or reduce deer numbers sufficiently.

Regulated Hunting

This is often the first method proposed as a solution for deer problems, and is advocated by both state wildlife management agencies and hunters. Successful deer reduction via hunting depends on a community's established objectives. For example, hunting, where permitted, may be useful in reducing some level of DVCs, or when implemented before deer populations become too large. This method, along with sterilization, comprised the core of Cornell's initial deer management approach. Our experiences with regulated hunting at Cornell, along with many other communities in the U.S., suggest difficulty in reducing deer abundance to a level that achieves ecological goals. The lack of success in reducing deer populations further may result from a collection of problems including lack of access, hunting regulation impediments, and hunter behavior and preferences. Many areas may remain closed to hunters due to landowner preferences, and deer will quickly find these refugia. Hunting regulations (short seasons, lack of ability to shoot multiple bucks or does, discharge distances) may prevent dedicated individuals from filling more than the usual one or two tags that most hunters use per season. High hunting pressure in certain areas will result in changed deer behavior (animals may become increasingly nocturnal or change travel routines), decreasing hunter success. Furthermore, most hunters do not see themselves as deer managers, and consider hunting their recreation. Even successful individuals rarely shoot more than two or three deer per year, and others may need to be educated about techniques when pursuing suburban deer. Our harvest success rate in the EAB program of <30%, and the many hours hunters spent in the field to harvest a deer, suggest that improvements in the regulated hunting approach are necessary to achieve goals for deer impact reduction.

Capture and Euthanize

Methods used to capture and euthanize deer include drop nets, Clover traps, or darting to capture deer, followed by penetrating captive bolt, exsanguination, firearms, or chemical euthanization. In most instances, these methods will require contracting with professionals from USDA/APHIS/Wildlife Services, law enforcement, or private contractors. Although we have successfully used Clover traps and penetrating captive bolt, a technique approved by the U.S. Food and Drug Administration, the American Veterinary Medical Association and by Cornell's Institutional Animal Care and Use Committee, to euthanize deer in dense suburban areas, staff time and expense were concerns for its continued use. In addition, this method resulted in vehement opposition from a minority of local residents.

A Deer Manager's Toolbox – Lethal Control *continued*

The capture-and-euthanize approach has been halted by court order in some communities where attempted. Use of dart rifles and immobilization drugs to capture deer is quick and effective, but using this method in conjunction with euthanasia renders deer meat unfit for human consumption, one of the key conditions that many communities stipulate for deer control. Being able to donate deer meat for consumption is why we chose to use Clover traps and penetrating captive bolt.

Bait and Shoot

This is the only method we are aware of that has demonstrated quick reductions in suburban deer populations. While bait and shoot has clearly reduced deer numbers and DVCs in numerous suburban communities, we are not able to assess whether deer reductions have also resulted in reductions in ecological impacts. We are pursuing this work on Cornell lands, but we cannot provide much evidence at this time. Bait and shoot methods may be divided into either volunteer contributions, such as in our DDP efforts at Cornell, or contractual services by professionals. In both instances, participants bait deer into locations where discharge of bows, crossbows, or firearms is safe; and deer are shot at close range. This method is most effective on naïve deer herds unfamiliar with hunting. Although hunted deer tend to be much more cautious, bait-and-shoot methods can still lead to population reductions. Using contractual services is expensive, but time spent afield is greatly reduced, and costs are generally much less than fertility control. Bait-and-shoot techniques are clearly the most likely to reduce deer populations to the lowest levels possible, given all of today's options.

Regulated Commercial Hunting

Under current laws and regulations, this method is not legal in most states. This proposed method may include contracting deer management out to approved individuals or companies, or expanding the ability of recreational hunters to sell meat or other deer parts. Contractors or individuals would be able to sell venison at market prices to cover their time and costs. Numerous and notable wildlife professionals in the U.S. support and continue to debate this method. North American wildlife management agencies have not moved forward with the idea of bringing back commercial hunting, and the sale of wild-caught venison is prohibited in most states. Moreover, hunters who consider it a threat to their recreational pursuits vehemently oppose commercial hunting. Ironically, venison sold in U.S. stores is either farm-raised or imported from New Zealand, where white-tailed deer were introduced and have become an invasive pest species, and where deer are commercially hunted.

A Deer Manager's Toolbox – Nonlethal Control

Change Ornamental Planting Regimes

The recommendations to use non-palatable plantings often contain non-native, sometimes invasive species, and thus not ecologically-acceptable options. Furthermore, widely planting just a few reliably deer-resistant plants will greatly reduce local biodiversity with unacceptable consequences for native insects and birds that require native species as food and shelter.

Repellents (Chemical and Physical)

Repellents in various forms (chemical or nonchemical, such as scare devices in gardens or along roadways) may have short-term effects, if at all, but they are not a permanent solution, despite widespread claims.

A Deer Manger's Toolbox – Nonlethal Control *continued*

Fences

Although some deer can clear an 8-foot-high fence, depending on terrain, this minimum height can be effective for keeping deer out of high-value areas permanently, but it excludes other wildlife, has high initial costs, and pushes deer into adjacent unfenced areas. Fences will remain an essential option to guard roads, high-value ornamental plantings, or threatened populations of native species. However, they have no effect on overall deer abundance in a community.

Fertility Control

At present, sterilization can only be performed on deer in New York State as part of approved scientific studies and requires a DEC License to Collect and Possess (LCP) research animals. In other states, you should contact your state wildlife agency to determine applicable laws and regulations. Such regulations change frequently, and you need to keep up to date. Until further data are gathered and analyzed, this technique continues to be experimental, and is not an approved method routinely available to managers. See below for a more in-depth treatment of fertility control.

Deer Fertility Control

Attempting to manage a suburban deer herd using fertility control alone will not likely be successful in areas with high deer densities. Deer are long-lived (>12 years), and without mortality, sterilized female deer will continue ecological and social impacts unabated, except for the gradual attrition of deer killed by vehicles. Modeling has shown that removing a female deer has two to three times the impact on population growth than sterilizing a female deer. Managing a deer herd via vehicle collisions is both inhumane and costly for community residents.

Surgical Sterilization

Modeling studies have suggested that a high percentage (80% or more) of female deer must be treated to have measurable effects (either population stabilization or decline) over a period of five to 10 years. Male deer are not sterilized because a single buck can mate with dozens of female deer, and capturing all male deer in an open population is extremely difficult. In many suburban deer herds where hunting is limited, deer survival is high, with DVCs as the primary mortality factor. Garden and ornamental plants subsidize deer herds, resulting in high quality food sources and deer in good condition, even at very high densities. Consequently, reproductive rates are also high, with most adult females producing twin fawns, and occasionally triplets. Under these conditions, treating at least 90% of the females should be the minimum goal, and sterilization rates of 95% or more are desirable. If less than 50% of the female deer in an area are treated, there is little chance to have any measurable population-level effects.

Surgical sterilization of female deer is very expensive and limited by scale. In a research project conducted in Cayuga Heights, New York, deer were captured, anesthetized, and transported by skilled personnel. The animals were then sterilized (removal of the animals' ovaries) by licensed veterinarians in temporary surgical facilities. The entire procedure cost about $1,000 per animal, on average. However, this cost per deer is not constant because the easy-to-capture deer are treated first with little effort ($700–800 per deer). Yet much greater effort is needed to catch the last remaining individuals to reach target sterilization levels. This greatly increases treatment costs per deer. Once 85% or more of the females have been sterilized, it may cost >$3,000 per animal to treat the last 10 to 15% of remaining females. All treated deer should also be marked with ear tags to distinguish treated animals from unsterilized ones.

Application of fertility control in free-ranging deer is scale limited. Catching and treating female deer is technically and economically feasible on relatively small areas, from 2–5 mi^2. Given typical suburban deer densities of 100 deer/mi^2 or more in the northeastern U.S., in areas greater than five square miles, the practicality diminishes because of the cost and time involved in detecting, and then capturing and surgically treating, hundreds of deer. In addition, even if the initial sterilization goal of 90–95% can be achieved, there will be ongoing annual maintenance costs to treat immigrating untreated females.

To catch and treat a high percentage of deer will require not only sustained effort and planning, but also cooperation from landowners and local police agencies. With sufficient trap sites, possibly 50–60% of the female deer in an area can be caught by stationary traps (e.g., Clover traps or drop nets; Fig. 28). Once this level is achieved, mobile darting from a vehicle at night will be needed to catch wary female deer that are reluctant to approach baited sites. Because it is illegal to have loaded firearms (dart rifles) in a vehicle in some states, police collaboration (officers are exempt from this rule) may be needed for mobile darting and animal recovery on private lands. This technique may also require permission from private landowners to discharge or access property for deer recovery.

Without this flexibility, it will be difficult to achieve the high treatment rates necessary for the anticipated long-term population reductions. Even under ideal scenarios in open populations (where immigration is a possibility), our experience shows that the anticipated population declines were not achieved on the Cornell campus. Even when 90% or more of the females were sterilized over five years, immigration of both males and females from the surrounding areas offset mortality, and the herd size remained stable.

Figure 28. Groups of deer are best captured together via drop nets when possible. *Photo – IDRM Program.*

Immunocontraceptive Vaccines

A number of different approaches and techniques exist that can be considered contraceptive agents. These include steroidal contraceptive drugs, and vaccines such as GnRH (GonaCon™) or Porcine Zona Pellucida (PZP). Many of the same limitations noted for surgical sterilization (e.g., cost, scale, permitting, and access to deer) also apply to any application of immunocontraceptive vaccines. In addition, current vaccines and adjuvants (material in a vaccine designed to enhance the immune response) require that treated female deer be given booster shots every year or two. Ideally, all treated animals should be individually marked (e.g., ear tags) to avoid focusing efforts on deer already treated. In field experiments to date, it has been difficult to keep free-ranging deer on a booster schedule. After deer have been trapped and tagged, experienced deer become bait shy, and may be difficult to approach within dart range (15–25 yards), even in a suburban setting.

Steroidal contraceptive drugs do exist, but they are not practical for free-ranging deer. Steroidal drugs persist in deer carcasses, so that they can impact other species (e.g., humans or scavengers) after meat consumption. It is very unlikely that any steroidal drug would be registered by the U.S.

Environmental Protection Agency (EPA) for application in free-ranging deer.

The USDA/APHIS/Wildlife Services-National Wildlife Research Center (NWRC) has developed an immunocontraceptive vaccine (GonaCon™) that is EPA-registered for use on female deer in the U.S. However, GonaCon™ is not currently registered in New York State, given no cooperator or local entity has requested its use and agreed to pay the costs for a lengthy registration process. GonaCon™ must be state-registered as a Restricted Use Pesticide, which can only be administered by USDA/APHIS/Wildlife Services staff, state wildlife personnel, or persons working under their authority. Many state wildlife agencies consider the GonaCon™ vaccine experimental, and as for surgical sterilization, a research license (LCP) is required to capture, tag, and treat free-ranging deer. Initially, this may cost about $400 to $500 per deer, but as for surgical sterilization, the costs increase as a higher percentage of the herd is vaccinated. That is because unvaccinated deer become increasingly difficult to locate and capture. The current EPA label states the vaccine must be hand-injected, requiring deer capture and immobilization. The efficacy of the vaccine diminishes after a year or two, and the same animals would need to be recaptured and hand-injected with booster shots, at high cost.

Porcine Zona Pellucida (PZP) is the most commonly used immunocontraceptive vaccine for deer and other wildlife. As would be the case for GonaCon™, a research permit is required to treat female deer in New York. There have been many research trials with PZP vaccines in deer in New York (e.g., Seneca Army Depot, Irondequoit, Fire Island National Seashore, Hastings-on-Hudson), and elsewhere (e.g., National Institute of Standards and Technology, Maryland, and Fripp Island, South Carolina). The Humane Society of the United States is currently studying a longer-lasting adjuvant that could provide multiple-year effects with fewer booster doses. Preparation of a reliable, single-dose immunocontraceptive vaccine has been difficult, and at this time, none are currently available.

Research data from Seneca Army Depot in Romulus, New York, indicated that about 13 to 14% of female deer treated with either a GnRH or PZP immunocontraceptive vaccine became pregnant and delivered fawns (usually a single fawn). The reasons for these failures are not well understood, but could be due to variability in the immune system response of individual females. As for other vaccines, not all animals respond to the same dose of drug in the same way, and resulting antibody titers can be quite variable. This may partially account for the higher than anticipated pregnancy rates (31.2%) for PZP-treated deer in the Fripp Island, South Carolina, study discussed below. The formulations of the GnRH and PZP immunocontraceptive vaccines used at Seneca Army Depot were prepared by the NWRC. Annual booster doses were recommended for each female deer. We observed that if deer were not given booster shots in the fall, about 28 to 29% of those deer treated with either GnRH or PZP vaccines would produce a single fawn during the following summer. Not treating deer with GnRH contraceptive vaccines for two consecutive fall seasons resulted in 57% pregnancy rates for those female deer. In addition, we noted depletion of bone marrow fat in about 10% of female deer treated with a PZP vaccine. The cause for this anomaly is unknown. Bone marrow fat is usually the last body fat metabolized during a severe winter. Wildlife managers use levels of bone marrow fat to determine if winter-killed deer died of malnutrition. Consequently, there is potential for mortality of PZP-treated deer during a severe winter in northern states.

Population reductions in deer herds treated with immunocontraceptive vaccines depend on the proportion of deer treated, along with mortality, immigration, and emigration rates. While the proportion of deer treated can be controlled under ideal circumstances, and hunting or culling can influence mortality rates, usually there is no control over emigration or immigration unless the herd is fenced, or on an island. While numerous studies concerning the efficacy of PZP in deer have been conducted, population reductions have been reported at only three sites: Fire Island National

Seashore, the National Institute of Standards and Technology (NIST), and Fripp Island. Reductions in deer numbers have been variable, however, because of the lack of control over mortality and immigration rates at these sites, and because of treatment intensity and ability to administer boosters effectively. With the mostly-fenced herd at NIST, deer population reductions started after two years, declined at a modest 6–8% for 5 years, then numbers stabilized. Further reductions were apparently offset by immigration. At Fripp Island, deer populations declined by 35% during 2006 to 2010 (from 357 deer to 231). Most does observed (91–94%) were ear tagged and had been treated with PZP immunocontraceptive vaccines. Despite this high level of treatment, overall annual pregnancy rates for treated females averaged 31.2% over the five-year study. Pregnancy rates were variable, in part, because different formulations of PZP were used at different times. Although deer populations were reduced at NIST and Fripp and Fire Islands, the densities remained at >100 deer/mi^2, continuing their devastating ecological impacts.

A contragestation (abortion) agent (prostaglandin F2α) has proven to be safe and highly effective in deer. Any risk to secondary consumers is minimal because prostaglandin F2α is rapidly metabolized by treated females. The use of this material in free-ranging deer would still be experimental and require a research permit, and there are several limitations. The drug has to be administered by injection or darting each year early in pregnancy. As for contraceptive vaccines, all treated female deer would have to be tagged. Negative public perceptions of abortion agents may also limit acceptance of the technique.

Currently, darting and hand-injection are the only potential methods for delivering immunocontraceptive vaccines. In some areas, dart rifles that use blanks containing gunpowder are considered firearms, and are restricted to legal discharge setbacks close to occupied buildings (Fig. 27). CO_2-powered dart rifles, however, may be exempt from these restrictions.

Research underway to collar deer at automated, unmanned feeding stations with acaricide-treated collars for tick control may allow delivery of immunocontraceptive vaccines in the future (if successful). However, devices to collar deer are experimental, and none are currently registered in New York, or anywhere in the U.S. Furthermore, such automated stations have not been invented for delivering immunocontraceptive vaccines, and would be problematic to operate in the field. The device would have to be designed to safely and accurately inject deer of widely differing body sizes, and exclude deer that have already been treated. They would also have to be resistant to human tampering and vandalism. The accidental injection of a human with the vaccine, in the course of any tampering, would raise a significant liability issue.

The NWRC has a goal of developing an orally-effective immunocontraceptive vaccine for deer. To date, this has not been feasible, as it is difficult to get drugs through a ruminant digestive system, and have the drugs absorbed in suitable doses. A delivery system (e.g., feeders available only to deer) would also have to be designed to avoid the unintentional contraception of other non-target wildlife species.

Because each female only needs to be captured and treated once, and efficacy of treatment is substantially higher with surgical sterilization, it is clear that surgical sterilization is currently a better option than immunocontraception. Also with surgical sterilization, efficacy rates are usually between 96% and 100%, which is far higher than immunocontraceptive vaccines (currently about 85 to 90% efficacy rates). However, neither technique has proven effective at achieving desired deer population reductions in island or fenced deer populations, let alone in wild, free-ranging deer populations.

Selected References

Augustine D. J., and L. E. Frelich. 1997. Effects of white-tailed deer on populations of an understory forb in fragmented deciduous forests. Conservation Biology 12:995–1220.

Barlow, N. D., J. M. Kean, and C. J. Briggs. 1997. Modeling the relative efficacy of culling and sterilization for controlling populations. Wildlife Research 24:129–141.

Beaudette, A. 2007. Effects of surgical sterilization upon home range area of a suburban white-tailed deer population. Senior Honor's Thesis, Department of Natural Resources, Cornell University, Ithaca, New York, 14853.

Beringer, J., L. P. Hansen, J. A. Demand, J. Sartwell, M. Wallendorf, and R. Mange. 2002. Efficacy of translocation to control urban deer in Missouri: costs, efficiency, and outcome. Wildlife Society Bulletin 30:767–774.

Boone, J. L., and W. G. Wiegert. 1994. Modeling deer herd management: sterilization is a viable option. Ecological Modeling 72:175–186.

Boulanger, J. R., P. D. Curtis, E. G. Cooch, and A. J. DeNicola. 2012. Sterilization as an alternative deer control technique: a review. Human-Wildlife Interactions 6(2):273–282.

Boulanger, J. R., G. R. Goff, and P. D. Curtis. 2012. Use of "earn-a-buck" hunting to manage local deer overabundance. Northeastern Naturalist 19(Special Issue 6):159–172.

Bressette J. W., H. Beck, and V. B. Beauchamp. 2012. Beyond the browse line: complex cascade effects mediated by white-tailed deer. Oikos 121:1749–1760.

Cambronne, A. 2012. Deerland: America's hunt for ecological balance and the essence of wildness. Headwaters Communications, Guilford, Connecticut, USA.

Clover, M. R. 1954. A portable deer trap and catch-net. California Fish and Game 40:367–373.

Comisky, L, A. A. Royo, and W. P. Carson. 2005. Deer browsing creates rock refugia gardens on large boulders in the Allegheny National Forest, Pennsylvania. American Midland Naturalist 154:201–206.

Côté, S. D., T. P. Rooney, J. P. Tremblay, C. Dussault, and D. M. Waller. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology and Systematics 35:113–147.

Curtis, P. D., A. N. Moen, and M. E. Richmond. 1998. When should wildlife fertility control be applied? Pages 1–4 *in* P. D. Curtis, editor. Workshop on the Status and Future of Wildlife Fertility Control. The Wildlife Society, Buffalo, New York, USA.

Curtis, P. D., B. Boldgiv, P. M. Mattison, and J. R. Boulanger. 2009. Estimating deer abundance in suburban areas with infrared-triggered cameras. Human-Wildlife Conflicts 3:116–128.

Decker, D. J., and N. A. Connelly. 1989. Deer in suburbia – pleasures and pests. The Conservationist 43:46–49.

deCalesta, D. S. 2013. Reliability and precision of pellet-group counts for estimating landscape-level deer density. Human-Wildlife Interactions 7(1):60–68.

DeNicola, A. J., and S. C. Williams. 2008. Sharpshooting suburban white-tailed deer reduces deer-vehicle collisions. Human-Wildlife Conflicts 2(1):28–33.

Diamond, J. 1992. Must we shoot deer to save nature? Natural History August:2–8.

DiTommaso, A., S. H. Morris, J. D. Parker, C. L. Cone, and A. A. Agrawal. 2014. Deer browsing delays succession by altering aboveground vegetation and belowground seed banks. PLoS One 9(3):1–9.

Eschtruth, A. K., and J. J. Battles. 2009. Acceleration of exotic plant invasion in a forested ecosystem by a generalist herbivore. Conservation Biology 23:388–399.

Frank, E. S., and S. L. Sajdak. 1993. Sterilization as a method of controlling an urban white-tailed deer population. AAZPA Regional Proceedings, 485–490.

Heckel C. D., N. A. Bourg, W. J. McShea, and S. Kalisz. 2010. Nonconsumptive effects of a generalist ungulate herbivore drive decline of unpalatable forest herbs. Ecology 91:319–326.

Hobbs, N. T., D. C. Bowden, and D. L. Baker. 2000. Effects of fertility control on populations of ungulates: general, stage-structured models. Journal of Wildlife Management 64:473–491.

Horsley, S. B., S. L. Stout, and D. S. DeCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13:98–118.

Huijser, M. P., J. W. Duffield, A. P. Clevenger, R. J. Ament, and P. T. McGowen. 2009. Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada; a decision support tool. Ecology and Society 14(2):15.

Jacobson, H. A., J. C. Kroll, R. W. Browning, B. H. Koerth, and M. H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. Wildlife Society Bulletin 25:547–556.

Jessup, D. A., and K. R. Jones. 1983. Immobilization of mule deer with ketamine and xylazine, and reversal of immobilization with yohimbine. Journal of the American Veterinary Medical Association 183:1339–1340.

Jones, J. M., and J. H. Witham. 1990. Post-translocation survival and movements of metropolitan white-tailed deer. Wildlife Society Bulletin 18:434–441.

Kilpatrick, H. J., S. M. Spohr, and A. J. DeNicola. 1997. Darting urban deer: techniques and technology. Wildlife Society Bulletin 25:542–546.

Kilpatrick, H. J., A. M. LaBonte, and K. C. Stafford, III. 2014. The relationship between deer density, tick abundance, and human cases of Lyme disease in a residential community. Journal of Medical Entomology 51(4):777–784.

Knight, T. M., J. L. Dunn, L. A. Smith, J. Davis, and S. Kalisz. 2009. Deer facilitate invasive plant success in a Pennsylvania forest understory. Natural Areas Journal 29:110–116.

Laver, P. N., and M. J. Kelly. 2008. A critical review of home range studies. Journal of Wildlife Management 72:290–298.

MacLean, R. A., N. F. Matthews, D. M. Grove, E. S. Frank, and J. Paul-Murphy. 2006. Surgical technique for tubal ligation in white-tailed deer (*Odocoileus virginianus*). Journal of Zoo and Wildlife Medicine 37:354–360.

Martin, T. G., P. Arcese, and N. Scheerder. 2011. Browsing down our natural heritage: deer impacts on vegetation structure and songbird populations across an island archipelago. Biological Conservation 144:459–469.

McCullough, D. R., K. W. Jennings, N. B. Gates, B. G. Elliot, and J. E. Didonato. 1997. Overabundant deer populations in California. Wildlife Society Bulletin 25:478–483.

McGraw. J. B., and M. A. Furedi. 2005. Deer browsing and population viability of a forest understory plant. Science 307:920–922.

McShea, W. J., S. L. Monfort, S. Hakim, J. F. Kirkpatrick, I. K. M. Liu, J. W. Turner, Jr., L. Chassy, and L. Munson. 1997. Immunocontraceptive efficacy and the impact of contraception on the reproductive behaviors of white-tailed deer. Journal of Wildlife Management 61:560–569.

McShea, W. J. 2012. Ecology and management of white-tailed deer in a changing world. Annals of the New York Academy of Science 1249:45–56.

Merrill, J. A., E. G. Cooch, and P. D. Curtis. 2003. Time to reduction: factors influencing management efficacy in sterilizing overabundant white-tailed deer. Journal of Wildlife Management 67:269–281.

Merrill, J. A., E. G. Cooch, and P. D. Curtis. 2006. Managing an overabundant deer population by sterilization: effects of immigration, stochasticity and the capture process. Journal of Wildlife Management 70:268–277.

Nuttle, T., E. H. Yerger, S. H. Stoleson, and T. E. Ristau. 2011. Legacy of top-down herbivore pressure ricochets back up multiple trophic levels in forest canopies over 30 years. Ecosphere 2:art 4.

Raizman, E. A., J. D. Holland, and J. T. Shukle. 2012. White-tailed deer (*Odocoileus virginianus*) as a potential sentinel for human Lyme disease in Indiana. Zoonoses and Public Health 60(3):227–233.

Romin, L. A., and J. A. Bissonette. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin 24(2):276–283.

Rooney, T. P. 2001. Deer impacts on forest ecosystems: a North American perspective. Forestry 74:201–208.

Rutberg, A. T., R. E. Naugle, J. W. Turner, Jr., M. A. Fraker, and D. R. Flanagan. 2013. Field testing of single-administration porcine zona pellucida contraceptive vaccines in white-tailed deer (*Odocoileus virginianus*). Wildlife Research 40(4):281–288.

Rutberg, A. T., R. E. Naugle, and F. Verret. 2013. Single-treatment porcine zona pellucida immunocontraception associated with reduction of a population of white-tailed deer (*Odocoileus virginianus*). Journal of Zoo and Wildlife Medicine 44(4):S75–S83.

Skinner, B. G. 2007. Surgical sterilization of female white-tailed deer in suburban Chicago, Illinois: social causes and biological impacts. Thesis, University of Wisconsin, Madison, Wisconsin, USA.

Sterba, J. 2012. Nature wars: The incredible story of how wildlife comebacks turned backyards into battlegrounds. Crown Publishers, New York, New York, USA.

Tilghman, N. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53(3):524–532.

Vercauteren, K. C., C. W. Anderson, T. R. Van Deelen, D. Drake, W. D. Walter, S. M. Vantassel, S. E. Hygnstrom. 2011. Regulated commercial harvest to manage overabundant white-tailed deer: an idea to consider? The Wildlife Society Bulletin 35(3):185–194.

Waas, J. R., J. R. Ingram, and L. R. Matthews. 1999. Real-time physiological responses of red deer to translocations. Journal of Wildlife Management 63:1152–1162.

Warren R. J. 2011. Deer overabundance in the USA: recent advances in population control. Animal Production Science 51:259–266.

Werden, L., I. K. Barker, J. Bowman, E. K. Gonzales, P. A. Leighton, L. R. Lindsay, C. M. Jardine. 2014. Geography, deer, and host biodiversity shape and the pattern of Lyme disease emergence in the Thousand Islands Archipelago of Ontario, Canada. PLoS ONE 9(1):e85640.

White, G. C. 1996. NOREMARK: population estimation from mark-resighting surveys. Wildlife Society Bulletin 24:50–52.

Williams, S. C., A. J. DeNicola, T. Almendinger, and J. Maddock. 2013. Evaluation of organized hunting as a management technique for overabundant white-tailed deer in suburban landscapes. Wildlife Society Bulletin 37:137–145.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecological Society of America 70:164–168.

Wright, R. G. 1993. Wildlife management in parks and suburbs: alternatives to sport hunting. Renewable Resources Journal 11:18–22.

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White-tailed deer (*Odocoileus virginianus*) **are one of the most pressing problems for habitat conservation and forest regeneration**. Deer-related impacts to woodlands and suburban communities are not new, and have been occurring for decades. What has changed is the magnitude of the losses, and greater public awareness of negative impacts. Although deer are still a valued recreational resource, many stakeholders view deer as "pests" because of the pervasive economic, health, and safety impacts in the eastern U.S.

Challenges

- Deer management must be based on clearly articulated outcomes, sound science and informed policy decisions.
- Forest ecosystem sustainability, and the health and safety of community residents, all depend on a successful outcome.
- Agencies, community leaders and managers need to be held accountable to provide appropriate information to residents and decision makers about the status of the health of their communities and deer-related impacts. It is their civic duty to reduce deer related impacts despite sometimes vocal public opposition to lethal management. Continuing failed approaches (including sterilization) to appease a minority wastes public resources and endangers species, habitats and human health.
- It will take strong agency leadership, and local community support, to develop and sustain deer management programs. Changes in procedures and approaches will need to be based on measurable evidence, not just deer numbers alone, but also on deer related impacts.

The Cornell University campus is no different from many other communities throughout the east, with a mix of fragmented forests, farm lands, and suburban development. We developed the Integrated Deer Research and Management Program to study the effectiveness of management approaches for deer in developed landscapes. It is our hope that other communities will learn from our experiences, as it does not serve public interests to waste time and money on programs that are likely to fail. Our goal is to conserve both deer and forest habitats for future generations, and reduce negative impacts associated with overabundant deer populations. Despite our best efforts over seven years, we have yet to achieve measurable reductions in deer-related impacts. Our study illustrates the enormity of the deer management challenge facing communities throughout North America. However, we believe we have found new approaches that may be successful in the next few years.

Cornell University
Department of Natural Resources
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