Deer Management Options

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Stewardship Handbook
for Natural Lands in Southeastern Pennsylvania

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Deer Overabundance

Forest fragmentation, the extirpation of large predators, and cultural norms about hunting have resulted in the proliferation of white-tailed deer to unprecedented population densities. Researchers believe that native forests evolved with deer densities of 5–10 per square mile (1 square mile = 640 acres). ***Deer populations are no longer kept at ecologically sustainable levels*** as they were for more than 99% of their existence, first by large predators and more recently by Native Americans, for whom venison was a major source of food.

A diverse array of predators regulated deer populations for millions of years before humans arrived in our region, including the timber wolf, dire wolf, grizzly bear, giant short-faced bear, mountain lion, American cheetah, and jaguar. Human hunters arrived in what is now southeastern Pennsylvania at least 13,000 years ago, forcing out most of the other major predators, but American Indians, timber wolves, and mountain lions continued to regulate deer populations until Europeans arrived and expelled all three. For the first two centuries after William Penn's arrival, the human population grew exponentially and unlimited hunting began eroding the delicate balance between predators and deer that had prevailed for eons. By 1900, white-tailed deer were nearly extinct in Pennsylvania and other eastern states because of over-harvesting. By instituting game laws, state agencies successfully rebuilt the deer population. Unfortunately, these hunting rules, which largely persisted through the 20th century, focused on providing a "maximum sustained yield" of game for recreational hunters and the deer population consequently soared to unprecedented levels in just a few decades. There is general agreement among scientists, resource managers (foresters, wildlife biologists, farmers, hunters) and landowners (rural and suburban) that this strategy has led to the degradation of forests, agricultural lands, and suburban landscaping throughout the state. (A detailed summary of this issue can be found in the 2005 report by the Deer Management Forum, titled Managing White-tailed Deer in Forest Habitat From an Ecosystem Perspective, available at http://pa.audubon.org.) The simple reason for this is that abnormally high deer populations affect all vegetation layers of the forest, including shrubs, herbs, and

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Browsing by overabundant deer populations is the most significant factor in forest decline in Pennsylvania.

the seeds and seedlings that would have become the next generation of canopy trees, if not consumed by deer.

Statewide, the deer density now averages 25 deer per forested square mile, two to five times the desired density of 5–10 per square mile (2003 PA Game Commission census). In some Pennsylvania suburban areas, populations have risen above 100 per square mile. Deer densities at this level threaten the perpetuation of forest communities, which depend on the ongoing establishment of tree seedlings and saplings in sufficient numbers to occupy the gaps that are created by periodic natural or human disturbance. A density of 15–20 deer per forested square mile has been found in some areas to be a maximum level allowing minimal advance tree and shrub regeneration (a sufficient number of

David Steckel

DEGRADED FOREST – There are no young trees to replace the old ones; no shrubs or low trees for birds to find food, nesting sites or cover; and no wildflowers to provide food or cover for ground-nesting birds and small mammals, or nectar for pollinators. Deer overbrowsing, along with stresses on hydrology and the impact of invasive species, can degrade a healthy forest community to the point where it becomes unsustainable.

David Steckel

HEALTHY FOREST – How can you tell you're in a healthy forest? You can't see through it, at least in summer. Lush and three-dimensional, this forest is home to a complex, diverse community of life. It is the natural result of good stewardship. Deer may be present but at a density low enough that the forest can sustain itself. Water and nutrients are available in appropriate amounts, and exotic plants have not displaced the natives.

established seedlings and saplings available to replace existing trees and shrubs following mortality or disturbance of existing vegetation), with a density of 5–10 per square mile needed to sustain a high diversity of native species, including native herbaceous plants.

Deer are browsers, which means their diet consists mainly of newly grown twigs of woody plants, primarily trees and shrubs. When populations are high, deer can consume all of the established seedlings, as well as many tree seeds (particularly acorns) and herbaceous plants. Over 100 species of native wildflowers and other plant species have been extirpated from Pennsylvania; at least some of these losses have been partly a result of overbrowsing by deer, and many more species are known to be in trouble in the state from the same cause. Browsing by overabundant deer dramatically reduces the survival of native flora and has led to the collapse of plant species diversity in the forest understory and the near cessation of tree reproduction in vast areas of Pennsylvania forests. The resulting lack of cover, food, and structural diversity within forests *(see photos at left)* has undoubtedly reduced wildlife populations, particularly of small mammal, bird, and amphibian species. Native oaks, which are highly preferred food for deer, are not regenerating, which means that wildlife-rich oak forests will cease to exist as adult trees age and die. Furthermore, exotic (non-native) invasive plant species are generally avoided by deer and other plant-eating wildlife (which is one of the reasons they are invasive), so deer have contributed to their proliferation by stripping the forests of their native competitors.

Part of the problem in understanding the forest health problem is that it is *too* easy to "see the forest for the trees." Most forests in our region still look healthy, with a canopy of large trees that have

A density of 15–20 deer per forested square mile has been found in some areas to be a maximum level allowing minimal advance tree and shrub regeneration, with a density of 5–10 per square mile needed to sustain a high diversity of native species, including native herbaceous plants.

grown since the last extensive clearing in the late 19th and early 20th centuries. The spread of invasive introduced shrub and understory tree species into natural areas over the last few decades has filled in the vegetation layers vacated by native species as the result of high deer densities. Most forests still look superficially healthy because they are green. Forests with an understory stripped of vegetation have a park-like structure, with tall canopy trees and a uniform low understory or no understory at all. Forests in some parts of our region have looked like this for so long that many people have the impression it is normal and natural.

The best chance for successful regeneration is within forest gaps where more sunlight is available for growth. However, the number of seedlings in a typical forest gap in southeastern Pennsylvania is usually many times less than in a gap in a healthy forest. Successful regeneration in a gap hinges on a few seedlings surviving a host of stresses (buck rubs, invasive vines, drought, insects, windthrow) over the many decades it takes to reach the canopy.

The elimination of tree regeneration not only removes the defining component of the future forest (canopy trees), it greatly amplifies the effects of other stressors by freeing up growing space to invasive plant species and physically creating the disturbed soil conditions to promote their spread. This, in turn, compromises the many benefits—environmental, ecological, and economic (timber production)—that forests provide.

In forests that have been subjected to overbrowsing for many years, the deer density will probably need to be lowered even further than the eventual optimal level for a period of time to allow the forest to regenerate. The section on estimating deer impact under **Wildlife Management** *(page 104)* provides guidelines developed by Penn State University and the US Forest Service for visually assessing deer impact on a forest community.

The decision to restore any forest must start with the goal of reducing and maintaining deer density at an appropriate level. Unless this goal is achieved first, the management of other stressors becomes a short-term lesson in futility that ultimately ends with the demise of the current canopy trees—and by definition, the forest itself—through natural decline or the next major wind event.

Deer Management Options

Wherever deer are present on natural lands in southeastern Pennsylvania, there is a strong likelihood that the population is higher than the ecosystem can sustain without substantial losses of native plant and animal species, forest structural diversity, and advance tree regeneration and the proliferation of exotic (non-native) invasive plant species, black-legged ticks, and the bacterium that causes Lyme disease. That is because deer populations are no longer regulated as they were for millions of years, first by native predators and more recently by Native Americans hunting to supply their families with food. Year-round, geographically pervasive predation is the only force that has been demonstrated to be capable of limiting deer population numbers in most of our region, but all of their major predators are gone and will not be returning. Foods preferred by deer are so abundant across southeastern Pennsylvania that competition for food does not limit deer numbers, at least not until they are so plentiful that browsing has caused catastrophic changes to native ecosystems. Recreational hunting as it

has been practiced since game laws were first instituted over a century ago is very different from predation or subsistence hunting. It does not regulate deer numbers at levels that allow native species diversity, forest structure, and advance tree regeneration to be sustained. However, the Pennsylvania Game Commission has been making changes to hunting regulations recently in recognition of the problems created by overabundant deer, expanding the hunters' "tool kit," extending hunting seasons, and allowing non-recreational culls in some circumstances. This has broadened landowners' options if they wish to reduce deer impacts on their natural lands. This section is designed to help a land manager determine which option or options are most appropriate for his or her property.

No management

No deer management is an option if natural factors (predators, disease, famine) and human activities (hunting, car accidents) within the area are maintaining the deer population at a level that does not adversely affect important natural or cultural resources. Another basis for no management that applies even where deer are overabundant and there is clear evidence of adverse ecosystem impacts is a landowner's belief that wild animals should not be harmed, perhaps coupled with the hope that nature or human ingenuity will eventually remedy the impacts without the need for lethal methods. In most situations in southeastern Pennsylvania, landowners with conservation priorities that include wildlife habitat, natural plant communities, or income from timber harvesting are likely to see those priorities compromised by the consequences of the no-management option.

Failure to manage the deer population will make healthy natural forest communities unsustainable in southeastern Pennsylvania.

David Steckel

Choosing not to manage deer can result in a park-like forest with only canopy trees and an herbaceous layer dominated by exotic invasive species.

An instructive example of the effects of the no-management approach is a 3,400-acre preserve north of Carlisle, Pennsylvania, managed by Natural Lands Trust. This property has suffered from extreme deer overabundance (densities over 100 per square mile) since the late 1960s when hunting was prohibited by the donor's will. The deer population has remained high—despite the total lack of understory vegetation—through the consumption of the annual mast crop (acorns, beech nuts, hickory nuts, etc. from the existing canopy trees), the few tree seedlings that are able to germinate, and agricultural crops on adjacent farm fields. As a result, the forest resembles a park with canopy trees and a carpet of

Japanese stiltgrass spread and sustained by deer disturbance of the soil. Studies of forest gaps—the usual site of dense regeneration—by biologists at Dickinson College show a complete absence of tree seedlings. Computer models confirm the obvious: in the best case scenario, one without a major wind event or forest pathogen, the forest will gradually degrade into an impoverished savanna community with extremely low native species diversity as the current canopy trees decline and die.

Based on the current understanding of deer ecology and results on properties with high-density deer populations, failure to manage the deer population will make healthy natural forest communities unsustainable in southeastern Pennsylvania. The loss of native species diversity and structural variation in the understory will reduce habitat for local and migratory wildlife. A forest without a diverse understory lacks cover for ground-nesting birds such as ovenbird, worm-eating warbler, and Louisiana waterthrush and protected feeding and nesting areas for other forest-interior birds, including barred owl, Acadian flycatcher, wood thrush, cerulean warbler, northern parula, American redstart, Kentucky warbler, and hooded warbler. A forest devoid of an understory also lacks shelter and moist conditions preferred by reptiles and amphibians, including salamanders, frogs, and turtles. The likely shift in plant dominance to exotic invasive species from natives, which are preferred browse for deer, will decrease food resources for insects (a key link in the food web sustaining larger animals), birds (the growth and survival of young birds, and often adults as well, depend on insects to supply fat and protein), and aquatic invertebrates in associated forest streams (they are largely unable to digest leaves of exotic plant species).

Without deer management, perpetuation of some semblance of natural forest communities would require the use of artificial regeneration (planted trees and tall shrubs) to regenerate the forest until the deer population collapses through disease or starvation. Trees and shrubs will need to be tall enough (>5 feet) when planted to escape browsing of terminal buds and be planted in numbers sufficient to maintain at least a 60% closed canopy under pressure from environmental stresses and pests and pathogens. The land manager will also need to accept the likely loss or severe degradation of the native herb layer.

Active management

Active methods to control deer overbrowsing can be grouped into two categories: those that restrict or deter deer access to desired vegetation and those that reduce the deer population within a tract of land. The current tools used to modify white-tailed deer behavior include barriers, repellents, and lethal removal. Two other approaches that are often talked about but are infeasible at present or are prohibited in the state are contraceptives and trap and transfer.

Barriers

Barriers physically restrict deer from interacting with vegetation in the treated area. Options under this method include tree shelters, netting, and deer exclosure fencing. Tree shelters and netting protect individual trees or shrubs; fencing excludes deer from all the vegetation in a specific area. Physical barriers have proven to be effective in protecting trees and shrubs in formal landscapes and forest vegetation although they can be expensive if used over a large area.

Tree shelters are useful to protect seedlings in open areas (estate areas, forest

gaps, and edges) until they reach 6 feet in height and are above the maximum browsing height of deer. However, their cost and maintenance requirements might limit their use by some landowners (financial assistance for planting and tree shelters may be available from the Pennsylvania Bureau of Forestry or the USDA Natural Resource Conservation Service). A 5-foot tree shelter with support stake costs $5 to $6 depending on the quantity purchased. A per-acre cost at a 12-foot x 12-foot spacing will therefore run $1,500–$1,800, plus tree seedlings and installation. Tree shelters also require periodic monitoring and maintenance as they are attractive to deer as rubs and are sometimes targets of vandals.

Fencing holds more promise as a deer management tool, but it involves significant up-front expense and frequent monitoring to ensure the integrity of the fence. Deer fencing around significant areas of land are 8–12 feet high and constructed of box wire, plastic mesh, or electrified wire (shorter fencing can be effective if the enclosed area is very small or narrow, such as a vegetable garden). The Pennsylvania Bureau of Forestry uses two 4-foot sections (8-foot total height) of box wire fencing kept tight to the ground to protect tree regeneration following timber harvests. Bowman's Hill Wildflower Preserve in Bucks County fenced 80 of its 100 acres with electrified wire in the early 1990s, effectively protecting its wildflower collection. Tyler Arboretum, near Media, Delaware County, in 2000 installed a 12-foot-tall, 2-mile-long deer fence around 105 acres of its collection at a cost of $350,000 (including more than $50,000 to provide vehicular access and a portion placed in the endowment for continuing maintenance). In addition to its high initial cost, fencing requires constant monitoring to quickly repair any breaks caused by falling limbs or vandals and restricts not only deer movement, but also the movement of several other animal species. Cost estimates for large-scale fencing projects are currently on the low end about $8–$10 per running foot of fence and, depending on site characteristics and materials used, can range up to $30 or more per running foot, including installation.

Gary Gimbert

Tree shelters are useful to protect seedlings in open areas (forest gaps and edges) from deer damage until they reach six feet in height and are above normal browsing height.

Costs and monitoring are complicated by internal roads, paths, or streams, requiring gates and stream crossing devices. One option that reduces the cost is to use temporary fencing, enclosing large (a quarter to half of the forested area) sections on a rotating basis to protect vital forest regeneration from deer browsing while maintaining accessibility to the rest of the forest for management and recreation. However, once advance tree regeneration is established and the fence is moved, the previously fenced areas are open to understory degradation again by deer browsing.

Fencing can also be used as an instructional and monitoring tool. Small (10 meter square) deer exclosures can be built at a relatively low cost (approximately $300 per exclosure) to be monitored and compared to the existing forest. These study and demonstration areas provide a picture of the forest's potential when browsing impacts from deer are removed. They also provide a feasible, more understandable, and far more useful barometer of deer overabundance than estimating deer density. The state of the forest within the exclosure can guide deer management outside.

Repellents

Repellents create unpleasant sensory experiences that discourage deer from physically interacting with vegetation in the treated area. Repellents include periodic loud sounds, bright lights, or foul-tasting foliar sprays, often with a base of capsaicin, the fiery alkaloid in chili peppers. Repellents can be effective in small areas where the goal is to reduce browsing damage to tolerable limits.

The main drawbacks to repellents are cost (approximately $150 per acre, plus application) and their short-term effectiveness. Deer, particularly those in dense populations, quickly adapt to these tactics. The manager must be committed to continually monitoring application needs and experimenting with new products as deer adapt. Although foliar sprays may be useful for landscape and other special plantings, repellents are usually impractical for natural lands.

The use of contraceptives to manage the deer population on natural lands in southeastern Pennsylvania is not only prohibited by law, except as part of an established research program, but it is also infeasible at this time due to the high cost.

Contraceptives

Contraceptives to prevent pregnancy in deer have been tested and are a subject of ongoing research. The two major types of contraceptives are immunocontraceptives and hormonal contraceptives.

Immunocontraceptives "vaccinate" an animal against egg proteins. When an ovary releases an egg, the deer's immune system views the egg as a foreign body and rejects it before it can implant itself within the uterus. Although very expensive and labor-intensive, immunocontraceptives have proven effective in arresting deer population growth under certain circumstances, such as on islands or within fenced parks or zoos where deer are confined to a relatively small area.

At present, the cheapest and most common method for administering immunocontraceptives is through the use of dart guns—close-range arms that are accurate to about 40 yards. Most population biologists feel that in order to stop herd growth in deer, they have to prevent pregnancy in 90% of the female population. Immunocontraceptives developed so far have to be readministered periodically to sustain sterility in each individual doe.

Hormonal contraceptives work primarily by preventing ovulation in does. The most effective method for administering this type of contraceptive is through subcutaneous implants. Although one treatment can be effective for multiple years there are logistical and health concerns associated with the use of hormonal contraceptives in natural areas on free-ranging deer (entering

and leaving properties at will). The first is the need to immobilize each deer to apply the treatment, which is logistically difficult, very expensive, and stressful to the animal, often leading to self-injury or death. Potentially more problematic is the unknown consequences of introducing these hormones into the food supply.

Currently, there are no contraceptives for free-ranging deer that are approved by the FDA or any other governing body. Also, the effects of deer contraceptives on other animals (including humans) have not been studied. Because deer in southeastern Pennsylvania are free ranging, there is a high probability of human consumption of treated animals. It is even more likely that hormonal contraceptives will enter the food chain when treated deer die and are consumed by other animals, for instance, raccoons, opossums, foxes, coyotes, turkey vultures, crows, or turtles. Introducing hormonal contraceptives into the environment and food chain could have unknown and far-reaching effects.

The use of contraceptives to manage the deer population on natural lands in southeastern Pennsylvania is not only prohibited by law, except as part of an established research program, but it is also infeasible at this time due to the high cost (over $1,000 per doe annually for immunocontraceptives), the potential health risks of hormonal contraceptives, and the high mobility of the local deer herd. The fact that deer are free ranging throughout the region makes treating enough of the right animals almost impossible.

Trap and Transfer

Trapping or darting deer (requiring a permit from the Pennsylvania Game Commission) and moving them to another location is the most expensive, difficult, and ineffective deer control method. It is an option fraught with problems, the greatest of which is finding a location willing to accept more deer. This problem has become more difficult with the recent spread of chronic wasting disease (CWD) to nearby states (West Virginia and New York). Attracting well-fed deer into baited traps is the next challenge. Finally, survival rates of transported deer have been low. At present, the Pennsylvania Game Commission has a policy of issuing no permits for trapping and transferring deer.

Trapping or darting deer and moving them to another location is the most expensive, difficult, and ineffective deer control method.

Lethal Removal

Hunting is the most frequently used deer population reduction and maintenance method commonly available to landowners and land managers. Other lethal removal options, including deprivation permits for farmers and culls by sharpshooters are available, but tightly controlled by the Pennsylvania Game Commission. All lethal means of deer management focus on reducing the number of does by mainly targeting antlerless deer. Removing bucks has almost no effect on the year-to-year rate of population increase, decrease, or maintenance.

A controlled, recreational hunting program in most cases is the most practical deer management tool available in southeastern Pennsylvania at this time.

Hunting is the most frequently used deer population reduction and maintenance method commonly available to landowners and land managers.

A controlled hunting program is probably the most effective deer management tool available to landowners in southeastern Pennsylvania at this time.

Drew Gilchrist

However, scientific evidence is still lacking that it is fully effective over a broad range of situations for reducing impacts of deer to levels adequate for the restoration and maintenance of ecosystem health. The likelihood of success rests to a large degree on the level of experience, skill, and dedication of the particular set of hunters who are the mainstay of the program.

There are several concerns surrounding the effective use of a deer-hunting program that should be considered by any land manager prior to implementation. The foremost issue is the safe use of firearms or archery in a region with a growing population and increasing use of natural lands. This is a particular concern in communities where natural lands are part of the common open space that is used by the local community. Any hunting program should be closely monitored by the land manager and controlled by restrictions that minimize the potential conflict between hunters and other users of the natural areas. These should include limitations on hunting areas and times, notification of appropriate persons when hunting is in progress, and an easy way to identify permitted hunters by other users. Most importantly, all hunters should be carefully screened for firearm proficiency and a history of ethical hunting practices. Any hunter who violates any program rule should be immediately removed from the program.

Ideally, hunting can lower the deer population to a level where only a few deer need to be removed each year to maintain the population at a level that allows healthy regeneration of the forest. Achieving this maintenance level is often complicated by ongoing suburban development in the surrounding landscape, which temporarily concentrates more deer on the remaining natural lands. If this is the case, it will probably require an extended period of more intense hunting, targeting mainly does, until the conversion of unprotected natural areas in the landscape to residential or other uses is complete. Perpetuating a maintenance level is also complicated by the fact that with a lower population, it may take hunters as much time to search out and remove a few deer as it now takes to remove a few dozen deer. The land manager will need to engage proficient, dedicated hunters to maintain the population at acceptable levels. Until additional options become available, recreational hunting will be the most widely used long-term method of keeping the population in check and allowing for limited forest regeneration until a point where populations stabilize in the surrounding area, which could be decades.

There are several potential alternatives and modifications within the lethal removal option that can be employed to reduce deer populations. The first is the use of archery, particularly on small

properties or properties with numerous residential structures on its borders. This would expand the hunting area (the safety zone for archery is 50 yards; firearms require a 150 yard safety zone) and extend the hunting time during the year by several weeks. An added benefit of allowing expanded access by hunters is that permitted hunters will monitor for unwarranted hunting while they are in the field.

In some situations, it is more efficient to engage a local hunting club to implement a deer population control program. They can handle all program administration, including proficiency tests, the scheduling of hunting times, and data collection on the separate harvest rates of does and bucks. The group should provide proof of insurance and be in close contact with the property landowner or manager to avoid conflicts with other activities in hunting areas.

Another alternative for expanding the number of deer harvested each year is enrollment in the Pennsylvania Game Commission's Deer Management Assistance Program (DMAP). This program provides additional permit applications (coupons) to landowners that they can then give to hunters. One coupon is granted for every 5 acres of farmland and every 50 acres of other land cover (forest, meadow, successional). Additional permits above the standard formula are available if the landowner submits a management plan with their request. Unlike in past years, the landowner is no longer required to open their land to the general public.

A final option does not involve recreational hunting at all. It is the use of sharpshooters to remove deer. Under this option qualified professional sharpshooters are hired to euthanize a high quantity of deer within a property. This requires a special permit from the Pennsylvania Game Commission. The process is very rigorous and requires the landowner to make a convincing case that hunting within current game laws is not a viable option for managing the deer population at desired levels. However, this is probably the safest (removal is usually done at night using infrared sighting scopes, over isolated baiting stations located where shots are directed into the ground) and quietest (sharpshooters use rifle silencers) removal method and is the most effective

Summary of Active Deer Management Options

METHOD	COMMENTS	MOST APPROPRIATE APPLICATIONS
Tree Shelters	High cost and maintenance requirements	Converting small open areas to forest. Protecting landscape plantings.
Deer Fencing	Significant up-front cost, frequent monitoring	Establishing tree regeneration in overbrowsed forest areas. Creating demonstration areas. Protecting collections (arboretums).
Repellents	Impractical in natural areas	Protecting landscape plantings in small areas.
Contraceptives	High cost, permit/license	Maintaining populations in areas enclosed by fencing or isolated by significant natural boundaries (e.g., water, mountains).
Trap and Transfer	Expensive, difficult, transfer location, permit/license	Removing deer that are in an area that puts humans or themselves in immediate danger.
Lethal Removal	Currently most effective, safety concerns	Reducing and maintaining populations in areas large enough to provide appropriate safety zones.

option for reducing the deer population in the shortest time. The cash outlay is relatively high but the time demands on the land manager can be considerably lower than that required to run a controlled hunting program. The venison is dressed and donated to charitable food banks or government-run institutions. Removal of other signs of the cull such as bloodied leaves may also be a part of the sharpshooters' services. Culls must be performed annually, at least until ecosystem restoration is achieved. Once the deer population is reduced and overbrowsing impacts are alleviated, a controlled hunting program—if it is permissible or feasible—may be adequate to maintain the desired deer population density.

Estimating Deer Impact

Monitoring vegetation indicators is a practical way to assess the effect of deer on forested areas. Vegetation can be assessed by two methods: (1) comparing the overall influence of deer browsing on existing vegetation to an established index or (2) quantitative sampling. The US Forest Service and Penn State University have developed a five-level deer impact index to visually assess the level of deer influence on forest health:

Deer Impact Index 1
Very low: No deer browsing. Occurs only within a well-maintained deer exclosure.

Monitoring vegetation indicators is a practical way to assess the effect of deer on forested areas.

Deer Impact Index 2
Low: Species composition and height of regeneration is determined mainly by available light, nutrients, and seed source. There is a well-developed shrub layer and native wildflowers are abundant and grow to their full size.

Deer Impact Index 3
Moderate: Evidence of browsing is common with a greater reduction in height and abundance of the most-preferred species than of the least-preferred species.

Deer Impact Index 4
High: Preferred species are sparse or absent and all plants are nearly the same height as a result of browsing. Vegetation in the shrub layer is sparse except for the least-preferred species (e.g., spicebush, American beech, exotic invasive shrubs).

Deer Impact Index 5
Very high: A pronounced browse line is evident with virtually no vegetation below the browse line except for two rhizomatous fern species, hay-scented fern and New York fern or exotic invasive herbaceous species such as Japanese stiltgrass and garlic mustard.

The deer impact index is a qualitative measure; its utility for detecting change over intervals as short as one or two years is weak and its usefulness depends heavily on the level of experience and knowledge of the evaluator on food-plant preferences of deer, expected maximum sizes of various plant species under a variety of habitat conditions, and how to distinguish signs of deer browsing from plant damage by other animals and causes other than herbivory. Please note that these impact levels apply to later successional stages, particularly maturing, mature, and old-growth forests. Young forests (up to approximately 30 years old) typically have a dense canopy that prevents sunlight from reaching the

forest floor. In this stage—called the pole or stem exclusion stage—the understory is largely free of shrubs and herbs due to heavy shade. As the forest matures and the canopy thins from the death of weaker trees, there is sufficient light to support a shrub layer on which deer can browse.

Quantitative sampling is more time-consuming but its interpretation involves less judgment and specialized expertise. A quantitative approach could include periodic surveys along a transect or cataloging vegetation change within fixed plots. The latter could be used in conjunction with the construction of deer exclosures. Methods need to be scientifically rigorous if the results are to be sufficiently credible to serve as the basis for labor-intensive and potentially costly deer management procedures. For example, the protocol should include:

- random selection of areas to be sampled;
- sampled areas large enough and sufficiently dispersed to include the variety of plant resources found within the property;
- sufficient replication and interspersion of treatments across the entire sampling area, for example, deer fencing, repellents, hunting; and
- sufficient number of samples to increase the likelihood of early detection of relatively subtle differences and to minimize the chances of confusing the effects of deer browsing with the effects of other factors that influence plant species composition.

The data gathered within sampling plots or along transects may include:

- percent cover of each plant species below 6 feet above the ground surface (maximum height of deer browsing),
- number of seedlings and saplings of each tree species, and
- special measures of indicator species (forest-floor species known to be vulnerable to deer but somewhat tolerant of moderate levels of browsing, for instance, Canada mayflower, Indian cucumber-root, and several trillium species); measures may include height of tallest plant or length of longest leaf in the plot, and number of flowering/fruiting individuals versus number of non-flowering/fruiting individuals of each indicator species in the plot.

The US Forest Service has developed assessment procedures for determining the current level of deer impact on forest regeneration as well as the level of competition from invasive species and other plants (e.g., ferns, mountain-laurel) that might interfere with the growth of established seedlings after a timber harvest. A copy of this assessment procedure is outlined in the Forest Service General Technical Report NRS-11 available from the US Forest Service, Northern Research Station, 359 Main Road, Delaware, OH 43015 or http://nrs.fs.fed.us/pubs/2471.

Estimating Deer Abundance

It is often said that a density of 15–20 deer per forested square mile is a maximum level allowing minimal advance tree and shrub regeneration, and a density of 5–10 per square mile is needed to sustain a high diversity of native species, including native herbaceous plants. These numbers come from a small set of studies in large forest tracts of a single forest type in northwestern Pennsylvania, in which deer density was known because the research areas were fenced, emptied of deer, and then restocked with exactly the numbers of

deer needed to achieve specific densities. This was excellent research, but we also know that deer density interacts with a host of other factors in determining the level of browsing impact on various forest ecosystem functions. Those other variables include forest type, understory species composition, landscape context, soil type, soil moisture regime, forest-floor light level, length of growing season, alternative food sources, historical land use, patterns of seasonal movement by deer, and legacy effects of prolonged high deer numbers (e.g., depleted seed bank, scarcity of live seed sources within dispersal distance, and disproportionate abundance of non-preferred understory plant species). These interactions are complex, unpredictable, and severely constrain the potential usefulness of deer density alone as a predictor of ecosystem impacts.

Where resources are limited, which is certainly the case for most managers of natural lands in southeastern Pennsylvania, it may be cost-ineffective to divert time and money from vital tasks, including deer management, to estimating deer density. Keeping careful track of the number of does killed each year by hunters or sharpshooters, in combination with rigorous monitoring of ecosystem indicators (see previous section) is sufficient in most cases for tracking progress in achieving and maintaining a deer density that allows forest ecosystems to be sustainable.

However, if the resources are available, it is desirable to monitor deer abundance to make certain that management actions intended to reduce or maintain deer populations actually do so. Making a full count of any animal species in the wild is nearly impossible, but several methods have been developed to estimate the abundance of white-tailed deer.

Survey methods can be classified into two general types: indirect methods based on monitoring deer signs (e.g., tracks, fecal pellets) and direct methods that require capturing or observing deer. Direct methods may deliver more accurate and precise population estimates but they tend to be prohibitively expensive.

Direct methods include aerial surveys, which have the advantage of covering large areas quickly and easily, although hiring pilots and renting aircraft are expensive. The main problem with using aerial surveys for white-tailed deer in this region is visual obstruction by vegetation. Although the region contains a predominantly deciduous forest and aerial surveys are performed only in winter, a large percentage of deer can be obscured by evergreen trees and shrubs, topographic features, and even the trunks and branches of deciduous trees and shrubs. Researchers have shown that thermal imagery—flying at night using infrared-sensitive instruments—is far more effective than daytime aerial survey methods. It is ideally done on very cold winter nights, when the thermal contrast is greatest. Sources of error include counting two or more deer lying or standing together as one and missing deer that are partially obscured by evergreen foliage, tree trunks, or topography. A recent review evaluating the application of thermal imagery technology in a variety of deciduous forest environments reported inconsistent results, with 11 to 69% of the deer missed in the audited surveys and an average detection rate of 56% of the total deer present in the study areas.

Another direct approach is the mark-recapture method, which involves marking individual deer and comparing the proportion of marked deer recaptured or killed in a subsequent roundup or hunt. This method is highly labor-intensive and extremely expensive because a large number of deer need to be marked—at

least 45% of the deer if the population is small (less than 200). In addition, the method is based on the assumptions that marks are never lost and deer do not emigrate from the study area. The mark-recapture method has been shown to overestimate deer populations because of unknown mortality of marked deer and emigration from study areas. Accurate monitoring of mortality and emigration requires the use of radio-collars in place of marks. Another problem with this method is that every deer is assumed to have the same probability of being recaptured or taken by hunters, which is likely to be violated owing to differences between older and younger deer in wariness, ability to evade pursuers, and hunter preference. The only place the mark-recapture method has been used is in a small minority of scientific research projects that are well funded; it is beyond the budgets of most land managers and researchers.

Most indirect methods do not provide estimates of absolute abundance, but are intended to provide an index of relative abundance that can be used to detect changes over time within a particular area. For example, counts of the abundance of deer trails, tracks, deer sightings per kilometer walked on foot, intensity of browsing, abundance of fecal pellet groups, and number of deer killed on roads have all been used as indices of abundance. All of the index methods assume that potential sources of variability in the index (e.g., deer defecation rates, hunter effort, movement by deer across the landscape) are constant in a specific area over time so that the changes in the index over time reflect changes in population size alone.

Counting fecal pellet groups is the most widely applied means of indirectly estimating deer density. A typical method is to visit a large sample of uniform-sized plots across the study area and eradicate all existing pellet groups on each plot, then return to those plots several weeks or months later and count the newly deposited pellet groups. Deer density can be estimated by assuming a daily defecation rate per individual deer. The assumptions of this method are that a random sample of plots has been selected, deer movement across the study area is the same from year to year, the defecation rate is known and remains constant among deer and surveys, and pellet groups are counted accurately on the plots. In practice, the pellet group technique has often been applied somewhat differently. Surveys are usually performed in winter and the number of days is taken to be the time since leaf drop. This removes the labor requirement of first eliminating all existing pellet groups on plots, but results are distorted by the precarious assumptions that all pellet groups deposited prior to leaf fall have been covered by leaves and that leaf drop occurred on a specific day.

If the resources are available, it is desirable to monitor deer abundance to make certain that management actions intended to reduce or maintain deer populations actually do so.

Although widely used, pellet group counts are subject to many sources of error, which may be minimized by careful design and execution of the specific protocol. They include observer skill and fatigue in detecting pellet groups, choice of plot shape, habitat (vegetation) influences on detection of pellet groups, and decay rate of pellets. The most sophisticated surveys apply the technique of "distance sampling" to account for differential detection among habitats, factor in the decay rates of pellet groups, and use a statistically based sampling design. However, even

NATURAL LANDS TRUST REGULATED HUNTING PROGRAM
Rules and Regulations

Natural Lands Trust conducts controlled deer hunts on properties to manage deer populations consistent with the preserve's natural resource management goals. Hunters receiving permits for the deer management program are expected to conduct themselves in a safe, honest, and ethical manner. Any hunter who does not act accordingly will have his or her hunting permit revoked immediately. Listed below are the requirements that must be met to receive a permit, examples of what the Trust considers unacceptable behavior, and the regulations that must be followed while hunting on any Trust preserve.

Permit Requirements

1. All hunters must attend a preseason orientation course to be conducted by the preserve manager.
2. All hunters must present proof that they have completed the Pennsylvania Game Commission hunter-trapper education course. Bowhunters must present proof that they have completed a bowhunter education course.
3. Hunters must have an antlerless deer license for the deer management unit of the preserve.
4. All hunters must pass a proficiency test using the sporting arm they plan to hunt with. For **firearms**, a hunter must place 4 out of 5 slugs in a 9-inch paper plate at 45 yards. No buckshot allowed. Shooting from a treestand 10 feet above the ground, an **archer** must place 5 out of 6 arrows in the vitals of a 3-D target. The target will be placed at 5, 10, and 15 yards from the base of the tree.

Unacceptable Behavior *(includes, but is not limited to, the following)*

1. Shooting in marginal situations such as at running deer, when vital organs are obstructed, and at excessive distances.
2. Disrespect of Trust employees, adjacent landowners, and other preserve users.
3. Consumption of alcoholic beverages or use of controlled substances.
4. Failing to appropriately follow up every shot.
5. Displaying game animals unnecessarily.

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the most careful surveys are based on a number of questionable assumptions, including a constant defecation rate and no variation in decay rates among habitat types. Research on defecation rates indicates that they vary among seasons (presumably because of dietary changes) and among age and sex classes and that pellet decomposition rates differ according to habitat type. Despite their limitations, however, pellet group counts may be the most practical means of monitoring changes over time in deer densities in natural areas.

Natural Lands Trust's Deer Management Program

At Natural Lands Trust, our goal is to preserve and enhance the plant communities within our preserve system to maximize wildlife benefits. With that goal in mind and based on an understanding of the requirements of the state wildlife code, we have instituted a deer management program that focuses on reducing deer populations to a level that will allow advance tree regeneration and survival of native herbaceous species. While we employ small exclosures to protect certain plants and for demonstration purposes, over most of our lands we implement controlled hunts to reduce the numbers of deer.

The rules that hunters must adhere to reflect an overriding concern for safety, not only for the participants of the management program, but for other preserve users such as walkers and bird-watchers *(see sidebars)*. A mandatory proficiency test ensures that hunters are familiar and competent with their sporting arm and a flagged map locates hunter positions for the preserve manager and other hunters. Participants wear bright NLT armbands that allow preserve managers as well as others to tell from a distance if a hunter has permission to hunt. The rules place due emphasis on removing does from the population, because it is almost exclusively the doe removal rate that influences population size. Preferentially harvesting does is capable

NATURAL LANDS TRUST REGULATED HUNTING PROGRAM
Rules and Regulations

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Hunting Regulations

1. The Trust will determine the days and hours of hunting permitted at a site.
2. Hunters must comply with all Pennsylvania Game Commission regulations (including returning report cards).
3. Hunters must endeavor to harvest an antlerless deer. Any hunter that does not make a good faith effort to harvest an antlerless deer will have their permit revoked. Archers must take an antlerless deer before being eligible to harvest a buck.
4. Hunters must hunt at least 20 hours.
5. Only two shells can be loaded at any one time (one shell in the chamber, one in the magazine).
6. Only portable tree stands may be used and hunters must wear a safety belt. No screw-in steps are allowed. All tree stands must be removed by January 26th, or they will be forfeited.
7. Crossbows and .410 shotguns are not allowed.
8. Hunters must follow the hunting procedure listed below.

Hunting Procedure

A metal box will be placed in a convenient spot, accessible to all hunters. The box will contain armbands, a map of the preserve, and the hunting log. **Prior to each hunting stand the hunter must**: (1) remove one of the armbands from the box and put it on the exterior of his or her hunting coat (once the supply of armbands is exhausted, no additional hunters may hunt until a hunter returns from the field and returns an armband to the metal box); (2) mark the map to indicate where they plan to hunt; (3) sign in on the hunting log; and (4) display a parking permit on the dashboard of their vehicle. **While hunting, the hunter must**: (1) wear the armband; and (2) carry the permit. **At the end of each stand, the hunter must**: (1) return the armband to the metal box; (2) remove the mark from the map; and (3) fill in the hunting log completely.

Termination Procedure

If the preserve manager witnesses a case of unacceptable behavior or a violation of one of the hunting regulations by a permitted hunter, or is informed of such an incident by a reliable source, he will abide by the following procedure to address each incident:

1. The preserve manager will verbally inform the hunter of the infraction.
2. The hunter will be provided the opportunity to respond to the accusation.
3. If, in the opinion of the preserve manager, the hunter has clearly exhibited an unacceptable behavior or has violated one of the hunting regulations, he will verbally inform the hunter that his hunting permit is revoked immediately.
4. If there are legitimate extenuating circumstances surrounding a violation of hunting regulation 6 or 8, the hunter will be given a warning. A second violation of these regulations will result in immediate loss of hunting privileges. Violations of any other hunting regulation or unacceptable behavior rule will not receive a warning and will result in immediate termination of hunting privileges.
5. The hunter will be notified in writing of a warning or the loss of hunting privileges.

Jack Stefferud

Dan Barringer

As part of its deer management program, Natural Lands Trust regulates the hunters it permits on its preserves. Requiring a certain level of proficiency and mapping hunter locations help protect the safety of all preserve users.

of bringing populations to tolerable levels far more quickly than would a random removal strategy; preferentially harvesting bucks has almost no effect on birth rates and therefore will not control the population size.

Operating the program requires relatively little staff time to administer. In fact, staff time expended in administration is readily made up through time saved by the reduction in staff patrolling time during the hunting season. Permitted hunters monitor unwarranted access to the preserve during the hunting season, enabling managers to attend to other responsibilities.