

Commentary

After decades of suburban deer research and management in the eastern United States: where do we go from here?

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Abstract: State wildlife agencies have regulatory authority and oversight over deer (*Cervidae*) management in the United States. However, increased urban sprawl and overabundant deer populations have created increased human–deer conflicts. Because of the growing controversy surrounding the use of traditional management practices such as regulated hunting in suburban areas in the eastern United States, managers are now using specialized tools and management approaches to reduce deer conflicts in urban areas. However, this has created new challenges as they try to meet the desires of diverse stakeholder groups. Although deer management programs in urban areas differ somewhat in every state, effective management options remain limited. Essentially the same management tools that were used for 3 decades have not changed, even with substantial investments in deer research. Despite public support for deer fertility control, it is still largely experimental and expensive. Immunocontraceptive vaccines are seldom used because of the cost and difficulty of retreating free-ranging deer. Surgical sterilization of deer has shown promise, but the scale of application remains limited by cost and the number of deer that need to be handled. Lethal deer removal remains the only method that has consistently reduced deer numbers in an acceptable time frame at multiple scales. Even in areas where urban deer numbers have been substantially reduced using lethal methods, the resulting effects on deer populations and human–deer conflicts have been poorly documented. In highly fragmented, developed landscapes, removing enough deer to demonstrate impact reduction has been a difficult and expensive process. It usually takes multiple approaches across several years to achieve desired results. Thus, the lack of long-term planning and sufficient budgets needed to sustain management efforts may impede overall program success and sustainability. Herein, I review the lessons learned from multiple deer research and management efforts from suburban areas in the eastern United States and highlight potential directions for future urban deer management programs.

Key words: fertility control, human–wildlife conflicts, hunting, immunocontraception, management, *Odocoileus virginianus*, stakeholders, suburban, white-tailed deer

THE AMERICAN PUBLIC places a high value on wildlife, yet at the same time, wildlife may cause challenging problems (Decker and Connelly 1989, Conover et al. 1995). Arguably, no other species in North America has created more management controversy than white-tailed deer (*Odocoileus virginianus*; deer; Figure 1). Deer may damage property, threaten human health and safety (Insurance Institute for Highway Safety [IIHS] 2019), impact biodiversity (deCalesta 1994, Waller and Alverson 1997), and spread tick-borne diseases to people and pets (Raizman et al. 2013, Kilpatrick et al. 2014), among other concerns (Warren 1997). National estimates of the cost of wildlife damage to agriculture exceed \$1.5 billion USD annually in the 1990s, and similar losses were associated with accidents caused by collisions between wildlife and vehicles (Conover et al. 1995). Deer are thus considered by some as one of the most dangerous animals in the United States because 200 or more people lose their lives each year in deer-related vehicle accidents (IIHS 2019). Thousands of Lyme disease cases are reported annually to the federal Centers for Disease Control and Prevention ([CDC] 2019), and the economic cost of these health concerns is unknown but substantial. Newer tick-borne diseases (e.g., Powassan virus) may have additional negative



Figure 1. Mature white-tailed deer (*Odocoileus virginianus*) buck along a roadside in Old Forge, New York, USA (photo courtesy of P. Curtis).



Figure 2. A Citizen Task Force for setting white-tailed deer (*Odocoileus virginianus*) management objectives in New York State, USA (photo courtesy of Cornell Center for Conservation Social Sciences).

impacts because human fatality rates may be much higher.

Despite these negative impacts, deer also have tremendous positive values totaling billions of dollars annually. Deer are the most sought-after big game species in the eastern United States, as 8.1 million deer hunters spend about 115 million days afield annually (U.S. Fish and Wildlife Service [USFWS] 2018). Total hunting expenditures in the United States were \$26.2 billion USD in 2016, and big game hunting generated \$14.9 billion USD of that total (USFWS 2018).

Many people also enjoy photographing and viewing deer and other wildlife. More than 86 million people enjoyed watching wildlife in 2016, adding another \$75.9 billion USD to the economy. Deer embody positive feelings of wildness and beauty for many stakeholders. These extreme positive and negative values are what make deer management so contentious.

This is especially true in suburban areas with diverse stakeholder groups having a wide range of attitudes and values toward deer (DeNicola et al. 2000, Westerfield et al. 2019).

So, after decades of deer management, and tens of millions of dollars spent on research, why haven't wildlife professionals made more progress in resolving suburban deer management issues? The purpose of this paper is to highlight several of the primary barriers to managing deer in urban environments. Similar to other urban wildlife concerns, deer management tends to be a “wicked problem” (McCance et al. 2017), a situation where wide-ranging human values lead to different interpretations of desirable outcomes and acceptable methods for achieving them. Varying groups of stakeholders perceive different impacts from wildlife (positive and negative), making it difficult to find a single management response that is accepted across all segments of a suburban community. Local governments also lack management authority over deer and other wildlife species (Westerfield et al. 2019).

The authority to manage deer rests with state wildlife agencies. Thus, municipal officials must work with agency staff to establish and achieve desired objectives. Antiquated laws and regulations may also limit the application of innovative approaches. Wildlife agencies primarily manage deer abundance and associated impacts via hunting regulations (Westerfield et al. 2019). When options other than hunting are suggested by communities, the state wildlife agency may lack regulatory authority to implement new approaches. Additionally, in areas with high human density, municipalities often have discharge ordinances to protect public safety, which may eliminate hunting as a practical management alternative. I intend to discuss these and other barriers along with potential solutions for addressing suburban deer management concerns.

Stakeholder engagement

Community-based management (CBM) is becoming the norm in several disciplines, including deer management (Decker et al. 2004; Figure 2). People expect a say in management issues that affect their lives, and wildlife management concerns are no exception (Curtis and Hauber 1997). The CBM process usually

involves a collaboration of public wildlife management agencies with entities such as local governments, interest groups, non-governmental organizations (NGOs), and residents (Chase et al. 2000, Schusler 1999). Reducing deer problems for residents typically requires approaching deer management at a community scale (New York State Department of Environmental Conservation [NYSDEC] 2018). This requires making management decisions as a community rather than as individuals, and taking actions at a large enough geographic scale that they will affect deer community-wide (Pomeranz et al. 2014). Benefits of CBM include greater credibility and trust in wildlife agency staff, more informed stakeholders with enhanced public decision-making, and greater likelihood of developing successful and sustainable deer management efforts. The CBM process may also produce local capacity-building (Raik 2002) and enhance social networks for more effective management outcomes (Lauber et al. 2008).

Deer conflicts occur in urban, suburban, and exurban areas associated with villages, towns, cities, and other populated areas with high human densities (Westerfield et al. 2019). In my experience, deer-related problems and concerns are often greatest at the suburban-rural interface of many communities. In these locations, deer find suitable woody cover for foraging and protection from winter weather, along with a diversity of food resources provided by home landscape ornamentals and garden plantings. Deer may also receive protection from hunting associated with firearms discharge ordinances that are intended to protect public safety in suburban communities. The mix of quality habitat and food resources as well as high deer survival rates allows for rapid population growth (i.e., potential doubling of herd size every 2–3 years), and the likelihood that community tolerance of deer-related impacts (e.g., plant damage, deer-vehicle collisions, tick-borne diseases, etc.) will be quickly exceeded. Deer suffer from the “tragedy of becoming common,” when they are no longer viewed as wildlife, but as pests or pets (Leong 2009).

Depending on the diversity of stakeholders and opinions in a geographic location, deer management can go smoothly or become very contentious. Even deer management programs

in communities with relatively close proximity may have very different approaches and outcomes (Boulanger et al. 2014, NYSDEC 2018). At a minimum, state wildlife agencies often want to see some form of public engagement before issuing permits for taking deer out of season or experimenting with fertility control methods (NYSDEC 2018). Strong community support is needed to provide funding and sustain deer management programs (Decker et al. 2004). Often, public values and attitudes will determine whether a management effort will succeed or fail (Purdy and Decker 1989, Messmer et al. 1997). Wildlife managers are tackling these issues by engaging community members in various ways to more effectively incorporate local perspectives, knowledge, and circumstances into deer management decisions (Raik et al. 2006).

Clarifying objectives and outcomes

Stakeholders frequently jump to discussing deer management approaches and costs without clearly identifying their desired objectives and outcomes (Decker et al. 2004, NYSDEC 2018). This can result in polarization within communities as interest groups promote different management alternatives. Often, communities end up choosing between lethal or nonlethal approaches for reducing deer numbers depending on which stakeholder groups have the greatest power and political connections. However, without clarifying the goals in advance, it is difficult to evaluate the cost and potential effectiveness of various management alternatives.

If communities clearly articulate the objectives for management, that may open up additional methods or possibilities. Is a deer population reduction the only way to achieve the desired management goals? What other alternatives might work as well without manipulating deer numbers? In some cases, deer management goals can be met without removing deer (e.g., fencing to protect sensitive plant communities, or highway segments with high numbers of deer-vehicle collisions (Hedlund et al. 2004, Mastro et al. 2008). If reducing deer density is needed, which methods can achieve the management goal most efficiently? Without defining clear goals and a time horizon, it is very difficult to predict the potential success of

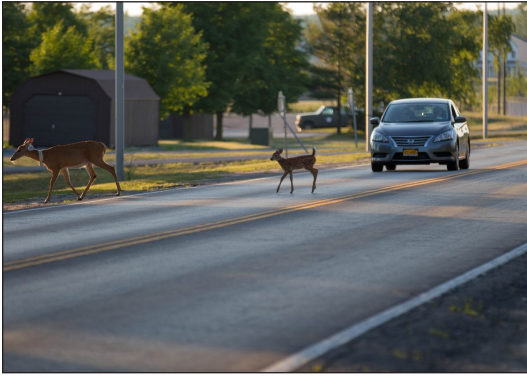


Figure 3. White-tailed deer (*Odocoileus virginianus*) crossing the road in front of a vehicle at Fort Drum near Watertown, New York, USA (photo courtesy of M. Feehan).

deer management programs. If communities and wildlife agencies are going to make progress toward solving urban deer challenges, they must communicate well and work together in a true partnership (Westerfield et al. 2019). It is important to determine what will make a program successful and to implement agreed-upon strategies to achieve urban deer management goals.

Once the goals are clear, a common understanding and database are needed to evaluate management options (Decker et al. 2004). One role of wildlife managers is to provide the technical background information needed for stakeholders to make informed decisions (Westerfield et al. 2019). Also, managers need to clearly articulate the legal and regulatory framework that impacts management decisions (NYSDEC 2018). An approach that works in a community or state may not be available in a neighboring state. Managers have a professional responsibility to set the sideboards for deer management decisions. Any deer management approach selected must be legal and feasible under existing state and local laws and regulations (NYSDEC 2018, Westerfield et al. 2019).

Program success should not be defined in terms of deer numbers, but rather in reducing negative deer impacts (Riley et al. 2002, Northeast Section of The Wildlife Society [NE TWS] 2016). Communities sometimes reach a stalemate with different stakeholders arguing about how many deer are present and how many need to be removed (Curtis and Hauber 1997). If the focus is put on reducing negative

impacts, then knowing the actual number of deer in an area is not all that relevant. Also, reliably estimating deer abundance may be expensive and time-consuming (Curtis et al. 2009). Deer populations should be reduced until the point that management goals and impact reductions are achieved. That means stakeholders need to agree about what impacts are important and how they are to be measured (Riley et al. 2002). This may not be as easy as it might seem, particularly if management goals are not clearly defined in measurable terms.

Documenting impacts

Studies have shown that numbers of deer–vehicle collisions (DVCs) often increase as local deer populations grow larger (Etter et al. 2000, Hussain et al. 2007, Grovenburg et al. 2008, Rutberg and Naugle 2008; Figure 3). Consequently, one would logically conclude that a reduction in deer abundance would lead to a decline in DVC numbers (Mastro et al. 2008). However, managers generally have a poor understanding of the relationship between deer densities and associated levels of negative impacts, or how best to measure those. Studies have clearly documented that reducing deer abundance can lower the number of DVCs (DeNicola and Williams 2008). However, the shape of the curve may not always be linear. The rates of DVCs are complicated by several factors (e.g., road density, highway speeds, traffic volume, landscape characteristics, etc.), so this is a complex relationship. As biologists and managers, we recommend that communities reduce deer densities to lower accident rates—but by how much, and over what time frame? “As much as possible” does not seem like a very satisfying or measurable target for management. Yet, surprisingly few communities have done a good job of documenting this relationship (DeNicola and Williams 2008).

Even finding reliable statistics for the number of DVCs in an area may be challenging. The DVC data are often compiled by municipal police or transportation departments. Tracking changes in DVC numbers can be complicated by the fact that different levels of government have responsibility for different roads. Within a given county, DVC data might be collected by state, county, village, and town road departments or police agencies, depending

on political jurisdictions. Police agencies and highway departments often document collision statistics differently, and these numbers may not be tabulated or readily available. This information is also not readily shared. Thus, it may be very difficult to document the effects of deer management unless there is a concerted effort to collect and report DVC data in a consistent manner. Geographic Information System mapping of DVCs can help identify hotspots and potential focus areas for management activities.

Although tick-borne diseases are a major concern throughout much of the Northeast and Lyme disease is often a major driver for initiating a community deer management program, it is difficult to reliably monitor changes in human infection rates. There are several reasons for this. First, deer population reduction is not likely to reduce the incidence of Lyme disease (Jordan et al. 2007, Kugeler et al. 2015; Figure 4) unless deer densities remaining are extremely low (3–5 deer/km² [8–13 deer/mi²]; Elias 2019). These low levels of deer abundance are possibly unattainable in fragmented suburban landscapes. Second, measuring tick abundance and testing ticks for the presence of the Lyme-causing bacteria is expensive. Other methods for developing an index for tick-borne diseases are even more complicated and difficult. Lyme disease is reportable to the federal Centers for Disease Control and Prevention, so it is possible to track reported Lyme disease rates by county in the United States (CDC 2019). However, it is unclear if physician reporting rates have been constant over time. In areas with high tick abundance and disease rates, doctors may treat patients with a tick bite without confirming or reporting infections. Also, ticks may carry other diseases (e.g., ehrlichiosis, babesiosis, or Powassan virus) that may not be identified or reported. Consequently, measuring changes in human disease rates associated with deer densities is very complicated. However, the literature clearly shows that areas with high deer densities and high tick infection rates generally have high levels of human Lyme disease cases (Raizman et al. 2013, Kilpatrick et al. 2014).

High deer abundance can negatively impact plant communities and biodiversity (Tilghman 1989, deCalesta 1994, deCalesta and Stout 1997,



Figure 4. Blacklegged (*Ixodes scapularis*) and lone star (*Abyomma americanum*) ticks on the ears of a white-tailed deer (*Odocoileus virginianus*) from Long Island, New York, USA (photo courtesy of P. Priolo).



Figure 5. White-tailed deer (*Odocoileus virginianus*) feeding at a browse line about 1.8 m (6 ft) above ground at the tree line edge (photo courtesy of M. Feehan).

Waller and Alverson 1997, Horsley et al. 2003, Rooney and Waller 2003, Côté et al. 2004). But assessing deer damage to plant communities and biodiversity is not a simple process. There are many different ways to measure deer impacts to woody vegetation or wildflowers, and no single method is ideal for all situations and landscape scales (Figure 5). Methods that seem to work well on large landholdings (deCalesta 2013) may not be suitable for small properties. Timing may be critical for documenting wildflower impacts, and the time frame and sampling method may not fit agency staffing or time constraints. Although numerous studies clearly document deer impacts to plant communities and biodiversity, developing a quick and reliable index for measuring effects at the community level has been challenging. A newer approach, the oak-sentinel method (Blossey et al. 2019), is showing promise but



Figure 6. Successful deer hunter on Cornell University lands at the Arnot Teaching and Research Forest near Ithaca, New York, USA (photo courtesy of G. Goff).

needs further implementation and evaluation. This method may be particularly useful at places where deer impacts are so severe that native wildflowers and tree seedlings are essentially absent from forest understories.

If managers are going to make progress on assessing deer impacts, standardized and relatively simple protocols are needed that can be adapted to a variety of scales (e.g., individual property, community, and landscape). Given the diversity of habitats and situations where deer cause conflicts, there is unlikely to be a single approach that will work in all areas. Researchers and agency staff need to invest more time and effort in developing simple, low-cost methods for evaluating deer impacts at multiple scales. Rawinski (2018) has been developing the “Ten-Tallest” seedling approach, Blossey et al. (2019) have used oak sentinel seedlings to evaluate deer browsing pressure, and Waller et al. (2017) is using the twig-age method for assessing deer impacts. In addition, I am helping develop and implement the new Assessing Vegetation Impacts from Deer (AVID) citizen science protocol for use in New York State and the Northeast (Curtis et al. 2018). All of these vegetation assessment methods need further refinement and evaluation at multiple scales.

Means versus ends in management

In some situations, diverse stakeholder groups can agree that a reduction in negative deer-related impacts (and possibly deer numbers) is warranted at a community scale. However,

contention develops over the actual means or methods used to achieve the deer management goal. Debates over using lethal versus nonlethal methods can quickly become contentious and polarizing. Stakeholders rarely change their core values or beliefs about management approaches, and some will not cross ethical lines associated with killing animals (Lauber et al. 2007). In such cases, wildlife managers need to develop community consent and political support for management actions (Curtis and Hauber 1997), knowing that some groups will continue to oppose certain methods.

Wildlife managers must integrate the varying desires and goals of the public into deer program efforts if they are going to be effective and sustainable over time (Decker et al. 1996, Organ and Ellingwood 2000, Riley et al. 2002). Deer committees need to be representative of diverse community interests and have a clear process for decision-making (Decker et al. 2004). It helps to have support from elected officials with good credibility and political sway. It is critical for community members to have a say in deer management decisions (Westerfield et al. 2019). This usually requires public meetings and possibly a human dimensions survey to learn about stakeholder acceptance associated with different deer management approaches. Just because a local deer committee is formed does not mean that consensus will be reached concerning management approaches. Varying levels of public support may hinder implementing deer management efforts in a timely manner (Curtis and Hauber 1997, Northeast Deer Technical Committee 2009, Westerfield et al. 2019). In some communities, it takes many years and multiple deer committees recommending different approaches before effective deer management solutions are finally implemented.

The role of hunting

State wildlife agencies often promote regulated public hunting as the solution for deer management issues (NYSDEC 2018, Westerfield et al. 2019; Figure 6). This is not surprising, as recreational hunting has been a valuable deer management tool in rural areas for decades (Riley et al. 2003). It is currently the only viable method for managing deer abundance and associated impacts at a landscape scale (McCabe

and McCabe 1984, Westerfield et al. 2019) and the most economical approach (Conover 2001). However, hunting in suburban areas presents unique challenges associated with the diversity of stakeholders and fragmented landscapes. Regulated hunting can reduce deer abundance under some conditions and may result in some improvement in tree regeneration (Jenkins et al. 2014, 2015). However, recreational hunting alone may not reduce deer densities to acceptable levels depending on specific management goals and the level of ecosystem recovery desired (Williams et al. 2013, Blossey et al. 2019). Even when deer numbers are reduced, it may take decades for plant communities to recover because of the legacy effects of chronic deer over-browsing (Webster et al. 2005, Royo et al. 2010, Nuttle et al. 2014). Some sensitive plant species are so thoroughly destroyed by deer that they may need to be planted and protected if they are to be restored.

In suburban areas, unless park lands are involved, most deer will occur on private lands. Landowners must grant permission to access those deer no matter whether lethal or nonlethal management approaches are used. Based on my personal experiences, if access to deer is restricted, then management efforts will likely fail. In suburban areas, people are concerned about public safety. If deer are going to be shot and recovered, that often means coordinating management activities in collaboration with local police agencies (Boulanger et al. 2014). Police are often needed to approve shooting site locations or temporarily close public roads or trails in park areas. Depending on whether this is seen as part of normal duties or added work assignments, safety protocols may add substantial cost to deer management efforts. This is well worth the investment so that community members feel safe and continue to support management programs.

Access to deer may be a limiting factor no matter what management approach is chosen. If there are no large parks or public landholdings in a community, landowner permission will likely be needed for hunting, sharpshooting, trapping, darting, and potential recovery of immobilized or harvested deer (Boulanger et al. 2014). In communities with many small parcels and no large areas of public land, deer management can be a tremendous challenge. It may mean working

with groups of neighboring landowners who have similar attitudes, goals, and are willing to grant access for deer management activities. Coordinating these efforts can be very time-consuming, and it should be done by someone with an understanding of deer behavior so suitable sites with appropriate cover are selected. Often, signed permission forms must be kept on file with local police agencies in case anyone questions the management activities. Successful programs will require cooperation of all levels of government along with funding, staffing, and shared responsibility with community members (Messmer et al. 1997).

In many communities, there may be state laws or local discharge ordinances that could limit the use of firearms, bows, or dart rifles (NYSDEC 2018, Westerfield et al. 2019). For example, in New York State, under current Environmental Conservation Law, it is illegal to bait deer within 91.4 m (300 ft) of a public road, even with a state-issued deer damage permit. State law also prohibits the shooting of firearms within 152.4 m (500 ft) of a house (without the owner's permission); school building or playground; public structure; or occupied farm structure, factory, or church. In New York, the setback distance for crossbows and vertical bows is 76.2 m (250 ft) and 45.7 m (150 ft), respectively. Because of the shorter setback distances for archery equipment, bow-hunting is by far the most common type of hunting in urban and suburban settings.

Sometimes local ordinances or regulations can be changed by public vote or approval of elected officials. It is usually more difficult to change state laws, which requires legislative action. If elected officials are unwilling to modify restrictive regulations and there are no large landholdings where activities can occur, lethal deer management may not be possible. The only way to change this is for the community to elect officials who are supportive of deer management efforts and will diligently pursue access to private lands, along with changes to restrictive policies or regulations.

If hunting cannot be used, it may mean hiring professional sharpshooters or using trained volunteers to remove deer (Figure 7). This will require special permits from the state wildlife agency and approval from local elected officials. Such deer damage permits may allow the use of

bait, night-lighting, and rifles or bows in areas that are closed to hunting (NYSDEC 2018). In addition to the state permit, usually local police will either be directly involved in the activities or grant permission to the shooters. The permits usually also specify the times activities can occur and procedures for disposition of deer carcasses. This may cause logistical concerns if hundreds of deer need to be processed in just a few days. Temporary cooler space may be needed if it is not readily available, and the community may need to contract with a local butcher to process the deer. If handled properly, the meat can be donated to local food banks or other charitable organizations. This is not a simple process, and such culling programs often require professional oversight. Every effort should be made to ensure that the venison resulting from community hunts or culls gets consumed. Hunters who are given access to private lands can promote positive relationships by offering to share meat with the landowners. During a controlled hunt or cull, the community may wish to require that some or all of the meat be donated to local charities. Use of the venison may be a key component of community support for suburban deer management programs.

If there are only a few places in a community where deer can be safely shot, or if community members are unwilling to support methods that involve shooting, alternative approaches to population reduction will be necessary. Professionals can be hired to capture deer with traps, nets, or immobilizing darts, and then kill the deer with either a captive bolt device or chemical injection (e.g., potassium chloride). However, there are several negative consequences of these methods. Trapping causes stress and possible injury for the deer (Figure 8). Use of a captive bolt on a wild, non-sedated animal is challenging for the operator. In addition, use of chemicals renders the carcasses unsafe for human consumption, so the deer must be taken to landfills, and the meat is wasted. Such waste may reduce community and political support for deer management efforts. In addition, community leaders and elected officials may experience bulk email letter campaigns from animal welfare groups intended to stop the program. Communities should have a well-developed communication



Figure 7. Sharpshooter baiting site with corn at dusk for white-tailed deer (*Odocoileus virginianus*) removal after dark on Cornell University lands near Ithaca, New York, USA (photo courtesy of Cornell Integrated Deer Research and Management Program).



Figure 8. White-tailed deer (*Odocoileus virginianus*) under drop net prior to capture at Fort Drum near Watertown, New York, USA (photo courtesy of M. Feehan).

plan in place to deal with such controversy.

Fertility control

State and federal wildlife resources agencies have poured millions of dollars into research efforts to develop nonlethal approaches for deer management to satisfy animal welfare interests (Fagerstone et al. 2002). Some techniques work well for managing fertility of individual animals or in small, closed populations over long time frames (Kirkpatrick et al. 1997, Rutberg and Naugle 2008). However, none of these nonlethal techniques has worked as a stand-alone method for managing deer populations over longer time frames or at large spatial scales (Nielsen et al. 1997, Fagerstone et al. 2010, Boulanger et al.



Figure 9. Preparing a female deer (*Odocoileus virginianus*) for sterilization surgery at the Cornell University College of Veterinary Medicine, Large Animal Surgery Suite, Ithaca, New York, USA (photo courtesy of P. Curtis).

2012). Communities that start with managing deer by fertility control often either add lethal deer removal after a few years in a combined approach, switch to lethal deer removal alone, or abandon deer management altogether (Boulanger et al. 2014).

During the past few decades, several deer fertility control studies have been conducted across the United States (Figure 9). Approaches have included steroid implants (Matschke 1977), immunocontraceptive vaccines (Turner et al. 1992, Kirkpatrick et al. 1997, Rudolph et al. 2000, Curtis et al. 2002, Rutberg and Naugle 2008, Gionfriddo et al. 2009, Warren 2011), abortion agents (DeNicola et al. 1997), and surgical sterilization (Frank and Sajdak 1993, MacLean et al. 2006, Boulanger et al. 2012, Boulanger and Curtis 2016). Research on steroids was discontinued when it was found that these drugs could be passed through the food chain, and any type of federal registration for use in deer would be unlikely. The 2 most commonly used immunocontraceptive vaccines include either porcine zona pellucida (PZP) or gonadotropin-releasing hormone (GnRH) as antigens (Turner et al. 1992, Kirkpatrick et al. 1997, Curtis et al. 2002).

A GnRH-agonist vaccine (Gonacon®, Environmental Protection Agency [EPA] Registration

#56228-40) produced by the U.S. Department of Agriculture (USDA) National Wildlife Research Center (Gionfriddo et al. 2009) was the first vaccine registered by the EPA for use as a deer control agent in 2015; however, state registrations and field applications of the drug have been very limited. A PZP-based contraceptive vaccine was federally registered by the Humane Society of the United States with U.S. EPA (Registration #86833-1) for use in horses (*Equus caballus*) and burros (*E. asinus*; ZONASTAT-H), with a sublabel approved for cervids (ZONASTAT-D) in 2017. However, some state wildlife agencies still consider both of these immunocontraceptive vaccines to be experimental, requiring state research permits for any field applications in deer.

The primary limitations of both immunocontraceptive vaccines for deer have been the delivery system and required booster treatments. Only injectable forms of the vaccines have produced the desired immune response and reduced deer fertility (usually 80–90% reduction in fawning rates). The current Gonacon® label requires that treated deer be captured and the vaccine hand-injected. Although darting can effectively deliver this vaccine, the current EPA label does not allow for this. The EPA label recommends annual booster shots for each deer. This adds substantially to the time and cost for management programs. Consequently, communities have not been able to afford the cost of capturing deer multiple times to deliver booster doses of vaccines. The EPA label for ZONASTAT-D allows for remote injection of this vaccine via dart projector. However, this PZP vaccine requires a prime dose, with a second booster dose delivered 2 weeks later. As for Gonacon®, annual booster doses are recommended for each deer to maintain 90–95% efficacy. It will be very difficult and expensive to capture a high enough proportion of deer (likely 95% or greater each year) in an area because some deer are always bait-shy or will not approach trap sites. As more deer are captured and treated, the cost per deer will increase substantially to catch an increasingly smaller fraction of untreated deer.

Modeling has shown that 80% or more of female deer in a local herd must be treated to see potential population reductions in reasonable time frames (Barlow et al. 1997; Hobbs et al.

2000; Cowan et al. 2003; Merrill et al. 2003, 2006), given the typically high survival and reproductive rates for suburban deer. When taking immigration into account in an open population, field experience has shown that the proportion of female deer requiring treatment approaches 95% or more (Boulanger et al. 2014, Boulanger and Curtis 2016). Reaching this high percentage of treated female deer is only feasible by combining multiple trapping methods along with mobile darting at night for those deer that will not approach baited trap sites. This is expensive and time-consuming, but it is feasible on areas several square miles in size with good road access.

With the current technology available, communities should not consider deer fertility control as a viable, stand-alone deer management approach (Boulanger et al. 2014, NYSDEC 2018). However, there are circumstances where deer sterilization may be combined with lethal deer removal to enhance the effectiveness of both approaches. These situations will still be scale- and cost-limited but may be needed because of political and social pressure for implementing nonlethal deer management. The Wildlife Society (TWS) has adopted a Standing Position, which recognizes that application of wildlife fertility control should be based on appropriate science and species population biology (TWS 2016). In some instances, it may be necessary to reduce the population with lethal methods before fertility control can be used effectively to limit future population growth. The Wildlife Society also recommends additional research into development of cost-effective fertility control techniques, including improved delivery systems. Wildlife professionals also recognize that fertility control products must have minimal health effects on both target and non-target species and must be safe for human consumption if used in food animals.

Management implications for the future

Suburban deer management will continue to raise important challenges and concerns for wildlife management agencies. Public tolerance of wildlife will decline if these issues are not addressed effectively. We are at the threshold of a sea change in public opinion; a deer on the cover of the December 2012 issue of *Time*

magazine was labeled as a “pest.” Many people now view deer as rats with hooves rather than as graceful and majestic forest animals. Deer no longer symbolize wild places because they have become far too common in many suburban backyards and found dead along our nation’s highways. Human health and safety concerns will likely drive deer management efforts in many communities. People will not tolerate high levels of tick-borne diseases or deer–vehicle accidents. When costs exceed the perceived benefits of deer, stakeholders will pressure elected officials to take action and reduce conflicts (Decker and Connelly 1989, Decker et al. 2004).

Although protecting biodiversity and forest ecosystems is critically important (Blossey et al. 2019), this argument may carry insufficient weight for many stakeholders. As long as plants grow and the forest is green, most people will not perceive the negative deer impacts to plant communities easily seen by foresters, arboriculturalists, and ecologists. Even though numerous studies (Tilghman 1989, Waller and Alverson 1997, Rooney and Waller 2003, Royo et al. 2010, Nuttle et al. 2014) have shown that deer browsing impacts a wide range of plants and animals, the average landowner does not see or understand this. Unfortunately, the consequence will be that our nation’s forests will slowly degrade and continue to lose plant and animal biodiversity. Although there are many drivers for this, deer populations are the single most important factor affecting forest regeneration (Blossey et al. 2019), and deer are a species we have the ability to manage at a landscape scale. It will take major changes in deer management programs to achieve desired positive enhancement of forest regeneration at any meaningful scale. We cannot afford to fence and exclude deer from many sensitive plant communities and forest regeneration areas. I do not believe the political fortitude currently exists to make the needed legislative and regulatory changes, and there is far too much infighting between stakeholder groups who have an interest in deer management.

Most elected officials do not have the background or political will to deal with deer management concerns. Community leaders will need management expertise in order to develop cost-effective solutions for reducing deer conflicts

(Boulanger et al. 2014, NYSDEC 2018, Westerfield et al. 2019). This means finding biologists or managers who are willing to donate time to provide guidance or contracting with wildlife management professionals or agency staff (e.g., White Buffalo or USDA Wildlife Services). There will be some costs involved in running an urban deer management program, and it could vary greatly depending on the amount of volunteer help available, professional expertise required, and the scale of the effort. Each community will have a different capacity for developing and implementing a program (Decker et al. 2004, Baumer and Pomeranz 2017), and many simply will not be able to afford it. If community-wide programs cannot be developed, landowners will need to resolve deer issues on a property-by-property basis using fencing, repellents, and other measures to reduce negative impacts. This brings up issues concerning equity and justice, as only more wealthy communities impacted by deer can generally afford to hire professional expertise and pay the annual costs associated with deer management.

It will be difficult for hunting alone to achieve deer management objectives in highly fragmented suburban habitats. Success will depend on the willingness of private landowners to grant access for deer hunting. Field experience has shown that when pressured by hunting, deer quickly learn to avoid hunters and find safe havens or refuge areas within their home ranges (Little et al. 2016, Marantz et al. 2016). Deer tend to move less when risk is high and remain in well-known portions of their home ranges. In addition, state and local discharge regulations will determine where bows and firearms can legally be used to take deer. This will likely result in mapping areas where landowners provide access to deer on a parcel-by-parcel basis to determine safe shooting zones and areas where hunting can effectively occur. The situation may be easier in communities that have larger blocks of contiguous forest or park lands to provide hunting access.

Deer hunters, while often a potential part of the solution, may also create controversy and try to block management efforts. Hunters may be opposed to reducing deer numbers to the low levels needed to sustain biodiversity and forest recovery (Curtis et al. 2019). Also, hunters may

not support programs that include professional sharpshooters who take deer during night at baited sites. The element of “fair chase” is ingrained in many hunters and conservationists. These stakeholders do not want to see someone else taking “their” deer with methods that they may deem unacceptable.

Given the challenges associated with suburban deer management, some wildlife professionals have discussed the potential commercialization of deer removal from problem locations with wildlife agency oversight (Curtis et al. 2005, VerCauteren et al. 2011). Such discussions have resulted in both strong support and opposition for proposed programs. This deer removal approach would essentially privatize a public resource and may not be supported under the current North American Model of Wildlife Conservation (Organ et al. 2012). Existing state and federal laws would need to be changed to allow commercial harvest and sale of wild-caught venison (Curtis et al. 2005, VerCauteren et al. 2011). This is a radical departure from a long history of public deer hunting and conservation. Are wildlife professionals and society ready to take this step to satisfy stakeholder interests and reduce negative deer-related impacts? It appears this approach is still far too contentious, and it has divided the wildlife management profession.

The Northeast Section of The Wildlife Society developed a position statement concerning management of overabundant deer (NE TWS 2016). This position statement provides valuable insight and experience for municipalities looking to reduce human–deer conflicts. The potential contentious nature of deer management means that communities need to understand the different values and opinions regarding management options when faced with the issue of deer overabundance. Stakeholder values and measurable impacts should be used to decide whether human–deer conflicts are unacceptable. Communities should take steps to quantify impacts, such as monitoring the number of deer–vehicle collisions, to confirm whether or not a problem actually exists. Deer density estimates should not be used to evaluate management success, as they are difficult and expensive to obtain, often disputed, and may not directly relate to the impacts that are important. While the Northeast Section of TWS acknowledges hunting may not

be socially acceptable to all communities, they state it to be the most effective management option when dealing with human–deer conflict. While I agree with much of the information in this TWS position statement, my experience is that hunting alone will often not suffice to reach deer management goals in fragmented suburban landscapes. Culling programs are much quicker and more cost-effective for rapidly reducing deer numbers and associated negative impacts. In order to gain political support for deer management, it is often reasonable for communities to allow recreational hunting during open seasons, then remove additional deer with culling permits to reach management objectives. Again, having sufficient access to deer is absolutely critical for either hunting or culling programs to be successful.

Many resources are available for communities struggling with chronically overabundant deer populations. The Community Deer Advisor (2016) web platform was created as a collaboration between Cornell University and The Nature Conservancy to help communities successfully manage deer at a local level. Community-based management is the foundation for Community Deer Advisor information. The recommendations concerning the process of CBM are based on social science research and lessons learned from deer management case studies in multiple states. This website is the single most comprehensive source of information for communities dealing with deer impacts, and it includes an extensive resource library. The CBM guides link contains PDF-formatted copies of several state and national guides developed to help communities with the process. In addition, there is a CBM starter kit with templates for developing both deer management and communication plans. Another excellent resource is the community examples section with detailed information from >40 communities around the United States that have developed suburban deer management plans. The goal is to allow communities to learn from each other so that mistakes are not repeated, and people can quickly see the common features of successful deer management programs.

So, where do we go from here? I think it is time for an honest assessment of CBM pro-

grams across the country and a critical evaluation of what really works (or fails). The dogma that hunting can solve suburban deer problems with locally overabundant herds is simply no longer a reality. Hunting may well be part of a solution but is not necessarily the solution for reaching deer management goals. Commercial harvesting of deer (VerCauteren et al. 2011) under tightly controlled state-agency guidelines is a possible solution, but not the only one. Programs must be diverse and flexible to match different deer management goals and community capacity (Decker et al. 2004, Westerfield et al. 2019). For communities with little contention and sufficient wooded open space, inexpensive volunteer-run programs may be sufficient. However, for those municipalities with diverse stakeholders and opinions, professional expertise may be required for guiding both the decision-making process along with on-the-ground program implementation.

Who should pay for the specialized deer management approaches required in suburban areas? To date, most state wildlife agencies have required local communities to pay for management applications requiring anything beyond conventional hunting programs. Most attention has been paid to wealthier communities in the United States that have the ability to pay for professional management expertise (e.g., Cayuga Heights, New York; Hilton Head Island, South Carolina; Princeton, New Jersey; etc.). Successful deer management is similar to mowing the lawn; it requires regular maintenance and attention. In open deer populations, high immigration rates may pose problems (Merrill et al. 2006). Also, any female deer surviving will continue to produce fawns unless they are sterilized. So, communities that can get ahead of the deer production/immigration curve often have an annual budget set aside for deer management, usually taxpayer funded. Even very successful programs require yearly maintenance to maintain low levels of deer abundance and associated impacts. The worst thing that can be done is to start a deer management effort, achieve success, then stop the program when the management goal is reached. If the population is open and habitat quality is good, deer will eventually repopulate the area and start reproducing. Suburban deer populations can double in size every 2–3 years,

so it does not take long for herds to increase and impact levels to rise once a program is stopped. I believe that it is less expensive to spend a small amount annually for program maintenance, rather than let deer numbers build and conduct a major control program every 3 or 4 years.

The bottom line is that there is no simple and inexpensive solution for managing chronically overabundant deer in fragmented suburban areas. With the increasing spread of Lyme and other tick-borne diseases and other associated negative impacts such as vehicle collisions and plant damage, public tolerance for high deer abundance will continue to decline. For wildlife biologists and managers, this will continue to be one of the most intractable management issues we will continue to face. This is often high-visibility work, and public support for wildlife management programs may well depend on how agency staff address these stakeholder concerns. Effective public engagement will be necessary to develop political support and funding for suburban deer management programs. Wildlife professionals need to be honest with stakeholders about viable deer management solutions, be open to new ideas and approaches, and critically evaluate the cost-effectiveness of any management efforts that are implemented. This includes developing simple, inexpensive, and reliable impact indicators to evaluate the success of any deer management programs.

So, what does the future hold? This is something that wildlife agency staff, community leaders, and affected stakeholders need to think critically about, and work together on, to improve suburban deer management in the future. Successful programs will require creativity and flexibility to adjust to varying community goals and landscape characteristics. Elected officials will need to explore new models for sustainable funding of long-term programs, including maintenance costs, once initial community goals and deer management objectives are achieved. Some form of community education is also needed if stakeholders are going to make informed decisions concerning deer management alternatives. This will likely include a partnership between wildlife agencies and community-based groups (e.g., Cooperative Extension associations or non-governmental organiza-

tions). Successful deer management programs may take many forms depending on community capacity and goals, and there is definitely no “one-size-fits-all” approach that can be implemented. Communities in some western states are now experiencing suburban ungulate conflicts similar to those in the eastern United States. These issues will continue to spread as deer populations increase in areas at the urban-rural interface with residential sprawl and hunting season closures. It will take management creativity and additional resources to make any meaningful long-term changes in reducing negative deer-related impacts at a landscape scale.

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