Wildlife Society Bulletin 35(3):161–167; 2011; DOI: 10.1002/wsb.47

Original Article

CPR for Urban Deer Management Objectives: Clarity, Practicality, and Relevance

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ABSTRACT Effective management of formerly scarce and now abundant game species has been identified as a considerable challenge facing the North American model of wildlife conservation. White-tailed deer (*Odocoileus virginianus*) management efforts in developed landscapes are often contentious and face numerous obstacles to implement. We drew upon our experiences conducting, overseeing, and assessing deer management in urban–suburban–exurban settings, and summarized a variety of literature to identify both biological and social complexities encountered. We concluded that many challenges may be addressed by developing clear fundamental and enabling program objectives, related to practical limitations, and measured through metrics relevant to fundamental desires of stakeholders. Although managers often seek to implement programs to address fundamental objectives related to condition of deer populations or impacts on plant communities, the greatest public concerns often relate to threats to public safety (e.g., risk of being involved in a deer–vehicle collision or contracting Lyme disease) and property (e.g., costs from deer–vehicle collisions or damaged landscaping). Establishing practical expectations requires considering the biological complexities of deer management regarding the potential of 1) density-dependent reproductive responses, 2) time lags between population response to management and changes in condition indices and vegetation response, and 3) nonlinear relationships between deer densities and several key fundamental objectives. Relevance to public expectations for some objectives requires developing appropriate metrics of success and potentially pursuing an alternative to the typical enabling objective of reducing the deer population. Paying attention to CPR—clarity, practicality, and relevance of management programs—can resuscitate the public's trust in managers' abilities to effectively manage public trust resources.

KEY WORDS enabling objectives, fundamental objectives, *Odocoileus virginianus*, urban deer, white-tailed deer.

The public trust doctrine that developed out of North American case law established wildlife as a public trust resource, and natural resource management agencies as trustees, charged with the responsibility and authority to sustainably manage wildlife populations for the benefit of all (Bean 1983). Natural resource agency organic acts, or laws that create agencies and define how authority is delegated to departments (Fischman 2003), mandate the conservation and protection of all natural resources, but they also typically commit agencies to providing for the use and enjoyment of those resources by current and future generations. The traditional approach used by agencies to meet their conservation, use, and management mandates has been through adoption of scientifically based regulations that provide for surplus wildlife consumption (Geist et al. 2001). As some formerly scarce game species have grown to levels of abundance, numerous population management challenges related to recreational harvest have emerged. Declining hunting participation, loss of access, and insufficient demands for consuming game all restrict capabilities to manage some species, particularly as urban–suburban–exurban (hereafter, called urban) expansion and sprawl has occurred (Ankney 1996, Brown et al. 2000, Riley et al. 2003, Storm et al. 2007). Increasing human–wildlife conflict and the corresponding potential for humans to value these species less represent a substantial threat to the North American model of wildlife conservation (Geist et al. 2001).

Coincident with the expansion of wildlife populations and conflict in urban settings, public concepts of wildlife management have evolved, stakeholders engaged in management decisions have diversified, and general mistrust of government and political conflict surrounding wildlife policies have increased (Tyler 1998, Peyton 2000, Nie 2004). Thus, wildlife managers are challenged to maintain the public's trust while also managing those resources as a trust, or "an equitable right or interest in a property held by one person on behalf of another" (Cayne 1989:1059). In the face of public demands and expectations on an

Received: 7 January 2011; Accepted: 9 June 2011

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increasingly human-dominated landscape, this requires caution by authorities attempting to use their expertise to implement programs to manage and conserve all natural resources, while remaining accountable as public servants.

Crafting effective, publicly acceptable solutions to implement, maintain, and evaluate white-tailed deer (*Odocoileus virginianus*) management in urban settings can be particularly challenging (Raik et al. 2006). We describe some of the unique difficulties presented by deer management in these environments and develop recommendations to guide managers in establishing objectives that will aid them in addressing both social challenges and biological complexities. Implementing CPR—attaining sufficient clarity, practicality, and relevance of management programs for deer in urban settings—can resuscitate public trust in managers' abilities to effectively manage public trust resources.

DEER MANAGEMENT AND CONFLICT ON DEVELOPED LANDSCAPES

We have observed the initiation of many deer management programs in developed landscapes under a simply stated intention to reduce deer populations. Managers and citizens, however, may hold different views regarding desired management outcomes. In response to their obligation to conserve and protect all natural resources, natural resource managers often seek to implement programs specifically to address poor physical condition of deer or impacts of herbivory on plant communities that can occur at high deer population densities (Augustine and Frelich 1998, McShea and Rappole 2000, Keyser et al. 2005). However, the greatest public concerns regarding abundant deer populations in such settings often relate to assessed or perceived threats to public safety and property, specifically the risk of being involved in a deer–vehicle collision (DVC), potential of contracting Lyme disease, or facing costs from involvement in a DVC or damages incurred to landscaping (Decker and Gavin 1987, Stout et al. 1993, Loker et al. 1999, Storm et al. 2007). Local citizens, politicians, and even agency administrators often fail to recognize or adequately consider the long-term nature and biological complexities of managing wildlife populations (Williams and Johnson 1995, Porter 1997). Furthermore, stakeholder groups differ in the relative importance they ascribe to factors to be addressed through deer management. Marcoux and Riley (2010) found 81% of southeast Michigan, USA drivers felt DVCs were a serious problem. Only 57% of southern Michigan deer hunters, however (and only 46% statewide), felt that the number of DVCs represented a moderate to very extensive problem in the area where they hunt (Frawley and Rudolph 2008). Thus, hunters are likely to be uncooperative with, if not directly opposed to, assisting with efforts to mitigate DVC rates through deer population reduction. Elected officials may be unwilling to publicly acknowledge that not all competing interests will be satisfied with any given management program, and may adjust their position or reduce or eliminate resources committed to a program as they perceive shifting public concerns or become aware of differing viewpoints (Woolf and Roseberry 1998).

Our experiences have shown that conflict surrounding deer management programs in urban settings can often lead to a desire for quick resolution, and groups opposing a particular program or management in general often mount great pressure on public officials to discontinue or reduce efforts. Similarly, Raik et al. (2006) reviewed a case study in which a community in New York, USA prior to committing to sustained dialogue and deliberation, alternated between allowing and prohibiting firearms discharge as public nuisance complaints rose and fell. Maintaining support for programs can be more difficult if discussions prior to initiating management focus solely on a perceived need to address deer "overabundance," without further clarification of this overly vague goal (McShea et al. 1997). In the absence of clear, practical, and relevant objectives that are tied specifically to desired outcomes in advance of program initiation, management efforts will be subject to quick abandonment or reduction in effort or resources as local citizens and officials seek to reduce conflict over often controversial actions.

CLARITY: IDENTIFYING FUNDAMENTAL AND ENABLING OBJECTIVES

Clarity in program objectives is critical to ensure transparency, gain trust, and maintain commitment to meeting desired goals. This can best be ensured through identification of both fundamental and enabling objectives necessary to meet desired management outcomes. Fundamental objectives relate to the overarching desire for initiating management actions, whereas enabling objectives are outcomes or actions needed to reach fundamental objectives (Riley et al. 2002, Enck et al. 2006, Decker et al. 2008). In this context, deer population reduction should be identified as an enabling objective, because there are no reasons that a given population size is inherently suitable or acceptable. Any concerns that are overarching desires leading to the initiation of a management intervention (e.g., deer physical condition, impacts on plant communities, or threats to public safety or property) would represent fundamental objectives. These fundamental objectives are related, to some extent, to the enabling objective of a reduced deer population.

A variety of methods may be appropriate for identifying enabling and fundamental objectives depending upon the management setting and authorities involved. Managers working with deer populations in communities entirely or predominantly in private ownership would best be served by engaging the community in the decision-making process (Chase et al. 2000, Raik et al. 2006). Managers and administrators of parks and preserves within developed landscapes may possess the authority to initiate management as they feel necessary to protect park resources and visitors, but should expect that they will encounter public resistance or pressure for involvement from citizens, organizations, or local politicians. Regardless of the specific context, we recommend first involving an appropriate set of stakeholders in setting transparent objectives, to guard against program abandonment prior to reaching fundamental objectives. Overall support for agencies and acceptance of rules has been shown to be more strongly related to individuals' perceptions of the fairness of decision processes and treatment by authorities than the perceived favorableness of the outcome of decisions (Tyler 2000). Managers should anticipate disagreement among groups regarding the appropriateness or importance of fundamental and enabling objectives; however, using an inclusive and fair process to identify all program objectives may be more important for garnering support than avoiding controversial objectives.

PRACTICALITY: BIOLOGICAL COMPLEXITIES AND FUNDAMENTAL AND ENABLING OBJECTIVES

Managers should take steps to account for a number of complexities that may influence the relationships between fundamental and enabling objectives. To demonstrate a variety of complexities that warrant managers' attention, we summarized selected research findings based on the common instance in which managing deer abundance is the enabling objective for meeting fundamental objectives addressing deer condition, impacts on plant communities, rate of DVC, Lyme disease transmission, and damage to landscaping. Our review was not intended as an assessment of whether such relationships should be expected to be universally encountered, but rather as a means to illustrate potential confounding factors to efforts to reach fundamental objectives solely through manipulation of deer abundance.

Deer Abundance, Recruitment, and Physical Condition

Recruitment rate is the number of individuals that are born and survive to a specified age per female in the population (McCullough 1984), and so incorporates some elements of both reproduction and mortality. The extent to which recruitment rate is density-dependent will influence annual population growth at different population sizes. This relationship will influence the effectiveness of management efforts at achieving population management, as well as the ability to address fundamental objectives. McCullough (1979), Nielsen et al. (1997), and Rudolph et al. (2000) accounted for variable rates of density-dependent recruitment when constructing models to predict management impacts across ranges of deer densities. Density-dependence is a complicating factor commonly considered in the management of deer populations, although White and Bartmann (1997) concluded that flawed methodologies and the difficulty in accounting for additional factors (such as environmental variation) suggest that the evidence for the occurrence of density-dependent effects on reproduction and mortality is not entirely conclusive.

Additional confounding factors include time lags between the point at which population change occurs and responses are noted in metrics relating to fundamental objectives. In their assessment of commonly collected metrics of physical condition and recruitment, Keyser et al. (2005) noted that those measures most consistently related to deer density estimates showed 2-year lags in their response. They used long-term data sets in their analyses (a min. of 15 yr duration), and used 3-year running averages to reduce the influence of annual changes in weather and habitat conditions. Accounting for potential lags and annual variation will obviously be much more difficult for those managers just initiating a program.

Time Lags in Vegetation Response

Managers of parks or preserves within developed landscapes may wish to lower deer densities to reduce impacts of herbivory on vegetation. Concerns may exist regarding direct impacts on plant species or due to potential changes in habitat characteristics and subsequent effects on abundance and diversity of other wildlife species. Vegetation response to deer reductions may also be related to site factors such as soil chemistry or quality, lighting regime, and the presence of competing vegetation (McShea and Rappole 2000, Sage et al. 2003, Thompson and Sharpe 2005). Such factors may limit the effectiveness of deer population reduction as an enabling objective, or at least may result in variable responses corresponding to variable site factors across the management area. Furthermore, Augustine and Frelich (1998) demonstrated that, even under complete protection from deer herbivory, individual plants of Trillium species (*Trillium* spp.) required 2 growing seasons for flowering rates and leaf area to increase. Such time lags may complicate determination of the effectiveness of deer population reduction at meeting fundamental objectives, particularly under variable effort or success at deer removal.

Effects of Deer Density on Abundance of Ticks and Lyme Disease Incidence

White-tailed deer are not effective reservoirs of the bacterial spirochete (*Borrelia burgdorferi*), which is the pathogen for Lyme disease (Telford et al. 1988, Wilson and Childs 1997). However, the black-legged ticks (*Ixodes scapularis*) that serve as a vector for the disease feed primarily on deer (Piesman et al. 1979, Wilson et al. 1990), and their distribution is closely tied to the abundance of deer (Wilson et al. 1985, Duffy et al. 1994). The Lyme disease pathogen is reservoired by a variety of small mammals and birds, which is fed upon by immature black-legged ticks (Levine et al. 1985, Donahue et al. 1987, Rand et al. 2004, Piesman 2006). Risk of infection depends upon both abundance and prevalence of infection among vectors. Reservoir species maintain the spirochete, but deer maintain the vector population that provides the route of infection when they feed upon humans. Removal of deer from Monhegan Island in Maine, USA was highly effective at reducing adult tick abundance, but an estimated deer population reduction of 47% over 3 years within a New Jersey, USA suburban Lyme disease–endemic area produced no detectable change in the incidence rate within the human population (Rand et al. 2004, Jordan et al. 2007).

Reduction of deer may initially increase the number of ticks seeking alternate hosts, and the reduction of nymphs and adults should be expected to lag 1 year and 2 years following declines in larval abundance, respectively, due to the 2-year life cycle of black-legged ticks in northern regions (Yuval and Spielman 1990, Wilson and Childs 1997, Rand et al. 2004, Jordan et al. 2007). Such responses are likely to lead to fluctuating exposure of humans to tick bites and subsequent instability and time lags in Lyme disease prevalence. If Lyme disease prevalence is a concern among local citizens and community leaders, yet not clearly identified as a fundamental objective of a deer reduction program, it may be assumed that a reduction of the deer population will produce a desired reduction in Lyme disease prevalence. In settings where Lyme disease prevalence is identified and monitored as a fundamental objective, these potential interactions and lags should be addressed and identified as suggestive of the need for sustained management effort in order to pursue the objective over the long term.

Nonlinear Relationship Between Deer Density and DVCs

Concerns regarding threats to public safety and damages related to DVCs are common reasons for initiation of deer management programs in urban settings. Factors such as land cover and traffic volume have been determined to be significant variables (in addition to deer densities) influencing the rate of DVC at the landscape level (Sudharsan et al. 2005, Farrell and Tappe 2007). Within a specific community, down to the level of a specific location, a number of site factors may influence fine-scale deer movements or driver visibility and affect rate of DVC in addition to or independent of deer density (Bashore et al. 1985, Finder et al. 1999, Hubbard et al. 2000, Nielsen et al. 2003).

Potential Interaction Between Management and Deer Movements

The frequency that deer use, or travel through, specific locations can influence the level of impacts of browsing activities, rate of DVC, and risk of exposure to Lyme disease. Kilpatrick et al. (2001) found a positive relationship between home range size and deer density. Areas receiving enhanced use by deer could continue to sustain high levels of conflict even as overall deer densities are reduced. Even if impacts across the management area are generally reduced, persistence of problem areas sustained by these shifting deer movement patterns in response to reduced densities could lead to divergent assessments of the success of management in meeting fundamental objectives.

Kilpatrick and Stober (2002) demonstrated that the location of bait sites within deer home ranges caused shifts in core areas that received the most use by these deer. They concluded use of bait may enhance success of capturing deer, improve treatment with acaricides, or facilitate lethal removal. Net benefits of any efforts to use bait to enhance management success must exceed any potentially increased level of impacts caused by the concentrated deer use of these areas.

RELEVANCE: IDENTIFYING METRICS AND ALTERNATIVE ENABLING OBJECTIVES

Evaluating program success according to distinct categories of fundamental and enabling objectives illustrates what is at risk if such considerations are not introduced prior to initiating management interventions. Where management is implemented, initial gains toward the enabling objective of a reduced deer population may not directly relate to fundamental objectives due to time lags and nonlinear relationships between deer densities and these various overarching objectives. Lack of progress toward these underlying needs for management would fail to meet communities' needs. Measures of responses to management must be articulated in a way directly relevant to these needs if managers wish to address community interests. For example, judgment regarding whether the extent of damage to landscaping is reduced to an acceptable level is best made by residents themselves. In communities where this is of primary concern, it may be best to conduct a survey regarding perceptions of the amount of or tolerance for damage, rather than attempting to produce direct measures of browsing impact on landscaping (Kilpatrick and Walter 1999). In anticipation of potential time lags between population reduction and improvement in metrics of deer condition, managers committed to this fundamental objective should clearly associate a reasonable time frame for measurable success as management is initiated, to avoid the appearance of excusing lack of quick progress. We recommend clearly delineating and establishing measurable levels for all enabling and fundamental objectives to which a program is committed at the outset. This will help prevent quick abandonment or reductions in management effort that may be recommended by local citizens and officials following initial progress only toward accomplishing deer population reduction.

In addition to establishing appropriate metrics for evaluating progress relevant to primary management concerns, considering the relationship between fundamental and enabling objectives may reveal other solutions. Additional or alternative enabling objectives may enhance management success by offering more practical or effective ways at reaching fundamental objectives. In addition to reducing deer densities, successfully meeting a fundamental objective related to condition or composition of vegetation may require additional enabling objectives such as controlling competing vegetation (Sage et al. 2003). Reductions in deer populations may be ineffective at reducing Lyme disease prevalence, yet the variety and abundance of immature tick hosts prevents their control and removal from being a viable intervention (Rand et al. 2004, Piesman 2006). An alternative enabling objective to deer population reduction may be a tick control program. Piesman (2006) suggested that applying acaricides directly to residential properties to control ticks may be the best option for Lyme disease prevention, though he also identified perceived risk among the public regarding acaracide treatment as a significant barrier to implementation. Somewhat less effective vector control may be implemented through the application of acaricides to deer, but practical implementation requires establishment of treatment stations supplied with bait to encourage deer visitation and self-application (Solberg et al. 2003, Piesman 2006). The practices of baiting and supplemental feeding are themselves controversial and an increasing number of agencies have restricted or prohibited it entirely (Rudolph et al. 2006). Finally, vegetation management may offer an alternative enabling objective by reducing use by ticks or deer of areas frequented by community residents. Allan et al. (2010) demonstrated that removal of honeysuckle from natural areas in the St. Louis, Missouri, USA region reduced deer activity in these areas as well as the number of lone star ticks (*Amblyomma americanum*) infected with ehrlichiosis. Where fundamental objectives are adopted to address Lyme disease, managers may need to engage in public education either to raise awareness of the limited effectiveness of deer population reduction as an enabling objective or to increase acceptance of acaracide application or vegetation management as more effective alternative enabling objectives.

A reduced deer population may be only partially effective as an enabling objective for the fundamental objective of reducing DVCs. Considering the significance of land cover and traffic volume in addition to deer densities at the landscape level, few alternative enabling objectives are likely to be feasible to implement at this broad scale. Alternatives may be available to managers who wish to address concerns at a municipal scale, or at a particular problem location, by considering the site factors that can influence DVCs independently of deer density (Bashore et al. 1985, Finder et al. 1999, Hubbard et al. 2000, Nielsen et al. 2003). Influencing decisions regarding roadside fencing, vegetation management, or road engineering by working in concert with local government officials or transportation planners may offer viable alternative enabling objectives. Finally, education to improve driver awareness has been suggested as an enabling objective to reach the fundamental objective of reducing DVCs (Allen and McCullough 1976, Romin and Bissonette 1996). Marcoux and Riley (2010) suggested such efforts must target misperceptions that DVCs are random events if educators are to effectively aid drivers in identifying areas of greatest risk or behaviors that might reduce the risk of a collision.

DISCUSSION

Caughley (1981) cautioned that a simple characterization of wildlife in a given area as "overpopulated," without considering the underlying reason this conclusion is reached, would commonly lead to inappropriate management. Rutberg (1997) pointed out that a lack of data and failure to test assumptions regarding the complex dynamics of deer ecology and management on developed landscapes will not go unnoticed by the public, and can fuel additional conflict in these already controversial settings. We, therefore, recommend that managers ensure clarity in management by identifying both fundamental and enabling objectives to be addressed prior to initiating programs. Practical expectations for management must be developed only after considering the uncertainties regarding biological complexities that may exist in the relationship between fundamental and enabling objectives. Management may be made relevant to public desires by ensuring metrics to evaluate management are specifically related to the nature of the concern leading to management, and by considering additional or potentially alternative enabling objectives. Such efforts will aid in directing management to fundamentally desired outcomes, and will help ensure that future conflict will be less likely to erode support for maintaining programs until such outcomes are reached or determined to be infeasible. In some settings, managers do face legal obligations to identify outcomes such as addressing impacts on plant communities as fundamental objectives, but this does not absolve them of their public trust responsibility to sustainably manage wildlife populations for the benefit of all. Management implemented under our recommended CPR approach will be more likely to be viewed as sufficiently transparent to engender greater public trust.

ACKNOWLEDGMENTS

This paper was developed based on a presentation delivered at a symposium held during the 2008 Annual Meeting of The Wildlife Society. We thank C. K. Nielsen and W. F. Porter for their leadership in coordinating that symposium as well as editing this special section of the Wildlife Society Bulletin. M. L. Gore, S. Hanisch, J. S. Kahler, B. A. Muter, and S. J. Riley provided valuable comments on an earlier draft version of this manuscript. We are indebted to many managers, community leaders, and passionate citizens for their involvement in the discussions and work that shaped the experiences and perspectives we have offered here.

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Associate Editor: Nielsen.