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Ecological and social carrying capacity considerations for optimal management of urban white-tailed deer

Erin Christine McCance[1,2] and Richard K. Baydack[1]

[1]Department of Environment and Geography, Professor, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.
[2]104 Cloverwood Road, Wpg, MB, Canada.

*Corresponding author. E-mail: erin.mccance@umanitoba.ca Tel: (204) 475-2354. Fax: (204) 474-7699.

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ABSTRACT

With urbanization occurring at rapid rates, city boundaries are extending into previously undeveloped spaces, leaving many species seeking suitable habitat within urban environments. As a result, humans and wildlife compete more than ever before for available space and resources, creating real problems for wildlife managers. Taking white-tailed deer as a case in point, urban wildlife management must consider a number of factors as belonging essentially to both the "ecological" and "social" carrying capacity. Entertaining ecological and social carrying capacity considerations calls for an integrated approach to wildlife management in urban settings, management that translates into feasible, future-oriented practices, and lend itself to species co-existence within the complex dynamics of modern metropolitan spaces.

Key words: Ecology, human dimensions, *Odocoileus virginianus*, social carrying capacity, spatial geography, urban white-tailed deer management.

INTRODUCTION

The urban-wildland boundary has become increasingly obscure. Urbanization is occurring at an alarming rate, extending city boundaries into previously undeveloped spaces. Many species, therefore, find themselves compressed for space and are forced to seek suitable habitat within urban environments. These human induced land-use changes are relatively recent, yet they are occurring at a rapid rate. As a result, humans and wildlife now compete more and more for space and resources, creating a very real problem for wildlife managers. In the face of this, wildlife management has evolved into a diverse and complex field that is marked not by consensus, so much as by debate, over what management strategies should be adopted. Added to this, contemporary wildlife management is informed by a large number of disciplinary perspectives, some of which are beyond the purview of conventional managers, who may be inclined, then, to resist these perspectives when considering their management approaches. Taking white-tailed deer as a case in point, a survey of recent literature pertaining to urban wildlife management is undertaken. Wildlife management is, and necessarily must remain, a multidisciplinary pursuit; there is no going back to an earlier and simpler "before." Therefore, effective wildlife management must be multifaceted, that is, one that considers a number of factors as belonging essentially to both the "ecological" and "social" carrying capacity on which any management must depend. Contemporary wildlife management will inevitably be fluid rather than static; complex rather than simple; marked by contention rather than consensus; and importantly, open to multiple research perspectives and stakeholder interests.

Urban white-tailed deer (*Odocoileus virginianus*) provide a good case study of ways in which contemporary wildlife managers are faced with increasingly complex human-wildlife problems. Many urban centers throughout North America are experiencing growing urban white-tailed deer populations (Brown et al., 2000; Doerr et al., 2001). The highly resilient and adjustable nature of white-tailed deer has contributed to their ability to survive in human altered landscapes. White-tailed deer have been successful in their capacity to adapt and thrive in urban, metropolitan environments. White-tailed deer find refuge in urban centers due to hunting restrictions; firearms discharge

laws, and minimal predation (Adams et al., 2006; Conover et al., 1995; Messmer et al., 1997). Growing WTD populations along with hunter accessibility limitations, and conflicting social attitudes and perceptions with regard to wildlife, have resulted in higher deer densities throughout most of their North American range (Brown et al., 2000; DeNicola et al., 1997; Kilpatrick et al., 2007; McDonald et al., 2007; Merrill et al., 2006). Urban environments provide white-tailed deer with adequate shelter, available water and both natural and human supplemented food sources (Adams et al., 2006). These factors, coupled with a high birth rate (Adams et al., 2006; DeNicola, 2000; McCullough, 1982), have resulted in increasing white-tailed deer populations in largely human populated areas.

Given human population growth and trends toward urbanization, urban areas need to be designed in ways that incorporate natural spaces within the urban matrix and support the co-existence of species in order to slow the rate of biodiversity loss and potential species extinctions. White-tailed deer, however, are a generalist species that have been able to adapt to heavily human manipulated spaces. In these expanding urban/suburban zones, dominated by high human population density, increasing white-tailed deer populations present numerous challenges for wildlife managers (Decker and Gavin, 1987; Stout et al., 1997).

A concept of ecological carrying capacity

Traditionally, ecological carrying capacity and biological carrying capacity were defined and translated into management objectives and actions that did not involve the complexities and multi-disciplinary perspectives that inform the field today. Wildlife management does not have an extensive history in metropolitan areas since prior to the mid-twentieth century, North America was predominately a rural society (Adams and Lindsay, 2010). As such, wildlife management plans were constructed with a rural landscape in mind. An overabundant white-tailed deer population in a given area, devoid of high human population density, would suggest a reduction in deer population size as a viable solution. Today, the parameters of ecological carrying capacity are far more difficult to contain. Several factors deserve to mention include spatial geographies, human population growth and urbanization, urban habitats and ecological function, overabundance, and zoononses. While the concept of ecological carrying capacity has been defined as the maximum population size of a given species that an area can support without damaging the area or reducing its future capacity to support the species (Hanley et al., 1999), the term carrying capacity itself, while widely used, remains limited and vague (Buckley, 1999; Del Monte-Luna et al., 2004; NcNab, 1985). The long term effects of grazing by wild ungulates on the vegetation stability, species composition and the productivity of their food supplies are still relatively poorly understood (McNab, 1985). Detection thresholds of species impacts on the ecosystem can be variable depending on the parameter measured and sampling techniques used and given the complexity of ecosystem function, the practical applications of the detection of impact can be difficult to achieve (Buckley, 1999). McNab suggests that problems occur when we take the idea of range management carrying capacity and apply it to the management of wild ungulates in natural areas where management objectives are entirely different (McNab, 1985). If we adopt the vegetation categorization that is used for vegetation conditions for managing livestock and apply this categorization of vegetation when managing wild ungulates, then vegetation conditions at K carrying capacity would be categorized as only “fair” or “poor” under this system (McNab, 1985). These practical obscurities are especially true in urban environments where habitats are “out of balance,” highly modified, manipulated and manicured and ecological carrying capacity is even more difficult to determine.

Spatial geographies

Numerous scholars have now begun to challenge the traditional geography boundaries humans have established with relation to the proper places animals should physically occupy (Philo and Wilbert, 2000; Wolch and Lassiter, 2000; Brownlow, 2000; Jones, 2000; Emel and Wolch, 1998; Gullo et al., 1998; Lynn, 1998). These human constructed spatial orderings of animal geography situate wild animals in relation to space, place, environment and landscape. Animals in zoos are “in place,” and we have identified boundaries upon which some animals are welcomed to occupy space within our daily lives while others are clearly thought to be “out of place” (Philo and Wilbert, 2000). Owain Jones suggests that human and non-human relations are inevitably embedded in the complex spatialities of the world (Jones, 2000). This is a multi-dimensional issue given our current concerns for environmental integrity, environmental ethics, and reconnection with nature. Looking at the relationship between animals and humans, which remains deeply complex and shifting, means a likely range of focus across a number of disciplines. Farm animals, laboratory animals, wild animals, zoo animals, domestic pet animals, all have become defined by cultural space where humans perceive animals as either “in or out of place.” The invisibility of the individual non-human “other” within dominant systems of ethics is the key factor in determining spatialization boundaries. Jones argues that there is a need to focus on non-human geographies as little to no attention is given to wildlife (Jones, 2000). More than ever before, scholars are deconstructing these spatial orderings and challenging the

wild/domestic dichotomy (Clement, 2007) and conventional notions of inclusion and exclusion (Philo, 1998). These investigations into human-animal relations have given rise to new terms of reference such as zoopolis (Emel and Wolch, 1998), zoontologies (Wolfe, 2008), zoographies (Calarco, 2008) and to the study of urban animal ecology. If we entertain the notion of "letting animals back in" (Emel and Wolch, 1998) and open ourselves to the idea of urban "shared spaces" designed for species co-existence (Emel and Wolch, 1998; Gullo et al., 1998; Jones, 2000; Philo and Wilbert, 2000), what does this mean for wildlife managers in practical management terms? It has become increasingly critical for urban spaces to be designed for the co-existence of both human and non-human species and as such, wildlife management can no longer ignore the need to open the process of articulating management objectives and actions to the consideration of perspectives across multiple disciplines and to the involvement of stakeholders at all levels of management action. Such considerations have implications for "ecological" carrying capacity. Urban ecosystems that are "out of balance" due to the human exclusion of predatory species, function differently and as such, face challenges when those species populations that we consider to be tolerable grow and potentially become overpopulated.

Human population growth and urbanization

The latter half of the twentieth century represented a time when First World societies underwent a transition from rural, agricultural, to urban lifestyles (Adams et al., 2006). Population growth and capitalization, coupled with the influx of people into urban centers, resulted in stretched city limits and the creation of infrastructure in previously natural, undeveloped habitat. Adams et al. (2006) define an urban environment as one that has a large central place and adjacent densely settled census blocks that together have a total population of at least 50,000 people (US Census Bureau, 2001). The United Nations estimates the human population of North America, currently 352 million people, will reach 448 million people by 2050 (http://unstats.un.org). Today, roughly 80% of Canadians live in urban/suburban areas (Canadian Education Association web page accessed on March 5, 2008), as do 80% of Americans (Adams et al., 2006; Adams and Lindsey, 2010). As such, many metropolis areas are not defined by a single city center but rather from a series of extended suburban areas, one connecting to another, creating what Gillham defines as "the limitless City" (Gillham, 2002). Suburbs are no longer easily defined as low-density residential housing surrounding city centers. The industrial revolution changed North America. Cities centered on large-scale factory production were developed and over time residents within these communities began to realize the negative environmental and social consequences brought on by having large-scale factory production within city spaces. In response to these polluted, noisy, and dirty city neighbourhoods, people retreated to the urban-wildland interface. Suburbs and urban sprawl was the result (Gillham, 2002). In the latter quarter of the twentieth century, suburbs increasingly emerged, stretching out from city centers. By the start of the twenty-first century, more people lived and worked in the suburbs in North America than in city centers (Gillham, 2002). Cities are some of the most profoundly altered ecosystems on earth (Collins et al., 2000). Despite the emergence of environmentalism, the animal rights movement, and rising concerns about habitat loss and declining biodiversity, urbanization is still occurring at rapid rates (Gullo, 1998). Biodiversity is increasingly reduced and as E.O. Wilson suggests, the global rate of extinction is substantially higher as the result of human land changes and resource use; if the current rate of biodiversity loss continues, we will experience the most extreme extinction event in the past 65 million years (Wilson, 1988). These loses will be devastating for humans as many of our medicines, foods, fibers, and economies survive on wild species. This is not to mention the impact species loss has on the health and viability of a functioning ecosystem. Natural processes such as maintaining air quality, soil production, nutrient cycling, moderating climate, producing fresh water, mitigating pollution, degradation of wastes and controlling disease and parasites will break down (Hilty et al., 2006). In addition to the losses referred to above, are those associated with cultural, emotional, and spiritual enrichment that these species provide (Hilty et al., 2006). Human demand for resources and our footprint on the land leaves many wildlife species struggling with a loss of available habitats (Hilty et al., 2006).

As Wolch (1998) contends, there is a mainstream theory that urbanization transforms "empty" land through the process of "development" to produce "improved" land, a movement toward the "highest and best use" of space. She argues, however, that this transformation is not of "empty" space at all but of wildlands that are teeming with non-human life. These human induced land-use changes result in massive ecological destruction and a denaturalization of the environment characterized by improvised soil quality, drainage, and vegetation. Urban ecology is often dominated by invasive species, in systems that are out of balance as some species are welcome while other species such as predators, considered intolerable, are excluded. Wolch (1998) argues that human practices have altered the global environment as never before. The consideration of ecological carrying capacity now must confront the phenomenon of urbanization, at least, if overall biodiversity loss, species extinctions and the destruction of these "empty spaces" are regarded as intolerable. In the twenty first century, it is a new ball game. For example,

Wolch, an urban planner very much involved in the development of urban-wildlife co-habituation in Southern California, provides research that is important to consider when defining ecological carrying capacity, and which thereby enlarges ecological carrying capacity beyond its traditional scope. The point is that neither "ecology" nor "ecological carrying capacity" is currently separable from other research areas such as; philosophy, animal ethics, "new" geography, architecture, sociology, anthropology, among others.

Urban habitats and ecological function

As a result of the aforementioned land-use changes and the influx of wildlife finding refuge in urban areas, many urbanites, generations removed from living in connection with nature, now reside in close proximity to wildlife. The ecology of urban wildlife habitats are highly modified through the use of pesticides, fertilizers, and the burning of fossil fuels, all contributing to the loss of diversity and overall ecosystem function (Adams and Lindsay, 2010). Unlike natural ecosystems, urban ecosystems are unstable with overloaded biochemical cycles and have incomplete food chains and modified abiotic structure. City environments have their own microclimates and derive their energy primarily from sources other than the sun. These "heat islands" have variations in temperature, relative humidity, precipitation, and wind in comparison with their natural ecosystem counterparts. Urban development affects water runoff, infiltration, and purification processes. All together, urban ecology differs from natural ecology and as such, ecosystem function is affected presenting challenges when determining the ecological carrying capacity of wildlife residing in these incomplete and modified environments.

Coupled with this, many urbanites have an increasing tendency to attribute anthropomorphic qualities to wildlife, regarding wildlife species as they would their domesticated pets (Adams et al., 2006). In combination with this, there is an increase in urbanites who choose to build homes on urban edges, attempting to reconnect with nature in their back yards. Growing interests in viewing wildlife are emerging. As Daniel Decker et al. (2001) states, the U.S. Fish and Wildlife Service in 1996 estimated that 61 million people spent about 1.3 billion hours watching and feeding wildlife close to their homes, and in Canada in 1991, an estimated 84.3 million days were spent by Canadians engaged in primary non-consumptive wildlife activities (Environment Canada web pages, accessed on March 10, 2008). Feeding and attracting wildlife to their property provides urbanites the opportunity to view wildlife. Adams et al. (2006) suggest that the installation of feeders and wildscaping yards are the primary methods urbanites use to reconnect the natural world to their constructed environments. New housing developments have emerged promoting natural landscapes and increasing likelihood of wildlife viewing opportunities for homeowners. San Julian (1987) suggests that many home owners are trying to attract animals by developing their backyards into islands of urban wildlife habitat and in doing so, they are creating pockets of habitat that usually support more animals than an equal amount of woodland acreage because of supplemental food supplied by residents. City design itself has created habitat islands: some examples of the pockets of habitat or remnant habitat patches (RHP) are city parks, buffer corridors along river edges, cemeteries, and golf courses. Adams et al. (2006) suggest that RHP's become islands embedded in a matrix of urban/suburban landscape. Small RHP's that are fragmented and isolated with no connectivity to other natural habitat areas can result in dwindling wildlife populations (Adams et al., 2006). Wildlife populations unable to adapt to human manipulated habitats diminish while others, able to adapt to urban environments and small RHP's, flourish.

Overabundance

Since white-tailed deer find adequate food sources within urban spaces, and given that urban centers may provide a "safe haven" for them due to hunting restrictions, firearms discharge laws, and minimal predation (Adams et al., 2006; Conover et al., 1995; Messmer et al., 1997), urban white-tailed deer have the tendency to follow a J-curve, explosive population growth pattern (Adams and Lindsey, 2010). High deer densities may lead to over-browse of flora; however, given the protectionist attitudes of many urban residents and the availability of both natural and human supplied food sources, a population crash of urban white-tailed deer, outside of potential disease effects, is unlikely to occur (Adams and Lindsey, 2010).

In some geographic regions, white-tailed deer populations are considered to have surpassed the biological and ecological carrying capacity of area, where overabundant deer populations over-browse on flora and permanently alter the ecosystem (Conover, 2002; Whittaker, 2001). Deer are perceived to be overabundant when their population in a given area limits the abundance or the occurrence of other resources, or interferes with valuable ecosystem processes (Healy et al., 1997). It is important to note, that like carrying capacity, the term overabundance can be difficult to define and determine and is therefore often vague and thresholds are based on value judgements (Healy et al., 1997; McNab, 1985). White-tailed deer cause commercial and residential property damage by eating natural and managed flora, and pose a significant human health and safety concern (Conover, 1995; Decker and Gavin, 1987; DeNicola et al., 2000; Messmer et al., 1997; VerCauteren et al., 2006).

White-tailed have multiple and often substantial impacts

over their wide range of distribution. Several researchers classify white-tailed deer as a keystone species since they effect: the distribution or abundance of many other species; community structure by modifying patterns of relative abundance among competing species; and community structure by affecting abundance of species at multiple trophic levels (deCalesta and Stout, 1997; Waller and Alverson, 1997). Research has illustrated that deer influence an abundance of woody species; that deer browse can be a significant problem for regenerating certain species; and that deer influence patterns of seedling recruitment (Waller and Alverson, 1997). Deer also impact herbaceous plant growth. If deer graze long enough in an area, or their population density is high enough, it can remove herbaceous species altogether. High deer densities are known to have been responsible for the local extinctions of several herbaceous species. In addition to the effects deer have on flora, local fauna is also impacted. High deer density has been shown to: reduce the abundance of canopy nesting birds in the area; reduce bird species diversity; compete with squirrels and snow shoe hares for acorns and oak mast; and impact higher trophic levels with the incidence of disease transmission (deCalesta, 1994; Waller and Alverson, 1997).

Zoonoses

White-tailed deer have substantial impacts on overall ecosystem health and integrity as they are host to a number of diseases that affect a number of species at multiple trophic levels. White-tailed deer carries a number of bacterial, fungal, and viral diseases. Some of these diseases affect the host, while others do not. Diseases such as Brucellosis, and Malignant Catarrhal Fever (MCF) impact white-tails and have had an impact on cattle found within their range (Hesselton and Hesselton, 1982). Other diseases, such as Anthrax and Tuberculosis, affect white-tailed deer and are feared for their potential transmission to humans (Hesselton and Hesselton, 1982). White-tailed deer carries deer ticks, which are the source of Lyme disease that has become a public health safety concern (American Lyme Disease Foundation web pages, accesses on March 4, 2008). Giant Liver Flukes occur in white-tailed deer. Giant liver flukes are generally not a huge concern for deer and elk, but their transmission to moose and caribou can be debilitating (Hesselton and Hesselton, 1982). *Parelaphostrongylus tenuis*, meningeal worm, or brain worm, is carried by white-tailed deer and transmitted to other big game species via snails and slugs (University of Saskatchewan web pages, accessed on March 10, 2008). Brain worm does not impact white-tails, yet is thought to have affected co-existence of white-tails with caribou, moose, and mule deer as these species may be affected by the transmitted disease. The role that meningeal worm has played in the relationship between white-tails and other cervids is still unresolved scientifically (Gilbert, 1992). Absolutely, white-tailed deer significantly impact ecosystems, and their colonization of new ecosystems may result in numerous ecological changes.

A concept of social carrying capacity

The concept of social (cultural) carrying capacity is defined as the maximum wildlife population that a society will accept within a given area (Decker and Purdy, 1988; Riley et al., 2002). Social carrying capacity is difficult to determine since it is based on a variety of views of a large number of stakeholders. Researchers have referred to the understanding of how human beliefs and preferences affect decisions on the management of wildlife populations as wildlife acceptance capacity (WAC) (Decker and Purdy, 1988; Riley et al., 2002). The WAC concept represents the maximum wildlife population level in an area that is acceptable to people. What makes WAC even more complex is that the threshold of acceptance is not static. Stakeholders' acceptance of wildlife population size may change.

Challenges of multiple stakeholders

Stakeholders often do not see eye-to-eye on the acceptable wildlife population size or on the course of management action that should be taken to alleviate the conflicts. As regards urban deer, Healy et al. (1997) suggest that the knowledge of human attitudes and values will be essential in all stages of deer management decisions and human dimensions is an important part of improving stakeholder knowledge and gaining stakeholder support. These local stakeholders have diverse opinions, attitudes and tolerances toward urban wildlife populations. Community leaders and wildlife professionals must find ways to create strategies that integrate ecological, biological and social considerations. Given this, solutions to the complexity of urban/suburban wildlife management may be more about the process used to make the decisions rather than the decision themselves (Decker and Chase, 1997).

Regardless of the discipline, capacity in social science is directed toward three main positions: institutional, community, and individual (Raik et al., 2003). To increase capacity, efforts should be directed at institutional, community and individual levels through consultation, empowerment, and collaboration on important decisions made within the community (Raik et al., 2003). The benefits and liabilities an urban wildlife population presents to various stakeholders differ (Conover, 2002).

Cognitive hierarchy

Peirce et al. (2001) explain that human dimensions

research draws from the theories and methods of social science disciplines and that cognitive and motivational approaches are used extensively in human dimensions research. Cognitive approaches examine concepts such as values, attitudes and norms, essentially investigating the process that leads from human thought through to human action, and in doing so provides managers with insights on how they may predict human behaviour (Manfredo, 2008). Understanding motivational approaches helps managers better understand human behaviour. The cognitive hierarchy describes the process from human values to behaviour (Peirce et al., 2001). Values, which are fundamental, deeply rooted, slow to change, and are often formed early in life by family teachings, cultural learnings, and religious beliefs, are tied to one's identity and signify modes of conduct or qualities of life that are held dear (Manfredo and Dayer, 2004; Peirce et al., 2001). Wildlife value orientations are derived from values. They represent an individual's basic patterns of beliefs about wildlife use and may be situated on a spectrum between extreme positions such as animal rights and total domination over animals to more neutral positions such as wildlife appreciation (Manfredo and Dayer, 2004). Wildlife value orientations influence attitudes and behaviours. An attitude is an individual's tendency or orientation, either favourable or unfavourable, his or her manner, disposition, feeling, or position with regard to another person, concept, action or thing. It is important to understand an individual's (or community's) attitudes and the beliefs that shape attitudes since they can influence behaviour (Manfredo, 2008). Social norms are also important. Social norms are standards of behaviour shared by the members of a social group. Social norms suggest what people should do, or what most people of a collective group are doing (Peirce et al., 2001). Social norms are shared beliefs about the acceptability of an action and are highly situational (Zinn et al., 2000). Norms influence behaviour and as such, by understanding social norms, managers may be better able to predict behaviour. Information on both attitudes and norms will provide managers with guidance for structuring more effective prevention, management, education, and participation strategies (Manfredo and Dayer, 2004).

Shifting stakeholder attitudes

As noted above, public attitudes toward wildlife shifted in the latter portion of the twentieth century. More than ever before in recorded history, public concern and awareness for the protection of the natural environment and animal welfare is on the rise. Wildlife management in the twenty first century thus faces the difficult task of addressing, and assessing, the numerous and diverse attitudes and beliefs of these newly introduced stakeholders, for whom ethical and humane treatment of animals has become an important concern. As the wild-urban interface continues to blur, human-wildlife interaction is increasing. Public opinion on animal treatment is strong, divided, and shifting. Fundamental to wildlife management today is this highly fluid public opinion on how animals, including problem animals, should be treated.

Researches conducted by Manfredo et al. (2003) and Manfredo (2008) suggest that increasing affluence, education and urbanization has resulted in a shift in attitudes from traditional utilitarian focus to protection oriented with respect to wildlife. This societal shift suggests traditional uses and management of wildlife may no longer be preferred by the majority of urbanites. This presents challenges for wildlife managers called upon to reduce human-wildlife conflict and manage urban wildlife populations. The protectionist orientation with regard to wildlife may be connected to the growing non-consumptive interests in wildlife. Urbanites spending considerable time and money attracting wildlife to their property to increase their connectivity to the natural world and to increase wildlife viewing opportunities quickly became aware of some of the downfalls that accompany living in close proximity to wildlife (Decker and Chase, 1997). Attracting wildlife has led to property damage, vehicle accidents, and human health and safety concerns. As a result, of these inter-related changes brought on by urban sprawl, habitat modification and fragmentation, changing public attitudes and uses of wildlife, human-wildlife conflict has increased in urban areas.

Human-wildlife conflict

As white-tailed deer populations continue to grow in urban environments, the number of human-deer conflicts is increasing (Adams et al., 2006). White-tailed deer cause property damage and present a human health and safety concern (Decker and Gavin, 1987). They cause private property damage by eating ornamental trees, shrubs, flower beds, vegetable gardens and fertilized lawns (Swihart et al., 1998; Conover, 1997; VerCauteren et al., 2005). Again, it is evident here, the overlap and fluidity that exists between "ecological" and "social" carrying capacities.

White-tailed deer also pose a significant human safety concern, and are involved in an increasing and alarming number of motor vehicle accidents. In the United States, deer-vehicle accidents are a nation-wide problem. In 1991, there were 1 million driver vehicle accidents that occurred in the United States causing more than $1 billion in vehicle damage and over 200 human fatalities (Conover et al., 1995). In Contra Costa Country, in the Northeastern Bay area in California, Animal Control Officers removed 1200 deer carcasses from roads in 1996 in a largely urbanized area (McCullough et al., 1997). Similarly, in Canada, deer-

vehicle collisions are increasingly a concern. As deer populations continue to grow, and the number of vehicles on the road each year continues to increase, the number of serious collisions with deer is increasing (Canada Safety Council web pages accessed on September 9, 2008). Public awareness campaigns are in place to warn motorists of the danger, and new ways to prevent vehicles from hitting wildlife are being explored. Deer-vehicle collisions (DVC) represent a human-wildlife conflict of serious concern as they may result in significant risk to human safety, deer mortality, and vehicle damage (Finder et al., 1999). Conover et al., found that 92% of deer hit by a vehicle die (Conover et al., 1995). Previous research has shown that DVC are not spatially or temporally random (Finder et al., 1999, Bashore et al., 1985). Although many communities have developed databases that track the frequency and location of deer-vehicle collisions, there has been little analysis of the factors that influence DVC locations in urban areas (Nielsen et al., 2003). Gaining more knowledge of the factors that influence deer movement onto or across roads and highways is needed to help reduce the occurrence of DVC on existing roads and for planning future road design and placement (Finder et al., 1999). Wildlife scientists have recently begun to use innovative technology (e.g. GIS, remote sensing, and multivariate statistics) to research landscape influences such as vegetation, land use, topography, and traffic patterns on DVC over large scales and urban landscapes (Nielsen et al., 2003). Landscape influences on DVC in urban areas remains relatively unstudied and although deer-removal programs have been implemented to reduce local deer populations, DVC are still commonly occurring (Nielsen et al., 2003). With WTD populations growing and vehicular traffic increasing, the potential exists that DVC will occur more often.

As noted, white-tailed deer are also a human health and safety concern since they are a host for diseases transmittable to humans, which has both ecological and social impacts, another example of the overlap that exists between these two terms. A well-known white-tailed deer transmittable disease is Lyme disease. Conover et al. (1995) report that in 1991, there were 11,639 reported cases of wildlife related diseases in the U.S. which resulted in 192 deaths, of which Lyme disease accounted for 81% of these cases. McCullough et al. (1997) suggest that deer moving back and forth between wildlands and urban areas bring ticks into frequent contact with humans and therefore the presence of deer in urban environments increases the risk of Lyme Disease (McCullough et al., 1997), a bacterial infection that people can contract from the bite of an infected blacklegged (deer) tick. In the United States in 1991, 16, 273 Lyme disease cases were reported, with an overall incidence of: 6.0 per 100,000 population (Government of the United States, Lyme disease web pages accessed on March 10, 2008). In 2002, with growing urban deer populations, the incidence of Lyme disease increased to 23,000 new cases being reported in the United States where deer played a major role in transmission (Lauber et al., 2007). With an increasing urban deer population, there is an increasing threat of human contact with deer ticks in many North American metropolitan centers.

White-tailed deer also cause significant losses for agricultural producers. In the United States, white-tails are estimated to have caused $100 million in agricultural damage in 2001 (Conover, 1997). In many metropolitan areas, where growing urban white-tailed deer populations exist, agricultural land located both inside and just outside of urban areas can experience substantial damage. White-tails have also significantly impacted the timber industry by feeding on growing trees and saplings and retarded tree growth, altering the density and diversity of woody species (Conover et al., 1995; Waller and Alverson, 1997).

As urbanites become aware of some of the downfalls - such as agricultural losses and Lyme disease transmission -that accompany living in close proximity to wildlife, they call on wildlife managers to reduce property damage and other human-wildlife conflict. A study of Metropolitan residents in the United States found that residents spend a significant amount of time and money attracting wildlife to their property; however, interestingly, these same residents are also likely to take wildlife management into their own hands when human-wildlife conflicts occur (Conover, 1997). Of those surveyed in the Conover study, 57% actively tried to enhance wildlife populations in their neighborhoods; however, when nuisance problems developed, 69% of the same residents actively tried to manage the wildlife in their areas (Conover, 1997). Conover suggests that wildlife management has to shift in the 21st century to focus on urban wildlife conflict, such as escalating urban deer populations, and increasing incidence of human-deer conflict where traditional methods of game management may no longer be feasible. Conover (1997) argues, residents in urban areas have taken matters into their own hands and attempted resident-management, becomes problematic when large mammals such as urban white-tailed deer are involved. Residents experiencing human-wildlife conflict that feel the need to take matters into their own hands may lead to frustration, emotionally charged positions between residents and further exacerbate an already sensitive issue.

Wildlife management in urban centers must first seek to understand and then attempt to take into account, the numerous and diverse values of these newly introduced stakeholders. It is important to recognize that wildlife management does not exist within a vacuum and therefore there are social, cultural and political influences that are a part of the context in which management action is derived (Messmer et al., 1997). As noted by various scholars such as Decker (2001), Manfredo (1989), Riley et al. (2002) and Messmer et al. (1997), among others, although biological

and ecological data will always be essential in effective wildlife management, inevitably wildlife management is a human activity with human defined goals and objectives and as such, humans ultimately determine the course of action (Manfredo and Dayer, 2004). It is apparent that the effectiveness of long-term successful urban wildlife management action will depend on the ability of managers to integrate the biological, ecological and human dimensions of wildlife management (Riley et al., 2002). Wildlife management can no longer be contained to one field and increasingly, successful wildlife management must be interdisciplinary in nature.

Looking forward

Throughout the twentieth century, urbanization and capital expansion have progressively engulfed undeveloped land; yet, today, there is recognition of the implications of this development and a growing concern for the environment, habitat loss, and reduction of global biodiversity. The importance of acknowledging ecosystem integrity is becoming increasingly apparent and as Wolch (1999) suggests, we must entertain the notion of a "zoopolis," the contemporary urban centre that is populated by both humans and animals, and that must be designed for their co-existence. Management of wildlife in urban spaces is highly complex and involves a myriad of considerations, both ecological and social in nature. Practical wildlife management must acknowledge this complexity and incorporate both ecological and social considerations into the formulation of management objectives and then translate into feasible, future-oriented practices in contemporary urban settings. It seems apparent to me that before long, managers will also be asked to consider the principle of moral carrying capacity (Lynn, 1998), over and above the biological, ecological and social dynamics of urban wildlife management.

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