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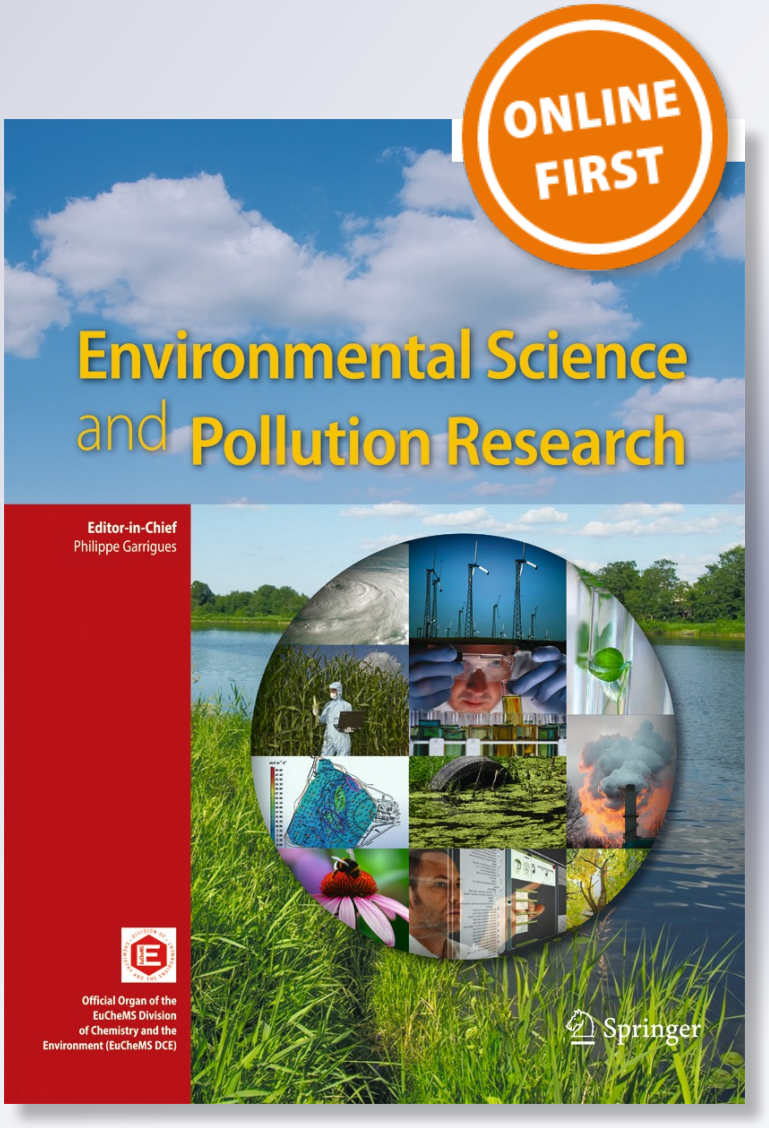

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RESEARCH ARTICLE

Benefits to rare plants and highway safety from annual population reductions of a "native invader," white-tailed deer, in a Chicago-area woodland

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Abstract Overabundant white-tailed deer are one of the most serious threats to woodland plant communities in the Chicago area. Moreover, the abundant deer in a highly populated area causes economic harm and poses hazards to human safety through collisions with vehicles. The artificial conditions causing the overabundance and resulting consequences qualify the white-tailed deer in the Chicago area to be considered as "native invaders". We examined the benefits of culling deer at a Chicago-area woodland preserve by comparing browse rates on four endangered plant species from years before culling began with years with culling. We also examined deer–vehicle collision and traffic flow rates on area roads from years before culling began and years with culling to assess whether population reductions may have benefited road safety in the area. All four endangered plant species (three orchid species and sweet fern) had lower browse rates in years with culls, although the decreased browsing rates were statistically distinguishable for only two of the species (grass pink orchid and sweet fern). After first verifying that traffic flow rates did not decrease from pre-cull years to years with culls, we analyzed the Illinois Department of Transportation data from area roads based on deer–vehicle collisions causing >US$500 in damage and showed a one-third reduction in deer–vehicle collisions. An economic analysis showed a cost savings during the cull years of US$0.6 million for reducing browsing to just these four monitored plant species and the reduction in deer–vehicle collisions.

Keywords Deer cull · Deer–vehicle collisions · Endangered species · Orchids · Sweet fern

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R. M. Engeman (✉)
National Wildlife Research Center, Wildlife Services, USDA/APHIS, 4101 LaPorte Ave., Fort Collins, CO 80521, USA
e-mail: richard.m.engeman@aphis.usda.gov

T. Guerrant · G. Dunn · S. F. Beckerman
Wildlife Services, USDA/APHIS, 3430 Constitution Drive, Suite 121, Springfield, IL 62711, USA

C. Anchor
Forest Preserve District of Cook County, 28W040 State Route 58, Elgin, IL 60120, USA

Introduction

Native species under certain circumstances are being recognized as becoming "invasive" in their native range (Carey et al. 2012; Simberloff 2011). Included among the three circumstances where native species function as invaders, according to Carey et al. (2012), are when "human-mediated environmental change facilitates population growth of native species via elevated survivorship and reproduction" and when "habitat modifications or other changes in the environment may increase the per capita effect of native species on the resident community." Both of these circumstances directly apply to white-tailed deer (*Odocoileus virginianus*) in urbanized settings. Populations thrive and reproduce in the absence of large predators (including hunting), while natural habitats are restricted by urbanization to reserves and open spaces, placing greater pressure on the plant communities within them, especially rare species. Negative interactions with humans also increase in urbanized settings holding high numbers of deer.

Even though the population in the Chicago Metropolitan Statistical Area is nearly 9.5 million people (Mackun and Wilson 2011), considerable biodiversity protection takes place in and around Chicago (Heneghan et al. 2012), which includes a network of forest preserves. Overabundant white-tailed deer are one of the most serious threats to these woodland plant

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communities in the Chicago area (CRBC 1999). Deer populations can grow rapidly without sufficient predation or population management. At the same time, deer habitat has been concentrated to limited open spaces by development where deer consume high quantities of plants to the point where native plants, and the animals relying on them, suffer (CRBC 1999; Crawley 1983; Urbanek et al. 2012a, 2012b). Overabundant white-tailed deer populations are one of the primary stressors (along with invasive plants, fire suppression, and reduced light) contributing to the deteriorated health of natural lands in the Chicago area (Chicago Wilderness 2010; Heneghan et al. 2012). A region-wide 1998 study (Bowles et al. 1998) documented substantial changes over time in forest structure, including reductions in shrub species density and richness, which were partially ascribed to deer browsing. Prominent among the recommended actions for protecting and restoring Chicago-area natural areas was the call for continued and expanded management efforts, with deer being regularly harvested "to limit numbers to levels that support a balance that sustains a full range of native plants and provides diverse habitat for birds and other animals" (CRBC 1999). More recently, a report assessing the state of Chicago-area wilderness (TCWC 2006) reinforced the findings of CRBC (1999) that excessive deer populations in natural areas around Chicago should be controlled, and a position paper by Chicago Wilderness (2010) also endorsed such white-tailed deer management.

Besides impacts to plant communities, large deer populations naturally lead to greater opportunities for collisions with vehicles on area roadways, thereby causing economic harm and posing hazards to human safety (Chicago Wilderness 2010). This national safety and economic problem (Huijser et al. 2008) is well reflected on the Chicago area roadways where a radio telemetry study in DuPage and Cook Counties, Illinois (Chicago and area) found automobiles and trains to account for >60 % of urban deer mortality (Etter 1998). The Illinois Strategic Highway Safety Plan called for a determination of accurate impact of deer crashes (Illinois 2009).

Zander Woods Forest Preserve (ZWFP) is one of the Chicago-area protected woodlands negatively impacted by overabundant white-tailed deer, and a winter culling program began in March 2007 to alleviate their negative impacts. We examine here the effects of the annual culls beginning in 2007 on four state-listed endangered plant species and the rate of deer–vehicle collisions on nearby roadways.

Methods

Study area

The ZWFP is a 179-ha protected natural area in the Cook County Forest Preserve District. The property is located in Cook County, Illinois on the southeast side of Chicago, a little more than 30 km from the city center. The ZWFP preserves a mixture of woodlands and wetlands in which a wide variety of native plants can be found, including a number of plants listed as endangered or threatened by the Illinois Endangered Species Protection Board. The unique vegetation in this site has been recognized for many years (Armstrong 1963). As with most urban area reserves, the deer are not recreationally hunted in ZWFP, and the majority of mortality is likely due to collisions with vehicles (Etter 1998).

Deer removal

Sharpshooting by professionals has been recognized as the most effective and adaptable culling method in urban settings (Huijser et al. 2008). Annual deer culls were initiated in ZWFP in March 2007, with subsequent annual culls conducted from January to March in 2008 and from December to March in 2009 and 2010. Deer removal was carried out by US Department of Agriculture/Wildlife Services, the Federal agency with responsibility for managing conflicts with wildlife (US Department of Agriculture/Animal and Plant Health Inspection Service et al. 1997). The deer were removed under the authority of a Deer Population Control Permit issued by the Illinois Department of Natural Resources, with the sharpshooters having met the requirements of the Illinois Department of Natural Resources. The removals were conducted at night by a 3–5-person crew using centerfire rifles and nocturnal vision-enhancing devices, such as spotlights and infrared devices.

Take assessments

No annual population estimates had been made by either state or local agencies for ZWFP. Nevertheless, an effective annual cull operation would be expected to bring down the deer numbers each year, even for an open population. The data were recorded on the numbers of deer taken each month and the hours of effort used to take those deer. Because the annual time frame for the culls and the personnel and qualifications of sharpshooters remained consistent, we could examine within-year impacts to the deer population. Between-year population impacts were not appropriate. Although the culls always ended in March, they were initiated in different months for 3 of the 4 years. Thus, even for March, the only month with take data for all 4 years, comparisons among the years would not be valid because they would be confounded by differing cumulative take from culling in different numbers of months prior to March.

Browse rates on endangered plants

Each year from 2001–2009, individual plants from select species were located by the Cook County Forest Preserve District staff walking transects through the ZWFP in areas with

high deer damage and where the species of interest were likely to be found. The same transects were used each year, improving the precision of assessments across years (e.g., Engeman 2005; Ryan and Heywood 2003). Each identified individual plant was monitored through the growing season for browsing and impacts to fruiting bodies. Four plant species, state-listed as endangered (Illinois Endangered Species Protection Board 2011), had sufficient monitoring data during years with and without culls to effectively analyze browse rates prior to annual culls in comparison to browse rates in years with a deer cull. The four endangered plants with suitable data to assess browse rates before and during the deer cull years included grass pink orchid (*Calopogon tuberosus*), yellow-fringed orchid (*Platanthera ciliaris*), sweet fern (*Comptonia peregrina*), and snakemouth orchid (*Pogonia ophioglossoides*).

The proportion of the monitored plants browsed was calculated each year for each species. For each species, the proportion browsed in the pre-cull years was compared to the proportion browsed in the years with a cull using a two-sample *t* test.

Deer–vehicle collision rates

Analyzing the rates of deer–vehicle collisions on the roadways nearby the ZWFP posed challenges, and our evaluations had to be restricted to 2009 and before. Our analyses were reliant on the data available from the Illinois Department of Transportation on deer collisions and traffic flow. Up until 2009, all crashes with a value ≥US$500 in damage were recorded, but in 2009, the threshold for reporting was raised to ≥US$1,500, making data on numbers of deer–vehicle collisions from 2010 (and later) incomparable to the previous years.

Nine area roadways with deer collision data available during the pre-cull and cull years were used as experimental units in the analyses (I-80, IL394, Thornton Lansing Rd, Cottage Grove, Vincennes Rd, Glenwood Lansing Rd, Stoney Island Rd, 186th Ave, and Torrence Ave). The collision data were available as groupings into 2-year periods, as 2005–2006 (pre-cull) and 2007–2008 (cull). The data were analyzed in a randomized block ANOVA, with individual roads serving as the blocks upon which the years before and the years with cull observations were made.

We also wanted to assess the traffic flows on these roads, as this also is a determinant in the number of collisions taking place. However, traffic flow data were only obtained every few years. Each of our study roads had the average daily rate of traffic flow measured in 2001 (pre-cull) and then again more recently during the cull years. Unfortunately, "recent" was either 2006 or 2008, creating an inconsistency among the traffic flow measurements among the roads for the years with a cull. Still, as long as the 2006 and 2008 traffic flow measurements were at least as great as those from 2001, then any reductions in deer–vehicle collision rates could not be attributed to reduced flows.

Table 1 Take rates (deer/h) of white-tailed deer removed during the culling operations at the Zander Woods Forest Preserve, a protected woodland in the Chicago area

	Month			
Winter	December	January	February	March
2006–2007	No cull	No cull	No cull	2.88
2007–2008	No cull	2.28	2.08	2.08
2008–2009	2.73	0.53	1.52	1.40
2009–2010	2.80	1.53	1.43	0.80

Results

Take assessments

Each winter, the take rate for deer (deer/h) was highest in the initial month of that year's cull (Table 1). Take rates in the subsequent months decreased monotonically each year, except for 2009 where the January take rate was exceptionally low relative to adjacent months and the results for January in the other years (Table 1). This was easily explained by a blizzard in the second week of January 2009 and subsequent extremely cold temperatures thwarting the culling activities.

Browse rates on endangered plants

The deer browsing on the three orchid species involved the consumption of fruiting bodies and stems all the way to the ground, while the deer browsing of sweet ferns resulted in the loss of fruiting bodies, but not necessarily the stem. The browse rates were higher for all four endangered plant species

Table 2 Browsing rates on four Illinois endangered plant species by white-tailed deer in the Chicago area Zander Woods Forest Preserve during the years prior to initiating deer culls and during the years with deer culls. *P* value results for comparing browse rates in the pre-cull years to years with culls are also shown

Endangered plant species	Pre-cull years (2001–2006)		Years with cull (2007–2009)		*P* value
	Mean % browsed	Total *n* (all years)	Mean % browsed	Total *n* (all years)	
Grass pink orchid	89.1	251	66.2	108	0.0073
Yellow-fringed orchid	41.0	68	35.7	24	0.757
Sweet fern	70.8	120	16.7	60	0.0021
Snakemouth orchid	16.2	424	12.1	160	0.863

Table 3 Final (March) take rates (deer/h) of white-tailed deer removed each year during the culling operations at the Zander Woods Forest Preserve in the Chicago area and the final browse rates each year on each of four monitored endangered plant species

Year	March take rate	Grass pink orchid	Yellow-fringed orchid	Sweet fern	Snakemouth orchid
2007	2.88	76.5	50.0	40.0	25.0
2008	2.08	64.7	0.0	10.0	11.4
2009	1.40	57.5	57.1	0.0	0.0

during the pre-cull years than during the years with culling (Table 2), with the rates statistically detectable for grass pink orchid ($F_{1,7}$=13.94, p=0.007) and sweet fern ($F_{1,7}$=22.35, p=0.002). For the grass pink orchid, the average browsing rate decreased 25.7 %, dropping from an average browsing rate of 89.1 % (SE=3.4), a nearly complete loss of plants, down to an average of 66.2 % browsed (SE=5.5) during the cull years (Table 2). The decrease in browsing during the years with culling was even more dramatic for sweet fern, dropping from an average of 70.8 % (SE=5.7) browse rate during the pre-cull years to an average of only 16.7 % (SE=12.0) during the years with deer culls (Table 2), a 76 % decline in browse rate. The average browse rates for yellow-fringed orchid and snakemouth orchid also were lower during the years with culling than those during the years prior to culling, although these improvements were to a lesser degree than for the other two species and not statistically apparent (Table 2). The browse rate for yellow-fringed orchid went from 41.0 % (SE=7.9) average in the pre-cull years down to 35.7 % (SE=18.0) in the cull years ($F_{1,7}$=0.10, p=0.757). In comparison to the other species, the average pre-cull browse rate on snakemouth orchids was relatively low at 16.2 % (SE=14.9), albeit at 12.1 % (SE=7.2), the rate was lower still in the cull years ($F_{1,7}$=0.03, p=0.863).

Examination of the browse rates during the years with culls (2007–2009) alongside the final month's (March) take rate provides another angle for considering year-to-year efficacy of the culls. While for the reasons stated earlier, the deer take rates from year to year are not comparable due to differing spans of effort, we can see in Table 3 that March, the final month of culling each year, produced monotonically decreasing take rates from 2007 to 2009. During that same span, three of the four monitored endangered plant species also showed a monotonic decrease in browse rates. If the cullings were simply removing the annual surplus of deer each winter, with the population remaining approximately the same during the growing season, then neither year-to-year March take rates nor browse rates on the endangered plants would be expected to decline monotonically.

Deer–vehicle collision rates

The average number of deer–vehicle collisions across the nine ZWFP-area roads having such data declined from 10.0 deer/2-year period (SE=2.83) during the pre-cull years to 6.7 deer/2-year period (SE=2.32) with culling ($F_{1,8}$=5.97, p=.040). A comparison of recent cull year traffic flows to pre-cull traffic rates was useful in determining whether this reduction in collisions could be ascribed to reductions in deer numbers or to reductions in traffic. The average daily volume of traffic, averaged across the nine ZWFP-area roads went from 26,785 (SE=13912) for the pre-cull measurements up to 28,528 (SE=13,677) for measurements during the more recent years, but this increase in traffic was not statistically detectable from these highly variable data ($F_{1,8}$=1.24, p=0.29). Nevertheless, all indications were that traffic did not decrease, and most likely increased from the pre-cull years to the years with a cull, during which time deer–vehicle collisions decreased.

Discussion

We had 4 years of take data during the 4 years of deer culls (winters 2007–2010), 3 years of browse rate data on four state-listed endangered plants (2007–2009), and the same 3 years of deer–vehicle collisions. During the cull years, we found indications of deer population decline each year, positive effects towards reducing browsing on endangered plant species, and road safety improvement. Should the culls continue and long-term (≥10 years) data be consistently available on browse rates on the listed plants, stronger inferences about plant conservation provided through deer culling should also become apparent. Similarly, additional long-term data on deer–vehicle collisions

Table 4 Assuming the average browse rates observed during the years with deer culls had occurred during the years without deer culls, the number of the four Illinois endangered plant species monitored that would have been spared browsing at the Chicago area Zander Woods Forest Preserve is estimated

Plant	Number of plants monitored pre-cull	Total number of browsed pre-cull	Mean browse rate from cull years	Estimated browse using rate from cull years	Estimated number saved assuming browse rate from cull years
Grass pink orchid	251	221	66.2	166	55
Yellow-fringed orchid	68	26	35.7	24	2
Sweet fern	120	115	16.7	20	95
Snakemouth orchid	424	62	12.1	51	11

would be needed to overcome the changes in collision reporting since 2009 and make additional inferences on impacts to road safety from continued culling.

Recently, the average comprehensive costs of deer–vehicle collisions (Huijser et al. 2008) were estimated as follows: US$1,840 in vehicle repair costs, US$2,702 in medical costs, US$125 in towing and law enforcement costs, US$2,000 cost for monetary values of the animal, and US$50 for carcass removal. Thus, the average total cost for a deer–vehicle collision was US$6,717. These costs are increasing annually. For example, using insurance claims data (only) during the final half of 2010 and the first half of 2011, the costs were reported by the State Farm Insurance as US$3,171, up 2.2 % from the year before (Luedke 2011). Using its claims, the data, in conjunction with state-licensed driver counts from the Federal Highway Administration, the State Farm calculated the chances of an Illinois motorist striking a deer over the next 12 months from the issuance of the report at 1 in 250 (Luedke 2011). Farrell and Tappe (2007) examined broad-scale factors contributing to deer–vehicle collisions and identified primary components of (1) predominantly forested matrix with high edge density and contrast, and (2) an urban environment with high road densities, human population densities, and average daily traffic counts. While their study took place in Arkansas, these factors are also in play in the ZWFP area in the Chicago area. For the nine roads used in our study, there were 30 more cumulative collisions with deer between the 2 years prior to initiating deer culls in the ZWFP than in the first 2 years with deer culls. Using the US$6,717 average comprehensive costs of deer–vehicle collisions above (Huijser et al. 2008), this reduction in collisions amounts to cost savings of US$201,510 just for these nine roads for which data were reported (there are many other area roads for which records of deer collision data are not kept).

We can also estimate the value of reducing browsing on the listed plants. The success of conservation measures is usually evaluated on the basis of resource improvement, but an economic perspective allows managers and administrators to have some fiscal perspective on rewards for budgetary expenditures on conservation issues. A variety of methods exist to apply conservative monetary values for rare species (e.g., Engeman et al. 2002b, 2004). Among the practical and applied means for placing a societal value on a species when no other data are available are statutory penalties. This method has a successful history of providing societal economic values for rare wildlife species, game species, and other protected species (Bodenchuk et al. 2002; Engeman et al. 2002b, 2004, 2009; Sementelli et al. 2008; Shwiff et al. 2003, 2007; Smith et al. 2003, 2007). In Illinois, the illegal take of a state-listed plant species is a class A misdemeanor, and the maximum fine for a class A misdemeanor is US$2,500.

Applying a calculation approach like what has been done for economically evaluating the management methods used to reduce predation on sea turtle nests (e.g., Engeman et al. 2002a), we can estimate the reduction in the number of plants browsed in the pre-cull years had culls occurred assuming the average browse rates from the years with deer culls. The calculations are shown in Table 4, with an estimated 55 grass pink orchids, 2 yellow-fringed orchids, 95 sweet ferns, and 11 snakemouth orchids escaping browsing had the culls been in place then. This is a total of 163 additional endangered plants that would not have been browsed. Using the civil penalty of US$2,500 for harming the Illinois endangered plant species in any manner represents a value of US$407,500 for these four species alone, without regard to other plants for which monitoring data did not exist. This considers only the plants harmed. Because their fruiting bodies were lost to browsing, this minimal approach does not take into account the lost breeding potential for the browsing losses, further emphasizing the conservative nature of estimated costs from losses. Thus, by looking only at narrow browsing impacts to only four endangered plants plus vehicle collisions from overabundant white-tailed deer in the ZWFP, over a US$0.6 million in negative impacts have been estimated to have been averted during the years with deer culls from this woodland reserve.

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