EVALUATION OF LOCALIZED DEER MANAGEMENT FOR REDUCING AGRICULTURAL DAMAGE CAUSED BY WHITE-TAILED DEER IN MINNESOTA

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SUMMARY OF FINDINGS

Minimizing damage caused by white-tailed deer (*Odocoileus virginianus*) is an important consideration for managing deer densities in Minnesota. I conducted this study to assess the effectiveness of localized management of deer (i.e., targeted removal of deer in a limited area) to reduce damage to agricultural crops in southeast Minnesota. The objective was to evaluate the effectiveness of localized management for reducing fine-scale deer abundance and to examine whether damage caused by deer to agricultural crops is reduced on properties where deer densities are lowered. I completed 3 field seasons during 2014-2016. I used baited infrared camera surveys to estimate deer abundance on focal properties. I evaluated yields of corn in fenced and unfenced plots to estimate the impacts of browsing by deer. Corn yield loss was seemingly low on most properties, and there was no difference in corn damage between properties where localized management was used versus normal sport-hunting. Corn damage could not be explained solely by deer abundance at the property level. However, extra deer harvest opportunities were utilized when requested. Deer management was >2 times as intensive on properties where integrated management was used versus normal sport-hunting. The results of this study will provide a basis for improving the framework for future application of localized management in agricultural regions.

INTRODUCTION

Damage caused by white-tailed deer can be severe in the United States with ≥$100 million lost annually by agricultural producers (Conover 1997). Results from previous studies have demonstrated only through anecdotal evidence that population reduction of deer can reduce damage to agriculture (McShea et al. 1993, Frost et al. 1997, Conover 2001). In some situations, localized management has effectively reduced the abundance of deer to maintain lowered deer densities over time (McNulty et al. 1997). As a result, damage to resources targeted for protection should be reduced because fewer deer are available to cause damage. However, conditions including high deer densities in surrounding areas (Miller et al. 2010), seasonal migratory behavior of deer (Vercauteren and Hygnstrom 1998), and colonization by deer from adjacent populations (Comer et al. 2007) may inhibit the creation of sufficient temporal periods of low deer densities to provide resource protection. Studies of the effectiveness of localized management to reduce damage to specific properties in agricultural settings are lacking.

Minimizing damage caused by deer is an important consideration in managing their populations in Minnesota. In many deer permit areas in Minnesota, deer are managed at or near population goals annually. However, complaints of deer damage from agricultural producers are common. During years 2003-2012, wildlife managers fielded an average of 130 complaints annually about damage caused by deer. Complaints of depredation by deer in Minnesota include consumption of forage stored for livestock, damage to specialty crops (e.g., produce, Christmas trees, nursery stock), row crops (corn [*Zea mays*] and soybeans [*Glycine max*]), alfalfa (*Medicago sativa*), and forest stands. Deer damage is reported throughout Minnesota, but a distinct cluster of complaints occurs in the southeast region of the state (Nelson and Engel 2013).

In southeast Minnesota, the majority of complaints involve standing row crops and alfalfa in the field. Farmers who enter into a Cooperative Damage Management Agreement with the Minnesota Department of Natural Resources (MNDNR) are eligible for cost-sharing to install exclusion fencing. However, funds for deer damage assistance are limited and fencing is only practical for protecting areas that are relatively small (i.e., stored forage and specialty crops). Sound and visual deterrents and taste and smell repellents have proven ineffective for reducing deer damage in agricultural fields (Belant et al. 1996, Belant et al. 1998, Gilsdorf et al. 2004). Therefore, most attempts to reduce damage to standing crops in southeast Minnesota involve the use of localized deer damage management techniques such as shooting permits and depredation permits (herein, localized management).

MNDNR Regional Offices have issued shooting permits to agricultural producers experiencing extreme damage caused by deer for use outside of hunting seasons. Shooting permits allow landowners to shoot deer at any time of day or night and with a high-powered rifle. For years 2004 through 2012, an average of 95 shooting permits for nuisance deer were issued annually for use during summer and winter (Nelson and Engel 2013). In southeast Minnesota, landowners with support from local legislators requested shooting permits to be issued during the regular hunting seasons to reduce depredation to standing row crops. As an alternative to their request, a pilot program using depredation permits allocated to specific properties was instituted in 2012 in southeast Minnesota (Luedtke 2013). Depredation permits were to be used by private sport-hunters during regular hunting seasons. Additionally, a temporary MNDNR position, the Landowner Assistance Specialist, was created to administer the program in Fillmore, Goodhue, Houston, Olmsted, Wabasha, and Winona counties.

Depredation permits allowed up to 15 hunters per property to harvest up to 5 antlerless deer in addition to established bag limits during regular hunting seasons; up to 75 deer could be harvested on an individual property using depredation permits. To be eligible, applicants had to demonstrate: 1) a history of deer damage documented through complaints to the MNDNR Area Wildlife Office, 2) crop losses, 3) enrollment in a Cooperative Damage Management Agreement with MNDNR including a plan for deer hunting management, and 4) hunting was allowed on the property during the previous hunting season.

Localized management in southeast Minnesota increased deer harvest on individual properties from previous years and anecdotally landowners and hunters involved in the program were satisfied (Luedtke 2013). However, the effect of localized management on agricultural damage caused by deer is unknown. Also, logistical limitations and eligibility guidelines restrict the number of properties where depredation permits may be issued annually. Given the onerous nature of administering localized management from an agency perspective, it is important to establish whether such management aids in reducing agricultural damage as intended.

The purpose of this study is to evaluate whether localized management of deer reduces agricultural damage and to provide a basis for improving the framework for future application of localized management in Minnesota. No previous studies have examined the effectiveness of localized management for reducing damage to agricultural crops. Other research has suggested that using recreational hunting to institute localized management of overabundant deer and effectively reduce damage may be difficult (Simard et al. 2013). If localized management can be used to minimize damage, these techniques should be used wherever feasible in Minnesota. Otherwise, alternative strategies for balancing local deer populations with social carrying capacity should be explored.

OBJECTIVES

1. To evaluate the effects of localized white-tailed deer management techniques – including shooting permits and depredation permits – on localized deer densities in southeast Minnesota.
2. To quantify the amount of damage caused by white-tailed deer to corn crops relative to localized management in southeast Minnesota.

STUDY AREA

This study was conducted in the Minnesota counties of Fillmore, Houston, and Winona. Southeast Minnesota is characterized by a mosaic of rolling limestone uplands dominated by agriculture (Mossler 1999). Typical crops include corn, soybeans, alfalfa, and small grains. Steep ravines cut by narrow streams are interspersed throughout the uplands. Ravines are rocky and primarily forested by mature hardwoods (Omernik and Gallant 1988).

Pre-fawn deer densities in the southeast Minnesota deer permit areas included in this study averaged 5 deer per km^2 (Grund 2013), which represents the highest deer densities found in the farmland zone of Minnesota. An average of 1.5 deer per km^2 was harvested in these deer permit areas during 2012, which was nearly twice the statewide average (McInenly 2013).

METHODS

Experimental Design

My objective was to evaluate the effectiveness of localized management for reducing fine-scale deer abundance and to examine whether damage caused by deer to agricultural crops is reduced on properties with higher management intensity. Therefore, I examined deer depredation to crops and deer abundance on individual focal properties in southeast Minnesota. On properties used as treatments, localized management strategies were integrated with regular sport-hunting. On control properties, normal sport-hunting was allowed by the landowner. I included 7 focal properties in the study, including 4 treatments and 3 controls.

Data Collection

Deer Abundance Estimates on Focal Properties

To aid in estimating deer abundance and management intensity (i.e., deer harvested per deer available for harvest) on focal properties, I used baited infrared camera surveys to obtain estimates of the abundance of deer at a fine scale in the area of crop fields designated for evaluation. This method of survey was conducted according to previous research by Jacobson *et al* (1997) and a pilot study I conducted in southeast Minnesota during 2013 (G. D'Angelo, unpublished data). The abundance of deer in an area can be determined using baited surveys, where bucks can be uniquely identified by antler characteristics and their number used to infer the number of does and fawns visiting a bait site repeatedly. Cameras were placed at a density of 1 camera per 65 hectares in wooded or brushy habitat immediately adjacent to crop fields. This relatively high density of cameras was intended to reduce bias associated with capturing adult bucks at a higher rate at lower camera densities because males have larger home ranges (Jacobson et al. 1997). A bait site was established at each camera location during a 7-day pre-baiting period. During pre-baiting, whole kernel corn and trace mineral salts were placed at each bait site in a quantity sufficient to maintain consistent access by deer 24 hours per day. Following this acclimatization period, an infrared camera was set to record still photographs of deer 24 hours a day at 10-minute intervals during a 14-day survey period. As in the pre-baiting period, bait was provided ad libitum. I generated deer abundance estimates using data pooled from all cameras on a property. Deer abundance estimates were obtained during August. This timing increased the likelihood that: 1) fawns were mobile with their dams and available for survey, 2) antler growth of bucks was sufficient to uniquely identify individuals, 3) deer photographed near crop fields were those that caused damage during the growing season and were available for harvest in the same area, and 4) harvest mortality and disturbance of deer by hunting activities was minimized since the survey preceded deer hunting seasons. I present estimates of deer abundance as deer per camera to standardize across the range of property sizes in the study.

Management Intensity

I asked agricultural producers to report deer harvested on their properties by season. I quantified management intensity as: number of deer harvested divided by the total number of deer estimated to be on the property via infrared camera surveys. Herein, I describe properties under the 2 aforementioned management strategies: hunting (herein HUNT, i.e., hunting conducted by sport-hunters during the regular season framework), or integrated management (herein INT, i.e., hunting was integrated with localized management strategies including depredation and shooting permits outside of the regular season framework).

Corn Evaluations

Within each field, I delineated 8 plots, which were stratified into interior (>10 m from the field edge) and edge (0-5 m from the field edge). Each plot included 2 paired 5-m X 5-m subplots (~6/1000th acre) separated by 5 m and within the same rows of corn. One subplot of each pair was fenced to exclude deer and the other subplot was an unfenced control. Within each pair, the treatment and control were assigned randomly. Square exclosures were constructed with 2-m high heavy-duty plastic mesh attached to 4 2.4-m u-posts. Exclosures surrounding subplots were approximately 6 m X 6 m to reduce the effect of fencing on plants within the subplot. Exclosures were installed immediately following planting and herbicide treatment or initial cultivation for control of weeds. When necessary, exclosures were removed for $\leq$24 hours to allow farmers to conduct additional field treatments. I evaluated corn crops near the estimated date of plant maturity before senescence (approximately 130 days after planting). Within each subplot I recorded the number of rows, number of plants, and for 30 randomly selected plants, I measured plant height, level of herbivory per plant, and classified the quality of each ear of corn relative to damage caused by deer. I estimated grain yield (total seeds produced per 30 plants) for fenced and unfenced subplots, and calculated the percent corn loss for each fenced and unfenced plot as: ((total seeds in fenced plot minus total seeds in unfenced plot) divided by total seeds in the fenced plot) multiplied by 100. I consulted with the agricultural producer to determine the variety of corn planted in each field.

RESULTS AND DISCUSSION

I conducted this study beginning in spring 2014 through 2016, including 3 growing seasons for corn and 3 deer hunting seasons. HUNT was used to manage deer on 3 properties and INT was used on 4 properties. In each year, I sampled 112 subplots in corn fields including 56 unfenced subplots and 56 fenced subplots. In 2014, I excluded from analysis 2 pairs of fenced and unfenced subplots (i.e., 4 subplots total) on 1 property because the growth of corn plants was severely affected by soil erosion. In 2015, I excluded from analysis 2 pairs of fenced and unfenced subplots (i.e., 4 subplots total) on 1 property because of damage caused by raccoons (*Procyon lotor*). In 2016, I excluded from analysis 1 pair of fenced and unfenced subplots on 2 properties (i.e., 2 subplots on each property) because of damage caused by raccoons.

Deer abundance via infrared camera surveys was similar among HUNT and INT properties across years (Table 1, $t = 1.105$, $df = 19$, $P = 0.283$). Among HUNT properties, deer abundance was similar among years (2014: $\bar{x}$ = 20 deer per camera, SE = 4; 2015: $\bar{x}$ = 25 deer per camera, SE = 2; 2016: $\bar{x}$ = 26 deer per camera, SE = 5; $F_{2,6}$ = 0.668, P = 0.547). Also, among INT properties deer abundance was similar among years (2014: $\bar{x}$ = 20 deer per camera, SE = 3; 2015: $\bar{x}$ = 21 deer per camera, SE = 5; 2016: $\bar{x}$ = 21 deer per camera, SE = 3; $F_{2,9}$ = 0.026, P = 0.974).

Agricultural producers on INT properties used extra deer harvest opportunities in all years. Management intensity on INT properties was >2 times the management intensity on HUNT properties (Table 1, HUNT: $\bar{x}$ = 0.15, SE = 0.02; INT: $\bar{x}$ = 0.37, SE = 0.05; t = -3.838, df = 19, P = 0.001). Among HUNT properties, management intensity was similar among years (2014: $\bar{x}$ = 0.19, SE = 0.02; 2015: $\bar{x}$ = 0.13, SE = 0.05; 2016: $\bar{x}$ = 0.13, SE = 0.01; $F_{2,6}$ = 1.416, P = 0.313). Among INT properties, management intensity was similar among years (2014: $\bar{x}$ = 0.44, SE = 0.10; 2015: $\bar{x}$ = 0.42, SE = 0.06; 2016: $\bar{x}$ = 0.24, SE = 0.04; $F_{2,9}$ = 3.323, P = 0.154).

Despite increased harvest pressure for deer on INT properties versus HUNT properties during all years, corn yield loss did not differ between management strategies (Table 2; HUNT: $\bar{x}$ = 12.1, SE = 2.8; INT: $\bar{x}$ = 8.1, SE = 2.9; $F_{1,160}$ = 0.685, P = 0.409), among properties ($F_{6,155}$ = 0.519, P = 0.793), or among years (All years: $\bar{x}$ = 10.2%, SE = 2.0; 2014: $\bar{x}$ = 6.5%, SE = 2.6; 2015: $\bar{x}$ = 15.9%, SE = 3.9; 2016: $\bar{x}$ = 8.2%, SE = 3.8; $F_{2,159}$ = 2.00, P = 0.138). Corn yield loss was >3.5 times greater for edge plots versus interior plots ($F_{1,160}$ = 8.57, P = 0.004) when pooled by property across all 3 years. Notably, during 2015 when corn yield loss was greatest overall, corn yield loss was nearly 5 times greater on edge plots versus interior plots for all properties ($F_{1,52}$ = 8.60, P = 0.005).

The primary objective of this study was to evaluate the effectiveness of localized management for reducing fine-scale deer abundance and to examine whether damage caused by deer to agricultural crops was reduced on properties where deer densities were lowered. Deer abundance was similar among all properties in this study during all years, despite management intensity on INT properties being 2-3 times greater than on HUNT properties. Generally, deer densities in southeast Minnesota were high relative to other regions of the state (D'Angelo and Giudice 2016). Although a higher proportion of deer estimated to be using INT properties were harvested annually, deer on adjacent properties likely filled any voids created by localized management. Property sizes in the region were generally smaller than deer home ranges (Stewart et al. 2009), which complicates reducing deer densities sufficiently on focal properties. Agricultural fields were highly interspersed and bordered with forested cover for deer, so even at lowered deer densities, damage can occur since deer can access fields frequently. Temporary reductions in deer abundance on INT properties may have reduced annual corn losses since deer harvest on these properties occurred throughout the corn growing season. The level of corn damage that may have occurred had localized management not been used is not known.

Overall corn yield loss was seemingly low on most properties. There was no difference in corn damage between properties where localized management was used versus normal sport-hunting, and the level of corn damage could not be explained by deer abundance at the property level. Plots along the edge of corn fields experienced greater losses of corn. Our results demonstrate that this trend occurred on most properties in each year of our study. Deer typically cause greater damage on field edges, especially those nearer escape cover (DeVault et al. 2007, Stewart et al. 2007, Hinton et al. 2017), likely because risk (e.g., predation, hunting) is less.

Extra deer harvest opportunities were used by landowners when requested. Management was more intensive on INT properties versus HUNT properties. Also, deer were harvested earlier and more continuously throughout the growing season, corn drydown period, and crop harvest seasons on INT properties. Increased deer harvest pressure on INT properties may have prevented corn damage from being worse had additional deer not been harvested. Therefore, extra opportunities to harvest deer should be afforded on properties where landowners consult with MNDNR staff about their concerns for potential deer damage. These concerns are legitimate as my data demonstrated. Landowners are basing their concerns on prior experiences and current conditions. The results of this study will provide a basis for improving the framework for future application of localized management in agricultural regions. Wildlife managers with local knowledge may be best suited to make recommendations about deer management strategies. Within the regulatory framework, they should be afforded the ability to adapt deer harvest permit levels for specific situations to most effectively minimize crop losses and to foster positive relationships with agricultural producers and hunters.

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Table 1. Estimates of the abundance of white-tailed deer, management intensity of deer, and corn damage caused by deer on 7 privately owned properties in southeast Minnesota, during 2014-2016.

Property	Deer management strategy[1]	Estimated deer abundance (deer per camera)[2]			Management intensity[3]			% Corn loss[4]		
		2014	2015	2016	2014	2015	2016	2014	2015	2016
A	HUNT	26	27	30	0.16	0.08	0.13	7	37	8
B	HUNT	22	26	33	0.21	0.23	0.12	-1	29	8
C	HUNT	13	22	16	0.21	0.07	0.14	14	0	6
D	INT	26	35	19	0.35	0.28	0.32	24	0	6
E	INT	21	17	14	0.39	0.50	0.29	-6	23	15
F	INT	22	18	23	0.28	0.54	0.19	0	4	16
G	INT	11	12	29	0.74	0.36	0.16	12	16	-2

[1]On properties with HUNT management deer harvest was conducted by sport-hunters during the regular season framework. On properties with INT management deer harvest was through integrated methods including by sport-hunters during the regular season framework and using depredation and shooting permits outside of the regular season framework.

[2]Deer abundance estimated from infrared camera surveys indexed as deer per camera with camera densities of 1 camera per 65 ha on each focal property.

[3]Proportion of the number of deer estimated to be using a property that were harvested.

[4]Negative values indicate higher average yield estimates in unfenced subplots versus subplots fenced to exclude deer.

Table 2. Estimates of corn damage caused by white-tailed deer on edge and interior sampling plots on 7 privately owned properties in southeast Minnesota, during 2014-2016. Edge plots were along the field edge and interior plots were >10 m from the field edge.

		% Corn loss								
		All			Edge			Interior		
Year	Deer management strategy[1]	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
2014	HUNT	24	6.6	3.1	12	3.8	4.4	12	9.5	4.3
	INT	30	6.5	4.1	15	11.1	7.1	15	1.8	3.9
2015	HUNT	24	22.2	6.7	12	35.9	12.0	12	8.6	3.3
	INT	30	10.7	4.5	14	19.4	8.5	16	3.2	3.0
2016	HUNT	24	7.4	3.1	12	9.2	5.6	12	5.6	2.7
	INT	30	8.7	6.5	14	18.1	13.3	16	8.0	3.2

[1]On properties with HUNT management deer harvest was conducted by sport-hunters during the regular season framework. On properties with INT management deer harvest was through integrated methods including by sport-hunters during the regular season framework and using depredation and shooting permits outside of the regular season framework.