EVALUATION OF CORN AND SOYBEAN DAMAGE BY WILDLIFE IN NORTHERN INDIANA

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Abstract: In 2003 we began a multifaceted research program to investigate aspects of wildlife damage to corn and soybean crops in northern Indiana. Moreover, we examined movement patterns, habitat use, and home-range characteristics of species commonly associated with row-crop damage to determine how their spatial ecology related to the extent and timing of depredation events. Here, we present a summary of our research, covering field surveys of crop damage (160 fields over two years), statistical models investigating landscape-level effects on the probability of crop damage (both within fields and among fields), radio-telemetry studies of raccoons (*Procyon lotor*), and stakeholder surveys. We recorded 582,515 depredation events (73,100 to corn and 509,415 to soybeans) over two years of field sampling. Raccoons and white-tailed deer (*Odocoileus virginianus*) were responsible for >97% of the damage to corn (87% and 10%, respectively); deer (61%) and groundhogs (*Marmota monax*; 38%) were responsible for nearly all damage to soybeans. Surveyed fields exhibited a high variance in levels of crop damage by wildlife. Statistical modeling indicated that crop damage was best predicted by a combination of local and landscape variables, although proximity to forest patches consistently was the most important indicator of crop damage. Radio-collared raccoons constricted their home ranges when crop depredation was most severe, and exhibited increased use of forest fragments and crop fields over other habitat types. Our surveys suggested that most landowners suffered noteworthy crop damage by wildlife, but their perceptions regarding the species responsible for economic losses did not correspond closely with data from field surveys. In addition to regulated hunting, we suggest that targeted removals of depredating species, concentrated along crop-forest interfaces, may be an effective, cost-effective means of reducing corn and soybean damage in heavily affected areas.

***Key words*:** agriculture, corn, crop, damage, Indiana, raccoon, soybean, white-tailed deer

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INTRODUCTION

Although many types of agricultural operations suffer substantial economic losses to wildlife (Conover 2002), damage to field corn and soybeans is particularly problematic. Corn is the most economically important crop produced in the U.S.—9.5 billion bushels were produced in 2001, generating a crop worth more than $19 billion (National Corn Growers Association 2002). In 1993, damage to field corn by wildlife was quantified in the 10 top corn-producing states. Wildlife-caused losses averaged 1.7 bushels/ha, for an estimated loss in the ten states of 35 million bushels worth $92 million (Wywialowsky 1996). Assuming that the remaining corn-producing states had depredation levels similar to those of the reported 10-state average, an estimated $113 million of ripening field corn was lost to wildlife in the U.S. in 1993 alone (Wywialowsky 1996). Damage to soybeans caused by wildlife is not as well documented, although many states have recognized a potential problem (Wallace et al. 1995).

In addition to direct economic losses, negative perceptions related to crop damage by vertebrates are likely the fundamental causes of most conflicts arising between agricultural and wildlife interests. Farmers' perceptions of wildlife damage (both real and perceived) can influence land-management practices that affect wildlife (Decker et al. 2001, Daley et al. 2004). As such, crop damage from wildlife can result in two distinct challenges for managers: first, economic losses can be substantial, especially for small-scale producers, and second, because the majority of land in the Midwest is privately owned, negative perceptions of landowners and crop producers toward wildlife can lead to overall public attitudes and resultant policies that are detrimental to healthy wildlife populations. The development of viable solutions to such conflicts is the primary means to a more productive and sustainable coexistence between agriculture and wildlife in human-dominated landscapes.

In 2003 we began a multifaceted research program aimed at quantifying the amount and type of crop damage caused by vertebrates in a large region (1165 km^2) of northcentral Indiana. Land use in the study area, which lies in the Upper Wabash River Basin (UWB), is predominately row-crop, hay, and small grains agriculture (88%) with small woodlots (mostly <20 ha) and human development interspersed in the agricultural matrix. The primary goal of our research was to quantify the extent and frequency of crop depredation by wildlife species in the agricultural regions of northern Indiana using a stratified random sampling of depredation events in crop fields (corn and soybean) while concurrently using telemetry data to document the spatial ecology and movement patterns of white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), and wild turkey *(Meleagris gallopavo)* in the same agricultural matrix. We also developed statistical models that identify landscape-level effects on the probability of crop damage (both within fields and among fields) and assessed landowner perceptions of wildlife damage by means of a survey sent to over 1,500 landowners in the study area and surrounding region. In the present paper, we summarize our research findings, focusing on damage surveys, statistical models, stakeholder surveys, and spatial ecology of raccoons, the species responsible for most damage to corn. Then, we consider the most appropriate management strategies for alleviating crop damage in the study area and similar midwestern landscapes.

CORN AND SOYBEAN FIELD SURVEYS

We surveyed 160 northern Indiana agricultural fields (100 corn and 60 soybean) ranging in size from 1 to 125 ha, from planting (May) until harvest (October) in 2003 and 2004 (MacGowan et al. 2006a, 2006b, Humberg et al. 2007). Across seasons, we documented 73,100 depredation events (any damage to a single plant) in corn fields and 509,415 in soybean fields (Humberg et al. 2007). We attributed 87% of the depredation events in corn fields to raccoons and 10% to white-tailed deer. White-tailed deer (61%) and woodchucks (38%) were responsible for almost all damage to soybeans. Although we attributed no crop damage to wild turkeys during our field surveys, a separate investigation later documented minor wild turkey damage to emerging soybeans in southern Indiana (MacGowan et al. 2006c). Most fields suffered only light or moderate damage; however, there was a great deal of variation in wildlife damage across fields. For example, the average number of depredation events per corn field was 731 ± 1,440 SD (Humberg et al. 2007).

We also documented differences in the temporal patterns of corn depredation by raccoons and white-tailed deer. Whereas white-tailed deer damaged corn consistently from emergence in May through harvest in October, raccoons damaged corn infrequently until the beginning of the reproductive stage (early to mid-June). Raccoon damage to corn plants peaked during the milk (R-2) stage of plant development and continued through harvest in October (Humberg et al. 2007).

STATISTICAL MODELS OF CROP DAMAGE BY WILDLIFE

We used our field survey data and a GIS database from the study area (Retamosa 2006) to construct statistical models that identify habitat and landscape elements associated with wildlife damage to corn and soybean crops. On a field-level basis, Retamosa et al. (2008) found that the intensity of damage to corn and soybeans was best predicted by a similar suite of local and landscape variables. Overall, the intensity of crop damage (corrected for field size) increased as field size decreased, and as the proportion of a field's perimeter adjacent to wooded areas, the amount of wooded areas, the amount of forest edge, and the mean size of forest patches increased (Retamosa et al. 2008).

We also evaluated whether habitats surrounding corn and soybean fields influenced the location of wildlife damage within fields. DeVault et al. (2007) demonstrated that for both field types, wildlife damage locations were significantly closer to forest patches, but further from developed areas, than random point locations within fields. As such, field edges adjacent to wooded areas were more likely to incur damage than interior portions of fields. Interestingly, much like the analyses conducted by Retamosa et al. (2008), model results examining damage locations within fields were similar for both corn and soybeans (DeVault et al. 2007).

Beasley and Rhodes (2008) examined the relationship between raccoon damage to field corn and raccoon abundance. They used mark-recapture techniques to estimate raccoon abundance in 14 northern Indiana forest patches and then modeled the relationship between raccoon abundance estimates and intensities of raccoon damage in adjacent corn fields. They found a positive linear relationship (R^2 = 0.43) between raccoon abundance and raccoon damage to field corn (Beasley and Rhodes 2008).

STAKEHOLDER SURVEYS

Despite the fact that most (78%) producers reported having at least one crop damaged by wildlife the previous 12 months (Humberg et al. 2007), less than half took some type of action to control wildlife during that time. Landowners who suffered damage that exceeded their tolerance were more likely to take action to control wildlife damage and seek help from others. Of those reporting damage, harvest during the season was the most common method (48%) of wildlife damage control, followed by fencing and scare devices (7% each), chemical control (4%), depredation permits (3%), and habitat removal (3%). Sixty-six percent of landowners reported success in lessening wildlife damage to crops after harvesting raccoons, although fewer reported success after harvesting deer and groundhog (*Marmota monax*) (51% and 52%, respectively).

For deer damage to both soybeans and corn, and raccoon damage to corn, the general attitudes landowners had for each species were related to whether or not the damage exceeded their tolerance. Regardless of the level of damage, landowners considered groundhogs as a nuisance. There was no relationship between damage caused by deer (soybeans and corn), raccoon (corn), and tree squirrels (corn) exceeding landowners' tolerance and hunting or trapping on the property during the previous 12 months or 5 years.

SPATIAL ECOLOGY OF RACCOONS

From May 2003 through June 2005, Beasley et al. (2007a) examined home range characteristics of 60 adult raccoons in northern Indiana to identify shifts in the size of home ranges and core-use areas among seasons defined by crop availability and crop developmental stage (non-growing, growing, and maturation). Male raccoons in their study area maintained significantly larger home range and core area sizes (92 ha; 20 ha, respectively) than did females (58 ha; 13 ha, respectively), and both sexes maintained smaller home ranges than those reported for raccoons in other agricultural ecosystems (Beasley et al. 2007a). Home range sizes varied little as a function of crop availability or developmental stage for both sexes in their study; however, home ranges of males were smallest during the corn maturation stage, whereas home ranges of females were smallest during the corn growing season. Beasley et al. (2007a) suggested that the lack of differences among seasonal home range sizes, despite the presence of an ephemeral superabundant food source (i.e., corn) during the maturation season, was likely due to the close proximity of foraging and denning resources across seasons in their study area.

Beasley et al. (2007b) also performed habitat selection analyses for 55 adult raccoons during the growing and maturation seasons at 3 hierarchical orders defined by raccoon movement behavior. They observed both seasonal and intersexual differences in habitat selection patterns for raccoons, although these patterns of habitat selection were not consistent across hierarchical orders of scale. However, both sexes consistently selected forest cover over other available habitats across seasons, suggesting that raccoon distribution and abundance in highly fragmented landscapes is likely dependent on the availability and distribution of forest cover, or habitats associated with forest (i.e. water), within the landscape (Beasley et al. 2007b). Seasonal differences in habitat selection were most pronounced at the core area scale, where raccoon selection of agricultural lands was highest during the corn maturation season. The non-random use of agriculture observed by Beasley et al. (2007b) during the maturation season was strongly reinforced by the observations of substantive raccoon

damage to field corn at the onset of the milk (R-2) stage in their study area (Humberg et al. 2007).

DISCUSSION

Population levels of raccoons and white-tailed deer, the two species responsible for the vast majority of crop damage in northern Indiana, likely are at or near all-time highs in the Midwest (Mumford and Whitaker 1982, Gehrt et al. 2002, Plowman 2003). These species have directly benefited from intense agricultural development in the region, both in terms of increased food sources (i.e., field corn) and the increased availability of edge habitats associated with the fragmentation of forested lands. Controlled harvest through the regulation of sport hunting and trapping and the general lack of natural predators has ensured that populations of both species remain large. Management strategies designed to reduce crop damage by these species must incorporate the ecological and behavioral attributes of each within the context of the agriculturally dominated landscape they inhabit.

Our current research indicates that raccoons are responsible for the vast majority (87%) of depredation to field corn in northern Indiana. Therefore, any management program designed to reduce crop depredation in the Midwest must successfully address the adverse effects of raccoons on field corn production. Past research indicated that raccoons are rarely dissuaded from damaging crops by traditional deterrents like frightening devices and repellents (Boggess 1994). The available evidence suggests that, of the commonly used deterrents, complete exclusion from agricultural commodities is the only reliable way to reduce damage from raccoons (Boggess 1994). Because fencing large crop fields is rarely cost-effective (Conover 2002), the reduction or removal of local raccoon populations or subpopulations may be the only remaining, viable alternative for reducing crop depredation by raccoons at local scales.

Wildlife removal by lethal means is frequently the most effective deterrent to crop depredation, and often is less costly than other depredation deterrent strategies. In his review of lethal control methods to reduce wildlife damage, Conover (2002) suggested that the most effective programs are those that target only depredating individuals or subpopulations for removal. Ultimately the success of any lethal control strategy depends upon our understanding of the ecology and behavior of the target species, and data on a variety of biological attributes such as abundance, demography, and movement behavior are necessary if lethal control programs are to be effective (Conover 2002).

Our data indicate that targeted removals of raccoons may be a cost-effective method for reducing depredation to corn crops in heavily damaged areas. Raccoons in northern Indiana concentrate movements in forested areas (Beasley et al. 2007a) and maintain small home ranges and core areas across seasons (Beasley et al. 2007b). Furthermore, in northern Indiana there is a positive linear relationship between raccoon abundance in woodlots and raccoon damage to field corn in adjacent fields (Beasley and Rhodes 2008). Thus, we recommend that raccoon removals should be concentrated within forested areas, particularly during the non-growing season when food resources are limited to such locations (Beasley 2005).

Unlike raccoons, white-tailed deer do not rely entirely on woodlots for cover in agricultural landscapes. As such, white-tailed deer are distributed more evenly than raccoons throughout the UWB. Furthermore, the wide-ranging movement behavior of this species makes localized

removals of deer to reduce crop damage very difficult, and recent studies have shown that frightening devices are ineffective in reducing deer depredation to field corn (Gilsdorf et al. 2004a, Gilsdorf et al. 2004b). Yoder (2002) demonstrated that deer damage to crops can be minimized by a reduction in deer densities; as such, controlled harvest (i.e., legal hunting) over large areas is likely the best method available to control field corn depredation by white-tailed deer.

In addition to active management of raccoons and regulated hunting of white-tailed deer, we believe that reductions in crop losses from many wildlife species might be accomplished by altering the landscape structure itself, thus indirectly making field crops less vulnerable to depredation by vertebrates. Considerable strides have been made in manipulating habitats and landscapes to reduce damage by arthropod pests by providing favorable conditions for their natural enemies (Landis et al. 2000). However, few studies have considered vertebrate pest management at the landscape scale (VanVuren and Smallwood 1996, Retamosa 2006), probably due to difficulties in actually modifying landscapes for experimental purposes. For example, most studies testing the effectiveness of crop depredation deterrents have been conducted on small agriculture fields confined to one localized geographic area (e.g., Belant et al. 1996). This is unfortunate given the fact that many of the recognized limitations to crop depredation deterrents reveal the need for long-term solutions to depredation problems at the scale of entire landscapes. Populations, and in some cases metapopulations, of depredating vertebrate species usually operate across vast landscapes that may include a myriad of different structural features, including agricultural fields of many types and sizes. Thus, the effectiveness of most deterrent devices has not been tested within the spatial and biological contexts necessary for a comprehensive understanding of crop depredation in modern agricultural landscapes (VanVuren and Smallwood 1996).

Ultimately, successful strategies for minimizing wildlife crop depredation occurring in the complex, fragmented landscapes that characterize our nation's most productive agricultural regions will require creative multidisciplinary approaches which incorporate both the composition and configuration of biological attributes of agricultural ecosystems. Extant research (Conover 2002) and our statistical models (DeVault et al. 2007, Retamosa et al. 2008) suggest that the size and shape of crop fields, the presence and spatial features of woodlots and other habitat types, the proximity to urban areas and water bodies, and crop rotation patterns contribute substantially to the intensity of damage by wildlife. Thus, our modeling efforts, which incorporate spatial features of the landscape, detailed data on species-specific crop damage, and animal movement patterns, demonstrate the need for multidisciplinary approaches in addressing crop depredation by wildlife and reveal the potential importance of developing planting strategies and landscape management plans that serve to prevent or minimize crop damage by vertebrates in fragmented agricultural landscapes.

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