6-1-1996

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Abstract : One asset of wildlife to landowners is the potential but understudied role of birds and other species as endemic natural enemies of crop pests. Enhancing such natural enemies as part of sustainable agricultural systems offers promise for maintaining agricultural competitiveness while providing wildlife habitat in intensively farmed areas. The University of Nebraska has established an agroforestry research team to address interdisciplinary questions and outreach associated with this topic. Included are studies of bird, mammal, and insect use of woody and herbaceous corridors and adjacent cropfields in east-central Nebraska. Uncultivated areas needed to sustain natural enemies of crop pests also provide other benefits. Properly planned windbreak edges, for example, can enhance stewardship of soil and water by preventing erosion, conserving moisture, and increasing dryland crop yields. Management practices that enhance endemic natural enemies of crop pests and provide other benefits can better ensure long-term continuation of agriculture and living wild resources, an opportunity for extension education and future research.

INTRODUCTION

Typical agricultural systems are managed as monocultures with large fields of one plant type such as corn, soybeans, or wheat. Such monocultures are used to increase production efficiency and to make management easier, but the result is that the aim of conventional agriculture is to reduce biological diversity (Gerard 1995). This conference session is focused on an appropriate question of what good is having diversity of habitats and wildlife in farming systems; is it a liability or an asset to landowners and how can we best enhance the positive values? One way to approach this is to find opportunities that combine the needs of biological conservation with the needs of people so that both might benefit. Habitat is often the primary need of wildlife on farms, whereas people need, as examples, sufficient income, crop protection from pest insects, soil and water stewardship, and aesthetic and recreational opportunities for the family. Various fee hunting approaches can provide farm income from wildlife as a crop or product that is harvested from the land. Other values of wildlife to farms stem from the role of wildlife or their habitats as a part of the agricultural system. Integrating biological resources into agricultural systems to provide compatible and beneficial functions can help ensure the sustainability of both agriculture and native plants and animals.

Diversity in current agricultural systems is primarily through edges such as windbreaks, riparian zones, or other habitats that are outside or adjacent to the crop system (e.g., Stauffer and Best 1980, Best 1983, Bryan and Best 1991). Properly planned windbreak edges can enhance stewardship of soil and water by preventing erosion, conserving moisture, and increasing dryland crop yields and profits (Brandle et al. 1988, 1992). Windbreaks and other vegetated field edges in intensively farmed areas provide essentially the only habitat diversity available for wildlife, including birds, spiders, and predatory insects that are endemic natural enemies of crop pests (Johnson and Beck 1988, Trnka et al. 1990, Johnson et al.1992). Although birds do forage and occasionally nest in crop fields, including strip intercropping systems, nest success in fields is low, and adjacent uncultivated areas are essential habitat components for nearly all birds that use fields (Sunderman 1995, Fitzmaurice 1995, Stallman and Best 1996)

NATURAL ENEMIES OF CROP PESTS

There is limited information available on natural enemies of crop pests in agroecosystems, but information available is encouraging, as indicated in the following examples. Downy woodpeckers (*Picoides pubescens*) are important predators of overwintering European corn borers (*Ostrinia nubilalis*) in North Dakota (Frye 1972), Louisiana (Floyd et al. 1969), and Arkansas (Wall and Whitcomb 1964). Northern flickers (*Colaptes auratus*) are an important predator of southwestern corn borers

(*Diatraea grandiosella*) in Arkansas (Wall and Whitcomb 1964) and Mississippi (Black et al. 1970). The woodpeckers consume the larvae by pecking into the stalks after harvest. McEwen et al. (1986) studied winter wheat fields in Montana and found that horned larks (*Eremophila alpestris*) and McCown's longspurs (*Calcarius mccownii*), two grassland birds, had high proportions of cutworms (mostly pale western cutworms, *Agrotis orthogonia*), grasshoppers, ants, and beetles in their diet, and concluded that bird predation could supplement other controls. Other studies have recorded birds consuming pest insects on tobacco (Stewart 1975), cabbage (Strandberg 1981), corn (Stewart 1973), rice (Zhang 1992), and orchard crops (Wearing 1979, Roland et al. 1986, Zhang 1992). Madden (1982) found that avian predators of the wood wasp (*Sirex noctilio*) in pine plantations in Tasmania enhanced the effectiveness of other biological control agents and recommended, as has been done for other monocultures, increased habitat diversity for birds by interruption of pure stands with corridors of natural vegetation.

Although there are some data on small mammal use of windbreaks (Yahner 1982, 1983), little is known about associated effects on adjacent crops or the role of small mammals in agroforestry systems. Small mammals that occur in crop fields can have both positive and negative effects. Some may dig and consume newly planted corn (Johnson 1986), but some also consume weed seeds, unwanted waste grain, and crop-damaging insects (Zimmerman 1965, Whitaker 1966, Beasley and McKibben 1976, Holm 1984, Young 1984) including grasshoppers, wireworms, cutworms, and corn earworms (*Heliothis zen*) (Gillette 1889, Orcutt and Aldrich 1892, Fitzpatrick 1925, Holm 1984, Getz and Brighty 1986). One cutworm may damage three to four corn seedlings (Archer and Musick 1977, Clement and McCartney 1982), so each cutworm consumed by a predator may represent the saving of several corn plants. Studies of bat food habits have found that big brown bats (*Eptesicus fuscus*) eat spotted cucumber (corn rootworm) beetles (*Diabrotica undecimpunctata*, Whitaker 1972) and alfalfa weevils (*Hypera postica*, Bellwood 1979 as cited by Humphrey 1990). Further, the calm air on the leeward side of windbreaks appears well suited for bats or birds to attack flying insects.

Although it is unlikely that natural predators could control a widespread pest insect outbreak, they apparently contribute, along with other biological control factors, to regulation of insect populations and to prevention of outbreaks, especially when pest numbers are low to moderate (Pimentel 1961, Getz and Brighty 1986, Zhang 1992, Trnka et al. 1990, Johnson et al. 1992).

UNIVERSITY OF NEBRASKA PROGRAM

The University of Nebraska has established an agroforestry team to address the interdisciplinary questions and outreach associated with agroecosystems, including biological control of insect pests. Agroforestry systems blend the benefits of agricultural and forestry practices into more sustainable land management systems. Various studies by team members have compared birds, small mammals, insects, and spiders in woody and non-woody edges (Dix et al. 1995). Two complementary studies evaluated bird use of woody and herbaceous corridors and adjacent cropfields in east-central Nebraska (Fitzmaurice 1995, Sunderman 1995). They considered the conservation values of woody and herbaceous edges for birds and the potential birds may have as natural enemies of crop insect pests.

In a comparison of windbreaks versus herbaceous fencerows (Sunderman 1995), bird species richness and abundance were greater in the windbreak edges during all seasons ($P \leq 0.05$), with the exception that richness did not differ in winter ($P = 0.15$). In adjacent cropfields, mean species richness was greater in fields bordered by woody edges in late summer ($P \leq 0.03$) and approached significance in spring ($P \leq 0.07$), but did not differ in summer, fall, or winter ($P \geq 0.39$). Bird abundance in cropfields bordered by woody edges approached higher than in herbaceous-edged fields during spring ($P = 0.09$), but the reverse occurred in winter ($P = 0.09$). Bird abundance did not differ between the two field types during summer, late summer, or fall ($P \geq 0.52$). In late summer and fall, bird abundance varied considerably among sites, in part due to flocks of house sparrows (*Passer domesticus*), common grackles (*Quiscalus quiscula*), and American robins (*Turdus migratorius*). In winter, most (81%) birds observed using fields were flocks of horned larks.

Ten small mammal species, including species known to consume crop insect pests, were captured at these windbreak sites during 1,293 trap-nights. The 394 captures occurred in all edge types and in fields out to 200m (transect length) from edges. White-footed mouse (*Peromyscus leucopus*) was the most common species captured in woody edges, and deer mouse (*P. maniculatus*) the most common in fields. Deer mice and grasshopper mice (*Onychomys leucogaster*) were distributed evenly throughout fields ($P > 0.05$), whereas white-footed mice were concentrated within 50 meters of the edge ($P < 0.05$).

A study comparing woody versus herbaceous riparian corridors and adjacent cropfields (Fitzmaurice 1995) had results generally similar to those in the windbreak study. In the riparian study, bird species richness was higher in woody edges than in herbaceous ($P \leq 0.06$) during all sampling periods except late summer, when it showed the same trend ($P = 0.13$). Bird abundance appeared to be higher in woody edges during spring, fall, and winter

($P \leq 0.18$) but did not differ during summer and late summer ($P \geq 0.52$). In fields, bird species richness and abundance did not differ between those with woody versus herbaceous edges ($P \geq 0.56$) except during the wet 1993 spring when richness and abundance were higher in fields with herbaceous edges ($P \leq 0.06$). The herbaceous-edged fields, during spring 1993, had four woodland bird species and high numbers of red-winged blackbirds (*Agelaius phoeniceus*) that contributed to these spring 1993 results. There was confounding woody vegetation present at some of the herbaceous sites, which appeared to increase the observations of woody-habitat species at those sites.

In both studies, species composition varied between woody and herbaceous sites, reflecting vegetation present and bird habitat preferences. Bird numbers in cropfields were generally higher within about 50m of the edge, but open-area species such as horned larks avoided edges. Bird use of fields changed through the season along with crop growth and increased vertical structure; with omnivorous ground feeders predominant early in the growing season; and with lower canopy, upper canopy, or aerial foragers present throughout the growing season. Results overall indicate that woody edges generally had greater species richness and abundance than did herbaceous edges, but that the two edge types accommodate different species, an important point for management decisions. Although bird numbers were generally higher near field edges, foraging by various species of both birds and small mammals occurred throughout the field area studied, indicating potential predation impact on insect crop pests out to at least 200 m from edges.

Another study is currently in progress to evaluate birds, insects, and habitat variables in organic and nonorganic systems by examining field pairs, with each pair comprising one organic and one nonorganic field similar in edge and environment. Preliminary results from 1995 indicate that species richness may not differ between the organic and nonorganic pairs, but that abundance is higher in the organic.

MANAGEMENT CONSIDERATIONS

Woody corridors in agricultural landscapes can help reduce soil erosion, shelter crops from wind damage and desiccation, enhance moisture conservation, and serve as filters for field runoff, important for ground and surface water quality. They also provide wildlife habitat important to a variety of species in intensively farmed landscapes (Best et al. 1990). The woody vegetation and associated wildlife provide recreational and aesthetic benefits in rural areas and may enhance the quality of life for farm families.

Field-edge windbreaks and riparian corridors, which tend to become naturally established with woody vegetation, are among the few woody habitats within the Midwestern farming region. Some landowners clear the trees and shrubs, in part to increase crop area or to better accommodate farming equipment, but clearing the trees also removes benefits of the woody vegetation. A more thorough understanding of the values of these habitats will enable landowners to make better-informed management decisions about them. Determination of the bird species and numbers using woody and non-woody corridors and their adjacent cropfields establishes baseline data for evaluating how such areas might be managed to enhance natural enemies of crop pests.

Our results from Nebraska indicate that field-edge vegetation benefits a wide variety of bird species, including insectivores and omnivores that likely have value as natural enemies of crop pests. Further, neotropical migrant bird species, many of which are in decline, apparently benefit from the woody vegetation as habitat during migration and perhaps nesting. Herbaceous edges contribute habitat for additional species. Field edges with woody vegetation, in comparison to non-woody, appear generally to have greater overall species richness, more neotropical migrant bird species, and generally more individuals. Herbaceous edges, however, provided habitat for species such as dickcissels (*Spiza americana*) that do not frequent woody areas. Bird abundance within the cropfields studied was generally similar regardless of edge type, but species composition differed. In fields, bird species richness and abundance appear to be influenced by the edge vegetation present in the overall agricultural landscape and, in some cases, by the edge vegetation adjacent to a particular field.

The best type of edge for a particular site may be determined, in part, by its location in relation to adjacent or nearby habitats. Research and management decisions should consider the effects of edge vegetation in relation to adjacent habitats in the landscape and with natural resource conservation in mind. For example, grassland edges adjacent to grassland fields would probably have benefits for grassland bird species, whereas a narrow grassland edge isolated by a broad expanse of row crops, would be of limited value. Similarly, a network of windbreaks or woodland edges, such as in our studies, would have benefits for woodland-edge bird species, especially if other woodland habitats were nearby. So the overall amount or network pattern of a habitat type may be an important management variable. Because both woody and herbaceous edges support specific bird species, landscape management plans should consider the amounts of similar habitats, woody or herbaceous, that are available near the respective edge types

Pest insects are susceptible to predation both in the cropfield and in the field edge. At field edges, natural enemies can attack pest insects that come to the field edge for some life cycle need or that are blown there by the wind. Predation pressure on insect crop pests from birds and small mammals, based on predator foraging locations, appears to be highest within 50 m of field edges but occurs throughout fields at least 200 m from edges. The edge non-crop habitats are necessary components for most of the natural enemy complex and most were more abundant within 50 m of the edge. Avoiding pesticide application on strips of cropland adjacent to field borders might reduce their harmful effects to predators without increasing economic losses to crop damage. The Conservation Headlands program in Europe involves pesticide application strategies to protect field edges and to reduce negative impacts on desirable species (Hassall et al. 1992, Sotherton et al. 1993). Similar approaches merit evaluation for potential benefits on Midwestern farms.

Extension personnel have the opportunity to communicate to clientele what is known about natural enemies of crop pests in sustainable agriculture and to encourage research to fill data gaps. There are management practices that currently can be used to enhance biological control of crop pests and, for the future, opportunities to involve landowners in identifying and testing sustainable approaches that better ensure long-term continuation of agriculture and living wild resources.

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