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Vertebrates for Biological Control of Insects in Agroforestry Systems

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VERTEBRATES FOR BIOLOGICAL CONTROL OF INSECTS IN AGROFORESTRY SYSTEMS

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Abstract. – Agroforestry systems offer options for maintaining agricultural competitiveness while enhancing stewardship of soil, water, and living wild resources. Trees, as part of agroforestry systems, prevent soil erosion, conserve moisture, and increase dryland crop yields. Moreover, windbreaks and similar field borders provide wildlife habitat and sustain natural enemies of crop pests. Although certain rodents and birds may cause crop damage in some situations, many birds, small mammals, and other predatory organisms consume pest insects and offer a potential key to buffering pest outbreaks and reducing pesticide use. There are specific practices that currently can be used to enhance biological control of crop pests and, for the future, numerous research needs that must be addressed to better ensure long-term continuation of agriculture and living wild resources.

Agriculture faces the demands of competition in a global marketplace as well as increasing pressures for long-term environmental stewardship of the land. New approaches to help meet these seemingly conflicting needs may lie in the emerging science of agroforestry, which blends the benefits of agricultural and forestry practices into more sustainable land management systems.

Properly planned windbreaks can be used to protect soil, conserve moisture, and improve dryland crop yields and profits (Brandle et al. 1988, 1992). Windbreaks and similar woody habitat benefit wildlife in agroecosystems and provide habitat diversity that supports natural enemies of crop pests (Johnson and Beck 1988, Trnka et al. 1990). Windbreaks provide benefits to wildlife in several ways, including protection from wind and adverse weather, escape or refuge cover, food and foraging sites, reproductive habitat, and travel corridors. Johnson and Beck (1988), in a review of shelterbelt literature, reported that at least 108 species of birds and 28 species of mammals have used shelterbelt habitats. In agricultural areas, 29 species of birds benefit substantially from shelterbelts, 37 moderately, and 42 very little or accidentally. At least 57 species of birds have been recorded using shelterbelts during the breeding season and, of these, 28 are known to nest in them. The importance of windbreaks and hedgerows to birds and other wildlife is also documented in China, Europe, and other geographical areas (O'Connor and Shrubb 1990, Trnka et al. 1990, Zhang 1992). Research in the midwest, mainly Iowa, showed the importance of grassed waterways (Bryan and Best 1991), woody and herbaceous edges around crop fields (Best et al. 1990), riparian areas (Stauffer and Best 1980), and fencerows (Best 1983, Shalaway 1985) to birds in agricultural landscapes.

EFFECTS OF EDGES IN AGROECOSYSTEMS

Biological communities typically have a wide variety of plant and animal species that interact together in a system. Agricultural landscapes, in contrast, are designed as intense monocultures with various biological system functions replaced by external inputs of synthetic pesticides, petroleum products, or fertilizers. Diversity of plant and animal life is primarily associated with crop field edges where the crop and another plant community meet. Thus, 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 rather than mixed in (Pollard 1971). Understanding the function of these edges in relation to the crop is needed for optimum benefit to both wildlife and crops. Variables such as vegetation types, spacing, and pattern of edge habitats affect the wildlife species present and associated impacts on crop pests.

Predators associated with edges may affect

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crop pests either in the crop field or in the edge habitat. For example, birds living in a windbreak may forage in the crop field or, alternatively, may consume pest insects that are blown to the edge by strong winds or attracted there for some life cycle need. Further, the calm air on the leeward side of windbreaks appears well suited for bats or birds to attack flying insects.

In Iowa and Illinois, Best et al. (1990) studied breeding birds in cornfield centers and perimeters (outside 50 m of crop) and in adjacent edge habitats that had either herbaceous or woody vegetation. In comparing edge types, they found about twice as many bird species (woody: 50 species; herbaceous: 23 species) and more than seven times as many individuals in the woody cover edge as in the herbaceous edge. Although the type of edge (herbaceous vs. woody vegetation) influenced the species composition of birds in cornfields, edge type did not significantly affect the overall numbers and species richness of birds in cornfields. However, cornfield perimeters, compared to centers, had 6 to 7 more bird species and about 5 times as many birds.

Trnka et al. (1990) found 50 avian species in a windbreak-crop (barley, wheat, corn) system, of which 7 occurred exclusively in fields and 33 exclusively in windbreaks, leaving 10 species that used both habitat areas. The 43 species recorded in windbreaks had 965 individuals and the 17 species in fields had 414 individuals. They found 10 small mammal species (207 individuals) in windbreaks and 5 species (66 individuals) in fields, but sampling techniques may have obscured the presence of others in the fields.

Preliminary research in Nebraska during June and July, 1991, indicated a greater variety and number of birds in corn and soybean fields near windbreaks or other woody cover than in similar crop fields without such shelter nearby (R. J. Johnson et al., unpublished data). Twenty-seven bird species used windbreak vegetation. Censuses in cornfields found 5 bird species (16 individuals) in windbreak-sheltered fields, 5 species (15 individuals) in unsheltered fields with woody cover nearby, and 1 species (2 individuals) in open fields with no woody cover within approximately 400 meters. Censuses in soybean fields found 14 bird species (66 individuals) in sheltered fields compared to 8 bird species (58 individuals) in open fields away from woody cover. Wheat fields near windbreaks had 13 to 18 bird species, with no apparent differences related to the degree of wind protection. Most of the birds identified and the activities observed during these censuses appeared beneficial to agriculture, and no bird damage to crops was observed.

The above results indicate that windbreaks or similar woody cover near fields increase bird and mammal species diversity in the crop fields and field edges. Such diversity in habitat and fauna appears to bring stability to the agricultural system and contributes to the conservation of biological diversity in agricultural landscapes (Pimentel 1961, Trnka et al. 1990, Zhang 1992).

NATURAL ENEMIES OF CROP PESTS

There is limited information available on vertebrates as natural enemies of crop pests. However, information available is promising. For example, downy woodpeckers (*Picoides pubescens*) were found to be 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 (yellow-shafted) flickers (*Colaptes auratus*) were an important predator of southwestern corn borers (*Diatraea grandiosella*) in Arkansas (Wall and Whitcomb 1964) and Mississippi (Black et al. 1970). Black et al. (1970) concluded that northern flickers were a key factor in the reduction of overwintering corn borer populations in Mississippi. 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 in tobacco (Stewart 1975), cabbage (Strandberg 1981), corn (Stewart 1973), rice (Zhang 1992) and orchards (Wearing 1979, Roland et al. 1986, Zhang 1992). Madden (1982) found that avian predators of the woodwasp (*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 consume weed seeds and crop-damaging insects (Zimmerman 1965, Whitaker 1966, Beasley and McKibben 1976, Holm 1984, Young 1984) including grasshoppers, wireworms, cutworms, and corn earworms (*Heliothis zea*) (Gillette 1889, Orcutt and Aldrich 1892, Fitzpatrick 1925, Holm 1984, Getz and Brighty 1986), and waste grain that could produce unwanted volunteer crops during the following growing season. One cutworm may damage 3 to 4 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). Studies of bat food habits are difficult because food in the intestinal tract, especially from soft-bodied insects, is often no longer recognizable. It is likely that further study would show that bats also consume various other crop pests such as corn borer moths.

IMPACT ON CROP PESTS

The potential impacts of birds or other vertebrates as natural enemies in regulating the populations of crop pests is not well understood and has received limited research attention in the United States. Although it is unlikely that natural predators could ever completely eliminate a pest population, they appear capable of keeping pest numbers below thresholds at which damage becomes an economic problem.

Research in forest ecosystems shows that bird communities exert sufficient feeding pressure on low-density spruce budworm (*Choristoneura fumiferana*) populations to dampen the seriousness of infestations (Crawford and Jennings 1989). Birds also may have an impact on populations of the larch sawfly (*Pristiphora erichsonii*, Buckner and Turnock 1965), Douglas-fir tussock moth (*Orgyia pseudotsugata*, Torgersen and Mason 1987), and gypsy moth (*Lymantria dispar*, Whelan et al. 1989).

In grassland systems, it appears that avian and small mammal predators, especially shrews (*Sorex spp.*), reduce insect populations at low to moderate densities and, along with other biological control factors, contribute to regulation of insect populations (McEwen 1987, Joern 1986, Churchfield et al. 1991, Fowler et al. 1991). However, Feare (1984) reported that although European starlings (*Sturnus vulgaris*) in New Zealand are encouraged with nest boxes, primarily to control populations of the grass grub (*Costelytra zealandica*), available data show that the birds exert control only under certain conditions (East and Pottinger 1975).

Regarding agroforestry systems, Zhang (1992) reviewed the role of birds in biological pest control in China and described several studies in which birds considerably reduced pest problems and the need for alternative controls. Trnka et al. (1990) studied a windbreak-crop system in Moravia (Czechoslovakia) and argued that windbreaks enhanced the diversity of vertebrate and invertebrate organisms and the self-regulating processes associated with system stability. Others in the United States have presented similar perspectives on the potential ecological value of birds in suppressing agricultural pest populations (e.g. Black et al. 1970, Stewart 1975, Getz and Brighty 1986, McEwen et al. 1986). Thus, although there are questions about the overall ecological value of birds as natural enemies of pest insects (Peterson 1980), the general conclusion from forest, grassland, and agricultural ecosystems is that birds and other natural enemies, although unlikely to control widespread pest insect outbreaks, do have a role in preventing outbreaks through predation when pest numbers are low to moderate.

Reports from areas where diversity is lacking testify to the importance of natural system controls in buffering pest outbreaks. In the Knesha area of Bulgaria, an explosion of field rodent populations in recent years resulted in crop losses of up to 20-25% of the planted seed and emerging seedlings (H. D. Jose, Univ. of Nebraska, Lincoln; W. Petersen, USDA Soil Conservation Service, Iowa City, Iowa; and N. Danielson, farmer, Rochert Minnesota; unpub. report). Apparently, the underlying cause of the rodent outbreaks was the nearly complete lack of natural habitat diversity, resulting in an unstable system. Agricultural areas in northeastern Bulgaria, which had comprehensive windbreak plantings, had no such rodent problems. In a similar example, Summers-Smith (1988) reported that a Eurasian tree sparrow (*Passer montanus*) eradication program in China, described in detail by Suyin (1959), was followed by insect outbreaks and crop damage. Apparently the sparrow eradication campaign was based on oversimplification of a complex biological balance; the tree sparrow has now returned to favor in China and is even encouraged (Summers-Smith 1988). Summers-Smith (1988) also sites reports from Germany of Eurasian tree sparrows, encouraged with nest boxes, that kept fruit trees free of pests so that it was not necessary to spray them, and of tree sparrows that controlled an infestation of asparagus beetles (*Crioceris aspergi*) in asparagus fields.

PRACTICES TO ENHANCE BIOLOGICAL CONTROL

Using vertebrates for biological control of insect pests should not be viewed as a panacea to solve all pest problems. Rather, it is a technique to use along with cultural practices, resistant varieties, wise use of appropriate pesticides, and other strategies in an integrated pest management program to ensure long-term sustainable agricultural systems. Below are some approaches that currently can be used to facilitate biological control in integrated management programs:

1) Use pesticides properly according to label directions and only when truly needed. Judicious pesticide use is important when incorporating biological control, because pesticides may adversely affect nontarget (natural enemies) as well as target (pest) species (Pimentel 1991). Scouting techniques, developed through integrated pest management (IPM) research, can determine when pest insects in specific fields are at population levels that warrant control. Pesticides can then be used to control insect pest populations only when they are at economically-important levels. Preventive but unneeded pesticide applications are thus avoided. The overall result is timely insect pest control and reduced pesticide inputs.

2) Select pesticides that allow the benefits of biological control to continue. Using pesticides that do not kill, repel, or otherwise harm natural enemies of the pest allows the double-pronged attack from both pesticide and natural enemies (Blais and Parks 1964, McEwen et al. 1986). For example, McEwen et al. (1986) found that rates of chlorpyrifos used in Montana against pale western cutworms in winter wheat fields appeared to have little affect on horned larks and McCown's longspurs, two bird species that consumed quantities of cutworms. Recent research on biological control of European corn borers in crop fields shows that Bt (*Bacillus thuringiensis*), a bacterial insecticide, is toxic to the borers but harmless to most beneficial insects, earthworms, birds, and mammals (Lewis 1975, Hardin 1991). These examples indicate that integrated control of pests using both pesticides and natural enemies is feasible and available with current technology.

3) Plant and maintain an interspersion of woody cover in agricultural landscapes. Properly designed windbreaks increase net yields and profits in dryland agricultural systems because of their effects on moisture conservation and crop wind protection (Brandle et al. 1992). Moreover, windbreaks, woody riparian corridors, and other natural-vegetation habitats in agricultural landscapes appear to bring greater stability and contribute to conservation of biological diversity (Pimentel 1961, Johnson and Beck 1988, Trnka 1990). Currently we lack sufficient data to quantify the effects of such diversity on regulation of crop insect pests, but the potential impacts of natural enemies appear promising as a key part of integrated control programs.

4) Encourage incentives such that the creative energy and know-how skills of land managers are directed towards long-term sustainability rather than towards coping with regulatory disincentives. Many farmers are already finding ways to reduce pesticide use and to increase or maintain windbreaks, riparian areas, and other habitats. Sometimes governmental programs, such as the requirements for maintaining a commodity crop base, although well-intentioned and perhaps initially well planned, may discourage use of crop rotations, pivot corners or other odd areas for wildlife or natural enemies, or other appropriate conservation or stewardship practices. We need to encourage programs and incentives, with active participation by landowners and all others concerned, to better ensure the long-term continuation and stewardship of agricultural and

biological systems in concert with society goals.

RESEARCH NEEDS AND THE FUTURE

Predator-prey relationships in agroforestry systems are not well studied, particularly on what overall impact natural enemies of crop pests might have under proper management conditions. Data are needed on vertebrate use of windbreaks throughout the year and on relationships among vertebrate use, wind-flow patterns, insect populations, and other system components. Another need is to determine optimum habitat amounts, connectivity, and arrangement patterns needed in a broad-scale agricultural landscape. Effective habitat for natural enemies to thrive and exert impact on pests may involve interspersion of windbreaks, corridors, patches, or other types of woody cover over large areas (Davidson 1981). One prediction would be that the need for pesticide use would be lower in areas or regions that have appropriate habitat for natural enemies, a prediction measurable perhaps using insect scouting techniques.

Specific management practices might enhance the ability of vertebrate natural enemies to exert greater predation force on prey species (Takekawa et al. 1982). For example, what effects would supplemental winter and fall food have on woodpecker predation of corn borers, or what impact would lights at field edges have on bat predation of crop pests? What would be the optimum timing for such enhancements and what other system variables might contribute to the outcome? Results from other locations indicate that enhancements such as nest boxes and conservation of insectivorous bird species may reduce pest populations and the need for pesticide use (Summers-Smith 1988, Zhang 1992), but these approaches need objective evaluation in the Great Plains.

Numerous variables may affect the potential role and impact of vertebrates in agroforestry systems. Included are amount, spacing, and pattern of woody cover and other plant diversity (Forman and Godron 1981, Yahner 1988, Loman and Von Schantz 1991); tillage and crop rotation practices; pesticide use; weather and annual climate patterns; and interrelationships with other organisms and system components. Research on such topics is needed. Multi-disciplinary approaches are necessary to address effectively the interrelated roles of agroforestry system components and to develop viable management options.

As we look to the future and begin to bring more focus on pest management using biological control, we need also to remember the broader perspective of sustainable control. Sustainability is to ensure the long-term continuation of natural biological systems and living wild resources upon which agricultural production and human life support systems ultimately depend. Sustainable control must incorporate the realities of human need for food and the economic requirements for viable food production systems. Biological control fits as a promising but understudied technique that could supplement other methods in integrated control programs. Successful biological control strategies will increase profitability by lowering input costs while maintaining pest levels below economically-damaging levels. As our understanding of agroforestry systems improves, biological control may become a critical key in meeting needs for both agricultural production and environmental stewardship. The task before us is to find and employ the ecological strands of life that unite agricultural and forestry systems into more sustainable land management options.

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