Effects of Temperate Agriculture on Neotropical Migrant Landbirds

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Abstract — The ecology of Neotropical migrant landbirds in temperate farmland is reviewed to develop management recommendations for the conservation of migrants. Migrants constitute about 71% of bird species using farmland and 86% of bird species nesting there. The number and abundances of Neotropical migrants using farmland are greatest in uncultivated edges with trees and shrubless in uncultivated, grassed areas (grassed fencerows, waterways, terrace berms, road verges, and land set aside in the Conservation Reserve Program); and least in rowcrops. Causes of recent declines in abundance of farmland migrants are not clear, but recent decades also saw increasing agricultural mechanization and chemical use that probably lowered breeding productivity of migrants. Major nesting losses of migrants in farmland are from predation, agricultural field operations, and brood parasitism by Brown-headed Cowbirds (*Molothrus ater*), but few migrants in farmland have been studied. Farmland also has become more homogeneous as farm size increased, uncultivated areas have been removed, and farms have specialized on one or a few commodities. These changes probably have created farmland that often lacks the food, shelter, safe nesting sites, or appropriate interspersion of these needed to attract and sustain Neotropical migrants. Agricultural practices that promote breeding productivity and survival of Neotropical migrants include reduced tillage and inorganic fertilizer inputs and use of integrated pest management programs. The importance of farmland heterogeneity and uncultivated areas with shrubs and trees for enhancing populations of Neotropical migrants is emphasized.

Introduction

The ecology of Neotropical migrant landbirds in temperate farmland is reviewed in this paper to develop management recommendations for their conservation. We focus on migrants during the breeding season and migration because research on impacts of agriculture on migrants in winter, although potentially of great importance to migrant conservation (Greenberg 1992, Petit et al. this proceedings), is very limited. Neotropical migrants using temperate farmland can be classified as field or edge species. Fields are areas worked for crop production, and migrants found in fields often were formerly grassland species. Edges include field borders but also uncultivated areas within fields, such as grassed waterways or terrace berms. Edges with woody vegetation often are used by forest edge species. The distinction between fields and edges, although simple, is important because these areas receive very different agricultural treatment, and hence, migrants using these areas are affected differently.

Effects of agricultural activities on Neotropical migrants merit consideration because a large proportion of North America is farmed (about 52% of the land area of the contiguous 48

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Table 1. — Factors influenced by agriculture that are contributing to the decline of the Neotropical migrant landbirds that are listed as threaten or endangered or are candidates for these lists (listed species taken from Finch [1991]).

Migrant species	Habitat use	Factors contributing the to decline in abundance	References
Swainson's Hawk (Buteo swainsoni)	savannahs, prairies shelterbelts	habitat loss to agriculture pesticide contamination	Risebrough et al. 1989. Houston et al. 1991 Schmutz 1987
Yellow-billed Cuckoo (Coccyzus americanus)	open woodlands thickets	habitat loss to agriculture	Gaines and Laymon 1984
Willow Flycatcher (Empidonax traillii)	swamps, thickets	cowbird parasitism range and cattle management	Taylor and Littlefield 1986; Harris 1991
Bell's Vireo (Vireo bellii)	riparian thickets fencerows	habitat loss to agriculture cowbird parasitism	Goldwasser et al. 1986 Franzreb 1990
Black-capped Vireo (Vireo atricapillus)	riparian woodlands	habitat loss to agriculture	Grzybowski et al. 1986
Golden-cheeked Warbler (Dendroica chrysoparia)	mature oak-juniper woodlands	cowbird parasitism	Pulich 1976
Bachman's Warbler (Vermivora bachmanii)	palmetto and cypress swamps	habitat loss to agriculture	Terborgh 1989 Hamel 1986
Kirtland's Warbler (Dendroica kirtlandii)	jack pine stands	cowbird parasitism	Walkinshaw 1983
Peregrine Falcon (Falco peregrinus)	cosmopolitan	pesticide contamination	Cade et al. 1988

states, USDA 1992: and 11% of Canada, Freemark and Boutin 1992), and because agriculture is implicated in the decline of all nine Neotropical migrants currently listed as threatened or endangered or that are candidates for listing (Table 1). Abundances of some field migrants have declined over 80% in agricultural areas during the past 20 years (Robbins 1982, Graber and Graber 1983, Castrale 1985, Zaletel and Dinsmore 1985, Bollinger et al. 1990, Bollinger and Gavin 1992), and some edge migrants also are declining (e.g., Black-billed Cuckoo, *Coccyzus erythropthalmus*, Northern Baltimore Oriole, *Icterus glabula*, White-eyed Vireo: see Sauer and Droege 1992, James et al. 1992: scientific names are listed in the Appendix except if given). How agriculture has contributed to declines is often not clear, but recent decades also saw rapid change in agricultural practices (methods used in crop production including type of crop grown) and farmland structure (types, relative coverage, and spatial distribution of habitat features in farmland including uncultivated areas).

Recent changes in agricultural practices and farmland structure may have reduced favorability of agricultural fields for foraging and nesting by migrants (Castrale 1985, Best 1986, O'Connor and Shrubb 1986). Potentially harmful changes in agricultural practices include agricultural mechanization (Rasmussen 1982) and chemical use (Gard et al. this proceedings), whereas farmland structure has become more homogeneous as farm size increased and farms specialized on producing one or a few commodities (Barrett et al. 1990). Of particular importance to Neotropical migrants, the percentage of farmland in hay or pasture (USDA 1990), or in uncultivated, semi-natural habitats such as fencerows (Best 1983, Warner 1992a), has decreased in proportion to increases in the area of intensively cultivated rowcrops.

To understand how agricultural practices or farmland structure may affect populations of Neotropical migrants, we reviewed field and farm-scale studies of migrants, as well as broad-scale, long-term studies. Studies at different spatial and temporal scales provided complementary information. Field and farm-level studies were particularly useful in identifying how agricultural practices may be affecting reproduction and survival of migrants, and they documented migrant use of farmland habitat features such as fields, fencerows or grassed waterways (e.g., Rodenhouse and Best 1983, Basore et al. 1986, Bollinger et al. 1990, Best et al. 1990). Long-term, broad-scale studies contributed to assessing the ability of farmland dominated by different crop types to sustain migrant populations. Because agriculture is rapidly changing, we consider prospects for migrants in agriculture of the future, and we conclude by proposing general management recommendations for the conservation of Neotropical migrants in farmland.

USE OF FARMLAND BY NEOTROPICAL MIGRANTS

Results of Field and Farm-scale Studies

Results of studies at the level of the field or farm clearly identify three major patterns. First, Neotropical migrants constitute the majority of bird species using farmland (Table 2). In northcentral and northeastern North America, migrants make up 71% of bird species reported to use farmland and 86% of bird species identified as nesting there. The number of migrant species nesting in crop fields, however, is low relative to

Table 2. — The percentage of Neotropical migrant landbird species observed using farmland or reported nesting in different crops or uncropped areas of northcentral and northeastern North America (from species lists compiled by Freemark et al. [1991] except where noted). "List A" species breed in North America and spend the nonbreeding season primarily south of the United States border; "list B" species breed and winter extensively in North America, but some populations winter south of the United States (Gauthreaux 1992). Unlisted species are residents and migrants whose winter ranges do not extend south of the United States border.

	Species observed (%)			Total number of species		% of nesting species that are migrants
	Migrants					
Category	List A	List A & B	Unlisted	Observed	Nesting	
Crops						
Red Clover	37	74	26	35	6	100
Oats[1]	34	72	28	29	9	89
Alfalfa	33	70	30	27	6	100
Grapes	32	76	24	25	0	
Hay	31	74	26	39	12	75
Corn (tilled)	30	75	25	44	17	88
Wheat[2]	27	68	32	22	10	70
Blueberries	23	65	35	26	0	
Pasture	22	70	30	37	9	89
Cherries	22	56	44	18	0	
Soybean (tilled)[3]	21	73	27	33	10	80
Means	29.1	70.5	29.5	30.5	7.2	86.4
Uncropped						
Fencerow[4]	35	70	30	54	26	73
Grassed waterway[5]	31	69	31	39	11	82
Shelterbelt[6]	51	76	24	45	18	67

[1] Includes species from Frawley (unpublished data).
[2] Includes species from Rodgers (1983).
[3] Includes species from Best (1986).
[4] Includes species from Shalaway (1985), and the classification "strip cover" in Basore et al. (1986).
[5] Includes species from Bryan and Best (1991).
[6] Includes species from Martin and Vohs (1978), Cassel and Weihe (1980), Yahner (1982).

uncultivated areas (Freemark et al. 1991). The proportion of migrants differs somewhat among crops, but migrants are strongly represented in widely divergent crop types such as corn, hay and vineyards (Table 2). Furthermore, migrants constitute the majority of bird species using field or edge areas (Table 2).

Second, species richness and abundances of Neotropical migrants in farmland are greatest in uncultivated edge with trees and shrubs, less in uncultivated grassed edge and least in rowcrops (Table 3). Furthermore, migrant richness and abundances are greater in wider strips of uncultivated edge

Table 3. — The number of species and abundance of Neotropical migrant landbirds in edge versus field vegetation types. Values are numbers per 100 ha, except for Best (1983) and Shalaway (1985) that are per 10 km of fencerow.

Edge						
Wooded		Grassed		Field		
Species	Abundance	Species	Abundance	Species	Abundance	Reference
31	2,193	18	365	15	18	Best et al. 1990
45	2,600			11	136	Graber & Graber 1963[1]
		19	1596	14	42	Camp 1990[2]
		24	1952	12	638	Bryan & Best 1991[3]
20	128	9	75			Best 1983[4]
5	73	4	106			Shalaway 1985[5]

[1] Graber and Graber's (1963) "edge shrub" habitat corresponds with the wooded edge category in this table, but their study only provides total bird abundances for this habitat. To identify migrants, we used species lists provided by Graber and Graber for "shrub-grown" habitat of northern, central and southern zones combined. Number of species given here for wooded edge is, therefore, based on the number of migrant species in summer "shrub-grown" habitat of all zones combined. Abundance for the wooded edge category in this table was calculated using total abundance of all species in "edge shrub" habitat times the proportion of total abundance that migrants composed in "shrub-grown" habitat of all zones combined.
[2] Average of results from 1990 and 1991.
[3] Average of results from 1987 and 1988.
[4] Number of species and individuals per 10 km of "herbaceous" or "continuous shrubs and trees" fencerow.
[5] Only nesting species are included for "grass" and "wooded" fencerows. Abundances = abundances of nests/10 km of fencerow. The study only included 4.6 km of fencerow.

vegetation (Best 1983, Shalaway 1985, Johnson and Beck 1988), Uncultivated wooded areas include wooded fencerows or edges of fields bordering woodland; grassed edge includes some fencerows, waterways, terrace berms, road verges and most land set aside in the Conservation Reserve Program (92% of CRP land is enrolled as perennial grassland; Agricultural Stabilization and Conservation Service, Washington, D. C., unpublished data). This pattern of migrant abundances also occurs in Europe (O'Connor and Shrubb 1986).

Third, breeding productivity of migrants nesting in farmland is often low relative to the number of offspring estimated to balance adult and juvenile mortality (Table 4). Breeding productivity is particularly low in hayfields and rowcrops, but it can also be low in edge including road verges (DeGeus 1990, Camp 1990, Warner 1992b), grassed waterways (Bryan 1990) and edge strip cover in general (Basore et al. 1986). Unfortunately, breeding productivity information is available only for few migrant species nesting in farmland, and few migrants have been studied in more than one crop type.

County-level Associations between Crops and Migrants

To assess the ability of farmland to sustain populations of Neotropical migrants, we reviewed long-term studies conducted by O'Connor and coworkers (see Lauber 1991, Boone 1991, O'Connor and Boone 1990, O'Connor et al. 1992) of associations by county between bird species abundances (N = 105 bird species) and coverage of 23 major crop categories. These associations were determined by using decision tree analysis (described in detail by Lauber [1991]) of Breeding Bird Survey abundances and USDA agricultural statistics over a 17-year period (1973-89). Because associations were tested on a county-by-county basis, results reflect large-scale associations rather than field-scale use of individual crops.

After examining county-level species-crop associations for 52 migrant species (listed in the Appendix) and 23 crop categories, six observations are noteworthy. First, 11 of 23 crop categories (including CRP) were associated with significantly

Table 4. — The productivity (fledglings per breeding pair per season) of Neotropical migrant landbirds breeding in farmland. The level needed to balance mortality of adults and juveniles is about three or greater fledglings/pair/year (e.g., Rodenhouse and Best 1983, Probst 1986, Sullivan 1989) except for Loggerhead Shrikes which is 5.5 (Brooks and Temple 1990).

Migrant species	Number of nests	Fledglings/ breeding pair/year	Nesting losses (%)[1] Predation	Agriculture	Parasitism	Nesting habitat	Reference
Vesper Sparrow	45	2.8	29	27	11	Corn/soybean	Rodenhouse & Best 1983
	74	2.9[2]				Corn/soybean	Perritt & Best 1989
	10	2.4	50	10	0	Alfalfa	Frawley 1989
	35	1.4[3]	54	0	9	No-till/strip cover[4]	Basore & Best unpubl. data
Grasshopper Sparrow	41	0.8[3]	80	2	2	No-till/strip cover	Basore & Best unpubl. data
Loggerhead Shrike	222	2.2	86	0	0	Roadside[5]	DeGeus 1990
	100	3.3				Pasture	Tyler 1992
Bobolink	33	0.3	9	85	0	Hayfield	Bollinger et al. 1990
Dickcissel	34	0.2	18	50	21	Alfalfa	Frawley 1989
	69	1.7[3]	28	23	3	Oat field	Frawley & Best unpubl. data
	27	2.2	44	7	19	Waterway[6]	Bryan 1990
Red-winged Blackbird	41	0.4	29	41	10	Alfalfa	Frawley 1989
	133	1.2[3]	50	1	20	No-till/strip cover	Basore & Best unpubl. data
	65	0.9[3]	20	42	5	Oat field	Frawley & Best unpubl. data
	63	1.0	27	33	16	Waterway	Bryan 1990
	73		55	1	4	Roadside[5]	Camp 1990
Western Meadowlark	9	0.1	56	1	0	Alfalfa	Frawley 1989
	15	0.7[3]	47	20	0	No-till/strip cover	Basore & Best unpubl data
Killdeer	12	6.9[3]	8	0	0	No-till/strip cover	Basore & Best unpubl data
Mourning Dove	13	0.4[3]	31	8	0	Oat field	Frawley & Best unpubl. data
	12	1.5[3]	33	17	0	No-till/strip cover	Basore & Best unpubl. data

[1] Losses as a percentage of all nests to predation, agricultural activity or brood parasitism. Nests considered lost to parasitism were deserted due to this cause or fledged only cowbird young.

[2] Calculated as the mean number of successful nests per female for 1984 and 1985 (mean = 0.77) times mean clutch size (3.8) from Rodenhouse and Best (unpubl. data). Missing values indicate data either not gathered or reported.

[3] Breeding productivity calculated as (number of fledgings per successful nest) * (nesting success) * (two nesting attempts). Each female was assumed to make two nesting attempts.

[4] Includes nests in no-till corn and soybeans and adjacent strip cover.

[5] Roadsides adjacent to corn and soybeans.

[6] Grassed waterways within corn and soybean fields.

more migrant than resident bird species (Table 5). Second, up to 65% of the bird species significantly associated with a crop were Neotropical migrants. Soybeans and sorghum had the highest number of significant associations, but many of those associations were negative. High proportions of negative associations may indicate that these crops are grown using management practices unfavorable to migrants, or that farmland structure in these areas is altered in ways that are inimical to migrants. Third, 50 of 52 migrants tested were significantly associated with one or more crop categories, and fourteen migrant species were associated with 10 or more crop categories (Appendix). Positive associations between migrant abundances and crop coverages (N = 216) greatly outnumbered negative ones (N = 91). Because positive associations indicated that these migrants were more abundant where crop coverage was greater, this result suggests that agriculture or factors associated with agriculture in some way enhanced their populations. Irrespective of the processes involved, these results imply a surprising level of positive associations between migrants and agriculture.

Fourth, the percentage of county area in the Conservation Reserve Program was positively associated with the abundance of 19 migrant species (Table 5), 12 of which were field species. Interpretation of this result, however, is not clear because Lauber (1991) found that many of the associations with CRP-enrolled land were manifest before the advent of the CRP. Probably some basic features of land in these areas, e.g., amounts or types of edge, are key to sustaining populations of migrants. Fifth, the strongest positive associations were usually found for bird species that consume the crop before harvest or as waste grain. Twenty-four of 50 migrants associated with a crop consumed one or more of the crops (these species are identified in the Appendix), and values of the positive associations for consumers of grains were about four times those for non-consumers (Rodenhouse et al. 1993). Last, 44% of the significant associations (including positive and negative associations) occurred between crops and Neotropical migrants that neither nest in nor consume the crops involved, e.g., Eastern Kingbird. Many

Table 5. — Proportion of Neotropical migrants (N = 52 species) and residents (N = 53) significantly associated with major crops. Association was determined using Breeding Bird Survey abundances and USDA agricultural statistics by county for 1973 - 1989. For Neotropical migrant species the number of positive and negative associations are also listed.

	Percent of species associated with crop			Fisher exact	Number of significant associations	
Crop category	Migrants	Residents	Chi-square[1]	probability	Positive	Negative
Soybean	65.4	32.1	11.66	<0.01	17	13
Sorghum	63.5	26.4	14.57	<0.01	16	15
Oats	61.5	22.6	16.3	<0.01	18	6
Corn for grain	57.7	37.7	4.19	0.05	21	8
Barley	57.7	35.9	5.03	0.03	14	3
Winter wheat	53.9	22.6	10.84	<0.01	20	5
Alfalfa	32.7	11.3	7.01	0.01	7	2
All hay[2]	32.7	13.2	5.65	0.02	9	4
All wheat[3]	32.7	13.2	5.65	0.02	14	2
Corn for silage	28.9	15.1	2.90	0.10	4	5
Spring wheat	28.9	26.4	0.08	0.83	11	4
Durum wheat	26.9	20.8	0.55	0.50	8	5
Other hay[4]	23.1	7.6	4.90	0.03	5	3
Sunflower seed	21.2	17.0	0.30	0.63	9	1
Peanuts	19.2	17.0	0.09	0.80	0	5
Cotton	15.4	11.3	0.38	0.58	3	3
Flaxseed	15.4	17.0	0.05	1.00	5	0
Rice	13.5	15.1	0.06	1.00	4	1
Sugar beets	13.5	17.0	0.25	0.79	3	3
Dry beans	9.6	3.8	1.44	0.27	3	0
Tobacco	9.6	7.6	0.14	0.74	5	0
Potatoes	7.7	11.3	0.40	0.74	1	2
CRP[5]	40.4	15.1	8.40	<0.01	19	2
				Totals	216	91

[1] Chi-square value for a test of equal percentage of migrants and residents associated with each crop category.
[2] Includes the categories alfalfa and other hay.
[3] Includes winter wheat, spring wheat and durum wheat.
[4] Includes all types of hay excluding alfalfa.
[5] Conservation Reserve Program.

migrants, therefore, probably are primarily affected by either uncultivated edge within farmland, or by combinations of cultivated and uncultivated areas.

Results of large-scale, long-term studies, therefore, provide new insights and emphasize some of the same patterns identified by field and farm-scale studies. Migrants strongly dominate the bird communities of farmland, and numerous major crops are positively associated with some migrant species. These positive crop-migrant associations are strongest for species that consume foods provided by the crop. But positive associations between migrants that neither nest in crop nor consume the crop emphasize the importance of uncultivated edge, CRP-enrolled lands, and possibly other as yet unidentified habitat features of farmland in sustaining populations of some migrants.

ECOLOGY OF NEOTROPICAL MIGRANTS IN FARMLAND

The patterns of migrant abundances identified above probably reflect ecological conditions and resources available to Neotropical migrants in farmland. In this section, we review how agricultural practices and farmland structure may affect those conditions and resources needed by migrants.

Food Availability and Diets of Migrants

Many Neotropical migrants are wholly or partly insectivorous (Freemark et al. 1991), and agricultural practices often reduce arthropod abundances in croplands. Each field operation buries some crop residue (Sloneker and Moldenhauer 1977), thereby reducing habitat for litter arthropods or killing overwintering individuals. Abundance of litter-dwelling arthropods is greater in fields where plant litter on the soil surface is more dense (Edwards and Lofty 1969, Culin and Yeargan 1983, House and Stinner 1983). In contrast, abundance of foliage-dwelling arthropods in fields is dependent on crop development and may be little influenced by amount of surface-litter (Basore et al. 1987). Among other practices that reduce arthropod abundance, inorganic fertilizers can lead to reductions in the soil organic matter that sustains soil fauna (Hendrix et al. 1990). Herbicides also reduce within-field plant species diversity that is correlated with arthropod diversity (Chiverton and Sotherton 1991), and insecticides directly reduce arthropod abundance (reviewed by Gard et al. this proceedings).

The field and edge structure of farmland often both creates cultivated areas with low food abundance and retains uncultivated areas with high food abundance. Areas with permanent vegetation, even if only grasses, and no-till cropland often support higher arthropod abundances than conventionally tilled crop fields (Dambach 1948; Lewis 1965, 1969; House and All 1981; Warbuton and Klimstra 1984; House and Parmelee 1985; Hokkanen and Holopinen 1986; Brust and House 1988), but differences among arthropod species may be large and the trend reverses during pest outbreaks in the crop (Duelli et al. 1990). Arthropod abundance is also greater near permanently vegetated field edges than in field centers (Price 1976, Mayse and Price 1978, Kemp and Barrett 1989) and greater in fields surrounded by complex habitats (e.g., old fields and woodland) than by simple ones (e.g., rowcrops) (Altieri and Whitcomb 1980). Weed seeds consumed by omnivorous and granivorous migrants are also usually most abundant in and near uncultivated areas, both because seeds disperse from uncultivated areas receiving little or no weed control and because permanent vegetation concentrates wind dispersed arthropods and seeds (Pasek 1988). Homogenization of farmland structure, by draining moist-soil areas within cropland or removing uncultivated areas to consolidate fields, therefore, likely lowers diversity and abundances of plants, seeds and arthropods within fields and landscapes. Whether reductions in food abundance or patchy food distributions limit reproductive success or survival of migrants using farmland is unknown.

Foraging by Neotropical migrants in farmland may contribute to crop production by reducing abundances of pest insects and weed seeds. Although populations of beneficial insects also might be reduced, it seems rarer for birds to consume beneficial insects in agricultural habitats (Woronecki and Dolbeer 1980, Bollinger and Caslick 1985, Rodenhouse and Best, unpubl. data). Unfortunately, the quantitative contribution by avian communities to pest control is rarely known. Bendell et al. (1981), however, found that the economic benefit of pest control by Red-winged Blackbirds only compensated for 20% of crop damage caused by this species. Thus, Neotropical migrants may also reduce crop yields by feeding on crops.

A variety of crops are damaged by migrant birds, but few species are responsible. In fact, fewer than 10 of the 215 Neotropical migrants are currently reported to cause significant damage to agricultural crops over wide geographic areas. The principal migrants involved are the Red-winged Blackbird, Brown-headed Cowbird, American Robin, Bobolink, Dickcissel, Gray Catbird, Northern Oriole, and Yellow-headed Blackbird. Of these, Red-winged Blackbirds cause by far the most economic loss. When bird damage to agricultural crops occurs, total yield on a state or nationwide basis is typically reduced by less than 1-2% (e.g., Dolbeer 1990), but economic losses to individual farmers may be severe. Bird damage to crops, however, is minor relative to damage by insects, weeds, and diseases which combine to reduce potential yields by over 20% (Boyer 1982).

The migrants most frequently mentioned as damaging fruit crops in North America are American Robins, Gray Catbirds, and Northern Orioles. Crops eaten include cherries, grapes, blueberries, and strawberries (e.g., Seamans and Caslick 1983; Tobin et al. 1988, 1991). Bobolinks and Dickcissels are considered pests on wintering grounds in South America because of their rice-eating habits (Dyer and Ward 1977). Migrant birds visiting feedlots (primarily Brown-headed Cowbirds) may also reduce "yield" of livestock by consuming livestock feed and by fouling food or transmitting diseases (Glahn 1983).

Crop damage by Neotropical migrants is probably influenced by farmland structure. Damage to corn by Red-winged Blackbirds increased in North America from the late 1960's to the early 1980's due perhaps to increases in the area producing grain (White et al. 1985, Clark et al. 1986), and to decreased acreages of small grain stubbles, hayfields, and uncultivated lands which, in turn, led to increased reliance on corn for food by red-wings (Besser and Brady 1986). Crop damage is also usually concentrated in space and time. Most fields receive little or no damage, but those located near roosting concentrations of birds (e.g., cornfields near marshes) can be heavily damaged, and most crop damage occurs near the time of crop maturation (Bollinger and Caslick 1985). Crop damage also tends to be highest where crop and landscape diversity is lowest (Stone and Danner 1980).

Sheltering Vegetation, Perching and Nesting Sites

The presence of sheltering vegetation may be needed for some migrants, particularly edge species, to use farmland during breeding or migration (Castrale 1985). For example, foraging sites may only become suitable when they include, in addition to food, refuges for escape from predators or adverse weather and safe perching sites for preening, resting, or sunbathing (Lima et al. 1987, Nakamura and Matsuoka 1987, Johnson and Beck 1988). The availability of such sites for edge migrants is positively associated with vertical vegetation complexity created by shrubs and trees and with farmland heterogeneity (Johnson and Beck 1988, O'Connor and Boone 1990). Complex vegetation structure, however, also provides nesting sites (e.g., Yahner 1982, 1983) and song perches (e.g., Rodenhouse and Best 1983), conceals bird movements from predators or brood parasites (Schneider 1984, Lima et al. 1987) and creates favorable microclimatic conditions for nesting or other activities (McNaughton 1988).

Farmland complexity, which is determined by the number and spatial locations of crop types and types of uncropped areas (e.g., grassy waterways, wooded fencerows, shelterbelts) is currently declining in most agricultural areas. Causes include increased use of large equipment, enlarged field sizes, trends toward producing and rotating fewer crops (e.g., Barrett et al. 1990), and consolidation of farms, thus increasing average farm size (USDA 1990) and correspondingly reducing spatial diversity. Consequently, availability of protective shelter in farmland has declined as uncropped habitats, such as fencerows, are removed. From 30 to 80% of fencerows in midwestern agricultural regions have been removed since the 1930's (Mohlis 1974, Vance 1976, Taylor et al. 1978, Baltensperger 1987), and those that remain often contain only herbaceous vegetation (Rodenhouse and Best 1983).

Reproductive Success

The absence of safe nesting sites may be the factor most limiting reproduction and survival of migrants in cropland. Agricultural practices that can destroy nests, fledglings, or adults in fields include primary tillage, disking, cultivation, rotary hoeing. (e.g., Rodenhouse and Best 1983, Rodgers 1983), chemical applications (reviewed by Gard et al. this proceedings) and mowing (e.g., Bollinger et al. 1990, Frawley and Best 1991). Mowing hayfields at night is particularly destructive to adult birds that are attending nests or roosting in hayfields at night (Frawley, pers. comm.). Predation, however, usually causes most nesting losses in rowcrop fields and edge (Table 4). Agriculture may indirectly imperil birds by increasing the spatial concentration of predators that feed on adults, juveniles or nest contents (Gates and Gysel 1978). Edge created by agriculture can serve as travel lanes for predators (Fritzell 1978, Johnson and Adkisson 1985, Glueck et al. 1988), and birds nesting in or near these lanes often have low nesting success (Gates and Gysel 1978, Basore et al. 1986, Bryan 1990, DeGeus 1990, Johnson and Temple 1990, Camp 1990). However, Shalaway (1985) reported high nesting success (58% of nests fledged at least one young) in a wooded fencerow, but he noted that this fencerow lacked small mammalian predators that often destroy bird nests. Nesting success in rowcrops (e.g., Rodenhouse and Best 1983, Basore et al. 1986) and hayfields is also often low (e.g., Frawley 1989, Bollinger et al. 1990). Nest predation in or near farmland is probably proportional to predator abundance, and predation rates in farmland can be equal to or higher than those in uncropped habitats (O'Connor and Shrubb 1986, Angelstam 1986). But, the causes of high rates of nest predation in farmland have not been clearly identified, because predator densities in farmland seldom have been quantified.

Shifts in agricultural practices and farmland structure probably have also enhanced brood parasitism of Neotropical migrants by Brown-headed Cowbirds (Brittingham and Temple 1983). More than 200 bird species are parasitized by Brown-headed Cowbirds, and most hosts are Neotropical migrants (Robinson 1992a). Brood parasitism by cowbirds often severely reduces reproductive success of Neotropical migrants in farmland (Table 4). The effect of farmland structure on brood parasitism (i.e., fragmentation of native vegetation by agriculture and creation of edge) is manifested by higher rates of brood parasitism near field edges with elevated perches for cowbirds than away from field edges and elevated perches (Best 1978, Johnson and Temple 1990). Present rates of brood parasitism, nest predation, and destruction of nests by agricultural operations are probably novel conditions for most migrants breeding in farmland, because agricultural mechanization and rapid increases in cowbird abundances have occurred during mostly the past 45 years. Whether migrants that evolved to use fields and/or edges created by agriculture are also capable of adjusting to high nesting losses caused by agriculture is unknown (Best and Rodenhouse 1984).

Population Sources and Sinks

The impacts of agricultural activities on vegetation structure, food abundance, and nesting success described above may create population sources and sinks. Population sources are characterized by local reproduction that exceeds that needed to balance local mortality of adults and juveniles, but replacement level reproduction is not achieved in population sinks (Wiens and Rotenberry 1981). Locations of sources and sinks in farmland may vary in space and time because agricultural activities and environmental conditions (e.g., weather) also vary.

If source and sink areas occur for Neotropical migrants in farmland, identification of these areas will be important for bird conservation (Howe and Davis 1991), because it could lead to management that mitigates sinks and protects sources. Identification of sources and sinks should be possible by documenting reproductive success in farmland features receiving different agricultural practices or by comparing reproductive success among farmlands of different structure. Few studies of this kind have been carried out. Thus whether sources and sinks occur generally in farmland is unknown, but studies of the reproductive ecology of migrants nesting in rowcrop field and edge (see Table 4) strongly suggest that sinks do exist.

PROSPECTS FOR NEOTROPICAL MIGRANTS IN AGRICULTURE

Because agriculture is currently undergoing rapid change, it is important to consider agricultural practices and farmland structures in the future as a part of developing management recommendations for the conservation of Neotropical migrants. Previous sections of this paper have dealt exclusively with past and present effects of agriculture on migrants. In this section, we consider how anticipated changes in agriculture might affect these species. We review Lower Input Sustainable Agriculture (LISA: see Edwards et al. 1990) in detail because it may offer better prospects than conventional agriculture for conservation of migrants (Papendick et al. 1986, Robinson 1991).

Several futures for agriculture are likely, but in each a proportion of farms accept sustainable agricultural practices (National Research Council 1989, Batie and Taylor 1989, Kirschenmann 1991). Very likely farming will develop along two tracks. Some farms will be large in size, externally owned and intensively managed; whereas others will be small, owner-operated (often part-time) and less intensively managed. Large farms will be clustered on the most productive soils in rural areas, whereas small farms will tend to be located near urban areas where non-farm income can be obtained. Prospects for Neotropical migrants on large, intensively managed farms will be poor because monoculture would be carried out in large, homogeneous fields with the aid of extensive chemical use. But prospects for migrants on small farms might be good, because operators of small farms would likely maximize profits by minimizing purchased inputs (i.e., machinery, fuel, inorganic fertilizer and pesticides) and diversifying farm production to include a variety of crop and animal products (National Research Council 1989, Van Dyne et al. 1992). Smaller field sizes, greater within-field plant and arthropod diversity, and enhanced landscape diversity will result. Together, these changes in practices and landscapes envisioned for small farms might benefit reproduction and survival of birds (Papendick et al. 1986, Robinson 1991). The extent of benefit, however, would depend on the relative areas of the two farming types and their spatial interspersion.

The changes projected for small farms are those being developed by LISA programs (Keeney 1989, National Research Council 1989). These systems differ from conventional agriculture in placing greater emphasis on retention of soil and soil nutrients, diversification of crops produced, management of crop and soil microclimate (National Research Council 1989, Edwards et al. 1990) and maximization of biological control of crop pests (weeds, pathogens and plant-feeding arthropods) by using integrated pest management (IPM) systems. Practices used to achieve these ends include establishing permanent cover on highly erodible land, reducing the frequency and intensity of tillage, including cover crops or green manures in production systems, rotating crops in multi-year cycles (Parr et al. 1990) and various forms of polyculture including agroforestry (Garrett 1991). Livestock may increasingly become a part of these production systems because it increases the on-farm use of forages included in crop rotations for weed control and maintenance of soil fertility (Benbrook 1990). Production of livestock will probably benefit migratory birds through enhanced arthropod abundances on manure-fertilized soils (O'Connor and Shrubb 1986, Rogers and Freemark 1991). Establishment of native prairie grasses as forage crops would likely increase the value of pasture and hayfields for wildlife, because of the nesting cover provided and because these warm-season forage crops are mowed or grazed later in the avian breeding season than cool-season forage crops such as alfalfa (e.g., George et al. 1979). Agroforestry provides opportunities to enhance the amount of wooded vegetation in farmland, to greatly increase farmland diversity and to contribute to crop production and farm profit (Wilson and Diver 1991).

The adoption of integrated pest management (IPM) procedures would probably result in increased food abundance for Neotropical migrants, because within-field diversity and abundance of plant and arthropod species would be enhanced by control based on "economic thresholds" (Luna and House 1990). According to IPM, pest populations (plant and animal) are monitored closely, and pesticides are only used when pest populations threaten to reduce crop yield, and hence, cause economically important damage. Perhaps most important for migrants, management of uncultivated habitats will become a central part of pest management planning in IPM. For example, uncultivated strips of perennial vegetation might be established within crop fields, or field borders might be widened for pest management purposes (Thomas et al. 1991, El Titi and Landes 1990, Rodenhouse et al. 1992). Such uncultivated habitats enhance populations of arthropods within croplands, and they effectively reduce field size (Price 1976). Reduced field size would increase the amount of cropland suitable for use by migrants when nesting or migrating (Best et al. 1990). Wider field borders may reduce rates of nest predation, particularly when complex vegetation structure is allowed to develop within field borders (Gates and Gysel 1978, Angelstam 1986, Johnson and Temple 1990). Including birds in IPM research and planning would greatly raise awareness of potential contributions of Neotropical migrant bird species to agriculture. Ongoing negative impacts of chemical pesticides on migrant reproduction and survival also would be reduced by using IPM, because lesser amounts of toxic chemicals would be used (Luna and House 1990).

Trends in agriculture strongly suggest continued use of agricultural chemicals (e.g., inorganic fertilizers and pesticides; Brady 1982), even if application rates are lowered by use of IPM techniques. Application rates of inorganic fertilizers may fall as a result of better monitoring of available nutrients and use of crop rotations including legumes (Jarrell 1990). The amount of pesticide applied will also continue to fall as applications become more highly targeted in space and time (Andow and Rosset 1990). For example, herbicide applications can be confined to bands along crop rows, and broadcast spraying of field margins and border vegetation may become less common (Sotherton 1991). Whether these changes in chemical use will benefit wildlife is currently being investigated (Kendall 1992).

Implementation of sustainable production practices projected for small farms could be profitably employed by large farms as well (National Research Council 1989) to benefit Neotropical migrants. But development of these methods has just begun, and additional research investigating the long-term profitability of low input sustainable agriculture will be required to gain widespread acceptance (Madden and Dobbs 1990). Long-term farm programs such as CRP are needed because they allow opportunities for creative research of bird responses to farm management, as well as time for monitoring and adjusting management to benefit migrants and agriculture (Hays et al. 1989). Because of costs of research, training, and transition to sustainable farming systems, agricultural policy will play a key role in development and implementation of sustainable agriculture (O'Connell 1990).

MANAGEMENT RECOMMENDATIONS AND RESEARCH NEEDS

The potential impact of changes in agriculture on populations of Neotropical migrants is great because a large number of Neotropical migrant species are associated with farmland and vast areas of North America are farmed (397.6 million hectares are farmland in the contiguous 48 states, USDA 1992; and 67.8 million hectares are in Canada, Freemark and Boutin 1992). Furthermore, most cultivated land is devoted to few crops, and these are produced using methods that differ surprisingly little among most farm operators. Thus, relatively few changes in management might be both widely accepted and have broad impact on Neotropical migrants. The key to acceptance is that management recommendations do not reduce, and preferably enhance, farm profits. Such recommendations can be developed when research on migrants and other farmland wildlife are included as an integral part of interdisciplinary research on agricultural production systems and when this research considers farmland structure as well as agricultural practices. Developing such recommendations, however, is greatly hindered by the paucity of current knowledge about the ecology of Neotropical migrants in farmland and by rapid change in agriculture. Avian ecologists will have the greatest impact on the direction of changes in agriculture when they work with interdisciplinary teams developing farm management systems.

Highest research priority should be placed on determining the dynamics of Neotropical migrants in farmland (Robinson 1992b, Warner 1992a). Very likely, this will include identifying habitat features, agricultural practices, and farmland structures that may create and maintain population sources and/or sinks. Studies of the annual breeding productivity and survival of migrants nesting in fields and edges are few, and potential source areas that should be protected or expanded have not yet been identified. Because of the current paucity of information, special emphasis should be placed on determining the effects of agricultural practices on the abundance and activities of nest predators in farmland. Intensive study of mechanisms causing population change would be complemented by monitoring abundances of Neotropical migrants in farmland and farmland features (e.g., fencerows), and by developing spatially-explicit computer models to simulate population dynamics of migrants (Freemark et al. this proceedings). Documenting the dynamics of Neotropical migrants in farmland will require adequately replicated research on large spatial scales, but this research is essential for developing management plans that will aid migrant populations.

We propose in this section general management recommendations for the conservation of Neotropical migrants that use farmland. These recommendations are grouped into two categories: those that focus on agricultural practices and those that address farmland structure. Agricultural practices influence the local reproduction and survival of migrants that obtain food, shelter, and nesting sites within farmland. Recommendations for farmland structure are proposed because the presence of suitable habitat features largely determines the presence of migrant species.

It is important to note that the purpose of these management recommendations is to identify agricultural practices and farmland structures that will favor Neotropical migrant landbirds. Assessment of the economic impact of implementing these practices is not considered in detail in this paper, but recent reports (National Research Council 1989, Batie and Taylor 1989, Dobbs and Cole 1992, Van Dyne et al. 1992) have supported the economic viability of some sustainable agricultural systems that incorporate a number of these recommendation. The economic viability of other recommendations such as crop residue management (e.g., Weersink et al. 1992) and IPM have been evaluated elsewhere (reviewed by National Research Council 1989). However, additional research is needed before a full assessment of the impacts of these recommendation on farm profitability can be made.

Agricultural Practices

1. Crop residue should be retained on the soil surface. Residue sustains populations of arthropods that are food for migrants, and it will provide cover for foraging or breeding birds.
2. Integrated pest management (IPM) should be used for management of pest weeds and arthropods. IPM will reduce destruction of non-target arthropods that are food for many migrants and minimize exposure of migrants to harmful chemicals.
3. The number of field operations that destroy nests should be minimized, and methods that destroy fewest nests (e.g., subsurface tillage) should be used where possible. In hayfields, spring mowing should be delayed as long as possible, nighttime mowing avoided, and mowings should be spaced as widely as possible in time to allow greatest probability of successful nesting.
4. Inorganic fertilizers should be applied only based on measured soil requirements because their excessive use can harm soil organisms that are food for some migrants.
5. Uncultivated areas such as fencerows or grassed waterways should neither be sprayed with herbicide nor mowed wherever possible. Necessary field operations such as thinning woody plant growth in fencerows or mowing grassed waterways should be carried out either before or after the avian breeding season to prevent destruction of nests.

Farmland Structure

1. Uncultivated edge or its ecological equivalent should be preserved and allowed to develop complex vegetation structure. Complex strip vegetation is used in numerous ways by migrant species, but such strip cover also reduces soil erosion and movement of agricultural chemicals off fields. Alley cropping, including strips of trees between rowcrops, might achieve these objectives and also retain more land area in crop production.
2. Farmland diversity should be maintained or enhanced. This can be done in several ways.
   a. Unmowed grassed strips could be maintained within fields for grassland birds that do not nest near edges. Grassed strips would also be refuges for arthropods, and hence, food sources for migrants.
   b. Crop diversity could be increased by adding to the number of crops rotated.
   c. Field sizes could be reduced by using land removed from production, e.g., CRP land could be allocated to strip cover within fields or along field edges to reduce field sizes.
   d. Actual or potential wetlands could be preserved and protected by encircling them with broad buffer zones of natural vegetation.

Agricultural Policy and Extension

The favorability of farmland for Neotropical migrants will depend on farmer attitudes and involvement (Nassauer and Westmacott 1987). Farmer cooperation will be strongly influenced by agricultural policy and education of farmers through various forms of outreach (Kurzejeski et al. 1992). Agricultural policy determines compliance with conservation regulations, sets funding levels for research and farmer education about advances in agriculture and strongly influences land use through programs such as the CRP. Education of both farmers and policy makers about the importance of farmland in sustaining populations of migratory birds will raise awareness of this consideration among farmers when making land-use decisions or among policy makers when assessing potential impacts of policy implementation (Jahn and Schenck 1990). Because both agricultural practices and farmland structure are strongly influenced by agricultural policy, successful conservation programs for Neotropical migrants in agriculture will necessarily begin with policy decisions that foster agricultural practices and farmland structures that favor migrant reproduction and survival.

Much more needs to be done to facilitate dissemination of information about the effects of agriculture on Neotropical migrants and other wildlife. Studies that evaluate the effects of agricultural practices or farmland structure on migratory birds are of little value in effecting land-use changes if their results are only reported in technical journals. Few, if any, farm operators read such literature; thus, technical information must be converted to a form or format that is both readable and accessible to the audience actually responsible for farmland management. Several forms of outreach have proven effective in communicating new research findings and other technical information. Perhaps the most frequently used is the USDA Extension Service which provides publications and employs specialists trained in information transfer and education of general audiences (Sauer 1990). Also effective are workshops and demonstration farms which provide hands-on exposure to new and alternative land-management methods. In our view, conservation of Neotropical migrants in farmland will be most effectively promoted when those who have knowledge of the effects of agriculture on Neotropical migrants play an active role in shaping contemporary and future agriculture.

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APPENDIX

Common name	Scientific name	Migratory status[1]	Number of significant crop associations[2]	Consumes grains[3]
American Goldfinch	*Carduelis tristis*	B	5	Yes
American Kestrel	*Falco sparverius*	B	7	No
American Robin	*Turdus migratorius*	B	3	No
Baird's Sparrow	*Ammodramus bairdii*	A	3	Yes
Barn Swallow	*Hirundo rustica*	A	10	No
Bobolink	*Dolichonyx oryzivorus*	A	8	Yes
Brewer's Blackbird	*Euphagus cyanocephalus*	B	8	Yes
Bronzed Cowbird	*Molothrus aeneus*	C	1	Yes
Brown-headed Cowbird	*Molothrus ater*	B	9	Yes
Chestnut-collared Longspur	*Calcarius ornatus*	B	7	Yes
Chipping Sparrow	*Spizella passerina*	A	6	Yes
Common Nighthawk	*Chordeiles minor*	A	14	No
Common Yellowthroat	*Geothlypis trichas*	A	6	No
Dickcissel	*Spiza americana*	A	10	Yes
Eastern Bluebird	*Sialia sialis*	B	10	No
Eastern Kingbird	*Tyrannus tyrannus*	A	12	No
Eastern Meadowlark	*Sturnella magna*	B	17	Yes
Eastern Phoebe	*Sayornis phoebe*	B	7	No
Ferruginous Hawk	*Buteo regalis*	B	3	No
Grasshopper Sparrow	*Ammodrammus savannarum*	A	16	Yes
Gray Catbird	*Dumetella carolinensis*	A	2	No
Horned Lark	*Ermophila alpestris*	B	12	Yes
House Wren	*Troglodytes aedon*	A	9	No
Indigo Bunting	*Passerina cyanea*	A	9	Yes
Killdeer	*Charadrius vociferus*	B	14	No
Lark Bunting	*Calmospiza melanocorys*	A	8	Yes
Lazuli Bunting	*Passerina amoena*	A	6	Yes
Lesser Nighthawk	*Chordeiles acutinennis*	A	0	No
Loggerhead Shrike	*Lanius ludovicianus*	B	8	No
Long-billed Curlew	*Numenius americanus*	A	5	No
McCown's Longspur	*Calcarius mccownii*	B	1	Yes
Mississippi Kite	*Ictinia mississippiensis*	A	3	No
Mourning Dove	*Zenaida macroura*	B	10	Yes
Northern Mockingbird	*Mimus polyglottos*	B	5	No
Prairie Falcon	*Falco mexicanus*	B	1	No
Purple Finch	*Carpodacus purpureus*	B	9	Yes
Red-tailed Hawk	*Buteo jamaicensis*	B	4	No
Red-winged Blackbird	*Agelaius phoeniceus*	B	13	Yes
Savannah Sparrow	*Passerculus sandwichensis*	B	8	Yes
Say's Phoebe	*Sayornis saya*	B	7	No
Short-eared Owl	*Asio flammeus*	B	2	No
Song Sparrow	*Melospiza melodia*	B	8	Yes
Swainson's Hawk	*Buteo swainsoni*	A	9	No
Turkey Vulture	*Cathartes aura*	B	6	No
Vesper Sparrow	*Pooecetes gramineus*	B	12	Yes
Water Pipit	*Anthus spinoletta*	B	0	No
Western Bluebird	*Sialia mexicana*	B	4	No
Western Kingbird	*Tyrannus verticalis*	A	10	No
Western Meadowlark	*Sturnella neglecta*	B	9	Yes
White-eyed Vireo	*Vireo flavifrons*	A	8	No
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	A	11	Yes
Yellow Warbler	*Dendroica petechia*	A	5	No

[1] Migratory status: A, includes species that breed in North America and spend their nonbreeding period south of the United States; B, includes species that breed and winter in North America, but some populations winter south of the United states; C includes species that breed primarily south of the United States but their ranges extend north of the U. S. border (Gauthreaux 1992).

[2] Number of statistically significant associations at the county level between breeding bird Survey abundances and the proportion of county area planted to one of 22 major crop types or in the Conservation Reserve Program; see text for details.

[3] Indicates species that consume crop grains or weed seeds; crop grains may be consumed as waste grain. The primary source of information about bird diets was Martin et al. (1961).