

4. CORN

In North America, corn (*Zea mays*) is undoubtedly among those row crops of most value to waterbirds. Most corn production in the U.S. occurs in the “Corn Belt” (Figure 4-1), where six states (Iowa, Illinois, Nebraska, Minnesota, Indiana, and Ohio) account for approximately 80% of the national production (Acquaah 2005). Although this region coincides with the wintering ranges, migratory pathways, and breeding grounds of a number of waterbird species, corn fields are used primarily by geese and blackbirds during nonbreeding periods. Terrestrial invertebrates available in corn fields may be an important resource for some shorebirds and landbirds, but corn kernels are by far the primary resource sought after by most waterbirds. High in caloric value, waste or ripening corn accounts for the majority of the diets of geese, cranes, and blackbirds that forage in corn fields throughout North America. A number of researchers contend that in regions where wetland habitat has been lost and natural food resources compromised, availability of waste corn has become increasingly important to the survival and reproductive condition of waterfowl and cranes (McLandress and Raveling 1981, Baldassarre and Bolen 1984, Krapu et al. 1995, Krapu et al. 2004). Krapu et al. (1995) even suggest that present-day geese arrive on Arctic breeding grounds in better physiological condition (greater and less variable fat reserves) than did geese prior to modern corn agriculture. This chapter summarizes the state of current knowledge regarding the occurrence and abundance of waterbird species in corn fields, important corn resources for waterbirds, how waterbirds use corn fields, and the impacts of corn production practices, other management activities, and landscape features of corn fields on waterbirds.

USE BY WATERBIRDS

Documented use of cornfield habitats by waterbirds comes both from Europe and North America. In North America, the primary regions where corn is grown (Krapu et al. 2004), and for which there is documentation of cornfield use by waterbirds, include the seven WWL focal BCRs (in bold throughout text) - **Prairie Potholes** (BCR 11), **Prairie Hardwood Transition** (BCR 23), **Eastern Tallgrass Prairie** (BCR 22), **Central Mixed-Grass Prairie** (BCR 19), **Shortgrass Prairie** (BCR 18), **Central Hardwoods** (BCR 24), and **Mississippi Alluvial Valley** (BCR 26) - as well as areas of southeastern Canada (southern Ontario and Quebec, Canada: BCR 12, BCR 13), the eastern U.S. (BCRs 27-30), the southeastern U.S. (BCR 27, 31), southwestern British Columbia (BCR 5), the Gulf of Mexico Coast (BCR 37), southwestern North America (southwestern U.S. and northern Mexico: BCR 33, BCR 34, BCR 35, BCR 36), and the western U.S. (Great Basin BCR 9; California BCR 32).

In North America, corn fields are used by a moderately diverse group of birds, primarily waterfowl, but also cranes, shorebirds, and some WWL landbirds (mostly blackbirds). One study in southern Quebec documented 90 bird species in cornfield habitats during migration and breeding, of which 23 were WWL species (Kirk et al. 2001). In documenting use of corn fields by waterbirds, we considered cornfield habitats to include field interiors as well as edge habitats (hedgerows, buffer strips, terraces; Boutin et al. 1999a, b), but species that exclusively use cornfield edges are not included here. Most species use cornfield habitats for foraging during nonbreeding periods, and few species use cornfield habitats for nesting. Overall, 45 species of waterbirds (all WWL species except Cackling Goose, which was split from Canada Goose after the project began; G. Butcher, pers. comm.) have been observed using cornfield habitats in North

America. Of these, 11 are considered to be “Conservation Priority Species” by the National Audubon Society - listed under the Endangered Species Act, on the Audubon WatchList, USFWS Birds of Conservation Concern, and/or exhibiting significant population declines according to Christmas Bird Count or Breeding Bird Survey data. Table 4-1 summarizes the occurrence of species in corn for all of North America, and within focal BCRs for the WWL project. BCR regional species lists - species considered relatively abundant in each BCR (see Introduction) - are also shown.

Waterfowl

Corn is an important food source for wintering geese in Europe (Farago 1994). In North America, various waterfowl species including geese, swans, and dabbling ducks have been commonly observed in corn fields, primarily during nonbreeding periods. Available literature indicates that at least 14 species of waterfowl (2 whistling-ducks, 1 swan, 5 geese, 6 dabbling ducks) use corn fields in winter, spring or fall migrations (Table 4-1), and sometimes in large numbers. Two of these species – American Black Duck and Northern Pintail – are Conservation Priority Species. Waterfowl have been documented in corn fields at northern latitudes of North America primarily during migration and during the breeding season, at mid latitudes during both migratory periods and winter, and at southern latitudes during winter months only. Most of the information pertaining to use of corn fields by waterfowl concerns diet and foraging ecology, and few researchers have presented data on species’ abundance and density in corn fields. From the few studies that have documented abundances, however, it appears that all waterfowl species, especially geese, can reach abundances of hundreds to thousands of birds in individual fields (Winner 1959, Nagel 1965, Harvey et al. 1988, Petrie et al. 2002).

In southeastern Canada (BCR 13), five species (Tundra Swan, Canada Goose, Snow Goose, American Black Duck, Mallard) have been observed foraging in corn fields during either spring or fall migrations (Reed et al. 1977, Giroux and Bergeron 1996, Kirk et al. 2001, Petrie et al. 2002, Bechet et al. 2004). In the **Prairie Potholes** region (BCR 11), Snow Geese, Canada Geese, and Mallards forage in corn fields during spring migration (Gregoire and Ankney 1990, Alisauskas and Ankney 1992, Linz et al. 2002), and corn becomes especially important in the diet of spring-migrating Snow Geese as birds move northward (Alisauskas and Ankney 1992). In Wisconsin (**Prairie Hardwood Transition**; BCR 23), spring migrant Tundra Swans have been observed foraging in corn fields (Thompson and Lyons 1964), and Craven and Hunt (1984) and Gates et al. (2001) found that corn was the crop most commonly ingested by Canada Geese during fall and spring migrations through the state.

In the **Eastern Tallgrass Prairie** region (BCR 22), Snow Geese rely heavily on corn habitat in Iowa, Missouri, Nebraska and Kansas during winter and spring/fall migrations (Frederick and Klaas 1982, Alisauskas 1988, Davis et al. 1989, Gregoire and Ankney 1990, Alisauskas 1998), and Canada Geese commonly forage in Illinois corn fields during fall (Jarvis 1976, Havera 1998) and in Missouri corn fields in winter (Kahl and Samson 1984, Eggeman et al. 1989). In Ohio, fall migrating and wintering American Black Ducks and Mallards (flocks of 100s-1000s) commonly travel to corn fields from nearby water bodies to forage on corn (Winner 1959), and fall migrant Mallards use corn fields in Illinois (Anderson 1959, Bellrose et al. 1979). Fall migrant American Wigeon have been observed in corn fields of Illinois (Havera 1998). In the **Central Hardwoods** region (BCR 24), Canada Geese commonly forage in corn fields of

southern Illinois in fall and winter (Goodman and Fisher 1962, Raveling et al. 1972, Paine and Tacha 1987, Gates et al. 2001). In Nebraska (**Central Mixed-Grass Prairie**; BCR 19), wintering Mallards frequent corn stubble fields (Jorde et al. 1984), and corn is an important component of the diet of spring migrating Greater White-fronted Geese (Krapu et al. 1995). In Texas (**Shortgrass Prairie**; BCR 18), migrating and wintering Mallard, Northern Pintail, Green-winged Teal, Blue-winged Teal, and American Wigeon make daily foraging flights from permanent playas to nearby corn fields (Sell 1979, Moore 1980, Baldassarre and Bolen 1984, Sheeley and Smith 1989). In Arkansas (**Mississippi Alluvial Valley**; BCR 26), Mallards have been observed foraging in corn fields during winter (Wright 1959).

In the eastern U.S. (BCRs 27, 28, 30), several waterfowl species (Tundra Swan, Canada Goose, Snow Goose, American Black Duck) commonly use corn fields in winter (Schwalbe and Schwalbe 1974, Munro 1981, Bortner 1985, Harvey et al. 1988, Malecki et al. 1988, Earnst 1992, Hill and Frederick 1997), with Canada Goose flocks observed in the 100s-1000s (Harvey et al. 1988). Farther south in the southeastern U.S. (BCR 27), American Black Ducks forage in Tennessee corn fields during fall and winter (Byrd 1991). In northwestern British Columbia (BCR 5), Mallard and American Wigeon have been observed foraging in corn fields of coastal agricultural land during fall migration and through winter (Hirst and Easthope 1981, Baldwin and Lovvorn 1994a, Baldwin and Lovvorn 1994b, Lovvorn and Baldwin 1996). In southwestern North America, wintering Black-bellied and Fulvous Whistling-Ducks are common in corn fields in northwestern Mexico (BCRs 33 and 34) (Lawrence 1874, Kramer and Euliss 1986), and wintering Snow, Ross's, and Greater White-fronted Geese are abundant in corn fields in New Mexico (BCR 35) and throughout northern Mexico (BCRs 33, 34, 35, 36) (Taylor and Kirby 1990, Leyva-Espinosa 1993, Ely and Dzubin 1994, Kitchell et al. 1999, Drewien et al. 2003). In the western U.S., Tundra Swans have been observed feeding in corn fields in Utah (BCR 9) during severely cold spring weather (as many as 500-600 in a single field; Nagel 1965), and Tundra Swans (Tate and Tate 1966, Paullin 1996), Greater White-fronted Geese (Ely and Dzubin 1994), "Aleutian" Cackling Geese (Stabins et al. 2002), and Northern Pintail (Miller 1985) are among the common waterfowl feeding in California (BCR 32) corn fields during fall and/or winter.

Six waterfowl species have been documented using corn fields and associated habitats (field edges) during the breeding season (Table 4-1). Researchers have not confirmed nesting by any of these species in corn fields, but the species' presence suggests that they at least use corn fields for feeding, if not for nesting. In cornfield interiors and edges in southern Ontario (BCR 13), Canada Geese are commonly observed in low numbers (at least tens, probably larger numbers), and American Black Duck, Mallard and Blue-winged Teal are present but uncommon during the breeding season (Boutin et al. 1999a, Kirk et al. 2001). In North Dakota, (**Prairie Potholes**; BCR 11), female Mallards and Northern Pintails have been observed consuming limited amounts of corn (among other plant seeds) during the post-laying period (Krapu 1974, Swanson et al. 1985). In southern Texas along the Gulf Coast (BCR 37), Black-bellied Whistling-Ducks have been known to consume minimal amounts of corn during the breeding period (Bolen and Forsyth 1967).

Shorebirds

Shorebirds have been documented wintering in corn fields in Europe, and at northern and mid latitudes of North America primarily during migrations and the breeding season. In France, wintering Eurasian Woodcock (*Scolopax rusticola*) have been observed foraging nocturnally in corn stubble, feeding mainly on earthworms (Duriez et al. 2005). Ten shorebird species have been documented using North American corn fields during winter/migration, and three during the breeding season (Table 4-1). Six of these shorebirds (American Golden-Plover, Mountain Plover, Lesser Yellowlegs, Buff-breasted Sandpiper, Upland Sandpiper, and American Woodcock) are considered Conservation Priority Species by the WWL project. Many of the species that occur in corn fields are typically associated with terrestrial habitats, especially the plovers, Upland Sandpiper, and American Woodcock.

Shorebirds are somewhat occasional visitors to corn fields in various locations during migration and winter. In southern Ontario (BCR 13), Black-bellied Plover, Killdeer, Lesser Yellowlegs (rare), Spotted Sandpiper (rare), Pectoral Sandpiper (rare), Upland Sandpiper (rare), and American Woodcock have been observed foraging in corn fields and edge habitats during fall migration, with Killdeer the most abundant species (Boutin et al. 1999a, Kirk et al. 2001). In the **Prairie Potholes** region (BCR 11), Killdeer and Wilson's Snipe have been observed foraging in corn fields of South Dakota in March and April (Linz et al. 2001). In the **Eastern Tallgrass Prairie** region (BCR 22), American Golden-Plover flocks in the hundreds frequent corn stubble fields in spring (April) migration in northern Indiana (Braile 1999), and spring migrant Buff-breasted Sandpipers commonly forage in wet corn stubble fields in the Rainwater Basin of Nebraska (J.G. Jorgenson, unpubl. data). In southern Indiana (**Central Hardwoods**; BCR 24), incidental winter use of harvested corn fields by foraging Killdeer is fairly common (Castrale and Speer 1984a, 1984b, 1984c, 1984d, 1984e, Castrale 1985). In the eastern U.S., radio-marked wintering American Woodcock have been observed foraging at night in corn fields in coastal Georgia and Virginia (BCRs 27 and 30, respectively) (Krementz et al. 1995). Near Guadalajara, Mexico, migrant Upland Sandpipers have been observed foraging in corn fields in agricultural areas (Houston and Bowen 2001).

A few shorebird species also occur in corn habitats in low numbers during the breeding season. Killdeer are certainly most common, and appear to forage and/or nest in corn fields in most places where their range and that of corn co-occur. In southeastern Canada (BCR 13), Killdeer have been documented foraging in corn fields and sometimes cornfield edges during the breeding season (Jobin et al. 1998, Boutin et al. 1999a, Boutin et al. 1999b, Kirk et al. 2001), and they have been observed exhibiting territorial behaviors and thus are presumably a cornfield nesting species in this region (Boutin et al. 1999b). In the **Prairie Hardwood Transition** region (BCR 23), Renfrew and Ribic (2001) confirmed nesting by Killdeer in field interiors. In the **Eastern Tallgrass Prairie** region (BCR 22), Killdeer are commonly observed foraging and nesting in corn fields of Iowa and Ohio (Dambach and Good 1940, Good and Dambach 1943, Guth 1969, Gremaud 1983, Basore et al. 1986, Best 1986, Best 2001, Hultquist and Best 2001). In Indiana (**Central Hardwoods**; BCR 24), Killdeer commonly occur in tilled corn fields (Castrale 1985). In the **Central Mixed-Grass Prairie** region (BCR 19), Killdeer forage and potentially nest in newly planted corn fields (Ducey and Miller 1980, Beecher et al. 2002), with documented mean densities of up to 21 ± 10 (SE) birds/km² (Beecher et al. 2002). Finally, in the

Shortgrass Prairie region (BCR 18), Killdeer have been observed foraging and resting in newly planted corn fields (Sterner et al. 2003).

In the **Central Mixed-Grass Prairie** region (BCR 19), Upland Sandpipers forage and potentially nest in corn fields before corn crop emergence (Ducey and Miller 1980, Beecher et al. 2002), with documented mean densities of up 11 ± 7 (SE) birds/km² (Beecher et al. 2002). In the **Shortgrass Prairie** region (BCR 18), Mountain Plover have been observed foraging and resting in newly planted corn fields during the breeding season in Colorado (Sterner et al. 2003), and two out of 52 Mountain Plover nests found in Colorado, Kansas and Oklahoma were found in sprouting corn (Shackford et al. 1999).

Wading Birds

Only three wading bird (Ciconiiformes) species have been documented using corn fields in North America. Great Blue Heron and Black-crowned Night-Heron have been observed in low numbers in corn fields and cornfield edges during fall migration in southern Ontario (BCR 13) (Boutin et al. 1999a, Kirk et al. 2001), and wintering White-faced Ibis occasionally forage in corn fields in Nevada (BCR 9) (Bray 1986, Bray and Klebenow 1988). There are no documented cases of wading birds using corn fields as foraging or nesting habitat during the breeding season.

Other Waterbirds

Among other waterbirds (orders Pelecaniformes, Gaviiformes, Podicipediformes, Gruiformes, and Charadriiformes), cranes, rails, and gulls are the only groups with a documented association with corn habitats. Corn fields appear to be of most value to nonbreeding cranes. In Europe, large numbers of Common Cranes commonly forage in corn fields in winter and during migration (Guzman et al. 1999, Vegvari 2002). In North America, corn is an important resource for both Sandhill and Whooping Cranes (both Conservation Priority Species). Sandhill Cranes commonly forage in corn fields in spring, summer and especially after the fall harvest in southern Wisconsin and Michigan (**Prairie Hardwood Transition**; BCR 23) (Hoffman 1976, Melvin 1978, Walkinshaw 1985). In Nebraska (**Central Mixed-Grass Prairie**; BCR 19), corn fields appear to be extremely valuable habitat to thousands of spring migrating Sandhill Cranes (Walkinshaw 1956, Lewis 1979, USFWS 1981, Iverson et al. 1982, Krapu et al. 1984, Krapu et al. 1985, Reinecke et al. 1989, Folk and Tacha 1991, Davis 2003). Davis (2003) estimated that 42-55% of between 120,000–280,000 cranes (range of yearly peak numbers) annually forage on waste corn in the region. In the **Eastern Tallgrass Prairie** region (BCR 22), 100s to 1000s of Sandhill Cranes have been observed during spring and fall migrations foraging in individual corn fields in Indiana, and observations suggest birds select habitat in greater proportion than its availability in both seasons (Lovvorn and Kirkpatrick 1982a, 1982b). In the southeastern U.S., Sandhill Cranes forage in corn fields in southeastern Mississippi (BCR 27) in fall and winter (Valentine 1981) and in Florida (BCR 31) during winter and spring (Wenner and Nesbitt 1987, Nesbitt and Williams 1990). In southwestern and western North America, wintering Sandhill Cranes are commonly observed in corn stubble in Arizona (BCR 34) (Perkins and Brown 1981), New Mexico (BCR 35) (Walker and Schemnitz 1987), and California (C. Elphick, pers. obs.). Finally, the federally endangered Whooping Crane has been documented foraging in New Mexico corn fields during fall, winter, and spring (Lewis 1995).

In Iowa (**Prairie Potholes**, BCR 11 and **Eastern Tallgrass Prairie**, BCR 22), Virginia Rail have been observed with broods in corn field habitat during the post-breeding period (Johnson and Dinsmore 1985). Ring-billed Gulls have been observed in corn fields in southern Ontario (BCR 13) during fall migration and summer, although in low numbers (Jobin et al. 1998, Kirk et al. 2001), and several species of gulls will roost and feed in corn fields elsewhere (C. Elphick, pers. obs.).

Landbirds

Many landbird species have been documented using corn fields and their associated habitats in North America. Raptors, Mourning Dove, swallows, corvids, certain wrens, American Robin, certain warblers, sparrows, icterids, finches, and introduced European Starlings and House Sparrows account for most of the documented landbirds reported in corn fields. Except for swallows which typically forage aerially on insects over the corn crop (Boutin et al. 1999a), most of these landbirds forage on the ground or on resources found on corn stalks. A total of 13 WWL landbird species have been documented in corn fields, primarily at northern latitudes of North America (Table 4-1). All species have been documented using corn fields during the nonbreeding season, and nine species during the breeding season. Of these, only Rusty Blackbird is on the WWL conservation priority list. In southern Ontario (BCR 13), four WWL landbird species (Purple Martin, Bank Swallow, Swamp Sparrow, Red-winged Blackbird) regularly forage in corn fields and cornfield edges during fall migration, with Red-winged Blackbirds often occurring in flocks of several thousand birds (Tyler and Kannenberg 1980, Gartshore et al. 1982, McNicol et al. 1982, Boutin et al. 1999a, Boutin et al. 1999b, Kirk et al. 2001). An additional seven species have been documented during fall in low numbers in southern Ontario corn fields (Tree Swallow, Northern Rough-winged Swallow, Palm Warbler, Northern Waterthrush, Common Yellowthroat, Lincoln's Sparrow, Rusty Blackbird) (Boutin et al. 1999a, Boutin et al. 1999b, Kirk et al. 2001). In the **Central Hardwoods** region (BCR 24), corn was prevalent in the stomach contents of wintering Red-winged Blackbirds, and minimally present in the diet of Rusty Blackbirds (Robertson et al. 1978). In the eastern U.S., fall migrant Red-winged Blackbirds forage in corn fields in New York (BCR 28), and wintering Swamp Sparrows have been reported in corn fields in Maryland (BCR 29) (Woodward 1979). In the southeastern U.S. (BCR 27), Red-winged Blackbirds forage heavily in Tennessee corn fields in fall and winter (Dolbeer et al. 1978), Boat-tailed Grackle commonly consume corn during fall and winter in Florida (Haag et al. 1987), and wintering Swamp Sparrows have been observed foraging in corn fields and field borders in North Carolina (Marcus et al. 2000).

Many WWL landbird species use cornfield habitats during the breeding season, but like shorebirds, they tend to occur in low numbers. In southeastern Canada (BCR 12, BCR 13), four WWL landbird species (Tree Swallow, Bank Swallow, Common Yellowthroat, Red-winged Blackbird) regularly occur in corn fields and are associated with edge habitats during the breeding/post-breeding season. Cornfield nesting by Red-winged Blackbirds also has been commonly observed (Bird and Smith 1964, Hintz and Dyer 1970, Jobin et al. 1998, Boutin et al. 1999a, Boutin et al. 1999b, Kirk et al. 2001). An additional three WWL species (Purple Martin, Northern Rough-winged Swallow, Swamp Sparrow) have been observed more rarely in corn fields and edge habitats of this region during the breeding season (Boutin et al. 1999a, Kirk et al. 2001). In the Dakotas and Manitoba (**Prairie Potholes**; BCR 11), Red-winged and Yellow-headed Blackbirds frequent corn fields from spring through fall (Bird and Smith 1964, DeGrazio

et al. 1971, Mott et al. 1972, Linz et al. 1984, Bruggers et al. 1986, Twedt and Crawford 1995). Throughout the **Eastern Tallgrass Prairie** region (BCR 22), Common Yellowthroats and Red-winged Blackbirds are common species observed both foraging and nesting in corn fields and edge terraces in Kansas, Iowa, Indiana, and Ohio (Dambach and Leedy 1948, Stickley et al. 1972, Zimmerman and Tatschl 1975, Stehn and deBecker 1982, Gremaud 1983, Basore et al. 1986, Bernhardt et al. 1987, Best 2001, Blackwell and Dolbeer 2001, Hultquist and Best 2001), and Purple Martins have been documented foraging over corn fields in Illinois (Graber et al. 1972). In the eastern U.S., Red-winged Blackbirds commonly forage in corn fields during spring, summer, and post-breeding periods in New York (BCR 28) and Virginia (BCR 29) (Ingram et al. 1973, Stone et al. 1984, Dolbeer et al. 1995), and Rusty Blackbirds have been observed foraging on ripening corn in Massachusetts (BCR 30) during the post-breeding period (Brewster 1906). In the **Central Mixed-Grass Prairie** region (BCR 19), Beecher et al. (2002) observed Red-winged Blackbirds and Northern Rough-winged Swallows in Nebraska corn fields at mean densities of up to 41 ± 10 (SE) birds/km² (blackbirds) and 21 ± 10 birds/km² (swallows).

RESOURCES

Corn fields provide valuable foraging resources for some waterbirds, primarily granivorous and grazing species during nonbreeding periods. Corn fields are also used for nesting by a few waterbird species. Here we review what is known about the abundance, availability, consumption and use of these resources by waterbirds in North America.

Foraging Resources

Corn fields provide foraging resources to many waterbirds, primarily during the nonbreeding season, but also to some species during the breeding season. The resources available to foraging waterbirds include corn kernels (either as waste corn or from live corn ears), sprouting vegetation from corn seeds, and terrestrial invertebrate prey (including corn crop pests).

Corn Kernels

Corn kernels appear to be an important food resource for many waterbirds, primarily for waterfowl during nonbreeding seasons. Waterbirds acquire corn either from the live ears of standing stalks or more commonly from the ground where loose kernels and ears are left in fields after harvest (waste corn). Although there are some accounts of geese foraging in standing corn (Reed et al. 1977, Harvey et al. 1988, Hill and Frederick 1997), most researchers by far have observed waterbirds foraging on waste corn in stubble fields after harvest. New waste corn becomes available to foraging waterbirds after the fall harvest and is potentially available until the following summer's growing season. Over this period, abundance diminishes due to decay, sprouting, wildlife consumption, field plowing and growth of stalks precluding access to the soil (Best 2001).

In North America, estimates for the average amount of waste corn left after harvest typically range from 203 ± 40 (SE) to 447 ± 28 kg/ha (Dolbeer et al. 1978, Frederick and Klaas 1982, Baldassarre et al. 1983, Baldassarre and Bolen 1984, Frederick et al. 1984, Warner et al. 1985, Krapu et al. 1995). In Spain, Guzman et al. (1999) estimated similar (494 ± 89 kg/ha) amounts of waste corn in stubble fields. The initial amount of waste corn left in fields can be affected greatly by corn kernel moisture at harvest. Baldassarre et al. (1983) documented that the amount of waste corn in fields harvested at 14-21% moisture was at least twice that in fields harvested at

moisture levels greater than 22%. Additional post-harvest farming practices, such as cattle grazing, hand salvage of waste corn, disking, and plowing, may further reduce either the abundance of waste corn, or its availability to birds (Baldassarre et al. 1983). For fields that are disked and/or plowed after harvest in the fall, waste corn available on field surfaces may be reduced by as much as 77-97% (Frederick and Klaas 1982, Baldassarre et al. 1983, Baldassarre and Bolen 1984, Warner et al. 1984, Giroux and Bergeron 1996). Moreover, a current trend towards increased harvester efficiency (primarily from improved combine headers) also threatens to diminish waste corn resources, especially from waste corn ears (Krapu et al. 2004). Influences of these reductions in waste corn availability and abundance on waterbirds are further discussed under **Effect of Corn Production Methods**.

Researchers have documented waterbirds foraging on waste corn primarily in late fall, winter and during spring migration. The waterbirds that forage most heavily on waste corn include Black-bellied Whistling-Ducks in winter (Kramer and Euliss 1986); Canada Geese in fall (Craven and Hunt 1984, Paine and Tacha 1987, Havera 1998, Gates et al. 2001), winter (Kahl and Samson 1984, Paine and Tacha 1987, Harvey et al. 1988, Eggeman et al. 1989, Gates et al. 2001), and spring (Reed et al. 1977, Giroux and Bergeron 1996, Gates et al. 2001, Linz et al. 2002); Cackling Geese in fall and winter (Stabins et al. 2002); Snow Geese in fall (Frederick and Klaas 1982), winter (Alisauskas 1988, Davis et al. 1989, Hill and Frederick 1997, Kitchell et al. 1999) and spring (Davis et al. 1989, Alisauskas and Ankney 1992, Giroux and Bergeron 1996); Greater White-fronted Geese in winter (Leyva-Espinosa 1993, Ely and Dzubin 1994) and spring (Krapu et al. 1995); Tundra Swans in winter (Schwalbe and Schwalbe 1974, Tate and Tate 1966, Paullin 1996) and spring migration (Nagel 1965); dabbling ducks (American Black Duck, Mallard, Northern Pintail, Green-winged Teal, Blue-winged Teal, American Wigeon) in fall and winter (Anderson 1959, Bellrose et al. 1979, Sell 1979, Hirst and Easthope 1981, Baldassarre and Bolen 1984, Jorde et al. 1984, Baldwin and Lovvorn 1994a, Baldwin and Lovvorn 1994b, Lovvorn and Baldwin 1996, Havera 1998); Sandhill Cranes during fall migration (Hoffman 1976, Lovvorn and Kirkpatrick 1982a, Walkinshaw 1985), winter (Perkins and Brown 1981, Walker and Schemnitz 1987, Nesbitt and Williams 1990), spring migration (Hoffman 1976, Lewis 1979, Iverson et al. 1982, Davis 2003), and summer (Hoffman 1976); Red-winged Blackbirds in winter (Dolbeer et al. 1978, Williams and Jackson 1981), spring (Mott et al. 1972), summer (Bird and Smith 1964, Hintz and Dyer 1970, Mott et al. 1972, Bernhardt et al. 1987), and fall (Mott et al. 1972); Rusty Blackbirds during the post-breeding period (Brewster 1906); and Boat-tailed Grackles in fall and winter (Haag et al. 1987).

During the breeding season, corn kernels are less available and thus generally less important to the few waterbird species that breed in cornfield habitats than they are to nonbreeding waterbirds. Corn was seldom found in the diets of Northern Pintails (a Conservation Priority Species) during pre-breeding, nesting, and post-breeding periods in North Dakota (Krapu 1974). Red-winged Blackbird and Rusty Blackbird (a Conservation Priority Species) are the two species for which heavy reliance on corn resources has been documented during the breeding or immediate post-breeding season. Red-winged Blackbirds forage on waste corn early in the season (Giltz and Stockdale 1960, Hintz and Dyer 1970, McNicol et al. 1982, Gremaud 1983), and later in the season both species take ripening kernels from the ears of standing corn (Brewster 1906, Hintz and Dyer 1970, Bollinger and Caslick 1985, Dolbeer 1990). Gremaud

(1983) documented a strong positive correlation between the numbers of breeding Red-winged Blackbirds and waste corn abundance in Iowa corn fields.

Studies of the consumption of corn and its prevalence in the diet of waterbirds are fairly well documented. Throughout mid-continental North America, waste corn accounted for the majority (>50% of esophageal contents) of the examined diets of Snow and Canada Geese during studies conducted in fall (Frederick and Klaas 1982, Craven and Hunt 1984, Gates et al. 2001), winter (Alisauskas et al. 1988, Eggeman et al. 1989, Hill and Frederick 1997, Gates et al. 2001), and spring (Reed et al. 1977, Alisauskas and Ankney 1992, Giroux and Bergeron 1996, Gates et al. 2001). Gates et al. (2001) documented that adult Canada Geese deposited on average 84% (female) to 92% (male) of their spring lipid reserves during a 4-week spring-staging period in Wisconsin, where diets included on average 50% waste corn (% dry mass). In a study of spring-staging Greater White-fronted Geese in Nebraska, Krapu et al. (1995) observed that 76% of foraging geese occurred in corn fields, and that waste corn accounted for an average of 90% of the diet (% dry mass) of collected geese. In contrast, corn accounts for a comparatively smaller proportion of the documented fall and winter diets of dabbling ducks in various locales, ranging from 5% or less for American Black Ducks (a Conservation Priority Species) and American Wigeon (Byrd 1991, Baldwin and Lovvorn 1994a, Baldwin and Lovvorn 1994b, Lovvorn and Baldwin 1996) to moderate proportions (23-47%) of the diets of Mallard, Northern Pintail, Blue-winged Teal, and American Wigeon (Anderson 1959, Sell 1979, Sheeley and Smith 1989, Havera 1998). Corn accounts for more than 80% (by volume) of the diet of wintering Sandhill Cranes (a Conservation Priority Species) in New Mexico (Walker and Schemnitz 1987), and more than 90% (by volume) of the diet of cranes staging in Nebraska in spring (Lewis 1979, Iverson et al. 1982, Reinecke and Krapu 1986). Various studies of breeding Red-winged Blackbirds conducted at northern latitudes (southern Ontario, Manitoba, South Dakota) have found that blackbirds forage moderately on corn during the breeding season (accounting for as much as 24% of the diet by volume, and 56% frequency of occurrence) but consumption of corn can be heavy (as much as 27% by volume and occurrence in the diets of 83-93% of individuals) in early fall as corn kernels mature (Bird and Smith 1964, Hintz and Dyer 1970, Mott et al. 1972). Corn accounted for as much as 53% to 71% of the diet of wintering Red-winged Blackbirds in Tennessee (Dolbeer et al. 1978) and Ohio (Williams and Jackson 1981), and is a primary food item of Boat-tailed Grackles in Florida during fall and winter (Haag et al. 1987).

Energy Value of Corn. Corn kernels have high caloric value compared to other cereal crops. Tested with Canada Geese, the apparent metabolizable energy (AME) of corn is 3.97 kcal/g, marginally higher than other cereal crops including sorghum (3.96 kcal/g) and wheat seed (3.85 kcal/g) (Joyner et al. 1987). The estimated value for true metabolizable energy (TME) of corn assayed with Canada Geese and Mallard varies from 3.67 to 3.90 kcal/g, comparable to sorghum (3.78 kcal/g), but higher than soybeans (2.65 to 3.55 kcal/g), rice (2.82 to 3.34 kcal/g), and wheat seed (3.38 kcal/g) (Reinecke et al. 1989, Petrie et al. 1998). Moreover, the energy content of corn is easily assimilated - digestibility assayed with Canada Geese was estimated at 88%, higher than sorghum (87%), rice (67%) and soybeans (62%) (Petrie et al. 1998). Although the caloric content of corn may be high, studies indicate that various waterbird species supplement their diet with other sources of protein and various nutrients that are in short supply from cereal grains (Delnicke and Reinecke 1986, Miller 1987).

Weed Seeds

We found only one reference to waterbirds foraging on weed seeds present in corn fields, but agricultural weed seeds are known to be an important food source for many bird species in general (Martin et al. 1951). Robertson et al. (1978) documented weed seeds in the diets of wintering Red-winged and Rusty Blackbirds foraging in southwest Kentucky corn fields.

Green Vegetation

In general, the green vegetation of corn plants appears to be of relatively little value to waterbirds, although some icterids have been observed consuming the new vegetation from sprouting corn seeds in spring (Stone and Mott 1973, Rogers and Linehan 1977).

Terrestrial Invertebrates

Terrestrial invertebrates are likely an important food resource for some insectivorous waterbirds frequenting cornfield habitats during both the nonbreeding and breeding seasons. Little information exists, however, on the abundance or waterbird consumption of invertebrate resources in corn fields. Insect pests such as the corn rootworm beetle (*Diabrotica longicornis*) European corn borer (*Ostrinia nubilalis*), and corn earworms (*Heliothis zea*) commonly occur in corn fields throughout the year, and their consumption by Red-winged Blackbirds have been regularly observed in Ontario, Canada, as well as Ohio, Iowa, and Kentucky during the breeding season (Robertson et al. 1978, McNicol et al. 1982, Bollinger and Caslick 1985, Dolbeer 1990, Best 2001). Sterner et al. (2003) observed Killdeer and Mountain Plovers (a Conservation Priority Species) foraging on insects in newly planted corn fields in Colorado during the breeding season, and swallows will forage on insects flying over fields of growing corn during migration and breeding (Boutin et al. 1999a, Boutin et al. 1999b, Beecher et al. 2002). In Illinois, Warburton and Klimstra (1984) documented the abundance of various invertebrates (especially spiders and beetles) in corn fields during the avian breeding season. Earthworms are an important cornfield resource available to ground-foraging birds (Eiserer 1980, Braile 1999). In Indiana corn fields during the fall, (Mackay and Kladvko 1985) documented average earthworm densities in untilled fields of up to 16 ± 8 (SD) worms/m² (biomass: 4.4 ± 2.0 g/m²). Many shorebird species are known to consume earthworms (Skagen and Oman 1996), and these prey are likely to be important to the various shorebird species that have been documented foraging in corn fields.

Soil-dwelling forms (larvae or root feeders) of corn insect pests are most abundant in winter, spring and early in the breeding season, whereas forms associated with growing corn plants increase in abundance towards the latter part of the breeding season (Chiang 1978, Best 2001). Earthworms are also most accessible in winter, spring or early in the breeding season while corn plants are small and substrates uncovered by vegetation. Thus, for those bird species that forage primarily on invertebrates on the ground or in low herbaceous cover (e.g., waterfowl, shorebirds), terrestrial invertebrate foods will be most available in winter, spring, and early in the breeding season. In Iowa, Best (2001) documented a decline in the abundance of ground-foraging species, and an increase in the abundance of shrub/tree foraging species occurring in corn fields as the breeding season progressed, attributing these patterns in part to temporal changes in the abundance and availability of different terrestrial invertebrates.

Breeding Resources

North American corn fields appear to provide limited breeding resources, and are used during breeding by only a small number of waterbird species. There are a few species for which nesting in corn fields has been observed, and virtually no information on the use of corn fields by these species for brood-rearing.

Nesting Habitat

Confirmed accounts of waterbirds nesting in North American cornfield habitats exist for three species: Killdeer, Red-winged Blackbird, and Common Yellowthroat (Dambach and Good 1940, Good and Dambach 1943, Basore et al. 1986, Best 1986, Boutin et al. 1999b, Best 2001, Renfrew and Ribic 2001, Beecher et al. 2002). Undoubtedly the species with the most widespread geographic documentation of nesting in corn fields is the Killdeer, for which nests have been documented in corn fields of the **Prairie Hardwood Transition** (BCR 23) (Renfrew and Ribic 2001), **Eastern Tallgrass Prairie** (BCR 22) (Dambach and Good 1940, Good and Dambach 1943, Basore et al. 1986, Best 1986, Best 2001), and which probably nest in corn fields of the **Central Mixed-Grass Prairie** (BCR 19) (Beecher et al. 2002), southern Ontario (Boutin et al. 1999b), and elsewhere (C. Elphick, per. obs.). Basore et al. (1986) documented nest densities varying from 1 ± 2 (SE) to 5 ± 6 nests/km² among fields managed with and without tillage, and observed that individuals more commonly used microhabitats with sparse residue and short vegetation between rows of newly planted corn. Likewise, Best (2001) observed Killdeer nesting before and shortly after corn planting while substrates were still relatively unvegetated. Red-winged Blackbirds also commonly nest in corn fields and cornfield edges in various locales (Basore et al. 1986, Boutin et al. 1999b, Best 2001) at low densities of 1 ± 4 nests/km² (Basore et al. 1986), with nests in fields typically woven among growing cornstalks (Yasukawa and Searcy 1995). In the **Eastern Tallgrass Prairie** (BCR 22), Common Yellowthroats have been confirmed nesting in no-till corn fields (Best 1986) and in strip cover around corn fields (Basore et al. 1986). Although these species have been documented as nesting in corn fields, their nesting success in corn fields is virtually unknown and represents a major knowledge gap (see **Summary and Synthesis – Knowledge Gaps and Research Needs – Resources**). In Spain, studies conducted with artificial nests documented high rates of nest predation (86%) in corn fields, considerably higher than fields planted to other cereal grains such as wheat and barley (51%) (Pescador and Peris 2001).

Brood-rearing/Post-fledging Habitat

We found no literature on the use of corn fields as brood-rearing or post-fledging habitat for any of the species documented to nest in corn, or for any waterbird species moving in from other habitats.

Resting Habitat

Spring migrant Sandhill Cranes have been known to roost in corn fields in Nebraska (**Central Mixed-Grass Prairie**; BCR 19) (Sparling and Krapu 1994).

EFFECTS OF CORN PRODUCTION METHODS

A number of studies have investigated how corn farming methods affect waterbirds using cornfield habitats during both nonbreeding and breeding seasons. Here we summarize these impacts following the phenology of corn production from soil and residue management to harvest methods, and review influences of other corollary aspects of corn production such as

field size, management of field margins, hunting and landscape context. Table 4-2 provides a synopsis of the current state of knowledge on these topics.

Soil and Residue Management in Preparation for Planting

Methods for preparing the soil for new corn plantings are varied. Under conventional management, corn residues are reduced in the fall either by plowing the residue into the soil or by burning it (although burning is less common; F. Koppatschek, ABG Inc., pers. comm.). The fields are then disked and harrowed in spring to create a smooth, residue-free surface for new plantings (Best 1986). In contrast, no-till or conservation tillage methods involve leaving the corn residue on the surface (no fall burning/plowing or spring disking), seeds are 'slot planted' directly into the soil through the previous crop's residue, and herbicides may be used in lieu of mechanical weeding (Best 1986).

Effects of residue management practices on food resources for waterbirds during nonbreeding periods are varied, and there have been only a few studies assessing waterbird responses to these practices. As fall plowing tends to bury surface resources such as waste corn, it is not surprising that many researchers have documented large decreases in the post-harvest availability of waste corn on the surface of plowed fields (Frederick and Klaas 1982, Baldassarre and Bolen 1984, Warner et al. 1985, Giroux and Bergeron 1996) and associated low use of plowed fields by Canada Geese, Greater White-fronted Geese and Sandhill Cranes (a Conservation Priority Species) during winter and spring migration (Reed et al. 1977, Frederick and Klaas 1982, Lovvorn and Kirkpatrick 1982a, Krapu et al. 1984, 1995; Davis 2003). In contrast, plowing may temporarily expose benthic invertebrates in corn fields; in Europe, shorebirds, wading birds and gulls will flock to recently plowed grain fields to forage on newly-exposed invertebrates, sometimes actively following farm machinery (Barnard and Thompson 1985, O'Connor and Shrubbs 1986, Lack 1992). In addition, fall burning can improve availability of waste corn to foraging birds by removing plant residue without destroying many of the ears and kernels (Baldassarre et al. 1983), and winter foraging geese have been known to select burned fields even though unburned fields may harbor greater amounts of waste corn (Baldassarre and Bolen 1984). Presence of residue appears to greatly affect terrestrial invertebrate communities. In Indiana, presumably due to greater availability of decomposing plant matter, earthworms were more abundant in untilled corn (density: 16 ± 8 (SD) worms/m²; biomass: 4.4 ± 2.0 g/m²) than in tilled fields (density: 8 ± 8 worms/m²; biomass: 3.1 ± 3.0 g/m²) that were sampled in the fall (Mackay and Kladivko 1985). Braile (1999), however, did not observe disproportionate use of untilled corn fields by American Golden-Plovers (a Conservation Priority Species) in another Indiana study. Not only do increased residues in no-till fields increase productivity of earthworms, but Mackay and Kladivko (1985) also discovered during a greenhouse study that earthworm activity consequently increased residue incorporation and breakdown, significantly reducing the need for conventional tillage.

Few researchers have examined the impacts of tillage practices on resources and waterbird use of fields during the breeding period. From spring until fall harvest, Warburton and Klimstra (1984) documented greater abundances of most invertebrates (predators, scavengers, other) in no-till corn fields than in conventionally tilled fields in southern Illinois, crediting these abundances to greater vegetation and residue available in no-till fields. Overall, more species and total numbers of breeding birds using corn fields were observed in no-till corn fields of Illinois and Indiana

than in fields with less crop residue (Warburton and Klimstra 1984, Castrale 1985), with Killdeer the only species more abundant in tilled fields (Castrale 1985). Authors ascribe these patterns to better foraging and nesting habitat in no-till fields. Basore et al. (1986) observed that nest densities of Killdeer were higher in no-till fields (5 ± 6 nests/km²) compared to tilled fields (2 ± 3 nests/km²), but compared to other species Killdeer tended to nest in no-till fields where residue cover was relatively sparse and weedy vegetation was short. As far as we could determine, the influence of increased residue on nest success in corn fields has not been evaluated for any species. Based on studies of nest success in non-waterbird species (Rodenhouse and Best 1983, Best 1986), fewer waterbird nests are presumably lost to farm machinery in no-till than in conventionally tilled corn fields. Best (1986) warns, however, that while nest densities of some species may be higher in no-till corn fields, these habitats may act as population sinks by attracting nesting birds to habitats that receive frequent machinery disturbances. Assessing the population consequences of such farming activities would contribute important new knowledge on the value of these habitats (see **Knowledge Gaps and Research Needs** below).

Sowing Methods

Simply by virtue of its timing, corn sowing negatively affects the few waterbird species that nest in corn fields. Whether by conventional or no-till methods, corn is generally planted in the spring (April, May) in North America, coincident with the beginning of nest initiation by the few species breeding in corn fields. Consequently, many early nests are lost due to the activities of farm machinery during planting operations (Rodenhouse and Best 1983, Basore et al. 1986). In no-till fields, the tires from farm machinery usually cause greater disturbance to ground nests between rows of residue than to those within rows (Best 1986). Moreover, as farmers do not necessarily replant corn in the previous year's rows, nests positioned within rows of crop residue are not necessarily protected from destruction during sowing operations (Best 1986).

Pesticide Use and Organic Farming

The corn industry has used a number of pesticides early in the growing season (April, May) to combat various weeds and insect pests responsible for losses to yield and revenue. The number of herbicide applications may be high in no-till fields (Beecher et al. 2002). Insecticides that have been used to combat invertebrate pests such as the Corn Rootworm (*Diabrotica* spp.), Wireworm (*Agriotes* spp.) and Seed Corn Maggot (*Delia platura*) include organophosphates (chlorpyrifos, fonofos, terbufos, phorate, diazinon, methyl parathion), organochlorines (lindane), carbamates (carbofuran), pyrethroids, and nicotinoids (Best 1992, Boutin et al. 1999b, Beecher et al. 2002; F. Koppatschek, ABG Inc., pers. comm.). Herbicides that have been used to control weeds in corn fields include triazines (atrazine – most common, cyanazine, metribuzin), anilines (alachlor), thiocarbamates (EPTC), nitriles (bromoxynil), benzoic acid compounds (chloramben, dicamba), and other compounds such as 2,4,-D, bentazon, acetochlor, metolachlor (Boutin et al. 1999b, Beecher et al. 2002; F. Koppatschek, ABG Inc., pers. comm.). Of these chemicals, many of the insecticides are classified as moderately to highly toxic to birds (EXTOXNET 2007). Organophosphates (all but diazinon) and carbofuran are particularly lethal, especially when applied to fields in granular form (Flickinger et al. 1980, Hill and Camardese 1984, Balcomb et al. 1984a, Smith 1987, Osten et al. 2005). In contrast, most herbicides used in corn fields are practically nontoxic to slightly toxic to birds (EXTOXNET 2007). The Environmental Protection Agency initiated a ban on carbofuran use in 1994 (EXTOXNET 2007). Most of the

highly toxic organophosphates are “restricted-use” pesticides and therefore may still be purchased and used by certified growers.

Pesticides can affect waterbirds either directly by causing death or affecting their health, or indirectly by impacting the food resources on which birds rely. Although there has been only moderate documentation of the effects of these chemicals on waterbirds in corn fields, additional information can be garnered from research conducted on other crops such as rice. Because pesticides are applied in the spring, the WWL species most at risk are species that occur in corn fields during the breeding season.

There are few specific accounts of bird mortalities caused directly by pesticide applications in corn fields (Stinson et al. 1994, Boutin et al. 1999b), perhaps partly because of factors contributing to a low probability of carcass detection (Balcomb 1986). More studies have assessed the relative risk to species using corn fields based on the phenology of use and habitat associations (Best and Gionfriddo 1991, Best and Fischer 1992, Mineau 1993, Boutin et al. 1999b, Beecher et al. 2002). Inarguably most of the insecticides used in corn fields are known to be deadly to birds. Carbofuran is acutely toxic (Mineau 1993) and many fatal waterbird and landbird poisonings from carbofuran were reported in ricefields in the 1980s (Flickinger et al. 1986). Likewise, waterfowl deaths from the organophosphate methyl parathion were reported in Louisiana ricefields (White et al. 1983). In Virginia, Stinson et al. (1994) observed mortalities for four waterbird species (Swamp Sparrow, Red-winged Blackbird, Rusty Blackbird - a Conservation Priority Species, Boat-tailed Grackle) in corn fields treated with carbofuran. In this study, most (58%) carcasses were found within 18 m of field edges, which is where spillages most commonly occur because they are turnaround areas (Boutin et al. 1999b). Boutin et al. (1999b) cite unpublished data from Illinois and Iowa on the mortalities of Killdeer and Red-winged Blackbird from granular pesticides in corn fields, and considered these two WWL species to be among many other ground foragers to be at greatest risk of death from similar exposure in corn fields elsewhere. In a study of bird use of organic and nonorganic corn fields in Nebraska, Beecher et al. (2002) did not find evidence for lethal poisonings of birds - including WWL species Killdeer, Upland Sandpiper (a Conservation Priority Species), Northern Rough-winged Swallow, and Red-winged Blackbird - by various organophosphates and carbofuran. Most species, however, foraged in disproportionately greater numbers organic fields, and thus species' contact with pesticides in this study may have been low. Many studies emphasize the risk to species foraging in corn fields concurrent with or shortly after insecticide application, either because birds may mistake granules of pesticide for food or grit, or may inadvertently consume seeds coated with pesticides or invertebrates with adhering granules (Balcomb et al. 1984b, Best 1992, Best and Fischer 1992, Stafford et al. 1996). Short-term hazing of birds in recently-treated fields might provide a means of reducing the impact of pesticides.

An additional source of mortality associated with pesticide use can come from the physical application of pesticides. Most pesticides are applied to fields early in the growing phase, coincident with the timing of nest initiation for many species (Best 1986). Farm machinery used to apply chemicals to fields can damage nests of birds breeding in corn fields, particularly those species that tend to nest in between (as opposed to within) corn crop rows (e.g., Killdeer; Best 1986). For fields managed without pesticides (organic farming; see below) and reliant instead on

tillage for weed control, however, mortality incurred by farm machinery is also an issue (Beecher et al. 2002).

Perhaps the most serious effect of pesticide use in corn fields is the resulting decrease in the abundance of potential foods eaten by waterbirds. Most insecticides targeting crop pests are broad-spectrum chemicals that will also kill non-target invertebrates (EXTOXNET 2007). For instance, granular carbofuran is highly toxic to the invertebrate foods found in ricefields (Flickinger et al. 1980, Osten et al. 2005). Not surprisingly, Beecher et al. (2002) observed greater species richness and abundance of terrestrial invertebrates in organic corn fields than in those fields to which pesticides had regularly been applied. Moreover, by denuding weed grasses and forbs in corn fields, herbicides reduce the abundance of other important foods to some species (e.g., shorebirds, sparrows, wrens) such as seeds and the arthropods that feed on pest plant species (Altieri 1987, 1992, Freemark and Boutin 1995, Beecher 1998, Gibbons et al. 2006). The negative impacts of herbicides may be especially great in GM corn fields where the glyphosate herbicides used for weed control target all plant species except the GM crop. Some researchers have found a significant reduction in the abundance of weeds and weed seeds in various GM crops treated with glyphosate herbicides as opposed to conventional herbicide treatments (Fawcett and Slife 1978, Peterson et al. 2002, Heard et al. 2003), and lower diversity and abundance of granivorous songbirds in corn fields planted to GM corn compared to conventional corn has been documented in Britain (Chamberlain et al. 2007).

Alternatives to conventional insecticide use are being considered by the corn industry. New pesticides with fewer adverse impacts on wild birds are being evaluated as replacements for carbamates (Avery et al. 1998), and biological control of corn crop pests using invertebrate predators and parasites or by insect-eating birds is also receiving increased attention (Dix et al. 1995, Barbosa 1998). One class of GM crops in which a crop is genetically engineered to produce insecticidal proteins of *Bacillus thuringiensis* (“*Bt* crops”) conferring a built-in resistance to lepidopteran and coleopteran insect pests, has been under recent consideration and scrutiny as a potential alternative to conventional insecticide use in corn (Naranjo et al. 2005a, Romeis et al. 2006). Although a major environmental concern with *Bt* crops is their potential impact on beneficial non-target invertebrates, including those used in biological control (Romeis et al. 2006), available evidence suggests that densities of various terrestrial non-target arthropods and other insects are in fact unaffected by the insecticidal properties of *Bt* corn (Bitzer et al. 2005, Daly and Buntin 2005, Dively 2005, Pilcher et al. 2005, Bhatti et al. 2005a, Bhatti et al. 2005b). Consequently, researchers have proposed that the planting of *Bt* corn provides a number of environmental and economic advantages by significantly reducing the need for conventional, broad-spectrum insecticides, and by increasing opportunities for biological control (Bhatti et al. 2005a, Bhatti et al. 2005b, Naranjo et al. 2005a, Romeis et al. 2006). Depending on the extent to which terrestrial invertebrates in corn fields are an important food resource for waterbirds using corn fields (a significant knowledge gap, see **Summary and Synthesis – Knowledge Gaps and Research Needs** below), the adoption of *Bt* corn may immediately benefit a number of waterbirds. Testing this hypothesis should be a high priority for future researchers, especially given that 32% of field corn in the U.S. was planted to GM cultivars producing *Bt* toxins in 2004 (Naranjo et al. 2005), and that there is an increasing yearly trend in the area allocated to *Bt* crops worldwide (Romeis et al. 2006b).

In some areas, organic farming may be an environmentally friendly yet economically viable alternative to widespread pesticide use (Rogers and Freemark 1991). In Europe, several researchers contend that organic farming probably enhances biodiversity in agricultural landscapes in general (Hole et al. 2004, Bengtsson et al. 2005). To our knowledge, only one North American study has assessed the effects of organic cornfield farming on bird use. Beecher et al. (2002) found that organically managed Nebraska corn fields, on which no pesticide or synthetic fertilizer had been applied for at least three years, attracted more species and higher abundances of breeding shorebirds and landbirds [including WWL species Killdeer, Upland Sandpiper, Northern Rough-winged Swallow, Red-winged Blackbird] than non-organic fields. They attribute this higher use of organic corn fields to better quality and quantity of invertebrate and plant food resources both within fields and towards field edges. Because organic fields rely on more frequent tillage, however, Beecher et al. (2002) caution that organic corn fields may act as ecological traps by attracting species to more productive fields that simultaneously pose a greater risk of nest failure.

Management of Pest Bird Species

In some northern locales in North America, fall-migrating geese and Red-winged Blackbirds have caused significant damage to ripening corn prior to harvest (Hunt and Bell 1973, Dolbeer 1981, Bernhardt et al. 1987, Dolbeer 1990, Wywiałowski 1996). Measures to deter geese from feeding in corn fields have included increasing the availability of corn on nearby wildlife refuges, implementing scare tactics to haze birds from fields, and increasing hunting pressure on corn fields and refuges (Hunt and Bell 1973). While improving food conditions on refuges may initially appear to reduce the conflict caused by crop damage, in some locales it has exacerbated the problem by contributing to increased goose population growth (Hunt and Bell 1973). Conventional methods to deter blackbirds and other icterids include propane exploders, hawk kites, reflective ribbons, and shooting (Dolbeer 1990). In South Dakota (**Prairie Potholes**; BCR 11), avicide (DCR-1339) treated bait is commonly broadcast in corn fields during spring migration to cull blackbirds en route to breeding grounds where they cause major damage to sunflower crops (Linz et al. 2001, Linz et al. 2002, Linz et al. 2004). These lethal measures to control blackbirds in corn fields pose considerable threat to other, non-target, granivorous species that also forage in corn fields during spring migration (Linz et al. 2001, Linz et al. 2002, Linz et al. 2004). Potential alternative measures to control damage to cereal grains by blackbirds include adjusting the timing of farm production practices (planting, harvest) so that crop resources are not most abundant and available during peak abundances of pest species (White et al. 1985, Brugger et al. 1992), using chemical repellants (Dolbeer 1981, Avery 1989, Avery and Decker 1991, Avery et al. 1993, Avery et al. 1995, Avery et al. 1996, Avery et al. 1997), and behavioral-based deterrents (Daneke and Decker 1988, Avery et al. 1999). The feasibility and efficacy of implementing these measures on a large scale, however, have not been evaluated.

Harvest Methods

A trend towards increased corn harvest efficiency (Krapu et al. 2004) may be problematic for species such as Sandhill Cranes (a Conservation Priority Species) and Greater White-fronted Geese, which have a diet that comprises 90% or more waste corn (Reinecke and Krapu 1986, Krapu et al. 1995). Krapu et al. (2004) documented a 27-47% reduction in waste corn abundance in corn fields in the Central Platte River Valley in Nebraska between 1978 and 1998 that was primarily due to an increase in the efficiency of corn ear retrieval by combine headers.

Other factors that have decreased amount of waste corn in fields include improved vigor of *Bt* and other genetically modified crop types (F. Koppatschek, ABG Inc., pers. comm.). Over this 20-year period, researchers have documented a concomitant 46% decrease in the fat content of spring-staging Sandhill Cranes, and lower daily fat storage rates in Greater White-fronted Geese (see Krapu et al. 2004). If such trends in harvest efficiency are representative of corn fields elsewhere, these observations have far-reaching implications for the long-term viability of many North American waterbird populations that are reliant on waste corn.

Crop Rotation, Fallow Land

To maintain soil fertility and help with pest problems, corn is often grown in rotation with soybeans and other cereal crops (Beecher et al. 2002, Krapu et al. 2004). In as much as crops like soybeans can provide interim habitat of some value to waterbirds (see SOYBEAN chapter), crop rotation does not appear to affect waterbirds using corn fields adversely. We did not find any specific references to use of fallow fields previously planted to corn.

EFFECTS OF OTHER MANAGEMENT ACTIVITIES

Other management activities that occur in corn fields may additionally influence waterbird use. We briefly review these here.

Management of Field Margins

Management of cornfield margins is important to those WWL species that use edge habitat in addition to cornfield interiors, such as Canada Goose, American Black Duck (a Conservation Priority Species), Mallard, Black-bellied Plover, Killdeer, American Woodcock (a Conservation Priority Species), Great Blue Heron, Black-crowned Night-Heron, Common Yellowthroat, Swamp Sparrow, and Red-winged Blackbird (Basore et al. 1986, Jobin et al. 1998, Boutin et al. 1999a, Boutin et al. 1999b, Best 2001, Hultquist and Best 2001). In fact, some of these species are more abundant in field margins because of the greater quantity and quality of resources towards the edge compared to the interior (Best et al. 1990, Boutin et al. 1999a, b).

Consequently, Beecher et al. (2002) suggest that managing field margins using organic farming methods (no pesticides, fertilizers; biological control) could greatly benefit many species, even if the interiors of these fields are managed following conventional methods. Potentially, wildlife gains obtained by taking this approach could offset losses caused by increasing field sizes. Moreover, cornfield edges can provide habitat to bird species that are potentially useful for biological pest control (Jobin et al. 2001, Kirk et al. 2001), and thus crop management practices that enhance edge habitat could indirectly benefit all waterbirds using corn fields by decreasing the need to use pesticides.

Hunting Activity

Recreational goose and crane hunting is common in corn fields of North America. Such hunting can help to control population growth in species (e.g., geese) that cause ecological problems (Bechet et al. 2004), and can provide valuable extra revenue to farmers, especially where waterfowl damage to corn crops has had an economic impact (Winner 1959, Hunt and Bell 1973, Reinecke et al. 1989). Hunting plays a key role in regulating population size of the mid-continent population of Sandhill Cranes (a Conservation Priority Species) that migrate through the **Prairie Potholes** (BCR 11) and **Central Mixed-Grass Prairie** (BCR 19) regions, and winter along the Gulf Coast (Sharp and Vogel 1992) Aside from incurring mortality, hunting activities

can negatively affect waterbirds through frequent disturbances. Bechet et al. (2004) found that spring-migrating Snow Geese were adversely affected by disturbance from cornfield hunting in SE Canada. Hunting disturbances lowered the foraging efficiency of individuals, and these birds exhibited reduced body condition potentially lowering their future reproductive success (Bechet et al. 2004). Bechet et al. (2004) suggest limiting waterfowl hunting during spring migration in order to lessen these negative affects.

EFFECTS OF LANDSCAPE FEATURES

Landscape attributes of corn fields themselves may significantly affect waterbird use. We briefly review what is known regarding such potential influences here.

Field Size

The recent trend towards larger corn fields has resulted in a decrease in the amount of cornfield margin habitat (commonly defined as edge and cornfield habitat within 50 m of the edge) important to some waterbirds (see **Management of Field Margins**; Best 1986, Boutin et al. 1999b). The direct relationship between corn field size and diversity and abundance of waterbirds has not been documented. Important plant and invertebrate food resources for breeding birds tend to be most abundant towards cornfield edges (Kemp and Barrett 1989, Best et al. 1990, Sotherton 1991), however, and smaller corn fields with more edge are thus expected to provide more resources to some species than will large fields with little edge habitat. In contrast, larger fields could be preferred by species that seek open foraging habitat to avoid predators.

Landscape Context

Studies in wetland landscape ecology (Naugle et al. 1999, Riffell et al. 2003, Taft and Haig 2006) suggest that waterbird use of agricultural fields can be affected by habitat features of the surrounding landscape, or by the “landscape context” of fields. The coverage, placement and connectivity of various features in the surrounding landscape may be important, including that of other suitable habitat, natural wetlands, hunting refuges, and roads and other sources of disturbance. Understanding how features such as these influence waterbird use of corn fields could affect a number of management decisions. Few studies have touched on this issue for corn fields specifically, but those that do suggest that landscape context can influence waterbird use of corn fields. Stone-curlew (*Burhinus oediconemus*) in England, for instance, are more likely to breed in corn fields that are close to short semi-natural grassland or sheep pasture and greater than 3 km from the nearest road (Green et al. 2000). In southern Ontario, Kirk et al. (2001) documented greater abundances of Common Yellowthroat and Tree Swallow in corn fields adjacent to wetlands. Blackbird damage to corn crops tend to be greater in fields that are near woodlands or water bodies (Dolbeer 1980, Bollinger and Caslick 1985, Besser and Brady 1986, Otis and Kilburn 1988, Dolbeer 1990). In Iowa, cornfield use by breeding Killdeer was greatest in fields close to pasture habitat (Gremaud 1983). Finally, in Indiana, Lovvorn and Kirkpatrick (1982a) found that spring and fall migrant Sandhill Cranes were more likely to use corn fields near roost sites.

SUMMARY AND SYNTHESIS

The following is a summary of the major themes relating to the use of corn fields by waterbirds, waterbird resources found in cornfield habitats, positive and negative effects of corn production

practices on waterbirds, and gaps in our knowledge of these topics. We synthesize these topics to provide a sense of the present avian conservation challenges that relate to corn agriculture, and of the future research needed to resolve these issues.

Waterbird Use

Available information indicates that the resources and habitat provided by North American corn fields are used by a moderate number of waterbird species (Table 4-1), but may be particularly vital to migrating and wintering geese (e.g., Frederick and Klaas 1982, Craven and Hunt 1984, Davis et al. 1989, Alisauskas and Ankney 1992, Krapu et al. 1995, Havera 1998, Gates et al. 2001) and Sandhill Cranes, a Conservation Priority Species (e.g., Iverson et al. 1982, Krapu et al. 1984, 1985; Davis 2003). Corn fields are used by the greatest numbers of birds during nonbreeding periods, and thousands of waterfowl and cranes have been observed foraging in corn fields during winter, spring and fall migrations (e.g., Nagel 1965, Harvey et al. 1988, Petrie et al. 2002). Various other granivorous and/or ground-foraging shorebirds, wading bird and landbird species also use cornfield habitats during the breeding season and migration, but in much lower numbers (e.g., Dolbeer et al. 1978, Castrale 1985, Basore et al. 1986, Boutin et al. 1999a, 1999b; Kirk et al. 2001, Beecher et al. 2002). Shorebird species using cornfield habitats are primarily associated with terrestrial habitats (e.g., Upland Sandpiper, American Woodcock), and many are visual foragers (i.e., plovers). WWL landbirds using corn fields are primarily aerial insectivores that forage over the fields (e.g., swallows), ground foragers (e.g., sparrows) or generalist species (e.g., blackbirds).

WWL Species and Bird Conservation Regions

Of the 216 species identified for the Waterbirds on Working Lands project, 45 species have been observed in corn fields in North America, of which 11 are species of conservation priority (Table 4-1). Of these 45 species, 42 use corn fields during winter or migration, and 23 have been documented foraging or nesting in cornfield habitats during the breeding/post-breeding season. On average, use of corn fields has been documented for only 7% (range: 1% in Mississippi Alluvial Valley BCR 26 to 14% in Eastern Tallgrass Prairie BCR 22) of those species considered to be relatively abundant within each BCR (i.e., species on BCR regional lists). Whether these low numbers represent gaps in knowledge or are a true representation of the diversity of waterbirds using corn fields with the BCRs is uncertain (see **Knowledge Gaps and Research Needs** below).

Corn Resources

The foraging resources provided to waterbirds by corn fields include corn kernels (e.g., Baldassarre et al. 1983, Baldassarre and Bolen 1984, Warner et al. 1985, Krapu et al. 1995), weed seeds (Robertson et al. 1978), new shoots of corn vegetation (Rogers and Linehan 1977), and terrestrial invertebrates (Robertson et al. 1978, McNicol et al. 1982, Warburton and Klimstra 1984, Bollinger and Caslick 1985, Mackay and Kladvko 1985, Dolbeer 1990, Best 2001). Caloric value of corn ranks the highest among cereal crops and moist-soil seeds (Joyner et al. 1987, Reinecke et al. 1989, Petrie et al. 1998). Corn pest insects, earthworms, and arthropods are among the terrestrial invertebrates that are eaten by some waterbird species. These invertebrates are most accessible to birds in winter, spring and early in the breeding season before growth of the corn crop. Waterfowl and cranes rely heavily on waste corn (e.g., Iverson et al. 1982, Reinecke and Krapu 1986, Alisauskas and Ankney 1992, Krapu et al. 1995, Havera

1998); terrestrial invertebrates are likely to be important to shorebirds (Skagen and Oman 1996) and some landbirds (e.g., Bollinger and Caslick 1985, Dolbeer 1990, Boutin et al. 1999a, Beecher et al. 2002); and other landbirds such as blackbirds obtain a mixed diet of corn (in milk stage from ripening ears) and invertebrates (Bird and Smith 1964, Dolbeer et al. 1978, Best 2001). For a few ground- or shrub-nesting species frequenting corn fields during the breeding season, cornfield habitats (including edges) can provide nesting habitat (Renfrew and Ribic 2001, Basore et al. 1986, Best 2001). Among WWL species, Killdeer and Red-winged Blackbird are most likely to be found nesting in corn fields.

Practices Benefiting Waterbirds

Available information indicates that some methods involved in producing corn both directly and indirectly benefit the waterbird species using corn fields. Practices that positively influence the suitability of fields for many waterbirds during all phases of the annual cycle include some conventional tillage and some 'no-till' practices for different species, lessened use of harmful pesticides, and organic farming (Table 4-2).

Conventional and no-till practices have different effects on different species. Fall plowing activities associated with conventional tillage potentially increase access to terrestrial invertebrates important to some waterbirds such as shorebirds and landbirds (O'Connor and Shrubbs 1986, Lack 1992). Likewise, fall burning conventionally practiced in lieu of plowing may increase access to waste corn resources by removing cornstalk residue without destroying ears and kernels (Baldassarre et al. 1983). In contrast, no-till practices improve waterbird access to waste corn by leaving it on the surface rather than plowing it under (Frederick and Klaas 1982, Baldassarre and Bolen 1984, Warner et al. 1985, Giroux and Bergeron 1996), and decomposing residues contribute to increased earthworm and other invertebrate abundances in spring and summer (Warburton and Klimstra 1984, Mackay and Kladivko 1985). Moreover, no-till practices are associated with better conditions for nest concealment and lower nest failure rates by breeding birds (Rodenhouse and Best 1983, Basore et al. 1986, Best 1986). The potential to control corn crop pests via *Bt* engineered corn, or using other non-pest insects or insect-eating birds (biological control), may be promising measures to reduce reliance on pesticides (Dix et al. 1995, Barbosa 1998, Romeis et al. 2006a, b). Finally, organic farming practices may strongly benefit migrant and breeding waterbirds by increasing the quality and quantity of invertebrate and plant food resources both within corn fields and in cornfield margins (Beecher et al. 2002).

Practices Negatively Affecting Waterbirds

Compared to the positive effects of corn agriculture, there appear to be more practices that adversely impact waterbirds and that present future obstacles and challenges towards improving the wildlife conservation value of corn fields. These negative effects have far-reaching implications for sustaining waterbird populations that have become dependant on cornfield resources for survival and reproduction. Cornfield management practices with negative effects include some conventional tillage practices, some no-till practices, timing of sowing, pesticide use (particularly herbicides used in GM corn), measures used to control geese and blackbird pests, increased harvest efficiency, increased field size, and disturbance from hunting on agricultural land (Table 4-2).

There are more negative effects associated with conventional tillage practices than with no-till practices, and while the negative effects of no-till influence nonbreeding birds, the negative effects of conventional tillage impact waterbirds during both nonbreeding and breeding periods. Although lack of plowing or burning in no-till fields may not increase fall and winter access to invertebrates and waste corn, respectively, fall plowing activities associated with conventional tillage can severely bury waste corn, making it unavailable to foraging waterbirds such as geese and Conservation Priority Species Sandhill and Whooping Cranes (e.g., Frederick and Klaas 1982, Baldassarre and Bolen 1984, Warner et al. 1985, Krapu et al. 1995, Davis 2003), and the longterm abundance of invertebrates important to shorebirds and landbirds during spring and summer may be lower in conventionally tilled fields than in no-till fields (Warburton and Klimstra 1984, Mackay and Kladivko 1985). Further, because there are more passes by farm machinery during spring and summer in conventionally-managed fields, more waterbird nests are likely destroyed in tilled fields (Best 1986). Finally, nest concealment resources are fairly low in fields that have been disked and harrowed (Warburton and Klimstra 1984, Castrale 1985, Basore et al. 1986, Best 1986).

Because corn is planted at around the time many nests are initiated, sowing poses a risk to the few nesting waterbirds (and many other non-waterbirds), regardless of tillage method (Basore et al. 1986, Best 1986). For waterbirds using corn fields during the breeding season, the “restricted-use” insecticides applied to corn fields present mortality risk to waterbirds, either from direct ingestion or from nest destruction by the farm machinery used to apply chemicals to fields (e.g., Best 1992, Best and Fischer 1992, Stinson et al. 1994, Stafford et al. 1996, Boutin et al. 1999b, Beecher et al. 2002). Pesticides can also reduce weed seeds and invertebrate food resources for breeding or migrating birds (e.g., Flickinger et al. 1980, Osten et al. 2005, Freemark and Boutin 1995, Beecher et al. 2002, Chamberlain et al. 2007). Throughout corn growing regions, measures to control blackbird damage to corn and other crop types pose serious risk to the other non-target WWL species (potentially including Rusty Blackbird, a Conservation Priority Species) also occurring in corn fields during the breeding or post-breeding periods (e.g., Linz et al. 2001, 2002, 2004). Moreover, the trend towards increased harvester efficiency in some locales appears to be substantially reducing waste corn resources for wintering and migrant geese and cranes, which adversely impacts fat storage capabilities and potentially lowers reproductive fitness of these species (Krapu et al. 2004). Similarly, the disturbance associated with cornfield hunting activities can adversely affect goose foraging efficiency, fat storage rates, and ensuing reproductive success (Bechet et al. 2004).

Knowledge Gaps and Research Needs

Apart from rice, we probably know more about how waterbirds use corn fields and how they are affected by cornfield management practices than we do about other major row crops. Many gaps in knowledge, however, remain, and improving cornfield management for waterbirds will require additional work in the following areas.

Waterbird Use

Of the six focal BCRs for the WWL project in which corn is a major crop, we know the least about waterbird use of corn fields throughout the year in the **Prairie Hardwood Transition** (BCR 23), **Central Hardwoods** (BCR 24), and **Shortgrass Prairie** (BCR 18) regions (Table 4-1). Many of the observations of species using corn fields come from research conducted outside

focal BCRs in the corn-growing regions of southeastern Canada, southwestern North America, and the western U.S. Species reported only from these other regions include waterfowl (Tundra Swan, Ross' Goose, Blue-winged Teal), shorebirds (Black-bellied Plover, Lesser Yellowlegs, Pectoral Sandpiper, American Woodcock), wading birds (Great Blue Heron, Black-crowned Night-Heron), and landbirds (Purple Martin, Tree Swallow, Bank Swallow, Palm Warbler, Northern Waterthrush, Lincoln's Sparrow). Whether these species also use corn fields in the focal BCRs is unclear, and some may not, simply because their ranges do not overlap with the BCRs (e.g., Tundra Swan). For other species on this list, however, (e.g., Ross's Goose, Blue-winged Teal, American Woodcock, Great Blue Heron, Purple Martin), the lack of reported cornfield use in focal BCRs may represent a lack of published research from these BCRs. Recent work documenting use of corn fields by American Golden-Plover and Buff-breasted Sandpipers (e.g., Braile 1999, Jorgensen, unpubl. thesis) indicate that cornfield habitats throughout the Great Plains, especially those with shallow standing water, may be important to other shorebird species, particularly during spring migration (Skagen et al. 1999). Further work on the occurrence of these and other shorebirds' use of corn fields would be worthwhile. Finally, estimating the cumulative use of fields by certain species that are widespread in their use of corn but which occur in small numbers in any particular field (e.g., Killdeer) would provide a valuable landscape perspective on the overall importance of cornfield habitats.

Resources

Uncertainty remains regarding how a continued increase in harvest efficiency may affect waterbird populations. Additional studies that document the waste grain densities at which foraging birds abandon fields (the "giving-up density"), or that link the abundance of waste corn to waterbird survival and reproductive success, would be valuable. Better quantification of terrestrial invertebrate resources such as pest insects, earthworms and arthropods in corn fields and their consumption both by breeding species and nonbreeders (perhaps especially shorebirds) would further our understanding of the importance and sustainability of these resources for waterbirds. In order to evaluate the overall impact of GM corn on waterbirds given competing impacts of glyphosate herbicides on weed species resources (potentially negative) and *Bt* corn on non-target terrestrial invertebrates (potentially positive), we will need to improve our understanding of the relative importance of weed plant resources (seeds, new shoots) and terrestrial invertebrates as foraging resources for waterbirds. Moreover, further work in this area would allow us to better assess the role that waterbirds can play in biological control, and thus the potential to lessen the dependence on pesticide use.

For those species documented as nesting in corn fields, there is little published information on their breeding success in this habitat. Documentation of nesting success in corn fields and post-nesting habitat use by young birds would further our understanding of the overall importance of cornfield nesting resources to waterbirds. Studies of particular value would include assessing how nest success relates to increased residues in no-till fields, and patterns (e.g., timing, number of field passes) of in-field machinery use. Comparisons of nesting productivity in corn fields to other natural and agricultural habitats would also be worthwhile.

Effects of Crop Production Methods, Other Management Activities, and Landscape Features

The potential effects of most corn production practices are fairly well established, but current knowledge is based on research conducted on a small number of WWL species (Table 4-2). To

resolve whether conventional or conservation tillage most benefits waterbird communities using corn fields, we need to evaluate the positive and negative effects of all phases of both practices on more species during all phases of the annual cycle, with an ultimate decision weighted by the overall diversity, abundance, and perceived conservation value of the species that are affected by each practice. Such decisions may well differ among BCRs depending on the species present and the way in which corn resources are used by birds in different regions. Continued research on the impacts of alternatives to heavy pesticide use, including use of low toxicity chemicals, planting of GM *Bt* corn, and crop management practices (organic farming, biological control) on waterbirds and cornfield food resources would be immensely valuable. In particular, parsing out the organic farming practices that benefit high priority waterbird species would be a helpful step towards identifying aspects of organic farming that could be incorporated into conventional farming. Better quantification of the cost-effectiveness of the various alternatives to lethal control of bird pests (e.g., blackbirds) is needed before these methods can be commonly used. For all corn-growing regions and BCRs, greater understanding of the influence of landscape context on waterbird use of corn fields should enable more strategic broadscale approaches to conservation planning in agricultural landscapes.

Beyond quantifying the nest success and mortality of waterbirds in fields managed using various crop production techniques (e.g., for tillage, sowing, pesticide use/organic farming), an important future area of research will be to determine how aspects of cornfield management that influence these demographic parameters affect the overall stability of populations. Quantifying how field management activities contribute to birth and death rates and thus population dynamics - particularly for species of conservation priority - will be a crucial step towards devising crop production practices that are not detrimental to waterbirds using corn fields.

Finally, investigating the trade-offs between the benefits and costs of various corn farming methods to the conservation of waterbirds and the economics of corn production will be a vital focus for future research, enabling the ultimate design of sustainable conservation-oriented agronomic practices.

References

- Acquaah, G. 2005. Principles of Crop Production: Theory, Techniques, and Technology. Pearson Education, Upper Saddle River, New Jersey.
- Alisauskas, R. T. 1988. Nutrient reserves of Lesser Snow Geese during winter and spring migration. Ph.D. dissertation. University of Western Ontario, London, Ontario.
- Alisauskas, R. T. 1998. Winter range expansion and relationships between landscape and morphometrics of midcontinent Lesser Snow Geese. *Auk* **115**:851-862.
- Alisauskas, R. T., and C. D. Ankney. 1992. Spring habitat use and diets of midcontinent adult Lesser Snow Geese. *Journal of Wildlife Management* **56**:43-54.
- Altieri, M. A. 1987. *Agroecology: the scientific basis of alternative agriculture*. Westview Press, Boulder, Colorado.
- Altieri, M. A. 1992. Agroecological foundations in alternative agriculture in California. *Agriculture, Ecosystems & Environment* **39**:23-53.
- Anderson, H. G. 1959. Food habits of migratory ducks in Illinois. *Illinois Natural History Survey Bulletin* **27**:289-344.
- Avery, M. L. 1989. Experimental evaluation of partial repellent treatment for reducing bird damage to crops. *Journal of Applied Ecology* **26**:433-440.
- Avery, M. L., and D. G. Decker. 1991. Repellency of fungicidal rice seed treatments to red-winged blackbirds. *Journal of Wildlife Management* **55**:327-334.
- Avery, M. L., D. G. Decker, D. L. Fischer, and T. R. Stafford. 1993. Responses of captive blackbirds to a new insecticidal seed treatment. *Journal of Wildlife Management* **57**:652-656.
- Avery, M. L., D. G. Decker, J. S. Humphrey, E. Aronov, S. D. Linscombe, and M. O. Way. 1995. Methyl anthranilate as a rice seed treatment to deter birds. *Journal of Wildlife Management* **59**:50-56.
- Avery, M. L., D. G. Decker, J. S. Humphrey, and C. C. Laukert. 1996. Mint plant derivatives as blackbird feeding deterrents. *Crop Protection* **15**:461-464.
- Avery, M. L., J. S. Humphrey, and D. G. Decker. 1997. Feeding deterrence of anthraquinone, anthracene, and anthrone to rice-eating birds. *Journal of Wildlife Management* **61**:1359-1365.
- Avery, M. L., J. S. Humphrey, D. G. Decker, and A. P. McGrane. 1999. Seed color avoidance by captive red-winged blackbirds and boat-tailed grackles. *Journal of Wildlife Management* **63**:1003-1008.
- Avery, M. L., T. M. Primus, E. M. Mihaich, D. G. Decker, and J. S. Humphrey. 1998. Consumption of fipronil-treated rice seed does not affect captive blackbirds. *Pesticide Science* **52**:91-96.
- Balcomb, R. 1986. Songbird carcasses disappear rapidly from agricultural fields. *Auk* **103**:817-820.
- Balcomb, R., C. A. Bowen, D. Wright, and M. Law. 1984a. Effects on wildlife of at-planting corn applications of granular carbofuran. *Journal of Wildlife Management* **48**:1353-1359.
- Balcomb, R., R. Stevens, and C. I. Bowen. 1984b. Toxicity of 16 granular insecticides to wild-caught songbirds. *Bulletin of Environmental Contamination and Toxicology* **33**:302-307.
- Baldassarre, G. A., and E. G. Bolen. 1984. Field-feeding ecology of waterfowl wintering on the southern High Plains of Texas. *Journal of Wildlife Management* **48**:63-71.

- Baldassarre, G. A., R. J. Whyte, E. E. Quinlan, and E. G. Bolen. 1983. Dynamics and quality of waste corn available to postbreeding waterfowl in Texas. *Wildlife Society Bulletin* **11**:25-31.
- Baldwin, J. R., and J. R. Lovvorn. 1994a. Habitats and tidal accessibility of the marine foods of dabbling ducks and brant in Boundary Bay, British Columbia. *Marine Biology* **120**:627-638.
- Baldwin, J. R., and J. R. Lovvorn. 1994b. Expansion of seagrass habitat by exotic *Zostera japonica*, and its use by dabbling ducks and brant in Boundary Bay, British Columbia. *Mar. Ecol. Prog. Ser.* **103**:119-127.
- Barbosa, P. 1998. Conservation Biological Control. Academic Press, San Diego, California.
- Barnard, C. J., and D. B. A. Thompson. 1985. Gulls and Plovers: The Ecology and Behaviour of Mixed-species Feeding Groups. Columbia University Press, New York, NY.
- Basore, N. S., L. B. Best, and J. B. Wooley. 1986. Bird nesting in Iowa no-tillage and tillage cropland. *Journal of Wildlife Management* **50**:19-28.
- Bechet, A., J.-F. Giroux, and G. Gauthier. 2004. The effects of disturbance on behaviour, habitat use and energy of spring staging snow geese. *Journal of Applied Ecology* **41**:689-700.
- Beecher, N. A., R. J. Johnson, J. R. Brandle, R. M. Case, and L. J. Young. 2002. Agroecology of birds in organic and nonorganic farmland. *Conservation Biology* **16**:1620-1631.
- Beecher, N. B. 1998. Birds and agroecological relationships in organic and nonorganic farmland. M.S. thesis. University of Nebraska, Lincoln, Nebraska.
- Bellrose, F. C., F. L. Paveglio, Jr., and D. W. Steffeck. 1979. Waterfowl populations and the changing environment of the Illinois River Valley. *Illinois Natural History Survey Bulletin* **32**:1-54.
- Bengtsson, J., J. Ahnstrom, and A.-C. Wiebull. 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. *Journal of Applied Ecology* **42**:261-269.
- Bernhardt, G. E., L. Van Allsburg, and R. A. Dolbeer. 1987. Blackbird and starling feeding behavior on ripening corn ears. *Ohio J. Sci.* **87**:125-129.
- Besser, J. F., and D. J. Brady. 1986. Bird damage to ripening field corn increases in the United States from 1971 to 1981. *Fish and Wildlife Leaflet 7*, U.S. Fish and Wildlife Service.
- Best, L. B. 1986. Conservation tillage: ecological traps for nesting birds. *Wildlife Society Bulletin* **14**:308-317.
- Best, L. B. 1992. Characteristics of corn rootworm insecticide granules and the grit used by cornfield birds: evaluating potential avian risks. *American Midland Naturalist* **128**:126-138.
- Best, L. B. 2001. Temporal patterns of bird abundance in cornfield edges during the breeding season. *American Midland Naturalist* **146**:94-104.
- Best, L. B., and D. L. Fischer. 1992. Granular insecticides and birds: factors to be considered in understanding exposure and reducing risk. *Environmental Toxicology and Chemistry* **11**:1495-1508.
- Best, L. B., and J. P. Gionfriddo. 1991. Characterization of grit use by cornfield birds. *Wilson Bulletin* **103**:68-82.
- Best, L. B., R. C. Whitmore, and G. M. Booth. 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. *American Midland Naturalist* **123**:84-99.
- Bhatti, M. A., J. Duan, G. Head, C. Jiang, M. J. Mckee, T. E. Nickson, C. L. Pilcher, and C. D. Pilcher. 2005a. Field evaluation of the impact of corn rootworm (Coleoptera:

- Chrysomelidae)-protected *Bt* corn on ground-dwelling invertebrates. *Environmental Entomology* **34**:1325-1335.
- Bhatti, M. A., J. Duan, G. P. Head, C. Jiang, M. J. McKee, T. E. Nickson, C. L. Pilcher, and C. D. Pilcher. 2005b. Field evaluation of the impact of corn rootworm (Coleoptera: Chrysomelidae)-protected *Bt* corn on foliage-dwelling arthropods. *Environmental Entomology* **34**:1336-1345.
- Bird, R. D., and L. B. Smith. 1964. The food habits of the Red-winged Blackbird, *Agelaius phoeniceus*, in Manitoba. *Canadian Field-Naturalist* **78**:179-186.
- Bitzer, R. J., E. R. Marlin, C. D. Pilcher, C. L. Pilcher, and W.-K. F. Lam. 2005. Biodiversity and community structure of epedaphic and euedaphic springtails (Collembola) in transgenic rootworm *Bt* corn. *Environmental Entomology* **34**:1346-1376.
- Blackwell, B. F., and R. A. Dolbeer. 2001. Decline of the red-winged blackbird population in Ohio correlated to changes in agriculture (1965-1996). *Journal of Wildlife Management* **65**:661-667.
- Bolen, E. G., and B. J. Forsyth. 1967. Foods of the Black-bellied Tree Duck in south Texas. *Wilson Bulletin* **79**:43-49.
- Bollinger, E. K., and J. W. Caslick. 1985. Red-winged blackbird predation on northern corn rootworm beetles in field corn. *Journal of Applied Ecology* **22**:39-48.
- Bortner, J. B. 1985. Bioenergetics of wintering Tundra Swans in the Mattamuskeet region of North Carolina. M.S. thesis. University of Maryland, College Park, Maryland.
- Boutin, C., K. E. Freemark, and D. A. Kirk. 1999a. Spatial and temporal patterns of bird use of farmland in southern Ontario. *Canadian Field-Naturalist* **113**:430-460.
- Boutin, C., K. E. Freemark, and D. A. Kirk. 1999b. Farmland birds in southern Ontario: field use, activity patterns and vulnerability to pesticide use. *Agriculture, Ecosystems & Environment* **72**:239-254.
- Braile, T. M. 1999. Migration studies of shorebirds in west-central Indiana. M.S. thesis. Purdue University, West Lafayette, Indiana.
- Bray, M. P. 1986. Feeding ecology of White-faced Ibises in the Lahontan Valley, Nevada. P-R Rep., Federal Aid Project W-53-R, Study I, Jobs 02, Nevada Department of Wildlife, Reno, NV.
- Bray, M. P., and D. A. Klebenow. 1988. Feeding ecology of White-faced Ibises in a Great Basin valley, USA. *Colonial Waterbirds* **11**:24-31.
- Brewster, W. 1906. The birds of the Cambridge region of Massachusetts. Mem. Nuttall Ornithol. Club no. 4.
- Brugger, K. E., R. F. Labisky, and D. E. Daneke. 1992. Blackbird roost dynamics at Millers Lake, Louisiana: Implications for damage control in rice. *Journal of Wildlife Management* **56**:393-398.
- Bruggers, R. L., J. E. Brooks, R. A. Dolbeer, P. P. Woronecki, R. K. Pandit, T. Tarimo, and M. Hogue. 1986. Responses of pest birds to reflecting tape in agriculture. *Wildlife Society Bulletin* **14**:161-170.
- Byrd, V. E. 1991. Food habits of Black Duck wintering in west central Tennessee. Tennessee Technical University, Cookeville, TX.
- Castrale, J. S. 1985. Responses of wildlife to various tillage conditions. *Transactions of the North American Wildlife and Natural Resources Conference* **50**:142-156.
- Castrale, J. S., and R. T. Speer. 1984a. Thirty-sixth winter bird population study, No. 77: corn residue I. *American Birds* **38**:57.

- Castrale, J. S., and R. T. Speer. 1984b. Thirty-sixth winter bird population study, No. 80: disked cornfield I. *American Birds* **38**:58.
- Castrale, J. S., and R. T. Speer. 1984c. Thirty-sixth winter bird population study, No. 81: disked cornfield II. *American Birds* **38**:58.
- Castrale, J. S., and R. T. Speer. 1984d. Thirty-sixth winter bird population study, No. 84: disked cornfield with wheat cover crop. *American Birds* **38**:58.
- Castrale, J. S., and R. T. Speer. 1984e. Thirty-sixth winter bird population study, No. 86: plowed cornfield. *American Birds* **38**:58.
- Chamberlain, D. E., S. N. Freeman, and J. A. Vickery. 2007. The effects of GMHT crops on bird abundance in arable fields in the UK. *Agriculture, Ecosystems & Environment* **118**:350-356.
- Chiang, H. C. 1978. Pest management in corn. *Annual Review of Entomology* **23**:101-123.
- Craven, S. R., and R. A. Hunt. 1984. Fall food habits of Canada geese in Wisconsin. *Journal of Wildlife Management* **48**:169-173.
- Daly, T., and G. D. Buntin. 2005. Effect of *Bacillus thuringiensis* transgenic corn for lepidopteran control on nontarget arthropods. *Environmental Entomology* **34**:1292-1301.
- Dambach, C. A., and E. E. Good. 1940. The effect of certain land use practices on populations of breeding birds in southwestern Ohio. *Journal of Wildlife Management* **4**:63-76.
- Dambach, C. A., and D. L. Leedy. 1948. Ohio studies with repellent materials with notes on damage to corn by pheasants and other wildlife. *Journal of Wildlife Management* **12**:392-398.
- Daneke, D. E., and D. G. Decker. 1988. Prolonged seed handling time deters red-winged blackbirds feeding on rice seed. Pages 287-292 in A. C. Crabb and R. E. Marsh, editors. *Proceedings of the Vertebrate Pest Conference*. University of California, Davis, Monterey, CA.
- Davis, C. A. 2003. Habitat use and migration patterns of sandhill cranes along the Platte River, 1998-2001. *Great Plains Research* **13**:199-216.
- Davis, S. E., E. E. Klaas, and K. J. Koehler. 1989. Diurnal time-activity budgets and habitat use of Lesser Snow Geese *Anser caerulescens* in the middle Missouri River Valley during winter and spring. *Wildfowl* **40**:45-54.
- DeGrazio, J. W., R. I. Starr, J. L. Guarino, J. F. Besser, and T. J. DeCino. 1971. Use of 4-aminopyridine to protect ripening corn from blackbirds. *Journal of Wildlife Management* **35**:565-569.
- Delnicke, D., and K. J. Reinecke. 1986. Mid-winter food use and body weights of mallards and wood ducks in Mississippi. *Journal of Wildlife Management* **50**:43-51.
- Dively, G. P. 2005. Impact of transgenic VIP3A x Cry1Ab lepidopteran-resistant field corn on the nontarget arthropod community. *Environmental Entomology* **34**:1267-1291.
- Dix, M. E., R. M. Johnson, M. O. Harrell, R. M. Case, R. J. Wright, L. Hodges, J. R. Brandle, M. M. Schoeneberger, N. J. Sunderman, R. L. Fitzmaurice, L. J. Young, and K. G. Hubbard. 1995. Influences of trees on abundance of natural enemies of insect pests: a review. *Agroforestry Systems* **29**:303-311.
- Dolbeer, R. A. 1980. Blackbirds and corn in Ohio. Resource Publication 136, U.S. Fish and Wildlife Service.
- Dolbeer, R. A. 1981. Cost-benefit determination of blackbird damage control for cornfields. *Wildlife Society Bulletin* **9**:44-51.

- Dolbeer, R. A. 1990. Ornithology and integrated pest management: red-winged blackbirds *Agelaius phoeniceus* and corn. *Ibis* **132**:309-322.
- Dolbeer, R. A., P. P. Woronecki, and T. W. Seamans. 1995. Ranking and evaluation of field corn hybrids for resistance to blackbird damage. *Crop Protection* **14**:399-403.
- Dolbeer, R. A., P. P. Woronecki, A. R. J. Stickley, and S. B. White. 1978. Agricultural impact of a winter population of blackbirds and starlings. *Wilson Bulletin* **90**:31-44.
- Drewien, R. C., A. L. Terrazas, J. P. Taylor, J. M. O. Barraza, R. E. Shea, and R. G. Drewien. 2003. Status of lesser snow geese and Ross's geese wintering in the Interior Highlands of Mexico. *Wildlife Society Bulletin* **31**:417-432.
- Ducey, J., and L. Miller. 1980. Birds of an agricultural community. *Nebraska Bird Review* **48**:58-66.
- Duriez, O., Y. Ferrand, F. Binet, E. Corda, F. Gossmann, and H. Fritz. 2005. Habitat selection of the Eurasian woodcock in winter in relation to earthworms availability. *Biological Conservation* **122**:479-490.
- Earnst, S. L. 1992. Behavior and ecology of Tundra Swans during summer, autumn, and winter. Ph.D. dissertation. Ohio State University, Columbus, OH.
- Eggeman, D. R., D. D. Humburg, D. A. Graber, and L. J. Korschgen. 1989. Temporal changes in fall and winter foods of Canada Geese. *Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies* **43**:372-379.
- Ely, C. R., and A. X. Dzubin. 1994. Greater White-fronted Goose (*Anser albifrons*), No. 131. *in* A. Poole and F. Gill, editors. *The Birds of North America*. The Academy of Natural Sciences; The American Ornithologists' Union, Philadelphia, PA; Washington, D.C.
- EXTOXNET. 2007. The EXtension TOXicology NETwork. <http://extoxnet.orst.edu/ghindex.html>:(accessed 2 Jan 2007).
- Farago, S. 1994. Habitat use, daily activity and feeding of the geese of Lake Ferto. *Aquila* **101**:65-88.
- Fawcett, R. S., and F. W. Slife. 1978. Effects of 2,4-D and dalapon on weed seed production and dormancy. *Weed Science* **26**:543-547.
- Flickinger, E. L., K. A. King, W. F. Stout, and M. M. Mohn. 1980. Wildlife hazards from Furadan 3G applications to rice in Texas. *Journal of Wildlife Management* **44**:190-197.
- Flickinger, E. L., C. A. Mitchell, D. H. White, and E. J. Kolbe. 1986. Bird poisoning from misuse of the carbamate Furadan in a Texas rice field. *Wildlife Society Bulletin* **14**:59-62.
- Folk, M. J., and T. C. Tacha. 1991. Distribution of Sandhill Cranes in the North Platte River Valley 1980 and 1989. *Prairie Naturalist* **23**:11-16.
- Frederick, R. B., and E. E. Klaas. 1982. Resource use and behavior of migrating Snow Geese. *Journal of Wildlife Management* **46**:601-614.
- Frederick, R. B., E. E. Klaas, G. A. Baldassarre, and K. J. Reinecke. 1984. A method for sampling waste corn. *Journal of Wildlife Management* **48**:298-303.
- Freemark, K. E., and C. Boutin. 1995. Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: a review with special reference to North America. *Agriculture, Ecosystems & Environment* **52**:67-91.
- Gartshore, R. G., F. F. Gilbert, J. D. Somers, and R. J. Brooks. 1982. Feeding ecology of the red-winged blackbird in field corn in Ontario. *Journal of Wildlife Management* **46**:438-452.

- Gates, R. J., D. F. Caithamer, W. E. Moritz, and T. C. Tacha. 2001. Bioenergetics and nutrition of Mississippi Valley population Canada geese during winter and migration. *Wildlife Monographs* **146**:1-65.
- Gibbons, D. W., D. A. Bohan, P. Rothery, R. C. Stuart, A. J. Haughton, R. J. Scott, J. D. Wilson, J. N. Perry, S. J. Clark, R. J. G. Dawson, and L. G. Firbank. 2006. Weed seed resources for birds in fields with contrasting conventional and genetically modified herbicide-tolerant crops. *Proceedings of the Royal Society B* **273**:1921-1928.
- Giltz, M. L., and T. M. Stockdale. 1960. The red-winged blackbird story. Special Circulation 95, Ohio Agriculture Experimental Station, Ohio State University, Columbus, Ohio.
- Giroux, J. F., and R. Bergeron. 1996. Spring diets of sympatric Greater Snow Geese and Canada Geese in southern Quebec. *Canadian Journal of Zoology* **74**:950-953.
- Good, E. E., and C. A. Dambach. 1943. Effect of land use practices on breeding bird populations in Ohio. *Journal of Wildlife Management* **7**:291-297.
- Goodman, D. C., and H. I. Fisher. 1962. Functional anatomy of the feeding apparatus in waterfowl (Aves: Anatidae). Southern Illinois Press, Carbondale, Illinois.
- Graber, R. R., J. W. Graber, and E. L. Kirk. 1972. Illinois birds: Hirundinidae. Illinois Natural History Survey Biol. Notes 80.
- Green, R. E., G. A. Tyler, and C. G. R. Bowden. 2000. Habitat selection, ranging behaviour and diet of the stone curlew (*Burhinus oedicnemus*) in southern England. *Journal of Zoology* **250**:161-183.
- Gregoire, P. E., and C. D. Ankney. 1990. Agonistic behavior and dominance relationships among Lesser Snow Geese during winter and spring migration. *Auk* **107**:550-560.
- Gregoire, P. E., and C. D. Ankney. 1990. Agonistic behavior and dominance relationships among Lesser Snow Geese during winter and spring migration. *The Auk* **107**:550-560.
- Gremaud, G. K. 1983. Factors Influencing Nongame Bird Use of Rowcrop Fields. M.S. Thesis. Iowa State University, Ames, IA.
- Guth, R. W. 1969. Wheat, corn and fallow. *Audubon Field Notes* **23**:745.
- Guzman, J. M. S., A. S. Garcia, C. C. Amado, and A. M. del Viejo. 1999. Influence of farming activities in the Iberian Peninsula on the winter habitat use of common crane (*Grus grus*) in areas of its traditional migratory routes. *Agriculture, Ecosystems & Environment* **72**:207-214.
- Haag, K. R., J. C. Joyce, W. M. Hetrick, and J. C. Jordan. 1987. Predation on waterhyacinth weevils and other aquatic insects by three wetland birds in Florida. *Florida Entomologist* **70**:457-471.
- Harvey, W. F. I., R. A. Malecki, E. C. Soutiere, and W. F. Harvey. 1988. Habitat use by foraging Canada geese in Kent County, Maryland. *Transactions of the Northeast Section of The Wildlife Society* **45**:1-7.
- Havera, S. P. 1998. Waterfowl of Illinois: status and management. Phoenix Publishing, Urbana, IL.
- Heard, M. S., C. Hawes, G. T. Champion, S. J. Clark, L. G. Firbank, A. J. Haughton, A. M. Parish, J. N. Perry, P. Rothery, R. J. Scott, M. P. Skellern, G. R. Squire, and M. O. Hill. 2003. Weeds in fields with contrasting conventional and genetically modified herbicide-tolerant crops I: Effects on abundance and diversity. *Philosophical Transactions of the Royal Society of London B* **358**:1819-1832.

- Hill, E. F., and M. B. Camardese. 1984. Toxicity of anticholinesterase insecticides to birds: technical grade versus granular formulations. *Ecotoxicology and Environmental Safety* **8**:551-563.
- Hill, M. R. J., and R. B. Frederick. 1997. Winter movements and habitat use by greater snow geese. *Journal of Wildlife Management* **61**:1213-1221.
- Hintz, J. V., and M. I. Dyer. 1970. Daily rhythm and seasonal change in the summer diet of adult red-winged blackbirds. *Journal of Wildlife Management* **34**:789-799.
- Hirst, S. M., and C. A. Easthope. 1981. Use of agricultural lands by waterfowl in southwestern British Columbia. *Journal of Wildlife Management* **45**:454-462.
- Hoffman, R. H. 1976. Field usage by Sandhill Cranes in southern Michigan. *Proceedings of the International Crane Workshop* **1**:35-43.
- Hole, D. G., A. J. Perkins, J. D. Wilson, I. H. Alexander, P. V. Grice, and A. D. Evans. 2004. Does organic farming benefit biodiversity? *Biological Conservation* **122**:113-130.
- Houston, C. S., and D. E. Bowen, Jr. 2001. Upland Sandpiper (*Bartramia longicauda*), No. 580. *in* A. Poole and F. Gill, editors. *The Birds of North America*. The Academy of Natural Sciences; The American Ornithologists' Union, Philadelphia, PA; Washington, D.C.
- Hultquist, J. M., and L. B. Best. 2001. Bird use of terraces in Iowa rowcrop fields. *American Midland Naturalist* **145**:275-287.
- Hunt, R. A., and J. G. Bell. 1973. Crop depredations by waterfowl in Wisconsin. Pages 85-101 *in* *Proceedings of the Sixth Bird Control Seminar*, Bowling Green State University, Bowling Green, OH.
- Ingram, C. R., R. T. Mitchell, and A. R. Stickley. 1973. Hopper box treatment of corn seed with methiocarb for protecting sprouts from birds. Pages 206-215 *in* *Proceedings of the Sixth Bird Control Seminar*, Bowling Green State University, Bowling Green, OH.
- Iverson, G. C., T. C. Tacha, and P. A. Vohs. 1982. Food contents of Sandhill Cranes during winter and spring. Pages 95-98 *in* *Proceedings of the 1981 Crane Workshop*. National Audubon Society, Tavernier, Florida.
- Jarvis, R. L. 1976. Soybean impaction in Canada Geese. *Wildlife Society Bulletin* **4**:175-179.
- Jobin, B., L. Choiniere, and L. Belanger. 2001. Bird use of three types of field margins in relation to intensive agriculture in Quebec, Canada. *Agriculture, Ecosystems & Environment* **84**:131-143.
- Jobin, B., J.-L. DesGranges, and C. Boutin. 1998. Farmland habitat use by breeding birds in southern Quebec. *Canadian Field-Naturalist* **112**:611-618.
- Johnson, R. R., and J. J. Dinsmore. 1985. Brood-rearing and postbreeding habitat use by Virginia Rails and Soras. *Wilson Bulletin* **97**:551-554.
- Jorde, D. G., G. L. Krapu, R. D. Crawford, and M. A. Hay. 1984. Effects of weather on habitat selection and behavior of Mallards wintering in Nebraska. *Condor* **86**:258-265.
- Jorde, D. G., G. L. Krapu, R. D. Crawford, and M. A. Hay. 1984. Effects of weather on habitat selection and behavior of Mallards wintering in Nebraska. *Condor* **86**:258-265.
- Joyner, D. E., B. N. Jacobson, and R. D. Arthur. 1987. Nutritional characteristics of grains fed to Canada Geese. *Wildfowl* **38**:89-93.
- Kahl, R. B., and F. B. Samson. 1984. Factors affecting yield of winter wheat grazed by geese. *Wildlife Society Bulletin* **12**:256-262.
- Kemp, J. C., and G. W. Barrett. 1989. Spatial patterning: impact of uncultivated corridors on arthropod populations within soybean agroecosystems. *Ecology* **70**:114-128.

- Kirk, D. A., C. Boutin, and K. E. Freemark. 2001. A multivariate analysis of bird species composition and abundance between crop types and seasons in southern Ontario, Canada. *Ecoscience* **8**:173-184.
- Kitchell, J. F., D. E. Schindler, B. R. Herwig, D. M. Post, M. H. Olson, and M. Oldham. 1999. Nutrient cycling at the landscape scale: the role of diel foraging migrations by geese at the Bosque del Apache National Wildlife Refuge, New Mexico. *Limnology and Oceanography* **44**:828-836.
- Kramer, G. W., and N. H. Euliss, Jr. 1986. Winter foods of Black-bellied Whistling-Ducks in northwestern Mexico. *Journal of Wildlife Management* **50**:413-416.
- Krapu, G. L. 1974. Feeding ecology of pintail hens during reproduction. *Auk* **91**:278-290.
- Krapu, G. L., D. E. Facey, E. K. Fritzell, and D. H. Johnson. 1984. Habitat use by migrant Sandhill Cranes in Nebraska. *Journal of Wildlife Management* **48**:407-417.
- Krapu, G. L., G. C. Iverson, K. J. Reinecke, and C. M. Boise. 1985. Fat deposition and usage by arctic-nesting sandhill cranes during spring. *Auk* **102**:362-368.
- Krapu, G. L., K. J. Reinecke, D. G. Jorde, and S. G. Simpson. 1995. Spring-staging ecology of midcontinent greater white-fronted geese. *Journal of Wildlife Management* **59**:736-746.
- Krementz, D. G., J. T. Seginak, and G. W. Pendleton. 1995. Habitat use at night by wintering American Woodcock in coastal Georgia and Virginia. *Wilson Bulletin* **107**:686-697.
- Lack, P. C. 1992. *Birds on Lowland Farms*. HMSO, London, England.
- Lawrence, G. N. 1874. *Birds of western and northwestern Mexico*. Mem. Boston Soc. Nat. Hist. **2**:265-319.
- Lewis, J. C. 1979. Taxonomy, food, and feeding habitat of Sandhill Cranes, Platte Valley, Nebraska. Pages 21-27 in *Proceedings of the 1978 Crane Workshop*, Colorado State University, Ft. Collins, Colorado.
- Lewis, J. C. 1995. Whooping Crane (*Grus americana*), no. 153. in A. Poole and F. Gill, editors. *The Birds of North America*. The Academy of Natural Sciences; The American Ornithologists' Union, Philadelphia, PA; Washington, DC.
- Leyva-Espinosa, R. I. 1993. Habitat use and movements of Greater White-fronted Geese wintering in Chichuahua, Mexico. M.S. thesis. Iowa State University, Ames, IA.
- Linz, G. M., H. J. Homan, and R. L. Wimberly. 2001. Avian use of various bait mixtures offered in harvested cornfields during spring migration in South Dakota. Pages 345-358 in *Pesticides and Wildlife*, American Chemical Society Symposium Series. American Chemical Society, Washington, D.C.
- Linz, G. M., M. J. Kenyon, H. J. Homan, and W. J. Bleier. 2002. Avian use of rice-baited corn stubble in east-central South Dakota. *International Biodeterioration & Biodegradation* **49**:179-184.
- Linz, G. M., G. A. Knutsen, H. J. Homan, and W. J. Bleier. 2004. Attractiveness of brown rice baits to non-target birds in harvested corn and soybean fields. *Pest Management Science* **60**:1143-1148.
- Linz, G. M., D. L. Vakoch, J. F. Cassel, and R. B. Carlson. 1984. Food of red-winged blackbirds, *Agelaius phoeniceus*, in sunflower fields and corn fields. *The Canadian Field-Naturalist* **98**:38-44.
- Lovvorn, J. R., and J. R. Baldwin. 1996. Intertidal and farmland habitats of ducks in the Puget Sound region: a landscape perspective. *Biological Conservation* **77**:97-114.
- Lovvorn, J. R., and C. M. Kirkpatrick. 1982a. Field use by staging eastern Greater Sandhill Cranes. *Journal of Wildlife Management* **46**:99-108.

- Lovvorn, J. R., and C. M. Kirkpatrick. 1982b. Recruitment and socially-specific flocking tendencies of eastern Sandhill Cranes. *Wilson Bulletin* **94**:313-321.
- Mackay, A. D., and E. J. Kladvko. 1985. Earthworms and rate of breakdown of soybean and maize residues in soil. *Soil Biology and Biochemistry* **17**:851-857.
- Malecki, R. A., S. E. Sheaffer, and J. W. Enck. 1988. Influence of agricultural land use changes on wintering Canada geese in the Atlantic flyway. *Transactions of the Northeast Section of The Wildlife Society* **45**:8-17.
- Marcus, J. F., W. E. Palmer, and P. T. Bromley. 2000. The effects of farm field borders on overwintering sparrow densities. *Wilson Bulletin* **112**:517-523.
- Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. *American wildlife and plants*. McGraw-Hill Book Co., New York, NY.
- McNicol, D. K., R. J. Robertson, and P. J. Weatherhead. 1982. Seasonal, habitat, and sex-specific food habits of red-winged blackbirds: implications for agriculture. *Canadian Journal of Zoology* **60**:3282-3289.
- Melvin, S. M. 1978. Ecology of non-breeding Wisconsin sandhill cranes, with emphasis on crop damage and migration. M.S. thesis. University of Wisconsin.
- Miller, M. R. 1985. Time budgets of northern pintails wintering in the Sacramento Valley, California. *Wildfowl* **36**:53-64.
- Miller, M. R. 1987. Fall and winter foods of Northern Pintails in the Sacramento Valley, California. *Journal of Wildlife Management* **51**:405-414.
- Mineau, P. 1993. The hazard of carbofuran to birds and other vertebrate wildlife. Technical Report Series No. 177, Environment Canada, Canadian Wildlife Service, Hull, Quebec.
- Moore, J. L. 1980. Aspects of the ecology and hunting economics of migratory waterfowl on the Texas High Plains. M.S. thesis. Texas Tech University, Lubbock, Texas.
- Mott, D. F., R. R. West, J. W. DeGrazio, and J. L. Guarino. 1972. Foods of the Red-winged Blackbird in Brown County, South Dakota. *Journal of Wildlife Management* **36**:983-987.
- Munro, R. E. 1981. Field feeding by *Cygnus columbianus columbianus* in Maryland. Pages 261-272 in G. V. T. Matthews and M. Smart, editors. *Proceedings of the Second International Swan Symposium*, IWRB, Sapporo, Japan; Slimbridge, Glos., UK.
- Nagel, J. 1965. Field feeding in Whistling Swans in northern Utah. *Condor* **67**:446-447.
- Naranjo, S. E., G. Head, and G. P. Dively. 2005a. Field studies assessing arthropod nontarget effects in *Bt* transgenic crops: introduction. *Environmental Entomology* **34**:1178-1180.
- Naugle, D. E., K. F. Higgins, S. M. Nusser, and W. C. Johnson. 1999. Scale-dependent habitat use in three species of prairie wetland birds. *Landscape Ecology* **14**:267-276.
- Nesbitt, S. A., and K. S. Williams. 1990. Home range and habitat use of Florida Sandhill Cranes. *Journal of Wildlife Management* **54**:92-96.
- O'Connor, R. J., and M. Shrubbs. 1986. *Farming and Birds*. Cambridge University Press, Cambridge, England.
- Osten, J. R. V., A. Soares, and L. Guilhermino. 2005. Black-bellied whistling duck (*Dendrocygna autumnalis*) brain cholinesterase characterization and diagnosis of anticholinesterase pesticide exposure in wild populations from Mexico. *Environmental Toxicology and Chemistry* **24**:313-317.
- Otis, D. L., and C. M. Kilburn. 1988. Influence of environmental factors on blackbird damage to sunflower. Fish and Wildlife Technical Report 16, U.S. Fish and Wildlife Service, Washington, D.C.

- Paine, C. R., and T. C. Tacha. 1987. Habitat use and activity patterns of Canada Geese associated with Rend Lake, Illinois. *Transactions of the Illinois Academy of Sciences* **80**:327-332.
- Paullin, D. G. 1996. Tundra swan use in California's Central Valley. Pages 48-52 *in* Proceedings and Papers of the Fifteenth Trumpeter Swan Society Conference: Trumpeter Swans: A Vision for the 21st Century.
- Perkins, D. L., and D. E. Brown. 1981. The sandhill Crane in Arizona. No. 11, Arizona Game Fish Dep. Spec. Publ.
- Pescador, M., and S. Peris. 2001. Effects of land use on nest predation: an experimental study in Spanish croplands. *Folia Zoologica* **50**:127-136.
- Peterson, D., J. Scursoni, and F. Forcella. 2002. Weed diversity and yield in glyphosate-tolerant soybean from Minnesota to Louisiana. *North Central Weed Science Society Abstracts* **57**:129.
- Petrie, M. J., R. D. Drobney, and D. A. Graber. 1998. True metabolizable energy estimates of Canada goose foods. *Journal of Wildlife Management* **62**:1147-1152.
- Petrie, S. A., S. S. Badzinski, and K. L. Wilcox. 2002. Population trends and habitat use of Tundra Swans staging at Long Point, Lake Erie. *Waterbirds* **25**:143-149.
- Pilcher, C. D., M. E. Rice, and J. J. Obrycki. 2005. Impact of transgenic *Bacillus thuringiensis* corn and crop phenology on five nontarget arthropods. *Environmental Entomology* **34**:1302-1316.
- Raveling, D. G., W. E. Crews, and W. D. Klimstra. 1972. Activity patterns of Canada Geese during winter. *Wilson Bulletin* **84**:278-295.
- Reed, A., G. Chapdelaine, and P. Dupuis. 1977. Use of farmland in spring by migrating Canada Geese in the St. Lawrence Valley, Quebec. *Journal of Applied Ecology* **14**:667-680.
- Reinecke, K. J., R. M. Kaminski, D. J. Moorehead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi Alluvial Valley. Pages 203-247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. *Habitat management for migrating and wintering waterfowl in North America*. Texas Tech University Press, Lubbock, TX.
- Reinecke, K. J., and G. L. Krapu. 1986. Feeding ecology of sandhill cranes during spring migration in Nebraska. *Journal of Wildlife Management* **50**:71-79.
- Renfrew, R. B., and C. A. Ribic. 2001. Grassland birds associated with agricultural riparian practices in southwestern Wisconsin. *Journal of Range Management* **54**:546-552.
- Riffell, S. K., B. E. Keas, and T. M. Burton. 2003. Birds in North American Great Lakes coastal wet meadows: is landscape context important? *Landscape Ecology* **18**:95-111.
- Robertson, R. J., P. J. Weatherhead, F. J. S. Phelan, G. L. Holroyd, and N. Lester. 1978. On assessing the economic and ecological impact of winter blackbird flocks. *Journal of Wildlife Management* **42**:53-60.
- Rodenhouse, N. L., and L. B. Best. 1983. Breeding ecology of Vesper Sparrows in corn and soybean fields. *American Midland Naturalist* **110**:265-275.
- Rogers, C. A., and K. E. Freemark. 1991. A feasibility study comparing birds from organic and conventional (chemical) farms in Canada. Technical report series 137, Environment Canada, Canadian Wildlife Service, Ottawa, Ontario.
- Rogers, J. G., Jr., and J. T. Linehan. 1977. Some aspects of grackle feeding behavior in newly planted corn. *Journal of Wildlife Management* **41**:444-447.
- Romeis, J., M. Meissle, and F. Bigler. 2006. Transgenic crops expressing *Bacillus thuringiensis* toxins and biological control. *Nature Biotechnology* **24**:63-71.

- Schwalbe, G. P., and P. W. Schwalbe. 1974. Corn stubble, winter wheat, and hayfields. *American Birds* **28**:722-723.
- Sell, D. L. 1979. Fall foods of teal on the Texas High Plains. *Southwest Naturalist* **24**:373-375.
- Shackford, J. S., D. M. Leslie, Jr., and W. D. Harden. 1999. Range-wide use of cultivated fields by mountain plovers during the breeding season. *Journal of Field Ornithology* **70**:114-120.
- Sharp, D. E., and W. O. Vogel. 1992. Population status, hunting regulations, hunting activity, and harvest of mid-continent Sandhill Cranes. Pages 24-32 in D. W. Stahlecker, editor. *Proceedings of the 1991 North American Crane Workshop*. International Crane Foundation, Baraboo, WI.
- Sheeley, D. G., and L. M. Smith. 1989. Tests of diet and condition bias in hunter-killed Northern Pintails. *Journal of Wildlife Management* **53**:765-769.
- Skagen, S. K., and H. D. Oman. 1996. Dietary flexibility of shorebirds in the western hemisphere. *Canadian Field-Naturalist* **110**:419-444.
- Skagen, S. K., P. B. Sharpe, R. G. Waltermire, and M. B. Dillon. 1999. Biogeographical profiles of shorebird migration in midcontinental North America. Biological Science Report USGS/BRD/BSR--2000-0003, U.S. Geological Survey, Fort Collins, CO.
- Smith, G. J. 1987. Pesticide use and toxicology in relation to wildlife: organophosphorus and carbamate compounds. Resource Publication 170, U.S. Fish and Wildlife Service.
- Sotherton, N. W. 1991. Conservation headlands: a practical combination of intensive cereal farming and conservation. Pages 373-397 in L. G. Firbank, N. Carter, J. F. Darbyshire, and G. R. Potts, editors. *The Ecology of Temperate Cereal Fields*. Blackwell Scientific Publications, Oxford, UK.
- Sparling, D. W., and G. L. Krapu. 1994. Communal roosting and foraging behavior of staging Sandhill Cranes. *Wilson Bulletin* **62**:77.
- Stabins, H. C., C. E. Grue, D. A. Manuwal, and S. L. Paulus. 2002. Time allocation by Aleutian Canada geese during the nonbreeding season in California. *California Fish and Game* **88**:186-195.
- Stafford, T. R., L. B. Best, and D. L. Fischer. 1996. Effects of different formulations of granular pesticides on birds. *Environmental Toxicology and Chemistry* **15**:1606-1611.
- Stehn, R. A., and S. M. deBecker. 1982. Corn damage and breeding red-winged blackbird population density in western Ohio. *Wildlife Society Bulletin* **10**:217-223.
- Sterner, R. T., B. E. Petersen, S. E. Gaddis, K. L. Tope, and D. J. Poss. 2003. Impacts of small mammals and birds on low-tillage, dryland crops. *Crop Protection* **22**:595-602.
- Stickley, A. R. J., R. T. Mitchell, R. G. Heath, C. R. Ingram, and E. L. J. Bradley. 1972. A method for appraising the bird repellency of 4-aminopyridine. *Journal of Wildlife Management* **36**:1313-1316.
- Stinson, E. R., L. E. Hayes, P. B. Bush, and D. H. White. 1994. Carbofuran affects wildlife on Virginia corn fields. *Wildlife Society Bulletin* **22**:566-575.
- Stone, C. P., and D. F. Mott. 1973. Bird damage to sprouting corn in the United States. Special Science Report on Wildlife 173, U.S. Fish and Wildlife Service.
- Stone, W. B., S. R. Overmann, and J. C. Okoniewski. 1984. Intentional poisoning of birds with parathion. *Condor* **86**:333-336.
- Swanson, G. A., M. I. Meyer, and V. A. Adomaitis. 1985. Foods consumed by breeding Mallards on wetlands of south-central North Dakota. *Journal of Wildlife Management* **49**:197-203.

- Taft, O. W., and S. M. Haig. 2006. Importance of wetland landscape structure to shorebirds wintering in an agricultural valley. *Landscape Ecology* **21**:169-184.
- Tate, J. J., and D. J. Tate. 1966. Additional records of Whistling Swans feeding in dry fields. *Condor* **68**:398-399.
- Taylor, J. P., and R. E. Kirby. 1990. Experimental dispersal of wintering Snow and Ross' Geese. *Wildlife Society Bulletin* **18**:312-319.
- Thompson, D. Q., and M. D. Lyons. 1964. Flock size in a spring concentration of Whistling Swans. *Wilson Bulletin* **76**:282-285.
- Twedt, D. J., and R. D. Crawford. 1995. Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), No. 192. in A. Poole and F. Gill, editors. *The Birds of North America*. The Academy of Natural Sciences; The American Ornithologists' Union, Philadelphia, PA; Washington, DC.
- Tyler, B. M., and L. W. Kannenberg. 1980. Blackbird damage to ripening field corn in Ontario. *Canadian Journal of Zoology* **58**:469-472.
- USFWS. 1981. The Platte River ecology study. Northern Prairie Wildlife Research Center, Special Research Report 781-129/467 Reg. 8.
- Valentine, J. M., Jr. 1981. The Mississippi Sandhill Crane, 1980. Pages 167-174 in J. C. Lewis and H. Masatomi, editors. *Crane research around the world*. International Crane Foundation, Baraboo, WI.
- Vegvari, Z. 2002. Autumn staging and habitat selection by common cranes *Grus grus* in the Hortobagy National Park, Hungary. *Folia Zoologica* **51**:221-225.
- Walker, D. L., and S. D. Schemnitz. 1987. Food habits of Sandhill Cranes in relation to agriculture in central and southwestern New Mexico. Pages 201-212 in *Proceedings of the 1985 Crane Workshop*. Platte River Whooping Crane Habitat Maintenance Trust, Grand Island, Nebraska.
- Walkinshaw, L. H. 1956. Sandhill Cranes killed by flying into power line. *Wilson Bulletin* **68**:325-326.
- Walkinshaw, L. H. 1985. Nest attentiveness by Florida Sandhill Cranes. *Florida Field Naturalist* **13**:67-68.
- Warburton, P. B., and W. D. Klimstra. 1984. Wildlife use of no-till and conventionally-tilled corn fields. *Journal of Soil and Water Conservation* **39**:327-330.
- Warner, R. E., S. P. Havera, and L. M. David. 1985. Effects of autumn tillage systems on corn and soybean harvest residues in Illinois. *Journal of Wildlife Management* **49**:185-190.
- Wenner, A. S., and S. A. Nesbitt. 1987. Wintering of greater sandhill cranes in Florida. Pages 196-200 in *Proceedings 1985 Crane Workshop*. Platte River Whooping Crane Maintenance Trust, Grand Island, NE.
- White, D. H., C. A. Mitchell, E. J. Kolbe, and W. H. Ferguson. 1983. Azodrin poisoning of waterfowl in rice fields in Louisiana. *Journal of Wildlife Disease* **19**:373-375.
- White, S. B., R. A. Dolbeer, and T. A. Bookhout. 1985. Ecology, bioenergetics, and agricultural impacts of a winter-roosting population of blackbirds and starlings. *Wildlife Monographs* **93**:1-42.
- Williams, R. E., and W. B. Jackson. 1981. Dietary comparisons of Red-winged Blackbirds, Brown-headed Cowbirds, and European Starlings in north-central Ohio. *Ohio J. Sci.* **81**:217-225.
- Winner, R. W. 1959. Field-feeding periodicity of black and mallard ducks. *Journal of Wildlife Management* **23**:197-202.

- Woodward, P. W. 1979. Thirty-first winter bird-population study, No. 113: cornfield II. *American Birds* **33**:51.
- Wright, T. W. 1959. Winter foods of Mallards in Arkansas. *Southeast Association of Game and Fish Commissioners* **13**:291-296.
- Wywiałowski, A. P. 1996. Wildlife damage to field corn in 1993. *Wildlife Society Bulletin* **24**:264-271.
- Yasukawa, K., and W. A. Searcy. 1995. Red-winged Blackbird (*Agelaius phoeniceus*), No. 184. *in* A. Poole and F. Gill, editors. *The Birds of North America*. The Academy of Natural Sciences; The American Ornithologists' Union, Philadelphia, PA; Washington, DC.
- Zimmerman, J. L., and J. L. Tatschl. 1975. Floodplain birds of Weston Bend, Missouri River. *Wilson Bulletin* **87**:196-206.

Table 4-1. Waterbird species reported in or in association with cornfield habitats in North America and in focal BCRs during winter, migration, and breeding seasons. Use by landbirds presented only for species on the Waterbird on Working Lands (WWL) species list. Species on each BCR regional list are considered relatively abundant (compared to other focal BCRs) within the BCR. Under Migration, “S” refers to spring migration, and “F” refers to fall migration. “(?)” “ under Nesting indicates probable nesting based on territorial behavior. Apparent absences may reflect incomplete information in the published literature for a given season or region.

GROUP Common name	On WWL Species List	Species of Conservation Priority	North America ^a				Prairie Potholes (BCR 11) ^b				
			Winter	Migration	Breeding		On BCR 11 Regional List	Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WATERFOWL											
Black-bellied Whistling-Duck	X		X		X						
Fulvous Whistling-Duck	X		X								
Tundra Swan	X		X	S/F							
Snow Goose	X		X	S/F					S		
Ross’s Goose	X		X								
Greater White-fronted Goose	X		X	S							
Canada Goose	X		X	S/F	X		X		S		
Cackling Goose			X								
American Black Duck	X	X	X	F	X						
Mallard	X		X	S/F	X		X		S		
Northern Pintail	X	X	X	F	X		X			X	
Green-winged Teal	X		X	F			X				
Blue-winged Teal	X			F	X		X				
American Wigeon	X		X	F			X				
SHOREBIRDS											
Black-bellied Plover	X				F			X			
American Golden-Plover	X	X			S			X			
Killdeer	X		X		S/F	X	X	X		S	
Mountain Plover	X	X				X	X	X			
Lesser Yellowlegs	X	X			F (rare)			X			
Buff-breasted Sandpiper	X	X			S			X			
Pectoral Sandpiper	X				F (rare)			X			
Spotted Sandpiper	X				F (rare)			X			
Upland Sandpiper	X	X			S/F	X		X			
Wilson’s Snipe	X				S			X		S	
American Woodcock	X	X	X		F			X			

Table 4-1. Continued.

GROUP Common name	On WWL Species List	Species of Conservation Concern	North America				On BCR 11 Regional List	Prairie Potholes (BCR 11) ^b			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WADING BIRDS											
Great Blue Heron	X			F			X				
Black-crowned Night-Heron	X			F			X				
White-faced Ibis	X		X								
OTHER WATERBIRDS											
Sandhill Crane	X	X	X	S/F	X		X				
Whooping Crane	X	X	X	S/F							
Ring-billed Gull	X			F	X		X				
Virginia Rail	X				X		X		X		
WWL LANDBIRDS											
Purple Martin	X			F	X		X				
Tree Swallow	X			F	X		X				
N. Rough-winged Swallow	X			F	X		X				
Bank Swallow	X			F	X		X				
Palm Warbler	X			F							
Northern Waterthrush	X			F (rare)			X				
Common Yellowthroat	X			F	X	X	X				
Lincoln's Sparrow	X			F (rare)	rare						
Swamp Sparrow	X		X	F	X		X				
Red-winged Blackbird	X		X	S/F	X	X	X		X		
Rusty Blackbird	X	X	X	F (rare)			X				
Yellow-headed Blackbird	X			S/F	X		X	S/F	X		
Boat-tailed Grackle	X		X	F							

Table 4-1. Continued.

GROUP Common name	On WWL Species List	On BCR 23 Regional List	Prairie Hardwood Transition (BCR 23) ^b				On BCR 22 Regional List	Eastern Tallgrass Prairie (BCR 22) ^b			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WATERFOWL											
Black-bellied Whistling-Duck	X										
Fulvous Whistling-Duck	X										
Tundra Swan	X	X		S		X					
Snow Goose	X					X	X	S/F			
Ross's Goose	X										
Greater White-fronted Goose	X										
Canada Goose	X	X	X	F/S		X	X	F			
Cackling Goose											
American Black Duck	X	X				X	X	F			
Mallard	X	X				X	X	F			
Northern Pintail	X										
Green-winged Teal	X					X					
Blue-winged Teal	X	X				X					
American Wigeon	X	X				X		F			
SHOREBIRDS											
Black-bellied Plover	X	X				X					
American Golden-Plover	X	X				X		S			
Killdeer	X	X				X				X	X
Mountain Plover	X										
Lesser Yellowlegs	X	X				X					
Buff-breasted Sandpiper	X	X				X					
Pectoral Sandpiper	X	X				X					
Spotted Sandpiper	X	X				X					
Upland Sandpiper	X	X				X					
Wilson's Snipe	X	X				X					
American Woodcock	X	X				X					

Table 4-1. Continued.

GROUP Common name	On WWL Species List	On BCR 23 Regional List	Prairie Hardwood Transition (BCR 23) ^b				On BCR 22 Regional List	Eastern Tallgrass Prairie (BCR 22) ^b			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WADING BIRDS											
Great Blue Heron	X	X					X				
Black-crowned Night-Heron	X	X					X				
White-faced Ibis	X										
OTHER WATERBIRDS											
Sandhill Crane	X	X		S/F	X				S/F		
Whooping Crane	X										
Ring-billed Gull	X	X					X				
Virginia Rail	X	X					X			X	
WWL LANDBIRDS											
Purple Martin	X	X					X			X	
Tree Swallow	X	X					X				
N. Rough-winged Swallow	X	X					X				
Bank Swallow	X	X					X				
Palm Warbler	X										
Northern Waterthrush	X										
Common Yellowthroat	X	X					X			X	X
Lincoln's Sparrow	X										
Swamp Sparrow	X	X					X				
Red-winged Blackbird	X	X					X			X	X
Rusty Blackbird	X						X				
Yellow-headed Blackbird	X	X									
Boat-tailed Grackle	X										

Table 4-1. Continued.

GROUP Common name	On WWL Species List	On BCR 19 Regional List	Central Mixed-Grass Prairie (BCR 19) ^b				On BCR 18 Regional List	Shortgrass Prairie (BCR 18) ^b			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WATERFOWL											
Black-bellied Whistling-Duck	X	X									
Fulvous Whistling-Duck	X										
Tundra Swan	X										
Snow Goose	X	X				X					
Ross's Goose	X	X				X					
Greater White-fronted Goose	X	X		S							
Canada Goose	X	X				X					
Cackling Goose											
American Black Duck	X										
Mallard	X	X	X			X	X	F			
Northern Pintail	X	X				X	X	F			
Green-winged Teal	X	X				X	X	F			
Blue-winged Teal	X	X				X		F			
American Wigeon	X	X				X	X	F			
SHOREBIRDS											
Black-bellied Plover	X	X				X					
American Golden-Plover	X	X				X					
Killdeer	X	X			X	(?)			X		
Mountain Plover	X	X							X	X	
Lesser Yellowlegs	X	X									
Buff-breasted Sandpiper	X	X		S							
Pectoral Sandpiper	X	X									
Spotted Sandpiper	X	X									
Upland Sandpiper	X	X			X						
Wilson's Snipe	X	X									
American Woodcock	X	X									

Table 4-1. Continued.

GROUP Common name	On WWL Species List	On BCR 19 Regional List	Central Mixed-Grass Prairie (BCR 19) ^b				On BCR 18 Regional List	Shortgrass Prairie (BCR 18) ^b			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WADING BIRDS											
Great Blue Heron	X	X					X				
Black-crowned Night-Heron	X	X					X				
White-faced Ibis	X	X					X				
OTHER WATERBIRDS											
Sandhill Crane	X	X		S			X				
Whooping Crane	X										
Ring-billed Gull	X	X					X				
Virginia Rail	X						X				
WWL LANDBIRDS											
Purple Martin	X	X									
Tree Swallow	X	X					X				
N. Rough-winged Swallow	X	X				X	X				
Bank Swallow	X	X					X				
Palm Warbler	X										
Northern Waterthrush	X										
Common Yellowthroat	X	X					X				
Lincoln's Sparrow	X	X					X				
Swamp Sparrow	X	X									
Red-winged Blackbird	X	X				X	(?)	X			
Rusty Blackbird	X	X									
Yellow-headed Blackbird	X	X						X			
Boat-tailed Grackle	X										

Table 4-1. Continued.

GROUP Common name	On WWL Species List	On BCR 24 Regional List	Central Hardwoods (BCR 24) ^b				On BCR 26 Regional List	Mississippi Alluvial Valley (BCR 26) ^b			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WATERFOWL											
Black-bellied Whistling-Duck	X										
Fulvous Whistling-Duck	X										
Tundra Swan	X										
Snow Goose	X	X					X				
Ross's Goose	X										
Greater White-fronted Goose	X						X				
Canada Goose	X	X	X	F			X				
Cackling Goose											
American Black Duck	X	X					X				
Mallard	X	X					X	X			
Northern Pintail	X	X					X				
Green-winged Teal	X	X					X				
Blue-winged Teal	X	X					X				
American Wigeon	X	X					X				
SHOREBIRDS											
Black-bellied Plover	X						X				
American Golden-Plover	X						X				
Killdeer	X	X	X			X	X				
Mountain Plover	X										
Lesser Yellowlegs	X	X					X				
Buff-breasted Sandpiper	X						X				
Pectoral Sandpiper	X						X				
Spotted Sandpiper	X	X					X				
Upland Sandpiper	X	X					X				
Wilson's Snipe	X	X					X				
American Woodcock	X	X					X				

Table 4-1. Continued.

GROUP Common name	On WWL Species List	On BCR 24 Regional List	Central Hardwoods (BCR 24) ^b				On BCR 26 Regional List	Mississippi Alluvial Valley (BCR 26) ^b			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WADING BIRDS											
Great Blue Heron	X	X					X				
Black-crowned Night-Heron	X	X					X				
White-faced Ibis	X										
OTHER WATERBIRDS											
Sandhill Crane	X										
Whooping Crane	X										
Ring-billed Gull	X	X					X				
Virginia Rail	X	X					X				
WWL LANDBIRDS											
Purple Martin	X	X					X				
Tree Swallow	X	X					X				
N. Rough-winged Swallow	X	X					X				
Bank Swallow	X	X					X				
Palm Warbler	X										
Northern Waterthrush	X						X				
Common Yellowthroat	X	X					X				
Lincoln's Sparrow	X						X				
Swamp Sparrow	X	X					X				
Red-winged Blackbird	X	X					X				
Rusty Blackbird	X	X	X				X				
Yellow-headed Blackbird	X										
Boat-tailed Grackle	X						X				

Table 4-1. Continued.

^aSome information from comprehensive multi-species surveys conducted in Canada:

Boutin, C., K. E. Freemark, and D. A. Kirk. 1999a. Spatial and temporal patterns of bird use of farmland in southern Ontario. *Canadian Field-Naturalist* **113**:430-460.

Boutin, C., K. E. Freemark, and D. A. Kirk. 1999b. Farmland birds in southern Ontario: field use, activity patterns and vulnerability to pesticide use. *Agriculture, Ecosystems & Environment* **72**:239-254.

Jobin, B., J.-L. DesGranges, and C. Boutin. 1998. Farmland habitat use by breeding birds in southern Quebec. *Canadian Field-Naturalist* **112**:611-618.

Kirk, D. A., C. Boutin, and K. E. Freemark. 2001. A multivariate analysis of bird species composition and abundance between crop types and seasons in southern Ontario, Canada. *Ecoscience* **8**:173-184.

^bNo comprehensive multi-species surveys conducted in BCR.

Table 4-2. Summary of corn resources and their use by waterbirds during the different phases of corn production in North America. Grey shaded boxes indicate not applicable, or resource not available during the time period.

RESOURCES	SOWING (Spring)	PRE-HARVEST (Growing Crop, Summer)	HARVEST (Fall)	POST-HARVEST (Winter, Early Spring)	CROP ROTATION, FALLOW LAND
FORAGING RESOURCES ○ Corn Kernels	waste corn – Black-bellied Whistling Duck, breeding blackbirds ^{1,2,3}	ripening corn - breeding blackbirds ⁴⁻⁷	waste corn - fall migrant waterfowl, cranes, blackbirds ⁸⁻²²	waste corn - migrant and wintering waterfowl, cranes, blackbirds ^{5,10-38}	waste corn depleted by the time field is fallow ³⁹
○ Weed Seeds				blackbirds ⁴⁰	
○ Green Vegetation (new shoots of corn)	blackbirds, grackles ^{41,42}				
○ Terrestrial Invertebrates	migrant and breeding shorebirds, landbirds (earthworms, soil-dwelling larval forms of insects, flying insects) ^{4,5,39,43-45}	breeding landbirds (insects associated with growing corn) ³⁹		migrant and wintering shorebirds, landbirds (earthworms, soil-dwelling larval forms of insects, flying insects) ^{4,5,39,43-45}	
BREEDING RESOURCES ○ Nesting Habitat	only three species (Killdeer, Red-winged Blackbird, Common Yellowthroat) documented nesting in cornfields ^{39,46-52}	only three species (Killdeer, Red-winged Blackbird, Common Yellowthroat) documented nesting in cornfields ^{39,46-52}			
○ Brood-rearing/Post-fledgling Habitat		no information, but cornfields likely used by Killdeer and other breeding waterbirds	no information, but cornfields likely used by Killdeer and other breeding waterbirds		

Table 4-2. Continued.

Sources:

- 1 Giltz, M. L., and T. M. Stockdale. 1960. The red-winged blackbird story. Special Circulation 95, Ohio Agriculture Experimental Station, Ohio State University, Columbus, Ohio.
- 2 McNicol, D. K., R. J. Robertson, and P. J. Weatherhead. 1982. Seasonal, habitat, and sex-specific food habits of red-winged blackbirds: implications for agriculture. *Canadian Journal of Zoology* **60**:3282-3289.
- 3 Bolen, E. G., and B. J. Forsyth. 1967. Foods of the Black-bellied Tree Duck in south Texas. *Wilson Bulletin* **79**:43-49.
- 4 Bollinger, E. K., and J. W. Caslick. 1985. Red-winged blackbird predation on northern corn rootworm beetles in field corn. *Journal of Applied Ecology* **22**:39-48.
- 5 Dolbeer, R. A. 1990. Ornithology and integrated pest management: red-winged blackbirds *Agelaius phoeniceus* and corn. *Ibis* **132**:309-322.
- 6 Hintz, J. V., and M. I. Dyer. 1970. Daily rhythm and seasonal change in the summer diet of adult red-winged blackbirds. *Journal of Wildlife Management* **34**:789-799.
- 7 Brewster, W. 1906. The birds of the Cambridge region of Massachusetts. Mem. Nuttall Ornithol. Club no. 4.
- 8 Anderson, H. G. 1959. Food habits of migratory ducks in Illinois. *Illinois Natural History Survey Bulletin* **27**:289-344.
- 9 Baldwin, J. R., and J. R. Lovvorn. 1994a. Habitats and tidal accessibility of the marine foods of dabbling ducks and brant in Boundary Bay, British Columbia. *Marine Biology* **120**:627-638.
- 10 Baldwin, J. R., and J. R. Lovvorn. 1994b. Expansion of seagrass habitat by exotic *Zostera japonica*, and its use by dabbling ducks and brant in Boundary Bay, British Columbia. *Mar. Ecol. Prog. Ser.* **103**:119-127.
- 11 Byrd, V. E. 1991. Food habits of Black Duck wintering in west central Tennessee. Tennessee Technical University, Cookeville, TX.
- 12 Craven, S. R., and R. A. Hunt. 1984. Fall food habits of Canada geese in Wisconsin. *Journal of Wildlife Management* **48**:169-173.
- 13 Frederick, R. B., and E. E. Klaas. 1982. Resource use and behavior of migrating Snow Geese. *Journal of Wildlife Management* **46**:601-614.
- 14 Gates, R. J., D. F. Caithamer, W. E. Moritz, and T. C. Tacha. 2001. Bioenergetics and nutrition of Mississippi Valley population Canada geese during winter and migration. *Wildlife Monographs*:1-65.
- 15 Haag, K. R., J. C. Joyce, W. M. Hetrick, and J. C. Jordan. 1987. Predation on waterhyacinth weevils and other aquatic insects by three wetland birds in Florida. *Florida Entomologist* **70**:457-471.
- 16 Havera, S. P. 1998. Waterfowl of Illinois: status and management. Phoenix Publishing, Urbana, IL.
- 17 Hoffman, R. H. 1976. Field usage by Sandhill Cranes in southern Michigan. *Proceedings of the International Crane Workshop* **1**:35-43.
- 18 Lovvorn, J. R., and J. R. Baldwin. 1996. Intertidal and farmland habitats of ducks in the Puget Sound region: a landscape perspective. *Biological Conservation* **77**:97-114.
- 19 Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. American wildlife and plants. McGraw-Hill Book Co., New York, NY.
- 20 Mott, D. F., R. R. West, J. W. DeGrazio, and J. L. Guarino. 1972. Foods of the Red-winged Blackbird in Brown County, South Dakota. *Journal of Wildlife Management* **36**:983-987.
- 21 Sell, D. L. 1979. Fall foods of teal on the Texas High Plains. *Southwest Naturalist* **24**:373-375.
- 22 Stabins, H. C., C. E. Grue, D. A. Manuwal, and S. L. Paulus. 2002. Time allocation by Aleutian Canada geese during the nonbreeding season in California. *California Fish and Game* **88**:186-195.
- 23 Alisauskas, R. T., and C. D. Ankney. 1992. Spring habitat use and diets of midcontinent adult Lesser Snow Geese. *Journal of Wildlife Management* **56**:43-54.
- 24 Baldassarre, G. A., and E. G. Bolen. 1984. Field-feeding ecology of waterfowl wintering on the southern High Plains of Texas. *Journal of Wildlife Management* **48**:63-71.
- 25 Davis, C. A. 2003. Habitat use and migration patterns of sandhill cranes along the Platte River, 1998-2001. *Great Plains Research* **13**:199-216.
- 26 Giroux, J. F., and R. Bergeron. 1996. Spring diets of sympatric Greater Snow Geese and Canada Geese in southern Quebec. *Canadian Journal of Zoology* **74**:950-953.
- 27 Harvey, W. F. I., R. A. Malecki, E. C. Soutiere, and W. F. Harvey. 1988. Habitat use by foraging Canada geese in Kent County, Maryland. *Transactions of the northeast section of The Wildlife Society* **45**:1-7.
- 28 Kahl, R. B., and F. B. Samson. 1984. Factors affecting yield of winter wheat grazed by geese. *Wildlife Society Bulletin* **12**:256-262.
- 29 Krapu, G. L., K. J. Reinecke, D. G. Jorde, and S. G. Simpson. 1995. Spring-staging ecology of midcontinent greater white-fronted geese. *Journal of Wildlife Management* **59**:736-746.
- 30 Linz, G. M., M. J. Kenyon, H. J. Homan, and W. J. Bleier. 2002. Avian use of rice-baited corn stubble in east-central South Dakota. *International Biodeterioration & Biodegradation* **49**:179-184.
- 31 Nagel, J. 1965. Field feeding in Whistling Swans in northern Utah. *Condor* **67**:446-447.
- 32 Paullin, D. G. 1996. Tundra swan use in California's Central Valley. Pages 48-52 *in* Proceedings and Papers of the Fifteenth Trumpeter Swan Society Conference: Trumpeter Swans: A Vision for the 21st Century.
- 33 Reed, A., G. Chapdelaine, and P. Dupuis. 1977. Use of farmland in spring by migrating Canada Geese in the St. Lawrence Valley, Quebec. *Journal of Applied Ecology* **14**:667-680.
- 34 Schwalbe, G. P., and P. W. Schwalbe. 1974. Corn stubble, winter wheat, and hayfields. *American Birds* **28**:722-723.
- 35 Tate, J.J., and D.J. Tate. 1966. Additional records of Whistling Swans feeding in dry fields. *Condor* **68**:398-399.
- 36 Iverson, G. C., T. C. Tacha, and P. A. Vohs. 1982. Food contents of Sandhill Cranes during winter and spring. Pages 95-98 *in* Proceedings of the 1981 Crane Workshop. National Audubon Society, Tavernier, Florida.
- 37 Lewis, J. C. 1979. Taxonomy, food, and feeding habitat of Sandhill Cranes, Platte Valley, Nebraska. Pages 21-27 *in* Proceedings of the 1978 Crane Workshop, Colorado State University, Ft. Collins, Colorado.
- 38 Walker, D. L., and S. D. Schemnitz. 1987. Food habits of Sandhill Cranes in relation to agriculture in central and southwestern New Mexico. Pages 201-212 *in* Proceedings of the 1985 Crane Workshop. Platte River Whooping Crane Habitat Maintenance Trust, Grand Island, Nebraska.

Table 4-2. Continued.

- 39 Best, L. B. 2001. Temporal patterns of bird abundance in cornfield edges during the breeding season. *American Midland Naturalist* **146**:94-104.
- 40 Robertson, R. J., P. J. Weatherhead, F. J. S. Phelan, G. L. Holroyd, and N. Lester. 1978. On assessing the economic and ecological impact of winter blackbird flocks. *Journal of Wildlife Management* **42**:53-60.
- 41 Rogers, J. G., Jr., and J. T. Linehan. 1977. Some aspects of grackle feeding behavior in newly planted corn. *Journal of Wildlife Management* **41**:444-447.
- 42 Stone, C. P., and D. F. Mott. 1973. Bird damage to sprouting corn in the United States. Special Science Report on Wildlife 173, U.S. Fish and Wildlife Service.
- 43 Boutin, C., K. E. Freemark, and D. A. Kirk. 1999a. Spatial and temporal patterns of bird use of farmland in southern Ontario. *Canadian Field-Naturalist* **113**:430-460.
- 44 Braile, T. M. 1999. Migration studies of shorebirds in west-central Indiana. M.S. Purdue University.
- 45 Sterner, R. T., B. E. Petersen, S. E. Gaddis, K. L. Tope, and D. J. Poss. 2003. Impacts of small mammals and birds on low-tillage, dryland crops. *Crop Protection* **22**:595-602.
- 46 Dambach, C. A., and E. E. Good. 1940. The effect of certain land use practices on populations of breeding birds in southwestern Ohio. *Journal of Wildlife Management* **4**:63-76.
- 47 Good, E. E., and C. A. Dambach. 1943. Effect of land use practices on breeding bird populations in Ohio. *Journal of Wildlife Management* **7**:291-297.
- 48 Basore, N. S., L. B. Best, and J. B. Wooley. 1986. Bird nesting in Iowa no-tillage and tillage cropland. *Journal of Wildlife Management* **50**:19-28.
- 49 Best, L. B. 1986. Conservation tillage: ecological traps for nesting birds. *Wildlife Society Bulletin* **14**:308-317.
- 50 Boutin, C., K. E. Freemark, and D. A. Kirk. 1999b. Farmland birds in southern Ontario: field use, activity patterns and vulnerability to pesticide use. *Agriculture, Ecosystems & Environment* **72**:239-254.
- 51 Renfrew, R. B., and C. A. Ribic. 2001. Grassland birds associated with agricultural riparian practices in southwestern Wisconsin. *Journal of Range Management* **54**:546-552.
- 52 Beecher, N. A., R. J. Johnson, J. R. Brandle, R. M. Case, and L. J. Young. 2002. Agroecology of birds in organic and nonorganic farmland. *Conservation Biology* **16**:1620-1631.

Table 4-3. Summary of documented impacts of corn production methods and landscape features on waterbird groups and WWL species using cornfields in North America. Open boxes without text indicate potential data gaps or areas for further

	SOIL AND RESIDUE MANAGEMENT (Conventional Tillage vs. No-till)	SOWING	PESTICIDE USE, ORGANIC FARMING	HARVEST METHODS	FIELD SIZE
ALL WATERBIRDS	<p>conventional – mixed effects on fall/winter food availability: plowing potentially increases temporary access to invertebrate prey^{1,2} and burning increases access to waste corn³, but plowing buries waste corn substantially³⁻⁶</p> <p>no-till – Mixed effects on food resources all year: more waste corn in unplowed fields³⁻⁶, but may be less available than in burned fields³; invertebrate abundances higher in no-till fields^{7,8} Nesting cover enhanced during breeding season⁸⁻¹⁰</p>	<p>farm machinery used to plant corn can destroy nests and eggs of early breeders^{10,14}</p>	<p>mortalities from organochlorines, organophosphates, or carbamates documented for some species^{16,17}; new shoots/seeds of weed species and invertebrate foods reduced by pesticide use¹⁸⁻²²; organic farming increases food resources for breeding birds¹⁸; potential damage to nests from pesticide applications¹⁵</p>	<p>increased harvest efficiency has diminished waste corn resources²⁷</p>	<p>more edge habitat associated with smaller fields, thus more food resources for species attracted to edges²⁸⁻³⁰</p>
Waterbird Species Richness	<p>more species in no-till than conventional fields during breeding season^{8,9}</p>				
Waterbird Abundances	<p>greater abundances of breeding birds in no-till than conventional fields^{8,9}; nest densities (based on few species) higher in no-till¹⁰</p>				

Table 4-3. Continued.

	SOIL AND RESIDUE MANAGEMENT (Conventional Tillage vs. No-till)	SOWING	PESTICIDE USE, ORGANIC FARMING	HARVEST METHODS	FIELD SIZE
WATERFOWL	<p>conventional – mixed effects on waste corn availability in fall/winter: increases after burning but decreases after fall plowing³⁻⁶.</p> <p>no-till – waste corn available throughout nonbreeding season⁴⁻⁶</p>			<p>increased harvest efficiency has diminished waste corn resources²⁷</p>	
○ Swans					
○ Geese	<p>conventional – mixed effects on waste corn availability for geese in fall/winter: increases after burning but decreases after fall plowing³⁻⁶. Lower use of fall-plowed fields^{4,11-13}</p> <p>no-till – waste corn available throughout nonbreeding season⁴⁻⁶</p>			<p>increased harvest efficiency has diminished waste corn resources²⁷</p>	
○ Dabbling Ducks					

Table 4-3. Continued.

	SOIL AND RESIDUE MANAGEMENT (Conventional Tillage vs. No-till)	SOWING	PESTICIDE USE, ORGANIC FARMING	HARVEST METHODS	FIELD SIZE
SHOREBIRDS	<p>conventional - plowing may temporarily invert invertebrate resources^{1,2}; Less nesting cover for ground nesters in tilled fields^{8,9}; More nests lost than in no-till fields due to more passes by farm machinery^{14,15}.</p> <p>no-till - greater nesting cover in no-till^{8,9}; Fewer nests lost than in tilled fields because fewer passes by farm machinery^{14,15}; Nest densities (based on few species) higher in no-till¹⁰</p>	<p>early nests may be lost to farm machinery during planting^{10,14}</p>	<p>documented mortalities from carbamate and organophosphate use¹⁷; Risk of mistaking granular formulations as seeds or grit, or ingesting granules adhering to invertebrates²³⁻²⁶;</p> <p>weed seeds and invertebrate foods reduced by pesticides¹⁸⁻²²; application by farm machinery may destroy nests¹⁵; organic farming can increase food resources for breeding birds and some species more abundant during breeding season¹⁸</p>		
WADING BIRDS	<p>plowing may expose invertebrate resources^{1,2}</p>				
OTHER WATERBIRDS	<p>conventional – mixed effects on waste corn availability for Sandhill Cranes in fall/winter: increases after burning but decreases after fall plowing³⁻⁶.</p> <p>lower use of fall-plowed fields^{4,11-13}</p> <p>no-till – waste corn available throughout nonbreeding season⁴⁻⁶</p>			<p>increased harvest efficiency has diminished waste corn resources for cranes²⁷</p>	

Table 4-3. Continued.

	SOIL AND RESIDUE MANAGEMENT (Conventional Tillage vs. No-till)	SOWING	PESTICIDE USE, ORGANIC FARMING	HARVEST METHODS	FIELD SIZE
LANDBIRDS	<p>Conventional - plowing may help expose invertebrate resources^{1,2} (short-term benefit); Less nesting cover for ground nesters in tilled fields^{8,9}; More nests lost than in no-till fields due to more passes by farm machinery^{14,15}.</p> <p>No-till - greater nesting cover in no-till^{8,9}; Fewer nests lost than in tilled fields because fewer passes by farm machinery^{14,15}.</p>	<p>Early nests may be lost to farm machinery during planting^{10,14}</p>	<p>Documented mortalities from carbofuran use^{16,17}; Risk of mistaking granular formulations as seeds or grit, or ingesting granules adhering to invertebrates²³⁻²⁶; weed seeds and invertebrate foods reduced by pesticides¹⁸⁻²²; Application by farm machinery may destroy nests¹⁵; Organic farming can increase food resources for breeding birds and some species more abundant during breeding season¹⁸</p>		

Sources:

- 1 O'Connor, R. J., and M. Shrubbs. 1986. *Farming and Birds*. Cambridge University Press, Cambridge, England.
- 2 Lack, P. C. 1992. *Birds on Lowland Farms*. HMSO, London, England.
- 3 Baldassarre, G. A., and E. G. Bolen. 1984. Field-feeding ecology of waterfowl wintering on the southern High Plains of Texas. *Journal of Wildlife Management* **48**:63-71.
- 4 Frederick, R. B., and E. E. Klaas. 1982. Resource use and behavior of migrating Snow Geese. *Journal of Wildlife Management* **46**:601-614.
- 5 Warner
- 6 Giroux, J. F., and R. Bergeron. 1996. Spring diets of sympatric Greater Snow Geese and Canada Geese in southern Quebec. *Canadian Journal of Zoology* **74**:950-953.
- 7 Mackay, A. D., and E. J. Kladviko. 1985. Earthworms and rate of breakdown of soybean and maize residues in soil. *Soil Biology and Biochemistry* **17**:851-857.
- 8 Warburton, P. B., and W. D. Klimstra. 1984. Wildlife use of no-till and conventionally-tilled corn fields. *Journal of Soil and Water Conservation* **39**:327-330.
- 9 Castrale, J. S. 1985. Responses of wildlife to various tillage conditions. *Transactions of the North American Wildlife and Natural Resources Conference* **50**:142-156.
- 10 Basore, N. S., L. B. Best, and J. B. Wooley. 1986. Bird nesting in Iowa no-tillage and tillage cropland. *Journal of Wildlife Management* **50**:19-28.
- 11 Reed, A., G. Chapdelaine, and P. Dupuis. 1977. Use of farmland in spring by migrating Canada Geese in the St. Lawrence Valley, Quebec. *Journal of Applied Ecology* **14**:667-680.
- 12 Krapu, G. L., K. J. Reinecke, D. G. Jorde, and S. G. Simpson. 1995. Spring-staging ecology of midcontinent greater white-fronted geese. *Journal of Wildlife Management* **59**:736-746.
- 13 Davis, C. A. 2003. Habitat use and migration patterns of sandhill cranes along the Platte River, 1998-2001. *Great Plains Research* **13**:199-216.
- 14 Rodenhouse, N. L., and L. B. Best. 1983. Breeding ecology of Vesper Sparrows in corn and soybean fields. *American Midland Naturalist* **110**:265-275.
- 15 Best, L. B. 1986. Conservation tillage: ecological traps for nesting birds. *Wildlife Society Bulletin* **14**:308-317.
- 16 Stinson, E. R., L. E. Hayes, P. B. Bush, and D. H. White. 1994. Carbofuran affects wildlife on Virginia corn fields. *Wildlife Society Bulletin* **22**:566-575.
- 17 Boutin, C., K. E. Freemark, and D. A. Kirk. 1999b. Farmland birds in southern Ontario: field use, activity patterns and vulnerability to pesticide use. *Agriculture, Ecosystems & Environment* **72**:239-254.
- 18 Beecher, N. A., R. J. Johnson, J. R. Brandle, R. M. Case, and L. J. Young. 2002. Agroecology of birds in organic and nonorganic farmland. *Conservation Biology* **16**:1620-1631.
- 19 Altieri, M. A. 1987. *Agroecology: the scientific basis of alternative agriculture*. Westview Press, Boulder, Colorado.
- 20 Altieri, M. A. 1992. Agroecological foundations in alternative agriculture in California. *Agriculture, Ecosystems & Environment* **39**:23-53.
- 21 Freemark, K. E., and C. Boutin. 1995. Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: a review with special reference to North America. *Agriculture, Ecosystems & Environment* **52**:67-91.
- 22 Beecher, N. B. 1998. *Birds and agroecological relationships in organic and nonorganic farmland*. M.S. University of Nebraska, Lincoln, Nebraska.

Table 4-3. Continued.

- Sources:
- 23 Balcomb, R., R. Stevens, and C. I. Bowen. 1984b. Toxicity of 16 granular insecticides to wild-caught songbirds. *Bulletin of Environmental Contamination and Toxicology* **33**:302-307.
 - 24 Best, L. B. 1992. Characteristics of corn rootworm insecticide granules and the grit used by cornfield birds: evaluating potential avian risks. *American Midland Naturalist* **128**:126-138.
 - 25 Best, L. B., and D. L. Fischer. 1992. Granular insecticides and birds: factors to be considered in understanding exposure and reducing risk. *Environmental Toxicology and Chemistry* **11**:1495-1508.
 - 26 Stafford, T. R., L. B. Best, and D. L. Fischer. 1996. Effects of different formulations of granular pesticides on birds. *Environmental Toxicology and Chemistry* **15**:1606-1611.
 - 27 Krapu, G. L., D. A. Brandt, and R. R. Cox. 2004. Less waste corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications for wildlife management. *Wildlife Society Bulletin* **32**:127-136.
 - 28 Kemp, J. C., and G. W. Barrett. 1989. Spatial patterning: impact of uncultivated corridors on arthropod populations within soybean agroecosystems. *Ecology* **70**:14-128.
 - 29 Best, L. B., R. C. Whitmore, and G. M. Booth. 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. *American Midland Naturalist* **123**:84-99.
 - 30 Sotherton, N. W. 1991. Conservation headlands: a practical combination of intensive cereal farming and conservation. Pages 373-397 *in* L. G. Firbank, N. Carter, J. F. Darbyshire, and G. R. Potts, editors. *The Ecology of Temperate Cereal Fields*. Blackwell Scientific Publications, Oxford, UK.

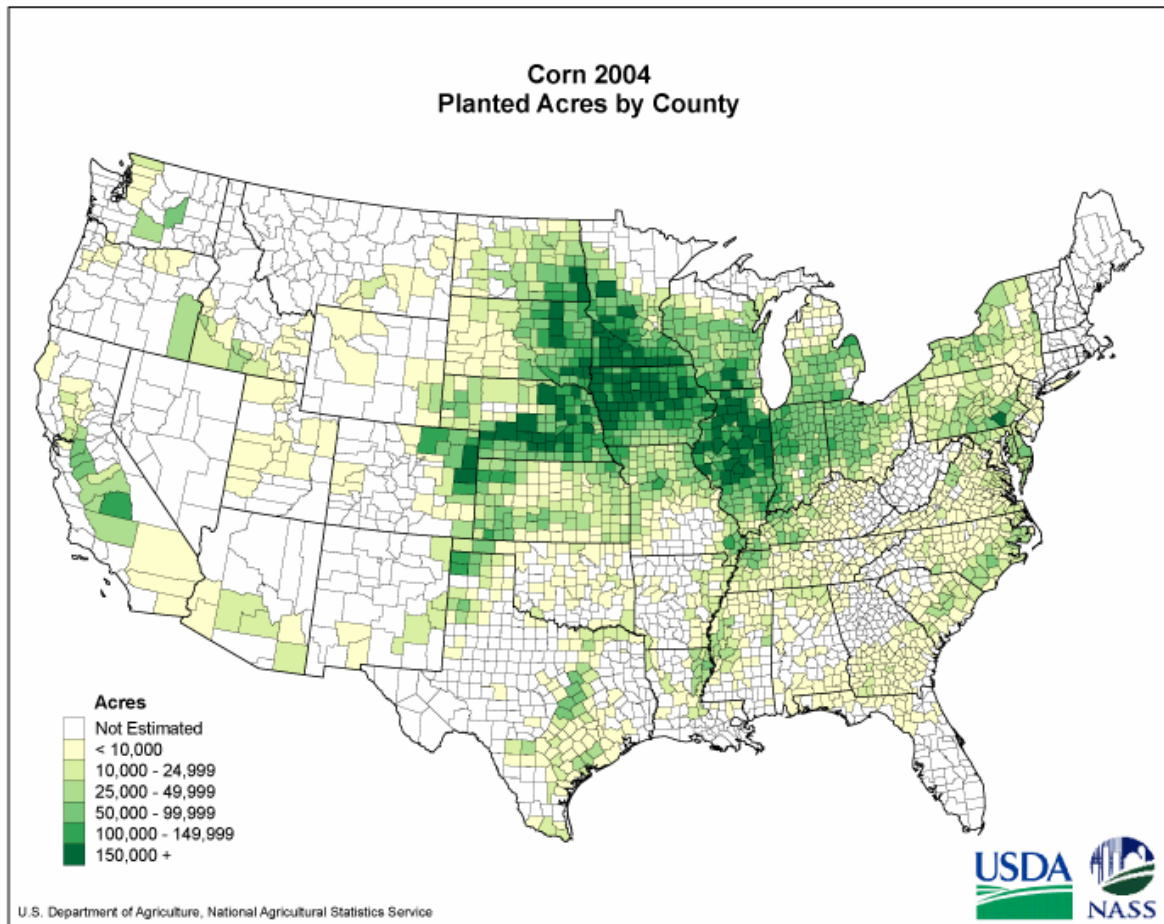


Figure 4-1. Map of the distribution of corn planted in the United States during 2004, the most recent year for which data are available. From the United States Department of Agriculture National Agricultural Statistics Service (<http://www.usda.gov/nass/aggraphs/cropmap.htm>; accessed 2 Jan 2007).