7. SOYBEANS

Compared to rice, corn, wheat, and sorghum, land planted to soybeans (*Glycine max*) offers habitat of questionable value to waterbirds, particularly since the advent and widespread adoption of growing genetically modified (GM) varieties. The major soybean production region of the U.S. generally overlaps with the "Corn Belt," where seven states (Iowa, Illinois, Minnesota, Indiana, Ohio, Missouri, and Nebraska) account for 72% of the national production; an additional 10% of U.S. production occurs in another seven states (Arkansas, Mississippi, North Carolina, Kentucky, Tennessee, Louisiana, Alabama) in the southern and southeastern U.S. (Acquaah 2005). Figure 7-1 summarizes the typical spatial distribution of soybeans planted in North America.

Across North America, the collective diversity of waterbirds using soybean fields is fairly high compared to other crops, consisting primarily of geese, cranes, shorebirds, and some WWL landbirds, all of which primarily use the crop during nonbreeding periods. It is important to recognize, however, that relatively high use of soybean fields does not necessarily equate to high value of soybean fields. The energy value of soybeans is fairly low, and deterioration in the body condition of birds can occur when soybeans are consumed in large quantities. In general, most waterbirds foraging in soybean fields appear only to supplement their diet with protein from soybeans or other food resources (invertebrates) in fields, as soybeans in most cases only account for a minority of the foods consumed by individuals. Birds tend to use soybean habitat in proportion to its availability across the landscape, and there are some observations of waterbirds avoiding soybean habitat. Effects of soybean production methods on waterbirds are varied, and much is unknown. Among crop production practices, however, the intentional winter flooding of soybean fields that have not been denuded of weedy vegetation holds the most potential to provide foraging habitat for shorebirds and ducks, and ultimately to increase the overall wildlife conservation value of land planted to soybeans.

This chapter summarizes the state of current knowledge regarding the occurrence and abundance of waterbird species in soybean fields, resources for waterbirds in soybean fields, how waterbirds use soybean fields, and the impacts of soybean production practices and other management activities on waterbirds.

USE BY WATERBIRDS

Most of what is known about waterbird use of soybean fields has been ascertained from studies conducted in North America. Waterbird use of soybean fields has been documented primarily in seven WWL focal BCRs (in bold throughout text) - **Prairie Potholes** (BCR 11), **Prairie Hardwood Transition** (BCR 23), **Eastern Tallgrass Prairie** (BCR 22), **Shortgrass Prairie** (BCR 18), **Central Mixed-Grass Prairie** (BCR 19), **Central Hardwoods** (BCR 24), and **Mississippi Alluvial Valley** (BCR 26). Additional records of waterbirds using soybean fields also come from southern Canada (BCR 13), the eastern U.S. (BCR 27, BCR 28, BCR 29, BCR 30), the southeastern U.S. (BCR 27), and from along the Gulf of Mexico Coast (BCR 37). Waterbird use of soybean fields tends to occur during migrations and the breeding season at northern latitudes, during all times of the year at mid latitudes, and during winter at southern latitudes (Table 7-1).

Overall, 40 species of waterbirds have been documented in soybean fields in North America. Of these species, seven 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. Knowledge of waterbird use of soybean fields is derived almost entirely from single-species studies, suggesting that only a few species occur in fields at a time in most locales (except flooded soybean fields of the **Mississippi Alluvial Valley**, BCR 26; see below). Most species use soybean fields for foraging or resting during nonbreeding periods, and very few use them for nesting. Moreover, it is important to recognize that many of these 40 species were documented using soybean fields prior to the 1990s when widespread conversion to GM crops meant a reduction in the availability of non-crop food resources such as weed seeds (see below **RESOURCES - Foraging Resources)**. Species occurrences in soybeans for all of North America and by focal BCR for the WWL project are summarized in Table 7-1. BCR regional species lists, or species considered relatively abundant in each BCR (see Introduction), are also shown.

Waterfowl

The diversity and abundances of waterfowl species observed in North American soybean fields are modest. Nine species (1 swan, 3 geese, 5 dabbling ducks) have been observed foraging or resting in soybean fields, all during nonbreeding periods, and a few during the breeding season (Table 7-1). Although not documented in soybeans, Ross's Goose and Cackling Goose also likely use soybean fields during migrations and winter. Because most published studies pertaining to the use of soybean fields by waterfowl concern diet and foraging ecology, few researchers have presented data on species' abundance and densities. From the few studies that have documented waterfowl abundance, we know that some goose species can reach numbers in the hundreds to thousands in individual fields (Kahl and Samson 1984, Harvey et al. 1988, Twedt and Nelms 1999, Gates et al. 2001, Petrie et al. 2002).

In general, during nonbreeding periods throughout northern and mid latitudes of North America, swans and geese may forage in soybean fields, but their use generally appears to match what would be expected given the vast agricultural dominance of soybeans in some areas. Fields planted to soybean have been used by spring and fall-migrating Tundra Swans in southern Ontario (BCR 13) (Petrie et al. 2002), and Canada Geese in Wisconsin (**Prairie Hardwood Transition**; BCR 23) (Hunt and Bell 1973, Gates et al. 2001). In the eastern U.S., wintering Canada Geese and Snow Geese have been observed foraging in harvested soybean fields, although use appears to be minimal (Malecki et al. 1988, Hill and Frederick 1997) or in proportion to availability of the crop within the landscape (Harvey et al. 1988). Tundra Swans have been observed in soybean fields in coastal North Carolina and Maryland in winter (Munro 1981, Bortner 1985, Earnst 1992). In the **Eastern Tallgrass Prairie** region (BCR 22), Canada Geese have been recorded foraging in soybean fields during fall migration and winter in Illinois and Missouri (Jarvis 1976, Kahl and Samson 1984, Havera 1998). In northern Missouri, soybean use was generally proportional to the crop's availability across the landscape in October, but low use relative to availability from November through April suggested avoidance during winter and spring (Kahl and Samson 1984). In other locales in the **Eastern Tallgrass Prairie** region, Snow Geese likewise appear to forage on soybeans to a limited extent (Frederick and Klaas 1982, Davis et al. 1989), with only 4% of geese observed in soybean fields during fall migration in

Nebraska (Frederick and Klaas 1982), and only trace amounts of soybeans found in the diets of wintering geese in Iowa, Missouri, and Kansas (Davis 1985, Alisauskas 1988). In the **Central Mixed-Grass Prairie** region (BCR 19), spring-migrating Snow Geese and Greater White-fronted Geese forage only minimally in soybean fields in Oklahoma and Nebraska (Alisauskas and Ankney 1992, Krapu et al. 1995). In Illinois (**Central Hardwoods** region, BCR 24), 10% of Canada Goose flocks observed from fall through winter foraged in soybean fields (Paine and Tacha 1987).

At more southern latitudes, primarily during winter, five dabbling duck species join geese as the most common waterfowl observed in soybean fields. In the **Mississippi Alluvial Valley** (BCR 26), soybeans accounted for a substantial portion of the diet of Mallards and Wood Ducks in Mississippi (Delnicki and Reinecke 1986), and were eaten by most Mallards (although to a limited extent) sampled in Arkansas (Wright 1959). Duck use of soybean fields that are purposely flooded (see **Effects of Soybean Production Methods – Soybean Field Flooding** below) can also be quite high. Wintering Northern Pintail commonly occur in flooded soybean fields in Louisiana (Smith et al. 1989). In flooded soybean fields in Arkansas and Mississippi, Twedt and Nelms (1999) observed average winter densities of 230 birds/km^2 for Mallard, and 110 birds/km^2 for Northern Shoveler, densities greater than those observed for these species in flooded rice in the same region. In coastal Texas and Louisiana (BCR 37), researchers have documented incidental to moderate use of soybean fields by fall-migrant Mottled Ducks, and by wintering Snow Geese, Greater White-fronted Geese, and Northern Pintail (a Conservation Priority Species), with most accounts indicating that these species only use soybean fields in proportion to their availability in the landscape (Hobaugh 1984, Leslie and Chabreck 1984, Cox and Afton 1997).

During the breeding season, waterfowl appear to use soybean fields only incidentally. In South Dakota (**Prairie Potholes**; BCR 11), Linz et al. (2004) documented the presence of Canada Geese and Mallards in growing soybean fields, but their use of fields (feeding or nesting) were not described. Along the Gulf of Mexico Coast (BCR 37), Mottled Ducks, a Conservation Priority Species, have been documented foraging in flooded soybean fields in Louisiana during the post-breeding period in July (Zwank et al. 1989).

Shorebirds

In some locales, soybean fields can attract fairly high diversities and abundances of shorebirds, and birds are presumably foraging on the invertebrates present in fields. As many as 15 shorebird species have been recorded in soybean fields in North America, primarily during winter and migration periods (Table 7-1). In southern Ontario (BCR 13), Killdeer have been documented regularly in soybean fields during fall migration, and Spotted Sandpipers also occur rarely in fall (Boutin et al. 1999a, Kirk et al. 2001). In the eastern U.S. (Virginia, North Carolina; BCRs 27 and 30) and southeastern U.S. (Georgia; BCR 27), wintering American Woodcock (a Conservation Priority Species) commonly forage and roost at night in soybean fields (Stribling and Doerr 1985, Krementz et al. 1995). In the **Eastern Tallgrass Prairie** region (BCR 22), hundreds of American Golden-Plovers (a Conservation Priority Species) have been observed foraging or resting in individual soybean fields in Indiana during spring migration (Braile 1999). In the **Central Hardwoods** (BCR 24), Castrale (1995) observed Killdeer in soybean fields during winter in Indiana.

Soybean fields that are intentionally flooded have been documented to receive fairly high use by nonbreeding shorebirds. In the **Mississippi Alluvial Valley** (BCR 26), Twedt et al. (1998) documented use of intentionally flooded soybean fields during winter and spring by eight species [Killdeer, Greater Yellowlegs, Lesser Yellowlegs (a Conservation Priority Species), Semipalmated Sandpiper, Western Sandpiper, Long-billed and Short-billed Dowitchers, Wilson's Snipe] and an additional five species during spring migration [Black-bellied Plover, American Golden-Plover (a Conservation Priority Species), Least Sandpiper, Pectoral Sandpiper, White-rumped Sandpiper]. Mean densities (among fields) of all shorebirds combined varied monthly over the winter from about 40 birds/km^2 at the end of November to 300 birds/km^2 in February (Twedt et al. 1998).

Killdeer appear to forage and nest in soybean fields in most places where their range and that of soybean farming co-occur (Table 7-1). In southern Ontario and Quebec (BCR 13), Killdeer commonly occur in soybean fields (Jobin et al. 1998, Boutin et al. 1999a, Kirk et al. 2001), and in one study Killdeer exhibited territorial behavior suggesting potential nesting activity in soybeans (Boutin et al. 1999b). In the **Eastern Tallgrass Prairie** region (BCR 22), Killdeer commonly nest in soybean fields in Ohio (Phillips 1959). In the **Central Hardwoods** region (BCR 24), Castrale (1995) observed Killdeer using soybean fields during the breeding period in Indiana. Finally, In the **Shortgrass Prairie** region (BCR 18), Killdeer were present in soybean fields during the nesting season in Colorado (Sterner et al. 2003). In Iowa (**Eastern Tallgrass Prairie**; BCR 22), Basore et al. (1986) documented 2 ± 4 (SD) Killdeer nests per km^2 in no-till soybeans planted into corn residue.

Wading Birds

Only one wading bird species has been observed using soybeans habitat (Table 7-1). Kirk et al. (2001) recorded Great Egrets as a rare visitor to soybean fields in southern Ontario (BCR 13) during the breeding season.

Other Waterbirds

Of the remaining waterbird species (particularly in the orders Pelecaniformes, Podicipediformes, Gruiformes, and Charadriiformes), only cranes and rails have been observed in soybean fields (Table 7-1). During spring and fall migrations in Indiana (**Eastern Tallgrass Prairie** region; BCR 22), Sandhill Cranes (a Conservation Priority Species) have been observed in soybean fields, although levels of use are no greater than the availability of soybean habitat in the landscape, and soybeans are potentially even avoided (Lovvorn and Kirkpatrick 1982a, 1982b). In terms of the typical abundances observed, Lovvorn and Kirkpatrick (1982a) observed roughly 19,600 cranes in 62 Indiana soybean fields after fall harvest; by spring, only ~3,800 cranes were found in 26 fields. In Nebraska (**Central Mixed-Grass Prairie;** BCR 19), spring migrant Sandhill Cranes have been documented in soybeans, but use was proportional to the availability of soybean habitat across the landscape (Davis 2003). Lingle et al. (1991) observed limited use of soybean fields by Whooping Cranes (a Conservation Priority Species) during spring and fall migrations in Nebraska. Although various gull species commonly occur in agricultural fields, we found no reference to their occurrence in soybean fields during our review.

Two rail species have been recorded in soybean fields during the breeding season. In Iowa (**Prairie Potholes** BCR 11 and **Eastern Tallgrass Prairie** BCR 22), Sora have been observed in soybean habitat during the post-breeding period when adults are typically with broods (Johnson and Dinsmore 1985). Additionally, in the **Prairie Potholes** region (BCR 11), low numbers of American Coots have been documented in soybean fields (behavior not specified) during the breeding period in South Dakota (Linz et al. 2004).

Landbirds

Eleven species of WWL landbirds have been observed in land planted to soybeans in North America (Table 7-1), although five of these species occur in such low numbers as to be considered rare soybean users. Two of these species have been observed in soybean fields in winter, ten during fall migration, and seven during the breeding season. Most accounts are from northern latitudes of North America (southern Canada, BCR 13). During fall migration, five WWL landbird species (Purple Martin, Tree Swallow, Northern Rough-winged Swallow, Bank Swallow, Red-winged Blackbird) occur commonly, and five additional species (Palm Warbler, Northern Waterthrush, Common Yellowthroat, Lincoln's Sparrow, Swamp Sparrow) are incidental visitors in soybean fields of southern Ontario (BCR 13; Boutin et al. 1999a). Common Yellowthroats have also been observed in soybean stubble in Maryland (BCR 29) during winter (Woodward 1981); and Red-winged Blackbirds are regular winter occupants of soybean fields in western Tennessee (BCR 27) (Dolbeer et al. 1978).

A handful of WWL landbird species also use North American soybean fields during the breeding season. Blackbirds are quite commonly observed in soybean fields. In southern Canada (BCR 13), Red-winged Blackbirds have been observed exhibiting territorial behaviors suggesting potential nesting activity in soybean fields (Boutin et al. 1999b). In the **Prairie Potholes** region (BCR 11), Red-winged and Yellow-headed Blackbirds were documented in soybean fields during the breeding period in South Dakota (Linz et al. 2003). In the eastern U.S. (BCR 28), incidental use of soybean fields by Swamp Sparrows has been documented in Pennsylvania (Schwalbe and Schwalbe 1982). Finally, in the **Central Hardwoods** region (BCR 24), Castrale (1995) observed modest numbers of Red-winged Blackbirds foraging in soybean fields in Indiana. In southern Ontario and Quebec (BCR 13), aerially-foraging swallows (Purple Martin, Northern Rough-winged Swallow, Bank Swallow, Tree Swallow) have been observed over soybean fields (Jobin et al. 1998, Boutin et al. 1999a, Boutin et al. 1999b, Kirk et al. 2001).

RESOURCES

In general, the foraging resources provided by soybean fields (with the exception of potential invertebrate resources) are of limited value to waterbirds during winter and migration, and very few species have been observed relying on soybean resources during the breeding period (Table 7-2). Here we review what is known about the abundance and availability of soybean resources, and of their consumption and use by waterbirds in North America.

Foraging Resources

Under certain conditions, soybean fields can provide foraging resources to some waterbirds, primarily during the nonbreeding season. Potential resources include waste soybeans, new shoots and seeds of weed species growing in soybean fields, terrestrial invertebrates, and aquatic invertebrates (Table 7-2).

Soybeans

Soybeans are consumed by a select group of waterbirds (Table 7-2). We did not find reference to any waterbirds foraging on ripening soybeans prior to harvest, and thus available accounts indicate that when consumed, soybeans are acquired entirely from stubble fields after harvest (waste soybeans). In terrestrial settings, waste soybeans become available to foraging waterbirds immediately after the fall harvest, but abundance of soybeans decreases dramatically between fall (mid November) and winter (mid-January) via bird consumption and deterioration, with virtually no soybeans left in fields by February (Hobaugh 1984, Leslie and Chabreck 1984, Warner et al. 1985). Deterioration of soybeans is accelerated by standing water, and fields that are intentionally flooded (see **Effects of Soybean Production Methods – Winter Field Flooding** below) are typically devoid of soybeans after three months (Nelms and Twedt 1996). In North America, estimates of the mean amount of waste soybeans available in fields post harvest range from 141 to 195 kg/ha (Hobaugh 1984, Warner et al. 1985), although these figures may be outdated due to improvements to harvester efficiency.

Researchers have documented only five waterbird species consuming soybeans, all during non-breeding periods. These species include Canada Geese in fall and winter (Jarvis 1976, Gates et al. 2001); Snow Geese in winter and spring (Alisauskas 1988, Alisauskas and Ankney 1992); Greater White-fronted Geese in winter (Leslie and Chabreck 1984) and spring (Krapu et al. 1995); Mallard in winter (Wright 1959, Delnicki and Reinecke 1986); and Wood Duck in winter (Delnicki and Reinecke 1986). Most studies that have documented crane use of soybean fields have not established that birds were feeding on soybeans. Although cranes potentially eat soybeans while foraging in fields, Krapu et al. (2004) sampled a large number of wintering cranes in Nebraska and found that not one had consumed soybeans. There are no accounts of waterbirds foraging on soybeans during the breeding season.

Diet studies indicate that soybeans account for a variable proportion of the diet of these species. During fall migration, soybeans accounted for only 3% (dry mass) of the diet of Canada Geese in Wisconsin, but for as much as 28% of Canada Goose diets in Illinois (Gates et al. 2001). For Snow Geese, trace amounts (% dry mass and frequency of occurrence) of soybeans were consumed by wintering geese in Iowa (Alisauskas 1988), and only 11 ± 27 (SD) % (dry mass) of goose diets included soybeans during spring migration in Oklahoma (Alisauskas and Ankney 1992). Similarly, trace amounts of soybeans were found in the diet of Greater White-fronted Geese during spring in Nebraska (Krapu et al. 1995). Of foods consumed by Mallards in Mississippi during winter, soybeans accounted for 29% (dry mass) and 33% (frequency of occurrence) of the diet (Delnicki and Reinecke 1986); in Arkansas, however, only 6% (by volume) of this species' diet was soybeans (Wright 1959). Soybeans accounted for 33% (dry mass) and 34% (frequency of occurrence) of the diets of wintering Wood Ducks in Mississippi (Delnicki and Reinecke 1986).

Consumption of soybeans may pose a significant risk to some waterbirds, as has been documented for fall-migrant geese. Lack of precipitation during soybean harvest in September and October can lead to dry soybeans. If not moist and swollen when ingested, soybeans can lead to esophageal impaction, causing high mortality rates in fall-migrating goose populations (Hanson and Smith 1950, Durant 1956, Wise 1967, Jarvis 1976). At one wildlife refuge in Illinois over four autumns with different weather conditions, Jarvis (1976) documented Canada

Goose mortalities from dry soybean impaction of between 100 and 3000 birds, or 1% to 20% of the fall refuge population. Suggestions for alleviating the hazard of soybean impaction include: disking harvested soybean fields to restrict access to waste beans, hazing, and supplementing food resources with waste corn (Jarvis 1976).

Energy Value of Soybeans. Soybean caloric value ranks fairly low compared to cereal grains. Estimated apparent metabolizable energy (AME) of soybeans assayed with Canada Geese was 3.03 kcal/g, lower than corn (3.97 kcal/g), sorghum (3.96 kcal/g) and wheat seed (3.53 to 3.85 kcal/g) (Sugden 1971, Storey and Allen 1982, Joyner et al. 1987). Tested with Mallards and Canada Geese, estimated true metabolizable energy (TME) values for soybeans range from 2.65 kcal/g (Reinecke et al. 1989) to 3.55 kcal/g (Petrie et al. 1998), lower than corn (3.67 – 3.90 kcal/g), and sorghum seed (3.78 kcal/g), but within a similar range as rice (2.82 – 3.34 kcal/g) and wheat seed (3.38 kcal/g). Moreover, the energy from soybeans is not as easily assimilated as most cereal grains. Digestibility of soybeans assayed with Canada Geese was estimated at 63%, lower than rice (67%), sorghum (87%), and corn (88%), although higher than the green forage of winter wheat (55%) (Petrie et al. 1998).

Although the protein content of soybeans is extremely high [42% of dry weight compared to only 11% for corn and 12% for sorghum (Baldassarre et al. 1983, Alisauskas 1988, Ensminger et al. 1990)], protein does not appear to be readily available to waterbirds when the soybeans are in a raw form (Loesch and Kaminski 1989). The fiber content of soybeans is also fairly high, at 6% compared to only 2% for both corn and sorghum (Baldassarre et al. 1983, Ensminger et al. 1990). While some researchers suggest that soybeans are a potential source of protein for pre-breeding birds (Leslie and Chabreck 1984), others have questioned this idea, maintaining that soybeans may be detrimental to waterbirds that eat them. Concerns arise from documentation that soybeans consumed in large quantities (often during periods of drought) can lead to a profound deterioration of body mass and condition (Delnicki and Reinecke 1986, Loesch and Kaminski 1989), perhaps from undigested soybeans containing chemicals that interfere with digestive enzymes and nutrient assimilation (Reinecke et al. 1989).

New Shoots and Seeds of Weed Species

Prior to the widespread adoption of GM soybeans and use of glyphosate herbicides in the late 1990s (see below **Effects of Soybean Production Methods – Pesticide Use and Organic Farming**), the new shoots and seeds of other plants ('weed species') growing in soybean fields were likely an important food source for some waterbirds (Table 7-2), particularly in mid-winter and spring. A number of studies conducted prior to this agro-industry transition support this notion. Hobaugh (1984) stressed the importance of sprouting green vegetation of various grasses and composites available in soybean fields to Snow Geese in winter. Leslie and Chabreck (1984) recorded continued Greater White-fronted Goose use of soybean fields through the winter and suggested geese were foraging on observed sprouting green vegetation of weed species. Alisauskas and Ankney (1992) observed spring migrating Snow Geese foraging in soybean fields in South Dakota, but found no soybeans in the esophagi of sampled individuals, suggesting that birds may have been foraging on the new shoots and seeds of weed species present in these fields. Similarly, Dolbeer et al. (1978) documented weed seeds but no soybeans in the diet of Red-winged Blackbirds foraging in soybean fields during winter. Krapu et al. (2004) suggested

that prior to GM soybean production, the weed seeds available in soybean fields compensated greatly for the relatively low nutritional value of soybean fields to wintering waterbirds.

Terrestrial Invertebrates

Terrestrial invertebrates such as earthworms and insect pests may be an important food resource for some waterbirds frequenting soybean fields, but little information exists regarding their abundance or consumption by waterbirds (Table 7-2). As most waterbirds are ground-foragers, terrestrial invertebrates in soybean fields would be most accessible during winter and spring before major growth of soybean and weed vegetation. Earthworms are common in soybean fields, with average densities of up to 141 worms/m^2, and average biomasses of 26.5 g/m^2 documented in untilled fields during the fall (Mackay and Kladivko 1985, Braile 1999). Earthworms are a common prey item for shorebirds foraging in many environments (Skagen and Oman 1996) and may be the main prey of shorebirds that forage in dry soybean fields (Table 7-1). Indeed, Braile (1999) commonly observed American Golden-Plovers (a Conservation Priority Species) feeding on earthworms in soybean fields during spring migration in Indiana. During the migration and breeding seasons, swallows have been observed foraging on various flying insects associated with soybean crops (Boutin et al. 1999a). Insect pests such as the Green Cloverworm (*Plathypena scabra*) and Mexican Bean Beetle (*Epilachna varivestis*) commonly occur in soybean fields (Kemp and Barrett 1989), but the degree to which these species are eaten by waterbirds has not been documented.

Aquatic Invertebrates

In soybean fields that are intentionally flooded during the winter, such as in the **Mississippi Alluvial Valley** (BCR 26) and along the Gulf Coast (BCR 37), aquatic invertebrates may be an important resource for many nonbreeding waterbirds (Table 7-2). In two studies conducted prior to widespread GM soybean production, documented high use by Northern Shoveler and several shorebird species in flooded fields in earlier studies suggests high abundance of aquatic invertebrates that are potentially similar to those observed in flooded rice fields (Twedt et al. 1998, Twedt and Nelms 1999). With less decaying non-crop plant matter in the predominantly GM soybean fields of today, however, invertebrate communities in flooded soybean fields may be diminished compared to those studied by Twedt et al. (1998) and Twedt and Nelms (1999).

Breeding Resources

During the breeding season, resources provided to waterbirds by soybean fields in North America appear to be limited. Only two species have been confirmed or suspected to nest in soybeans, and accounts of the use of soybean fields for brood-rearing or post-fledging are rare.

Nesting Habitat

Two waterbird species have been documented as confirmed or probable nesters in soybean fields. In Iowa and Ohio (**Eastern Tallgrass Prairie**; BCR 22), Killdeer have been observed on nests positioned between rows of growing soybeans (Phillips 1959, Basore et al. 1986). In southern Ontario (BCR 13), Boutin et al. (1999b) observed Killdeer and Red-winged Blackbird exhibiting territorial behaviors in soybean fields, suggesting probable nesting.

Brood-rearing/Post-fledging Habitat

We found no reference to the use of soybean fields as brood-rearing or post-fledging habitat by Killdeer or Red-winged Blackbirds, even where nesting was likely (Phillips 1959, Basore et al. 1986). Zwank et al. (1989) did observe incidental use of flooded soybean fields by Mottled Ducks (a Conservation Priority Species) in Louisiana (BCR 37) during the brood-rearing period, and Johnson and Dinsmore (1985) documented a radio-marked adult Sora in a soybean field in Iowa (**Prairie Potholes** BCR 11 and **Eastern Tallgrass Prairie** BCR 22) during the post-breeding period when adults are typically with their broods.

Resting Habitat

Use of soybean fields for resting has only been explicitly documented for spring migrant American Golden-Plovers in Indiana (**Eastern Tallgrass Prairie**; BCR 22) (Braile 1999). However, in regions with recreational hunting pressure, such as the **Mississippi Alluvial Valley** (BCR 26) and Gulf of Mexico Coast (BCR 37), it is likely that flooded soybean fields that are not hunted provide important daytime refuge for many waterbirds, similar to that provided by flooded rice fields in some areas (Miller 1985, Rave and Cordes 1993, Cox and Afton 1998).

EFFECTS OF SOYBEAN PRODUCTION METHODS

Documentation of the impacts of soybean farming methods on waterbirds is limited. The following is a summary of the known impacts, following the chronology of soybean production from soil and residue management in preparation for planting to oybean harvest methods. Table 7-3 provides a synopsis of the current state of knowledge on these topics.

Soil and Residue Management in Preparation for Planting

To prepare the soil for new soybean plantings, farmers practice methods that vary from the conventional (residues reduced by plowing in fall; soil smoothed by disking and harrowing in spring; use of rotary hoe to dislodge germinating weeds) to no-till or reduced till (none or reduced plowing or disking; slot planting seeds into previous crop residue; use of herbicides to control weeds) management (Castrale 1985, Warner et al. 1985, Boutin et al. 1999b). Approximately 40% of soybean cropland in the U.S. is managed under no-till (F. Koppatschek, ABG, Inc., pers. comm.). The effects of plowing activities on the abundance and availability of waterbird foods in soybean fields have been assessed by only a few researchers, likely because soybean fields are in fact seldom plowed (F. Koppatschek, ABG, Inc., pers. comm.). Warner et al. (1985) documented surface waste soybean abundances in Illinois that were four times as large in unplowed fields (48 kg/ha) as in fields that had been chisel-plowed (12 kg/ha) after harvest. Although plowing has been known to result in a short-term increase in the availability of soil invertebrates with quick responses observed by foraging shorebirds, wading birds, and gulls (Barnard and Thompson 1985, O'Connor and Shrubb 1986, Lack 1992), sustained abundances of invertebrates in tilled fields may be lower than in fields where crop residues are not removed or manipulated. In Indiana, Mackay and Kladivko (1985) observed greater densities of earthworms in no-till soybean fields (mean density among sites: 141 ± 9 (SD) worms/m^2; biomass: 26 ± 8 g/m^2) than in fields that had been plowed (density: 62 ± 12 worms/m^2; biomass: 12 ± 5 g/m^2), presumably due to greater availability of crop residues as a long-term food source for the earthworms.

Accounts of the effects of tillage practices on foraging waterbird use of soybean fields are few and inconclusive. In Indiana (**Eastern Tallgrass Prairie**, BCR 22), spring migrant American Golden-Plovers (a Conservation Priority Species) selected no till soybean fields over tilled fields (Braile 1999), and summer resident Red-winged Blackbirds used no-till soybean fields more frequently than tilled fields (Castrale 1985). However, summering Killdeer were only observed in tilled soybean fields despite the presence of no-till fields in the study area (Castrale 1985).

Although the tillage practices occurring during spring to prepare for new soybean plantings have the potential to affect nesting waterbirds adversely, impacts on nest densities and success have not been documented, perhaps because so few waterbirds have been documented nesting in soybean fields. Basore et al. (1986) observed Killdeer nest densities of 2 ± 4 (SD) nests/km^2 in soybean fields that had been planted into corn residue in Iowa (**Eastern Tallgrass Prairie**; BCR 22). Although the Basore et al. (1986) study does not provide any figures for nest densities on tilled soybean fields, Killdeer nest densities on no-till soybean fields were still fairly low, and similar to densities observed on tilled corn fields (2 ± 3 nests/ km^2).

Winter Field Flooding

In the **Mississippi Alluvial Valley** (BCR 26), a coalition of federal, state, non-government conservation organizations, and private landowners have coordinated efforts (e.g., Mississippi Partners Project) to increase the area of flooded habitat for waterfowl during winter by developing water control capabilities (installing levees and water control structures) and retaining floodwater on agricultural land (Baxter and Wolfe 1972, Reinecke et al. 1989, Baxter et al. 1996). Along with a majority of the rice habitat, a minority of soybean fields in the region are flooded through this effort (Twedt et al. 1998). In some soybean growing regions, winter flooding can accelerate soybean residue decomposition (Wright 1959, Nelms and Twedt 1996). In addition to aiding farmers in soil and residue management, winter soybean flooding may significantly increase the value of soybean fields as foraging habitat to many waterfowl and shorebird species that forage on aquatic invertebrates, provided water depths are managed appropriately to provide access to invertebrates (Twedt et al. 1998, Twedt and Nelms 1999; see also RICE chapter). Twedt and Nelms (1999) documented high densities of dabbling ducks in flooded soybean fields, especially species that favor aquatic invertebrates, such as Northern Shoveler (DuBowy 1996). Similarly, Twedt et al. (1998) observed greater shorebird densities in flooded soybean fields than in moist-soil wetlands or rice fields. Such high use of soybeans compared to rice and moist-soil units was attributed to sparse vegetative cover (allowing greater solar incidence which promotes invertebrate production), and to looser soils (making benthic invertebrates more accessible to probing foragers) (Twedt et al. 1998). Many of the management recommendations that have been developed for other flooded habitats, such as rice fields (Elphick and Oring 1998, Elphick and Oring 2003) or impounded wetlands (Colwell and Taft 2000, Taft et al. 2002), particularly those related to water depth manipulations that most benefit a diversity of foraging waterbird species, would likely apply to flooded soybean fields (see RICE chapter).

Sowing Methods

The impact of sowing methods on waterbirds has not been documented explicitly for fields planted to soybeans. Soybeans are planted in spring (May, June; Boutin et al. 1999b), coincident with the beginning of nest initiation by the few species that may nest in soybean fields. Unless

measures are taken to locate and avoid active nests, field passes by farm machinery to plant soybeans could damage nests not already impacted by earlier spring tillage practices.

Pesticide Use and Organic Farming

Soybean farmers use various pesticides, primarily herbicides, to control weeds and insect pests responsible for losses to soybean yield and revenue. Carbamates (carbaryl) and pyrethroids are one class of insecticides used to combat soybean defoliators such as the Soybean Aphid (*Aphis glycines*), Green Cloverworm (*Plathypena scabra*), and Mexican Bean Beetle (*Epilachna varivestis*) (Kemp and Barrett 1989; F. Koppatschek, ABG, Inc., pers. comm.). Chemicals containing carbaryl are "general-use pesticides," and thus may be used with minimal restrictions (EXTOXNET 2007). Herbicides used to control weeds in soybean fields include triazines (atrazine, cyanazine, metribuzin), thiocarbamates (EPTC), nitriles (bromoxynil), benzoic acid compounds (chloramben), and other compounds such as glyphosate, sulfonylurea, 2,4,-D, bentazon, acetochlor, metolachlor (Boutin et al. 1999b, Krapu et al. 2004). While carbamates are classified as moderately to highly toxic to birds, herbicides in soybean fields are practically nontoxic to slightly toxic to birds (EXTOXNET 2007).

Little documentation exists on the direct (i.e., causing mortality to birds or nests) or indirect (i.e., diminishing food resources) impacts of pesticide use in soybean fields on waterbirds. We found no accounts of direct mortality or nest damage associated with pesticide applications in soybean fields, although it is not clear that this has been studied. Because pesticides are applied to soybean fields during the summer months, the WWL species most at risk are the few waterfowl, shorebirds and landbird species occurring in soybean fields during the breeding season (Table 7-1). For four WWL species occurring in soybean fields in southern Ontario (BCR 13), Boutin et al. (1999b) assessed the relative risk of adverse impacts from pesticide use based on the number of months in which species were observed in fields, species densities, and timing of pesticide application relative to timing and mode of foraging and nesting activity in fields. They concluded that Killdeer and Red-winged Blackbirds were at medium risk to the dangers of pesticide use in soybean fields, whereas Purple Martins and Bank Swallows (< 1 month use) were at low risk. Risk of nest damage from farm machinery passes to apply pesticides may be as high or higher in no-till soybean fields as in conventionally tilled fields. The presence of residues in no-till precludes the mechanical removal of weeds, and thus 1-2 herbicide applications are required to control weed growth in the crop (Castrale 1985; F. Koppatschek, ABG, Inc., pers. comm.). Indirect effects of pesticide use in soybean fields may be more serious than direct effects, as they can substantially degrade the overall value of soybean habitat to waterbirds. As the soybean insecticides that target crop pests are broad-spectrum chemicals that will kill non-target invertebrates as well (EXTOXNET 2007), it is likely that terrestrial invertebrate food resources are also affected by any insecticides used in soybean fields. Indirect effects of herbicide use include exterminating new shoots and preventing seed production by weed species, both of which remove foods on which some geese and landbirds depend (Dolbeer et al. 1978, Hobaugh 1984, Leslie and Chabreck 1984) and reduce the overall value of soybean fields to these waterbirds (Boutin et al. 1999b, Krapu et al. 2004). The negative impacts of herbicides are especially acute in GM soybean fields where the glyphosate herbicides used for weed control target all plant species except the GM crop (Krapu et al. 2004). Research conducted in various crops, including soybeans, has found a marked reduction in the abundance of weeds and weed seeds in GM crops treated with glyphosate herbicides as opposed to

conventional herbicide treatments (Fawcett and Slife 1978, Peterson et al. 2002, Heard et al. 2003). With GM soybeans rapidly replacing conventional soybeans in the U.S., valuable foraging resources provided by weed species in soybean fields are becoming scarce (Krapu et al. 2004).

Kemp and Barrett (1989) conducted an experimental study in which they provide a convincing case for the use of uncultivated corridors (strips of unfarmed land running through a field) as a promising alternative to pesticide use for the regulation of insect pests in soybean agroecosystems. Uncultivated corridors that are grassy, in particular, can provide a significant source of natural predators and fungal pathogens that prey on or infect soybean insect pests. Kemp and Barrett (1989) suggest that the ultimate success of such methods depends on elucidating the spatial patterning (size, shape and location) of the crop and corridor areas that most effectively encourages biological control.

Management for Bird Pest Species

A lack of literature pertaining to management of bird pests in soybean fields implies that bird pests are not an issue for soybean farmers. This is likely because accounts of waterbird use indicate that neither the new shoots of soybean plants nor ripening soybeans themselves are typically consumed by waterbirds.

Harvest Methods

Throughout North America, soybean harvest occurs during the late fall months of October and November (Hobaugh 1984, Boutin et al. 1999b), after which time waste soybeans are at their peak in abundance (Hobaugh 1984, Warner et al. 1985). We found no specific references to the effects of soybean harvest methods nor harvest efficiency on waterbird use of soybean fields.

Crop Rotation, Fallow Land

As a legume, soybeans often serve as a rotational crop for other major row crops, including corn, rice, cotton, and wheat (Wright 1959, Hobaugh 1984, Leslie and Chabreck 1984, Acquaah 2005). Waterbirds using soybean habitats are likely to benefit greatly from the periodic planting of fields back to corn, rice or wheat, all of which provide important resources for certain species (see CORN, RICE, and WHEAT chapters).

Use of fallow fields previously planted to soybeans has been addressed by only a few researchers. Leslie and Chabreck (1984) found that wintering Greater White-fronted Geese in Louisiana (BCR 37) tended to avoid fallow fields that had been previously planted to rice or soybeans, potentially because tall vegetation obstructed their view of approaching predators. In contrast, Hobaugh (1984) documented Snow Geese use of fallow non-GM soybean fields in Texas (BCR 37), but only during February, coincident with a documented late winter spike in the abundance of sprouting green weedy vegetation (grasses and composites) in fields.

EFFECTS OF OTHER MANAGEMENT ACTIVITIES

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

Hunting Activity

To our knowledge, the extent and impacts of recreational hunting on soybean fields *per se* have not been evaluated. In regions with recreational hunting pressure on public and private lands such as the **Mississippi Alluvial Valley** (BCR 26) and Gulf of Mexico Coast (BCR 37), however, non-hunted flooded soybean fields may provide important daytime refuge habitat for many waterbirds, as is true for flooded rice fields that are not hunted (Miller 1985, Rave and Cordes 1993, Cox and Afton 1998).

EFFECTS OF LANDSCAPE FEATURES

Various landscape attributes of soybean fields may affect waterbird use, and we briefly review what is known regarding such potential influences here.

Field Size

We found two studies that referred to the importance of soybean field size to waterbirds. In the **Mississippi Alluvial Valley** (BCR 26), Twedt et al. (1998) found that shorebird abundances were significantly correlated with flooded soybean field size. Shorebird densities, however, did not vary with field size, implying that flooding several small fields of equal area to a large one would result in similar shorebird use. Kemp and Barrett (1989) suggest that natural pest control through the management of uncultivated corridors is most effective for small soybean fields, primarily because the regulation of insect pests by natural predators or pathogens from source corridors only extends a short distance (on the order of tens of meters) into the soybean crop.

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 could 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, roost sites, and roads and other sources of disturbance. We did not find any studies that explicitly examined potential influence of landscape context on waterbird use of soybean fields. Nonetheless, understanding the importance of landscape context could affect a number of management decisions for soybean fields. This topic is likely to be especially important in regions where fields are being actively flooded to increase waterbird use (Elphick 1998).

SUMMARY AND SYNTHESIS

The following is a review of the major themes relating to the use of soybean fields by waterbirds, resources available to waterbirds in soybean fields, positive and negative effects of soybean production practices on waterbirds, and gaps in knowledge of these issues. In summarizing these topics, we also highlight the current avian conservation challenges and future research needs presented by soybean agriculture.

Waterbird Use

Available information on the use of soybean fields indicates that the habitat and resources provided by North American soybean fields are of limited importance to most waterbirds. Waterbirds have been observed in soybean fields during nonbreeding periods, particularly in winter (Table 7-1), with geese, ducks, shorebirds, and cranes seen foraging in dry (for geese,

cranes) or flooded (ducks, shorebirds) fields (Jarvis 1976, Lovvorn and Kirkpatrick 1982a, Kahl and Samson 1984, Harvey et al. 1988, Twedt et al. 1998, Twedt and Nelms 1999, Gates et al. 2001). Flooded soybean fields, especially, may draw large numbers of a diversity of waterbird species (Twedt et al. 1998, Twedt and Nelms 1999). Various other species, such as swallows and blackbirds, use soybean fields throughout the year, but typically in relatively low numbers (Boutin et al. 1999a, b; Dolbeer et al. 1978). During the breeding season, soybean fields are used to only a limited extent for nesting or as foraging habitat (e.g., Phillips 1959, Johnson and Dinsmore 1985, Basore et al. 1986, Zwank et al. 1989, Castrale 1995, Boutin et al. 1999a, b; Linz et al. 2003, 2004).

WWL Species and Bird Conservation Regions

Of the 216 species identified for the Waterbirds on Working Lands project, 40 have been observed in soybean fields in North America, of which seven are Conservation Priority Species (Table 7-1). Of these 40 species, 23 use soybean fields during winter, 22 during spring and/or fall migration, and 15 during the breeding season. Only Killdeer, however, has been confirmed nesting in soybeans. On average, use of soybean fields has been documented for only 6% (range: 1% in **Prairie Hardwood Transition** BCR 23 to 12% in the **Mississippi Alluvial Valley** BCR 26) of those species considered to be relatively abundant within a given BCR (i.e., the focal species on BCR regional lists). Whether these low numbers represent gaps in knowledge or are a true representation of the use of soybean fields in these regions is uncertain (see **Knowledge Gaps and Research Needs** below).

Soybean Field Resources

The foraging resources available to waterbirds in fields planted to soybeans include waste soybeans (e.g., Jarvis 1976, Delnicki and Reinecke 1986, Alisauskas and Ankeny 1992, Gates et al. 2001), new shoots and seeds from weed species growing in soybean fields (Dolbeer et al. 1978, Hobaugh 1984, Leslie and Chabreck 1984), and terrestrial invertebrates (Mackay and Kladivko 1985, Braile 1999, Boutin et al. 1999a); aquatic invertebrates are also available to birds in flooded fields (Twedt et al. 1998, Twedt and Nelms 1999; Table 7-2). Waste soybeans become available after fall harvest, and quickly decline in abundance and availability towards late winter (Hobaugh 1984, Leslie and Chabreck 1984, Warner et al. 1985). Soybeans usually account for only a minor portion of the diet of those species that forage in soybean fields (e.g., Wright 1959, Alisauskas et al. 1988, Alisauskas and Ankney 1992, Gates et al. 2001). Soybeans are high in protein and fiber content (e.g., Baldassarre et al. 1983, Ensminger et al. 1990), but the protein present in soybeans is not readily available to birds. Moreover, caloric value and digestibility of soybeans rank fairly low compared to waste grain from cereal crops (e.g., Joyner et al. 1987, Petrie et al. 1998), and if ingested dry, soybeans pose considerable risk of esophageal impaction leading to death (Jarvis 1976). Some researchers have found that the low digestibility of soybeans can lead to significant deterioration in physiological condition of waterbirds, especially if soybeans are consumed in large quantities (e.g., Delnicki and Reinecke 1986, Loesch and Kaminski 1989, Krapu et al. 2004). New shoots and seeds of weed species in winter and early spring are an additional resource of importance in non-GM soybean fields for grazing species such as geese (Hobaugh 1984, Leslie and Chabreck 1984). Terrestrial invertebrates such as earthworms and insect pests may be important to some shorebirds, other waterbirds, and landbirds throughout the year, but little research has been conducted with respect to their abundances in fields and their relative importance to waterbirds. For soybean fields that are

flooded in winter, available aquatic invertebrates may be a food resource of immense value to nonbreeding waterbirds, especially dabbling ducks and shorebirds (Twedt et al. 1998, Twedt and Nelms 1999). Soybeans appear to provide limited resources for waterbirds during the breeding period, as soybean nesting has been confirmed for only one WWL species (Killdeer; Phillips 1959, Basore et al. 1986), and anecdotal observations of birds present in soybean fields post-breeding only suggest the possibility of brood-rearing in this habitat (Johnson and Dinsmore 1985, Zwank et al. 1989). Use of soybean fields for resting has only been observed for migrating American Golden-Plovers (Braile 1999), but in regions where soybean fields are intentionally flooded, some non-hunted fields may provide important resting areas for local waterbird communities.

Practices Benefiting Waterbirds

A number of methods commonly used by soybean growers clearly benefit waterbirds using soybean fields. Practices positively influencing the suitability of fields for many waterbirds include some conservation or 'no-till' practices, winter field flooding, biological insect pest control, and the fallowing of soybean fields (Table 7-3). No-till practices are associated with greater abundance and availability of earthworms (Mackay and Kladivko 1985). Winter field flooding has the potential not only to benefit farmers by increasing decomposition of soybean residues (e.g., Wright 1959, Nelms and Twedt 1996) but also to provide abundant aquatic invertebrate resources for waterfowl and shorebirds (Twedt et al. 1998, Twedt and Nelms 1999), provided the vegetation and soil conditions are suitable for invertebrate recruitment, and water depths are appropriately managed (cf. Elphick and Oring 1998, Taft et al. 2002). Use of uncultivated corridors (strips of unfarmed land running through fields) to achieve biological control of soybean insect pests has been established as a promising alternative to pesticide use in soybean fields (Kemp and Barrett 1989). Finally, fallowing of soybean fields may benefit some waterbirds such as geese by providing green forage from weed species in late winter when waste grains are diminishing in availability across the landscape (Hobaugh 1984).

Practices Negatively Affecting Waterbirds

Some soybean farming practices potentially impact waterbirds, or the suitability of soybean fields for waterbirds, in adverse ways, and these conflicts represent challenges towards maximizing the conservation value of soybean habitat. Potentially harmful production practices include conventional tillage that decreases the abundance and availability of food resources, and continued use of some pesticides, especially when used in conjunction with GM soybeans (Table 7-3).

Documented earthworm abundances are low in fields that have been plowed, presumably due to a lack of surface residues that can decompose over the long-term and provide resources for soil invertebrates (Mackay and Kladivko 1985). With nesting cover fairly low in conventionally tilled soybean fields, nest success of the few soybean-nesting waterbirds may be low (Basore et al. 1986). Herbicide use in soybean fields will substantially diminish important goose foraging resources provided by the new shoots and seeds of weed species, particularly the use of glyphosates, which result in the widespread eradication of all non-crop plant species (Dolbeer et al. 1978, Hobaugh 1984, Leslie and Chabreck 1984, Boutin et al. 1999b, Peterson et al. 2002, Krapu et al. 2004). For the few shorebird and landbird species that forage or initiate nests in soybean fields coincident with timing of pesticide application, exposure to "restricted-use" but

still moderately toxic pesticides, or damage to nests from farm machinery applications, are significant potential threats (Boutin et al. 1999b).

Knowledge Gaps and Research Needs

While the current state of knowledge regarding soybean field use by waterbirds, resources provided by soybean fields, and effects of soybean production practices appears to be fairly good, there are a number of information gaps that need to be addressed in order to improve soybean field management for waterbirds. In particular, the widespread changes that have resulted from the introduction of GM soybeans, especially with regard to herbicide use, may render many past studies obsolete. Competing hypotheses suggest that GM crops result in less herbicide use, which has environmental benefits, but also that the more targeted and efficient herbicide use that is possible with GM crops will result in reduced food resources in soybean fields. New research will be needed to distinguish these alternatives.

Waterbird Use

Use of soybean fields by waterbirds has been better documented for some focal BCRs (e.g., **Eastern Tallgrass Prairie**, BCR 22 and **Mississippi Alluvial Valley**, BCR 26) than others (**Prairie Potholes** BCR 11, **Prairie Hardwood Transition** BCR 23, **Central Mixed-Grass Prairie** BCR 19 and **Central Hardwoods** BCR 24; Table 7-1). There are some species for which observations in soybean fields are only from research conducted outside focal BCRs in southern Canada (BCR 13), the eastern U.S. (BCR 29, BCR 30), the southeastern U.S. (BCR 27), and the Gulf of Mexico Coast (BCR 37). This list includes only a few waterfowl (Tundra Swan, Mottled Duck), one shorebird (American Woodcock), and four landbird species (Purple Martin, Tree Swallow, Northern Rough-winged Swallow, Bank Swallow). Some of these species (e.g., Mottled Duck and Tundra Swan) would not have been observed in soybean fields in certain focal BCRs simply because their ranges do not overlap with the region, or because they only pass through briefly during migration. For other species on this list, however, (e.g., American Woodcock in the **Prairie Potholes** BCR 11), lack of published data on their use of soybean fields in a focal BCR may represent a real knowledge gap. Recent work documenting use of soybean fields by large numbers of American Golden-Plovers (e.g., Braile 1999) indicates that soybean habitats throughout the Great Plains, especially those with some 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 soybean fields would be worthwhile. More generally, the paucity of studies that have attempted to document the full range of species that use soybean fields in many areas might represent a shortcoming in our understanding of the degree to which soybean habitat is used. Alternatively, the small number of such studies might simply reflect the limited value of this habitat in many areas. One efficient approach to distinguishing these alternatives would be to initiate a volunteer-based, citizen science project centered around the goal of collecting comprehensive information on the numbers and species of birds using agricultural fields containing focal crops such as soybeans. Finally, estimating the cumulative use of fields by certain species that are widespread in their use of soybeans but which occur in small numbers in any particular field (e.g., Killdeer) would provide a valuable landscape perspective on the overall use of soybean habitats by some species.

Resources

More recent assessments of the amount of waste soybeans typically left in fields would be helpful, as existing estimates are potentially outdated, and the amount of waste soybeans may be different today due to changes in overall production levels and harvester efficiency. Aside from the few studies on earthworm densities in Indiana soybean fields, there has been no assessment of the abundance of terrestrial invertebrate resources, such as insect pests that may be important foraging resources for waterbirds, or of their consumption by waterbirds at various times of the year. Further work in this area would contribute to our understanding of the overall level of importance of soybean fields, and towards advancing biological control methods and lessening dependence on pesticide use. Likewise, in flooded soybean fields, quantification of the densities, biomass and timing of availability of aquatic invertebrates important to shorebirds and waterfowl will aid in evaluating and fine-tuning use of winter flooding as a crop management technique that augments the probable low conservation value of soybean fields. For Killdeer, Red-winged Blackbirds, and any other species potentially nesting in soybean fields, assessments of nest densities and success rates on tilled and non-tilled lands will add to a more complete understanding of the relative value of soybean fields as nesting habitat for waterbirds. Finally, it would be helpful to understand the use and importance of flooded soybean fields as resting and refuge habitat for waterbirds subjected to recreational hunting pressure.

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

There are many gaps in our knowledge of the impacts of soybean production methods and other activities on waterbirds (Table 7-3). To resolve which tillage methods will most benefit waterbirds, it will be crucial to understand the effects of tillage on terrestrial and aquatic invertebrate resources, on associated foraging waterbird use, and on nest densities and reproductive success of the few waterbird species nesting in soybeans. In regions where retention of water in the fields during winter is feasible, quantifying the efficacy of soybean field flooding to break down crop residues, and identifying optimal flooding regimes for invertebrate productivity and waterbird use, should help in evaluating the economic and conservation costs and benefits of adopting winter flooding as a widespread management tool. Although these questions have been addressed to some extent for soybean fields in the Mississippi Alluvial Valley (BCR 26), we need to assess whether flooding methods (primarily flooding regimes and water depth management) could be more efficient in the MAV, and if soybean flooding methods established in this region could be transferred to other areas where soybeans are grown. Consulting the management recommendations developed for flooded rice (e.g., Elphick 1998, Elphick and Oring 1998, Elphick and Oring 2003) and impounded wetlands (e.g., Colwell and Taft 2000, Taft et al. 2002) should also help in devising efficient landscape management strategies for soybean field flooding in regions outside of the MAV. Damage to nests from sowing operations has not been quantified for land planted to soybeans, probably because soybeans fields are perceived to contain few nesting birds. If the cumulative numbers of nests across the landscape, however, proves to be significant, it would be valuable to quantify the degree of damage to nests from sowing operations, and to investigate whether variation in sowing methods could be used to reduce the number of nests that are destroyed. Effects of pesticides on waterbirds foraging or nesting in soybeans also have not been studied, and the impacts of insecticides on invertebrate food resources important to waterbirds have yet to be documented. Quantifying the benefits of organic farming and further evaluating the effects of biological control (including the role of field size and the benefits of corridor strips) would

contribute greatly towards lessening dependence on pesticide use. Understanding the extent and impact of recreational waterfowl hunting activities in soybean fields would aid in assessing the degree of disturbance and impact on waterbird body condition and potentially subsequent reproductive success of some waterbirds, particularly geese. Knowledge of the importance of field size and landscape context to waterbirds using soybean fields should enable more strategic landscape approaches to conservation planning for soybean dominated agroecosystems. Addressing each of these questions for Conservation Priority Species should certainly take precedence.

Beyond quantifying the nest success or adult 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 these demographic parameters together influence the stability of populations. Quantifying how these various parameters contribute to birth and death rates and influence the population dynamics of waterbird species - particularly Conservation Priority Species - will be a crucial step towards devising crop production methods that are not detrimental to waterbirds using soybean fields. Additionally, if concerns about the negative effects of soybean fields prove to be warranted, such that populations are likely to suffer if birds use the crop, then research to identify ways of discouraging field use may be needed.

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

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Table 7-1. Waterbird species reported in soybean fields 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.

			North America [a]					**Prairie Potholes (BCR 11)** [b]			
					Breeding					Breeding	
GROUP Common name	On WWL Species List	Species of Conservation Priority	Winter	Migration	Foraging	Nesting	On BCR 11 Regional List	Winter	Migration	Foraging	Nesting
WATERFOWL											
Tundra Swan	X		X	S/F							
Snow Goose	X		X	S/F							
Greater White-fronted Goose	X		X	S							
Canada Goose	X		X	S/F	X		X			X	
Wood Duck	X		X				X				
Mallard	X		X	F	X		X			X	
Northern Pintail	X	X	X	S			X				
Northern Shoveler	X		X				X				
Mottled Duck	X	X		F	X						
SHOREBIRDS											
Black-bellied Plover	X		X				X				
American Golden-Plover	X	X	X	S			X				
Killdeer	X		X	F	X	X	X				
Greater Yellowlegs	X		X				X				
Lesser Yellowlegs	X	X	X				X				
Pectoral Sandpiper	X		X				X				
Spotted Sandpiper	X			F (rare)			X				
Semipalmated Sandpiper	X		X				X				
Western Sandpiper	X		X								
Least Sandpiper	X		X				X				
White-rumped Sandpiper	X		X				X				
Long-billed Dowitcher	X		X				X				
Short-billed Dowitcher	X		X								
Wilson's Snipe	X		X				X				
American Woodcock	X	X	X				X				

Table 7-1. Continued.

GROUP Common name	On WWL Species List	Species of Conservation Priority	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 Egret	X				X (rare)						
OTHER WATERBIRDS											
Sandhill Crane	X	X		S/F			X				
Whooping Crane		X		S/F							
American Coot	X				X		X			X	
Sora	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 (rare)							
Northern Waterthrush	X			F (rare)			X				
Common Yellowthroat	X		X	F (rare)			X				
Lincoln’s Sparrow	X			F (rare)							
Swamp Sparrow	X			F (rare)	X (rare)		X				
Red-winged Blackbird	X		X	F	X	(?)	X			X	
Yellow-headed Blackbird	X				X		X			X	

Table 7-1. 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											
Tundra Swan	X	X					X				
Snow Goose	X						X	X	S/F		
Greater White-fronted Goose	X										
Canada Goose	X	X		S/F			X	X	F		
Wood Duck	X	X					X				
Mallard	X	X					X				
Northern Pintail	X										
Northern Shoveler	X	X					X				
Mottled Duck	X										
SHOREBIRDS											
Black-bellied Plover	X	X					X				
American Golden-Plover	X	X					X		S		
Killdeer	X	X					X			X	X
Greater Yellowlegs	X	X					X				
Lesser Yellowlegs	X	X					X				
Pectoral Sandpiper	X	X					X				
Spotted Sandpiper	X	X					X				
Semipalmated Sandpiper	X	X					X				
Western Sandpiper	X										
Least Sandpiper	X	X					X				
White-rumped Sandpiper	X	X					X				
Long-billed Dowitcher	X	X					X				
Short-billed Dowitcher	X	X									
Wilson’s Snipe	X	X					X				
American Woodcock	X	X					X				

Table 7-1. 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 Egret	X	X					X				
OTHER WATERBIRDS											
Sandhill Crane	X	X					X		S/F		
Whooping Crane											
American Coot	X	X					X				
Sora	X	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										
Common Yellowthroat	X	X					X				
Lincoln’s Sparrow	X										
Swamp Sparrow	X	X					X				
Red-winged Blackbird	X	X					X			X	
Yellow-headed Blackbird	X	X									

Table 7-1. Continued.

GROUP Common name	On WWL Species List	On BCR 19 Regional List	Central Mixed-Grass Prairie (BCR 19) [b]				On BCR 24 Regional List	Central Hardwoods (BCR 24) [b]			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WATERFOWL											
Tundra Swan	X										
Snow Goose	X	X		S			X	X			
Greater White-fronted Goose	X	X		S							
Canada Goose	X	X					X	X	F		
Wood Duck	X	X					X				
Mallard	X	X					X				
Northern Pintail	X	X		S			X				
Northern Shoveler	X	X					X				
Mottled Duck	X						X				
SHOREBIRDS											
Black-bellied Plover	X	X									
American Golden-Plover	X	X									
Killdeer	X	X					X	X		X	
Greater Yellowlegs	X	X					X				
Lesser Yellowlegs	X	X					X				
Pectoral Sandpiper	X	X									
Spotted Sandpiper	X	X					X				
Semipalmated Sandpiper	X	X					X				
Western Sandpiper	X	X									
Least Sandpiper	X	X					X				
White-rumped Sandpiper	X	X									
Long-billed Dowitcher	X	X									
Short-billed Dowitcher	X										
Wilson’s Snipe	X	X					X				
American Woodcock	X	X					X				

Table 7-1. Continued.

GROUP Common name	On WWL Species List	On BCR 19 Regional List	Central Mixed-Grass Prairie (BCR 19) [b]				On BCR 24 Regional List	Central Hardwoods (BCR 24) [b]			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WADING BIRDS											
Great Egret	X	X					X				
OTHER WATERBIRDS											
Sandhill Crane	X	X		S							
Whooping Crane				S/F							
American Coot	X	X					X				
Sora	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										
Common Yellowthroat	X	X					X				
Lincoln’s Sparrow	X	X									
Swamp Sparrow	X	X					X				
Red-winged Blackbird	X	X					X			X	
Yellow-headed Blackbird		X									

Table 7-1. Continued.

GROUP Common name	On WWL Species List	On BCR 26 Regional List	Mississippi Alluvial Valley (BCR 26) [C]			
					Breeding	
			Winter	Migration	Foraging	Nesting
WATERFOWL						
Tundra Swan	X					
Snow Goose	X	X				
Greater White-fronted Goose	X	X				
Canada Goose	X	X				
Wood Duck	X	X	X			
Mallard	X	X	X	F		
Northern Pintail	X	X	X			
Northern Shoveler	X	X	X			
Mottled Duck	X	X				
SHOREBIRDS						
Black-bellied Plover	X	X	X			
American Golden-Plover	X	X	X			
Killdeer	X	X	X			
Greater Yellowlegs	X	X	X			
Lesser Yellowlegs	X	X	X			
Pectoral Sandpiper	X	X	X			
Spotted Sandpiper	X	X				
Semipalmated Sandpiper	X	X				
Western Sandpiper	X	X	X			
Least Sandpiper	X	X	X			
White-rumped Sandpiper	X	X	X			
Long-billed Dowitcher	X	X	X			
Short-billed Dowitcher	X	X	X			
Wilson’s Snipe	X	X	X			
American Woodcock	X	X				

Table 7-1. Continued.

GROUP Common name	On WWL Species List	On BCR 26 Regional List	Mississippi Alluvial Valley (BCR 26) [C]			
					Breeding	
			Winter	Migration	Foraging	Nesting
WADING BIRDS						
Great Egret	X	X				
OTHER WATERBIRDS						
Sandhill Crane	X					
Whooping Crane						
American Coot	X	X				
Sora	X	X				
WWL LANDBIRDS						
Purple Martin	X	X				
Tree Swallow	X	X				
N. Rough-winged Swallow	X	X				
Bank Swallow	X	X				
Palm Warbler	X					
Northern Waterthrush	X					
Common Yellowthroat	X	X				
Lincoln’s Sparrow	X	X				
Swamp Sparrow	X	X				
Red-winged Blackbird	X	X				
Yellow-headed Blackbird						

Table 7-1. Continued.

[a]Some 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.

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.

[b]No comprehensive multi-species surveys conducted in BCR.

[c]Information primarily from shorebird wintering community study:

Twedt, D. J., C. O. Nelms, V. E. Rettig, and S. R. Aycock. 1998. Shorebird use of managed wetlands in the Mississippi Alluvial Valley. American Midland Naturalist **140**:140-152.

Table 7-2. Summary of soybean resources available to waterbirds during the different phases of soybean production in North America. Gray 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)	**FALLOW LAND**
FORAGING RESOURCES O **Soybeans**	waste soybeans (low availability) – geese and potentially cranes [1-6]		waste soybeans (most available in fall) –geese and potentially cranes [5-9]	waste soybeans (less available) – waterfowl [1,7,8,10-13]	
O **Weed Species: new shoots and seeds**	new shoots likely an important resource for spring migrant geese [1]; weed seeds potentially important to spring migrant landbirds, but not studied	weed seeds potentially important to breeding landbirds, but not studied	weed seeds potentially important to fall migrant landbirds, but not studied	new shoots important resource for wintering geese [11,12] weed seeds eaten by blackbirds[14]	new shoots important resource for wintering geese [11]; weed seeds potentially important to wintering and migrant landbirds, but not studied
O **Terrestrial Invertebrates**	earthworms important to spring migrant shorebirds, landbirds [15-17]	earthworms, insects potentially important to breeding shorebirds, landbirds, but not studied [17,18]	earthworms, insects potentially important to breeding shorebirds, landbirds, but not studied [17,18]	earthworms, insects potentially important to wintering shorebirds, landbirds, but not studied [17,18]	earthworms, insects potentially important to shorebirds, landbirds, but not studied [17,18]
O **Aquatic Invertebrates (in Flooded Soybean)**	probably spring migrant dabbling ducks and shorebirds, but not studied			wintering dabbling ducks (esp. Northern Shoveler) and shorebirds, although resource abundance and consumption by birds has not been quantified [19,20]	

Table 7-2. Continued.

RESOURCES	**SOWING** (Spring)	**PRE-HARVEST** (Growing Crop, Summer)	**HARVEST** (Fall)	**POST-HARVEST** (Winter)	**FALLOW LAND**
BREEDING RESOURCES o **Nesting Habitat**	Killdeer, Red-winged Blackbird documented nesting in soybean fields [21,22]	Killdeer, Red-winged Blackbird documented nesting in soybean fields [21,22]			
o **Brood-rearing/ Post-fledging Habitat**		potentially Sora, Mottled Duck [23,24]			

Sources:

1 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.
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3 Davis, C. A. 2003. Habitat use and migration patterns of sandhill cranes along the Platte River, 1998-2001. Great Plains Research **13**:199-216.
4 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.
5 Lingle, G. R., G. A. Wingfield, and J. W. Ziewitz. 1991. The migration ecology of Whooping Cranes in Nebraska. Pages 395-401 *in* Proceedings of the 1987 International Crane Workshop. International Crane Foundation, Baraboo, Wisconsin.
6 Lovvorn, J. R., and C. M. Kirkpatrick. 1982a. Field use by staging eastern Greater Sandhill Cranes. Journal of Wildlife Management **46**:99-108.
7 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.
8 Jarvis, R. L. 1976. Soybean impaction in Canada Geese. Wildlife Society Bulletin **4**:175-179.
9 Lovvorn, J. R., and C. M. Kirkpatrick. 1982b. Recruitment and socially-specific flocking tendencies of eastern Sandhill Cranes. Wilson Bulletin **94**:313-321.
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11 Hobaugh, W. C. 1984. Habitat use by Snow geese wintering in southeast Texas. Journal of Wildlife Management **48**:1085-1096.
12 Leslie, J. C., and R. H. Chabreck. 1984. Winter habitat preferences of White-fronted Geese in Louisiana. Transactions of the North American Wildlife and Natural Resources Conference **49**:519-526.
13 Wright, T. W. 1959. Winter foods of Mallards in Arkansas. Southeast Association of Game and Fish Commissioners **13**:291-296.
14 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.
15 Braile, T. M. 1999. Migration studies of shorebirds in west-central Indiana. M.S. Purdue University.
16 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.
17 Mackay, A. D., and E. J. Kladivko. 1985. Earthworms and rate of breakdown of soybean and maize residues in soil. Soil Biology and Biochemistry **17**:851-857.
18 Kemp, J. C., and G. W. Barrett. 1989. Spatial patterning: impact of uncultivated corridors on arthropod populations within soybean agroecosystems. Ecology **70**:114-128.
19 Twedt, D. J., and C. O. Nelms. 1999. Waterfowl density on agricultural fields managed to retain water in winter. Wildlife Society Bulletin **27**:924-930.
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Table 7-3. Summary of documented impacts of soybean production methods and landscape features on waterbird groups using soybean fields in North America. Open boxes without text indicate potential data gaps or areas for further research.

	SOIL AND RESIDUE MANAGEMENT Conventional Tillage vs. No till	**WINTER FLOODING**	**SOWING**	**PESTICIDE USE, ORGANIC FARMING**	**HARVEST METHODS**	**FIELD SIZE**
ALL WATERBIRDS	conventional: plowing buries waste soybeans [1], but known to increase access to invertebrate prey in other crop types[2,3] ; no documentation of rates of nest loss from farm machinery passes for any species. no-till: earthworm abundances higher in no-till fields [4]	species richness and abundances high for some groups on flooded fields [7,8]	farm machinery used to plant crop may destroy nests and eggs of early breeders, but undocumented for soybean fields	no documented mortalities from carbamate use; seeds and new shoots of weed species reduced by herbicides, especially glyphosates used on GM crops [9-12]; potential damage to nests from pesticide applications, but unstudied; uncultivated corridor management potential means of natural soybean pest control [13]		shorebird abundances (but not densities) correlated with flooded soybean field size [8]; natural pest control with uncultivated corridors most effective for small fields [13]
Waterbird Species Richness		shorebird species richness high on flooded fields [7,8]				
Waterbird Abundances	mixed effects – during breeding season some foraging species more abundant in no-till, others more abundant in conventionally tilled fields, but few species studied [5,6]	abundances of some groups high on flooded fields [7,8]				shorebird abundances (but not densities) correlated with flooded soybean field size [8]
WATERFOWL	conventional plowing buries waste soybeans [1]	abundances of some species high on flooded fields [7]		seeds and new shoots of weed species reduced by herbicide use [9-12]		
o **Geese**	conventional plowing buries waste soybeans [1]			seeds and new shoots of weed species reduced by herbicide use [9-12]		

O **Dabbling Ducks**	conventional plowing buries waste soybeans [1]	Northern Shoveler abundances high on flooded fields [7]		seeds and new shoots of weed species reduced by herbicide use [9-12]		

Table 7-3. Continued.

	SOIL AND RESIDUE MANAGEMENT Conventional Tillage vs. No till	**WINTER FLOODING**	**SOWING**	**PESTICIDE USE, ORGANIC FARMING**	**HARVEST METHODS**	**FIELD SIZE**
SHOREBIRDS	plowing known to increase access to invertebrate prey in other crop types, [2,3] but earthworm abundances higher in no-till fields [4] mixed effects of tillage practices on abundances of foraging species – more spring migrant American Golden-Plovers observed in no-till [5], but more foraging Killdeer during breeding season in conventionally tilled fields [6]	shorebird species richness and abundances high on flooded fields [8]	farm machinery used to plant crop may destroy nests and eggs of early breeders, but undocumented for soybean fields	potential damage to nests from pesticide applications, but unstudied		shorebird abundances (but not densities) correlated with flooded soybean field size [8]
WADING BIRDS						
OTHER WATERBIRDS	conventional plowing buries waste soybeans [1]			potential damage to nests from pesticide applications, but unstudied		
LANDBIRDS	higher abundances of foraging Red-winged Blackbird during breeding season in no-till fields [6]		farm machinery used to plant crop may destroy nests and eggs of early breeders, but undocumented for soybean fields	seeds and new shoots of weed species reduced by herbicide use [9-12]; potential damage to nests from pesticide applications, but unstudied		

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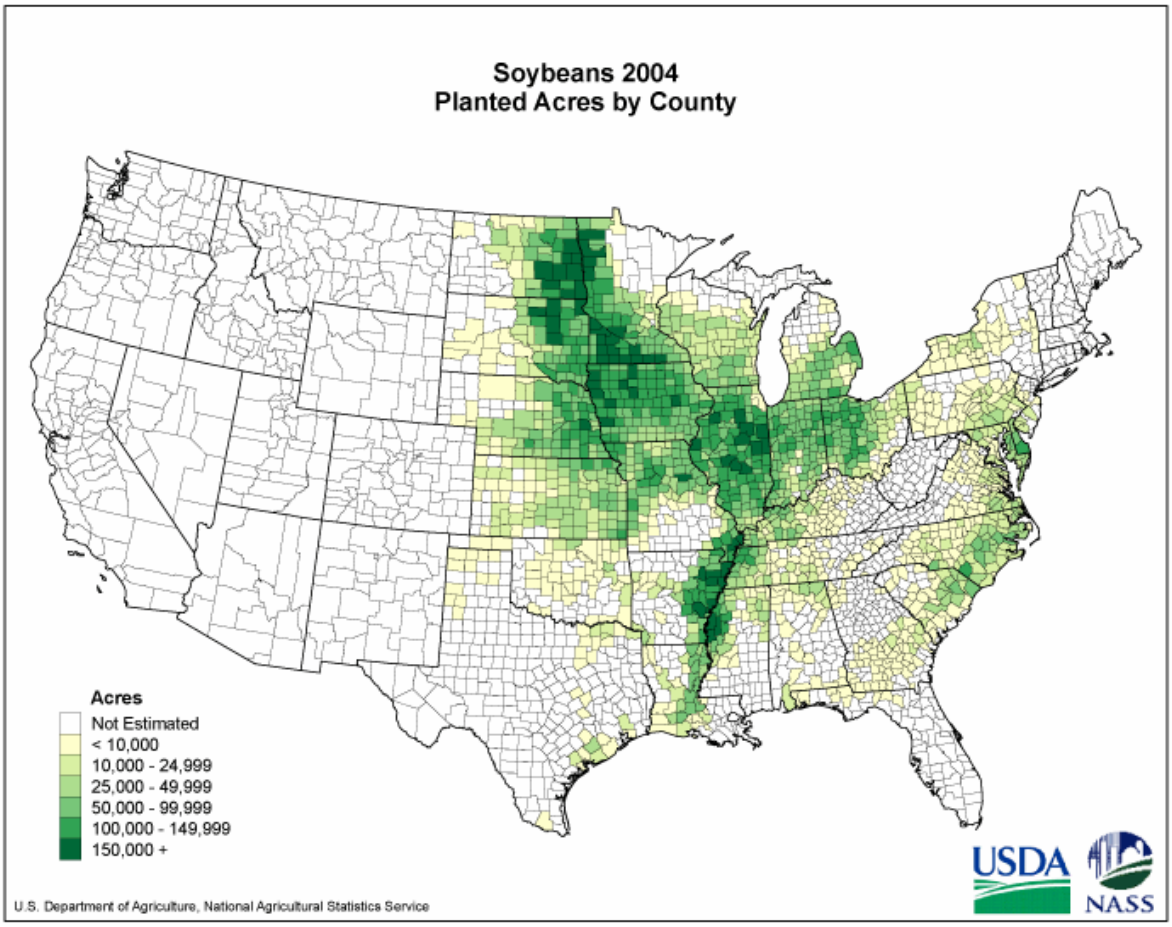

Figure 7-1. Map of the distribution of soybeans planted in the United States during 2004, the most recent year for which data are available. From the United States Department of Agriculture National Agricultural Statistics Service (http://www.usda.gov/nass/aggraphs/cropmap.htm; accessed 2 Jan 2007).