6. SORGHUM

Land planted to sorghum (*Sorghum bicolor*) provides habitat and resources of some value to a number of waterbirds in North America. In the U.S., production of sorghum is most intensive in Kansas and Texas, but other states at southern latitudes from California east to Georgia, and Midwestern states from Oklahoma north to South Dakota, are additional production areas (Acquaah 2005). This distribution of sorghum cropland (Figure 6-1) coincides with the wintering ranges, migratory pathways, and breeding grounds of a number of waterbirds. However, documentation of sorghum resource use is limited primarily to nonbreeding periods by waterfowl, some shorebirds, cranes, and blackbirds, and thus it is uncertain whether knowledge is complete regarding waterbird use of sorghum resources throughout the annual cycle, and in each of the focal BCRs in which sorghum is grown. Waste sorghum grain is a valuable food resource with high energy value, and sorghum seed accounts for a large proportion of the wintering diets of some species, particularly cranes and blackbirds. Abundance and availability of other food resources (terrestrial invertebrates, green forage) potentially used by waterbirds foraging in sorghum fields have been little studied, and effects of most sorghum production methods on waterbirds are virtually unknown. Given the potential value of sorghum resources to many waterbird species, filling remaining information gaps will be crucial to understanding waterbird-sorghum interactions, the value of sorghum to waterbirds, and to developing management strategies that maximize any benefits of land planted to sorghum. This chapter summarizes the state of current knowledge regarding the occurrence and abundances of waterbird species in sorghum fields, sorghum resources of importance to waterbirds, how waterbirds use sorghum fields, and the impacts of sorghum production practices, other management activities, and landscape features of fields on waterbirds.

USE BY WATERBIRDS

Most of what is known regarding waterbird use of sorghum fields has come from research conducted in North America. Waterbird use of sorghum has been observed in four WWL focal regions (in bold throughout text) - **Eastern Tallgrass Prairie** (BCR 22), **Central Mixed-Grass Prairie** (BCR 19), **Shortgrass Prairie** (BCR 18), and **Mississippi Alluvial Valley** (BCR 26) - as well as the eastern U.S. (BCR 30), the southeastern U.S. (BCR 27), the southcentral U.S. (BCR 21), the Gulf of Mexico Coast (BCR 37), California (BCR 32), and southwestern North America (BCR 35, BCR 36). In general, waterbirds use sorghum fields at all times of the year at mid latitudes, and during winter and migrations at southern latitudes (Table 6-1).

The collective diversity of waterbirds using sorghum fields in North America is fairly high, consisting primarily of geese, cranes, shorebirds, and some WWL landbirds (Table 6-1). Overall, 37 waterbird species have been documented in North American sorghum fields, of which 9 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. While most studies documenting waterbird use of sorghum fields have had a single-species focus, a couple of community studies have documented concurrent use of sorghum fields in a region by as many as 19 (Dennis 1997) to 24 (Ballard 1993) WWL waterbird species. By far the most waterbird species use sorghum fields for

foraging during nonbreeding periods, and very few use them for nesting. Species occurrences in sorghum for all of North America, and by focal BCR for the WWL project, are summarized in Table 6-1. BCR regional species lists - species considered relatively abundant in each BCR (see Introduction) - are also shown.

Waterfowl

Sorghum fields have been known to attract fairly high diversities and abundances of waterfowl, particularly in southern latitudes. In North America, 13 species of waterfowl (4 geese, 2 whistling-ducks, and 7 dabbling duck species) have been documented foraging in fields planted to sorghum, almost all during winter and/or spring and fall migrations (Table 6-1). Although most studies have not quantified abundances, a few researchers have observed as many as tens of 1000s of geese per km^2 in sorghum habitat (Ballard 1993, Dennis 1997, Gates et al. 2001).

At northern and mid latitudes of North America, three species of geese have been observed in sorghum fields during fall migration and winter. In the **Eastern Tallgrass Prairie** region (BCR 22), Snow and Canada Geese have been known to forage fairly heavily on sorghum grain during winter in Iowa, Missouri and Kansas (Alisauskas et al. 1988, Eggeman et al. 1989); and in Illinois, sorghum fields receive occasional winter use by foraging Canada Geese (Paine and Tacha 1987, Havera 1998, Gates et al. 2001). In Delaware, Maryland, and Virginia (eastern U.S.; BCR 30), wintering Snow Geese have been documented foraging in sorghum to a limited extent, with at most only 4% of bird observations occurring in fields planted to sorghum (Hill and Frederick 1997). In the **Central Mixed-Grass Prairie** region (BCR 19), Greater White-fronted Geese have been recorded using sorghum fields during spring migration, but only minimally and in proportion to availability of habitat across the landscape (Krapu et al. 1995).

At southern latitudes, three geese and eight duck species have been documented using sorghum fields during fall migration and into winter. In the **Mississippi Alluvial Valley** region (BCR 26), only 1% of wintering Mallards observed were foraging in sorghum fields (Wright 1959). However, in southern Texas (Gulf of Mexico Coast; BCR 37), waterfowl use of no-till sorghum fields is relatively intensive in fall and winter (Ballard 1993, Ballard and Tacha 1995, Dennis 1997). In fall, Dennis (1997) observed average (across fields) densities of 814 birds/km^2 for five duck species combined [American Wigeon, Gadwall, Green-winged Teal, Mottled Duck (Conservation Priority Species), Northern Pintail (Conservation Priority Species)]; by winter, duck abundances declined to only 2 birds/km^2, but geese arrived to use sorghum fields in high abundances of 4,203 Canada Geese/km^2, 3,925 Snow Geese/km^2, and 21,478 Greater White-fronted Geese/km^2. Ballard (1993) also observed high abundances of winter foraging ducks and geese in southern Texas sorghum fields: densities were 3,910 birds/km^2 for six species of ducks (Black-bellied Whistling-Duck, Mottled Duck, Northern Pintail, Blue-winged Teal, Green-winged Teal, Gadwall), and 3,889 birds/km^2 for three goose species combined (Canada Goose, Snow Goose, Greater White-fronted Goose). Modest reliance on sorghum has been documented for wintering Black-bellied Whistling-Duck in Sinaloa, Mexico (Kramer and Euliss 1986), and for Snow Goose and Ross's Goose in northern Mexico (BCR 35, BCR 36) with 13% of sites used by goose flocks planted to sorghum (Drewien et al. 2003).

Black-bellied Whistling-Duck are the only waterfowl species documented using sorghum fields during the breeding season. Along the Gulf of Mexico Coast in Texas (BCR 37), whistling-

ducks foraged in sorghum fields soon after the June harvest through to early fall, with sorghum seeds accounting for nearly half of the foods consumed (Bolen and Forsyth 1967).

Shorebirds
Sorghum fields support modest diversities and abundances of shorebirds in some locales in North America. Nine shorebird species have been recorded in sorghum fields, primarily during fall migration and winter at southern latitudes (Table 6-1). In southern Texas (Gulf of Mexico Coast; BCR 37), seven species [Black-bellied Plover, Killdeer, Long-billed Curlew (Conservation Priority Species), Spotted Sandpiper, Upland Sandpiper (Conservation Priority Species), Western Sandpiper, Wilson's Snipe) have been observed in sorghum fields in fall and winter, with snipe most abundant (Ballard 1993, Dennis 1997). During fall migration, Dennis (1997) documented average densities across fields of 156 birds/km^2 for all upland game birds (which included Wilson's Snipe) and 2,100 birds/km^2 for all non-game species (including Killdeer, Long-billed Curlew, Spotted Sandpiper, Upland Sandpiper, Western Sandpiper). For wintering birds, average densities for upland game (including Wilson's Snipe) varied from 589 birds/km^2 (Dennis 1997) to 769/km^2 (Ballard 1993) and for non-game species from 2,100 birds/km^2 [including Killdeer, Long-billed Curlew, Spotted Sandpiper, Western Sandpiper; Dennis 1997] to 2,580 birds/km^2 (including Black-bellied Plover; Ballard 1993).

Only two shorebird species have been documented using sorghum fields during the breeding season (Table 6-1). Killdeer have occasionally nested in sorghum in eastern Nebraska (**Eastern Tallgrass Prairie**; BCR 22) (King and Savidge 1995), and Mountain Plovers (a Conservation Priority Species) fairly commonly nest in growing sorghum fields in central Nebraska (**Central Mixed-Grass Prairie**; BCR 19) and in Colorado, Kansas, and Oklahoma (**Shortgrass Prairie**; BCR 18) (Shackford 1996, Shackford et al. 1999). Shackford (1996) also documented Mountain Plover adults using the shade provided by sorghum fields in the **Shortgrass Prairie** region (BCR 18) to protect themselves and their broods from the summer heat. In the Texas panhandle (**Shortgrass Prairie**; BCR 18), Killdeer are commonly encountered foraging in sorghum fields during summer (Flickinger and Pendleton 1994).

Wading Birds
Six wading bird species have been anecdotally encountered foraging in sorghum fields in southern Texas (Gulf Coast; BCR 37) during fall migration and winter (Ballard 1993, Dennis 1997): Cattle Egret, Great Egret, Snowy Egret, Little Blue Heron (Conservation Priority Species), Tricolored Heron and White Ibis (Table 6-1).

Other Waterbirds
Three other waterbirds have been recorded in sorghum fields. During fall/spring migrations and throughout the winter, cranes are common visitors to some sorghum fields in North America (Table 6-1). In the **Central Mixed-Grass Prairie** region (BCR 19), Whooping Cranes (a Conservation Priority Species) were observed foraging on occasion in sorghum fields during spring or fall migrations in Nebraska (Lingle et al. 1991), Oklahoma (Howe 1989), and Kansas (Howe 1989), and spring migrant Sandhill Cranes (Conservation Priority Species) have been observed foraging to a limited extent in sorghum fields in Nebraska (Lewis 1979, Krapu et al. 1984). Farther south in Texas and New Mexico, sorghum grain appears to be an important food resource for nonbreeding cranes. Significant sorghum grain-foraging by Sandhill Cranes in fall

and especially winter has been documented in western Texas (**Shortgrass Prairie**; BCR 18) (Iverson et al. 1982, Iverson et al. 1985a, 1985b), in southern Texas (BCR 36, BCR 37) (Guthery 1976, Ballard 1993, Dennis 1997), and southwestern New Mexico (BCR 35) (Walker and Schemnitz 1987), with documented densities in southern Texas as high as 237 birds/km^2 during fall migration, and 17,100 birds/km^2 in winter (Dennis 1997). Iverson et al. (1985a) documented a Sandhill Crane preference for sorghum in winter, as use of fields was in much greater proportion than availability of sorghum across the landscape. Whooping Cranes have also occurred in sorghum fields of east-central Texas (southcentral U.S., BCR 21; Howe 1989), and Ballard (1993) recorded the presence of Sora in sorghum fields of southern Texas (Gulf Coast; BCR 37) during winter.

Landbirds

Only seven species of WWL landbirds have been observed using sorghum fields, primarily during migrations and winter (Table 6-1). During fall and winter, Red-winged Blackbirds forage heavily in sorghum in Oklahoma (**Central Mixed-Grass Prairie**; BCR 19) (Goddard 1969), but blackbird use is less intensive in Arkansas (**Mississippi Alluvial Valley**; BCR 26) and Tennessee (southeastern U.S., BCR 27) (Neff and Meanley 1957, Dolbeer et al. 1978). In southern Texas (Gulf Coast; BCR 37), Purple Martin, Northern Rough-winged Swallow, Sedge Wren (a Conservation Priority Species), Lincoln's Sparrow, and Red-winged Blackbirds were among the non-game species foraging in sorghum fields in fall and winter (Ballard 1993, Dennis 1997). For all non-game bird species combined, Ballard (1993) and Dennis (1997) reported high densities varying from 2,100-2,890 birds/km^2 throughout the fall and winter period, with Red-winged Blackbirds accounting for the majority of individuals. Finally, in California (BCR 32), Red-winged and Yellow-headed Blackbirds forage heavily on sorghum grain during the fall and winter (Crase and DeHaven 1978), and sorghum seeds are common in the diet of fall migrant and wintering Boat-tailed Grackle in north-central Florida (BCR 31) (Haag et al. 1987).

Blackbirds forage in sorghum fields during the breeding season as well. In the **Shortgrass Prairie** region (BCR 18), Flickinger and Pendleton (1994) observed modest use of sorghum fields by breeding Red-winged Blackbirds in Texas. In California (BCR 32), Red-winged Blackbirds and Yellow-headed Blackbirds commonly forage on grain sorghum during the summer months (Crase and DeHaven 1978).

RESOURCES

Overall, the foraging resources provided by sorghum fields are of some value to geese, ducks, and cranes, and potentially to several shorebirds and WWL landbirds, primarily during winter and migration. Few species have been observed relying on sorghum resources during the breeding period (Table 6-2). Here we review what is known about the abundance and availability of sorghum resources, and of their use by waterbirds of North America.

Foraging Resources

Foraging resources provided for waterbirds by sorghum fields include sorghum seeds, new shoots or 'green forage' of weed species, and most likely terrestrial invertebrate prey (including crop pests) (Table 6-2).

Seed

Sorghum grain is an important food resource for some granivorous waterbirds especially during nonbreeding periods (Table 6-2). These species acquire sorghum seed either from maturing seed heads of growing plants or more commonly from heads or loose seed in stubble fields after harvest (waste sorghum). Although sorghum seeds have been found in the diet of Red-winged Blackbirds in spring while seed is ripening (Crase and Dehaven 1978), all other accounts are from waterbirds foraging on waste grain (see below). New sorghum waste seed becomes available to foraging waterbirds after the summer harvest and is potentially available until late winter by which time most seed has decomposed or been consumed (Iverson et al. 1985a, Ballard 1993, Dennis 1997). In North America, estimates for average amounts of waste sorghum grain left in fields range from 148 kg/ha to 510 kg/ha (Iverson et al. 1985a, Ballard 1993, Dennis 1997). Moisture content of sorghum at harvest can affect the amount of waste grain – harvesting at a lower moisture content level than the optimum for storage (13%) leads to greater seed head shattering during cutting, and thus to greater amounts of waste sorghum in fields (Ballard 1993).

Eight North American waterbird species have been documented foraging on sorghum seed, most during nonbreeding periods. These species include Snow Geese in winter (Alisauskas 1988, Ballard 1993, Hill and Frederick 1997); Canada Geese in fall (Gates et al. 2001) and winter (Ballard 1993, Gates et al. 2001); Greater White-fronted Geese in winter (Ballard 1993); Black-bellied Whistling-Duck in summer (Bolen and Forsyth 1967); Mallard in winter (Wright 1959); Sandhill Crane (Conservation Priority Species) during spring migration (Lewis 1979, Iverson et al. 1982) and in winter (Guthery 1976, Iverson et al. 1982, Iverson et al. 1985a, Walker and Schemnitz 1987, Ballard 1993); Red-winged Blackbird during fall (Goddard 1969, Crase and DeHaven 1978), winter (Goddard 1969, Crase and DeHaven 1978, Dolbeer et al. 1978) spring, and summer (Crase and Dehaven 1978); and Yellow-headed Blackbird in summer and fall (Crase and Dehaven 1978). Additionally, a study from Saudi Arabia found that Glossy Ibis (a WWL species) and Black-tailed Godwit (*Limosa limosa*) sometimes feed on ripe sorghum grains (Rahmani and Shobrak 1992).

Sorghum seeds account for a variable and sometimes highly significant proportion of the seasonal diets of these species. During fall and winter, sorghum seeds were found in only 6-7% of the diet of Canada Geese in Illinois (Gates et al. 2001), but Snow Geese foraged heavily on sorghum seed during winter in Iowa, Missouri, and Kansas, with seeds accounting for as much as 36% (by volume) of the foods consumed by birds (Alisauskas et al. 1988). Sorghum seed constituted less than 1% of the diets of Mallards sampled in Arkansas during winter (Wright 1959), but was a significant food resource accounting for nearly 50% of food volume consumed by Black-bellied Whistling-Ducks during the breeding season in coastal Texas (Bolen and Forsyth 1967). For cranes, documented proportions of diets with sorghum seed have varied from less than 10% in Nebraska during spring migration (Lewis 1979) and in New Mexico during winter (Walker and Schemnitz 1987), to as much as 37% (Guthery 1976) and 97% (Iverson et al. 1982) during winter in Texas. Iverson et al. (1985a) estimated average winter sorghum seed consumption rates in southern Texas that were as high as 467g seed/crane/day, with 1.4 million kg of total seeds consumed by cranes over a one month period. The amount of sorghum seed recorded in the diets of Red-winged Blackbirds varies from 3% in winter in Tennessee (Dolbeer et al. 1978) to 18% in winter and 12% in summer in California (Crase and DeHaven 1978).

Sorghum seeds are a common component of the diet of Red-winged Blackbirds during fall and winter in Oklahoma, observed in 93% of crops and gizzards examined (Goddard 1969). Finally, for Yellow-headed Blackbirds, sorghum seeds accounted for 12% of the foods ingested during the breeding season, and 32% of foods eaten during fall migration in California (Crase and Dehaven 1978).

Energy Value of Sorghum Seed. Compared to other cereal grains, the caloric value of sorghum seed is relatively high. Assayed with Canada Geese, estimated apparent metabolizable energy (AME) of sorghum seed is 3.96 kcal/g, very similar to corn (3.97 kcal/g), and higher than wheat seed (3.85 kcal/g) and soybeans (3.03 kcal/g assayed with domestic Embden Geese) (Storey and Allen 1982, Joyner et al. 1987). Also tested with Canada Geese, estimated true metabolizable energy (TME) for sorghum seeds is 3.78 kcal/g, only slightly lower than corn (3.90 kcal/g), and higher than rice (2.82 kcal/g) and soybeans (3.55 kcal/g) (Petrie et al. 1998). Moreover, the energy from sorghum seeds is easily assimilated. Assayed with Canada Geese, digestibility of sorghum was estimated at 87%, similar to corn (88%), and higher than rice (67%), soybeans (63%), and the green forage of winter wheat (55%) (Petrie et al. 1998). Although the caloric content of sorghum seed may be high, protein (of dry weight: 11%) and fiber (2%) contents are fairly low (Ensminger et al. 1990) and thus waterbirds foraging on sorghum seed likely supplement their diet with other sources of protein.

Green Forage

The new shoots of weed species growing in sorghum fields may be an important source of protein for some waterbirds, especially in mid-winter and spring after waste sorghum has decayed or been consumed (Table 6-2). Although availability of green forage from weed species has been quantified in some locales (Ballard 1993, Dennis 1997), there are no direct accounts of green forage consumption by waterbirds. In southern Texas, Ballard (1993) observed greatest abundance of weedy green forage in sorghum fields where residue had been shredded and left in fields until February planting; peak forage biomass (25 kg/ha) occurred in October due to patterns of fall precipitation. Dennis (1997) quantified green forage biomass as high as 369 kg/ha on sorghum fields with moderate residue (>50% cover) during winter in southern Texas, but did not observe any correlations between waterbird densities and green forage availability throughout the study period.

Terrestrial Invertebrates

Terrestrial invertebrates such as earthworms and insect pests may be an important food resource in sorghum fields, but we found no direct information regarding their abundance or consumption by waterbirds (Table 6-2). As most waterbirds are ground-foragers, terrestrial invertebrates in sorghum fields would be most accessible between summer harvest and late winter planting before major growth of sorghum vegetation. Earthworms are a common prey item for shorebirds foraging in many environments (Skagen and Oman 1996), and may be important for shorebirds that forage in sorghum fields during fall and winter (Table 6-1). It is also likely that swallows observed over sorghum fields during nonbreeding periods forage on flying insects associated with crop. In both cases, however, data are lacking. During the breeding season, Bolen and Forsyth (1967) found insects and mollusks in the diet of Fulvous Whistling-Ducks feeding in sorghum fields of coastal Texas. Common sorghum pests include the Corn Earworm

(*Helicoverpa zea*), aphids, and Greenbug (*Schizaphis graminum*), but the degree to which these species are eaten by waterbirds has not been documented.

Breeding Resources
Few resources for breeding waterbirds are provided by North American sorghum fields. Only two species have been confirmed as nesting in sorghum, and we found only one account of sorghum habitat being used as brood-rearing or post-fledging habitat.

Nesting Habitat
Two waterbird species have been confirmed nesting in sorghum fields. King and Savidge (1995) report occasional nesting by Killdeer in sorghum fields in Nebraska (**Eastern Tallgrass Prairie**; BCR 22). Of 52 Mountain Plover (a Conservation Priority Species) nests found on agricultural lands in Colorado, Kansas, Oklahoma (**Shortgrass Prairie**; BCR 18), 14% were in sorghum fields (Shackford et al. 1999).

Brood-rearing/Post-fledging Habitat
Shackford (1996) observed Mountain Plovers with broods seeking shade under sorghum plants, and this shorebird may be the only waterbird that uses sorghum fields for brood-rearing.

EFFECTS OF SORGHUM PRODUCTION METHODS
Impacts of most sorghum farming methods on waterbirds are virtually unknown. The following is a summary of the few known effects, from soil and residue management to methods of harvesting sorghum grain. We also review any available information pertaining to the influences of other aspects of sorghum farming such as field size, hunting activity, and landscape context. Table 6-3 provides a synopsis of the current state of knowledge on these topics.

Soil and Residue Management in Preparation for Planting
Between summer harvest and late winter planting, sorghum farmers practice a variety of tillage methods from conventional to no-till in order to prepare the soil for planting. Although conventional practices of plowing and disking to maintain surface residues below 20% cover are most common, some sorghum farmers practice conservation tillage methods that vary from shredding stubble and disking only lightly, to leaving stubble and plowing at a later date closer to the timing of planting, to multiple shredding events of the residue left on fields, to leaving standing stalks in fields with no subsequent manipulations (Ballard 1993, Flickinger and Pendleton 1994, Dennis 1997).

Sorghum residue management practices in fall and winter potentially influence the short and long-term abundance and availability of food resources for waterbirds. In western Texas (**Shortgrass Prairie**; BCR 18), Iverson et al. (1985a) documented that field plowing buried virtually all waste sorghum and wintering cranes ceased using sorghum fields after plowing. In other crops, plowing activity has been known to increase the immediate availability of soil invertebrates for shorebirds and wading birds (O'Connor and Shrubb 1986, Lack 1992), but higher long-term abundances of invertebrates such as earthworms have been observed in no-till fields where crop residues were allowed to remain in fields (Mackay and Kladivko 1985). Influence of tillage on terrestrial invertebrate abundances has not been evaluated for sorghum fields, although observed densities of nonbreeding non-game species (including some waterbirds

that likely forage on terrestrial invertebrates) were greater in various reduced or no-till sorghum fields monitored in Texas (Gulf of Mexico Coast, BCR 37; Ballard 1993, Dennis 1997).

Accounts of the effects of tillage on nonbreeding waterbird use indicate that most waterbirds prefer sorghum fields with minimal tillage. In southern Texas (Gulf of Mexico Coast; BCR 37), both Ballard (1993) and Dennis (1997) found that the species richness of bird communities (including some waterbirds) using sorghum fields in fall and winter was greater on fields that had received modest tillage activity than on either no-till (stalks left standing) or fields receiving a convention tillage treatment. Ballard (1993) also observed higher densities of waterfowl in fields where straw had been shredded twice ("double-shredded"; ducks: average densities 39 birds/ha; geese: 39 birds/ha) than in fields with either greater or fewer tillage manipulations (for all field types, ducks: average densities < 8 birds/ha; geese: < 6 birds/ha). For upland game birds (which included the Conservation Priority Species Sandhill Crane), densities were greatest (8 birds/ha) on fields where straw had been shredded and then disked after residues were allowed to remain in fields, and non-game species [including Cattle Egret, Great Egret, Little Blue Heron (Conservation Priority Species), Snowy Egret, Tricolored Heron, White Ibis, Black-bellied Plover, Upland Sandpiper (Conservation Priority Species), Wilson's Snipe, Sora, Purple Martin, Sedge Wren (Conservation Priority Species), Lincoln's Sparrow, Red-winged Blackbird] were most abundant on no-till and reduced till fields (stalks left standing: 18 birds/ha; double-shredded: 19 birds/ha; shredded then later disked: 21 birds/ha) (Ballard 1993). Dennis (1997) reported similar waterbird density results. Goose and crane densities tended to be higher in double-shredded fields, and non-game birds [including Snowy Egret, Killdeer, Long-billed Curlew (Conservation Priority Species), Spotted Sandpiper, Upland Sandpiper, Western Sandpiper, Northern Rough-winged Swallow, Red-winged Blackbird] were generally more abundant on fields in which residue coverage was 30% or greater (Dennis 1997). Lastly, Flickinger and Pendleton (1994) observed greater diversity and abundances of breeding landbirds in reduced-till than in conventionally tilled sorghum fields in Texas, but abundances of the WWL species present (Killdeer and Red-winged Blackbird) were no different among field types.

There have been no assessments of the influence of winter sorghum residue management on subsequent spring nest densities or nest success rates for the two shorebird species (Killdeer and Mountain Plover) documented nesting in sorghum.

Sowing Methods

Although sorghum is planted in late spring (May) when incubating adults and nests are at risk, we found no references to nest loss due to sowing methods. It is not unlikely, however, that the farm machinery involved in planting sorghum would incur damage and loss to any nests.

Pesticide Use and Organic Farming

We found few references to the pesticides commonly used to combat weeds and insect pests in sorghum fields. Common sorghum insect pests include the Corn Earworm (*Helicoverpa zea*), aphids, and Greenbug (*Schizaphis graminum*), and organophosphates such as terbufos have been used to combat these (EXTOXNET 2007). Herbicides used to control weeds on both conventional and reduced-till sorghum fields in Texas include triazines (atrazine, propazine), anilines (alachlor) and other compounds such as glyphosate, 2,4-D, and metolachlor (Flickinger

and Pendleton 1994). While the organophosphates used may be highly toxic to birds, herbicides used in sorghum are all categorized as practically nontoxic to slightly toxic (EXTOXNET 2007). Even though most of the organophosphates are "restricted-use" pesticides, they may be purchased and administered on fields by certified growers.

We found no information pertaining to the direct (causing mortality to birds or loss of nests) or indirect (diminishing food resources) impacts of pesticide use in sorghum fields on waterbirds. However, because pesticides are applied to sorghum fields during spring after late winter planting, the WWL species most at risk are the very few waterfowl, shorebird, crane and blackbird species documented in sorghum fields during spring migration or foraging and/or nesting in sorghum during the early part of the breeding season (Table 6-1). On conservation tillage fields, which are presumed to require greater number of herbicide applications to control weeds (Best 1986), there may be great risk of nest damage due to the larger number of passes by farm machinery. Flickinger and Pendleton (1994), however, found that reduced-till sorghum fields in Texas (**Shortgrass Prairie**; BCR 18) in fact incurred fewer herbicide applications than conventional fields. Possible indirect effects of pesticide use include herbicides reducing availability of green forage from weed species important to some geese and landbird species (Ballard 1993, Dennis 1997), and broad-spectrum insecticides killing non-target invertebrate food resources as well as crop pests (EXTOXNET 2007).

Management of Bird Pest Species

In some locales, blackbirds have been known to cause depredations to sorghum seed yields (Goddard 1969, Crase and Dehaven 1978). The main strategy used to lessen damage is to prescribe chemical repellents such as methiocarb to render sorghum unpalatable to blackbirds (DeHaven et al. 1971, Crase and DeHaven 1976). Such use of repellents poses little risk to desirable non-target species some of which may aid farmers by consuming insect pests. In Saudi Arabia, ibis and godwits have also been reported to cause crop damage in inundated sorghum fields (Rahmani and Shobrak 1992), but the extent of this problem is unclear and similar problems seem unlikely in North America under current production methods.

Harvest Methods

We found no specific references to the effects of sorghum harvest methods nor harvest efficiency on waterbirds using sorghum fields. In North America, however, sorghum is harvested during summer, from June through September/October depending on location (Bolen and Forsyth 1967, Guthery 1976, Dennis 1997), and thus sorghum waste seed is most abundant in early autumn, coincident with the arrival of migrant nonbreeding waterbirds. Because sorghum is harvested during part of the nesting season, incubating adults and nests for the few waterbird species documented nesting in sorghum fields may be at risk.

Crop Rotation, Fallow Land

Sorghum is grown in rotation with winter wheat, rice, and cotton (Ballard 1993, Flickinger and Pendleton 1994). The first two of these crops provide conservation value to many waterbirds (see RICE, WHEAT chapters), thus waterbird species using sorghum fields are likely to fare well with the periodic planting of fields back to these crops. Cotton, in contrast, is used far less by waterbirds (see COTTON chapter) and rotation from sorghum into cotton is likely to reduce

resources available for birds. Waterbird use of fallow sorghum fields has been documented by a few researchers. During one fall/winter season in southern Texas (BCR 37), Ballard (1993) observed 2,724 Canada Geese, 5,379 Snow Geese, and 297 Greater White-fronted Geese using 300 ha of fallow land that previously had been sorghum or cotton. The green forage from growing weed species is the resource that most likely attracts geese to fallow fields. In the **Shortgrass Prairie** region (BCR 18), fallow fields previously planted to sorghum have also been used by Red-winged Blackbirds in Texas (Flickinger and Pendleton 1994) and nesting Mountain Plover (a Conservation Priority Species) in Colorado, Kansas, and Oklahoma (Shackford et al. 1999).

EFFECTS OF OTHER MANAGEMENT ACTIVITIES

Hunting Activity

To our knowledge, the extent and impacts on waterbirds of recreational hunting in sorghum fields have not been evaluated. It is likely, however, that general patterns found for similar crops, such as wheat and corn, also apply to sorghum.

EFFECTS OF LANDSCAPE FEATURES

Field Size

We did not find any literature pertaining to the importance or effect of field size on waterbird use of sorghum fields, but again, the limited data on this topic from other crops probably also applies to sorghum.

Landscape Context

Studies in wetland landscape ecology (Naugle et al. 1999, Riffell et al. 2003) 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 influence of landscape context on waterbird use of sorghum fields. Ballard (1993), however, states that waterbirds in southern Texas (BCR 37) tended to forage in sorghum fields that were near roosts or other traditional areas used by waterfowl. Understanding the importance of landscape context could affect a number of management decisions for sorghum fields, but for now any recommendations must be based on the limited knowledge of waterbird responses to landscape features available for other crops and more natural systems.

SUMMARY AND SYNTHESIS

Here we review the major themes of what is known regarding sorghum use by waterbirds, resources provided by sorghum fields, positive and negative effects of sorghum production practices on waterbirds, and gaps in our knowledge of these effects. We end by briefly highlighting future research needs and current waterbird conservation challenges presented by sorghum agriculture.

Waterbird Use

Available literature suggests that habitat and resources provided by sorghum agriculture in North America are important to many waterbirds (Table 6-1), primarily granivorous species such as waterfowl (e.g., Alisauskas et al. 1988, Ballard 1998, Dennis 1997, Gates et al. 2001, Drewien et al. 2003), cranes (e.g., Lewis 1979, Krapu et al. 1984, Howe 1989, Iverson et al.1982, Iverson et al. 1985a, b) and blackbirds (e.g., Goddard 1969, Crase and DeHaven 1978, Dolbeer et al. 1978, Ballard 1993, Dennis 1997). Highest abundances of these species have been observed in sorghum fields during fall migration and winter, with 1000s of cranes and blackbirds observed foraging in fields at any one time (Dennis 1997), and shorebirds, wading birds and other landbird species in relatively low abundances (Ballard 1993, Dennis 1997). Sorghum fields are used by very few waterbird species during the breeding season either as foraging or nesting habitat (Bolen and Forsyth 1967, Crase and DeHaven 1978, Flickinger and Pendleton 1994, King and Savidge 1995, Shackford et al. 1999) (Table 6-1).

WWL Species and Bird Conservation Regions

Of the 216 species identified for the Waterbirds on Working Lands project, 36 species have been documented using sorghum fields, of which 9 are species of conservation priority (Table 6-1). Of these 36 species, 30 species have been observed using sorghum fields during winter, 30 species during migration (primarily fall), and only five species during the breeding season with only Killdeer and Mountain Plover confirmed nesting. On average, use of sorghum fields has been documented for only 4% (range: 2% in Mississippi Alluvial Valley BCR 26 to 6% in the Shortgrass Prairie region BCR 18) of those species considered to be relatively abundant within a given BCR (i.e., the focal species on BCR regional lists). Given documented use of sorghum fields by additional species in other BCRs, we believe these low numbers represent gaps in knowledge rather than a true representation of low use of sorghum fields in these regions (see **Knowledge Gaps and Research Needs** below).

Sorghum Resources

Sorghum seed and the green forage of weed species are widely available to waterbirds foraging in sorghum fields (Iverson et al. 1985a, Ballard 1993, Dennis 1997); terrestrial invertebrates are another probable but undocumented food resource (Table 6-2). Waste sorghum becomes available after mid-summer harvest, but quickly dissipates in availability by late winter. Although most waterbird species consume modest amounts of waste sorghum during fall and winter (e.g., Dolbeer et al. 1978, Lewis 1979, Alisauskas et al. 1988, Gates et al. 2001), seed has been documented to account for a significant proportion of the diets of some species, particularly breeding Black-bellied Whistling-Duck (Bolen and Forsyth 1967), wintering Sandhill Cranes (a Conservation Priority Species; e.g. Guthery 1976, Iverson et al. 1982, Iverson et al. 1985a), and wintering Red-winged Blackbird (Crase and DeHaven 1978, Goddard 1969). Sorghum seed is easily digested and high in caloric value, comparable to corn (Joyner et al. 1987, Petrie et al. 1998). New shoots of weed species in winter and early spring may be additional resources of importance in sorghum fields for grazing species such as geese, particularly after peak availability of waste sorghum (Ballard 1993, Dennis 1997). Terrestrial invertebrates found in sorghum fields such as earthworms and insect pests may be important to some shorebirds, other waterbirds, and landbirds throughout the year, but their abundances in fields and their consumption by waterbirds has not been studied. Literature suggests that sorghum fields provide limited resources for waterbirds during the breeding period (e.g., King and Savidge 1995,

Shackford et al. 1999), as sorghum nesting has been confirmed for only two WWL shorebird species (however, see **Knowledge Gaps and Research Needs** below), and a few observations of birds present in fields post-breeding suggest little use of sorghum fields for brood-rearing.

Practices Benefiting Waterbirds

There are only a few sorghum crop production practices known to benefit waterbirds using sorghum fields. Practices that have been documented as positively influencing the suitability of fields for waterbirds include some conservation tillage practices, and fallowing of sorghum fields. Reduced or no-till practices are associated with greater fall and winter abundance and availability of waste sorghum (Iverson et al. 1985a), and potentially of terrestrial invertebrates (Mackay and Kladivko 1985), although the latter has not been confirmed explicitly for sorghum fields (see **Knowledge Gaps and Research Needs** below). Corresponding waterbird use of sorghum fields is generally much greater on fields with minimal tillage than those conventionally managed for minimal crop residues (Ballard 1993, Dennis 1997). Fallowing of sorghum fields may benefit some waterbirds such as geese by providing green forage of weed species in late winter when sorghum seed and other waste grains have diminished in availability across the landscape (Ballard 1993).

Practices Negatively Affecting Waterbirds

The only sorghum production practice that has been documented to adversely affect waterbirds is that of conventional plowing burying sorghum waste grain (Table 6-3). The plowing under of sorghum residue has been demonstrated to virtually eliminate access to sorghum waste seed for foraging waterbirds, and cranes have been know to respond by evacuating fields after plowing (Iverson et al. 1985a).

Knowledge Gaps and Research Needs

Although there is some general knowledge of waterbird use of sorghum fields and resources, there are many unknowns regarding how sorghum crop production methods impact waterbirds. A focus on filling these knowledge gaps should facilitate the development of management strategies that improve the conservation value of sorghum habitat for waterbirds.

Waterbird Use

Knowledge of waterbird use of sorghum fields in each of the four focal BCRs appears grossly incomplete. In fact, for most of the species listed in Table 6-1, observations of sorghum use are from research conducted in other North American BCRs, especially in the Gulf of Mexico Coast region. This list of species includes many waterfowl [Ross's Goose, Fulvous Whistling-Duck, Black-bellied Whistling-Duck, Northern Pintail (Conservation Priority Species), Blue-winged Teal, Gadwall, American Wigeon, Mottled Duck (Conservation Priority Species)], shorebirds [Black-bellied Plover, Long-billed Curlew (Conservation Priority Species), Wilson's Snipe, Upland Sandpiper (Conservation Priority Species), Spotted Sandpiper, Western Sandpiper), wading birds [Cattle Egret, Great Egret Snowy Egret, Little Blue Heron (Conservation Priority Species), Tricolored Heron, White Ibis], other waterbirds (Sora), and WWL landbirds [Purple Martin, Northern Rough-winged Swallow, Sedge Wren (Conservation Priority Species), Lincoln's Sparrow, Yellow-headed Blackbird]. Some of these species may not have been observed in a focal BCR simply because their ranges do not overlap with the region (e.g., whistling-duck species). A number of species on this list, however, regularly occur throughout

focal BCRs at various times of the year (e.g., many of the dabbling duck species in Table 6-1). Thus, for the focal BCRs, a lack of documentation of sorghum use by most of the species in Table 6-1 likely represents a real knowledge gap. An effort to document fully the waterbird use of sorghum fields throughout mid-continent BCRs where sorghum is grown would enable more comprehensive evaluation of the importance of North American sorghum habitat to waterbirds.

Resources

Although various shorebird and landbird species have been observed in sorghum, there have been no assessments of the abundances, life history traits, or consumption of terrestrial invertebrate resources such as earthworms or insect pests present in sorghum fields that are likely important foraging resources for these waterbirds. Research in this area would not only contribute to our understanding of the overall importance of sorghum fields to waterbirds, but would also help to advance biological control methods potentially lessening any dependence on pesticide use. Additionally, although the green forage of weed species appears to be abundant in sorghum fields in fall and winter, the degree to which waterbirds rely on this resource is unknown. With sorghum use studies potentially biased towards nonbreeding periods when sorghum seed is most available to foraging birds, there may be more to learn about the degree to which waterbirds nest in sorghum. Growing sorghum fields likely provide similar nesting resources for breeding waterfowl as are found in wheat fields, and thus it is possible that dabbling ducks nest in sorghum more than has been documented. For any species nesting in sorghum, quantifying nest densities and success rates on tilled and non-tilled lands will add to a more complete understanding of the importance of sorghum nesting resources to waterbirds.

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

We know very little about how sorghum production methods impact waterbirds (Table 6-3). To date, all research on the effects of tillage practices has been conducted in Texas. To fully understand the impact of sorghum tillage methods on waterbirds will require research on a larger geographic scale to examine the effects of plowing and residue management on terrestrial invertebrate abundance and availability, associated foraging waterbird use, and nest densities and reproduction success. Similarly, the direct and indirect effects of pesticide use on sorghum fields have not been documented. For those waterbirds occurring in sorghum fields in spring, coincident with timing of pesticide application, it would be helpful to evaluate exposure to "restricted-use" but moderately toxic pesticides, and the typical damage to nests from farm machinery passes. The extent to which herbicides affect the amount of green forage for grazing species and insecticides diminish important terrestrial invertebrate resources is also in need of documentation for sorghum fields. Impact of summertime harvest operations on nest success of the few waterbirds nesting in sorghum would be valuable to examine. Understanding the extent of recreational waterfowl hunting activities in sorghum fields would help to assess the degree of disturbance and potential influence on body condition and subsequent reproductive success for affected waterbirds, particularly geese. Finally, understanding the importance of field size and landscape context of fields to waterbirds using sorghum would enable more strategic conservation planning for agricultural landscapes in which sorghum is a common row crop.

References

Acquaah, G. 2005. Principles of crop production: theory, techniques, and technology. Pearson Prentice Hall, 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., C. D. Ankney, and E. E. Klaas. 1988. Winter diets and nutrition of midcontinental lesser Snow Geese. Journal of Wildlife Management **52**:403-414.

Ballard, B. M. 1993. Sorghum management for waterfowl wintering in southern Texas. M.S. thesis. Texas A&M University, Kingsville.

Ballard, B. M., and T. C. Tacha. 1995. Habitat use by geese wintering in southern Texas. Southwest Naturalist **40**:68-75.

Best, L. B. 1986. Conservation tillage: ecological traps for nesting birds. Wildlife Society Bulletin **14**:308-317.

Bolen, E. G., and B. J. Forsyth. 1967. Foods of the Black-bellied Tree Duck in south Texas. Wilson Bulletin **79**:43-49.

Crase, F. T., and R. W. DeHaven. 1976. Methiocarb: Its current status as a bird repellent. Pages 46-50 *in* Proceedings of the 7th Vertebrate Pest Control Conference, Monterey, California, March 9-11.

Crase, F. T., and R. W. DeHaven. 1978. Food selection by five sympatric California blackbird species. California Fish and Game **64**:255-267.

DeHaven, R. W., J. L. Guarino, F. T. Crase, and E. W. J. Schafer. 1971. Methiocarb for repelling blackbirds from ripening rice. International Rice Commission Newsletter **20**:25-30.

Dennis, M. H. 1997. Evaluation of sorghum stubble management alternatives in southern Texas (*Sorghum bicolor*, migratory birds). M.S. thesis. Texas A&M University, Kingsville, TX.

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.

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.

Ensminger, M. E., J. E. Oldfield, and W. W. Heinemann. 1990. Feeds and Nutrition. Ensminger Publishing, Clovis, CA.

EXTOXNET. 2007. The EXtension TOXicology NETwork. http://extoxnet.orst.edu/ghindex.html:(accessed 2 Jan 2007).

Flickinger, E. L., and G. W. Pendleton. 1994. Bird use of agricultural fields under reduced and conventional tillage in the Texas Panhandle. Wildlife Society Bulletin **22**:34-42.

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.

Goddard, S. V. 1969. Fall and winter food habits of Red-winged Blackbirds and Brown-headed Cowbirds in western Oklahoma. Wilson Bulletin **81**:336-337.

Guthery, F. S. 1976. Foods and feeding habitat of Sandhill Cranes in southern Texas. Pages 117-125 *in* Proceedings of the 1975 Crane Workshop, Oklahoma State University, Stillwater, OK.

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.

Havera, S. P. 1998. Waterfowl of Illinois: status and management. Phoenix Publishing, Urbana, IL.

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.

Howe, M. A. 1989. Migration of radio-marked whooping cranes from the Aransas-Wood Buffalo population: patterns of habitat use, behavior, and survival. Fish and Wildlife Technical Report 21, U.S. Fish and Wildlife Service.

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.

Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1985a. Habitat use by Sandhill Cranes wintering in western Texas. Journal of Wildlife Management **49**:1074-1083.

Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1985b. Distribution and abundance of sandhill cranes wintering in western Texas. Journal of Wildlife Management **49**:250-255.

Joyner, D. E., B. N. Jacobson, and R. D. Arthur. 1987. Nutritional characteristics of grains fed to Canada Geese. Wildfowl **38**:89-93.

King, J. W., and J. A. Savidge. 1995. Effects of the Conservation Reserve Program on wildlife in southeast Nebraska. Wildlife Society Bulletin **23**:377-385.

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., 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., 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.

Lack, P. C. 1992. Birds on Lowland Farms. HMSO, London, England.

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.

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.

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.

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.

Neff, J. A., and B. Meanley. 1957. Status of Brewer's Blackbird on the Grand Prairie of eastern Arkansas. Wilson Bulletin **69**:102-105.

O'Connor, R. J., and M. Shrubb. 1986. Farming and Birds. Cambridge University Press, Cambridge, England.

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.
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.
Rahmani, A. R., and M. Y. Shobrak. 1992. Glossy Ibises (*Plegadis falcinellus*) and Black-tailed Godwits (*Limosa limosa*) feeding on sorghum in flooded fields in southwestern Saudi Arabia. Colonial Waterbirds **15**:239-240.
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.
Shackford, J. S. 1996. The importance of shade to breeding mountain plovers. Oklahoma Ornithological Society. Bulletin **29**:17-21.
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.
Skagen, S. K., and H. D. Oman. 1996. Dietary flexibility of shorebirds in the western hemisphere. Canadian Field-Naturalist **110**:419-444.
Storey, M. L., and N. K. Allen. 1982. Apparent and true metabolizable energy of feedstuffs for mature, nonlaying female Embden geese. Poultry Science **61**:739-745.
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.
Wright, T. W. 1959. Winter foods of Mallards in Arkansas. Southeast Association of Game and Fish Commissioners **13**:291-296.

Table 6-1. Waterbird species reported in sorghum 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. Apparent absences likely reflect incomplete information in the published literature for a given season or region.

			North America [a]					**Eastern Tallgrass Prairie (BCR 22)** [b]			
	On WWL				Breeding		On BCR 11			Breeding	
GROUP Common name	Species List	Species of Conservation Priority	Winter	Migration	Foraging	Nesting	Regional List	Winter	Migration	Foraging	Nesting
WATERFOWL											
Snow Goose	X		X				X	X			
Ross's Goose	X		X								
Greater White-fronted Goose	X			S							
Canada Goose	X		X	S/F			X	X	S/F		
Fulvous Whistling-Duck	X				X						
Black-bellied Whistling-Duck	X		X		X						
Mallard	X		X				X				
Mottled Duck	X	X	X	F							
Northern Pintail	X	X	X	F							
Blue-winged Teal	X		X	F			X				
Green-winged Teal	X		X	F			X				
Gadwall	X		X	F			X				
American Wigeon	X		X	F			X				
SHOREBIRDS											
Black-bellied Plover	X		X	F			X				
Killdeer	X				X	X	X				X
Mountain Plover	X	X			X	X					
Long-billed Curlew	X	X	X	F							
Wilson's Snipe	X		X	F			X				
Upland Sandpiper	X	X		F			X				
Spotted Sandpiper	X		X	F			X				
Western Sandpiper	X		X	F							

Table 6-1. Continued.

GROUP Common name	On WWL Species List	Species of Conservation Priority	North America [a] Winter	North America [a] Migration	North America [a] Breeding Foraging	North America [a] Breeding Nesting	On BCR 22 Regional List	Eastern Tallgrass Prairie (BCR 22) [b] Winter	Eastern Tallgrass Prairie (BCR 22) [b] Migration	Eastern Tallgrass Prairie (BCR 22) [b] Breeding Foraging	Eastern Tallgrass Prairie (BCR 22) [b] Breeding Nesting
WADING BIRDS											
Cattle Egret	X		X	F							
Great Egret	X		X	F			X				
Snowy Egret	X		X	F			X				
Little Blue Heron	X	X	X	F							
Tricolored Heron	X		X	F							
White Ibis	X		X	F							
OTHER WATERBIRDS											
Sandhill Crane	X	X	X	S							
Whooping Crane	X	X		S/F							
Sora	X		X	F			X				
WWL LANDBIRDS											
Purple Martin	X		X	F			X				
N. Rough-winged Swallow	X		X	F			X				
Sedge Wren	X	X	X	F			X				
Lincoln’s Sparrow	X		X	F							
Red-winged Blackbird	X		X	S/F	X		X				
Yellow-headed Blackbird	X			F	X						
Boat-tailed Grackle	X		X	F							

Table 6-1. Continued.

GROUP Common name	On WWL Species List	On BCR 18 Regional List	Shortgrass Prairie (BCR 18) [b]				On BCR 19 Regional List	Central Mixed-Grass Prairie (BCR 19) [b]			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WATERFOWL											
Snow Goose	X	X					X				
Ross's Goose	X	X					X				
Greater White-fronted Goose	X						X		S		
Canada Goose	X	X					X				
Fulvous Whistling-Duck	X										
Black-bellied Whistling-Duck	X						X				
Mallard	X	X					X				
Northern Pintail	X	X					X				
Blue-winged Teal	X	X					X				
Green-winged Teal	X	X					X				
Gadwall	X	X					X				
American Wigeon	X						X				
Mottled Duck	X										
SHOREBIRDS											
Black-bellied Plover	X	X					X				
Killdeer	X	X			X		X				
Mountain Plover	X	X			X	X	X			X	X
Long-billed Curlew	X	X					X				
Wilson's Snipe	X	X					X				
Upland Sandpiper	X	X					X				
Spotted Sandpiper	X	X					X				
Western Sandpiper	X	X					X				

Table 6-1. Continued.

GROUP Common name	On WWL Species List	On BCR 18 Regional List	Shortgrass Prairie (BCR 18) [b]				On BCR 19 Regional List	Central Mixed-Grass Prairie (BCR 19) [b]			
			Winter	Migration	Breeding			Winter	Migration	Breeding	
					Foraging	Nesting				Foraging	Nesting
WADING BIRDS											
Cattle Egret	X						X				
Great Egret	X						X				
Snowy Egret	X	X					X				
Little Blue Heron	X						X				
Tricolored Heron	X										
White Ibis	X										
OTHER WATERBIRDS											
Sandhill Crane	X	X	X	S			X		S		
Whooping Crane	X								S/F		
Sora	X	X					X				
WWL LANDBIRDS											
Purple Martin	X						X				
N. Rough-winged Swallow	X	X					X				
Sedge Wren	X										
Lincoln's Sparrow	X	X					X				
Red-winged Blackbird	X	X			X		X	W	S/F		
Yellow-headed Blackbird	X	X					X				
Boat-tailed Grackle	X										

Table 6-1. Continued.

GROUP Common name	On WWL Species List	On BCR 26 Regional List	Mississippi Alluvial Valley (BCR 26) [b]			
			Winter	Migration	Breeding	
					Foraging	Nesting
WATERFOWL						
Snow Goose	X	X				
Ross's Goose	X					
Greater White-fronted Goose	X	X				
Canada Goose	X	X				
Fulvous Whistling-Duck	X					
Black-bellied Whistling-Duck	X					
Mallard	X	X	X			
Northern Pintail	X	X				
Blue-winged Teal	X	X				
Green-winged Teal	X	X				
Gadwall	X	X				
American Wigeon	X	X				
Mottled Duck	X	X				
SHOREBIRDS						
Black-bellied Plover	X	X				
Killdeer	X	X				
Mountain Plover	X					
Long-billed Curlew	X	X				
Wilson's Snipe	X	X				
Upland Sandpiper	X	X				
Spotted Sandpiper	X	X				
Western Sandpiper	X	X				

Table 6-1. Continued.

GROUP Common name	On WWL Species List	On BCR 26 Regional List	Mississippi Alluvial Valley (BCR 26) [b]			
					Breeding	
			Winter	Migration	Foraging	Nesting
WADING BIRDS						
Cattle Egret	X	X				
Great Egret	X	X				
Snowy Egret	X	X				
Little Blue Heron	X	X				
Tricolored Heron	X	X				
White Ibis	X	X				
OTHER WATERBIRDS						
Sandhill Crane	X					
Whooping Crane	X					
Sora	X	X				
WWL LANDBIRDS						
Purple Martin	X	X				
N. Rough-winged Swallow	X	X				
Sedge Wren	X	X				
Lincoln's Sparrow	X	X				
Red-winged Blackbird	X	X	W	F		
Yellow-headed Blackbird	X					
Boat-tailed Grackle	X	X				

[a]Much information from comprehensive multi-species surveys conducted in southern Texas:
Ballard, B. M. 1993. Sorghum management for waterfowl wintering in southern Texas. Texas A&I University, Kingsville.
Dennis, M. H. 1997. Evaluation of sorghum stubble management alternatives in southern Texas (Sorghum bicolor, migratory birds). Texas A&M University, Kingsville, TX.
[b]No comprehensive multi-species surveys conducted in BCR.

Table 6-2. Summary of sorghum resources available to waterbirds during the different phases of sorghum production in North America. Gray shaded boxes indicate not applicable, or resource not available during the time period.

RESOURCES	SOWING (Late Winter)	PRE-HARVEST (Growing Crop, Spring, Summer)	HARVEST (Summer)	POST-HARVEST (Fall, Winter)	FALLOW LAND
FORAGING RESOURCES o **Sorghum Grain**	waste grain – waterfowl, cranes, blackbirds [1-12]	waste grain – cranes, blackbirds [1,2,13] developing seeds – blackbirds [2]	developing seeds – blackbirds [2]	waste grain – waterfowl, cranes, blackbirds [1-12]	
o **Weed Species: new shoots**	quantified for sorghum fields in Texas, but consumption by waterbirds undocumented [7,14]			quantified for sorghum fields in Texas, but consumption by waterbirds undocumented [7,14]	food resource on fallow land, but has not been quantified
o **Terrestrial Invertebrates**			insects, mollusks found in diet of Fulvous Whistling Duck feeding in sorghum [15]		
BREEDING RESOURCES o **Nesting Habitat**		Killdeer, Mountain Plover documented nesting in sorghum fields [16,17]	Killdeer, Mountain Plover documented nesting in sorghum fields [16,17]		
o **Brood-rearing/Post-fledging Habitat**			Mountain Plover seek shade for brood in sorghum fields [18]		

Table 6-2. Continued.

Sources:

1 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.
2 Crase, F. T., and R. W. Dehaven. 1978. Food selection by five sympatric California blackbird species. California Fish and Game **64**:255-267.
3 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.
4 Goddard, S. V. 1969. Fall and winter food habits of Red-winged Blackbirds and Brown-headed Cowbirds in western Oklahoma. Wilson Bulletin **81**:336-337.
5 Alisauskas, R. T., C. D. Ankney, and E. E. Klaas. 1988. Winter diets and nutrition of midcontinental lesser Snow Geese. Journal of Wildlife Management **52**:403-414.
6 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.
7 Ballard, B. M. 1993. Sorghum management for waterfowl wintering in southern Texas. Texas A&I University, Kingsville.
8 Wright, T. W. 1959. Winter foods of Mallards in Arkansas. Southeast Association of Game and Fish Commissioners **13**:291-296.
9 Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1985a. Habitat use by Sandhill Cranes wintering in western Texas. Journal of Wildlife Management **49**:1074-1083.
10 Guthery, F. S. 1976. Foods and feeding habitat of Sandhill Cranes in southern Texas. Pages 117-125 *in* Proceedings of the 1975 Crane Workshop, Oklahoma State University, Stillwater, OK.
11 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.
12 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.
13 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.
14 Dennis, M. H. 1997. Evaluation of sorghum stubble management alternatives in southern Texas (Sorghum bicolor, migratory birds). Texas A&M University, Kingsville, TX.
15 Bolen, E. G., and B. J. Forsyth. 1967. Foods of the Black-bellied Tree Duck in south Texas. Wilson Bulletin **79**:43-49.
16 King, J. W., and J. A. Savidge. 1995. Effects of the Conservation Reserve Program on wildlife in southeast Nebraska. Wildlife Society Bulletin **23**:377-385.
17 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.
18 Shackford, J. S. 1996. The importance of shade to breeding mountain plovers. Oklahoma Ornithological Society. Bulletin **29**:17-21.

Table 6-3. Summary of documented impacts of sorghum production methods and landscape features on waterbird groups using sorghum 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	**SOWING**	**PESTICIDE USE, ORGANIC FARMING**	**HARVEST METHODS**	**FIELD SIZE**
ALL WATERBIRDS	conventional tillage plowing buries waste sorghum grain substantially [1] no difference in species' abundances between conventional and no/reduced-till, but few species studied; no comparison of nest densities or nest success between conventional and no/reduced-till	undocumented, but likely to impact birds as sowing occurs in late spring	no documentation of mortalities from pesticide use; green forage of weed species potentially reduced by herbicide use; potential damage to nests from pesticide applications, but unstudied; herbicide use may not be as high in no-till sorghum fields as often assumed [4]	potential damage to nests from summertime harvest operations, but unstudied; waste sorghum most abundant fall to early winter [1]	
Waterbird Species Richness	higher richness in reduced till than no-till or conventional till during fall and winter [2, 3]				
Waterbird Abundances	greater waterbird abundances in no-till and reduced-till than conventional; no comparison of nest densities between conventional and no/reduced-till				
WATERFOWL	conventional plowing buries waste sorghum important to geese [1] greater bird densities in reduced-till than in no-till or conventional [2, 3]			waste sorghum most abundant fall to early winter [1]	
o **Geese**	conventional plowing buries waste sorghum important to geese [1] greater bird densities in reduced-till than in no-till or conventional [2, 3]			waste sorghum most abundant fall to early winter [1]	

Table 6-3. Continued.

	SOIL AND RESIDUE MANAGEMENT Conventional Tillage vs. No-till	**SOWING**	**PESTICIDE USE, ORGANIC FARMING**	**HARVEST METHODS**	**FIELD SIZE**
o **Dabbling Ducks**	conventional plowing buries waste sorghum important to some ducks [1] greater bird densities in reduced-till than in no-till or conventional [2]			waste sorghum most abundant fall to early winter [1]	
SHOREBIRDS	greater non-game bird densities in no-till and reduced-till than in conventional [2, 3] no difference in Killdeer densities between conventional and reduced-till fields [4] no comparison of nest densities or nest success between conventional and no/reduced-till			potential damage to nests from summertime harvest operations, but unstudied	
OTHER WATERBIRDS	conventional plowing buries waste sorghum, crane use of sorghum fields ceases after late winter plowing [1] greater crane densities in reduced-till than in no-till or conventional [2, 3]			waste sorghum most abundant fall to early winter [1]	
LANDBIRDS	greater non-game bird densities in no-till and reduced-till than in conventional [2, 3] no difference in Red-winged Blackbird densities between conventional and reduced-till fields [4]			waste sorghum most abundant fall to early winter [1]	

Sources:

1 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.

2 Ballard, B. M. 1993. Sorghum management for waterfowl wintering in southern Texas. Texas A&I University, Kingsville.

3 Dennis, M. H. 1997. Evaluation of sorghum stubble management alternatives in southern Texas (Sorghum bicolor, migratory birds). Texas A&M University, Kingsville, TX.

4 Flickinger, E. L., and G. W. Pendleton. 1994. Bird use of agricultural fields under reduced and conventional tillage in the Texas Panhandle. Wildlife Society Bulletin **22**:34-42.

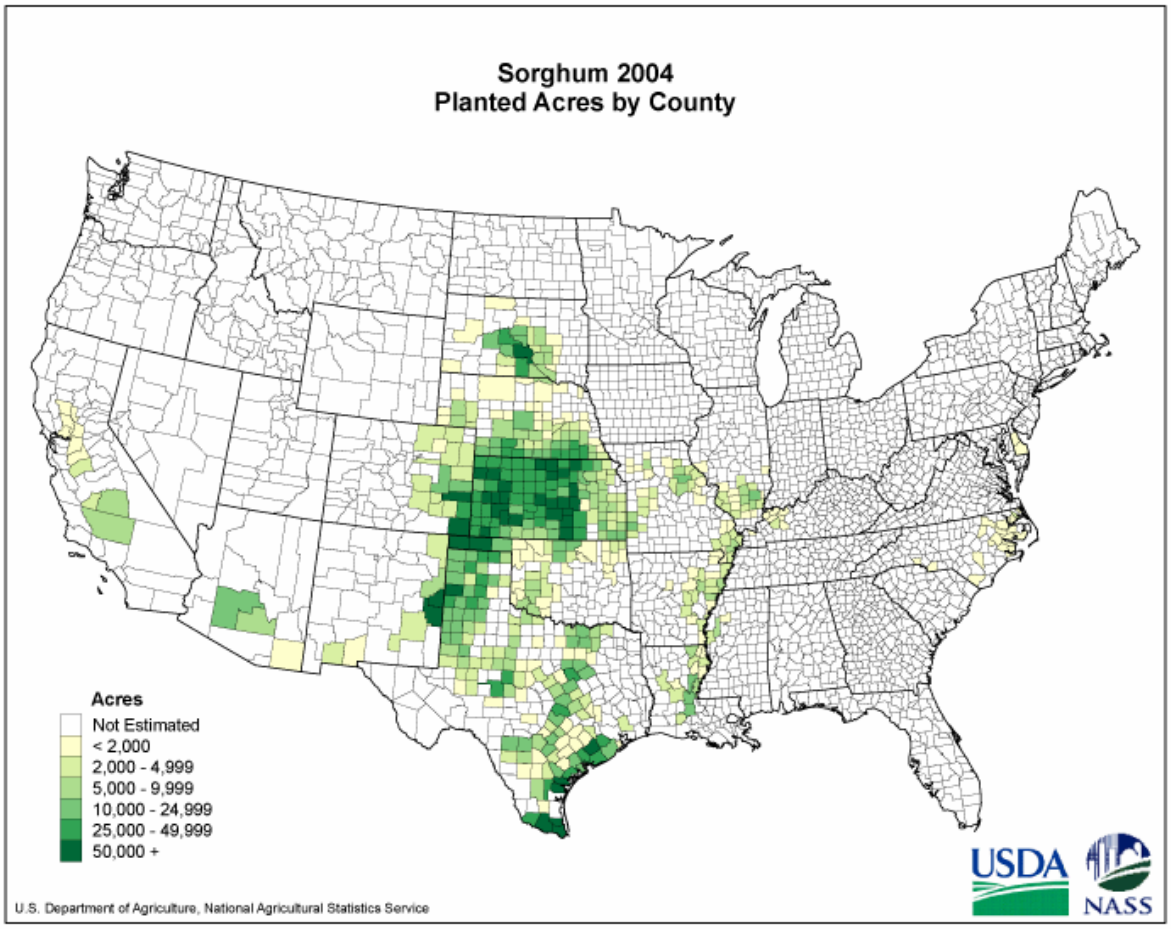

Figure 6-1. Map of the distribution of sorghum planted in the United States during 2004, the most recent year for which data are available. From the United States Department of Agriculture National Agricultural Statistics Service (http://www.usda.gov/nass/aggraphs/cropmap.htm; accessed 2 Jan 2007).