5. WHEAT

After rice and corn, wheat (*Triticum* spp.) is one of the most valuable WWL focal crops to waterbirds. In regions where native wetlands have been lost and natural food resources compromised, wheat resources have become increasingly important in helping to sustain certain waterbirds through nonbreeding periods, with potential to influence geographic distributions, migratory patterns, survival, and subsequent reproductive success (Raveling 1979, McLandress and Raveling 1981, Krapu et al. 2004). Additionally, wheat stubble and growing wheat crops also serve as breeding habitat for some waterbirds.

Wheat is generally grown in arid regions where soil quality is poor (Acquaah 2005). In North America, wheat has two distinct growing seasons. Winter wheat, accounting for 70-80% of U.S. production (MAWG 2007), is planted in fall, harvested in summer and is generally grown at latitudes spanning from the Gulf Coast to prairie Canada (Acquaah 2005; Figure 5-1). Spring wheat is sown in early spring, harvested in late summer/early fall, and produced primarily at northern latitudes in the U.S. and in southern Canada (Acquaah 2005; Figure 5-2). There are hundreds of varieties of winter and spring wheat in North America that generally fall into seven commercial classes differing in hardness, color, kernel shape, protein content, and corresponding market use (Acquaah 2005, MAWG 2007). The widespread geographic range of cropland planted to winter wheat coincides with the wintering ranges, migratory pathways, and breeding grounds of a number of waterbirds. In contrast, land planted to spring wheat overlaps with the migratory pathways and breeding grounds of a more limited group of waterbirds. Consequently, the resources provided by winter wheat are of value to a greater number of waterbird species over a larger proportion of the year than are resources provided by spring wheat. Differences in the timing of resource availability and of crop production practices between winter and spring wheat may have significant consequences for waterbirds using wheat fields (Podruzny et al. 2002).

This chapter summarizes the state of current knowledge regarding the occurrence and abundance of waterbird species in wheat fields, important wheat resources for waterbirds, how waterbirds use wheat fields, and the impacts of wheat production practices and other management activities on waterbirds. Because different crop phenologies and geographic distributions of the two types of wheat affect the spatio-temporal availability of wheat resources for waterbirds, throughout this chapter we separately synthesize information on waterbird use and foraging resources for *Winter Wheat* and *Spring Wheat*.

USE BY WATERBIRDS

Most of what is known about waterbird use of wheat fields has been ascertained from studies conducted in North America, and from additional studies conducted elsewhere, primarily in Europe. Waterbird use of wheat has been documented primarily from the WWL focal regions (in bold throughout text) including the **Prairie Potholes** (BCR 11), **Prairie Hardwood Transition** (BCR 23), **Eastern Tallgrass Prairie** (BCR 22), **Shortgrass Prairie** (BCR 18), **Central Mixed-Grass Prairie** (BCR 19), and **Central Hardwoods** (BCR 24) regions. Additional records of waterbird use of wheat occur in southern Ontario, Canada (BCR 12), the eastern U.S. (BCR 28, BCR 29, BCR 30), the southeastern U.S. (BCR 27), the Gulf of Mexico

Coast (BCR 37), southwestern North America (New Mexico and northern Mexico: BCR 34, BCR 35, BCR 36), and the western U.S. (Great Basin BCR 9, Northern Rockies BCR 10, and California BCR 32).

Collectively, North American wheat fields are used by a fairly diverse group of waterbirds, primarily geese, dabbling ducks, cranes, shorebirds, and a few WWL landbirds. Geese and Sandhill Cranes use wheat fields in the greatest numbers. Current knowledge of waterbird use of wheat is almost entirely derived from single-species studies. This lack of multi-species studies is consistent with a literature that suggests that at any given time and locale, wheat fields are used by few waterbird species. Waterbird diversity seems to be greatest during the breeding season when up to eight duck species may nest concurrently in wheat fields (Milonski 1958, Cowan 1982).

In North America, 31 waterbird species total have been documented in wheat fields - 26 species in winter wheat, and 16 species in spring wheat. Eleven species have occurred in both winter and spring wheat. All of these species have been identified as WWL focal species. Eleven of these species 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. Winter wheat is primarily used by foraging geese and cranes during nonbreeding periods, and by nesting dabbling ducks and shorebirds during the breeding season. Use of winter wheat fields by landbirds included on the WWL species list occurs both in winter and during the nesting period. Spring wheat fields are used primarily by breeding dabbling ducks (including Northern Pintail, a Conservation Priority Species) and shorebirds, but also a few waterfowl species during fall migration, cranes during breeding and migration, and Red-winged Blackbirds during spring/fall migrations and the breeding season. Table 5-1 summarizes the occurrence of species in winter and spring wheat for all of North America, and within focal BCRs for the WWL project. BCR regional species lists, or species considered relatively abundant in each BCR (see Introduction), are also shown.

Winter Wheat

Waterfowl

Worldwide, records indicate that waterfowl are the waterbird group most likely to use wheat resources. In Europe, winter wheat has become a vitally important foraging resource for waterfowl during nonbreeding periods - swans forage in wheat fields during winter (Laubek 1995, Nilsson 1997); geese during fall (Madsen 1985), winter (Williams and Forbes 1980, Amat 1986, Farago 1994, Giroux and Patterson 1995, McKay et al. 1996, Therkildsen and Madsen 2000, Fox et al. 2005), and spring (Williams and Forbes 1980, Fox et al. 2005); and Eurasian Wigeon (*Anas penelope*) during fall, winter, and spring (Owen and Thomas 1979, Williams and Forbes 1980). In North America, at least 12 waterfowl species (1 swan, 5 geese, 6 duck species) have been observed in winter wheat fields. Goose and swan use of wheat fields occurs in winter and during spring and fall migrations primarily throughout the mid latitudes of North America (including most of the focal BCRs; Table 5-1). Most dabbling ducks, in contrast, have been documented in winter wheat fields only during the breeding season (at northern latitudes including the **Prairie Potholes** and northern **Central Mixed-Grass Prairie** regions; Table 5-1). Much of the published information about the use of wheat fields by waterfowl concerns diet and

foraging ecology, and consequently few researchers have presented data on species' abundance and densities in wheat fields. Those studies that have documented bird numbers suggest that waterfowl, particularly geese, can reach abundances of hundreds to thousands of birds in individual fields (Nagel 1965, Harvey et al. 1988, Petrie et al. 2002).

In North America, there are many records of geese and swans using winter wheat fields during the nonbreeding period, primarily in the midwestern U.S., including in many WWL focal BCRs (Table 5-1). At northern latitudes, winter wheat fields are used by spring-migrating Snow Geese in the Dakotas (**Prairie Potholes** region; BCR 11) (Alisauskas and Ankney 1992), by spring and fall migrant Canada Geese in Wisconsin (**Prairie Hardwood Transition** region; BCR 23) (Gates et al. 2001) and spring and fall migrant Tundra Swans in southern Ontario (BCR 13; Petrie et al. 2002). In the **Eastern Tallgrass Prairie** region (BCR 22), wheat fields are commonly used by foraging Snow Geese during migrations and winter in Iowa, Missouri and Kansas (Alisauskas 1988, Davis et al. 1989), and Canada Geese frequent wheat fields during migrations and winter in Missouri (Kahl and Samson 1984, Eggeman et al. 1989) and Illinois (Havera 1998), using wheat in greater proportion than its availability in the landscape during fall and spring (Kahl and Samson 1984). Frederick and Klaas (1982) noted that Canada Geese in eastern Nebraska (BCR 22) foraged but also spent considerable time resting in winter wheat fields during fall migration. In the **Shortgrass Prairie** region (BCR 18), wheat fields are used by wintering Canada Geese in Texas (White et al. 1982) and in the **Central Mixed-Grass Prairie** region (BCR 19), and by Greater White-fronted Geese in Nebraska during spring migration (Krapu et al. 1995). In the **Central Hardwoods** region (BCR 24), Canada Geese forage in wheat fields in fall and winter in southern Illinois (Hanson 1962, Bell and Klimstra 1970, Paine and Tacha 1987, Gates et al. 2001).

Reports from the eastern U.S. show that Snow and Canada Geese forage in wheat fields during winter in New Jersey (Mason and Clark 1996), and in Maryland and Virginia (Harvey et al. 1988, Malecki et al. 1988), and that Tundra Swans forage in wheat fields in coastal North Carolina and Maryland in winter (Munro 1981, Bortner 1985, Earnst 1992). At more southern latitudes, researchers have documented use of winter wheat fields in winter by Greater White-fronted Geese along the Gulf of Mexico Coast in Louisiana (BCR 37; Leslie and Chabreck 1984), by Snow Geese and Ross's Geese in northern Mexico (BCR 35 and 36) (Drewien et al. 2003), and by Black-bellied Whistling-Ducks in northwestern Mexico (Kramer and Euliss 1986). Within the Great Basin (BCR 9) of the western U.S., Tundra Swans have also been observed foraging in wheat fields in Utah during spring migration (Nagel 1965), and migrant (spring and fall) Canada and Cackling Geese are common visitors to winter wheat fields in the Klamath Basin of northeastern California (Raveling and Zezulak 1991, McWilliams and Raveling 1998). During fall and winter, Tundra Swans and Northern Pintail (a Conservation Priority Species) commonly forage in winter wheat fields in the Central Valley of California (BCR 32) (Tate and Tate 1966, Miller 1985, Paullin 1996, Stabins et al. 2002).

Five duck species have been documented using North American winter wheat fields during the breeding season (Table 5-1). In the **Prairie Potholes** region (BCR 11), Mallard, Northern Pintail, Northern Shoveler, Blue-winged Teal, and Gadwall have been observed nesting in winter wheat stubble in North Dakota (Duebbert and Kantrud 1987), and waste wheat seed regularly occurred in the diet of female Mallards during both laying and post-laying periods (Swanson et

al. 1985). In the **Central Mixed-Grass Prairie** region (BCR 19), nests of five dabbling duck species, including Blue-winged Teal, Mallard, Northern Pintail, Northern Shoveler, and Gadwall, have been found in both growing green wheat fields and wheat stubble in Nebraska (Evans and Wolfe 1967, Baxter and Wolfe 1972). Finally, in the western U.S., nests of Mallards have been observed in green winter wheat fields of California (BCR 32) (Earl 1950).

Shorebirds

Worldwide, shorebirds are known to use winter wheat fields to some degree. In Britain, Northern Lapwings (*Vanellus vanellus*) may forage or nest in winter wheat fields (Henderson et al. 2000), and have been documented foraging on newly exposed invertebrates in burnt wheat stubble in the fall (Watson 1989). In France, wintering Eurasian Woodcock (*Scolopax rusticola*) have been observed foraging nocturnally in winter wheat stubble, feeding mainly on earthworms (Duriez et al. 2005).

In North America, six shorebird species have been recorded in low numbers in winter wheat fields (Table 5-1). Aside from observations of radio-marked wintering American Woodcock (a Conservation Priority Species) foraging nocturnally in winter wheat fields in coastal Georgia (BCR 27) and Virginia (BCR 30) (Krementz et al. 1995), all other shorebird records in wheat occur during the breeding season. In the **Prairie Potholes** region (BCR 11), Marbled Godwit has been confirmed as nesting in mulched winter wheat in North Dakota (Higgins 1974), and Long-billed Curlew (a Conservation Priority Species) have been observed foraging with young in winter wheat in Saskatchewan (Foster-Willfong 2003). In the **Eastern Tallgrass Prairie** (BCR 22), Killdeer have been observed in green winter wheat fields in Indiana (Guth 1971). In the **Shortgrass Prairie** region (BCR 18), Mountain Plovers (a Conservation Priority Species) have been observed nesting in both growing wheat and wheat stubble in Colorado, Kansas and Oklahoma (Shackford 1996, Shackford et al. 1999). In the **Central Mixed-Grass Prairie** region (BCR 19), Mountain Plovers and Upland Sandpipers nest in winter wheat fields of the Platte River Valley of Nebraska (Faanes and Lingle 1995, Shackford 1996, Shackford et al. 1999). Additionally, Shackford (1996) documented Mountain Plover adults using the shade provided by wheat to protect themselves and their broods from the summer heat. In the western U.S., Long-billed Curlew have been documented nesting in wheat stubble in agricultural fields of the Great Basin (Pampush 1980).

Wading Birds

In North America, White-faced Ibis have been observed foraging in winter wheat fields during the breeding period in Nevada (BCR 9) (Bray 1986, Bray and Klebenow 1988).

Other Waterbirds

Literature on wheat field use by other waterbirds in Europe and North America indicates at least low to moderate importance of wheat resources to cranes during the nonbreeding season (Table 5-1). In Europe, Common Cranes (*Grus grus*) have been observed foraging in winter wheat fields during fall migration in Hungary (Vegvari 2002) and during winter in Spain (Guzman et al. 1999), but crane numbers and estimates of use in relation to availability of wheat habitat for these studies indicate only minimal use of wheat fields by cranes. In Scotland, Mew Gulls (*Larus c. canus*) commonly forage on invertebrates exposed in recently burnt winter wheat stubble in the fall (Watson 1989). In North America, fall migrating Sandhill Cranes have shown

a preference for foraging in newly harvested winter wheat fields in southern Michigan (**Prairie Hardwood Transition**; BCR 23), but use diminished in late fall and birds even appeared to avoid wheat during spring when wheat plants were fully grown (Hoffman 1976). Likewise, wintering Sandhill Cranes in Texas (**Shortgrass Prairie**; BCR 18), have been observed in harvested wheat fields, sometimes selecting habitat in greater proportion than the availability of wheat across the landscape (Iverson et al. 1985a). Spring migrating Sandhill Cranes foraged in Nebraska (**Central Mixed-Grass Prairie;** BCR 19) winter wheat fields only minimally (Lewis 1979, Krapu et al. 1984) or used wheat habitats in proportion to their availability in the landscape (Davis 2003). By contrast, Whooping Cranes (a Conservation Priority Species) have been observed in wheat fields to a greater extent than expected during spring and fall migrations in Nebraska, with this crop accounting for as much as 13% of all cropland observations (Lingle et al. 1991). In Indiana (**Eastern Tallgrass Prairie;** BCR 22) during spring and fall migrations, hundreds to thousands of Sandhill Cranes have been observed foraging in individual winter wheat fields, but observations suggest that birds were not selecting habitat in any greater proportion than its availability (Lovvorn and Kirkpatrick 1982a, 1982b).

Elsewhere in North America, Whooping Cranes have been documented foraging in winter wheat fields of Colorado and New Mexico (BCR 16) during spring and fall migrations (Lewis 1995), and wintering Sandhill Cranes are common in winter wheat fields of southern New Mexico (BCR 35; Walker and Schemnitz 1987). In the western U.S., Sandhill Cranes have been observed foraging in winter wheat fields during spring and fall migrations in Wyoming (BCR 10; Rowland et al. 1992), and during fall migration in Oregon (BCR 9; Littlefield 1986). Littlefield (1986) documented crane use of winter wheat both before and after fall harvest, but noted a preference for wheat shortly after harvest when grain was most available.

We found only one record documenting use of winter wheat fields by other waterbird species during the breeding period (Table 5-1). Hoffman (1976) observed Sandhill Cranes foraging in wheat fields in southern Michigan (**Prairie Hardwood Transition**; BCR 23), but field use during summer was substantially lower than during spring or fall migrations.

Landbirds

Five species of passerines from the WWL list have been documented using winter wheat fields in North America (Table 5-1). During nonbreeding periods, waste wheat seed accounted for a large proportion of the diet of Red-winged Blackbirds in spring in South Dakota (**Prairie Potholes;** BCR 11) (Mott et al. 1972). In contrast, wheat accounted for only a minor portion of the diets of wintering Red-winged and Rusty Blackbirds (a Conservation Priority Species) in Kentucky and Tennessee (**Central Hardwoods**; BCR 24) (Dolbeer et al. 1978, Robertson et al. 1978). In the eastern U.S., wintering Common Yellowthroats were observed in agricultural field strips in Maryland (BCR 29) that included winter wheat stubble (Woodward 1981).

Two blackbird species have been documented foraging in wheat fields during the breeding period. Low numbers of summering Red-winged Blackbirds have been observed foraging in small grain fields that included winter wheat in Ohio and Indiana (**Eastern Tallgrass Prairie;** BCR 22) (Dambach and Good 1940, Good and Dambach 1943, Guth 1969). Likewise, modest numbers of Red-winged and Yellow-headed Blackbirds have been recorded foraging in winter wheat fields in Texas (**Shortgrass Prairie;** BCR 18) during the breeding season (Flickinger and

Pendleton 1994). In the eastern U.S., minimal amounts of waste wheat seed were found in the diets of Red-winged Blackbirds collected in wheat fields in Maryland (BCR 30) during late summer (Meanley 1961). In the western U.S., Yellow-headed Blackbirds forage in wheat fields in Utah during the breeding season (Knowlton and Telford 1947), and in California (BCR 32) wheat fields in spring (Crase and DeHaven 1978).

Red-winged and Tricolored Blackbirds have been documented to nest in winter wheat fields in various locales: Red-winged Blackbirds in Nebraska (**Central Mixed-Grass Prairie;** BCR 19), Illinois (**Eastern Tallgrass Prairie**; BCR 22) and North Carolina (BCR 27) (Case and Hewitt 1963, Graber and Graber 1963, Ducey and Miller 1980), and Tricolored Blackbirds (a Conservation Priority Species) in California (BCR 32) (Beedy et al. 1991).

Spring Wheat

Waterfowl

Use of spring wheat fields by waterfowl occurs primarily during the breeding season and occasionally during fall migration. Clark et al. (1986) observed fall-migrant Mallard and Northern Pintail foraging in spring wheat in Saskatchewan (**Prairie Potholes**; BCR 11) in mid September between the period of field swathing and grain harvest (Table 5-1). Eight duck species have been documented using North American spring wheat fields during the breeding season (Table 5-1). In North Dakota, (**Prairie** Potholes; BCR 11), waste wheat seed regularly occurred in the diet of female Northern Pintail during both laying and post-laying periods (Krapu 1974), and Mallard and Gadwall have been observed nesting in spring wheat stubble (Higgins 1977, Lokemoen et al. 1990). In North Dakota, South Dakota, and Minnesota, five duck species (Mallard, Northern Pintail, Northern Shoveler, Blue-winged Teal, and Gadwall) have been documented nesting in small grain fields (Klett et al. 1988, Greenwood et al. 1995) that likely included spring wheat. Studies in Manitoba (also **Prairie Potholes**) have additionally documented spring wheat stubble nesting by Green-winged Teal, American Wigeon and Lesser Scaup, with Blue-winged Teal, Mallard and Northern Pintail the most abundant species (Milonski 1958, Cowan 1982).

Shorebirds

We found one account of shorebirds using fields planted to spring wheat in North America. In North Dakota (**Prairie Potholes** region; BCR 11), Higgins (1975) observed five species (Killdeer, Willet, Upland Sandpiper, Marbled Godwit, and Wilson's Phalarope; the latter three are Conservation Priority Species) nesting in 'growing small grain fields' that most definitely included spring wheat.

Wading Birds

We did not find any records of wading bird species using fields planted to spring wheat at any time of the year.

Other Waterbirds

In Saskatchewan (**Prairie Potholes**; BCR 11), spring wheat is a major component of the diet of Sandhill Cranes (a Conservation Priority Species) during spring and fall migrations (Munro 1950, Iverson et al. 1982, Iverson et al. 1987) as well as during the breeding season (Munro 1950). Whooping Cranes have also been documented using spring wheat fields during fall and

spring migrations through Saskatchewan (Howe 1989, Lewis 1995, Johns et al. 1997). Rates of Whooping Crane use were high (62% of foraging sites in spring, 57% of sites in fall) but generally matched habitat availability in a spring wheat dominated landscape (Johns et al. 1997).

Landbirds

The Red-winged Blackbird is the only landbird species on the WWL list that has been recorded using spring wheat fields, with all published records occurring during the breeding season (Table 5-1). In Manitoba (**Prairie Potholes;** BCR 11), Bird and Smith (1964) documented moderate to high consumption by Red-winged Blackbirds of both maturing and post-harvested spring wheat seed. In Ontario (BCR 12), Hintz and Dyer (1970) similarly observed a lot of spring wheat seed in the diets of Red-winged Blackbirds during mid-summer. Red-winged Blackbird nesting has also been documented in spring wheat fields in North Dakota (**Prairie Potholes;** BCR 11) (Koford et al. 2000).

RESOURCES

The foraging resources provided by winter and spring wheat appear to be of value to several granivorous and grazing waterbirds, primarily to geese and cranes during nonbreeding periods, and a number of species have also been documented nesting in wheat habitats (Tables 5-2 and 5-3). Here we review what is known about the abundance and availability of winter and spring wheat resources, and of their use by waterbirds in North America.

Foraging Resources

Food resources available to waterbirds foraging in wheat fields include wheat seed (either as waste grain or from mature seed heads on the wheat stalk), and the new leaves and shoots (or 'green forage') of growing wheat. Use of each of these foods differs between winter and spring wheat primarily because of differences in crop phenology relative to species' occurrence in an area. Weed seeds and terrestrial invertebrates are probable additional food resources, but their importance to foraging waterbirds in wheat fields is unknown.

Energy Value of Wheat

The caloric value of wheat seed ranks moderately high compared to other cereal grains and the green forage of wheat is also of nutritional value to grazing waterbirds. Tested with Canada Geese, the apparent metabolizable energy (AME) of wheat seed is 3.85 kcal/g, lower than corn (3.97 kcal/g) and sorghum (3.96 kcal/g), but higher than other cereals such as rice (3.53 kcal/g, assayed with Mallard) (Sugden 1971, Joyner et al. 1987) and soybeans (3.03 kcal/g, assayed with geese in Europe) (Storey and Allen 1982). Similarly, true metabolizable energy (TME) of wheat seed fed to Mallards was estimated at 3.38 kcal/g, a value that is lower than corn (3.67 kcal/g), but similar to rice (3.34 kcal/g), and higher than soybeans (2.65 kcal/g) (Reinecke et al. 1989).

The caloric value of green forage from wheat plants has been estimated at 2.54 kcal/g AME (Buchsbaum et al. 1986) and 2.40 kcal/g TME (Petrie et al. 1998). Digestibility of wheat forage (assayed with Canada Geese) has been estimated at only 55%, lower than soybeans (63%), rice (67%), sorghum (87%), and corn (88%) (Petrie et al. 1998). Although the caloric content and digestibility of wheat leaves/shoots are fairly low, wheat vegetation provides grazing species such as geese and swans with other nutritional components such as protein and fiber that are not as available in some other grains (McArdle 1967, McLandress and Raveling 1981). The protein

and fiber content of growing wheat vegetation (27% and 17% of dry weight, respectively) are high compared to corn (10% protein; 2% fiber) and sorghum (11% protein; 2% fiber) (Ensminger et al. 1990, Gates et al. 2001). For grazing species such as swans and geese, the relatively high protein content of wheat shoots makes this crop an important resource during the pre-breeding phase of the annual cycle when resources for egg-laying are essential (Alisauskas and Ankney 1992).

Foraging Resources in Winter Wheat

Winter wheat is planted over a wide geographic area from the Gulf of Mexico Coast to southern Canada and eastern Washington, and from the eastern U.S. to California (Acquaah 2005, OSU 2007). Winter wheat fields are planted in fall (between Sept-Nov) and harvested from spring to late summer (May-August, depending on latitude). Thus, collectively, winter wheat foraging resources are available to foraging birds nearly year-round (Table 5-2).

Seed. The seed of winter wheat is an important food resource for a select group of granivorous waterbirds (geese, cranes and blackbirds) during breeding and nonbreeding periods (Table 5-2). These species acquire wheat seed either from maturing seed heads of growing plants or from stubble fields after harvest (waste seed). Cranes have been observed foraging in standing winter wheat (Littlefield 1986), and blackbirds commonly forage in winter wheat fields during the breeding season (e.g., Flickinger and Pendleton 1994), potentially eating maturing seed. All other records, however, are of waterbirds foraging in harvested fields (see below). New waste seed becomes available to foraging waterbirds after the spring/summer harvest and is potentially available until late winter when growing wheat plants prevent access to waste seed on the ground. For North America, we found no estimates of the amount of waste seed typically found in fields planted to winter wheat. In Spain, however, Guzman et al. (1999) estimated that the average amount of waste seed was 156 ± 30 (SD) kg/ha in winter wheat stubble fields that averaged total yields of 1660 ± 193 kg seed/ha. The amount of waste grain left after harvest can be affected by factors diminishing wheat seed yields, such as goose grazing on green forage, excessive soil moisture, and soil type (Kahl and Samson 1984).

Researchers have documented six waterbird species foraging on the waste seed of winter wheat at various times of the annual cycle. These species include Snow Geese in spring (Alisauskas and Ankney 1992); Black-bellied Whistling-Ducks in winter (Kramer and Euliss 1986); Mallards during the breeding season (Swanson et al. 1985); Sandhill Cranes (a Conservation Priority Species) in spring (Lewis 1979, Rowland et al. 1992), fall (Hoffman 1976, Littlefield 1986, Rowland et al. 1992), and winter (Walker and Schemnitz 1987); Red-winged Blackbirds in spring, summer, fall (Meanley 1961, Mott et al. 1972, Crase and DeHaven 1978) and winter (Dolbeer et al. 1978, Robertson et al. 1978), and Yellow-headed Blackbirds during the breeding period (Knowlton and Telford 1947).

Studies indicate variation in the importance of wheat seed in the diets of waterbirds foraging in winter wheat fields. In some years, wheat grain accounted for the majority of the spring diet of Snow Geese migrating through North Dakota (Alisauskas and Ankney 1992), but for Black-bellied Whistling-Ducks wintering in northwestern Mexico, on average (among individuals) wheat grain generally comprised only 5-7% (by volume) and 8-13% (frequency of occurrence) of the diet (Kramer and Euliss 1986). Wheat seed accounted for only a minor portion (2%

frequency of occurrence and volume) of the diet of Sandhill Cranes during winter in New Mexico (Walker and Schemnitz 1987) and spring in Nebraska (Lewis 1979). The diet of Red-winged Blackbirds comprised little wheat seed during winter in Kentucky (Robertson et al. 1978) and Tennessee (Dolbeer et al. 1978), but use was higher for migrant blackbirds in spring (42% of diet) and fall (12%) in South Dakota (Mott et al. 1972).

During the breeding season, winter wheat seed regularly occurred in the diet of both laying and post-laying Mallards (Swanson et al. 1985) in North Dakota. Use by breeding Red-winged Blackbirds varied regionally, with winter wheat seed accounting on average for as much as 16-24% of the diet in South Dakota (Mott et al. 1972), but only 1-2% of the diet in studies from Maryland (Meanley 1961) and California (Crase and Dehaven 1978). In Utah, wheat seed accounted for a substantial portion of the agricultural seeds eaten by breeding Yellow-headed Blackbirds (Knowlton and Telford 1947).

Green Forage. The new leaves and shoots of winter wheat are a valuable foraging resource for grazing waterbirds such as geese and swans that rely on green forage for protein (Table 5-2). This resource is most prevalent from fall to early spring, and most observations come from this period. The waterbirds most commonly observed foraging on green winter wheat vegetation include Tundra Swans in winter (Tate and Tate 1966) and spring (Nagel 1965); Snow Geese in winter (Alisauskas 1988, Mason and Clark 1996); Canada Geese in fall (Kahl and Samson 1984, Eggeman et al. 1989, Gates et al. 2001), winter (White et al. 1982, Kahl and Samson 1984, Eggeman et al. 1989, Gates et al. 2001, Stabins et al. 2002) and spring (Kahl and Samson 1984, Gates et al. 2001); Cackling Geese in winter (Stabins et al. 2002); Greater White-fronted Geese in winter (Leslie and Chabreck 1984) and spring (Krapu et al. 1995); and Sandhill Cranes during spring (Lewis 1979). Dolbeer et al. (1978) also documented trace amounts of new winter wheat shoots in the diets of wintering Red-winged Blackbirds.

For many waterbird species, the new leaves and shoots of winter wheat play an important role in supplementing a diet primarily composed of corn. On average (among individuals), new wheat vegetation accounted for as much as 29% by volume of the diet of fall migrant Canada Geese in Illinois, but declined to 6% of the diet during winter, and accounted for only 2% of the diet during their spring migration through Wisconsin (Gates et al. 2001). Similarly, in Missouri, Canada Goose consumption of new wheat vegetation during the fall and winter varied from 0% to 26% (% diet by volume) among time periods and years (Eggeman et al. 1989). The green forage from winter wheat fields is thought to supplement a primarily corn-dominated (>50% by volume) diet for Canada and Cackling Geese wintering in California (Stabins et al. 2002), Snow Geese wintering in Iowa, Missouri and Kansas (Alisauskas et al. 1988), and Greater White-fronted Geese migrating through Nebraska in spring (Krapu et al. 1995). Similarly, wheat forage accounted for 7% (by occurrence) of the diet of Sandhill Cranes feeding mainly on corn during spring migration through Nebraska (Lewis 1979).

Foraging Resources in Spring Wheat

Spring wheat is planted primarily in the Northern Plains of the U.S. (Montana, North Dakota, South Dakota, Minnesota) and southern Canada (Acquaah 2005; OSU 2007). In contrast to winter wheat, spring wheat is planted in spring (April-May) and harvested in fall (August-Sept). As a result, fields planted to spring wheat provide a shorter period in which many foraging

resources are available to waterbirds, primarily during the breeding season and fall migration (Table 5-3).

Seed. The seed of spring wheat appears to be an important food resource to some breeding and fall-migrating granivorous waterbirds (Table 5-3). As in winter wheat fields, these species acquire wheat seed either from maturing seed heads of growing plants or from stubble fields after harvest (waste seed). Although Red-winged Blackbirds will remove seed from ripening heads (Bird and Smith 1964), all other observations are of birds foraging on waste grain (see below). New waste seed becomes available to foraging waterbirds after the fall harvest and is potentially available until growth of the next crop (often winter wheat planted in rotation; W. Hohman, pers. comm.) precludes access to seeds on the ground. Clark et al. (1986) estimated that the amount of waste seed left in spring wheat fields in Saskatchewan immediately after harvest was no greater than 2% of a maximum average yield of 3663 ± 234 (SE) kg/ha, thus approximately 73 kg/ha or less. As with winter wheat, the amount of waste seed left after harvest can be affected by factors diminishing wheat seed yields (see above; Kahl and Sampson 1984), and by increasing efficiency of harvest equipment.

Consumption of spring wheat seed has been documented for four waterbird species. Fall migrant Mallard and Northern Pintail in Saskatchewan forage heavily on wheat grain immediately after September swathing during the fall harvest (Clark et al. 1986). During the breeding season, spring wheat seed regularly occurred in the diet of both laying and post-laying Northern Pintails in North Dakota (Krapu 1974). In Saskatchewan, Munro (1950) found spring wheat seed in the stomachs of collected Sandhill Cranes from summer through fall, and spring wheat seed was a major component (47% frequency of occurrence, 98% by volume) of the diet of spring migrants studied by Iverson et al. (1982). Red-winged Blackbirds have been documented foraging heavily on spring wheat seed in summer and fall (Bird and Smith 1964, Hintz and Dyer 1970). In Manitoba, spring wheat accounted for an average of 37% (among individuals and months May - Oct) of the blackbird diet by volume, with heaviest wheat consumption (as much as 95% of the diet) in late spring (Bird and Smith 1964). In Ontario, Hintz and Dyer (1970) found that wheat seed was most common in blackbird diets (up to 76% average frequency of occurrence) from July to mid August as seed was maturing, but declined as soon as preferred waste corn became available.

Green Forage. We found no reference to waterbirds foraging on the green vegetation of spring wheat. This lack of information is not surprising because the mid-summer timing of new shoot production in spring wheat does not coincide with the migratory periods when grazing waterbird species are most likely to use the crop.

Foraging Resources in both Winter and Spring Wheat

Weed Seeds. Although weed seeds are known to be an important food source for many bird species in general (Martin et al. 1951), we did not find any explicit references quantifying weed resources within wheat fields, nor of waterbirds foraging on weed seeds in wheat fields.

Terrestrial Invertebrates. Terrestrial invertebrates are likely to be an important food resource for some of the waterbirds that forage in wheat fields during both the nonbreeding and breeding seasons. Little information exists, however, on the abundance or waterbird consumption of

invertebrate foods in wheat fields. Foster-Willfong (2003) noted that Long-billed Curlews (a Conservation Priority Species) probably reared their broods in wheat fields due to high densities of grasshopper and carabid beetles. An important resource for various shorebird species in general (Skagen and Oman 1996), earthworms are likely to be another important invertebrate food for shorebirds foraging in wheat fields. Several studies have documented earthworm abundance in wheat fields, finding higher numbers of worms in no-till than in tilled wheat fields (Edwards 1975, Edwards and Lofty 1975, Barnes and Ellis 1979). We did not find any studies, however, that evaluated waterbird consumption of earthworms or any other terrestrial invertebrate resource (native species or insect pests) in wheat fields.

Breeding Resources

Wheat fields in North America are used by a number of nesting waterbirds and may also provide brood-rearing/post-fledging habitat to these species, although the latter has been little documented.

Nesting Habitat

Eleven species of waterbirds have been confirmed nesting in fields planted to winter wheat (Table 5-2), and 14 species in spring wheat (Table 5-3). Eight duck species [Mallard, Northern Pintail, Northern Shoveler, Green-winged Teal, Blue-winged Teal, Gadwall, American Wigeon, Lesser Scaup] have been documented nesting in winter or spring wheat stubble in Manitoba and North Dakota (**Prairie Potholes;** BCR 11; Cowan 1982, Milonski 1958, Duebbert and Kantrud 1987, Lokemoen et al. 1990), and five of these species (Mallard, Northern Pintail, Northern Shoveler, Blue-winged Teal, Gadwall) have also been found nesting in winter wheat stubble fields to the south in Nebraska (**Central Mixed-Grass Prairie;** BCR 19; Evans and Wolfe 1967, Baxter and Wolfe 1972). In Saskatchewan, ducks may nest in wheat stubble from the previous year or in growing spring wheat following seeding (J. Devries, Ducks Unlimited Canada, pers. comm.). In North Dakota, Duebbert and Kantrud (1987) found that the combined nest densities of Mallard, Northern Pintail, Northern Shoveler, Blue-winged Teal, and Gadwall nesting in stubble varied from 6 to 8 nests/km^2 over two years. Average nest success rates for these same species varied from 29% in North Dakota to 42% in Manitoba (Cowan 1982, Duebbert and Kantrud 1987). Also in North Dakota wheat stubble, Lokemoen et al. (1990) documented low nest densities of 0.4 nests/km^2 for Blue-winged Teal, and 1.1 nests/km^2 for Mallard, but found that success rates in wheat were no different than other cover types. In Nebraska, ducks have been observed nesting in both wheat stubble and green wheat, but nests in green wheat tend to produce fewer young, presumably because the lack of ground litter makes it harder to conceal nests (Evans and Wolfe 1967, Baxter and Wolfe 1972). In California (BCR 32), Earl (1950) observed that 43% of Mallard nests in agricultural fields were in green wheat, and that birds seemed to prefer the cover provided by growing winter wheat over that provided by rice, barley or pasture. It is possible, however, that subsequent changes since the 1950s in the proportion of the California Central Valley landscape planted to each of these cereal crops has changed Mallard nesting patterns.

Four shorebird species (Mountain Plover, Upland Sandpiper, Long-billed Curlew, Marbled Godwit; all Conservation Priority Species) have been confirmed nesting in winter wheat fields in various locales including the **Prairie Potholes** (BCR 11), **Shortgrass Prairie** (BCR 18), **Central Mixed-Grass Prairie** (BCR 19), and Great Basin (BCR 9) (Higgins 1974, Shackford et

al. 1999, Pampush 1980), and three additional species (Killdeer, Willet, and Wilson's Phalarope, a Conservation Priority Species) have been observed nesting in small grain fields that most likely included spring wheat (Higgins 1975). In North Dakota (**Prairie Potholes**; BCR 11), Higgins (1975) found that, while shorebird nest densities were greatest in standing grain stubble, success rates were highest in fields with growing wheat. Out of 46 Mountain Plover nests found mostly in growing winter wheat fields across four states (Wyoming, BCR 10; Colorado, Kansas, Oklahoma, **Shortgrass Prairie** BCR 18), 33% were considered potentially successful (hatching not directly confirmed) as these were not lost to farm machinery, weather, or predators (Shackford 1996, Shackford et al. 1999). Finally, Red-winged Blackbird nests have been found in winter wheat fields in Nebraska (**Central Mixed-Grass Prairie**, BCR 19; Ducey and Miller 1980), and Tricolored Blackbird nests in winter wheat fields in California (BCR 32; Beedy et al. 1991).

Brood-rearing/Post-fledging Habitat

Waterfowl typically move their broods to nearby open water habitats shortly after hatching, and so wheat fields are unlikely to be important brood-rearing habitat for nesting ducks. Long-billed Curlews use wheat fields during brood rearing in Saskatchewan (Foster-Willfong 2003), and Shackford (1996) observed adult Mountain Plovers in various locales with broods seeking shade in winter wheat. It is likely that other shorebird species that nest in wheat may routinely use this crop for brood-rearing. None of the studies reporting Red-winged Blackbirds breeding in wheat mention the use of the crop as post-fledging habitat, but it also seems likely that young landbirds would continue to use wheat or adjacent field edges after fledging.

EFFECTS OF WHEAT PRODUCTION METHODS

There have been only a handful of studies examining the potential effects of winter or spring wheat farming practices on waterbirds. The following is a summary of these impacts, following the phenology of wheat production from soil and residue management to harvest methods. Table 5-4 provides a synopsis of the current state of knowledge on these topics.

Soil and Residue Management in Preparation for Planting

Wheat farmers use both conventional and no-till methods to prepare the soil for new plantings (Cowan 1982, Duebbert and Kantrud 1987, Flickinger and Pendleton 1994). Conventional practices potentially involve reducing previous crop residues by plowing or burning after harvest, smoothing soil shortly before planting by disking and harrowing, use of rotary hoe to dislodge germinating weeds, and planting seeds in prepared fields. Reduced or no-till methods typically entail leaving some to all residual wheat on fields (plowing minimal or none; no disking), slot-planting seeds directly into crop residues, and use of herbicides (potentially greater than with conventional methods) to combat weeds. In North America, the relative impacts of these methods on the abundance and availability of waterbird food resources in wheat fields have not been documented, and comparisons of species' use of conventional vs. no-till wheat fields are generally lacking. In other crops, such as corn, plowing has been shown to bury waste grain, and this has substantially affected waterbird use (Reed et al. 1977, Frederick and Klaas 1982, Baldassarre and Bolen 1984, Krapu et al. 1995, Giroux and Bergeron 1996, Davis 2003). In Europe, wintering swan use of plowed wheat fields in Denmark was exceptionally low compared to unplowed fields (Laubek 1995). Plowing, however, can also increase availability of soil invertebrates for species such as shorebirds and wading birds, as has been demonstrated in grain

fields in Europe (O'Connor and Shrubb 1986, Lack 1992). In Texas (**Shortgrass Prairie**; BCR 18), Flickinger and Pendleton (1994) observed greater diversity and abundances of breeding landbirds in reduced-till than in conventionally tilled winter wheat fields, although abundances of species from the WWL list (Red-winged Blackbird, Yellow-headed Blackbird) were no different among field types.

Because many of the tillage activities occur between spring and fall for winter wheat, and in early spring for spring wheat, tillage practices may greatly impact those waterbird species that nest in wheat fields. A number of studies have investigated the effects of field condition (presence/absence of crop residue) and farm machinery activities (disking, planting, herbicide applications) associated with conventional vs. no-till practices on the nest densities and success rates of waterbirds breeding in wheat fields. In North Dakota (**Prairie Potholes**; BCR 11), Higgins (1977) found that nest densities of seven duck species [Mallard, Northern Pintail (a Conservation Priority Species), Northern Shoveler, Blue-winged Teal, Green-winged Teal, Gadwall, Lesser Scaup] in tilled cropland (which included spring wheat) were only 1.7 nests/km^2, 12 times lower than in untilled upland habitats. For six duck species (Mallard, Northern Pintail, Northern Shoveler, Blue-winged Teal, Gadwall, Lesser Scaup) breeding in spring wheat fields in Manitoba (**Prairie Potholes**; BCR 11), Cowan (1982) documented higher nest success (42% overall) in no-till than in conventionally tilled fields (13% overall). In North Dakota, for virtually the same species group as examined in the studies of Cowan (1982) and Higgins (1977), Duebbert and Kantrud (1987) documented fairly high nest densities (8 nests/km^2) and fairly good nest success rates (26-29% among two years) in untilled winter wheat fields. These higher nest densities and success on no-till wheat fields were attributed to greater nesting cover and lower frequency of farm machinery passes (Macaulay 1981, Cowan 1982, Duebbert and Kantrud 1987).

Shackford et al. (1999) found that farm machinery passes accounted for 71% of the nest losses of Mountain Plover (a Conservation Priority Species) monitored in conventional winter wheat fields of Wyoming (BCR 10), Colorado, Oklahoma, and Kansas (**Shortgrass Prairie**; BCR 18). Similarly, in North Dakota (**Prairie Potholes**; BCR 11), 78% of nest failures in Killdeer, Willet, Upland Sandpiper, Marbled Godwit, and Wilson's Phalarope (the latter three species are Conservation Priority Species) were attributed to farm machinery passes in tilled wheat fields, and nest success was approximately three times lower in tilled cropland (wheat included) than in untilled upland (Higgins 1975). Although comparisons of nest success between conventional and no-till fields have not been conducted for spring wheat fields, nest loss is potentially much greater on conventional fields planted to spring wheat because tillage activities coincide with the peak of nest initiation for most species (Shackford et al. 1999, Podruzny et al. 2002).

Sowing Methods

Because winter wheat is sown in late summer/fall (Flickinger and Pendleton 1994), planting activities for winter wheat pose little risk to nesting birds. In contrast, planting operations for spring wheat are likely to impact waterbird nest success whether the crop is grown under a conventional or a no-till system (Shackford et al. 1999, Podruzny et al. 2002). Unless measures are taken to locate and avoid active nests, field passes by farm machinery used to plant spring wheat undoubtedly destroy the nests and eggs of any breeding birds that have not already been impacted by spring tillage conducted in preparation for planting.

Sowing of winter wheat in late summer and fall is especially timely for wintering swans and geese that rely on the new green forage of growing wheat throughout the winter and during spring pre-breeding periods (e.g., Tate and Tate 1966, White et al. 1982, Kahl and Samson 1984, Leslie and Chabreck 1984, Alisauskas 1988, Krapu et al. 1995, Gates et al. 2001, Stabins et al. 2002). However, the impact of grazing geese on wheat seed yields is a common economic concern (see below).

Pesticide Use and Organic Farming

The wheat industry has used various pesticides to control weeds and insect pests responsible for losses to wheat seed yield and revenue. Insecticides that have been used to combat invertebrate pests such as Greenbugs (*Schizaphis graminum*), Army Worms (*Pseudaletia unipuncta*), and Russian Wheat Aphids (*Diuraphis noxia*) include organophosphates (parathion) and organochlorines (dieldrin, heptachlor) (Graber et al. 1965, White et al. 1982, Blus et al. 1984). Herbicides used to control weeds on both conventional and reduced-till fields include pyrethroids, triazines (atrazine) and other compounds such as glyphosate, 2,4-D, metsulfuran, and metolachlor (Flickinger and Pendleton 1994; F. Koppatschek, ABG Inc., pers. comm.). Of these chemicals, the insecticides used are classified as moderately to highly toxic to birds, and the herbicides as only slightly to moderately toxic (EXTOXNET 2007). Although most of the organophosphates and organochlorines are "restricted-use" pesticides, they may still pose a current threat as they may be purchased and administered on fields by certified growers (EXTOXNET 2007).

For these pesticides used on wheat fields, we found little documentation of the direct (causing mortality) or indirect (e.g., diminishing food resources) impacts on waterbirds. Because pesticides are applied as early as late summer for winter wheat, and in spring for spring wheat, the WWL species that would be most at risk are those occurring in wheat fields during the breeding season. The most vulnerable life-stage, therefore, might be developing birds, which are both actively growing and least able to move to other areas. Detailed studies in cereal crops elsewhere in the world have implicated pesticide use in the reduced abundance of invertebrate prey, which in turn has caused reduced survival of newly hatched birds causing widespread population declines (Potts 1986, Campbell et al. 1997).

Insecticides that are still available for controlling wheat pests have been responsible for waterbird mortality in the past. In Texas (**Shortgrass Prairie**; BCR 18), White et al. (1982) documented lethal poisonings of 1480 Canada Geese, 20 Greater White-fronted Geese, 75 Mallards, and 25 Northern Pintails that had been foraging during winter on the green vegetation of winter wheat sprayed with organophosphate insecticides to combat a Greenbug infestation. Also in Texas, 200 wintering Canada Geese were found dead near winter wheat fields recently sprayed with parathion for control of Russian Wheat Aphids (Flickinger et al. 1991). In the Columbia Basin of Washington, use of heptachlor was indicted as the cause of the deaths and lowered reproductive success of Canada Geese foraging in wheat (Blus et al. 1984). In Illinois (**Eastern Tallgrass Prairie**; BCR 22), Graber et al. (1965) reported probable Red-winged Blackbird mortalities in hayfields due to applications of dieldrin in neighboring wheat fields. In contrast, herbicide use appears to be relatively innocuous. Laboratory experiments have found no impact of several herbicides on the hatchability of chicken eggs (Batt et al. 1980, Wayland et

al. 1987). In the field, Duebbert and Kantrud (1987) found no adverse effects of herbicide use on ducks nesting in winter wheat in North Dakota (**Prairie Potholes**; BCR 11).

An additional source of mortality associated with pesticide use can come from the physical application of chemicals (Best 1986). Since applications in wheat fields generally occur during the nesting season, farm machinery used to apply chemicals to fields may damage nests. Moreover, on conservation tillage fields, which potentially require more herbicide applications to control weeds (Best 1986), nest damage might be expected to be especially high. In one North Dakota (**Prairie Potholes**; BCR 11) study that directly assessed nest loss from pesticide applications in wheat, however, multiple ground sprayings in no-till winter wheat did not damage any waterfowl nests (Duebbert and Kantrud 1987). The relatively high duck nesting success in these fields suggested that any negative effect due to increased herbicide passes is more than compensated for by reduced tillage (also see above). Moreover, Flickinger and Pendleton (1994) found that conventional wheat fields in Texas (**Shortgrass Prairie**; BCR 18) actually incurred more herbicide applications than reduced-till wheat fields, contrary to popular belief regarding the greater herbicide use required for conservation tillage.

We did not find any literature evaluating effects of organic farming and biological control of crop pests on waterbirds using wheat fields *per se*. In other crop types, these methods have gained much recognition as being environmentally friendly and economically viable alternatives to widespread pesticide use (Rogers and Freemark 1991, Dix et al. 1995, Barbosa 1998), and they probably enhance biodiversity in agricultural landscapes (Hole et al. 2004, Bengtsson et al. 2005), although this needs further study.

Management for Pest Bird Species

During the growing season, damage to sprouting (in fall, winter) or jointing (in spring) winter wheat by nonbreeding geese and passerines (blackbirds, grackles, starlings) is a common concern among wheat farmers in North America (Pirnie 1954, Dolbeer et al. 1978, Knittle and Porter 1988, Mason and Clark 1996). Although grazing geese can severely impact subsequent wheat seed yields (Kahl and Samson 1984), damage from foraging icterids is relatively minimal (Dolbeer et al. 1978). Strategies to lessen goose damage to wheat include planting unattractive cover crops and lure crops (Owen 1990, Gauthier and Bedard 1991), using auditory and visual tactics (white plastic or mylar flagging) to haze birds from fields (Knittle and Porter 1988, Heinrich and Craven 1990, Mason et al. 1993, Mason and Clark 1994), increasing hunting pressure (Hunt and Bell 1973), and using non-lethal chemical repellents such as methyl anthranilate in tandem with visual cues that signal prior unpleasant feeding experiences (Mason 1988, Mason et al. 1989, Mason and Clark 1996). Aside from hunting, these tactics do not pose any significant mortality risk to geese or other non-target waterbirds using wheat fields. However, the frequent disturbances to foraging birds – both pest and non-pests - that are associated with many of these techniques may negatively impact species (including geese) by lowering pre-breeding body condition and the subsequent reproductive success of individuals (Bechet et al. 2004).

Harvest Methods

Throughout North America, winter wheat is harvested anywhere from late spring to late summer, and spring wheat in late summer/early fall. Since foraging waterbirds can more easily access

mature wheat seed off the ground in stubble post-harvest than from mature seed heads on plant stems prior to harvest (Littlefield 1986), the availability of wheat seed for breeding and fall-migrating waterbirds in any locale will depend on the timing of harvest. In Saskatchewan (**Prairie Potholes**; BCR 11), Clark et al. (1986) found that fall migrant Mallard and Northern Pintail foraged most heavily on spring wheat grain during a brief period immediately after swathing (when wheat plants have been cut and laid down) but before the grain was collected from fields, as this was the period of both maximum wheat seed abundance and availability.

In general, the risk to nesting birds of wheat harvest operations depends on latitude. This risk is minimal at southern latitudes, as winter wheat is generally harvested before the initiation of waterbird nests, and waterfowl tend to then nest in the stubble of winter wheat. At northern latitudes, both winter wheat and spring wheat are harvested in late summer/early fall, and thus there is some potential for the destruction of any late active nests (or incubating females) in growing wheat at the time of harvest. Use of flushing bars as implemented during hay-cutting operations may minimize the mortality of eggs and incubating females in wheat fields.

Crop Rotation, Fallow Land

To maintain soil fertility and control crop pests and disease, winter and spring wheat are often grown in rotation with other cereal grain crops such as corn, oats, barley and sorghum, or cattle fodder crops such as alfalfa and clover (Evans and Wolfe 1967, Flickinger and Pendleton 1994, Krapu et al. 2004, W. Hohman, pers. comm.). Winter wheat is generally not planted again to winter wheat, but instead remains fallow until the next spring growing season when spring wheat and other crops may be planted. Many of the same waterbirds that use wheat fields may also benefit from fallow land or from the interim habitat provided by these other crops (see CORN, SORGHUM chapters). However, for waterfowl that initiate nests in winter wheat stubble fields in the spring, which are then immediately planted to a cover crop such as alfalfa instead of remaining fallow through one growing season ('summerfallow'), planting and/or late summer/fall haying-cutting of the rotation crop can be a major source of egg or hen mortality (Evans and Wolfe 1967, Podruzny et al. 2002).

EFFECTS OF OTHER MANAGEMENT ACTIVITIES

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

Management of Field Margins

We found only one reference in the literature to the use or importance of wheat field margins to waterbirds. Rowland et al. (1992) suggested that migrant Sandhill Cranes (a Conservation Priority Species) used smaller fields only if field margin vegetation was relatively open, enabling birds to watch for predators. Understanding the use and importance of wheat field margins to waterbirds would be an important first step towards assessing the need to develop organic management practices (e.g., biological pest control) along wheat field edges that benefit waterbirds. This has been a topic of considerable focus for corn habitats (Beecher et al. 2002).

Hunting Activity

Recreational waterfowl and Sandhill Crane hunting is common in North American wheat fields (Johnson 1976, Mason and Clark 1996), and may be practiced to control or compensate (through

hunting revenues) for crop damage (Hunt and Bell 1973). During the 2004-05 hunting season, over 33,800 Sandhill Cranes were harvested in North America (Sharp et al. 2005). For the mid-continent population (the largest of all North American crane populations), analyses of the long-term (1982-2004) harvest and population trends indicate that although harvest rates have increased, so far there has been no clear change (negative or positive) in the abundance of cranes over the time period (Sharp et al. 2005). The point at which harvest may negatively impact crane population growth is unclear, but subsistence harvest levels are a topic of focus for harvest-monitoring in the U.S. and Canada (Sharp et al. 2005). In addition to incurring mortality, other negative effects of recreational hunting in wheat fields potentially include repeated disturbances to foraging birds, which could adversely affect body condition and subsequent reproductive success, and the risk that hunting pressure could hasten migratory movements before conditions are optimal (Johnson 1976, Bechet et al. 2004).

EFFECTS OF LANDSCAPE FEATURES

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

Field Size

We found only one reference examining the influence of wheat field size on waterbird use. Rowland et al. (1992) suggested that if fields were not adjacent to a roost site, migrant Sandhill Cranes (a Conservation Priority Species) preferred fields larger than 4 ha in size, and smaller fields were only used if field margin vegetation was relatively open, enabling birds to watch for predators.

Landscape Context

Studies in wetland landscape ecology (Naugle et al. 1999, Riffell et al. 2003) suggest that waterbird use of wheat fields could be affected 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. Understanding how these factors influence waterbird use of wheat fields could affect a number of management decisions. We found only one study that addressed this issue specifically for waterbirds in wheat fields. In Indiana (**Eastern Tallgrass Prairie**; BCR 22), Lovvorn and Kirkpatrick (1982a) found that spring and fall migrant Sandhill Cranes were more likely to use wheat fields near roost sites. Clearly with a growing appreciation of the potential importance of landscape features, additional research in this area is warranted.

SUMMARY AND SYNTHESIS

The following is a summary of the major themes relating to wheat field use by waterbirds, resources provided by wheat fields, positive and negative effects of wheat 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 wheat agriculture.

Waterbird Use

Available information indicates that the habitat and resources provided by North American wheat fields are important to a fairly limited group of waterbirds (Table 5-1). This crop,

however, can be highly valuable to swans, geese, and cranes during the nonbreeding season (e.g., Iverson et al. 1982, Alisauskas et al. 1988, Alisauskas and Ankney 1992, Krapu et al. 1995, Gates et al. 2001, Stabins et al. 2002), and - as long as nests are not destroyed by field machinery - to breeding dabbling ducks in summer (e.g., Krapu 1974, Swanson et al. 1985, Duebbert and Kantrud 1987). The greatest waterbird abundances have been observed in winter wheat fields during nonbreeding periods, with up to thousands of swans, geese, and cranes seen foraging in fields at a time (Harvey et al. 1988, Petrie et al. 2002). Various other waterbird species use wheat fields throughout the year, but in low numbers. A few shorebirds use wheat fields for nesting or brood-rearing (Higgins 1974, 1975; Pampush 1980, Shackford 1996, Shackford et al. 1999), and a few generalist landbird species (blackbirds) use wheat fields in winter and spring (Mott et al. 1972, Dolbeer et al. 1978) and during the breeding season (Knowlton and Telford 1947, Meanley 1961, Flickinger and Pendleton 1994, Crase and DeHaven 1978). While use of winter wheat fields occurs year-round, use of spring wheat occurs primarily from spring to early fall (e.g., Bird and Smith 1964, Higgins 1977, Clark et al. 1986, Lokemoen et al. 1990, Johns et al. 1997, Koford et al. 2000; Table 5-1).

WWL Species and Bird Conservation Regions

Of the 216 species identified for the Waterbirds on Working Lands project, 26 species have been observed in winter wheat fields in North America, of which 10 are species of conservation concern (Table 5-1). Fourteen species use winter wheat during winter or migration, and 15 species have been documented foraging and/or nesting in winter wheat during the breeding season. In spring wheat fields, 16 waterbird species have been documented, with most use (15 species) occurring during the breeding season (Table 5-1). On average, use of wheat fields has been documented for only 7% (range: 2% in **Prairie Hardwood Transition** BCR 23 and **Central Hardwoods** BCR 24 to 17% in **Prairie Potholes** BCR 11) 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 wheat fields in these regions is unknown (see **Knowledge Gaps and Research Needs** below). Given the relative distribution of spring wheat and focal species, it is not surprising that records of waterbird use of spring wheat come primarily from the **Prairie Potholes** and other northern regions during migration or breeding, with confirmed use by 16 species (Table 5-1).

Wheat Resources

The foraging resources provided to waterbirds by fields planted to winter or spring wheat include wheat seed (e.g., Mott et al. 1972, Hoffman 1976, Krapu 1974, Dolbeer et al. 1978, Iverson et al. 1982, Lovvorn and Kirkpatrick 1982a, b; Kahl and Samson 1984, Swanson et al. 1985, Alisauskas and Ankney 1992, Davis 2003), and the new leaves/shoots or 'green forage' of growing wheat (e.g., Gates 1965, Tate and Tate 1966, Kahl and Samson 1984, Alisauskas et al. 1988, Krapu et al. 1995, Mason and Clark 1996, Stabins et al. 2002). Caloric value for wheat seed ranks moderately high compared to other cereal grains (Sugden 1971, Joyner et al. 1987, Reinecke et al. 1989). The green forage of wheat, although fairly low in caloric value (Buchsbaum et al. 1986, Petrie et al. 1998), is high in protein and fiber (McArdle 1967, McLandress and Raveling 1981) and therefore of great importance to grazing swans and geese in preparation for egg-laying (Alisauskas and Ankney 1992). For the most part, the abundance and importance of weed seeds and terrestrial invertebrate resources in wheat fields have not been evaluated. Geese, dabbling ducks, cranes, and blackbirds forage on maturing or waste wheat

seed available in fields shortly before and after harvest, and swans and geese additionally graze on the green forage of winter wheat during nonbreeding periods. It is assumed that shorebirds forage on invertebrates when in wheat fields, but we are only aware of one study that illustrates the potential for this activity (Foster-Willfong 2003). For some ground- or shrub-nesting species such as dabbling ducks, shorebirds, and Red-winged Blackbird, wheat fields appear to provide potentially valuable nesting habitat (e.g., Higgins 1974, 1975; Ducey and Miller 1980, Cowan 1982, Duebbert and Kantrud 1987, Lokemoen et al. 1990, Shackford et al. 1999). Mountain Plover and Long-billed Curlew (Conservation Priority Species) have been documented caring for broods in wheat habitats (Shackford et al. 1999, Foster-Willfong 2003), and it is likely that other temperate-breeding shorebirds similarly use the habitat throughout the breeding cycle.

Practices Benefiting Waterbirds

Some methods to produce wheat are clearly more beneficial to waterbirds that use wheat fields than others. Waterbirds generally benefit from conservation or 'no-till' practices, and when harvest and planting are timed to provide waste grain or new shoots, respectively, during periods of peak migratory waterbird movements through a region (Table 5-4).

No-till practices are associated with higher nest densities and lower nest failure rates, most likely due to greater nest concealment and fewer farm machinery passes compared to tilled lands (Higgins 1975, 1977; Cowan 1982, Duebbert and Kantrud 1987, Shackford et al. 1999). In many locales, winter wheat fields are harvested and waste wheat becomes available just prior to the arrival of fall migrant waterbirds, and growing winter wheat fields provide valuable shoots and leaves at an opportune time for wintering geese and swans preparing for the proceeding breeding season.

Practices Negatively Affecting Waterbirds

Several wheat production practices potentially impact waterbirds in negative ways, representing challenges to improving the wildlife conservation value of wheat fields. These negative effects may have far-reaching implications for some waterbird species currently dependant on the agricultural resources of wheat fields for survival and reproduction. Practices that can be harmful include conventional tillage, sowing when waterbird nests are active, continued use of some pesticides, and frequent disturbances associated with hazing and/or hunting of bird pest species (Table 5-4).

Due to disking and harrowing activities, there is relatively little vegetation in which birds can conceal their nests in conventionally tilled wheat fields, and this is thought to reduce nest success (Macaulay 1981, Cowan 1982, Duebbert and Kantrud 1987). Moreover, in both winter and spring wheat fields, farm machinery passes for tillage operations coincide with nest initiation and incubation in wheat-nesting waterbirds, and associated low nest success and high risk of mortality have been reported for some species (e.g., Higgins 1975, 1977; Cowan 1982, Duebbert and Kantrud 1987, Shackford et al. 1999). Because spring wheat is planted in tandem with nest initiation, spring seeding operations are an additional threat to waterbirds nesting in spring wheat (Shackford et al. 1999, Podruzny et al. 2002). For waterbirds occurring in wheat fields during the breeding season, application of "restricted-use" insecticides present considerable mortality risk to waterbirds, either from direct exposure (e.g., Graber et al. 1965, White et al. 1982, Flickinger et al. 1991), or potentially from nest destruction by farm machinery used to apply

chemicals to fields. Finally, hazing (to reduce crop damage) and hunting of goose flocks may result in excessive disturbances to all birds foraging in wheat fields, hastening migratory movements before conditions are optimal, or adversely affecting foraging efficiency, fat storage rates and ultimately the reproductive success of individuals (e.g., Bechet et al. 2004).

Knowledge Gaps and Research Needs

Although the current state of knowledge for waterbird use of wheat fields and effects of wheat production practices is fairly good, there are a number of information gaps that need to be addressed in order to improve wheat field management for waterbirds.

Waterbird Use

Use of wheat fields by waterbirds has been better documented for some focal BCRs (e.g., **Prairie Potholes** BCR 11 and **Central Mixed-Grass Prairie** BCR 19) than others (e.g., **Prairie Hardwood Transition** BCR 23 and **Central Hardwoods** BCR 24; Table 5-1). Some species listed in this documented have only been observed using wheat fields in areas outside the focal BCRs of the WWL project (e.g., Tundra Swan, Ross' Goose, Cackling Goose, American Woodcock, Common Yellowthroat). Some of these species may not have been observed in wheat fields in the focal BCRs simply because they are rare or only present briefly during migrations in those areas (e.g., Tundra Swan). For other species that regularly occur in a particular region (e.g., Ross's Goose in **Shortgrass Prairie**; American Woodcock in **Prairie Potholes**), the lack of documentation in a given BCR may just represent a lack of appropriate research or documentation. More generally, the paucity of studies that have attempted to document the full range of species that use wheat fields in many areas might represent a shortcoming in our understanding of the value of this habitat. 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 fields containing focal crops such as wheat.

Resources

There has been no quantification of the potential value to waterbirds of the terrestrial invertebrates (pest insects, earthworms, etc.) found in wheat fields, or of their consumption by waterbirds, particularly shorebirds and passerines on the WWL list. Knowledge of these resources and their use would further our understanding of the importance of wheat field resources for waterbirds. Moreover, further work in this area could contribute to advancing the techniques of biological control and lessen dependence on pesticide use. More detailed documentation of the reproductive success of ducks and shorebirds that nest in wheat - particularly Conservation Priority Species such as Northern Pintail, Mountain Plover, Upland Sandpiper, Long-billed Curlew, and Marbled Godwit - would further our understanding of the overall value of wheat to nesting waterbirds. How success relates to crop residue levels in fields of varying tillage practices would be particularly helpful.

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

There are a number of gaps in current knowledge regarding the effects of crop production methods, other activities, and landscape features of wheat fields on waterbirds (Table 5-4). Even for those practices that have been studied, research has focused on only a limited number of

species. Influence of tillage methods on the abundance and availability of waterbird food resources throughout the year (e.g., plowing influencing access to waste grain, crop residues influencing invertebrate productivity) has not been evaluated for agricultural land planted to wheat. Where waterbirds nest in spring wheat, 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. If nest destruction cannot be prevented, the development of methods that discourage birds from nesting in these fields might reduce the crop's potential to act as sink habitat that contributes to population declines. Effects of pesticides on waterbirds foraging or nesting in wheat have been little studied, and the indirect impacts of insecticides on wheat-related food resources (invertebrates, forbs, weed seeds) have yet to be documented. Potential benefits to waterbirds of alternatives to chemical use, such as organic farming and biological pest control have not been evaluated for wheat fields or margins. Studies that quantify the economic costs to farmers of crop damage from foraging waterbirds in tandem with the negative impacts of pest control measures (such as hazing and hunting) on both pest and non-pest (e.g., Sandhill Cranes) waterbird species should enable one to identify when, and if, compensation to farmers from conservation organizations is appropriate. Finally, understanding the importance of field size and landscape context to waterbirds using wheat fields should enable more strategic landscape approaches to conservation planning. Addressing these questions for Conservation Priority Species should certainly take precedence.

Finally, although some research has attempted to compare the impacts of various wheat production alternatives (e.g., no-till vs. tillage, timing of sowing) on the nest success or adult mortality of waterbirds (mostly waterfowl), how these parameters together influence the stability of populations has not been assessed. Quantifying how these various parameters contribute to birth and death rates and influence the population dynamics of waterbird species, particularly species of conservation priority, will be a crucial step towards devising crop production methods that are not detrimental to waterbirds using wheat fields.

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Table 5-1. Waterbird species reported in wheat fields in North America and in focal BCRs during winter, migration, and breeding seasons. Records from Canadian portion of the Prairie Potholes (BCR 11) are included. 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. There is no column for the Winter period under Spring Wheat because this crop is grown farther north than the winter distributions of most waterbirds. For both winter and spring wheat under Migration, "S" refers to spring migration, and "F" refers to fall migration. Most documentation of species occurrence based on single-species studies. Apparent absences may reflect incomplete information in the published literature for a given season or region.

			North America						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
GROUP Common name	On WWL Species List	Species of Conservation Priority	Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WATERFOWL									
Tundra Swan	X		X	S/F					
Snow Goose	X		X	S/F					
Ross's Goose	X		X						
Greater White-fronted Goose	X		X	S					
Canada Goose	X		X	S/F					
Cackling Goose			X	S					
Black-bellied Whistling-Duck	X		X						
Mallard	X				X	X	F	X	X
Northern Pintail	X	X	X	F		X	F	X	X
Northern Shoveler	X					X			X
Green-winged Teal	X								X
Blue-winged Teal	X					X			X
American Wigeon	X								X
Gadwall	X					X			X
Lesser Scaup	X								X (rare)
SHOREBIRDS									
Killdeer	X				X				X
Mountain Plover	X	X			X	X			
Upland Sandpiper	X	X				X			X
Long-billed Curlew	X	X				X			
Marbled Godwit	X	X				X			X
Willet	X								X
Wilson's Phalarope	X	X							X

American Woodcock	X	X	X							

Table 5-1. Continued.

			North America							
			Winter Wheat					Spring Wheat		
					Breeding				Breeding	
GROUP Common name	On WWL Species List	Species of Conservation Priority	Winter	Migration	Foraging	Nesting		Migration	Foraging	Nesting
WADING BIRDS										
White-faced Ibis	X				X					
OTHER WATERBIRDS										
Sandhill Crane	X	X	X	S/F	X			S/F	X	
Whooping Crane	X	X		S/F				S/F		
WWL LANDBIRDS										
Common Yellowthroat	X		X							
Red-winged Blackbird	X		X		X	X		S/F	X	X
Yellow-headed Blackbird	X				X					
Tricolored Blackbird	X	X				X				
Rusty Blackbird	X	X	X							

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 11 Regional List	Prairie Potholes (BCR 11)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WATERFOWL									
Tundra Swan	X								
Snow Goose	X			S					
Ross's Goose	X								
Greater White-fronted Goose	X								
Canada Goose	X	X							
Cackling Goose									
Black-bellied Whistling-Duck	X								
Mallard	X	X			X	X	F		X
Northern Pintail	X	X				X	F	X	X
Northern Shoveler	X	X				X			X
Green-winged Teal	X	X							X
Blue-winged Teal	X	X				X			X
American Wigeon	X	X							X
Gadwall	X	X				X			X
Lesser Scaup	X	X							X (rare)
SHOREBIRDS									
Killdeer	X	X							X
Mountain Plover	X	X							
Upland Sandpiper	X	X							X
Long-billed Curlew	X	X			X				
Marbled Godwit	X	X				X			X
Willet	X	X							X
Wilson's Phalarope	X	X							X
American Woodcock	X	X							

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 11 Regional List	Prairie Potholes (BCR 11)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WADING BIRDS									
White-faced Ibis	X								
OTHER WATERBIRDS									
Sandhill Crane	X	X					S		
Whooping Crane	X						S/F		
WWL LANDBIRDS									
Common Yellowthroat	X	X							
Red-winged Blackbird	X	X					S/F	X	X
Yellow-headed Blackbird	X	X							
Tricolored Blackbird	X								
Rusty Blackbird	X	X							

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 23 Regional List	Prairie Hardwood Transition (BCR 23)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WATERFOWL									
Tundra Swan	X	X							
Snow Goose	X								
Ross's Goose	X								
Greater White-fronted Goose	X								
Canada Goose	X	X	X	S/F					
Cackling Goose									
Black-bellied Whistling-Duck	X								
Mallard	X	X							
Northern Pintail	X								
Northern Shoveler	X	X							
Green-winged Teal	X								
Blue-winged Teal	X	X							
American Wigeon	X	X							
Gadwall	X	X							
SHOREBIRDS									
Killdeer	X	X							
Mountain Plover	X								
Upland Sandpiper	X	X							
Long-billed Curlew	X								
Marbled Godwit	X								
Willet	X								
Wilson's Phalarope	X	X							
American Woodcock	X	X							

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 23 Regional List	Prairie Hardwood Transition (BCR 23)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WADING BIRDS									
White-faced Ibis	X								
OTHER WATERBIRDS									
Sandhill Crane	X	X		S/F	X				
Whooping Crane	X								
WWL LANDBIRDS									
Common Yellowthroat	X	X							
Yellow-headed Blackbird	X	X							
Red-winged Blackbird	X	X							
Tricolored Blackbird	X								
Rusty Blackbird	X								

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 22 Regional List	Eastern Tallgrass Prairie (BCR 22)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WATERFOWL									
Tundra Swan	X	X							
Snow Goose	X	X	X	S/F					
Ross's Goose	X								
Greater White-fronted Goose	X								
Canada Goose	X	X	X	S/F					
Cackling Goose									
Black-bellied Whistling-Duck	X								
Mallard	X	X							
Northern Pintail	X								
Northern Shoveler	X	X							
Green-winged Teal	X	X							
Blue-winged Teal	X	X							
American Wigeon	X	X							
Gadwall	X	X							
SHOREBIRDS									
Killdeer	X	X			X				
Mountain Plover	X								
Upland Sandpiper	X	X							
Long-billed Curlew	X								
Marbled Godwit	X	X							
Willet	X								
Wilson's Phalarope	X	X							
American Woodcock	X	X							

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 22 Regional List	Eastern Tallgrass Prairie (BCR 22)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WADING BIRDS									
White-faced Ibis	X								
OTHER WATERBIRDS									
Sandhill Crane	X			S/F					
Whooping Crane	X								
WWL LANDBIRDS									
Common Yellowthroat	X	X							
Red-winged Blackbird	X	X				X			
Yellow-headed Blackbird	X								
Tricolored Blackbird	X								
Rusty Blackbird	X	X							

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 18 Regional List	Shortgrass Prairie (BCR 18)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WATERFOWL									
Tundra Swan	X								
Snow Goose	X	X							
Ross's Goose	X	X							
Greater White-fronted Goose	X								
Canada Goose	X	X	X						
Cackling Goose									
Black-bellied Whistling-Duck	X								
Mallard	X	X							
Northern Pintail	X	X							
Northern Shoveler	X	X							
Green-winged Teal	X	X							
Blue-winged Teal	X	X							
American Wigeon	X	X							
Gadwall	X	X							
Lesser Scaup	X	X							
SHOREBIRDS									
Killdeer	X	X							
Mountain Plover	X	X			X	X			
Upland Sandpiper	X	X							
Long-billed Curlew	X	X							
Marbled Godwit	X								
Willet	X	X							
Wilson's Phalarope	X	X							
American Woodcock	X								

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 18 Regional List	Shortgrass Prairie (BCR 18)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WADING BIRDS									
White-faced Ibis	X	X							
OTHER WATERBIRDS									
Sandhill Crane	X	X	X						
Whooping Crane	X								
WWL LANDBIRDS									
Common Yellowthroat	X	X							
Red-winged Blackbird	X	X			X				
Yellow-headed Blackbird	X	X			X				
Tricolored Blackbird	X								
Rusty Blackbird	X								

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 19 Regional List	Central Mixed-Grass Prairie (BCR 19)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WATERFOWL									
Tundra Swan	X								
Snow Goose	X	X							
Ross's Goose	X	X							
Greater White-fronted Goose	X	X		S					
Canada Goose	X	X							
Cackling Goose									
Black-bellied Whistling-Duck	X	X							
Mallard	X	X				X			
Northern Pintail	X	X				X			
Northern Shoveler	X	X				X			
Green-winged Teal	X	X							
Blue-winged Teal	X	X				X			
American Wigeon	X	X							
Gadwall	X	X				X			
Lesser Scaup	X	X							
SHOREBIRDS									
Killdeer	X	X							
Mountain Plover	X	X			X	X			
Upland Sandpiper	X	X				X			
Long-billed Curlew	X	X							
Marbled Godwit	X								

Willet	X	X								
Wilson's Phalarope	X	X								
American Woodcock	X	X								

Table 5-1. Continued.

			Central Mixed-Grass Prairie (BCR 19)							
			Winter Wheat				Spring Wheat			
					Breeding				Breeding	
GROUP Common name	On WWL Species List	On BCR 19 Regional List	Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting	
WADING BIRDS										
White-faced Ibis	X	X								
OTHER WATERBIRDS										
Sandhill Crane	X	X		S						
Whooping Crane	X			S/F						
WWL LANDBIRDS										
Common Yellowthroat	X	X								
Red-winged Blackbird	X	X				X				
Yellow-headed Blackbird	X	X								
Tricolored Blackbird	X									
Rusty Blackbird	X	X								

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 24 Regional List	Central Hardwoods (BCR 24)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WATERFOWL									
Tundra Swan	X								
Snow Goose	X	X							
Ross's Goose	X								
Greater White-fronted Goose	X								
Canada Goose	X	X		F					
Cackling Goose									
Black-bellied Whistling-Duck	X								
Mallard	X	X							
Northern Pintail	X	X							
Northern Shoveler	X	X							
Green-winged Teal	X	X							
Blue-winged Teal	X	X							
American Wigeon	X	X							
Gadwall	X	X							
SHOREBIRDS									
Killdeer	X	X							
Mountain Plover	X								
Upland Sandpiper	X	X							
Long-billed Curlew	X	X							
Marbled Godwit	X								

Willet	X		
Wilson's Phalarope	X		
American Woodcock	X	X	

Table 5-1. Continued.

GROUP Common name	On WWL Species List	On BCR 24 Regional List	Central Hardwoods (BCR 24)						
			Winter Wheat				Spring Wheat		
					Breeding			Breeding	
			Winter	Migration	Foraging	Nesting	Migration	Foraging	Nesting
WADING BIRDS									
White-faced Ibis	X								
OTHER WATERBIRDS									
Sandhill Crane	X								
Whooping Crane	X								
WWL LANDBIRDS									
Common Yellowthroat	X	X							
Red-winged Blackbird	X	X	X						
Yellow-headed Blackbird	X								
Tricolored Blackbird	X								
Rusty Blackbird	X	X	X						

Table 5-2. Summary of winter wheat resources available to waterbirds during the different phases of wheat production in North America. Grey shaded boxes indicate not applicable, or resource not available during the time period.

RESOURCES	**SOWING** (Fall)	**PRE-HARVEST** (Growing Crop, Winter, Spring)	**HARVEST** (Spring, Summer)	**POST-HARVEST** (Summer to Spring of Following Year)	**FALLOW LAND**
FORAGING RESOURCES o Wheat Seed	waste wheat seed from previous crop – fall migrating cranes and blackbirds [1-4]	waste wheat seed from previous crop, and mature wheat seed heads from current crop – wintering waterfowl, cranes, blackbirds [5-7]	swathed wheat seed – spring migrant waterfowl, cranes, blackbirds [3,4,8-11]	waste wheat seed - breeding dabbling ducks, cranes, blackbirds[1,4,12-15]	
o Green Wheat Leaves/Shoots	fall migrant geese [8,16-17]	wintering and spring migrant swans, geese, blackbirds [6,8,16-23]	spring migrant swans, geese, cranes [8,16,24,25]		
o Weed Seeds					
o Terrestrial Invertebrates					
BREEDING RESOURCES o Nesting Habitat		dabbling ducks, shorebirds, blackbirds confirmed nesting in growing wheat fields [26-33]	dabbling ducks, shorebirds, blackbirds confirmed nesting in growing wheat fields [26-33]	dabbling ducks, shorebirds confirmed nesting in wheat stubble during spring of following year [26,30,32-35]	
o Brood-rearing/Post-fledging Habitat			Mountain Plover observed with broods seeking shade in fields [33]	Mountain Plover observed with broods seeking shade in fields [33]	

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Table 5-3. Summary of spring wheat resources available to waterbirds during the different phases of wheat production in North America. Grey shaded boxes indicate not applicable, or resource not available during the time period.

RESOURCES	**SOWING** (Spring)	**PRE-HARVEST** (Growing Crop, Summer)	**HARVEST** (Late Summer)	**POST-HARVEST** (Late Summer – Early Fall)	**FALLOW LAND**
FORAGING RESOURCES o Wheat Seed	migrant cranes [1-3]	mature wheat seed heads from growing crop – breeding waterfowl, cranes, blackbirds [1-4]	swathed and waste wheat seed – late summer migrant dabbling ducks, cranes, blackbirds [1-6]	waste wheat seed – migrant dabbling ducks, cranes [1-3,7]	
o Green Wheat Leaves/Shoots					
o Weed Seeds					
o Terrestrial Invertebrates					
BREEDING RESOURCES o Nesting Habitat	dabbling ducks, shorebirds, landbirds documented nesting in growing wheat fields [8-15]	dabbling ducks, shorebirds, landbirds documented nesting in growing wheat fields [8-15]	dabbling ducks, shorebirds, landbirds documented nesting in growing wheat fields [8-15]	dabbling ducks documented nesting in wheat stubble [8,11,14-15]	
o Brood-rearing/Post-fledging Habitat					

Table 5-3. Continued.

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Table 5-4. Summary of documented impacts of winter and spring wheat production methods and landscape features on waterbird groups using wheat fields in North America. Open boxes without text indicate potential areas for further research.

	SOIL AND RESIDUE MANAGMENT Conventional Tillage vs. No Till	**SOWING**	**PESTICIDE USE, ORGANIC FARMING**	**HARVEST METHODS**	**FIELD SIZE**
ALL WATERBIRDS	effects of conventional vs. no-till practices on wheat food resources undocumented; nest densities and nest success higher on no-till winter and spring wheat fields due to greater cover and lower frequency of farm machinery passes [1-4]	farm machinery to plant spring wheat likely destroys nests/eggs of early breeders [6,7]	mortalities from organochlorines and organophosphates documented for some species [8-10] Potential damage to nests from applications	some potential for the destruction of late active nests (or incubating females) in growing wheat at the time of harvest, flushing bars on harvesters may help alleviate loss; Wheat seed most abundant and accessible after harvest, so timing of harvest in relation to timing of granivorous waterbird use important [12,13]	some species may prefer bigger fields [13]
Waterbird Species Richness	species richness of waterbird community during all phases of annual cycle relatively unstudied; one study documented greater diversity of landbird species (non WWL) in reduced-till than conventional winter wheat fields during breeding season [5]				
Waterbird Abundance	no reported difference in abundances between conventional and no-till winter wheat fields throughout year, but documentation available for only a few landbird species [5]				

Table 5-4. Continued.

	SOIL AND RESIDUE MANAGMENT Conventional Tillage vs. No Till	**SOWING**	**PESTICIDE USE, ORGANIC FARMING**	**HARVEST METHODS**	**FIELD SIZE**
WATERFOWL	dabbling duck nest densities and nesting success higher on no-till winter and spring wheat fields due to increase in cover and lower frequency of farm machinery passes [1-3]	farm machinery to plant spring wheat likely destroys nests/eggs of early breeders [6]	potential damage to nests from applications	some potential for the destruction of late active nests (or incubating females) in growing wheat at the time of harvest, flushing bars on harvesters may help alleviate loss; wheat seed most abundant and accessible after harvest, so timing of harvest in relation to timing of granivorous waterbird use important [12,13]	
o **Swans**				wheat seed most abundant and accessible after harvest, so timing of harvest in relation to timing of granivorous waterbird use important [12,13]	
o **Geese**			documented mortalities from organophosphates [8-10]		
o **Dabbling Ducks**	higher nest densities and nest success on no-till fields [1-3]		documented mortalities from organophosphate use [8] Potential damage to nests from applications	some potential for the destruction of late active nests (or incubating females) in growing wheat at the time of harvest, flushing bars on harvesters may help alleviate loss; Wheat seed most abundant and accessible after harvest, so timing of harvest in relation to timing of granivorous waterbird use important [12,13]	

Table 5-4. Continued.

	SOIL AND RESIDUE MANAGMENT Conventional Tillage vs. No Till	**SOWING**	**PESTICIDE USE, ORGANIC FARMING**	**HARVEST METHODS**	**FIELD SIZE**
SHOREBIRDS	higher nest success on no-till wheat than untilled upland [4]; nests losses to farm machinery passes on conventional fields documented [4,6]; nesting densities and nest success potentially higher on winter wheat fields (tilled in summer/fall) than spring wheat fields (tilled in spring) because farm machinery passes do not coincide with peak nesting period [6]	farm machinery to plant spring wheat likely destroys nests/eggs of early breeders [7]	potential damage to nests from applications	some potential for the destruction of late active nests (or incubating females) in growing wheat at the time of harvest, flushing bars on harvesters may help alleviate loss	
OTHER WATERBIRDS				wheat seed most abundant and accessible after harvest, so timing of harvest in relation to timing of granivorous waterbird use important [12,13]	cranes prefer to forage in big fields [14]
LANDBIRDS		farm machinery to plant spring wheat likely destroys nests/eggs of early breeders	documented probable mortalities from organochlorine use [11] Potential damage to nests from applications	wheat seed most abundant and accessible after harvest, so timing of harvest in relation to timing of granivorous waterbird use important [12,13]	

Sources: 1 Higgins, K. F. 1977. Duck nesting in intensively farmed areas of North Dakota. Journal of Wildlife Management **41**:232-242.
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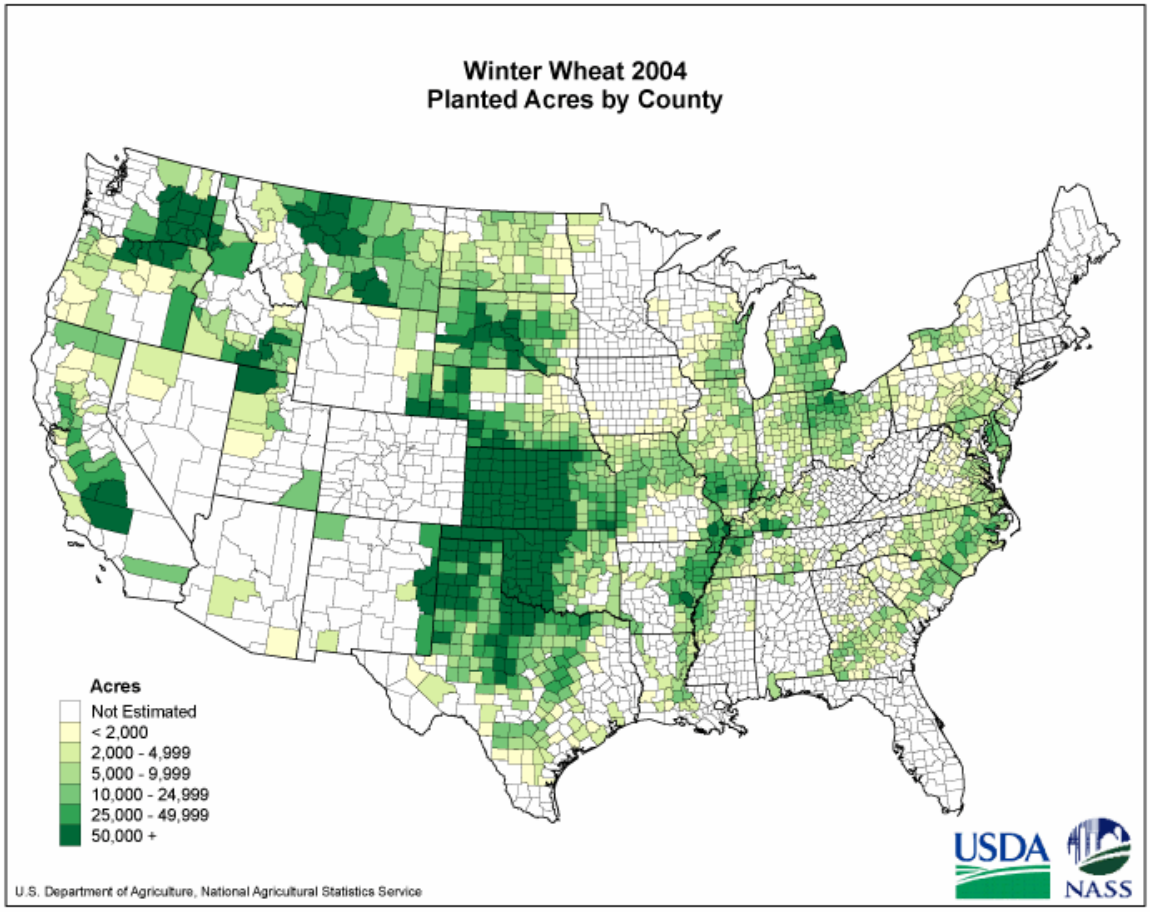

Figure 5-1. Map of the distribution of winter wheat planted in the United States during 2004, the most recent year for which data are available. From the United States Department of Agriculture National Agricultural Statistics Service (http://www.usda.gov/nass/aggraphs/cropmap.htm; accessed 2 Jan 2007).

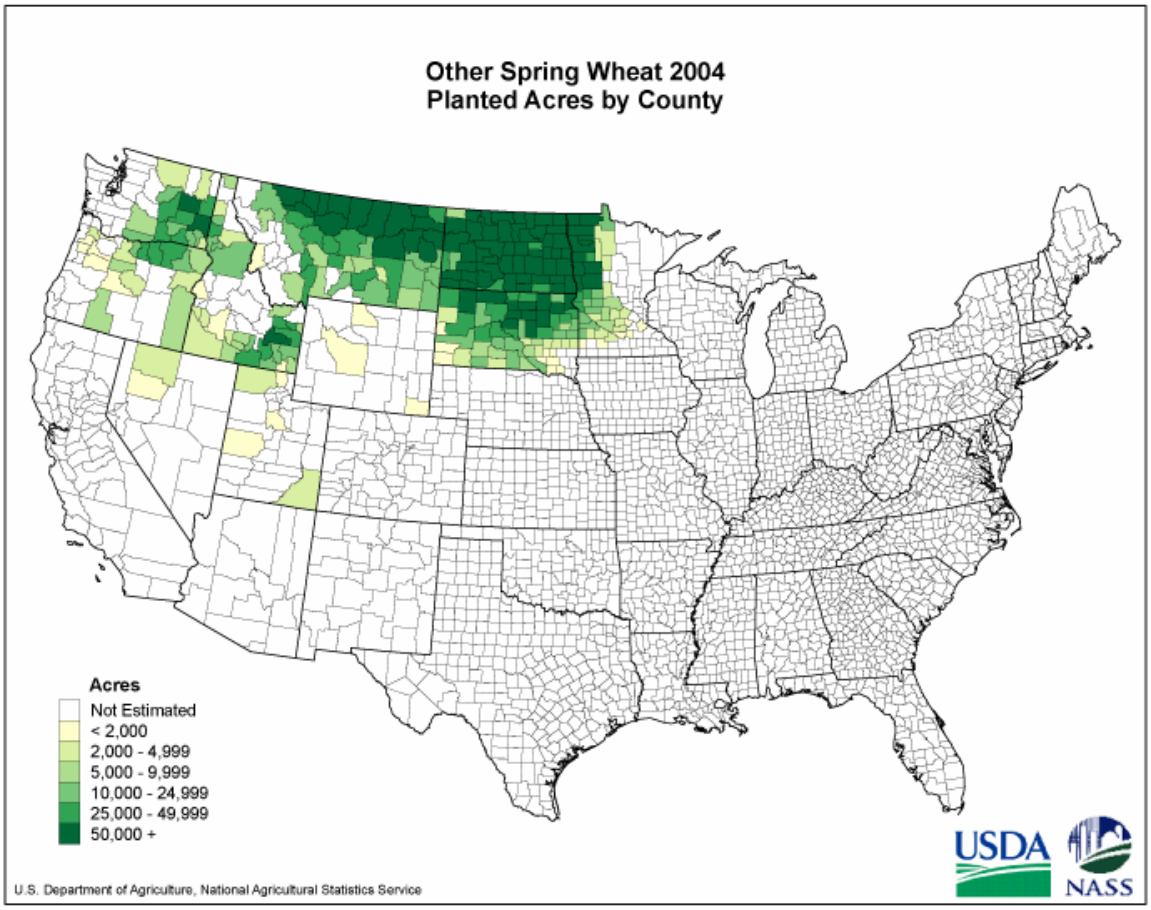

Figure 5-2. Map of the distribution of spring wheat planted in the United States during 2004, the most recent year for which data are available. From the United States Department of Agriculture National Agricultural Statistics Service (http://www.usda.gov/nass/aggraphs/cropmap.htm; accessed 2 Jan 2007).