3. RICE

Among row crops worldwide, rice (*Oryza sativa*) is undeniably the crop most associated with use by waterbirds. Rice is typically grown where wetlands formerly occurred, on hydric soils of limited suitability for other crop types (Eadie et al. 2007). With about 86% of ricelands worldwide flooded intentionally or naturally for at least part of the year (Chang and Luh 1991), most rice fields function as valuable surrogate seasonal wetland habitat for waterbirds. Since the world's rice landscapes occur where extensive wetlands formerly existed, the geographic distribution of ricelands overlaps directly with a number of regions of historic importance as habitat for wintering or migrating waterbirds (Eadie et al. 2007). Not surprisingly then, the majority of documented use of row crops by waterbirds has been in ricelands.

In North America, major rice growing regions are in the Sacramento Valley of California (Coastal California, or BCR 32), along the Gulf Coast of Texas and Louisiana (Gulf Coast Prairie, or BCR 37), and in the **Mississippi Alluvial Valley** (MAV; BCR 26) of Arkansas, Missouri, Mississippi and Louisiana (Setia et al. 1994, Eadie et al. 2007). In the Mississippi Alluvial Valley, rice is grown both in the lowland valleys of each state, and in the upland prairie of Arkansas. Figure 3-1 summarizes the typical spatial distribution of rice planted in the U.S. portion of North America (USDA 2007).

This chapter summarizes the state of current knowledge regarding the occurrence and abundance of waterbird species in rice fields, important ricefield resources for waterbirds, how waterbirds use rice fields, and the impacts of rice production practices and other management activities on waterbirds. Eadie et al. (2007) conducted an extensive review of the value of North American riceland habitats to wildlife, focusing mostly on waterbird species. Much of the information they provide for North America we summarize here.

USE BY WATERBIRDS

Waterbird use of rice fields has been documented in detail primarily in Japan (Lane and Fujioka 1998, Shimada et al. 2000, Fujioka et al. 2001, Maeda 2001, Shimada 2002, Sundar 2004, Maeda 2005), the Mediterranean region of Europe (Fasola 1986, Fasola and Ruiz 1996, Kazantzidis et al. 1996, Fasola and Ruiz 1997, Tourenq et al. 2001, Tourenq et al. 2003), and North America (Remsen et al. 1991, Elphick and Oring 1998, Twedt et al. 1998, Elphick and Oring 2003). In North America, waterbird use of rice has been documented in the **Mississippi Alluvial Valley** (BCR 26), a WWL focal region (in bold throughout text), as well as along the Gulf Coast of Mexico, and in California.

Throughout the world, rice fields are used by a diversity of foraging waterbird species, including waterfowl, shorebirds, wading birds and some landbirds. Across the world's rice growing regions, most species use rice habitat for foraging, and a few species use fields and associated habitats for nesting (Alisauskas 1988, Fasola and Ruiz 1997, Eadie et al. 2007). The documented number of aquatic species (e.g., Pelicaniformes, Gaviiformes, Podicipediformes, Gruiformes, Ciconiiformes, Anseriformes, Charadriiformes) common to rice fields at any time of the year varies among regions from 19 (Maeda 2001) to 30 (Tourenq et al. 2001) to over 45 (Elphick and Oring 1998, Elphick and Oring 2003). For landbirds, observed species richness values have been as high as 31 (Maeda 2001) and 56 (Elphick 2004). In California (BCR 32), at least 118 bird species representing 38 families have been recorded in rice fields during winter (Eadie et al. 2007). In North America, 104 waterbird species have been documented in rice fields, of which 30 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. All species but Cackling Goose and Eurasian Wigeon have been identified as WWL focal species (exclusion of Cackling Goose is solely because it was only split from Canada Goose very recently; G. Butcher, National Audubon Society, pers. comm.). Species commonly associated with rice fields in North America including those in the **Mississippi Alluvial Valley** (BCR 26) are summarized in Table 3-1. A list of species considered relatively abundant in BCR 26 (see Introduction), is also shown.

Waterfowl

Prominence of waterfowl within waterbird communities using rice fields varies across major rice growing regions of the world. In Japan, the diversity and abundance of waterfowl in rice fields is fairly low, with Greater White-fronted Goose common in winter, and Spot-billed Duck (*Anas poecilorhynnch*) typically observed in rice fields during migration at densities of about 30 birds/km^2 (Fujioka et al. 2001, Maeda 2001, Shimada 2002, Maeda 2005). In Europe, flooded rice fields in Spain provide important wintering habitat to a number of waterfowl species (Fasola and Ruiz 1997). In Italy and France, however, where few rice fields are intentionally flooded during the nonbreeding season, only a few waterfowl species in very low abundances (average densities < 5 birds/km^2) have been observed (Tourenq et al. 2001, Tourenq et al. 2003).

In North America, in contrast, waterfowl are the most prominent and abundant waterbird group using rice fields, particularly during the nonbreeding season. In California (BCR 32), 15 species of geese and dabbling ducks commonly use rice fields primarily during winter (Eadie et al. 2007). In winter, diurnal waterfowl densities in rice fields averaged (mean ± SE) about 730 (± 123) birds/km^2, with some fields attaining average densities as high as 3600 birds/km^2 (Elphick and Oring 2003). The most abundant waterfowl species using California rice fields in winter and during migration are Lesser Snow, Ross's, and Greater White-fronted Geese, Northern Pintail (a Conservation Priority Species), Northern Shoveler, Green-winged Teal, Mallard, and American Wigeon (Heitmeyer et al. 1989, Day and Colwell 1998, Elphick and Oring 1998). As many as 15 species of waterfowl have been observed in Gulf Coast (BCR 37) rice fields in winter (Remsen et al. 1991), and Hobaugh et al. (1989) observed as many as 2 million waterfowl wintering in rice fields of eastern Texas alone. In the Gulf Coast region, recreational hunting pressure has resulted in high use of rice fields at night (Rave and Cordes 1993, Cox 1996, Cox and Afton 1997), and thus typical winter field densities for these species are not well known. Common wintering species observed in Gulf Coast rice fields include Greater White-fronted Goose, Lesser Snow Goose, Northern Shoveler, Northern Pintail, and Green-winged Teal (Remsen et al. 1991, Cox and Afton 1997). Blue-winged Teal and Greater White-fronted Goose are common during migration (Hobaugh et al. 1989). Rice fields are usually too shallow for birds that dive to feed underwater, but species such as Bufflehead, Common Merganser, Ruddy Duck, and Conservation Priority Species Canvasback and Redhead, have been observed occasionally in California rice fields that are maintained at deeper average depths (Elphick and Oring 1998), and diving duck species can occur in rice fields in any locale during extreme flooding events (Eadie et al. 2007). Diving ducks sometimes also use deep-water canals that carry water to and from rice fields (C. Elphick, personal observation).

In the **Mississippi Alluvial Valley** (BCR 26), nine waterfowl species have been commonly observed in rice fields in the winter (Eadie et al. 2007), including Lesser Snow Goose, Greater White-fronted Goose, Mallard, Northern Shoveler, Northern Pintail, Gadwall, and American Wigeon (Reinecke et al. 1989, Twedt and Nelms 1999). Mallards are by far the most abundant wintering waterfowl species using rice fields in this region, and Reinecke et al. (1992) estimated that 20-40% of the 1-1.5 million wintering Mallards they counted with aerial surveys were in rice fields. Twedt and Nelms (1999) observed diurnal densities of 10 birds/km^2 for waterfowl wintering in rice fields. Few other estimates of abundance are available in this region because, like in the Gulf Coast region, diurnal hunting pressure has caused most use of MAV rice fields to occur at night (Rave and Cordes 1993, Cox and Afton 1997).

Worldwide, rice fields and associated habitats (field edges, irrigation canals, ditches) are also used during the breeding season by a few species of waterfowl (Fasola and Ruiz 1997). In North America, Fulvous Whistling-Ducks and Mottled Duck (a Conservation Priority Species) in the Gulf Coast region (Lynch 1943, Stutzenbaker 1988, Zwank et al. 1989, Hohman et al. 1994, Durham and Afton 2003, Pierluissi 2006) and Mallards in California (Yarris 1995) commonly use rice fields for nesting and foraging. The Sacramento Valley supports the largest breeding population of Mallards in California, and rice plays a key role in maintaining the state's population (McLandress et al. 1996).

Shorebirds

During winter and migration, rice fields worldwide are used as foraging habitat by a wide diversity of shorebird species, and in very large numbers in some locales. In Japan, a handful of species typically use flooded rice fields during migration, and average densities of the most common shorebird species can be as high as 600 birds/km^2 (Fujioka et al. 2001, Maeda 2001, Maeda 2005). In Europe, some regions such as northwest Italy (Fasola and Ruiz 1997) and the Ebro Delta of Spain (Martinez-Vilalta 1985) are highly important to shorebirds, providing foraging habitat during migration (22 species in Italy) and winter (12-20,000 birds in Ebro Delta ricelands). Rice fields are used less by migratory shorebirds in the Camargue region of France, with 11 species occurring at fairly low densities (< 4 birds/km^2) in spring (Tourenq et al. 2001, 2003).

In North America, 10 shorebird species are common in flooded California (BCR 32) rice fields in winter and during spring migration (Eadie et al. 2007). Elphick and Oring (2003) observed mean shorebird densities of 252 ± 72 birds/km^2, and some fields attained average winter densities as high as 2600 birds/km^2. Dunlin and Long-billed Dowitchers are the most abundant shorebird species in California rice fields, but Killdeer, Greater Yellowlegs, Long-billed Curlew (a Conservation Priority Species), Wilson's Snipe, and Least Sandpiper are also quite common (Day and Colwell 1998, Elphick and Oring 1998, Shuford et al. 1998). Along the Gulf Coast (BCR 37), five species of shorebird commonly use rice fields (Eadie et al. 2007), and Rettig (1994) observed that as many as 30 shorebird species may use rice fields in this region at some time during the year. Remsen et al. (1991) estimated that up to 225,000 shorebirds wintering in a 3522 sq. km area of rice fields (density of ~64 birds/km^2) along the Gulf Coast of Louisiana, and migratory shorebird numbers can also be high, especially during spring (Remsen et al. 1991, Rettig 1994). Common Gulf Coast ricefield species include Killdeer, Lesser Yellowlegs (a Conservation Priority Species), Western Sandpiper, Pectoral Sandpiper, Dunlin, and Long-billed Dowitcher (Remsen et al. 1991, Rettig 1994).

Comparatively little published data exist on shorebird use of rice fields during the nonbreeding season in the **Mississippi Alluvial Valley** (BCR 26). Radio-marked Pectoral Sandpipers have been documented in wet, harvested rice fields during fall migration in Mississippi (Lehnen and Krementz 2005), and Twedt et al. (1998) observed average densities on MAV rice fields as high as 150 birds/km^2 during winter, with Killdeer, Wilson's Snipe, Dunlin, Western Sandpiper, and Lesser Yellowlegs the most common species.

Worldwide, most shorebirds breed farther north than where rice is grown (Eadie et al. 2007). In Japan, one species of plover has been observed foraging in rice fields in very low densities (< 5 birds/km^2) during the breeding season (Maeda 2001). In Europe, Black-tailed Godwits (*Limosa limosa*), Pied Avocets (Recurvirostra avosetta) and Black-winged Stilts (*Himantopus himantopus*) sporadically nest in rice fields in northwestern Italy and the Ebro Delta of Spain (Fasola and Ruiz 1997). In North America, breeding Killdeer are common in rice fields across all rice-growing regions, American Avocets and Black-necked Stilts nest and forage in and around rice fields along the Gulf Coast and in California, and Wilson's Phalaropes (a Conservation Priority Species) have been seen on occasion in rice fields during the breeding period in California (Shuford et al. 2004, Eadie et al. 2007).

Wading Birds

Across rice growing regions worldwide, wading birds (Ciconiiformes) such as herons, egrets, storks, bitterns and ibis are perhaps the waterbird group that is most consistently found foraging in rice fields during the nonbreeding season. In Japan, five species of herons and egrets are common in rice fields during migration, varying in average densities from about 100 to almost 500 birds/km^2 (Fujioka et al. 2001, Maeda 2001, Maeda 2005). In Europe, a great diversity of foraging wading birds (9 species in France, 11 species in Italy) are common in rice fields during the nonbreeding period, although most species usually occur at low densities of < 5 birds/km^2 (Fasola and Ruiz 1997, Lombardini et al. 2001, Tourenq et al. 2001, Tourenq et al. 2003).

In North America, seven wading bird species [Great Egret, Snowy Egret, Great Blue Heron, American Bittern (Conservation Priority Species), Black-crowned Night-Heron, White-faced Ibis, and occasionally Cattle Egret] winter in California (BCR 32) rice fields (Day and Colwell 1998, Elphick and Oring 1998). Along the Gulf Coast (BCR 37), as many as 10 species of wading birds (Great Egret, Snowy Egret, Great Blue Heron, Cattle Egret, Little Blue Heron (Conservation Priority Species), Black-crowned Night-Heron, White-faced Ibis, White Ibis, Glossy Ibis, and to a lesser extent Least Bittern) are found in rice fields in fall and winter (Remsen et al. 1991, Rettig 1994). White-faced Ibis are by far the most numerous wintering wading bird species in California, with up to 50 birds/km^2 in flooded fields (Elphick and Oring 1998), and tens of thousands of wintering White and White-faced Ibis have been estimated to occur in rice fields of the Gulf Coast region (Remsen et al. 1991, Ryder and Manry 1994).

Although there is no direct information on wading bird use of rice fields in the **Mississippi Alluvial Valley** (BCR 26) during the nonbreeding period (Eadie et al. 2007), it is likely that wading bird communities at least in the lower MAV are similar to those found in Gulf Coast rice fields.

In most rice growing regions, wading birds forage or nest in rice fields and associated habitats during the breeding season. In Japan, herons and egrets commonly forage in rice fields near breeding colonies, with individual species reaching average densities of 5-30 birds/km^2 (Lane and Fujioka 1998, Maeda 2001). In Europe, wading birds commonly foraging in ricelands during the breeding season (Lombardini et al. 2001, Tourenq et al. 2001), and bitterns (Portugal) and storks (Italy) will nest in associated ricefield habitats such as along the edges of irrigation canals or on pylons (Fasola and Ruiz 1997). In North America, a number of wading bird species [Great Egret, Snowy Egret, Great Blue Heron, American Bittern, Black-crowned Night-Heron, White-faced Ibis in California of BCR 32; additionally Cattle Egret, Little Blue Heron along the Gulf Coast of BCR 37] commonly forage in rice habitats during the breeding season (Cogswell 1977, Shuford et al. 1996, Eadie et al. 2007). Along the Gulf Coast, Least Bittern have been documented nesting in growing rice, although detected nest densities are typically low (<1 nest/km^2; Hohman et al. 1994, Pierlussi 2006).

Other Waterbirds

Worldwide, there are other waterbirds in the orders Pelecaniformes (cormorants), Podicipediformes (grebes), Gruiformes (cranes, rails, coots), and Charadriiformes (gulls, terns) that may forage in rice fields. In Europe, a number of crane, coot, gull and tern species commonly forage in rice fields throughout the year, some gull species reaching average densities of 100 birds/km^2 (Fasola and Ruiz 1997, Guzman et al. 1999, Tourenq et al. 2001, Tourenq et al. 2003).

In North America, the most common waterbird species from this group wintering in California (BCR 32) rice fields are American Coot (in flooded fields), Conservation Priority Species Sandhill Crane (feeding and roosting in rice), Sora (in vegetation fringing fields) and Ring-billed Gull (Day and Colwell 1998, Elphick and Oring 1998). In the fall or winter along the Gulf Coast (BCR 37), Soras, Virginia Rail, and Sandhill Crane, King Rail (Conservation Priority Species), and Yellow Rail (Conservation Priority Species) commonly occur in rice fields or associated drainage canals, and Gull-billed Tern (a Conservation Priority Species) forage in flooded fields (Meanley 1953, 1956, Guthery 1976, Cardiff and Smalley 1989, Meanley 1992, Parnell et al. 1995). Most rice fields are typically too shallow for waterbirds that dive to feed underwater, but in California, Pied-billed Grebes frequently use the deeper water found in ditches that supply fields with water and occasionally occur in the fields themselves (Elphick 1998).

In the **Mississippi Alluvial Valley** (BCR 26), Soras, Virginia Rails, King Rails, and Yellow Rails are common fall migrant and wintering species foraging in rice fields and associated drainage canals (Meanley 1953, 1956, 1992; Cardiff and Smalley 1989; J. Stafford, Illinois Natural History Survey, pers. comm.). Soras have also been observed during fall migration in Arkansas rice fields (Meanley 1960).

In addition, many of these waterbird species nest in rice fields or along irrigation canals. In Europe, various species of gulls, terns, and rallids nest within fields, some on floating nests in flooded ricelands (Fasola and Ruiz 1997). In North America, California rice fields support almost half of the state's breeding population of Black Terns (Shuford et al. 2001), a WWL Conservation Priority Species. In the Gulf Coast region, King Rail, Common Moorhen, and Purple Gallinule will commonly nest in rice fields (Meanley 1953, 1956, 1992; Cardiff and Smalley 1989, Hohman et al. 1994, Pierluissi 2006). King Rails also nest in rice fields of the **Mississippi Alluvial Valley** (**BCR 26**) (Meanley 1953, 1956, 1992).

Landbirds

Worldwide, a diversity of raptor, songbird and other bird species have been observed using rice fields and their associated habitats, with hawks, falcons, owls, wrens, sparrows, and blackbirds accounting for most of the documented reports (Cardiff and Smalley 1989, Remsen et al. 1991, Rave and Cordes 1993, Maeda 2001). In Japan, Fujioka et al. (2001) observed seven landbird species frequenting flooded open fields during fall migration, two of which (a wagtail and a warbler) were associated with aquatic habitats. Throughout the year, Maeda (2001) documented 31 landbird species using rice fields in Japan, with species most abundant in mid-winter, and levees and fallow fields important to some species.

In North America, most documented use of rice fields has been during nonbreeding seasons (Table 3-1). In California (BCR 32), nine WWL landbird species have been observed in ricefield habitats during winter – Bald Eagle (Conservation Priority Species), Belted Kingfisher, Black Phoebe, Marsh Wren, Common Yellowthroat, Lincoln's Sparrow, Red-winged Blackbird, Tricolored Blackbird (Conservation Priority Species), and Yellow-headed Blackbird (Crase and DeHaven 1978, Elphick 1998, Elphick 2004). Bald Eagles regularly hunt for wintering waterfowl over California rice fields (Elphick 1998). While Red-winged Blackbirds are often observed in flooded fields, Belted Kingfisher, Marsh Wren and Black Phoebe are restricted to field edges and drainage ditches where there is greater vegetative cover (Elphick 2004). Crase and DeHaven (1978) found that rice was the dominant food item eaten by wintering Red-winged Blackbirds (44% of diet), Yellow-headed Blackbirds (38%), and Tricolored Blackbirds (38%). In the Gulf Coast region (BCR 37), 10 species [Bald Eagle, Belted Kingfisher, Eastern Phoebe, Purple Martin, Fish Crow, Sedge Wren (Conservation Priority Species), Common Yellowthroat, LeConte's Sparrow (Conservation Priority Species), Boat-tailed Grackle, Red-winged Blackbird] are associated with rice habitats in winter (Cardiff and Smalley 1989, Remsen et al. 1991, Rave and Cordes 1993). Bald Eagles commonly hunt for abundant wintering waterfowl over southwest Louisiana rice fields (Rave and Cordes 1993). Icterids including WWL species Red-winged Blackbird and Boat-tailed Grackle, are particularly abundant in Gulf Coast rice fields in winter, foraging on waste grain left after harvest (Remsen et al. 1991). During fall, LeConte's Sparrow and Sedge Wren can be abundant in unharvested rice fields (Cardiff and Smalley 1989).

Landbird use of **Mississippi Alluvial Valley** (BCR 26) rice fields during the nonbreeding season has not been well studied, although various blackbird species are abundant in winter (Eadie et al. 2007). In a rice-growing area of the Lower MAV and Gulf Coast, studies in the 1960s documented as many as 200 million wintering Red-winged Blackbirds, Boat-tailed Grackles, Brown-headed Cowbirds and European Starlings (Meanley 1971).

Little information exists regarding use of rice fields by WWL landbirds during the breeding season. In the **Mississippi Alluvial Valley** (BCR 26), breeding Red-winged Blackbirds are highly abundant in rice fields – Meanley (1971) estimated 44,000 breeding male Red-winged Blackbirds in a 2300 km^2 riceland area. In California (BCR 32), Tricolored Blackbirds have been known to consume sprouting rice during the breeding season (Beedy and Hamilton 1999).

RESOURCES

Rice fields worldwide provide various important resources for foraging and nesting birds. Availability and use of these resources in different locales have been quantified to varying degrees. Here we outline what is known about abundance and use of ricefield resources for North America only, drawing from information worldwide only where information is lacking for North America.

Foraging Resources

Rice fields provide various food resources for foraging waterbirds at all times of the year. These resources include rice and moist soil seeds, green vegetation and roots, and both invertebrate and vertebrate prey (Table 3-2). Here we review what is known about the abundance and availability of ricefield resources, and of their consumption and use by waterbirds in North America.

Rice and Moist Soil Seed

The seeds of rice and moist soil plants that typically grow in rice fields are an important resource for many waterfowl and some shorebird species during nonbreeding and breeding seasons (Table 3-2). In North America, new waste rice becomes available to foraging waterbirds after fall harvest and is often available through to spring (Eadie et al. 2007). Research on rice consumption suggests that waterfowl in particular forage heavily on rice waste grain (Singleton 1951, Miller and Newton 1999, Dabbert and Martin 2000, Rutka 2004). In California, van Groenigen et al. (2003) compared the amount of rice remaining on sites that excluded foraging wintering waterfowl to that on paired control plots that waterfowl could access, and found significant depletion of rice waste grain in control plots, with greatest depletion rates on plots that started with the greatest amount of waste grain. In another waterfowl exclosure experiment in the **Mississippi Alluvial Valley** (BCR 26), waterfowl were estimated to have consumed 30% of rice available in the early winter (Rutka 2004).

Among rice growing regions in North America, estimates of the amount of rice seed left after harvest range from an average (among fields) of 49 to over 600 kg/ha dry weight (Rutka 2004, Kross 2006, Stafford et al. 2006, Eadie et al. 2007). Amount of documented waste grain in North American rice fields varies from 3 to 6% of the rice yield (Eadie et al. 2007), and larger yields result in greater abundance of rice seed for waterbirds (Miller et al. 1989). A number of other factors influence the amount and availability of rice seed after harvest. These include variation in the type, operation and harvest settings of the combine harvester (McNeal 1950, Miller et al. 1984, Miller et al. 1985, Miller and Wylie 1996, Wilson et al. 2001); weather and seed moisture during harvest (Wilson et al. 2001); post-harvest field treatments such as method of straw disposal and presence/absence of flooding (Day and Colwell 1998, Elphick and Oring 1998, Stafford 2004, Kross 2006) and seed deterioration rates (Neely 1956, McGinn and Glasgow 1963, Manley 1999, Rutka 2004). How these factors influence abundance and availability of rice seed for waterbirds is reviewed under **Effect of Rice Crop Production Methods**.

In the southeastern U.S. including the **Mississippi Alluvial Valley** (BCR 26), rice yields have increased and recent estimates suggest a corresponding overall increase in the amount of waste rice in fields (Harmon et al. 1960, Smith and Sullivan 1980, Reinecke et al. 1989, Manley 1999). Moreover, along the Gulf Coast (BCR 37), a long growing season permits an early first harvest allowing a second "ratoon" crop grown by irrigating and fertilizing rice after harvesting the first crop. The yield from this second crop is usually less than from the first, and sometimes entire ratoon crops may be left in fields if the yield is not large enough to warrant harvesting (Hobaugh 1984). In the **Mississippi Alluvial Valley** (BCR 26), however, only one crop is typically harvested, and Manley (1999) has suggested that loss of waste rice from this one crop to germination, decomposition, and other foraging wildlife species may be extensive after harvest and before the majority of waterbirds arrive. From early to late winter, Rutka (2004) documented a 46% loss of waste rice in MAV rice fields due to deterioration alone. Stafford (2004) estimated a 71% decline in mean abundance of waste rice between harvest (271 kg/ha) and early winter (78 kg/ha) due to a combination of germination, decomposition, and other foraging wildlife, and has consequently warned that estimates of winter waterfowl carrying capacity for the MAV may, in fact, be grossly overestimated.

Moist-soil wetland plants also grow in rice fields, and their seeds become available to waterbirds after rice harvest. Documented densities of moist-soil seeds in commercial rice fields in North American vary from 12 to 44 kg/ha dry weight (Eadie et al. 2007), although Kross (2006) recently estimated average densities as high as 496 kg/ha in the **Mississippi Alluvial Valley** (BCR 26). Fallow rice fields in the MAV have been known to produce abundances of moist-soil seeds as high as 374 kg/ha (Smith and Sullivan 1980). A wide variety of moist-soil plants are present in North American rice fields, with the seeds of a few (e.g., Barnyardgrass *Echinochloa crus-galli* and smartweeds *Polygonum* spp.) particularly important resources for waterbirds (Miller 1987). Some of these moist-soil plants are considered weeds, the most common of which are Barnyardgrass and Red Rice (*Oryza punctata*). Weed seeds may be prolific enough to cause great losses to rice production (Eadie et al. 2007), but they are also a substantial food source consumed by nonbreeding waterbirds (Davis et al. 1961, Reinecke et al. 1989, McAbee 1994). Documented reductions in weed seed yields due to foraging waterbirds have been great (McAtee 1923, Smith and Sullivan 1980). Foraging wintering waterfowl reduced abundance of Red Rice grain by almost 97% in Arkansas rice fields (Smith and Sullivan 1980); long winter flood durations (from fall through early March) substantially reduce winter weed seed yields in Mississippi (Manley 1999, Manley et al. 2005); and in California, waterfowl exclosure experiments have shown that by springtime flooded plots accessible to waterfowl had significantly lower biomass of grassy weed seeds than enclosed plots (van Groenigen et al. 2003).

Few studies have examined the abundance of rice or moist-soil seeds available in rice fields to foraging waterbirds during the breeding season. Bourne (1982) observed that most food consumed by breeding Black-bellied Whistling-Ducks in Guyana was rice seed eaten before germination. However, moist-soil seeds comprised the bulk of diet of juveniles collected after rice had germinated. In coastal Louisiana, Hohman et al. (1996) estimated previously fallow rice fields that had been tilled, flooded and ready for planting in spring contained an average of 1014 kg/ha of moist-soil seeds, the most common of which were signalgrass (*Brachiaria*), beakrush (*Rhynchospora*), and flatsedge (*Cyperus*). Correspondingly, breeding adult Fulvous Whistling-Ducks consumed greater quantities of these moist-soil seeds than rice and other foods (Hohman et al. 1996). However, data from another Louisiana study documented that rice from flooded fields accounted for 78% of the spring diet of Fulvous Whistling-Ducks (Meanley and Meanley 1959), with the remainder of the diet comprised of moist-soil plants from dry-planted fields.

Energy Value of Rice. Rice seed provides valuable energy to those waterbird species that consume it. Compared to other cereal crops and moist-soil seeds, the caloric value of rice seed is moderately high. In a study comparing apparent metabolizable energy (AME) of the seeds of rice and various moist-soil plants, rice AME (3.53 kcal/g) ranked second only to seeds of swamp timothy (3.71 kcal/g), and AME for other moist-soil seeds ranged from 2.72 kcal/g to 3.33 kcal/g (Miller 1987). Estimated true metabolizable energy (TME) values assayed with Canada Geese and Mallard are 2.82 to 3.34 kcal/g for rice, not as high as for corn (3.67 to 3.90 kcal/g) or sorghum (3.78 kcal/g), but similar to wheat seed (3.38 kcal/g) and soybeans (2.65 to 3.55 kcal/g) (Reinecke et al. 1989, Petrie et al. 1998). Moreover, the energy content of rice is moderately easy to assimilate - digestibility assayed with Canada Geese was estimated at 67%, lower than corn (88%) and sorghum (87%), but slightly higher than soybeans (62%) (Petrie et al. 1998). Although the caloric content of rice may be adequate, rice is not a complete food. Studies indicate that various waterbird species supplement their diet with other sources of protein and various nutrients that are in short supply from cereal grains (Delnicke and Reinecke 1986, Miller 1987).

Green Vegetation and Rootstock

For some waterbirds, the vegetation and roots of rice and other plants growing in rice fields are important foraging resources (Table 3-2). Geese and blackbirds have been observed foraging on the new shoots of germinating rice (either newly planted or from waste seed) and moist-soil plants (Hobaugh 1984, Leslie and Chabreck 1984, Alisauskas et al. 1988, Day 1997, Beedy and Hamilton 1999). Although the green forage biomass available to birds in rice fields has not been quantified, researchers have documented winter increases in ricefield green forage coincident with peak use of rice fields by geese (Hobaugh 1984, Leslie and Chabreck 1984, Hobaugh 1985, Alisauskas et al. 1988, Manley et al. 2004). American Coots and Tricolored Blackbirds (a Conservation Priority Species) have also been documented eating newly sprouting sown rice during the breeding season (van Way 1986, Beedy and Hamilton 1999). Finally, it is not uncommon for nonbreeding swans and geese to forage on the roots of rice plants or tubers of wetland plants such as sago pondweed (*Potamogeton pectinatus*) that may be growing in flooded rice fields (Limpert and Earnst 1994, Stabins et al. 2002).

Aquatic Invertebrates

Aquatic invertebrates are another important resource for many waterfowl and shorebird species during nonbreeding and breeding seasons (Table 3-2). Abundances of aquatic invertebrates in flooded rice fields can be impressive. Quantified biomass values for winter and spring are comparable to those documented in other important wetlands, including green-tree reservoirs and managed moist-soil wetlands (Duffy and LaBar 1994, Wherle et al. 1995, Gray et al. 1999). Loughman and Batzer (1992) estimated larval midge (Chironomid) peak densities of 400 individuals/m^2 in California rice fields in mid-winter (February). Other abundant invertebrates included aquatic worms (Oligochaeta), seed shrimp (Ostracoda), water fleas (Cladocera), and copepods (Copepoda). In the **Mississippi Alluvial Valley** (**BCR 26**) and Gulf Coast (BCR 37) regions, average winter biomasses of invertebrates observed in rice fields (Gastropoda, Insecta, Oligochaeta, and Ostracoda) have been 6.3 kg/ha and 7.0 kg/ha, respectively (McAbee 1994). Even greater invertebrate biomasses have been observed in early spring: 22.0 kg/ha in Gulf Coast rice fields (Hohman et al. 1996) and 21.1-31.7 kg/ha in rice fields in the **MAV** (Manley 1999). Along the Gulf Coast of Louisiana, aquatic invertebrates from rice fields are an important resource for breeding Fulvous Whistling-Ducks (Hohman et al. 1996).

Crayfish may be an important resource for larger waterbirds such as large shorebirds, most wading birds, American Coots, and gulls and terns. In California during winter, various herons, White-faced Ibis, Long-billed Curlew (a Conservation Priority Species) and Ring-billed Gulls (kleptoparasitic on ibis and curlew) have been frequently observed foraging on crayfish in rice fields and irrigation ditches (C. Elphick, personal observation). While in rotation as crayfish stock ponds, Huner et al. (2002) documented a number of wading birds (Yellow-crowned Night-Heron, Great Egret, Snowy Egret, Glossy Ibis, White Ibis, White-faced Ibis), gulls, and terns to commonly forage on crayfish from winter through spring.

Aquatic Vertebrate Prey

The fish, reptile and amphibian species found in rice fields can be an important food resource for some wading birds during all times of the year. During the breeding season in Japan, Lane and Fujioka (1998) observed abundant frogs, tadpoles and fish in rice fields frequented by breeding egrets and herons. In Europe, availability of vertebrate prey from rice fields is an important factor influencing breeding success of many wading bird species (Fasola and Ruiz 1997). In southern Europe, documented densities of amphibians in rice fields vary from 0.1 to 9.3 adults/100 m^2, and from 0.6 to 118.2 tadpoles/100 m^2 (Fasola and Ruiz 1997). Fish densities were documented for Ebro Delta rice fields at 4.8 individuals/100 m^2 (Fasola and Ruiz 1997).

Less is known about the abundance of vertebrate prey and their consumption by wading birds wintering or breeding in North American habitats (Eadie et al. 2007), but they are likely important resources for these species (Table 3-2). Pacific Treefrogs (*Hyla regilla*) and the introduced Bullfrog (*Rana catesbeiana*) are common in California ricefield habitats throughout the year (Eadie et al. 2007). Additional less abundant reptilian and amphibian prey species include Western Fence Lizards (*Sceloporus occidentalis*), Western Toads (*Bufo boreas*), and Western Spadefoot Toads (*Scaphiopus hammondii*) in California, and Southern Leopard Frogs (*Rana sphenocephala*) in the MAV (Eadie et al. 2007). Small mammals have been commonly observed in **Mississippi Alluvial Valley** rice fields (Stafford 2004, Stafford et al. 2006). Herons and egrets have been observed capturing and consuming various fish, amphibians (frogs, large tadpoles), birds (blackbirds), and small mammals (mice, rats) in California rice fields (C. Elphick, personal observation).

Breeding Resources

North American rice fields provide breeding resources to a number of waterbird species. Associations with rice vary from nesting in rice fields and associated habitats, to actual use of rice vegetation for nest bowl construction, to rearing broods in flooded fields (Table 3-2). In

North America, waterfowl, rallids, and bitterns are the most common species nesting in rice fields (Eadie et al. 2007). Shorebirds, Black Terns (a Conservation Priority Species), and numerous landbird species also nest in and around the edges of rice fields, but less is known about these species' use of rice habitat for breeding.

Nesting Habitat

In North America, 13 waterbird species have been documented nesting in ricefield habitat (Table 3-1). Shorebirds such as Killdeer, American Avocet, and Black-necked Stilt commonly use rice habitats for nesting (Shuford et al. 2004, Eadie et al. 2007). In California (BCR 32), Mallards, Black Terns, and probably Cinnamon Teal commonly nest in rice fields or habitats associated with rice fields, such as densely-vegetated water control levees in and around the fields, as well as in "set-aside" fields withheld from rice production (Yarris 1995, McLandress et al. 1996, Shuford et al. 2001). Along the Gulf Coast (BCR 37), growing rice is commonly flooded to shallow depths (7-10 cm) for irrigation during the growing season (Huner et al. 2002), making them especially attractive to species that tend to build floating nests in emergent vegetation (Helm et al. 1987, Hohman et al. 1994, Pierluissi 2006). In southwest Louisiana, for example, Hohman et al. (1994) documented average waterbird nest densities (5 species total) of 37.2 ± 4.4 (SE) nests/km^2, with greatest nest densities observed for King Rails (15.9 ± 3.1 nests/km^2), a Conservation Priority Species; Fulvous Whistling-Ducks (15.1 ± 3.3 nests/km^2); and Purple Gallinules (5.1 ± 1.4 nests/km^2). Also in southwestern Louisiana rice fields, Pierluissi (2006) observed greatest nest densities for Purple Gallinules (16.0 ± 6.1 nests/km^2), and Fulvous Whistling-Ducks (13.7 ± 3.3 nests/km^2) but fewer King Rail nests (4.8 ± 0.9 nests/km^2); Common Moorhen and Least Bittern nests were present at fairly low densities of 2.8 ± 1.0 nests/km^2 and 0.9 ± 0.5 nests/km^2, respectively. In two years studied by Pierluissi (2006), nest survival rates varied from 52-79% for Purple Gallinules, 50-52% for King Rails, and 39-43% for Fulvous Whistling-Ducks. Fulvous Whistling-Ducks nest in rice fields with a lot of weedy species [e.g., Barnyardgrass (*Echinochloa crus-galli)*, paspalums (*Paspalum* spp.) and smartweeds *Polygonum* spp.], but construct their nest bowl from rice vegetation (Bolen and Rylander 1983). In southwest Louisiana, Helm et al. (1987) reported higher clutch sizes, nest densities and nest success of Common Moorhens and Purple Gallinules in rice fields than in natural freshwater marshes. Finally, in the **Mississippi Alluvial Valley** (BCR 26), Red-winged Blackbirds are an abundant nesting species within ricefield habitats (Meanley 1971).

Brood-rearing Habitat

Waterbird broods are commonly observed feeding or loafing in flooded rice fields, but relatively little is known about habitat use and survival of broods (Eadie et al. 2007; Table 3-2). In the rice-growing regions of California, few natural or refuge wetlands are flooded during the breeding season and thus flooded rice fields and associated irrigation ditches and canals are the primary habitats used by Mallard broods (Yarris 1995). However, brood survival is influenced by timing of ricefield flooding and subsequent plant growth. Yarris (1995) observed predation rates on early-hatched ducklings to be high because broods are restricted to irrigation ditches or open rice fields with little emergent cover; survival of broods hatched later in the season increased when fields were flooded and growing rice plants provided sufficient concealment from predators.

Resting Habitat

Rice fields and associated features (field edges, levees) provide important habitat for resting (sleeping, standing, preening) waterbirds, primarily during the nonbreeding season after harvest (Eadie et al. 2007; Table 3-2). In flooded rice fields of California, wintering Northern Pintails (a Conservation Priority Species) spend about 60% of the day resting (Miller 1985). Elphick (2000) observed that seven species of shorebirds and one wading bird (Great Egret) each spent between 5-35% of the time during the day sleeping or preening while in ricefield habitats. Flooded rice fields can also serve as important daytime refuge habitat for waterbirds in regions with human hunting pressure. Miller (1985) found that pintails repeatedly returned to unhunted rice fields by day after having foraged elsewhere at night. Likewise, in several 60 ha experimental ricefield "refuges" set aside for no hunting in Louisiana, fairly high densities of pintail spent over 50% of their time resting, fed in refuge rice fields during the day more often than in nearby marshes, and left rice fields only at night to forage elsewhere (Rave and Cordes 1993). Such ricefield refuges appear to be as important to pintail as traditional wetland refuges (Cox and Afton 1998).

EFFECTS OF RICE PRODUCTION METHODS

A number of studies have documented how farming practices involved in rice production can affect waterbirds, from influencing use of fields to the success of nests to the survival of adults. Here we summarize effects following the chronology of rice production from soil and residue management to harvest methods. Table 3-3 provides a synopsis of the current state of knowledge on these topics.

Soil and Residue Management in Preparation for Planting

Rice farmers use a number of manipulation methods to manage rice straw residue and prepare the soil for new plantings. These vary from conventional burning and plowing to no-till practices of leaving straw on fields (Day and Colwell 1998, Elphick and Oring 2003, Pierluissi 2006). Although the oldest method of residual rice straw management has been to burn, effects of burning straw on waterbird use of rice fields have generally gone unstudied. Burning can decrease abundance of seeds by destroying them (Miller et al. 1989, Kross 2006), but may potentially increase access to grain and seeds for some species by removing straw (Eadie et al. 2007). Day and Colwell (1998) found no difference in the number of waterbird species using burned fields versus fields where straw had been managed in other ways. By removing rice straw cover, however, burning may temporarily increase access to small mammal prey for some wading bird species, as has been documented for raptors in California (Smallwood et al. 1996).

To accelerate rice straw decomposition rates, winter flooding (see below) has been used in conjunction with various straw incorporation methods, from conventional plowing of straw into the soil to more contemporary methods of rolling the straw to flatten it and mix it with the soil, chopping straw to increase its surface area, leaving straw on fields unmanipulated, and others (Manley et al. 2005, Eadie et al. 2007). Little research has been conducted on precisely how these methods influence waterbird use of rice fields, but potential positive effects include increasing the abundance of invertebrate foods (Helmers 1993, Lawler and Dritz 2005), decreasing vegetation cover and thus improving access to substrates, or increasing visibility so that birds can more easily scan for predators (Twedt et al. 1998); potential negative effects include decreasing access and nutritional content of seeds by burying them (Nelms and Twedt

1996, Stafford 2004, Kross 2006) or decreasing the ease with which predators can be seen. In general, plowing, rolling, and disking the soil may decrease availability of waste rice and weed seeds (Stafford 2004, Kross 2006) or the ability of small species to maintain predator vigilance, and some studies have demonstrated an apparent preference for unplowed stubble fields by various waterbird species (Hobaugh 1984, Maeda 2001, Shimada 2002). In California, Day and Colwell (1998) found no differences in waterbird species richness among fields where residual straw had been burned, plowed or chopped prior to flooding. In another California study, Elphick and Oring (2003) documented the greatest species richness of waterbirds in fields that had been rolled after flooding and the least in fields where straw had been physically removed. Although differences among straw treatments were only slight, total waterbird densities were greatest in fields that had just been flooded with no straw removed or manipulated, and where straw had been rolled before flooding (Elphick et al. 2007). While waterfowl densities did not differ among field types, shorebird densities (primarily Killdeer, Dunlin, Least Sandpiper and Long-billed Dowitcher) were greatest in fields with plow-incorporated straw, and some wading bird species (White-faced Ibis and American Bittern, a Conservation Priority Species) were more abundant in fields where straw had not been manipulated at all (Elphick and Oring 1998). Interpreting these results, however, is complicated because water depth (see next section) varied among straw incorporation methods. For instance, fields with plow-incorporated straw generally had shallower water depths, making more of the field accessible to the shorter-legged shorebird species that tended to select this habitat (Elphick and Oring 1998).

Flooding and Water Depth Management
In some rice-growing regions, particularly in North America, rice fields are intentionally flooded after fall harvest for the duration of the waterbird nonbreeding season (Hobaugh et al. 1992, Fasola and Ruiz 1997, Twedt et al. 1998, Tourenq et al. 2001, Elphick and Oring 2003). In California, the incidence of winter flooding has increased in recent years in response to legislation (Rice Straw Burning Act, AB 1378, 1991) forcing growers to seek alternative methods to burning for residual straw disposal, and winter flooding has been shown to greatly increase straw decomposition rates (Bird et al. 2000, Manley et al. 2005). In the Gulf Coast (BCR 37) and **Mississippi Alluvial Valley** (BCR 26) regions, more widespread adoption of winter flooding has resulted from cooperative farmer incentive programs established to provide waterfowl foraging habitat (Baxter et al. 1996). Recent estimates (~ year 2000) document that in the MAV and California, respectively, at least 80,000 ha and 130,000 ha of harvested rice fields were typically flooded by landowners during the winter (Uihlein 2000, Eadie et al. 2007).

Winter flooding is the one crop production method that has most influenced the diversity and abundance of waterbird species using rice fields. Flooding is what functionally transforms rice croplands into artificial or surrogate wetlands, attracting numerous waterbird species (Fasola and Ruiz 1997, Eadie et al. 2007). In any wetland system, presence of shallow water boosts the reproduction of invertebrates and greatly influences access to invertebrate and seed foods (Fredrickson and Taylor 1982). Manley et al. (2004) found that flooded rice fields in the **Mississippi Alluvial Valley** (BCR 26) harbored greater densities of aquatic invertebrates than unflooded fields. In California, waterbird species richness and densities are higher in intentionally flooded rice fields than in those that only receive passive flooding (Elphick and Oring 1998, 2003). Out of 31 waterbird species analyzed, 23 (74%) were significantly more abundant in flooded fields (Elphick and Oring 1998). On average, waterfowl were twice as abundant in flooded as in unflooded fields. Out of 34 landbird species analyzed, 4 (11%) species (Black Phoebe, Marsh Wren, American Pipit, Song Sparrow) were more abundant in flooded fields (Elphick 2004). In Gulf Coast Louisiana rice fields, flocks of Greater White-fronted Geese occur more frequently in harvested rice fields that are wet than in those that are dry, and use wet rice disproportionate to its abundance (Leslie and Chabreck 1984).

Not all waterbirds are preferentially and unconditionally drawn to winter-flooded rice fields. In California, Great Blue Herons and Sandhill Cranes (a Conservation Priority Species) were significantly more abundant in unflooded than in flooded fields (Elphick and Oring 2003). Great Egrets were more likely to spend time sleeping in unflooded rice fields than in either flooded rice or managed moist-soil wetlands (Elphick 2000), perhaps indicating subtle differences in the way habitats are used by certain species. Moreover, for some wading bird and shorebird species, attraction to flooded rice may be mediated by the amount of vegetation cover in fields (Eadie et al. 2007), with tall stubble attracting some species (e.g., American Bitterns) and deterring others (e.g., small shorebirds). In rice fields of the Gulf Coast of Louisiana, from the fall through spring nonbreeding periods, Rettig (1994) observed 70% of migrant shorebirds in wet fields with less than 50% vegetation cover, although this habitat only comprised 19% of available habitat. Wading bird species were also most abundant in wet fields that were less than 50% covered by rice vegetation.

Flooding rice fields in winter confers a number of other indirect benefits to waterbirds. Increased densities of waterfowl foraging in flooded fields may help reduce biomass of weed seeds that otherwise would encourage farmer use of herbicides (Maul and Cooper 2000, Eadie et al. 2007). Flooding rice fields accelerates decomposition of residual straw (Bird et al. 2000) and production of valuable invertebrate foods may increase where there is abundant senescing detritus (Fredrickson and Taylor 1982). By accelerating decomposition rates, flooding also reduces the need for tillage (Bird et al. 2000).

The depth to which rice fields are flooded will greatly influence the occurrence and densities of species attracted to flooded fields. In general, research indicates that rice fields used by waterfowl and wading birds have significantly deeper water than fields not used by these groups, and that fields used by shorebirds have significantly shallower water than those without shorebirds (Elphick and Oring 2003). Median water depths used by various waterbird species in California rice fields were: 24-33 cm for diving species, 18-26 cm for geese, 14-22 cm for dabbling ducks, 9-20 cm for wading birds, and 3-13 cm for shorebirds (Elphick and Oring 1998). Evaluations of the overlap in foraging depths used by different species suggest that depths between 10-20 cm will simultaneously benefit the most waterbirds, and that maintaining average depths towards the lower end of this range may be optimal because fewer species are excluded from a shallow field than from a deep field (Elphick and Oring 1998, 2003). Indeed, waterbird species richness peaked at intermediate depths (Elphick and Oring 2003). In California, most rice fields are typically flooded to depths greater than 20 cm for much of the winter, and only attain depths where waterbird use is expected to be greatest in early spring, when rice growers begin to drain fields (Elphick and Oring 2003).

Sowing and Stand Density

Timing of rice planting may influence various aspects of waterbird use of rice fields. In eastern Australian rice fields, Richardson and Taylor (2003) found that wading bird use of rice fields declined four to six weeks after sowing as vertebrate prey would became less accessible in growing rice. Moreover, planting rice in early spring may reduce loss to insect pests and has been suggested as a non-lethal alternative to using pesticides (Eadie et al. 2007). New sprouting rice from early spring plantings, however, may be more vulnerable to grazing by waterbirds such as geese and coots, which are present in rice fields during early spring before they migrate north (Piper 1944, van Way 1986). Along the Gulf Coast of North America, researchers recommend planting rice around the end of April to minimize damage from blackbirds (Wilson et al. 1989). The effect of timing of rice seed planting on nest success is generally unknown: timing did not affect nest density or nest success of various waterbirds (including Fulvous Whistling-Duck, Purple Gallinule, and Conservation Priority Species King Rail) documented breeding in Louisiana rice fields (Pierluissi 2006), but the planting window evaluated was relatively short.

The method of rice sowing has also been shown to influence bird use or nest success in some locales. Rice can be sown either by aerially dispersing seed in flooded habitat (“water-seeded”), or by spreading or drilling seed on dry ground (“dry-seeded”) (Hohman et al. 1994, Richardson and Taylor 2003, Tourenq et al. 2003). In the Camargue region of southern Europe where rice is planted in spring, use of fields during spring migration was higher in water-seeded than in dry-seeded fields. In Gulf Coast rice fields of Louisiana, Hohman et al. (1994) observed no differences in nest densities of five species of waterbirds (Fulvous Whistling-Duck, Purple Gallinule, Common Moorhen, Least Bittern, and King Rail) among water-seeded and dry-seeded fields sown in spring. However, for unknown reasons, apparent nest success of Fulvous Whistling-Ducks was twice as high in water-seeded rice fields than in dry-seeded fields (Hohman et al. 1994).

Finally, density of rice plants may be important to the breeding birds that nest in rice fields. Hohman et al. (1994) found that the nest densities of four waterbird species tended to be greater in dense (45.2 ± 7.5 nests/km^2) than in more sparsely vegetated (29.2 ± 3.9 nests/km^2) rice stands.

Irrigation

Along the Gulf Coast, rice is commonly irrigated by shallow flooding (7-10 cm) during the summer growing season (Huner et al. 2002, Pierluissi 2006). Such irrigation attracts breeding waterbirds such as rallids (rails, gallinules, coots) and bitterns that tend to build their nests near or over water (Helm et al. 1987, Hohman et al. 1994, Pierluissi 2006).

Pesticide Use

The rice industry has used a number of pesticides to combat animal and plant pests responsible for major losses in revenue. Insecticides that have been used to combat animal pests such as the Rice Water Weevil (*Lissorhoptrus oryzophilus*) include organochlorines (e.g., aldrin, dieldrin or toxaphene), organophosphates (e.g., methyl parathion, also called Azodrin), carbamates (e.g., carbofuran, also called Furadan), and pyrethroids. Herbicides such as molinate, propanil, bensulfron methyl, and thiobencarb have been used to minimize economic loss from plant pests such as Barnyardgrass and Red Rice. Impacts of some of these chemicals on waterbirds have been documented, with negative effects varying in severity from impacting invertebrate food resources to causing avian mortality.

Many pesticides used in rice fields have been observed to decrease abundance of waterbird foods. Granular carbofuran is highly toxic to the fish and invertebrate resources on which many foraging waterbirds depend (Flickinger et al. 1980, Osten et al. 2005). For instance, significant decreases in macroinvertebrate abundances were observed in Senegal rice fields after the application of carbofuran (Mullié et al. 1991). In the Camargue region of southern Europe, Tourenq et al. (2003) observed lower waterbird use of older rice fields with a longer history of pesticide application, and attributed this to greatly altered invertebrate communities. Moreover, the more recent advent of genetically modified (GM) rice varieties and concomitant use of herbicides that target all plant species except the GM crop pose a serious threat to the weed seed resources important to granivorous waterbirds.

Most of the pesticides historically used in rice fields have been deadly to birds, and there are many past cases of waterbird mortalities caused by pesticides. From the late 1950s through the 1970s throughout rice fields along the Gulf Coast of Texas, various insecticides were responsible for the deaths of large numbers of wintering and migrating waterfowl, mostly Snow Geese and Blue-winged Teal (Hobaugh et al. 1989). Field observations and experiments indicate that exposure to seeds treated with the organochlorine aldrin lead to significant casualties (Flickinger and King 1972, Flickinger 1979). Granular carbofuran is highly toxic to birds (Flickinger et al. 1980, Osten et al. 2005). In the 1980s, fatal waterbird and landbird poisonings from carbofuran were reported in rice fields of Texas (Flickinger et al. 1986) and California (Littrell 1988). White et al. (1983) documented lethal poisoning of waterfowl by methyl parathion in Louisiana rice fields. In the early 1980s, the herbicide molinate was responsible for the death of thousands of fish in rice field drain waters of California (CH2MHill 1996).

Since the mid 1970s, however, tighter regulation of the use of harmful pesticides has been enacted, and safer alternative pesticides and crop management practices that reduce loss to pests are under consideration (Eadie et al. 2007). Pesticide treated rice seed (including aldrin) and aerial applications of toxaphene are now banned, and carbamate applications are severely restricted (Hobaugh et al. 1989). Correspondingly, large waterbird die-offs have not been reported in Texas since these regulatory changes (Hobaugh et al. 1989). Pesticide loading into rivers and drainage canals has been greatly reduced through various voluntary regulatory programs (e.g., CH2M Hill 1996). New pesticides (e.g., fipronil) with fewer adverse impacts on wild birds (Avery et al. 1998) are being evaluated as replacements for carbamates. Delayed flooding and early planting are alternative practices suggested to reduce crop losses to animal pests (Eadie et al. 2007). Moreover, encouraging wintering waterfowl to forage on weed seeds by flooding fields to appropriate depths may also decrease the need for herbicides (McAtee 1923, Fontenot 1973, Smith and Sullivan 1980, Manley et al. 2005, Eadie et al. 2007).

Management of Pest Bird Species

Some waterbird species such as coots and blackbirds can significantly reduce rice seed yields by feeding on the new shoots of rice or on seed during the 'dough' stage prior to hardening (Piper 1944, Neff 1957, Gorenzel et al. 1986, van Way 1986, Avery 1989). Although control methods such as hazing, shooting, use of avicides, and lethal baiting have had some success in reducing crop damage (Neff 1957, White et al. 1985, Wilson et al. 1986, Avery et al. 1995), lethal measures may result in the death of desirable non-pest waterbirds (White et al. 1985, Primus et al. 1997). Potential non-lethal alternative methods of control include adjusting the timing of farm production practices (planting, harvest) so that crop resources are not most abundant and available during peak abundances of pest species (White et al. 1985), use of chemical repellants affecting the palatability of seeds (Avery 1989, Avery and Decker 1991, Avery et al. 1993, Avery et al. 1995, Avery et al. 1996, Avery et al. 1997), or use of deterrents affecting the foraging behavior of birds (e.g., propagation of seeds that prolong seed handling time or capitalize on seed color avoidance) (Daneke and Decker 1988, Avery et al. 1999).

Harvest Methods

During rice harvest, the travel speed and settings of the combine harvester, as well as the weather and seed moisture at the time of harvest, have all been demonstrated to affect the amount and timing of waste rice available to foraging waterbirds (Wilson et al. 2001, Miller et al. 1984, Miller et al. 1985). Miller et al. (1985) found that abundance of waste rice decreased with increased harvester travel speed, but Wilson et al. (2001) documented an increase in waste rice available as harvest speed increased beyond 2 mph. Under wet weather conditions, harvester efficiency is reduced, thus increasing the amount of waste rice available to birds. Farmers, however, typically delay harvesting under wet conditions, thus substantially setting back the timing of waste rice availability for waterbirds (Miller et al. 1985). Delayed harvest can also result from severe weather events that knock down or “lodge” rice vegetation, and such lodging typically impairs harvester efficiency, resulting in an increase in the availability of waste rice (J. Stafford, Illinois Natural History Survey, pers. comm.).

The type of combine header used to harvest rice influences the height of the remaining rice stubble and the amount of waste grain left in fields, in turn influencing the use of fields by waterbirds (Day and Colwell 1998, Eadie et al. 2007). Whereas “strip” harvesters efficiently strip grain off the stalk, leaving taller stubble and less waste grain, conventional harvesters collect grain by cutting rice stalks closer to the base, leaving shorter stubble and more waste grain (Miller and Wylie 1996, Day and Colwell 1998, Shimada 2002, Eadie et al. 2007). Increases in numbers of geese wintering in rice fields in northern Japan have been attributed to a corresponding replacement of reapers with modern conventional combine harvesters that actually leave more waste grain in fields (Shimada 2002). In California, Day and Colwell (1998) observed fewer waterbird species on average in fields that had been strip-harvested than in conventionally harvested fields, but it was not clear for most species whether the difference was due to vegetation height influencing predator detection, or to grain food abundance. Tall species such as Great Egret and Great Blue Heron, which are carnivorous and thus less likely to be influenced by grain abundance were the species most often observed in fields that had been strip-harvested (Day and Colwell 1998), and secretive species such as American Bittern and Sora may be attracted to such cover (C. Elphick, personal observation). In contrast, Day and Colwell (1998) observed smaller granivorous species such as geese, which are shorter than the height of the stubble, in strip-harvested fields in lower numbers compared to conventionally harvested fields. Eadie et al. (2007) suggest that the potential negative effects of tall stubble on smaller granivores could be easily alleviated by cutting stubble after harvest is complete.

Timing of harvest may also alter food availability in rice fields. In the **Mississippi Alluvial Valley** (BCR 26), Manley (1999) documented that in fields with quick maturing rice varieties enabling early harvest in August-September, 79-93% of the waste grain had disappeared due to germination, decomposition and granivory by mid December. Stafford (2004) documented similar declines in waste rice abundance in Mississippi rice fields, estimating that the MAV may in fact only support 17-48% of estimated wintering waterfowl carrying capacity projected for the region by the Lower Mississippi Valley Joint Venture. In some regions of the Gulf Coast, second ratoon rice crops are grown without re-sowing simply by irrigating and fertilizing harvested fields. Ratoon crops provide an important fresh fall food resource for wintering waterbirds (Hobaugh et al. 1989). In the **Mississippi Alluvial Valley** (BCR 26) in particular, where availability of waste grain from early maturing rice crops alone may be insufficient to support targeted wintering waterbird populations (Stafford et al. 2006), ratoon crops may be an extremely valuable resource.

Crop Rotation, Secondary Crops, and Fallow Land

In many rice-growing regions, weeds, pests and the need to maintain soil fertility preclude continuous rice production. Thus, in the **Mississippi Alluvial Valley** (BCR 26), rice is grown in rotation with soybeans (Twedt et al. 1998), and along the Gulf Coast of Texas, rice fields are planted in rotation with other row crops such as sorghum or soybeans (Hobaugh et al. 1989). In California, only 30% of rice is grown in rotation with other cereal crops because few other crops are capable of growing in the poorly-drained soils where rice is grown (Hill et al. 1992). Flooded soybean and other cereal grain (oats, barley, wheat) fields may provide valuable interim habitat for some waterbird species (see WHEAT and SOYBEAN chapters). However, while rotation out of rice generally facilitates the growth of seed-producing plants important to waterfowl and other granivorous species (Hobaugh et al. 1989), rice rotation with soybeans may not provide the same results. Rotating rice with herbicide-resistant soybeans allows producers to kill weed plants that would normally arise in the following year's rice crop, and may seriously diminish the availability of weed species resources in rice fields (J. Stafford, Illinois Natural History Survey, pers. comm.).

Along the Gulf Coast (BCR 37) and in the **Mississippi Alluvial Valley** (BCR 26), rice is commonly grown in rotation with catfish or crayfish (Horn and Glasgow 1964, Rettig 1994). Since these fields remain flooded during rotation, they retain aquatic invertebrate communities that provide food for waterbirds, and use is determined primarily by water depth management. When fully flooded for catfish or crayfish (typically to depths of 20-60 cm), these fields can provide valuable foraging habitat for diving waterbirds, or resting habitat for waterbirds that feed in nearby shallower rice fields (Horn and Glasgow 1964, Huner et al. 2002). During flood-up and drawdown, however, they also may provide valuable habitat to shallow-water species such as migrating shorebirds and wading birds (Huner et al. 2002). Along the Gulf Coast of Louisiana, Rettig (1994) observed similar abundances of migrating and wintering shorebirds foraging in drawn down rice fields being used for crayfish production as were observed in fields under rice production. A number of researchers have suggested that crayfish impoundments play an important role in maintaining populations of many waterbirds, primarily wading birds (Fleury and Sherry 1995, Huner 1995, Huner and Musumeche 1999).

Many rice fields are also left fallow in some years (Hobaugh et al. 1989, Hill et al. 1992). In California, for example, because few row crops are grown in rotation with rice, over 2/3 of fields not in production for rice are kept fallow (Hill et al. 1992). Plowed fallow rice fields can produce abundant green forage and moist-soil and weed seed resources (e.g., over 450 kg/ha in Louisiana) for foraging waterbirds (Horn and Glasgow 1964, Hobaugh et al. 1989). In a Northern Pintail habitat use study in the Gulf Coast region, Cox and Afton (1997) documented preference for fallow rice fields during the day, but use of fallow rice fields proportionate to their abundance at night. Mottled Ducks (Conservation Priority Species) on the Gulf Coast are more likely to nest in rice fields that are fallow than in those with a current crop (Durham and Afton 2003). In Japan, Fujioka et al. (2001) found that the diversity and abundances of foraging waterbirds during post-breeding and migratory periods were high in fallow rice fields, with open flooded fallow fields receiving greater use than dry or vegetated fallow fields. Also in Japan, Maeda (2001) observed similar patterns of fallow ricefield use by various waterbirds and landbirds during all seasons.

EFFECTS OF OTHER MANAGEMENT ACTIVITIES

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

Management of Edge Habitat

Influence of the management of ricefield edges (irrigation ditches, canals, levees) on waterbirds has been addressed by only a few researchers. In Japan, Lane and Fujioka (1998) compared wading bird use and invertebrate and vertebrate prey abundance in conventional shallow earthen ditches, in deep concrete-sided ditches and in rice fields adjacent to these two ditch types. Abundances of amphibian and fish prey were higher in conventional ditches and adjoining rice fields than in concrete ditches and the rice fields they irrigated. Of five wading bird species, only one egret species was more abundant in conventional ditches and fields. However, the other four species occurred in low numbers overall, possibly precluding finding any patterns in use among field and ditch types. In a similar region of Japan, Maeda (2001) observed that waterbirds used rice fields irrigated by either ditch type, but no species occurred within ditches of either kind, even though these presumably contained prey.

Hunting Activity

Recreational waterfowl hunting is a common pastime on rice fields around the world (Hobaugh et al. 1989, Reinecke et al. 1989, Mathevet and Tamisier 2002), and in some regions such as along the Gulf Coast of North America, hunting revenues are a major economic incentive to keeping lands in production for rice (S. King, USGS Biological Resources Division, Louisiana State University, pers. comm.). It is important to recognize, however, that the presence or absence of hunting activities can highly influence waterbird abundances and temporal patterns of ricefield use. In North America, the percentage of rice fields receiving hunting pressure varies from 75% in California to over 95% along the Gulf Coast (Hobaugh et al. 1989, Garr 2002). Hunting activities generally deter most waterfowl from using fields until night when hunting temporarily ceases (Eadie et al. 2007). Northern Pintail use rice fields that are not subjected to hunting as refuge resting and feeding sites by day, traveling at night to feed in nearby day-hunted rice fields or wetlands (Miller 1985, Rave and Cordes 1993). In California, the high percentage (25%) of non-hunted refuge rice fields has been evoked as responsible for a general northward shift in the distribution of wintering pintail from the southern San Joaquin Valley where the majority of wetlands receive hunting pressure to the relatively less hunted Sacramento Valley rice-growing region (Fleskes et al. 2002).

EFFECTS OF LANDSCAPE FEATURES

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

Field Size

The size and physical dimensions of rice fields may influence the diversity and densities of waterbirds using them (Hohman et al. 1999, Treca 1999), although this issue has been addressed by only a few researchers. In Gulf Coast Louisiana, Hohman et al. (1999) found greater diversity and densities of waterbirds in larger rice fields, but Rettig (1994) found no relationship between shorebird densities and rice field size. Maeda (2005) observed a significant positive correlation between waterbird species richness and the width of narrow rice field strips that are typical along upland rivers in Japan.

Landscape Context

In addition to crop production methods, studies in wetland landscape ecology (Naugle et al. 1999, Riffell et al. 2003) suggest that waterbird use of rice fields could be affected by habitat features of the surrounding landscape, or by the “landscape context” of fields. The coverage, placement and connectivity of various features in the surrounding landscape may be important, including that of other suitable habitat, natural wetlands, hunting refuges, and roads and other sources of disturbance. From a regional management perspective, landscape context issues of particular interest include understanding the extent to which modifications to the quantity or quality of surrounding flooded habitats, either rice or natural wetland, might impact the use and value of individual rice fields. How would a decline in the acreage of rice in a region impact the value of flooded rice as habitat for waterbirds, and similarly, how will the modification of natural wetlands in an area impact the value of rice fields in that region?

The few studies that have addressed this issue for rice suggest that landscape context does influence use of individual rice fields by waterbirds. In California, Shuford et al. (1996) found that wintering White-faced Ibis foraged primarily in rice fields within 5 km of managed wetlands, which they likely used for nocturnal roosting. Also in California, Elphick (1998) observed a positive relationship between the densities of wintering waterbirds in fields and the amount of managed refuge wetland surrounding fields. Duck densities in rice fields also increased with greater amounts of flooded rice habitat within a 5-km radius. Such increases in waterbird densities at individual sites with increasing area of habitat in a region suggest that waterbirds are disproportionately attracted to regions where flooded habitats are concentrated. Context may be influential during the breeding season as well. In southwestern Louisiana, Pierluissi (2006) documented higher densities of Purple Gallinule and King Rail nests in rice fields with higher edge coverage by irrigation canals and trees. Purple Gallinule nest density also increased with the proportion of rice fields within a 1 km radius, and the density of Fulvous Whistling-Duck nests increased with the proportion of the surrounding habitat planted to growing soybeans. In California, rice fields that are surrounded by growing wheat and barley commonly receive Mallard broods hatching from these fields (Yarris 1995, McLandress et al.

1996). Understanding how landscape context influences use of rice fields by waterbirds could affect a number of management outcomes, including whether fields will attract enough foraging waterfowl to achieve enhanced straw decomposition rates (Bird et al. 2000, van Groenigen et al. 2003), or whether new rice fields or restored wetland sites expected to benefit wildlife will receive adequate use by waterbirds.

SUMMARY AND SYNTHESIS

The following is a summary of the major themes relating to waterbird use of rice fields, waterbird resources found in rice habitats, positive and negative effects of rice production and other practices on waterbirds, and gaps in our knowledge of these topics. We synthesize these things to provide a sense of the present challenges faced by wildlife managers in rice systems, and of the future research needed to resolve these challenges.

Waterbird Use

A great wealth of information indicates that resources provided by rice fields are used by many waterbird species in North America (Table 3-1), and that ricelands provide extremely valuable habitat to waterbirds, particularly in regions where wetlands have been significantly reduced (e.g., Remsen et al. 1991, Elphick and Oring 1998, Twedt et al. 1998, Elphick and Oring 2003, Elphick 2004). In North America, most waterbirds use rice fields for foraging during nonbreeding periods. Among waterbird groups, use of rice fields is by far the best-documented for waterfowl, with large numbers of birds observed foraging in fields during migration and winter, and some species nesting and rearing broods in rice habitats in spring and summer. There is also strong evidence that various shorebirds, wading birds, other waterbirds, and WWL landbirds also rely heavily on rice fields for a number of resources. Shorebirds use rice fields as foraging habitat primarily in winter and during migration, sometimes in numbers similar to waterfowl. Although less abundant, wading birds and some other waterbird species (mostly coots, rails, and gulls) maintain a constant presence throughout the year, using rice habitats for both foraging and nesting. Landbird use has been documented primarily during nonbreeding periods, but some species also breed in rice fields.

WWL Species and Bird Conservation Regions

Of the 216 species identified for the Waterbirds on Working Lands project, 104 species have been observed in rice fields in North America, of which 30 are WWL species of Conservation Priority (Table 3-1). Of these 104 species, at least 101 use rice fields during winter or migration, and only 20 species (including 6 Conservation Priority Species) have been documented foraging or nesting in rice habitats during the breeding season. Species observed in North American rice habitats during the breeding season include three species of waterfowl [Fulvous Whistling-Duck, Mottled Duck (Conservation Priority Species), Mallard], three shorebirds (Killdeer, American Avocet, Black-necked Stilt), nine wading birds [White-faced Ibis, Great Egret, Little Blue Heron (Conservation Priority Species), Great Blue Heron, Black-crowned Night-Heron, Snowy Egret, Cattle Egret, American Bittern (Conservation Priority Species), Least Bittern], four other waterbird species [King Rail (Conservation Priority Species), Common Moorhen, Purple Gallinule, Black Tern (Conservation Priority Species)], and two WWL landbirds [Red-winged Blackbird, Tricolored Blackbird (Conservation Priority Species)]). In the **Mississippi Alluvial Valley** (BCR 26), only 24 out of the 118 WWL focal species identified for this region have been documented using rice fields - all 24 during winter or migration, and only two species (King Rail and Red-winged Blackbird) during the breeding season (Table 3-1). This low number could be caused by a general lack of available documentation of use of MAV rice fields by species other than waterfowl (see below **Knowledge Gaps and Research Needs**).

Rice Resources

The foraging resources provided to waterbirds by rice fields include rice and moist soil weed seeds (e.g., Reinecke et al. 1989, McAbee 1994, Hohman et al. 1996, van Groenigen et al. 2003), green forage (e.g., Leslie and Chabreck 1984, Alisauskas et al. 1988, Beedy and Hamilton 1999), aquatic invertebrates (e.g., Loughman and Batzer 1992, McAbee 1994, Hohman et al. 1996, Huner et al. 2002), and aquatic vertebrates (e.g., Fasola and Ruiz 1997, Lane and Fujioka 1998). The caloric value of rice seed ranks moderately high compared to other cereals and moist-soil seeds (Reinecke et al. 1989, Petrie et al. 1998). Little is known about variation in the abundance of aquatic invertebrates across rice-growing regions, but densities appear to be comparable to those typically found in some highly-productive moist-soil wetland impoundments. Dabbling ducks and geese rely on some mixture of moist-soil and weed seeds, green forage, and invertebrates; shorebirds feed heavily on invertebrates; and wading birds and other waterbirds obtain a mixed diet including vertebrate prey such as amphibians and fish available in rice habitats. For a smaller subset of waterbird species, breeding resources provided by ricelands include nesting habitat (including vegetation for nest bowl construction), and brood-rearing habitat where fields and associated habitats are flooded (e.g., Yarris 1995, McLandress et al. 1996, Hohman et al. 1994, Shuford et al. 2001, Pierluissi 2006). In North America, species associated with rice habitats during the breeding season (either for foraging or nesting) include representatives from all waterbird groups, although waterfowl, wading birds and rails have been most frequently studied. Flooded rice fields also provide resting habitat for virtually all waterbird species studied during nonbreeding periods (Miller 1985, Rave and Cordes 1993, Cox and Afton 1998, Elphick 2000).

Practices Benefiting Waterbirds

Available information indicates that waterbirds can benefit from many agronomic practices and at all phases of rice production. Current practices that positively influence the suitability of fields for many waterbirds include some residual straw management techniques, shallow winter flooding, lessened use of harmful pesticides, and fallow and secondary crop rotations (Table 3-3). While the positive effects of some of these practices have been explicitly documented within **Mississippi Alluvial Valley** (BCR 26) rice fields, responses to other practices have been learned from rice fields elsewhere in North America or from other parts of the world.

Although the relative value of different straw management methods remain somewhat unclear (Elphick and Oring 2003, Elphick et al. 2007), there is some evidence that incorporating straw by plowing might favor invertebrate reproduction and therefore the waterfowl and shorebird species that forage heavily on invertebrates in rice fields. Winter flooding boosts invertebrate productivity (Frederick and Taylor 1982), and where fields are managed at shallow average depths (10-20 cm), a diversity of waterbirds are guaranteed access to available invertebrates and seed resources (Elphick and Oring 1998, 2003). Promising alternatives to lethal pesticides used extensively in the past include use of less dangerous chemicals, delayed spring flooding, early planting, and management to encourage waterfowl to forage on weed seeds (Fontenot 1973, Smith and Sullivan 1980, Eadie et al. 2007). Rotation of rice fields with alternative crops such as soybeans, or crayfish as commonly practiced along the Gulf Coast (BCR 37) or in the **Mississippi Alluvial Valley** (BCR 26) may benefit waterbirds by providing important interim foraging habitats (see also SOYBEAN chapter) and by increasing rice seed yields available to birds after future harvests (e.g., Hobaugh et al. 1989, Twedt et al. 1998, Huner et al. 2002). Periodic fallowing of habitat can dramatically boost green forage and moist-soil resources for waterfowl and other granivores (Horn and Glasgow 1964, Hobaugh et al. 1989). Finally, research suggests that by attracting waterbirds to flooded rice fields, rice growers will in turn benefit from enhanced straw decomposition, reduced weed pressure, and a decreased need for herbicides (Bird et al. 2000).

Practices Negatively Affecting Waterbirds

Despite the many benefits of rice farming, there are some farming practices that may adversely impact waterbirds and that present future obstacles or challenges towards maximizing the conservation value of ricelands. These practices may ultimately reduce the carrying capacity of many rice-growing regions to sustain waterbird populations through nonbreeding periods. Potentially negative practices include improper management of water depth, straw incorporation methods that decrease access to waste grain, continued pesticide use, and both early harvests and new mechanical harvest methods, which reduce food availability to waterbirds (Table 3-3).

Post-harvest straw management practices such as disking, rolling, chopping and burning all potentially decrease the availability of waste grain and other foods to waterbirds (Nelms and Twedt 1996). Complete removal of straw for other uses (construction, ethanol production), a new straw management practice gaining some attention in the rice industry, would make flooding rice fields to enhance decomposition unnecessary and ultimately diminish their value to waterbirds (Eadie et al. 2007). For many rice fields, water depths are typically managed deeper than the average 10-20 cm depth expected to provide access to the greatest diversity of foraging waterbirds (Elphick and Oring 2003). Shallow flooding should be promoted not only to benefit the most species, but also because it reduces water costs to growers and is unlikely to compromise yields (Elphick and Oring 1998, 2003). Maintaining shallow depths in the face of evaporative water loss may be achieved by reserving water (blocking field drainage outlets and retaining any rainwater) in select fields (Eadie et al. 2007). Until safer pesticides or alternative control measures are widely established across rice-growing regions, sporadic crisis use of more harmful pesticides will continue to pose a threat to waterbirds using rice fields (Eadie et al. 2007). Finally, in regions where quick-maturing rice varieties allow for early harvests (particularly in the MAV), loss of waste rice due to germination, decomposition and other foraging wildlife may be substantial before the arrival of wintering waterfowl (Manley 1999). Research indicates that the method of strip harvesting further reduces the amount of waste grain available to waterbirds (Miller and Wylie 1996, Day and Colwell 1998, Shimada 2002).

Knowledge Gaps and Research Needs

Of the nine focal row crops reviewed in the Waterbirds on Working Lands project, we know the most by far about how waterbirds use ricelands and are affected by rice production practices. Meeting the full conservation potential of rice fields, however, will require an effort to fill some key remaining knowledge gaps. We briefly summarize these here.

Waterbird Use
Among the three major rice-growing regions in North America, we know the least about waterbird use of rice fields in the **Mississippi Alluvial Valley** (BCR 26), especially for shorebird, wading bird and WWL landbird species that regularly occur in the region (see Table 3-1). Moreover, in regions where hunting pressure is high, we do not have a complete picture of waterfowl use of rice fields because most surveys have been conducted during the day, while much use occurs at night. In general, we do not know much about how waterbirds select particular rice fields at various spatial scales, especially in relation to the abundance of food resources. For all rice-growing regions, there are large gaps in our knowledge of the ecology of waterbirds that use rice habitats for nesting, brood-rearing, and foraging during the breeding season, especially species other than waterfowl and rails. Understanding how conservation priority species (Table 3-1) use ricelands throughout the year will be vital. There is little information on how WWL landbirds use and benefit from rice habitats. Finally, there is relatively little information on the use and value of ancillary habitats associated with rice fields, in particular the drainage ditches that deliver water to fields, and which might provide important habitat for some species during both the breeding and nonbreeding seasons.

Resources
Understanding the carrying capacity of rice-growing regions to support wintering and migratory waterbird populations will require greater information on the abundance and availability of rice resources (rice, moist-soil seeds, green forage, and invertebrates) and their consumption by waterbirds. In the **Mississippi Alluvial Valley** (BCR 26), research to determine if ratoon crops can be grown at northern (i.e. Arkansas) latitudes, and to what extent they act to complete the rice resource base for waterbirds, would be helpful. Little is known about the abundance of rice and moist soil seeds (including weed seeds) and their importance to nesting species during the breeding season. Documentation of breeding success in rice habitats would be valuable, particularly how success relates to availability of food resources, management practices, and predator activity. Reliance of wading birds on vertebrate prey and the abundance of these foods in various rice habitats, particularly irrigation ditches, have not been evaluated in North American rice fields but have been found to be important elsewhere in the world. More generally, the factors limiting populations of waterbirds that use rice fields are generally not known and so it remains difficult to fully assess how changing management practices will affect species abundance.

Effects of Crop Production Methods, Other Management Activities, and Landscape Features
While the proximate, short-term effects of some practices are fairly well established, others are relatively unknown and require further research (Table 3-3). Understanding the cost-effectiveness of the various alternatives to lethal control of bird pests (e.g., blackbirds) is needed before widespread adoption of such practices occur. How harvest (timing and harvester type) and straw incorporation (burning, rolling, plowing, chopping) methods impact availability of food resources and waterbird use of rice fields remains somewhat uncertain, and requires further research. Although these relationships have been fairly well established for California rice fields, we need better documentation of the phenology and intensity of use by some species in other rice-growing regions, particularly in the **Mississippi Alluvial Valley** (BCR 26). From the farmer's perspective, studies that examine the economic trade-offs involved in winter-flooding would be valuable, especially assessing the consequences of hunting (which provides increased

revenue through leasing fees) versus no-hunting (which might provide benefits in the form of increased straw decomposition, weed seed control, etc.). Since so many species use rice fields, and different species require different conditions, no single set of management practices will benefit all species that use the crop. In order to maximize the benefits that waterbirds as a group can gain from using rice fields during nonbreeding periods, the trade-offs between different waterbird species need to be examined. In particular, studies that examine the costs and benefits of different strategies for managing water depth, timing and duration of winter-flooding, and alternative uses of fields (e.g., crayfish farming, waterfowl hunting), etc. would be helpful. Continued research on alternatives to pesticide use including use of low toxicity chemicals or crop management practices that reduce the need for chemical control would be immensely valuable. A greater understanding of the role of landscape context in the use of rice fields by waterbirds should enable the development of more comprehensive landscape management strategies for each rice-growing region.

Finally, although some research has attempted to compare the impacts of various rice production alternatives (e.g., pesticide use, timing of sowing and flooding) on the nest success, brood survival or adult mortality of waterbirds, 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 rice fields. The most exciting and valuable future research questions will undoubtedly involve evaluating how to balance the economic viability of rice production practices in each region with the efficient use and allocation of water and the management of rice habitats in ways that simultaneously benefit farmers and multiple waterbird species.

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Table 3-1. Waterbird species reported in or in association with rice fields in North America and in focal BCR 26 (Mississippi Alluvial Valley) during winter, migration, and breeding seasons. Use by landbirds presented only for species on the Waterbird on Working Lands (WWL) species list. Rare species (only a few records for species) are indicated with “rare.” Apparent absences may reflect incomplete information in the published literature for a given season or region.

GROUP Common name	On WWL Species List	On MAV - BCR 26 Regional List	WWL Conservation Priority Species	Occurrence in North America: Winter[a]	Occurrence in North America: Migration[a]	Occurrence in North America: Breeding Foraging	Occurrence in North America: Breeding Nesting	Occurrence in BCR 26 (MAV): Winter[a]	Occurrence in BCR 26 (MAV): Migration[a]	Occurrence in BCR 26 (MAV): Breeding Foraging	Occurrence in BCR 26 (MAV): Breeding Nesting
WATERFOWL											
Tundra Swan	X			X							
Fulvous Whistling-Duck	X				F	X	X				
Wood Duck	X	X		X	F						
Lesser Snow Goose	X	X		X	S/F			X			
Ross’s Goose	X			X	S/F						
Greater White-fronted Goose	X	X		X	S/F			X			
Canada Goose	X	X		X	S/F			X			
Cackling Goose				X	S/F						
Common Goldeneye	X	X		rare	S/F (rare)						
Canvasback	X	X	X	rare	S/F (rare)						
Redhead	X	X	X	rare	S/F (rare)						
Ring-necked Duck	X	X		rare	S/F (rare)						
Bufflehead	X	X		rare	S/F (rare)						
Greater Scaup	X	X	X	rare	S/F (rare)						
Common Merganser	X			rare	S/F (rare)						
Hooded Merganser	X	X		rare							
Ruddy Duck	X	X		rare	S/F (rare)						
Mallard	X	X		X	S/F	X	X	X			
Mottled Duck	X	X	X	X	F	X	X				
Northern Pintail	X	X	X	X	S/F			X			
Northern Shoveler	X	X		X	S/F			X			
Cinnamon Teal	X			X	S/F						
Green-winged Teal	X	X		X	S/F			X			
Blue-winged Teal	X	X		X	S/F						
American Wigeon	X	X		X	S/F			X			
Eurasian Wigeon				X							
Gadwall	X	X		X	S/F			X			

Table 3-1. Continued.

GROUP Common name	On WWL Species List	On MAV - BCR 26 Regional List	WWL Conservation Priority Species	Occurrence in North America: Winter[a]	Occurrence in North America: Migration[a]	Occurrence in North America: Breeding Foraging	Occurrence in North America: Breeding Nesting	Occurrence in BCR 26 (MAV): Winter[a]	Occurrence in BCR 26 (MAV): Migration[a]	Occurrence in BCR 26 (MAV): Breeding Foraging	Occurrence in BCR 26 (MAV): Breeding Nesting
SHOREBIRDS											
Black-bellied Plover	X	X		X	S/F						
American Golden-Plover	X	X	X		S						
Semipalmated Plover	X	X			S/F						
Killdeer	X	X		X	S/F	X	X				
American Avocet	X	X		X	S/F	X	X				
Black-necked Stilt	X	X		X	S/F	X	X				
Greater Yellowlegs	X	X		X	S/F			X			
Lesser Yellowlegs	X	X	X	X	S/F			X			
Long-billed Curlew	X	X	X	X	S						
Whimbrel	X		X		S						
Willet	X	X			S						
Solitary Sandpiper	X	X	X		S/F (rare)						
Dunlin	X	X		X	S/F			X			
Least Sandpiper	X	X		X	S/F						
Western Sandpiper	X	X		X	S/F			X			
Semipalmated Sandpiper	X	X			S/F						
Buff-breasted Sandpiper	X	X	X		S						
White-rumped Sandpiper	X	X			S						
Pectoral Sandpiper	X	X			S/F				F		
Spotted Sandpiper	X	X			S/F (rare)						
Upland Sandpiper	X	X	X		S/F (rare)						
Stilt Sandpiper	X	X	X		S/F						
Long-billed Dowitcher	X	X		X	S/F						
Wilson's Snipe	X	X		X	S/F			X			
Wilson's Phalarope	X	X	X		S/F						
Red-necked Phalarope	X		X		S						

Table 3-1. Continued.

GROUP Common name	On WWL Species List	On MAV - BCR 26 Regional List	WWL Conservation Priority Species	Occurrence in North America: Winter[a]	Occurrence in North America: Migration[a]	Occurrence in North America: Breeding Foraging	Occurrence in North America: Breeding Nesting	Occurrence in BCR 26 (MAV): Winter[a]	Occurrence in BCR 26 (MAV): Migration[a]	Occurrence in BCR 26 (MAV): Breeding Foraging	Occurrence in BCR 26 (MAV): Breeding Nesting
WADING BIRDS											
Wood Stork	X	X	X		F (rare)						
Roseate Spoonbill	X				F (rare)						
White-faced Ibis	X			X		X					
Glossy Ibis	X	X		X							
White Ibis	X	X		X	F						
Great Egret	X	X		X	F	X					
Great Blue Heron	X	X		X	F	X					
Snowy Egret	X	X		X	F	X					
Little Blue Heron	X	X	X	X	F	X					
Tricolored Heron	X	X			F (rare)						
Cattle Egret	X	X		X	F	X					
American Bittern	X	X	X	X	F (rare)	X					
Least Bittern	X	X				X	X				
Black-crowned Night-Heron	X	X		X	F (rare)	X					
Green Heron	X	X		rare							
Yellow-crowned Night-Heron	X	X			F (rare)						
OTHER WATERBIRDS											
Pied-billed Grebe	X	X		X							
Eared Grebe	X			rare							
Clark's Grebe	X		X	rare							
American White Pelican	X	X		X							
Double-crested Cormorant	X	X		X							
Sora	X	X		X				X	F		
Virginia Rail	X	X		rare	F (rare)			X			
King Rail	X	X	X	X	F (rare)	X	X	X			X

Table 3-1. Continued.

GROUP Common name	On WWL Species List	On MAV - BCR 26 Regional List	WWL Conservation Priority Species	Occurrence in North America				Occurrence in BCR 26 (MAV)			
						Breeding				Breeding	
				Winter[a]	Migration[a]	Foraging	Nesting	Winter[a]	Migration[a]	Foraging	Nesting
OTHER WATERBIRDS											
Yellow Rail	X	X	X	X				X			
Clapper Rail	X		X		F (rare)						
American Coot	X	X		X	F			X			
Common Moorhen	X	X		X	F (rare)	X	X				
Purple Gallinule	X					X	X				
Sandhill Crane	X		X	X	S/F						
Ring-billed Gull	X	X		X							
California Gull	X			X							
Herring Gull	X	X		X							
Black Tern	X		X			X	X				
Gull-billed Tern	X		X	rare							
Forster's Tern	X	X	X	X							
WWL LANDBIRDS											
Bald Eagle	X		X	X				X			
Belted Kingfisher	X			rare				X			
Black Phoebe	X			X							
Eastern Phoebe	X	X		X							
Fish Crow	X	X		rare							
Purple Martin	X	X		rare							
Sedge Wren	X	X	X	rare							
Marsh Wren	X	X		X							
Common Yellowthroat	X	X		X							
Lincoln's Sparrow	X	X		X							
LeConte's Sparrow	X	X	X	rare							
Red-winged Blackbird	X	X		X	S/F	X	X	X		X	X
Yellow-headed Blackbird	X			X							
Tricolored Blackbird	X		X	X		X					
Boat-tailed Grackle	X	X		X				X			

Table 3-2. Summary of rice resources available to waterbirds during the different phases of rice production in North America. Gray shaded boxes indicate not applicable, or resource not available during the time period.

RESOURCES	SOWING (Spring)	**PRE-HARVEST** (Growing Crop, Summer)	**HARVEST** (Fall)	**POST-HARVEST** (Late Fall, Winter, Early Spring)	**CROP ROTATION, FALLOW LAND**
FORAGING RESOURCES o Waste Rice	breeding waterfowl [1]		nonbreeding waterfowl, cranes [2-4]	migrant and wintering waterfowl, cranes, blackbirds [2-8]	
o Moist Soil Seeds		breeding waterfowl [1,9]	nonbreeding waterfowl, cranes [3,6,10-14]	migrant and wintering waterfowl, cranes [3,6,10-14]	fallow fields - nonbreeding waterfowl [10,15-17]
o Green Vegetation (new shoots of rice and moist soil seeds)	new shoots - spring migrant geese and American Coot [18-22]	new rice shoots – blackbirds [23]		new shoots - wintering geese [18-21] roots – swans [24]	fallow fields - nonbreeding waterfowl [10,15-17]
o Aquatic Invertebrates	breeding waterfowl [9], probably shorebirds and wading birds			migrant and wintering waterfowl, shorebirds, wading birds, other waterbirds [8,25-27]	crayfish as secondary crop - breeding and nonbreeding wading birds, shorebirds [17,28,29]
o Aquatic Vertebrate Prey	probably important to spring migrant wading birds, but undocumented	probably important to breeding wading birds, but undocumented		probably important to nonbreeding wading birds, but undocumented	
BREEDING RESOURCES o Nesting Habitat	13 species (3 waterfowl, 4 shorebird, 1 wading bird, 4 other waterbirds, 1 landbird) documented nesting in ricefield habitats [32-39]	13 species (3 waterfowl, 4 shorebird, 1 wading bird, 4 other waterbirds, 1 landbird) documented nesting in ricefield habitats [32-39]			Mottled Ducks prefer to nest in fallow ricefields along Gulf Coast [40]
o Brood-rearing Habitat				post-breeding waterfowl (Mallard) [38] and probably shorebirds, but undocumented	
RESTING HABITAT				all waterbirds [41-44]	

Table 3-2. Continued.

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Table 3-3. Summary of documented impacts of rice production methods, other management practices, and landscape features on waterbirds using rice fields in North America.

	SOIL AND RESIDUE MANAGEMENT	WINTER FLOODING	FLOOD DEPTH	SOWING METHODS (wet vs. dry)	STAND DENSITY	PESTICIDES organochlorines, organophosphates, carbamates	HARVEST METHODS (conventional vs. stripper-header)	CROP ROTATION, FALLOW LAND	MANAGEMENT OF EDGE HABITAT	FIELD SIZE
ALL WATERBIRDS	burning may decrease abundance, but may also increase access to seeds [1]; best straw treatment depends on waterbird group, but further research needed	higher in flooded overall [3-5]	10-20 cm [3]	no difference in nest density, but few species studied [6]	positively correlated with nest density, but few species studied [6]	negatively impacts all birds [7-13]	conventional leaves more waste rice and shorter residual straw than stripper; influences on waterbirds needs more research [2]	boosts growth of moist-soil plants[14]; secondary crops provide interim habitat [11,15]; effects on waterbirds untested	effects largely unknown	bigger fields attract more species and higher densities overall [16,17]
Waterbird Diversity	highest when straw rolled after flooding; lowest when straw removed prior to flooding [2,3]	higher in flooded [3-5]	10-20 cm [3]				higher in conventional[2]			+ correlated [16,17]
Waterbird Abundances	highest when fields flooded with no straw manipulation and when straw rolled before flooding [3]	higher in flooded [3-5]	10-20 cm [3]							+ correlated [16,17]

Table 3-3. Continued.

	SOIL AND RESIDUE MANAGEMENT	WINTER FLOODING	FLOOD DEPTH	SOWING METHODS (wet vs. dry)	STAND DENSITY	PESTICIDES organochlorines, organophosphates, carbamates	HARVEST METHODS (conventional vs. stripper-header)	CROP ROTATION, FALLOW LAND	MANAGEMENT OF EDGE HABITAT	FIELD SIZE
WATERFOWL	densities no different among treatments	higher densities in flooded [3-5]	14-33 cm [3]	no difference in nest density [6]	positively correlated with nest density [6]		higher in conventional [2]			
o **Geese**			18-26 cm [3]							
o **Dabbling Ducks**		higher densities in flooded [3-5]	14-22 cm [3]	no difference in nest density [6]	positively correlated with nest density [6]		higher in conventional [2]			
SHOREBIRDS	densities highest in fields that were plowed and then flooded [3]	higher densities in flooded [3-5]	3-13 cm [3]	effects largely unknown	effects largely unknown		higher in conventional [2]			
WADING BIRDS	densities highest when fields flooded with no straw manipulation [3]	higher densities of most species in flooded [3-5]	9-20 cm [3]	effects largely unknown	effects largely unknown		higher in conventional [2]			
OTHER WATERBIRDS	effects largely unknown	higher densities of most species in flooded [3-5]		effects largely unknown	positively correlated with nest density [6]		higher in conventional [2]			
LANDBIRDS	effects largely unknown	higher densities of some species in flooded [5]	not applicable	effects largely unknown						

Table 3-3. Continued.

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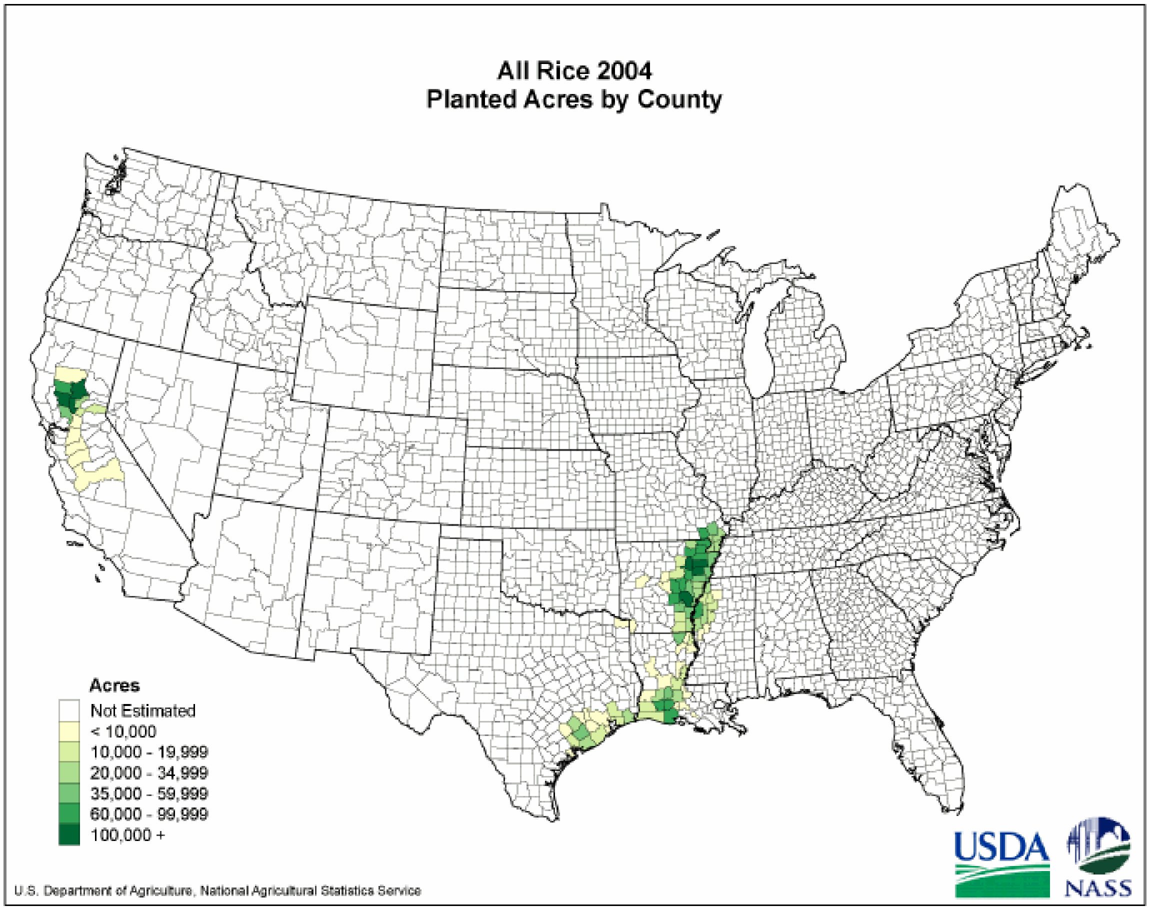

Figure 3-1. Map of the distribution of rice planted in the United States during 2004, the most recent year for which data are available. From the United States Department of Agriculture National Agricultural Statistics Service (http://www.usda.gov/nass/aggraphs/cropmap.htm; accessed 2 Jan 2007).