SECTION ONE

Wildlife Values of North American Ricelands

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ABSTRACT

Ricelands have become an indispensable component of waterbird habitat and a leading example of integrating agricultural and natural resource management in the Mississippi Alluvial Valley, Gulf Coast, and Central California. Residual rice, weed seeds, and invertebrates provide food for many avian species during fall and winter. In North America, considerable information exists on the use of ricefields by wintering waterbirds, the value of ricelands as breeding habitat for birds, and the effects of organic chemicals on birds that feed in ricefields. Recent research has also examined the influence of field management practices, such as winter flooding and post-harvest straw manipulation, on the suitability of ricefields for wildlife. Whereas early studies focused on detrimental effects of wildlife on rice production (e.g., crop depredation), it has become apparent that waterbirds may benefit producers by enhancing straw decomposition, reducing weed and pest pressure, and providing additional income through hunting and wildlife viewing opportunities. A comprehensive evaluation of agronomic and environmental issues is needed to meet the challenges of producing food and sustaining wildlife in twenty-first-century ricelands. Changes in agricultural markets, pressures of increased urban development, conflicting needs for limited resources such as water, endangered species constraints, and concerns over water quality must be addressed in developing a sustainable, mutually beneficial partnership among the rice industry, wildlife, and environmental interests. Research is also needed to evaluate potential reductions in the wildlife carrying capacity of ricelands resulting from new harvest and field management techniques, crop conversion, or loss of rice acreage. Key uncertainties include: (1) changes in waste grain abundance and availability due to various harvest and post-harvest management practices; (2) evaluating food depletion by birds feeding in ricefields and determining threshold food levels required to maintain bird use; (3) quantifying use of ricefields by nonwaterfowl species throughout the year; and (4) determining the amount and distribution of rice habitat needed to meet objectives of the North American Waterfowl Management Plan and the United States Shorebird Conservation Plan.

INTRODUCTION

Worldwide loss of wetlands to human development has been extensive. In North America, more than half of all wetland habitats south of the Canada–United States border have been drained in the past two centuries (Tiner 1984, Dahl 1990). The conversion of natural habitats to agricultural land has affected wetlands disproportionately because these areas tend to have very rich soils. Moreover, wetland losses have considerable impact on regional biotas because wetlands generally are very productive biologically. Rice agriculture has had perhaps the greatest influence of any agricultural crop on wetland habitat for wintering waterbirds. Rice typically is grown in areas where wetlands formerly occurred, and because of their hydrology, these areas often have limited suitability for other agricultural uses. Approximately 86% of the land under rice cultivation worldwide is inundated for at least part of the year, either through irrigation, rainwater, or deepwater flooding (Chang and Luh 1991).

In North America, rice is grown throughout the lower Mississippi Alluvial Valley (MAV or Delta) of Arkansas, Missouri, Mississippi, and Louisiana, and in the non-Delta prairie of Arkansas, along the Gulf Coast of Texas and Louisiana, and in California's Central Valley (see Figure 1; Setia et al. 1994). These areas overlap directly with three of the most important winter habitats for North American waterfowl, recognized under the North American Waterfowl Management Plan (NAWMP) as: (1) the Lower Mississippi Valley Joint Venture (LMVJV), (2) the Gulf Coast Joint Venture (GCJV), and (3) the Central Valley Joint Venture (CVJV) (Figure 1). Rice and waterfowl have shared a history in these regions for over a century (Horn and Glasgow 1964).

In the early 1900s, this history was mostly one of conflict (Horn and Glasgow 1964). Waterfowl were attracted to ricefields when they arrived on wintering grounds because rice harvests occurred relatively late and natural wetlands were being rapidly converted to other uses. With few food sources available, the concentrations of birds feeding on rice resulted in significant reductions in production. For example, in 1917, five years after the first commercial crop of rice in California, the total loss of grain to ducks was estimated to be worth $1 million (Hill 1999). By 1943 this total had increased to $1.75 million (Horn and Glasgow 1964). These conflicts were subsequently alleviated by the passage of legislation such as the Lea Act in 1948, which provided funds to acquire and develop more wetland habitat for waterfowl. By the 1970s, new cultivars of rice and changing planting and crop management practices led to a shortened growing season, such that the harvest was complete before the greatest concentrations of waterfowl arrived on the wintering areas (Hill 1999). Combined with the efforts of federal and state wildlife areas, the conflicts between rice agriculture and wildlife were greatly reduced and new opportunities arose for environmental stewardship in the use of ricelands for agricultural production and wildlife benefits (Hill 1999). Indeed, the recent history of ricelands and wildlife is now one of cooperation rather than conflict. Ricelands have become an indispensable component of waterbird habitat and a leading example of compatible agricultural and natural resource management.

In this chapter, we review the values that riceland habitats provide for wildlife. To date, most research on this topic has focused on the use of ricefields by wintering waterbirds (Sykes and Hunter 1978, Hobaugh 1982, Remsen et al. 1991, Rave and Cordes 1993, Rettig 1994, Day and Colwell 1998, Elphick and Oring 1998, Elphick and Oring 2003); the foraging ecology of waterbirds and food resources available in ricefields (Meanley 1956, Hobaugh 1985, Miller 1987, Alisauskas et al. 1988, Miller et al. 1989, Miller and Wylie 1995, Hohman et al. 1996, Anderson et al. 1999, Elphick 2000); the role of ricefields as breeding habitat for waterbirds, especially rails (Rallidae) and whistling ducks (Dendrocygninae) in the southeastern states (Meanley and Meanley 1959, Helm et al. 1987, Turnbull et al. 1989a, Hohman and Weller 1994, Hohman et al. 1996); and the effects of organic chemicals on birds that feed in ricefields (Flickinger and King 1972, Turnbull et al. 1989b). However, much remains unknown about the role that rice agriculture will play in the future conservation of waterbird populations in the United States.

Several recent changes in the U.S. rice industry have resulted in increased interest in the role of ricefields as wildlife habitat. In California, legislation was introduced in 1991 to restrict the area of fields that could be burned following harvest (Rice Straw Burning Act, AB 1378, 1991). Previously, burning was the preferred method for disposing of post-harvest straw and stubble in preparation for the next crop. The act required that producers seek new ways of removing this material from their fields. Agronomists found that flooding fields soon after harvest and retaining water on the fields until early spring increased the rate of straw decomposition and effectively removed much of the straw. Moreover, for many years producers in all three rice-growing regions have flooded ricefields in winter for duck hunting. Winter flooding, therefore, provides producers with an alternative to burning, increases opportunities for waterfowl hunting, and creates a large area of potential waterbird habitat (Payne and Wentz 1992, Brouder and Hill 1995). This last benefit is viewed as especially important, given the extensive losses of wetland habitat in regions traditionally important to wintering waterbirds.

Two other changes in the United States rice industry occurred at about the same time: (1) increased use of stripper-header harvesters (Bennett et al. 1993), which strip the grain from the stalk, and (2) reductions in the acreage of rice farmed in some production areas. The new harvesters are faster than conventional "cutter-bar" combines, leave taller stubble because rice stalks are not cut, and leave less spilled grain in the fields. The abundance and availability of grain in winter ricefields may be reduced as a consequence, adversely impacting birds that feed on spilled grain (Miller and Wylie 1995, Day and Colwell 1998). The reduction in rice acreage, particularly in the rice prairie regions of Texas (Hobaugh et al. 1989, Setia et al. 1994) highlights the important role of ricefields as waterbird habitat. For example, more than 1.5 million waterfowl winter in the Texas rice prairies and are dependent on the agricultural practices and land-use patterns associated with rice farming (Hobaugh 1984, Hobaugh et al. 1989). Recently, rice production has declined by more than 60% in this region (Hobaugh et al. 1989), yet little has been done to evaluate the function of ricelands in the mosaic of habitats required for wintering waterbirds.

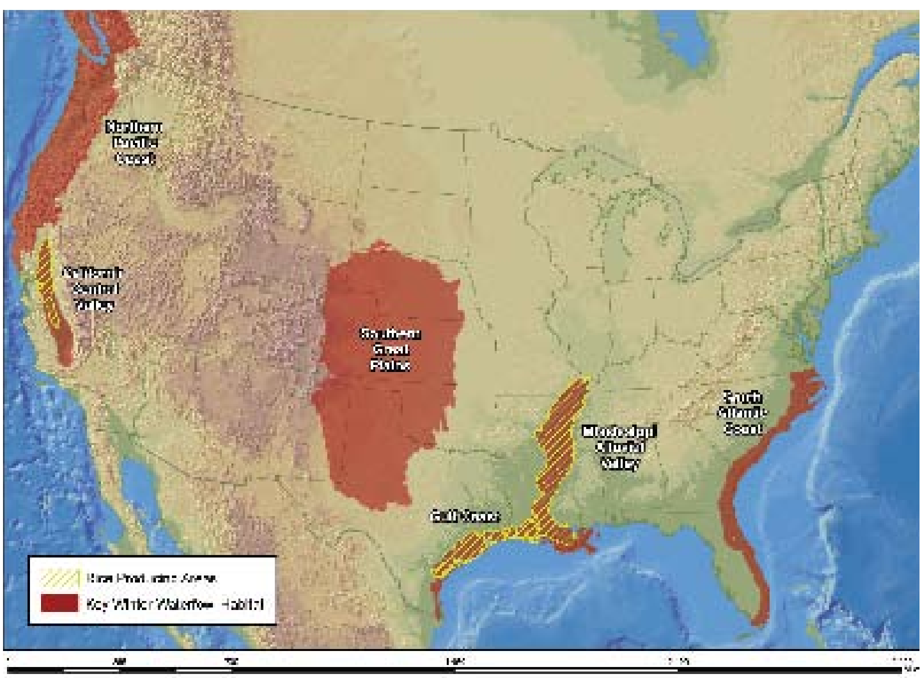
Our objectives in this chapter are fivefold: (1) we review available information on the use of ricefields by waterfowl and other wetland-dependent wildlife; (2) we evaluate the resource benefits (food and habitat) provided to wildlife; (3) we examine the benefits and costs to producers of attracting wildlife to ricefields; (4) we consider some of the future ecological and economic challenges that face both rice producers and wildlife managers; and (5) we outline key research needs. We hope that such a synthesis will provide a valuable resource to both rice producers and wildlife managers.

USE OF RICEFIELDS BY WILDLIFE

Despite their apparent homogeneity, North American ricefields are used by a wide variety of wildlife species. For example, at least 118 bird species representing 38 different families were recorded in California ricefields during winter (C. S. Elphick, unpublished data), and more than 140 species have been recorded across other numerous studies in California (Resource Management International 1997, Jones & Stokes Inc. 2005). Not surprisingly, many of these species are rare and their reliance on ricefield habitats is unclear, but many others occur in substantial numbers and clearly gain much from their use of ricefields. Waterbirds constitute the bulk of the wildlife species that use ricefields, and they are by far the best studied group, but many raptors, songbirds and non-avian wildlife species also occur. A summary of the common species of wildlife found in or associated with ricefields is provided in Table 1.

Waterfowl - Waterfowl (Anseriformes—ducks, geese, and swans) are the most conspicuous group of birds inhabiting ricefields during the nonbreeding season, and flooded rice habitat is exceedingly important for many species. The North American Waterfowl Management Plan considers flooding of ricefields by private landowners in the MAV, Gulf Coast, and California's Central Valley to be a critical component of winter habitat needed to sustain continental waterfowl populations. In California, wintering waterfowl densities in fields that had been intentionally flooded to enhance rice straw decomposition and provide hunting opportunities averaged about 730 ± 123 (SE) birds/km^2 (Elphick and Oring 2003). Mean densities averaged across all fields, however, are misleading, as waterfowl form highly aggregated distributions and use is influenced by a variety of factors (see Effects of Ricefield Management, pages 34–46). Densities of up to 3,600 birds/km^2 are common, especially for dabbling ducks and geese

FIGURE 1 Rice-Producing Areas in Relation to Key Winter Waterfowl Habitat



(C. S. Elphick, unpublished data). Waterfowl also use fields that received only passive flooding (rain), although at significantly lower densities (383 ± 141 birds/km^2; max. = 2,878 birds/km^2; Elphick and Oring (2003), unpublished data). In California, Lesser Snow Geese, Ross's Geese, Greater White-fronted Geese, Northern Pintails, Northern Shovelers, Green-winged Teal, Mallards, and American Wigeon (scientific names provided in Table 1, pages 12–15) are the most common waterfowl species found in ricefields, although many other species occur (Day and Colwell 1998, Elphick and Oring 1998). For example, important numbers of both Tule White-fronted Geese and Aleutian Cackling Geese can be found among the goose flocks in this region. All of these estimates are based on diurnal counts, and no estimates are available for waterfowl densities in California ricefields at night. Many duck species visit ricefields at night and nocturnal use, especially during the hunting season, may greatly exceed diurnal use (Miller 1985, Rave and Cordes 1993, Cox and Afton 1996, 1997).

In the Gulf Coast and MAV regions, few estimates of waterfowl densities are available, again because use of ricefields often occurs at night (Rave and Cordes 1993, Cox and Afton 1997). One study in the MAV, however, indicated that diurnal densities of waterfowl using ricefields generally averaged less than 10 birds/km^2 during winter (Twedt and Nelms 1999). Mallards are the most abundant waterfowl species in the MAV, especially in Arkansas (Reinecke et al. 1989); 20–40% of the 1–1.5 million Mallards in the region were recorded in ricefields during aerial surveys conducted in early and late winter (Reinecke et al. 1992). The most common species using ricefields in the Gulf Coast region are Greater White-fronted Geese, Lesser Snow Geese, Northern Shovelers, Northern Pintails, and Green-winged Teal (Remsen et al. 1991, Cox and Afton 1997, Cox et al. 1998). Focused studies on Greater White-fronted Geese and Northern Pintails in this region have shown that ricefields provide important foraging habitat for these birds (Leslie and Chabreck 1984, Cox and Afton 1997). Species found frequently in ricefields in the MAV include Mallards, Northern Shovelers, Gadwall, American Wigeons, Northern Pintails, Greater White-fronted Geese, and Lesser Snow Geese (Reinecke et al. 1992, Twedt and Nelms 1999).

Waterfowl numbers peak in midwinter when these three regions collectively support about half of the dabbling ducks and geese in North America [based on estimates that 25%, 20%, and <5% of the total continental waterfowl population are found in the Gulf Coast region (Chabreck et al. 1989), Central Valley (Heitmeyer et al. 1989), and Mississippi Delta (Reinecke and Loesch 1996), respectively].

Although less important to waterfowl during the breeding season, ricefields do provide nesting habitat for some ducks. In particular, ricefields in Louisiana and Texas (and farther south in the Americas) are used by large numbers of Fulvous Whistling Ducks, both as breeding and foraging sites (Hohman and Lee 2001). In California, Mallards are one of the most common waterbirds breeding in ricefield habitats, using harvested and set-aside fields for nesting, and raising broods in growing rice and irrigation ditches (Yarris 1995, D. Shuford, personal communication).

Shorebirds - In addition to waterfowl, ricefields are used by large numbers of shorebirds. In the Sacramento Valley of California up to 140,000 shorebirds can be found in winter, with about 75% of these birds in ricefields (Shuford et al. 1998). California's Central Valley as a whole supports more shorebirds during winter and spring migration than any other inland region in western North America, and the Sacramento Valley holds more than a third of Central Valley shorebirds from August to April (almost half in midwinter; Shuford et al. 1998). Mean (± SE) shorebird density in winter flooded fields was 252 ± 72 birds/km^2, with much lower densities in fields that were not intentionally flooded (Elphick and Oring 2003). As with waterfowl, there was much variation among fields, and average densities for individual fields peaked at 2,600 birds/km^2 (C. S. Elphick, unpublished data).

The most abundant shorebirds in California ricefields during winter are Dunlin and Long-billed Dowitcher, although substantial numbers of Killdeer, Greater Yellowlegs, Long-billed Curlews, Wilson's Snipe, and Least Sandpipers also occur (Day and Colwell 1998, Elphick and Oring 1998, Shuford et al. 1998). In the Sacramento Valley, Dunlin and Least Sandpipers are almost exclusively (>90% of all birds) found in flooded ricefields during midwinter, as are the bulk of the Killdeer, Greater Yellowlegs, and Long-billed Dowitchers that use the valley (Shuford et al. 1998). Wilson's Snipe are present and abundant in Central Valley ricefields, but no censuses have been conducted.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Least Sandpiper and Dunlin

Fewer data exist on shorebird use of ricefields in the MAV and Gulf Coast rice-growing regions, although large numbers of shorebirds are present at times. Based on a single day survey, Remsen et al. (1991) calculated that up to 225,000 shorebirds might winter in the rice-growing region of south-central Louisiana. At least 30 shorebird species have been recorded in agricultural fields in this region (Rettig 1994). In Louisiana ricefields, large numbers of shorebirds are present from late October until mid-May, with peaks during migration in April and early May. Total shorebird numbers at the peak of spring migration exceeded those at the fall peak by threefold (Rettig 1994), although this result could be a consequence of the prolonged fall migration and does not necessarily mean that fewer birds use the region in fall. Densities in flooded rice were higher than in spring due to generally drier conditions and a reduction in suitable habitat. Long-billed Dowitchers, Western Sandpipers, Pectoral Sandpipers, Killdeer, Dunlins, and Lesser Yellowlegs were the most abundant shorebird species in the region (Remsen et al. 1991, Rettig 1994). In the south-central rice-growing regions, use of ricefields by species other than waterfowl increases greatly toward the coast. In the MAV, Killdeer are by far the most common wintering shorebird in ricefields, although Wilson's Snipe, *Calidris* sandpipers, and Lesser Yellowlegs also are fairly common (Twedt et al. 1998).

Although most North American shorebirds breed farther north than where rice is grown, Killdeer, Wilson's Phalaropes, American Avocets, and Black-necked Stilts all nest in and around ricefields; Killdeer, especially, are often very common (D. Shuford, personal communication). Water-control levees subdividing fields make particularly good nest sites as these narrow strips of land provide protection from mammalian predators that avoid water.

Wading Birds - The third major group of waterbirds that use ricefields are long-legged wading birds (order Ciconiiformes). These include herons, egrets, bitterns, and ibis. In California, White-faced Ibis are by far the most numerous wading birds found in ricefields, with mean densities of almost 50 birds/km^2 in winter-flooded fields (Elphick and Oring 1998). More than half of all White-faced Ibis wintering in the Sacramento Valley are counted in ricefields (Shuford et al. 1996). Ibis also predominate among wading birds along the Gulf Coast, where White-faced Ibis are joined by White Ibis and smaller numbers of Glossy Ibis. Tens of thousands of White and White-faced Ibis have been estimated to use winter ricefields in south-central Louisiana (Remsen et al. 1991, Ryder and Manry 1994).

Herons and egrets frequently use ricefields throughout the year. In both California and along the Gulf Coast, Great Egrets, Snowy Egrets, and to a lesser extent Great Blue Herons, are commonly found foraging in rice habitats (Remsen et al. 1991, Rettig 1994, Day and Colwell 1998, Elphick and Oring 1998). In Louisiana, Cattle Egrets can be very common and Little Blue Herons are found frequently (Rettig 1994). American Bitterns are relatively common in ricefields throughout the year in California, (C. S. Elphick; D. Shuford, personal communication). This species is found in the vegetation surrounding ricefields and in associated drainage ditches or in fields that have been harvested with stripper-headers or left fallow with relatively tall vegetation. They will also feed farther out in the fields, especially when rice is growing. Black-crowned Night-Herons use ricefields in both California and Louisiana (Rettig 1994, Elphick and Oring 1998); their numbers are probably underestimated because they typically use fields only at night. Most other North American wading birds also use ricefields in small numbers.

Many wading birds find food and cover in winter managed ricefields throughout North America

Other Waterbirds - In addition to these three major groups, there are a variety of other waterbirds that occur in ricefields. Members of the order Gruiformes are most numerous and conspicuous. In California in winter, American Coots are one of the most abundant species in flooded fields, Sandhill Cranes frequently feed and roost in rice, and Soras are occasionally flushed from the vegetation fringing fields (Day and Colwell 1998, Elphick and Oring 1998). In Gulf Coast and MAV ricefields, Soras and Virginia, King and Yellow Rails all occur in ricefields and associated drainage canals during the nonbreeding season (Meanley 1956, Cardiff and Smalley 1989), and King Rails remain throughout the summer to breed (Meanley 1953;1956;1992). Common Moorhens and Purple Gallinules also both nest in ricefields.

Although ricefields are typically too shallow for birds that dive underwater, grebes, cormorants, and diving ducks do occur during extreme flooding events. Several of these species, especially Pied-billed Grebes in California, frequently use the deeper water found in ditches that supply fields with water. Wildlife use of these drainage ditches has not been well studied in North America; however, this habitat likely increases the variety of species that benefit directly from rice agriculture (e.g., see Lane and Fujioka 1998). Several species of gulls and terns also use ricefields. Gulls are most common during the nonbreeding season; in California, Ring-billed Gulls are often found in association with White-faced Ibis and Long-billed Curlews from which they frequently "steal" food. Black Terns also breed in California ricefields (Lee 1984, Dunn and Agro 1995), which support almost half of the state's breeding population (Shuford et al. 2001), and Gull-billed Terns winter in Louisiana fields (Parnell et al. 1995). Further information on waterbird use of ricefields—including most species discussed here—is included in a review of the value of rice farming to waterbirds in Europe (Fasola and Ruiz 1997).

Raptors - Use of ricefields is not restricted to waterbirds. High densities of raptors also use ricefields in California and along the Gulf Coast during winter. In California, at least 15 species in the order Falconiformes (hawks, falcons, and allies) and four species of owls hunt over ricefields. Northern Harriers are by far the most common bird of prey using California ricefields (Elphick 2004). Red-tailed and Cooper's Hawks are the next most abundant raptor species, and scavenging Turkey Vultures (Ciconiiformes) also are very common. Burrowing Owls nest in the levees around ricefields, and both Northern Harriers and Short-eared Owls nest in fallow ricefields (Resource Management International 1997).

Relatively high raptor densities, although lower species diversity, have been reported from Louisiana where Red-tailed Hawks, Northern Harriers, and American Kestrels are the most common species (Cardiff and Smalley 1989, Remsen et al. 1991, Rave and Cordes 1993). Rare species frequently seen hunting over ricefields include Bald Eagles and Peregrine Falcons (Rave and Cordes 1993, Elphick 2004), both of which hunt aquatic birds and likely benefit from the abundance of waterfowl and shorebirds in rice habitats. Raptor use of MAV ricefields has not been well studied, although Red-tailed Hawks and Northern Harriers are abundant there in winter. Great Horned Owls also are common where bottomland forests persist and are predators to waterfowl in the MAV (K. J. Reinecke, personal observation). Interactions between raptors and waterbirds, however, have not been studied in great detail in any of the three rice-growing regions. In the Sacramento Valley, wintering hawks (Accipitridae) and falcons (Falconidae) are more likely to be found in areas of rice stubble than would be expected by chance during the nonbreeding season; during summer, both groups apparently avoided rice habitats (Smallwood et al. 1996). During spring, though not during winter, White-tailed Kites forage in areas with abundant rice habitat more often than expected by chance (Erichsen et al. 1996).

Other Birds - A wide variety of other birds also use ricefields and their associated habitats. Sparrows and blackbirds (and their allies) are most common, but the list ranges from flycatchers to finches (Cardiff and Smalley 1989, Remsen et al. 1991, Elphick 2004). Savannah Sparrows, Horned Larks, American Pipits, and meadowlarks (Eastern and Western) all feed throughout winter ricefields. In the South, LeConte's Sparrows and Sedge Wrens can be found in unharvested fields in late fall. Blackbirds (mostly Red-winged and Brewer's), grackles (Common and Boat-tailed), and Brown-headed Cowbirds feed on grain, often in large flocks. In California, four species of blackbirds, as well as cowbirds, feed on rice in harvested fields (Crase and DeHaven 1978). Upwards of 2 million mixed species of blackbirds have been counted at roosts in the Sacramento Valley (R.W. DeHavne, unpublished data). Additionally, the Tricolored Blackbird, a species of concern in California, nests in colonies in permanent wetlands associated with growing ricefields in the Sacramento Valley. Studies conducted during the 1960s estimated that there were about 44,000 breeding male Red-winged Blackbirds in a 2,300 km^2 region of the Arkansas Grand Prairie, and that about 200 million blackbirds and starlings (approximately 43% Red-winged Blackbirds, 22% Common Grackles, 20% Brown-headed Cowbirds, 11% European Starlings, 3% Boat-tailed Grackles) wintered in the Lower Mississippi Valley and Louisiana–Texas Gulf Coast regions (Meanley 1971). Most of these species have experienced significant continental declines since the 1960s (Sauer et al. 2002), so current numbers are likely to be considerably smaller, although still large among migratory bird populations. Ring-necked Pheasants are abundant in ricefields in California and provide significant hunting opportunity in the fall and early winter.

In winter, most other species are restricted to microhabitats along the edges of fields and to drainage ditches, which typically provide more cover than do harvested fields. Marsh Wrens nest in the cattails along the edges of California ricefields; Black Phoebes take advantage of the many bridges and water control structures that provide good nest sites; and Loggerhead Shrikes are a common sight perched on a post or a wire along the edge of a field.

Reptiles and Amphibians - Various reptiles and amphibians use ricefields throughout the year, although there has been little systematic research on their abundance or the importance of ricefields for most species. One review of species known to occur in ricefields or associated habitats lists 18 species of reptiles and 6 species of amphibians (Resource Management International 1997). Many of these species, however, are almost certainly very rare or only incidental in rice habitats.

In California, much attention has been focused on the Giant Garter Snake, which is endemic to Central Valley wetlands and listed as threatened by the U.S. Fish and Wildlife Service. Radio telemetry studies have found that Giant Garter Snakes regularly use ricefields during summer, and rarely during winter. About one-fifth of all snake locations occurred in ricefields, and about half of all snakes studied used ricefields at some time (Wylie et al. 1997). The

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Giant Garter Snake

introduced Bullfrog is perhaps the most common amphibian found in ricefields, although the Pacific Treefrog also occurs. Other reptiles and amphibians seen in California ricefields, or in nearby habitats, include Common Garter Snakes, Gopher Snakes, Common Kingsnakes, California Mountain Kingsnakes, Racers, California Whipsnake, Western Fence Lizard, Western Pond Turtles, Western Toads, and Western Spadefoot Toads (G. Wylie, personal communication). In Arkansas, Southern Leopard Frogs occur in high densities during winter in most fields (D. Rutka, personal communication). Information on reptiles and amphibians in southern rice states is limited.

Mammals - In all North American rice-growing regions, numerous small rodents occur in drier fields. Muskrats and American Beavers occasionally try to make their homes within ricefields, damaging levees and altering water levels. In California, Northern River Otters are sometimes seen in ditches that supply water to fields. Other mammals that are often found around the edges of ricefields in California include California Ground Squirrels, Black-tailed Jackrabbits, Striped Skunks, Northern Raccoons, and Coyotes (see also Table 1). In the Gulf Coast and MAV, medium-sized mammals frequently found along the edges of ricefields include White-tailed Deer, Striped and Spotted Skunks, Northern Raccoons, Coyotes, Bobcats, Nine-banded Armadillos, Virginia Opossums, American Minks, and Eastern Cottontails (K. Reinecke, personal observation; D. Rutka, personal communication).

TABLE 1 Species of wildlife found in or in association with ricefields in California (CA), the Gulf Coast (GC), and the Mississippi Alluvial Valley (MAV). This list does not include uncommon, rare, or incidental species.

COMMON NAME	LATIN NAME	CA	GC	MAV
Waterfowl				
Fulvous Whistling-Duck	*Dendrocygna bicolor*		X	
Tundra Swan	*Cygnus columbianus*	X		
Greater White-fronted Goose	*Anser albifrons*	X	X	X
Tule Gr. White-fronted Goose	*Anser anser elgasi*	X		
Lesser Snow Goose	*Chen caerulescens caerulescens*	X	X	X
Ross's Goose	*Chen rossii*	X	X	X
Cackling Goose	*Branta hutchinsii*	X		
Aleutian Canada Goose	*Branta hutchinsii leucopareia*	X		
Canada Goose	*Branta canadensis*	X	X	X
Gadwall	*Anas strepera*	X	X	X
American Wigeon	*Anas americana*	X	X	X
Mallard	*Anas platyrhynchos*	X	X	X
Mottled Duck	*Anas fulvigula*		X	
Cinnamon Teal	*Anas cyanoptera*	X		
Blue-winged Teal	*Anas discors*		X	
Northern Shoveler	*Anas clypeata*	X	X	X
Northern Pintail	*Anas acuta*	X	X	X
Green-winged Teal	*Anas crecca*	X	X	X
Canvasback	*Aythya valisineria*	X		
Ring-necked Duck	*Aythya collaris*	X	X	X
Shorebirds				
Black-bellied Plover	*Pluvialis squatarola*	X	X	X
Killdeer	*Charadrius vociferus*	X	X	X
Black-necked Stilt	*Himantopus mexicanus*	X	X	X
American Avocet	*Recurvirostra americana*	X	X	
Greater Yellowlegs	*Tringa melanoleuca*	X	X	X
Lesser Yellowlegs	*Tringa flavipes*		X	X
Willet	*Tringa semipalmata*		X	X
Whimbrel	*Numenius phaeopus*	X		

COMMON NAME	LATIN NAME	CA	GC	MAV
Long-billed Curlew	*Numenius americanus*	X		
Western Sandpiper	*Calidris mauri*	X	X	X
Least Sandpiper	*Calidris minutilla*	X	X	X
Pectoral Sandpiper	*Calidris melanotos*		X	X
Dunlin	*Calidris alpina*	X	X	X
Long-billed & Short-billed Dowitcher	*Limnodromus scolopaceus & L. griseus*	X	X	X
Wilson's Snipe	*Gallinago delicata*	X	X	X
Wilson's Phalarope	*Phalaropus tricolor*	X	X	
Waders				
American Bittern	*Botaurus lentiginosus*	X		X
Least Bittern	*Ixobrychus exilis*		X	
Great Blue Heron	*Ardea herodias*	X	X	X
Great Egret	*Ardea alba*	X	X	X
Snowy Egret	*Egretta thula*	X	X	X
Little Blue Heron	*Egretta caerulea*		X	X
Cattle Egret	*Bubulcus ibis*	X	X	X
Black-crowned Night-Heron	*Nycticorax nycticorax*	X	X	
Yellow-crowned Night-Heron	*Nycticorax violaceus*		X	X
White Ibis	*Eudocimus albus*		X	X
Glossy Ibis	*Plegadis falcinellus*		X	
White-faced Ibis	*Plegadis chihi*	X	X	
Sandhill Crane	*Grus canadensis*	X		X
Other Waterbirds				
Pied-billed Grebe	*Podilymbus podiceps*	X	X	X
Yellow Rail	*Coturnicops noveboracensis*		X	X
King Rail	*Rallus elegans*		X	X
Virginia Rail	*Rallus limicola*		X	X
Sora	*Porzana carolina*	X	X	X
Purple Gallinule	*Porphyrula martinica*		X	
Common Moorhen	*Gallinula chloropus*	X	X	
American Coot	*Fulica americana*	X	X	X

COMMON NAME	LATIN NAME	CA	GC	MAV
Ring-billed Gull	*Larus delawarensis*	X		
Gull-billed Tern	*Sterna nilotica*		X	
Black Tern	*Chlidonias niger*		X	
Raptors				
Turkey Vulture	*Cathartes aura*	X		
White-tailed Kite	*Elanus leucurus*	X	X	X
Northern Harrier	*Circus cyaneus*	X	X	X
Cooper's Hawk	*Accipiter cooperii*	X		
Red-tailed Hawk	*Buteo jamaicensis*	X	X	X
American Kestrel	*Falco sparverius*	X	X	X
Great Horned Owl	*Bubo virginianus*	X	X	X
Burrowing Owl	*Athene cunicularia*	X		
Short-eared Owl	*Asio flammeus*	X		
Other Birds				
Ring-necked Pheasant	*Phasianus colchicus*	X		
Mourning Dove	*Zenaida macroura*	X	X	X
Black Phoebe	*Sayornis nigricans*	X		
Loggerhead Shrike	*Lanius ludovicianus*	X	X	X
Horned Lark	*Eremophila alpestris*	X	X	X
Sedge Wren	*Cistothorus platensis*		X	X
Marsh Wren	*Cistothorus palustris*	X		
European Starling	*Sturnus vulgaris*	X	X	X
American Pipit	*Anthus rubescens*	X	X	X
Savannah Sparrow	*Passerculus sandwichensis*	X	X	X
Henslow's Sparrow	*Ammodramus henslowii*		X	X
LeConte's Sparrow	*Ammodramus leconteii*		X	X
Red-winged Blackbird	*Agelaius phoeniceus*	X	X	X
Eastern and Western Meadowlark	*Sturnella magna & S. neglecta*	X	X	X
Brewer's Blackbird	*Euphagus cyanocephalus*	X		
Common Grackle	*Quiscalus quiscula*		X	X
Boat-tailed Grackle	*Quiscalus major*		X	

COMMON NAME	LATIN NAME	CA	GC	MAV
Brown-headed Cowbird	*Molothrus ater*	X	X	X
Reptiles and Amphibians*				
Giant Garter Snake	*Thamnophis gigas*	X		
Common Garter Snake	*Thamnophis sirtalis*	X		
Gopher Snake	*Pituophis melanoleucas*	X		
Common Kingsnake	*Lampropeltis getulus*	X		
California Mountain Kingsnake	*Lampropeltis zonata*	X		
Racer	*Coluber constrictor*	X		
California Whipsnake	*Masticophis lateralis*	X		
Western Fence Lizard	*Sceloporus occidentalis*	X		
Western Pond Turtle	*Clemmys marmorata*	X		
Western Toad	*Bufo borea*	X		
Western Spadefoot Toad	*Scaphiopus hammondii*	X		
Bullfrog	*Rana catesbeiana*	X		
Southern Leopard Frog	*Rana utricularia*			X
Pacific Treefrog	*Hyla regilla*	X		
Mammals				
Muskrat	*Ondatra zibethicus*	X	X	X
Nutria	*Myocastor coypus*		X	X
California Ground Squirrel	*Spermophilus beecheyi*	X		
Black-tailed Jackrabbit	*Lepus californicus*	X		
Eastern Cottontail	*Sylvilagus floridanus*		X	X
American Beaver	*Castor canadensis*	X	X	X
Northern River Otter	*Lontra canadensis*	X	X	X
Striped Skunk	*Mephitis mephitis*	X	X	X
American Mink	*Mustela vison*	X	X	X
Northern Raccoon	*Procyon lotor*	X	X	X
Nine-banded Armadillo	*Dasypus novemcinctus*		X	X
Virginia Opossum	*Didelphis virginia*		X	X
Coyote	*Canis latrans*	X	X	X

*Information on amphibians and reptiles was not available for ricefields in the GC or MAV

RESOURCE BENEFITS TO WILDLIFE

Winter Habitat

Food Resources - Harvested ricefields provide a variety of food resources for foraging waterfowl, shorebirds, and wading birds, including rice seeds (Table 2, pages 20–25), moist soil seeds (Table 3, page 26), green vegetation (Hobaugh 1984, Leslie and Chabreck 1984, Alisauskas et al. 1988), and invertebrates (Loughman and Batzer 1992). These food resources are integral to planning for waterfowl habitat requirements, which are almost entirely bio-energetically-based (Heitmeyer 1989, Reinecke and Loesch 1996), throughout the primary waterfowl wintering regions in North America (Figure 1).

Rice Seed - Wildlife and agriculture researchers have conducted numerous studies, beginning in the 1940s, to determine the amount of rice seed left after harvest in all major rice- growing regions. These estimates range from an average of 134 to more than 600 kg/ha dry weight (Table 2). The amount of rice remaining after harvest is related to the harvest yield, with larger yields producing larger losses (Miller et al. 1989). Losses generally have ranged from 3–6% of yield. In the past, yields and losses were higher in California, compared to lower yields and losses in southern growing areas (Miller et al. 1989). However, in recent years, yields have increased markedly in the southeast as higher yielding varieties have been adopted; recent estimates suggest that grain losses have likewise increased (Table 2). Long growing seasons in the South also permit early harvest, and harvest along the Gulf Coast is early enough (e.g., July) to allow a second or "ratoon" crop of rice to be grown by irrigating and fertilizing rice after harvesting the first crop. Rice yield from the second crop is less than from the first and only rice seed from the second crop is available when waterfowl arrive. Occasionally, production from second crops is not sufficient to warrant harvesting and the entire crop is left in the fields; currently, the best data on seed availability following harvest of the second rice crop in the Gulf Coast area are from Hobaugh (1984; Table 2).

Farther north in the MAV only a single rice crop is harvested, and recent research has indicated that loss of rice seed to germination, decomposition, and consumption by other wildlife species may be extensive after harvest and before waterfowl arrive (Manley 1999, Stafford 2004, Kross 2006). Manley et al. (2004) reported a reduction of 79–99% of waste grain between harvest and early winter. Stafford (2004) and Stafford et al. (2006), in an extensive analysis throughout the MAV, found a 71% reduction between harvest and early winter, similar to the 78% reduction reported by Kross (2006). These studies indicate that the amount of waste rice available to waterfowl when they arrive in the MAV is much less than previously assumed, requiring wildlife planners to adjust predictions considerably for the number of wintering birds that can be supported in ricefield habitats. Comparison of waste rice available in Texas post-harvest (August) relative to late fall (Oct.–Nov.) suggests that significant early season depletion may also occur in the Gulf Coast region (Table 2; Hobaugh 1984, Wilson et al. 2001).

Factors influencing the amount of rice seed lost during harvest include competency of the combine harvester operator (McNeal 1950), harvester travel speed (Wilson et al. 2001) and settings (Miller et al. 1984a, Miller et al. 1985), weather and seed moisture during harvest (Wilson et al. 2001), harvester maintenance (Wilson et al. 2001), and potentially the age of the combine (Miller et al. 1989) and the type of header (cutter-bar or stripper) (Miller and Wylie 1996). Uncertainty remains as to the effect of stripper-header versus conventional harvesters on the amount of waste rice remaining for wildlife. Miller and Wylie (1996) did not find a significant difference in waste rice available when stripper-headers were used (344 kg/ha) compared to conventional harvesters (388 kg/ha). Stafford (2004) and Stafford et al. (2006) found a trend toward more waste rice being available post-harvest when stripper-headers were used, where as Kross (2006) found no difference.

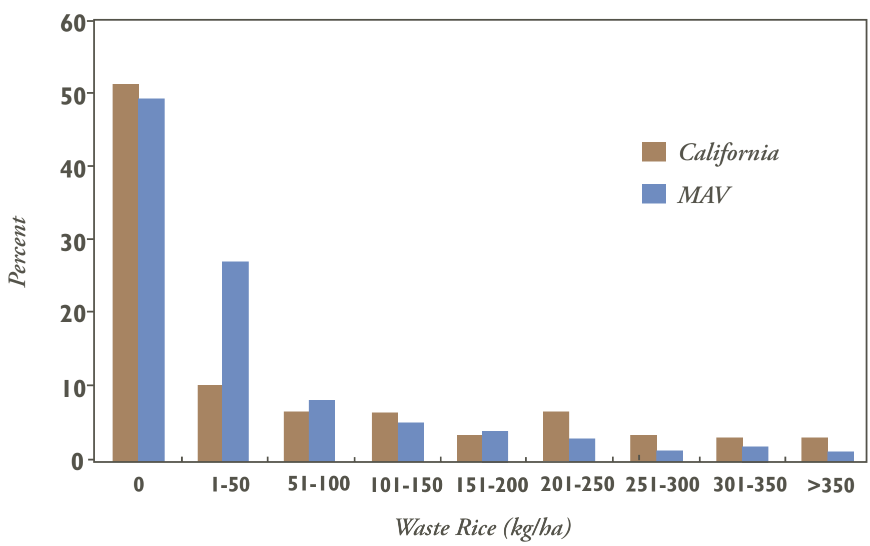
Rice ready for harvest

The amount of rice seed available to waterfowl and other birds further depends on post-harvest field treatments, such as straw disposal (burn, chop, roll, disk, plow, none), flooding or not (Day 1997, Day and Colwell 1998, Elphick and Oring 1998, Rutka 2004), and loss of seeds relative to the time interval between rice harvest and arrival of wintering waterfowl (Neely 1956, McGinn and Glasgow 1963, Manley 1999, Stafford 2004, Kross 2006, Stafford et al. 2006). Since the harvest is the most expensive operation in rice farming (Huey 1971), seed losses are economically important to producers and have recently been shown to reach about $30/ha on average (Wilson et al. 2001). However, there are limits to the efficiency that can be achieved during harvest, because of the need to maintain high-quality headrice (uncracked, unbroken marketable seed). To achieve the high-quality grain that is required to maximize income per ha, fields are usually harvested at efficiency rates below those that give maximum yield (Miller et al. 1984b).

Rice loss during harvest is highly variable. For example, in California, Miller and Wylie (1996) found that variation in the amount of leftover rice was greater *within* than *among* fields for strip harvested rice, with estimates ranging from 126 to 750 kg/ha among fields, and <50 kg/ha to >1,000 kg/ha within fields. The distribution of rice seed was also more patchy in stripped versus conventionally harvested fields. The high variability in the amount of rice grain available after harvest is illustrated in Figure 2 for ricefields in California (Eadie and Burns, unpublished data) and the MAV (data from Stafford 2004). Most samples contained <50 kg/ha but samples from some sites yielded >1,000 kg/ha.

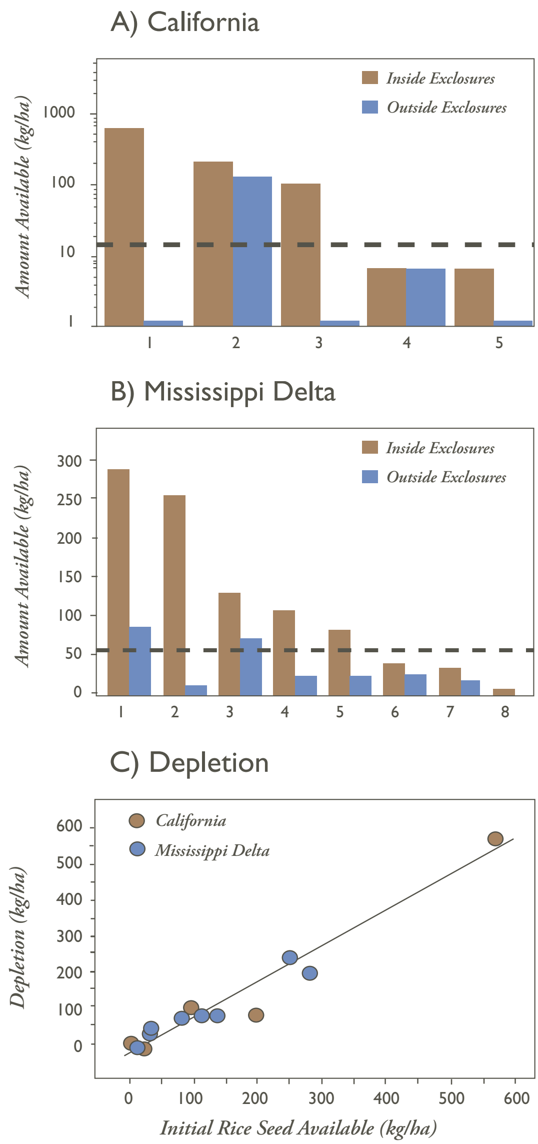
Comparisons of the amount of waste grain at sites protected with exclosures (5x5m chicken wire mesh, designed to prevent access by waterbirds) and paired control sites (open plots allowing free access by waterbirds) indicate that significant depletion of waste grain occurs during winter in California (Figure 3A). Rutka (2004) found similar patterns using exclosures in the MAV (Figure 3B). Over-winter depletion of rice seed ranged 66–72% and waterfowl consumed up to 30% of rice available in early winter. In both regions, the amount of depletion varied among sites, and the greatest levels of depletion were observed on sites with the greatest amount of rice remaining after harvest (Figure 3C). Rutka further evaluated the response of waterfowl to three experimental treatments: unharvested (U), partially harvested (PH), and harvested (H). When plots were equally available at each site, waterfowl foraged first in the unharvested plots, followed by the partially harvested plots, and last in the harvested plots, in direct relation to the quantity of rice seed available (U>PH>H). Despite the differences in rice biomass available before use, the biomass remaining at all sites did not differ (average 48.7 kg/ha), indicating a common giving-up density of rice seed below which birds will abandon a site (Rutka 2004). These results suggest that foraging birds respond directly to the availability of waste grain and deplete rice seed in a density dependent manner.

FIGURE 2 Waste Rice (kg/ha)



Frequency distribution of estimates of mean waste rice seed available in ricefields in California (measured using exclosures; Eadie and Burns, unpublished data) and in the MAV (data from Stafford 2004).

FIGURE 3 Amount Available and Depletion of Rice Seed in California and the Mississippi Delta



Variation in waste rice availability and depletion by waterbirds. The magnitude of depletion was evaluated by comparing control (open) plots to plots with experimental exclosures to prevent access by waterbirds and other foragers. Similar patterns were found in California (A; data from Eadie and Burns, unpublished note: log scale) and the Mississippi delta (B, data from Reinecke, unpublished, Rutka 2004). The dashed line indicates the average amount of rice seed left in fields after depletion. The overall level of depletion was directly proportional to the amount of waste rice initially available (C).

TABLE 2 Density (kg/ha dry weight) of rice seed left in fields after harvest in California, Texas, Arkansas, Louisiana, and Mississippi.

LOCATION	YR (MTH) OF TESTS	HARVEST TYPE /FIELD	FIELD STATUS	# FIELDS	SAMPLES	MEAN kg/ha	SOURCE
Arkansas	1947–49 (Aug.–Oct.)	Conventional	Harvested	unk	variable	164	McNeal 1950[1]
Arkansas	1979 (Oct.)	Conventional	Harvested	1	6	134	Smith and Sullivan 1980
Arkansas	1983 (Nov.)	Conventional	Harvested	9	10	223	Reinecke et al. 1989
Arkansas	1984 (Nov.)	Conventional	Harvested	8	10	140	Reinecke et al. 1989
California	1955 (Oct.)	Conventional	Harvested	unk	n/a	173	Curley and Goss 1964, unpubl. report[2]
California	1978 (Oct.)	Conventional	Harvested	4	unk	484	M. Dennis 1978, unpubl. report
California	1978 (Oct.)	Conventional	Burned	4	unk	195	M. Dennis 1978, unpubl. report
California	1985 (Sept.–Nov.)	Conventional	Burned	89	2	276	Miller et al. 1989
California	1985 (Sept.–Oct.)	Conventional	Harvested	111	2	387	Miller et al. 1989
California	1985 (Sept.–Oct.)	Conventional	Harvested	66	2	375	USDA 1989, Miller and Wylie 1996
California	1985–86 (Sept.–Oct.)	Conventional	Harvested	126	2 or 8	388	Miller et al. 1989
California	1985–86(Sept.–Nov.)	Conventional	Burned	100	2 or 8	276	Miller et al. 1989

LOCATION	YR (MTH) OF TESTS	HARVEST TYPE /FIELD	FIELD STATUS	# FIELDS	SAMPLES	MEAN kg/ha	SOURCE
California	1986 (Sept.–Nov.)	Conventional	Burned	11	8	278	Miller et al. 1989
California	1986 (Sept.–Oct.)	Conventional	Harvested	15	8	395	Miller et al. 1989
California	1986 (Sept.–Oct.)	Conventional	Harvested	81	2	395	USDA 1986, Miller and Wylie 1996
California	1987 (Sept.–Oct.)	Conventional	Harvested	?	2	368	USDA 1987, Miller and Wylie 1996
California	1988 (Sept.–Oct.)	Conventional	Harvested	?	2	627	USDA 1988, Miller and Wylie 1996
California	1989 (Sept.–Oct.)	Conventional	Harvested	?	2	468	USDA 1989, Miller and Wylie 1996
California	1993 (Sept.–Oct.)	Stripper	Harvested	17	8	344	Miller and Wylie 1996
California	2000 (Feb.)	Conventional	Harvested	5	15	175	Eadie and Burns, unpubl. data
Louisiana	1958 (Nov.)	Conventional	Harvested	7	20	160	Harmon et al. 1960
Mississippi	1995 (post-harvest; Aug.–Sept.)	Conventional	Harvested	35	15+	491	Manley 1999, Manley et al. 2004
Mississippi	1996 (post-harvest; Aug.–Sept.)	Conventional	Harvested	35	15+	493	Manley 1999, Manley et al. 2004
Mississippi	1995 (late-season; Dec.)	Conventional	Harvested (stubble, long flood)	6	15+	42	Manley 1999, Manley et al. 2004

LOCATION	YR (MTH) OF TESTS	HARVEST TYPE /FIELD	FIELD STATUS	# FIELDS	SAMPLES	MEAN kg/ha	SOURCE
Mississippi	1995 (late-season; Dec.)	Conventional	Harvested (stubble, short flood)	6	15+	30	Manley 1999, Manley et al. 2004
Mississippi	1995 (late-season; Dec.)	Conventional	Harvested (stubble, open)	6	15+	39	Manley 1999, Manley et al. 2004
Mississippi	1995 (late-season; Dec.)	Conventional	Harvested (disked, long flood)	6	15+	37	Manley 1999, Manley et al. 2004
Mississippi	1995 (late-season; Dec.)	Conventional	Harvested (disked, short flood)	6	15+	33	Manley 1999, Manley et al. 2004
Mississippi	1995 (late-season; Dec.)	Conventional	Harvested (disked, open)	35	15+	81	Manley 1999, Manley et al. 2004
Mississippi	1996 (late-season; Dec.)	Conventional	Harvested (stubble, long flood)	6	15+	5	Manley 1999, Manley et al. 2004
Mississippi	1996 (late-season; Dec.)	Conventional	Harvested (stubble, short flood)	6	15+	10	Manley 1999, Manley et al. 2004
Mississippi	1996 (late-season; Dec.)	Conventional	Harvested (stubble, open)	6	15+	12	Manley 1999, Manley et al. 2004
Mississippi	1996 (late-season; Dec.)	Conventional	Harvested (disked, long flood)	6	15+	9	Manley 1999, Manley et al. 2004
Mississippi	1996 (late-season; Dec.)	Conventional	Harvested (disked, short flood)	6	15+	9	Manley 1999, Manley et al. 2004
Mississippi	1996 (late-season; Dec.)	Conventional	Harvested (disked, open)	35	15+	6	Manley 1999, Manley et al. 2004
MAV (AR, LA, MS, MO)	2000–01 (early winter)	Conventional & Stripper	Harvested (flooded)	40	10	127	Rutka 2004

LOCATION	YR (MTH) OF TESTS	HARVEST TYPE /FIELD	FIELD STATUS	# FIELDS	SAMPLES	MEAN kg/ha	SOURCE
MAV (AR, LA, MS, MO)	2000–01 (late winter)	Conventional & Stripper	Harvested (flooded)	40	10	36	Rutka 2004
MAV (AR, LA, MS, MO)	2001–02 (early winter)	Conventional & Stripper	Harvested (flooded)	72	10	84	Rutka 2004
MAV (AR, LA, MS, MO)	2001–02 (late winter)	Conventional & Stripper	Harvested (flooded)	72	10	28	Rutka 2004
MAV (AR, LA, MS, MO)	2000 (Late Sept.–early Oct.)	Conventional & Stripper	Harvested	47	10	340 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000 (late Oct.)	Conventional & Stripper	Harvested	40	10	302 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000 (mid-Nov.)	Conventional & Stripper	Harvested	40	10	153 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000 (early Dec.)	Conventional & Stripper	Harvested	40	10	116 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2001 (Late Sept.–early Oct.)	Conventional & Stripper	Harvested	70	10	247 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2001 (late Oct.)	Conventional & Stripper	Harvested	36	10	103 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2001 (mid-Nov.)	Conventional & Stripper	Harvested	36	10	41 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2001 (early Dec.)	Conventional & Stripper	Harvested	69	10	54 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2002 (Late Sept.–early Oct.)	Conventional & Stripper	Harvested	40	10	226 [4]	Stafford 2004, Stafford et al. 2006

LOCATION	YR (MTH) OF TESTS	HARVEST TYPE /FIELD	FIELD STATUS	# FIELDS	SAMPLES	MEAN kg/ha	SOURCE
MAV (AR, LA, MS, MO)	2002 (late Oct.)	Conventional & Stripper	Harvested	50	10	97 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2002 (mid-Nov.)	Conventional & Stripper	Harvested	50	10	81 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2002 (early Dec.)	Conventional & Stripper	Harvested	50	10	65 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000–02 (post-harvest)	Conventional	Harvested		10	226 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000–02 (post-harvest)	Stripper	Harvested		10	355 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000–02 (early winter)	Conventional	Harvested		10	85 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000–02 (early winter)	Stripper	Harvested		10	68 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000–02 (early winter)	Conventional & Stripper	Harvested (stubble)		10	123 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000–02 (early winter)	Conventional & Stripper	Harvested (disked)		10	79 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000–02 (early winter)	Conventional & Stripper	Harvested (rolled)		10	72 [4]	Stafford 2004, Stafford et al. 2006
MAV (AR, LA, MS, MO)	2000–02 (early winter)	Conventional	Harvested (mowed)		10	60 [4]	Stafford 2004, Stafford et al. 2006
Mississippi & Arkansas (MAV)	2003–04 (post-harvest; Sept.–Oct.)	Stripper & Conventional (no difference)	Harvested (all treatments)	22	10	304	Kross 2006

LOCATION	YR (MTH) OF TESTS	HARVEST TYPE /FIELD	FIELD STATUS	# FIELDS	SAMPLES	MEAN kg/ha	SOURCE
Mississippi & Arkansas (MAV)	2003–04 (late-season; Nov.)	Stripper & Conventional (no difference)	Harvested (standing stubble)	5	10	105	Kross 2006
Mississippi & Arkansas (MAV)	2003–04 (late-season; Nov.)	Stripper & Conventional (no difference)	Harvested (burned)	3	10	72	Kross 2006
Mississippi & Arkansas (MAV)	2003–04 (late-season; Nov.)	Stripper & Conventional (no difference)	Harvested (mowed)	4	10	67	Kross 2006
Mississippi & Arkansas (MAV)	2003–04 (late-season; Nov.)	Stripper & Conventional (no difference)	Harvested (rolled)	5	10	51	Kross 2006
Mississippi & Arkansas (MAV)	2003–04 (late-season; Nov.)	Stripper & Conventional (no difference)	Harvested (disked stubble)	5	10	48	Kross 2006
Mississippi & Arkansas (MAV)	22003–04 (late-season; Nov.)	Stripper & Conventional (no difference)	Harvested (all treatments)	22	10	66	Kross 2006
Mississippi & Arkansas (MAV)	2003–04 (late-season; Nov.)	Stripper & Conventional (no difference)	Harvested (all treatments)	22	10	66	Kross 2006
Mississippi & Arkansas (MAV)	2003–04 (late-season; Nov.)	Stripper & Conventional (no difference)	Harvested (all treatments)	22	10	66	Kross 2006
Texas	1978 (Oct.–Nov.)	Conventional	Harvested	10	20	140	Hobaugh 1984
Texas	2000–01 (Aug.)	Conventional	Harvested	?	9	374	Wilson et al. 2001[3]

[1] Tests conducted on harvester combine efficiency in standing rice (n = 138 tests) and down rice (n = 22 tests), not fields per se.
[2] Tests conducted on harvester combine efficiency in standing rice (n = 6 tests), not in fields per se.
[3] Tests conducted on harvester combine efficiency in standing rice (n = 9 tests at optimum harvester speed, assuming 5.4% total loss of seed), not fields per se.
[4] Values are bias-corrected for undercounting (missed) seeds.

TABLE 3 Density (kg/ha dry weight) of seeds other than domestic rice left in fields after harvest (except as noted) in California, Texas, Arkansas, Louisiana, and Mississippi.

LOCATION	YR (MTH) OF COLLECTION	HARVEST TYPE	FIELD STATUS	# FIELDS	SAMPLES /FIELD	MEAN kg/ha	SOURCE
Arkansas	1979 (Oct.)	Conventional	Harvested	1	6	374	Smith and Sullivan 1980
Arkansas	1983–84 (Nov.)	Conventional	Harvested	17	10	12	Reinecke et al. 1989
Arkansas	1984–85 (Nov.)	Conventional	Harvested	17	10	37	Reinecke et al. 1989
California	1985 (Sept.–Nov.)	Conventional	Harvested	111	2	28	M. R. Miller, unpubl. data
California	1992 (Nov.–Jan.)	Conventional	Harvested	6	3	44	Loughman and Batzer 1992
Louisiana	1958 (Dec.)	Conventional	Harvested	9	20	33	Harmon et al. 1960
Louisiana	1958 (Jan.)	Conventional	Harvested	9	20	26	Harmon et al. 1960
Louisiana	1958 (Nov.)	Conventional	Harvested	7	20	39	Harmon et al. 1960
Louisiana	1960 (Nov.)	N/A	Fallow	18	25	368	Davis et al. 1961
Mississippi	1995–96 (Dec.)	Conventional	Harvested	35	15+	11	Manley 1999, Manley et al. 2004
Mississippi	1996–97 (Dec.)	Conventional	Harvested	35	15+	4	Manley 1999, Manley et al. 2004
MAV (AR, LA, MS, MO)	2002–04 (Oct.–Nov.)	Conventional	Harvested	35	15	4	Manley 1999, Manley et al. 2004

TABLE 4 The most abundant moist-soil seeds found in harvested ricefields in California, Louisiana, Arkansas, and Mississippi.

CALIFORNIA (M. R. Miller, unpubl.)	LOUISIANA (Harmon et al. 1960)	ARKANSAS (K. J. Reinecke, unpubl.; Smith and Sullivan 1980)	MISSISSIPPI (Manley 1999, Manley et al. 2004)
Echinochloa	*Oryza sativa var.*	*Oryza sativa var.*	*Echinochloa*
Scirpus	*Echinochloa*	*Echinochloa*	*Paspalum*
Polygonum	*Brachiaria*	*Cyperus*	*Polygonum*
Paspalum	*Cyperus*	*Polygonum*	*Sesbania*
Ammania	*Paspalum*	*Panicum*	
Cyperus	*Polygonum*	*Brachiaria*	
	Caperonia	*Poa*	
	Eleocharis	*Euphorbia*	
		Sida	
		Digitaria	
		Convolvulus	

Moist-soil Plants - Moist-soil plants, considered weeds by most producers, grow in ricefields and their seeds are available to waterfowl and other waterbirds after harvest of the rice crop. Estimates of the quantity of these seeds typically range from 12 to 44 kg/ha dry weight in commercial fields, but occasionally are much higher (Table 3). Additionally, fallow fields may provide an abundant "crop" of moist-soil seeds, such as red rice (*Oryza sativa* var.) (Smith and Sullivan 1980). A wide variety of seeds are present, but only a few are important, such as barnyardgrass (*Echinochloa* spp.) and smartweeds (*Polygonum* spp.), which have been found in ricefields throughout the rice-growing regions in North America (Table 4).

Green Vegetation - Following harvest, rice and moist-soil seeds germinate and produce green vegetation that is consumed primarily by geese (Hobaugh 1984, Leslie and Chabreck 1984, Alisauskas et al. 1988, Day 1997). Manley et al. (2004) estimated as much as 59 kg/ha (dry mass) of green forage available in Mississippi ricefields. No other quantitative estimates of this forage have been made in any of the other rice-growing states. However, Hobaugh (1984) developed an index to the growth and availability of green forage in harvested ricefields in Texas. He found that the green forage index increased markedly in ricefields from January to March, coinciding with heaviest use of this food by Lesser Snow Geese (Hobaugh 1984, 1985; Alisauskas et al. 1988). Researchers have not quantified either the production or use by waterfowl of green forage in California ricefields.

Aquatic earthworms (Class Oligochaeta) are very abundant in ricefields and provide an important food source for waterfowl and shorebirds

Aquatic Invertebrates - Aquatic invertebrates are always present in harvested ricefields that are flooded; however, estimates of numbers and biomass are limited. Loughman and Batzer (1992) estimated the density of midge (Chironomidae) larvae and other aquatic invertebrates in flooded ricefields that had been burned, rolled, or not treated in California's Sacramento Valley. Midge densities generally increased during winter, from an estimated 50 larvae/m^2 in November to >400 larvae/m^2 in February, declining thereafter as fields dried. Other abundant invertebrates included aquatic worms (Oligochaeta), seed shrimp (Ostracoda), water fleas (Cladocera), and copepods (Copepoda). McAbee (1994) estimated 7.0 kg/ha of aquatic invertebrates in Louisiana ricefields in winter. Hohman et al. (1996) found 22.0 kg/ha of aquatic invertebrates in Gulf Coast ricefields in early spring; and in Mississippi, Manley (1999) found that invertebrate mass averaged 6.3 kg/ha and peaked at 21.1–31.7 kg/ha by March. These values appear to be in the range of estimates determined for other Mississippi wetlands, including green-tree reservoirs [9.8 kg/ha (Wherle et al. 1995) vs. 11.1 kg/ha (Duffy and LaBar 1994)], naturally flooded forests [40.6 kg/ha (Wherle et al. 1995)] and managed moist-soil marshes (or wetlands) [31 kg/ha (Gray et al. 1999)]. In Mississippi ricefields, aquatic invertebrates consisted primarily of Gastropoda, Insecta, Oligochaeta, and Ostracoda (Manley 1999). Unlike seeds, which are produced once a year and then decline thereafter, invertebrates are continually produced. Thus the densities listed here may seem relatively low compared to seed densities, but total production of invertebrates over the winter period may be quite high.

Energy Value of Rice Relative to Other Seeds and Grain - Rice seed has relatively high caloric value compared with other cereal grains and moist-soil seeds (See Table 5 with scientific names, page 30). For instance, Miller (1987) estimated apparent metabolizable energy (AME) values (Miller and Reinecke 1984) for selected moist-soil seeds and rice from digestibility coefficients (Harris 1966) and metabolizable energy of digestible protein, fat, and nitrogen-free extract (Vohra 1972). AME for rice was 3.53 kcal/g, second only to swamp timothy at 3.71 kcal/g. Other moist-soil seeds ranged from 2.72 kcal/g to 3.33 kcal/g (Table 5). Reinecke et al. (1989) provided estimates of AME and true metabolizable energy (TME), Miller and Reinecke (1984) assayed with Mallards for several grains, including rice, and Petrie et al. (1998) provided similar data for Canada Geese. Estimates for rice TME ranged from 3.34 to 3.76 kcal/g compared to 3.67 to 3.90 kcal/g for corn. Soybean TME was 2.65 kcal/g and wheat TME was 3.38 kcal/g. Other estimates of TME assayed with a variety of waterfowl are available for various foods and range from 1.08 kcal/g for smartweeds to 3.47 kcal/g for wild rice (Sherfy 1999) and 4.03 kcal/g for chufa tubers (Petrie et al. 1998; summarized in Table 5). In summary, rice ranks as one of the most energetically valuable grains and seeds consumed by waterfowl.

Rice, however, is not a complete food. Protein and other nutrients may be in short supply in grains, and winter diets need to be supplemented with other seeds, green vegetation, and invertebrates to provide protein. For example, evidence from studies of food use suggests that Mallards included snails in their diet when feeding in ricefields to obtain additional nutrients (Delnicki and Reinecke 1986). Similarly, Northern Pintails wintering in the Sacramento Valley often consumed moist-soil seeds, green sprouts, and invertebrates immediately upon returning to managed marshes in national wildlife refuge sanctuaries after having fed all night in harvested ricefields (Miller 1987).

Refuge/Loafing Benefits - Waterfowl and other wetland birds use harvested ricefields for purposes other than feeding, although provision of food is probably the most critical function of these fields. Northern Pintails using flooded fields in the Sacramento Valley during mid- and late winter spent about 60% of the day loafing and only 10% feeding, because most feeding was nocturnal (Miller 1985) and most rice seed in the fields was consumed by this time. Similar results were reported for several Louisiana ricefields that were set aside as small (60 ha) experimental refuges. Rave and Cordes (1993) studied the use of these ricefield refuges by Northern Pintails, the most common species, and found that pintails spent more than 50% of their time resting and 21% feeding. Additionally, Pintails fed more often on these ricefields during the day than on nearby marsh areas. They also discovered, as did Miller

TABLE 5 Estimates of Apparent Metabolizable Energy (AME) and True Metabolizable Energy (TME) of rice compared to other waterfowl food items.

FOOD ITEM	LATIN NAME	MEASURE	ENERGY USED	SOURCE (kcal/g)
Rice	*Oryza sativa*	AME	3.53	Miller 1987
Rice	*Oryza sativa*	TME	3.34–3.76	Reinecke et al. 1989, Petrie et al. 1998
Acorns	*Quercus spp*	TME	2.35–2.91	Petrie 1994; R.M. Kaminski, unpubl.; K.J. Reinecke, unpubl.
Barnyardgrass	*Echinochloa crusgalli*	AME	3.33	Miller 1987, Reinecke et al. 1989
Barnyardgrass	*Echinochloa crusgalli*	TME	2.61–3.29	Petrie et al. 1998, Sherfy 1999, Sherfy et al. 2001, Checkett et al. 2002
Coast barnyardgrass	*Echinochloa walteri*	TME	2.82–2.86	Hoffman and Bookhout 1985
Chufa tubers	*Cyperus esculentus*	TME	4.03	Petrie et al. 1998
Corn	*Zea mays*	TME	3.67–3.90	Reinecke et al. 1989, Petrie et al. 1998
Panicum	*Panicum spp.*	TME	2.54–2.75	Sherfy 1999, Checkett et al. 2002
Paspalum	*Paspalum spp*	TME	2.56	Checkett et al. 2002
Pigweed	*Amaranthus spp*	TME	2.88	Checkett et al. 2002
Roughseed bulrush	*Scirpus mucronatus*	AME	2.72	Miller 1987
Smartweeds	*Polygonum spp*	AME	3.16	Miller 1987
Smartweeds	*Polygonum spp*	TME	1.08–1.52	Hoffman and Bookhout 1985, Checkett et al. 2002
Soybean	*Glycine max*	TME	2.65	Reinecke et al. 1989, Petrie et al. 1998
Swamp timothy	*Heleochloa schoenoides*	AME	3.71	Miller 1987
Wheat	*Triticum aestivum*	TME	3.38	Reinecke et al. 1989, Petrie et al. 1998
Wild rice	*Zizania aquatica*	TME	3.47	Sherfy 1999
Yellow bristlegrass	*Setaria lutescens*	TME	2.88	Checkett et al. 2002

(1985), that all Pintails left the refuge ricefields after sunset to forage elsewhere during the night, and then returned shortly before sunrise. Rave and Cordes (1993) concluded that large numbers of Pintails would use relatively small harvested ricefields as roosting habitat. However, a subsequent study (Cox and Afton 1998, Cox et al. 1998) indicated radio-marked Pintails used ricefield "mini-refuges" at about the same rate as a traditional refuge and recommended that ricefield refuges be increased in size and located only in areas likely to receive high use.

Wading birds also use ricefields for roosting during the day. In California, time budgets showed that seven species of shorebirds each spent 5–35% of their time sleeping or preening while they were in ricefield habitats (Elphick 2000). Great Egrets also devoted about 5% of their time to these activities while using rice habitats, and were more likely to spend time sleeping in unflooded ricefields than in either flooded rice or managed moist-soil wetlands. At night, both shorebirds and egrets typically left ricefields presumably to roost elsewhere (Elphick, personal observations).

Amount of Ricefield Habitat Available in Winter - The food resources available to waterfowl and other wildlife in harvested ricefields are determined by the amount of food per unit area (density) and the extent of habitat available. At least in winter, the area of harvested rice flooded for waterfowl is greatest in the Sacramento Valley, followed closely by the MAV. Management of rice for waterfowl also is substantial along the Gulf Coast of Louisiana and Texas, but work has not been completed to determine the exact area of habitat involved. Obtaining habitat inventories in these regions is a priority because large waterfowl populations are present and rice production is decreasing due to rising costs and other market forces (Hobaugh et al. 1989).

In the Sacramento Valley of California, harvested rice traditionally was burned to reduce the quantity of straw and, at that time, producers flooded a total of about 24,000 ha (≈60,000 acres) to provide duck hunting opportunities. Since the passage of state legislation to reduce field burning in fall, rice producers have adopted field flooding after harvest as part of a straw disposal program. Today, the area flooded in the Sacramento Valley after harvest might be as high as 120,000 ha (≈297,000 acres), or 60% of the total land farmed for rice (Fleskes et al. 2005). Much of this flooded land is hunted; however, a significant proportion is not, and these fields serve as *de facto* refuges scattered throughout the Sacramento Valley. Summarizing habitat status in the 1980s, Heitmeyer et al. (1989) suggested that landowners in the Sacramento Valley purposely flooded about 32,000 ha (≈79,000 acres) of rice and even more was available when rains and flooding occurred. By winter 1993–94, Spell et al. (1995) estimated that landowners in the Sacramento Valley had responded to California's legislation and increased flooding of ricefields to 57,702 ha (≈143,000 acres). The most recent analysis, which combined remote sensing data and landowner surveys in the Sacramento Valley, yielded an estimate of 129,548 ha (≈320,000 acres) in winter 2000–01 (Ducks Unlimited, Inc., Western Regional Office, unpublished data). Thus flooding of ricefields in the Sacramento Valley probably has increased more than fivefold in the past two decades.

In the MAV, the first quantitative data on management of ricefields are from Uihlein (2000), who employed aerial surveys to estimate ricefield extent managed to impound water. During winters 1992–93 through 1994–95 an average of 80,830 ha/year (≈200,000 acres) of ricefields were flooded by closing water-control structures and maintaining levee systems. Recently completed landscape analyses using remote sensing and geographic information systems technology estimated an average 59,490 ha/year (≈147,000 acres) of ricefields were managed for flooding across the MAV portions of Arkansas, Mississippi, and Missouri in winters 2002–04 (Ducks Unlimited, Inc. Southern Regional Office, unpublished data). Data for northeast Louisiana were not available. Over the past decade, active incentives, research, and extension education programs have been employed to sustain these winter management practices (Baxter et al. 1996).

In all regions, there remains additional potential to increase the area of land flooded. Even in cases where there is little economic incentive for producers to actively flood their fields, simply closing off drains to hold rainwater in the fields would provide additional habitat at minimal cost. Since fields managed in this way will often have relatively shallow water, this approach would be especially beneficial for shorebirds (Elphick and Oring 2003).

Breeding Habitat

Food Resources (seeds/invertebrates) - Far less research has been conducted on the resources available to wildlife in ricefields during the breeding season, or on the value of those resources for supporting populations of management interest. In contrast to the fall and winter, few studies have examined the abundance of food in fields during spring and summer. Perhaps the best information comes from studies of whistling ducks, but many other species also breed in fields (see Use of Ricefields by Wildlife, page 4), and further research on the conditions that favor successful reproduction would be of great value.

Rice culture has probably been responsible for the expansion of the nesting range of the Fulvous Whistling Duck throughout the rice belt in Louisiana (Lynch 1943). This species has been present in Texas ricefields for some time and uses fields for nesting and feeding. Diet data from Louisiana show that rice seed in water-planted fields makes up as much as 78% of the spring diet (Meanley and Meanley 1959), but mostly other seeds are consumed where rice is dry-planted, such as *Fimbristylis*, *Paspalum*, *Eleocharis*, *Cyperus*, *Echinochloa*, and *Barsenia* spp. Hohman et al. (1996) estimated that tilled ricefields flooded and ready for planting in Louisiana contained an average of 1,014 kg/ha of moist-soil seeds, the most common of which were signalgrass (*Brachiaria*), beakrush (*Rhynchospora*), and flatsedge (*Cyperus*). These investigators also estimated that 22 kg/ha of aquatic invertebrates, especially aquatic earthworms (Oligochaeta), were present in the fields. This is the only data set of seed and invertebrate availability in ricefields during the growing season of which we are aware. The estimate for seeds is very high, relative even to moist-soil habitat in managed wetlands (Hohman et al. 1996). However, the fields studied had been fallow the previous year, which enhanced growth of seed-producing plants and probably increased density of seeds available in fall (Davis et al. 1961) compared to what would have been available if the fields had been farmed previously. Fulvous Whistling Ducks consumed greater quantities of signalgrass, beakrush, and flatsedge seeds than other foods in spring, although the whistling ducks consumed barnyardgrass and aquatic earthworms in disproportionately large amounts relative to their availability.

Black-bellied Whistling Ducks are present in south Texas in small, but perhaps increasing numbers (Bolen and Rylander 1983), and may nest in the Rio Grande Valley and in the vicinity of Corpus Christi. This species is more attracted to natural lakes than are Fulvous Whistling Ducks, but they have been reported feeding in ricefields during the nesting season in Guyana (Bourne 1982). Plant material made up 90–97% of total foods consumed by adults, and most of this was rice seed eaten before germination. Juvenile whistling ducks, collected later in the nesting season after rice had germinated, consumed mostly *Paspalum* sp. seeds. Other food important to adults and juveniles included barnyardgrass and *Scleria pterota* seeds. Few ricefield invertebrates were consumed. No information on the density of these foods in the ricefields was available.

Nest Sites - Fulvous Whistling Ducks nest over water in ricefields in cover characterized by rice mixed with heavy infestations of weeds, such as barnyardgrass, *Paspalums*, smartweeds, and others (Bolen and Rylander 1983). However, these ducks construct the nest bowl from rice plants. Mottled ducks live year-round in the coastal regions of Louisiana, Mississippi, Texas, and Florida and are closely associated with ricelands. Although detailed nest studies in rice have not been conducted, it is believed that ricefields are an important breeding habitat for Mottled Ducks, especially in Louisiana (Stutzenbaker 1988).

Mallard hen and ducklings on nest in California's Sacramento Valley

Mallards and probably Cinnamon Teal in California nest on boundary and interior water-control levees in ricefields where cover is dense enough, as well as in "set-aside" lands withheld from rice production (Yarris 1995, McLandress et al. 1996). Mallards also nest in growing wheat and barley fields that are adjacent to ricefields, and move their broods to ricefields after hatch. The Sacramento Valley, where virtually all of the Central Valley's rice is grown, supports the largest breeding population of Mallards in California. Rice agriculture is key to Mallard abundance in California, although adjacent managed wetland and upland habitats on federal and state wildlife areas are critical as well (McLandress et al. 1996).

King Rails nest in ricefields in the Gulf Coast and MAV (Meanley 1953, 1956, 1992). Hohman et al. (1994) documented nesting by 5 species of waterbirds in ricefields of southwestern Louisiana, with an average of 37.2 waterbird nests/km^2. King Rails (15.9 nests/km^2), Fulvous Whistling Ducks (15.1 nests/km2) and Purple Gallinules (5.1 nests/km^2) were common, while Common Moorhen and Least Bittern nests were found at lower densities. Nesting densities tended to be higher in "dense" than in "less dense" stands of rice, but were not affected by planting practices (water-seeded vs. dry-seeded). Apparent nest success of Fulvous Whistling Ducks in dry-seeded fields was half that in water-seeded ricefields (Hohman et al. 1994). Helm et al. (1987) also reported high nest densities of Common Moorhens and Purple Gallinules in southwestern Louisiana and found that clutch sizes and nest success were greater for nests in ricefields than in freshwater marshes. Shorebirds, Black Terns, and numerous passerines also frequently nest in ricefields, although there has been little systematic study of the characteristics of rice habitats that most benefit these species.

Brood Habitat - Although broods of waterbirds are observed feeding and loafing in flooded ricefields, quantitative data are few. In California, flooded fields are frequently used by Mallard broods in the rice-growing regions of the Sacramento Valley (Yarris 1995). Hatching success of Mallards nesting near ricefields is apparently high, but little is known about survival and brood habitat use. Since natural emergent wetlands are scarce in spring in the Sacramento Valley, with less than 10% of wetlands on wildlife areas flooded during the breeding season (Yarris 1995), the main habitats available to Mallard broods are flooded ricefields and associated irrigation ditches and canals. Yarris (1995) found that Mallard hens and their broods restricted their movements to irrigation canals until ricefields were flooded; once the rice plants were tall enough to provide cover, broods used ricefields almost exclusively. Survival of early-hatched ducklings was lower than that of late-hatched young, in marked contrast to the pattern observed in most other breeding areas. This difference was related to the timing of ricefield flooding (Yarris 1995). Predation on early broods was high and survival averaged only 0.10–0.14 in two years of study, because these broods were restricted to either irrigation ditches or open ricefields with little emergent cover. Later, the growth of rice plants provided sufficient cover to conceal broods from predators and Mallard hens avoided irrigation canals where predators tended to concentrate; survival of late-hatching ducklings was significantly higher (0.59 in both years). Thus the value of ricefields depends critically on the time of season; for early-nesting females, ricefields present poor-quality habitats whereas the opposite is true for later-nesting birds. Yarris (1995) proposed that the benefits of flooded ricefields during the breeding season could be maximized for Mallards in California if efforts were focused on providing alternative early-season wetlands.

EFFECTS OF RICEFIELD MANAGEMENT

Numerous studies show that various aspects of ricefield management influence the use of fields by wildlife. Much of this research has focused on waterbirds. In North America, limited research has been conducted on other groups of birds, and even less is known about the effects of management on most amphibians, reptiles, or mammals. In this section, we summarize the major management activities that influence bird use of ricefields.

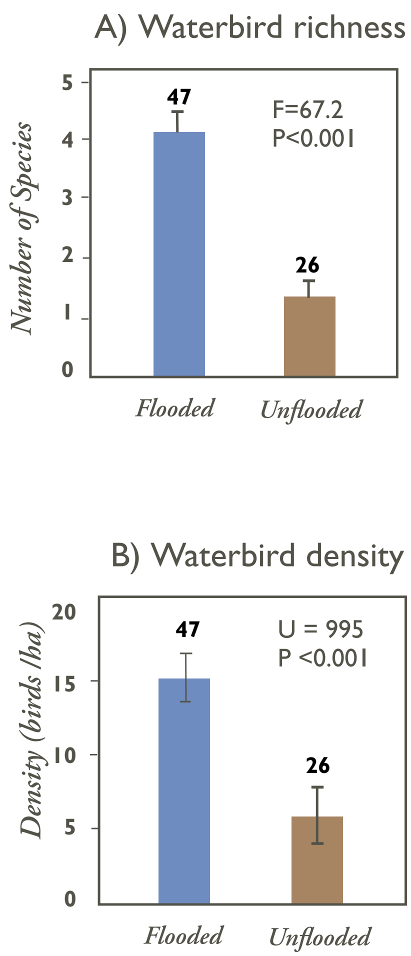
Flooding During the Nongrowing Season - Winter flooding clearly affects bird use of ricefields in numerous ways. In California, bird abundance differs significantly between flooded and unflooded fields (Table 6). Twenty-eight (28) species were more abundant in flooded fields, while 14 species were more abundant in unflooded fields (Elphick and Oring 1998, Elphick 2004). Overall, waterbird species richness and densities were higher in flooded fields than unflooded fields (Figure 4A; Elphick and Oring 2003). Flooded fields are used on average by about twice as many waterfowl as are unflooded fields (Figure 4B; Elphick and Oring 2003). Much of the use of unflooded fields can be attributed to geese, with significantly higher densities of most duck species in flooded fields. Not surprisingly, ducks, shorebirds, long-legged waders, and other aquatic birds used flooded fields in higher numbers than unflooded fields (Elphick and Oring 1998). In Louisiana, Greater White-fronted Goose flocks occurred far more frequently in "puddled" wet-harvested rice than in dry-harvested rice and used wet rice more frequently than expected based on relative abundance (Leslie and Chabreck 1984). Both Great Blue Herons and Sandhill Cranes were more abundant in unflooded fields than flooded fields (Elphick and Oring 1998), however, as were several species of raptors and passerines (Table 6). Not all passerines were found at reduced levels in flooded fields; Black Phoebes, Marsh Wrens, American Pipits, and Song Sparrows were all more common in flooded fields, and a dozen other species were equally common in the two habitats (Elphick 2004).

Flooding and the extent of vegetation cover influence the use of ricefields by shorebirds and wading birds in southern Louisiana (Rettig 1994). In this region, about 70% of shorebirds were found in wet fields with less than 50% vegetation cover, even though this habitat only constituted about 19% of the available habitat. Between August and October, this habitat was especially rare and shorebirds were highly concentrated in the small areas available. Wading birds also achieved their highest densities in wet fields with less than 50% vegetation cover, with the exception that Cattle Egrets occurred at similar densities in dry fields with less than 50% cover and those with more than 50% cover (Rettig 1994).

One indication of the importance of winter-flooded fields comes from a large study of waterfowl movement patterns in California. Using radiotelemetry, researchers found that Northern Pintails in the vicinity of the Grasslands Ecological Area in the San Joaquin Valley make daily trips to feed in available ricefields immediately after they were flooded. This result is especially interesting because rice is a very rare habitat in the vicinity of the Grasslands Ecological Area, and the only two fields of rice were quite distant from sanctuaries (Fleskes 1999). This same study showed a large-scale shift of the Northern Pintail population from the San Joaquin Valley into the rice-growing region of the Sacramento Valley in early December, coincident with widespread ricefield flooding (Fleskes et al. 2002).

Water Depth - Although flooded fields typically receive greater waterbird use than unflooded fields, there is considerable variation in the occurrence and densities of each species in different flooded fields. Some of this variation can be attributed to differences in water depth among paddies. In California, fields in which wading birds or waterfowl were present were significantly deeper than those in which these groups were absent, whereas the opposite was true for shorebirds (Elphick and Oring 2003). The depth ranges used by different species varied considerably (Elphick and Oring 1998); median depths for different groups of waterbirds are summarized in Table 7. Waterbird species richness peaked at intermediate water depths (Elphick 1998). Analyses of the depths at which most species are capable of using fields (Elphick and Oring 1998) and the conservation benefits for waterbirds (Elphick and Oring 2003) suggest that depths between 10 and 20 cm should be preferred for waterbird management (Figure 5A). Favoring the lower end of this range is probably ideal, because deeper water excludes more species. These assessments assume that ricefields are too shallow to be an appropriate habitat to manage for waterbirds that feed by diving underwater. However, in California, large flocks of Canvasbacks are seen diving in ricefields that have been flooded deeply by rainfall (M. R. Miller, personal observation).

FIGURE 4



Species richness (A) and density (B) of waterbirds is higher in flooded than in unflooded ricefields in California. Data from Elphick and Oring (2002).

Error bars are ± 1 SE. Numbers above bars are sample sizes.

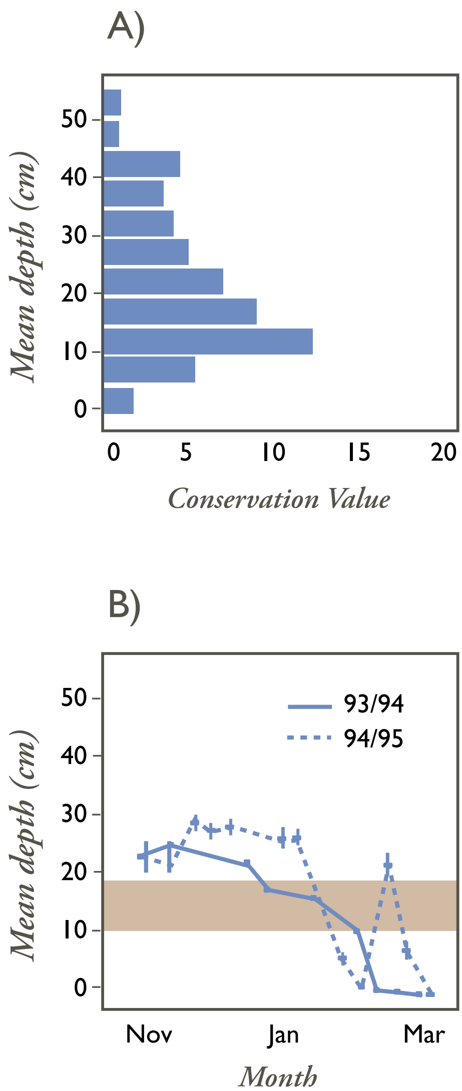
TABLE 6 Abundance of different groups of waterbirds in flooded and unflooded ricefields. Values in table indicate the number of species that were more abundant in flooded ricefields, unflooded ricefields, or that did not differ significantly ($P < 0.05$). Data from Elphick and Oring (1999).

TAXA	MORE ABUNDANT IN FLOODED	MORE ABUNDANT IN UNFLOODED	NO DIFFERENCE
Ducks	8	0	1
Geese	0	0	3
Shorebirds	9	0	0
Herons	2	1	1
Raptors	0	6	6
Land Birds	4	6	12
Others	5	1	0
All species	28	14	23

TABLE 7 Median water depths used by waterbirds in California ricefields.

TAXA	MEDIAN WATER DEPTH
Shorebirds	3–13 cm
Herons & Ibis	9–20 cm
Dabbling Ducks	14–22 cm
Geese	18–26 cm
Diving Species	24–34 cm

FIGURE 5



The conservation value of different water depths (A) and the seasonal changes in water depth in California ricefields (B). Conservation value is indexed by the water depths used by different species of waterbirds and their relative abundance in North America (from Elphick and Oring 1998). Shaded region in B represents depth used by most waterbirds.

Error bars are ± 1 SE.

Unfortunately in California, during much of the winter, fields are flooded to depths greater than 20 cm (Figure 5; Elphick and Oring 1998). Only in early spring, when producers begin to drain their fields, do average water depths fall into the range favored by most waterbirds. Consequently, one simple method for enhancing flooded fields would be to decrease average water depths. Such management would likely benefit producers by reducing water costs for winter flooding and would not compromise straw decomposition goals (Elphick and Oring 1998, Elphick and Oring 2003). Moreover, simply blocking field drainage outlets and holding back rainwater could achieve shallow conditions. Relations between water depth and waterbird distribution have not been studied in detail in the other two rice-growing regions. Based on water depth selection in moist-soil habitats in the MAV (cf. Fredrickson and Taylor 1982: Figure 6) and similarities in the composition of waterbird assemblages in the three regions, we expect waterbird responses to depth to be similar to those found in California.

Post-Harvest Straw Manipulation - Straw manipulation, intended to alter decomposition rates, generates another potential source of variation in bird use of winter-flooded fields. Various manipulations are conducted in conjunction with flooding, including: (1) rolling the straw to flatten and mix it with the soil, (2) disking to incorporate straw into the soil, and (3) chopping straw to increase the surface area over which microbial action can occur, among others. *A priori* one might expect manipulation methods designed to increase decomposition rates to alter food abundance, and thus affect bird use of fields. For example, in managed wetlands, disking vegetation has been proposed as a technique to increase invertebrate densities, and thus benefit shorebirds and other species that feed on invertebrates (e.g., Helmers 1993). While methods that increase straw decomposition might enhance the invertebrate prey base, they might also decrease the availability of spilled grain and weed seeds. Increased straw decomposition will likely also increase decomposition and lessen the nutritional value of seeds (Nelms and Twedt 1996). In addition, methods such as rolling and disking might bury seeds deeper in the substrate and reduce their availability or ease of discovery. For some species, residue manipulation might alter use patterns by changing factors other than food availability. For example, rolling stubble to improve access and visibility for birds (e.g., when scanning for predators) has been proposed as a method to enhance harvested ricefields as shorebird habitat in the MAV (Twedt et al. 1998). Experiments with moist-soil habitat show that use by shorebirds increased when cover was reduced, but that use by rails increased when there was dense residual cover (Rundle and Fredrickson 1981).

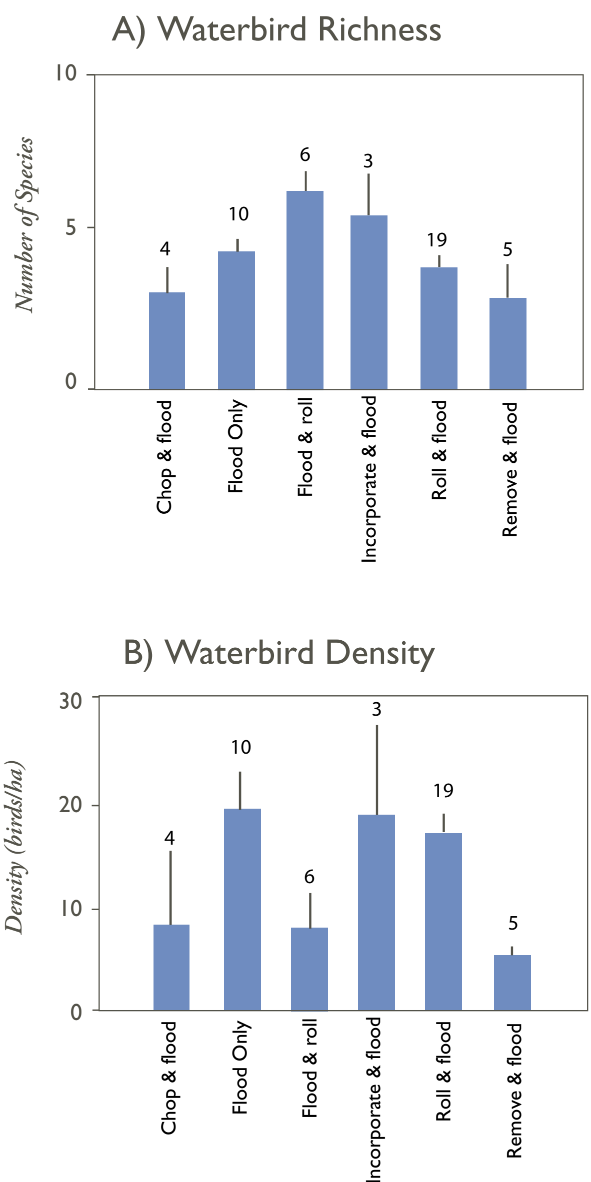
Rice straw roller in action in the Mississippi Delta

Waterbird species richness varied among different straw manipulation methods (Figure 6), and more species used fields that had been rolled after flooding, whereas the fewest used fields where straw had been removed (Figure 6A; Elphick and Oring 2003). Overall waterbird densities also differed among straw management treatments (Figure 6B). As a group, wading bird densities differed significantly among treatments, although this effect was apparently caused by the greater use of fields that were flooded without any additional manipulation by just two species: White-faced Ibis and American Bittern (Elphick and Oring 1998, Elphick and Oring 2003). Shorebird densities also differed among manipulation treatments (Elphick and Oring 2003), with greatest densities in fields where straw had been incorporated by disking as predicted by Helmers (1993) and others. This effect was caused primarily by the responses of short-legged species: Killdeer, Dunlin, Least Sandpiper, and Long-billed Dowitcher. In fact, the one long-legged shorebird for which an effect was seen (American Avocet) responded to straw manipulation in the same manner as the ibises and bitterns (Elphick and Oring 1998).

Interpreting these results is more complex than would first appear, because water depth interacted with residue management method. Fields where straw was incorporated, which were used by short-legged shorebirds more than other treatments, also had shallower water on average than fields subjected to other treatments. Similarly, fields used most by the three longer-legged species were, on average, among those with the deepest water (Elphick and Oring 1998). Fully evaluating the effects of straw manipulations awaits the use of experiments that control for the effect of water depth. In addition, small sample sizes for some straw manipulation methods in the study by Elphick and Oring limit the inferences that can be drawn. Finally, straw treatment effects were detected for an additional six species (a heterogeneous group including a grebe, a heron, a goose, a duck, and two shorebirds). Each of these effects, however, could have been caused by geographical variation in the abundance of these species within the Sacramento Valley (Elphick and Oring 1998). Again, critical tests to distinguish between a straw manipulation effect and a geographical effect have yet to be conducted.

The effects of straw manipulation in unflooded fields have not been studied, but some of the same issues might apply in this habitat. Disking dry fields may partially bury grain, thus reducing accessibility to some species (e.g., sparrows, blackbirds), but maybe not to others (e.g., geese). Burning rice stubble also can alter grain availability, either by destroying grain while reducing abundance (Miller et al. 1989) or, potentially, by making grain more accessible by removing large amounts of straw. The relative importance of these effects likely varies among species, depending on their foraging methods. Burning also might influence the availability of prey to predators higher up the food chain. In California, burned rice stubble received greater use by falcons than did unburned stubble during the fall. This difference, however, did not persist through the winter and was not evident for hawks (i.e., all Accipitridae; Smallwood et al. 1996), suggesting that it might simply be a short-term effect whereby prey become temporarily more vulnerable due to the loss of cover in burned fields.

FIGURE 6



The effect of different treatments of straw management on the diversity (number of species) and density of waterbirds in California ricefields. Data from Elphick and Oring (2002).

Error bars are ± 1 SE. Numbers above bars are sample sizes.

HARVEST MANAGEMENT

The effects of harvest method on waterbird use have been studied in California, comparing conventional cutter bar with stripper header technology (Day and Colwell 1998). The relative roles of resulting straw height and food availability following these two harvest mathods are not clear, and waterbird use is further influenced by post-harvest straw manipulations (e.g., chopping, rolling), especially in fields where stripper headers were used. If stalks are not cut, smaller birds such as ducks may become dependent on geese to visit fields first and disturb vegetation sufficiently to create openings. Geese, however, would also deplete food, and may themselves be deterred from entering uncut fields. For example, past studies suggest that relatively few geese are found in stripped fields in the Sacramento Valley of California (Day and Colwell 1998, C. S. Elphick; personal observation).

Small species that prey on invertebrates, such as *Calidris* sandpipers, might avoid stripped fields simply because the tall stubble makes movement difficult and obscures their field of view when scanning for predators. Great Egret and Great Blue Heron, both carnivores tall enough to see over the top of tall stalks, were among the few species to be found in the majority of stripped fields. Other species, such as American Bittern and perhaps certain rails, might occur more frequently in fields with taller stubble but this hypothesis remains untested. For granivorous species, interpreting differences in habitat use is more complicated than for carnivores because stripped fields differ from those harvested conventionally both in food abundance and habitat structure.

Organic Chemicals - A number of organic chemicals are used in the rice industry and have the potential to impact wildlife. Organochlorines (e.g., aldrin, dieldrin, or toxaphene), organophosphates (e.g., Azodrin or methyl parathion), and carbamates (e.g., carbofuran, also called Furadan) have been used to deal with the large losses (up to $50 million annually) to the rice industry caused by pests such as the rice water weevil (*Lissorhoptrus oryzophilus*). Plant pests, particularly watergrass (barnyardgrass) and red rice, also cause extensive losses, reducing rice yields by 20–65%. Crop rotation, winter flooding, and herbicides such as molinate, propanil, bensulfron methyl or thiobencarb have all been used to manage weeds.

Acute insecticide poisoning did occur in the late 1950s through the 1970s, when large numbers of waterfowl, particularly Snow Geese and Blue-winged Teal (*Anas discors*), died annually throughout the Texas rice prairies (Hobaugh et al. 1989). Studies of the effect of aldrin exposure to wildlife indicated that the treatment of seeds with aldrin could lead to significant wildlife mortalities (Flickinger and King 1972, Flickinger 1979) and weight loss in Snow Geese (Flickinger 1979). Granular carbofuran was observed to be highly toxic to birds, fish, and invertebrates (Flickinger et al. 1980). Bird poisoning from the accidental misuse of carbofuran was recorded in a Texas ricefield (Flickinger et al. 1986) and a series of losses of waterfowl and raptors in California from 1984 to 1988 was attributed to carbofuran (Littrell 1988). Poisoning of waterfowl by Azodrin was observed in Louisiana ricefields (White et al. 1983). Analyses of the effect of ethyl and methyl parathion in California ricefields indicated that neither chemical was acutely hazardous to wildlife in or adjacent to ricefields. However, Ring-necked Pheasants, American Coots, and house mice exposed to methyl parathion exhibited significant inhibition of brain cholinesterase activity, suggesting that sub-lethal impacts may be of concern. In California, more than 65,000 carp, catfish, black bass, and crappie died in ricefield drain waters of the Sacramento Valley between 1980 and 1983 as the result of molinate poisoning (CH2M Hill 1996).

Regulation and changes in the use of permitted organic chemicals beginning in the mid-1970s resulted in significant improvements for wildlife (Hobaugh et al. 1989). Use of aldrin was cancelled in 1974, pesticide treated rice seed and aerial applications of toxaphene were cancelled in 1982, and applications of carbamates were restricted (Hobaugh et al. 1989). No large numbers of wildlife casualties from insecticide poisoning have been reported in Texas since these changes were enacted (Hobaugh et al. 1989). Granular carbofuran was phased out from legal use beginning in 1991 and was severely restricted by 1994 because of concern for its impact on wildlife. New organic chemicals such as fipronil, which may have fewer adverse effects on wild birds (Avery et al. 1998b), are being evaluated to replace carbofurans. In California, voluntary and regulatory programs have been highly successful in reducing pesticide and herbicide loading into the major waterways and rivers (CH2M Hill 1996).

Pesticide use remains a contentious issue in some states. In 2002, Louisiana petitioned the Environmental Protection Agency (EPA) for an emergency use permit for granular carbofuran to control rice water weevils on up to 40,470 ha. An initial permit to treat more than 4,000 ha was reduced to cover only 1,000 ha. The EPA subsequently revoked that permit after a public comment period that drew comments from 55 conservation organizations. This case underscores the fact that pesticide use remains an area of potential conflict between wildlife and rice interests. However, ongoing research has suggested that newer, less toxic insecticides may do a better job than carbofuran at the same or lower cost, and that alternative field management practices, such as delayed flooding and early planting, may help to significantly reduce losses of rice to water weevils or other pests (Louisiana State University Agricultural Center, unpublished data). Holding herbicides such as molinate in flooded fields for up to 4 weeks and installing recirculation systems have greatly reduced molinate concentrations in rice drain waters (Hill et al. 1994, CH2M Hill 1996). Moreover, if practices such as winter flooding promote use of ricefields by waterfowl, foraging by birds on weed seeds could lead to a substantial reduction in weed pressure and a reduced need for herbicides (see below).

Crop Management - Patterns of crop rotation and method of planting can affect the value of ricefields for wildlife. In a large proportion of the rice-growing area in North America, continuous rice production cannot be maintained due to weed and pest problems and reductions in soil fertility. For example, in the Texas rice prairie, rice is either planted in rotation with crops such as soybean or grain sorghum, used for cattle pasture, or fallowed (Hobaugh et al. 1989). Soybean fields provide some foraging habitat for waterfowl and fallow fields can produce average food values of 450 kg/ha in Louisiana (Horn and Glasgow 1964). Fall plowing of fallow land provides a seedbed for the germination of forbs and grasses, and rotation of ricefields facilitates the growth of seed-producing plants, all of which provides important food sources for waterfowl (Hobaugh et al. 1989).

In the MAV, rice is grown in rotation with soybeans, and in Arkansas and Louisiana some producers use a rotation of rice with crayfish aquaculture. Fields used to grow crayfish are flooded to a depth of 60 cm (Horn and Glasgow 1964). The value of these flooded fields to waterfowl is limited to providing loafing habitat from which birds fly to feed in nearby ricefields (Horn and Glasgow 1964). In southern Louisiana, Rettig (1994) found no significant difference in winter shorebird abundance between ricefields used for crayfish production and other fields. Huner (1995) and Huner and Musumeche (1999) suggested that crayfish impoundments play a valuable role in sustaining wetland vertebrates in the South, and Fleury and Sherry (1995) proposed that the growth of wading bird populations along the Gulf Coast is a result of the increased food available in rice and commercial crayfish farms.

In contrast to the Gulf Coast and MAV, only about 30% of rice in California is grown in rotation with other crops since rice is one of the few crops capable of growing in the poorly drained soils of the Sacramento Valley (Hill et al. 1992). Accordingly, more than 65% of the ricefields in California remain in rice production each year, or are left fallow in alternate years. Ricefields that have been fallowed the previous year are often used for drill-seeded rice, in which seed is sown directly with a triple disk (Hill et al. 1992). Because the field is irrigated only intermittently, the value of these habitats for early-season waterbird use is more limited.

In some regions of southern Louisiana and southeastern Texas, producers obtain a second or "ratoon" rice crop by simply reflooding harvested fields without re-seeding. Ratoon crops could provide an important benefit to waterfowl by making rice available in October and November when most birds begin to arrive on the wintering grounds (Hobaugh et al. 1989). In the Lower MAV, the availability of waste rice decreased 79–99% between harvest in August–September and early December (Manley 1999). More recent estimates suggest a loss of 71–78% (Kross 2006, Stafford et al. 2006). The reasons for this rapid loss of grain before the period of peak waterfowl demand are uncertain, but germination of seeds, consumption by rodents and blackbirds, and decomposition probably contribute. Whatever the cause, these results have serious implications for efforts of the Lower Mississippi Valley Joint Venture to provide sufficient food resources to sustain waterfowl populations over winter.

Effects of Landscape - All of the issues discussed so far relate to the management of individual fields. The recent surge of interest in landscape ecology, however, has led to the realization that species distributions also can be influenced by the nature of total landscapes. In the realm of rice agriculture, an understanding of the ways in which landscape patterns influence wildlife use of fields could affect a variety of management decisions. For example, if the number of birds that use a ricefield depends on its location relative to other features in the landscape then this relationship might influence whether producers can confidently rely on their fields to attract enough waterfowl to achieve required levels of straw decomposition (see Agronomic Impacts of Winter Wetland and Waterfowl Management in Ricelands, page 65). Similarly, if a conservation group wanted to buy water to flood agricultural land to enhance its value to wildlife, then they should flood those fields in the landscape where the management would benefit the maximum number of target species. Whether logistical issues will make it possible to truly manage landscapes with the express goal of influencing wildlife use patterns remains to be seen; however, the first step in evaluating whether such landscape-level management is feasible is to determine whether, and how, landscape features influence use patterns.

Relatively little research has been conducted on this issue, but there are some studies that suggest that landscape features do influence bird use of individual fields. Various features might be important, including but not limited to: (1) areas of natural habitat, (2) areas where hunting is prohibited, (3) areas with an abundance of suitable habitat, (4) areas connected by suitable habitat, and (5) areas distant from roads or other sources of disturbance. For example, Shuford et al. (1996) found that all White-faced Ibis in California occurred within 5 km of managed wetlands during winter, despite the presence of foraging habitat farther away. Ibises typically use managed wetlands for overnight roosting and fly to feed in ricefields during the day, and this behavior apparently influences their use of the landscape. Many other species, including waterfowl, shorebirds, herons, and blackbirds also leave ricefields daily to roost in other locations, and anecdotal observations suggest that at least some of these species are most commonly found in fields close to refuges. In the Sacramento Valley, the abundance of particular habitat types in the landscape surrounding a field influenced the numbers of birds using the field (Elphick 1998). Landscape effects differed among the four waterbird groups considered (geese, ducks, shorebirds, and long-legged waders), although some relationship between average bird densities and landscape features existed in all cases. The spatial scale over which landscape features were measured also influenced the relationships detected, and the scale at which patterns were found varied among waterbird groups. In most cases, bird densities increased as the amount of managed refuge wetland in the surrounding landscape increased. Duck densities, in contrast, were not correlated with the amount of surrounding wetland habitat, but did increase in relation to increased amount of flooded rice habitat nearby (Elphick 1998).

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Waterfowl habitat can easily be integrated into the rice-dominated landscape

In another study, Reinecke et al. (in review) showed that the number of Mallards counted during winter in different aerial survey units was correlated with the area of rice and other habitat managed by private landowners in the MAV (Reinecke et al. 1992). Additionally, the density or concentration of ricefields managed by private landowners explained the spatial distribution of radio-marked Northern Pintails (Cox and Afton 1997, Cox et al. 1998) moving from the Gulf Coast into the MAV during winter.

EQUIVALENCE OF RICELANDS TO NATURAL WETLANDS

Ricefields clearly provide benefits to a variety of wildlife species; however, the extent to which ricefields substitute for the function of natural wetlands is less clear. The few studies that have directly compared the number of species (richness) or abundance of individuals in ricefields to natural or seminatural wetlands have produced mixed results. Twedt and Nelms (1999) evaluated waterfowl densities on rice, soybean, and managed moist-soil wetlands in Arkansas and Mississippi. Waterfowl densities differed significantly among habitat types. Densities of Northern Shovelers were highest in soybean fields and lowest on ricefields. Densities of Mallards and other waterfowl were highest in moist-soil habitats but lowest on rice (Twedt and Nelms 1999). In contrast, Reinecke et al. (1992) found that the proportion of Mallards counted in the MAV was highest in ricefields, followed by soybean and moist-soil habitats.

Tourenq et al. (2001) compared the abundance, species richness, and community composition of waterbirds in ricefields and natural marshes of the Camargue region of the Mediterranean. They found that natural marshes supported substantially greater numbers of waterbirds (99% of all individuals were observed in natural marshes) during the summer. Species richness was also lower in ricefields. However, these results may not be applicable to other areas since the Camargue still has a substantial area of natural marshes in contrast to most other regions (Tourenq et al. 2001), including most of the Mediterranean and California. Fasola and Ruiz (1996, 1997) summarized the use of ricefields by shorebirds, gulls, terns, ducks, and herons throughout Italy, Spain, France, Greece, and Portugal, and concluded that ricefield systems were critical for a variety of waterbirds, primarily as feeding habitat and to a lesser extent as breeding habitat. Fasola and Ruiz (1996) emphasized the need to recognize the importance of ricefields for the conservation of Mediterranean waterbirds. Arinaitwe (1993) compared waterbird diversity in ricefields and natural wetlands of Uganda. The species richness of Afrotropical birds was lower in ricefields, but the abundance of some species, particularly large wading birds and ducks, was higher.

One difficulty in interpreting the results of such studies is that the highest quality habitats are not necessarily those with the highest densities of individuals (van Horne 1983, Vickery et al. 1992, Sutherland 1996). Rather, habitat quality is likely better indicated by measures of survival or breeding success. On the wintering grounds, the highest quality habitats are those that provide an abundance of food, loafing sites, and protection from predators and adverse weather conditions. Accordingly, Elphick (2000) evaluated the quality of ricefields and seminatural wetlands by comparing food abundance, predation threat, feeding performance, and time budgets of eight species of waterbirds in California. Overall invertebrate abundance did not differ significantly between flooded rice, unflooded rice, and seminatural (moist-soil) wetlands, although species composition was not the same (C. S. Elphick, unpublished data). Waste rice grain, as expected, was more abundant in ricefields, whereas other seeds were more abundant in moist-soil habitats. Predation threat (mostly from birds of prey) was significantly lower in flooded ricefields compared to the other two habitats. Few significant differences were found between the feeding rates, the proportions of capture attempts that were successful, and the time allocation of birds feeding in flooded ricefields and seminatural wetlands. When differences were found, their magnitude was typically small. Elphick (2000) suggested that, while flooded ricefields in California should not be considered a replacement for natural wetlands, flooded ricefields are a valuable contribution to the wetland habitat in an area where more than 90% of historical wetlands have been drained.

Ricefields likely are not a replacement for natural wetlands in the MAV because the bottomland forests and swamps once covering this area were instrumental for storing floodwaters of the Mississippi River and tributaries, removing sediment and nutrients from river overflow, and creating extensive year-round fish and wildlife habitat (Eddleman et al. 1988, Hohman and Lee 2001). A few species of birds nest in ricefields, such as Fulvous Whistling Ducks, which also feed in the fields during the growing season (Hohman et al. 1996), and wading birds feed on frogs, small fish (e.g., *Lepomis cyanellus*), and crayfish (*Procambarus* spp.) wherever fields are flooded. However, 50 or more bird species can be found breeding, even in relatively small plots, in bottomland forests (Twedt et al. 1999). Mammals, amphibians, and reptiles also are common in bottomland forests, and during floods many fish species move from rivers into these forests to forage and some also to spawn. Bottomland forests in the MAV (Baker et al. 1991), as in large river systems worldwide, serve an important nursery function for fishes and generally are a rich habitat for wildlife.

In winter and during migration, ricefields provide a rich source of energy in the form of rice seeds for waterfowl and other granivorous birds and invertebrates for shorebirds. While geese and several species of ducks and shorebirds are attracted to open ricefields, other species such as Wood Ducks and Hooded Mergansers primarily inhabit forested wetlands (Fredrickson and Heitmeyer 1988). Ricefields in the MAV serve mostly as foraging sites for waterfowl and can replace much of the energy once provided by acorns in forested wetlands; however, ricefields have less physical cover, less nutritional diversity, and are more susceptible to disturbance. In contrast, moist-soil habitats and seasonally flooded bottomland hardwoods provide diverse foods and nutrient sources (Heitmeyer and Fredrickson 1990, Combs and Fredrickson 1996). Moreover, moist-soil habitat provides relatively high densities of food (Fredrickson and Taylor 1982) and bottomland forests provide extensive cover, which protects waterfowl from thermal extremes and provides freedom from disturbance.

Habitat Complexes - Local habitat complexes can satisfy management objectives more effectively than individual habitats because the strengths of one habitat can offset the weaknesses of another. For example, forested wetlands have low management costs, and low and variable production of food with high diversity and nutrient value. Moist-soil habitats have intermediate management costs and relatively high but variable production of food with high nutrient value. Rice production costs are born by the producer as a commercial enterprise, and food production can be extremely high if the crop is not harvested and moderate if harvested. In either instance energy from spilled grain is the primary resource available, although moist-soil seeds, invertebrates, and green sprouting vegetation are also available and used by foraging waterfowl. A common management practice in the MAV is to ensure that each necessary habitat is available within daily flight range of major roost sites on refuges. When this practice is used, the rich energy sources in ricefields are complemented by natural foods with more diverse nutrients in moist-soil or forested wetlands, while the lack of cover and high disturbance in ricefields are offset by the protection provided by forested wetlands.


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Waterfowl feeding in a Mississippi Delta ricefield

At larger spatial scales, ricefields on private land can form regional habitat complexes with public management areas to restore wetland landscapes, increase access for hunting, provide additional opportunities for bird watching, and maintain historical bird distributions better than the small number of state and federal wildlife areas can alone. Thus even if ricefields do not function in a manner equivalent to natural wetlands, their management can be integrated effectively with the management of natural wetlands to achieve much larger goals. A comprehensive management strategy for wildlife on agricultural lands requires an integrated perspective that focuses not only on the value of ricefield habitat, but also the distribution of ricefields in the regional landscape.

TRADE-OFFS OF PROVIDING HABITAT FOR WILDLIFE

Historically, the presence of foraging wildlife in agricultural fields was regarded as detrimental or, at best, neutral. In the early period of rice growing in the United States, waterfowl and other wildlife species caused extensive damage to rice and were viewed as pest species (Neale 1918, Ellis 1940, Jones 1940, Frith 1957, Lane et al. 1998, Post et al. 1998). In the recent past, however, it has become evident that there are several positive agronomic benefits of providing habitat for wildlife in rice-production systems. These benefits range from improved water quality, increased decomposition of straw residue, reduced weed and pest pressure, and the development of alternative sources of income. However, these benefits are not entirely without costs; the field management required may increase operational costs, water for flooding ricefields is limited and expensive in some areas, and provision of habitat for wildlife may attract undesirable species. A realistic appraisal of the potential of ricelands to provide wildlife habitat on a sustainable basis must also consider the agronomic costs and benefits involved. Below, we summarize some of these trade-offs, particularly from the perspective of how such tradeoffs might impact wildlife, or in turn, how wildlife might influence these trade-offs.

Potential Benefits

Increased straw decomposition - A major by-product of rice production is the large quantity of rice straw left after harvest (Brouder 1993, Brandon et al. 1995, Brouder and Hill 1995). Winter flooding of ricefields has been shown to enhance residue decomposition and reduces the number of tillage operations required in the spring (Brouder 1993, Brandon et al. 1995, Brouder and Hill 1995, Burnham 1995, Manley et al. 1995, Brouder et al. 1996, Manley 1999, Eagle et al. 2000). Recently, it has been suggested that foraging waterfowl attracted to flooded ricefields may provide a reciprocal benefit to producers by enhancing straw decomposition in winter-flooded fields (Smith 1992, Gannon 1994, Brouder and Hill 1995, Burnham 1995, Rush 1996, Bird et al. 2000). Studies by Bird et al. (2000) and van Groenigen et al. (2003) demonstrate that foraging activities by waterfowl can lead to a substantial reduction of straw residue, exceeding that of the more costly and time-consuming mechanical rolling of the straw.

Improved water quality and reduced soil loss - Active flooding of winter ricefields and/or retention of winter precipitation on ricefields offer potential cost savings to producers by reducing erosion, decreasing herbicide requirements, and retaining soil nutrients (McDowell et al. 1989, Maul and Cooper 2000). Retention of water on agricultural lands could also reduce bacterial concentrations and the conveyance of low-quality runoff and sediment loss into rivers and streams (Maul and Cooper 2000). Manley (1999) evaluated the agronomic value of post-harvest treatment and winter flooding in the MAV. Winter flooding significantly reduced mass exports of suspended and dissolved solids, and most important nutrients. These results suggest that winter flooding can provide agronomic and environmental benefits by reducing loss of soil and nutrients from agricultural fields.

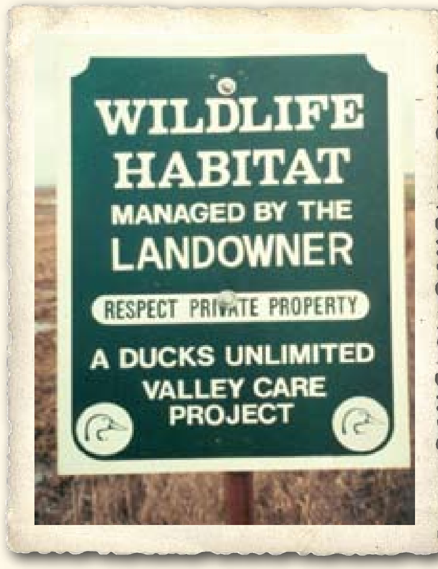
Control of weed seeds and insect pests - Waterfowl are attracted to winter-flooded ricefields because of an abundance of food, primarily the waste rice seeds left after harvest. However, rice seed is not the sole source of energy for waterfowl and moist-soil weed seeds and invertebrates are both substantial food sources (Davis et al. 1961, Miller 1987, Reinecke et al. 1989, McAbee 1994, Hohman et al. 1996; see Tables 3 & 4). Plants such as watergrass (barnyardgrass) and red rice and invertebrates such as rice water weevils and crayfish are serious pests and can cause substantial loss of rice production (McAtee 1923, Fontenot 1973, Grigarick and Way 1982, Sommer and Goldman 1983). The possibility that foraging waterfowl could provide an agronomic benefit by feeding on weed and invertebrate pest species has been recognized for decades (McAtee 1923, Fontenot 1973, Smith and Sullivan 1980). Several field studies have demonstrated that both winter flooding and feeding by ducks could reduce the abundance of weed seeds (Manley 1999, van Groenigen et al. 2003, Manley et al. 2005). Comparable quantitative studies have not been undertaken to evaluate the degree to which waterbirds reduce invertebrate pests, although invertebrates are a major diet item for several species of waterfowl (Pirot et al. 1984, Euliss and Grodhaus 1987, Miller 1987, Gonzalez-Solis et al. 1996), shorebirds (Baldassarre and Fischer 1984, Remsen et al. 1991, Barbosa 1996, Davis and Smith 1998), and waders (Fasola 1982, 1986, Fasola et al. 1993, Sawara et al. 1994, Fasola et al. 1996, Mukherjee and Borad 2001). Foraging by waterbirds may also reduce the density of mosquito larvae, an important health concern in California. Batzer and Resh (1992a, 1992b) demonstrated that management actions to improve habitat for waterfowl could simultaneously reduce the abundance of mosquitoes. However, Lawler and Dritz (2005) found that incorporation of straw residue and winter flooding could lead to increased abundance of mosquitoes and other insects. While this may have the benefit of increasing the availability of invertebrate prey for waterfowl and waterbirds, it poses increased difficulties for mosquito control.

Increased nutrients - Large concentrations of waterbirds using ricefields for feeding and loafing could be an important nutrient vector, and might potentially reduce the need for fertilizer applications. Increased nutrient input into wetlands as a result of waterfowl use has been recorded in several areas (Have 1973, Brandvold et al. 1976, Brierley et al. 1976, Manny et al. 1994). In one year alone, it was estimated that the 40,000 Lesser Snow Geese and Ross's Geese overwintering on the Bosque del Apache National Wildlife Refuge in New Mexico excreted 15,000 kg N and nearly 1,800 kg P, of which about 60% was loaded into the wetlands of the refuge and the remainder into nearby agricultural lands where the geese were feeding (Post et al. 1998). Enhanced decomposition of rice straw as a result of waterfowl activity could also facilitate incorporation of nutrients into the soil (Bird et al. 2000).

Hunting revenue and wildlife viewing - Many producers in all three major rice-growing regions flood their fields after harvest to attract ducks for recreational hunting. In some cases, this is simply for personal use, but a considerable number of producers lease some of their land to other hunters. A quantitative assessment of the economic value of hunting leases in ricelands has not been undertaken, but anecdotal data suggest that revenues from sport hunting provides an additional economic incentive to flood ricefields in winter. A recent survey in California of 179 producers enrolled in a rice enhancement project indicated that more than 75% allowed hunting on their land (Garr 2002). Annual hunting leases range from $1,000 to $3,000 per hunter (or higher), depending on the location of the property. In the Texas rice prairies, more than 95% of all rice-prairie habitats are subject to some form of recreational waterfowl hunting (Hobaugh et al. 1989), and hunting leases range $5–$10/ha. It is estimated that waterfowl hunters bring in millions of dollars to local communities through leases, day-hunting privileges, food, lodging, gasoline, and hunting supplies (Hobaugh et al. 1989). For example, Grado et al. (2001) estimated that the economic impacts generated from waterfowl hunting expenditures exceed $700,000 for the 1998–99 waterfowl-hunting season on public lands and private lodges in the Mississippi Delta. If those expenditures were extrapolated to the entire state, Grado et al. (2001) estimated that the total economic impact of waterfowl hunting would exceed $27 million.

An additional source of income for rice-growing regions is the increasing interest in wildlife viewing, which generates more than $20 billion annually in the United States (Kerlinger 1993). Small, rural communities, in particular, may be able to benefit from effective marketing of their bird-watching opportunities (Lingle 1991, Kerlinger 1993). High densities and good visibility of a diverse array of waterbirds in flooded ricefields may allow rice-growing communities to capitalize on these additional opportunities.

Public support and partnerships - Growing public interest in environmentally sensitive methods of crop production can be effectively used to improve the economic viability of progressive cropping systems. Across the United States, population growth and urban expansion are threatening prime farmlands, while at the same time, agriculture is often viewed to be in direct conflict with natural resource conservation. Future protection of agricultural lands may be best achieved by directly integrating sustainable production with wildlife habitat enhancement (Brouder and Hill 1995). Rice producers in California, the Gulf Coast, and the MAV are well situated to benefit from current societal perspectives given the many benefits that ricelands provide for wildlife. Cooperative efforts between rice producers and wildlife managers offer a unique opportunity to develop a model system for conjunctive use of agricultural land to promote multiple goals: enhanced habitat for wildlife, sustainable agricultural production, improved water quality, and improved public perception of the value of agricultural land (Brouder and Hill 1995). The long-term sustainability and support of rice agriculture in North America ultimately may depend on these less-tangible societal benefits than on many of the direct agronomic benefits that are typically considered.



Cooperative partnerships and landowner participation are essential for providing waterfowl habitat on ricelands

Potential Costs

Attracting nondesirable wildlife - Provision of habitat for wildlife has a potential drawback of enhancing populations of nondesirable species, such as weeds and animal pests. For example, concerns have been raised that the large numbers of waterfowl attracted to flooded ricefields could lead to increased weed pressure if seeds are transported to fields either by internal passage or by adherence of mud to feet and feathers of birds (Powers et al. 1978). However, studies with captive waterfowl indicate that only minute percentages of seeds from problem weeds such as red rice and barnyardgrass remained intact or germinated after passing through the intestinal tract (de Vlaming and Proctor 1968, Powers et al. 1978).

Flooded ricefield habitats are also attractive to invertebrate pests such as crayfish. Due to their burrowing habits, crayfish can cause extensive damage to irrigation systems in ricefields (Grigarick and Way 1982). Crayfish can also damage newly planted rice, reducing the percentage of seedlings surviving by 68–100% (Grigarick and Way 1982). Harvest of crawfish may provide a method to control overabundance and increase revenues for producers. For example, crayfish aquaculture has become an important additional economic venue for rice producers in Louisiana, and some producers alternate rice crops with crayfish (Horn and Glasgow 1964). Moreover, the development of crayfish aquaculture has been credited with helping to increase populations of colonial wading birds in the southern United States (Fleury and Sherry 1995) and to promote increased wildlife diversity in general (Huner 1995, Huner and Musumeche 1999). The potential to develop crayfish aquaculture programs in other states is unknown (Sommer and Goldman 1983), but at least one study has indicated that a successful program could be developed for northern crayfish in Vermont (Nolfi 1983), and Sommer and Goldman (1983) recommended further evaluation of the potential for harvest in California.

Blackbirds and coots are other species of wildlife that are attracted to flooded and dry-harvested ricefields and can cause problems for producers; this is particularly so in the southeastern states, but also true in California (DeHaven 1971, Crase and DeHaven 1978). Red-winged and Brewer's blackbirds, grackles and Brown-headed Cowbirds feed on grain and can occur in enormous flocks. For example, in the 1960s it was estimated that more than 200 million blackbirds and starlings wintered in the Lower Mississippi Valley and Louisiana–Texas Gulf Coast regions (Meanley 1971). Crop depredation, particularly on newly seeded crops and sprouting rice seeds, can be extensive (Neff 1957, Gorenzel et al. 1986, Avery 1989), resulting in more than $8 million in damage in Texas (Decker et al. 1990) and Louisiana (Wilson et al. 1989). Control methods have achieved mixed success and included hazing, shooting, avicides, and lethal baiting (Neff 1957, White et al. 1985, Wilson et al. 1986a, Avery et al. 1995, Rodriguez and Avery 1996, Avery and Mason 1997, Avery et al. 1998b). Studies of blackbird population dynamics suggest that lethal methods may have limited success due to high daily turnover rates within flocks (White et al. 1985), and there is some concern for collateral effects of avicides or lethal baits on nontarget species (Primus et al. 1997). Alternatively, changes in field management relative to spring migration and the time of breakup of large wintering flocks could mitigate some of the impacts (Wilson et al. 1986b, Wilson et al. 1987, Wilson et al. 1989, Brugger and Dolbeer 1990, Brugger et al. 1992). Research focusing on the development of repellants that affect the palatability of seeds or the foraging behavior of birds also holds considerable promise (Moulton 1979, Daneke and Decker 1988, Avery 1989, Avery and Decker 1991, Avery et al. 1995, Avery et al. 1996, Avery et al. 1997, Avery and Mason 1997, Avery et al. 1998a, Avery et al. 1999).

American Coots also cause crop damage by grazing on newly sprouted grain (Piper 1944, van Way 1986). In 1944, crop losses of more than $200,000 were caused by coots in California (Piper 1944), and grazing by high densities of coots on some areas in Louisiana have caused producers to replant rice several times (C. W. Jeske, unpublished data). Lethal control has been a traditional management technique (Piper 1944, van Way 1986). Development of nonlethal methods of control would be desirable to reduce negative impacts on wildlife and to maintain public support for agricultural programs. At present, some level of coot and blackbird damage to rice crops appears inevitable, particularly in southern rice regions, and further research on methods to reduce this source of agriculture-wildlife conflict is clearly warranted.

Water-quality problems - The increased nutrients loaded into wetlands and ricefields resulting from waterbird use (see above) may not always be beneficial and could lead to water-quality concerns. Impairment of water quality as a consequence of waterbird use has been implicated in a number of cases (Have 1973, Brandvold et al. 1976, Brierley et al. 1976, Manny et al. 1994, Mukherjee and Borad 2001). Runoff or drainage from these areas might further affect the quality of water of receiving streams and rivers, and impact fish and aquatic communities downstream (Cooper 1987, 1993).

A number of factors mitigate against these impacts. For example, the degree of nutrient loading in ricefields will be determined by the extent to which birds use these areas for feeding versus loafing. If used primarily as feeding sites, with birds flying off to other areas to roost and loaf, a net export rather than import of nutrients could result (see, for example, Mukherjee and Borad 2001). Much waterfowl use of ricefields occurs at night, when birds fly from roosting sites to feed and then return to loaf at safe sites during the day (Miller 1985, Cox and Afton 1997, 1998, Cox et al. 1998). Consequently, levels of nutrient loading sufficient to negatively impact water quality may not occur. Moreover, provision of loafing sites in flooded ricefields may provide a further ecosystem service by dispersing birds, as Post et al. (1998) advocate, thereby alleviating potential water-quality problems on wildlife refuges where birds have historically concentrated.

Economics of water and post-harvest management - Management of ricelands to promote wildlife values can impose a direct financial cost to the producer, particularly if winter flooding is involved. These costs include the direct expense of purchasing water, which is variable among regions (Hobaugh et al. 1989, Manley 1999, Williams et al. 2001, Manley et al. 2005). Winter flooding often involves additional post-harvest management actions such as disking fields, rolling straw into the soil, chopping straw, and post-flooding incorporation. While these activities are related more directly to residue management rather than to the provision of wildlife habitat per se, these expenses must be evaluated relative to other post-harvest management actions that may be less expensive but also less wildlife-friendly. A full agronomic evaluation of both the costs and the benefits of winter flooding, particularly with respect to wildlife values (including hunting revenues and cost savings from wildlife activities), has not yet been attempted. However, Manley (1999) and Manley et al. (2005) made an important start in this direction by estimating the savings in direct costs to producers in the MAV from winter flooding. While that analysis did not cover all the possible costs and benefits of providing winter-flooded habitat for wildlife (for example, water costs would be considerably higher in California and the Gulf Coast), it shows clearly that direct agronomic and economic benefits are not only possible, but indeed likely.

FUTURE CHALLENGES AND RESEARCH NEEDS

Our review suggests that there are many opportunities for the rice industry and wildlife to mutually benefit from a variety of crop and harvest management practices. However, several challenges remain and must be addressed in developing a sustainable and productive future. Changes in agricultural markets, pressures of increased urban development, endangered species constraints, conflicting needs for limited resources such as water, and concerns over water quality will all play a role in the extent to which compatible use of ricelands for rice production and wildlife habitat will receive public and private support.

Here we outline some of these challenges. Several have been touched on in earlier sections of this chapter, while others will be dealt with in different chapters of this book. These challenges fall into three general categories that address the uncertainty regarding the long-term ability of ricelands to support wildlife, resulting from: (1) reductions in the quantity of rice habitat, due to farm economics, urban growth, and water scarcity; (2) reductions in the quality of rice habitats, as influenced by ricefield management practices; and (3) potential conflicts with other resource users. These categories are not mutually exclusive, but serve to highlight major areas of potential concern.

Today's challenges mandate careful planning and collaborative conservation actions

Reduction in the quantity of rice habitat

Decline in rice acreage: Farm economics - The drastic loss of rice acreage in the Texas prairies highlights the concern of the ability of ricelands to provide wildlife habitat on a sustainable basis. Because of increases in the cost of production, frozen payment yields, reduced target prices, and reductions in farm program benefits, rice producers in several regions have operated at a loss (Schnepf and Just 1995). Accordingly, rice acreage may be vulnerable in some areas, particularly in the Gulf Coast region and possibly in California. Even with government support, the net returns per hundered pounds (cwt) rice were negative in both regions starting in the early 1990s (-$0.13/cwt Gulf coast and -$0.57/cwt California); only the non-Delta region of Arkansas ($0.36/cwt) and the MAV ($0.62/cwt) maintained a positive net return (Schnepf and Just 1995). The high cost of production in Texas has been attributed to: (1) lack of an alternative crop to include in a rotation to spread fixed costs, (2) abbreviated time periods for critical field operations due to weather, (3) high costs of pest management, and (4) high water pumping and distribution costs and increased competition for scarce water resources

(Schnepf and Just 1995). California faces high costs of general farm overhead, taxes, and insurance as well as high costs for custom operations, drying, and storage. Schnepf and Just (1995) also note that California rice producers face the most stringent air and water pollution controls in the nation, and several additional economic problems confront the entire state's rice industry: (1) competition with urban users for an increasingly scarce water supply; (2) water-quality issues, particularly concerning pesticide runoff; (3) restrictions on rice straw burning; and (4) urban growth.

In addition to these challenges, rice acreage in a number of regions may decline via conversion to other crops or changes in management practices. For example, there was a rapid conversion of rice to soybean-milo farming in parts of the Texas rice prairie in the 1970s, and some rice producers in California's Central Valley have experimented with cotton farming as an alternative to rice production. Regulation of water discharges from ricefields as mandated by the Clean Water Act and reductions in water supply (see below) could further impact the suitability of ricefields for wildlife by encouraging more producers to dry-seed fields, rather than water-seeding. The result would be fewer flooded fields for spring-migrating waterbirds, an issue of particular concern in the Gulf Coast region (Hobaugh et al. 1989). Cultivation of rice on dry fields has been spreading rapidly in the rice-producing areas of the Mediterranean region, with significant impacts on the value of ricefields for waterbirds (Fasola and Ruiz 1996, 1997).

Expanding urban growth and human disturbance - The population of California is projected to grow by almost 20 million people in the next two decades. Much of that growth will occur in California's Central Valley, including the Sacramento Valley, where rice accounts for more than 30% of crop acreage and provides 25% of the crop revenue (Lee et al. 2001). There will be considerable pressure on ricelands as urban growth expands (Schnepf and Just 1995), including both direct conversion of riceland to urban areas, and indirect pressure through increased competition for scarce water, pubic concern about water quality, and conflicts with other resource users. Direct conversion of riceland may be at greatest risk in California, but all rice-growing regions will face constraints on water availability and quality in response to urban growth (Schnepf and Just 1995).

Increased human disturbance of wildlife, as a result of growing urban populations near ricelands and other wetland habitats, may also reduce the suitability of ricefields. For example, edges of ricefields near roads receive less use by waterfowl and other waterbirds, reducing their value (Wolder 1993). Density of breeding birds was reduced by 20–95% in areas adjacent to busy roads and highways in the Netherlands (Reijnen et al. 1995, Reijnen et al. 1997). Understanding how such disturbances impact wetland use will be important in determining the size and distribution of individual fields that will provide the greatest benefits to wildlife.

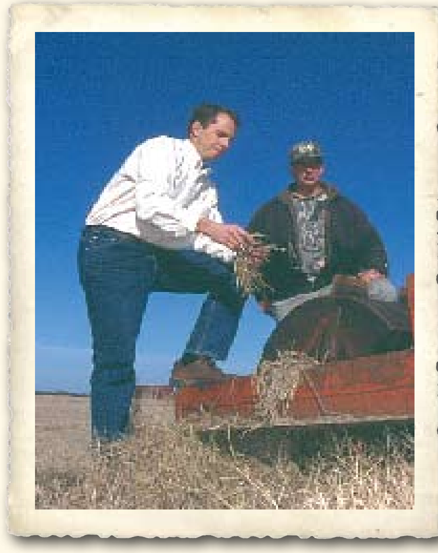
Maintaining mosaics—increased fragmentation of rice acreage - Because of the large acreage of rice in areas that were once native wetlands, and the proximity of ricelands to existing natural and managed wetlands, ricefields play a critical role in maintaining habitat connections in regional landscapes (Heitmeyer 1989, Heitmeyer et al. 1989, Reinecke et al. 1989, Heitmeyer 2002). For example, ricelands extend hundreds of miles along the MAV, and in doing so, connect native remnant wetlands and provide a key habitat corridor to the large number of waterfowl that use this region in fall and winter (Reinecke et al. 1989, Heitmeyer 2002). Loss of rice acreage or conversion to other crops will not only impact the total amount of habitat available, but will also lead to increased fragmentation of these habitats, further reducing their value to wildlife and their ability to sustain viable populations. A challenge for wildlife managers in the next decade will be to determine not only the amount of rice agriculture needed as part of the habitat mosaic to support desired wildlife populations, but also the juxtaposition and distribution of rice required in the regional landscape. Likewise, the potential use of wildlife services for agronomic purposes (e.g., to enhance straw decomposition or pest reduction) will require an understanding of how waterbird populations might be distributed most effectively to maximize these benefits.

Reduction in the quality of habitat related to ricefield management

Changes in harvest methods leading to reduced food availability for water birds - The increasing use of strip harvesting could impact the quantity of waste grain available in ricefields, the accessibility of ricefields to wildlife, and the agronomic benefits that producers may realize through waterbird use. We reviewed studies undertaken in California that examined bird use (Day and Colwell 1998) and the amount of waste rice available (Miller and Wylie 1996, Table 2). However, studies on the amount of waste rice were conducted when strip harvesting was in its infancy; improved operator efficiency could lead to further reductions in waste rice available for waterbirds (Miller and Wylie 1996). If so, planning for the habitat needs of winter waterbirds could be considerably affected. For example, the Central Valley Joint Venture Implementation Plan assumes that agricultural lands will meet approximately 22% of the energy needs for winter waterfowl, primarily rice (Heitmeyer 1989). However, this estimate was based on an assumption that agricultural crops provide an average of 280 kg/ha of food, a value that may be much lower if harvester efficiency has improved. As a consequence, planning efforts may underestimate the acreage of either agricultural lands or managed wetlands that would be needed to sustain waterbird populations over winter.

Progressively earlier harvests, facilitated by the development of rice varieties that mature more quickly, could also alter food availability in ricefields (Manley 1999, Manley et al. 2004, Stafford 2004, Kross 2006, Stafford et al. 2006). In the MAV, 71–93% of the residual rice left after harvest had disappeared by 10 December, and little remained by the time ricefields were flooded for arriving waterfowl. Habitat goals for the Lower Mississippi Valley Joint Venture assume that ricelands will provide more than 1,800 duck-use days/ha of foraging value, yet more recent data suggest that this value may be reduced by half, and could be as little as 84 duck-use days/ha in some years if the accessibility of residual rice is also taken into consideration (Manley 1999, Manley et al. 2004, Stafford 2004, Kross 2006, Stafford et al. 2006). Clearly, changes in the timing and methods of harvest could considerably influence the value of ricelands for wildlife and landscape level planning efforts for waterbirds. This remains a critical area for ongoing research and monitoring.

Straw management and rice burning - The development of new methods to manage rice straw residues and limitations on practices such as burning will provide continuing challenges and opportunities to producers and wildlife interests. Winter flooding has been demonstrated to be effective and highly beneficial to waterbirds, but issues remain regarding the timing, depth, and duration of winter floods. The agronomic benefits of attracting waterbirds remain to be verified, particularly in the MAV and Gulf Coast regions. Other post-harvest management activities such as disking, rolling, chopping, and burning could affect the availability and accessibility of waste grain and other food items, and it is unclear yet how these practices might influence the value of ricefields to wildlife in the future. The rice industry is actively researching other uses for waste straw, such as bailing and off-site removal for use in construction or ethanol production; these practices could reduce incentives to flood ricefields in winter with the result that their value to waterbirds would be diminished. An evaluation of the projected trends in winter flooding and other post-harvest management alternatives is needed to develop long-term plans for wintering waterbird populations.



Rice straw management remains a challenge in all rice-growing regions

Organic chemicals and water quality - Considerable progress has been made in the past several decades to reduce the effects of agricultural organic chemicals on wildlife, and the rice industry has been very responsive in this regard (Hobaugh et al. 1989). However, the ongoing struggle to control pests such as the rice water weevil and the resulting large economic consequences suggest that there will be continued challenges to develop new organic chemicals or other control measures that successfully limit the resulting damage while minimizing negative impacts on nontarget species. The recent debate over the proposed emergency use of Furadan in Louisiana illustrates the potential political and ecological volatility of these issues. Additional concerns have been raised over the quality of water released from ricefields, particularly on fish and aquatic organisms downstream (Cooper 1991, 1993). These include the chemical residues from insecticides, herbicides, and fertilizers, as well as the influence of elevated water temperature, salinity, and concentrations of trace elements such as selenium (Cooper 1993, CH2M Hill 1996, Maul and Cooper 2000). Water quality might be further impacted by nutrient input from large numbers of waterbirds (Brandvold et al. 1976, Brierley et al. 1976, Manny et al. 1994, Maul and Cooper 2000, Mukherjee and Borad 2001). Issues relating to water quality and nonpoint source pollution, as they impact wildlife both in and downstream of ricefields, will remain a significant challenge and a focus for future research.

Blackbirds are unwelcome guests at soon-to-be harvested ricefields

Pest wildlife species - A final management concern deals with the large numbers of species that are attracted to ricefields that impact rice production negatively, such as blackbirds and coots. Management of these species by lethal measures is becoming less acceptable to the general public, runs the risk of alienating support for the rice industry, and may negatively impact species that are ecologically, if not economically, desirable. Yet, in some regions, the economic impact of these species on rice producers is considerable. Several avenues of research into methods to mitigate these impacts are promising, including: (1) adjusting the time of farm operations to avoid the peak periods of bird abundance, possibly by as little as 1–2 weeks (White et al. 1985, Brugger et al. 1992); (2) development of chemical repellants (Avery 1989, Avery and Decker 1991, Avery et al. 1993, Avery et al. 1995, Avery et al. 1996, Avery et al. 1997); or (3) development of other behavioral-based methods to reduce seed depredation (Daneke and Decker 1988, Avery et al. 1999). Whether such measures can be implemented cost-effectively at an operational scale remains to be determined and further research and development will be required.

Conflicts with other user groups

Water use, availability, and increased demands on water - Potential conflicts over increasingly limited water supplies will likely prove to be an ongoing challenge for the rice industry, particularly in California and the Gulf Coast. Irrigation is essential to rice cultivation, not only for germination and growth but also for effective weed and pest control, and more recently for straw decomposition. In California, approximately 2.35 million acre-feet (MAF) of water, or 2.6% of the state's annual average water supply, is used to irrigate rice (CH2M Hill 1996). By comparison, other irrigated crops used 21.7 MAF (25.3%) while urban water use increased from 2 to 6 MAF (7%) in the period 1960–90 (CH2M Hill 1996). Water for environmental purposes, such as maintaining sufficient flows in rivers for endangered salmon and providing water to state and federal wildlife refuges, was estimated to be 24 MAF. Agricultural, environmental, and urban needs for water are projected to increase (U.S. Fish and Wildlife Service 2000). Even at current levels, the estimated water shortfall to allow optimal management of Central Valley private wetlands is more than 0.6 MAF per year (U.S. Fish and Wildlife Service 2000). These shortfalls will exacerbate conflicts over water, even among groups that provide habitat for wildlife. For example, with the restriction on rice straw burning in California, winter flooding may be one of the few viable options. Increased winter flooding, while clearly providing wildlife benefits, could have a significant negative influence on water supplies available to manage public and private wetlands (U.S. Fish and Wildlife Service 2000). Resolving these conflicts will be an important component in maintaining productive agriculture-wildlife partnerships.

Standing water is visible in ricefields throughout much of the growing season and in winter flooded fields, and hence rice is viewed by the public as a water-intensive crop. However, comparisons with other vegetable, fruit, and nut crops, as well as dairy products, indicate that rice is an efficient converter of water to food energy. For example, estimates of the amount of water required to produce a typical individual serving range from over 1,200 gallons for an 8 oz. beef steak, 47 gallons per cup of flour, and 25 gallons per ounce of rice (CH2M Hill 1996). Changes in rice cultivation practices, such as laser-leveling fields and adopting more efficient water management systems that recycle irrigation water have reduced water demands and improved water quality.

Nonetheless, increasing urban demands and water requirements for environmental purposes will continue to place constraints on water availability and cost. Lee et al. (2001) examined the effect of reduced irrigation water supply on the Sacramento Valley region in California using an economic simulation model. They found that a 25% reduction in surface water supply would reduce overall crop revenues by almost $15 million, of which $13 million (90%) would occur in rice. Total acreage losses of rice varied between 0.1% and 4%, with higher values in counties where rice was prominent. Results from Lee et al. (2001) also suggest that reduced availability of water would cause producers to switch from crops such as rice, pastureland, or alfalfa to small grains. Clearly, constraints on water supplies could have significant impacts on both the rice industry and the wildlife that depend on it.

Endangered species concerns - Thirty (30) plant and animal species of special status are known to utilize ricelands in California (Table 8; Resource Management International 1997). Most notable are species such as King Rails, which are found frequently in ricelands of the Gulf Coast and considered a game species, but are rare and considered endangered, threatened, or of special concern in Midwestern states (Meanley 1953, 1956, 1969, 1992, Reid et al. 1994). The Giant Garter Snake, a state and federally threatened species, spends up to 50% of its time in ricefields (Wylie et al. 1997). Species such as Aleutian Cackling Geese, Bald Eagles, and Swainson's Hawks, all of which are of state or federal concern, are found feeding in or over ricefields at least occasionally (see Table 8).

The occurrence of species of special status in ricefields has been viewed as both detrimental and beneficial. On the negative side, some producers may be concerned that by providing habitat for wildlife and attracting species of special status, farming operations may be constrained or impeded by endangered species regulations. In contrast, and on the positive side, few rice farming operations have been shown to adversely affect species of special status. Indeed, many rice producers view the presence of special-status species in ricelands as a benefit, highlighting the positive contributions of the rice industry to environmental issues (Resource Management International 1997). For some populations of declining species, such as Northern Pintails, ricefields may provide critically needed habitat on the winter grounds (Miller and Wylie 1995, Miller and Newton 1999). Nonetheless, the risk remains that special-status species could be affected by farming activities. Monitoring, research, and policy development will be required to ensure that producers maintain profitable farming operations without adversely impacting wildlife populations.

TABLE 8 Special-status wildlife species known to use ricefields, including fallow fields and check levees. Status categories are: E—endangered, T—threatened, C—candidate, SP—state protected, FP—federally protected, and SC—species of concern. Sources: Resource Management International (1997), Jones & Stokes (2005), and Brouder and Hill (1995).

COMMON NAME	LATIN NAME	OCCURRENCE IN RICE	STATUS	
			FEDERAL	STATE
Aleutian Cackling Goose	*Branta hutchinsii leucopareia*	occasional		SC*
Fulvous Whistling-Duck	*Dendrocygna bicolor*	occasional		SC
Double-crested Cormorant	*Phalacrocorax auritus*	rare		SC
Long-billed Curlew	*Numenius americanus*	regular	FP	
Great Blue Heron	*Ardea herodias*	regular		SN
White-faced Ibis	*Plegadis chihi*	regular		SC
Great Egret	*Ardea alba*	regular		SN
Snowy Egret	*Egretta thula*	regular		SN
Greater Sandhill Crane	*Grus canadensis tabida*	regular		T, SP
King Rail	*Rallus elegans*	regular		E, T, SC
Snowy Plover	*Charadrius alexandrinus*	rare	T	SC
Mountain Plover	*Charadrius montanus*	rare	FP, SC	SC
Long-billed Curlew	*Numenius americanus*	rare	FP	SC
Black Tern	*Chlidonias niger*	rare		SC
Bald Eagle	*Haliaeetus leucocephalus*	rare	T*	SE, SC
Golden Eagle	*Aquila chrysaetos*	rare		SC, SP
White-tailed Kite	*Elanus leucurus*	occasional	SC	SP
Northern Harrier	*Circus cyaneus*	regular		SC
Swainson's Hawk	*Buteo swainsoni*	occasional	FP	T
Ferruginous Hawk	*Buteo regalis*	incidental		SC
Peregrine Falcon	*Falco peregrinus*	rare	E*	E, SP
Prairie Falcon	*Falco mexicanus*	incidental	FP	SC
Merlin	*Falco columbarius*	incidental		SC
Burrowing Owl	*Athene cunicularia*	rare	FP	SC
Short-eared Owl	*Asio flammeus*	occasional		SC
Long-eared Owl	*Asio otus*	rare		SC
Tricolored Blackbird	*Agelaius tricolor*	occasional	FP	SC
Loggerhead Shrike	*Lanius ludovicianus*	rare	FP	SC
Bank Swallow	*Riparia riparia*	rare		SC

COMMON NAME	LATIN NAME	OCCURRENCE IN RICE	STATUS	
			FEDERAL	STATE
Giant Garter Snake	*Thamnophis gigas*	regular	T	T
Western Pond Turtle	*Clemmys marmorata*	occasional		SC
Western Spadefoot Toad	*Scaphiopus hammondii*	incidental		SC

* Recently recovered and removed from list.

Redistribution of birds and hunter success - Increased provision of habitat for wildlife, particularly through winter flooding, may have unintended consequences. Surveys indicate that about 75% of the flooded ricefields in California are hunted (Garr 2002), leaving up to 25% as sanctuary for feeding and loafing birds (CVHJV Technical Committee 1996). Not unexpectedly, these areas have been highly attractive to wintering waterfowl with the result that the historical winter distribution of birds has shifted northward; fewer birds use the more southern San Joaquin Valley or do so for shorter periods of time, while more birds remain in the Sacramento Valley (Fleskes et al. 2002). The biological impacts of such a shift in distribution are not well known, although the increased energy needs for birds in the Sacramento Valley and reduced needs in the San Joaquin Valley have important implications for the Central Valley Habitat Joint Venture Implementation Plan.

Shifts in traditional distribution patterns of waterfowl may also have contributed to reduced hunting success on duck clubs and public areas in the San Joaquin Valley (CVHJV Technical Committee 1996). This has two consequences: First, public support for winter flooding practices may wane and the partnerships between the rice industry and waterfowl organizations that have supported such initiatives will be challenged. Second, private support to develop and maintain managed wetland habitats—key components of the habitat mosaic needed for wintering waterbirds—could be negatively impacted if reduced hunting success leads to a decline in interest and investment by the private sector. In the long-term, it is hard to envision how providing more habitat to over-wintering birds would not be beneficial, particularly if winter habitat influences survival or body condition. However, during periods when poor breeding conditions limit the number of birds flying south to the wintering grounds, the disenfranchisement of traditional supporters of the rice industry (i.e., waterfowl hunters and organizations) could be significant and will require ongoing monitoring, research, and public education to maintain a mutually beneficial balance.

Too much success—overabundance of midcontinent Lesser Snow Geese - A final challenge facing rice-wildlife partnerships concerns another unintended consequence of providing habitat for wildlife—that of the explosive increases in populations of midcontinent Lesser Snow Geese. In the late 1960s, midwinter inventories of Lesser Snow Geese were <1 million birds, but by the mid-1990s, this number had almost tripled to nearly 3 million birds (Bateman et al. 1988, Abraham and Jeffries 1997, Ben-Ari 1998). The impact of this dramatic increase has been profound, particularly on important arctic ecosystems where geese nest. Heavy grubbing and grazing by the large number of geese in the Hudson Bay Lowlands has caused extensive depletion of vegetation (Abraham and Jeffries 1997, Ben-Ari 1998). The removal of the insulating vegetative layer over the thin soil surface has led to erosion and increased evaporation, bringing inorganic salts from the underlying marine sediments to the surface and causing the soil to become hypersaline (Ben-Ari 1998). This increased salinity, in turn, has impeded the growth of other plants, resulting in large areas of the tundra becoming barren and desertlike, while inedible salt-tolerant plants dominate other areas. The final result is a large-scale alteration of highly sensitive arctic ecosystems, with the prospects for recovery being low and requiring decades (Abraham and Jeffries 1997).

Several reasons have been proposed for the rapid increase in the midcontinent Lesser Snow Goose population, but among the foremost has been the development of rice agriculture in the MAV and Gulf Coast region (Ankney 1996, Abraham and Jeffries 1997). The historical winter grounds for much of the midcontinent population extended along the northern Gulf of Mexico east to the Mississippi River Delta (Bateman et al. 1988). Snow geese spent the winter in a narrow band of brackish marsh along the coasts of Louisiana and Texas and rarely ventured inland (Bateman et al. 1988). However, as rice culture developed and expanded in Louisiana and Texas in the late 1940s, geese began to use the ricefields adjacent to the coastal marshes to feed, returning daily to the coastal marshes to roost. When landowners began creating "rest ponds," geese began to stay in the inland rice region and no longer returned daily to the coast (Hobaugh 1984, Bateman et al. 1988). With more than 160,000 ha (≈395,000 acres) of new habitat in rice production, the provision of safe roost sites and a food source that provided an energy rich diet (Hobaugh 1985, Alisauskas et al. 1988), over-winter survival was greatly improved, contributing to the population expansion (Abraham and Jeffries 1997). Other factors also played a role, such as increased refuges on migration routes, reduced harvest rates, and climate amelioration in the Arctic, but the post-war increase in rice production in the MAV and Gulf Coast has been viewed as one of the most significant contributing factors (Abraham and Jeffries 1997).

The paradox in this situation is evident. While the benefits of providing winter habitat for waterfowl have been highly lauded, the rice industry and wildlife community now find themselves in a situation where there appears to be too much habitat in some areas for some species. The immediate solution to the midcontinent Lesser Snow Geese crisis is through increased harvest, if sufficiently high levels can be attained logistically and politically (Ankney 1996, Batt 1997). However, some biologists have suggested that it would be prudent to consider alternative agricultural practices less beneficial to geese (see sources in Ben-Ari 1998). At the same time, the loss of rice acreage has been greatest in the Gulf Coast region (Setia et al. 1994), leading to concern over the impacts on other wildlife in this area. Concerted efforts have been made for decades to work with producers to promote wildlife use of ricelands. For example, the mini-refuge program in Louisiana leases small tracts of private agricultural lands to expand existing sanctuaries and provide feeding areas for species such as Northern Pintails (Rave and Cordes 1993, Cox and Afton 1998). In this case, the management prescription for declining species such as pintails is contradictory to overabundant species such as Snow Geese. Clearly, the role of riceland habitat in the management of North American wildlife is becoming increasingly complex.

Research Needs

Our goal in this chapter has been to summarize the current state of knowledge of the value of ricelands to wildlife, and to identify some of the challenges that face producers and wildlife managers in the future. It is clear that we know much about how wildlife use and benefit from ricelands, likely more so than for any other agricultural commodity. However, it is also clear that a number of challenges remain. An ongoing program of research and monitoring is needed to address key information gaps. Here we list what we believe are the most important areas of needed research and extension education identified by our review.

Quality of ricefields as foraging habitat for wildlife - A number of factors have been identified that could have important impacts on the foraging carrying capacity of ricefields for wildlife, particularly waterfowl and other waterbirds. Of specific concern, research is needed to:

1. Determine the availability of waste rice left in fields as a function of harvest method (stripper header, conventional header) and age and type of harvester.
2. Estimate the production of food sources other than rice, such as weed seeds and especially invertebrates.
3. Evaluate the influence of alternative straw management practices (burning, disking, chopping, bailing, flooding, rolling) on use of ricefields, availability of food, and access by wildlife to food.
4. Determine optimal water depths and the timing and duration of winter flooding to maximize benefits to a diversity of waterbirds and other aquatic organisms.
5. Monitor the impact of the development of new rice varieties that may be harvested earlier or more effectively.
6. Assess the loss of waste grain to germination, seed decomposition, and other grain consumers after harvest and before winter flooding, particularly in the MAV.
7. Establish the minimum threshold density of waste rice and other foods in ricefields needed to retain or encourage use by wildlife.
8. Quantify food production and wildlife use of ricefields during the breeding season.
9. Undertake detailed surveys of nest sites and brood habitat for birds, reptiles and amphibians to assess year-round value of ricelands.
10. Conduct paired comparisons of the suitability of ricelands versus natural wetlands, including measures of foraging success, time allocation, breeding success, and survival in addition to estimates of use and abundance.
11. Evaluate landscape features (e.g., size and juxtaposition of ricefields within habitat complexes, proximity to refuges, effect of disturbance) that influence use of ricefields by wildlife.
12. Develop models to predict the impact of changes in the amount or quality of ricelands on wildlife populations and their distributions, especially for species that have now come to use ricefields heavily.
13. Evaluate the potential of fallow ricefields or retired ricefields to produce waterbird habitat under different management practices and develop management protocols to facilitate restoration of abandoned ricefields.

Reducing areas of potential conflict - A second area of research deals with potential conflicts with other resource users, particularly those requiring limited water supplies. These information needs are more general and in many cases will require sociological and economic analyses in addition to biological assessments. These include the need to:

1. Evaluate the potential for conflicts with species of special status. Specifically, address the concern of producers that providing habitat for wildlife will also attract endangered species and limit farming activities, examine potential conflicts with instream water needs for endangered fish, and assess potential impacts of rice farming activities on special-status species.
2. Continue to develop management practices to improve water quality and reduce downstream impacts.
3. Continue research on alternative low-toxicity organic chemicals, changes in pest management practices, or changes in cultural practices to reduce the quantity and frequency of chemical applications to control weeds and invertebrate pests.
4. Continue research on cost-effective, nonlethal methods to reduce crop depredation by wildlife (especially blackbirds and coots) without reducing the quality of ricefields for other wildlife.
5. Assess the biological, social, and economic implications of changes in the amount of flooded rice area with respect to overabundant wildlife populations, redistribution of birds, support from the hunting community and long-term impacts on funds for wetland restoration.
6. Assess the biological, social, and economic consequences of possible reductions in water availability, increased water and production costs, and conversion of rice to other crops on the quantity and quality of rice acreage available to support wildlife.

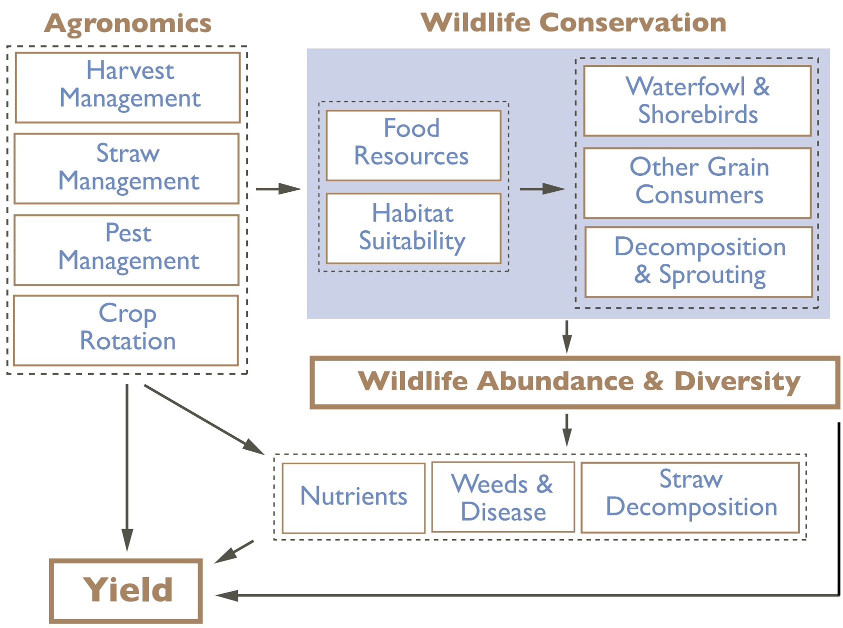
Agronomic value of providing habitat for wildlife - A final area of research concerns the agronomic value of attracting wildlife to ricelands. It is becoming increasingly clear that producers may benefit directly through the services provided by wildlife. However, efforts to quantify these benefits have been limited and, with the exception of Manley et al. (2005), there has yet to be an attempt to evaluate these in economic terms. Ultimately, the ability of ricelands to provide habitat for wildlife on a sustainable basis will be determined by the extent to which producers view such practices as beneficial and in their best interest. As Esslinger (1996) points out, "it is easy to recommend to a landowner what he/she needs to do to manage for wildlife, but we cannot overlook the fact that those recommended practices must be compatible with rice production and maintain the productivity of the cropland. We need to identify best management practices for waterfowl and other waterbirds that are also beneficial or neutral with respect to use of the land for rice culture." Accordingly, studies are needed to determine the various costs and potential savings to producers of managing ricelands for wildlife. The results may provide important incentives to producers to provide habitat for wildlife.

These studies should:

1. Evaluate the agronomic value of attracting waterfowl and other wildlife to ricefields by measuring effects of straw decomposition, reduction of weed seeds and invertebrate pests, nutrient dynamics, and ultimately crop yield.
2. Assess the economic costs and benefits of attracting waterfowl and other wildlife, in terms of costs of tillage operations, herbicides, pesticides, fertilizers, water, labor, and revenues via hunting leases and wildlife viewing.
3. Develop landscape-level planning mechanisms to determine where it would or would not benefit producers to provide habitat to maximize agronomic benefits (e.g., sites with low bird densities may not benefit to the same extent as sites with high densities).
4. Evaluate ongoing incentive programs, and develop new programs, to encourage rice producers to provide habitat for wildlife.
5. Establish interdisciplinary studies to conduct integrated agronomic analyses that fully consider the biological, social, and economic benefits and costs to rice producers and wildlife populations.

We view this last research objective as particularly important. The habit in the past has been for agronomists to consider only the factors that influence rice production and yield (left side of Figure 7) while wildlife biologists have instead focused on the effect of farm management on habitat suitability and food availability for wildlife populations (top and right side of Figure 7). A thorough assessment of the agricultural and environmental consequences of integrating rice production with wildlife and water conservation would provide enormous benefits to producers, environmentalists, and policy-makers. Such an undertaking would develop integrated management prescriptions to improve the economic viability of rice production in the major rice-growing regions, enhance the conservation of natural resources on agricultural lands, and develop recommendations to reduce water use conflicts in this key agricultural sector.

FIGURE 7



A framework to integrate agronomic values and wildlife conservation in ricelands. Agronomic considerations address management practices that influence rice yield. These practices also strongly influence the value of ricelands for wildlife. Providing habitat for wildlife can, in turn, provide agronomic and economic benefits to producers. An integrated framework explicitly acknowledges and develops these mutually beneficial linkages.

SUMMARY

1. Riceland has considerable value as wildlife habitat, especially wetland-dependant wildlife, and is an important component of the mosaic of habitats needed to sustain wildlife populations in areas where wetlands have been significantly reduced.
2. Numerous species of waterfowl, shorebirds, wading birds, raptors, and other birds, mammals, reptiles, and amphibians depend on ricefields for foraging, loafing, nesting, and brood rearing; these include a number of species of special conservation status.
3. Several field management practices affect the use and suitability of ricefields for wildlife, including harvest methods, winter flooding, crop management, post-harvest straw manipulation, and use of pesticides or herbicides.
4. The ability of ricelands to provide habitat for wildlife depends on factors that may affect the carrying capacity of these habitats, changes in farm management practices, and conflicts with other resource users.
5. Further information is needed on how the carrying capacity of ricelands might be affected by harvest and straw management practices, constraints on water supplies, and loss or conversion of rice acreage.
6. There is also a need to evaluate potential conflicts with species of special status, impacts on water quality, and the effect of pesticides and lethal control of pest species.
7. Provision of rice habitat may have unintended consequences of causing shifts in bird distribution patterns or facilitating population growth of overabundant species. Management plans are needed to promote the value of ricelands to wildlife without contributing to environmental exigencies or alienating the cooperation of rice producers.
8. There is significant potential for direct benefits to producers in attracting wildlife to ricefields, including better water quality, enhanced straw decomposition, reduced weed and invertebrate pest pressure, additional revenue through hunting leases, and increased public support.
9. There is a need to document and evaluate these benefits economically, relative to costs of alternative management practices. Ultimately, an interdisciplinary analysis is required to consider both wildlife values and agricultural values in an integrated agronomic analysis.

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