Fish and Wildlife Benefits Associated with Wetland Establishment Practices

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ABSTRACT Efforts to establish wetlands through restoration and creation actions have increased in recent decades in response to regulatory and voluntary incentive programs. This paper summarizes the findings of studies conducted to document fish and wildlife response to these practices. The majority of published studies describe bird response to wetland restoration, with most reporting bird communities in restored wetlands to be similar to those of natural reference wetlands. Studies also indicate that invertebrates and amphibians generally respond quickly to and colonize newly established wetland habitats. Key factors reported as correlated with wildlife species richness include wetland size, availability of nearby wetlands habitats, diversity of water depths and vegetation, wetland age, and maintenance and management activity. Key knowledge gaps in our understanding of fish and wildlife response to wetland establishment practices are identified, including the need for studies on biota other than birds and long-term monitoring of wetland condition and wildlife response over time.

Wetlands have been shown to provide a variety of ecological, biological, and hydrologic functions that provide economic, aesthetic, recreational, educational, and other values to society (Mitsch and Gosselink 1986, National Research Council 1992, Heimlich et al. 1998). However, these values were poorly recognized in the United States during the 19th and most of the 20th centuries. Numerous federal incentives encouraged wetland drainage, ranging from direct support for wetland "reclamation" under the Swampland Acts of 1849, 1850, and 1860, to agricultural subsidies that indirectly supported conversion of wetlands to crop production (U.S. Department of the Interior 1988, Heimlich et al. 1998).

Conversion of wetlands to agricultural production has greatly impacted fish and wildlife habitats throughout the world (Lemly et al. 2000). In North America at the time Europeans arrived, there were approximately 221 million to 224 million acres of wetlands in what is now the conterminous United States (Dahl 1990). By 1992, 45 percent to 50 percent of the original wetland area in the lower 48 states had been converted to agricultural and other uses, with losses approaching 90 percent in some states (Heimlich et al. 1998).

The 1985 Food Security Act's Wetlands Conservation (Swampbuster) provision and the 1986 Tax Reform Act largely eliminated indirect government support for wetland conversion (Heimlich et al. 1998). Since 1985, the Conservation Title of the 1990, 1996, and 2002 Farm Bills has supported the protection and restoration of wetland resources through a variety of U.S. Department of Agriculture (USDA) conservation programs.

Example of wetland conversion (i.e., draining) for agricultural production. (Photo courtesy of USFWS)

Wetland Conservation Practices

A variety of conservation practices that affect wetlands are implemented through USDA conservation programs and technical assistance provided by Natural Resources Conservation Service (NRCS) conservation planners to owners and operators of agricultural lands and other USDA clients. For the Conservation Reserve Program (CRP), similar wetland-related conservation practices with slightly different codes and definitions are applied by the Farm Service Agency. For the purpose of this chapter, practices that are typically viewed as directly affecting wetland function have been selected for treatment. While other conservation practices relating to land treatment and management can and do affect wetland functions in a variety of ways (Lowrance et al. 2006), those practices are addressed in other chapters of this publication. Practices addressed here are those listed and defined in Table 1. There are a number of other practices that are typically used in wetland restoration and management activities (e.g., dike, structure for water control, tree/shrub establishment, etc.). However, these practices are also used in a

Table 1. USDA conservation practices with direct connection to wetland function.

Practice (Acres)	NRCS Practice code	FSA Practice code (CRP)	Definition[1]
Wetland Creation	658		The creation of a wetland on a site that was historically non-wetland.
Wetland Enhancement	659		The rehabilitation or reestablishment of a degraded wetland, and/or the modification of an existing wetland.
Wetland Restoration	657	CP23[2] CP27[3] CP31[4]	The rehabilitation of a degraded wetland or the reestablishment of a wetland so that soils, hydrology, vegetation community, and habitat are a close approximation of the original natural condition that existed prior to modification to the extent practicable.
Wetland Wildlife Habitat Management	644		Retaining, developing, or managing wetland habitat for wetland wildlife.
Shallow Water Development and Management	646	CP9	The inundation of lands to provide habitat for fish and/or wildlife.

[1]Definitions are from the NRCS National Conservation Practice Standards from the National Handbook of Conservation Practices (www.nrcs.usda.gov/technical/Standards/nhcp.html).
[2]Includes CP23 (floodplain wetland) and CP23a (non-floodplain wetland) restoration.
[3]Wetland restoration through the CRP Farmable wetland program, including buffer areas (CP28).
[4]Tree planting associated with wetland restoration on land enrolled in CRP.

Table 2. Practices related to wetlands planned in FY 2004 under a variety of USDA conservation programs.[1]

Practice	NRCS Practice code	WRP	WHIP	EQIP	CTA	CRP	All programs[2]
		Conservation Program (acres)					
Wetland Wildlife Habitat Management	644	75,102	36,769	15,100	178,538	30,877	444,474
Shallow Water Development and Management	646	4,461	4,922	6,549	8,399	1,408	26,759
Wetland Restoration	657	98,613	9,316	1,088	38,829	71,862	220,878
Wetland Creation	658	3,493	119	205	3,389	1,118	8,324
Wetland Enhancement	659	5,026	601	827	30,586	710	37,795

[1]WRP—Wetlands Reserve Program; WHIP—Wildlife Habitat Incentives Program; EQIP—Environmental Quality Incentives Program; CTA—Conservation Technical Assistance; CRP—Conservation Reserve Program.
[2]Total includes acres planned under programs not listed.
Source: USDA System 36 database.

wide variety of other applications that do not have to do with wetlands and therefore are not included in this chapter.

Cost-share and technical assistance is available through several USDA conservation programs. Table 2 provides acreages of wetland conservation practices planned during FY 2004 under various USDA conservation programs. Table 2 is intended to give readers an idea of the types of wetlands conservation activities under way during a single planning year, rather than a comprehensive cumulative total of all wetlands affected across all programs.

Documented Fish and Wildlife Response

This paper compiles available literature that describes fish and wildlife response to conservation practices applied to wetland systems. Documented effects are grouped by major taxa reported in the literature. Much of the literature relates to a combination of practices. In many instances, wetland restoration and creation are indistinguishable in terms of fish and wildlife response. In other cases, wetland enhancement measures studied are indistinguishable from wetland management actions, and many wetlands that are managed for wildlife have been previously subject to wetland restoration (e.g., see Marburger 2002, Bryan et al. 2003). For this reason, it is difficult to sort the literature by NRCS defined conservation practices listed in Table 2. Where possible, distinctions are made between two broad categories of wetland conservation activity: 1) wetland establishment (including Wetland Restoration and Wetland Creation) and 2) wetland management (including Wetland Wildlife Habitat Management, Shallow Water Development and Management, and Wetland Enhancement). This paper focuses primarily on summarizing the literature on fish and wildlife response to wetland establishment practices.

Rewa (2000) summarized the literature related to the fish and wildlife response to the Wetlands Reserve Program by examining reported effects of wetland restoration and creation reported in the literature and extending these findings to the WRP where applicable. Information contained in that review related to wetland practices and the fish and wildlife response reported is included here, along with additional results reported since the 2000 report was completed.

Invertebrates

Several studies have shown that soon after wetlands are restored or created, they are quickly colonized by a variety of aquatic invertebrates and other animals (Reaves and Croteau-Hartman 1994, Juni and Berry

2001). Brown et al. (1997) found similar invertebrate taxa between natural wetlands and restored wetlands in New York. Insects with aerial dispersal colonized restored wetlands more rapidly than less mobile invertebrates. In recently constructed coal surface mine sediment ponds, Fowler et al. (1985) found 66 and 44 invertebrate taxa in the first and second years sampled, respectively, indicating rapid invertebrate colonization.

The invertebrate fauna of restored wetlands is typically characterized as very similar to natural wetlands with similar vegetation structure (Brown et al. 1997, Zimmer et al. 2000, Juni and Berry 2001). Mayer and Galatowitsch (1999) found diatom species richness and composition in restored prairie wetlands in North Dakota to be similar to that of natural wetlands. LaGrange and Dinsmore (1989) found a total of 18 wetland invertebrate species in four formerly drained prairie wetland basins several years after the basins were reflooded. In a survey of 156 restored seasonal and semi-permanent wetlands of 12 different ages in Minnesota and South Dakota, Sewell and Higgins (1991) found 31 taxa of aquatic macroinvertebrates in restored wetlands, 12 of which occurred in wetlands the first year following restoration. Restored prairie pothole wetlands are generally believed to be readily and adequately colonized by invertebrates, although invertebrate community differences between restored and natural wetlands may have gone unnoticed due to the low taxonomic resolution at which most invertebrate communities are sampled (Knutsen and Euliss 2001).

Benthic invertebrate communities are strongly associated with wetland vegetation (Streever et al. 1995). In a created freshwater herbaceous wetland in central Florida, Streever et al. (1995) found three of five common Chironomid genera were more abundant in areas with greater than 50 percent herbaceous cover than more open areas and greater abundance of all five common genera in areas with greater than 80 percent vegetation cover. Transplantation of remnant wetland soil that increases the rate of wetland plant growth can also increase overall invertebrate abundance in restored wetlands (Brown et al. 1997).

Invertebrate taxa can be used to assess biotic response to restored wetlands (Brown et al. 1997). However, significant spatial and temporal variation must be considered. Dodson and Lillie (2001) found zooplankton taxon richness in restored wetlands in Wisconsin mimicked that of least-impacted reference wetlands within six to seven years after restoration. Ettema et al. (1998) found spatial distribution within a restored wetland in Georgia varied substantially among nematode taxa, with substantial temporal variation within taxa. Distribution of nematode taxa did not correlate well with soil resource patterns. In a rehabilitated wetland in northern Spain, Valladares Diez et al. (1994) found that a diverse community of Coleoptera had developed, but most species found belong to early successional groups or are ubiquitists. In the same restored wetland, Gonzales Martinez and Valladares Diez (1996) found aquatic Heteroptera and Odonata communities to be similar to natural immature wetlands (ubiquitists and pioneers). In general, the communities of beetles, dragonflies, and aquatic heteraopterans are representative of recent wetlands, with evidence of changes toward a more stable and mature environment.

The presence of fish in restored wetlands may also influence how invertebrates respond to restored wetland conditions. Zimmer et al. (2000, 2002) found the presence of fathead minnows (*Pimephales promelas*) to have a major influence on the invertebrate community structure in restored prairie wetlands in Minnesota. However, Dodson and Lillie (2001) found no influence of the presence of fish on the zooplankton community of restored wetlands in Wisconsin.

Fish

The effect of wetland establishment on fish communities has not been extensively investigated. Wetland geomorphic and geographic setting appears to have a significant influence on how the fish community responds. Within two years of development of a constructed wetland in east-central Florida, Langston and Kent (1997) observed a rich and abundant fish community that was similar to natural wetlands in the area. They surmised that in this geographic setting, fish may have been introduced to the wetland through irrigation or transport by local fauna.

In other settings, such as shallow prairie wetlands that are typically isolated from deeper water bodies, fish have not played a significant role in the development of biological communities inhabiting these wetlands. Recent studies have shown that introduction of fish into historically fish-free prairie wetlands can negatively affect native fauna such as invertebrates, amphibians, and waterbirds (Knutsen and Euliss 2001). Likewise, agricultural ponds in Minnesota free of fish have been found to be more likely to support diverse populations of amphibians than those with fish (Knutson et al. 2004).

Herpetofauna

Several studies illustrate rapid amphibian colonization of constructed and restored wetlands. Lehtinen and Galatowitsch (2001) found restored wetlands in Minnesota to be rapidly colonized by eight amphibian species, all of which established breeding populations. Fowler et al. (1985) documented 12 species of breeding amphibians in newly constructed coal surface mine sediment ponds in western Tennessee, and all nine ponds surveyed contained at least one breeding amphibian species. Anderson (1991) found American toads *(Bufo americanus)*, green frogs *(Rana clamitans)*, and leopard frogs *(Rana pipiens)* using recently restored wetlands in Wisconsin. Lacki et al. (1992) found that a wetland constructed for treatment of mine water drainage in east-central Ohio supported greater abundance and species richness of herpetofauna than surrounding natural wetlands. This was primarily due to the large number of green frogs and pickerel frogs *(Rana palustris)* and numerous species of snakes found using this site.

Stevens et al. (2002) found a greater number of anurans calling from restored wetland basins on Prince Edward Island than from similar reference wetlands. This may have been due in part to the greater amount of microtopography in restored wetlands resulting from the actions of removal of fill material from these sites as the primary restoration action.

Landscape condition and surrounding land use appear to be critical components that influence amphibian colonization and use of restored wetlands. In glacial marshes in Minnesota, Lehtinen et al. (1999) found amphibian species richness was lower with greater wetland isolation and road density at all spatial scales in both tallgrass prairie and northern hardwood forest ecoregions. Limited dispersal capability likely contributes to slow colonization of restored wetlands by amphibians in fragmented landscapes (Lehtinen and Galatowitsch 2001). Likewise, elimination of small wetlands that are relied upon by reptiles and amphibians can have a devastating effect on habitat availability and populations of these animals (Gibbs 1993).

Although studies have shown rapid amphibian colonization of restored and created wetlands accessible by dispersing individuals, there remains significant uncertainty concerning the long-term viability and population dynamics in these sites (Petranka et al. 2003).

Birds

The response of birds to wetland conservation practices is better documented than for other wildlife taxa (Knutsen and Euliss 2001). Numerous studies have documented extensive bird use of restored freshwater wetlands (Guggisburg 1996, Sleggs 1997, Muir Hotaling et al. 2002, Stevens et al. 2003, Brasher and Gates 2004). LaGrange and Dinsmore (1989) found a total of 11 bird species in four formerly drained prairie wetland basins several years after the basins were reflooded. Anderson (1991) monitored wildlife use of small restored wetlands in Wisconsin and documented ducks and duck broods and nesting marsh wrens *(Cistothorus palustris)*, sandpipers, and woodcock *(Scolopax minor)* using these habitats. Fletcher and Koford (2003) observed an increase in many bird species of management concern in response to restoration of prairie-wetland complexes in Iowa. Although no quantitative data were collected, Oertel (1997) noted substantial increases in wetland-associated wildlife use following restoration of a 55-acre wetland in northern New York. Dick (1993)

High density waterfowl use of a wetland. (Photo courtesy of W. Meinzer, USFWS) observed wetland-dependent birds using an 80-acre restored wetland site in south-central Pennsylvania during the first year after restoration. Bird groups observed included winter raptors, wintering and migrating ducks, geese and tundra swans *(Cygnus columbianus)*, foraging wading birds, waterfowl and shorebirds, and other birds. Breeding mallards *(Anas platyrhynchos)*, wood ducks *(Aix sponsa)*, sora *(Porzana carolina)*, sedge wrens *(Cistothorus platensis)*, common snipe *(Gallinago gallinago)*, spotted sandpiper *(Actitis macularius)*, and pied-billed grebe *(Podilymbus podiceps)* were documented. Restoration of the wetland increased bird diversity by 60 percent during the first year. In restored wetlands in central New York, Kaminski (2005) found survival probabilities for female nesting mallards to be comparable with those of mallard populations in natural wetland systems.

In most situations, birds rapidly colonized restored wetlands, usually in the first year after restoration. Delehanty and Svedarsky (1993) found breeding black terns *(Chlidonias niger)* using a restored prairie wetland during the second and third breeding seasons after restoration. As many as 40 adults were present in the marsh during the third breeding season, and a minimum of seven young were fledged. Sewell and Higgins (1991) found 12 species of waterfowl using restored wetlands of varying ages in Minnesota and South Dakota. During the first five years after restoration, White and Bayley (1999) documented 50 shorebird species, 44 waterfowl species, 15 raptor species, and 28 other new bird species using a 1,246-ha formerly drained northern prairie wetland that was restored and flooded with municipal wastewater. In the case of bottomland hardwood wetland restoration, studies have shown that birds associated with grasslands and scrub-shrub communities readily use these sites as they transition from open field to forested habitats (Twedt et al. 2002, Twedt and Best 2004). These studies show how quickly wetland-associated birds respond to restored wetland habitats. However, bird response to created bottomland hardwood wetlands may be somewhat less predictable due to the variability of wetland (or non-wetland) conditions established. For example, Snell-Rood and Cristol (2003) found that created bottomland hardwood wetlands in Virginia had significantly lower bird species richness and diversity than similar reference wetlands. The authors of this study hypothesized that the lack of bird response was likely due to unnatural patterns of hydrology and poor vegetation development in created wetland sites.

In most studies in the literature, bird use was found to increase with the size of restored wetlands examined. Brown and Dinsmore (1986) found more diverse bird communities in larger prairie marshes. Among restored emergent wetlands in Wisconsin, Guggisberg (1996) found that large restored wetlands had greater non-game bird species richness than did small wetlands. In restored herbaceous wetlands in northern Iowa, Hemesath and Dinsmore (1993) found that breeding bird species richness increased with wetland size, regardless of how long the wetlands were restored or the duration of prior drainage. Analysis of data collected on bird use of wetlands restored in central Iowa under the Farmable Wetlands Conservation Reserve program imply a strong correlation between wetland size and bird species richness (R. N. Harr, Iowa State University, unpublished data). However, others have documented changes in the bird community with the amount of time following wetland restoration in response to changes in vegetation (Wilson and Twedt 2005). Vanrees-Siewert and Dinsmore (1996) found that total bird species richness increased with the age of restored prairie wetlands in Iowa, while waterfowl use (breeding and total) was influenced more by restored wetland size, regardless of age.

Habitat structure in restored wetlands appears to be a primary element that determines bird use of individual wetland sites. Density of waterfowl breeding pairs was lower in borrow ponds constructed along a highway in North Dakota than in natural basins of similar size (Rossiter and Crawford 1981, 1986). This was attributed to lack of a shallow water area and emergent wetland vegetation in borrow area wetlands. During drought conditions, Ruwaldt et al. (1979) found spring waterfowl pair use in South Dakota was greater in semi-permanent natural wetlands and artificial stock ponds than in other wetland types, indicating the importance of surface water availability to breeding waterfowl.

Bird use of restored wetland systems has been shown to be similar to that of natural wetlands with similar habitat structure. Ratti et al. (2001) did not detect any difference in bird abundance, species richness, or species diversity between 39 natural prairie wetlands and 39 restored wetlands in North and South Dakota. Brown and Smith (1998) found that the number of bird species and individuals did not differ between restored and natural wetlands in New York for the three bird groups studied (wetland-dependent, wetland-associated, and non-wetland birds). They found bird communities were more similar among restored sites than between restored and natural wetland sites. Thompson (2004) found similar bird species richness and diversity among restored and natural wetlands in Michigan, with restored sites supporting higher densities of wetland dependent birds. Delphey and Dinsmore (1993) found species richness of breeding birds was higher at natural wetlands than restored prairie wetlands. However, duck species richness and pair counts did not differ between natural and restored wetlands. Drought during the study may have influenced results.

Brown (1999) found more plant species valuable as food sources for wetland birds and greater coverage of these species occurred in restored wetlands than in natural wetlands in New York. Differences in bird similarity between natural and restored wetlands may disappear as restored wetlands develop over time (Brown and Smith 1998).

While bird use is related to the size of restored wetlands, it is also influenced by the proximity to other wetland habitats (Reaves and Croteau-Hartman 1994). The condition of upland habitats adjacent to wetlands and the surrounding landscape greatly influences use of restored wetlands by many bird species. Local wetland conditions dictate habitat suitability for some wetland bird species that are relatively sedentary, while wide-ranging species are greatly affected by the condition of the landscape surrounding wetland habitats. Naugle et al. (1999) found that while pied-billed grebes and yellow-headed blackbirds *(Xanthocephalus xanthocephalus)* used wetlands in South Dakota based on the condition of the habitat within wetlands, use of wetlands by black terns, a wide-ranging species, was dictated more by the use and condition of the surrounding landscape.

Habitat diversity within individual wetlands is associated with bird use. Fairbairn and Dinsmore (2001) found bird diversity to be positively associated with the percentage of wetland area with emergent vegetation within wetland complexes, total wetland area within three km, and total area of semipermanent wetlands within three km of wetland complexes. Likewise, McKinstry and Anderson (2001) found the presence of emergent and submersed wetland vegetation and the presence of nearby wetlands to be important factors in determining waterfowl use of created wetlands on mined lands in Wyoming. Naugle et al. (2000) found black tern use of prairie wetlands was largely correlated with wetland area, amount of semi-permanent wetland area within the wetland, and grassland area in the surrounding upland matrix. Black tern use was associated with large wetland basins located in high-density wetland complexes, illustrating the importance of considering entire landscapes in habitat assessments and conservation efforts.

Landscape Factors

Wildlife response to wetland restoration may be as much a function of the presence of other wetlands nearby and overall landscape condition as the state of wetland habitats evaluated (Griffiths 1997, Haig et al 1998). Fairbarn and Dinsmore (2001) found the percent of emergent vegetation in wetland complexes in Iowa and the total area of wetland in the surrounding landscape to be important predictors of bird species richness. Likewise, Ratti et al. (2001) speculated that the higher avian density they observed in restored prairie wetlands was likely due to the presence of upland cover adjacent to restored sites, which provided superior habitat for upland nesting waterfowl and other birds compared with existing remaining wetlands, many of which were surrounded by active cropland. Whereas studies have shown the use of restored wetlands in the Prairie Pothole Region of the North American upper Midwest by waterfowl for migrating, breeding, and rearing young, wetland complexes providing a variety of wetland conditions are more beneficial than isolated restored basins (Knutsen and Euliss 2001).

Amphibians are particularly sensitive to landscape factors (Lehtinen et al. 1999, Guerry and Hunter 2002). Linkages between wetland habitats and adjacent uplands and the condition of those upland habitats are important aspects determining the value of wetland habitats for semi-aquatic amphibians (Semlitsch 1998). Midwestern landscapes that include a complex of habitat types, including wetlands, have been shown to be beneficial to amphibians (Knutson et al. 1999). In agricultural ponds in Minnesota, Knutson et al. (2004) found amphibian species richness to be highest in smaller ponds with low nitrogen concentrations resulting from minimal livestock access. They concluded that small farm ponds, properly managed, may help sustain amphibian populations in landscapes that lack natural wetland habitats.

Recently restored wetland in Ohio enrolled in the Wetlands Reserve Program. (Photo by K. Schneider, USDA NRCS)

Wetland establishment activities are intended to put in place features that support development of wetland functions over time. Short-term and long-term changes in physical conditions over time result in shifts in habitat suitability for a wide variety of species. For example, Braile and Dunning (2003) noted high shorebird use of a restored wetland complex in Indiana shortly after restoration—associated with an abundance of mudflats and open, shallow water habitats—and a dramatic decrease in shorebird use as the site became vegetated. Likewise, Wilson and Twedt (2005) noted the use of restored bottomland hardwood wetlands by forest-dwelling land birds as soon as trees established on the site grow tall enough to begin to provide the necessary habitat structure.

Practice Application Principles

Several key factors driving fish and wildlife response to wetland establishment practices are apparent within the knowledge base provided by the literature.

Wetland Size

In general, larger restored wetlands and wetland complexes have been shown to be associated with greater wildlife species richness (Hemesath and Dinsmore 1993, Guggisberg 1996). Waterfowl use has been shown to increase with wetland size (Vanrees-Siewert and Dinsmore 1993). However, small prairie wetlands have been shown to be extremely important for migrating and breeding waterfowl (Krapu et al. 2000).

Wetland Age

Wildlife use of established wetlands is in part dictated by the amount of time since the physical restoration or creation action was taken. Whereas bird species richness has been shown to increase with wetland age (Vanrees-Siewert and Dinsmore 1993), wildlife response is highly species-specific. Shorebirds, wading birds, and some waterfowl species have been noted to heavily use mudflats and open water habitats in recently restored wetlands (White and Bayley 1999). Use of recently restored wetlands by shorebirds and other species associated with open areas generally declines with wetland age and emergent vegetation growth (Braile and Dunning 2003). In bottomland hardwood wetland restoration, use by species associated with early successional habitats declines as forest landbird use increases with wetland maturation (Twedt and Best 2004, Wilson and Twedt 2005).

Hydrologic and Topographic Features

The condition of habitats provided in established wetlands is greatly influenced by the water depth and periodicity as well as surface microtopography and other surface features. Although there has been limited effort expended on quantifying how various microtopographic features influence wildlife response in restored and created wetlands, evidence is emerging that indicates that restored wetlands with greater diversity of surface features, supporting a wider variety of water depths and vegetation, are associated with greater wildlife species richness (Tweedy et al. 2001).

Proximity to Other Wetland Habitats

Wetlands established in the vicinity of other wetland habitats typically have greater value for many wildlife species. Amphibian habitat value is particularly influenced by the availability of nearby wetlands (Lehtinen et al. 1999). Greater wildlife response has been observed in complexes of restored wetlands than in isolated basins (Reaves and Croteau-Hartman 1994, Beyersbergen et al. 2004).

Surrounding Landscape Features

Land use, vegetation type, and overall condition of upland habitats surrounding established wetlands typically has a direct affect on the value of these wetland habitats for many species. For example, restored prairie wetlands established in unfragmented prairie landscapes have greater value for wetland birds than those established in intensively managed agricultural landscapes (Naugle et al. 2000). The amount of wetland habitat within several km of examined prairie wetland sites has also been observed as a predictor of wetland bird species richness (Fairbain and Dinsmore 2001).

Regional Water Conditions

Regional water conditions can have a dramatic effect on the quality of wetland habitats, both natural and established (Austin 2002). Seasonal and long-term climate variation is of particular significance in prairie wetlands where cyclical drought and deluge patterns are common (Euliss et al. 2004).

Sources of Population Recolonization

Wetlands that are established in areas that are far removed or otherwise isolated from source populations for recolonization may be of lesser value to many species. This is particularly true for some aquatic invertebrates (Knutsen and Euliss 2001) and amphibians (Lehtinen and Galatowitsch 2001) with limited ability to traverse significant distances across non-wetland habitats.

Maintenance and Management

Establishment of appropriate wetland hydrology and vegetation are important factors in determining fish and wildlife value. However, maintenance of established wetland conditions and management of water regime and vegetation are equally important. Whereas wetlands managed to enhance wildlife value have been shown to generate increased use by target species (Kaminski 2005), others that are not properly maintained limit restoration success (Hicks 2001).

Knowledge Gaps

Wetland establishment through restoration and creation actions has become a common practice in wetland management and regulatory activities (National Research Council 1992, 2001). While there has been considerable improvement in our understanding of the effectiveness of these activities and in our ability to effectively establish a suite of wetland functions through these actions, controversy remains regarding what should be considered successful wetland establishment (Malakoff 1998, Middleton 2001).

In many instances, it is difficult to directly discern the effects of specific wetland conservation practices on wildlife use of the affected areas from broader population changes or temporal shifts in landscape conditions (Naugle et al. 1999). For example, Fletcher and Koford (2003) found only two of six wetland-nesting bird species populations increased in response to restoration of wetland complexes in Iowa, likely due to the high variability among restored sites and years, or lag time in recolonization. They also recognized that temporal dynamics of bird populations can affect estimates of population change at individual wetland sites. Wide-ranging and highly mobile species such as waterbirds pose a particular challenge for resource managers, where the presence of numerous wetlands on the landscape is more likely to influence local habitat use of individual restored sites than the local habitat conditions in those sites (Haig et al. 1998).

These issues illustrate some of the challenges resource managers face in enumerating fish and wildlife response to wetland establishment and management practices. Numerous gaps in our understanding remain to be filled before a more complete picture may be assembled. Some of the more significant data gaps apparent in the literature include:

- Most of the studies conducted have focused on breeding birds. Much less is known about bird use of these habitats during migration, wintering, and other non-breeding periods.
- The paucity of studies on wildlife other than birds is apparent in the literature. Additional work is needed on general response of fish and other non-bird biota to wetland establishment practices during all life stages.
- The literature contains numerous studies indicating that many wildlife species, primarily wetland

habitat generalists, are able to exploit habitats made available through wetland establishment practices (Knutsen and Euliss 2001). Much less is known about how wetland habitat specialists may be affected by these practices.

- The widespread practice of wetland restoration and creation is a relatively recent trend; most of these wetlands have been established within the last 20 years. Whereas age seems to be an important factor in dictating fish and wildlife habitat value, greater effort is needed to gain a better understanding of the long-term viability and condition of the habitats provided.
- There is great variety in the types of activities undertaken to restore and create wetland habitats and a wide variety of wetland types in various hydrogeographic settings that are established. It is difficult to generalize the findings among these diverse wetland habitats. Greater understanding is needed on the primary factors that influence wildlife value among the habitats established.
- The presence of invasive plants or animals can greatly influence the condition of wetland habitats. This is particularly the case in created wetlands where vegetation establishment is less predictable and invasive plants are more likely to become established in response to greater disturbance and challenges of establishing wetland vegetation (Snell-Rood and Cristol 2003). Additional study is needed to better understand how invasive and non-native species influence habitat use and suitability.

Conclusion

There are a number of studies that imply that restored wetlands provide wildlife habitat value similar to natural reference wetlands. Fewer studies are available describing wildlife response to created wetlands. Most studies focus on bird response to wetland restoration. These studies reveal that while wetland-associated birds respond positively to the habitats established, species composition and community structure are highly variable and depend on local wetland conditions and landscape factors. Many researchers conclude that wildlife species richness is expected to increase over time with the expected increase in vegetation complexity in most restored wetland sites. Long-term monitoring is necessary to gain a better appreciation for how restored and created wetlands develop over time and how various groups of wildlife respond to the habitats provided. Long-term and cyclical weather patterns, regional population trends, management activities, and landscape and surrounding land use changes must be factored into these monitoring efforts.

Wetland conservation practices supported by USDA programs and technical assistance are tracked under broad categories of wetland establishment (Wetland Restoration and Wetland Creation) and management (Wetland Wildlife Habitat Management, Wetland Enhancement, Shallow Water Development and Management). A wide variety of activities and wetland types are established and managed through these practices. A better understanding of the diversity of these practices is needed in order to directly relate findings in the literature on wetland restoration and creation to USDA conservation practices. ■

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