Appendix I: Wildlife Response to Wetland Restoration and Creation: An Annotated Bibliography

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This annotated bibliography provides summaries of published literature on topics related to wildlife use and other biological responses to wetland restoration and creation. While some articles on estuarine wetlands are included, the focus of this effort is on inland freshwater wetland restoration and creation. Publications specific to water quality, flood abatement, and other wetland functions and values are excluded unless they also cover aspects of biological response. Similar bibliographies have been assembled by other authors in the past. The purpose of this bibliography is to complement previous works and to provide a narrower wildlife focus on recent peer-reviewed papers and publications. Unpublished data, reports, and other "gray literature" are not included.

Almendinger, J. E. 1998. A method to prioritize and monitor wetland restoration for water-quality improvement. Wetlands Ecology and Management 6:241-251.

Method developed for prioritizing wetland restoration sites to maximize water quality improvement benefits was applied to the Minnesota River Basin. Wetlands were assessed for their potential to provide water quality benefits using three types of effectiveness: (1) problem effectiveness (Did the site occur in an area with known water quality problems?); (2) function effectiveness (Was the site likely to improve water quality more or less than other sites?); and (3) information effectiveness (Did the site fit within a research plan to gain information on how wetlands improve water quality?). While water quality benefits were emphasized, the paper recognizes that wetland restoration should be multidisciplinary, integrating other benefits such as wildlife habitat and flood abatement.

Anderson, B. W., and R. D. Ohmart. 1984. Avian use of revegetated riparian zones. Pages 626-631 *in* R. E. Warner and K. M. Hendrix, eds. California riparian systems: ecology, conservation, and productive management. California Water Resources Report 55. University of California Press, Berkeley.

Study of avian use of revegetated riparian areas along the lower Colorado River. Vegetation growth and avian colonization occurred rapidly after restoration. Cottonwood, willow, and quail bush were positively associated with avian use. Avian use of riparian areas was further enhanced by elimination of exotic salt cedar and leaving native vegetation.

Anderson, B. W., R. D. Ohmart, and J. Disano. 1979. Revegetating the riparian floodplain for wildlife. Pages 318-331 *in* R. R. Johnson and J. F. McCormick, tech. coords. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. U.S. Forest Service General Technical Report WO-12.

Study of bird responses to vegetation characteristics along the lower Colorado River. Horizontal and vertical foliage diversity and presence of cottonwood and/or willow trees were positively correlated with the number of bird species using an area. Presence of the exotic salt cedar was negatively associated with both bird density and number of species present. Growth of annual plants in riparian floodplain areas was important for attracting large concentrations of wintering birds the first winter after planting.

Anderson, R. E. 1991. Wisconsin wetlands restored. Soil and Water Conservation News 12:14.

Description of wetland restoration activities on CRP lands in Ozaukee County, Wisconsin. In two years, 110 small wetlands were restored. After having been cropped for decades, wetland plants returned to restored wetlands the year following restoration. Monitoring of restored wetlands documented use by ducks and duck broods, meadow voles, butterflies, American toads, green frogs, leopard frogs was mentioned. Marsh wrens, sandpipers, and woodcock began nesting in restored wetlands two years after establishment.

Barry, W. J., A. S. Garlo, and C. A Wood. 1996. Duplicating the mound-and-pool microtopography of forested wetlands. Restoration and Management Notes 14:15-21.

A method was described for establishing pit-and-mound microtopography while creating a forested wetland on degraded uplands in New Hampshire. Approximately 128 acres of former sand and gravel pits were developed into forested wetland to meet mitigation requirement of a highway construction project. Pit-and-mound microtopography was established with a bulldozer so that half the area was occupied by mounds (16-ft base width, 4-ft top width, and 2-ft height above pit bottoms) and half the area was occupied by pools. Wetland topsoil was spread over the area. Bare-root seedlings of woody plants were planted in the pools and on the sides of mounds, while larger balled and burlap and container stock trees and shrubs were planted on tops of mounds. Plantings were irrigated during summer and early fall to aid establishment. Follow-up monitoring of the vegetation showed a high rate of success from planting stock and natural regeneration.

Bedford, B. L. 1999. Cumulative effects on wetland landscapes: Links to wetland restoration in the United States and southern Canada. Wetlands 19:775-788.

Analysis of cumulative wetland impacts from a regional perspective was recommended for wetland restoration planning. To characterize the diversity of settings created by the complex interactions of hydrology, geology, and climate in specific landscapes, assessments should identify the kinds, numbers, relative abundance, and spatial distribution of wetland templates. These profiles should be used to guide wetland restoration decision-making to match wetland type and location to proper hydrogeologic setting, thereby increasing the chance for success of individual restoration projects.

Bijlmakers, L. L., and E. O. A. M. de Swart. 1995. Large-scale wetland-restoration of the Ronde Venen, The Netherlands. Water Science and Technology 31:197-205.

A plan for large-scale wetland restoration and improvement of water quality in a hydrologic unit in The Netherlands was presented. Major elements of the strategy were the optimal use of specific hydrological and ecological characteristics of the area.

Brown, S. C. 1999. Vegetation similarity and avifaunal food value of restored and natural marshes in northern New York. Restoration Ecology 7:56-68.

Development of plant communities in 13 restored emergent wetlands in northern New York was contrasted to nearby natural wetlands for three years following restoration. 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 general, plant communities at restored sites became increasingly similar to those of natural wetlands over time. Natural recolonization appeared to be an effective technique for restoring wetlands on abandoned agricultural fields.

Brown, M., and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. Journal of Wildlife Management 50:392-397.

Study examined bird use of Iowa's prairie marshes in relation to wetland size and proximity to other wetlands. Marsh size and isolation from other marshes explained 75 percent of the variability in bird species richness. Species richness was often greater in wetland complexes than in larger isolated marshes. Authors concluded that marsh size and isolation were important considerations in siting marsh restorations.

Brown, S. C., and C. R. Smith. 1998. Breeding season bird use of recently restored versus natural wetlands in New York. Journal of Wildlife Management 62: 1480-1491.

Bird use of 18 restored wetlands and eight natural herbaceous wetlands in northern New York was documented during the three-year period following restoration. Abundance of bird species and individuals did not differ between restored and natural wetlands for all three bird groups studied (wetland-dependent, wetland-associated, and nonwetland birds). Bird density appeared lower at recently restored wetlands than at natural wetlands. Bird communities were more similar among restored sites than between restored and natural wetland sites. Differences in bird similarity between natural and restored wetlands may disappear as restored wetlands develop over time.

Brown, S. C., K. Smith, and D. Batzer. 1997. Macroinvertebrate responses to wetland restoration in northern New York. Environmental Entomology 26:1016-1024.

Macroinvertebrate communities in recently restored wetlands in northern New York were contrasted with those of comparable natural wetlands in the same area. Most invertebrate taxa found in natural wetlands also could be found in similar numbers in restored wetlands. Insects with aerial dispersal colonized restored wetlands more rapidly than less mobile invertebrates. Transfer of remnant wetland soil increased rate of wetland plant growth and overall invertebrate abundance. Use of this technique, along with reintroduction of some less mobile taxa, could improve efforts to reestablish natural macroinvertebrate communities to newly restored wetlands.

Burney, J. L. Jr., S. T. Bacchus, and J. B. Lee. 1989. An evaluation of wildlife utilization in a man-made freshwater wetland system in central Florida, U.S.A. Pages 24-48 *in* F. J. Webb Jr., ed. Proceedings of the 16th Annual Conference on Wetlands Restoration and Creation. Hillsborough Community College, Plant City, Florida.

A 1,200-acre wetland complex (deep marsh, mixed marsh, created hardwood swamp, littoral zone) was constructed on and adjacent to Lake Chipster near Orlando, Florida, to process tertiary treated wastewater from a nearby Orlando wastewater treatment facility. Wildlife species observed using the complex were documented from Spring 1987 (prior to the first release of wastewater into the wetland but after wetland construction had commenced) to Spring 1989. Visual/auditory observations and various trapping methods were used to determine species composition.

Colburn, B. 1997. Once-upon-a-time-wetlands. Sanctuary 36:16-18.

The challenge of restoring freshwater wetland was discussed. Projects in California and Massachusetts were described to illustrate how wetland restoration can benefit both wildlife and human populations.

Confer, S. R., and W. A. Niering, 1992. Comparison of created and natural freshwater emergent wetlands in Connecticut (U.S.A.). Wetlands Ecology and Management 2:143-156.

Five 3- to 4-year-old created palustrine/emergent wetland sites were compared with five nearby natural wetlands of comparable size and type. Hydrologic, soil, and vegetation data were compiled over a nearly two-year period (1988-90). Created sites that were located along major highways, exhibited more open water, greater water depth, and greater fluctuation in water depth than natural wetlands. Common cattail was the characteristic emergent vegetation at created sites, whereas a more diverse mosaic of emergent wetland species was often associated with cattails at the natural sites. Wildlife use at all sites ranged from occasional to rare, with more species observed in the natural than created wetlands (39 vs. 29 spp.). Whereas emergent vegetation in created wetlands was frequently restricted to the littoral zone, emergent species were more widely scattered throughout natural wetlands. This pattern in created sites was probably related to their steeply sloped shorelines. The low to moderate wildlife activity at created sites was attributed to their small size as well as their isolation. Authors indicated that > 10 years was needed to adequately assess created wetlands and recommended establishment demonstration areas.

Degani, G., Y. Yehuda, and M. Gophen. 1998. Temporal variation in fish community structure in a newly created wetland lake (Lake Agmon) in Israel. Wetlands Ecology and Management 6:151-157.

A 110-ha wetland lake (Lake Agmon) was restored in Israel to encourage ecotourism. Fish were introduced into the lake to control mosquitoes. This study examined the fish community during the first two years following restoration of the lake. Results indicated that the fish community had not stabilized by the end of the second year after restoration.

Deitz, K. B., J. A. O'Reilly, G. S. Podniesinski, and D. J. Leopold. 1996. Rebuilding microtopography and planting woody species restores abandoned agricultural land (New York). Restoration and Management Notes 14:171-172.

Methods of restoring wetland plant communities in abandoned New York muck farms were investigated including (1) addition of donor wetland topsoil, (2) artificially creating mounds to mimic natural microtopography, and (3) direct planting of woody species seedlings at various elevations on created hummocks. Herbivory and competition from herbaceous plants resulted in poor seedling survival. When measures were taken to control these factors, seedling survival improved substantially, and species growth and survival were linked to elevation and soil saturation. Results illustrated the importance of restoring microtopography to maximize species richness in forested wetland restorations and limiting water depth around hummocks to discourage muskrats from burrowing into hummocks (which can lead to collapse of soil and flooding of seedlings). To reduce herbivory, measures such as fencing, planting large nursery stock, or transplanting larger trees and shrubs from donor sites should be considered.

Delehanty, D. J., and W. D. Svedarsky. 1993. Black tern colonization of a restored prairie wetland in northwestern Minnesota. Prairie Naturalist 25:213-218.

Black tern colonization was documented in a prairie wetland system that was restored five years after being drained. Breeding black terns used the wetland during the second and third breeding seasons after restoration (10 and 26 nests initiated, respectively). Forty adults were present in the marsh during the third breeding season and a minimum of seven young were fledged.

Delphey, P. J., and J. J. Dinsmore. 1993. Breeding bird communities of recently restored and natural prairie potholes. Wetlands 13:200-206.

Breeding bird communities of recently restored prairie wetlands in northern Iowa were compared with those of similar natural wetlands. Species richness of breeding birds was higher at natural wetlands; however, duck species richness and pair counts did not differ between natural and restored wetlands. Incomplete vegetation structure at recently restored wetlands likely depressed bird species richness. Drought during the study may have influenced results. Authors concluded that long-term studies during various periods of precipitation were needed to determine success of prairie pothole restoration efforts.

Despain, W. 1995. A summary of the SWCS WRP survey. Journal of Soil and Water Conservation 50: 632-633.

Paper summarized results from a 1992 survey of landowners from seven pilot states seeking their perspectives on and reactions to the initial Wetlands Reserve Program. Perspectives among landowners included how wetlands were defined, environmental benefits of wetlands, understanding of governmental and nongovernmental wetlands programs, and perspectives on the role of government in wetland conservation. Three groups of landowners identified by survey included those who (1) expressed no interest in WRP due to lack of program knowledge or program constraints, (2) began the enrollment process, but withdrew because of their frustration with the sign-up process or concerns about financial matters or long duration of easements, and (3) participated in the program.

Detenbeck, N. E., S. M. Galatowitsch, J. Atkinson, and H. Ball. 1999. Evaluating perturbations and developing restoration strategies for inland wetlands in the Great Lakes Basin. Wetlands 19:789-820.

Paper evaluated physical and biological responses to wetland perturbations in the Great Lakes Basin. Important disturbance mechanisms included sedimentation and turbidity, changes in retention time, eutrophication, and changes in hydrologic timing. Responses to these disturbances included (1) shifts in plant species composition, (2) reduced wildlife production, (3) decreased local or regional biodiversity, (4) reduced fish and/or other secondary production, (5) increased flood peak/frequency, (6) increased above-ground production, and (8) loss of aquatic plant species with high light compensation points. Authors advocated wetland restoration strategies derived at the ecoregion scale using information on current and historic wetland extent and type distributions, and distributions of species of special concern that are dependent on certain wetland types or habitat type mosaics. Authors further suggested regional strategies promote restoration of all appropriate wetland types.

Dick, T. 1993. Restored wetlands as management tools for wetland-dependent birds. Pennsylvania Birds 7:4-6.

Bird use was described for an 80-acre restored wetland site in south-central Pennsylvania. Wetland-dependent birds were observed using this site during the first year after restoration. Bird groups observed included winter raptors, wintering and migrating ducks, geese and tundra swans, foraging wading birds, waterfowl and shorebirds. At least 50 mallard ducklings and numerous wood duck ducklings were produced during the first year. Breeding sora, sedge wrens, common snipe, spotted sandpiper and pied-billed grebe also were documented. The transition from fallow agricultural field to emergent marsh increased bird diversity by 60 percent during the first year.

Elphick, C. S., and L. W. Oring. 1998. Winter management of Californian rice fields for waterbirds. Journal of Applied Ecology 35:95-108.

Wintering waterbird use of flooded rice fields with varying water depths and rice straw residue manipulations was studied in the Sacramento River Basin of California's Central Valley. Intentionally flooded rice fields received significantly greater use by 24 of 31 waterbird species studied. No differences were detected among various straw manipulation practices for most species. Several small shorebird species used fields where straw was incorporated into the soil more than fields with less straw manipulation. Species differed in their use of different water depths; however, depth was a poor predictor of bird use. Depths of 15-20 cm resulted in frequent use by the greatest number of species. Flooding of rice fields increased suitable habitat for most waterbird species studied.

Ettema, C. H., D. C. Coleman, and S. L. Rathbun. 1998. Spatiotemporal distributions of bacterivorous nematodes and soil resources in a restored riparian wetland. Ecology 79:2721-2734.

Spatial and temporal variability in bacterivorous nematode populations and their relationship to soil characteristics (microbial respiration, inorganic nitrogen, moisture, and soil organic matter) were studied in a 0.7-ha restored riparian wetland in the Coastal Plain of Georgia. Results indicated that spatial distribution within the wetland varied substantially among individual nematode taxa, with substantial temporal variation within taxa. Distribution of nematode taxa did not correlate well with soil resource patterns.

Euliss, N. H., and D. M. Mushet. 1999. Influence of agriculture on aquatic invertebrate communities of temporary wetlands in the Prairie Pothole Region of North Dakota, U.S.A. Wetlands 19:578-583.

Paper compared aquatic invertebrate communities of temporary prairie pothole wetlands that were farmed with those that occur in grassland settings. More taxa and greater numbers of cladoceran resting eggs, planorbid and physid snail shells, and ostracod shells were found in grassland wetlands than farmed wetlands. Authors concluded that the aquatic communities of temporary prairie pothole wetlands were negatively impacted by intensive agriculture.

Fairbairn, S. E. 1999. Local and landscape-level influences on wetland bird communities of the Prairie Pothole Region of Iowa. Thesis. Iowa State University, Ames.

An analysis of the effects of site and landscape characteristics on the number of species and density of wetland birds in Prairie Pothole Region of Iowa, 1997-1998. At the landscape scale, annual differences were detected in relations of habitat features to bird diversity. Significant predictors of diversity were percentage of wetland area in complex with emergent vegetation, total wetland area within 3 km of complex, total area of semipermanent wetlands within 3 km of complex. At local scale, a habitat diversity index measuring the evenness of distribution of various habitats within a wetland was a significant predictor of bird diversity in both years. Models were presented that related habitat characteristics to densities of 18 species of wetland-associated birds.

Fowler, D. K., D. M. Hill, and L. J. Fowler. 1985. Colonization of coal surface mine sediment ponds in southern Appalachia by aquatic organisms and breeding amphibians. Pages 261-285 *in* R. E. Brooks, D. E. Samuel, and J. B. Hill, eds. Wetlands and water management on mined lands, proceedings of a workshop. Pennsylvania State University, School of Forestry. University Park.

Basic water quality parameters were measured and aquatic plants, invertebrates, and breeding amphibians were sampled in nine newly constructed coal surface mine sediment ponds in western Tennessee. Ten species of aquatic plants colonized the ponds; 61 invertebrate taxa were observed the first year of sampling and 44 taxa the second year. Twelve species of breeding amphibians were documented in the study with individual ponds having 1-9 amphibian species. Results provided evidence of rapid colonization of surface mine wetlands by aquatic flora and fauna.

Gabrey, S. W., A. D. Afton, and B. C. Wilson. 1999. Effects of winter burning and structural marsh management on vegetation and winter bird abundance in the Gulf Coast Chenier Plain, U.S.A. Wetlands 19:594-606.

Effects of marsh burning to enhance waterbird habitats and manage vegetation in Gulf Coast marshes on nontarget wintering birds were studied through a series of experimental burns in impounded and unimpounded marshes in south Louisiana. Burning of impoundments influenced vegetation structure, which influenced bird abundance and species composition. Blackbirds preferred recently burned plots, while sparrows and wrens avoided burned plots until vegetation had recovered for one year following burning. The authors recommended patchy burns be used at both local and landscape levels to meet goose management objectives while providing suitable habitats for nontarget birds.

Galatowitsch, S. M., A. G. van der Valk, and R. A. Budelsky. 1998. Decision-making for prairie wetland restoration. Great Plains Research 8:137-155.

A conceptual framework was outlined for wetland restoration decision-making in the prairie region based on optimizing wetland restoration success at both landscape and site scales. The framework recognized that restoration efforts should focus on restoring prairie wetland complexes rather than on isolated wetland basins. Authors recommended that concept should be used in evaluating success of prairie wetland restoration efforts.

Galatowitsch, S. M., and A. G. van der Valk. 1996. Characteristics of recently restored wetlands in the Prairie Pothole Region. Wetlands 16:75-83.

Basin morphology, hydrology, and vegetation zone development was characterized in 62 recently restored prairie wetlands in Iowa, Minnesota, and South Dakota. In general, restored wetlands had basin morphologies that were comparable to similarly sized natural wetlands. Most restored basins met or exceeded predicted hydrology, although 20 percent of restored wetlands were considered hydrologic failures. Most restored wetlands had developed emergent and submersed aquatic vegetation zones, but only a few developed wet prairie and sedge meadow zones. Restored wetlands were unable to replace wetland complexes due to the limited number of basins affected. Greater emphasis should be placed on restoring complexes of wetlands representing a variety of wetland classes and sizes.

Galatowitsch, S. M., and A. G. van der Valk. 1996. Vegetation and environmental conditions in recently restored wetlands in the Prairie Pothole Region of the U.S.A. Vegetatio 126:89-99.

Vegetation, hydrology, and soil and water quality characteristics of 10 natural prairie wetlands in Iowa were compared with 10 restored wetlands three years after reflooding. Restored basins supported more species of submerged aquatic vegetation than did natural wetlands. However, stands of emergent and wet meadow species were sparse in restored wetlands compared to natural wetlands. Fluctuations in water levels were similar for both restored and natural wetlands. Results indicated that propagules of submersed aquatic plants were able to colonize restored basins rapidly, while other guilds of wetland plants may take longer to become established.

Galatowitsch, S. M., and A. G. van der Valk. 1993. Natural revegetation during restoration of wetlands in the southern Prairie Pothole Region of North America. Pages 129-142 *in* Wheeler, B. D., S. C. Shaw, W. J. Foit, and R. A. Robertson, editors. Restoration of Temperate Wetlands. Wiley and Sons, New York.

Sixty-two recently restored prairie pothole wetlands were examined to determine patterns in the composition and structure of the vegetation among restored wetlands and to compare the vegetation of restored wetlands to natural wetlands. Results showed that basins reflooded for three years had approximately half of the wetland plant species of comparable natural wetlands. Ditch-drained wetlands contained refugia of wetland species and were rapidly recolonized by emergent perennial wetland plants that propagated vegetatively. Tile-drained basins were more thoroughly drained and lacked wetland plant refugia; these basins were typically colonized by mudflat annuals and submersed aquatics upon reflooding. Recolonization of these restored tile-drained basins was likely due to dispersal rather than recruitment from the seed bank. Regardless of drainage history, restored prairie wetlands lacked the perimeter zones of wet prairie and sedge meadow vegetation.

Gibbs, J. P. 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. Wetlands 13:25-31.

Loss of small, legally unprotected wetlands in a 600-km^2 area in Maine was modeled to assess potential impacts to wetland-associated wildlife populations. Loss of small wetlands resulted in a 19% decline in total wetland area, a 62% decline in total wetland number, and a 67% increase in average inter-wetland distance. Landscape available for terrestrial-dwelling, aquatic-breeding amphibians, based on a 1,000-m maximum migration distance, decreased from 90% with small wetlands to 54% without small wetlands. The model indicated that local populations of turtles, small birds, and small mammals, stable under conditions with small wetlands, faced a significant risk of extinction after loss of small wetlands. Simulation provided evidence of the importance of small wetlands for certain taxa of wetland animals.

Gonzales Martinez, S. C., and L. F. Valladares Diez. 1996. The community of Odonata and aquatic Heteroptera (Gerromorpha and Nepomorpha) in a rehabilitated wetland: the Laguna de la Nava (Palencia, Spain). Archiv fur Hydrobiologie 136:89-104.

The Odonata and aquatic Heteroptera communities in a restored wetland in northern Spain was characterized. Aquatic Heteroptera species richness in the restored wetland was higher than that recorded in other saline permanent waters. Species of both ubiquitists and pioneers were associated with immature wetlands. The presence of some long-lived dragonflies and heteropterans with little mobility indicate a certain maturity of the system. In general, the communities of dragonflies and aquatic heteropterans were representative of recent wetlands, with evidence of changes toward a more stable and mature environment.

Guggisberg, A. C. 1996. Nongame bird use of restored wetlands in Manitowoc County, U.S. Fish and Wildlife Service and Partners for Wildlife Program Final Report. Wisconsin Department of Natural Resources, Madison. 60 pp.

Nongame bird use and vegetation growth were summarized for 143 recently restored herbaceous wetlands in southeastern Wisconsin. Cattails quickly colonized smaller restored wetlands, while larger basins developed greater vegetation diversity. Shorebird use of restored wetlands was very limited. In general, large restored wetlands had greater nongame bird species richness than did small wetlands.

Hashisaki, S. 1996. Functional wetland restoration: An ecosystem approach. Northwest Science 70:348-351.

Review of the history of wetland mitigation and evolution of functional restoration. The author also described the tools that have been developed specifically to support the move toward functional wetland restoration, including the hydrogeomorphic wetland classification system and the associated functional assessment methodology.

Hemesath, L. M., and J. J. Dinsmore. 1993. Factors affecting bird colonization of restored wetlands. Prairie Naturalist 251-11.

Breeding marsh birds were surveyed in restored wetland basins in northern Iowa. Bird species richness increased with wetland size but was unrelated to age of restored wetlands. Birds rapidly colonized restored wetlands, usually in the first year after restoration. Duration of drainage affected development of marsh vegetation but had no effect on bird species richness. Authors recommended that restoration efforts concentrate on large wetland basins that were recently drained or frequently flood.

Hey, D., and N. S. Filippi. 1995. Flood reduction through wetland restoration: The Upper Mississippi River Basin as a case history. Restoration Ecology 3: 4-17.

In light of the failure of large-scale flood control measures to reduce impacts of flooding in the Mississippi River Basin, authors presented a flood management strategy that used wetlands to intercept and hold precipitation and reduce flood flows. The strategy maintains that the basin's flooding problems can be solved in an ecologically sound manner by restoring 13 million acres of wetlands on existing drained hydric soils in the basin.

Hruby, T., and M. Scuderi. 1995. Integrated planning for wetland restoration and mitigation. Restoration and Management Notes 13:45-46.

Authors described an integrated planning process to replace lost wetland function attributed to potential development in the Mill Creek Basin in King County, Washington. A Special Area Management Plan under development would ensure performance of wetland function and allow continued economic growth and expansion in the basin.

Johnson, P. 1996. The role of U.S. agricultural programs in protecting waterfowl. Pages 9-11 *in* J. T. Ratti, ed. Proceedings of the 7th International Waterfowl Symposium. Ducks Unlimited, Inc., Institute for Wetlands and Waterfowl Research, Memphis, Tennessee.

The author described the history of the Natural Resources Conservation Service (NRCS) and provided examples of how agencies could work together with private landowners to conduct conservation work on private lands to benefit waterfowl and other wildlife. USDA conservation programs such as the Conservation Reserve Program, Wetlands Reserve Program, and Small Watersheds Program, and the technical assistance provided to landowners by NRCS conservationists and other government and private technicians were identified as critical elements of implementing conservation on the land.

King, S. L., and B. D. Keeland. 1999. Evaluation of reforestation in the Lower Mississippi River Alluvial Valley. Restoration Ecology 7:384-359.

Efforts to restore bottomland hardwood forest in the Lower Mississippi River Alluvial Valley were reviewed based on a survey of individuals involved in wetland restoration activities. Over the past 10 years, 77,698 ha were reforested, with an additional 89,009 ha planned for reforestation in the next five years. Oaks were the most common species planted, and bare root seedlings were the most common plant materials used. Reforestation efforts were based upon the principles of landscape ecology, but local problems such as drought, herbivory, and flooding limited success. While broad-scale hydrologic restoration was desired, significant past hydrologic alterations and social considerations frequently limited extent of hydrology restoration feasible. Local hydrologic alteration to provide habitat features was important. More extensive analysis was needed to evaluate functional success of these efforts. Authors concluded that additional incentives like the Wetlands Reserve Program were needed to expand reforestation activities on private lands.

Lacki, M. J., J. W. Hummer, and H. J. Webster. 1991. Avian diversity patterns at a constructed wetland: Use of ecological theory in the evaluation of a mine land reclamation technique. International Journal of Surface Mining and Reclamation 5:101-105.

Birds were surveyed at a constructed cattail wetland in Ohio. Comparison surveys also were completed at three nearby natural wetlands. Results demonstrated the constructed wetland exhibited the fewest number of bird feeding guilds per survey and an intermediate level of bird abundance relative to all sites examined. The constructed wetland supported a bird community with a significantly lower species evenness index, suggesting a more harsh and variable habitat relative to the natural wetlands. Data suggested that the availability of adequate nesting habitat strongly influenced the patterns for avian diversity observed.

Lacki, M. J., J. W. Hummer, and H. J. Webster. 1992. Mine-drainage treatment wetland as habitat for herptofaunal wildlife. Environmental Management 16:513-520.

Reptile and amphibian use of a wetland constructed for treatment of mine water drainage in east-central Ohio was compared to herpetofauna in natural wetlands within the surrounding watershed. The constructed wetland supported the greatest abundance and species richness of herpetofauna among the sites surveyed, primarily due to the large number of green frogs and pickerel frogs and numerous species of snakes found using this site. Results reveal that wetlands created for water quality improvements can provide habitat for reptiles and amphibians.

Langston, M. A., and D. M. Kent. 1997. Fish recruitment to a constructed wetland. Journal of Freshwater Ecology 12:123-129.

The fish community of a 31.6-ha constructed wetland in east-central Florida was sampled over a two-year period. A rich and abundant fish community rapidly developed. This community was similar to that of natural wetlands in the area. Fish may have been introduced to the study wetland by irrigation, transport on terrestrial or flying animals, or a combination of sources.

Lant, C. L., S. E. Kraft, and K. R. Gillman. 1995. The 1990 Farm Bill and water quality in corn belt watersheds: Conserving remaining wetlands and restoring farmed wetlands. Journal of Soil and Water Conservation 50:201-205.

A mail and interview survey was conducted in 10 corn belt counties to (1) assess interest in enrolling farmed wetlands in CRP and WRP and (2) elicit farmer and landowner attitudes toward Swampbuster. Enrollment of farmed wetlands into CRP increased from 2-8% of eligible acreage at an annual rental rate of $90/acre/yr to 52-64% at $140/acre/yr to 81-83% at $400/acre/yr. Potential for WRP enrollments increased from 4% of eligible acreage at $500/acre for a 30-yr easement to 26% at $2,500/acre. Swampbuster was highly unpopular with 68% of respondents who claimed that it was a violation of their property rights.

LaGrange, T. G., and J. J. Dinsmore. 1989. Plant and animal responses to restored wetlands. Prairie Naturalist 21:39-48.

Plants and animals were surveyed in four formerly drained wetland basins several years after the basins were reflooded. A total of 45 plant species, 18 wetland invertebrate species, and 11 bird species were detected. Duration of drainage was unknown and ages of restorations not specified. Authors concluded that removal or blockage of tile lines was an easy and cost-effective way to restore wetlands.

Lehtinen, R. M., S. M. Galatowitsch, and J. R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19:1-12.

Paper assessed the effects of habitat loss and fragmentation on amphibian assemblages in 21 glacial marshes in Minnesota. Wetlands studied occurred in both tall-grass prairie and northern hardwood forest ecoregions. Amphibian species richness was lower with greater wetland isolation and road density at all spatial scales in both ecoregions. Data suggested that decreases in landscape connectivity through fragmentation and habitat loss can affect amphibian assemblages, and reversing those landscape changes should be an important part of a regional conservation strategy.

Lewis, R. R. III, J. A. Kusler, and K. L. Erwin. 1994. Lessons learned from five decades of wetland restoration and creation in North America. Pages 233-240 *in* Proceedings of the Conference on Challenges and Opportunities in the Marine Environment. Marine Technology Society, Washington, D.C.

Although thousands of wetlands have been restored over the last 50 years, very little effort has been placed on short-term or long-term monitoring of these sites. Authors recommended that restored wetlands be monitored for rates of revegetation, use by animal species, development of soil profiles, patterns of succession, and evidence of persistence.

Lowrance, R., G. Vellidis, and R. K. Hubbard. 1995. Denitrification in a restored riparian forest wetland. Journal of Environmental Quality 24:808-815.

Subsurface water denitrification rates in a newly restored, southeastern coastal plain riparian forested wetland were studied. Restoration consisted of reestablishing woody vegetation in a former riparian forested wetland that had been logged and subsequently grazed for several years; no hydrology modifications were necessary. Denitrification rates were measured monthly within the restored wetland before and after application of liquid manure on adjacent uplands. Denitrification rates were found to be comparable to mature riparian forests.

Malakoff, D. 1998. Restored wetlands flunk real-world test. Science 280:371-372.

Author argued that it is difficult to precisely predict vegetation and wildlife response to created tidal wetlands. The failure of a created wetland near San Diego, California, to attract the light-footed clapper rail, a species for which the wetland was constructed to benefit, illustrates this point. Author recommended that additional time and allowance for natural processes to shape the wetland should be considered in implementing mitigation projects.

Mayer, P. M., and S. M. Galatowitsch. 1999. Diatom communities as ecological indicators of recovery in restored prairie wetlands. Wetlands 19:765-774.

Diatoms were used to assess the recovery of northern prairie wetlands in eastern South Dakota restored after drainage. Diatom communities in eight natural wetlands were compared with eight restored wetlands. Diatom species richness and composition were similar at restored and natural wetlands. Diversity and equitability at restored and reference sites were similar within a sampling period, but both decreased over the growing season in natural wetlands. Diatoms may have limited use as ecological indicators in prairie wetland because of the unique interaction between diatom life history and the cyclic hydrology of prairie wetlands and because diatom community structure was highly variable among reference wetlands.

McKinstry, M. C., and S. H. Anderson. 1994. Evaluation of wetland creation and waterfowl use in conjunction with abandoned mine lands in northeast Wyoming. Wetlands 14:284-292.

Ninety-two wetlands created on formerly mined lands in northeast Wyoming were studied to determine the capability of a Wetland Habitat Value (WHV) model to predict waterfowl use. While the size of most wetlands was less than expected by pre-construction plans, the WHV model was able to accurately predict use of wetlands by migrating Canada geese, dabbling ducks, and diving ducks. Authors concluded that WHV models may be useful for estimating lost waterfowl habitat functions, but caution should be exercised not to overestimate post-construction wetland size and habitat availability.

McLeod, M., R. Reed, and L. D. Wike. 2000. Elevation, competition control, and species affect bottomland forest restoration. Wetlands 20:162-168.

Analysis of the effects of planting elevation and early successional vegetation control on growth and survival of six species of bottomland hardwood tree seedlings (bald cypress, water tupelo, willow oak, Nuttall oak, overcup oak, and cherrybark oak). Survival among tree species differed but was not affected by any of the vegetation competition control measures (mowing or herbicide application). However, growth and survival did vary with planting elevation: bald cypress and water tupelo survival and height were greatest at lower elevations; height and survival of cherrybark oak and willow oak were greatest at higher elevations; and overcup oak and Nuttall oak were not affected by elevation. Thus, whereas controlling herbaceous vegetation did not affect survival or growth, relative planting elevation was important because of site flooding and variation among species in flood tolerances.

Melvin, S. L., and J. W. Webb Jr. 1999. Differences in the avian communities of natural and created *Spartina alterniflora* salt marshes. Wetlands 18:59-69.

Bird diversity within and among bird groups (shorebirds, sparrows, herons and egrets, and waterfowl) was lower in created salt marsh than in natural marshes studied on the Texas Gulf Coast. Lower bird diversity was attributed to lower vegetation diversity and structure in created marsh than in natural marshes.

Metzker, K. D., and W. J. Mitsch. 1997. Modelling self-design of the aquatic community in a newly created freshwater wetland. Ecological Modelling 100:61-86.

A simulation model was constructed to predict the development of a fish community in a recently constructed freshwater marsh in Ohio. Modelled interactions included intra- and interspecific competition, predation, feeding, reproduction, fish effects on system abiotic components, and mortality. The fish community underwent several major changes in structure during the first four years of the simulation before establishing a stable state with a high-biomass population dominated by carp. The results indicated that the fish community in wetlands had a strong self-design trajectory, tending toward almost complete dominance by carp unless typical wetland environmental conditions were significantly altered.

Mitsch, W. J., A. van der Valk, and E. Jaworski. 1994. Wetland restoration at a former Nike missile base in the Great Lakes Basin. Restoration Ecology 2:31-42.

Restoration alternatives were evaluated at a former military base adjacent to the lower Detroit River, Michigan. Construction of wetlands resembling conditions before establishment of the military base was recommended for its low maintenance and opportunity for research on wetland design and construction in protected bays in the Great Lakes region.

Mitsch, W. J., and R. F. Wilson. 1996. Improving the success of wetland creation and restoration with know-how, time, and self-design. Ecological Applications 6:77-83.

A review of the literature available on the success of mitigation wetlands to replace lost wetland function revealed a high rate of failure due to problems with mitigation wetland construction, limited permit requirements, poor monitoring and follow-up, and lack of mitigation project implementation. To improve success of compensatory mitigation projects, three primary concepts were provided and discussed: (1) improve understanding of wetland function, (2) allow mitigation wetlands sufficient time to develop, and (3) allow natural processes to "self-design" the newly established wetland system. Recommended time scales for judging success of wetland establishment projects were 15-20 years for freshwater emergent wetlands and 50 years for some tidal salt marshes. Predictive modeling based on these time scales may be useful in projecting success of wetland mitigation projects.

Montgomery, J. A. 2000. The use of natural resource information in wetland ecosystem creation and restoration. Ecological Restoration 18:45-50.

Author discussed the need for wetland restoration and creation practitioners to communicate effectively with their colleagues in other disciplines. He emphasized the need for communication between earth scientists and biological scientists in wetland restoration and creation. Forthcoming compilation of papers addressing this need (*Use of Natural Resource Information in Wetland Ecosystem Creation and Restoration*) was discussed.

Munro, J. W. 1991. Wetland restoration in the mitigation context. Restoration and Management Notes 9: 80-86.

Author provided recommendations for improvements to wetland mitigation requirements, regulations, and guidelines.

Naugle, D. E., K. F. Higgins, M. E. Estey, R. R. Johnson, and S. M. Nusser. 2000. Local and landscape-level factors influencing black tern habitat suitability. Journal of Wildlife Management 64:253-260.

Local and landscape factors affecting habitat suitability for black terns were evaluated in 834 randomly selected wetlands in eastern South Dakota. Significant variables associated with black tern use included wetland area, total semipermanent 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. Black terns typically occurred in wetlands within landscapes when less than 50 percent of upland grasslands were tilled. This illustrates the importance of including entire landscapes in habitat assessments. Future wetland conservation efforts should maintain the integrity of entire prairie landscapes in addition to individual wetland attributes.

Naugle, D. E., K. F. Higgins, S. M. Nusser, and W. C. Johnson. 1999. Scale-dependent habitat use in three species of prairie wetland birds. Landscape Ecology 14:267-276.

Study examined the effect of scale on habitat use of prairie wetlands by pied-billed grebes, yellow-headed blackbirds, and black terns in South Dakota. Whereas occurrences of pied-billed grebes and yellow-headed blackbirds were influenced by local wetland conditions and characteristics independent of landscape patterns, habitat use by black terns was related to features in the surrounding landscape. Yellow-headed blackbirds used both large and small wetlands, while pied-billed grebes exhibited area sensitivity by using only larger basins. Results indicated the need to consider entire landscapes, rather than individual patches, in determining habitat suitability for wide-ranging species such as the black tern.

Newman, J. M., and J. C. Clausen. 1997. Seasonal effectiveness of a constructed wetland for processing milkhouse wastewater. Wetlands 17:375-382.

Study assessed the effectiveness of the wetland in reducing nutrients, five-day biochemical oxygen demand, bacteria, total suspended solids, and fecal coliform bacteria in effluent from a milkhouse in central Connecticut. While the wetland was effective in partially meeting these objectives, preliminary indications were that the treatment of wastewater did not meet design standards, especially in winter when biological activity was reduced.

Northern Prairie Science Center and Midcontinent Ecological Science Center. 1996. Wetland restoration bibliography. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. http:/www.npwrc.usgs.gov/resource/literatr/wetresto/wetresto.htm (Version 06JUL2000).

An annotated bibliographic database intended to provide scientists, managers, educational institutions (or students), and policymakers with ready access to current information on wetland restoration. A bibliography originally developed and provided by the USGS/BRD Midcontinent Ecological Science Center served as the foundation for this bibliography. USGS/BRD Northern Prairie Science Center developed a program for viewing and searching the bibliography on the Web and assumed responsibility for maintaining and updating the database.

Nuttle, T., and L. W. Burger Jr. 1996. Response of breeding bird communities to restoration of hardwood bottomlands. Proceedings of the Annual Conference of the Southeastern Fish and Wildlife Agencies 50: 228-236.

Much of the original hardwood bottomland in the Mississippi Alluvial Valley has been converted to crop lands. Land management agencies began restoring hardwood bottomland because of its importance to wildlife. Bird communities were studied in bottomland hardwood restoration plantings of age 0-4, 7-15, and 21-27 years and natural sawtimber stands (> 50 years in age) in the southern Delta region of Mississippi. Mean number of species (species richness) increased with stand age. Mean total abundance did not differ among age classes. Relative to bird communities of natural sawtimber forest at Yazoo National Wildlife Refuge and Delta National Forest, respectively, Morisita's index of similarity was 85.4% and 74.3% for 21- to 27-year-old plantations, 41.9% and 35.0% for 7- to 15-year-old plantations, and 4.6% and 2.6% for 0- to 4-year-old plantations. Plantations in the 21-27 and 7-15-year-old age classes supported a substantial portion of the potential forest bird community, but still lacked area-sensitive and certain late-successional species. Plantations in the youngest age class were dominated by two abundant species, red-winged blackbird and dickcissel. Nevertheless, young plantations provide temporary habitat for regionally declining grassland bird species. Authors suggested that management prescriptions that mimic natural succession such as mixed plantings or thinning might enhance the restoration effort and promote earlier colonization by birds requiring mature forests.

Oertel, B. 1997. Wildlife habitat and wetland restoration on former cropland. Land and Water 41:45-47.

A description of how a 55-acre wetland was restored in northern New York and the landowner's enthusiasm for the wildlife response. Although no quantitative data were presented, anecdotal evidence was provided for substantial increases in wetland-associated wildlife use of the area.

Padgett, D. J., and G. E. Crow. 1994. Foreign plant stock: Concerns for wetland mitigation. Restoration and Management Notes 12:168-171.

Paper discussed concerns and issues related to use of non-indigenous and nonlocal plant materials in wetland establishment projects. To maximize success of establishment projects, minimize impacts to native wetland species and genetic stocks through competition and genetic swamping, and address the ethical considerations of introducing new species to the flora of a region, the authors strongly emphasized the need to acquire plant materials from local genetic stocks. Observation of nearby natural wetlands should guide planning for species composition of constructed wetlands.

Phinn, S. R., D. A. Stow, and J. B. Zedler. 1996. Monitoring wetland habitat restoration in southern California using airborne multispectral video data. Restoration Ecology 4:412-422.

Use of high-spatial-resolution digital video imagery to detect patches of marsh vegetation in a restored coastal marsh in California was described. Data were used to assess restored wetland habitat conditions for the light-footed clapper rail. Preliminary field-checking results indicated that this approach was an accurate, noninvasive, and cost-effective means of providing ecological information for restoration monitoring in southern California wetlands.

Prescott, K. L., and I. K. Tsanis. 1997. Mass balance modelling and wetland restoration. Ecological Engineering 9:1-18.

Phosphorus and suspended solids loading to a Lake Ontario coastal marsh were studied through the use of mass balance models. The study was conducted to increase understanding of degraded ecosystems to enable successful restoration actions. The models predicted average concentrations well, but variations in field data were not discerned by the models. The majority of phosphorus and suspended solids loading were shown to be derived through resuspension of sediments, while other inputs included rural runoff and combined sewage outflows.

Reaves, R. P., and M. R. Croteau-Hartman. 1994. Biological aspects of restored and created wetlands. Proceedings of the Indiana Academy of Science 103:179-194.

Authors reviewed literature on the biological aspects of restored and created wetlands. In general, restored wetlands were more similar to natural wetlands than were created wetlands, and the biota of restored wetlands more closely resembled that of natural wetlands. Following restoration of wetland hydrology, native aquatic plants returned to restored wetlands within one year. As restored wetlands develop, they were colonized by a variety of aquatic invertebrates and other animals. Use of restored wetlands was related to the size of the wetland and proximity to other wetland habitats. In most instances, restored wetlands exhibited biological characteristics of nearby, similar-sized natural wetlands within 10 years after restoration. Plant communities and other wetland attributes of created wetlands differed from natural or restored wetlands because of altered hydrology or different water sources (e.g., effluent from wastewater treatment facility).

Richardson, M. S., and R. C. Gatti. 1999. Prioritizing wetland restoration activity within a Wisconsin watershed using GIS modeling. Journal of Soil and Water Conservation 54:537-542.

A geographic information system was developed for a watershed in southern Wisconsin to locate drained wetlands and their owners and rank drained wetlands for restoration based on their potential to improve water quality. GIS data layers for soils, cropping management, topography, hydrology, and land cover were used to estimate potential eroded sediments entering streams. GIS was used to delineate sub-watersheds of each drained wetland basin, estimate the delivered sediments that could be trapped if the drained basin were restored, and rank the drained wetlands for restoration within strata of topographic contours.

Rossiter, J. A., and R. D. Crawford. 1981. Evaluation of constructed ponds as a means of replacing natural wetland habitat affected by highway projects in North Dakota. University of North Dakota, Department of Biology Report FHWA-ND-RD-(2)-79A. University of North Dakota, Grand Forks. 171 pp.

Waterbirds, aquatic plants, macroinvertebrates, water quality, and soils were monitored in 18 artificial wetlands created by landfill extraction for Interstate 29 expansion in 1976 and 1977. Density of breeding pairs of waterfowl in artificial wetlands was greater in 1979 (wet year) than in 1980 (dry year), but was lower than natural basins of similar size in both years. Differences were attributed to dispersion and density of vegetation, macroinvertebrate abundance, water quality, and wetland basin topography. Authors recommended that borrow areas be designed with maximum shoreline, gradual slopes, and variable bottom elevations.

Rossiter, J. A., and R. D. Crawford. 1986. Evaluation of constructed ponds as a means of replacing natural wetland habitat affected by highway projects in North Dakota - Phase II. University of North Dakota, Department of Biology Report FHWA-ND-RD(2)-81A. University of North Dakota, Grand Forks. 169 pp.

Waterbird use and the abundance and diversity of aquatic plants and invertebrates were surveyed in 20 constructed wetlands created by landfill extraction for Interstate 29 expansion between 1976 and 1980. Characteristics of constructed wetlands were compared with six nearby natural basins of similar size. Compared to natural basins, constructed wetlands had greater waterfowl density and number of plant taxa and reduced diversity and abundance of invertebrates. Wetland size was determined to be the most important factor affecting waterfowl pair density and duckling production. Authors recommended that borrow areas be designed with maximum shoreline, gradually sloping sides, topsoil replacement on the substrate, and variable bottom elevations.

Ruwaldt, J. J. Jr., L. D. Flake, and J. M. Gates. 1979. Waterfowl pair use of natural and man-made wetlands in South Dakota. Journal of Wildlife Management 43:375-383.

Spring waterfowl pair use of natural ponds and lakes, streams, stock ponds, and dugouts in South Dakota was examined in 1973-74. Semipermanent wetlands and stock ponds contained proportionally more pairs of most waterfowl species than other wetland categories. Lack of water due to drought conditions apparently decreased waterfowl use of other wetland types.

Saracco, J. F., and J. A. Collazo. 1999. Predation on artificial nests along three edge types in a North Carolina bottomland hardwood forest. Wilson Bulletin 111:541-549.

Study conducted in North Carolina bottomland hardwood forest compared predation rates on artificial bird nests in three edge types: forest-farm, forest-river, and transition zone between dominant forest types. Nest predation was higher in forest-farm edges than in other edge types.

Schneller-McDonald, K., L. S. Ischinger, and G. T. Auble. 1990. Wetland creation and restoration: Description and summary of the literature. U.S. Fish and Wildlife Service Biological Report 90. 198 pp.

An annotated bibliography containing 1,100 records of literature on the subject of wetland creation and restoration. This hard copy document was the companion to the Wetland Creation/Restoration database. Since this version was produced, the database has been updated by USGS (see above Northern Prairie Science Center and Midcontinent Ecological Science Center 1996).

Sewell, R. W., and K. F. Higgins. 1991. Floral and faunal colonization of restored wetlands in west-central Minnesota and northeastern South Dakota. Pages 103-133 *in* F. J. Webb, Jr., ed. Proceedings of the Fourteenth Annual Conference on Wetlands Restoration and Creation. Hillsborough Community College, Plant City, Florida.

One hundred fifty-six restored seasonal and semipermanent basins of 12 different ages were surveyed in three counties of northeast South Dakota and six counties in west-central Minnesota to determine trends in species abundance and richness of waterfowl, aquatic macroinvertebrates, fish, and hydrophytes. A large diversity of flora and fauna colonized wetlands as early as one year after restoration. Twelve species of waterfowl were observed in all age classes of the restored basins. Thirty-one taxa of macroinvertebrates occurred in restored basins, 12 of which were in age class 1 basins. Four fish species inhabited restored basins of all ages. An average of over 16 taxa of aquatic hydrophytes had coverage values of greater than or equal to 5% of the total wetland area in restored basins. This study demonstrated that wetland managers can expect extensive floral and faunal colonization of prairie wetlands within one year of restoration.

Shreffler, D. K., C. A. Simenstad, and R. M. Thom. 1990. Temporary residence by juvenile salmon in a restored estuarine wetland. Canadian Journal of Fisheries and Aquatic Science 47(11):2079-2084.

Use of a recently restored estuarine wetland in Washington by out-migrating juvenile Pacific salmon was studied. Mark/recapture data indicate that 0.06% of juvenile chum salmon and 0.59% of juvenile fall chinook salmon entered the wetland. Estimated residence times of individual salmon ranged from 1 to 43 days. Data revealed that the restored wetland provided habitat for temporary residence of migrating juvenile chum and fall chinook salmon. Comparisons to natural wetland systems were not feasible.

Shreffler, D. K., C. A. Simenstad, and R. M. Thom. 1992. Foraging by juvenile salmon in a restored wetland. Estuaries 15:204-213.

Paper evaluated the functional value of a restored estuarine wetland in Washington as a foraging area for juvenile chum salmon and fall chinook salmon during their spring seaward migrations. Fish foraged selectively, primarily on chironomid insects. A detritus-based food chain suggested that the restored wetland provided productive foraging habitat for migrating juvenile chum and fall chinook salmon during their early residency in the estuary.

Smith, J. W., and D. D. Humburg. 1990. Reclaiming Missouri's Wetlands. Missouri Conservationist 51:7-9.

Authors described Missouri's plan to protect, restore, and manage wetland habitats. Efforts on public and private lands were outlined.

Streever, W. J., D. L. Evans, and T. L. Crisman. 1995. Chironomidae (Diptera) and vegetation in a created wetland and implications for sampling. Wetlands 15:285-289.

Distribution of Chironomids and emergent vegetation was examined in a created freshwater herbaceous wetland in central Florida. Three of the five common genera were more abundant in areas with greater than 50% herbaceous cover than areas with reduced vegetation. Samples from areas with greater than 80% vegetation cover showed greater abundance of all five common genera. Results indicated a strong association of benthic invertebrate communities with wetland vegetation.

Tsihrintzis, V. A., G. M. Vasarhelyi, and J. Lipa. 1995. Multiobjective approaches in freshwater wetland restoration and design. Water International 20:98-105.

Authors described a riparian corridor and freshwater wetland designed to meet California environmental requirements associated with land development actions. The project was designed to provide three functions: (1) flood control for existing and proposed developments, (2) urban stormwater runoff treatment, and (3) freshwater habitat for fish and wildlife. The project emphasized hydraulic analysis and design, biotic design, environmental function and effectiveness, management, operation, monitoring and maintenance, and project permit requirements.

Twedt, D. J., and J. Portwood. 1997. Bottomland hardwood reforestation for Neotropical migratory birds: Are we missing the forest for the trees? Wildlife Society Bulletin 25:647-652.

Breeding birds were studied on recently reforested bottomland hardwood sites in the Lower Mississippi River Alluvial Valley. Thirty-six avian species held breeding territories in cottonwood plantings aged 5-7 years (*n* = 12). Conversely, on oak plantings aged 4-6 years (*n* = 3), only nine bird species held breeding territories and most were grassland species. Thus, fast-growing species act as catalysts for the colonization of these emerging forests by Neotropical migratory birds. When reforesting agricultural sites, planting fast-growing tree species, alone or in concert with heavy-seeded species, represents a superior alternative to monotypic plantings of oaks. Fast-growing trees can rapidly provide habitat for forest-breeding, Neotropical migratory birds and enhance forest diversity. Reforestation using fast-growing species on private lands provides quick financial return through harvest of pulpwood.

Twedt, D. J., and W. B. Uihlein. In press. Reforestation priorities for migratory land birds in the Mississippi Alluvial Valley. *In* Ecology and management of bottomland hardwood systems: The state of our understanding. L. H. Fredricksen, editor. Memphis, Tennessee.

Authors proposed a method for geographically prioritizing reforestation efforts in the Lower Mississippi Alluvial Valley (MAV) based on habitat needs of forest breeding landbirds. Priorities were based on three parameters: (1) distance to extant forest, (2) distance to contiguous forest patches between 1,012 and 40,000 ha in size, and (3) distance to forest cores with contiguous area less than 5,200 ha. Information on the proportion of forest cover and average size of forest patches within landscapes of 50,000, 150,000, and 200,000 ha also was considered and combined with the three distance parameters to yield a single raster using a weighting system that gave emphasis to existing forest cores, larger forest patches, and moderately forested landscapes. Spatially explicit reforestation priorities were used to simulate reforestation of 368,000 ha of the highest priority lands in the MAV. Bird Conservation Regions developed within the Partners in Flight MAV Bird Conservation Plan encompassed approximately 70% of the area with highest priority for reforestation. Lands enrolled in the Wetlands Reserve Program also contained a high proportion of lands with high reforestation priority.

Tydeman, C. 1981. The general value of man-made wetlands for wildlife in Europe. Pages 5-19 *in* Wildlife on man-made wetlands. Buckinghamshire, England.

This report reviewed artificial wetland types and their importance for conservation and wildlife in Europe. Types of artificial wetlands included ponds and scrapes, extractive industries (i.e., coal and clay pits, etc.), gravel extraction pits, incidental wetlands, lagoons, canals, and reservoirs. Garden ponds were especially important habitat for amphibians as breeding sites. Wetlands brought about by extractive industries were beneficial to waterfowl, plants, and insects. Canals were beneficial to aquatic plants, insects, and amphibians. The author concluded that artificial wetlands were as important and beneficial to conservation and wildlife as "natural" wetlands.

Valladares, L. F., J. Garrido, and B. Herrero. 1994. The annual cycle of the community of aquatic Coleoptera (Adephaga and Polyphaga) in a rehabilitated wetland pond: The Laguna de La Nava (Palencia, Spain). Annales de limnologie 30:209-220.

The aquatic Coleoptera community was characterized in a restored wetland in northern Spain. The aquatic beetle community in the restored basin corresponded to that of a medium- or large-sized wetland with abundant plant life, but recent in origin. A diverse community of Coleoptera developed in the rehabilitated wetland, but most species belonged to early successional groups or were ubiquitists. Further study may reveal further changes in the beetle community through time.

Vanrees-Siewert, K. L., and J. J. Dinsmore. 1996. Influence of wetland age on bird use of restored wetlands in Iowa. Wetlands 16:577-582.

Restored prairie wetlands of varying ages were studied in northern Iowa to determine relationships between bird use and wetland age. Mean number of breeding bird species was greater in four-year-old wetlands than one-year old-wetlands. Mean number of all bird species, waterfowl species, and breeding waterfowl did not change with wetland age. Total and breeding bird species richness increased with percent cover of emergent vegetation. Waterfowl use (breeding and total) was influenced more by wetland size than vegetation, whereas total bird species richness and breeding bird species richness were influenced more by vegetation characteristics. Results indicated that waterfowl habitat was provided shortly after wetlands were restored, and total bird species richness increased with wetland age. Study illustrated the value of long-term restorations in supporting diverse bird communities in restored wetlands.

Wallace, P. M., D. M. Kent, and D. R. Rich. 1996. Responses of wetland tree species to hydrology and soils. Restoration Ecology 4:33-39.

The flood tolerance of nine tree species common in Florida forested wetlands was examined by subjecting seedlings grown on various soil types to 11 months of continuous shallow inundation or moist soil conditions. Pond cypress, red maple, and pond pine seedlings suffered no mortality; pop ash, sweetgum, slash pine, and loblolly bay experienced low to moderate (1% to 24%) mortality; and swamp red bay suffered significant mortality (46%). Greatest growth occurred on moist organic soil, while least seedling growth occurred on stockpiled topsoil and inundated soils. Results suggested that red maple, pop ash, pond pine, pond cypress, and bald cypress can survive to at least one year under a broad range of hydrological and soil conditions. First year growth can be maximized by maintaining moist, but not inundated, soil conditions. Transfer of organic soils to restoration sites also will benefit seedling growth and survival.

Weinhold, C. E., and A. G. van der Valk. 1989. The impact of duration of drainage on seed banks of northern prairie wetlands. Canadian Journal of Botany 67:1878-1884.

An analysis of seed banks in 30 extant and 52 drained and cultivated prairie potholes (range, 5-70 years post-drainage) in Iowa, Minnesota, and North Dakota. Number of species in the seed bank declined from a mean of 12.3 in extant potholes to 2.1 in potholes drained 70 years ago. Seed density was 3,600 seeds/m^2 in extant potholes, 7,000 seeds/m^2 up to five years after drainage, but only 160 seeds/m^2 in potholes 70 years after drainage. About 60% of species present in seed banks of extant or recently drained wetlands were not detected in wetlands that had been drained > 20 years.

Weinstein, M. P., J. H. Balletto, J. M. Teal, and D. F. Ludwig. 1997. Success criteria and adaptive management for a large-scale wetland restoration project. Wetlands Ecology and Management 4:111-127.

Restoration trajectories and success criteria were developed for a 4,050-ha tidal salt marsh to be restored on Delaware Bay, New Jersey, to offset loss of finfish from operation of a local power plant. Objectives for the restoration included returning the natural hydroperiod and drainage configuration to diked salt hay land and brackish marsh dominated by *Phragmites australis.* Restoration success was monitored by measuring macrophyte production, vegetation composition, benthic algal production, and drainage features, including stream order, drainage density, channel length, bifurcation ratios and sinuosity. These parameters were combined into a single success index. Adaptive management thresholds and corrective measures were provided to guide the restoration process through time.

Weller, J. D. 1995. Restoration of a south Florida forested wetland. Ecological Engineering 4:143-151.

A drained forested wetland in south Florida was restored by reestablishing pre-drainage hydrology and removing exotic vegetation (Brazilian pepper). These actions resulted in restoring wetland characteristics, including increased groundwater elevation and duration of surface water. Results ensured the conservation of 34 rare fern species and encouraged the return of 16 wetland bird species, eight fish species, six species of turtles, six species of snails, two frog species, and the American alligator.

Weller, M. W. 1990. Waterfowl management techniques for wetland enhancement, restoration, and creation useful in mitigation procedures. Pages 517-528 *in* J. A. Kusler and M. E. Kantula, eds. Wetland creation and restoration: The status of the science. Island Press, Washington, D.C.

Paper provided general concepts for enhancing waterfowl habitat in wetlands restored, enhanced, or created to meet mitigation requirements. Working with natural processes to maximize habitat quality was emphasized. Design considerations included geomorphology, landscape position, and habitat patch size and pattern. Wetland complexes should be emphasized; vegetation diversity and interspersion with water, and wetland configuration and edge also were emphasized. Contouring with earth-moving equipment may be used to create water depths associated with desired plant communities. Inputs of sediment and excess nutrients should be controlled on adjacent uplands and water control structures must be engineered to handle peak flows. Steps should be taken to control erosion and turbidity within managed wetland systems. Special needs of target wildlife species should be considered in managing wetlands. Seed bank and plant community may be managed through water level manipulation, herbivory, and fire. Specific examples of management of palustrine emergent wetlands, moist soil impoundments, tidal estuarine wetlands, and green-tree reservoirs were provided.

White, J. S., and S. E. Bayley. 1999. Restoration of a Canadian prairie wetland with agricultural and municipal wastewater. Environmental Management 24:25-37.

A 1,246-ha formerly drained northern prairie wetland was restored using municipal wastewater. Five years after restoration, the basin provided habitat for wildlife and increased abundance and species richness for target species. Fifty shorebird species, 44 waterfowl species, 15 raptor species, and 28 other new bird species returned to the marsh since restoration. Specific management actions were taken to further enhance wildlife habitat quality, such as water level manipulation and installation of artificial nesting structures.

Wilson, R. F., and W. L. Mitsch. 1996. Functional assessment of five wetlands constructed to mitigate wetland loss in Ohio, U.S.A. Wetlands 16:436-451.

Hydrology, soils, vegetation, wildlife use, and water quality measurements were taken in five created or restored wetlands in Ohio to evaluate their effectiveness in replacing lost wetland ecological function. Four of the five wetlands demonstrated medium to high ecosystem function success. While habitat structure was provided in replacement wetlands, wildlife use of restored/created wetlands appeared to be affected more by surrounding land use than within-wetland habitat structure.

Wilson, R. R., and D. J. Twedt. In press. Bottomland hardwood establishment and avian colonization of reforested sites in the Mississippi Alluvial Valley. *In* Ecology and management of bottomland hardwood systems: The state of our understanding. L. H. Fredricksen, editor. Memphis, Tennessee.

Bottomland hardwood establishment and avian colonization were evaluated in 120 reforested sites throughout the Lower Mississippi Alluvial Valley (MAV). Planted and naturally invading trees were generally slow to develop vertical cover, resulting in grassland bird species dominating the avian community for up to 15 years after planting. Because colonization by forest birds was dependent on tree height, the authors recommended inclusion of at least one fast-growing tree species in planting stock to encourage rapid avian colonization.

Wolf, R. B., L. C. Lee, and R. R. Sharitz. 1986. Wetland creation and restoration in the United States from 1970 to 1985: An annotated bibliography. Wetlands 6:1-88.

Annotated bibliography of publications on the topic of wetland creation and restoration in the United States.

Young, P. 1996. The "New Science" of Wetland Restoration. Environmental Science and Technology 30:292A-296A.

Authors discussed the complexity of creating wetlands that adequately replicate natural wetland functions. The importance of understanding how wetlands function and adequately establishing wetland hydrology in wetland construction work was emphasized. Several examples were presented to illustrate the complexity of wetland construction (San Diego Bay) and restoration (Florida Everglades) projects.

Zedler, J. B. 1987. Why it's so difficult to replace lost wetland functions. Pages 121-123 *in* J. Zelazny and J. S. Feierabend, eds. Proceedings of a Conference - Increasing our Wetland Resources. National Wildlife Federation - Corporate Conservation Council, Washington, D.C.

Author discussed challenges faced by wetland restoration practitioners. These included (1) differing views on wetland restoration goals, (2) complexity of original wetland systems, (3) inadequate understanding of long-term wetland development processes and how wetland components interact, (4) lack of background information on potential restoration sites, and (5) transient nature of plant and animal species. Authors concluded that long-term monitoring and research were needed to address these issues.

Zedler, J. B., G. D. Williams, and J. S. Desmond. 1997. Wetland mitigation: Can fishes distinguish between natural and constructed wetlands? Fisheries 22:26-28.

Fish communities in excavated tidal channels were compared with natural tidal channels in a southern California tidal wetland. Native fish colonized the excavated channels with densities higher than that measured in natural channels. Findings indicated that southern California coastal fishes did not discriminate between natural and constructed wetland channels.