



Effects of Cropland Conservation Practices on Fish and Wildlife Habitat

Stephen J. Brady, USDA Natural Resources Conservation Service

Central National Technology Support Center
PO Box 6567
Fort Worth, Texas 76115
Email: stephen.brady@ftw.nrcs.usda.gov

ABSTRACT A literature review of commonly applied cropland soil and water conservation practices and their impact on fish and wildlife habitat is presented. Agriculture has had the most extensive effect on wildlife habitat of any human-induced factor in the United States. Any practice that improves runoff water quality and/or reduces sediment delivery will have beneficial effects to aquatic ecosystems. Many soil and water conservation practices have additional benefits to wildlife when applied in a habitat-friendly manner, but may have little or no benefit when applied otherwise. Wildlife and agriculture can coexist if land is managed to conserve sufficient biological integrity in the form of plant communities and habitat elements compatible with the surrounding landscape.

A variety of soil and water conservation practices are widely applied to croplands for the primary purposes of controlling soil erosion, managing runoff water, conserving soil moisture, improving soil quality, protecting crops, managing nutrients and pests, or otherwise avoiding soil degradation. While each conservation practice has specific primary purposes for application, many also affect other resources. Primary effects are often well documented in the literature and to some extent secondary effects are also recognized. Unfortunately, however, there is little documentation of broader ecological effects to other resources such as fish and wildlife habitat. Allen and Vandever (2003) studied Conservation Reserve Program (CRP) participants, reporting most farm

operators recognize economic, environmental, and societal benefits stemming from establishment of CRP conservation practices, with greater than 75 percent of farm operators responding to their survey identifying wildlife as an important product of their conservation activities. This paper reviews literature documenting effects of cropland soil and water conservation practices on fish and wildlife habitat. Cropland is defined here to include land used for the production of food, feed, fiber, and oil seed crops. This definition includes land used to grow row crops, close grown crops, orchards, vineyards, and tame hay, but excludes forest, pasture, range, and native hay (i.e., marsh hay or wild hay). The term habitat is used generically in this discussion to refer to resources or conditions present that will produce

occupancy by some wildlife species. Proper use of the word habitat requires a species-specific definition (Hall et al. 1997), which is impractical in this review.

The goal of reducing soil erosion rates down to the tolerable level has been based on soil characteristics for continued production. Each soil map unit is assigned a tolerable soil loss limit or “T-value” to represent the amount of erosion loss it can withstand without sacrificing long-term productivity. Soil characteristics such as depth of the A horizon, depth to bedrock or other restricting layer, texture, and similar attributes help determine the tolerable limit for each soil map unit. T-values typically range from 1 to about 4 or 5 tons/acre/year (2.2 to 9 or 11.2 tons/ha/year). While the T-value is a useful concept for maintaining long-term sustainability of the site, there are conditions on the landscape where those values could result in excessive sediment delivery to receiving waters to the detriment of fish and other aquatic organisms. In addition to the T-value and soil sustainability concerns, site conditions in relation to receiving waters should be considered when evaluating soil conservation treatment alternatives for cropland.

There were 369.7 million acres (149.6 million ha) of cropland in the 48 conterminous states in 2001 (USDA NRCS 2003) representing about 27 percent of nonfederal rural land. Nearly 85 percent of cropland is cultivated annually while the remainder is used to produce perennial or semi-perennial crops. About 56 percent of cropland is classified as prime farmland, while 27 percent is classified as highly erodible land (HEL). Soil erosion rates were at, or below, the tolerable level on about 72 percent of all cropland in 2001. From 1982 to 2001 soil erosion rates on all cropland declined from 3.1 billion tons (2.8 billion metric tons) per year to 1.8 billion tons per year (1.6 billion metric tons) (USDA NRCS 2003), a net reduction of 1.3 billion tons per year (1.2 billion metric tons), or 42 percent. One can only conclude that extensive conservation treatment has been applied to achieve this significant reduction. However, 18 percent of the non-HEL and 55 percent of HEL cropland still exhibit soil erosion rates greater than the tolerable level (USDA NRCS 2003). This represents 103.8 million acres (42 million ha) of cropland, or 28 percent, where additional conservation treatment is needed immediately.

While cropland soil conservation practices can affect the quality of fish and wildlife habitat, it needs

to be recognized that land use is the principal factor determining the base level of abundance of endemic wildlife species in agricultural ecosystems (Edwards et al. 1981). The extent and intensity of land use determines how much of the landscape is available as wildlife habitat since land use determines the kinds, amounts, relative permanence, and distribution of vegetation. The extent to which cropland conservation practices enhance or diminish the landscape’s ability to meet habitat needs of terrestrial wildlife is a function of how significantly conservation complements the mix of perennial or residual cover types. Wildlife habitat management is largely based upon managing plant communities and related resources to furnish fundamental needs such as cover and food for wildlife. In agricultural ecosystems, this often includes using agronomic practices and crops in the management plan. The literature is replete with studies documenting wildlife response to various vegetation and land management practices (e.g., nesting cover, winter cover, food plots, etc.). However, little has been published documenting specific effects of most soil and water conservation practices on terrestrial wildlife habitat. The same is true for wetland and aquatic habitats; however, conservation practices that reduce soil erosion and sediment delivery or that otherwise improve the quality of runoff water (e.g., vegetative filter or buffer strips) play significant roles in improving aquatic habitat quality.

Agricultural Land Use Effects on Habitat

Perhaps no human activity has had a more profound impact on American wildlife than has agriculture (Burger 1978). Farris (1987:2) concluded that “farm legislation has a greater impact on wildlife habitat than any other human-related factor in this country, including all of our combined wildlife management efforts.” Initially, as forest and prairies were converted to agricultural uses, there were positive responses by some species to habitat openings and additional food resources that agriculture provided. However, most wildlife species began to decline when agriculture expanded to the point of replacing extensive tracts of native habitats. Variability among wildlife species exists in their ability to respond to agricultural land use intensification; however, for many

species there are thresholds of disturbance beyond which further agricultural expansion or intensification is not tolerated. Those thresholds vary by species as well as by landscape setting; consequently, definitive thresholds have not been defined. An analysis of breeding birds in Iowa agricultural landscapes (Best et al. 1995) found potential numbers of nesting species increased from 18 to 93 over four landscape management scenarios representing a progression from intensively farmed row crop monoculture to a diverse mosaic of crop and non-crop habitats.

The following discussion furnishes a brief summary of land management and technological changes driving agricultural land use intensification that have affected the quality and distribution of wildlife habitats and populations associated with agricultural ecosystems. More specific details are available in the following references: Baxter and Wolfe (1973), Burger (1978), Taylor et al. (1978), Samson (1980), Edwards et al. (1981), Warner et al. (1984), Warner and Etter (1985), Wooley et al. (1985), Potts (1986), Robbins et al. (1986), Berner (1984, 1988), Brady (1985, 1988), Brady and Hamilton (1988), and Flather and Hoekstra (1989), Warner and Brady (1994), Flather et al. (1999), Heard et al. (2000), and Higgins et al. (2002).

Agricultural land use effects were first manifest by extensive conversion of native habitats to diversified, small-scale agricultural production. Forest and wetland wildlife were dramatically impacted while shifts in presence, abundance, and distribution of grassland wildlife occurred somewhat gradually at first. The mixed agricultural landscape coupled with low intensity farming practices retained connectivity among habitat patches. As native prairie was converted to non-native forage grasses and legumes, many grassland birds were able to persist because this pseudo-prairie was structurally complex and heterogeneous. Between the early 1900s and 1950 in Illinois, for example, there was little change in most grassland bird populations (Forbs and Gross 1922, Graber and Graber 1963), as introduced forage grasses and legumes offered a pseudo-prairie for most grassland birds (Warner 1994). These forage crops were important for livestock production and legumes were important to supply nitrogen in rotation with grains. Soon after World War II, horses were replaced by machinery, greatly reducing the need for forages, and

nitrogen became commercially available, eliminating the need for legumes in rotations. The growing presence of livestock confinement facilities and feedlots further reduced the need for pasture and rangeland as agriculture became even more industrialized and landscapes became less diverse in the crops produced and habitat provided. Improved varieties of alfalfa replaced mixed forage stands (Warner 1994) and the development of improved crop varieties, herbicides, and pesticides further permitted row crop agriculture to expand (Burger 1978). Transportation and marketing developments along with vertical integration of businesses allowed specialized agricultural products to be produced where natural conditions were most optimum, then shipped fresh to markets. Farms and rural grain markets became specialized and many landscapes became dominated by just one or two crops. Grassland birds typically declined in relative abundance by 80 percent to more than 97 percent during this period (Graber and Graber 1963, Robbins et al. 1986, Herkert 1991, Warner 1994). During the 30-year period beginning in 1956, dramatic declines in the hunter harvest of ring-necked pheasants (*Phasianus colchicus*) and northern bobwhite quail (*Colinus virginianus*) in Illinois were highly correlated with increasing amounts of row crops, while declines in the harvest of cottontail rabbits (*Sylvilagus floridanus*) were highly correlated with declines in hay and small grains (Brady 1988). At the same time, survival of ring-necked pheasant chicks to 5 to 6 weeks of age declined from 78 percent to 54 percent (Warner 1979). This decline was the result of fewer acres of forage crops, small grains, and idle areas where chicks forage for insects. Consequently, due to the diminished presence of suitable cover and less available food, the area needed to ensure survival of pheasant broods nearly tripled (Warner 1984, Warner et al. 1984).

Soil and Water Conservation Practice Effects on Habitat

Generally, as soil conserving measures increase, upland wildlife habitat quality also improves (Lines and Perry 1978, Miranowski and Bender 1982). Direct changes in land use can have greater effects on habitat quality than changes in management practices can (Miranowski and Bender 1982). This is illustrated by

data from Illinois where between 1967 and 1982, a 46 percent decline in the harvest of farmland game was attributed to a 48 percent increase in area of “cropland adequately treated” for soil erosion control (Brady and Hamilton 1988). However, during the same period the proportion of cropland used for row crops increased from 70 percent to 85 percent. Within the context of the landscape setting and with the assumption that certain minimum habitat elements are available, then cropland conservation practices can have a beneficial effect on fish and wildlife habitat. However, they represent the last increment of habitat elements within the landscape context. Soil and water conservation practices offer benefits to wildlife only when installed to complement existing habitat within the landscape setting. Of course any practice that improves runoff water quality or reduces sediment delivery is beneficial to aquatic systems. In most cases, selection of soil and water conservation practices that also benefit wildlife requires land users to choose features that enhance wildlife habitat from among unequal options. For example, native grasses such as switchgrass (*Panicum virgatum*) may furnish greater long-term and seasonal benefits to wildlife than introduced grasses such as smooth brome (*Bromus inermis*).

In the following section, the effect on fish and wildlife habitat of commonly applied soil and water conservation practices is discussed. Some conserva-

tion practices were combined together for discussion as appropriate. Definitions and purposes of each practice are provided in Appendix A. Published literature is reviewed, but there is a paucity of relevant literature documenting specific effects for many practices on wildlife and their habitats.

Conservation Tillage

(residue management; no-till, strip-till, mulch-till, ridge-till)

Conservation tillage is practiced on more than 111 million acres (45 million hectares) world-wide, primarily to protect soils from erosion and compaction, to conserve moisture, and reduce production costs (Holland 2003). The agronomic values of conservation tillage are generally very good, accounting for its widespread adoption. It is also believed this conservation practice generally improves habitat values of crop fields for some wildlife species. Various forms of intermediate tillage (strip or mulch tillage) may be used to chop or shred crop residue to facilitate planting, or to incorporate soil amendments or pesticides, all of which reduce the value of the cropland to wildlife, due to additional disturbance as well as diminished availability of cover and food resources.

Robertson et al. (1994) studied soil-dwelling invertebrates in a semi-arid agro-ecosystem in northeastern Australia. They reported that the highest population densities of detritivores and predators occurred in zero-tilled fields while conventional cultivation displayed the lowest abundance. Populations of these beneficial invertebrates in reduced tilled fields were intermediate. The numbers of herbivorous soil insects were similar between tillage treatments at each sampling time. The authors concluded zero tillage may further increase the ecological sustainability of agro-ecosystems by maintaining high populations of soil-ameliorating fauna and predators of insect pests. Altieri (1999) explored the role of biodiversity as it pertains to crop protection and soil fertility. He suggests the persistence of biodiversity-mediated renewal processes and ecological services depend on the maintenance of biological integrity and diversity in agro-ecosystems. No-till fields have a greater abundance and diversity of arthropods than conventionally tilled fields. This increased diversity was reported to be the result of greater abundances of beneficial insects (Blumberg and Crossley 1983, Warburton and Klimstra 1984). While many of these arthropods are



No-till production techniques for soil conservation in Alabama. (Photo courtesy of USDA NRCS)

important food resources for birds and mammals, Basore et al. (1987) found no increase in insect numbers in no-till fields vs. conventionally tilled fields during the pheasant brood rearing period in Iowa.

Several studies report on nesting and nest success of birds in minimum tillage crop fields. Best (1986) suggested minimum tilled crops represent ecological traps that attract nesting birds away from safer habitats only to see the nests destroyed by subsequent farming operations. Certainly this could happen, especially in ridge-till systems where cultivation is required. Cropping systems that reduce the number of field operations should be used where possible and maximum amount of crop residues should be retained on the soil surface (Rodenhouse et al. 1993).

Warburton and Klimstra (1984) found a greater abundance of invertebrates, birds, and mammals in no-till than in conventionally tilled cornfields in southern Illinois. Castrale (1985) found deer mice (*Peromyscus spp*) to exhibit a negative relationship with residue amounts, while house mice (*Mus mus*) were more dependent on greater residue in no-tilled row crop fields. Clark and Young (1986) reported no relationship between deer mouse abundance and the varying residue amounts in conventional vs. no-till row crops. The increased residue amounts created by no-till generally result in greater diversity rather than density of small mammals. Concerns over crop damage by small mammals in no-till fields are not warranted (Stallman and Best 1996) in crop fields. However, that may not be true where corn is no-tilled into pasture or hayfields (Best 1985).

Basore et al. (1986) found substantially greater diversity and density of birds nesting in Iowa no-till fields (12 species, 36 nests/247 acres or 100 ha) than in conventionally tilled fields (4 species, 4 nests/247 acres). Nest success was comparable to levels recorded in idle areas, such as fencerows and waterways. Duebbert and Kantrud (1987) found that minimum tillage in fall-seeded crops was more attractive and productive for nesting ducks than was conventional tillage in North Dakota. Nest success was 27 percent for 5 duck species and nest density was 7 nests/247 acres (100 ha). Cowan (1982) found nest density was 1.4-1.5 times greater in no-till fields, and duck nest success in no-till winter wheat was 42 percent vs. 13 percent on conventionally tilled farms. Loekmoen and Beiser (1997) report equivalent, or higher, nest

success in minimum tillage fields than recorded within conventionally tilled fields.

Martin and Forsyth (2003) studied bird use of fields used for spring cereals, winter wheat, and summer fallow farmed using either conventional or minimum tillage (i.e., no-till or strip-till) in southern Alberta, Canada. The authors found savannah sparrows in spring cereal and winter wheat and chestnut-collared longspurs in summer fallow tended to prefer minimum tillage. Minimum till spring cereal and winter wheat were more productive for savannah sparrows (*Passerculus sandwichensis*) than were conventionally tilled habitats. Summer fallow of either tillage regime did not appear to be as productive as were minimum tilled cereal fields for savannah sparrows. Chestnut-collared longspurs (*Calcarius ornatus*) occurred predominantly in minimum till summer fallow and spring cereal habitat. McCown's longspurs (*Calcarius mccownii*) tended to have higher productivity in minimum till plots. The authors concluded that minimum tillage appeared to confer benefits in productivity to bird species that nested in farmland. Shutler et al. (2000) reported higher relative abundance of 37 upland bird species in Saskatchewan on wild than on farmed sites, as well as higher abundance on minimum tillage than on conventionally tilled farms.

Cotton generally provides the least suitable habitat for most early successional songbirds among the major agricultural crops in the southeastern United States due to the high intensity of tillage practices and dependence on pesticides to maintain productivity. Cederbaum et al. (2004) reported both conservation tillage and clover stripcropping systems improved conditions for birds in cotton, with strip-cropped fields providing superior habitat. Although the clover treatment attracted the highest avian and arthropod densities, conservation tilled fields still provided more wildlife and agronomic benefits than did conventional management.

Rodenhouse and Best (1983) reported vesper sparrow (*Pooecetes gramineus*) nests produced an average of 2.8 young/pair in conventionally tilled croplands, probably below replacement levels. They suggested breeding success likely would be greater if the number of tillage operations was reduced and crop residue was retained on the fields. These authors (1994) also reported on foraging patterns

of vesper sparrows in Iowa corn and soybean fields, concluding the sparrows preferred to forage in fields with the most crop residue. Therefore, reduced tillage farming methods may enhance foraging opportunities for this species.

Crop residues left undisturbed over winter furnish additional wildlife benefits from conservation tillage. Undisturbed harvested crop fields receive greater use by wintering wildlife than do fall-tilled crop fields in Indiana (Castrale 1985). The waste grain is an important source of energy for many wildlife species. (Baldassarre et al. 1983). However, that benefit is compromised when intermediate tillage methods are employed. Multiple-pass tillage operations commonly used for corn, or single-pass tillage with twisted shank chisel plows, may be as detrimental to the availability of waste grain as the moldboard plow (Warner et al. 1989).

Pesticide effects were neatly summarized in the NRCS Wildlife Habitat Management Institute's literature review (USDA NRCS 1999):

Although the increased attractiveness of no-till crop fields as nesting and brood rearing habitat was shown to have potential pesticide exposure, Little (1987) pointed out that greater usage of herbicides was not necessarily required for no-till or reduced tillage farming. Flickinger and Pendleton (1994) reached the same conclusion in a Texas study that measured the use of herbicides in reduced and conventionally tilled fields. In addition to conservation tillage not having to greatly increase the use of herbicides and insecticides above those used in conventional tillage, some work has shown that less toxic choices are available. Some herbicides, such as glyphosate, are very low in toxicity and have little direct impact on nests (Cowan 1982, Castrale 1985, Nicholson and Richmond 1985). Although insecticides also are of concern, Best (1985) noted that insecticide use had more to do with cropping sequence than tillage practices. Also, recent studies of the impacts of direct spraying and the consumption of poisoned insects on bobwhite quail chicks in North Carolina showed that modern

insecticides are less toxic than those used in the past (Palmer et al. 1998).

In summary, conservation tillage systems, i.e., no-till, have widely been reported to provide improved habitat values over conventional tillage systems. Reports consistently indicate no-till fields have greater densities and more species of birds than found within conventionally tilled fields. In relation to the needs for wildlife habitat, the best systems are those leaving the greatest amounts of crop residue on the surface and those having the fewest number of disturbances from farming operations. Mulch-till systems may meet soil conservation standards, but the intermediate tillage treatments they employ adversely affect wildlife food and cover.

Grassed Waterways

Grassed waterways have been extensively established to safely remove concentrated flows of runoff water from agricultural fields. The size of grassed waterways is highly variable depending upon topography, soil texture, and local rainfall patterns. Typical waterway size in Illinois or Iowa is about 35 to 60 feet (11-18 m) wide with lengths ranging from a few hundred feet to nearly one-half mile (60-800 m). Bryan and Best (1991) reported 48 species using smooth brome grass waterways during the breeding season in Iowa, compared with only 14 species using adjacent corn and soybean fields. Total bird abundance was also



Grassed waterway in an agricultural field in Missouri. (Photo by C. Rahm, USDA NRCS)

higher, averaging 2,198 birds observed/census/247 acres (100 ha) in waterways, compared with 682 in crop fields. The peak of bird species abundance (53 percent) occurred during July 4 to July 22. The temporal patterns in bird abundance were attributed primarily to aspects of the waterways and surrounding cropland that changed over time, such as vegetation height. In a subsequent paper (1994) these authors reported 10 bird species nested in waterways, achieving a nest density of 1,104 nests/247 acres (100 ha). Nest success was low (8.4 percent red-winged blackbirds, 22 percent dickcissels), with 57 percent of all nest losses due to predation, while 16 percent of nests lost were attributed to mowing. The authors believed nest success could be increased by delaying mowing until late August or September. Grassed waterways also are assumed to provide habitat value during other seasons of the year, but those have not been documented.

Bryan and Best (1994) noted, "Annual mowing is not necessary to maintain grass vigor after the waterway is established; however, mowing every three to four years may be required." This statement is correct as it relates to grass vigor, but it is in conflict with NRCS guidance for waterway maintenance. Grassed waterways are designed to have a convex or trapezoidal shape with maximum depths ranging from about 1 to 3 feet (0.3-1 m) deep. They are typically designed with capacity to carry runoff from the 10-year storm event at a non-erosive velocity to a stable outlet. The grass type, slope, and shape help determine the hydrologic retardance factor. Waterways typically are densely seeded to grasses such as smooth brome or tall fescue and designed based upon the assumption of regular mowing. The purpose of regular mowing is to maintain velocity and encourage grass density by production of rhizomes and tillers. As grasses grow taller, hydrologic retardance increases, causing a reduction in the runoff velocity. Sediment is deposited into the dense sod as runoff velocity decreases, causing the waterway ultimately to lose capacity. Sediment then builds up in the waterway to the point that it can no longer receive runoff from the adjacent field. The water then runs down the unprotected (i.e., cropland) sides of the waterway, causing additional gullies. Typical cost (in 2005) to build a grassed waterway ranges from about \$2,000 - \$2,400 per acre (Gene Barickman and Mark Lindflott, personal

communication). Wetter site conditions also may require drainage tile for part or all of the length of the waterway, adding an additional \$1.25 to \$2.00 per linear foot. Waterways with taller grasses (or a higher mowing height) to benefit wildlife can be accommodated during the planning phase by designing for higher water velocities. However, all grassed waterways require good maintenance to ensure proper functioning and protection of investment.

Grade Stabilization Structures

These structures are installed to control gully erosion and to reduce head cutting uphill. Grade stabilization structures are often required at the downstream end of a grassed waterway to provide a stable outlet. Grade stabilization structures may be made of concrete, corrugated metal, or treated lumber and are designed to handle concentrated flows. These structures typically have berms on each side to direct water over the notch or toward the inlet of a pipe in front of an earthen dam. The berm or dam is designed to provide temporary storage of water while it is released at a controlled rate (determined by the weir or pipe size). On-farm applications typically are designed for the 10-year storm event to flow through the pipe or over the weir with temporary water storage up to the 25-year storm event behind the berms or dam. Peak storm flows in excess of the 25-year event would be routed around the berms to an emergency spillway. Grade stabilization structures provide wildlife habitat to the extent that they permit small terrestrial and wetland habitats to develop with associated shallow pools that may be permanently or seasonally flooded.

Little has been published about the wildlife benefits of grade stabilization structures with the exception of pipe drop structures. The latter have been studied in Mississippi. Smiley et al. (1997) recorded 100 species of vertebrate wildlife using the habitats created by pipe drop structures. The highest species richness at pipe drop structures occurred in scrub-shrub and intermittent riverine wetlands. Habitat values are optimized with larger and deeper pool sizes and a buffer of robust grasses to trap sediment before it is delivered to the pool area. Cooper et al. (1997) reported the highest percent capture abundance among all habitat types occurred with amphibians, followed by fish, birds, mammals, and

reptiles. Habitat benefits were minimal for sites smaller than 0.2 ac (0.08 ha), sites lacking woody vegetation, and sites that did not have at least 20 percent of their area below the inlet weir elevation (Shields et al. 2002).

Grass Backed and Grass Ridged Terraces

Terraces have been extensively used to manage runoff water and reduce sheet erosion. Terraces are best suited to deep soils on long gentle slopes but are poorly suited to soils that are shallow (to bedrock) or occur on short, choppy slopes where contour farming is difficult. Terraces may be broad-based and farmed or may be narrow-based with grassed ridges or grassed back slopes. Grassed back slope terraces are usually built on steeper sites, while the grass ridged terraces are narrow-based (about 10 to 14 feet wide, or 3 to 4.3 meters) and more appropriate for slopes. Grassed terraces are less expensive to build than are broad-based terraces, but the grassed portion is lost from crop production. Broad-based terraces have no direct benefit to wildlife, but the grassed terraces increase the diversity and interspersions of vegetative types in cropland settings. Terrace construction could lead to the loss of habitat if waterways are replaced with underground tile outlets or if new field alignments remove old, grown-up fencerows and odd areas of habitat.

Hultquist and Best (2001) observed 26 bird species using grassed terraces in Iowa. Red-winged

blackbirds and dickcissels accounted for 58 percent of the total bird abundance. Bird abundance in terraces was less than in other strip-cover habitats such as grassed waterways and roadsides, but greater than in rowcrops. However, all terraces evaluated were dominated by smooth brome grass averaging over 70 percent cover. Therefore, results may be different on terrace systems with greater plant diversity or those dominated by native warm season grasses and/or forbs, which generally are believed to provide greater quality habitat for wildlife.

Beck (1982) reported 35 species of vertebrates using grassed back slope terraces in Iowa. Additionally, he reported pheasant nest success was 22.5 percent, or one successful nest per 12.5 acres (5 ha) of grass in these terraces. While this density is low, it is an improvement over no grassy cover or no nests at all from broad-based terraces.

Filter Strips and Field Border Strips

These two practices have been combined for discussion because their ecological effects are similar. Filter strips are established between agricultural fields and “environmentally sensitive” areas such as streams and aquatic systems. Field border strips are established around the perimeter of crop fields. Filter strips reduce erosion, trap sediments, filter pollutants, and provide wildlife food and cover. Few studies have been reported on these two practices until recently. Both practices have become increasingly popular as a result of the USDA National Conservation Buffer Initiative and the Conservation Reserve Program practice “CP33” (Bobwhite Buffers). The latter provides land rental payments to land users who participate.

Puckett et al. (2000) examined how the addition of filter strips around crop fields and along crop field drainage ditches impacted northern bobwhite quail in North Carolina. The authors reported that the presence of filter strips shifted habitat use patterns, especially during spring and early summer, and improved crop fields as habitat for breeding bobwhite quail. Bobwhites occurring on filter strip sections of their study area had significantly smaller breeding season ranges than those captured where filter strips were not present. Filter strips have the potential to increase quail recruitment by providing what is often the only



Example of strip-till production, an intermediate tillage technique. (Photo courtesy of USDA NRCS)

available nesting and brood-rearing cover during spring and early summer (Puckett et al. 2000).

Smith et al. (2005a) reported field border effects over winter differed by bird species and adjacent plant community types in Mississippi, but greater densities of several sparrow species were observed along most bordered transects. Smith et al. (2005b) also studied bird response to field borders during the breeding season and concluded from their Mississippi study that “within intensive agricultural landscapes where large-scale grassland restoration is impractical, USDA conservation buffer practices such as field borders may be useful for enhancing local breeding bird richness and abundance.” Smith (2004) suggested the percentage of the land base established in field borders may play a greater role in eliciting population responses of northern bobwhite than field border width. Smith (2004:87) summarized his results with this statement: “Therefore, given my results in the context of those reported in Puckett et al. (1995, 2000) and Palmer et al. (Tall Timbers Research Station, unpublished data), I suggest that at least 5 percent to 10 percent of a site be placed in field border habitats to elicit measurable responses from northern bobwhite populations. USDA conservation practices, such as the recently announced CP-33 practice, may provide opportunities to enhance northern bobwhite habitat with minimal changes in primary land use.”

Conover (2005) conducted a three-year study to evaluate the response of breeding and wintering avian communities to field borders in an agricultural landscape in Mississippi. Results from his study revealed substantial avian benefits provided by field borders. Field border habitat generally provided greater avian richness, abundance, and conservation value over traditional “ditch-to-ditch” row-crop practices. Field borders were particularly valuable if established at widths greater than 33 feet (10 m) and when vegetative composition was dominated by forbs. During the breeding season nearly all species that commonly inhabit field edges had significantly greater abundances on bordered margins. Avian richness, abundance, and conservation value were higher in bordered field margins and adjacent agricultural fields regardless of width. Avian response to field borders was variable by species. Dickcissels (*Spiza americana*) appeared to benefit mostly from wide

borders and were not abundant on narrow-bordered margins. Nesting birds displayed extreme preference for wide border nest-sites. Dickcissel and red-winged blackbird (*Agelaius phoeniceus*) nest success estimates were comparable to other studies, suggesting field border habitat does not likely represent an ecological trap. Nest-site selection favored borders with increased forb composition over grass and greater vertical cover.

Kammin (2003) studied 92 filter strips in central Illinois and reported 89 species of birds using them. Seventeen species nested in filter strips, but 76 percent of 411 active nests were destroyed by predation. The author concluded filter strips provide adequate cover and food resources to support several bird species, but are only marginally suitable as breeding habitat due to elevated rates of predation.

Bromley et al. (2002) studied bird response to field borders in North Carolina and found that farms with field borders had higher nest density, particularly for field sparrows (*Spizella pusilla*) and common yellowthroats (*Geothlypis trichas*) and had greater nesting bird diversity than did farms without field borders. However, songbird nest success was low because of heavy depredation, which was not reduced by removing mesomammal predators such as raccoons (*Procyon lotor*), opossums (*Didelphis virginianum*), and foxes (*Vulpes vulpes*). Northern bobwhite abundance during summer was greater on farms containing field borders. Consistently more bobwhite coveys were heard on farms with field borders than heard on farms without field borders. However, the authors reported no differences in the number of coveys heard between predator reduction and non-reduction farms. Farms with both field border and predator reduction had more coveys heard compared with other farm blocks, but predator reduction would usually not be economically feasible.

Henningsen and Best (2005) studied grassland bird use of riparian filter strips in Iowa and found 46 bird species using filter strips, with 41 species in sites dominated by cool season grasses and 31 species in sites dominated by warm season grasses. Mean species richness did not differ among sites. Seven bird species were significantly more abundant in filter strips lacking nearby woody vegetation compared with those adjacent to a wooded edge, and mean spe-

cies richness was significantly greater in non-wooded sites. There were no significant differences in relative nest abundance between cool and warm season grass-dominated sites. Nine avian species nested in cool season grass sites; seven species nested in warm-season grass sites. Twenty-seven percent of all nests were successful, while 62 percent were depredated.

Hedgerows

Hedgerows consist of rows of shrubs or small trees planted along the side of a field. There is an extensive literature base documenting the value of hedgerows for insects in Europe where some hedgerows may be centuries old. In the United States, Best (1983) reported on bird use of woody fencerows and Best et al. (1990) reported on the importance of edge habitats for birds in Iowa. Best (1983) reported as many as 30 species of birds using fencerows in Iowa farmlands during the breeding season. Fencerows with greater coverage of trees and shrubs supported a more diverse and abundant avifauna. A monotypic row of a single shrub species was not found to support the diverse bird communities that could occur from multiple woody species providing diverse structure. Hedgerows and other linear covers are generally perceived to be beneficial to most wildlife species inhabiting agriculturally dominated landscapes (Cable 1991). However, when established in landscapes dominated by grasslands, they may serve to fragment grassland habitats with negative consequences for grassland wildlife (O’Leary and Nyberg 2000).

Contour Strip Cropping

No literature citations were found documenting the wildlife effects of this practice, but inferences can be drawn from other work. Contour strip cropping is a technique used to control erosion by interspersing strips about 90 to 120 feet (27 to 36 m) wide of close-grown crops (e.g., hay and small grains such as oats) on the contour between strips of row crops. Alternating strips of corn, oats, and hay can provide the juxtaposition and configuration of cover types necessary to provide for the needs of wildlife during periods of limited mobility, such as when pheasants are tending young broods (Warner et al. 1984,

Warner 1988). As previously noted, ring-necked pheasant brood survival to 5 to 6 weeks of age had significantly declined from 78 percent to 54 percent in Illinois during a 30-year period concomitant to a threefold increase in the foraging area observed for pheasant broods (Warner 1979, 1984, Warner et al. 1984). This decline was the result of fewer acres of forage crops, small grains, and idle areas that chicks use to forage for insects. Contour strip cropping can make a substantial contribution to minimizing this problem by increasing the diversity of vegetation covers in a relatively small area.

System Effects

In those parts of the country where agricultural land uses are part of a matrix consisting of forest, range, and other land uses, wildlife abundance is usually not a problem unless it becomes one of crop depredation. However, wildlife habitat can be a daunting challenge where intensive land uses prevail. The fundamental principle guiding preservation and enhancement of wildlife habitats in such situations is to conserve as much of the biological integrity of the landscape as possible in the form of natural, or nearly natural, plant communities—“to keep every cog and wheel is the first precaution of intelligent tinkering” (Leopold 1966). Relatively natural habitats in agriculturally dominated landscapes often occur as riparian corridors, wetlands, woodlots, “odd” areas that aren’t farmed for some reason, and brushy or weedy fencerows and roadsides. The greater the extent of those residual patches of biotic integrity, the greater the probability wildlife species will respond to the habitat elements provided, often secondarily, from the soil and water conservation practices described above. Any one of those practices alone may not have a great effect, but when implemented as part of a holistic resource management system, the cumulative effect can be substantial. The combination of grass-ridged terraces, grassed waterways, conservation tillage, and field border strips will provide habitat, food resources, and travel lanes, greatly enriching the biological characteristics of the landscape. Many other combinations of conservation practices can also be combined to enhance biological resources to fit various other landscape settings.

Wildlife response to land management activities is scale-dependent and the geographic scale of concern is dependent upon the wildlife species of interest. Grizzly bears demand huge landscapes, while meadow voles require very little. Most of the individual cropland soil and water conservation practices described here fall below the habitat thresholds for many species. Wildlife may utilize those habitat elements for part of their life cycle, but not all of it. Consequently, it does not make sense to try to elucidate direct cause and effect relationships at too fine a scale, as other habitat elements on the landscape confound the interpretation. Rather, the research needed should be at the resource management system level, where wildlife response to large scale agricultural land management systems is conducted while land use is controlled. Individual wildlife benefits from any traditional conservation practice may not be immediately obvious. However, when used in combination and in relation to landscapes that provide covers other than those annually disturbed, the conservation practices described above can only serve to elevate the quality of the landscape for terrestrial species. The water quality benefits described for many of these conservation practices undoubtedly reach far beyond the borders of fields containing the conservation activities. ■

Acknowledgement

Appreciation is extended to Art Allen and Jon Haufler for their comments on a previous draft of the manuscript.

Literature Cited

- Allen, A. W., and M. W. Vandever. 2003. A national survey of Conservation Reserve Program (CRP) participants on environmental effects, wildlife issues, and vegetation management on program lands: Biological Science Report, USGS/BRD/BSR-2003-0001: U.S. Government Printing Office, Denver, Colorado. 51 p.
- Altieri, M. A. 1999. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems and Environment* 74:19-31.
- Baldassarre, G. A., R. J. Whyte, E. E. Quinlan, and E. G. Bolen. 1983. Dynamics and quality of waste corn available to post-breeding waterfowl in Texas. *Wildlife Society Bulletin* 11:25-31.
- Basore, N. S., L. B. Best, and J. B. Wooley, Jr. 1986. Bird nesting in Iowa no-tillage and tilled cropland. *Journal of Wildlife Management* 50:19-28.
- Basore, N. S., L. B. Best, and J. B. Wooley, Jr. 1987. Arthropod availability to pheasant broods in no-tillage fields. *Wildlife Society Bulletin* 11:343-347.
- Baxter, W. L., and C. W. Wolfe, Jr. 1973. Life history and ecology of the ring-necked pheasant in Nebraska. Nebraska Game, Fish, and Parks Commission, Lincoln, USA.
- Beck, D. W. 1982. Wildlife use of grassed backslope terraces. Abstract of paper presented at the 44th Midwest Fish and Wildlife Conference.
- Berner, A. H. 1984. Federal land retirement programs: a land management albatross. *Transactions of the North American Wildlife and Natural Resources Conference* 49:118-131.
- Berner, A. H. 1988. Federal pheasants-impact of federal agricultural programs on pheasant habitat. Pages 45-93 in D. L. Hallett, W. R. Edwards, and G. V. Burger, editors. *Pheasants: symptoms of wildlife problems on agricultural lands*. North-Central Section, The Wildlife Society, Milwaukee, Wisconsin, USA.
- Best, L. B. 1983. Bird use of fencerows: implications of contemporary fencerow management practices. *Wildlife Society Bulletin* 11:343-347.
- Best, L. B. 1985. Conservation vs. conventional tillage: wildlife management considerations. Pages 315-326 in F. M. D'Itri, editor. *A systems approach to conservation tillage*. Lewis Publishers. Boca Raton, Florida, USA.
- Best, L. B. 1986. Conservation tillage: ecological traps for nesting birds? *Wildlife Society Bulletin* 14:308-317.
- Best, L. B., H. Campa, III, K. E. Kemp, R. J. Robel, M. R. Ryan, J. A. Savidge, H. P. Weeks, Jr., and S. R. Winterstein. 1997. Bird abundance and nesting in CRP fields and cropland in the Midwest: a regional approach. *Wildlife Society Bulletin* 25:864-877.
- Best, L. B., K. E. Freemark, J. J. Dinsmore, and M. Camp. 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. *American Midland Naturalist* 134:1-29.
- Best, L. B., R. C. Whitmore, and G. M. Booth. 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. *American Midland Naturalist* 123:84-99.
- Blumberg, A. Y., and D. A. Crossley, Jr. 1983. Comparison of soil surface arthropod populations in conventional tillage, no-tillage and old field systems. *Agro-Ecosystems* 8:247-253.
- Brady, S. J. 1985. Important soil conservation techniques that benefit wildlife. Pages 55-62 in *Proceedings of the workshop on technologies to benefit agriculture and wildlife*. U.S. Office of Technology Assessment OTA-BP-F-34.
- Brady, S. J. 1988. Potential implications of sodbuster on wildlife. *Transactions of the North American Wildlife and Natural Resources Conference* 53:239-248.
- Brady, S. J., and R. Hamilton. 1988. Wildlife opportunities within federal agricultural programs. Pages 95-109 in D. L. Hallett, W. R. Edwards, and G. V. Burger, editors. *Pheasants: symptoms of wildlife problems on agricultural lands*. North Central Section, The Wildlife Society, Milwaukee, Wisconsin, USA.
- Bromley, P. T., S. D. Wellendorf, W. E. Palmer, and J. F. Marcus. 2002. Effects of field borders and mesomammal reduction on northern bobwhite and songbird abundance on three farms in North Carolina. Page 71 in S. J. DeMaso, W. P. Kuvlesky, Jr., F. Hernandez, and M. E. Berger, editors. *Quail V: Proceedings of the Fifth National Quail Symposium*. Texas Parks and Wildlife Department, Austin, Texas, USA.

- Bryan, G. G., and L. B. Best. 1991. Bird abundance and species richness in grassed waterways in Iowa rowcrop fields. *American Midland Naturalist* 126:90-102.
- Bryan, G. G., and L. B. Best. 1994. Avian nest density and success in grassed waterways in Iowa rowcrop fields. *Wildlife Society Bulletin* 22:583-592.
- Burger, G. V. 1978. Agriculture and wildlife. Pages 89-107 in H. P. Brokaw, editor. *Wildlife and America*. Council on Environmental Quality. U.S. Government Printing Office. Washington, D.C., USA.
- Cable, T.T. 1991. Windbreaks, wildlife, and hunters. Pages 35-55 in J.E. Rodiek and E.G. Bolen, editors. *Wildlife and habitats in managed landscapes*. Island Press. Washington D.C., USA.
- Castrale, J. S. 1985. Responses of wildlife to various tillage conditions. *Transactions of the North American Wildlife and Natural Resources Conference* 50:142-156.
- Cedarbaum, S. B., J. P. Carroll, and R. J. Cooper. 2004. Effects of alternative cotton agriculture on avian and arthropod populations. *Conservation Biology* 18:1272-1282.
- Clark, W. R., and R. E. Young. 1986. Crop damage by small mammals in no-till cornfields. *Journal of Soil and Water Conservation* 41:338-341.
- Conover, R. R. 2005. Avian response to field borders in the Mississippi alluvial valley. M. S. Thesis. Mississippi State University, Mississippi, USA.
- Cooper, C. M., P. C. Smiley, Jr., J. D. Wiggington, S. S. Knight, and K. W. Kallies. 1997. Vertebrate use of habitats created by installation of field-scale erosion control structures. *Journal of Freshwater Ecology* 12:199-207.
- Cowan, W. F. 1982. Waterfowl production on zero tillage farms. *Wildlife Society Bulletin* 10:305-308.
- Duebbert, H. F., and H. A. Kantrud. 1987. Use of no-till winter wheat by nesting ducks in North Dakota. *Journal of Soil Water Conservation* 42:50-53.
- Edwards, W. R., S. P. Havera, R. F. Labisky, J. A. Ellis, and R. E. Warner. 1981. The abundance of cottontails (*Sylvilagus floridanus*) in relation to agricultural land use in Illinois. Pages 761-789 in K. Myers and C. D. MacInnes, editors. *Proceedings of the world lagomorph conference*, University of Guelph, Guelph, Ontario, Canada.
- Farris, A. 1987. Proposed study of the conservation reserve program. *Wildlife Habitat Protection Committee, International Association of Fish and Wildlife Agencies*. Washington, D.C., USA.
- Flather, C. H., S. J. Brady, and M. S. Knowles. 1999. *Wildlife resource trends in the United States: a technical document supporting the 2000 USDA Forest Service RPA Assessment*. General Technical Report RMRS-GTR-33.
- Flather, C. H., and T. W. Hoekstra. 1989. An analysis of the wildlife and fish situation in the United States: 1989-2040. *USDA Forest Service General Technical Report RM-178*.
- Flickinger, E. L., and G. W. Pendleton. 1994. Bird use of agricultural fields under reduced and conventional tillage in the Texas panhandle. *Wildlife Society Bulletin* 22:34-42.
- Forbs, S. A., and A. O. Gross. 1922. The numbers and local distribution in summer of Illinois land birds of the open country. *Illinois Natural History Survey Bulletin* 14:187-218.
- Graber, R. R., and J. W. Graber. 1963. A comparative study of bird populations in Illinois, 1906-1909 and 1956-1958. *Illinois Natural History Survey Bulletin* 28:383-528.
- Hall, L. S., P. R. Krausman, and M. L. Morrison. 1997. The habitat concept and a plea for standard terminology. *Wildlife Society Bulletin* 25:173-182.
- Heard, L. P., A. W. Allen, L. B. Best, S. J. Brady, W. Burger, A. J. Esser, E. Hackett, D. H. Johnson, R. L. Pederson, R. E. Reynolds, C. Rewa, M. R. Ryan, R. T. Molleur, and P. Buck. 2000. A comprehensive review of Farm Bill contributions to wildlife conservation, 1985-2000. W. L. Hohman and D. J. Halloum, editors. *USDA Natural Resources Conservation Service, Wildlife Habitat Management Institute, Technical Report, USDA/NRCS/WHMI-2000*.
- Henningsen, J. C., and L. B. Best. 2005. Grassland bird use of riparian filter strips in southeast Iowa. *Journal of Wildlife Management* 69:198-210.
- Herkert, J. R. 1991. Prairie birds of Illinois: population response to two centuries of habitat change. *Illinois Natural History Survey Bulletin* 34:393-399.
- Higgins, K. F., D. E. Naugle, and K. J. Forman. 2002. A case study of changing land use practices in the Northern Great Plains, USA: an uncertain future for waterbird conservation. *Waterbirds* 25 (Special Publication):42-50.
- Holland, J. M. 2003. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture, Ecosystems and Environment* 103:1-25.
- Hultquist, J. M., and L. B. Best. 2001. Bird use of terraces in Iowa rowcrop fields. *American Midland Naturalist* 145:275-287.
- Kammin, L. 2003. Conservation buffer filter strips as habitat for grassland birds in Illinois. M. S. Thesis. University of Illinois, Urbana-Champaign, Illinois, USA.
- Leopold, A. 1966. *A Sand County almanac with essays on conservation from Round River*. Oxford University Press. New York, New York, USA.
- Lines, I. L., and C. J. Perry. 1978. A numerical wildlife habitat evaluation procedure. *Transactions of the North American Wildlife and Natural Resources Conference* 43:284-301.
- Little, C. E. 1987. Beyond the mongongo tree: good news about conservation tillage and environmental tradeoff. *Journal of Soil and Water Conservation* 42:28-31.
- Lokemoen, J. T., and J. A. Beiser. 1997. Bird use and nesting in conventional, minimum-tillage, and organic cropland. *Journal of Wildlife Management* 61:644-655.
- Marcus, J. F., P. T. Bromley, and W. E. Palmer. In press. The effects of farm field borders on over wintering sparrow densities. *Wilson Bulletin*.
- Martin, P. A., and D. J. Forsyth. 2003. Occurrence and productivity of songbirds in prairie farmland under conventional vs. minimum tillage regimes. *Agriculture, Ecosystems and Environment* 96:107-117.
- Miranowski, J. A., and R. L. Bender. 1982. Impact of erosion control policies on wildlife habitat on private lands. *Journal of Soil and Water Conservation* 37:288-291.
- Nicholson, A. G., and M. E. Richmond. 1985. Conservation tillage vs. conventional tillage: potential benefits to farm wildlife in New York. *New York Fish and Game Journal* 32:189-196.
- O'Leary, C. H., and D. W. Nyberg. 2000. Treelines between fields reduce the density of grassland birds. *Natural Areas Journal* 20(3): 243-249.
- Palmer, W. E., K. M. Puckett, J. R. Anderson, and P. T. Bromley. 1998. Effects of foliar insecticides on survival of northern bobwhite quail chicks. *Journal of Wildlife Management* 62:1565-1573.
- Potts, G. R. 1986. *The partridge: pesticides, predation and conservation*. Collins, London, U.K.
- Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr.,

- and L. T. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: a management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505-516.
- Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and L. T. Sharpe. 2000. Effects of filter strips on habitat use and home range of northern bobwhite on the Alligator River National Wildlife Refuge. Proceedings of the National Quail Symposium 4:26-31.
- Robbins, C.S., D. Bystrak, and P. H. Geissler. 1986. The breeding bird survey: its first fifteen years, 1965-1979. U.S. Fish and Wildlife Service Resource Publication 157.
- Robertson, L. N., B. A. Kettle, and G. B. Simpson. 1994. The influence of tillage practices on soil macrofauna in a semi-arid agroecosystem in northeastern Australia. Agriculture, Ecosystems and Environment 48:149-156.
- Rodenhouse, N. L., and L. B. Best. 1983. Breeding ecology of vesper sparrows in corn and soybean fields. American Midland Naturalist 110:265-275.
- Rodenhouse, N. L., and L. B. Best. 1994. Foraging patterns of vesper sparrows (*Pooecetes gramineus*) breeding in cropland. American Midland Naturalist 131:196-206.
- Rodenhouse, N.L., L. B. Best, R. J. O'Connor, and E. K. Bollinger. 1993. Effects of temperate agriculture on neotropical migrant landbirds. Pages 280-295 in D. M. Finch and P. W. Stangel, editors. Status and management of neotropical migratory birds. USDA Forest Service General Technical Report GTR RM-229.
- Samson, F. B. 1980. Island biogeography and the conservation of non-game birds. Transactions of the North American Wildlife and Natural Resources Conference 45:245-251.
- Shields, Jr., F. D., P. C. Smiley, Jr., and C. M. Cooper. 2002. Design and management of edge-of-field water control structures for ecological benefits. Journal of Soil and Water Conservation 57:151-157.
- Shutler, D., A. Mullie, and R. G. Clark. 2000. Bird communities of prairie uplands and wetlands in relation to farming practices in Saskatchewan. Conservation Biology 14:1441-1451.
- Smiley, P. C., Jr., C. M. Cooper, K. W. Kallies, and S. S. Knight. 1997. Assessing habitats created by installation of drop pipes. Pages 903-908 in S.S. Wang, E. J. Langendoen, and F. D. Shields, Jr., editors. Proceedings of the conference on management of landscapes disturbed by channel incision. Oxford, Mississippi, USA.
- Smith, M. D. 2004. Wildlife habitat benefits of field border management practices in Mississippi. Ph.D. Dissertation. Mississippi State University, Mississippi State, Mississippi, USA.
- Smith, M. D., P. J. Barbour, L. W. Burger, Jr., S. J. Dinsmore. 2005a. Density and diversity of overwintering birds in managed field borders in Mississippi. Wilson Bulletin: in press.
- Smith, M. D., P. J. Barbour, L. W. Burger, Jr., S. J. Dinsmore. 2005b. Breeding bird abundance and diversity in agricultural field borders in the black belt prairie of Mississippi. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 59: in press.
- Stallman, H. R., and L. B. Best. 1996. Small mammal use of an experimental strip intercropping system in northeastern Iowa. American Midland Naturalist 135:266-273.
- Taylor, M. W., C. W. Wolfe, and W. L. Baxter. 1978. Land-use change and ring-necked pheasants in Nebraska. Wildlife Society Bulletin 6:226-230.
- USDA Natural Resources Conservation Service. 2003. 2001 National Resources Inventory, Resources Inventory Division, Washington, D.C., USA. www.nrcs.usda.gov/technical/land/nri01/nri01eros.html
- USDA Natural Resources Conservation Service. 2005. Conservation Practice Physical Effects [national template]. National Bulletin. [ftp://ftp.wcc.nrcs.usda.gov/watershed/cppe/](http://ftp.wcc.nrcs.usda.gov/watershed/cppe/)
- USDA Natural Resources Conservation Service. Wildlife Habitat Management Institute. 1999. Conservation tillage and terrestrial wildlife. Fish and Wildlife Literature Review, Number 1. [ftp://ftp-fc.sc.egov.usda.gov/WHMI/WEB/wildlife/ctlit.pdf](http://ftp-fc.sc.egov.usda.gov/WHMI/WEB/wildlife/ctlit.pdf)
- Warburton, D. B., and W. D. Klimstra. 1984. Wildlife use of no-till and conventionally tilled corn fields. Journal of Soil and Water Conservation 39:327-330.
- Warner, R. E. 1979. Use of cover by pheasant broods in east-central Illinois. Journal of Wildlife Management 43:334-346.
- Warner, R. E. 1984. Effects of changing agriculture on ring-necked pheasant brood movements in Illinois. Journal of Wildlife Management 48:1014-1018.
- Warner, R. E. 1988. Habitat management: how well do we understand the pheasant facts of life? Pages 129-146 in D. L. Hallett, W. R. Edwards, and G. V. Burger, editors. Pheasants: symptoms of wildlife problems on agricultural lands. North-Central Section, The Wildlife Society, Milwaukee, Wisconsin, USA.
- Warner, R. E. 1994. Agricultural land use and grassland habitat in Illinois: future shock for Midwestern birds? Conservation Biology 8:147-156.
- Warner, R. E., and S. J. Brady. 1994. Managing farmlands for wildlife. Pages 648-662 in T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.
- Warner, R. E., and S. A. Etter. 1985. Farm conservation measures to benefit wildlife, especially pheasant populations. Transactions of the North American Wildlife and Natural Resources Conference 50:135-141.
- Warner, R. E., S. A. Etter, G. B. Joselyn, and J. A. Ellis. 1984. Declining survival of ring-necked pheasant chicks in Illinois agricultural ecosystems. Journal of Wildlife Management 48:82-88.
- Warner, R. E., S. P. Havera, L. M. David, and R. J. Siemers. 1989. Seasonal abundance of waste corn and soybeans in Illinois. Journal of Wildlife Management 53:142-148.
- Wooley, J. B., Jr., L. B. Best, and W. R. Clark. 1985. Impacts of no-till row cropping on upland wildlife. Transactions of the North American Wildlife and Natural Resources Conference 50:157-168

Appendix A

Definitions and purposes of cropland conservation practices (Conservation Practice Physical Effects, USDA NRCS).

Residue Management, No Till/Strip Till:

Managing the amount, orientation, and distribution of crop and other plant residues on the soil surface year-round, while growing crops in narrow slots, or tilled or residue-free strips in soil previously untilled by full-width inversion implements.

This practice may be applied as part of a conservation management system to support one or more of the following: reduce sheet and rill erosion, reduce wind erosion, maintain or improve soil organic matter content, conserve soil moisture, manage snow to increase plant-available moisture or reduce plant damage from freezing or desiccation, and to provide food and escape cover for wildlife.

Residue Management, Mulch Till: Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round, while growing crops where the entire field surface is tilled prior to planting.

This practice may be applied as part of a conservation system to support one or more of the following: reduce sheet and rill erosion, reduce wind erosion, maintain or improve soil organic matter content and tilth, conserve soil moisture, manage snow to increase plant-available moisture, and provide food and escape cover for wildlife.

Residue Management, Ridge Till: Managing the amount, orientation, and distribution of crop and other plant residues on the soil surface year-round, while growing crops on pre-formed ridges alternated with furrows protected by crop residue.

This practice may be applied to support one or more of the following purposes: reduce sheet and rill erosion, reduce wind erosion, maintain or improve soil organic matter content, manage snow to increase plant-available moisture, modify cool wet site conditions, and provide food and escape cover for wildlife.

Residue Management, Seasonal: Managing the amount, orientation, and distribution of crop

and other plant residues on the soil surface during a specified period of the year, while planting annual crops on a clean-tilled seedbed, or when growing biennial or perennial seed crops.

This practice may be applied to support one or more of the following purposes: reduce sheet and rill erosion, reduce soil erosion from wind, reduce off-site transport of sediment, nutrients or pesticides, manage snow to increase plant-available moisture, and provide food and escape cover for wildlife.

Contour Buffer Strips: Narrow strips of permanent, herbaceous vegetative cover established across the slope and alternated down the slope with parallel, wider cropped strips.

This practice may be applied to support one or more of the following purposes: reduce sheet and rill erosion; reduce transport of sediment and other water-borne contaminants down slope, on-site or off-site; or enhance wildlife habitat.

Contour Farming: Tillage, planting, and other farming operations performed on or near the contour of the field slope.

This practice may be applied to support one or more of the following purposes: reduce sheet and rill erosion or reduce transport of sediment and other water-borne contaminants.

Herbaceous Wind Barriers: Herbaceous vegetation established in rows or narrow strips in the field across the prevailing wind direction.

This practice may be applied to support one or more of the following purposes: reduce soil erosion and/or particulate generation from wind, protect growing crops from damage by wind-borne soil particles, manage snow to increase plant-available moisture, and provide food and cover for wildlife.

Strip Cropping: Growing row crops, forages, small grains, or fallow in a systematic arrangement of equal-width strips across a field.

This practice may be applied to support one or more of the following purposes: reduce soil erosion from water and transport of sediment and other water-borne contaminants, reduce soil erosion from wind, and protect growing crops from damage by wind-borne soil particles.

Filter Strip: A strip or area of herbaceous vegetation situated between cropland, grazing land, or disturbed land (including forestland) and environmentally sensitive areas.

This practice may be applied to support one or more of the following purposes: reduce sediment, particulate organics, and sediment-absorbed contaminant loadings in runoff, reduce dissolved contaminant loadings in runoff, serve as Zone 3 of a Riparian Forest Buffer, Practice Standard 391, reduce sediment, particulate organics, and sediment-absorbed contaminant loadings in surface irrigation tailwater, restore, create or enhance herbaceous habitat for wildlife and beneficial insects, and maintain or enhance watershed functions and values.

Grade Stabilization Structure: A structure used to control the grade and head cutting in natural or artificial channels.

Grassed Waterway: A natural or constructed channel that is shaped or graded to required dimensions and established with suitable vegetation.

This practice may be applied as part of a conservation management system to support one or more of the following purposes: to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding; to reduce gully erosion; and to protect/improve water quality.

Sediment Basin: A basin constructed to collect and store debris or sediment.

This practice may be applied to support one or more of the following purposes: preserve the capacity of reservoirs, wetlands, ditches, canals, diversion, waterways, and streams; prevent undesirable deposition on bottom lands and developed areas; trap sediment originating from construction sites or other disturbed areas; and reduce or abate pollution by providing basins for deposition and storage of silt, sand, gravel, stone, agricultural waste solids, and other detritus.

Terrace: An earth embankment, or a combination ridge and channel, constructed across the field slope.

This practice may be applied as part of a resource management system to reduce soil erosion and retain runoff for moisture conservation.

Water and Sediment Control Basin: An earth embankment or a combination ridge and channel generally constructed across the slope and minor watercourses to form a sediment trap and water detention basin.

This practice may be applied to support one or more of the following purposes: improve farmability of sloping land, reduce watercourse and gully erosion, trap sediment, reduce and manage onsite and downstream runoff, and improve downstream water quality.

Hedgerow Planting: Establishment of dense vegetation in a linear design.

This practice may be applied to provide one or more of the following functions: food, cover, and corridors for terrestrial wildlife; food and cover for aquatic organisms that live in watercourses with bank-full width less than 5 feet; to intercept airborne particulate matter; to reduce chemical drift and odor movement; to increase carbon storage in biomass and soils, living fences, boundary delineation, contour guidelines, screens and barriers to noise and dust; and improvement of landscape appearance.

Field Border: A strip of permanent vegetation established at the edge or around the perimeter of a field.

This practice may be applied to support one or more of the following purposes: reduce erosion from wind and water, soil and water quality protection, management of harmful insect populations, provide wildlife food and cover, increase carbon storage in biomass and soils, and improve air quality.