Design and management of edge-of-field water control structures for ecological benefits

F.D. Shields, Jr., P.C. Smiley, Jr., and C.M. Cooper

ABSTRACT: Stream channel incision often triggers formation of tributary gullies. These gullies erode and extend into fields, generating sediments that pollute downstream waters and degrade aquatic habitats. Standard practice for gully treatment involves damming using an earthen embankment with drainage provided by an L-shaped metal pipe. To date, thousands of these structures, also known as drop pipes, have been constructed in riparian zones adjacent to agricultural areas, but environmental criteria have played no role in design. Sixteen drop pipe sites (defined as the region of temporary or permanent impoundment created by the structure) in northwestern Mississippi were sampled for fish, amphibians, reptiles, birds, and mammals; and physical habitat characteristics were assessed by sampling vegetation and surveying site topography. Speciose sites (those yielding 65 to 82 vertebrate species) were relatively large [≥ 0.09 ha (.22 ac)], with a significant pool area. Depauperate sites (only 11 to 20 species captured) were smaller, with no pool area and little woody vegetation. Considerable environmental benefits could be realized by slightly modified design and management of drop pipe structures. Results of this study suggest habitat benefits are minimal for sites smaller than 0.1 ha (0.2 ac), for sites lacking woody vegetation, and for sites that do not have at least 20% of their area below the inlet weir elevation.

Keywords: Amphibians, birds, ecological impairment, erosion control, fish, gully, mammals, reptiles, riparian zone, species diversity

Accelerated erosion associated with channel bed lowering is a major problem in many agricultural watersheds (Wang et al. 1997, Darby and Simon 1999). Whenever bed lowering is extensive enough to lower the energy grade line in a channel, the base level for all points upstream is also lowered, elevating stream power and sediment yield. Overland flow passing over the top of banks becomes more erosive, frequently triggering gully development and expansion. Through repetitive surveys of two such gullies in Northern Mississippi, Cooper et al. (2000) showed that gully volume increased by factors of three and six during only two years). Gullies and other types of erosion from agricultural lands have been cited as the leading source of sediment in waterways (Pimentel et al. 1987, U. S. EPA 1998). Piest and Bowie (1974) reported that sediment emanating from four Iowa gullies comprised about 20% of the total sediment yield from their watersheds, which ranged in size from 30 to 60 ha (70 to 140 ac). Similar long term studies of gullies in agricultural watersheds in northern Mississippi indicated annual sediment yields of 50,000 to 250,000 t km^{-2} (140,000 to 700,000 T mi^{-2}) of gully area, but that gullies comprised a declining fraction of total sediment yield in larger watersheds since much of the sandy sediment derived from gullies was stored as colluvium (Miller et al. 1962). Gullies that form within riparian zones between fields and streams are often treated with water control structures similar to those that have been in use for decades (Uhland and Wooley 1929, Ramser 1932, Jepson 1939). The typical structure consists of an L-shaped corrugated metal pipe passing through an earthen embankment placed at the downstream end of the gully (Figure 1). These drop pipes retain runoff on the edge of fields, allow sediment deposition at field level where it may be reclaimed, and dissipate excessive runoff energy as flow is conducted down to channel level through the pipe. Properly designed structures can practically halt gully advancement (Cooper et al. 2000). Drop pipes are also valuable in undulating landscapes where they drain discontinuous parallel terraces. One study in such a setting showed sediment trapping efficiency exceeded 97% (Mielke 1985). A study of relatively intensive gully treatment in the Southern Plains showed that small [4 to 6 ha (10 to 15 ac)] watershed remediation (including building a runoff detention pond) reduced sediment yield sixfold and halved nutrient loss (Sharpley et al. 1996). Sediment and contaminant retention are enhanced by permanent or semi-permanent pool formation upstream of the pipe inlet (Schepers et al. 1985).

Drop pipe structures are generally placed in gullies deeper than 3 m (10ft), and embankments are typically 4.5 to 6 m (15 to 20 ft) high. Minimum safety factors for embankments are 1.3, dictating side slopes of 1V on 2H to 1V on 3H. Pipes are sized to convey the two- to ten-year event based on standard Soil Conservation Service (now called the Natural Resources Conservation Service) runoff curve number computations (Rawls et al. 1993), and an emergency spillway is provided to convey flows larger than the design discharge (Trest 1997). Design discharges are typically less than 5.7 m^3 s^{-1} (200 cfs), and the vertical distance from the inlet weir crest to the outlet pipe invert is less than 9 m (30 ft)(USDA 1992). Pipe diameter and length are used to compute head-discharge relations, and pipe diameter is adjusted to avoid orifice flow at discharges less than or equal to design flow. Drop pipes may

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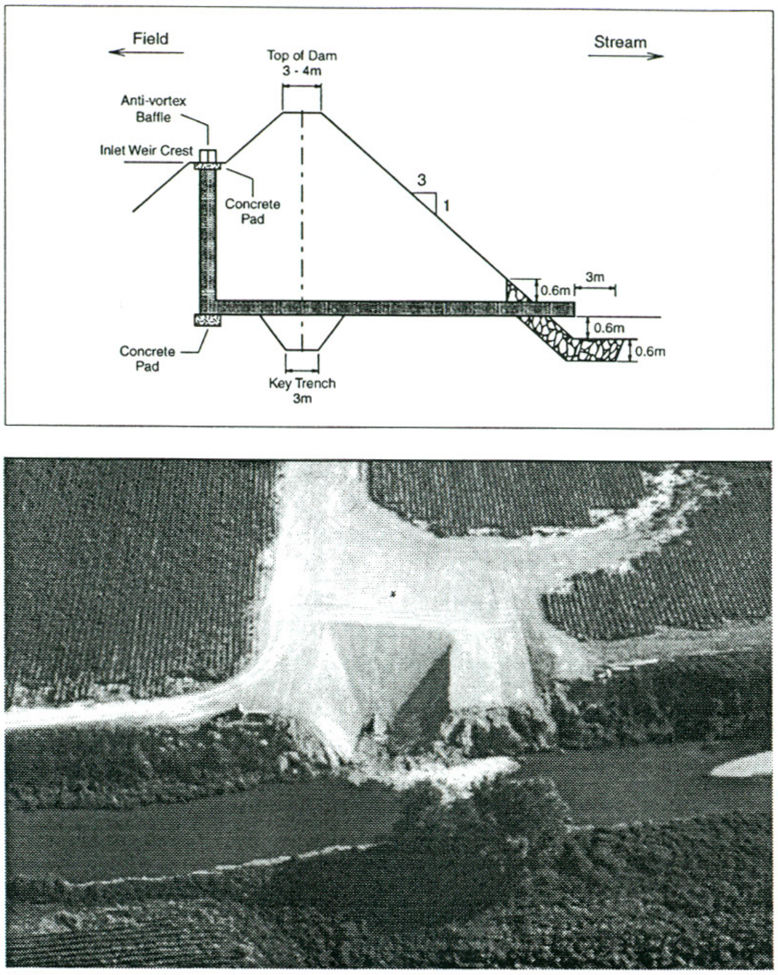
Figure 1

Schematic of drop pipe structure including earthen embankment, and oblique air photo of recently completed drop pipe viewed from downstream (stream channel) side of the embankment.



be designated non-storage structures, which are sized to pass the two- to five-year event, or temporary storage structures, which are designed to impound runoff from the 25-year event (U. S. Army Corps of Engineers 1990). Water retention is governed by site factors (soils, topography, water supply) and by the elevation of the inlet weir and emergency spillway.

Pipe materials are typically either aluminized or galvanized polymer-coated metal. Seepage through the earthen embankment is controlled with seepage collars for structures with conduits 1.2 m (4 ft) in diameter or smaller, and with annular filter drainage rings for larger conduits. Where the structure will impound water permanently, a filter drainage diaphragm is used. Concrete pads are provided at the top and bottom of the vertical pipe, and an anti-vortex baffle is placed in the inlet to maintain weir flow and avoid vibration during very large events. Outlets are supported with grouted riprap and secured with screw anchors. In addition, stone erosion protection is provided at the outlet for structures larger than 1.2 m (4 ft) in diameter. Since top-of-bank gullies occur frequently along streams experiencing incision (channel bed lowering), large numbers of these structures are sometimes required. For example, 2,800 drop pipes were planned to treat riparian gullies along channels draining 16 watersheds in the hill region of the Yazoo River basin in northwestern Mississippi with a total area of 6,800 km^2 (2,600 mi^2) (Trest 1997).

Embankments, pools, and entry and exit channels associated with drop pipes partially replace massive habitat losses in the agricultural landscape. Wetland area has declined dramatically throughout much of the United States, primarily due to draining and clearing for agriculture (The Conservation Foundation 1987, Schmidt et al. 1991), and channelization activities (U.S. Department of the Interior 1982) with attendant channel incision (Hupp 1997). Hefner and Brown (1985) estimated that 50% of the nation's wetland resources were in 10 southeastern states and that 84% of the losses of wetlands between the mid 1950s and mid 1970s occurred in the Southeast. Nearly all losses of freshwater wetlands were attributed to agricultural development. In Mississippi, 59% of original wetland area has been lost, and of that, 54% has been converted to agriculture (U.S. Department of the Interior 1991). Similar losses (up to 70% of overall riparian habitat lost or altered) have been reported for North American riparian corridors (U.S. Department of the Interior 1982, Naiman et al. 1993). Losses of wetlands that support amphibian populations are of special concern because amphibians comprise very high levels of biomass in some ecosystems (Burton and Likens 1975), but are apparently declining worldwide (Blaustein et al. 1994). Habitat loss for amphibians is of special concern in the southeastern United States (Dodd 1997).

Drop pipe structures in Mississippi often create wetland habitats for fish, amphibians, reptiles, birds, and mammals with 75 vertebrate species reported (Smiley et al. 1997, Cooper et al. 1997), including 57 species of birds (Smiley et al., in preparation), 10 species of small mammals (Smiley and Cooper, in preparation), and 8 fish species (Smiley et al. 1999). Vertebrate species richness has been documented to compare favorably with other types of freshwater wetland habitats such as the red maple (*Acer rubrum*) swamps of the Northeast (Cooper et al. 1997). Water quality (Knight et al. 1997) and sediment quality (Steevens and Benson 1998, Steevens 1999) conditions in drop pipe pools appear adequate for aquatic and semi-aquatic species of plants and animals, with generally better water quality in deeper pools.

A survey of 180 drop pipes in Mississippi during 1994 revealed that only 7.2% of the sites provided habitat typified by pool development, vegetative structure, and relatively large area (site area definition described below) (Figure 2a). Sites with minimal vertebrate habitat value (no permanent pool, monotypic exotic herbaceous vegetation,

Figure 2

Range of habitat conditions commonly found in northwestern Mississippi drop pipe areas.
(a) Large wetland with permanent pool, woody debris, and shoreline woody vegetation.
(b) Small site lacking permanent pool and showing effects of periodic mowing.

restricted area, Figure 2b) were most common, comprising 61% of sites surveyed (Shields et al. 1995). Habitat conditions reflected landowner practices, site topography, and design, but intentional consideration of ecological values in design and management was not observed. Past drop pipe habitat research has examined trends in vertebrate species richness across a continuum of created habitat characteristics. Vertebrate species richness was found to increase from a minimum in small, terrestrial riparian habitats to a maximum within large permanent wetland habitats having the greatest vegetative structure (Cooper et al. 1997, Smiley et al. 1997). The importance of particular habitat variables, however, has not been examined.

Other workers have suggested modifications to drop pipe and retention basin design to enhance effluent water quality (Jarrett 1993), but design criteria for habitat values have not been discussed. The purpose of this paper is to quantitatively examine the importance of selected habitat variables on vertebrate taxa in order to extract design and management criteria that will lead to increased levels of vertebrate diversity.

Methods and Materials

Sixteen drop pipe sites adjacent to incised streams in northwestern Mississippi were selected for study. Sites were selected to represent a wide range of habitat conditions (size, pool development, vegetation). Nine of the sixteen sites had storage pools that provided aquatic habitat. Drop pipes were constructed between 1969 and 1992; ten of the structures were emplaced between 1986 and 1988.

Sites were surveyed using a total station and prism pole. Surveyed areas encompassed the drop pipe embankment, drop pipe inlet, pool, and natural vegetation surrounding the pool. Site perimeters were subjectively determined based on vegetation (e.g., transition from natural vegetation to cultivated areas) and topography. The upstream face of the earthen embankment was used as one site boundary. Survey data were input to a commercial software package that produced a three-dimensional digital model of each site using a kriging algorithm (Golden Software, Inc. 1999). The digital models were then used to plot contour maps for each site and to compute areas and volumes corresponding to selected elevations [+50 cm, 0 cm, and -25 cm (1.6 ft, 0 ft, -0.8 ft)] relative to the inlet weir crest. Resulting volumes (as a percent of total volume) varied widely for our 16 study sites. Although the survey data sets did not contain a depiction of the water surface, these quantities areas and volumes were selected because they were amenable to control via design and management and were highly indicative of the ability of a site to create and retain aquatic habitat.

Terrestrial vegetation was sampled at each site by conducting a census of all plants in two or three 1 m x 1 m (3.3 ft x 3.3 ft) quadrats located along each of three transects that originated at the drop pipe inlet and radiated outward along lines pointing due north and at 120 and 240 degrees away from due north. If a pool was present, quadrat one on each transect was located at the pool margin. Quadrats two and three were always located in the middle of the terrestrial habitat and at the margin of the drop pipe habitat and agricultural field, respectively. For description, plant communities were stratified by height as they were sampled, with tiers assigned to intervals of 0 to 0.55 m, 0.56 to 1.8 m, and > 1.8 m (0 to 1.8 ft, 1.8 to 5.9 ft, and > 5.9 ft). For each quadrat and tier, the three most dominant plant species based on the amount of area occupied were recorded.

A simple index was computed that reflected the dominance of woody plants taller than 1.8 m (5.9 ft), with added weight given to quadrats adjacent to pool shorelines. The index was computed using only data from tier 3 [height > 1.8 m (5.9 ft)]. Sites with no woody plants taller than 1.8 m (5.9 ft) produced an index of 0, while a site where woody species comprised the three most abundant species in tier 3 of all quadrats would produce an index of 1.0.

Sites were sampled seasonally for vertebrates using traditional approaches over a three year period (1994 - 1996). Sampling details are provided elsewhere (Cooper et al. 1997, Smiley et al. 1997), and will only be summarized here. Fish were collected from sites with permanent pools using hoop nets, seines, and backpack electroshockers. Sites were fished with electroshockers once, with seines on four to five dates, and with hoopnets on 10 dates in spring and summer. Small mammals, amphibians, and reptiles were captured using a network of alternating pitfall and Sherman live traps stationed along transects that enclosed each site. Traps were used for seven to nine consecutive nights during each season. Reptiles and amphibians were also captured using fishing gear. Birds were sampled 10 to 16 times per season using 10 min unlimited radius point counts from the earthen embankment of the drop pipe structure. Sampling time of day and observers were rotated among sites to account for observer and temporal biases. Vertebrate sightings and captures that resulted from opportunistic encounters were also recorded.

Data resulting from vertebrate sampling were used to compute species richness and abundance by faunal group and for all vertebrates for each site. The number of species for each faunal group and the total number of vertebrate species were used in multiple linear regression analyses with key physical quantities as independent variables. Faunal similarity of sites was explored using detrended correspondence analysis (DCA) of species abundances. DCA is one of a family of analysis techniques used to find patterns in a data set comprised of a list of abundances of various species at a number of sampling sites. The underlying patterns in species distribution often reflect gradients of habitat quality or interspecific interactions. Although a full explanation of DCA is beyond the scope of this paper, readers wishing more information may consult textbooks or "Ordination Methods for Ecologists," http://www.okstate.edu/artsci/botany/ordinate/, a web site built and maintained by Mike Palmer, Botany Department, Oklahoma State University, Stillwater, Oklahoma 74078. We set up our DCA to omit species represented by a single capture (McCune and Mefford 1999). Rare species were downweighted, and raw species abundances were standardized by dividing by the mean abundance for each species. Key physical habitat variables were compared to axes derived from the DCA to explore relationships between habitat and faunal response.

Table 1. Physical characteristics of riparian habitats created by installation of 16 edge-of-field water control structures (drop pipes), northwestern Mississippi.

Site characteristic	Median	Mean	Standard Deviation	Maximum	Minimum
Site area, ha	0.113	0.158	0.158	0.649	0.017
Site area below weir crest, %	13.5	24.2	28.5	77.0	0.0
Woody index, %	15.0	18.3	17.1	54.0	0.0

Results and Discussion

Site areas ranged from 0.02 to 0.65 ha (0.05 to 1.6 ac). Survey data were analyzed to produce five quantities that were descriptive of site topography: total site area, mean depth (total site volume divided by total site area), percent of site area below the inlet, and the volume (both dimensional volume and percent of total volume) below a horizontal plane located 50 cm (19.7 in) above the inlet elevation. Three of these variables were dropped from the analysis because of significant intercorrelation ($r > 0.62$, $p < 0.012$). Summary statistics for the two remaining variables, total site area and percent of site area with an elevation lower than the inlet, are presented in Table 1.

Summary statistics for our woody vegetation index are also tabulated in Table 1. The woody vegetation index was not correlated with any of the physical variables derived from survey data ($r < 0.43$, $p > 0.1$). Although 133 plant species were recorded, dominant species were similar among sites. Native black willow (*Salix nigra*) was most dominant in tier 3 [> 1.8 m (5.9 ft) high] for five of the 16 sites, while no plants were reported in tier 3 for five sites. Other woody species reported as dominants included white ash (*Fraxinus americana*), sycamore (*Platanus occidentalis*), and winged elm (*Ulmus alata*). Lower tiers were dominated by the exotics kudzu (*Pueraria lobata*), bermuda grass (*Cynodon dactylon*), and Japanese honeysuckle (*Lonicera japonica*) in that order, and by the natives goldenrod (*Solidago* spp.) and blackberry (*Rubus argutus*). Values of our woody vegetation index varied from 0 to 0.54 with a mean of 0.18. Four of the 16 sites received index scores of 0.00.

The mean species richness of all vertebrate classes combined was 44.3 (standard deviation (S.D.)= 26.2). Mean species richness per site varied among the different vertebrate classes. Fish were captured from only two sites, and the mean species richness was 5.5, while a total of eight fish species was documented. Mean species richness was 5.9 (S.D. = 4.8) for amphibians, 3.8 (S.D. = 3.8) for reptiles, 11.8 (S.D. = 4.3) for mammals, and 22.0 (S.D. = 14.0) for birds. Species richness for the four main faunal groups (amphibians, reptiles, mammals, and birds) exhibited a high level of intercorrelation ($r > 0.68$, $p < 0.004$). The abundance of birds was positively correlated with abundances of amphibians, reptiles, and mammals ($r > 0.52$, $p < 0.04$), but abundances of these three groups were not intercorrelated. No fish and few amphibians were collected from sites without a storage pool [i.e., sites in which the mean depth below the weir crest was between 0 and 6 cm (0 and 2.3 in.)]. For sites with storage pools, the abundances of fish and amphibians were inversely related. No fish were captured at the seven shallower sites [mean depth below the weir crest between 6 and 69 cm (2 and 27 in.)], but an average of 213 amphibians were collected from each site. However, a total of 1,308 fish and only 42 amphibians were taken from the two deeper sites [mean depths below the weir crest of 72 and 89 cm (28 and 35 in.)]. Neither of the sites yielding fish supported high levels of woody vegetation (woody vegetation index = 8% for both sites), so we were unable to observe the combined effect of extreme values of these two habitat variables.

Multiple linear regression analyses showed the strong positive association between habitat variables and vertebrate species richness (Table 2). Standard coefficients for the physical variables (woody vegetation index, fraction of the site below inlet weir elevation, and total site area) were positive in all cases, and all equations were statistically significant ($p \leq 0.004$). The fraction of site area lower than the inlet weir elevation, an expression of the availability of aquatic habitats, was most important in the regressions for the numbers of amphibian and reptile species, while total site area was most influential in regressions for the numbers of terrestrial (bird and mammal) species. Woody vegetation was apparently most influential for mammals. When the total number of

Table 2. Standard coefficients[1] for multiple linear regression for number of species.

Vertebrate class	Woody vegetation index, %	Fraction of site area below inlet weir elevation	Total site area	Coefficient of determination, r^2	p
Amphibians	0.31	0.55	0.39	0.83	<0.001
Reptiles	0.25	0.53	0.32	0.66	0.004
Birds	0.28	0.48	0.57	0.92	<0.001
Mammals	0.42	0.23	0.58	0.75	<0.001
All vertebrates	0.29	0.48	0.57	0.94	<0.001

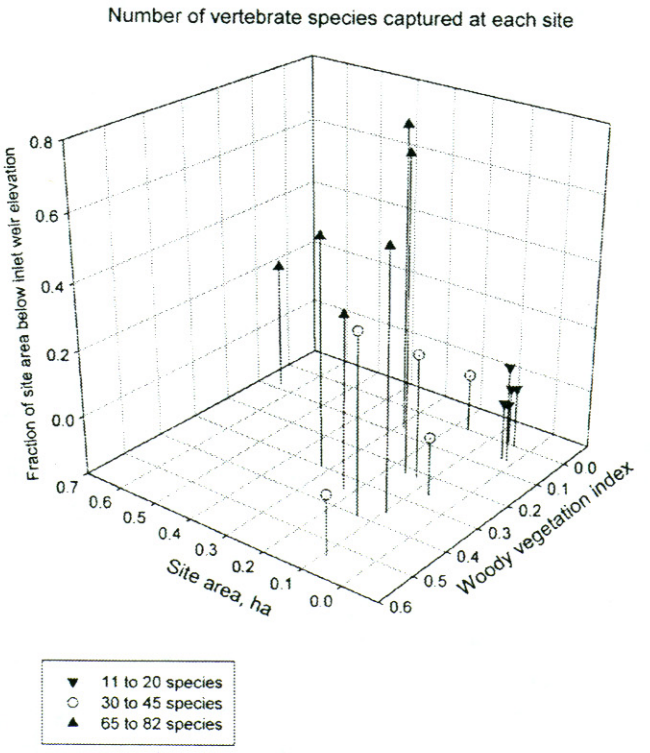
[1] Standard coefficients are obtained by multiplying regression coefficients by the ratio of the standard deviation of the independent variable and the standard deviation of the dependent variable to obtain dimensionless values that are comparable.

vertebrate species captured at each site is examined in light of the three physical variables, clear gradients emerge (Figure 3). Speciose sites (those yielding 65 to 82 vertebrate species) were relatively large (> 0.09 ha (0.2 ac), with a significant pool area. Depauperate sites (only 11 to 20 species captured) were smaller than 0.1 ha (0.25 ac), with no pool area and little woody vegetation. Sites with moderate levels of species richness were of intermediate size with a range of pool and vegetation conditions.

A matrix representing the abundance of 119 species at the 16 drop pipe sites produced three axes in DCA, but only the first two were significant. DCA axis I was inversely related to the woody vegetation index (r = -0.58), and DCA II was inversely related to total site area (r = -0.53) and to the fraction of site area with an elevation lower than the inlet weir (r = -0.44). Since only the two sites that supported fish had extensive pools but little woody vegetation, correlations between our DCA axes and pool area were weakened. Overall, however, community structure (species richness, abundance, and composition) responded positively to increases in woody vegetation, pools, and site area, as indicated by sites that the DCA analysis identified as most different (Table 3). Only the feral dog and a few avian species [e.g., dickcissel (*Spiza americana*) and the common grackle (*Quiscalus quiscula*)] plotted high on both DCA axes I and II, showing association with small sites without pools or significant woody vegetation (Figure 4). The region of the DCA plane defined by low values of DCA I and II corresponded to larger, brushy sites with permanent pools that were speciose, being populated by reptiles [e.g., mud turtle (*Kinosternon subrubrum*) and skinks (*Eumeces* spp.)], birds [e.g., Louisiana waterthrush (*Seiurus motacilla*) and white-eyed vireo (*Vireo griseus*)], and numerous amphibians [e.g., tree frogs (*Hyla* spp.) and toads (*Bufo* spp)]. Most mammal species plotted in the middle of the DCA plane.

Figure 3

Sixteen drop pipe habitats in northwestern Mississippi included in this study plotted in 3-dimensional space with axes corresponding to key physical habitat variables. Symbols indicate the total number of vertebrate species captured during the course of this study.



Areas adjacent to edge of field water control structures represent small fragments of a formerly extensive habitat—riparian forested wetland. Although these areas are small and often of marginal quality, evidence from other regions indicate that they have considerable value and importance. A study of fragments of remaining Florida scrub revealed that the ecological response to fragmentation varies by species, making generalization difficult, but that even small fragments are likely to be of considerable value, and that habitat reclamation and management is an important strategy for retaining conservation value (McCoy and Mushinsky 1999). Simulations showed that the loss of small [<4.05 ha (10 ac)] wetlands in a 600 km^2 (230 mi^2) area in central Maine resulted in a 67% increase of the average interwetland distance and a decrease from 90 to 54% in the portion of the landscape within maximum migration distance for amphibians (Gibbs 1993). Migration distances are important for amphibians, as many live in terrestrial habitats, but breed in wetlands. Model simulations also revealed that local populations of turtles, small birds, and small mammals faced a significant risk of extinction after the loss of small wetlands. Moler and Franz (1987) produced similar findings regarding the value of small, isolated wetlands in the southeastern coastal plain. A group of 28 small [<3.7 ha (9.1 ac)], isolated wetlands supported a diverse assemblage of animals quite different from that found in 13 larger wetlands. Even the smallest of these areas were extremely productive of amphibian species

Table 3. Characteristics of sites identified as extremes based on detrended correspondence analysis (DCA) of species abundance.

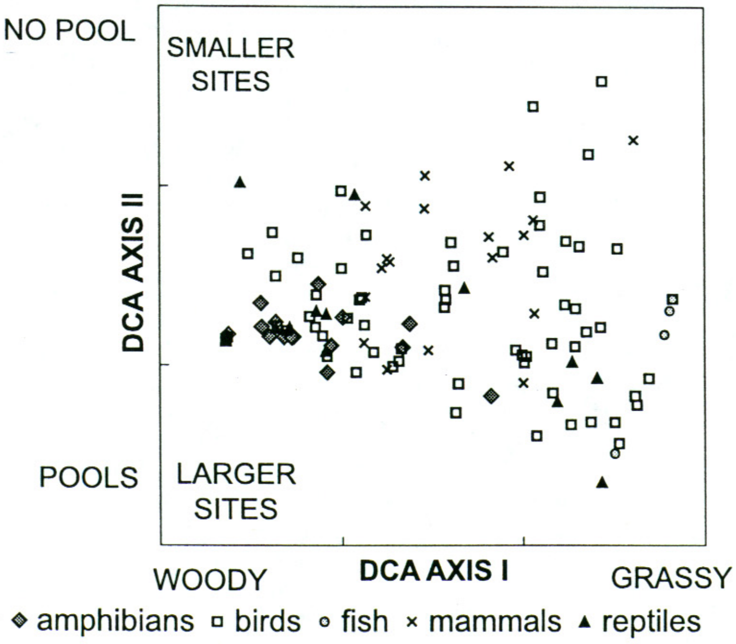
	Site H15	Site H23
DCA Axis I	0	199
DCA Axis II	72	298
Total area, ha	0.32	0.17
Woody vegetation index	0.30	0.0
Fraction of site area lower than inlet weir, %	52	0
Total number of species	79	35
Total number of captures	896	379
Number of species in each vertebrate class with more than 5 captures	7 amphibians, 2 reptiles, 8 birds, 7 mammals	6 birds and 7 mammals

that were absent from open marshes and riparian and forested wetlands. Many amphibians cannot survive predation in larger wetlands, but reach high densities in smaller, ephemeral pools and ponds. Receding water levels in these areas allow wading birds and reptiles to access concentrated prey organisms. Semlitsch and Bodie (1998) used similar reasoning to interpret findings regarding the presence and distribution of natural wetlands smaller than 1.2 ha (3.0 ac) on the upper coastal plain of South Carolina. They argued that small wetlands are extremely valuable for maintaining biodiversity, and that the loss of small wetlands causes a direct reduction in connections among remaining species populations, especially amphibians.

Our results clearly show that the riparian vertebrate communities within drop pipe sites were positively associated with increasing levels of habitat area, pool development, and vegetative structure, confirming earlier qualitative findings (Cooper et al. 1997, Smiley et al. 1997 and 1999). Furthermore, the physical attributes we measured are amenable to control through design decisions and management actions. Designers should avoid creating sites smaller than 0.1 ha (0.2 ac), sites lacking woody vegetation (producing indices < 0.2) and sites that do not have at least 20% of their area below the inlet weir elevation. Such sites provide minimal habitat value and are already common (Shields et al. 1995). Some landowners may resist restricting production in larger areas adjacent to drop pipes, but even smaller sites [<0.2 ha (0.5 ac)] can be valuable habitats with adequate pool development and vegetative structure (Figure 3).

Figure 4

Ordination of all vertebrate species with more than one individual captured from 16 drop pipe sites in this study. Ordination is based on first two axes of detrended correspondence analysis (DCA) using species abundance at each site divided by mean across all 16 sites.



Although additional testing is warranted, our findings indicate that habitat manipulations can target specific faunal groups (Table 2). Larger site areas favor birds and mammals, while reptiles and amphibians respond positively to larger storage pools. Amphibians are favored by shallower [mean depth < 70 cm (28 in)] pools, while fish dominate deeper, more permanent pools (Moler and Franz 1987, Smiley et al. 1999). Mammals are positively influenced by the dominance of woody vegetation > 1.8 m (5.9 ft) tall. Smiley and Cooper (In preparation) reported that diversity and abundance of small mammals were significantly lower in drop pipe habitats that lacked pools and vegetative cover. Bird species richness, abundance, and diversity were positively influenced by vegetative structure, pool depth, and habitat area.

Site area and pool volume are influenced by dam placement, excavation to prepare for dam and pipe placement, and selection of the weir inlet elevation. In some cases, it may be possible to increase pool area and volume by borrowing material for the embankment from within the site. Many of the design features suggested for ponds or constructed wetlands might be useful, such as excavating storage pools with sinuous shorelines and providing a diversity of depths including peninsulas and islands. Finally, vegetation conditions over the long term are dependent upon management activities [cutting, burning, use of herbicides, removing exotic vegetation such as kudzu (*Pueraria lobata*)], as are the depth and volume of the pool (in-field erosion control, sediment removal, and redistribution on cultivated areas). Our data show that these types of measures pay definite dividends in faunal species richness.

Summary and Conclusion

Edge-of-field drop pipes in northwestern Mississippi and in similar settings elsewhere currently serve as environmental assets, trapping sediments and other nonpoint source contaminants. Downstream sediment loads are reduced as drop pipes prevent erosion due to gully extension, and the small ponds, wetlands, and backwaters associated with drop pipes are extremely valuable habitat elements in the agricultural landscape. Drop pipes may be designed and managed to increase the number of bird, mammal, and reptile species resident in the resulting habitats. Fish and amphibians appear dependent upon the depth of water in the permanent pool, with fish dominating deeper [mean depth > 70 cm (28 in)] pools and amphibians dominating shallower ones. Few individuals representing a few opportunistic species will be found in small drop pipe habitats that are periodically cleared of natural vegetation and that do not hold water.

Acknowledgements

Collection of data described herein required extensive field work by many people. Among these were Ken Kallies, Jonathan Maul, John Wigginton, Todd Randall, Kim Damon, and Ezekiel Cooper. Additional contributions were made by Sam Testa, Scott Knight, Seth Martin, Chip Butts, and David Horn. Paul Mitchell prepared Figure 1. An earlier version of this paper was reviewed by Andrew Sheldon, Scott Knight, and Paul Rodrigue.

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