

## PATTERNS OF AVIAN NEST PREDATORS AND A BROOD PARASITE AMONG RESTORED RIPARIAN HABITATS IN AGRICULTURAL WATERSHEDS

JONATHAN D. MAUL<sup>\*,†</sup>, PETER C. SMILEY, JR.<sup>‡</sup> and CHARLES M. COOPER  
*USDA-ARS, National Sedimentation Laboratory, 598 McElroy Drive, Oxford,  
Mississippi, U.S.A.*

(\*author for correspondence, e-mail: jmaul@siu.edu)

(Received 28 January 2004; accepted 22 September 2004)

**Abstract.** In fragmented edge-dominated landscapes, nest predation and brood parasitism may reduce avian reproductive success and, ultimately, populations of some passerine species. In the fragmented agroecosystem of northwest Mississippi, placement of drop-pipe structures has been used as a restoration technique for abating gully erosion along stream banks. These actions have formed small herbaceous and woody habitat extensions into former agricultural lands. We quantified species relative abundances, species richness, and evenness of avian nest predators and a brood parasite within four categories of constructed habitat resulting from drop-pipe installation. Differences in the abundance of two nest predators, cotton mouse (*Peromyscus gossypinus*) and blue jay (*Cyanocitta cristata*), were observed among constructed habitats. However, relative abundances of other predators such as common grackle (*Quiscalus quiscula*), American crow (*Corvus brachyrhynchos*), and hispid cotton rat (*Sigmodon hispidus*), and the obligate brood parasite brown-headed cowbird (*Molothrus ater*) did not differ among four habitat categories. Although species richness, abundance, and evenness of potential nest predators were generally similar among the constructed habitats, predator species composition varied, suggesting that these habitats supported different predator communities. This difference is important because as each predator species is added to or deleted from the community, variation may occur in the framework of prey search methods, predator strategies, and potentially overall predation pressure. We suggest that land managers using drop-pipes as part of stream restoration projects allow for the development of the constructed habitat with the largest area and greatest vegetative structure.

**Keywords:** agricultural watershed, avian nest predators, brown-headed cowbird, Mississippi, riparian habitat, stream restoration

### 1. Introduction

Nest predation and brood parasitism are ecological processes that reduce avian reproductive success (Mayfield, 1977; Ricklefs, 1969). Increased rates of predation and brood parasitism by the brown-headed cowbird (*Molothrus ater*) have been attributed to fragmentation of habitats (Brittingham and Temple, 1983; Wilcove, 1985) and have been suggested to negatively impact some populations of passerine

<sup>†</sup>Present address: Environmental Sciences Program, Arkansas State University, P.O. Box 847, State University, Arkansas 72467, U.S.A.

<sup>‡</sup>Present address: Department of Wildlife and Fisheries, Mississippi State University, P.O. Box 9690, Mississippi State, Mississippi 39762, U.S.A.

species (Robinson *et al.*, 1995a). Agricultural field edges and forest fragments are typical locations of elevated brood parasitism and predation rates (Brittingham and Temple, 1983; Gates and Gysel, 1978; Wilcove, 1985). These rates may be exceptionally high in agricultural landscapes (Robinson, 1992) where feeding and breeding sites for brown-headed cowbirds, which are usually separate (Rothstein *et al.*, 1980, 1984), are numerous and close to one another (Robinson *et al.*, 1995a, 1995b). Furthermore, habitat edges may act as travel corridors for mammalian predators (Bergin *et al.*, 1997; Small and Hunter, 1988), facilitating nest finding.

In the loess hills of northern Mississippi, contemporary forest habitat patches often consist of narrow riparian corridors that remained after historical forest clearing for agriculture. These corridors are both small in area and encompassed by agricultural fields, and may be locations that experience high nest predation and brood parasitism. Gully erosion occurs frequently along these riparian corridors, resulting in the loss of large amounts of sediment from the streambank and adjacent agricultural fields (Shields *et al.*, 2002). Current methods for management of gully erosion along such corridors have formed small herbaceous and woody habitat extensions into the adjacent agricultural area (Cooper *et al.*, 1997; Smiley *et al.*, 1997). In this study, we monitored the relative abundances of potential avian nest predators, brood parasites, and parameters of the entire predator community at constructed riparian habitats resulting from erosion control practices. These responses were compared among four general categories of the created riparian habitats. Results of this study can be used to identify how current erosion control practices can be adjusted to benefit avifauna, as well as provide baseline data to generate hypotheses for future study of avian nest predation and brood parasitism in agricultural watersheds.

## 2. Study Sites and Methods

### 2.1. STUDY AREA

The study was conducted on Long and Hotophia Creeks in Panola County, Mississippi. Land use in the Long Creek watershed was approximately 19% cropland, 36% pasture, 41% forest, and 4% miscellaneous (USCOE, 1992), while the Hotophia Creek watershed was 8% cropland, 40% pasture, 50% forest, and 2% miscellaneous (Grissinger *et al.*, 1990). In both watersheds, most farming activity was concentrated in the floodplain areas surrounding the creeks and their tributaries and was predominantly cotton and soybean production. Row crop activities usually occurred right to the incised creek bank resulting in only a narrow herbaceous or woody riparian area. Both watersheds have experienced significant erosion problems (e.g., losses of 94,000 tons of soil annually from the streambank) (Grissinger *et al.*, 1990; USCOE, 1992). An erosion control structure called a drop-pipe (Figure 1) was installed at locations of gully erosion along these creeks for stabilizing streambanks and reducing soil loss. Thousands of drop-pipes have been installed throughout

TABLE I  
 Characteristics of constructed riparian habitats in Panola County, Mississippi, 1994 to 1996

Habitat	Area (ha)	Pool volume (m <sup>3</sup> )	Plant species richness	Woody Vegetation index
Type I	0.06	14.8	22.3	0.014
Type II	0.10	41.4	22.3	0.213
Type III	0.13	425.5	26.3	0.301
Type IV	0.37	1343.4	46.3	0.201

Note. Means are given for each habitat type ( $n = 4$ ).

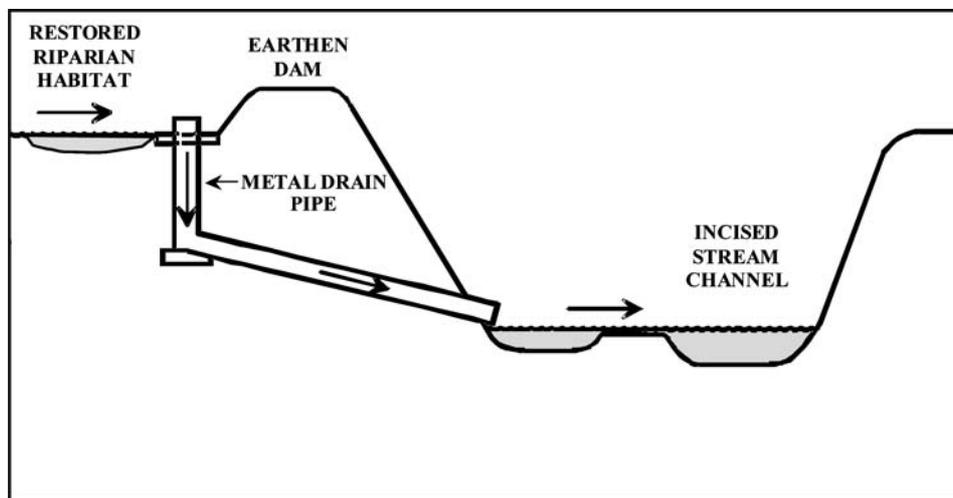


Figure 1. Cross section of a drop-pipe erosion control structure typical of those installed on Long and Hotophia creeks in Panola County, Mississippi. Arrows indicate direction of water flow through the structure.

agricultural watersheds of northern Mississippi as a regional management effort to control frequent and extensive gully erosion (Shields *et al.*, 2002). While fulfilling their purpose of stabilizing the streambank and minimizing soil loss from fields, the structures simultaneously allowed for the development of small herbaceous and woody habitats (<0.65 ha) extending into the adjacent row crops. Essentially, these structures had a widening effect on the riparian corridor. Based on a pre-study survey of 180 drop-pipe sites, the created habitats were found to generally fit one of four discrete types defined by characteristics such as vegetative structure, habitat area, and pool volume (Table I). Habitat classification and delineation protocol were described previously (Cooper *et al.*, 1997; Smiley *et al.*, 1997).

Briefly, Type I habitats were characterized by herbaceous vegetation and having the least amount of woody vegetation. The four dominant plant species were

bermuda grass (*Cynodon dactylon*), goldenrod (*Solidago* spp.), paspalum grass (*Paspalum* spp.), and panic grass (*Panicum* spp.). Type II habitats were characterized by herbaceous vegetation with scattered shrubs and saplings with the four dominant species being Japanese honeysuckle (*Lonicera japonica*), goldenrod, white ash (*Fraxinus americana*), and blackberry (*Rubus argutus*). Type III habitats contained an ephemeral pool surrounded by a ring of vegetation. The four most frequently occurring plant species within the Type III habitats were black willow (*Salix nigra*), bermuda grass, ragweed (*Ambrosia artemisiifolia*), and the introduced kudzu (*Pueraria lobata*). Type IV habitats had permanent pools, an input stream, and woody and herbaceous vegetation. The four most frequently occurring plant species in Type IV habitats were blackberry, goldenrod, partridge pea (*Cassia fasciculata*), and bermuda grass. Woody species found in Type III and IV habitats included boxelder (*Acer negundo*), white ash, sweetgum (*Liquidambar styraciflua*), sycamore (*Platanus occidentalis*), black willow, and winged elm (*Ulmus alata*).

To further quantify vegetative structure, an index of woody vegetative cover was developed and calculated for each site (Shields *et al.*, 2002). The index indicates dominance of woody vegetation above 1.8 m and ranges from 0 (site lacking woody vegetation >1.8 m in height) to 1 (site dominated by woody vegetation above 1.8 m in height) (Shields *et al.*, 2002). This index provides an estimate of vertical vegetation structure, which can be an important habitat feature within the context of nest predation and brood parasitism. Among our study sites, the woody vegetation index was lowest in the Type I sites and greatest in the Type III sites (Table I). However, the largest trees were observed within the Type IV habitats.

While ecological characteristics enabled discrete categorization, site categories resembled a progression from small terrestrial herbaceous habitats (Type I) to larger terrestrial habitats that contained woody vegetation, generally greater vegetative structure, and permanent pools (Type IV) (Table I). A fifth category of unmanipulated (i.e., no drop-pipe) control sites with active gully erosion was also examined during the study and referred to as gully sites. These sites consisted of eroding gullies cutting perpendicular to the creek into adjacent fields and had a perimeter of row crops, herbaceous vegetation, or kudzu. Four replicate sites of each habitat type and gully sites were selected for the study, for a total of 20 sites.

## 2.2. PREDATOR SAMPLING

Ten-minute, unlimited radius point counts were conducted at each site to determine presence and relative abundance of avian predator species and brood parasites. Sampling was conducted over 3 years during the periods of 3 June to 9 June 1994; 5 May to 24 June 1995; and 1 May to 21 May 1996. Sites of habitat type I through IV were visited 12–14 times and gully sites were visited 8–10 times during the study. We repeated counts at the same point because our primary objective was to characterize the avian predators within and around the constructed drop-pipe habitats (Ralph *et al.*, 1995). Point counts were conducted between 0600 and 1130

(CST) and sites were rotated in censusing order and among observers to account for potential temporal and observer biases.

For avian surveys, the constructed habitat was defined as the area of herbaceous and woody vegetation that extended from the drop-pipe at the creek bank into row crop area. This generally accounted for all non-agricultural area on the field-side of the structure. The analogous habitat component for the gully sites was defined as the area of gully erosion (i.e., area that row crops would have existed without severe gully erosion). To maximize information on species within the constructed habitats, point counts were located at the drop-pipe structure where the entirety of the constructed habitat could be surveyed effectively and covered an area that included the constructed habitat and adjacent habitats (i.e., agricultural fields, creek bank, riparian vegetation, etc.). For the gully habitats, point counts were conducted at the leading point of the gully. During point counts, position of each bird was noted as occurring either within the constructed habitat or within the adjacent habitats.

Relative abundance of each species was calculated for each study site by dividing the number of individuals observed during point counts by the number of point counts multiplied by 100 (Hutto *et al.*, 1986). Mean relative abundance was determined for each habitat type from the four replicate sites. Generating a relative abundance from data collected at constructed and adjacent habitats was important because constructed habitats may only constitute a small portion of typical breeding bird territories, foraging ranges of potential avian predators (Andren, 1992), and area covered by daily movements of brown-headed cowbirds (Rothstein *et al.*, 1984). Thus, detections in adjacent habitats may very well present a potential predation or parasitism threat. However, to address our study objective (i.e., compare potential avian predator and brood parasite abundances among the constructed habitats), such relative abundances may be biased because point counts included observations of individuals in constructed as well as adjacent habitats. Consequently, we calculated an additional mean relative abundance using only data from birds observed within the constructed habitat. By separating data as such, we were able to identify relative abundance of potential avian nest predators and brood parasites within the constructed habitats and address our specific objective without losing valuable information on birds within the local vicinity.

In addition, birds observed prior to and after point counts were recorded to contribute more information on bird species in the study area. Thus, three types of data are reported for each avian predator or parasite species and habitat type combination: (1) mean number of individuals detected only within the constructed habitat during point counts, (2) mean number of individuals detected within both constructed and adjacent habitats during point counts, and (3) cumulative number of additional detections that occurred prior to or after point counts.

Small mammals were sampled within constructed habitats using folding live traps (7.6 × 8.9 × 22.9 cm) baited with rolled oats and pitfall traps (19 L buckets buried flush with the ground) during four trapping periods: 28 June to 1 July 1994;

18 July to 27 July 1994; 17 April to 26 April 1995; and 13 July to 20 July 1995. All captured animals were identified to species following Choate *et al.* (1994). Traps were checked daily during each trapping period and closed between trapping periods. Wood covers were placed over pitfall traps and aluminum covers were placed over live traps to reduce trap-related mortality. At each site, traps were positioned at least 1 m from the agricultural field edge, placed 5 m apart, and alternated by trap type (folding live trap or pitfall trap). In the gully sites, small mammals were only sampled with folding traps because burying pitfall traps could initiate further erosion in these unstable areas. Data from gully sites were excluded from analyses since comparisons of small mammal abundance between gully sites and constructed habitat sites would be invalid due to unevenness of sampling technique and effort.

Pools within Type III and IV habitats prevented the use of the standard grid-like trap array; thus, trap transects were situated to enclose the perimeter of all four types of constructed habitats. The large size of the Type IV habitats made surrounding the entire site impractical; therefore, trap transects were placed to surround the pools present within these habitats. In general, the number of traps at each site was proportional to the total area of the constructed habitat.

Because the number of traps within a site varied (positively correlated with habitat area), an index of relative abundance of each species was calculated for each site by dividing the number of individuals captured by the total number of trap nights (TN). Trap nights are a common index of trapping effort, and defined as the product of the total number of traps and the number of nights the traps remained open at each study site. Using abundance/TN corrected for variation in trapping effort among sites.

Predator status of each small mammal species was categorized as follows: (1) known predator documented in published literature, (2) congener documented as avian nest predator, and (3) predator status unknown or evidence that they may not consume bird eggs.

Snakes and other reptiles were sampled using pitfall traps (19 L buckets) during the same four trapping periods described previously for small mammals. Pitfall traps were positioned 10 m apart, encircled each habitat, and were checked every day while traps were open. Snakes were also sampled during nocturnal surveys at each site during the period of 28 June to 1 July 1995, between sunset and 0200 CST. Nocturnal surveys involved a systematic search of a site and ranged from 5 to 45 min depending on the size and vegetative complexity of each site. All snakes captured in pitfall traps or observed during surveys were identified to species (Conant and Collins, 1991) and released. Additional opportunistic observations during site visits occurred between 17 April and 27 July of 1994 and 1995.

### 2.3. PREDATOR COMMUNITY ANALYSIS

In addition to examining variability of abundance of individual predator species among created habitat types, patterns in the overall predator community were also

examined. Species included in the predator community analysis were as follows: avian predators detected within the constructed habitat during point counts at each site known from previously published literature, small mammals of predator status 1 or 2 captured at each site, and known reptile predators captured at each site (i.e., opportunistic observations were not included in the community analysis). Over the entire study period the following predator community indices were calculated for each site: (1) species richness (total number of predator species [ $s$ ]), (2) abundance (total number of predators [ $N$ ]), and (3) evenness (the inverse of Simpson's diversity index [ $1/D$ ; Magurran, 1988]). Simpson's diversity index was calculated as:

$$D = \sum \left( \frac{n_i(n_i - 1)}{N(N - 1)} \right)$$

where  $n_i$  is the number of individuals of predator species  $i$  and  $N$  is the total number of predators observed (Magurran, 1988). Habitat means of each community index were generated from the four replicate sites of each habitat type.

In order to examine the similarity of overall species composition of predator communities between pairs of habitat types, Jaccard community similarity coefficients (Magurran, 1988) were calculated for each habitat pair by summing all avian, mammal, and reptilian predator species present at the four replicate sites of each respective habitat (i.e., sum of the total number of predator species present at each habitat type from all four sites). The Jaccard community similarity coefficient ( $C_J$ ) was calculated as:

$$C_J = \frac{P_j}{P_a + P_b - P_j}$$

where  $P_j$  is the number of predator species shared between two habitat types and  $P_a$  and  $P_b$  are the number of predator species in each of the two habitat types  $a$  and  $b$ , respectively, during a paired comparison (Magurran, 1988). A single community coefficient value was determined for each habitat comparison, ranging from 1 indicating complete similarity to 0 indicating complete dissimilarity between two communities (Magurran, 1988). The Jaccard index was used as a community similarity coefficient because it is less sensitive to high abundance of individual species than other similarity coefficients (e.g., Morista-Horn index; Magurran, 1988). Because of the size of these habitats, addition of species to the predator community potentially may be more detrimental than increasing abundances of single species because with each additional species, a different framework of prey search method and strategy is potentially introduced.

#### 2.4. STATISTICAL ANALYSES

Relative abundance data for avian species, small mammal species, and predator community variables ( $s$ ,  $N$ , and  $1/D$ ) were compared among the four types of

constructed habitat types with analysis of covariance (ANCOVA) ( $\alpha = 0.05$ ) (PROC GLM, SAS Institute Inc., 1989). Habitat area was included in the model as a covariate to control for variation due to area and to assist our interpretation of habitat effects. Data that failed to satisfy the normal distribution and homogeneity of variance assumptions of ANCOVA despite  $\log(x + 1)$  transformations (Zar, 1984) were compared among the four types of constructed habitats and gully sites with ANCOVA on ranks ( $\alpha = 0.05$ ) (PROC GLM, SAS Institute Inc., 1989). Tukey multiple comparison tests were used to separate means upon significant ANCOVAs. Data on birds observed prior to and after point counts were not subjected to statistical testing.

### 3. Results

#### 3.1. NEST PREDATORS AND BROOD PARASITE

The obligate nest parasite brown-headed cowbird (Brittingham and Temple, 1983) and three known avian nest predators including blue jay (*Cyanocitta cristata*) (Thompson and Nolan, 1973), American crow (*Corvus brachyrhynchos*) (Hannon and Cotterill, 1998; Yahner and Cypher, 1987), and common grackle (*Quiscalus quiscula*) were observed during point counts.

Twelve brown-headed cowbirds were detected on the study sites, including four during unlimited radius point count surveys. Within constructed habitats, the four species did not differ in relative abundance among habitat types (Tables II and III). When comparing relative abundance data from both constructed and adjacent

TABLE II  
Mean  $\pm$  SE relative abundance of the avian brood parasite brown-headed cowbird (*Molothrus ater*) and avian nest predator blue jay (*Cyanocitta cristata*) among constructed riparian habitats and eroding gullies in Panola County, Mississippi, 1994 to 1996

Habitat	Brown-headed cowbird			Blue jay		
	Within habitat	All habitats <sup>a</sup>	Additional detections <sup>b</sup>	Within habitat	All habitats	Additional detections
Gully	3.1 $\pm$ 3.1	5.4 $\pm$ 3.2	4	0.0 $\pm$ 0.0	19.8 $\pm$ 6.3 A	3
Type I	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	4	0.0 $\pm$ 0.0	3.9 $\pm$ 2.2 B	2
Type II	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0	0.0 $\pm$ 0.0	8.3 $\pm$ 3.4 AB	4
Type III	0.0 $\pm$ 0.0	4.2 $\pm$ 4.2	0	2.1 $\pm$ 2.1	2.1 $\pm$ 2.1 B	1
Type IV	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0 B	4
<i>P</i>	0.406	0.233		0.530	0.006	

Note. *P* values are from one-way ANCOVA on ranks. Means that do not share a common letter are different ( $P < 0.05$ , Tukey multiple comparisons test).

<sup>a</sup>Relative abundance from observations within constructed habitat and adjacent habitats.

<sup>b</sup>Detections prior to and after point counts.

TABLE III

Mean  $\pm$  SE relative abundance of two avian nest predators, American crow (*Corvus brachyrhynchos*) and common grackle (*Quiscalus quiscula*), in constructed riparian habitats or eroding gullies in Panola County, Mississippi, 1994 to 1996

Habitat	American crow			Common grackle		
	Within habitat	All habitats <sup>a</sup>	Additional detections <sup>b</sup>	Within habitat	All habitats	Additional detections
Gully	0.0 $\pm$ 0.0	14.1 $\pm$ 8.1	0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0
Type I	0.0 $\pm$ 0.0	16.1 $\pm$ 10.3	5	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	1
Type II	0.0 $\pm$ 0.0	20.5 $\pm$ 7.4	6	0.0 $\pm$ 0.0	16.7 $\pm$ 9.6	3
Type III	0.0 $\pm$ 0.0	4.2 $\pm$ 4.2	6	2.1 $\pm$ 2.1	4.2 $\pm$ 4.2	3
Type IV	1.8 $\pm$ 1.8	7.0 $\pm$ 5.1	3	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0
<i>P</i>	0.406	0.413		0.406	0.176	

Note. *P* values are from one-way ANCOVA on ranks.

<sup>a</sup>Relative abundance from observations within constructed habitat and adjacent habitats.

<sup>b</sup>Detections prior to and after point counts.

habitats, however, blue jays differed among habitats ( $P = 0.006$ ); they were more abundant in the vicinity of gully sites than the Type I, III, and IV sites (Table II).

Nine small mammal species were recorded during the study, of which hispid cotton rat (*Sigmodon hispidus*) and white-footed mouse (*Peromyscus leucopus*) are important nest predators (predator status 1) and often consume small passerine eggs (DeGraaf and Maier, 1996; Ettel *et al.*, 1998). Three species were grouped into predator status 2 (i.e., congeners documented as avian nest predators). These included: (1) southern short-tailed shrew (*Blarina carolinensis*), closely related northern short-tailed shrew (*Blarina brevicauda*) which has been documented depredate nests (Gates and Gysel, 1978; Reitsma *et al.*, 1990); (2) woodland vole (*Microtus pinetorum*), congeneric with meadow vole (*Microtus pennsylvanicus*) reported to depredate avian nests (Hannon and Cotterill, 1998; Maxson and Oring, 1978); and (3) cotton mouse (*Peromyscus gossypinus*), congeneric with deer mouse (*Peromyscus maniculatus*) which has depredated avian nests (Fenske-Crawford and Niemi, 1997; Maxson and Oring, 1978; Reitsma *et al.*, 1990). Four additional small mammal species captured during the study whose role as avian nest predators was unclear (predator status 3) include house mouse (*Mus musculus*), southeastern shrew (*Sorex longirostris*), least shrew (*Cryptotis parva*), and marsh rice rat (*Oryzomys palustris*). Marini and Melo (1998) reported that captive marsh rice rats did not consume Japanese quail (*Coturnix coturnix*) eggs.

More hispid cotton rats were captured during the study than any other small mammal species. Only cotton mouse differed in relative abundance among habitat types ( $P = 0.011$ ) (Table IV) and was greater in the Type II and III habitats than Type I habitat (Table IV). Relative abundance of woodland vole approached significance ( $P = 0.064$ ; Table IV).

TABLE IV

Mean  $\pm$  SE relative abundance of small mammal nest predator species captured at constructed riparian habitats in Panola County, Mississippi, 1994 to 1996

Habitat	Southern short-tailed shrew	Woodland vole	Cotton mouse	White-footed mouse	Hispid cotton rat
Type I	0.56 $\pm$ 0.22	0.17 $\pm$ 0.17	0.00 $\pm$ 0.00 A	0.26 $\pm$ 0.26	11.63 $\pm$ 1.85
Type II	0.36 $\pm$ 0.16	0.97 $\pm$ 0.10	1.51 $\pm$ 0.53 B	0.83 $\pm$ 0.83	14.60 $\pm$ 3.90
Type III	0.67 $\pm$ 0.23	1.54 $\pm$ 0.56	1.39 $\pm$ 0.39 B	2.10 $\pm$ 1.03	10.16 $\pm$ 3.84
Type IV	0.41 $\pm$ 0.25	0.93 $\pm$ 0.59	0.61 $\pm$ 0.29 AB	1.43 $\pm$ 0.60	9.52 $\pm$ 1.92
<i>P</i>	0.772	0.064	0.011	0.405	0.687

*Note.* *P* values for southern short-tailed shrew and hispid cotton rat from ANCOVA, others from ANCOVA on ranks. Means that do not share a common letter are different ( $P < 0.05$ , Tukey multiple comparisons test).

More than half (62.2%) of the reptile data were generated from opportunistic observations. Of the ten snake species observed or captured at the study sites, black racer (*Coluber constrictor*) and garter snake (*Thamnophis sirtalis*) are reported avian nest predators (Best, 1978; Best and Stauffer, 1980). These species occurred in the Type III and IV constructed habitats, which contained pools with the least variable hydrologic regimes compared to pools within Type I and II habitats. Only one black racer was observed throughout the study (within a Type III habitat site) while garter snakes were captured at Type III habitats and additionally observed at Type IV habitat sites. Relative abundance of these two reptilian predator species were not subjected to statistical analyses due to low sample size.

### 3.2. PREDATOR COMMUNITY

Nine predator species were quantitatively detected within drop-pipe habitats during the study: three avian, two small mammals of predator status 1, three small mammals of predator status 2, and one reptilian predator. Species richness, abundance, and evenness of the predator community did not differ among the four created habitat types (Table V). The Jaccard community coefficient varied among the habitat pairs with Type II and III habitats being more similar than all other pairs (Table V). The threshold Jaccard index value for considering two communities similar is subjective, but scores greater than 0.7 have been used to indicate similarity in species composition between two communities (Matthews *et al.*, 1988). The observed Jaccard community coefficient indicated that Type II and III habitats shared 63% of all nest predator species, whereas Type I and IV habitats were the most dissimilar, sharing only 20% of all nest predator species (Tables V and VI).

TABLE V  
 Mean  $\pm$  SE predator species richness ( $s$ ), abundance ( $N$ ), and evenness ( $1/D$ ) among constructed riparian habitats in Panola County, Mississippi, 1994 to 1996

Habitat	$s$	$N$	$1/D$	Type I	Type II	Type III
Type I	1.5 $\pm$ 0.3	8.3 $\pm$ 2.4	1.1 $\pm$ 0.1	–	–	–
Type II	2.3 $\pm$ 0.5	20.3 $\pm$ 5.8	1.3 $\pm$ 0.1	0.40	–	–
Type III	3.5 $\pm$ 1.0	26.0 $\pm$ 8.1	1.7 $\pm$ 0.5	0.25	0.63	–
Type IV	2.0 $\pm$ 0.7	18.3 $\pm$ 6.1	1.1 $\pm$ 0.1	0.20	0.50	0.33
$P$	0.258	0.212	0.360			

Note.  $P$  values for  $s$  and  $N$  are from one-way ANCOVA, while the  $P$  value for  $1/D$  is from one-way ANCOVA on ranks. Columns with headings Type I, Type II, and Type III contain Jaccard predator community similarity coefficients ( $C_j$ ) between habitat pairs indicated by row and column headings.

TABLE VI  
 Predator species detected (+) at each constructed riparian habitat type in Panola County, Mississippi, 1994 to 1996

Predator species	Habitat type			
	I	II	III	IV
Blue Jay			+	
American crow				+
Common grackle			+	
Southern short-tailed shrew	+	+	+	
Cotton mouse		+	+	
White footed mouse		+	+	+
Woodland vole		+	+	+
Hispid cotton rat	+	+	+	+
Garter snake			+	

## 4. Discussion

### 4.1. BROOD PARASITE

Although the Type III and IV habitats may have provided a greater diversity of nesting substrate for hosts (i.e., shrubs and overstory) and potential perching sites for female brown-headed cowbirds than the other habitat types, relative abundance of the brood parasite did not differ among constructed habitats or the census area surrounding the constructed habitats. The total number of cowbirds detected during point count surveys were fewer than observed at nearby Holly Springs National Forest where Horn (1995) recorded 94 brown-headed cowbirds during fixed-radius point count surveys ( $n = 400$ ) in pine and hardwood forest

patches. This may be indicative of the pattern described by Rothstein *et al.* (1984) whereby brown-headed cowbirds occupy forested sites that contain potential hosts during morning egg laying hours rather than foraging sites such as agricultural areas.

Quantifying brood parasitism pressure relative to brown-headed cowbird presence or abundance from census data is equivocal. However, Robinson *et al.* (1995a) suggested that census data could be useful to identify locations where parasitism may be a significant problem. Hoover and Brittingham (1993) found parasitism rates to be correlated to brown-headed cowbird abundance. Because of the lack of information on brown-headed cowbird parasitism in agricultural areas of Mississippi, census data are critical in determining background information on potential brood parasitism in this region, particularly since brown-headed cowbirds populations are increasing at their greatest rate in the southeastern United States (Robinson *et al.*, 1995a) and tend to have an affinity for edge habitats such as the created habitats studied here.

#### 4.2. NEST PREDATORS

Predation pressure and density of some avian nest predators is positively related to the amount of agriculture in the landscape (Andren, 1992), with highest predation rates at farmland and woodlot edges (Andren, 1992; Hannon and Cotterill, 1998). Habitats in this study and many riparian areas of north Mississippi can be considered entirely edge habitats because of their small size. Among the habitat types in this study, blue jay relative abundance was greater at locations with unmanipulated gullies than at locations with Type III and IV habitats. This variability may be related to the cline of vegetative characteristics among habitat types, i.e., lack of woody vegetation and more openness associated with gully sites and dense shrubs and vines such as kudzu found in the Type III and IV habitats. Yahner and Cypher (1987) suggested that dense shrub growth inhibited foraging efficiency of corvid predators such as blue jays and American crows, possibly because these species often use visual cues to find nests (Picozzi, 1975). This suggests that the Type III and IV habitats may benefit nesting birds by providing a source of cover. At locations with gully sites, blue jays were often observed perched within mature trees on the streambank over-looking the open habitats, creek, and riparian area.

Of the potential predators observed within the constructed habitats, all observations occurred in the Type III and IV habitats. However, of individuals in constructed as well as adjacent habitats, more were observed in the habitat adjacent to the Type I, II, and gully sites. The increased vegetative structure of the Type III and IV habitats may have provided locations for potential avian nest predators to perch. Additionally, increased vegetative structure may allow coexistence of predators and prey within Type III and Type IV habitats, but this hypothesis needs to be tested in future research.

Several small mammal species were captured within every habitat type and hispid cotton rat was captured at every site. Among the small mammal species observed during the study, hispid cotton rat may exert the greatest predation pressure on avian nests based on their ubiquity among all sites and relatively larger gape size than *Peromyscus* spp. (DeGraaf and Maier, 1996; Ettel *et al.*, 1998), thus ability to consume a greater range of egg sizes (Ettel *et al.*, 1998; Haskell, 1995). Ettel *et al.* (1998) concluded that the hispid cotton rat might be an important nest predator for passerines after observing captive individuals consume 80% of presented zebra finch (*Poephila guttata*) eggs. The only small mammal species that differed in relative abundance among constructed habitats was the cotton mouse, being absent from the Type I habitat sites. This variability may be attributable to the species' preference for flooded habitats (Choate *et al.*, 1994); a characteristic lacking in the Type I sites.

Among the constructed habitats, pool volume increased at a greater rate than terrestrial area from Type I to Type IV habitats. Thus, terrestrial habitat area was not proportional to the total habitat area and may have influenced abundances of small mammal species that may depend on terrestrial substrate. The similarity of relative abundances among habitat types in mammalian species other than the cotton mouse may be a result of this relationship.

Snakes are important nest predators of ground- and shrub-nesting species (Best, 1978), cavity nesting species (Jackson, 1974), and open-cup tree nesting species (Wilson and Cooper, 1998). Two species captured that are known nest predators, black racer and garter snake, were only observed in the Type III and IV habitats. Snake abundance was not quantified, making variability of this parameter among the constructed habitats unclear. Likely, snakes were dependent on the diverse vegetation and aquatic prey resources (e.g., amphibians) abundant in the deeper pools of the Type III and IV habitats.

#### 4.3. PREDATOR COMMUNITY

In addition to analysis of individual predator species, consideration of the predator community is important because the system studied here likely follows a predator-prey model of multiple interactions between a group of distinct predators and a group of avian prey species (Holt and Lawton, 1994) (i.e., mammalian and reptilian predators tend to be generalists). Also, among predator species there appears to be variation in response to habitat manipulations at the local and landscape level (Chalfoun *et al.*, 2002).

Reitsma *et al.* (1990) tested the hypothesis that nest predation was primarily due to the abundance of two mammal predators and concluded that the combined effects of a suite of nest predators beyond the two mammal species (i.e., a broader predator community) potentially contributed to nest predation; removal of the two mammal predators from study plots did not result in decreased nest predation on artificial nests. In this study, nest predator community indices, measured by  $s$ ,  $N$ , and

1/ $D$ , were similar, suggesting little variation in the species richness and abundance of predators among the constructed habitats. However, the species composition of predator communities (Jaccard community coefficients) tended to vary among pairs of created habitat types, suggesting that these habitats may support different communities (Table V). For example, Type IV habitat had four fewer predator species than the Type III habitat and Type I habitat was most dissimilar to Type III and IV habitats (Tables V and VI). These findings are consistent with Picman and Schriml (1994) who reported variability in predator communities among different habitat types.

Although composition of predator communities tend to vary among habitat types, Reitsma *et al.* (1990) described a spatially variable pattern of nest predation where a predator species was unevenly distributed among sites of the same habitat category. We observed that the variability of small mammal relative abundances differed among habitat types and was species-specific (Table IV). This observation stimulated our interest in the variation of abundances occurring within a habitat type. An uneven distribution of white-footed mouse was observed among sites within both habitat Types III and IV. Most captures occurred at only two of the four sites. Within habitat Types I and II, the white-footed mouse was absent at all but one site. A similar pattern was observed for hispid cotton rat, where relative abundance was up to 5.4 times greater at one Type III site than another Type III site. This pattern is important because changes in a single species or component of the predator community may influence the overall pattern of predation pressure on nests. For example, a bird nesting at one of the Type III habitat sites may experience predation pressure from a different suite of predators than at another Type III site. These effects may be unevenly distributed among species of avian prey if some predators are species specific or prefer certain species over another in their predation tactics (Martin, 1987, 1988), resulting in impacts on nesting success of individual species rather than nesting success of the overall avian community. These relationships should be considered when generating management decisions.

#### 4.4. ASSUMPTIONS

Because the study objectives did not include quantifying reproductive success or identifying sources of nest failure, this study invoked two assumptions: (1) that the study sites served as nesting habitat for avian species and (2) that the observed species actually exerted brood parasitism and predation pressure on host and prey species. Although not quantified, evidence of breeding activity in the constructed habitats was observed. For example, within the focal habitats, 22 species were observed during the nesting period (Cooper *et al.*, 1997), singing males were observed possibly on established territories (J. Maul, unpublished observation), and eight nests were fortuitously located (P. Smiley, J. Maul, unpublished observation). Despite these assumptions, information on the abundance of avian nest predators

and brood parasites in habitats resulting from restoration practices are useful to avian ecologists and landscape managers.

## 5. Conclusions

Results from this study suggest that aside from blue jay and cotton mouse, relative abundance of potential nest predators did not differ among the constructed habitats. However, examination of the overall predator community showed that variation in the composition of predator species does occur among constructed habitat types. Determining which predator community was least detrimental to the breeding success of avifauna in these constructed habitats was beyond the scope of this study. Nonetheless, we suggest the Type IV habitats may be most useful for avian conservation because many sites had lower avian predator species richness, abundance, and evenness than the Type II and III sites, overall they had greater avian richness and abundance (Cooper *et al.*, 1997; Shields *et al.*, 2002), and they contribute most to the area of the riparian corridor. Several studies have indicated that wider riparian habitat may benefit the overall avian community (Keller *et al.*, 1993; Robbins *et al.*, 1989). The use of this erosion control technique in stream restoration projects should also be considered at the watershed level. Grouping drop pipes (and the resulting created habitats) together whenever possible will form contiguous blocks of riparian habitat and better support broad scale avian conservation efforts.

If these habitats provide nesting substrate for avian species and the nesting success of those species is very low (Rodenhouse and Best, 1983), these locations may act as population sinks (Gates and Gysel, 1978; Robinson *et al.*, 1995b). Recent studies have indicated, however, that these effects in some small habitats may not occur for some species, such as wood thrush (*Hylocichla mustelina*) (Friesen *et al.*, 1999; Roth and Johnson, 1993), and that maintaining small habitat patches may ultimately be very important for avian conservation.

Habitats resulting from drop-pipe installation convert agricultural land into a non-crop edge habitat and improve a severely degraded situation. These habitats are small and their overall importance to birds is difficult to determine because avian territories are typically larger than drop-pipe created habitats. However, the effects of habitat characteristics on nest predation at spatial scales similar to those of this study have been observed (Filliater *et al.*, 1994; Martin and Roper, 1988; Tarvin and Garvin, 2002; Tarvin and Smith, 1995), suggesting that variation in drop-pipe habitat characteristics could be important to nest predation processes.

Installation of structures at these sites inevitably will occur based on landowner desire to reduce soil loss and watershed restoration projects. Fortunately, it is possible to amend design criteria to guide the development of habitats resulting from installation of these erosion control structures (Shields *et al.*, 2002), and the results of this study can be used to assist avian conservation efforts when implementing this erosion control technique.

### Acknowledgments

We thank the following for assisting in data collection for this project, reviewing previous drafts of the paper, or both: E. Cooper, K. Damon, J. Farris, D. Feldman, D. Horn, K. Kallies, S. Knight, S. Martin, R. Maul, C. Milam, T. Randall, S. Testa III, and J. Wigginton. We also thank F. Shields Jr. and C. Butts for quantifying drop-pipe habitat area and pool volume, F. Shields Jr. for providing data on indices of woody vegetation, the Ecotoxicology Research Facility discussion group for providing helpful comments on the manuscript, and P. Mitchell for generating Figure 1. The U.S. Army Corps of Engineers, Vicksburg District provided cooperative funding for this project and the Natural Resources Conservation Service provided landowner and site information.

### References

- Andren, H.: 1992, 'Corvid density and nest predation in relation to forest fragmentation: A landscape perspective', *Ecology* **73**, 794–804.
- Bergin, T. M., Best, L. B. and Freemark, K. E.: 1997, 'An experimental study of predation on artificial nests in roadsides adjacent to agricultural habitats in Iowa', *Wilson Bull.* **109**, 437–448.
- Best, L. B.: 1978, 'Field sparrow reproductive success and nesting ecology', *Auk* **95**, 9–22.
- Best, L. B. and Stauffer, D. F.: 1980, 'Factors affecting nesting success in riparian bird communities', *Condor* **82**, 149–158.
- Brittingham, M. C. and Temple, S. A.: 1983, 'Have cowbirds caused forest songbirds to decline?', *Bioscience* **33**, 31–35.
- Chalfoun, A. D., Thompson, F. R., III and Ratnaswamy, M. J.: 2002, 'Nest predators and fragmentation: A review and meta-analysis', *Conserv. Biol.* **16**, 306–318.
- Choate, J. R., Jones, J. K., Jr. and Jones, C.: 1994, *Handbook of Mammals of the South-Central States*, Louisiana State University Press, Baton Rouge, Louisiana.
- Conant, R. and Collins, J. T.: 1991, *Peterson Field Guides, Reptiles and Amphibians*, Houghton Mifflin Company, New York.
- Cooper, C. M., Smiley, P. C., Jr., Wigginton, J. D., Knight, S. S. and Kallies, K. W.: 1997, 'Vertebrate use of habitats created by installation of field-scale erosion control structures', *J. Freshw. Ecol.* **12**, 199–207.
- DeGraaf, R. M. and Maier, T. J.: 1996, 'Effect of egg size on predation by white-footed mice', *Wilson Bull.* **108**, 535–539.
- Ettel, T. L., Buehler, D. A. and Houston, A. E.: 1998, 'Egg size and cotton rat predation', *Wilson Bull.* **110**, 575–578.
- Fenske-Crawford, T. J. and Niemi, G. J.: 1997, 'Predation of artificial ground nests at two types of edges in a forest-dominated landscape', *Condor* **99**, 14–24.
- Filliater, T. S., Breitwisch, R. and Nealen, P. M.: 1994, 'Predation on Northern Cardinal nests: Does choice of nest site matter', *Condor* **96**, 761–768.
- Friesen, L., Cadman, M. D. and MacKay, R. J.: 1999, 'Nesting success of neotropical migrant songbirds in a highly fragmented landscape', *Conserv. Biol.* **13**, 338–346.
- Gates, J. E. and Gysel, L. W.: 1978, 'Avian nest dispersion and fledging success in field-forest ecotones', *Ecology* **59**, 871–883.
- Grissinger, E. H., Darden, R. W. and Blackmarr, W. A.: 1990, Preliminary Watershed Characterization: Hotophia Creek Demonstration Erosion Control Project, *Technical Report*, USDA Agricultural

- Research Service Technology Applications Project Report No. 9, National Sedimentation Laboratory, Oxford, Mississippi.
- Hannon, S. J. and Cotterill, S. E.: 1998, 'Nest predation in aspen woodlots in an agricultural area in Alberta: The enemy from within', *Auk* **115**, 16–25.
- Haskell, D. G.: 1995, 'Forest fragmentation and nest predation: Are experiments with Japanese Quail eggs misleading?', *Auk* **112**, 767–770.
- Holt, R. D. and Lawton, J. H.: 1994, 'The ecological consequences of shared natural enemies', *Annu. Rev. Ecol. Syst.* **25**, 495–520.
- Hoover, J. P. and Brittingham, M. C.: 1993, 'Regional variation in cowbird parasitism of Wood Thrushes', *Wilson Bull.* **105**, 228–238.
- Horn, D. J.: 1995, The Influence of Patch Characteristics on Bird Assemblages in a Fragmented Landscape, *Master of Science Thesis*, The University of Mississippi, Mississippi.
- Hutto, R. L., Pletschet, S. M. and Hendricks, P.: 1986, 'A fixed-radius point count method for non-breeding and breeding season use', *Auk* **103**, 593–602.
- Jackson, J. A.: 1974, 'Gray rat snakes versus red-cockaded woodpeckers: Predator-prey adaptations', *Auk* **91**, 342–347.
- Keller, C. M. E., Robbins, C. S. and Hatfield, J. S.: 1993, 'Avian communities in riparian forests of different widths in Maryland and Delaware', *Wetlands* **13**, 137–144.
- Magurran, A. E.: 1988, *Ecological Diversity and Its Measurement*, University Press, Cambridge, United Kingdom.
- Marini, M. A. and Melo, C.: 1998, 'Predators of quail eggs, and the evidence of the remains: Implications for nest predation studies', *Condor* **100**, 395–399.
- Martin, T. E.: 1987, 'Artificial nest experiments: Effects of nest appearance and type of predator', *Condor* **89**, 925–928.
- Martin, T. E.: 1988, 'Processes organizing open-nesting bird assemblages: Competition or nest predation', *Evol. Ecol.* **2**, 37–50.
- Martin, T. E. and Roper, J. J.: 1988, 'Nest predation and nest-site selection of a western population of the Hermit Thrush', *Condor* **99**, 51–57.
- Matthews, W. J., Cashner, R. C. and Gelwick, F. P.: 1988, 'Stability and persistence of fish faunas and assemblages in three midwestern streams', *Copeia* **4**, 945–955.
- Maxson, S. J. and Oring, L. W.: 1978, 'Mice as a source of egg loss among ground-nesting birds', *Auk* **95**, 582–584.
- Mayfield, H.: 1977, 'Brown-headed cowbird: Agent of extermination', *Am. Birds* **31**, 107–113.
- Picman, J. and Schriml, L. M.: 1994, 'A case study of temporal patterns of nest predation in different habitats', *Wilson Bull.* **106**, 456–465.
- Picozzi, N.: 1975, 'Crow predation on marked nests', *J. Wildlife Manage.* **39**, 151–155.
- Ralph, C. J., Droege, S. and Sauer, J. R.: 1995, 'Managing and Monitoring Birds using Point Counts: Standards and Applications', in: C. J. Ralph, J. R. Sauer and S. Droege (eds.), *Monitoring Bird Populations By Point Counts*, USDA Forest Service General Technical Report PSW-GTR-149, Pacific Southwest Research Station, Albany, California, pp. 161–168.
- Reitsma, L. R., Holmes, R. T. and Sherry, T. W.: 1990, 'Effects of removal of red squirrels, *Tamiasciurus hudsonicus*, and eastern chipmunks, *Tamias striatus*, on nest predation in a northern hardwood forest: An artificial nest experiment', *Oikos* **57**, 375–380.
- Ricklefs, R. E.: 1969, 'An analysis of nesting mortality in birds', *Smithsonian Contrib. Zool.* **9**, 1–48.
- Robbins, C. S., Dawson, D. K. and Dowell, B. A.: 1989, 'Habitat area requirements of breeding forest birds of the middle Atlantic states', *Wildlife Monogr.* **103**, 1–34.
- Robinson, S. K.: 1992, 'Population Dynamics of Breeding Neotropical Migrants in a Fragmented Landscape', in: J. M. Hagan, III and D. W. Johnston (eds.), *Ecology and Conservation of Neotropical Migrant Landbirds*, Smithsonian Institution Press, Washington, DC, pp. 408–418.

- Robinson, S. K., Rothstein, S. I., Brittingham, M. C., Petit, L. J. and Grzybowski, J. A.: 1995a, 'Ecology and Behavior of Cowbirds and their Impact on Host Populations', in: T. E. Martin and D. M. Finch (eds.), *Ecology and Management of Neotropical Migratory Birds*, Oxford University Press, New York, pp. 428–460.
- Robinson, S. K., Thompson, F. R., III, Donovan, T. M., Whitehead, D. R. and Faaborg, J.: 1995b, 'Regional forest fragmentation and the nesting success of migratory birds', *Science* **267**, 1987–1990.
- Rodenhouse, N. L. and Best, L. B.: 1983, 'Breeding ecology of vesper sparrows in corn and soybean fields', *Am. Midl. Nat.* **110**, 265–275.
- Roth, R. R. and Johnson, R. K.: 1993, 'Long-term dynamics of a Wood Thrush population breeding in a forest fragment', *Auk* **110**, 37–48.
- Rothstein, S. I., Verner, J. and Stevens, E.: 1980, 'Range expansion and diurnal changes in dispersion of the brown-headed cowbird in the Sierra Nevada', *Auk* **97**, 253–267.
- Rothstein, S. I., Verner, J. and Stevens, E.: 1984, 'Radio-tracking confirms a unique diurnal pattern of spatial occurrence in the parasitic brown-headed cowbird', *Ecology* **65**, 77–88.
- SAS Institute Inc.: 1989, *SAS/STAT User's guide Version 6, Fourth Edition, Vol. 2.*, SAS Institute Inc., Cary, North Carolina.
- Shields, F. D., Jr., Smiley, P. C., Jr. and Cooper, C. M.: 2002, 'Design and management of edge-of-field water control structures for ecological benefits', *J. Soil Water Conserv.* **57**, 151–157.
- Small, M. F. and Hunter, M. L.: 1988, 'Forest fragmentation and avian nest predation in forested landscapes', *Oecologia* **76**, 62–64.
- Smiley, P. C., Cooper, C. M., Kallies, K. W. and Knight, S. S.: 1997, 'Assessing Habitats Created by Installation of Drop Pipes', in: S. Y. Wang, E. J. Langendoen and F. D. Shields, Jr. (eds.), *Management of Landscapes Disturbed by Channel Incision, Stabilization, Rehabilitation, and Restoration*, The Center for Computational Hydroscience and Engineering, Mississippi University, Mississippi, pp. 887–892.
- Tarvin, K. A. and Garvin, M. C.: 2002, 'Habitat and nesting success of Blue Jays (*Cyanocitta cristata*): Importance of scale', *Auk* **119**, 971–983.
- Tarvin, K. A. and Smith, K. G.: 1995, 'Microhabitat factors influencing predation and success of suburban Blue Jay *Cyanocitta cristata* nests', *J. Avian Biol.* **26**, 296–304.
- Thompson, C. R. and Nolan, V., Jr.: 1973, 'Population biology of the yellow-breasted chat (*Icteria virenx* L.) in southern Indiana', *Ecol. Monogr.* **43**, 145–171.
- USCOE: 1992, *Demonstration Erosion Control Project Long Creek Watershed*, U.S. Army Corps of Engineers, Vicksburg District, Vicksburg, Mississippi.
- Wilcove, D. S.: 1985, 'Nest predation in forest tracts and the decline of migratory songbirds', *Ecology* **66**, 1211–1214.
- Wilson, R. R. and Cooper, R. J.: 1998, 'Breeding biology of acadian flycatchers in a bottomland hardwood forest', *Wilson Bull.* **110**, 226–232.
- Yahner, R. H. and Cypher, B. L.: 1987, 'Effects of nest location on depredation of artificial arboreal nests', *J. Wildlife Manage.* **51**, 178–181.
- Zar, J. H.: 1984, *Biostatistical Analysis*, Prentice-Hall, Englewood Cliffs, New Jersey.