Avian and Small Mammal Communities on Different Successional Stages of Reclaimed Kaolin Mines in Georgia

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Abstract: Although surface mining may affect wildlife communities adversely, the degree of impact depends upon the extent of mining activity and the reclamation efforts employed. We compared breeding bird and small mammal communities on sites of different successional stages in 1995 and 1996 to evaluate the wildlife value of the reclamation prescriptions currently used on kaolin surface mines in east-central Georgia. Sites were grouped according to tree ages during the first year of the study (age class I, 2–4 years; age class II, 5–7 years; and age class III, 8–11 years). Avian abundance in 1995 was greatest in age classes I and II. In 1996, avian abundance was more than twice as great in age class I than in the 2 other age classes. Species richness in both years was greater in age class II. Avian diversity was greater in the 2 oldest age classes in 1995, but was not different among classes in 1996. Cotton rats *(Sigmodon hispidus)* were the most common small mammals captured. In December, total small mammal captures were lower in the older age classes. Reclaimed kaolin mines provide habitat for many avian and mammalian species, but efforts to encourage development of a shrub layer in older habitats may increase avian abundance. The establishment of heterogeneous ground cover also may lengthen the time in which stands are available to small mammal species.

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The structural character and species composition of vegetational communities exert strong influences on the composition of wildlife communities (MacArthur and

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MacArthur 1961, Roth 1976). Surface mining can impact wildlife and habitats adversely because the structure and composition of the habitats are altered drastically (Whitmore and Hall 1978). The degree of impact depends on the type and extent of mining activity and the reclamation procedures implemented (Haynes et al. 1982). During the reclamation process, mining companies have opportunities to create habitats that possess characteristics suitable to some species and, with planning, can develop successional habitats that may be valuable to species that are rare or in decline (Whitmore 1980). However, much more research on mine reclamation in the southeastern United States has focused on site stabilization, erosion control, or other physical aspects than on habitat restoration for wildlife. For example, all of the early studies on reclaimed kaolin mines in Georgia focused on soil composition, vegetation establishment, and tree growth (e.g., Parks et al. 1967, Troth 1971, May 1975) but did not address the values of these sites to wildlife. There have been no studies of the avian and small mammal communities on kaolin mine reclamation sites in the southeastern United States.

Kaolin is a white aluminosilicate that has commercial uses ranging from pottery clay to the coating on high-quality, glossy paper (Ga. Mining Assoc. 1994). Kaolin is found in a belt of subsurface deposits that extends over 30 counties in east-central Georgia. In the kaolin mining process, the overburden is removed by draglines and scrapers. The kaolin is transported to a stockpile where it is mixed with water and dispersing chemicals. The slurry is pumped to processing facilities to prepare the clay for commercial use. When the deposits are exhausted, the overburden is replaced and the site is reclaimed.

The kaolin-mining industry in Georgia is required by state law (the Georgia Surface Mining Act of 1968 [Ga. L. 1968 p. 9 §§1–14]) and federal law (the Surface Mining Control and Reclamation Act of 1977 [30 U.S.C. 1201–1328]) to reclaim affected land after mining is completed. Before mining begins, a reclamation plan to return mined lands to a condition capable of supporting premining uses (Haynes 1979) must be approved. On kaolin mine sites in east-central Georgia, reclamation efforts typically include land shaping to create slopes $\leq 30\%$, fertilizing soils with a nitrogen, phosphorous, and potassium fertilizer, and planting a herbaceous ground cover such as sericea lespedeza *(Lespedeza cuneata)* and bahia grass *(Paspalum notatum).* After about 2 years, reclaimed areas usually are planted with loblolly pine *(Pinus taeda)* seedlings. The resulting habitat consists of a dense ground cover and a pine-dominated canopy.

To provide baseline data of current habitat conditions, we estimated small mammal and avian use of reclaimed kaolin mines and compared our data to previous studies on other reclaimed sites and naturally-revegetated lands. We also compared avian community parameters (abundance, diversity, and species richness) and small mammal abundance among reclaimed kaolin mines of 3 successional stages.

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Methods

This study was conducted on reclaimed kaolin mines located between the Lower Piedmont and Upper Coastal Plain physiographic regions of Georgia. Twenty sites were grouped into 3 classes according to tree ages during the first year of the study. We selected classes to represent different stages of forest succession prior to full canopy closure. The tree-age classes were: age class I, 2–4 years ($N=5$); age class II, 5–7 years ($N=7$); and age class III, 8–11 years ($N=8$). Sites ranged in size from 4–34 ha.

We conducted avian counts on each site 3 times per month from mid-May to mid-July 1995–1996, using 5-minute, fixed-radius (50-m) point counts (Hutto et al. 1986, Ralph et al. 1995). Each site contained 1 randomly-located point within the stand. Counts were made in the morning hours from 1 hour after sunrise until 1100 hours. Only those birds detected within the 50-m radius were included in abundance and diversity calculations. Species detected outside of the 50-m radius and those detected en route to count points were recorded for inclusion in species richness calculations. No counting was done on excessively windy or rainy days (Ralph et al. 1995).

Avian abundance is reported as the mean number of birds detected per site, per visit, within each age class. Diversity was calculated using the Shannon Index (Shannon and Weaver 1967) and is reported as mean diversity per site in each age class. Species richness is the mean number of species detected per site in each age class. Means of total abundance, diversity, richness, and abundance by habitat preference and migratory strategy (Whitcomb et al. 1981, Freemark and Collins 1992) were transformed to approximately a normal distribution using a 0.5 square root transformation (Steel and Torrie 1960). Comparisons among means were made by analysis of variance and Tukey's Studentized Range Test was used to compare means ($\alpha=0.05$).

We trapped small mammals in September and December 1995. Two trap lines located 15 m apart were placed near the center of each site and baited with peanut butter and rolled oats. Ten traps were placed 15 m apart on each line. A combination of Museum Special™ mouse traps ($N=7$) and Victor™ rat traps ($N=3$) was used on each line (Smith et al. 1971). Each site was sampled for 3 nights per month, yielding 1,200 trap-nights per month.

Small mammals were identified to species by external characteristics except for *Peromyscus* species which were identified using cranial measurements (Laerm and Boone 1994). Capture rates are reported as the mean number of small mammal captures per site per 100 trap nights in each age class. A 0.5 square root transformation was used to transform means to approximate a normal distribution (Steel and Torrie 1960). Comparison of capture rates among age classes was made with analysis of variance and Tukey's Studentized Range Test was used to compare means ($\alpha=0.05$).

Vegetation parameters were measured in 0.04-ha plots (James and Shugart 1970) located at each avian count point. An additional plot was selected in a random direction and at a random distance from each count point. We identified woody stems to species, and grouped trees into diameter-at-breast-height (d.b.h.) classes of <3 cm, 3–<6 cm, 6–<9 cm, 9–<15 cm, 15–<21 cm, and ≥21 cm. Ground cover was estimated using an ocular tube at 1-m intervals along 2 22.6-m transects within each plot. Percent canopy cover was estimated using a spherical densiometer, and canopy height was measured using a clinometer. Vegetation profile was measured using a 3-m density board divided into 0.5-m intervals (Nudds 1977). The observer stood at the center of the plot and the density board was placed on the perimeter of the plot (a distance of 11.3 m) in each cardinal direction. An index of percent foliar coverage for each 0.5-m interval was recorded. All vegetation data are reported as means per site within each age class. Means were transformed to approximate a normal distribution using a 0.5 square root transformation (Steel and Torrie 1960). Comparisons among means were made with analysis of variance and Tukey's Studentized Range Test was used to compare means ($\alpha=0.05$).

Results

For the first several years after reclamation, habitats on the reclaimed kaolin mine sites consisted of dense, low-growing vegetation with little overstory (Table 1). Ground cover in sites of age class I consisted almost exclusively of sericea lespedeza. Percent ground cover did not differ among age classes in 1995, but was greater in age class I in 1996. The 2 older age classes had cover consisting primarily of sericea lespedeza but also contained some bahia grass. Various other species were present in small numbers.

Tree height and percent canopy cover increased with stand age (Table 1). Age classes II and III had denser profiles than age class I in the higher intervals. In both years, the profile intervals that should include most shrub species (i.e., 0.5–1.0 m, 1.0–1.5 m, and 1.5–2.0 m) were less dense in age class III than in the 2 younger age classes. The vegetation profile at all intervals up 2.0 m was lowest in age class III in both years. Although shrub species were present on most sites, they were relatively rare. Woody stems consisted almost exclusively of loblolly pine. The density of small woody stems was greatest in age class I sites. Woody stem density in the shrub layer (<3 cm dbh) in both years decreased with increasing age of the stands and tree height.

Avian abundance differed between years ($P<0.05$), so data were not pooled. Total abundance in 1995 was greatest in stands of age classes I and II (Table 2). In 1996, abundance was more than twice as great in sites of age class I than in the 2 older age classes. Avian diversity was higher in the 2 oldest age classes in 1995, but was not different among classes in 1996. Species richness in both years was greater in age class II.

Fifty-two avian species were detected on our sites over both years. The most common species in the youngest reclamation sites were seed-eating species typical of pastures. These included field sparrow *(Spizella pusilla),* blue grosbeak *(Guiraca caerlua),* indigo bunting *(Passerina cyanea),* and red-winged blackbird *(Agelaius phoeniceus).* In intermediate-aged sites abundance of these species declined slightly and the abundance of species that inhabit mid-successional sites increased. The most

Table 1. Mean (SE) values for vegetation characteristics of 3 age classes of reclaimed kaolin-mine sites in east-central Georgia.

	1995						1996					
	Age class I (N = 5)		Age class II (N = 7)		Age class III (N = 8)		Age class I (N = 5)		Age class II (N = 7)		Age class III (N = 8)	
Tree height (m)	2.2	(0.1) B[a]	6.9	(0.6) A	8.6	(1.0) A	3.0	(0.1) B	8.8	(0.5) A	10.0	(1.0) A
Canopy cover (%)	1.3	(1.3) B	48.0	(8.8) A	65.9	(10.5) A	3.3	(1.1) B	66.2	(7.6) A	72.1	(9.0) A
Ground cover (%)	89.6	(0.0) A	67.9	(0.1) A	60.5	(10.6) A	91.0	(0.0) A	57.3	(0.1) B	42.7	(0.1) B
Woody stem density per ha												
<3 cm d.b.h.	1128.3	(146.6)	651.2	(313.9)	255.7	(113.4)	1167.9	(34.1)	892.3	(382.7)	391.8	(240.2)
>3–6 cm d.b.h.	328.7	(98.2)	387.4	(139.7)	146.0	(49.4)	496.7	(102.0)	315.9	(117.4)	241.0	(141.7)
>6–9 cm d.b.h.	2.5	(2.5)	540.4	(148.4)	170.0	(44.0)	114.9	(34.1)	406.3	(163.2)	223.3	(101.0)
>9–15 cm d.b.h.	0		426.6	(90.4)	561.6	(113.4)	33.4	(24.5)	656.0	(83.4)	634.2	(99.0)
>15–21 cm d.b.h.	0		17.7	(9.1)	119.0	(30.9)	0		162.1	(60.5)	325.2	(71.7)
>21 cm d.b.h.	0		0		8.5	(4.5)	0		3.5	(1.9)	17.0	(7.4)
Vegetation profile[b]												
0.0–0.5 m	3.9	(0.0)	3.0	(0.3)	2.5	(0.4)	3.9	(0.1)	3.0	(0.3)	2.3	(0.3)
0.5–1.0 m	3.1	(0.1)	2.5	(0.3)	1.6	(0.4)	3.4	(0.1)	2.1	(0.3)	1.5	(0.4)
1.0–1.5 m	2.1	(0.3)	2.3	(0.3)	1.0	(0.4)	2.1	(0.3)	1.7	(0.3)	0.9	(0.3)
1.5–2.0 m	1.8	(0.4)	2.9	(0.3)	1.2	(0.4)	2.0	(0.3)	2.0	(0.3)	1.1	(0.4)
2.0–2.5 m	1.3	(0.3)	2.8	(0.4)	1.3	(0.3)	1.6	(0.3)	2.0	(0.3)	1.1	(0.4)
2.5–3.0 m	1.1	(0.3)	3.2	(0.3)	1.9	(0.3)	1.5	(0. 3)	2.3	(0.4)	1.3	(0.4)

a. Means followed by the same letter, within the same year and row, are not different at $\alpha = 0.05$ (Tukey's Studentized Range Test).

b. Index of percent foliar coverage: 0 = 0%, 1 = 1%–25%, 2 = 26%–50%, 3 = 51%–75%, and 4 = 76%–100%.

Table 2. Mean (SE) abundance, richness, and diversity of breeding bird species in 3 age classes of reclaimed kaolin-mine sites in east-central Georgia in 1995 and 1996.

Age Class	*N*	Abundance	Richness	Diversity[a]
1995				
I	5	0.46 (0.05) AB	16.20 (1.28) B	0.27 (0.16) B
II	7	0.50 (0.30) A	23.43 (1.13) A	0.92 (0.09) A
III	8	0.31 (0.03) B	18.00 (1.60) B	1.09 (0.13) A
1996				
I	5	0.56 (0.07) A	12.60 (1.03) B	0.13 (0.13) A
II	7	0.23 (0.03) B	20.57 (1.39) A	0.57 (0.23) A
III	8	0.24 (0.04) B	13.88 (1.73) B	0.44 (0.18) A

a. Bird species diversity computed using the Shannon Index: $-\Sigma p_i \log_e p_i$.

b. Means followed by the same letter, within the same year and column, are not different at $\alpha = 0.05$ (Tukey's Studentized Range Test).

common birds in sites of age class II were Eastern towhee *(Pipilo erythrophthalmus)* and Northern bobwhite *(Colinus virginianus).* Tree-nesting species such as the Northern cardinal *(Cardinalis cardinalis),* common grackle *(Quiscalus quiscula),* and Carolina wren *(Thryothorus ludovicianus)* were most abundant in age class III sites.

Year-round and permanent resident avian species (i.e., birds that maintain year-round home ranges on the grounds [Whitcomb et al. 1981]) and short-distance migrants (i.e., species that move a few hundred kilometers to a different wintering area [Whitcomb et al. 1981]) were slightly more abundant in age classes I and II in 1995, and were significantly more abundant in age class I in 1996 (Table 3). Abundance of neotropical migrants (i.e., species that migrate to the neotropical region for the winter [Whitcomb et al. 1981]) did not differ among age classes in either year, but were slightly higher in age class I in both 1995 and 1996. Edge species, defined as birds that use forest perimeters, nearby fields, or large clearings within a forest during the breeding season (Freemark and Collins 1992), were slightly more common in the 2 younger age classes in 1995. In 1996, edge species in age class I were more than 3 times as abundant than in age class II, and more than 4 times as abundant than in age class III. Interior-edge species, defined as those which have territories located entirely within the forest but use forest edges (Freemark and Collins 1992), were most common in age class II in both years. Interior species (i.e., those which nest only within the interior of forests and rarely occur near the edge [Freemark and Collins 1992]) were present in small numbers in both years and were observed only in the older age classes.

Small mammal abundance was different between September and December 1995 ($P<0.05$) so data were not pooled. We captured 250 mammals: 97 individuals (5 species) in September and 153 individuals (7 species) in December with an overall capture success of 10.4%. Cotton rats accounted for 88.7% of the September captures, followed by the cotton mouse *(Peromyscus gossypinus,* 4.1%), and unidentified *Peromyscus* spp. (individuals that could not be identified to species using cranial measurements, 4.1%). One individual each was captured of the least shrew

Table 3. Mean (SE) avian abundance by migratory strategy and habitat preference in 3 age classes of reclaimed kaolin-mine sites in east-central Georgia.

	1995						1996					
	Age class I ($N = 5$)		Age class II ($N = 7$)		Age class III ($N = 8$)		Age class I ($N = 5$)		Age class II ($N = 7$)		Age class III ($N = 8$)	
Migratory strategy[a]												
Year-round residents[b]	0.34	(0.04) AB[c]	0.40	(0.03) A	0.23	(0.03) B	0.46	(0.07) A	0.18	(0.02) B	0.19	(0.03) B
Neotropical migrants	0.12	(0.03) A	0.10	(0.01) A	0.08	(0.01) A	0.09	(0.02) A	0.05	(0.01) A	0.05	(0.01) A
Habitat preference												
Edge	0.44	(0.05) A	0.35	(0.03) AB	0.18	(0.03) B	0.54	(0.06) A	0.14	(0.02) B	0.13	(0.03) B
Interior/edge	0.02	(0.01) B	0.14	(0.02) A	0.10	(0.02) AB	0.02	(0.01) B	0.09	(0.02) A	0.09	(0.01) AB
Interior	0		0.01	(0.01) A	0.03	(0.01) A	0		0		0.02	(0.01)

[a] Migratory strategy and habitat preference modified after Whitcomb et al. (1981) and Freemark and Collins (1992).

[b] Includes species classified by above as short-distance migrants but which are year-round residents in Georgia.

[c] Means followed by the same letter, within the same year and row, are not different at $\alpha = 0.05$ (Tukey's Studentized Range Test).

Table 4. Mean (SE) capture rates of small mammals per 100 trapnights on 3 age classes of reclaimed kaolin-mine sites in east-central Georgia in 1995.

Species	September			December		
	Age class *N* = 5	Age class II *N* = 7	Age class III *N* = 8	Age class I *N* = 5	Age class II *N* = 7	Age class III *N* = 8
Cryptotis parva		0.24 (0.24)		1.00 (0.67) A[a]	1.67 (0.73) A	0.21 (0.21) A
Mus musculus				0.67 (0.67)		
Ochrotomys nuttalli		0.24 (0.24)				
Oryzomys palustris				1.33 (0.82) A		0.63 (0.44) A
Peromyscus gossypinus	0.60 (0.60) A	0.14 (0.14) A	0.83 (0.45) A	1.00 (1.00) A		0.42 (0.27) A
Peromyscus leucopus		0.24 (0.24)				
Peromyscus polionotus					0.71 (0.50)	
Peromyscus spp.[b]	0.07 (0.07) A	0.10 (0.10) A	0.21 (0.21) A	1.00 (1.00) A		0.21 (0.21) A
Sigmodon hispidus	12.67 (2.01) A	5.71 (2.97) A	5.00 (2.78) A	29.33 (5.42) A	2.62 (2.12) B	4.79 (3.30) B
Total captures	13.33 (1.90) A	6.67 (2.84) A	6.04 (2.83) A	34.33 (4.88) A	5.00 (2.91) B	6.25 (3.60) B

a. Means followed by the same letter, within the same month and row, are not different at $\alpha = 0.05$ (Tukey's Studentized Range Test).

b. Includes individuals that could not be identified using cranial measurements.

(Cryptotis parva), golden mouse *(Ochrotomys nuttalli),* and white-footed mouse *(P. leucopus).* In December, cotton rats accounted for 78.4% of the captures, followed by least shrew (7.8%), rice rat *(Oryzomys palustris,* 4.6%), cotton mouse (3.3%), unidentified *Peromyscus* spp. (2.6%), old field mouse (*P. polionotus,* 2.0%), and house mouse (*Mus musculus,* 1.3%).

There were no within-species differences in capture rates per 100 trapnights among age classes in September (Table 4). In December, captures rates of cotton rats were higher in age class I sites. The total capture rate in December was higher in the youngest age class.

Discussion

The existing prescriptions for reclamation of kaolin mine sites in Georgia accomplish the goals of rapid vegetative growth on poor soils for soil stabilization and erosion control. However, the resulting vegetative community is virtually a monoculture of sericea lespedeza during the first 5 years and a true shrub layer, typical of most old-field successional habitats in the region (Johnston and Odum 1956), never fully develops. On most sites, the landowners request that loblolly pine plantations be established and the shrub layer on such sites consists mostly of loblolly pine saplings until the pines reach the stage of canopy cover.

There are no published reports that can serve as baselines for comparison of avian community dynamics on mine reclamation areas in similar habitats of the southeastern United States. However, Johnston and Odum (1956) examined the avian communites in fallow agricultural fields in Georgia, and Shugart and James (1973) conducted a similar study in Arkansas. In both of these studies, researchers found that abandoned fields developed a rich shrub community and avian diversity and richness increased throughout the development of the shrub stage for about 20 years until canopy closure. On the reclaimed kaolin mine sites in Georgia, avian abundance and diversity never reached the magnitude reported for the fallow habitats and peaked at a much younger age. The absence of a true shrub stage and rapid development of the planted pines likely contributed to the reduced avian community paramenters in the reclamation areas. Nevertheless, we detected more species (52) on the kaolin reclamation areas than were detected on the successional habitats in Georgia (42) and Arkansas (47).

The composition of the small mammal community on the kaolin sites paralleled those found on other reclaimed mine lands. For example, on Texas strip mine reclamation areas, a single species dominated the vegetation ground layer and cotton rats were the most abundant mammalian species (Gust and Schmidly 1986). The mammalian communities of most reclamation sites are dominated by seed-eating or herbivorous rodents. The re-sorting of the sediments during removal of the overburden eliminates the litter layer normally associated with undisturbed soils which probably reduces invertebrate populations.

Our results also are comparable to previous studies on pine plantations in the Georgia Piedmont (Atkeson and Johnson 1979, Langley and Shure 1980). These studies reported high abundances of cotton rats in the early-successional stages of pine stands, but low abundances of all small mammal species after canopy closure. One previous study reported trap success of 7.7% (Atkeson and Johnson 1979), which is lower than our success of 10.4%. Apparently, current methodology to reclaim kaolin-mine sites results in habitat capable of supporting an abundant small mammal community. This, in turn, likely provides a prey base for several species of avian and mammalian predators. Factors which delay canopy closure in pine plantations may extend the length of time in which the stand would provide habitat for some small mammals (Atkeson and Johnson 1979).

Our capture rates may be conservative estimates of abundance for some species. Some species of small mammals may be less susceptible to snaptraps than to other trap types. Shrews, for example, may be more susceptible to pitfall traps than snaptraps (Edwards 1952, Blackburn and Andrews 1992, Maddock 1992, Kalko and Handley 1993). Likewise, some rodents, such as *Peromyscus* spp., may be more susceptible to live traps (Duran 1968, Kalko and Handley 1993). The type of bait used (Fowle and Edwards 1954) and season (Fitch 1954) also may determine which species are captured.

Management Implications

Avian abundance and richness in our study peaked much earlier than did density and richness in a previous study in the Georgia Piedmont (Johnston and Odum 1956).Composition of small mammal captures in our study, however, paralleled those of previous studies in the region (Atkeson and Johnson 1979, Langley and Shure 1980) and decreased as stands approached canopy closure. Commercial or precommercial thinnings in closed canopy stands should be considered to enhance herbaceous groundcover and enhance habitat conditions for small mammals.

Avian habitat conditions likewise could be enhanced in thinned stands by the development of a shrub layer for avian cover and nesting substrate. Consideration should be given to those shrub species that provide wildlife food and survive on reclaimed surface mines. Several plant species are suitable for reclamation sites and also are preferred wildlife food. Suitable trees include cherries (*Prunus* spp.), oaks (*Quercus* spp.), and autumn olive (*Eleagnus* spp.). Suitable shrubs include blackberry (*Rubus* spp.), elderberry (*Sambucus* spp.), sumacs (*Rhus* spp.), mulberries (*Morus* spp.), wild rose (*Rosa* spp.), wax myrtle *(Myrica cerrifera)* and hawthorns (*Crataegus* spp.) (Hunt and Shaw 1979). In addition, several herbaceous and grass species can grow on reclaimed mine sites. Ladino clover *(Trifolium repens)* was grown successfully in kaolin-mine spoil in a greenhouse by adding phosphorous and potassium to the soil (Parks et al. 1967). Birdsfoot trefoil *(Lotus corniculatus),* alfalfa *(Medicago sativa),* and red clover *(T. pratense)* produced high yields on coal-mine spoils in western Kentucky (Powell et al. 1983), as did many cool-season grasses, such as perennial ryegrass *(Lolium perenne)* and annual wheat *(Triticum aestivum)* (Powell et al. 1982).

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