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ANURAN HABITAT USE ON ABANDONED AND RECLAIMED MINING AREAS OF SOUTHWESTERN INDIANA

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ABSTRACT. We surveyed wetland habitats on abandoned and reclaimed strip mines in southwestern Indiana to determine species richness and species-habitat relations of anurans at 40 wetland sites during the 2000 breeding season. Nine anuran species were detected, including the state-endangered crawfish frog (*Rana areolata*). Reproduction was confirmed for seven species, and evidence of breeding was detected at all wetland types, both abandoned and reclaimed. Bullfrogs (*Rana catesbeiana*), green frogs (*Rana clamitans*), and Blanchard's cricket frogs (*Acris crepitans blanchardi*) showed preferences for open water habitats relative to ephemeral wetlands. Metamorphs of spring peeper (*Pseudacris crucifer*), southern leopard frog (*Rana sphenocephala*), Fowler's toad (*Bufo fowleri*), Cope's gray treefrog (*Hyla chrysoscelis*), and bullfrog were observed at sediment basin and ephemeral site types. Post-mining landscapes provide opportunity to restore ephemeral habitats and grassland habitats; both are declining due to human land use, and both provide habitat for anurans. Topographic and vegetative heterogeneity on once-mined lands may provide a sufficiently diverse landscape to support the full range of anuran species in the area.

Keywords: Frogs, mining, conservation, habitat use, landscape management

Wetland habitats are lost during coal mining through removal of surface layers and alteration of hydrology. In addition, acid mine drainage makes mined areas inhospitable to wildlife, particularly amphibians, due to low water and soil pH (Andren et al. 1988; Nawrot & Klimstra 1989). However, a variety of wetlands is left behind after mining, and wetlands in which pH is not too low may offer potential wildlife habitat.

Surface mining of coal has been conducted in Indiana since the 1920s. State laws began to address reclamation in 1941. The Surface Mining Control and Reclamation Act (SMCRA) of 1977 resulted in national reclamation standards, but emphasized restoring mined lands to the original land use (e.g., timber production and agriculture), with less emphasis on wildlife habitat development (Nawrot & Klimstra 1989). Nevertheless, actions undertaken through SMCRA can enhance reclaimed mining wetlands by developing the littoral zone and by establishing prairie areas that include ephemeral wetlands (Nawrot & Klimstra 1989; Indiana Department of Natural Resources 1998).

Aquatic vegetation, aquatic invertebrates, and amphibians may colonize newly-reclaimed sedimentation ponds in surface mines within a year of construction (Fowler et al. 1985). In abandoned areas, final-cut lakes, sediment basins, and ephemeral wetlands offer a diversity of microhabitats, are often less accessible to people, and are recolonized by local plant species rather than planted to monotypic crops or pasture vegetation typical of reclaimed areas (Suchecki & Evans 1978; Nawrot & Klimstra 1989).

We investigated anuran use of wetlands on abandoned and reclaimed mines in southwestern Indiana, and we related species presence to habitat parameters. Information on anuran response to wetland parameters can be used for future wetland design in reclaimed mining areas. With global concern about amphibian population decline, exploring habitat availability and quality within reclaimed mining wetland areas can provide valuable information on the usefulness of these areas for amphibian conservation.

METHODS

Abandoned and reclaimed coal mining areas in Daviess, Dubois, Gibson, Green, Knox, Pike, Sullivan, Vanderburgh, and Warrick counties were surveyed during the summer of 1999 (Fig. 1). Reclaimed wetland sites were

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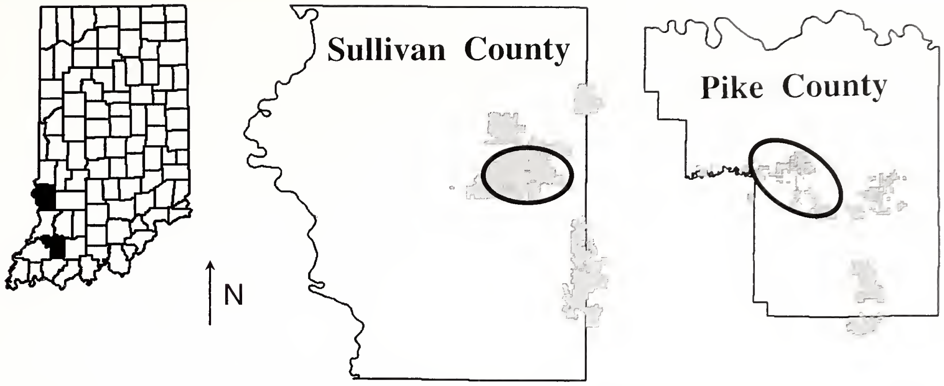

Figure 1.—Study areas in Sullivan County and Pike County, Indiana. Shaded areas show state fish and wildlife areas. Ovals show approximate extent of study.

defined as sites reclaimed according to SMCRA regulations post-1982. Reclamation history was determined for each wetland, and water pH was measured. Sites with pH < 5 were not used because studies have shown that lower pH values harm or kill frog eggs and larvae (Andren et al. 1988). Less than 1% of 52 sites we considered had pH < 5, with the lowest pH at 2.8.

We selected two study areas in the region described above. In each area, we established a call monitoring route with listening points placed to allow calls to be assigned unambiguously to a single wetland, lake, or bottomland site. The Minnehaha study area consisted of 23 sites in Sullivan County and site locations in the Minnehaha Fish and Wildlife Area and Kindall Mining Company mines, near Dugger, Indiana. Mines in this study area were active from about 1960–1980. The Patoka study area of 17 sites in Pike County included site locations in Black Beauty Coal Company mines, Sugar Ridge Fish and Wildlife Area, and Patoka River National Wildlife Refuge and Management Area, near Oakland City, Indiana. Mines in the Patoka study area were active from about 1930–1950 and again in the 1990s. The Patoka study area included two naturally-occurring wetlands that had never been mined (Snaky Point Marsh and an oxbow of the Patoka River). The Minnehaha site had two wetlands that had never been mined, but both were substantially affected by mining activity.

Wetland sites within the study areas were categorized as final-cut lakes, sediment basins, or ephemeral sites. A final-cut lake is a permanent aquatic site that results from the final removal of surface layers to extract coal from a coal layer. A sample of final-cut lakes in the study area for which we could obtain data had an average surface area of 11.45 ha. A final-cut lake encompasses the access road into the pit, as well as the last portion of the pit, which typically was not refilled when work on the pit ended. Depth of final-cut lakes varies from shallow water over the access road to depths > 30 m over the steep-walled, abandoned pit (Carter et al. 1974). Sediment basins are semi-permanent to permanent ponds or wetlands that are designed to collect sediment and debris from the mining site (Rowe 1979). Sediment basins in our study area averaged 3 ha in area and 5 m in depth. Ephemeral sites, as defined for this study, are depressional wetlands that hold water only part of the year and that do not have inflow from or outflow to a stream or lake (National Research Council 2001); all our examples of this type were ≤ 0.3 ha in size. Ephemeral sites are not created deliberately but rather occur when heavy clay soils retain water wherever depressions happen to occur. The final selection of study sites encompassed six abandoned and one reclaimed sediment basin at Minnehaha and five abandoned and six reclaimed sediment basins at Patoka; three abandoned and three reclaimed ephemeral sites at Minnehaha and two abandoned and no reclaimed ephemeral sites at Patoka; nine abandoned and one reclaimed final-cut lakes at Minnehaha and four abandoned and no reclaimed final-cut lakes at Patoka.

Call surveys were conducted from 24 February to 10 August 2000 on nights following rain, with temperatures above 12.7 °C, relatively high humidity, and good listening conditions. Call surveys at each study area started after sunset and followed the same route between the sites for 2.5–3 hours (3 minutes per listening station) for all surveys. Larger wetland sites had multiple call survey points to ensure detection of all species present. North American Amphibian Monitoring Program (NAAMP) call index values were assigned for all species at all stations: 0 (no frogs of given species calling), 1 (individuals discernable with space between calls), 2 (calls of individuals discernible but some overlapping), or 3 (full chorus, calls constant and continuous). Where multiple wetlands occurred in close proximity, we selected listening stations that would permit frogs to be correctly assigned to the surrounding wetlands.

Tadpole surveys were conducted to confirm successful anuran reproduction at study sites. Surveys were conducted from March to August 2000 using dip nets, minnow traps, and seines. When possible, tadpoles were identified to species according to morphological characteristics and timing of breeding cycle (Altig et al. 1998). Predators observed while surveying and trapping were noted.

We visually estimated percent perimeter coverage of wetland and upland vegetation around the perimeter of each wetland site. Percent cover of tall emergent, short emergent, floating leaf shoreline vegetation, and unvegetated shoreline were recorded. Percent cover of closed (tree), mixed tree (tree, shrub, and herbaceous), and mixed shrub (shrub and herbaceous) cover types were estimated in a 20 m band around each site. The 20 m distance was assumed to be cover utilized by anurans that may use upland habitats (e.g., Blanchard's cricket frogs (*Acris crepitans blanchardi*), southern leopard frogs (*Rana sphenocephala*), and Cope's gray tree frogs (*Hyla chrysoscelis*)).

For statistical purposes, a species was considered present if it was heard calling at any call index level > 0. Tests were considered significant when $P \leq 0.05$. We used contingency-table tests to compare call frequencies among frog species and among site types; the null hypothesis for these tests is that, for the species in question, the calling intensity was independent of wetland type.

Tests of habitat relations were conducted with the two study areas combined as there was no reason to suppose relationships would be location-specific. We did not test for habitat relationships for crawfish frogs due to low numbers of observations of this species. We used Spearman rank correlations to identify relationships between species presence and vegetative cover types as there was no *a priori* reason to expect such associations to be linear. Mann-Whitney U and Kruskal-Wallis tests were conducted to identify differences in proportion of wetland and upland vegetative cover types (Ambrose & Ambrose 1995); data did not regularly meet assumptions for t-tests and one-way ANOVAs; we report Z statistics for these tests. Subscripts of M and P are used to denote statistical results from the Minnehaha and Patoka study sites, respectively. We used contingency-table tests to test for selection among ephemeral, sediment-basin and final-cut sites by each anuran species by determining whether the observations of calling frogs were distributed as expected based on the proportions (availability) of the three site types.

We report species richness findings but do not present statistical tests because sample sizes were too small. Due to the introductory nature of this research, some exploratory statistical results are discussed.

RESULTS

Species richness.—Nine anuran species were detected during this study: bullfrog (*Rana catesbeiana*), chorus frog (*Pseudacris triseriata*), Cope's gray treefrog, Blanchard's cricket frog, Fowler's toad (*Bufo fowleri*), green frog (*Rana clamitans*), southern leopard frog, spring peeper (*Pseudacris crucifer*), and the crawfish frog (*Rana areolata*), a state-listed endangered species. Of these, all were detected at Minnehaha, and all but the crawfish frog were detected at the Patoka study area. At abandoned sites at both study areas, total species richness at ephemeral sites (the species count across all ephemeral sites) was lower than at sediment basins and final-cut lakes (Table 1). However, differences between the least and most rich categories were only one and three species at Patoka and Minnehaha, respectively. Median species richness was also lowest at ephemeral sites at Patoka. At Minnehaha, median species richness differed by only a single species among ephemeral, sedi-

Table 1.—Anuran species richness at wetland sites on reclaimed and unreclaimed areas within the Minnehaha and Patoka study areas in southwestern Indiana. Entries show range of species richness within a category, median species richness, total species richness within the category, and sample size. For categories with n = 1, medians and totals are not shown. Categories with no sites are shown as "nd."

	Minnehaha		Patoka	
Wetland type	Abandoned	Reclaimed	Abandoned	Reclaimed
Sediment basin	5–7, 6, 9 (6)	8 (1)	1–6, 5, 8 (5)	4–6, 5, 8 (6)
Ephemeral	2–6, 5, 6 (3)	3–7, 3, 7 (3)	1–7, 4, 7 (2)	nd
Final cut	2–8, 5, 9 (9)	8 (1)	5–7, 6, 8 (4)	nd

ment basin, and final-cut sites. Sample sizes from reclaimed sites were too small to permit comparison. The naturally-occurring wetlands that had never been mined in Patoka (a marsh and an oxbow wetland) supported eight of the nine species in the region; crawfish frogs, which prefer grassland sites, were absent.

Species preference for ephemeral, sediment basin, and final-cut sites.—Bullfrogs, green frogs, and Blanchard's cricket frogs all used final-cut sites in higher proportions than expected, and ephemeral sites in lower proportions (χ^2 = 20.327, df = 2, P < 0.001; χ^2 = 9.812, df = 2, P = 0.007; χ^2 = 18.307, df = 2, P < 0.001). Other significant, but less pronounced, preferences were shown by Fowler's toad (avoiding ephemeral sites: χ^2 = 6.305, df = 2, P = 0.043) and southern leopard frog (tendency to prefer sediment basins and final-cut lakes: χ^2 = 6.49, df = 2, P = 0.039).

Upland and wetland cover.—The three upland and four wetland cover types generally did not differ significantly in their proportions within a wetland site type between the Patoka and Minnehaha study areas, or within a study area, tested among wetland site types (each upland and wetland cover type was tested separately). The Patoka study area had significantly higher estimated tree cover around final-cut sites than the more recently mined Minnehaha study area (Mann-Whitney U test: $Z = -1.957$, n_M = 10, n_P = 4, P = 0.05) and nearly significantly greater tree cover at ephemeral sites (Mann-Whitney U test: Z = -2.619, n_M = 6, n_P = 2, P = 0.07). Within the Patoka study area, sediment basin sites had lower tree cover than final-cut or ephemeral sites (χ^2 = 6.21, df = 2, P = 0.045). Sediment basin sites had more tall emergent cover than the other two wetland types (χ^2 = 6.524, df = 2, P = 0.038) when the study areas were combined (no between-study-area differences were significant).

Species–wetland habitat relationships.—Number of detections of Blanchard's cricket frogs was positively associated with total wetland vegetation in sediment basin sites (i_s = 0.680, n = 18, P = 0.002) and ephemeral sites (i_s = 0.770, n = 8, P = 0.025), but not at final-cut sites where wetland vegetation was rare (median proportion of shoreline in wetland vegetation = 0, n = 14). Fowler's toads were strongly associated with total wetland vegetation at sediment basin sites only (i_s = 0.601, n = 18, P = 0.008). Other correlations were either not significant, or were inconsistent among wetland types.

Predators.—The following vertebrate predators were observed: raccoon (*Procyon lotor*), great blue heron (*Ardea herodias*), green heron (*Butorides striatus*), rainbow trout (*Oncorhynchus mykiss*), largemouth bass (*Micropterus salmoides*), sunfish (*Lepomis* spp.), mosquitofish (*Gambusia affinis*), minnows (Cyprinidae), water snakes (*Nerodia sipedon*), midland painted turtle (*Chrysemys picta marginata*), red-eared slider (*Trachemys scripta elegans*), common snapping turtle (*Chelydra serpentina serpentina*), and western lesser siren (*Siren intermedia nettingi*). The following invertebrate predators were also observed: crayfish (Decapoda), dragonflies (Anisoptera), predaceous diving beetle (Dytiscidae), giant water bug (Belostomatidae), water scorpion (Nepidae), and dobsonfly (Corydalidae). Ephemeral sites generally only had invertebrate predators such as predaceous diving beetle, crayfish, and dragonflies, whereas final-cut and sediment basin sites had vertebrate predators such as fish, snakes, and turtles. Fish were present at 86% of final-cut sites and 72% of sediment basin sites.

Evidence of breeding.—Evidence of hylid

Table 2.—Evidence of hylid and ranid breeding at all wetland types at the Minnehaha and Patoka study areas (Rl = ranid larvae; Rm = ranid metamorphs; Hl = hylid larvae; Hm = hylid metamorphs). Categories with no sites are shown as "nd."

	Minnehaha		Patoka	
Wetland type	Abandoned	Reclaimed	Abandoned	Reclaimed
Sediment basin	Rl, Hl, Rm	Rl	Rl, Hl, Rm, Hm	Rl, Hl
Ephemeral	Rl, Hl, Rm, Hm	Rl, Hl	—	nd
Final cut	Rl, Hl	—	Rl, Rm	nd

and ranid breeding was detected at all wetland site types and in both reclaimed and abandoned sites (Table 2). Larvae were present at 29% of 14 final-cut sites, 44% of 18 sediment basin sites, and 50% of 8 ephemeral sites. Spring peeper, southern leopard frog, and bullfrog metamorphs were observed at ephemeral sites at the Minnehaha study area. Fowler's toad and southern leopard frog metamorphs were observed at sediment basin sites at the Minnehaha study area. Cope's gray treefrog metamorphs were observed at a sediment basin site at the Patoka study area.

DISCUSSION

Presence of nine frog species and evidence of breeding for both hylid and ranid species at all types of wetland sites demonstrate that surface mining landscapes offer habitat for Indiana anuran species. Observation of metamorphs further indicates the conservation potential of reclaimed and unreclaimed mining sites. Of the species potentially resident at the two study sites, but not found during this study, the eastern spadefoot is a species of special concern in the state and has not actually been observed in either county. Wood frogs have not actually been observed in either county, but they are relatively common in the region and may have been missed due to their short, early calling window.

The herpetofauna at abandoned mines in southern Indiana was known to approximate richness and abundance of adjacent cropland and natural areas (Suchecki & Evans 1978), but this is the first study to demonstrate high richness (relative to potential richness) at more recently disturbed (1990s) reclaimed areas in Indiana. Studies on newly reclaimed (1980s) sedimentation ponds in Tennessee have documented similar anuran richness (10 species; Fowler et al. 1985); we provide further evidence of breeding for seven anuran species at both sediment basin and ephemeral sites. Less than 1% of sites investigated for selection in our study had pH < 5; and the limestone-based soils in southern Indiana may improve chances for full remediation of acid mine drainage, and increase the likelihood of amphibian recolonization.

Habitat relationships documented during this study confirm that anurans on mined areas continue to show the habitat behavior observed in more traditional settings. Bullfrogs and green frogs are known to favor open water, and although cricket frogs are less strongly linked to permanent open water, they are not considered to favor ephemeral areas (Minton 2001). The only links to vegetation-B-Blanchard's cricket frog and Fowler's toad to wetland vegetation cover—may simply have been a response to value of the vegetation as escape cover. The greater tree cover found in the vicinity of sites at the less-recently-mined Patoka study area did not alter species richness relative to the more-recently-mined Minnehaha study area: both study areas had essentially the full species complement they might be expected to support.

Possibly, the topographic variation that results from mining, and the eventual vegetative heterogeneity, whether from natural processes or from reclamation, provide a sufficiently diverse landscape to support breeding, non-breeding, and corridor habitat for the full range of anuran species (Kolosvary & Swihart 1999; Knutson et al. 2000). In particular, mining landscapes may provide more of one limiting habitat type—ephemeral wetlands—than most other land uses.

As mining spoil is removed and replaced as a part of the mining process, swale areas can result through incomplete filling between spoil piles, which in turn results in ephemeral wetlands. Thus, ephemeral wetlands can be rather common on once-mined lands, although they are seldom created purposefully (Deanna Luzynski, Indiana Division of Reclamation; Bernie Rottman, Black Beauty Coal Company, pers. commun.).

Small isolated or ephemeral wetlands are becoming increasingly rare elsewhere in human-dominated landscapes, due to filling and draining (Lehtinen et al. 1999); mining landscapes may offset some of this loss (Dodd & Cade 1998). Ephemeral or semi-permanent wetland areas can support high levels of amphibian species richness and are important for breeding and recruitment (Dodd & Cade 1998; Semlitsch & Bodie 1998; Kolozsvary & Swihart 1999; Nyberg & Lerner 2000). Additionally, isolated ephemeral wetlands improve connectivity and reduce migration distances to breeding sites (Semlitsch & Bodie 1998). Habitat connectivity is known to be a limiting landscape feature for amphibian dispersal and for recovery of disturbed or extirpated populations (Semlitsch 2000).

Grassland habitats are also enhanced on restored mined lands; whereas elsewhere in Indiana, prairies have been almost entirely converted to row crops and pasture (Jackson 1997). The state-endangered crawfish frog's former range in Indiana was restricted to prairie and prairie-forest ecotone in the western part of the state (Minton 2001). Regionally, habitat loss due to development and agriculture has led to population declines for this species in Illinois, Indiana, Iowa, Kansas, and Missouri (Redmer 2000). However, restoration activities on mine lands tend to create grassland cover more commonly than tree cover (Bajema et al. 2001). Mine lands in Indiana now provide over 180 sq km of grassland habitat, and have become important conservation areas for grassland birds displaced from their original habitats by agriculture (Bajema et al. 2001). Crawfish frogs, too, may actually be favored by restoration of mine lands to grassland cover.

The presence of fish in 86% of the final-cut sites and 72% in the sediment basin sites has potential to diminish amphibian breeding success. Largemouth bass feed heavily on tadpoles (Hamilton & Powles 1997), and mosquitofish are known to consume frog eggs (McDiarmid & Altig 1999). The effects of stocking of largemouth bass, sunfish, and mosquitofish on amphibians should be considered when managing the landscape for amphibians. Enhancement of wetlands that do not contain fish should be considered.

Based on the findings of this study, considerations for amphibians in wetland design for reclaimed landscapes include: (1) preservation/enhancement of ephemeral areas within the landscape; (2) enhancement/restoration of grassland habitat, possibly in the same swale areas that favor ephemeral wetlands; and (3) maintaining a variety of wetland habitat types and wetland complexes, with and without fish, within the mining landscape.

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