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Article

Mine Spoil Prairies Expand Critical Habitat for Endangered and Threatened Amphibian and Reptile Species

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Abstract: Coal extraction has been occurring in the Midwestern United States for over a century. Despite the pre-mining history of the landscape as woodlands, spent surface coalfields are often reclaimed to grasslands. We assessed amphibian and reptile species on a large tract of coal spoil prairie and found 13 species of amphibians (nine frog and four salamander species) and 19 species of reptiles (one lizard, five turtle, and 13 snake species). Two state-endangered and three state species of special concern were documented. The amphibian diversity at our study site was comparable to the diversity found at a large restored prairie situated 175 km north, within the historic prairie peninsula.

Keywords: amphibian; reptile; declines; habitat loss; prairie

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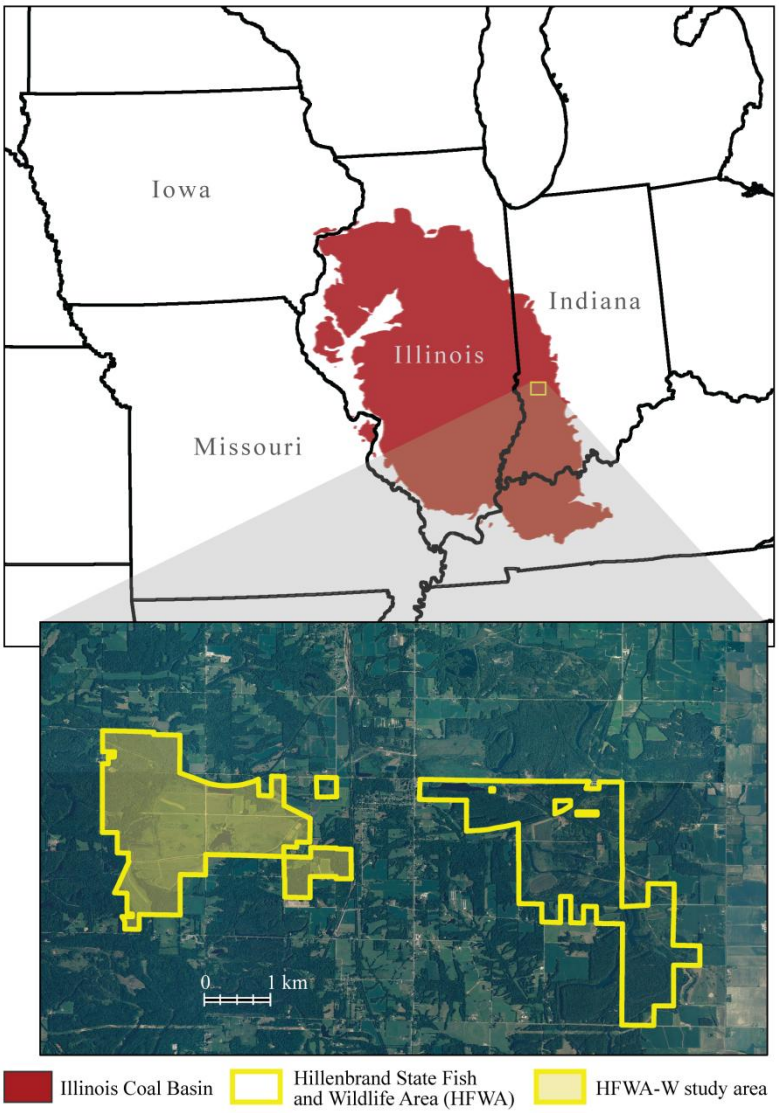
1. Introduction

In the Central United States, the coalfields in the Illinois Basin extend in a rough oval running northwest to southeast, from the Iowa-Illinois Quad Cities through central and southern Illinois into western and southwestern Indiana and west-central Kentucky (Figure 1) [1].

Figure 1. Extent of the coal fields in the Illinois Basin and the Hillenbrand study area.



These strata consist of a broad downwarp centered in southern Illinois, and therefore lie in a bowl shape—deeper in the middle than along their margins. Margins consist of multiple seams and are shallow enough to be mined using surface drag-line techniques. Prior to being mined, these lands were eastern deciduous forest cleared for agriculture [1]. Historical mine spoils were planted with trees; recent reclamation projects generally involve seeding soils with non-native grasses and other herbaceous vegetation. Advantages of non-native herbaceous revegetation included rapid aerial seeding and low costs. Additionally, these non-native species have demonstrated a tolerance for the notoriously unstable, acidic, nutrient poor, and droughty soils of mine spoils [1,2]. They also provided

quick erosion control, and a rapid economic return through livestock grazing. While native species assemblages also might have performed these roles, there was no concerted or systematic effort to find suitable native plants to use in restoration efforts [1]. Within the past ten years, some Indiana Department of Natural Resources (DNR) land managers have been eliminating non-native herbaceous plantings (especially fescue) on reclaimed mine lands, replacing them with native grassland species, and instituting burning regimes for prairie maintenance, creating what we term mine spoil prairies [1].

The presence of mine spoil prairies has shifted grassland habitats southward in Indiana, from the historic native prairie peninsula of the northwestern portion of the state [3,4]—destroyed by agriculture but currently being restored in part in the Kankakee Sands area—to the reclaimed mine spoil prairies of the southwestern portion of the state. Reclaimed mine spoil prairies are not restorations *per se*, as these areas were not extensive grasslands at the time of European settlement. Instead their history was primarily deciduous forest with scattered prairies [3,5] cleared for agriculture then dug for coal before being reclaimed. Despite the fact that these grasslands are about 175 km south of the historic prairie peninsula, they have been colonized by a large number of native grassland birds, including Henslow's Sparrows (*Ammodramus henslowii*), Dickcissels (*Spiza americana*), Bobwhite Quail (*Colinus virginianus*), Northern Harriers (*Circus cyaneus*), and Short-eared Owls (*Asio flammeus*) [6-8]. Prairie restorations have also been shown to support increases in grassland-dependent small mammal numbers [9,10].

In Indiana, and in fact throughout the Illinois Basin, mine spoil prairies have not been systematically surveyed for amphibians and reptiles, although a subset of these grasslands have been surveyed for amphibian calls and larvae [11]. Amphibians are among the most threatened vertebrate groups on the planet, with one in three species threatened or extinct [12-14]. Reptiles are similarly threatened [15]. One major reason for these declines is habitat loss [15-17], and it follows that habitat reclamation and restoration projects, including artificial habitats created on post-mined lands, should be assessed for their value to support amphibian and reptile diversity, especially threatened and endangered species. Our field site is located on a reclaimed coal spoil in southwestern Indiana. During the first field season of a large programmatic study designed to understand the biology of Crawfish Frogs (*Lithobates* [*Rana*] *areolatus*) on reclaimed coal spoil grasslands, we documented a large number of amphibian and reptile species. Here, we describe this diversity and discuss its importance.

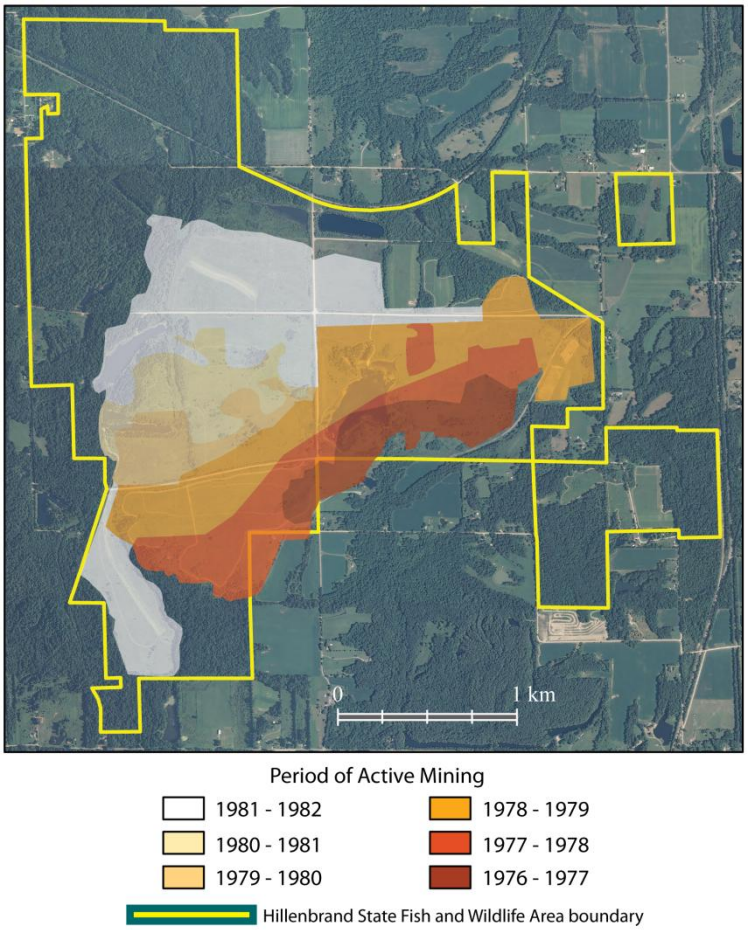
2. Materials and Methods

2.1. Study Site

Our field site is located in Hillenbrand State Fish and Wildlife Area (HFWA; 1,468 ha) in northwestern Greene County, Indiana (Figure 1). HFWA, along with the Chinook Fish and Wildlife Area (927 ha) located to the north, and the Minnehaha Fish and Wildlife Area (~2,428 ha) located to the west, represent a large complex of reclaimed mine spoils managed as prairie by the Indiana Department of Natural Resources' (DNR) Division of Fish and Wildlife. Our HFWA field sites are in the western section of the property (HFWA-W, or Hillenbrand-1 [6]), encompassing 729 ha of essentially continuous habitat interrupted by occasional gravel roads, wildlife food plots, and a railroad track.

HFWA-W was surface mined for coal between 1976 and 1982 in a southeastern to northwestern direction (Figure 2). When the extraction was completed (1982–1983), the area was graded to the approximate original contours, topsoil was added to a depth of approximately 15–38 cm, and the ground revegetated, primarily with non-native tall fescue. Since 1999, the DNR management plan has been to replace the original fescue with native prairie grasses and forbs (predominant prairie species include Big Bluestem [*Andropogon gerardii*], Little Bluestem [*Schizachyrium scoparium*], Partridge Pea [*Chamaecrista fasciculata*], Yarrow [*Achillea millefolium*], Black-eyed Susan [*Rudbeckia hirta*], Purple Coneflower [*Echinacea purpurea*], Rosinweed [*Silphium integrifolium*], Compass Plant [*Silphium laciniatum*], and Blazing Star [*Liatris* sp.]). Because of limitations of time and personnel, this has been an ongoing process. Generally, areas have been revegetated in 30–40 acre blocks (R. Ronk, Indiana DNR, personal communication).

Figure 2. Pattern of coal mining in the Hillenbrand study area.



Today, HFWA-W consists of continuous native prairie plantings interspersed with wildlife food plots (corn [*Zea mays*] and soybeans [*Glycine max*]) and scattered trees (willows [*Salix* sp.], American sycamores [*Plantanus occidentalis*], and shingle oaks [*Quercus imbricaria*] are among most common native species; Figure 3A and 3B). Reflecting the general southeast to northwest direction of mining activities, final cut lakes are located along the northern and western edges of the site; a large contoured lake (Moss Lake) is located south centrally (Figure 3A). At least nine wetlands, ranging in hydroperiod from seasonal through semi-permanent to permanent support amphibian reproduction. Dozens of

small, seasonal wetlands are scattered throughout the prairie and may support amphibian reproduction during wet years. The area surrounding HFWA-W consists of agricultural fields bordered by tree lines and woodlots.

Figure 3. Hillenbrand Fish and Wildlife Area looking southwest across Moss Lake **(A)** and looking east from a site north of Moss Lake **(B)**. Photos taken by MJL on 15 March 2009 (A) and 30 September 2009 (B).

A

B

2.2. Drift Fences

Drift fences with pitfall traps [18] were our primary method of collecting amphibians; many reptiles were also captured in these arrays. Drift fences consisting of 0.91 m tall erosion fencing buried 10–15 cm were constructed around four seasonal or semipermanent wetlands. Pitfall traps, consisting of pairs (inside and outside the fence) of square-shaped, 15-L buckets, were placed every 10 m along the fences. Buckets, perforated to facilitate drainage, were covered with half lids to prevent escape and

to deter raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), and feral cat (*Felis catus*) predation. Sponges moistened daily were placed in buckets, as were short stakes to allow small mammals to escape. Total length of drift fencing was 920 m and included 183 buckets (one bucket in a perennially wet area was removed). Drift fences were checked daily, and the results reported in this study (from 3 March–15 August 2009) represent a total of about 152 km of drift fence sampling.

2.3. Visual Encounters

Visual encounters typically occurred while walking between drift-fenced wetlands and between locations of radiotelemetered Crawfish Frogs, which could be any time of day from dawn to after dusk. We estimate that from 3 March–31 July 2009 we walked about 3 km/d (per individual [x 2]), for a total of approximately 450 km of on-site foot travel. A second means of encountering animals involved driving within HFWA-W during daily visits to the site—which again could be anytime of day from dawn to after dusk—representing a minimum of 6 km/d, totaling at least 900 km of road travel. Reptiles, especially snakes and Eastern Box Turtles (*Terrapene carolina*), were usually encountered while traveling through and working at the study site.

2.4. Statistics

Shannon–Wiener diversity indices for each group except lizards (one species) were calculated [19].

2.5. Species Status

Global Species status was determined from the IUCN (the International Union for Conservation of Nature) Red List of Threatened Species (http://www.iucnredlist.org). Indiana state status was determined from http://www.in.gov/dnr/naturepreserve/4666.htm.

3. Results and Discussion

3.1. Amphibians

Four species of salamanders (order Caudata) and nine species of frogs and toads (order Anura) were encountered (Table 1). Adults and juveniles, were captured along our drift fences. Occasionally, older juveniles and postbreeding adults also were captured. With the exception of treefrogs (Hylidae), especially Cope's Gray Treefrogs (*Hyla chrysoscelis*), which are capable of climbing fences, total numbers of animals presented in Table 1 likely reflect relative abundances of species at our field site, although each of the four study wetlands had different species compositions, and species shared were present in different ratios.

Salamander species from two families were found (Table 1). Ambystomatids included Marbled Salamanders (*Ambystoma opacum*), Small-mouthed Salamanders (*A. texanum*), and Eastern Tiger Salamanders (*A. tigrinum*). Salamandrids included Eastern Newts (*Notophthalmus viridescens*). Each

of these four species are widespread in North America. Life history stages encountered included pre- and postbreeding adults and post-metamorphic juveniles. Eft-stage newts were also collected.

Marbled Salamanders were the most abundant amphibians at our study site (Table 1). Small-mouthed Salamanders were the second-most abundant salamanders but were encountered in less than half the numbers of Marbled Salamanders. Eastern Newts were also common. Eastern tiger salamanders, normally considered a grassland species and common in other portions of southwestern Indiana, were sparse. Marbled Salamanders, Tiger Salamanders and Eastern Newts had not previously been reported from Greene County [20] and therefore represent new county records. The Shannon–Wiener diversity index (or ―effective number of species" [19]) for salamanders is 2.48.

Frogs representing three families were collected (Table 1). Fowler's Toads (*Anaxyrus* [*Bufo*] *fowleri*) were the only toads found. Treefrogs included Northern Cricket Frogs (*Acris crepitans*), Cope's Gray Treefrogs, Spring Peepers (*Pseudacris crucifer*), and Western Chorus Frogs (*P. triseriata*). True frogs included Crawfish Frogs, American Bullfrogs (*Lithobates* [*Rana*] *catesbeianus*), Green Frogs (*L. clamitans*), and Southern Leopard Frogs (*L. sphenocephalus*).

Table 1. Amphibian species and numbers (adults and juveniles) encountered.

Scientific Name	Common Name	IUCN Status	Indiana Status	Number
Salamanders				
Ambystomatidae				
Ambystoma texanum	Small-mouthed Salamander	Least Concern	None	1215
Ambystoma tigrinum	Eastern Tiger Salamander	Least Concern	None	26
Ambystoma opacum	Marbled Salamander	Least Concern	None	2739
Salamandridae				
Notophthalmus viridescens	Eastern Newt	Least Concern	None	430
Frogs				
Bufonidae				
Anaxyrus(Bufo) fowleri	Fowler's Toad	Least Concern	None	6
Hylidae				
Acris crepitans	Northern Cricket Frog	Least Concern	Special Concern	13
Hyla chrysoscelis	Cope's Gray Treefrog	Least Concern	None	3
Pseudacris crucifer	Spring Peeper	Least Concern	None	168
Pseudacris triseriata	Western Chorus Frog	Least Concern	None	899
Ranidae				
Lithobates (*Rana) areolatus*	Crawfish Frog	Near Threatened	Endangered	377
Lithobates (Rana) catesbeianus	American Bullfrog	Least Concern	None	12
Lithobates (Rana) clamitans	Green Frog	Least Concern	None	2550
Lithobates (Rana) sphenocephalus	Southern Leopard Frog	Least Concern	None	166

Green Frogs were the most abundant frog found at our field site, but Western Chorus Frogs, Spring Peepers, Northern Cricket Frogs, and Crawfish Frogs also were common. Fowler's Toads and American Bullfrogs were encountered occasionally. Crawfish Frogs are state endangered and listed as

Near Threatened on the IUCN Red List (http://www.iucnredlist.org); Northern Cricket Frogs are a state species of special concern. The Shannon-Wiener diversity index for frogs is 3.79.

3.2. Reptiles

One juvenile Common Five-lined Skink (*Plestiodon fasciatus*) was caught in a pitfall trap and several others were observed basking during late July mornings (Table 2).

Table 2. Reptile species and numbers (adults and juveniles).

Scientific Name	Common Name	IUCN Status	Indiana Status	Number Encountered
Snakes				
Colubridae				
Coluber constrictor	North American Black Racer	Least Concern	None	6
Lampropeltis calligaster	Yellow-bellied Kingsnake	Least Concern	None	3
Lampropeltis getula	Common Kingsnake	Least Concern	None	4
Lampropeltis triangulum	Eastern Milksnake	Not Evaluated	None	1
Opheodrys aestivus	Rough Greensnake	Least Concern	Special Concern	2
Natricidae				
Clonophis kirtlandii	Kirtland's Snake	Near Threatened	Endangered	1
Nerodia sipedon	Northern Water Snake	Least Concern	None	1
Storeria dekayi	Dekay's Brownsnake	Least Concern	None	1
Thamnophis sauritus	Eastern Ribbonsnake	Least Concern	None	5
Thamnophis sirtalis	Common Gartersnake	Least Concern	None	7
Xenodontidae				
Carphophis amoenus	Worm Snake	Least Concern	None	1
Diadophis punctatus	Ring-necked Snake	Least Concern	None	2
Heterodon platirhinos	Eastern Hog-nosed Snake	Least Concern	None	1
Turtles				
Chelydridae				
Chelydra serpentina	Common Snapping Turtle	Least Concern	None	16
Emydidae				
Chrysemys picta	Painted Turtle	Not Evaluated	None	108
Trachemys scripta	Red-eared Slider	Least Concern	None	6
Terrapene carolina	Eastern Box Turtle	Near Threatened	Special Concern	43
Kinosternidae				
Sternotherus odoratus	Stinkpot	Least Concern	None	2
Lizards				
Scincidae				
Plestiodon fasciatus	Common Five-lined Skink	Least Concern	None	5

Turtles were common, both in terms of relative abundance and species encountered (Table 2). Painted Turtles (*Chrysemys picta*) were most abundant, followed by Eastern Box Turtles and Common

Snapping Turtles (*Chelydra serpentina*). Red-eared Sliders (*Trachemys scripta*) and Stinkpots (*Sternotherus odoratus*) were encountered much less often. Stinkpots and Eastern Box Turtles were new county records. Eastern Box Turtles are considered Near Threatened on the IUCN Red List and are a species of special concern in Indiana, but through a special legislative provision passed in 2004 are provided the equivalent of endangered status. The Shannon-Wiener diversity index for turtles is 2.88.

Snakes were the most species-rich group encountered (Table 2). We found 13 species including North American Black Racers (*Coluber constrictor*), Rough Greensnakes (*Opheodrys aestivus*), Yellow-bellied Kingsnakes (*Lampropeltis calligaster*), Common Kingsnakes (*Lampropeltis getula*), and Eastern Milksnakes (*Lampropeltis triangulum*). We also found Eastern Gartersnakes (*Thamnophis sirtalis*), Eastern Ribbonsnakes (*Thamnophis sauritus*), Kirtland's Snakes (*Clonophis kirtlandii*), Northern Water Snakes (*Nerodia sipedon*), and Dekay's Brownsnakes (*Storeria dekayi*). In addition we found Ring-necked Snakes (*Diadophis punctatus*), Eastern Hog-nosed Snakes (*Heterodon platirhinos*), and Worm Snakes (*Carphophis amoenus*). Despite their species richness, snakes were encountered infrequently, making estimates of abundance spurious. Kirtland's Snakes are a state endangered species and considered Near Threatened on the IUCN Red List. Rough Greensnakes are a state species of special concern. Kirtland's Snakes, Eastern Ribbonsnakes, Dekay's Brownsnakes, Common Kingsnakes, Eastern Milksnakes, and Ring-necked Snakes represent new county records [20]. The Shannon-Wiener diversity index for snakes is 9.31.

3.3. Perspective

Grasslands are one of the most threatened ecosystems on earth [21-24]. In North America, native grasslands once stretched across the United States from Canada to Mexico, and east from the Rocky Mountains as far as Ohio. Globally, more than 95% of historic tallgrass prairie has been converted to agriculture and other uses. Short- and mid-grass prairies continue to be converted to agriculture. In the United States only about 9% of historic grasslands remain [16,25]. In Indiana, only 404 of the original 2,800,000 ha of tallgrass prairie remain, a loss of 99.9% [4]. Our study site alone offers nearly twice this habitat area.

Most grassland loss is due to intensive agriculture [16,21-24]. It follows that where habitats are lost, animals that rely on these habitats also will be lost too [6,26-28]. The recently completed "State of the Birds" report notes that of 46 grassland-breeding bird species, 48% are of conservation concern, including four with populations that are federally endangered [29]. Further, of the 42 grassland species with sufficient monitoring data, 23 show significant declines. This report points out that some of the American landscape's most iconic birds, including Eastern and Western Meadowlarks, Bobolinks, Short-eared Owls, and Northern Bobwhites are showing steep declines. What holds for birds also holds for other vertebrate classes, including amphibians and reptiles [16]. But compared with North American bird species, amphibians and reptiles lack the advantage of flight, and therefore cannot seek out suitable but distant habitats [14,16,30].

In an attempt to reverse these declines, prairies are being restored to different degrees and at various scales in many parts of the historic North American grasslands [4]. In these regions, the extent of natural recolonizations depends on the size of the restoration, its proximity to other prairies, and the

presence of dispersal corridors between sites. In the absence of natural recolonizations, restorations of plant communities and repatriations of distant or non-mobile animal populations have been variously, and sometimes spectacularly, successful. For example, it is clear that bird communities respond positively to the presence of mine spoil prairies [6-8,31-34], what has yet to be evaluated is how relatively non-mobile native amphibians and reptiles respond. In particular, we continue to be interested in the two situations represented by our study site: 1) grasslands created beyond the limits of the historic grassland ecoregions, and 2) created grasslands established on reclaimed coal mines. Given the environmentally destructive reputation that surface coal mining has [35], and the negative impacts that coal mining has on amphibians [11,36-38] it is startling that such a richness of amphibian and reptile species exists on the reclaimed mine spoil prairie habitat of our study site.

Judging by the number of amphibian and reptile species found on our field site (32 species) and by the number of these species whose conservation status has generated concern at either the state or global levels (five species), mine spoil prairies create habitat that can be naturally colonized by both obligate and facultative grassland species. Of the amphibian and reptile species found at our study site to date, nearly half (15 species) typically are considered true obligate grassland species or can be found on grassland edge [20,39], including Eastern Tiger Salamanders [40], Fowler's Toads, Northern Cricket Frogs, Chorus Frogs, Spring Peepers, Crawfish Frogs, Southern Leopard Frogs, Eastern Gartersnakes, Eastern Ribbonsnakes, Kirtland's Snakes, Dekay's Brownsnakes, Racers, Rough Greensnakes, Yellow-bellied Kingsnakes, and Eastern Hog-nosed Snakes. From these data we conclude that mine spoil prairies have the potential to partially offset the loss of grassland habitat in other regions.

While we are surprised at the number of new county records discovered (11 species), these cannot entirely be due simply to the presence of mine spoil prairies. Populations of these species must have been in the vicinity, perhaps on prairie remnants, forest-edge habitat, or railroad right-of-ways, prior to their expansion into the mine spoils. Further, Greene County has not had a long history of systematic biological surveys (but see [41]), and our effort represents the first season-long, intensive search for amphibians and reptiles here. Put another way, had we spent just as much time at other sites in the county we may have been able to locate many, and perhaps most, of the new species reported here.

It is also interesting to consider the number of obligate woodland or woodland-edge species we discovered. These include Cope's Gray Treefrogs, Marbled Salamanders, Small-mouthed Salamanders, Eastern Newts, Eastern Box Turtles, Five-lined Skinks, Racers, Rough Greensnakes, Black Kingsnakes, Milksnakes, Ring-necked Snakes (~~"t~~he only Indiana snake that prefers heavy forest over dry, open woods or forest edge" [20,39]), Worm Snakes (a ~~"f~~orest animal" that ~~"d~~isappears from deforested areas" [20]), and Eastern Hog-nosed Snakes. For example, we were astonished at the number of Marbled Salamanders (~~"a~~ hardwood forest species" [20]), which had never before been documented in Greene County, and equally surprised at the small number of Eastern Tiger Salamanders, the only species of salamander at our study site with an affinity for grasslands. It may be that forest habitat is close enough that species venture into adjacent, undisturbed grasslands. It may also be that the grassland habitat at our field site is so new that species are still in the process of sorting themselves ecologically. That is, the current assemblage may reflect a combination of both initial presence (who got there first) and interspecific interactions, which may not yet be fully developed. In the case of Tiger Salamanders, it may be that soil type (a preference for friable soils) may be limiting.

Our data support the observation that Spotted Salamanders (*A. maculatum*) behaviorally avoided grassland habitats (we did not find Spotted Salamanders) [42], but grasslands did not appear to hinder the movements of most other amphibian and reptile species.

For additional perspective we compared our amphibian data to the amphibian species list (amphibian diversity indices have not been generated and reptile data have not been published) generated at Kankakee Sands, a prairie reconstruction begun in 1996 with 8,741 ha along the Illinois-Indiana border situated in the former prairie peninsula [43]. The Kankakee Sands restoration currently encompasses 8,903 ha, and includes over 25 shallow wetland basins designed specifically to maximize amphibian breeding habitat, and contains the largest prairie in Indiana's historic prairie peninsula. Eight species of frogs and one species of salamander have been found on the Kankakee Sands property (Table 3). An early survey of the site showed that amphibian breeding locations increased from six prior to restoration to 44 four years later, after restoration. Kankakee Sands is roughly the same age as our study site at Hillenbrand (established in 1996, whereas habitat restoration at Hillenbrand began in 1998), and comparing the two amphibian assemblages demonstrates an overall similarity in frog species (Table 3): Fowler's Toads, Western Chorus Frogs, Spring Peepers, American Bullfrogs, and Green Frogs are present at both sites. Each site has Leopard Frogs (Northern Leopard Frogs [*L. pipiens*] at Kankakee Sands, Southern Leopard Frogs at Hillenbrand). Each site also has Gray Treefrogs (it is not clear whether Eastern Gray Treefrogs [*H. versicolor*] or Cope's Gray Treefrogs are present at Kankakee). Each site has species not present at the other site: Kankakee Sands has American Toads (*A. americanus*), while Hillenbrand has Northern Cricket Frogs, a species of special concern that has declined precipitously in northern Indiana [20,30,44], and Crawfish Frogs, which are state endangered.

Table 3. A comparison of the amphibian species found at Kankakee Sands, a grassland restoration located in the former prairie peninsula of Illinois and Indiana, with the amphibian species found at our study site at Hillenbrand Fish and Wildlife Area, former eastern deciduous forest located about 175 km south of the original prairie peninsula.

Kankakee Sands	**Hillenbrand Fish and Wildlife Area**
Frogs	
Northern Leopard Frog	Southern Leopard Frog
Western Chorus Frog	Western Chorus Frog
Fowler's Toad	Fowler's Toad
American Toad	
Gray Treefrog	Cope's Gray Treefrog
Spring Peeper	Spring Peeper
American Bullfrog	American Bullfrog
Green Frog	Green Frog
	Crawfish Frog
	Northern Cricket Frog
Salamanders	
Eastern Tiger Salamander	Eastern Tiger Salamander
	Small-mouthed Salamander
	Marbled Salamander
	Eastern Newt

The species composition of salamanders differs between Hillenbrand and Kankakee Sands (Table 3). Although Eastern Tiger Salamanders are present at both sites, they are the only salamander species present at Kankakee Sands, whereas Hillenbrand supports robust populations of Marbled Salamanders, Small-mouthed Salamanders, and Eastern Newts, perhaps reflecting the history of woodlands in the area and the presence of nearby eastern deciduous forest habitats. Taking into account species distributions (in general more species are found in southwestern Indiana than northwestern Indiana [20]), these data suggest that the Hillenbrand mine spoil prairie reclamation supports about the same degree of amphibian species richness as the Kankakee Sands native prairie restoration. This finding points to the potential value of mine spoil prairies as critical habitat for both common and threatened amphibian and reptile species. We suggest that planning and permitting decisions for final reclamation and post-mine land use by coal operators, regulatory agencies, and state and federal fish and wildlife agencies take into account the considerable conservation value of these prairie habitats.

4. Conclusions

While the act of surface mining coal can reduce and perhaps eliminate populations of amphibians and reptiles, reclamation projects can provide habitat that supports species, including threatened and endangered species. Mine spoil prairies in the southeastern corner of the Illinois Basin provide habitat for a surprising number of amphibian and reptile species, including two state endangered species also recognized as ―Near Threatened" by the IUCN, and three species of special concern, one of which is recognized as ―Near Threatened" by the IUCN. We conclude that mine spoil prairie reclamations can support roughly the same degree of amphibian richness as native prairie restorations, and suggest that planning and permitting decisions for final reclamation and post-mine land use by coal operators, regulatory agencies, and state and federal fish and wildlife agencies take into account the considerable conservation value of these prairie habitats.

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References

1. Brothers, T.S. Surface-mine grasslands. *Geograph. Rev.* **1990**, *80*, 209-225.
2. Cole, C.A.; Lefebvre, E.A. Soil and water characteristics of a young surface mine wetland. *Environ. Manage.* **2006**, *15*, 403-410.

3. Transeau, E.N. The prairie peninsula. *Ecology* **1935**, *16*, 423-437.
4. Sampson, F.B.; Knopf, F.L.; Ostlie, W.R. Regional trends of biological resources. In *Status and Trends of the Nation's Biological Resources*; Mac, M.J., Opler, P.A., Puckett Hacker, C.E., Doran, P.D., Eds.; U.S. Department of the Interior, U.S. Geological Survey: Reston, VA, USA, 1998; pp. 437-472.
5. Jones, S.R.; Cushman, R.C. *The North American Prairie*; Peterson Field Guide Series; Houghton Mifflin: New York, NY, USA, 2004.
6. DeVault, T.L.; Scott, P.E.; Bajema, R.A.; Lima, S.L. Breeding bird communities of reclaimed coal mine grasslands in the American Midwest. *J. Field Ornithol*. **2002**, *73*, 268-275.
7. Scott, P.E.; DeVault, T.L.; Bajema, R.A; Lima, S.L. Grassland vegetation and bird abundances on reclaimed midwestern coal mines. *Wildl. Soc. Bull*. **2002**, *30*, 1006-1014.
8. Scott, P.E.; Lima, S.L. Exotic grasslands on reclaimed midwestern coal mines: an ornithological perspective. *Weed Technol*. **2004**, *18*, 1518-1521.
9. Hingtgen, T.M.; Clark, W.R. Small mammal recolonization of reclaimed coal surface-mined land in Wyoming. *J. Wildl. Manage.* **1984**, *48*, 1255-1261.
10. Stone, E.R. Measuring impacts of restoration on small mammals in a mixed-grass Colorado prairie. *Ecol. Restor*. **2007**, *25*, 183-190.
11. Timm, A.; Meretsky, V. Anuran habitat use on abandoned and reclaimed mining areas of southwestern Indiana. *Proc. Indiana Acad. Sci.* **2004**, *113*, 140-146.
12. Stuart, S.; Chanson, J.S.; Cox, N.A.; Young, B.E.; Rodrigues, A.S.L.; Fischman, D.L.; Waller, D.L. Status and trends of amphibian declines and extinctions worldwide. *Science* **2004**, *306*, 1783.
13. Gascon, C., Collins, J.P., Moore, R.D., Church, D.R., McKay, J.E., Mendelson, J.R., III, Eds. Amphibian Conservation Action Plan. In *Proceedings of the IUCN/SSC Amphibian Conservation Summit*; World Conservation Union (IUCN): Gland, Switzerland, 2005.
14. Lannoo, M.J., Ed. *Amphibian Declines: The Conservation Status of United States Species*; U. California Press: Berkeley, CA, USA, 2005.
15. Gibbons, J.W.; Scott, D.E.; Ryan, T.J.; Buhlmann, K.A.; Tuberville, T.D.; Metts, B.S.; Greene, J.L.; Mills, T.; Leiden, Y.; Poppy, S.; Winne, C.T. The global decline of reptiles, déjà vu amphibians. *BioScience* **2000**, *50*, 653-666.
16. Gallant, A.L.; Klaver, R.W.; Casper, G.S.; Lannoo, M.J. Global rates of habitat loss and implications for amphibian conservation. *Copeia* **2007**, *2007*, 967-979.
17. Sodhi, N.S.; Bickford, D.; Diesmos, A.C.; Lee, T.M.; Koh, L.P.; Brook, B.W.; Sekercioglu, C.H.; Bradshaw, C.J.A. Measuring the meltdown: drivers of global amphibian extinction and decline. *PLoS ONE* **2008**, *3*, e1636; doi:10.1371/journal.pone.0001636.
18. Corn, P.S. Straight-line drift fences and pitfall traps. In *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*; Heyer, W.R., Donnelly, M.A., McDiarmid, R.W., Hayek, L.-A.C., Foster, M.S., Eds.; Smithsonian Institution Press: Washington, DC, USA, 1994; pp. 109-117.
19. Jost, L. Entropy and diversity. *Oikos* **2006**, *113*, 363-374.
20. Minton, S.A., Jr., Ed. *Amphibians and Reptiles of Indiana*, revised 2nd ed.; Indiana Acad. Sci.: Indianapolis, IN, USA, 2001.

21. Estes, J.R., Tyrl, R.J., Brunken, J.N., Eds. *Grasses and Grasslands, Systematics and Ecology*; U. Oklahoma Press: Norman, OK, USA, 1982.
22. Brown, L. *Grasslands (Audubon Society Nature Guides)*; Alfred A. Knopf: New York, NY, USA, 1985.
23. Williams, J.; Diebel, P. The economic value of prairie. In *Prairie Conservation: Preserving North America's Most Endangered Ecosystem*; Sampson, F.B., Knopf, F.L., Eds.; Island Press: Covelo, CA, USA, 1996; pp. 19-35.
24. Mac, M.J., Opler, P.A., Puckett Hacker, C.E., Doran, P.D., Eds. *Status and Trends of the Nation's Biological Resources*; U.S. Department of the Interior, U.S. Geological Survey: Reston, VA, USA, 1998.
25. United Nations Environment Programme, World Bank, and World Resources Institute. *World Resources 2000–2001: People and Ecosystems, the Fraying Web of Life*; Elsevier Science: Amsterdam, The Netherlands, 2000.
26. Herkert, J.R. Prairie birds of Illinois: population response to two centuries of habitat change. *Illinois Nat. Hist. Surv. Bull*. **1991**, *34*, 393-399.
27. Warner, R.E. Agricultural land use and grassland habitat in Illinois: future shock for midwestern birds? *Cons. Biol*. **1994**, *8*, 147-156.
28. Larson, D.L.; Euliss, N.; Lannoo, M.J.; Mushet, D.M. Amphibians of the northern grasslands. In *Status and Trends of the Nation's Biological Resources*; Mac, M.J., Opler, P.A., Puckett Hacker, C.E., Doran, P.D., Eds.; U.S. Department of the Interior, U.S. Geological Survey: Reston, VA, USA, 1998; pp. 450-451.
29. *State of the Birds, 2009*. Available online: http://www.stateofthebirds.org/habitats/grasslands (accessed 17 August, 2009).
30. Lannoo, M.J., Ed. *The Status and Conservation of Midwestern Amphibians*; U. Iowa Press: Iowa City, IA, USA, 1998.
31. Whitmore, R.C.; Hall, G.A. The response of passerine species to a new resource: reclaimed surface mines in West Virginia. *Amer. Birds* **1978**, *32*, 6-9.
32. Wray, T., II; Strait, K.A.; Whitmore, R.C. Reproductive success of grassland sparrows on a reclaimed surface mine in West Virginia. *Auk* **1982**, *99*, 157-164.
33. Bajema, R.A.; Lima, S.L. Landscape-level analyses of Henslow's Sparrow (*Ammodramus henslowii*) abundance in reclaimed coal mine grasslands. *Amer. Midl. Nat.* **2001**, *145*, 288-298.
34. Bajema, R.A.; DeVault, T.L.; Scott, P.E.; Lima, S.L. Reclaimed coal mine grasslands and their significance for Henslow's Sparrows in the American Midwest. *Auk* **2001**, *118*, 422-431.
35. Adamus, P. *Impacts on Quality of Inland Wetlands of the United States: A Survey of Indicators, Techniques, and Applications of Community Level Biomonitoring Data*; EPA/6000/3-90/073; EPA: Washington, DC, USA, 1990.
36. Gore, J.A. The distribution of Desmognathine larvae (Amphibia: Plethodontidae) in coal surface impacted streams of the Cumberland Plateau, USA. *J. Freshwater Ecol.* **1983**, *2*, 13-23.
37. Turner, L.T.; Fowler, D.K. *Utilization of Surface Mine Ponds in East Tennessee by Breeding Amphibians*, *Draft*; Surface Mine Reclamation Research, Final report SMR 4; TVA-Land and Forest Resources: Norris, TN, USA, 1980.

38. Turner, L.J.; Fowler, D.K. *Utilization of Surface Mine Ponds in East Tennessee by Breeding Amphibians*; Office of Biological Services 81/08, U.S. Fish and Wildlife Service: Washington, DC, USA, 1980.
39. Kingsbury, B.; Gibson, J. *Habitat Management Guidelines for Amphibians and Reptiles of the Midwest*; Partners in Amphibian and Reptile Conservation (PARC), 2002. Available online: http://www.parcplace.org (accessed 17 August, 2009).
40. Mierzwa, K.S. Status of Northeastern Illinois amphibians. In *Status and Conservation of Midwestern Amphibians*; Lannoo, M.J., Ed.; U. Iowa Press: Iowa City, IA, USA, 1998; pp. 115-124.
41. Brodman, R. Amphibian and reptiles from twenty-three counties of Indiana. *Proc. Indiana Acad. Sci*. **2003**, *112*, 43-54.
42. Rittenhouse, T.A.G.; Semlitsch, R.D. Grasslands as movement barriers for a forest-associated salamander: migration behavior of adult and juvenile salamanders at a distinct habitat edge. *Biol. Cons*. **2006**, *131*, 14-22.
43. *Kankakee Sands Prairie Restoration*. Available online: http://www.nature.org/wherewework/northamerica/states/indiana/work/art23509.html (accessed 17 August, 2009).
44. Minton, S.A., Jr. Observations on Indiana amphibian populations: A forty-five year overview. In *Status and Conservation of Midwestern Amphibians*; Lannoo, M.J., Ed.; U. Iowa Press: Iowa City, IA, USA, 1998; pp. 115-124.