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AMPHIBIAN HABITAT CREATION ON POST-INDUSTRIAL LANDSCAPES: A CASE
STUDY IN A RECLAIMED COAL STRIP-MINE AREA

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Abstract: While habitat loss is a major driver of amphibian and reptile declines globally, a subset of post-industrial landscapes, reclaimed and restored, are creating habitat for these animals in the United States. In southwestern Indiana, along the southeastern edge of the Illinois Coal Basin, post-SMCRA (Surface Mining Control and Reclamation Act of 1977) grassland restorations are recreating prairies in a region where they occurred naturally as openings (pockets) in deciduous forest, but were destroyed by agricultural activities following Euro-American settlement. Furthermore, it is likely, given the speed of re-colonization by 34 species of amphibians and reptiles (9 frog, 5 salamander, 13 snake, 5 turtle, and 2 lizard species), that the grasslands associated with railroad spur-line right-of-ways act as corridors to facilitate movement of these species into these relatively large sites. We suggest that reclaimed, restored, and properly managed landscapes can support reproducing populations of amphibians and reptiles, including species in decline across other portions of their range.

Keywords: coal mining; grassland; re-colonization; recruitment; reptiles; restoration

Introduction

“Then the coal company came with the world’s largest shovel

And they tortured the timber and stripped all the land.

Well, they dug for their coal ‘til the land was forsaken

And they wrote it all down as the progress of man.

And Daddy won’t you take me back to Muhlenburg County

Down by the Green River where Paradise lay.

Well I’m sorry my son, but you’re too late in asking

Mr. Peabody’s coal train has hauled it away.”

(Prine 1971)

John Prine’s lament epitomizes the environmentalist attitude toward visibly destructive resource extraction, and we will not downplay the impacts such activities have on natural ecosystems and landscapes, such as the region around Paradise, Kentucky. But, as with nature, even destructive resource extraction is nuanced, and here we present one example where the net effect of landscape change involving resource extraction has come full circle, creating an ecosystem that now approximates the historic (pre-European settlement) condition. Amphibians and reptiles have responded in kind, and this example offers a model for future reclamation and restoration activities.

The Historic Condition

Working out of the University of Chicago, Transeau (1935) mapped the historic prairie habitats of North America, with an emphasis on the eastern prairie peninsula. His map (reproduced here; Fig. 1) is inelegant by today's standards (the black of the prairie covering political boundaries). It nevertheless highlights the presence of isolated (pocket) prairies along the edges of this region in southern Missouri, southern Illinois, southwestern and north-central Indiana, southwestern Michigan, and southern Wisconsin. These prairies were a diverse mixture of grasses and forbs (predominant species included Big Bluestem [*Andropogon gerardii* Vitm.], Little Bluestem [*Schizachyrium scoparium* (Michx.)], Partridge Pea [*Chamaecrista fasciculata* (Michx.)], Yarrow [*Achillea millefolium* L.], Black-eyed Susan [*Rudbeckia hirta* L.], Purple Coneflower [*Echinacea purpurea* (L.)], Rosinweed [*Silphium integrifolium* Michx.], Common Milkweed [*Asclepias syriaca* L.], Compass Plant [*Silphium laciniatum* L.], Indian Grass [*Sorghastrum nutans* (L.)], and Blazing Star [*Liatris* sp. Gaertn.]; Lannoo et al. 2009). Frequent wildfires prevented encroachment by surrounding woody plant species (Steinauer and Collins 1996). The historic fauna of these pocket prairies presumably resembled the fauna of the larger grassland peninsula, with some reduction of the species pool based on the size of the isolate (Island Biogeography Theory; MacArthur and Wilson 1967). In southwestern Indiana, the cultural memory of these habitats is retained in the names of places (e.g., Prairietown, Hoosier Prairie) and natural areas (e.g., Prairie Creek).

Modification Following Settlement

Settlers plowed these prairies (as well as adjacent forests following logging) for agriculture in the mid- to late-nineteenth century, and the landscape remained in agricultural

production for over a century. At the same time, geologists recognized the presence of coal in the region—deposits that would eventually come to be called the Illinois Basin (Fig. 2). This vast area of the central Midwest runs along the Iowa/Illinois border from the Quad Cities (i.e., Davenport and Bettendorf in Iowa, and Rock Island, Moline, and East Moline in Illinois) east to the Joliet region (near Chicago, Illinois), southeast to western Kentucky (including Muhlenberg County), west to St. Louis (home of Peabody Coal headquarters), and back north to the Quad Cities (Korose and Elrick 2010). The Illinois basin is bowl-shaped, and coal is extracted from its margins using surface mining techniques (see below).

As mentioned above, the history of coal extraction in southwestern Indiana is about as old as the region's agriculture. Prior to 1977, coal extraction was crude, with overburden piled—one shovel-full dumped directly beside the previous—on the surface, and planted with acid-tolerant white pine seedlings by state reclamation biologists. (The largest shovel in this region could move up to 88 m³ of overburden with a single scoop [Pearce 2010]). The pit was then kept open and allowed to fill with groundwater to become a small recreational lake. The net effect of this activity has produced local landscapes resembling an upside-down egg carton, with a lake and white pines look reminiscent of northern or medium-altitude western forests.

Reclamation procedures changed in 1977 with the implementation of the federal Surface Mining Control and Reclamation Act (SMCRA). In accordance with this legislation, extraction industries must comply with national reclamation standards (OSMRE 2008). Under SMCRA guidelines, habitats destroyed as a result of coal mining must be restored to their previous use, a historical use, or to a standard that is equally or more economically productive. In southwestern Indiana, historic surface-mined sites are now being used as agricultural fields, housing developments, and recreational sites. When reclaimed sites are targeted for wildlife habitat, they

have historically been planted to grasslands because soil compaction produced by the heavy earthmoving equipment used to re-contour these sites restricts the ability of tree roots to penetrate the soil and become established (Bajema et al. 2001).

A Return to the Historic Condition

As considered by Lannoo et al. (2009) and Terrell et al. (2014), three factors have likely influenced the recolonization of post-industrial sites by native animal species in this region: 1) there can be no doubt that the emphasis on grassland construction has expanded the available prairie habitat in the central and southern portions of the Midwest; 2) the patchiness of these sites has mimicked the layout of historic pocket prairies; and 3) the maintenance of railroad right-of-ways as grasslands may have provided dispersion corridors that facilitated immigration into these newly created habitats. The unaided colonization of our study site by 34 species of amphibians and reptiles over the past three decades suggest aspects of the current landscape permit dispersal movements in these species (Semlitsch 2000).

The Amphibian and Reptile Response

While habitat destruction, disease, invasive species, pollution, and the collection of wild-caught animals to supply the pet trade are all factors known to negatively influence amphibian populations (Collins and Storfer 2003; Stuart et al. 2004; Daszak et al. 2005), habitat loss is likely the most important general cause of amphibian declines (Collins and Storfer 2003; Bradford 2005; Gallant et al. 2007). Although less publicized, reptiles are facing a comparable crisis for similar reasons (Gibbons et al. 2000; Reading et al. 2010; Sinervo et al. 2010; Chessman 2011; Böhm et al. 2013).

Habitat loss due to energy extraction has received much recent attention globally (Nikiforuk 2010; Reece and Krupa 2013). As is true for most types of disturbance, energy extraction both destroys habitat for amphibians and reptiles and introduces contaminants that compromise future reclamation and restoration efforts. For example, oil sands surface mining in northeastern Alberta, Canada has resulted in clearing large portions of the Boreal Forest and draining wetlands; processing of these oil-permeated sands then results in waste byproducts that either exclude or compromise amphibian populations (Pollet and Bendell-Young 2000; Hersikorn et al. 2010; Hersikorn and Smits 2011). In the midwestern United States, surface mining for coal has altered and in some cases destroyed amphibian habitat (Glick 2001; Pitts and Casebeer 2004).

As part of a collaborative project, we have documented the biology of Crawfish Frogs (*Lithobates areolatus* [Baird and Girard, 1852]) over the past seven years at a reclaimed mine spoil prairie in southwest Indiana (Lannoo et al. 2009; Kinney et al. 2010; Terrell et al. 2014). We also noted the diversity and relative abundance of other amphibians and reptiles while collecting data in 2009–2010. Here, we summarize these data on the species of amphibians and reptiles present, numbers of animals collected, and among amphibians, juvenile recruitment (*sensu* Hocking et al. 2008) and juvenile malformation rates. Our data show that areas once stripped of their ecology but since reclaimed, restored, and properly managed can be colonized by amphibians and reptiles to produce successfully breeding and presumably sustainable populations with low malformation rates. These sites also host species of conservation concern, and can assist in recovery efforts when such actions are warranted.

Materials and Methods

Our study site is located on the western region of the Hillenbrand Fish and Wildlife Area (HFWA-W) in Greene County, Indiana (Fig. 2). HFWA-W comprises 729 hectares that was historically (pre-1850s) eastern deciduous forest punctuated by pocket prairies (Transeau 1935; Jones and Cushman 2004), then converted to agricultural fields (beginning in the mid- to late-nineteenth century and extending into the twentieth century) prior to being surface mined for coal. From 1976–1982, this site was a 30-m deep, open-pit strip mine, where we assume (although cannot prove) that no amphibians or reptile species occurred (Lannoo et al. 2009). Post mining, this area was contoured and seeded to herbaceous cover vegetation. In 1988, this property was purchased by the Indiana Department of Natural Resources (IDNR) for use as a state fish and wildlife area, and was gradually re-seeded to native prairie species. HFWA-W is now managed by the IDNR Division of Fish and Wildlife (Lannoo et al. 2009).

As a result of mining activities, post-mining habitat restoration, and erosion control, HFWA-W now contains several bodies of water ranging in hydroperiod from ephemeral wetlands (< 0.5 ha), through semi-permanent wetlands, to large final-cut lakes (~ 10 ha; Fig. 2, 3). As part of our project to study Crawfish Frogs at HFWA-W, the presence of other amphibian and reptile species was monitored at two of these wetlands, Nate's Pond and Cattail Pond, as well as surrounding uplands in 2009–2010 (Kinney 2011). The exact ages of our study wetlands are unknown, but we estimate these wetlands formed from natural slumping 11–27 years prior to the initiation of our project in 2009. To assess Crawfish Frog populations, we encircled wetlands with drift fence and pitfall traps to monitor animals entering and exiting from 5 March–16 October (2009) and 1 March–19 August (2010). Throughout the breeding season, pitfall traps were checked once daily—immediately after sunrise—and repeatedly during warm rainy nights

when frogs migrate. We noted all amphibians and reptiles captured at the fences, as well as opportunistic observations of reptiles that resulted from conducting other research activities in the prairie uplands.

We identified captured amphibians and reptiles to species and life history stage (juvenile or adult). We classified natal juveniles as those exiting the wetlands and immigrating juveniles as those entering. Adults were sexed, and juveniles were examined for external malformations. Definitions of malformation types follow Meteyer (2000) and Lannoo (2008). All procedures were in accordance with IACUC number 3-24-2008 issued by Indiana State University, and Scientific Purposes License numbers 09-0084 and 10-0027 issued by the Indiana Department of Natural Resources.

Results

Species Diversity and Abundance

We found 14 species of amphibians, including five species of salamanders and nine species of frogs and toads (Table A1). We also found 20 species of reptiles, including 13 snake, 5 turtle, and 2 lizard species (Table A1). Eleven species were new county records for Greene County, Indiana (Lannoo et al. 2009; Kinney et al. 2010; Terrell et al. 2014). We captured a total of 15,844 amphibians and 334 reptiles (Table A1). In total, amphibians constituted 98% of our observations, in large part because of their fecundity and our emphasis on capture techniques that targeted amphibian breeding wetlands (i.e., drift fences and pitfall traps encircling wetlands). We found that most of these pond-breeding amphibians, such as Marbled Salamanders (*Ambystoma opacum* (Gravenhorst, 1807)), Smallmouth Salamanders (*A. texanum* (Matthes, 1855)), Eastern Newts (*Notophthalmus viridescens* (Rafinesque, 1820)), *L. areolatus*, Green

Frogs (*L. clamitans* (Latreille, 1801)), and Southern Leopard Frogs (*L. sphenoccephalus* (Cope, 1886)), are successfully reproducing (Tables A2, A3), and are recruiting breeding adults into their populations (Table 2).

Juvenile Recruitment and Immigration

Numbers of juveniles produced varied by wetland and across years. At Nate's Pond, juvenile *A. opacum*, *A. texanum*, *N. viridescens*, *L. areolatus*, and *L. sphenoccephalus* were produced in large numbers (Table A2). At Cattail Pond, only *L. clamitans* were produced in large numbers (Table A3). Under drying conditions in 2010 at Nate's Pond, juvenile *L. clamitans* metamorphosed in one season. In addition to supporting successful reproduction, each wetland received immigrant juveniles from other sites. The most abundant immigrant species at Nate's Pond were *A. opacum*, *L. clamitans*, and *L. sphenoccephalus* (Table A2), while at Cattail Pond, *L. clamitans* and *L. sphenoccephalus* predominated (Table A3).

Malformation Rates and Types

Out of a total of 8,064 metamorphosing juveniles, we detected 126 malformations, a 1.6% malformation rate (Table 1). At Nate's Pond, we found 90 malformations among the 6,388 metamorphosing juveniles, a 1.4% rate. The major malformation types at Nate's Pond were missing (amelia) or foreshortened (ectromely) limbs, followed by digits missing elements (ectrodactyly), foreshortened (brachydactyly), fused (syndactyly), or duplicated (polydactyly). We also found low numbers of small eyes (microphthalmia), duplicated limbs (polymely), and curved spines (scoliosis; Table 1). Malformations were spread across three salamander and three

frog species, with *A. texanum* having the highest rate (6.2%) and *A. opacum* having the greatest number of malformation types (7 of 9 observed).

At Cattail Pond, we found 36 malformations among the 1,676 metamorphosing juveniles, a 2.1% malformation rate. The major malformation type at Cattail Pond was eye discoloration, which affected *L. clamitans* juveniles. Two salamander species (*A. opacum* and *A. texanum*) had the highest rates of malformations, which generally consisted of missing or foreshortened limbs or digits, with single instances of a foreshortened digit, duplicated finger, and duplicated limb (Table 1).

Discussion

Our findings emphasize the value of mine spoil prairies as critical habitat for amphibian and reptile populations (Lannoo et al. 2009; Kinney et al. 2010; Terrell et al. 2014). From 1976–1982, our study site was an open-pit strip mine, with likely no amphibian or reptile species. In the past seven years, we have discovered 14 species of amphibians and 20 species of reptiles (Table A1). Two of these species, *L. areolatus* and Kirtland's Snakes (*Clonophis kirtlandii* (Kennicott, 1856)), are listed as endangered in Indiana; three species, Eastern Box Turtles (*Terrapene carolina* (L., 1758)), Northern Cricket Frogs (*Acris blanchardi* Harper, 1947), and Rough Greensnakes (*Opheodrys aestivus* (L., 1766)), are listed as species of special concern (Lannoo et al. 2009). Further, several species are represented by relatively high abundances (Table A1) and are recruiting breeding adults into their populations (Table 2).

Post-industrial landscapes can be contaminated with chemical products or byproducts, many of which are known to have an impact on amphibian development (Rowe et al. 1998; Hopkins et al. 2000; Lannoo 2008). The fact that malformation rates at our wetland sites were comparable with background rates of malformations (2.1%; Table 1; Lannoo 2008), suggests no

obvious influence of contaminants resulting from past mining activities on the health of current amphibian populations, although we recognize that more subtle effects may be occurring, for example on immune systems (Davidson et al. 2007; but see Kinney et al. 2011).

While the diversity of amphibians and reptiles observed at this site might be surprising given its industrial history (Lannoo et al. 2009), our species richness is similar to values found at other restored wetlands in the Midwest. For example, Brodman et al. (2006) reported 10 amphibian species collected at a restored prairie (Kankakee Sands) in northwestern Indiana, Timm and Meretsky (2004) documented nine frog and toad species at a reclaimed mine area in southwestern Indiana (near HFWA-W), Walston and Mullin (2007) reported 10 amphibian species at a pond in Illinois, and Hocking et al. (2008) reported 15 amphibian species at ponds located within an oak-hickory forest in Missouri. Similarly, our amphibian and reptile abundance levels were comparable to those found by Palis (2007) at constructed wetlands on a conservation preserve, with juveniles accounting for the majority of captures.

The diversity and abundance of amphibians and reptiles at HFWA-W may be attributed to at least four factors: 1) the presence of a variety of wetland and upland habitat types; 2) the presence of nearby (3 km; Engbrecht et al. 2013) offsite source populations with access to the site; 3) ecosystem management practices by IDNR biologists; and 4) railroad right-of-ways managed as grasslands that might be serving as wildlife corridors (Terrell et al. 2014). A reduction in any one of these factors would reduce recolonization success. At our study site, most wetlands are the result of natural slumping or depressions created during post-mining reclamation. While these basins were created incidentally, their structure provides insight into how restoration biologists can favor amphibians and reptiles when re-contouring reclaimed habitats. Because the ecology of HFWA-W was destroyed by mining activities 35 years ago, the

colonization of amphibians and reptiles at this site must have been a relatively recent event, originating from offsite populations and perhaps facilitated by railroad spur lines (Lannoo et al. 2009). The habitat surrounding HFWA-W consists of a mosaic of pre-SMCRA forested mined land, livestock pasture, and agricultural fields.

Galán (1997), working in Spain, reported that during the initial years following mining, the first amphibians captured on his study sites were juveniles. Similarly, we suspect juvenile dispersal was the driving force behind colonization events at HFWA-W (Lannoo et al. 2009). Newly metamorphosed individuals were captured immigrating into each wetland, and may be driving metapopulation dynamics (Sinsch 1997; Marsh and Trenham 2000; Semlitsch 2000; Semlitsch 2008).

Galán (1997) suggested that more than 10 years are needed for amphibian and reptile communities to reach pre-disturbance diversity and abundance levels. If Galán's estimation is true, amphibian and reptile communities at HFWA-W should now be at pre-mining population levels (mining activities at HFWA-W ended in 1982). In fact, amphibian and reptile diversity and abundance numbers at this site are likely higher than before mining activities, when the site was used for agriculture, and certainly higher than when the site was a working mine. We base this assumption on the well-established intolerance of amphibians and reptiles to intensive agricultural activity and surface mining (Boccardy and Spaulding 1968; Bonin et al. 1997; Bishop et al. 1999; Gallant et al. 2007; Ribeiro et al. 2009). Plowing kills amphibians and reptiles and reduces essential habitat to inadequate remnants, thereby reducing the diversity of these animals (Bonin et al. 1997; Bishop et al. 1999; Ribeiro et al. 2009). Because of their burrow philopatry and defensive behaviors, Crawfish Frogs in particular are susceptible to the effects of plowing (Thompson 1915; Wright and Wright 1949). Active surface mining

completely destroys terrestrial and aquatic habitats and excludes nearly all wildlife (Boccardy and Spaulding 1968). Nevertheless, the presence of mining and subsequent reclamation to grassland in southwestern Indiana has paradoxically resulted in a resurgence of grassland habitat in this region of the state, and it appears that the amphibians and reptiles of the region have responded in a robust way. This response has produced a species assemblage that may approximate the pre-settlement community, and has provided habitat for several threatened and endangered species of amphibians and reptiles.

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Table 1. Malformation rates in newly metamorphosed amphibians at Hillenbrand Fish and Wildlife Area-West in 2009–2010 sorted by wetland, species, and malformation type. Definitions of malformation types follow Meteyer (2000) and Lannoo (2008). Data from Kinney et al. (2010), Kinney (2011), and Terrell et al. (2014).

Nate's Pond

Species	Total Number of Juveniles	Amelia	Ectromely	Brachydactyly	Ectrodactyly	Polydactyly	Syndactyly	Microphthalmia	Polymely	Scoliosis	Species Malformation Rate
<i>Ambystoma texanum</i>	211	4	6	2	0	1	0	0	0	0	6.2%
<i>Ambystoma opacum</i>	1,694	19	11	16	17	2	3	0	0	1	4.1%
<i>Pseudacris crucifer</i> (Wied-Neuwied, 1838)	40	1	0	0	0	0	0	0	0	0	2.5%
<i>Lithobates sphenoccephalus</i>	868	0	1	0	0	0	0	1	1	0	0.3%
<i>Lithobates areolatus</i>	2,389	1	1	0	0	0	0	1	0	0	0.1%
<i>Notophthalmus viridescens</i>	1,186	0	1	0	0	0	0	0	0	0	0.1%
Total	6,388	25	20	18	17	3	3	2	1	1	–

Table 1 continued

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Malformations Rate by Type	–	0.4%	0.3%	0.3%	0.3%	0.1%	0.1%	0.0%	0.0%	0.0%	–
Overall Malformation Rate											1.4%

Cattail Pond

Species	Total Number of Juveniles	Eye Discoloration	Amelia	Ectromely	Ectrodactyly	Polydactyly	Polymely	Species Malformation Rate
<i>Ambystoma texanum</i>	72	0	2	1	0	1	0	5.6%
<i>Ambystoma opacum</i>	63	0	0	2	1	0	0	4.8%
<i>Lithobates clamitans</i>	1,541	19	5	4	0	0	1	1.9%
Total	1,676	19	7	7	1	1	1	–
Malformations Rate by Type	–	1.1%	0.4%	0.4%	0.1%	0.1%	0.1%	–
Overall Malformation Rate								2.1%

Table 2. Recruitment at Nate’s and Cattail ponds as represented by metamorphic individuals originally captured exiting ponds in 2009 and recaptured returning to ponds in 2010. Data from Kinney et al. (2010), Kinney (2011), and Terrell et al. (2014).

Nate's Pond

		No. of
Species	Common Name	Individuals
<i>Ambystoma opacum</i>	Marbled Salamander	11 ^a
<i>Ambystoma texanum</i>	Small-mouthed Salamander	1 ^b
<i>Lithobates sphenoccephalus</i>	Southern Leopard Frog	5 ^c
^a 3 females, 7 males, 1 juvenile; ^b 1 male; ^c 5 males		

Cattail Pond

		No. of
Species	Common Name	Individuals
<i>Lithobates clamitans</i>	Green Frog	1 ^a
<i>Lithobates sphenoccephalus</i>	Southern Leopard Frog	2 ^b
^a 1 male ; ^b 1 female, 1 male		

Figure Captions

Fig. 1. Historic prairie habitats of North America. The region of pocket prairies in southwestern Indiana is highlighted (from Transeau 1935, reproduced with permission of Ecology, vol. 16, p. 424–425, © 1935 Wiley).

Fig. 2. Illinois Coal Basin and aerial image of Hillenbrand Fish and Wildlife Area-West, Greene County, Indiana. Yellow lines demarcate boundaries of state-owned property. Note that HFWA-W consists of a large central grassland punctuated with lakes and small seasonal and semi-permanent wetlands, surrounded by forested (dark green) and agricultural (light green or brown) areas. We indicate the location of an active coal mine (A) that borders the northwestern edge of the property, and railroad tracks (B and C; potential wildlife corridors). As well, we note our two study ponds (Cattail [D] and Nate's [E]).

Fig. 3. Wetland localities and permanence at Hillenbrand Fish and Wildlife Area-West, Greene County, Indiana. Our study wetlands (Nate's and Cattail) are semi-permanent ponds, along with six additional wetlands that dry occasionally. Six wetlands are ephemeral and dry nearly every year.

Fig. 1. Transeau’s (1935) historic prairie habitats of North America. The region of pocket prairies in southwestern Indiana is highlighted.
71x56mm (300 x 300 DPI)

Fig. 2. Illinois Coal Basin and aerial image of Hillenbrand Fish and Wildlife Area-West, Greene County, Indiana. Yellow lines demarcate boundaries of state-owned property. Note that HFWA-W consists of a large central grassland punctuated with lakes and small seasonal and semi-permanent wetlands, surrounded by forested (dark green) and agricultural (light green or brown) areas. We indicate the location of an active coal mine (A) that borders the northwestern edge of the property, and railroad tracks (B and C; potential wildlife corridors). As well, we note our two study ponds (Cattail [D] and Nate's [E]).
115x73mm (300 x 300 DPI)

Fig. 3. Wetland localities and permanence at Hillenbrand Fish and Wildlife Area-West, Greene County, Indiana. Our study wetlands (Nate's and Cattail) are semi-permanent ponds, along with six additional wetlands that dry occasionally. Six wetlands are ephemeral and dry nearly every year.
92x98mm (300 x 300 DPI)

Appendix A

Table A1. Number of individual amphibians and reptiles collected at Hillenbrand Fish and Wildlife Area-West, sorted by species, wetland, and year. Dashed entries represent incidental captures away from these wetlands. Data from Kinney et al. (2010), Kinney (2011), and Terrell et al. (2014).

		Nate's	Nate's	Cattail	Cattail	
Scientific Name	Common Name	2009	2010	2009	2010	Total
Salamanders						
<i>Ambystoma opacum</i>	Marbled Salamander	1,479	904	75	83	2,541
<i>Ambystoma texanum</i>	Small-mouthed Salamander	646	561	579	597	2,383
<i>Ambystoma tigrinum</i> (Green, 1825)	Eastern Tiger Salamander	4	—	22	12	38
<i>Notophthalmus viridescens</i>	Eastern Newt	809	627	297	203	1,936
<i>Plethodon cinereus</i> (Green, 1818)	Eastern Red-backed	—	1	—	—	1
	Salamander					
Total		2,938	2,093	973	895	6,899

Table A1 continued

Frogs						
<i>Acris blanchardi</i>	Northern Cricket Frog	11	15	18	21	65
<i>Anaxyrus fowleri</i> (Hinckley, 1882)	Fowler’s Toad	2	4	—	—	6
<i>Hyla chrysoscelis</i> Cope, 1880	Cope’s Gray Treefrog	1	11	—	—	12
<i>Lithobates areolatus</i>	Crawfish Frog	367	2161	42	22	2,592
<i>Lithobates catesbeianus</i> (Shaw, 1802)	American Bullfrog	8	8	25	47	88
<i>Lithobates clamitans</i>	Green Frog	149	139	1980	506	2,774
<i>Lithobates sphenoccephalus</i>	Southern Leopard Frog	947	604	300	209	2,060
<i>Pseudacris crucifer</i>	Spring Peeper	140	73	13	5	231
<i>Pseudacris triseriata</i> (Wied-Neuwied, 1838)	Western Chorus Frog	511	372	112	122	1,117
Total		2,136	3,387	2,490	932	8,945

Table A1 continued

Snakes						
<i>Carphophis amoenus</i> (Say, 1825)	Eastern Wormsnake	1	—	—	—	1
<i>Clonophis kirtlandii</i>	Kirtland’s Snake	—	—	—	—	—
<i>Coluber constrictor</i> L., 1758	North American Racer	1	—	2	—	3
<i>Diadophis punctatus</i> (L., 1766)	Ring-necked Snake	1	—	—	—	1
<i>Heterodon platirhinos</i> (Latreille, 1801)	Eastern Hog-nosed Snake	—	—	—	—	—
<i>Lampropeltis calligaster</i> (Harlan, 1827)	Yellow-bellied Kingsnake	—	—	—	—	—
<i>Lampropeltis getula</i> (L., 1766)	Common Kingsnake	—	—	—	—	—
<i>Lampropeltis Triangulum</i> (Lacépède, 1789)	Milksnake	—	—	—	—	—
<i>Nerodia sipedon</i> (L., 1758)	Northern Watersnake	—	—	1	—	1
<i>Opheodrys aestivus</i> (L., 1766)	Rough Greensnake	—	—	—	—	—
<i>Storeria dekayi</i> (Holbrook, 1839)	Dekay’s Brownsnake	1	13	2	—	16
<i>Thamnophis sauritus</i> (L., 1766)	Eastern Ribbonsnake	3	3	5	—	11
<i>Thamnophis sirtalis</i> (L., 1758)	Common Gartersnake	1	2	5	4	12
Total		8	18	15	4	45

Table A1 continued

Turtles						
<i>Chelydra serpentina</i> (L., 1758)	Snapping Turtle	5	1	18	4	28
<i>Chrysemys picta</i> (Schneider, 1783)	Painted Turtle	30	14	117	37	198
<i>Sternotherus odoratus</i> (Latreille, 1801)	Eastern Musk Turtle	—	—	—	—	—
<i>Terrapene carolina</i>	Eastern Box Turtle	25	17	4	7	53
<i>Trachemys scripta</i> (Thunberg, 1792)	Pond Slider	4	2	3	1	10
Total		64	34	142	49	289
Lizards						
<i>Plestiodon fasciatus</i> (L., 1758)	Common Five-lined Skink	—	—	—	—	—
<i>Scincella lateralis</i> (Say, 1823)	Little Brown Skink	—	—	—	—	—
Total		—	—	—	—	—
Grand Total		5,146	5,532	3,620	1,880	16,178 ₁

Table A2. Numbers of amphibians captured at Nate’s Pond in a drift fence/pitfall trap array, sorted by year, sex, and life history stage. Note that *A. opacum*, *A. texanum*, *N. viridescens*, *L. areolatus*, and *L. sphenoccephalus* predominate. Here, subadults are defined as animals intermediate in size between newly metamorphosed juveniles and adults; natal juveniles indicate recently metamorphosed animals dispersing from our study wetlands; immigrating juveniles indicate juveniles from other wetlands entering our study wetlands. Data from Kinney et al. (2010), Kinney (2011), and Terrell et al. (2014).

2009

Species				Natal	Immigrating		
	Female	Male	Subadult	Juveniles	Juveniles	Unknown	Total
<i>Acris blanchardi</i>	7	3	—	1	—	—	11
<i>Ambystoma opacum</i>	133	254	48	943	101	—	1,479
<i>Ambystoma texanum</i>	131	159	114	199	29	14	646
<i>Ambystoma tigrinum</i>	—	—	—	1	3	—	4
<i>Anaxyrus fowleri</i>	—	—	—	—	2	—	2
<i>Hyla chrysoscelis</i>	—	—	—	—	—	1	1
<i>Lithobates areolatus</i>	31	38	1	286	11	—	367

Table A2 continued

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<i>Lithobates catesbeianus</i>	—	—	—	—	8	—	8
<i>Lithobates clamitans</i>	10	4	—	47	88	—	149
<i>Lithobates sphenoccephalus</i>	54	71	14	625	183	—	947
<i>Notophthalmus viridescens</i>	41	43	—	667	58	—	809
<i>Plethodon cinereus</i>	—	—	—	—	—	—	—
<i>Pseudacris crucifer</i>	53	51	—	35	1	—	140
<i>Pseudacris triseriata</i>	279	196	—	32	1	3	511
Total	739	819	177	2,836	485	18	5,074

2010

Species				Natal	Immigrating		
	Female	Male	Subadult	Juveniles	Juveniles	Unknown	Total
<i>Acris blanchardi</i>	3	4	5	—	—	3	15
<i>Ambystoma opacum</i>	46	62	5	751	27	13	904
<i>Ambystoma texanum</i>	248	251	42	12	3	5	561

Table A2 continued

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<i>Ambystoma tigrinum</i>	—	—	—	—	—	—	—
<i>Anaxyrus fowleri</i>	3	—	—	—	1	—	4
<i>Hyla chrysoscelis</i>	—	—	—	1	9	1	11
<i>Lithobates areolatus</i>	22	20	2	2,103	14	—	2,161
<i>Lithobates catesbeianus</i>	1	—	1	1	5	—	8
<i>Lithobates clamitans</i>	9	8	1	21	100	—	139
<i>Lithobates sphenoccephalus</i>	13	23	1	243	323	—	603
<i>Notophthalmus viridescens</i>	48	35	15	519	10	—	627
<i>Plethodon cinereus</i>	—	—	—	—	—	1	1
<i>Pseudacris crucifer</i>	36	26	—	5	6	—	73
<i>Pseudacris triseriata</i>	192	172	1	6	—	1	372
Total	621	601	73	3,662	498	24	5,479

Table A3. Numbers of amphibians captured at Cattail Pond in a drift fence/pitfall trap array, sorted by year, sex, and life history stage. Note that *L. clamitans* predominate. Here, subadults are defined as animals intermediate in size between newly metamorphosed juveniles and adults; natal juveniles indicate recently metamorphosed animals dispersing from our study wetlands; immigrating juveniles indicate juveniles from other wetlands entering our study wetlands. Data from Kinney et al. (2010), Kinney (2011), and Terrell et al. (2014).

2009

Species	Female	Male	Subadult	Natal	Immigrating	Unknown	Total
				Juveniles	Juveniles		
<i>Acris blanchardi</i>	3	6	—	4	4	1	18
<i>Ambystoma opacum</i>	22	22	—	15	15	1	75
<i>Ambystoma texanum</i>	155	243	96	59	21	5	579
<i>Ambystoma tigrinum</i>	2	10	—	1	9	—	22
<i>Anaxyrus fowleri</i>	—	—	—	—	—	—	—
<i>Hyla chrysoscelis</i>	—	—	—	—	—	—	—
<i>Lithobates areolatus</i>	14	14	—	11	3	—	42

Table A3 continued

<i>Lithobates catesbeianus</i>	6	1	2	4	11	1	25
<i>Lithobates clamitans</i>	11	18	17	1,507	424	3	1,980
<i>Lithobates sphenoccephalus</i>	18	98	4	47	131	2	300
<i>Notophthalmus viridescens</i>	110	88	—	49	45	5	297
<i>Plethodon cinereus</i>	—	—	—	—	—	—	—
<i>Pseudacris crucifer</i>	8	4	—	1	—	—	13
<i>Pseudacris triseriata</i>	59	41	—	10	1	1	112
Total	408	545	119	1,708	664	19	3,463

2010

Species	Natal			Immigrating		Unknown	Total
	Female	Male	Subadult	Juveniles	Juveniles		

Table A3 continued

<i>Acris blanchardi</i>	6	7	2	—	3	3	21
<i>Ambystoma opacum</i>	11	8	3	48	11	2	83
<i>Ambystoma texanum</i>	275	272	29	13	6	2	597
<i>Ambystoma tigrinum</i>	4	2	—	2	4	—	12
<i>Anaxyrus fowleri</i>	—	—	—	—	—	—	—
<i>Hyla chrysoscelis</i>	—	—	—	—	—	—	—
<i>Lithobates areolatus</i>	7	14	—	—	1	—	22
<i>Lithobates catesbeianus</i>	3	4	16	1	23	—	47
<i>Lithobates clamitans</i>	34	42	13	34	382	1	506
<i>Lithobates sphenoccephalus</i>	33	34	—	47	95	—	209
<i>Notophthalmus viridescens</i>	51	37	7	86	22	—	203
<i>Plethodon cinereus</i>	—	—	—	—	—	—	—
<i>Pseudacris crucifer</i>	3	2	—	—	—	—	5
<i>Pseudacris triseriata</i>	59	49	3	9	1	1	122
Total	486	471	73	240	548	9	1,827

Appendix A Literature Cited

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