Herpetological Conservation and Biology 1(2):101-108
Submitted: 10 May 2006; Accepted: 12 November 2006

AMPHIBIAN BIODIVERSITY RECOVERY IN A LARGE-SCALE ECOSYSTEM RESTORATION

ROBERT BRODMAN[1,2]*, MICHAEL PARRISH*[1]*, HEIDI KRAUS*[1] *AND SPENCER CORTWRIGHT*[3]

[1]*Biology Department, Saint Joseph's College, Rensselaer, Indiana, 47978, USA*
[2]*Corresponding author, e-mail: bobb@saintjoe.edu*
[3]*Biology Department, Indiana University Northwest, Gary, Indiana, 46408 USA.*

***Abstract*.—Amphibians are important components of ecosystem function and processes; however, many populations have declined due to habitat loss, fragmentation and degradation. We studied the effect of wetlands ecosystem restoration on amphibian population recovery at Kankakee Sands in northwest Indiana, USA. We also tested predictions about colonization in relation to proximity to existing nature preserves and species characteristics. Prior to restoration activities (1998), the amphibian community at Kankakee Sands consisted of fourteen populations of seven species at seven breeding sites. By 2001, this community increased to 60 populations at 26 sites; however, species richness had not increased. By 2002 the community increased to 143 populations of eight species at 38 sites, and by 2003 there were 172 populations of ten species at 44 sites. Abundance index values increased 15-fold from 1998-2003. These increases best fit the exponential growth model. Although survival through metamorphosis was substantial during wetter than average years (2002 and 2003), during other years restored wetlands dried before larvae of most species transformed. Amphibian colonization was greatest near a nature preserve with the greatest amphibian diversity. The earliest colonists included fossorial species and those species whose habitat includes wet and mesic sand prairie. However, the fossorial Tiger Salamander (*Ambystoma tigrinum*) was the last species to colonize Kankakee Sands.**

Key Words.— amphibians; applied ecology; ecosystem restoration; prairie; savanna; wetlands

INTRODUCTION

Amphibians are essential components of many natural ecosystems. They are indicators of ecosystem health (Freda and Dunson 1986; Hager 1998) and have important functions in natural food webs (Cortwright 1988; Fauth and Resetarits 1991; Holomuzki et al. 1994). Amphibian populations have declined in the US Midwest (Lannoo et al. 1994; Christiansen 1998; Thurow 1999) and on a global scale (Houlahan et al. 2000; Stuart et al. 2004). Habitat loss, degradation and fragmentation are major threats to amphibian conservation (Knutson et al. 1999; McCollough 1999; Dodd and Smith 2003). For example, the sand prairie-savanna-wetland mosaic of the Grand Kankakee Marsh, Beaver Lake and wet-mesic sand prairie ecosystems in northwest Indiana south of the Kankakee River was drained, cleared, and converted to agriculture in the late 19th and early 20th century (Smallwood and Osterholz 1990). Remaining habitats suitable for use as amphibian breeding sites are now highly fragmented and degraded. Habitat alteration is estimated to have reduced amphibian populations 90-95% in northwest Indiana (Brodman and Kilmurry 1998; Brodman et al. 2002). Remaining populations are often restricted to small uncultivated patches and three state-owned natural areas (Brodman and Kilmurry 1998).

Corridors and connectivity of remaining patches of habitat have a positive affect on animal movement and diversity (Debinski and Holt 2000). Because aquatic amphibian eggs and larvae are vulnerable to predation by fish, the primary management objective for conserving amphibians is to preserve complexes of small ephemeral and large semi-permanent wetlands adjacent to terrestrial habitat favorable for adult survival (McWilliams and Bachmann 1988; Semlitsch and Bodie 1998). Terrestrial buffer zones should extend at least 200 m beyond the wetland margin (Semlitsch 1998). A substantial amount (3000 ha) of farmland at Kankakee Sands in Newton County, Indiana, USA, is being restored to sand prairie (especially wet-mesic sand prairie), sand oak savanna and marsh habitats by The Nature Conservancy (Fig. 1). The intent of the restoration at Kankakee Sands is to form 8500 ha of contiguous habitat by connecting three disjunct state-owned natural areas: Willow Slough Fish & Wildlife Area, Beaver Lake Prairie, and Conrad Savanna Nature Preserves. These habitats are dominated by sandy ecosystems that are distinct, and ecologically diverse (Meyer 1936, Smith and Minton 1957; Schneider 1966; Post 1997). The Indiana Natural Heritage Data Center (INHDC) considers these sandy habitats to feature significant high quality natural communities and less than 0.5% of these remain in Indiana. The INHDC has ranked natural communities at the state level. State data on natural communities has been synthesized by NatureServe into global ranks. Sand prairie is considered globally rare and state imperiled in Indiana, while sand oak savanna is globally and state imperiled. The most globally significant native community in the area is wet-mesic sand prairie which is considered to be globally critically imperiled and has been almost eliminated from Indiana (INHDC). Habitat restoration is required to conserve the unique amphibian community that is associated with these sandy, now fragmented, ecosystems (Smith and Minton 1957; Brodman 1998a).

Wetland habitat restoration has been shown to facilitate repatriation of a few focal amphibian species (Cortwright 1998; Sexton et al. 1998; Merovich and Howard 2000; Pechmann et al. 2001); however, little is known about the long-term colonization of amphibian populations at the ecosystem or landscape level. The large-scale habitat restoration at Kankakee Sands provides an opportunity to study colonization and recovery of amphibian biodiversity in a fragmented landscape and to assess landscape-level ecosystem restoration as a tool for biodiversity conservation.

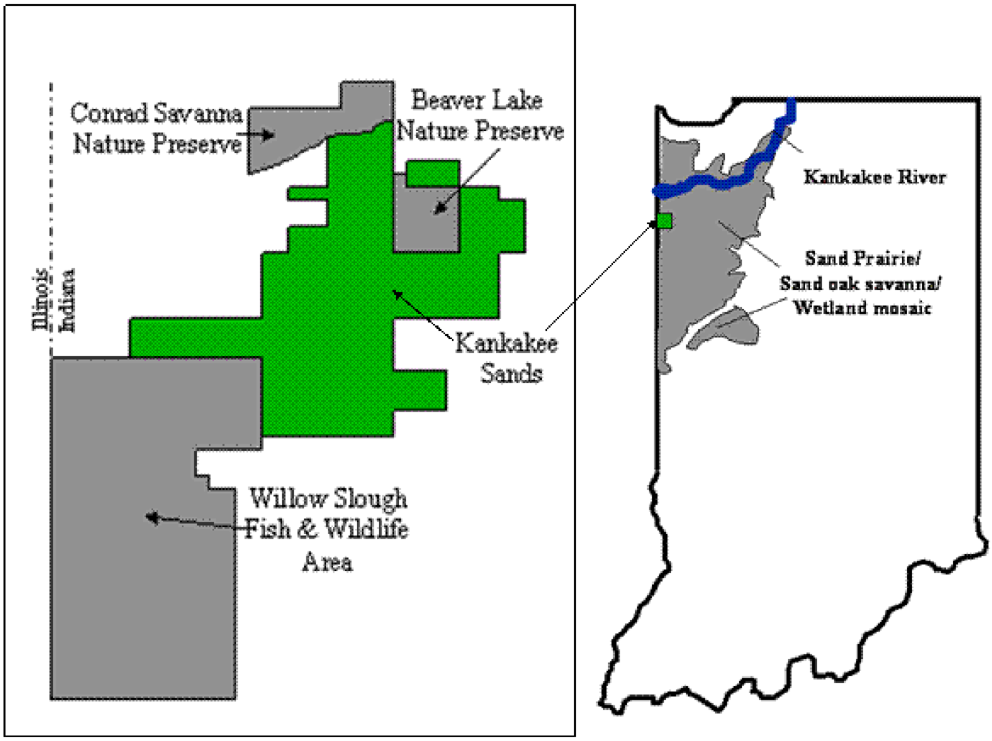

FIGURE 1. Map showing the sand prairie, sand oak savanna, wetland mosaic natural region of northwest Indiana and the location of Kankakee Sands with its connections to Willow Slough Fish and Wildlife Area, Beaver Lake Nature Preserve, and Conrad Savanna Nature Preserve.

sandy ecosystems that are distinct, and ecologically diverse (Meyer 1936, Smith and Minton 1957; Schneider 1966; Post 1997). The Indiana Natural Heritage Data Center (INHDC) considers these sandy habitats to feature significant high quality natural communities and less than 0.5% of these remain in Indiana. The INHDC has ranked natural communities at the state level. State data on natural communities has been synthesized by NatureServe into global ranks. Sand prairie is considered globally rare and state imperiled in Indiana, while sand oak savanna is globally and state imperiled. The most globally significant native community in the area is wet-mesic sand prairie which is considered to be globally critically imperiled and has been almost eliminated from Indiana (INHDC). Habitat restoration is required to conserve the unique amphibian community that is associated with these sandy, now fragmented, ecosystems (Smith and Minton 1957; Brodman 1998a).

Wetland habitat restoration has been shown to facilitate repatriation of a few focal amphibian species (Cortwright 1998; Sexton et al. 1998; Merovich and Howard 2000; Pechmann et al. 2001); however, little is known about the long-term colonization of amphibian populations at the ecosystem or landscape level. The large-scale habitat restoration at Kankakee Sands provides an opportunity to study colonization and recovery of amphibian biodiversity in a fragmented landscape and to assess landscape-level ecosystem restoration as a tool for biodiversity conservation.

We collected data on amphibian populations for five years during a six year period to assess the effect of ecosystem restoration on amphibian biodiversity. For the purpose of this study, an amphibian population is defined by each species that is detected breeding at a wetland or found in adjacent uplands. For example if a site has four species of amphibians breeding in a wetland and using adjacent upland habitat, then that site would have four amphibian populations. Amphibian populations are considered distinct if breeding sites are separated by $\geq$ 200 m. Therefore, a species found at two water bodies separated by $\leq$ 200 m are considered to be the same population.

Our objectives were to: 1) Determine the number of amphibian breeding sites, the number of amphibian populations at each breeding site, the abundance of each population at each site, and the number of species (species richness) of amphibians at Kankakee Sands prior to restoration and in restored habitats; 2) Test the following predictions of colonization: a) colonization will be faster in the southwestern habitats of Kankakee Sands that are adjacent to species rich Willow Slough (Brodman et al, 2002) and recovery of amphibian diversity will generally move from southwest to northeast, b) species that can dig into the cultivated soil during dry periods, such as toads (genus *Bufo*) and Tiger Salamanders (*Ambystoma tigrinum*), and those species that survive well in mesic and wet prairies, such as Northern Leopard Frogs (*Rana pipiens*) and Western Chorus Frogs (*Pseudacris triseriata*), will colonize wetlands before other species.

MATERIALS AND METHODS

We located amphibian breeding sites and identified species at each site using standard North American Monitoring Protocols (Karns 1986; Heyer et al. 1994). We used a combination of call surveys, seines, dip-nets, minnow traps, terrestrial search and seize, and drift fences with funnel traps to increase the likelihood of detecting the presence of rare species. We conducted nocturnal frog call surveys three times each year at each natural and restored wetland. Surveys occurred during appropriate climatic conditions for the breeding season of each frog species from April through June in 1998, 2000 - 2003. We sampled each wetland with seines, dip-nets and minnow traps twice a year, once during April or early-May and once during the period from mid-May through mid-July. Habitat restoration began in 1999. Wetland were restored by plugging and filling drainage ditches, breaking drainage tiles, and scraping and recontouring soil in wetland basins to depths up to 1 m. Prairie restoration was conducted by application of herbicides, prescribed burns and planting prairie plants. Some stretches (8-12 m long) of the drainage ditches were not plugged because they harbored important native wetland plants.

We conducted terrestrial search and seizure to focus on detection of terrestrial adults and newly metamorphosed juveniles. The terrestrial search included visual searches for individuals on the ground and by searching under any cover objects that we encountered. We searched upland habitat surrounding each wetland twice each year, once during April or early-May and once from mid-May through mid-July.

TABLE 1.—Amphibian survey results at Kankakee Sands 1998-2003. Data are the number of breeding populations of each species for each year, linear* and exponential** regression coefficients of determination (r^2) and *P* values.

Species	1998	2000	2001	2002	2003	r^2	*P*
American Toad, *Bufo americanus*	1	4	5	6	9	0.98*	0.003
Fowler's Toad, *B. fowleri*	2	3	9	16	20	0.96**	0.008
Eastern Gray Treefrog, *Hyla versicolor*	1	2	9	21	18	0.95**	0.014
Cope's Gray Treefrog, *H. chrysoscelis*	0	0	0	0	2	0.64*	0.245
Spring Peeper, *Pseudacris crucifer*	4	12	14	29	39	0.99**	0.001
Chorus Frog, *P. triseriata*	2	6	9	26	42	0.99**	0.001
Bullfrog, *Rana catesbieana*	0	0	0	3	3	0.81*	0.099
Green Frog, *R. clamitans*	2	2	6	16	11	0.88**	0.05
Northern Leopard Frog, *R. pipiens*	2	4	8	27	27	0.96**	0.008
Tiger Salamander, *Ambystoma tigrinum*	0	0	0	0	1	0.64*	0.245
Total populations	14	33	60	144	172	0.99**	0.002
Number of sites	7	14	27	38	44	0.99**	0.002
Percentage of units occupied	50	67	83	92	100	0.99*	0.001
Species richness	7	7	7	8	10	0.79*	0.113
Mean species richness/site	2.0	2.4	2.2	3.8	3.9	0.87*	0.05

We used drift fence arrays to detect the presence and movement of terrestrial amphibians. We constructed drift fences from aluminum window screen to form three "arms" that extended 6 m from a common center point (Fig. 2). We placed funnel traps along the ends of each arm. Moisture and shade were provided for trapped animals. Traps were checked at sunrise each morning, and animals were examined and released. In June 2001, we established 10 drift fence arrays in four clusters. We checked the arrays six days a week from 12 June until 20 July. In April 2002 we established eight new drift fences giving us a total of 18 arrays in six clusters. Two were added to the 2001 clusters (giving a total of three arrays per cluster) and the remaining six formed two new clusters. We checked the arrays four days a week from 12 April to 5 May 2002 and every day from 6 May until 23 July 2002.

The presence of species was recorded at breeding sites each year. Abundance was estimated using an ordinal scale of frog call intensity and capture per effort. Each population was given a relative abundance index value of 1-5 according to Karns (1986) and Brodman (2003). Linear and exponential regression (α = 0.05) was used to analyze trends in the number of amphibian breeding sites, populations, relative abundance index, species richness, and percentage of occupancy of amphibians among management units from 1998-2003.

RESULTS

The abundance of each species at each site varied each year during the study (Fig. 3). Amphibians significantly increased at

FIGURE 2. Drift fence arrays in restored wetland ecosystems (Photographed by Robert Brodman).

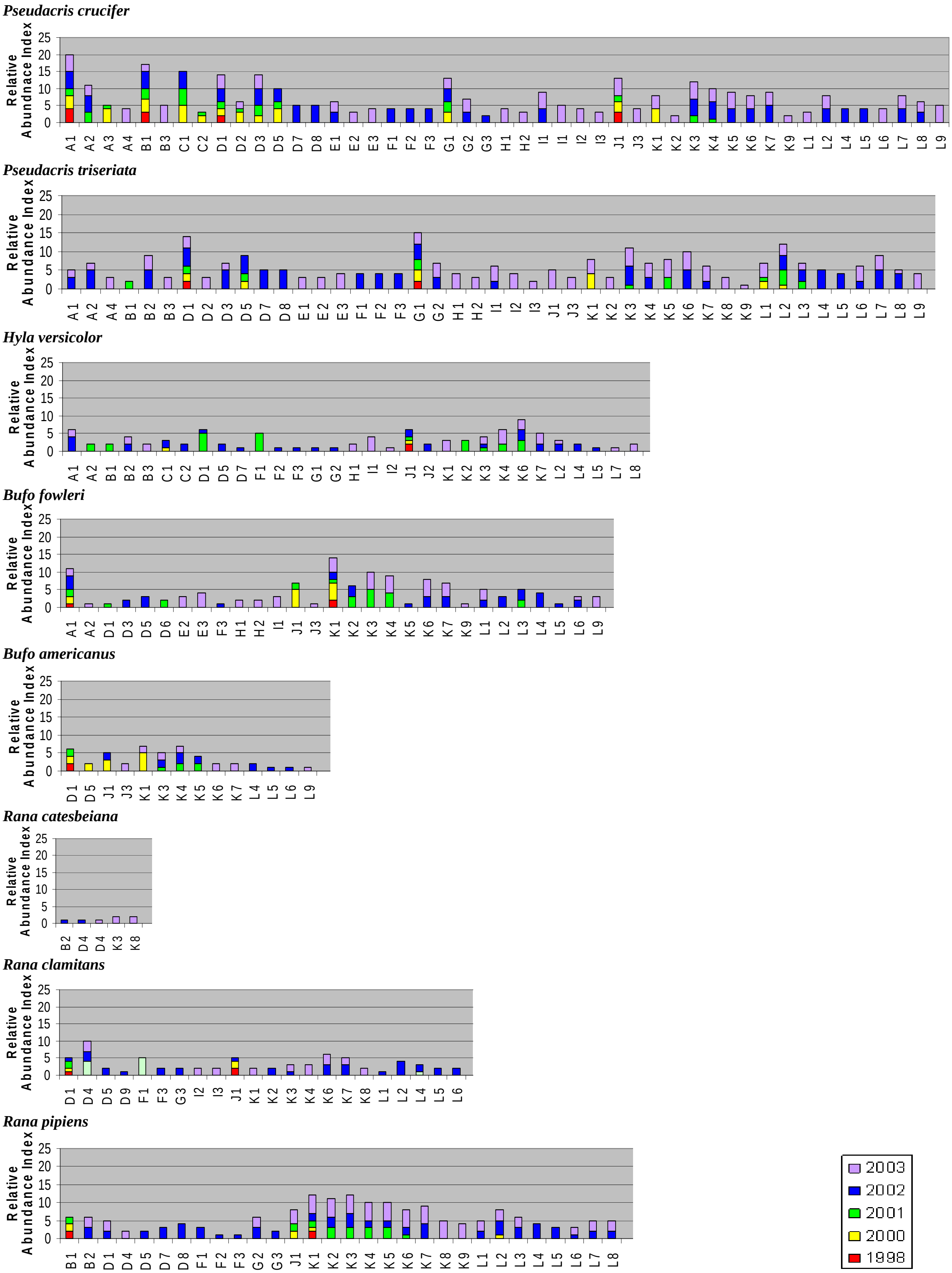

FIGURE 3. The abundance of amphibians among breeding sites from 1998, 2000-2003. Values are relative abundance index scores (1-5) for each amphibian species at each breeding site during each survey year. Breeding amphibians are represented by red bars 1998, yellow bars in 2000, green bars in 2001, blue bars in 2002 and purple bars in 2003. Sites A-L are oriented from north to south.

Kankakee Sands from 1998-2003 (Table 1). The number of sites with breeding amphibians increased more than six-fold and the total number of populations increased by more than an order of magnitude since restoration activities began in 1999 (Table 1). Relative abundance index scores significantly increased from a total of 30 in 1998 to 453 in 2003 ($r^2 = 0.968$, $P = 0.003$) and the mean relative abundance index score per population significantly increased from 2.14 in 1998 to 2.63 in 2003 ($t = 14.617$, $df = 3$, $P = 0.001$). All seven species that were present in 1998 became significantly more common since habitat restoration began in 1999 and breeding activities spread into every land management unit by 2003 (Table 1). Three species colonized restored habitats at Kankakee Sands: the American Bullfrog (*Rana catesbieana*) colonized between 2001 and 2002, and the Cope's Gray Treefrog (*Hyla chrysoscelis*) and the Tiger Salamander colonized between 2002 and 2003. The mean species richness per breeding site increased significantly from 2.0 in 1998 to 3.9 in 2003 ($F = 7.979$, $df = 1, 41$, $P = 0.007$). A linear regression model best explained the increase in the percentage of management units with breeding populations of amphibians, species richness, and the mean species richness per breeding sites (Table 1). An exponential growth regression model best explained the increase in the number of amphibian breeding sites and total number of amphibian populations (Table 1).

The species with the greatest rate of increase between 1998 and 2000 were American Toads (*Bufo americanus*), Western Chorus Frogs and Spring Peepers (*Pseudacris crucifer*; Table 1). The species with the greatest rate of increase between 2000 and 2001 were Eastern Gray Treefrogs (*Hyla versicolor*) and Green Frogs (*Rana clamitans*). Fowler's Toads (*B. fowlerii*), Bullfrogs, and Northern Leopard Frogs had the greatest rate of increase between 2001 and 2002. Western Chorus Frogs, Spring Peepers, and American Toads had the greatest increases between 2002 and 2003. Overall, Western Chorus Frogs, Spring Peepers, Northern Leopard Frogs and Fowler's Toads had the greatest increases during the survey period. A linear regression model best explained the increase in the number of breeding populations of American Toads, and an exponential growth regression model best explained the increase in the number of breeding populations of Fowler's Toads, Eastern Gray Treefrogs, Spring Peepers, Western Chorus Frogs, Green Frogs, and Northern Leopard Frogs (Table 1).

The first areas of colonization and the greatest increases in the number of breeding populations were in the southwestern units (Fig. 3; sites J, K, L) adjacent to Willow Slough ($\chi^2 = 53.22$, $df = 2$, $P < 0.001$). These units compose 25% of Kankakee Sands, but supported 56% of the new populations. The units furthest from Willow Slough also composed 25% of Kankakee Sands, but supported only 10% of the new populations. Amphibians colonized these more distant units (Fig. 3; sites C, G, H) later than other units.

During 2001, we captured 54 adult and 60 metamorphosed

FIGURE 4. Dead tadpoles in wetland that dried in 2001 (Photographed by Robert Brodman).

juvenile frogs; whereas, during 2002 we captured 60 adult and 1234 metamorphosed juvenile frogs. All of the species identified in the call surveys were also observed during searches or in traps. However two species were dominant. More than half the adults found in terrestrial searches and traps were Fowler's Toads and 90% of the juveniles found in terrestrial searches and traps were Northern Leopard Frogs. In 2001, tadpoles were observed in the restored wetlands. Although some tadpoles survived to metamorphosis, many died when the wetlands dried in late spring 2001 (Fig. 4). Spring rains during 2002 flooded many of the wetlands, including drainage ditch remnants. Although many of the wetlands began drying in June, most tadpoles survived through metamorphosis in deep remnant ditches (Fig. 5). However, we observed minnows (cyprinids) and sunfish (centrarchids) in these ditches. We found tadpoles and metamorphosed juveniles at all of the wetlands where frog calls were heard in 2002 and 2003. Tadpoles of Northern Leopard Frogs and toads (*Bufo* sp.) were the most abundant amphibian larvae observed in restored wetlands, but tadpoles of Spring Peepers, Chorus Frogs, Green Frogs, American Bullfrogs and treefrog (*Hyla* sp.) and Tiger Salamander larvae were also observed. Wetland depth changed rapidly during all years. Many wetlands ≤1.0 m deep dried completely within a week, and several wetlands went through repeated cycles of refilling and drying from May through July. All tadpoles in wetlands that occasionally refilled a few days after drying were dead.

DISCUSSION

We observed rapid colonization of amphibians into restored wetlands and exponential growth in the number of populations following a large-scale ecosystem restoration. Within five years of beginning the restoration, all 10 species found on adjacent lands were breeding at Kankakee Sands. Our observation of a mean of 3.9 species per breeding site in 2003 compares favorably to a mean of 4.9 species of pond-breeding amphibians per wetland found at state fish and wildlife areas and nature preserves in the region (Brodman and Killmurry 1998; Brodman et al. 2002).

We predicted that fossorial species and prairie species would colonize wetlands before other species. The data generally supported this hypothesis. Both prairie species (Western Chorus Frogs and Northern Leopard Frogs) and two of the three fossorial species (American Toads and Fowler's Toads) were among the five species with the greatest number of colonizing populations (Table 1). The Spring Peeper also was among the earlier colonizing species, but the fossorial Tiger Salamander was slow to colonize.

These results are similar to those reported for restored wetlands on former agricultural lands in Minnesota (Lehtinen and Galatowitsch 2001). Lehtinen and Galatowitsch (2001) found that eight species of amphibians rapidly colonized restored wetlands. Restored wetlands had 67% as many species as nearby natural wetlands and the mean species richness per wetland was 71% as much in restored compared to nearby natural wetlands. The species with the greatest increases in Minnesota were Western Chorus Frogs and Northern Leopard Frogs. Our observation that pond-breeding salamanders are slower than frogs in colonizing restored wetlands supports the findings of other studies (Lehtinen and Galatowitsch 2001; Pechmann et al. 2001).

Although many tadpoles survived through metamorphosis at most wetlands in 2002 and 2003, very few survived in 2001. Remnant ditches are important in keeping late-stage tadpoles and newly metamorphosed froglets from desiccating; however, several ditches harbor fish populations that entered restored wetlands during flooding events. Predatory fish can eliminate amphibians from isolated, small wetlands by eating eggs and tadpoles (Paton and Crouch 2002). Studies of isolated wetlands in Rhode Island suggest that few species have 95% of tadpoles metamorphose and emigrate from breeding ponds prior to 31 July, and that species using semi-permanent wetlands require inundation until mid-November (Paton and Crouch 2002). Maintaining water levels of restored wetlands through August (Paton and Crouch 2002) and keeping the wetlands fish-free are primary management concerns.

Species of frogs that were known to inhabit Kankakee Sands prior to the degradation of the sandy wetland habitat rapidly colonized the restored wetlands. Further study is needed to determine whether amphibian populations at restored wetlands are source or sink populations. There is potential for this community to increase further if source populations of Smallmouth Salamanders (*Ambystoma texanum*), Eastern Newts (*Notophthalamus viridescens*), Cricket Frogs (*Acris crepitans*), Crawfish Frogs (*Rana areolata*) and Plain's Leopard Frogs (*R. blairi*) in adjacent counties are able to colonize Kankakee Sands. Additional studies are required to determine what, if any, barriers are preventing emigration of these species into the restored habitat of Kankakee Sands.

Acknowledgements.—We thank Jeanette Jaskula and Sarah Rock for conducting surveys in 2000. We thank Marissa Marlin for assisting us in making drift fences and conducting surveys in 2001, and Michael Oskorep and Adam Walker for assisting us in making drift fences and conducting surveys in 2002. We thank Adam Walker, Ryan Dorton, Randy Hoffman, Tony Kretz, and

FIGURE 5. A restored seasonal wetland connected to a semi-permanent remnant ditch in the foreground (Photographed by Robert Brodman).

Shannon Finerty for conducting surveys in 2003. We thank Chip O'Leary for providing maps and giving advice. This study was supported and funded by the Efroymson Restoration Foundation and the Indiana Chapter of The Nature Conservancy.

LITERATURE CITED

Brodman, R. 1998a. The biogeography of Midwestern amphibians. Pp. 24-30 *In* The Status and Conservation of Midwest Amphibians. Lannoo, M. (Ed.). Iowa University Press, Iowa City.

_____. 2003. Amphibians and reptiles from 23 counties of Indiana. Proceedings of the Indiana Academy of Science 112: 43-54.

_____., S. Cortwright, and A. Resetar. 2002. Historical changes of reptiles and amphibians of Northwest Indiana Fish and Wildlife properties. American Midland Naturalist 147:135-144.

_____. and M. Kilmurry. 1998. The status of amphibians in rural northwest Indiana, Pp. 125-136 *In* The Status and Conservation of Midwest Amphibians. Lannoo, M.J. (Ed.). Iowa University Press, Iowa City.

Christiansen, J. L. 1998. Iowa's declining amphibians and reptiles. Journal of the Iowa Academy of Science 105:109-114.

Cortwright, S.A. 1988. Intraguild predation and competition: an analysis of net growth shifts in larval amphibian prey. Canadian Journal of Zoology 66:1813-1821.

Cortwright, S.A. 1998. Ten- to eleven-year population trends of two pond-breeding amphibian species, red-spotted newts and green frogs. Pp 61-71 *In* The Status and Conservation of Midwest Amphibians. Lannoo, M.J. (Ed.). Iowa University Press, Iowa City.

Debinski, D.M. and R.D. Holt. 2000. A survey and overview of habitat fragmentation experiments. Conservation Biology 14:342-355.

Dodd, C.K., and L.L. Smith. 2003. Habitat destruction and alteration: historical trends and future prospects for amphibians. Pp. 94-112 *In* Amphibian Conservation. R.D. Semlitsch (Ed.). Smithsonian Institution Press, Washington, D.C.

Fauth, J.E. and W.J. Resetarits, Jr. 1991. Interactions between the salamander *Siren intermedia* and the keystone predator *Notophthalmus viridescens*. Ecology 72:827-838.

Freda, J. and W.A. Dunson. 1986. Effects of low pH and other chemical variables on the local distribution of amphibians. Copeia 1986:454-466.

Hagar, H.A. 1998. Area-sensitivity of reptiles and amphibians: Are there indicator species for habitat fragmentation? Ecoscience 5:139-147.

Heyer, W. R., M.A. Donnelly, R.Q. McDiarmid, L.A.C. Hayek and M.S. Foster. 1994. Measuring and Monitoring Biological Diversity, Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Holomuzki, J.R., J.P. Collins, P.E. Brunkow. 1994. Trophic control of fishless ponds by tiger salamander larvae. Oikos 71:55-64.

Houlahan, J.E., C.S. Findlay, B.R. Schmidt, A.H. Meyer, and S.L. Kuzmin. 2000. Quantitative evidence for global amphibian declines. Nature 404:752-755.

Karns, D.R. 1986. Field herpetology: Methods for the study of amphibians and reptiles in Minnesota. James Ford Bell Museum of Natural History, Occational Paper 18.

Knutson, M.G., J.S. Sauer, D.A. Olsen, M.J. Mossman, L.M. Hemesath, and M.J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, U.S.A. Conservation Biology 13:1437-1446.

Lannoo, M. J., K. Lang, T. Waltz, and G.S. Phillips. 1994. An altered amphibian assemblage: Dickinson County Iowa, 70 years after Frank Blanchard's survey. American Midland Naturalist 131:311-319.

Lehtinen, R. M., and S. M. Galatowitsch. 2001. Colonization of restored wetlands by amphibians in Minnesota. American Midland Naturalist 145:388-396.

McCollough, M.C.B. 1999. Conservation of Maine's amphibians and reptiles. Pp. 15-24 *In* Maine Amphibians and Reptiles. Hunter, M.L., A.J.K. Calhoun and M. McCollough (Eds.). University of Maine Press, Orono.

McWilliams, S.R. and M.D. Bachmann. 1988. Using life history and ecology as tools to manage a threatened salamander species. Journal of the Iowa Academy of Science 95:66-71.

Merovich, C.E. and J.H. Howard. 2000. Amphibian use of constructed ponds on Maryland's eastern shore. Journal of the Iowa Academy of Science 107:151-159.

Meyer, A.H. 1936. The Kankakee Marsh of northern Indiana and Illinois. Papers of the Michigan Academy of Sciences, Arts and Letters 21:359-396.

Paton, P.W.C. and W.B. Crouch. 2002. Using the phenology of pond-breeding amphibians to develop conservation strategies. Conservation Biology 16:194-204.

Pechmann, J.H.K., R.A. Estes, D.E. Scott, and J.W. Gibbons. 2001. Amphibian colonization and use of ponds created for trial mitigation of wetland loss. Wetlands 21:93-111.

Post, T.W. 1997. Where the tallgrass waved: The Grand Prairie natural region. Pp. 188-193 *In* The Natural Heritage of Indiana. Jackson, M.T. (Ed.). Indiana University Press. Bloomington and Indianapolis.

Schneider, A.F. 1966. Physiography. Pp 40-56 *In* Natural Features of Indiana. Lindsey, A.A. (Ed.). Indiana Academy of Science, Indianapolis.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology 12:1113-1119.

Semlitsch, R.D. and J.R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Sexton, O.J., C.A. Phillips, T.J. Bergman, E.B. Wattenberg, and R.E. Preston. 1998. Abandon not hope: Status of repatriated populations of spotted salamanders and wood frogs at Tyson Research Center, St.Louis County, Missouri. Pp. 340-344 *In* The Status and Conservation of Midwest Amphibians. Lannoo, M.J. (Ed.). Iowa University Press, Iowa City.

Smallwood, B.F. and L.C. Osterholz. 1990. Soil survey of Jasper County Indiana. United States Department of Agriculture, Soil Conservation Service. 205 p.

Smith, P.W. and S.A. Minton. 1957. A distributional summary of the herpetofauna of Indiana and Illinois. American Midland Naturalist 58:341-351.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman, and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306: 1783-1786.

Thurow, G.R. 1999. Herpetofaunal changes in McDonough County, Illinois. Transactions of the Illinois State Academy of Science 92:147-161.

ROBERT BRODMAN is a Professor of Biology and Environmental Science, and Chair of the Biology Department at Saint Joseph's College in Indiana where he teaches a variety of Biology, Zoology and Ecology classes. He is pictured here at Kankakee Sands with a lovely bullsnake. He received his Ph.D. in Ecology from Kent State University working under Dr. Lowell P. Orr. His research includes studies on the population ecology and behavior of pond-breeding amphibians, the community ecology of the herpetofauna of the Midwest, and conservation biology. He is currently a co-chair of the Midwest Region of Partners for the Conservation of Amphibians and Reptiles.

SPENCER CORTWRIGHT is a Professor of Biology and Chair of the Biology Department at Indiana University Northwest (IUN) where he teaches Biology and Ecology classes and is a Fellow at the Indiana University Center for Regional Excellence. He is pictured here at a habitat restoration that he is managing at IUN. He received his Ph.D. in Indiana University working under Dr. Craig Nelson. His research includes studies on the ecology of pond-breeding amphibians, habitat restoration and conservation biology. He is currently involved in long-term amphibian population studies initiated in the 1980's.

MIKE PARRISH is a Lake Manager at Kiawah Island, South Carolina. He received his B.S. degree in Environmental Science from Saint Joseph's College. He is pictured at Kanakee Sands in a restored wetland. He conducted four-years of undergraduate research in herpetology with Dr. Bob Brodman including a two-year internship at Kankakee Sands.

HIEDI KROUSE is a Biology Teacher at a high school in Valparaiso, Indiana. She received her B.S. degree in Biology from Saint Joseph's College. She is pictured at Kanakee Sands with an eastern gartersnake. She conducted four-years of undergraduate research in herpetology with Dr. Bob Brodman including a two-year internship at Kankakee Sands.