RESEARCH ARTICLE

Immediate Herpetofaunal Responses to Prescribed Burning in Wetlands of Southeastern Michigan

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ABSTRACT

Prescribed fire is an increasingly common and effective management tool for ecological restoration of wetlands in the US Midwest. Prescribed fire is reported to have adverse effects on sensitive wetland fauna such as reptiles and amphibians, but surprisingly few empirical data are available to support management recommendations meant to protect herpetofauna from prescribed burning. We examined the effects of prescribed fires one day and one month after burning in eight wetlands across two wetland types in southeastern Michigan using abundance, species richness, and diversity of herpetofauna as metrics. Most amphibian communities returned to pre-burn levels of the three metrics by one month after the burn; reptile communities appeared to be more negatively affected by prescribed fire although sample sizes were extremely low. Response of individual species to burning was more variable; two previously detected amphibians and four previously detected reptiles were not detected by the end of the project, suggesting that some herpetofauna may respond negatively to fire while the most common species are unaffected. Only one individual of the 126 herpetofauna located in this study apparently experienced direct mortality after fire. We noted differences in species richness and diversity between wetland types that were probably attributable to differences in these metrics prior to burning. Although in some cases amphibian communities experienced few or only short-lived negative impacts of fire, we caution that fire effects are likely to be species-specific, such that prescribed burns should always be planned thoughtfully from this perspective.

Keywords: amphibians, grassy wetlands, prairie fens, prescribed fire, reptiles

Prescribed fire is an increasingly common and effective management tool for ecological restoration in the US Midwest and elsewhere in the eastern United States. Prescribed fire is most typically used in upland forests as a method of reducing fuels and associated wildfire risk (USDA and USDI 2001, Pilliod et al. 2003) and managing understory vegetation where fire suppression has significantly impacted ecosystems (Leach and Givnish 1996). The practice of prescribed burning in wetlands in this region is also common, but its impacts are far less researched and largely unknown (Kirby et al. 1988, Robertson 1997).

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In the Upper Midwest, fire is important for maintaining plant diversity in alkaline, groundwater-fed wetlands (prairie fens) (Moran 1981, Spieles et al. 2010) and other low-lying, occasionally flooded grasslands that may include wet-mesic prairies (Kost et al. 2007). As in terrestrial systems, removal of fire from wetland systems has been shown to facilitate succession and shrub and non-native plant invasion, subsequently decreasing herbaceous plant species richness and altering ecosystem structure (White 1965, Collins et al. 1981, Wheeler 1988). Land managers therefore often utilize prescribed burns to mitigate the encroachment of invasive plants, to restore earlier stages of succession, and to encourage the regeneration of native wetland plants (Bowles et al. 1996, Middleton 2002, Flores et al. 2011) or improve habitat for wetland bird species (Thompson and Shay 1985, Apfelbaum and Sams 1987).

Potentially adverse effects of prescribed burning on wetland fauna are intuitive given the direct dangers of fire and the ecological requirements of sensitive species and populations (Greenberg 2002). Amphibians and reptiles are of particular concern because many have patchy or narrow geographical distributions, occur in restricted habitats exposed to management activities, or may be threatened or endangered (Pilliod et al. 2003). In the eastern US, prescribed burning typically occurs in the spring and late fall when conditions are moist and amphibians are most active, unlike historical natural fires that usually occurred during the summer when herpetofauna were less active (Pilliod

Table 1. Prescribed burn site information describing location, wetland type (prairie fen or grassy wetland), coordinates, elevation (m), size (ha), and date the wetland was burned. All prescribed burns except Bald Mountain (2009) occurred in 2011.

ID	Location	Wetland Type	Coordinates	#	Area (ha)	Date Burned
1	Lakeville Swamp Nature Sanctuary-Lakeville, MI	prairie fen	42° 49.103' N, 83° 08.924' W	282	0.88	5-May
2	Bald Mountain Recreation Area-Lake Orion, MI	prairie fen	42° 47.250' N, 83° 11.033' W	300	6.5	27-Mar
3	Olson Park- Ann Arbor, MI	prairie fen	42° 19.033' N, 83° 43.950' W	275	0.20	4-May
4	Hartland, MI	prairie fen	42° 38.781' N, 83° 40.696' W	311	0.81	9-May
5	Manchester, MI	prairie fen	42° 05.393' N, 84° 06.736' W	283	4.0	11-May
6	Grosse Ile Nature and Land Conservancy- Grosse Ile, MI	grassy wetland	42° 10.667' N, 83° 09.100' W	181	0.61	9-May
7	Olson Park- Ann Arbor, MI	grassy wetland	42° 19.033' N, 83° 43.900' W	275	0.20	4-May
8	Stoney Creek Metropark- Shelby Township, MI	grassy wetland	42° 43.768' N, 83° 06.977' W	264	1.6	6-May

et al. 2003, MWPARC 2009). Moreover, modern populations likely experience very different fire intensities and severities with prescribed fire compared to what would have occurred as part of the natural disturbance regime (Pilliod et al. 2003, Greenberg and Waldrop 2008). As such, management recommendations to protect amphibians and reptiles during prescribed burns are very strong (e.g., MWPARC 2009). Surprisingly few empirical data exist, however, to support these recommendations (Pilliod et al. 2003); we are aware of no published study examining herpetofaunal response to burning in wetlands in the Upper Midwest, and most recommendations appear to be based on burning conducted in upland forests in the southeastern US (de Maynadier and Hunter 1995, Pilliod et al. 2003, Greenberg and Waldrop 2008) or the Pacific Northwest (Bury 2004).

Based on those empirical studies conducted outside the Upper Midwest, effects of prescribed burns on herpetofauna appear to be mixed at best. Pilliod et al. (2003) described amphibian responses to fire as "species-specific, incompletely understood, and variable among habitat and regions." The wide variety of life histories of herpetofauna—ranging from fully aquatic, to aquatic during the breeding and larval life stages but otherwise terrestrial, to fully terrestrial—are one reason for such mixed results. Pilliod et al. (2003) predicted varying short, intermediate, and long-term responses of amphibians to fire and its associated changes in habitat over time. Some studies have suggested that burning negatively impacts amphibians (e.g., Jones et al. 2000, Schurbon and Fauth 2003), while others suggest that species respond individualistically to fire (e.g. Means and Campbell 1982, Ford et al. 1999, Moseley et al. 2003, Greenberg and Waldrop 2008) or indicate no detectable effects of prescribed fire on herpetofauna (Ford et al. 1999, Bury 2004, Masterson et al. 2008, Perry et al. 2009). The most immediate negative impact associated with recommendations against prescribed fire is direct mortality (MWPARC 2009), but mortality of herpetofauna is thought to be rare and unlikely to change population abundance (Lyon et al. 1978, Means and Campbell 1981, Russell et al. 1999, Smith 2000, Pilliod et al. 2003, Greenberg and Waldrop 2008). Empirical data in wetlands is critical for understanding impacts of prescribed fire on herpetofauna, especially as prescribed fire is increasingly used for ecological restoration in wetlands of the Upper Midwest and other regions.

The objective of our study was to determine the immediate effects of prescribed burns on herpetofaunal abundance (number of individuals present), species richness (number of species present), and diversity (equality of the abundances of all species present) in prairie fens and grassy wetlands of southeastern Michigan. We addressed: (1) How are herpetofaunal abundance, richness, and diversity affected by prescribed burns one day after the fire?; and (2) How are herpetofaunal abundance, richness, and diversity affected by prescribed burns one month after the fire, once vegetation has re-established? We hypothesized that herpetofauna would decrease in abundance, richness, and diversity the day after the burn due to mortality and individuals leaving the newly burned habitat, but would reach pre-burn levels one month after the burn.

Methods

Study Sites

Five prairie fens and three grassy wetlands in southeastern Michigan were used to assess impacts of prescribed

Table 2. Numbers of individuals and species found in five prairie fen wetlands one day before, one day after, and one month after prescribed burning in southeastern Michigan, May 2011.

Species		One Day Before Burn	One Day After	One Month After
Amphibians				
eastern American toad	*Anaxyrus americanus americanus*	2	5	4
northern leopard frog	*Lithobates pipiens*	0	9	1
green frog	*Lithobates clamitans*	15	22	13
wood frog	*Lithobates sylvaticus*	6	3	1
eastern gray tree frog	*Hyla versicolo*	2	4	2
western chorus frog	*Pseudacris triseriata triseriata*	0	2	0
Reptiles				
eastern garter snake	*Thamnophis sirtalis*	5	6	0
eastern Massasauga rattlesnake	*Sistrurus catenatus catenatus*	0	1	0
northern water snake	*Nerodia sipedon*	0	2	1
common snapping turtle	*Chelydra serpentina*	1	0	0
common map turtle	*Graptemys geographica*	0	0	1
painted turtle	*Chrysemys picta*	1	0	0
All amphibians		25	45	21
All reptiles		7	9	2
Total		32	54	23

fire on herpetofauna. Prairie fens in this region are found in glacial interlobate areas (Albert 1995, Bowles & McBride 1996) and are fed by mineral-rich groundwater, usually associated with small lakes or rivers (Spieles et al. 2010), such that water is rarely unavailable. Prairie fens are dominated by emergent grasses, sedges, forbs, and occasionally scattered shrubs. The three grassy wetlands include a stand of *Phragmites australis* (common reed) along the Detroit River (Wetland 6), and two wet-mesic prairies (Wetlands 7 and 8, Table 1). Wet-mesic prairies experience occasional water inundation in the spring and tend to have loamy soil that retains water (Kost et al. 2007), but dry out substantially during part of the growing season when the water table falls (Slaughter and Kost 2010). The eight wetlands were generally small compared to most burned areas examined in the literature, ranging from 0.2–6.5 ha in area (Table 1). Five of the eight wetlands were located on private property.

Field Methods

All prescribed burns were of low intensity and completed in the spring by environmental consulting firms or the Michigan Department of Natural Resources using hand ignition techniques to shrubs just above ground level. Prescribed burns were conducted over the entire area of each of the eight wetlands treated. Private ownership of many of our study sites precluded us from leaving objects or disturbing sites in a way necessary to utilize multiple survey techniques such as pitfall traps, coverboards, and funnel traps (Greenberg et al. 1994). Therefore, we performed visual encounter surveys for herpetofauna using a zig-zagged pattern across the wetland, conducted by 1–3 people who underwent extensive training prior to sampling such that survey competencies were standardized. At least 8 person-hours were spent at each site; longer survey time was expended on larger sites to ensure the same survey effort per unit area. Visual encounter surveys offer the widest range of effective herpetofaunal identification over all habitat types (Welsh 1987; Crosswhite et al. 1999). Our survey techniques included overturning all coarse woody debris and rocks to search for reptiles or amphibians in these refugia and then returning them to their original position. Visual encounter surveys were done one day before the burn, one day after the burn, and one month after the burn between 10:00 and 13:00 on sunny days in May and June 2011. All encountered herpetofauna were identified to species.

Analytical Methods

Mean abundance, species richness, and Shannon-Wiener diversity indices were standardized for overall herpetofauna, amphibians, and reptiles by dividing values by the area surveyed. Initial (pre-burn) herpetofaunal abundance and richness were compared between prairie fens and grassy wetlands with analysis of variance (ANOVA). A series of repeated-measures ANOVA was used to examine changes over time (measured one day before the burn, one day after, and one month after) for the pooled (n = 8) data set in abundance and species richness for amphibians, reptiles, and all herpetofauna. Wetland type

Table 3. Numbers of individuals and species found at three grassy wetland sites one day before, one day after, and one month after prescribed burning in southeastern Michigan, May 2011.

Species		One Day Before Burn	One Day After	One Month After
Amphibians				
green frog	*Lithobates clamitans*	0	1	1
wood frog	*Lithobates sylvaticus*	1	1	3
eastern gray tree frog	*Hyla versicolor*	2	4	2
blue spotted salamander	*Ambystoma laterale*	1	0	0
Reptiles				
Butler's garter snake	*Thamnophis butleri*	0	0	1
All amphibians		4	6	6
All reptiles		0	0	1
Total		4	6	7

was used as a between-subjects factor in the repeated-measures ANOVA to determine differences between fens and grassy wetlands, and time as a within-subjects factor to determine if there are differences among the three measurements periods for the above variables. We also tested for a wetland type-by-time interaction to determine if prescribed burn effects differ between the two types of wetlands over time. We performed a t-test for diversity indices (Hutcheson 1970) to determine if amphibian, reptile, and overall herpetofauna Shannon-Wiener diversities were equal in grassy wetlands and prairie fens. All variables were tested for assumptions of normality and equal variances without significant departures from these assumptions found. All statistical analyses were conducted using MYSTAT 12 (Systat Software, Inc. 2007) at alpha = 0.05.

Results

We observed an overall herpetofaunal total of 36 individuals before, 60 individuals one day after, and 30 individuals one month after the burn across the eight wetland sites. Amphibians in particular accounted for 25 (69%), 45 (75%), and 21 (70%) of these individuals, respectively. Most of our overall herpetofaunal detections were in prairie fens, where 32 (89%) individuals were observed the day before, 54 (90%) the day after and 23 (77%) individuals one month after a fire (Table 2). We only observed 4, 6, and 7 individuals, respectively, at grassy wetlands, and 76% of the herpetofauna found were represented by wood frogs (*Lithobates sylvaticus*) and eastern gray tree frogs (*Hyla versicolor*) (Table 3). The only mortality observed was a single northern leopard frog (*L. pipiens*) that had presumably been killed by the prescribed burn in Wetland 7 at Olson Park.

In prairie fens, amphibian abundance varied greatly between sites the day before the burn (CV = 125%), and the day after (CV = 118%), compared to one month after (CV = 67%). Amphibian abundance was less variable in grassy wetlands, though sample sizes were much smaller. Mean amphibian abundance (averaged across 5 sites) for prairie fens increased the day after the burn and then returned to pre-burn levels within a month; mean amphibian abundance in grassy wetlands increased slightly after the burn (Figure 1A). Mean reptile abundance in prairie fens was highly variable among sites at all sample periods, with CV ranging from 99% to 158%, probably due to the low number of observations in all but two wetlands. Only one reptile was detected in grassy wetlands (Table 3). Mean reptile abundance (based on very few individuals) increased one day after the burn but decreased one month later in prairie fen habitats, and the only reptile detected in grassy wetlands was found one month after the burn (Figure 1B).

Direct response to prescribed fire appeared to vary species by species when examined by abundance. Over both wetland types, four amphibian species (northern leopard frog, green frog (*L. clammitans*), eastern gray tree frog, and eastern American toad (*Anaxyrus americanus americanus*)) increased the day after the burn, then returned to pre-burn levels; one amphibian (western chorus frog (*Pseudacris triseriata triseriata*)) and one reptile species (eastern Massasauga rattlesnake (*Sistrurus catenatus catenatus*) appeared only the day after the burn in very low numbers (Tables 2, 3). Two reptile species (common map turtle [*Graptemys geographica*] and Butler's garter snake [*Thamnophis butleri*]) appeared only one month after the burn, again in very low numbers (Tables 2, 3). In addition, one amphibian species (wood frog) decreased without returning to pre-burn levels, and three reptiles (eastern garter snake (*Thamnpohis sirtalis*), common snapping turtle (*Chelydra serpentina*), and painted turtle (*Chrysemys picta*)) and one amphibian species (blue spotted salamander (*Ambystoma laterale*)) disappeared by one month after the burn, although all but wood frog and eastern garter snake included only one individual (Tables 2, 3).

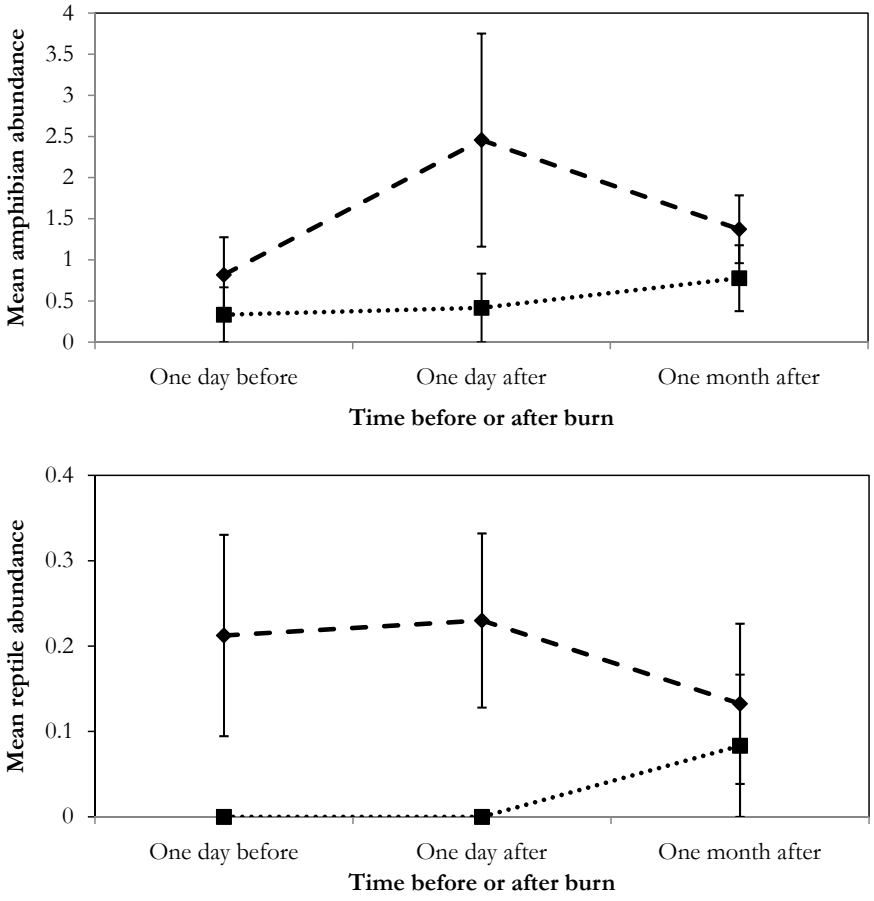

Figure 1. Mean (± S.E.) abundance in fens (diamonds, hatched line) and grassy wetlands (squares, dotted line) one day before prescribed burning, one day after, and one month after the burn for (top) amphibians and (bottom) reptiles in southeastern Michigan, May 2011.

Table 4. Results of repeated measures ANOVA for abundance and richness for total herpetofauna, all amphibians, and all reptiles in response to wetland type (fens and grassy wetlands; df = 1, 6), time (one day before, one day after, and one month after prescribed burning; df = 2, 12), and wetland type-by-time interaction. (df = 2, 12). Italics indicate a significant difference.

	Wetland Type		Time		Wetland Type x Time	
	F-stat	*p*	F-stat	*p*	F-stat	*p*
Total Herpetofauna						
Abundance	1.191	0.32	1.120	0.36	1.423	0.28
Richness	1.185	0.32	0.295	0.75	*3.793*	*0.05*
Amphibians						
Abundance	2.124	0.20	1.452	0.27	1.583	0.25
Richness	0.593	0.47	0.429	0.66	2.265	0.15
Reptiles						
Abundance	1.840	0.22	0.372	0.70	1.251	0.32
Richness	2.244	0.19	0.923	0.42	1.418	0.28

Amphibian species richness was highly variable in both prairie fens (CV range = 92%–147%) and grassy wetlands (CV range = 87%–173%). When averaged across sites, amphibian species richness increased one day after the burn but decreased again to near (or slightly higher than) initial values one month later in both wetland types (Figure 2A). Reptile species richness was highly variable at all sample time points for prairie fens (CV range = 131%–181%), and included only a single species after one month in grassy wetlands (Figure 2B). Mean reptile species richness remained almost unchanged one day after the burn in both types of wetlands, but decreased one month after the burn in prairie fens (Figure 2B).

Total herpetofaunal abundance and richness did not differ between wetland type or over time (Table 4). However, the wetland type × time interaction term was significant in the repeated-measures ANOVA for total herpetofaunal richness, suggesting that overall richness was significantly higher in fens vs. grassy wetlands over time ($p = 0.053$). Amphibian and reptile abundance and richness did not differ between wetland types, nor did they differ over time for the pooled data set or within wetland types over time. Shannon-Wiener diversity for reptiles was significantly higher for prairie fens compared to grassy wetlands for all time periods, and was significantly higher for amphibians in prairie fens one month after the burn (Table 5).

Discussion

Similar to studies conducted outside of the Upper Midwest, our study provided mixed results about whether prescribed fire used to manage wetlands negatively impacts reptile or amphibian abundance, species richness, or diversity. When analyzed as a group, mean amphibian abundance and species richness increased the day after the burn (but see caveats below) and were either near or slightly

Table 5. Mean Shannon-Wiener Diversity Index values for total herpetofauna, amphibians, and reptiles in prairie fens (PF; n = 5) vs. grassy wetlands (GW; n = 3) one day before, one day after, and one month after prescribed burning in southeastern Michigan, May 2011. Diversity index values were compared using the t-test developed by Hutcheson (1970). Significant differences in mean diversity values between wetland types are shown in italics.

	One Day Before					One Day After					One Month After				
	PF	GW	t	df	*p*	PF	GW	t	df	*p*	PF	GW	t	df	*p*
Total Herpetofauna	0.67	0.45	2.01	5	0.15	0.66	0.45	2.35	6	0.07	0.68	0.46	1.76	5	0.07
Amphibians	0.69	0.48	1.81	6	0.18	0.69	0.48	1.76	5	0.15	*0.69*	*0.47*	*2.71*	*6*	*0.04*
Reptiles	*0.68*	*0.45*	*4.76*	*4*	*0.01*	*0.67*	*0.47*	*5.58*	*4*	*0.01*	*0.67*	*0.45*	*3.99*	*5*	*0.02*

above pre-burn levels by one month after the burn in both wetland types. Amphibian diversity was significantly higher one month after the burn. Reptile detection was too low to make definitive conclusions and was near absent in grassy wetlands, but generally decreased by one month after the burn in prairie fens. When analyzed by species, several species were apparently lost from the set of wetlands—usually those that were initially uncommon or presumably more difficult to detect—and there was at least one apparent case of direct mortality (assuming that heavy scavenging of fire-killed individuals did not occur prior to sampling the next day). Though mixed, these results at least suggest that impacts of prescribed burning on amphibians may differ depending on the temporal scale examined. Our results for amphibians are largely consistent with several others that documented a lack of significant negative effects on amphibians in forested terrestrial ecosystems after a period of post-fire recovery (Ford et al. 1999, Moseley et al. 2003, Bury 2004, Masterson et al. 2008, Greenberg & Waldrop 2008, Perry et al. 2009).

Because of our low numbers of visual encounters, it remains difficult to make definitive conclusions about the effects of prescribed burning. Repetition of the burning treatment (i.e., number of sites with prescribed burns) in studies such as ours is necessary if post-fire trends are to be considered robust. However, the ability to choose wetlands with dense herpetofaunal communities is subsequently limited, particularly given the narrow prescription window and short decision time for burning in this region when immediate pre-burn survey data are necessary. We suspect that these are the likely reasons for the lack of empirical data on herpetofauna and prescribed burning in the Upper Midwest. Notably, the number of our visual encounters, though low, are similar to values of many other amphibian studies when standardized for area (1.7 individuals/ha one day before, 3.0 one day after, and 1.4 one month after). For example, Kirkland et al. (1996) observed a mean of 0.5 individuals/ha for a 9-ha oak forest in south-central Pennsylvania in April and June; Greenberg and Waldrop (2008) noted 7.8 individuals/ha for a thrice-replicated 14-ha experimental block in a hardwood forest in North Carolina; and Keyser et al. (2004) found 8.9 individuals/ha in a 15-ha oak forest in the Virginia Piedmont. Nevertheless, our low number of encounters increases the likelihood

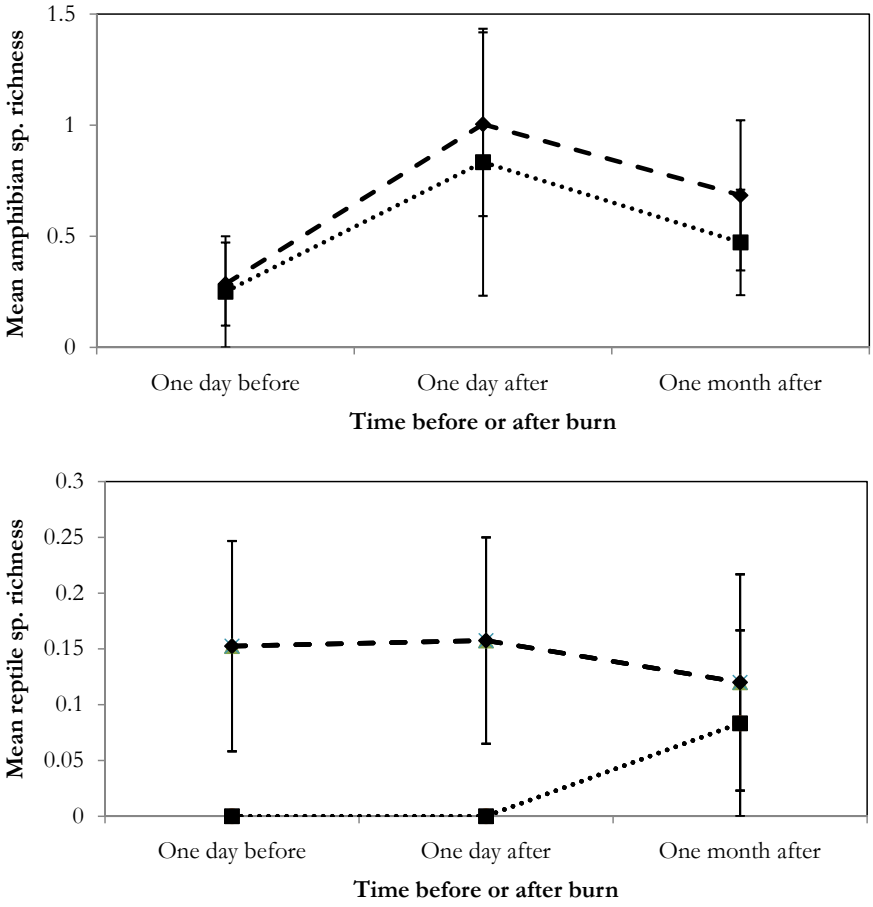

Figure 2. Mean (± S.E.) species richness in fens (diamonds, hatched line) and grassy wetlands (squares, dotted line) one day before prescribed burning, one day after, and one month after the burn for (top, A) amphibians and (bottom, B) reptiles in southeastern Michigan, May 2011.

that some herpetofaunal responses were missed during sampling (Type II error, Greenberg and Waldrop 2008), and generally precluded us from detecting significant results. Reptile detection, in particular, was limited in our study, making it extremely difficult to conclude that burning had either positive or negative impacts. However, ours is the first quantitative study of its kind in wetlands of the Upper Midwest that are increasingly being managed with prescribed fire, however, and our results—with appropriate caveats—should at least motivate additional research and long-term monitoring that will either refute or substantiate current general recommendations against prescribed burning.

We observed a general increase in amphibian abundance and species richness the day after the burn that is probably explained by: (1) vegetation loss and thus increased ease of visual observation during sampling; and (2) the process of migration by individuals within or away from the burned area immediately after the fire. As such, abundance and richness sampled after post-fire vegetation had recovered (one month after the burn) are likely to be better indicators of burning impacts than those sampled the day after the burn. Mean amphibian abundance and species richness approximated pre-burn levels one month after the burn once vegetation had recovered. Amphibian abundance and richness in prairie fens was similar to pre-burn abundance and richness even when species such as northern leopard frogs and wood frogs had begun to emigrate to terrestrial sites later in the season after they bred. These results suggest that the fire had little detectable effect on overall amphibian abundance and richness after a short period of post-fire recovery, perhaps in part because of immigration from outside the burned area. Pilliod et al. (2003) suggest that short-term responses like those in our study are not necessarily indicative of longer-term trends, however; some amphibians may increase over a period of years as a response to increased productivity or may benefit from predator or competitive release, while others may decrease if they are sensitive to fire. We emphasize that interpreting negative impacts depends strongly on temporal scale as well as understanding the role of disturbances in the ecosystem dynamics of herpetofaunal habitat.

Consistent with some studies of prescribed burning effects in forests (e.g., Kirkland et al. 1996, Keyser et al. 2004, Greenberg et al. 2008, Perry et al. 2009), we observed that herpetofauna species responded to prescribed fire individualistically rather than uniformly. The trends in amphibian abundance over time were dominated by green frogs, which represented nearly 40% of all the individuals observed in this study over all time periods. Studies by Kirkland et al. (1996) and Greenberg and Waldrop (2008) noted similar dominance by 1–2 species in their sampling, and we caution that the trends in our data are heavily biased by the dispersal abilities and tolerances of this single species. Visual encounters of other species were few, but more abundant herpetofauna in the region such as eastern American toads and eastern gray tree frogs remained stable or increased after burning, while wood frogs and eastern garter snakes declined. Several herpetofauna species disappeared after burning, but in all cases but one (eastern garter snake) only one individual was located in the set of eight wetlands; likewise, single individuals of northern leopard frog, northern water snake (*Nerodia sipedon*), and Butler's garter snake were found after one month when no individuals of these species were found prior to the burn. We therefore caution that individual species may be negatively affected by prescribed burning even if negative effects upon the greater herpetofauna community are not detected, such that impacts on sensitive species may be disproportionate.

We found no convincing evidence that herpetofaunal responses to prescribed fire differ by wetland type. Total herpetofauna species richness was significantly higher in prairie fens compared to grassy wetlands over time, while amphibian diversity was significantly higher one month after the burn. However, abundance, richness, and diversity of both amphibians and reptiles was higher in prairie fens vs. grassy wetlands prior to the burning treatment (Tables 2, 3), and mean abundance and richness was higher or similar to pre-burn levels one month after the burn in both wetland types for amphibians (Figure 1A, 2A). Higher abundance, richness, and diversity in fens rather than grassy wetlands is probably because of the permanent supply of water in prairie fens that was lacking in the grassy wetlands we surveyed. In any case, grassy wetlands contained too few individuals in this study for appropriate statistical comparison between the wetland types. We speculate that herpetofauna population response to fire is an extremely site-specific process that cannot be generalized for all burning prescriptions, and further research into the importance of wetland type for post-fire responses of herpetofauna is needed.

Caveats and Future Research Needs

We present several caveats in interpreting our results for application to future management activities in wetlands of the Upper Midwest. In light of the low number of observed individuals in our study, we encourage future research that utilizes methodology other than visual encounters alone, such as drift fences and pitfall traps, which are likely to provide a larger and more accurate representation of amphibian communities of the wetlands in question. Second, we encourage long-term studies designed to monitor herpetofauna over months or even years, which are likely to capture significant responses to prescribed fire that we

were unable to capture over the short temporal scale of this study. Related to this issue is the possibility that long-term use of post-burn wetlands may differ from those never burned, which would have significant implications for assessing prescribed fire effects on amphibians and reptiles. An important part of long-term studies would include detailed examinations of changes in water quality due to fire, which may have significant impacts on juvenile amphibian development and survival in wetlands as well as future impacts on amphibian breeding populations. Fourth, we emphasize that the spatial arrangement of wetlands on the landscape may be critical for understanding the impacts of prescribed fire, because the proximity and quality of potential source populations are likely to be important for recolonization of burned wetlands by herpetofauna. Finally, we reiterate that impacts of burning may vary by species even if little or no impact is detected on the community as a whole, across wetland types, and with burn intensity, and restoration efforts that employ prescribed burns should therefore always proceed cautiously.

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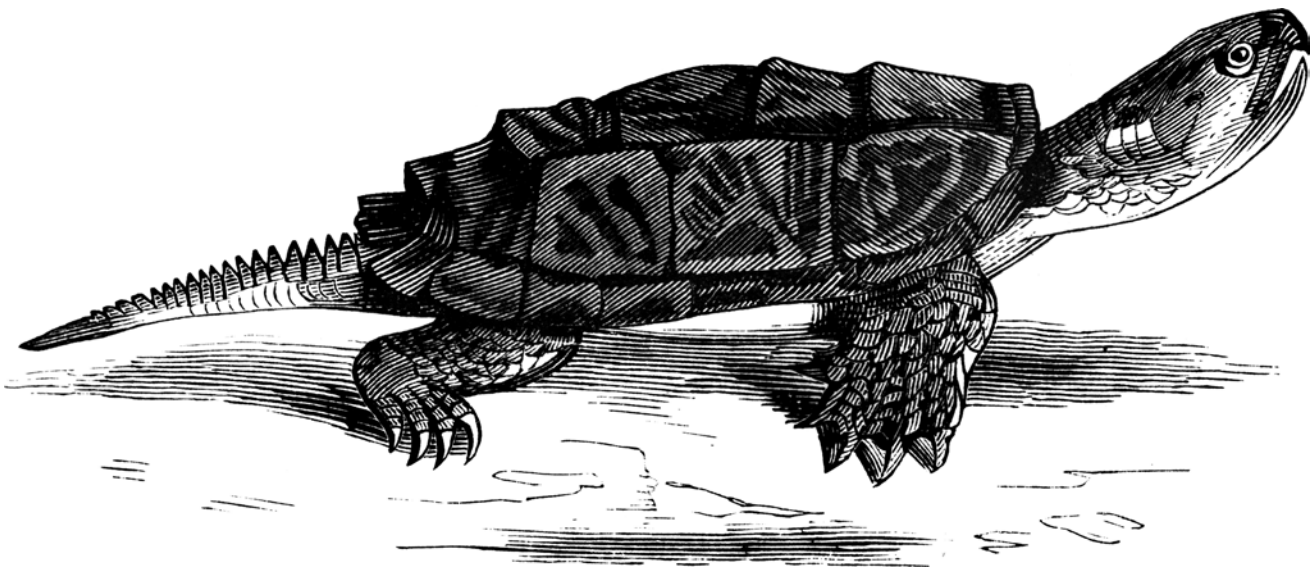

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