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FRESHWATER TURTLE COMMUNITY COMPOSITION IN STRIP PIT LAKES ON MINED LANDS

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Abstract.—**Creating and managing undeveloped lands is important for the perpetuation of species and communities they comprise, particularly for turtles, which are often impacted by human disturbance and are ill-equipped to adapt to sustained anthropogenic disturbance. Reclaimed land at the site of former surface mining operations often provides a large matrix of wetland, prairie, and woodland habitat that is protected from development. Such sites support robust communities of birds and amphibians, but few investigations have assessed their suitability for aquatic reptiles. To examine their suitability for turtle communities, we surveyed strip pit lakes and naturally occurring lakes at Mined Lands Wildlife Area in southeastern Kansas, USA. Community composition was different between the two classes of wetland due to differences in the abundance of *Chelydra serpentina serpentina* (Eastern Snapping Turtle), *Chrysemys picta bellii* (Western Painted Turtle), and *Sternotherus odoratus* (Eastern Musk Turtle). Catch per unit effort, however, only varied significantly for *C. s. serpentina*, which were captured at lower rates in strip pits. All other species were at least as abundant in strip pit lakes as in natural lakes, and *C. p. bellii* were slightly more abundant in strip pits. *Sternotherus odoratus* were very abundant in a single strip pit lake. Canonical correspondence analysis associated *C. s. serpentina* with shallow water and high percentage of canopy cover, while *C. p. bellii* were associated with deep water. *Sternotherus odoratus* were associated with abundant submerged vegetation; however, habitat features only explained 12% of the variation in species occurrence. Strip pit lakes appear to provide suitable habitat for most of the turtle species encountered, with the notable exception of *C. s. serpentina*, and may even be preferred over natural oxbows by some species.**

Key Words.—community; *Chelydra serpentina*; *Chrysemys picta*; habitat; mined lands; reclamation

INTRODUCTION

The alteration of habitat by human activity is a considerable threat to many groups of animals, and the behavioral patterns, life-history traits, and habitat use of freshwater turtles make them particularly vulnerable to anthropogenic disturbance. As semi-aquatic animals, the persistence of freshwater turtle populations is dependent on wetlands, and there has been an enormous loss of a wide variety of wetlands over the last century (Davidson 2014). Even where wetlands persist, degradation often leads to loss of habitat heterogeneity, which in turn may make wetlands, even those that are protected from destruction, inhospitable to certain turtle species (Dreslik and Phillips 2005).

Freshwater turtles rely on presence of suitable terrestrial habitat as well as wetlands and are therefore also susceptible to anthropogenic alteration of buffer zones surrounding wetlands (Burke and Gibbons 1995; Steen et al. 2012). Females of most species must use terrestrial habitats to nest and some species use upland terrestrial habitat during overwintering and estivation. Many putatively aquatic species of turtle also travel overland to move among discrete wetlands and the composition of surrounding terrestrial habitats is an important factor for healthy turtle populations (Quesnelle et al. 2013). Terrestrial activities expose turtles to numerous additional risks that result from human activity, such as road mortality and deadly encounters with agricultural equipment (Aresco 2005; Howell and Seigel 2019). Even natural sources of mortality, such as predation by terrestrial carnivores, are exacerbated by human activity. The creation of edge habitats is a common result of human environmental disturbance and rates of predation on turtle nests are highest near habitat edges (Temple 1987).

Threats resulting from habitat alteration have the potential to affect semi-aquatic animals generally, but the life history of turtles renders them singularly ill-suited to adapt to such threats. Despite high reproductive output, annual adult recruitment in turtles is very low due to high juvenile mortality rates and delayed maturation (Congdon et al. 1993, 1994). Therefore, stability in these populations is highly dependent on low adult mortality. Turtle populations thus have far lower capacity for recovery from catastrophic population declines relative to shorter-lived species with faster generational turnover. Even brief periods of high adult mortality may lead to population declines that persist for decades and even very slight increases in chronic adult mortality rates can doom populations to extirpation (Brooks et al. 1991; Congdon et al. 1993, 1994; Keevil et al. 2018).

For these reasons, areas in which both wetland and terrestrial habitats used by turtles are protected from human activity have the potential to serve as important refuges for diverse turtle communities. Somewhat counterintuitively, a promising source of such protected lands is one that has been created through human habitat disturbance. Strip mining for coal from the late 19th through the late 20th centuries left many landscapes across the U.S. (including in Indiana, Ohio, Illinois, Iowa, Missouri, and Kansas) pockmarked with deep holes and pits from which coal had been extracted (Riley 1960; Brooks 1989; Kansas Department of Wildlife, Parks, and Tourism [KDWPT]. 2014. Mined Land Wildlife Area brochure. KDWPT, Pittsburg, Kansas, USA. Available from https://ksoutdoors.com/KDWPT-Info/Locations/Wildlife-Areas/Southeast/Mined-Land [Accessed 20 November 2020].). Natural succession, and later legislation that required the reclamation of such areas, led to many such pits being converted to lakes and the surrounding land being managed to re-establish prairie and forest habitats (Stiles et al. 2017). Although management has typically been targeted on promoting populations of game animals for hunting and angling, the changes have generally benefited a range of non-game species as well. Mined lands are inhabited by diverse communities of mammals (Yeager 1942) but have also been found to provide suitable habitat for birds (Brenner and Hofius 1990; Bajema and Lima 2001; Devault et al. 2002) and herpetofauna (Myers and Klimstra 1963; Lannoo et al. 2009; Terrell et al. 2014; Stiles et al. 2017).

In light of the importance of protecting networks of high-quality wetland and upland habitat for freshwater turtle conservation and the promising nature of mined lands as a source of these habitat complexes, we conducted a study to compare the composition of turtle communities inhabiting strip pit lakes to those in natural wetlands. Our primary goal in this study was to ascertain whether turtle community composition varied between these two types of wetlands. If strip pits serve as suitable habitat refuges for turtle communities, we would expect turtle communities within them to exhibit similar diversity as natural wetlands. We aimed to determine whether any of the species present are more likely to occur in one type of wetland over the other and to assess what, if any, environmental variables are correlated with higher community diversity or higher abundance of individual species.

MATERIALS AND METHODS

Study site.—Mined Land Wildlife Area (MLWA), which encompasses properties in Crawford, Cherokee, and Labette counties in southeastern Kansas, USA, is the site of formerly extensive strip-mining operations that began in the 1920s and ended in 1974. Assembled from properties donated to the state of Kansas over the last 90 y, the MLWA now comprises approximately 5,868 ha. This includes roughly 607 ha of water in the form of over 1000 lakes and ponds that have formed in the abandoned strip mines that cover the landscape. These range in size from 0.1 to 24.3 ha and from < 2 m to 18 m deep. Of the 5,261 ha of land, about 30% hosts native warm-season and non-native cool-season grass prairie. The remainder consists primarily of woodland areas (KDWPT 2014, *op. cit.*). Since the land was acquired, collaboration between the Kansas Department of Health and Environment and the Kansas Department of Wildlife, Parks and Tourism has used reclamation funds to execute a series of restoration plans to improve habitat, develop wetlands, and attract anglers (Andra Stefanoni, unpubl. report). The majority of MLWA lies in the Middle Neosho River Watershed, which drains 3,694 km^2 of primarily agricultural land. The watershed is 46.8% pasture and grassland, 39.0% cropland, and 9.6% woodland. The remaining 4.6% is made up of urban areas and wetlands (Kansas State University. 2012. Kansas watershed restoration and protection strategy (WRAPS) project. Kansas State University Research and Extension, Manhattan, Kansas, USA. Available from https://www.bae.ksu.edu/watershed/extension/wraps/Neosho%20River%20WRAPS%20AssessReport.pdf [Accessed 20 November 2020].). The Neosho River and its tributaries Cherry and Lightning creeks have formed several oxbow lakes in both agricultural and wooded areas across Labette and Cherokee counties, and although many oxbows have been highly modified for agricultural use, they are likely the most representative examples of the natural habitat that has been historically available to the freshwater turtle communities of the region.

Trapping regime.—We selected five strip pits from across MLWA and five naturally occurring lakes in Labette, Cherokee, and Crawford counties in which to trap (Fig. 1). We selected these sites for canoe accessibility, absence of concrete boat ramps, and, in the case of oxbows, successfully obtaining landowner permission to access the wetlands. Strip pits were located on MLWA West Mineral Units 24, 30, 37, 40, and 42. Natural lakes were located on the Harmon Wildlife Area, MLWA Pittsburg Units 5/6, and pieces of private property near the towns of Oswego and Chetopa. Initial trapping at these locations occurred between late May and late July 2017. In 2018, we returned to seven of these bodies of water to repeat the trapping regimen used in 2017. An additional strip pit on MLWA West Mineral Unit 27 was added in 2018. We were unable to return to three of the natural lakes due to low water levels that prevented trapping (two wetlands) or loss of landowner permission (one wetland).

We first surveyed each site to identify locations with suitable depth, slope, and natural anchor points for deploying traps, and marked these locations with a handheld GPS unit. We then used a random number generator to determine at which subset of locations traps

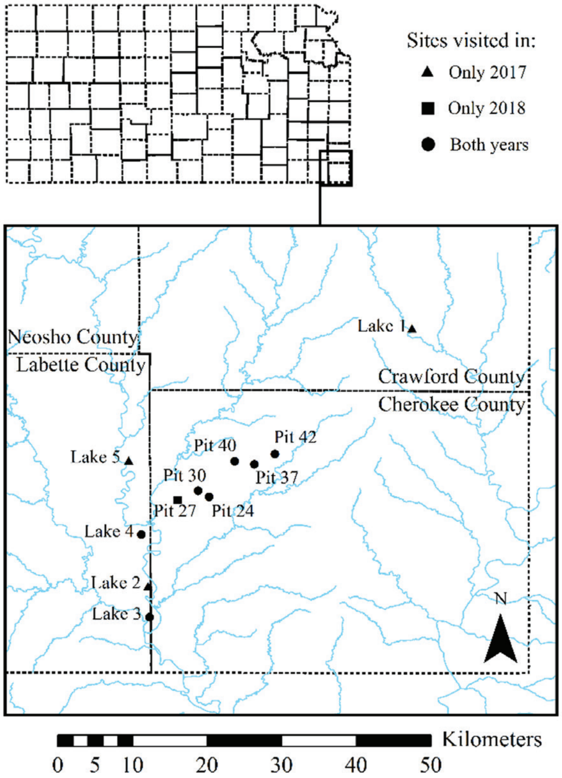

Figure 1. Locations of the lakes and strip pits that were surveyed for freshwater turtles in and around Mined Lands Wildlife Area, Kansas, USA.

would be deployed. We randomly selected trap locations separately in 2017 and 2018, but by chance some locations were used in both years. Traps included 0.9-m diameter, 0.75-m diameter, and 0.6-m diameter single-throated hoop traps, as well as double-ended, single-throated 0.3-m diameter crawfish traps (McKnight et al. 2015). We baited all traps with canned sardines and equipped traps with buoys to prevent complete submersion in the event of flooding.

We attempted to use approximately the same proportions of each type of trap at each wetland, but this was often not possible at sites where banks were too steep for the smaller hoop traps or a site was too shallow for the largest traps. Due to the wide variation in wetland size among our sites, we divided the lakes into size classes and increased the number of traps used with increasing size class. At eight sites up to 5 ha in size, we set 12 hoop traps and six crawfish traps apiece. We set 18 hoop traps and nine crawfish traps at one oxbow lake that was 9 ha in size and 24 hoop traps and 12 crawfish traps at one oxbow lake that was 12 ha in size.

We checked traps daily, identifying the species and age class (adult or juvenile) of all captured turtles, as well as the sex of adults. We weighed, measured, and marked all turtles for future identification. Marking was done using a rotary tool to mark unique codes into the marginal scutes in emydids and kinosternids (adapted from Cagle 1939) and by injecting a PIT tag for marking *Apalone spinifera spinifera* (Eastern Spiny Softshell Turtles; Buhlmann and Tuberville 1998). We used both methods for marking *Chelydra serpentina serpentina* (Eastern Snapping Turtles). We individually identified recaptured animals, and each underwent the same biometric measurements as new captures.

Habitat metrics.—We measured a suite of habitat features at each trap location and an approximately equal number of randomly selected locations along the shoreline at each site. These features included depth 1 m from shore, percentage canopy cover, type of aquatic vegetation present, abundance of surface basking structure, abundance of submerged structure, and depth and water clarity at the center of the wetland perpendicular from the shore at each point. We measured depth to the nearest 5 cm with a metered pole or with a depth line if the depth was > 2 m. We measured overstory canopy cover with a concave densiometer. For aquatic vegetation, we described the category of the dominant vegetation growth forms (submerged, emergent, floating, and woody). We assigned a rank of 0 (no structure) to 3 (extensive structure) for surface and submerged woody structure. A single observer made these assessments at all locations.

Statistical analysis.—For analyses in which the experimental units were individual trap locations, we excluded data from the crawfish traps because the small throat diameter of those traps makes them effectively unavailable to large-bodied individuals including most *C. s. serpentina* and adult *A. s. spinifera*, *Trachemys scripta elegans* (Red-eared Sliders), and *Pseudemys concinna concinna* (Eastern River Cooters). For other analyses, we used data from all trap types within a wetland to provide a maximally robust sampling of the community. We calculated species richness values for each wetland and generated an average species richness value for each wetland type as an indicator of community diversity. To identify differences in capture rates between wetland types, we used a Generalized Linear Model (GLM) to compare catch per unit effort (CPUE) for each trap with site as a factor nested within wetland type. We performed this test separately for each species (excluding Mississippi Map Turtles, *Graptemys pseudogeographica kohnii*, due to their extremely low frequency of encounter). We used Minitab 18 (Minitab, Inc., State College, Pennsylvania, USA) for these analyses.

We calculated Simpson's Diversity Index for each site and, after confirming normality with a Shapiro-Wilk test, used a *t*-test to compare the diversity of strip pits versus natural lakes. We also calculated the Bray-Curtis Similarity Index for each pair of sites to determine the uniformity of community composition among sites of the same and different wetland types. We performed these and all following analyses in Program R using the

Table 1. Total number of unique individuals (divided by sex and age class) of each species at each natural site, and percentage of community made up by each species at each site near Mined Lands Wildlife Area, Kansas, USA. Abbreviations are M = Male, F = Female, J = Juvenile. Common names of species are *Apalone s. spinifera* = Eastern Spiny Softshell Turtle, *Chrysemys picta bellii* = Western Painted Turtle, *Chelydra s. serpentina* = Eastern Snapping Turtle, *Graptemys pseudogeographica kohnii* = *Graptemys pseudogeographica kohnii, Pseudemys c. concinna* = Eastern River Cooter, *Sternotherus odoratus* = Eastern Musk Turtle, *Trachemys scripta elegans* = Red-eared Slider.

Site	Species	M	F	J	Total	Percentage
Lake 1	*Sternotherus odoratus*	2	0	0	2	3.8%
	Chelydra s. serpentina	6	8	1	15	28.8%
	Chrysemys picta bellii	1	0	0	1	1.9%
	Trachemys scripta elegans	22	10	0	32	61.5%
	Apalone s. spinifera	1	1	0	2	3.8%
Lake 2	*Trachemys scripta elegans*	40	24	4	68	98.6%
	Apalone s. spinifera	0	1	0	1	1.4%
Lake 3	*Sternotherus odoratus*	0	1	0	1	0.2%
	Chelydra s. serpentina	4	3	0	8	1.9%
	Pseudemys c. concinna	0	1	0	1	0.2%
	Graptemys pseudogeographica kohnii	0	1	0	1	0.2%
	Chrysemys picta bellii	1	0	0	1	0.2%
	Trachemys scripta elegans	206	150	40	396	95.2%
	Apalone s. spinifera	2	5	1	8	1.9%
Lake 4	*Chelydra s. serpentina*	8	8	5	21	3.0%
	Pseudemys c. concinna	4	1	4	9	1.3%
	Chrysemys picta bellii	0	0	1	1	0.1%
	Trachemys scripta elegans	313	234	118	668	95.4%
	Apalone s. spinifera	0	1	0	1	0.1%
Lake 5	*Chelydra s. serpentina*	1	1	0	2	5.4%
	Trachemys scripta elegans	25	10	0	35	94.6%

package Vegan (R Core Team 2018; Oksanen et al. 2018). We used Fisher's Exact Tests to compare the community composition (based on counts of unique individuals of each species captured) between strip pits and natural lakes. For this test we used only the counts from the first year in which each body of water was trapped. Using only the bodies of water that were trapped in both years, we also used Fisher's Exact Test to compare the community composition between 2017 and 2018 for each wetland type because in each case there were several species for which fewer than five individuals were expected and there were occasionally times when fewer than one individual was expected.

We performed a Correspondence Analysis (Palmer 1993) based on CPUE with each trap location as a data point. This is an indirect form of Ordination Analysis that depicts associations of species along environmental gradients without determining what those gradients are. We followed this with a Canonical Correspondence Analysis (CCA), which includes the specific habitat gradients along which the species are distributed. CCA uses weighted averaging combined with Multivariate Regression to analyze the interactions between the correspondence of species occurrences with each other and with a suite of environmental variables (ter Braak 1986; Palmer 1993).

Results

Over the course of 2,517 net nights, we recorded 4,245 captures of 2,351 individual turtles representing seven species. We captured six species in both natural lakes and strip pits, including *P. c. concinna*, *T. s. elegans*, *A. s. spinifera*, *Sternotherus odoratus* (Eastern Musk Turtle), *C. s. serpentina*, and *Chrysemys picta bellii* (Western Painted Turtle). Additionally, we captured a single female *G. p. kohnii* at Lake 3.

Average species richness across both years was 4.2 for natural lakes and 5.5 for strip pits. *Trachemys s. elegans* was the most commonly captured species at all 11 sites and comprised over 90% of the turtle community at five sites (four natural lakes and one strip pit; Tables 1, 2). *Chelydra serpentina serpentina* made up an average of 7.8% of turtle communities in natural lakes, but only 0.8% of turtle communities in strip pits. Conversely, *C. p. bellii*

Table 2. Total number of unique individuals (divided by sex and age class) of each species at each strip pit site, and percentage of community made up by each species at each site at Mined Lands Wildlife Area, Kansas, USA. Abbreviations are M = Male, F = Female, J = Juvenile. Common names of species are *Apalone s. spinifera* = Eastern Spiny Softshell Turtle, *Chrysemys picta bellii* = Western Painted Turtle, *Chelydra s. serpentina* = Eastern Snapping Turtle, *Pseudemys c. concinna* = Eastern River Cooter, *Sternotherus odoratus* = Eastern Musk Turtle, *Trachemys scripta elegans* = Red-eared Slider.

Site	Species	M	F	J	Total	Percentage
Pit 24	*Sternotherus odoratus*	2	0	0	2	2.2%
	Chelydra s. serpentina	1	0	0	1	1.1%
	Chrysemys picta bellii	5	2	0	7	7.8%
	Pseudemys c. concinna	2	0	0	2	2.2%
	Trachemys scripta elegans	62	15	1	78	86.7%
	Apalone s. spinifera	0	2	0	2	2%
Pit 30	*Sternotherus odoratus*	4	1	0	5	4.2%
	Chelydra s. serpentina	1	0	0	1	0.8%
	Pseudemys c. concinna	1	0	0	1	0.8%
	Trachemys scripta elegans	69	35	3	107	89.9%
	Apalone s. spinifera	1	4	0	5	4.2%
Pit 37	*Sternotherus odoratus*	7	3	0	10	5.0%
	Chelydra s. serpentina	2	1	0	3	1.5%
	Chrysemys picta bellii	30	18	0	48	23.8%
	Pseudemys c. concinna	3	0	0	3	1.5%
	Trachemys scripta elegans	90	45	2	137	67.8%
	Apalone s. spinifera	0	1	0	1	0.5%
Pit 40	*Sternotherus odoratus*	1	0	0	1	0.7%
	Chrysemys picta bellii	8	3	0	11	7.7%
	Pseudemys c. concinna	1	0	0	1	0.7%
	Trachemys scripta elegans	53	73	6	133	93.7%
	Apalone s. spinifera	2	6	0	8	5.6%
Pit 42	*Sternotherus odoratus*	3	2	0	5	1.8%
	Chelydra s. serpentina	1	0	0	1	0.4%
	Chrysemys picta bellii	39	15	2	56	19.6%
	Trachemys scripta elegans	125	79	19	223	78.2%
	Apalone s. spinifera	0	1	0	1	0.4%
Pit 27	*Sternotherus odoratus*	48	81	0	129	57.6%
	Chelydra s. serpentina	2	0	0	2	0.9%
	Chrysemys picta bellii	2	0	0	2	0.9%
	Pseudemys c. concinna	3	0	0	3	1.3%
	Trachemys scripta elegans	47	34	6	87	38.8%
	Apalone s. spinifera	0	1	0	1	0.4%

comprised an average of 9.7% of strip pit communities versus only 0.4% of communities in natural lakes. *Sternotherus odoratus* were also more abundant in strip pits, comprising an average of 9.2% of communities in strip pits and an average of only 0.8% of communities in natural lakes. In the case of *S. odoratus*, this measure was heavily skewed by unusually high density in a single strip pit (Pit 27). We captured all other species at comparatively low rates (< 6% of community at any given site and < 3% of combined community in each type of wetland).

CPUE was not significantly different between strip pits and natural lakes for any species except *C. s. serpentina*, which were captured at lower rates in the strip pits ($F_{1, 226}$ = 6.58, P = 0.020; Table 3). Although not significant (t = 1.61, df = 6, P = 0.158), Simpson diversity appeared to be higher on average in strip pits than in natural lakes although diversity in both groups was variable (Fig. 2). Bray-Curtis similarity in community composition was generally higher between pairs of pits than between pits and lakes or between pairs of lakes (Pit-Pit $\bar{x}$ = 0.63; range, 0.37–0.84: Pit-Lake $\bar{x}$ = 0.41; range, 0.20–0.86: Lake-Lake $\bar{x}$ = 0.37; range, 0.10–0.76; Table 4).

Species representation varied significantly between strip pits and natural lakes (Fisher's Exact Test, P < 0.001;

Table 3. Average daily catch (± standard deviatyion) per hoop trap of each species in each type of wetland near Mined Lands Wildlife Area, Kansas, USA. Asterisks (*) indicate a significant difference between wetland types. *P*-values were generated from a Generalized Linear Model comparing capture rates of individual trap locations between wetland types, with site as a factor nested within wetland type. Common names of species are *Apalone s. spinifera* = Eastern Spiny Softshell Turtle, *Chrysemys picta bellii* = Western Painted Turtle, *Chelydra s. serpentina* = Eastern Snapping Turtle, *Pseudemys c. concinna* = Eastern River Cooter, *Sternotherus odoratus* = Eastern Musk Turtle, *Trachemys scripta elegans* = Red-eared Slider.

Species	CPUE (Lakes)	CPUE (Pits)	*P*-value
Trachemys scripta elegans	2.62 ± 2.10	1.91 ± 1.60	0.797
Sternotherus odoratus	0.01 ± 0.03	0.09 ± 0.25	0.251
*Chelydra s. serpentina**	0.07 ± 0.13	0.01 ± 0.04	0.020
Pseudemys c. concinna	0.01 ± 0.06	0.01 ± 0.04	0.808
Apalone s. spinifera	0.02 ± 0.06	0.03 ± 0.09	0.573
Chrysemys picta bellii	0.01 ± 0.03	0.22 ± 0.41	0.162

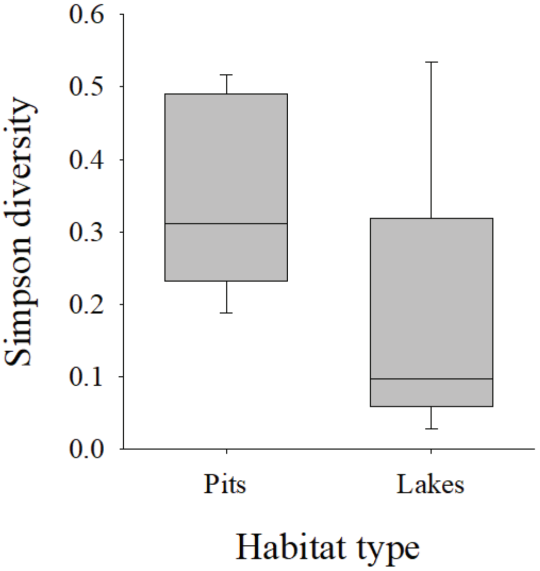

Figure 2. Boxplot of Simpson diversity index values of turtles for strip pit lakes (n = 6) and natural lakes (n = 5) from Mined Lands Wildlife Area, Kansas, USA. Vertical lines indicate minimum and maximum values for each habitat type.

Fig. 3). Community composition was not significantly different between 2017 and 2018 in strip pits (Fisher's Exact Test, $P = 0.528$) but did vary between years in natural lakes (Fisher's Exact Test, $P < 0.001$; Fig. 4). Correspondence analysis grouped *T. s. elegans*, *P. c. concinna*, and *A. s. spinifera* together near the intersection of axes 1 and 2 (Fig. 5). *Chrysemys picta bellii* and *C. serpentina* were grouped with these species on axis 1, but *C. p. bellii* had low scores on axis 2 while *C. serpentina* had high scores on axis 2. *Sternotherus odoratus* had a similar score on axis 2 to *T. s. elegans*, *P. c. concinna*, and *A. s. spinifera*, but had high scores on axis 1 (Fig. 5).

After identifying environmental variables that appeared to be important to the species that were present, we used CCA to include habitat parameters in the analysis (Fig. 6). The CCA generated a first axis primarily driven by the abundance of submerged vegetation such as *Ceratophyllum* (coontail) and *Myriophyllum* (watermilfoil). Axis 2 was influenced mainly by mid-channel depth and canopy cover. *Chrysemys picta bellii* were associated with deep water and, to a lesser extent, plentiful submerged vegetation. *Chelydra serpentina serpentina* were associated with shallow water and greater canopy cover. *Sternotherus odoratus* were most strongly associated with abundant submerged vegetation. All the associations were rather weak, however, because only 12% of the observed variation in species captures was explained by the relationship between species capture rates and habitat variables explained only.

Discussion

Based on the data we collected, it appears evident that the strip pits of the Mined Land Wildlife Area provide habitat for most turtle species that is at least as suitable as that provided by other available wetlands in the surrounding agricultural landscape. With the prominent exception of the near absence of *C. s. serpentina* from the strip pits of MLWA, we failed to detect any metric by which the strip pits were inferior to the natural lakes in terms of diversity or the presence of specific species. Several lines of evidence, including comparisons of Simpson diversity between the two classes of wetlands, the CPUE of *C. p. bellii* between the two classes of wetlands, and a visual

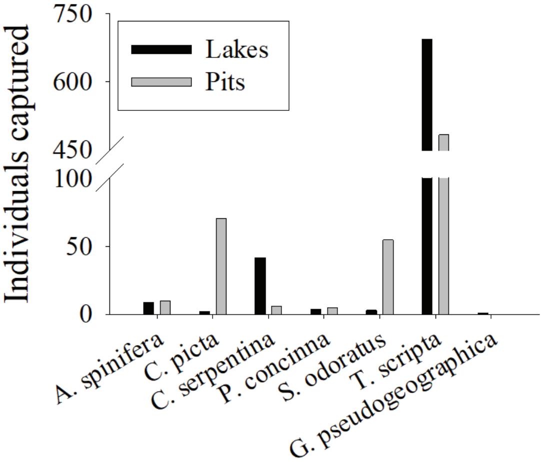

Figure 3. Number of individual turtles captured in each wetland type from Mined Lands Wildlife Area, Kansas, USA. compiled from the first trapping season in each wetland. *Apalone spinifera spinifera* = Eastern Spiny Softshell Turtle, *Chrysemys picta bellii* = Western Painted Turtle, *Chelydra serpentina serpentina* = Eastern Snapping Turtle, *Pseudemys concinna concinna* = Eastern River Cooter, *Sternotherus odoratus* = Eastern Musk Turtle, *Trachemys scripta elegans* = Red-eared Slider.

Table 4. Bray-Curtis similarity values for each pair of sites from near Mined Lands Wildlife Area, Kansas, USA. Larger values indicate greater community similarity, with 1.00 indicating identical communities.

Site	Pit 24	Pit 27	Pit 30	Pit 37	Pit 40	Pit 42	Lake 1	Lake 2	Lake 3	Lake 4
Lake 5	0.56	0.28	0.46	0.31	0.37	0.22	0.76	0.66	0.16	0.10
Lake 4	0.21	0.20	0.27	0.32	0.32	0.46	0.13	0.18	0.73	
Lake 3	0.33	0.29	0.44	0.47	0.50	0.65	0.19	0.28		
Lake 2	0.86	0.47	0.73	0.51	0.62	0.39	0.55			
Lake 1	0.53	0.28	0.43	0.31	0.35	0.21				
Pit 42	0.47	0.37	0.56	0.78	0.67					
Pit 40	0.72	0.49	0.84	0.83						
Pit 37	0.62	0.49	0.72							
Pit 30	0.80	0.55								
Pit 27	0.54									

assessment of differences in the abundance of *C. p. bellii* and *S. odoratus*, while not statistically significant, together suggest the possibility that strip pits on the MLWA may even provide superior habitat for turtle communities than that which is available in other parts of southeastern Kansas. Because we only sampled six of the thousand or more lakes and ponds at MLWA, it seems likely that a broader sampling of these bodies of water would reveal stronger patterns than we were able to detect and might also detect individual ponds with unusual community compositions akin to the very high abundance of *S. odoratus* we observed at Pit 27.

High abundance of *T. s. elegans* is a common feature of turtle assemblages in much of the central U.S. In previous studies, *T. s. elegans* has comprised 73% of captures in eastern Oklahoma, USA, farm ponds (Riedle et al. 2009), an average of 80% of individuals in central Oklahoma farm ponds (Stone et al. 2005), 81% of captured individuals in central Illinois, USA (Bluett et al. 2011), and 82% of individuals at a state park swamp in southeastern Missouri, USA (Glorioso et al. 2010). *Chrysemys picta bellii* were found to represent a larger proportion (59%) in Kansas agricultural pond assemblages than *T. s. elegans* (29%) elsewhere in Kansas (House et al. 2011). It is possible that the location of our study area, which lies near the edge of the range of *C. picta* (Ernst and Lovich 2009), accounts for the comparative rarity of this species at many of our sites.

The low numbers of *C. s. serpentina* we found in the strip pits is perhaps not surprising given that the species has a reported preference for shallow habitats (Bodie et al. 2000). Not only are many of the strip pits quite deep (some of those we surveyed were > 10 m), but the slope from the shore to the center is also comparatively steep. At times it could be difficult to find locations where a trap could be set at an angle far enough from the vertical to be suitable for trapping turtles. As a result, not even the edges of many of the strip pits can really be said to match

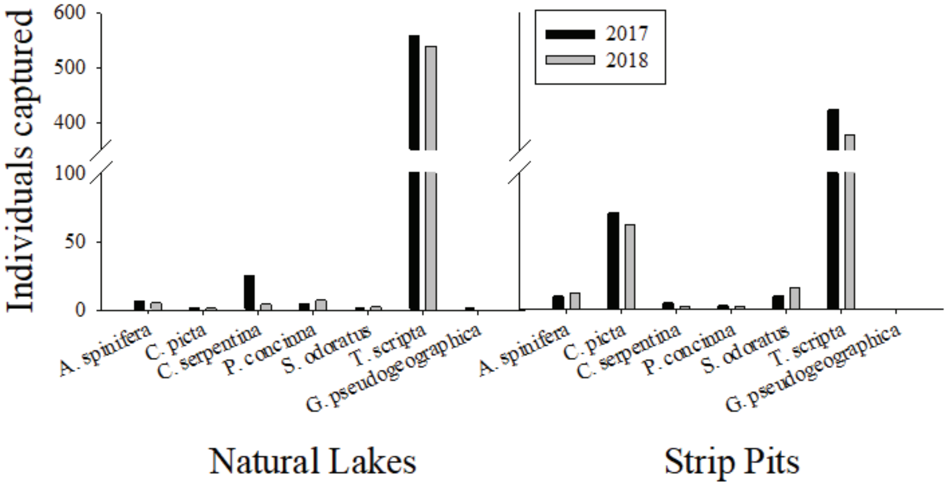

Figure 4. Number of individual turtles captured in each wetland type from Mined Lands Wildlife Area, Kansas, USA in 2017 and 2018, compiled only from bodies of water that were trapped in both years. *Apalone spinifera spinifera* = Eastern Spiny Softshell Turtle, *Chrysemys picta bellii* = Western Painted Turtle, *Chelydra serpentina serpentina* = Eastern Snapping Turtle, *Pseudemys concinna concinna* = Eastern River Cooter, *Sternotherus odoratus* = Eastern Musk Turtle, *Trachemys scripta elegans* = Red-eared Slider.

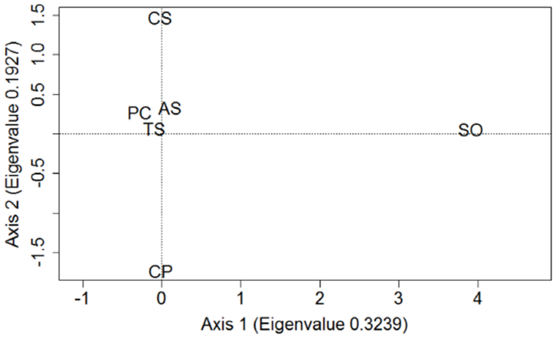

Figure 5. Distribution of species scores from the first two axes of a Correspondence Analysis of turtle capture rates (per trap location) in eleven bodies of water in southeastern Kansas, USA. Species abbreviations used in this figure are as follows: AS = *Apalone spinifera spinifera* (Eastern Spiny Softshell Turtle), CP = *Chrysemys picta bellii* (Western Painted Turtle), CS = *Chelydra serpentina serpentina* (Eastern Snapping Turtle), PC = *Pseudemys concinna concinna* (Eastern River Cooter), SO = *Sternotherus odoratus* (Eastern Musk Turtle), TS = *Trachemys scripta elegans* (Red-eared Slider). Total inertia was 0.805.

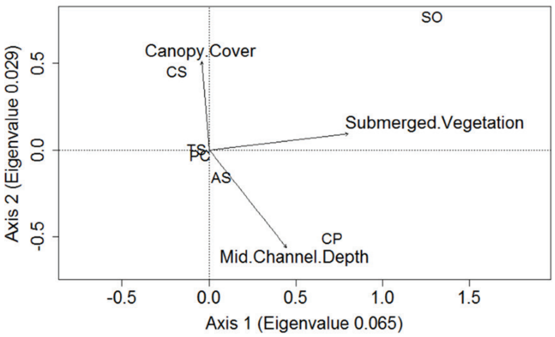

Figure 6. Ordination of turtle species from eleven bodies of water in southeastern Kansas, USA, based on Canonical Correspondence Analysis of CPUE at each trap and the habitat metrics associated with the location of each trap. Species abbreviations used in this figure are as follows: AS = *Apalone spinifera spinifera* (Eastern Spiny Softshell Turtle), CP = *Chrysemys picta bellii* (Western Painted Turtle), CS = *Chelydra serpentina serpentina* (Eastern Snapping Turtle), PC = *Pseudemys concinna concinna* (Eastern River Cooter), SO = *Sternotherus odoratus* (Eastern Musk Turtle), TS = *Trachemys scripta elegans* (Red-eared Slider). Total inertia was 0.805.

the habitat preferences of this species. This interpretation is supported by the CCA results, which associated *C. s. serpentina* with shallow water as well as high canopy cover, as has previously been reported for the species (Riedle et al. 2015).

Although there was not a significant difference in the average capture rates of *C. p. bellii* in strip pits relative to natural lakes, it was the case that five of the six pits had at least twice as many *C. p. bellii* as the natural lake where they were most abundant and two had substantial populations of at least several dozen individuals. Although often associated with shallower habitats in much of their range (Ernst and Lovich 2009), *C. p. bellii* in the Nebraska (USA) Sandhills are associated with lakes and open waters rather than ponds or marshes (Bury and Germano 2003). A similar preference may be driving our results, but with the low percentage of variation explained by habitat variables in the CCA, it is possible that factors other than those we considered are responsible for the presence of *C. p. bellii* in strip pits while they are largely absent from natural lakes. One possibility is that interactions with other species are factoring into the distribution of *C. p. bellii* in this region. The near complete segregation of *C. p. bellii* and *C. s. serpentina* is interesting, but the available literature is equivocal on whether *C. serpentina* negatively impact *C. picta*. *Chrysemys picta* avoid the odor of *C. serpentina* musk (Woolley 1996) and avoid traps containing *C. serpentina* in trap surveys (Frazer et al. 1990). In other cases, however, there has been no correlation between the relative abundance of *C. serpentina* and *C. picta* (Dreslik and Phillips 2005) and *C. picta* has been observed to use the much larger *C. serpentina* as basking platforms (Legler 1956), both of which suggest it is unlikely that *C. serpentina* are responsible for excluding *C. picta* from entire wetlands. Alternatively, it is possible that the somewhat reduced abundance of *T. s. elegans* in the pits could allow for greater numbers of *C. p. bellii*. *Chrysemys picta* tend to occur at lower densities at sites where they co-occur with *T. s. elegans* and other studies have suggested a causal relationship (Dreslik and Phillips 2005; Dreslik et al. 2005); however, there is little evidence to suggest direct competition between the two species.

Although CCA associated *S. odoratus* with abundant submerged vegetation, the extremely high density of this species in Pit 27 relative to all the other bodies of water we surveyed makes it difficult to make any inferences about why the population in that particular wetland is so robust. The distribution of these turtles was not well explained by habitat and it is possible some other factor of the landscape or some historical event led to this high density. Pit 27 is one of the shallower pits we surveyed and the slope from the banks to mid-channel was less steep in many places than that in most other pits. This combination of traits may create more suitable shallow-water habitat for *S. odoratus* than is present in many of the other pits; however, this difference is not dramatic and could probably only account for a small portion of the difference in assemblage makeup relative to other pits and cannot explain the difference relative to assemblages in natural lakes at all. The upland vegetation is not discernably different from that of several other pits that did not have large numbers of *S. odoratus*. Pit 27 is closer to the Neosho River than any other pits we surveyed but several of the natural lakes were closer still, suggesting that colonization from a larger body of water also is unlikely to account for the difference. Another possibility is that Pit 27 supports some S. *odoratus* food source in unusual abundance, but we were unable to explore this possibility quantitatively.

Visual assessment of variation in community structure between years in natural lakes makes it clear that the primary driver of the change from 2017 to 2018 was the steep decrease in the number of snapping turtles captured in 2018. The summer of 2018 was much drier than that of the previous year, which seems to have reduced *C. s. serpentina* activity. As part of another project conducted in parallel with this one, 10 *C. s. serpentina* were equipped with radio-transmitters in Lake 4 and its surrounding ponds from autumn of 2017 to autumn of 2018 (unpubl. data). Several of these turtles became undetectable even via telemetry in June and July of 2018, and several of those that we were able to locate had buried themselves at the edge of ponds where they remained for weeks or months. It is likely that similar behavior was also occurring at Lake 3, the other natural lake that was surveyed in both years.

Low annual duration of drying is one of the strongest drivers of high turtle diversity in floodplain wetlands (Bodie et al. 2000) and the resistance of strip pits to drying may be an important component in explaining the diversity of turtle assemblages in strip pits. When wetlands cease to exist, turtles must either leave, estivate, or perish. If drying is a common occurrence in natural ponds in southeastern Kansas, then such habitats must be frequently depopulated and recolonized from other habitats (such as rivers or larger bodies of water). The greater depth of strip pits allows them to persist under more extreme drought conditions than natural lakes. It is possible that the higher diversity in strip pits is the result of more stable communities, particularly if *T. scripta* is more adept at recolonizing dried and refilled wetlands than are other species. It seems unlikely that distance alone would limit the dispersal of turtles back into these lakes (four of the five lakes are < 1 km from the Neosho River); the high abundance of *T. scripta* throughout the area provides a very large pool of potential colonizers relative to other species that are less abundant and less ubiquitous across the landscape.

Taken together, the results of our study indicate that reclaimed mined lands can provide habitats that will support communities of turtles that are at least as robust as those in other types of wetlands in the region. Although one common species does not appear to use these habitats with great frequency, all other species were at least as abundant in strip pits as elsewhere and some may prove to be significantly more abundant with additional surveys. It will therefore be valuable for managers of mining reclamation sites to take turtle communities into consideration in the execution of future restoration projects. If management for general habitat restoration and the development of recreational fisheries has created environments capable of supporting healthy turtle communities, it seems probable that deliberate consideration of turtle needs in future restorations could produce very effective refuges.

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