



MSU Graduate Theses

Fall 2019

Freshwater Turtle Community Composition in Mined Land Strip Pit Lakes and the Effects of Learned Trap Avoidance on Capture Rates of *Sternotherus odoratus* and *Trachemys scripta*

Ethan Craig Hollender

Missouri State University, Hollender112358@live.missouristate.edu

As with any intellectual project, the content and views expressed in this thesis may be considered objectionable by some readers. However, this student-scholar's work has been judged to have academic value by the student's thesis committee members trained in the discipline. The content and views expressed in this thesis are those of the student-scholar and are not endorsed by Missouri State University, its Graduate College, or its employees.

Follow this and additional works at: <https://bearworks.missouristate.edu/theses>

 Part of the [Biodiversity Commons](#), [Biology Commons](#), and the [Ecology and Evolutionary Biology Commons](#)

Recommended Citation

Hollender, Ethan Craig, "Freshwater Turtle Community Composition in Mined Land Strip Pit Lakes and the Effects of Learned Trap Avoidance on Capture Rates of *Sternotherus odoratus* and *Trachemys scripta*" (2019). *MSU Graduate Theses*. 3449.

<https://bearworks.missouristate.edu/theses/3449>

This article or document was made available through BearWorks, the institutional repository of Missouri State University. The work contained in it may be protected by copyright and require permission of the copyright holder for reuse or redistribution.

For more information, please contact bearworks@missouristate.edu.

**FRESHWATER TURTLE COMMUNITY COMPOSITION IN MINED LAND STRIP
PIT LAKES AND THE EFFECTS OF LEARNED TRAP AVOIDANCE ON
CAPTURE RATES OF *STERNOTHERUS ODORATUS*
AND *TRACHEMYS SCRIPTA***

A Master's Thesis

Presented to

The Graduate College of

Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Biology

By

Ethan Craig Hollender

December 2019

Copyright 2019 by Ethan Craig Hollender

**FRESHWATER TURTLE COMMUNITY COMPOSITION IN MINED LAND STRIP
PIT LAKES AND THE EFFECTS OF LEARNED TRAP AVOIDANCE ON CAPTURE
RATES OF *STERNOTHERUS ODORATUS* AND *TRACHEMYS SCRIPTA***

Biology

Missouri State University, December 2019

Master of Science

Ethan Craig Hollender

ABSTRACT

Turtles are among the most threatened groups of organisms on the planet and as such are in need of protected habitat where healthy communities can be maintained. The reclamation of land that was formerly the site of surface strip mining provides a matrix of reclaimed terrestrial landscapes rich with lakes and ponds that have the potential to function as such habitat. To determine the suitability of these habitats for turtle communities, I compared the turtle communities of strip pit lakes and natural lakes in southeastern Kansas. Of the seven species of aquatic turtle I encountered, Common Snapping Turtles (*Chelydra serpentina*) were the only turtles that were captured in significantly lower numbers in strip pits. All other turtle species fared at least as well in strip pits as in natural lakes. Species richness and Simpson's diversity were also at least as high in strip pits as in natural lakes. It is critical in community research that the sampling methods used to assess abundance of different species provide an accurate depiction of community structure. Many sampling methods are biased, and while many of these biases have been investigated, little is known about the ability of turtles to learn to avoid traps. To determine whether turtles learn to avoid locations where they have been trapped, I simultaneously surveyed a strip pit with two sets of traps for 35 days. One set of traps was stationary for the duration of the experiment while the other set was moved and later returned to their original locations. Slider Turtles (*Trachemys scripta*) were captured at higher rates in the moved group during the second period and Eastern Musk Turtles (*Sternotherus odoratus*) were captured at higher rates in the moved group during the third period. Both groups of traps provided similar abundance estimates for *T. scripta*, but the stationary group underestimated the abundance of *S. odoratus* to a degree that would have misidentified the most common species in the community.

KEYWORDS: community, turtles, mined lands, *Trachemys scripta*, *Sternotherus odoratus*, *Chelydra serpentina*, *Chrysemys picta*, habitat reclamation, trapability

**FRESHWATER TURTLE COMMUNITY COMPOSITION IN MINED LAND STRIP
PIT LAKES AND THE EFFECTS OF LEARNED TRAP AVOIDANCE
ON CAPTURE RATES OF *STERNOTHERUS ODORATUS*
AND *TRACHEMYS SCRIPTA***

By

Ethan Craig Hollender

A Master's Thesis
Submitted to the Graduate College
Of Missouri State University
In Partial Fulfillment of the Requirements
Master of Science, Biology

December 2019

Approved:

Day B. Ligon, Ph.D., Thesis Committee Chair

Brian D. Greene, Ph.D., Committee Member

La Toya T. Kissoon-Charles, Ph.D., Committee Member

Julie Masterson, Ph.D., Dean of the Graduate College

In the interest of academic freedom and the principle of free speech, approval of this thesis indicates the format is acceptable and meets the academic criteria for the discipline as determined by the faculty that constitute the thesis committee. The content and views expressed in this thesis are those of the student-scholar and are not endorsed by Missouri State University, its Graduate College, or its employees.

ACKNOWLEDGEMENTS

I am extremely grateful to my advisor, Dr. Day Ligon, who over the course of my undergraduate and graduate studies has given me nearly a decade of advice, support, patience, and a series of extraordinary research opportunities. It would be difficult to overstate how much I have learned from Dr. Ligon and how much he has fostered the joy I take in reptile ecology. I am also very appreciative of my committee members, Dr. La Toya Kissoon-Charles and Dr. Brian Greene, for their support and advice on this project.

I would like to thank my lab mates, past and present, for the daily infusions of cheerfulness they have always provided. In particular I would like to thank Denise Thompson and Travis Anthony for their encouragement during my earliest forays into research, Donald McKnight for his extensive advice and mentorship over the last five years, and Kameron Voves for her helpful input throughout this project.

My parents, Wendy and Craig, and my brothers, Aaron, Joshua, and Joel, have always been enthusiastic in my successes and compassionate in my failures and I am very grateful for the atmosphere of love and support they have built.

I owe a great debt of gratitude to the people of Kansas, where this research was carried out. In particular, I would like to thank Daren Riedle for his advice, David Jenkins for the information he provided about MLWA, and the landowners of Oswego and Chetopa for their kindness in allowing me to work on their property. This research was possible with Chickadee Checkoff Grants from the Kansas Department of Wildlife, Parks, and Tourism and additional funding from Missouri State University.

Finally, I would like to thank my wonderful girlfriend and partner, Casey Dimond, for her unflagging love, support, understanding, and encouragement throughout my graduate studies.

TABLE OF CONTENTS

Overview	Page 1
Mined Lands as Wildlife Habitat	Page 1
Trapping Bias and Community Structure	Page 2
Thesis Chapters	Page 2
Chapter 1: Freshwater Turtle Community Composition in Mined Land Strip Pit Lakes	Page 4
Abstract	Page 4
Introduction	Page 5
Methods	Page 7
Results	Page 11
Discussion	Page 13
Literature Cited	Page 17
Chapter 2: Learned Trap Avoidance in Freshwater Turtles and Its Effects on Capture Rates, Abundance Estimates, and Inferences about Community Structure	Page 31
Abstract	Page 31
Introduction	Page 32
Methods	Page 35
Results	Page 37
Discussion	Page 38
Literature Cited	Page 40
Summary	Page 49
Additional References	Page 51

LIST OF TABLES

Chapter 1

Table 1. Total number of individuals of each species at each natural lake	Page 20
Table 2. Total number of individuals of each species at each strip pit	Page 21
Table 3. Average daily catch per hoop trap for each species in natural lakes and strip pits	Page 23
Table 4. Bray-Curtis similarity values for each pair of sites	Page 24

Chapter 2

Table 1. Number of unique individuals and capture events for each species	Page 43
---	---------

LIST OF FIGURES

Chapter 1

- Figure 1. Map of the locations of surveyed natural lakes and strips pits Page 25
- Figure 2. Box plot of Simpson diversity values for natural lakes and strip pits Page 26
- Figure 3. Number of individuals of each species captured in each wetland type Page 27
- Figure 4. Number of individuals of each species captured in each year for each wetland type Page 28
- Figure 5. Distribution of species scores from the first two axes of correspondence analysis Page 29
- Figure 6. Ordination of turtle species and habitat metrics with canonical correspondence analysis Page 30

Chapter 2

- Figure 1. Locations of traps during first and third trapping periods Page 44
- Figure 2. Locations of traps during the second trapping period Page 45
- Figure 3. Mean *Trachemys scripta* capture rates per day Page 46
- Figure 4. Mean *Sternotherus odoratus* capture rates per day Page 47
- Figure 5. Schumacher-Eschmeyer abundance estimates generated from moved traps, stationary traps, and all traps for *Trachemys scripta* and *Sternotherus odoratus* Page 48

OVERVIEW

Mined Lands as Wildlife Habitat

Freshwater turtles are among the most vulnerable groups of animals in the world today, in large part because their life history makes their populations extremely susceptible to even slight increases in adult mortality (Congdon et al. 1993, 1994; Lovich et al. 2018). As aquatic animals, freshwater turtles are highly dependent on wetlands, which have historically been one of the most frequently altered and destroyed habitat types in the world. Streams and rivers are subject to frequent channelization, impoundment, diversion, and pollution. Even in those areas where aquatic habitats are protected, the amphibious lifestyle of many turtle species leaves them exposed to risk when agricultural development and other human projects alter the surrounding terrestrial habitat (Howell and Siegel 2018; Burke and Gibbons 1995).

Although they are the site of dramatic past human impacts on the landscape, mined lands that have fallen out of use and have been allowed to undergo natural succession (or in some cases have been deliberately restored) can provide protected habitats for wildlife (Stiles et al. 2017). Taxa as varied as birds and amphibians have successfully established breeding populations at formerly mined lands (Devault et al. 2002; Lannoo 2009). In several cases, freshwater turtles have been encountered on mined lands, but few studies have focused on turtle communities specifically.

Identifying any differences between communities of turtles at formerly mined sites and those in other available habitat types, and if possible determining the drivers of those differences, will help determine whether mined lands (particularly as currently managed for game species)

are suitable as habitat refuges for healthy turtle communities and may lead to the development of management policies that could further enhance such communities.

Trapping Bias and Community Structure

An accurate assessment of community structure requires a representative sample of the community under investigation. Acquiring such a sample can be difficult when available sampling methods are more effective for some species or demographic groups than for others. Past studies have identified biases related to sex, species, and size class and have made recommendations for overcoming such biases (Ream and Ream 1966; Tesche and Hodges 2015). The possibility that the experience of being captured can bias the future probability that an individual will be captured is another issue of concern in wildlife surveys, as such an effect would alter estimates of abundance and survival (Nichols et al. 1984).

Although the proposition has not been tested in turtles, there is evidence that other taxa avoid areas where they have encountered traps, even in some cases comparatively non-invasive camera traps (Muraoka 2007; Schipper 2007). Determining whether turtles also avoid locations where they have been captured is important in designing trapping regimes that will more accurately sample a population over time. The identification of differences between species is also of considerable importance, as such variation could lead to incorrect inferences about community structure if not accounted for.

Thesis Chapters

The Mined Lands Wildlife Area in southeastern Kansas contains over a thousand lakes and ponds (many of them strip pit lakes) and lies within a larger agricultural region with several

oxbow lakes and other natural bodies of water, providing an excellent opportunity to compare turtle communities between the two types of lake. The presence of some strip pits with communities that include multiple species in some abundance also allowed me to conduct an experiment testing whether turtles learn to avoid trap locations.

Chapter 1 is focused on the turtle communities of the Mined Lands Wildlife Area. In it, I compare the turtle communities in the strip pit lakes with those in natural lakes. I describe differences in the diversity between the two types of habitat as well as the patterns of occurrence and abundance of individual species between the two habitat types. I also discuss the patterns of how species co-occur within these communities and some of the possible factors driving these patterns.

Chapter 2 deals with learned trap avoidance in turtles. Here I describe variation in capture rates over time when traps are moved versus when they remain stationary. I explore the different ways in which this variation manifests in two species with very different behavior in how they utilize their environment and how these differences in behavior affect the necessity of considering learned trap-avoidance in the development of sampling procedures. Finally, I discuss the differences in abundance estimates based on samples generated by each of the trapping regimes I used and the impacts that differences in those estimates have on community-wide assessments.

I conducted my thesis research with approval from the Missouri State University Institutional Animal Care and Use Committee (protocol No. 17-025.0-A) and with possession of scientific collecting permits SC-097-2017 and SC-071-2018 from the State of Kansas.

FRESHWATER TURTLE COMMUNITY COMPOSITION IN MINED LAND STRIP PIT LAKES

Abstract

Creating and managing undeveloped lands is important for the perpetuation of species and communities they comprise, particularly for turtles, often subjected to human disturbance and 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 protected from heavy development. Such sites support robust communities of birds and amphibians, but few investigations of their suitability for aquatic reptiles have been conducted. To examine their suitability for turtle communities, I surveyed strip pit lakes and naturally occurring lakes at Mined Lands Wildlife Area in southeastern Kansas. Community composition was different between the two classes of wetland due to variation in the abundance of *Chelydra serpentina serpentina* (Eastern Snapping Turtle), *Chrysemys picta bellii* (Western Painted Turtle), and *Sternotherus odoratus* (Eastern Musk Turtle). However, catch per unit effort 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 ones, and *C. p. bellii* were slightly more abundant in strip pits. *Sternotherus odoratus* were very abundant in a single strip pit. 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.

Introduction

The alteration of habitat by human activity is a considerable threat to many groups of animals. 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 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 therefore are also susceptible to anthropogenic alteration of buffers zones surrounding wetlands (Burke and Gibbons 1995; Steen et al. 2012). Females of all 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 terrestrial habitats around wetlands is an important component of 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 feature of human environmental disturbance, and rates of predation on turtle nests are higher 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 reductions 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 century left many landscapes across the United States (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 2014). 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 toward 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, I conducted a study to compare the composition of turtle communities inhabiting strip pit lakes to those in natural wetlands.

Methods

Study site. Mined Land Wildlife Area (MLWA), which encompasses properties in Crawford, Cherokee, and Labette counties in southeastern Kansas, is the site of formerly extensive strip-mining operations that began in the 1920s and ended in 1974. Cobbled together from properties donated to the state of Kansas over the last 90 years, the MLWA now comprises approximately 5,868 ha. This includes roughly 607 ha of water in the form of over 1,000 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 up 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 (Kansas Department of Wildlife, Parks, and Tourism 2014). 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 (Stefanoni 2014).

The majority of MLWA lies in the Middle Neosho River Watershed (HUC 11070205), which drains 3,694 km² 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 (KSU 2011). The Neosho River and its tributaries Cherry Creek and Lightning Creek have formed several oxbow lakes across Labette and Cherokee counties. These exist in both agricultural and wooded areas, and although many have been highly modified for agricultural purposes they are likely the most representative examples of the natural habitat that has been historically available to the region's freshwater turtle communities.

Trapping regime. I selected five strip pits from across MLWA and five naturally occurring lakes in Labette, Cherokee, and Crawford counties (Figure 1). These sites were selected based on 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, I 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. I was 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).

I 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. I then used a random number generator to determine at which locations traps would be deployed. Trap locations were randomly selected separately in 2017 and 2018, but 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). All traps were baited with canned sardines and equipped with buoys to prevent complete submersion in the event of flooding or trap rolling.

I attempted to use approximately the same proportions of each type of trap at each wetland, but this was often not possible when a site had banks that 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, I divided the lakes into size classes and increased the number of traps used with increasing size class. Sites up to 5 ha received 12 hoop traps and six crawfish traps. Sites that were 5–10 ha received 18 hoop traps and nine crawfish traps. Sites larger than 10 ha received 24 hoop traps and 12 crawfish traps. Each of the latter two categories contained only a single oxbow lake. The remaining eight sites were all less than 5 ha.

I checked traps daily, identifying the species and age class (adult or juvenile) of all captured turtles, as well as the sex of adults. I 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 and by injecting a PIT tag for marking *Apalone spinifera hartwegi* (Western Spiny Softshell Turtles) (Cagle 1939; Buhlmann & Tuberville 1998). Both methods were used for marking *Chelydra serpentina serpentina* (Eastern Snapping Turtles). Recaptured animals were individually identified and underwent all of the same biometric measurements as new captures.

Habitat metrics. I 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 included depth 1 m from shore, percent canopy cover, type of aquatic vegetation present,

abundance of surface basking structure, abundance of submerged structure, as well as depth and water clarity at the center of the wetland perpendicular from the shore at each point.

Depth was measured to the nearest 5 cm with a metered pole or with a depth line if the depth was greater than 2 m. Canopy cover was measured with a concave densiometer. Aquatic vegetation was described by category of dominant vegetation growth forms (submerged, emergent, floating, and woody). Surface and submerged woody structure were assigned a rank from 0 (no structure) to 3 (extensive structure). A single observer made these assessments at all locations.

Statistical analysis. For analyses in which the experimental units were individual trap locations, data from the crawfish traps were excluded 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. hartwegi*, *Trachemys scripta elegans* (Red-eared Sliders), and *Pseudemys concinna concinna* (Eastern River Cooters). For other analyses, data were drawn from all trap types within a wetland to provide a maximally robust sampling of the community. To identify differences in capture rates between wetland types, I used a generalized linear model (GLM) to compare catch per unit effort (CPUE) for each trap with site as a factor nested inside wetland type. I performed this test separately for each species (excluding *Graptemys pseudogeographica kohnii* (Mississippi Map Turtles) due to the extremely low frequency with which I encountered them). This analysis was performed in the statistical package Minitab 18 (Minitab 2017).

I calculated Simpson's diversity index for each site and used a t-test to compare the diversity of strip pits versus natural lakes. I also calculated the Bray-Curtis similarity index for

each pair of sites. These and all following analyses were performed in Program R using the package Vegan (R Core Team 2018; Oksanen et al 2018).

I 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 I 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, I also used Fisher's exact test to compare the community composition between 2017 and 2018 for each wetland type. Fisher's exact tests were used 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, rendering a chi-square test inappropriate.

I performed a correspondence analysis (Palmer 1993) based on catch per unit effort 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. I 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, I recorded 4,245 captures of 2,351 individual turtles representing seven species. Six species were captured in both natural lakes and strip pits, including the *P. c. concinna*, *T. s. elegans*, *A. s. hartwegi*, *Sternotherus odoratus* (*Eastern Musk*

Turtle), *C. s. serpentina*, and *Chrysemys picta bellii* (Western Painted Turtle). Additionally, I 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. *T. s. elegans* was the most commonly captured species at all 11 sites, and at five sites (four natural lakes and one strip pit) *T. s. elegans* comprised over 90% of the turtle community. *Chelydra serpentina serpentina* made up an average of 7.8% of turtle communities in natural lakes, but only 0.8% of the turtle communities in strip pits. Conversely, *C. p. bellii* were much more abundant in strip pits than in naturally occurring lakes, comprising an average of 9.7% of strip pit communities versus only 0.4% of communities in naturally occurring 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). All other species were captured at comparatively low rates (< 6% of community at any given site and < 3% of combined community in each type of wetland). Tables 1 and 2 detail how many individuals of each species were found at each site, as well as combined proportional representation of each species in the community for 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 ($P = 0.020$, Table 3). Simpson diversity appears to be higher on average than that in natural lakes although diversity in both groups was variable and the difference was not significant ($t = 1.61$, $df = 6$, $P = 0.158$, Figure 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 $\bar{x} = 0.63$, Pit-Lake $\bar{x} = 0.41$, Lake-Lake $\bar{x} = 0.37$, Table 4).

Species representation varied significantly between strip pits and natural lakes ($P < 0.0001$, Figure 3). Community composition in strip pits was not significantly different between 2017 and 2018 ($P = 0.5278$) but did vary between years in natural lakes ($P = 0.0005$, Figure 4). Correspondence analysis grouped *T. s. elegans*, *P. c. concinna*, and *A. s. hartwegi* together near the intersection of axes 1 and 2. *Chrysemys picta bellii* and *C. serpentina* were grouped with these species on axis 1, but *C. p. bellii* had high scores on axis two while *C. serpentina* had low scores on axis 2. *Sternotherus odoratus* had a similar score on axis 2 to *T. s. elegans*, *P. c. concinna*, and *A. s. hartwegi*, but had high scores on axis one (Figure 5).

After identifying environmental variables that appeared to be important to the species that were present, I used canonical correspondence to include habitat parameters in the analysis (Figure 6). The CCA generated a first axis primarily driven by the abundance of submerged vegetation such as *Ceratophyllum* and *Myriophyllum*. 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. However, all the associations were rather weak, as evidenced by the fact that the relationship between species capture rates and habitat variables explained only 12% of the observed variation in species captures.

Discussion

Based on the data collected in this study, it appears evident that the strip pits of the Mined Lands Wildlife Area provide habitat that is at least as suitable as that provided by other available wetlands in the surrounding agricultural landscape for most turtle species. With the prominent

exception of the near absence of *C. s. serpentina* from the strip pits of MLWA, I failed to detect any metric by which the strip pits were inferior to the natural lakes in terms 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 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. As only six of the thousand or more lakes and ponds at MLWA were surveyed for this study, it seems likely that a broader sampling of these bodies of water would reveal stronger patterns than I was able to detect, and could also detect individual ponds with unusual community compositions akin to the very high abundance of *S. odoratus* I observed at Pit 27. The low levels at which *C. s. serpentina* were 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 I surveyed were > 10 m in depth), but the slope from the shore to the center is also very 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 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 is 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 of those had substantial populations of at least several dozen individuals. Although often associated with shallower habitats in much of their range (Ernst & Lovich 2009), *C. p. bellii* in the Nebraska Sandhills are associated with lakes and open waters rather than ponds or marshes (Bury & Germano 2003). A similar preference may be driving my results, but with the low percentage of variation explained by habitat variables in the CCA, it is possible that factors other than those I 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 Painted Turtles in this region. The near complete segregation of *C. p. bellii* and *C. s. serpentina* is interesting, but the available literature is mixed 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 1990). However, in other cases there has been no correlation between the relative abundance of *C. serpentina* and *C. picta* (Dreslik and Phillips 2005), and *C. picta* been observed to use the much larger *C. serpentina* as basking platforms (Legler 1956), both of which suggest that the possibility that *C. serpentina* are responsible for excluding *C. picta* from entire wetlands is unlikely. 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 researchers have suggested a causal relationship (Dreslik and Phillips 2005; Dreslik et al. 2005). However, there is little evidence of direct competition between the two species.

Although CCA associates *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. Much of the distribution of these turtles was not explained by habitat, and it is possible some other factor of the landscape or a quirk of history has led to this high density. 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 that year. 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, there were ten *C. s. serpentina* equipped with radio-transmitters in Lake 4 and its surrounding ponds from the autumn of 2017 to the autumn of 2018. Several of these turtles became undetectable even via telemetry in June and July of 2018, and several of those that I was able to continue tracking buried themselves at the edge of ponds and remained there for weeks or months. It is likely that similar behavior was also occurring at Lake 3, the other natural lake that was trappable during both years.

Taken together, the results of this study indicate that reclaimed mined lands can provide habitats that will support communities of turtles 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 any frequency, all other species were at least as abundant in strip pits as elsewhere, and some may potentially 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.

Literature Cited

- Aresco, M.J. 2005. The effect of sex-specific terrestrial movements and roads on the sex ratio of freshwater turtles. *Biological Conservation* 123: 37–44.
- Bajema, R.A., and S.L. Lima. 2001. Landscape-level analyses of Henslow's Sparrow (*Ammodramus henslowii*) abundance in reclaimed coal mine grasslands. *American Midland Naturalist* 145: 288–298.
- Bodie, J.R., R.D. Semlitsch, and R.B. Renken. 2000. Diversity and structure of turtle assemblages: associations with wetland characters across a floodplain landscape. *Ecography* 23: 444–456.
- Brenner, F.J., and D.L. Hofius. 1990. Wildlife use of mitigated wetlands on surface mined lands in western Pennsylvania. *Journal of the American Society of Mining and Reclamation* 1990: 373–384.
- Brooks, R.P. 1989. Wetland and waterbody restoration and creation associated with mining. Pp. 117–136 *In* *Wetland Creation and Restoration: The Status of the Science*. Kusler, J.A., and M.E. Kentula (Eds.). United States Environmental Protection Agency.
- Brooks, R.J., G.P. Brown, and D.A. Galbraith. 1991. Effects of a sudden increase in natural mortality of adults on a population of the Common Snapping Turtle (*Chelydra serpentina*). *Canadian Journal of Zoology* 69: 1314–1320.
- Burke, V.J., and Gibbons, J.W. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina bay. *Conservation Biology* 9: 1365–1369.
- Buhlmann, K.A. and Tuberville, T.D. 1998. Use of passive integrated transponder (PIT) tags for marking small freshwater turtles. *Chelonian Conservation and Biology* 3: 102–104
- Cagle, F.R. 1939. A system of marking turtles for future identification. *Copeia* 1939: 170–173.
- Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's Turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. *Conservation Biology* 7: 826–833.
- Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1994. Demographics of Common Snapping Turtles (*Chelydra serpentina*): implications for conservation and management of long-lived organisms. *American Zoologist* 408: 397–408.
- Davidson, N.C. 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research* 65: 934–941.
- Devault, T.L., P.E. Scott, R.A. Bajema, and S.L. Lima. 2002. Breeding bird communities of reclaimed coal-mine grasslands in the American Midwest. *Journal of Field Ornithology* 73: 268–275.

- Dreslik, M.J., A.R. Kuhns, and C.A. Phillips. 2005. Structure and composition of a southern Illinois freshwater turtle assemblage. *Northeastern Naturalist* 12: 173–186.
- Dreslik, M.J., and C.A. Phillips. 2005. Turtle communities in the upper Midwest, USA. *Journal of Freshwater Ecology* 20: 149–164.
- Ernst, C.H., and J.E. Lovich. 2009. Painted Turtles. Pp.184–211 *In* *Turtles of the United States and Canada*. 3rd Edition. Johns Hopkins University Press. Baltimore, Maryland, USA.
- Frazer, N.B., J.W. Gibbons, and T.J. Owens. 1990. Turtle trapping: preliminary tests of conventional wisdom. *Copeia* 1990: 1150–1152.
- Howell, H.J., and R.A. Seigel. 2019. The effects of road mortality on small, isolated turtle populations. *J. Herpetology* 53: 39–46.
- Kansas Department of Wildlife, Parks, and Tourism. 2014. Mined Land Wildlife Area brochure.
- Kansas State University. 2011. Middle Neosho watershed restoration and protection strategy. Kansas State University Research and Extension.
- Keevil, M.G., R.J. Brooks, and J.D. Litzgus. 2018. Post-catastrophe patterns of abundance and survival reveal no evidence of population recovery in a long-lived animal. *Ecosphere* 9: 1–21.
- Lannoo, M.J., V.C. Kinney, J.L. Heemeyer, N.J. Engbrecht, A.L. Gallant, and R.W. Klaver. 2009. Mine spoil prairies expand critical habitat for endangered and threatened amphibian and reptile species. *Diversity* 1: 118–132.
- Legler, J.M. 1956. A social relationship between snapping and painted turtles. *Transactions of the Kansas Academy of Sciences* 59: 461–462.
- McKnight, D.T., J.R. Harmon, J.L. McKnight, and D.B. Ligon. 2015. Taxonomic biases of seven methods used to survey a diverse herpetofaunal community. *Herpetological Conservation and Biology* 10: 666–678.
- Minitab 18 Statistical Software (2017). State College, PA: Minitab, Inc. www.minitab.com
- Myers, C.D., and W.D. Klimstra. 1963. Amphibians and reptiles of an ecologically disturbed (strip-mined) area in southern Illinois. *American Midland Naturalist* 70: 126–132.
- Oksanen, J., F.G. Blanchet, M. Friendly, R. Kindt, P. Legendre, D. McGlenn, P.R. Minchin, R. B. O'Hara, G. L. Simpson, P. Solymos, M.H.H. Stevens, E. Szoecs and H. Wagner (2018). *vegan: Community Ecology Package*. R package version 2.5-3. <https://CRAN.R-project.org/package=vegan>
- Palmer, M. W. 1993. Putting things in even better order: the advantages of canonical correspondence analysis. *Ecology* 74: 2215–2230.

- Quesnelle, P.E., L. Fahrig, and K.E. Lindsay. 2013. Effects of habitat loss, habitat configuration and matrix composition on declining wetland species. *Biological Conservation* 160: 200–208.
- R Core Team (2018) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. <https://www.R-project.org>
- Riedle, J.D., R.T. Kazmaier, J. Killian, and W.B. Littrell. 2015. Assemblage structure of an eastern Texas aquatic turtle community. *Herpetological Conservation and Biology* 10: 695–702.
- Riley, C. V. 1960. The ecology of water areas associated with coal strip-mined lands in Ohio. *Ohio Journal of Science* 60: 106–121.
- Steen, D.A., J.P. Gibbs, D.A. Buhlmann, J.L. Carr, B.W. Compton, J.D. Congdon, J.S. Doody, J.C. Godwin, K.L. Holcomb, D.R. Jackson et al. 2012. Terrestrial habitat requirements of nesting freshwater turtles. *Biological Conservation* 150: 121–128.
- Stefanoni, A. B. Work at Mined Land Wildlife Area removes hazards, improves fishing. *Joplin Globe* [Joplin, MO] 27 May 2014. http://www.joplinglobe.com/news/local_news/work-at-mined-land-wildlife-area-removes-hazards-improves-fishing/article_4f1938fa-5283-55e7-ad17-3561e254c76b.html
- Stiles, R.M., J.W. Swan, J.L. Klemish, and M.J. Lannoo. 2017. Amphibian habitat creation on postindustrial landscapes: a case study in a reclaimed coal strip-mine area. *Canadian Journal of Zoology* 95: 67–73.
- Temple, S.A. 1987. Predation on turtle nests increases near ecological edges. *Copeia* 1987: 250–252.
- Ter Braak, C. J. F. 1986. Canonical correspondence analysis: A new eigenvector technique for multivariate direct gradient analysis. *Ecology* 67: 1167–1179.
- Terrell, V.C.K., J.L. Klemish, N.J. Engbrecht, J.A. May, P.J. Lannoo, R.M. Stiles, and M.J. Lannoo. 2014. Amphibian and reptile colonization of reclaimed coal spoil grasslands. *Journal of North American Herpetology* 2014: 59–68.
- Woolley, P.A. 1996. Responses of *Chelydra serpentina* and *Chrysemys picta* to the musk of other turtles. *Bulletin of the Chicago Herpetological Society* 31: 201–202.
- Yeager, L.E. 1942. Coal-stripped land as a mammal habitat, with special reference to fur animals. *American Midland Naturalist* 27: 613–635.

Table 1: Total number of unique individuals (divided by sex and age class) of each species at each natural site, and proportion of community made up by each species at each site. M = Male, F = Female, J = Juvenile.

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

Table 2: Total number of unique individuals (divided by sex and age class) of each species at each strip pit site, and proportion of community made up by each species at each site. M = Male, F = Female, J = Juvenile.

Site	Species	M	F	J	Total	Proportion
Pit 24	<i>Sternotherus odoratus</i>	2	0	0	2	2.20%
	<i>Chelydra serpentina serpentina</i>	1	0	0	1	1.10%
	<i>Chrysemys picta bellii</i>	5	2	0	7	7.80%
	<i>Pseudemys concinna concinna</i>	2	0	0	2	2.20%
	<i>Trachemys scripta elegans</i>	62	15	1	78	86.70%
	<i>Apalone spinifera hartwegi</i>	0	2	0	2	2.20%
Pit 30	<i>Sternotherus odoratus</i>	4	1	0	5	4.20%
	<i>Chelydra serpentina serpentina</i>	1	0	0	1	0.80%
	<i>Pseudemys concinna concinna</i>	1	0	0	1	0.80%
	<i>Trachemys scripta elegans</i>	69	35	3	107	89.90%
	<i>Apalone spinifera hartwegi</i>	1	4	0	5	4.20%
Pit 37	<i>Sternotherus odoratus</i>	7	3	0	10	5.00%
	<i>Chelydra serpentina serpentina</i>	2	1	0	3	1.50%
	<i>Chrysemys picta bellii</i>	30	18	0	48	23.80%
	<i>Pseudemys concinna concinna</i>	3	0	0	3	1.50%
	<i>Trachemys scripta elegans</i>	90	45	2	137	67.80%
	<i>Apalone spinifera hartwegi</i>	0	1	0	1	0.50%
Pit 40	<i>Sternotherus odoratus</i>	1	0	0	1	0.70%
	<i>Chrysemys picta bellii</i>	8	3	0	11	7.70%
	<i>Pseudemys concinna concinna</i>	1	0	0	1	0.70%
	<i>Trachemys scripta elegans</i>	53	73	6	133	93.70%
	<i>Apalone spinifera hartwegi</i>	2	6	0	8	5.60%

Table 2 continued: Total number of unique individuals (divided by sex and age class) of each species at each strip pit site, and proportion of community made up by each species at each site. M = Male, F = Female, J = Juvenile.

Site	Species	M	F	J	Total	Proportion
Pit 42	<i>Sternotherus odoratus</i>	3	2	0	5	1.80%
	<i>Chelydra serpentina serpentina</i>	1	0	0	1	0.40%
	<i>Chrysemys picta bellii</i>	39	15	2	56	19.60%
	<i>Trachemys scripta elegans</i>	125	79	19	223	78.20%
	<i>Apalone spinifera hartwegi</i>	0	1	0	1	0.40%
Pit 27	<i>Sternotherus odoratus</i>	48	81	0	129	57.60%
	<i>Chelydra serpentina serpentina</i>	2	0	0	2	0.90%
	<i>Chrysemys picta bellii</i>	2	0	0	2	0.90%
	<i>Pseudemys concinna concinna</i>	3	0	0	3	1.30%
	<i>Trachemys scripta elegans</i>	47	34	6	87	38.80%
	<i>Apalone spinifera hartwegi</i>	0	1	0	1	0.40%

Table 3. Average daily catch per hoop trap of each species in each type of wetland with standard deviations. 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.

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

Table 4: Bray-Curtis similarity values for each pair of sites. 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									

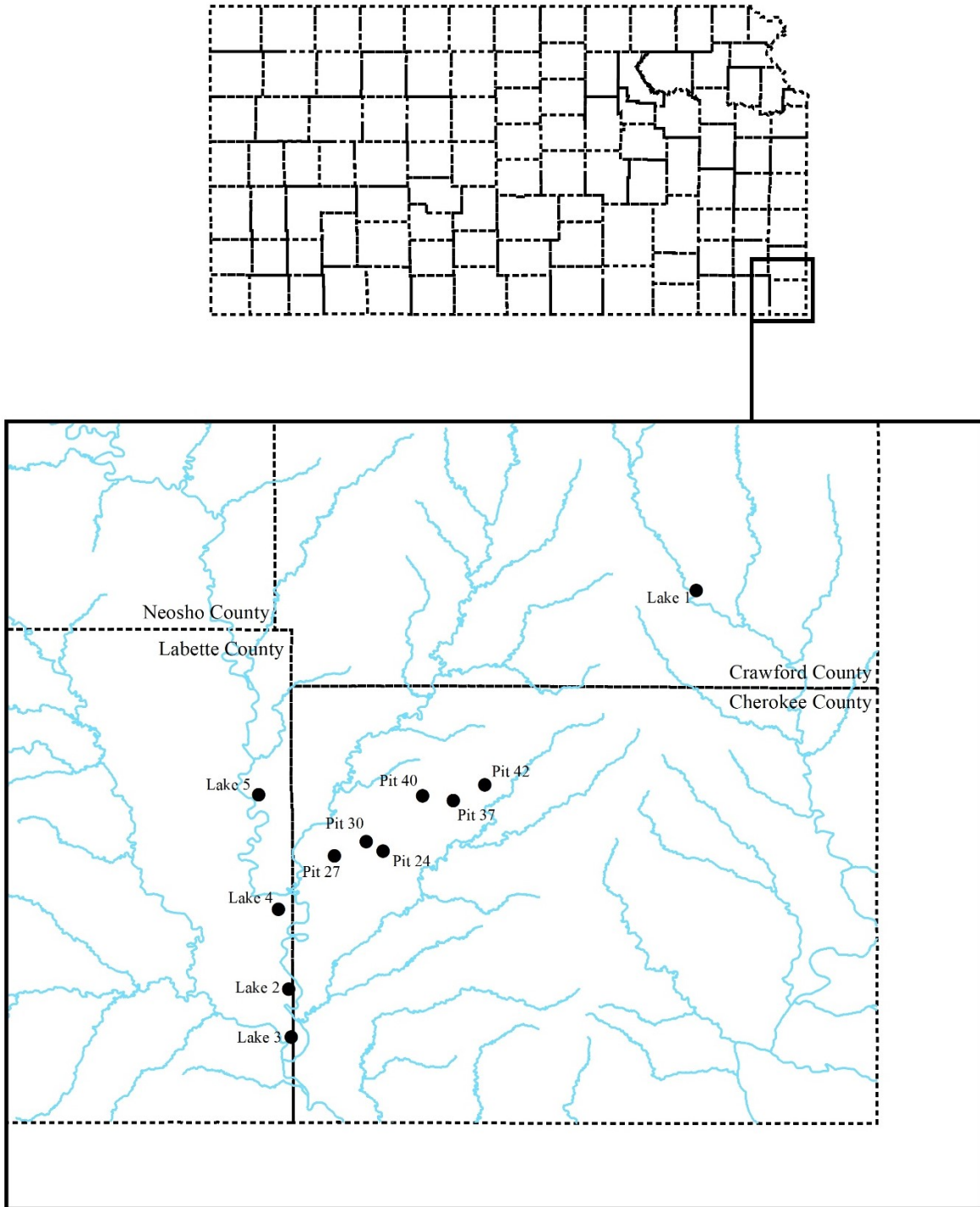


Figure 1. Map depicting the location of the lakes and strip pits that were surveyed.

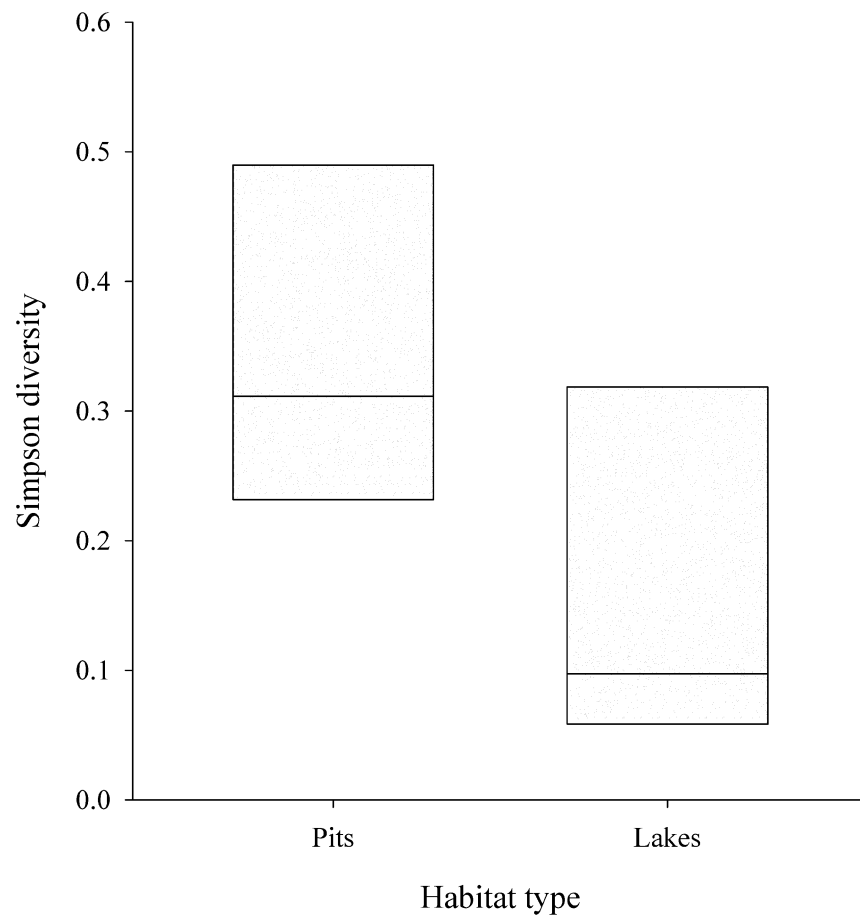


Figure 2: Boxplot of Simpson diversity index values for strip pits and natural lakes. Differences between the two groups were not significant ($t = 1.61$, $df = 6$, $P = 0.158$).

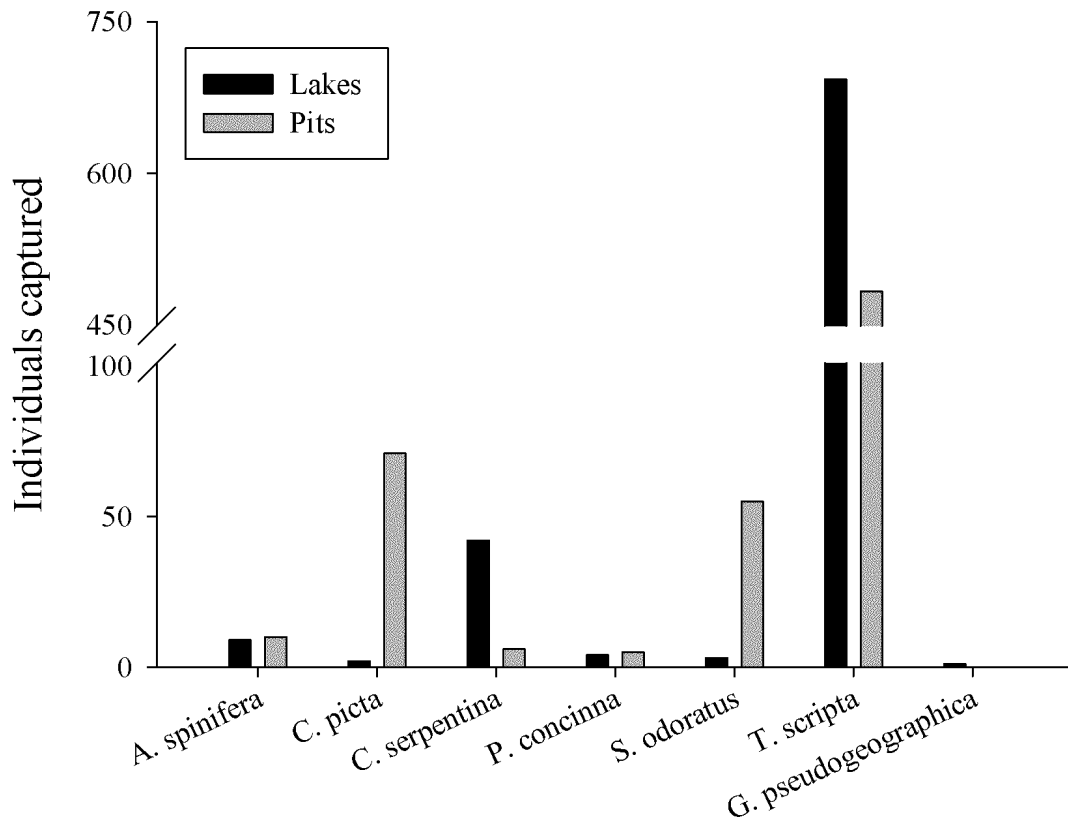


Figure 3. Number of individuals captured in each wetland type compiled from the first trapping season in each wetland. A Fisher's exact test detected a significant difference in species proportional representation between wetland types ($p < 0.0001$).

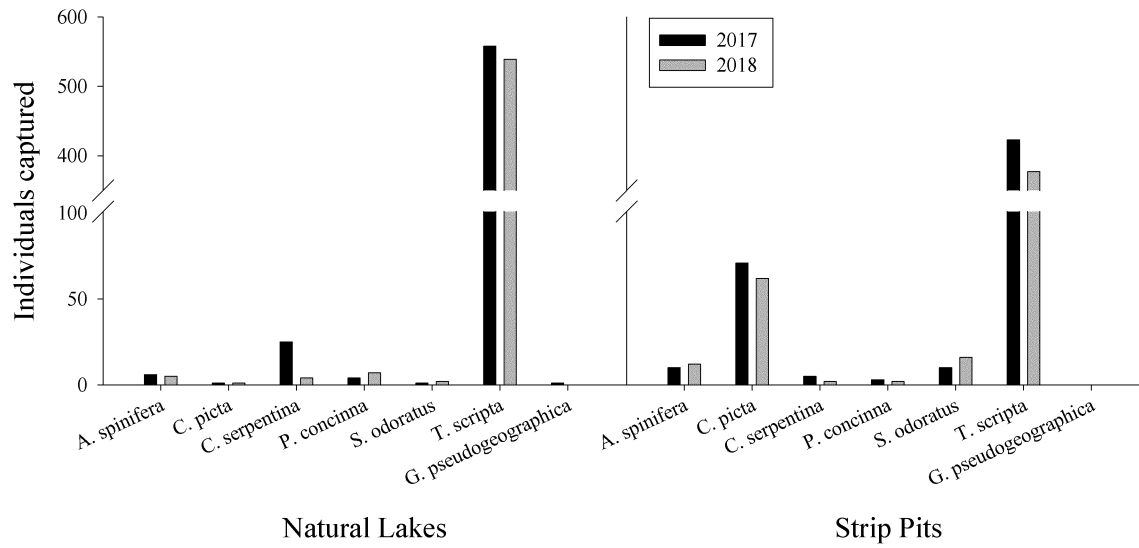


Figure 4. Number of individuals captured in each wetland type in 2017 and 2018, compiled only from bodies of water that were trapped in both years. Fisher’s exact tests detected a significant difference in species proportional representation between years in natural lakes ($p = 0.0005$) but not in strip pits ($p = 0.5278$).

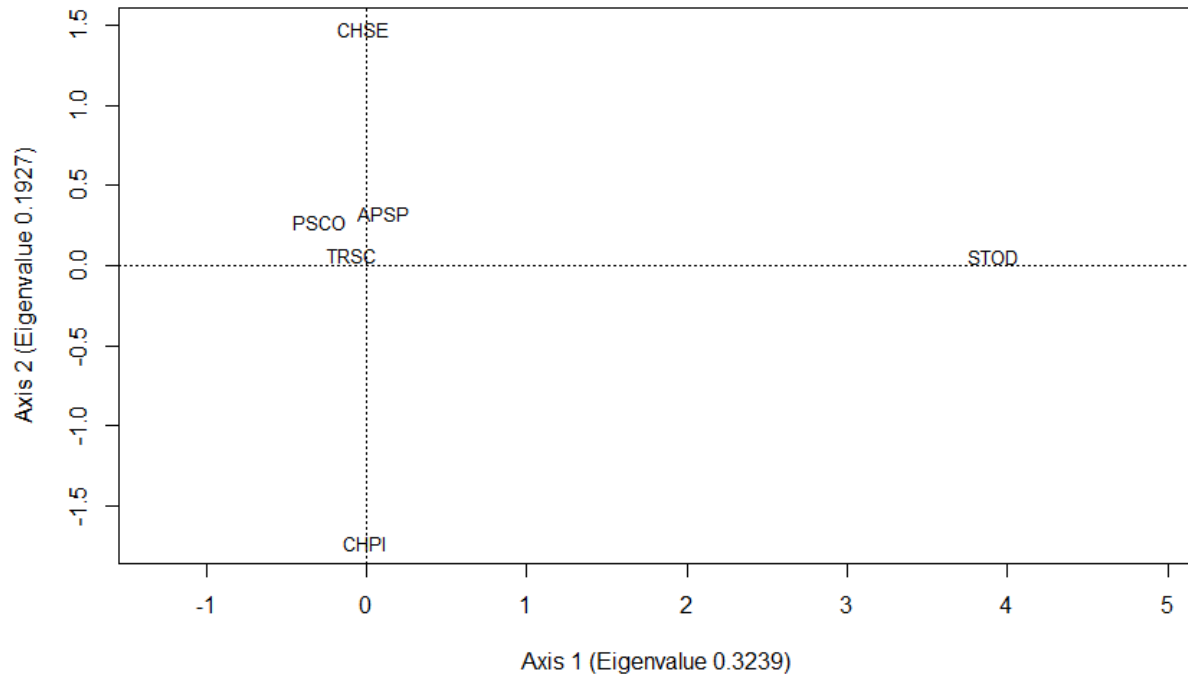


Figure 5. Distribution of species scores from the first two axes of a correspondence analysis of turtle capture rates (per trap location) in eleven bodies of water in southeastern Kansas. Species abbreviations used in this figure are as follows: APSP = *Apalone spinifera hartwegi*, CHPI = *Chrysemys picta bellii*, CHSE = *Chelydra serpentina serpentina*, PSCO = *Pseudemys concinna concinna*, STOD = *Sternotherus odoratus*, TRSC = *Trachemys scripta elegans*. Total inertia was 0.805.

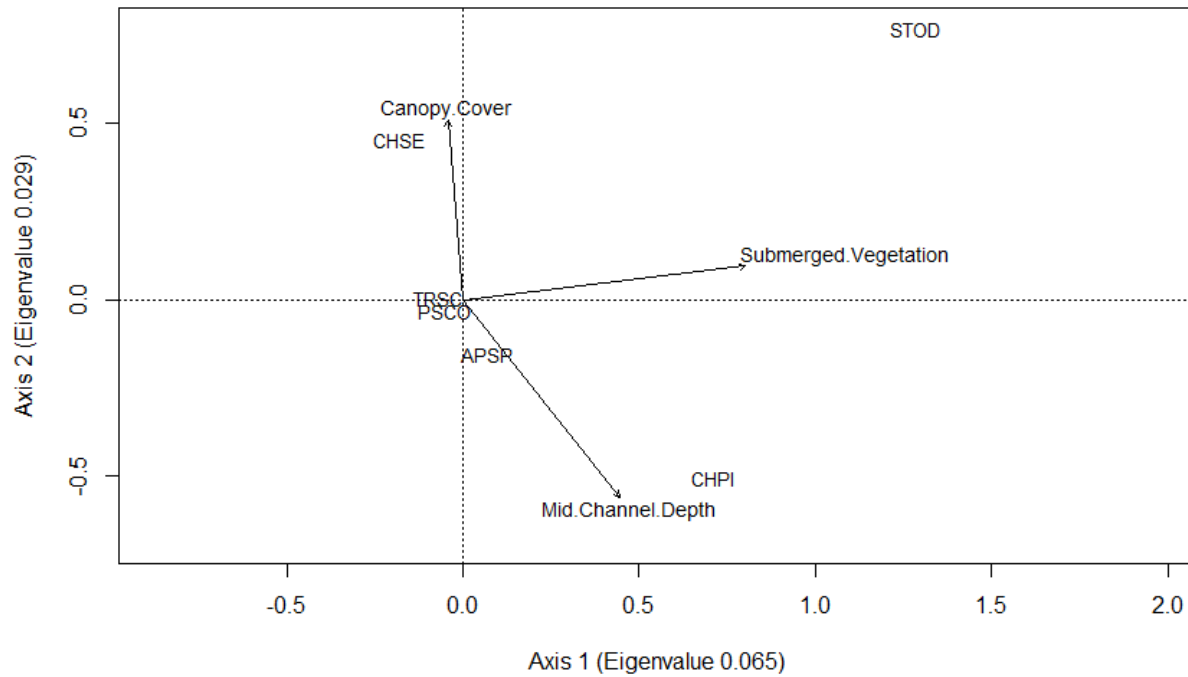


Figure 6. Ordination of turtle species from eleven bodies of water in southeastern Kansas based on canonical correspondence analysis of CPUE at each trap and the habitat metrics associated with each trap's location. Species abbreviations used in this figure are as follows: APSP = *Apalone spinifera hartwegi*, CHPI = *Chrysemys picta bellii*, CHSE = *Chelydra serpentina serpentina*, PSCO = *Pseudemys concinna concinna*, STOD = *Sternotherus odoratus*, TRSC = *Trachemys scripta elegans*. Total inertia was 0.805.

LEARNED TRAP AVOIDANCE IN FRESHWATER TURTLES AND ITS EFFECTS ON CAPTURE RATES, ABUNDANCE ESTIMATES, AND INFERENCES ABOUT COMMUNITY STRUCTURE

Abstract

Context. Understanding the effects of learned behavioral responses to capture on recapture rates and abundance estimates is important to developing accurate descriptions of turtle populations and communities. Although variation in the willingness of individual turtles to be trapped is commonly mentioned in the literature, few studies have experimentally tested learned trap avoidance (or fondness) in turtles.

Aims. To determine whether relocating traps will lead to increased capture rates, whether this effect varies among species, and whether such relocations yield more accurate depictions of community structure.

Methods. I studied a community of turtles in a small lake in southeastern Kansas that included populations of Slider Turtles (*Trachemys scripta*) and Common Musk Turtles (*Sternotherus odoratus*). I trapped the lake for 35 consecutive days in June and July 2018 using two concurrently-set groups of traps. One group of traps remained stationary for the duration of the study, while traps comprising the other group were moved to new locations on day 14 and returned to their original locations on day 28, thus dividing the trapping season into three periods.

Key results. Traps in the moved group captured more *T. scripta* than those in the stationary group during the second period and more *S. odoratus* during the third period. Schumacher-Eschmeyer abundance estimates based on captures from the moved group, the

stationary group, and the pool of all captures were similar for *T. scripta*. For *S. odoratus*, the stationary group of traps produced an abundance estimate much lower than those generated from the moved group and the pool of all captures.

Conclusions. Relocating traps had different effects on our sampling of different species, and yielded abundance estimates that revealed a different dominant species than that determined with stationary traps.

Implications. The movement patterns and catchability of individuals of different species within a community must be taken into consideration when developing trapping regimes. Even fairly high intensity trapping over a long period may not generate an accurate sample of the community if different species experience the spatial environment in substantially different ways.

Introduction

Effective wildlife conservation requires a thorough understanding of the population or community under consideration. This includes an accurate assessment of the population's abundance and demographic structure, and such an assessment can only be achieved through sampling that truly represents the population from which the sample is drawn. Most sampling methods are biased against certain species in a community and against certain demographic groups within a population. Size bias in sampling is common in surveys that use passive trapping and may stem from a physical aspect of the traps that precludes certain size classes from entering the trap or allows others to escape (Willson et al. 2008; Luhring et al. 2016), although in some cases it is unclear whether the bias stems from the physical exclusion of certain size classes or an ontological shift in behavior (Rodda et al. 2007; Hancock and Legg 2012). Interestingly, size

biases in sampling even extends to the naturally selected samples of the fossil record. For instance, the size distributions of arthropods preserved in amber are skewed toward the small end of the distribution (Solórzano Kraemer et al. 2015). Large-bodied dinosaur taxa are discovered and described faster than small-bodied taxa, and are usually discovered in more complete form, leading to more accurate understanding of the communities of large-bodied species of the past (Brown et al. 2013).

Sampling methods that generate sex-biased capture rates are also quite common across many taxa, presumably (and sometimes demonstrably) the result of differences in behavior between the sexes (Gehrt and Fritzell 1996; Vanderkist et al. 1999; Moeller et al. 2005; Altermatt et al. 2009). Recent studies have also documented strong male bias in the fossil record of several large mammal species, as well as male bias in most mammalian groups in natural history collections (Pečnerová et al. 2017; Gower et al. 2019). These kinds of biases, if not recognized, can stymie efforts to examine real biases in the sex ratio of a population (Thorbjarnarson 1997; Stoks 2001). When a sample of a population provides an unrepresentative size distribution, sex ratio, or population density, any conclusions about demographic structure, as well as both absolute and relative abundance in a community, will likewise be biased (Ream and Ream 1966; McKnight et al. 2015; Tesche and Hodges 2015).

Although considerable work has been done to identify sources of population sampling bias, and many strategies developed to ameliorate them, little experimental attention has been paid to the temporally-induced biases that may arise with sustained sampling in an area. For instance, learned trap avoidance in response to capture has been documented in mammals (Wood and Slade 1990; Pelton and Van Manen 1996; Schipper 2007), birds (Buckland and Hereward 1982; Muraoka and Wichmann 2007), and fish (Gilbert et al. 2001).

In the study of turtle communities, obtaining representative samples is particularly difficult due to the broad variation in size, diet, and habits that exist among species (Cagle 1942; Vogt 1980) and sometimes between the sexes and age classes within a species (Ream and Ream 1966; Gibbons 1969; Gamble 2006; Steen et al. 2006). The possibility that turtles learn to avoid traps, and that some species may learn faster than others, has been suggested (Mahoney and Lindeman 2016), but no tests have been performed on learned trap avoidance in turtles. This lack of information is problematic, as many population size estimators assume equal catchability, although this assumption has historically been ignored in estimates of turtle population size (Lindeman 1990).

If turtles behave differently after they have been captured, population estimates based on capture-mark-recapture will be altered by the resultant inflation or deflation of recapture rates. Turtles may become enamored of the free resources obtained from baited traps (trap-happy) or may become wary of entering traps in the future because of the perceived danger they pose (trap-shy). It can safely be presumed that trap-happy turtles are drawn to the bait used in traps, but it is unclear what cues trap-shy turtles use to identify and avoid traps. Different bait types have been shown to attract unique subsets of individuals in a population of painted turtles (*Chrysemys picta*), but switching bait types does not increase recapture rates (Mali et al. 2012), suggesting that turtles that learn to avoid traps are not avoiding a particular bait odor. One possibility is that turtles can become wary of specific locations where they have been captured in the past. At least some birds and mammals avoid areas where they have been captured (Buckland and Hereward 1982; Schipper 2007), and indeed, relocating traps to counteract decreased capture rates (presumed to be the result of learned trap-shyness) over a long session of trapping has been reported in at least one study (Selman et al. 2013). However, there have been no experimental

investigations into whether such relocations of traps in fact increase recapture rates of turtles. Therefore, I performed an experiment to determine whether turtles learn to avoid locations at which they have previously been trapped. Specifically, I endeavored to learn 1) whether capture rates decline over the duration of an extended bout of trapping, 2) whether relocating traps ameliorates this effect, and 3) how the effects vary among species.

Methods

Study site. I executed my study at a 1.1-hectare strip pit lake at Mined Land Wildlife Area (MLWA) in southeastern Kansas. This lake was selected for its accessibility, well-vegetated surroundings, moderate depth, lack of connectivity to surrounding bodies of water, and small size. The lake is immediately adjacent to a dirt road with low vehicle traffic and has a dirt path from the road to the water's edge. There was evidence that recreational fishing occurs, but I did not encounter anyone fishing during the course of my experiments. The lake is surrounded by woodland except for the portion of the shoreline that abuts the road, and most of the lakebed has a covering of submerged vegetation. The turtle community in this lake had not been surveyed prior to this study.

Trapping regime. I surveyed the perimeter of the lake and identified 33 locations with depth, slope, and woody anchors appropriate for deploying traps. I marked these locations with a handheld GPS unit and used a random number generator to select 16 of these locations for the initial period of trap deployment (Figure 1). On 23 June 2018 I deployed a 0.6-m diameter single-throated, flat-bottomed hoop net baited with canned sardines at each of these locations. Half of these traps were then randomly assigned to a stationary control group and the other half to an experimental group. The traps were left in their initial locations for 14 days. At the end of

this period, each of the eight experimental traps was assigned to a new location randomly selected from the remaining unused potential trap locations (Figure 2). After another 14 days, the experimental traps were returned to their initial locations. I continued trapping for a final seven days after returning traps to their initial locations and terminated the experiment on 28 July 2018.

Throughout the experiment I checked traps daily, identifying the species and age class (adult or juvenile) of all captured turtles, as well as the sex of adults. I measured mass, straight-line carapace length, and plastron length 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 and by injecting a PIT tag for softshells (Cagle 1939; Buhlmann and Tuberville 1998). Both methods of marking were applied to common snapping turtles. All recaptured animals were individually identified.

Statistical analysis. All statistical analyses were performed using Minitab 19 statistical software. I used a mixed effects model to test for differences in mean daily CPUE between the control and experimental groups of traps for each of the three periods of the study. I performed this analysis separately for both *T. scripta* and *S. odoratus*. In these six tests, trap group was treated as a fixed variable and trap location was included as a random variable nested within trap group to account for any features of individual trap locations that may have influenced capture rates. Day was also included as a covariate to test for declines in capture rates over time.

I calculated estimates of population size for each species using the Schumacher-Eschmeyer method (Schumacher & Eschmeyer 1943) with five capture periods of equal duration (7 days) using the samples generated from each trap group, as well as from all captures across both groups.

Results

I captured 225 individual turtles of six species a total of 641 times (Table 1). The vast majority of these were *T. scripta* (39.6% of individuals and 60.1% of captures) and *S. odoratus* (56.9% of individuals and 37.4% of captures).

Daily capture rate per trap declined over the duration of the experiment for both *T. scripta* ($F_{1, 529} = 28.53, P = < 0.001$) and *S. odoratus* ($F_{1, 529} = 4.07, P = 0.044$). Capture rates also declined significantly within the first ($F_{1, 205} = 15.75, P < 0.001$) and second ($F_{1, 206} = 29.21, P < 0.001$) trapping periods for *T. scripta* and within the second ($F_{1, 206} = 4.72, P = 0.031$) and third ($F_{1, 92} = 4.68, P = 0.033$) periods for *S. odoratus*.

The moved trap group produced 204 captures of 78 *T. scripta* and 167 captures of 103 *S. odoratus*. The stationary trap group produced 181 captures of 75 *T. scripta* and 73 captures of 44 *S. odoratus*. Among *T. scripta*, 73.8% of individuals were captured in both groups of traps. Only 15.7% of *S. odoratus* individuals were captured in both groups. Over the full duration of the experiment, the moved trap group did not produce significantly more captures per trap for either *T. scripta* ($F_{1, 529} = 0.54, P = 0.469$) or *S. odoratus* ($F_{1, 529} = 4.04, P = 0.055$); however, the moved group did capture significantly more turtles per trap in the second trapping period for *T. scripta* ($F_{1, 206} = 7.28, P = 0.017$, Figure 3) and in the third trapping period for *S. odoratus* ($F_{1, 92} = 8.57, P = 0.009$, Figure 4).

For *T. scripta*, the moved trap group produced a similar population estimate ($N = 87$) to the stationary group ($N = 84$), both of which congruent with the estimate obtained by pooling captures from both groups ($N = 90$), Figure 5). For *S. odoratus*, the estimate based on the moved trap group ($N = 163$) was similar to that generated by pooling all captures from both trap groups ($N = 167$), but the moved group estimate had considerably wider confidence intervals (105–363

compared to 129–240). The estimate derived from the stationary trap group yielded a far lower estimate (N = 57) for *S. odoratus*.

Discussion

The observed decline in capture rates over time suggests that, on average, turtles of both species may be exhibiting learned trap avoidance. This is supported in *T. scripta* by the increased capture rate in the moved group of traps relative to the stationary group. Furthermore, that capture rates can be increased by relocating traps shows that at least part of the decline is the result of turtles learning to avoid specific locations rather than traps generally.

Both sexes of *S. odoratus* were consistently captured in traps they had visited before with greater frequency than would be expected. While this could be interpreted as trap-happy behavior, this is unlikely because very few individuals were captured more than three times.

Data from both trap groups were sufficient to produce estimates for *T. scripta* that were comparable to that generated using pooled captures, despite each group having only half the number of traps as the total pool. This, and the fact that nearly three-quarters of *T. scripta* individuals were detected in both trap groups, implies that for highly mobile species of turtle it is relatively safe to assume that each trap has a nearly equal chance of catching each turtle. This is emphatically not true of small, relatively sedentary species. Only 15.7% of *S. odoratus* individuals appeared in both trap groups, strongly suggesting that the assumption that each trap is equally likely to catch each turtle is violated. This is likely an artifact of the activity patterns typical of this species. *Sternotherus odoratus* are not particularly vagile animals and spend much of their time foraging by walking along the bottom. Estimates of home range sizes for *S. odoratus* are quite variable, but in one study conducted in Oklahoma, average home range sizes

were as low as 0.02 hectares for males and 0.05 hectares for females (Mahmoud 1969). There is also evidence that at least some *S. odoratus* have a strong homing instinct and will return to locations very near their first capture if they are released in distant parts of their home ponds (Andres and Chambers 2006). It is likely that there are simply few traps that are within the home range of an individual and that when they are captured it will be in one of these few traps. The total number of traps that are functionally available to a given individual will therefore be considerably lower than the number of traps in the wetland. The abundance estimate of the stationary group reflects this. Many turtles were simply not available for capture at these trap locations, and as a result the population size is underestimated. The moved trap group, however, was able to provide an estimate very close to that of the full pool of traps (albeit with greater uncertainty) by making some traps available, at least part of the time, to a larger proportion of the population. This is important to consider because it means that generating an accurate estimate of abundance for species like *S. odoratus* requires either setting considerably more traps than is required for sampling more vagile species or relocating traps throughout a survey period.

It is worth noting that the estimate generated from the stationary pool underestimates the abundance of *S. odoratus* to a degree that renders interpretations of the entire community structure incorrect. It is clear from the estimates based on the full pool of traps (and even from the number of individuals actually captured) that there are many more *S. odoratus* than *T. scripta* in the lake in which I conducted the study. However, the stationary trap group generated population estimates that indicate that *S. odoratus* is less abundant than *T. scripta*, or at most that the population sizes are roughly equal. Furthermore, this estimate of *S. odoratus* abundance has considerably tighter confidence intervals than the other two estimates, which could easily mislead investigators into believing they have produced a reliable estimate, despite the warning

of Koper and Brooks (1998) that narrow confidence intervals should not necessarily be interpreted as indicative of an accurate estimate.

Literature Cited

- Altermatt, F., Baumeier A., and Ebert, D. (2009). Experimental evidence for male biased flight-to-light behavior in two moth species. *Entomologia Experimentalis et Applicata* **130**, 259–265.
- Andres, K.M., and Chambers, R.M. (2006). A test of philopatry by common musk turtles. *American Midland Naturalist* **156**, 45–51.
- Brown, C.M., Evans, D.C., Campione, N.E., O'Brien, L.J., and Eberth, D.A. (2013). Evidence for taphonomic size bias in the Dinosaur Park Formation (Campanian, Alberta), a model Mesozoic terrestrial alluvial-paralic system. *Palaeogeography, Palaeoclimatology, Palaeoecology* **372**, 108–122.
- Buckland, S.T., and Hereward, A.C. (1982). Trap-shyness of yellow wagtails *Motacilla flava flavissima* at a pre-migratory roost. *Ringing and Migration* **4**, 15–23.
- Buhlmann, K.A., and Tuberville, T.D. (1998). Use of passive integrated transponder (PIT) tags for marking small freshwater turtles. *Chelonian Conservation and Biology* **3**, 102–104.
- Cagle, F.R. (1939). A system of marking turtles for future identification. *Copeia* **1939**, 170–173.
- Cagle, F.R. (1942). Turtle populations in southern Illinois. *Copeia* **1942**, 155–162.
- Gamble, T. (2006). The relative efficiency of basking and hoop traps for painted turtles (*Chrysemys picta*). *Herpetological Review* **37**, 308–312.
- Gehrt, S.D., and Fritzell, E.K. (1996). Sex-biased response of raccoons (*Procyon lotor*) to live traps. *American Midland Naturalist* **135**, 23–32.
- Gibbons, J.W. (1969). Ecology and population dynamics of the chicken turtle, *Deirochelys reticularia*. *Copeia* **1969**, 669–676.
- Gilbert, D.J., McKenzie, J.R., and Davies, N.M. (2001). Evidence from tag recapture experiments that fish learn to avoid fishing gear. *Journal of Agricultural, Biological, and Environmental Statistics* **6**, 281–291.
- Gower, G., Fenderson, L.E., Salis, A.T., Helgen, K.M., van Loenen, A.L., Heiniger, H., Hofman-Kamińska, E., Kowalczyk, R., Mitchell, K.J., Llamas, B, and Cooper, A. (2019). Widespread male sex bias in mammal fossil and museum collections. *Proceedings of the National Academy of Sciences* **116**, 19019–19024.

- Hancock, M.H., and Legg, C.J. (2012). Pitfall trapping bias and arthropod body mass. *Insect Conservation and Diversity* **5**, 312–318.
- Koper, N., and Brooks, R.J. (1998). Population-size estimators and unequal catchability in painted turtles. *Canadian Journal of Zoology* **76**, 458–465.
- Lindeman, P. V. (1990). Closed and open model estimates of abundance and tests of model assumptions for two populations of the turtle *Chrysemys picta*. *Journal of Herpetology* **24**, 78–81.
- Luhring, T.M., Connette, G.M., and Schalk, C.M. (2016). Trap characteristics and species morphology explain size-biased sampling of two salamander species. *Amphibia-Reptilia* **37**, 79–89.
- Mahmoud, I.Y. (1969). Comparative ecology of the Kinosternid turtles of Oklahoma. *Southwestern Naturalist* **14**, 31–66.
- Mahoney, S.M., and Lindeman, P. V. (2016). Relative abundance and diet of spiny softshells (*Apalone spinifera*) in a Lake Erie population. *Canadian Field-Naturalist* **130**, 275–280.
- Mali, I., Brown, D.J., Jones, M.C., and Forstner, M.R.J. (2012). Switching bait as a method to improve freshwater turtle capture and recapture success with hoop net traps. *Southeastern Naturalist* **11**, 311–318.
- McKnight, D.T., Harmon, J.R., McKnight, J.L., and Ligon, D.B. (2015). Taxonomic biases of seven methods used to survey a diverse herpetofaunal community. *Herpetological Conservation and Biology* **10**, 666–678.
- Moeller, B.A., Hellgren, E.C., Ruthven, D.C. III, Kazmaier, R.T., and Synatzske, D.R. (2005). Temporal differences in activity patterns of male and female Texas horned lizards (*Phrynosoma cornutum*) in southern Texas. *Journal of Herpetology* **39**, 336–339.
- Muraoka, Y., and Wichmann, G. (2007). Trap response of wood sandpipers *Tringa glareola*. *Ornis Fennica* **84**, 140–142.
- Pečnerová, P., Díez-del-Molino, D., Dussex, N., Feuerborn, T., von Seth, J., van der Plicht, J., Nikolskiy, P., Tikhonov, A., Vartanyan, S., and Dalén, L. (2017). Genome-based sexing provides clues about behavior and social structure in the woolly mammoth. *Current Biology* **27**, 3505–3510.
- Pelton, M.R., and Van Manen, F.T. (1996). Benefits and pitfalls of long-term research: A case study of black bears in Great Smoky Mountains National Park. *Wildlife Society Bulletin* **24**, 443–450.
- Ream, C., and Ream, R. (1966). The influence of sampling methods on the estimation of population structure in painted turtles. *American Midland Naturalist* **75**, 325–338.

- Rodda, G.H., Savidge, J.A., Tyrrell, C.L., Christy, M.T., and Ellingson, A.R. (2007). Size bias in visual searches and trapping of brown treesnakes on Guam. *Journal of Wildlife Management* **71**, 656–661.
- Schipper, J. (2007). Camera-trap avoidance by kinkajous *Potos flavus*: rethinking the “non-invasive” paradigm. *Small Carnivore Conservation* **36**, 38–41.
- Schumacher, F.X., and Eschmeyer, R.W. (1943). The estimation of fish populations in lakes or ponds. *Journal of the Tennessee Academy of Science* **18**, 228–49.
- Selman, W., Qualls, C., and Owen, J.C. (2013). Effects of human disturbance on the behavior and physiology of an imperiled freshwater turtle. *Journal of Wildlife Management* **77**, 877–885.
- Solórzano Kraemer, M.M., Kraemer, A.S., Stebner, F., Bickel, D.J., and Rust, J. (2015). Entrapment bias of arthropods in Miocene amber revealed by trapping experiments in a tropical forest in Chiapas, Mexico. *PLOS One* **10**, 1–24.
- Steen, D.A., Aresco, M.J., Beilke, S.G., Compton, B.W., Condon, E.P., Dodd, C.K. Jr., Forrester, H., Gibbons, G.W., Greene, J.L., Johnson, G., Langen, T.A., Oldham, M.J., Oxier, D.N., Saumure, R.A., Schueler, F.W., Sleeman, J.M., Smith, L.L., Tucker, J.K., Gibbs, J.P. (2006). Relative vulnerability of female turtles to road mortality. *Animal Conservation* **9**, 269–273.
- Stoks, R. (2001). Male-biased sex ratios in mature damselfly populations: Real or artefact? *Ecological Entomology* **26**, 181–187.
- Tesche, M.R., and Hodges, K.E. (2015). Unreliable population inferences from common trapping practices for freshwater turtles. *Global Ecology and Conservation* **3**, 802–813.
- Thorbjarnarson, J. (1997). Are crocodylian sex ratios female biased? The data are equivocal. *Copeia* **1997**, 451–455.
- Vanderkist, B.A., Xue, X., Griffiths, R. and Martin, K. (1999). Evidence of male-bias in capture samples of marbled murrelets from genetic studies in British Columbia. *Condor* **101**, 398–402.
- Vogt, R.C. (1980). New methods for trapping aquatic turtles. *Copeia* **1980**, 368–371.
- Willson, J.D., Winne, C.T., and Keck, M.B. (2008). Empirical tests of biased body size distributions in aquatic snake captures. *Copeia* **2008**, 401–408.
- Wood, M.D., and Slade, N.A. (1990). Comparison of ear-tagging and toe-clipping in prairie voles, *Microtus ochrogaster*. *Journal of Mammalogy* **71**, 252–255.

Table 1: The raw number of unique individuals and number of capture events for each of the six species encountered during this study.

Species	Unique Individuals	Total Captures
<i>Trachemys scripta</i>	88	385
<i>Sternotherus odoratus</i>	127	240
<i>Chelydra serpentina</i>	2	3
<i>Pseudemys concinna</i>	3	3
<i>Chrysemys picta</i>	2	4
<i>Apalone spinifera</i>	1	6
Total	225	641



Figure 1: The locations of traps during the first and third trapping periods. Circles represent traps of the stationary group and squares represent traps of the moved group.



Figure 2: The locations of traps during the second trapping period. Circles represent traps of the stationary group and squares represent traps of the moved group.

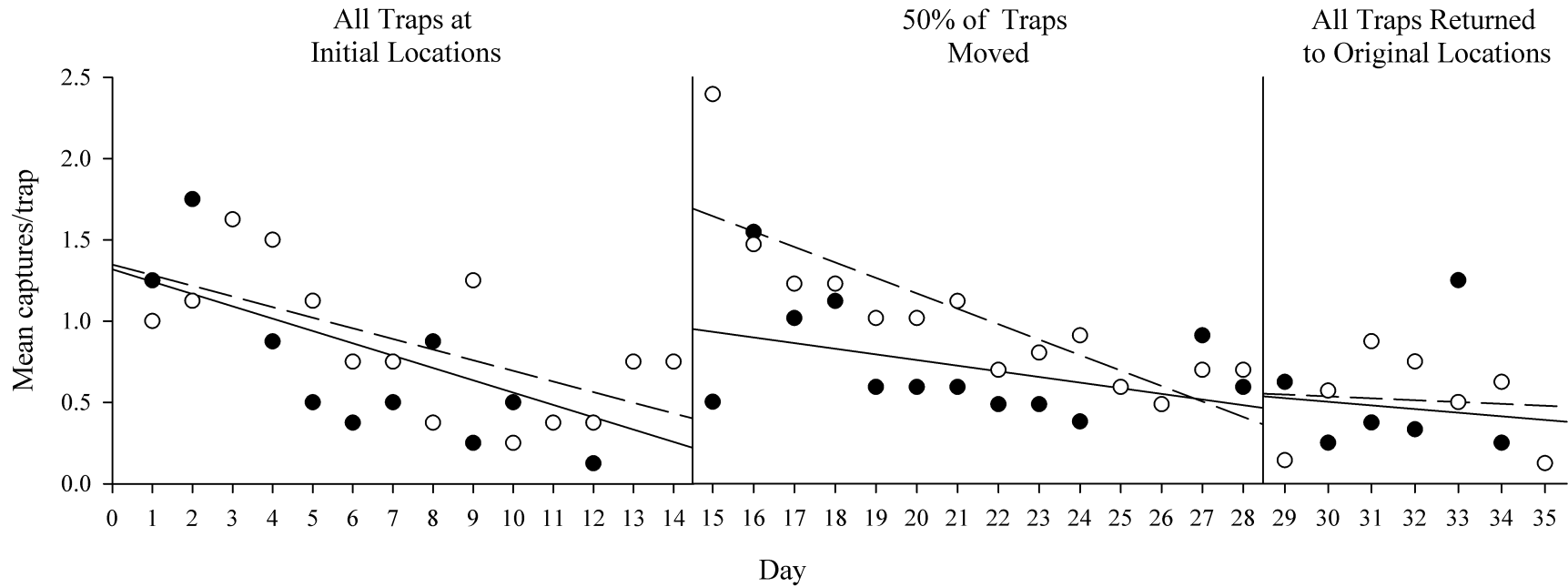


Figure 3: Mean *Trachemys scripta* captures per trap per day. Filled circles represent daily means for the stationary trap group. Open circles represent daily means for the moved trap group. Although only the daily mean value for each for each day is shown for the sake of readability, regression lines are those for raw number of captures/trap, with each trap providing a data point for each day. Solid lines are regressed on traps from the stationary group. Broken lines are regressed on traps from the moved group. Group means were significantly different only during the second trapping period ($F_{1, 206} = 7.28, P = 0.017$).

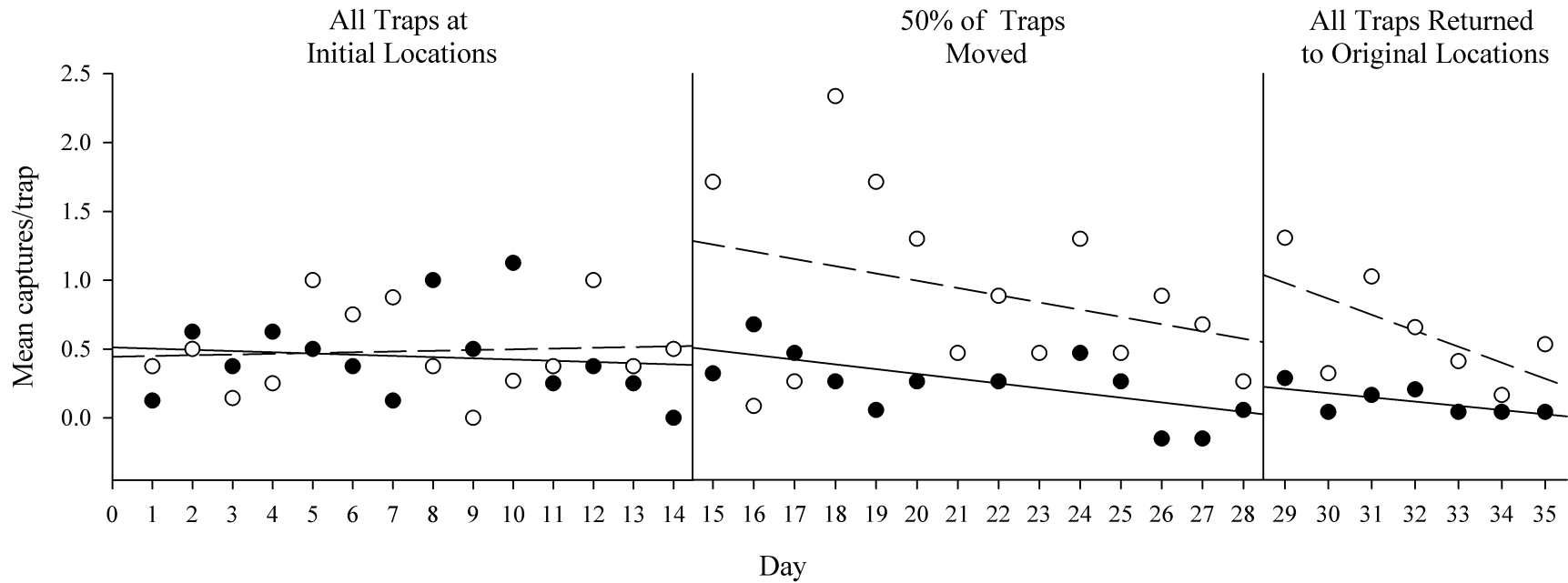


Figure 4: Mean *Sternotherus odoratus* captures per trap per day. Filled circles represent daily means for the stationary trap group. Open circles represent daily means for the moved trap group. Although only the daily mean value for each for each day is shown for the sake of readability, regression lines are those for raw number of captures/trap, with each trap providing a data point for each day. Solid lines are regressed on traps from the stationary group. Broken lines are regressed on traps from the moved group. Group means were significantly different only during the third trapping ($F_{1, 92} = 8.57$, $P = 0.009$).

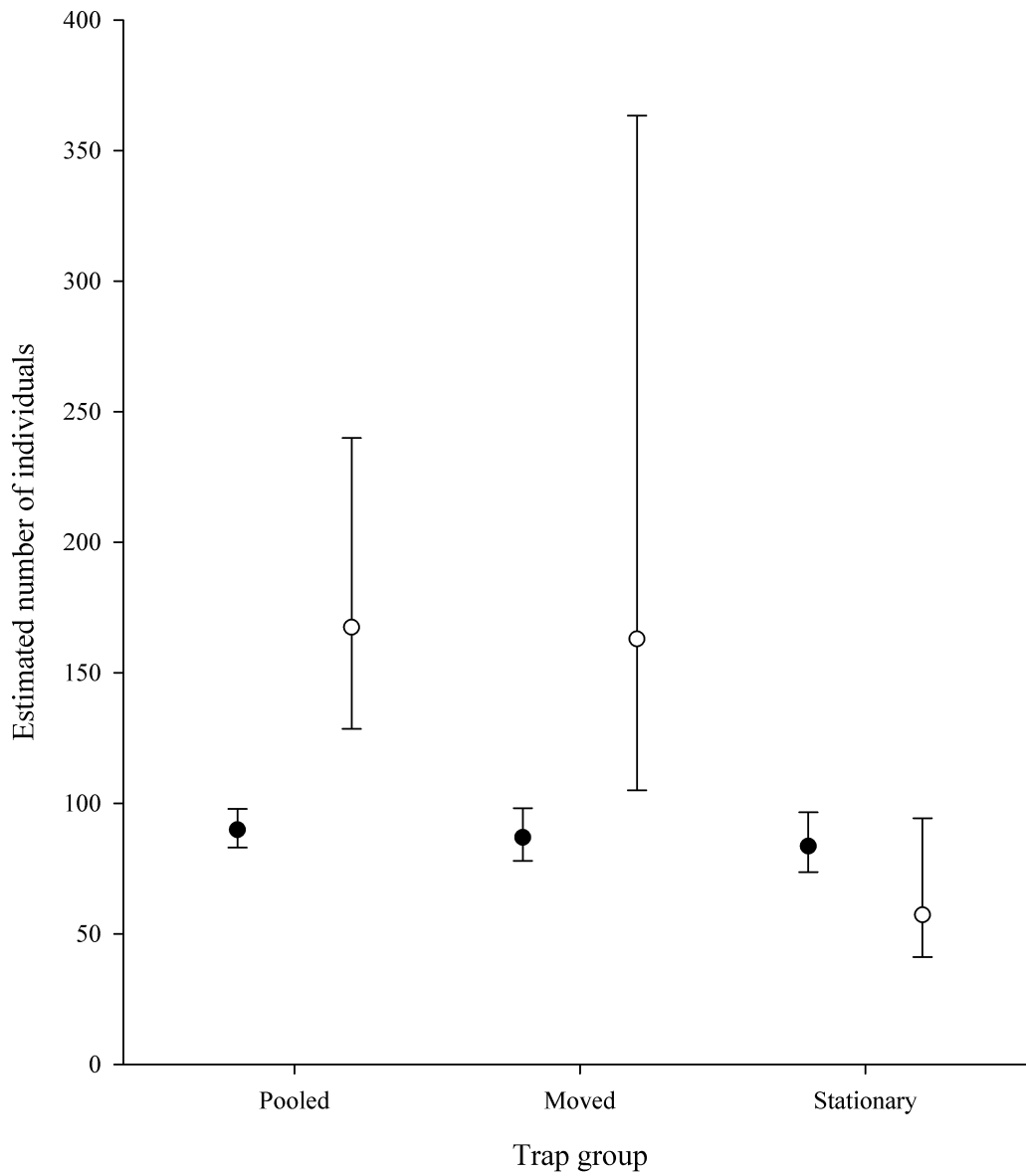


Figure 5: Schumacher-Eschmeyer abundance estimates for *Trachemys scripta* (closed circles) and *Sternotherus odoratus* (open circles) generated with five capture periods of seven days for each of the two trap groups and for the pool of all captures. Error bars represent 95% confidence intervals for each estimate of abundance.

SUMMARY

I performed trapping surveys of the turtle communities at six strip pit lakes and five natural lakes in and around the Mined Lands Wildlife area in southeastern Kansas. Six species were encountered in both types of lake, although which species occurred in any individual lake varied considerably. One additional species was encountered in a natural lake, but only a single individual was ever caught. Species richness and Simpson diversity were at least as high in the strip pits as they were in natural lakes. Species representation in the community varied between lake types. Common Snapping Turtles were captured at lower rates in strip pits than in natural lakes. All other species of freshwater turtle were captured in strip pits at least at similar frequencies to those at which they were captured in natural lakes. Painted turtles appear to be more abundant in strip pits, but the difference was not significant. Species representation within communities varied between years in natural lakes but not in strip pits. This appears to be driven by consistent dry weather that caused Common Snapping Turtles to largely abandon the natural lakes for estivation or other bodies of water. Variation in water depth, canopy cover, and presence of submerged vegetation may be involved in the distribution of the species encountered, but the environmental factors I measured only accounted for a small proportion of the variation in species abundance between trap locations. Overall, strip pit lakes at MLWA appear to be providing adequate habitat to support robust turtle communities.

I also performed an experiment to test the ability of turtles to learn to avoid traps. This consisted of two groups of traps being used to simultaneously survey the community of a strip pit. One group remained stationary for the 35 day duration of the experiment. The other group was relocated twice. In the first period of the experiment, both groups of traps were in their

original locations. In the second period, traps in the moved group were relocated to new locations. In the third period, both groups were again in their initial locations. Capture rates of both Slider Turtles and Eastern Musk Turtles declined over the course of the experiment. Capture rates of Slider Turtles were higher in the moved group than in the stationary group during the second period but were not significantly different during the other two periods. Capture rates of Eastern Musk Turtles were similar between the two groups during the first and second periods but were higher in the moved group during the third period. This suggests that both species are learning to avoid the locations of traps. Abundance estimates based on captures from each trap group were similar to the estimate based on a pool of all traps for Slider Turtles. For Eastern Musk Turtles, the abundance estimate generated by the moved traps was similar to that generated from the pool of all traps, but the estimate derived from only the stationary trap group was far lower. This discrepancy was large enough to invert inferences about the most abundant species in the community. Estimates derived from the moved trap group correctly showed that Eastern Musk Turtles were the most abundant species in the community, while estimates from the stationary trap group erroneously portrayed Slider Turtles as the most abundant species. This demonstrates that the periodic relocation of traps allows for more accurate inferences about the structure of turtle communities that would otherwise require considerably greater trapping effort.

ADDITIONAL REFERENCES

- Burke, V.J., and Gibbons, J.W. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina bay. *Conservation Biology* 9: 1365–1369.
- Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding’s Turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. *Conservation Biology* 7: 826–833.
- Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1994. Demographics of Common Snapping Turtles (*Chelydra serpentina*): implications for conservation and management of long-lived organisms. *American Zoologist* 408: 397–408.
- Devault, T.L., P.E. Scott, R.A. Bajema, and S.L. Lima. 2002. Breeding bird communities of reclaimed coal-mine grasslands in the American Midwest. *Journal of Field Ornithology* 73: 268–275.
- Howell, H.J., and R.A. Seigel. 2019. The effects of road mortality on small, isolated turtle populations. *J. Herpetology* 53: 39–46.
- Lannoo, M.J., V.C. Kinney, J.L. Heemeyer, N.J. Engbrecht, A.L. Gallant, and R.W. Klaver. 2009. Mine spoil prairies expand critical habitat for endangered and threatened amphibian and reptile species. *Diversity* 1: 118–132.
- Lovich, J.E., J.R. Ennen, M. Agha, and J.W. Gibbons. 2018. Where have all the turtles gone, and why does it matter? *BioScience* 68: 771–781.
- Muraoka, Y., and Wichmann, G. 2007. Trap response of Wood Sandpipers *Tringa glareola*. *Ornis Fennica* 84: 140–142.
- Nichols, J.D., J.E. Hines, and K.H. Pollock. Effects of permanent trap response in capture probability on Jolly-Seber capture-recapture model estimates. *Journal of Wildlife Management* 48: 289–294.
- Ream, C., and R. Ream. 1966. The influence of sampling methods on the estimation of population structure in painted turtles. *American Midland Naturalist* 75: 325–338.
- Schipper, J. 2007. Camera-trap avoidance by Kinkajous *Potos flavus*: rethinking the “non-invasive” paradigm. *Small Carnivore Conservation* 36: 38–41.
- Stiles, R.M., J.W. Swan, J.L. Klemish, and M.J. Lannoo. 2017. Amphibian habitat creation on postindustrial landscapes: a case study in a reclaimed coal strip-mine area. *Canadian Journal of Zoology* 95: 67–73.

Tesche, M.R., and K.E. Hodges. 2015. Unreliable population inferences from common trapping practices for freshwater turtles. *Global Ecology and Conservation* 3: 802–813.