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A SURVEY OF THE FRESHWATER TURTLES IN EASTERN OKLAHOMA

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

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1. To conduct an intensive two-year survey of the freshwater turtle species of eastern Oklahoma.

2. To systematically survey and compare turtle populations from sites with little or no historical commercial harvest to sites with known historical commercial harvest.

3. To conduct an experimental study in a group of suitable streams in eastern Oklahoma designed to measure the impact of simulated commercial turtle harvest on natural communities of freshwater turtles.

Summary of Progress:

The attached Master's Thesis titled "A survey of the freshwater turtles of eastern Oklahoma" by Eric P. Johansen from Oklahoma State University serve as the final report.

Prepared by: Eric Johansen and Stanley Fox

Date: 13 June 2012

Approved by: [signature]

Fisheries Division Administration
Oklahoma Department of Wildlife Conservation

[signature]

John D. Stafford
Federal Aid Coordinator
Oklahoma Department of Wildlife Conservation

A SURVEY OF THE FRESHWATER TURTLES OF EASTERN OKLAHOMA

By

ERIC P. JOHANSEN

Bachelor of Science in Biology
Austin Peay State University
Clarksville, TN
2009

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A SURVEY OF THE FRESHWATER TURTLES OF EASTERN OKLAHOMA

Dissertation Approved:

Dr. Stanley Fox

Thesis Adviser

Dr. David M. Leslie Jr.

Dr. Jason Belden

Dr. Sheryl A. Tucker

Dean of the Graduate College

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CHAPTER I

HISTORICAL COMPARISONS OF 35 SITES ACROSS EASTERN OKLAHOMA PREVIOSULY SAMPLED BY RIEDLE 1997–1999.

ABSTRACT

Over 852,000 turtles were reported harvested in Oklahoma in 1994–2010. At these rates of harvesting, turtle populations in Oklahoma may be unable to sustain themselves. Without swift changes, the aquatic turtles of Oklahoma may reach a point where they cannot recover. I conducted an intensive 2-year survey of the freshwater turtle species of eastern Oklahoma, covering 35 sites that were previously surveyed for freshwater turtles by Riedle (2001) in 1997–1999. The results of my study were used to determine if there has been a decline in aquatic turtle species in eastern Oklahoma. Preliminary findings were also reported to the Oklahoma Department of Wildlife Conservation (ODWC) to give them current information as they considered continuing the present state-wide ban on commercial harvesting of turtles in public waters through the duration of my study. Using the data collected by Riedle in 1997–1999, I sampled at the same sites in 2009–2010 and compared catch per unit effort (CPUE), species richness, and species diversity separately for northeastern and southeastern Oklahoma. I found a significant decrease in CPUE now compared to 1997–1999 across both the northeastern and the southeastern sites. I also saw significant declines in species richness and species diversity, but only for

northeastern sites. I also compared carapace lengths in 2009–2010 between northeastern and southeastern sites for the three most harvested species. In two of the three species, turtles were significantly smaller in the northeast. Overall, it appears that harvest has played a role in the decline of aquatic turtle species across eastern Oklahoma since Riedle's surveys in 1997–1999. These declines have been more severe in northeastern than southeastern Oklahoma.

INTRODUCTION

Worldwide declines in biodiversity, with special attention to the rapid extinction of reptiles and amphibians, especially turtles, have recently been documented (van Dijk et al. 2000) Aquatic turtles and tortoises are at higher risk than any other group of reptiles, with approximately 55 percent of turtle species worldwide considered threatened (Turtle Taxonomy Working Group 2010). The severity of the crisis faced by turtles was highlighted by Rhodin (1999), who recognized 293 turtle species and subspecies as threatened with extinction or already extinct.

Like with most taxa, turtles are declining because of threats that stem from a variety of human and non-human induced impacts, including unsustainable harvest, pollution, urbanization, fragmentation, pathogens, nest predation, and disease (Gibbons et al. 2000, Rizkalla et al. 2006). Turtles have high nest predation from predators like raccoons (*Procyon lotor)*, and recent work has brought attention to nests being infested by ants and even phorid flies (Holcomb et al. 2011). An important disease implicated in turtle declines is a contagious respiratory ailment caused by the bacterium *Mycoplasma agassizii* whose symptoms are similar to pneumonia, which affects turtles' lungs and can devastate wild turtle populations (Ernst 2009; Gibbons et al. 2000). Turtles are often kept as pets and release of pet turtles into the wild can be an avenue for the introduction of pathogens into wild populations. The introduction of reptiles and amphibians released by pet owners also can be damaging to ecosystems because of the introduction of potentially invasive, exotic species. Approximately 1.8 million reptiles are imported into the United States (U.S.) each year, and nearly 90 %of those are non-native species (Perry and Farmer. 2011). Recently, a widespread and growing exploitation of turtles has led to near extinction of many turtle species, especially in Asia (Thorbjarson et al. 2000, Shi et al. 2007). Turtles illustrate a type III survivorship curve and therefore they are slow to reproduce and their reproductive success is low (Gibbons 1968), factors that make them slow to recover from population declines. The export of turtles to Asia for food, medicine, and the pet trade has played an unusually large role in turtle declines in the U.S. (Compton 2000, Gibbons et al. 2000, Cheung and Dudgeon 2006). The influence of Asian markets on North American turtle declines has increased since bans were placed on the import of turtles by the European Union and United Kingdom, consequently sending nearly all turtles harvested in the U.S. to Asia. Approximately 32 million turtles were exported to Asia from the United States between 2002 and 2005 (Senneke 2006). In 1997, 97% of all reptiles exported from the United States were turtles, which are the most sought animal in the pet trade. Over 950,000 individuals of 157 turtle species were found in a 35-month survey of markets in Hong Kong, China, and 124 of the species were aquatic (Cheung and Dudgeon 2006).

Not all exports are wild-caught turtles; currently, turtle farms in Louisiana account for approximately 90% of all turtles exported from the United States, but this does not alleviate all conservation concerns. Turtles face problems from a process called ranching, in which gravid females are collected from natural habitats, and their eggs and young are harvested in captivity and the juveniles are then sold. This is similar to conservation programs that capture gravid females and rerelease the juveniles into the wild to increase genetic variation in natural populations but in this former case, juveniles are not released into the wild. Ranching also can reduce native population numbers (Franke and Telecky 2001). Some estimates report that approximately 9 million reptiles and amphibians were kept as pets in the United States in 2000, with the most common types being turtles and tortoises, of which many are listed as captive-bred (Franke and Telecky 2001).

In the United States, 32 states do not allow turtle harvesting. Of the 18 states that allow harvesting, some have placed temporary bans on commercial turtle harvesting (Center for Biological Diversity 2008). In response to concerns from conservation and health groups in scientific literature (Heck 1998, Riedle et al. 2004) and popular media (Center for Biological Diversity 2008, Hylton 2008), the Oklahoma Department of Wildlife Conservation (ODWC) enacted a three-year moratorium on turtle harvesting in May 2008 and then granted a two-year extension on commercial harvest of turtles from public waters in April 2011, set to expire May 2013. Prior to the moratorium being established, regulations on the capture and possession of all turtles were overseen by the ODWC. The specific reptile regulations can be found online at the ODWC website under OAC Title 800:25-7 Part 3, or OAC Title 800:15 Subchapter 9. These regulations provide little control over means and location of turtle harvest, or the numbers taken; however, previous regulations did prohibit all harvesting of Alligator Snapping Turtle (*Macrochelys temminckii)* and Northern Map Turtle (*Graptemys geographica)*. With no regulations governing size of harvested individuals, both mature and immature individuals can be collected, with the most pressure being on larger individuals because turtles are sold by the pound. Although some populations of reptiles, e.g., some anoles, some geckos, and a few snake species, can sustain at least a moderate level of commercial harvesting (Fitch, 1998 and Franke and Telecky 2001), this is not true of most native turtle populations.

There are approximately 320 species of turtles in the world, and 17 of these can be found in Oklahoma (Ernst 2009). Oklahoma has 5 of the 7 families of turtles found in the United States and Canada (Ernst et al. 2009), and the eastern one-third of Oklahoma has 14 of the 15 species of freshwater turtles found within the state (Table 1; Conant and Collins 1998, Sievert and Sievert 2005). Turtle assemblages in Oklahoma are noteworthy because there are unique combinations of species not present in other places, and several species approach their northernmost longitudinal geographic range boundaries (Stone 2005). The ecological status of most turtle species is not well known (Oklahoma Natural Heritage Inventory 2003). The Oklahoma Natural Heritage Inventory lists 5 species of aquatic turtles as Rare Oklahoma Vertebrates: Alligator Snapping Turtle (*M. temminckii*), Chicken Turtle (*Deirochelys reticularia*), Northern Map Turtle (*G. geographica*), Mississippi Map Turtle (*Graptemys pseudogeographica kohnii*), and Painted Turtle (*Chrysemys picta*). Two species are listed as species of special concern in ODWC's Comprehensive Wildlife Conservation Strategy: *M. temminickii* and *G. geographica*. A study focusing on the status and distribution of *M. temminckii*, a protected species in Oklahoma, concluded that many historical populations in eastern Oklahoma have been extirpated, and only two protected localities with sizeable, healthy populations were found (Riedle et al. 2004). In a broad survey of Oklahoma aquatic turtles from 1997 to 1999, Riedle (2001) found serious population declines in multiple species of freshwater turtles in multiple river drainages.

The 3-year moratorium on turtle harvest from public waters enacted in May 2008 by the ODWC provided an opportunity for further assessment of the freshwater turtle populations of eastern Oklahoma during which harvest was eliminated. Consequently, I sampled turtles in eastern Oklahoma, surveying the same sites that Riedle (2001) did in 1997–1999. I expected that aquatic turtle populations in Oklahoma would follow the same trends of worldwide reptile declines, and therefore I expected to collect significantly fewer turtles than collected by Riedle. Harvest was reducing numbers and possibly species richness while Riedle was trapping; however, the majority of harvesting occurred after Riedle's study. Legal harvest began in 1994 and continued for almost 10 years after Riedle finished his study, likely reducing numbers each year until the moratorium took effect in May 2008. I predicted that numbers, after only one year of moratorium, would still be low due to the fact that turtles take a long time to mature. I also hypothesized that species richness and diversity would be lower in my samples than in those of Riedle. I further hypothesized that size distributions would be biased toward smaller turtles, and as a consequence of reduced competition, extant turtles might have a higher condition index.

METHODS

Study Sites

I selected 20 sites from northeastern Oklahoma and 15 sites from southeastern Oklahoma. Three sites (Pennington Creek, Walnut Creek, and Green Leaf) of the 38 sites originally surveyed by Riedle in 1997–1999 had been altered enough that the sites were excluded from my study. For example, one site was now dry or had little running water compared with 10 years ago, preventing trapping using standard aquatic trapping techniques. Sites were classified as creeks, ponds, river, sloughs, or lakes. I had 17 creeks: Mountain Fork Creek, Sandy Creek, Gaines Creek, Buffalo Creek, Bell Creek, Big Cabin Creek, Grove Greek, Big Vian Creek, Little Vian Creek, Hezekiah Creek, Dirty Creek, Spring Creek, 14 Mile Creek, Mill Creek^2 and Dutchess Creek. I had 10 rivers: Glover River, Little River (combined sites), Kiamichi River, Poteau River, Caney River, Deep Fork River, Verdigris River, Spring River, Illinois River, and Neosho River^2 (*^{2} represents two creeks with the same name, or a stretch of river that was trapped twice). I had 4 lakes: Red Lake, Twin Lakes, Ft. Gibson Lake, and Sally Jones Lake; two ponds: Dick's Pond and Goose Pen Pond; and two sloughs: Horton Slough and 41 Cutoff Oxbow. For consistency, I during 2009–2010, sampled the sites sampled by Riedle in 1997–1999 at approximately the same time of the year. The northeastern and southeastern sites were surveyed by two separate crews. Northeastern sites were surveyed by the author and southeastern sites were surveyed by Dr. Tim Patton (Southeastern Oklahoma State University, Durant, Oklahoma). Minor differences in trapping protocol (e.g., number of traps per site, duration of trapping) are discussed in the methods section below.

Trapping Methods

All traps used for this study were commercial hoop nets, 2.1 m in length and constructed of three 1.05-m diameter hoops covered with 2.5-cm square mesh (Memphis Net and Twine Company, Memphis Tennessee). These are the same trap dimensions previously used by Riedle (2001). Following the methods of Riedle (2001), nets were baited with fresh dead fish. Bait fish were caught with gill nets, or by incidental capture in the turtle nets. If no fresh fish were available, sardines were used as bait. I mostly used blue gill, sunfish, catfish, and carp species as bait, but other species were also sometimes used. I used roughly the same quantity of bait for each trap, cutting larger fish into two or more pieces and punching holes in the sides of smaller fish to better release scent. Traps were set in the late afternoon or early evening and checked the following morning in the northeast; traps were set continuously for 24 hours in the southeast (see below for applied correction). Traps were positioned so that a portion of the trap extended above the water to prevent drowning of captured turtles and placed in a location likely to yield turtles based on tree cover, snags, and basking areas. Both field crews were experienced with turtle trapping and both crews met with Daren Riedle prior to data collection in order to determine exact trap localities and trap setting methods that Riedle used in his previous study (Riedle 2001). At each site, I set traps along a 100-m transect. Any animals that died in the course of the study were deposited in the Oklahoma State University Collection of Vertebrates. A minimum of 30 net nights was used to compare to each site surveyed by Riedle in 1997–1999 (Figure 1, Table 2). If > 30 net nights were used by Riedle, that number was matched, but only at the northeastern sites. The southeastern crew used a constant 30 net nights at all sites. Geographical coordinates were taken at each site with handheld GPS units (Garmin™ eTrex Vista C) (Appendix 1). Catch per unit effort (CPUE) served to standardize results between the northeastern and southeastern sites of this study and those of Riedle (2001). CPUE was adjusted for southeastern sites using (15/24) X (turtles per night net) because those traps were left out for 24 hours, compared to the 15 hours per trap set at northeastern sites. This correction assumes a linear relationship of turtle captures over a 24-hour period, which is probably not the case for all species. However, without detailed knowledge of capture rates over daytime and nighttime hours per species, the correction applied is an unbiased and necessary one; traps kept out more hours will capture more turtles. I did not adjust for species richness because I presumed that the 15-hour trapping period would capture the same species as the 24-hour period, just not the same numbers per species. Because the Shannon-Weiner index of species diversity uses species proportions (and it is unlikely that the longer session would yield more species as argued above), the different trapping durations should not affect this metric.

Marking Methods.

All turtles captured were recorded and uniquely marked using a Dremel™ (7.2V Cordless MultiPro or 10V Cordless MultiPro) to create notches at the outer edge of the marginal scutes of the carapace (Figure 2; Cagle 1939). Small holes in specific marginal scutes of both species of snapping turtles were drilled, and a short white zip tie was placed in these holes to ensure they would not close prematurely. Softshell turtles were marked using a modified version from Plummer (2008): using special numbered steel tags (National Wing Brand™, Jiffy Model, style 893) attached to the posterior right side of the carapace. These marking techniques allowed me to determine whether animals were recaptured on subsequent trapping occasions.

Individuals were sexed when possible by the presence of secondary sexual characteristics. Males of most species have longer claws and thicker tails, with the cloacal opening located nearer the posterior marginal scutes. Turtles were considered juveniles if their carapace length measured < 100 mm and they showed no obvious secondary sexual characteristics (Tucker et al. 2008). *Apalone* species can be sexed even as juveniles using presence of dots on the carapace of males; females lack this definitive circle pattern on the carapace (Ernst 2009). Straight-line carapace length (SCL), from the first marginal scute behind the head to last marginal scute near the tail, and straight-line plastron length (SPL), from intergular scute (first scute behind lower neck) to anal scute, were measured to the nearest millimeter using calipers. Mass was measured to the nearest gram for individuals < 1000 g and to the nearest 10 grams for those > 1000 g. Any injuries and abnormalities also were noted. All turtles recaptured were measured and weighed each time they were captured. All turtles were released at the site of capture after all data were collected. Turtles that needed further processing were placed in a transfer container with approximately 8 cm of water from the local site, preventing desiccation. All field methods were approved by the OSU Institutional Animal Care and Use Committee (Protocol No. 72345). All individuals engaged in trapping had a valid Oklahoma Scientific Collectors Permit.

Statistical Analyses

Trap success was measured as turtles per net night using CPUE, comparing each location from Riedle 1997–1999 to my success using a paired t-test for northeastern (n = 20) and southeastern (n = 15) sites separately. Species richness (number of species captured) was compared using the same method for all sites. The Shannon-Wiener index of species diversity was also compared using the same method, first with all species and then after removing *T. scripta* from the analysis. This was done because *T. scripta* dominated the total number of turtles captured and was potentially biasing the diversity measure.

Using the same paired *t*-test for CPUE, I analyzed Red-ear Sliders (*T. scripta*), Softshell Turtles (both *Apalone* species pooled), and Common Snapping Turtles (*Chelydra serpentina*) separately. These three "species" are the most likely to be harvested because they provide the most profit for turtle harvesters. I also used standard t-tests to compare body sizes for each of these three species from northeastern and southeastern sites. I first tested for sexual dimorphism in body size. If there was no significant sexual dimorphism for a species, sexes were pooled for analysis of body size. If there was significant sexual dimorphism, sexes were analyzed separately. I used statistical software Statistical Package for the Social Sciences (SPSS) version 18 and 19 (IBM Corp., Armonk, New York).

RESULTS

In the northeastern sites, I captured 986 turtles during 774 net nights compared to 2595 turtles during 598 net nights by Riedle in 1997–1999 (Figure 3). CPUE (species pooled) at paired sites from my study was significantly lower than in 1997–99 ($t = 4.841$, $df = 19$, $p < 0.001$) (Figure 4). Species richness at paired sites also was significantly lower now compared to 1997–99 ($t = 3.684$, $df = 19$, $p = 0.002$) (Figure 5). Species diversity at paired sites did not differ significantly from 1997–99 to now (paired t-test: $t = .088$, $df = 17$, $p = 0.505$). After data for *T. scripta* were removed, species diversity showed significant declines at northeastern sites ($t = 2.199$, $df = 19$, $p = 0.040$).

In the southeastern sites, I captured a total of 1018 turtles during 460 net nights compared to 991 turtles during 397 net nights captured by Riedle in 1997–1999 (Figure

3). To account for the difference in trapping methods, that total of 1018 turtles was adjusted downward to 636 (0.625 x 1018). The southeastern sites showed a less severe decline in CPUE than the northeastern sites, although it was still significantly lower now than in 1997–1999 (t =3.043, df = 14, p = 0.009) (Figure 6). Species richness at paired sites did not differ between now and 1997–1999 (t = -1.017, df = 14, p = 0.326). Species diversity at paired sites also was not different now compared to 1997-99 (t = -0.366, df = 12, p = 0.477). Even after removal of data for *T. scripta*, species diversity still showed no significant declines at southeastern sites (t = 0.739, df = 9, p = 0.403).

I separately analyzed *T. scripta*, *Apalone* spp., and *C. serpentina* because they provide the most profit for turtle harvesters and generally are the most harvested. CPUE at paired sites in northeastern Oklahoma for each species was significantly lower now compared to 1997–99 (*C. serpentina*: t = 2.124, df = 19, p = 0.047; *Apalone* spp.: t = 2.393, df = 19, p = 0.027; and *T. scripta*: t = 4.066, df = 19, p = 0.001). I also analyzed prevalence of each species (number of sites occupied) using a chi-squared test for heterogeneity to determine if there were significantly fewer occupied sites now compared to 1997–99. For one of these species, C. *serpentina*, prevalence was significantly lower now (X^2 = 3.950, df = 1, p = 0.047); however, *Apalone* spp. (X^2 = 0.125, df = 1, p = 0.723) and *T. scripta* (X^2 = 0.0, df = 1, p = 1.00) did not have significantly different prevalence (Figure 7).

In southeastern Oklahoma, CPUE of *T. scripta* at paired sites had significantly lower CPUE now than in 1997–99 (t = 2.4883, df = 14, p = 0.026). CPUE did not differ now compared to 1997–99 for the other two most harvested species (*C. serpentina*: t = 0.523, df = 14, p = 0.690, and *Apalone* spp.: t = -1.734, df = 14, p = 0.105). I also analyzed prevalence at the southeastern sites and found no significant differences in two of the three most harvested species (*C. serpentina*: $X^2 = 0.354$, df = 1, $p = 0.552$, and *T. scripta*: $X^2 = 0.969$, df = 1, $p = 0.325$). Significantly *higher* prevalence now compared to 1997–99 was found in *Apalone* spp., ($X^2 = 3.889$, df = 1, $p = 0.049$) (Figure 8).

Finally, I analyzed differences in body size between sites in northeastern ($n = 20$) and southeastern ($n = 15$) Oklahoma for the three most likely harvested species. Sexual dimorphism was evident for two species (*Apalone* spp.: $t = 6.596$, df = 57, $p < 0.001$; *T. scripta*: $t = -6.114$, df = 1623, $p < 0.001$) but not the third (*C. serpentina*: $t = -0.498$, df = 30, $p > 0.05$). For the first two species, sexes were analyzed separately. *Apalone* males and females from the northeastern sites were both significantly smaller (males: $t = -3.758$, df = 16, $p = 0.002$; females: $t = -4.712$, df = 39, $p < 0.001$) (Figure 9). *T. scripta* males from northeastern Oklahoma were significantly *larger* ($t = 2.174$, df = 1126, $p = 0.030$), but no differences were found for females ($t = 1.563$, df = 495, $p = 0.119$) (Figure 10). In *C. serpentina* with no sexual dimorphism, the northeastern sites had significantly smaller turtles than the southeastern sites ($t = -4.181$, df = 27, $p < 0.001$) (Figure 11).

DISCUSSION

Long-term field studies are useful for management and recovery of threatened or uncommon species (Heppell 1998). Comparing our results to Riedle from 1997–1999 at the exact same sites in Oklahoma after 10+ years allows for an evaluation of how turtle populations have been affected by anthropogenic impacts, including harvest. It seems that turtles are indeed struggling to keep up with changes in their habitats, and the lack of regulations on the harvesting of turtles is surely having a negative impact. Often it is desirable to prioritize management efforts because of funding difficulties (Heppell 1998);

however, the management effort in this case is simple—a continuation of the ban on commercial turtle harvesting in Oklahoma. With a continued ban, new studies will be able to focus on other issues that relate to turtle declines, including disease, habitat destruction, and pollution (Gibbons et al. 2000).

Similar to turtles, mussel species of Oklahoma were once harvested. Mussel harvest brought in more money per year than licenses for aquatic turtle harvest until 2007 when regulations were placed on mussel harvest due to severe declines (ODWC Report 2001–2010). So losing funds provided by the sale of licenses for commercial turtle harvest should not be an economic issue for the state of Oklahoma. Average return on a turtle harvested from Oklahoma waters can be computed as income received by ODWC for all harvest permits divided by total number of turtles harvested during the 10 year data set (ODWC report 2001–2010). This works out to be an average return per turtle of $0.047. This simply is an insignificant economic benefit, yet a hugely detrimental conservation impact. Although many mussel populations across the state are still vulnerable, they had one less challenge to deal with once commercial harvesting was eliminated. Just like turtles, mussels face many challenges in dealing with human influences, and overharvesting has played a large role in their declines. However, by instituting the moratorium, at least the negative anthropogenic effect of overharvesting appears to have been curbed by the state of Oklahoma.

Riedle, in his 1997–99 study (Riedle 2001), remarked on turtle declines in eastern Oklahoma, emphasizing the declines in southeastern Oklahoma. It seems that turtle populations in northeastern Oklahoma are now declining most dramatically, while those in southeastern Oklahoma have already reached bottom and are possibly beginning to recover, e.g., species richness and prevalence are not less now compared to 1997–1999, even though significant declines in total turtles are still evident. If portions of southeastern Oklahoma are truly beginning to recover, it has taken 10+ years of low or no harvesting to do so and yet the southeastern sites still have significantly lower current CPUE. Without controlled regulation of harvest, these slow-to-mature aquatic species of turtles will be unable to maintain stable populations and we will likely see population crashes in turtles across Oklahoma, with a concomitant devastating loss of genetic diversity. With little cultural or economic benefit to Oklahoma or the majority of its residents, unregulated turtle harvesting is damaging to our state's turtle populations. If Oklahoma and the ODWC decide not to follow along with other states that are adapting turtle regulations and bans (e.g., Texas) even more harvesters may enter Oklahoma and remove even more turtles, pushing the already stressed populations over the edge. Turtle harvest additionally may be directly harmful to residents who purchase or capture these turtles for food; a study underway to quantify mercury in *C. serpentina* and *T. scripta* across eastern Oklahoma suggests that consumption of turtle meat may impose a public health hazard (J. B. Belden, pers. comm.).

Turtles sold for meat are sold by the pound, and therefore the most profitable turtles will be the larger ones. These larger turtles are the breeding stock for the maintenance of stable populations. Compounding the problem is that in many species, adult females are the larger sex, so their removal disproportionately lowers the fecundity of the population, likely to values below replacement levels. Although my three most harvested species are the most sought, all turtles are susceptible to harvest, especially when considering the pet trade (Table 3). With over 800,000 Oklahoma turtles purchased from collectors since harvest began in 1994, commercial harvest would seem to have played a role in population declines across Oklahoma (Figure 12). The numbers reported are from the buyers of turtles and are not verified. They also do not include turtles collected for personal use. With this in mind, I can assume the number of turtles removed from the wild to be higher than the actual number reported.

In the late 1970s', prior to the legalization of harvest, large snapping turtles were often collected and sold to local restaurants (anonymous, Pers. Comm.). Therefore, with legal harvest during1994–2008, it is not surprising that few of the largest-sized adult turtles were captured in the present study, particularly in the northeast where harvest has likely been more recent and intense. The scarcity of the larger size classes at the northeastern sites suggests that heavy trapping pressures have removed large turtles, leaving only smaller ones.

I, like Hays and McBee (2010), generally found a unimodal size distribution, with the majority of the turtles from all eastern Oklahoma sites falling in the smaller to middle size classes. This was evident for *C. serpentina*, both sexes of *Apalone* spp., and female *T. scripta*. Lack of sexual dimorphism in *C. serpentina* may be due to a small sample size because it has been documented that male *C. serpentina* are generally larger (Ernst 2009). Opposite to the trends observed in *Apalone* and *Chelydra*, I found significantly larger *T. scripta* at northeastern sites. Even though these size differences were statistically significant (because of very large sample sizes for this species), they were small in magnitude (mean size difference ca. 3 mm), so they may be biologically unimportant. Alternatively, *T. scripta* males may currently encounter less interspecific competition and thus grow larger in the northeast, with its current impoverished turtle communities.

In summary, an overall reduction of turtle populations can be noticed across eastern Oklahoma. Significant declines in CPUE were found for both northeastern and southeastern sites separately. Data also show that the populations of all three of the most harvested species are significantly lower at northeastern sites, and of one of these at the southeastern sites. The reduction in prevalence of *C. serpentina,* the heaviest-bodied turtle in our study (excluding *M. temminckii* because it cannot be legally harvested), at both the northeastern and southeastern sites (the latter reduction not statistically significant) is strong evidence that harvesting has taken place across eastern Oklahoma. The state of Oklahoma has considered for some time the need to monitor the unregulated harvest of aquatic turtles. It is now time to take this consideration to the next level. In light of studies like Congdon et al. (1993), in which it was shown that the capacity for recovery of populations of aquatic turtles is slow and weak, and my results showing statistically significant reductions in CPUE across eastern Oklahoma, the ODWC should be prompted to permanently ban commercial turtle harvesting in all public waters. More data can be collected, but waiting too to take action data can handicap conservation efforts (Congdon et al. 1994). Turtles are among the last vertebrate species that can be legally harvested commercially in Oklahoma (minnows also can be harvested in the state). With the recent protection of endangered mussels in Oklahoma, harvesting regulations have become very strict and total harvest has consequently decreased, encouraging news for protected species (ODWC Reports 2001–2010).

The future of the moratorium and the protection it provides Oklahoma turtles is unknown. However, prior to the moratorium, *Macrochelys temminckii* was protected because of its rarity and low reproductive rate. This species had declined drastically across its range (Riedle 2004). *M. temminckii*, listed by the ONHI as rare, has a few relatively large and healthy populations in eastern Oklahoma (T. Patton, D. B. Ligon, and D. B. Moore, pers. comm., and E. P. Johansen, pers. observ.). With the conclusion of this study showing a significant decline in total turtles in eastern Oklahoma, there is the possibility that action will be taken to place the same protection on all Oklahoma turtles, i.e., causing a permanent ban on commercial turtle harvesting, if not all harvesting. If these regulations fail to take place soon, turtle populations, once depleted, could take decades to recover, even if harvests were to stop completely. Recognizing declines in long-lived species that have reports of substantial harvesting levels that could lead to severe reductions of local populations should prompt the ODWC to avoid conflicts between turtle harvesting and turtle conservation. This is especially true considering the few benefits that the stakeholders of Oklahoma receive from legal commercial harvest. I hope stakeholders do not need to wait for populations to be so reduced that they cannot recover before a plan to address recovery is put in place. As for any long-lived species, unsustainable harvest of adults and older juveniles for any period of time will eliminate genetic diversity and possibly put entire populations at risk of extinction.

LITERATURE CITED

Cagle, F.R. 1939. A system of marking turtles for future identification. Copeia 1939:170–173.

Center for Biological Diversity 2008. Website accessed on 1 Sep 2008: http://www.biologicaldiversity.org/campaigns/southern_freshwater_turtles/index.html

Cheung, S. M., and D. Dudgeon. 2006. Quantifying the Asian turtle crisis: market surveys in southern China, 2000–2003. Aquatic Conservation-Marine and Freshwater Ecosystems 16:751–770.

Compton, J. 2000. An overview of Asian turtle trade. In: P.P. van Dijk, B. L. Stuart, and A. G. J. Rhodin (eds.), Asian turtle trade: proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. Chelonian Research Monographs 2:33–84

Conant, R., and J. T. Collins. 1998. Reptiles and amphibians of eastern/central North America. Peterson Field Guide. Third edition. Houghton Mifflin Co., Boston, Massachusetts, USA.

Congdon, J.D., A. E. Dunham, and R. C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's Turtle (*Emydoidea blandingi*): 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 34(3):397–408.

Ernst, C. H., and J. E. Lovich. 2009. Turtles of the United States and Canada. Second Edition. Johns Hopkins University Press, Maryland.

Franke, J., and T. M. Telecky. 2001. Reptiles as pets: An examination of the trade in live reptiles in the United States. The Humane Society of the United States, Washington D.C.

Gibbons, J. W. 1968. Population structure and survivorship in Painted Turtles, *Chrysemys picta*. Copeia 2:260–268.

Gibbons, J. W., D. E. Scott, T. J. Ryan, K. A. Buhlmann, T. D. Tuberville, B. S. Metts, J. L. Greene, T. Mills, Y. Leiden, S. Poppy, and C. T. Winne. 2000. The global decline of reptiles, déjà vu amphibians. Bioscience 50:653–666.

Hays, K.A. and K. McBee. 2010. Populations demographics of Red-Eared Slider Turtles (*Trachemys scripta*) from Tar Creek superfund site. Journal of Herpetology. 44(3):441–446.

Heck, B. A. 1998. The Alligator Snapping Turtle (*Macroclemys temminckii*) in southeast Oklahoma. Proceeding of the Oklahoma Academy of Science. 78:53–58.

Heppell, S. S. 1998. Application of life-history theory and population model analysis to turtle conservation. Copeia 1998:367–375.

Holcomb, S.R. and J.L. Carr. 2011. Infestation of a naturally incubated nest of the alligator snapping turtle (Macrochelys temminckii) by the phorid fly *Megaselia scalaris*. Southwestern Association of Naturalist 56(3):427–430.

Hylton, S. 2008. State urged to prohibit turtle harvesting. Tulsa World March 31, 2008.

Oklahoma Department of Wildlife Conservation. Collection of annual reports, 2001–2010. Oklahoma City, OK.

Oklahoma Natural Heritage Inventory. 2003. Working list of rare Oklahoma vertebrates. http://www.biosurvey.ou.edu/download/heritage/verteb0503.pdf. Accessed on March 30, 2010.

Perry, G. and M. Farmer. 2011. Reducing the risk of biological invasion by creating incentives for pet sellers and owners to do the right thing. Journal of Herpetology 45(1):134–141.

Plummer, M. 2008. A notching system for marking Softshell Turtles. Herpetological Review 39:64–65.

Riedle, J. D. 2001. The ecology of the Alligator Snapping Turtle, *Machrochelys temminckii*, in Oklahoma. Unpublished M. S. thesis, Oklahoma State University, Stillwater.

Riedle, J.D., P.A. Shipman, S.F. Fox, and D.M. Leslie, Jr. 2004. Status and distribution of the Alligator Snapping Turtle, *Macrochelys temminckii*, in Oklahoma. Southwestern Naturalist 50:79–84.

Rhodin A. 1999. Celebrate the Turtle: Perception and preservation. Paper presented at Powermill 1999, 4th Occasional Freshwater Turtle Conference, 13-16 Aug 1999; Laughlin, NV, USA.

Rizkalla, C. E. and R. K. Swihart. 2006. Community structure and differential responses of aquatic turtles to agriculturally induced habitat fragmentation. Landscape Ecology 21:1361–1375.

Senneke, D. 2006. Declared turtle trade from the United States. World Chelonian Trust.

Sievert, G., and L. Sievert. 2005. A field guide to Oklahoma's amphibians and reptiles. Oklahoma Department of Wildlife Conservation, Oklahoma City, USA.

Shi, H., Parham, J.F., Lau, M., and Chen, T.H. 2007. Farming endangered turtles to extinction in China. Conservation Biology 21:5–6.

Stone, P. A., S. M. Powers, and M. E. Babb. 2005. Freshwater turtle assemblages in central Oklahoma farm ponds. Southwestern Naturalist 50:166–171.

Turtle Taxonomy Working Group Rhodin, A.G.J., P.P. van Dijk, J.B. Iverson, and H.B. Shaffer. 2010. Turtles of the world, 2010 update: annotated checklist of taxonomy, synonymy, distribution, and conservation status.

Tucker, J. K., C. R. Dolan, J. T. Lamer, and E. A. Dustman. 2008. Climatic warming, sex ratios, and Red-Eared Sliders (*Trachemys scripta elegans*) in Illinois. Chelonian Conservation and Biology 7:60–69.

Van Dijk, PP. 2000. The status of turtles in Asia. Asian turtle trade. Proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. Chelonian Research Monographs 2:15–23.

Table 1. Species of aquatic turtles in eastern Oklahoma with indication of capture from the 35 sites surveyed during the summers of 2009 and 2010.

Common name	Scientific name	Captured
Common Snapping Turtle	*Chelydra serpentina*	Y
Alligator Snapping Turtle	*Macrochelys temminckii*	Y
Mud Turtle	*Kinosternon subrubrum*	Y
Razor-backed Musk Turtle	*Sternotherus carinatus*	Y
Stinkpot	*Sternotherus odoratus*	Y
Painted Turtle	*Chrysemys picta*	N
Chicken Turtle	*Deirochelys reticularia*	N
Northern Map Turtle	*Graptemys geographica*	N
Ouachita Map Turtle	*Graptemys ouachitensis*	Y
Mississippi Map Turtle	*Graptemys pseudogeographica kohnii*	Y
River Cooter	*Pseudemys concinna*	Y
Red-eared Slider	*Trachemys scripta*	Y
Smooth Softshell	*Apalone mutica*	Y
Spiny Softshell	*Apalone spinifera*	Y

Table 2. The 38 sites sampled by Riedle in 1997–1999 and by the author in 2009–2010, showing number of net nights. Sites are listed from north to south. A zero in the 2009–2010 column indicates this site was not trapped. Region is NE = northeastern and SE = southeastern.

County	Site #	Location	Number of Net Nights 1997–1999	Number of Net Nights 2009–2010	Region (NE or SE)
Osage	1	Caney River	65	65	NE
Ottawa	2	Spring River	29	30	NE
Ottawa	3	Neosho River	20	30	NE
Craig	4	Big Cabin Creek	25	30	NE
Mayes	5	Spring Creek	20	30	NE
Mayes	6	Neosho River	10	30	NE
Wagoner	7	Ft. Gibson Lake	19	30	NE
Cherokee	8	14 Mile Creek	15	30	NE
Wagoner	9	Verdigris River	38	38	NE
Wagoner	10	Green Leaf Lake	15	0	NE
Okmulgee	11	Walnut Creek	10	0	NE
Okmulgee	12	Deep Fork River	40	40	NE
Okmulgee	13	Grove Creek	20	30	NE
Sequoyah	14	Illinois River	16	30	NE
Sequoyah	15	Horton Slough	49	49	NE
Sequoyah	16	Big Vian	97	97	NE
Sequoyah	17	Little Vian	64	64	NE
Muskogee	18	Dirty Creek	28	30	NE
Sequoyah	19	Hezekiah Creek	18	30	NE

Sequoyah	20	Sally Jones Lake	3	30	NE
McIntosh	21	Dutchess Creek	13	30	NE
McIntosh	22	Mill Creek	9	30	NE
LeFlore	23	Poteau River	57	30	SE
Latimer	24	Gaines Creek	13	30	SE
Pittsburgh	25	Buffalo Creek	13	30	SE
Johnston	26	Pennington Creek	9	0	SE
Johnston	27	Sandy Creek	14	30	SE
Marshall	28	Dick's Pond	25	30	SE
Johnston	29	Goose Pen Pond	14	30	SE
Marshall	30	Bell Creek	8	30	SE
Johnston	31	Twin Lakes	9	30	SE
Pushmataha	32	Kiamichi River	15	30	SE
Pushmataha	33	Mill Creek	4	30	SE
McCurtain	34	Glover River	8	30	SE
McCurtain	35	Mountain Fork	32	30	SE
McCurtain	36	Little River	149	30	SE
McCurtain	37	41 Cutoff Oxbow	26	30	SE
McCurtain	38	Red Lake	10	30	SE

Table 3. Number of Oklahoma turtles by species purchased by commercial turtle buyers between 1994 and 2010, based on reports from the Oklahoma Department of Wildlife Conservation. Years 2000, 2002, and 2009 were absent in the reports. Non-reported purchases are denoted by an asterisk (*).

Species	1994	1995	1996	1997	1998	1999	2001	2003	2004	2005	2006	2007	2008	2010
Trachemys scripta	6,165	8,623	37,253	84,206	41,996	49,035	27,312	93,236	70,184	29,456	46,273	20,489	9,966	10,540
Apalone spinifera	4043	4,111	9,453	21,029	13,784	16,214	9,250	5,983	8,849	3,532	3,529	3,427	1,569	853
Apalone mutica	2,772	2,993	4,570	13,683	12,487	5,509	11,313	4,386	1,436	631	310	2,168	24	0
Chelydra serpentina	481	1,135	4,451	9,179	3,753	5,077	3,600	11,386	11,565	4,164	7,195	3,233	1,565	1,109
Sternotherus odoratus	1	67	251	209	464	950	250	1397	269	0	544	122	37	97
Sternotherus carinatus	0	46	66	25	0	0	*	*	*	*	*	*	*	*
Pseudemys concinna	3	0	49	207	50	163	180	148	542	115	85	207	97	50
Kinosternon flavescens	46	83	76	245	196	212	204	966	*	*	531	45	24	15
Kinosternon subrubrum	2	857	0	5	0	0	*	*	*	*	*	*	*	105
Chrysemys picta	0	15	0	8	0	50	*	*	*	*	*	*	*	*
Graptemys ouachitensis	10	1,013	196	586	624	593	611	260	109	162	5,148	84	0	1
Graptemys pseudogeographica	0	3	25	718	26	324	194	1	9	0	199	269	23	12
Total	13,523	18,946	56,390	130,100	73380	78,217	52,914	177,763	93,263	38,060	63,814	30,044	13,305	12,782

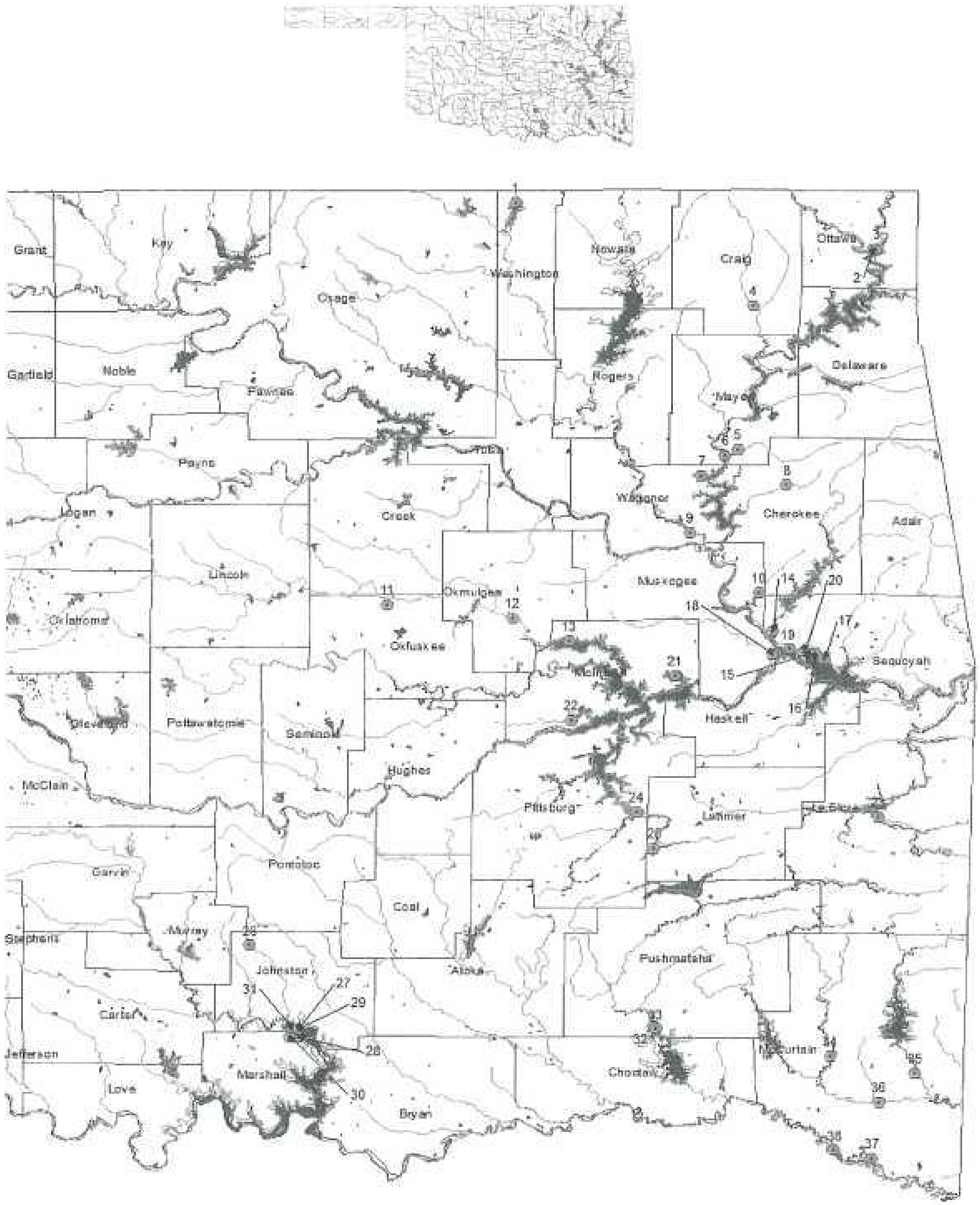


Figure 1. Map of eastern Oklahoma showing 38 sites surveyed in 1997–1999 and 35 sites surveyed in 2009–2010. Numbers and sites listed in Table 2.

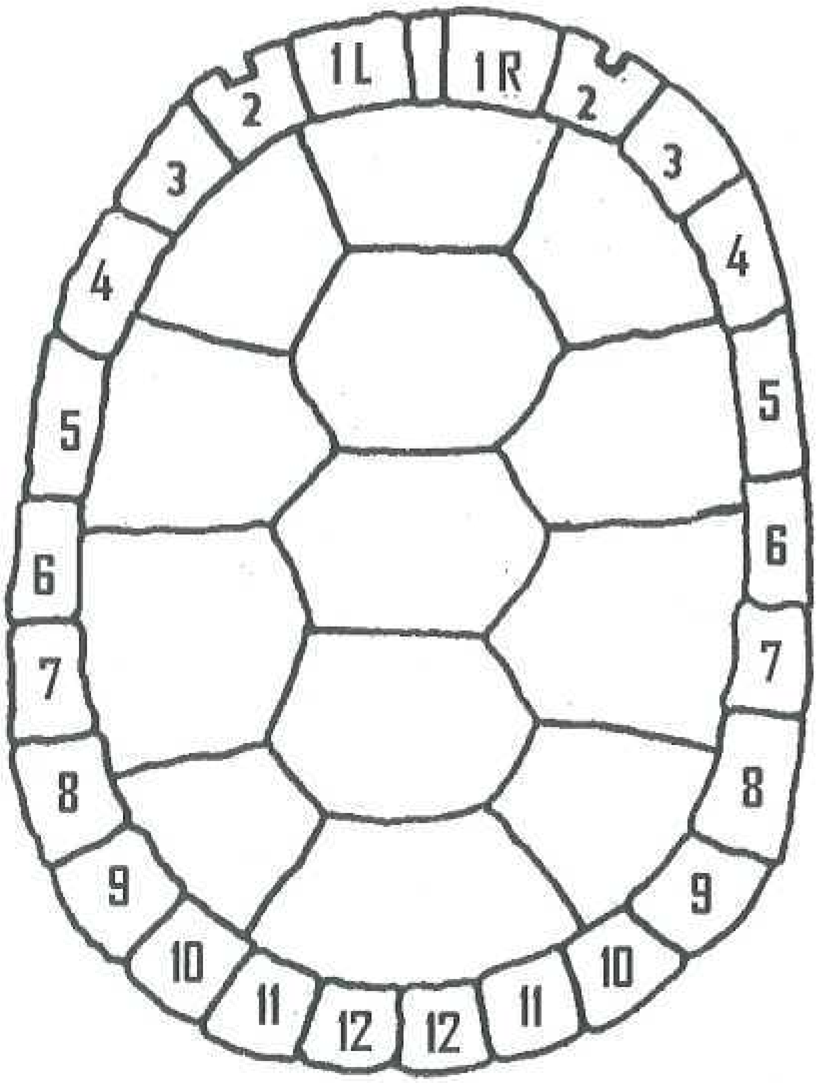


Figure 2. Example of individual scute marking (2R 2L) on carapace for aquatic turtles (*Trachemys scripta*). Individual species have specific number of scutes (*T. scripta* has 12 along each side). Scutes 4, 5, and 6 are never marked due to connection of the carapace with the plastron (bridge) and marking this area could cause potential injury.

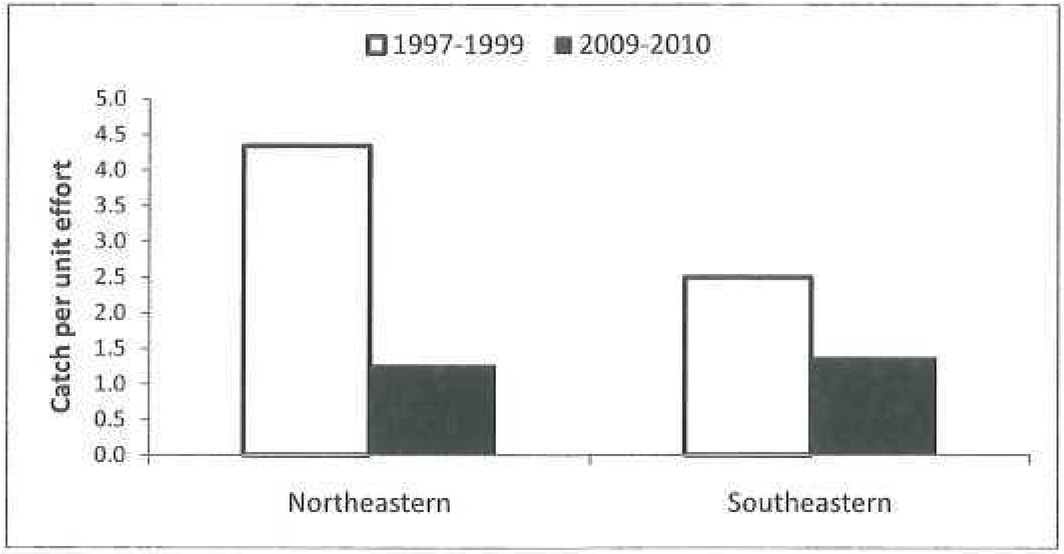


Figure 3. Catch per unit effort for all sites combined in 1997–1999 and 2009–2010, with northeastern ($n = 20$) and southeastern ($n = 15$) sites shown separately.

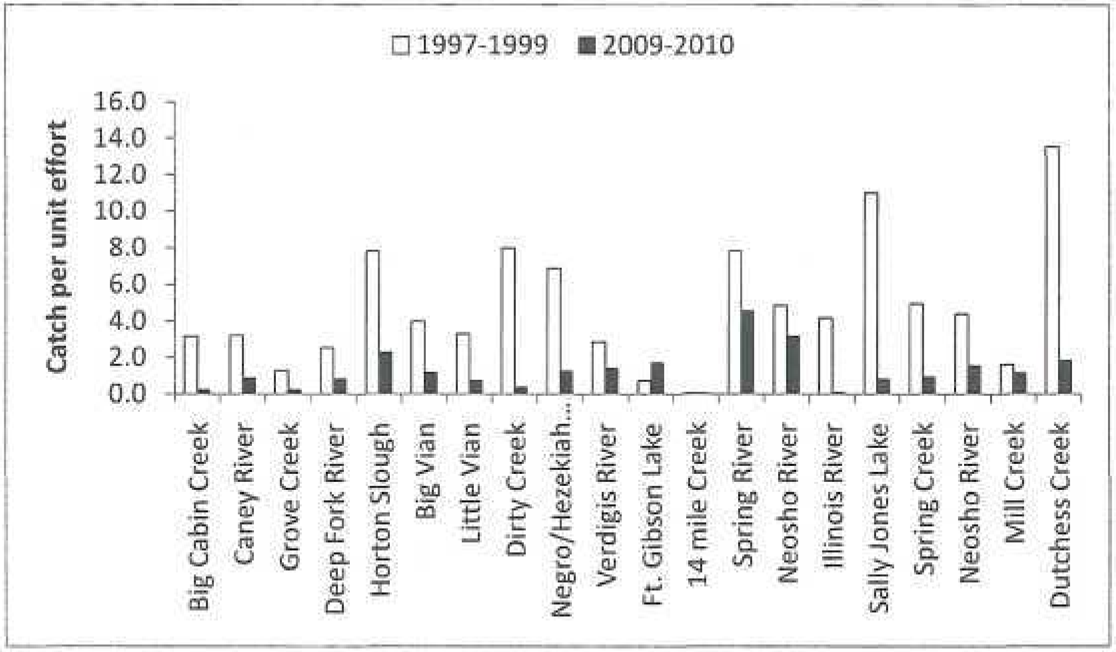


Figure 4. Catch per unit effort at sites of northeastern Oklahoma in 1997–1999 and 2009–2010. Declines were found in 18 of the 20 sites sampled.

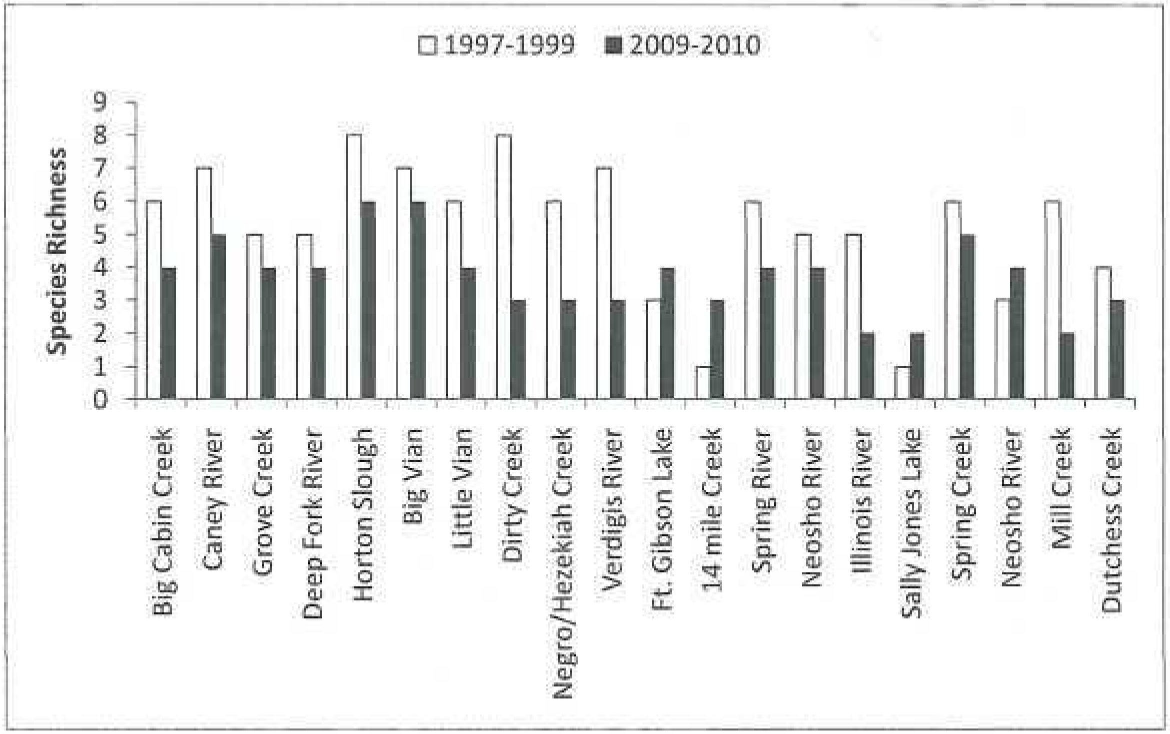


Figure 5. Species richness at sites of northeastern Oklahoma in1997–1999 and 2009–2010. Declines were found in 17 of the 20 sites sampled.

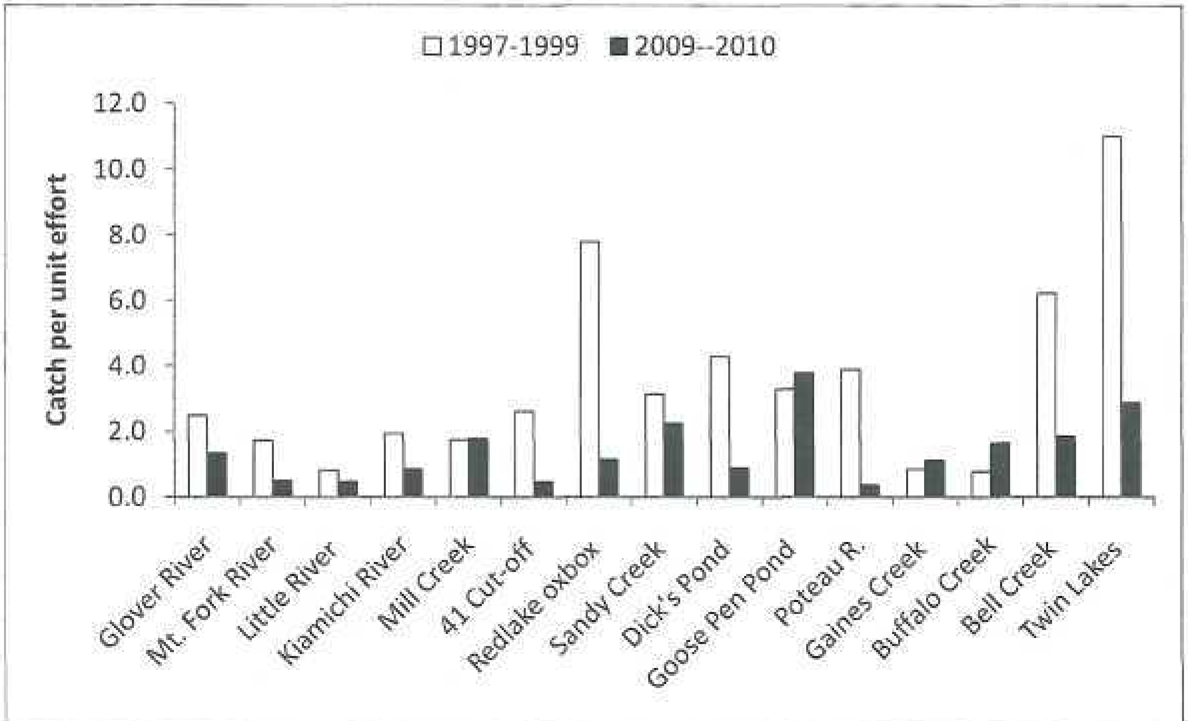


Figure 6. Catch per unit effort at sites of southeastern Oklahoma in 1997–1999 and 2009–2010. Declines were found in 11 of the 15 sites sampled.

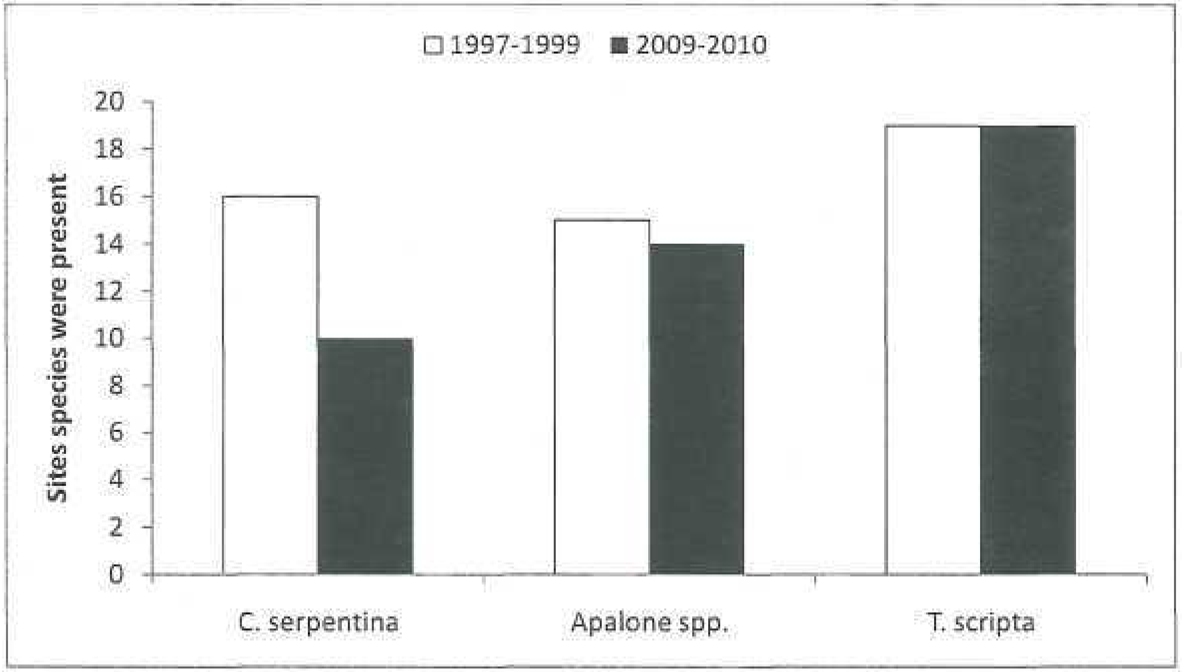


Figure 7. Prevalence of three most commonly harvested "species" for sites in northeastern Oklahoma (n = 20) in 1997–1999 and 2009–2010. *Apalone spinifera* and *A. mutica* are pooled into *Apalone* spp.

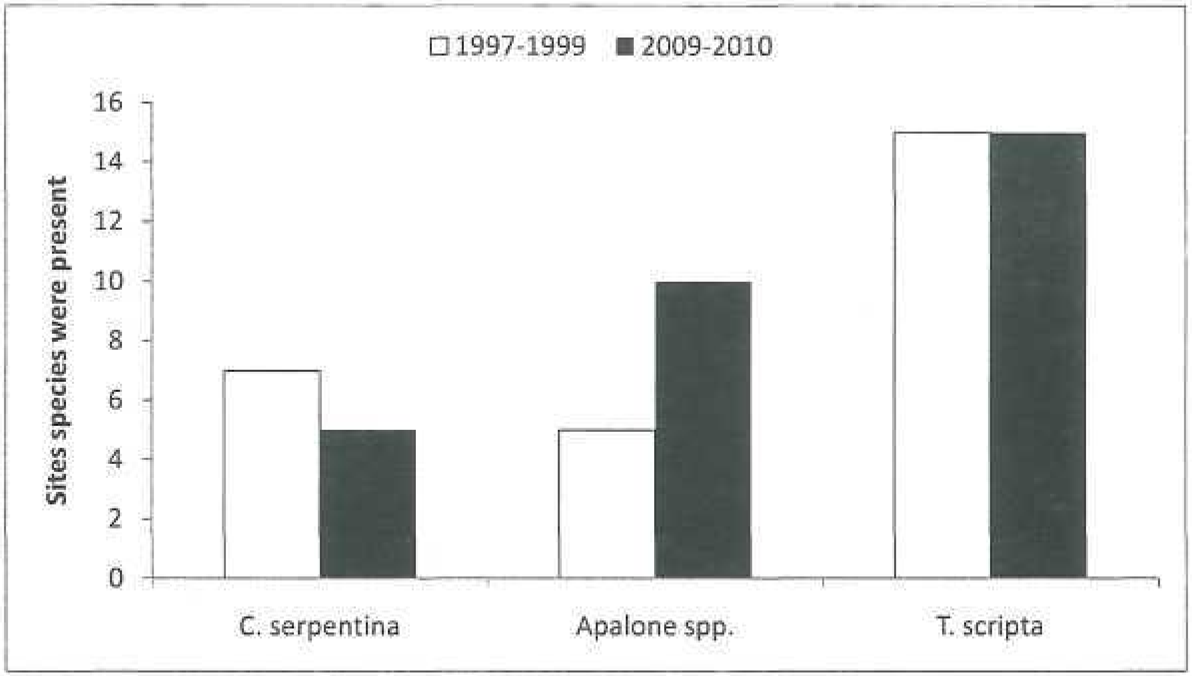


Figure 8. Prevalence of three most commonly harvested "species" for sites in southeastern Oklahoma (n = 15) in 1997–1999 and 2009–2010. *Apalone spinifera* and *A. mutica* are pooled into *Apalone* spp.

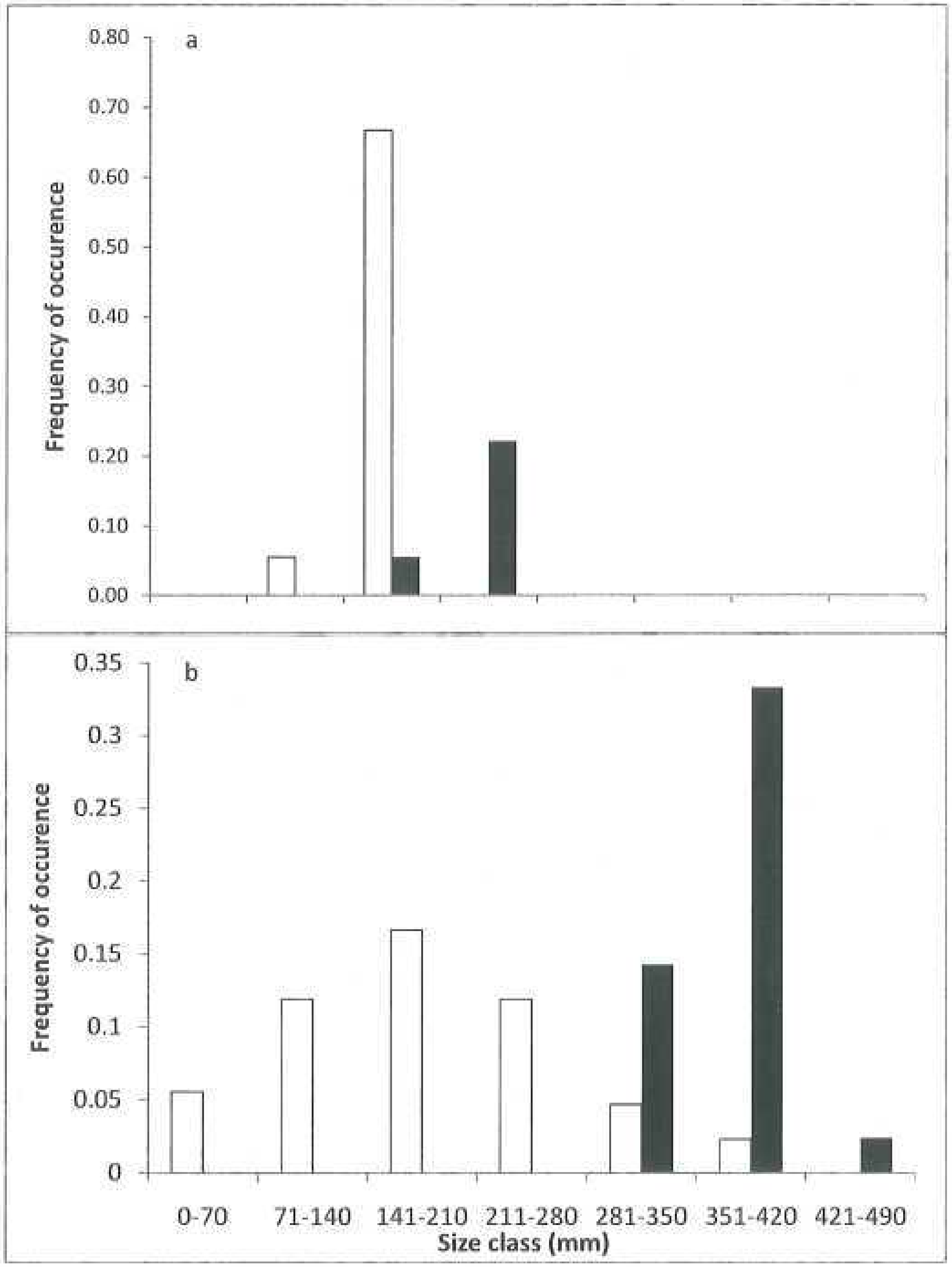


Figure 9. Size class distributions of a) male and b) female *Apalone* spp. in northeastern (open bars) and southeastern (closed bars) Oklahoma.

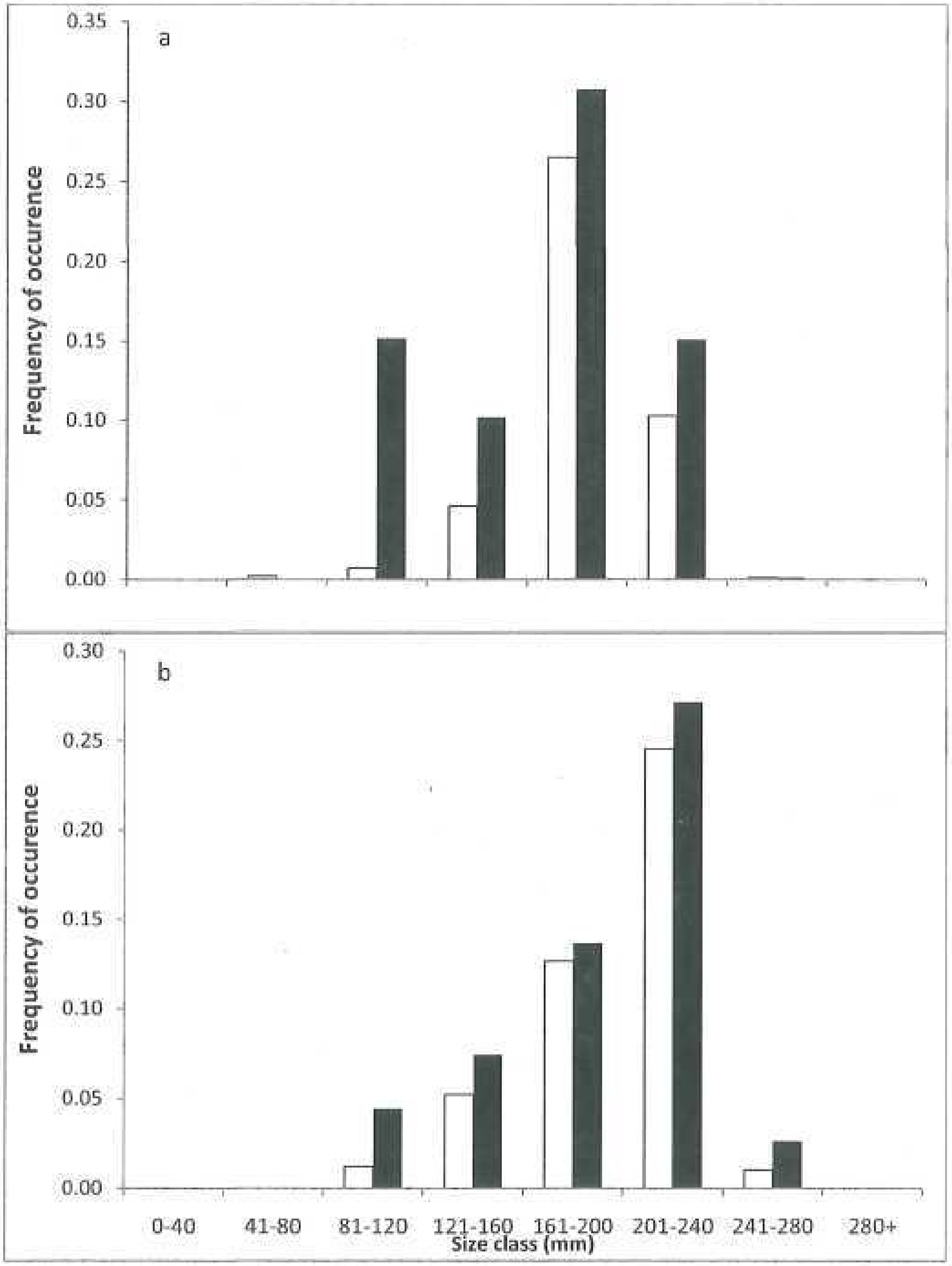


Figure 10. Size class distributions of a) male and b) female *T. scripta* in northeastern (open bars) and southeastern (closed bars) Oklahoma.

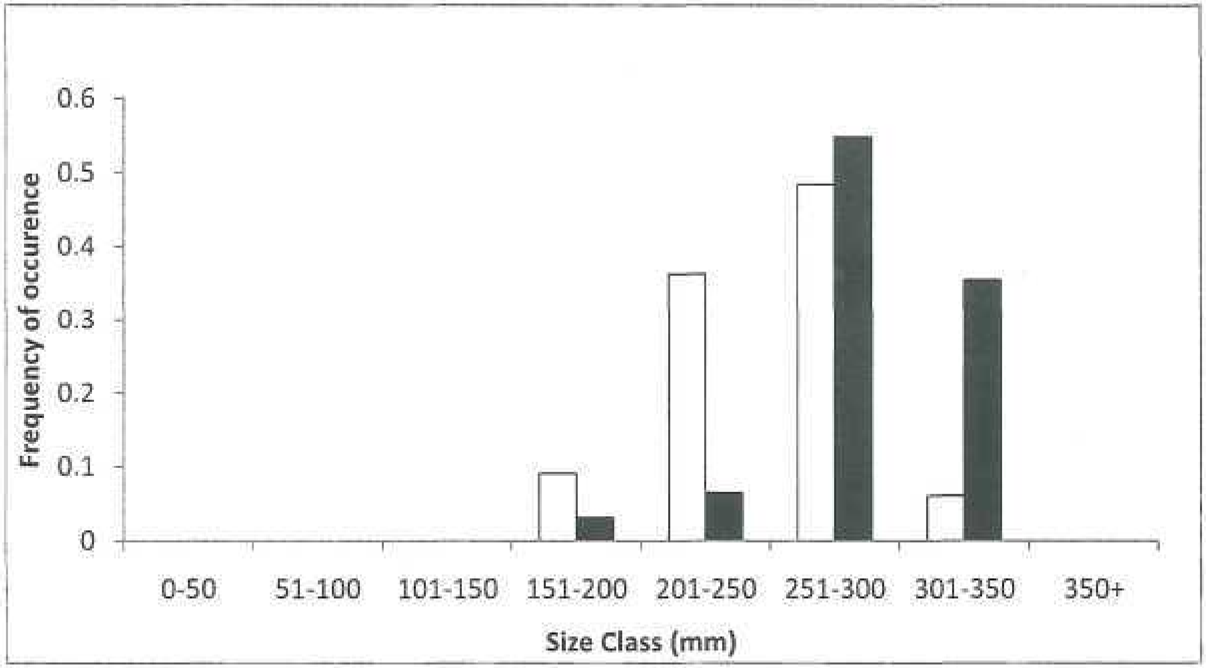


Figure 11. Size class distributions of *C. serpentina* in northeastern (open bars) and southeastern (closed bars) Oklahoma.

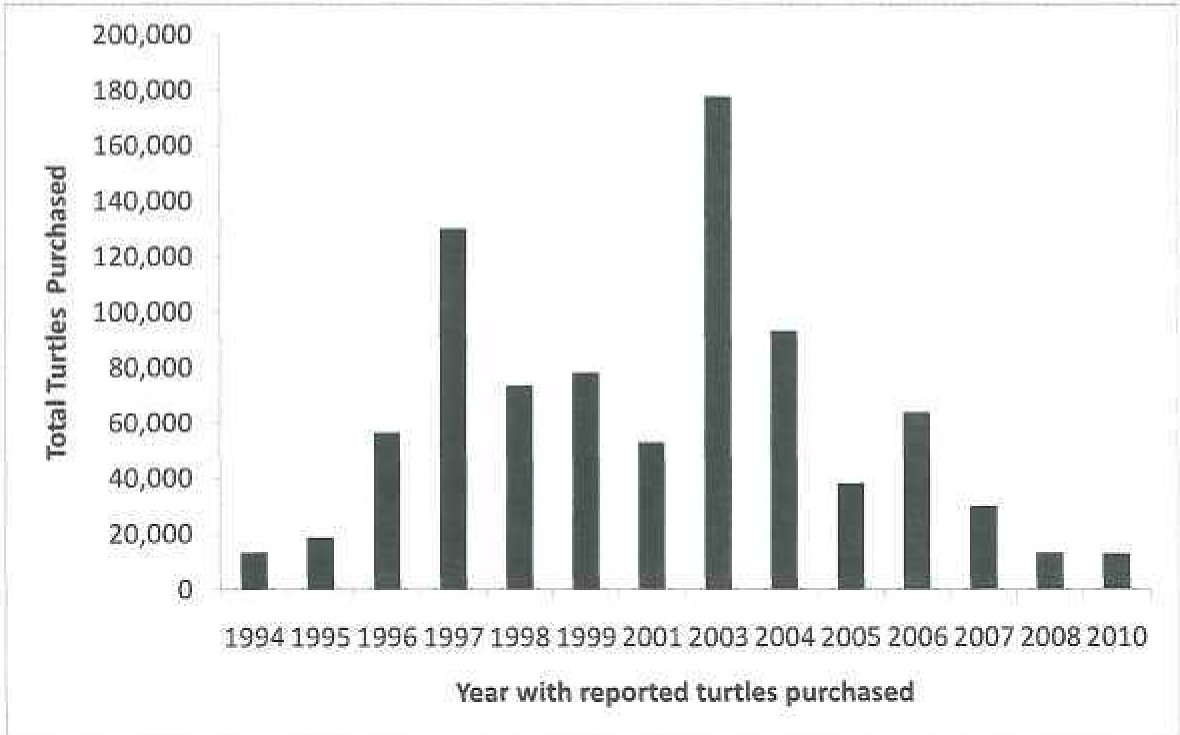


Figure 12. Total turtles purchased in Oklahoma per year for all species. Years 2000, 2002, and 2009 are not included due to the fact that they were not included in the ODWC annual reports, 2001–2010.

CHAPTER II

DOES SIMULATED HARVEST OR DIFFERENT LEVELS OF COMMERCIAL HARVEST IMPACT AQUATIC TURTLES?

ABSTRACT

Aquatic turtles are among the most vulnerable of vertebrate species. Freshwater turtles are long lived, are slow to mature, have low reproductive and survival rates, and are highly sensitive to overharvesting. Freshwater turtles cannot sustain any significant level of harvest from the wild without leading to population crashes. Stable populations need sufficient breeding adults to offset natural mortality and human impacts. In addition to commercial harvest, wild turtles also face problems that are intensified by the anthropogenic effects of water pollution, road mortality, incidental take or death from fisheries, introduction of pathogens, introduction of invasive species, and habitat loss, all of which contribute to turtle declines. I conducted two experiments in the summers of 2010–2011. I first used four sites (two control and two treatment) to determine the effects of simulated turtle harvest on population and community structure. Turtles were removed and held off-site in year one from the two treatment sites; trapping resumed at all sites in year two. I found no statistical decrease in catch per unit effort, species richness, or species diversity due to simulated harvest. This is likely due to small sample sizes and a confounding tendency of lower catch per unit effort, species richness

richness, and species diversity at both treatment and control sites in year two compared to year one. These non-significant changes at both treatment and control sites across years confounded with and overrode any effect of simulated harvest. I also did not find any change in body size of the three most harvested species with regard to simulated harvest. Second, I investigated the possible effects that previous presumed harvest has had on the turtle community structure by analyzing 22 sites: 11 harvest and 11 no-harvest sites. No-harvest sites were those on wildlife refuges or other protected areas. Harvest sites were those not located on wildlife refuges or other protected areas. Harvest and no-harvest sites were paired by major habitat and geographical location. I statistically compared these pairs and found slightly higher catch per unit effort, species richness, and species diversity at no-harvest sites, but none of these differences were statistically significant. Larger average carapace lengths and slightly higher condition indices were found for Red-eared Sliders (*Trachemys scripta*) at no-harvest sites, but again these were not statistically significant. The lack of non-significant results may be caused by paired sites being similar with respect to their supposed level of harvest. Another possible explanation for lack of differences might relate to post-harvesting homogenizing effects: past harvesting has reduced turtle abundance at some localities, and then natural restocking of those relatively depleted localities happens from unharvested localities with undisturbed communities. The end result is that all localities of a large area affected by turtle dispersal may come to have the same, depressed turtle abundance.

INTRODUCTION

Turtles first appeared in the fossil record nearly 200 million years ago (Behler 1995). Today, turtles are found throughout the world, from rivers and lakes, to oceans, and even deserts (Behler 1995). Turtles were the dominant vertebrate in the upper Eocene and lower Oligocene, and these charismatic creatures have remained virtually unchanged since then (Corsini et al. 2011). Turtles' life history makes them especially susceptible to overharvesting and exploitation (Congdon et al. 1993). No population can grow without bounds; eventually it encounters difficult conditions or shortages of necessary resources that prevent further growth (Pianka 1994). If additional anthropogenic stresses are placed on these populations, they can decline and even disappear. This time seems to have come for turtles. Turtles are encountering multiple onslaughts from humans, and many might soon face extinction. Nevertheless, species of turtles are often less studied than other vertebrate groups (Hopkins 2000).

The oldest turtles can live over a hundred years, although they may no longer be able to successfully reproduce at that age. The Alligator Snapping Turtle (*Macrochelys Temminckii*) reaches sexual maturity at 11–13 years of age and can reach ages over 70 years (Ernst and Lovich 2009). Most aquatic turtles have shorter life spans. For example, Red-eared Sliders (*Trachemys scripta*), the most common species captured in our study, can live for 20 –30 years in wild populations (Gibbons 1990). Female *T. scripta* mature between 6–10 years of age; males mature at 3–5 years of age. *T. scripta* has a wide geographic distribution, unlike its other less common emydid relatives (Hays and McBee 2010).

As with many taxa, turtles are declining because of a variety of anthropogenic threats, including unsustainable harvest, pollution, urbanization, fragmentation, introduced pathogens, introduced invasive species, and enhancement of conditions favoring mesopredators that depredate nests (Gibbons 2000, Rizkalla and Swihart 2006).

Aquatic turtles in their natural environment illustrate a classic type III survivorship curve and are slow to reach sexual maturity. High mortality of eggs due to environmental stress and nest predation often result in low reproductive success and population declines in aquatic turtles (Gibbons 1968, Daigle and Jutras 2006). A key to the success of many species of turtles is high adult and sub-adult survivorship.

Excessive removal of adults for any reason can have detrimental effects on any population. Humans have likely used reptiles for both food and for trade throughout history (Cheung and Dudgeon 2006). Human exploitation of these species has resulted in population declines, local and regional extirpations, and possibly even extinction in some of the rarest species (Thorbjarson et al. 2000). Turtle farms export many turtles, and a common method to stock these farms is through ranching: capturing wild gravid females to harvest their hatchlings that are subsequently produced in captivity. Ranching reduces native population numbers (Franke and Telecky 2001, Shi et al. 2007). Not only does the removal of adults have a negative population effect, but also when mature turtles are removed from a locality, it can take a long time for their previous offspring to mature and begin to reproduce. In a world where exotic pets are more attractive because of their rarity, an intensive pet trade has developed and involves turtle farms in the United States (Deschamps et al. 2008).

An often overlooked issue within the reptile world is the release of pet turtles into the wild, which can be an avenue for the introduction of pathogens into wild populations, or of invasive turtle species. *T. scripta* is a good example of a turtle involved in the pet trade that is often released after it becomes too big for a pet. This practice has spread *T. scripta* into Europe (Deschamps et al 2008). Stronger pet trade regulations would help alleviate the excessive removal of turtles from the environment and introductions of exotic new species elsewhere. A change in the current policy that focuses on a blend of bans and taxation in addition to repercussions for releasing of pets could help. With nearly 1.8 million reptiles imported into the United States each year, and nearly 90 percent of these being non-native, it is a positive thing that most states' climatic conditions do not support the growth or reproduction of these intruders (Perry et al. 2011).

It has been 60 years since Cagle and Chaney first began setting turtle traps to determine population numbers (Frazer et al. 1990). Trapping turtles on a non-scientific basis was likely done well before this and it continues today. Like many species of turtles throughout the United States and the world, the Diamondback Terrapin (*Malaclemys terrapin*) is thought to be declining throughout its range. Although the collecting of *M. terrapin* is now illegal in all states, they are still killed by accidental drowning in crab traps. A recent study focusing on 21 years of mark recapture data shows that these incidental captures have had an impact on the demographics of the terrapin populations. There has been a shift toward larger turtles being more prevalent in the population because large turtles cannot enter crab traps (Dorcas et al. 2007). In contrast, most populations are changed demographically by non-random removal of the largest individuals. Average size of venomous Mamushi Snakes (*Gloydius blomhoffii*) in Japan has decreased in hunted populations, and this change has been shown to be genetic (Sasaki et al. 2009). Largest snakes are disproportionately removed from populations. This same phenomenon is shown in catfish, where trophy fish are sought (Pitlo 1997). High market value places higher pressures on sought after species, usually the largest species; the channel catfish (*Ictalurus punctatus*) and flathead catfish (*Pylodictis olivaris*) are valued in the fish world and make up over a third of the annual fish harvest (Pitlo 1997). The largest or rarest fish, snakes, and turtles sell for the most money.

In the United States, 32 states do not allow turtle harvesting. Of the 18 states that do so, some have placed temporary bans on commercial turtle harvesting (Center for Biological Diversity 2008). In response to concerns from conservation and health groups in scientific literature (Heck 1998, Riedle et al. 2004) and popular media (Center for Biological Diversity 2008, Hylton 2008), the Oklahoma Department of Wildlife Conservation (ODWC) enacted a 3-year moratorium on commercial turtle harvesting from public waters in May 2008 and then granted a 2-year extension in April 2011, set to expire May 2013. Prior to the moratorium being established, regulations on the capture and possession of turtles were overseen by the Oklahoma Department of Wildlife Conservation (ODWC). The specific reptile regulations can be found online at the ODWC website under OAC Title 800:25-7 Part 3, or OAC Title 800:15 Subchapter 9. These regulations provide little control over means and location of turtle harvest, or the numbers taken; however, previous regulations did prohibit all harvesting of *M. temminckii* and *Graptemys geographica* (Northern Map Turtle). With no regulations governing size of harvested individuals, both mature and immature individuals can be collected, with most harvest of larger individuals because turtles are sold by the pound. Aquatic turtle populations in Oklahoma appear to be experiencing the same declines and negative effects from harvesting as in the rest of the world (Chapter 1). In just an eight-year period, 680,000 turtles (most of these probably adults) were purchased from harvesters in Oklahoma waters, many of these to be sold into Asian markets (ODWC

2001–2010). Removal of just a few breeding females from a wild population can have detrimental effects on genetic diversity.

I conducted two experiments related to the effect of commercial turtle harvest. In the first, I simulated harvest at some sites by temporarily removing turtles in one year (treatment), while trapping and not removing turtles at other sites (control). I returned to the same sites in the second year and trapped turtles to evaluate differences in turtle communities. I hypothesized that simulated harvest would decrease total turtle numbers, species richness, and species diversity. Populations with simulated harvest would fail to return to near prior numbers after just one year, and size distributions would be biased toward smaller turtles, but these might have a higher condition index. In the second experiment, I compared turtle communities at paired sites of supposed harvest and no-harvest. No-harvest sites were those on wildlife refuges or other protected areas. Harvest sites were those not located on wildlife refuges or other protected areas. I hypothesized that harvest sites would have fewer turtles and decreased species richness and species diversity compared to no-harvest sites. Size distributions would be biased toward smaller turtles at harvested sites, but these smaller turtles might have a higher condition index.

METHODS

Simulated Harvest

I removed turtles to simulate commercial turtle harvest (treatment) at two sites within the Sequoyah National Wildlife Refuge (SNWR) in eastern Oklahoma: Horton Slough (HS) and Hezekiah Creek (HC). My two control sites where turtles were trapped but not removed were also within the SNWR: Little Vian Creek (LV) and Dirty Creek (DC) (Figure 13). From the two treatment sites, I removed 182 turtles, which were subsequently placed in fenced holding ponds located near Lake Carl Blackwell in Stillwater, OK, for safe keeping until the study was completed and they were returned. All trapping occurred in summers 2010 and 2011 on SNWR in Sequoyah and Muskogee counties, Oklahoma. The refuge is 51,376 ha and encompasses the Canadian and Arkansas rivers and their confluences.

Three-ring hoop traps (2.1 m in length and constructed of three 1.05-m diameter hoops covered with 2.5-cm square mesh; Memphis Net and Twine Company, Memphis Tennessee) were baited with fresh dead fish. I mostly used blue gill, sunfish, catfish, and carp species as bait, but other species were also sometimes used. I used roughly the same quantity of bait for each trap, cutting larger fish into two or more pieces and punching holes in all smaller fish in order to help spread the scent. I placed traps in a location likely to yield turtles based on tree cover, snags, and basking areas. At each site, I set traps along a 100-m transect. Traps were set from early evening until morning (approximately 15 hours: from 5–6 pm until 8–9 am when first traps were checked). A net night is defined as one trap set overnight. During late spring (May– early June) 2010, traps were first set at the two selected treatment streams and control sites (50 net nights per site) to index pre-treatment population levels. Later in the same year (mid June–August), additional intensive trapping was carried out at the two treatment sites to remove turtle species that can be legally harvested by permitted trappers (i.e., not *M. temminckii* or *G. geographica*). At each site, I set 10 traps continuously for five days, removing turtles once on the first and last days and twice on days 2–4. Then, in late 2010, I went back to the control and removal sites and trapped for an additional 30 net nights per site. Each treatment site received nearly 1,000 hours' worth of trapping effort. This removal effort was judged sufficient at making a noticeable impact on the populations at these sites, and capture success substantially decease over the five days of continuous trapping (Appendix 2).

Each "harvested" turtle received a unique carapace notch identifying its origin if it did not already carry one, and turtles were translocated and maintained in outdoor ponds (enclosed by a fence of 2.5-cm chicken wire buried 30 cm deep and standing 1.5 m tall) at facilities of Oklahoma State University near Lake Carl Blackwell (Payne County). Two adjacent ponds, each approximately 0.1 ha, were fenced as a single unit and used to house the turtles collected from the field sites. A total of 162 turtles was placed in the ponds, and the turtles were fed turtle pellets once a week. Ponds were visited once a week to monitor physical condition of the turtles, remove any turtles that appeared sick or found dead, and insure that the ponds had proper water flow. I also maintained the fence. During winter months it was not necessary to feed the turtles because they overwintered naturally in a state of brumation.

Harvest vs. No-Harvest

During summer 2009, I attempted to identify localities of current or previous commercial turtle harvest through conversations with ODWC biologists, local game wardens, law officers, local residents, and turtle trappers or buyers. Unfortunately, past records of permits issued by ODWC to trap turtles are incomplete and include as trapping localities only counties or groups of counties, with no specific localities. Due to lack of reporting records and reluctance of local residents to share such information, I abandoned my search for known previously harvested sites. Instead, I selected sites on and off wildlife refuges or other protected areas, assuming that such refuges or protected sites are not trapped or not trapped as heavily as sites outside them. Sites with presumably less turtle harvest would include for example, National Wildlife Refuges and lands held by The Nature Conservancy. Twelve sites paired by major habitat and geographical location (pairs 1–6) were chosen from northeastern Oklahoma and ten (pairs 7–11) from southeastern Oklahoma, for a total of 11 pairs (n = 22; Table 4). Each site was trapped for 30 net nights, and paired sites were trapped near the same time of year to eliminate any effect the weather had on trap success. Details of bait and trap placement were as in the first experiment. All sites were located in eastern Oklahoma and spanned from Creek County in northeastern Oklahoma to McCurtain County in southeastern Oklahoma (Figure 14). Sites included streams, rivers, and publicly owned lakes or reservoirs, but not private farm ponds. As in the simulated harvest study described above, I used CPUE, community structure, size distribution, and body condition as dependent variables in comparisons of harvest vs. no-harvest sites. Northeastern sites were surveyed by the author and southeastern sites were surveyed by Dr. Tim Patton (Southeastern Oklahoma State University, Durant, Oklahoma).

Marking Methods

All turtles captured were recorded and uniquely marked using a Dremel™ (7.2V Cordless MultiPro or 10V Cordless MultiPro) to create notches at the outer edge of the marginal scutes of the carapace (Cagle 1939). For both species of snapping turtles, small holes in specific marginal scutes were drilled, and a short white zip tie was placed in these holes to ensure they would not close prematurely. Softshell turtles were marked using a modified version from Plummer (2008): use of special numbered steel tags

(National Wing Brand™, Jiffy Model, style 893) attached to the posterior right side of the carapace.

Individuals were sexed when possible by the presence of secondary sexual characteristics. Males of most species have longer claws and thicker tails, with the cloaca located nearer the posterior marginal scutes. Turtles were considered juveniles if their carapace was < 100 mm and they showed no obvious secondary sexual characteristics (Tucker et al. 2008). *Apalone* species can be sexed even as juveniles using presence of dots on the carapace of males; females lack this definitive circle pattern on the carapace (Ernst 2009). Straight-line carapace length (SCL), from the first marginal scute behind the head to last marginal scute near the tail, and straight-line plastron length (SPL), from intergular scute (first scute behind lower neck) to anal scute, were measured to the nearest millimeter using calipers. Mass was measured to the nearest gram for individuals < 1000 g and to the nearest 10 grams for those > 1000 g (Table 5). To determine condition, I followed Jakob et al. (1996) using (a slope-adjusted ratio index = mass/(SCL^{slope}) where slope is the slope of a regression of log mass vs. log SCL. Known turtles were measured and weighed each time they were captured. All turtles were released at the site of capture after all data were collected (except in the case of the simulated harvest). Turtles that needed further processing were placed in a transfer container with approximately 8 cm of water from the local site, preventing desiccation. All field methods were approved by the OSU Institutional Animal Care and Use Committee (Protocol No. 72345). All individuals engaged in trapping had a valid Oklahoma Scientific Collectors Permit.

Statistical Analyses

For the simulated harvest experiment, year one minus year two differences in CPUE by site were evaluated using an independent samples t-test comparing treatment and control sites (significant values were set at $p \leq 0.05$ in one-tailed tests because I predicted the direction of change). Species richness (number of species captured at a site) and species diversity were compared by the same method. I used the General Linear Mixed Model (Glimmix) Procedure in SAS (two-way ANOVA) to evaluate any differences in carapace lengths due to simulated harvest (significant values were set at $p \leq 0.05$ in two-tailed tests). I analyzed carapace length changes in only three species, Stink Pot (*Sternotherus odoratus*), Ouachita Map Turtle (*Graptemys ouachitensis*), and Red-eared Slider (*Trachemys scripta*), because they were the only species found in each category (treatment or control) and year (2010 or 2011).

For the harvest vs. no-harvest study I used paired t-tests to evaluate differences in CPUE, species richness, and species diversity (significant values were set at $p \leq 0.05$ in one-tailed tests because I predicted the direction of change). Using a two-tailed independent samples t-test, I also compared carapace lengths of *T. scripta* between harvest and no-harvest sites because it was the most common species and found at 21 of the 22 sites. I used statistical software SPSS version 18 and 19 and Statistical Analysis System (SAS) version 9.3, SAS Institute Inc, Cary, North Carolina, USA

RESULTS

Simulated Harvest

Year one minus year two differences in CPUE (sum of all turtles captured at each site over all net nights; all sites with same number of net nights) ($t = 0.242$, df = 2, $p > 0.05$), species richness ($t = 0.832$, df = 2, $p > 0.05$), and species diversity ($t = 0.685$, df =

2, $p > 0.05$) did not differ. Inspection of CPUE for each treatment by year (Figure 15) suggested that year two generally yielded fewer turtles than year one, independent of treatment. I pooled treatments and tested this statistically and found this year difference to be significant ($t = 3.858$, df = 3, 2-tailed $p = 0.0155$). Species richness looked to show the same year differences (Figure 16), and I repeated the analysis as used for CPUE. Species richness also was significantly less in year two regardless of treatment ($t = 2.635$, df = 3, 2-tailed $p = 0.039$). Species diversity was not different between years when treatments were pooled ($t = -7.35$, df = 3, 2-tailed $p > 0.05$).

To analyze body size differences between years due to harvest simulation, I ran the Glimmix two-way ANOVA procedure in SAS on three selected species, separately by species. In these analyses, a significant interaction between treatment and year indicated an effect of simulated harvest on body size. For *G. ouachitensis*, I found no significance for the interaction term ($F_{1, 35.69} = 2.30$, $p > 0.05$). Therefore, I removed the interaction term from the model and tested for the main effects of treatment ($F_{1,1} = 0.07$, $p > 0.05$) and year ($F_{1, 35.69} = 0.06$, $p > 0.05$); neither main effect showed a significant change. I repeated the same statistical analyses for *S. odoratus* and *T. scripta* and likewise found no significant effect of the interaction term or either main effect for either species (all $p > 0.05$).

Harvest vs. No-harvest

CPUE (sum of all turtles captured at each site over all net nets; all sites with same number of net nights) was higher, but not significantly so, at no-harvest (mean = 51.18) than harvest sites (mean = 41.00) ($t = -1.227$, df = 10, $p = 0.124$) (Figure 17). I also analyzed these data for differences in species richness and species diversity and found no difference between paired harvest and no-harvest sites in species richness ($t = -0.122$, df $=10$, $p > 0.05$) (Figure 18) or in species diversity ($t = -0.141$, df$=10$, $p > 0.05$). However, in both cases the higher mean was found at no-harvest sites. Carapace lengths of *T. scripta* between harvest and no-harvest sites did not differ ($t = -1.724$, df $= 669$, $p > 0.05$) (Figure 19). However, trends toward larger turtles were found in the no-harvest sites compared to the harvest sites (mean = 182.19) and (mean = 177.61), respectively. I also found no differences in condition indices of *T. scripta* between harvest and no-harvest sites ($t = -0.465$, df $= 669$, $p > 0.05$). The condition indices were nearly identical (mean = 0.306) and (mean = 0.312), with the no-harvest mean slightly higher.

DISCUSSION

Results of both of these studies relating to commercial turtle harvest in Oklahoma were inconclusive. For the simulated harvest study, I paired sites for both size and type of water body. Additionally, I chose all sites on the SNWR, hoping to eliminate any confound with turtle harvesting. Nevertheless, I saw no significant differences between control and treatment sites. Because of the inordinate effort to intensively trap both treatment and control sites, my sample sizes of number of sites were minimal. This low sample size means low statistical power to detect differences and almost surely is one reason I did not observe differences due to harvest simulation. Unfortunately, the amount of effort to increase the sample size of this time- and labor-intensive experiment stands as a significant impediment. Each treatment and control pair took 15 days to trap and removed turtles had to be transported back to Oklahoma State University. It was just not possible to increase the sample size. Furthermore, for some unknown reason, I captured significantly fewer turtles at both the control and treatment sites in year two. This decrease in turtles the second year confounded with and overrode any effort to simulate commercial harvest. The same was found for species richness, where higher species richness was found in 2010 than 2011. The extremely dry and hot summer of 2011 could have played a role in the decreased capture of turtles that year. I likewise did not find a difference in carapace length as a result of simulated harvest for selected species *S. odoratus*, *G. ouachitensis*, and *T. scripta*. Again, it is likely that low statistical power and unusual weather conditions in 2011 contributed to this inconclusive result.

Turning to my comparison of harvest and no-harvest sites, I failed to find significant differences between the two types of sites. There is a slight trend, however, that the no-harvest sites had more total turtles captured, higher species richness, and higher species diversity, as well as greater mean carapace length and body condition for just *T. scripta*. These inconclusive results are probably not caused by a lack of statistical power; sample sizes were adequate and it was a powerful paired design. Lack of significant differences may have been caused by paired sites being similar with respect to their supposed level of harvest. Sites were selected on and off refuges as a way to identify no-harvest and harvest sites, respectively. It may well have been that sites on SNWR were actually harvested for turtles, that not all sites off SNWR (or similarly non-protected sites) received relatively high harvest, or both. Another possible explanation for lack of differences might relate to post-harvesting homogenizing effects: past harvesting has reduced turtle abundance at some localities, and then natural restocking of those relatively depleted localities happens from unharvested localities with undisturbed communities. The end result is that all localities of a large area affected by turtle dispersal may come to have the same, depressed turtle abundance.

LITERATURE CITED

Behler, J. L. 1995. National Audubon Society field guide to North American reptiles and amphibians. Chanticleer Press, Inc., New York.

Cagle, F.R. 1939. A system of marking turtles for future identification. Copeia 1939:170–173.

Center for Biological Diversity 2008. Website accessed on 1 Sep 2008: http://www.biologicaldiversity.org/campaigns/southern_freshwater_turtles/index.html

Cheung, S. M., and D. Dudgeon. 2006. Quantifying the Asian turtle crisis: market surveys in southern China 2000–2003. Aquatic Conservation-Marine and Freshwater Ecosystems 16:751–770.

Congdon, J.D., A. E. Dunham, and R. C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's Turtle (*Emydoidea blandingi*): Implications for conservation and management of long-lived organisms. Conservation Biology 7:826–833.

Corsini, J.A., T.R. Smith, and M.B. Leite. 2011. Turtle decline in the early Oligocene of Western Nebraska. Journal of Herpetology 45(2):238–243.

Daigle, C., and J. Jutras. 2006. Quantitative evidence of decline in a southern Quebec Wood Turtle (*Glyptemys insculpta*) population. Journal of Herpetology 39:130–132.

Deschamps, P. T., V. Delmas, R. Lorrilliere, V. Servais, A. Cadi, and A. P. Julliard. 2008. Red-eared Slider Turtles (*Trachemys scripta elegans*) introduced to French Urban Wetlands: An integrated Research and Conservation Program.

Dorcas, M.E., J.D. Wilson, and J.W. Gibbons. 2007. Crab trapping causes populations decline and demographic changes in Diamond Back Terrapins over two decades. 137:334–440.

Ernst, C. H., and J. E. Lovich. 2009. Turtles of the United States and Canada. Second Edition. Johns Hopkins University Press, Maryland., USA.

Franke, J., and T. M. Telecky. 2001. Reptiles as pets: An examination of the trade in live reptiles in the United States. The Humane Society of the United States, Washington D.C.

Frazer, N.B., J.W. Gibbons, and T.J. Owens. 1990. Turtle Trapping: Preliminary tests of conventional wisdom. Copeia (4):1150–1152.

Gibbons, J. W. 1968. Population structure and survivorship in Painted Turtles, *Chrysemys picta*. Copeia 2:260–268.

Gibbons, J.W. 1990. The Slider Turtle. In: Gibbons, J.W. (ed.), Life history and ecology of the Slider Turtle. Smithsonian Institution Press, Washington D.C., USA.

Gibbons, J. W., D. E. Scott, T. J. Ryan, K. A. Buhlmann, T. D. Tuberville, B. S. Metts, J. L. Greene, T. Mills, Y. Leiden, S. Poppy, and C. T. Winne. 2000. The global decline of reptiles, déjà vu amphibians. Bioscience 50:653–666.

Hays, K.A. and K. McBee. 2010. Populations demographics of Red-Eared Slider Turtles (*Trachemys scripta*) from Tar Creek superfund site. Journal of Herpetology. 44(3):441–446.

Heck, B. A. 1998. The Alligator Snapping Turtle (*Macroclemys temminckii*) in southeast Oklahoma. Proceedings of the Oklahoma Academy of Science. 78:53–58.

Hopkins, W.A. 2000. Reptile toxicology: challenges and opportunities on the last frontier of vertebrate ecotoxicology. Environmental Toxicology & Chemistry 19(10):2391–2393.

Hylton, S. 2008. *State urged to prohibit turtle harvesting*. Tulsa World March 31, 2008.

Jakob E.M., S.D. Marshall, and G.W. Uetz. 1996. A comparison of body condition indices. Oikos 77(1):61–67.

Oklahoma Department of Wildlife Conservation. Collection of annual reports. 2001–2010. Oklahoma City, OK.

Perry, G. and M. Farmer. 2011. Reducing the risk of biological invasion by creating incentives for pet sellers and owners to do the right thing. Journal of Herpetology 45(1):134–141.

Pianka ER. 1994. Evolutionary Ecology. 5th ed. HarperCollins College Publishers. New York, NY., USA.

Pitlo, Jr. J. 1997. Response of upper Mississippi River Channel Catfish populations to changes in commercial harvest regulations. North American Journal of Fisheries Management, 17(4):848–859.

Plummer, M. 2008. A notching system for marking softshell turtles. Herpetological Review 39:64–65.

Rizkalla, C. E. and R. K. Swihart. 2006. Community structure and differential responses of aquatic turtles to agriculturally induced habitat fragmentation. Landscape Ecology 21:1361–1375.

Shi, H., Parham, J.F., Lau, M., and Chen, T.H. 2007. Farming endangered turtles to extinction in China. Conservation Biology 21:5–6.

Sasaki, K., S. F. Fox, and D. Duvall. 2009. Rapid evolution in the wild: changes in body size, life history traits and behavior in hunted populations of the Japanese Mamushi Snake. Conservations Biology 23(1):93–102.

Thorbjarson, J., C.J. Lagueux, D. Bolze, M.W. Klemens, and A.B. Meylan. 2000. Human use of turtles: a worldwide perspective. In: Turtle Conservation, M.W. Klemens, editor. Smithsonian Institute Press. Washington D.C. 33–84

Tucker, J. K., C. R. Dolan, J. T. Lamer, and E. A. Dustman. 2008. Climatic warming, sex ratios, and Red-Eared Sliders (*Trachemys scripta elegans*) in Illinois. Chelonian Conservation and Biology 7:60–69.

Van Dijk, PP. 2000. The status of turtles in Asia. Asian Turtle Trade. In proceedings of a workshop on conservation and trade of freshwater Turtles and Tortoises in Asia. Chelonian Research Monographs 2: pp. 15–23

Table 4. Selected paired sites for the harvest vs. no-harvest study 2010–2011. Sites are listed north to south.

Paired site number	Harvest	No-harvest	County(ies)
1	Spring Creek	Verdigris River	Mayes & Wagoner
2	Lake Sahoma	Heyburn Lake	Creek
3	Illinois River	Arkansas River	Sequoyah
4	Big Vian	Big Vian	Sequoyah
5	Sulfur Creek	Dirty Creek	Sequoyah
6	Mill Creek	Dutchess Creek	McIntosh
7	Old Washita River	Goose Pen	Marshall & Johnston
8	Little River @ Garvin	Little River DMR	McCurtain
9	Glover River Hwy 3	Glover R. 4 South	McCurtain
10	Red Lake	Pintail Lake	McCurtain
11	41 Cut-off Oxbow Lake	Forked Lake	McCurtain

Table 5. Explanation of turtle metrics.

Metric	Explanation
Body Mass	Mass of the turtle to the nearest gram.
Carapace length	Straight-line maximum carapace length (between scutes 1R/1L and 12R/12L) measured to nearest mm.
Plastron length	Straight-line maximum plastron length measured to nearest mm.

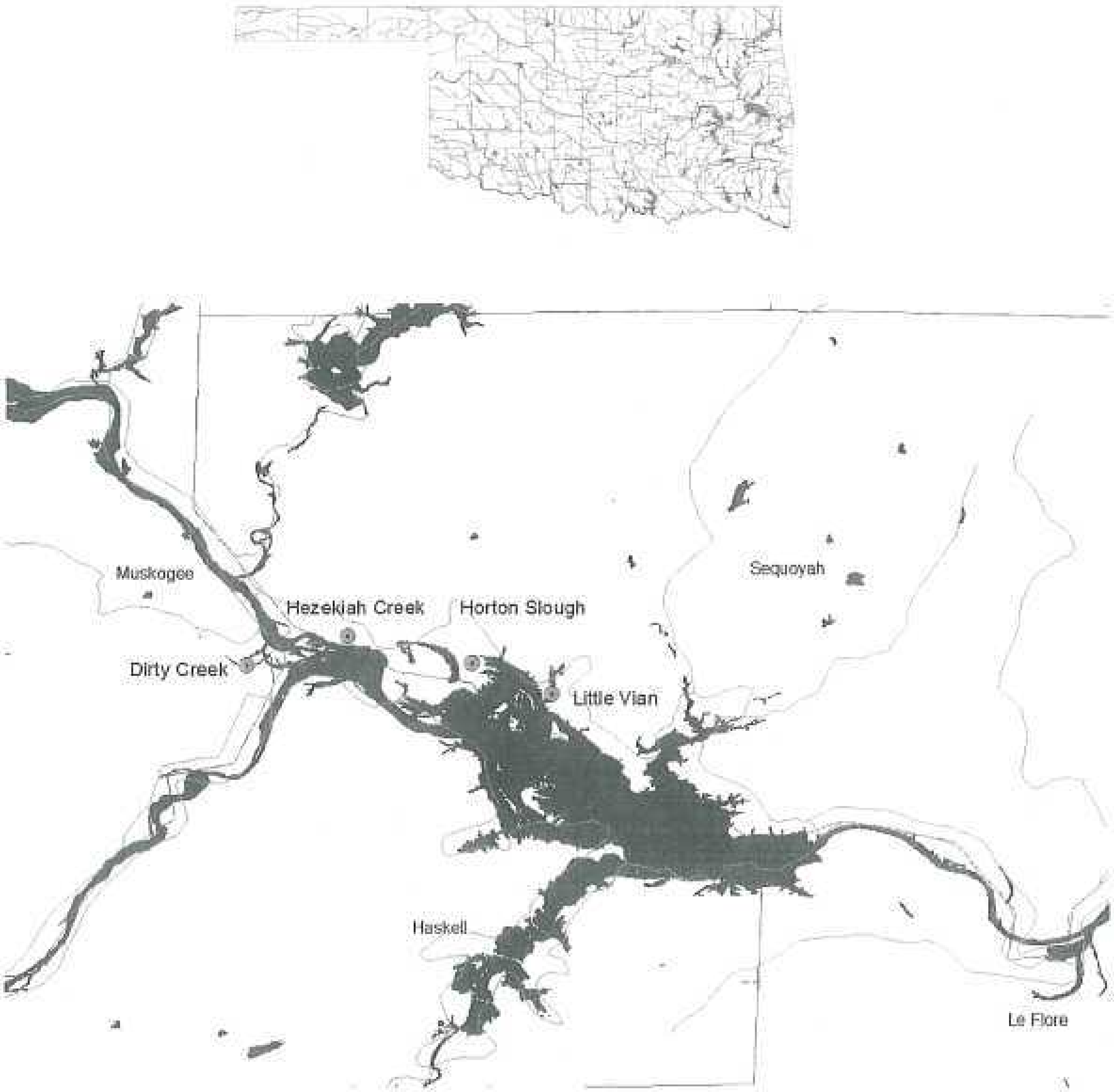


Figure 13. Map of eastern Oklahoma showing treatment (n = 2) and control (n = 2) sites surveyed in 2010–2011 for the simulated harvest study. Sites described in text.

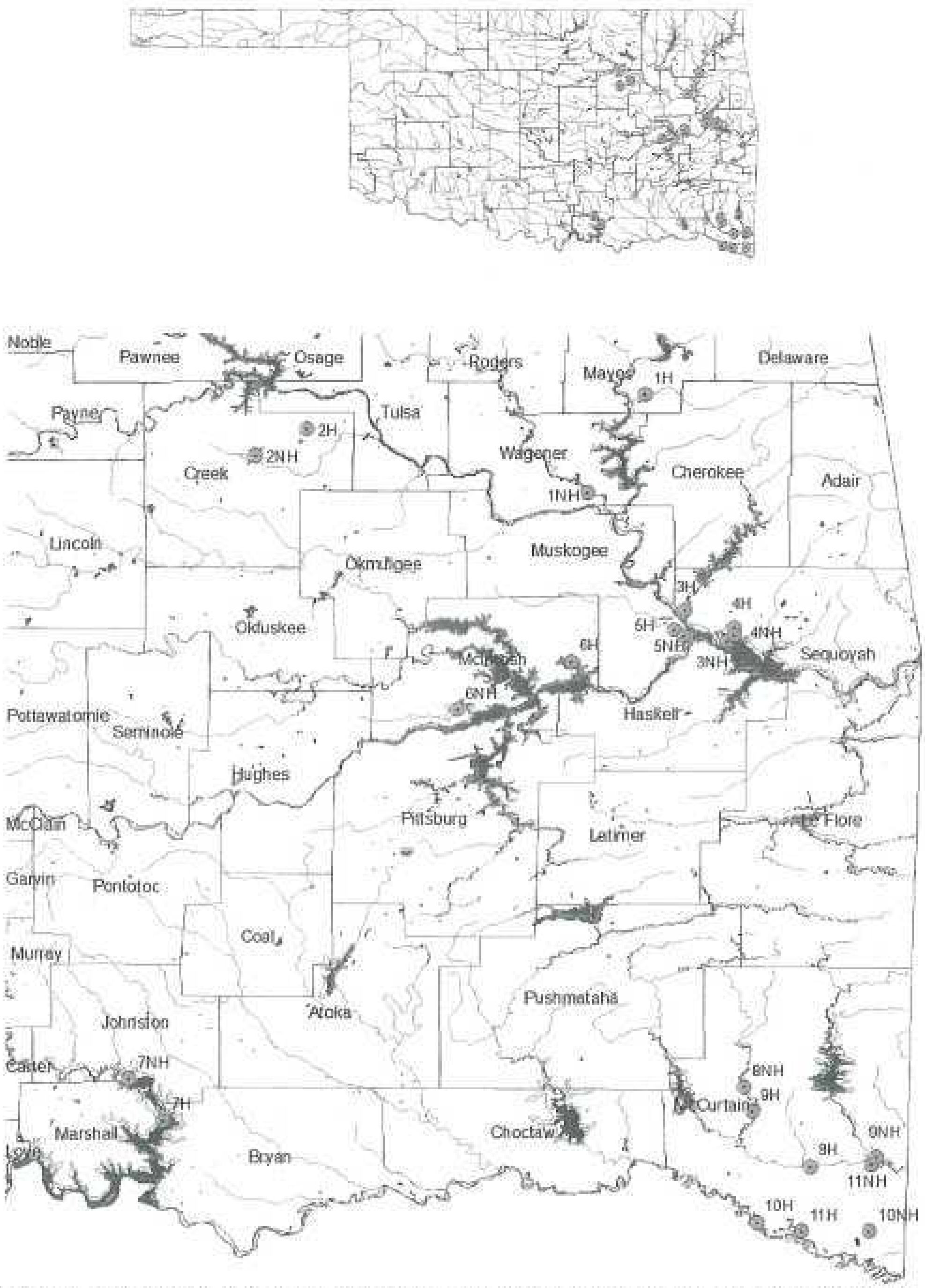


Figure 14. Map of eastern Oklahoma showing paired harvest (H) and no-harvest (NH) sites. Trapping was done by the author and Dr. Tim Patton in summers of 2010–2011. Site numbers are in Table 4.

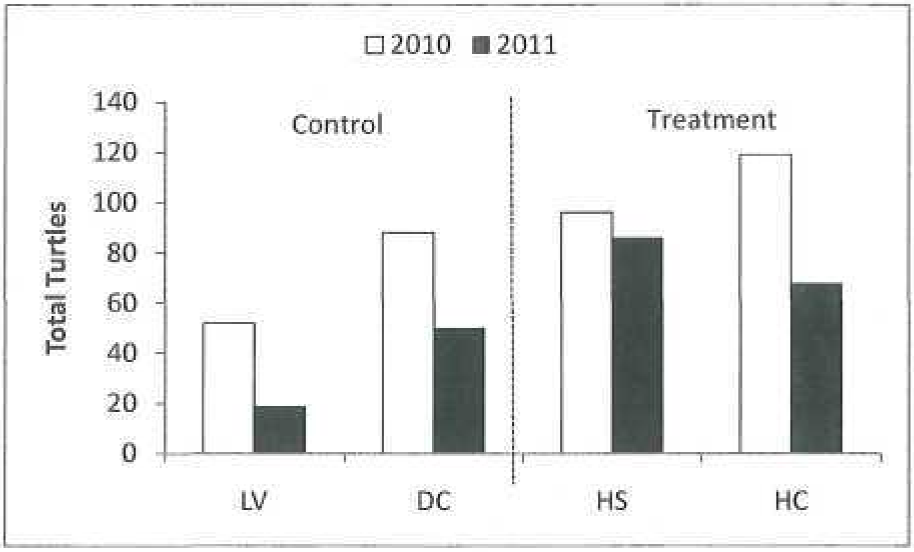


Figure 15. Total turtles (or CPUE: equal effort for all sites) for all species combined in years one and two for control and treatment sites during 2010–2011. Site names are listed in text.

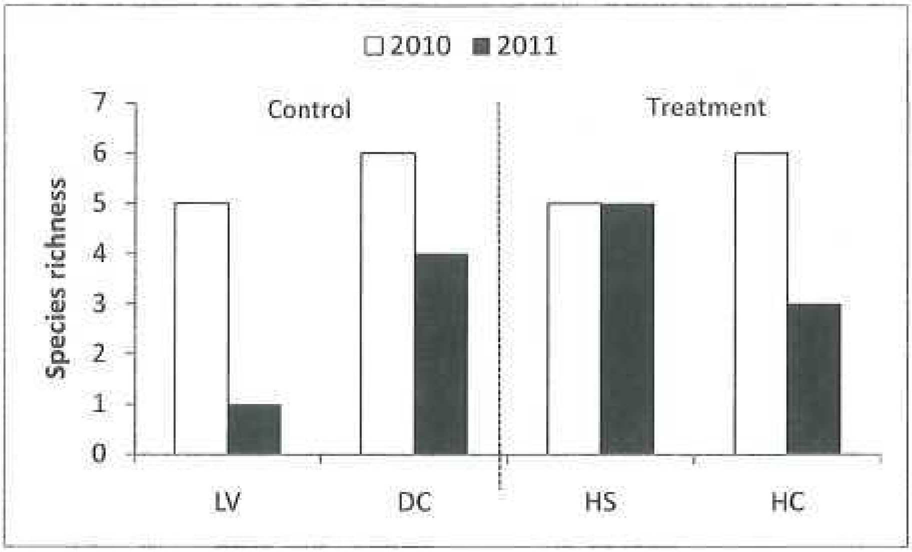


Figure 16. Species richness in years one and two for control and treatment sites during 2010–2011. Site names are listed in text.

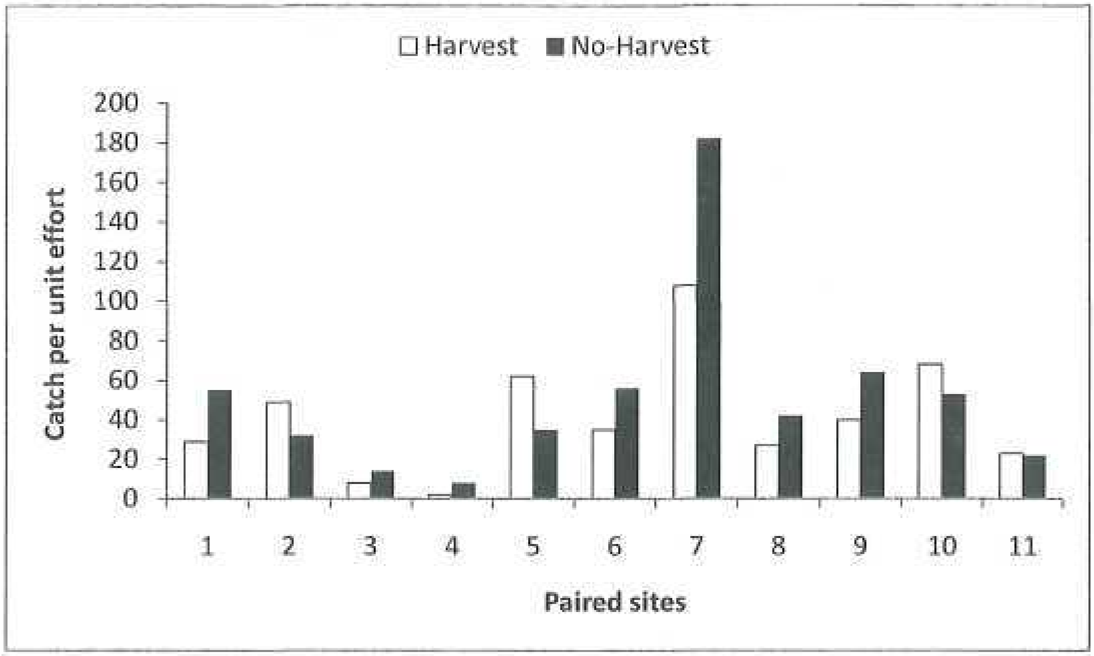


Figure 17. Catch per unit effort at paired harvest and no-harvest sites during summers 2010–2011. Paired sites are listed in Table 4.

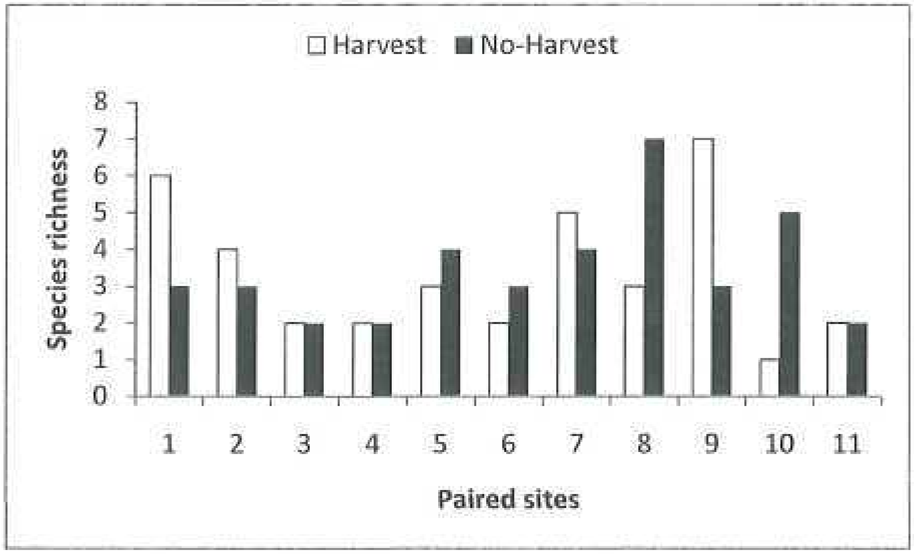


Figure 18. Species richness of paired harvest and no-harvest sites during summers of 2010–2011. Sites are listed in Table 4.

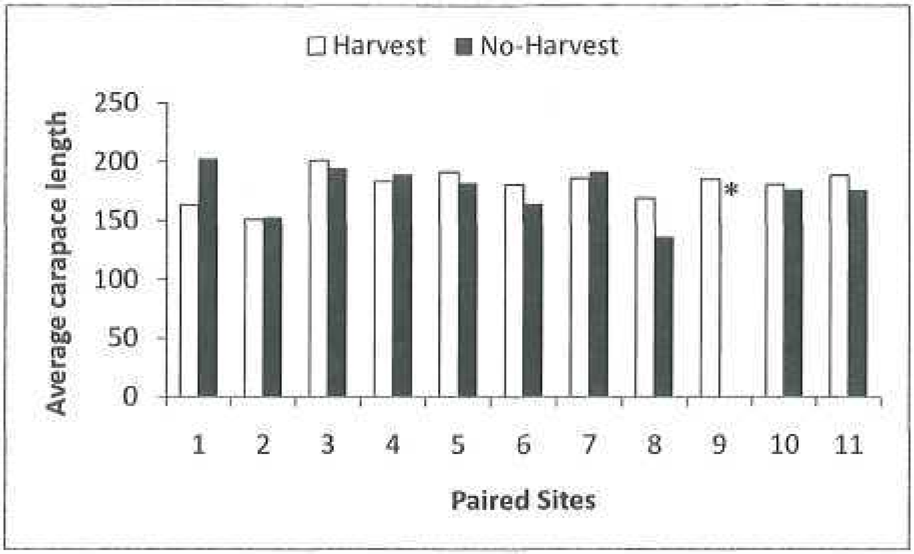


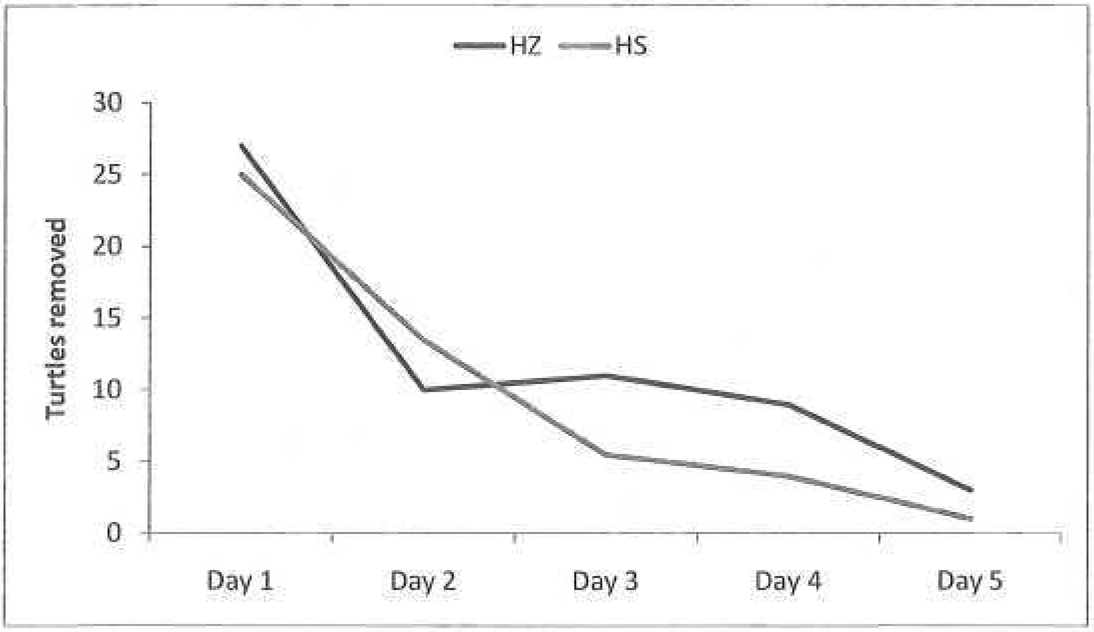
Figure 19. Average carapace length for *T. scripta* at harvest and no-harvest sites during summers 2010–2011. Asterisk (*) denotes no sliders were captured at site. Sites are listed in Table 4.

APPENDICES

Appendix 1. List of sites and GPS locations for all sites. Site numbers are listed in Table 2. Coordinates are listed in UTM.

Site Number	Longitude	Latitude	Region (NE or SE)
1	-95.943	36.959	NE
2	-94.763	36.805	NE
3	-94.755	36.804	NE
4	-95.161	36.614	NE
5	-95.210	36.134	NE
6	-95.254	36.113	NE
7	-95.329	36.044	NE
8	-95.052	36.014	NE
9	-95.368	35.854	NE
10	-95.142	35.653	NE
11	-96.362	35.612	NE
12	-95.951	35.568	NE
13	-95.765	35.490	NE
14	-95.094	35.523	NE
15	-94.970	35.449	NE
16	-94.955	35.451	NE
17	-94.926	35.431	NE
18	-95.098	35.447	NE
19	-95.041	35.464	NE
20	-94.992	35.456	NE
22	-95.757	35.225	NE
21	-95.415	35.373	SE
23	-94.744	34.901	SE
24	-95.541	34.917	SE
25	-95.483	34.796	SE
26	-96.810	34.469	SE
27	-96.654	34.189	SE
28	-96.647	34.162	SE

29	-96.654	34.189	SE
30	-96.678	34.163	SE
31	-96.671	34.193	SE
32	-95.484	34.198	SE
33	-95.476	34.190	SE
34	-94.902	34.100	SE
35	-94.622	34.042	SE
36	-94.740	33.944	SE
37	-94.763	33.760	SE
38	-94.889	33.786	SE



Appendix 2. Declines in number of turtles captured over five successive days of removal trapping at two treatment sites in summer 2010.

VITA

Eric P. Johansen

Candidate for the Degree of

Master of Science

Thesis: A SURVEY OF THE FRESHWATER TURTLES OF EASTERN OKLAHOMA.

Major Field: Zoology

Biographical:

Education:

Completed the requirements for the Master of Science in Zoology at Oklahoma State University, Stillwater, Oklahoma, in December, 2011.

Completed the requirements for the Bachelor of Science in Biology at Austin Peay State University, Clarksville, Tennessee, in 2009.

Experience:

Introduction to Biology Laboratory. Supervisor: Dr. Donald French. Oklahoma State University, Department of Zoology, August 2009 – December 2009.

Animal Biology Laboratory. Supervisor: Drs. Meredith Hamilton and Mary Towner. Oklahoma State University, Department of Zoology, August 2010 – December 2010.

Graduate Research Assistant. Supervisor: Dr. Stanley Fox. Oklahoma State University, May 2009-December 2011.

Undergraduate Research Assistant. Supervisor: Dr. A. Floyd Scott. Center of Excellence in Field Biology, Austin Peay State University, August 2005 – May 2009.

Presentations:

Johansen, Eric, Stanley Fox, David M. Leslie Jr., and Tim Patton. August 17, 2011. Current Status of Turtle Populations in Eastern Oklahoma. 9th Annual Symposium. Turtle Survival Alliance (TSA), Orlando Florida.

Professional Memberships: Southwestern Association of Naturalists, Society of the Study of Reptiles and Amphibians, Turtle Survival Alliance.

Name: Eric P. Johansen Date of Degree: December, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: A SURVEY OF THE FRESHWATER TURTLES OF EASTERN OKLAHOMA.

Pages in Study: 69 Candidate for the Degree of Master of Science

Major Field: Zoology

Scope and Method of Study: The purpose of this study was to assess the effects of commercial harvesting on turtle populations across eastern Oklahoma. I also analyzed differences between harvest and no-harvest sites. Lastly, I temporarily removed turtles from selected sites to understand the short-term impacts of harvest on populations. For all objectives, I captured turtles using baited, three-ring, hoop traps.

Findings and Conclusions: Objective 1: Commercial harvest has likely played a role in the decline of turtle populations in both northeastern and southeastern Oklahoma. Significant declines in catch per unit effort were found since surveys in 1997–1999. Species richness and species diversity also were significantly lower, but only in northeastern Oklahoma. The northeast appeared to have more severe declines since 1997–1999, indicating that heavier or more recent harvesting occurred there. Objective 2: I did not find significant decreases in number of turtles, species richness, or species diversity one year after turtles were temporarily removed. Turtles at all sites (treatment and control) showed non-significant decreases in numbers, species richness, and species diversity in the second year of the study, confounding comparisons of paired treatment and control sites. Likewise, I did not find significant changes in size distributions of three common species one year after removal when I compared paired treatment and control sites. More replications would likely yield stronger results. Objective 3: No-harvest sites compared to harvest sites had more turtles, larger turtles, and slightly higher species richness and species diversity, but these differences were not statistically significant. It is likely that my sites identified as no-harvest and harvest sites in fact did not differ much in harvest intensity. Nevertheless, species of Oklahoma turtles were in decline in 1997–1999 and have continued to decline since, especially in the northeast. Although I did not demonstrate experimentally or by strategic comparison of sites that commercial harvest has played a role, numbers of turtles harvested from Oklahoma waters reported by the Oklahoma Department of Wildlife Conservation 1994–2010 are staggering. Almost certainly, commercial harvest has had a negative impact on Oklahoma turtles and should be regulated or prohibited.

ADVISER'S APPROVAL: Dr. Stanley Fox