Habitat Associations of Aquatic Turtle Communities in Eastern Oklahoma

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North American river systems have experienced an array of anthropogenic influences. Very little baseline data exist for tracking population trends in relation to these activities. Between 1997 and 1999, we sampled 67 sites in 16 counties of eastern Oklahoma during a survey for the Alligator Snapping Turtle, *Macrochelys temminckii*. We captured 93% (13/14) of the aquatic turtle species that have been recorded from eastern Oklahoma. Canonical Correspondence Analysis of site-by-species-by-habitat separated some turtles by habitat type: (1) those of faster flowing, less turbid stretches with more pools and runs (*Pseudemys concinna, Sternotherus carinatus*), (2) those of middle, slower reaches of streams and backwater habitats (*Chelydra serpentina, Macrochelys temminckii, Sternotherus odoratus, Trachemys scripta*), and (3) those of lower reaches with slow-moving deep water with clay substrates and steep, overhanging banks (*Apalone spinifera, Graptemys ouachitensis, Graptemys pseudogeographica*). We compared our data with previous distributional records to reveal one range extension and one possible range contraction. We observed differences in capture rates among the 12 rivers in our study, with particularly low capture rates in the southeastern Kiamichi, Mountain Fork, and Little rivers.

INTRODUCTION

Historically fish were the most important vertebrate group used to measure aquatic ecosystem health. Thus, ecologists rapidly adopted standardized sampling methods for fish to infer the biological condition of watersheds (Natural Resources Conservation Service 2003). In contrast, fisheries ecologists largely overlooked aquatic turtles as environmental sentinels, and instead paid most attention to their role as predators of, and competitors with, game fish (Lagler 1943). Attitudes toward the importance of aquatic turtles have changed, and now aquatic turtles, especially their species interactions, biomass and densities, are recognized to be important to assess aquatic ecosystem health (Bury 1979).

Past studies have focused on single species or groups of species such as kinosternids (Mahmoud 1969) and *Graptemys* (Vogt 1981;

Fuselier and Edds 1994; Lindeman 1999). Moll and Moll (2004) provided a global perspective of aquatic turtle communities. Dreslik and Phillips (2005) summarized data from several studies in the midwestern United States and found a positive correlation between species diversity and latitude and shifts in species composition between lentic and lotic habitats (Bodie and others 2000), and terrestrial habitat use in fluctuating lentic environments (Buhlmann and Gibbons 2001) has been discussed. Increased interest in turtle community composition in man-made environments such as farm ponds is now more widespread (Stone and others 2005; Failey and others 2007).

Although numerous studies during the last three decades enriched our knowledge of freshwater chelonians, we need a better understanding of the relationships between turtles and ecological factors. Anthropogenic changes to stream systems may drastically alter community composition and dispersal of some species of aquatic turtles. Unfortunately, there are few baseline data published on regional turtle communities, which are essential to document the long-term effects of environmental changes on aquatic turtles. There are a few regional studies on turtle assemblages, but these are limited in scope (Cagle 1942; Cagle and Chaney 1950; Congdon and others 1986; Congdon and Gibbons 1996; and Dreslik and others 2005).

In the early 1990s, the international trade in turtles for food and medicinal purposes increased greatly (Compton 2000). In response to this demand, the Oklahoma Legislature passed a mandate (Title 29, Section 4-103A) legalizing commercial harvest of aquatic turtle species in Oklahoma. Although baseline data on turtle populations were not collected prior to enactment of legislation, we attempt here to elucidate possible trends in turtle populations that may be attributed to commercial harvest and other anthropomorphic perturbations. In 1997 we began a range-wide survey for *Macrochelys temminckii* in eastern Oklahoma (Riedle and others 2005) and we tracked by-catch of all aquatic turtles in order to develop baseline data needed to test for impacts of commercial harvest and environmental degradation in the state.

MATERIALS AND METHODS

We sampled sites throughout the eastern one-third of Oklahoma from May through August 1997–1999. Many of those sites were at or near historic sites where *M. temminckii* occurred previously (Black 1982; Carpenter and Krupa 1989; Heck 1998). We surveyed a variety of habitats to provide a thorough representation of the diversity of lotic habitats in eastern Oklahoma. These included previously lotic habitats such as reservoirs and oxbows, which have taken on more lentic qualities.

We sampled sites using commercial hoop nets (length = 2.1 m, diameter = 1.05 m, square mesh size = 2.5 cm). Nets were set upstream from submerged structures such as trees and log jams. We baited them with fresh fish suspended by a piece of twine on the hoop furthest from the opening of the trap. We set turtle nets in the late afternoon or evening and then checked them the following morning.

We recorded all individuals of all species of aquatic turtles captured at each site. Each site was generally sampled only 1-2 times/year, so no animals were marked. We collected basic habitat data at each site: aquatic regime (percent riffle, run, and pool); current (0 = none, 1 = little, 2 = some, or 3 = much); stream morphology (0 = straight or channelized, 1 = slight bends in the stream, 2 = several bends within the stream, 3 = winding or braided stream); percent tree canopy covering the trap site; percentages of substrate types (clay, mud, sand, gravel, rock, and bedrock); amount of detritus (0 = none, 1 = little, 2 = some, or 3 = much); amount of beaver activity (0 = none, 1 = little, 2 = some, or 3 = much); mean site width; mean site depth; (1 = 0--1 m, 2 = 1.1--2 m, 3 = 2.1--3 m, or 4 = > 3 m); turbidity (0 = very clear, 1 = clear, 2 = slightly turbid, or 3 = very turbid); bank rise (0 = no rise, 1 = slight to 45° rise, 2 = 90^0 rise, or 3 = steep rise, bank overhanging the water); percentages of cover types (logs, log jams, trees, brush, and overhanging bank); amount of total cover (0 = none, 1 = little, 2 = some, or 3 = much); number of feeder creeks draining into sample site; amount of aquatic vegetation (0 = none, 1 = little, 2 = some, or 3 = much); and percent vegetative cover on the bank. We used canonical correspondence analysis (CCA) to visualize the associations among sites, species and habitats (Palmer 1993). CCA is used to describe generalized patterns of species with habitat, not to test explicitly for specific habitat associations with statistical analyses.

We compared the results from our trapping efforts with earlier records published in Webb (1970) to infer possible changes in aquatic turtle distributions. In addition, capture rates were also compared between river systems.

RESULTS

We surveyed 67 sites during 1,075 net nights throughout eastern Oklahoma (Table 1) and captured 3,647 turtles of 13 species (Table 2). Our captures were dominated by *Trachemys scripta*, which made up 76% of all captures, followed by *Graptemys ouachitensis* at 8% of all captures. Our target species, *Macrochelys temminckii*, comprised only 2% of all turtle captures. Three species were represented by single individuals: *Apalone mutica*, *Chrysemys picta*, and *G. geographica*; thus we excluded them from the ordination analysis. Capture rates ranged 0.9–7.8 turtles per net night among 12 eastern Oklahoma rivers. *Trachemys scripta* was the dominant species at most sites, but occurred in disproportionately lower numbers in rivers where overall capture rates were low (Table 1).

Canonical Correspondence Analysis revealed two principal axes that represented variation along different environmental gradients (Figure 1). Sites on axis 1 that had negative values were slow, turbid streams/rivers with riffles, mud and detritus substrates, and had large amounts of dead woody vegetation in the water. Sites on axis 1 that had positive values were faster-flowing streams/rivers with more pools and runs, logs and log jams, and sandier substrates. The second axis represented an upstream-downstream gradient, with upstream sites low on this axis, and downstream sites high on this axis (Figure 1). Downstream sites were deeper, more sinuous streams/rivers with mostly clay substrates and steeper banks whereas upstream sites were shallower streams/rivers with substrates of gravel and rock, more aquatic vegetation, heavy bank vegetation with denser canopy, and more cover in general.

Trachemys scripta, *Chelydra serpentina*, *M. temminckii*, and *Sternotherus odoratus* were generally associated with the same habitat characteristics (Figure 1). Those four species plotted near the intersection of axis 1 and axis 2, all slightly negative on both axes, indicating their ecological generality with respect to habitat variables compared with the other turtle species. In contrast, *G. ouachitensis*, *G. pseudogeographica*, and *A. spinifera* were typically found in downstream, deeper stretches with clay substrates and steeper, overhanging banks, and thus had high values on axis 2. *Pseudemys concinna* and *S. carinatus* had high values on axis 1 and slightly negative values on axis 2, which suggests an affinity for more upstream sites with faster current, sandier substrate, more pools and runs (less riffles), and generally less turbidity than other sites.

Congeneric species exhibited differences in habitat characteristics as well (Fig. 1). *Graptemys ouachitensis* was associated with slow moving water, muddy substrates, and aquatic vegetation, whereas *G. pseudogeographica* was associated with clear, swift, rocky streams with deep pools and runs. Both species were captured together at numerous sites, but *G. ouachitensis* was always captured in greater numbers than *G. pseudogeographica* (Table 1). For the two species of *Sternotherus*, *S. odoratus* was more of

Table 1. Total net nights (NN), total captures (TCap.), captured per unit effort (C/UE), and proportional abundance of each species captured on all river systems sampled in Oklahoma. Rivers ordered from north to south. Species codes are as follows: MATE = *Macrochelys temminckii* CHSE = *Chelydra serpentina*, KISU = *Kinosternon subrubrum*, STCA = *Sternotherus carinatus*, STOD = *S. odoratus*, APSP = *Apalone spinifera*, APMU = *A. mutica*, CHPI = *Chrysemys picta*, GRGE = *Graptemys geographica*, GRPS = *G. pseudogeographica*, GROU = *G. ouachitensis*, PSCO = *Pseudemys concinna*, TRSC = *Trachemys scripta*.

River	NN	TCap.	C/UE	MATE	CHSE	KISU	STCA	STOD	APSP	APMU	CHPI	GRGE	GRPS	GROU	PSCO	TRSC
Caney	65	208	3.2	-	0.01	-	-	0.01	0.11	-	-	-	0.05	0.30	0.01	0.51
Neosho	109	334	3.06	-	0.03	-	-	0.05	0.03	-	-	0.01	0.01	0.09	0.01	0.75
Spring	29	227	7.83	-	0.09	-	-	0.01	0.01	-	-	-	0.01	0.03	-	0.85
Verdegris	38	108	2.84	-	0.02	0.01	-	-	0.03	-	-	-	-	0.14	-	0.79
Canadian	72	211	2.93	0.06	0.03	0.01	-	0.02	0.04	-	-	-	0.02	0.05	0.01	0.76
Illinois	16	67	4.18	-	0.04	-	-	0.07	-	-	-	-	-	0.12	0.01	0.75
D. Fork[1]	54	145	2.68	-	-	-	-	-	0.09	0.01	-	-	0.01	0.50	-	0.39
Arkansas	274	1382	5.04	0.04	0.01	-	-	0.01	0.02	-	-	-	0.01	0.05	0.02	0.85
Poteau	57	222	3.89	-	-	-	-	0.08	0.01	-	-	-	0.01	0.07	0.02	0.81
Kiamichi	47	60	1.27	0.03	-	-	0.78	-	0.02	-	-	-	-	0.02	0.02	0.13
M. Fork[2]	32	54	1.68	-	-	-	0.28	-	0.07	-	-	-	0.02	-	0.09	0.53
Little	181	163	0.9	0.02	-	-	0.54	-	0.06	-	-	-	-	0.02	0.05	0.31
Red	101	466	4.61	-	0.03	-	0.01	0.06	0.01	-	0.01	-	-	0.01	0.01	0.89

[1]Deep Fork River

[2]Mountain Fork River

a generalist, occupying slower moving and highly turbid water typical of the mid-reaches of eastern Oklahoma streams, whereas *S. carinatus* was captured in streams with sand or rock substrate and low turbidity, which is typical of the Kiamichi, Little, and Mountain Fork rivers where it was captured. Where geographic distributions of *S. odoratus* and *S. carinatus* overlapped, we noted an absence of *S. odoratus* from lotic sites.

The geographic distributions of turtle species based on our sampling were generally congruent with Webb (1970; Table 3). Notable differences include the capture of *G. geographica* in Mayes County, a species which was known previously in Oklahoma only from Delaware County. *Graptemys ouchatensis* was captured in 9 additional counties not reported in Webb (1970). Additionally, *M. temminckii*, which had been

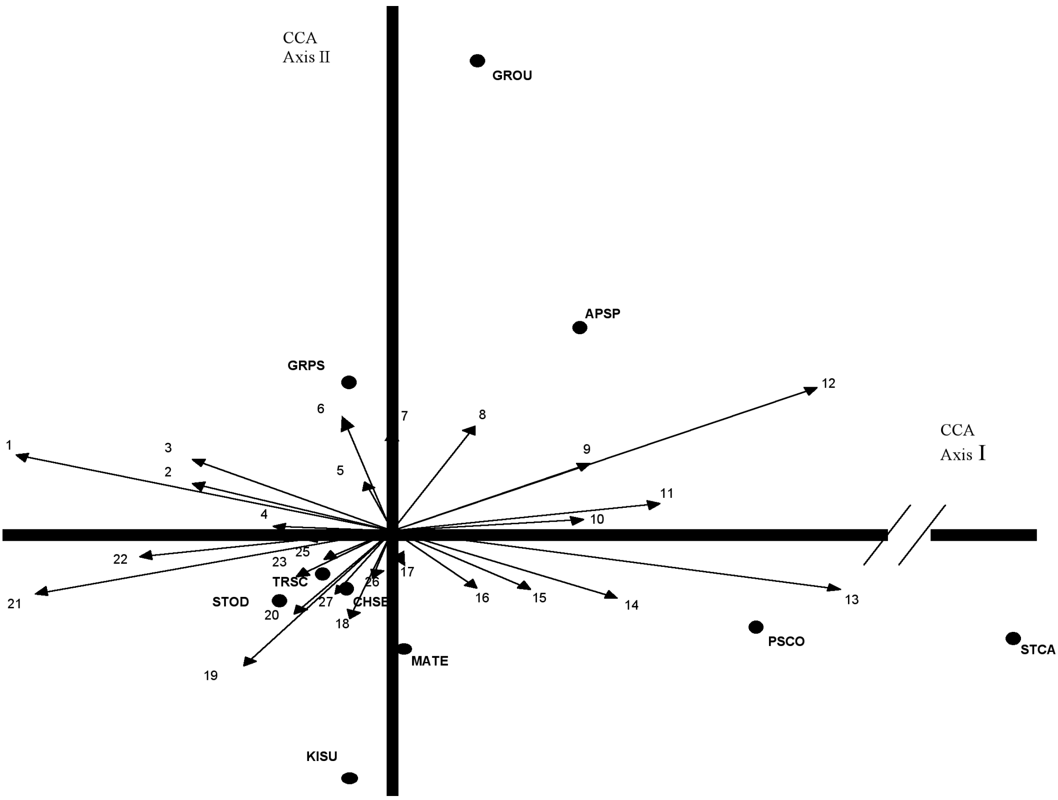

Figure 1. Species-habitat associations as determined by canonical correspondence analysis. Species scores (shown as points): MATE=*Macrochelys temminckii*, CHSE=*Chelydra serpentina*, KISU=*Kinosternon subrubrum*, STCA=*Sternotherus carinatus*, STOD=*Sternotherus odoratus*, APSP=*Apalone spinifera*, GROU=*Graptemys ouachitensis*, GRPS=*Graptemys pseudogeographica*, PSCO=*Pseudemys concinna*, and TRSC=*Trachemys scripta* (extremely rare species are excluded from analysis). Habitat vectors: 1=percent riffle, 2=amount of detritus, 3=water turbidity, 4= percent trees, 5=stream morphology, 6=mean stream depth, 7=bankrise, 8=percent clay substrate, 9=percent log cover, 10=percent log jam cover, 11=current, 12=percent sand substrate, 13= percent pool, 14=percent run, 15=percent gravel substrate, 16=percent rock substrate, 17=percent bedrock substrate, 18=number of feeder creeks, 19=amount of aquatic vegetation, 20=percent overhead canopy, 21=percent mud substrate, 22= percent brush, 23=percent cover from overhanging banks, 24=amount of beaver activity, 25=mean stream width, 26=amount of total cover, 27=percent bank vegetation.

Table 3. Comparison of distribution of turtle species (APMU = *Apalone mutica*, APSP = *A. spinifera*, CHPI = *Chrysemys picta*, CHSE = *Chelydra serpentina*, GRGE = *Graptemys geographica*, GROU = *G. ouachitensis*, GRPS = *G. pseudogeographica*, KISU = *Kinosternon subrubrum*, MATE = *Macrochelys temminckii*, PSCO = *Pseudemys concinna*, STCA = *Sternotherus carinatus*, STOD = *S. odoratus*, TRSC = *Trachemys scripta)* by county (CK = Cherokee, CG = Craig, JO = Johnston, LT = Latimer, LF = LeFlore, MA = Mayes, MC = McCurtain, MK = Muskogee, MT = McIntosh, OK = Okmulgee, OG = Osage, OT = Ottawa, PT = Pittsburgh, PM = Pushmataha, SQ = Sequoyah, WG = Wagoner) between this study and Webb (1970). R denotes captures made by the authors and W denotes county distribution in Webb (1970).

	CK	CG	JO	LT	LF	MA	MC	MK	MT	OK	OG	OT	PT	PM	SQ	WG
APMU			W				W		W	R	W			W		
APSP		R	W		R,W	R,W	R,W	R		R	R,W	R		R,W	R,W	R
CHPI							R,W									
CHSE	R,W	R,W	R,W	R,W	W	R	R,W	R,W	R	R,W	R,W	R,W	W		R,W	R
GRGE						R										
GROU	W	R	R		R,W	R	R,W	R	R,W	R	R	R		R	R	R,W
GRPS	R,W	R			R,W		R,W	R		R,W	R	R			R,W	
KISU			W	W	W	W	W		R	R,W			W		R*	R
MATE	W	W	W				R,W	R,W	R,W	W	W	W	W	R,W	R,W	W
PSCO	R	R	R,W	W	R,W	R,W	R,W	R		W	R,W	R	W	R,W	R,W	
STCA			R,W				R,W						R	R,W		
STOD	R,W		R,W	W	R,W	R,W	R,W	R		R	R,W	R,W		R	R,W	R
TRSC	R,W	R	R,W	R,W	R,W	R,W	R,W	R,W	R	R,W	R,W	R,W	W	R,W	R,W	R

R* = species not captured during normal survey, but observed crossing roads.

documented in 13 eastern Oklahoma counties (Webb 1970), was captured in only five counties during our surveys. Although we did capture *A. mutica* and *Kinosternon subrubrum*, we did not actively sample adequate habitat for those two species. Differences in distribution in Table 3 most likely reflect a sampling bias and not an actual range reduction.

Catch per unit effort was markedly less in three rivers in the southeastern corner of Oklahoma (Kiamichi, Mountain Fork, and Little rivers; Table 1). In these same rivers, the relative proportion of *T. scripta* was noticeably less as well.

DISCUSSION

We captured 13 of the 14 aquatic turtle species known to occur in eastern Oklahoma (Conant and Collins 1998). The one species we did not capture was the chicken turtle, *Deirochelys reticularia*, which occurs primarily in more ephemeral, lentic habitats, which we did not sample (Gibbons and others 1983; Gibbons and others 1990). Three species, *A. mutica, C. picta,* and *G. geographica,* were represented in our sample by only one individual. *Apalone mutica* is generally associated with sand bars along larger rivers (Plummer 1977; Ernst and others 1994), a habitat more prevalent in central and western Oklahoma.

Our trapping efforts were focused on one species, *M. temminckii*, so habitats sampled were biased towards those described by Pritchard (1989). Fresh, whole fish was the only bait type used. Several studies have shown bait selection in aquatic turtles (Ernst 1965; Vogt 1981; Voorhees and others 1991), and thus omnivorous species might be under-represented. Keeping these biases in mind, and the paucity of available turtle data, our study added to our knowledge of aquatic turtles in Oklahoma, including descriptions of aquatic turtle assemblages associated with *M. temminckii*, a species of concern in Oklahoma. *Macrochelys temminckii* has been extirpated from a large part of its range in Oklahoma due to historical harvest and habitat alteration (Riedle and others 2005). Identification of healthy turtle communities may help with prioritizing future management efforts, including reintroductions of *M. temminckii* into areas where it has been extirpated.

We can also begin to understand how species partition themselves within diverse aquatic turtle communities on a habitat-level scale. *Chrysemys picta* and *Kinosternon subrubrum* were observed frequently, although they were captured rarely during our surveys. The under representation of *C. picta* and *K. subrubrum* may have been due to differences in habitat use compared with the other species we captured. *Kinosternon subrubrum* inhabits shallow, water bodies with dense emergent vegetation such as marshes and sloughs (Mahmoud 1969; Ernst and others 1994). The three captures of *K. subrubrum* occurred in a man-made oxbow along the Verdigris River and small tributaries flowing into Eufala Reservoir. Several individuals were observed crossing roads near marshes in Muskogee and Sequoyah counties. In eastern Oklahoma, *C. picta* has been documented only in McCurtain County, in the extreme southeastern corner of the state. The one individual captured during our surveys was in an oxbow near the Red River in McCurtain County. While surveying the Little River in McCurtain County, we conducted visual inspections of several shallow oxbow lakes. Numerous individuals of *C. picta* were observed basking on dead woody debris in shallow oxbows adjacent to the river.

Sternotherus carinatus is found only in extreme southeastern Oklahoma, and *S. odoratus* was absent at these sites. We captured *S. carinatus,* but no *S. odoratus,* in the Kiamiachi, Little and Mountain Forks rivers. All three of those rivers exhibit higher flow and sand or gravel substrates than where we captured *S. odoratus*. While trapping oxbows and sloughs along the Red River, we captured primarily *S. odoratus*. Mahmoud (1969) compared the ecology of Oklahoman Kinosternid turtles and stated that *S. odoratus* and *S. carinatus* were very similar ecologically but used different habitats, with *S. carinatus* using deeper water and basking more than *S. odoratus*. This dichotomy in habitat use between these two closely related species of turtles was also evident from CCA of our data; *S. carinatus* was associated with faster current with more pools/runs and sandier substrates than *S. odoratus*. Additionally, we observed *S. carinatus* basking 1–2 m above the surface of the water, allowing us to catch several individuals by hand. No individuals of *S. odoratus* were ever observed basking.

Graptemys ouachitensis, the species captured second-most frequently in this study, and *G. pseudogeographica* were associated with larger, downstream, slow-moving sections of rivers, particularly at sites along the Caney and Deep Fork rivers. Fuselier and Edds (1994) discussed habitat partitioning among three species of *Graptemys* in southeastern Kansas. They noted that *G. ouachitensis* was a wider-ranging species in the state, while *G. pseudogeographica* avoided sites with sandy substrate. This avoidance of sandy substrate probably prevents *G. pseudogeographica* from ranging farther west than extreme eastern Kansas or Oklahoma.

Oklahoma exhibits a fairly diverse aquatic turtle fauna, with many species reaching the western extent of their distribution in the state (Conant and Collins 1998). To truly understand distribution and densities of our native aquatic turtle species, more in-depth studies need to be initiated. Without these valuable baseline data, we are all making inferences on a limited amount of information. Regardless, current commercial turtle harvesting practices are affecting aquatic turtles negatively. During the course of this survey, a large number of turtles were harvested (Table 4), which could bias any efforts at constructing baseline inventories for the state. For instance, in areas where capture rates were low, there was a shift in the dominant species captured away from *T. scripta*. Data from the number of turtles bought by commercial turtle buyers show that *T. scripta* was the most utilized of all aquatic turtle species, while *S. carinatus* was the least utilized. Ernst and others (1994) describes *T. scripta* as an ecological generalist and in our CCA, *T. scripta* fell out near the origin of axes 1 and 2, confirming its habitat generality. This species was by far the most common turtle of our study when all sites were combined. *Trachemys scripta* has been captured with equally high frequencies in other aquatic turtle surveys similar to ours in Arkansas (Wagner and others 1996), Illinois (Cagle 1942; Dreslik and others 2005), Kansas (Shipman and others 1995), Missouri (Shipman and Riedle 2008), and Oklahoma (Stone and others 2005). Yet in several southeastern Oklahoma rivers (Kiamichi, Mountain Fork, and Little rivers), we captured far fewer *T. scripta* than in the other rivers (capturing even more *S. carinatus* than *T. scripta* in two of these three rivers). We suspect that the abundance of *T. scripta* in some Oklahoma rivers has declined in recent times and that heavy commercial harvest of turtles has played a major role.

Although we focus on harvest as the primary cause for possible turtle declines in southeastern Oklahoma, other factors also may be involved. Heck (1998) and Riedle and others (2005) described several factors affecting health of aquatic ecosystems in eastern Oklahoma. These anthropogenic perturbations include channelization (Verdigris River), hypolimnetic release of cold water (Illinois and Mountain Fork River), and pollution (Little River). Many of these factors occur in rivers exhibiting low capture rates of turtles. It is likely a combination of habitat alteration and commercial harvest that are impacting aquatic turtle populations in southeastern Oklahoma.

The southeastern United States does exhibit some of the most diverse aquatic turtle communities in the world (Iverson 1992), but good regional baseline data are needed for management of these riverine systems. Even with the sampling biases in this study, the information gathered here is the best available

Table 4. Number of turtles by species purchased by commercial turtle buyers between 1994 and 1999. Data based on commercial turtle buyer reports submitted to the Oklahoma Department of Wildlife Conservation.

Species	1994	1995	1996	1997	1998	1999	Total
Trachemys scripta	6,165	8,623	37,253	84,206	41,996	49,035	227,278
Pseudemys concinna	3	0	49	207	50	163	472
Graptemys ouachitensis	10	1,013	196	586	624	593	3,022
G. pseudogeographica	0	3	25	718	26	324	1,096
Chrysemys picta	0	15	0	8	0	50	73
Apalone spinifera	4,043	4,111	9,453	21,029	13,784	16,214	68,634
A. mutica	2,772	2,993	4,570	13,683	12,487	5,509	42,014
Chelydra serpentina	481	1,135	4,451	9,179	3,753	5,077	24,076
Sternotherus odoratus	1	67	251	209	464	950	1,942
S. carinatus	0	46	66	25	0	0	137
Kinosternon flavescens	46	83	76	245	196	21	858
K. subrubrum	2	857	0	5	0 0	864	
Total	13,523	18,946	56,390	130,100	73,380	78,127	370,466

baseline data for aquatic turtles in eastern Oklahoma. We strongly urge future surveys to use more diverse sampling methods to: 1) gain a more complete picture of aquatic turtle assemblages in Oklahoma and 2) continue to track trends in abundances based on known perturbations of Oklahoma streams.

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