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Population Structure of the Alligator Snapping Turtle, *Macrochelys temminckii*, on the Western Edge of its Distribution

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ABSTRACT. – A mark-recapture project on *Macrochelys temminckii* was conducted between 1997 and 2000 at Sequoyah National Wildlife Refuge, Muskogee and Sequoyah counties, in eastern Oklahoma. Turtles were captured in all streams and exhibited equal sex ratios, marked sexual-size dimorphism, and population densities between 28 and 34 animals per km stretch of stream. There was evidence of past population perturbations, with very few large adults captured, and a cohort of subadults highly underrepresented.

Turtles have long been recognized as an integral part of aquatic communities, and all relevant literature on river turtle diversity, ecological roles, and community structure was recently reviewed in Moll and Moll (2004). Within this synopsis though, it is clear that outside of common species, such as the slider turtle, *Trachemys scripta* (Cagle 1950; Gibbons 1990), in-depth life history studies of individual species are noticeably absent. Detailed life-history strategies have been constructed only for a handful of species, most notably the Blanding's turtle, *Emydoidea blandingii* (Congdon et al. 1993), and the common snapping turtle, *Chelydra serpentina* (Congdon et al. 1994). The data collected on *C. serpentina* were representative only of populations at the northern reaches of the species' distribution and so did not demonstrate geographic variation in life-history strategies for that species. With many species of turtles facing various threats, a better understanding of these life-history strategies is much needed for developing sound management strategies.

The alligator snapping turtle, *Macrochelys temminckii*, is a large, riverine, bottom-dwelling species that occupies a predator-scavenger role in the southeastern United States (Moll and Moll 2000). Shipman and Riedle (1994) and Shipman and Neeley (1998) surveyed 2 populations in southeastern Missouri. In each, turtles were 2–24 kg in body mass; the sex ratio for the 2 populations was 1 male to 1.09 females. Trauth et al. (1998) surveyed 2 sites in Arkansas with a population sex ratio of 1:1 and reported that males were significantly larger than females. Males were also significantly larger than females from examination of specimens at a commercial meat-processing facility in Louisiana (Tucker and Sloan 1997). Based on growth curves, *M. temminckii* reached sexual maturity when the straight carapace length (CL) was 370 mm in males and 330 mm in females (Dobie 1971; Tucker and Sloan 1997).

Because of the apparent decline of the species throughout its range (Pritchard 1989; Ernst et al. 1994),

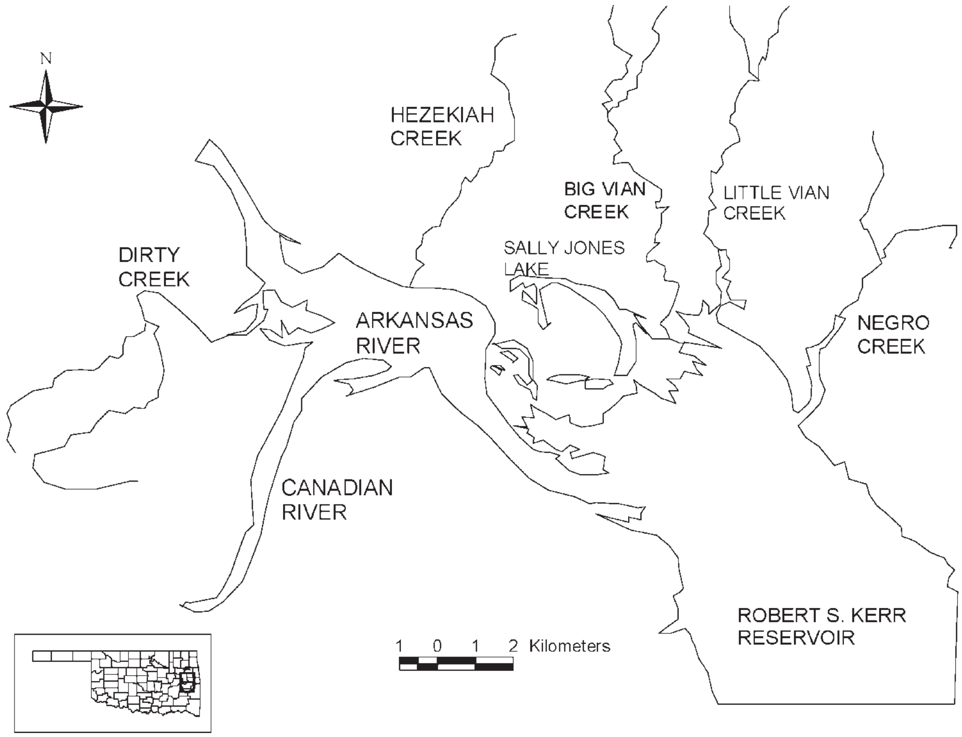

Figure 1. Sequoyah National Wildlife Refuge, Muskogee and Sequoyah counties, Oklahoma.

large unimpacted populations are difficult to find. Despite the need for aggressive conservation measures throughout its range, information on ecology and demography of unimpacted populations is largely nonexistent but obviously necessary for the management or restoration of impacted populations. The eastern third of Oklahoma was surveyed in 1997–1999 specifically for *M. temminckii*, which has experienced drastic declines throughout its range, and only 2 seemingly healthy populations were discovered (Riedle et al. 2005). Our objective was to describe the demographic structure of a population of *M. temminckii* by quantifying population size and density, sex ratio, sexual dimorphism, and size-class distribution, which are needed to develop conservation strategies.

Methods. — Sequoyah National Wildlife Refuge (SNWR) is a 51,376-ha area in Oklahoma that encompasses parts of the Canadian and Arkansas rivers and their confluence. Primary habitat was bottomland flood plain with many small tributaries that drained into both rivers. We sampled SNWR sporadically in 1997 and 1998, and more intensively in 1999 and 2000. Several small streams were surveyed, including Dirty Creek, Hezekiah Creek, Big Vian Creek, Little Vian Creek, and Negro Creek. Sally Jones Lake, a shallow lake connected to Big Vian Creek, also was surveyed (Fig. 1). Surveying was conducted again in 2001 to capture *M. temminckii* at sites where it was not previously captured. Throughout the study, Big Vian Creek and Little Vian Creek were sampled more intensively because of their easy access and were used to estimate population size and density. Both streams are tributaries of the Arkansas River, and their mouths were about 0.5 km apart. The navigable (by a 4.2-m flat-bottomed boat) stretches of both streams were surveyed. The navigable stretch of Little Vian Creek was 2 km in length, reaching from its mouth until the stream became shallow and predominated by riffles. Big Vian Creek was 4.5 km in length from the mouth to where the stream became very shallow and clogged with fallen logs.

All streams were sampled by using commercial hoop nets that were 2.1 m in length and constructed of four 1.05-m hoops covered with 2.5-cm mesh. Nets were set upstream from submerged structures, such as fallen trees. Nets were baited with fresh fish suspended by a piece of twine on the hoop furthest from the opening of the net. Bait fish were procured with gill nets or incidental capture in the turtle nets. Turtle nets were set late in the afternoon or evening and were checked the following morning.

We recorded basic morphometric data on each *M. temminckii* captured, including mass (to the nearest 0.1 kg), sex, and maximum CL and plastron length (PL) to the nearest millimeter. All individuals of *M. temminckii* captured were uniquely marked and fitted with numbered tags. The marking was done by using a hole drilled into specific marginal scutes along the carapace. We placed short plastic cable ties in all holes to ensure that they did not prematurely close. Numbered plastic cattle ear tags also were attached to one of the holes by a plastic cable tie.

Each *M. temminckii* was assigned to 1 of 3 groups based on sex and size. Sex was determined by the presence or absence of a penis. The penis, if present, can be felt by

Table 1. Number of individuals and composition of turtle species captured at Sequoyah National Wildlife Refuge, Oklahoma, between 1997–2000.

Species	*n*	% Total captures
Trachemys scripta	2287	82.8
Macrochelys temminckii	197	7.1
Graptemys ouachitensis	103	3.7
Chelydra serpentina	64	2.3
Apalone spinifera	40	1.4
Pseudemys concinna	32	1.1
Sternotherus odoratus	18	0.6
Graptemys pseudogeographica	17	0.6
Kinosternon subrubrum	1	<0.1

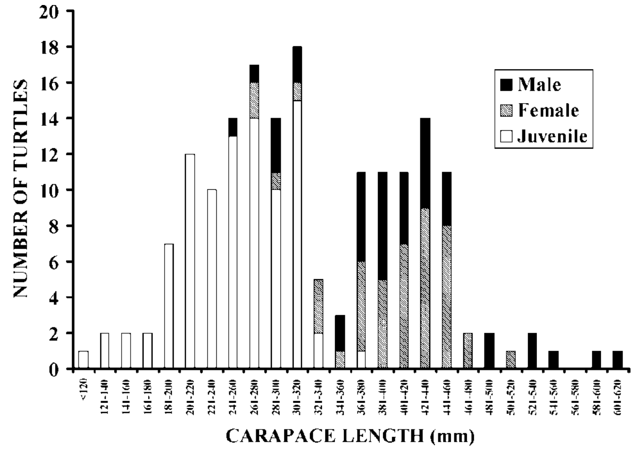

Figure 2. Size classes, based on carapace length in millimeters, of *Macrochelys temminckii* captured at Sequoyah National Wildlife Refuge, Oklahoma.

inserting a finger into the turtle's cloaca. Turtles that were too small to examine for a penis were classified as juveniles (sex unknown). Morphologic measurements were compared between males and females by using 2 sample *t*-tests. A χ^2 analysis of sexes by size class was used to compare number of males to females in 2 size classes: medium (361–480 mm) and large (481–620 mm).

Results. — Population Size and Density. — We surveyed for 565 net nights (1 net night = 1 net/night) between 1997 and 2000 on Dirty Creek, Hezekiah Creek, Big Vian Creek, Little Vian Creek, Sally Jones Lake, and Negro Creek and made 197 captures of *M. temminckii*. *Macrochelys temminckii* was not captured in Sally Jones Lake or Negro Creek between 1997 and 2000. We marked and released 157 *M. temminckii,* with a recapture rate of 21%. An additional 26 captures (22 new individuals, 4 recaptures) of *M. temminckii* were made in 2001, 4 of those on Negro Creek. Nine species of aquatic turtles were captured, and *M. temminckii* was the second most abundant, which represented 7% of all captures (Table 1).

We used a Lincoln-Peterson estimator of population size based on capture-mark-recapture data in 1997–2000. Estimated population sizes were 127.5 ± 24.5 standard error (SE) individuals, with a density of 28.3 turtles/km in Big Vian Creek, and 68.4 ± 18.2 SE individuals, with a density of 34.2 turtles/km in Little Vian Creek.

Size Distribution. — Mean sizes of turtles were 8.71 kg (range 0.22–46.4 kg), 330 mm CL (110–614 mm), and 240 mm PL (72–470 mm). We captured few small juveniles and large adults, and turtles with CL between 321 and 360 mm were noticeably underrepresented (Fig. 2).

Sex Ratio and Sexual-Size Dimorphism. — We captured 41 males, 47 females, and 91 juveniles. The male:female ratio (1:1.1) did not differ from 1:1 ($\chi^2 = 0.0036$, df $= 1$, $p = 0.952$). We were able to determine sex of males ≥240 mm CL and females ≥260 mm CL in most cases. We were able to determine sex of all individuals (except one) at CL > 360 mm (Fig. 2).

We evaluated sexual-size dimorphism of adult turtles based on the upper end of the range of size at sexual maturity (400 mm; Dobie 1971; Tucker and Sloan 1997). Males were significantly larger than females in CL ($t = 2.45$, df $= 53$, $p = 0.017$) and mass ($t = 2.84$, df $= 56$, $p = 0.006$). The number of males and females differed between the medium and large size classes ($\chi^2 = 4.76$, df $= 1$, $p = 0.029$); males were more abundant in the large adult cohort (Fig. 2).

Discussion. — *Macrochelys temminckii* was the second-most abundant species captured at SNWR, which occurred in high densities relative to most other populations in the state (Riedle et al. 2005). Because the Lincoln-Peterson estimator assumes no emigration or immigration, it may have overestimated population size, but *M. temminckii* was captured frequently and still exhibited a low recapture rate. Unfortunately, there is a paucity of information on absolute population densities of *M. temminckii* to compare with SNWR densities.

The adult sex ratio of 1:1.1 is similar to values from populations in Missouri and Arkansas (Shipman and Riedle 1994; Shipman and Neeley 1998; Trauth et al. 1998). Among the larger turtles (CL > 480 mm), males significantly outnumbered females (7:1). Although we were able to sex some individuals at relatively small sizes, our ability to sex small turtles was inconsistent from individual to individual (limited by the inability to insert a finger far enough into the cloaca to feel for the presence or absence of a penis). We also were not able to determine the size of sexual maturity, because we did no internal analysis of follicular or testicular maturation. We were, however, able to accurately sex all individuals (except one) with CL ≥ 380 mm, which was within the size range for sexually mature turtles in Louisiana (Tucker and Sloan 1997). Populations of *M. temminckii* in Louisiana reached sexual maturity at 13–21 years for females and 11–21 years for males, but estimates of age to maturity are not available for Oklahoma populations. A wide range of size classes was captured, which provided evidence for a stable population with good recruitment (Fig. 2), with some exceptions. Three cohorts were rare or absent from our sample: hatchling-size turtles, turtles in the size class 321–360 mm CL, and large adults.

Although the population of *M. temminckii* at SNWR appeared stable, there was evidence of current and historic population perturbations. Hatchling-size turtles were absent from our sample, and turtles <180-mm CL were rare. There may have been a trap bias toward larger turtles because the 2.5-cm mesh was small enough to contain hatchling turtles, but the throat, designed to capture larger turtles, may have been large enough to allow the escape of small turtles. Juvenile common snapping turtles, *Chelydra serpentina*, occupy small streams after hatching and disperse from those streams as they reach sexual maturity (Graves and Anderson 1987). This could also be occurring with hatchling *M. temminckii* at SNWR, with smaller turtles occupying smaller streams where we did not trap at all. Lastly, the absence of small turtles could be attributed to mammalian predation, principally raccoons, *Procyon lotor*. Raccoons have been identified as one of the most important predators on North American turtles (Stancyk 1982; Ernst et al. 1994), with raccoon related egg and hatchling mortality rates that reach 100% in many populations (Mitchell and Klemens 2000).

Individuals with 321–360-mm CL were underrepresented in our sample. One hypothesis may be that the refuge population experienced some past disturbance that may have had a negative impact on nest success, and that the underrepresented size-age class is the lingering "footprint" of such relative nest failure. Such a past disturbance, known to affect other species of turtles (Moll and Moll 2000), was the flooding of upstream areas after construction of the dam to make the Robert S. Kerr Reservoir downstream from SNWR. Construction of the dam began in April 1964, and the closure occurred in October 1970. Subsequently, stream levels rose significantly based on anecdotal information from SNWR personnel and the presence of remnant hardwood structure in the current streambed. This dramatic rise in water level may have temporarily destroyed nest sites along the streams. The time elapsed since this post-1970 flooding some 25 years ago may correspond to the age of the 321–360-mm CL underrepresented size class, although, based on Tucker and Sloan (1997), these turtles seem too young. Nevertheless, the growth rate of Oklahoma *M. temminckii* is unknown, and the time course of habitat disruption because of upstream flooding after the creation of a large reservoir is also unknown.

Large adults (25–55 kg) also were scarce in our sample; although, many such large individuals were captured throughout eastern Oklahoma in the past (Webb 1970; Carpenter and Krupa 1989). We captured 7 large males (25.0, 28.1, 34.5, 36.3, 41.8, 42.3, and 46.4 kg) and one large female (26.8 kg) while sampling at SNWR. One hypothesis for the scarcity of large turtles in our study is that historic harvest of large turtles may have occurred at SNWR. Shipman and Riedle (1994) and Trauth et al. (1998) reported differences in body size between harvested and unharvested populations, with the absence of larger turtles from exploited populations.

There is some evidence for an historical take of *M. temminckii* in Oklahoma (Carpenter and Krupa 1989; Pritchard 1989). Before SNWR was established in 1970, there may have been a significant harvest of *M. temminckii,* especially large ones, from that area, and not enough time has elapsed to allow for the current adult cohort to grow to larger body sizes. The current paucity of large adults supports this conclusion. If breeding adults were seriously depleted before the refuge was established, then there would have been very little recruitment of turtles (now represented by the missing size-age class). However, smaller turtles would have been commercially unimportant and left unharvested. These turtles have now grown into the small adult age class at SNWR (Fig. 2). Their offspring are the current subadults. A few turtles big enough to be commercially important before the refuge was established somehow escaped harvest and currently represent the largest size-age class at SNWR (Fig. 2).

Although the type and severity of historical impacts on populations of *M. temminckii* at SNWR are largely speculative, there is some evidence that total protection of the adult cohorts will allow populations of *M. temminckii* to recover over time. A large number of adults reaching sexual maturity and even more subadult turtles following behind, which suggests that the species can recover after historic disturbances, albeit slowly, are shown in Fig. 2. What remains unknown is what is happening with the hatchling cohorts and how that may affect the future stability of the population. Much work is needed in the future to more fully understand the life history of *M. temminckii* and its role in the aquatic turtle community.

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Potential Bacterial Pathogens Carried by Nesting Leatherback Turtles (*Dermochelys coriacea*) in Costa Rica

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Abstract. – **Between March and May 2003, the leatherback turtle (*Dermochelys coriacea*) nesting population of the Pacuare Nature Reserve (northern Caribbean coast of Costa Rica) was surveyed for potential bacterial pathogens associated with the cloaca and upper respiratory tracts. A total of 189 isolates that belong to 15 genera, including 113 gram-negative and 76 gram-positive bacteria, were identified from samples of 70 nesting females. The majority of the bacterial species recovered in this study, including 5 *Salmonella* isolates, may be considered as potential pathogens for sea turtles, as well as for humans.**

The leatherback sea turtle (*Dermochelys coriacea*) is the only surviving member of the Dermochelyidae and the largest of living chelonians. It is highly migratory and is distributed in temperate and tropical pelagic waters (Plotkin 2003). The leatherback turtle rookery of Caribbean Central America represents 1 of the 4 largest remaining rookeries worldwide, together with French Guiana/Suriname, Gabon, and Trinidad (Troëng et al. 2004).

Incidental capture in gillnet and longline fisheries, together with egg harvest, have been indicated as the principal factors involved in the decline of many leatherback populations (Kar and Bhaskar 1982; Spotila et al. 2000; Lewison et al. 2004; Sarti-Martinez et al. 2007; Alfaro-Shigueto et al. 2007). Marine pollution by several anthropogenic contaminants, primarily plastic debris, may also have an important impact on the survival of this species (Wehle and Coleman 1983; Barreiros and Barcelos 2001). However, there is insufficient information on the impact of marine debris throughout most of this species range, nor is there adequate knowledge on the health status of leatherbacks in the wild.

No information exists on the cloacal and nasal microflora of apparently healthy leatherback turtles. Only 1 report exists on the isolation of *Vibrio damsela* that causes lethal valvular endocarditis and septicemia in a