

Monitoring of a Reintroduced Population of Juvenile Alligator Snapping Turtles

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ABSTRACT. – Reintroduction is a common management tool for conserving imperiled species, but many reintroductions have included little or no postrelease assessment of project success. The alligator snapping turtle (*Macrochelys temminckii*) is a long-lived species that has experienced significant declines throughout its range, although suitable habitat remains. We report the findings of a reintroduction effort that was initiated in 2008 near the northwestern limit of the species' range. Two hundred forty-six *M. temminckii* were released into the Caney River and its tributary, Pond Creek, from 2008 to 2010. All turtles exhibited measurable growth by their first recapture 1–3 yrs after release, and no decline in body condition was observed, either in comparison to prerelease body condition or to the condition of animals in the same cohorts that remained in captivity. Apparent survival and recapture probabilities increased with age. Apparent survivorship values were higher for turtles released in the main channel of the Caney River, but recapture probabilities were higher in its tributary. Ultimately, survivorship values may have been influenced by low recapture rates and emigration, in addition to mortality.

KEY WORDS. – Reptilia; Testudines: Cheloniidae; *Macrochelys temminckii*; growth; Oklahoma; survivorship

Reintroduction is an increasingly important conservation management tool for species that have experienced population declines but for which suitable habitat persists (Snyder et al. 1996; Seddon et al. 2007, 2012). Reintroductions may be conducted to satisfy a variety of objectives (Seddon 2010), but they most frequently aim to either repopulate areas where a species has been extirpated or supplement depleted populations that lack sufficient numbers to recover without intervention (Seddon et al. 2007). Potential drawbacks to reintroductions include aberrant behavior resulting from captive rearing (Crane and Mathis 2010), low genetic diversity among released stock (Groombridge et al. 2012), and high mortality rates of released animals attributable to inexperience finding local resources or identifying and evading predators (Snyder et al. 1996; Reinert and Rupert 1999; Roe et al. 2010).

Quantifying successes and failures of reintroduction projects can be accomplished only with postrelease monitoring (Nichols and Armstrong 2012). Effective postrelease monitoring is often expensive, time consuming, and may require years or decades to determine the ultimate success or failure of a reintroduction project. As a result, postrelease monitoring efforts were not always incorporated into early reintroduction efforts (Sarrazin and Barbault 1996; Snyder et al. 1996; Seddon et al. 2007).

The alligator snapping turtle (*Macrochelys temminckii*) has experienced significant declines throughout its range, in part attributable to overharvest and habitat

modification (Pritchard 1989; Ernst and Lovich 2009). In Oklahoma, *M. temminckii* historically occurred across much of the eastern one-third of the state, but today it is restricted to just a few river segments in the east-central and southeastern portions of the state (Riedle et al. 2005, 2006). Surveys conducted over three years at 67 sites in 15 counties in eastern Oklahoma resulted in only 63 captures at 4 sites (Riedle et al. 2005). *Macrochelys temminckii* is currently listed as a Tier II Species of Special Concern in the Oklahoma Comprehensive Wildlife Conservation Strategy, and both harvest and possession are prohibited.

Reintroduction efforts to reestablish viable populations of *M. temminckii* in suitable habitat are warranted (Riedle et al. 2008a). A propagation program was initiated at Tishomingo National Fish Hatchery in 1999 to provide head-started animals for reintroduction efforts (Riedle et al. 2008a). Brood stock was acquired from a historically robust population along the Arkansas River near the Oklahoma/Arkansas border. *Macrochelys temminckii* occurring in the Mississippi River drainage exhibit low genetic heterozygosity and fairly uniform allele composition, a lack of private alleles, and fixation for the same mtDNA haplotype (Echelle et al. 2010). Brood stock exhibiting the Mississippi River haplotype would still maintain a natural pattern of genetic connection of populations. Prerelease surveys ranked potential release sites based on historical presence of the species, elimina-

tion of known or suspected extirpation factors, presence of suitable habitat, and the existence of a robust aquatic turtle assemblage (Riedle et al. 2005, 2008a).

A segment of the Caney River in northeastern Oklahoma was chosen as an experimental release site because it possessed all of the characteristics that were deemed important for this species' long-term success (Riedle et al. 2008a). There were few historical records for the species from the Caney River (Black 1982; Carpenter and Krupa 1989), but the habitat is comparable to that inhabited by extant populations in the state (Riedle et al. 2006). Because of its isolation from metropolitan areas, human activity on the Caney River and its tributaries is low in comparison to many rivers in the state and includes low levels of fishing, camping, swimming, and boating. Finally, Riedle et al. (2009) documented a robust aquatic turtle assemblage on the Caney River that included seven aquatic turtle species.

Mark-recapture surveys were conducted from 2008 to 2012 on the Caney River to measure growth rates, changes in body condition, and annual survival rates. Although none of these metrics are definitive measures of success, all are informative indicators of the trajectory of reintroduction efforts (Burke 1991).

METHODS

The extent of the Caney River that we sampled was restricted by limitations imposed by the navigability of the river and the availability of public access points. A total of 16.4 km of the river and one of its tributaries, Pond Creek, was sampled. We used hoop traps consisting of 76-cm-diameter hoops and 2.5-cm² mesh. The traps were stretched by attaching notched PVC pipes to the outermost hoops. Traps were baited with either canned sardines or fresh fish that were either by-catch in the hoop traps or caught in gill or trammel nets. Traps were set between 1300 and 1800 hrs and checked the following morning. We set 6–15 nets daily, alternating between the Caney River and Pond Creek. All individuals were identifiable from PIT tags that were implanted prior to release.

Change in size was assessed by comparing individual turtles' straight midline carapace length (MCL) at the time of release to the MCL at their first and second recapture and analyzed in a repeated-measures analysis of variance (ANOVA). Because animals are expected to grow at different size-specific rates, we calculated size-corrected growth by:

$$\left(\frac{\text{MCL}_i \text{MCL}_r}{\text{MCL}_r} \right)^{1/y}$$

where MCL_r was MCL at the time of release, MCL_i was the MCL at the i th recapture, and y was the number of years between captures.

Body condition was calculated by regressing \log_{10} (mass) on \log_{10} (MCL) and using the resulting residuals to generate a body condition index (Jakob et al. 1996). For

purposes of comparison between released and captive animals, head-started turtles that remained at the hatchery were included in measures of body condition. The hatchery turtles were divided into 2 groups: 1) individuals that were maintained indoors where they were fed dead fish and fish-based pellets ad libitum; and 2) individuals that were maintained for a year in an outdoor pond at the hatchery where they were exposed to natural cycles and required to forage. Differences in body condition among reintroduced and captive groups were analyzed in a repeated-measures ANOVA, with successive recaptures repeated for individuals. Finally, we assessed seasonal changes in body condition of released turtles by regressing body condition values against time of year (Julian date).

To track survivorship and recapture rates from the time of release in capture-recapture analyses, we defined each individual's release date as its first capture (Treglia 2010). We combined capture data from each sampling session to generate annual (1 per year) encounter histories for a total of 5 recapture events. Apparent survival (Φ) and recapture rates (p) were calculated using open population Cormack-Jolly-Seber (CJS) models (Lebreton et al. 1992) in Program MARK (White and Burnham 1999). We generated CJS model sets based on age at release (3-yr, 4-yr, and 5-yr) and release site (main channel vs. tributary). Models were generated to test whether Φ or p differed based on group (age or release site), time between samples, or a group-time interaction. Model selection was based on Akaike Information Criterion (AIC_c) values, with lower values denoting greater parsimony (Burnham and Anderson 2002).

RESULTS

Two hundred forty-six head-started juvenile *M. temminckii* were released in the Caney River system from 2008 to 2010 (Table 1). The trapping surveys in 2008 and 2009 consisted of 4 d each of trapping during the month of July. Fifteen traps were set daily, for a total effort of 60 trap nights in each of those 2 yrs. In 2010, we sampled in June and July for 11 d and a total of 189 trap nights. In 2011, we sampled May through August for 21 d with a total of 169 trap nights. In 2012, we sampled May through August for 23 d with a total of 171 trap nights. Two turtles initially released into the Caney River were subsequently recaptured in Pond Creek. Three turtles released in Pond Creek were later captured in the main channel of the Caney River.

Recaptured individuals consistently exhibited measurable increases in MCL, both in comparison to their size at release and at previous recaptures ($F_{2,27} = 82.05$, $p = 0.0005$; Fig. 1). Following release, turtles grew 5%–41% in length per year (mean = 17% \pm 1%) and 18%–442% in mass per year (mean = 82% \pm 11%). Mass correlated positively with MCL (slope = 0.63, $r^2 = 0.97$, $p = 0.0005$; Fig. 2). Body condition did not vary between animals that were maintained indoors or

Table 1. Age distribution, number, and size of alligator snapping turtles released in Pond Creek and the Caney River. Values reported are mean \pm SE.

| Release year | Release site | Year class | <i>n</i> | Mass (g) | Carapace length (mm) |
|--------------|--------------|------------|----------|--------------------|----------------------|
| 2008 | Pond Creek | 2004 | 46 | 1352 \pm 84.34 | 169.32 \pm 3.48 |
| | | 2005 | 44 | 328.67 \pm 9.26 | 109.69 \pm 1.18 |
| 2009 | Caney River | 2005 | 60 | 661.8 \pm 19.11 | 137.55 \pm 1.28 |
| 2010 | Caney River | 2003 | 2 | 2315 \pm 280 | 208.98 \pm 8.01 |
| | | 2005 | 23 | 834.57 \pm 40.56 | 138.74 \pm 4.78 |
| | | 2006 | 17 | 322.65 \pm 24.34 | 107.44 \pm 2.94 |
| | | 2007 | 54 | 174.17 \pm 6.58 | 86.6 \pm 1.07 |

outdoors in a hatchery pond, nor based on the times of initial release or recaptures of reintroduced individuals ($F_{3,301} = 0.24$, $p = 0.87$). Additionally, body condition did not correlate with time of year ($r^2 = 0.068$, $p = 0.101$, slope = 0.04). In 3 of the 4 yrs of monitoring, average annual growth rates were faster among turtles that were released than among those that remained in captivity during the same period (Fig. 3).

The population of released turtles included 97 3-yr-olds, 105 4-yr-olds, 31 5-yr-olds, 5 6-yr-olds, and 3 7-yr-olds. Because of the small number of older animals that were released, we only included turtles that were 3–5 yrs in our models. The best model to explain encounter histories based on age at release was the model $\Phi(\text{age})p(\text{age} \times \text{time})$, where survivorship varied by age, and recapture rates varied across age and time independently of one another (Table 2). Younger turtles had lower survivorship and lower recapture rates than did older ones, although recapture rates were low across all ages (Table 3).

The best model to explain encounter histories based on which stream turtles were released in was $\Phi(\text{time})p(\text{stream} \times \text{time})$, where survivorship varied across time,

and recapture rates varied across both stream and time independent of one another (Table 2). Mean survivorship for all sample periods was 0.59 ± 0.12 . The main channel of the Caney River had higher survivorship but lower recapture rates than did Pond Creek.

DISCUSSION

Dodd and Seigel (1991) stated that they were unable to find any examples of successful repatriations, relocations, or translocations of amphibians and reptiles in their review of the literature. Burke (1991) argued that there are many such examples and that, although many examples of introductions were not conducted for conservation purposes per se, the theoretical and empirical studies of biological invasions are directly relevant to repatriations, relocations, or translocations. These invasions include several genera of turtles that have become established outside of their native ranges (Kopecky et al. 2013; Masin et al. 2014). Recent translocations of *Gopherus polyphemus* (Tuberville et al. 2005, 2011) and *Terrapene carolina* (Cook 2004; Rittenhouse et al. 2007) suggest that relocations and translocations may be feasible options for

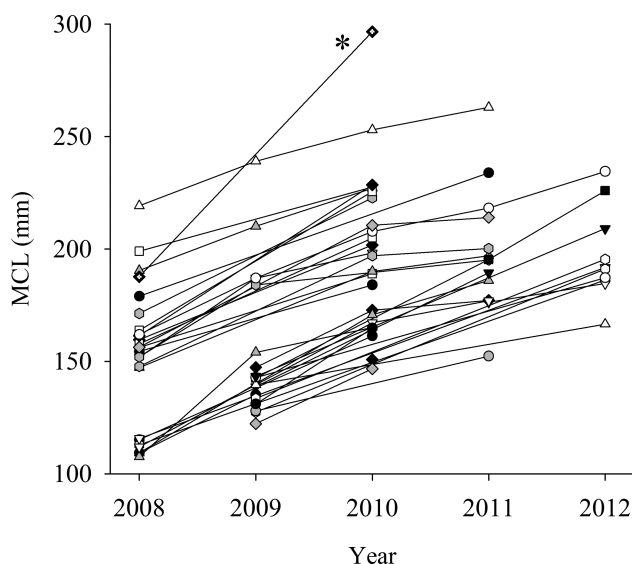


Figure 1. Straight midline carapace length (MCL) growth of 40 recaptured alligator snapping turtles. Each line connects points representing a single turtle. The first point in each set indicates size at the time of release and each subsequent point represents a recapture.

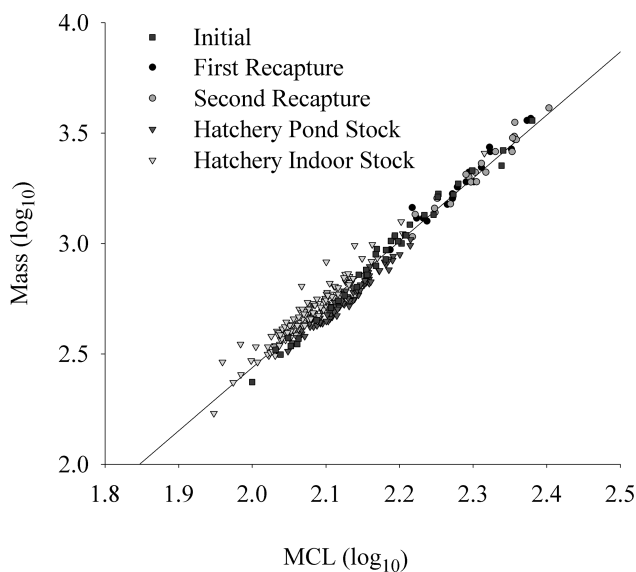


Figure 2. Relationship of mass to straight midline carapace length (MCL) of alligator snapping turtles recaptured from the Caney River and Pond Creek, as well as turtles that remained indoors or in an outdoor pond at Tishomingo National Fish Hatchery ($r^2 = 0.97$, $p = 0.0005$, slope = 0.63).

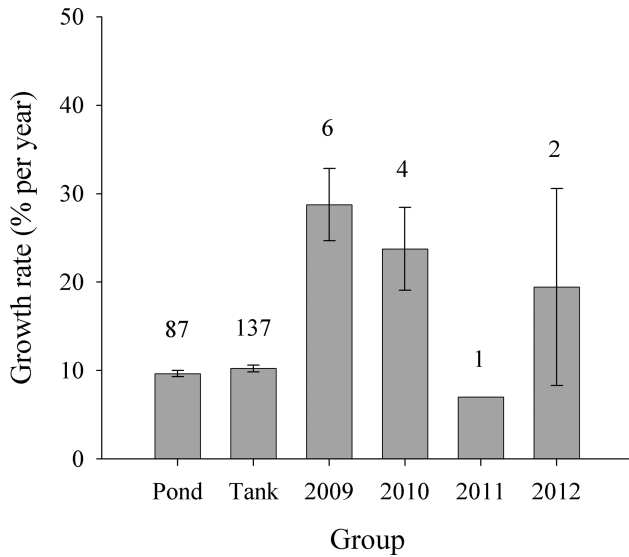


Figure 3. Average growth rate (MCL) of alligator snapping turtles measured under different conditions and by year of recapture after release. The sample size of each group is listed above its bar. Error bars are ± 1 SE.

conservation, but more information on each species' ecology is needed to improve future efforts.

All recaptured individuals in this study exhibited substantial and consistent growth, and body condition remained comparable to that of turtles that remained in captivity and were fed ad libitum. This suggests that reintroduced turtles successfully and quickly located the resources needed to survive and flourish. One noteworthy turtle exhibited exceptional growth (Fig. 1, identified with an asterisk). The individual was a year class 2004 male; MCL at release in 2008 was 187.6 mm, and MCL at second recapture in 2010 was 296.6 mm. This individual was larger than average in comparison to others in its cohort (mean = 173.0 mm) at the time of release and his MCL

Table 3. Survivorship (Φ) and recapture rates (p) ± 1 SE by group for age at release and stream (main channel vs. tributary) for *Macrochelys temminckii*.

| | Φ | p |
|---------------------|-----------------|-----------------|
| Age at release (yr) | | |
| 3 | 0.59 \pm 0.14 | 0.04 \pm 0.03 |
| 4 | 0.70 \pm 0.16 | 0.11 \pm 0.07 |
| 5 | 1.00 \pm 0.28 | 0.19 \pm 0.07 |
| Stream | | |
| Main channel | 0.72 \pm 0.20 | 0.09 \pm 0.04 |
| Tributary | 0.56 \pm 0.06 | 0.49 \pm 0.16 |

increased 28% per year, whereas mass increased 89% per year (mean increase in MCL = 9% and in mass = 75%). Even discounting this unusual outlier, growth of released turtles was robust. One-year growth of released turtles was higher than that of captive turtles kept outdoors in a pond stocked with a variety of sunfish, minnows, and shiners, and even higher than those maintained indoors year round where water temperature fluctuations were moderated and food was readily available.

Two previous studies of translocated and/or reintroduced *M. temminckii* also reported growth and body condition a year after release. In Louisiana, a subadult *M. temminckii* that was translocated to a site presumed to be outside of its natural home range exhibited modest growth one year after its release (Bogosian 2010). The single translocated animal grew approximately twice as much as resident subadults that were of comparable size and that were monitored during the same period. In a study conducted in southern Oklahoma, captive-reared *M. temminckii* were released into an oxbow and monitored for more than a year after release (Moore et al. 2012). The turtles in that study actually exhibited greater body condition after one year than did animals from the same cohort that remained in captivity.

Table 2. Cormack-Jolly-Seber model set analyzing the effect of age at release, release year, and stream (main channel vs. tributary) on survivorship and recapture rate of reintroduced *Macrochelys temminckii*.

| Model | AIC _c | Δ AIC _c | AIC _c weight | No. of parameters |
|--|------------------|---------------------------|-------------------------|-------------------|
| Age at release | | | | |
| $\Phi(\text{age}) p(\text{age} \times \text{time})$ | 394.96 | 0.00 | 0.50 | 15 |
| $\Phi(\text{time}) p(\text{age} \times \text{time})$ | 395.96 | 1.00 | 0.30 | 15 |
| $\Phi(\text{age} \times \text{time}) p(\text{age} \times \text{time})$ | 396.75 | 1.79 | 0.20 | 20 |
| $\Phi(\text{age} \times \text{time}) p(\text{age})$ | 422.92 | 27.96 | 0.00 | 15 |
| $\Phi(\text{time}) p(\text{age})$ | 425.34 | 30.38 | 0.00 | 7 |
| $\Phi(\text{age}) p(\text{age})$ | 429.83 | 34.87 | 0.00 | 6 |
| $\Phi(\text{age} \times \text{time}) p(\text{time})$ | 430.82 | 35.86 | 0.00 | 15 |
| $\Phi(\text{age}) p(\text{time})$ | 434.14 | 39.18 | 0.00 | 7 |
| $\Phi(\text{time}) p(\text{time})$ | 438.87 | 43.91 | 0.00 | 7 |
| Stream | | | | |
| $\Phi(\text{time}) p(\text{stream} \times \text{time})$ | 440.23 | 0.00 | 0.58 | 11 |
| $\Phi(\text{stream}) p(\text{stream} \times \text{time})$ | 441.48 | 1.26 | 0.31 | 10 |
| $\Phi(\text{stream} \times \text{time}) p(\text{stream} \times \text{time})$ | 443.52 | 3.29 | 0.11 | 14 |
| $\Phi(\text{stream} \times \text{time}) p(\text{stream})$ | 458.84 | 18.61 | 0.00 | 10 |
| $\Phi(\text{stream} \times \text{time}) p(\text{time})$ | 459.60 | 19.38 | 0.00 | 11 |
| $\Phi(\text{stream}) p(\text{stream})$ | 463.52 | 23.29 | 0.00 | 4 |
| $\Phi(\text{time}) p(\text{stream})$ | 463.94 | 23.71 | 0.00 | 6 |
| $\Phi(\text{stream}) p(\text{time})$ | 466.47 | 26.25 | 0.00 | 6 |
| $\Phi(\text{time}) p(\text{time})$ | 467.70 | 27.48 | 0.00 | 7 |

These previous studies, in combination with our results, suggest that *M. temminckii* can thrive in a novel environment and may be much better suited to reintroduction efforts than are other chelonians that apparently perform well only after acquiring information about the spatial distribution of patchy resources (Tuberville et al. 2005; Rittenhouse et al. 2007). Also, we should note that turtles in our study were introduced to a site where *M. temminckii* was no longer present. Presence of resident turtles may influence movements and dispersal of introduced individuals (Rittenhouse et al. 2007). Bertolero et al. (2007) reported results for *Testudo hermanni* when there were long intervals of time between releases. Individuals within the first release group of *T. hermanni* had significantly higher survivorship than did a second group released 10 yrs later.

Survival rates varied by age and release site; however, factors other than mortality seem likely to have contributed to our survival estimates. The models indicated low recapture probability in all cases, except in Pond Creek. Recapture rates for this species may be low even in high-density situations, although only a few studies to date report recapture information. Riedle et al. (2008b) reported recapture rates of only 21% at one site in eastern Oklahoma with densities of 28–34 turtles/km stretch of stream. Howey and Dinkelacker (2013) reported 27% recapture rates for a population in Arkansas with a density of 18 turtles/km stretch of stream. Although recapture rates were not reported, catch per unit effort ranged from 0.01–0.10 alligator snapping turtles per net night in low-density populations for several other studies in Oklahoma and Missouri (Riedle et al. 2005; Shipman and Riedle 2008; Lescher et al. 2013).

Although high mortality rates would certainly account for animals not being recaptured late in the study, so too would emigration out of the sampled area. The degree to which turtles emigrated from the study area is unknown, but there was ample opportunity for them to do so. The total available aquatic habitat into which turtles could have dispersed covers approximately 114 ha of the Caney River and Pond Creek and 10,765 ha of Hulah Lake. The total area of river in which turtles were released and subsequently trapped was equal to approximately 56 ha. Low recapture rates and emigration out of the immediate sampling area most likely influenced the apparent survival rates for this reintroduced population.

Little has been published about survival rates of *M. temminckii*, although two studies reported values for a population in decline and a population in recovery. Annual survival rates for the declining population in Oklahoma were 0.31 for adult females, 0.59 for adult males, and 0.46 for juveniles (East et al. 2013). Reasons for the decline are currently unknown. Annual survivorship for an Arkansas population recovering from historic commercial harvest was 0.88 for adult females, 0.96 for adult males, and 0.80 for juveniles (Howey and Dinkelacker 2013). Our survivorship rates varied by age

and release site. Pond Creek had the highest recapture rates, and, as the smaller of the two systems that we sampled, recapture rates were probably influenced less by emigration. The Pond Creek values may more accurately reflect the actual survival rates for reintroduced *M. temminckii* in the Caney River system.

Continued close monitoring of this reintroduced *M. temminckii* population will be necessary to ascertain the ultimate success of the endeavor. Several individuals that were released were on the cusp of attaining sexual maturity at the time we concluded this study. The onset of maturity will necessitate monitoring of nesting activity and nest depredation and will mark the beginning of a substantively new phase in the progression toward a viable, self-sustaining population.

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