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GROWTH AND VIABILITY OF A TRANSLOCATED POPULATION OF ALLIGATOR SNAPPING TURTLES (*MACROCHELYS TEMMINCKII*)

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Abstract.—Exploited for food, traditional medicine, and pets, many turtle populations have been over-harvested or even extirpated from historic ranges. Most turtles possess life-history characteristics that complicate conservation efforts. These characteristics include delayed sexual maturity and high embryo and juvenile predation rates. Restoration strategies include nest protection, head-starting, and translocations. We examined short-term results of these strategies on a reintroduced population of Alligator Snapping Turtles (*Macrochelys temminckii*) in southern Oklahoma. We released 16 hatchery-raised juveniles and 249 adult *M. temminckii* into pools adjacent to the Washita River near Lake Texoma on the border of Texas and Oklahoma, USA. We tracked mortality and conducted nest searches to document factors related to population sustainability. We used hoop nets to recapture individuals and track growth. We confirmed seven mortalities during 2007 and none in 2008. In 2007 we located eight nests, all of which were depredated, and 18 nests in 2008, one of which was detected before depredation and successfully protected until hatching. We compared growth rates of released juveniles and members of the same cohort that were kept in captivity. There was no significant difference in dimensional growth, but released juveniles gained more weight than those retained at the hatchery.

Key Words.—Conservation; growth; head-start; mortality; predation; reintroduction

INTRODUCTION

Freshwater ecosystems are among the most severely human-impacted ecosystems (Benke 1990; Lydeard and Mayden 1995; Sala et al. 2000; Dudgeon et al. 2006). Anthropogenic activities such as flood control, agriculture, industry, urbanization, deforestation, mining, and removal of water all contribute to the degradation of aquatic habitats and water quality, often at some distance from the source of impact (Benke 1990; Lydeard and Mayden 1995; Dudgeon et al. 2006). Deterioration of these habitats is a prime driver of loss of biological diversity (Mitchell and Klemens 2000; Moll and Moll 2000; Bodie 2001; Palmer et al. 2010; Strayer and Dudgeon 2010). Biological diversity is essential to ecosystem function (Duffy 2002; Cardinale et al. 2006; Dudgeon et al. 2006). Aquatic turtles have important roles in aquatic food webs and system energetics (Lagler 1943; Paine 1966; Iverson 1982; Congdon et al. 1986; Moll and Moll 2004).

Threats to aquatic turtles include alteration, fragmentation, and loss of habitat, as well as exploitation for food, pets, and traditional Asian medicine (Gibbons et al. 2000; Pritchard 2006). Turtles and turtle eggs have been harvested for food since the early Pleistocene (Auffenberg 1981), throughout human history (Iverson 1982; Frazer 2003), to modern times (Heinrich et al. 2010). The use of turtle parts for medicine has also been

well documented (Sodhi et al. 2004; Alves et al. 2008). Anthropogenic influences leading to habitat loss, alteration, or fragmentation are unlikely to wane, as humans require and modify more and more water and wetland habitat.

Turtles are long-lived and typically have high embryo and juvenile mortality rates, delayed sexual maturity, and protracted reproductive potential (Gibbons 1987; Wilbur and Morin 1988; Congdon et al. 1994). These life-history characteristics make turtles vulnerable to decline when exploitation of adults and juveniles is severe (Brooks et al. 1991; Congdon et al. 1993, 1994; Heppell et al. 1996; Heppell 1998). The Alligator Snapping Turtle, *Macrochelys temminckii*, is not protected at the US federal level (United States Fish and Wildlife Service 1991), but it is afforded varying levels of protection in every state where it occurs (Buhlmann and Gibbons 1997).

The best approach to turtle conservation is maintenance of large functional ecosystems and preservation of viable populations within native ranges (Soulé 1985; Snyder et al. 1996; Moll and Moll 2004). However, identifying and conserving large tracts of high-quality habitat is difficult and expensive. Protection of natural diversity is tenuous, and is subject to the political, economic, and cultural climate of the region. Often, conservation biology is a “crisis” discipline wherein particular ecosystems, habitats, or

TABLE 1. Pool area, number of released turtles, sex, and male-to-female ratios of translocated Alligator Snapping Turtles (*Macrochelys temminckii*) in the Washita River drainage in Oklahoma, 2007.

Pool	Hectares	Total Turtles	Males	Females	Unknown Sex	Male:Female Ratio
A	4	30	16	12	2	1.3:1
B	15	27	11	14	2	0.8:1
C	14	39	11	15	13	0.7:1
D	381	30	17	9	4	1.8:1
E	138	31	19	10	2	1.9:1
F	44	62	26	21	17	1.2:1
G	141	30	15	10	5	1.5:1

species become critically threatened, necessitating intensive and reactionary conservation efforts (Soulé 1985; Lyles and May 1987). There are three primary (reactionary) approaches to conservation of turtles: (1) protection of nests, (2) head-starting/reintroduction, and (3) translocations (Siegel and Dodd 2000).

Protection of marine turtle nests has had variable success (Dutton et al. 2005). This strategy typically involves patrolling nesting areas to discourage predators, application of predator exclusion devices, and/or relocation of threatened nests to safer areas. Head-starting has been used for several decades, primarily among marine species, but also has had a mixed record of success (Frazer 1992; Bowen et al. 1994). There are no management strategies that substitute for the protection of reproductively mature adults (Heppell et al. 1996; Heppell 1998). Here we report on our observations of nest predation, head-starting, and translocations of *M. temminckii* in Oklahoma.

MATERIALS AND METHODS

Adult turtles were confiscated in 2006 from a privately owned turtle farm in Arkansas that was in violation of permits. We obtained these turtles for reintroduction into portions of the historic range of *M. temminckii* in Oklahoma. In spring 2007, a multi-state, multi-agency effort (US Fish and Wildlife Service [USFWS], Oklahoma Department of Wildlife Conservation [ODWC], Arkansas Game and Fish Commission, Oklahoma State University, and the Tulsa Zoo) moved these turtles from the Joe Hogan State Fish Hatchery in Lonoke, Arkansas, where they were temporarily housed, to Tishomingo National Fish Hatchery. Each turtle received a health assessment from Tulsa Zoo and Oklahoma State University veterinary staff, an implanted Passive Integrated Transponder (PIT) tag (12 mm, 125 kHz; Biomark, Boise, Idaho), and a unique series of holes drilled in the posterior marginal scutes (Cagle 1939). Information gleaned from the owners of the turtle farm by the Arkansas Game and Fish Commission indicated that all turtles had been trapped in Arkansas

and therefore originated from the Mississippi River drainage. However, due to the large number of animals involved and immediacy of the translocation, origins were not validated with genetic testing.

Juvenile turtles were obtained from captive-bred stock produced at Tishomingo National Fish Hatchery in Johnston County, Oklahoma. Recent surveys found that the species declined over much of the western portion of its historic range (Riedle et al. 2005), and this facility implemented a captive propagation and head-start program in 1999 (Riedle et al. 2008) using adult *M. temminckii* obtained from Sequoyah National Wildlife Refuge in east central Oklahoma. This native population has been shown to be genetically similar to other populations within the Mississippi drainage (Echelle et al. 2009).

We recorded morphological measurements, including straight midline carapace length (MCL), midline plastron length (MPL), and mass. We released 249 adult turtles into seven pools (Fig. 1) at our study site on 11 April 2007 (Table 1). Turtles averaged 13.5 ± 7.5 kg (mean \pm 1 SD). Mean MCL was 37.7 ± 6.6 cm, and mean MPL was 28.8 ± 4.9 cm.

We selected 16 juveniles (mass = 904 ± 136 g; MCL = 14.8 ± 7.5 cm; MPL = 11.7 ± 2.9 cm) from the combined 2002 and 2004 cohorts at the hatchery. All received a PIT tag and unique set of carapace marks as described for the adults. We released these turtles 8 June 2007 into an oxbow where we had previously released adults. We retained 26 juveniles from the combined 2002 and 2004 cohorts at the hatchery for comparison with the ones released to the wild. We fed these turtles fish-based pellets and live and dead fish *ad libitum*. Water temperatures fluctuated seasonally, and light cycles were dictated by natural light exposure through windows. The density at which we maintained turtles varied with size, with larger animals housed at lower densities. However, growth rates of captive turtles were not density dependent (unpubl. data).

Study site.—We chose seven permanent water bodies adjacent to the Washita River immediately north of Lake

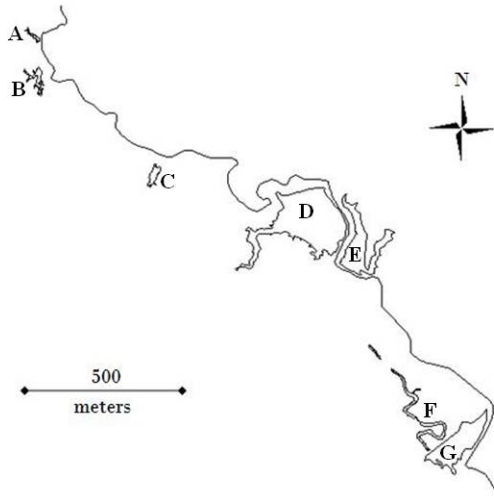


FIGURE 1. Map of release sites of Alligator Snapping Turtles (*Macrochelys temminckii*) adjacent to the Washita River where turtles were relocated in Johnston and Marshall counties, Oklahoma, in the spring of 2007. Letter designations correspond with those in Table 1.

Texoma for the initial turtle reintroduction (Table 1, Fig. 1). The pools were located on properties owned and managed by the US Army Corp of Engineers or the USFWS, and as such were likely to be better protected than other localities. Four of these pools were within the boundary of the Tishomingo National Wildlife Refuge Management Unit, which is co-managed with the ODWC. Two pools were coves of Lake Texoma isolated by Washita River sediment deposition. The last area was an artificial oxbow of the Washita River created during the construction of Lake Texoma. Pools varied in size from approximately 2 ha to over 300 ha and had riparian buffers that provided shaded margins, depths of 4–5 m, numerous snags, and submerged structure in the form of logs and root wads. All were located within the floodplain of the Washita River and became interconnected during high water events that typically occur seasonally. The climate of this area includes variably wet, hot summers and typically mild winters.

Methods.—To measure growth and body condition, we recaptured individuals using commercially available hoop nets baited with fresh or frozen fish. The single-throated, four-hoop nets (mesh size 2.5 cm) were 1 m diameter, and 2 m long (Memphis Net & Twine, Memphis, Tennessee). These were anchored at either end or attached to structure and stretched using Polyvinyl Chloride (PVC) pipe braces. We allowed 15–30 cm of airspace so captured animals could breathe. We used gill nets to procure bait at a site that was outside of the area where turtles were trapped, and primarily used catostomid species such as Smallmouth

Buffalo (*Ictiobus bubalus*). Some additional bait fish were acquired as by-catch in our turtle traps. Fish that we captured but that we did not immediately use were frozen for future trapping efforts. We suspended bait by wires or string from the third hoop, distal to the throat of the net (Cagle 1950). We typically deployed nets in the evening, and checked them before noon the next day. We recorded net location data and site descriptions, as well as morphological characteristics of trapped turtles. Depending on size, we measured MCL and MPL with 100-cm forestry calipers (Haglof, Sweden), or 300-mm vernier calipers. We weighed turtles < 5 kg with a top loading mechanical scale and larger turtles with a 50-kg spring scale. We visually searched banks of the release pools in an effort to locate nests or identify locations of pre-nesting activity.

We compared changes in MCL of released juveniles individuals to those within their cohort that were kept at the hatchery. Growth in length was first regressed against initial length because growth rates are typically size-specific. We assessed body condition using an index proposed by Jakob et al. (1996). Slope was obtained from a regression of log mass vs. log carapace length. We used this slope in the following formula: $\text{Body condition} = \text{mass}/(\text{MCL})^{\text{slope}}$. We computed change in condition as final condition minus initial condition for the same individual.

We investigated all reported instances of mortality. Depending on the condition of the carcass, remains were taken to the Tulsa Zoo for necropsy. We searched for nests in May and June, which was done primarily in conjunction with trapping activities. Most searches were limited to observations from a boat and infrequently involved searching on foot due to vegetation density. When we found viable nests, we installed a predator exclusion device constructed of plastic-coated heavy-gauge wire mesh over the intact nest. This consisted of 5 × 5 cm woven wire mesh of 12-gauge galvanized steel formed into a 70 × 90 × 31 cm tall open-bottomed cage anchored with 40-cm tent stakes.

RESULTS

We trapped May - August, and we sampled 180 net nights in 2007 and 322 net nights in 2008 (net night = one net set for one night). We acquired growth data on 8 juveniles and 24 adults. There were 50 recaptures of adults, 47 of which occurred in 2007. We recorded 23 recaptures of juveniles, five of which occurred in 2007. We did not include growth data for the adult turtles in the analyses. Slower growth rates exhibited by adult turtles, compounded by mass variation experienced by nesting females, precluded meaningful analyses.

We first compared dimensional growth between released turtles and those retained at the hatchery. The regression of change per day in MCL vs. initial MCL

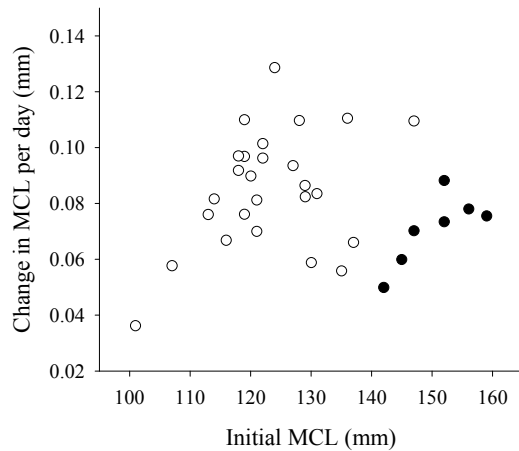


FIGURE 2. Midline carapace length (MCL) growth per day as a function of initial MCL in hatchery-raised Alligator Snapping Turtles (*Macrochelys temminckii*) later released (solid circles) and not released (open circles).

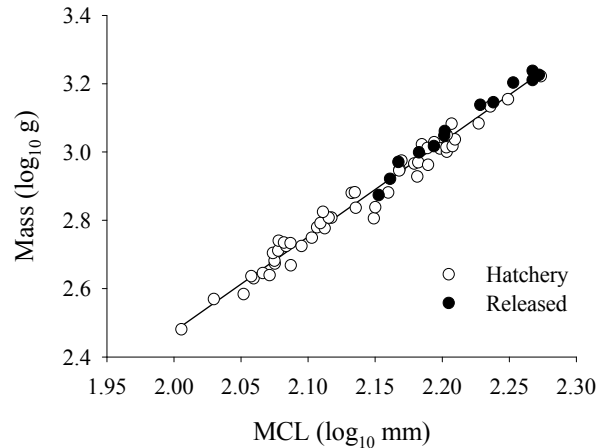


FIGURE 3. Log transformed mass vs. log transformed Midline carapace length (MCL) for all Alligator Snapping Turtles (*Macrochelys temminckii*) including both initial and final measurements. Regression line is significantly different than zero ($F_{1,62} = 3105.1$, $P < 0.001$), with a slope of 2.77.

was not significant (Fig. 2; $F_{1,31} < 0.001$, $P = 0.982$), so no correction for initial MCL was necessary. There was no significant difference in MCL change per day between the groups (captive animals = 0.085 ± 0.004 mm/day; released animals = 0.071 ± 0.005 mm/day; $t = -1.72$, $DF = 31$, $P = 0.090$). We then compared changes in body condition of these same groups of juveniles. We plotted log mass vs. log MCL to obtain the slope used in the formula for body condition (Fig. 3). Released juveniles significantly increased body condition compared to those retained at the hatchery ($t = 2.59$, $DF = 31$, $P = 0.015$).

We recorded seven confirmed instances of mortality, all within the first year of the study. Three were removed from trotlines (which apparently caused the turtles to drown), one was the victim of a gunshot to the head, and another suffered blunt trauma to the cervical portion of the vertebral column from an unknown source. We found two other turtles dead under suspicious circumstances: one large male was found on the bank where he had evidently been placed, and another was found floating while we investigated a report of a turtle snagged on a trotline. There were four other unconfirmed reports of turtles snagged on trotlines.

Unfortunately, locating nests was easiest after depredation. We identified disturbed nests of *M. temminckii* from morphology of eggshell remnants. Eggs of this species are easy to differentiate from those of other sympatric turtles because of their large size and nearly spherical shape. We located eight nests using this method in 2007 and 17 in 2008. We also located one intact nest containing 31 eggs 20 May 2008.

DISCUSSION

Due to the extirpation of Alligator Snapping Turtles at our study site, we could not compare the growth performance or fate of captive-reared turtles to wild counterparts under identical conditions. Nonetheless, the juvenile turtles that were released exhibited significantly improved body condition compared to those retained at the hatchery, suggesting that they encountered optimal conditions for growth in the wild. Survival rates of hatchery-raised juveniles a year after release was high, and there was evidence of survival for over two years after release (Jared Wood, pers. comm.).

The translocation effort was successful in that re-located adults survived the winter and reproduced. The discovery of nests, even depredated ones, was encouraging. The non-depredated nest was surrounded by a predator-exclusion device and later excavation proved that the nest produced hatchlings (Justin Roach, pers. comm.). We observed considerable nesting activity in the form of trial nest holes (pre-nests, Cagle 1950) at various stages of completion associated with substantial soil disturbance. Although we detected many depredated nests, the number was low in comparison to the number of adult females that were released. However, because we had limited manpower and a very large area to monitor, the depredated nest count should be considered a minimum estimate, and it is likely that more intensive and targeted searching efforts would locate more nests.

The low number of recaptures of translocated adult turtles in the second summer of the study was surprising given our recapture success in the first year. One explanation for this pattern is that a high proportion of adults did not survive to the second year. However, this

appears unlikely; no mortality was recorded among a subset of 16 animals that were equipped with radio transmitters at the time of release (Moore 2010), yet these animals were also not recaptured despite targeted efforts to do so. Additionally, the number of depredated nests observed in 2008 at two release sites closely matched the number of females that were released, suggesting high survival rates, at least among females. Based on this combination of data, the most parsimonious explanations for low recapture rates in the second year of our study are that animals became trap-shy or simply had sufficiently good foraging success that they were not readily attracted to baited nets.

Several studies have documented turtle mortality associated with human recreation (Bishop 1983; Barko et al. 2004; Boundy and Kennedy 2006; Galois and Ouellet 2007). Sloan and Taylor (1987) found one Alligator Snapping Turtle dead from a gunshot wound and another that drowned in an abandoned monofilament net. Santhuff (unpubl. report) removed one dead and one live *M. temminckii* from trotlines. The only recent Alligator Snapping Turtle of record in Kansas was found snagged on a trotline (Shipman 1993). Heck (1998) and Glass (1949) reported the deaths of multiple Alligator Snapping Turtles from encounters with fishing gear. During the course of this study, one of us (DBM) measured and released two wild Alligator Snapping Turtles at other locations in southeastern Oklahoma that had been caught by fishermen.

In this study, all cases of mortality were suspect and most were convincingly traced to anthropogenic origins. All of the trotlines that snagged turtles were abandoned and therefore illegal. They were covered with algae and for all appearances had been abandoned for a long time. It is also notable that the pool used most by local fishermen and outdoorsmen with the greatest cultural bias against this project (Kevin Vaughn, pers. comm.) was the site of five of the seven recorded mortalities. Community approval and support for conservation efforts is often overlooked, and more effort to engage local sportsmen would undoubtedly improve the long-term outlook for the reintroduced population.

Success cannot be declared until substantial recruitment of translocated turtles is observed, and therefore cannot be fully evaluated for several years (Germano and Bishop 2008). However, our initial results were promising. Several characteristics of Alligator Snapping Turtles make this long-lived species a seemingly good candidate for reintroductions. A proclivity for long-distance dispersal (Wickham 1922; Sloan and Taylor 1987; Shipman et al. 1995; Harrel et al. 1996; Shipman and Riedle 2008) coupled with a catholic diet (Allen and Neill 1950; Sloan et al. 1996; Elsey 2006), as well as year-round presence of sperm in mature males (Dobie 1971), forced copulations (Berry and Shine 1980), and probable sperm storage in females (Gist and

Jones 1989; Gist and Congdon 1998), all contribute to the species' reestablishment potential in the Washita River Basin.

Potential barriers to reintroduction success are mostly anthropogenic. Cultural resistance to a species whose presence is believed to negatively impact the local sport fishery is strong. Aquatic turtles often aggregate for nesting (Iverson 1991) and suitable nest sites could become rare as hydrology and riparian habitats are manipulated (Conner et al. 2005). Human development near turtle populations can lead to an increase in subsidized meso-predators, many of which are known to depredate turtle nests. Finally, dams impede dispersal and gene flow for this strictly aquatic species. For long-lived species with delayed sexual maturity, protection of adult turtles is vitally important.

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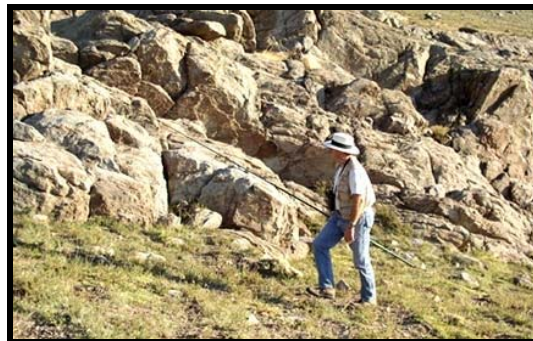
DAN MOORE, shown holding four Western Chicken Turtles (*Deirochelys reticularia miaria*), currently teaches biology and conservation courses at Murray State College in Tishomingo, Oklahoma. He earned a Bachelor's degree in Biology (2006) with a minor in conservation from Southeastern Oklahoma State University specializing in Botany and Zoology. He completed a Master's degree in Zoology (2011) at Oklahoma State University in Stillwater, Oklahoma examining movements and habitat selection of a reintroduced population of Alligator Snapping Turtles. His current focus is on turtle conservation and biology as well as aquatic systems restoration ecology. (Photographed by Jona Tucker)



DAY LIGON is an Assistant Professor in the Biology Department at Missouri State University in Springfield, Missouri. He received a Bachelor's degree in Biology from Lewis and Clark College in Portland, Oregon, where he studied seasonal movement patterns of Western Painted Turtles, a Master's degree from Oklahoma State University in Stillwater, Oklahoma studying kinosternids turtles native to the southwestern United States and Mexico, and a Ph.D. from OSU where he investigated effects of incubation temperature on the physiology, behavior, and morphology of several chelonians. Dr. Ligon's current research focuses primarily on conservation biology and physiological ecology of turtles. (Photographed by Jona Tucker)



BRIAN FILLMORE, shown with a Paddlefish (*Polyodon spathula*) is a Fisheries Biologist employed by the US Fish and Wildlife Service (USFWS) stationed at the Tishomingo National Fish Hatchery. He received his A.A. degree in Fish and Wildlife Management (2000) from Hocking College in Nelsonville, Ohio. He began a career with the USFWS at the Willow Beach and Mora National Fish Hatcheries in Arizona and New Mexico, respectively. He participated in the federal Student Career Experience Program (SCEP) for the USFWS and moved to Moscow, Idaho, where he earned a Bachelor's degree in Fisheries Resources (2004). Brian's current work includes culturing, rearing, stocking and reintroducing several species. (Photographed by Rebecca Fillmore)



STANLEY F. FOX is Regents Professor in the Department of Zoology at Oklahoma State University. He advised Dan Moore during his M.S. program. Dr. Fox received a Bachelor's degree in Biology from the University of Illinois, and a M.Phil. and Ph.D. in Ecology and Evolution from Yale University. He was a Postdoctoral Fellow at Rockefeller University where he conducted research on the behavioral ecology of juncos at the Millbrook Field Research Center. He moved to Boston University as a Visiting Assistant Professor (1975–1977), then to Oklahoma State University. Dr. Fox is a behavioral and evolutionary ecologist with interests in herpetological conservation, and social organization and sexual selection in lizards. (Photograph by Deb Fox)