Chelonian Conservation and Biology, 1998, 3(1):64–70

Population Structure and Movement Patterns of Alligator Snapping Turtles (*Macroclemys temminckii*) in Northeastern Arkansas

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ABSTRACT. – **Alligator snapping turtles (*Macroclemys temminckii*) were studied in northeastern Arkansas from August 1995 to July 1997. A total of 352 trap nights was conducted in three creeks (Dota, Salado, and Village). Turtles were weighed, measured, implanted with PIT tags, and released at the site of capture. Comparative population sampling was performed primarily in Salado and Village creeks, whereas Dota Creek was used mostly for a narrow-scale assessment of turtle movements. The largest population of turtles (*n* = 52) was found in Salado Creek in Independence County, a turbid, steep-walled, meandering, mostly lowland creek. Village Creek in Jackson County, a shallow, bottomland creek, yielded a total of 34 turtles. Both creeks had previously been subject to commercial turtle trapping. The observed adult sex ratio was 1:1 from all localities, but favored males in Salado Creek. Curved carapace length from all localities averaged 259.8 mm for subadults (*n* = 62), 446.3 mm for adult males (*n* = 19), and 372.1 mm for adult females (*n* = 17); turtles from Salado Creek (273.3 mm) were significantly larger than those from Village Creeek (273.3 mm), though there were no significant differences when comparing subadults or adults. Eleven turtles were recaptured in Salado Creek. Turtles moved both upstream and downstream with a maximum recorded distance of 1.8 km. Two turtles, fitted with radio transmitters in Dota Creek and monitored during the winter months of 1996–97, revealed differing vagilities. Overharvesting presumably contributed to the size-class differences observed in this study.**

KEY WORDS. – **Reptilia; Testudines; Chelydridae; *Macroclemys temminckii*; turtle; demography; population structure; morphometrics; movements; Arkansas; USA**

Our knowledge of the population ecology of many freshwater turtles remains inadequately understood (Bury, 1979). This is especially true for the alligator snapping turtle (*Macroclemys temminckii*), North America's largest freshwater turtle (Pritchard, 1989). The most recent literature reviews on the biology of alligator snappers (George, 1987; Pritchard, 1989; Lovich, 1993; Ernst et al., 1994) reveal little information concerning the population structure of this species.

Alligator snappers are of special interest to conservation biologists as well as state and federal agencies, because of widespread exploitation of the species by commercial trappers (Sloan and Lovich, 1995). Overharvesting for many decades in several southern states has contributed to a precipitous decline in the number of mature turtles of this long-lived species (Pritchard, 1989). The lack of population data, however, continues to hamper status determinations and practical management decisions in geographic areas (such as Arkansas) that harbor isolated populations of these turtles (Wagner et al., 1996). Arkansas may also represent one of the very few remaining geographic regions in which overexploitation of alligator snappers has not as yet depleted populations beyond the possibility of natural recovery.

Until recently, there were very few published records for *M. temminckii* in Arkansas (Dellinger and Black, 1938; Schwardt, 1938; Dowling, 1957; Pritchard, 1989; Lovich, 1993). However, in a statewide distributional survey conducted by the Arkansas Game and Fish Commission, Wagner et al. (1996) reported finding a total of 445 turtles from 56 (out of 75) counties. Their survey suggested that alligator snapping turtle populations in Arkansas are relatively widespread. Commercial turtling during recent years, however, appears to have affected the body-size distribution of this species (Wagner et al., 1994), and commercial trapping of the species has been prohibited in Arkansas since 1993 (Buhlmann, 1993). Sloan and Lovich (1995) reported that 676 kg of alligator snapping turtles from Arkansas were sold to a commercial fish house in Louisiana in 1984. Although the alligator snapping turtle is currently protected by the Arkansas Game and Fish Commission, information on population sizes is unavailable. Wagner et al. (1994) reported depressed populations of sexually mature turtles (greater than 32.5 cm carapace length) in Arkansas counties that had been open to commercial turtling in the past, and they indicated that these data were suggestive of overharvesting. If this trend is found to be representative of other counties as well, most Arkansas populations may be incapable of withstanding any additional depletion of adults.

The present study provides information on alligator snapping turtle populations in northeastern Arkansas. We focused our field work on drainage systems exhibiting diverse habitats and gathered information on a variety of population characteristics without sacrificing turtles. In addition, we used PIT tags and radio transmitters to document turtle movements.

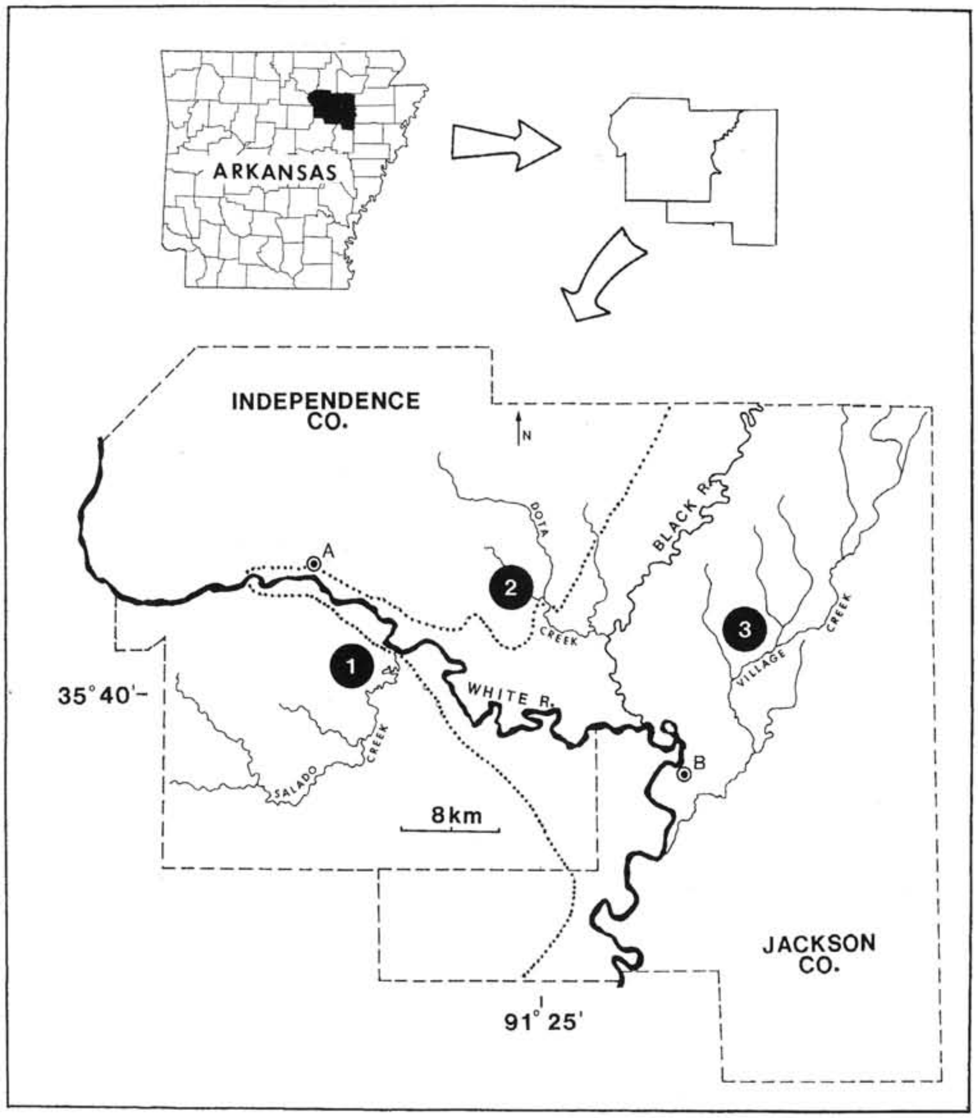

Figure 1. Map of Independence and Jackson counties of northeastern Arkansas showing drainage systems of three creeks (1 = Salado; 2 = Dota; 3 = Village) trapped for alligator snapping turtles (*Macroclemys temminckii*). A = Batesville; B = Newport. Dotted line roughly separates the Ozark Plateaus (Springfield and Salem) to the west from the Mississippi Alluvial Plain (to the east).

MATERIALS AND METHODS

Study Sites. — Turtles were trapped using 1.2 m diameter, double-throated hoop nets placed in three free-flowing streams (Salado and Dota creeks in Independence County and Village Creek in Jackson County; Figs. 1 and 2). These creeks, thought to be "turtled out" by the early 1990s, were chosen because of the relatively large numbers of alligator snappers found there in a recent census by Arkansas Game and Fish Commission personnel (B. Wagner, *pers. comm.*). Salado Creek (52 km) and Village Creek (55 km) drain directly into the White River, but each drainage differs physically and floristically in the sampling areas. The headwaters of Salado Creek originate in the eastern slopes of the Boston Mountains of the Interior Highlands; the lower 15 km flows through the Springfield Plateau (Foti, 1974). In contrast, the entire drainage of Village Creek occurs within the Mississippi Alluvial Plain (Foti, 1974; Holt and Harp, 1993). Another conspicuous difference between the two streams is reflected in floodplain features; Salado Creek (mostly an upland watershed) basically lacks a floodplain, while Village Creek, a lowland watershed, exhibits a wide floodplain constricted only by cultivated fields. Both creeks, however, share similar riparian habitat near their confluences with the White River. The placement of trap arrays was similar only near the mouths of these creeks.

In Salado Creek, a total of 25 permanent trapping stations (hereafter called net sites) was established on the lower 4 km. Mean linear distance between net sites (160 m) was calculated using 7.5 minute topographic maps and a laser rangefinder. This steep-banked creek is lined with deciduous trees and features numerous log jams, stumps, and submerged snags with turbid water nearly year-round (Fig. 2). The physiography of the creekbed varied among net sites, but the average creek dimensions were ca. 20–30 m in width and 2–4 m in depth. In contrast, trapping on Village

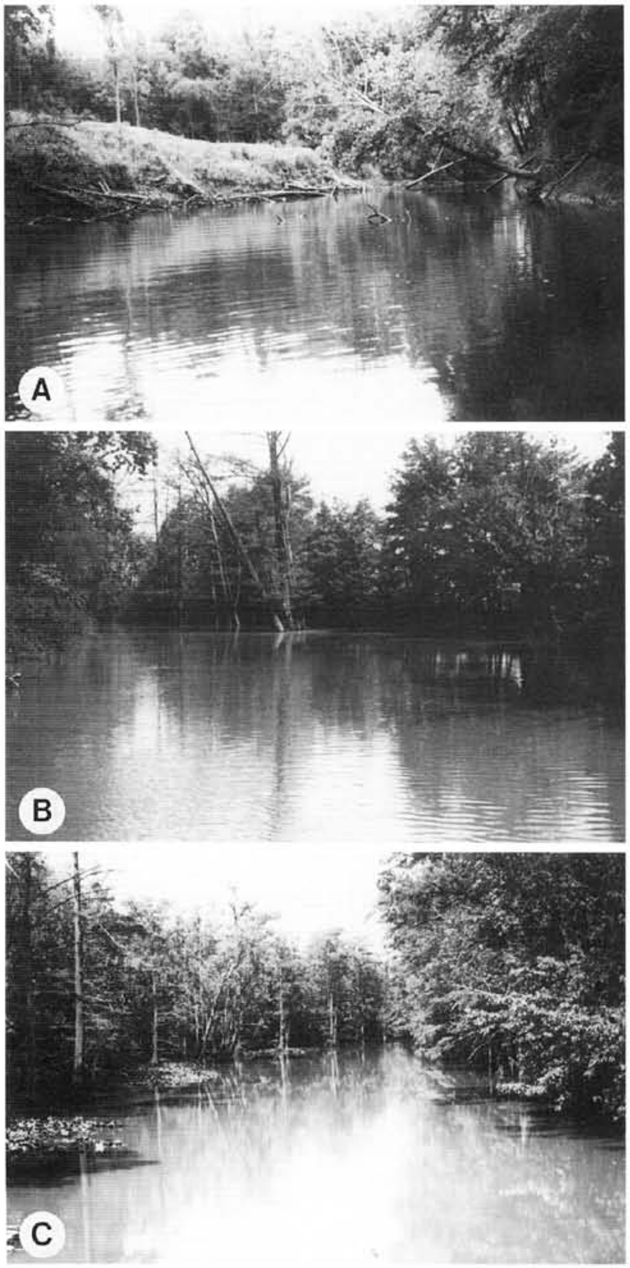

Figure 2. Habitat of alligator snapping turtles (*Macroclemys temminckii*) in three creeks from northeastern Arkansas. **A.** Salado Creek, facing north at net site 5, **B.** Dota Creek, facing northwest at net site 3, **C.** Village Creek, facing north at State Highway 226.

Creek was conducted only in a limited number of accessible habitats located in the lower 1 km of flowing water (mean distance between 13 net sites = 75 m) and in selected sites of the upper floodplain. This upper portion was dominated by cypress/tupelo habitats including swampy oxbow lakes, channels, and sloughs (Fig. 2) varying 0.25–2 km in width and from 1–3 m in depth. Most of upper Village Creek (tributaries north of Jackson County) consists of shallow, narrow, channelized canals (Holt and Harp, 1993). Daily major water-level fluctuation, which characteristically occurred in Salado Creek, was attributed to the variable cold-water discharge from two hydroelectric dams feeding the White River (above Batesville, Fig. 1). A 0.5 to 1.0 m nightly water-level change was normal for this creek and occasionally severely altered the catchability rates for turtles. Fluctuations in water level were less dramatic in Village Creek.

Dota Creek (Figs. 1 and 2) is mostly intermediate in habitat features compared to the other two creeks. The headwaters of this creek lie within the southeastern extremity of the Springfield Plateau (the southeastern limit of the Ozark Plateaus). Net sites were established only within the lower 2 km of the creek prior to its confluence with the Black River. The Black River seasonally overflows its banks causing flooding of Dota Creek along much of its floodplain. Dota Creek normally averages ca. 10–15 m in width and 2–3 m in depth. Little trapping was conducted in this creek; however, two turtles trapped were fitted with radio transmitters (supplied by Wildlife Materials, Inc., Carbondale, IL) along the left posterior margin of their carapaces. The transmitters (battery life ca. 600 days) were attached with screws. A portable receiver (TRX-1000S) was used with a Yagi 3-element directional antenna to obtain radio fixes.

Procedures. — The initial trapping period began on 26 August 1995 and ended 8 August 1996; traps were set approximately weekly during the summer months. Traps were placed in Village Creek beginning 26 August and in Salado Creek on 8 September; Dota Creek was sampled less frequently (see Movements). Additional trapping was conducted during the summer of 1997 in Salado Creek. Hoop traps were baited with whole fish (buffalo, carp, carpsuckers, and drum) or fish parts. Traps were baited in late afternoon and were examined the following morning. A trap night was defined as a single trap left overnight; the catchability rate (capture per unit effort) was then calculated by dividing the number of turtles by the number of trap nights.

For permanent identification, all alligator snappers were tagged with passive integrated transponder (PIT) tags hypodermically injected ventrolaterally in the postanal tail musculature. The following parameters were measured on all alligator snappers: curved carapace length (CCL, in mm, obtained by stretching a metal tape to the left of the middorsal keels), preanal tail length (PTL, in mm), postanal tail length (in mm), and mass (kg). Turtles were released at or near the point of capture.

The assignment of sex to live subadult alligator snappers is difficult, because marked sexual differences in morphology first appear at the onset of maturity (Carr, 1952). The minimum body size attained at sexual maturity in alligator snappers has only been reliably demonstrated by necropsy (Dobie, 1971). According to his study, PTL for mature males ranges from 115–266 mm, whereas the range in mature females is 48–114 mm. He also reported that sexual maturity is attained at 11–13 years of age for both sexes in Louisiana specimens; the smallest mature male and female were 370 and 330 mm in carapace length, respectively. We utilized Dobie's (1971) data on size and PTL to assist in sexing adult turtles.

The pronounced sexual dimorphism exhibited by adult turtles was quantified using a sexual dimorphism

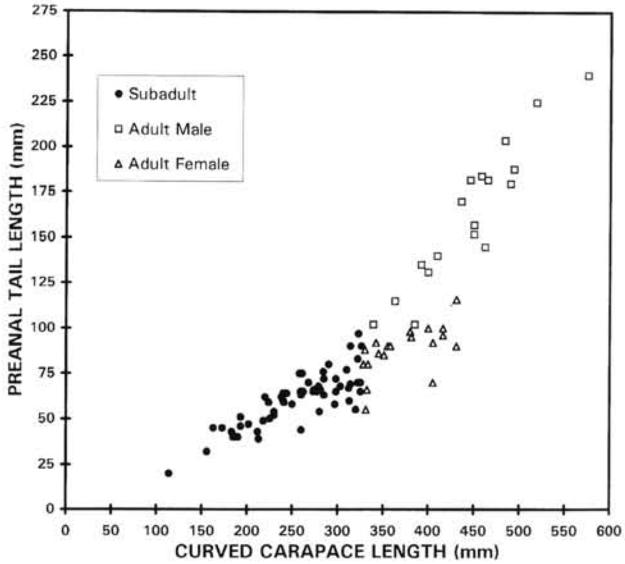

Figure 3. The relationship between curved carapace length (CCL) and preanal tail length (PTL) in alligator snapping turtles (*Macroclemys temminckii*) examined from northeastern Arkansas.

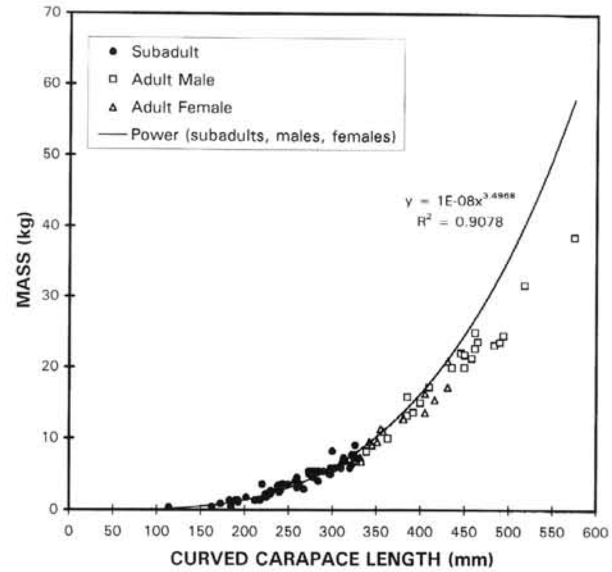

Figure 4. The relationship between curved carapace length and body mass in alligator snapping turtles (*Macroclemys temminckii*) examined from northeastern Arkansas.

index (SDI) following the methods outlined by Gibbons and Lovich (1990) and Tucker and Sloan (1997). SDI, a ratio of mean body size of the larger sex divided by mean body size of the smaller sex, is considered positive (+) when females are larger and negative (-) when males are larger (Gibbons and Lovich, 1990). Our use of CCL (as opposed to a midline carapace length) to measure body size for determining SDI differed from the above two studies.

Statistical analyses of data were performed using the computer statistical software packages found in SigmaStat (Jandel Scientific) and Excel (Microsoft); a least squares "best fit" trendline for the length-weight (mass) relationship was generated using the equation: $\mathbf{y} = \mathbf{cx}^{\mathbf{b}}$, where **y** = body mass, **x** = CCL, and **c** and **b** are constants. The coefficient of determination (R^2) displayed with trendline is not an adjusted R-squared value. Mean values are accompanied by ± 1 standard deviation; an alpha level of 0.05 was considered significant.

RESULTS

Sexual Dimorphism and Sexual Maturity. — Adult males from all localities were readily distinguishable from other individuals, primarily because their PTLs, in most instances, exceeded 125 mm (Fig. 3, CCL > 400 mm). CCL and PTL were both positively correlated in adult males ($r = 0.94$; df = 18; $p < 0.001$; regression equation PTL = -120.43 + 0.64 CCL; $F_{1,18} = 116.8$; $p < 0.001$) and adult females ($r = 0.60$; df = 19; $p = 0.007$; regression equation PTL = 5.98 + 0.22 CCL; $F_{1,19} = 9.5$; $p = 0.007$). The CCL of adult males from Salado Creek averaged 470.4 ± 49.8 mm (range 385–

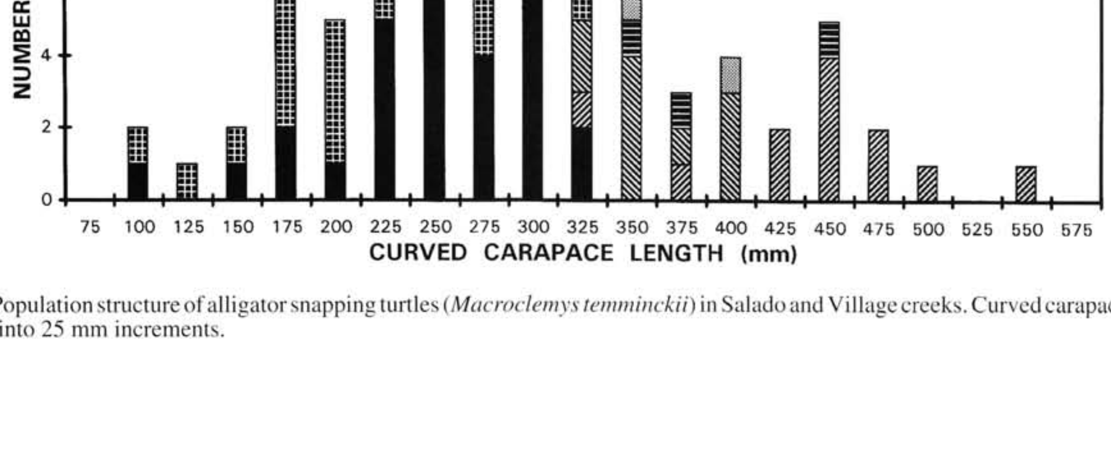

Figure 5. Population structure of alligator snapping turtles (*Macroclemys temminckii*) in Salado and Village creeks. Curved carapace length is divided into 25 mm increments.

Table 1. Data on movements of alligator snapping turtles (*Macroclemys temminckii*) in Salado Creek, Independence County, Arkansas, during 1996. CCL = curved carapace length.

Turtle	Sex	CCL (mm)	Mass (kg)	Net Site	Date of Capture	Date of Recapture	Direction Moved	Distance Moved (km)
A	?	273	4.54	17	10 May	17 May	Upstream	0.150
B	f	355	11.34	16	10 May			
				17		17 May	Upstream	0.110
				19		3 June	Upstream	0.338
				16		14 June	Downstream	0.550
C	f	322	7.71	13	27 April			
				10		17 May	Downstream	0.496
				21		14 June	Upstream	1.797
D	?	314	6.80	19	10 May	22 May	Downstream	0.338
E	f	313	7.25	20	22 May	3 June	Downstream	0.125
F	m	416	15.40	24	29 May	14 June	Downstream	0.139
G	m	458	21.30	25	14 June	26 June	Downstream	0.760
H	f	380	12.70	21	22 May	10 July	Upstream	0.620
I	m	448	19.96	10	9 July	1 August	Upstream	0.400
J	f	342	9.53	15	10 May	1 August	Upstream	0.490
K	?	261	3.85	24	10 July	1 August	Downstream	0.139

583 mm; $n = 17$), whereas the CCL of adult females averaged 365.6 ± 27.8 mm (range 355–416 mm; $n = 13$). Five adult males from Dota Creek averaged 429.2 ± 42.5 mm CCL (range 362–494 mm), and four adult females averaged 414.8 ± 23.6 mm (range 381–431 mm). The SDI for all adult turtles was calculated to be -1.2. Most adult females in our study were taken from Salado Creek; these females (> 330 mm CCL) had PTLs near or slightly exceeding 100 mm. We found no significant deviation from the expected 1:1 sex ratio ($\chi^2 = 0.08$; $n = 36$; $p = 0.78$) for adults from all localities.

Because values of PTL overlap in subadults, we calculated CCL/PTL ratios to assist in sexing these individuals, especially those nearing mature size. For example, adult ratio values ranged from 2.3 to 6.0, whereas subadult values were 3.5–5.8. Yet, sexing of adults using the ratio indicated that turtles greater than the minimum adult carapace size generally fell into two groups. Large adult males tended to have values ≤ 3.5 and adult females > 3.5 (usually clustered around 4.0). Most subadults (less than minimum adult carapace size) exhibited ratios greater than 3.6. Subadults that possessed a value > 4.5 were considered females and those between 3.6–4.5 were considered males. However, dissection of one drowned alligator snapper from Salado Creek with a CCL of 315 mm and a ratio of 3.5 revealed an immature female.

Body Mass. — Significant positive correlations were found between CCL and body mass for adult males ($r = .97$; $n = 17$; $p < 0.05$) and females ($r = .69$; $n = 13$; $p < 0.05$) in Salado Creek. The relationship between CCL and body mass of all alligator snappers from the three creeks is shown in Fig. 4. In Salado Creek, one female (CCL = 400 mm) had a body mass of 28 kg on 9 September 1995; interestingly, a comparable female (CCL = 416 mm) had a body mass of only 15.4 kg on 29 May 1996. The largest turtle recorded in this study (from Salado Creek) was captured twice. On 10 May 1996 this turtle had a CCL of 575 mm and a body mass of 38.5 kg; on 30 May 1997 the CCL and body mass were 583 mm and 41.7 kg, respectively.

Population Structure. — Subadults from all three creeks averaged 259.8 ± 47.3 mm CCL (range 114–326 mm; $n = 62$); likewise, adult males averaged 446.3 ± 56.3 mm CCL (range 339–583; $n = 19$), and adult females averaged 372.1 ± 36.3 mm CCL (range 330–431; $n = 17$). The mean CCL for all turtles from Salado Creek (330.4 mm) was significantly greater than the mean CCL for all turtles from Village Creek (273.3 mm; t-test, $t = 3.25$, df = 92, $p = 0.002$). Although we trapped turtles of a larger size and greater number in Salado Creek than in Village Creek (Fig. 5), there was no significant difference in the two populations with regard to body size between subadults (t-test, $t = 0.85$, df = 65, $p = 0.399$) or adults (t-test, $t = 0.885$, df = 25, $p = 0.385$) in both creeks. Moreover, the discrepancy in adult numbers between the two creeks was also not significant (Mann-Whitney Rank Sum test; T = 60, df = 27, $p = 0.553$).

Movements. — Recapturing PIT-tagged turtles from Salado Creek provided data on movements during the spring/summer activity season. A total of nine turtles was recaptured at least once; two turtles were recaptured twice, and one turtle was recaptured three times (Table 1). Movement data also revealed considerable variation in distance and direction of movement. As a whole, there were seven instances of upstream movement and seven in the downstream direction. In five turtles (Table 1: A, E, F, I, and K), the first recapture occurred one net site away from the first capture point; the average distance traveled was 191.0 m. The greatest distance moved between recaptures was ca. 1.8 km by a young adult female.

In five instances turtles were recaptured two or more net sites away from the previous capture (or recapture) point. Both upstream and downstream movements were observed in an adult female (B). A young adult female (C) moved from net site 13 on 27 April to net site 10 on 17 May — a movement downstream of ca. 495 m; then, on 14 June, this turtle was captured at net site 21, a movement upstream of ca. 1.8 km.

On 20 October 1996 an adult male (392 mm CCL, 13.6 kg) and a subadult (250 mm CCL, 3.6 kg) were trapped in

Dota Creek and fitted with radio transmitters. By the first monitoring date (15 November), the male had moved ca. 915 m upstream, whereas the subadult had moved ca. 300 m downstream. Both turtles were found in ca. 2 m of water. On 23 December the male could not be found, possibly because we were unable to move upstream beyond a log jam. The subadult, however, had not moved from the earlier position. Shortly after a flooding episode (25 January 1997), we recorded the male at a point ca. 2.4 km upstream from the previous radio fix site. The male was beneath an overhanging snag in ca. 1.3 m of water. Again, the subadult had not moved. Finally, on 22 March 1997 (following a recent flood), we located the male moving in shallow water associated with a thicket of flooded trees ca. 250 m south of the main creek channel and ca. 250 m east of the initial radio fix site; the subadult, now in an inundated area of open water, could not be located.

DISCUSSION

We observed significant differences in population structure between the two creeks in our study. Our results showed a marked disparity in individual size-class composition of *M. temminckii* between populations in Salado and Village creeks. Size-class data (Fig. 5) revealed a paucity of turtles > 330 mm CCL (i.e., adult turtles) in Village Creek; this was not the case in Salado Creek. If we assume that commercial turtling pressure had depleted most large adults from both creeks prior to 1993, then immigration represents a plausible explanation as to why more adults were recorded in Salado Creek. By comparison, both creeks contained relatively modest numbers of subadults. Subadult turtles are routinely released by trappers in Arkansas and elsewhere because they represent only a small amount of meat per unit time, effort, and investment (Sloan and Lovich, 1995).

Adult males tend to grow much larger than adult females and tend to have a more rapid growth rate than do females (Dobie, 1971; Tucker and Sloan, 1997). The SDI values reported by Gibbons and Lovich (1990) and Tucker and Sloan (1997) were slightly smaller (-1.15 and -1.1, respectively) than our value of -1.2. The largest adult turtles (> 435 mm CCL) recorded in Salado Creek were all males ($n = 9$). Immigration by males into new aquatic habitats has been demonstrated in other freshwater turtle species (Morreale et al., 1984; Tuberville et al., 1996). For example, Tuberville et al. (1996) recorded long-distance movements mostly by males of three non-resident turtle species (*Chrysemys picta*, *Clemmys guttata*, and *Kinosternon baurii*) at the Savannah River Site. They suggested that males possibly invade new habitats to increase the likelihood of reproductive encounters with females. If immigration is occurring, we predict the source of adult turtles (both sexes) to be from the upper non-navigable stretches and tributaries of Salado Creek rather than the White River and its year-round cold water. We base this opinion on the minimal number of turtle captures in traps from downstream and the increase in turtle numbers as traps were progressively set upstream.

The most thorough studies on movements by alligator snappers were conducted in bayou and swampy wetland habitats of northeastern Louisiana (Sloan and Taylor, 1987; Harrel et al., 1996) and in a creek in southeastern Kansas (Shipman, 1993). These studies, through the use of radio transmitters, recorded daily movements and habitat preferences for this species. Harrel et al. (1996) found that water temperature and cover were major factors influencing movements by subadults. The distance moved was significantly greater in males than females; movements were both upstream and downstream approximately 23% of the time from the previous fix points and upstream ca. 18.5% and downstream ca. 29.2% of the time from the initial capture sites. The mean distance moved (between fix points) of 12 subadults was 352.2 m for males and 160.3 m for females. Sloan and Taylor (1987) followed daily movements in 11 adults; again, turtles utilized areas that provided the most cover. Average daily movements ranged from 27.8 to 115.5 m. Shipman (1993) followed a single adult female for one year; he similarly found that this turtle chose specific core habitats characterized by some degree of cover. This turtle moved a linear distance of 6.5 km in the 11.5 months of the study.

Movement data from previous studies mentioned above as well as our results indicate that alligator snappers move extensively within their aquatic habitat. Harrel et al. (1996) calculated home-range length for subadults and found that males had significantly longer home ranges than females. Although we did not quantify home range for adult turtles in Salado Creek, females generally moved greater distances than males in our small sample (Table 1). Additional data are warranted before sexual differences in movement patterns can be understood. Small streams with localized turtle populations, however, provide a means of assessing the consequences of individual movements on population structure and stability. The potential benefits or risks of these movements have yet to be determined for alligator snappers as well as for other aquatic turtles (Plummer et al., 1997). The discovery of nesting sites and/or mating encounters within Salado Creek may shed light on why adults move the way they do in this creek.

Congdon et al. (1993) discussed the ramifications of continued depletion of adult turtles on population stability in long-lived species whose life histories are characterized by delayed maturity and repeated nestings to offset high nest mortality. High adult survivorship and longevity can compensate for low annual reproductive success (Gibbons, 1987). Our catchability rates for Salado and Village creeks were similar (average = 27.3%). This suggests that our sampling methods were comparable between the two creeks. The scarcity of adult alligator snappers in Village Creek likely reflects the direct impact of overharvesting followed by a near absence of adult recruitment from neighboring creeks and nearby aquatic habitats. Recently, Sloan and Lovich

(1995) and Tucker and Sloan (1997) pointed out several consequences resulting from sustained harvesting pressure on alligator snapping turtle populations. Their immediate concerns focused on proposed management practices which often recommend the setting of minimum size limits or the conducting of size-selective harvesting. The general consensus is that *Macroclemys temminckii* populations cannot tolerate continued depletion of large adults (i.e., size-selective removal), because these individuals have the highest reproductive value. Our results on adult vagility indicate that seasonal movements by both sexes into new habitats could help offset reproductive losses incurred by the removal of resident adults in some populations. At present, however, the greatest detriment to understanding population dynamics and/or recruitment in this species might be the lack of critical knowledge on nesting ecology and survivorship of hatchlings.

Acknowledgments

We thank the following individuals who either assisted us in the field or provided advice and support in various ways during this study: B. Ball, D. Jamieson, E. Poe, J. Trauth, K. Trauth, B. Wagner, J. Welch, H. Worley, and K. Rowe. Field work and collection permits were authorized by the Arkansas Game and Fish Commission. This research was funded by the Arkansas Game and Fish Commission and the U.S. Fish and Wildlife Service through Section 6 of the Endangered Species Act. We are also grateful for the thoughtful comments of J.R. Bodie, M.V. Plummer, and R.C. Vogt on earlier drafts of the manuscript. The helpful suggestions by P.C.H. Pritchard, A.G.J. Rhodin, J.B. Harrel, and an anonymous reviewer greatly improved the quality of the final version of the paper.

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Received: 9 November 1997
Reviewed: 27 April 1998
Revised and Accepted: 25 May 1998