

Aspects of the Life History and Ecology of the Sonoran Mud Turtle in Southeastern Arizona

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Abstract.—From 1990 through 1994 we conducted a mark-recapture study of *Kinosternon sonoriense* in the West Turkey Creek area of the Chiricahua Mountains in southeastern Arizona. A total of seven were found dead, 573 live individuals were marked, and 913 recaptures were made. Of the total number of marked individuals, approximately 5% were initially captured in stream pools and 90% in stock tanks. Population size is estimated to be approximately 750 individuals. Of the 573 individuals first found alive 18.5% were classified as juveniles; 35.8% and 45.7% were adult males and females, respectively.

The youngest adult female was 5 years old and the smallest had a carapace length (CL) of 106 mm. A minimum of 22% of the females captured twice during the reproductive season produced at least two clutches of eggs. Over all years, clutch size averaged 6.4 eggs; however, clutch size did vary as a function of year and location (e. g., stock tank system). Egg widths determined from X-radiographs averaged 16.5 mm (min. = 13.6 mm, max. = 18.8 mm). Both clutch size and egg widths were significantly and positively related to body size, but not to the age of females. The dry average mass of egg yolks averaged 0.96 g (min. = 0.73 g, max. = 1.25 g, $n = 6$), and was comprised of 28.75% (min. = 26.47%, max. = 29.87%, $n = 6$) non-polar lipids. Egg shells averaged 32.75 % of the total dry mass of the egg and were similar in proportion to eggs of other *Kinosternon*. Four hatchlings captured in early August weighed approximately 3.0 grams and were 22 mm CL.

INTRODUCTION

The mechanisms by which life history trait values of individuals are transduced into population parameters are important in developing life history theories and are of great practical value in formulating conservation and management programs. Major dichotomies in life history traits are predicted to occur in life histories of long- vs. short-lived organisms (Gadgil and Bossert, 1970; Tinkle et al., 1970; Williams, 1966). However, since life history studies are labor intensive, time consuming and expensive, studies that adequately document mean values, and the magnitude and causes of variation in life history trait values are

few. Since the problems that impede life history studies are magnified when the species studied are long-lived, the majority of quantitative life history data that exists is on short-lived organisms (Dunham et al., 1988; Tinkle, 1979, Tinkle et al., 1993). As a result, many assumptions and predictions of life history theories remain untested and formulation of conservation and management programs of long-lived organisms will continue to be based on little data.

Turtles of the genus *Kinosternon* are relatively long-lived (Gibbons and Semlitsch, 1982) and are excellent models for life history and demographic studies (Frazer et al., 1991). The Sonoran mud turtle (*Kinosternon sonoriense*) occurs in northwestern Mexico, as well as in the southwestern United States where it ranges from western New Mexico, through central and southern Arizona. It is the only native freshwater turtle that occurs in the Chiricahua Mountains of southeastern Arizona.

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In 1990 we initiated a proposed long-term study of an isolated, single species population of the Sonoran mud turtle (*K. sonoriense*) in southeastern Arizona. The goals of the study were to obtain long-term data on life history trait values and aspects of the natural history of Sonoran mud turtles. Such data will: 1) enhance our understanding of the ecology of sonoran mud turtles in particular and long-lived organisms in general, 2) allow tests of existing life history theories, and 3) expand the life history data base on long-lived organisms to provide a basis for formulating conservation and management programs for long-lived organisms.

MATERIALS AND METHODS

An intensive mark-recapture study of Sonoran mud turtles has been maintained on the El Coronado Ranch in southeastern Arizona for the past five years (1990-1994). The study area is located in the West Turkey Creek and associated stock tanks in Cochise County at approximately 1675 meters elevation in the Chiricahua Mountains.

Some turtles were captured by hand and with dip nets, but most were captured using baited hoop traps fitted with floats to prevent submergence during heavy rains. Each turtle was individually marked by notching the marginal scutes of the carapace, weighed, and measured (straight line anterior and posterior plastron length, carapace length, shell height and shell width at the bridge), and then released at the point of capture.

At first capture, turtles with fewer than 8 obvious growth rings on one of the plastral scutes were assigned an age based on the assumption that these rings were laid down annually in juveniles and young adults. Recaptures of juveniles over all age classes during the past 4 years support this assumption.

All females and larger juveniles were X-rayed to determine if they were carrying oviductal eggs (Gibbons and Greene, 1979). Data from X-radiographs, provided information on clutch size, clutch frequency, the relationships of clutch size to body size and age, and age at maturity. During 1994, 15 females were captured from Rock Creek (approximately 6 km north of West Turkey Creek) and injected with oxytocin (1.5 ml kg^{-1} body mass; Ewert and Legler, 1978) to induce egg laying. All eggs from 6 females ($n = 14$ eggs) were frozen and transported to the Savannah River Ecology Laboratory where eggs were separated into shells and

yolks (includes yolk and albumin). Egg yolks were dried to a constant weight, ground with a mortar and pestle, and non-polar lipids were extracted using a Soxtec apparatus with petroleum ether as a solvent (Fischer et al., 1991).

Parametric statistical tests were used when variables were continuous and assumptions of the tests were met. Otherwise, non-parametric tests, such as Spearman's Rank Correlation (RHO; SAS, 1988) were used. Unless otherwise stated, levels of significance were established at alpha 0.05. Measures of central tendency and dispersion are presented as the mean $\pm$ one standard error unless stated otherwise.

RESULTS

From 1990 to 1994, we marked 580 individuals and made 913 recaptures of these individuals. Approximately 5% of the turtles were first captured in stream pools and 90 % in stock tanks. Of the first 573 individuals captured alive, 18.5% were classified as juveniles, 35.8% and 45.7% were adult males and females, respectively.

Minimum age at sexual maturity was 5 years and the smallest turtle that produced a clutch of eggs was 106 mm CL. Mean size of all gravid females was 134.4 mm CL. Data from X-radiographs of gravid females provided direct evidence that between 1991 and 1994, 12 of 55 (22%) of the females captured twice during the reproductive season produced at least two clutches of eggs. However, the actual proportion of adult females that produce more than one clutch annually has yet to be determined. Clutch size averaged 6.4 eggs (min. = 2, max. = 11; SE = 0.125; $n = 230$; Fig 1a). However, clutch size was significantly lower in 1994 (4.9 eggs) compared to 1991-1992 (7.6 eggs) and 1993 (6.8 eggs). Over all years, clutch size was significantly and positively related to body size of females (Spearman's Rho = 0.622; Fig 1b). Average egg width per clutch determined from X-radiographs (XREW) averaged (16.5 mm; min = 13.6; max = 18.7; $n = 241$ clutches; Fig 2a). Egg size was significantly and positively related to body size of females (Fig 2b). Neither clutch size nor egg width was related to the age of females (ANOVAS, $P > 0.05$). Egg yolks averaged 60.2 % water by mass. The dry mass of egg yolks averaged 0.96 g (min. = 0.73 g, max. = 1.25 g, $n = 6$ clutches and 14 eggs), and was comprised of 28.75% (min. = 26.47%, max. = 29.87%) non-polar lipids. Egg shells averaged 32.75 % of the total dry mass of the egg.

Four hatchlings were captured August 5, 1993 and one on August 9, 1994; these hatchlings averaged 3.0 grams body mass and 22.2 mm in CL.

DISCUSSION

Twenty four thousand years ago, a large portion of Sulphur Springs Valley was part of Lake Cochise. As Lake Cochise dried, populations of *K. sonoriense* became isolated in the most permanent streams (e. g., West Turkey Creek) originating in the adjacent mountain ranges. The higher densities of turtles presently occupying stock tanks compared to West Turkey Creek stream bed proper, suggests that the turtles prefer the more lentic habitats of stock tanks. Based on simple Lincoln Indices, our first approximation of total population size in the Turkey Creek drainage basin is 700-800 individuals. If our estimation of

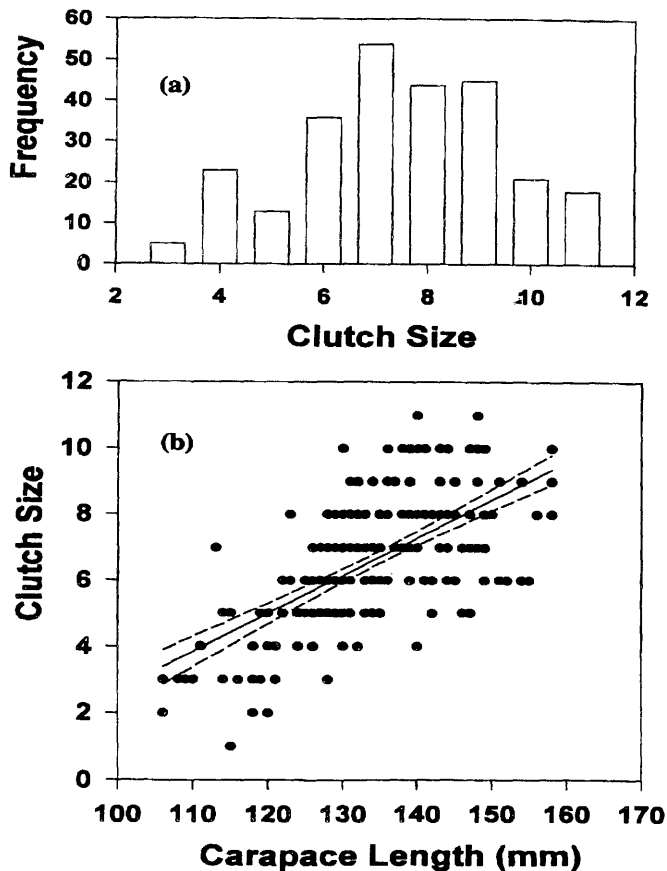


Figure 1.—(a) Frequency histogram of clutch sizes, and (b) the linear relationship (= solid line, and 95% confidence intervals = dashed lines) of clutch size to body size ($CS = -0.840 + 0.112 CL$; $R^2 = 0.42$; $n = 230$ clutches) of *Kinosternon sonoriense* females from West Turkey Creek in the Chiricahua Mountains.

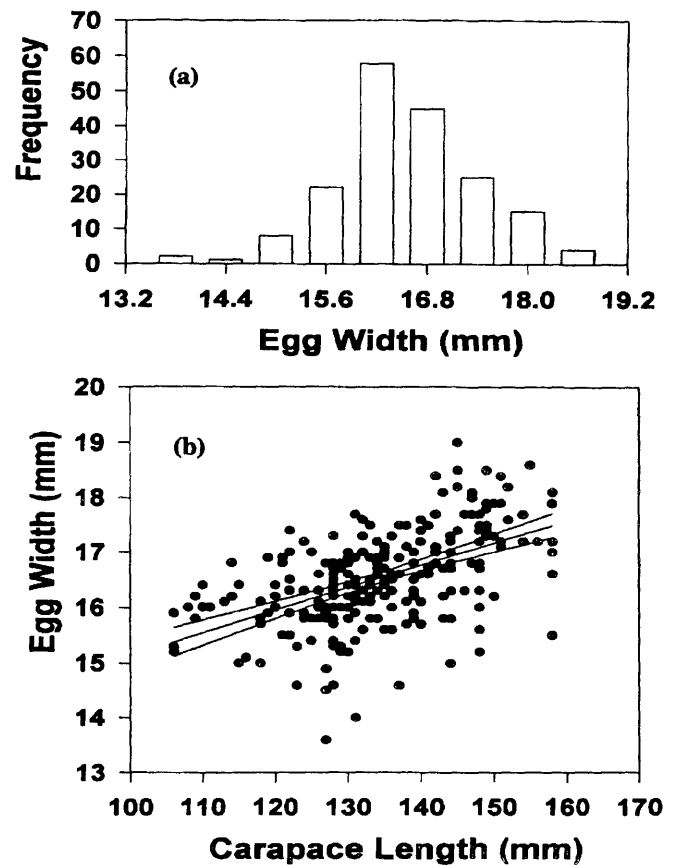


Figure 2.—(a) Frequency histogram of egg widths determined from X-radiographs and, (b) the linear relationship (= solid line, and 95% confidence intervals = dashed lines) of X-ray egg widths to body size ($XREW = 10.945 + 0.041 CL$; $R^2 = 0.29$; $n = 241$ clutches) of *Kinosternon sonoriense* females from West Turkey Creek in the Chiricahua Mountains.

total population size is accurate, then approximately two thirds of the population had been marked by the end of the 1994 field season.

Since the proportion of known-age individuals in the population will grow each year as we mark more juveniles, we hope to have over 50% of the population as known-age individuals within the next three years. The proportion of juveniles (excluding hatchlings) captured in the El Coronado population (18.5%) greater than that for a population of *K. subrubrum* (10.3% in South Carolina; J. W. Gibbons, unpublished data), and less than that found for painted turtles (*Chrysemys picta*; 40%) in Michigan (JDC, unpublished data). Although the proportion of juveniles captured in the El Coronado is different from other populations of turtles, differential trapping success of juveniles and adults among studies may have caused the differences in the relative numbers of juveniles among studies.

The minimum age at maturity of West Turkey Creek females was 5 years: an age value similar to that reported for other populations of Sonoran mud turtles (Rosen, 1987) in Arizona. Since age at maturity within a population of turtles may be highly variable (Congdon and van Loben Sels, 1993), and such variation can have substantial impact on life table calculations and models of population dynamics (Congdon et al., 1993, 1994), a single minimum value reported for at maturity is not quantitatively adequate description of this important life history trait.

Annual fecundity of females was determined by clutch size and clutch frequency. Based on the assumption of an equal primary sex ratio, an average clutch size of 6.4 eggs, and a reproductive frequency of 1.22, annual fecundity of females from West Turkey Creek is 3.7 female eggs. Average clutch size for the West Turkey Creek population is higher than those reported by Rosen (1987) for five populations of *K. sonoriense* (Beaver Creek, Indian Canal, Montezuma Well, Tule Creek, and Sharp Spring), and slightly smaller than those in three populations (Palm Lake, Granite Reef, and Sycamore Creek). Both body size and clutch size are larger than values reported for species of *Kinosternon* in the eastern United States (Gibbons, 1983). Since body size explains approximately 42% of the variation in clutch size in the West Turkey Creek population, an average increase of 5 eggs is associated with the 75 mm range of body size found between the smallest and largest adult female. The lack of association of reproductive traits with age found in *K. sonoriense* is similar to the lack of such relationships found in most other turtle species examined (Congdon and van Loben Sels, 1993; Frazer et al., 1991).

Size has been implicated as an important component of hatchling survival (Brooks et al., 1991), and is strongly influenced by maternal investment in the egg (Congdon and Gibbons, 1987). Since egg widths determined from X-radiographs were significantly and positively related to body size of adult females, larger females on average would produce larger eggs and thus larger hatchlings. An increase of 3 mm in average egg width is positively associated with the 75 mm range of body sizes found among adult females.

In addition to egg size, the proportional parental allocation of egg components such as water, protein, and lipids are also important aspects of hatchling quality (Congdon and Gibbons, 1990). The proportion of water, lipids, and shell in eggs

of West Turkey Creek females is similar to that found in *K. subrubrum* in South Carolina (Congdon and Gibbons, 1985). In general, females of turtle species with hatchlings that delay emergence from the nest allocate proportionately more non-polar lipids to eggs than do females of turtle species that have hatchlings that do not delay emergence (Congdon and Gibbons, 1985). The proportion of total dry mass of eggs represented by egg shells of *K. sonoriense* (32.75%) was more similar to five other species of turtles having brittle shelled eggs (40.70%), than to seven species having parchment shelled eggs (19.25%; Congdon and Gibbons, 1985).

The reproductive season for *K. sonoriense* extends at least from June to September (Rosen, 1987). Based on the duration of the reproductive season, and our observations of hatchling emergence in August, we propose the following scenario for egg incubation and embryonic development. Eggs are ovulated beginning in June and are held in the oviducts until the monsoon rains (July through August). Eggs are placed in nests some distance away from bodies of water. Development is postponed through embryonic diapause until the eggs are cooled during winter. Embryonic development remains in diapause through winter and then commences as eggs warm during the following spring. Development takes from 70 to 90 days and hatchlings delay emergence from the nest to coincide with the onset of summer rains. Since both nesting and hatchling emergence coincide with summer rains, the total time from egg laying to hatchling emergence is approximately 11 months.

The results presented here are preliminary as we are only in the fifth year of study. Our results do document that both clutch size and egg size are strongly correlated with body size of females within the population. Based on the size of the population and the proportion of juveniles, the population appears to be in no immediate danger. However, bullfrogs were introduced into the West Turkey Creek drainage about ten years ago, and their population numbers are high enough to be of concern if they are a major predator of turtle hatchlings. Life history studies show that high juvenile survivorship is required for populations of long-lived organisms to maintain population stability (Congdon et al., 1993, 1994). We plan to pay particular attention to the numbers, proportions, survivorships, and the age distribution of juveniles in this population over time.

ACKNOWLEDGMENTS

The following people made notable contributions to this study: Valer Austin, Peter Blanchette, Dana Henry, Erin Kaufman, Nancy Dickson, Amanda Field, , Joyce and Rose van Loben Sels. This manuscript was improved by comments from K. Buelman, J. W. Gibbons, R. Nagle, P. Niewiarowski. Editing of computer files, data analysis, and manuscript preparation were aided by contract DE-AC09-76SROO-819 between the University of Georgia and the U. S. Department of Energy.

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