ASPECTS OF THE REPRODUCTIVE ECOLOGY OF FEMALE TURTLES IN NEW MEXICO

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ABSTRACT.—Data on reproductive ecology of turtles in New Mexico are limited, and some species living there are among the least studied in the United States. We trapped 4 native species of turtles (*Apalone spinifera*, *Chrysemys picta*, *Pseudemys gorzugi*, and *Trachemys gaigeae gaigeae*) in the Río Grande and Black River (Pecos River drainage) of New Mexico in June 2012 and 2013 to collect data on female reproductive ecology, including clutch size, egg size, timing of egg production, and percentage of gravid females. During our sampling, we found shelled eggs via X-radiography in only 3 native species: *C. picta*, *P. gorzugi*, and *T. g. gaigeae*. Clutch and egg sizes were within the range of previously reported values, although clutch size for *P. gorzugi* (10 eggs) is only the second published record for that data-deficient species. Clutch size increased with body size in *T. g. gaigeae*. We observed few differences between reproductive parameters for turtles in New Mexico and their conspecifics and congeners elsewhere in the United States, other than the observation that female *C. picta* may mature at smaller body sizes in New Mexico relative to other western populations elsewhere in its vast, primarily eastern North American range.

RESUMEN.—Los datos sobre la ecología reproductiva de las tortugas en Nuevo México son limitados y algunas de las especies que viven allí están entre las menos estudiadas en los Estados Unidos. Capturamos cuatro especies de tortugas nativas (*Apalone spinifera*, *Chrysemys picta*, *Pseudemys gorzugi*, y *Trachemys gaigeae gaigeae*) en el Río Grande y Black River (drenaje del Río Pecos) de Nuevo México, en junio del 2012 y 2013, con el fin de recopilar datos sobre la ecología reproductiva femenina, incluyendo el tamaño de la puesta, el tamaño de los huevos, el momento de la producción de los huevos y el porcentaje de hembras grávidas. Durante nuestro muestreo, encontramos huevos con rayos X en sólo tres especies nativas: *C. picta*, *P. gorzugi*, y *T. g. gaigeae*. El tamaño de puesta y de los huevos se situó dentro del rango de valores previamente reportados, sin embargo el tamaño de la puesta de *P. gorzugi* (10 huevos) es tan sólo el segundo registro publicado sobre esta especie. El tamaño de la puesta aumenta con el tamaño del cuerpo de *T. g. gaigeae*. Además del hecho de que las hembras de *C. picta* podrían madurar a tamaños corporales relativamente más pequeños en Nuevo México, en relación con otras poblaciones del oeste, principalmente en el área del este de América del Norte, hemos observado algunas diferencias entre los parámetros reproductivos de las tortugas en Nuevo México, y entre sus conspecificos y congéneres en otros lugares de los Estados Unidos.

Research on turtles in the southwestern United States lags far behind that in the Southeast where turtle diversity is substantially higher (Buhlmann et al. 2009). Several southwestern turtle species (Lovich and Beaman 2008) rank among the most poorly studied species in the United States (Lovich and Ennen 2013), although information on one, *Trachemys gaigeae gaigeae*, is steadily increasing (Ernst 1992, Stuart and Ernst 2004, Stuart and Ward 2009). Recent reviews of the ecology of turtles in the United States (Ernst and Lovich 2009) and all reptiles and amphibians in New Mexico (Degenhardt et al. 1996) demonstrate that little has been published on the

ecology of turtles in New Mexico, with a few notable exceptions (e.g., Christiansen and Dunham 1972, Stuart 1995, Morjan and Stuart 2001). Even basic information on the distribution and native status (*sensu* Webb 1985) of southwestern turtles is still accumulating (Lovich et al. 2014). Although New Mexico is an arid state, it has a comparatively high diversity of native turtles, with 10 species currently recognized, 9 of which occupy aquatic environments for substantial portions of the year (Degenhardt et al. 1996).

Many turtles in New Mexico have wide distributions in the United States and Canada, with only small portions of their ranges

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extending into New Mexico. This contributes to the dearth of state-specific ecological and reproductive data for most turtle species that are otherwise fairly well studied outside New Mexico. For example, due to their wide distributions, some turtles such as *Chrysemys picta* are among the best studied (Lovich and Ennen 2013) based on research in other parts of the United States and Canada. Others, like *T. g. gaigeae* and *Pseudemys gorzugi*, continue to be poorly studied (Lovich and Ennen 2013) and have only limited information specifically from New Mexico. Ongoing population surveys of turtles in and around Elephant Butte Reservoir (EBR) on the Rio Grande and the Black River of New Mexico provided an opportunity to collect additional data on female reproductive ecology for several turtle species that we summarize in this paper.

METHODS

Several of the authors have monitored turtle populations in the Rio Grande and Pecos River in New Mexico for several decades. Turtle research in New Mexico began in the 1970s (Degenhardt and Christiansen 1974, Degenhardt et al. 1996) and intensified in the 1990s at EBR on the Rio Grande (Sierra Co.) near Truth or Consequences (Stuart and Painter 2002). Because of the paucity of information on reproductive ecology of female turtles in New Mexico, we trapped turtles during 2012 and 2013 (Lovich 2016) with hoop traps baited with canned sardines (Gibbons 1988) to collect data on clutch size, egg size, and percentage of gravid females. From 13 June to 15 June 2012, we trapped *T. g. gaigeae* and *C. picta* at EBR and in ponds below the dam and oxbows along the lower lake. We trapped *P. gorzugi* on the Black River, a tributary of the Pecos River in Eddy County, on 13 June. A replicate trapping effort was conducted at EBR from 19 June to 20 June 2013. The nesting season at EBR starts as early as 31 May for *T. g. gaigeae* (Morjan and Stuart 2001). Due to protracted drought, lake levels were extremely low during both sampling efforts (Woodhouse et al. 2013, Cook et al. 2015).

Turtle sex was determined based on differences in pre-cloacal tail length between males and females (Ernst and Lovich 2009), and straight-line carapace lengths (SLCL) were measured with tree calipers to the nearest

1 mm. Female turtles were X-rayed in the field with a portable digital X-ray system (Canon® and MinXray® TR-80 components) to determine clutch presence, clutch size, and egg width. X-radiographs were generated at 60 kV with an exposure of 0.1 s, settings that are considered safe for the females and embryos (Hinton et al. 1997). We X-rayed most females above or near the previously published minimum sizes at maturity for each species (Ernst and Lovich 2009, Legler and Vogt 2013). The exceptions included *P. gorzugi* and *T. g. gaigeae*, since timing of maturity is not well defined in either species and may vary latitudinally in the latter species (Stuart and Ward 2009). Females of *T. g. gaigeae* are assumed to mature at a carapace length of 160 mm (Legler and Vogt 2013) to 169 mm (Legler 1960). Our sample included 3 females between 135 mm and 160 mm SLCL that were X-rayed to test the lower estimate. Greatest egg widths (EW) were measured directly from digital images of X-radiographs to the nearest 0.01 mm using K-PACS software (version 1.5.0) after calibrating measurements with a penny placed on the X-ray detector plate during each exposure. Statistical analyses were conducted using SYSTAT (version 13.1) and Program R (version 3.2.3; R Core Team 2013). Turtles were released at the point of capture except for *Trachemys scripta* individuals. That taxon was removed from the Rio Grande basin by the New Mexico Department of Game and Fish because it is an invasive species.

RESULTS

During 2012, three female *C. picta* with SLCLs of 144, 148, and 149 mm were collected in an oxbow pond near EBR, and 2 were gravid. The smallest female (144 mm) contained 7 shelled eggs and the 148 mm female contained 8 shelled eggs (Table 1). Neither clutch was heavily shelled as would be expected if oviposition was imminent. EW ranged from 16.7 to 18.2 mm ($\bar{x}$ = 17.4, SD 0.3). Mean EW was not statistically different between the 2 females (Student's *t* test, pooled variance: t = -0.11, *df* = 13, *P* = 0.91).

Six female *P. gorzugi* ranging from 210 to 266 mm SLCL were collected on the Black River. Only one (242 mm SLCL) was gravid (17%), and she contained 10 shelled eggs with EWs from 27.2 to 30.5 mm ($\bar{x}$ = 29.3, SD 1.1).

TABLE 1. Summary of reproductive data for selected female aquatic turtles from New Mexico or adjacent states and Mexico. SLCL = straight-line carapace length, CL = carapace length (when SLCL is not specified in publication), NM = New Mexico. Data for *Trachemys g. gageae* do not include the suspected hybrid turtle discussed in the text. Additional information on the reproductive ecology of these species is summarized in Ernst and Lovich (2009). A dash means data were unavailable.

Species	Reproductive parameter					Comments
	Timing of observed reproductive condition	Clutch size	Egg size (mm)	Size of mature females (mm)	Known or suspected clutch frequency	
<i>Apalone spinifer</i>	13 June 13–15, 19–20 June	39 0	—	—	—	Logan Co., CO Sierra Co., NM
<i>Chrysemys picta</i>	May through mid-July 13–15, 19–20 June	$\bar{x} = 9$, (range 5–15)	31.4×18.4	$\bar{x} = 263$ SLCL > 138 CL	—	Christiansen and Moll (1973)
<i>Pseudemys gorzugi</i>	23 May 13 June	— 9 10	$\bar{x}$ width = 17.4 ($n = 15$ eggs, range 16.7–18.2, SD 0.3) $\bar{x}$ length = 42, $\bar{x}$ width = 31 $\bar{x} = 29.3$ ($n = 10$ eggs, range 27.2–30.5, SD 1.1)	144, 148 SLCL 240 CL —	— — —	Sierra Co., NM Black River (Pecos drainage), Eddy Co., NM Sierra Co., NM
<i>Trachemys g. gageae</i>	26 June 8 June 19 May–11 July 31 May 13–15, 19–20 June	6, 7, 9, 11 29 $\bar{x} = 15.4$, range 6–22 19 9, 12, 12, 18	— $\bar{x}$ length = 37.3, $\bar{x}$ width = 22.8 $\bar{x}$ length = 35.0, $\bar{x}$ width = 22.5, $\bar{x}$ mass = 10.7 g — $\bar{x}$ width = 23.7 ($n = 51$ eggs, range 22.0–26.4, SD 1.1)	170–180 CL — 228–266 CL 229 CL $\bar{x} = 211.8$ SLCL	— 2 — — —	Oviductal eggs, Chihuahua, Mexico according to Stuart and Painter (1997) Based on a single 224 mm SLCL female from Elephant Butte Reservoir, Socorro Co., NM Based on 12 adult females from southern Socorro Co., NM and 170 eggs Bosque del Apache National Wildlife Refuge, Socorro Co., NM. Contains additional details on nesting and hatchling overwintering Sierra Co., NM

Fig. 1. Female *Trachemys g. gaigeae* collected in the Rio Grande near the Elephant Butte Reservoir dam in New Mexico. Image was enhanced to make the 18 thinly shelled eggs more visible at the expense of the anterior and posterior margins of the carapace. A penny (19 mm diameter) is shown in the upper right-hand corner for scale.

Seven female *T. g. gaigeae* ranging from 135 to 245 mm SLCL were collected in or near EBR, of which 2 (29%) were gravid. One (220 mm SLCL) contained 18 thinly-shelled eggs (Fig. 1) with EW ranging from 22.2 to 24.4 mm ($\bar{x} = 23.2$, SD 0.58). The other (211 mm SLCL) contained 12 thinly-shelled eggs with EW ranging from 22.0 to 23.2 mm ($\bar{x} = 22.6$, SD 0.4). Mean EW in the larger female was statistically greater than mean EW in the smaller female, and variation in EW was greater between clutches than within (Student's *t*-test, pooled variance: $t = 2.96$, $df = 28$, $P = 0.003$).

In 2013, all samples came from EBR (Table 1). Eight female *Apalone spinifer* ranging in size from 201 to 315 mm SLCL were X-radio-

graphed and none had shelled eggs. A single *C. picta* (166 mm SLCL) had no shelled eggs. Only 2 out of 13 *T. g. gaigeae* (15%) had shelled eggs with the following data: 203 mm SLCL, 9 eggs with EW ranging from 24.7 to 26.4 mm ($\bar{x} = 25.5$, SD 0.6); and 213 mm SLCL, 12 eggs with EW ranging from 23.6 to 24.8 mm ($\bar{x} = 24.2$, SD 0.4). This time, mean EW in the smaller female was statistically greater than mean EW in the larger female, but again, variation in EW was greater between clutches than within (Student's *t* test, pooled variance: $t = 6.062$, $df = 19.000$, $P < 0.001$). The other 11 *T. g. gaigeae* without eggs ranged from 146 to 245 mm SLCL. One suspected hybrid, *T. g. gaigeae* $\times$ *T. scripta* (209 mm SLCL, with shell and head patterns

Fig. 2. Clutch size versus straight-line carapace length (SLCL) in *Trachemys g. gaigeae*, with standard error shown by the shaded region. Data include one suspected hybrid *T. g. gaigeae* $\times$ *T. scripta* with a clutch size of 11 eggs.

intermediate between the 2 species), had 11 shelled eggs with EW ranging from 22.6 to 24.9 mm ($\bar{x}$ = 23.9, SD 0.8). One out of 5 *T. scripta* females (20%) had shelled eggs (168 mm SLCL, 10 eggs) with EW ranging from 20.0 to 22.0 mm ($\bar{x}$ = 21.3, SD 0.6). The other 4 female *T. scripta* ranged from 132 to 225 mm SLCL.

The proportion of gravid to nongravid female *T. g. gaigeae*—the species with the largest sample size between years—in 2012 (2 out of 7) was not statistically different from the proportion for 2013 (2 out of 13) as shown by Fisher's exact test (P = 0.59). Although the sample size is small, clutch size increased with SLCL in the sample of *T. g. gaigeae*, including the suspected hybrid *T. g. gaigeae* $\times$ *T. scripta* specimen we examined (Fig. 2). The relationship between clutch size and SLCL was significant as shown by linear regression analysis ($F_{1,3}$ = 33.33, P = 0.01, R^2 = 0.92), with clutch size increasing by about 0.52 eggs per millimeter increase of SLCL.

DISCUSSION

Degenhardt et al. (1996) underscored the need for collecting state-specific data on turtles in New Mexico. They noted that extrapolation of data from eastern populations of tur-

tles to those of their congeners or conspecifics in New Mexico may not be appropriate. For example, they noted that *Trachemys* in New Mexico occur at comparatively high elevations in an otherwise arid landscape and at the westernmost edge of the range for the genus relative to eastern populations of *Trachemys*. These physiographic differences in habitat may be manifested in variation in reproductive ecology among regions.

Our results provide additional information on the reproductive ecology of female turtles in New Mexico, including only the second record (Table 1) of clutch size for *P. gorzugi*. In addition, our study supplements current knowledge on reproductive ecology for *T. g. gaigeae*, *C. picta*, *A. spinifera*, and suspected hybrid *T. g. gaigeae* $\times$ *T. scripta*. Furthermore, our records were taken during a long-term drought which has led to decreased surface water levels in EBR and other drainages in New Mexico (Woodhouse et al. 2013, Cook et al. 2015). The effect of drought on the reproductive output of these species is unknown. Others have shown that drought does affect aspects of aquatic turtle ecology (Anthonysamy et al. 2013), including reproductive output (Gibbons et al. 1983). Future research will be required to determine whether long-term drought is exerting changes in turtle

reproductive ecology in New Mexico. Despite the prudent cautionary note offered by Degenhardt et al. (1996) above, we found little difference between reproductive data for New Mexico *C. picta* and its conspecifics elsewhere in the United States, except as noted below.

Chrysemys picta is a wide-ranging species in North America, and size at maturity varies depending on subspecies and population. Christiansen and Moll (1973) found that females in New Mexico mature at about 139 mm carapace length, which is just below the size of our smallest gravid female (144 mm CL). Although numerous studies suggest a positive correlation between body size at sexual maturity and latitude for *C. picta* (Iverson and Smith 1993, see review in Ernst and Lovich 2009), minimum body size of sexually mature females from New Mexico appears to be well below the upper range of values previously reported for the species in western North America (about 165–177 mm CL; see review in Ernst and Lovich 2009). Clutch size also varies slightly from a mean of 9.9 eggs in New Mexico to 10.5 eggs in Illinois (Morjan 2003).

The range of *P. gorzugi* extends from New Mexico to Tamaulipas, Mexico, and the species is presently at risk from water diversion projects, habitat fragmentation, the pet trade, and limited gene flow (Bailey et al. 2008). Reproductive ecology of *P. gorzugi* is poorly known, and only one other record of clutch size is available in the literature (9 eggs; Degenhardt et al. 1996). The faint outline of eggs in the X-radiograph we observed suggested that the eggs were still being shelled, which means that nesting could have occurred within the month of June or possibly July.

Our data add to available reproductive studies of another comparatively data-deficient species, *T. g. gaigeae*. The clutch sizes of gravid females at our study area were within the known range of reproductive output in a single clutch (6–29 eggs; Ernst and Lovich 2009). Body size was positively correlated with clutch size in *T. g. gaigeae*. The general pattern of clutch size increasing with body size is well documented and has been suggested in several aquatic turtle species (see review in Ernst and Lovich 2009). However, our study is the first to suggest that relationship in *T. g. gaigeae*.

In addition, we recorded the presence of eggs in a suspected hybrid of *T. g. gaigeae* ×

T. scripta, further confirming reproductive interactions (see review in Stuart and Ward 2009) between invasive *T. scripta* and native *T. g. gaigeae*. Hybridization with *T. scripta* is considered one of several threats faced by *T. g. gaigeae*. Stuart and Ward (2009) note that the presence of breeding populations of *T. scripta* within the range of *T. g. gaigeae* is "...unconfirmed but appears likely." Our finding of both a gravid female *T. scripta* and a gravid suspected hybrid supports Stuart and Ward's "likely" conclusion.

Overall, we observed few differences between reproductive parameters for turtles in New Mexico and their conspecifics and congeners elsewhere in the United States. An exception is that females of *C. picta* may mature at smaller body sizes in New Mexico relative to other western populations elsewhere in the species' vast, primarily eastern North American range.

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