POPULATION ASSESSMENT OF TEXAS DIAMONDBACK TERRAPIN (*MALACLEMYS TERRAPIN LITTORALIS*) IN THE NUECES ESTUARY, TEXAS

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Abstract.—A preliminary assessment was made of Texas diamondback terrapin (*Malaclemys terrapin littoralis*) in the Nueces Estuary, Texas from September 2010-December 2010 and in October 2011. One hundred twenty-two terrapins were captured (105 individuals and 17 recaptures) using crab traps in salinities ranging from 6.7 PSU to 47.6 PSU and in water temperature above 18°C, for an overall CPUE of 0.47. Overall M:F sex ratio was 1.5:1, and the M:F sex ratio for recaptured terrapins was 3.75:1. The estimated population of terrapins in the study area was 347 (95% CI = 142-552).

The Texas diamondback terrapin (*Malaclemys terrapin littoralis*) is found in estuarine habitats along the Gulf Coast from western Louisiana to southern Texas (Carr 1952). The diamondback terrapin (*Malaclemys terrapin*) is listed as Near Threatened on the International Union for Conservation of Nature (IUCN) red list (IUCN 2012) and all subspecies are protected to some degree by the states within their range. Texas diamondback terrapins are a species of concern in Texas (Hogan 2003) and populations are thought to be declining (Mays 2010). The population of terrapins in the Nueces Estuary is near the southern limit of the species’ range. Due to the lack of freshwater inflow, precipitation, river diversions, urbanization, and river impoundments, hypersalinity is a common occurrence in the Nueces Estuary, and the estuary should not meet the brackish salinity regime required by terrapins. This research describes demographic and distributional data for terrapins inhabiting the Nueces Estuary and provides a record of tolerance to hypersalinity in the Texas diamondback terrapin.

MATERIALS AND METHODS

Terrapins were trapped October-December 2010 and in October 2011 at 13 stations in the tidal segment of the Nueces River, the Nueces Delta, and Nueces Bay (Fig. 1). Sampling events were 24 h
in duration with seven, five, and one sampling events occurring in October 2010, November 2010, and December 2010, respectively, and four sampling events occurred in October 2011. Habitat types in Nueces Bay include unvegetated bay bottom, oyster reef (*Crassostrea virginica*), seagrass beds (*Halodule wrightii* and *Ruppia maritima*), and vegetated shorelines (Tunnell et al. 1996; Pulich et al. 1997). Habitats in the Nueces Delta include vegetated marsh (*Spartina alterniflora, Borrichia frutescens*), mudflats, tidal creeks, and shallow ponds (Bureau of Reclamation 2000). Sampling stations were selected based on terrapin sighting/capture data and habitat preferences reported by Halbrook (2003) and Koza (2006): oyster reef (*n* = 6), tidal river (*n* = 3), and deltaic tidal creeks (*n* = 4).

Standard crab traps (59 by 59 by 43 cm), modified with chimneys (29 cm diameter by 61 cm height) to create a permanent air space, were baited with dead finfish or blue crab and deployed between
0800 h – 1500 h. Traps were checked the following day between 0800 h – 1500 h. The number of traps deployed during each sampling event was dependent on water level and tidal phase which restricted access to sampling stations. The number of traps set during each sampling event ranged from 12-20.

On first capture, terrapins were tagged in the webbing of a hind foot using a monel tag and then rinsed with isopropyl alcohol (National Band and Tag Co. 721 York Street, PO Box 72430, Newport, KY 41072). Monel tags were chosen as being the most cost effective for this study thereby providing a reliable alternative to traditional scute notching performed in this area previously by Halbrook (2003) and Koza (2006). Traditionally, monel tags have been used in sea turtle research, although the permanence of these tags has been questioned. Tag loss has been attributed to improper application, tag corrosion, and tissue necrosis (Henwood 1986; Limpus 1992; Rivalan et al. 2005). Rivalan et al. (2005) reported a high initial rate of tag loss and a rapid decrease in tag loss probabilities immediately after application in sea turtles. This was attributed to incorrect application of the tag which resulted in the immediate shedding of the improperly secured tags. In the current study, care was taken to ensure that tags were applied properly and that the locking mechanism was functioning correctly.

Carapace length, width, and height and plastron length and width were measured (mm) using calipers. Weight (g) was taken using a spring scale for the first two sampling events and with a digital scale for the remainder of the study. Sex was determined based on cloacal position in relation to the posterior margin of the carapace (Lovich & Gibbons, 1990). Terrapins were subsequently released at the site of capture.

Catch per unit effort (CPUE) was calculated as number of individuals captured per trap per 24 h. Distance between captures for recaptured terrapins was calculated. Jolly-Seber POPAN model in Program MARK v 6.1 was used to estimate abundance. This is an
open population model allowing for gene flow within the population. Assumptions for this model include: 1) animals retain their tags through the entire study, 2) tags are read properly, 3) sampling is instantaneous, 4) survival probabilities are equal for marked and unmarked individuals, 5) catchability is equal for marked and unmarked animals, and 6) the study area is constant. The POPAN model in Program MARK v 6.1 also allows for unequal time intervals between sampling occasions. Only 2010 data were included in the population estimate due to the lengthy time interval between 2010 and 2011 sampling. No population estimate was made for 2011 because limited sampling resulted in few recaptures.

Water temperature (°C) and salinity (PSU) were recorded at 0.3 m with a YSI 6920 at the time traps were deployed. In addition, salinity data collected from the Conrad Blucher Institute for Surveying and Science at Texas A&M University - Corpus Christi, Salt03 station (27.851561°N, 97.482028°W) was also used. Salt03 is a fixed monitoring station located in the middle of Nueces Bay.

RESULTS

Water temperatures during the study period ranged from 12.0 - 28.9°C, but terrapins were only captured in temperatures greater than 18°C. Recorded salinities ranged from 2.8 - 48.3 PSU, with terrapins captured from 6.7 - 47.6 PSU. An upward trend in salinity was observed throughout the sampling period with hypersaline conditions beginning in June 2011 (Fig. 2). Mean salinity for the 2010 sampling period was 21.1 PSU and hypersaline conditions were not observed, however, mean salinity for the October 2011 sampling event was 44.8 PSU and hypersalinity was observed.

One hundred twenty-two terrapins were captured: 105 individuals and 17 recaptures. Thirteen individuals were recaptured once and two individuals were recaptured twice. All but six terrapins were caught in the oyster reef habitat. No individual terrapin was captured
in both the oyster reef and tidal river habitats (Table 1). More terrapins were captured in 2010, with numbers of captures declining from October to December 2010, coinciding with seasonal water temperature declines. Trapping success was far greater in October 2010 compared to October 2011 despite an increase in effort of 50%. There was also a steady increase in salinities from October 2010 to October 2011, with salinities more than doubling during this time interval.

On average, female terrapins were larger than and nearly twice as heavy as males (Table 2). Overall M:F sex ratio was 1.5:1 and recapture sex ratio was 3.75:1. Sex ratios for the oyster reef and tidal river habitats were 1.6:1 \((n = 99)\) and 0.5:1 \((n = 6)\), respectively. Overall CPUE was 0.47. Catch per unit effort for the oyster reef, tidal river, and deltaic habitats were 0.59, 0.19, and 0.0, respectively. The minimum and maximum distances between captures for an
Table 1. Number of male and female diamondback terrapins captured (recaptures in parentheses) among 4 habitats in the Nueces Estuary, Texas during sampling events between October 2010 and October 2011. Catch per unit effort (CPUE) = number/24h/trap. Traps were set in oyster habitat and tidal river habitat during December 2010, but no terrapins were captured.

<table>
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<th>October 2011</th>
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<tr>
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<td>CPUE</td>
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<td>27</td>
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Table 2. Morphometric data, by sex, for *Malaclemys terrapin littoralis* in the Nueces Estuary, Texas. Measurements include carapace length (CL), carapace width (CW), carapace height (CH), plastron length (PL), plastron width (PW), and weight (WT).

<table>
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<th>PL (mm)</th>
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individual terrapin were 0.0 km and 1.6 km, respectively. Average distance between capture and recapture was 0.4 km. The average number of days between initial capture and recapture was 63 and ranged from 1 to 349, although sampling was not continuous during that period.

Minimal growth was observed for recaptured terrapins and all but one recaptured terrapin lost weight between captures; mean percent weight loss was 4.8%. Of the 15 recaptured individuals, weights for 10 were considered precise enough to indicate true weight loss as both weight upon initial capture and recapture were determined with a digital scale accurate to 1 gram. Based on the 2010 recapture data, the estimated population size in the Nueces Estuary is 347 (95% CI, range = 142-552).

**DISCUSSION**

This study documented Texas diamondback terrapins are able to tolerate hypersaline conditions in their southernmost known range, the Nueces Estuary. Salinity in Nueces Bay steadily increased to hypersaline levels beginning in June 2011 with no freshwater inflow relief. Because of limited resources, terrapin sampling did not take place between January and October 2011, leaving a data gap during the drought period when salinity was rising in Nueces Bay.

As a preliminary population assessment, the purpose of this study was to capture and mark as many individual terrapins as possible within the Nueces Estuary. Because of this sampling approach to put effort into trapping terrapins in habitats where they were being caught and or sighted, it resulted in an uneven sampling design among the three habitat types (river, oyster reef, and delta). While our data suggests that terrapins preferred the oyster reef habitat, as evidenced by the high numbers captured there, the results are likely the outcome of more intense sampling in that habitat compared to the riverine and deltaic habitats. Other factors that contributed to the uneven sampling design were: low water levels that restricted access...
to the oyster reefs and delta and the number of traps deployed during sampling events, which was limited by the capacity of the boat used.

In the Nueces Estuary, previous studies using crab traps have reported M:F sex ratios of 0.3:1 and 1.3:1 (Halbrook 2003; Koza 2006, respectively). Sex ratio (M:F) for this study (1.5:1), along with that of Koza (2006), is similar to other male-dominated sex ratios reported for this species (1.3:1 to 4.4:1, see Bishop 1983; Lovich & Gibbons 1990; Simoes & Chambers 1999; Butler 2000; Gibbons et al. 2001; Butler 2002; Radzio & Roosenburg 2005; Butler & Heinrich 2007). Female-biased sex ratios ranging from 0.1:1 to 0.7:1 have also been reported (Hurd et al. 1979; Yearicks et al. 1981; Seigel 1984; Roosenburg et al. 1997; Avissar 2006). For captive populations, a F:M sex ratio 5:1 produced the highest fertility (Hildebrand, 1932). Lovich and Gibbons (1990) list several factors that may influence sex ratios in wild terrapin populations: environmental sex determination (ESD), age at maturity, sampling bias, seasonal variation, and differential mortality between the sexes.

Sampling bias has been offered as an explanation for male biased sex ratios in studies that used crab traps to capture terrapins. The gape of trap openings may prevent mature females from entering, resulting in a male dominated sex ratio that may not be representative of the population. Crab traps were used in the current study and previously by Halbrook (2003), who reported a female dominated sex ratio, suggesting that sampling bias may not explain the male dominated sex ratio. Lovich and Gibbons (1990) defended their male dominated sex ratio (1.78:1), stating that the sex which matures fastest will dominate the population, hence the higher overall abundance of male to female terrapins in their study.

Halbrook (2003) focused her trapping efforts in the tidal portion of the Nueces River and on the oyster reefs in the west end of Nueces Bay, with the majority of captures occurring on or near the oyster reefs. Koza’s (2006) sampling was restricted to the oyster reefs. Both previous studies employed standard crab traps modified with
chimneys. The current study used crab traps modified with chimneys to sample both the tidal portion of the Nueces River and the previously mentioned oyster reefs, while also sampling the main channels of the Nueces Delta, although no terrapins were captured there. Trapping locations or trap type are unlikely to explain the differences between Halbrook’s (2003) female dominated sex ratio (0.3:1) and those reported by Koza (2006) (1.3:1) and this study (1.5:1), as all three studies sampled the same areas using the same trap type.

Seasonality may have contributed to the differences in sex ratios seen between the three studies in the Nueces Estuary. Seigel (1980) showed differences in sex ratios from the Indian River depending on the season sampled. Halbrook (2003) conducted the majority of her sampling during the summer, although all seasons were sampled at least once. When broken down by season, M:F sex ratios were 0.5:1, 0.26:1, 0.71:1, 0.83:1 for spring, summer, fall, and winter, respectively (Halbrook, 2003). Once mating has occurred in the spring, males may become more widespread and hence harder to capture. This may have resulted in Halbrook’s (2003) female biased sex ratio as the majority of her sampling, and her most strongly biased sex ratio, occurred in summer. Sampling in the current study occurred in the fall, and while Halbrook’s (2003) sex ratio for fall was still female dominated, it was less skewed towards females than her spring and summer sex ratios.

The average distance between capture and recapture for individual terrapins (0.4 km) was similar to previous research, suggesting high site fidelity and small home range in this species (Gibbons et al. 2001). Halbrook (2003) reported an average distance of 0.4 km between capture and recapture for individual terrapins, with a minimum of 0.0 km and a maximum of 3.2 km. Koza (2006) reported an average distance of 0.6 km between capture and recapture with a minimum of 0.0 km and a maximum of 1.4 km. Combined, these results support previous research suggesting limited movements for the species.
Halbrook (2003) reported a population estimate of 322 terrapins for the Nueces Estuary using the full Jolly-Seber model for open populations, with a 95% confidence interval ranging from 15-1404. This estimate is similar to the 347 reported in this study. Koza (2006) did not include a population estimate and his data were not presented in a manner conducive to constructing encounter histories. Because of this, no attempt was made to calculate a population estimate for Koza (2006).

Terrapins are an estuarine species that tolerate a wide range of salinities. To cope with variable salinities, terrapins have low integumentary permeability coupled with a lachrymal salt gland (Dunson 1985). Terrapins are unable to survive indefinitely in seawater due to increased concentration of urea in the blood (Gilles-Baillien 1970; Davenport & Ward 1993). In this study, terrapins were captured in salinities well above seawater suggesting that the Nueces Estuary terrapin population is able to cope with hypersaline conditions. Davenport and Ward (1993) showed that terrapins subjected to marine conditions without access to freshwater display depressed appetites and a steady decline in body weight attributed mostly to osmotic water loss. During this study, the Nueces Estuary experienced severe drought conditions induced by a lack of precipitation and freshwater inflow from the Nueces River.

Growth in captive terrapin populations is well documented (Barney 1922; Hildebrand 1929, 1932). Wild terrapins are reported to grow quickly before sexual maturity with a marked decline in growth (<5% per year) after reaching sexual maturity (Seigel 1984). Growth rates vary between populations in relation to latitude and other environmental factors (Brennessel 2006). Variability in growth rates have also been reported within local populations (Palmer & Cordes 1988). Koza (2006) reported a 6.54% average increase in weight and 1.3% average increase in carapace length for recaptured terrapins (n = 10) from the Nueces Estuary. In the current study, terrapins showed an average decrease in weight of 4.76% and an average increase of carapace length of 0.61%. Although growth rate
varies between and within wild populations, it can be assumed that some degree of growth, or weight gain, should have occurred between the initial capture and subsequent recapture of terrapins in this study.

Although this population appears to tolerate high salinities, these data suggest that growth may be slower in populations where salinities are higher than typical estuarine systems. Hildebrand (1932) suggested that sexual maturity in terrapins was related to size rather than age, and data from Seigel (1984) support this. Depressed appetite leading to weight loss coupled with slowed growth during high salinity periods could potentially delay sexual maturity in the Nueces Estuary terrapin population.

ACKNOWLEDGEMENTS

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LITERATURE CITED


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