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Life in Skinny Water: Observations of Juvenile Diamondback Terrapins (*Malaclemys terrapin*) Utilizing Shallow Water Habitats

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***Abstract*.—Relatively little is known about the juvenile years of many turtle species, particularly the habitats used. Prior turtle studies found that juveniles use different habitats compared to adults, and therefore, juveniles are typically undersampled. Diamondback Terrapins (*Malaclemys terrapin*) inhabit salt marsh, island, and mangrove habitats along much of the Atlantic and Gulf Coasts of the USA. Much information is known about adult terrapin ecology, but little information exists for the juvenile life stages. While sampling for terrapins in southwestern Louisiana from 2011–2016, I captured 20 juveniles (< 9.5 cm PL) by fyke net and 15 juveniles by manual searching via airboat. Juveniles were only 3.1% of fyke net captures (0.07/net day) and 6.0% of manual searching captures (0.44/airboat hour). Juveniles were observed exclusively in shallow water habitats (< 1 m), with many captured in < 10 cm of water. Fyke net bycatch of Alligator Gar (*Atractosteus spatula*), a top predator, increased above this depth. Juveniles likely use shallow water for a multitude of reasons. These may include increasing survival by having fewer predators and more cryptic habitats, while also promoting higher growth rates via improved thermoregulatory opportunities (i.e., shallow, warm water), fewer osmotic challenges, and possibly competitive avoidance with adult terrapins. The lack of juveniles in prior studies is likely due to a combination of sampling methodology, habitats sampled, and crypsis. These observations further support that high marsh is important habitat for juvenile terrapins and that such habitats should be included into terrapin and/or coastal conservation planning.**

Key Words.—airboat searching; Alligator Gar; *Atractosteus spatula*; coastal conservation

Introduction

For many turtle species, relatively little is known about the those years spent between hatching and adulthood (Carr 1952). For conservation planning, knowledge of juvenile habitat preferences is critical. Other authors have found that juveniles use different habitat than adults (e.g., Reich et al. 2007). Consequently, juveniles are typically under sampled in ecological or life-history studies of turtles (e.g., Selman and Lindeman 2015). Even though there may be considerable knowledge on adult habitat use, researchers and managers cannot presume that protection of the adult habitat confers similar protection to juvenile life stages. Without knowledge of juvenile habitats used, those areas may not be protected or they may be neglected in species management plans.

Diamondback Terrapins (*Malaclemys terrapin*; hereafter terrapin) inhabit saline/brackish marsh, island, and mangrove habitats from Texas to Massachusetts, USA (Ernst and Lovich 2009), with an isolated population existing on Bermuda (Parham et al. 2008). The primary habitats used by adult terrapins include tidal creeks, tidal ponds, shallow bays, and nearshore habitat in both marsh and mangroves (Butler et al. 2006). Adult females typically nest on well-drained beaches, islands, and dunes (Butler et al. 2006), as well as shell rakes (pers. obs.) and dredge spoil islands (Roosenburg et al. 2014). Although much information has been gained to understand adult terrapin life history and ecology (Butler et al. 2006, Ernst and Lovich 2009), little information exists to better understand the habitat used by juvenile life stages. To date, only a small number of publications detail juvenile habitat (Pitler 1985; Roosenburg et al. 1999). To my knowledge, a single unpublished report (Mann 1995) describes juvenile terrapin habitat along the Gulf of Mexico. Herein, I describe observations of 34 juvenile terrapins and their habitat in southwestern Louisiana, and I discuss the implications of these observations for the management of coastal marsh habitats for terrapins.

Materials and Methods

***Study sites*.**—I made field observations at three sites in southwestern Louisiana, USA (Fig. 1). The first

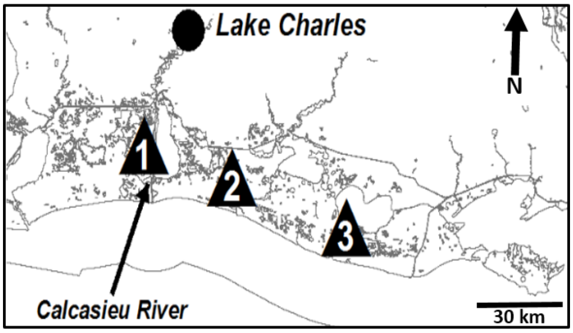

Figure 1. Sample sites for juvenile Diamondback Terrapins (*Malaclemys terrapin*) from 2011–2016 in Cameron and Vermilion parishes, Louisiana, USA. Site 1 is Rabbit Island, site 2 is Mud Lake, and site 3 is Rockefeller Wildlife Refuge.

site, Rabbit Island (RI), was a saltmarsh island located in Calcasieu Lake, a large estuarine lake in Cameron Parish. Rabbit Island was ~85 ha with a single tidal bayou inlet that connects large and small tidal ponds on the interior of the island. The dominant vegetation on the island was *Spartina alterniflora* (Smooth Cordgrass), *Distichlis spicata* (Saltgrass), and *Juncus roemerianus* (Black Needlerush). Rabbit Island is surrounded by West Cove of Calcasieu Lake, a shallow bottom estuary (mean depth < 1.82 m).

The second site was a large tidal saltmarsh near lower Mud Lake (ML), a shallow estuarine water body, also in Cameron Parish. Mud Lake was bordered by a relatively dense saltmarsh with a small number of tidal creek inlets and few tidal ponds. The saltmarsh was dominated by *S. alterniflora* and *D. spicata*, with smaller amounts of *J. roemerianus* and *Spartina cynosauroides* (Hogcane). Water levels are driven by tidal fluctuation, wind direction, and freshwater inflows from the Mermentau River.

The third site was an expansive tidal saltmarsh on Rockefeller Wildlife Refuge (RWR, Vermilion Parish, Louisiana, USA). The saltmarsh was dominated by *S. alterniflora* and *D. spicata*. It was a mosaic of habitat types used by terrapins including numerous tidal channels, large tidal ponds, and broken marsh (i.e., mixed marsh and small ponds). Water levels are driven by tidal fluctuation and wind direction. All three sites are described in detail by Selman et al. (2014).

Field methods.—From 2011–2016, I sampled for terrapins at these sites to determine multiple aspects of their ecology and life history in an understudied portion of their range. I sampled terrapins with unbaited, double-throated fyke nets with 7.62 m or 15.2 m lead nets (3.8 cm mesh size; Fish Net Company, Jonesville, Louisiana, USA). I stretched fyke nets completely across tidal creeks embedded within salt and brackish marshes, and they were tied and anchored to the banks using 3.1 m metal pipes sunk into the marsh. After I set each fyke net, I checked nets daily for three consecutive days, and I sampled each site during a single week in the spring (March-June). Nets were set in similar locations each year for five years at all sites (ML, 2012–2016; RI, 2012–2016; RWR, 2011–2015). For all net sets, I collected water depth (to the nearest 15 cm due to the soft substrate) at the mid-channel on the day the net was set. Because the channels are tidally influenced and water levels can vary across time and day, water depth collected herein is only an approximation of the daily and weekly water levels observed at that net site.

In addition to fyke nets, I captured terrapins via manual searching with an airboat during low water levels as described by Selman and Baccigalopi (2012). Briefly, I used an airboat to traverse salt marsh areas and methodically searched tidal ponds/creeks during low water conditions. Water levels in southwestern Louisiana are driven by tidal influxes, but are also subjected to wind driven tides. For the latter, northerly winds push water out of the marsh and can sometimes counteract higher tidal amplitudes. I could search extensive portions of marsh and tidal ponds at RWR, but search areas were more limited at ML due to a smaller number of tidal ponds and creeks. Because RI was located in the middle of Calcasieu Lake, I could safely access this site only by outboard motorboat, thus precluding searching by airboat. While searching from the airboat, I searched by focusing on terrapin mud burrows and active terrapins; terrapin tracks impressed in the mud substrate often led me to a mud burrow or active individual.

For all individuals captured using either method, I recorded the date, time of capture, GPS coordinate, and capture method. I used tree calipers to measure midline plastron length (PL in cm), and I measured body mass (g) using a spring scale in the field. I permanently marked individuals using drill holes on the marginal scutes according to Cagle (1939), and I tagged turtles with passive integrated transponders (12 mm PIT tags; Biomark, Boise, Idaho, USA). I determined the sex of individuals based on external sexually dimorphic characters: males are smaller, have longer tails, and have smaller relative head widths compared to females (Butler et al. 2006). For smaller individuals, I could not determine the sex using these methods, and I recorded them as juveniles. I released all individuals at their capture location.

Along with terrapins captured with fyke nets, I also recorded all fisheries bycatch in fyke nets. For this study, I was specifically interested in the number of captured gar per net day, with gar inclusive of both Alligator Gar (*Atractosteus spatula*) and Spotted Gar (*Lepisosteus oculatus*). Gar catch per unit effort (CPUE) was of interest because even though they have not been reported as terrapin predators, it seems plausible given they are

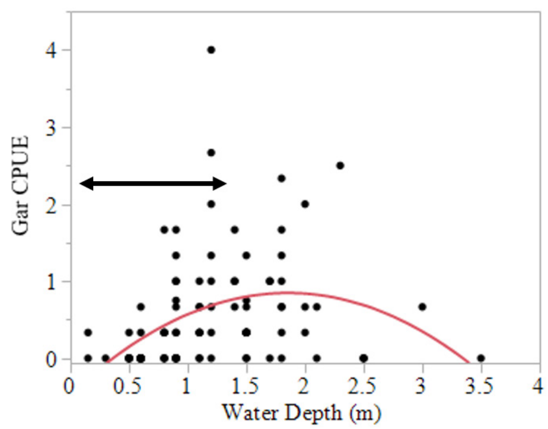

Figure 2. Gar (Alligator Gar, *Atractosteus spatula*, and Spotted Gar, *Lepisosteus oculatus*) catch per unit effort (CPUE) by water depth during terrapin sampling in southwestern Louisiana, USA, 2011–2016. The black arrow indicates the range of water depths where juveniles were captured during the study.

apex predators of estuaries in Louisiana (O'Connell et al. 2007). I used a second-order polynomial regression to determine if gar CPUE was equal for different water depths. I used JMP (v9.0.0, SAS Institute Inc., Cary, North Carolina, USA) for statistical analysis and accepted significance of tests at α = 0.05.

Results

Fyke net captures.—I sampled 286 net days across the three study sites (RI: 95 net days; RWR: 95 net days; ML: 96 net days), and this effort resulted in 633 terrapin captures. Of the 633 captures, only 19 juveniles < 9.5 cm PL were captured via fyke net (3.1%; 0.07/net days), and these were found only at the ML site in three of the five years sampled (2012, n = 13; 2013, n = 1; 2014, n = 5). The smallest juvenile captured by fyke net was 8.8 cm PL, and all juveniles captured via net were large enough to determine sex (six juvenile female, 13 juvenile male). I captured juveniles in fyke nets at ML when tidal creeks were 0.5–1.1 m deep, which was moderate to below the average water depth at this location across the five sample years and all net sets (mean: 0.9 m deep, range: 0.5–1.5 m deep). The mean water depths in 2012 (0.65 m) and 2014 (0.91 m) were lower compared to water depths in other sample years when I caught one or no juveniles (2013: 1.12 m; 2015: 1.05 m; 2016: 1.10 m). All net locations where I caught juveniles were 1.0–1.4 km from the nearest nesting location.

Even though a similar number of net nights were expended at RI and RWR, I caught no juveniles < 9.5 cm at these sites. Water depths at these locations, however, were typically deeper than those observed at ML (mean RWR: 1.6 m deep, range: 0.5–2.3 m deep; mean RI: 1.13 m deep, range: 0.15–3.5 m deep). Using a second-order polynomial regression, there was a significant relationship between gar CPUE and water depth ($F_{2,96} = 7.72$, $P < 0.001$, $r^2 = 0.14$). Gar CPUE was low when water depths were < 0.8 m, peaked between 1.2–2.3 m, and dropped when water depths were > 2.5 m (Fig. 2).

Figure 3. Saltmarsh habitat of Observation #1 on the edge of a tidal pond on Rockefeller Wildlife Refuge, Vermilion Parish, Louisiana, USA. The vegetation here is Smooth Cordgrass (*Spartina alterniflora*). (Photographed by Will Selman).

Airboat searching.—From 2011–2016, I searched for a total of 31.5 h (RWR: 25.5 h; ML: 6.0 h), and I caught 235 terrapins. I captured 14 juveniles < 9.5 cm PL via airboat searching (6.0%, 0.44 per airboat search hour). I found juveniles at both sites intensively searched by airboat (RWR and ML). The smallest individual I captured via airboat searching was 5.9 cm PL, and only six of 14 individuals were large enough to determine sex (five juvenile females, one juvenile male). Below are specific observations of the sites where juveniles were captured.

Observation #1: While searching tidal ponds at RWR by airboat on 17 May 2011 (1050), I captured a small juvenile terrapin of unknown sex (6.1 cm PL, 50 g, three annuli) at the edge of a tidal pond. It was located in shallow water habitat (~3–4 cm deep) among the stems of *S. alterniflora* and ~2 m inside the edge of the vegetation (Fig. 3). The vegetation featured new growth that was expanding into the tidal pond. Thus, it was more diffuse than more established *S. alterniflora* marshes and provided dappled sunlight on the mud substrate. The capture location was ~0.76 km from the nearest available nesting habitat.

Observation #2: While searching tidal ponds and creeks near ML by airboat on 24 June 2014 (~1300–1500), I captured one juvenile terrapin of unknown sex (6.6 cm PL, 85 g, four annuli) at the edge of a small tidal pond. I found a second juvenile of unknown sex (7.2 cm PL, 93 g, five annuli) in a nearby, small tidal creek (~1.5 m wide) that fed the pond where the previous individual was captured (~170 m straight line distance and between both captures). I located both of the juveniles in shallow

Figure 4. Saltmarsh habitat of Observation #3 at Cameron Parish, Louisiana, USA. The Saltwort (*Batis maritima*) dominated habitat strip where 10 juveniles were located is outlined (bright green plant species). (Photographed by Will Selman).

water habitat (< 5 cm deep). The first individual was among stems of *S. alterniflora* on the edge of the tidal pond (~0.97 km from the nearest available nesting location), while the second was in shallow water within the narrow tidal creek (~0.89 km from the nearest nesting location).

Observation #3: The Gulf of Mexico is located ~0.95–2.5 km south of ML, with a beach rim occurring along the shoreline. Because of unusually high-water levels during April 2016, I was able to search a dune swale (i.e., high marsh) directly behind the beach. This marsh is likely dry to moist with little standing water during most of the year. Thus, under normal water conditions, bare ground would be exposed in many areas, but with higher water, these openings in the vegetation appeared to be ponds (Fig. 4). I searched a narrow band of marsh (~30–100 m wide) that parallels the beach and was dominated by *Batis maritima* (Saltwort). Other plant species observed included *Salicornia bigelovii* (Glasswort), *Borrichia frutescens* (Sea Ox-eye Daisy), and *D. spicata*; all plant species are salt tolerant and indicative of a high salinity soils (Stutzenbacker 2010). The area was also grazed by Cattle (*Bos taurus*), and hoof prints were visible in the soil.

On 27 April 2016, I searched this *B. maritima* habitat, with mean water depths at ~10 cm (water depth range: mudflat, 20 cm); salinity was 4.9 ppt and the water temperature was 29.7° C. While initially searching the habitat for adult females coming to nest on the beach (unsuccessfully), I serendipitously captured three juveniles in this shallow water habitat between 1530–1615 (Fig. 5). I identified one as a juvenile female (9.4 cm PL, 220 g, seven annuli), and I could not determine the sex of the other two juveniles (6.2 cm PL, 73 g, three annuli; 7.8 cm PL, 145 g, five annuli). One of these individuals was nestled in a Cattle hoof print depression when it was captured (Fig. 6a). All individuals were captured ~0.20–0.36 km from the nearest available nesting location.

On 28 April 2016, I again searched the same *B. maritima* habitat, and the average water depth was lower than the previous day (mean: ~5 cm; water depth range: mudflat, 10 cm); salinity was 5.2 ppt and the water temperature was 27.3° C. In approximately one h of searching by airboat, I captured six additional juveniles in the same habitat between 915–1015. I identified two individuals as juvenile females (9.0 cm PL, 205 g, seven annuli;8.2 cm PL, 165 g, seven annuli), one was a juvenile male (9.4 cm PL, 215 g, seven annuli), and the other three were unsexable juveniles (5.9 cm PL, 58 g, three annuli; 6.9 cm PL, 105 g, five annuli; 8.3 cm PL, 155 g, six annuli). Similar to the observation on 27 April, one of these juveniles was also nestled in a Cattle hoof print when found (Fig. 6b). After retaining all six for an education/outreach event, I observed portions and

Figure 5. Juvenile Diamondback Terrapin (*Malaclemys terrapin*; red ellipse) in shallow Saltwort (*Batis maritima*) habitat in Observation #3 in Cameron Parish, Louisiana, USA. (Photographed by Gabe Giffin).

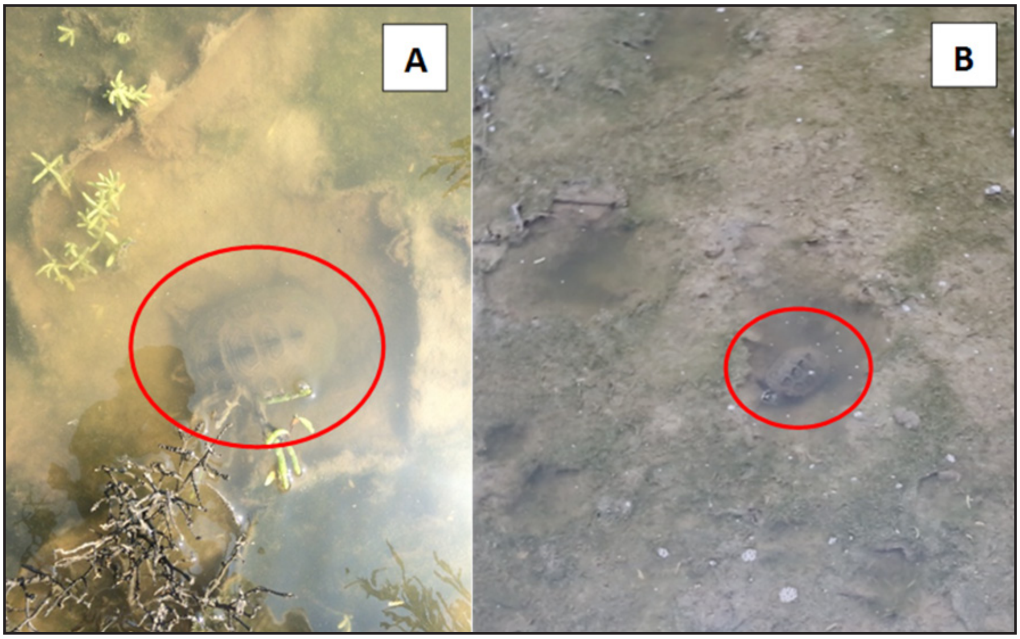

Figure 6. Juvenile Diamondback Terrapins (*Malaclemys terrapin*; red ellipses) hiding in Cattle (*Bos taurus*) hoof prints within Saltwort (*Batis maritima*) habitat in Observation #3 in Cameron Parish, Louisiana, USA. (A photographed by Will Selman; B photographed by Gabe Giffin).

whole fiddler crab (*Uca* sp.) claws in the feces of these turtles.

Observation #4: This field observation was made at RWR near the same location as Observation #1. Throughout much of the prior 2–3 d, wind directions were out of the north and tides reached their lowest point the evening/early night (~2000). Thus, water levels were low during this time with tidal ponds ranging from mudflat conditions to ~30 cm deep. While manually searching by airboat in a tidal pond on 5 May 2016 (~1700–1730), I caught a juvenile female (9.3 cm PL, 180 g, eight annuli) by hand. I initially observed terrapin tracks impressed in the mud coming from the marsh vegetation and out toward the pond. The small female was found burrowed in the mud ~3 m from the marsh edge. The capture location was ~1.95 km from the closest known available nesting location.

Discussion

Juveniles size classes.—Turtle ecological studies reporting a large number of juvenile captures are rare. Most turtle studies are biased toward adult captures, while juveniles typically make up fewer than 5% of the overall sample. However, given turtle demographics (e.g., low juvenile survivorship but high adult survivorship), one might suspect that there should be more many more juveniles available in the population to sample relative to adults for populations to persist. Under sampling of juveniles presumably occurs in most studies as a result or combination of ineffective sampling methodology (Ream and Ream 1966), habitat differences between adult and juvenile life stages (Congdon et al. 1992), and the secretive nature of juveniles (Morafka 1994; Pike and Grosse 2006).

The sampling methodology used in many turtle ecological studies targets adults. For example, baited hoop nets with 5.0 cm mesh are a standard method to capture many turtles, and this method has been used globally for ecological studies. However, sampling with this method may be ineffective for juveniles due to their small size and ability to escape through this size mesh; they may also be able move back through the throat of the net better than adults. Also, because juveniles may have different diets than adults (e.g., Platt et al. 2016), they may not be similarly attracted to baited hoop nets. The fyke nets used in this study had slightly smaller mesh size (3.8 cm) than typically used, but this still limited the capture sizes to individuals > 8.2 cm PL.

The location of habitats sampled may also factor into low numbers of juveniles in samples. For example, using stable isotope analysis, Reich et al. (2007) inferred that juvenile green sea turtles are oceanic during juvenile years, a very different habitat than nearshore waters used by subadults and adults. Juvenile *Graptemys* (map turtles and sawbacks) size classes are rare in ecological studies, and this is likely due to occupation of different riverine microhabitat (e.g., shallow water, near banks, and within thick tangles) in comparison to adults that use deeper water away from the bank (Selman 2012; Selman and Lindeman 2015). Thus, under sampling of juvenile *Graptemys* appears to be partly driven by microhabitat preferences by juveniles, and this habitat is not safely accessed by researchers in outboard boats. For terrapin sampling, fyke nets could only be set in water typically > 30 cm deep to ensure both net throats were in the water. However, most manual captures by airboat of juveniles were in water depths < 10 cm, so fyke nets were not capable of sampling the shallowest habitats.

Lastly, because juvenile turtles are much smaller than adults, they often blend in with the surrounding environment and are not easily detected (i.e., crypsis). Juveniles of many turtle species accomplish this by having different patterns and/or coloration than adults. As previously mentioned, in many cases, juvenile *Graptemys* have been observed in cryptic basking locations by hiding under vines or within root tangles rather than observed in the open channel of the river where adults are typically observed (pers. obs.). It is likely that many juvenile terrapins were not detected due to cryptic behaviors and habitats used while searching via airboat in this study.

Juvenile terrapins utilizing of shallow water habitat.—Early terrapin studies report juveniles as scarce (Coker 1906), with Hurd et al. (1979) capturing only one individual < 9.0 cm PL in a sample of 792 terrapins from a site in Delaware, USA. The longest running ecological study of a terrapin population is located near Kiawah Island, South Carolina, USA (1983 to present; Gibbons et al. 2001, Dorcas et al. 2007). Those investigators used trammel nets and seines to capture terrapins in tidal creeks, but it has had minimal success throughout the study using these methods to document individuals < 9.0 cm PL (Dorcas et al. 2007). However, most past and recent terrapin researchers have focused studies in tidal creeks, nesting beaches, and open bays. All of these areas are typically easier to access by researchers either on foot (beaches) or in outboard motorboat (tidal creeks/bays). Furthermore, in most studies away from nesting beaches, there is usually little manual searching effort in alternative habitats, with only a single study to date using manual searching as the primary capture method (Haskett 2011).

This is the first terrapin study that has extensively used manual searching with airboats, and this vehicle permitted me to search habitat previously inaccessible by foot or by outboard motorboat. By devoting a significant effort to search shallow water habitat by airboat, the sampling of juveniles increased nearly twofold (6.0% of sample) in comparison to fyke net captures (3.1% of sample). My observations using airboat searching also indicate that juveniles are cryptic, appear to use alternative habitat compared to adults, and are under sampled due to their behavior and their habitats used. Even though Haskett (2011) also used manual searching extensively, juveniles of unknown sex only composed 1.4% of the captures (2 of 138) in that study. Based on fyke net and manual searching observations, juveniles were found to exclusively use shallow water habitat (< 1.0 m), with many individuals observed in only a few centimeters of water. Without the ability to use an airboat, manual searching shallow water marsh habitat would prove difficult for field personnel, time consuming, and costly.

Presumably juveniles use these shallow water habitats to improve survival and growth. Shallow water likely promotes juvenile survival by having fewer predators and more cryptic habitats. Shallow water depths preclude entry by large aquatic fish (i.e., gar species, large Redfish, *Scianops ocellatus*) that may prey on smaller terrapin size classes. I found that bycatch of gar increased with water depths > 0.8 m and this is near the maximum depth where I observed juveniles. I believe that the decrease in gar CPUE in > 1.5 m water depths is a sampling artifact due to the ability of gar to swim under lead nets. Even though gar have not been documented as predators of juvenile terrapins, data suggest a plausible predatory connection with larger fish due to the absence of juveniles captured in deep water; juveniles also likely avoid these areas because of weaker swimming abilities. Furthermore, I rarely observed large wading birds (i.e., Great Blue Heron, *Ardea herodias*, and Great Egret, *Ardea alba*) that may be predators of juvenile terrapins in these shallow water habitats. My observations of birds using shallow tidal habitat (< 10 cm deep) were primarily species that would not be predators of small terrapins, including small shorebirds (e.g., Dunlin, *Calidris alpina*; Least Sandpipers, *Calidris minutilla*; Short-billed Dowitchers, *Limnodromus griseus*), larger probing shorebirds (e.g., Marbled Godwit, *Limosa fedoa*, and Willet, *Tringa semipalmata*), and sifting wading birds (e.g., American Avocet, *Recurvirostra americana*; Black-necked Stilt, *Himantopus mexicanus*; Roseate Spoonbill, *Platalea ajaja*). Also, the locations where I found juvenile terrapins provided significant detection challenges for locating juvenile terrapins (i.e., cryptic habitats). Slightly flooded vegetation, edges of marsh ponds, and terrapins in mud burrows all provided observation difficulties for us while manual searching. Even though the sample size for manual searching increased twofold over fyke net captures, it seems that these habitats could harbor numerous juveniles that went undetected due to the difficulty in sampling these habitats.

Shallow water habitats may also promote growth via better thermoregulatory opportunities, fewer osmotic challenges, and habitat partitioning/competitive avoidance with adult terrapins. Juveniles inhabiting shallow water during the growing season (~ late

February to mid-November in Louisiana) will have a warmer environment compared to deeper waters. Within a more stable and warmer environment, juvenile turtles grow faster due to longer periods of warm water temperatures compared to deeper and cooler habitats (Gibbons 1970; Gibbons and Harrison 1981; King et al. 1998). Mann (1995) captured 10 juvenile terrapins in Mississippi in high marsh where water was absent to < 1 cm deep. He suspected that juveniles inhabited this area because only the highest tides would flood the high marsh, thereby precluding daily osmotic challenges that would limit growth opportunities. Indeed, Dunson and Mazotti (1989) found in laboratory studies that juveniles in salinities above 21 ppt had no growth, but juveniles would grow in seawater (35 ppt) if given freshwater every two weeks. It seems likely that juveniles inhabiting high marsh could gain access to freshwater from rainfall to provide opportunities for growth with minimal osmotic pressure (i.e., even at high tides in Observation #3, salinities were < 6 ppt). However, these shallow water habitats during the summer may dry and become hypersaline (> 36 ppt), and therefore, these same habitats may be avoided by juveniles during different seasons. Last, adult terrapins are found at a wider range of water depths, so it may be that juveniles can avoid excessive competition from adults in shallower habitats. Indeed, in South Carolina, Tucker et al. (1995) found that terrapins of different sexes and size classes foraged in different habitats, with males and juveniles using marsh edges and adult females foraging at high tides on Marsh Periwinkle Snails (*Littorina irrorata*). Similar to Tucker et al. (1995), I found that at least some of these juveniles consumed small fiddler crabs (genus *Uca*), with adults consuming somewhat larger fiddler crabs at these same sites (Will Selman et al., unpubl. data). Interestingly, depressions in the marsh such as the Cattle hoofprints may provide ambush locations for juveniles. These depressions could provide opportunities for juveniles to have a sit-and-wait foraging style versus a more active foraging style; the latter strategy would make juvenile terrapins more prone to predation through increased detection. Alternatively, these depressions may provide slightly cooler water temperatures and may be used for thermoregulation.

Even though fyke nets were set at all sites for five years, juveniles were captured in nets at only one site (ML), and not during all years at that site. During normal water conditions at this site, water depths were typically > 1.0 m in the tidal channels and apparently too deep for juveniles. However, it appears that when water is shallower in tidal creeks during extended periods (e.g., north winds for several days, consistently low tide conditions), habitat that is typical of adults becomes more favorable to juveniles. It is also likely that high marsh becomes too dry during these periods, and juveniles may have narrow water depth preferences.

***Conservation and management*.**—These observations and prior descriptions of juvenile terrapin habitat (especially Mann 1995) point to shallow marsh and/or high marsh as an important habitat for juvenile life stages. Muldoon and Burke (2012) and Roosenburg et al. (unpubl. report) found that hatchlings have a propensity to move away from water and towards land (i.e., higher ground). This habitat is typically located between higher nesting habitats (e.g., beach rim) and deeper salt marsh/shallow bays that are more typical of adult terrapin habitats. Thus, the three primary life stages of terrapins (egg, hatchling/juvenile, and adult) require three markedly different habitats in Louisiana, and these differences in habitat use by life stage may occur in other portions of the species range. Because these three habitats typically form a gradient from higher beaches/dunes to deeper salt marshes, it is important to conserve a continuum to conserve all terrapin life stages. The Wildlife Action Plan for Louisiana (Holcomb et al. 2015) delineates important habitat for Species of Greatest Conservation Need in the state. The high marsh habitat described herein falls under the Coastal Dune Grassland/Coastal Dune Shrub Thicket habitat type via the inclusion of dune swales. This habitat type is considered critically imperiled in the state of Louisiana (S1), and terrapins are also included as a Species of Greatest Conservation Need in this habitat type (Holcomb et al. 2015). Terrapins use these dunes as nesting habitats. However, these observations of juveniles using dune swales extensively adds an additional level of conservation importance to this habitat. Along with Louisiana, such findings may be relevant for other state or regional plans that consider terrapins and terrapin habitats within their conservation framework. Even if terrapins have yet to be found in these locations, conserving the entire spectrum of dunes/beach rims, high marsh, and lower salt marshes should provide the habitat necessary for all terrapin life-history stages.

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