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Distribution and Abundance of Diamondback Terrapins (*Malaclemys terrapin*) in Southwestern Louisiana

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Abstract. – **The diamondback terrapin (*Malaclemys terrapin*) is a brackish-water turtle ranging from Texas to Massachusetts, as well as an isolated population on the island of Bermuda. Louisiana likely holds the most available habitat of any other state for the species (over 650,000 ha of brackish and salt marshes), yet little is known about terrapin distribution and abundance throughout coastal Louisiana. Knowledge is particularly scant in southwestern Louisiana, where only 12 specimen records exist, the most recent record being from 1972. We wanted to determine whether 1) terrapin populations persist in historical collection localities, 2) terrapin populations are present in additional coastal marsh localities, and 3) terrapin abundance differs among sites in southwestern Louisiana. We sampled for diamondback terrapins during 2011–2013 at 16 sites across southwestern Louisiana; all sites were near historical localities or other apparently suitable brackish or salt marsh habitats. We used unbaited fyke nets with 7.6- and 15.2-m leads to capture terrapins and manually searched tidal ponds by airboat. Terrapins ($n = 490$) were captured at 13 of 16 sample sites, with terrapin site abundance varying considerably (CPUE mean: 1.06 terrapins per net day; CPUE range: 0–7.06). High terrapin abundance was always associated with large expanses of unimpounded brackish and salt marshes, whereas low abundance was typically associated with smaller marsh sizes, channels, or bayous that no longer connected to the Gulf of Mexico, and the presence of crab traps. All sites with terrapin captures represent either a new locality or the first record for a locality in over 40 yrs. The results of this study underscore the continued need for better distribution and abundance data for poorly studied portions of a species' range, especially those that are of conservation concern.**

Key Words. – **Reptilia; Testudines; diamondback terrapin; *Malaclemys terrapin*; distribution; abundance; southwestern Louisiana; coastal wetlands; brackish and salt marsh**

The diamondback terrapin (*Malaclemys terrapin* Schoepff; hereafter referred to as terrapin) inhabits coastal salt marshes, estuaries, bays, mangrove swamps, and tidal creeks from Texas to Massachusetts (Ernst and Lovich 2009); an isolated population also inhabits salt ponds on the island of Bermuda (Parham et al. 2008). Throughout the terrapin's range, there are many areas that have limited data on the distribution and population status of the species (i.e., Big Bend region of Florida; Butler and Heinrich 2013). Knowing a species' distribution is critical 1) to better inform local and state managers on how to manage a species or 2) for biologists to conduct further field studies to determine life history and ecological aspects (Butler and Heinrich 2013). Currently, there is no federal protection for terrapins, but they are considered a species of conservation concern in all states throughout their range (Table 1).

Louisiana has approximately 653,000 ha of suitable brackish and salt marsh habitats (Sasser et al. 2008). This is the most area for any of the 16 United States within the terrapin's range and comprises 30% of the total available habitat range-wide (Table 1). Even though Louisiana holds considerable expanses of suitable habitat for terrapins, relatively little is known about the species in the state. There are only 34 location-validated museum specimens in the state, with 22 coming from Deltaic Plain marshes of southeastern Louisiana versus 12 from Chenier Plain marshes of southwestern Louisiana (Dundee and Rossman 1989; HerpNet Database search, www.herpnet2.org, accessed 6 September 2013). The last verifiable record from southwestern Louisiana is from Calcasieu Lake in 1972 (Cameron Parish, Louisiana State University Herpetology, specimen 86149). The imbalance of records among the 2 regions is likely attributable to the denser human population in southeastern versus southwestern Louisiana (i.e., more people available to encounter terrapins; 2010 US Census Interactive Map, http://www.census.gov/2010census/popmap/index.php, accessed 30 September 2013) and greater coverage of coastal brackish and salt marshes in southeastern Louisiana (531,605 ha, 81% of the total for the state) than in southwestern Louisiana (121,338 ha, 19%; Sasser et al. 2008). Nonetheless, most of these records represent accidental or opportunistic captures and were not associ-

Table 1. State status of terrapins (as determined by NatureServe and State Wildlife Action Plans, WAP), estimated salt marsh habitat, and percentage of total habitat by state throughout the diamondback terrapin's range (open water or bays are not considered), ordered by amount of habitat. NatureServe status is defined by state (S2 = Imperiled, S3 = Vulnerable, S4 = Apparently Secure), and all states have listed terrapins as a ''species of concern'' (SC). The state percentage of habitat is the amount of state habitat relative to the total habitat throughout the terrapin's range (estimated 2,186,791 ha). Asterisks (*) indicate that some listed habitat in Texas and Massachusetts may be outside of the terrapin's range because these states are on the periphery of the species' range.

State	NatureServe, state status	Estimated hectares of habitat	State percentage of total	Habitat classification or description	Source(s) for state terrapin status, estimated hectares of habitat (some WAPs contained information for both)
Louisiana	S2, SC	652,800	29.9	Brackish and salt marsh	Lester et al. 2005; Sasser et al. 2008
Florida	S4, SC	596,329	27.3	Mangrove, salt marsh, and tidal flat	Florida FWCC 2005
Texas	S3, SC	253,606*	11.6	Saltwater estuarine wetlands	Texas Parks and Wildlife 2005; Moulton et al. 1997, as cited by Texas Parks and Wildlife 2005
Georgia	S3, SC	152,976	7.0	Salt marsh	Georgia DNR 2005, http://coastalgadnr.org/eo/sm (accessed 9 October 2013)
South Carolina	NR, SC	111,900	5.1	Salt marsh and tidal flats	South Carolina DNR 2005; Field et al. 1991, as cited by South Carolina DNR 2005
Maryland	S4, SC	83,293	3.8	Tidal estuarine wetlands	Maryland DNR 2005
North Carolina	S3, SC	80,202	3.7	Salt and brackish marsh	North Carolina WRC 2005; Cashin et al. 1992, as cited by Deaton et al. 2010
Virginia	S3, SC	79,012	3.6	Estuarine wetland	Virginia Department of Game and Inland Fisheries 2005; Hershner et al. 2000, as cited by Moulds et al. 2005
New Jersey	NR, SC	70,281	3.2	Salt marsh	New Jersey DEP 2008
Mississippi	S2, SC	25,900	1.2	Coastal wetlands	Mississippi Museum of Natural Science 2005; Mississippi DMR 1999
Delaware	S4, SC	19,641	0.9	Tidal low marshes	Delaware Department of Natural Resources and Environmental Control 2007
Connecticut	S3, SC	17,500	0.8	Estuarine tidal wetland	Connecticut DEP 2005; Metzler and Tiner 1992, as cited by Connecticut DEP 2005
Massachusetts	S2, SC	16,188*	0.7	Salt marsh	Commonwealth of Massachusetts Executive Office of Environmental Affairs 2006
Alabama	S2, SC	14,326	0.7	Estuarine wetland	Alabama DCNR 2005; Traci Wood (Alabama DCNR, *pers. comm.*, September 2013)
New York	S3, SC	10,117	0.5	Tidal wetlands	New York State Department of Environmental Conservation 2005, 2010
Rhode Island	NR, SC	1678	< 0.1	Low/high salt marshes, brackish marsh, tidal flat	State of Rhode Island Department of Environmental Management 2005
Bermuda	VU	13.2	< 0.1	Salt ponds	Bermuda Department of Conservation Services 2007; M. Outerbridge, unpubl. data, 2007

ated with an intensive survey to document the distribution or abundance of terrapins within the state.

Along with a lack of specimen records across the state, there are few published studies that reference terrapins in Louisiana relative to other states within its range. Cagle (1952) investigated growth, reproduction, and subspecific status of a group of 96 individuals from near Dulac (Terrebonne Parish) in southeastern Louisiana. He mentioned that terrapins occur in ''isolated populations'' along the Louisiana coastline and that there was no consistency in the subspecific characteristics (either *Malaclemys terrapin pileata* or *Malaclemys terrapin littoralis*) of the individuals examined. Interestingly, it is not known how Cagle (1952) captured or acquired the specimens, but it is likely that they originated from commercial fishers working in brackish and salt marshes south of Dulac. Burns and Williams (1972) described reproduction in captive terrapins from southeastern Louisiana, whereas Davis (1973) described commercialization of terrapins in the 1920s and 1930s in the Barataria Bay region (Jefferson and Plaquemines Parishes). Recently, Butler et al. (2006) conducted a survey of 168 researchers or biologists with terrapin expertise across the 16 US coastal states that have terrapins. The single Louisiana respondent stated that 1) the status of terrapins was unknown within the state, 2) the main threat to terrapins was commercial harvest, and 3) that field studies should be initiated (Butler et al. 2006). Anderson and Alford (2014) described recent derelict crab trap roundups at 4 sites in southeastern Louisiana. Derelict crab traps have been lost or abandoned and continue to capture marine organisms, including terrapins. Terrapins were found at 3 of the 4 trap roundup sites and were one of the top bycatch species, composing approximately 5%–65% of the bycatch at the 3 sites.

Because of the vast amount of presumably suitable brackish and salt marsh habitat within Louisiana, as well as the lack of historical and current knowledge of terrapin populations in the state, we initiated a distribution and abundance study for the species in southwestern Louisiana. Specific objectives of this study were to 1) determine whether terrapin populations persist at or near historical collection localities, 2) attempt to document terrapins in new coastal marsh localities, and 3) compare terrapin abundance among sample sites.

METHODS

Study Sites. — We sampled for terrapins at 7 localities during spring 2011 on Rockefeller Wildlife Refuge (RWR; sites 8–14 in Table 2, Fig. 1), a 30,000-ha coastal refuge owned and operated by the Louisiana Department of Wildlife and Fisheries (LDWF). In spring 2012, we sampled 2 of the same sites on RWR from 2011 (sites 8 and 13) and 5 new localities on both public and private lands (Table 2; Fig. 1). In 2013, we sampled 4 of our 2012 sites and 4 new sites, including Marsh Island Wildlife Refuge (MIWR; sites 15 and 16). MIWR is similar to RWR as it is a large LDWF coastal property (28,300 ha), with vast expanses of presumably suitable habitat. All sites across all years are classified as coastal brackish or salt marshes, with all having current or historical connections to the Gulf of Mexico via tidal creeks or canals.

Sampling Methods. — We captured terrapins using 2 methods described by Selman and Baccigalopi (2012): unbaited fyke nets (with 1 or 2 leads of varying lengths) and manual searching. In 2011, we used unbaited fyke nets with either a single 7.6-m lead or with two 7.6-m leads. Leads were stretched completely across bayous by tying nets to 3.1-m steel pipes that were sunk on the edges of bayous. This prevented terrapins from going past the nets, while floats were placed within the net to prevent drowning of captured terrapins. We attempted to check nets every day from 2 to 4 consecutive days at each site. Following the results of 2011, we did not use double-lead fyke nets in 2012 or 2013 because they were more difficult to set than single-lead nets and there was no difference in the capture rates (Selman and Baccigalopi 2012). Therefore, in spring 2012 (12 March to 24 May) and 2013 (12 March to 23 May), we captured terrapins using unbaited fyke nets with either a single 7.6-m lead or a single 15.2-m lead. Catch per unit effort (CPUE) for this method is described as the number of terrapins captured per net day.

In spring 2011 (21 March to 2 June), we sampled 7 sites on RWR using manual searching by airboat in tidal ponds. With this method, terrapins were located by following tracks impressed by terrapins on the soft mud bottoms of tidal ponds or creeks or by finding terrapin ‘‘mud burrows’’ (Selman and Baccigalopi 2012); a single site (Flat Lake, site 13) was sampled in September and October 2011 using manual searching only. In 2012 and 2013, we opportunistically captured terrapins using this method at a select number of sites with suitable tidal pond or shallow creek habitats. CPUE for this method is defined as the number of terrapins captured per boat hour.

Because crab trap mortality is a major negative driver in terrapin population dynamics in some areas of their range (Dorcas et al. 2007; Grosse et al. 2009), we also collected data on the approximate number of crab traps at each site. Sections of bayou were driven by boat or airboat, with the distance of bayou traveled and the number of crab traps recorded to determine an approximate density of crab traps at each site (number of traps divided by linear kilometer of bayou).

Individual Measurements and Marking. — For each individual captured, we recorded the date, time of capture, GPS coordinate, and capture method; morphometric data and tissue samples were collected for related studies. Also, individuals were permanently marked using drill holes on the marginal scutes (using scutes 1–3, 8–12) according to Cagle (1939) and were tagged with passive integrated transponders (12-mm PIT tags; Biomark, Boise, ID). All individuals were released at their capture location within 24 hrs.

RESULTS

In 2011, we captured 137 unique individuals (31 ♂, 105 ♀, 1 juvenile) at 5 of the 7 sample sites on RWR (sites 8, 11–14 in Table 2). Of the 137 captures, 55 were captured by fyke net (23 ♂, 32 ♀; CPUE range: 0–2.1) and 82 via manual airboat capture (8 ♂, 73 ♀, 1 juvenile; CPUE: 3.6 per boat hour). The most successful sites were concentrated in the eastern portion of the refuge (sites 11–14; Table 2, Fig. 1), with two unsuccessful sites in the south central portion of the refuge (sites 9 and 10).

In 2012, we captured 202 unique individuals (99 ♂, 103 ♀) from the 2 RWR sites and 4 other sites in Cameron and Vermilion parishes. Of the 202 captures, 190 were captured by fyke net (98 ♂, 92 ♀; CPUE range: 0–7.4) and 12 via manual airboat capture (1 ♂, 11♀; CPUE: 5.5 per boat hour). Lower Mud Lake (site 6) of the Mermentau River was the most productive site with a total of 140 captures (65 ♂, 75 ♀) and a CPUE of 7.3 terrapins per net day (Table 2). Other high-CPUE sites included Rabbit Island in Calcasieu Lake (site 4, 1.3/net day) and the previously sampled Flat Lake site on RWR (1.4/net day); the latter had a similar CPUE relative to 2011 sampling (1.3/net day). Lower capture rates of terrapins were observed at 3 other sites (sites 3, 5, and 8), and no terrapins were captured at the Hwy 82 marsh site (site 2). No recaptures were recorded from either of the 2 RWR sites sampled in 2011.

In 2013, we captured 147 unique individuals (62 ♂, 85 ♀) at 6 of the 8 sample sites. Of these, 110 were captured by fyke net (52 ♂, 58♀; CPUE range: 0–2.9) and 37 via manual airboat capture (9 ♂, 28 ♀; CPUE: 4.8 per boat hour). Similar to 2012, Lower Mud Lake had the highest CPUE of all sample sites (2.9/net day) but much lower levels compared with 2012 (7.3/net day). Flat Lake (1.4/net day) and Rabbit Island (1.5/net day) had similar CPUEs compared with previous trapping efforts at both sites. Terrapins were captured at the 2 sites on MIWR (single females were captured at sites 15 and 16) and the

Table 2. Diamondback terrapin sampling sites, site characteristics, capture effort, and results in southwestern Louisiana 2011–2013. Sites with the same superscript numbers are considered part of the same larger marsh complex (described in text), and asterisks (*) represent new localities for terrapins in southwestern Louisiana. The plus sign (+) indicates high crab trap presence in bays adjacent to our sites at Marsh Island Wildlife Refuge, whereas the number sign (#) indicates individuals that were captured alive via crab trap and brought to W.S. CPUE = catch per unit effort, NWR = National Wildlife Refuge, RWR = Rockefeller Wildlife Refuge, MIWR = Marsh Island Wildlife Refuge.

		Site characteristics				Capture effort and results					
Site name, west (top) to east (bottom)	Sample yr(s)	Dominant vegetation type(s)	Type of land ownership	Approximate size of surrounding marsh	Active crab traps present, approximate density	Fyke net effort (net d)	Fyke net captures (recaptures)	Fyke net CPUE (terrapins/net d)	Manual search effort (boat hrs)	Manual search captures (recaptures)	Manual search CPUE (terrapins/boat hr)
1. Sabine Lake Bank*	2013	Black needlerush	Private	2250	Yes, 9.5	18	2	0.11	2.0	3	1.5
2. Hwy 82 Sabine Marsh	2012–2013	Black needlerush	State waters	27	No	10	0	0.0	0	—	—
3. Lighthouse Bayou*	2012	Smooth cordgrass	Private	1050	Yes, 11.9	18	1	0.06	0	—	—
4. Rabbit Island*[1]	2012–2013	Saltgrass	State lands	4600	Yes, 10.0	35	50 (1)	1.42	0	—	—
5. Sabine NWR*[1]	2012	Smooth cordgrass	Federal refuge	4600	No	18	5	0.28	0	—	—
6. Lower Mud Lake	2012–2013	Smooth cordgrass	Private	4100	No	36	187 (1)	5.19	2.0	9	4.5
7. Hog Bayou*	2013	Smooth cordgrass, leafy threesquare	Private	550	Yes, 16.5	17	0	0.0	0	4#	NA
8. Miller's Lake, RWR*	2011–2012	Smooth cordgrass	State refuge	215	No	30	14	0.46	0	—	—
9. Royalite Canal, RWR	2011	Smooth cordgrass	State refuge	105	No	12	0	0.0	0	—	—
10. Little Constance Bayou, RWR	2011	Smooth cordgrass	State refuge	825	No	8	0	0.0	1.0	0	0.0
11. Pigeon Bayou, RWR*[2]	2011	Smooth cordgrass	State refuge	5900	No	18	0	0.0	2.0	5	2.5
12. Cop Cop Bayou, RWR*[2]	2011	Smooth cordgrass	State refuge	5900	No	18	2	0.11	4.0	14	3.5
13. Flat Lake, RWR*[2]	2011–2013	Smooth cordgrass, saltgrass	State refuge	5900	No	59	95 (2)	1.61	15.5	78 (2)	5.03
14. Rollover Bayou, RWR*[2]	2011	Smooth cordgrass, hogcane	State refuge	5900	No	18	1	0.06	3.0	15	5.0
15. Southwest Pass, MIWR*	2013	Black needlerush	State refuge	1350	Yes+	12	1	0.08	0	—	—
16. Bayou Chene, MIWR*	2013	Smooth cordgrass, black needlerush	State refuge	1225	Yes+	12	1	0.08	2.0	3	1.5
Total						339	359	1.06	31.5	131	4.16

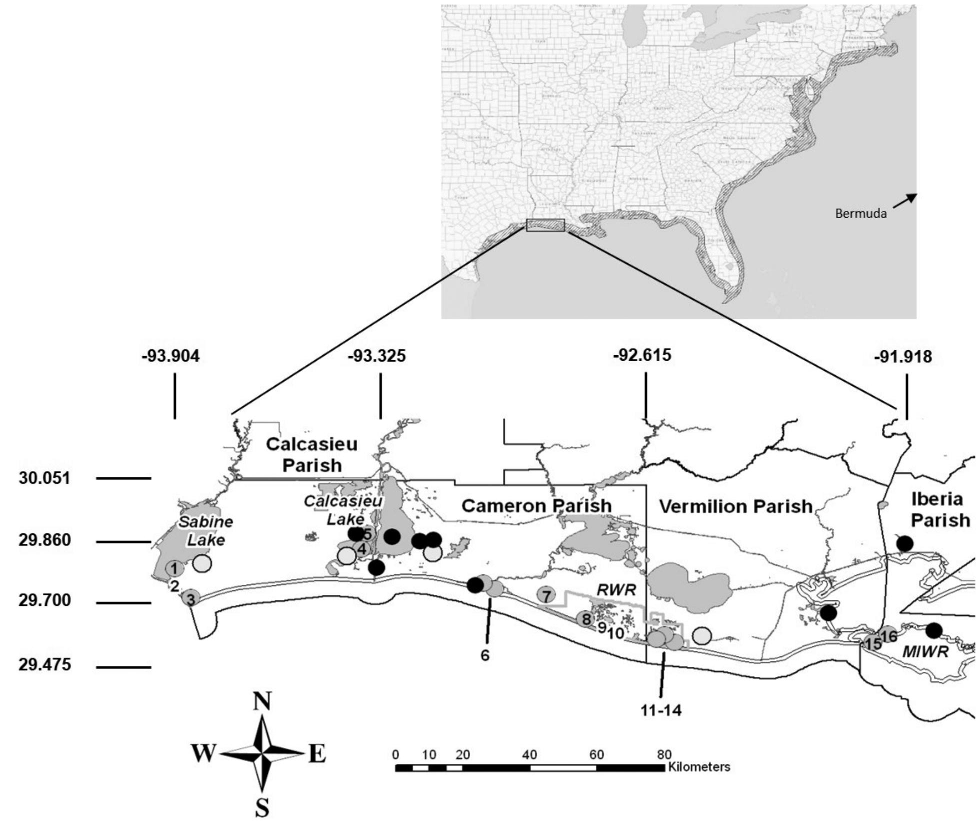

Figure 1. Diamondback terrapin distribution in the United States and Bermuda (shading in top map), with the study area in southwestern Louisiana (below). Solid black circles indicate historical specimens (or literature record from Dundee and Rossman, 1989, from MIWR), gray circles with site numbers indicate successful sites, and site numbers without circles indicate unsuccessful sites; site numbers correspond to those in Table 2. Light circles denote other verified localities (by W. Selman) or reliable reports since 2010.

Sabine Lake Bank site (site 1), whereas no terrapins were captured at the Sabine Hwy 82 marsh (site 2) and at the Hog Bayou site (site 7). However, for the latter, 4 small females (PL range: 12.7–14.2 cm) were brought alive to one of us (W.S.) from the surrounding marsh by the private property land manager. All 4 individuals were captured by a crab fisherman in crab traps in October 2012 (1) and April (3). Also, we had 6 long-term recaptures from 3 sites sampled in 2011 and 2012 (4 at Flat Lake and 1 each at Rabbit Island and Mud Lake).

The presence of crab traps was noted at 4 of the 16 sampling sites (Table 2), with active crab pots fished on private and state lands, as well as in state waters. All 3 sampled properties with stipulations forbidding crab fishing (Sabine NWR, RWR, MIWR) did not have active crab traps present within property boundaries; however, the 2 sites at MIWR had active crab traps located immediately beyond the boundary of the refuge in Vermilion Bay. For the 4 sites with actively fished crab traps, the mean number of crab traps observed was 12.0 per bayou kilometer (range: 9.5–16.5).

DISCUSSION

Distribution. — Our surveys confirm the presence of terrapins on private property, state and federal refuges (RWR, MIWR, Sabine NWR), and in estuaries of all 3 major river drainages in southwestern Louisiana (Sabine, Calcasieu, Mermentau rivers). Furthermore, terrapins were found at or in the vicinity of almost all historical localities and at 12 new localities (Table 2). All capture localities were in tidal channels and tidal ponds that have current connections to the Gulf of Mexico, whereas no individuals were captured via fyke net in channels that were not currently connected to the Gulf (sites 9 and 11). Three females were also captured while nesting on or in the vicinity of shell beaches at site 16 on MIWR. The habitats surrounding all capture locations are characterized as brackish or salt marshes and were dominated by salt-tolerant vegetation including saltgrass (*Distichlis spicata*), smooth cordgrass (*Spartina alterniflora*), and to a lesser extent, black needlerush (*Juncus roemerianus*) and leafy threesquare (*Schoenoplectus robustus*). These are similar to habitats described throughout the range of *M. terrapin* (Ernst and Lovich 2009).

There were only 3 sites where terrapins were not captured: Sabine Hwy 82 Marsh, Royalite Canal, and Little Constance Bayou. Presumably the small size of the Hwy 82 Marsh did not provide enough suitable habitat to support a terrapin population, even though beaches suitable for nesting were present. Captured individuals, although few, were found north (Sabine Lake Bank, site

1) and south (Lighthouse Bayou, site 3) of this site in the surrounding Sabine Lake estuary. Second, within RWR, the Royalite Canal (aka Old Humble Canal) was dredged in the early 1940s for oil field access on the refuge. Currently, beach sand plugs the outlet of the canal to the Gulf of Mexico, with the canal having intermittent connection for 15+ yrs (GoogleEarth archived satellite imagery). Also, there is a small amount of unmanaged surrounding salt marsh (i.e., marsh that is not impounded and water level/salinities regulated via water control structures) that may limit the presence of terrapins. Third, we were unsuccessful also in locating terrapins at the Little Constance Bayou site within RWR. We suspect the lack of terrapins at this site is either attributable to the small size of the surrounding marsh or because the site is ''downstream'' of the large Superior impoundment (~7,200 ha) on RWR. The Superior impoundment is connected via the Superior Canal into the lower sub-basins of the Mermentau River system, which includes approximately 292,000 ha of intermediate and freshwater marshes, as well as Grand Lake and White Lake (Selman et al. 2011). One of the main outlets of this system, the Little Constance Bayou water control structure, is 2.4 km upstream of the site, and this likely keeps salinities lower than nearby salt marsh habitats in the eastern part of RWR.

The only historical localities not investigated were near a prior collection locality on State Wildlife Refuge (Vermilion Parish, near old University of Southwestern Louisiana Field Station; LSU Herpetology, specimen 74149) and near Avery Island (Iberia Parish). For the latter, 3 specimens were collected in 1911 by E.A. McIlhenny (California Academy of Sciences Herpetology collection, specimens 33194–33196), an early Louisiana naturalist. It is unknown whether these specimens were collected on Avery Island or whether they were captured in nearby Vermilion Bay (6 km south). The latter seems to be a more likely source, because the McIlhenny family often ventured to northern Vermilion Bay to fish and, on 10 August 1872, caught 2 ''sea terrapins'' via seine (S.K. Bernard, McIlhenny Co. Archives, *pers. comm.*, October 2013). Further, terrapins were occasional table fare of E.A. McIlhenny in the 1930s (G. Osborn, unpubl. data, 2013), with terrapins likely captured at Vermilion Bay. In the mid-1900s, much of the wetlands surrounding Avery Island were considered ''excessively drained salt-marshes'' and ''brackish three-corner grass marshes'' (O'Neil 1949). However, these marshes have been subject to more freshwater inputs following the Atchafalaya River capturing more freshwater from the Mississippi River between 1900 and 1950 (Morgan et al. 1953, as cited by Roberts 1998), including the current collective discharge rate of 30% of both Red and Mississippi River discharges via the Old River Control Structure (Roberts 1998). Thus, over time the marshes surrounding Avery Island have converted from salt marsh to fresher marsh types (Sasser et al. 2008), are currently not as suitable as they once were for terrapins (W.S., *pers. obs.*), and were not sampled. Along with State Wildlife Refuge, we did not sample some other suitable habitat in southwestern Louisiana because of logistical difficulties and/or lack of access to private property. Sample sites where terrapins may be found in the future include the eastern and northern shores of Sabine Lake (e.g., Shell Island, Cameron Parish) and the northern portion of Calcasieu Lake (e.g., Turner Bay, Calcasieu Parish).

Terrapin Abundance, Site Characteristics, and Changes in Coastal Wetlands. — The sites with the highest terrapin abundance (CPUEs of $\geq$ 1 terrapin per fyke net day) were Lower Mud Lake, Flat Lake, and Rabbit Island in West Cove of Calcasieu Lake. Two of the 3 sites were associated with large river estuaries (Lower Mud Lake and Rabbit Island), whereas all 3 sites were associated with vast tracts of surrounding brackish and salt marsh (Table 2). However, there are some differences across these sites.

Lower Mud Lake is a small, inland tidal lake (~ 780 ha) situated near the outlet of the Mermentau River into the Gulf of Mexico. The lake is shallow ($\geq$ 1.0 m) and surrounded by extensive unmanaged brackish and salt marshes. Historically, the beach occasionally shoaled over the mouth of the river, effectively blocking excessive saltwater intrusion during low-water periods (L. Harper and B. Welch, *pers. comm.*, July 2013). However, in 1971, the Mermentau River Ship Channel (O'Neil 1949; Sasser et al. 2008) was dredged and is currently maintained at 4.6 m by the US Army Corps of Engineers (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2002). Salinities have increased, and marsh types have changed over time in the region attributable to saltwater intrusion (O'Neil 1949; Sasser et al. 2008). Salinities also fluctuate widely because of freshwater influxes from the Mermentau River basin. For example, salinities during the 2012 sampling ranged from 0.9 to 3.1 parts per thousand (ppt) attributable to high levels of rain preceding sampling, whereas in 2013, salinities ranged from 13.9 to 22.1 ppt. The marshes to the south and east of the lake are unmanaged tidal marshes and suitable habitat for terrapins, whereas the marshes to the north and west are impounded by levees. The latter maintain lower salinities and are not likely to be suitable habitats for terrapins. However, prior to impoundment, these marshes were tidal and terrapins occurred in Labove Bayou between Mud Lake and the community of Oak Grove (J. Carter, *pers. comm.*, May 2012). Crab fishing activity occurs at moderate levels in the area but, primarily, in the deeper channels associated with the current ship channel and the old river channel. However, the lake proper is apparently too shallow for crab fishers to navigate, and crab traps are absent throughout most of the available terrapin habitat. Further, CPUE at this site varied considerably across years (2012: 7.3; 2013: 2.9), with lower values in 2013 attributable to decreased water temperatures following a strong cold front on day 2 of trapping (water temperature decreased from 20.3°C to 10.3°C).

Rabbit Island is an 85-ha salt marsh island in West Cove of Calcasieu Lake. A tidal bayou enters the island from the eastern side, which permits tidal exchange to the interior of the island, including multiple tidal ponds of different sizes that contain terrapins (W.S., *pers. obs.*). West Cove is a shallow bottom estuary averaging ≤ 1.82 m, with the cove surrounded by approximately 4,600 ha of unmanaged brackish and salt marshes owned by both public (Sabine NWR) and private landowners. Prior to the initial creation of Calcasieu Pass in 1874 by the US Army Corps of Engineers (US War Department 1897), a ≤ 1.5-m-deep shoal at the mouth of the channel likely limited excessive saltwater intrusion (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2002). Therefore, Rabbit Island was likely situated within a low to medium salinity estuary of Calcasieu Lake. In 1937, the Calcasieu Ship Channel (CSC) was widened and deepened significantly (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2002) and was on the current track to a depth that is maintained at 12.2 m. This dramatic deepening permitted a greater tidal exchange and increased salinities throughout the region. Thus, the Calcasieu Lake estuary was converted to a moderate to high salinity estuary, with these changes likely improving the suitability of the area for terrapins. In fact, most specimen records from southwestern Louisiana are associated with the Calcasieu Lake estuary (Dundee and Rossman 1989). Finally, crab traps are present in the surrounding areas of West Cove and are seasonally present within the interior channels of the island (density 10.0/km), with this being the only site with a large terrapin CPUE and crab trap presence (Table 2). A lone derelict crab trap was found with the plastral remains of a single terrapin on the northern end of Rabbit Island (W.S., *pers. obs.,* 13 August 2013), indicating that this population is subject to derelict crab trap mortality.

The Flat Lake site is situated within a large, unmanaged brackish and salt marsh complex on the eastern side of RWR (Vermilion Parish). This marsh complex has high habitat diversity including small and large tidal channels, small and large tidal lakes and ponds of different depths, and areas of broken marsh (i.e., marsh with a series of small ponds). Most other salt marshes in the region have been impacted by oilfield exploration (i.e., properties bisected by canals and levee roads), altered via marsh impoundment, and/or linked to moderate to high levels of recreational and commercial fishing. However, this site is considered one of the few relatively undisturbed salt marshes in southwestern Louisiana, and public access is relatively limited. Further, RWR does not permit commercial fishing or the use of commercial or recreational crab traps on the property. This is important because many studies have shown that the presence of crab traps—both active and derelict—can lead to high levels of juvenile and adult terrapin mortality (Bishop 1983; Roosenburg 1992; Wood 1992). Interestingly, the deed of donation by the Rockefeller Foundation to the State of Louisiana in 1920 explicitly stated that it was a criminal offense for anyone to enter the refuge and ''destroy, kill, or pursue game, fish, birds, fur bearing animals or *terrapins*'' (emphasis added).

The sites with low terrapin densities were associated with the Sabine Lake estuary (sites 1–3) and MIWR (sites 15–16). Prior to this study, there was only a single terrapin record for the Sabine Lake estuary from the ''north end of Sabine Lake'' in Orange County, Texas (Texas Cooperative Wildlife Collection Herpetology Specimen #35596; HerpNet Database request, 20 September 2013). Therefore, our 6 individuals from 2 sites represent the first Louisiana terrapin records for this estuary. The Sabine Lake estuary has been similarly modified as the Calcasieu Lake estuary, with the original outlet at Sabine Pass having a shallow sandbar (2.1–3.0 m deep; US Naval War Records Office 1903) that limited navigation and prevented excessive saltwater intrusion into the lake (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2002). The Sabine-Neches Waterway was originally dredged to 1.82 m in 1880 (US War Department 1897), is currently maintained at 12.2 m, and is proposed for dredging to a greater depth of 13.7–16.7 m (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2002). At the 2 successful sites, there were a number of actively fished crab traps in the bayous (Table 2) and many more in the surrounding bays. For MIWR, there is a single literature record noted by Dundee and Rossman (1989) on the northern end of the island; this area is currently classified as intermediate to brackish marsh (Sasser et al. 2008) and is not as suitable for terrapins as the sampled marshes on the western end of the island. For the MIWR, CPUE was low, possibly attributable to spring flooding from the Atchafalaya River into Vermilion Bay that decreased salinities (1.4–2.8 ppt) and contributed to increased water levels across the island. For example, most of the marsh surrounding our net sites had 15–25 cm of water over the marsh; consequently, our nets within the channels may not have performed as well because of terrapins diffusing across the marsh rather than being concentrated in tidal channels. Therefore, it is possible that this effort is not representative of the population. Indeed, we found 3 nesting beaches on the island with many terrapin nesting depressions, and we captured 3 nesting females on a single beach. Nonetheless, the area surrounding MIWR sample sites had the highest commercial fishing activity of any site, as well as the highest densities of crab traps in the surrounding Vermilion Bay (W.S., *pers. obs.*). ''Thousands'' of crab traps occur along the northern shore of the island (T. Crouch, *pers. comm.*, May 2013), and it is likely that many more derelict traps occur in these areas.

CONCLUSIONS

All sample sites with terrapin captures represent either a new documented locality for terrapins or the first record in over 40 yrs for that locality (e.g., Lower Mud Lake). Several sample sites would be classified as having ''locally abundant'' terrapin populations, whereas at other sites yielded a smaller number or no individuals. The 3 sites with the highest CPUEs were generally associated with large areas of unmanaged salt and brackish marsh, whereas lower abundances were typically associated with 1) smaller marsh areas, 2) channels that no longer have permanent connection to the Gulf of Mexico, and 3) crab traps. For the latter, a high CPUE for terrapins was found at only 1 of 4 sites with crab traps present, whereas the other 3 sites had a low CPUE ($<$ 0.1 terrapins per net day) or terrapins were absent. Future studies in Louisiana should investigate the interaction between terrapins and crab traps, because terrapin crab trap mortality has been found to be significant in other parts of their range. The results of this study emphasize a need for better and more current distribution and abundance data for parts of the terrapin's range.

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