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## POPULATION ECOLOGY AND REHABILITATION OF INCIDENTALLY CAPTURED KEMP'S RIDLEY SEA TURTLES (*LEPIDOCHELYS KEMPII*) IN THE MISSISSIPPI SOUND, USA

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**Abstract.**—From 2010–2014, over 800 sea turtles were incidentally captured by recreational anglers in the Mississippi Sound, USA, mostly at coastal fishing piers. The majority of these hook and line captures were immature Kemp's Ridley Sea Turtles (*Lepidochelys kempii*). The mean minimum straight-line carapace length of the Kemp's Ridley Sea Turtles was 30.2 cm (19.2–59.4 cm). A large number of live recapture events (n = 161) were recorded, and the turtles showed a high degree of fidelity to the fishing pier of their original capture. Mean growth rate (2.74 cm/y; range, 0.13–7.3 cm/y) was lower than rates observed in other developmental habitats of Kemp's Ridley Sea Turtles. It was unclear if recent environmental disturbances have forced turtles to forage at piers due to decreased populations of natural prey. However, results from hematological and plasma biochemistry analyses were comparable to values observed in other populations. Further, we successfully rehabilitated and released 96% of the turtles. Nevertheless, hook and line incidental capture by recreational anglers represents a threat to immature Kemp's Ridley Sea Turtles in the Mississippi Sound, which is an important recruiting and developmental habitat for this species.

**Key Words.**—conservation; recreational fishery interactions; growth; hematology; plasma biochemistry

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### INTRODUCTION

Sea turtle interactions with commercial and artisanal fisheries have been extensively studied, and numerous strategies have been proposed to prevent or mitigate interactions (Lewison et al. 2013). However, sea turtle interactions with recreational fisheries have not been properly examined despite potential for harm to turtles from these interactions (Oravetz 1999). For example, from 2010–2013, over 20 million angler trips in the five Gulf of Mexico (GOM) states were recorded by NOAA's Marine Recreational Information Program (<http://www.st.nmfs.noaa.gov/recreational-fisheries> [Accessed 3 December 2014]). The state of Mississippi, USA, has numerous recreational fishing access points in its three coastal counties (<http://www.dmr.state.ms.us/images/reports/public-access-inventory.pdf>), and since 2010, an increasing number of sea turtle interactions have been reported in Mississippi, with most reports coming from coastal fishing piers (Sea Turtle Stranding and Salvage Network [STSSN], <http://www.sefsc.noaa.gov/species/turtles/strandings.htm>; Fig. 1). However, the northern Gulf of Mexico (nGOM; specifically Alabama, Mississippi, and Louisiana) has been historically understudied regarding sea turtle ecology and conservation. The lack of quality baseline

abundance and demographic data was highlighted during the response to the Deepwater Horizon oil spill (Bjorndal et al. 2011) when alarmingly high levels of sea turtle strandings were recorded in this region (STSSN; <http://www.sefsc.noaa.gov/species/turtles/strandings.htm>). Over 1,200 strandings of dead sea turtles have been documented since 2010, and most of these strandings were immature Kemp's Ridley Sea Turtles (*Lepidochelys kempii*). This critically endangered species was on an impressive trajectory for recovery until 2010 (Crowder and Heppell 2011), but recent nesting numbers have fueled concerns that some factor(s) is impeding its recovery (Gallaway et al. 2013; Caillouet 2014).

Previous studies have discussed the incidental capture of immature Kemp's Ridley Sea Turtles by recreational anglers at coastal fishing piers along the GOM coast of Florida (Rudloe and Rudloe 2005) and Texas (Cannon et al. 1994; Seney 2008). Rudloe and Rudloe (2005) reported 74 subadult Kemp's Ridley Sea Turtles were incidentally captured by recreational anglers from 1991–2003. In Texas, 118 immature Kemp's Ridley Sea Turtles were incidentally captured from 1980–1992 (Cannon et al. 1994) and 42 were captured from 2003–2007 (Seney 2008). In contrast, from 2010–2014, over 800 incidental captures have been reported from

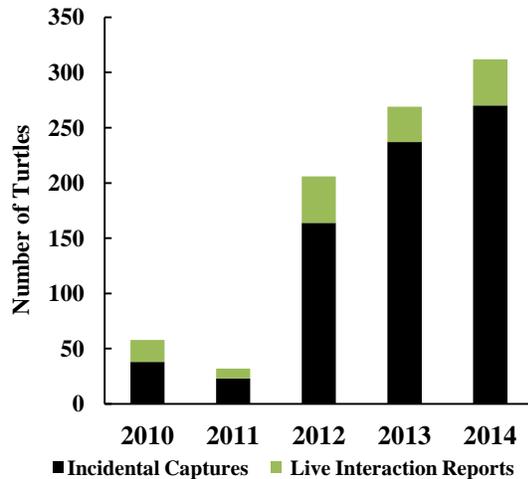


FIGURE 1. Number of reported live sea turtle interactions in Mississippi from 2010–2014. The majority of these live interactions were hook and line incidental captures.

recreational anglers in the Mississippi Sound (MS Sound), and similar to numbers of sea turtle strandings, the majority of incidental captures have been immature Kemp’s Ridley Sea Turtles. Such a large number of captured turtles offered an unprecedented opportunity to examine the population ecology and health of Kemp’s Ridley Sea Turtles from an understudied portion of its range.

For this study, we characterized incidentally captured sea turtles using a suite of morphological, growth, and health data. In addition, we quantified the fidelity of released turtles to the MS Sound using recapture data. The Bi-national Recovery Plan for Kemp’s Ridley Sea Turtles (National Marine Fisheries Service, U.S. Fish and Wildlife Service, and SEMARNAT 2010) identifies recreational hook and line capture as a threat to this species and calls for proper monitoring and reduction of this threat. The results presented in this manuscript, from a historically understudied developmental habitat (Carr 1980; Ogren 1989; Coleman 2013; Putman et al. 2013; Putman et al. 2015), will be crucial for informing future management and conservation of Kemp’s Ridley Sea Turtles and their habitats.

#### MATERIALS AND METHODS

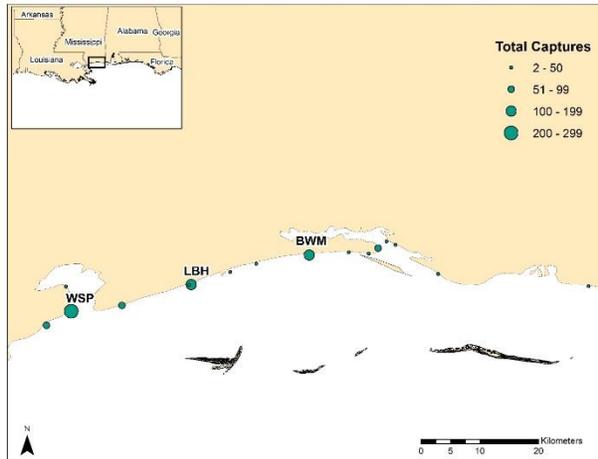
**Data collection.**—The MS Sound estuary encompasses an approximately 2,000 km<sup>2</sup> area separated from the GOM by six barrier islands (Cat, West Ship, East Ship, Horn, Petit Bois, and Dauphin Islands; Eleuterius 1978). Water depth ranges from 1–7 m, mean annual water temperature ranges from 9° C in winter to 32° C in summer, and salinity ranges from 0–33 parts per thousand (ppt; Christmas 1973). Salt marshes, oyster reefs, and artificial reefs in the MS Sound provide

habitat to a variety of crustacean and mollusk prey favored by Kemp’s Ridley Sea Turtles, most notably Blue Crabs (*Callinectes sapidus*; Shaver 1991; Seney and Musick 2005).

The Institute for Marine Mammal Studies (IMMS), located in Gulfport, Mississippi, USA, enhanced its sea turtle response and rescue program in the MS Sound during the Deepwater Horizon oil spill response in 2010. The IMMS staff manned a stranding hotline (24 h/d, 7 d/week), and recreational anglers who experienced an interaction with sea turtles were encouraged to report the interaction. We transported any sick or injured sea turtle to the IMMS rehabilitation facility where the turtle received a full veterinary exam. We obtained a series of diagnostic radiographs, and if a hook(s) was present, a staff veterinarian removed it if possible. We collected standard morphological measurements (Bolten 1999) using Haglöf calipers (Haglöf Instruments, Inc., Långsele, Sweden) for straight-line measurements, JorVet scale (Jorgensen Laboratories, Loveland, Colorado, USA) for weight, and a plastic measuring tape for curved measurements.

We also extracted a 5 mL sample of whole blood from the external jugular vein using a 5 cc syringe and 22 gauge needle. We divided the blood sample among one lithium heparin tube for whole blood and two plasma separator tubes. The plasma separator tubes were spun for 5 min in a Clay Adams Triac Centrifuge (Becton, Dickinson and Company, Franklin Lakes, New Jersey, USA). We divided the whole blood sample from the lithium heparin tube among four microhematocrit tubes and two blood smears. We centrifuged the microhematocrit tubes for 3 min. We sent one blood smear, one plasma separator tube (lithium heparin), and two microhematocrit tubes to an Antech Diagnostics (Irvine, California, USA) laboratory for hematology and plasma chemistry analyses. Hematology parameters included hematocrit, white blood cell estimate, absolute heterophils, absolute lymphocytes, absolute monocytes, and absolute eosinophils. Plasma biochemistry parameters included total protein, albumin, globulin, phosphorous, glucose, calcium, sodium, potassium, chloride, uric acid, iron, aspartate aminotransferase (AST), blood urea nitrogen (BUN), and creatine phosphokinase (CPK).

Once a turtle was medically cleared by an IMMS veterinarian for release, we attached two no. 681 Inconel flipper tags supplied by the Cooperative Marine Turtle Tagging Program (CMTTP) as well as a passive integrated transponder (PIT) tag (Biomark, Boise, Idaho, USA). Only turtles with a minimum straight-line carapace length (mSCL) of 25 cm and sufficient triceps muscle received tags. We attached the two flipper tags on the trailing edge of the front flippers, and we inserted the PIT tag in the triceps muscle in the left front flipper.



**FIGURE 2.** Locations of recreational fishing piers along the Mississippi Gulf Coast from which multiple reports of incidentally captured sea turtles via hook and line were documented from 2010–2014. Over 100 captures were reported from the identified piers (BWM: Broadwater Marina, LBH: Long Beach Harbor, WSP: Washington St. Pier).

Each tag had a unique identifying number that is maintained in the CMTTP database.

**Data analyses.**—Due to the inconsistency of recording morphological data in 2010, we included only morphological data from 2011–2014 in the analyses. We transformed weight and mSCL data via natural logarithm. We ran regressions of these transformed data by year to compare annual morphometric relationships. Recaptured turtles allowed us to calculate yearly growth rates. We used the equation from Schmid (1995, 1998):  $G = (\Delta \text{Length}/\text{Days}) \times 365$ , where  $G$  = growth rate in cm/y;  $\Delta \text{Length}$  = difference in initial and recapture mSCL; and  $\text{Days}$  = number of days between initial capture and recapture dates. In addition to live recaptures, we included mSCL measurements from tagged sea turtles that stranded dead if the measurements could be obtained. We included only the last measurement of the animal for individuals that were observed multiple times. Growth rates were pooled for recapture intervals (< 90 d, 90–180 d, and > 180 d) and for size ranges (20.0–29.9 cm and 30.0–39.9 cm).

We summarized the hematology and plasma biochemistry data from Kemp's Ridley Sea Turtles that were admitted with hooking injuries and classified as juveniles (<40 cm mSCL, Gregory and Schmid 2001). We tested all variables for normality using the D'Agostino-Pearson normality test; none of the variables displayed a normal distribution. Therefore, the median of each health variable was determined along with 2.5 and 97.5 percentiles and accompanying 95% confidence intervals (Horn et al. 2001; Walton 2001; Friedrichs et al. 2012) using the program R (R Core Team, 2014).

Prior to conducting these calculations, we identified and removed outliers within each variable using Dixon's outlier range statistic (Walton 2001; Friedrichs et al. 2012). The exclusion of outliers prevented data bias that could occur from including non-representative individuals or samples affected by pre-analytical or post-analytical errors (Friedrichs et al. 2012). We also included the means for each variable to allow for comparisons to other published Kemp's Ridley Sea Turtle health data (Carminati et al. 1994; Snoddy et al. 2009; Anderson et al. 2011).

## RESULTS

From 2010 to 2014, we admitted 775 sea turtles from Mississippi ( $n = 753$ ), Alabama ( $n = 20$ ), and Louisiana ( $n = 2$ ) to the IMMS sea turtle rehabilitation facility, with 732 of those representing hook and line incidental captures. The remaining 43 turtles were trawl or dredge captures, suffered from boat strikes, or were live strandings. Additionally, 101 incidental captures that were either released or escaped (i.e., broke the line) were also reported by anglers as interactions. Similar to the regional strandings, the vast majority of the incidental captures rehabilitated at IMMS were Kemp's Ridley Sea Turtles (98.4%), with very few Loggerhead Sea Turtles (*Caretta caretta*, 1.1%) or Green Sea Turtles (*Chelonia mydas*, 0.5%). Incidental captures were reported from March to November, with the highest numbers occurring in June (23.2%), July (28.2%), and August (15.9%). We documented incidental captures from over 20 public coastal piers in Mississippi and Alabama, and over 100 were reported from three locations: Washington St. Pier (Bay St. Louis, Mississippi,  $n = 219$ ), Broadwater Marina (Biloxi, Mississippi,  $n = 128$ ), and Long Beach Harbor (Long Beach, Mississippi,  $n = 122$ ; Fig. 2). Overall, we rehabilitated and released incidentally captured turtles with a 96% success rate, and for 2013 and 2014, the mean rehabilitation time was relatively short ( $\bar{X} \pm \text{SD}$ ;  $16.3 \pm 24.9$  d, range, 2–312 d).

For the turtles included in the morphological analyses ( $n = 684$ ), 87.7% had an mSCL of 25.0–34.9 cm, with the mean mSCL =  $30.2 \pm 3.7$  cm (19.2–59.4 cm, Fig. 3). In contrast, the mean mSCL of dead, stranded Kemp's Ridley Sea Turtles was  $36.0 \pm 7.5$  cm (18.2–65.6 cm). For each year, we observed a strong correlation ( $r > 0.97$ ) for the regressions between the natural log-transformed mSCL and weight data (Fig. 4). The regression equations were comparable between years: 2011,  $\ln \text{weight} = -8.20 + 2.82 (\ln \text{mSCL})$ ,  $r^2 = 0.97$ ; 2012,  $\ln \text{weight} = -7.73 + 2.70 (\ln \text{mSCL})$ ,  $r^2 = 0.96$ ; 2013,  $\ln \text{weight} = -8.17 + 2.81 (\ln \text{mSCL})$ ,  $r^2 = 0.95$ ; and 2014,  $\ln \text{weight} = -8.01 + 2.77 (\ln \text{mSCL})$ ,  $r^2 = 0.94$ .

We recorded 161 live recapture events between 2012–2014; the number of recaptures increased each year, from 14 turtles in 2012, 67 turtles in 2013, and 80 turtles

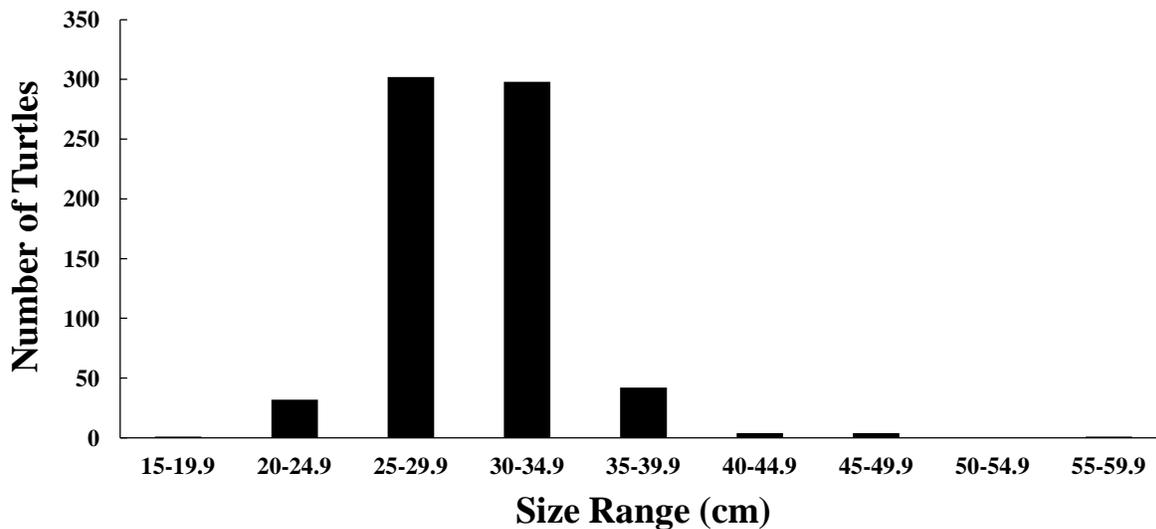


FIGURE 3. Size composition of incidentally captured Kemp’s Ridley Sea Turtles (*Lepidochelys kempii*) that were rehabilitated at the Institute for Marine Mammal Studies, Gulfport, Mississippi, USA.

in 2014. There were 29 turtles recaptured twice or more and two turtles were recaptured six times. Recapture events occurred 57% of the time at the original pier capture site, but when piers from the same general area (< 10 km apart) were grouped together, 71% of the recapture events occurred in the vicinity of the original pier.

We included growth data from 37 stranded, tagged turtles in the analysis. The range of durations between initial capture and most recent recapture was 12–1,121 d.

We assumed growth rates calculated from recapture intervals > 180 d to be the most reliable (n = 46). For the 20.0–29.9 cm size class, mean growth rate was  $2.9 \pm 1.8$  cm/y (0.1–7.3 cm/y), and  $2.5 \pm 1.5$  cm/y (0.4–6.2 cm/y) for the 30.0–39.9 cm size class (Table 1). We removed outliers in only two of the plasma biochemistry variables: AST (910 U/L) and Calcium (16.5 mg/dL). CPK was the only health parameter that was elevated compared to other published results (Table 2).

## DISCUSSION

Previous studies have documented hook and line captures of Kemp’s Ridley Sea Turtles in the Gulf of Mexico (Cannon et al. 1994, n = 118; Rudloe and Rudloe 2005, n = 74; Seney 2008, n = 42), but our study documents exceptionally higher numbers of reported captures in this region. Of the 728 incidentally captured turtles we rehabilitated at IMMS from 2010–2014, 716 were Kemp’s Ridley Sea Turtles. The large number of documented captures could be the result of several factors. In 2012, IMMS staff placed informational signs on how to properly report incidental captures at numerous public fishing piers, public boat launches, and bait shops, which may have influenced the dramatic increase of reported interactions between 2011 and 2012. Additionally, the population increase that has occurred due to conservation efforts (Crowder and Heppell 2011; Caillouet 2014), as well as ocean circulation patterns (Putman et al. 2013), could have resulted in turtles being present in our study region at levels not previously observed.

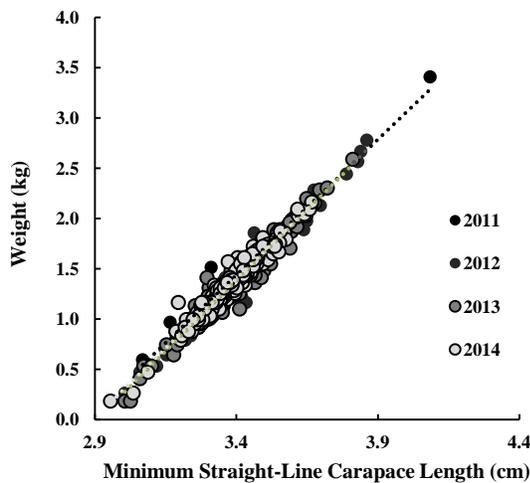


FIGURE 4. Plot of natural log transformations of minimum straight-line carapace length versus weight by year of incidentally captured Kemp’s Ridley Sea Turtles (*Lepidochelys kempii*) that were rehabilitated at the Institute for Marine Mammal Studies, Gulfport, Mississippi, USA.

**TABLE 1.** Comparison of mean growth rates (cm/y  $\pm$  standard deviation [SD]) with sample size (n), mean, and standard deviation (SD) of incidentally captured Kemp’s Ridley Sea Turtles (*Lepidochelys kempii*) from current study by size class, recapture interval, and by size class of those with a recapture interval longer than 180 days. Data were compared to data from published growth rates at Cedar Keys, Florida, USA (Schmid 1998) and Ten Thousand Islands, Florida, USA (Witzell and Schmid 2004).

Recapture Interval	Size Class	Mississippi Sound		Cedar Keys		Ten Thousand Islands	
		n	Mean $\pm$ SD	n	Mean $\pm$ SD	n	Mean $\pm$ SD
< 90 d	20-29.9 cm	64	4.1 $\pm$ 4.0			2	8.5 $\pm$ 1.8
	30-39.9 cm	52	3.4 $\pm$ 3.0	7	4.6 $\pm$ 2.8	13	8.0 $\pm$ 3.2
		54	4.1 $\pm$ 4.1				
90–180 d		16	5.5 $\pm$ 4.9	16	4.5 $\pm$ 2.6	25	6.5 $\pm$ 2.9
> 180 d		46	2.8 $\pm$ 1.7	13	3.6 $\pm$ 1.2	17	6.4 $\pm$ 2.8
>180 d	20-29.9 cm	27	2.9 $\pm$ 1.8				
	30-39.9 cm	19	2.5 $\pm$ 1.5				

Moreover, the MS Sound has experienced several environmental disturbances in recent years, which could have deteriorated natural foraging habitats or prey species of Kemp’s Ridley Sea Turtles (Table 3), thus, forcing them to feed at fishing piers (Rudloe and Rudloe 2005). The spring season (March to May) coincides with periodic flooding of the Mississippi River, which transports large volumes of cold water to the nGOM. While the system does not drain directly into the MS Sound, the Bonnet Carre´ spillway, near Montz, Louisiana, releases water during high flow periods into Lake Pontchartrain, which later reaches the MS Sound. The spillway rarely opens but leaks during high flow events at an approximate rate of 283 m<sup>3</sup>/s (U.S. Army Corps of Engineers. 2014. Bonnet Carre Spillway Overview. Available from <http://www.mvn.usace.army.mil/Missions/MississippiRiverFloodControl/BonnetCarreSpillwayOverview.aspx> [Accessed 26 July 2015]). Fresh water originating from the spillway has been implicated as a source of stress for many organisms including a favorite prey of Kemp’s Ridley Sea Turtles, Blue Crabs (LeBlanc et al. 2012; Gulf Engineers & Consultants, unpubl. report). The opening of the spillway in 2011 has been blamed for a 50% decrease in commercial landings of Blue Crabs in Mississippi (Mississippi Department of Marine Resources 2012), prompting the Secretary of Commerce to declare a disaster for the Mississippi crab fishery in 2011. However, commercial landings have been in decline for many years in this region, as mean catch per unit effort fell from 3.7 to 1.6 pounds of crabs per trap per day from the 1970s to the mid-1990s (Perry et al. 1998). The reasons for such dramatic declines are not fully understood, but are hypothesized to be linked to reduced recruitment of larval crabs resulting from shifting climate regimes in the region (Sanchez-Rubio et al. 2011). More work is needed to understand if or how these factors are influencing the number of incidental captures. Nevertheless, the potential for turtles to be incidentally captured by recreational anglers remains high and should be properly addressed.

In addition to the MS Sound, other Kemp’s Ridley Sea Turtle developmental habitats have been identified in Long Island Sound, New York, USA (Morreale and Standora 1998), Chesapeake Bay, Virginia, USA (Musick and Limpus 1997), the southeastern Atlantic coast from South Carolina to Cape Canaveral, Florida, USA (Henwood and Ogren 1987; Schmid 1995), Ten Thousand Islands, Florida (Witzell and Schmid 2004), Cedar Keys, Florida (Schmid 1998), northwestern Florida (Rudloe et al. 1991), and western Louisiana and Texas, USA (Metz 2004; Landry et al. 2005). Existence of capture and demographic data from other regions allows a comparison with the results of our study. However, it is necessary to discuss two aspects of these previous studies prior to comparing results. First, turtles were sampled using a variety of methods. Turtles were collected using tangle or strike netting techniques by Schmid (1998), Witzell and Schmid (2004), and Landry et al. (2005) and trawl surveys by Henwood and Ogren (1987) and Schmid (1995). Rudloe et al. (1991) documented turtles that were incidentally captured by commercial fisheries, and Morreale and Standora (1998) included turtles incidentally captured in commercial fisheries and cold stunned turtles. Second, the method to measure carapace lengths differed between studies. In our study and in Witzell and Schmid (2004), mSCL (midline of nuchal scute to posterior notch of supracaudal scutes) measurements were analyzed. Schmid (1995, 1998) reported standard straight-line carapace length (sSCL) (midline of nuchal scute to posterior margin of supracaudal scute) measurements, and Henwood and Ogren (1987), Rudloe et al. (1991), and Landry et al. (2005) did not specify which straight-line carapace lengths were analyzed. Despite these differences, comparing published data to our study results is informative.

The observed size range in incidentally captured Kemp’s Ridley Sea Turtles in Mississippi (19.2–59.4 cm) was similar to reported size ranges of Kemp’s Ridley Sea Turtles sampled in fishery-independent surveys (19.5–66.0 cm, Henwood and Ogren 1987;

**TABLE 2.** Summary of hematology data and plasma biochemistry data (n = sample size, Per. = percentile) from incidentally captured, immature Kemp’s Ridley Sea Turtles (*Lepidochelys kempii*) that were successfully rehabilitated and released and comparison to other published values for this species. Snoddy et al. (2009) and Carminati et al. (1994) calculated means ( $\pm$  SD) of the plasma biochemistry parameters. Anderson et al. (2011) calculated median values of the plasma biochemistry parameters. For Plasma Biochemistry Parameters, Nito. = nitrogen, amino. = aminotransferase, and phosphor. = phosphokinase.

Hematology Parameter	n	Unit	Median	Mean	2.5 Per.	97.5 Per.	Snoddy et al. 2009	Carminati et al. 1994	Anderson et al. 2011
Hematocrit	629	%	26	26.4	17	38		31.1 $\pm$ 13.55	
WBC Count	629	*10 <sup>3</sup> / $\mu$ L	9	10.08	6	19.88			
Absolute Heterophils	627	#/ $\mu$ L	7,650	8,041	3,480	16,000			
Absolute Lymph.	627	#/ $\mu$ L	1,440	1,719	630	4,200			
Absolute Eosinophils	627	#/ $\mu$ L	0	118.6	0	720			
Absolute Monocytes	627	#/ $\mu$ L	80	86.35	0	360			
Plasma Biochemistry Parameter									
Total Protein	628	g/dL	2.8	2.85	2	3.79	2.6 $\pm$ 0.9	3.1 $\pm$ 0.53	4
Albumin	628	g/dL	1	1	0.7	1.4	0.9 $\pm$ 0.3	1.3 $\pm$ 0.25	1.6
Globulin	626	g/dL	1.8	1.84	1.3	2.6	1.7 $\pm$ 0.6	1.8 $\pm$ 0.39	2.4
Calcium	627	mg/dL	7	7.05	5.1	9.29	13.5 $\pm$ 9.7	7.4 $\pm$ 0.98	7
Phosphorous	628	mg/dL	7	7.16	4.9	10.19	7.5 $\pm$ 4.0	6.8 $\pm$ 1.41	7.8
Glucose	628	mg/dL	105.5	110.1	42.1	206.8	112.3 $\pm$ 48.8	115.2 $\pm$ 41.6	116
Blood Urea Nitro.	626	mg/dL	57	60.19	25	119	68.3 $\pm$ 20.7	73.7 $\pm$ 21.1	122
Uric Acid	627	mg/dL	0.1	0.43	0	2.6	1.3 $\pm$ 1.2		1.2
Sodium	623	mEq/L	153	152.8	146	161.03	202 $\pm$ 86.7	153.3 $\pm$ 21.4	155
Potassium	623	mEq/L	4.2	4.31	3.2	5.8	6.3 $\pm$ 1.7	3.6 $\pm$ 1.32	4.4
Chloride	623	mEq/L	114	114.1	103	124	187 $\pm$ 128.7	115.2 $\pm$ 14	124
Aspartate amino.	627	U/L	108	118.7	58.08	248.85	108.8 $\pm$ 54.9	144.7 $\pm$ 42.3	523
Creatine phospho.	622	U/L	6,514	16,320	931	108,902	2,412.3 $\pm$ 2,235.4		812
Iron	585	ug/dL	36	41.34	9	110			

Schmid 1995; Schmid 1998; Witzell and Schmid 2004; Landry et al. 2005), incidentally captured by commercial fisheries (20.3–57.9 cm, Rudloe et al. 1991), and incidentally captured by recreational anglers (25–45 cm, Seney 2008). However, the mean size of Kemp’s Ridley Sea Turtles incidentally captured in Mississippi (30.2  $\pm$  3.7 cm mSCL) was lower than in other sampled populations (34.6–44.5 cm, Henwood and Ogren 1987; Rudloe et al. 1991; Schmid 1995; Schmid 1998; Witzell and Schmid 2004; Seney 2008). Although, when they only included summer captures, Rudloe et al. (1991) observed a mean size of 30.9 cm.

Disparity in size distribution was also observed. In our study, 98.6% of incidentally captured turtles were < 40 cm mSCL, and 87.7% of the turtles were in the 25.0–34.9 cm size class. In contrast, Schmid (1995) and Landry et al. (2005) reported that 65% and 77%, respectively, of sampled turtles were < 40 cm SCL, and only approximately 25% of Kemp’s Ridley Sea Turtles documented by Schmid (1998) at Cedar Keys, Florida, were < 40 cm SCL.

Interestingly, there was overlap in the size of incidental captures from Mississippi and juvenile Kemp’s Ridley Sea Turtles sampled in surface pelagic habitats sampled by Witherington et al. (2012). Approximately half of the 38 juvenile Kemp’s Ridley Sea Turtles documented by Witherington et al. (2012) were between 24.0–28.0 cm sSCL, and estimated to be

1–2 y old. Similarly, based on the size composition of the incidental captures from Mississippi and ages estimated for these size classes using skeletochronology (Larisa Avens, pers. comm.), an abundance of 1–2 y old Kemp’s Ridley Sea Turtles inhabit our study area. Witherington et al. (2012) stated support for the dispersal scenario for Kemp’s Ridley Sea Turtles hypothesized by Collard and Ogren (1990) because their data suggested that the turtles observed in the sampled pelagic habitats were nearing recruitment to estuarine and nearshore habitats of the nGOM and eastern GOM. Models described in Putman et al. (2013) and the size data reported in this study also provide reinforcement that the nGOM (and, specifically, the MS Sound) provide important recruiting grounds for juvenile Kemp’s Ridley Sea Turtles.

The high number of recaptures provided a suitable sample size to calculate growth rates for rehabilitated Kemp’s Ridley Sea Turtles. The growth rates reported in this study were lower for both size classes (20.0–20.9 cm and 30.0–30.9 cm) than those calculated from recaptures of Kemp’s Ridley Sea Turtles sampled from fishery-independent surveys conducted in Cedar Keys (Schmid 1998) and Ten Thousand Islands, Florida (Witzell and Schmid 2004). Morreale and Standora (1998) calculated an overall growth rate of 4.0  $\pm$  3.8 cm/y in immature Kemp’s Ridley Sea Turtles inhabiting the Long Island Sound. The growth rate for the 20.0–

**TABLE 3.** Large disturbances in the northern Gulf of Mexico since 2010 that may have affected sea turtle habitat use.

Event	Duration of disturbance	Additional notes
Deepwater Horizon oil spill <sup>a,b</sup>	4/20/10 – 9/19/10	5 million barrels of oil and 1.8 million gallons of Corexit® dispersant
2011 Opening of Bonnet Carre’ Spillway <sup>c</sup>	5/9/11 – 6/20/11	94.3% of spillway opened
Hurricane Isaac <sup>d</sup>	8/28/12 – 8/29/12	Storm surge of 8 ft. in Waveland, Mississippi, USA

<sup>a</sup>McNutt et al. 2012; <sup>b</sup>National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2010

<sup>c</sup>U.S. Army Corps of Engineers. 2014. Bonnet Carre Spillway Overview. Available from

<http://www.mvn.usace.army.mil/Missions/MississippiRiverFloodControl/BonnetCarreSpillwayOverview.aspx> (Accessed July 2015)

<sup>d</sup>Berg 2013

30.0 cm size class in Long Island Sound was  $2.2 \pm 1.6$  cm, similar to what we observed for the 20.0–29.9 size class, however, their sample only consisted of four turtles (Morreale and Standora 1998). Kemp’s Ridley Sea Turtles from Cape Canaveral, Florida, USA, that were recaptured > 180 d after initial capture displayed a mean growth rate of  $5.9 \pm 1.8$  cm/y (Schmid 1995). Landry et al. (2005) reported a mean growth rate 7.3 cm/y, but the range of growth rates for this Texas and Louisiana population of Kemp’s Ridley Sea Turtles was from 1.1–18.3 cm/y. The lower growth rates observed in our study could have resulted from the abnormal diets of turtles in the presence of the piers. Related to this, most of the previous studies that were used for comparison occurred prior to the recent population increases documented in this species. Decreases in growth rates due to density-dependence effects have been reported in sea turtles (Bjørndal et al. 2000), so population gains in the MS Sound could be reducing per capita resources and leading to lower growth rates if the region is nearing carrying capacity.

Although foraging at fishing piers potentially led to lower growth rates in this population, the dependable source of food might have resulted in high site fidelity observed in recaptures. Over 70% of pier recaptures occurred < 10 km from the location of initial capture. Rudloe and Rudloe (2005) also reported high site fidelity of recaptures in a Kemp’s Ridley Sea Turtle population located in northwestern Florida. Fifteen of 16 recapture events occurred near the initial capture location. However, Seney (2008) documented low fidelity to fishing piers by immature Kemp’s Ridley Sea Turtles in Texas. Rudloe and Rudloe (2005) also observed decreased growth rates (1.2–1.7 cm/y) in turtles that displayed site fidelity compared to other populations. Despite the overall lower growth rates observed in Mississippi compared to other populations, the mean growth rate increased from 2013 (2.3 cm/y, range 0.1–5.1 cm/y) to 2014 (3.2 cm/y, range 0.4–7.3 cm/y), although, the results of a Wilcoxon rank test did not reveal statistical significance ( $W= 163, P = 0.105$ ).

All of the hematology and plasma biochemistry variables we collected and available for comparison to

published values from other populations were similar except for CPK (Carminati et al. 1994; Snoddy et al. 2009; Anderson et al. 2011). The values for CPK in the Mississippi population was higher than those previously reported (Snoddy et al. 2009; Anderson et al. 2011), and this could be attributed to tissue damage caused by hook ingestion (Campbell 2006). However, Campbell (2006) did not recommend using CPK in evaluating health of a reptile. Furthermore, the time difference in obtaining blood samples between studies could have contributed to the discrepancy in CPK values. Snoddy et al. (2009) collected samples relatively soon ( $53 \pm 36.7$  m) after removing juvenile Kemp’s Ridley Sea Turtles from gillnets. In the current study, blood samples were often collected at least 2 h after capture (in most instances, much longer) due to the time required for response, radiographs, and hook removal.

Normal total protein concentrations for reptiles have been reported to be 3–7 g/dL (Campbell 2006), but the 95% range observed in this study was 2–3.79 g/dL. Hypoproteinemia is often caused by chronic malnutrition (Campbell 2006). However, low hematocrit values can also indicate malnutrition, and the observed hematocrit values were within the range reported for healthy juvenile turtles in the Chesapeake Bay (24–34%; George 1997). Also, based on glucose values, hypoglycemia, another indicator of malnutrition (Campbell 2006), was rarely observed. Therefore, despite lower growth rates, the results of the bloodwork analyses did not point to malnutrition in the population.

Even though the majority of the turtles were of good health and eventually released after a relatively short rehabilitation stay, all incidental captures by recreational anglers fall under the Endangered Species Act’s definition of Take. It defines this term as any action that “means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct” (Endangered Species Act, 16 U.S.C. Section 1532, <http://www.nmfs.noaa.gov/pr/pdfs/laws/esa.pdf>). Should a turtle that is successfully rehabilitated and released fall under the same category as a turtle that is permanently removed from the population? Does a turtle that is incidentally captured have a significantly

lower chance of survival than one that is not? In contrast to the high release rate, 20% of the Kemp’s Ridley Sea Turtles rehabilitated were recaptured at least once resulting in 161 recapture events. Turtles were often recaptured < 10 km from the original capture location, indicating that they remain in or return to the same area after release. Further, 30% of released turtles were recaptured more than once, and two turtles were recaptured six times from 2013–2014. For those two turtles, the probability of survival through rehabilitation six times would be about 78% ([rehabilitation success rate]<sup>6</sup> = [0.96]<sup>6</sup>), thus rehabilitation does not eliminate mortality. Recent biological opinions for sites in western Mississippi estimated overall post-release mortality at approximately 25–30% for turtles released following rehabilitation without gear attached (National Marine Fisheries Service, unpubl. report). The expected mortality rates are based on commercial longline interactions (Ryder et al. 2006), and at this time we are not aware of how comparable post-release mortality is between recreational and commercial fisheries. Nonetheless, significant potential exists for rehabilitated turtles to be recaptured, which puts them at risk for ingestion of anthropogenic debris (Seney 2008), additional hooking injuries, and related stress (Rudloe and Rudloe 2005; Seney 2008). This stress could be contributing to the lower growth rates observed in these turtles compared to other populations (Rudloe and Rudloe 2005).

Given the number of immature Kemp’s Ridley Sea Turtles recorded as stranded or incidentally captured, the MS Sound represents an important developmental habitat for this critically endangered species. It should be noted that the number of reported recreational fishery interactions is most likely an underestimate because of the lack of documented interactions from anglers on charter boats, private boats, and the beach. The comparison of these results to data obtained from turtles in the MS Sound sampled with fishery-independent surveys as well as updated data from other developmental habitats would elucidate any potential density-dependent effects. Moreover, as many studies have investigated sea turtle capture and survival rates in relation to baits and gear in commercial fisheries (e.g., Watson et al. 2005; Santos et al. 2012; Swimmer et al. 2014), conducting similar studies with recreational fishery gear and bait would help develop strategies to lessen the number of sea turtles interacting with this fishery as well as increase the survival of those individuals that do. Since 2012, the number of saltwater recreational fishing licenses permitted by Mississippi Department of Marine Resources has remained around 80,000 (pers. comm.). Thus, as sea turtle populations recover and a substantial fishing effort continues, the issue of sea turtle bycatch by recreational anglers will

persist until proper mitigation policies are identified and enacted.

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Coleman et al.—Rehabilitation of incidentally captured Kemp’s Ridley Sea Turtles.



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