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Post-nesting movement of wild and head-started Kemp's ridley sea turtles *Lepidochelys kempii* in the Gulf of Mexico

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ABSTRACT: Nesting by the endangered Kemp's ridley sea turtle *Lepidochelys kempii* has increased on the Texas coast during recent years. Movements of 28 individual adult females that nested on North Padre Island or Mustang Island, Texas, USA, were monitored using satellite telemetry. Platform transmitter terminals (PTTs; n = 36) were deployed on the 28 turtles between 1997 and 2006, with 1 individual receiving 3 PTTs during different years, 6 receiving 2, and 21 receiving 1. Of the 28 individuals, 17 were from the wild stock, 9 were head-started turtles (reared in captivity for the first months of life) that had been experimentally imprinted to Padre Island as hatchlings, and 2 were head-started turtles that had been obtained directly from Mexico as hatchlings. Locations were obtained from 9 to 841 d (mean = 277 d) following deployment. After they completed nesting for the season, most of the tracked turtles left south Texas and traveled northward, parallel to the coastline, with their last identified location in the northern or eastern Gulf of Mexico. Inter-nesting residency was documented off south Texas and post-nesting residency in USA Gulf of Mexico waters from south Texas to the tip of Florida. Movements and habitat utilization by wild and head-started turtles and by individuals during different tracking events were generally similar. However, all of the 5 turtles that briefly traveled southward to waters off the coast of Mexico were wild. Tracking data were used to aid with nest detection and protection, and development of a regulation by Texas Parks and Wildlife Department that closed near-shore south Texas waters to shrimp trawling. Findings from this study demonstrate the importance of near-shore Gulf of Mexico waters, particularly offshore from south Texas, to post-nesting Kemp's ridley turtles.

KEY WORDS: Kemp's ridley · Nesting · Satellite telemetry · Conservation · Texas · Gulf of Mexico

INTRODUCTION

The endangered Kemp's ridley turtle *Lepidochelys kempii* has been the focus of intensive, long-term, population restoration efforts. Most Kemp's ridley nesting occurs in the vicinity of Rancho Nuevo, Tamaulipas, Mexico (Márquez et al. 1982). Protection efforts at the Rancho Nuevo nesting beach began in 1966 (Márquez 1970), but the nesting population had been depleted and continued to plummet. By 1977, it was feared that the Kemp's ridley would become extinct within a few years unless immediate further steps were taken (Carr 1977). A bi-national, multi-agency, experimental imprinting and head-start project was conducted to increase Kemp's ridley turtle nesting at Padre Island National Seashore (PINS), located on North Padre Island, Texas, USA (Fig. 1). The objective was to establish a secondary nesting colony of this native species (Werler 1951, Hildebrand 1963, Carr 1967, Francis 1978) at the longest protected stretch of undeveloped barrier island beach in the USA as a safeguard against population extinction (Shaver 2005). Head-starting involved rearing the turtles in captivity for their first months of life, so that when they were released they

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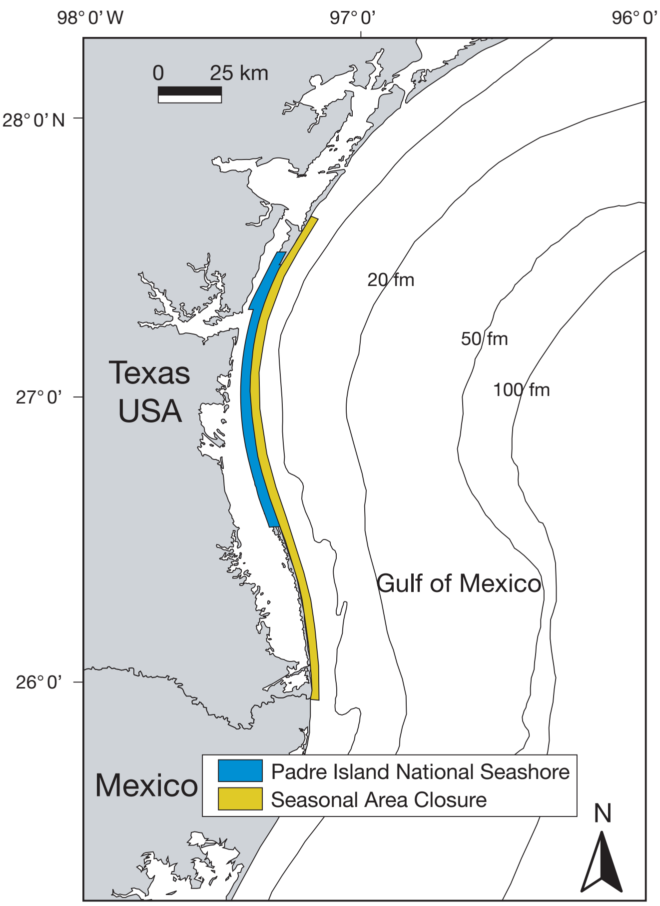

Fig. 1. Location of Padre Island National Seashore and the seasonal area closure in south Texas, USA. Depth in fathoms (= 1.8288 m)

were large enough to be tagged for future recognition and avoid most predators (Fontaine & Shaver 2005). From 1979 to 1989, head-started yearling turtles that had been experimentally imprinted to PINS ('Padre Island imprinted head-starts') were released, most into the Gulf of Mexico off south Texas (Fontaine & Shaver 2005). Additionally, in 1979 to 1981, 1984, and 1989 to 2000, head-started yearling turtles that had been obtained as hatchlings from Rancho Nuevo ('Mexico imprinted head-starts') were released, with the objective that they would return to Mexico to reproduce.

Detection of nesting is necessary to monitor nesting trends and help increase survival of nesting turtles and eggs. Systematic efforts to detect nesting began on the Texas coast at PINS in 1986 and expanded after that time (Shaver 2005). These efforts have been extremely challenging due to the hundreds of km that must be searched, limited patrol resources available, logistical difficulties, and nesting characteristics of this species. Kemp's ridley turtles nest primarily during the daytime, often on windy days, with their faint tracks blowing away quickly. They often nest in aggregations (arribadas), approximately 3 times per nesting season, with a mean inter-nesting interval of about 21 d (Márquez 1994, Rostal 2005).

Increasing numbers of Kemp's ridley nests were found in south Texas starting in the mid-1990s (Shaver 2005), but more dead adult Kemp's ridley turtles were being found washed ashore (stranded) there than anywhere else in the USA, and it was feared that this mortality could affect the success of restoration efforts in south Texas (Shaver & Caillouet 1998, Plotkin 1999, Shaver 2005). From 1995 to 2003, most of these stranded adults were located during times when Gulf waters off the Texas coast were open to shrimp trawling (Shaver 2005), and shrimp trawling had been identified as a causal factor in sea turtle strandings in Texas (Caillouet et al. 1991, 1995, 1996, Shaver 1998, 1999).

Satellite telemetry studies by Byles (1989), Mysing & Vanselous (1989), and Renaud et al. (1996) have shown that adult female Kemp's ridleys are primarily nearshore, shallow-water inhabitants, capable of swimming long distances in a directed manner. However, when our study was initiated in 1997, knowledge about movements and habitat utilization of adult female Kemp's ridley turtles in south Texas waters was limited and none known to have nested in south Texas or any other locale in the USA had been monitored via tracking. Our study was undertaken to gain information on movements and habitat utilization for Kemp's ridley turtles that nested on and near PINS by satellite tracking to enhance knowledge and aid with restoration efforts. Our objectives were to (1) gather information that could be used by management entities to protect adult females in the marine environment; (2) use tracking data to predict where and when Kemp's ridley turtles would lay additional clutches during a nesting season, to aid with nest detection for documentation and protection; (3) compare movements and habitat utilization of wild and the 2 groups of head-started turtles; and (4) compare movements and habitat utilization of individuals during different tracking events. Determining distribution and migratory pathways, and identifying marine habitat, are Priority 1 tasks in the Kemp's ridley recovery plan (USFWS & NMFS 1992).

MATERIALS AND METHODS

Transmitter deployment. Satellite platform transmitter terminals (PTTs, n = 36) were fitted on Kemp's ridley sea turtles after they nested on the south Texas coast (2 on Mustang Island, 1 on North Padre Island north of PINS, and 33 on PINS) between 1997 and 2006 (Table 1). PTTs used were models ST-6 (n = 22), ST-18 (n = 1), ST-14 (n = 3), and ST-20 (n = 10), manufactured

Table 1. *Lepidochelys kempii*. Adult female Kemp's ridley turtles that nested on North Padre Island or Mustang Island, Texas, USA, and tracked in the Gulf of Mexico using satellite telemetry. PTT: platform transmitter terminal. WI: turtle from the wild stock; PIHS; Padre Island imprinted head-start; MXHS: Mexico imprinted head-start. LC: location class for locations mapped (after screening using location rejection criteria described below; see 'Analysis of data')

PTT ID no.	Tag type	Individual ID no.	Origin	Year-class	Date deployed	Date last location	No. of days locations transmitted	LC						No. of locations mapped
								3	2	1	0	A	B	
7886	ST-6	5	WI	–	13 Jun 1997	13 Sep 1997	93	0	0	0	0	2	11	13
7687	ST-6	7	WI	–	21 Jun 1997	9 Aug 1998	415	1	2	4	37	50	105	199
7685A	ST-6	10	WI	–	10 May 1998	14 Feb 1999	281	0	0	0	2	6	25	33
7689	ST-6	8	PIHS	1984	25 Apr 1998	8 Dec 1998	228	2	0	6	11	35	66	120
7681A	ST-6	9	WI	–	25 Apr 1998	22 Sep 1998	151	0	0	6	4	10	42	62
21811	ST-6	11	PIHS	1986	22 May 1998	2 Jun 1999	377	0	0	3	20	56	170	249
18281	ST-6	14	PIHS	1984	9 Apr 1999	30 Nov 1999	236	0	0	3	12	24	48	87
18160	ST-6	16	WI	–	6 May 1999	8 June 2000	400	1	3	4	53	36	128	225
18277	ST-6	18	PIHS	1986	10 May 1999	27 May 1999	18	1	0	1	10	10	15	37
18308	ST-6	15	PIHS	1986	20 Apr 1999	31 Oct 1999	167	2	0	2	7	17	50	78
18299	ST-6	19	WI	–	26 May 1999	4 July 1999	40	0	0	0	0	10	12	22
18301	ST-6	20	WI	–	26 May 1999	8 Oct 1999	136	0	0	0	8	29	77	114
18277A	ST-6	21	WI	–	19 Apr 2000	25 July 2000	98	0	0	3	3	16	64	86
21811A	ST-6	22	WI	–	13 Apr 2000	14 Oct 2000	185	0	1	4	19	53	100	177
24857	ST-6	23	WI	–	22 Apr 2000	14 Nov 2000	207	3	4	18	14	16	43	98
29351	ST-6	8	PIHS	1984	24 Apr 2001	9 Jan 2002	261	3	22	82	81	63	79	330
24858	ST-6	20	WI	–	16 May 2001	14 May 2002	364	1	1	7	48	101	178	336
29350	ST-6	28	PIHS	1987	20 May 2001	1 June 2002	378	2	2	18	38	42	134	236
25220	ST-6	30	WI	–	24 Apr 2002	30 Jan 2003	282	0	1	11	43	71	195	321
25217	ST-6	12	PIHS	1987	26 Apr 2002	6 Jun 2003	407	6	17	50	125	147	201	546
25218	ST-6	31	WI	–	27 Apr 2002	11 Jun 2003	411	0	1	16	60	82	241	400
25219	ST-6	21	WI	–	29 Apr 2002	24 Mar 2003	330	0	0	9	29	68	174	280
15520	ST-18	45	PIHS	1987	13 May 2003	13 Aug 2004	459	2	7	9	19	31	57	125
17804	ST-14	42	MXHS	1993	9 Apr 2003	25 Sep 2004	536	9	22	28	32	82	141	314
17806	ST-14	43	MXHS	1992	5 May 2003	22 Aug 2005	841	15	36	56	33	129	294	563
17807	ST-14	44	WI	–	6 May 2003	1 Mar 2004	301	3	7	12	13	46	97	178
47789	ST-20	54	PIHS	1987	1 May 2004	30 Mar 2005	334	18	27	59	51	85	147	387
47790	ST-20	21	WI	–	1 May 2004	25 Sep 2004	148	5	13	13	23	52	101	207
47791	ST-20	55	WI	–	2 May 2004	17 May 2005	381	9	7	22	26	73	208	345
53628	ST-20	9	WI	–	23 Apr 2005	1 May 2005	9	0	1	1	0	1	3	6
53629	ST-20	68	WI	–	28 Apr 2005	29 Mar 2006	336	0	1	14	20	73	162	270
53630	ST-20	69	WI	–	28 Apr 2005	8 Jan 2006	256	4	6	8	12	45	135	210
53631	ST-20	28	PIHS	1987	8 May 2005	23 Sep 2005	139	3	6	28	33	61	104	235
62822	ST-20	30	WI	–	26 Apr 2006	2 Apr 2007	344	13	33	35	35	93	268	477
62943	ST-20	12	PIHS	1987	26 Apr 2006	24 Mar 2007	335	21	47	96	67	121	160	512
62823	ST-20	84	WI	–	26 Apr 2006	3 Aug 2006	100	3	3	5	8	38	68	125

by Telonics. The 36 PTTs were deployed to monitor movements of 28 individuals, with 1 individual receiving 3 PTTs during different years, 6 receiving 2, and 21 receiving 1. The turtles measured 57.2 to 66.5 cm straight line carapace length (mean = 62.4 ± 1.8 cm, n = 36) at the time of each PTT deployment.

Each turtle was examined for the presence of living, passive integrated transponder (PIT), coded wire, and metal flipper tags that could link them to head-starting (Caillouet et al. 1997, B. M. Higgins pers. comm.) or previous nesting. Turtles that possessed tags applied during head-starting were classified as head-started and those that lacked those tags were classified as being from the wild stock. The 28 individuals selected for tracking included 17 from the wild stock, 9 Padre Island imprinted head-starts, and 2 Mexico imprinted head-starts (Table 1). One of the Padre Island imprinted head-starts (Turtle 18) had been held head-started for 3 yr prior to release, whereas all other head-starts monitored had been reared for 9 to 11 mo. Each turtle was assigned an individual identification number (Table 1), which was a consecutive number for the Kemp's ridley turtles documented during nesting and non-nesting emergences on the Texas coast starting in 1991.

PTTs were attached to the second neural scute of the carapace using standard methods (Balazs et al. 1996), on a base of fiberglass insulation, fiberglass cloth, or silicon elastimer, using 3 thin layers of polyester resin and fiberglass cloth. Turtles were restrained by hand during the attachment procedure (approximately 3 h). After PTT attachment, each turtle lacking a PIT or metal flipper tag was marked and released at PINS.

Transmitters were programmed with the transmission (duty) cycle of 6 h on/6 h off. Data received by satellites were distributed to ground stations and processed and disseminated by Service Argos (Argos 1996) and later CLS America. When multiple transmissions were received from a transmitter during a satellite pass, a location and location class (LC) were provided. Locations of the turtles (latitude and longitude) were calculated by Service Argos and CLS America from the Doppler shift in transmission frequency detected by a satellite as it approached and then moved away from the transmitter (Argos 1996).

The calculation and accuracy of latitude and longitude was dependent on the number of messages received from a PTT during a satellite pass and the angle of the satellite relative to the PTT. Argos supplied LC for each calculated latitude and longitude; these included LC 3, 2, 1, 0, A, B, or Z (Argos 1996). Argos has estimated that accuracy in latitude and longitude for LC 3 is <150 m, from 150 to 350 m for LC 2, from 350 to 1000 m for LC 1, and >1000 m for LC 0 (Argos 1996). LC Z are rejected, invalid locations. Argos provides no estimation of location accuracy for LC A and LC B. Hays et al. (2001a) found that the accuracy of LC A was comparable to that of LC 1 and LC B had poorer accuracy than LC A, but the worst level of accuracy was found in LC 0.

Analysis of data. Location data were filtered using Satellite Tracking and Analysis Tool (STAT) (Coyne & Godley 2005). Locations were rejected if they met one or more of the following criteria: (1) the location elevation exceeded 0.5 m (i.e. was on land); (2) the rate of movement of a turtle between 2 consecutive locations exceeded 5 km h^{-1}; or (3) the turning angle was smaller than 5°. For each turtle, accepted locations were plotted sequentially using geographic information systems software (ArcView, Environmental Systems Research Institute) to depict sequence of movement. Composite plots of locations for wild turtles, Padre Island imprinted head-starts, and Mexico imprinted head-starts were compared visually, as were composite plots of locations for the same individuals during different tracking events.

The number of locations mapped and number of days from the date that the PTT was deployed to the date that the last location was mapped were calculated for each PTT. All means are followed by ±1 SD.

Use of tracking data for marine protection. During the late-1990s, prior to publication of this manuscript, Texas Parks and Wildlife Department (TPWD) requested data from this study to aid with their development of a regulation in association with revision of their shrimp fishery management plan. As requested, we provided the percentages of filtered locations that fell within specified timeframes and geographic boundaries off the Texas coast. They used these data to help delineate a time and area closure to shrimp trawling that they proposed to the TPWD Commission.

Use of tracking data to aid with nest detection. Tracking data were used to help predict where and when a turtle would nest again, to aid with nest location and protection. Data were queried daily starting by Day 10 after nesting, a few days prior to when the turtle could subsequently nest again. When the turtle was located close to shore in the vicinity of the nest site where they had been previously intercepted, we increased vigilance for nest detection there through slower or more frequent patrols, and sometimes more public education.

RESULTS

Tracking duration and location class

After filtering, 8003 locations were accepted and mapped including LC 3 (n = 127), LC 2 (n = 270), LC 1 (n = 633), LC 0 (n = 996), LC A (n = 1874), and LC B (n = 4103) (Table 1). For the 28 turtles monitored (n = 36 PTTs), the number of mapped locations ranged from 6 to 563 (mean = 222 ± 155) and the number of days from PTT deployment until the last accepted and mapped location from 9 to 841 d (mean = 277 ± 164 d) (Table 1).

Movements and habitat utilization

All turtles remained in the Gulf of Mexico and adjacent bays for the duration of the tracking period (Fig. 2a). Most locations were in near-shore Gulf of Mexico waters of ≤37 m (20 fm) water depth. After they completed nesting for the season, most of the tracked turtles left south Texas and migrated northward, parallel to the coastline, with their last identified locations in the northern or eastern Gulf of Mexico. One exception was Turtle 8 (PTT 29351), which appears to have been ill and drifted further offshore, based on dive data and the relatively large number of messages transmitted while in those offshore waters.

Considering all PTTs deployed collectively, internesting residency was documented off south Texas, and post-nesting residency in several Gulf of Mexico areas in the USA ranging from south Texas to the tip of Florida. The areas used most extensively by individuals overlapped and formed a 'hotspot' of distribution spanning from south Texas to the panhandle of Florida.

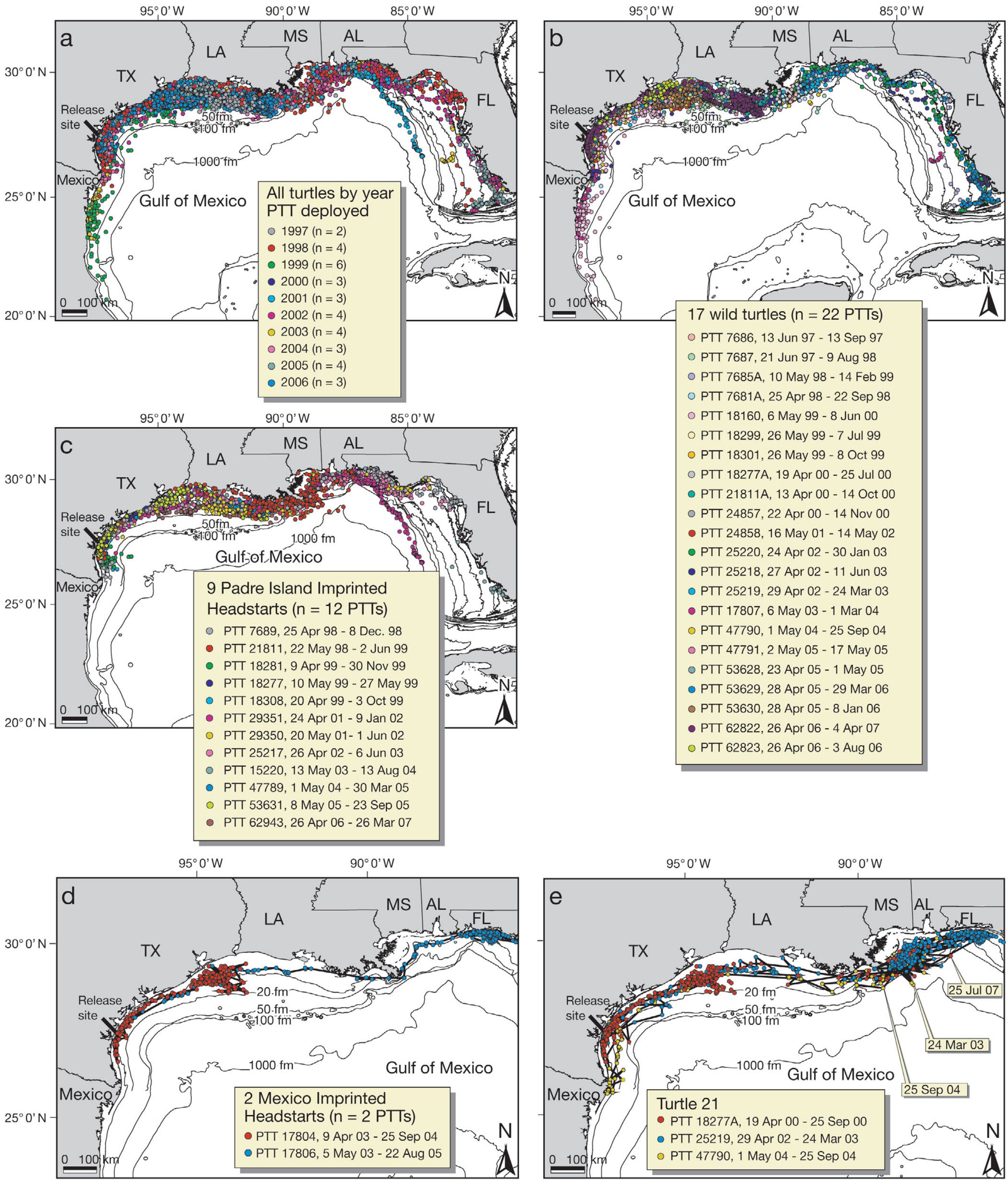

Fig. 2. *Lepidochelys kempii*. Locations of Kemp's ridley turtles tracked by satellite in the Gulf of Mexico after nesting in south Texas, USA. (a) All turles by year platform transmitter terminal (PTT) deployed; (b) 17 wild turtles; (c) 9 Padre Island imprinted head-starts; (d) 2 Mexico imprinted head-starts; (e) Turtle 21. TX: Texas; LA: Louisiana; MS: Mississippi; FL: Florida. Depth in fathoms (= 1.8288 m)

There were variations in movements and habitat use among the 36 tracks, many of which may have been related to tracking duration, number of nests remaining to be laid in a nesting season, re-migration interval, health status of the turtle, and year. None of the turtles tracked during 1999 and 2006 migrated further east than Louisiana, in contrast to during other years (Fig. 2a).

Comparisons of wild and head-started turtles

Movements and habitat utilization of the 17 wild individuals (n = 22 PTTs) (Fig. 2b), 9 Padre Island imprinted head-starts (n = 12 PTTs) (Fig. 2c), and 2 Mexico imprinted head-starts (n = 2 PTTs) (Fig. 2d) were generally similar. The most noteworthy differences were that all of the 5 turtles that briefly traveled southward to waters off the coast of Mexico were wild; the only 2 turtles that remained in south Texas waters after the nesting season was completed (Turtles 14 and 15) were Padre Island imprinted head-starts, and the turtle furthest offshore (Turtle 8, PTT 29351) was a Padre Island imprinted head-start which was likely ill (Fig. 2c).

Comparisons of movements during different events

Movements and habitat utilization of most of the individuals tracked during and after different nesting seasons were generally similar. Turtle 21 was fitted with 3 PTTs (Fig. 2e). During two of the tracks, this turtle did not venture further south of PINS, but during 1 track she briefly traveled southward to the uppermost coast of Mexico. However, after leaving south Texas, during all 3 tracks, she established residency and was last located off eastern Louisiana, Mississippi, Alabama, and the panhandle of Florida.

Six turtles (Turtles 20, 8, 28, 12, 30, and 9) received 2 PTTs. Turtle 20 (Fig. 3a) established residency and was last located off the upper Texas and western Louisiana coasts on both tracks. Turtle 8 (Fig. 3b) ventured to waters off the west coast of Florida during both tracks, although she remained further offshore during the second track, when she was likely ill. Turtle 28 (Fig. 3c) established residency off Louisiana during both tracks, but during the first track, which was 8 mo longer in duration, she migrated to and was last located off the panhandle of Florida. Turtle 12 (Fig. 3d) spent quite a bit of time in a large area from Louisiana to Florida during her first track; during her second track, she did not migrate further east than Louisiana, but that year (2006) none of the tracked turtles did, and she later migrated back to the south Texas coast. Turtle 30 (Fig. 3e) established residency off the coast of Louisiana and did not travel further east during her second track in 2006, one of the 2 years when no turtles traveled further east than Louisiana. During her first track, she spent quite a bit of time in that same area, but later migrated all the way to the tip of Florida. Turtle 9 (Fig. 3f) traveled to the west coast of Florida during the first track, but did not leave south Texas waters during her second track, which only lasted 9 d.

Use of tracking data for marine protection

Tracking data were used for protection of nesters. Since 1994, strandings of adult Kemp's ridleys in the USA have been concentrated on south Texas Gulf beaches. These strandings peaked in 1998, just as TPWD was initiating a revision of their shrimp fishery management plan. Most of these adults were located when Gulf waters off the Texas coast were open to shrimp trawling, and TPWD used data collected from this study to develop a regulation implemented starting in December 2000 that closed near-shore south Texas waters (out to 8 km from shore) to shrimp trawling during the entire Kemp's ridley mating and nesting seasons. This closure has likely helped limit strandings and increase nesting in Texas during recent years (Shaver 2005).

Use of tracking data to aid with nest detection

Turtles were documented nesting subsequently within a nesting season during 11 of the 36 PTT deployments. Data were successfully used to predict where and when many of these turtles nested again, thereby aiding with nest detection and protection. We attempted to use tracking data for 16 other turtles that lingered in south Texas or ventured into waters off the coast of Mexico, but the turtles were not found nesting again. Some nests of unknown maternity were found and could have been from the 16 turtles, but we were unable to conclusively, retrospectively link any to them through examination of nest location and tracking data. The heightened vigilance on nesting days predicted using the tracking data was also likely helpful in locating nests from other turtles that were not tracked.

DISCUSSION

Movements and habitat utilization

Adult female Kemp's ridley turtles in this study appeared to be mostly seasonal residents in the vicinity of the nesting beach. Turtles documented nesting

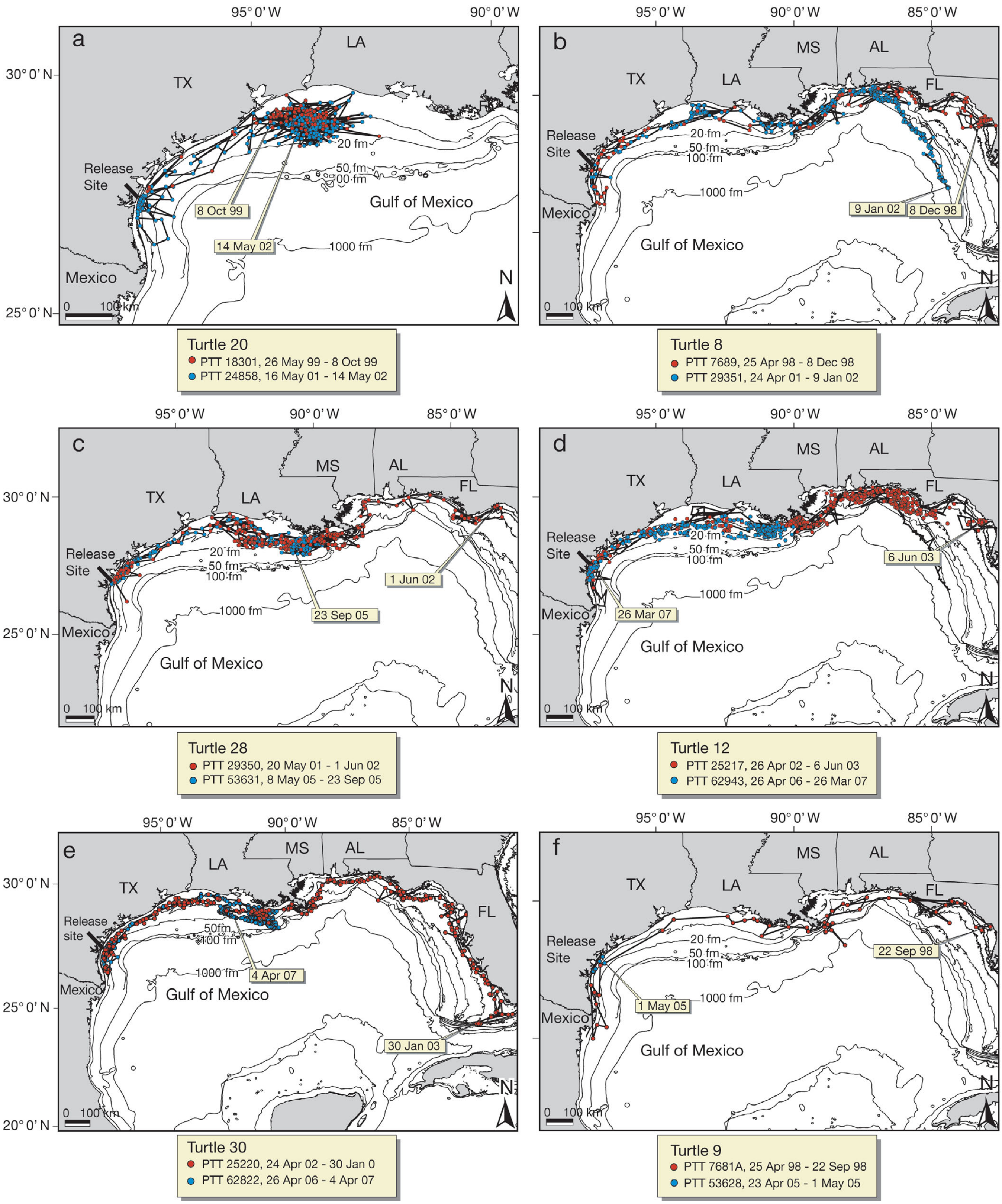

Fig. 3. *Lepidochelys kempii*. Locations of 6 turtles tracked by satellite in the Gulf of Mexico 2 times after nesting in south Texas, USA. (a) Turtle 20; (b) Turtle 8; (c) Turtle 28; (d) Turtle 12; (e) Turtle 30; (f) Turtle 9. TX: Texas; LA: Louisiana; MS: Mississippi; FL: Florida. Depth in fathoms (= 1.8288 m)

multiple times during a nesting season established inter-nesting residency offshore PINS and the nearby area. After completion of nesting, most tracked turtles migrated from waters offshore the nesting beach and moved northward, parallel to the coastline in near-shore Gulf of Mexico waters. Five turtles traveled to waters off the Tamaulipas coast and then migrated northward. They may have nested again, but were not observed and hence it is uncertain whether these were inter-nesting or post-nesting movements. Only two of the 28 individuals (n = 36 PTTs) remained offshore the nesting beach after the nesting season was completed, although one of the 4 turtles currently being tracked has also established post-nesting residency there (authors' unpubl. data). Post-nesting movements and residency for the 36 tracks ranged from south Texas to the tip of Florida, but high-use areas were concentrated from south Texas to the panhandle of Florida.

There were variations in movements and habitat use among the 36 tracks. Many of these variations may have been related to tracking duration, number of nests remaining to be laid in a nesting season, re-migration interval, health status of the turtle, and year, but these possibilities were not tested statistically due to limited sample sizes for these various parameters and uncertainty about subsequent nesting during tracking events.

Only Turtle 12 (PTT 62943) was tracked migrating away from the nesting beach after the end of the nesting season and back in advance of the upcoming nesting season. The mean re-migration interval for Kemp's ridley is 2 yr (TEWG 1998), but occasionally they nest at 1 yr intervals (authors' unpubl. data). Kemp's ridleys nest primarily between April and July. This turtle returned to waters offshore PINS on 23 March 2007 and the first Kemp's ridley nest found in south Texas that year was located on 24 April. Although she was not documented nesting during the 2007 nesting season, she may have nested but not been seen; nesting turtles are only seen at approximately half of the nests documented on the Texas coast and some nests are likely missed (Shaver 2005). It is possible that the transmitter failed in late March because it was damaged or dislodged during mating. Mating is thought to take place before or during the nesting season, about 30 d before oviposition of the first clutch of eggs (see Plotkin et al. 1996, Hays et al. 2001b). An adult female Kemp's ridley captured at a foraging area off the coast of Louisiana, USA, and outfitted with a satellite transmitter on 13 August 1994, moved to waters offshore from the upper Texas coast in late November 1994, arrived offshore from Rancho Nuevo in early March 1995, nested there on 23 April and 19 May 1995, and ceased transmitting there on 16 May 1995 (Renaud et al. 1996).

Other satellite telemetry studies of adult female Kemp's ridley turtles have demonstrated reproductive migrations between nesting and foraging areas (Byles 1989, Mysing & Vanselous 1989, Seney & Landry 2008, this Theme Section). Most adult female Kemp's ridleys fitted with satellite transmitters after nesting at Rancho Nuevo left waters offshore from there between May and July and traveled within near-shore Gulf of Mexico waters directly to distant feeding areas, where they established relatively circumscribed ranges (Byles 1989, Mysing & Vanselous 1989). Of the 6 turtles tracked by Seney & Landry (2008) after nesting on the upper Texas coast, only half were tracked away from that area and those traveled no further east than off Louisiana. The tracking durations lasted only 20 to 153 d and had they been longer perhaps additional and longer distance post-nesting migrations might have been documented. However, the 3 tracks of longest duration (88 to 153 d) were during 2006. None of the turtles tracked in our study during 1999 and 2006 migrated further east than Louisiana, in contrast to during other years when at least one turtle traveled further east (Fig. 2a). Perhaps foraging resources and conditions were more favorable in Texas and Louisiana coastal waters during 1999 and 2006, thus circumventing the need to expend additional energetic resources to travel further to forage.

This and other tracking studies (Byles 1989, Mysing & Vanselous 1989, Renaud & Williams 2005, Seney & Landry (2008) collectively confirm that adult female Kemp's ridleys range through coastal waters along the entire coastline of the Gulf of Mexico and this whole area should be considered important migratory, foraging, and/or inter-nesting habitat. There have been scattered nesting and stranding records along the Atlantic coast of the USA (see Shaver 2005, W. G. Teas pers. comm.), but that aspect of the adult female range was not captured in these tracking studies. Satellite telemetry studies have also confirmed the importance of Gulf of Mexico coastal waters to loggerhead *Caretta caretta* (Timko & Kolz 1982, Renaud & Carpenter 1994, Mansfield 2006) and green sea turtles *Chelonia mydas* (Shaver 2000).

Although most of the females tracked after nesting in Mexico and the USA were migratory, only 1 adult male tracked by Shaver et al. (2005) traveled northward and left waters off the nesting beach in Tamaulipas; all of the other tracked turtles remained resident there for up to 233 d. Differences in movement patterns for these turtles may be indicative of flexible strategies, where some individuals migrate and some remain resident. Crabs are the primary food item of adult Kemp's ridleys (Shaver 1991) and such flexibility would be important with the mobile prey exploited by Kemp's ridley turtles, which can vary in abundance temporally and spatially. Crabs are available off the south Texas and Tamaulipas coasts. However, females may migrate more frequently in search of more dispersed foraging opportunities where competition would be lessened or more optimum foraging sites, such as those thought to be off the mouth of the Mississippi River, USA, and Campeche Banks, Mexico (Hildebrand 1982). Migration destination may vary depending on nesting location. None of the turtles tracked after nesting in Texas during this study and by Seney & Landry (2008) traveled to foraging grounds in the far southern Gulf of Mexico, and none of the tracked turtles that nested at Rancho Nuevo (Byles 1989, Mysing & Vanselous 1989, Renaud & Williams 2005) traveled to or from foraging grounds in the northeastern Gulf of Mexico.

Location class and depth

After data filtering, 8003 locations of LC 3, 2, 1, 0, A, and B remained and were mapped. If the tracking maps had been prepared using only LC 3, 2, and 1 data, only 1030 locations would have remained. Although the general conclusions would have been the same, some details about movements would have been lacking and the tracking periods would have been shortened. Facing similar shortages of LC 3, 2, and 1 locations, some other researchers studying sea turtle movements have also included locations of LC 0, A, and B after extensive data screening (Hughes et al. 1998, Hays et al. 1999, 2001b). Most of the locations identified for the turtles monitored during our study were in near-shore waters 0 to 37 m depth and most of the locations of LC 3, 2, and 1 were within this region. Some of the locations furthest offshore into the Gulf of Mexico were questionable, but could not be ruled out using the rejection criteria we selected. Similar to turtles tracked during our study, other immature and adult Kemp's ridleys monitored in the Gulf of Mexico using satellite telemetry also inhabited primarily shallower water, but sometimes ventured further offshore (Renaud 1995, Renaud et al. 1996, Renaud & Williams 2005).

Results from this and other satellite telemetry studies have demonstrated that adult female and male Kemp's ridley turtles are primarily inhabitants of near-shore waters with relatively shallow depths (Byles 1989, Mysing & Vanselous 1989, Renaud et al. 1996, Renaud & Williams 2005, Shaver et al. 2005). This is in contrast to adult females and males in some olive ridley turtle *Lepidochelys olivacea* populations, which inhabit the oceanic zone with water depths greater than 3000 m (Plotkin 1994, unpubl., Plotkin et al. 1996, Morreale et al. 2007). However, coastal, continental shelf, and continental slope foraging habitats have also been documented for olive ridley (Whiting et al. 2007), and thus foraging habitats are apparently more variable for *L. olivacea* than for *L. kempii*. Furthermore, the along coast movements of adult Kemp's ridley turtles are quite similar to those described for some populations of loggerheads (Luschi et al. 2006), but quite different than the open-ocean movements described for leatherback *Dermochelys coriacea* and some olive ridley turtles (Luschi et al. 2003, McMahon et al. 2007).

Comparisons of wild and head-started turtles and different tracking events

Most of the head-start and wild Kemp's ridleys monitored generally exhibited similar movement patterns. Most used common inter-nesting residency areas, migratory pathways, and foraging areas. One of the most noteworthy differences was that all of the 5 turtles that briefly traveled southward to waters off the coast of Mexico were wild (Fig. 2b). Despite being tagged relatively early in the nesting season, none were detected nesting again and some may have traveled to Mexico to lay a subsequent clutch. To date, 4 wild Kemp's ridleys have been documented emerging on beaches in both south Texas and Mexico, but no head-started individuals have been recorded emerging in both countries (Shaver 2005, authors' unpubl. data).

After completion of the nesting season, all wild Kemp's ridleys with functional PTTs left waters off North Padre Island and were last located where they established residency off the coastal United States in the northern or eastern Gulf of Mexico. Some had traveled southward to Mexico temporarily, but most traveled directly northward. The other noteworthy difference between wild and head-started turtles was that the only 2 turtles that remained off the south Texas coast after the nesting season was completed were Padre Island imprinted head-starts (Fig. 2c). Both were fitted with transmitters in April 1999 and transmissions ceased at the beginning of October and end of November of 1999. However, it is important to note that one of the 4 turtles currently being tracked has also established post-nesting foraging residency off PINS and is a turtle from the wild stock.

Another minor difference between wild and head-started turtles was that the turtle located furthest offshore (Turtle 8, PTT 29351) was a Padre Island imprinted head-start, but this turtle was likely ill. Of the 2 Mexico imprinted head-starts tracked (Fig. 2d), 1 established residency off the upper Texas coast and 1 off the Panhandle of Florida. Some Padre Island imprinted head-starts and wild turtles also established residency in those locations.

Thus, the tracking data suggest that most of the nesting head-started Kemp's ridleys exhibited behaviors similar to wild turtles. A criticism of head-starting was the potential for abnormal behavior after a turtle was released into the wild (Mrosovsky 1983, Taubes 1992). Although some head-started juvenile Kemp's ridleys exhibited atypical evasive behaviors and were found in unusual locations (see Shaver & Wibbels 2007), tracking data collected during the present study indicate that at least some of these turtles eventually adopted natural behavior patterns. Turtle 18 had been head-started for 3 yr prior to release whereas all other head-starts monitored in our study were released after roughly 9 to 11 mo in captivity. The movements and habitat utilization of this turtle did not differ greatly from others monitored, indicating that it had adapted to conditions in the wild as had the others tracked that were held for less time.

The 7 turtles monitored during multiple tracking events generally exhibited similar movement patterns during those events. Most individuals took common near-shore migratory pathways and exhibited fidelity to inter-nesting and foraging habitats during the different tracking events. There were variations, but again, many of these may have been related to the number of nests remaining to be laid in a nesting season, length of the tracking event, re-migration interval, health status, and year (i.e. no turtles tracked during 2006 traveled further east than Louisiana).

Use of data for marine protection

Kemp's ridley is a native nester in Texas, but confirmed records that pre-date the initiation of the imprinting and head-starting project are exclusively from south Texas (Mustang Island to South Padre Island) (see Shaver 2005). Hildebrand (1963) suggested that scattered nesting of Kemp's ridley in south Texas and beaches adjacent to Rancho Nuevo might be remnants of nesting colonies that existed before the species declined. During the last few years, more nesting has occurred in these areas, as the Kemp's ridley nesting population has increased (Shaver & Caillouet 1998, Márquez et al. 2001, Shaver 2005).

Approximately 60 % of the Kemp's ridley nests documented in the USA have been from PINS, the site of the experimental imprinting project and most historic nesting records in Texas (Shaver 2005). During the study period, nests found were mostly from wild stock turtles, followed by Padre Island imprinted head-starts, and Mexico imprinted head-starts (Shaver 2005). Increasing numbers of nests were found beginning in the mid-1990s. Also starting in the mid-1990s, adult Kemp's ridley strandings in the USA increased and occurred most frequently on south Texas Gulf beaches, including PINS (Shaver 2005). Most of these dead adults were found during times when Gulf waters were open to shrimp trawling. In an attempt to decrease mortality of adult Kemp's ridleys in south Texas waters, several environmental groups and biologists suggested the creation of a marine reserve or an area closed to commercial fishing (Plotkin 1999, McDaniel et al. 2000). The TPWD regulation developed using data from the present study had the dual purpose of preventing overfishing in the shrimping industry in Texas and protecting adult Kemp's ridley turtles in south Texas waters. This regulation established a new annual closure of Gulf waters to shrimp trawling off North Padre Island, South Padre Island, and Boca Chica Beach out to 8 km from shore, from 1 December through mid-May each year, preceding the existing annual Texas Closure which typically extends from mid-May through mid-July. This regulation went into effect on 1 December 2000 and has helped protect adult Kemp's ridley turtles in south Texas (Lewison et al. 2003). The new closure likely contributed to the sharp increase in nesting documented on the Texas coast from 2002 to 2007 (Shaver 2005, authors' unpubl. data). Also, adult strandings did not rise during that time, even though they might have been expected to due to the increasing size of the Kemp's ridley population.

Use of data to aid with nest detection

It was hoped that tracking data could be used to predict where and when these turtles would nest again, to aid with detection and protection of their nests and nests of other turtles that emerged on the same day. Tracking data were successfully used to predict where and when some tracked turtles nested again. However, it cannot be quantified whether these 11 nests and others found on these days would have been located without the additional vigilance levied as a result of these predictions. This tool was useful for increasing awareness among patrollers and thereby perhaps increasing their ability to find nests within the very large target patrol area. Additionally, it cannot be concluded that the use of these predictions was unsuccessful for locating subsequent nesting by the 16 turtles that lingered in south Texas or ventured into Mexico for which additional nesting was not documented. Nests were found near the times and locations predicted for some of the 16 turtles and could have been from these turtles, but the nesting females had already entered the water. Georges et al. (2007) used surface times exceeding 10 min (assumed to be haulout) as a criterion to classify nesting events of leatherback turtles, but we were unable to use this since our PTTs did not transmit haulout data. We were unable to conclusively, retrospectively link any nests of unknown maternity to the 16 turtles using our tracking data, perhaps due to the limited precision of location data, duty cycle of the PTTs (i.e. 6 h on/6 h off), and quick nesting habits of the species. GPS transmitters which have a higher degree of location precision would likely be more suitable for use to predict nesting and identify it retrospectively. GPS tracking has been successfully used to examine small-scale movements of loggerhead turtles in near-shore waters (Schofield et al. 2007).

Conservation implications

Near-shore waters of the Gulf of Mexico provide vital migratory, foraging, and inter-nesting habitat for adult Kemp's ridley turtles. Evidence of a seasonally resident population of adult females underscores the need for protection of the marine habitat adjacent to the south Texas nesting beach during the mating and nesting seasons. The closure established by TPWD was likely important in limiting strandings and increasing nesting in south Texas, thereby aiding significantly in the long-term goal of establishing a secondary nesting colony there. The long-term effects of this closure on nesting and stranding levels should be evaluated. Additionally, as numbers of Kemp's ridleys nesting in south Texas continue to rise, the numbers that remain in south Texas after the nesting season is completed will also likely rise. The number of stranded turtles should be monitored to evaluate if the closure should be extended more months, greater distances from shore, or elsewhere northward off the Texas coast where inter-nesting residency, foraging, and migration occur. Satellite tracking data could again be used to help define closure parameters. Additional satellite transmitters should be deployed on adult females as nesting continues to increase in south Texas and tracking technology improves, to gather more information on nesting, seasonality, residency, movements, and habitat utilization. The data obtained could be useful for enhancing and developing effective recovery strategies (Godley et al. 2008, this Theme Section), including protected marine areas, for this critically endangered species.

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