Chelonian Conservation and Biology, 2005, 4(4):846–859

Analysis of the Kemp's Ridley Imprinting and Headstart Project at Padre Island National Seashore, Texas, 1978–88, with Subsequent Nesting and Stranding Records on the Texas Coast

DONNA J. SHAVER[1]

[1]*National Park Service, Padre Island National Seashore, P.O. Box 181300, Corpus Christi, Texas 78480-1300 USA [Fax: 361-949-1312; E-mail: donna_shaver@nps.gov]*

ABSTRACT. – **An experimental imprinting and headstart project was conducted to increase Kemp's ridley sea turtle (*Lepidochelys kempii*) nesting at Padre Island National Seashore (PINS), Texas, USA. From 1978–88, 22,507 eggs were collected at Rancho Nuevo, Tamaulipas, Mexico, for experimental imprinting to PINS by exposure of the eggs to PINS sand and exposure of the resulting hatchlings to PINS sand and surf. Overall, 77.1% of the eggs hatched. The pivotal sex determining temperature for Kemp's ridley eggs was estimated to be 30.2°C and the project turtles had an overall estimated sex ratio of 1.5F:1M. From 1979–89, 13,211 headstarted yearling turtles from this project were released, most into the Gulf of Mexico off south Texas. An additional 300 headstarted turtles from this project were released after 2–16 yrs in captivity. Additionally, 10,198 headstarted yearling turtles that had been obtained as hatchlings from Rancho Nuevo in 1978–80, 1983, and 1989–2000 were released, with the objective that they would return to Mexico to reproduce. Through 2004, 90% of the Kemp's ridley nests ever documented in the USA were in Texas. From 1985–2004, 171 confirmed Kemp's ridley nests were found on the Texas coast. From 1996–2004, 13 headstarted turtles that had been experimentally imprinted to PINS laid 24 clutches in south Texas. These turtles ranged from 10–18 yrs old when first detected nesting and were the first experimentally imprinted sea turtles confirmed to have returned to their imprinting site to nest. These turtles also represented the first confirmed nesting in the wild of headstarted sea turtles and first documentation of known-aged Kemp's ridley turtles nesting in the wild. Additionally, from 2002–04, eight headstarted individuals that had been obtained from Rancho Nuevo as hatchlings laid nine clutches in Texas. Although these findings suggest that the imprinting and headstarting projects enhanced nesting numbers in south Texas, from 1986–2003, more adult Kemp's ridley turtles were found stranded in Texas than in any other state in the USA. Strandings became increasingly concentrated on south Texas beaches during this time, with the largest numbers found between 1994–2003, generally coinciding with the increased number of nests. From 1995–2003, 152 of the 268 stranded adult Kemp's ridleys found in the USA were on south Texas beaches; 142 of the 152 were located during times when Gulf waters off the Texas coast were open to shrimp trawling.**

KEY WORDS. – **Reptilia; Testudines; Cheloniidae; *Lepidochelys kempii*; sea turtle; endangered; nesting; sex ratio; incubation temperature; pivotal temperature; conservation; Texas; USA**

The critically endangered Kemp's ridley turtle (*Lepidochelys kempii*) has been the subject of intensive, long-term population restoration efforts. Evidence suggests that only one genetically distinct stock of this species exists (Bowen et al., 1991). Most Kemp's ridley nesting occurs in the vicinity of Rancho Nuevo, Tamaulipas, Mexico (Fig. 1) (Márquez et al., 1982). In 1947, an estimated 40,000 adult females nested at Rancho Nuevo on one day (Hildebrand, 1963). The Mexican Government initiated protection efforts at the Rancho Nuevo nesting beach in 1966 (Márquez, 1970), and a program was conducted by P.C.H. Pritchard and the World Wildlife Fund in 1968, 1970, and 1973, but the nesting population had been depleted and continued to plummet. This has been interpreted by Pritchard (1997) as the usual occurrence when the stress has been massive egg collection, with populations continuing to drop until the pipeline is full again. 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 project was conducted from 1978–88 to aid in the recovery of Kemp's ridley turtles by increasing nesting and establishing a viable nesting colony at Padre Island National Seashore (PINS) (Fig. 1), located on North Padre Island, Texas, USA (Shaver, 1989, 1990; Shaver and Miller, 1999). The establishment of a secondary nesting colony could provide a safeguard for the species, so that if a political or environmental catastrophe occurred in Rancho Nuevo, there would be an area in the USA where this species could nest and be protected. PINS, the longest stretch of undeveloped barrier island beach in the United States, was selected because ridleys already nested there (Werler, 1951; Hildebrand, 1963; Carr, 1967; Francis, 1978); Rancho Nuevo is the peak of a bell-shaped nesting distribution curve, with tails reaching to south Texas in the north and to Veracruz in the south (Hildebrand, 1963; Shaver and Caillouet, 1998; Burchfield, 2003). Addition-

Figure 1. Map of the western Gulf of Mexico showing the locations of sites and NMFS Statistical Zones. Padre Island National Seashore is shown as the black shaded area on North Padre Island.

ally, PINS, a unit of the USA national park system, offered protection to nesting turtles.

Based on the strong nest site fidelity of adult females, Carr (1967) and others suggested that marine turtles might "imprint" to, and nest on, their natal beach. Attempts were made to experimentally imprint Kemp's ridley turtles to PINS in hopes that they would later return to nest. This imprinting project involved exposing Kemp's ridley eggs to PINS sand and hatchlings to PINS sand and surf. When the experimental imprinting project was initiated, it was unknown whether any of the experimentally imprinted turtles would return to nest in south Texas. Additionally, the role of incubation temperature in sex determination and the pivotal temperature (temperature at which a sex ratio of 1:1 is produced) for Kemp's ridley were unknown; it has since been learned for sea turtles that warm temperatures during the middle third of incubation produce females and cool temperatures males (Mrosovsky, 1994; Ackerman, 1997). During this project, data were collected on incubation temperatures, pivotal temperatures, beach temperatures, sex ratios, egg fertility rates, and embryology of unhatched eggs to evaluate incubation conditions, improve management techniques, and enhance understanding of poorly known aspects of the biology of this species.

Experimentally imprinted turtles were transferred to the National Marine Fisheries Service (NMFS) Laboratory in Galveston, Texas (Fig. 1) for rearing in captivity (headstarting) in an attempt to increase their likelihood of survival after release and to enable tagging for future recognition. Additional hatchlings were obtained directly from Rancho Nuevo and transferred to the NMFS Laboratory for headstarting, with the objective that these turtles would recruit into the population nesting in Mexico.

Efforts to detect nesting turtles from the experimental imprinting and headstarting projects began in 1986 in an attempt to determine results of these projects and locate and protect nests to enhance recruitment and thereby aid the program to establish a viable nesting colony. Most Kemp's ridley nests found on the Texas coast from 1979–2004 were transferred to the incubation facility at PINS. Although the Kemp's ridley population has recently shown promising signs of increase (Burchfield, 2003; Márquez et al., 2005), mortality of adult Kemp's ridley turtles, particularly in Texas, could impact the success of the experimental project (Shaver and Caillouet, 1998) and overall recovery efforts for the species. This paper reviews 26 years of work to increase Kemp's ridley nesting on the Texas coast, including the Padre Island imprinting project and associated egg incubation and other research, nest detection efforts and nesting, factors affecting the detection of nesting by project turtles, and strandings of adult Kemp's ridley turtles.

METHODS

Experimental Imprinting and Release of Headstarted Turtles. — Beginning in 1978, a program of experimental imprinting and headstarting was undertaken to increase nesting by Kemp's ridleys at PINS. From 1978–88, 22,507 Kemp's ridley eggs (about 2000/yr) were collected in Rancho Nuevo, Mexico (Fig. 1). The eggs were collected during oviposition and never allowed to touch Rancho Nuevo sand and were packed into Styrofoam boxes containing Padre Island sand. They were held in a concrete incubation facility at Rancho Nuevo and shipped to a screen-enclosed incubation facility at PINS during incubation, from a few days after the eggs were laid to a few days before hatching (Shaver and Fletcher, 1992).

Incubation boxes were opened about once per week and distilled water was gently sprayed onto the layer of sand at the top of the box if needed. Live and dead hatchlings and unhatched eggs were counted. Clutch and yearly hatching success were calculated by dividing the number of eggs that hatched by the total number of eggs. All live hatchlings were released on the beach at PINS and were allowed to crawl down the beach and enter the surf. After they swam approximately 5–10 m, most were captured using aquarium dip nets, counted, and shipped to the NMFS Laboratory for headstarting (Fontaine et al., 1985; Fontaine and Shaver, 2005).

Turtles were held at the NMFS Laboratory for at least 9 months. Before release, each was marked for future identification. Tagging methods varied for the different year-classes, as new technology developed (Fontaine et al., 1993; Caillouet et al., 1995a, 1997; Fontaine and Shaver, 2005). Turtles received up to four types of internal and external tags (Table 1). All turtles received external metal flipper tags. From the 1983 year-class on, virtually all turtles received living tags, where a small plug of the plastron was imbedded in the carapace on different scutes to designate different year-classes. All turtles from the 1984–88 year-classes re-

ceived internal coded wire tags. Passive integrated transponder (PIT) tags were applied to 247 individuals that were held for extended time periods; these 247 turtles originated from the 1978, 1982, 1984, 1986, 1987, and 1988 year-classes (Caillouet et al., 1997). Most of the experimentally imprinted turtles were released into the Gulf of Mexico offshore from the south Texas coast (Fontaine et al., 1990; Caillouet et al., 1995a).

From 1978–2000, over 10,000 hatchlings that emerged from nests incubated in a corral, crawled on the beach, and temporarily entered the surf in Rancho Nuevo, were retrieved and transported to the NMFS Laboratory for headstarting. Prior to release, they were marked with metal flipper tags, living tags (beginning with the 1983 year-class), and coded wire and PIT tags (beginning with the 1989 year-class). Most were released into the Gulf of Mexico offshore from Galveston Island (Caillouet et al., 1995a; B. Higgins, *pers. comm.*).

Incubation Temperatures, Incubation Periods, and Sex Ratios. — Beginning in 1982, incubation temperatures of eggs used for the experimental imprinting project were measured twice daily at Rancho Nuevo and once an hour at PINS (Shaver et al., 1988). A variety of techniques were used to determine the sex of dead individuals and older captive turtles. Sex was identified for dead late-stage embryos and hatchlings using gonadal histology, for larger dead turtles using necropsy, and for larger live turtles using laparoscopy, serum testosterone assays, and tail length evaluations (adults only).

Incubation period was calculated for each clutch and defined as the number of days from nest deposition to hatching detection; typically hatching was detected at pipping rather than at emergence onto the sand surface. Yearly mean incubation periods were calculated. Incubation periods and percent females for all clutches in the 1982–88 year-classes in which 10 or more individuals were positively identified to gender ($n = 31$) were correlated (Shaver, 1989).

Pivotal and Beach Temperatures. — Mean middle third temperatures and percent females, for all 1982–87 year-class clutches in which 10 or more individuals were positively identified to gender and mean middle third temperatures were below 31.5°C ($n = 20$), were correlated in an attempt to estimate the pivotal temperature for Kemp's ridley (Shaver et al., 1988).

A beach temperature profile study was undertaken during the summer of 1986 to examine temperatures at which Kemp's ridley sea turtle eggs would incubate at three beach locations on PINS and one at Rancho Nuevo (Shaver et al., 1988). Thermocouple probes, placed in the same topographical areas at all study sites, were arranged in six rows ranging from the mid-beach to the middle upslope of the second foredune. Ambient, sand surface, and 15, 30, and 45 cm substrate depth temperatures were recorded at PINS, but only ambient, sand surface, and 30 cm depth (mid-nest depth) temperatures were monitored at Rancho Nuevo. Temperatures were monitored once a week for a 24-hr period, from noon to noon, with readings made once every 2 h. Simultaneous study dates were scheduled from mid-April to mid-August to collect data for the entire nesting and incubation season. Data were collected on all 18 study dates at PINS and 11 of those dates at Rancho Nuevo. Temperatures from the four sites were compared with the estimated pivotal temperature for Kemp's ridley to predict seasonal trends in sex ratios.

Analysis of Unhatched Eggs from the Imprinting Project. — A total of 3902 unhatched eggs from the 1980 and 1982–88 year-classes were examined to quantify fertility rates and embryological stages of development at time of death. Eggs were preserved and examined after full-term clutch incubation (Shaver and Chaney, 1989). Eggs that did not contain embryos were either classified as infertile, fertile, or rotten. Embryo developmental stages were compared to those described by Crastz (1982) for the olive ridley (*Lepidochelys olivacea*) and were classified accordingly if they were compatible or were placed in additional erected stages if they were not. Data were grouped according to thirds of incubation during which death occurred. Eggs that were fertile but contained no identifiable embryos were considered to have succumbed during the first third of incubation. Student-Newman-Keuls Multiple Comparison Tests were used to compare embryonic mortality during thirds of the incubation period in the study years.

Nest Detection. — Efforts to detect and protect nesting Kemp's ridley turtles and their eggs on North Padre Island, and to determine results of the experimental imprinting project, began in 1986 (Shaver, 1990). From 1986–2004, patrols were conducted along the entire 128 km Gulf of Mexico shoreline of North Padre Island, including 104 km of PINS and 24 km north of the PINS boundary. Most of this area is sparsely visited and has treacherous driving conditions; only one access point to the southernmost 96 km of the target patrol area exists.

Patrols were conducted during daylight hours from about April through July. During patrols, the shoreline was searched for emergent sea turtles or their tracks. Mostly four-wheel drive trucks were used for patrols from 1986–92 and mostly all-terrain-vehicles (ATVs) from 1993–2004 (Shaver, 2004). Patrol effort increased over time (Shaver, 2004). From 1986–94, the entire North Padre Island target patrol area was covered from 2–5 days each week. From 1995–97, the entire area was covered 7 days each week. From 1998–2004, the entire area was repeatedly traversed each day. This repeated coverage increased the likelihood of observing nesting females and locating their eggs.

From 1986–98, North Padre Island was the only area on the Texas coast specifically patrolled to detect nesting sea turtles. However, repeated daily patrols were also conducted on South Padre Island beginning in 2000 and on Boca Chica Beach beginning in 1999 (Fig. 1). Educational programs alerting beach visitors to report nesting Kemp's ridley turtles were implemented at PINS in the mid-1980s and later expanded Texas coast-wide (Shaver, 1990; Shaver and Miller, 1999; Shaver, 2004). Visitor reports were investigated, resulting in documentation of nearly half of the

nesting Kemp's ridley turtles and Kemp's ridley nests found in Texas during the last two decades.

Whenever possible, Kemp's ridleys that nested in Texas were examined for the various tags used to mark turtles released from experimental imprinting and headstarting. Unfortunately, only some of the nesters were examined, since many re-entered the water before biologists arrived. Nesting turtles that were observed by biologists were marked with metal flipper and PIT tags.

Attempts were made to locate nests at all locations where nesting Kemp's ridleys or their tracks were found in Texas. Kemp's ridley nests were classified as confirmed when either eggs or emerging hatchlings were found, and either the nesting turtle or the hatchlings were examined to identity species.

Nests in the USA, Tag Returns, and Origin of Kemp's Ridleys Nesting in Texas. — To assess results of experimental imprinting and efforts to increase nesting in Texas, information was gathered on historic nesting in Texas, nesting in the USA since the initiation of the experimental imprinting project, tag returns in Texas, and the origin of nesting Kemp's ridleys. Information on historic nesting of Kemp's ridley at PINS and elsewhere in south Texas was gathered through literature reviews. Records of nesting on the Texas coast from 1978–2004 were obtained from the Texas nesting database and records from other USA states were obtained through literature reviews and personal communications. Texas nesting records were queried to determine the origin of Kemp's ridleys nesting on the Texas coast (e.g., headstarted animals experimentally imprinted to PINS, headstarted animals that had been obtained from Mexico as hatchlings, or wild stock). Turtles were deemed to be headstarted if they possessed a living, coded wire, PIT, and/or metal flipper tag linking them to headstarting. Age of headstarted turtles was calculated based on year-class identified by the tag and nesting date. The number of times that individuals nested during the same and different years and the distribution of nest locations were analyzed to assess nest site fidelity.

Incubation of Eggs from Nestings in Texas. — Kemp's ridley nests found in Texas since 1978 were protected to enhance recruitment. Of the 174 clutches located on the Texas coast from 1979–2004, five incubated *in-situ* (at the nest site) on North Padre and Mustang Islands, 22 were transferred to corrals (screen enclosures) on South Padre Island and Boca Chica Beach, and 147 were packed into styrofoam boxes and transported to an incubation facility at PINS (Table 2). For clutches held in styrofoam boxes at PINS from 1979–88, incubation procedures and data collection for incubating eggs, unhatched eggs, and hatchlings were the same as used simultaneously during the experimental imprinting project and from 1989–2004 were the same as used during 1988. Whenever possible, attempts were also made to calculate hatching success, count the number of hatchlings released, examine unhatched eggs, and calculate sex ratio based on gonadal histology from dead late-stage embryos and hatchings for clutches incubated *in-situ* and in corrals. Hatchlings from all clutches were examined to identify species. Most hatchlings were released on the beach at the incubation sites without marking or retrieval in the surf, but hatchlings from one clutch were released on the beach at PINS, recaptured after release, and transported to the NMFS Laboratory for headstarting.

Strandings. — Sea turtles found stranded on USA shores have been documented by the Sea Turtle Stranding and Salvage Network (STSSN) since 1980 (Shaver, 1998b). Turtles were found and documented during systematic surveys conducted in some areas and as a result of reports from the public. For each stranded turtle, information was collected on species, stranding date and location, tag numbers (if applicable), visible injuries, condition, and final disposition of the animal. The curved carapace length (CCL) and curved carapace width (CCW) or straight line carapace length (SCL) and straight line carapace width (SCW) of most turtles were measured. Information was recorded on standardized forms that were forwarded to the state and subsequently the national STSSN coordinators. The numbers of dead turtles reported by the STSSN provide minimum estimates of mortality since not all dead turtles actually wash ashore to be documented (Caillouet et al., 1991, 1996; Shaver, 1998b).

The STSSN database was queried for records of adult Kemp's ridley turtles found stranded in the USA from 1980–2003. The equation published by Teas (1993) was used to convert CCL to SCL for large Kemp's ridleys when SCL was lacking. Kemp's ridleys measuring 60.0 cm SCL or greater were considered to be adults (TEWG, 1998). Kemp's ridleys measuring less than 60.0 cm SCL have been documented nesting in both Mexico and the USA (Shaver, 1999b). Size is not always a reliable indicator of maturity since marine turtles do not begin to breed at a uniform or minimum size (Miller, 1997; Musick and Limpus, 1997; Limpus, 1998), but size is more reliable for ridleys than for other sea turtles because of their more uniform adult size and less gradual lateral fontanelle closure. Thus, SCL of > 60 cm was the only consistent criterion available to categorize dead Kemp's ridleys documented in the USA from 1980–2003 as adults (Shaver, 1991, 1998b; Manzella and Williams, 1992; TEWG, 1998).

Adult strandings in Texas were tallied by year and NMFS Statistical Zone, with Zones 18 and 19 located on the upper Texas coast and Zones 20 and 21 on the south Texas coast (Fig. 1). Strandings were also categorized as either offshore (Gulf of Mexico beaches) or inshore (bays and passes).

RESULTS AND DISCUSSION

Experimental Imprinting and Release of Headstarted Turtles

Of the 22,507 eggs collected in Rancho Nuevo, 77.1% hatched (Table 1) (Shaver, 1989). Between 1978 and 1988, only 287 of the hatchlings released on the beach at PINS

Table 1. Kemp's ridley eggs that were collected in Rancho Nuevo, Mexico from 1978–88 for experimental imprinting to Padre Island National Seashore (PINS). Eggs were hatched at PINS, hatchlings were released on the beach and captured there, and turtles were headstarted at the National Marine Fisheries Service (NMFS) Laboratory in Galveston, Texas. Data from Shaver et al. (1988), Shaver (1989, 1990), Caillouet (1995), and Caillouet et al. (1995a, 1997).

Year	No. eggs from Rancho Nuevo	Mean incubation period (days)	No. (%) eggs hatched	No. hatchlings died at PINS	No. hatchlings lost during release	No. hatchlings to Galveston	No. yearlings released[a]	Release location[b]	Tag types[c]	No. identified to gender[d]	% female
1978	2191	51.5	1931 (88.1)	64	19	1848	1266	F, N	E	32	34.4
1979	2053	52.0	1769 (85.7)	15	93	1661	1273	F	E	22	40.9
1980	2976	50.5	2502 (84.1)	14	65[e]	1611	1526	N	E	0	-
1981	2279	48.3	1898 (83.3)	11	19	1868	1639	N, B	E	4	100.0
1982	2017	51.0	1563 (77.6)	5	34	1524	1324	N, M, B	E	94	31.9
1983	2006	52.0	242 (12.1)	10	2	230	172	M	E, L	12	50.0
1984	1976	51.1	1792 (90.7)	239	9	1544	1017	N, M	E, L, M	160	28.8
1985	1978	48.8	1664 (84.1)	13	25	1623[f]	1471[f]	N, B, G	E, L, M	158	53.8
1986	2011	46.7	1776 (88.3)	1	16	1759	1629	M	E, L, M	53	83.0
1987	2001	47.6	1288 (64.3)	5	1	1282	1100	N	E, L, M	536	99.6
1988	1019	46.9	933 (91.6)	4	4	925	794	N	E, L, M	49	73.5
Total	22,507	49.7	17,358 (77.1)	381	287	15,875	13,211	-	-	1120	59.6[g]

[a] Excludes 300 turtles that were held in captivity for 2–16 years, 247 of which received passive integrated transponder (PIT) tags.
[b] Locations yearlings were released; F = Gulf of Mexico off Florida, N = Gulf of Mexico off North Padre Island, Texas, M = Gulf of Mexico off Mustang Island, Texas, G = Gulf of Mexico off Galveston, Texas, and B = bay or pass in Texas.
[c] Tag types applied to 65% or more of turtles released from individual year-class; E = external flipper tag, L = living tag, and M = internal coded wire tag.
[d] Determined for dead late-stage embryos and hatchlings using gonadal histology, for larger dead turtles using necropsy, and for larger live turtles using laparoscopy, serum testosterone assays, and tail length evaluations (adults only).
[e] Excludes 810 hatchlings from 11 clutches intentionally released into the Gulf of Mexico at PINS without tags.
[f] Excludes 69 hatchlings from a nest found at PINS that were headstarted at the NMFS Laboratory, from which 63 yearlings were ultimately released into the Gulf of Mexico off North Padre Island, Texas.
[g] Calculated as a mean of individual year-classes.

escaped in the surf during the imprinting/recapture procedure (Table 1); 810 from the 1980 year-class were intentionally released without capture. From 1978–88, 381 hatchlings died at PINS either prior to release or while temporarily held at PINS after release (Table 1). The highest mortality of hatchlings occurred in 1984, when they were retained at PINS for up to 5 days to receive living tags (Fontaine et al., 1993) (Table 1). During other years, hatchlings were generally held at PINS for only 0–3 days prior to shipment. Overall, 15,875 hatchlings from the 1978–88 year-classes were successfully transported to the NMFS Laboratory for headstarting (Fontaine et al., 1985; Fontaine and Shaver, 2005).

After headstarting, 13,511 turtles experimentally imprinted to PINS were released into USA waters, including 13,211 released after 9–11 mo in captivity and 300 after 2–16 yrs in captivity (Fontaine et al., 1990; Caillouet et al., 1995a). Most were released into the Gulf of Mexico, approximately 30 km offshore from Mustang Island and North Padre Island (Fontaine et al., 1990; Caillouet et al., 1995a). However, hundreds were released elsewhere in Texas and most from the 1978 and 1979 year-classes were released off the Gulf coast of Florida (Florida Bay and Homosassa Bay).

Additionally, 10,198 turtles that had been obtained as hatchlings from Rancho Nuevo in 1978–80, 1983, and 1989–2000 were released after 9–33 mo of headstarting (Caillouet et al., 1995a; Higgins, *pers. comm.*). Turtles from the 1978 year-class were released off Homosassa, Florida (n = 751) and North Padre Island (n = 1), 1979 year-class off Homosassa (n = 66), 1980 off Campeche, Mexico (n = 197), 1983 off Mustang Island (n = 18), 1993 off Mustang Island (n = 158), High Island, Texas (n = 1), and Panama City, Florida (n = 29), and 1989–92 and 1994–2000 year-classes off Galveston Island, Texas (n = 8977).

Research on Eggs from the Imprinting Project

Incubation Temperatures, Incubation Periods, and Sex Ratios. — Because of the potential masculinizing effects of incubating sea turtle eggs in styrofoam boxes (Dutton et al., 1985), it was essential to determine whether male-dominated sex ratios were being produced and if so, to develop and implement procedures to increase the production of females to better aid with nesting colony establishment and population recovery. Males predominated in most of the earlier year-classes (Table 1). After 1984, incubation facilities and practices at Rancho Nuevo and PINS were modified in an attempt to raise incubation temperatures and increase the proportion of females produced. These modifications were successful and 77.5% of the turtles examined from the 1985–88 year-classes were identified as females (Shaver et al., 1988). Considering the 1978–88 year-classes collectively, 59.6% of the turtles produced were females (Table 1), for an overall sex ratio of 1.5F:1M.

Yearly mean incubation periods ranged from 46.7 to 52.0 days and generally decreased throughout the project years (Table 1). The warmer incubation temperatures of the 1985–88 year-class clutches shortened incubation periods

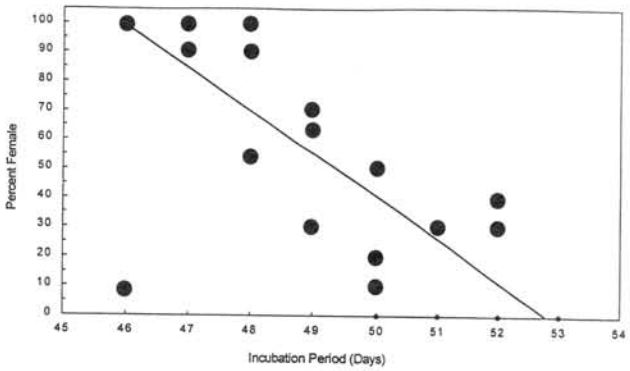

Figure 2. Relationship of incubation period to percent of females for 1982–88 clutches in which 10 or more individuals were positively identified to gender, $r^2 = 0.61$, $p < 0.001$.

and increased percentages of females produced (Shaver et al., 1988; Shaver, 1989). The best straight line regression of percent female (y) versus incubation period (x) was $y = 772.343–14.634x$, $r^2 = 0.61$, $p < 0.001$ (Fig. 2) (Shaver, 1989). Although this relationship is not expected to be straight-line below and above the incubation periods producing 0% and 100% females, respectively, fitting a variety of sigmoid curves to the data did not improve the fit. This equation can be used to estimate percent females for Kemp's ridley clutches with known incubation periods. However, for clutches in which hatching is not detected until emergence, the number of days from hatching until emergence should be subtracted from incubation period, before using the equation. Additionally, estimates must be interpreted with caution if incubation temperatures were not relatively constant during the incubation period (e.g., if they were high during the critical period for sex determination and low before or after).

Pivotal and Beach Temperatures. — All clutches with mean temperatures exceeding 30.8°C during the middle third of the incubation period produced 100% females. The best straight-line regression of percent female (y) versus mean temperature during the middle third of incubation (x) was $y = –1297.8747+44.7152x$, $r^2 = 0.68$, $p < 0.001$ (Fig. 3) (Shaver et al., 1988). Fitting a variety of sigmoid curves to the data did not improve the fit. The pivotal temperature was

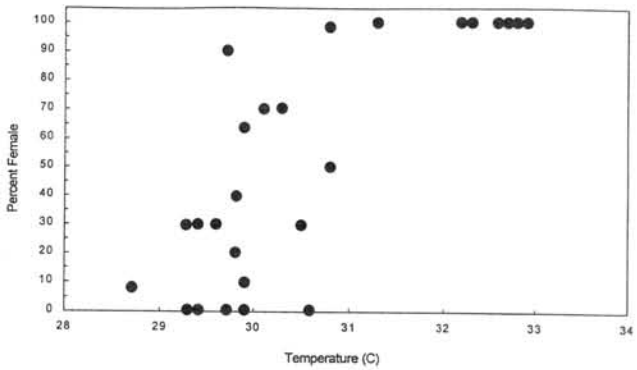

Figure 3. Relationship of mean middle third of incubation period temperatures to percent of females for 1982–87 clutches in which 10 or more individuals were positively identified to gender, $r^2 = 0.68$, $p < 0.001$.

estimated to be 30.2°C with 95% confidence intervals from 29.9–30.5°C (Shaver et al., 1988). Aguilar Reyes (1987), using slightly different temperature monitoring and gonad preservation techniques for nine Kemp's ridley clutches incubated in the beach at Rancho Nuevo, found that those with mean middle third temperatures under 28.6°C produced 100% males and over 31.2°C produced 100% females. Based on these findings, Aguilar Reyes (1987) estimated that the pivotal temperature for this species is approximately 30.0°C.

Based on findings of the beach temperature profile study, clutches that develop early in the nesting season should produce primarily males, later portions of the season primarily females, and middle of the season a mixture (Shaver et al., 1988; Shaver, 1989). Beach temperatures varied slightly with latitude and were warmest at the southern site, Rancho Nuevo, and coolest at the northern site, Closed Beach, PINS.

Analysis of Unhatched Eggs. — Unhatched eggs from the 1980 and 1982–88 year-classes were examined to determine whether procedures employed by the project were adversely affecting embryonic development and viability, and if so, to develop procedures to improve incubation techniques. At least 95% of the eggs from the study years were classified as fertile (Shaver and Chaney, 1989).

Significantly more embryos ceased development during the first third of incubation in the 1983 year-class than during the first third in any other year ($p = 0.01$). Excessive sand moisture and/or fungal infection probably contributed to the low hatching success (12.1%) and high early-stage mortality (Shaver and Chaney, 1989). Due to this finding, procedures were developed and implemented to reduce factors which might introduce or promote fungal infection, including using new incubation boxes for each clutch rather than reusing washed incubation boxes, and transporting dried sand to Rancho Nuevo for later re-hydration and use in egg shipment to PINS rather than shipping moist sand in sealed containers.

Significantly more embryos ceased development during the last trimester of incubation in the 1987 year-class than in any other year ($p = 0.01$). Prior to shipment to PINS, the incubation temperatures of three of these clutches reached 38.0°C on 4 days; only 2.1–12.1% of the eggs in these clutches hatched and most of the unhatched eggs contained late-stage embryos. These high temperatures probably caused the relatively low overall hatching success (64.3%) and high late-stage mortality of this year-class (Shaver, 1989; Shaver and Chaney, 1989). Bustard and Greenham (1968) and McGehee (1979) found no hatching of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) eggs, respectively, incubated at 38.0°C. Subsequently, procedures were developed and implemented using fans, incubation box lid removal, and ventilation to ensure that incubation temperatures did not exceed 36.0°C at the PINS and Rancho Nuevo incubation facilities.

A markedly similar pattern of embryonic death was found in 1982, 1984, 1986, and 1988 year-class eggs, with

highest mortality early in incubation and lowest mortality in the middle of incubation. This pattern of embryonic death may be typical for Kemp's ridleys since no factors were found to adversely influence embryonic survivorship during those 4 years and the trends of mortality were distinctively alike. Similar trends were found by Whitmore and Dutton (1985) in green and leatherback (*Dermochelys coriacea*) eggs and Blanck and Sawyer (1981) in loggerhead eggs.

Nestings in Texas

Historic Nesting in Texas. — Historic Kemp's ridley nesting levels in Texas are unclear and have been discussed by a few authors. A Kemp's ridley nest found at PINS in 1948 was the first confirmed Kemp's ridley nest documented in the USA (Werler, 1951). In 1889, Penrose reported observing numerous "3–4 ft" (ca. 91–122 cm) long turtles laying eggs in south Texas, at the mouth of the Rio Grande, in the sandy riverbank shores (from Fairbanks and Berkey, 1952). Neck (1978) thought that these were probably green turtles, but Hildebrand (1982) thought that they were probably Kemp's ridleys. The size described for these turtles would be more consistent with green turtles rather than Kemp's ridleys. The recent increase in numbers of green turtles nesting at Rancho Nuevo (P. Burchfield, *pers. comm.*) also supports the hypothesis that green turtles once nested in greater abundance in south Texas and Tamaulipas, Mexico, and that these were green turtles. Hildebrand (1963) suggested that scattered Kemp's ridley nesting in south Texas and a few areas in Mexico other than Rancho Nuevo might represent remnants of Kemp's ridley nesting colonies that existed before the tremendous depletion of the species. As the Kemp's population has increased during the last few years, more nests have been found in these other areas (Shaver and Caillouet, 1998; TEWG, 1998; Márquez et al., 1999, 2001), supporting his hypothesis.

Confirmed Nests in the USA. — Most Kemp's ridley nests confirmed in the USA were found in south Texas during recent years. From 1948–2004, 180 Kemp's ridley nests were documented on the Texas coast (Shaver and Caillouet, 1998; Shaver, 2000, 2001, 2002, 2004). Other possible nests were reported, but could not be fully documented. Additional nests likely went unnoticed, particularly on stretches of beach that were difficult to travel and sparsely visited or patrolled.

Of the 180 nests, 171 were found between 1985–2004, with an overall increase beginning in 1995 (Shaver, 1995a, 1996a, 1997, 1999a, 2000, 2001, 2002, 2004; Shaver and Caillouet, 1998; Shaver and Miller, 1999) (Fig. 4). The increase in the number of detected nests during that time may have reflected increased nesting, improved detection efforts, increased awareness and reporting by the public, or a combination of all factors.

Of the 180 nests, 170 were found in south Texas, in NMFS Statistical Zones 20 and 21, including 14 on Mustang Island, 119 on North Padre Island (106 at PINS), 25 on South Padre Island, and 12 on Boca Chica Beach (Fig. 1). The remaining 10 were found on the upper Texas coast, in NMFS Statistical Zones 18 and 19, including 2 on Bolivar Peninsula, 5 on Galveston Island, 1 on Quintana Beach, 1 in

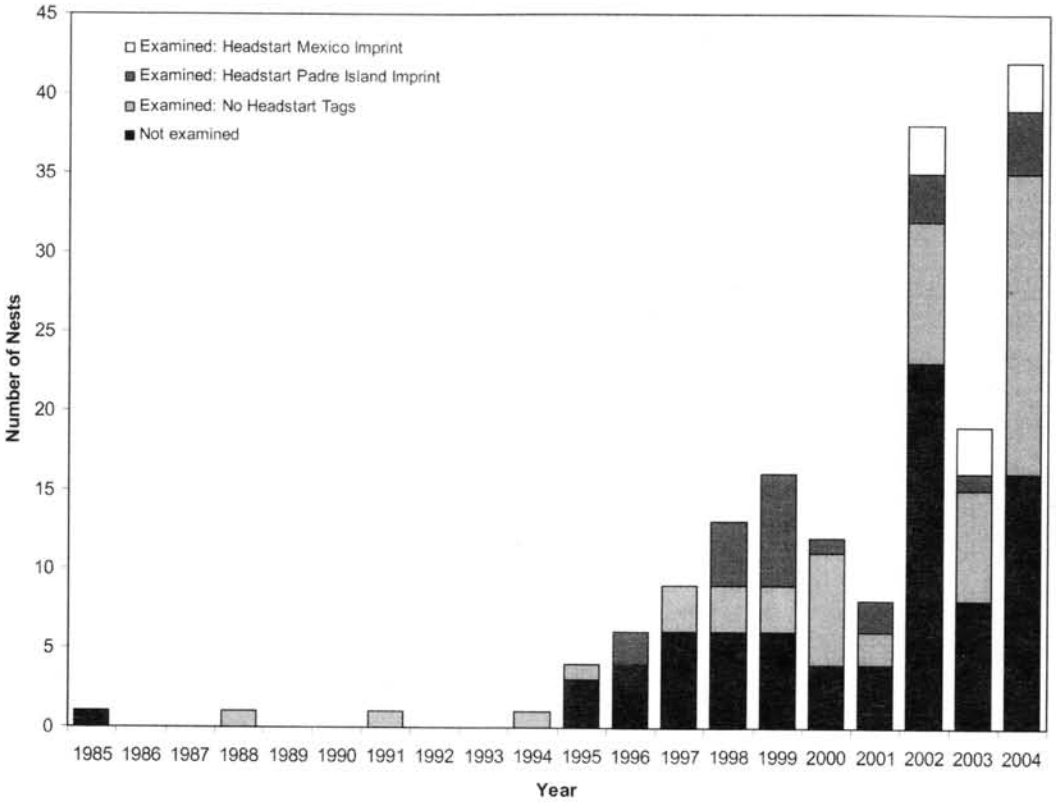

Figure 4. Number of confirmed Kemp's ridley nests found on the Texas coast, 1985–2004.

Surfside, Texas, and 1 on Matagorda Peninsula. From 1948–2004, more confirmed Kemp's ridley nests were located at PINS than at any other location in the USA (Shaver, 1992a, 2000, 2001, 2002, 2004; Shaver and Caillouet, 1998). The only published observation of Kemp's ridley turtles mating in the wild in USA was a pair seen in south Texas, near the southern end of PINS (Shaver, 1992b).

Only 20 Kemp's ridley nests have been documented from 1989–2004 in other USA locations outside Texas. These were on the coasts of Florida ($n = 15$), South Carolina ($n = 1$), North Carolina ($n = 2$), and Alabama ($n = 2$) (Meylan et al., 1990; Anonymous, 1992; Palmatier, 1993; Godfrey, 1996; Libert, 1998; Johnson et al., 1999, 2000; Foote and Mueller, 2002; Nicholas et al., in press; S. Cashes, *pers. comm.*; G. Harman, *pers. comm.*; S. MacPherson, *pers. comm.*; M. Rickard, *pers. comm.*; J. Steiner, *pers. comm.*). Bowen et al. (1994) suggested that these nesting turtles could have been from the Texas imprinting project, since there were no previous confirmed records of Kemp's ridleys nesting in these regions. The nests were found by beach patrollers who located the tracks left by the nesting females or by beach visitors who saw and reported the nesting turtles. Although examinations of available nesting turtles or their photographs revealed no external metal or living tags that linked them to the imprinting project, the turtles could have been from the earliest year-classes that were released without living tags. However, these 20 nests were not concentrated around sites where headstarted yearlings were released in the late 1970s (e.g., Homosassa and Florida Bay, Florida). Although 15 of the 20 nests were found in Florida, the coastline is substantially longer in Florida than in Alabama, South Carolina, and North Carolina, and the 15 were widely distributed on both east and west coasts.

Nesting by Project Turtles.—Experimentally imprinted and headstarted Kemp's ridley turtles were documented nesting on the Texas coast and near Rancho Nuevo, but a variety of factors possibly limited records and assessment of project results. Prior to 1985, no released turtles from this project would likely have been mature and able to nest (Wood and Wood, 1988; Caillouet et al., 1995b; Chaloupka and Zug, 1997; Schmid and Witzell, 1997; Zug et al., 1997). Of the 171 Kemp's ridley nests found in Texas since 1985, nesting turtles were examined for tags at 89 of the nests (Fig. 4) (Shaver and Caillouet, 1998; Shaver 2000, 2001, 2002, 2004). At 56 of those 89, the turtles did not possess any tags linking them to the project. However, 24 of the nests were conclusively linked to headstarted turtles experimentally imprinted to PINS during this project (Shaver, 1996a,b, 1997, 1998a,b, 2000, 2001, 2002, 2004; Shaver and Caillouet, 1998). Thirteen different project turtles laid these 24 clutches. The 13 individuals were identified by living tags and most also possessed coded wire tags. They represented five year-classes (1983–84 and 1986–88) and ranged from 10 to 18 yrs old when first detected nesting. Of the 13 project turtles, 7 were detected nesting once, 3 nesting twice within a year, 1 nesting twice within one year and once during one other year, and 2 nesting twice within one year and once during two other years. The 24 nests were found in south Texas, including on PINS ($n = 15$), North Padre Island north of PINS ($n = 4$), and Mustang Island ($n = 5$). Three of the six individuals recorded nesting more than once exhibited strong nest site fidelity at PINS (within 6 km), while the other three nested at two of these three areas.

The returns of these turtles from the experimental project represented the: 1) first nesting in the wild of known-aged Kemp's ridleys; 2) first confirmed records of headstarted sea turtles nesting in the wild; and, 3) first confirmed records of sea turtles experimentally imprinted to an area returning to that imprinting area to nest (Shaver, 1996a,b, 1997). These observations provided evidence in support of the imprinting and natal homing hypotheses (Owens et al., 1982). Initial supporting evidence that the turtles from this project may have been successfully experimentally imprinted was gathered for 4-mo old hatchlings during multiple choice laboratory studies conducted in the early 1980s (Grassman et al., 1984; Owens et al., 1986; Grassman, 1993).

However, not supporting the natal imprinting hypothesis, 8 headstarted individuals that had been obtained from Rancho Nuevo as hatchlings were documented laying 9 clutches in Texas from 2002–04 (Fig. 4). The individuals were from four year-classes (1989 and 1991–93) and were 10–15 yrs old when first detected nesting. Of the 8 individuals, 1 was found nesting twice within a year and the other 7 once. The 9 nests were found statewide, including on PINS ($n = 5$), Galveston Island ($n = 3$), and Bolivar Peninsula ($n = 1$). From 2002–04, all Kemp's ridleys examined while nesting on the upper Texas coast were from this grouping of headstarted individuals. The location of where these turtles were released as yearlings may have influenced nest site selection for some. Turtles from the 1993 year-class were released off Mustang Island and the only turtle recorded from this year-class was documented nesting twice at nearby PINS. Individuals from the 1989, 1991, and 1992 year-classes were released off Galveston Island and four turtles from these year-classes each nested once on Galveston Island or nearby Bolivar Peninsula. However, three other turtles from the 1989, 1991, and 1992 year-classes laid one clutch of eggs at PINS.

More turtles from this project might have been detected nesting in south Texas had the turtles from the earliest year-classes received living and coded wire tags. Some of the examined turtles that lacked project tags could have been members of the earliest year-classes, released without living and coded wire tags (Shaver, 1998a). Also, more from this project might have been detected nesting had patrol efforts been more comprehensive on North Padre Island (Shaver and Fletcher, 1992) and elsewhere in south Texas. Additional patrol effort would have increased opportunities to check the unexamined nesters for tags and perhaps locate other nestings that went undetected. Nesting observations were also likely limited by mortality of these turtles in the marine environment. Virtually all of the turtles imprinted to PINS were released before mandatory usage of Turtle Excluder Devices (TEDs), designed to reduce mortality of sea

turtles due to incidental capture in shrimp trawls. Caillouet et al. (1995a) reported tag returns for these turtles and predicted that few would survive to adulthood.

The number of observations of project turtles nesting in Texas also may have been limited by these turtles nesting elsewhere. However, of the thousands of Kemp's ridleys that have been examined for tags in Mexico since 1985 and the few that were examined when nesting elsewhere in the USA, only two were conclusively found to possess tags that connected them to headstarting. One experimentally imprinted to PINS was observed nesting at Rancho Nuevo in 1998 and was linked to the 1987 year-class by its living and coded wire tags (R. Márquez, *pers. comm.*). One turtle obtained from Mexico as a hatchling in 1989 (as verified by a living tag, coded wire tag, and metal flipper tag) nested twice in Mexico during 1999 (J. Peña, *pers. comm.*). Through 2004, no other headstarted turtles experimentally imprinted to PINS or obtained from Mexico as hatchlings were confirmed to have nested in the wild elsewhere.

Tag Returns from Other Nesters. — Tag returns were also recorded in south Texas for some Kemp's ridleys that were not experimentally imprinted or headstarted, with varying degrees of nest site fidelity found. Of the 40 nesting Kemp's ridley turtles not linked to experimental imprinting or headstarting that were documented on the Texas coast between 1991 and 2004, tag returns were recorded for 11 of these individuals. Three individuals nested in both south Texas and Mexico and thus showed a low degree of nest site fidelity. One of the three nested at PINS on 10 May 1998 and had a PIT tag that was implanted while she nested at Tepehuajes, Mexico, near Rancho Nuevo on 23 April 1996 (Shaver and Caillouet, 1998; Shaver, 1999b). The second turtle was tagged on 31 May 1998 after nesting at PINS and was observed nesting at Tepehuajes on 24 April 2000 and at Rancho Nuevo on 14 May 2000 (Shaver, 1999b, 2001). The third was tagged on 26 April 2004 after nesting on South Padre Island and was observed nesting at Rancho Nuevo on 23 May 2004 (Mays, *pers. comm.*; Peña, *pers. comm.*). These were the first three confirmed records of individual Kemp's ridley turtles nesting in both the USA and Mexico and indicate some movement of Kemp's ridleys between nesting beaches in south Texas and Mexico. Eight turtles not linked to experimental imprinting and headstarting were documented nesting more than once (during one year or different years) on the south Texas coast through 2004, some with very precise nest site fidelity.

Table 2. Kemp's ridley clutches found on the Texas coast from 1979–2004 and held in an incubation facility at Padre Island National Seashore[a]. Data from Shaver (1989, 1990, 1999b, 2000, 2001, 2002, 2004, unpublished data) and Caillouet (1995).

Year	No. clutches	No. eggs[b]	Mean incubation period (days)	% eggs hatched[c]	No. eggs hatched	No. hatchlings died at PINS before release[d]	No. hatchlings released	No. yearlings released	No. identified to gender[e]	% female
1979	1	67	54.0	97.0	65	0	65	0	0	-
1980	1	113	65.0	54.9	62	0	62	0	0	-
1985	1	97	48.0	72.2	70	1	0	63[f]	5	80.0
1988	1	104	57.0	91.3	95	0	95	0	4	25.0
1991	1	107	52.0	93.5	100	0	100	0	0	-
1994	1	111	47.0	90.1	100	0	100	0	10	60.0
1995	4	335	46.0	90.1	302	2	300	0	3	66.7
1996	6	590	48.7	62.7	370	1	369	0	23	60.9
1997	9	968	47.1	92.6	896	3	893	0	16	68.8
1998	13	1270	48.2	63.1	801	1	800	0	127	56.7
1999	16	1681	49.4	81.5	1370	2	1364	0	22	59.1
2000	11	1086	48.7	86.8	943	0	942	0	47	53.2
2001	5	542	48.4	76.9	417	4	411	0	46	52.2
2002	28	2773	45.4	67.4	1870	33	1833	0	167	92.8
2003	17	1546	46.4	84.2	1301	2	1299	0	43	79.1
2004	32	3033	45.4	86.1	2611	3	2608	0	—[g]	92.0[g]
Total[h]	147	14,423	49.8	80.7	11,373	52	11,241	63	513	65.1

[a] Excludes 1 clutch of 115 eggs laid in 1980 incubated *in-situ* (1.7% hatch, 2 hatchlings released), 1 clutch of 74 eggs laid in 2000 incubated in a corral (78.3% hatch, 58 hatchlings released), 3 clutches totaling 295 eggs laid in 2001 incubated in a corral (58.6% hatch, 173 hatchlings released), 3 clutches totaling 295 eggs laid in 2001 incubated in a corral (58.6% hatch, 173 hatchlings released), 3 clutches laid in 2002 incubated *in-situ* (est. 74.0% hatch, est. 208 hatchlings released), 7 clutches totaling 696 eggs laid in 2002 incubated in a corral (74.0% hatch, 495 hatchlings released), 2 clutches totaling 172 eggs laid in 2003 incubated in a corral (73.8% hatch, 127 hatchlings released), 1 clutch of 41 eggs laid in 2004 incubated in-situ (95.1% hatch, 37 hatchlings released), and 9 clutches totaling 854 eggs laid in 2004 incubated in a corral (76.5% hatch, 653 hatchlings released).

[b] Excludes broken eggs (including 3 from 1995, 12 from 1997, 2 from 1998, 3 from 1999, 7 from 2003, and 4 from 2004).

[c] Yearly percentages equal the number of eggs that hatched each year divided by the total number of eggs incubated each year.

[d] Excludes hatchlings that were too weak during release, were transferred to a rehabilitation facility, and subsequently died (including 1 from 1998, 4 from 1999, 1 from 2000, 2 from 2001, and 4 from 2002).

[e] Identified to gender by histological analysis of gonads from dead embryos and hatchlings.

[f] Includes all 69 hatchlings that were transferred to the National Marine Fisheries Service Laboratory in Galveston, Texas for headstarting, from which 63 yearlings were ultimately released into the Gulf of Mexico off North Padre Island, Texas.

[g] Results of histological analysis of gonads pending; % female estimated based on incubation period.

[h] Total percentages calculated as means of yearly percentages.

Origin of Kemp's Ridleys Nesting in Texas. — Based on tag returns through 2004, Kemp's ridleys currently nesting in south Texas are probably a mixture of headstarted turtles experimentally imprinted to PINS, headstarted turtles that were obtained from Rancho Nuevo as hatchlings, and turtles from the wild stock, with varying degrees of nest site fidelity and some wild individuals nesting both in Mexico and south Texas. They could also include the survivors or descendants from ca. 1227 hatchlings released in a separate project conducted at South Padre Island in 1963–67 (Francis, 1978; Burchfield, 2005). In contrast, Kemp's ridleys nesting on the upper Texas coast may only be headstarted individuals that were obtained from Rancho Nuevo as hatchlings, but more years of data collection are needed to investigate this hypothesis.

Incubation of Eggs from Nestings in Texas. — Hatching success for the 5 clutches incubated *in-situ* on North Padre and Mustang Islands was 56.9%, for the 22 clutches incubated in corrals on South Padre Island and Boca Chica Beach it was 72.2%, and for the 147 clutches incubated at the PINS incubation facility it was 80.7% (Table 2). Overall, 12,994 hatchlings were released on the beach (most at PINS) without retrieval in the surf. An additional 69 hatchlings from a clutch laid at PINS in 1985 were released on the beach, recaptured after release, and transported to the NMFS Laboratory. Sixty-three surviving yearlings from this clutch were ultimately released into the Gulf of Mexico or adjacent bays (Caillouet et al., 1995a). Considering the 147 clutches hatched in the PINS incubation facility collectively, 65.1% of the turtles released were females (Table 2), for an overall estimated sex ratio of 1.9F:1M.

Strandings

Mortality of adult Kemp's ridleys in south Texas waters may have reduced nesting on south Texas beaches. Two subadult males known to be from the experimental imprinting project and documented by the STSSN in the USA were found dead at PINS. These males measured slightly less than 60.0 cm SCL and hence were not categorized as adults. However, they may have been mature since each possessed the secondary sexual characteristics of a softened midplastron, elongated tail, and recurved claws on the anterior flippers. None of the stranded adults of SCL > 60 cm could be linked to the experimental imprinting and headstarting project except one that had only been at large for three weeks (W. Teas, *pers. comm.*) and one from the 1985 year-class that was found at PINS on 14 May 2001; both were eliminated from further analyses. However, some could have been from the project but were unidentifiable because they had been released without living tags, had shed their metal flipper tags, or were found stranded without front flippers and/or carapace scutes and therefore could not be thoroughly examined for tags (Shaver and Caillouet, 1998).

During every year from 1986–2003, more adult Kemp's ridleys were found stranded in Texas than in any other state in the USA (Fig. 5), even though adult Kemp's ridleys forage in, and migrate through, nearshore waters of several other USA states (USFWS and NMFS, 1992; TEWG, 1998; Shaver, 1999b, 2000, 2001, 2002, 2004). Adult strandings on Texas beaches in Zones 20 and 21 increased during this period (Fig. 5). From 1992–2003, adult strandings in the USA occurred most frequently on Texas beaches of Zones 20 and 21 (Fig. 5). The largest numbers were found there

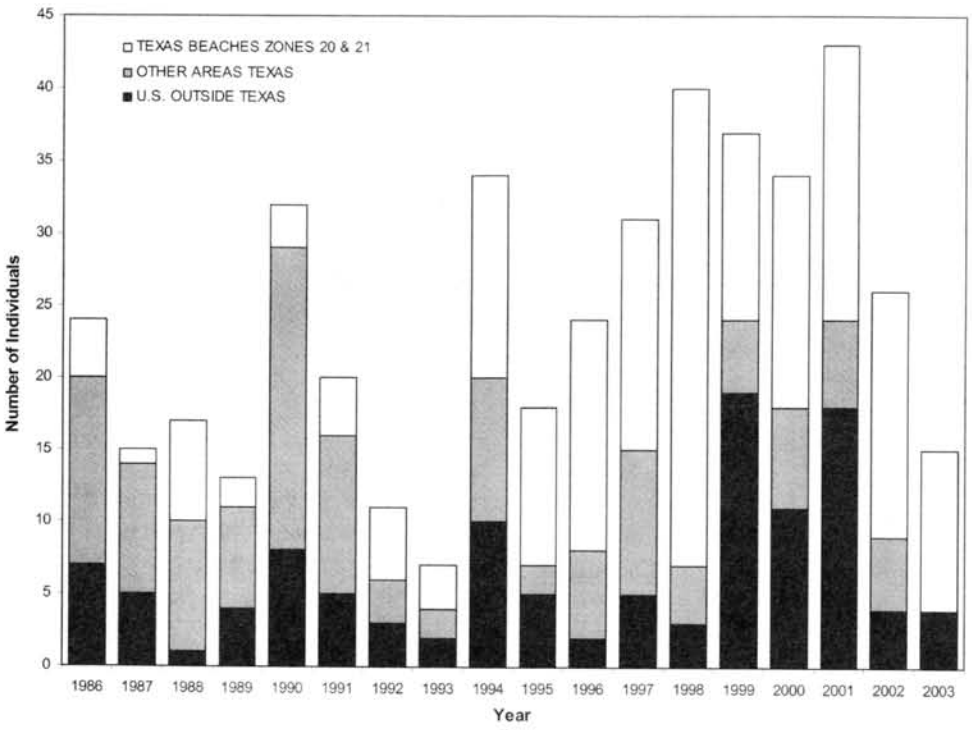

Figure 5. Number of adult Kemp's ridley turtles found stranded in the United States, 1986–2003.

from 1994–2003, roughly the same time that increased numbers of nests were detected. Of the 268 adult Kemp's ridleys found stranded in the USA from 1995–2003, 152 (56.7%) were found stranded on Texas beaches in Zones 20 and 21.

Virtually all of the adult Kemp's ridleys documented as stranded in the USA from 1980–2003 were dead. There are several sources of sea turtle mortality on the Texas coast (Magnuson, 1990; Caillouet et al., 1991, 1996; Shaver, 1998b, 1999b, 2000, 2001, 2002, 2004). These include both natural and human-related factors. Magnuson et al. (1990) concluded that for juveniles, subadults, and breeders in the coastal waters, the most important human-associated source of mortality is incidental capture in shrimp trawls, which accounts for more deaths than all other human activities combined. To decrease this mortality, mandatory use of TEDs began in USA Gulf of Mexico waters in 1990 (Caillouet et al., 1996). Despite reported high compliance with TED regulations, a relationship continued on the Texas coast between Gulf shrimping and strandings on beaches through 2003 (Caillouet et al., 1991, 1996; Shaver, 1994, 1995b, 1996c,d, 1998b, 1999a,b, 2000, 2001, 2002, 2004; Lewison et al., 2003). Of the 152 dead adults found offshore in Zones 20 and 21 from 1995–2003, 142 (93.4%) were located during times when Gulf waters off the Texas coast were open to shrimp trawling. Only 10 were found during the annual Texas Closure, when Gulf waters off the Texas coast out to 322 km from shore were closed to shrimp trawling from mid-May through mid-July. It could be argued that adults might be mostly in Mexico for nesting from mid-May through mid-July, but under that hypothesis they would also be mostly in Mexico for mating and nesting from March through mid-May, when strandings typically spiked in Zones 20 and 21 and shrimp trawling was ongoing.

Strandings of adult Kemp's ridleys in Texas peaked at 37 in 1998. Twenty-four of the 37 were found at PINS, including 14 found between March and July, during the Kemp's ridley mating and nesting seasons; 9 Kemp's ridley nests were located at PINS in 1998. In contrast, at Rancho Nuevo, where 2409 nests were documented during 1998, 6 dead adults were found between March and July. Thus, the number of dead adult Kemp's ridleys per nest in 1998 was 625 times larger for PINS than for Rancho Nuevo, where nearshore waters are closed to commercial fisheries during the sea turtle breeding season (Márquez et al., 1999).

It cannot be proven that the adults that succumbed in south Texas waters from 1980–2003 would have mated or nested in south Texas. Gulf waters off the south Texas coast are also used by Kemp's ridley turtles as foraging habitat (Shaver, 1991) and as a migratory corridor between foraging grounds in USA waters and nesting grounds on the Gulf coast of Mexico (Renaud et al., 1996; Shaver, 1999b, 2000, 2001, 2002, 2004). Slightly more than half of the stranded adults necropsied in Texas were females (Shaver and Caillouet, 1998) and the loss of each female represents a loss of up to three clutches per nesting season, potentially for many years of nesting. Adult females are more important than any other life stage with regard to potential immediate contributions toward the recovery of the species (TEWG, 1998). The deaths of adult female Kemp's ridleys in south Texas represents a substantial loss, whether the turtles would have nested in south Texas or elsewhere. The future of Kemp's ridley nesting in the USA and in Texas is dependent on the survival of adult turtles in this area.

Noting the large number of dead adults found stranded on south Texas beaches, the site of the experimental project and of most Kemp's ridley nests documented in the USA, several environmental groups and biologists recommended the creation of a marine reserve or a closed area to commercial fishing (Plotkin, 1999; McDaniel et al., 2000; Shore, 2000). Texas Parks and Wildlife Department (TPWD) regulations, passed in August 2000 to help sustain the shrimping industry in Texas, 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. This regulation went into effect on 1 December 2000 and may help protect adult Kemp's ridley turtles in south Texas (Lewison et al., 2003). Benefits may have occurred from 2001–04; the new closure may have contributed to the sharp increase in nesting documented in 2002 and 2004 (Fig. 4). Also, adult strandings did not rise from 2001–03 (Fig. 5), even though they might have been expected to rise due to the increasing size of the Kemp's ridley population.

More years of data collection for stranded adult and nesting Kemp's ridley turtles and nests in Texas, as well as protection efforts for various life stages, are needed to evaluate the experimental project and TPWD regulations, and help increase Kemp's ridley nesting in south Texas.

ACKNOWLEDGMENTS

I thank D. Owens for inviting me to present an earlier version of this paper at the Second Symposium on Kemp's Ridley Biology and Conservation, held at South Padre Island, Texas, on 2 March 1999. R. Márquez, the Instituto Nacional de la Pesca, and the government of Mexico are acknowledged for providing eggs for the experimental imprinting project. I thank numerous individuals that aided with the collection, transport, and incubation of eggs; release and transport of hatchlings; and headstarting and release of project turtles during the 1970s and 1980s. P.M. Burchfield, C.W. Caillouet, Jr., A.H. Chaney, D.W. Owens, T. Wibbels, and others aided with beach temperature, embryology, and sex ratio research. C.W. Caillouet, Jr., B. Higgins, T. Fontaine, D.B. Revera, J. Williams, and T. Williams provided information regarding the marking and release of headstarted turtles. A.F. Amos, H. Bennett, P.M. Burchfield, A. Cannon, D. Echols, C. Feit, B. Higgins, D. Hockaday, S. Kethan, J. Mays, J.E. Miller, C. Rubio, T. Torres, A. Wickham, and numerous other individuals assisted with the detection and investigation of nesting and stranded adult Kemp's ridley turtles and Kemp's ridley nests in Texas. Numerous volunteers with the STSSN are thanked for their assistance with

the documentation of stranded adult Kemp's ridleys in Texas and elsewhere in the USA. S. MacPherson, R. Márquez, J. Peña, W. Teas, and others provided helpful information on nests, nesting females, and stranded adults. P. Bohls, K. O'Connell, and C. Rubio prepared the figures for this manuscript. D. Owens and anonymous reviewers provided helpful suggestions for this paper. The work on North Padre Island was supported, assisted, or permitted by the U.S. Geological Survey, National Park Service, U.S. Fish and Wildlife Service, National Marine Fisheries Service, Texas Parks and Wildlife Department, Shell Oil Company, National Fish and Wildlife Foundation, Canon U.S.A., Inc., Unilever HPC, National Park Foundation, Department of the Interior Border Program, HEART, U.S. Marine Corps, U.S. Navy, U.S. Coast Guard, and many others. The efforts on South Padre Island and Boca Chica Beach were conducted by the Gladys Porter Zoo, U.S. Fish and Wildlife Service, University of Texas at Pan American, and others, and on Mustang Island by the University of Texas Marine Science Institute and others.

LITERATURE CITED

ACKERMAN, R.A. 1997. The nest environment and the embryonic development of sea turtles. In: Lutz, P.L. and Musick, J.A. (Eds.). The Biology of Sea Turtles. Boca Raton, FL: CRC Press, pp. 83-106.

AGUILAR REYES, H.M. 1987. Influencia de la temperatua de incubacion sobre la determinacion del sexo y la duracion del periodo de incubacion en la tortuga lora (*Lepidochelys kempi* Garman 1880). Thesis, Instituto Politecnico Nacional Escuela Nacional de Ciencias Biologicas, Mexico.

ANONYMOUS. 1992. First Kemp's ridley nesting in South Carolina. Marine Turtle Newsletter 59:23.

BLANCK, C.E. AND SAWYER, R.H. 1981. Hatchery practices in relation to early embryology of the loggerhead sea turtle, *Caretta caretta* (Linne). Journal of Experimental Marine Biology and Ecology 49:163-177.

BOWEN, B.W., MEYLAN, A.B., AND AVISE, J.C. 1991. Evolutionary distinctiveness of the endangered Kemp's ridley sea turtles. Nature 352:709-711.

BOWEN, B.W., CONANT, T.A., AND HOPKINS-MURPHY, S.R. 1994. Where are they now? The Kemp's Ridley Headstart Project. Conservation Biology 8:853-856.

BURCHFIELD, P.M. 2003. Report on the Mexico/United States of America Population Restoration Project for the Kemp's Ridley Sea Turtle, *Lepidochelys kempii*, on the coasts of Tamaulipas and Veracruz, Mexico. Department of the Interior, U.S. Fish and Wildlife Service. Unpublished, 48 pp.

BURCHFIELD, P.M. 2005. Texas turtles and the Kemp's Ridley Restoration Project. Chelonian Conservation and Biology 4(4):835-837.

BUSTARD, H.R. AND GREENHAM, P. 1968. Physical and chemical factors affecting hatching in the green sea turtle, *Chelonia mydas* (L.). Ecology 49(2):269-276.

CAILLOUET, C.W., JR. 1995. An update of sample sex composition data for head started Kemp's ridley sea turtles. Marine Turtle Newsletter 69:11-14.

CAILLOUET, C.W., JR., DURONSLET, M.J., LANDRY, A.M., JR., AND SHAVER, D.J. 1991. Sea turtle strandings and shrimp fishing effort in the northwestern Gulf of Mexico, 1986-1989. Fishery Bulletin 89(4):712-718.

CAILLOUET, C.W., JR., FONTAINE, C.T., MANZELLA-TIRPAK, S.A., AND SHAVER, D.J. 1995a. Survival of head-started Kemp's ridley sea turtles (*Lepidochelys kempii*) released into the Gulf of Mexico or adjacent bays. Chelonian Conservation and Biology 1(4):285-292.

CAILLOUET, C.W., JR., FONTAINE, C.T., MANZELLA-TIRPAK, S.A., AND WILLIAMS, T.D. 1995b. Growth of head-started Kemp's ridley sea turtles (*Lepidochelys kempii*) following release. Chelonian Conservation and Biology 1(3):231-234.

CAILLOUET C.W, JR., ROBERTSON, B.A., FONTAINE, C.T., WILLIAMS, T.D., HIGGINS, B.M., AND REVERA, D.B. 1997. Distinguishing captive-reared from wild Kemp's ridleys. Marine Turtle Newsletter 77:1-6.

CAILLOUET, C.W., JR., SHAVER, D.J., TEAS, W.G., NANCE, J.N., REVERA, D.B., AND CANNON, A.C. 1996. Relationship between sea turtle strandings and shrimp fishing effort in the Northwestern Gulf of Mexico: 1986-1989 versus 1990-1993. Fishery Bulletin 94(2):237-249.

CARR, A.F. 1967. So Excellent a Fishe: A Natural History of Sea Turtles. New York: Scribner, 280 pp.

CARR, A.F. 1977. Crisis for the Atlantic ridley. Marine Turtle Newsletter 4:2-3.

CHALOUPKA, M. AND ZUG, G.R. 1997. A polyphasic growth function for the endangered Kemp's ridley sea turtle, *Lepidochelys kempii*. Fishery Bulletin 95:849-856.

CRASTZ, F. 1982. Embryological stages of the marine turtle *Lepidochelys olivacea* (Escholtz). Revista de Biologia Tropical 30(2):113-120.

DUTTON, P.H., WHITMORE, C.P., AND MROSOVSKY, N. 1985. Masculinisation of leatherback turtle *Dermochelys coriacea* hatchlings from eggs incubated in Styrofoam boxes. Biological Conservation 31:249-264.

FAIRBANKS, H.R. AND BERKEY, C.P. 1952. Life and letters of R.A.F. Penrose. Journal of the Geological Society of America, 765 pp.

FONTAINE, C.T. AND SHAVER, D.J. 2005. Head-starting the Kemp's ridley sea turtle, *Lepidochelys kempii*, at the NOAA Fisheries Galveston Laboratory (1978 through 1992): a review. Chelonian Conservation and Biology 4(4):838-845.

FONTAINE, C.T., DURONSLET, M.J., REVERA, D.B., WILLIAMS, T.D., WILLIAMS, J.A., MANZELLA, S.A., STABENAU, E.K., LANDRY, A.M., JR., AND CAILLOUET, C.W., JR. 1990. Kemp's Ridley Head Start Experiment and Other Sea Turtle Research at the Galveston Laboratory: Annual Report - Fiscal Year 1989. NOAA Technical Memorandum NMFS-SEFC-266, 63 pp.

FONTAINE, C.T., MARVIN, K.T., WILLIAMS, T.D., BROWNING, W.J., HARRIS, R.M., INDELICATO, K.L.W., SHATTUCK, G.A., AND SADLER, R.A. 1985. The husbandry of hatchling to yearling Kemp's ridley sea turtles (*Lepidochelys kempi*). NOAA Technical Memorandum, NMFS-SEFC-158, 89 pp.

FONTAINE, C.T., REVERA, D.B, WILLIAMS, T.D., AND CAILLOUET, C.W., JR. 1993. Detection, Verification and Decoding of Tags and Marks in Head Started Kemp's Ridley Sea Turtles, *Lepidochelys kempii*. NOAA Technical Memorandum NMFS-SEFC-334, 40 pp.

FOOTE, J.J. AND MUELLER, T.L. 2002. Two Kemp's ridley (*Lepidochelys kempii*) nests on the central Gulf coast of Sarasota County, Florida, USA. In: Mosier, A., Foley, A., and Brost, B. (Compilers). Proceedings of the 20th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-477, pp. 217.

FRANCIS, K. 1978. Kemp's ridley sea turtle conservation programs at South Padre Island, Texas, and Rancho Nuevo, Tamaulipas, Mexico. In: Henderson, G.E. (Ed.). Proceedings of the Florida and Interregional Conference on Sea Turtles. Florida Marine Research Publications 33:51-52.

GODFREY, D. 1996. New riddles about Kemp's ridley. Velador 1996:1-5.

GRASSMAN, M. 1993. Chemosensory orientation behavior in juvenile sea turtles. Brain, Behavior and Evolution 1993(4):224-228.

GRASSMAN, M.A., OWENS, D.W., MCVEY, J.P., AND MÁRQUEZ-M., R. 1984. Olfactory-based orientation in artificially imprinted sea turtles. Science 224:83-84.

HILDEBRAND, H.H. 1963. Hallazgo del area de anidacion de la tortuga marina "lora", *Lepidochelys kempi* (Garman), en la costa occidental del Golfo de Mexico (Rept., Chel.). Ciencia, Mexico 22(4):105-112.

HILDEBRAND, H.H. 1982. A historical review of the status of sea turtle populations in the western Gulf of Mexico. In: Bjorndal, K.A. (Ed.). Biology and Conservation of Sea Turtles. Washington, DC: Smithsonian Institution Press, pp. 447-453.

JOHNSON, S.A., BASS, A.L., LIBERT, B., MARSHALL, M., AND FULK, D. 1999. Kemp's ridley (*Lepidochelys kempii*) nesting in Florida. Florida Scientist 62(3/4):194-204.

JOHNSON, S.A., BASS, A.L., LIBERT, B., MARSHALL, M., AND FULK, D. 2000. Kemp's ridley (*Lepidochelys kempii*) nesting in Florida, USA. In: Kalb, H., and Wibbels, T. (Compilers). Proceedings of the 19th Annual Symposium on Sea Turtle Conservation and Biology. NOAA Technical Memorandum NMFS-SEFC-443, p. 283.

LEWISON, R.L., CROWDER, L.B., AND SHAVER, D.J. 2003. The impact of turtle excluder devices and fisheries closures on loggerhead and Kemp's ridley strandings in the western Gulf of Mexico. Conservation Biology 17(4):1089-1097.

LIBERT, B. 1998. Kemp's ridley nesting in Volusia County. In: Epperly, S.P., and Braun, J. (Compilers). Proceedings of the 17th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-415, p. 219.

LIMPUS, C.J. 1998. Definition of "adult" for marine turtle growth models. In: Epperly, S.P., and Braun, J. (Compilers). Proceedings of the 17th Annual Symposium on Sea Turtle Conservation and Biology. NOAA Technical Memorandum NMFS-SEFC-415, p. 67.

MAGNUSON, J.J., BJORNDAL, K.A., DUPAUL, W.D., GRAHAM, G.L., OWENS, D.W., PETERSON, C.H., PRITCHARD, P.C.H., RICHARDSON, J.I., SAUL, G.E., AND WEST, C.W. 1990. Decline of the Sea Turtles: Causes and Prevention. National Research Council, National Academy Press, Washington, DC, 190 pp.

MANZELLA, S.A. AND WILLIAMS, J.A. 1992. The distribution of Kemp's ridley sea turtles (*Lepidochelys kempi*) along the Texas coast: an atlas. NOAA Technical Report NMFS 110, 52 pp.

MÁRQUEZ M., R. 1970. Las Tortugas marinas de Mexico. Thesis, I.P.N., Escuela Nacional de Ciencas Biologias.

MÁRQUEZ M., R., VILLANUEVA O., A., AND SANCHEZ P., M. 1982. The population of the Kemp's ridley sea turtle in the Gulf of Mexico - *Lepidochelys kempii*. In: Bjorndal, K.A. (Ed.). Biology and Conservation of Sea Turtles. Washington, DC: Smithsonian Institution Press, pp. 159-164.

MÁRQUEZ, R., DÍAZ, J., SÁNCHEZ, M., BURCHFIELD, P., LEO, A., CARRASCO, M., PEÑA, J., JIMÉNEZ, C., AND BRAVO, R. 1999. Results of the Kemp's ridley nesting beach conservation efforts in México. Marine Turtle Newsletter 85:2-4.

MÁRQUEZ-M., R., BURCHFIELD, P., CARRASCO, M.A., JIMÉNEZ, C., DÍAZ, J., GARDUÑO, M., LEO, A., PEÑA, J., BRAVO, R., AND GONZÁLEZ, E. 2001. Update on the Kemp's ridley turtle nesting in Mexico. Marine Turtle Newsletter 92:2-4.

MÁRQUEZ-M., R., BURCHFIELD, P.M., DÍAZ-F., J., SÁNCHEZ-P., M., CARRASCO-A., M., JIMÉNEZ-Q., C., LEO-P., A., BRAVO-G., R., AND PEÑA-V., J. 2005. Status of the Kemp's ridley sea turtle, *Lepidochelys kempii*. Chelonian Conservation and Biology 4(4):761-766.

MCDANIEL, C.J., CROWDER, L.B., AND PRIDDY, J.A. 2000. Spatial dynamics of sea turtle abundance and shrimping intensity in the U.S. Gulf of Mexico. Conservation Ecology 4(1):15.

MCGEHEE, M.A. 1979. Factors affecting the hatching success of loggerhead sea turtle eggs (*Caretta caretta*). M.S. Thesis, University of Central Florida, Orlando.

MEYLAN, A., CASTANEDA, P., COOGAN, C., LOZON, T., AND FLETEMEYER, J. 1990. Life history notes. *Lepidochelys kempi* (Kemp's ridley sea turtle). Reproduction. Herpetological Review 21(1):19-20.

MILLER, J.D. 1997. Reproduction in sea turtles. In: Lutz, P.L., and Musick, J.A. (Eds.). The Biology of Sea Turtles. Boca Raton, FL: CRC Press, pp. 51-81.

MROSOVSKY, N. 1994. Sex ratios of sea turtles. Journal of Experimental Zoology 270:16-27.

MUSICK, J.A. AND LIMPUS, C.J. 1997. Habitat utilization and migration in juvenile sea turtles. In: Lutz, P.L., and Musick, J.A. (Eds.). The Biology of Sea Turtles. Boca Raton, FL: CRC Press, pp. 137-163.

NECK, R.W. 1978. Occurrence of marine turtles in the lower Rio Grande of south Texas (Reptilia, Testudines). Journal of Herpetology 12:419-422.

NICHOLAS, M.A., DAVIS, T.L., BERRY, K.A., RUSSELL, R.R., AND DILLER, A.P. In press. Two additional species of marine turtles nest within Gulf Islands National Seashore's Florida District. In: Proceedings of the 21st Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum.

OWENS, D.W., COMUZZIE, D.C., AND GRASSMAN, M.A. 1986. Chemoreception in the homing and orientation behavior of amphibians and reptiles, with special reference to sea turtles. In: Duvall, D., Muller-Schwarze, D., and Silverstein, R.M. (Eds.). Chemical Signals in Vertebrates, Vol. IV, Ecology, Evolution and Comparative Biology. New York: Plenum Press, pp. 341-355.

OWENS, D.W., GRASSMAN, M.A., AND HENDRICKSON, J.R. 1982. The imprinting hypothesis and sea turtle reproduction. Herpetologica 38(1):124-135.

PALMATIER, R. 1993. Life history notes. *Lepidochelys kempii* (Kemp's ridley). Nesting. Herpetological Review 24(4):149-150.

PLOTKIN, P.T. 1999. Resolutions of the participants at the 19th Annual Symposium on Sea Turtle Biology and Conservation. Marine Turtle Newsletter 85:20-24.

PRITCHARD, P.C.H. 1997. A new interpretation of Mexican ridley population trends. Marine Turtle Newsletter 76:14-17.

RENAUD, M.L., CARPENTER, J.A., WILLIAMS, J.A., AND LANDRY, A.M., JR. 1996. Kemp's ridley sea turtle (*Lepidochelys kempii*) tracked by satellite telemetry from Louisiana to nesting beach at Rancho Nuevo, Tamaulipas, Mexico. Chelonian Conservation and Biology 2(1):108-109.

SCHMID, J.R. AND WITZELL, W.N. 1997. Age and growth of wild Kemp's ridley sea turtles, *Lepidochelys kempi*: cumulative results of tagging studies in Florida. Chelonian Conservation and Biology 2(4):532-537.

SHAVER, D.J. 1989. Results from eleven years of incubating Kemp's ridley sea turtle eggs at Padre Island National Seashore. In: Eckert, S.A., and Eckert, K.L. (Compilers). Proceedings of the 9th Annual Workshop on Sea Turtle Conservation and Biology. NOAA Technical Memorandum NMFS-SEFC-232, pp. 163-165.

SHAVER, D.J. 1990. Kemp's Ridley Project at Padre Island enters a new phase. Park Science 10(1):12-13.

SHAVER, D.J. 1991. Feeding ecology of wild and head-started Kemp's ridley sea turtles in south Texas waters. Journal of Herpetology 25(3):327-334.

SHAVER, D.J. 1992a. Kemp's ridley research continues at Padre Island National Seashore. Park Science 12(4):26-27.

SHAVER, D.J. 1992b. Life history notes: *Lepidochelys kempii* (Kemp's ridley sea turtle). Reproduction. Herpetological Review 23(2):59.

SHAVER, D.J. 1994. Sea turtle strandings along the Texas coast reach alarming levels. Marine Turtle Newsletter 66:8-9.

SHAVER, D.J. 1995a. Kemp's ridley sea turtles nest in south Texas.

Marine Turtle Newsletter 70:10-11.

SHAVER, D.J. 1995b. Sea turtle strandings along the Texas coast again cause concern. Marine Turtle Newsletter 70:2-4.

SHAVER, D.J. 1996a. Head-started Kemp's ridley turtles nest in Texas. Marine Turtle Newsletter 74:5-7.

SHAVER, D.J. 1996b. A note about Kemp's ridleys nesting in Texas. Marine Turtle Newsletter 75:25.

SHAVER, D.J. 1996c. Record numbers of sea turtle strandings along the Texas coast during 1994. In: Keinath, J.A., Barnard, D.E., Musick, J.A., and Bell, B.A. (Compilers). Proceedings of the 15th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-387, pp. 290-293.

SHAVER, D.J. 1996d. Sea turtle strandings along the Texas coast during 1994. In: University of New Orleans (Compiler). Proceedings from the 14th Annual Gulf of Mexico Information Transfer Meeting. Minerals Management Service, Gulf of Mexico OCS Region, MMS 96-0024, pp. 45-49.

SHAVER, D.J. 1997. Kemp's ridley turtles from an international project return to Texas to nest. In: University of New Orleans (Compiler). Proceedings from the 16th Annual Gulf of Mexico Information Transfer Meeting. Minerals Management Service, Gulf of Mexico OCS Region, MMS 97-0038, pp. 38-40.

SHAVER, D.J. 1998a. Kemp's ridley sea turtle nesting on the Texas coast, 1979-1996. In: Epperly, S.P., and Braun, J. (Compilers). Proceedings of the 17th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-415, pp. 91-94.

SHAVER, D.J. 1998b. Sea turtle strandings along the Texas coast, 1980-94. In: Zimmerman, R. (Ed.). Characteristics and Causes of Texas Marine Strandings. NOAA Technical Report NMFS 143, pp. 57-72.

SHAVER, D.J. 1999a. Kemp's Ridley Sea Turtle Project at Padre Island National Seashore, Texas. In: McKay, M., and Nides, J. (Eds). Proceedings from the 17th Annual Gulf of Mexico Information Transfer Meeting. Minerals Management Service, Gulf of Mexico OCS Region, MMS 99-0042, pp. 342-347.

SHAVER, D.J. 1999b. Padre Island National Seashore Kemp's Ridley Sea Turtle Project and Texas Sea Turtle Strandings 1998 Report. Department of the Interior, U.S. Geological Survey. Unpublished, 58 pp.

SHAVER, D.J. 2000. Padre Island National Seashore Kemp's Ridley Sea Turtle Project and Texas Sea Turtle Nesting and Stranding 1999 Report. Department of the Interior, U.S. Geological Survey. Unpublished, 54 pp.

SHAVER, D.J. 2001. Padre Island National Seashore Kemp's Ridley Sea Turtle Project and Texas Sea Turtle Nesting and Stranding 2000 Report. Department of the Interior, U.S. Geological Survey. Unpublished, 59 pp.

SHAVER, D.J. 2002. Kemp's Ridley Sea Turtle Project at Padre Island National Seashore and Texas Sea Turtle Nesting and Stranding 2001 Report. Department of the Interior, U.S. Geological Survey. Unpublished, 29 pp.

SHAVER, D.J. 2004. Kemp's Ridley Sea Turtle Project at Padre Island National Seashore and Texas Sea Turtle Nesting and Stranding 2002 Report. Department of the Interior, U.S. Geological Survey. Unpublished, 41 pp.

SHAVER, D.J. AND CAILLOUET, C.W., JR. 1998. More Kemp's ridley turtles return to south Texas to nest. Marine Turtle Newsletter 82:1-5.

SHAVER, D.J. AND CHANEY, A.H. 1989. An analysis of unhatched Kemp's ridley sea turtle eggs. In: Caillouet, C.W., Jr. and Landry, A.M., Jr. (Eds.). Proceedings of the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management. Texas A&M University, Sea Grant College Program, TAMU-SG-89-105, pp. 82-89

SHAVER, D.J. AND FLETCHER, M.R. 1992. Kemp's ridley sea turtles. Science 257:465-466.

SHAVER, D.J. AND MILLER, J.E. 1999. Kemp's ridley sea turtles return to Padre Island National Seashore. Park Science 19(2):16-17, 39.

SHAVER, D.J., OWENS, D.W., CHANEY, A.H., CAILLOUET, C.W., JR., BURCHFIELD, P. AND MÁRQUEZ M, R. 1988. Styrofoam box and beach temperatures in relation to incubation and sex ratios of Kemp's ridley sea turtles. In: Schroeder, B.A. (Compiler). Proceedings of the 8th Annual Workshop on Sea Turtle Conservation and Biology. NOAA Technical Memorandum NMFS-SEFC-214, pp. 103-108.

SHORE, T. 2000. Creating a Kemp's Ridley Marine Reserve in Texas: The missing link is a proven protection strategy. Endangered Species Update 17(2):35-39.

TEWG (TURTLE EXPERT WORKING GROUP). 1998. An Assessment of the Kemp's Ridley (*Lepidochelys kempii*) and Loggerhead (*Caretta caretta*) Sea Turtle Populations in the Western North Atlantic. NOAA Technical Memorandum NMFS-SEFSC-409, 96 pp.

USFWS AND NMFS (U.S. FISH AND WILDLIFE SERVICE AND NATIONAL MARINE FISHERIES SERVICE). 1992. Recovery Plan for the Kemp's Ridley Sea Turtle (*Lepidochelys kempii*). St. Petersburg, FL: National Marine Fisheries Service, 40 pp.

VALVERDE, R.A., CORNELIUS, S.E., AND MO, C.L. 1998. Decline of the olive ridley sea turtle (*Lepidochelys olivacea*) nesting assemblage at Nancite Beach, Santa Rosa National Park, Costa Rica. Chelonian Conservation and Biology 3(1):58-63.

WERLER, J.E. 1951. Miscellaneous notes on the eggs and young of Texas and Mexican reptiles. Zoologica 36:37-48.

WHITMORE, C.P. AND DUTTON, P.H. 1985. Infertility, embryonic mortality and nest-site selection in leatherback and green sea turtles in Suriname. Biological Conservation 34:251-272.

WOOD, J.R. AND WOOD, F.E. 1988. Captive reproduction of Kemp's ridley *Lepidochelys kempi*. Herpetological Journal 1(6):247-249.

ZUG, G.R., KALB, H.J., AND LUZAR, S.J. 1997. Age and growth in wild Kemp's ridley sea turtles *Lepidochelys kempii* from skeletochronological data. Biological Conservation 80:261-268.

Received: 2 December 2001
Revised and Accepted: 29 September 2004