

Describing Transient Infertility in Kemp's Ridley Sea Turtle (*Lepidochelys kempii*) in Texas, USA

The Kemp's Ridley Sea Turtle (*Lepidochelys kempii*; Fig. 1) is the smallest and most endangered species of sea turtle, nesting only in Mexico and the USA, with over 93% of USA nests in Texas. Extensive efforts have been implemented as part of a long-term, bi-national recovery effort to save the species, which has included translocation of eggs and head-starting of hatchlings (Shaver et al. 2016). While hatching success is highly variable in sea turtle populations and between individuals, in general sea turtles maintain a high rate of egg fertilization (Blanck and Sawyer 1981; Wyneken et al. 1988). Knowing the fertility status of individuals in a population can help guide conservation measures and serve as a proxy for the reproductive health of difficult-to-access males in a population (Glen and Mrosovsky 2004). Infertile eggs are rare and detection is problematic since early embryonic death is frequently mistaken for infertility (Wyneken et al. 1988; Abella et al. 2017). Rarer still are completely infertile clutches; nearly every clutch contains at least a few fertile eggs (Abella et al. 2017). Causes of infertile clutches are not well understood, but can indicate limited opportunities for mating or reproductive impairment. Rates of infertile clutch occurrence should be monitored and an increase should serve as a warning sign for population management concerns.

METHODS

Nesting Kemp's Ridley turtles and nests were found and documented on the Texas coast via reports from the public and during beach patrols from 1979–2018. Standardized regular patrols to detect nesting turtles began on North Padre Island in 1986 and expanded geographically and temporally in Texas as nesting increased (Shaver et al. 2016). When present, the nesting turtle was measured, including straight-line carapace length (nuchal notch to posterior tip; SCL), photographed, and flipper tagged with metal Inconel tags and/or passive integrated transponder tags for future recognition, if no tags were present. All sea turtle nests found in Texas, USA, were relocated to a safe incubation area by highly trained technicians and volunteers using best practices to maximize recruitment (Shaver et al. 2016). The contents of each nest, including all unhatched eggs, were examined upon hatching or completion of a typical full-term clutch incubation period, approximately 47–51 days, if no hatching was observed (Shaver and Chaney 1989). Visual evidence of fertility includes white spot formation on the eggshell surface, or a blood spot, eye

spot, or embryo of any size within the egg (Blanck and Sawyer 1981; Marquez-M. 1994; Wyneken et al. 1988; Abella et al. 2017). Although these signs indicate fertility, lack thereof does not completely exclude fertility. Since embryonic death can occur prior to egg laying at the gastrula stage or earlier and result in a fertile egg with no signs of fertility that are apparent without use of a microscope (Miller 1985), we report only apparent fertility as microscopes were rarely used in examination of eggs. However, because embryonic death at that early stage for an entire clutch of eggs would be extremely rare and infertility a more likely explanation, only clutches where every egg was visually lacking in signs of embryonic development were designated as infertile.

Records of *L. kempii* clutches in Texas from 1979–2018 were searched for examples of apparent complete infertility. Clutches were included only if their condition was such that eggs could be visually examined for signs of embryonic development; badly degraded clutches, depredated clutches, or clutches with abnormal circumstances (e.g., fewer than 50 eggs per clutch, eggs found in the surf, or eggs removed from a recently deceased turtle) were not included. Only clutches for which the mother was identified through tag returns were considered. Further, only individuals with two or more consecutive apparent infertile clutches were selected, to eliminate nests with possible movement-induced mortality (Limpus et al. 1979).

RESULTS

Five of 325 individuals observed nesting more than once laid two or more consecutive clutches that were apparently infertile; of the 27 clutches attributed to these five turtles, 12 were infertile (Table 1). These 12 clutches ranged in size from 79–132 eggs. The nests were widely geographically distributed across north (Bolívar Peninsula), central (Matagorda Island), and south (Mustang Island, North Padre Island, South Padre Island) Texas beaches. Photographs of all five turtles were examined and showed no

THOMAS F. BACKOF
DONNA J. SHAVER*
J. SHELBY WALKER

Division of Sea Turtle Science and Recovery, Padre Island National Seashore, Corpus Christi, Texas 78418, USA

CHRISTOPHER D. MARSHALL

Department of Marine Biology, Texas A&M University, Galveston, Texas, USA; Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas, USA

*Corresponding author; e-mail: donna_shaver@nps.gov



FIG. 1. Kemp's Ridley Sea Turtle (*Lepidochelys kempii*) returning to the sea after nesting at Padre Island National Seashore, Texas.

PHOTO COURTESY OF NPS

TABLE 1. Nests from five individuals, A–E, Kemp's Ridley Sea Turtles (*Lepidochelys kempii*), 1979–2018, exhibiting apparent transient infertility in Texas, USA.

Nest order	A			B			C			D			E		
	Lay date	Loc.	Hatch %*	Lay date	Loc.	Hatch %*	Lay date	Loc.	Hatch %*	Lay date	Loc.	Hatch %*	Lay date	Loc.	Hatch %*
1	6May1999	MI	0	2May2004	NPI	99	26Apr2006	MAT	0	19May2010	BP	0	15Jun2011	NPI	98
2	26May1999	MI	0	6Jun2004	MI	96	11May2006	MAT	0	2Jun2010	BP	0	17May2014	NPI	92
3	18May2002	NPI	0	23May2007	NPI	96	30Apr2007	MAT	99	4May2015	BP	73	26May2016	NPI	0
4	21May2004	MI	95	21May2008	NPI	98							1Jul2016	SPI	0
5	29May2005	MI	95	23Apr2012	NPI	0							17May2018	SPI	0
6	15May2007	MI	97	19May2012	NPI	0							23Jun2018	SPI	0
7				14May2014	NPI	84									
8				8Jun2014	NPI	98									
9				18May2016	NPI	95									

*Nests listed as 0% hatch were 100% infertile with the exception of Turtle A, Nest 1, which was 85% infertile.

Loc. = Location; MI = Mustang Island, NPI = North Padre Island, MAT = Matagorda Island, BP = Bolivar Peninsula, SPI = South Padre Island.

visible evidence of injuries or deformities that could have affected fertility. Each turtle had at least two measurements taken during separate nesting emergences. Turtle A measured 59.4 cm SCL at her fourth documented nest, which is slightly below the size used to categorize a Kemp's ridley turtle as mature (60 cm SCL; TEWG 1998). All other SCL measurements for this and the other four turtles were greater than 60 cm.

DISCUSSION

We document the first examples of transient infertility in *L. kempii*, infertility that is sporadic in the reproductive history of the turtle. There were few instances documented of Kemp's Ridley turtles that laid two or more consecutive infertile clutches on Texas beaches since 1979. All five turtles documented as such also laid fertile clutches, supporting the hypothesis that individual infertility is not permanent and binary, but instead can be intermittent and occur before or after fertile clutches laid by that individual. Turtles laid apparently infertile clutches at the beginning ($N = 2$), middle ($N = 2$), or end ($N = 1$) of the period of documentation. The two consecutive infertile clutches were documented during two nesting years for Turtle E, during one nesting year for Turtles B, C, and D, and for two different nesting years for Turtle A. No turtle had two separate events of consecutive infertility with fertile clutches between them.

Infertility may have been underestimated for individual Kemp's Ridley turtles by excluding clutches that we identified as infertile, either because the nesting individual was not known due to nesting not being observed ($N = 15$ clutches) or because it represented a single infertile clutch record for an individual ($N = 5$ clutches). Exclusion of Kemp's Ridelies with single records of infertility was necessary to limit nests that may have been fertile and perished due to alternative causes such as movement-induced mortality (Limpus et al. 1979) or those misclassified as infertile due to egg decomposition (Abella et al. 2017) or where embryonic death occurred prior to egg laying (Miller 1985) or researcher error (Wyneken et al. 1988).

Identification of embryonic development such as a blood spot within an egg (Blanck and Sawyer 1981; Wyneken et al. 1988) or a white spot on the eggshell surface (Marquez-M. 1994; Abella et al. 2017) is one of the currently accepted methods for

determining apparent egg fertility. A visible opaque external area of calcification, described as a white spot, appears on eggshells within 24–48 hours of egg deposition (Blanck and Sawyer 1981; Márquez-M. 1994; Abella et al. 2017), while infertile eggs remain unchanged and translucent over the entire egg surface (Marquez-M. 1994). Fertility of unhatched Kemp's Ridley eggs was identified during egg analysis after hatching (Shaver and Chaney 1989). Late-stage examination can lead to underestimating fertility due to egg decomposition (Wyneken et al. 1988) but is the preferred method for at-risk species. Waiting until the end of the incubation period, after hatching, to examine unhatched eggs protects any remaining developing embryos in live eggs within that clutch from potentially lethal disturbance (Limpus et al. 1979).

Each of the five turtles had at least one successful nest with >70% hatching, either before or after two consecutive infertile nests, thus permanent infertility is not supported. Nest infertility could be caused by reasons beyond epidemiological factors. Female turtles may refuse mates (Booth and Peters 1972) or may be reproductively immature, even though they have migrated and completed nesting activities. Infertility of nests might also be caused by low genetic diversity (Rafferty et al. 2011). Most Kemp's Ridley nests show multiple and unequal paternity (Kichler et al. 1999); thus, male quality (Abella et al. 2017) and availability (Hays et al. 2010) are potentially causative factors for unfertilized nests, particularly for turtles nesting on the northern coast of the Gulf of Mexico, where nesting is sparse (Shaver et al. 2016).

Infertility of sea turtle clutches is an emerging issue that may increase in prevalence as high female sex ratios increase in sea turtle populations with increasing egg incubation temperatures due to global climate change (Glen and Mrosovsky 2004; Marcovaldi et al. 2016; Jensen et al. 2018). Texas maintains an excellent hatching rate for Kemp's Ridley eggs (85% during the study period), with only 47 of 2615 nests (1.8%) having zero hatch due to all causes in this time span, clearly illustrating the success of our nest relocation strategy with respect to hatching rate. Although rare currently, future cases of infertility should be monitored in Kemp's Ridley and other sea turtle populations as an indicator of population health and to inform management decisions. Causes of intermittent infertility in sea turtles are theorized but not defined and warrant further study.

Acknowledgments.—We thank all partner organizations and individuals who assisted with finding and documenting Kemp's Ridley nests in Texas, USA, and National Park Service personnel who aided with analysis of unhatched eggs. All activities were performed in compliance with required state and federal permits and approved NPS Institutional Animal Care Protocols.

LITERATURE CITED

- ABELLA, E., R. M. GARCÍA-CERDÁ, AND A. MARCO. 2017. Estimating the fertilization rate of sea turtle nests: comparison of two techniques. *Basic Appl. Herpetol.* 31:33–44.
- BLANCK, C. E., AND R. H. SAWYER. 1981. Hatchery practices in relation to early embryology of the loggerhead sea turtle, *Caretta caretta* (Linné). *J. Exp. Mar. Biol. Ecol.* 49:163–177.
- BOOTH, J., AND J. A. PETERS. 1972. Behavioural studies on the green turtle (*Chelonia mydas*) in the sea. *Anim. Behav.* 20:808–812.
- GLEN, F., AND N. MROSOVSKY. 2004. Antigua revisited: the impact of climate change on sand and nest temperatures at a hawksbill turtle (*Eretmochelys imbricata*) nesting beach. *Glob. Change Biol.* 10:2036–2045.
- HAYS, G. C., S. FOSSETTE, K. A. KATSELIDIS, G. SCHOFIELD, AND M. B. GRAVENOR. 2010. Breeding periodicity for male sea turtles, operational sex ratios, and implications in the face of climate change. *Conserv. Biol.* 24:1636–1643.
- JENSEN, M. P., C. D. ALLEN, T. EGUCHI, I. P. BELL, E. L. LACASELLA, W. A. HILTON, C. A. M. HOF, AND P. H. DUTTON. 2018. Environmental warming and feminization of one of the largest sea turtle populations in the world. *Curr. Biol.* 28:154–159.
- KICHLER, K., M. T. HOLDER, S. K. DAVIS, R. MÁRQUEZ-M., AND D. W. OWENS. 1999. Detection of multiple paternity in the Kemp's ridley sea turtle with limited sampling. *Mol. Ecol.* 8:819–830.
- LIMPUS, C. J., V. BAKER, AND J. D. MILLER. 1979. Movement induced mortality of loggerhead eggs. *Herpetologica* 35:335–338.
- MARCOVALDI, M. A. G., M. LÓPEZ-MENDILAHARSU, A. S. SANTOS, G. G. LOPEZ, M. H. GODFREY, F. TOGNIN, C. BAPTISTOTTE, J. C. THOMÉ, A. C. C. DIAS, J. C. DE CASTILHOS, AND M. M. P. B. FUENTES. 2016. Identification of loggerhead male producing beaches in the South Atlantic: implications for conservation. *J. Exp. Mar. Biol.* 477:14–22.
- MARQUEZ-M., R. 1994. Synopsis of biological data on the Kemp's ridley turtle *Lepidochelys kempii* (Garman 1880). NOAA Tech. Memo-NMFS-SEFSC-343. Available from <http://www.sefsc.noaa.gov/species/turtles/techmemos.htm>.
- MILLER, J. D. 1985. Embryology of marine turtles. In C. Gans, F. Billet, and P. F. A. Maderson (eds.), *Biology of the Reptilia*. Vol. 14., pp. 271–328. Interscience, New York.
- RAFFERTY, A. R., P. SANTIDRIÁN TOMILLO, J. R. SPOTILA, F. V. PALADINO, AND R. D. REINA. 2011. Embryonic death is linked to maternal identity in the leatherback turtle (*Dermochelys coriacea*). *PLoS ONE* 6(6):e21038.
- SHAVER, D. J., AND A. H. CHANEY. 1989. Results from an examination of unhatched Kemp's ridley sea turtle eggs. In C. W. Caillout, Jr. and A. M. Landry, Jr. (eds.), *Proceedings from the 1st International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management*, pp. 82–89. Texas A&M University, Sea Grant College Program, TAMUSG-89-105.
- , C. RUBIO, J. S. WALKER, J. GEORGE, A. F. AMOS, K. REICH, C. JONES, AND T. SHEARER. 2016. Kemp's ridley sea turtle (*Lepidochelys kempii*) nesting on the Texas coast: geographic, temporal, and demographic trends through 2014. *Gulf Mex. Sci.* 2:158–178.
- 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 Tech. Memo-NMFS-SEFSC-409. Available from <http://www.sefsc.noaa.gov/species/turtles/techmemos.htm>.
- WYNEKEN, J., T. J. BURKE, M. SALMON, AND D. K. PEDERSEN. 1988. Egg failure in natural and relocated sea turtle nests. *J. Herpetol.* 22:88–96.