2019 Sea Turtle Strandings in Texas: A Summary of Findings & Analyses

October 2020

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
NOAA Technical Memorandum NMFS-OPR-66

Cover photo (background): Live stranded green turtle (*Chelonia mydas*) found in Kenedy County, Texas on 7/3/2020. Photo by Hilary Frandsen, Padre Island National Seashore.

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Recommended citation:

Stacy, B., R. Hardy, D. Shaver, C. Purvin, L. Howell, H. Wilson, M, Devlin, A. Krauss, C. Macon, M. Cook, Z. Wang, L. Flewelling, J. Keene, A. Walker, P. Baker, T. Yaw. 2020. 2019 Sea Turtle Strandings in Texas: A Summary of Findings and Analyses. Department of Commerce, National Marine Fisheries Service, NOAA Technical Memorandum NMFS OPR-66, 64 p.

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List of Acronyms

AMSEAS	American Seas Ocean Model
BPI	Beaching Probability Index
BSP	Brazos Santiago Pass
CFR	Code of Federal Regulations
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea
DA	Domoic acid
EEZ	Exclusive Economic Zone
ELISA	Enzyme-linked immunosorbent assay
GIS	Geographic Information System
GLM	Generalized linear model
GMT	Greenwich Mean Time
LC-MS/MS	Liquid chromatography with tandem mass spectrometry
NCOM	Navy Coastal Ocean Model
NDBC	National Data Buoy Center
NGOFS	Northern Gulf of Mexico Operational Forecast System
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
MLLW	Mean Lower Low Water
PbTx	Brevetoxins
PSP	Paralytic shellfish poisoning
SCL	Straight carapace length
STSSN	Sea Turtle Stranding and Salvage Network
STX	Saxitoxin
TPWD	Texas Parks and Wildlife Department

Acknowledgements

We greatly appreciate the many contributions, dedication, and hard work of the participants in the Sea Turtle Stranding and Salvage Network, the National Park Service, Texas Parks and Wildlife Department, USFWS Texas Coastal ES, and the United States Coast Guard. We also thank the organizations and their staff and volunteers that rehabilitate live sea turtles in Texas, including the Amos Rehabilitation Keep, Houston Zoo-NOAA Galveston Laboratory, Sea Turtle, Inc., Texas Sealife Center, and the Texas State Aquarium. We also thank Drs. Vicente Guzmán-Hernández and Eduardo Cuevas for contributing nesting data for Campeche, Mexico and Dr. Bryan Wallace for facilitating this collaboration. In addition, we appreciate the assistance of Wendy Teas and Lisa Belskis with access to stranding data; the collection of which is coordinated nationally by the NOAA Southeast Fisheries Science Center. Many thanks to Barbara Schroeder, Stacy Hargrove, Mary Kay Skoruppa, Dr. Tom deMaar, Dr. Joseph Flanagan, and staff of the Padre Island National Seashore, including Cynthia Rubio and Shelby Walker, for their thoughtful review of this report.

Executive Summary

This report presents information, analyses, and conclusions related to the investigation of sea turtle strandings in Texas during 2019. During this year, sea turtle strandings were more than two times above average based on statewide stranding numbers for the previous 5 and 10 years. We identified multiple causes based on analysis of stranding data, postmortem examinations, diagnostic testing, and study of environmental factors. Based on these results, four major features characterized sea turtle strandings in Texas in 2019, each with specific temporospatial distributions and different attributed causes:

1. **Numerous strandings of small juvenile green turtles (*Chelonia mydas*) during spring and summer.** Most of these occurred in NMFS zone 20 concurrent with strong onshore winds. These strandings were a substantial contributor to total statewide stranding numbers. Many were found alive and entrapped within inlet jetty rocks or stranded within the intertidal zone. Findings suggest that a combination of factors most likely contributed to these strandings including seasonal or ontogenetic (developmental) transition into nearshore waters, recent increases in green turtle nesting within the western Gulf of Mexico, use of man-made structures for foraging habitat, and environmental conditions.

2. **Stranded Kemp's ridley (*Lepidochelys kempii*) and loggerhead turtles (*Caretta caretta*) with findings suggestive of drowning by forced submergence.** Most of these turtles were found on the Upper Texas Coast during April and May. Observations are similar to reports from previous years that have implicated bycatch in shrimp trawls based on necropsy findings and reduction of these strandings following the annual closure of Texas state waters to commercial shrimping.

3. **Stranded loggerheads in poor nutritional condition.** Most of these strandings occurred in NMFS zone 20 and had comorbidities including ulcerative gastrointestinal disease and impaction by ingested sea pens (order Pennatulacea). Similar presentations have been observed sporadically in loggerheads found stranded in Texas during previous years and throughout other areas of the southeastern U.S. The cause(s) of this condition is not known at this time.

4. **Green turtle mass mortality event linked to illegal gillnetting.** These strandings occurred near the U.S.-Mexico border in November and December and are attributed to drowning in gillnets based on a concurrent discovery of illegal gillnets containing captured green turtles in adjacent coastal waters and exclusion of other causes.

These characteristics and events comprised a majority of strandings observed in Texas during 2019. In addition, many other well-known causes of sea turtle strandings were also identified during this period, including vessel strikes, entanglement and entrapment in fishing-related material, and wounds inflicted by predators.

1. Introduction

The Sea Turtle Stranding and Salvage Network (STSSN) is a cooperative network of federal and state agencies, authorized non-government organizations, and trained public participants that respond to and document stranded sea turtles on the Atlantic and Gulf of Mexico coasts of the U.S. and in U.S. territories within the Caribbean. Any sea turtle that is found on land or in the water that is either dead or alive, but is unable to undergo normal behaviors or movements (e.g., swimming, diving, feeding) is considered “stranded” and is documented by the STSSN. The Texas component of the STSSN is coordinated by the National Park Service (NPS) and has been operating since 1980. All sea turtles species that are commonly found in U.S. waters have been documented among strandings in Texas, including the Kemp’s ridley turtle (*Lepidochelys kempii*), green turtle (*Chelonia mydas*), loggerhead turtle (*Caretta caretta*), hawksbill turtle (*Eretmochelys imbricata*), and leatherback turtle (*Dermochelys coriacea*)(Shaver 1998). All sea turtles are listed as threatened or endangered under the U.S. Endangered Species Act of 1973 as amended (16 U.S.C. §1531 et seq.).

Sea turtle strandings are actively monitored and compared with historical records in order to track known causes of mortality or illness, detect new or previously unrecognized threats, and to identify changes or trends that could be relevant to population recovery or wildlife health. During 2019, sea turtle strandings in Texas substantially exceeded historical averages for much of the year, prompting an intensive investigation of possible contributing causes. This investigation included collection and review of stranding information and photographs, postmortem examination (necropsy) of dead turtles, review of available medical records for live turtles, biotoxin analyses, analysis of relevant weather and oceanographic data, and drift analysis for a selected subset of the strandings. Within this report, we present these results and our conclusions with regard to the determined causes of stranding and potential contributing factors that resulted in the highest number of annual sea turtle strandings ever recorded in Texas, with the exception of cold-stunning events.

2. Methods

2.1. Stranding documentation

Stranded sea turtles are documented by the Texas STSSN through a combination of opportunistic reporting by members of the public and discovery during the dedicated beach surveys to locate sea turtle nests, stranded turtles, or for other purposes. For each stranding, a STSSN participant completes a reporting form (Appendix A) and either photographs the turtle or documents all available information from the reporting party if the turtle is not directly observed by a stranding responder (e.g., from reports or photographs submitted by the public). The reporting form includes the date and location of discovery (including National Marine Fisheries Service (NMFS) statistical zone (Figure 2-1), circumstances, species identity, condition (i.e., alive or degree of decomposition), straight and curved carapace lengths and widths, and notation of any external abnormalities (e.g., injuries, entanglement, abnormal accumulations of epibiota). Straight carapace length (SCL) was used for size comparisons. If only curved measurements were collected, the straight measurement was derived using regression equations provided in Teas (1993).

2.2. Necropsy and diagnostic analyses

2.2.1. Postmortem examination

Necropsies were conducted using routine methods (Stacy et al. 2017), including examination of all organ systems to the degree afforded by postmortem condition. Gross findings were entered onto a standardized reporting form (Appendix A). Whenever possible, pericoelomic fat (representing nutritional condition) and any major abnormalities were photographed. Turtles that were minimally decomposed were sampled for histopathology. Briefly, tissues were preserved in 10% neutral phosphate-buffered formalin, processed into paraffin blocks, and 5µm sections were mounted on glass slides and stained with hematoxylin and eosin. In addition, decomposed turtles with gross abnormalities were selectively sampled for histopathology.

Photographic analysis of fat

Decomposition or scavenging frequently precluded accurate measurement of body weight for turtles that were found deceased. In lieu of body weight and when pertinent to investigation of the cause(s) of stranding, nutritional condition of green turtles was characterized based on photographic comparison of pericoelomic body fat. The degree of atrophy was classified as 1) no atrophy (robust), 2) mild atrophy, 3) moderate atrophy, or 4) severe atrophy (depleted) (Figure 2-2).

Biotoxin analysis

Frozen tissues were collected from a subset of stranded turtles for biotoxin analysis by the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute. Approximately 100 g of liver and 100 ml of stomach contents and feces were collected into individual plastic bags and frozen at -20˚C until analyzed. Kidney also was sampled from some turtles. Tissues were homogenized, and subsamples were taken for each toxin analyzed. Toxins were extracted using organic solvents (80% aqueous methanol for brevetoxins (PbTx); 50% aqueous methanol for domoic acid (DA); and 0.1M hydrochloric acid for saxitoxins (STX)). Extracts were screened for the presence of brevetoxins and brevetoxin metabolites using a competitive enzyme-linked immunosorbent assay (ELISA) performed according to Naar et al. (2002) with modifications as described by Flewelling et al. (2008). Toxin concentrations were calculated using a PbTx-3 standard curve and results are reported in ng PbTx-3 eq/g. Domoic acid analyses were also performed using the Direct cELISA ASP assay (Biosense Laboratories, Bergen, Norway) or liquid chromatography with tandem mass spectrometry (LC-MS/MS) based on the method of Wang et al. (2012). Extracts were analyzed for saxitoxin and other Paralytic Shellfish Poison toxins using Abraxis Saxitoxin (PSP) direct competitive ELISA. In addition, we reviewed the Texas Parks and Wildlife Department algal bloom website (TPWD 2020) and the National Oceanic and Atmospheric Administration's (NOAA) Gulf of Mexico Harmful Algal Bloom Bulletins (NOAA 2020) for field reports of water discoloration events and fish kills.

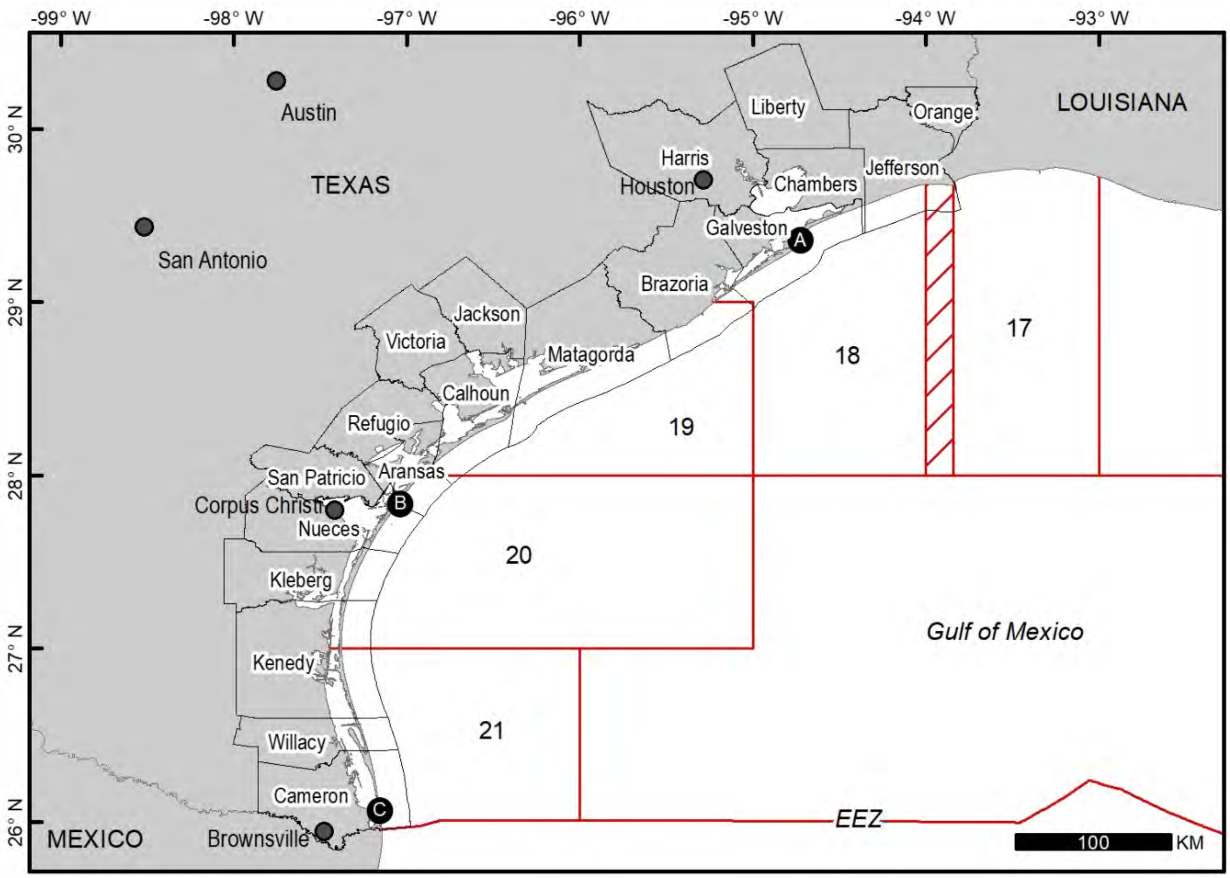


Figure 2-1. The Texas coastal counties and state waters (grey lines) where sea turtle strandings were documented within and along the shorelines of bays, lagoons, sounds, and Gulf of Mexico waters. National Marine Fisheries Service statistical zones (red lines) were used to group data into biogeographically similar regions. Strandings documented within the portion of zone 17 that overlaps Jefferson County, Texas (hatched polygon) were merged with zone 18 for the purposes of this study. In the current report, we refer to zones 18 and 19 as the Upper Texas Coast; zones 20 and 21 as the Lower Texas Coast. Labeled circles indicate the locations of the following NOAA National Data Buoy Center stations from which environmental data were obtained; Galveston Bay Entrance Channel (A), Aransas Pass (B), and South Padre Island Brazos Santiago (C).

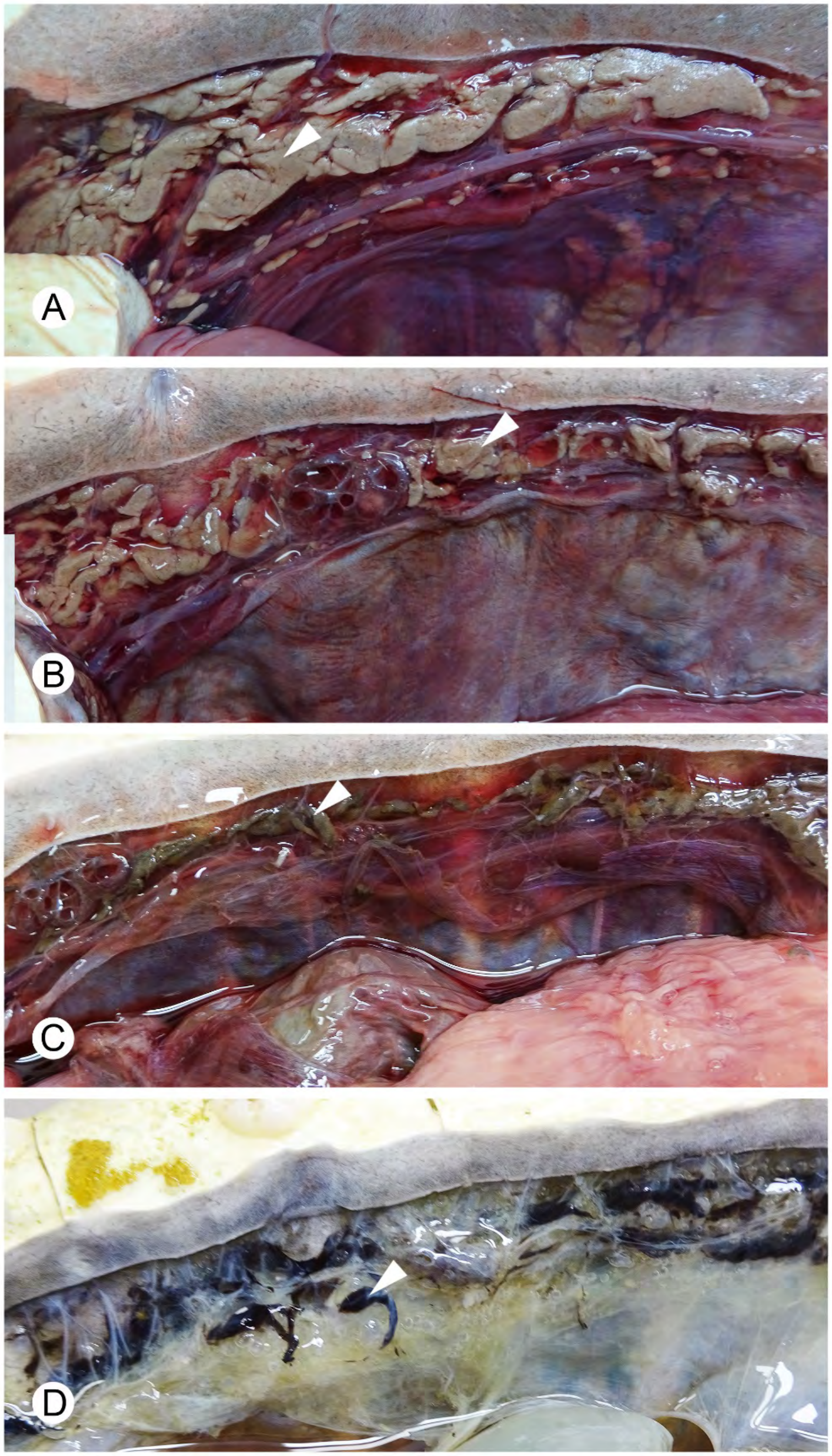
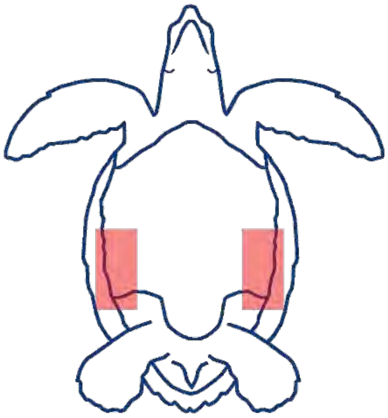


Figure 2-2. Examples of fat condition used to characterize the nutritional state of green turtles. Shown are fat deposits adjacent to the body cavity (coelom) beneath the lateral edges of the shell (red areas in diagram below). Depicted are examples of fat (white arrowheads) with no atrophy (i.e., non-depleted, robust) (A), mild atrophy (B), moderate atrophy (C), and severe atrophy (D). Fat becomes darker and more gelatinous as it is depleted and is black when completely exhausted.



2.3. Stranding characterization

2.3.1. Stranding circumstances, categories, photograph review

Stranding records from Texas were collated by the NPS and cross-referenced with the STSSN database maintained by the NOAA Southeast Fisheries Science Center. Stranding reports were reviewed for information relevant to the circumstances of stranding (Table 2-1). Our analysis focused on "traditional strandings"[1], which is implied in the use of "stranding" or "stranded sea turtle" throughout this report unless otherwise noted. The following were excluded from our analyses:

- 308 cold-stunned sea turtles that were found from November 13 to 19 during a discrete mass event concurrent with water temperatures below 10˚C.
- 51 reports involving recently emerged or released hatchlings, washbacks or posthatchlings (under 10 cm SCL), which included 10 hawksbill turtles.
- 162 incidentally captured turtles including those caught by recreational hook and line, captured by dredges, and entrained in power plant canals.
- One live green turtle that was illegally captured under unknown circumstances and abandoned at the San Antonio Zoo.

Strandings were compared with the previous 5 and 10-year statewide averages and by NMFS statistical zone. Other historical data relevant to either characterizing the strandings or investigating possible causes was retrieved from the NPS and NOAA stranding databases as necessary.

Stranding reports and all available photographs were reviewed for abnormalities or other indications of the cause of stranding. Stranded sea turtles were categorized based on predominant findings observed at the time of stranding or postmortem findings (if necropsied) using the criteria in Table 2-2. We created these categories to group strandings by the identified or most likely cause (e.g., trauma, disease-related) or to capture specific characteristics that could be used to identify possible causes for further investigation (i.e., those without major abnormalities). Briefly, turtles without abnormalities did not have an apparent cause of stranding or signs of poor health; and nutritional condition was determined to be within normal limits for an individual of that species.

Table 2-1. Circumstances of stranding recorded for sea turtles found in Texas during 2019. Records related to cold-stunned turtles, hatchlings, and post-hatchlings were excluded from this analysis.

Circumstance
None – alive or dead turtles found floating or on shore
Found entrapped/entrained in jetty rocks (alive or dead)
Live turtles beached/entrained by tide or coastal flooding event, or trapped within tidal pool
Observed alive on shore, returned to water without intervention
Found alive on shore entrained within thick *Sargassum* sp.

[1] Traditional stranding is defined as a dead, sick, or injured sea turtle that is found washed ashore, floating, or underwater that is not an incidental capture, a posthatchling, cold-stunning, or nesting-related event.

Those with major injuries had a wound(s) that was confirmed to have resulted in stranding or that was severe enough to have caused stranding if causation could not be confidently ascertained due to decomposition or other reasons. We did not include wounds that were healing (or healed) without apparent complication or those that were clearly caused by scavengers based on necropsy or field information. We identified the type of injury, such as wounds attributable to vessel strikes, entangling material or ligature wounds, and shark bites. Turtles with anomalous epibiota accumulation, that were clearly underweight or emaciated, or that had evidence of a major disease process were placed into the disease-related category.

Many of the green turtles documented during the spring and summer peaks in strandings were noted to have abrasions on the plastron and ventral surfaces of the flippers, consistent with trauma caused by foraging over jetty rocks or other rough substrates. As part of the general review of all photographs, images of the ventrum were specifically examined for the presence of these abrasions and to evaluate their relative severity. Abrasions were only noted if there was a clear inflammatory response in order to distinguish antemortem abrasions from postmortem excoriation of the skin during stranding. Abrasions less extensive than those shown in the example in Figure 2-3 were considered relatively mild, whereas those that were as or more extensive than this example were considered moderate or severe.

Table 2-2. Stranding categories and criteria applied to sea turtle strandings in Texas during 2019. Criteria were applied to both stranding findings and necropsy observations, if postmortem examination was conducted.

Category		
	Stranding	No visible abnormalities (e.g., injuries, abnormal epibiota, emaciation)
	Necropsy	Fair or good nutritional condition based on condition of muscle and fat AND no evidence of any significant disease process (including accumulated epibiota) AND no major injuries
	Stranding	Major injury present (does not include disarticulation or other changes attributable to decomposition or obvious scavenging). All injuries subcategorized as: B1 – vessel strike (parallel wounds or major blunt force injuries) B2 – fishing gear related (fishing line, tackle, netting) B3 – non-fisheries entrapment/entanglement B4 – shark bites B5 – other types of injuries
	Necropsy	Major injury identified that may have caused or contributed to stranding
	Stranding	Emaciation, anomalous epibiota, or other major non-injury abnormality
	Necropsy	Nutritional condition is diminished (severe atrophy of muscle/fat) OR significant pathological lesions indicating disease state
		Decomposition, scavenging, or inadequate documentation prevented categorization

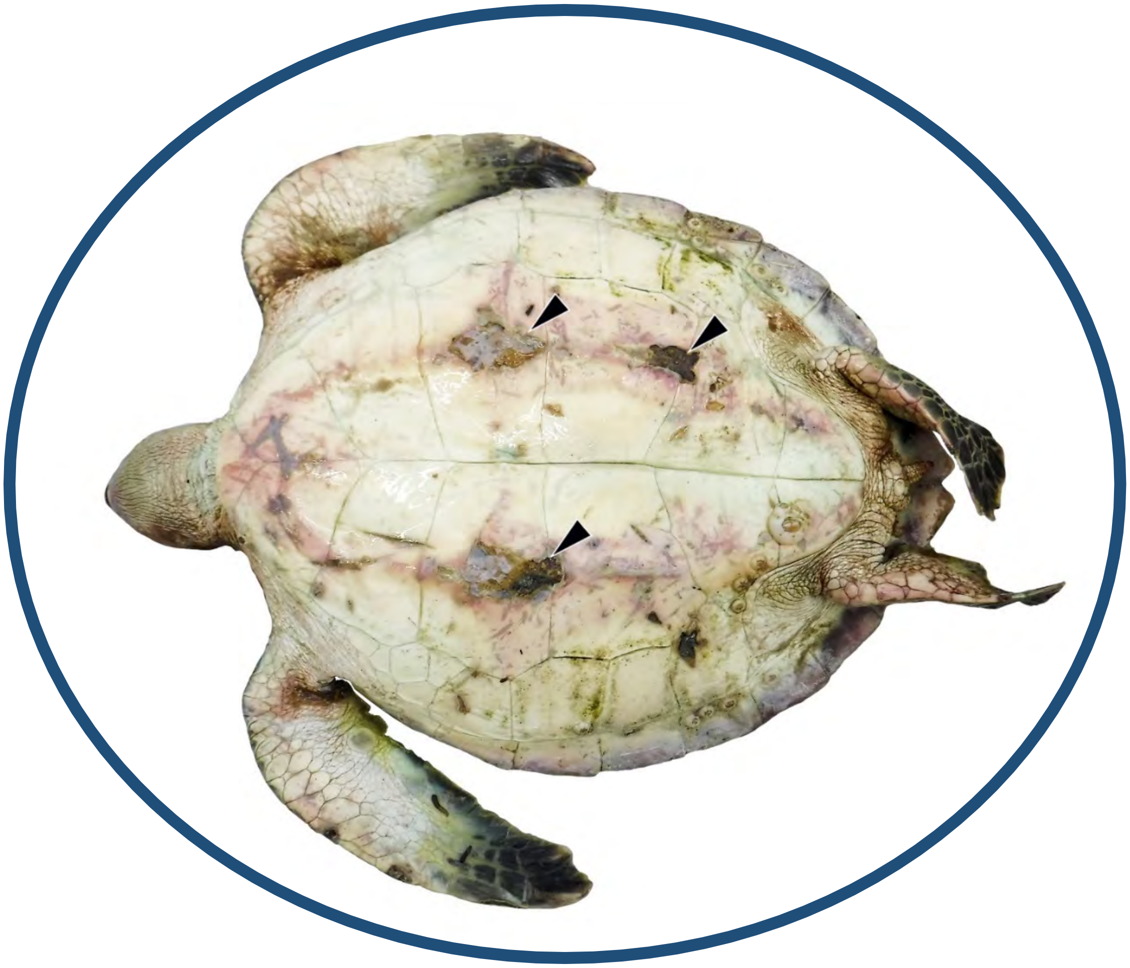


Figure 2-3. Ventral abrasions (arrowheads) on green turtles found stranded in Texas in 2019. Those less severe than this example were considered mild; whereas those as extensive or involving larger areas were considered more severe.

2.3.2. Spatial information associated with stranding records

The following spatial information associated with stranding records was verified: county, statistical zone, and water body classification.

The county in which strandings were documented was confirmed by intersecting stranding location with a modified version of the shapefile: Coastal Zone Management Program counties of the United States and its territories (Hartwell et al. 2013). This dataset was revised to extend state waters to nine miles and correct boundary digitization errors. The data source for the state waters boundary used in this revision was the Federal and State Waters dataset provided by the NOAA Office for Coastal Management (2020).

The STSSN assigns strandings to NMFS statistical zones. We developed a spatial polygon representation of these zones and intersected stranding records with those boundaries to confirm the stranding zone assignments. For the purposes of this study, we incorporated strandings within the portion of zone 17 that includes Texas waters into zone 18. The portion of zone 17 that overlaps with and is offshore of Texas is relatively small (Figure 2-1). The southern boundary of zone 21 was extended southward from the 26th parallel as needed to encompass all U.S. waters (Figure 2-1).

Zones 18 and 19 formed the Upper Texas Coast region and Lower Texas Coast refers to zones 20 and 21.

The STSSN classifies strandings as occurring within either inshore or offshore waters. Inshore strandings were found within or along the shores of bays, lagoons, sounds, and passes. Offshore strandings were documented within Gulf of Mexico waters or along Gulf-facing beaches. The boundary between inshore and offshore waters was based on the demarcation lines specified by the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (commonly referred to as COLREGS, 30 Code of Federal Regulations (CFR) § 80). We developed a spatial polygon dataset describing the inshore and offshore portions of all Gulf of Mexico and Atlantic Ocean waters within the U.S. Exclusive Economic Zone (EEZ). This boundary was based on the COLREGS lines where they were available (e.g., near inlets). The terrestrial boundary between the inshore and offshore zones was formed by digitizing a line along the shoreline, inshore of the areas that are influenced by waves or high tides (e.g., beaches). This delineation was based on recent aerial or satellite imagery and followed portions of the shoreline that appeared least susceptible to inundation (e.g., lines of permanent vegetation, roads) (Figure 2-4). We used existing stranding records and knowledge of sea turtle distribution to determine the landward boundary of inshore waters.

Because many green turtle strandings were associated with inlets, particularly those found entrapped in jetty rocks or entangled in fishing materials, we also created polygons around these structures in order to identify and describe strandings within these areas.

2.3.3. Comparison of strandings and nesting beach productivity

As subsequently presented in this report, the vast majority of sea turtle strandings in Texas during 2019 were small juvenile green turtles. Therefore, we wanted to examine the degree to which the high numbers of strandings may correlate with productivity of nesting beaches in the western Gulf of Mexico, which are the source of the green turtle foraging aggregation in Texas (Shamblin et al. 2016). To conduct this comparison, we compared strandings of green turtles less than or equal to 30 cm SCL in Texas over the previous decade with hatchling production from beaches in Campeche, Mexico, including Isla Aguada, Sabancuy, Isla del Carmen, and Cayo Acras (Guzmán 2020). This size class was selected to represent turtles that most recently recruited into their neritic phase (Witherington et al. 2012, Howell et al. 2016). The Campeche nesting data was used as a relative measure of annual nesting beach productivity in the region and is based on a combination of direct counts from nests in corrals and polystyrene foam boxes, and estimates from *in situ* nests using average clutch sizes and hatching success values. In addition, we considered published estimates of the duration of the surface-pelagic phase for green turtles in our comparisons of the stranding and nesting data (Zug and Glor 1998, Kubis et al. 2009, Goshe et al. 2010, Bjorndal et al. 2019).

Figure 2-4. Sea turtle strandings documented near Port Aransas, Texas during 2017–2019 (yellow points). The boundary between inshore and offshore waters (red, dashed line) followed the approximate midline between inshore and offshore waters along barrier islands. Near inlets, this boundary followed permanent structures (e.g., jetties) offshore to the COLREGS line.

2.4. Environmental analysis and modeling

2.4.1. Beaching Probability Index

The Beaching Probability Index (BPI) described the likelihood that dead or debilitated sea turtles floating at the sea surface will be deposited on shore based on prevailing wind and currents. BPI is an indicator of favorable beaching conditions, i.e., drifting carcasses will be more likely to beach if BPI is high and less likely to come ashore if BPI is low. This relationship between strandings and environmental conditions is relevant to understanding causes of stranding as well as the degree to which at-sea mortality may be represented by animals found on shore.

The BPI applied velocity and direction of surface currents and wind from the American Seas Ocean Model (AMSEAS) of the Regional Navy Coastal Ocean Model (NCOM) to predict and describe the probability that floating turtles would be brought onto shore. AMSEAS gives a 3 hr, ~2.8 km resolution, 1000 × 1510 grid domain of the Gulf of Mexico and Caribbean Sea, and included tidal, geostrophic, and atmospheric-driven water motion. Within the BPI simulation, surface currents and winds from AMSEAS were used to push particles for an 8-day period based on lab and field studies of decomposition and persistence of sea turtle carcasses in the environment (M. Cook, unpublished data). Each day, at 0 h Greenwich Mean Time (GMT), new particles were seeded onto a starting grid of 84,044 points spaced 1 NM apart. This uniform grid extended from the coast to 60 NM offshore (Figure 2-5), which is the furthest distance sea turtle carcasses were likely to drift based on our observations. The system maintained a running tally such that on any given day all objects that are still in motion and less than 8 days old were pushed forward. Particles that encountered shallow water (< 25 cm depth) stopped moving and were counted as "beached." The leeway value, the amount of "push" the wind gives a floating object, was set to 3.5% which is a value applicable to sea turtles or any other floating object which has about 50% of its area exposed above the sea surface (Nero et al. 2013).

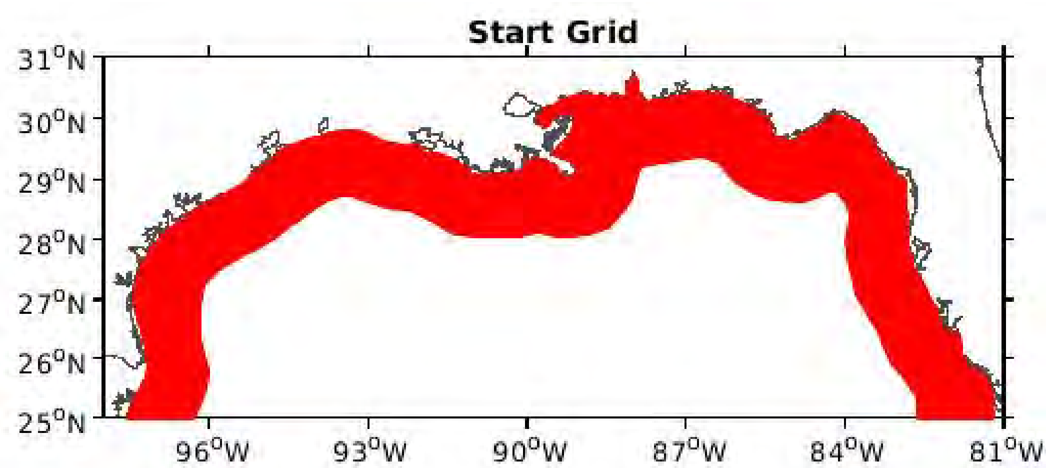


Figure 2-5. Beaching Probability Index (BPI) Start Grid for the northern Gulf of Mexico. The Start Grid is predefined as approximately 84,000 x, y starting locations spaced 1 NM apart to seed the BPI simulation.

Much of the Texas coastline is characterized by bays, lagoons, and sounds which are separated from the Gulf of Mexico by barrier islands. Narrow inlets provide the only interface between Gulf of Mexico and inshore waters. Due to Texas' coastal geomorphology and the resolution of the BPI, strandings that occurred inside barrier islands were not compared to the BPI. Comparisons of strandings and BPI were restricted to strandings classified as offshore (documented within Gulf of Mexico waters or on Gulf facing beaches) and strandings classified as inshore that were within 500 m of offshore waters (Figure 2-4). This distance was determined within a geographic information system (GIS), by calculating the distance from each stranding record to the nearest offshore boundary.

2.4.2. Analysis of environmental data

Water temperature, wind speed, and wind direction data were obtained from the NOAA National Data Buoy Center (NDBC, https://www.ndbc.noaa.gov/). Data were obtained from three NDBC stations that were situated in areas with the highest densities of sea turtle strandings: Galveston Bay Entrance (station GNJT2), Aransas Pass (station ANPT2), and SPI Brazos Santiago (station BZST2) (Figure 2-1). Tidal height data were obtained from the NOAA Center for Operational Oceanographic Products and Services (https://www.tidesandcurrents.noaa.gov).

2.4.3. Backcasting analysis

For a subset of sea turtles, we estimated the likely location where debilitation or mortality occurred using carcass backcasting methods outlined by Nero et al. (2013). We upgraded the model to obtain surface currents and wind forcing from the Northern Gulf of Mexico Operational Forecast System (NGOFS), which is a higher resolution model than the AMSEAS model used in Nero et al. (2013). The analysis involved backtracking the likely drift of the carcasses beginning at the location where they were discovered on shore. Turtle carcasses were backtracked as Lagrangian surface particles forced by water currents and winds at 15-minute time steps. The model was developed for turtles that are moderately or severely decomposed (STSSN codes 2 and 3) based on assumptions of decomposition rates, buoyancy, and persistence in the environment; therefore, only strandings in these conditions were included in backtracking analyses. We created summary heat-maps from selected backtracking results to show the probability density of where stranded sea turtles may have originated (i.e. where mortality may have occurred) based on algorithms that use carcass condition, sea temperature, and water depth.

2.5. Statistical analyses

Selected statistical analyses of parameters relevant to characterization of strandings or identification of possible causes applied parametric or non-parametric methods, as appropriate based on data characteristics. Data for zones 18 and 19 were often considered together (Upper Texas Coast), whereas zones 20 and 21 (comprising the Lower Texas Coast) were analyzed separately due to differences of interest related to the timing and characteristics of strandings. *P*-values less than .05 were considered significant. Proportions are only provided for sample sizes greater than ten; actual numbers are given whenever frequency of occurrence is stated for an observation.

Correlations between weekly mean BPI values and strandings during 2019 were examined separately for each region of interest (Upper Texas Coast, zone 20, and zone 21) in two ways. We evaluated the overall correlation between the two variables using Kendall's rank correlation implemented in R (R Development Core Team 2019). We also modeled the effect of weekly mean BPI values on stranding counts using a log-linked quasi-Poisson generalized linear model (GLM) implemented within R.

3. Results

3.1. 2019 Texas sea turtle strandings (statewide summary)

During 2019, 1,598 sea turtles were documented as stranded in Texas. Stranding data are presented by species and condition in Table 3-1. Reports included 1,320 green turtles, 129 Kemp's ridleys, 131 loggerheads, one olive ridley, and 17 sea turtles that could not be identified to species. Nearly half (48.3%) of green turtles were found alive. The vast majority of Kemp's ridleys and loggerheads were found dead (89.9% and 78.6%, respectively) and most were moderately or severely decomposed. Histograms of the straight carapace lengths (SCL) of stranded turtles are shown by species in Figure 3-1. Mean SCL for green turtles was 26.9 ± 9.2 cm (mean ± one standard deviation [SD], range: 12.0–95.3 cm, n = 1,244), 55.0 ± 14.2 cm (range: 17.1–68.5 cm, n = 125) for Kemp's ridleys, and 72.9 ± 10.0 cm (range: 27.3–100.9 cm, n = 116) for loggerheads. No hawksbill or leatherback turtles were documented as traditional strandings in 2019.

Strandings are presented by species and week in Table 3-2 and as compared with 5 and 10-year historical averages in Table 3-3. Figures 3-2 and 3-3 also show these comparisons graphically by week. Total statewide strandings were approximately 2.3 and 2.6 times the previous 5-year and 10-year averages, respectively. Strandings exceeding historical averages began in early April, peaked in mid-May, and continued through August. A second period in which strandings far exceeded historical averages occurred as a discrete peak in November. In comparison to total numbers of strandings by month across years, more strandings were documented in April through August and October through November 2019 than in any previous year since the establishment of the Texas STSSN. Moreover, the second highest numbers of monthly strandings were recorded in September and December 2019.

Necropsy was performed on 41.5% (378/911) of turtles that were found dead and 73 additional turtles that were found alive but later died. Stranding categories related to major findings and causes are presented by statistical zone in subsequent sections of this report.

Table 3-1. Sea turtle strandings in Texas during 2019 by condition. Corresponding proportions for each species are given in parentheses.

Species	Alive	Minimally or mildly decomposed	Moderately or severely decomposed	Desiccated or skeletal remains	Total
Green turtle	637 (48.3%)	198 (15.0%)	441 (33.4%)	44 (3.3%)	1320
Kemp's ridley	13 (10.1%)	16 (12.4%)	96 (74.4%)	4 (3.1%)	129
Loggerhead	28 (21.4%)	22 (16.8%)	71 (54.2%)	10 (7.6%)	131
Olive ridley	0 (-)	0 (-)	1 (-)	0 (-)	1
Undetermined	9 (52.9%)	0 (-)	4 (23.5%)	4 (23.5%)	17
Total	687	236	613	62	1,598

Table 3-2. Weekly summary of sea turtle strandings reported in Texas during 2019 by species; loggerhead (Cc), green turtle (Cm), Kemp's ridley (Lk), olive ridley (Lo), and turtles unidentified to species (Unk). The column "Live" contains the weekly count of reports involving stranded turtles that were discovered alive. The final two columns contain the weekly and cumulative stranding totals.

Date range	Week	Cm	Lk	Cc	Lo	Unk	Live	Weekly total	Cumulative
1/1–1/7	1	7	1	1	0	0	3	9	9
1/8–1/14	2	2	0	0	0	0	0	2	11
1/15–1/21	3	6	0	0	0	0	4	6	17
1/22–1/28	4	4	0	1	0	0	1	5	22
1/29–2/4	5	9	1	2	0	0	4	12	34
2/5–2/11	6	5	0	0	0	0	2	5	39
2/12–2/18	7	4	0	0	0	0	2	4	43
2/19–2/25	8	6	0	1	0	1	1	8	51
2/26–3/4	9	7	0	0	0	0	0	7	58
3/5–3/11	10	5	0	1	0	0	2	6	64
3/12–3/18	11	9	0	2	0	0	5	11	75
3/19–3/25	12	7	1	0	0	0	5	8	83
3/26–4/1	13	12	4	4	0	0	4	20	103
4/2–4/8	14	22	5	3	0	0	4	30	133
4/9–4/15	15	34	5	3	0	0	6	42	175
4/16–4/22	16	36	7	6	0	0	17	49	224
4/23–4/29	17	30	12	6	0	1	18	49	273
4/30–5/6	18	42	22	11	0	3	31	78	351
5/7–5/13	19	30	16	9	0	0	15	55	406
5/14–5/20	20	43	10	18	0	1	24	72	478
5/21–5/27	21	146	6	9	0	0	140	161	639
5/28–6/3	22	94	2	8	0	1	68	105	744
6/4–6/10	23	52	1	2	0	0	39	55	799
6/11–6/17	24	40	3	2	0	2	34	47	846
6/18–6/24	25	43	1	2	0	1	34	47	893
6/25–7/1	26	61	2	1	0	0	46	64	957
7/2–7/8	27	40	3	5	0	0	30	48	1,005
7/9–7/15	28	12	0	2	0	1	5	15	1,020
7/16–7/22	29	22	0	2	0	0	8	24	1,044
7/23–7/29	30	19	4	3	1	0	7	27	1,071
7/30–8/5	31	14	1	0	0	0	3	15	1,086
8/6–8/12	32	17	2	2	0	0	7	21	1,107
8/13–8/19	33	22	3	1	0	0	6	26	1,133
8/20–8/26	34	16	1	2	0	0	13	19	1,152
8/27–9/2	35	10	1	1	0	1	7	13	1,165

Table 3-2. *Continued.*

Date range	Week	Cm	Lk	Cc	Lo	Unk	Live	Weekly total	Cumulative
9/3–9/9	36	9	1	1	0	0	1	11	1,176
9/10–9/16	37	8	1	2	0	0	3	11	1,187
9/17–9/23	38	7	2	1	0	0	5	10	1,197
9/24–9/30	39	11	3	2	0	0	4	16	1,213
10/1–10/7	40	13	1	1	0	0	11	15	1,228
10/8–10/14	41	12	1	3	0	0	8	16	1,244
10/15–10/21	42	6	1	0	0	1	3	8	1,252
10/22–10/28	43	13	0	1	0	0	7	14	1,266
10/29–11/4	44	29	1	1	0	1	13	32	1,298
11/5–11/11	45	28	0	1	0	0	1	29	1,327
11/12–11/18	46	10	0	0	0	1	5	11	1,338
11/19–11/25	47	124	1	2	0	0	11	127	1,465
11/26–12/2	48	60	2	2	0	0	5	64	1,529
12/3–12/9	49	17	0	3	0	0	5	20	1,549
12/10–12/16	50	11	0	0	0	1	2	12	1,561
12/17–12/23	51	13	0	0	0	0	3	13	1,574
12/24–12/31	52	21	1	1	0	1	5	24	1,598

Table 3-3. Weekly and cumulative total numbers of sea turtle strandings reported in Texas during 2019. Weekly and cumulative average stranding counts for the previous five and ten years are provided in the final four columns.

	2019					
1/1–1/7	9	9	6.2	6.2	6.0	6.0
1/8–1/14	2	11	8.2	14.4	7.2	13.2
1/15–1/21	6	17	12.4	26.8	10.4	23.6
1/22–1/28	5	22	6.8	33.6	7.2	30.8
1/29–2/4	12	34	7.8	41.4	6.9	37.7
2/5–2/11	5	39	7.8	49.2	9.0	46.7
2/12–2/18	4	43	13.4	62.6	9.9	56.6
2/19–2/25	8	51	9.4	72.0	8.9	65.5
2/26–3/4	7	58	11.0	83.0	10.0	75.5
3/5–3/11	6	64	11.0	94.0	10.0	85.5
3/12–3/18	11	75	10.6	104.6	11.1	96.6
3/19–3/25	8	83	13.8	118.4	13.5	110.1
3/26–4/1	20	103	19.4	137.8	14.9	125.0
4/2–4/8	30	133	23.2	161.0	21.7	146.7
4/9–4/15	42	175	26.0	187.0	22.2	168.9
4/16–4/22	49	224	26.6	213.6	25.3	194.2
4/23–4/29	49	273	23.6	237.2	25.4	219.6
4/30–5/6	78	351	28.8	266.0	24.0	243.6
5/7–5/13	55	406	26.8	292.8	20.8	264.4
5/14–5/20	72	478	25.0	317.8	23.1	287.5
5/21–5/27	161	639	24.0	341.8	20.8	308.3
5/28–6/3	105	744	20.4	362.2	17.3	325.6
6/4–6/10	55	799	15.6	377.8	13.4	339.0
6/11–6/17	47	846	19.4	397.2	17.0	356.0
6/18–6/24	47	893	20.6	417.8	15.9	371.9
6/25–7/1	64	957	14.4	432.2	12.6	384.5
7/2–7/8	48	1,005	12.4	444.6	13.6	398.1
7/9–7/15	15	1,020	13.6	458.2	12.6	410.7
7/16–7/22	24	1,044	11.0	469.2	10.8	421.5
7/23–7/29	27	1,071	10.2	479.4	11.5	433.0
7/30–8/5	15	1,086	10.2	489.6	9.5	442.5
8/6–8/12	21	1,107	9.2	498.8	10.4	452.9
8/13–8/19	26	1,133	9.0	507.8	7.1	460.0
8/20–8/26	19	1,152	6.6	514.4	6.8	466.8
8/27–9/2	13	1,165	10.4	524.8	8.3	475.1
9/3–9/9	11	1,176	8.8	533.6	7.6	482.7
9/10–9/16	11	1,187	8.2	541.8	6.6	489.3
9/17–9/23	10	1,197	8.8	550.6	7.1	496.4

Table 3-3. *Continued.*

	2019					
9/24–9/30	16	1,213	8.8	559.4	7.3	503.7
10/1–10/7	15	1,228	9.2	568.6	8.6	512.3
10/8–10/14	16	1,244	8.4	577.0	8.0	520.3
10/15–10/21	8	1,252	9.4	586.4	8.4	528.7
10/22–10/28	14	1,266	7.4	593.8	5.8	534.5
10/29–11/4	32	1,298	10.6	604.4	8.4	542.9
11/5–11/11	29	1,327	7.6	612.0	7.3	550.2
11/12–11/18	11	1,338	7.6	619.6	7.1	557.3
11/19–11/25	127	1,465	11.6	631.2	10.5	567.8
11/26–12/2	64	1,529	15.6	646.8	12.2	580.0
12/3–12/9	20	1,549	11.6	658.4	9.1	589.1
12/10–12/16	12	1,561	10.8	669.2	9.3	598.4
12/17–12/23	13	1,574	11.2	680.4	8.3	606.7
12/24–12/31	24	1,598	17.8	698.2	12.3	619.0

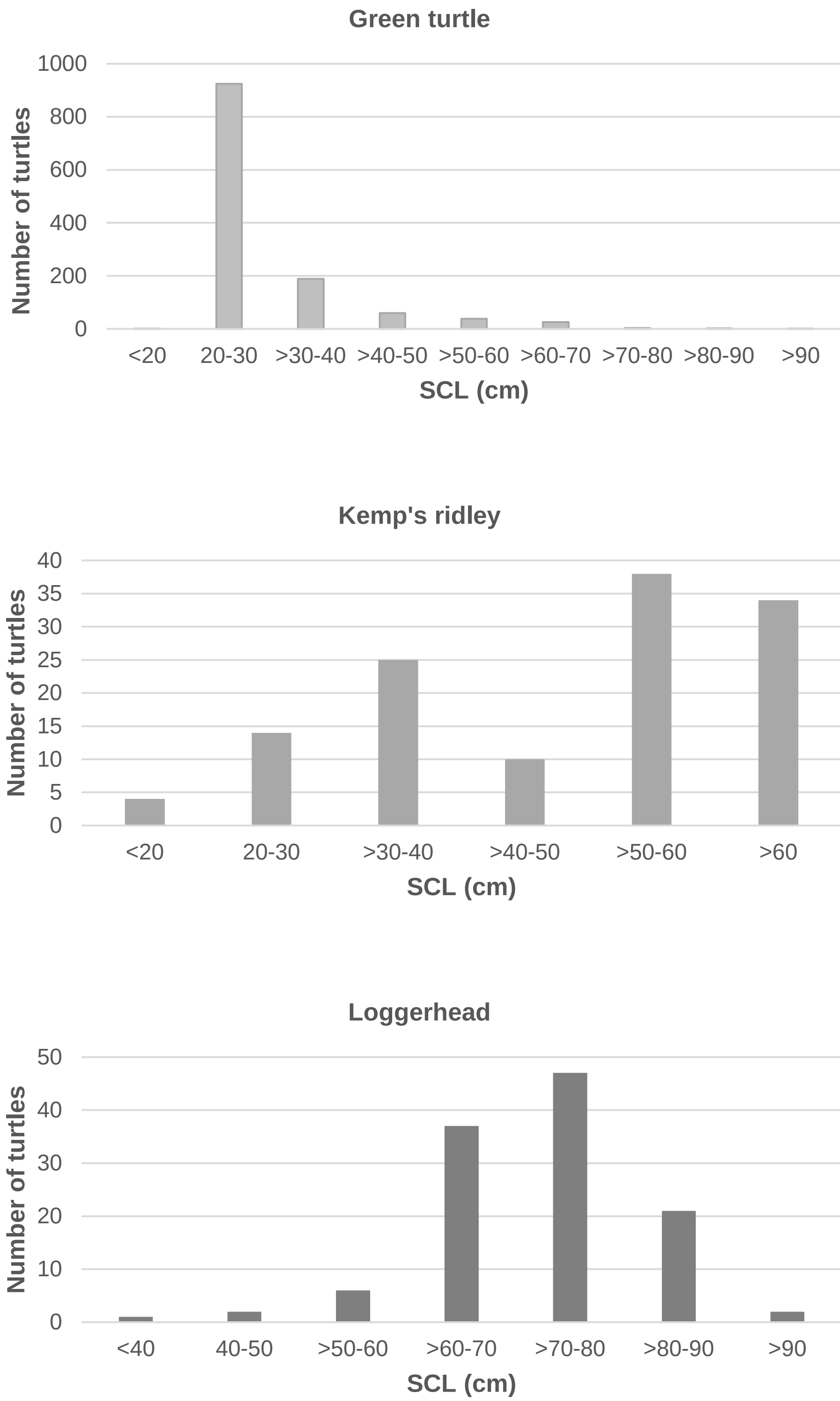


Figure 3-1. Histograms (by species) of straight carapace lengths (SCL, measured from nuchal notch to caudal tip of the carapace) for sea turtles found stranded in Texas in 2019.

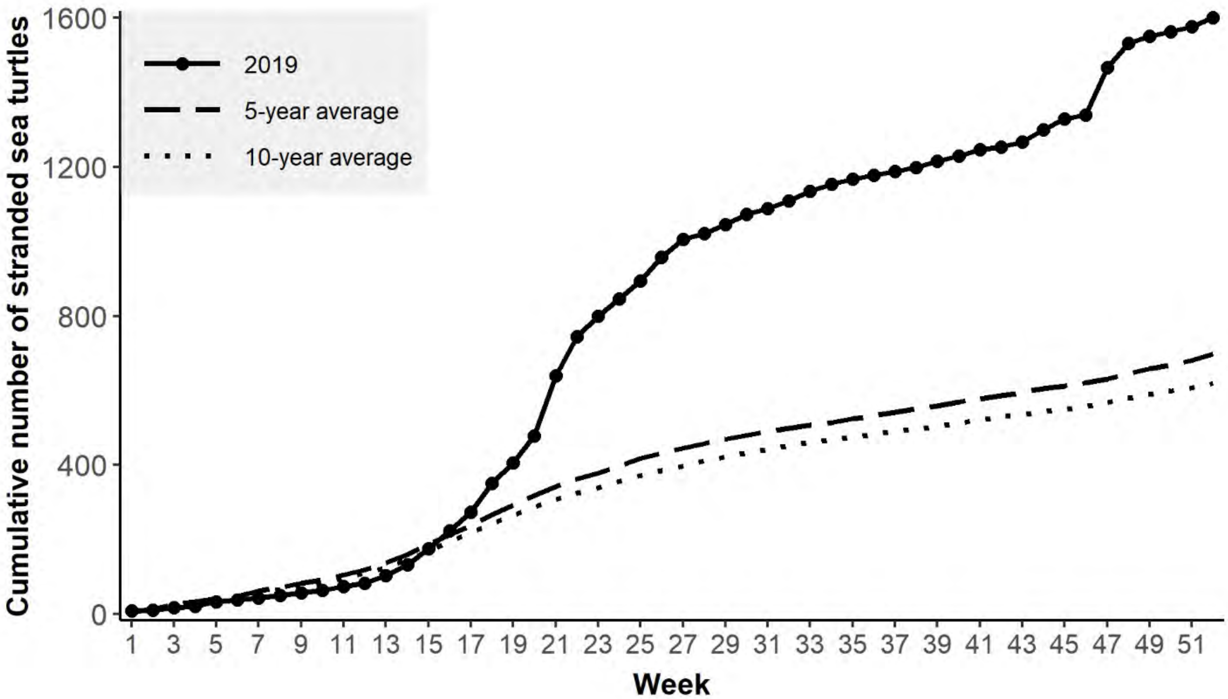


Figure 3-2. Cumulative total numbers of sea turtle strandings documented in Texas during 2019 compared to average stranding counts for the previous five and ten years.

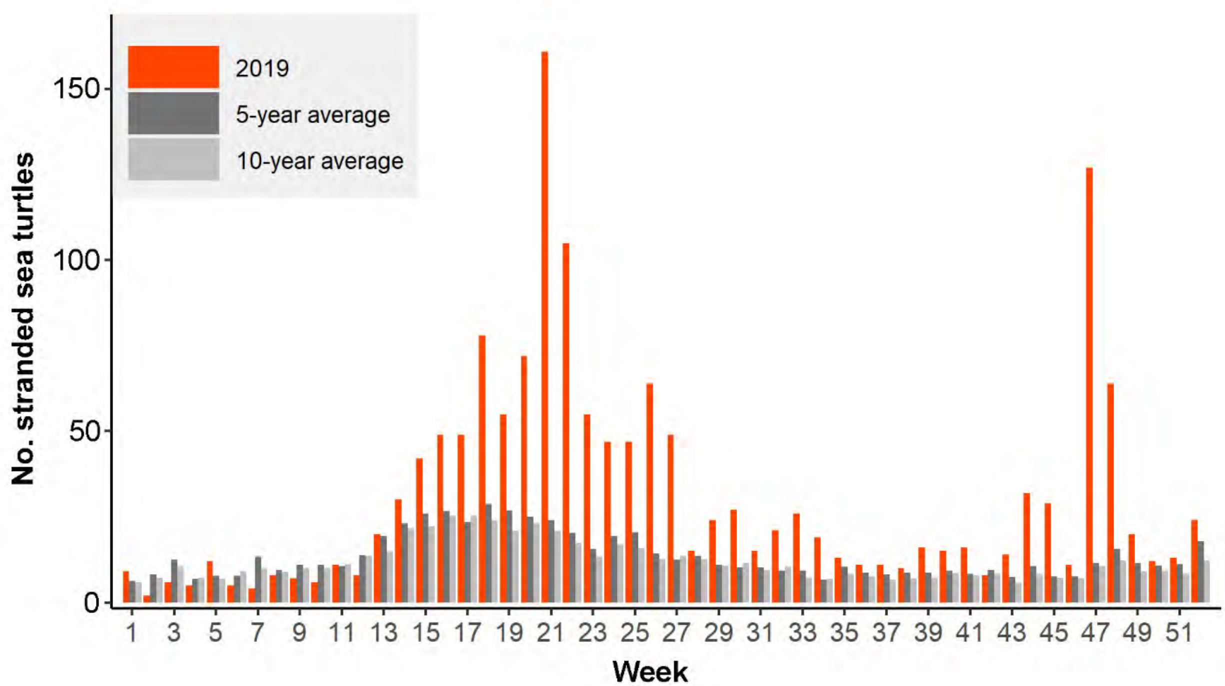


Figure 3-3. Weekly total numbers of sea turtle strandings documented in Texas during 2019 compared to weekly average stranding counts for the previous five and ten years.

3.2. 2019 Texas strandings by NMFS statistical zone

The majority of strandings occurred on the Lower Texas Coast, with more found in zone 20 than all other zones combined (Table 3-4). More than 85% of strandings in zones 20 and 21 were green turtles, which also were the majority of strandings in zone 19. Strandings in zone 18 included nearly equal proportions of green turtles and Kemp's ridleys. Similar numbers of Kemp's ridleys were found on the Upper and Lower Texas Coasts. Although loggerheads comprised a smaller proportion of strandings along the Lower Texas Coast (due to the large number of green turtle strandings), the highest total number of loggerheads were found in zone 20. Figures 3-4 and 3-5 show relative density of green turtle, Kemp's ridley, and loggerhead strandings on the Upper and Lower Texas Coasts, respectively. Strandings are shown graphically for each week by species and zone in Figures 3-6 through 3-8.

On the Upper Texas Coast, loggerhead and Kemp's ridley strandings were above average in late April through mid-May, again in early July, and again in late September; however, averages for the latter two periods are based on very few ($\leq$ 5) records. Most of the Kemp's ridleys (95.6%; 65/68) and loggerheads (71.0%; 22/31) in these zones were found dead and decomposed. Fewer green turtles stranded in zones 18 and 19; 26.2% (27/103) were found alive.

In zone 20, strandings exceeded previous historical averages for a 22-week period from mid-April to late September. Most (86.4%; 614/711) were green turtles, 70.4% (432/614) of which were found alive. This large spring peak in strandings represented 44.5% of total statewide stranding numbers in 2019. A large proportion of the loggerhead strandings in Texas in 2019 also were documented in zone 20 during this period (48.1%; 63/131). Most (77.8%; 49/63) were found dead. Strandings increased above average again in late October, but were lower than occurred during the spring months.

Strandings in zone 21 were also above average in the spring and summer, from March to June, and as in zone 20, were a combination of many live (46.6%; 68/146) and dead strandings. Most of the Kemp's ridleys that stranded in zone 21 were found during April and May and were infrequently encountered later in the year. A dramatic spike in strandings occurred in zone 21 in November continuing into December, far exceeding historical averages. Almost all of these strandings were green turtles found in the Boca Chica Beach area and, in contrast to previous months, only 6.5% (9/129) were found alive.

In summary, sea turtle strandings in Texas during 2019 were characterized by periods in which strandings exceeded historical averages within one or more statistical zones for weeks to months. These periods of elevated strandings were characterized by several prominent features: 1) increased numbers of dead Kemp's ridleys and loggerheads in zone 18 during April and May; 2) a large increase in live and dead green turtle strandings in zone 20 that spanned the spring and summer and comprised a substantial proportion of statewide strandings for the year; 3) many loggerhead strandings in zone 20 during April and May; and 4) a green turtle mortality event in zone 21 during November and December. In the next sections, we examine these four features in further detail by presenting detailed stranding and necropsy findings and related analyses by zone.

Table 3-4. Sea turtle strandings documented in Texas during 2019 by National Marine Fisheries Service statistical zone and species. Corresponding proportions are provided by species composition within each zone (upper columns) and zones were each species was found (lower columns).

Species				
Green turtle	62 (43.4%)	41 (64.1%)	857 (87.3%)	360 (87.3%)
Kemp's ridley	58 (40.6%)	10 (15.6%)	35 (3.6%)	26 (6.4%)
Loggerhead	21 (14.7%)	10 (15.6%)	80 (8.2%)	20 (4.9%)
Olive ridley	0 (-)	0 (-)	1 (0.1%)	0 (-)
Undetermined	2 (1.4%)	3 (4.7%)	9 (0.9%)	3 (0.7%)
Zone total	143	64	982	409

18	62 (4.7%)	58 (45.0%)	21 (16.0%)	0 (-)	2 (11.8%)
19	41 (3.1%)	10 (7.8%)	10 (7.6%)	0 (-)	3 (17.6%)
20	857 (64.9%)	35 (27.1%)	80 (61.1%)	1 (-)	9 (52.9%)
21	360 (27.3%)	26 (20.2%)	20 (15.3%)	0 (-)	3 (17.6%)
Species total	1,320	129	131	1	17

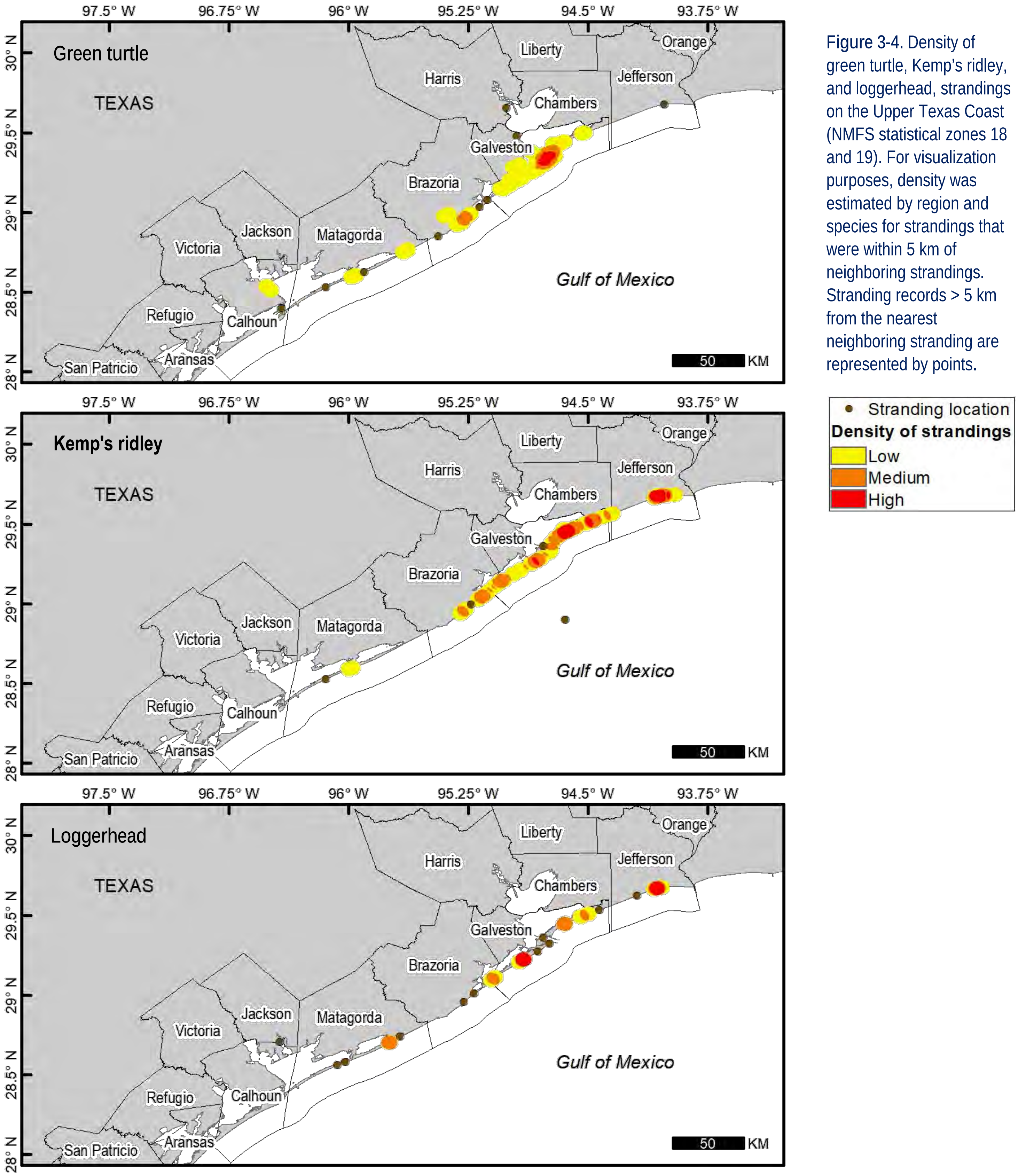
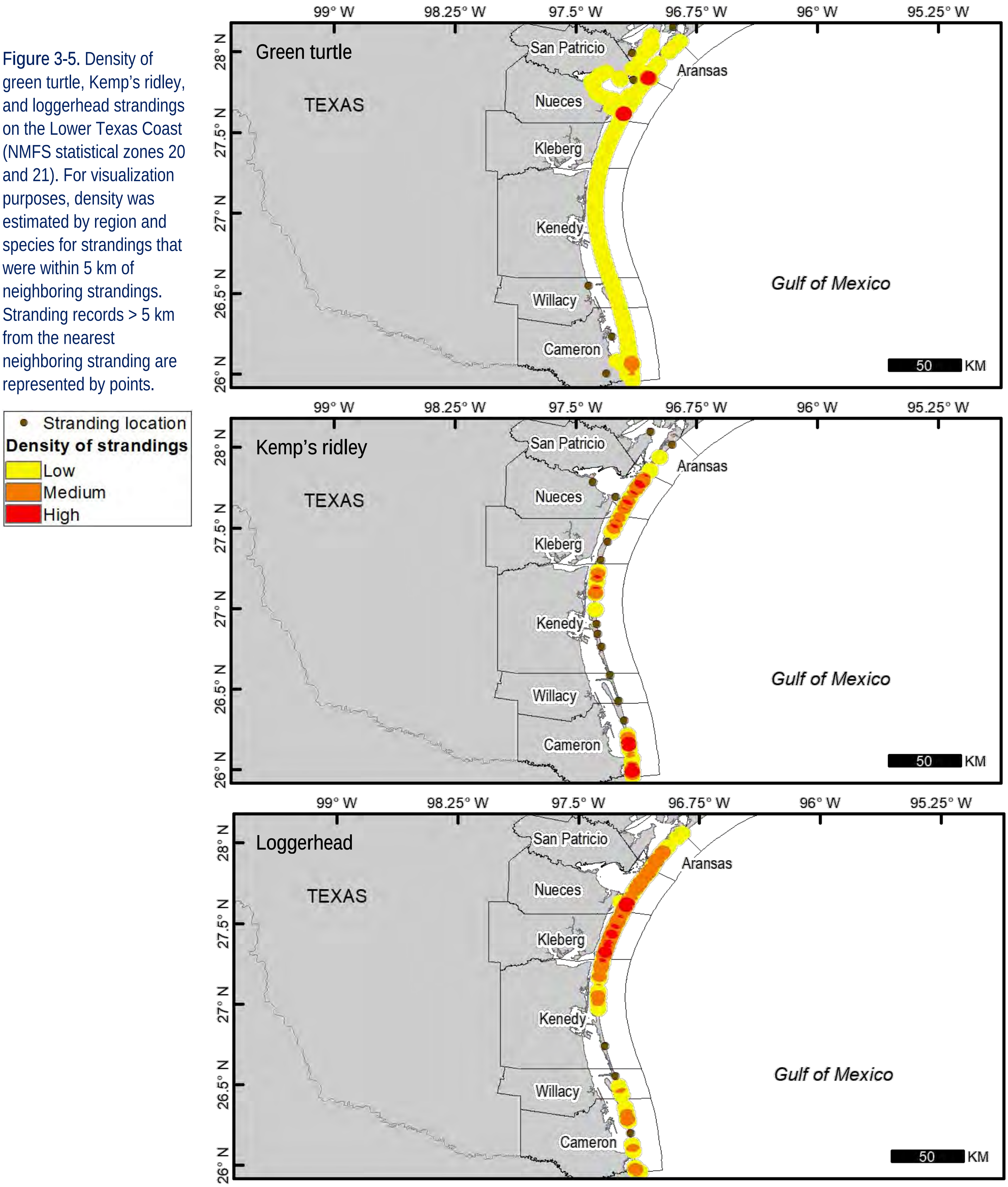


Figure 3-4. Density of green turtle, Kemp's ridley, and loggerhead, strandings on the Upper Texas Coast (NMFS statistical zones 18 and 19). For visualization purposes, density was estimated by region and species for strandings that were within 5 km of neighboring strandings. Stranding records > 5 km from the nearest neighboring stranding are represented by points.

Figure 3-5. Density of green turtle, Kemp's ridley, and loggerhead strandings on the Lower Texas Coast (NMFS statistical zones 20 and 21). For visualization purposes, density was estimated by region and species for strandings that were within 5 km of neighboring strandings. Stranding records > 5 km from the nearest neighboring stranding are represented by points.



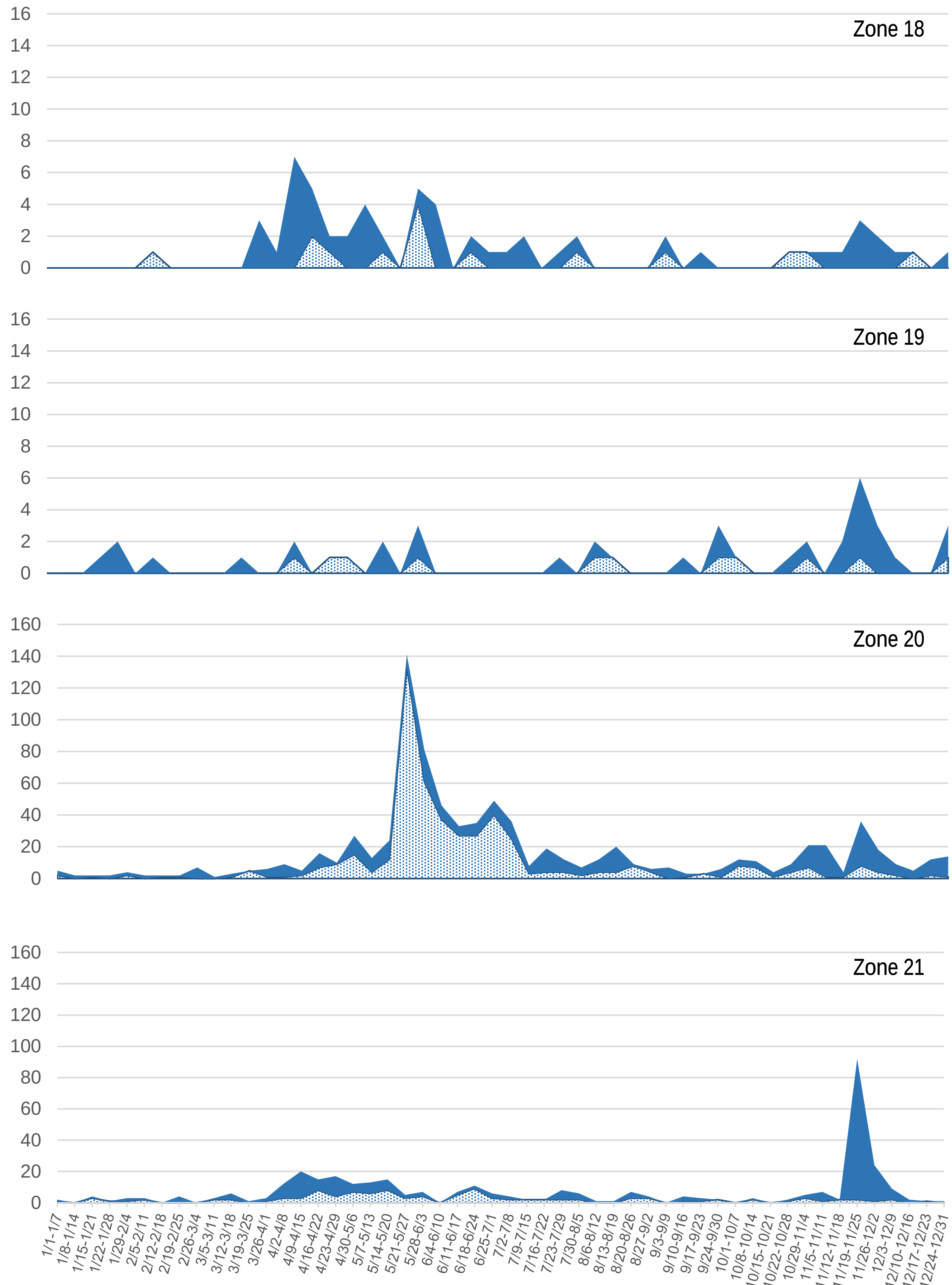


Figure 3-6. Stacked area graph of green turtle strandings in Texas by week and NMFS statistical zone. Week of stranding is shown on the x-axis; number of turtles is indicated by the y-axis. Live strandings are shown by the dotted area. Dead strandings are presented in blue.

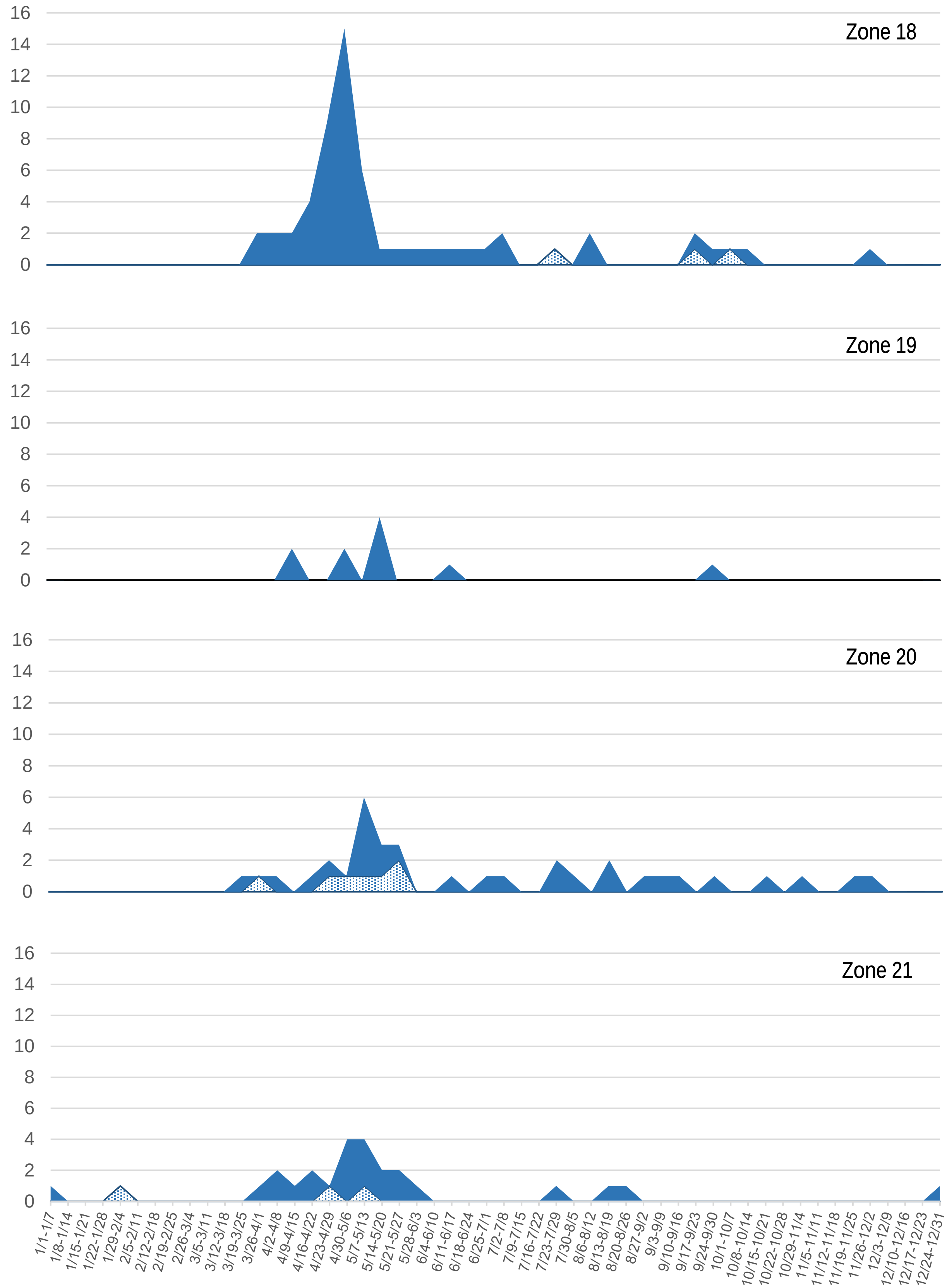


Figure 3-7. Stacked area graph of Kemp's ridley strandings in Texas by week and NMFS statistical zone. Week of stranding is shown on the x-axis; number of turtles is indicated by the y-axis. Live strandings are shown by the dotted area. Dead strandings are presented in blue.

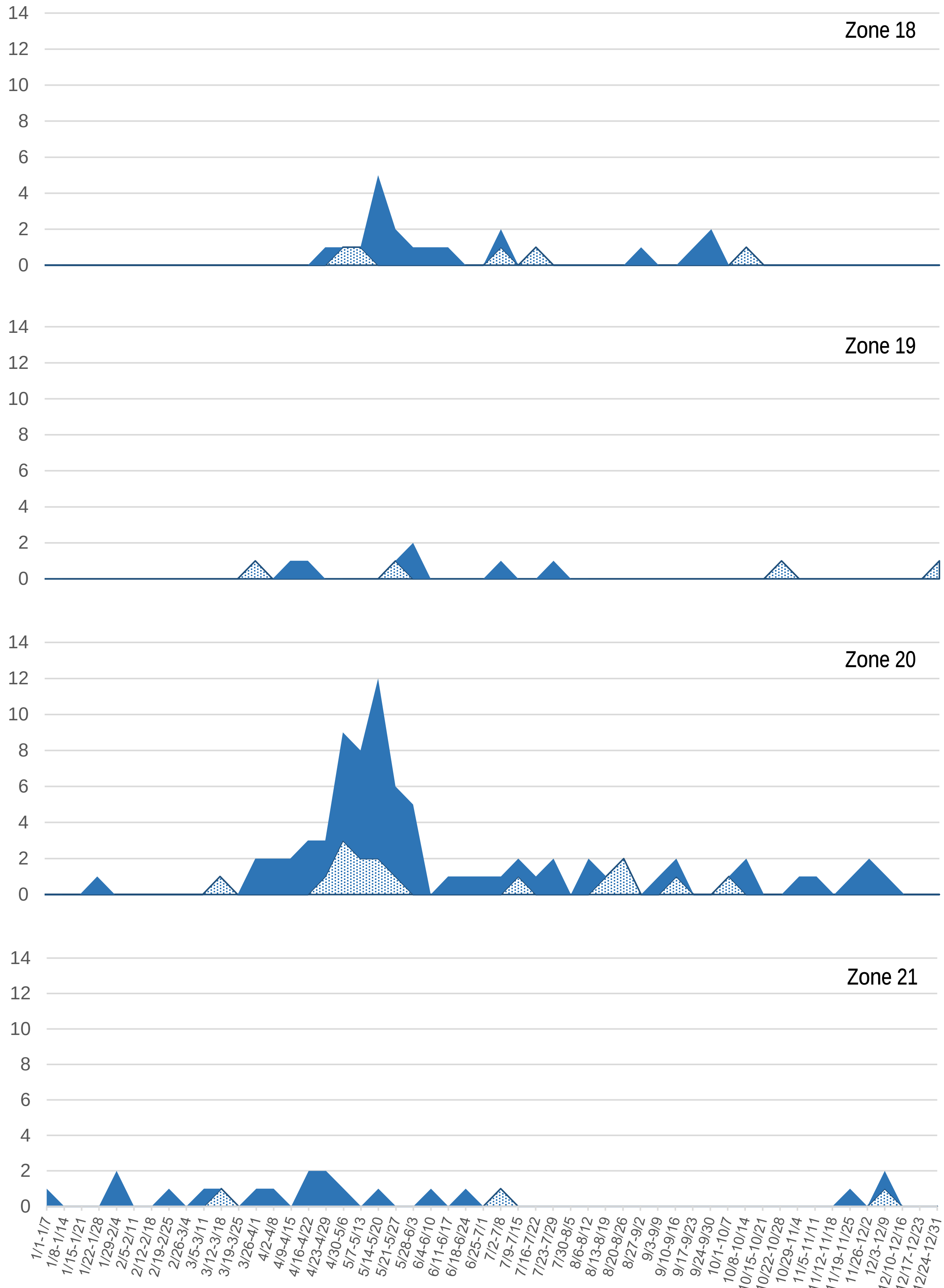


Figure 3-8. Stacked area graph of loggerhead strandings in Texas by week and NMFS statistical zone. Week of stranding is shown on the x-axis; number of turtles is indicated by the y-axis. Live strandings are shown by the dotted area. Dead strandings are presented in blue.

3.2.1. Zones 18 and 19

Environmental modeling and analyses

Sea turtle strandings exceeding historical averages in the Upper Texas Coast region during April through May occurred during periods of relatively high beaching probability based on the BPI model (Figure 3-9). Loggerhead and Kemp's ridley strandings fell to near average values during late May while beaching probability remained relatively high through mid-June. Winds during late May appeared stronger and more persistently shoreward than in previous weeks when strandings were higher, contributing to the elevated BPI during this period (Figure 3-10). The two periods of above average loggerhead and Kemp's ridley strandings during early July and late September also were concurrent with relatively high beaching probability (Figure 3-9).

During 2019, we observed a weak positive correlation between BPI and sea turtle strandings recorded along the Upper Texas Coast ($\tau = 0.33$). Within the GLM, BPI had a significant positive effect on Upper Texas Coast strandings. The relationship between the two was nonlinear (Figure 3-11), so BPI was also included as a quadratic term in the model and was significant.

There were no reported red tide events, other harmful algae blooms, or mass mortality of other animals on the Upper Texas Coast during 2019. In addition, no sea turtle strandings were documented in the Galveston Bay area during a vessel collision and subsequent fuel spill in the Houston Ship Channel in May 2019.

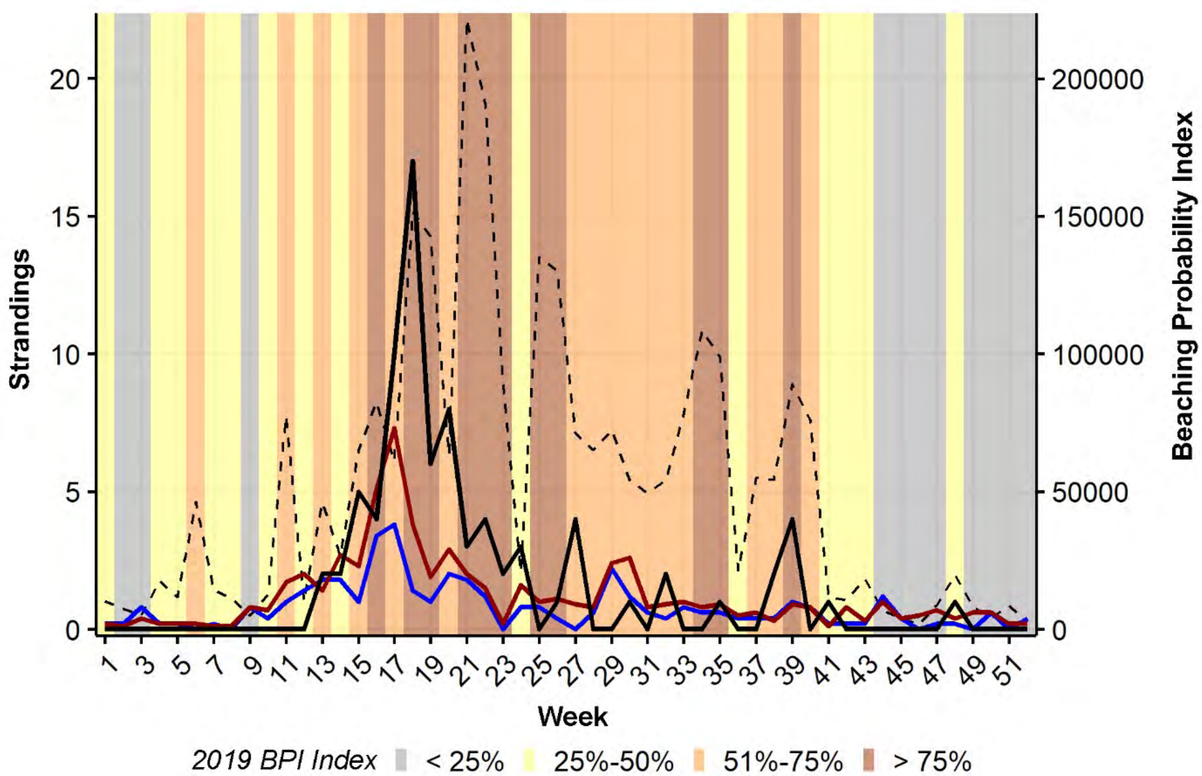


Figure 3-9. Weekly total numbers of Kemp's ridley and loggerhead sea turtle strandings involving dead turtles documented as "offshore" along the Upper Texas Coast (NMFS statistical zones 18 and 19) during 2019 (black line). Weekly average loggerhead and Kemp's ridley stranding counts for the previous five and ten years are also provided (blue and red lines, respectively). Beaching probability index is provided as quartiles (background shading) and scaled values (dashed line).

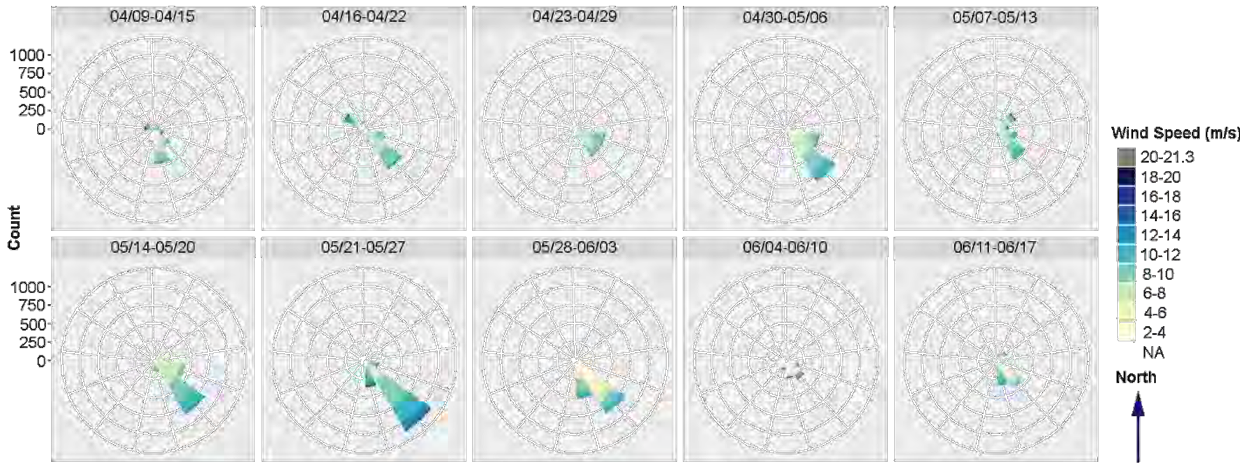


Figure 3-10. Weekly summary of wind velocity and direction collected from 9 April–17 June 2019 at the Galveston Bay Entrance NDBC station (GNJT2). Periods of strong onshore winds correspond to periods of relatively high Beaching Probability Index values along the Upper Texas Coast.

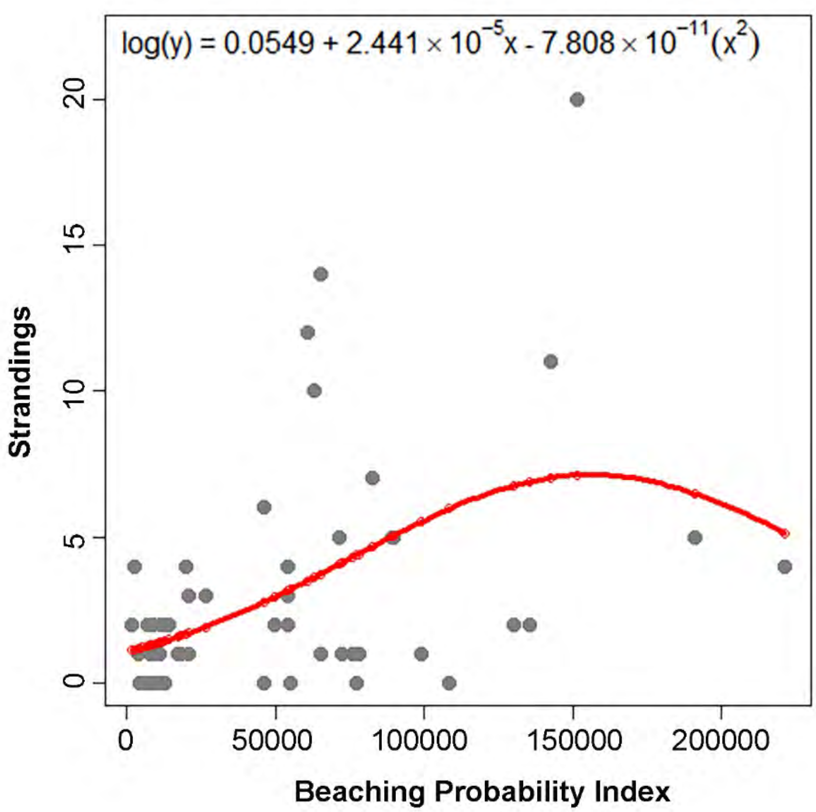


Figure 3-11. Weekly counts of sea turtle strandings recorded along the Upper Texas Coast during 2019 and the weekly average Beaching Probability Index (BPI). The red line represents a quasi-Poisson generalized linear model fit to the data describing the relationship between strandings and BPI.

Stranding and necropsy findings

Categories of stranding and necropsy observations are presented by species in Table 3-5 and are shown graphically by week in Figure 3-12. The most frequent finding among stranded Kemp's ridleys, particularly those found during the period of high numbers of strandings in April and May was the absence of any apparent cause of mortality (Figure 3-13). All were found dead; most were moderately or severely decomposed. This presentation was uncommon after May with only five similar observations during the rest of the year. Twelve ridleys from the April–May group without an apparent cause of stranding were necropsied, three (25%) had sediment within the respiratory tract and the gastrointestinal contents of three cases (25%) included fish. Similarly, seven loggerheads without an obvious cause of stranding were found around the same time; five were found dead and two were moribund and died within 24 hours of discovery. Three were examined, including both live strandings that died; and all had fish within their gastrointestinal tracts.

The probable locations of mortality for a subset of 28 turtles from this group (25 Kemp's ridleys and 3 loggerheads) were determined using the backcasting analysis. Results suggested that turtles recovered along the shorelines of Galveston, Chambers, and Jefferson counties likely originated from nearby Texas state waters, inshore of 10 m depth (Figure 3-14). A smaller number of turtles (n = 7) in this subset were recovered from Matagorda and Brazoria counties; probable origins of mortality for these turtles included waters farther from shore, near the 20 m depth contour (Figure 3-14).

With regard to other stranding categories, vessel strike-type injuries were the most common type of trauma observed in Kemp's ridleys and loggerheads on the Upper Texas Coast in 2019 (Table 3-6). The next most frequent injury type found in Kemp's ridleys was trauma caused by fishing-related materials.

The greatest proportion of loggerheads that could be categorized had indications of poor health (disease category), including various degrees of weight loss and accumulation of epibiota. A primary cause of these conditions was not identified.

Nearly half of the stranded green turtles on the Upper Texas Coast had major injuries, the most frequent types of which were trauma from vessel strikes and interaction with fishing-related materials (Table 3-6). Green turtle strandings without an obvious cause of mortality comprised just over 25% of reports for this species. In contrast to Kemp's ridleys and loggerheads without obvious causes of stranding, most (66.7%; 18/27) green turtles were found alive. These turtles had multiple similarities with green turtle strandings in other areas and will be further considered in the discussion of findings for zone 20.

Table 3-5. Categories of stranding and necropsy findings for sea turtles found stranded along the Upper Texas Coast (NMFS statistical zones 18 and 19) during 2019. Proportions of each category are provided by species in parentheses.

Species	No abnormalities	Major injuries	Disease related	Unclassified	Total
Green turtle	27 (26.2%)	49 (47.6%)	6 (5.8%)	21 (20.4%)	103
Kemp's ridley	34 (50.0%)	23 (33.8%)	1 (2.2%)	9 (13.2%)	68
Loggerhead	7 (22.6%)	3 (9.7%)	8 (25.8%)	13 (41.9%)	31
Olive ridley	0 (-)	0 (-)	0 (-)	0 (-)	0
Undetermined	0 (-)	1 (-)	0 (-)	4 (-)	5
Total	68	76	15	47	207

Table 3-6. Types of injuries observed in sea turtles found stranded along the Upper Texas Coast (NMFS statistical zones 18 and 19) during 2019. Fishing tackle/gear includes hooking injuries, entanglements, and internal injuries from ingestion. Proportions of each category are provided by species in parentheses.

Species	Vessel strike	Fishing tackle/gear	Non-fisheries entanglement / entrapment	Shark attack	Other	Total
Green turtle	35 (71.4%)	9 (18.4%)	1 (2.0%)	1 (2.0%)	3[a] (6.1%)	49
Kemp's ridley	14 (60.9%)	5 (21.7%)	0 (-)	2 (8.7%)	2 (8.7%)	23
Loggerhead	3 (-)	0 (-)	0 (-)	0 (-)	0 (-)	3
Olive ridley	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0
Undetermined	0 (-)	1 (-)	0 (-)	0 (-)	0 (-)	1
Total	52	15	1	3	5	76

[a]Two instances were turtles with ligature wounds (entanglements) in which the material was not identified.

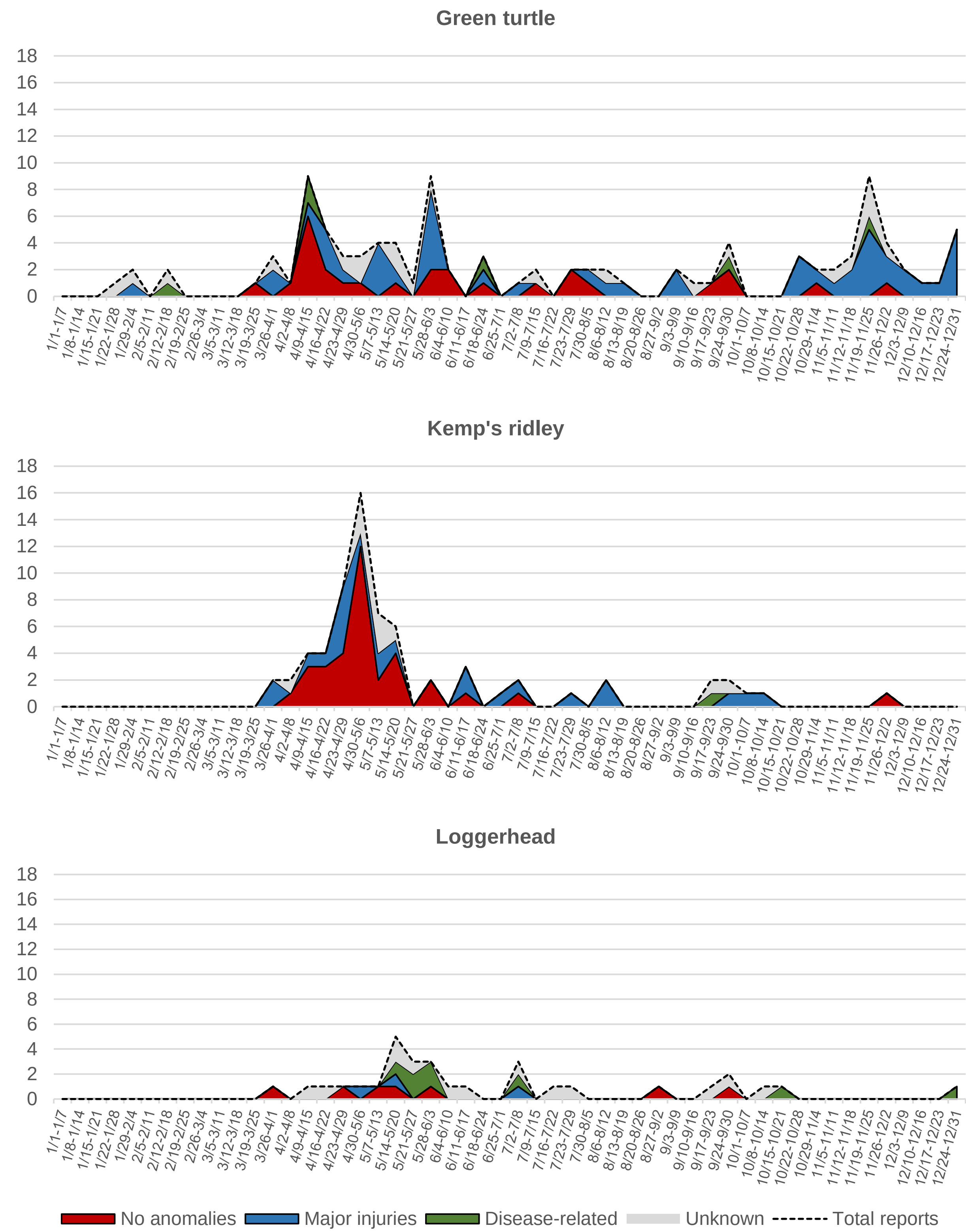


Figure 3-12. Categorization of stranding and necropsy observations by species and week for sea turtles found on the Upper Texas Coast (NMFS statistical zones 18 and 19). Week of stranding is shown on the x-axis; number of turtles for each category is shown on the y-axis.

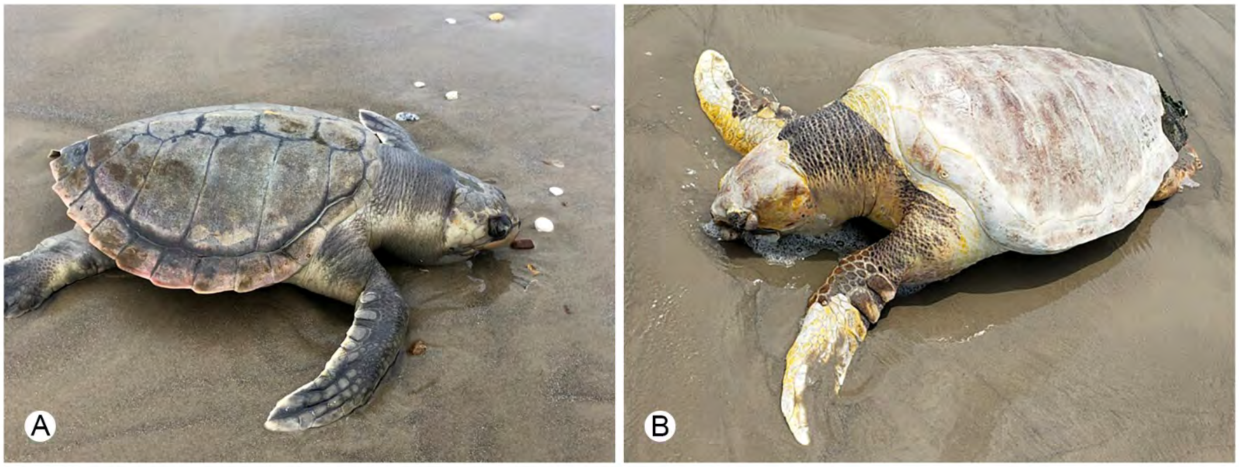


Figure 3-13. Kemp's ridley (A) and loggerhead turtle (B) found stranded in NMFS statistical zone 18. Both are decomposed and bloated. Neither have external injuries or other abnormalities and are in good nutritional condition, which is consistent with a relatively sudden cause of death.

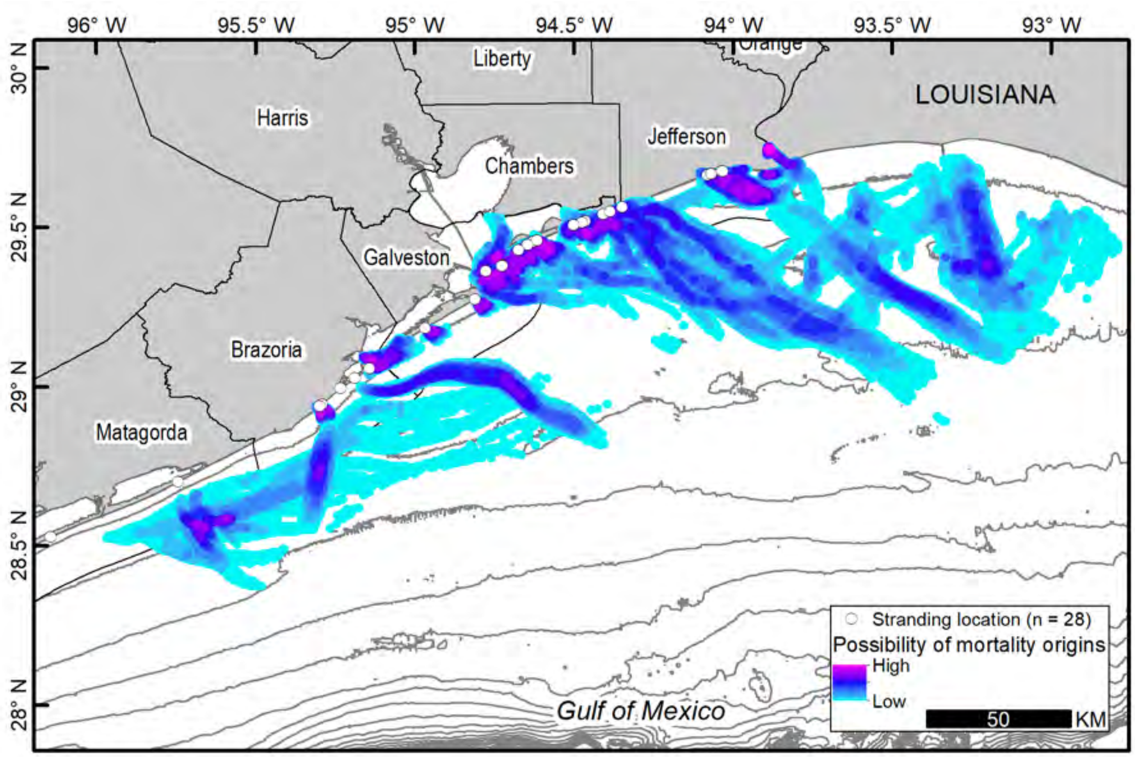


Figure 3-14. Heat map showing the possible locations where sea turtles may have died that were found stranded along the Upper Texas Coast. This map is derived from the cumulative result of backcasting analysis using the stranding locations (white circles) as input. Represented are 25 Kemp's ridleys and 3 loggerhead turtles that did not have any apparent injuries or other anomalies. Grey lines represent bathymetric contours at 10-m intervals.

3.2.2. Zone 20

Environmental modeling and analyses

During 2019, we observed a weak positive correlation between BPI and sea turtle strandings recorded within zone 20 (τ = 0.36). The peak period of green turtle strandings within zone 20 (April through September) occurred during a period of high BPI (Figure 3-15). The peak in strandings appeared to be shifted one week earlier than the period of elevated BPI. That is, the increase in strandings appeared to begin a week prior to elevated BPI and strandings declined a week prior to the decline in BPI (Figure 3-15). Strandings remained above average in zone 20 through late August. Strandings again increased to above average values during the week beginning on 22 October, a week when strandings in neighboring zone 21 also increased (discussed below), in spite of low BPI values.

Within the GLM, BPI had a significant positive effect on zone 20 strandings. The relationship between the two was nonlinear (Figure 3-16), so BPI was also included as a quadratic term in the model and was significant.

We summarized tidal height and wind data during a 24-week period at the time of elevated strandings (2 April–16 September). Tidal height ranged from -0.22 to 1.04 m (0.33 mean, ±0.20 SD) m relative to Mean Lower Low Water (MLLW) (Figure 3-17). Tidal height during this time period was highest at Aransas Pass on 10 and 11 May. Tidal heights during March were lower and ranged from -0.04 to 0.76 m (0.32 mean, ±0.16 SD) relative to MLLW. October tidal heights were similar to the period in question (range -0.02–1.05 m, 0.58 mean, ±0.18 SD).

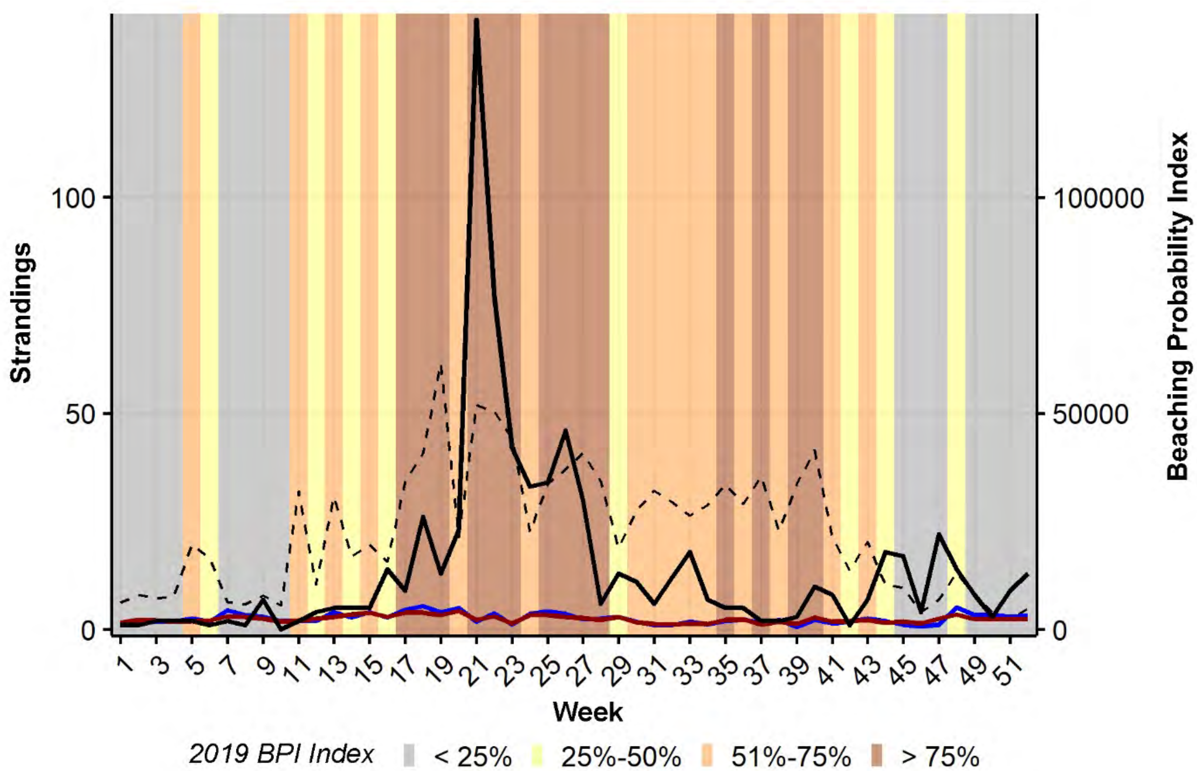


Figure 3-15. Weekly total numbers of green sea turtle strandings reported as “offshore” or within 500 m of “offshore” waters within NMFS statistical zone 20 during 2019 (black dotted line). Weekly average green turtle stranding counts for the previous five and ten years are also provided (blue and red lines, respectively). Beaching probability index is provided as quartiles (background shading) and scaled values (dashed line).

Persistent shoreward winds observed at Aransas Pass corresponded to periods of high BPI and high sea turtle strandings within zone 20 (Figure 3-18). During the 24-week period under consideration, the strongest winds were observed during the week of 21–27 May which is also the week during which the highest number of sea turtle strandings were recorded (n = 150).

No harmful algal blooms or concurrent mass stranding or mortality of other animals was reported in zone 20 during this period.

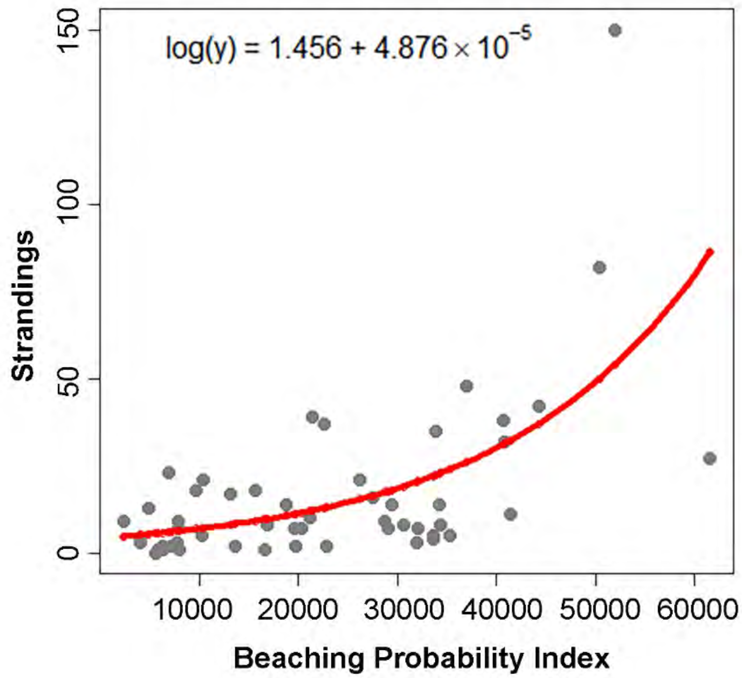


Figure 3-16. Weekly counts of sea turtle strandings recorded along the Texas coast within NMFS statistical zone 20 during 2019 and the weekly average Beaching Probability Index (BPI). The red line represents a quasi-Poisson generalized linear model fit to the data describing the relationship between strandings and BPI.

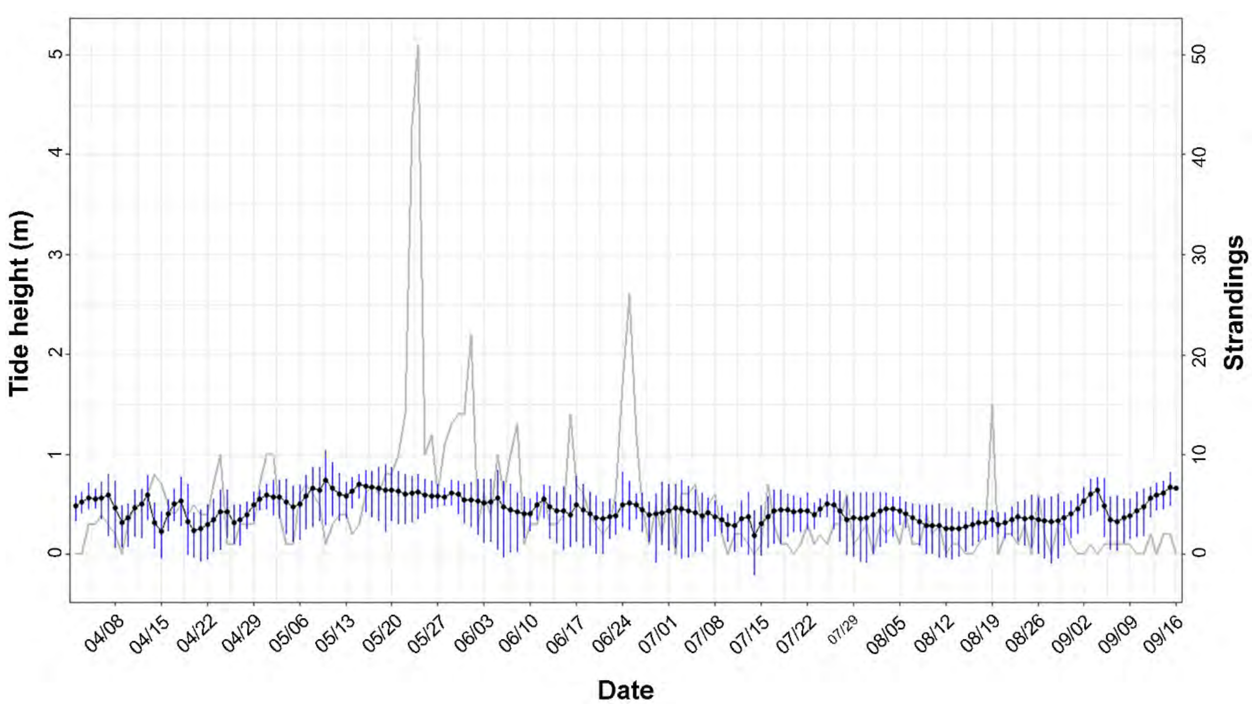


Figure 3-17. Tidal height (mean and range) collected from 2 April to 16 September 2019 at the Aransas Pass station (ANPT2). Daily total numbers of green sea turtle strandings reported as "offshore" or within 500 m of "offshore" waters within NMFS statistical zone 20 during 2019 (grey line).

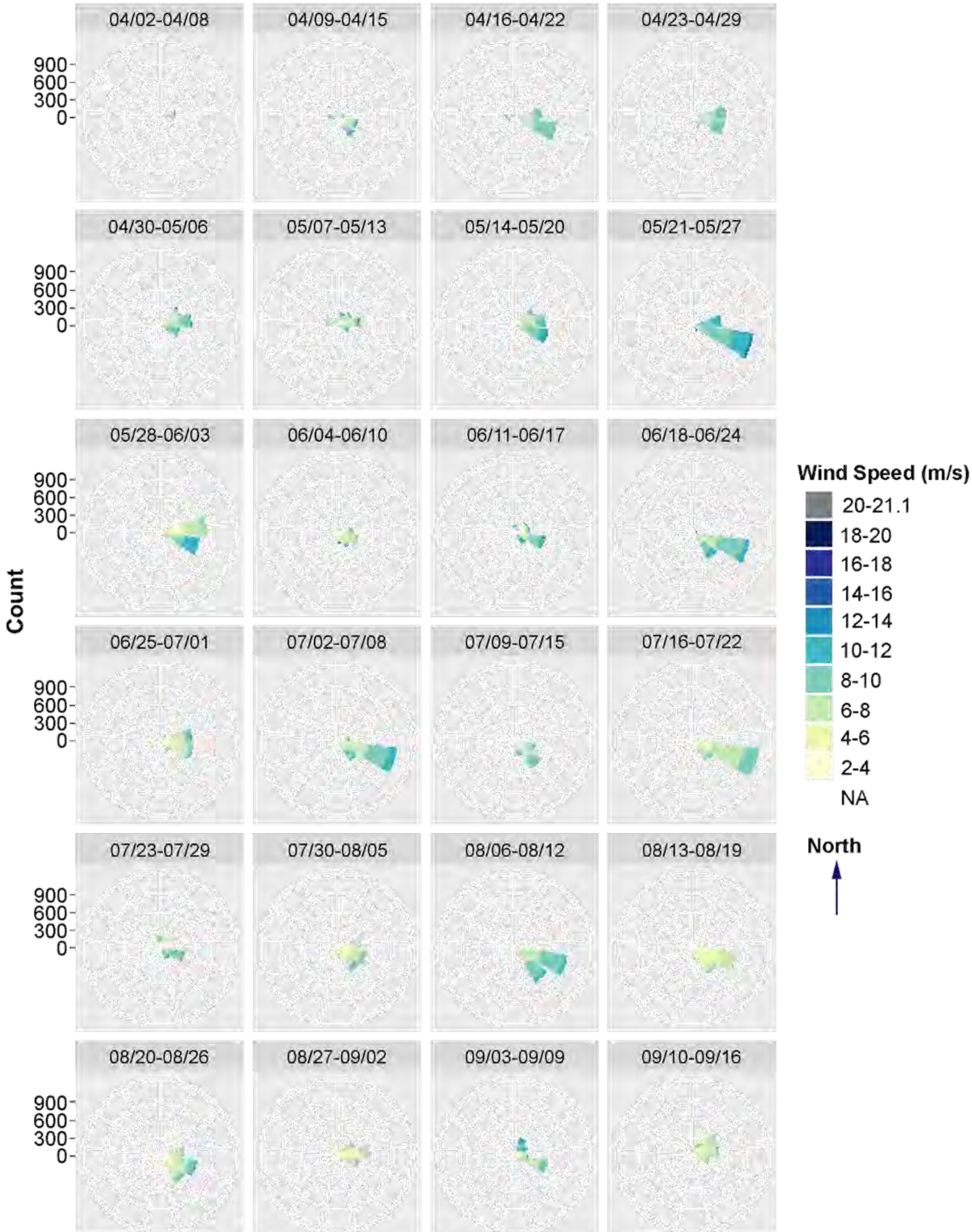


Figure 3-18. Weekly summary of wind velocity and direction collected from 2 April to 16 September 2019 at the Aransas Pass station (station ANPT2). This time period encompasses the peak sea turtle stranding period within zone 20. Periods of strong onshore winds correspond to periods of relatively high Beaching Probability Index values within zone 20.

Stranding and necropsy findings

Table 3-7 shows categories of stranding and necropsy observations for zone 20 by species. These data are presented graphically by week in Figure 3-19. Most (87.3%; 857/982) were juvenile green turtles; 49.2% (422/857) of which did not have major injuries or other apparent abnormalities except for abrasions on their plastron. Most (87.2%; 368/422) of these green turtles were found alive. In the following subsection, we present additional data and analyses related to these zone 20 green turtle strandings followed by additional subsections summarizing other causes of strandings in this zone by species. Types of injuries observed in zone 20 are summarized in Table 3-8.

Table 3-7. Categories of stranding and necropsy findings for sea turtles found stranded in NMFS statistical zone 20 in Texas during 2019. Proportions of each category are provided by species in parentheses.

Species	No abnormalities	Major injuries	Disease related	Other	Unclassified	Total
Green turtle	422 (49.2%)	244 (28.5%)	61 (7.1)	1 (0.1%)	129 (15.1%)	857
Kemp's ridley	4 (11.1%)	13 (36.1%)	8 (22.2%)	0 (-)	10 (28.6%)	35
Loggerhead	2 (2.5%)	11 (13.8%)	31 (38.8%)	0 (-)	36 (45.0%)	80
Olive ridley	0 (-)	1 (-)	0 (-)	0 (-)	0 (-)	1
Undetermined	0 (-)	3 (-)	0 (-)	0 (-)	6 (-)	9
Total	428	272	100	1	181	982

Table 3-8. Types of injuries observed in sea turtles found stranded in NMFS statistical zone 20 in Texas during 2019. Fishing tackle/gear includes hooking injuries, entanglements, and internal injuries from ingestion. Proportions of each category are provided by species in parentheses.

Species	Vessel strike type	Fishing tackle/gear	Non-fisheries entanglement / entrapment	Shark attack	Other	Total
Green turtle	86 (35.2%)	104 (42.6%)	9 (3.7%)	21 (8.6%)	24[a] (9.8%)	244
Kemp's ridley	3 (23.1%)	3 (23.1%)	0 (-)	5 (38.5%)	2 (15.4%)	13
Loggerhead	4 (36.4%)	3 (27.3%)	0 (-)	4 (36.4%)	0 (-)	11
Olive ridley	0 (-)	1 (-)	0 (-)	0 (-)	0 (-)	1
Undetermined	0 (-)	3 (-)	0 (-)	0 (-)	0 (-)	3
Total	93	114	9	30	26	271

[a]Five instances were turtles with ligature wounds (entanglements) in which the material was not identified.

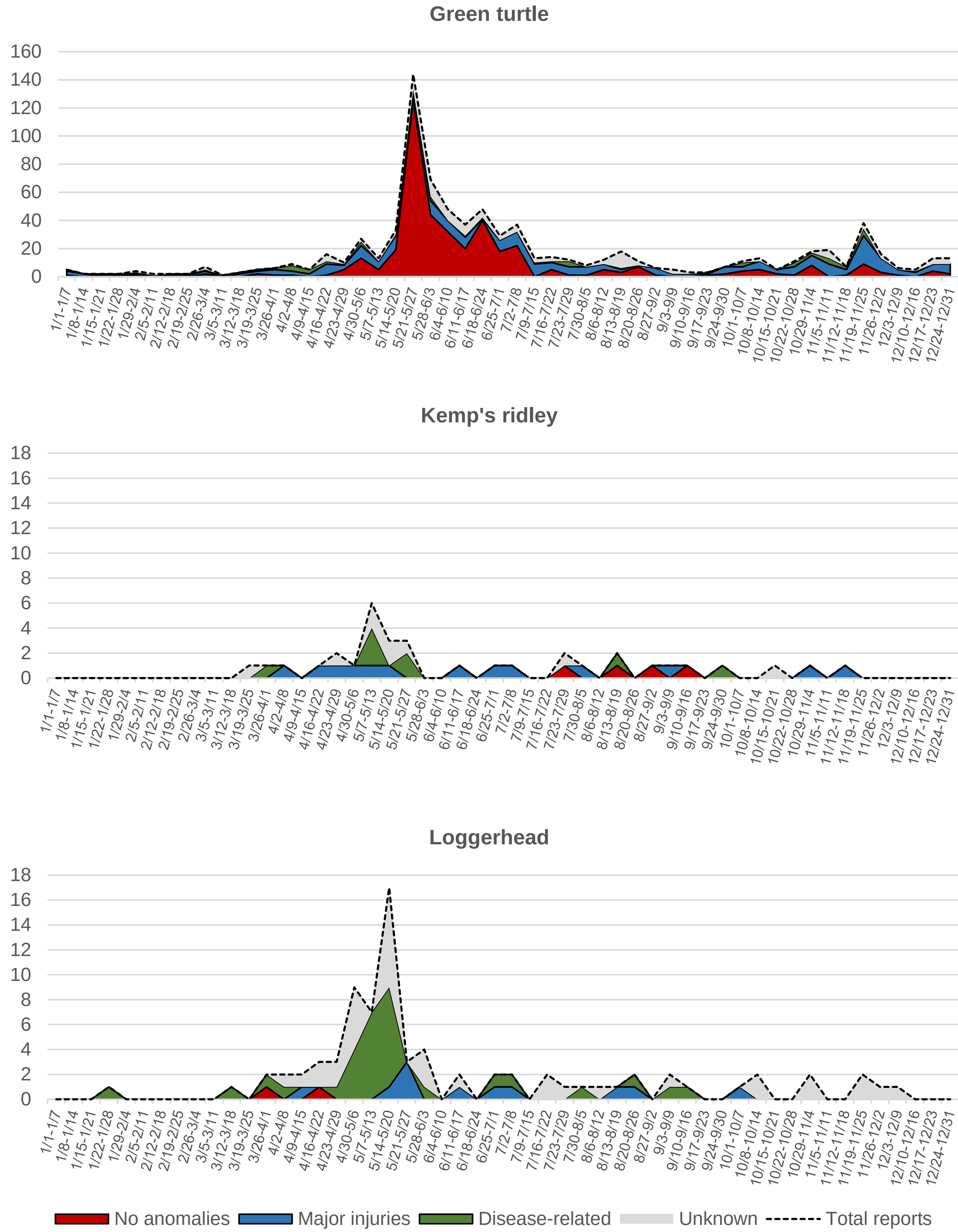


Figure 3-19. Categorization of stranding and necropsy observations by species and week for sea turtles found in NMFS statistical zone 20. Week of stranding is shown on the x-axis; number of turtles for each category is shown on the y-axis.

Green turtles without apparent abnormalities. Circumstances relevant to stranding were noted in many of these reports, the most frequent of which—representing nearly half of these cases—were descriptions of beaching or entrapment associated with tides or coastal flooding (26.6%; 108/422) and entrapment in jetty rocks (23.7%; 100/422) (Figure 3-20). Most of the latter incidences occurred at the Aransas Pass Channel (n=69) and Packery Channel (n=28). Five additional turtles without other abnormalities were described as entrapped in beached *Sargassum* sp. Also, 10 reports in zone 20 described live juvenile green turtles without evident abnormalities on shore that returned to the water and swam away with limited or no human intervention. Green turtle strandings with similar characteristics were also observed in other zones during mid-April through September, but in lower numbers. Sixty-eight were reported in zone 21, including 25 entrapped within jetty rocks (Brazos Santiago Pass, n=20; Port Mansfield Jetty, n=5) and 3 that returned to the water upon discovery. Eleven were found in zone 18, including 2 that were entrapped in jetty rocks. Only 3 green turtles were found in zone 19.

The mean straight carapace length of green turtles within this stranding category was 26.4 ± 3.9 cm (mean ± SD, range: 20.6–58.7, n = 410). Green turtles encountered as strandings elsewhere in Texas during 2019 were significantly larger (31.8 ± 10.4 cm SCL, n = 861, range: 12.0–95.3) (Figure 3-21). Turtles in this category fell between the expected sizes for the surface-pelagic (20.6 ± 2.2 cm, Witherington et al. 2012) and neritic (36.6 ± 8.9 cm, Shaver 2000, Howell et al. 2016) life history stages of green turtles reported for the Gulf of Mexico.

As previously mentioned, various degrees of plastron abrasions were frequently observed in these turtles. We were able to evaluate the plastron for 362 green turtles based on photographs, necropsy reports, and medical records. Abrasions were found in 83.7% of cases, including 89.6% (86/96) of those found in jetty rocks and 81.6% (217/266) of those found under other circumstances. The relative severity could be evaluated for 273 turtles; abrasions were mild in 75.1% and more extensive in 24.9%. Medical and necropsy records indicated that these wounds were especially severe and secondarily infected in at least 10 turtles admitted to rehabilitation, some of which also had deep abrasions involving the head, flippers, or carapace.

With regard to observations in live green turtles, behavior was recorded at the time of stranding for 52 turtles; 84.6% (n = 44) were described as active and 15.4% (n = 8) were noted to be weak or lethargic. No abnormal neurological signs were observed. At the time of compilation of this report, the rehabilitation outcome was reported[2] for 69.0% (254/368) of turtles that were found alive; 92.9% (n = 236) were released and 7.1% (n = 18) died. Of those that received treatment at rehabilitation facilities, over 81% (192/236) were released within 20 days of which 41.5% (98/236) were released after less than one week (Figure 3-22). Based on conversations with clinical veterinarians that provided treatment, their impressions were that most turtles responded quickly to supportive care (e.g., fluid therapy, feeding, and rest) and treatment of those with more extensive plastron abrasions.

[2] Rehabilitation records inevitably lag behind reports of other stranding data in the current records system. It is not anticipated that there will be major differences once the full complement of disposition data are available.

Figure 3-20. Packery Channel, one of two armored inlets where many stranded green turtles were found in NMFS statistical zone 20 (A, B). Six juvenile green turtles (arrowheads) are visible foraging on algae that grows on the jetty rocks (C). Two juvenile green turtles entrapped in the rocks prior to rescue by stranding responders (D).

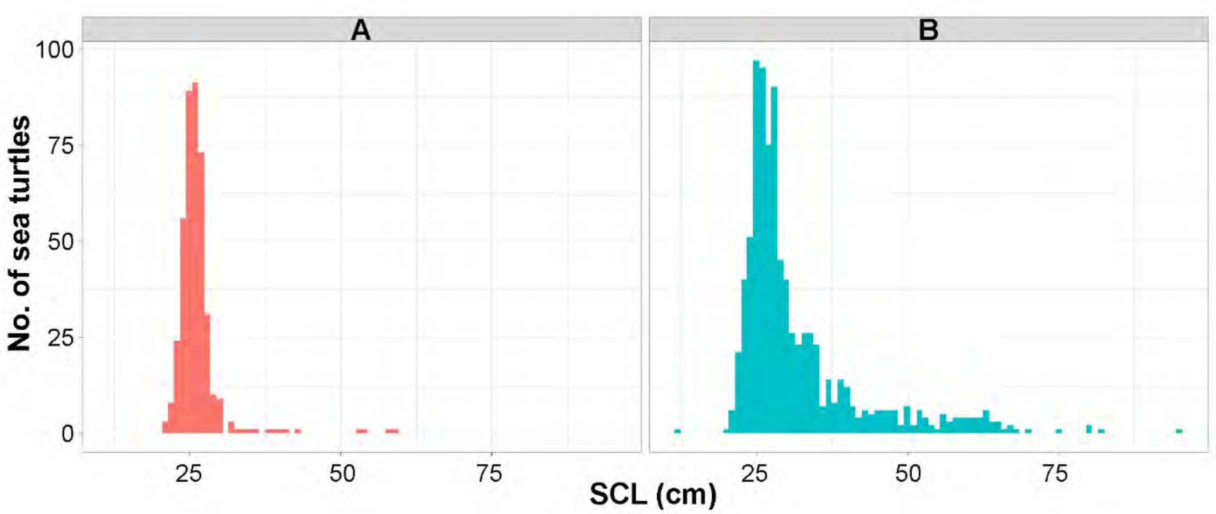


Figure 3-21. Straight carapace lengths (SCL) of green turtles stranded along the Texas coast during 2019. The histogram in panel A represents green turtles that were found both within zone 20 and categorized as having no abnormalities. The histogram in panel B represents the sizes of all other green turtle strandings in Texas; i.e., excluding those found in zone 20 and categorized as having no abnormalities.

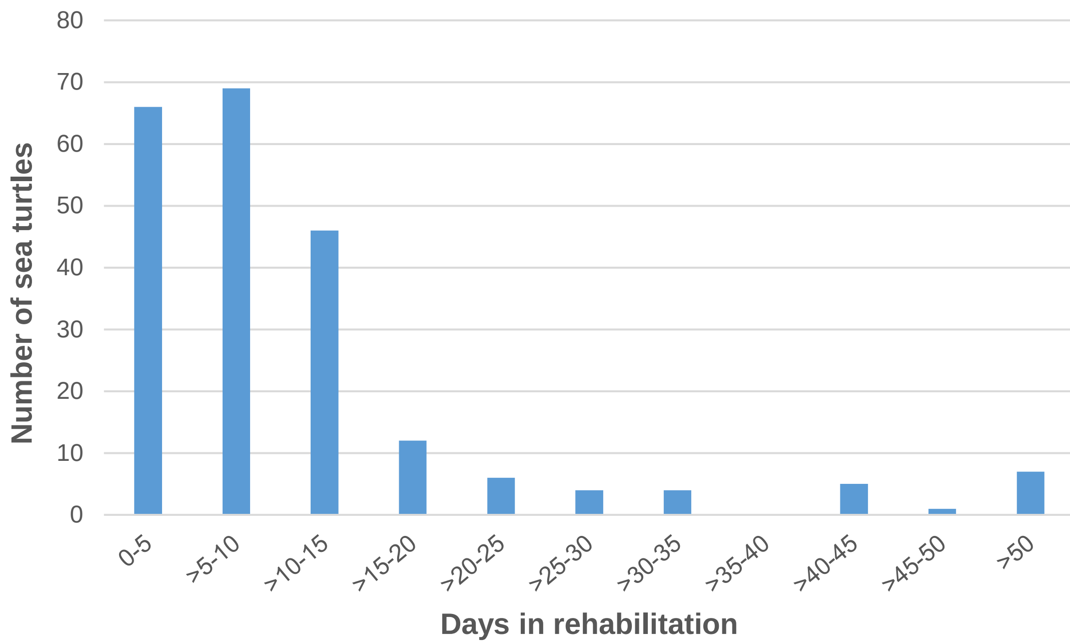


Figure 3-22. Histogram of rehabilitation durations for live green turtles without major injuries or other abnormalities admitted to rehabilitation facilities.

Necropsies were conducted on 47 green turtles from this group that were found dead or died after stranding. We found no internal evidence of disease as a cause of the strandings. Most (88.4%, 38/43) had evidence of recent feeding as indicated by the presence of food items within the esophagus or stomach. Of 18 turtles that were consistently evaluated by the same examiner, 22.2% (4/18) had a low volume of gastrointestinal contents indicative of reduced feeding, and 33.3% (6/18) had very firm colon contents suggestive of dehydration. Given the size distribution of strandings and the potential for some having recently transitioned from the oceanic zone, occurrence of *Sargassum* sp. within gastrointestinal contents was examined as an indicator of epipelagic feeding. *Sargassum* was noted in 10.0% (2/20) of zone 20 green turtles and 10.2% (11/108) of green turtles statewide, all of which were found in March through May. *Sargassum* sp. was not found in green turtles that stranded later in the year.

Condition of the pericoelomic fat was evaluated for 41 turtles of which 26.8% (n = 11) had non-atrophied fat. Fat was mildly atrophied in 41.5% (n = 17), moderately atrophied in 19.5% (n = 8), and severely atrophied in 9.8% (n = 4). We compared these proportions to the fat condition of green turtles that were found dead without injuries or other apparent abnormalities on Gulf beaches in zone 21 in November and December (to be discussed in Section 3.2.3.) to examine possible differences in nutritional condition. Greater proportions of turtles that stranded in spring and summer in zone 20 had various degrees of atrophy of their body fat, but this difference was not significant.

Biotoxin exposure was investigated as a potential contributing cause of strandings, particularly those without major injuries or other apparent abnormalities. Detailed results are provided in Appendix B. Samples from 39 individual green turtles that stranded in zones 20 and 21 were analyzed for biotoxins known to affect air-breathing marine vertebrates in the western hemisphere. Brevetoxins were detected in relatively low concentrations (22.4 and 34.2 ng/g) in the livers of two turtles. This level of exposure is well below mean values measured in sea turtles during red tides with associated sea turtle mortality (Foley et al. 2018) and during prior red tides in Texas (Walker et al. 2018). Domoic acid (DA) was detected in at least one sample type from 41.0% (16/39) of the turtles analyzed from zones 20 and 21. Of those that stranded during April and May, DA was detected in 17 of 19, whereas it was not detected in any turtles that stranded later in the year. The highest concentrations of DA detected in any sample by individual was < 10 ng/g in five turtles, > 10–100 ng/g in 9 turtles, and > 100 ng/g in 3 turtles. Plasma, from which DA is cleared relatively rapidly in other species (Tubaro and Hungerford 2007), was the only sample available for two of the turtles with concentrations < 10 ng/g. Domoic acid was detected in four of five plasma samples analyzed during April and May. The highest concentrations were found in feces with the greatest concentration measuring 1,104.8 ng/g by LC-MS/MS. In addition, saxitoxin was detected in low concentrations (< 10 ng/g) in feces of two green turtles from zone 21.

Green turtles with major injuries or evidence of disease. Types of injuries observed in green turtles found in zone 20 are shown in Table 3-8. The most frequent injuries were entanglement or entrapment in fishing materials followed by wounds consistent with vessel strikes. There was a significant association between strandings caused to recreation fishing tackle and inlet jetties, particularly those of Packery Channel and Aransas Pass Channel.

Of those green turtles with evidence of disease, this category was frequently assigned based on epibiota accumulation and/or diminished nutritional condition without apparent cause, although nearly half of the green turtles with evidence of disease (28/61) had moderate or advanced fibropapillomatosis often accompanied by marine leech (*Ozobranchus* sp.) infestation and evidence of anemia (pallor of visceral organs) at necropsy. Additional information on the occurrence of fibropapillomatosis in Texas can be found in Shaver et al. 2019.

Kemp's ridley strandings. Stranding category could be assigned to 71.4% (25/35) of Kemp's ridleys that stranded in zone 20. About half had traumatic injuries that, as with loggerheads found in this zone, included shark bite injuries, wounds caused by fishing-related materials, and vessel strikes (Table 3-8). Eight Kemp's ridleys were found in zone 20 with health-related findings, five of which were emaciated or had accumulated epibiota without other apparent abnormalities except for healed injuries (including amputations) in three turtles. One of these three turtles with healed injuries, an emaciated individual, also had recent shark bites attributable to scavenging or depredation. Other conditions identified in Kemp's ridleys included single cases of probable colitis, severe renal infection, and septicemia (embolic hepatitis) of unknown origin.

Loggerhead strandings. Of the loggerheads that stranded within zone 20 that could be assigned to a stranding category (n = 43), the greatest proportion (72.1%; 31/43) were disease-related. Of these, 81.3% were emaciated or very underweight as evidenced by gaunt external features and atrophy of muscle and fat (if necropsied). Diminished nutritional condition was accompanied by various degrees of epibiota accumulation. Of the 21 loggerheads within this category that were necropsied, ulcerative gastrointestinal disease was detected in 52.4% (11/21), six of which were impacted with the calcareous spines of sea pens (order Pennatulacea). Abundant sea pen spines that appeared impacted were found in two additional decomposed loggerheads in which the gastrointestinal tract could not be confidently evaluated. The other loggerheads with evidence of disease had bacterial infections involving other organ systems or a cause of poor nutritional condition could not be identified. Of the loggerheads found in zone 20 with major injuries, types of trauma included similar proportions of turtles with vessel strike injuries, wounds from fishing-related materials, and shark bites (Table 3-8). Two loggerheads stranded in zone 20 without injuries or other apparent cause; they were found in late March and April. One was in suitable condition for necropsy and had been feeding on fish and had sediment within the respiratory tract, similar to strandings in zone 18 during this time.

Other zone 20 observations. The first recorded stranding of an olive ridley in Texas was found in zone 20 during 2019. This turtle had multiple fibropapillomas and was entangled in fishing line. The species was confirmed by genetic analysis (P. Dutton, NOAA Southwest Fisheries Science Center).

Comparison of green turtle strandings and nesting beach productivity

The annual number of hatchlings produced in Campeche, MX correlated well with the number of green turtle turtles ≤ 30 cm SCL that stranded in Texas assuming that the mean age of recruitment is 2 years (Figure 3-23). This duration is within the range of current estimates for the Northwest Atlantic based on skeletal chronology and growth rates (Goshe et al. 2010; Bjorndal et al. 2019).

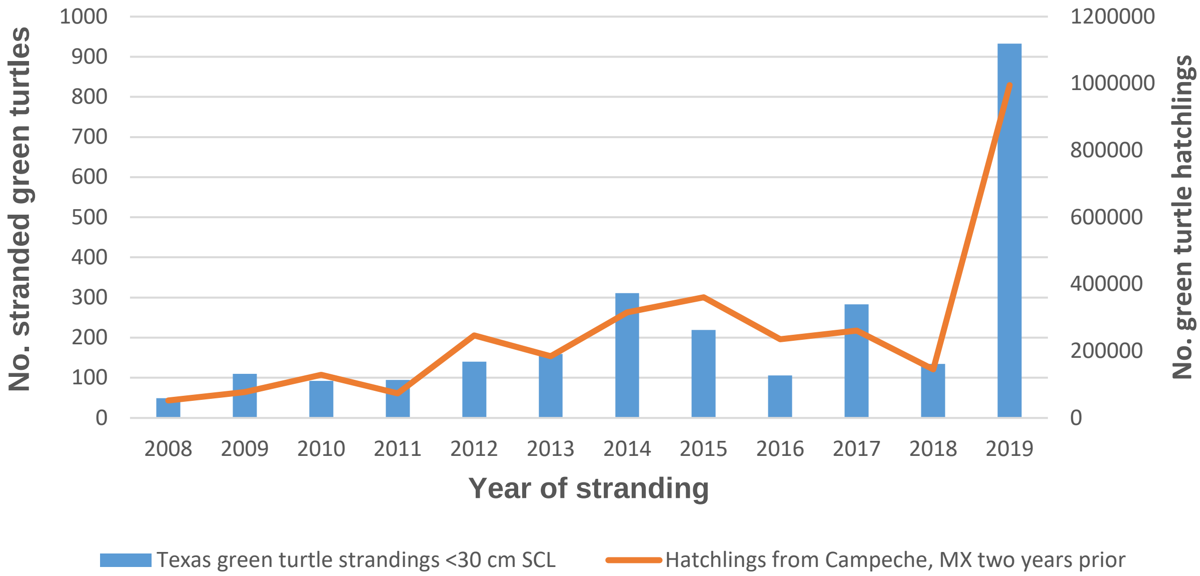


Figure 3-23. Numbers of stranded green turtles ≤ 30 cm straight carapace length (SCL) by year in Texas (bar graph) as compared with the number of hatchlings that emerged from nesting beaches in Campeche, Mexico 2 years prior to the year of stranding (data provided by Vicente Guzmán-Hernández and Eduardo Cuevas). This comparison assumes an average age of recruitment into the neritic zone of 2 years.

3.2.3. Zone 21

Environmental modeling and analyses

Similar to zone 20, strandings in zone 21 were above average during the late spring and early summer months of 2019. This initial peak occurred from late-March to early-June, slightly earlier in the year than that of zone 20. From mid-June to September 2019 strandings oscillated between periods of above average reports followed by brief returns to typical stranding levels. BPI was variable during this time (Figure 3-24). Periods of above average strandings lagged behind periods of elevated BPI by one to two weeks.

During 2019, we did not observe an overall significant correlation between BPI and sea turtle strandings recorded within the zone 21 portion of the Texas Coast ($\tau = -0.17$, $p = .08$). Within the GLM, however, BPI had a significant negative effect on zone 21 strandings. The relationship between the two was nonlinear (Figure 3-25), so BPI was also included as a quadratic term in the model and was significant.

Offshore strandings of green turtles within zone 21 increased to above average levels during late October culminating into the discrete mass event in the Boca Chica Beach area within November and extending into December. This event comprised a substantial proportion of total strandings within this zone during 2019. As strandings began to increase in October, BPI was falling (Figure 3-24). The peak period of elevated strandings occurred from 20 to 28 November when BPI was low

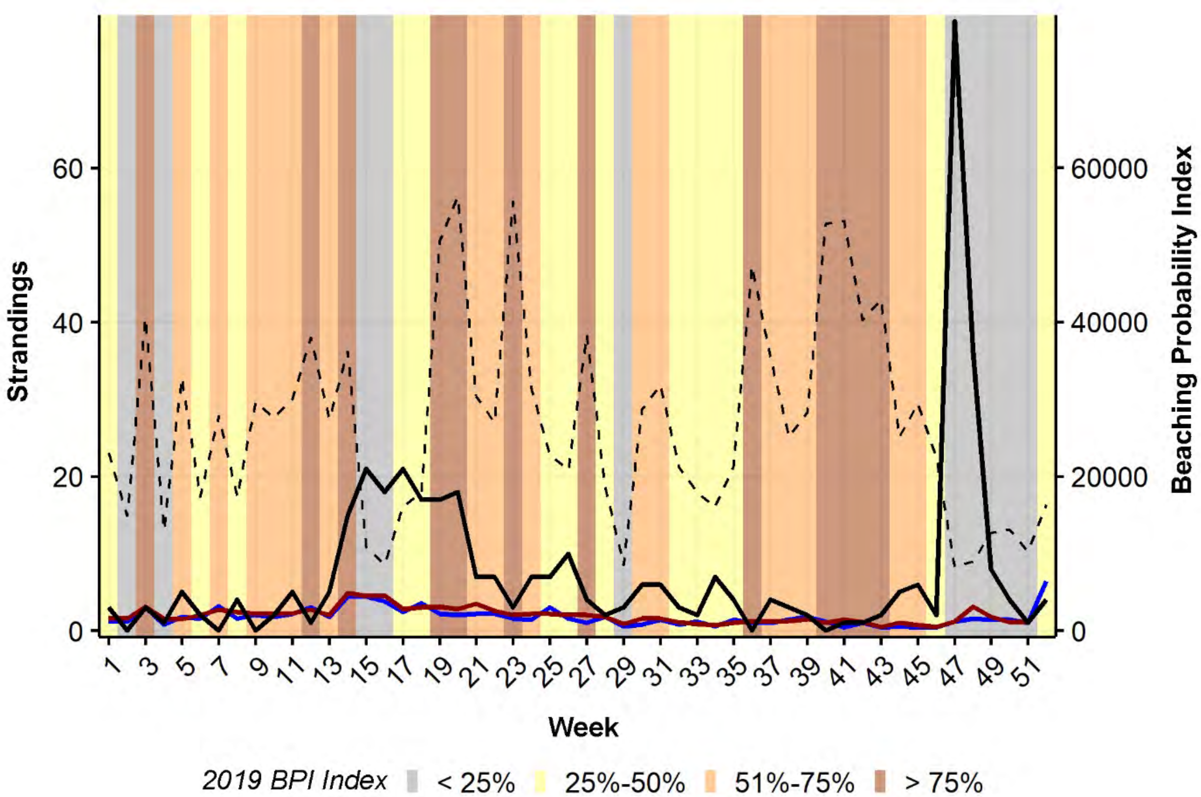


Figure 3-24. Weekly total numbers of sea turtle strandings reported as “offshore” or within 500 m of “offshore” waters within NMFS statistical zone 21 during 2019 (black dotted line). Weekly average stranding counts for the previous five and ten years are also provided (blue and red lines, respectively). Beaching probability index is provided as quartiles (background shading) and scaled values (dashed line). Note the discrete mortality event in November–December (weeks 46-50).

(Figure 3-26). This period of elevated strandings differs from the pattern observed during previous months in two ways. First, weekly stranding counts were 2–4 times higher than the spring stranding peak in zone 21 when BPI was relatively high. Second, the week 47 stranding peak lagged the previous BPI peak by 6 weeks instead of the possible 1–2 week lag that was observed in the preceding months.

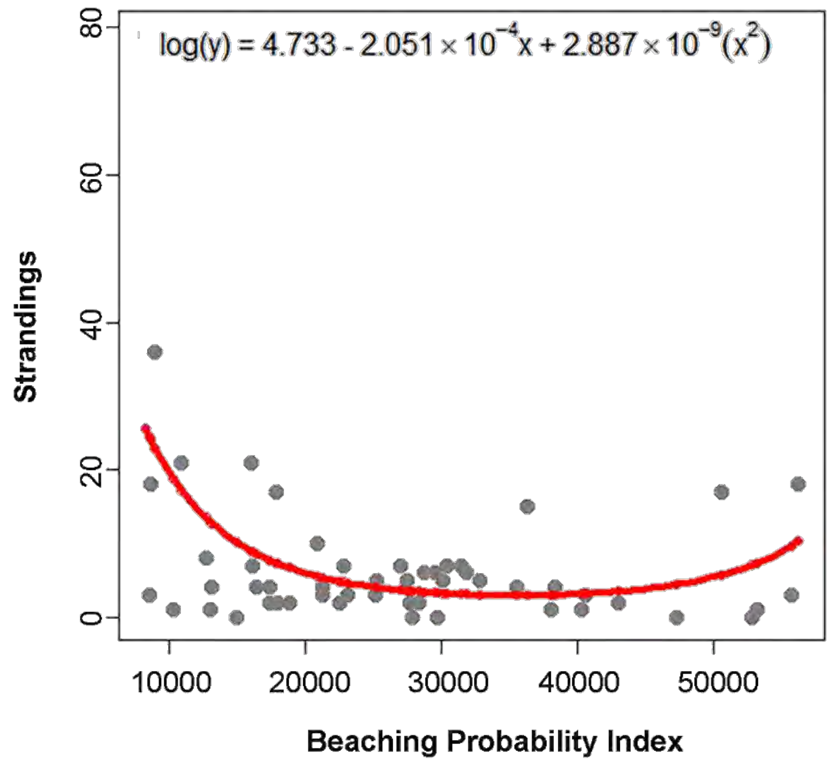


Figure 3-25. Weekly counts of sea turtle strandings recorded along the Texas coast within NMFS statistical zone 21 during 2019 and the weekly average Beaching Probability Index (BPI). The red line represents a quasi-Poisson generalized linear model fit to the data describing the relationship between strandings and BPI.

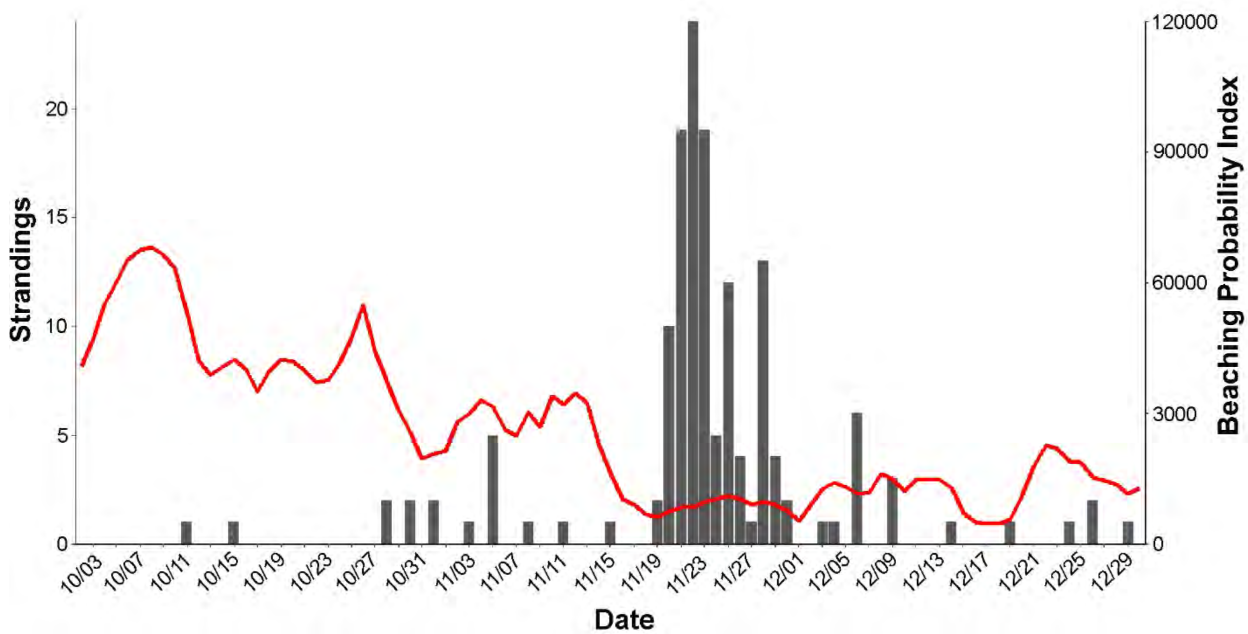


Figure 3-26. Daily total sea turtle strandings reported as “offshore” or within 500 m of “offshore” waters within zone 21 from October to December 2019 (bars). The corresponding NMFS statistical zone 21 Beaching Probability Index is indicated by the red (red line).

Stranding and necropsy findings

Stranding categories are presented by species in Table 3-9 and are shown graphically by week in Figure 3-27. Green turtles were the predominant species (88.0%; 360/409) found stranded in zone 21. Types of injuries observed within zone 21 are given in Table 3-10.

Table 3-9. Categories of stranding and necropsy findings for sea turtles found stranded in NMFS statistical zone 21 in Texas during 2019. Proportions of each category are provided by species in parentheses. Green turtle stranding data for 11/1 through 12/15/2019 and Gulf of Mexico-facing shores (i.e., excluding waters inside barrier islands) are shown separately due to a mortality event during this period.

Species					
			All months		
Green turtle	173 (48.1%)	94 (26.1%)	21 (5.8%)	72 (20.0%)	360
Kemp's ridley	6 (23.1%)	8 (30.8%)	4 (15.4%)	8 (30.8%)	26
Loggerhead	2 (10.0%)	5 (25.0%)	9 (45.0%)	4 (20.0%)	20
Undetermined	0 (-)	0 (-)	0 (-)	3 (-)	3
Total	181	107	34	87	409
			11/1 through 12/15, Gulf shore only		
Green turtle	69 (60.0%)	13 (10.9%)	5 (4.2%)	32 (26.9%)	119

Table 3-10. Types of injuries observed in sea turtles found stranded in NMFS statistical zone 21 in Texas during 2019. Fishing tackle/gear includes hooking injuries, entanglements, and internal injuries from ingestion. Proportions of each category are provided by species in parentheses for sample sizes > 10.

Species	Vessel strike type	Fishing tackle/gear	Non-fisheries entanglement / entrapment	Shark attack	Other	Total
Green turtle	28 (29.8%)	28 (29.8%)	6 (6.4%)	22 (23,4%)	10[a] (10.6%)	94
Kemp's ridley	1	4	1	2	0	8
Loggerhead	2	0	0	3	0	5
Undetermined	0	0	0	0	0	0
Total	31	32	7	27	10	107

[a]Four instances were turtles with ligature wounds (entanglements) in which the material was not identified.

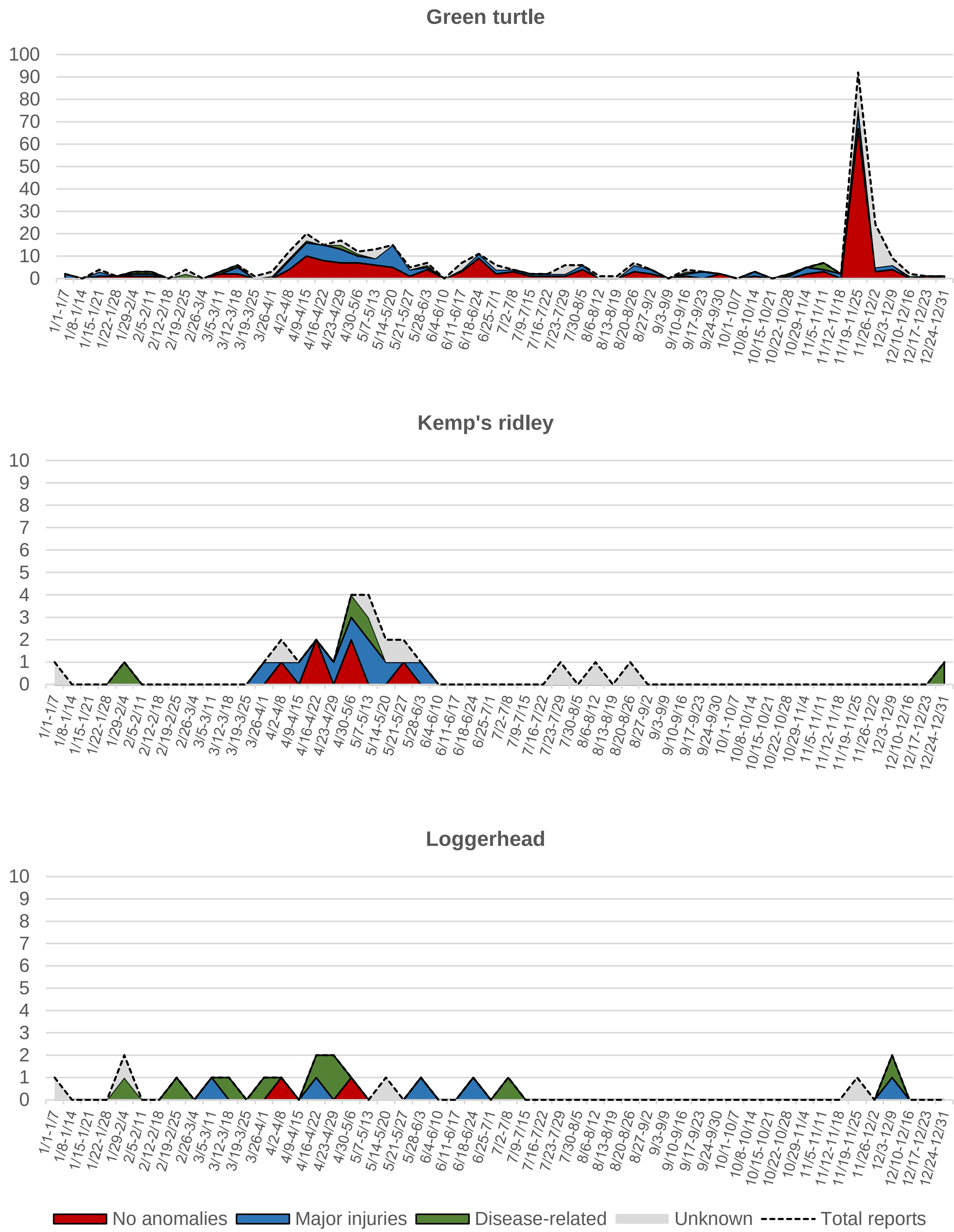


Figure 3-27. Categorization of stranding and necropsy observations by species and week for sea turtles found in NMFS statistical zone 21. Week of stranding is shown on the x-axis; number of turtles for each category is shown on the y-axis.

Green turtle strandings – spring and summer. Green turtles that stranded during mid-April through September, when strandings markedly exceeded historical averages in zone 20, had similar findings to green turtles that stranded in other zones during this period (see subsection 3.2.2.). Of the 148 green turtles that stranded in zone 21 during this time, 45.9% (68/148) did not have major injuries or other apparent abnormalities, 35.8% (53/148) had major wounds, 3.4% (5/148) had evidence of disease, and 14.9% (22/148) could not be categorized. The majority (64.7%; 44/68) of those without injuries or other abnormalities were found alive and, as previously mentioned, 25 were found entrapped in jetty rocks and three were observed on shore and returned to the water with minimal or no intervention. In addition, 59.6% (34/57) had plastron abrasions. Results of biotoxin analyses related to these strandings are presented in subsection 3.2.2.

Types of traumatic injuries observed in green turtles were similar to those observed other zones and included vessel strikes, wounds caused by fishing-related materials, and shark bites. As for zone 21, there was a significant association between interactions with recreational fishing tackle and stranding at or near an armored inlet (Brazos Santiago Pass). Findings related to disease states were also similar to other zones and included moderate or advanced degrees of fibropapillomatosis (42.9%; 9/21); epibiota accumulation (57.1%; 12/21)—often without evident cause, and heavy infestation by marine leeches (38.1%; 8/21).

Boca Chica Beach green turtle mortality event. Table 3-9 shows categories of stranded green turtles found in zone 21 encompassing a substantial spike in strandings in November. One hundred and eighteen green turtles stranded on Gulf-facing shores within zone 21 from November 1 to December 10. Most (n = 90) were found south of the Brazos Santiago Pass (BSP). Three were found on November 6, followed by a large pulse during November 21–23, and then smaller pulses through December 10. Of these strandings, 87 were in suitable condition for categorization, 79.3% (69/87) did not have major injuries or other indications of disease (Figure 3-28). All but one of these turtles was found dead. Sixty-three turtles without an externally evident cause of stranding were examined by necropsy and found to be in good or fair nutritional condition based on robustness of musculature and body fat. Three had superficial abrasions on one or more of their front flippers.

Most turtles (81.0%; 51/63) had food items within the esophagus and stomach indicative of recent feeding, although 17.8% were subjectively assessed to have reduced digesta volume, which may reflect seasonally reduced levels of foraging during winter. Water within the stomach can occur when animals swallow water during drowning and was noted during necropsy. Water admixed with gastric contents was noted in 44.4% (28/63) of turtles. Of 22 necropsied turtles that were minimally decomposed (i.e., with the least degree of postmortem change), increased froth or fluid was noted in the respiratory system of 59.1% (n = 13). Particulate material (sediment) was found in the lungs of 6.3% (4/63) of examined turtles. Collectively, these findings were consistent with a sudden cause of mortality, such as drowning of otherwise apparently healthy sea turtles.

We examined the postmortem condition of turtles found during this event, including those that could not be categorized due to poor postmortem condition, in order to identify any apparent temporal trend in the mortality (i.e., suggestive of a single event vs. continuous mortality). Those turtles that were the least decomposed tended to be found earlier in the event and the more decomposed tended to be found later (Figure 3-29); however, different postmortem conditions were represented throughout the event. This pattern suggested that the mortality occurred at multiple time points, but other factors likely influenced the degree of decomposition at stranding, such as mortality occurring at multiple different locations and variation in the postmortem interval prior to documentation by stranding responders (e.g., longer periods of drifting prior to beaching or other delays in detection).

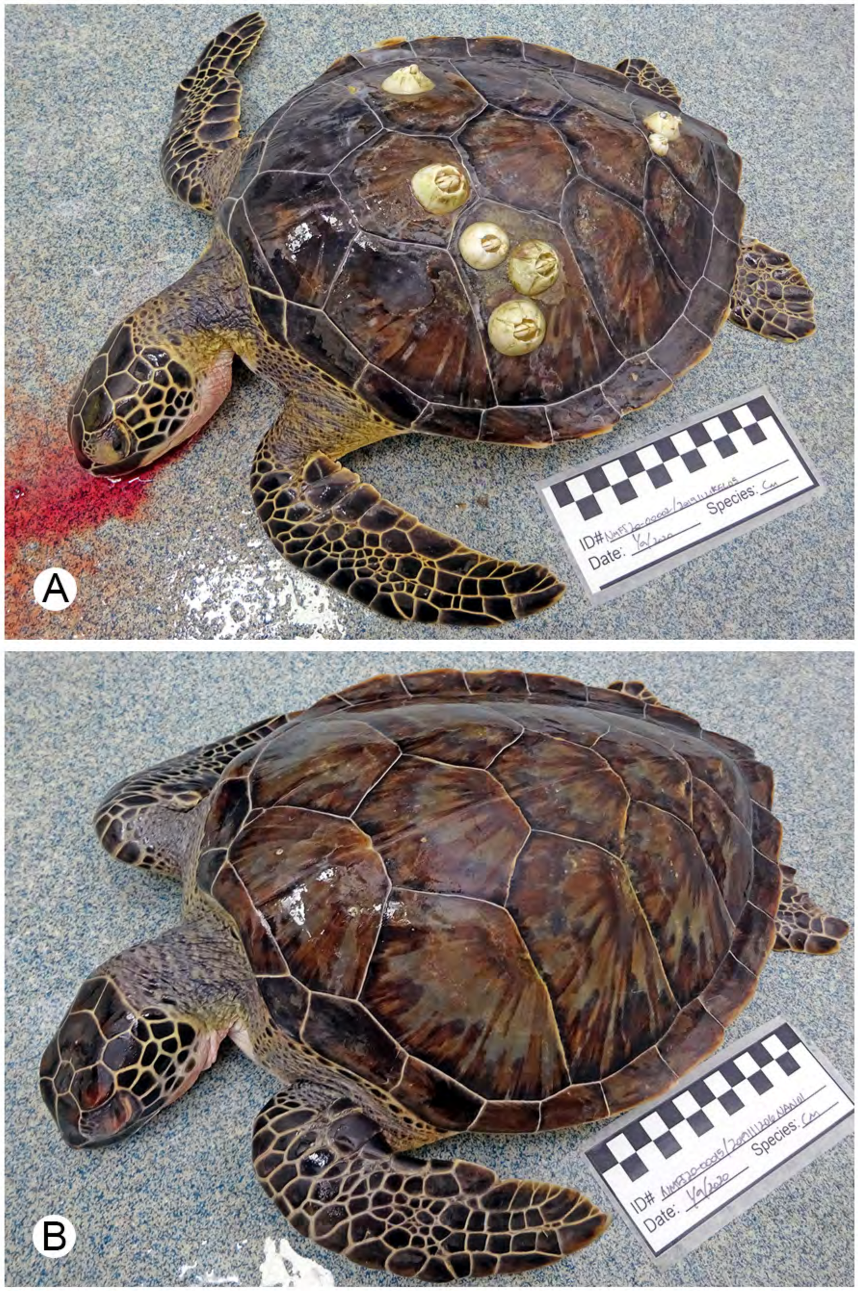


Figure 3-28. Green turtle found stranded during a mortality event in the Boca Chica Beach area of NMFS statistical zone 21 (A). There are no visible injuries or other abnormalities, which is similar to the green turtle shown in (B) that was removed from a gillnet illegally set off of Boca Chica Beach. The blood-tinged fluid flowing from the mouth in (A) is due to decomposition.

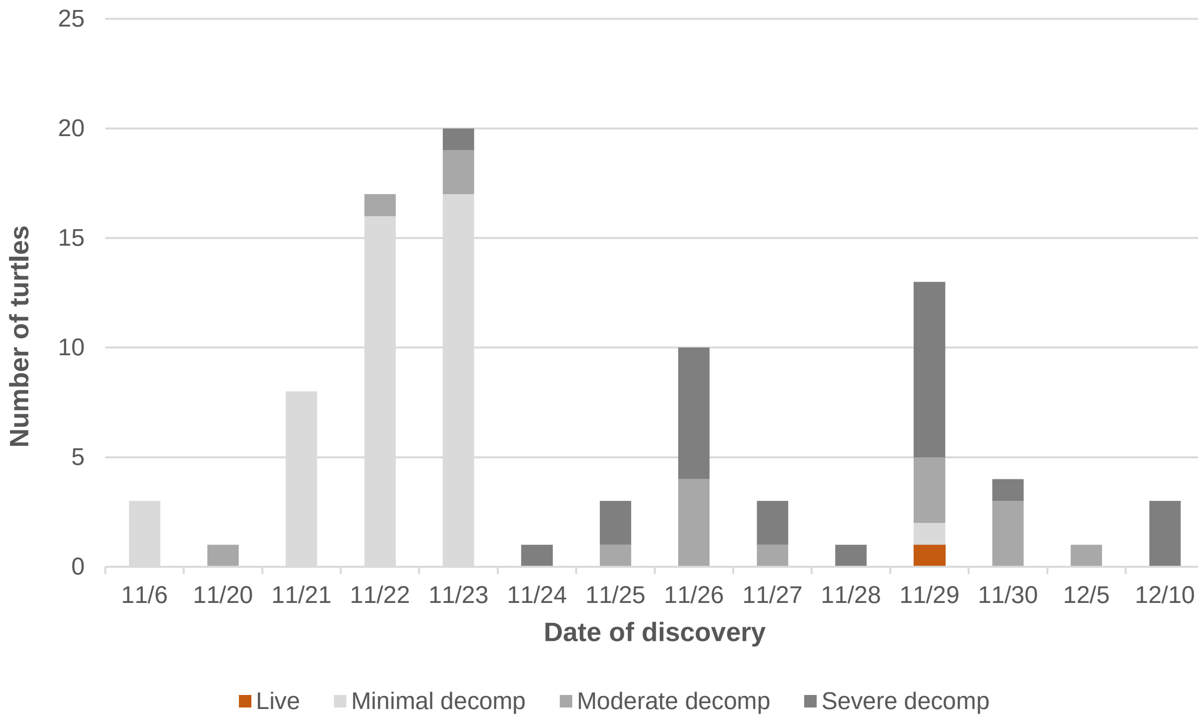


Figure 3-29. Condition (live and degree of decomposition) of green turtles found during the Boca Chica mortality event.

The only other sea turtle strandings during the period and in this area were three loggerheads found north of the BSP. One loggerhead had been caught on a large circle hook, another was in poor nutritional condition, and the third could not be categorized due to decomposition. Observations of other dead wildlife during the period of elevated strandings included the partial remains of sharks found on Boca Chica Beach, some of which had clearly evident sharply incised wounds consistent with having been butchered.

During our investigation, we were contacted by members of the public and media that were concerned that a Space X rocket explosion at a Boca Chica facility on November 21 may have caused the green turtle deaths. We did not find any necropsy evidence of chemical or traumatic injury to suggest that the turtles were killed by the explosion. The local stranding response organization and federal and state resource agencies did not report finding other affected wildlife, including those that tend to be more sensitive to chemical toxicity such as birds and fish. Moreover, the first strandings associated with Boca Chica mortality event were found prior to the explosion.

We also investigated various possible non-anthropogenic causes of sudden mortality. In order to determine whether cold-stunning may have been a factor, we reviewed meteorological data for this area during October–December 2019. During this period, water temperature at the BSP NDBC station ranged from 11.6 to 30.6°C (mean 20.9°C, Figure 3-30). The coolest water temperatures occurred during 12–15 November following the passage of a cold front. Water temperatures ranged from approximately 12 to 17°C during this period, and did not reach or persist below 10°C in Gulf waters, which are the conditions that cause major hypothermic stunning events (Witherington and Ehrhart 1989; Foley et al. 2007).

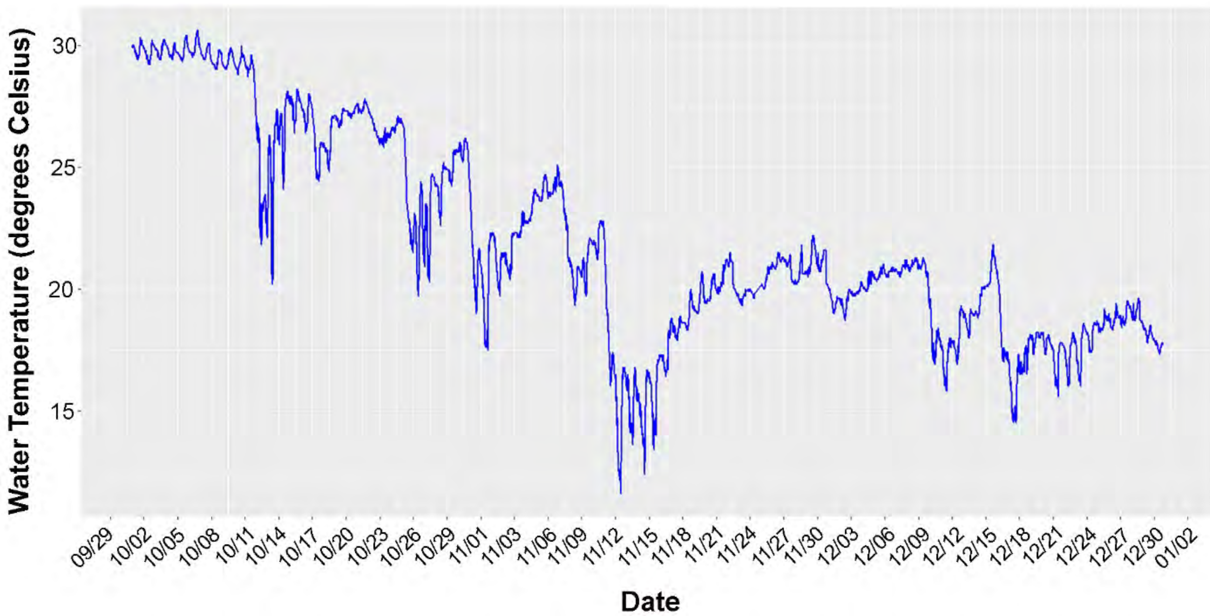


Figure 3-30. Weekly water temperature collected from October to December 2019 at the Brazos Santiago Pass NDBC station (BZST2). Water temperatures fell to a minimum of 11.6 C following the 12 November cold front. Water temperatures reached 20 C and remained moderate during the peak stranding period. Mean water temperature during this period was 20.9 C (range 11.6–30.6).

Samples from five representative cases were analyzed for known biotoxins of interest in the Gulf of Mexico, including brevetoxins, domoic acid, and saxitoxins. All were below limits of detection (see Appendix B). There were no reports of harmful algal blooms or water discoloration events within the period or area of the strandings.

Drowning due to forced submergence was suspected by exclusion of other known causes of sudden mortality afflicting sea turtles. As the mortality was occurring, Dr. Donna Shaver, the Texas STSSN State Coordinator, requested that the United States Coast Guard conduct patrols of the area due to concerns about potential fisheries interactions as a cause of the strandings and ongoing interdiction of illegal fishing in waters of South Texas. Two illegally set gillnets containing live and dead green turtles were recovered in coastal waters adjacent to Boca Chica Beach where the strandings were found. One dead green turtle recovered from a net was retained for necropsy and had findings similar to those observed in the stranded turtles (Figure 3-28).

We modeled the likely origins of mortality for a subset of 31 green turtles that fit model parameters and case characteristics for the Boca Chica mortality event. Based on the results of the backcasting model, the likely locations of mortality for this group of turtles was within both U.S. and Mexican waters, inshore of the 20 m bathymetric contour (Figure 3-31).

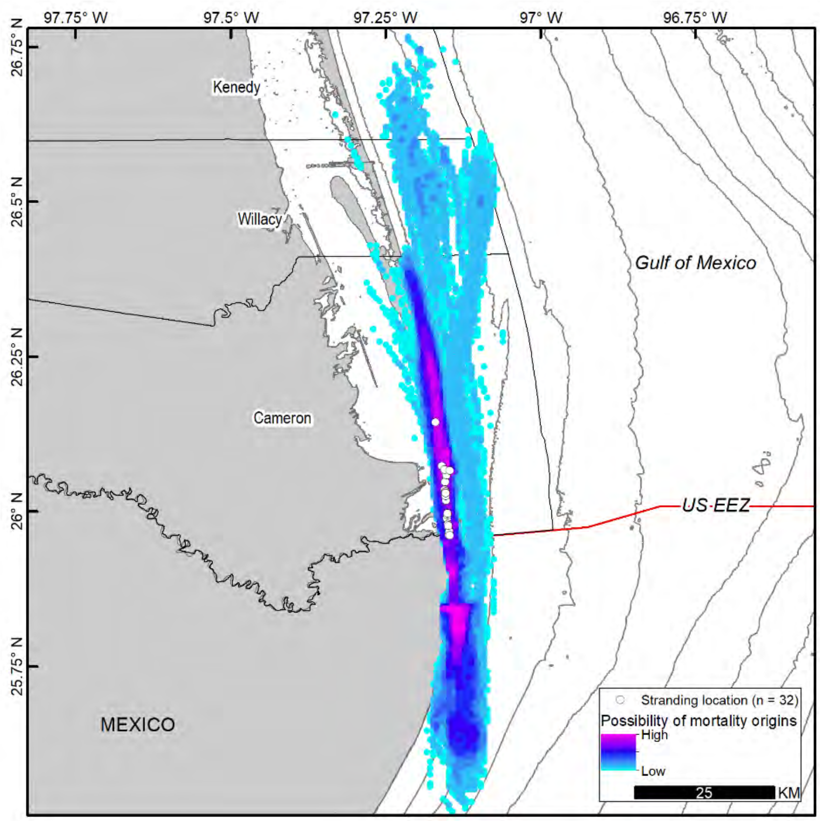


Figure 3-31. Heat map showing the possible locations where green turtles may have died that were found stranded during the Boca Chica mortality event in zone 21. This map is derived from the cumulative result of backcasting analysis using the stranding locations (white circles) as input. Represented are 32 green turtles found during this event. Grey lines represent bathymetric contours at 10-m intervals.

Kemp's ridley strandings. Table 3-9 shows assigned stranding categories for Kemp's ridley turtles found in zone 21. The greatest proportion of those for which a category could be assigned had injuries, half of which were associated with fishing materials (Table 3-10). Six turtles were found in zone 21 that had no injuries or other abnormalities, suggesting a relatively sudden cause of death; all stranded in April or May and all were necropsied. Evaluation of one of these turtles was limited due to decomposition. Of the remaining five without an evident cause of stranding, sediment was found within the respiratory tract of three turtles, two had food items within their stomachs indicative of recent feeding, and one had been feeding on fish.

Loggerhead strandings. Categories for loggerhead turtles found stranded in zone 21 are shown in Table 3-9. Of those that could be categorized, most had evidence of poor health as observed in turtles found in zone 20. All but one were in poor nutritional condition and 7 of 9 had various degrees of epibiota accumulation, often without an identified cause. Based on the five that were necropsied, two loggerheads had severe internal infections and the gastrointestinal tract of one contained abundant sea pens. Injuries involving loggerheads found in zone 21 included vessel strikes and shark bites (Table 3-10). Two loggerheads were found in zone 21 that did not have injuries or other apparent abnormalities. The first was found in April and had not fed recently but no other evidence of illness was found during necropsy. The other loggerhead, which was found in May, was in good nutritional condition, had recently ingested fish, and had intrapulmonary sediment consistent with drowning.

4. Discussion and Conclusions

We attribute the notable number of sea turtle strandings in Texas during 2019 to multiple contributing causes based on our review of the circumstances of stranding, findings from examinations of live and deceased turtles, and results of laboratory and environmental analyses. We discuss these findings and the basis for our conclusions by zone in the following sections.

4.1. Zones 18 and 19

Greater than average numbers of Kemp's ridley and loggerhead turtles stranded on the Upper Texas Coast during April and May. Most were found dead and did not have any major injuries or indications of disease, were in good nutritional condition, and had evidence of recent feeding, including consumption of finfish. These findings are consistent with a relatively sudden cause of death; forced submergence or underwater entrapment are primary considerations based on exclusion of other causes. There were no harmful algal blooms or other environmental phenomena expected to result in strandings with these findings. Additional stranded Kemp's ridleys and loggerheads with similar findings were encountered in fewer numbers during the same months in other areas of Texas, particularly within zone 21.

Our findings are similar to previously reported observations for sea turtle strandings during spring in this region (Zimmerman 1994, Shaver 1995, Lewison et al. 2003). Prior studies have pointed to commercial shrimp trawlers fishing in nearshore waters as the suspected cause of these seasonal strandings. As in prior years, in 2019 these strandings largely stopped following closure of Texas state waters to commercial shrimping on May 15.

Using modeling of beaching probability and backcasting, we were able to provide some new insight into these strandings. The period of above average strandings on the Upper Texas Coast was concurrent with elevated and increasing BPI. Similar to previous years, strandings peaked by the end of April and weekly stranding reports declined thereafter, although BPI remained high and reached its highest point of the year in late May. This disparity in stranding rate and BPI suggests that environmental conditions remained favorable for beaching of drifting dead or debilitated turtles but other causal factors had declined. That is, one or multiple of the following may be responsible for the decline in strandings during late May: source(s) of mortality diminished, fewer sea turtles were present in the area, or there was less interaction between sea turtles and causes of mortality. Therefore, these results are consistent with capture in shrimp trawls having contributed to the spring peak in strandings, specifically those with indications of forced submergence. Moreover, backcasting suggested that these turtles likely died within nearshore waters adjacent to where they stranded.

If the stranded turtles were killed by trawls, it is unclear why strandings did not resume with re-opening of the nearshore waters to shrimping on July 15 despite BPI remaining favorable for beaching of dead turtles. There are numerous possible explanations for these observations that remain speculative at this time. For example, potential seasonal changes in sea turtle distribution or habitat use could affect the likelihood of interaction between turtles and causes of mortality during summer months. Kemp's ridleys likely move inshore or offshore in response to water temperature and prey availability and adults migrate through the area in early spring on their way south to nest (Shaver et al. 2016). Also, there may be decreased discovery of carcasses during the summer due to higher carcass decomposition or scavenging rates. It will be important to study BPI as related to sea turtle strandings on the Upper Texas Coast during additional years to better understand the influence of beaching probability on stranding trends in this region.

In addition to strandings of sea turtles with findings suggestive of forced submergence, a large proportion of sea turtles, particularly Kemp's ridleys and green turtles also had major injuries. Most were the result of vessel strikes and capture or entanglement in fishing-related materials, which are well known threats to sea turtles. Also, stranding of green turtles, including those found alive, during the spring months on the Upper Texas Coast were similar to observations further south and will be summarized in the next section.

4.2. Zone 20

Green turtle strandings in zone 20 comprised more than half (53.6%) of all strandings statewide in 2019 and were a major contributor to the highest number of annual sea turtle strandings ever recorded in Texas, with the exception of mass cold-stunning events. Over 85% of these green turtles were found alive and nearly half were found beached or entrained within tide pools resulting from tidal or coastal flooding events or were entrapped in jetty rocks. Green turtles stranded under similar circumstances but in smaller numbers in other areas along the Texas coast.

The peak period of strandings in April through July occurred when oceanographic conditions favored beaching of sea turtles. A majority of strandings within zone 20 occurred during an extended period of relatively high BPI and strong, shoreward winds from late April to the middle of June. The peak in zone 20 strandings in May lagged BPI peaks by approximately one week, which may reflect prevailing wind direction or currents. Winds appeared more easterly during late April and early May when BPI was highest. During March through October, mean wind speeds were greatest when daily stranding counts were highest. Spikes in southeasterly wind speed appeared to correspond to or precede peaks in strandings.

The highest tides of the year occurred during May when the greatest number of strandings also occurred, but the peaks and trends in strandings and tides did not coincide. Strandings in zone 20 were increasing in late April and early May as tides peaked. However, daily tidal heights fell after 10 May while strandings peaked during 23 and 24 May. Additional spikes in strandings occurred on 1, 8, 16, and 26 June while daily tidal heights continued to trend downward into July.

We investigated other potential factors that may have contributed to large numbers of small green turtles being brought into nearshore waters and at risk of becoming entrapped in shoreline features. With regard to life history, these turtles were a smaller cohort relative to other strandings in Texas. Their size range overlapped with both the higher end of surface-pelagic phase and lower end of neritic phase green turtles (Shaver 2000, Foley et al. 2007, Witherington et al. 2012) and is consistent with the size at which green turtles recruit to neritic habitat associated with armored inlets (Howell et al. 2016). Some individuals in this group had evidence of recent pelagic feeding (ingestion of *Sargassum* sp.) offering further support that these green turtles recently recruited from the surface-pelagic phase. *Sargassum* was found in turtles that stranded during May or earlier but not in later months, suggesting that arrival may have occurred primarily in the spring. In addition, 2017 was a remarkable year in terms of hatchling production in the western Gulf of Mexico. Nesting beach productivity correlates well with strandings of small juvenile green turtles in Texas if the average age of recruitment into the neritic zone is assumed to be 2 years, which is consistent with published estimates (Zug and Glor 1998, Kubis et al. 2009, Goshe et al. 2010). This correlation in conjunction with other findings suggests that a large cohort of juveniles recruiting from the surface-pelagic phase significantly contributed to the high number of green turtle strandings in 2019.

We did not find evidence that underlying disease contributed to stranding of these green turtles, most of which were in fair or good nutritional condition and appeared to have been actively foraging. Most live green turtles admitted to rehabilitation facilities for veterinary evaluation generally responded well to supportive treatment and were released after only a few days or weeks of care. Abnormalities observed in live turtles and those that were necropsied were largely attributable to physiological effects of exertion associated with stranding and secondary infection of the ventral abrasions.

One of our most interesting findings with regard to the health status of the stranded green turtles was domoic acid exposure, which among those analyzed was detected in most of the turtles found in April and May. The effects of domoic acid, which primarily manifests in other species as a neurotoxin, are unknown in sea turtles. No neurological abnormalities were observed in live turtles. Most of the domoic acid concentrations measured during this investigation are similar to those detected in free-ranging cetaceans without any apparent associated ill effect (Fire et al. 2011; Twiner et al. 2011). During other sea turtle stranding investigations, we have measured domoic acid in the gastrointestinal contents at much higher concentrations (e.g., > 10,000 ng/g) in green turtles both with and without any associated clinical signs (unpublished data). On the other hand, domoic acid is metabolized relatively quickly, and the concentrations we measured could be the residual indication of a much higher prior exposure. In addition, various multisystemic effects have been associated with domoic acid in other species (e.g., Viera et al. 2016; Levin et al. 2008). Based on current understanding of domoic acid, absence of abnormal neurological signs, and prior observations in sea turtles, there is not strong support that this biotoxin played a role in Texas strandings in 2019. In general, further studies of the effects of domoic acid on sea turtles are warranted given the health concerns reported in other animals.

In summary, we found multiple environmental factors and relevant population and life history observations that likely contributed to the large numbers of green turtle strandings in zone 20 during spring and summer and the similar concurrent strandings in other zones. Rough onshore conditions created by persistently high shoreward winds created conditions that favored entrapment/entrainment of turtles within jetty rocks and intertidal zones. The dietary affinity of juvenile green turtles in Texas for macroalgae growing on man-made jetties (Howell et al. 2016) is clearly associated with multiple risks, including entrapment in the rocks and entanglement in lost or discarded fishing tackle, which is especially abundant in these areas. The small size of the affected cohort and some evidence of pelagic feeding suggests that at least a proportion of these green turtles may have recently undergone a habitat transition either from recruitment from their surface-pelagic phase to the neritic phase or related to seasonal movements. Notable increases in hatchling production in the western Gulf, particularly in 2017, likely have resulted in greater numbers of juveniles moving into nearshore habitat. The energetic costs of such a transition could have been a factor in their vulnerability to entrapment and beaching. Additional study of habitat use by small juvenile green turtles (SCL < 30 cm) in Texas, patterns of seasonal movement and recruitment, and broader compilation of nesting beach productivity data for Mexico may yield additional insight into 2019 observations. Lastly, the role of domoic acid exposure is uncertain at this time but appears to be an incidental observation based on comparison with data available from other areas.

Strandings in zone 20 also included more loggerheads than were documented in the other zones. The majority of these turtles had evidence of poor health including diminished nutritional condition, ulcerative gastrointestinal disease, and impaction of the large intestine by sea pens. Both emaciation and impactions from indigestible components of natural prey species are relatively common observations in stranded loggerheads in the southeastern U.S. The etiopathogenesis of these disorders is poorly understood and likely has many possible contributing causes. Gastrointestinal disease can lead to poor nutritional condition or can occur secondarily from altered digestive motility (which has multiple possible causes), reduced immune function, intense parasitism, and other problems. It is frequently difficult or impossible to identify a specific initiating cause because sea turtles tend to have been ill for weeks or months prior to stranding. In addition, some possible causes, such as environmental or prey-based factors, are not easily detected.

4.3. Zone 21

Stranding reports for zone 21 initially peaked during late spring to early summer, as in neighboring zone 20, and strandings had multiple findings that were similar to observations in other zones. Specifically, there were strandings of live green turtles with findings and circumstances similar to the larger numbers found in zone 20 during this time. A few stranded Kemp's ridley and loggerhead turtles also were found in April and May with findings suspicious for drowning by forced submergence or other sudden cause, as observed during the spring in zone 18. In November, a dramatic spike in strandings occurred due to the green turtle mortality event in the Boca Chica Beach area of southern Cameron County near the U.S.-Mexico border.

Unlike other zones within Texas, we observed a negative and non-linear relationship between stranding reports in zone 21 and BPI. The BPI was lowest during periods when stranding reports were highest in this region, including during the Boca Chica Beach mortality event in the fall, suggesting that environmental conditions were not favorable for beaching of drifting turtles. This observation implies that factors other than those considered in the BPI model contributed to stranding patterns in zone 21 and that beachcast strandings may have represented a relatively small fraction of at-sea mortality. The proportion of at-sea mortality likely discovered as strandings is highly variable across studies, ranging from < 5% to > 50% (e.g., Mancini et al. 2011, Koch et al. 2013). Such studies have not been undertaken in the western Gulf of Mexico, but stranding probability generally is influenced by distance from shore, wind, and currents—all of which are incorporated into the BPI model used in the current analyses.

We ultimately attributed the Boca Chica Beach mortality event to bycatch in gillnets based on the following: 1) concurrent documentation of live and dead green turtles in illegally set nets in adjacent Texas coastal waters; 2) postmortem findings consistent with death by forced submergence; and 3) exclusion of other possible causes. Although we only observed skin abrasions attributable to net capture in a few turtles, absence of apparent injuries is common in turtles drowned in gillnets in our experience based on examination of turtles known to have died in this manner. Moreover, such injuries become less detectable with decomposition.

Backcasting indicated that the turtles most likely originated from within Texas coastal waters, which aligns with seizure of gillnets near the strandings, as well as further south from within Mexican coastal waters. The prevailing coastal currents for this region and period flow north, which is consistent with the northward drift trajectory produced by the backcasting model. Carcasses originating from Mexico inherently have a lower probability of reaching the U.S. coast and there is no monitoring of adjacent beaches in Mexico. Based on the number of dead turtles found, the oceanographic conditions during this period, and the predicted locations of origin, we conservatively estimate that the number of turtles killed likely numbered in the hundreds. Notably, 101 dead stranded green turtles also were found on beaches in La Pesca, Tamaulipas, Mexico in November 2019 and were attributed to illegal artisanal gillnet fishing (Burchfield 2020).

Other potential causes of the mortality event that we examined included exposure to biotoxins and cold-stunning, which are among the few non-anthropogenic causes of sea turtle stranding that can manifest as sudden debilitation or death of seemingly healthy individuals. No biotoxins known to be associated with sea turtle mortality were detected in any of the samples from this event. Cold-stunning in Texas waters primarily occurs in shallow inshore waters of lagoons and bays and results in a high proportion of live stranded turtles (Shaver et al. 2017). These characteristics are different from those of the Boca Chica Beach mortality event in which most turtles were found dead and on Gulf-facing beaches. Nonetheless, we investigated the potential for an atypical cold-stunning event and found that Gulf water temperatures near the mortality event did not fall below the cold-stunning threshold prior to or during the strandings. Strandings due to cold-stunning did occur in zone 21 (and other zones) in 2019 (during 12–19 November) in lagoons and bays after shallower, inshore water temperatures persistently fell below 10°C. As with previous cold-stunning events in Texas, and in contrast to the Boca Chica Beach strandings, 95% (293/308) of cold-stunned turtles were found alive.

In summary, findings related to sea turtle strandings in zone 21 during 2019 were similar to those encountered elsewhere in the state for much of the year. A notable difference in zone 21 is that there was less correlation between environmental factors that influence stranding probability and actual stranding numbers as compared to areas further north. This disparity suggests other factors influenced strandings in this part of Texas and warrants additional study. Of particular relevance to sea turtle conservation management is that beachcast carcasses in zone 21 may have represented a relatively small proportion of at-sea mortality in this region. This consideration is especially significant with regard to the potential magnitude of the green turtle mortality event in the Boca Chica area and the detection of sea turtles killed by illegal fishing in the western Gulf of Mexico.

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Appendices

Appendix A: Example data forms

SEA TURTLE STRANDING AND SALVAGE NETWORK – STRANDING REPORT

OBSERVER'S NAME / ADDRESS / PHONE:
First ________________ M.I.____ Last ______________________
Affiliation ____
Address ____
____
Area code/Phone number ___________________________________

STRANDING DATE:
Year 20☐☐ Month ☐☐ Day ☐☐
Turtle number by day ☐☐

Coordinator must be notified within 24 hrs; this was done by ☐ *phone* ☐ *email* ☐ *fax*

SPECIES: (check one)
☐ CC = Loggerhead
☐ CM = Green
☐ DC = Leatherback
☐ EI = Hawksbill
☐ LK = Kemp's Ridley
☐ LO = Olive Ridley
☐ UN = Unidentified
Check Unidentified if not positive. Do Not Guess.

STRANDING LOCATION: ☐ Offshore (Atlantic or Gulf beach) ☐ Inshore (bay, river, sound, inlet, etc)
State ______________________ County/Parrish ______________________
Descriptive location (be specific) ______________________________
____
____
Latitude ______________________ Longitude ______________________

Carcass necropsied? ☐ Yes ☐ No
Photos taken? ☐ Yes ☐ No
Species verified by coordinator?
☐ Yes ☐ No

CONDITION: (check one)
☐ 0 = Alive
☐ 1 = Fresh dead
☐ 2 = Moderately decomposed
☐ 3 = Severely decomposed
☐ 4 = Dried carcass
☐ 5 = Skeleton, bones only

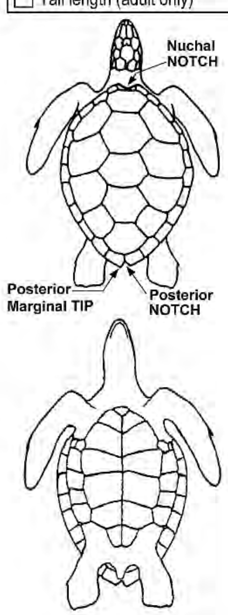
FINAL DISPOSITION: (check)
☐ 1 = Left on beach where found; painted? ☐ Yes* ☐ No(5)
☐ 2 = Buried: ☐ on beach / ☐ off beach;
carcass painted before buried? ☐ Yes* ☐ No
☐ 3 = Salvaged: ☐ all / ☐ part(s), what/why? ________
____
____
☐ 4 = Pulled up on beach/dune; painted? ☐ Yes* ☐ No
☐ 6 = Alive, released
☐ 7 = Alive, taken to rehab. facility, where? __________
____
☐ 8 = Left floating, not recovered; painted? ☐ Yes* ☐ No
☐ 9 = Disposition unknown, explain ______________
____
**If painted, what color?* ______________________

SEX:
☐ Undetermined
☐ Female ☐ Male
Does tail extend beyond carapace?
☐ Yes; how far?_______ cm / in
☐ No
How was sex determined?
☐ Necropsy
☐ Tail length (adult only)

TAGS: ***Contact coordinator before disposing of any tagged animal!!***
Checked for flipper tags? ☐ Yes ☐ No
Check all 4 flippers. If found, record tag number(s) / tag location / return address
____
____
____
PIT tag scan? ☐ Yes ☐ No
If found, record number / tag location
____
____
Coded wire tag scan? ☐ Yes ☐ No
If positive response, record location (flipper)
____
Checked for living tag? ☐ Yes ☐ No
If found, record location (scute number & side)
____

CARAPACE MEASUREMENTS: (*see drawing*)

Using calipers		**Circle unit**
Straight length (NOTCH-TIP)	________	cm / in
Minimum length (NOTCH-NOTCH)	________	cm / in
Straight width (Widest Point)	________	cm / in
Using non-metal measuring tape		**Circle unit**
Curved length (NOTCH–TIP)	________	cm / in
Minimum length (NOTCH-NOTCH)	________	cm / in
Curved width (Widest Point)	________	cm / in
		Circle unit
Weight ☐ actual / ☐ est.	________	kg / lb



Mark wounds / abnormalities on diagrams at left and describe below (note tar or oil, gear or debris entanglement, propeller damage, epibiota, papillomas, emaciation, etc.). **Please note if no wounds / abnormalities are found.**
____
____
____
____
____
____

SEA TURTLE STRANDING & SALVAGE NETWORK – SHORT GROSS NECROPSY REPORT

IDENTIFICATION

1. STSSN #: ________________________ **2. Other identifier(s)/#:** ________________________ **3. Rehab:** ☐Yes ☐No

4. Found dead: ☐Yes ☐No **5. If no, date of death** ____/____/______ leave blank if unknown (Use mm/dd/yyyy for dates)

6. Euthanized: ☐Yes ☐No **7. Frozen/Thawed:** ☐Yes ☐No **8. Condition at necropsy:** ☐1 ☐2 ☐3 ☐4 ☐5

9. Date necropsied: ____/____/______ **10. Examiner:** __________________ **11. Affiliation:** ______________________

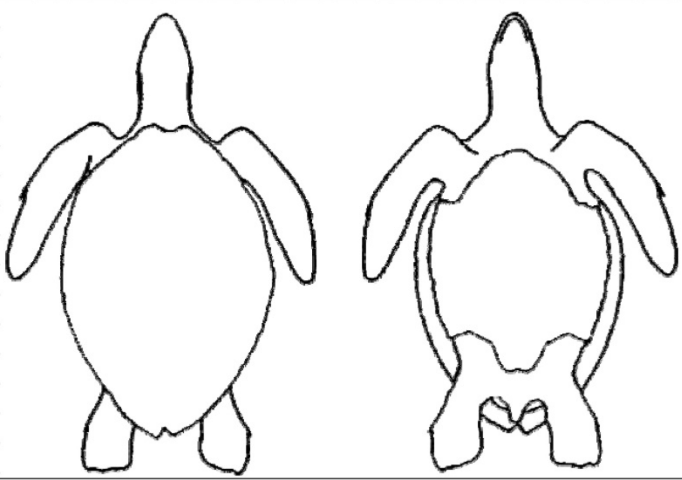
12. Necropsy description: ☐External & internal examination ☐External examination only ☐Incomplete carcass

13. Disposition of carcass: ☐Buried on beach ☐Buried off site ☐Rendered ☐Incinerated ☐Other

14. Species: ☐CC ☐CM ☐DC ☐LK ☐EI ☐LO ☐HYBRID ☐UNK **15. Sex:** ☐Male ☐Female ☐Undetermined

SUMMARY COMMENT SECTION & DIAGRAM

Comments (include any continuation from previous sections: ______________________________



SPECIMEN COLLECTION INVENTORY

Specimen (label w/ ID#)	Fixed	Frozen-bagged	Frozen-Foil	Other (specify)	Location

ANATOMIC LOCATION CODES: Head (H) Neck(N) Eyes(E) Mouth(M) Carapace(C) Plastron(P) Tail(T) Vent(V) Front flipper - Right(R) Left(L) Rear flipper - Right(F) Left(G) All appendages(Y) Pectoral girdle(J) Pelvis(I) Mouth(O) Esophagus(Es) Stomach(St) Small intestine(Si) Colon(Co) Cloaca(Cl)

EXTERNAL TRAUMA/EVIDENCE OF HUMAN INTERACTION: ☐Y ☐N ☐CBD — Enter anatomic codes after numbered entries; enter numbers by applicable descriptors in shaded areas

☐1-Parallel chop wounds_____ ☐2-Single linear/chop wound_____ ☐3-Blunt/crushing_____ ☐4-Amputation____
☐ 5-Entanglement-type_____ ☐6-Hook/line_____ ☐7-Bite wound _____ ☐8-Incised/mutilation_____ ☐9-Other_____

☐Hemorrhage___ ☐Exudate/fibrin___ ☐Partial healing___ ☐Completely healed___ ☐None___ CBD___
☐Coelom breached___ ☐Brain/spinal cord damaged___ ☐Lung exposed___ ☐Other organs exposed___

Entangling/attached material: ☐Y ☐N Describe:_______________________________________ Saved? ☐

OTHER EXTERNAL ANOMALIES: ☐Y ☐N ☐CBD

☐ 10-Heavily encrusted w/ epibiota ☐ 11-Leeches ☐12-Gooseneck barnacles
☐13-FP______ ☐14-Ulceration/dermatitis______ ☐15-Masses (non-FP or uncertain)______ ☐16-Other_________

☐<5% surface affected___ ☐10-25% affected___ ☐>25-50% affected___ ☐>50% affected___

Comments:

MUSCLE STATUS: ☐Well-muscled/No atrophy ☐Mild to moderate atrophy ☐Severe atrophy ☐CBD
FAT STATUS: ☐Abundant/No atrophy ☐Mild to moderate atrophy ☐Severe atrophy ☐CBD

COELOM: ☐No findings ☐Exudate/fibrin ☐Blood clots ☐Encysted parasites ☐Organs/tissues pale ☐Other ☐CBD
Comments:

HEART & MAJOR VESSELS: ☐No findings ☐Abnormal ☐CBD **Blood in heart chambers:** ☐Y ☐N
Comments:

LIVER & GALL BLADDER: ☐No findings ☐Atrophy (shrunken, black) ☐Trauma ☐Other ☐CBD
Comments:

GI TRACT: ☐No findings ☐Abnormal ☐CBD
☐17-Ulcers/exudate_____ ☐18-Trauma_____ ☐ 19-Internal FP_____ ☐20-Fluke eggs_____ ☐21-Impaction______
☐22-Obstruction ______ ☐23-Intussusception______ ☐24-Plication ______ ☐25-Other______

☐<5% affected____ ☐5-25%____ ☐>25-50%____ ☐>50%____ ☐N/A

Foreign material: ☐Y ☐N Describe:_______________________________________ Saved? ☐

Esophagus: ☐ Empty ☐ Contents, describe: ______________________________
Stomach: ☐ Empty ☐ Contents, describe: ______________________________
Intestine (first ½): ☐ Empty ☐ Contents, describe: ______________________________
Intestine (last ½): ☐ Empty ☐ Contents, describe: ______________________________
Comments:

UROGENITAL: ☐No findings ☐Abnormal ☐Internal FP ☐Other ☐CBD **Sex:** ☐Male ☐Female ☐Unk
Comments:

RESPIRATORY: Trachea/bronchi: ☐No findings ☐Some froth ☐Copious froth ☐Sand/sediment ☐Exudate ☐CBD
Lungs: ☐No findings ☐Wet/frothy ☐Trauma ☐Sand/sediment ☐Exudate ☐Internal FP ☐Other ☐CBD
Comments:

BRAIN & SPINAL CORD: ☐No findings ☐Trauma ☐Inflammation/exudate ☐Fluke eggs ☐Other ☐CBD
Comments:

Appendix B: Biotoxin analysis results

Appendix B. Biotoxin analysis for green turtles that stranded in Texas in zones 20 and 21. Category refers to predominant stranding and necropsy observations, including A = no major abnormalities; B = traumatic injuries; C = health-related; D = unable to categorize; and IC = incidental capture by fisheries. Biotoxin analytic results are reported for brevetoxins (PbTx), domoic acid (DA), and saxitoxins (STX) in ng/g based on detection by validated enzyme-linked immunosorbent assays (ELISA). Results that were below limits of detection (< LD), samples that were not analyzed (-), and analyses of samples from a green turtle mortality event in the Boca Chica Beach region also are indicated (BC).

Identifier	Species	Stranding date	Zone	Category	Sample type	PbTx	DA	STX
20190408AMO01	Cm	4/8/2019	20	C	Liver	< LD	4.8	< LD
					Gastric	< LD	4.2	< LD
					Feces	< LD	< LD	< LD
20190421TNS01	Cm	4/21/2019	20	D	Liver	22.4	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190502AMW01	Cm	5/2/2019	20	A	Plasma	< LD	0.5	< LD
20190502MNA01	Cm	5/2/2019	20	A	Plasma	< LD	0.7	< LD
20190503EAE01	Cm	5/3/2019	20	A	Plasma	< LD	< LD	< LD
20190504NRH01	Cm	5/4/2019	20	IC	Plasma	< LD	< LD	< LD
					Feces	< LD	41.0	< LD
20190504SSP01	Cm	5/4/2019	20	B	Feces	< LD	17.0	< LD
20190511AMO01	Cm	5/11/2019	20	A	Plasma	< LD	0.5	< LD
					Feces	< LD	246.4	< LD
20190515APS01	Cm	5/15/2019	20	A	Liver	< LD	< LD	< LD
					Gastric	< LD	7.7	< LD
					Feces	< LD	12.6	< LD
20190519DXG02	Cm	5/19/2019	20	A	Liver	< LD	8.5	< LD
					Gastric	< LD	6.7	< LD
					Feces	< LD	224.3	< LD
20190531AMO03	Cm	5/31/2019	20	A	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190601NFP03	Cm	6/1/2019	20	A	Liver	< LD	< LD	< LD
					Feces	< LD	8.0	< LD
20190612HSL02	Cm	6/12/2019	20	A	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD

Appendix B. *Continued.*

Identifier	Species	Stranding date	Zone	Category	Sample type	PbTx	DA	STX
20190705AMW01	Cm	7/5/2019	20	A	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190716EAE01	Cm	7/16/2019	20	B	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190716EAE04	Cm	7/16/2019	20	B	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190716EAE05	Cm	7/16/2019	20	B	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190724AMW01	Cm	7/24/2019	20	B	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190726CLC01	Cm	7/26/2019	20	A	Liver	34.2	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190804AMO02	Cm	8/4/2019	20	B	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190810AMO01	Cm	8/10/2019	20	A	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20190412JDP01	Cm	4/12/2019	21	A	Liver	< LD	3.9	< LD
					Gastric	< LD	5.2	< LD
					Feces	< LD	17.5	5.1
20190414EQY01	Cm	4/14/2019	21	A	Liver	< LD	5.7	< LD
					Gastric	< LD	14.2	< LD
					Feces	< LD	22.2	< LD
20190415ELP03	Cm	4/15/2019	21	A	Liver	< LD	24.4	< LD
					Gastric	< LD	134.4	-
					Feces	< LD	1104.8[a]	8.7
20190416AMM01	Cm	4/16/2019	21	A	Liver	< LD	29.9	< LD
					Gastric	< LD	64.7	< LD
					Feces	< LD	53.2	< LD

[a]Result is for detection by liquid chromatography-mass spectroscopy

Appendix B. *Continued.*

Identifier	Species	Stranding date	Zone	Category	Sample type	PbTx	DA	STX
20190423EQY01	Cm	4/23/2019	21	D	Liver	< LD	12.9	< LD
					Gastric	< LD	16.9	< LD
					Feces	< LD	82.0	< LD
20190424LES04	Cm	4/24/2019	21	A	Liver	< LD	4.6	< LD
					Gastric	< LD	34.5	< LD
					Feces	< LD	8.7	< LD
20190519LES01	Cm	5/19/2019	21	A	Liver	< LD	4.8	< LD
					Gastric	< LD	6.9	< LD
					Feces	< LD	17.3	< LD
20190804NAN01	Cm	8/4/2019	21	B	Liver	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20191122MAD05	Cm	11/22/2019	21	A	Liver	< LD	< LD	< LD
BC					Kidney	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20191122MAD06	Cm	11/22/2019	21	A	Liver	< LD	< LD	< LD
BC					Kidney	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20191122MAD08	Cm	11/22/2019	21	A	Liver	< LD	< LD	< LD
BC					Kidney	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20191122MAD13	Cm	11/22/2019	21	A	Liver	< LD	< LD	< LD
BC					Kidney	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD
20191122MAD17	Cm	11/22/2019	21	A	Liver	< LD	< LD	< LD
BC					Kidney	< LD	< LD	< LD
					Gastric	< LD	< LD	< LD
					Feces	< LD	< LD	< LD