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Overwintering behavior of juvenile sea turtles at a temperate foraging ground

Most freshwater and terrestrial turtle species that inhabit temperate environments hibernate to survive extreme cold periods. However, for sea turtles, the question of whether these species use hibernation as an overwintering strategy has not been resolved (Ultsch 2006). Felger et al. (1976) suggested that sea turtles bury themselves in mud on the seafloor and remain dormant throughout the winter, presumably not surfacing during that time. Additional researchers have described sea turtles in temperatures <15°C as lethargic, mud-covered and buried in bottom sediment (Carr et al. 1980, Mendonça 1983, Ogren and McVea 1995). However, more recent studies suggest that sea turtles may not be as dormant in cold temperatures as previously suggested (Hochscheid et al. 2007). Resolving this question is difficult due to the unpredictability of winter weather patterns and the cost of advanced tracking tools required to assess these fine-scale behaviors. However, in January 2018, unusually calm and clear marine conditions coupled with exceptionally cold weather provided us the opportunity to observe and film turtle behavior at a foraging ground in the northern Gulf of Mexico. These images, combined with previously gathered data from vessel-based surveys and water temperature loggers, have enabled us to piece together one of the most comprehensive views of sea turtle overwintering behavior to date.

St. Joseph Bay, located in Northwest Florida, supports a year-round assemblage of foraging turtles including threatened green turtles (*Chelonia mydas*) and loggerheads (*Caretta caretta*), and endangered Kemp’s ridleys (*Lepidochelys kempii*). Although winter temperatures in St. Joseph Bay frequently fall below 15°C, some individuals there forgo seasonal migrations and remain within the bay year-round (Avens et al. 2012, Lamont et al. 2015). However, turtles that do not migrate risk exposure to extreme cold. When temperatures drop below 10°C, turtles lose the ability to dive and eventually strand along the shoreline (termed “cold stunning”). St. Joseph Bay has repeatedly been the site of large cold stunning events. In January 2010, more than 1,700 turtles stranded and, most recently, in January 2018, more than 1,200 turtles stranded during approximately 2 weeks of extreme cold. The USGS, in partnership with the Florida Fish and Wildlife Conservation Commission, leads the response to recover these stranded turtles and transport them to a rehabilitation center (see https://www.usgs.gov/news/scientists-volunteers-rescue-about-1000-cold-stunned-sea-turtles). Although we have been researching turtles in St. Joseph Bay since 2001, documenting overwintering behavior has been challenging and has required use of multiple methods, field observations, and some luck to help fill this knowledge gap.

We began this investigation 7 yr ago by conducting random vessel-based surveys throughout St. Joseph Bay to locate turtle “hot spots” to aid in future captures. Surveys were conducted on 32 d from December 2011 to December 2012, during which we documented the behavior of 99 turtles. During observations, we also recorded environmental conditions including water temperature. Turtles were sighted on the bottom (41%), when swimming (40%) and on the surface (18%). Mean surface water temperature when turtles were observed on the bottom (22.4°C ± 9.8°C) and while swimming (21.9°C ± 10.4°C) was warmer than while turtles were observed at the surface (13.8°C ± 2.3°C).

Because water temperature varies throughout the water column, the following winter, from October 2012 through April 2013, we gathered temperatures throughout the water column at one site in St. Joseph Bay. Temperatures were recorded using Onset (Bourne, MA) HOBO tidbit data loggers deployed at three different, approximate, depths: (1) 0.5 m off the bottom, (2) in the middle of the water column (~2.9 m), and (3) 0.5 m below the surface. Not surprisingly, mean surface temperatures (17.4°C ± 2.7°C; range 11.6–35.4°C) were warmer than mean bottom temperatures (16.9°C ± 2.7°C; range 11.7–32.5°C). Our informal surveys coupled with water temperature data indicated that turtles were basking at the surface to thermoregulate during cold temperatures. Body temperatures of inactive adult green and loggerhead turtles are generally within 1–2°C of sea temperature (Standora et al. 1982). However, the body temperature of one adult loggerhead was raised 3.8°C above water temperature while that individual was basking in the sun (Sapsford and Van der Riet 1979) and when overcast, the turtle’s body temperature remained equal to the water temperature, despite basking.

During winter 2012–2013, we also deployed acoustic tags on 12 juvenile green turtles in St. Joseph Bay to better understand turtle movements (Lamont et al. 2015). Rather than moving into warmer Gulf of Mexico waters during periods of cold, as has been reported elsewhere (González Carman et al. 2012), individuals remained in St. Joseph Bay but moved from shallow seagrass habitat to deep water. When temperatures warmed, turtles moved back to their foraging home ranges in shallow waters. Slowly we were gathering information on turtle behavior during periods of extreme cold; however, the only definitive way to know what turtles were doing was to observe them directly. In January 2018, we finally got our chance.

From January 2 to January 19, 2018 a period of extreme cold affected the northern Gulf of Mexico during which water temperatures in St. Joseph Bay dropped as low as 2°C and more than 1,200 turtles stranded. On January 16, the sea was abnormally calm and exceptionally clear. On this day in St. Joseph Bay, using our boat-based Garmin (echoMAP 74sv with GT41-TM transducer), we recorded sea surface temperatures over deep water (>5 m) that ranged from 9.5°C to 10°C. In these deep waters, we observed several turtles basking at the surface; when approached by the boat, these individuals immediately dove which indicated they were not physiologically impaired by the cold temperatures (Anderson et al. 2011). As we headed into shallower water (2–5 m) at the southern end of the bay, we could see through the water column to the seafloor. Water temperatures in these shallower habitats ranged from 8.0°C to 9.0°C. In these clear waters, turtles swam in the water column and rested on the seafloor. Using a GoPro Hero4 Black 2 mounted on a 96.5 cm pole and hand-held in the water column, we captured video images of two juvenile greens and one juvenile Kemp's ridley (Fig. 1).

In total, we captured 5:03 min of video. During 1:03 min of on-screen time, the first juvenile green swam (57% of the

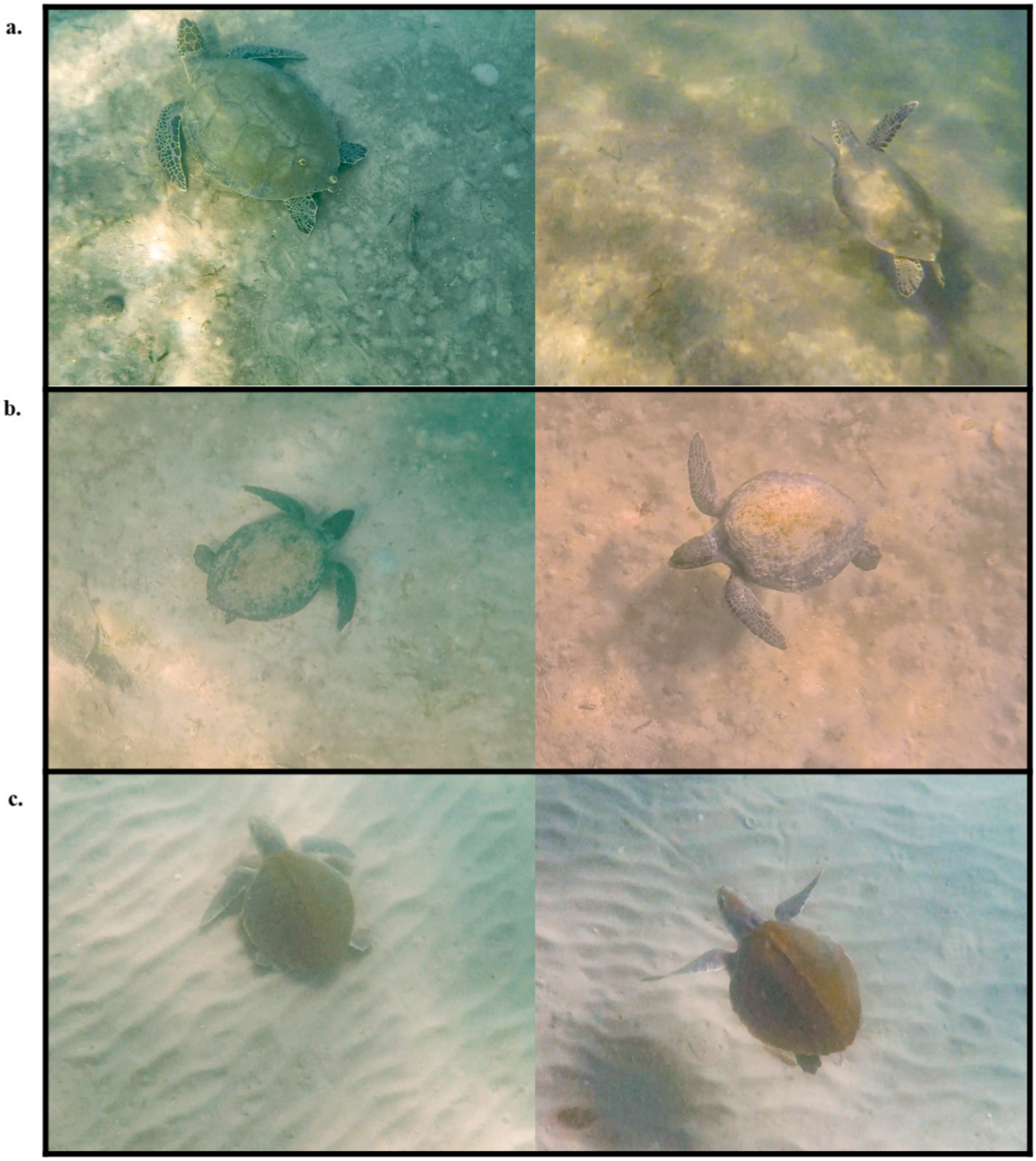

Fig. 1. Still images taken from video clips documenting overwintering behavior of three juvenile sea turtles resting on the bottom (left) and swimming (right) in St. Joseph Bay, FL on January 16, 2018 during an extreme cold event. Images in rows (a) and (b) are of juvenile greens and images in row (c) are of a juvenile Kemp's ridley. These photographs were taken in water temperatures ranging between 8–9°C.

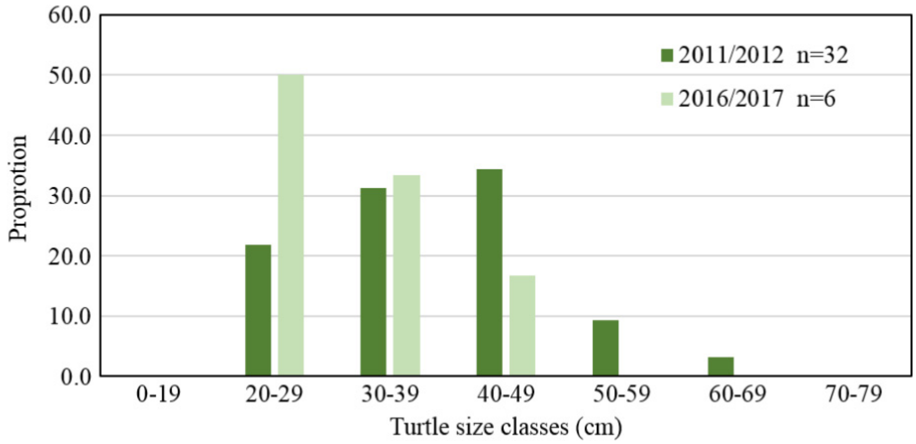

Fig. 2. In the 2 yr following a large cold stunning event in St. Joseph Bay, FL in 2010, nearly 34% of captured turtles in St. Joseph Bay were 40–49 cm straight carapace length. Six years after the stun (2016–2017), only 9% of turtles captured in the bay were 40–49 cm straight carapace length. These preliminary data (note the small sample size in 2016/2017) indicate disproportionate mortality of small individuals during the 2010 cold stun may have caused a shift in size classes of turtles in St. Joseph Bay.

time), crawled (14%), and rested on the bottom (29%). The second green was captured on screen for 29 sec and rested on the bottom (29% of the time) and actively swam (71%). The juvenile Kemp's ridley was captured on-screen for 50 s and swam (68% of the time) and crawled on the seafloor (32%).

These observations, along with our previous survey and water temperature data, indicate that turtles alternate relatively short periods (i.e., hours) of resting on the seafloor with periods of basking in the sun and warmer surface waters. During winter, loggerheads in the Mediterranean spend several hours (i.e. 6–8 h) resting on the bottom while making infrequent trips to the surface for gas exchange (Hochscheid et al. 2005). Our observations and the images captured in St. Joseph Bay support their findings and are in opposition to Felger et al. (1976) suggestion that sea turtles remain dormant in winter for periods lasting several months.

By the time we captured these images, more than 800 turtles had already stranded in St. Joseph Bay (strandings started on January 2) yet, after 2 weeks of cold temperatures, we observed relatively active and apparently healthy individuals. Our images suggest these turtles are not hibernating to survive the cold; are there physiological or behavioral differences that allow some individuals to survive extreme cold while others do not? In the two largest cold stun events (2010 and 2018), a disproportionate number (45% in 2010 and 79% in 2018) of small turtles (<40 cm straight carapace length; SCL) stranded. These mortality events may serve as a primary force regulating the structure of juvenile turtle populations at temperate foraging sites. A 20 cm turtle will be 30 cm in 3–4 yr and 40 cm in 5–7 yr; disproportionate removal of small turtles during the cold stun will affect larger size classes many years after the event. This appears to result in a variable size class structure with peaks in abundance of larger (40–49.9 cm) individuals in the years immediately following an event (i.e. 2011/2012) followed by a shift to smaller size classes as new recruits enter the population (Fig. 2). In addition to size structure, this mortality most likely impacts other aspects of demography such as growth and survival. Green turtle growth rates exhibit density dependence and may vary with changes in abundance (Bjorndal et al. 2000). Cold stun mortality may help prevent density dependent reductions in growth rates. In addition, smaller individuals in a population typically have lower survival rates; cold stuns may further reduce survival rates for smaller turtles. Examining the demographics of this population would help us understand the impacts of cold stun events on turtles at temperate foraging sites.

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