

Diving behaviour of an immature Kemp's ridley turtle (*Lepidochelys kempii*) from Gullivan Bay, Ten Thousand Islands, south-west Florida

Christopher R. Sasso* and Wayne N. Witzell

National Marine Fisheries Service, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL 33149, USA.

*Corresponding author, e-mail: chris.sasso@noaa.gov

We report on the first successfully deployed time-depth recorder on an immature Kemp's ridley turtle in a coastal foraging habitat in south-west Florida. The turtle exhibited three distinct dive patterns interpreted as: post release stress (26 h) post release transition (8 h) and normal (>34 h). The normal pattern consists of short periods on the surface followed by longer periods on the bottom in 2–3 m of water which we speculate is foraging behaviour. Overall, the turtle spent 94% of the time submerged during the normal period. The turtle spent significantly more time submerged at night than during the day, suggesting the turtle was resting. Night dives were consistently longer than dawn, day or dusk dives.

INTRODUCTION

Marine research scientists and resource managers need to determine habitat utilization of threatened and endangered sea turtles to formulate effective recovery strategies. An important aspect of habitat utilization is determining diving, resting, and foraging behaviour of immature turtles to understand their niche in the various coastal developmental habitats. The research necessary to address in-water behaviour of immature sea turtles has been slow to develop because of the difficulty in capturing, tracking and recapturing the turtles, the lack of equipment small enough to be deployed without adversely affecting normal behaviour, and equipment that is resistant to corrosive salt water.

Recent advances in technology have made it possible to track detailed diving behaviour through the development of waterproof data loggers or time-depth recorders (TDRs). These small devices are usually attached to the carapace of the turtle and can be set to record detailed dive profile information. However, because of the archival nature of TDRs, the turtle must be recaptured to retrieve the instrument. Therefore, TDRs are typically placed on nesting turtles for ease of recapture. The TDRs have been used on nesting loggerhead turtles from Japan (Sakamoto et al., 1990a,b, 1993) and from Cyprus (Houghton et al., 2002); green turtles (*Chelonia mydas*) from Cyprus (Hochscheid et al., 1999) and from Ascension Island (Hays et al., 2000, 2001a,b). Time-depth recorders were used on immature Caribbean hawksbills (van Dam & Diez, 1997). A newer system for collecting diving profiles is a combination of data logger integrated with a satellite platform terminal transmitter (PTT), which can download detailed dive profiles between transmissions. This has been successfully used on Caribbean leatherback turtles (*Dermodochelys coriacea*) (Hays et al., 2004).

While detailed diving behaviour and dive profiles have been provided for some sea turtle species, dive profiles are lacking for immature Kemp's ridley turtles (*Lepidochelys kempii*) on developmental foraging grounds. Several telemetry studies have reported some basic dive information, but were only able to provide general descriptions or summarized accounts of dive behaviour due to the limitations inherent in commonly utilized data gathering instruments (VHF radio, sonic, satellite PTT). Additionally, these studies were performed in differing habitats and on turtles engaged in migration rather than on foraging grounds as described here. All these factors undoubtedly affect the reported diving behaviour. Renaud (1995) reported the number of dives and average dive duration by day/night by season for four migrating ridleys from Texas, Florida and North Carolina using satellite transmitters, and Gitschlag (1996) provided the number of dives and average dive duration by night/day for two larger immature ridleys migrating from Georgia to Florida by using VHF radio and depth sensitive sonic transmitters. Morreale & Standora (1998) tracked small ridleys from a developmental habitat in temperate New York (Long Island Sound) with VHF radio and sonic telemetry, and provided simplified dive profiles. More recently, Schmid et al. (2002) tracked several immature ridleys at the Cedar Keys in north-western Florida with VHF radio and sonic telemetry and reported brief dive observations.

While past studies have described Kemp's ridley diving behaviour, results were only generalized accounts of diving behaviour due to the limited capabilities of the VHF radio, sonic, and satellite telemetry equipment used in the studies. This is the first attempt to utilize TDR data loggers to study dive profiles and dive behaviour of a wild immature Kemp's ridley sea turtle. Our data were collected by a TDR deployed on an extremely rare immature Kemp's ridley turtle in a coastal developmental habitat in south-west Florida.

Table 1. Submergence variables for the post release stress and transition phases of an immature *Kemp's ridley* turtle from south-west Florida.

Variable	Stress phase 1100 20 May to 1300 21 May (N=878)		Transition phase 1300 to 2100 21 May (N=106)		
	Mean (SD)	Maximum	Mean (SD)	Maximum	Maximum
Surface time (seconds)	20.5 (19.0)	122.0	11.6 (8.0)	46	
Total dive time (minutes)	1.5 (1.6)	14.8	4.3 (6.6)	21.9	
Descent time (seconds)	10.5 (7.7)	30.0	9.1 (2.7)	16.0	
Bottom time (seconds)	64.5 (97.6)	870.0	237.4 (398.1)	1298.0	
Ascent time (seconds)	14.2 (7.6)	82.0	13.2 (4.3)	34.0	

N, number of dives; SD, standard deviation.

MATERIALS AND METHODS

This study took place in Gullivan Bay, Ten Thousand Islands, south-west Florida (25.88°05'N 81.58°40'W), and was a part of a larger study of immature turtles in that area (Witzell & Schmid, 2003, 2004; Witzell et al., 2005). Maps and a detailed description of the study area can be found in Witzell & Schmid (2004). The area has a mean depth of 3 m with a tidal range of 0.6 m. The turtles selected for this study were also selected for studies of home ranges and local movements that employed VHF radio and sonic telemetry. The turtles were captured by a run-around gill-net (Witzell & Schmid, 2003) weighed, measured, tagged, and the VHF radio/sonic telemetry equipment attached before immediate release at the original capture site. The TDR equipment was attached to three individuals as well.

The attached TDR tags were LTD 1200–100 manufactured by Lotek Wireless, Inc. which measured 18×57 mm and weighed 1g in seawater. Accuracy of these tags, measured in pounds per square inch (PSI), is reported by

the manufacturer to be 0.75 psi (0.5% of 150 psi). The TDRs for this study were programmed to measure pressure depth (pressure) every 2 seconds. The tags were fastened with wire to the base of a monofilament lanyard of a VHF radio transmitter float that was attached to the turtle through a hole drilled in the posterior marginal scute. A sonic transmitter was also attached to the turtle with nylon wire ties through holes drilled in the rear marginal scutes. Although location data generated from VHF and sonic tracking were not used in the present analysis, they facilitated recapture of the turtles for TDR recovery by allowing the turtle to be relocated.

The data were archived in the tag until downloaded and then converted to depth in metres by multiplying the recorded psi by 0.6803. Dive data was assessed using the software MultiTrace (Jensen Software Systems, Laboe, Germany). A dive was defined as having begun when the turtle descended below a dive threshold of 0.5 m. Dive data was summarized by period of the day: 1, dawn—0500 to 0800 h; 2, day—0800 to 1800 h; 3, dusk—1800 to 2100 h; and 4, night—2100 to 0500 h. The dive variables reported here are surface time, total dive time, descent time, bottom time, and ascent time. Tests for a significant difference among period of day for each of the five dive variables were performed using an analysis of variance (ANOVA). For ANOVAs that were significant at $P=0.05$, a Tukey's post-hoc test was used to determine which periods of day were significantly different from one another at the $P=0.05$ level. We did not assess dive types as been described elsewhere (e.g. Houghton et al., 2002) because the turtle in this study remained in very shallow water (2–3 m) and did not exhibit the multiple dive types observed in turtles from deeper water.

RESULTS

Two of the TDR tags were recovered, but only one of the two recovered tags functioned correctly. The successful TDR was deployed at 1100 h on 20 May 2003 and recovered at 0930 h on 17 June 2003. The turtle was 41.0 cm (straight carapace length) and weighed 10.8 kg. The total calculated time between first capture and recapture was 27 d, 22 h and 30 min, although the TDR stopped recording data on 7 June 2003, resulting in almost 16 days of continuous TDR data collection. The turtle remained in

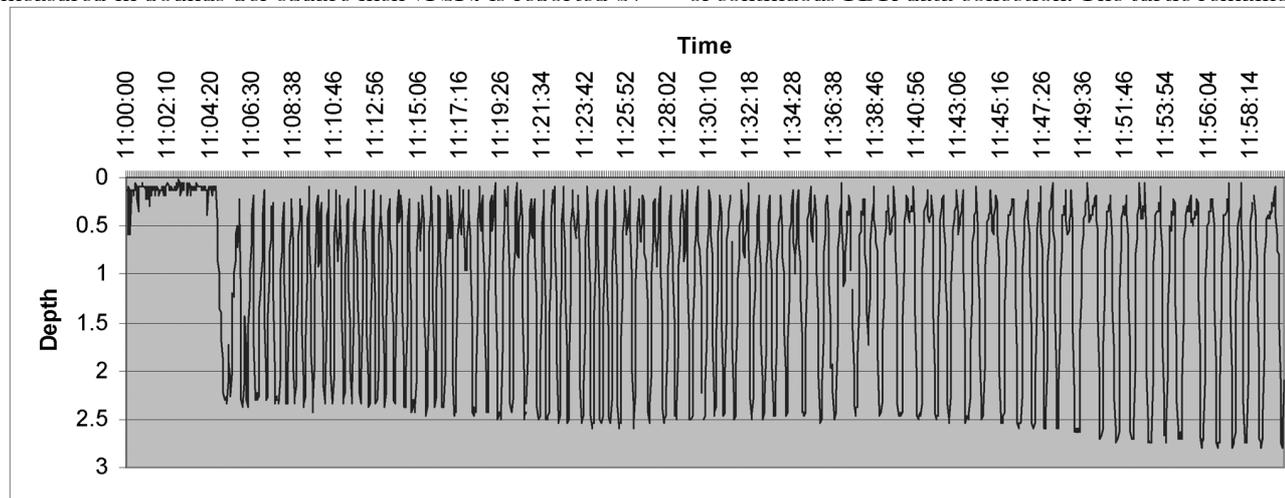


Figure 1. Post-release dive profile from 20 May (early stress period).

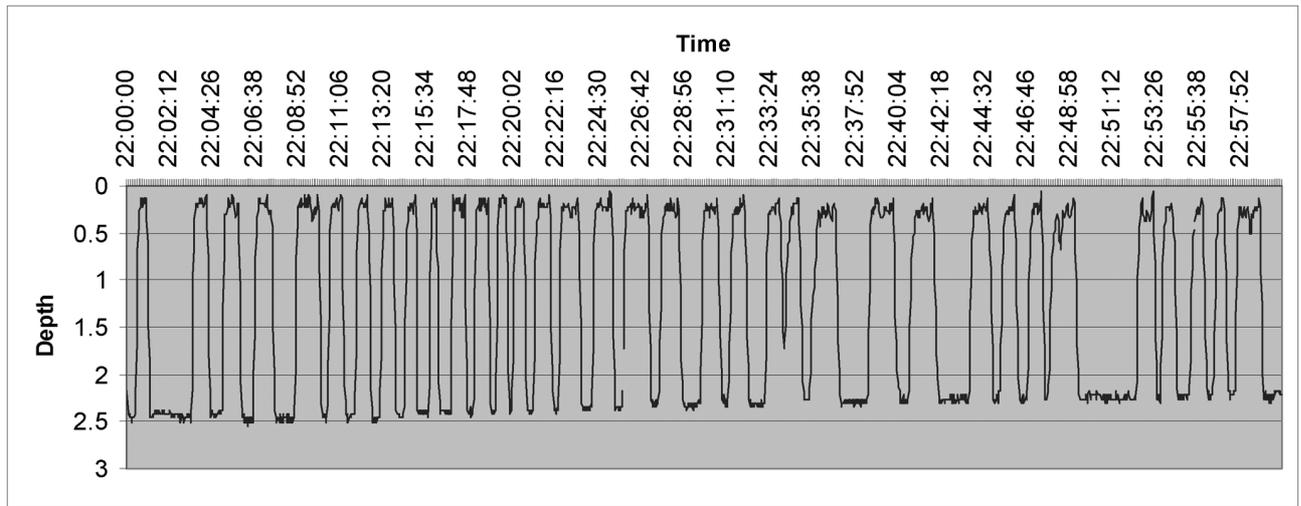


Figure 2. Dive profile from 20 May (later stress period).

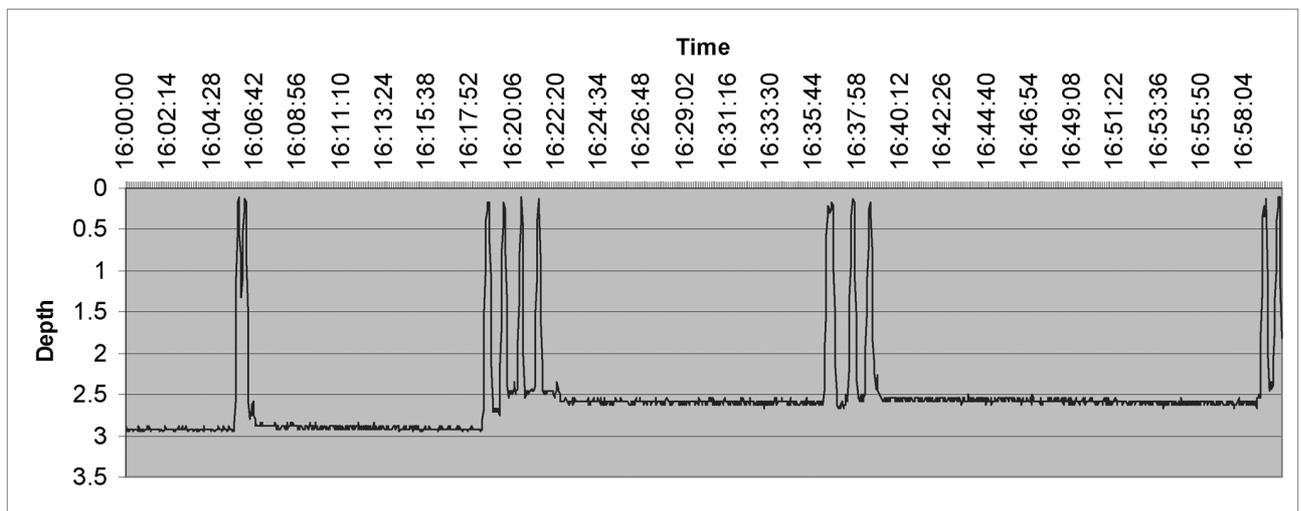


Figure 3. Dive profile from 21 May (transition period).

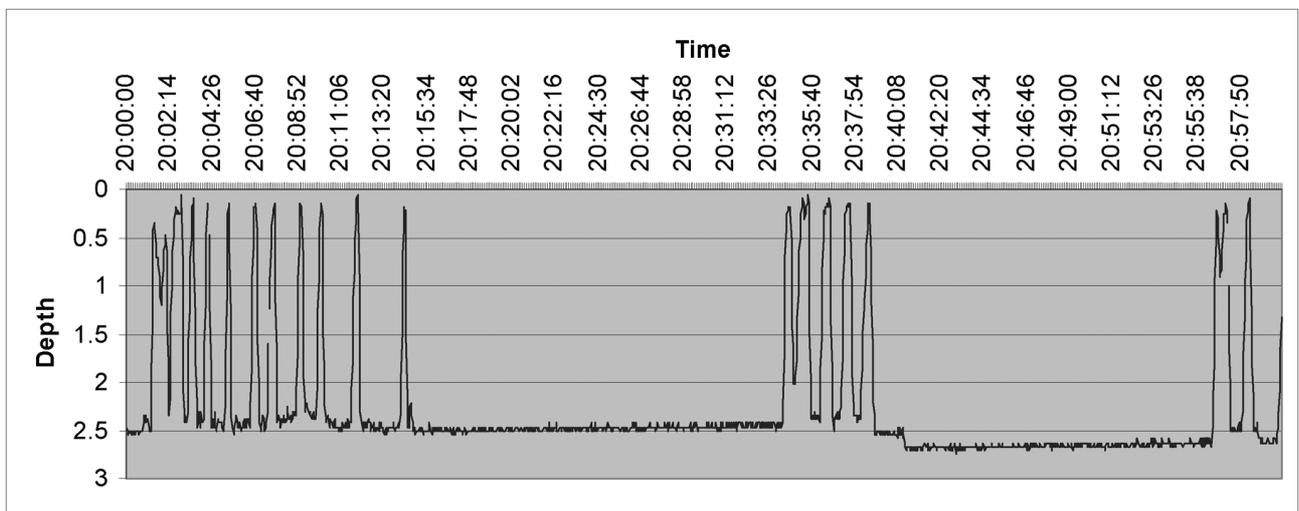
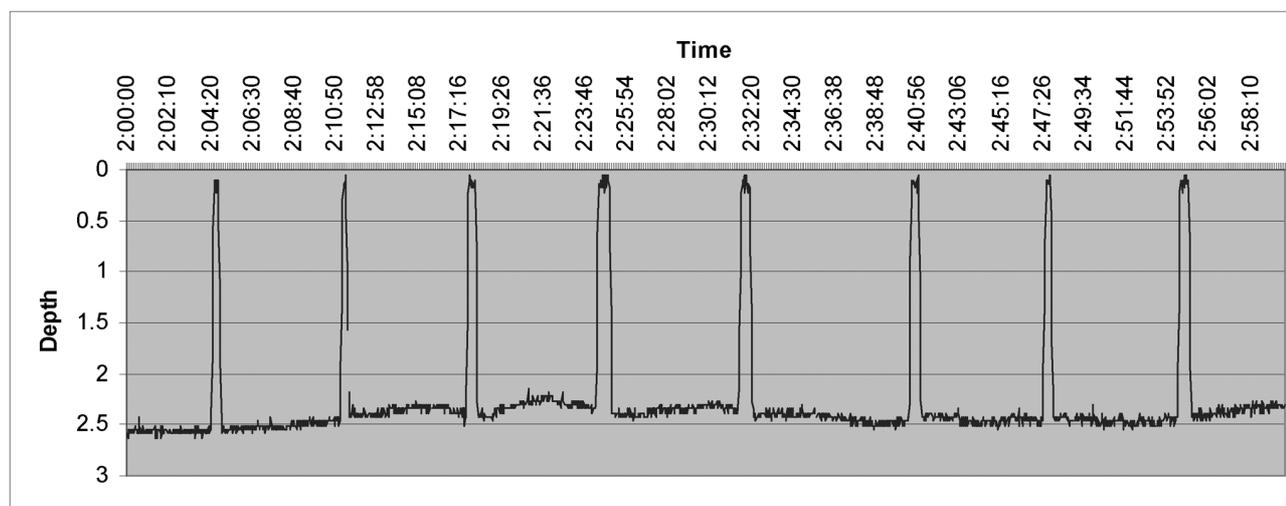
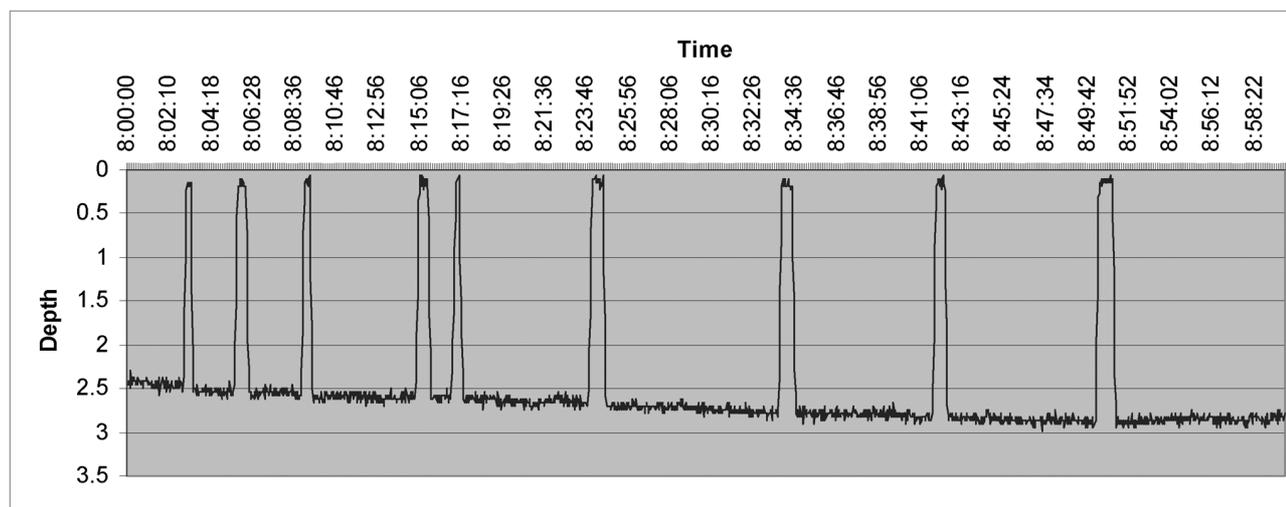


Figure 4. Dive profile from 21 May (transition period).

Table 2. Dive data for normal dive behaviour (22 May to 7 June) from an immature *Kemp's ridley* turtle from south-west Florida.

Variable	Dawn 0500 to 0800 (N=552)		Day 0800 to 18.00 (N=1922)		Dusk 1800 to 2100 (N=514)		Night 2100 to 0500 (N=1169)	
	Mean (SD)	Maximum	Mean (SD)	Maximum	Mean (SD)	Maximum	Mean (SD)	Maximum
Surface time (seconds)	22.8 (14.3)	84.0	19.3 (25.6)	834.0	19.4 (13.1)	76.0	23.8 (12.6)	74.0
Total dive time (minutes)	5.2 (3.3)	18.7	4.8 (5.0)	22.1	5.3 (4.1)	20.0	6.4 (2.7)	12.8
Descent time (seconds)	9.5 (3.5)	36.0	10.3 (3.7)	36.0	10.1 (3.8)	34.0	7.4 (2.1)	18.0
Bottom time (seconds)	288.1 (199.7)	1100.0	263.4 (298.2)	1310.0	295.5 (246.1)	1182.0	370.0 (162.2)	756.0
Ascent time (seconds)	11.7 (5.9)	46.0	13.7 (5.2)	40.0	12.2 (7.5)	56.0	8.0 (3.1)	36.0

N, number of dives; SD, standard deviation.

**Figure 5.** Dive profile from 26 May (normal period).**Figure 6.** Dive profile from 26 May (normal period).

an estimated area of 3.8 km² for the duration of the deployment (unpublished data).

The turtle was radio tracked for several days during this period, and spent much of its time in the channel between Gullivan and Turtle keys before being recaptured once again in front of Gullivan Key 27 days later (see Witzell & Schmid, 2004). The mean maximum depth of the

turtle dives was 2.27 m (± 0.54) for dawn, 2.59 m (± 0.70) for day, 2.14 m (± 0.63) for dusk, and 2.14 m (± 0.35) for night. The deepest recorded dive of 5.27 m occurred during the day. These dive depths are consistent with bottom depth for the area.

Examination of the dive profiles suggested three distinctly different activity phases. The first phase lasted

26 hours from release at 1104 on 20 May until 1300 21 May where the animal appeared engaged in a dive pattern of short, frequent dives. This behaviour was observed only during this early phase (Table 1, Figures 1 & 2). The next profile was from 1300 to 2100 on 21 May where the animal appeared to be in a transition phase with longer dives and short surface times following the previous post-release stress period (Table 1, Figures 3 & 4). The duration of this transition period was about 8 hours. After the stress and transition phase dive profiles, the turtle settled into a dive pattern that continued for 17 days until the TDR stopped recording data on 7 June (Table 2, Figures 5 & 6). During this period, interpreted as a normal diving pattern, the turtle spent 94% of the time submerged throughout the day.

During the normal phase, all variables were significantly different ($P < 0.05$) among the four periods of day for all tests. The Tukey's post-hoc tests (Table 3) revealed that night was different from day and dusk for all variables and different than dawn for all variables except surface time. In all cases, total dive and bottom time were

Table 3. Results of Tukey's Post-Hoc tests for dive parameters for an immature *Kemp's ridley* turtle from south-west Florida.

Period of day comparison	Surface time	Total dive time	Descent time	Bottom time	Ascent time
Dawn-day	*		*		*
Dawn-dusk	*		*		
Dawn-night		*	*	*	*
Day-dusk				*	*
Day-night	*	*	*	*	*
Dusk-night	*	*	*	*	*

*, indicates a significant difference at the 0.05 level.

greater by approximately 60 to 90 s at night with shorter ascent and descent times.

Dawn and dusk had similar patterns with surface time being a few seconds shorter at dusk (22.8 ± 14.3 s vs 19.4 ± 13.1 s, Table 3). While surface time was different between dawn and day, this was likely due to the high

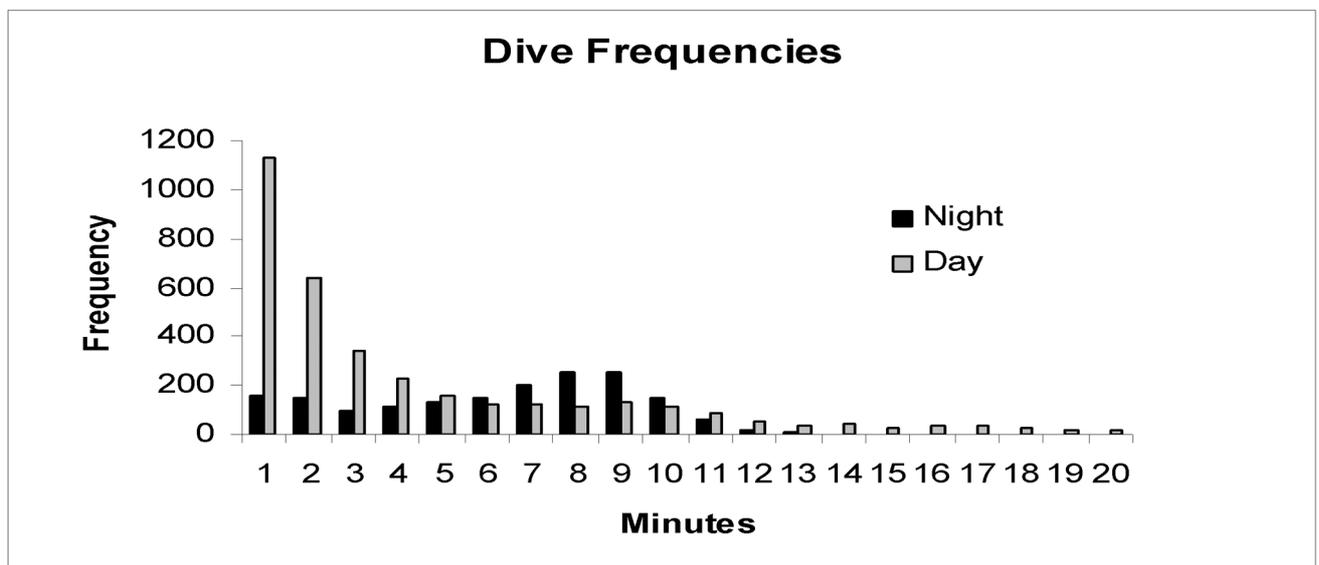


Figure 7. Histogram of dive duration for day and night.

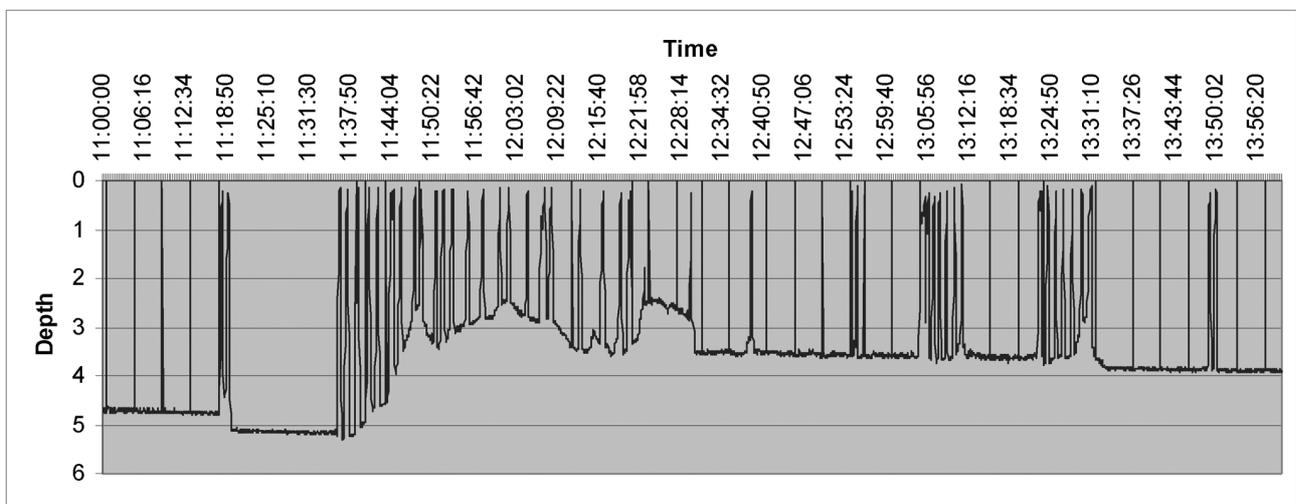


Figure 8. Dive profile demonstrating the possible behavioural effect of approaching vessels.

variability of surface time during the day (19.3 ± 25.6 s) compared to dawn (22.8 ± 14.3 s). Similarly, the difference in bottom time between day (263.4 ± 298.2 s) and dusk (295.5 ± 246.1 s) may be attributed to the greater variability in bottom time during the day. Differences in dive frequency between night and day are shown in Figure 7.

DISCUSSION

These results presented here are the first data from a TDR deployed on an immature Kemp's ridley in foraging habitat. One unique finding is the apparent lack of multiple dive types as described by Houghton et al. (2002). This is not entirely surprising given that the turtle spent the entire time in shallow habitat rarely more than three metres in depth. The area is usually 2–3 m deep and relatively flat with occasional 3–4 m troughs usually located in the channels between the mangrove islands and is typical of the entire Ten Thousand Islands area.

The data reported here indicate three dive phases: post-release stress, transition, and normal. The long interval of capture stress and transition combined (34 h) indicates that handling and instrument deployment on turtles causes abnormal behaviour at initial release and exceeds the 24 h settling back to normalcy period assumed by Schmid et al. (2002, 2003) for tracking immature ridleys in north-western Florida. Our data also demonstrate a distinct difference in diving behaviour between night and other periods of the day for a juvenile Kemp's ridley turtle on foraging grounds in south-west Florida. The shorter ascent and descent times at night, along with the longer bottom and total dive time, suggesting the turtle was resting on the bottom, but quickly returning to the surface to breathe when necessary. The higher variability during the day compared to other periods suggest that the turtle is engaging in a variety of behaviours during the day including presumed foraging and travelling. Normal daytime activities were punctuated with short periods of rapid diving, suggesting escape behaviours from either large coastal sharks or, more likely, from recreational fishing boats that often utilize the channel frequented by the turtle. Another reason for some of the escape behaviour might have been caused by the tracking vessel, which approached the turtle within 10–20 m during tracking days in order to obtain a geographical position (Figure 8).

There are several accounts of diving studies performed on immature Kemp's ridley turtles but there are presently no published accounts of Kemp's ridley turtle diving behaviour using data loggers. The existing studies either use VHF radio or satellite transmitter technologies on migrating turtles (Renaud, 1995; Gitschlag, 1996), or turtles from New England waters (Morealle & Standora, 1998). Along with differences in turtle sizes, water temperature, and behaviour (migrating vs foraging), different attachment protocols (tether vs backpack) may affect surfacing and diving estimates. Consequently, meaningful comparisons among diving behaviour studies are not possible. The closest comparable study to the present study is from the Cedar Keys in terms of geographical proximity, specimen size, and foraging

behaviour, although they used tethered VHF radio telemetry to estimate dive patterns (Schmid et al., 2002) rather than from direct data collection as in TDR.

The Cedar Keys turtles had an estimated mean surface duration of 18 ± 15 s and mean dive duration of 8.4 ± 6.4 min (Schmid et al., 2002). Schmid et al. reported that an increase in rate of movement corresponded to an increased number of surfacings and shorter surface and submergence times, and also noted there were longer submergence intervals during the night and suggested reduced nocturnal movements. The Cedar Key dive patterns were similar to those from south-west Florida, although the mean day and night surface times in south-west Florida were longer than at Cedar Key (19.3 ± 25.6 s and 23.8 ± 12 s) respectively, and the mean day and night dive durations were shorter than at Cedar Key (4.8 ± 5.0 min and 6.4 ± 2.7 min) respectively. Habitat depths at Cedar Key were similar with the habitat occupied less than 4 m and 1–2 m being the preferred habitat.

Schmid et al. (2002) concluded that the Cedar Keys ridleys were possibly using olfactory and auditory cues to forage for large crabs at night, but provided no dietary evidence to support this supposition. The ridleys in south-west Florida, however, were found to feed largely on sedentary tunicates and not large crabs (Witzell & Schmid, 2005). The water in the study area is often turbid and it is unknown what mechanisms the turtles use to locate the solitary tunicates, particularly at night.

While we examined behaviour for dawn and dusk, we found no evidence that the behaviour of this turtle reflected any heightened crepuscular pattern of activity as suggested by Morreale & Standora (1998) for New York ridleys. Instead, values for the variables at dawn and dusk were similar to those for day, but with less variability.

Conclusions

The use of a TDR on a foraging immature ridley turtle has revealed several behavioural patterns: post release stress (26 h), post release transition (8 h), and normal (>34 h). The normal pattern consists of short periods on the surface followed by longer periods presumed foraging on the bottom in 2–3 m of water. This routine was occasionally interrupted by short periods of rapid diving that may be attributed to either prey escape behaviour or to disturbance by fishing boats or the tracking vessel. The turtle also spent significantly more time submerged at night than during the day, but apparently remained active. Overall, 94% of the time was spent submerged. The reported surface to submergence ratio is important information that should be factored into any airborne or vessel visual surveys. Accurate diving behaviour can best be described with data collected with data loggers (e.g. TDRs), and results from telemetry studies which utilize VHF radio and/or sonic tracking should be interpreted carefully because of the possibility of disturbing the animals with tracking vessels. Lastly, researchers need to account for an extended acclimation period (>34 h for this study) after the turtle has been released before normal behavioural data can be considered reliable.

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REFERENCES

- Gitschlag, G.R., 1996. Migration and diving behavior of Kemp's ridley (Garman) sea turtles along the US southeastern Atlantic coast. *Journal of Experimental Marine Biology and Ecology*, **205**, 115–135.
- Hays, G.C., Adams, C.R., Broderick, A.C., Godley, B.J., Lucas, D.J., Metcalfe, J.D. & Prior, A.A., 2000. The diving behaviour of green turtles at Ascension Island. *Animal Behaviour*, **59**, 577–587.
- Hays, G.C., Broderick, A.C., Glen, F., Godley, B.J. & Nichols, W.J., 2001a. The movements and submergence behavior of male green turtles at Ascension Island. *Marine Biology*, **139**, 395–399.
- Hays, G.C. et al., 2001b. The diving behavior of green turtles undertaking oceanic migration to and from Ascension Island: dive durations, dive profiles and depth distribution. *Journal of Experimental Biology*, **204**, 4093–4098.
- Hays, G.C., Houghton, J.D.R., Isaacs, C., King, R.S., Lloyd, C., & Lovell, P., 2004. First records of oceanic dive profiles for leatherback turtles, *Dermochelys coriacea*, indicate behavioural plasticity associated with long-term migration. *Animal Behaviour*, **67**, 733–743.
- Hochscheid, S., Godley, B.J., Broderick, A.C. & Wilson, R.P., 1999. Reptilian diving: highly variable dive patterns in the green turtle *Chelonia mydas*. *Marine Ecology Progress Series*, **185**, 101–112.
- Houghton, J.D.R., Broderick, A.C., Godley, B.J., Metcalfe, J.D. & Hays, G.C., 2002. Diving behaviour during the internesting interval for loggerhead turtles *Caretta caretta* nesting in Cyprus. *Marine Ecology Progress Series*, **227**, 63–70.
- Morreale, S.J. & Standora, E.A., 1998. Early life stage ecology of sea turtles in northeastern US waters. *US Department of Commerce, National Ocean and Atmospheric Administration, National Marine Fisheries Service, NOAA Technical Memorandum NMFS-SEFSC-413*, 49 pp.
- Renaud, M.L., 1995. Movements and submergence patterns of Kemp's ridley turtles (*Lepidochelys kempii*). *Journal of Herpetology*, **29**, 370–374.
- Sakamoto, W., Naito, Y., Uchida, I. & Kureha, K., 1990a. Circadian rhythm on diving motion of the loggerhead turtle *Caretta caretta* during inter-nesting and its fluctuations induced by the oceanic environmental events. *Nippon Suisan Gakkaishi*, **56**, 263–272.
- Sakamoto, W., Uchida, I., Naito, Y., Kureha, K., Tujimura, M. & Sato, K., 1990b. Deep diving behavior of the loggerhead turtle near the frontal zone. *Nippon Suisan Gakkaishi*, **56**, 1435–1443.
- Sakamoto, W., Sato, K., Tanaka, H. & Naito, Y., 1993. Diving patterns and swimming environment of two loggerhead turtles during internesting. *Nippon Suisan Gakkaishi*, **59**, 1129–1137.
- Schmid, J.R., Bolten, A.B., Bjorndal, K.A. & Lindberg, W.J., 2002. Activity patterns of Kemp's ridley turtles, *Lepidochelys kempii*, in the coastal waters of the Cedar Keys, Florida. *Marine Biology*, **140**, 215–228.
- Schmid, J.R., Bolten, A.B., Bjorndal, K.A., Lindberg, W.J., Percival, H.F. & Zwick, P.D., 2003. Home range and habitat use by Kemp's ridley turtles in west-central Florida. *Journal of Wildlife Management*, **67**, 196–206.
- Van Dam, R.P. & Diez, C.E., 1997. Diving behavior of immature hawksbill turtles (*Eretmochelys imbricata*) in a Caribbean reef habitat. *Coral Reefs*, **16**, 133–138.
- Witzell, W.N., Geis, A.A., Schmid, J.R. & Wibbels, T., 2005. Sex ratio of immature Kemp's ridley turtles (*Lepidochelys kempii*) from Gullivan Bay, Ten Thousand Islands, south-west Florida. *Journal of the Marine Biological Association of the United Kingdom*, **85**, 205–208.
- Witzell, W.N. & Schmid, J.R., 2003. Multiple recaptures of a hybrid hawksbill-loggerhead turtle in the Ten Thousand Islands, southwest Florida. *Herpetological Review*, **34**, 323–325.
- Witzell, W.N. & Schmid, J.R., 2004. Immature sea turtles in Gullivan Bay, Ten Thousand Islands, Southwest Florida. *Gulf of Mexico Science*, **2004**, 54–61.
- Witzell, W.N. & Schmid, J.R., 2005. Diet of immature Kemp's ridley turtles (*Lepidochelys kempii*) from Gullivan Bay, Ten Thousand Islands, southwest Florida. *Bulletin of Marine Science*, **77**, 191–199.

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