Aquatic Mammals 2010, *36*(1), 1-8, DOI 10.1578/AM.36.1.2010.1

Linking Dive Behavior to Satellite-Linked Tag Condition for a Bottlenose Dolphin (*Tursiops truncatus*) along Florida's Northern Gulf of Mexico Coast

Brian C. Balmer,[1, 2] Lori H. Schwacke,[3] and Randall S. Wells[1]

[1]*Chicago Zoological Society c/o Mote Marine Laboratory, Sarasota, FL 34236, USA; E-mail: bbalmer@mote.org*
[2]*University of North Carolina Wilmington, Wilmington, NC 28403, USA*
[3]*NOAA's Ocean Service, Charleston, SC 29412, USA*

Abstract

Satellite-linked telemetry is a valuable method to identify small cetacean movement patterns and dive behavior. Data collection from satellite-linked tracking is less labor intensive than comparable radio tracking studies in which intensive field work is required post-tagging. However, there are few studies that have assessed the effects of satellite-linked transmitter attachment and retention on the tagged individual. Dolphin X08, a 24-y-old, male bottlenose dolphin (*Tursiops truncatus*) captured and released along the northern Gulf coast of Florida during a health assessment project, was tagged with a SPLASH satellite-linked transmitter (Wildlife Computers, Redmond, WA, USA) to remotely obtain data on movement patterns and dive behavior. In addition to the satellite-linked transmitter, a VHF radio transmitter was mounted to X08's dorsal fin to provide short-term movement pattern data and to allow for position acquisition to observe X08 with the satellite-linked transmitter. X08's satellite-linked tag transmitted location data for 54 days and dive duration data for 35 of those days. X08's VHF tag transmitted for over 94 days and allowed for complete monitoring of the satellite-linked tag's life. Dive duration data changed throughout the course of the satellite-linked tag transmissions. These dive data, along with follow-up observations, suggest that as the stability of the satellite-linked tag on the dorsal fin decreased, the number of longer dives increased, possibly to mitigate the amount of time that the satellite-linked tag came into contact with the water surface. This study was the first to identify movement patterns and dive durations of a bottlenose dolphin along the northern Gulf coast of Florida as well as to monitor satellite-linked tag condition throughout the transmission period.

Key Words: satellite-linked telemetry, dive durations, radio telemetry, bottlenose dolphin, *Tursiops truncatus*

Introduction

Satellite-linked transmitters have been used on a variety of cetacean species to determine movement patterns and dive behavior (Mate et al., 1995; Read & Westgate, 1997; Watkins et al., 1999; Bloch et al., 2003; Corkeron & Martin, 2004; Baumgartner & Mate, 2005; Hobbs et al., 2005; Wells et al., 2008, 2009). Still, little information is available on impacts of tags on animals or the reasons for cessation of transmissions. Such information is crucial for interpreting the likely fates of animals after tagging when they cannot be observed directly. Mate et al. (1995) presented information on the condition of a bottlenose dolphin tagged with a satellite-linked transmitter after the tag had been shed; the animal showed no adverse effect. Read et al. (1997) evaluated the effects of ST-10 PTT (Telonics, Mesa, AZ, USA) flat panel, side-mounted satellite-linked transmitters on two adult male bottlenose dolphins in Sarasota Bay, Florida; described how the attachment pins failed; and documented tag loss apparently without serious injury to the dolphins.

In 2005, we had the opportunity to monitor a bottlenose dolphin tagged with a newer satellite-linked transmitter through the duration of attachment and to relate transmitted data to the condition of the tag and attachments. The SPLASH satellite-linked tag (Wildlife Computers, Redmond, WA, USA) used in this study had a similar design to the ST-10 PTT described by Read et al. (1997) but was of a much smaller configuration (Figure 1).

Materials and Methods

St. Joseph Bay, on the northern Gulf coast of Florida (Figure 2), has been affected by three unusual mortality events (UMEs) in recent years (Waring et al., 2009). To investigate the potential causes and impacts of these events, bottlenose dolphins in and around St. Joseph Bay were temporarily captured and restrained for health assessments

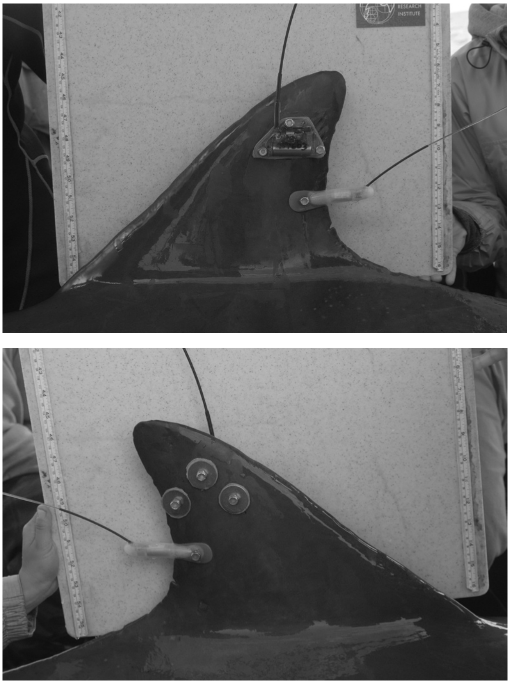

Figure 1. X08 with SPLASH satellite-linked transmitter and VHF radio tag

in 2005 and 2006, using practices similar to those implemented by the Sarasota Dolphin Research Program (Wells et al., 2004).

To define the population units impacted by the UMEs, VHF radio transmitters (MM130, Backmount Transmitter, Advanced Telemetry Systems, Inc., Isanti, MN, USA) were mounted to dorsal fins of individual bottlenose dolphins in a modified plastic casing with a one-hole attachment known as a bullet tag (Trac Pac, Ft. Walton Beach, FL, USA). Battery life of the radio tag was estimated to be approximately 90 d. VHF radio tags allow for obtaining real-time locations via vessel, vehicle, and aerial tracking. However, this technique is labor intensive, allows for location only data, and is logistically difficult to perform for prolonged periods covering a broad geographic range. One 24-y-old male, Dolphin X08, received both a SPLASH satellite-linked transmitter and a VHF radio tag (Figure 1). The SPLASH satellite-linked transmitter provides location data for the user defined duty cycle (8 h/d) as well as dive duration data over the entire day for the duration of the tag's life. All data are uploaded via satellite, reducing the need for intensive follow-up monitoring over an extended geographic range.

The casing of the satellite-linked transmitter involved a three pin design that attached directly to the left side of the dorsal fin. Delrin pins of 0.64-cm diameter and non-stainless steel lock nuts were used for attachment of both the satellite-linked and radio transmitters. The pins on the opposite side of the dorsal fin from the satellite tag were secured by non-stainless steel lock nuts with the nylon locking ring scored with stainless steel 3.0-cm diameter washers to facilitate shedding (Figure 1). The sides of the satellite tag and each washer that would be in contact with the fin were padded with 0.5-cm-thick closed cell foam to mitigate the possible effects of the tag and washers on the dorsal fin. The satellite-linked tag was attached to the upper third of the animal's dorsal fin, while the VHF radio tag was attached to the lower third.

Prior to tag attachment, the dorsal fin was cleaned with ethanol. At each attachment point, a local anesthetic (lidocaine 2% with epinephrine) was used prior to hole preparation. Holes were made through the dorsal fin using a cordless power drill with a sterilized 0.6-cm laboratory cork borer.

The SPLASH satellite-linked transmitter was set to a duty cycle of 8 h to conserve battery life (i.e., 8 h on, 16 h off). Using the identified duty cycle, battery life of the satellite tag was estimated to be up to 100 d. Location and dive duration data were obtained using *Service Argos* (Argos, 1996). Quality of location data was dependent on number of uplinks during a satellite pass, time between signals, position of the satellite tag on the animal, and stability of the transmitter oscillator (Westgate et al., 1999). Location data received from the satellite transmitter was divided into four categories:

- Class 3 (greater than five uplinks received in one satellite pass; position accuracy about 150 m)
- Class 2 (five uplinks received in one satellite pass; position accuracy about 350 m)
- Class 1 (four uplinks received in one satellite pass; position accuracy about 1 km)
- Class 0 (less than four uplinks received in one satellite pass; position accuracy greater than 1 km)

Only Class 3 and 2 data were used to plot locations of X08 during the tracking period.

Post-release, X08 was radio-tracked daily by vessel whenever possible; however, if poor weather conditions limited vessel tracking, locations were obtained via vehicle and/or plane. During each sighting of X08, latitude and longitude were recorded, left and right dorsal fin photos were obtained, and behavioral states were noted.

Results

Location Data

X08's satellite-linked tag transmitted for a total of 54 d from 25 April to 17 June 2005, yielding 91

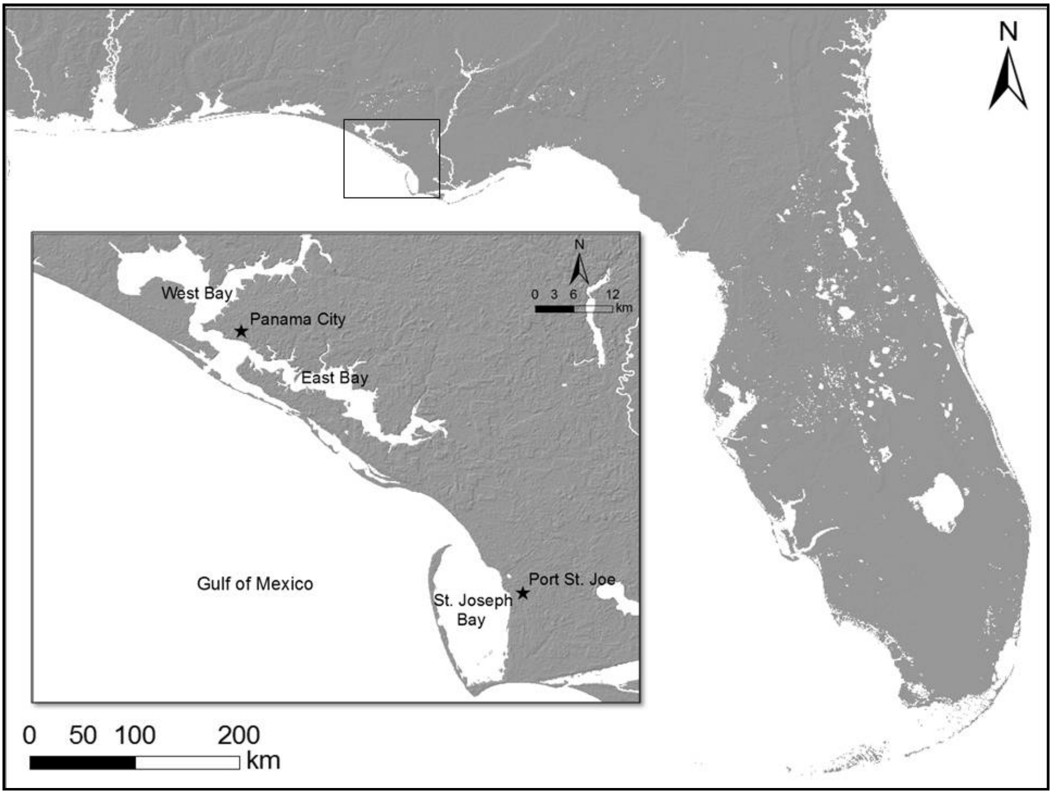

Figure 2. St. Joseph Bay and surrounding Gulf waters, located along Florida's northern Gulf coast

Class 2 and 3 locations. X08's radio tag transmitted for a minimum of 94 d, at least until the last day of the study, 25 July. During this time period, 45 sighting locations were obtained from vessel ($n = 32$), vehicle ($n = 8$), and aerial tracking ($n = 5$). After 25 July, the field season ended in the region, preventing complete monitoring of radio tag life from attachment to battery failure. Sighting histories from the location data for both the satellite and radio tags are comparable to actual sighting records (Figure 3). X08's range during the tracking period extended approximately 40 km along the northern Gulf coast of Florida with the majority of locations near Panama City, Florida.

Dive Duration Data

Dive duration data from the satellite tag were obtained for 35 nonconsecutive days over a 50-d period from 27 April to 15 June 2005. During this time, 20,928 dives were recorded with a mean number of 598 (± 36 SD) dives/d. The total number of dives/d was similar for all 35 d of dive duration data; however, the types of dive changed over the course of the dive duration data (Figure 4). The number of short- (30 to 60 s) and long-duration dives (90 to 120 s and > 120 s) remained constant for approximately 17 d. At day 18, the number of short-duration dives began to decrease and the number of long-duration dives began to increase. From day 24 until the last dive duration transmission, dive type stabilized with more long dives and fewer short dives than observed for the first 23 d.

Tag Condition

X08's satellite-linked tag remained in the same position as on the attachment date for approximately 23 to 28 d (Figure 5). On the 28th day post tag attachment, the leading pin was observed to be missing the nut and washer on the right side of the fin (Figure 6). Migration of the satellite tag out of the dorsal fin was observed from this day forward. After 35 d of attachment, the lead pin was observed pulling out of the dorsal fin (Figure 7). The position of the lead pin coupled with moderate bio-growth on the tag created a large amount of drag on the dorsal fin. Because of poor weather and field logistics, we were unable to observe X08 for the following 13 d. After 48 d of tag attachment, severe migration of the satellite tag out of the dorsal fin and heavy bio-growth were observed (Figure 8). On day 54, satellite transmissions stopped, but the radio tag continued to function

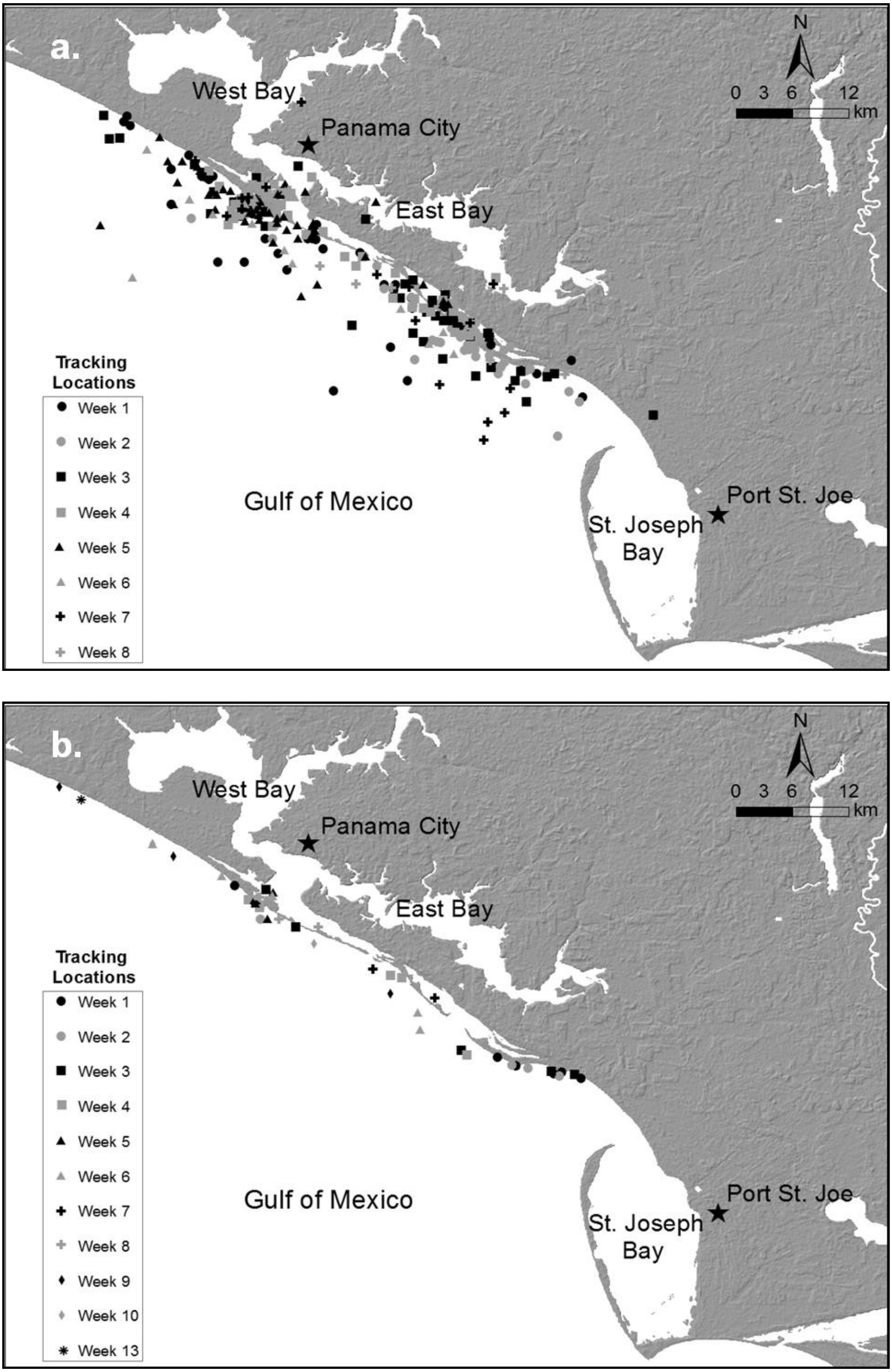

Figure 3. Tracking locations of X08 from (a) satellite-linked and (b) radio transmitters

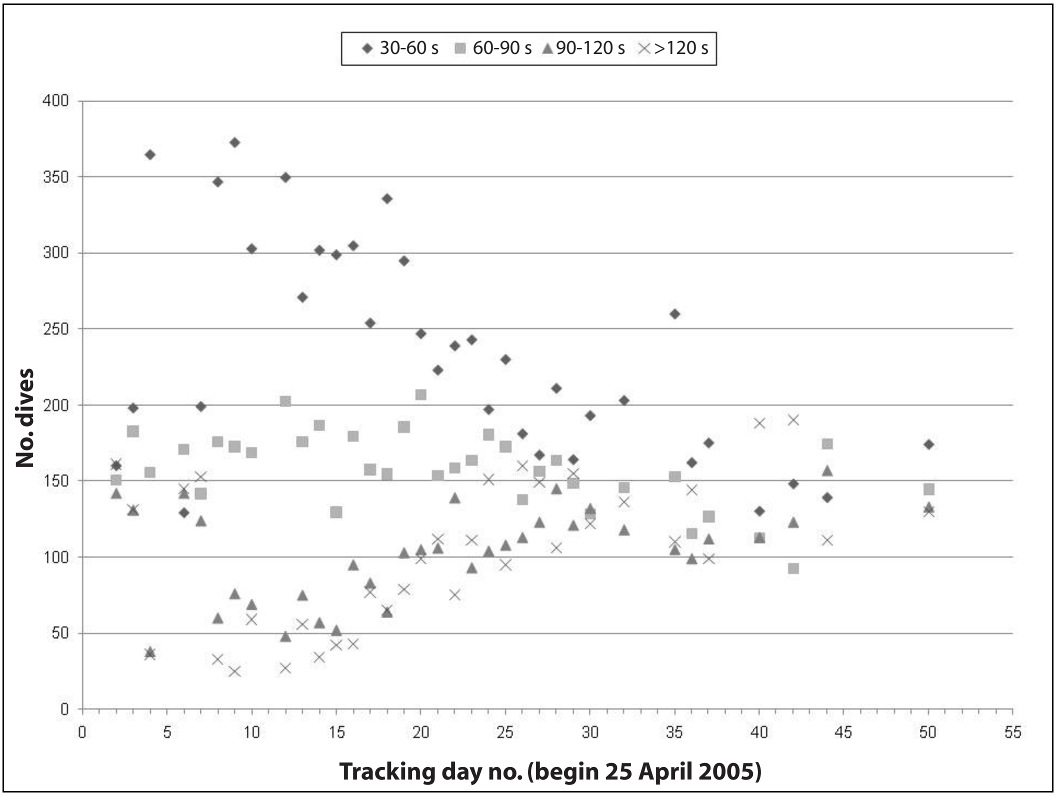

Figure 4. Dive duration data obtained from satellite-linked transmitter

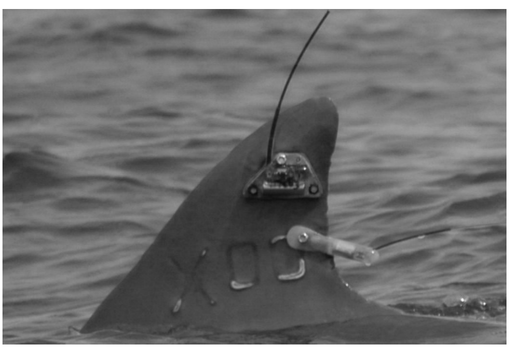

Figure 5. X08 with satellite transmitter showing no signs of migration—Day 15

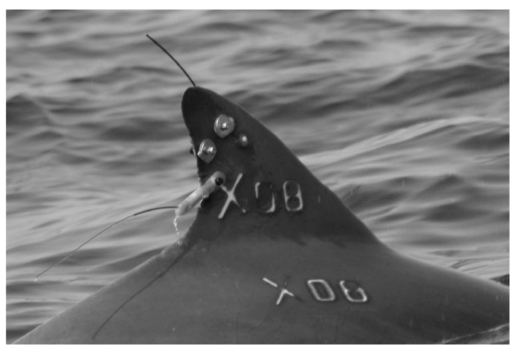

Figure 6. X08 with lead attachment pin missing nut and washer, right side—Day 28

allowing for additional observations. During the entirety of the follow-up radio tracking, obtaining photos of X08 was of moderate difficulty due to the animal's behavior; the animal became extremely evasive once the severe tag migration period began at 48 d. On the 62nd day after tag attachment, X08 was observed without the satellite-linked tag but still with a functional radio tag (Figure 9).

Discussion

Location, Dive Duration, and Tag Condition

The attachment of both a satellite-linked and a radio tag to an individual bottlenose dolphin (X08) allowed for both dive duration and movement pattern data to be obtained and for follow-up monitoring to assess the condition and orientation of the satellite-linked tag on the animal.

Figure 7. X08 with lead attachment pulling out of left side of fin and moderate bio-growth—Day 35

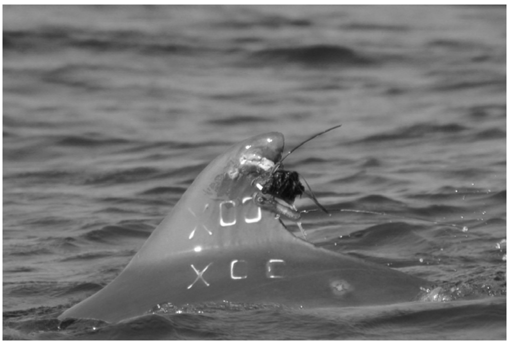

Figure 8. X08's dorsal fin, left side, showing severe migration and heavy bio-growth—Day 48

Figure 9. X08 without satellite tag—Day 62

X08's satellite-linked transmitter remained in the same position on the dorsal fin for approximately 23 to 27 d. From day 23 to day 28 (the first time the broken attachment was observed), no sightings were obtained of X08 because of poor weather and logistical constraints. The dive duration data from this period of time suggest a change in the behavior of X08. Prior to day 24, the number of X08's short dives gradually decreased while the number of long dives gradually increased (Figure 4). From approximately day 23 until tag failure (at day 54), X08's dive patterns stabilized with a relatively high number of long dives and a relatively low number of short dives as compared with the first 23 d of observation. Although no sightings were obtained from day 24 to day 27, photographs from day 23 and day 28 along with the dive duration data provided insight into the change in X08's behavior. The shearing of the lead pin observed first on day 28 suggests that the satellite-linked tag had lost stability on the dorsal fin. This loss of stability and subsequent increase in long dives might indicate that X08 was trying to minimize the time at which its dorsal fin and satellite tag were above or broke the water's surface. Thus, from this time until when the satellite tag fell off, X08 might have changed its behavior from a high number of short dives with few long dives to a high number of long dives to mitigate the effects of the unstable satellite-linked tag interacting with the water's surface.

X08's satellite-linked tag yielded 91 Class 2 and 3 locations over 54 d. In addition, 20,928 dives were recorded over the 35 d of dive duration data. X08's radio tag transmitted for a minimum of 94 d, with 45 sighting locations obtained over that time period. The expectation from placing both satellite-linked and radio tags on X08's dorsal fin was that the satellite-linked tag's battery life would exceed that of the radio tag. After radio tag failure, continuing movement patterns from satellite-linked telemetry could then be obtained. In this study, however, radio telemetry exceeded expectations, and the radio tag lasted longer than the satellite-linked tag. For the 54 d the satellite tag transmitted, though, it provided more detailed location data than was possible using solely a radio tag. In addition, the satellite-linked transmitter provided detailed dive duration data as well as insight into satellite tag condition for the 35 d of dive duration transmissions.

The three-point attachment design of the satellite-linked transmitter did not function as expected. Nut corrosion was expected to be the primary factor in release of the satellite-linked tag, which would have resulted in only minor damage to the dorsal fin. However, in X08's case, the delrin pin of the lead attachment broke first. With the lead attachment unstable, the orientation of the satellite-linked tag's antenna was altered, reducing the number of successful uplinks received, especially for longer messages such as dive data (Figure 10). The amount of bio-growth on the satellite tag could also have played a factor in diminishing the quality of location data received. The failure of the lead pin also contributed to an increase in drag pressure exerted on the dorsal fin, resulting in increased migration by the other two attachment pins.

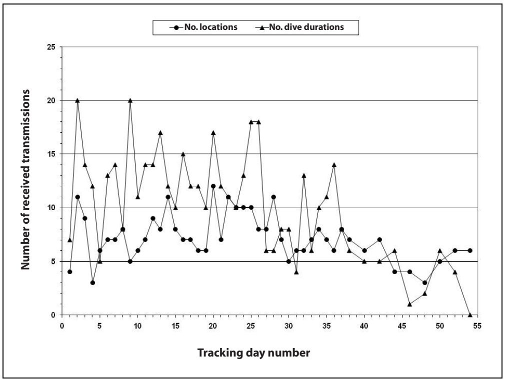

Figure 10. Changes in daily transmission rates of satellite-linked transmitter

Although X08's satellite-linked tag was not shed as designed, these were the first data obtained on coastal bottlenose dolphin movement and dive duration patterns along the northern Gulf coast of Florida. The follow-up radio-tracking also identified potential reasons for satellite-linked tag failure and suggested causes for changes in dive duration over time and with changes in attachment condition.

Summary

Before considering a cetacean satellite-linked or radio tagging project, there are many factors that need to be considered. Any type of tagging project has inherent risks that can affect individuals, ranging in severity from short-term stress to death. The foremost question that needs to be addressed relates to whether the goals of the research project supersede the negative effects incurred by tag attachment on a certain number of individuals of that species. Wilson & McMahon (2006) provide a detailed outline for assessing if research goals fit with a tracking project.

The SPLASH satellite-linked transmitter used in this study has been successful in identifying movement patterns and dive durations of numerous small cetacean species including bottlenose dolphins off Bermuda (Klatsky et al., 2007), Risso's dolphins (*Grampus griseus*) in the Gulf of Mexico and Atlantic Ocean (Wells et al., 2009; R. Wells, pers. obs.), rough-toothed dolphins (*Steno bredanensis*) in the Atlantic Ocean (Wells et al., 2008; R. Wells, pers. obs.), and Franciscana dolphins (*Pontoporia blainvillei*) in the Atlantic coastal waters off Argentina (R. Wells, pers. obs.). While it has not been possible to directly observe any of these animals to determine if the tag attachments remained stable until being jettisoned as designed, none of those individuals demonstrated the changing pattern of dives described here for X08.

Although X08's satellite tag collected the first data on movement patterns and dive behavior for a bottlenose dolphin along Florida's northern Gulf coast, the tag was not jettisoned as designed, which led to dorsal fin damage and also behavior changes in the dive patterns of the tagged individual. The results presented in this study suggest that more research is needed to determine the effects of multiple pin satellite-linked tag attachment designs on dorsal fins of small, coastal odontocetes, especially in areas where the tagged individuals might try to rub the tags on the sea floor. Reducing the size of satellite-linked transmitters to allow a single-pin design similar to that of the bullet radio tag would be valuable for future studies on movement patterns of coastal cetaceans.

NOAA Disclaimer

This publication does not constitute an endorsement of any commercial product or intend to be an opinion beyond scientific or other results obtained by the National Oceanic and Atmospheric Administration (NOAA). No reference shall be made to NOAA, or this publication furnished by NOAA, to any advertising or sales promotion which would indicate or imply that NOAA recommends or endorses any proprietary product mentioned herein, or which has as its purpose an interest to cause the advertised product to be used or purchased because of this publication.

Acknowledgments

This research was funded by NOAA Fisheries, the Disney Wildlife Conservation Fund, the Chicago Zoological Society, and the University of North Carolina Wilmington. It was conducted under NMFS Scientific Research Permit Numbers 522-1569-01 and 522-1527-00 and UNCW IACUC Permit Number 2004-012. We would also like to thank the staff at the St. Joseph Bay State Buffer Preserve for lodging and logistical support; all the participants in the capture-release health assessments; Michael Scott and the marine mammal staff from Center for Coastal Environmental Health and Biomolecular Research for additional field equipment; Bill McLellan, Ann Pabst, Douglas Nowacek, Stephanie Nowacek, Captain Dan Aspenleiter, and Gerry Compeau for their logistical support; Bob and Chong Murphy for aerial surveys; Andrew Westgate for radio-tracking suggestions; Christina Lockyer for age determination; and Stephanie Schilling, Michelle Barbieri, Ross Kinard, and Leigh Hardee for their relentless tracking under sometimes less-than-ideal field conditions.

Literature Cited

Argos. (1996). *User's manual: Satellite based data collection and location system*. Landover, MD: Service Argos, Inc. 176 pp.

Baumgartner, M. F., & Mate, B. R. (2005). Summer and fall habitat of North Atlantic right whales (*Eubalaena glacialis*) inferred from satellite telemetry. *Canadian Journal of Fisheries Aquatic Science*, *62*, 527-543.

Bloch, D., Heide, J., Mads, P., Stefansson, E., Mikkelsen, B., & Ofstad, L. (2003). Short-term movements of long-finned pilot whales (*Globicephala melas*) around the Faroe Islands. *Wildlife Biology*, *9*, 47-58.

Corkeron, P. J., & Martin, A. R. (2004). Ranging and diving behaviour of two "offshore" bottlenose dolphins, *Tursiops* sp., off eastern Australia. *Journal of the Marine Biological Association of the United Kingdom*, *84*, 465-468.

Hobbs, R. C., Laidre, K. L., Vos, D. J., Mahoney, B. A., & Eagleton, M. (2005). Movements and area use of belugas, *Delphinapterus leucas*, in a subarctic Alaskan estuary. *Arctic*, *58*, 331-340.

Klatsky, L. J., Wells, R. S., & Sweeney, J. C. (2007). Offshore bottlenose dolphins (*Tursiops truncatus*): Movement and dive behavior near the Bermuda Pedestal. *Journal of Mammalogy*, *88*, 59-66.

Mate, B. R., Rossbach, K. A., Nieukirk, S. L., Wells, R. S., Irvine, A. B., Scott, M. D., et al. (1995). Satellite-monitored movements and dive behavior of a bottlenose dolphin (*Tursiops truncatus*) in Tampa Bay, Florida. *Marine Mammal Science*, *11*, 452-463.

Read, A. J., & Westgate, A. J. (1997). Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. *Marine Biology*, *130*, 315-322.

Read, A. J., Westgate, A. J., Wells, R. S., Waples, D. M., Allen, B. M., Scott, M. D., et al. (1997). *Testing attachment techniques for satellite transmitters on bottlenose dolphins near Sarasota, Florida* (NOAA Contract Report No. 40ETNF700036). Miami, FL: Southeast Fisheries Center. 29 pp.

Waring, G. T., Josephson, E., Fairfield, C. P., & Maze-Foley, K. (2009). *U.S. Atlantic and Gulf of Mexico marine mammal stock assessments* (NOAA Technical Memorandum NMFS-NE 194). 453 pp.

Watkins, W. A., Daher, M. A., DiMarizo, N. A., Samuels, A., Wartzok, D., Fristrup, K. M., et al. (1999). Sperm whale surface activity from tracking by radio and satellite tags. *Marine Mammal Science*, *15*, 1158-1180.

Wells, R. S., Early, G. A., Gannon, J. G., Lingenfelser, R. G., & Sweeney, P. (2008). *Tagging and tracking of rough-toothed dolphins (*Steno bredanensis*) from the March 2005 mass stranding in the Florida Keys* (NOAA Technical Memorandum NMFS-SEFSC-574). 44 pp.

Wells, R. S., Manire, C. A., Smith, D., Gannon, J. G., Fauquier, D., & Mullin, K. D. (2009). Movements and dive patterns of a rehabilitated Risso's dolphin, *Grampus griseus*, in the Gulf of Mexico and Atlantic Ocean. *Marine Mammal Science*, *25*, 420-429.

Wells, R. S., Rhinehart, H. L., Hansen, L. J., Sweeney, J. C., Townsend, F. I., Stone, R., et al. (2004). Bottlenose dolphins as marine ecosystem sentinels: Developing a health monitoring system. *EcoHealth*, *1*, 246-254.

Westgate, A. J., Read, A. J., Cox, T. M., Schofield, T. D., Whitaker, B. R., & Anderson, K. E. (1999). Monitoring a rehabilitated harbor porpoise using satellite telemetry. *Marine Mammal Science*, *14*, 599-604.

Wilson, R. P., & McMahon, C. R. (2006). Measuring devices on wild animals: What constitutes acceptable practice? *Frontiers in Ecology and the Environment*, *4*, 147-154.