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Short Note

Evaluation of a Single-Pin, Satellite-Linked Transmitter Deployed on Bottlenose Dolphins (*Tursiops truncatus*) Along the Coast of Georgia, USA

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Electronic tags using the ARGOS system (CLS, 2008) have proven to be valuable tools in assessing small cetacean movement patterns and habitat use (e.g., Read & Westgate, 1997; Corkeron & Martin, 2004; Klatsky et al., 2007; Balmer et al., 2008; Wells et al., 2008, 2009). While tag design and success rates have varied, problems associated with package size, attachment position on the dorsal fin, and number of attachment pins have, in some cases, shortened the predicted attachment duration or caused adverse impacts to the dorsal fins of the animals (Read & Westgate, 1997; Scott et al., 1990; Balmer et al., 2010). One of the most recent iterations in the evolution of smaller satellite-linked tags for dolphins used a 65 g, side-mounted tag, which attached to the upper third of the dorsal fin with three plastic pins (Balmer et al., 2010). This tag design has been used to determine movement patterns and dive durations in several species of small cetaceans, including bottlenose dolphins (*Tursiops truncatus*) 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 this tag design appears to be relatively robust, a recent deployment of the tag demonstrated that the design is not well-suited for coastal bottlenose dolphins (Balmer et al., 2010). It is generally believed that most dorsal fin packages release after galvanic corrosion of the attachment fasteners allow the attachment pins to fall out, resulting in minimal dorsal fin damage. However, there have been few studies that have provided detailed follow-up monitoring from tag attachment to tag failure. In this case, Balmer et al. (2010) identified that one of the attachment pins sheared prior to fastener corrosion, resulting in tag migration and damage to the dorsal fin as well as changes in the animal's dive behavior. These results motivated the development of a new satellite-linked tag attachment design that would minimize negative impacts to the dorsal fin while maximizing transmitter longevity.

A new prototype satellite-linked transmitter (Kiwisat 202 Cetacean Fin Tag Model K2F161) was developed by Sirtrack (Havelock North, NZ) (Figure 1). It had a mass in air of 37 g and was attached to the trailing edge of the dorsal fin via a modified plastic housing and two semi-rigid, plastic flanges. The tag was secured to the fin with a single, 0.64-cm (¼") Delrin pin with each end threaded for M6 × 1 (¼"-20) non-stainless steel (corrodible) lock-nuts. The nylon ring inside the steel lock-nuts was scored to facilitate pin slide out (and tag loss) once the steel had rusted away. The lock-nuts were tightened to a level in which there was a 1 to 2 mm gap between each plastic flange and the dorsal fin surface. This allowed for limited tag movement and reduced risk of pressure necrosis. The basic tag design and attachment location for this prototype were similar to conventional single-pin VHF radio bullet tags (Trac Pac, Fort Walton Beach, FL, USA) that have been used to successfully monitor individual dolphins (e.g., Balmer et al., 2008). However, the overall size and weight of the satellite-linked transmitter was larger than that of the radio bullet tag (37 g, 75 mm × 20 mm × 25 mm and 16 g, 52 mm × 15 mm × 15 mm, respectively). Thus, it was unclear what effect this larger, single-pin transmitter would have on the dorsal fin.

The goals of this new satellite-linked transmitter design aimed to minimize detrimental effects on tagged individuals while maximizing satellite-linked transmission duration. Specifically, we wanted a tag that would provide daily locations of the dolphins for periods up to 50 d and would either detach from the animal via fastener corrosion or pin breakage. In the event that tag migration occurred, it was reasoned that the attachment location, within 3 to 4 cm of the trailing edge of the dorsal fin, would minimize potential tissue damage. It is worth noting that many species of small odontocetes, and bottlenose dolphins in particular, frequently bear natural notches along the trailing edges of their dorsal fins (reviewed in Scott et al., 1990) and can therefore tolerate minor tissue damage in this region of the dorsal fin. This study assessed the efficacy of the Kiwisat 202 Cetacean Fin Tag and its impact on instrumented dorsal fins.

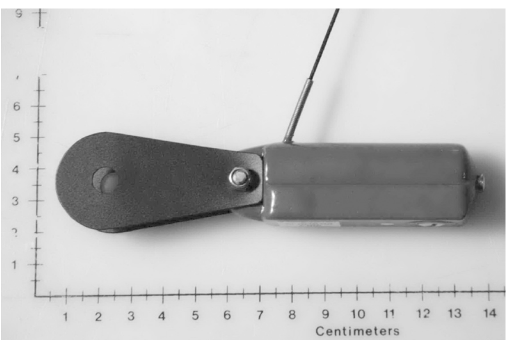

Figure 1. Sirtrack Kiwisat 202 Cetacean Fin Tag (Model K2F161) (Havelock North, NZ)

In August 2009, the National Oceanic and Atmospheric Administration (NOAA), with multiple partner organizations and agencies, conducted 10 d of bottlenose dolphin health assessments at two sites along the coast of Georgia: (1) the Turtle/Brunswick River Estuary (TBRE) near the city of Brunswick, Georgia, and (2) the waters surrounding the Sapelo Island National Estuarine Research Reserve (SINERR) near the city of Darien, Georgia (Figure 2). These sites were chosen to examine potential health impacts on bottlenose dolphins from elevated environmental contaminant exposures (Kannan et al., 1997, 1998; Maruya & Lee, 1998; Maruya et al., 2001; Pulster et al., 2005) and identify fine-scale movement patterns of individual dolphins in these polluted waters. Dolphins were captured, sampled, examined, tagged, and released using practices similar to those pioneered for health assessment and monitoring of bottlenose dolphins in Sarasota Bay, Florida (Wells et al., 2004). Each individual was freeze-branded on the dorsal fin with a letter ("Z") and two digit number ("01," "02," "03," etc.). Even numbers were given to males and odd numbers to females. A tooth sample was also collected from individual dolphins to estimate dolphin age (Hohn et al., 1989).

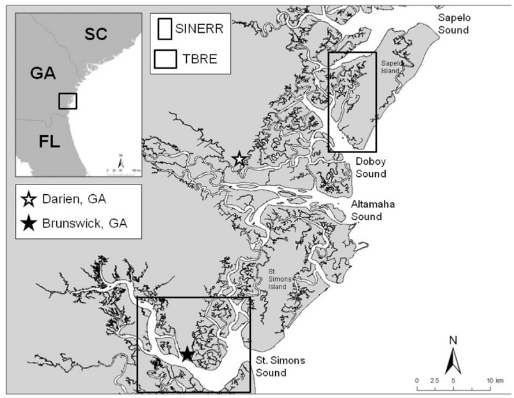

Figure 2. Turtle/Brunswick River Estuary (TBRE) and Sapelo Island National Estuarine Research Reserve (SINERR) field sites

To determine movement patterns in this region, 28 bottlenose dolphins were tagged with conventional VHF radio transmitters (MM130, Backmount Transmitter, Advanced Telemetry Systems, Inc., Isanti, MN, USA) using a single-pin attachment along the trailing edge of the dorsal fin (Balmer et al., 2008). Three adult male dolphins (Z04, Z08, and Z22) also received prototype satellite-linked transmitters, the Kiwisat 202 Cetacean Fin Tags (Figures 3a, 4a & 5a). The VHF radio transmitters were attached to the upper third of the dorsal fin to maximize signal strength for the follow-up radio tracking portion of the study. The satellite-linked transmitters were attached to the lower third of the dorsal fin to optimize tag stability and attachment duration. The Kiwisat 202 Cetacean Fin Tags provided location-only data for a defined duty cycle (6 h/d) for the life of the tags. Transmitter battery life for this duty cycle was estimated by Sirtrack to be at least 50 d and was supplemented by a saltwater switch which turned

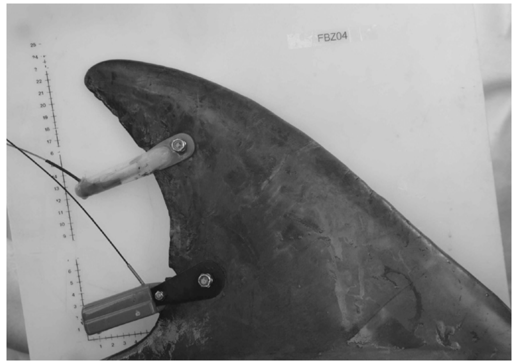

Figure 3a. Z04 with VHF radio transmitter (top) and Kiwisat 202 Cetacean Fin Tag (bottom)

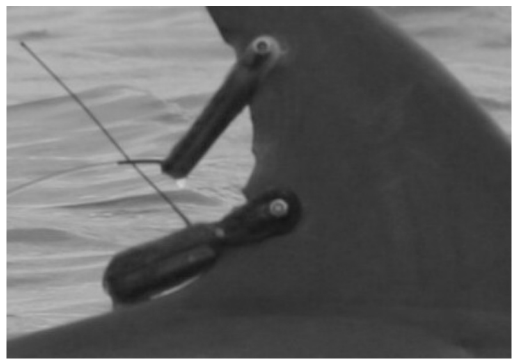

Figure 3b. Day 39: Z04 with slight migration and slight biogrowth of satellite-linked transmitter

Figure 3c. Day 62: Z04 without satellite-linked transmitter

the transmitter off when submerged to conserve battery life. In addition to testing the suitability of the new design, the satellite-linked tags provided locations of animals outside of the area defined for VHF radio tracking surveys. The VHF radio transmitters allowed routine follow-up observations of both animal and tag condition using radio telemetry during vessel surveys, while the satellite-linked transmitters provided animal locations both within and outside of the VHF radio survey area for all three individuals.

Kiwisat 202 Cetacean Fin Tags were attached along the lower third of each animal's dorsal fin, approximately 3.5 cm cranial to the trailing edge. Prior to tag attachment, the dorsal fin was scrubbed with chlorhexiderm and rinsed with ethanol. At the attachment position, a local anesthetic (lidocaine 2% with epinephrine) was injected with a Miltex 76-50 N-tralig injector (Miltex Inc., York, PA, USA) prior to drilling the pin attachment hole using a cordless power drill with a sterilized 0.6-cm thin walled brass bore (see Balmer et al., 2008; Wells et al., 2009). Delrin pins and steel lock-nuts were used for attachment of both the VHF radio and the satellite-linked transmitters.

Z04's satellite-linked tag transmitted for a total of 57 d after deployment, while the VHF radio tag transmitted for 65 d. This allowed for comprehensive monitoring of the condition of the satellite-linked tag from attachment to release. Slight caudal migration in the dorsal fin and minor biofouling (accumulation of algae) were first observed on the satellite-linked tag beginning on Day 39 (Figure 3b); the tag remained in this condition for the remainder of the life of the satellite-linked tag (through Day 56). Satellite-linked location data transmissions ceased on Day 57, and the animal was not resighted using VHF radio telemetry until Day 62. At this time, the animal was observed without the satellite-linked transmitter but with a small, well-healed hole evident at the tag attachment location (Figure 3c). These observations suggest that either the Delrin pin sheared or a nut was lost, which allowed the pin to slide out of the attachment hole. Based on the relatively good condition of the nut on the VHF radio tag at Day 62 (Figure 3c), we reason that the former is much more likely.

Z08's satellite-linked tag transmitted for 71 d, while the VHF radio tag transmitted for 28 d. Although Z08's VHF radio tag failed before the satellite-linked tag, Z08's male associate, Z10, had a VHF radio tag that transmitted for 103 d. The close associations of these two males permitted a complete follow-up of Z08's satellite-linked tag. Between Days 37 and 64, Z08's satellite-linked tag was observed progressively migrating out of the dorsal fin, while an increasing amount of biofouling was evident on the satellite-linked tag (Figure 4b). Satellite-linked transmissions ceased on Day 71, and the animal was not resighted again until Day 77 by which time the satellite-linked tag was no longer present. The animal did have an open notch in the lower part of the dorsal fin (Figure 4c), suggesting that the satellite-linked tag migrated out of the dorsal fin. Z08 was resighted on Day 103, and it was documented to have a

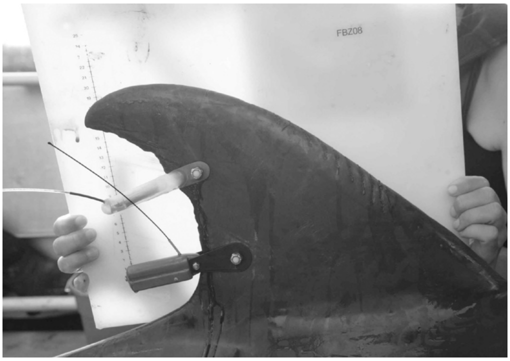

Figure 4a. Z08 with VHF radio transmitter (top) and Kiwisat 202 Cetacean Fin Tag (bottom)

Figure 5a. Z22 with VHF radio transmitter (top) and Kiwisat 202 Cetacean Fin Tag (bottom)

Figure 4b. Day 64: Z08 with severe migration and heavy biogrowth of satellite-linked transmitter

Figure 5b. Day 20: Z22 with no migration and no biogrowth of satellite-linked transmitter

Figure 4c. Day 77: Z08 without satellite-linked transmitter

Figure 5c. Day 71: Z22 with satellite-linked transmitter

fully healed dorsal fin notch at the location of the former satellite-linked tag.

Z22's satellite-linked tag transmitted for 55 d, while the VHF radio tag transmitted for 20 d. Z22 was observed four times between Day 1 and Day 20. On Day 20, Z22's satellite-linked transmitter showed no migration or biofouling (Figure 5b). Z22 was resighted on Day 71, at which time the satellite-linked tag showed only slight migration and no biofouling (Figure 5c). This result suggests that battery or electronics failure caused the tag to fail prior to tag loss. Thus, the attachment design was well-matched to the battery life in this configuration; however, for longer deployments, a stronger attachment mechanism may need to be considered. Due to logistical constraints, we were unable to provide any additional follow-up monitoring of Z22's satellite-linked tag.

The attachment of satellite-linked and VHF radio transmitters enabled follow-up monitoring to assess the impact of the prototype Kiwisat 202 Cetacean Fin Tags and to identify the likely causes of tag loss. All three satellite-linked tags transmitted longer than the 50-d estimate of battery life provided by Sirtrack (Table 1). The modes of failure in all three documented tags were different, with Z22's satellite-linked transmitter failing prior to tag loss. Z04's satellite-linked transmitter was probably lost due to shearing of the Delrin pin, and Z08's satellite-linked tag was apparently lost after it migrated caudally out of the dorsal fin. In both cases, healing at the former tag attachment site was documented: in the case of Z04, only 8 d after tag loss; and in Z08, 39 d post tag loss. Similar modes of tag loss have been observed in VHF radio-tagged individuals during the long-term study of bottlenose dolphins in Sarasota Bay (Scott et al., 1990). Previously tagged Sarasota dolphins have been observed for over 20 y post tagging, suggesting no serious long-term effects.

Although our data are limited, tag loss via pin shear seems to be less traumatic to the dorsal fin tissues than pin migration, at least in terms of healing time. Despite this, the dolphin that did experience pin migration had completely healed in just over 1 mo. While it would be prudent to design tags that could not migrate, given how little we understand about the physical and mechanical interactions between dorsal fins and the things we attach to them, this does not seem likely in the near future, making the present design more appealing. Future studies are necessary to evaluate the effectiveness of different diameter Delrin pins and their effect on tag attachment duration. The results from this study suggest that the single-pin attachment design of the Kiwisat 202 Cetacean Fin Tag is a significant improvement in tagging small cetaceans over the previous multi-pin, side-mount designs (e.g., Balmer et al., 2010). The 43% weight reduction from earlier side-mount tags, reduction in the number of attachment pins from three to one, and repositioning of the tag attachment from the middle-upper third to the lower trailing edge of the dorsal fin reduced potential damage to major venous regions in the dorsal fin and minimized long-term effects to the tagged individuals. In addition, these satellite-linked transmitters provided location data comparable to other previous satellite-linked tag transmission durations (e.g., Klatsky et al., 2007). With a more relaxed duty cycle and higher repetition rate, the current battery configuration could easily be extended out past 100 d. Investigating different tag construction materials (i.e., more pliable plastics and epoxy molds) and streamlining the tag shape would also likely contribute to improved retention times. Anti-fouling paints on the exterior surface of transmitters may be advantageous to reduce drag and improve tag retention. However, caution must be taken to ensure that the chemicals utilized in anti-fouling paints do not have negative effects on the tagged animal. Future studies are needed to identify the optimal tag attachment location on the trailing edge of the dorsal fin to minimize drag and maximize tag retention.

The capability to provide direct observational monitoring for the life of a satellite-linked transmitter not only provides additional details of movement patterns for the individual animal, but it also increases our knowledge of how to improve current tag designs (Hays et al., 2007). Future research is necessary to refine this new design and determine its success on other small cetacean species as well as on bottlenose dolphins in different habitats.

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Table 1. Satellite-linked and radio tracking summaries for three dolphins tagged along the Georgia coast

Dolphin ID	Sex	Length (cm)	Age	Tagging date	# of days transmitting (satellite)	# of days transmitting (radio)	Reason for tag failure (satellite)	Reason for tag failure (radio)
Z04	M	241	16	5 Aug 2009	57	65	Delrin pin sheering or nut loss	Migration
Z08	M	257	27	6 Aug 2009	71	28	Migration and biofouling	Migration
Z22	M	251	32	11 Aug 2009	55	20	Battery or electronic failure	Delrin pin sheering or nut loss
				Mean ± S.D.	**61 ± 9**	**37 ± 24**		

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