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Satellite-Linked Telemetry Study of a Rehabilitated and Released Atlantic Spotted Dolphin in the Bahamas Provides Insights into Broader Ranging Patterns and Conservation Needs

Charlotte Dunn,[1,2] Diane Claridge,[1,2] Denise Herzing,[3,4] Cassie Volker,[3] Kelly Melillo-Sweeting,[5] Randall S. Wells,[6] Ted Turner,[7] and Kelly O'Sullivan[7]

[1]*Bahamas Marine Mammal Research Organisation, Abaco, Bahamas*
E-mail: cdunn@bahamaswhales.org
[2]*Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, Scotland*
[3]*Wild Dolphin Project, Jupiter, FL 33468, USA*
[4]*Department of Biological Sciences, Florida Atlantic University, Boca Raton, FL 33431, USA*
[5]*Dolphin Communication Project, Port Saint Lucie, FL 34985, USA*
[6]*Chicago Zoological Society's Sarasota Dolphin Research Program, c/o Mote Marine Laboratory, Sarasota, FL 34236, USA*
[7]*Dolphin Cay, Atlantis, Nassau, Bahamas*

Abstract

Despite dedicated longitudinal studies, lack of information on ranging patterns of "resident" dolphins can limit our ability to apply conservation directives at the appropriate scale. Herein, we present satellite-linked telemetry data on movements over 108 days (1,067 Argos locations) for an adult male Atlantic spotted dolphin (*Stenella frontalis*) in The Bahamas. This individual ("Lamda") has been known to researchers in the Bimini area since 2010 and was seen there wild swimming on 7 August 2018. On 26 August 2018, Lamda live-stranded in the Berry Islands, approximately 110 km east of Bimini. Lamda was transported to Dolphin Cay in Nassau on 30 August where he was diagnosed with pneumonia, gastric ulceration, gastritis, myopathy, and dehydration. On 29 October 2018, Lamda was airlifted to the Bimini area, instrumented with a SPOT6 Finmount location-only satellite-linked tag, and released. He travelled rapidly south, covering 410 km in 48 hours, stopping near Cuba, well beyond what was previously considered his normal range. Lamda stayed in this southern area (3,572 km^2) for 13 days, but there were no opportunities to document behaviors or potential associations with other dolphins. Over the next 16 days, Lamda traveled back to Bimini; and on 7 January 2019, he was observed in a group with other known Atlantic spotted dolphins. He remained in the Bimini area (1,203 km^2) until his tag stopped transmitting on 14 February 2019 and has since been seen 24 times near Bimini, through the end of August 2019. Assuming Lamda's movements are representative of ranging patterns by non-rehabilitated dolphins, these data provide insights that have important implications for the conservation of this species. Notably, the majority of Lamda's locations were in the Bimini area where there is pressure from increasing tourism, and his locations in the southern area overlap with existing petroleum licenses where test drilling is scheduled.

Key Words: ranging patterns, telemetry, Atlantic spotted dolphin, *Stenella frontalis*, rehabilitation, conservation, Bahamas

Introduction

Monitoring the movements of animals that have been released after rehabilitation is responsible and can provide insight into broader ranging patterns of a species that is studied within an area predetermined by study design and logistics. In The Bahamas, Atlantic spotted dolphins (*Stenella frontalis*) have been studied using photo-identification methods, with individual life histories documented since 1985 (Herzing, 1997). The primary focus of these longitudinal studies has been behavioral ecology (Herzing, 1996; Kaplan & Connor, 2007; Dudzinski et al., 2009; Melillo-Sweeting et al., 2013). Most of this work has taken place in two relatively small study areas: White Sand Ridge on Little Bahama Bank (LBB) (480 km^2) and off Bimini Island on Great Bahama Bank (GBB) (960 km^2) (Figure 1). The population structure of Atlantic spotted dolphins as well as the relationships and extent of movement within

these two areas are well-studied (Danaher-Garcia et al., 2019). However, habitat use and ranging patterns by Atlantic spotted dolphins elsewhere in The Bahamas is unknown as sighting reports from these areas are largely from the public on an opportunistic basis, although Herzing et al. (2017) documented the one-time movement of spotted dolphins between these two areas, suggesting longer range movements do occur.

The existing studies by the Wild Dolphin Project (WDP) and the Dolphin Communication Project (DCP) have predominantly used either small vessels that conduct daily surveys and return to land at the end of each day or medium-sized vessels that travel to areas where dolphin sighting rates have been historically high and remain nearby for multiple days observing the animals. Given the vast extent of the western side of the Bahama banks (700 km long), the potential dolphin habitat is large.

On LBB, Atlantic spotted dolphins move offshore to forage at night and inshore to socialize and rest during the day (Herzing & Elliser, 2013). Offshore nocturnal feeding has also been observed off Bimini (WDP, unpub. data), with shallow bank waters used for daytime socializing and rest (Melillo et al., 2009; Dudzinski et al., 2012). Given its proximity to Florida, Bimini's marine environment has growing pressure from tourism with cruise ships and many activities, including increasing wild dolphin watching, swim-with programs, and high-speed boating. Ongoing and potentially increasing vessel noise disturbance could have an impact on the health of these animals, as well as an increased risk of the more direct consequences of vessel strikes in waters shared by resting dolphins and high-speed vessels.

Figure 1. Map of The Bahamas showing Little Bahama Bank and Bimini on Great Bahama Bank where studies of Atlantic spotted dolphins (*Stenella frontalis*) have taken place

This article presents the first case of a stranding, rehabilitation, release, and satellite tracking of an individual Atlantic spotted dolphin previously known by researchers. Through this collaborative effort, new questions about the extended range of small, coastal dolphins are posed.

Methods

The Bahamas Marine Mammal Stranding Network, run by The Bahamas Marine Mammal Research Organisation (BMMRO), received a report of a dolphin in distress at Great Stirrup Cay in the Berry Islands, The Bahamas, on 26 August 2018. The animal had been sighted initially that morning hanging vertically in shallow water close to shore, with its tail touching the sandy bottom. BMMRO informed the Atlantis Dolphin Cay facility to initiate a rescue operation. The Atlantis team arrived on site the following day and intubated the animal with 1 liter of fluids for dehydration and administered an antibiotic injection (Meropenem). The dolphin was not sighted on 28 August but was found dry-stranded on a beach on 29 August and was transported to the Atlantis facility in Nassau via seaplane the next day.

The dolphin was transported directly from the stranding site to a harbourside, open-ocean facility at Atlantis Dolphin Cay in Nassau where he remained for the entirety of his rehabilitation. Shortly after arriving at Dolphin Cay, identification photographs of the dolphin were shared with WDP and DCP to determine if they had any records of this individual. Similar to Würsig & Würsig (1977) and Herzing (1996), they used a series of marks from archived photographs to match the rescued dolphin to the catalogued animal known as "Lamda" (Figure 2).

Lamda was initially placed in a small medical pen adjacent to a larger sea pen during his early recovery for 24 h. This was due to his initial lack of mobility, his need for flotation support, and to facilitate emergency treatment. He was then moved to the larger sea pen and treated for pneumonia, gastric ulceration, gastritis, myopathy, and dehydration. Treatments included calcium; vitamin E; antibiotics for 5 wks, including a-carbapenem, penicillin and a-quinolone; antifungals; dextrose and fluids; vitamins; an opioid agonist

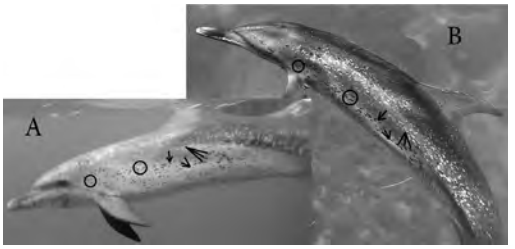

Figure 2. Atlantic spotted dolphin, Lamda, showing the natural pattern of spots used to match the catalogued individual observed off Bimini (A) to the rescued animal (B)

analgesic; a H-2 antagonist; low dose glucocorticoids; and swimming physiotherapy. There were no treatments during the last 4 wks of the 9-wk rehabilitation period.

Handling protocols during rehabilitation were strictly maintained to avoid incidental/adventitious conditioning of behavior not supportive of wild release and survival. Lamda was offered tossed-only (no hand feeding) capelin or herring every 2 h from 0630 until 0030 h EST and had a maximum daily intake of 8.5 kg. During his rehabilitation, Lamda put on 0.45 kg per day, and his treatment removed all signs of pneumonia, gastritis, gastric ulcers, and gastro-intestinal stasis. As Lamda's health stabilised, his activities expanded, including increased vocalisations, sea pen exploration, fish chasing, and periodic preying on needlefish. Combined with rapid health recovery, a relatively short duration in managed care, knowledge of the animal's home range, and logistical capabilities to facilitate a low-risk transport to his former range, a wild-release plan was initiated. Final diagnostics for a last health assessment, including repeat thoracic radiographs and blood sampling, concluded normal health; and permission from the Bahamas Department of Marine Resources was granted to transport, tag, and release Lamda.

Given Lamda's long-term use of the area, Bimini was chosen as the release site; and on 29 October 2018, Lamda was transported from the Atlantis Dolphin Cay facility via a flatbed truck to Nassau International Airport and into a Caravan seaplane. Lamda and six personnel flew to the Bimini area where the seaplane landed on the water in Bimini harbour. Lamda was transferred to a small vessel which transported him to an area known to be frequented by Atlantic spotted dolphins where he was released into the ocean.

While aboard the small vessel, 15 min prior to his release, Lamda was fitted with a SPOT6 location-only tag (PTT 128251; Wildlife Computers, Inc., Redmond, WA, USA) provided by the Chicago Zoological Society's Sarasota Dolphin Research Program (Figure 3). The tag was attached

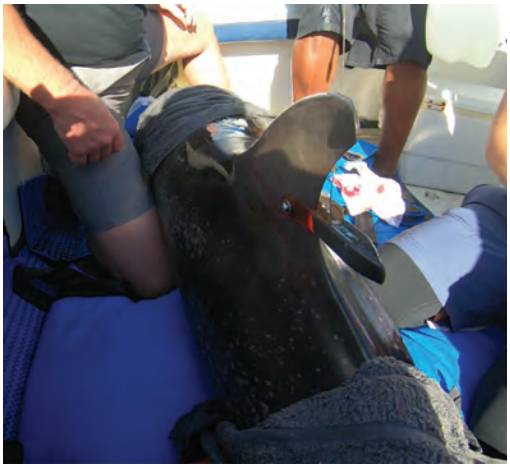

Figure 3. Lamda just after being fitted with SPOT6 tag (Wildlife Computers, Inc.) aboard the release vessel on 29 October 2018

as per protocols used by Wells et al. (1999) and programmed to transmit 315 locations per day made up of 35 transmissions per hour for each transmission hour block. Transmission blocks were selected to (1) optimize satellite availability, (2) make remote tracking available for searching for the tagged animal in real time, and (3) optimize transmission times to keep battery consumption to a minimum. The tag was set to transmit between 0500-1159 h and 2100-2259 h EST until 4 November when it changed to 0400-1059 h and 2000-2159 h EST due to daylight savings time. These allocations were based on the ARGOS online satellite pass prediction values, looking for satellites with > 20° elevation for at least 3 min. This took advantage of all satellites and provided location data first thing in the morning before heading into the field and while in the field. The potential battery life was estimated as 180 to 240 d.

Satellite-linked telemetry location estimates and spatial error information from this tag were retrieved via the Argos system (www.Argos-system.org). The predicted locations were estimated at regular intervals from irregularly spaced Argos telemetry fixes by fitting a Continuous Time Correlated Random Walk (CTCRW) model (Johnson et al., 2008) using the *R* package 'crawl' (Version 2.1; Johnson, 2017) to filter out spatial outliers. This CTCRW model uses error ellipse estimates that rely on the Argos Kalman-filter algorithm (Lowther et al., 2015). To search for nocturnal feeding forays as previously described by Herzing & Elliser (2013), locations were split into day and night using sunrise and sunset (https://www.timeanddate.com; Bimini Islands, Bahamas) as delimiters.

In December 2019, January 2020, and February 2020, an 11-m outboard vessel was used by DCP to search for Lamda using locations received from the tag. Once the tag had detached, searches for Lamda around the Bimini area were made through August 2019 using boat-based surveys by WDP and DCP, utilizing established data collection protocols (e.g., Herzing, 1997; Danaher-Garcia et al., 2019).

Results

Lamda was known previously to WDP and DCP. DCP first observed this male in 2010 when he was estimated to be 2 to 3 y old based on limited spot development and close interaction with his presumed mother. Prior to stranding, Lamda had been documented 37 times between 2010 and 2018 (2010, 2 d; 2011, 2 d; 2012, 1 d; 2013, 2 d; 2014, 6 d; 2015, 3 d; 2016, 5 d; 2017, 7 d; and 2018, 9 d) and was last seen by WDP near Bimini on 7 August 2018. When Lamda was present, group sizes ranged from 6 to 45 individuals. At the time of his stranding, Lamda was estimated to be at least 10 y old.

Satellite-linked telemetry data showed that, immediately following release, Lamda swam south continuously for 48 h, covering 410 km, to an area well beyond what was considered his normal range. He did remain within habitat appropriate for this species, however. He spent 13 d in this southern area and then 16 d traveling back to his release site, staying close to the western edge of the GBB (Figure 4).

High-quality observed locations around the Bimini area provided 335 daytime positions and 424 nighttime positions. Plotting the day and night locations of Lamda around the Bimini area suggests a slight movement offshore and a greater area used at night (Figure 5); however, there are no significant differences between day and night (Wilcoxon-Signed Rank test, p value 0.17).

Once back in the Bimini area, several attempts to observe Lamda were made by DCP before successfully sighting him on 7 January 2019 in a group of approximately 26 dolphins (Figure 6; a video of this sighting is available in the Supplemental Material section of the *Aquatic Mammals* website: https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147). This was a mixed species (*S. frontalis* with common bottlenose dolphins [*Tursiops truncatus*]), mixed age, mixed sex group. Surface and underwater recordings indicated that Lamda appeared physically well, and the tag attachment remained secure. This sighting was within Lamda's pre-stranding range and included his previous known associates.

Lamda's tag last transmitted on 14 February 2019. Photographs of Lamda on 2 May 2019, also taken near Bimini, show the tag no longer attached and the wound healing (Figure 7).

At the time of publication, Lamda had been seen 24 times post-release in group sizes ranging between 3 to 46 (mode: 20 animals). He was last sighted on 28 August 2019.

Discussion

Based on exceeding the 42-d post-release tracking threshold identified by Wells et al. (2013), the rehabilitation and release of Lamda has been deemed a success. Previous data on release following rehabilitation of dolphins with pneumonia show that only one in four bottlenose dolphins' releases were successful (Wells et al., 1999). Although Davis et al. (1996) documented tag data for a released Atlantic spotted dolphin, our study presents the first documentation of rehabilitation, release, and post-release monitoring, including after tag detachment, of a stranded Atlantic spotted dolphin back to the wild.

Lamda's short time under human care and short transport to his release site likely contributed to Lamda's successful re-adaptation to the wild (Wells et al., 2013). In many rehab–release cases, it is not possible to directly observe the released cetaceans because they are not accessible to observers. Lamda provided a unique opportunity for follow-up monitoring: his nearshore habitat use enabled repeated observations for several months post-release, along with the ability to monitor his body condition and his re-assimilation socially with other dolphins.

Lamda was observed within similar group types pre- and post-stranding—that is, he was observed in both single species and mixed species (*S. frontalis* and *T. truncatus*) groups as well as mixed age and mixed sex groups. The group sizes in which Lamda was seen post-release had similar variance to those he had been seen in across the years pre-stranding; however, he was sighted more frequently post-release. A possible explanation for the increase in Lamda sightings in 2019 may be that the scar from the tag made him more readily identifiable, even from a distance. The lack of sightings since August 2019 is due to decreased field work in The Bahamas following Hurricane Dorian on 1 September 2019, and more recently because of COVID-19.

Atlantic spotted dolphins have been documented moving off the bank edge at night to feed both off Bimini (Herzing, pers. comm., 2019) and White Sand Ridge, LBB (Herzing & Elliser, 2013). Although our satellite-derived locations also suggest this pattern, there may not have been

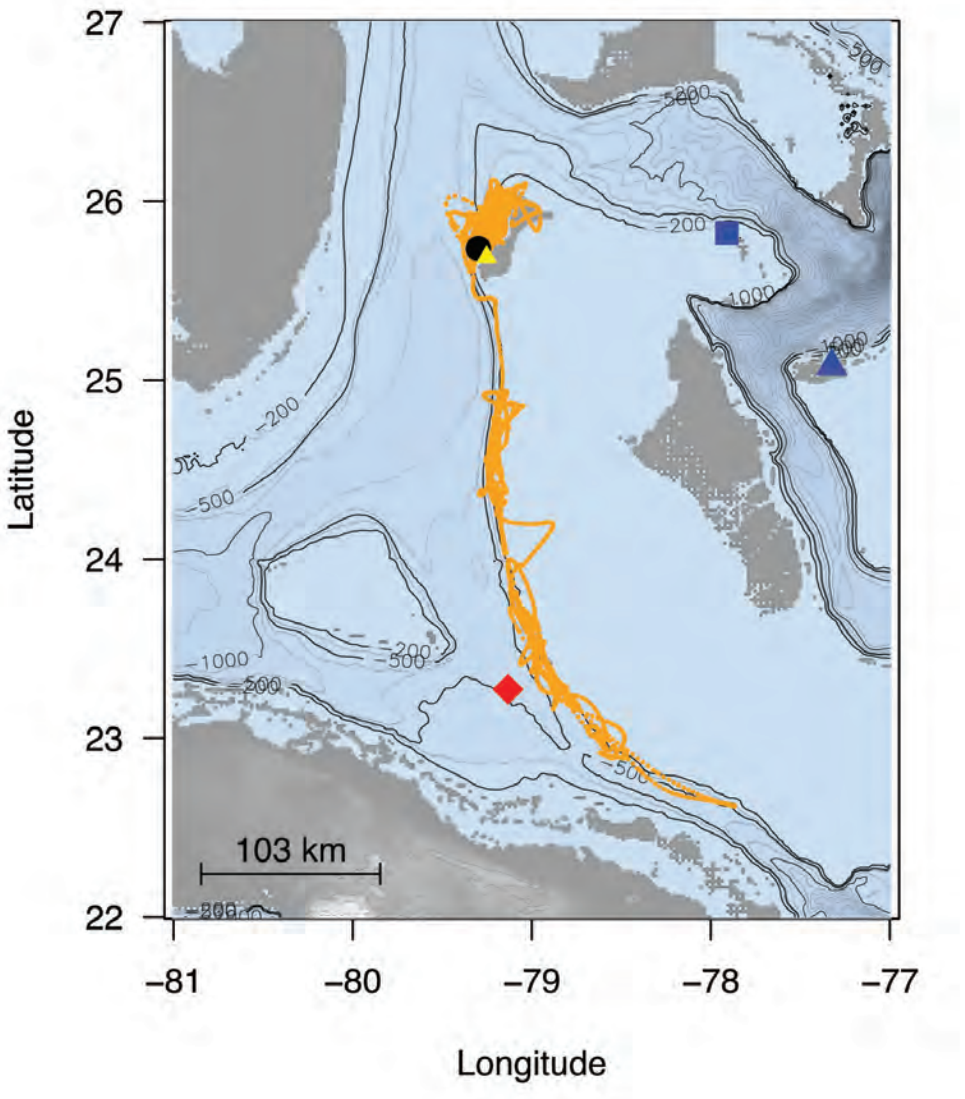

Figure 4. Satellite-linked track of Lamda's movements from his 29 October 2018 release until his tag stopped transmitting on 14 February 2019, showing the scale for 1° of longitude; blue square = Lamda's stranding location in the Berry Islands, blue triangle = rehabilitation location in Nassau, black circle = release location near Bimini, yellow triangle = his location at last transmission, and red diamond = the Bahamas Petroleum Company's Exploratory Drilling Well. Water depth contours indicated in meters.

enough spatial resolution to show fine-scale movement with Argos telemetry given the steepness of the edge of the bank. GPS technology might have provided better resolution for fine-scale analyses; however, suitable tags were not available at the time of Lamda's release.

Public sighting records collected by BMMRO over the last three decades have documented Atlantic spotted dolphins distributed throughout The Bahamas, including the area where Lamda stranded; in the Berry Islands (BMMRO, unpub. data); and along the southwestern edge of the GBB (Melillo et al., 2009), where he was tracked immediately following release.

There is important significance for conservation from our findings. Although Lamda and

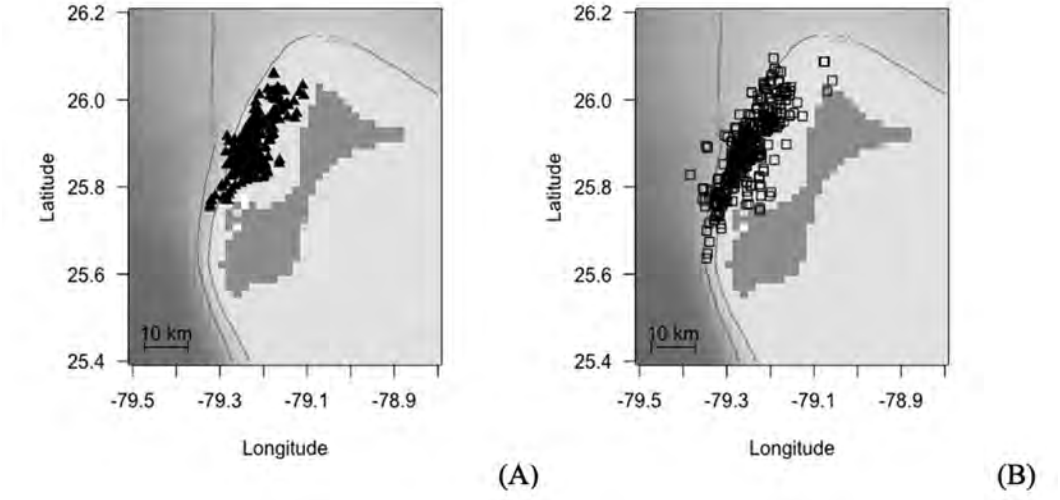

Figure 5. Enlarged map of the Bimini area (gray shape) showing the bathymetry (m) and Lamda's satellite-linked locations during the day (A) and night (B) from 28 November 2018 to 14 February 2019

Figure 6. Lamda near Bimini with his tag still securely attached, 7 January 2019

Figure 7. First sighting of Lamda without his tag on 2 May 2019

his known associates are considered resident to the Bimini area, it is not uncommon for several weeks or more to pass between observations of any one individual. The high speed and consistent directionality of Lamda's travel post-release suggest that he was not travelling in a random direction but that his previous movements may have included these more distant areas. The southern area overlaps with existing petroleum licenses where test drilling is scheduled despite the lack of information on cetacean use of the proposed drill site. However, his return to Bimini and then high use of the area suggest that the Bimini area may in fact be a preferred habitat for this group of Atlantic spotted dolphins. The marine environment immediately surrounding Bimini is experiencing increasing pressure from tourism, which includes increased boat traffic. Several of the spotted dolphins that moved from LBB to the Bimini area of the GBB were observed with severe boat propeller marks during the first 2 y after their move (Herzing et al., 2017).

Resident dolphin populations provide valuable opportunities to conduct longitudinal research projects, often serving as the baseline from which future changes can be gleaned. However, Lamda's individual tracking data points to the gap in knowledge of the true extent of this species' range. This further insight into the behavioral ecology of Atlantic spotted dolphins raises additional conservation concerns, supporting the need for continued and expanded study.

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