MARINE MAMMAL SCIENCE, 32(1): 161–180 (January 2016)

DOI: 10.1111/mms.12255

# A comparison of postrelease survival parameters between single and mass stranded delphinids from Cape Cod, Massachusetts, U.S.A.

**Sarah M. Sharp, Charles T. Harry, Jane M. Hoppe, Kathleen M. Moore, Misty E. Niemeyer, Ian Robinson, Kathryn S. Rose, W. Brian Sharp,**[1] International Fund for Animal Welfare, Marine Mammal Rescue and Research Program, 290 Summer Street, Yarmouth Port, Massachusetts 02675, U.S.A.; **Scott Landry,** Center for Coastal Studies, 5 Holway Avenue, Provincetown, Massachusetts 02657, U.S.A.; **Jessica Richardson,** Nicholas School of the Environment, Duke University, Durham, North Carolina 27708, U.S.A.; **Michael J. Moore,** International Fund for Animal Welfare, Marine Mammal Rescue and Research Program, 290 Summer Street, Yarmouth Port, Massachusetts 02675, U.S.A. and Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, U.S.A.

## Abstract

The viability of healthy single stranded dolphins as immediate release candidates has received little attention. Responders have been reluctant to release lone delphinids due to their social needs, even when they pass the same health evaluations as mass stranded animals. This study tracked postrelease success of 34 relocated and released satellite tagged delphinids from single and mass strandings. Three postrelease survival parameters (transmission duration, swim speed, and daily distance) were examined to evaluate whether they differed among single stranded/single released (SS/SR), mass stranded/single released (MS/SR), or mass stranded/mass released (MS/MR) dolphin groups. Comparisons were also made between healthy and borderline release candidates. Satellite tags transmitted for a mean of 21.2 d (SD = 19.2, range = 1–79), daily distance traveled was 42.0 km/d (11.25, 20.96–70.72), and swim speed was 4.3 km/h (1.1, 2.15–8.54). Postrelease parameters did not differ between health status groups, however, SS/SR dolphins transmitted for a shorter mean duration than MS/MR and MS/SR groups. Postrelease vessel-based surveys confirmed conspecific group location for two healthy, MS/SR dolphins. Overall, these results support the potential to release healthy stranded single delphinids; however, further refinement of health assessment protocols for these challenging cases is needed.

Key words: dolphin, stranding, single release, health, satellite telemetry, postrelease monitoring, Cape Cod, *Delphinus delphis*, *Lagenorhynchus acutus*, *Globicephala melas*.

[1]Corresponding author (e-mail: bsharp@ifaw.org).

Strandings of cetaceans have occurred on Cape Cod, Massachusetts for hundreds of years (Thoreau 1864, Geraci 1978, McFee 1990). This area is particularly well-known for its frequent occurrence of mass stranding events (Mead 1979, Walsh *et al.* 2001, Wiley *et al.* 2001, Bogomolni *et al.* 2010) when two or more cetaceans, excluding mother-calf pairs, strand in the same geographic area during the same tide cycle (Wilkinson 1991). The historic and consistent character of mass strandings on Cape Cod suggests a natural etiology (Geraci *et al.* 1999). Cape Cod's protruding hook-shape, gently sloped beaches, fine-grained sediment, and large tidal fluxes are similar to features of other mass stranding-prone areas in New Zealand and Australia, suggesting that coastal topography may play a role in causing these events (Dudok van Heel 1962, Mead 1979, Brabyn and McLean 1992). The highly social nature of the *Delphinidae* family makes them especially susceptible to stranding in groups (Nawojchik *et al.* 2003, Geraci and Lounsbury 2005); however, strandings of individual delphinids also occur on Cape Cod shores (Bogomolni *et al.* 2010).

Between 1999 and 2012, the International Fund for Animal Welfare's (IFAW) Marine Mammal Rescue and Research Program (formerly the Cape Cod Stranding Network) responded to strandings on Cape Cod and in southeastern Massachusetts, including over a quarter (28%) of all the live stranded odontocetes in the United States.[2] These cases consisted of 499 live mass stranded and 250 live single stranded dolphins, and were comprised primarily of Atlantic white-sided dolphins (*Lagenorhynchus acutus*), short-beaked common dolphins (*Delphinus delphis*), and long-finned pilot whales (*Globicephala melas*). Lack of sufficient local rehabilitation space prompted initial attempts to relocate and release stranded cetaceans back to the sea (Wiley *et al.* 2001). A shift in common stranding species from pilot whales to the more portable dolphins, and improvements in response procedures, supportive care, and health assessments over the years led to an increase in release rates of mass stranded odontocetes on Cape Cod, from 14% (1999–2004) to 61% (2005–2012). A recent study on satellite tagged dolphins from this area indicated that the majority of mass stranded/mass-released delphinids appeared to survive postrelease (Sampson *et al.* 2012).

Decades of postmortem examinations on Cape Cod and elsewhere have shown that most mass stranded dolphins lack significant disease or injury (Reynolds and Odell 1991, Geraci and Lounsbury 2005, Bogomolni *et al.* 2010), while the same has not held true for single stranded cetaceans (Geraci and St. Aubin 1979, Bogomolni *et al.* 2010). However, when applying current mass stranding health assessment procedures to single stranded animals, biologists and veterinarians found that some single stranded individuals on Cape Cod were in apparent good health, raising the question of their viability as release candidates. In general, it is not recommended to release a social cetacean alone, even if deemed healthy, unless there is a high likelihood that the animal will regain contact with a herd (Geraci and Lounsbury 2005). Without prior knowledge of conspecifics in surrounding waters, it is difficult for stranding responders to know whether immediate release of a single delphinid is advisable. Sampson *et al.* (2012) and Wells *et al.* (2013*a*) have demonstrated the viability of immediate relocation and release of healthy mass stranded delphinids with satellite telemetry, but to the authors' knowledge, no studies have evaluated the viability of

[2]Based on live odontocetes stranding data downloaded from the NOAA Marine Mammal Health and Stranding Response Program's National Stranding Database available at https://mmhsrp.nmfs.noaa.gov/mmhsrp/ (accessed 2 August 2013).

stranded single delphinids or animals with borderline (*vs.* healthy) health status as immediate release candidates.

In an attempt to provide further insight into the appropriateness of reintroduction of single and borderline health status delphinids, we tracked 34 relocated and released satellite tagged animals from both mass and single strandings. Three postrelease survival parameters (transmission duration, swim speed, and daily distance traveled) were selected as objective indicators of postrelease success, based on the results of Sampson *et al.* 2012. These parameters were examined to evaluate differences between health assessment group (healthy and borderline release candidates) and stranding/release type (single stranded/single released [SS/SR], mass stranded/single released (MS/SR), and mass stranded/mass released [MS/MR] dolphins), with the expectation that each of these parameters would be decreased in failing dolphins.

## Methods

### *Stranding Response*

Dolphins that stranded on Cape Cod and southeastern Massachusetts between January 2010 and June 2012 were included in this study. Standard event data (date, time, location, species, sex, mass/single stranding) and morphometric data (length, axillary girth, weight) were collected for each stranded animal. Stranding response was executed following standard IFAW protocols including supportive care, health assessment, blood analysis, overland transport in an enclosed trailer, satellite and ID tagging, and release from an appropriate shore location (IFAW 2015*a, b*). Animals were also evaluated externally for signs of human interaction utilizing nationally recognized methods (Moore and Barco 2013).

The health of all stranded dolphins was evaluated based on physical examination, behavioral/stress assessment, and on-site hematological and clinical chemistry analysis. Health evaluation criteria were as follows: respirations equally spaced and of normal depth (approximately 2–10 breaths/min); heart rate steady and strong with normal sinus arrhythmia (40–100 beats/min); absence of substantial eye, blowhole, or integument trauma; minimal to no flatulence, belching, or gaseous feces; minimal to no thrashing or arching; lack of opaque, colored, or foamy discharge from any orifice; sufficiency of palpebral and menace reflexes; and sufficiency of muscle and blubber mass, as judged by the degree of body wall convexity ventral to the base of the dorsal fin. Neurological status was assessed by the overall alertness and responsiveness of the animal, looking for a calm demeanor and absence of convulsions.

For in-field diagnostic blood analyses, blood was drawn from the dorsal fluke periarterial venous rete or the superficial ventral caudal peduncle vessels and processed according to the protocol in Sharp *et al.* (2014) on the VetScan HM2 Hematology System (Abaxis, Union City, CA) and the Vetscan Classic (Abaxis, Union City, CA) or the i-STAT 1 System handheld analyzer (Abbott Laboratories, Abbott Park, IL) for clinical chemistry. Blood values were compared to the best available species-specific data (Bossart *et al.* 2001), with allowances for minor stranding-related abnormalities such as leukopenia, hemoconcentration, and elevated glucose and BUN (Walsh *et al.* 2001). All animals included in this study were deemed releasable based on the combined results from blood analysis, physical examination, and behavioral assessment. Once considered releasable, dolphins were transported directly from the stranding site to an appropriate release location. Transport was conducted in a climate-controlled, enclosed trailer, with dolphins lying in ventral recumbency on a bed of 10–15 cm of vinyl-covered, open-cell foam to minimize crush injuries and damage to pectoral flippers. The dolphins' respiration rate and behavior were monitored continuously throughout transport and recorded approximately every 15 min. Responders also evaluated the dolphins for hypo- or hyperthermia approximately every half-hour, using a gloved hand to feel the temperature of their pectoral flippers and dorsal fin. To assist their compromised thermoregulatory ability out of water, responders covered cold dolphins in dry thermal blankets, and warm/hot dolphins in wet sheets, as needed. When possible, standard prerelease medications were administered under the direction of the IFAW veterinarian. Calcium (Cal-Pho-Sol, Neogen Vet, Lexington, KY; 22 mg/kg IM) and vitamin E/selenium (Intervet/Schering-Plough Animal Health, Kenilworth, NJ; 0.06 mg/kg selenium IM) were injected, given the likelihood of stranding-induced exertional myopathy. Dexamethasone (0.22 mg/kg IM) was administered to expedite recovery from the acute stress of the stranding event.

Dolphin release sites were chosen based on the following criteria: few to no reported cetacean strandings on record, near-shore steep bathymetric slope, parking lot in close proximity to waterline (to minimize dolphin carrying distance), relatively flat ground (no cliffs or stairs), minimal offshore sandbars, and within a 1 h drive from the stranding location. At the release site, dolphins were carried in stretchers by hand, or on a custom-made dolphin cart (Edson International, Inc., New Bedford, MA) with beach wheels (Wheeleez, Benicia, CA) from the trailer to the waterline, where they were staged on foam mats prior to release. After staging, responders carried each animal into the water on a stretcher and allowed the dolphin to swim away following a short acclimatization period in the water.

### *Satellite Tagging*

In order to monitor postrelease success, satellite tags were deployed on live stranded social cetaceans that were relocated and released the same day that they stranded. In addition to the initial standard health assessment described above, the animal's condition was reevaluated at the release site to determine that the animal was still a tagging candidate after overland transport.

Two different tag configurations were used during this study. The first configuration involved a single pin tag housing both an Argos-linked Kiwisat 202 Platform Transmitter Terminal (PTT) and a VHF transmitter (Sirtrack Ltd., Havelock North, New Zealand) that was specifically designed for minimally invasive attachment on small delphinids (weight: 60 g; L × W × H: 10.0 × 2.5 × 2.0 cm) (Balmer *et al.* 2011). Each of these satellite-VHF combination tags was equipped with a 3.6 V lithium battery and a salt water switch to conserve battery life when the animal submerged. Two separate 1-mm-thick, nylon-coated, stranded, stainless steel cable antennae (Argos: 175 mm long; VHF: 350 mm long) were integrated into the tag to facilitate transmissions.

The second tagging configuration involved a combination of two separate single pin tags: a time-depth recording satellite tag and a VHF transmitter tag. The MK10-A satellite tag (Wildlife Computers, Redmond, WA) had a single 185 mm flexible whip antenna, wet/dry sensor and 3.5 V AA battery (weight: 72.0 g, L × W × H: 7.6 × 3.0 × 2.0 cm). The separate single pin VHF tag (MM130B, Backmount

Transmitter, Advanced Telemetry Systems (ATS), Isanti, MN) had a 295 mm long flexible whip antenna and a 3.6V lithium battery (weight: 33.5 g, L × D: 7.3 × 2.0 cm).

Kiwisat202 and MK10-A tags were attached at a location one-third the dorsal fin height distal to the base of the fin and 35 mm cranial to the trailing edge. The yellow VHF tags were mounted above the MK10-A satellite tags, two-thirds the fin height from the fin base and 10–35 mm cranial to the trailing edge. To increase visibility of tagged animals at sea, some dolphins with single pin satellite-VHF combination tags were additionally tagged with a small yellow or orange AllFlex plastic sheep (bullet) tag with unique identification number (Allflex USA, DFW Airport, TX) on the distal half of the dorsal fin, 10–20 mm cranial to the trailing edge.

Tagging occurred in the enclosed transport trailer according to an attachment protocol based on Balmer *et al.* (2011) and Sampson *et al.* (2012). Briefly, a sterile, zinc-plated brass cork borer bit on a cordless drill was used to create the attachment point, and a disinfected, threaded Delrin pin with zinc-coated, nylon insert, steel lock nuts was used to attach the satellite tag. A summary of satellite tag transmission programming is included in Table 1. Expected battery life of the Kiwisat202 was 45 d for both the satellite and VHF transmissions. The MK10-A tags were expected to transmit for 190–220 d.

### *Postrelease Surveys*

Opportunistic vessel-based surveys were conducted on single released satellite tagged dolphins in order to monitor postrelease social integration. When weather, sea conditions, and the animal's location permitted, animals were located based on Argos positions and their travel trajectory. Once in proximity to the most recent satellite position, the directional VHF receiver (Telonics TR4 with a directional Yagi antenna) was utilized to find the tagged individual for visual observation. Upon sighting, the animal and any associated conspecifics were photo-documented using a Canon 40D SLR camera with 300 mm lens. Photos were examined for evidence of tag migration, damage to the dorsal fin, and infection.

### *Satellite Tag Data*

Location data were obtained using Argos System tracking services through CLS America (CLS 2011). Data quality varied with the geometrical conditions of the satellite passes, the stability of the transmitter oscillator, the number of messages collected and their distribution in the pass (CLS 2011), as well as the position of the tag on the animal (Westgate *et al.* 1998). Location class data received from the satellite transmitter were divided into seven categories by the Argos System (3, 2, 1, 0, A, B, Z) based on the estimated position error, which ranged from within 2.5 km (Class 0) to within 250 m (Class 3). Classes A and B had no associated accuracy information and Class Z was comprised of invalid locations.

Argos data were subsequently filtered according to Sampson *et al.* (2012) in order to utilize all location class data (except Z) using the R ArgosFilter algorithm for speed, distance, and angle between positions (Freitas *et al.* 2008). Maximum velocity was set to 25 km/h and the ArgosFilter was configured to remove all spikes between two positions with angles smaller than 15 and 25 degrees if their extension was larger than 2,500 m and 5,000 m, respectively. Locations of greater than 12 h from the last transmission were additionally removed from distance and speed analyses to prevent

*Table 1.* Summary of satellite tagged delphinids including postrelease performance parameters.

| IFAW ID | Release date | Species | Sex | Tag type | Satellite tag duty cycle | Stranding/ release type | Health status | # Trans-mission days | Total distance traveled (km) | Mean daily distance (km/ 12 h day) | Mean speed (km/h) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-060Dd | 26 February 2010 | *D. delphis* | F | Kiwisat 202 | 12 h on/ 12 h off | MS/MR | Healthy | 22 | 680.4 | 32.40 | 3.28 |
| 10-063Dd | 27 February 2010 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off | MS/SR | Healthy | 44 | 1,040.6 | 34.69 | 3.56 |
| 10-073La | 7 March 2010 | *L. acutus* | M | Kiwisat 202 | 12 h on/ 12 h off | MS/SR | Healthy | 13 | 524.4 | 43.08 | 4.62 |
| 10-092La | 12 March 2010 | *L. acutus* | M | Kiwisat 202 | 12 h on/ 12 h off | MS/SR | Healthy | 79 | 754.6 | 39.71 | 3.82 |
| 10-214Gm | 6 November 2010 | *G. melas* | M | MK10-A | 12 h on/ 12 h off[a] | SS/SR | Healthy | 31 | 516.0 | 51.60 | 5.96 |
| 10-230Dd | 29 November 2010 | *D. delphis* | M | MK10-A | 12 h on/ 12 h off | SS/SR | Healthy | 21 | 739.8 | 35.23 | 4.11 |
| 10-238Dd | 3 December 2010 | *D. delphis* | F | MK10-A | 12 h on/ 12 h off | SS/SR | Healthy | 21 | 765.0 | 34.77 | 4.40 |
| 11-006La | 31 January 2011 | *L. acutus* | F | Kiwisat 202 | 12 h on/ 12 h off[b] | SS/SR | Borderline | 1 | 8.6 | N/A | 2.15 |
| 11-022Dd | 14 February 2011 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/SR | Borderline | 37 | 2,616.7 | 70.72 | 8.54 |
| 11-026Dd | 19 February 2011 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | SS/SR | Healthy | 1 | 0.0 | N/A (Died) | N/A |
| 11-057Dd | 1 March 2011 | *D. delphis* | F | Kiwisat 202 | 12 h on/ 12 h off[b] | SS/SR | Healthy | 1 | 71.9 | 26.34 | 3.07 |
| 11-085Dd | 11 March 2011 | *D. delphis* | F | MK10-A | 12 h on/ 12 h off[b] | SS/SR | Borderline | 8 | 246.3 | 30.79 | 3.2 |

*(Continued)*

*Table 1. (Continued)*

| IFAW ID | Release date | Species | Sex | Tag type | Satellite tag duty cycle | Stranding/ release type | Health status | # Trans- mission days | Total distance traveled (km) | Mean daily distance (km/ 12 h day) | Mean speed (km/h) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11-107La | 20 March 2011 | *L. acutus* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | SS/SR | Borderline | 1 | 60.2 | 30.68 | 2.81 |
| 11-143La | 4 April 2011 | *L. acutus* | F | MK10-A | 12 h on/ 12 h off | SS/SR | Healthy | 1 | 72.8 | 24.27 | 4.81 |
| 11-284Dd | 21 November 2011 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | SS/SR | Healthy | 25 | 1,418.6 | 55.25 | 5.42 |
| 12-003Dd | 12 January 2012 | *D. delphis* | F | Kiwisat 202 | 12 h on/ 12 h off[b] | SS/SR | Borderline | 6 | 330.8 | 48.81 | 4.29 |
| 12-008Dd | 12 January 2012 | *D. delphis* | F | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 30 | 1,327.5 | 43.49 | 4.07 |
| 12-020Dd | 14 January 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 10 | 365.5 | 35.54 | 3.60 |
| 12-027Dd | 15 January 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/SR | Healthy | 1 | 41.9 | 20.96 | 3.64 |
| 12-032Dd | 16 January 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 31 | 1,498.2 | 46.88 | 4.70 |
| 12-078Dd | 19 January 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 41 | 1,696.3 | 56.62 | 5.22 |
| 12-112Dd | 1 February 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 67 | 3,608.6 | 53.13 | 4.91 |
| 12-124Dd | 4 February 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 44 | 2,106.2 | 46.66 | 4.24 |
| 12-126Dd | 5 February 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Borderline | 1 | 60.1 | 53.59 | 4.52 |

*(Continued)*

*Table 1.* (*Continued*)

| IFAW ID | Release date | Species | Sex | Tag type | Satellite tag duty cycle | Stranding/ release type | Health status | # Trans-mission days | Total distance traveled (km) | Mean daily distance (km/ 12 h day) | Mean speed (km/h) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12-160Dd | 9 February 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 30 | 1,400.4 | 45.67 | 4.30 |
| 12-172Dd | 13 February 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Borderline | 14 | 798.8 | 53.34 | 4.92 |
| 12-194Dd | 1 March 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 24 | 1,046.6 | 39.66 | 3.79 |
| 12-197Dd | 6 March 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 21 | 1,009.9 | 47.26 | 4.44 |
| 12-202Dd | 9 March 2012 | *D. delphis* | F | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/SR | Borderline | 22 | 1,023.1 | 44.37 | 4.34 |
| 12-204Dd | 11 March 2012 | *D. delphis* | F | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/SR | Borderline | 41 | 1,860.2 | 44.18 | 4.27 |
| 12-214Dd | 26 March 2012 | *D. delphis* | M | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Borderline | 12 | 599.4 | 47.42 | 4.07 |
| 12-218Dd | 27 March 2012 | *D. delphis* | F | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Borderline | 1 | 25.4 | 23.98 | 2.26 |
| 12-221Dd | 27 March 2012 | *D. delphis* | F | Kiwisat 202 | 12 h on/ 12 h off[b] | MS/MR | Healthy | 9 | 422.1 | 51.31 | 4.78 |
| 12-226Dd | 1 April 2012 | *D. delphis* | M | MK10-A | 12 h on/ 12 h off | MS/SR | Healthy | 11 | 388.3 | 32.35 | 4.50 |

*Note*: SS = single stranded, MS = mass stranded, SR = single released, MR = mass released.
[a]= Transmitting every third day.
[b]= On continuously for first 24 h.

skewing the data set due to long time periods between transmissions (Austin *et al.* 2003, Sampson *et al.* 2012). Swim speed and distance traveled between each set of satellite positions were calculated from great circle distances in the R ArgosFilter algorithm (Freitas *et al.* 2008, Sampson *et al.* 2012). From these data, daily average speeds and daily distances traveled (based on 12 h days) were calculated for each animal. For the tags programmed to transmit for the first 24 h, only the first 12 h of that day's transmissions were used for calculating daily distance traveled. Also, in order to prevent skewing the data set with daily distances from short transmission days, daily travel distances were only utilized from days when the tag transmitted ≥5 h. ESRI ArcGIS 10 software was used to create satellite track maps for each animal.

### *Staff Poll*

Dolphins that were satellite tagged during the study period fell into one of two general categories: healthy (released without reservation) or borderline (released with some reservations, but considered to have no obvious negative indicators and a reasonably good chance at postrelease survival). Since these satellite tagging categories were not always clearly denoted on the datasheets at the time of release, a single-blind *post hoc* staff poll was undertaken to separate out the two groups. Photos and data including vital signs, physical condition, behavior, and select blood values were compiled by the lead author and presented to the six IFAW staff biologists and two veterinarians for batched review. IFAW staff evaluated the cases and categorized each animal as either healthy or borderline. Final categorization for each case was based on a majority vote and any animal with a tied score was categorized as borderline.

### *Statistical Analyses*

The effects of health status (healthy *vs.* borderline) and stranding/release type (single stranded/single released [SS/SR] *vs.* mass stranded/single released [MS/SR] *vs.* mass stranded/mass released [MS/MR]) on survival were evaluated by comparing dolphins based on three postrelease performance parameters: the number of satellite tag transmission days (transmission duration), swim speed, and daily distance traveled. Multiple linear regressions were performed to test whether stranding/release type or health status was informative in predicting transmission duration, swim speed, and daily distance traveled. The Huber-White sandwich estimate of variance and bootstrap sampling and estimation were built into the linear regression model to account for sample dependence due to dolphins transmitting during overlapping time periods (Froot 1989, Williams 2000) and nonnormal distribution of the data (Hall and Wilson 1991, Field and Welsh 2007), respectively. *Post hoc* Kruskal-Wallis tests were performed on statistically significant regression results for between-group analyses. Additionally, multiple linear regression analyses were performed by group and individual to assess the relationship between days since release and the dependent variables daily distance and daily swim speed. The Huber-White sandwich estimate of variance for the regression models was used to account for within-animal correlation of measurements due to repeat sampling from the same animal over time (Froot 1989, Williams 2000, Sampson 2012). Distances and speeds for the group regressions were limited to days when at least two dolphins were transmitting within a group to prevent a single animal from skewing the data set. Only dolphins with >2 d transmission duration were used for individual regressions.

Regression analyses were performed using STATA/IC 13.1 for Windows (StataCorp LP, College Station, TX). MedCalc for Windows, version 14.12.0 (MedCalc Software, Ostend, Belgium) was used to perform Kruskal-Wallis tests. Significance level for all tests was defined as $\alpha < 0.05$. Unless otherwise noted, results are presented as mean (SD, range).

## Results

During the study period, 434 dolphins (*Delphinidae* family) stranded within the coverage area, 195 of which were alive (45%). Of the live dolphins, 24 were euthanized (12%), 36 died (19%), 8 were released and later died (4%), and 127 were released and were not known to have restranded (65%). Satellite tags were deployed on 34 (25%) of the released dolphins to evaluate long-term survival. Of the satellite tagged animals, the blind *post hoc* staff poll deemed 23 healthy and 11 to be in borderline health. One of the satellite tagged dolphins was found dead at the release site the morning after release (11-026Dd, healthy, SS/SR), but no others were known to restrand after release.

The 34 satellite tagged dolphins included 22 males and 12 females that stranded in 22 separate mass stranding events and 11 single stranding events (Table 1). The majority of animals were short-beaked common dolphins (*Delphinus delphis*, $n = 28$), with five Atlantic white-sided dolphins (*Lagenorhynchus acutus*), and one long-finned pilot whale (*Globicephala melas*) included in the data set. There were 11 SS/SR dolphins, 8 MS/SR, and 15 MS/MR. Strandings occurred between Barnstable and Truro, MA on Cape Cod with the majority occurring in the Town of Wellfleet ($n = 21$). Only one animal, the sole *G. melas*, stranded outside of Cape Cod Bay, on the Atlantic Ocean side of Cape Cod.

Twenty-eight Sirtrack Kiwisat202 tags were deployed during the study period (SS/SR = 6, MS/SR = 7, MS/MR = 15; healthy = 18, borderline = 10). Six Wildlife Computer MK10-A tags with time-depth recorders (TDR) were deployed (SS/SR = 5, MS/SR = 1; healthy = 5, borderline = 1). Overall, the 34 satellite tags transmitted for a mean of 21.2 d (19.2), with durations ranging between 1 ($n = 8$) and 79 d ($n = 1$) and totaling to 722 delphinid-days of transmissions. Dolphins traveled an average total distance of 856.6 km (821.6, 0–3,609) over the life of the tags. Mean daily distance traveled was 42.0 km/d (11.25, 20.96–70.72) and mean dolphin swim speed was 4.3 km/h (1.1, 2.15–8.54). Satellite tracks of all dolphins, presented by health status and stranding/release group, are found in Figures S1–S6.

### *Stranding/Release Type*

Two of 15 (13%) MS/MR dolphins (both borderline), 1/8 (13%) healthy MS/SR dolphin, and 5/11 (46%) SS/SR dolphins (3 healthy, 2 borderline) transmitted for less than a day. One of the SS/SR dolphins with a single day transmission duration was the aforementioned known failure (11-026Dd, healthy). Transmission durations varied significantly among stranding/release groups with SS/SR dolphins having a shorter mean duration than both MS/SR and MS/MR dolphins (Ht = 6.24, $P$ = 0.0442, Table 2). Mean daily distance and mean swim speed did not differ among stranding/release types (Table 2).

*Table 2.* Summary of postrelease parameters by health status (healthy *vs*. borderline) and stranding/release type, presented as mean (SD, range).

| Group | *n* | # days tag transmitted | Dolphin-days | Daily distance (km/12 h day) | Swim speed (km/h) | Distance over days since release regression (± correlation) $R^2$ | Distance over days since release regression $F$(DF, $n$) | Distance over days since release regression $P$ | Speed over days since release regression (± correlation) $R^2$ | Speed over days since release regression $F$ (DF, $n$) | Speed over days since release regression $P$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Healthy | 23 | 25.1 (20.8, 1–779) | 578 | 40.8 (10.1, 21.0–56.6) | 4.3 (0.7, 3.1–6.0) | (+) 0.043 | 19.49 (1, 424) | 0.0001* | (+) 0.009 | 3.88 (1, 440) | 0.050 |
| Borderline | 11 | 13.1 (14.5, 1–41) | 144 | 44.8 (13.6, 24.0–70.7) | 4.1 (1.7, 2.2–8.5) | (–) 0.014 | 1.33 (1, 133) | 0.251 | (+) 0.000 | 0.01 (1, 135) | 0.917 |
| SS/SR | 11 | 10.6* (11.5, 1–31) | 117 | 37.5 (11.4, 24.3–55.3) | 4.0 (1.2, 2.2–6.0) | (+) 0.062 | 4.39 (1, 86) | 0.039* | (+) 0.086 | 0.03 (1, 89) | 0.008* |
| MS/SR | 8 | 31.0 (24.8, 1–79) | 248 | 41.3 (14.3, 21.0–70.7) | 4.7 (1.6, 3.6–8.5) | (–) 0.000 | 0.00 (1, 157) | 0.964 | (–) 0.000 | 0.03 (1, 161) | 0.852 |
| MS/MR | 15 | 23.8 (17.7, 1–67) | 357 | 45.1 (9.0, 24.0–56.6) | 4.2 (0.8, 2.3–5.2) | (+) 0.015 | 4.82 (1, 312) | 0.029* | (+) 0.006 | 1.89 (1, 323) | 0.171 |

*Note*: SS = single stranded, MS = mass stranded, SR = single release, MR = mass release; *R*2 = linear regression coefficient of determination, "*" denotes statistical significance ($P < 0.05$).

Both mass stranded/mass release (MS/MR) and single stranded/single release (SS/SR) dolphins showed weak positive correlations between daily distance traveled and days since release (Table 2), indicating that these groups had a slight overall increase in daily distance traveled over time. SS/SR dolphins also exhibited a weak positive correlation between swim speed and days since release (Table 2).

### *Health Status*

Most dolphins transmitted for more than one day, but 4/23 (17%) healthy and 4/11 (36%) borderline dolphins transmitted for one day or less. No statistical differences were found between borderline and healthy animals for transmission duration, mean daily distance, or mean daily speed (Table 2). Mean transmission duration for healthy dolphins was 25.1 d (20.8, 1–79) and for borderline dolphins was 13.1 d (14.5, 1–41); however, mean daily distance and swim speed were more comparable between the two groups. Healthy dolphins exhibited a weak positive correlation between daily distance traveled and days since release (Table 2), whereas borderline dolphins did not. No significant relationship was found between daily speed and days since release for either healthy or borderline dolphins (Table 2).

### *Individual Dolphins*

Of all the individual dolphins, only two MS/SR dolphins, 10-073La (healthy) and 12-204Dd (borderline), had significantly negative correlations between daily distance traveled and days since release ($F_{1,10} = 6.72$, $R^2 = 0.3919$, $P = 0.027$; $F_{1,35} = 4.80$, $R^2 = 0.147$, $P = 0.035$, respectively). 12-204Dd also had a weak negative correlation between swim speed and days since release ($F_{1,35} = 6.13$, $R^2 = 0.140$, $P = 0.018$). 10-063Dd (healthy, MS/SR) displayed positive correlations between days since release and both the dependent variables daily speed ($F_{1,18} = 12.77$, $R^2 = 0.389$, $P = 0.002$) and daily distance ($F_{1,18} = 8.13$, $R^2 = 0.280$, $P = 0.011$). 12-214Dd (borderline, MS/MR) exhibited a weak positive correlation between swim speed and days since release ($F_{1,10} = 7.13$, $R^2 = 0.473$, $P = 0.024$).

### *Postrelease Surveys*

Two vessel-based surveys were successful in locating tagged dolphins and, in both cases, confirmed that healthy MS/SR dolphins (10-063Dd and 10-092La) were able to locate groups of conspecifics. One dolphin (10-063Dd) was observed for 12 d following release in a group of 8–12 conspecifics, which included a satellite tagged healthy MS/MR dolphin that had been released 4 h before the single stranded dolphin. The healthy MS/SR dolphin, 10-063Dd, was observed in close association with (side by side within a body length and traveling in the same direction) and cosurfacing with other animals in the group and exhibiting strong swimming behavior. The second dolphin to be resighted (10-092La) was observed 5 d after release in close association with 3–5 conspecifics within a larger, more dispersed group of over 200 *L. acutus* (spread over one square mile). Two days later (7 d postrelease), another survey found the animal in close association with the same nontagged dolphin (photo-matched through dorsal fin shape and markings) in a small cluster of 2–8 dolphins within a larger group of 150–200 conspecifics. During both sightings, the behavior of 10-092La was similar to the other observed free-swimming *L. acutus* in the area at that time. Behavior was best described as traveling, but more specifically milling, with overall movement in a particular direction.

Additionally, the satellite tracks of single released dolphins in two separate instances paralleled those of other satellite tagged dolphins in time and space, including one of the above postrelease resight dolphins, 10-063Dd. Within 36 h of release, 10-063Dd's satellite track began to parallel that of 10-060Dd, the MS/MR tagged dolphin with which it was later resighted (Fig. S7). Their tracks ran parallel for 8 d, subsequently separated for 2 d, and then reunited for 1.5 d before separating again for the remaining tag life. In a second instance, the satellite track of 10-230Dd (healthy, SS/SR) paralleled that of 10-238Dd (SS/SR), beginning 6 d after the second animal was released (Fig. S8) and continuing for 11 d before they separated. No resights on this second set of animals (10-230Dd and 10-238Dd) were possible due to weather conditions.

## Discussion

This study represents the largest published data set of postrelease monitoring on stranded delphinids from a single geographic location and is also the first to evaluate the success of borderline release candidates and single social delphinids that were relocated and released the day of stranding. While this is a substantial data set for stranded animals, the overall sample size is small for providing statistical power and the nature of the work makes controlling for a variety of confounding factors difficult, if not impossible; thus, it is important to interpret the results cautiously. Borderline release candidates were not found to differ statistically from healthy dolphins in any of the three postrelease parameters; however, 36% of borderline cases failed after only 1 d, compared to 17% of healthy cases. It is unclear whether these failures are due to animal death or tag failure and further investigations are needed to evaluate if death within the first 24 h of release is higher in borderline dolphins. Single stranded/single released dolphins exhibited shorter transmission durations on average than their mass stranded counterparts, but did not differ in mean daily distance traveled or mean speed. Healthy dolphins, MS/MR dolphins and SS/SR dolphins demonstrated slight increases in daily distance traveled over time, while SS/SR dolphins additionally exhibited a slight increase in speed over time after release.

The longest transmission duration of all the animals in this study (79 d) was posted by a healthy, MS/SR *L. acutus* (10-092La), suggesting that animals from this stranding/release class are capable of survival. The longest duration from the MS/MR group was 67 d (12-112Dd, healthy) and the SS/SR group had the shortest maximum duration of 31 d (10-214Gm, healthy). The metric of 3 wk transmission duration as an indicator of success for *D. delphis* released from Cape Cod, Massachusetts was established in an earlier publication (Sharp *et al.* 2014). Based on this metric, 9/15 (60%) MS/MR dolphins, 5/8 (63%) MS/SR dolphins, and 4/11 (36%) SS/SR dolphins would qualify as successes.

It should be noted that the transmission durations in this study are markedly shorter than those published in Sampson *et al.* (2012) with a mean of 117 d and in Wells *et al.* (2013*a*), which established a 6 wk survival metric. While the difference could indicate that the dolphins included in this study had a lower success rate (only 2/15 [13%] MS/MR dolphins, 2/8 [25%] MS/SR dolphins, and 0/11 [0%] SS/SR dolphins would be considered successes according to the 6 wk metric), it could also reflect pertinent differences in tagging protocol, species, and sea conditions. The expected battery life of the majority of Sirtrack tags was only 45 d due to an intensified duty cycle (12 h on, 12 h off), which was selected to increase postrelease sighting opportunities. Both cited studies also used three point attachment satellite tags, which provide a sturdier attachment platform, but were not selected in this study to reduce health impacts. Wells *et al.* (2013*a*) reported on mainly bottlenose dolphins (*Tursiops truncatus)*, which have considerably more robust dorsal fins than the predominant species in the current study (*D. delphis*). These factors, combined with the harsher offshore conditions in the northwest Atlantic Ocean (in comparison to southeastern US waters), would decrease the expected life of the tag and the duration of attachment, making the overall shorter transmission duration less likely a result of decreased postrelease survival of the animals in this study.

In a recent case occurring outside the study period, two MS/MR common dolphins restranded on Cape Cod 47 d postrelease with wounds on their dorsal fins consistent with tag migration out of the fin through the trailing edge (IFAW, unpublished data). One dolphin was satellite and ID tagged, the second dolphin was ID tagged only. The associated satellite tag had ceased transmitting 6 d prior to the restranding event. The satellite tag attachment site showed evidence of granulation tissue consistent with a tag pull though around the time of transmission cessation. Between the two stranding events, the satellite tagged dolphin lost 2.7 kg (2.9%) and the ID tagged dolphin lost 1.6 kg (2.4%), differences easily within the error margin of the field scale. While the animals may not have gained weight, this finding strongly suggests that they were feeding prior to restranding. Both dolphins were assessed as healthy, relocated, and reintroduced for a second time. This case provides evidence supporting the hypothesis that single pin satellite tag duration may be shorter in delphinids with thinner dorsal fins (41 d in this case) due to earlier tag migration compared to dolphins with more robust fins, such as bottlenose dolphins (71 d in a case reported by Balmer *et al.* 2011).

The lack of difference in postrelease parameters between healthy and borderline dolphins indicates that animals categorized by responders as “borderline” may be equally capable of postrelease survival as “healthy” dolphins. This finding supports the option to release dolphins lacking definitively positive health evaluations in the absence of any strong negative indicators. Thorough health evaluations including point-of-care blood analysis should be performed in the field prior to release, whenever possible, in order to make best informed decisions for each case. While the mean daily distance traveled between the healthy and borderline groups did not differ, healthy dolphins exhibited a positive correlation between daily distance traveled and days since release, whereas borderline dolphins did not. This may suggest that healthy dolphins traveled farther than borderline dolphins towards the end of the life of their satellite tag, indicating increasing strength over time. However, daily distance data represents the minimum distance traveled by an animal and does not account for fine scale movement patterns or vertical distance traveled while diving. Borderline dolphins did not show a decrease in daily distance traveled over time, which would have been a more convincingly negative indicator.

The observed similarity in postrelease parameters between health status groups could alternatively suggest that current health assessment protocols are imperfect at distinguishing between clinically healthy and questionable release candidates. In a previous study, health assessments were found to be useful in predicting postrelease success in some but not all cases (Sharp *et al.* 2014), indicating that health assessment protocols, while currently worthwhile, could benefit from further refinement. Moreover, the retrospective evaluation of health status may not have been as accurate as prospective categorization, and thus, future studies should categorize health status at the time of stranding.

Stranding/release type analyses showed that single stranded delphinids had shorter transmission durations on average than mass stranded dolphins, but did not differ in mean speed or daily distance traveled. The observed difference in transmission duration was likely due to the large percentage of SS/SR dolphins (5/11, 46%) that transmitted for 1 d or less, compared to only 13% of MS/SR and MS/MR dolphins. While this suggests that a subset of single stranded dolphins may not be as fit for release as mass stranded dolphins, four SS/SR dolphins (all deemed healthy) transmitted for over 21 d, which was the previously utilized "survival" cutoff for dolphins in this geographic area. Additionally, the SS/SR group demonstrated an increase in daily distance traveled and swim speed over time, indicating increasing physical ability with time. These results could also indicate that single stranded dolphins had to cover a larger area to survive compared to mass stranded dolphins or could simply reflect a change in behavior based on environmental or prey conditions. Regardless, these results show no indication of a decrease in activity level (distance traveled or speed) over time for this group, which would be more indicative of postrelease failure. Based on the sum of these results, it is not unreasonable to consider singly stranded social delphinids as potentially viable immediate release candidates if deemed healthy by diagnostic screening standards. However, the three SS/SR dolphins with <1 d transmission duration that were categorized as healthy provide additional support for necessary refinement of health assessment protocols and data interpretation.

Results from the stranding/release type analyses also support the release of healthy single dolphins from mass strandings if no other conspecifics from the stranding are suitable release candidates, since MS/SR dolphins did not differ from MS/MR dolphins with regard to postrelease parameters. Like SS/SR dolphins, MS/SR dolphins' daily distance traveled also increased with time, further indicating stable to increased activity over time.

In addition to the confirmed death of 11-026Dd (healthy, SS/SR), the seven additional dolphins (three healthy, four borderline) with <1 d transmission time, were also likely failures postrelease. This finding suggests that certain preexisting diseases may be undetected by current health assessment protocols, a conclusion that was also drawn in our previous publication examining health assessment parameters as predictors of postrelease survival in stranded short-beaked common dolphins (Sharp *et al.* 2014). The case of 11-026Dd also had the additional factor of extremely rough sea conditions at the release site, which may have contributed to the animal's demise. Future studies investigating additional influences on postrelease success, such as tidal cycle, weather, sea conditions, and season may provide additional insights allowing for better future release decisions. Tag failure, whether from tag migration, fouling, or malfunction, has been documented to occur in satellite tags deployed on cetaceans (Balmer *et al.* 2011, Wells *et al.* 2013*a*) and could reduce transmission durations without animal death, inflating the number of dolphins considered postrelease failures. The case of 11-057Dd, whose tag transmitted for 23.42 h and then went silent is suggestive of this fate, but not conclusive, due to the nearly exactly 24 h transmission duration. Of the two dolphins resighted postrelease, no obvious tag migration or fouling had occurred, but both animals were sighted within 2 wk of release, a short timeframe which may not have been representative of tag status at later dates. Other malfunctions such as programming errors or loss of waterproof seal would not be visible from vessel based surveys, but these are likely the best platform from which to evaluate tag *vs.* dolphin failure and should be conducted whenever possible to improve satellite tag data interpretation.

MS/SR dolphins 10-073La and 12-204Dd, were the only individuals to have a significant negative correlation between daily distance traveled and days since release. 12-204Dd also had a negative correlation with daily speed and days since release. 10-073La only transmitted for 13 d postrelease and had a strong negative correlation, whereas12-204Dd transmitted for 41 d and had only weak negative correlation. These results suggest that the fate of 10-073La may have been negative in nature, while the fate of 12-204Dd is less convincingly so. Alternatively, this trend may not necessarily be a reflection of health status or survival, and may in fact be due to other behavioral explanations such as feeding activity, or social interactions.

The dolphins in this study have swim speeds within or near the ranges previously reported for satellite tagged conspecifics. Mean swim speeds for *D. delphis* in this study (4.3 km/h) were slightly lower than those reported previously (4.7 and 5.4 km/h) for two mass stranded *D. delphis* from Cape Cod that were immediately relocated and released and considered successful (Sampson *et al.* 2012). Compared to Mate *et al.*'s (1994) report of a single rehabilitated and released *L. acutus* in the Gulf of Maine swimming an average of 5.7 km/h, the *L. acutus* in this study were slower with a mean swim speed of 3.6 km/h. However, their mean speed fell within the range of mean speeds (3.4–6.6 km/h) reported for immediately relocated and released *L. acutus* from Cape Cod that were considered successfully reintroduced by Sampson *et al.* (2012). The mean swim speeds of two individual *L. acutus* fell below the range reported in Sampson *et al.* (2012), both borderline animals (11-107La and 11-006La). The average *G. melas* swim speed of 5.96 km/h exceeded those reported by Mate *et al.* (2005) in a rehabilitated and released pilot whale (2.7 km/h in July, 1.5 km/h in August, and 1.0 km/h in September), but fell within the range of speeds (<2–8 km/h) documented in a single rehabilitated and released short-finned pilot whale (*Globicephala macrorhynchus*) from Florida (Wells *et al.* 2013*b*). It should be emphasized that the reported speeds and distances here reflect only minimum values because they were obtained from straight line tracks between satellite positions, and do not account for fine scale movement patterns. However, these data are comparable with other satellite tag derived data reported in the literature.

The documented daily distances traveled in this study were relatively consistent with values published in the literature. *D. delphis* herds have been documented to travel as far as 120 km/d off southern California (Evans 1974) and *D. delphis* in this study traveled a maximum documented daily distance of 95.1 km/12 h duty cycle (mean 44.2 km/12 h), which is slightly higher than the reported maximum of 120 km/24 h. The *G. melas* in this study traveled an average of 51.6 km/12 h duty cycle, consistent with the Nawojchik *et al.* (2003) report of two rehabilitated and released pilot whales averaging a 65.6 km/18 h duty cycle during the 17 d immediately following their release. The *L. acutus* traveled an average of 40.2 km/12 h duty cycle, which is consistent with the mean daily travel distance reported by Mate *et al.* (1994) of 77 km/24 h from a rehabilitated and released *L. acutus* in the Gulf of Maine. Unfortunately, the daily distance metric also has inherent uncertainties indicative of using satellite telemetry to evaluate postrelease success, including the difficulty of discerning the difference between a failing animal and one that is milling or diving normally in a productive area without significant stretches of horizontal travel.

While satellite tag transmission duration, swim speed, and daily distance parameters provide remote approximations of survival, for social animals, long term postrelease success is likely dependent on the ability to find a group of conspecifics (Whaley and Borkowski 2009). In this study, the ability of single released dolphins to do so within a week of release (and in one instance, likely within 36 h) was established in four cases (10-063Dd, 10-092La, 10-230Dd, and 10-238Dd). Although one pair of *D. delphis* that successfully met up was released only 4 h apart from one another (10-060Dd and 10-063Dd), the second pair was released 4 d apart and 10-230Dd was approximately 53 km from the release site when 10-238Dd was returned to the sea. Additionally, 10-092La (SS/SR) was observed with a group of over 200 conspecifics, within 30 km of the release site on the Atlantic Ocean side of Cape Cod's northern tip on the fifth and seventh postrelease days. Given the confirmed success of some single healthy delphinids in locating groups of conspecifics from nearly 50 km away, and seemingly integrating therein, it seems very reasonable to consider the reintroduction of single delphinids even if the status of nearby conspecifics is not known.

Directed vessel-based surveys on single released delphinids were extremely challenging due to weather constraints, the delay between tag transmission and the availability of satellite fixes, the fast movement and low profile of the animals, and the limited time when the tag clears the surface of the water making it available for VHF signal detection. However, these attempts, when successful, provided invaluable data regarding the success of these animals in reestablishing social connections, which is simply not possible to obtain with remote monitoring methods. Responders are encouraged to make attempts to track single delphinids whenever possible to continually improve understanding of postrelease success for these more challenging stranding cases.

The findings of this study may be specific to animals on Cape Cod due to this locale's unique propensity for strandings of suspected natural etiology and high proportion of live delphinids. The importance of rigorous health assessments and identification marking prior to release, including satellite tagging, cannot be underscored enough if similar studies are to be conducted in other locations. With those caveats, the results of this study cautiously support the reintroduction of single social cetaceans that have been assessed as viable release candidates, considering a subset of SS/SR dolphins did just as well as their mass stranded counterparts after release. However, the need to further refine health assessment protocols is clear due to the shorter transmission duration for the SS/SR group, which included animals deemed healthy. The lack of difference in postrelease parameters between health status groups further supports this need. Investigations to better examine health status categorization in a prospective manner (*vs. post hoc* polling) are also recommended, as is research into other potential influences on postrelease survival, such as time spent out of water, sea conditions, tidal cycle, weather, and season.

## Acknowledgments

Stranding response for this study was conducted under the International Fund for Animal Welfare's Stranding Agreement with the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA NMFS). All stranding protocols, including satellite tagging, were approved by NOAA NMFS and the Woods Hole Oceanographic Institution's Institutional Animal Care and Use Committee (IACUC). Stranding response conducted during the study period was partially funded by the John H. Prescott Marine Mammal Rescue Assistance Program (Grants: NA11NMF4390078, NA11NMF4390079, NA11NMF 4390093). This project would not have been possible without the vision and support of Barbara Birdsey and the Pegasus Foundation. Brian Balmer, Aaron Barleycorn, Randy Wells, Sea

Rogers Williams, and Andrew Westgate provided assistance with attachment protocols to help initiate this project. Randy Wells and the Chicago Zoological Society/Sarasota Dolphin Research Project graciously provided additional satellite tags and technical support during the busy stranding season of 2012. The Northeast Region Stranding Network was also instrumental in providing assistance, including animal care and data collection, especially during that year. Finally, the authors thank the IFAW Marine Mammal Rescue and Research volunteers for making this project possible through their amazing dedication to improving animal welfare and stranding science.

## Literature Cited

Austin, D., J. I. McMillan and W. D. Bowen. 2003. A three-stage algorithm for filtering erroneous Argos satellite locations. Marine Mammal Science 19:371–383.

Balmer, B. C., R. S. Wells, L. H. Schwacke, *et al*. 2011. Evaluation of a single-pin, satellite-linked transmitter deployed on bottlenose dolphins (*Tursiops truncatus*) along the coast of Georgia, USA. Aquatic Mammals 37:187–192.

Bogomolni, A. L., K. R. Pugliares, S. M. Sharp, *et al*. 2010. Mortality trends of stranded marine mammals on Cape Cod and southeastern Massachusetts, USA, 2000 to 2006. Diseases of Aquatic Organisms 88:143–155.

Bossart, G. D., T. H. Reidarson, L. A. Dierauf and D. A. Duffield. 2001. Clinical pathology. Pages 383–436 *in* L. A. Dierauf and F. M. D. Gulland, eds. CRC handbook of marine mammal medicine. 2nd edition. CRC Press, Boca Raton, FL.

Brabyn, M. W., and I. G. McLean. 1992. Oceanography and coastal topography of herd-stranding sites for whales in New Zealand. Journal of Mammalogy 73:469–476.

CLS (Collection, Location, Satellites). 2011. Argos user's manual. Worldwide tracking and environmental monitoring by satellite. Available at http://www.argossystem.org/documents/userarea/argos_manual_en.pdf.

Dudok van Heel, W. H. 1962. Sound and Cetacea. Netherlands Journal of Sea Research 1:407–507.

Evans, W. E. 1974. Radiotelemetric studies of two species of small odontocete cetaceans . Pages 385–394 *in* W. E. Shevill, ed. The whale problem: A status report. Harvard University Press, Cambridge, MA.

Field, C. A., and A. H. Welsh. 2007. Bootstrapping clustered data. Journal of the Royal Statistical Society, Series B 69:369–390.

Freitas, C., C. Lydersen, M. A. Fedak and K. M. Kovacs. 2008. A simple new algorithm to filter marine mammal Argos locations. Marine Mammal Science 24:315–325.

Froot, K. A. 1989. Consistent covariance matrix estimation with cross-sectional dependence and heteroskedasticity in financial data. Journal of Financial and Quantitative Analysis 24:333–355.

Geraci, J. R. 1978. The enigma of marine mammal strandings. Oceanus 21:38–47.

Geraci, J. R., and V. J. Lounsbury. 2005. Marine mammals ashore: A field guide for strandings. 2nd edition. National Aquarium, Baltimore, MD.

Geraci, J. R., and D. J. St. Aubin. 1979. Stress and disease in the marine environment: Insights through strandings. Pages 223–233 *in* J. R. Geraci and D. J. St. Aubin, eds. Biology of marine mammals: Insights through strandings. National Technical Information Service, Springfield, VA. PB-293 890.

Geraci, J. R., J. Harwood and V. J. Lounsbury. 1999. Marine mammal die-offs: Causes, investigations, and issues. Pages 367–395 *in* J. R. Twiss and R. R. Reeves, eds. Conservation and management of marine mammals. Smithsonian Institution Press, Washington, DC.

Hall, P., and S. R. Wilson. 1991. Two guidelines for bootstrap hypothesis testing. Biometrics 47:757–762.

IFAW. 2015*a*. Cetacean health assessment protocol. Available at https://www.ifaw.org/IFAW_MMRR_Cet_Assessment.

IFAW. 2015*b*. Cetacean transportation protocol. Available at https://www.ifaw.org/IFAW_MMRR_Cet_Transport.

Mate, B. R., K. M. Stafford, R. Nawojchik and J. L. Dunn. 1994. Movements and dive behavior of a satellite-monitored Atlantic white-sided dolphin (*Lagenorhynchus acutus*) in the Gulf of Maine. Marine Mammal Science 10:116–121.

Mate, B. R., B. A. Lagerquist, M. Winsor, J. Geraci and J. H. Prescott. 2005. Movements and dive habits of a satellite-monitored longfinned pilot whale (*Globicephala melas*) in the Northwest Atlantic. Marine Mammal Science 21:136–144.

McFee, W. E. 1990. An analysis of mass strandings of the longfinned pilot whale, *Globicephala melaena*, on Cape Cod. M.S. thesis, Northeastern University, Boston, MA. 85 pp.

Mead, J. G. 1979. An analysis of cetacean strandings along the eastern coast of the United States. Pages 54–68 *in* J. R. Geraci, and D. J. St. Aubin, eds. Biology of marine mammals: Insights through strandings. Marine Mammal Commission, Washington, DC. NTIS PB-293-890.

Moore, K. T., and S. G. Barco. 2013. Handbook for recognizing, evaluating, and documenting human interaction in stranded cetaceans and pinnipeds. U. S. Department of Commerce, NOAA Technical Memorandum, NOAA-TM-NMFSSWFSC 510. 102 pp. Available at https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-510.pdf.

Nawojchik, R., D. J. St. Aubin and A. Johnson. 2003. Movements and dive behavior of two stranded, rehabilitated long-finned pilot whales (*Globicephala melas*) in the northwest Atlantic. Marine Mammal Science 19:232–239.

Reynolds, J. E., III, and D. K. Odell, eds. 1991. Marine mammal strandings in the United States. Proceedings of the Second Marine Mammal Stranding Workshop, Miami, Florida, 3–5 December 1987. U. S. Department of Commerce, NOAA Technical Report NMFS 98. 157 pp. Available at http://www.nmfs.noaa.gov/pr/pdfs/health/marine_mammal_strandings.pdf.

Sampson, K., C. Merigo, K. Lagueux, *et al*. 2012. Clinical assessment and postrelease monitoring of 11 mass stranded dolphins on Cape Cod, Massachusetts. Marine Mammal Science 28:E404–E425.

Sharp, S. M., J. S. Knoll, M. J. Moore, *et al*. 2014. Hematological, biochemical, and morphological parameters as prognostic indicators for stranded common dolphins (*Delphinus delphis*) from Cape Cod, Massachusetts, U.S.A. Marine Mammal Science 30:864–887.

Thoreau, H. D. 1864. Cape Cod. Parnassus Imprints, Orleans, MA.

Walsh, M. T., R. Y. Ewing, D. K. Odell and G. D. Bossart. 2001. Mass strandings of cetaceans. Pages 83–96 *in* L. A. Dierauf and F. M. D. Gulland, eds. CRC Handbook of marine mammal medicine, 2nd edition. CRC Press, Boca Raton, FL.

Wells, R. S., D. A. Fauquier, F. M. D. Gulland, F. I. Townsend and R. A. DiGiovanni, Jr. 2013*a*. Evaluating postintervention survival of free-ranging odontocete cetaceans. Marine Mammal Science 29:E463–E483.

Wells, R. S., E. M. Fougeres, G. Cooper, *et al*. 2013*b*. Movements and dive patterns of short finned pilot whales (*Globicephala macrorhynchys*) released from a mass stranding in the Florida Keys. Aquatic Mammals 39:61–72.

Westgate, A. J., A. J. Read, T. M. Cox, T. D. Schofield, B. R. Whitaker and K. E. Anderson. 1998. Monitoring a rehabilitated harbor porpoise using satellite telemetry. Marine Mammal Science 14:599–604.

Whaley, J. E., and R. Borkowski. 2009. Policies and best practices: Marine mammal stranding response, rehabilitation, and release: Standards for release. NOAA Marine Mammal Health and Stranding Response Program and USFWS Fisheries and Habitat Conservation Marine Mammal Program. 92 pp. Available at http://www.nmfs.noaa.gov/pr/pdfs/health/release_criteria.pdf.

Wiley, D. N., G. Early, C. A. Mayo and M. J. Moore. 2001. Rescue and release of mass stranded cetaceans from beaches on Cape Cod, Massachusetts, USA; 1990–1999: A review of some response actions. Aquatic Mammals 27:162–171.

Wilkinson, D. M. 1991. Program review of the marine mammal stranding networks. Report to Assistant Administrator for Fisheries. U.S. Department of Commerce, NOAA, NMFS, Silver Spring, MD. 171 pp. Available at http://www.nmfs.noaa.gov/pr/pdfs/health/program_review.pdf.

Williams, R. L. 2000. A note on robust variance estimation for cluster-correlated data. Biometrics 56:645–646.

Received: 27 April 2014
Accepted: 28 May 2015

## Supporting Information

The following supporting information is available for this article online at http://onlinelibrary.wiley.com/doi/10.1111/mms.12255/suppinfo.

*Figure S1*. Satellite tracks of healthy MS/MR delphinids from Cape Cod, Massachusetts, U.S.A.

*Figure S2*. Satellite tracks of borderline MS/MR delphinids from Cape Cod, Massachusetts, U.S.A.

*Figure S3*. Satellite tracks of healthy MS/SR delphinids from Cape Cod, Massachusetts, U.S.A.

*Figure S4*. Satellite tracks of borderline MS/SR delphinids from Cape Cod, Massachusetts, U.S.A.

*Figure S5*. Satellite tracks of healthy SS/SR delphinids from Cape Cod, Massachusetts, U.S.A.

*Figure S6*. Satellite tracks of borderline SS/SR delphinids from Cape Cod, Massachusetts, U.S.A.

*Figure S7*. Satellite tracks of IFAW10-060Dd and IFAW10-063Dd, released separately. Confirmed traveling together by postrelease vessel based survey.

*Figure S8*. Satellite tracks of IFAW10-230Dd and IFAW10-238Dd, released separately.