Final

# Spatial Use by Odontocetes Satellite Tagged off Cape Hatteras, North Carolina in 2015

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*Prepared by*

Robin W. Baird[1], Daniel L. Webster[1], Zach Swaim[2], Heather J. Foley[2], David B. Anderson[1], and Andrew J. Read[2]

[1]Cascadia Research Collective
218 ½ W. 4th Avenue
Olympia, WA 98501

[2]Duke University Marine Laboratory
135 Duke Marine Lab Road
Beaufort, NC 28516

*Submitted by:*

Virginia Beach, VA

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Cuvier's beaked whale (*Ziphius cavirostris*) off Cape Hatteras. Photographed by Heather Foley, Duke University, taken under National Oceanic and Atmospheric Administration Scientific Permit No. 14809 (Douglas Nowacek) and National Oceanic and Atmospheric Administration General Authorization Letter of Confirmation 16185 held by Duke University.

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## Acronyms and Abbreviations

| | |
|---|---|
| EEZ | Exclusive Economic Zone |
| hr | hour(s) |
| km | kilometer(s) |
| LIMPET | Low-Impact Minimally-Percutaneous External-electronics Transmitter |
| m | meter(s) |
| min | minute(s) |
| photo-ID | photo-identification |
| SD | standard deviation |
| SPOT | Smart Position and Temperature |

# 1. Introduction

In 2014 a study was initiated off Cape Hatteras, North Carolina, to examine the spatial use and diving behavior of a number of species of odontocetes, with particular emphasis on Cuvier's beaked whales (*Ziphius cavirostris*) and short-finned pilot whales (*Globicephala macrorhynchus*). During the first year of that effort, remotely deployed Low-Impact Minimally-Percutaneous External-electronics Transmitter (LIMPET) satellite tags were used to obtain movement data from 3 Cuvier's beaked whales, 16 short-finned pilot whales, 5 common bottlenose dolphins (*Tursiops truncatus*, hereafter bottlenose dolphins), and 1 short-beaked common dolphin (*Delphinus delphis*), ranging over periods from 1.3 to 193.8 days (Baird et al. 2015; Foley et al. 2015a; Thorne et al. 2015). This report summarizes information obtained through additional field efforts undertaken in 2015.

The present work is intended to complement ongoing research by Duke University off Cape Hatteras (hereinafter referred to as the Duke program) by providing information on the movement and diving behavior of these species over the medium term (weeks to months). The Duke program is focusing on shorter-term dive behavior (i.e., hours to days) using Digital Acoustic Tags and longer-term movements (i.e., months to years) using photo-identification (photo-ID) techniques (Swaim et al. 2014). The photo-ID work has demonstrated a high degree of re-sightings, particularly of short-finned pilot whales, suggesting some residency in the Cape Hatteras Study Area. Attempts were made in the field to obtain digital images of all tagged animals to ensure that linkages could be drawn between the photo-ID and satellite tagging work. Photographic matches of tagged animals and their associates are presented in the annual report of the Duke program (Foley et al. 2015b, 2016).

# 2. Methods

Two types of Argos-linked satellite tags were used in this study, a location-only Smart Position and Temperature 5 (SPOT5) or a location-depth SPLASH10 (both produced by Wildlife Computers, Redmond, Washington), both in the LIMPET configuration (Andrews et al. 2008). Tags were remotely deployed using a DAN-INJECT JM 25 pneumatic projector (DanWild LLC, Austin, Texas), and were attached with two surgical-grade titanium darts with backward-facing petals. Target area for all tags was the dorsal fin or the base of the fin. Two dart lengths were used depending on the species. Short darts (4.4-centimeter) were used on bottlenose dolphins, and long darts (6.8-centimeter) were used on short-finned pilot whales, sperm whales (*Physeter macrocephalus*), and Cuvier's beaked whales.

For each tag type (i.e., location-only or location-depth), there were different programming combinations depending on species, based on the average number of respirations per hour from previous tagging studies and taking into account the speed of surfacing and likelihood of the tag remaining attached for longer than approximately 30 days, which varies by species (Cascadia Research Collective, unpublished).

- The number of hours (hr) transmitting per day for location-only tags by species was: short-finned pilot whales—12 hr, bottlenose dolphins—14 hr, and Cuvier's beaked

whales—18 hr. For location-depth tags, this was: short-finned pilot whales and sperm whales—17 hr and Cuvier's beaked whales—20 hr.

- Location-only tags programmed for deployment on bottlenose dolphins transmitted daily through the lifespan of the tags (expected battery life of 34 days), while those deployed on short-finned pilot whales were duty-cycled to transmit daily for the first 60 days, then every third day for 7 transmission days (i.e., covering a span of 21 days), then every fifth day for the remainder of the tag attachment. For deployments on Cuvier's beaked whales, duty-cycling was set with transmissions daily for 80 days, then every second day for 5 days of transmissions, and the remainder of transmissions every fifth day.
- Location-depth tags on Cuvier's beaked whales were set to transmit every day for 25 days, then every other day for 4 transmission days (i.e., covering a span of 8 days), then every third day for the remainder of the tag life. For short-finned pilot whales, location-depth tags were programmed to transmit daily for the first 20 days, every third day for 4 transmission days, and every ninth day for the duration of tag attachment.
- The total number of possible tag transmissions per day was varied to reflect the number of hours transmitting per day and the average number of respirations per hour for each species. Given this, the theoretical battery life for location-only tags was 156 calendar days for short-finned pilot whales, 135 calendar days for Cuvier's beaked whales, and 34 calendar days for bottlenose dolphins, while the theoretical battery life for location-depth tags was 41 calendar days for short-finned pilot whales and sperm whales, and 63 calendar days for Cuvier's beaked whales.

Location-depth tags were programmed to provide dive statistics (e.g., start and end time, maximum depth, and duration) for any dives that exceeded the species-specific depth threshold. Thresholds were defined as: short-finned pilot whales—30 meters (m), sperm whales—30 m, and Cuvier's beaked whale—50 m. For the purposes of comparative analyses, dive statistics were only calculated for dives exceeding 50 m for all species. Prior to each field effort, satellite pass predictions were carried out using the Argos website to determine the best hours of the day for transmissions given satellite overpasses for the approximate 2-month period starting at the beginning of each deployment period.

Filtered location data were processed with R 3.2.2 (packages *sp* 1.2-2, *rgeos* 0.3-15, *raster* 2.5-2) to determine depth, distance from shore, and distance from the 200-m isobath. Depth values were generated from 3 arc-second data from the U.S. Coastal Relief Model for regions off the U.S. Atlantic coast (www.ngdc.noaa.gov/mgg/coastal/crm/data/netcdf/ne_atl_crm_v1.nc.gz and www.ngdc.noaa.gov/mgg/coastal/crm/data/netcdf/se_atl_crm_v1.nc.gz) where available, and with 30 arc-second data from the General Bathymetric Chart of the Oceans 2014 (www.gebco.net/) in other areas. The 200-m isobath dataset used was from the "Data Basin" on-line mapping tool (databasin.org/datasets/75e1256c18bb4ac48d4ca6d6fe65e06e). Given the inherent lack of precision associated with Argos-derived locations, combined with the steep continental shelf-edge and slope topography, we report median and maximum depths of tagged animal locations. Maximum depths are less likely to be influenced by Argos location quality or the steep slope given that the deepest locations of most tagged individuals were well seaward of the continental shelf (see **Results**).

Probability-density maps were generated using all filtered satellite-tag data for all individuals of each of three species where multiple individuals were satellite tagged in both 2014 and 2015, with data from both years incorporated. Kernel-density polygons corresponding to the 50, 95, and 99 percent densities were generated using the R package *adehabitatHR* version 0.4.11[1] . Polygons were plotted in Google Earth Pro version 7.1.2.2041.

When more than one tag was deployed on the same species, we assessed whether individuals were acting in concert during the period of overlap by measuring the straight-line distance between pairs of individuals when locations were obtained during a single satellite overpass (approximately 10 minutes [min]). We used both the mean distances between pairs of individuals and the maximum distance between pairs to assess whether individuals were acting independently, following protocols described by Schorr et al. (2009) and Baird et al. (2010).

Pseudotracks were created to provide a visual display of the approximate location and depth of dives between known surface locations. Dive locations should be assumed to be inaccurate, with the least accurate positions in the middle of the segments between the two surface locations. Pseudotrack lines are generated using a custom R script (Version 3.1.2; R Core Team 2014) that produces a Keyhole Markup Language (KML) file for display in Google Earth Pro. For each segment between two surface locations, animal speed and bearing was calculated between the two points. The distance of the dives from the start of the segment was calculated by multiplying the elapsed time since the start of the segment by the speed. Positions were generated along the segment by using the starting position of the segment, bearing, and distance as input in the *destPoint* function of the R package *geosphere* (Version 1.3-11; Hijmans 2014).

# 3. Results

Field efforts were undertaken for tagging in May, June, and October 2015 (see Foley et al. 2016 for details). Thirty-three tags were available for deployment: 10 location-depth and 23 location-only tags (SPLASH10 and SPOT5, respectively). Thirty tags were deployed (**Table 1**), and one location-only tag was lost during a deployment attempt.

Four location-only tags were deployed on bottlenose dolphins in four different groups (on four different days), with attachment durations ranging from 18.4 to 28.8 days (**Table 1**). Assessment of distance between individuals that had temporally overlapping tag data (TtTag026, TtTag027, and TtTag028) indicated that all individuals were acting independently for the periods of overlap (**Figure 1**). Cumulative distances moved by these four individuals ranged from 1,144 to 1,467 kilometers (km), yet the individuals remained a mean distance from tagging locations of 14.9 to 41.1 km, with a maximum distance moved from the tagging location of 163.8 km (**Table 2**; **Figure 2**). Median depths determined at locations of tagged individuals ranged from 477 to 1,363 m, with maximum depths at tagged animal locations ranging from 1,778 to 2,360 m. All but one individual spent the majority of their time beyond the shelf break (**Table 3; Figure 2, 3**).

[1] https://www.movebank.org/node/14620

The kernel-density map shows the core of the habitat used by the tagged bottlenose dolphins is on the continental slope off Cape Hatteras (**Figure 4**).

A single location-depth tag was deployed on a sperm whale, and location data were obtained over a 13-day period (**Table 1**). The cumulative distance moved by this individual was 676 km, yet the individual remained a mean distance of 71.5 km from the tagging location (maximum of 164.5 km, **Table 2**). Over the first 11 days of the 13-day period, the whale moved to within 20 km of where it was tagged (**Figures 5, 6**). The median depth of tagged animal locations over the 13-day span was 2,673 m (**Table 3**). Just over 5 days of dive data were obtained from this individual, with 91 dives deeper than 50 m, and maximum dive depths and durations of 1,295 m and 55.7 min, respectively (**Table 4**). A pseudotrack showing a series of dives to over 1,000 m deep off the edge of the continental shelf is shown in **Figure 7**.

Tag data were obtained from six Cuvier's beaked whales, with two location-only tags and four location-depth tags (**Table 1**), although for one individual (ZcTag040) location data were obtained for only a 2-day period (**Table 2**). Tags were deployed on two individuals in the same encounter in June 2015, although assessment of distance between the two individuals during the period of tag overlap indicates that the individuals did not act in concert (median distance apart = 16.3 km; maximum = 113.2 km; **Figure 8**). Other pairs of individuals with overlapping tag data, tagged in separate groups (ZcTag042 and ZcTag043) or on different days, generally acted independently (**Figure 8**).

Movement patterns of the six individuals varied, with one (ZcTag040) remaining a mean distance of 11.8 km (standard deviation [SD]=5.8) from the tagging location, while another (ZcTag038) remained a mean of 33.3 km (SD=26.5) from the tagging locations (**Table 2**). In general all tagged individuals remained in a relatively small area near the tagging locations (**Figures 9, 10, 11**). A probability-density distribution from tag data obtained in both 2014 (Baird et al. 2015) and 2015 (**Table 1**) suggests that the core range for individuals tagged off Cape Hatteras is relatively small (**Figure 12**) and broadly overlaps with the core range of tagged bottlenose dolphins (**Figure 4**). From the location-depth tags deployed, 58.6 days of dive data were obtained, recording 2,967 dives deeper than 50 m (**Table 4**). An example of a pseudotrack of dive and location data over an approximate 20-hour period is shown in **Figure 13**, with deep dives during this example ranging from 887 to 1,599 m. Maximum dive depths and dive durations documented were 2,351 m and 87.5 min for ZcTag038 and 1,807.5 m and 114.7 min for ZcTag041 (**Table 4**). Median depths at locations of tagged individuals ranged from 1,124 to 1,616 m (maximum from 1,964 to 2,700 m; **Table 3**), suggesting that many of the dives were likely to, or close to, the sea floor.

Nineteen satellite tags were deployed on short-finned pilot whales, with 15 location-only tags, and four location-depth tags (**Table 1**). The attachment durations ranged from 8.8 to 199.1 days (median = 57 days). Three tags were still transmitting as of 31 January 2016, so the maximum deployment should be considered preliminary until the last of the currently deployed tags cease transmitting. The tags were deployed during 14 different encounters, with one to three tags deployed during each encounter.

Distances between all possible pairs of individuals with overlapping tag data obtained during the same satellite overpasses were calculated (*n*=84 pairs). For pairs of whales tagged within the same encounter, the mean distance apart ranged from 2.1 to 656.8 km, with maximum distances between individuals within a pair of 7.2 to 988.6 km (**Table 5**). For pairs tagged in different encounters during the same day, mean distance apart ranged from 21.7 to 617.3 km, with maximum distances apart ranging from 48.4 to 1227.3 km (**Table 5**). Determining at what mean and maximum distances apart to consider whether the animals were acting in concert is problematic, in part given the inherent inaccuracies associated with Argos-derived locations. For false killer whales, another odontocete with strong social bonds, Baird et al. (2011) considered animals with mean distances apart of less than 5 km and maximum distances apart of less than 25 km to be members of the same social group. Using these criteria, only two pairs of individuals (both individuals of each pair tagged within the same encounter) would be considered members of the same social group (**Table 5**). One other individual, GmTag127, might have been associated with one of those pairs of individuals (GmTag129 and GmTag130) that were tagged almost 1 month later, with mean distances of 5.8 and 15.1 km, and maximum distances of 13.9 and 27.9 km (**Table 5**), although there was only an overlap of less than 3 days where all three tags were transmitting.

Mean and maximum distances moved varied considerably among individuals (**Table 2**), as did the typical depths used (**Table 3**), suggesting considerable variability in movement patterns and habitat use among pilot whale groups off the U.S. Atlantic coast. The individual with the longest duration tag (GmTag130, 199 days) remained strongly associated with the shelf break for the entire period, with movements from offshore of Cape Fear, North Carolina, to north of Cape May, New Jersey (**Figure 14**). Two of the tagged whales were documented moving seaward of the U.S. Exclusive Economic Zone (EEZ), GmTag131 (**Figure 15**) and GmTag139 (**Figure 16**), with GmTag131 entering the Canadian EEZ. These were the only two pilot whales tagged in 2015 with median distances from the 200-m isobaths of more than 10 km (GmTag131 median = 274.3 km; GmTag139 median = 154.4 km). These were not the longest deployments, at 94.1 and 64.2 days, respectively. There were five deployments of over 100 days where the animals stayed entirely within the EEZ, and four of the five remained less than 40 km from the 200-m isobaths (**Tables 1, 3**). One individual with a 101-day track (GmTag142) spent most of its time in a small area in relatively shallow water off Cape Hatteras (median depth=744 m; **Table 3**), but made two offshore excursions and several excursions along the shelf break (**Figure 17**). A map showing combined track and location data from all pilot whales tagged in 2014 (*n*=18) and 2015 (*n*=19) is shown in **Figure 18**, with a probability-density representation shown in **Figure 19**. As with Cuvier's beaked whales and bottlenose dolphins, the core range centers off Cape Hatteras, North Carolina.

# 4. Discussion

This study provides information on the movements and habitat use of four different species of odontocetes along the east coast of the U.S. and builds upon work begun in 2014 (Baird et al. 2015). The combined efforts represent the first dedicated satellite tagging on free-ranging small and medium-sized odontocetes off the U.S. Atlantic Coast. Tag deployments have provided

additional long-distance movement information for Cuvier's beaked whales off the U.S. Atlantic Coast, as well as long-term and long-distance movements of short-finned pilot whales in the area, information that prior to 2014 had only been obtained from previously stranded individuals released off Florida (Wells et al. 2013).

We obtained data from four tagged bottlenose dolphins that appeared to be acting independently over the duration of tag overlap (**Figure 1**). The tagged bottlenose dolphins displayed high site fidelity, remaining on the edge and slope of the continental shelf off Cape Hatteras (**Figures 2 and 3**). Only one of the four tagged bottlenose dolphins spent much time on the continental shelf (TtTag028, **Table 3**), and the individuals remained a median distance offshore ranging from 35 to 58 km (**Table 3**). These findings indicate that the individuals are all part of the western North Atlantic offshore stock of bottlenose dolphins (Waring et al. 2015).

Six Cuvier's beaked whales were tagged in 2015 compared to three in 2014. All animals remained in or near the core area of the 2014 tagged animals, staying near the continental slope off Cape Hatteras (**Figure 10**). None of the animals tagged in 2015 traveled north or south outside the core area, providing more evidence of a resident, rather than an oceanic population, and in general, depths used by Cuvier's beaked whales in 2015 were slightly shallower than those in 2014 (Baird et al. 2015). The extensive dive-data records obtained from four individuals in 2015 and two individuals in 2014 will allow for a comparison of diving patterns of this species with data obtained elsewhere (i.e., Hawai'i, California, Italy; Baird et al. 2006, 2008; Schorr et al. 2014; Tyack et al. 2006).

While the photo-ID work suggests that short-finned pilot whales display a high degree of site fidelity off Cape Hatteras, satellite tagging demonstrates that these animals cover a significant range up and down the continental slope, from Powell Canyon (south of Georges Bank) in the north, to off Cape Fear (North Carolina) in the south, with movements at least occasionally beyond the EEZ (**Figures 15 and 16**). The movement of one individual into Canadian waters appears to be the first confirmed record of short-finned pilot whales off eastern Canada (Stacey and Baird 1993; J. Lawson, DFO, personal communication), although there have been pilot whale sightings near the Canadian EEZ that were confirmed as short-finned by genetic sampling or inferred as short-finned by a genetic/habitat model (Waring et al. 2015). There were high concentrations of locations in the canyons along the shelf break, including Norfolk Canyon, Washington Canyon, Baltimore Canyon, Wilmington Canyon, and Hudson Canyon. Unlike most of the other pilot whales that stayed along the continental slope, GmTag139 travelled across deep water to the New England Seamount Chain (**Figure 16**), and GmTag142 made several offshore excursions, while spending most of its time along the continental slope (**Figure 17**). The considerable variability in movement patterns and habitat use likely reflects patterns that vary by social group, and understanding site fidelity and association patterns determined through photo-ID will help in interpreting such variability.

Even though short-finned pilot whales cover a much larger range, their core range (**Figure 19**) appears to be centered in the same area as the bottlenose dolphins (**Figure 4**) and Cuvier's beaked whales (**Figure 12**), although it is a much larger area that extends north to offshore of Virginia. Unlike the other whales and dolphins, the 90 percent and 95 percent polygons extend

much farther, along the continental slope all the way into Canadian waters, and out across the abyssal plain to the New England Seamount chain. Even though more study is necessary to determine the structure and habitat use of these stocks, the importance of the continental slope to the east of Cape Hatteras (North Carolina) is becoming apparent.

# 5. Acknowledgments

We thank Joel Bell (Naval Facilities Engineering Command Atlantic) for his support. Tagging of the sperm whale was undertaken under National Marine Fisheries Service Scientific Research Permit No. 14450-04 issued to the Southeast Fisheries Science Center. Tagging of other species was undertaken under National Marine Fisheries Service Scientific Research Permit No. 15330 issued to Cascadia Research Collective.

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# Appendix A

## Figures

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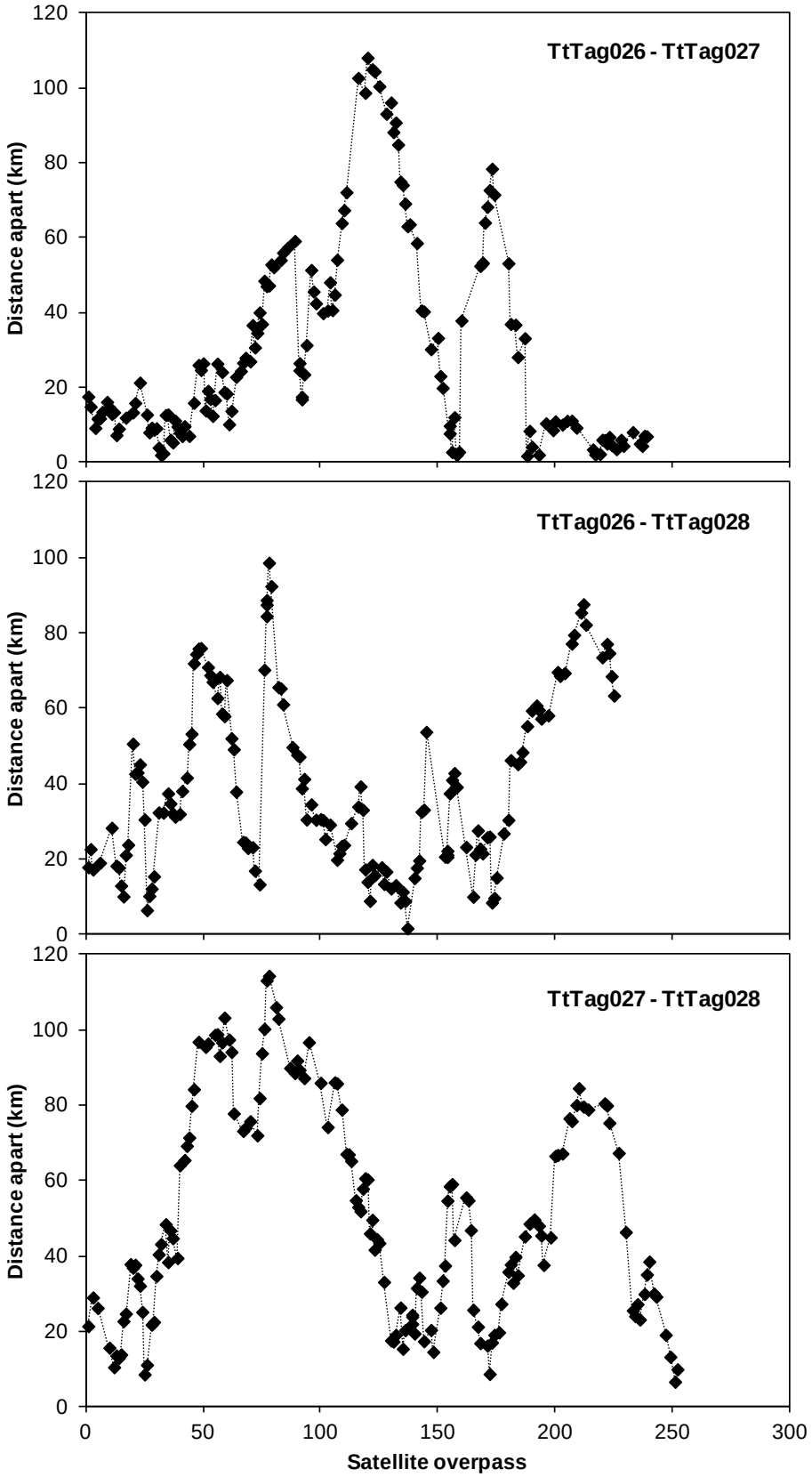


**Figure 1. Plots of distances between pairs of individual tagged bottlenose dolphins with temporally overlapping tag data. The x- and y-axis scales are the same for comparison.**

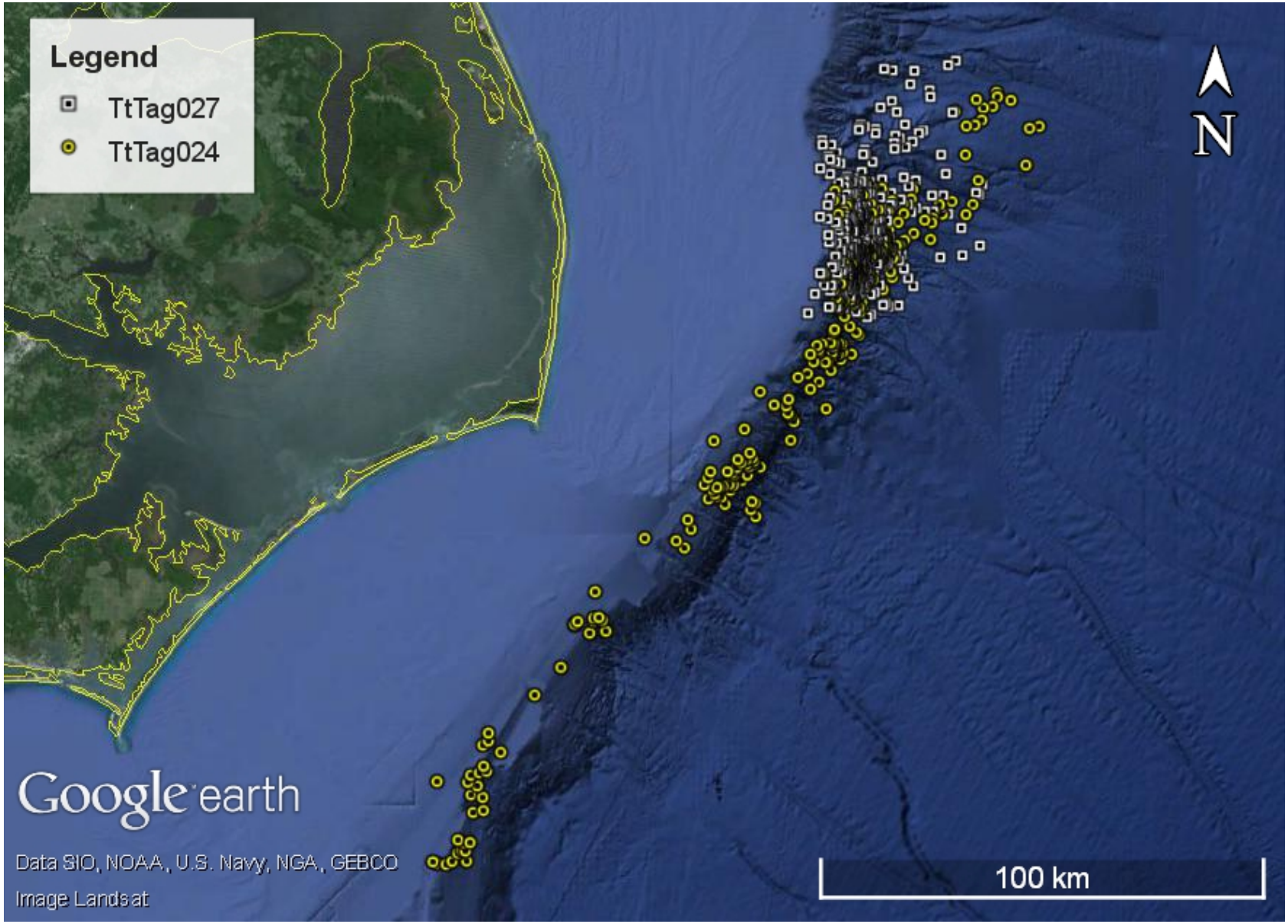


**Figure 2. All filtered locations of bottlenose dolphins TtTag024 (tagged 19 May 2015) and TtTag027 (tagged 20 October 2015) over the 18.4-day and 28.8 day tag-attachment durations, respectively.**

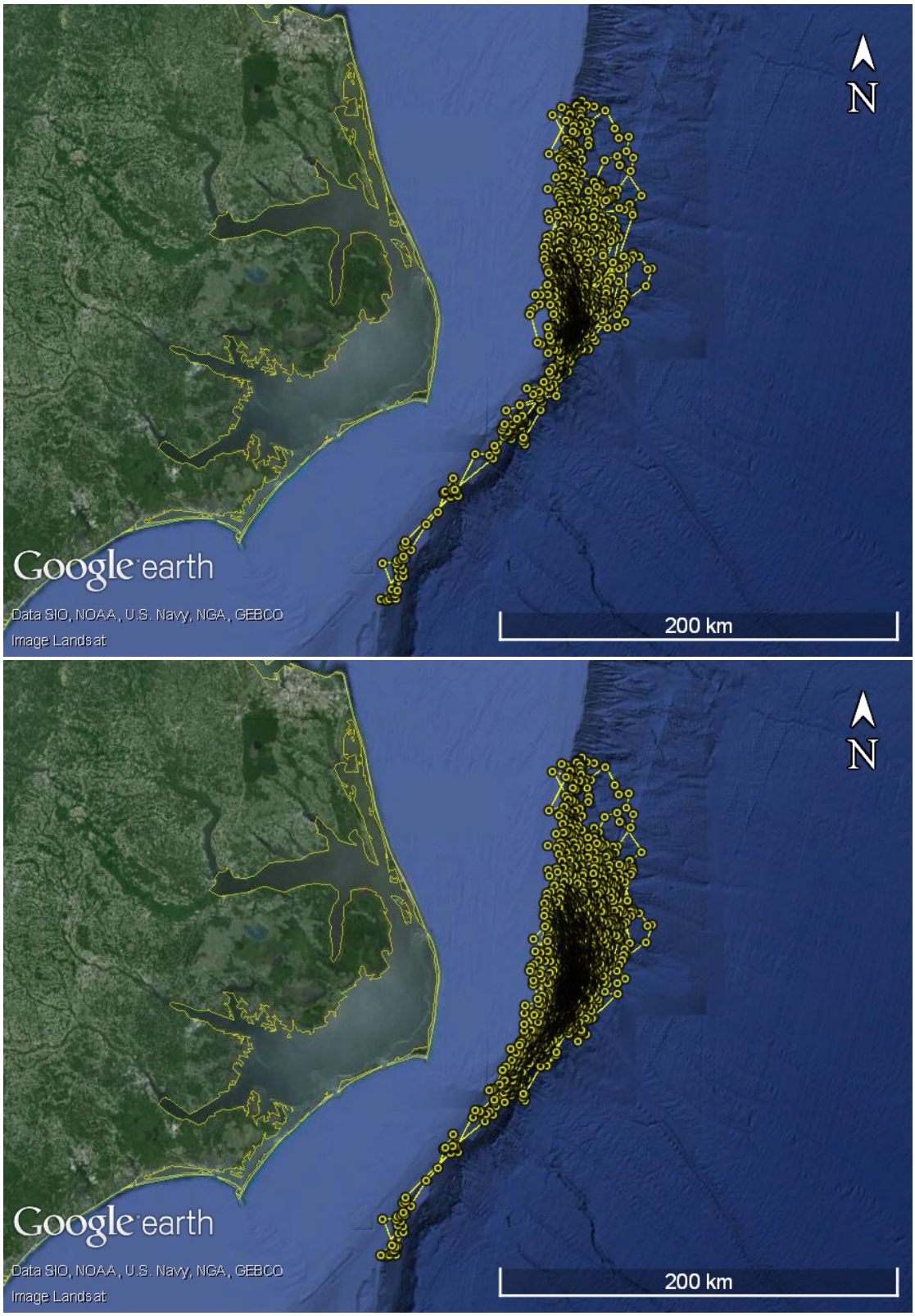


**Figure 3. Top. All filtered locations of all four satellite-tagged bottlenose dolphins tagged off North Carolina in 2015. Bottom. All filtered locations from 2014 (*n*=5) and 2015 (*n*=4). Locations are shown as yellow circles and consecutive locations for each individual joined by a yellow line in both maps.**

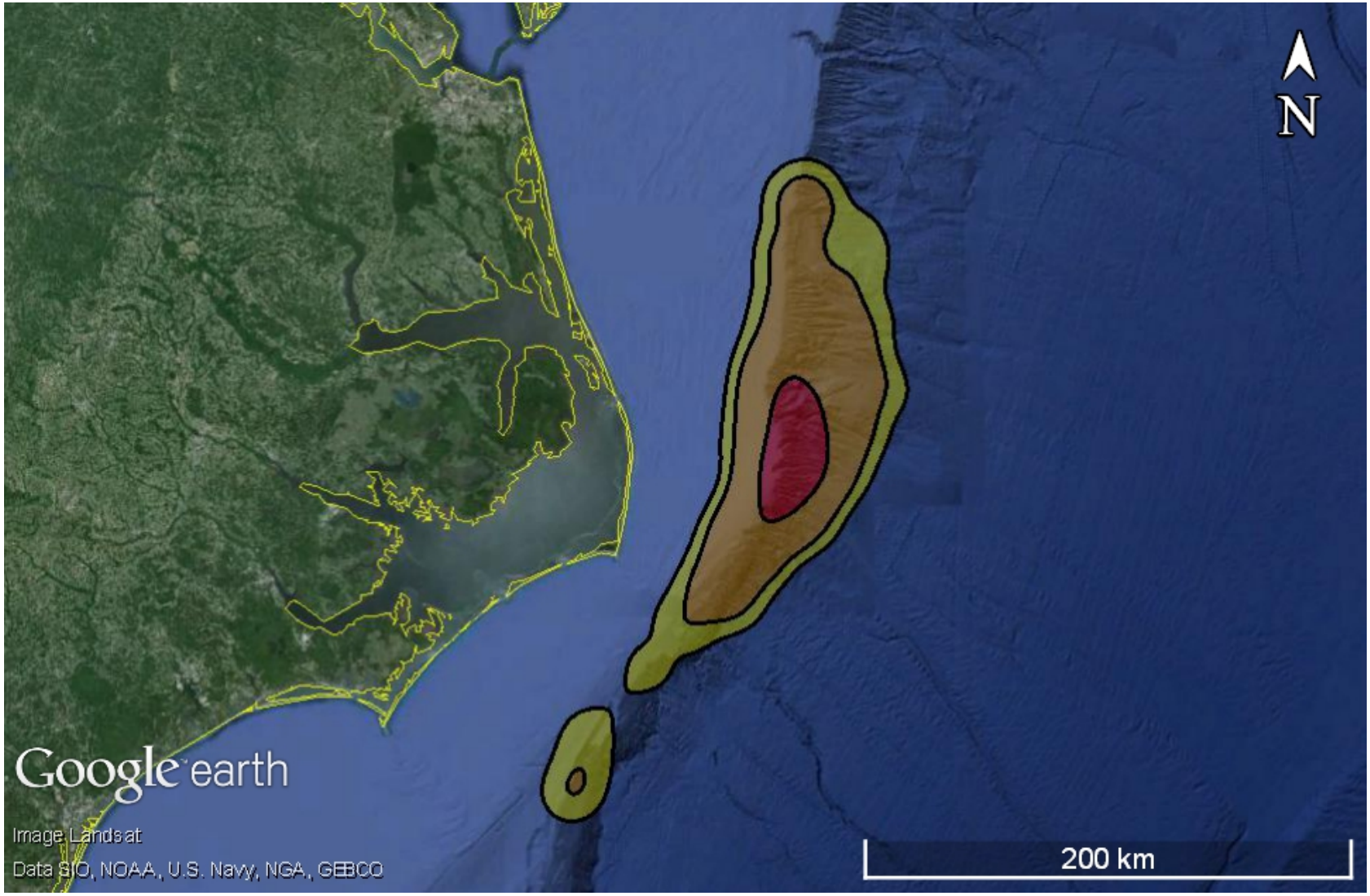


**Figure 4. A probability-density representation of bottlenose dolphin location data from all individuals tagged in 2014 (*n*=5) and 2015 (*n*=4). The red area indicates the 50% density polygon (the "core range"), the orange represents the 95% polygon, and the yellow represents the 99% polygon.**

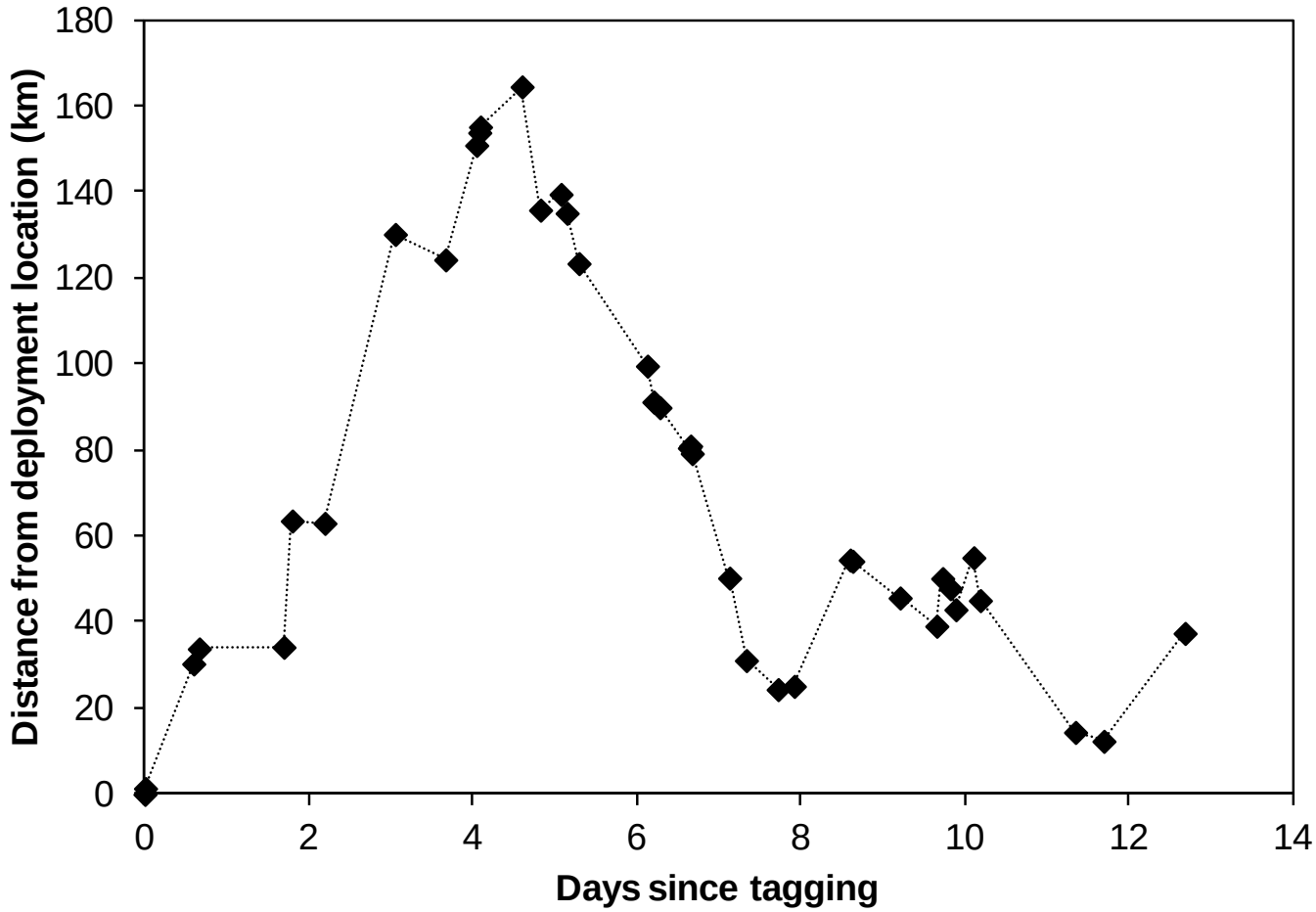


**Figure 5. Distance from deployment location by day for the sperm whale satellite-tagged off North Carolina.**

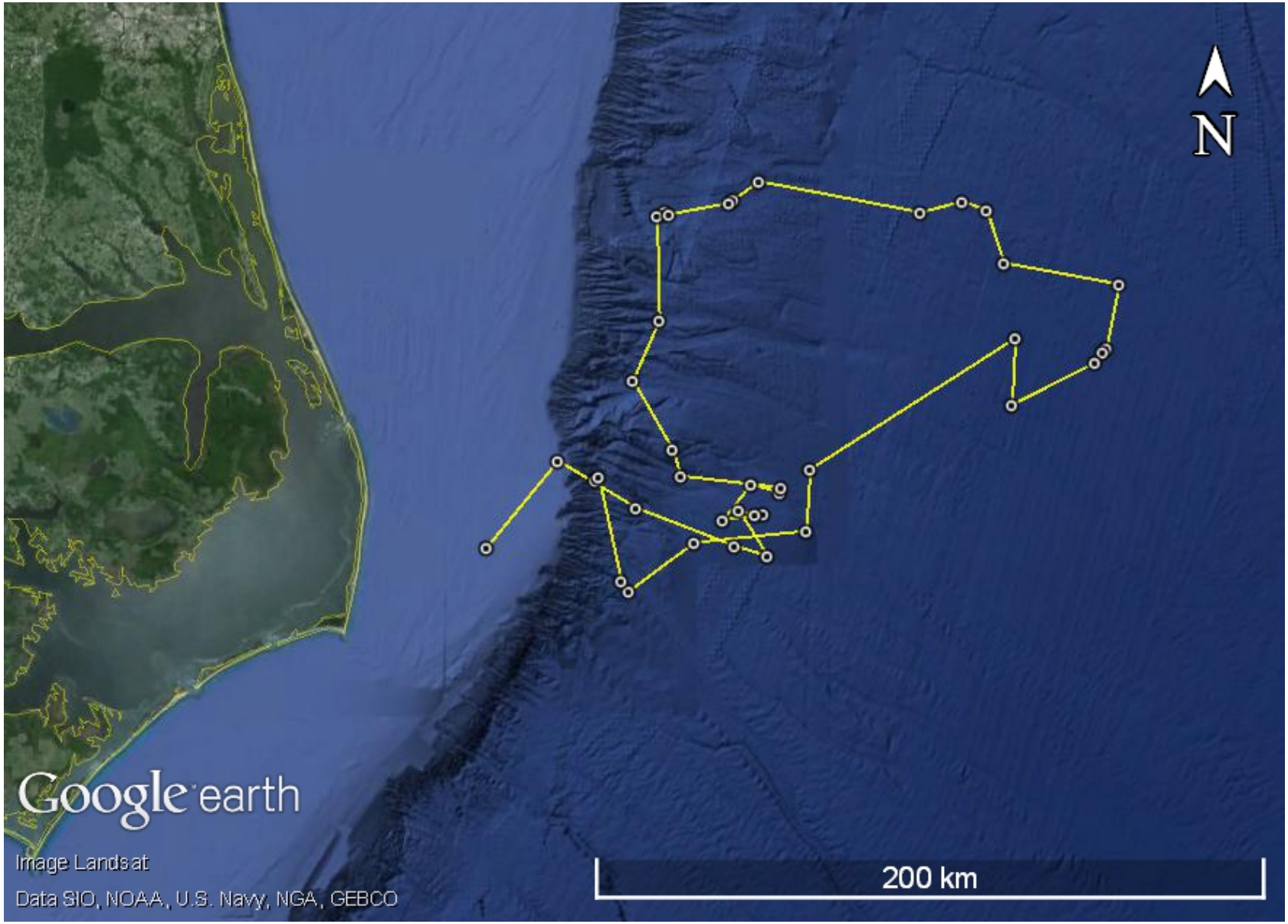


**Figure 6. All filtered locations (white circles) over a 13-day period of a sperm whale tagged off North Carolina, with consecutive locations joined by a yellow line.**

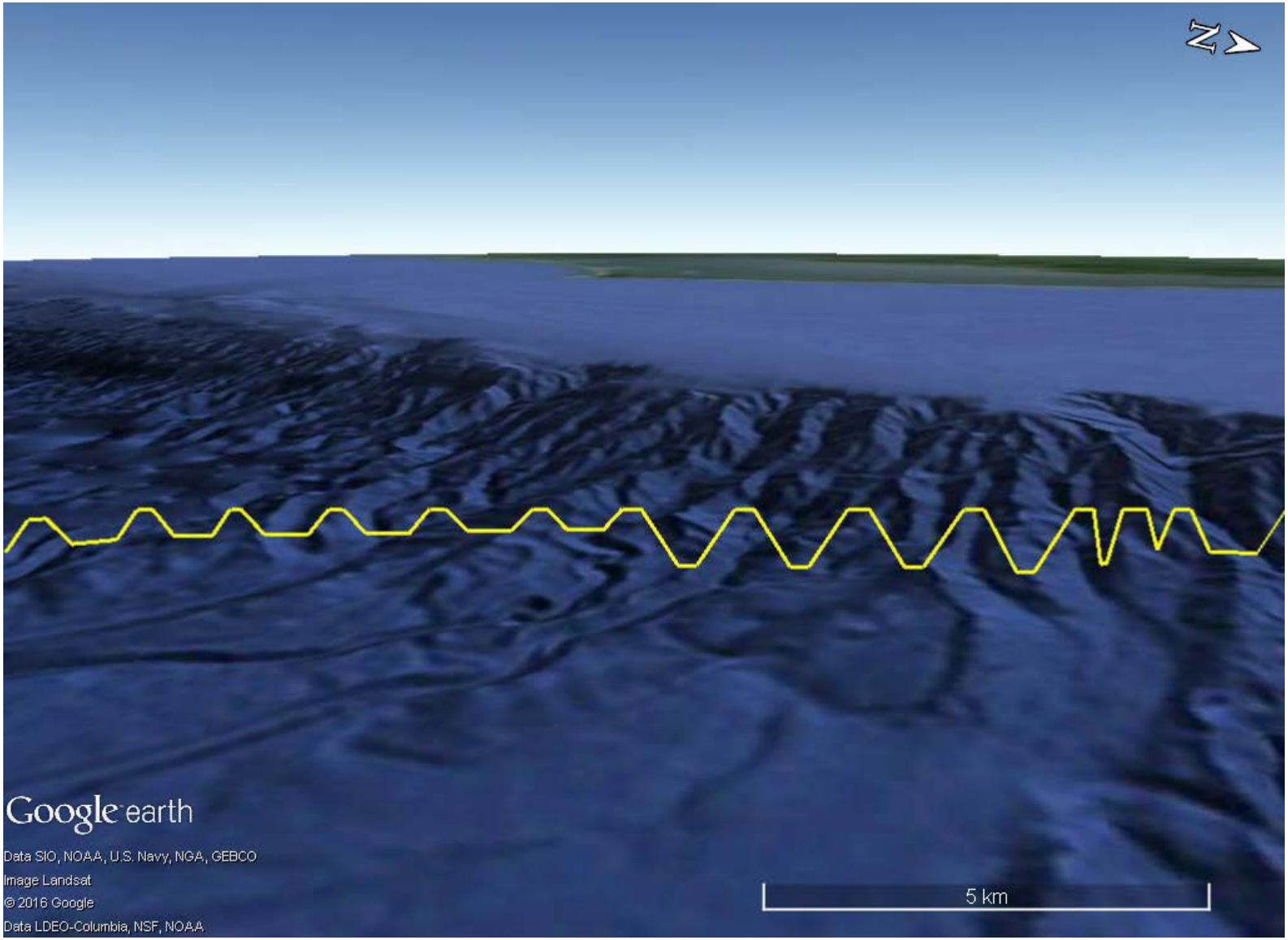


**Figure 7. An example pseudotrack of location and depth data from sperm whale PmTag026 over a 10-hr period starting on 14 June 2015 at 2320 (GMT), as the animal transits generally from the north (right side of figure) to the south. The individual was located on the offshore edge of the continental slope, with this perspective from offshore of the track and the land of Cape Hatteras visible in the back. The vertical (depth) axis is exaggerated. The deep dives shown here range from 1,039 to 1,199 m in depth.**

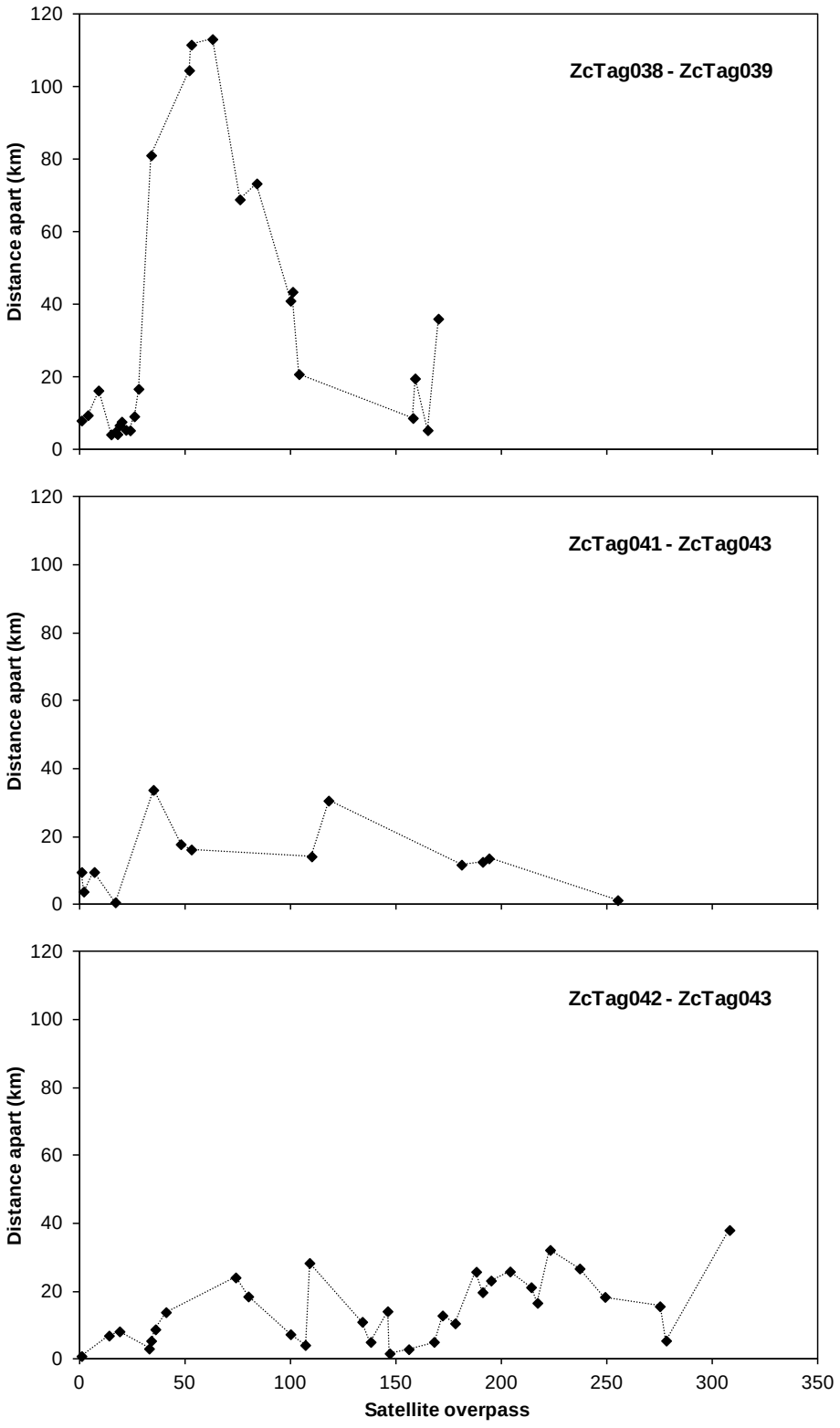


**Figure 8. Distances between pairs of Cuvier's beaked whales with overlapping tag data. ZcTag038 and ZcTag039 were in the same group when tagged. ZcTag041 and ZcTag043 were tagged six days apart, while ZcTag042 and ZcTag043 were tagged on the same day but in different groups. Distance data indicated that individuals were generally acting independently during the periods of tag overlap. The x-axis and y-axis scales are the same for all three graphs.**

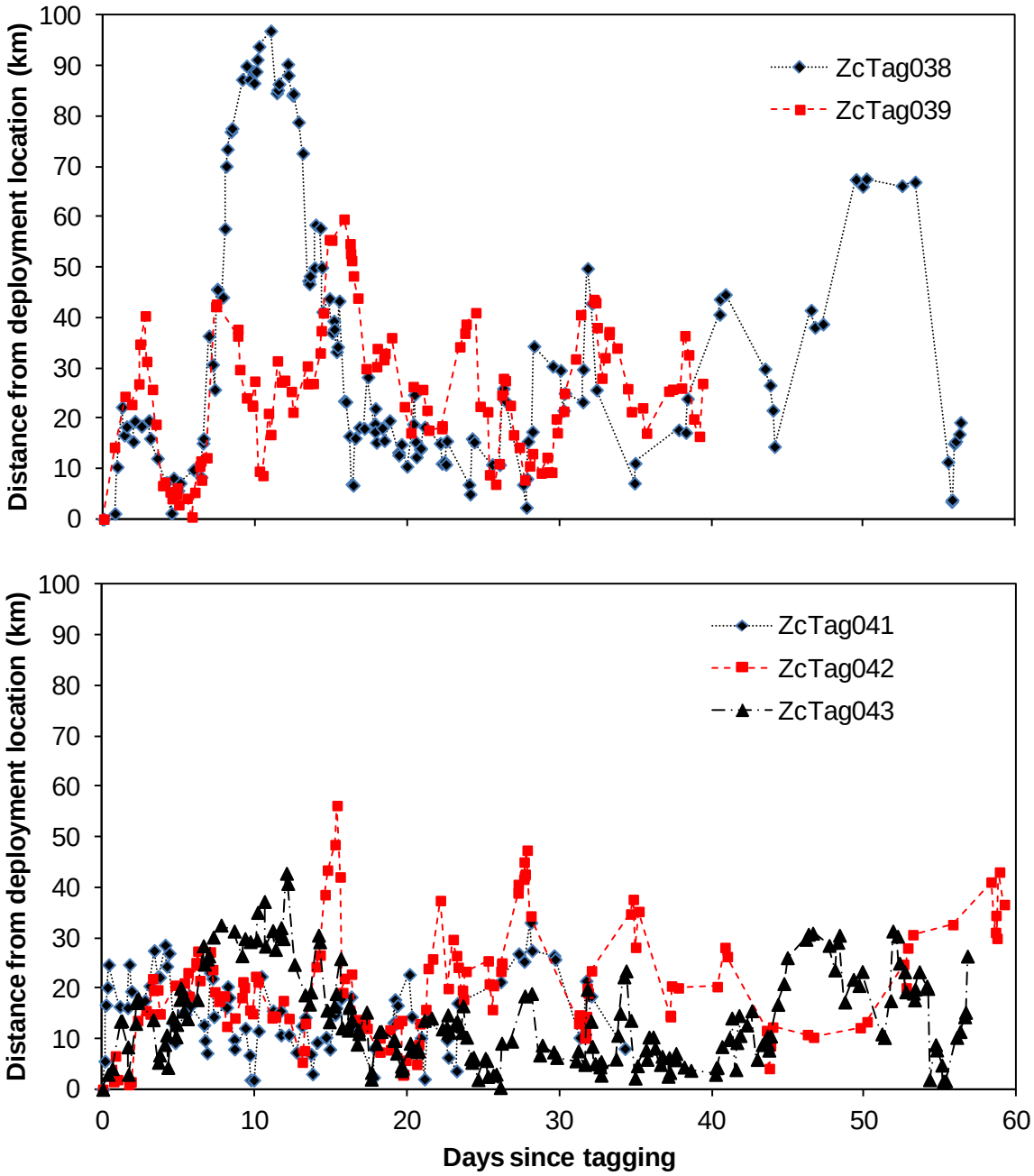


**Figure 9. Distance from tagging location by day for satellite-tagged Cuvier's beaked whales tagged off North Carolina in 2015. Top. Two individuals tagged within the same group on 14 June 2015. Bottom. Three individuals tagged in October 2015, with ZcTag042 and ZcTag043 tagged on the same day. The x-axis and y-axis scales are the same for both graphs.**

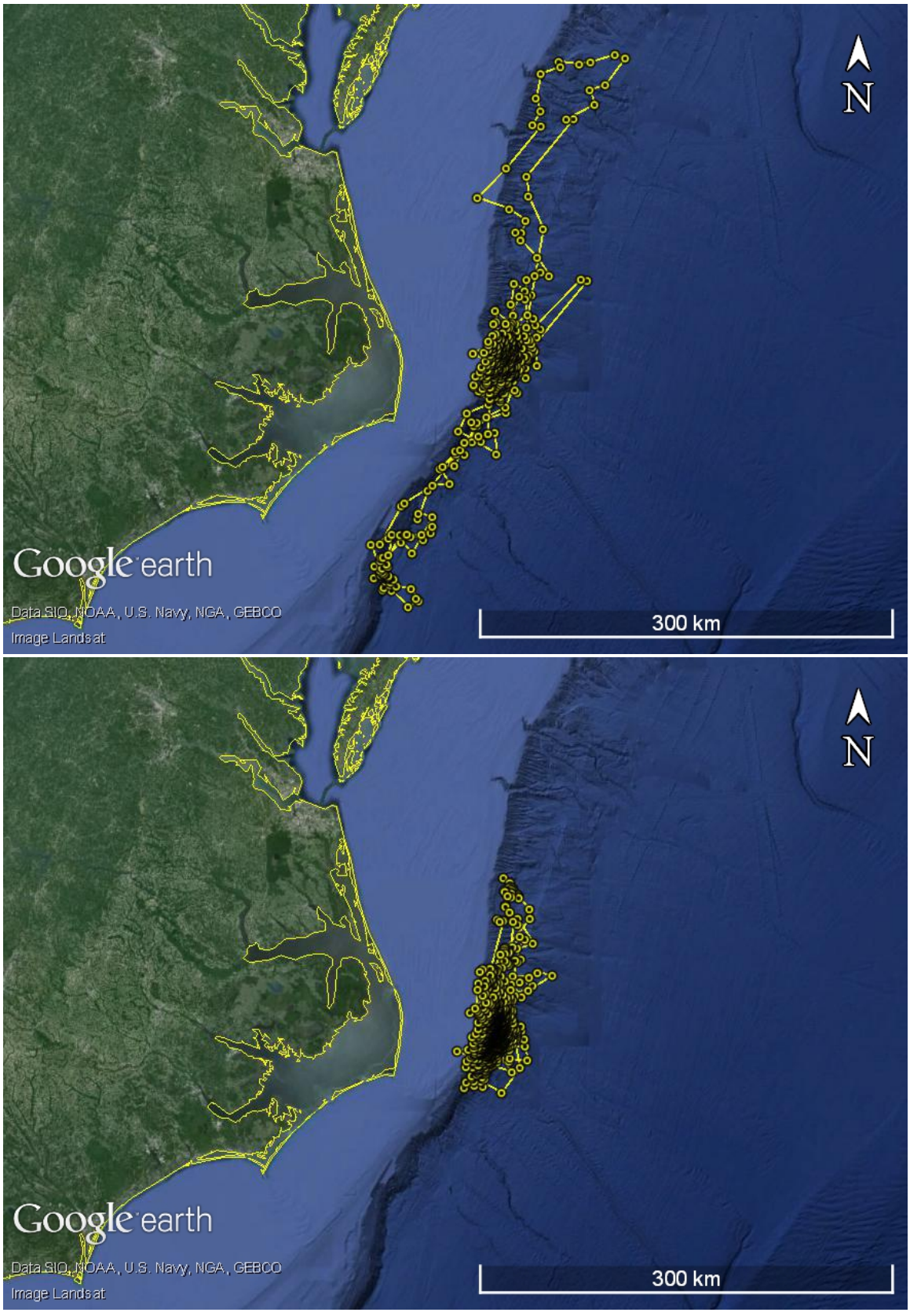


**Figure 10. All filtered locations (yellow circles) of Cuvier's beaked whales tagged in 2014 (top, *n*=3) and 2015 (bottom *n*=6), with consecutive locations joined by lines.**

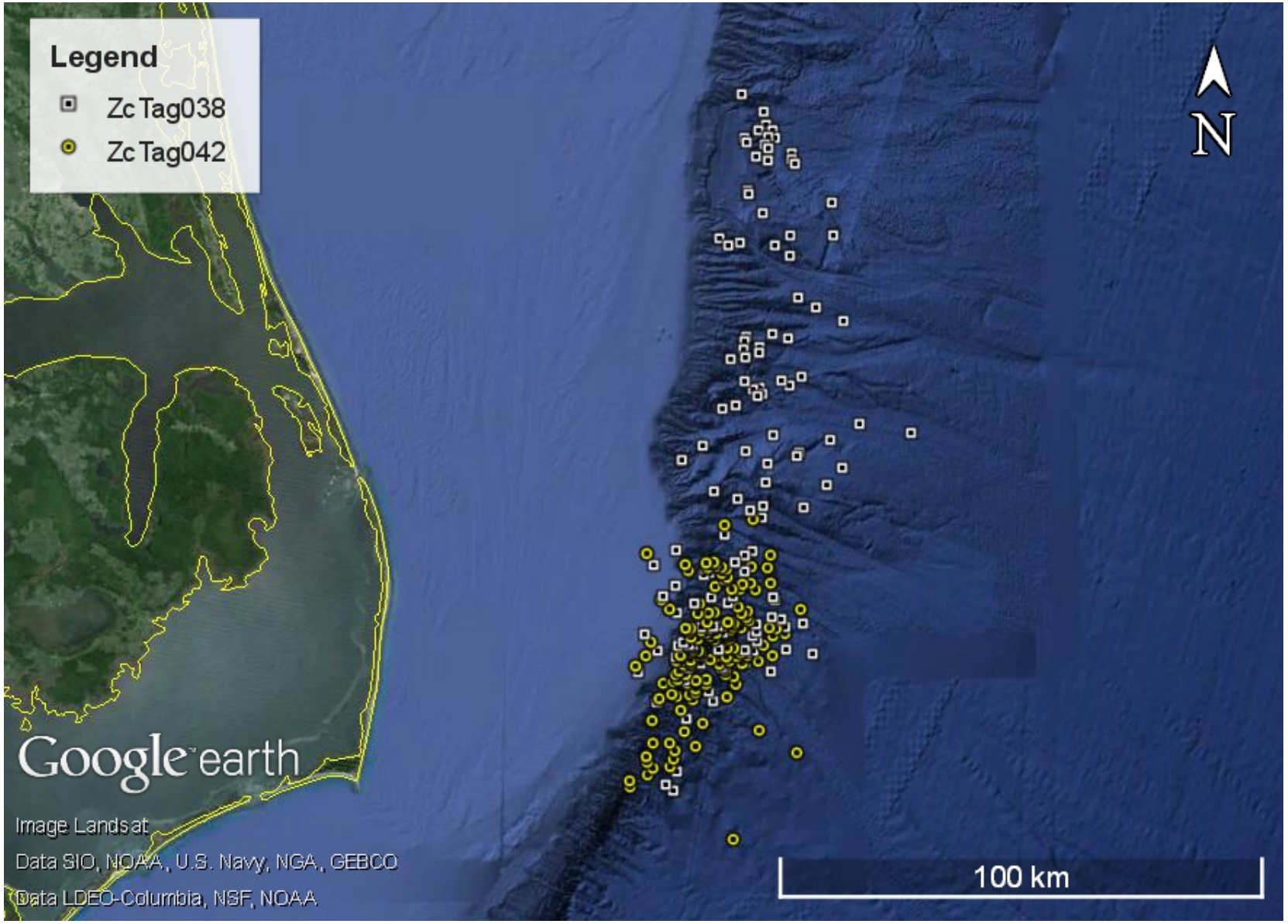


**Figure 11. All filtered locations of Cuvier's beaked whale ZcTag038 (tagged 14 June 2015) and ZcTag042 (tagged 21 October 2015) over 56.4-day and 59.2-day periods, respectively.**

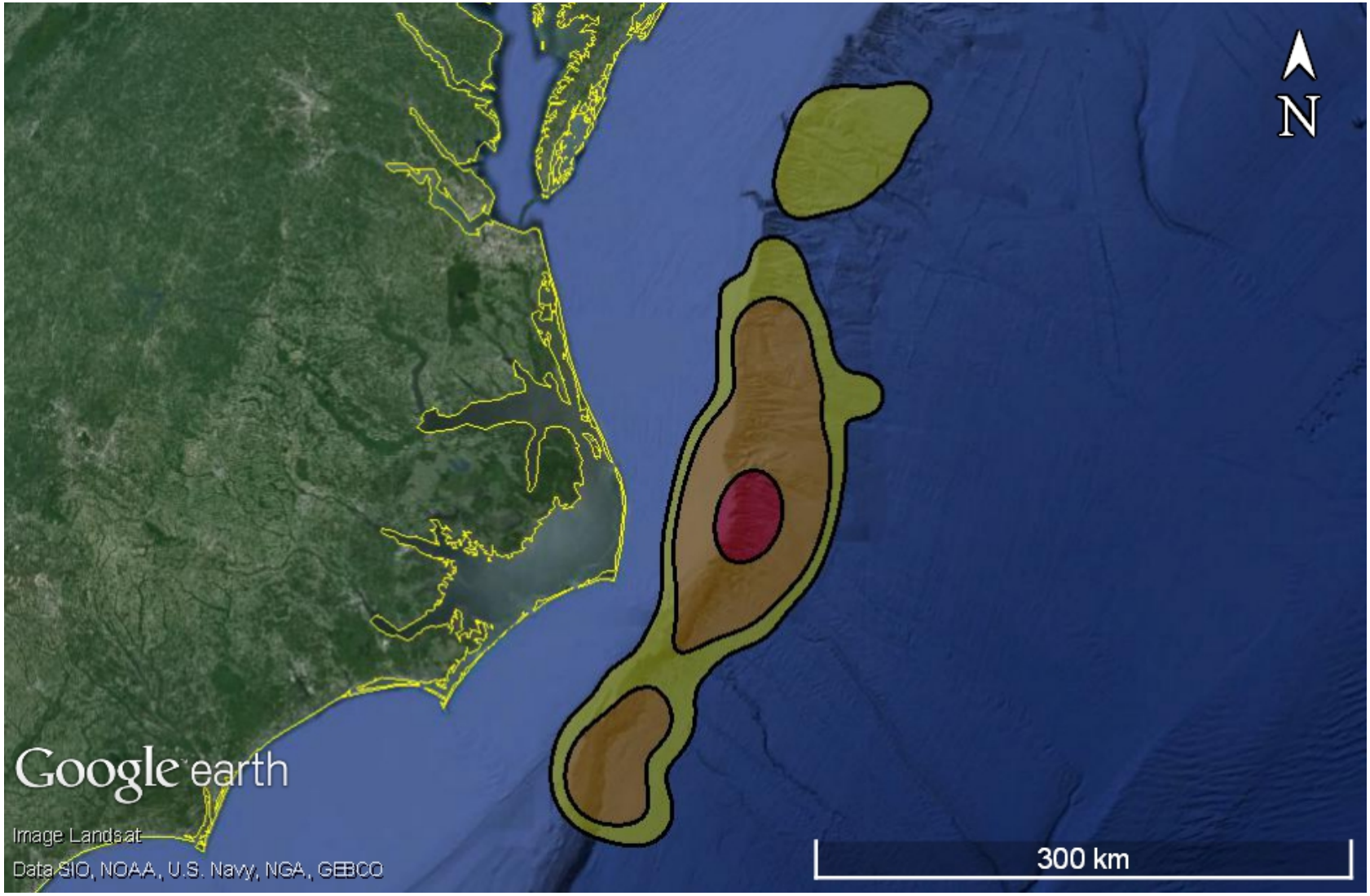


**Figure 12. A probability-density representation of Cuvier's beaked whale location data from all individuals tagged in 2014 (*n*=3) and 2015 (*n*=6). The red area indicates the 50% density polygon (the "core range"), the orange represents the 95% polygon, and the yellow represents the 99% polygon.**

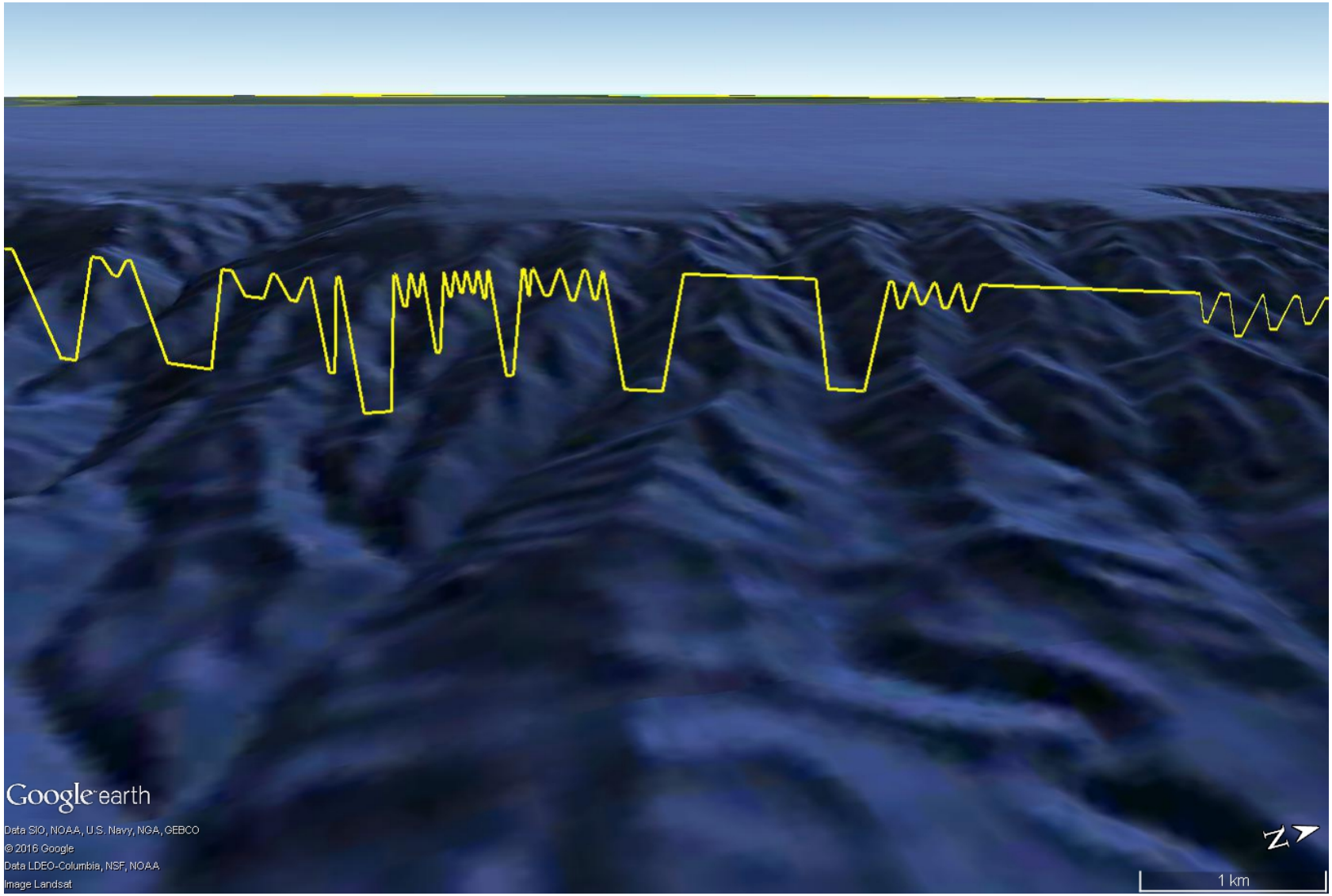


**Figure 13. An example pseudotrack of location and depth data from Cuvier's beaked whale ZcTag042 over a 20-hr period starting on 4 November 2015 at 0727 (GMT), traveling from right to left. The individual was located on the continental slope, with this perspective from offshore of the track and the land of Cape Hatteras visible in the back. The vertical (depth) axis is exaggerated. The deep dives shown here range from 887 to 1599 m in depth.**

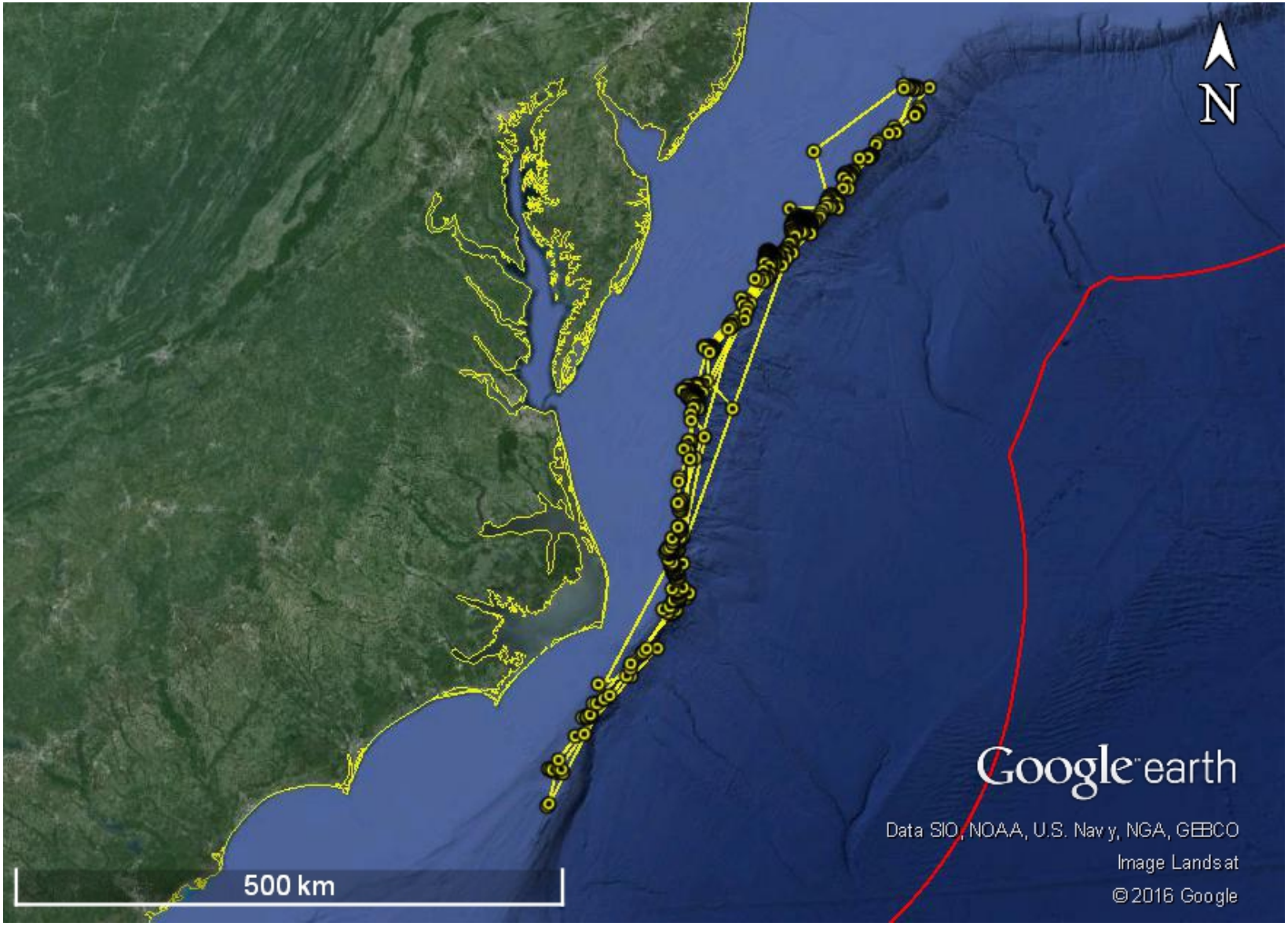


**Figure 14. Map showing all filtered locations (yellow circles) of short-finned pilot whale GmTag130 tagged on 16 June 2015 off North Carolina, over a 199-day period, with consecutive locations joined by a yellow line. The U.S. Exclusive Economic Zone boundary is shown in a solid red line.**

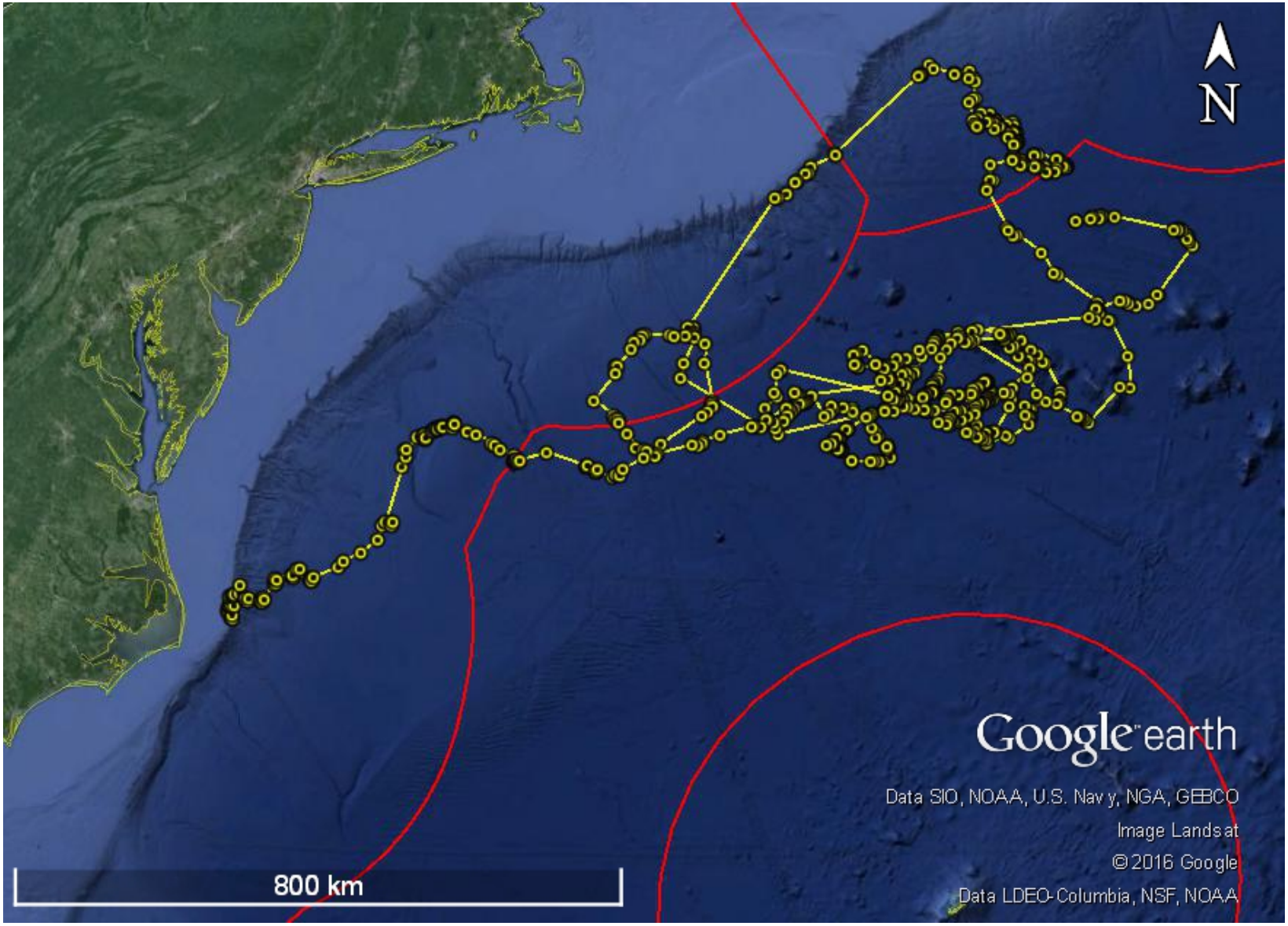


**Figure 15. Map showing all filtered locations (yellow circles) of short-finned pilot whale GmTag131 tagged on 16 June 2015 off North Carolina, over a 94-day period, with consecutive locations joined by a yellow line. The Exclusive Economic Zone boundaries of the U.S., Canada, and Bermuda are shown as solid red lines. GmTag131 was tagged during the same encounter as GmTag130 (see Figure 12).**

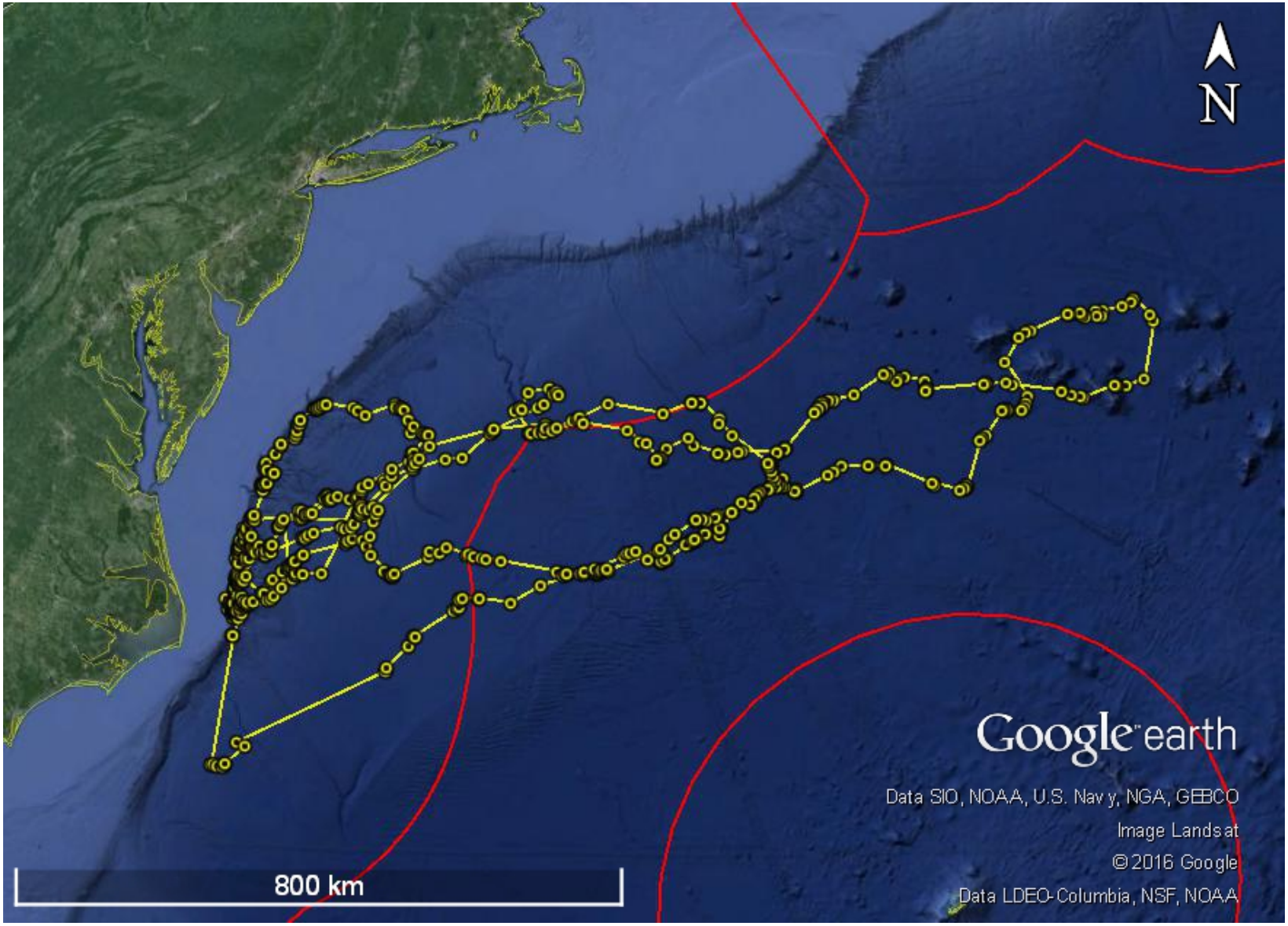


**Figure 16. Map showing all filtered locations (yellow circles) of short-finned pilot whale GmTag139 tagged on 20 October 2015 off North Carolina, over a 64-day period, with consecutive locations joined by a yellow line. The Exclusive Economic Zone boundaries of the U.S., Canada, and Bermuda are shown as solid red lines.**

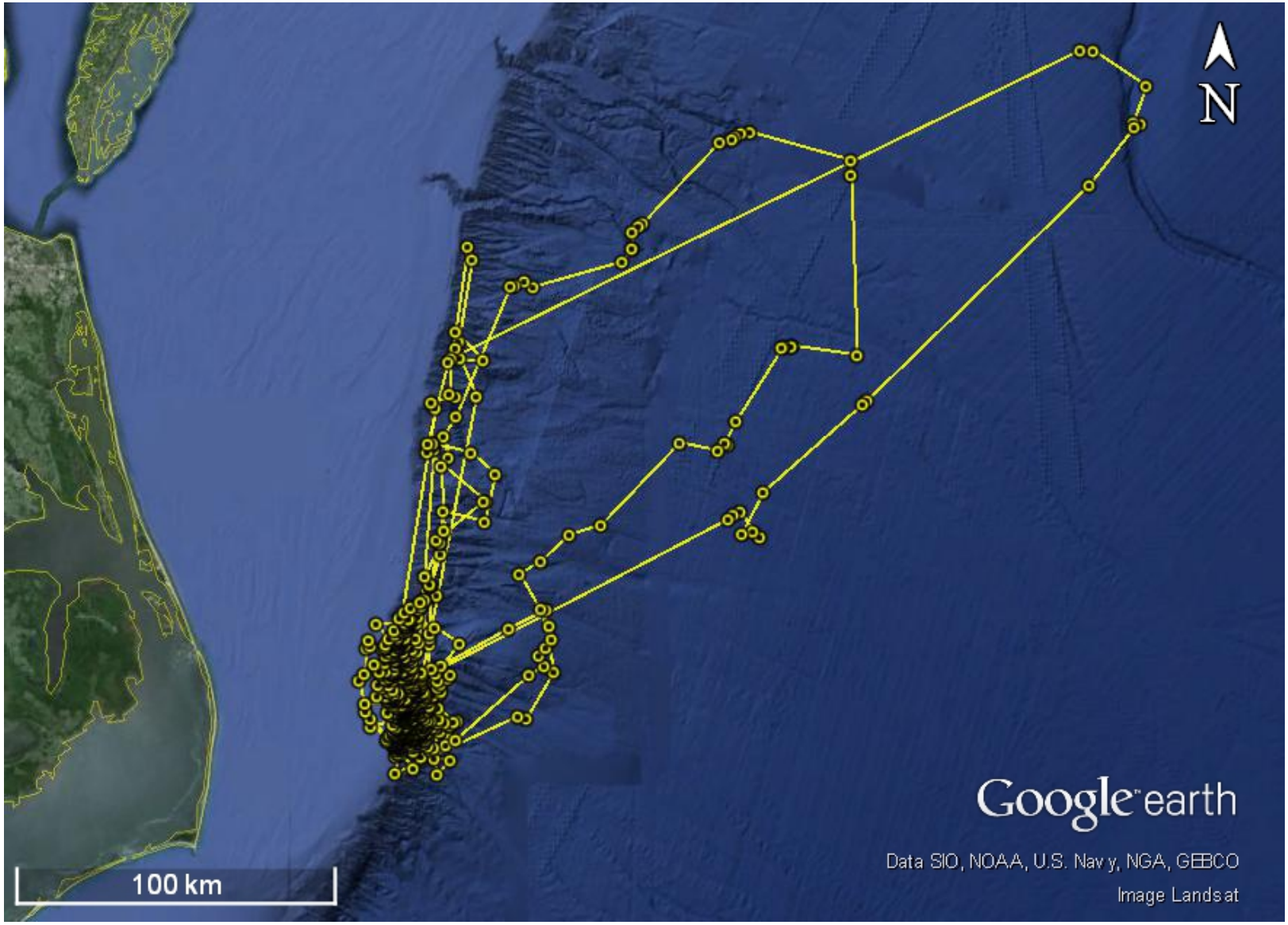


**Figure 17. Map showing all filtered locations (yellow circles) of short-finned pilot whale GmTag142 tagged 21 October 2015 off North Carolina, over a 101-day period, with consecutive locations joined by a yellow line. The U.S. Exclusive Economic Zone boundary is shown in a solid red line.**

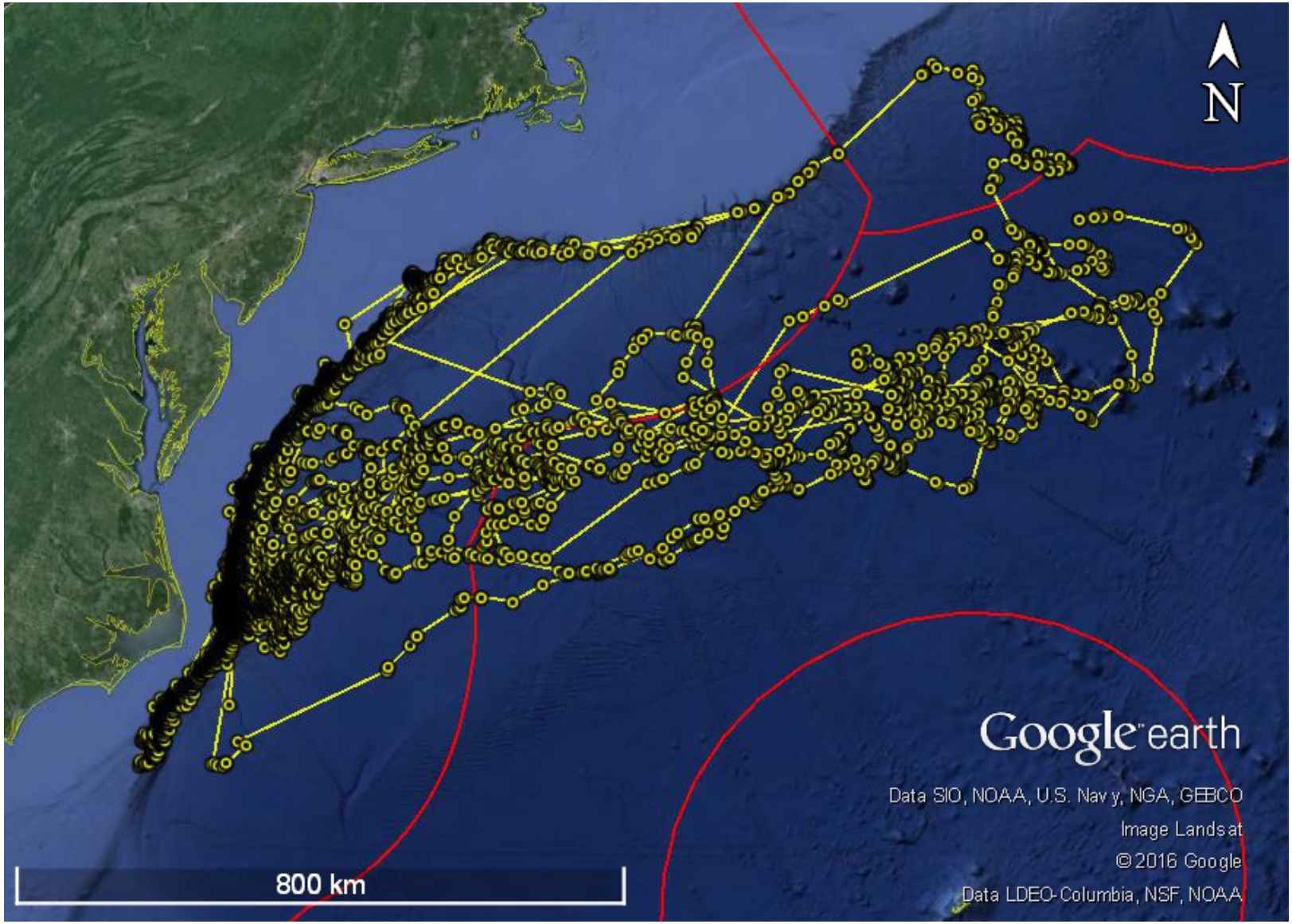


**Figure 18. Map showing all filtered locations (yellow circles) of short-finned pilot whale tagged off North Carolina in 2014 (*n*=17) and 2015 (*n*=19). See Baird et al. 2015 for details of deployments in 2014. The Exclusive Economic Zone boundaries for the U.S., Canada, and Bermuda are shown with solid red lines.**

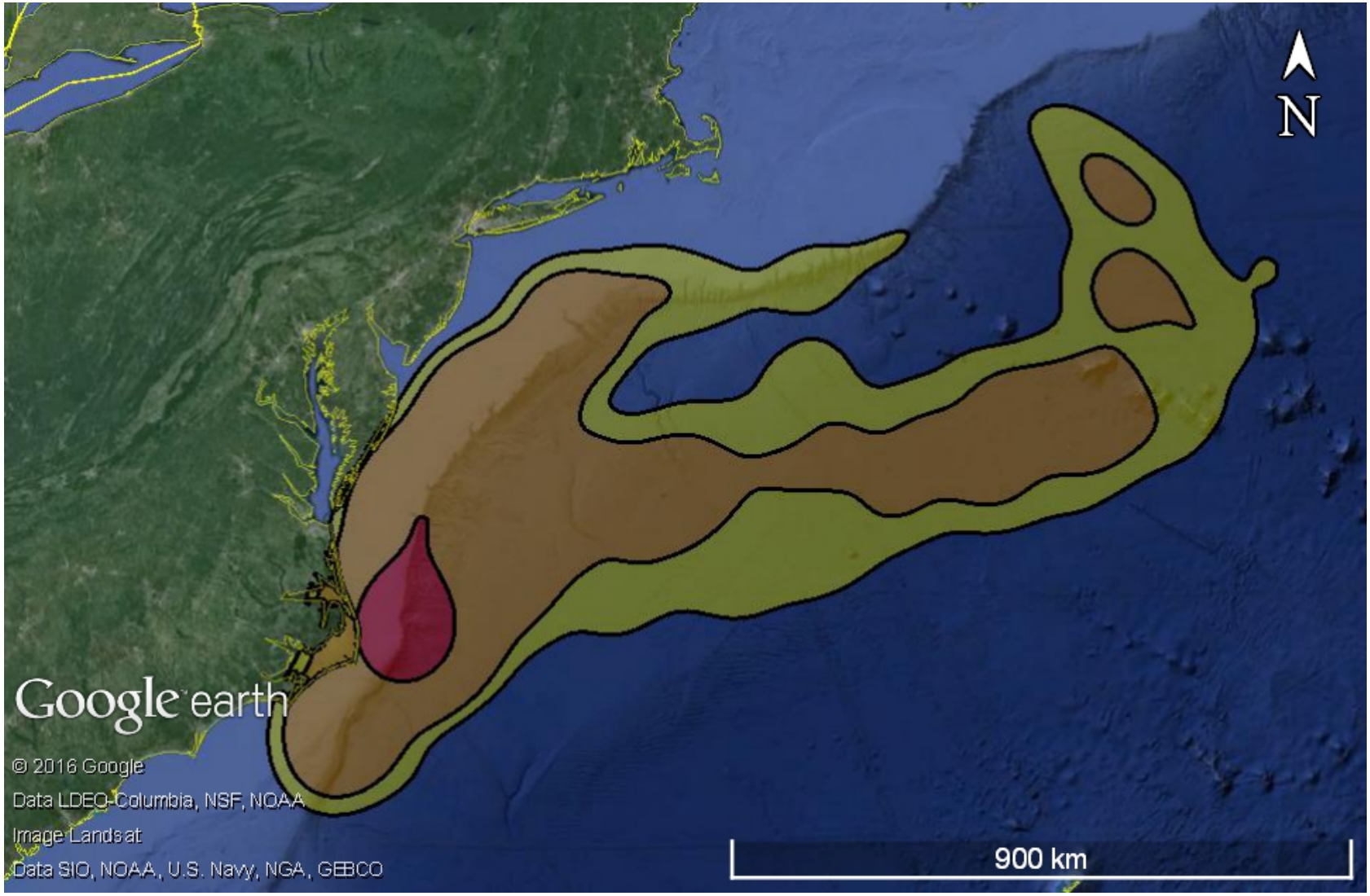


**Figure 19. A probability-density representation of short-finned pilot whale location data from all individuals tagged in 2014 (*n*=17) and 2015 (*n*=19). The red area indicates the 50% density polygon (the "core range"), the orange represents the 95% polygon, and the yellow represents the 99% polygon.**

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# Appendix B

## Tables

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**Table 1. Summary details on satellite tag deployments off Hatteras, North Carolina, during 2015.**

| Species[1] | Tag ID | Tag Type | Deployment Date | Sighting # | Tag duration (days) | Deployment Latitude (N) | Deployment Longitude (W) |
|---|---|---|---|---|---|---|---|
| Tt | TtTag024 | SPOT5 | 5/19/2015 | 2 | 18.4 | 35.54 | 74.70 |
| Tt | TtTag026 | SPOT5 | 10/15/2015 | 5 | 19.9 | 35.66 | 74.76 |
| Tt | TtTag027 | SPOT5 | 10/20/2015 | 11 | 28.8 | 35.68 | 74.67 |
| Tt | TtTag028 | SPOT5 | 10/21/2015 | 4 | 22.7 | 35.66 | 74.79 |
| Pm | PmTag026 | SPLASH10 | 6/14/2015 | 11 | 12.8 | 35.63 | 74.72 |
| Zc | ZcTag038 | SPLASH10 | 6/14/2015 | 1 | 56.4 | 35.60 | 74.74 |
| Zc | ZcTag039 | SPOT5 | 6/14/2015 | 1 | 39.4 | 35.64 | 74.71 |
| Zc | ZcTag040 | SPLASH10 | 6/14/2015 | 12 | 2.0 | 35.63 | 74.69 |
| Zc | ZcTag041 | SPLASH10 | 10/15/2015 | 2 | 34.3 | 35.61 | 74.77 |
| Zc | ZcTag042 | SPLASH10 | 10/21/2015 | 5 | 59.2 | 35.62 | 74.75 |
| Zc | ZcTag043 | SPOT5 | 10/21/2015 | 7 | 56.8 | 35.63 | 74.75 |
| Gm | GmTag122 | SPOT5 | 5/16/2015 | 1 | 58.1 | 35.78 | 74.86 |
| Gm | GmTag123 | SPLASH10 | 5/16/2015 | 5 | 14.0 | 35.73 | 74.81 |
| Gm | GmTag124 | SPOT5 | 5/16/2015 | 8 | 60.9 | 35.71 | 74.79 |
| Gm | GmTag125 | SPOT5 | 5/19/2015 | 12 | 139.2 | 35.63 | 74.79 |
| Gm | GmTag126 | SPOT5 | 5/19/2015 | 13 | 44.6 | 35.65 | 74.79 |
| Gm | GmTag127 | SPLASH10 | 5/19/2015 | 13 | 30.8 | 35.65 | 74.79 |
| Gm | GmTag128 | SPOT5 | 6/16/2015 | 7 | 38.7 | 35.58 | 74.78 |
| Gm | GmTag129 | SPOT5 | 6/16/2015 | 8 | 8.8 | 35.60 | 74.77 |
| Gm | GmTag130 | SPOT5 | 6/16/2015 | 8 | 199.1 | 35.61 | 74.78 |
| Gm | GmTag131 | SPOT5 | 6/16/2015 | 8 | 94.1 | 35.61 | 74.78 |
| Gm | GmTag134 | SPOT5 | 10/15/2015 | 4 | 57.4 | 35.67 | 74.76 |
| Gm | GmTag135 | SPLASH10 | 10/15/2015 | 4 | 31.2 | 35.65 | 74.76 |
| Gm | GmTag136 | SPOT5 | 10/16/2015 | 5 | 106.3* | 35.54 | 74.80 |
| Gm | GmTag137 | SPOT5 | 10/20/2015 | 1 | 102.4* | 35.62 | 74.81 |
| Gm | GmTag138 | SPLASH10 | 10/20/2015 | 1 | 25.0 | 35.61 | 74.81 |
| Gm | GmTag139 | SPOT5 | 10/20/2015 | 7 | 64.2 | 35.67 | 74.63 |
| Gm | GmTag140 | SPOT5 | 10/20/2015 | 14 | 12.6 | 35.67 | 74.71 |
| Gm | GmTag141 | SPOT5 | 10/20/2015 | 15 | 34.2 | 35.67 | 74.73 |
| Gm | GmTag142 | SPOT5 | 10/21/2015 | 10 | 101.4* | 35.63 | 74.77 |

Gm = *Globicephala macrorhynchus*; Tt = *Tursiops truncatus*, Zc = *Ziphius cavirostris;* , *Tags still transmitting as of 31 January 2016;. Key: Spot = Smart Position and Temperature

**Table 2. Characteristics of movements in relation to tagging distance for satellite-tagged odontocetes tagged off North Carolina in 2015.**

| Tag ID | # locations after filtering | Mean (SD) distance from tagging location (km) | Maximum distance from tagging location (km) | Total distance traveled (km) |
|---|---|---|---|---|
| TtTag024 | 184 | 41.1 (44.5) | 163.8 | 1,145.5 |
| TtTag026 | 222 | 26.8 (21.6) | 89.3 | 1,378.2 |
| TtTag027 | 302 | 14.9 (5.8) | 32.6 | 1,467.2 |
| TtTag028 | 240 | 34.3 (28.1) | 99.9 | 1,152.2 |
| PmTag026 | 39 | 71.5 (47.7) | 164.5 | 676.4 |
| ZcTag038 | 147 | 33.3 (26.5) | 96.9 | 1,343.0 |
| ZcTag039 | 119 | 25.2 (13.3) | 59.6 | 935.7 |
| ZcTag040 | 12 | 11.8 (5.8) | 16.4 | 53.6 |
| ZcTag041 | 84 | 15.2 (7.3) | 33.0 | 669.5 |
| ZcTag042 | 137 | 20.6 (11.3) | 56.2 | 1,081.7 |
| ZcTag043 | 210 | 14.2 (9.2) | 42.8 | 1,203.4 |
| GmTag122 | 429 | 56.7 (85.1) | 336.2 | 2,839.8 |
| GmTag123 | 147 | 52.7 (51.7) | 151.1 | 821.5 |
| GmTag124 | 486 | 81.1 (92.6) | 337.9 | 2,848.6 |
| GmTag125 | 415 | 53.3 (59.2) | 212.1 | 3,137.0 |
| GmTag126 | 273 | 242.0 (174.8) | 529.5 | 2,142.8 |
| GmTag127 | 317 | 54.6 (60.4) | 165.8 | 1,315.8 |
| GmTag128 | 251 | 35.8 (45.2) | 168.9 | 1,728.7 |
| GmTag129 | 89 | 74.7 (62.3) | 168.0 | 475.9 |
| GmTag130 | 752 | 261.2 (119.7) | 490.9 | 5,809.2 |
| GmTag131 | 594 | 844.4 (323.4) | 1317.6 | 5,953.5 |
| GmTag134 | 488 | 27.0 (36.8) | 194.6 | 2,591.6 |
| GmTag135 | 280 | 39.9 (48.0) | 193.6 | 1,620.3 |
| GmTag136* | 570 | 17.4 (29.8) | 173.5 | 2,594.2 |
| GmTag137* | 618 | 88.7 (86.9) | 315.9 | 4,634.9 |
| GmTag138 | 278 | 192.8 (64.3) | 290.9 | 1,498.0 |
| GmTag139 | 506 | 390.0 (329.0) | 1218.1 | 6,905.5 |
| GmTag140 | 11 | 47.0 (58.7) | 155.5 | 367.5 |
| GmTag141 | 321 | 70.4 (59.7) | 201.0 | 2,164.2 |
| GmTag142* | 537 | 30.3 (50.4) | 298.2 | 3,614.5 |

Key: Tt = *Tursiops truncatus* (bottlenose dolphin); Pm = *Physeter macrocephalus*; Gm = *Globicephala macrorhynchus* (short-finned pilot whale); km = kilometer(s); Zc = *Ziphius cavirostris* (Cuvier's beaked whale); *Tags still transmitting as of 31 January 2016.

**Table 3. Depth and distance from shore and the 200-m isobath from GIS analysis of filtered satellite-tag locations.**

| Tag ID | Depth (m) | | Distance from shore (km) | | | Distance from 200-m isobath (km) | |
|---|---|---|---|---|---|---|---|
| | Median | Max | Min | Median | Max | Median | Max |
| TtTag024 | 1,263.7 | 2,360.2 | 35.0 | 64.0 | 107.4 | 3.5 | 42.8 |
| TtTag026 | 1,363.5 | 2,101.3 | 55.2 | 70.0 | 118.4 | 6.0 | 38.7 |
| TtTag027 | 1,210.6 | 2,349.4 | 57.9 | 65.1 | 92.7 | 2.4 | 28.7 |
| TtTag028 | 477.5 | 1,777.9 | 44.6 | 65.0 | 104.5 | 4.0 | 19.3 |
| PmTag026 | 2,673.4 | 3,479.1 | 37.1 | 113.8 | 228.5 | 45.5 | 159.1 |
| ZcTag038 | 1,600.7 | 2,378.9 | 52.7 | 75.0 | 109.6 | 11.5 | 45.0 |
| ZcTag039 | 1,522.8 | 2,629.3 | 41.0 | 64.5 | 90.9 | 4.7 | 31.5 |
| ZcTag040 | 1,124.6 | 1,964.6 | 61.4 | 64.0 | 73.3 | 1.4 | 10.0 |
| ZcTag041 | 1,240.1 | 2,409.3 | 50.3 | 64.5 | 81.2 | 4.2 | 19.6 |
| ZcTag042 | 1,616.6 | 2,700.5 | 52.0 | 66.1 | 86.4 | 5.9 | 28.7 |
| ZcTag043 | 1,163.7 | 2,059.0 | 47.7 | 64.5 | 75.7 | 2.5 | 16.1 |
| GmTag122 | 358.4 | 1,940.5 | 50.7 | 61.8 | 140.4 | 3.7 | 21.5 |
| GmTag123 | 623.3 | 1,801.5 | 52.2 | 71.9 | 118.2 | 3.2 | 16.5 |
| GmTag124 | 945.2 | 3,635.0 | 39.4 | 74.3 | 291.0 | 7.0 | 166.4 |
| GmTag125 | 309.8 | 2,106.5 | 45.1 | 63.2 | 114.0 | 3.4 | 19.1 |
| GmTag126 | 327.5 | 1,796.0 | 45.8 | 113.6 | 158.5 | 2.4 | 18.1 |
| GmTag127 | 325.7 | 1,591.3 | 47.7 | 61.6 | 120.7 | 3.6 | 16.0 |
| GmTag128 | 449.6 | 2,145.3 | 50.3 | 62.1 | 121.3 | 3.7 | 24.6 |
| GmTag129 | 402.0 | 1,759.8 | 53.3 | 70.6 | 110.3 | 3.8 | 10.3 |
| GmTag130 | 435.3 | 2,269.4 | 41.0 | 124.5 | 164.1 | 2.0 | 37.3 |
| GmTag131 | 4,726.6 | 5,219.9 | 57.6 | 456.9 | 663.7 | 274.3 | 501.8 |
| GmTag134 | 920.2 | 2,919.9 | 43.0 | 63.4 | 148.4 | 4.1 | 84.4 |
| GmTag135 | 950.5 | 2,999.1 | 36.4 | 64.8 | 148.6 | 3.9 | 84.6 |
| GmTag136* | 690.8 | 2,092.2 | 46.2 | 61.6 | 116.0 | 2.9 | 23.5 |
| GmTag137* | 500.3 | 2,353.3 | 50.3 | 81.3 | 135.6 | 4.0 | 31.5 |
| GmTag138 | 823.3 | 2,994.8 | 58.7 | 104.6 | 218.9 | 5.2 | 116.1 |
| GmTag139 | 3,448.9 | 5,246.2 | 57.1 | 265.8 | 658.7 | 154.5 | 509.2 |
| GmTag140 | 1,134.7 | 1,659.2 | 64.1 | 74.1 | 104.5 | 4.9 | 10.9 |
| GmTag141 | 1,182.5 | 3,362.9 | 52.0 | 93.8 | 228.9 | 7.7 | 141.6 |
| GmTag142* | 744.1 | 3,653.8 | 46.0 | 61.9 | 276.6 | 5.2 | 164.5 |

Key Tt = *Tursiops truncatus* (bottlenose dolphin); Gm = *Globicephala macrorhynchus* (short-finned pilot whale); km = kilometer(s); m = meter(s); Zc = *Ziphius cavirostris* (Cuvier's beaked whale)

**Table 4. Summary of diving behavior data from location-depth tags.**

| Tag ID | # days behavior data | % of total record | # dives >50 m | Max dive depth (m) | Max dive duration (min) |
|---|---|---|---|---|---|
| PmTag026 | 5.4 | 48.3 | 91 | 1,295.5 | 55.7 |
| ZcTag038 | 34.4 | 61.0 | 1,517 | 2,351.5 | 87.6 |
| ZcTag040* | 0.8 | 44.4 | 35 | 1,615.5 | 68.3 |
| ZcTag041 | 23.3 | 72.1 | 969 | 1,807.5 | 114.7 |
| ZcTag042* | 10.1 | 53.8 | 446 | 2,159.5 | 90.3 |
| GmTag123 | 7.1 | 56.7 | 382 | 991.5 | 19.5 |
| GmTag127 | 22.7 | 80.6 | 977 | 1,199.5 | 23.9 |
| GmTag135 | 21.9 | 77.6 | 860 | 1,071.5 | 24.6 |
| GmTag138 | 13.5 | 63.1 | 455 | 1,231.5 | 21.9 |

Key: % = percent; Pm = *Physeter macrocephalus* (sperm whale); Gm = *Globicephala macrorhynchus* (short-finned pilot whale); m = meter(s); min = minute(s); Zc = *Ziphius cavirostris* (Cuvier's beaked whale). *Depth transducer failed prior to end of transmission period (data shown only for period prior to transmitter failure).

**Table 5. Distances between selected pairs of short-finned pilot whales with temporally overlapping tag data. Distances are calculated when locations are received during the same satellite overpass. All pairs tagged within the same group and on the same day are shown, and selected pairs tagged on different days are included.**

| Pair | Mean distance apart (km) | Max distance apart (km) | Timing of tagging |
|---|---|---|---|
| GmTag126-127 | 68.9 | 385.7 | Same group |
| GmTag130-131 | 656.8 | 988.6 | Same group |
| GmTag134-135 | 2.0 | 16.0 | Same group |
| GmTag137-138 | 85.6 | 265.2 | Same group |
| GmTag129-130 | 2.1 | 7.2 | Same group |
| GmTag129-131 | 170.3 | 351.3 | Same group |
| GmTag122-124 | 123.1 | 343.4 | Same day |
| GmTag122-123 | 44.6 | 159.3 | Same day |
| GmTag123-124 | 155.8 | 340.5 | Same day |
| GmTag125-126 | 193.8 | 424.7 | Same day |
| GmTag125-127 | 42.1 | 154.6 | Same day |
| GmTag128-129 | 77.5 | 180.3 | Same day |
| GmTag128-130 | 218.3 | 335.2 | Same day |
| GmTag128-131 | 671.3 | 1,043.2 | Same day |
| GmTag137-139 | 362.5 | 1,227.3 | Same day |
| GmTag137-140 | 35.2 | 140.5 | Same day |
| GmTag137-141 | 67.8 | 200.8 | Same day |
| GmTag138-139 | 278.3 | 1,119.7 | Same day |
| GmTag138-140 | 89.3 | 223.2 | Same day |
| GmTag138-141 | 101.1 | 263.0 | Same day |
| GmTag139-140 | 44.1 | 149.4 | Same day |
| GmTag139-141 | 430.5 | 1,240.9 | Same day |
| GmTag140-141 | 21.7 | 48.4 | Same day |
| GmTag122-125 | 40.2 | 216.2 | Different day |
| GmTag125-130 | 184.3 | 437.7 | Different day |
| GmTag127-129 | 15.1 | 27.9 | Different day |
| GmTag127-130 | 5.8 | 13.9 | Different day |
| GmTag136-137 | 85.0 | 284.4 | Different day |
| GmTag137-142 | 83.0 | 279.7 | Different day |

Key: Gm = *Globicephala macrorhynchus* (short-finned pilot whale); km = kilometer(s)

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