

# Atlantic Behavioral Response Study (Atlantic-BRS)

## 2025

*ANNUAL PROGRESS REPORT*



PREPARED BY

*Southall Environmental Associates*



*Duke University*

*CREEM—University of St Andrews*



University of  
St Andrews



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Science  Stewardship  Protection

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## Acronyms and Abbreviations

°N	degrees North
°W	degrees West
Atlantic-BRS	Atlantic Behavioral Response Study
BRS	behavioral response study
CAS	continuous active sonar
CEE	controlled exposure experiment
dB	decibel(s)
DTAG	digital acoustic recording tag
DUML	Duke University Marine Lab
EDT	Eastern Daylight Time
FM	frequency-modulated
HARP	High-frequency Acoustic Recording Package
Hz	hertz
ID	Identification Number
IDDI	inter-deep-dive-interval
kHz	kilohertz
km	kilometer(s)
kt	knot(s)
lat	latitude
LIMPET	Low-impact Minimally Percutaneous Electronic Transmitter
LMR	Living Marine Resources
lon	longitude
m	meter(s)
Max. (or max)	Maximum
MFAS	mid-frequency active sonar
min	minute(s)
N/A	not applicable
NAVFAC	Naval Facilities Engineering Systems Command
nm	nautical mile(s)
NPS	Naval Postgraduate School
ONR	Office of Naval Research
PAS	pulsed active sonar
photo-ID	photo-identification
R/V	Research Vessel
RL	received level
RMS	root mean square
SEA	Southall Environmental Associates

SLTDR (or sat tag)	satellite-linked, time-depth recording tag
SOCAL-BRS	Southern California Behavioral Response Study
SPL	sound pressure level
SPOT	Smart Position and Temperature
U.S.	United States
USFF	U.S. Fleet Forces Command
USS	United States Ship
UTC	Coordinated Universal Time
Zc ( <i>Ziphius</i> )	<i>Ziphius cavirostris</i>



# Executive Summary

The Atlantic Behavioral Response Study (Atlantic-BRS) is a multi-institutional, multi-phase collaboration of experienced scientists working together with the United States (U.S.) Navy. It directly addresses some of the highest priority regulatory questions, species (including beaked whales [family Ziphiidae]), and challenges facing the U.S. Navy in meeting its mandated regulatory requirements for training and testing under several federal statutes. This series of studies has evolved from historical and ongoing U.S. Navy-funded studies under their Marine Species Monitoring Program, the Living Marine Resources Program, and the Office of Naval Research Marine Biology Program. This project occurs off Cape Hatteras, North Carolina, and has evolved into a multi-phased effort to evaluate and quantify the behavioral responses of high-priority marine mammal species to different kinds of U.S. Navy mid-frequency active sonar (MFAS) systems. These include simulations of pulsed active sonar (PAS); operational PAS from SQS-53C systems on U.S. Navy surface vessels; and continuous active sonar (CAS), also from simulated sources and operational surface vessels.

An adaptive multi-scale approach prioritizing many simultaneously tagged individuals for baseline monitoring and conducting behavioral response studies is applied for key species: primarily goose-beaked whales (*Ziphius cavirostris*; hereafter *Ziphius*); and, secondarily, short-finned pilot whales (*Globicephala macrorhynchus*). This program includes the first measurements of sonar exposure (from multiple military systems) and behavioral responses of priority marine mammal species to military sonar using controlled exposure experiments (CEEs) off the U.S. Atlantic coast, now with multiple sonar systems. Building on earlier field seasons (see [Southall et al. 2018](#), [2019](#), [2020](#), [2021](#), [2022](#), [2023](#), [2024](#), [2025](#)), this project has yielded the largest and most comprehensive data set available for *Ziphius* baseline behavior and responses to U.S. Navy sonar.

The 2025 field season, which occurred in a single continuous effort from June through September, included one of the study team's most successful campaigns to date in terms of tagging and field operations; U.S. Navy operational coordination; and the fielding of a new, key piece of equipment developed by the U.S. Navy. Multiple CAS-capable vessels were scheduled for possible coordination, thanks to sustained coordination and planning between the field team and U.S. Fleet Forces Command. These efforts yielded among the largest number of beaked whale tags deployed in any U.S. Navy-supported field seasons ( $n=14$ ), with excellent performance in terms of the duration of tags (nine tags exceeding 30-day duration, including the team's longest-ever duration at over 250 days and still transmitting as of 1 June 2026), and high-priority beaked whales monitored in CEEs. The study team conducted two CEEs in 2025 with 11 total *Ziphius* CAS-exposure events. This included extensive coordination with the United States Ship (USS) *Donald Cook* (DDG-75) to conduct the second-ever operational CAS CEE ( $n=7$ ) as well as the first-ever CEE with a newly constructed MFAS high-power experimental source simulating CAS signals ( $n=4$ ).



Extensive analytical effort continued to substantially advance the existing, large, baseline data sets for baseline behavior; analytical and technological tools for evaluating MFAS received levels; and new analytical tools for quantifying behavioral responses to MFAS. A very large sample size (more than tripling the available data from all earlier beaked whale studies combined), *Ziphius* MFAS response paper focused on simulated PAS signals was published.



# 1. Overview

## 1.1 Overall Project Design and Objectives

The Atlantic Behavioral Response Study (Atlantic-BRS) is a research program with sequential phases that measures the exposure and responses of high-priority protected species to United States (U.S.) Navy sonar sources and directly supports environmental compliance requirements. Source selection and experimental design is coordinated directly with the U.S. Navy's Marine Species Monitoring Program to address U.S. Navy needs for regulatory compliance assessment. This program has been unique in the amount and reliability of direct coordination with operational U.S. Navy assets (surface vessels, including U.S. Navy destroyers with operational SQS-53C sonar systems) to project full-power mid-frequency active sonar (MFAS) in strategically targeted, realistic conditions to meet monitoring objectives.

The project brings together a research collaboration of scientists from Duke University, Southall Environmental Associates (SEA), Bridger Consulting, Calvin University, and the University of St. Andrews to measure baseline behavior and the effects of different kinds of active military sonar systems on marine mammals off the coast of Cape Hatteras, North Carolina. The overall experimental design was adapted from methods initially developed in the [Southern California Behavioral Response Study](#) (SOCAL-BRS), funded primarily by the U.S. Navy's Living Marine Resources (LMR) program and Office of Naval Research (ONR) Marine Biology program. Novel integrations and strategic deployments of different tag sensors and controlled exposure experiments (CEEs) on variable time and space scales, including different types of active acoustic sources, have been applied to the primary focal species: goose-beaked whales (*Ziphius cavirostris*; referred to hereafter as *Ziphius*), and secondary focal species short-finned pilot whales (*Globicephala macrorhynchus*). This collaboration has had substantial success in tagging beaked whales and conducting CEEs due to reliable coordination with operational MFAS (1 to 10 kilohertz [kHz]) systems from U.S. Navy surface vessels (e.g., SQS-53C-equipped surface vessels).

The overall objective of the study is to directly measure exposure behavioral responses to U.S. Navy MFAS and quantify behavioral response probability for these types of responses in relation to key exposure variables (e.g., received sound level, proximity, animal behavioral state). These measurements have and will directly contribute to more informed assessments of the probability and magnitude of potential behavioral responses of these species. The focus of these studies in recent years has been solely on the highest-priority species for the U.S. Navy in meeting their mandated requirements to assess the impacts of training and testing activities on protected species, specifically *Ziphius*. This has included baseline behavior and exposure-response, and providing sufficiently large sample sizes to begin addressing exposure population consequences for this high-priority species. In 2025, however, analytical effort also pivoted back to earlier CEEs with pilot whales as well, in coordination with several U.S. Navy research labs, thus directly addressing focal areas for the U.S. Navy's Marine Species Monitoring Program for multiple species.

Many U.S. Navy-funded studies of marine mammal responses to MFAS, including the SOCAL-BRS, focused on the use of short-term, high-resolution acoustic tag sensors (or alternative short-duration monitoring means) to measure fine-scale behavior in response to experimentally controlled noise exposure. Other studies have used coarser-scale, longer-term measurements of movement and diving behavior associated with incidental exposures during sonar training operations. The Atlantic-BRS project applies both approaches, expanding the temporal and spatial scales of previous behavioral response studies (BRSs) by combining (1) short-term, high-resolution acoustic archival tags (or digital acoustic recording tags [DTAGs]) providing short-term (hours) but very high-resolution movement and calibrated acoustic data with (2) satellite-linked, time-depth recording tags (SLTDRs or “sat tags”]) providing much longer-term (weeks to months) data on movement and increasingly higher resolution dive data, which are simultaneously deployed on multiple individuals of focal species in the same CEEs. Strategically specified categories of potential behavioral responses are evaluated using a variety of custom and adapted proven and published statistical methods. These are tuned to address specific, biologically meaningful types of responses, namely (1) potential avoidance of sound sources that influence habitat usage, (2) changes in foraging behavior, and (3) changes in social behavior.

Earlier field seasons involved pulsed active sonar (PAS) signals (approximately 1.5-second duration; 25-second duty cycle; approximately 6 percent duty cycle) from both simulated and operation MFAS sources. These results (respectively) have recently been ([Southall et al. 2026](#)) and are currently being finalized for publication in peer-reviewed scientific journals. Beginning in 2023, the Atlantic-BRS project began investigating responses to continuous active sonar (CAS). While CAS signals are similar to PAS in frequency and overall modulation patterns, they are presented either continuously (100 percent duty cycle; as in this study) or nearly continuously (greater than 50 percent duty cycle). And while the total output power of these signals may be similar in terms of total energy, the root-mean-square (RMS) sound pressure levels (SPLs) are consequently lower. Therefore, the overall exposure context is quite different, and there is interest in directly measuring and contrasting exposure and response from CAS stimuli with the large PAS data set obtained thus far. This shift to focus on CAS was also done to address specified need topics identified by the U.S. Navy’s LMR program, which is providing supporting supplemental funding for the program in coordination with the U.S. Navy’s marine species monitoring program.

This annual progress report covers the 2025 field season and subsequent analyses. It provides a synthesis of experimental methods; field efforts; tagging results; and exposure-response results for two CEEs, including the second operational CAS CEE conducted with the United States Ship (USS) *Donald Cook* and the first-ever high-power experimental source CEE simulating CAS operations. It also includes a detailed analysis of the Kinéis satellite data receiving system relative to legacy ARGOS systems (**Section 3**). Finally, it includes a synthesis of peer-reviewed papers that have been or are in the process of being published (see **Section 4**).

## 1.2 Experimental Design

The Atlantic-BRS program applies multiple tracking and monitoring methodologies and platforms, incorporating approaches and tools transitioned from multiple programs funded by the U.S. Navy. These included quantitative measurements of individual behavior using tags of several types, small-vessel-based individual and group focal follow observations, targeted collection of individual tissue biopsy samples, photo-identification (photo-ID), and remote passive acoustic monitoring from archival recorders.

The CAS CEE experimental design was deliberately held consistent with that used to evaluate PAS MFAS and includes identical duration CEE phases (pre-exposure [no MFAS]), exposure (specified MFAS transmissions), post-exposure, tagging approaches, and on-water vessel and observer operations to make the results in terms of animal response be as comparable in terms of methodology and context as possible. Source positions are determined *in situ* based on U.S. Navy-developed modeling tool results based on MFAS signal output parameters to achieve target received levels (RLs) at focal receiving individuals. For CAS signals, these are calculated and matched to PAS exposures in terms of signal energy (sound exposure level (SEL) in “dB re 1  $\mu\text{Pa}^2\text{-s}$ ”) given the difference in temporal patterns between repeated signals. Source movement was also designed to be identical for CAS-capable ships as in PAS CEEs. The Atlantic-BRS team used unclassified stimulus parameters provided via U.S. Fleet Forces Command (USFF) for CAS signals, including a slightly lower fundamental frequency range (2.5 to 3.2 kHz [650-hertz (Hz) bandwidth]) and a 50-second sweep duration that was repeated continuously (100 percent duty cycle). Unclassified source levels were not available, so an equal energy assumption (10 log duration) was used to approximate levels for individual CAS and PAS ping. This resulted in an estimated (per ping) 218-decibel (dB) RMS source level estimate for the CAS signal band.

As noted, through close coordination with collaborators at USFF, the methods had been successfully applied during the Atlantic-BRS and by seven different U.S. Navy surface vessels during earlier field efforts, resulting in eight CEEs with PAS stimuli. This approach includes a period prior to CEEs during which baseline behavioral data were collected—a 60-minute minimum for animals with DTAGs and a 24-hour minimum for animals with sat tags. Most baseline SLTDR data periods were much longer (weeks to many months) in practice for sat tags. Pre-exposure baseline behavioral data collection primarily involved data from tag sensors, supplemented by focal follows of tagged animals when possible. Transmissions were designed to occur for 60 minutes, with the transmitting ship transiting in a direct course at a net (over-ground) speed of 8 knots with an oblique approach toward focal tagged whales. For a more detailed discussion of the methodological foundation for the Atlantic-BRS experimental design and how it was developed and evolved, readers are referred to earlier project reports and published papers from other U.S. Navy-funded work (Southall et al. [2012](#), [2016](#), [2019](#); [2026](#); [Schick et al. 2019](#), [2024](#)). Atlantic-BRS publications referenced in this report (see **Section 4**) provide additional details regarding the design and implementation of these methods.

Based on focal animal locations, the starting position and course for the transmitting vessel was determined using custom propagation modeling tools developed and supported by the Naval Postgraduate School (NPS). The experimental design allows for positioning of MFAS sources, resulting in target RLs at focal individuals based on their position, and accounting for local bathymetry and dynamic oceanographic conditions. However, other individuals were incidentally exposed at a variety of RLs that were not explicitly controlled but estimated (with error) from positions derived from either sat tags or field observations. The course of the vessel was designed to result in an escalation in RL at the presumed location of focal individuals based on their movement. Given the large number of tagged individuals exposed during CEEs, individuals have had (by design) varied MFAS exposure conditions in terms of range and RL. For PAS stimuli, target (and repeatedly achieved) RLs (in terms of per ping RMS values) for focal animals ranged from 120 to 160 dB, depending upon species and the aggregate location of focal individuals (120 to 140 dB for beaked whales, 135 to 160 dB for pilot whales). For CAS stimuli, these target levels were adjusted based on a 10 log (50-second) offset to account for the much longer stimulus duration (i.e., beaked whale target RLs for CAS signals ranged from approximately 103 to 123 dB SPL). These target RLs were identical for experimentally simulated CAS signals, although horizontal ranges were smaller given the approximately 18 dB difference in output power between operational (assumed) and experimental (known output; measured) source levels.

Satellite-transmitting tag setting approaches successfully developed during earlier efforts were maintained to provide up to 20 days of continuous, relatively high-duration (5-minute time series) dive data, with ARGOS positional data being collected for weeks or months longer. This was done to increase the data resolution during a focal period when U.S. Navy ships were expected to be available. The objective was, therefore, to conduct one operational MFAS CEE within an approximately 2-week window following sat tag deployments, with subsequent tagging effort for potentially conducting additional CEEs based on ship availability.

### 1.3 Overall Analytical Approach

Behavioral response analyses focus on how whales change their behavior from baseline conditions during periods of MFAS exposure in known contexts during CEEs. Analyses of potential response type, probability, and severity apply methods developed during other BRSs and Atlantic-BRS efforts to date, including close coordination with other U.S. Navy-funded analytical development teams. Specific questions and methods are derived for differences in available data (tag type) and species in question, specifically considering questions of (1) potential avoidance behavior, (2) potential changes in behavioral state, and (3) potential changes in social behavior.

In earlier phases of the field effort, extensive progress was made in developing systematic methods to process the tens of thousands of hours of tag, acoustic, and visual data collected during many tag deployments made each year. While increasingly efficient, these complex processes require extensive time and effort to process raw data; filter and finalize integrated data streams; and, ultimately, quantify behavior to address these three questions. In each of the previous reports, several tables and figures describing detailed aspects of data processing and analyses were provided to demonstrate these approaches. These evolved and became more

complex within the first several years; however, by 2019 (see [Southall et al. 2020](#): Section 1.3), they were sufficiently mature that they were maintained and have continued to be applied in a consistent manner to subsequent data sets. These approaches have recently been published in a high-profile peer-reviewed journal evaluating all aspects of behavioral response described above for a relatively large sample size (for any marine mammal species, but especially beaked whales) of *Ziphius* exposure events ( $n=72$ ; [Southall et al. 2026](#)).

## 1.4 Field Logistics and Configuration

Atlantic-BRS field efforts for 2025 were conducted intermittently and adaptively given field conditions and U.S. Navy vessel schedules, across a single field season that ran from June through September. Tagging priority was placed on *Ziphius* during the 2025 field season. Field operations involved up to a dozen research personnel on several platforms, coordinating with U.S. Navy vessels as possible.

Field teams included a small boat-based team (crew of four to five) aboard the Duke University Research Vessel (R/V) *Richard T. Barber* (hereafter R/V *Barber*), an 8-meter (m), aluminum-hulled vessel, conducting advanced deployment of sat tags as well as DTAGs during target windows. The field crew transited offshore daily when sea conditions were suitable; located animals; deployed tags; and collected photo-ID, biopsy, and other data from groups. During periods of good conditions for locating tagging candidates, resighting tagged individuals, collecting photo-ID and additional biopsy samples, and/or attempting DTAG deployments and CEEs, an additional research crew (approximately six science personnel) worked from the Duke University R/V *Shearwater*, a 24-m fast catamaran. This vessel is capable of working offshore for multiple days, along with, in reasonable conditions and daylight hours, the R/V *Barber* (which maintained a shore base of operations). The R/V *Shearwater* provides excellent elevated tag tracking and visual observation platforms before, during, and after CEEs. One or both vessels were involved in 2025 tag deployment, CEEs, and re-sighting and biopsy sampling of focal individuals.

Three DTAGs from the University of Michigan were leased for planned field periods and available for deployment during strategic windows. Up to 30 Low-impact Minimally Percutaneous Electronic Transmitter (LIMPET) satellite-linked tags were also available. Priority was placed on the use of SPLASH10-333 satellite-transmitting tags that provide position and depth data, given the interest in feeding and diving behavior. Almost all tags available and deployed were of this type. However, two location-only Smart Position and Temperature (SPOT)-365 tags were deployed early in the field season to obtain initial assessments of overall distribution and movement as well as provide options to relocate previously tagged animals for deployments closer to CEE periods.

Coordination between the Atlantic-BRS team and USFF representatives facilitating U.S. Navy vessel participation in CEEs began months in advance of field operations and included advance briefing of potential participant vessels. During CEE periods, dedicated U.S. Navy personnel coordinated with vessels in the field, remotely from onshore sites through secure communications. The team scheduled multiple potential vessels during different periods throughout the field season to maximize the probability of a successful CEE based on tags deployed, weather, and realized vessel availability. The combined team successfully identified

and scheduled two CAS-capable ships for participation with the Atlantic-BRS project during 2025. Importantly, this included some novel scheduling approaches to coordinate with vessels from several home ports, including ships transiting to and from operating areas off the Virginia coast and through the study area. One of these ships was successfully integrated into a successful CEE (#25\_01; described in detail below). A second ship was scheduled but based on operational requirements transited through the study area during nighttime periods outside the experimental and permit-authorized CEE design.

The field team successfully deployed eight tags on the primary focal species (*Ziphius*) ahead of the first available CAS-capable ship in July. The second CAS CEE ever conducted with any marine mammal species occurred in collaboration with the USS *Donald Cook*, with seven tagged *Ziphius*. Four additional tags were deployed in September ahead of the possible second operational vessel. When that ship became unavailable for coordination within CEEs, the field team pivoted to the use of newly constructed, high-power, experimental source simulating CAS signals and conducted the first-ever successful such CEE (#25\_02).

## 2. Field Effort

### 2.1 Summary of 2025 Field Effort: Accomplishments and Assessment

#### Field Dates:

- **15–30 May:** Early season field windows; several scouting trips out of Beaufort for possible alternative beaked whale areas farther south; field conditions generally not workable for tagging.
- **3 June:** First possible field effort for advance tag deployment team (R/V *Barber*); some field personnel deployed and ready to go at Manteo field site.
- **4–20 June:** R/V *Barber* team staged; conditions generally not suitable for tagging.
- **21–22 June:** Back-to-back R/V *Barber* team days in relatively good conditions result in **two *Ziphius* sat tag deployments** with location-only (SPOT-6) tags intended to provide long-term baseline and overall movement patterns, as well as means of identifying groups later.
- **1–9 July:** Several R/V *Barber* efforts in workable conditions but no deployment of tags.
- **12–14 July:** Three outstanding back-to-back days for tagging teams result in **six total *Ziphius* sat tag deployments** ahead of the U.S. Navy ship scheduled for 19 July.
- **19 July:** Atlantic-BRS **completes successful full CAS CEE sequence (#2025\_01) in coordination with the USS *Donald Cook* with one focal and seven non-focal tagged *Ziphius* ( $n=8$  total tagged beaked whales)**. R/V *Shearwater* and R/V *Barber* teams on water before, during, and after for resighting and follow-up data collection.
- **20–30 July:** R/V *Barber* team multiple all-day efforts in marginal to good conditions for tagging and resights; **two additional *Ziphius* sat tag deployments** ahead of U.S. Navy ship scheduled for mid-August.
- **1 August:** CAS-capable MFAS source is successfully field tested for final trials at Dodge Pond; preparations to acquire source for possible simulated CAS CEEs
- **20–21 August:** **Second possible CAS-capable ship scheduled** for this period. Substantial in-person coordination with this vessel transiting through the study area is conducted, with the ship poised to support. However, a powerful hurricane (Hurricane Erin) came through the overall area, rendering any field effort around this period unquestionably impossible. Coordination is pivoted for the same vessel with additional options on transit back through the area in late September.
- **1–10 September:** R/V *Barber* team multiple all-day efforts in marginal to some good conditions for tagging, resights, biopsy effort; **four additional *Ziphius* sat tag deployments** ahead of the U.S. Navy ship scheduled for mid-September.
- **4–6 September:** Atlantic-BRS team acquires, receives training on use of, and delivers CAS-capable MFAS source to Duke University Marine Lab (DUML), with staging for possible CAS CEEs in 2026.

- **18–22 September:** R/V *Shearwater* and R/V *Barber* teams on water in advance of possible CAS-capable U.S. Navy ship rescheduled from August. Ship available and prepared for coordination, but operational requirements mean vessel transits area during nighttime periods, which are not possible for CEEs with current experimental protocols and permit authorizations. Atlantic-BRS team pivots to conduct first-ever **simulated CAS CEE sequence (#2025\_02), with one focal and three non-focal tagged *Ziphius* ( $n=4$  total tagged beaked whales).**
- **24–30 September:** Additional follow-up data collection and resight effort on several days.
- **1 June 2026:** Last 2025 *Ziphius* sat tag (Zctag151) still transmitting positional data.

### Accomplishments:

- Successfully deployed 14 sat tags on beaked whales, resulting in tens of thousands of hours of movement and behavioral data, including several early-season SPOT tags that provided awareness on distribution and resight potential through the end of the field season.
- Conducted the second successful CAS CEE with U.S. Navy operational sources for any species and *Ziphius* ( $n=7$ ) with any CAS source.
- Successfully obtained, tested, fielded, and calibrated new operational CAS-capable MFAS sound source.
- Conducted first-ever simulated CAS CEE for any species, including *Ziphius* ( $n=4$ ), with high-power experimental MFAS source.
- Obtained thousands of photo-ID images.
- Continued success with research platform R/V *Shearwater*, which was highly successful in locating and tracking animals, including successful overnight tracking ahead of and following CEE, and serving as a base of operations for CAS-capable MFAS source.
- Sustained efforts to relocate sat-tagged animals in the field using goniometer detections, increasing chances of subsequent tag deployments. This improved animal pseudotracks by providing high confidence surface locations. This resulted in relocating groups to deploy additional tags as well as many photo-ID re-sights to evaluate group composition, social interactions, and biopsy samples.

### Assessment of Field Approach:

- The combined team with USFF again successfully identified multiple CAS-capable ships and scheduled two for direct participation with the Atlantic-BRS project during 2025. This included efforts to coordinate with vessels operating from nearby Norfolk Naval Station as well as a vessel transiting through the study area from a different geographical location for training and testing within the Norfolk operating area. Both scheduled ships were in the transiting context, which provided multiple coordination opportunities. One was successfully conducted and included some operational lessons-learned in terms of field communications (now becoming easier with additional options). The second ship was poised to coordinate

both on the way up, though this was not possible given conditions from Hurricane Erin, and on the way back; however, this was not possible given the ship timing of passage through the area during nighttime operations. These outcomes highlight the successes and multiple options for transiting vessels, but also the challenges of timing given operational requirements. A hybrid approach that includes specifically scheduled vessels during local training operations, if possible, as well as adaptive approaches for transiting vessels is logical moving forward, in sustained close coordination with USFF.

- The study team again experienced mostly challenging early-seasons conditions, but remained ready to go and, for the first time in several years, deployed some tags in June. Given the coordinated scheduling with U.S. Navy ships, these were strategically selected as SPOT location-only tags to enable longer-duration monitoring of movement and re-locate groups for subsequent tag deployments. This strategy was effective and included the longest-duration locational data for any *Ziphius* in the study's data set. Subsequent adaptive efforts to deploy additional batches of tags during the weeks prior to scheduled ships were again very effective and resulted in many target whales for both CEE periods.
- Sat tags collected and transmitted continuous, high-quality, dive data due to earlier progress in tag programming strategies to minimize gaps in tag data as well as improve temporal resolution on diving and behavioral data. The team successfully collected continuous dive data for up to 24-day periods, strategically covering CEE periods, as designed. Long-duration (more than 250 days) functioning of location-reporting tags in reporting ARGOS positions occurred. Importantly, the study team observed a major increase in the quality and quantity of the data received from satellite-transmitting tags due to the integration of new low-Earth orbiting satellites (Kinéis) within the ARGOS network. This is a major development and improvement that is addressed in **Section 3** of this report, with comparisons of results from the legacy and new data processing systems.

## 2.2 Tag Deployments

A researcher from Bridger Consulting, in coordination with the Atlantic-BRS team aboard Duke University vessels, conducted sat tag deployments. **Table 1** provides a summary of sat tag deployments for 2025. The study team deployed a total of 14 satellite-transmitting tags, all on *Ziphius*.

The study team filtered ARGOS positional data using the following approach and parameters. The team removed location quality Z data. Additionally, the team used a bounding box to exclude points far outside the study area, inside the outer banks, or on land. The team also removed positions flagged as suspect in the comments field for larger deviations from mean longitude, latitude, or median speed. The team ran an additional speed angle distance filter from the R package trip (function *sda*) with the following parameters:  $vmax = 10$  kph,  $ang = \{15, 25\}$  (degrees), and  $distlim = \{2500, 5000\}$  (meters) (Freitas et al. 2008; Freitas 2022). Finally, the team applied a fitted continuous time correlated random walk model at a 5-minute resolution using the *crwPredict* function in the *crawl* package (Johnson et al. 2008; 2022). The team retained model fit objects to predict locations and draw 100 imputed tracks to highlight predictions and the associated uncertainty in location. **Figure 1** shows the predicted tracks for the entire deployment for all *Ziphius* tagged during 2025.

**Table 1. Satellite tag deployments on *Ziphius cavirostris* (Zc) during Atlantic-BRS in 2025.**

Species/ Tag ID	Deployment Date	Deployment Latitude (°N)	Deployment Longitude (°W)	Dive Data Streams	Tag Duration (days)
ZcTag151_DUML <sup>a,b</sup>	21 June 2025	35.6264	-74.7974	N/A	340.0+
ZcTag152_DUML <sup>a</sup>	22 June 2025	35.5512	-74.6787	N/A	0.0
ZcTag153_DUML <sup>c</sup>	12 July 2025	35.7369	-74.7175	5-minute time series	33.0
ZcTag154_DUML <sup>c</sup>	12 July 2025	35.7350	-74.7005	5-minute time series	44.9
ZcTag155_DUML <sup>c</sup>	13 July 2025	35.5601	-74.6732	5-minute time series	54.2
ZcTag156_DUML <sup>c</sup>	13 July 2025	35.6488	-74.7373	5-minute time series	15.1
ZcTag157_DUML <sup>c</sup>	14 July 2025	35.6223	-74.7616	5-minute time series	53.8
ZcTag158_DUML <sup>c</sup>	14 July 2025	35.5207	-74.7611	5-minute time series	45.9
ZcTag159_DUML <sup>c</sup>	30 July 2025	35.7256	-74.7438	5-minute time series	41.7
ZcTag160_DUML <sup>c</sup>	30 July 2025	35.8525	-74.6198	5-minute time series	0.0
ZcTag161_DUML <sup>c</sup>	4 September 2025	35.5650	-74.7785	5-minute time series	27.1
ZcTag162_DUML <sup>c</sup>	4 September 2025	35.5749	-74.7628	5-minute time series	51.8
ZcTag163_DUML <sup>c</sup>	5 September 2025	35.6386	-74.7642	5-minute time series	0.7
ZcTag164_DUML <sup>c</sup>	5 September 2025	35.6034	-74.7863	5-minute time series	36.0

Key: ID = Identification Number; °N = degrees North; °W = degrees West; N/A = not applicable

<sup>a</sup> SPOT-365 tags

<sup>b</sup> Tag still transmitting as of 1 June 2026

<sup>c</sup> SPLASH10-333 tags

Individual (by animal) plots showing all track imputations as well as the best overall track are shown for the entire tag deployment periods for each tagged *Ziphius* that reported sufficient positional data (**Figure 2** through **Figure 13**). For tags that were active during the CAS CEE, the location of the source vessel at the start of the experiment is indicated on the individual plots.

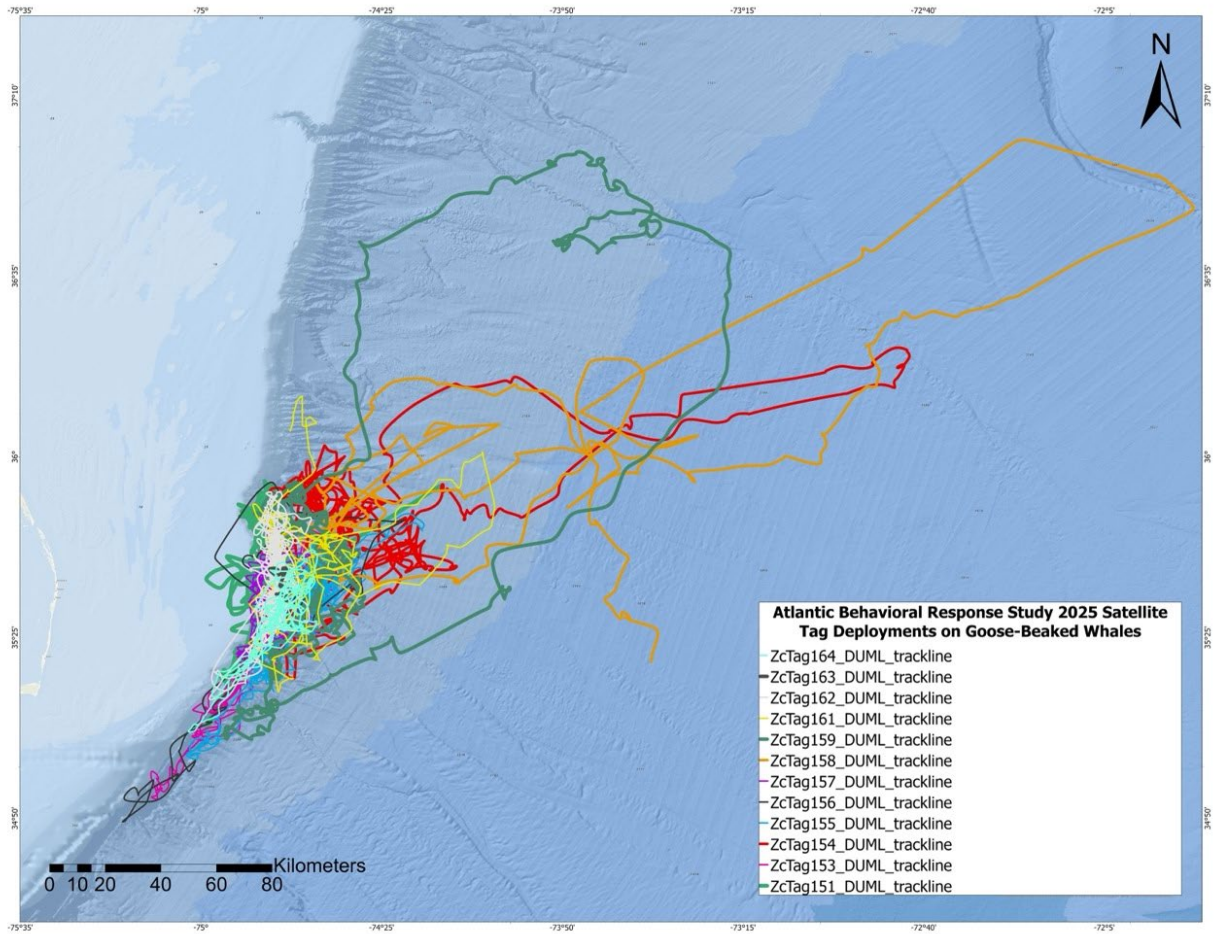
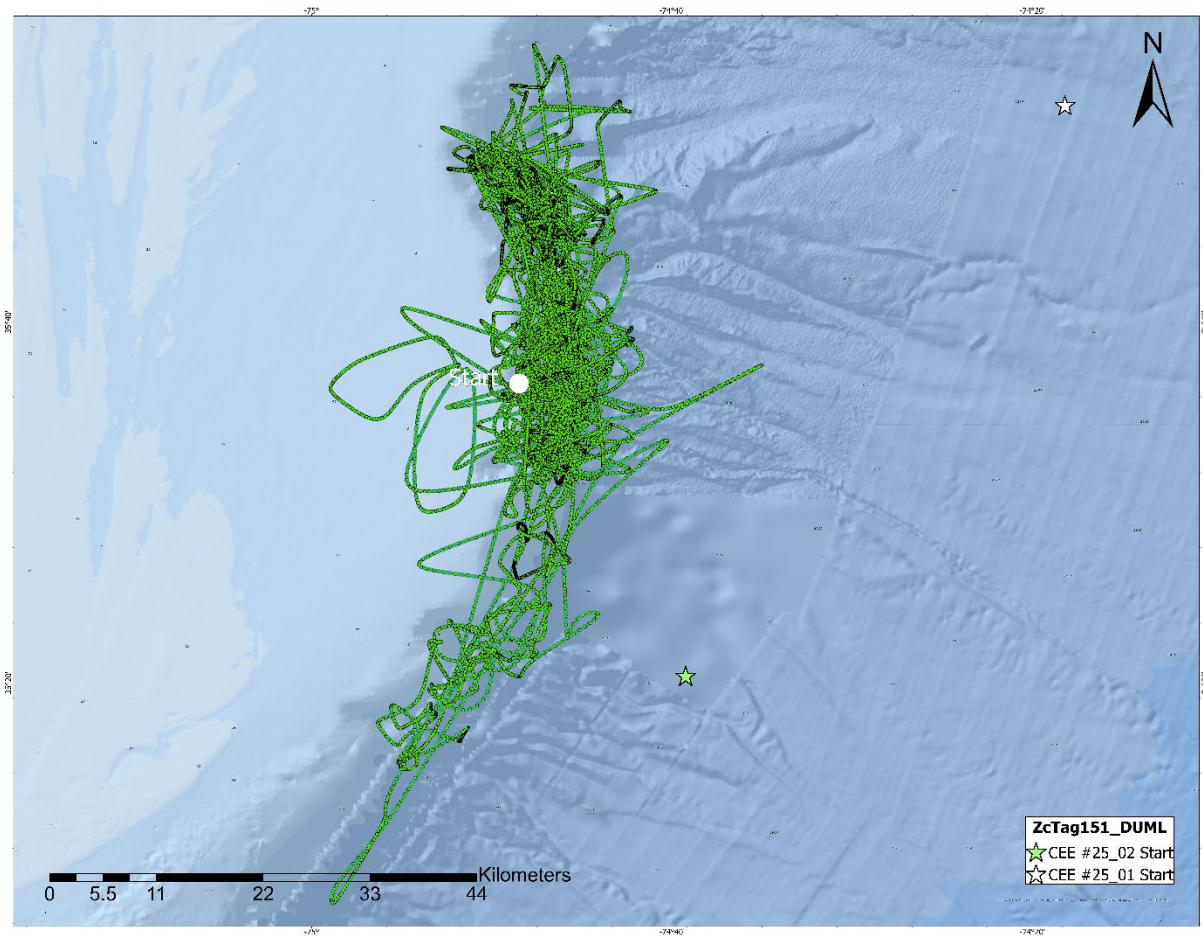
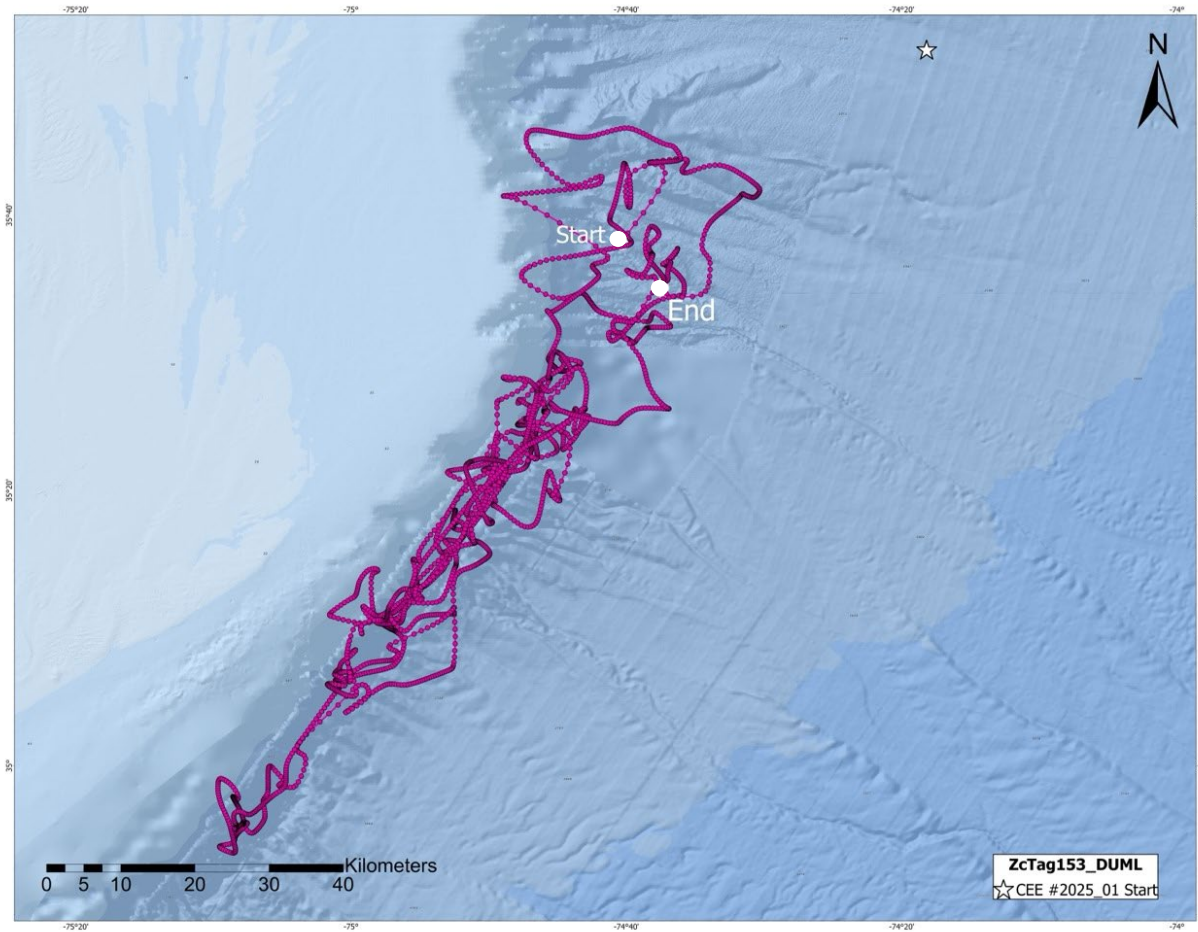


Figure 1. Predicted tracks for tagged beaked whales ( $n=12$ ) with sufficient spatial data during Atlantic-BRS 2025 field effort.



**Figure 2.** Predicted locations for ZcTag151\_DUML (tag still transmitting as of 1 June 2026) drawn from the fitted continuous time correlated random walk model. This tag was transmitting during both CEEs. The CEE start locations for the USS *Donald Cook* for CEE #25\_01 and for the (drifting) R/V *Shearwater* for simulated CAS CEE #25\_02 are shown, as well as the tag transmission start point.



**Figure 3.** Predicted locations for ZcTag153\_DUML (tag duration 33 days) drawn from the fitted continuous time correlated random walk model. The CEE start locations for the USS *Donald Cook* for operational CAS CEE #25\_01 are shown, as well as the tag transmission start and end points.

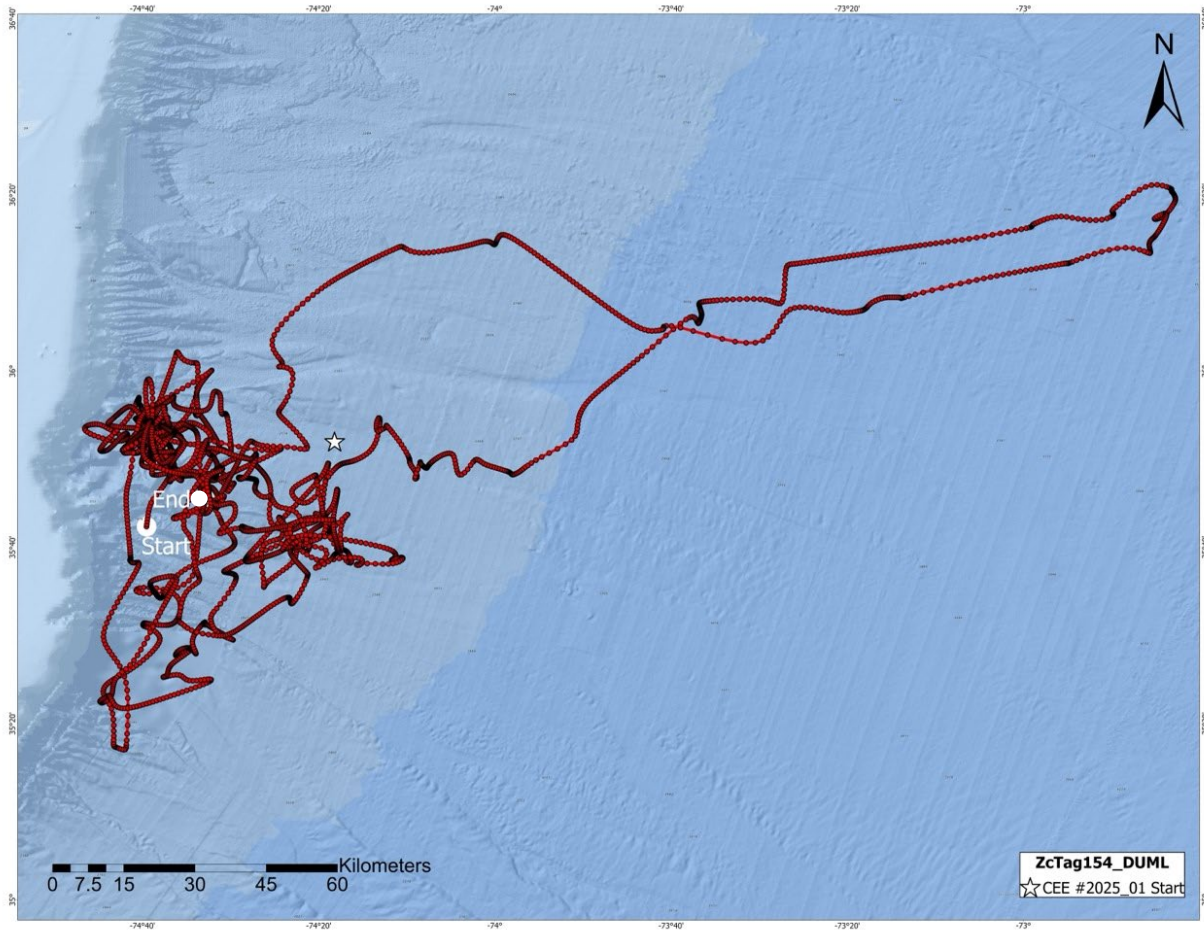


Figure 4. Predicted locations for ZcTag154\_DUML (tag duration 44.9 days) drawn from the fitted continuous time correlated random walk model. The CEE start locations for the USS *Donald Cook* for operational CAS CEE #25\_01 are shown, as well as the tag transmission start and end points.

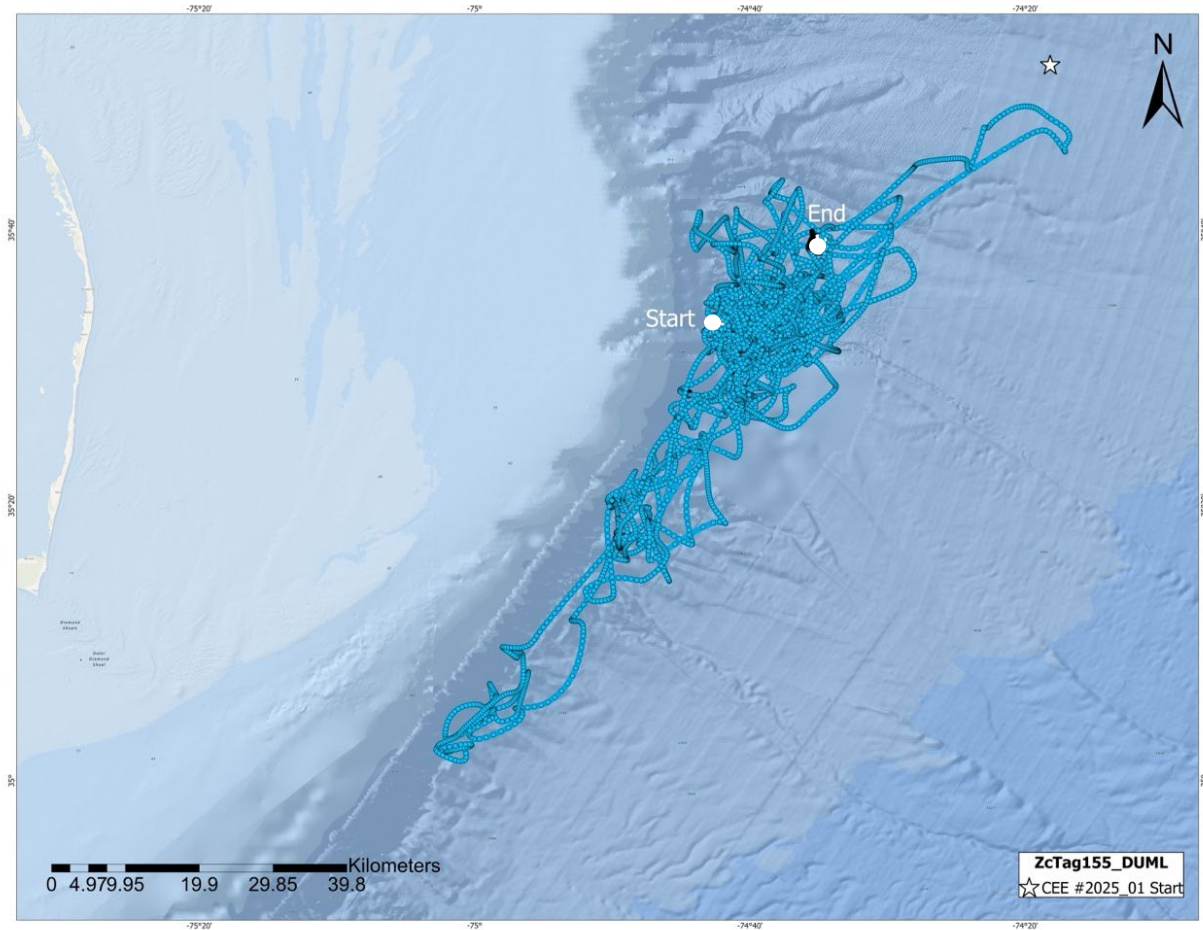
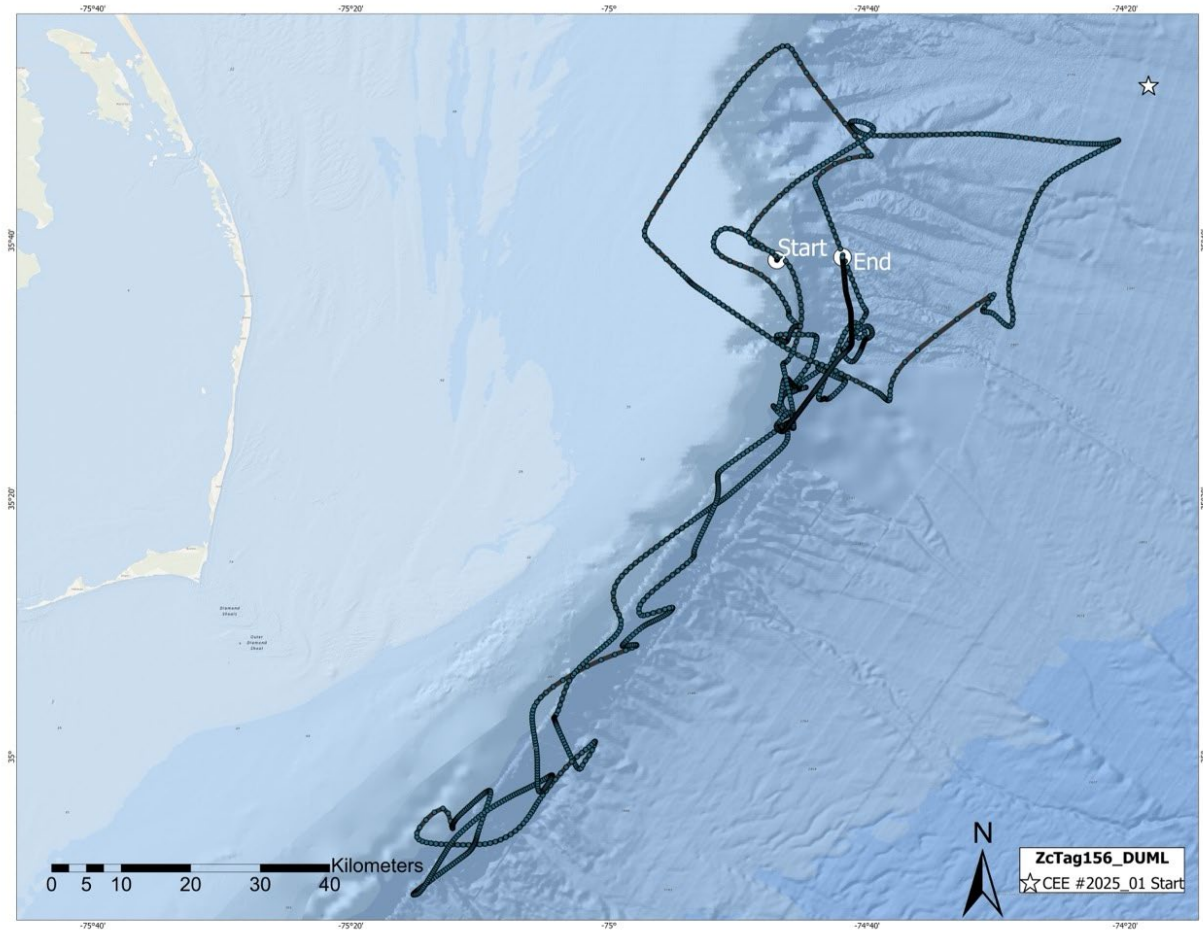
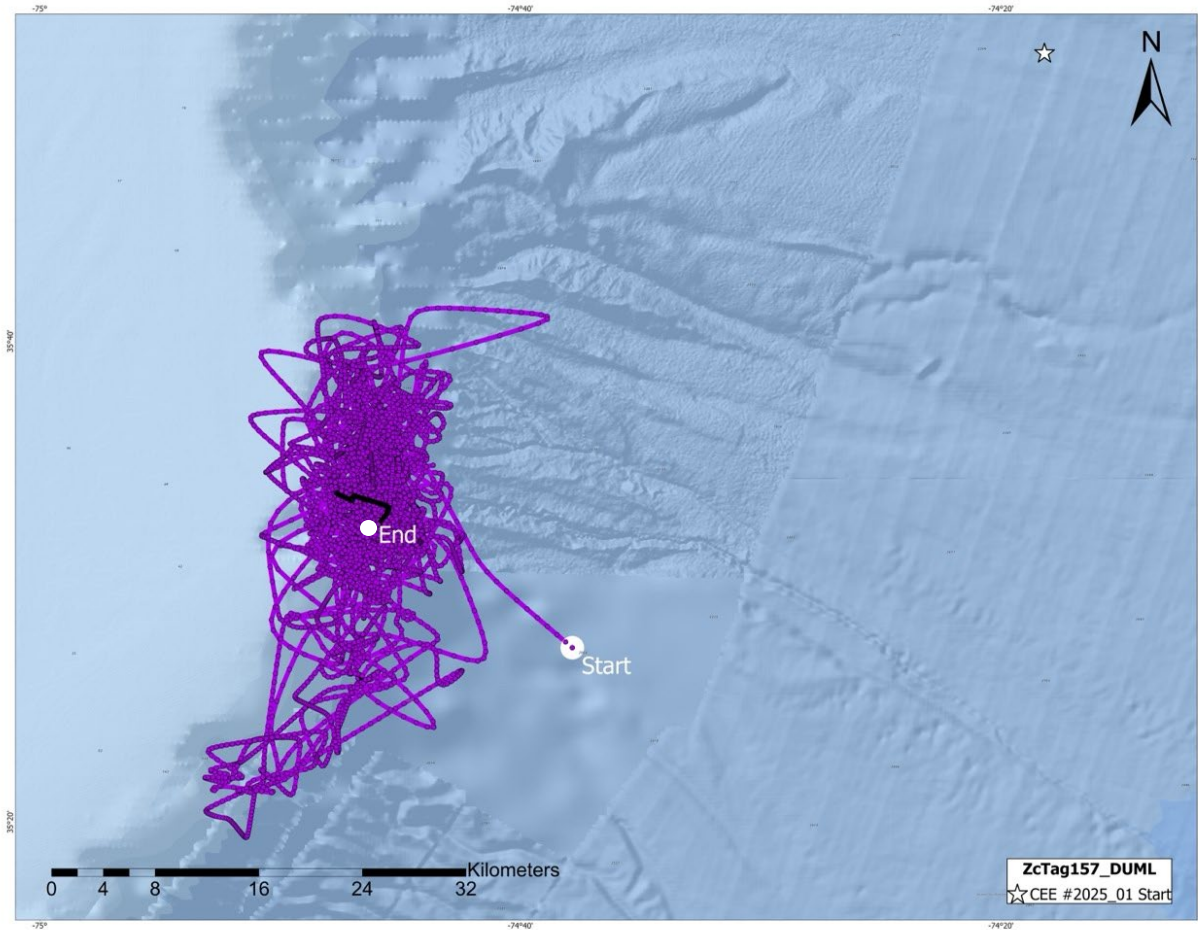


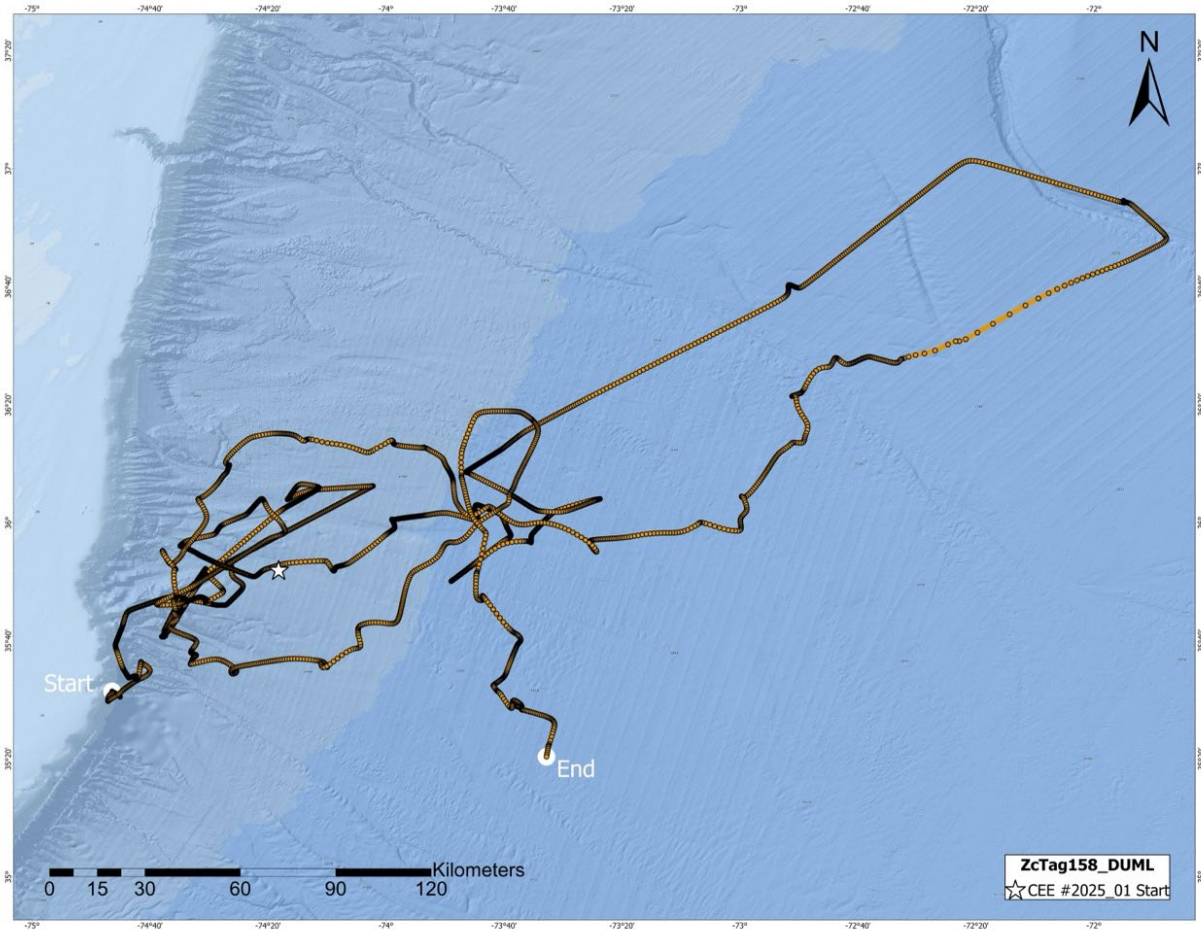
Figure 5. Predicted locations for ZcTag155\_DUML (tag duration 54.2 days) drawn from the fitted continuous time correlated random walk model. The CEE start locations for the USS *Donald Cook* for operational CAS CEE #25\_01 are shown, as well as the tag transmission start and end points.



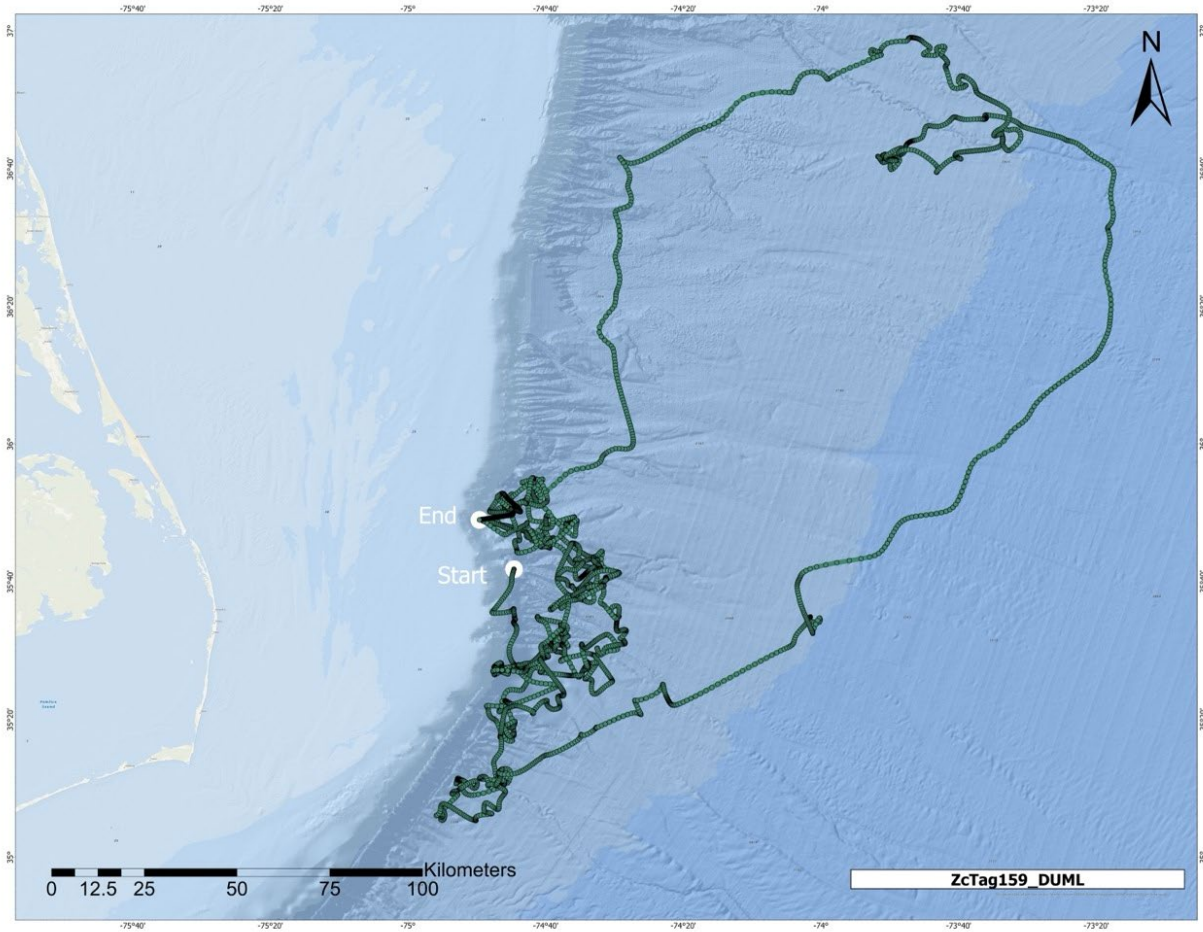
**Figure 6.** Predicted locations for ZcTag156\_DUML (tag duration 15.1 days) drawn from the fitted continuous time correlated random walk model. The CEE start locations for the USS *Donald Cook* for operational CAS CEE #25\_01 are shown, as well as the tag transmission start and end points.



**Figure 7.** Predicted locations for ZcTag157\_DUML (tag duration 53.8 days) drawn from the fitted continuous time correlated random walk model. The CEE start locations for the USS *Donald Cook* for operational CAS CEE #25\_01 are shown, as well as the tag transmission start and end points.



**Figure 8.** Predicted locations for ZcTag158\_DUML (tag duration 45.9 days) drawn from the fitted continuous time correlated random walk model. The CEE start locations for the USS *Donald Cook* for operational CAS CEE #25\_01 are shown, as well as the tag transmission start and end points.



**Figure 9.** Predicted locations for ZcTag159\_DUML (tag duration 41.7 days) drawn from the fitted continuous time correlated random walk model. Tag transmission start and end points are shown; transmission was not active for either CEE.

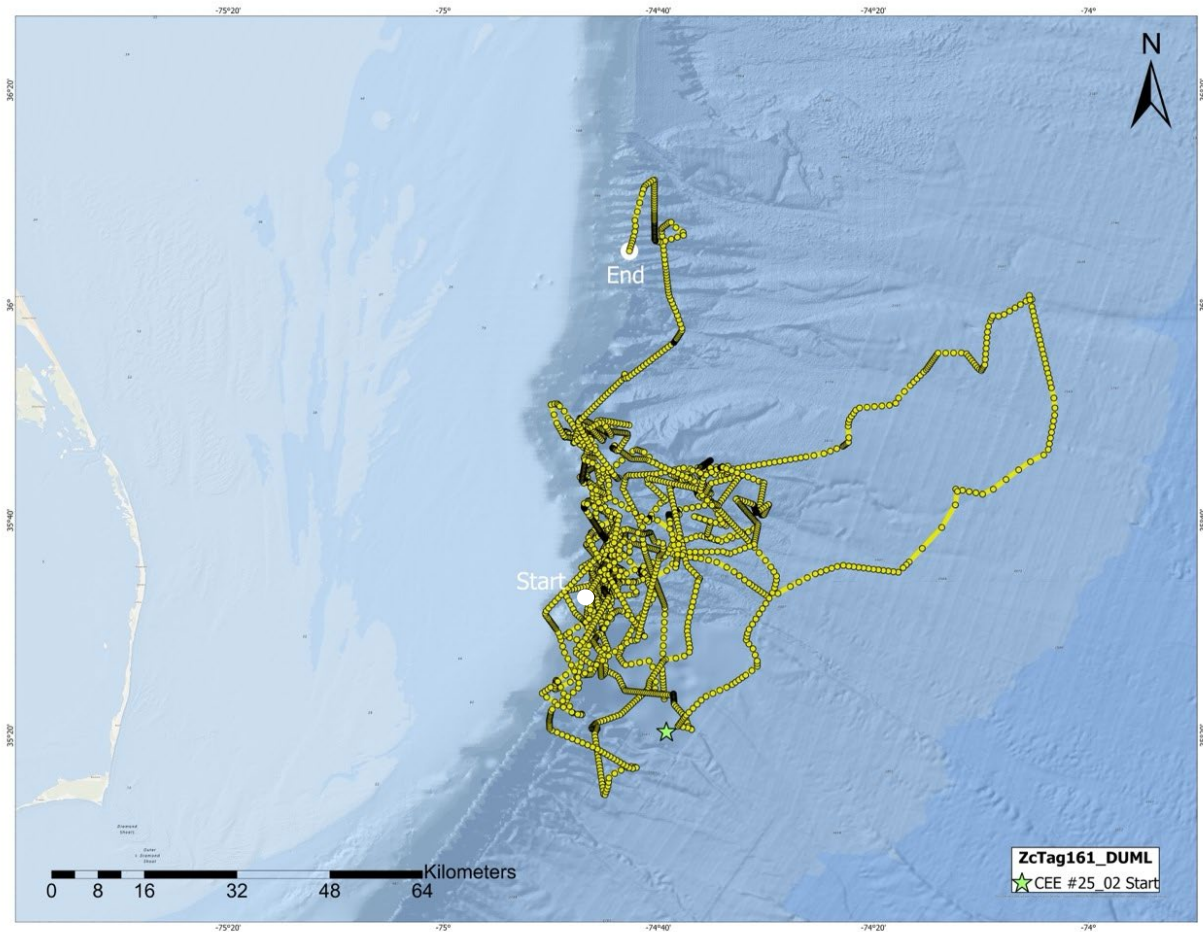


Figure 10. Predicted locations for ZcTag161\_DUML (tag duration 27.1 days) drawn from the fitted continuous time correlated random walk model. The CEE start location for the (drifting) R/V *Shearwater* for simulated CAS CEE #25\_02 is shown, as well as the tag transmission start and end points.

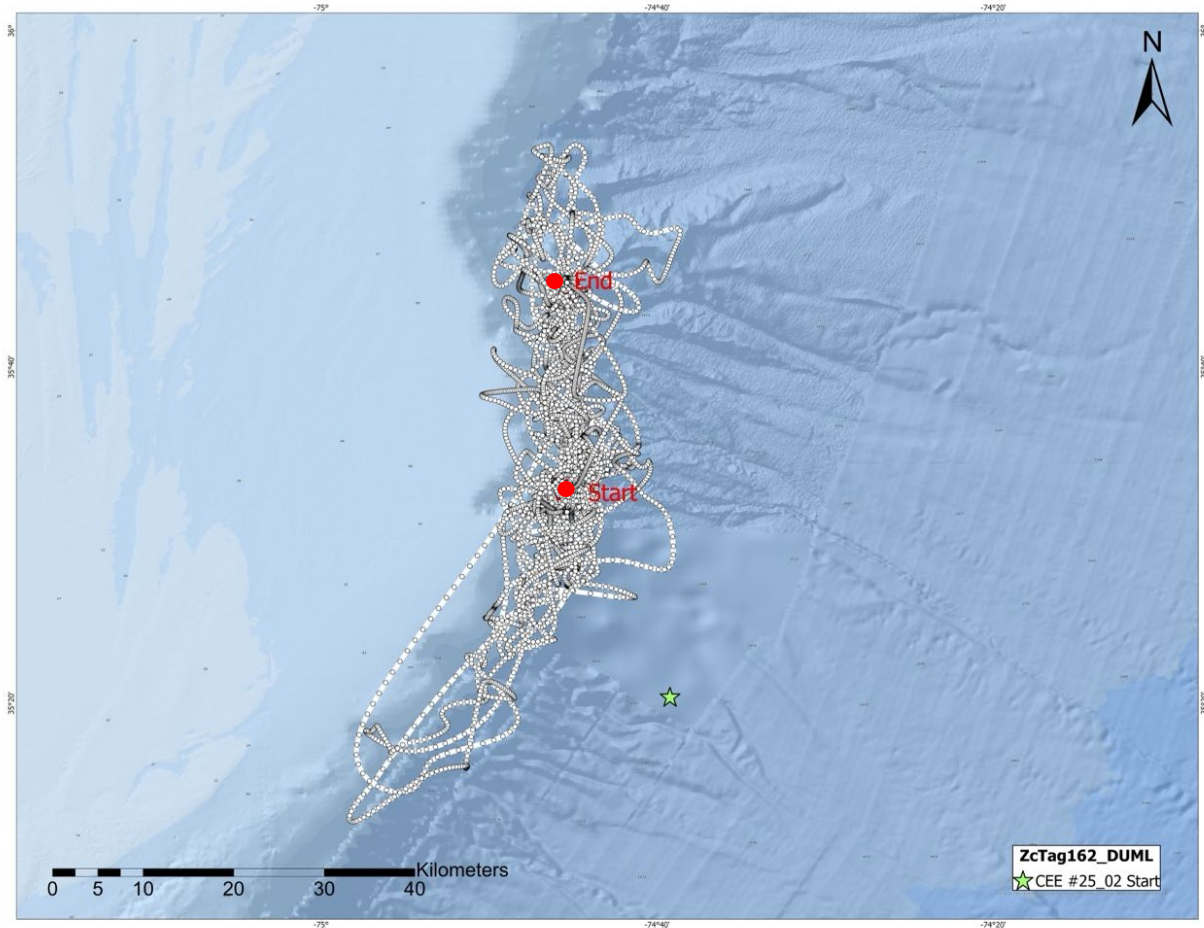


Figure 11. Predicted locations for ZcTag162\_DUML (tag duration 51.8 days) drawn from the fitted continuous time correlated random walk model. The CEE start location for the (drifting) R/V *Shearwater* for simulated CAS CEE #25\_02 is shown, as well as the tag transmission start and end points.

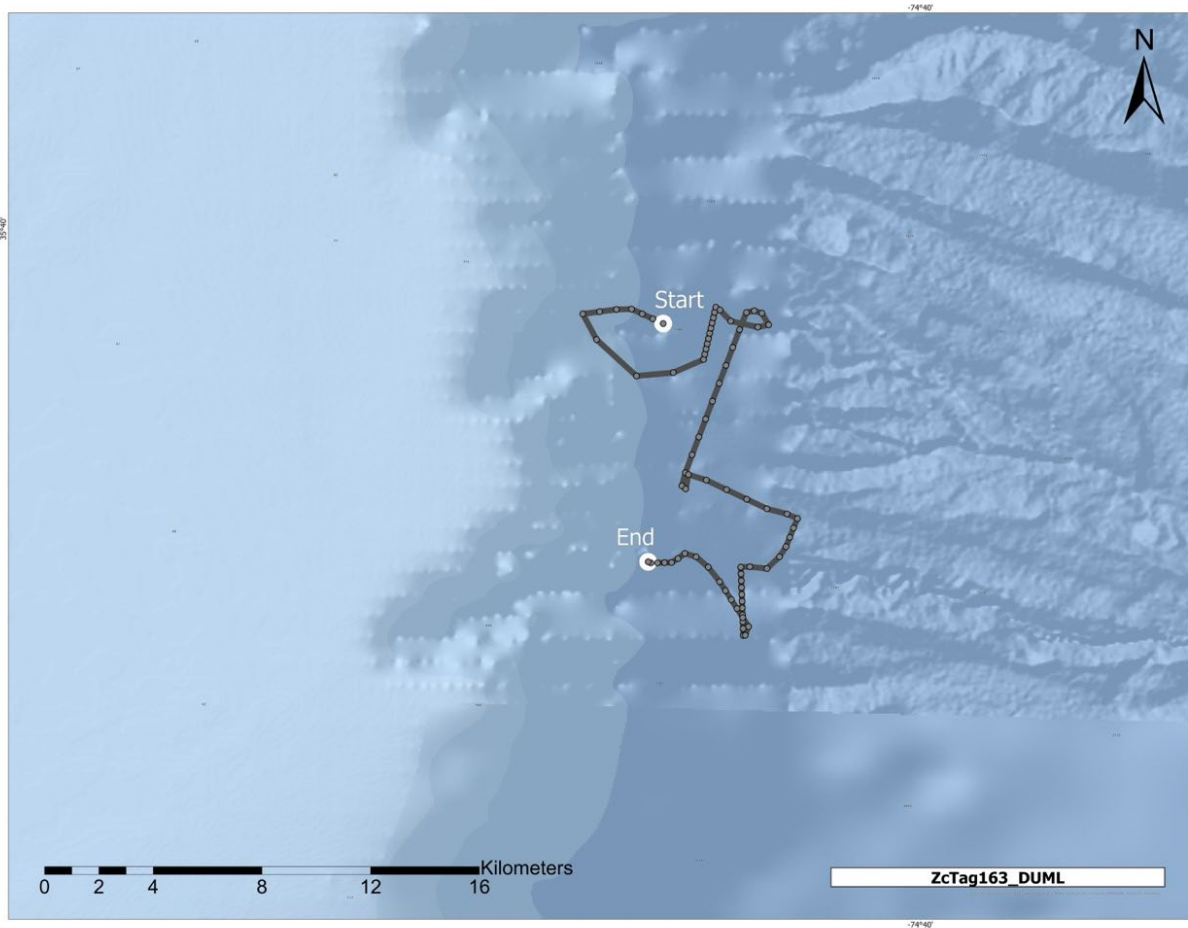


Figure 12. Predicted locations for ZcTag163\_DUML (tag duration 0.7 day) drawn from the fitted continuous time correlated random walk model. Tag transmission start and end points are shown; transmission was not active for either CEE.

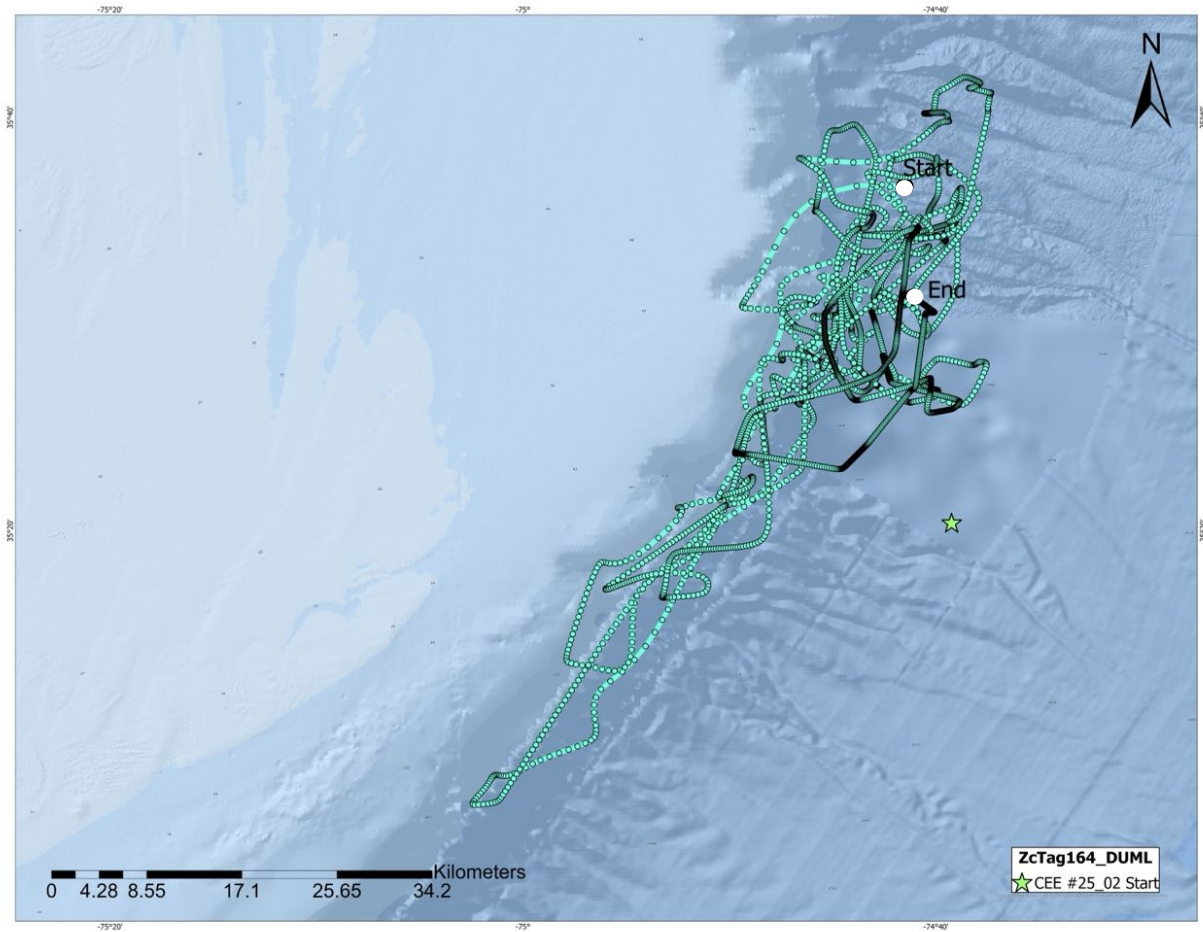


Figure 13. Predicted locations for ZcTag164\_DUML (tag duration 36 days) drawn from the fitted continuous time correlated random walk model. The CEE start location for the (drifting) R/V *Shearwater* for simulated CAS CEE #25\_02 is shown, as well as the tag transmission start and end points.

## 2.3 CEEs Conducted

Two CEE sequences were conducted during the Atlantic-BRS 2025 field effort (**Table 2**). A dedicated CAS-capable ship (USS *Donald Cook*) was scheduled and coordinated with the Atlantic-BRS team in July to support the second operational MFAS CAS CEE by this project. Seven *Ziphius* (with one SPOT and six SPLASH-10 tags) were monitored visually (focal) and remotely (non-focal) during this experiment (CEE #25\_01). The team tested, fielded, and deployed a new CAS-capable experimental sound source simulated operational CAS in the first-ever CEE with CAS signals conducted in September with four *Ziphius* (with one SPOT and three SPLASH-10 tags) in CEE #25\_02

**Table 2. CEEs conducted during Atlantic-BRS 2025 field efforts.**

CEE ID	Date	CEE Type	Focal Whales <sup>a</sup>	Non-focal Whales <sup>a</sup>	CEE Duration (min)	Start CEE Source Latitude (°N)	Start CEE Source Longitude (°W)
#25_01	7/19/25	Operational MFAS CAS	ZcTag156	ZcTag151 ZcTag153 ZcTag154 ZcTag155 ZcTag157 ZcTag158	54	35.8667	-74.303
#25_02	9/19/25	Simulated MFAS CAS	ZcTag161	ZcTag151 ZcTag162 ZcTag164	30	35.3397	-74.6539

Key: ID = Identification Number; °N = degrees North; °W = degrees West; min = minute(s)

<sup>a</sup> Zc = *Ziphius cavirostris*

### 2.3.1 CEE #25\_01: Operational MFAS CAS (USS *Donald Cook*)

This experiment was closely coordinated with the USS *Donald Cook* following months of advance planning and days of adaptive sequential position requests provided ahead of this CEE based on the movement patterns of focal and non-focal whales. These sequential requests and vessel coordination provided through USFF contacts are provided in **Table 3** and depicted spatially in **Figure 14**. **Table 4** provides selected associated RL model predictions generated *in situ* for different focal animals' known or estimated locations at multiple depths using the custom NPS sound propagation planning tool and available information regarding CAS stimuli source (note: all 30 model runs for different configurations, and possible focal animals are available on request from the project team). Differences between the PAS and CAS MFAS signals are discussed above; RL estimates provided herein are RMS values per modeled CAS transmission. RL model runs (25, 26, 27, and 28 in **Table 4**) for the start and end of CAS-vessel transmissions for the focal individual (ZcTag156) that informed the final requested vessel tracks are shown for reference (**Figure 15** through **Figure 18**).

A narrative summary and spatial depiction of animal locations before, during, and after CAS CEE sequence (#25\_01) for all focal and non-focal individuals (see **Table 5**; **Figure 19** through **Figure 26**) is provided following the RL model predictions.

**Table 3. Sequential positioning for USS *Donald Cook* ahead of Atlantic-BRS CEE #25\_01.**

<b>Position Request for USS <i>Donald Cook</i></b>	<b>Description</b>	<b>Latitude (°N)</b>	<b>Longitude (°W)</b>	<b>Heading</b>
1	Nominal initial position (provided weeks in advance)	35.9000	-74.500	Not specified
2	16 July 1400 EDT – 72-hour pre-CEE revised position based on three possible focal animal, higher-quality ARGOS locations at multiple depths	35.8500	-74.450	Not specified
3	17 July 1200 EDT – 48-hour pre-CEE revised position based on four possible focal animal higher quality ARGOS locations at multiple depths	35.8500	-74.350	170
4	18 July 1200 EDT – 24-hour pre-CEE revised position based on three possible focal animal, higher-quality ARGOS locations at multiple depths	35.9000	-74.300	175
5	Final requested position 19 July 1100 EDT based on higher quality ARGOS locations and known/actual positions from selected focal whale Zc156	35.9500	-74.300	175
6	Actual position and course from USS <i>Donald Cook</i> navigation (INS 01)	35.8667	-74.303	193–196 heading maintained; made 173 true course

Key: EDT = Eastern Daylight Time; °N = degrees North; °W = degrees West; Zc = *Ziphius cavirostris*

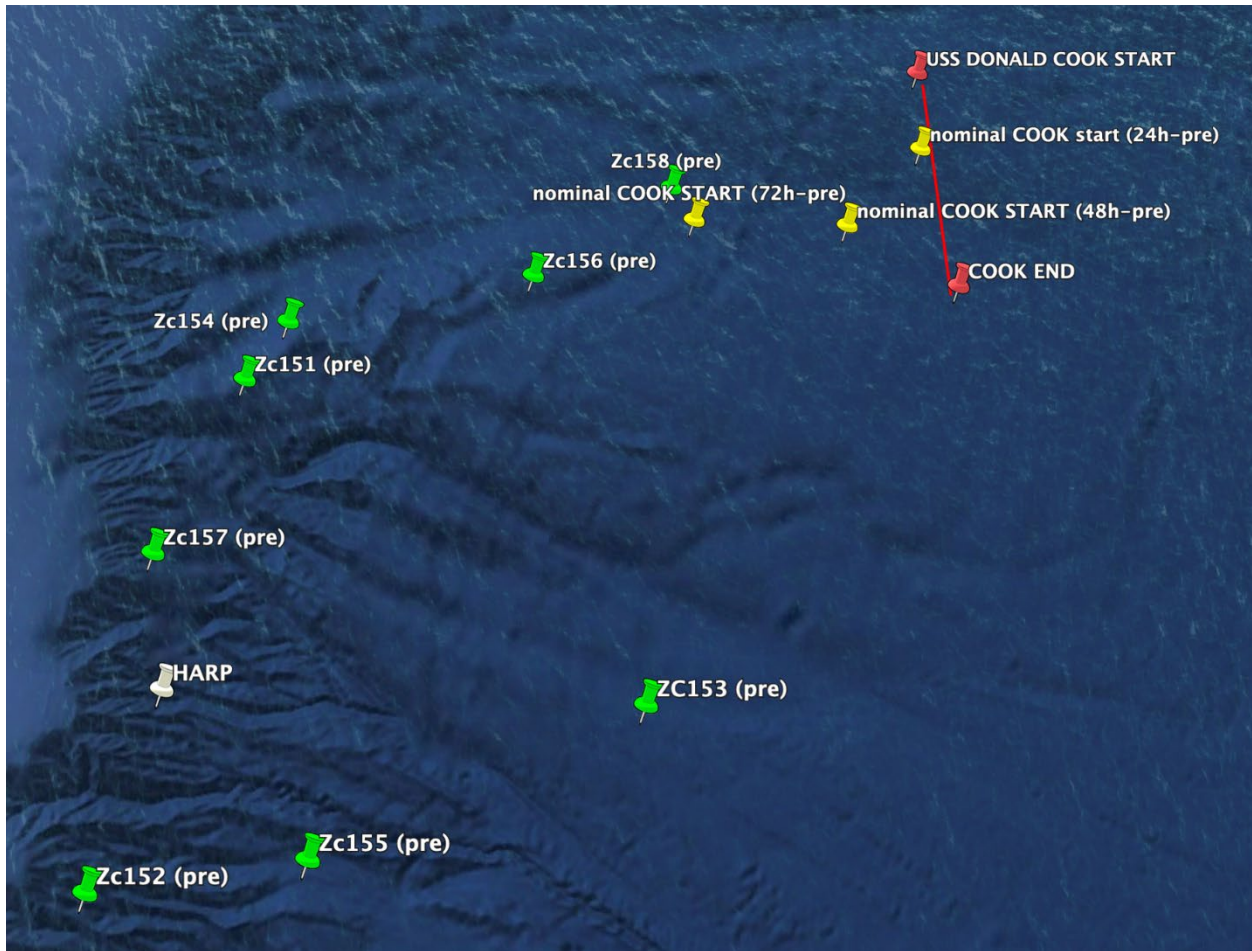


Figure 14. Sequential requested start positions for the USS *Donald Cook* on specified days in advance (yellow pins) as well as the final start and end positions (red pins; red track approximately 8 nm) requested on the day of CEE #2025\_01. Vessel positions are shown relative to sequential focal animal (ZcTag156) and non-focal whales (ZcTags 151, 153, 154, 155, 157, 158) position estimates (green pins) used in RL modeling and to inform the vessel position requests.

Table 4. RL model runs for CEE #25\_01.

Model Run	Runtime	Focal Animal (Depth – m)	Animal Latitude (°N)	Animal Longitude (°W)	Estimated Range (nm) Start–End	Model RL Start	Model RL End	Model RL Max.
10	16 July 1000 EDT	Zc153 (100)	35.6050	-74.6680	21–16	97	120	120
11	16 July 1200 EDT	Zc153 (1,800)	35.6050	-74.6680	17–13	106	120	120
12	17 July 1000 EDT	Zc153 (100)	35.6150	-74.5730	17–12	111	120	120
13	17 July 1100 EDT	Zc153 (1,900)	35.6150	-74.5730	16–11	106	120	120
17	18 July 1000 EDT	Zc153 (100)	35.7290	-74.6540	14–13	100	120	120
19	18 July 1200 EDT	Zc153 (1,600)	35.7290	-74.6540	13–11	107	121	121
25	19 July 0600 EDT	Zc156 (100)	35.7917	-74.3864	8–11	117	132	134
26	19 July 0800 EDT	Zc156 (2,000)	35.7917	-74.3864	8–11	113	122	122
27	19 July 1000 EDT	Zc156 (100)	35.8095	-74.4685	12–10	114	126	126
28	19 July 1200 EDT	Zc156 (1,900)	35.8095	-74.4685	13–11	117	122	122

Key: EDT = Eastern Daylight Time; Max. = Maximum; °N = degrees North; nm = nautical mile(s); °W = degrees West; Zc = *Ziphius cavirostris*

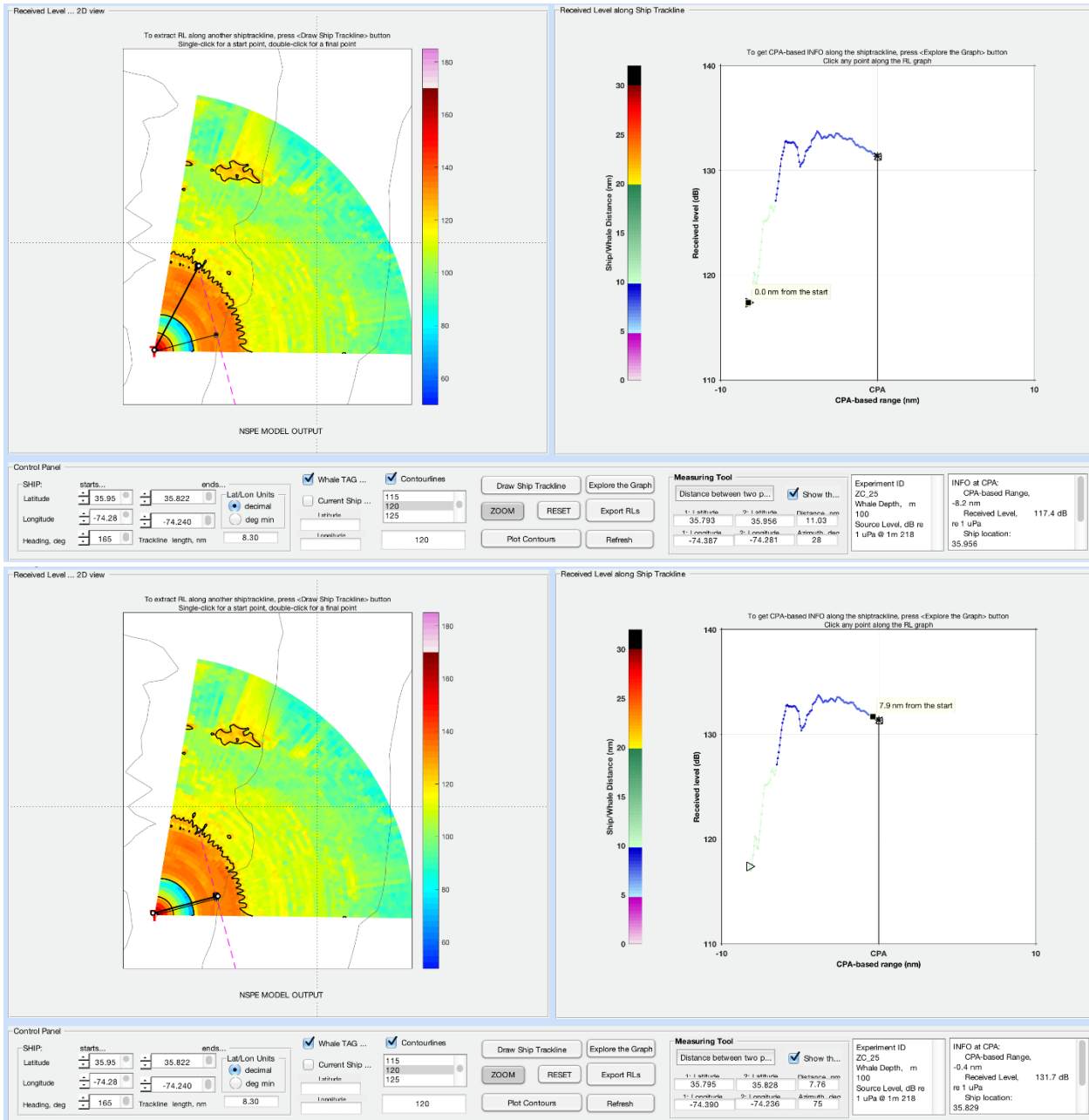


Figure 15. RL model prediction at 100-m depth (model run 25 from Table 4) for focal whale ZcTag156 ahead of Atlantic-BRS CEE #25\_01 for the start (top; vessel-animal range: 11.0 nm; modeled RL = 117.4 dB) and end (bottom; vessel-animal range: 7.8 nm; modeled RL = 131.7 dB) of the modeled vessel track.

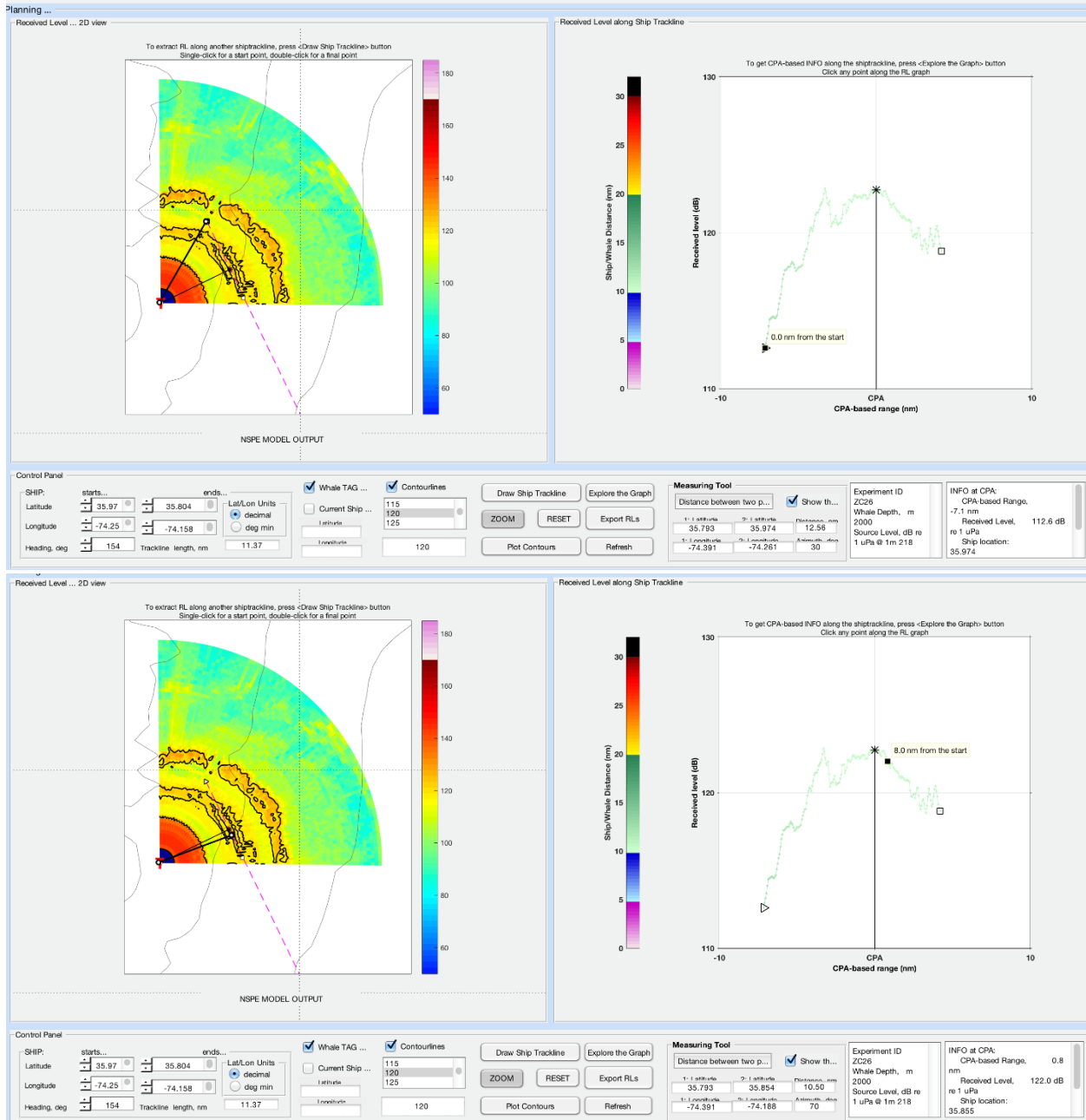


Figure 16. RL model prediction at 2,000-m depth (model run 26 from Table 4) for focal whale ZcTag156 ahead of Atlantic-BRS CEE #25\_01 for the start (top; vessel-animal range: 12.6 nm; modeled RL = 112.6 dB) and end (bottom; vessel-animal range: 10.5 nm; modeled RL = 122.0 dB) of the modeled vessel track.

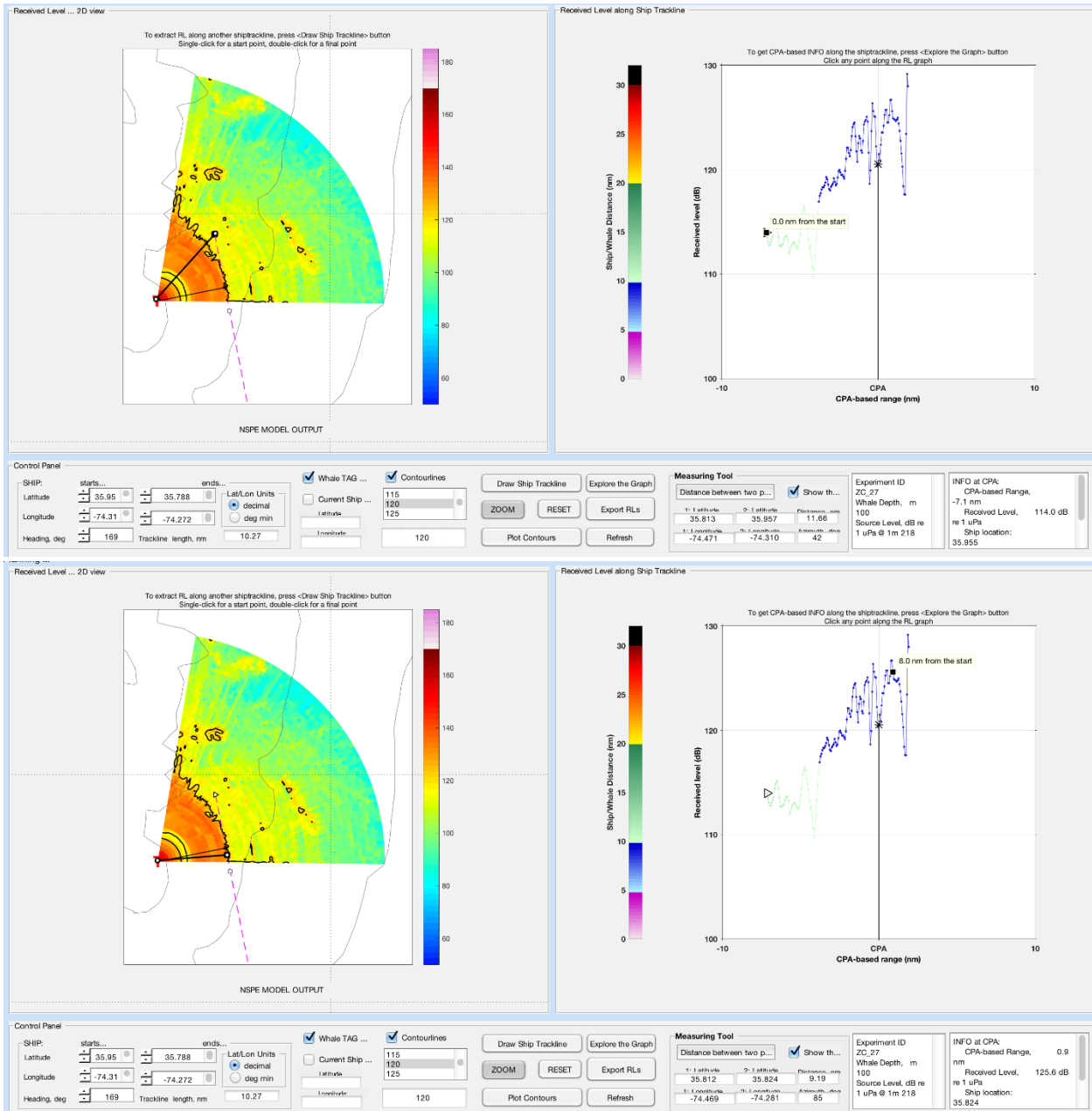


Figure 17. RL model prediction at 100-m depth (model run 27 from Table 4) for focal whale ZcTag156 ahead of Atlantic-BRS CEE #25\_01 for the start (top; vessel-animal range: 11.7 nm; modeled RL = 114.0 dB) and end (bottom; vessel-animal range: 9.2 nm; modeled RL = 125.6 dB) of the modeled vessel track.

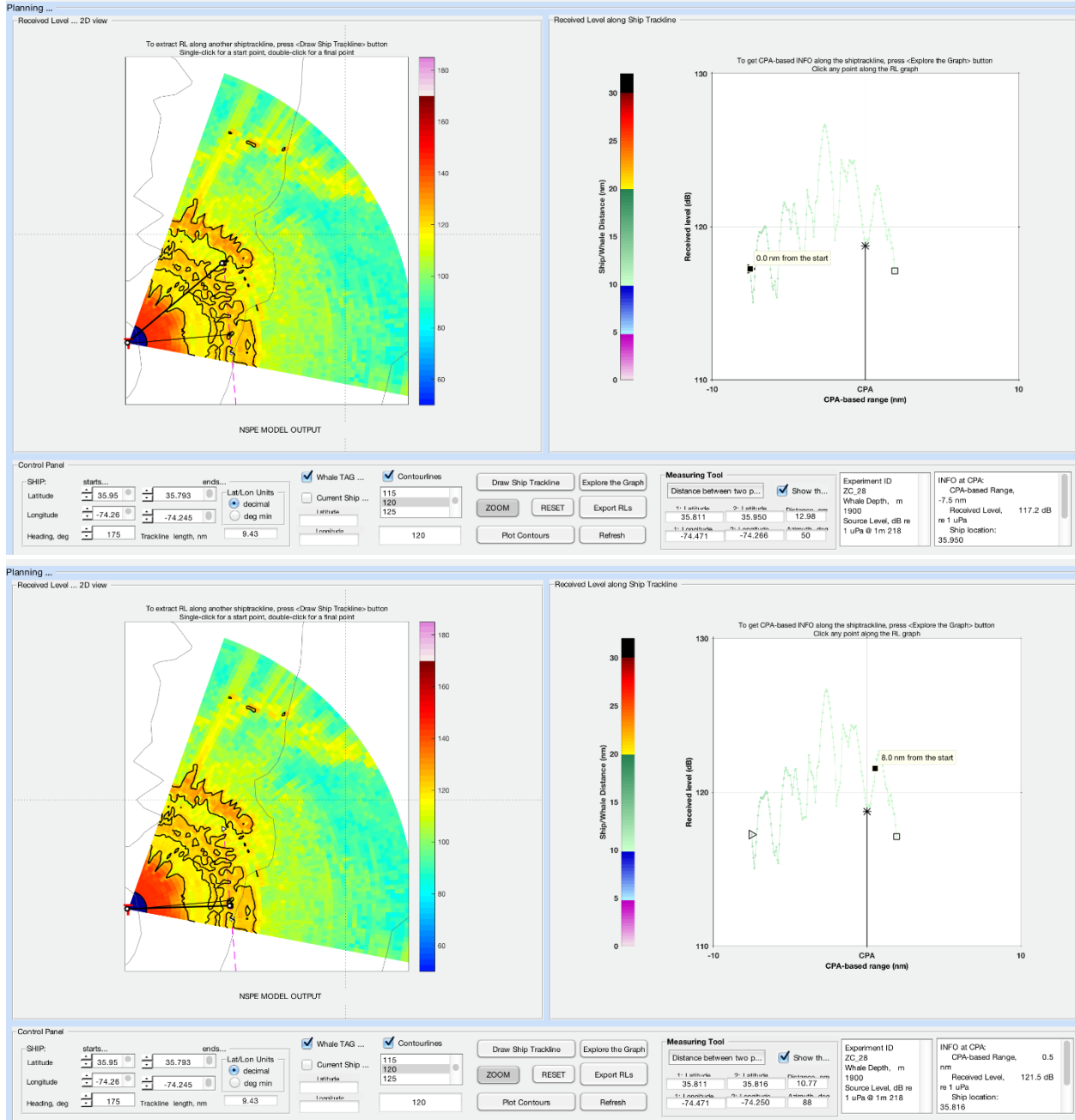


Figure 18. RL model prediction at 1,900-m depth (model run 28 from Table 4) for focal whale ZcTag156 ahead of Atlantic-BRS CEE #25\_01 for the start (top; vessel-animal range: 13.0 nm; modeled RL = 117.2 dB) and end (bottom; vessel-animal range: 10.8 nm; modeled RL = 121.5 dB) of the modeled vessel track.

Table 5. Metadata summary for Atlantic-BRS CEE #25\_01.

**CEE #25\_01 - Narrative Summary**

With support from the Navy’s Marine Species Monitoring Program, NAVFAC, and U.S. Fleet Forces Command, a successful controlled exposure experiment (CEE) was conducted in collaboration between the *USS Donald Cook* and the Atlantic Behavioral Response Study (BRS) team. This CEE was conducted on 19 July 2025 off the continental shelf break east of Cape Hatteras, NC (see tables and maps for specific locations). This experiment marks just the second such set of direct measurements ever made (following a 2024 coordination with the *USS Thomas Hudner*) of operational, full-scale, continuous active (mid-frequency) sonar (CAS) for one of the U.S. Navy’s highest priority species for impact assessment (*Ziphius*). It also included a large increase in sample size from the three individuals tested in the first-ever such CEE 2024 (just one having associated diving data), with a total of seven individual beaked whales tagged and monitored during the *USS Donald Cook* CEE (including six with associated dive data). There appears to be less obvious broad spatial movement (horizontal avoidance) evident than in some prior MFAS PAS CEEs and individuals in the 2024 CAS CEE. However, diving responses are evident in many focal and incidental whales with dive-sensing tags, including extended or altered dive patterns relative to non-exposed dives before exposure, with some possible interesting differences relative to prior MFAS PAS findings.

**CEE #25\_01**

<b>Date:</b>	19 July 2025
<b>Type:</b>	Continuous Active Sonar (CAS) from <i>USS Donald Cook</i>
<b>Signal parameters:</b>	<ul style="list-style-type: none"> <li>- Linear FM upsweeps: 2508-3158 Hz bandwidth (650 Hz bandwidth)</li> <li>- 50s sweep duration; 100% duty cycle; 60-min total transmit duration</li> <li>- Vessel positioned using in situ modeling</li> <li>- Requested straight line transit 8 kt (effective speed over ground)</li> <li>- Source level: assumed to be 218 dB RMS (across band)</li> </ul>
<b>Start time (UTC):</b>	22:50
<b>Start lat/lon (source):</b>	35.8667; -74.303
<b>End time (UTC):</b>	23:42 (54 min exposure duration; slightly less than requested)
<b>End lat/lon (source):</b>	35.7667; -74.2867
<b>Beaked whales tagged during CEE:</b>	(n=7) – ZcTag156 (focal sat tag animal); Non-focal whales: ZcTag151; ZcTag153; ZcTag154; ZcTag155; ZcTag157; ZcTag158
<b>Estimated Range (start CEE):</b>	~12 nm @ start (focal follow locations) for focal
<b>Modeled Max RL:</b>	Variable for final position model runs/depths ->117-134 dB RMS (across band) = 134-151 dB Sound Exposure Level (SEL) per ping (based on model runs 25-28; see Table 4)

Key: FM = frequency-modulated; kt = knot(s); lat = latitude; lon = longitude; min = minute(s); NAVFAC = Naval Facilities Engineering Systems Command; nm = nautical mile(s); UTC = Coordinated Universal Time; Zc = *Ziphius cavirostris*

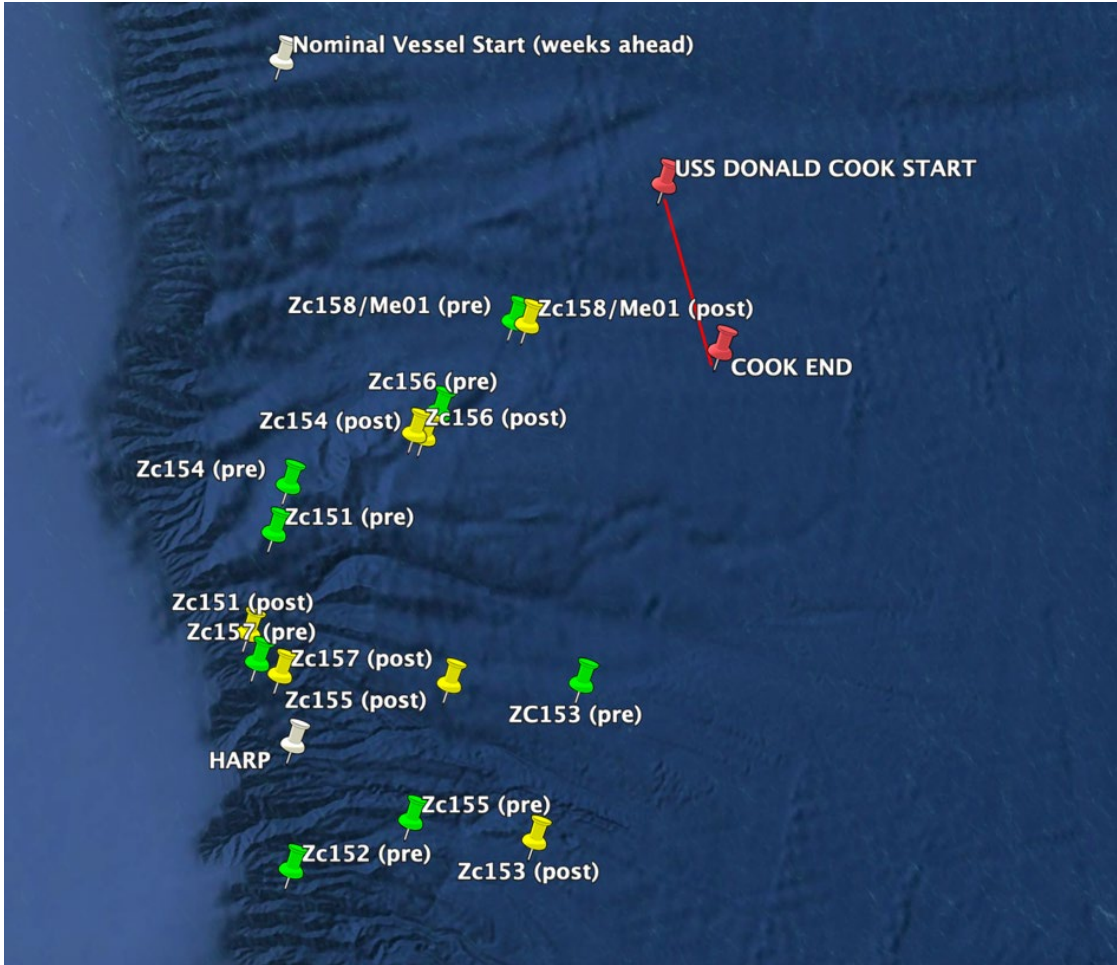


Figure 19. Broad view of focal whale (ZcTag156) and other tagged beaked whales (ZcTags 151, 153, 154, 155, 157, 158) before (green pins) and after (yellow pins) CAS CEE #25\_01. The actual start and end locations (red pins) and track (red line) for the USS *Donald Cook* are shown.

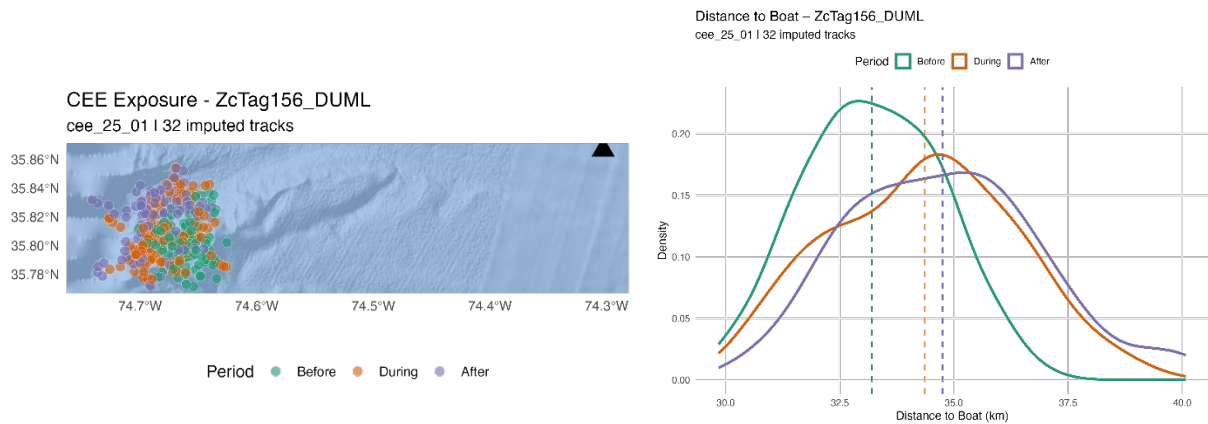


Figure 20. Imputed track locations (left) and corresponding estimated distances to the USS *Donald Cook* (right) at the start of CEE #25\_01 for focal whale ZcTag156. Positions and distances are provided for 1-hour windows before (green), during (red), and after (purple) experimental CAS transmissions.

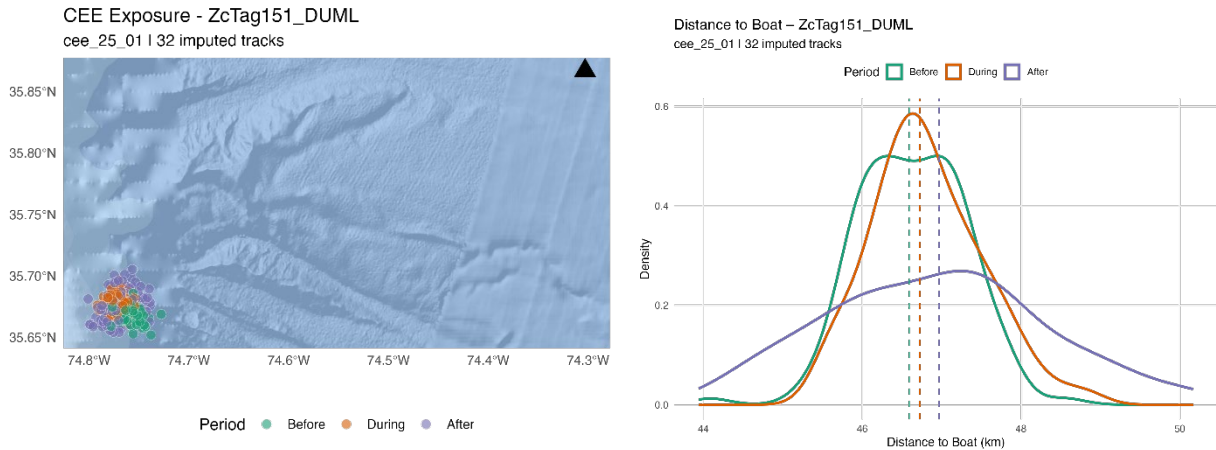


Figure 21. Imputed track locations (left) and corresponding estimated distances to the USS *Donald Cook* (right) at the start of CEE #25\_01 for non-focal whale ZcTag151. Positions and distances are provided for 1-hour windows before (green), during (red), and after (purple) experimental CAS transmissions.

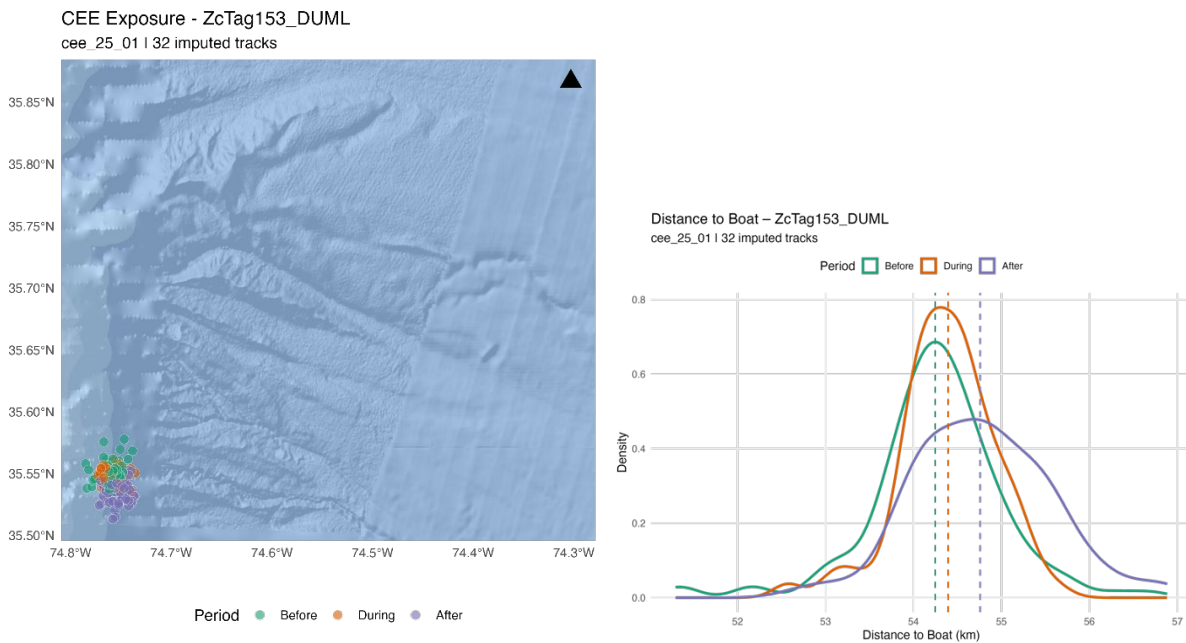
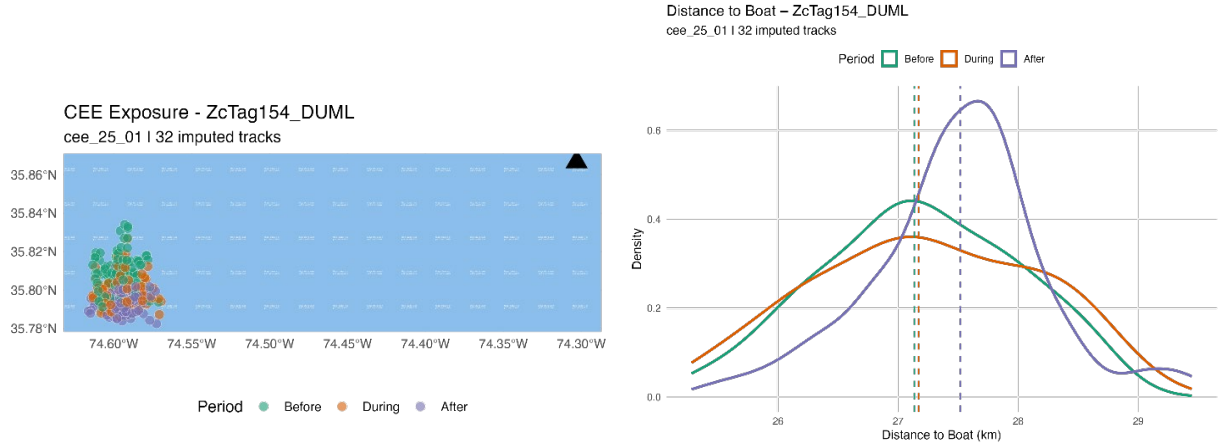
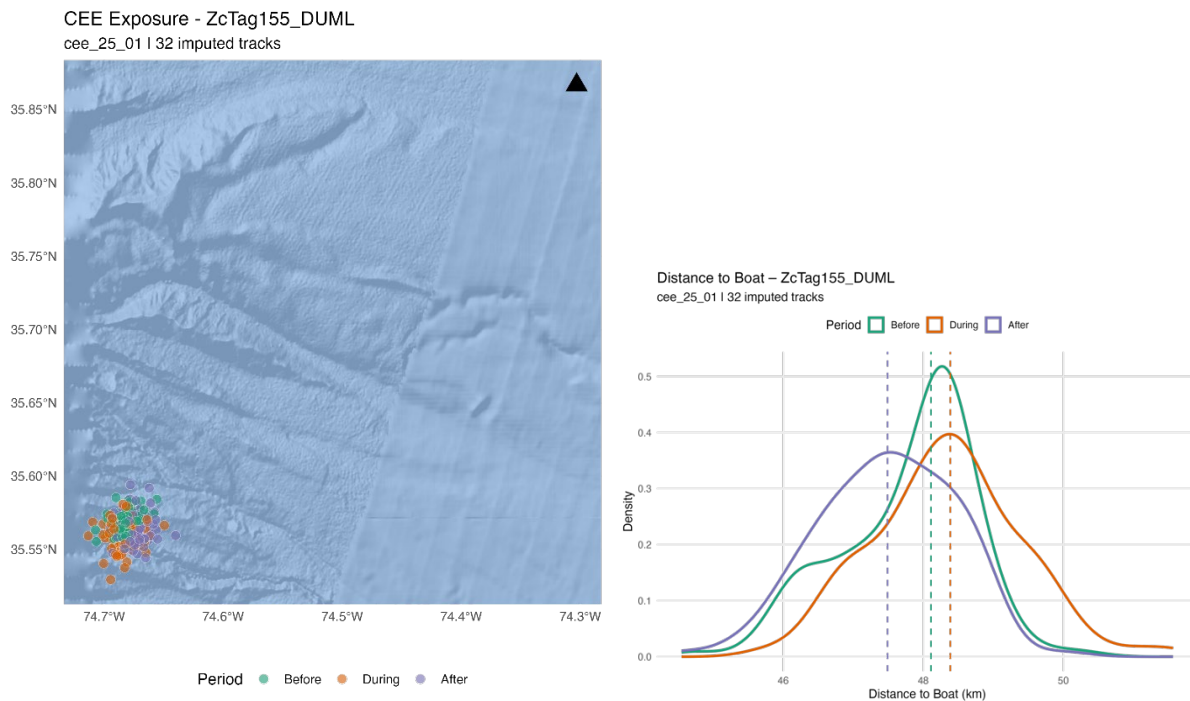


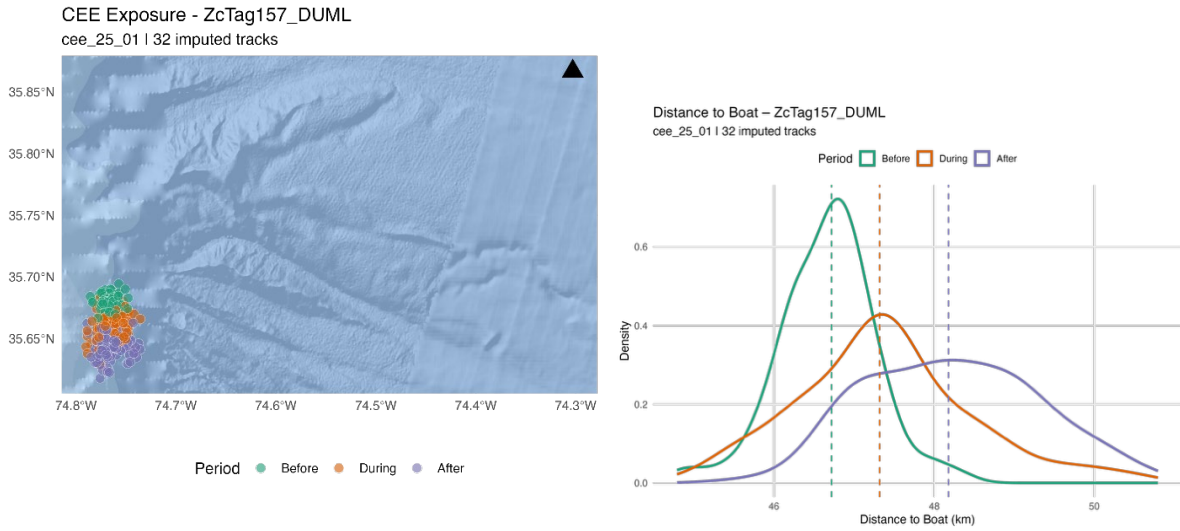
Figure 22. Imputed track locations (left) and corresponding estimated distances to the USS *Donald Cook* (right) at the start of CEE #25\_01 for non-focal whale ZcTag153. Positions and distances are provided for 1-hour windows before (green), during (red), and after (purple) experimental CAS transmissions.



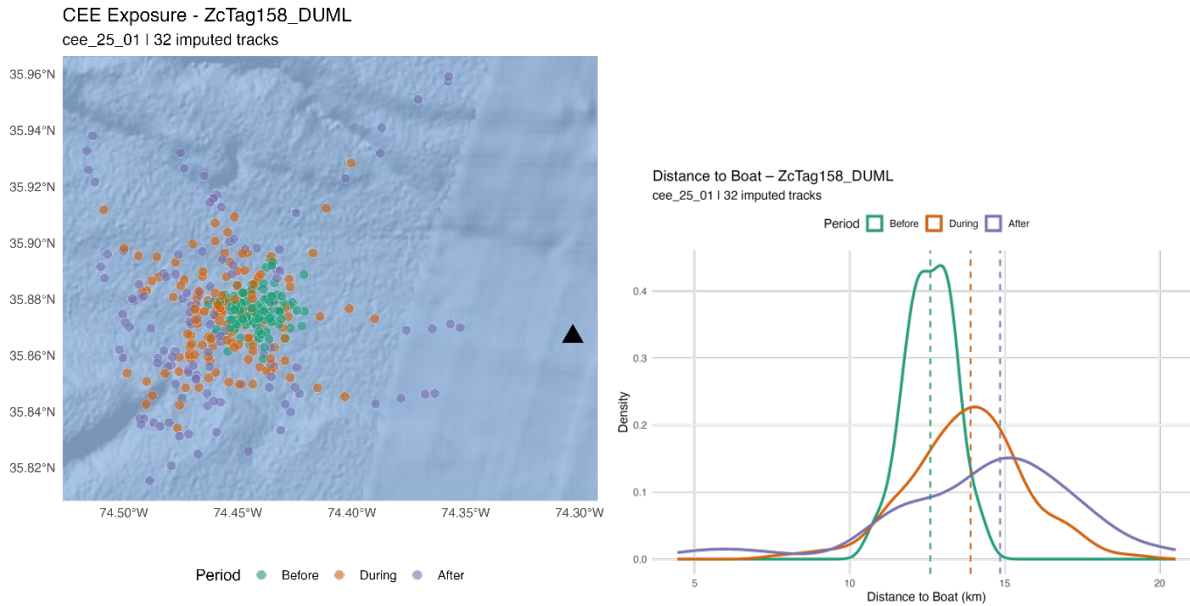
**Figure 23.** Imputed track locations (left) and corresponding estimated distances to the *USS Donald Cook* (right) at the start of CEE #25\_01 for non-focal whale ZcTag154. Positions and distances are provided for 1-hour windows before (green), during (red), and after (purple) experimental CAS transmissions.



**Figure 24.** Imputed track locations (left) and corresponding estimated distances to the *USS Donald Cook* (right) at the start of CEE #25\_01 for non-focal whale ZcTag155. Positions and distances are provided for 1-hour windows before (green), during (red), and after (purple) experimental CAS transmissions.



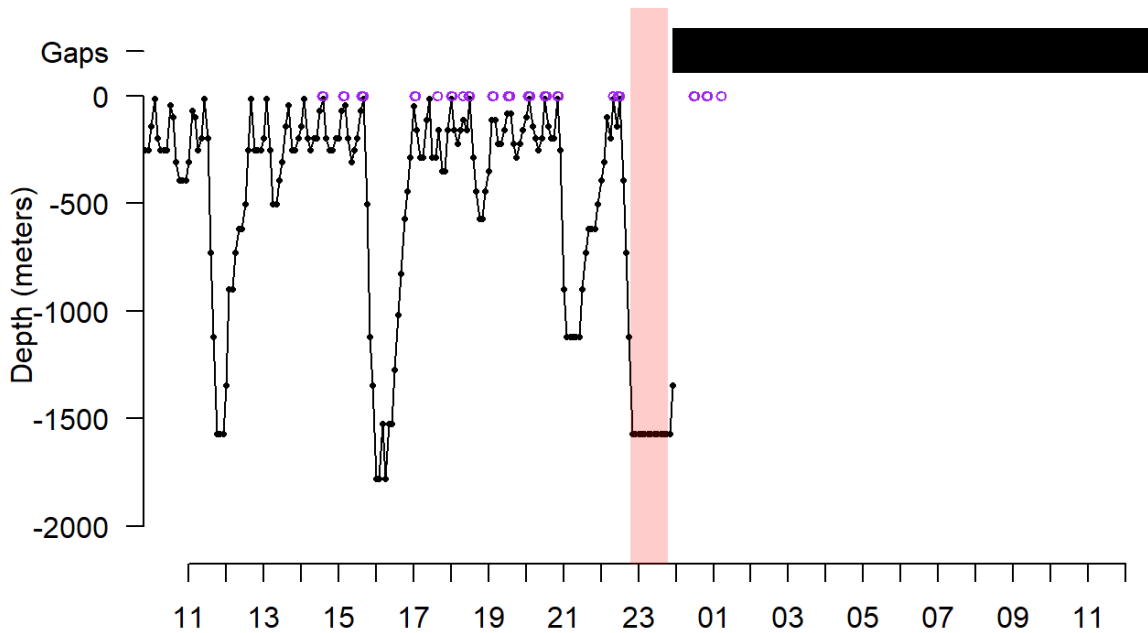
**Figure 25.** Imputed track locations (left) and corresponding estimated distances to the USS *Donald Cook* (right) at the start of CEE #25\_01 for non-focal whale ZcTag157. Positions and distances are provided for 1-hour windows before (green), during (red), and after (purple) experimental CAS transmissions.



**Figure 26.** Imputed track locations (left) and corresponding estimated distances to the USS *Donald Cook* (right) at the start of CEE #25\_01 for non-focal whale ZcTag158. Positions and distances are provided for 1-hour windows before (green), during (red), and after (purple) experimental CAS transmissions.

Dive plots for focal whale ZcTag156 and non-focal whales for which dive-sensing tags were operational (ZcTag153, ZcTag154, ZcTag155, ZcTag157, ZcTag158) during CEE #25\_01 are given in standard formats. **Figure 27**, **Figure 28**, **Figure 30**, **Figure 32**, **Figure 34**, and **Figure 36** show (for these individuals sequentially) 12-hour periods occurring before and after CEE #25\_01, which was 1 hour in duration (pink vertical bars). Coordinated Universal Time (UTC) time (+4 hours from Eastern Daylight Time [EDT]) is indicated on the x-axis, with depth indicated on the y-axis. Black horizontal bars, if any, at the top of plots indicate gaps in successful reception of dive data. **Figure 29**, **Figure 31**, **Figure 33**, and **Figure 35** compare different dive parameters (for the same focal and non-focal whales respectively) during the CEE #25\_01 exposure period (purple arrows) to the same parameters for all baseline dives for that individual over weeks prior to the CEE. Each panel indicates the percentile for that dive parameter for the exposure dive relative to all baseline dives. Dive parameters include (from top left to bottom right): dive duration, maximum dive depth, dive ascent duration, inter-deep-dive-interval (IDDI), IDDI of previous dive, number of “bounce” (non-foraging) dives, mean duration of bounce dives, mean maximum depth of bounce dives, and absolute maximum depth of bounce dives.

### ZcTag156\_DUML: CEE 25\_01 // 2025-07-19 22:48:00



**Figure 27.** Available dive data for focal whale ZcTag156 before, during, and after Atlantic-BRS CEE #25\_01 (pink shading denotes the CAS exposure period, black horizontal bar indicates no dive data received; purple circles indicate signal reception from goniometer).

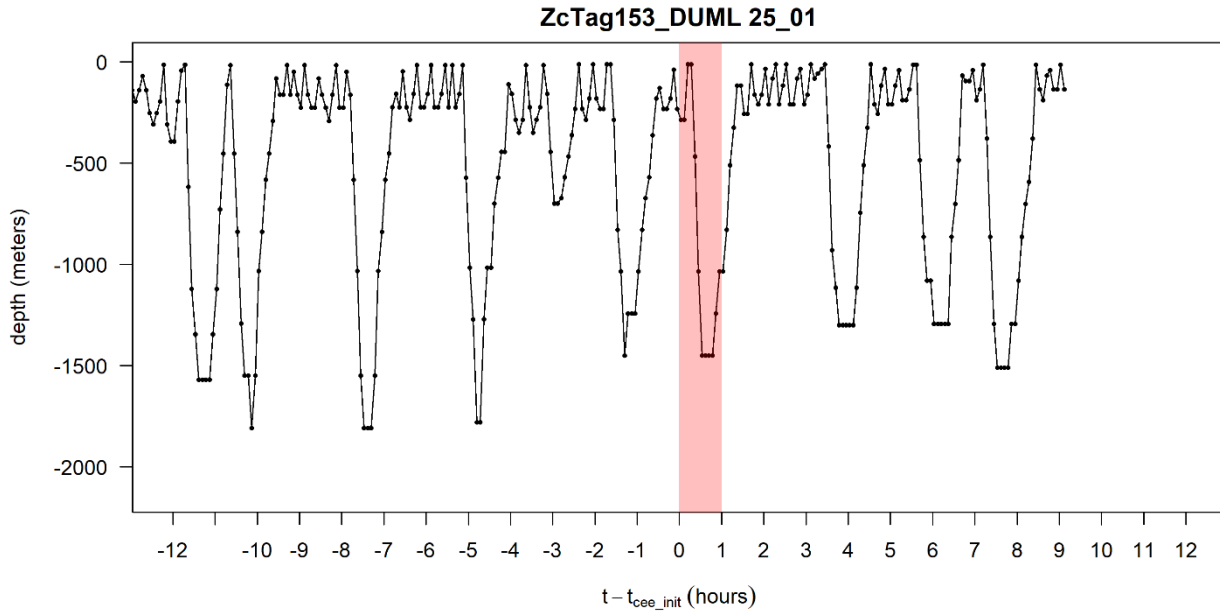


Figure 28. Available dive data for non-focal whale ZcTag153 before, during, and after Atlantic-BRS CEE #25\_01 (pink shading denotes the CAS exposure period).

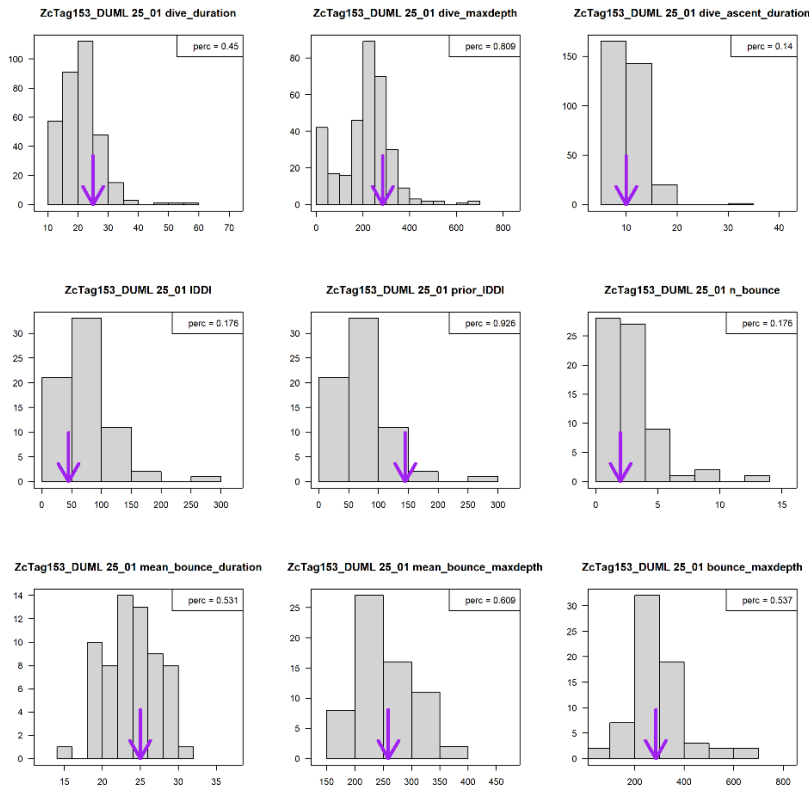


Figure 29. Dive parameters non-focal whale ZcTag153 for dives before (gray bars) and during (pink arrows) Atlantic-BRS CEE #25\_01. Exposure dive percentiles for parameters relative to baseline dives are provided.

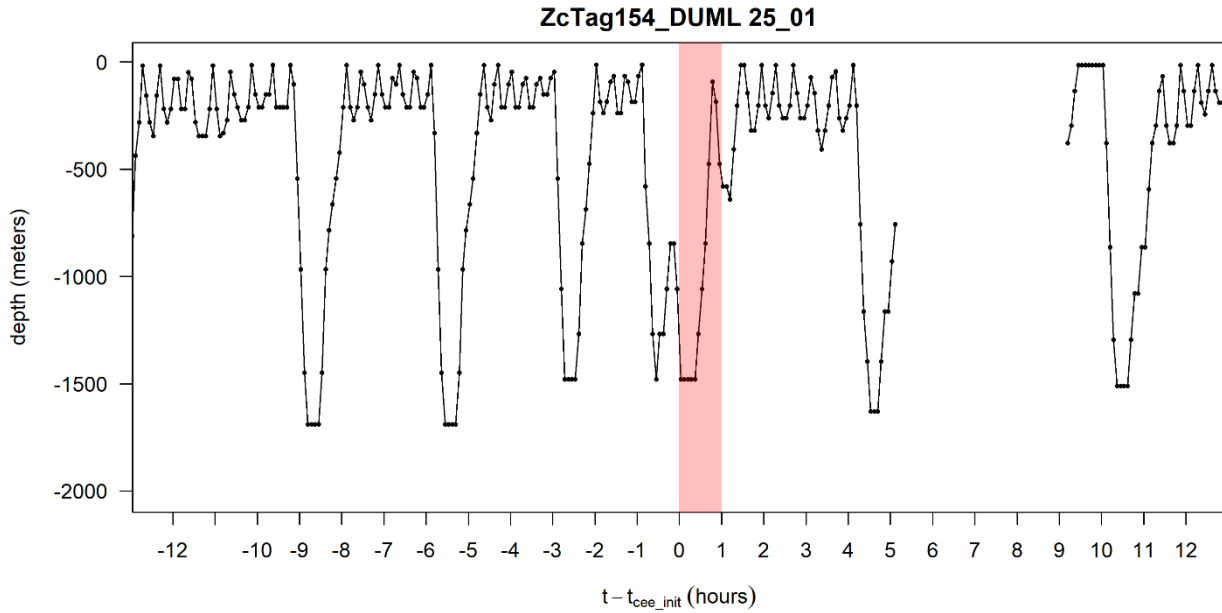


Figure 30. Available dive data for non-focal whale ZcTag154 before, during, and after Atlantic-BRS CEE #25\_01 (pink shading denotes the CAS exposure period).

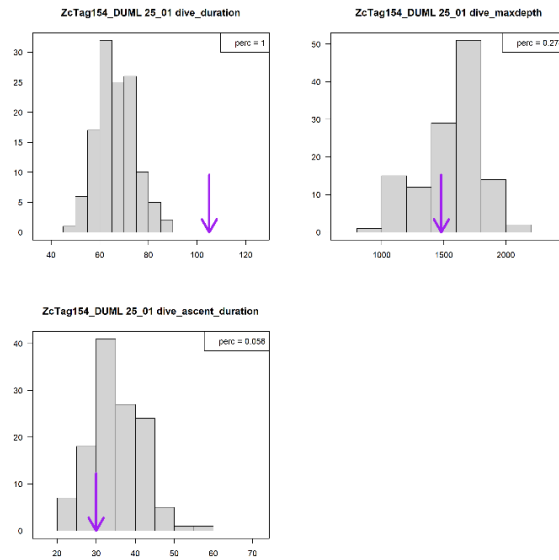


Figure 31. Dive parameters non-focal whale ZcTag154 for dives before (gray bars) and during (pink arrows) Atlantic-BRS CEE #25\_01. Exposure dive percentiles for parameters relative to baseline dives are provided.

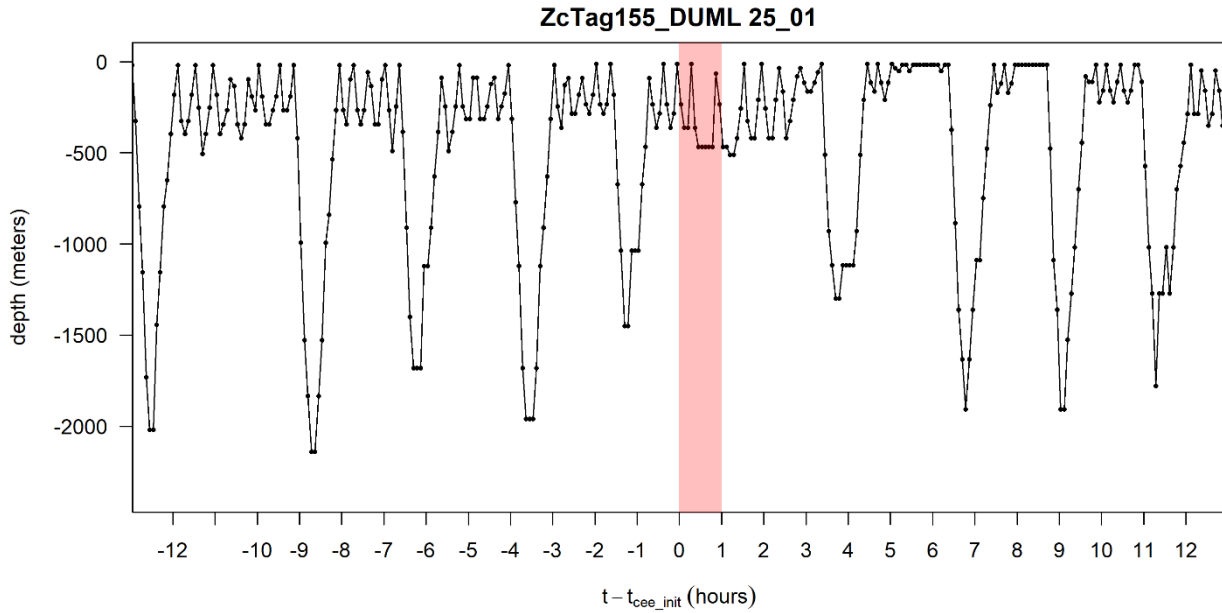


Figure 32. Available dive data for non-focal whale ZcTag155 before, during, and after Atlantic-BRS CEE #25\_01 (pink shading denotes the CAS exposure period).

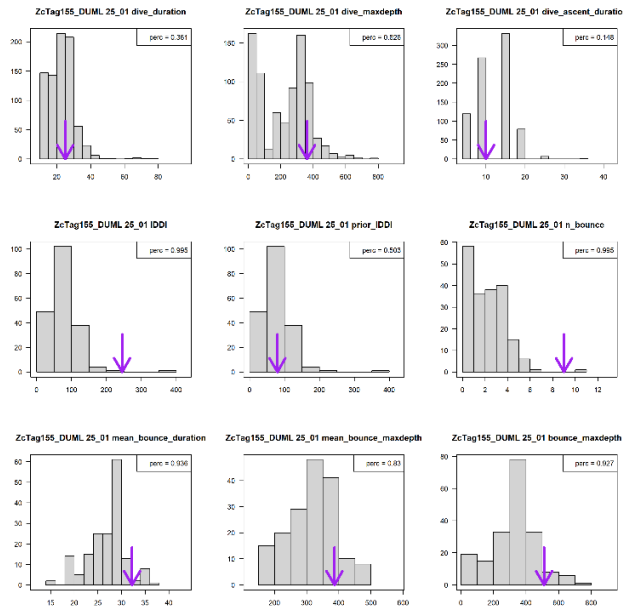


Figure 33. Dive parameters non-focal whale ZcTag155 for dives before (gray bars) and during (pink arrows) Atlantic-BRS CEE #25\_01. Exposure dive percentiles for parameters relative to baseline dives are provided.

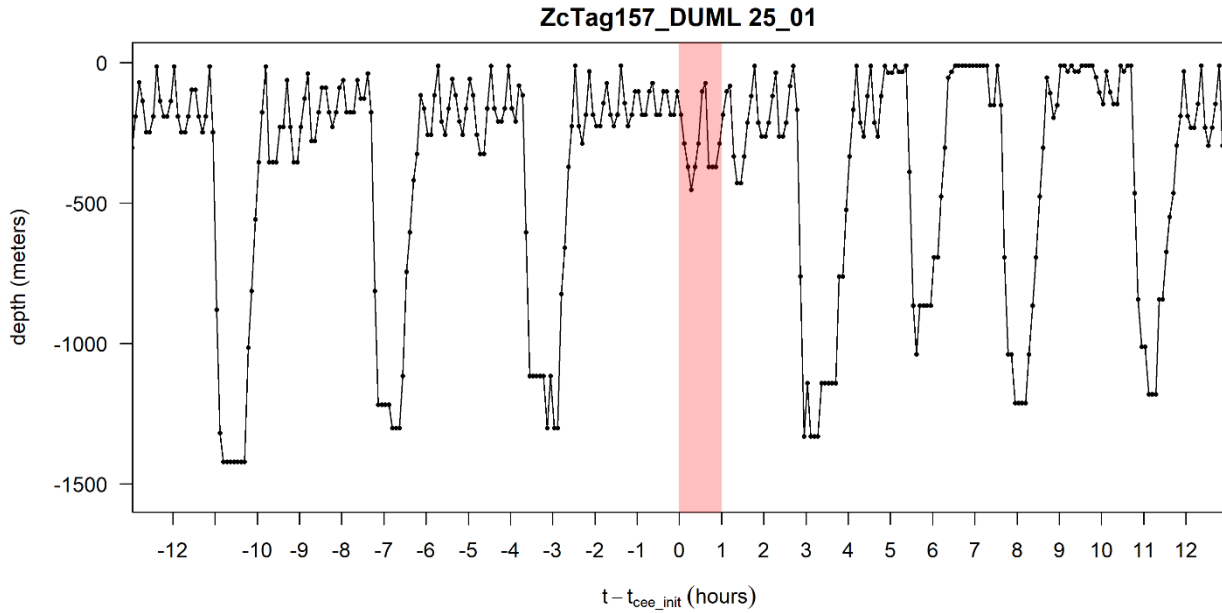


Figure 34. Available dive data for non-focal whale ZcTag157 before, during, and after Atlantic-BRS CEE #25\_01 (pink shading denotes the CAS exposure period).

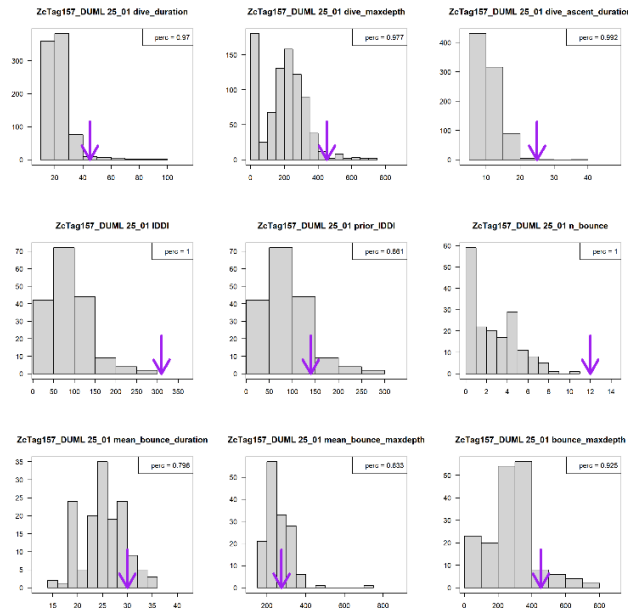


Figure 35. Dive parameters non-focal whale ZcTag157 for dives before (gray bars) and during (pink arrows) Atlantic-BRS CEE #25\_01. Exposure dive percentiles for parameters relative to baseline dives are provided.

### ZcTag158\_DUML: CEE 25\_01 // 2025-07-19 22:48:00

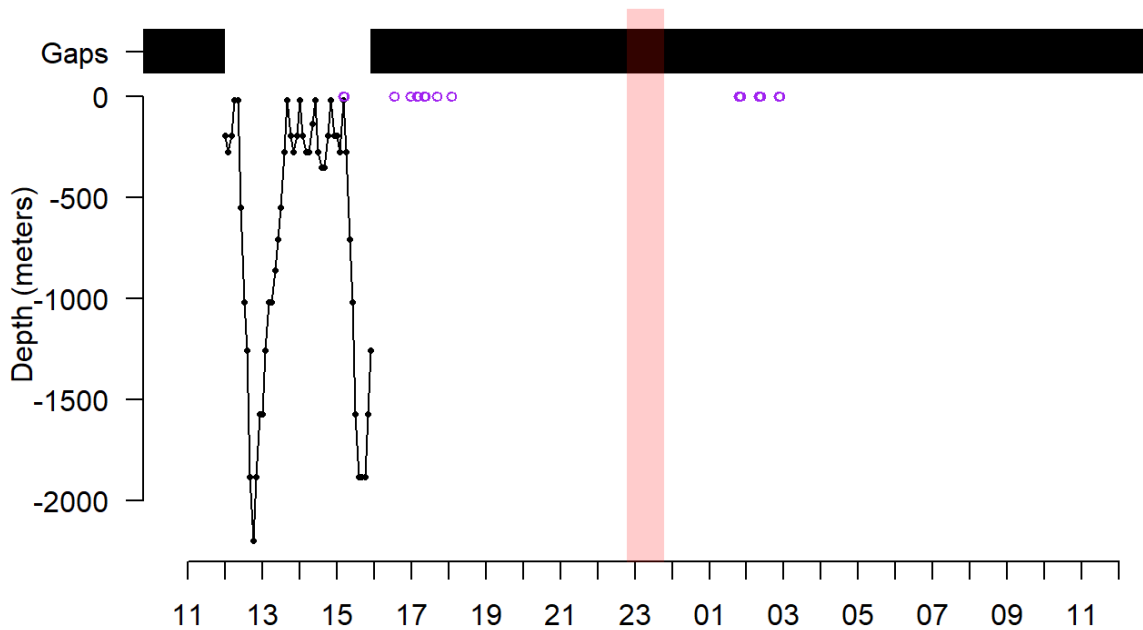
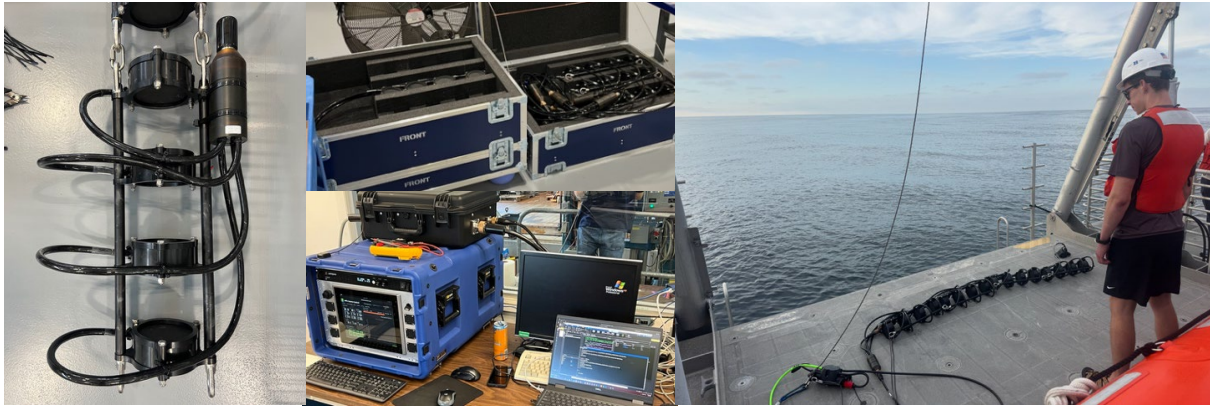


Figure 36. Available dive data for non-focal whale ZcTag158 before, during, and after Atlantic-BRS CEE #25\_01 (pink shading denotes the CAS exposure period; black horizontal bar indicates no dive data received; purple circles indicate signal reception from goniometer).

#### 2.3.2 CEE #25\_02: Experimentally Simulated CAS

The BRS team deployed additional sat tags in September ahead of a scheduled coordination with a CAS-capable U.S. Navy ship. Due to operational constraints, the ship had to transit through the study area during nighttime periods when neither the experimental design nor research authorizations for this study are consistent with CEEs. The field team was prepared for this contingency following acquisition, testing, calibration, and preparations for a new experimental CAS-capable high-power acoustic source (developed with coordination and support from the U.S. Navy's LMR program). **Figure 37** provides images of the source being deployed from the R/V *Shearwater*.



**Figure 37.** Selected images of CAS-capable MFAS sound source that was acquired, tested, calibrated, and used for the first time in field operations in Atlantic-BRS CEE #25\_02.

In coordinating the spatial configuration for CEE #25\_02 using the CAS-capable experimental source, the field team conducted 10 RL model predictions generated *in situ* for different focal and non-focal animals' known or estimated locations at multiple depths using the custom NPS sound propagation planning tool, as shown in **Table 6**. Overall differences between the PAS and CAS MFAS signals are discussed above. The experimentally simulated CAS source signals were identical in overall frequency bandwidth (650 Hz), total duration (50 seconds), and duty cycle (100 percent), but differed slightly in frequency range (3,150 to 3,800 Hz) and 1-m source level (200 dB RMS across band; 203 dB peak). The RL estimates provided herein are RMS values per modeled CAS transmission, and the target (per ping: 122 dB RMS) RL was matched to that for operational (ship-based) CAS CEEs. RL model runs (33 and 34 in **Table 6**) for the start and end of CAS-vessel transmissions for the focal individual (ZcTag161) that informed the final CAS source (deployed from R/V *Shearwater*) position are shown for reference (**Figure 38** and **Figure 39**). A narrative summary and spatial depiction of animal locations before, during, and after CAS CEE sequence (#25\_02) for all focal and non-focal individuals (see **Table 7**; **Figure 40** through **Figure 44**) is provided following the RL model predictions.

Table 6. RL model runs for CEE #25\_02.

Model Run	Runtime	Focal Animal (Depth – m)	Animal Latitude (°N)	Animal Longitude (°W)	Estimated Range (nm) Start–End	Model RL Start	Model RL End	Model RL Max.
31	18 Sept 2100 EDT	Zc161 (100)	35.4063	-74.4225	1.5–1.2	114	120	120
32	18 Sept 2200 EDT	Zc161 (2,500)	35.4063	-74.4225	1.5–1.2	130	124	131
33	19 Sept 1000 EDT	Zc161 (100)	35.3522	-74.6293	1.5–1.3	122	127	127
34	19 Sept 1030 EDT	Zc161 (2,200)	35.3522	-74.6293	1.5–1.3	124	131	131
35	19 Sept 1000 EDT	Zc162 (100)	35.2452	-74.9353	15.5–16.0	108	101	109
36	19 Sept 1030 EDT	Zc162 (800)	35.2452	-74.9353	15.5–16.0	105	105	107
37	19 Sept 1100 EDT	Zc164 (100)	35.6556	-74.7288	18.5–19.0	106	110	111
38	19 Sept 1130 EDT	Zc164 (1,300)	35.6556	-74.7288	18.5–19.0	102	102	104
39	19 Sept 1100 EDT	Zc151 (100)	35.6969	-74.7431	21.5–22.0	97	101	101
40	19 Sept 1130 EDT	Zc151 (1,100)	35.6969	-74.7431	21.5–22.0	108	107	109

Key: Max. = Maximum; °N = degrees North; nm = nautical mile(s); °W = degrees West; Zc = *Ziphius cavirostris*

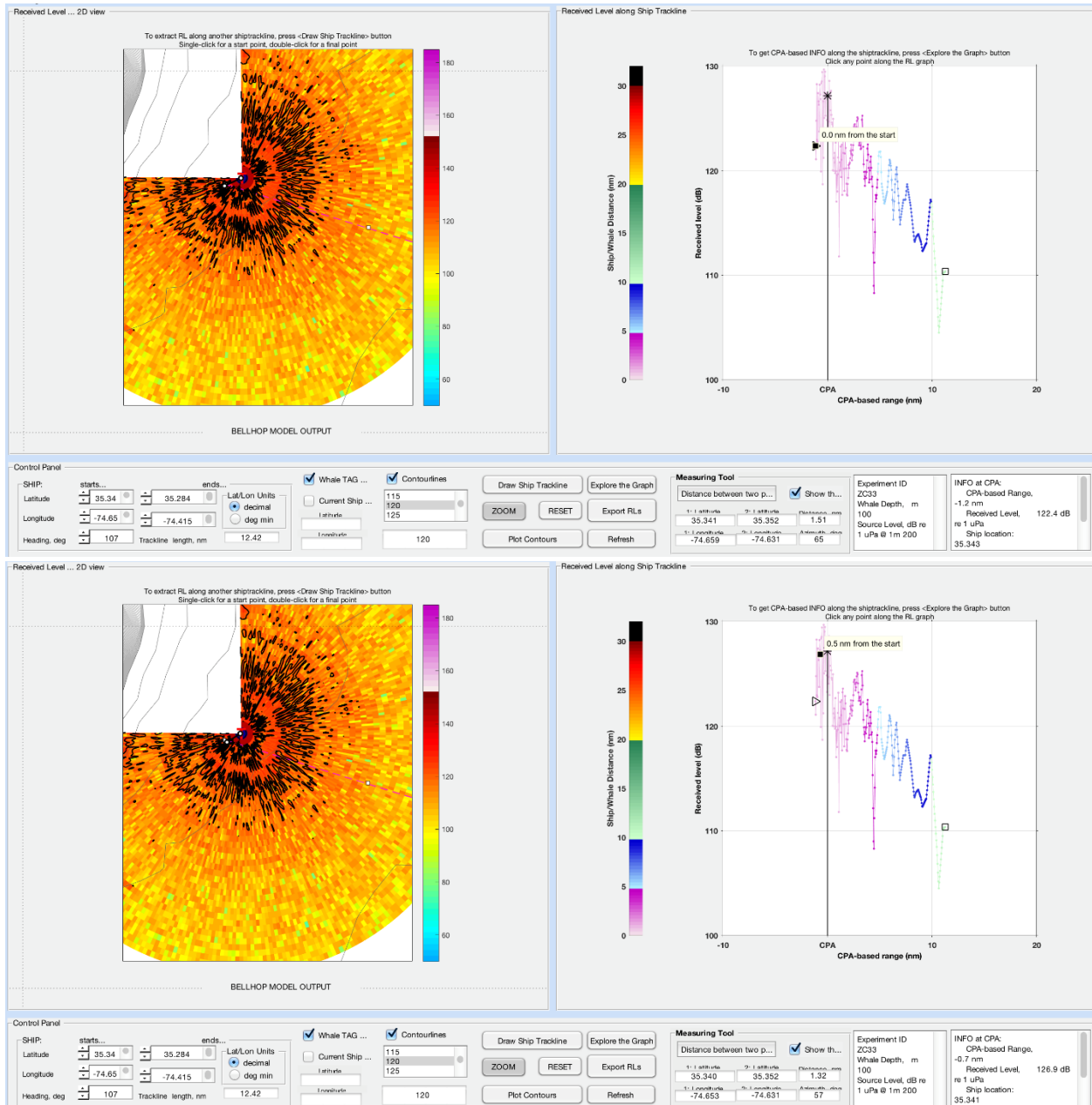
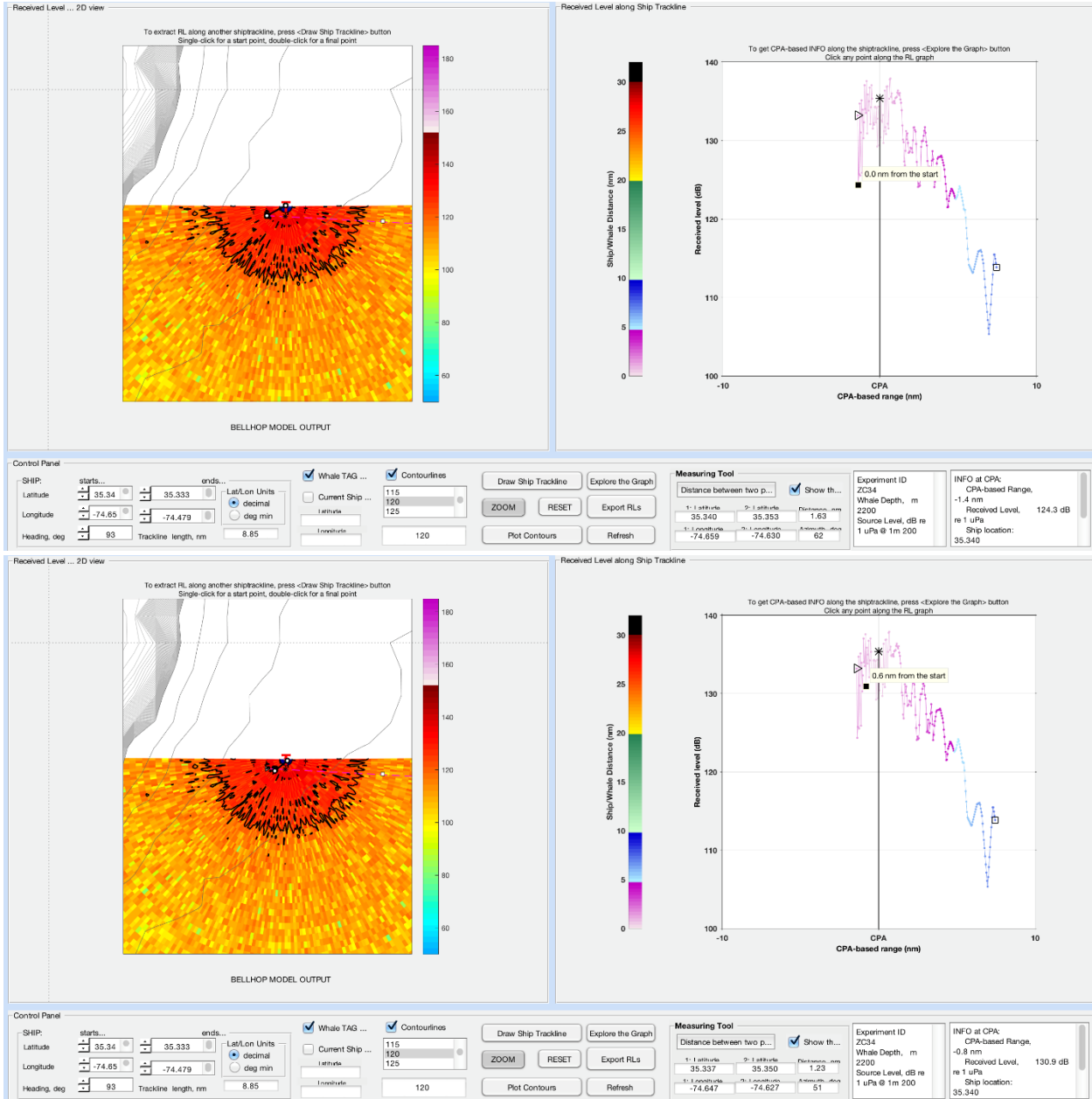


Figure 38. RL model prediction at 100-m depth (model run 33 from Table 6) for focal whale ZcTag161 ahead of Atlantic-BRS CEE #25\_02 for the start (top; vessel-animal range: 1.5 nm; modeled RL = 122.4 dB) and end (bottom; vessel-animal range: 1.3 nm; modeled RL = 126.9 dB) of the modeled vessel track.



**Figure 39.** RL model prediction at 2,200-m depth (model run 34 from Table 6) for focal whale ZcTag161 ahead of Atlantic-BRS CEE #25\_02 for the start (top; vessel-animal range: 1.6 nm; modeled RL = 124.3 dB) and end (bottom; vessel-animal range: 1.2 nm; modeled RL = 130.9 dB) of the modeled vessel track.

Table 7. Metadata summary for Atlantic-BRS CEE #25\_02.

<b>CEE #25_02 - Narrative Summary</b>	
<p>Prior to field operations in September of 2025 that were targeted toward coordinating a second CAS CEE with a scheduled operational Navy ship, the Atlantic-BRS team successfully obtained, tested, fielded, and calibrated new operational CAS-capable MFAS sound source. When operational limitations precluded coordination with the Navy vessel, the BRS team adapted to conducting the first-ever CEE simulating U.S. Navy CAS signals for any species including <i>Ziphius</i> with this high-power experimental MFAS source. This CEE was directed toward focal whale ZcTag161 at a range of ~1.5 nm and with non-focal whales (ZcTag151 (also incidental in CEE #25_01), ZcTag162, and ZcTag164). Initial analyses suggest horizontal avoidance evident in the focal and two of three non-focal individuals. Some diving responses are evident in the focal and non-focal whales with functioning dive-sensing tags. This includes extended or altered dive patterns relative to non-exposed dives prior to CAS exposure.</p>	
<b>CEE #25_02</b>	
<b>Date:</b>	19 September 2025
<b>Type:</b>	Continuous Active Sonar (CAS) from Experimental Source Simulation
<b>Signal parameters:</b>	<ul style="list-style-type: none"> <li>- Linear FM upsweeps: 3100-3850 Hz bandwidth (650 Hz bandwidth)</li> <li>- 50s sweep duration; 100% duty cycle; 30-min total transmit duration</li> <li>- Vessel positioned using in situ modeling</li> <li>- Source level: calibrated as 200 dB RMS (across band); -18 dB re: operational CAS source level</li> </ul>
<b>Start time (UTC):</b>	16:26
<b>Start lat/lon (source):</b>	35.3397; -74.6539
<b>End time (UTC):</b>	16:56 (30 min exposure duration)
<b>End lat/lon (source):</b>	35.3386; -74.6391
<b>Beaked whales tagged during CEE:</b>	(n=4) – ZcTag161 (focal sat tag animal); Non-focal whales: ZcTag151; ZcTag162; ZcTag164
<b>Estimated Range (start CEE):</b>	~1.5 nm @ start (focal follow locations) for focal
<b>Modeled Max RL:</b>	Variable for final position model runs/depths ->122-131 dB RMS (across band) = 140-149 dB Sound Exposure Level (SEL) per ping (based on model runs 33-34; see Table 6)

Key: FM = frequency-modulated; lat = latitude; lon = longitude; min = minute(s); nm = nautical mile(s); Zc = *Ziphius cavirostris*

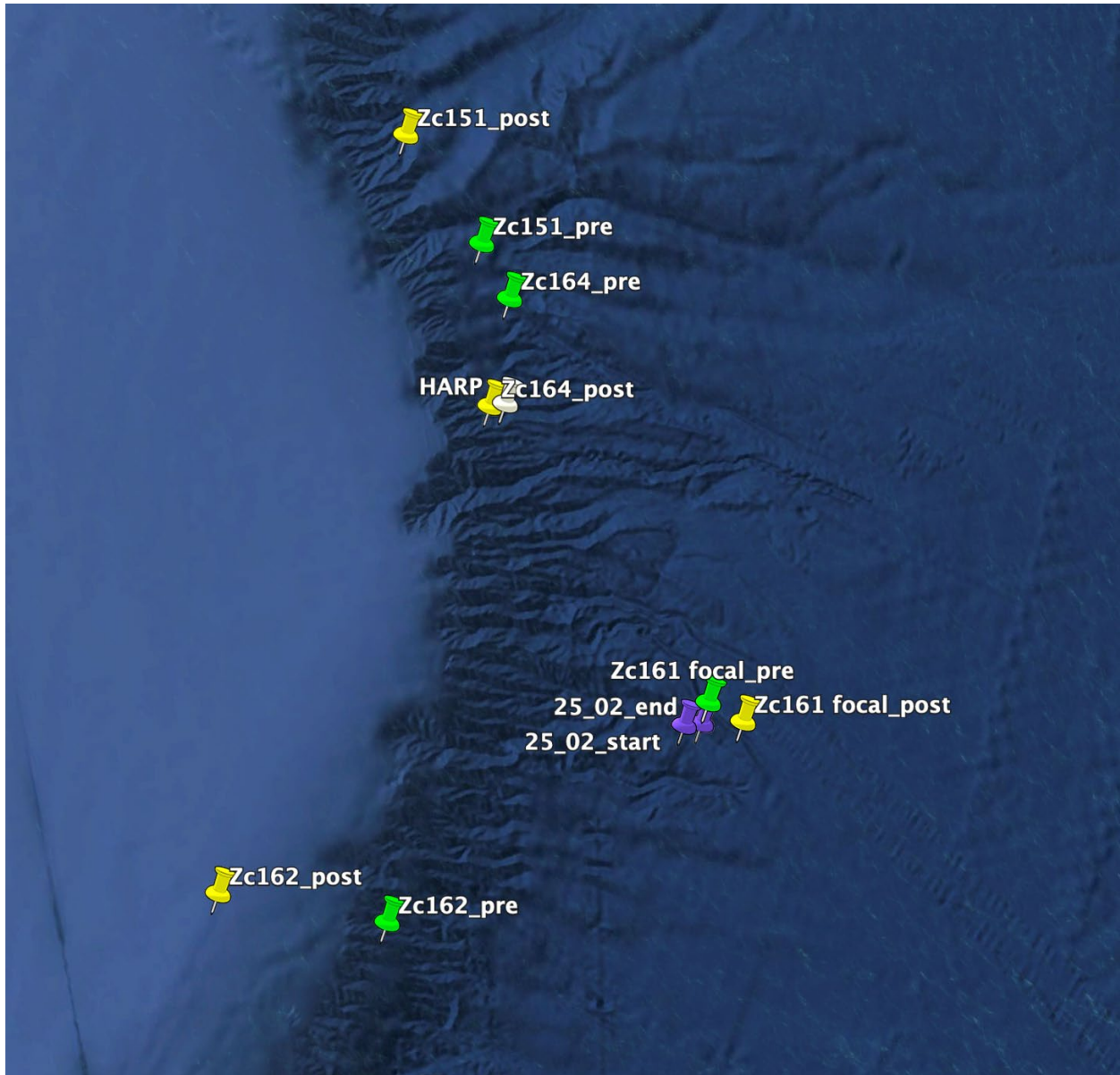
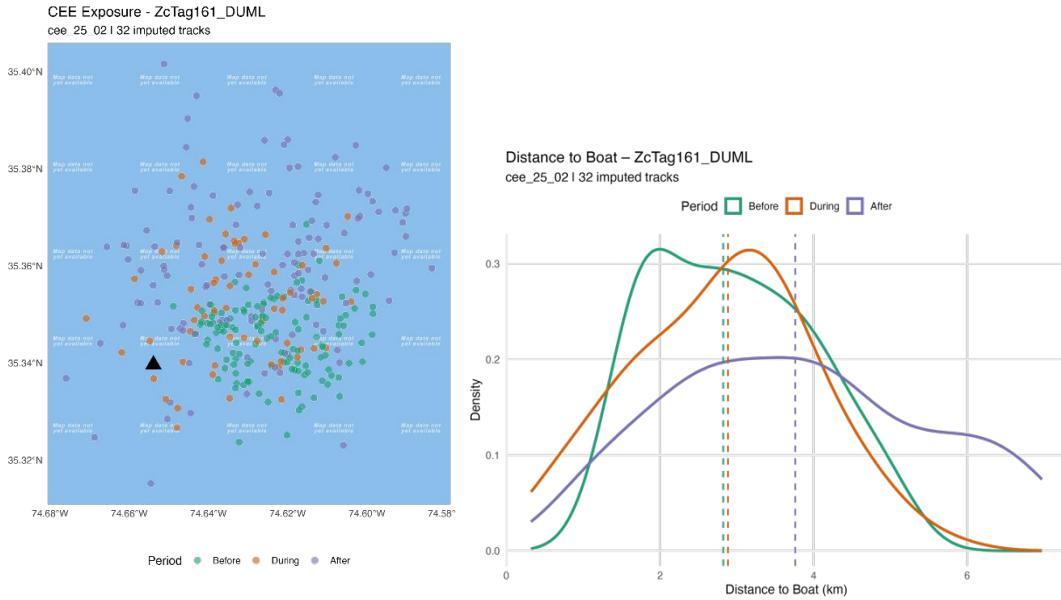
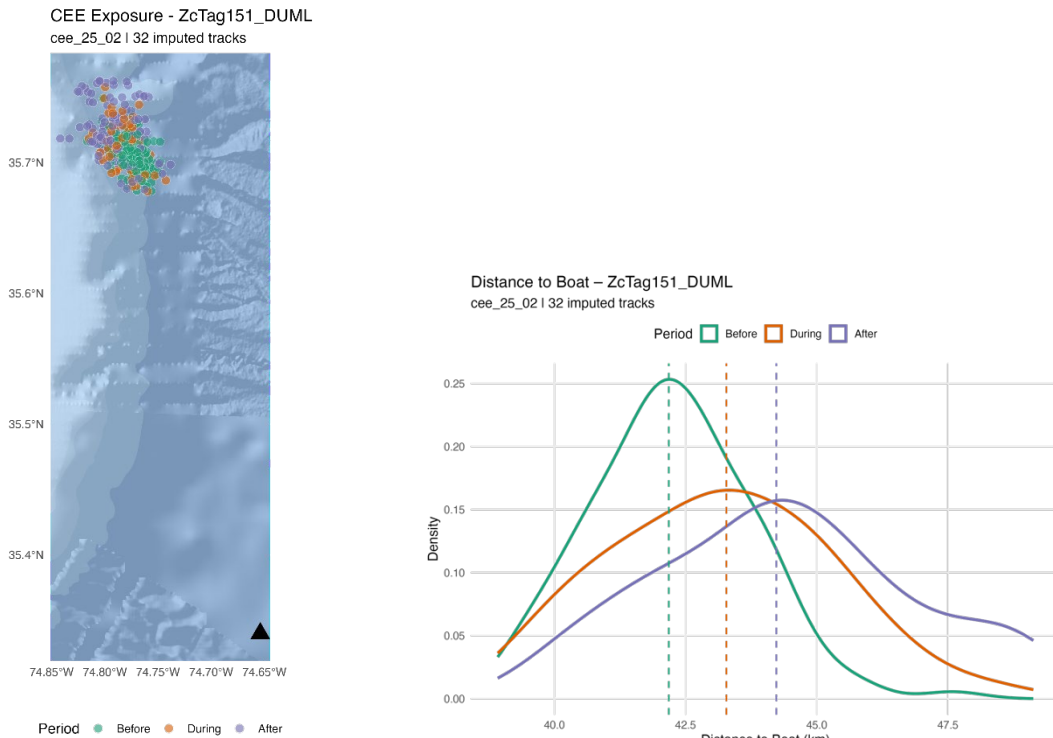


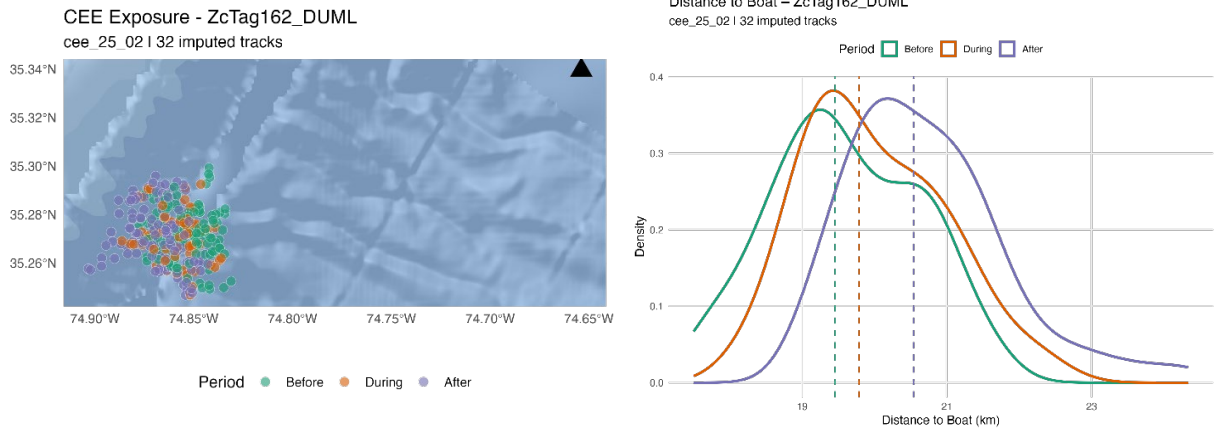
Figure 40. Broad view of focal whale (ZcTag161) and other tagged beaked whales (ZcTag151, ZcTag162, ZcTag164) before (green pins), and after (yellow pins) simulated CAS CEE #25\_02. The actual start and end locations (purple pins) and for the R/V *Shearwater* (from which source was deployed) and the recording High-frequency Acoustic Recording Package (HARP; white pin) are shown.



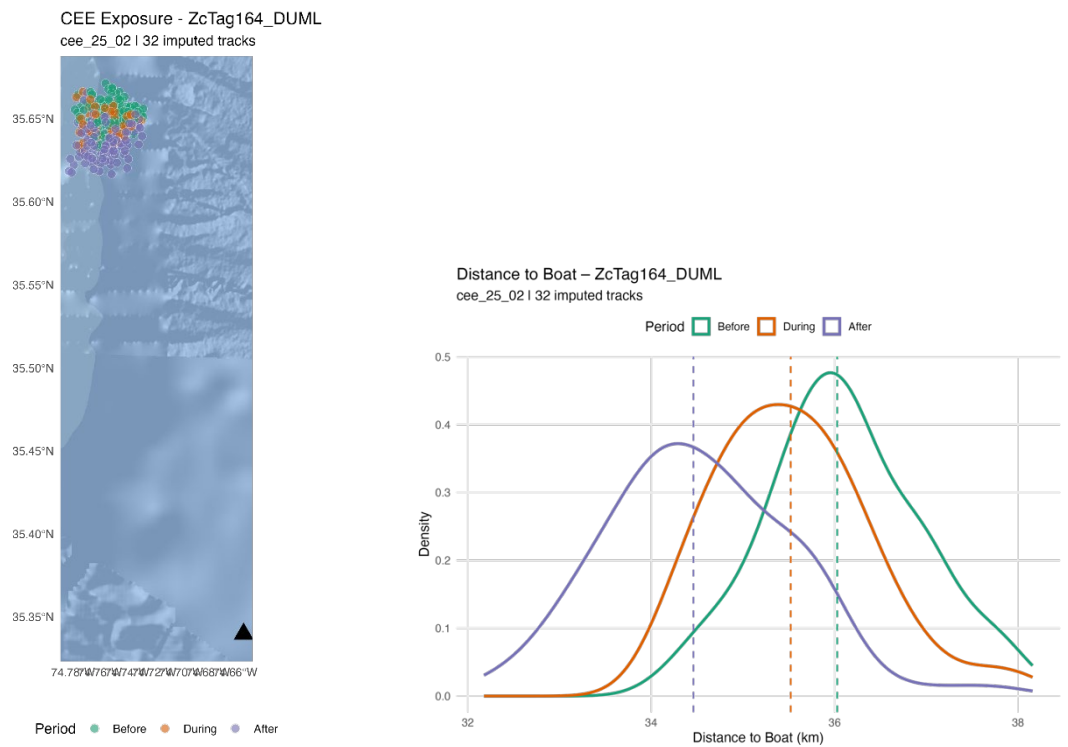
**Figure 41.** Imputed track locations (left) and corresponding estimated distances to the R/V *Shearwater* (right) at the start of CEE #25\_02 for focal whale ZcTag161. Positions and distances are provided for 30-minute windows before (green), during (red), and after (purple) experimental CAS transmissions.



**Figure 42.** Imputed track locations (left) and corresponding estimated distances to the R/V *Shearwater* (right) at the start of CEE #25\_02 for non-focal whale ZcTag151. Positions and distances are provided for 30-minute windows before (green), during (red), and after (purple) experimental CAS transmissions.

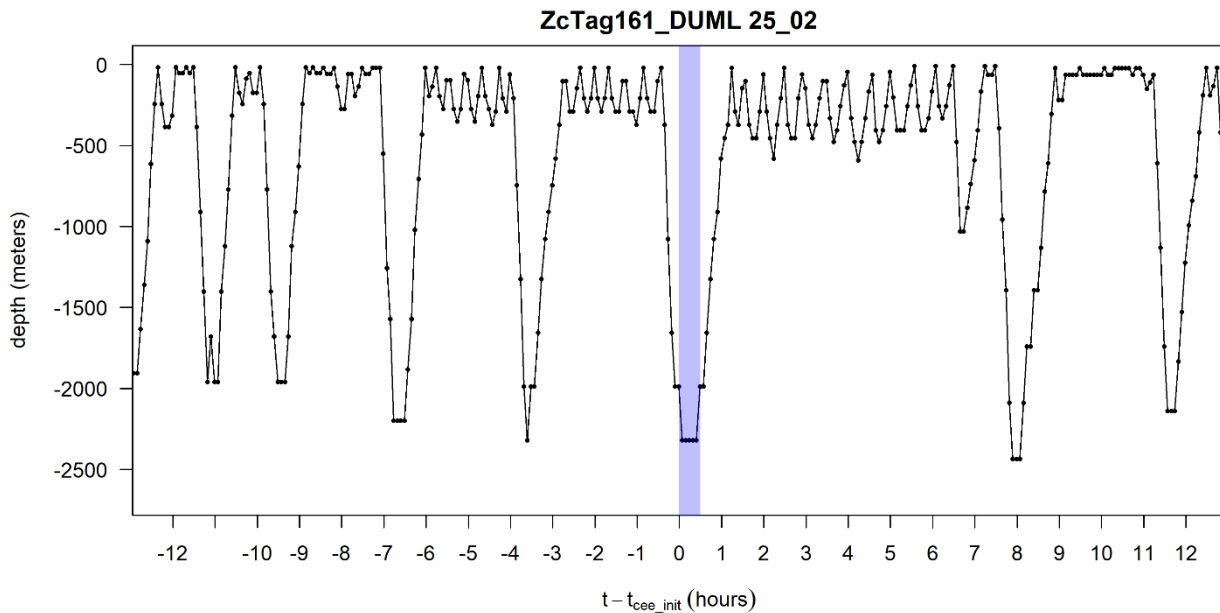


**Figure 43.** Imputed track locations (left) and corresponding estimated distances to the R/V *Shearwater* (right) at the start of CEE #25\_02 for non-focal whale ZcTag162. Positions and distances are provided for 30-minute windows before (green), during (red), and after (purple) experimental CAS transmissions.



**Figure 44.** Imputed track locations (left) and corresponding estimated distances to the R/V *Shearwater* (right) at the start of CEE #25\_02 for non-focal whale ZcTag164. Positions and distances are provided for 30-minute windows before (green), during (red), and after (purple) experimental CAS transmissions.

Dive plots for focal whale ZcTag161 and non-focal whales for which dive-sensing tags were operational (ZcTag162, ZcTag164) during CEE #25\_02, are given in standard formats. **Figure 45, Figure 47, and Figure 49** show (for these individuals sequentially) 12-hour periods occurring before and after CEE #25\_02, which was 30 minutes in duration (blue vertical bars). UTC time (+4 hours from EDT) is indicated on the x-axis, with depth indicated on the y-axis. Black horizontal bars, if any, at the top of plots indicate gaps in dive data. **Figure 46 and Figure 48** compare different dive parameters (focal whale ZcTag161 and non-focal whale ZcTag162, respectively) during the CEE #25\_02 exposure period (purple arrows) to the same parameters for all baseline dives for that individual over weeks prior to the CEE. Each panel indicates the percentile for that dive parameter for the exposure dive relative to all baseline dives. Dive parameters include (from top left to bottom right): dive duration, maximum dive depth, dive ascent duration, IDDI, IDDI of previous dive, number of “bounce” (non-foraging) dives, mean duration of bounce dives, mean maximum depth of bounce dives, and absolute maximum depth of bounce dives.



**Figure 45.** Available dive data for focal whale ZcTag161 before, during, and after Atlantic-BRS CEE #25\_02 (blue shading denotes the CAS exposure period).

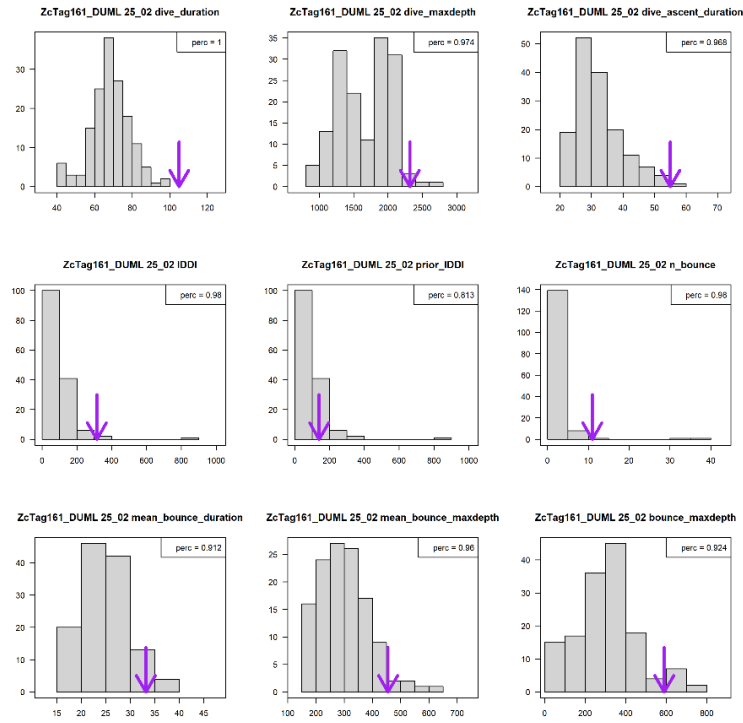


Figure 46. Dive parameters for focal whale ZcTag161 for dives before (gray bars) and during (pink arrows) Atlantic-BRS CEE #25\_02. Exposure dive percentiles for parameters relative to baseline dives are shown.

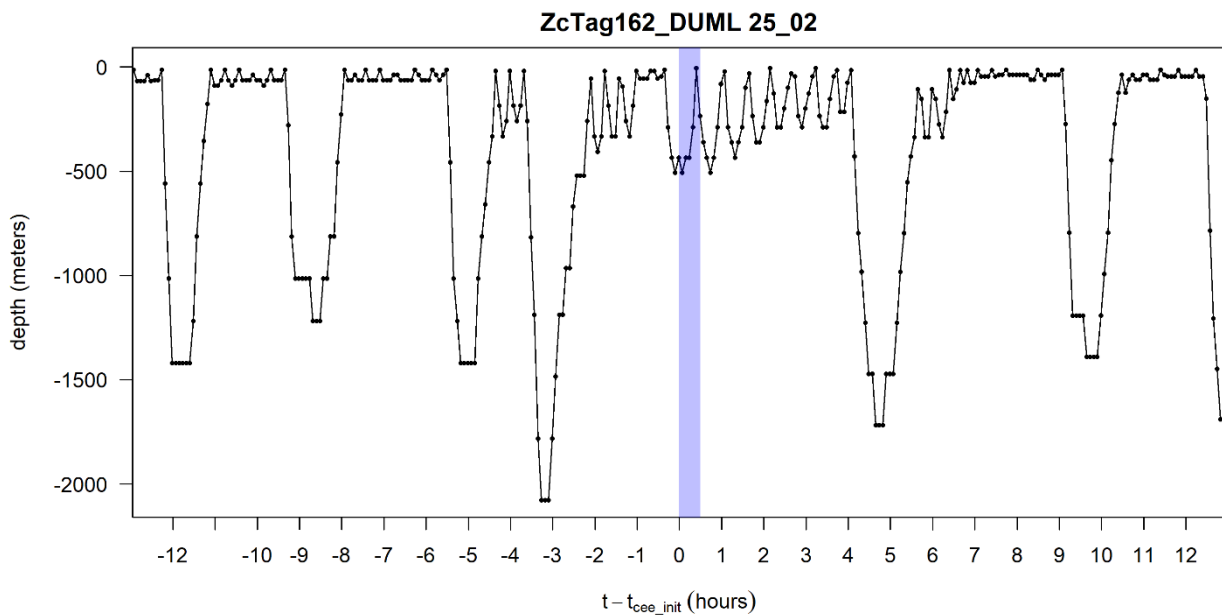


Figure 47. Available dive data for non-focal whale ZcTag162 before, during, and after Atlantic-BRS CEE #25\_02 (blue shading denotes the CAS exposure period).

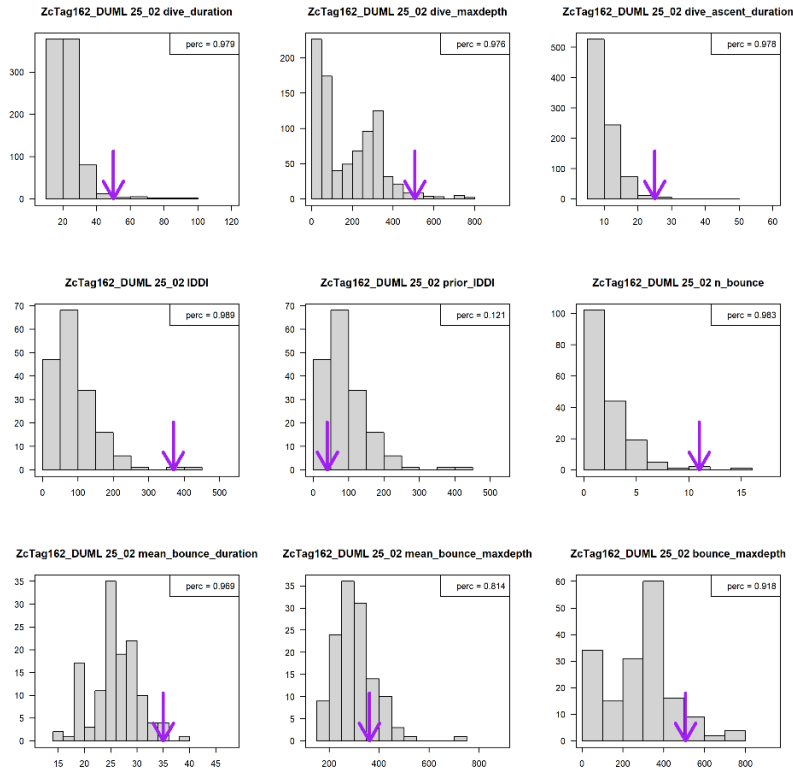


Figure 48. Dive parameters for non-focal whale ZcTag162 for dives before (gray bars) and during (pink arrows) Atlantic-BRS CEE #25\_02. Exposure dive percentiles for parameters relative to baseline dives are shown.

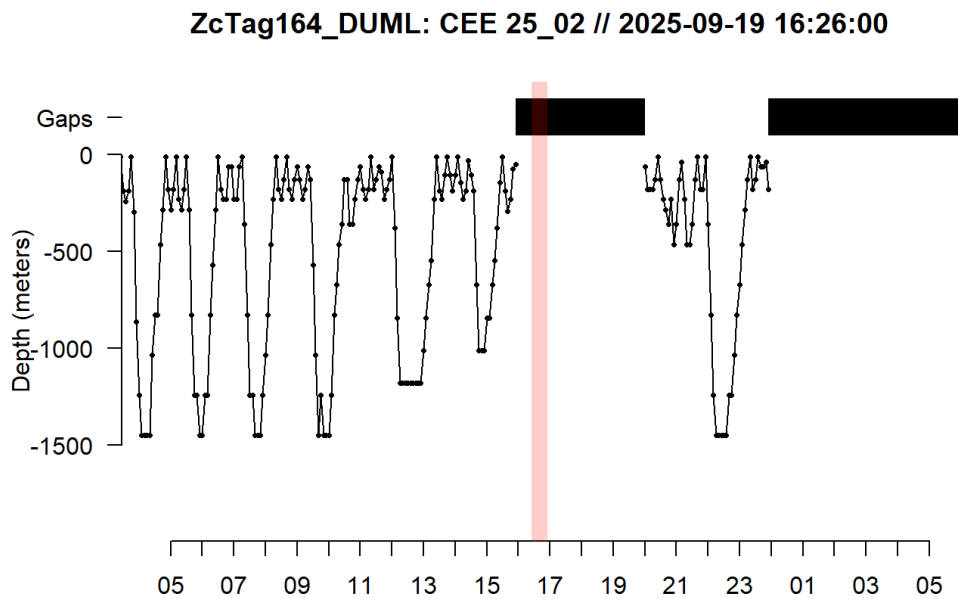


Figure 49. Available dive data for non-focal whale ZcTag164 before, during, and after Atlantic-BRS CEE #25\_02 (pink shading denotes the CAS exposure period, black horizontal bar indicates no dive data).

## 2.4 Preliminary Results

Preliminary results from both CEEs conducted in 2025 yield some interesting initial observations. It should be clearly recognized that additional analyses are ongoing and will be integrated with additional planned experiments with both additional operational and simulated CAS exposures before broader conclusions and assessments are reached. However, the CEEs in 2025 substantially increase both the sample size for operational CAS CEEs (by 7 to  $n=10$ ) and include the first-ever CEE with a MFAS source simulating U.S. Navy CAS ( $n=4$ ). Some short-term (hours) changes in both movement and diving behavior are evident from initial analyses presented above in focal and non-focal whales during and following CAS exposures at variable source-whale exposure ranges in both CEEs.

For the operational CAS CEE (#25\_01), focal whale ZcTag156 and five of six non-focal whales demonstrate movement away from the active CAS source for ranges of approximately 1 to 4 kilometers (km; approximately 0.5 to 2 nautical miles [nm]) over the period of and immediately within (1 hour) of the exposure. However, all of these individuals remained within the study area and appeared to resume normal movement patterns, with larger scale movements for several individuals (e.g., ZcTag154; **Figure 4**) occurring days to weeks after CEEs. These kinds of responses, seen in operational PAS CEEs, would be best described as temporary horizontal avoidance but did occur in six of seven exposed individuals, including several at more than 40-km source-whale range. Diving responses, including extended dive durations and extended IDDI, were also evident in the focal and several non-focal whales, though with some caveats and interesting differences from many PAS CEE exposed whales. For example, focal whale ZcTag156 appears to have an extended deep dive during exposure relative to baseline dives prior to exposure; unfortunately, gaps in the dive data for this individual preclude a more complete analysis of the post-dive behavior (see **Section 5** for more consideration of this exposure event). Several non-focal whales at ranges of approximately 20- to 40-km (approximately 10 to 20 nm) source-whale range exhibited some similar diving responses as demonstrated in previous PAS CEEs, including extended IDDI with more bounce dives than baseline conditions. However, while some atypical aspects of bounce dives are apparent in some individuals, none of the individuals exposed during bounce dive sequences appear to have prematurely initiated presumably non-foraging deep dives as observed in many PAS CEE whales.

These observations were generally quite similar to those seen for the first simulated CAS CEE. It is important to note that while the sources are quite different between these exposures in output power and source-whale range, and are slightly different in frequency bandwidth of CAS signals, other features are quite similar, including duty cycle, frequency modulation pattern, duration, and RL conditions. That is to say, for similar RL signals from a simulated CAS source much closer (approximately 3 to 20 km [approximately 1.5 to 11 nm]) versus 15- to 50-km (approximately 8 to 27 nm) source-whale range, the study team saw similar kinds of temporary (hours) horizontal avoidance and diving responses in exposed whales as operational CAS sources. This included a very extended deep dive during and atypically long IDDI following exposure in focal whale ZcTag161. Interestingly, the study team also observed an absence of initiation of deep dives during bounce dive sequences for non-focal whale ZcTag162 exposed during a surface series that, instead, is extended to an atypically long surface series (and IDDI).

## 3. Kinéis Satellite System Assessment

### 3.1 Background

In 2025, three National Oceanic and Atmospheric Administration satellites carrying ARGOS instruments were decommissioned, leaving only five remaining satellites. While future satellite launches are planned with additional ARGOS instruments, a new constellation of ARGOS-capable small nanosatellites also came online during 2025 at the beginning of the field season in late June. Called Kinéis, this system includes 20 satellites with ARGOS capabilities, and the system boasts greatly improved ARGOS temporal coverage for most of the Earth's surface ([Wildlife Computers 2025](#)).

The study team did not have real-time access to the data for the 2025 season, but expect to have real-time or near-real-time access during subsequent field seasons. The study team was able to access the new data after the conclusion of the field season. All the SPLASH10-333 tags deployed during 2025 were deployed after Kinéis was operational. The first tag, a SPOT-365 was deployed several days before. At the time of this report, this tag is still transmitting. In theory, Kinéis should provide a significant increase in tracking performance, but the exact benefit is hard to predict exactly given the complicated interaction between animal behavior, geography, weather, and satellites that influences the resultant data ([Cioffi et al. 2023](#)). In this section, a brief comparison of actual performance between the legacy ARGOS satellites and the new Kinéis constellation on the same cohort of deployed ARGOS-linked tags are discussed.

### 3.2 Methodology

For the SPOT-365 tag deployed before Kinéis was operational, the legacy ARGOS data was clipped to the same period. Additionally, since this tag is still transmitting (as of 1 June 2026), some of the final statistics may become out of date.

Currently, positional uncertainty is reported differently on Kinéis compared to the legacy system, which uses error ellipses and a parameter that indicates the orientation in degrees of the ellipses. Kinéis-derived positions currently only report error radiuses. For this reason, some caution is advised in directly interpreting the comparisons of reported errors between the two sets of positions. Additionally, there is a large average error difference between Kinéis-derived and legacy positions; for this reason, any location class comparisons are not reported herein because they may not be functionally equivalent.

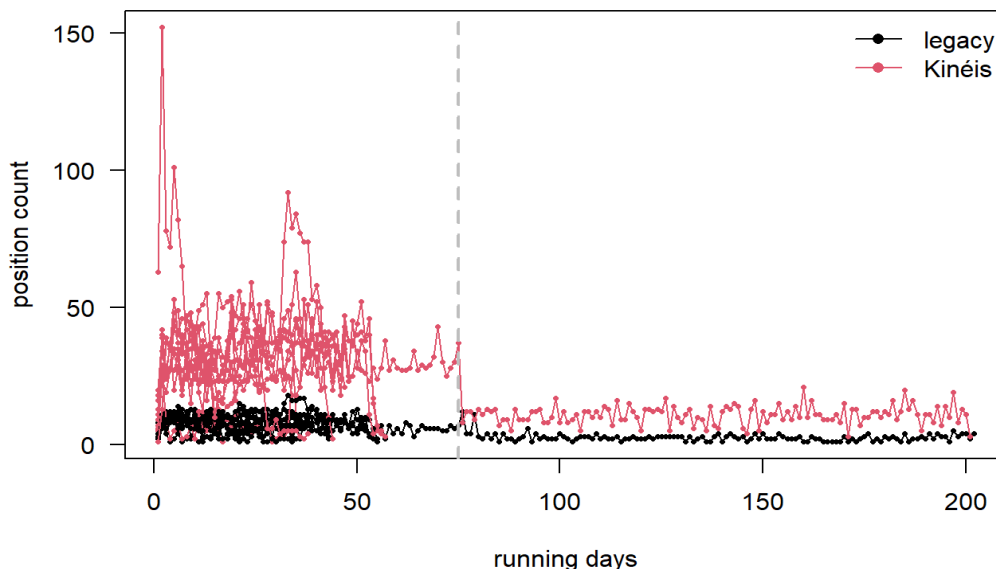
Comparisons were made using the Locations data stream downloaded from the Wildlife Computers data portal representing the legacy system positions and positional data from Kinéis, downloaded directly from a new ARGOS/Collecte Localisation Satellites portal.

### 3.3 Performance Assessment and Comparison

#### 3.3.1 Number of Positions

At the time of this report, 11 tags had ceased transmitting between 0.7 to approximately 55 days of positions (mean is 37 days, standard deviation is 17 days). A single SPOT tag (ZcTag151) has been transmitting for more than 250 days.

Kinéis delivered 3.1 to 5.7 times the number of positions (mean is 4.2, standard deviation is 0.7) as the legacy system. Day-to-day performance was fairly consistent, with Kinéis outperforming the legacy system on nearly every day, with only a few exceptions. There appeared to be a periodic cycle to the Kinéis positions, perhaps created by the geometry of the constellation (**Figure 50**).



**Figure 50.** Daily number of received positions for each tag transmitting during the 2025 field season ( $n=11$ ) on both the legacy ARGOS and new Kinéis systems. Broken gray line indicates beginning of duty cycling on the SPOT-365 tag (ZcTag151).

Hourly position counts were higher and more consistent throughout the day on Kinéis compared to the legacy system (**Figure 51**). Since there was some uncertainty about the operational date for Kinéis, and performance within the study area with *Ziphius* was not known at the time of tag programming, the tags were programmed assuming only access to the legacy ARGOS system data. Therefore, the study team included a blackout period during which the tags did not transmit, from 0400 to 0800 UTC, during which satellite coverage in the field site was worst and follow boats were unlikely to be on scene to pick up incidental transmissions using the ARGOS goniometer. Nevertheless, it seems likely that Kinéis would have relatively good coverage during this time as well given its overall consistency.

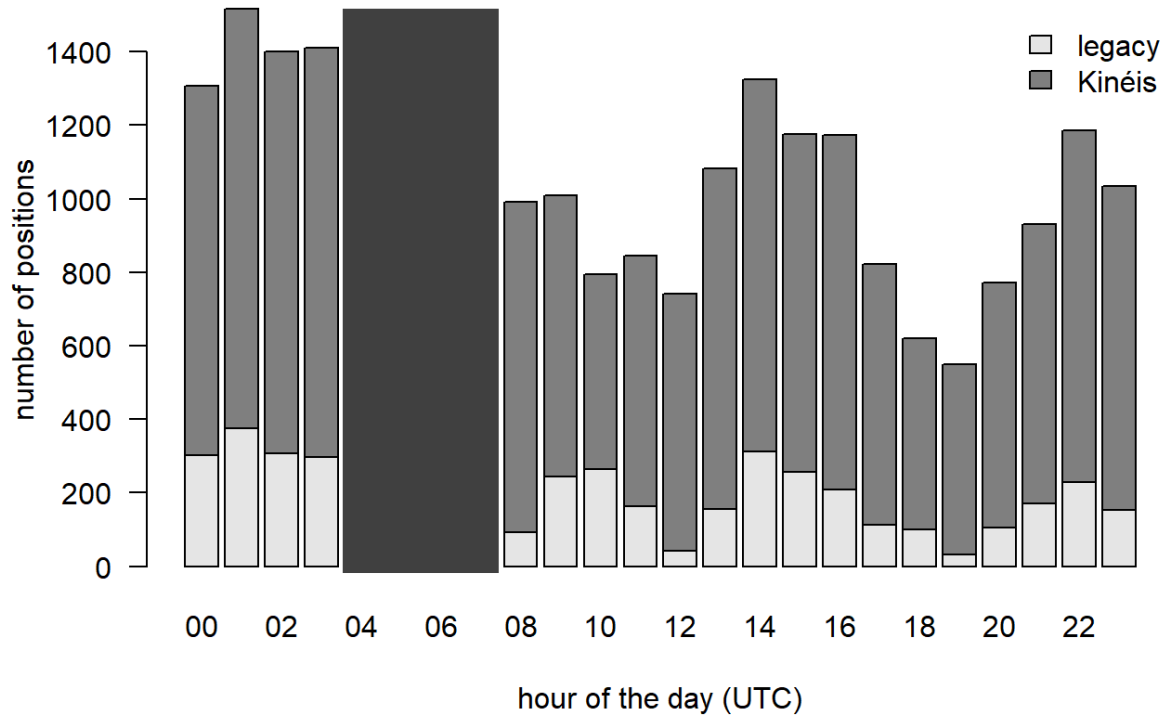
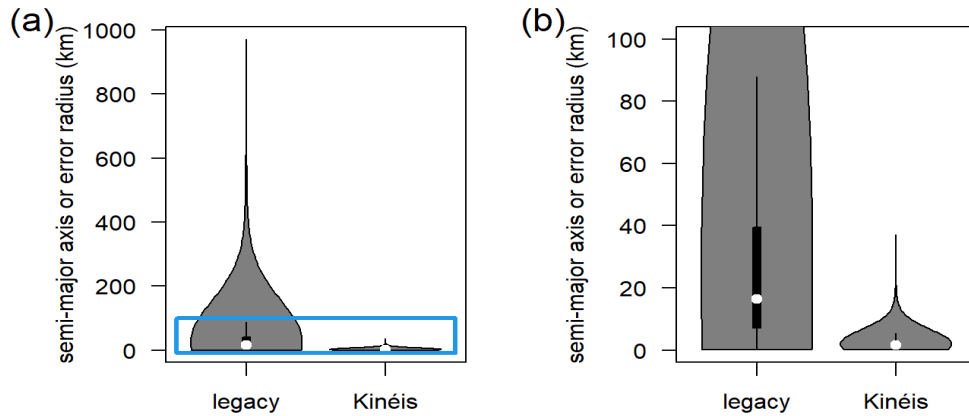


Figure 51. Hourly number of total positions collected on all tags ( $n=12$ ) transmitting during the 2025 field season ( $n=12$ ) on both the legacy ARGOS and new Kinéis systems. Dark gray bar shows the programmed no-transmit period.

### 3.3.2 Reported Error

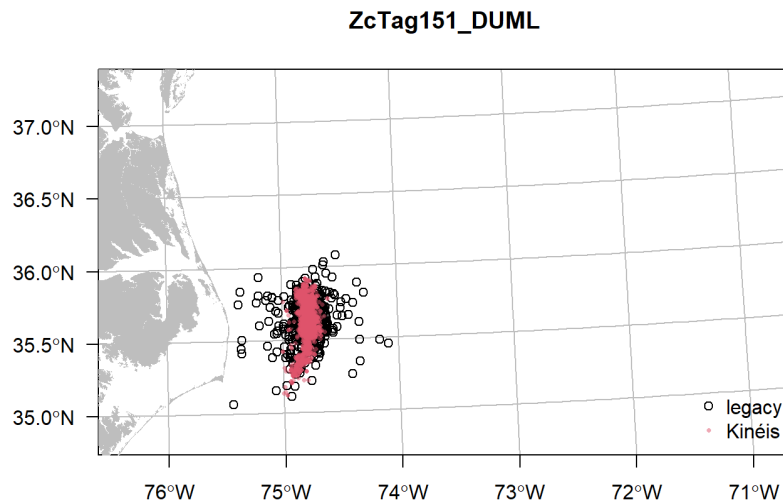
Reported error was also markedly lower for the Kinéis data compared to the legacy positions. Note again, however, that the error is reported differently for each system, so direct comparisons should be made with caution. Nevertheless, mean error radius on Kinéis when compared to semi-major axis on the legacy system was more than an order of magnitude smaller (approximately 2.3 km compared to 39 km). Additionally, Kinéis seems much less susceptible to outliers, as the semi-major axis error for the legacy system had a much longer tail (**Figure 52**). The legacy ARGOS systems use of polar orbiting satellites generates relatively eccentric ellipses typically orientated with their semi-major axis close to the east-west line. North-south (semi-minor axis) error tends to be much less and was smaller on average than the Kinéis error radius (2 km compared to 2.4 km).



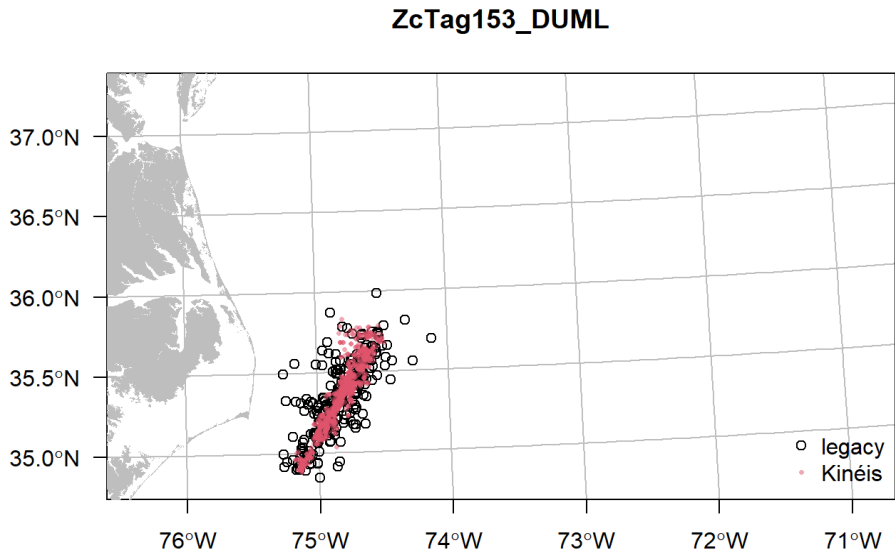
**Figure 52.** Comparison of distributions of reported error from tags deployed during the 2025 field season ( $n=12$ ) on both the legacy ARGOS system (error ellipses semi-major axis) and the new Kinéis system (error radius); (b) is a zoom in on (a), indicated by the blue rectangle.

### 3.3.3 Position Overview

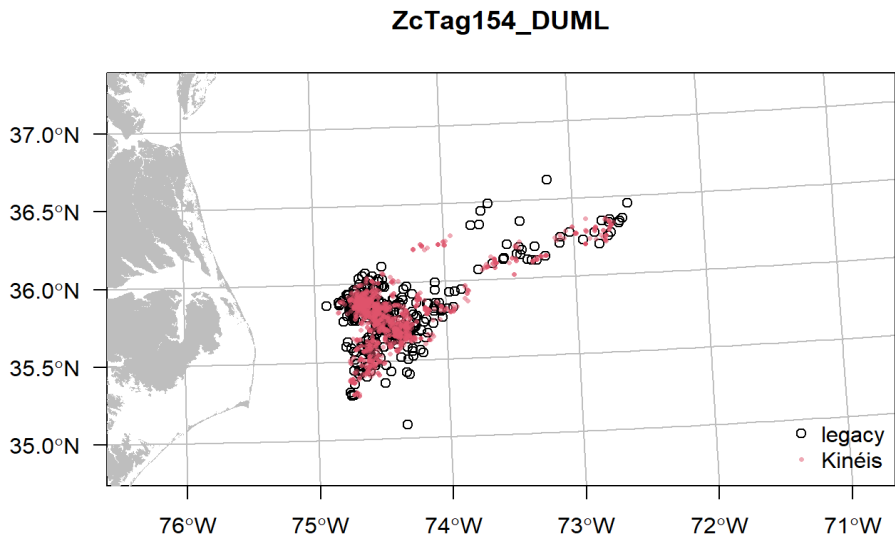
These numerical improvements noted above between Kinéis and the legacy system are borne out in raw location plots of both systems for each tag (**Figure 53** through **Figure 64**). In many cases, the Kinéis data appears more similar to modeled output than raw, relatively unfiltered positions. Note that some positions from the legacy system were omitted for clarity and ability to compare visually when they were hundreds of km outside the field site, but all Kinéis positions are visible within the bounding box.



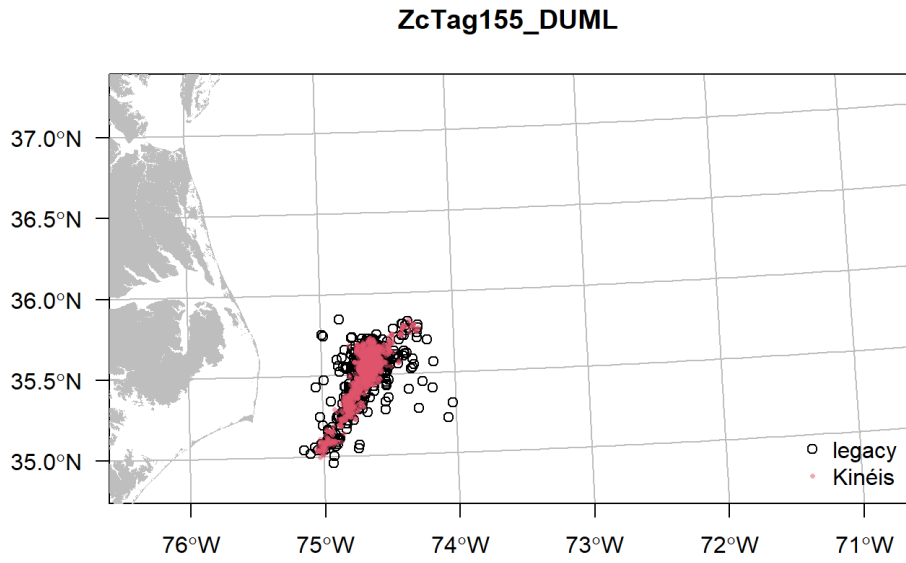
**Figure 53.** Comparison of raw positions of ZcTag151 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.



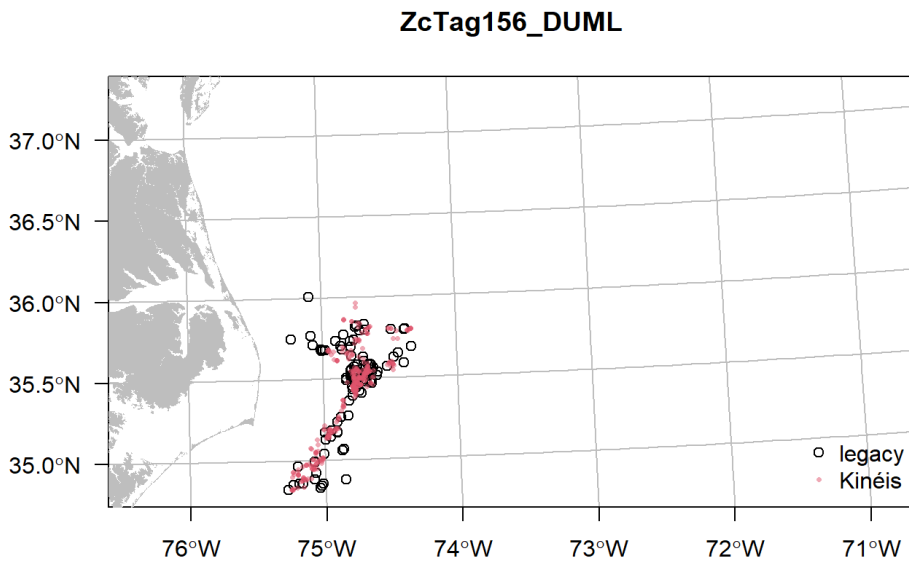
**Figure 54.** Comparison of raw positions of ZcTag153 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.



**Figure 55.** Comparison of raw positions of ZcTag154 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.



**Figure 56.** Comparison of raw positions of ZcTag155 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.



**Figure 57.** Comparison of raw positions of ZcTag156 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.

### ZcTag157\_DUML

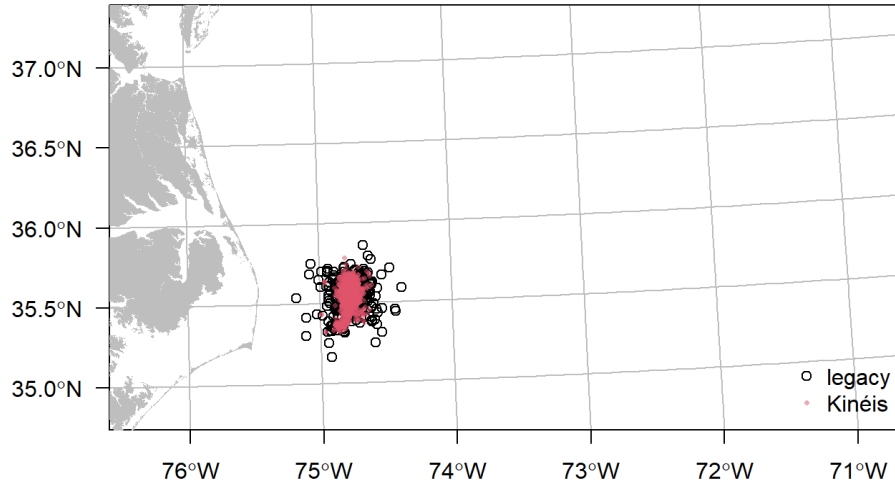


Figure 58. Comparison of raw positions of ZcTag157 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.

### ZcTag158\_DUML

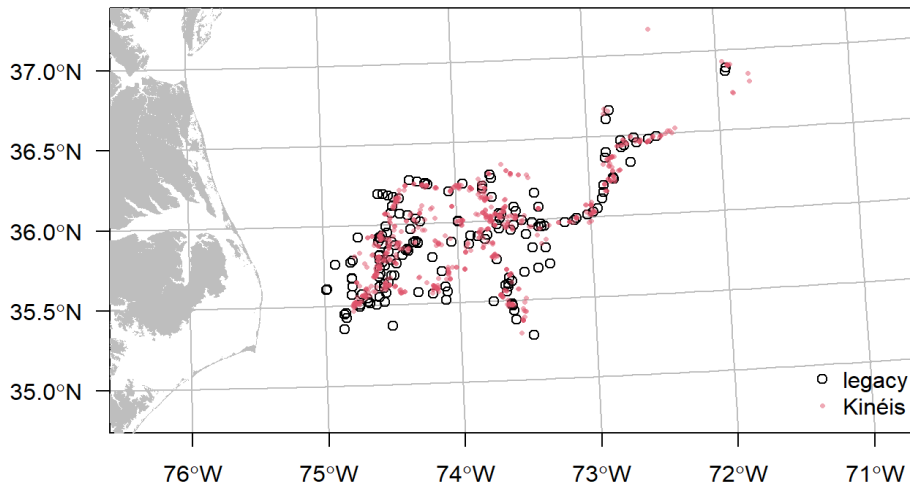
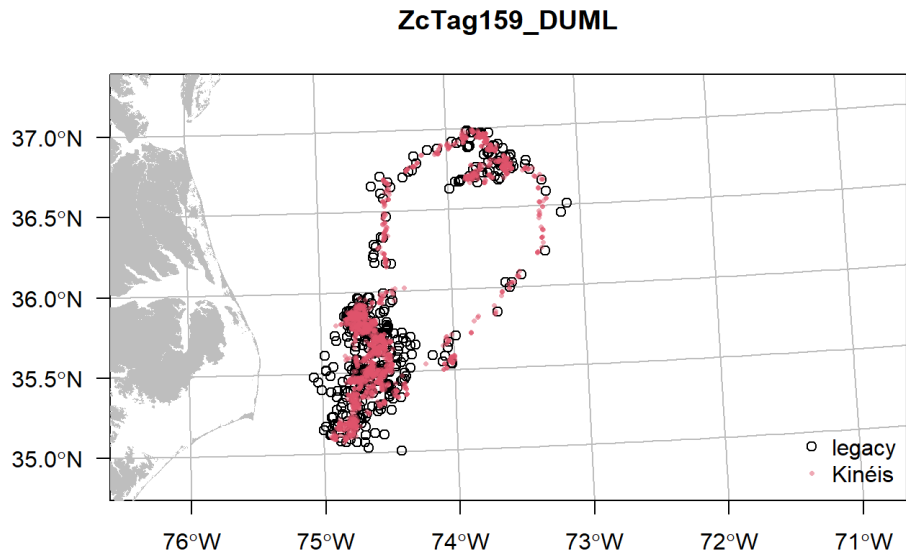
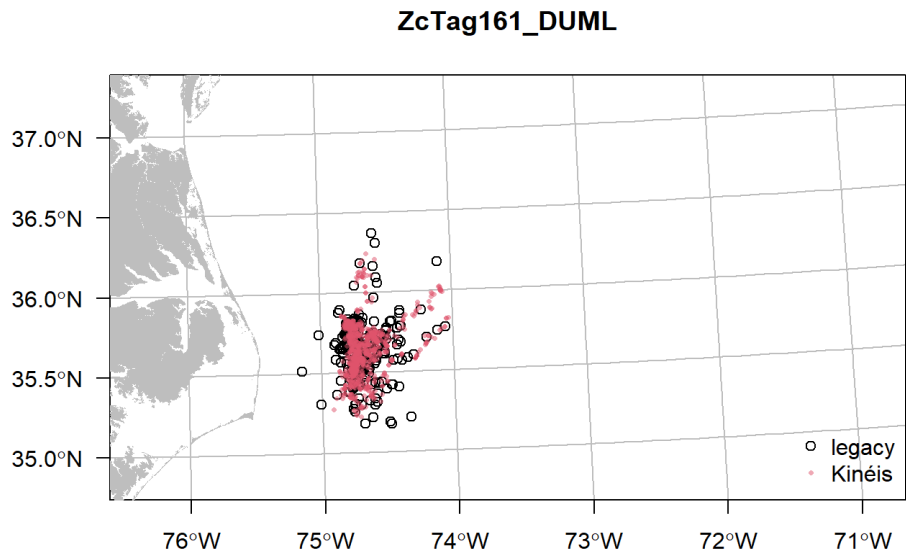


Figure 59. Comparison of raw positions of ZcTag158 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.



**Figure 60.** Comparison of raw positions of ZcTag159 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.



**Figure 61.** Comparison of raw positions of ZcTag161 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.

### ZcTag162\_DUML

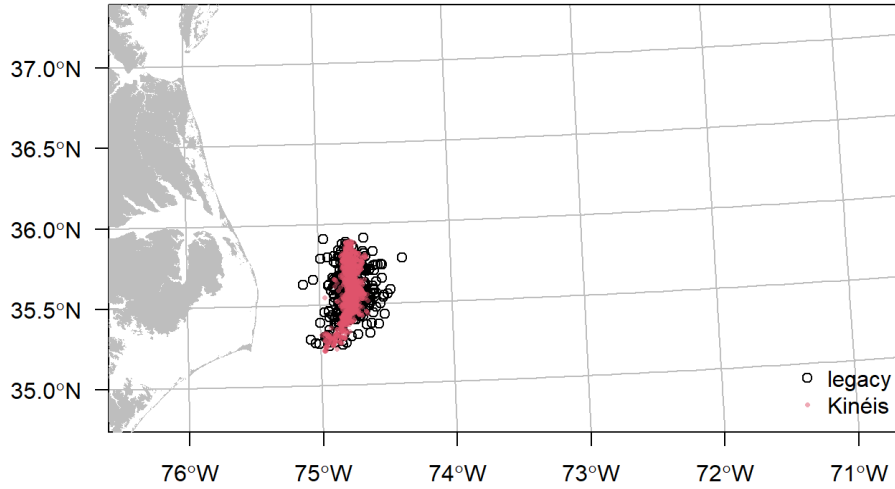


Figure 62. Comparison of raw positions of ZcTag162 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.

### ZcTag163\_DUML

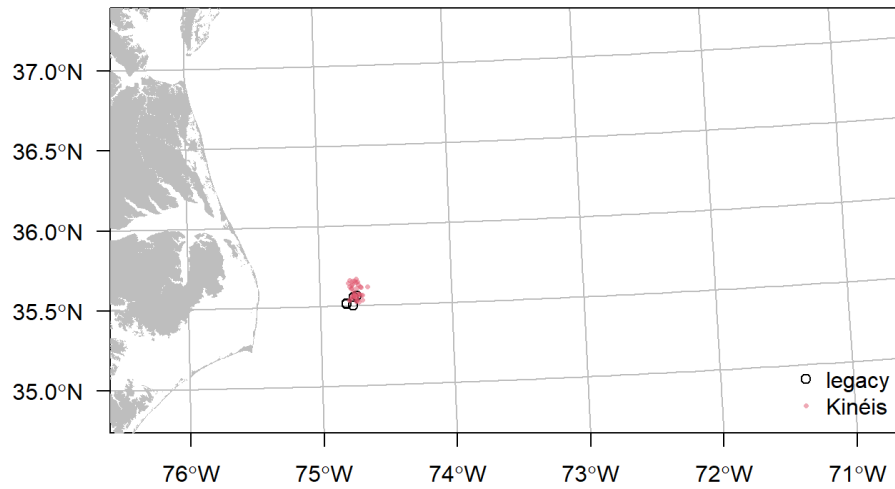
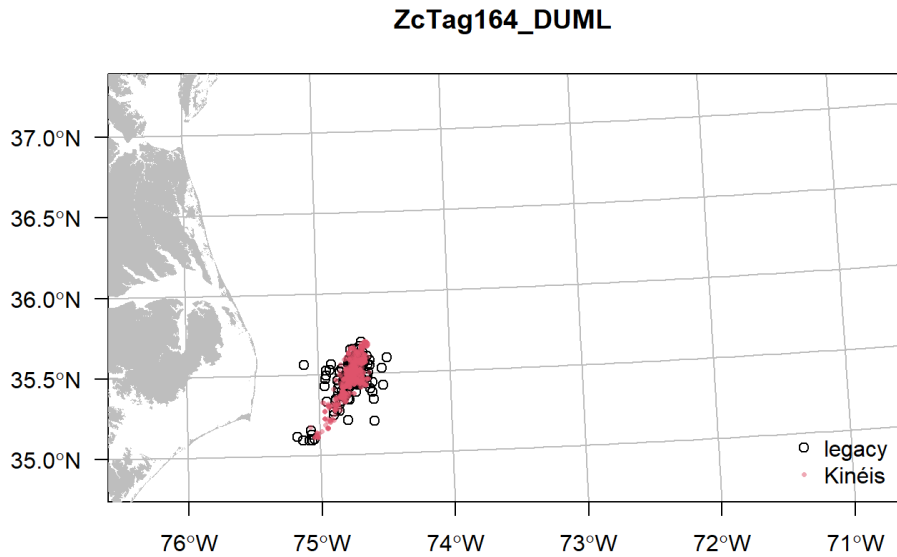


Figure 63. Comparison of raw positions of ZcTag163 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.



**Figure 64.** Comparison of raw positions of ZcTag164 received on both the legacy ARGOS and new Kinéis systems. Some very distant legacy system positions may be clipped by the bounding box.

### 3.3.4 Data Messages

Data messages are sent along with the transmissions used to solve position. Therefore, the more positions (and in general the more high-quality positions) are received, the higher the number of data messages that can be sent from tag to satellite.

The Kinéis data streams have not yet been fully integrated into the Wildlife Computers data portal, but they can be downloaded manually. Due to malfunctions with the Kinéis portal, only a subset ( $n=9$ ) of the tags was able to be downloaded and decoded at the time of this report.

For these tags, between 2.6 and 4.4 times the number of data messages were received on Kinéis compared to the legacy system with a mean data message increase of 3.6 times. The corrupt message rate (those messages that could not be decoded) was similar for both at 16 and 20 percent, respectively, for the Kinéis and legacy systems.

### 3.3.5 Kinéis Benefits, Challenges, and Future Directions for Programming

The new Kinéis system is fully backward compatible with existing tags, which allowed the study team to recover data even from tags deployed before the system came online, with no special configuration necessary. While the system is active, the team should be able to access the data during future field seasons. There are slight differences in the data processing pipelines, but these differences should be relatively straightforward to overcome.

Kinéis provides clear benefits in the form of a larger number of lower error positions per unit time. These data should improve position and RL modeling substantially. Additionally, since near real-time position data will be available in subsequent field seasons, the Kinéis data will improve the study team's ability to relocate tagged animals in the field by providing more and lower error positions to start the search from. It is important to note that only reported errors are addressed herein, since the study did not have a large enough number of known positions in 2025. Alternatively, the study could use FastGPS in the future to independently assess the accuracy and precision of Kinéis data.

Kinéis effectively increases the study's data bandwidth because of greater satellite availability. This is especially important for infrequent surfacers such as *Ziphius*. The study team should be able to remove the programmed data blackout as well as collect more data and positions overnight. The study team will have to consider battery life trade-offs, however, because as the tags are currently programmed, this would increase battery consumption by approximately 17 percent. Additionally, it may be possible to take advantage of increased data bandwidth to increase the duration or resolution of data collection for time-series depths, for example. Again, battery life trade-offs will have to be considered. While more time-series data was received on all tags on Kinéis when compared to the legacy system, poor performing tags still failed to transmit all their data even on Kinéis, so there is still risk in increasing the study team's data collection.

The main drawbacks to Kinéis currently appear to be in data curation and integration. At the time of this report, there is no automatic integration with the Wildlife Computers portal, but there are instructions for manually combining data. The Kinéis portal currently suffers from serious performance limitations and errors.

The study team plans to quantify the benefit to RL modeling in realistic scenarios and compare it to the inclusion of FastGPS data. No FastGPS equipped tags were deployed during the 2025 field season, so their performance on the Kinéis system is currently unknown; however, the study team can assume the effective increase in data bandwidth could result in the transmission of a greater number of FastGPS positions. FastGPS still represents a significant data burden on ARGOS-linked tags, so it will be important to measure the benefit of the addition of FastGPS in downstream analyses. There may be diminishing returns of FastGPS when using large numbers of Kinéis-derived locations, since FastGPS positions tend to be infrequent on species such as *Ziphius*.

## 4. Atlantic-BRS Publications

The Atlantic-BRS project has consistently produced peer-reviewed publications both directly through the project and in collaboration with the ONR-funded Double Mocha effort, which developed analytical tools and methods that are now being applied for Atlantic-BRS analyses. The pace of earlier publications was relatively high, including earlier baseline behavioral and methodological development publications, but has slowed slightly with focus on ongoing efforts to produce several sequential, complex, behavioral response papers with direct application and high relevance to U.S. Navy environmental compliance processes.

Considerable effort by the entire team comprising multiple in-person workshops, many dozens of virtual meetings, and most of the year in review and revision led to the publication of the first of these papers, accepted at the end of 2025 and published just after the start of 2026 ([Southall et al. 2026](#)). This paper includes 72 *Ziphius* exposure-response analytical events in 13 experiments over 5 years of the project, surpassing the available data set previously available across all other beaked whale studies for all species previously tested.

**Table 8** provides a current, comprehensive summary of 24 papers across the entire Atlantic-BRS program that have been published ( $n=13$ ), are in review, or are in advanced ( $n=3$ ) or moderate ( $n=8$ ) stages of development. Direct links to publications are provided when available.

**Table 8. Atlantic-BRS publications and manuscripts published or in review and advanced stages of preparation.**

Category	Nominal Title/Subject	Lead Author (Institution)	Status
Baseline behavior	Diving behaviour of Cuvier's beaked whales ( <i>Ziphius cavirostris</i> ) off Cape Hatteras, North Carolina	Shearer (Duke)	<a href="#">Published</a>
Methodology – technology	Mind the gap – Optimising satellite tag settings for time series analysis of foraging dives in Cuvier's beaked whales	Quick (Duke)	<a href="#">Published</a>
Methodology – technology	Accounting for positional uncertainty when modeling RLs for tagged cetaceans exposed to sonar	Schick (Duke)	<a href="#">Published</a>
Baseline behavior	Extreme diving in mammals: first estimates of aerobic dive limits in Cuvier's beaked whales	Quick (Duke)	<a href="#">Published</a>
Methodology – technology	Continuous-time discrete-state modeling for deep whale dives	Hewitt (Duke) [Double Mocha]	<a href="#">Published</a>
Baseline behavior	Residency and movement patterns of Cuvier's beaked whales ( <i>Ziphius cavirostris</i> ) off Cape Hatteras, North Carolina, USA	Foley (Duke) [primarily pre-BRS tags but includes 2017]	<a href="#">Published</a>
Baseline behavior	Adult male Cuvier's beaked whales ( <i>Ziphius cavirostris</i> ) engage in prolonged bouts of synchronous diving	Cioffi (Duke)	<a href="#">Published</a>
Methodology – technology	Kernel density estimation of conditional distributions to detect responses in satellite tag data	Hewitt (Duke) [Double Mocha]	<a href="#">Published</a>
Methodology – technology	Varying-Coefficient Stochastic Differential Equations with Applications in Ecology	Michelot (St. Andrews) [Double Mocha]	<a href="#">Published</a>
Methodology – technology	Continuous-time modelling of behavioural responses in animal movement	Michelot (St. Andrews) [Double Mocha]	<a href="#">Published</a>
Methodology – technology	Trade-offs in telemetry tag programming for deep-diving cetaceans: data longevity, resolution, and continuity	Cioffi (SEA)	<a href="#">Published</a>
Methodology – technology	Estimating RLs and horizontal avoidance with dynamic covariates in exposed animals	Schick (SEA)	<a href="#">Published</a>
CEE exposure-response	Behavioral responses of Goose-beaked whales ( <i>Ziphius cavirostris</i> ) to simulated mid-frequency active military sonar	Southall (SEA)	<a href="#">Published</a>
CEE exposure-response	Behavioral responses of Goose-beaked whales to operational mid-frequency active military sonar systems off Cape Hatteras, NC	Southall (SEA)	Final preparation
Baseline behavior	Wound-healing from satellite tag deployments in <i>Ziphius</i>	Read (Duke)	Final preparation
Baseline behavior	Benthic foraging tactics in <i>Ziphius</i>	Kootstra/Quick (University of Plymouth)	Final preparation
Baseline behavior	Shallow night intervals in <i>Ziphius</i>	Cioffi (SEA)	In preparation

Category	Nominal Title/Subject	Lead Author (Institution)	Status
Baseline behavior	Possible orientation behavior in <i>Ziphius</i>	Quick (University of Plymouth)	In preparation
Baseline behavior	More than metronomes: variation in diving behaviour of goose-beaked whales ( <i>Ziphius cavirostris</i> )	Quick (University of Plymouth)	In preparation
Methodology – technology	Improvements to received level estimates with the use of Fastloc tags in behavioral response studies	Cioffi (SEA)	In preparation
Baseline physiology	Baseline variation of steroid hormones in short-finned pilot whales ( <i>Globicephala macrorhynchus</i> )	Wisse (Duke)	In preparation
Disturbance exposure-response	Measuring stress responses in short-finned pilot whale biopsies: are field methods confounding our data?	Wisse (Duke)	In preparation
Methodology – technology	Improvements to received level estimates with the use of Fastloc tags in behavioral response studies	Cioffi (SEA)	In preparation
Methodology – technology	Detecting changes in foraging behavior in goose-beaked whales exposed to sonar using coarse resolution data	Cioffi (SEA)	In preparation

## 5. Overall Assessment and Recommendations

### 5.1 General Assessment of Atlantic-BRS 2025 Accomplishments

- This field season produced the second-most sat tags, the most baseline data, the longest reporting sat tag (more than 340 days and still functioning as of 1 June 2026), and the most exposure events for *Ziphius* over the entire course of the project.
- The Atlantic-BRS team conducted the second CEE with U.S. Navy ship-based full-scale CAS MFAS projected from the USS *Donald Cook*. This CEE included a relatively large ( $n=7$ ) number of simultaneously tagged individual *Ziphius*, as called for in the project experimental design. This significantly increased the total CAS CEE sample size from the first event in 2025. This event was planned and executed as scheduled, and conducted largely as planned (see discussion below) through close coordination with the Atlantic-BRS and USFF team, as well as *in situ* bridge-to-bridge coordination based on real-time animal behavior.
- Efforts to deploy additional tags following this successful CEE ahead of a second scheduled ship window were successful in two different waves, yielding multiple additional depth-reporting tags as well as residual location-only sensors from earlier deployments. Unfortunately, sea state or animal configuration conditions precluded the deployment of DTAGs on *Ziphius* in 2025.
- A second CAS-capable ship was scheduled and available in the context of multiple transits through the project study area. Unfortunately, the ship was unable to coordinate CEEs with the Atlantic-BRS team for different reasons. The initial availability occurred during a period when extreme sea conditions associated with a major hurricane (Hurricane Erin) precluded any field effort. The second availability was during nighttime periods when experimental design and permits would not allow CEE operations.
- The ability to adapt to these changing conditions and conduct meaningful CAS CEEs using experimental simulations of operational signals was enabled thanks to the development, acquisition, testing, and fielding of a new CAS-capable MFAS sound source. The Atlantic-BRS team conducted the first-ever simulated CAS CEE with *Ziphius* using this source following the second potential U.S. Navy ship window. This source was assessed to function extremely well in terms of signal quality, repeatability, and output power (exceeding expectations). It is also rugged, well-designed, and easy and safe to handle and deploy as well as appears very well suited to the task for which it was designed; it should be noted that this source is both CAS and PAS capable.
- Operational conditions (wind, sea state) experiences were again relatively poor during earlier periods of possible field effort (May to June), although more success occurred in June than during the previous several years. The study team continue to see a longer-term pattern of fewer overall windows of ideal conditions and has consequently extended periods of adaptive effort to achieve research objectives, influencing the team to focus on windows of potential U.S. Navy ship coordination from July through September.
- Deployment strategies and sat tag programming settings were maintained as developed during earlier study years, again with very positive results in terms of data quality. The study

team, however, deployed several location-only tags during earlier portions of the field year, with anticipated (and experienced) longer durations to monitor longer-term habitat use patterns and provide options to relocate *Ziphius* groups for additional tag deployments.

- The introduction and availability of the Kinéis satellite system for receiving sat tag location and dive data has provided major improvements in data quantity and quality (see **Section 3** for a detailed comparison with legacy ARGOS systems).
- The publication of a very large sample size ( $n=72$ ) exposure-response paper for *Ziphius* with simulated PAS ([Southall et al. 2026](#)) represents one of the biggest accomplishments of the project and most notable contributions to U.S. Navy environmental compliance analyses to date.

## 5.2 Future Effort and Recommendations

- The successful completion of a second operational ship CAS CEE through coordination with the USS *Donald Cook* with a large sample size of tagged *Ziphius* and the conduct of a simulated CAS CEE were both very positive developments in 2025. The study team believes the primary goal for 2026 is to replicate the overall approach and increase sample size focused on *Ziphius*, with a priority for conducting CEEs with (multiple) CAS ships but with a secondary back-up option for using the new experimental MFAS source for periods it is available (it is noted that the Atlantic-BRS will be coordinating both training and dual-use of the new source with the LMR-funded pinniped BRS study occurring later during the summer in California). It is possible that with another successful season of sat tag and DTAG deployments as well as multiple CAS-capable ships, a comparable desired sample size of operational CAS to PAS CEEs will be achieved during 2026.
- The study team again recommends a single, condition-adaptive field effort beginning as early as June with an emphasis on U.S. Navy ship coordination focused on July and August but extending into September if necessary. Field communications may be improved during 2026 given potential new options for bridge-to-bridge communications through satellite-linked cellular calling that began coming online from the U.S. Navy side during 2025.
- Coordination with U.S. Navy vessels should continue using the established methods of advance planning through USFF. The adaptive approach of engaging various home-ported and transiting vessels was effective during 2025, as demonstrated by the successful coordination with the USS *Donald Cook*. However, the challenges of this model were also clear when a second operation was precluded by poor sea state and daylight conditions. Therefore, in discussions with USFF, the study team recommends a multi-pronged strategy for future seasons. This would involve scheduling multiple, dedicated vessels for the Atlantic-BRS during planned training within the Norfolk operating area, while also retaining the flexibility to coordinate with transiting ships of opportunity at other times.
- Given the repeated and proven record of successful tag deployments of both sat tags and DTAGs, the study team does not recommend any substantial changes in the overall patterns of field and tagging effort. The study team believes that the combination of advance deployment of sat tags in weeks to days ahead of CEEs and DTAG deployments as well as in the day to hours ahead of CEEs should be maintained in the context of the multi-scale

design. The team continues to believe that priority should be given to simultaneously deploying DTAGs within groups with sat-tagged individuals.

- Following the extensive optimization of sat-tag time-series settings for the Atlantic-BRS field site (see Cioffi et al. [2023](#)), no substantive changes to sat-tag program setting are anticipated. The study team's experience with and assessment of possible changes to tag transmission schedules or other considerations (e.g., battery life) will be informed by the assessment of tag transmission results from the new Kinéis system relative to the legacy ARGOS system, as discussed in **Section 3**.
- Field efforts to locate tagged animals with validated locations using goniometer detections, visual observations, and photo-ID should be maintained as much as possible before, and especially after, CEEs given the substantial and demonstrated improvements in spatial movement data (especially given significant improvements in data from the introduction of the Kinéis system), RL model estimates, and other factors. Particular emphasis should be placed on *in situ* goniometer acquisition of sat-tag data for focal whales to ensure periods around CEEs do not include gaps in data records; these gaps in the post-exposure period of focal whale ZcTag156 for CEE #25\_01 were unfortunately not filled in later through satellite-only transmissions.

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