Behavioral Responses of Humpback Whales to Approaching Ships in Virginia Beach, Virginia: 2023 Annual Progress Report

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Cover Photo Credit:

Humpback whale (*Megaptera novaeangliae*) diving near the coast of Virginia Beach, Virginia. Photographed by Anne Harshbarger, Duke University, taken under General Authorization 16185 held by Andrew Read, Duke University.

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Acronyms and Abbreviations

°C	degrees Celsius
CATS	Customized Animal Tracking Solutions
CBBT	Chesapeake Bay Bridge-Tunnel
dB	decibel(s)
DTAG	digital acoustic tag
kHz	kilohertz(s)
km	kilometer(s)
m	meter(s)
$m^2 \cdot nmi^{-2}$	square meters per square nautical mile
NASC	nautical area scattering coefficient
R/V	research vessel
SBES	split beam echosounder systems
U.S.	United States

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1. Introduction

The western North Atlantic population of humpback whales (*Megaptera novaeangliae*) is one of the most well-studied populations of baleen whales, with long-term photo-identification studies dating back to the early 1970s (Katona et al. 1979). These whales breed and give birth in the Caribbean during winter (Whitehead and Moore 1982), with little feeding on the breeding grounds or during migration. They travel up to 7,000 kilometers (km) (Stevick et al. 1999) from breeding grounds to summer feeding areas ranging from the Gulf of Maine to Norway. Individual whales return to discrete feeding grounds each summer within the Gulf of Maine, Gulf of St. Lawrence, Newfoundland, Greenland, Iceland, and Norway (Katona and Beard 1990; Stevick et al. 2003a, 2006). There is little exchange between feeding grounds, and individuals show high site fidelity both within and between years (Katona and Beard 1990, Clapham et al. 1993, Stevick et al. 2006). However, individuals from all feeding grounds have been observed on the Caribbean breeding grounds (Stevick et al. 2003a).

These migratory patterns are the norm for most adults, but some younger humpback whales remain on feeding grounds or make only partial migrations during winter (Whitehead 1987, Christensen et al. 1992). Since the mid-1980s, juvenile humpback whales have been documented feeding along the mid-Atlantic coast during winter, and the number of animals using this area during the colder months is growing (Swingle et al. 1993, 2017; Wiley et al. 1995). Many of these humpback whales appeared to be sexually immature animals based on estimates of body length (Swingle et al. 1993, Wiley et al. 1995, Barco et al. 2002).

Photo-identification efforts have been ongoing since the mid-1990s, and a number of live and stranded animals in the mid-Atlantic have been matched to the Gulf of Maine feeding aggregation, with a few matches to other summer feeding aggregations (Barco et al. 2002). Currently, based on field work conducted since 2015, 245 unique individuals are in the local humpback catalog maintained by HDR, with many whales being re-sighted in the mid-Atlantic area over multiple years. Results from satellite-tagging studies and photo-identification efforts near Virginia Beach, Virginia, show that animals remain in this area for weeks to months, often feeding in shipping lanes (Aschettino et al. 2020, 2023). Foraging behavior is evident from focal-follow observations of lunge feeding and defecation, and Area Restricted Search behavior is shown by state-space modeling (Aschettino et al. 2020).

Ship-strike mortality is an important conservation issue for large whales, particularly in the highly industrialized waters along the United States' (U.S.'s) Atlantic Coast, which has the highest occurrence of ship strikes in North America (Jensen and Silber 2004). The North Atlantic humpback whale population is recovering from the effects of past commercial whaling (Katona and Beard 1990, Smith et al. 1999, Stevick et al. 2003b, Ruegg et al. 2013,). However, the pace of this recovery has been slowed by mortality caused by entanglement in fishing gear and collisions with large vessels (Barco et al. 2002).

Since January 2016 (through 7 February 2024), 212 humpback whales have stranded on the U.S. East Coast, and the National Marine Fisheries Service declared an Unusual Mortality Event in April 2017 (NOAA 2024). One-third of these strandings occurred along the mid-Atlantic, and half of the animals examined post mortem showed evidence of ship strike or entanglement.

Within the Virginia Beach area, high rates of ship strikes have been reported, with 10 percent of cataloged whales showing evidence of ship-strike injuries (Aschettino et al. 2023). Additionally, three animals added to the Mid-Atlantic catalog during winter 2016/17 were later killed by collisions with ships (Aschettino et al. 2018).

Humpback whales near Virginia Beach are constantly exposed to vessel traffic. Hampton Roads (Virginia) is the sixth busiest port in the U.S., and Baltimore (Maryland) is the sixteenth busiest. Vessel access to both ports is through shipping lanes that pass through the mouth of Chesapeake Bay at Virginia Beach, making these shipping lanes extraordinarily busy. This continuous exposure to ships could cause animals to become habituated to ship approaches and, therefore, perhaps less responsive. Habituation to vessel traffic has been documented by baleen whales near Cape Cod, Massachusetts (Watkins 1986). Humpback whales remain within the Virginia Beach area for days to months, and have been re-sighted over multiple years (Aschettino et al. 2023). This suggests that the disturbance from repeated ship exposures is not causing long-term displacement but may put the whales at heightened risk of being struck, given multiple encounters. Whales are more likely to remain in good foraging areas even if they are risky, because the potential to be gained from productive foraging outweighs the heightened risk (Christiansen and Lusseau 2014). Therefore, responses to oncoming vessels within this area may be short lived and subtle, and require fine-scale sampling to detect. Understanding the behavior of these animals around ships is critical to developing measures to reduce the risk of ship-strike mortality and promote the recovery of this population.

The primary objective of this work is to build upon the ongoing Mid-Atlantic Humpback Whale project conducted under the U.S. Navy's Marine Species Monitoring Program by deploying high-resolution digital acoustic tags (DTAGs) to measure humpback whale responses to close ship approaches. In this project, the following questions are addressed:

1. Do humpback whales respond to ship approaches, and if so, which behavioral or movement parameters change?
2. Which aspects of a ship approach (including the ship's acoustic and behavioral characteristics) elicit which types of responses?
3. Does the behavioral context of the animal (foraging/nonforaging) affect the probability of responding to a ship approach?

The first four field seasons of this project conducted during winters 2019 through 2022 resulted in 15 DTAG deployments, several of those with accompanying satellite-telemetry tags deployed by HDR (see Shearer et al. 2019, 2020, 2021, 2022, 2023 for details). The fifth and final field season began on 6 February 2023 and ended on 9 February 2023, and is covered in this report. No tags were deployed during this year's effort. Instead, mapping for potential prey was conducted using a split-beam, high-precision, scientific echosounder within the shipping lanes of the study area in order to determine regions of higher prey density in relation to the shipping channels and provide context to the whale's spatial movements and behavior.

During acoustic surveys with scientific echosounders, high-frequency sound is propagated into the water column and reflected off organisms having differing density than the surrounding water. The echo or backscatter provides information about the density, depths, and spatial locations of organisms throughout the water column. The acoustic survey provides a non-invasive and non-destructive means to estimate areas of biomass hotspots to understand the spatial and temporal behavior of the potential prey field.

2. Methods

2.1 Study Area

Fieldwork was conducted in the coastal waters off Virginia Beach, Virginia, within 20 km from shore (**Figure 1**). The area is very shallow, with shipping lanes dredged to approximately 20 meters deep; areas outside the shipping lanes are only 9 to 12 meters deep. Two shipping lanes allow traffic to pass from the north and south, converging just east of the Chesapeake Bay Bridge-Tunnel (CBBT). Large commercial ships follow designated channels through the CBBT on their way to and from the ports of Hampton Roads, Virginia, and Baltimore, Maryland, and military ships use these channels to access the world's largest naval station in Norfolk, Virginia.

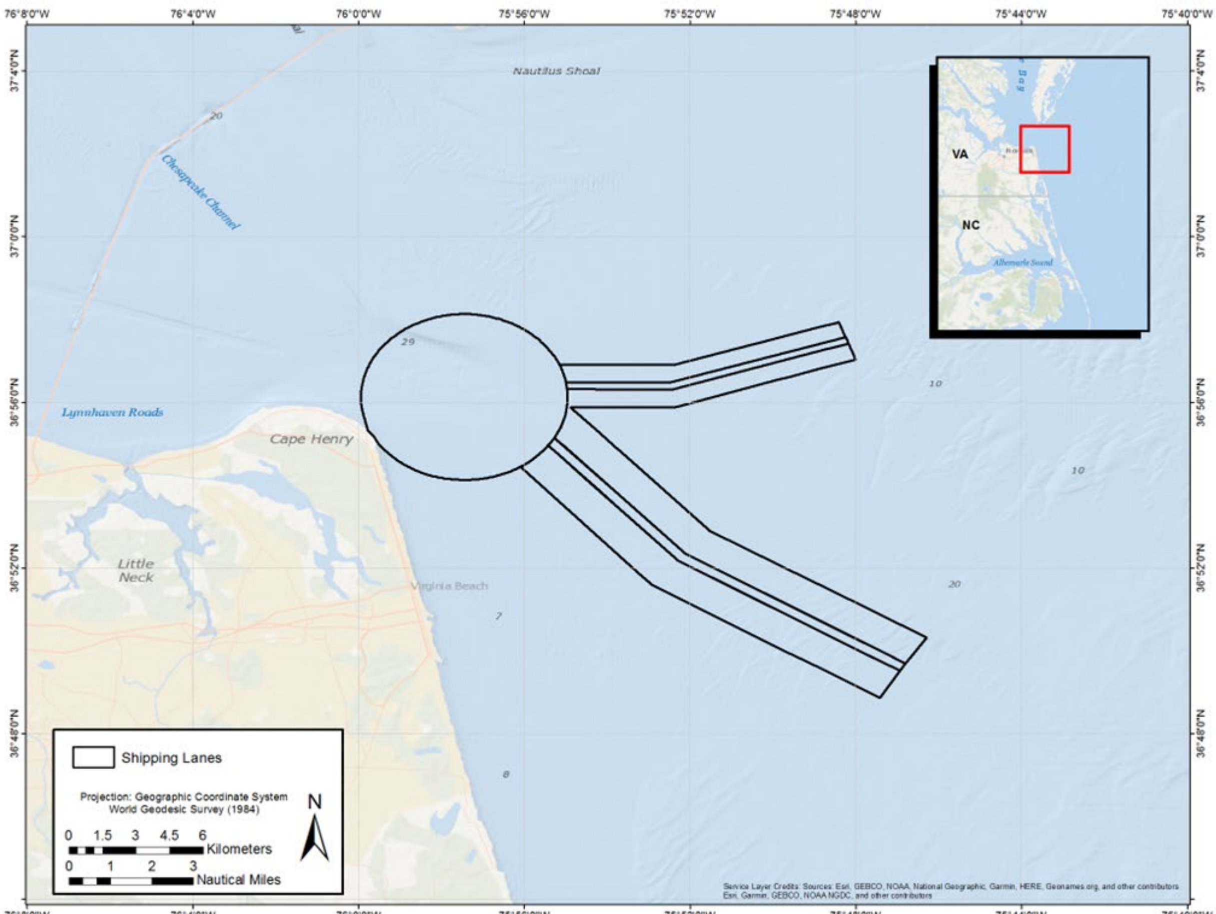

Figure 1. Map of the Virginia Beach study area, including the shipping lanes entering the Chesapeake Bay.

2.2 Data Collection

Fieldwork operations were conducted from the 23-meter catamaran, the Research Vessel (R/V) *Shearwater* (**Figure 2**).

Figure 2. The R/V *Shearwater*.

2.2.1 Survey Design

The study team designed two separate surveys for this project: a systematic survey to map the main channel, and a focused survey around an actively tagged whale.

2.2.1.1 SYSTEMATIC SURVEY

The goal of the systematic survey was to map the prey fields in the main shipping channel to the south and east of the turning basin (**Figure 3**). The study team chose this area due to the overlap between the spatial positions of humpback whales satellite tagged during previous years by HDR and consistent foraging within these areas detected in previous DTAG deployments. The study team designed the survey to encompass areas both within and directly outside the shipping lanes in order to facilitate comparisons between these areas of interest. The team also designed the survey to cover the same tracklines at different time points in order to assess diurnal differences in prey distribution. Line spacing for this survey was set at 250 meters due to the required amount of time to complete the full main scheme survey with overlapping data between night and day.

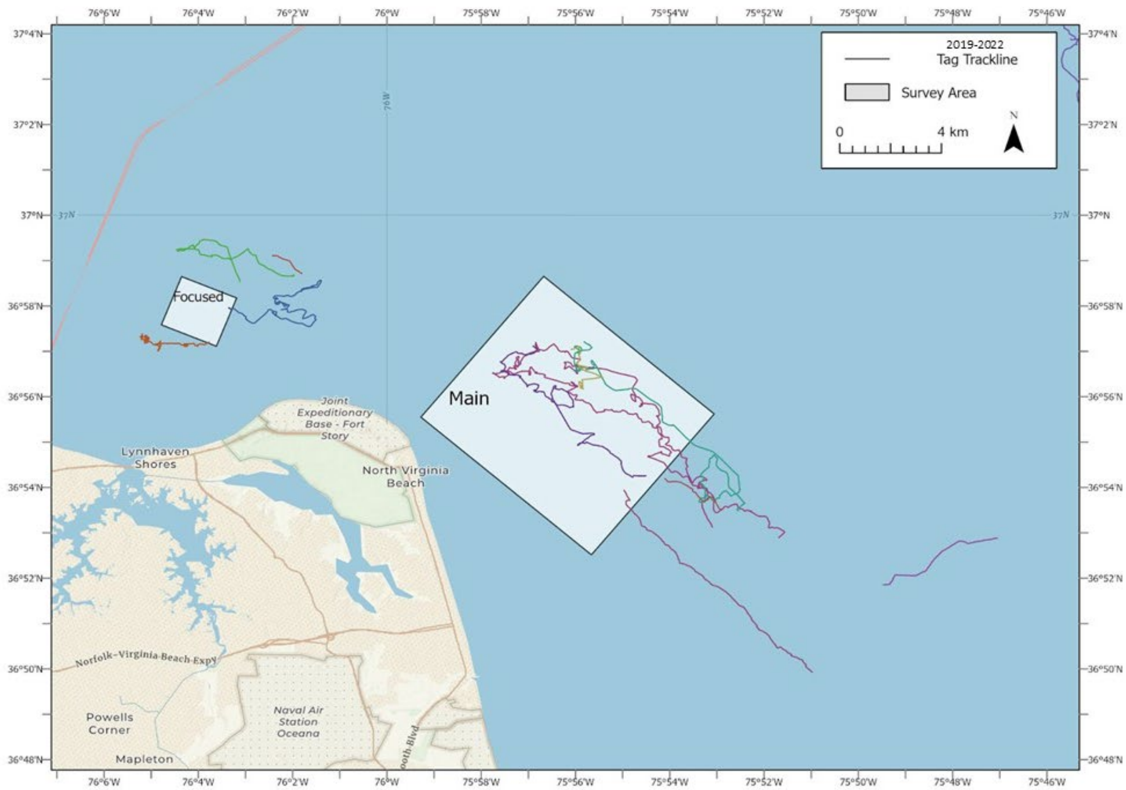

Figure 3. The light-gray polygons represent the main and focused survey locations inside the main shipping channel of Virginia Beach inlet with the multicolor lines representing the 2019 to 2022 DTAG data used in the survey design.

2.2.1.2 FOCUSED SURVEY

If whales were tagged during the survey (by colleagues at HDR), the study team planned to conduct focused surveys near the actively tagged whale in order to compare the whale's behavior with in situ prey data. The team planned two focused surveys: a systematic grid survey in the vicinity of the tagged whale and an opportunistic following survey during which the field team would communicate locations of the tagged whale to the vessel operator. The vessel operator would then survey in an irregular pattern over the last location of the tagged whale until the next sighting (**Figure 3**).

2.2.2 Water Column Acoustic Mapping

For all surveys, prey mapping of the water column was completed using a suite of hull-mounted Kongsberg split beam echosounders (38 kilohertz [kHz], 70 kHz, and 120 kHz). The resulting echosounder data are paired with the ship's global positioning system (Furuno SC-33) to provide a high-resolution, geolocated estimate of backscatter intensity in the full water column (**Figure 4**). Prior to the start of the survey, the field team conducted an in situ calibration of all echosounders to account for installation offsets and environmental effects on sound speed. The systems were all within the factory-recommended specifications, and the team applied gain offsets to the acquisition computer. The SBESs were set up with minimum pulse length and pulse rate to optimize vertical resolution and minimize acoustic interference (**Table 1**).

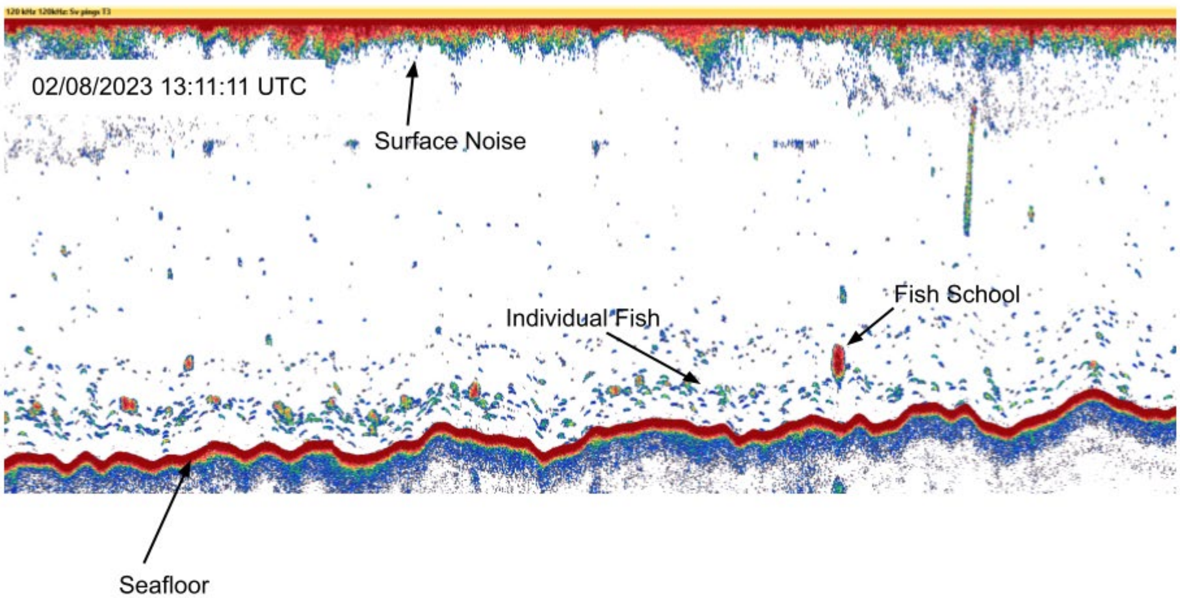

Figure 4. Example echogram describing the main features. Red color represents strong echo returns and blue represents weak echo returns.

Table 1. Split-beam echosounder settings.

Setting	ES120-7C	ES70-7C	ES38-10
Absorption depth (meters)	1	1	1
Acidity (pH)	8	8	8
Effective pulse duration (milliseconds)	0.099	0.086	0.119
Frequency (kHz)	120	70	38
Major axis 3-dB beam angle (degrees)	7.19	6.86	8.66
Major axis angle offset (degrees)	-0.19	0.22	-0.04
Major axis angle sensitivity	23	23	18.5
Minor axis 3-dB beam angle (degrees)	7.11	7.88	8.79
Minor axis angle offset (degrees)	-0.06	0.65	-1.21
Minor axis angle sensitivity	23	23	18.5
Number of transducer segments	4	4	3
Pulse duration (milliseconds)	0.128	0.128	0.256
SA (NASC) correction factor (dB)	-0.1	-0.31	0.21
Salinity (parts per thousand)	25.8	25.8	25.8
Sampling frequency (kHz)	250	250	125
Sound speed (meters/second)	1,469.95	1,469.95	1,469.95
Temperature (°degrees Celsius)	7.7	7.7	7.7
Transceiver impedance (ohms)	5,400	5,400	5,400
Transceiver sampling frequency (kHz)	1,500	1,500	1,500
Transducer gain (dB)	24.58	24.91	21.3
Transmitted power (watts)	250	750	1500
Time-varied gain range correction	SimradEK80	SimradEK80	SimradEK80
Two-way beam angle (dB re 1 steradian)	-20.7	-20.7	-18

2.3 Data Analysis

SBES data were processed using Echoview v13 (Echoview Software Pty Ltd.). The team used bottom and surface tracking algorithms to delineate the seabed and eliminate surface noise due to the sea state. The surface and bottom lines were manually reviewed and edited to exclude additional noise in the water column. The surface and bottom line were used to isolate the water column to estimate the relative acoustic backscatter or nautical area scattering coefficient (NASC). The data was grouped into 50-minute bins of sequential pings along the survey tracks and exported as a comma delimited file with spatial position, time, and the nautical area scattering coefficient ($m^2 \cdot nmi^{-2}$) for each 50-minute bin. NASC is used as a proxy for biomass in the water column.

3. Results

3.1 Acoustic survey effort

The team conducted a total of 302 linear km of acoustic survey effort during the 2-day cruise. This included 258 km surveyed within the main shipping channel (systematic survey, **Figure 5**), and 44 km of focused survey near a humpback whale tagged with a video and movement-recording Customized Animal Tracking Solutions (CATS) tag (**Figure 6**). The team conducted surveys during Beaufort Sea States 2 through 5. The beginning of the systematic survey within the main shipping lanes was conducted in a Beaufort Sea State 5 (5- to 6-foot seas), which created data-quality issues over the first 12 hours until the sea state subsided.

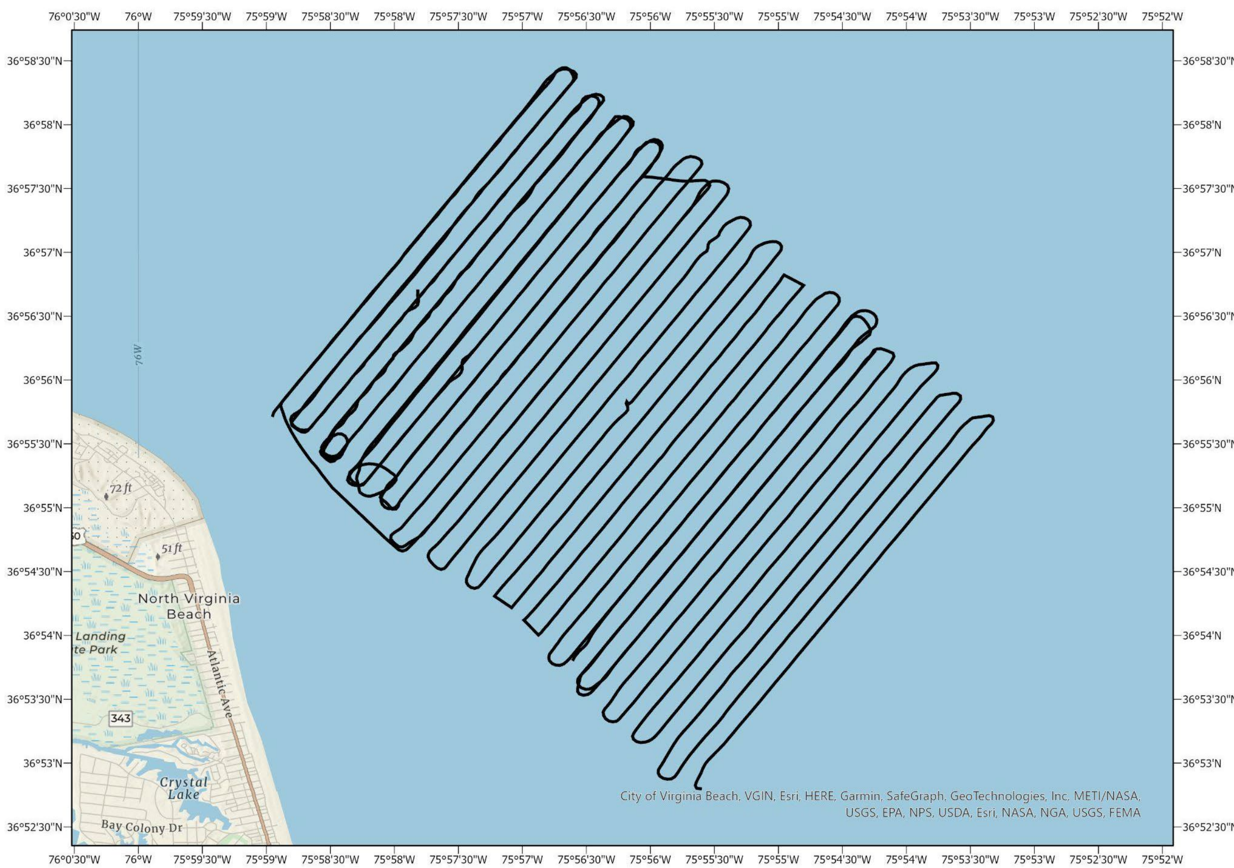

Figure 5. R/V *Shearwater* systematic survey tracks.

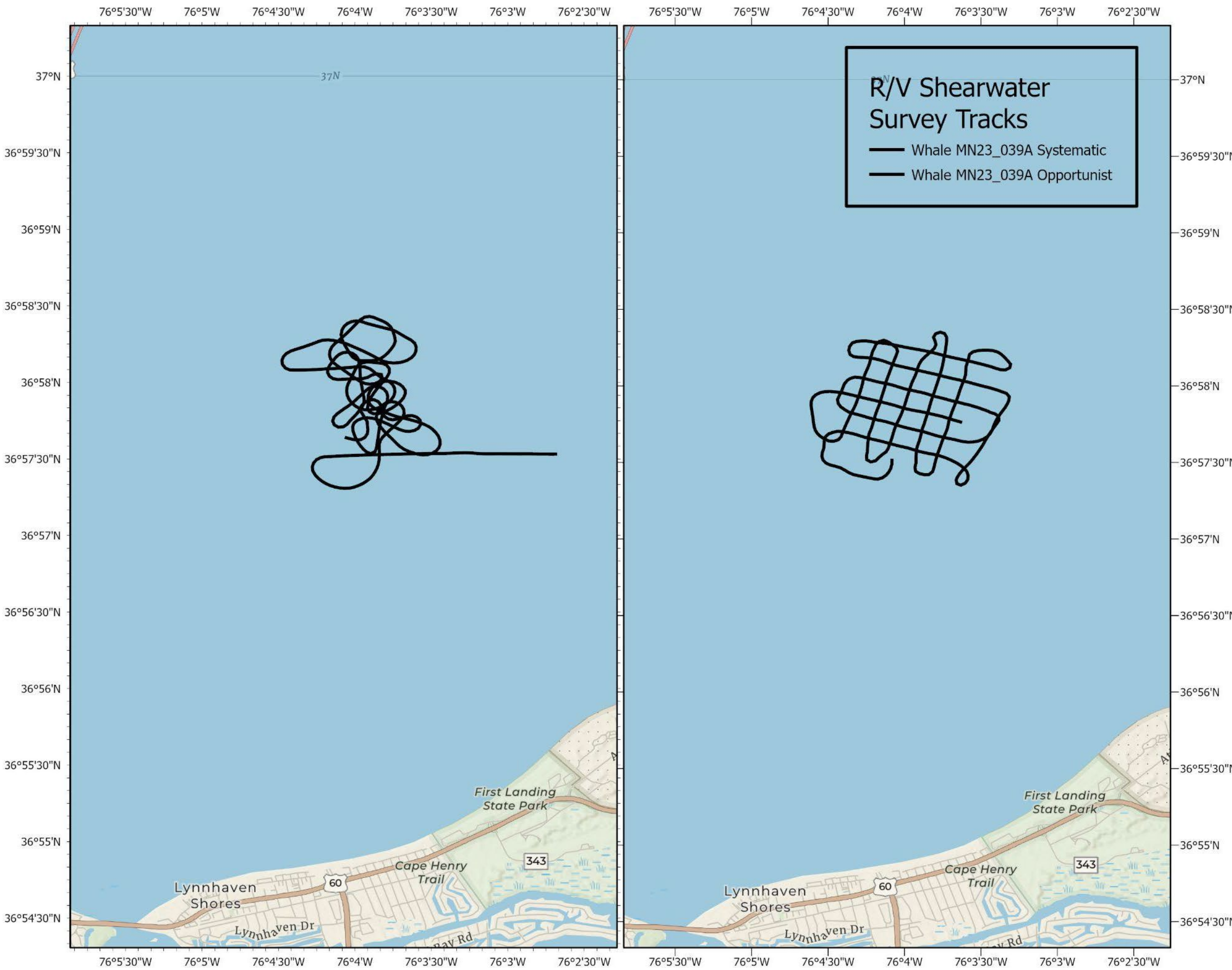

Figure 6. R/V *Shearwater* focused survey tracks.

3.2 Water Column Acoustic Mapping

3.2.1 General Prey Field Characteristics

Individual fish as well as fish schools of varying sizes were detected during the main acoustic survey. The prey field within the main shipping channel was composed of mostly small individual fish (**Figure 7**) throughout the water column, with denser schools forming around nautical twilight. Large schools of densely packed fish with seabirds diving through the school (**Figure 8**) were seen during the tagging event inside the inlet.

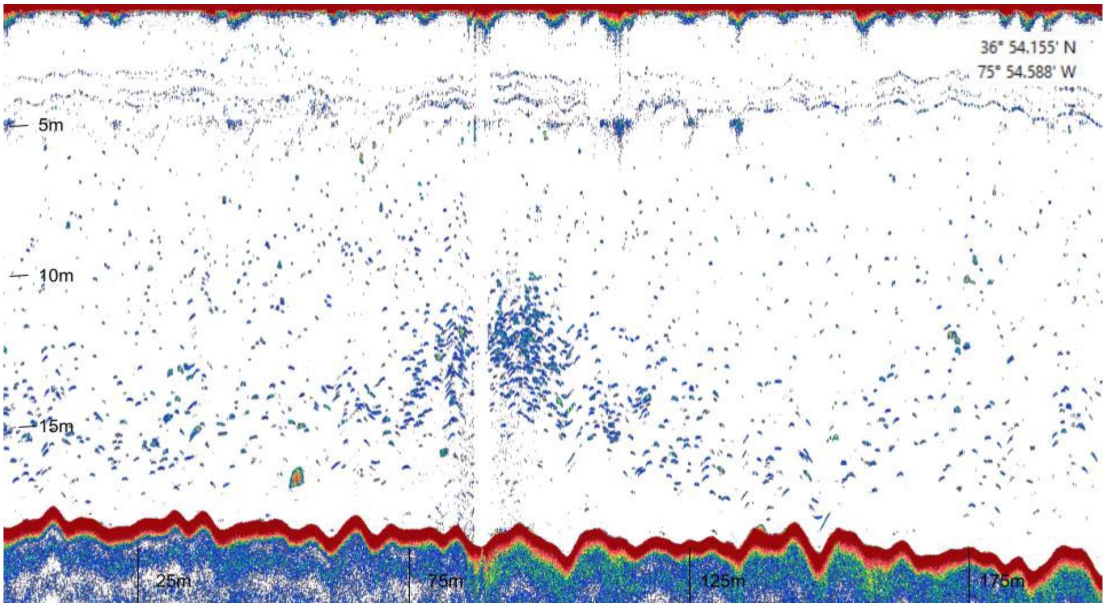

Figure 7. Example echogram showing individual scattered fish. Red color represents strong echo returns and blue represents weak echo returns.

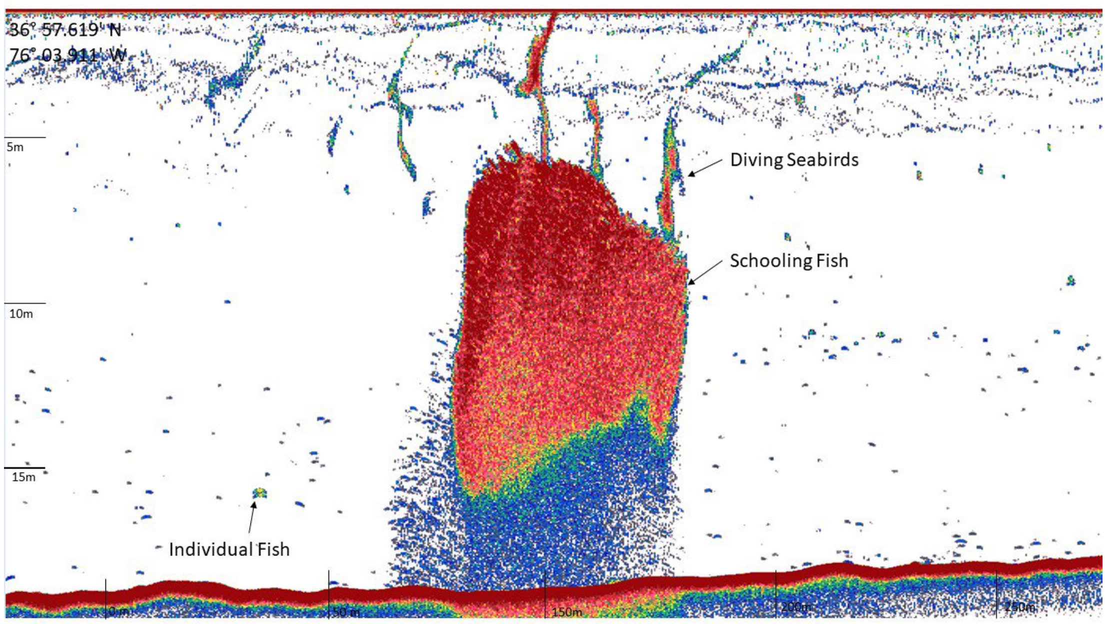

Figure 8. Example echogram showing a large fish school in the water column.

3.2.2 Systematic Survey

The main survey revealed scattered fish throughout the water column (**Figure 9**) relatively consistently over the full survey area, with higher-density areas found within the western and eastern portions of the survey area. The area of highest backscatter occurred within the northeastern edge of the survey area, near the location where the shipping lanes join the turning basin. Although whale tags were deployed in previous years and are not concurrent with this prey survey, the areas of higher prey density to the north and east roughly correspond to whale tracks, which tended to stay on the northern side of the shipping lanes, indicating that it is possible that features in the environment may aggregate prey in these areas consistently (**Figure 9**).

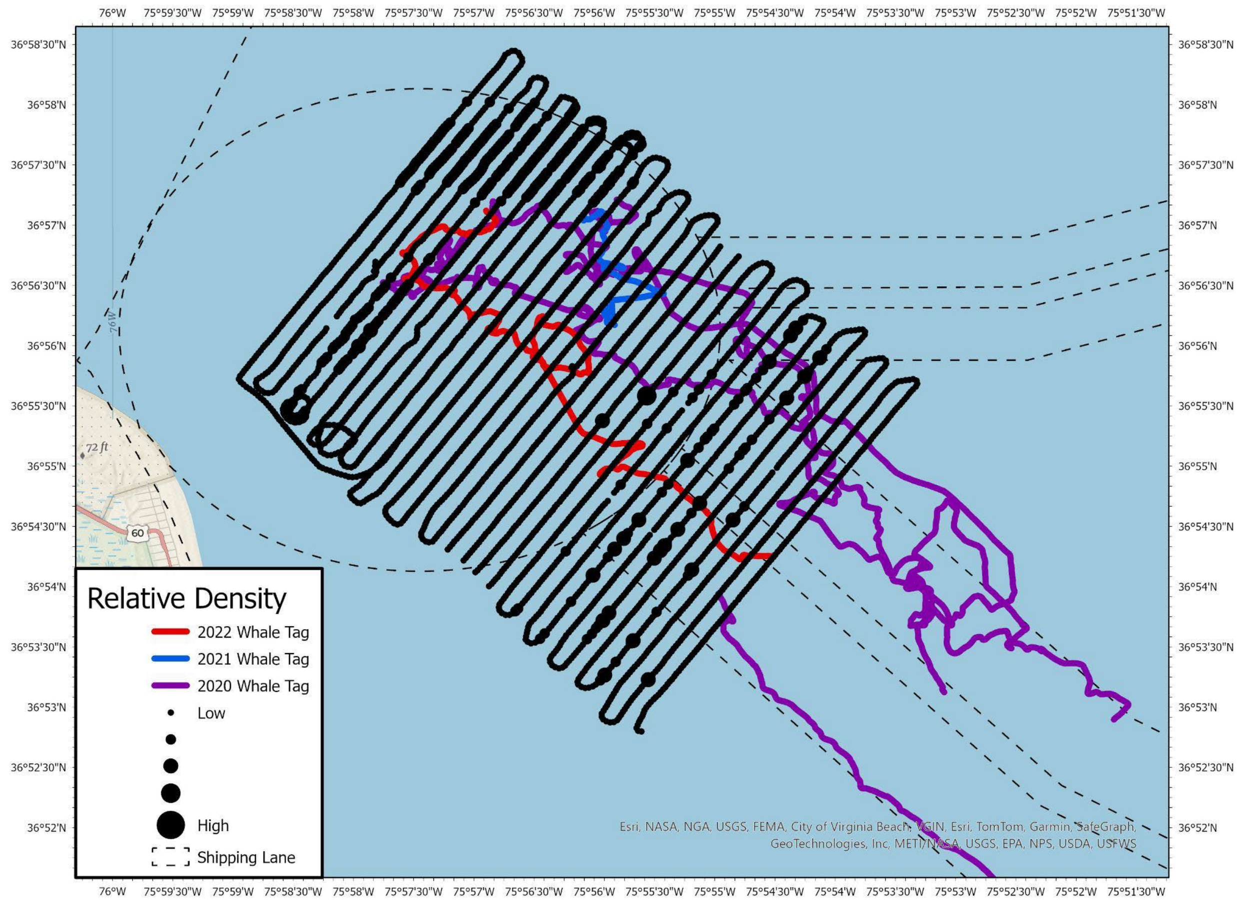

Figure 9. Survey tracklines for the main survey showing change in relative density across the survey area. Tracklines of whales tagged in previous years are overlaid on the survey lines.

3.2.3 Focused (Whale-Follow) Survey

The focused survey had complete spatial coverage of the area in which the whale was sighted during the survey (**Figure 10**). Areas of high backscatter density were found throughout much of the focused survey, particularly the opportunistic survey following the whale's most recent position (**Figure 10**). Large fish schools were occasionally seen during the systematic grid survey (**Figure 11**).

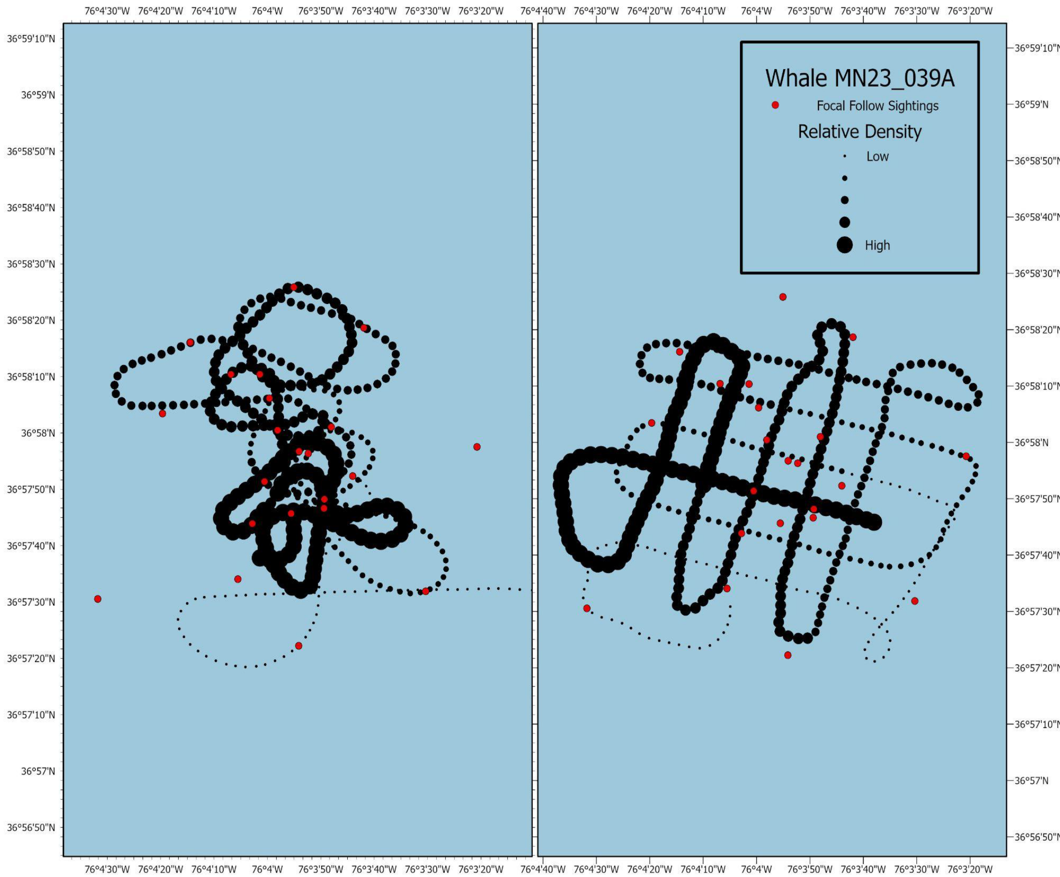

Figure 10. Focused survey tracklines for the opportunistic survey (left) following whale MN23_039A and the systematic grid (right). Estimated whale positions are shown as red circles.

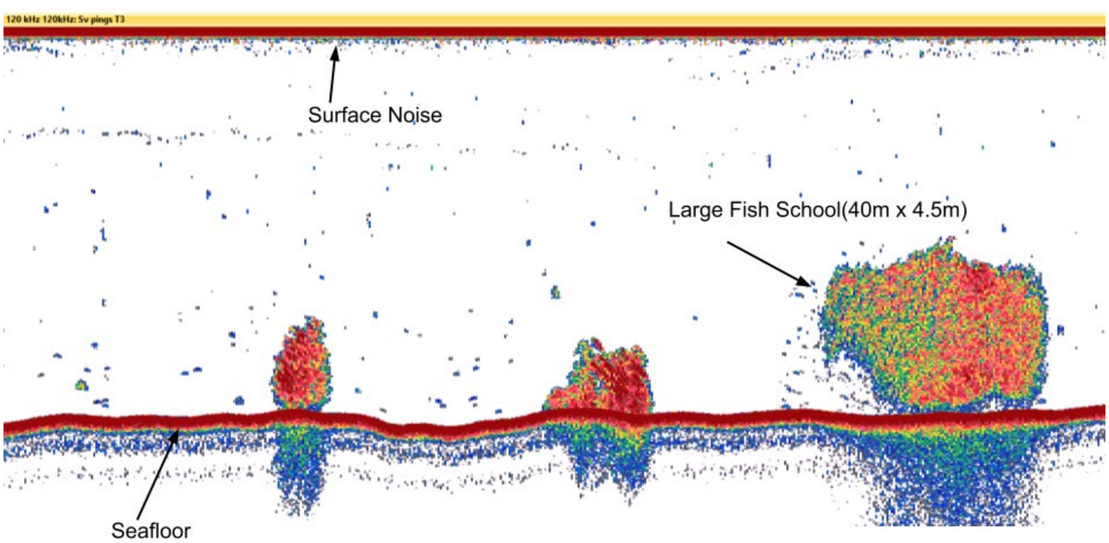

Figure 11. Large fish school seen in the systematic survey of whale MN23_039A.

4. Discussion and Future Analysis

The water-column prey survey work conducted during 2023 supports previous years' research within this area, which have documented high levels of foraging behavior in humpback whales tagged near the Virginia Beach shipping lanes. Although the primary goal of this work is to determine humpback responses to approaching ships, foraging behavior is likely to be both a response to disturbance (cessation of foraging) and a potential predictor of how likely animals are to react to an approaching threat. As such, it is important to understand the prey fields within the area in order to provide context for the documented foraging behavior.

One goal of this project was to conduct prey mapping concurrently with a tagged animal in order to assess prey density and whale spatial use of the water column in relation to prey in real time. The study team was able to achieve two focused surveys near a whale that HDR tagged with a CATS tag, including a systematic grid survey and an opportunistic following survey. Unfortunately, technical difficulties occurred during the tag offload, and the study team was unable to access the tag data.

Within the Virginia Beach shipping lanes study area, prey density was not evenly distributed. Areas of high density were found throughout the systematic survey, but were primarily concentrated on the northeastern side of the turning basin and along the edges of the shipping channel, with lower densities in the middle and southwestern portions of the survey. Whales tagged during previous years followed a similar pattern of foraging near the edges of the shipping lanes. During the focused whale-follow survey, the tagged whale appeared to be actively foraging from focal-follow observations (although the tag data are not available to confirm this). High prey density, including large fish schools measuring up to 40 by 4.5 meters, were occasionally found during the whale-follow survey. This correlation between concurrent likely foraging behavior by the tagged whale and dense prey schools illustrates the likelihood of these whales foraging on patchy but dense prey resources within this area.

During the 2023 study year, the team analyzed foraging behavior from all tags deployed to date, quantifying foraging rates, diel patterns, and kinematics. This manuscript is currently in review. The 2023 field season concluded the field effort portion of this project. Additional analyses are currently being conducted, including:

- Comparing prey survey results with known locations of foraging behavior from DTAG records to assess spatial and diel foraging patterns
- Combining satellite tag locations, foraging lunges, and bathymetry data from animals tagged with both satellite tags and DTAGs to analyze fine-scale spatial context of foraging behavior (location in water column, use of shipping lanes)
- Analyzing behavioral responses to approaching ships, including foraging behavior cessation, water column use, and spatial avoidance.

These analyses will continue to contribute to ongoing efforts to understand the behavior of humpback whales within the Virginia Beach shipping lanes study area in order to develop potential mitigation measures for ship strikes.

5. Acknowledgements

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