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Final Supplemental Site-Specific Environmental Assessment for Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight

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Final Supplemental Site-Specific Environmental Assessment for Pioneer Array Modifications and Relocations to the Mid-Atlantic Bight

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DEFINITIONS & ACRONYMS

~	approximately
ADCP	Acoustic Doppler Current Profiler
ARF	U.S. Academic Research Fleet
AUV	autonomous underwater vehicle
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
CGSN	Coastal and Global Scale Nodes
CVOW	Coastal Virginia Offshore Wind
DCM	North Carolina Division of Coastal Management
EA	environmental assessment
EFH	Essential Fish Habitat
EM	electromechanical
ESA	Endangered Species Act
FONSI	Finding of No Significant Impact
HAPC	Habitat Areas of Particular Concern
IMO	International Maritime Organization
km	kilometer
km^2	square kilometer
LNM	Local Notice to Mariners
m	meter
m^2	square meter
MAB	Mid-Atlantic Bight
MMPA	Marine Mammal Protection Act
Mooring Site	2 km by 2 km area surrounding each mooring location of the Pioneer Array
NARW	North Atlantic right whale
NC Survey Final EA	North Carolina Survey Final Environmental Assessment
NEPA	National Environmental Policy Act
NES	New England Shelf
NLAA	not likely to be adversely affected
nm	nautical mile
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOTMAR	Notice to Mariners
NSF	National Science Foundation
NWP	Nationwide Permit
O&M	operations and maintenance
OCS	Outer Continental Shelf
OOI	Ocean Observatories Initiative
OOIFB	Ocean Observatories Initiative Facility Board
PATON	Private Aids to Navigation

PEA	Programmatic Environmental Assessment
Project	Pioneer Array
Project Area	~13 nm to 45 nm offshore off the coast of Nags Head, North Carolina
Proposed Action	Relocating the Pioneer Array with modifications to the MAB
ROV	remotely operated vehicle
SAFMC	South Atlantic Fisheries Management Council
SER	Supplemental Environmental Report
SOP	Standard Operating Procedure or Special Operating Procedure
SSEA	Site-Specific Environmental Assessment
SSSEA	Supplemental Site-specific Environmental Assessment
Tetra Tech	Tetra Tech, Inc.
UNOLS	University-National Oceanographic Laboratory System
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USCG	U.S. Coast Guard

1 PURPOSE

This Supplemental Site-specific Environmental Assessment (SSSEA) has been prepared to assess the potential impacts on the human and natural environments associated with proposed changes to components of the U.S. National Science Foundation (NSF) Ocean Observatories Initiative (OOI) Coastal Pioneer Array, including: 1) proposed relocation from the northern Mid-Atlantic Bight (MAB) on the New England Shelf (Pioneer NES) to the southern MAB east of Nag's Head, North Carolina (henceforth "Pioneer MAB"; Figure 1); 2) modifications in the mooring design; and 3) inclusion of additional scientific instrumentation. The SSSEA tiers to OOI documentation previously prepared pursuant to the National Environmental Policy Act of 1969 (42 United States Code [U.S.C.] §4321 *et seq.*; NEPA),[1] including a Programmatic Environmental Assessment (PEA; NSF 2008); a Site-specific Environmental Assessment (SSEA; NSF 2011a); Findings of No Significant Impacts (FONSIs; NSF 2009a, 2011b); and Supplemental Environmental Reports (SER; NSF 2009b, 2013, 2015). The SSSEA was prepared in compliance with NEPA, the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (Title 40 Code of Federal Regulations [CFR] 1500-1508), and NSF procedures for implementing NEPA and Council on Environmental Quality regulations (45 CFR 640). The NEPA process ensures that environmental impacts of proposed major federal actions are considered in the decision-making process.

The SSSEA focuses on activities and associated potential impacts that were not previously assessed in OOI NEPA documentation. The SSEA was prepared by the NSF to assess the potential impacts on the human and natural environments associated with proposed site-specific requirements in the design, installation, and operation of the OOI that were initially assessed in the PEA (NSF 2008,) and the 2009 SER (NSF 2009b). The SSEA analysis concluded that installation and operations and maintenance (O&M) of the proposed OOI infrastructure, as presented in the 2011 Final SSEA, would not have a significant impact on the environment and a FONSI was signed on January 31, 2011 (NSF 2011b). In addition, SERs were prepared in 2013 and 2015 to determine if proposed OOI design modifications since completion of the 2011 SSEA would result in significant impacts to the environment not previously assessed in the SSEA, including cumulative impacts. Based on the analysis in the 2013 and 2015 SERs, there were no additional impacts on any resource area with implementation of the proposed OOI design modifications, and the 2013 and 2015 SERs concluded that the FONSI for the 2011 SSEA was still warranted (NSF 2011b), and additional NEPA documentation was not necessary.

1.1 Background of the OOI Coastal, Regional, and Global Scale Nodes

The following is a brief summary and background of the OOI based upon the information provided in the 2011 SSEA. For a more detailed description of the purpose, goals, and design of the OOI, and the mission of the NSF, which remain unchanged, please refer to the 2008 PEA; 2011 SSEA; and 2009, 2013, and 2015 SERs.

To provide the U.S. ocean sciences research community with the basic sensors and infrastructure required to make sustained, long-term, and adaptive measurements in the oceans, the NSF Division of Ocean Sciences supported the creation of the OOI major facility. The final design and form of the OOI was the result of planning guided by input from the U.S. and international scientific community. OOI builds upon recent technological advances, experience with existing ocean

[1] Previous OOI NEPA documentation is available on the NSF website: https://www.nsf.gov/geo/oce/envcomp/.

observatories, and lessons learned from several successful pilot and test bed projects. The OOI is an interactive, globally distributed, and integrated network of cutting-edge technological capabilities for ocean observations. This network of sensors enables the next generation of complex ocean studies at the coastal, regional, and global scales.

The OOI infrastructure includes cables, buoys, deployment platforms, moorings, junction boxes, electric power generation (e.g., solar, wind, and undersea cabled power supplies), mobile assets (i.e., autonomous underwater vehicles [AUV] and gliders), and two-way communications systems. This large-scale infrastructure supports sensors located at the sea surface, in the water column, and at or beneath the seafloor.

As described in detail in the PEA, the OOI design is based upon three main physical infrastructure elements across global, regional, and coastal scales. At the global and coastal scales, mooring observatories provide locally generated and/or stored power to seafloor and platform-mounted instruments and sensors, and use satellite or other wireless technologies to link to shore stations and the Internet. Up to four Global Scale Nodes or mooring arrays for ocean sensing are installed in the Eastern Pacific and Atlantic Oceans. The Regional-scale Nodes off the coast of Oregon consist of seafloor and mooring observatories with various physical, chemical, biological, and geological sensors linked with submarine cables to shore that provide power and Internet connectivity. The Coastal Scale Nodes are represented by the Endurance Array off the coast of Washington and Oregon and the Pioneer Array (Project) off the east coast of the U.S. The Pioneer Array was designed and planned to be relocatable approximately every 5 years with new locations proposed by the scientific community.

1.2 Scope of this SSSEA

The scope of the environmental impact analysis of this SSSEA is tiered from the previously prepared PEA, associated FONSIs, and SERs. It focuses only on those activities and the associated potential impacts, including cumulative impacts, not previously assessed in the tiered NEPA documents:

- Relocation of the Pioneer Array from the original Pioneer NES to the proposed Pioneer MAB location;
- Modifications to the mooring components and mobile assets as applied to the proposed Pioneer MAB relocation; and
- Inclusion of additional scientific instrumentation.

All other components, installation, and O&M activities of the OOI would remain unchanged from the description and analysis presented in the PEA, SSEA, and SERs. Section 2.0 describes in detail the proposed changes to the Pioneer Array addressed in this SSSEA. Although O&M would remain the same, Standard Operating Procedures (SOP, also referred to as Special Operating Procedures in previous documentation) were reviewed and were included in this SSSEA for context. For the Pioneer MAB Array, the surrounding area of potential effect would consist of seven sites that would have 10 total moorings deployed, with three sites accommodating two moorings side-by-side. Each mooring site would include an area of 2-kilometer (km) x 2 km (1 nautical miles [nm] x 1 nm) surrounding the site center. In addition, there would be mobile assets, such as AUVs and gliders that would operate around the moorings (see Figure 1).

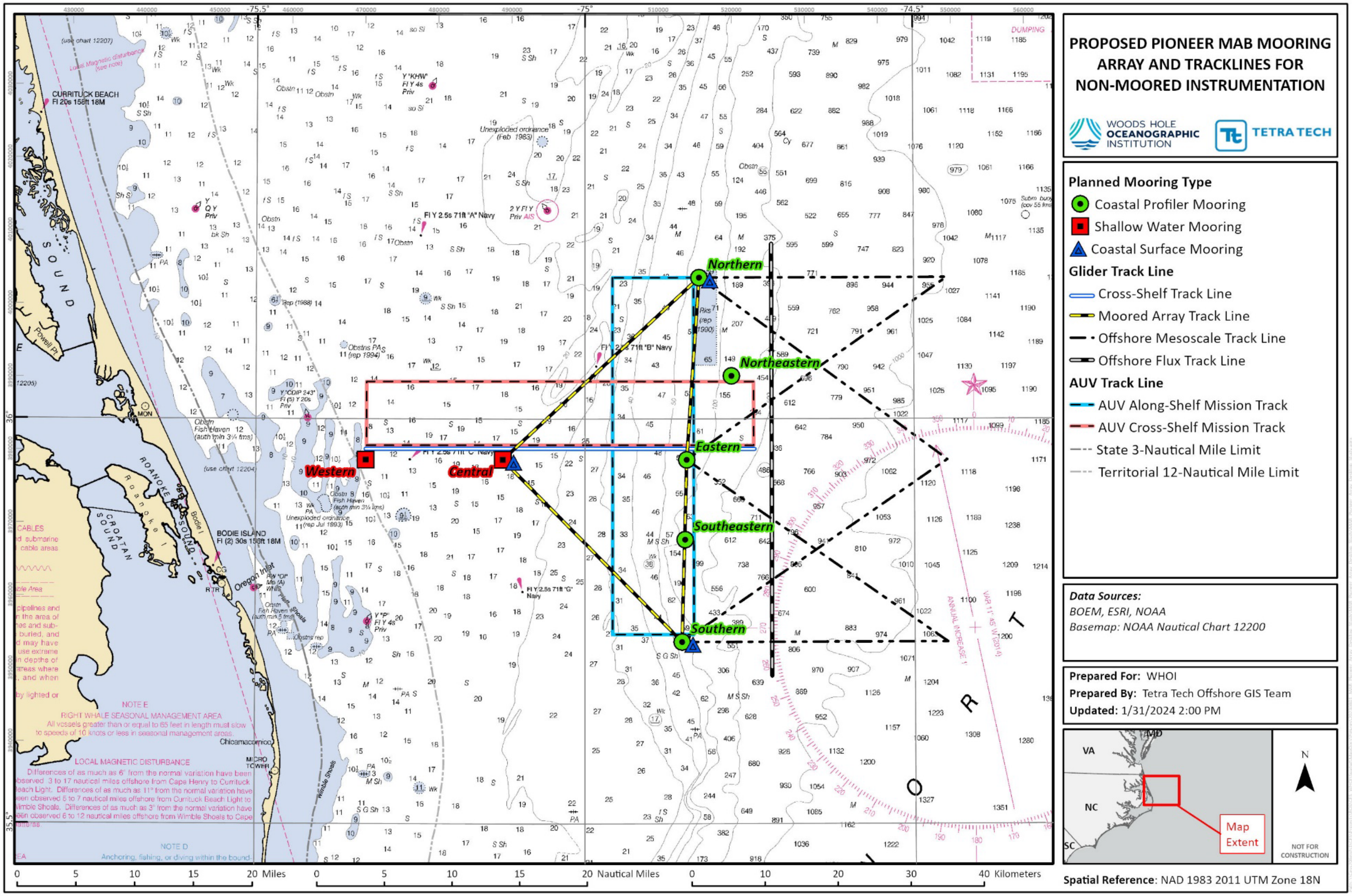

Figure 1. Proposed Pioneer MAB Array of Moorings and Surface Expressions of Underwater Track Lines for Mobile Assets

2 DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

In this SSSEA, two alternatives were evaluated: 1) Proposed Action: Relocating the Pioneer Array with modifications to the MAB; and 2) No Action.

2.1 Proposed Action: Relocating the Pioneer Array with Modifications to the MAB

2.1.1 Pioneer MAB Array

The MAB of eastern North America is characterized by a relatively broad shelf, a persistent equator-ward current originating from the north, a well-defined shelf break front separating shelf and slope waters, distributed buoyancy inputs from rivers, variable wind forcing, and intermittent offshore forcing by Gulf Stream rings and meanders. The Pioneer MAB Array would be designed to resolve transport processes and ecosystem dynamics within the shelf-slope front, which is a region of complex oceanographic dynamics, intense mesoscale variability, and enhanced biological productivity. It collects high-resolution, multidisciplinary, synoptic measurements spanning the shelf and shelf-break on horizontal scales from a few kilometers to several hundred kilometers.

The proposed Pioneer MAB Array would be a T-shaped array located off the coast of Nags Head, North Carolina, starting approximately (~) 24 km (13 nm) offshore, extending ~59 km (32 nm) east/west and 49 km (26 nm) north/south across the continental shelf, centered at the shelf-break front (Figure 1 and Table 1), referred to as the Project Area.

Similar to the original Pioneer NES array, the Pioneer MAB Array would employ Shallow Water Moorings, Coastal Surface Moorings, Coastal Profiler Moorings, Gliders, and AUVs to sample on multiple horizontal scales from the air-sea interface to the seafloor. The Shallow Water Moorings (Figure 1) would be equipped with a small surface expression for navigational aids and data telemetry equipment, a profiling vehicle to sample the water column, and would be moored to the seabed with an inductive wire and electromechanical (EM) stretch hoses, allowing incorporation of a benthic node for seabed instrumentation. The Coastal Profiler Moorings (Figure 3) would be similar to the Shallow Water Moorings but would not have a benthic node. The Coastal Surface Moorings (Figure 4) would be equipped with a surface expression carrying navigational aids, data telemetry systems, instrumentation to measure surface meteorology and air-sea fluxes, fitted with power generation capability, and moored with EM stretch hoses to the seafloor, allowing incorporation of a benthic node for science user instrumentation.

2.1.2 Pioneer MAB Array Components

The Pioneer MAB Array would consist of two lines of moorings running east/west and north/south in a T-shape across the continental shelf (Figure 1). The east/west line would consist of two Shallow Water Moorings (Figure 2), a Coastal Profiler Mooring (Figure 3), and a Coastal Surface Mooring (Figure 4). The north/south line would consist of Coastal Surface Moorings and Coastal Profiler Moorings. In total, 10 moorings would be deployed in 7 locations, as the Coastal Surface Moorings are paired with other moorings at the same location (Figure 1).

Table 1. Planned Mooring Types and Locations

Mooring Name	Mooring Type	Water Depth (meters)	Latitude (°N)	Longitude (°E)
Western	Shallow Water	30	35.9500	-75.3333
Central	Shallow Water and Coastal Surface	30	35.9500	-75.1250
Eastern	Coastal Profiler	100	35.9500	-74.8457
Northern	Coastal Profiler and Coastal Surface	100	36.1750	-74.8267
Southern	Coastal Profiler and Coastal Surface	100	35.7250	-74.8530
Northeastern	Coastal Profiler	300	36.0536	-74.7776
Southeastern	Coastal Profiler	300	35.8514	-74.8482

The Shallow Water Moorings (Figure 2) would be deployed in 30-meter (m) water depths, and the Coastal Profiler Moorings (Figure 3) would be deployed in 100-m and 300-m water depths. The Northeastern and Southeastern Coastal Profiler Moorings were initially proposed to be deployed in 600-m water depth. Taking into consideration comments received during the NEPA public comment period (see Appendix G), these moorings would be deployed in 300-m water depths to mitigate potential impacts on longline fisheries. Additional information regarding this change can be found in Section 3.1.2.6.1 Fisheries. The Coastal Surface Moorings (Figure 4) would be deployed in 30-m and 100-m water depths (see Table 1).

Gliders and AUVs would run missions in the vicinity of the moored array. The approximate surface expressions of the underwater track lines indicating the glider and AUV paths are shown in Figure 1. Both gliders and AUVs move slowly forward (0.25 m per second or 0.5 miles per hour for gliders, 3 m per second or 6 miles per hour for AUVs), while also moving up and down in the water column. The planned tracks are approximate and would be adjusted as needed to account for bathymetry and currents, and therefore may curve as needed to cover the area of concern. Four (4) gliders would be used to provide monitoring capability along and across the continental shelf and within the slope sea offshore. Gliders would be deployed on a 60- to 90-day rotation schedule and would run continuously along their pre-determined paths (Figure 1). The gliders are piloted from shore using satellite communications during short intervals when the vehicles are on the surface, and procedures are in place to maintain the gliders at depth through charted marine traffic areas. Two (2) AUVs would be used to provide monitoring capabilities along and across the continental shelf near the moored array. AUVs would be deployed for limited periods of ~4 days every 2 months. AUVs are piloted from a research ship which would remain in the deployment area and monitor vessel traffic.

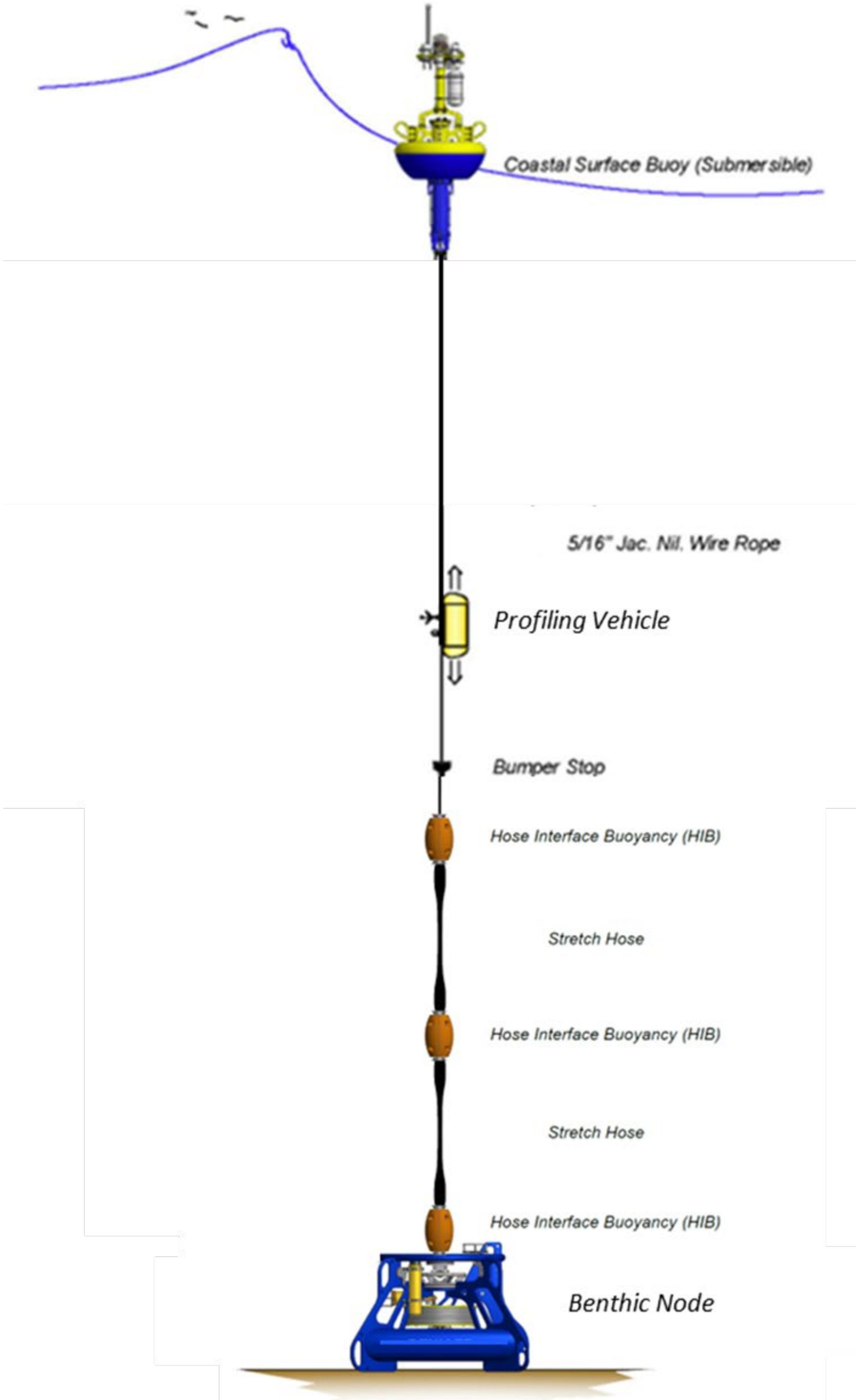

Figure 2. Proposed Shallow Water Mooring Design

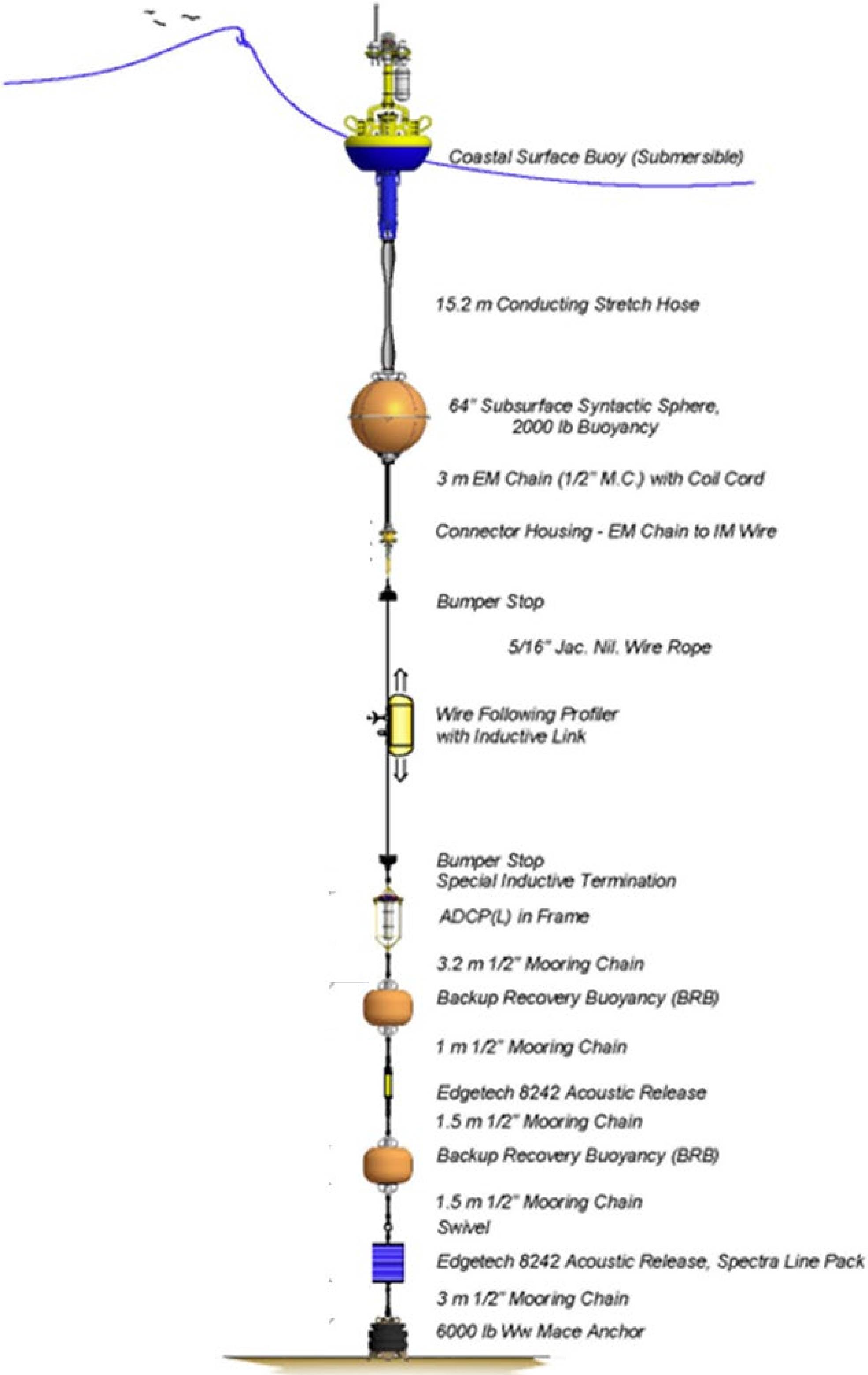

Figure 3. Proposed Coastal Profiler Mooring Design

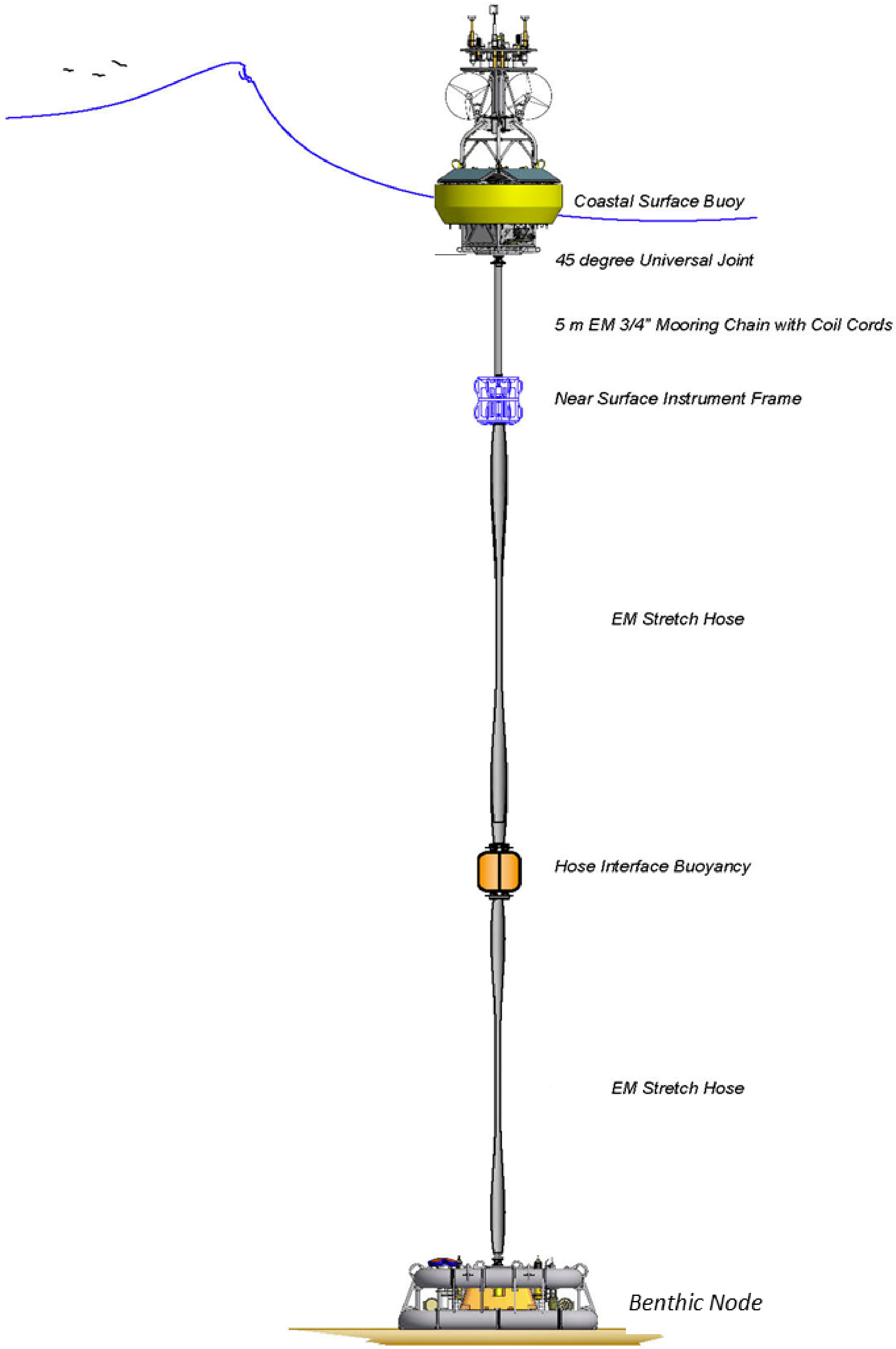

Figure 4. Proposed Coastal Surface Mooring Design

2.1.3 Proposed Pioneer Array Location and Design Modifications

As assessed in this SSSEA, the proposed changes in the Pioneer Array location and configuration would include:

- Relocation to the MAB;
- Modifications to the moored array; and
- Inclusion of additional scientific instrumentation.

2.1.4 Relocation of Pioneer to the MAB

As part of the original design of OOI, the Pioneer Array was expected to be relocated approximately every 5 years. In 2020, the NSF and the OOI Facilities Board (OOIFB) announced the process for the potential relocation of the Pioneer Array. The NSF, along with the OOIFB, organized a series of workshops to select the location, develop the science themes, layout the infrastructure, and recommend instrumentation. The site selection and design process steps undertaken are described in more detail in Appendix A.

The six baseline science themes found in the OOI Science Plan (https://ooifb.org/ooi-science-plan/) were initially developed by the scientific community for OOI and were retained as guidance for the Pioneer Array relocation:

1. Ocean-atmosphere exchange and coastal storm response;
2. Climate variability and ecosystems;
3. Coastal dynamics and biogeochemical cycling;
4. Seafloor processes;
5. Physical oceanography of the shelf and slope; and
6. Interactions of physical and biological processes.

The scientific community also highlighted three topics specific to the Pioneer MAB Array within the baseline themes:

1. Dynamical processes at the shelf break, including wind forcing, frontal instability, and Gulf Stream influences;
2. Physical/biogeochemical coupling, including carbon, nutrients, and particulates, and considering ecosystem response to cycling and transport; and
3. Episodic events and impacts, such as freshwater outflows and hurricanes.

Also, based on the third NSF-sponsored workshop, the science community confirmed the utilization of the existing mooring components, with minor modifications, from the Pioneer NES Array reviewed in the previous SSEA and SERs.

To support the environmental assessment of the proposed new location, regulatory (Appendix B), desktop (Appendix C), and marine archeology studies (Appendix D) were undertaken by OOI and its contractor, Tetra Tech, Inc. (Tetra Tech). Further details of the efforts to identify locations for the moorings in the Project Area were included in the Coastal and Global Scale Nodes (CGSN) Site Characterization (Appendix E). A remotely operated vehicle (ROV) was used to inspect and verify that anchoring the scientific moorings within each proposed 2-km by 2-km (1-nm by 1-nm) square, or Mooring Site, would have minimal to no impacts to environmental resources (Appendix F).

2.1.5 Modifications to the Moored Array

A list of components previously assessed in the PEA, SSEA, and SERs for Pioneer NES Array versus the proposed components for Pioneer MAB Array in this SSSEA is provided in Table 2.

Table 2. Pioneer NES/MAB Component Comparison

Component	Pioneer NES	Pioneer MAB
Moorings	3 Coastal Surface Moorings with Benthic Node (8 m^2 footprint each)	3 Coastal Surface Moorings with Benthic Node (8 m^2 footprint each)
	7 Coastal Profiler Moorings with anchor (1 m^2 footprint each)	5 Coastal Profiler Moorings with anchor (1 m^2 footprint each)
	–	2 Shallow Water Moorings with Benthic Node (4 m^2 footprint each)
AUVs	2 AUVs, Mission Box = 8,537 km^2	2 AUVs, Mission Box = 4,318 km^2
Gliders	6 Gliders, Mission Box = 24,507 km^2	4 Gliders, Mission Box = 17,143 km^2

AUV–autonomous underwater vehicle; km^2–square kilometer; m^2–square meter; MAB–Mid-Atlantic Bight; NES–New England Shelf

The Coastal Surface and Coastal Profiler Moorings proposed for the Pioneer MAB Array location are identical in design to the Pioneer NES Array moorings. The new deployment depths would alter the length of the riser components but would not alter the design or material types. The original SSEA and both the 2013 and 2015 SERs noted that the Coastal Surface Moorings could be powered by a methanol fuel cell. The fuel cells were never deployed and have been removed, eliminating the risk of a potential spill of alcohol-based fuel.

Two Shallow Water Moorings are proposed at the new MAB location. These moorings would operate similarly to the existing Coastal Profiler Mooring, utilizing an instrumented vehicle that moves up and down along a taut wire, but are designed for shallow water. The Shallow Water Mooring would consist of the following (Figure 2):

- A small surface expression mounted with aids to navigation, data telemetry equipment, and battery housing for the mooring operation;
- A profiler vehicle containing scientific instrumentation for sampling the water column;
- A mooring riser consisting of inductive wire and EM stretch hoses; and
- A benthic node containing seafloor instrumentation.

All components of the Shallow Water Mooring are based on existing designs, incorporating elements of both the Coastal Surface Moorings and Coastal Profiler Moorings from Pioneer NES Array. As with all the Pioneer Array moorings, the benthic node and anchor of the Shallow Water Moorings are designed to be fully recoverable, minimizing impacts to the seabed. The capability to fully recover all mooring anchors was proven in November 2022 when Pioneer NES was recovered, and all infrastructure was removed from the seabed successfully. The Pioneer MAB Array designs would be deployed, recovered, and maintained using the same procedures as the original Pioneer NES Array moorings.

2.1.6 Inclusion of Additional Scientific Instrumentation

During the Pioneer Array relocation planning process, additional measurements were requested by the scientific community:

- **Phytoplankton Imaging:** submersible flow cytometry (i.e., a measure of light scattering and fluorescence from a single cell or particle) and high-resolution imagery of suspended particulates.
- **Turbidity:** a measure of clarity based on light scattered by suspended particulates.
- **Near-surface Velocity**: a measure of water velocity in the upper 20 m of the water column.
- **Suspended Particulates:** a measure of the size of suspended particulates.

The Pioneer Array moorings were designed to allow the addition of new instrumentation. The few instruments requested could be incorporated into the Pioneer infrastructure with only minor modifications in bracketry. New instrumentation includes phytoplankton imaging via imaging flow cytometry on coastal surface moorings, turbidity using optical measurement on coastal surface moorings, near-surface velocity using acoustic measurement on coastal profiler mooring and shallow water moorings, and suspended particulates using optical measurement on coastal surface moorings.

2.1.7 Installation and O&M of Pioneer Array

The Pioneer MAB Array is proposed to be deployed in April 2024. Following deployment, the moored array would be serviced using a University-National Oceanographic Laboratory System (UNOLS) Global or Ocean Class vessel in April/May and August/September of each year (i.e., every 6 months). These periods offer the most suitable weather and sea conditions to perform the mooring recoveries and re-deployments. Vessel scheduling issues and other unforeseen events (e.g., weather) might require that some maintenance cruises occur outside of the planned time window in a given year. Other activities during the maintenance cruises include Glider recoveries/deployments as necessary, and AUV surveys. Since Gliders have an endurance of 75-90 days, they require recoveries and deployments between maintenance cruises using small research or charter vessels. AUV surveys are planned for every 2 months, and would also require small vessel cruises except for the two times per year that surveys are conducted during the mooring maintenance cruises. A proposed schedule for installation, operations, and maintenance is included below in Table 3.

Table 3. Proposed Schedule for Installation and Operation and Maintenance

Operation	Description	Date	Duration	Vessel
Deployment at MAB	First deployment of moorings, gliders, and AUVs at planned MAB site	April 2024	~24 days	UNOLS Research Vessel
Spring Maintenance Cruise	Spring recovery and replacement of moorings, deployment of gliders & AUVs	April/May	~24 days	UNOLS Research Vessel
Fall Maintenance Cruise	Fall recovery and replacement of moorings, deployment of gliders & AUVs	August/September	~24 days	UNOLS Research Vessel
Glider Operations	Deployment and recovery of gliders based on vehicle endurance	Every 75-90 days	~2-3 days	Small research or charter vessel
AUV Operations	AUV surveys of Pioneer MAB, vehicles deployed for ~2 days, then recovered	Every 2 months	~5-7 days	Small research or charter vessel

The methods for the installation of the Pioneer MAB Array infrastructure, and for conducting routine O&M activities, would be the same as those described in the 2011 SSEA (refer to Section 2.2.6 of the PEA [NSF 2008]). Installation and O&M activities follow standard methods and procedures currently used by the ocean observing community, such as the National Oceanic and Atmospheric Administration's (NOAA) National Data Buoy Center; regional ocean observing programs funded by the NOAA Integrated Ocean Observing System (https://www.ioos.nolaa.gov); and other federal agencies (e.g., U.S. Department of Energy, see: https://www.pnnl.gov/projects/wind-forecast-improvement-project-3). The moorings deployed at Pioneer NES included anchors and benthic nodes that were designed to be fully recoverable minimizing impacts to the seabed. Following the last recovery of the Pioneer NES Array in November 2022, all seabed infrastructure was recovered successfully proving the effectiveness of the design. There would be no changes to the installation of the Pioneer MAB Array components, as addressed in Sections 2.1.1.3 and 2.1.1.4 and Tables 2 and 3 of the 2013 and 2015 SERs.

2.1.8 Special Operating Procedures for Installation and Operation and Maintenance of the Proposed Modifications to the Pioneer Array

The proposed modifications to the Pioneer Array do not require any changes or additions to the SOPs that were presented in the 2011 SSEA (NSF 2011a, Section 2.2.10, Table 2-13).

The SOPs presented in Table 4 would continue to be followed to avoid and minimize any potential impact to ocean uses/users, (e.g., marine traffic and commercial fishing activities).

Table 4. Standard Operating Procedures

Standard Operating Procedures
1. All Pioneer Array moorings would be permitted as Private Aids to Navigation (PATONs) through the U.S. Coast Guard (USCG). Surface buoys would be marked per USCG requirements, with all required lights and markings, with locations appearing in the Notice to Mariners (NOTMAR) and Local Notice to Mariners (LNM). Surface buoys would be marked with contact information, which would be included in the NOTMAR and LNM with suggested buffer zones* around moorings. Should any vessel accidentally snag Ocean Observatories Initiative (OOI) moorings or equipment, they would be instructed to contact that number and/or the USCG. As Pioneer Array moorings would be considered PATONs, they are protected by USCG rules and regulations pertaining to Aids to Navigation (33 Code of Federal Regulations [CFR] 66 and 33 CFR 70). Penalties for interference, collision, and vandalism can be levied by the USCG in accordance with 33 CFR 70. So long as surface buoys are marked per regional USCG requirements, all lights and markings are operating correctly, and the infrastructure is on the marked location (i.e., as described in NOTMAR and LNM), the OOI project is not liable for snagging of or damage to any gear or vessel.
2. Locations for all moorings and associated components of the Pioneer Array would be published on NOAA charts once moorings are listed in the USCG NOTMAR and LNM. In addition, accurate locational information would be made available to fishers to assist their avoidance of the instruments.
3. The coordinates for Pioneer Array autonomous underwater vehicles (AUV) and glider mission boxes would be published through a NOTMAR. Gliders and AUVs would be marked with the name of the owning organization and a contact telephone number that fishers can call to report potential entanglements.

2.2 Alternatives Considered

An alternative to conducting the Proposed Action is the “No Action” alternative, which is to not relocate the Pioneer Array with modifications to the MAB. Under the “No Action” alternative, the NSF would not provide funding to relocate the Pioneer Array with modifications to the MAB. If the Pioneer Array with modifications was not relocated to the MAB, the “No Action” alternative would result in no disturbance to the marine environment. Although the “No Action” alternative is not considered a reasonable alternative because it does not meet the purpose and need for the Proposed Action, it is included and carried forward for analysis in Section 3.0.

Although the Pioneer Array could be relocated to several sites to collect critical oceanographic data, extensive effort was undertaken by the NSF, OOI, the scientific community, and interested parties to evaluate potential sites for relocating the array, narrowing the selection based on scientific justification to the proposed MAB site, as described in Section 2.1.4. For this reason, relocating the Pioneer Array to other locations as an alternative was eliminated from further consideration. Given that the Pioneer Array is designed to be relocated approximately every 5 years, other locations would be considered and evaluated for future opportunities.

3 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

As this SSSEA tiers off previous documents evaluating the Pioneer NES Array, the affected environment and environmental consequences are the same as those previously discussed and assessed in the 2011 SSEA and 2013 and 2015 SERs; only the changes in the geographic location and the minor array infrastructure modifications proposed for the Pioneer MAB Array are assessed. No additional impacts from operating the Pioneer NES Array were observed by or reported to OOI. Additional resources that are generally evaluated in preparation of an environmental assessment (EA) were not evaluated in this SSSEA because it was determined that implementation of the Proposed Action would be unlikely to have any effect on those resources. Overall, O&M is anticipated to remain at similar levels to prior operations of the Pioneer NES Array. Therefore, these proposed changes (i.e., relocation and array modifications) are the main scope of the analysis in this SSSEA.

3.1 Proposed Action

3.1.1 Array Modifications

The new array instrumentation (e.g., sensors) would be mounted on or incorporated into the existing mooring designs. The type of measurement, method, impact, and mooring to be installed on-site are listed in Table 5.

Table 5. Impact of New Scientific Measurements

Measurement	Method	Impact	Installation
Phytoplankton Imaging	Imaging flow cytometry. Utilizes a combination of natural fluorescence and microscopy.	No adverse impact	Coastal Surface Mooring
Turbidity	Optical measurement. Detection of light scattered by suspended particles.	No adverse impact	Coastal Surface Mooring
Near-surface Velocity	Acoustic Doppler Current Profiler utilizes acoustics (>180 kHz) to measure currents. Existing instrument class in OOI.	Acoustic source considered *de minimis*; acoustic frequencies used (>180 kHz) not audible by fish/marine mammals and of low power. No adverse impact	Coastal Profiler Mooring, Shallow Water Mooring
Suspended Particulates	Optical measurement. Particle size estimation through the analysis of laser diffraction.	Illuminated area <1 cm^3 No adverse impact	Coastal Surface Mooring

cm^3–cubic centimeter; kHz–kilohertz

Acoustic Doppler Current Profiler (ADCP) instruments would be used to perform the near-surface velocity measurements. ADCPs are an existing OOI instrument class and were reviewed as part of the original SSEA and PEA. The ADCPs would operate at frequencies higher than those frequencies considered audible by fish and marine mammals (i.e., greater than 180 kilohertz).

The potential impacts from the moorings would be the same as those already assessed in the PEA, 2011 SSEA, and 2013 and 2015 SERs, which concluded that no significant effects on the environment were expected. For these reasons, none of the new instrumentation or measurements would be anticipated to result in significant or adverse impact to the marine environment, including marine biological resources.

3.1.2 Relocation, Installation, and O&M Activities

This section builds from the PEA, 2011 SSEA, and 2013 and 2015 SERs and focuses only on those resources potentially subject to impacts from the Relocation, Installation, and O&M activities.

3.1.2.1 Geological Resources

Regional sediment classification maps (Appendix E) summarize bottom characteristics along the southern portion of the Mid-Atlantic Bight and suggest that, in the OOI mooring region, the seabed is mainly sandy, with some gravelly sediment on the inshore shelf and possible sandy clay or silt on the slope. The seabed surveys performed by OOI in February/March 2023 and October/November 2023 (Appendix F) confirmed the seabed types at each mooring location.

The planned Pioneer MAB Array has the equivalent number of moored components as the original Pioneer NES Array. Although it would have a slightly larger footprint (~37 square meters [m^2] versus 31 m^2 of seabed impacted; see Table 2) the difference was determined to be negligible. As reviewed in the previous SSEA, 2008 PEA, and 2013 and 2015 SERs, the temporary placement of benthic nodes and mooring anchors would result in short-term, insignificant impacts to surface sediments in the immediate vicinity of the proposed Pioneer Array assets, and there would be no significant impacts to marine geological resources. Over time, the natural movement of sediments by ocean currents and burrowing organisms would reestablish natural bottom topography.

Upon conclusion of approximately 5 years of operations, the entire system, including anchors, would be removed and relocated in alignment with the 2011 PEA and other OOI environmental documentation. In November 2022, OOI successfully recovered all Pioneer NES Array infrastructure components, including anchors, leaving nothing on the seabed or in the water column. For these reasons, direct and indirect impacts from the proposed activities on geological resources are not anticipated to be significant.

3.1.2.2 Air Quality

Overall, there would be no change in the level of planned operations and management of the Pioneer Array with the relocation. Proposed activities would result in minor temporary emissions from surface vessels during installation and maintenance activities of the Pioneer MAB Array (Appendix C: page 3-36). These emissions would not be anticipated to represent a substantial increase or decrease above existing NES operating conditions, as only a small number of vessels would be used. Upon conclusion of approximately 5 years of operations, the entire system, including anchors, would be removed and relocated in alignment with the 2011 PEA and other OOI environmental documentation.

The Pioneer MAB array would be located outside the jurisdiction of any state. O&M activities would likely be undertaken by vessels within the U.S. Academic Research Fleet (ARF), or similar types of vessels, which follow high maintenance standards, including International Maritime Organization (IMO) standards. Although there are no emissions standards for vessels or activities operating beyond 22 km (12 nm) of shore and no mitigation would be required, to reduce impacts on air quality, ARF vessels typically use ultra-low sulfur fuel (less than 15 parts per million of sulfur) and employ Ship Energy Efficiency Management Plans to reduce and minimize fuel consumption (e.g., speed optimization), generally resulting in lower emissions.

For these reasons, direct and indirect impacts from the proposed activities on air quality would be negligible and are not anticipated to be significant.

3.1.2.3 Water Quality

Although the Project would require a federal Nationwide Permit (NWP), given the location of the Project several kilometers outside of state waters, the Project is not anticipated to affect state water quality. As Section 401 Water Quality Certifications are automatically associated with NWPs, a separate authorization application and approval would not be required *(*Appendix C: page 3-34*)*. Proposed installation, operation, and maintenance activities at the proposed Pioneer MAB Array would not introduce any materials or substances into the marine environment that would adversely affect marine water quality. The Project would not alter currents or circulation regimes. A minor and localized area for which the benthic nodes and anchors would be placed would likely have some re-suspension of sediment, but these effects would be very brief and temporary. Therefore, no direct or indirect impacts to water quality with implementation, operation, or eventual removal of the Pioneer MAB Array are anticipated.

3.1.2.4 Cultural Resources

Potential impacts to cultural resources from the proposed Pioneer MAB Array would only be associated with the placement of 10 benthic nodes and mooring anchors on the seafloor greater than 24 km (13 nm) offshore. The NOAA Marine Cadastre wreck database was referenced (Figure 5; Appendix A: page 14); a desktop review of NOAA, Bureau of Ocean Energy Management (BOEM), and Esri data was performed (Appendix C); and a marine archeology study was undertaken by OOI and Tetra Tech during the planning phase to avoid known cultural resources and wreck locations (Appendix D). In February and March 2023, a site survey was conducted of each proposed mooring site and surrounding 2 km by 2 km (1 nm by 1 nm) square to determine if any known or unknown cultural resources (e.g., shipwrecks) would be present (Appendix F). No cultural resources or hazards were located within the survey areas and all documented wrecks or submerged cultural resources would be avoided by greater than the recommended distance of 50 m. Any overlaps of symbology in Figure 5 are due to the scale of the symbols being larger than the Mooring Sites to be visible in the figure. Therefore, the placement of the proposed Pioneer MAB Array should avoid and not result in impacts to cultural resources.

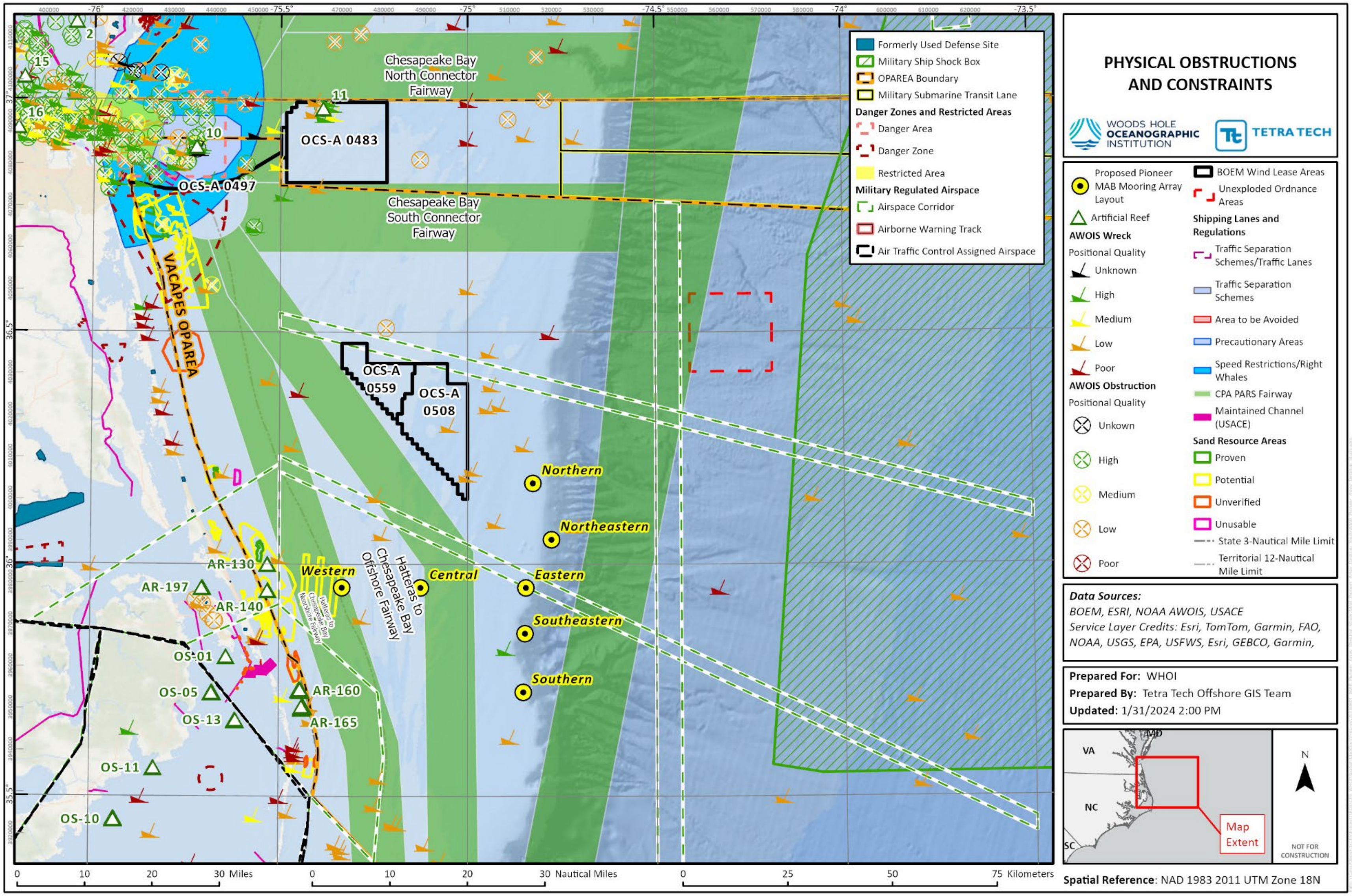

Figure 5. Physical Obstructions and Constraints

3.1.2.5 Marine Biological Resources

There are 36 species of marine mammals (7 large whales, 18 dolphins [including larger oceanic dolphin species], 1 porpoise, 5 beaked whales, 4 seals, and 1 manatee) that occur in the Southeast Atlantic Outer Continental Shelf (OCS) region, and all are protected by the Marine Mammal Protection Act (MMPA). Six of these species are federally listed under the Endangered Species Act (ESA) as threatened or endangered and are known to be present, at least seasonally, in the Mid-Atlantic, five of which have the likely potential of occurring in the Project Area:

- Blue whale (*Balaenoptera musculus*)
- North Atlantic right whale (*Eubalaena glacialis*);
- Fin whale (*Balaenoptera physalus*);
- Sei whale (*Balaenoptera borealis*); and
- Sperm whale (*Physeter macrocephalus*).

Appendix C provides more detailed information on the known marine mammal distributions within coastal North Carolina and the Project Area and summary of key information for each species. Appendix C also indicates species that were not further analyzed as they are unlikely to occur in the Project Area.

The five species of sea turtles that have historically been reported to occur in Mid-Atlantic waters off the coast of North Carolina include the following:

- Atlantic hawksbill (*Eretmochelys imbricata*);
- Green (*Chelonia mydas*);
- Kemp's ridley (*Lepidochelys kempii*);
- Leatherback (*Dermochelys coriacea*); and
- Loggerhead (*Caretta caretta*).

Appendix C provides the known sea turtle distributions within coastal North Carolina and the proposed array area and summary of key information for each species, all of which are listed as threatened or endangered under the ESA.

The vessels and activity associated with installation of 10 moorings and associated scientific sensors on the seafloor may cause marine species to temporarily avoid the immediate vicinity of the proposed Pioneer MAB Array, but this impact would not be significant due to the small scale and temporary nature of the proposed activities (estimated time to deploy a mooring with one vessel is 12 to 24 hours). The vessel used for mooring deployment would move very slowly (0.5 to 2 knots) during the activity and therefore would not pose a vessel strike or collision threat to marine mammals or sea turtles. Furthermore, vessels of the ARF would follow National Marine Fisheries Service (NMFS) standard oceanographic marine mammal vessel strike avoidance guidance and special measures, such as those triggered by temporary Dynamic Management Areas, for the North Atlantic right whale (NARW). Entanglement of marine species is not anticipated because of the rigidity and tautness of the mooring cables and the ability of marine species to detect and avoid the mooring lines. Once installed on the seabed, the proposed mooring anchors and scientific sensors would be equivalent to other hard structures on the seabed, again posing no risk of adverse effect on marine organisms. No known vessel strikes or entanglements were associated with the Pioneer NES Array. Therefore, no significant impacts would be anticipated from the Proposed Action on marine mammal and sea turtle species in the proposed Project Area. While ESA-listed species may be affected, based on and consistent with past OOI NEPA documents, they would not likely be adversely affected (NLAA). However, based on Pioneer NES Array experience, potential impacts, and other experience with similar research technology, any impacts to marine mammals or sea turtles from the Proposed Action would be anticipated to be very minor and temporary, and thus a determination of no effects may be more appropriate. However, for consistency with past documentation and to ensure compliance with ESA, a NLAA determination for marine mammals and sea turtles was made.

Impacts from the placement of proposed mooring anchors or nodes on the seafloor would include temporary mechanical disturbance of soft sediments and long-term coverage of relatively small areas of substrate by the anchors and scientific sensors. Due to the large water depth in the Project Area, and attenuation of light to such depths, the presence of ESA-listed plant species is not expected. In addition, the video survey of the Project site (Appendix F) indicates that the existence of ESA-listed vegetation is unlikely. This video survey also indicates that the presence of ESA-listed invertebrates is unlikely. Given the footprint of moorings and scientific equipment (~37 m^2), no significant impact would be anticipated from the Proposed Action on ESA-listed plants or invertebrates, therefore, the Proposed Action is likely to have no adverse effects on these species.

Based on the expected size and number of anchors and scientific sensors on the seafloor, ~37 m^2 of Effective Fish Habitat (EFH) may potentially be impacted during installation activities. (See Appendix C, Table 3-1 for a comprehensive list of EFH which overlaps with the Project Area.) Over time, the natural movement of sediments by ocean currents and burrowing organisms would reestablish natural bottom topography. Upon conclusion of approximately 5 years of operations, the entire system, including anchors, would be removed and relocated in alignment with the 2011 PEA and other OOI environmental documentation. The short-term and minor increases in turbidity and sedimentation resulting from system installation and removal would not affect the ability of EFH to support healthy fish populations, and affected areas are expected to recover quickly.

The use of up to four gliders (survey area of ~17,143 square kilometers [km^2]) and two AUVs (survey area of ~4,318 km^2) around the Pioneer MAB Array is not expected to affect marine species, as the proposed gliders and AUVs would move within the water column similar to a dolphin or whale. The proposed operational area for AUVs would be smaller than for Pioneer NES, resulting in an overall smaller footprint. Gliders are sealed, contain no motors, fuels, or hazardous materials; and move at very slow speeds (~0.5 knot), thereby eliminating the potential for collisions with marine mammals. AUVs also move at low speeds (~3.5 knots) with little potential for collisions with marine species. AUV batteries are sealed with little potential for leakage. Therefore, the use of gliders and AUVs associated with the proposed Pioneer MAB Array would not be anticipated to have a significant impact on marine species, including no adverse effects on ESA-listed species or their critical habitat, in the Project Area.

The Pioneer MAB Array also does not incorporate any new acoustic instrument classes and, therefore, is not expected to result in any significant acoustic impacts to marine species, fish, and marine mammals.

Specific sensitive areas were considered during early planning and placement of the Pioneer MAB Array:

- **Artificial Reefs:** Artificial reefs AR-130, -140, -145, -160, -165 are located west of the Project Area (Figure 5) with the closest mooring greater than 3.5 km (1.9 nm) away. Pioneer MAB Array would therefore be anticipated to have no impact on artificial reefs.
- **Fishery Nursery Areas:** The southern moorings would be located within a Primary/Secondary Nursery Habitat. There is a moratorium against excavation or filling activities in April through September. Since these activities are not associated with the Pioneer MAB Array operations, there would be no anticipated impact on fishery nursery areas.
- **Critical Habitat:** Four of the Pioneer MAB Array moorings would be located within the loggerhead sea turtle Constricted Migratory Corridor (Figure 6); however, they would not be anticipated to impede sea turtle migration. Therefore, the proposed activities are not likely to adversely affect ESA-listed loggerhead sea turtle critical habitat. The Pioneer MAB Array would not overlap with loggerhead sea turtle Coastal Critical Habitat Designation (sargassum habitat).
- **North Atlantic Right Whale Migratory Corridor and Seasonal Management Areas:** All of the Pioneer MAB Array moorings are located within the NARW migratory corridor (Figure 6); however, the migratory corridor does not require special management considerations or additional protective measures. The proposed activities are small scale and temporary, therefore installation and maintenance are not likely to pose risks of entanglement or collision. The Pioneer MAB Array avoids the two designated NARW critical habitats and does not overlap with the Mid-Atlantic Seasonal Management Areas.
- **EFH**: EFH may be defined as the waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity (16 U.S.C. § 1801(10)), where the term "necessary" indicates habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. Managed fish with designated EFH in the Project Area were identified using the online EFH Mapper (see Appendix C). The Pioneer MAB Array is located within an area that contains EFH for species managed by the New England Fishery Management Council, Mid-Atlantic Fishery Management Council, and South Atlantic Fisheries Management Council (SAFMC). While Figure 6 does not explicitly show EFH within the Project Area, EFH exists for certain life stages of 36 fish species managed by the Councils, as previously stated, particularly for sharks, tuna and other Highly Migratory Species. The 36 managed species that may occur seasonally or year-round in the Project Area are listed in Table 3-1 of Appendix C. The small scale and temporary nature of the array would have little to no impact on EFH, and no adverse effects on EFH are expected.
- **Habitat Areas of Particular Concern (HAPC)**: The Pioneer MAB Array's southernmost mooring (Figure 6) is located within a joint Snapper-grouper/Coral Reefs and Hardbottom/Dolphin and Wahoo HAPC designated by the SAFMC. The small scale and temporary nature of the array would have little to no impact on HAPC. The Pioneer MAB Array survey also did not find any indication of corals (Appendix F).

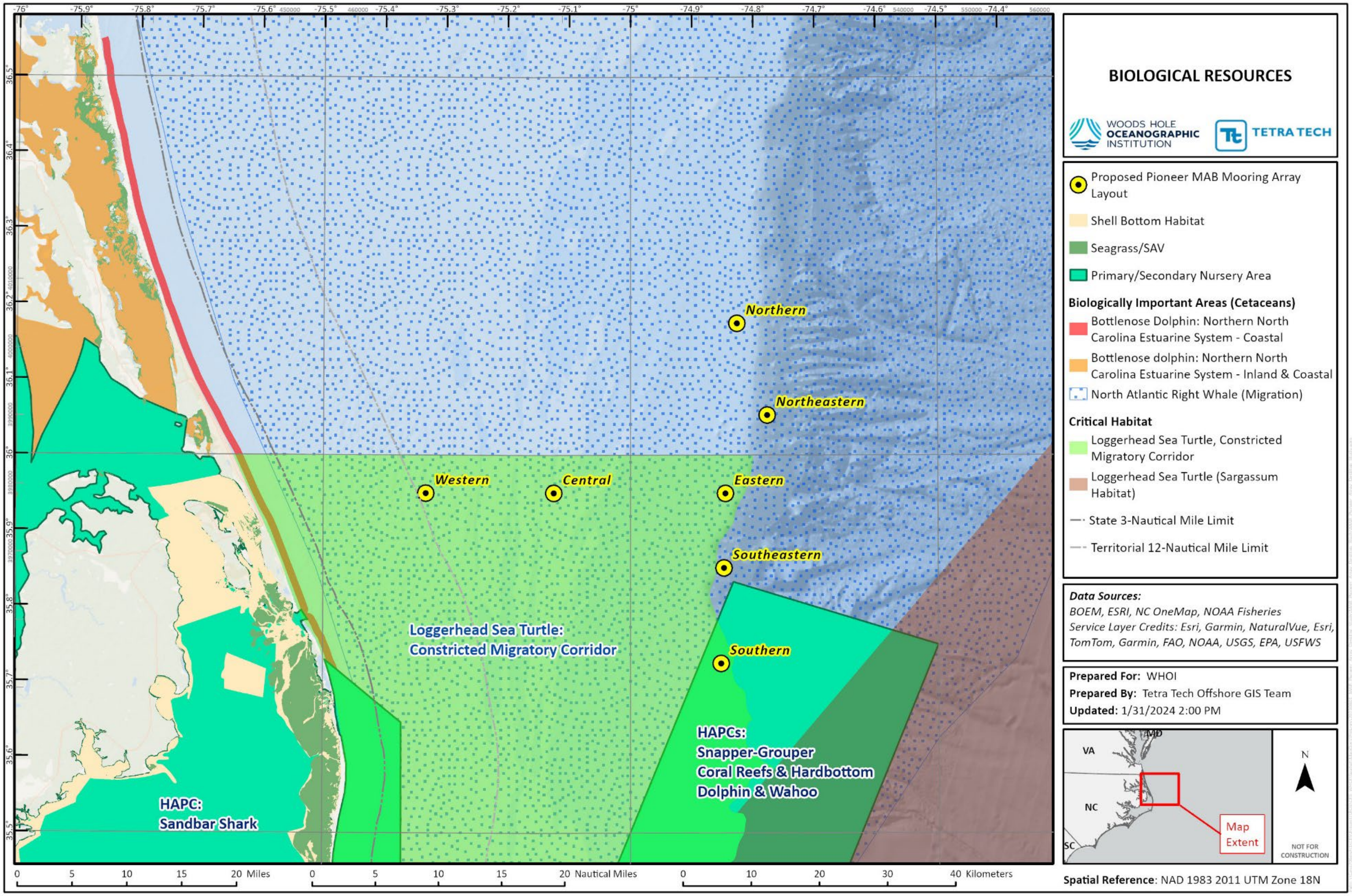

Figure 6. Biological Resources

In summary, the proposed activities, including Pioneer MAB Array location, installation, and O&M, are not anticipated to have significant effects on marine species, and no adverse effects are anticipated on ESA-listed species or designated loggerhead sea turtle critical habitat. Although the proposed activities may affect EFH and HAPC, no adverse effects on EFH or HAPC are expected. The NSF consulted with NMFS, pursuant to ESA Section 7 and the Magnuson-Stevens Act Fishery Conservation and Management Act, for EFH; NMFS concurred with NSF's determinations (see Section 4).

3.1.2.6 Socioeconomics

Review of resources within and around the Project Area indicated that recreational boating and fishing, charter fishing, shellfishing, sailboat races, sightseeing, bird and wildlife viewing (including whale watching), surfing, swimming, watersports, visiting beaches, and other activities are common to this part of coastal North Carolina. Due to the distance from shore, most of these activities would not occur near or within the proposed Pioneer MAB Array site; the activities that may be impacted or overlap with the Pioneer MAB Array site are discussed further below.

3.1.2.6.1 Fisheries

Detailed information regarding fisheries resources, including information on commercial and recreational fisheries, are included in Sections 3.1.1 and 3.3.6 of Appendix C. Additionally, the NSF recently prepared a Final EA titled, *Final Environmental Assessment/Analysis of Marine Geophysical Surveys by R/V Marcus G. Langseth off North Carolina, Northwest Atlantic Ocean* (NC Survey Final EA; NSF 2023) for a project that occurred slightly south of the proposed Pioneer MAB Array Project Area; the NC Survey Final EA included information on fisheries (Sections 3.7 and 4.1.6.5) and is incorporated by reference herein as if fully set forth.

In North Carolina waters, commercial fishery catches are predominantly various shellfish and finfish. Typical commercial fishing vessels in the North Carolina area include trawlers, gill netters, lobster/crab boats, dredgers, longliners, and purse seiners. In 2021, marine recreational fishers in the waters of North Carolina caught ~22 million fish for harvest or bait, and over 60 million fish in catch and release programs (NSF 2023). These catches were taken by over more than 17.9 million trips. Most of the trips (97 percent) occurred within 5.6 km (3.0 nm) from shore (NSF 2023).

As part of community outreach for the Pioneer Array relocation, OOI made presentations to the scientific community and to the general public, describing the Pioneer MAB Array plans and discussing potential space-use conflicts. It was noted that fishing activities would not be precluded in the Pioneer MAB Array area, although a safe distance from each Mooring Site (nominally outside of the 2 km by 2 km (1 nm by 1 nm) region at each mooring) would need to be maintained. Representatives of the fishing community attended some of these meetings, and follow-on conversations were conducted with representatives of the commercial longline fishing industry. It was noted during these discussions that the furthest offshore moorings (Northeastern and Southeastern, see Figure 6) may limit the ability of fishers to deploy free-drifting gear due to the possibility of entanglement. Based on 9 years of experience with the Pioneer NES Array, in the presence of similar types of fisheries, it is anticipated that entanglement would be rare and incidental (e.g., a portion of a longline set fouled in a mooring riser) and that fishers would continue to be able to operate in the area. Additionally, to further reduce the potential for space-use conflict, as noted previously and in Table 4, all mooring locations would be declared to the U.S. Coast Guard (USCG) and U.S. Army Corps of Engineers (USACE), locations would be published on NOAA charts, Notices to Mariners (NOTMAR), and Local Notices to Mariners (LNM), which would be created and regularly updated throughout the lifetime of the project. Beyond these measures, OOI would continue to conduct outreach and coordinate with commercial fishery organizations to minimize potential impacts to fishing activities.

Although there may be overlap with some fisheries industries, given past experience, the relatively small footprint of the Pioneer MAB Array, and the fact that fisheries would not be precluded from the area, any impacts would not be anticipated to be significant. Feedback on the Draft SSSEA during the NEPA public comment period was received from an individual longline fisher (see Appendix G). Comments included concern for the original 600-m water depth location of the Northeastern Coastal Profiler Mooring. The primary issue was the potential for the mooring to impede longline fishing activities. The offshore moorings are needed to maintain a cohesive array and to accomplish the described science mission. Placement between the 300-m and 600-m contour is required to ensure ocean processes are measured beyond the shelf break. In response to the concerns raised, the originally planned 600-m locations (Northeastern and Southeastern moorings) would be moved westward to the 300-m contour. This new mooring position would reduce the likelihood of impacts to longline fishing activity .

3.1.2.6.2 Tourism, Recreation, Vessel Traffic, Other

Based on boat size and tour duration, there are several dolphin or other wildlife watching tour vessels that operate in the general region but would not be expected to venture far offshore. The NC Survey Final EA (NSF 2023) included information on whale watching (Section 4.1.6.6) and is incorporated by reference herein as if fully set forth. Once installed, the Pioneer MAB array would not be anticipated to have any impacts on wildlife watching industry; even during installation and maintenance, the impacts would be negligible involving at most, very brief, temporary displacement from the site and minor visual impacts (e.g., observation of the installation vessel).

Wreck SCUBA diving is a popular recreational activity in the waters off North Carolina and typically occurs at depths less than 100 m (NSF 2023); due to avoidance of wrecks, impacts from the Proposed Action would not be anticipated on SCUBA activities.

Vessel traffic, as noted in the NC Survey Final EA, occurs throughout the region. The additional vessel traffic associated with the installation and O&M of the Pioneer MAB Array would not be anticipated to conflict with other vessel traffic or significantly increase activity above current levels.

While other human activities could occur in the area, in addition to those noted above, it would not be anticipated that the Pioneer MAB Array would impact these activities, as they would not be prohibited from occurring within the proposed array area. Although a small buffer would be incorporated around array moorings, these would be noted on navigation charts and the array could be easily avoided. Further, the Pioneer MAB Array would be short term and temporary. For these reasons, while there may be minimal overlap with tourism, recreation, and vessel traffic, no significant impacts are anticipated.

3.1.2.6.3 Marine Infrastructure

There are no existing or publicly planned cables that would run near the planned mooring locations. Therefore, no impacts are anticipated on marine infrastructure.

3.1.2.6.4 Sand Resource Areas and Dredged Material Disposal Sites

The BOEM Marine Minerals Program identifies Atlantic OCS sediment aliquots with sand resource areas based on reconnaissance- and/or design-level OCS studies, categorizing them as Proven, Potential, Unverified, or Unusable. Access to and identification of potential OCS sand resources is crucial for the long-term management of coastal restoration, beach nourishment, and habitat reconstruction to mitigate future coastal erosion, land loss, flooding, and storm damage along the U.S. Atlantic Ocean. Therefore, seabed disturbance within these resource areas should be avoided. These areas are typically within territorial sea (12 nm from land), nearshore of the proposed mooring locations. The Western mooring, being just seaward of the 12-nm territorial boundary, is close, but does not overlap with the nearest sand resource area.

Dredged material disposal sites are selected and permitted sites for dredged material to be placed after excavation. Just as sand resource areas are necessary for coastal restoration, disposal areas are vital to maintain safe navigable waterways. Seabed disturbance within these permitted sites should be avoided, but there are no disposal sites near the proposed mooring locations.

For the reasons noted above, no impacts are anticipated on Sand Resource Areas and Dredged Material Disposal Sites from the Proposed Action.

3.2 Cumulative Impacts and Other Projects within the Project Area

Cumulative effects refer to the impacts that result from a combination of past, existing, and reasonably foreseeable projects and human activities. Cumulative effects can result from multiple causes, multiple effects, effects of activities in more than one locale, and recurring events.

A desktop study was undertaken by Tetra Tech in support of Pioneer MAB planning to review other activities that could occur in the Project Area (Appendix C). Additionally, the NC Survey Final EA Section 4.1.6 included information on cumulative effects of past, present, and reasonably foreseeable projects that is also relevant for the Pioneer MAB Array Project and is, therefore, incorporated by reference as if fully set forth herein. The NC Survey Final EA and the desktop study undertaken by Tetra Tech found the following activities could occur in the Project Area (see also Figure 5 and Figure 6):

- Research;
- Offshore energy development;
- Sand borrow activities;
- Vessel traffic;
- Military activities;
- Fisheries; and
- Tourism/whale watching.

Additionally, to better understand stakeholder interests and activities undertaken in the Project Area, OOI conducted several outreach activities to academic institutions, federal agencies and regulators, and ocean users in the region which are also noted below and in Appendix G.

As noted in the NC Survey Final EA and the desktop study (Appendix C), research has occurred and is anticipated to continue to occur off the coast of North Carolina, however no specific details are known at this time. Other research activities in the Pioneer MAB Array Area can be accommodated and appropriate coordination would avoid space-use conflict.

Offshore wind lease areas off the southern coast of Virginia and the northern coast of North Carolina, near the proposed mooring locations, can be seen in Figure 5. Lease Area OCS-A 0497 is the Dominion-leased Coastal Virginia Offshore Wind (CVOW) Pilot Project, Lease Area OCS-

A 0483 is the Dominion-leased CVOW Commercial Project, Lease Area OCS-A 0559 is the Avangrid-leased Kitty Hawk North Project, and Lease Area OCS-A 0508 is the Avangrid-leased Kitty Hawk South Project. The CVOW Pilot and Commercial Project have existing and planned cable routes north of the Project Area. The Kitty Hawk North Project is currently planning to route its export cable from the lease area to the southern Virginia coast. The Kitty Hawk South Project has a potential export cable route option running south through the Pioneer MAB Project Area. However, there is only a moderate chance that the export cable would be routed south through the Project Area, and, if it is routed south, it would not be constructed within the next 10 years. In the event the Pioneer MAB Array is still in place by the time a potential export cable would run through the Project Area, it would be easy to avoid the Pioneer MAB Array mooring locations due to the distance between moorings along the continental shelf. There were additional draft wind energy areas alongside the Kitty Hawk North and South lease areas and another east of the OCS, but as of July 2023, those areas were not progressed to the final wind energy area stage (BOEM 2023). BOEM identified the deep-water wind energy areas, off the OCS, may be possible lease areas after more studies. However, construction on any of these deepwater wind energy areas would occur beyond the ~5-year Pioneer MAB Array Project operation period. BOEM and the U.S. Department of Energy have contacted the NSF and OOI to collaborate and coordinate activities in the Pioneer MAB Array Project Area. OOI confirmed the array location and that mobile asset operations do not impact or overlap with planned wind energy construction sites.

Vessel traffic in the Project Area is low and the locations of the moorings would be recorded on navigational charts. The Western mooring is just east of the St. Lucie to Chesapeake Bay Nearshore Fairway and the Central mooring would be just west of the St. Lucie to Chesapeake Bay Offshore Fairway (Figure 5).

Military operations in the vicinity of the Project Area include Virginia Capes and Cherry Point OPAREAS (Figure 5). The U.S. Navy was contacted regarding the location of moored infrastructure to ensure the array would not conflict with activities within the Virginia Capes Complex. The USCG would be contacted prior to the deployment of moorings as part of the Private Aids to Navigation (PATON) approval process and the array would be included on nautical charts and easily visible and avoidable. As all moorings locations and associated components of the Pioneer Array would be published in NOAA charts, NOTMARs, and LNMs, it is anticipated that the USCG and U.S. Department of Defense would provide further detail regarding ongoing and upcoming military use in the Project Area should there be an unanticipated shift in level or location of activities.

Several institutions, state and federal agencies, tribal communities, and other ocean users from across the U.S. were invited to the Pioneer relocation workshops sponsored by the NSF and organized by the OOIFB (Appendix G). These potential stakeholders included NOAA, BOEM, National Aeronautics and Space Administration, USACE, USCG, U.S. Navy, offshore energy developers, and academic institutions.

Although these and the other noted human activities (e.g., whale watching, vessel traffic, etc.) could occur within the Project Area, it is anticipated that the Pioneer MAB Array would not interfere with these other activities due to the small footprint, localized/temporary nature (approximately 5 years) of the project, and avoidance measures put in place. This anticipation of no interference is guided by past experience with the Pioneer NES Array. More details are included in Appendix C. Overall, the combination of the proposed activities with other activities occurring in the region would be expected to produce only a negligible increase in overall disturbance effects on the marine environment; therefore, no significant impacts are anticipated.

3.3 No Action Alternative

An alternative to conducting the proposed activity is the "No Action" alternative, that is, do not deploy the Pioneer Array to MAB and modify the array. If the Pioneer Array was not modified and deployed to MAB, the "No Action" alternative would result in no disturbance to the marine environment attributable to the proposed activity; however, valuable data about the marine environment, including climate variability, would be lost. Oceanographic data of significant scientific value that would provide knowledge for our oceans in general and the southern MAB in particular would not be collected. This would limit the ability of the greater scientific community to gain new insights on how oceanic processes operate and change under different conditions in both the short and long term. The "No Action" alternative would not meet the purpose and need for the proposed activity.

4 OTHER CONSIDERATIONS REQUIRED BY NEPA

The public outreach process for Pioneer MAB Array started in 2020 with presentations at several locations to obtain input (Appendix G). Participants from the Phase I Innovations Lab were invited to apply and many who had been interested in seeing the Pioneer Array move from the NES to the MAB, remained engaged. Additionally, applications from scientists, educators, engineers, and from government agencies, philanthropic, fishing community and other stakeholders were encouraged. Furthermore, as also noted in Section 4.1, as part of planning efforts, OOI coordinated with potential stakeholders to avoid potential space-use conflicts, including the U.S. Navy, and several outreach activities were undertaken (Appendix G).

On September 29, 2023, the Draft SSSEA was posted on the NSF website (http://www.nsf.gov/geo/oce/envcomp/index.jsp) for a 30-day public comment period, and notices were sent to tribes, government agencies, and potential interested parties (Appendix G). Six comments were received (see Appendix G). Of these, only one comment was actionable, which resulted in the movement of the original 600-m contour Northeastern and Southeastern Coastal Profiler Moorings to the 300-m contour area; see Section 3.1.2.6.1 Fisheries for further information.

As noted in the PEA, if the proposed site-specific activities associated with the proposed installation and operation of the OOI (i.e., the Proposed Action described in this SSSEA) were to potentially impact additional or larger areas or include activities not previously proposed in the PEA and SER, then consultations with federal regulatory agencies, as applicable and appropriate, would occur. Therefore, the NSF took into consideration compliance with other relevant statutes and processes, including those described below.

4.1 Marine Mammal Protection Act of 1972 (16 U.S.C. 1631 et seq.)

The NSF considered the potential impacts of the Proposed Action on marine mammals pursuant to the MMPA. Given the Proposed Action, the NSF determined that impacts on marine mammals would not be anticipated. Further, based on discussions and correspondence with NOAA in March 2022 during the generation of the regulatory study (Appendix B), it was determined that the Proposed Action, including anchoring of the Pioneer MAB Array, would not require an Incidental Harassment Authorization or Letter of Authorization and no further action was required pursuant to the MMPA.

4.2 Endangered Species Act of 1973 (16 U.S.C. Ch. 35 §1531 et seq.)

The NSF considered the potential impacts of the Proposed Action on ESA-listed species and their designated critical habitat as pursuant to the ESA. Based on and consistent with past OOI NEPA documents, a NLAA determination for ESA-listed marine mammals, sea turtles, and critical habitat, was determined. However, based on Pioneer NES Array experience, potential impacts, and other experience with similar research technology, any impacts to marine mammals or sea turtles from the Proposed Action would be anticipated to be very minor and temporary, and thus a determination of no effects may be more appropriate. However, for consistency with past documentation and to ensure compliance with ESA, an NLAA determination for marine mammals and sea turtles was made. Given the proposed activities, the NSF determined the Proposed Action may affect but is not likely to adversely affect ESA-listed plant species in the Project Area. Therefore, on November 17, 2023, NSF initiated informal consultation with NMFS pursuant to Section 7 the ESA. NMFS reviewed the consultation request submitted by NSF and recommended including blue whale (*Balaenoptera musculus*) as a species likely to occur in the Project Area. On December 7, 2023, NMFS concurred with NSF's determination that the proposed action is not likely to adversely affect the ESA-listed species and designated critical habitat under NMFS jurisdiction (see Appendix G).

4.3 Coastal Zone Management Act of 1972 (16 U.S.C. §§1451 et seq.)

In June 2022, after reviewing information about the Proposed Action provided by OOI, the North Carolina Division of Coastal Management (DCM), Department of Environmental Quality confirmed completion of a Federal Consistency Determination (DCM2022041). Further, DCM concurred that the proposed Pioneer MAB Array activity was consistent with North Carolina's federally approved coastal management program. Although the state confirmed consistency, as part of their review, the DCM noted concerns about the two moorings furthest offshore potentially impacting the Highly Migratory Pelagic long lining fishery. OOI took this information into consideration, and as discussed in Section 3.1.2.6.

4.4 Magnuson-Stevens Fishery Conservation and Management Act–Essential Fish Habitat (Public Law 94-265; 16 U.S.C. Ch. 38 §1801 et seq.)

Although the proposed activities may affect EFH, no adverse effects on EFH are expected. The Pioneer MAB Array's southernmost mooring is located within a joint Snapper-grouper/Coral Reefs and Hardbottom/Dolphin and Wahoo HAPC designated by the SAFMC. Given the small scale and temporary nature of the array the associated proposed activities are not likely to adversely affect areas designated as EFH or HAPC. On November 17, 2023, the NSF intiated consultation with NMFS for EFH. On January 3, 2024, NMFS concurred with NSF's determination, offering no EFH conservation recommendations (Appendix G).

4.5 National Historic Preservation Act

Desktop and marine archeology studies were used to locate the mooring sites and avoid all documented shipwrecks and cultural resources. The site survey performed by OOI (Appendix F) supported the planning documentation and no evidence of shipwrecks or cultural resources were located. As part of the NEPA public comment period, the North Carolina State Historic Preservation Office reviewed the project and provided written confirmation that they are aware of no historic resources that would be affected by the project pursuant to Section 106 of the National Historic Preservation Act (Appendix G).

4.6 Tribal Engagement

Planning studies did not identify tribal concerns; the proposed activities would not impair reserved tribal rights, including, but not limited to, reserved water rights and treaty fishing and hunting rights. No tribal cultural or historic resources were identified at the proposed array mooring locations in the Pioneer MAB Array marine archaeology study (Appendix D).

4.7 Permitting and Licensing Activities

OOI, as operator of the array, is responsible for obtaining all licenses and permits for the proposed Project:

- In March 2022, as part of permitting / licensing processes, the USACE confirmed the relocation of the Pioneer Array would require the use of NWP#5 (Scientific Measurement Devices), without the need for application or submittal of a Preconstruction Notification due to the low likelihood of impacts to resources (Appendix B).
- In August 2022, although not part of an official permitting / licensing process, OOI notified the U.S. Navy of the proposed relocation of the Pioneer Array to the MAB, providing infrastructure locations and an overview of O&M activities. In February 2023, OOI received confirmation from the U.S. Navy that the planned array location did not conflict with any U.S. Navy infrastructure.
- In June 2023, OOI completed the self-certification memorandum in support of NWP#5 activities, confirming adherence to USACE guidelines. Pursuant to NWP#5, proposed activities can have no significant impacts on the environment, including takes of ESA-listed species, EFH, designated critical resource waters, tribal rights, cultural resources, and navigation. The USACE District Engineer considered the activities and determined they would avoid and minimize adverse effects, both temporary and permanent, to waters of the United States to the maximum extent practicable in the Project Area. Mitigation in all forms (avoiding, minimizing, rectifying, reducing, or compensating for resource losses) is required to the extent necessary to ensure that the individual and cumulative adverse environmental effects are no more than minimal.
- Prior to deployment of the new array, OOI would request PATONs from the USCG for each mooring location, have the array marked on navigational charts, perform Local Notices to Mariners, and update notifications to the U.S. Navy.

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Appendix A: Site Design: Pioneer Mid-Atlantic Bight Array

CGSN Site Design:
Pioneer Mid-Atlantic Bight Array

Control Number: 3210-00008
Version: 1-00
Date: 2023-02-06
Authors: Derek Buffitt, Al Plueddemann, Sheri N. White

Coastal and Global Scale Nodes
Ocean Observatories Initiative
Woods Hole Oceanographic Institution

Template 3101-00100 Version 1-01

Revision History

Version	Description	ECR No.	Release Date
0-01	Initial Draft		
0-02	Formatting updates and minor edits		
0-03	Completed draft		
0-04	Updated mooring locations, Draft for PDR		
0-05	Updated to address PDR comments		
1-00	Initial Release	ECR-947	2023-02-06

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1.0 Purpose

The purpose of this report is to provide an overview of the planning process and array configuration decisions for the new Pioneer Mid-Atlantic Bight (MAB) Array. This overview will include site selection, array layout, mooring types, instruments, and mobile assets.

2.0 Reference Documents

Table 1: Reference Documents

Document ID / Source	Document Title
3210-00001	Pioneer MAB Regulatory Study
3210-00002	Pioneer MAB Desktop Study
3210-00003	Pioneer MAB Maritime Archeology Study
3210-00007	CGSN Site Characterization: Pioneer Mid-Atlantic Bight Array
3102-00026	Analysis of Pioneer MAB Coastal Surface Mooring
3102-00027	Analysis of Pioneer MAB Coastal Profiler Mooring

3.0 Definitions & Acronyms

CGSN	Coastal & Global Scale Nodes
EM	Electro-Mechanical
HIB	Hose Interface Buoyancy
MFN	Multi-Function Node
MAB	Mid-Atlantic Bight
NC DEQ	North Carolina Department Environmental Quality
NDBC	National Data Buoy Center
NES	New England Shelf
NSF	National Science Foundation
NSIF	Near Surface Instrument Frame
OOI	Ocean Observatories Initiative
OOIFB	Ocean Observatories Initiative Facilities Board
PM	Profiler Mooring
PMO	Program Management Office
SM	Surface Mooring
SW	Shallow Water Mooring
USACE	United States Army Corps of Engineers
VACAPES OPAREA	Virginia Capes Operating Area
WHOI	Woods Hole Oceanographic Institution

4.0 Site Summary

The Pioneer Array is proposed to be relocated in the spring of 2024 to a location off the coast of Nags Head in North Carolina. The preliminary plan is for the moored array to be constituted in a sideways "T" shape, with seven mooring sites between about 13 nautical miles (nm) and 45 nm offshore, outside of state waters (Figure 1). The Pioneer MAB Array will consist of:

- Three Surface Moorings located in 30 m and 100 m water depths
- Five Profiler Moorings located in 100 m and 600 m water depths
- Two Shallow-Water Moorings located in 30 m water depths

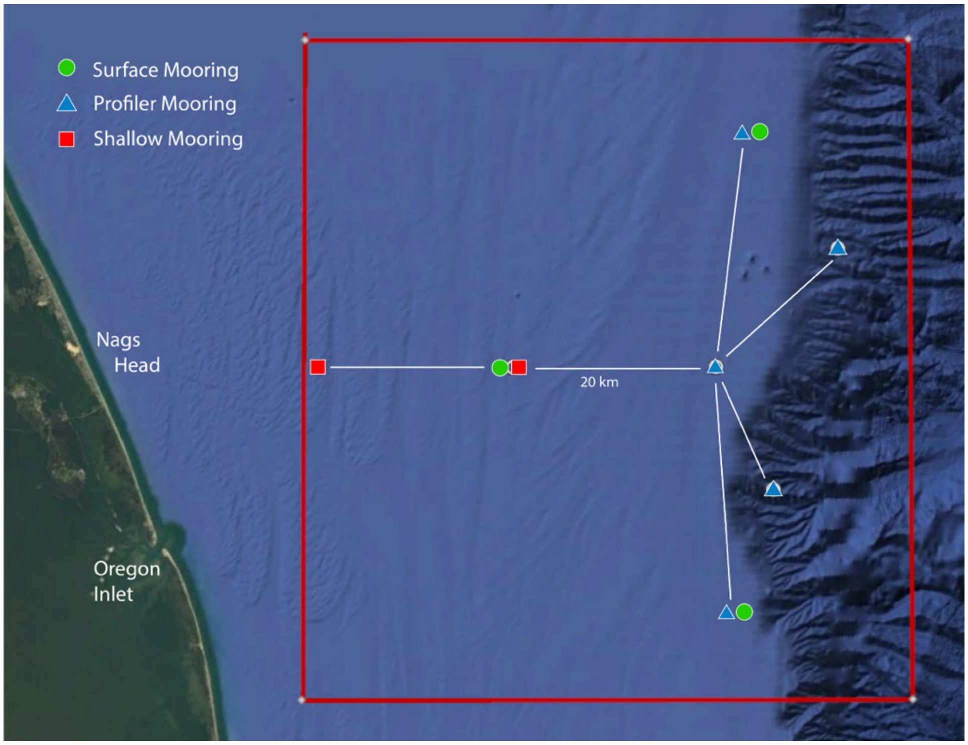

Figure 1: Pioneer MAB Proposed Array Layout

5.0 Timeline

- December 2020: The National Science Foundation (NSF) & Ocean Observatories Initiative Facilities Board (OOIFB) announce a participatory process for the potential selection of a new Pioneer Array location and request applicants for future Innovations Labs.
- January 2021: **Micro Lab #1** – Introduce Innovations Lab process, provide overview of existing Pioneer Array infrastructure and environment.
- March 2021: **Innovations Lab #1** – Science community explores possible locations for the Pioneer Array based on scientific questions that require an ocean observatory to advance knowledge.
- April 2021: NSF decision to re-locate Pioneer Array to Mid-Atlantic Bight.
- May 2021: **Micro Lab #2** – Introduce objectives and goals for Innovations Lab #2, provide technical considerations for relocation of existing Pioneer Array.
- June 2021: **Innovations Lab #2** – Science community discusses how the existing Pioneer Array sensors and platforms can be optimized to achieve science and education goals at the new site. Community also discusses what enhancements to the Pioneer infrastructure could be made.
- July 2021: CGSN kicks off relocation planning and engineering.
- April 2024: Planned first Pioneer MAB deployment.

6.0 Roles & Responsibilities

- **National Science Foundation (NSF):** Funds the operations and management of the Ocean Observatories Initiative. NSF also funded the Pioneer Array relocation process by supporting two Innovations Labs; attended the Innovations Labs, answered community questions on the decision process and selected NSF Innovations Lab 1 and 2 organizers and panelists.
- **Ocean Observatories Initiative Facilities Board (OOIFB):** Proposed and managed the Pioneer Array relocation decision process, including two Micro Labs and a two-phase (virtual) community workshop series called Innovations Labs.
- **NSF Panelists:** Interdisciplinary Innovations Lab participants selected by NSF. Served as members of the organizing committee, participated in selecting applications for Innovations Labs, attended all labs and provided subject matter expertise, provided recommendation for site selection following Innovations Lab #1, and provided feedback on community discussions in Innovations Lab #2.
- **OOI Program Management Office (PMO) and Coastal and Global Scale Nodes (CGSN):** Provided technical expertise on the existing Pioneer New England Sheff (NES) Array, answered question in the Innovations Labs concerning system capabilities, potential risks, and logistical considerations. Following the relocation decision, refining the Innovations Labs' recommendations to be operable and maintainable within existing budget constraints.

7.0 Community Input

Community input is a significant component of the Pioneer Array relocation process. Multiple approaches to receiving community input are exercised during an ongoing, multi-stage process, as summarized below. Every stage seeks interdisciplinary participation to the science community and other stakeholders to ensure the new array is suited to meet science goals. The first and second Micro Labs each drew over 80 participants to the virtual discussion. The cornerstones of the process were two Innovations Labs, supported by NSF and managed by the OOIFB. Each lab had over 30 selected participants from diverse areas of the ocean science community. Participants were selected with the goal of achieving a broad range of disciplines and professional expertise, career stage, gender, cultural background, and life experience. The Innovations Labs resulted in a report from OOIFB to NSF, and NSF subsequently provided relevant information to OOI about regional science themes and array design recommendations for relocation of the Pioneer Array to the MAB.

1. **Micro Labs:** The OOIFB used these meetings to introduce the Innovations lab process to the science community, as well as provide a timeline for activities. The existing Pioneer NES Array infrastructure was also presented. Initial thoughts on science themes and questions were also requested from the science community.
2. **Innovations Labs:** Applications for participation were requested by the NSF. The Innovations Labs were supported by NSF and managed by the OOIFB. CGSN provided information on existing infrastructure, instruments, and mobile assets to support community discussions. In Innovations Lab #1, ad-hoc, interdisciplinary teams from multiple institutions pitched potential locations for the Pioneer Array. In Innovations Lab #2, following selection of the MAB location by NSF, participants were placed in interdisciplinary teams to discuss science themes, array layout, instrument allocation, and mobile asset usage.
3. **Focus Group:** Following the kickoff of relocation activities by CGSN, an interdisciplinary Focus Group was created to review and provide feedback on engineering and science questions posed by the CGSN operations and management team. The scope of Focus

Group feedback included consideration of science drivers, array design, instrumentation, and sampling plans. The Group and/or individuals were also asked to answer questions or provide input on specific issues in their area of expertise at other times during the process. In addition to providing breadth and depth of cross-disciplinary expertise from active researchers, the membership list sought to ensure a mix of early career and senior participants, gender equity, representation of regional institutions, inclusion of OOIFB members, and inclusion of Innovations Lab participants.

a. Kendra Daly, University of South Florida, Professor, Biological Oceanography; zooplankton ecology and marine food webs; long history with OOI; OOIFB Chair; Innovations Lab organizer.

b. John Wilkin, Rutgers University, Professor, Marine and Coastal Sciences; physics/modeling; familiar with OOI; member of original NES Pioneer focus group; Innovations Lab participant; OOIFB member.

c. Harvey Seim, University of North Carolina, Professor, Marine and Environmental Sciences; physics/observations; familiar with OOI; PI in the PEACH project; Innovations Lab panelist.

d. Sophie Clayton, Old Dominion University, Asst Professor, Ocean and Earth Sciences; physics/biogeochemistry; familiar with OOI; Co-Chair, OOI Biogeochemical (BGC) sensor working group; Innovations Lab participant.

e. Hilary Palevsky, Boston College, Asst Professor, Earth and Environmental Sciences; biogeochemistry, carbon cycle and climate; familiar with OOI; Co-Chair, OOI BGC sensor working group.

f. Tammi Richardson, Professor, University of South Carolina, Biological Sciences, biology and ecosystems, phytoplankton, Innovations Lab panelist.

g. Erin Meyer-Gutbrod, University of South Carolina, Asst Professor, Earth, Ocean and Environment, marine ecosystems, population dynamics, Innovations Lab participant.

h. Emily Eidam, Oregon State University, Asst Professor, Earth, Atmospheric and Ocean Sciences, sediment transport, plumes, Innovations Lab participant.

4. **Subject Matter Experts:** Where necessary, Subject Matter Experts (SMEs) were sought out to support the generation of specifications or requirements for the new array. As examples, SMEs were requested to provide feedback on:

- Appropriate data units, expected measurement levels, and potential sampling rates for new sensors,
- Mooring locations and spacing,
- Mobile asset tracklines and appropriate sensor measurements dependent on location of line.

5. **Ocean Modeling Input:** The relocation process also benefited from discussions with John Wilkin (Rutgers University) and Ruoying He (North Carolina State University). Their ocean modeling results were found to be relevant to the moored array design and mobile asset trackline issues being assessed by CGSN.

8.0 Site Selection

Innovations Lab #1 focused on the development of pitches from various teams on potential new locations for the Pioneer Array. There were 32 selected participants from multiple institutions as well as the NSF, NSF Panel, OOIFB, OOI PMO, and CGSN for a total of 47 participants. Eight (8) pitches were made during the Innovations Lab, see Table 2below.

Table 2: Innovations Lab #1 Participant Pitches

#	Pitch	Location	Collaborators
1	Canyon Influences on Shelf Biogeochemistry	Juan de Fuca Canyon	• University of Washington • Northwest Indian Fisheries Commission
2	A Gulf of Mexico Multidisciplinary Shelf-slope Observing Array	Gulf of Mexico	• OceanGeeks LLC • Florida Institute of Oceanography • University of Southern Mississippi • Texas A&M University • Louisiana Universities Marine Consortium • Georgia Tech University • University of South Florida
3	Southern Mid-Atlantic Bight	Cape Hatteras to Norfolk Canyon	• North Carolina State University • Old Dominion University • East Carolina University • Virginia Institute of Marine Science • Bureau of Ocean Energy Management • University of North Carolina
4	Gulf of Alaska Array	Gulf of Alaska	• University of Alaska, Fairbanks
5	A Taste of the Gulfstream: Relocating to the Charleston Gyre	South Atlantic Bight	• Old Dominion University • Virginia Institute of Marine Science • University of North Carolina • North Carolina State University
6	Ecosystem Responses to Shelfbreak and Canyon Exchange Processes in a Changing Ocean: Southern New England	New England Shelf	• Woods Hole Oceanographic Institution • Massachusetts Maritime Academy • Northeastern Regional Association of Coastal Ocean Observing Systems • Bristol Community College
7	Puerto Rico/Virgin Islands Passage Throughflow: A Tropical Overlay of Science and Broader Impacts	Puerto Rico & Virgin Islands	• OceanGeeks LLC • University of South Florida
8	Coastal Upwelling Experiments and Simulations	Central California	• Monterey Bay Crescent Ocean Research Consortium (consortium of 27 institutions and agencies)

Following the Innovations Lab #1, the NSF Panel provided a ranking of the various locations based on intellectual merit, science drivers, and ability to achieve goals in a 5-year deployment. NSF requested budget and technical feedback from CGSN to support the decision process. In April 2021, NSF announced that the Southern Mid-Atlantic Bight was selected as the new location. The location is now named Pioneer Mid-Atlantic Bight (MAB) Array.

9.0 Science Themes

During the Micro Labs and Innovations Labs #1 and #2, participants were asked to contribute to a “virtual wall” of science questions within several themes. Input to the science questions was organized for Innovations Lab #2 based on:

- Several broad themes derived from the overarching OOI Science Themes,
- Prior theme contributions from Innovations Lab #1, and
- Information on research interests provided by participants from the registration process.

For informational purposes, the six OOI Science Themes are:

- Climate variability, ocean food webs, and biogeochemical cycles
- Ocean-atmosphere exchange
- Coastal ocean dynamics and ecosystems
- Turbulent mixing and biophysical interactions
- Global and plate-scale geodynamics
- Fluid-rock interactions and the sub-seafloor biosphere

Not all contributions to the virtual wall were phrased as science questions, and the input could be more accurately described as a collection of topics relevant to coastal ocean science as seen through the filter of the OOI Science Themes and the Pioneer Array relocation process. Over 140 entries to the virtual wall were provided by Innovations Lab participants. A review of the Innovations Lab input revealed over 120 science topics plus approximately 20 topics describing relevant technology and instrumentation.

The full list of topics was presented at Innovations Lab #2, which included 34 selected participants. After presentation, review and discussion, the participants voted on the science topics. Topics with two or fewer votes were not considered to represent a consensus among the participants. This resulted in 23 “highly ranked” topics with three or more votes, including three “top-ranked” topics with six or seven votes. A review and consolidation of the “highly-ranked” topics revealed several similar or common elements:

- Mechanisms of cross-shelf exchange,
- Influence of the shelfbreak front and jet,
- Influence of the Gulf Stream,
- Sub-mesoscale dynamics, and
- The links between ocean dynamics and higher trophic levels.

Less common elements considered important due to their unique applicability to the region were:

- Freshwater plumes,
- Canyons, and
- Methane seeps.

Considering the original six OOI Science Themes, accommodating common elements of the highly ranked Innovations Lab science topics, and accounting for unique regional characteristics resulted in three overarching regional science themes for the Pioneer MAB Array:

- **Dynamics of shelf-slope exchange**, including Wind forcing, frontal instability, and Gulf Stream influences.
- **Biogeochemical cycling and transport**, including carbon, nutrients, and particulates, and considering the ecosystem response to cycling and transport.
- **Extreme events**, including major storms, hurricanes, and freshwater outflows

10.0 Array Layout

Following the science theme discussions, the Innovations Lab #2 participants were broken into groups by regional science theme. They were then tasked with generating a diagram depicting what areas of the MAB could best address the OOI Science Themes, and by extension the MAB regional science themes. Figure 2shows a composite regional map showing the areas of interest grouped by science theme as generated by all of the groups.

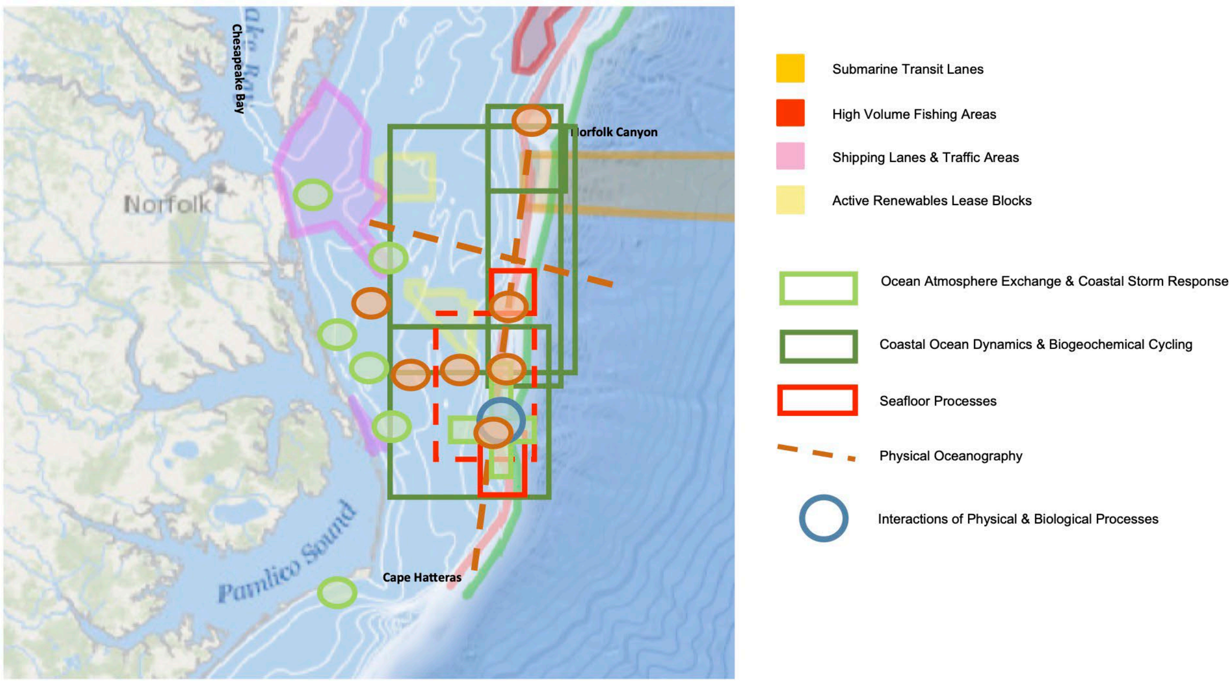

Figure 2: Overlapping Areas of Science Themes

The Innovations Lab Panelists then recommended an area of interest where all themes overlapped and where conflict with other seabed users could most easily be mitigated. This map was presented to the participants for discussion and to layout the mooring infrastructure (Figure 3).

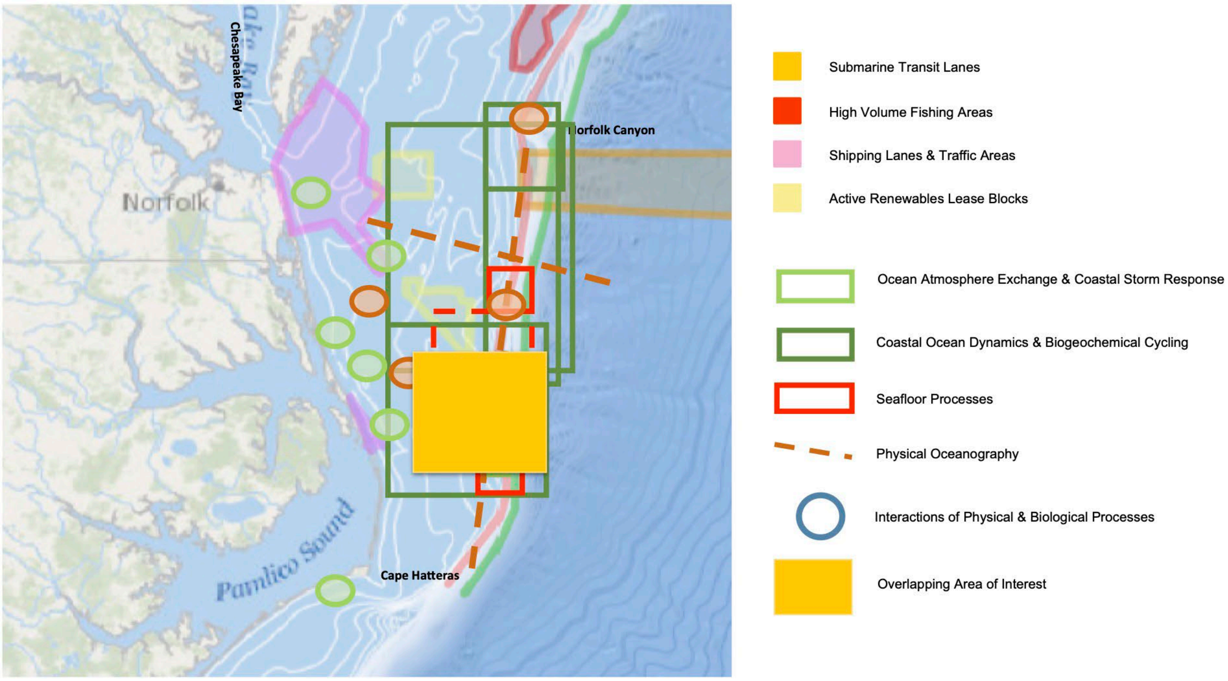

Figure 3: Scientific Overlapping Area of Interest

The participants were then placed into four (4) interdisciplinary teams. They were asked to layout the existing Pioneer mooring infrastructure (surface & profiler moorings) in an array they believed was best suited to answer the themes previously discussed. The participants were provided with the existing mooring designs, environmental operating limits, and instrument allocations. The teams were also asked if additional infrastructure was required, which they should add to their layouts.

The four teams generated the layouts shown in Figure 4 through Figure 7.

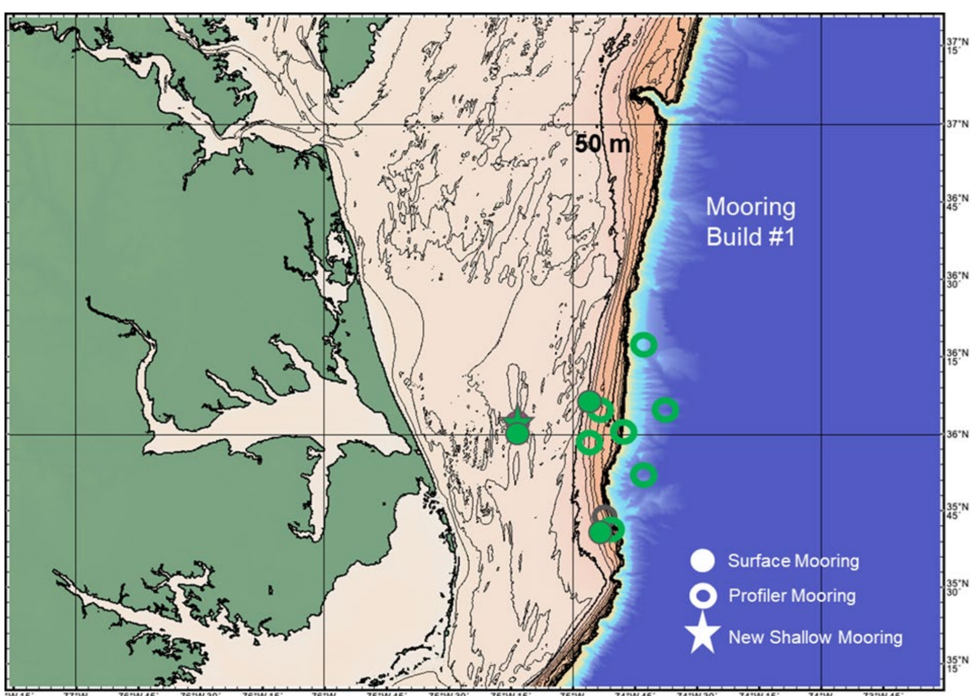

Figure 4: Innovations Lab Mooring Layout #1

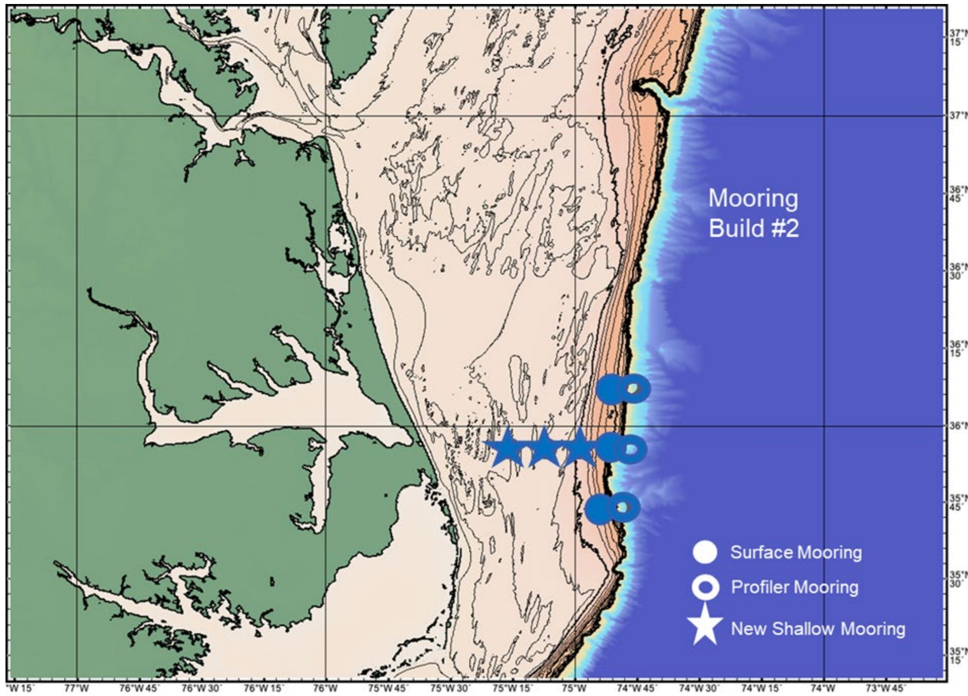

Figure 5: Innovations Lab Mooring Layout #2

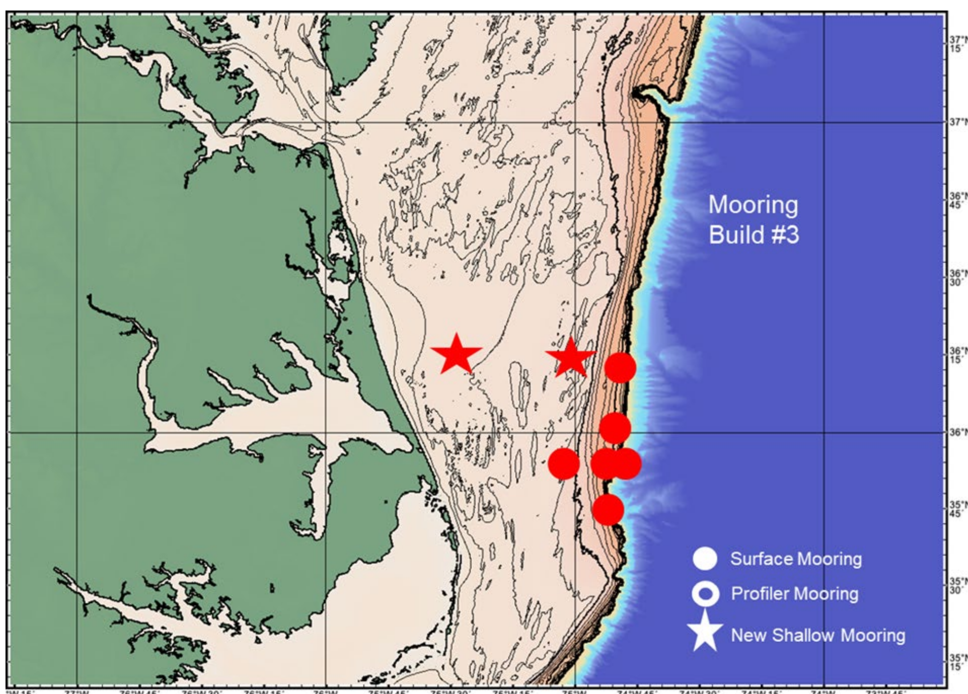

Figure 6: Innovations Lab Mooring Layout #3

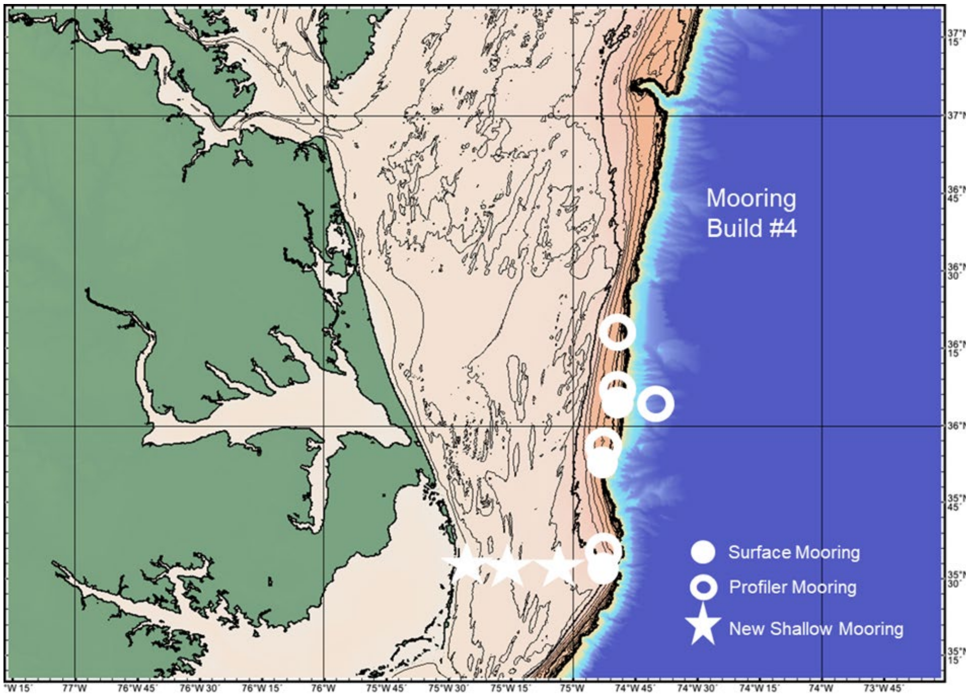

Figure 7: Innovations Lab Mooring Layout #4

Following review and discussion, the participants were asked to vote on the preferred array layout. The layout with the most support among the participants was “Mooring Build #2”. This layout included:

- 3 x surface moorings
- 3 x profiler moorings
- 3 x shallow moorings

The Innovations Lab Panelists then generated a consensus mooring layout based on the existing infrastructure. This mooring layout maintained a recommendation for shallow water moorings, although it was recognized that shallow water moorings would be in ~30 m water depth and that Pioneer does not currently include that specific infrastructure. Thus, implementation of shallow moorings was considered a recommendation to be evaluated by the operators. This layout was presented to the participants for discussion and comment (Figure 8). The Panelists then met with the NSF and agreed the consensus array design represented the layout to move forward with for planning and potential refinement based on CGSN assessment and engineering review:

- 3 x surface moorings
- 5 x profiler moorings
- 2 x shallow moorings

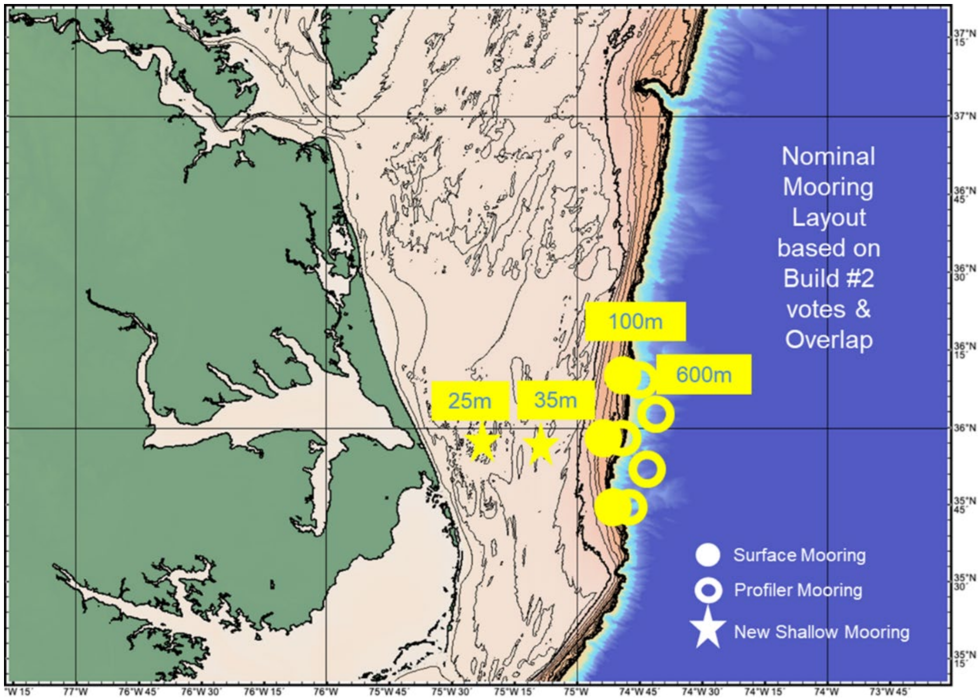

Figure 8: Innovations Lab Final Mooring Layout

Following kickoff of the planning and engineering phase in July 2021, CGSN reviewed several sources for potential conflicts with the proposed mooring locations. These included:

- Fishing Activity
- Military Operations & Training Areas
- Vessel Traffic & Traffic Schemes
- Offshore renewable energy lease areas
- Submarine Cables
- Wrecks & Obstructions
- Corals

The array was found to be:

- Outside of high revenue fishing areas (Figure 9);
- Inside a single military operating area (VACAPES OPAREA), outside of submarine transit areas, and outside of regulated air corridors (Figure 10);
- Outside of proposed fairways and traffic schemes – however, the shallow moorings were adjusted to maintain a minimum of 1km separation (Figure 11);
- Outside of proposed wind farm leases (Figure 12);
- Distant from known submarine cables (Figure 13);
- Distant from charted unexploded ordinance or wreck areas (Figure 14);
- Outside of charted coral habitats (Figure 15)

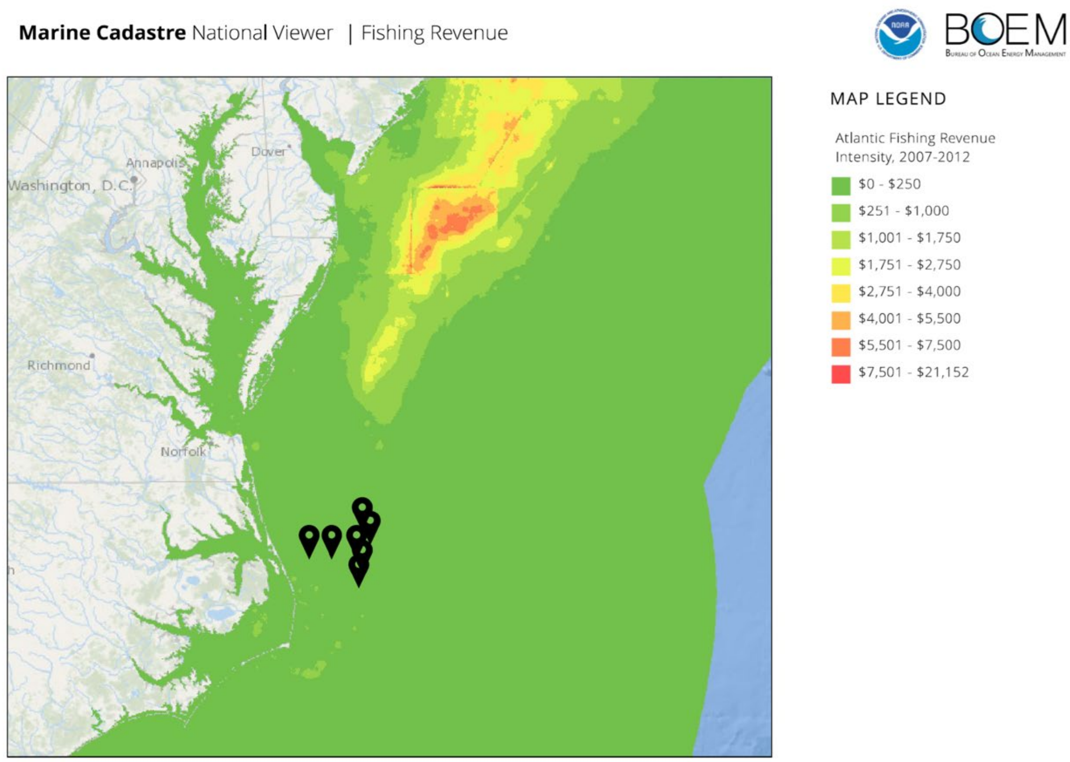

Figure 9: Fishing Revenue

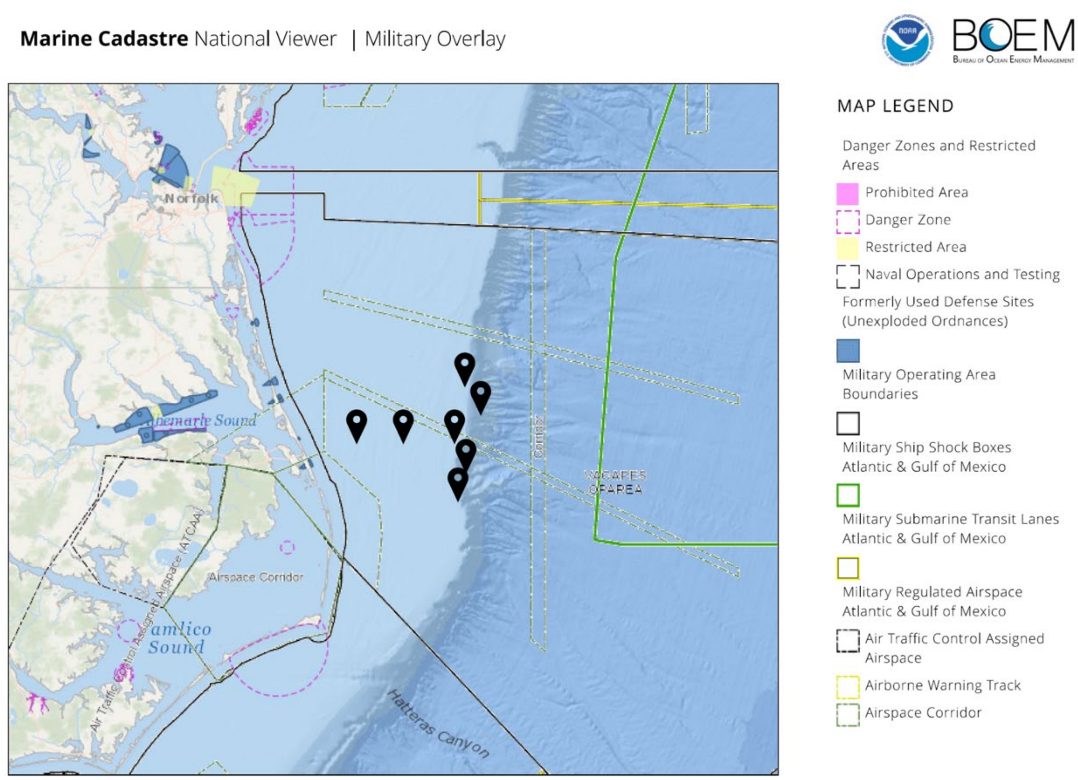

Figure 10: Military Areas

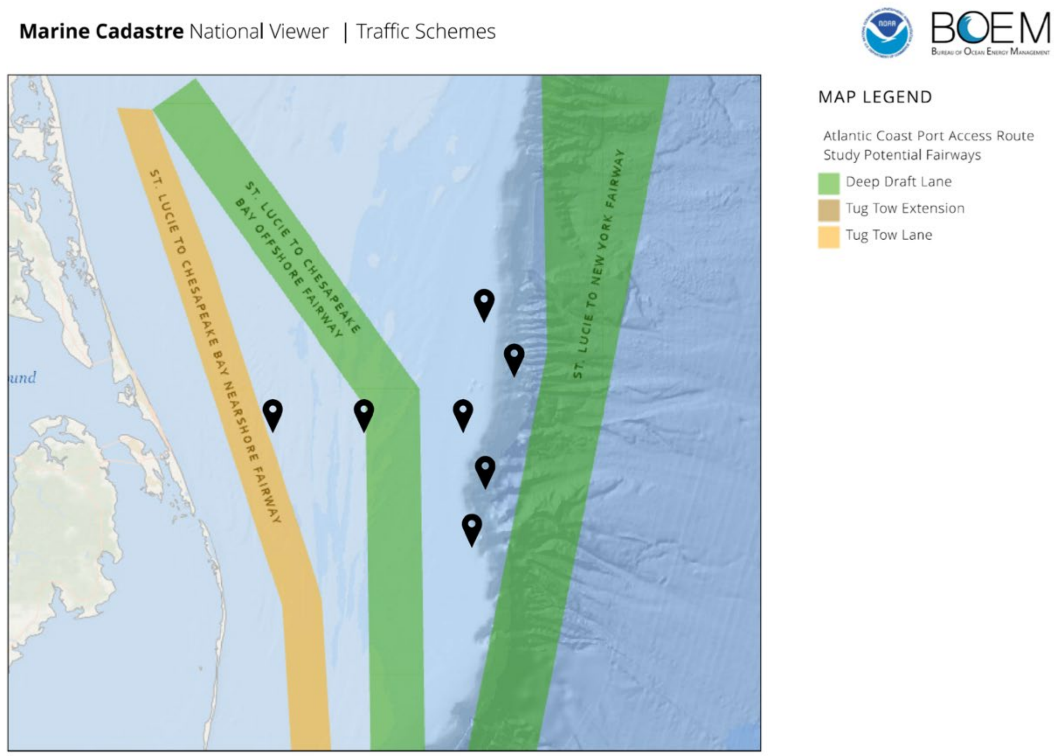

Figure 11: Proposed Traffic Schemes

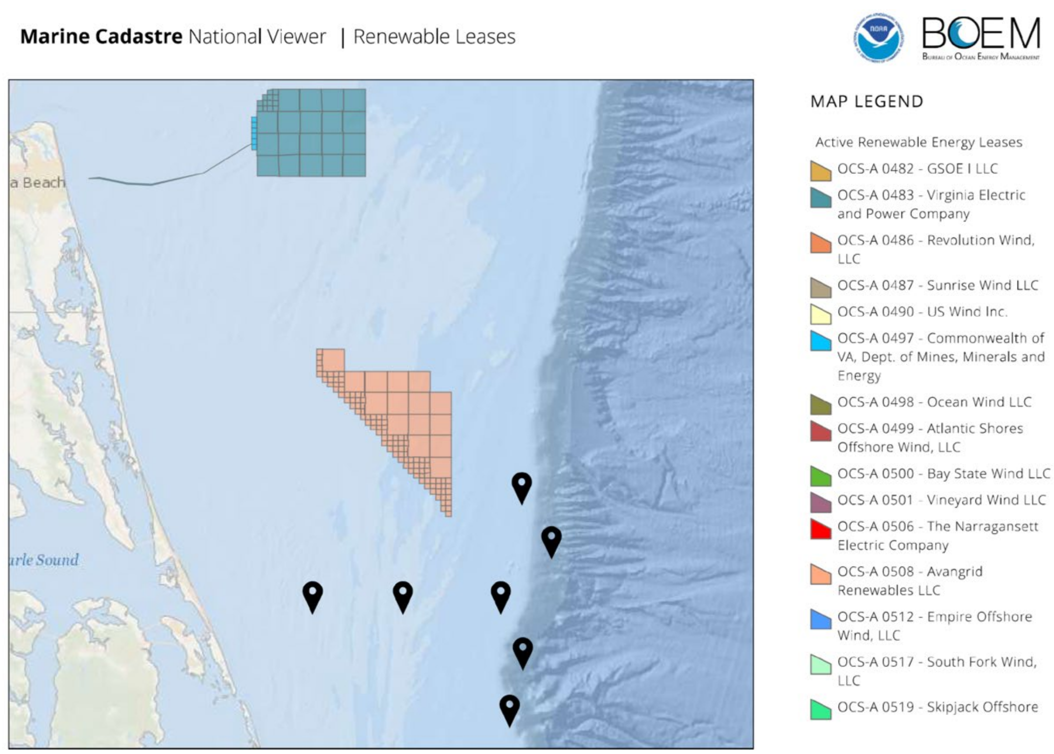

Figure 12: Planned Renewable Leases

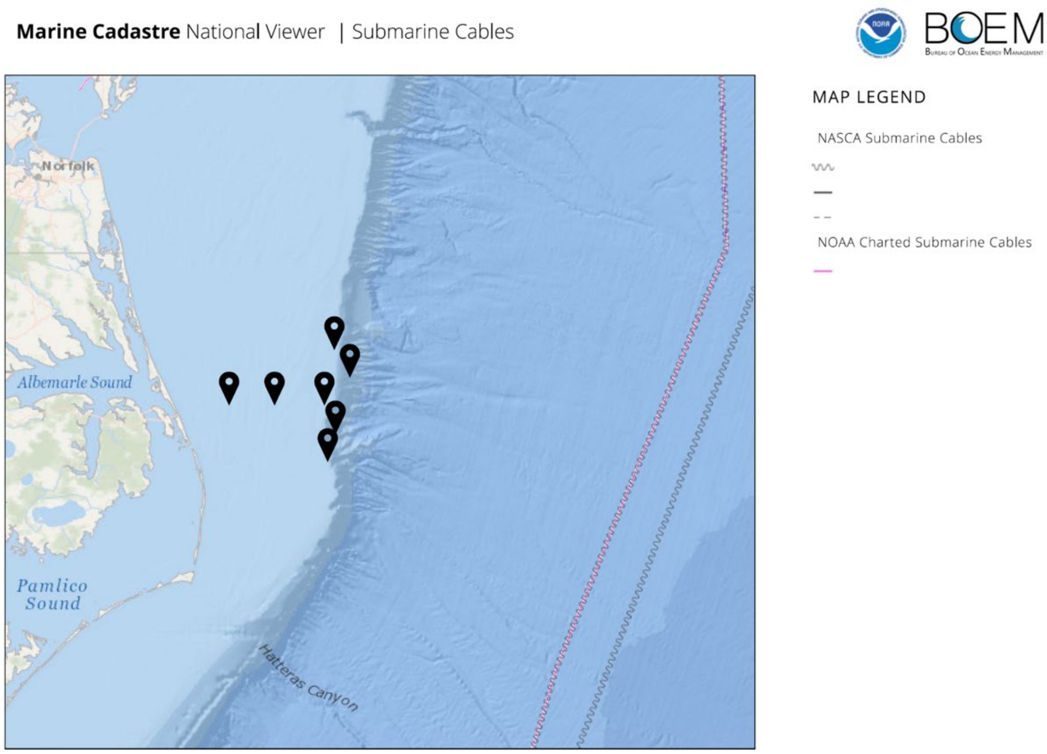

Figure 13: Submarine Cables

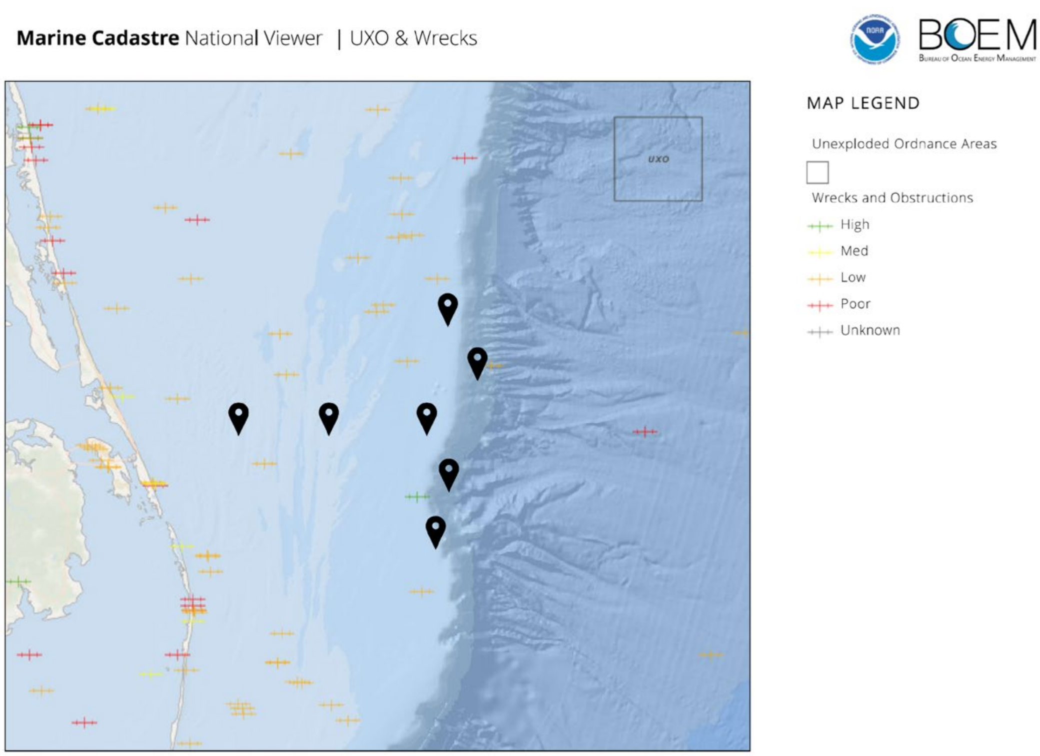

Figure 14: Known Unexploded Ordinance & Wrecks

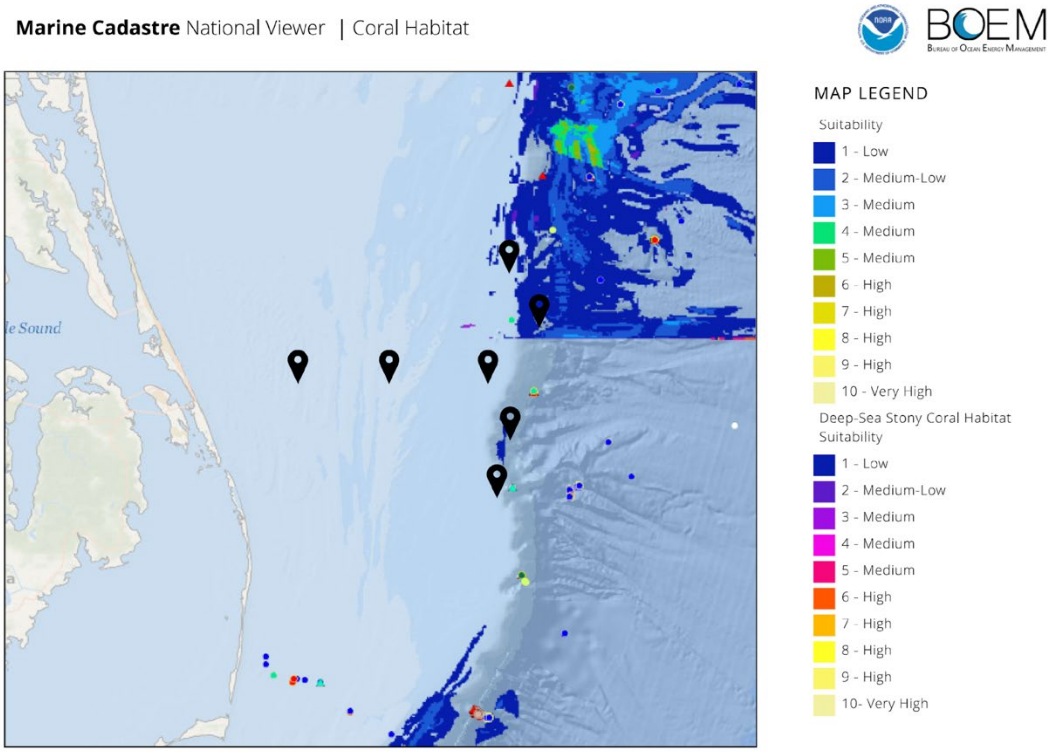

Figure 15: Coral Habitat

CGSN hired TetraTech in January 2022 to complete a regulatory study, desktop study, and marine archeological study. Final reports were completed in December 2022. TetraTech findings confirmed the CGSN array layout as feasible without any major risks. During the study:

- The United States Army Corps of Engineers (USACE) confirmed the array would fall under Nationwide Permit #5 and saw no major issues.
- The North Carolina Department Environmental Quality (NC DEQ) confirmed the array location was outside state waters and also did not see any major issues.
- The desktop study did not find any major physical or environmental risks and the marine archeological report confirmed that the planned layout did not impact any known wrecks.

During this time CGSN also discussed the mooring layout with the Focus Group and other SMEs. It was noted that oceanographic modeling and the desire for interdisciplinary observations at mid-shelf indicated the position of the central surface mooring would be best co-located near the central shallow water mooring, rather than on the 100 m contour with a profiler mooring. This new position will better distribute the heavily-instrumented surface moorings within the array, and will result in an “imbedded triangular array” made up of the three surface moorings to capture cross-shelf process and, potentially, freshwater outflows from the Chesapeake area. This layout was vetted with the Focus Group in September 2022 and resulted in the current mooring layout shown in Figure 16 and in Table 3.

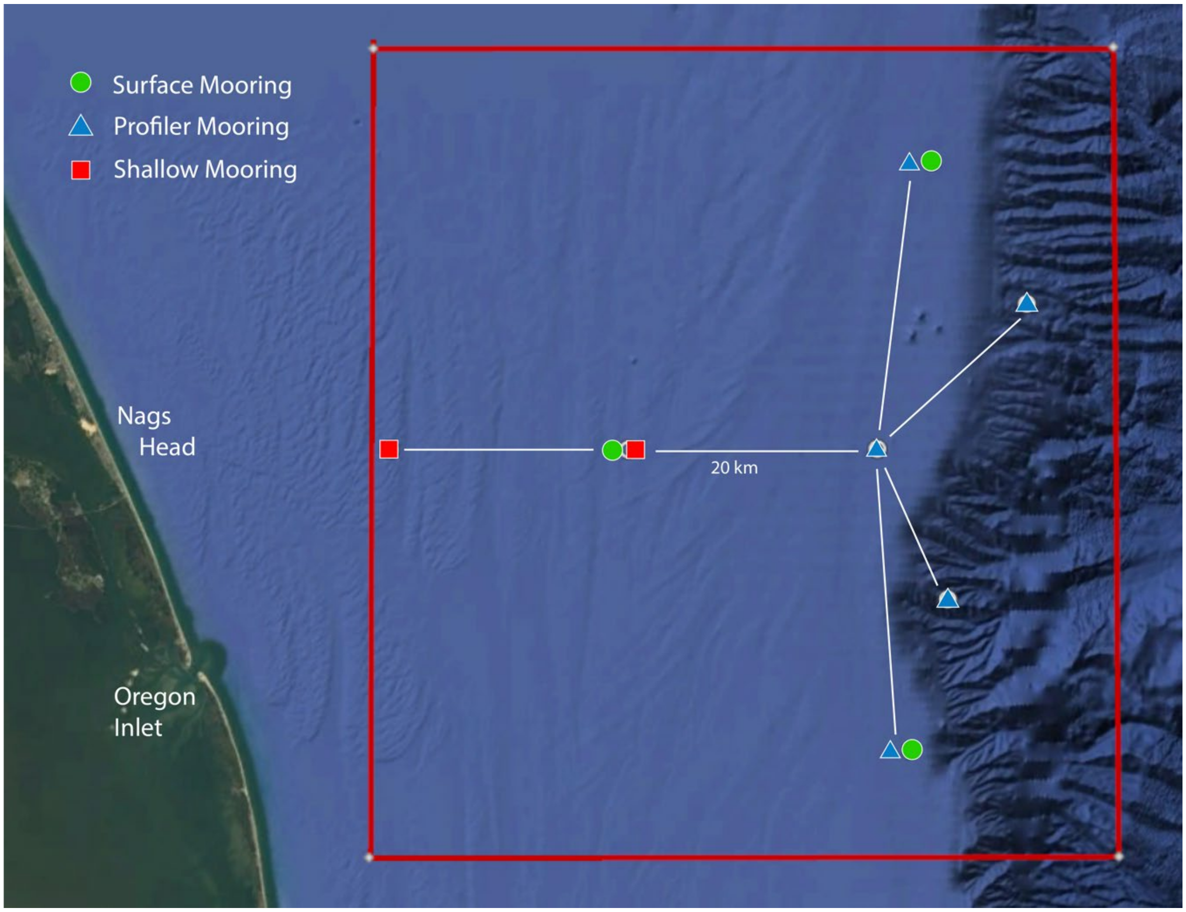

Figure 16: Current Array Layout

Table 3: Table of Planned Mooring Locations

Site	North		West		Depth (m)	Mooring Types	Notes
	lat (deg)	lat (min)	lon (deg)	lon (min)			
Western	35	57.00	75	20	30	Shallow Mooring	
Central	35	57.00	75	7.5	32	Shallow Mooring, Surface Mooring	Planned 2023 test mooring location
North	36	10.50	74	49.60	100	Profiler Mooring, Surface Mooring	
Eastern	35	57.00	74	50.74	100	Profiler Mooring	
Southern	35	43.50	74	51.18	100	Profiler Mooring, Surface Mooring	
Northeast	36	03.80	74	44.56	600	Profiler Mooring	Planned 2023 test mooring location
Southeast	35	50.20	74	49.45	600	Profiler Mooring	

11.0 Mooring Types

As part of the Innovations Lab #2, the groups who proposed the array layouts also reviewed individual mooring types. The existing infrastructure, Surface Moorings (Figure 17) and Profiler Moorings (Figure 18), were accepted by all groups but suggestions on instrumentation were provided, this will be discussed in Section 12.0. Each group also suggested mooring requirements for the shallow mooring. All groups recommended a shallow mooring design with near-surface, mid-water and seabed measurement capabilities.

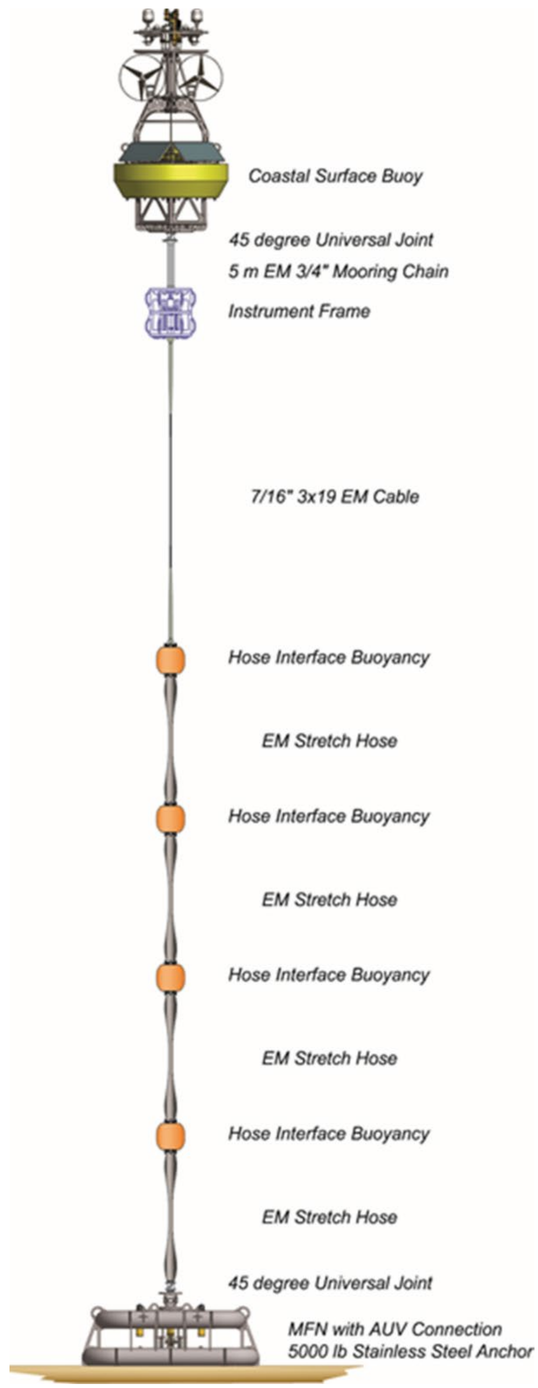

Figure 17: Pioneer Coastal Surface Mooring

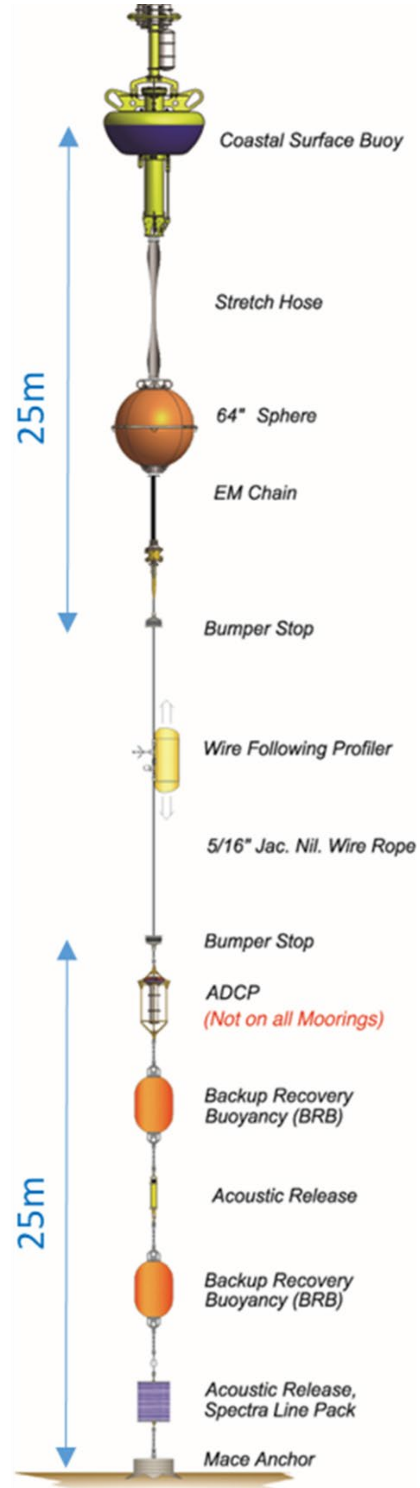

Figure 18: Pioneer Coastal Profiler Mooring

Mooring analyses were completed for both the Coastal Surface Mooring and the Coastal Profiler Mooring. Based on the analyses, no major re-design for the MAB environment is required. For further information, please review the mooring analysis reference documents (3102-00026, 3102-00027). Test deployments of the moorings at the MAB location are planned in calendar Q1 2023.

Minor engineering updates to the Coastal Surface Mooring to accommodate the new location/environment or instrument requests includes:

- Updated instrument clamping for Near Surface Instrument Frame (NSIF)
- Updated instrument clamping for the seabed Multi-Function Node (MFN)
- Increased NSIF size to accommodate additional/larger instruments
- No electro-mechanical cable is required since moorings will be located in water depths of 100 m or shallower.

Minor engineering updates to the Coastal Profiler Mooring to accommodate the new location/environment or instrument requests includes:

- Updated instrument clamping for the 64” sphere
- Updated instrument clamping to accommodate instruments on the base of the buoy
- Increased linepack size for Profiler Moorings deployed in 600 m water depth.

Based on the Innovations Lab #2 feedback, CGSN selected two potential shallow mooring designs for review:

- The existing Endurance Inshore Surface Mooring (ISSM) with a surface expression, NSIF, and seabed MFN (Figure 19)
- A new, simpler design for a Shallow Water Mooring, incorporating a ratcheting profiler vehicle and smaller seabed MFN.

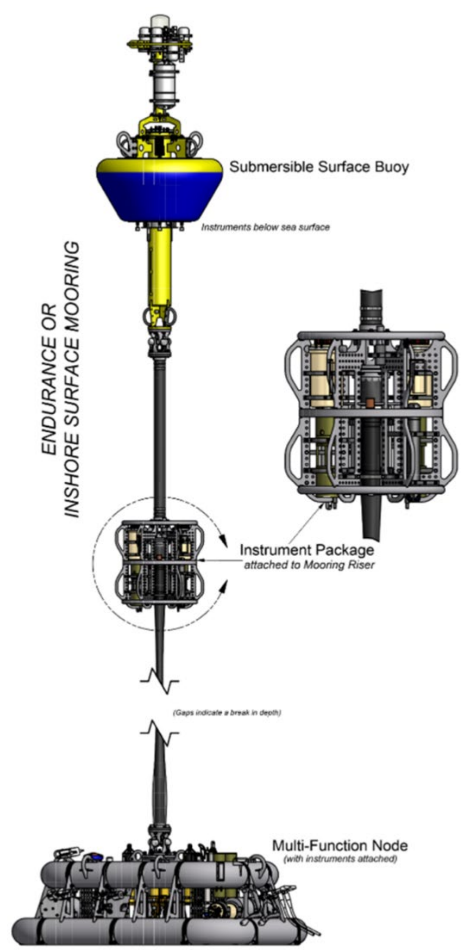

Figure 19: Endurance Inshore Surface Mooring

CGSN has performed a budgetary impact assessment and the Endurance Array ISSM design appears to be more costly than the Shallow Water Mooring. This is due to:

- Greater number of instruments, increasing procurement and refurbishment costs
- Larger, more costly MFN.

In addition, Innovations Lab input clearly indicated the desire for vertically-resolved near-surface measurements that could not be provided by the Endurance Array ISSM design. CGSN believes the Shallow Water Mooring design with a profiling body could measure the upper 80% of the water column, while the multi-function node provides some near seabed instrumentation. Co-locating one of the Surface moorings, as discussed in Section 10.0, with a Shallow Water Mooring would also meet the science measurement recommendations. The Endurance Array ISSM alone would not be able to provide the same water column resolution.

All mooring types were presented to the Focus Group in September 2022. Selection of the final Shallow Water Mooring design is pending a Request For Information (RFI) process currently underway with vendors. Final technical details and budgetary impacts will be assessed in Q1 2023 and a design review process specific to the shallow mooring will be implemented. A test deployment is scheduled for calendar Q3 2023.

12.0 Instrument Selection

Over 40 different instruments, measurements, or measurement concepts were identified from the input of the Innovations Lab #2 participants. Seven measurement concepts were mentioned by all four of the breakout groups:

1. CTD measurements near the surface, focusing on the upper 25 m that is unresolved by the Coastal Profiler Moorings and only sparsely sampled by the Coastal Surface Moorings,
2. Phytoplankton imaging near the surface, in the upper 10 m,
3. Passive acoustics, from a combination of marine mammal listening hydrophones and fish/mammal tag receivers,
4. Turbidity measurements in the water column,
5. Turbidity measurements in the Bottom Boundary Layer,
6. Turbulent velocity and/or velocity profiles in the Bottom Boundary Layer,
7. Methane measurements near the shelfbreak.

An additional five measurement concepts were endorsed by three of the four groups:

1. Velocity profiles near the surface,
2. Nitrate measurements on gliders,
3. Additional CTD measurements in the water column, particularly on Shallow Water Moorings,
4. Multibeam bathymetry and/or sub-bottom profiling from AUVs,
5. Particulate measurements in the Bottom Boundary Layer.

Thirty other concepts were mentioned by just one or two groups, and had features that would make them difficult to implement (e.g. not commercially available, complex and/or expensive) or difficult to justify (e.g. not well aligned with the MAB regional science themes). CGSN reviewed all of the instrument and measurement concepts, consolidating where possible, and focusing on the twelve that had multi-group consensus and relevance to the MAB science themes. Feasibility (e.g. cost, complexity, technical readiness) was also considered. The result was a tiered priority list (Table 4):

- Tier 1: Recommend for implementation as a new OOI core measurement
- Tier 2: Evaluate for potential implementation and/or accommodation when requested by an outside PI
- Tier 3: Eliminate, not a commercial-off-the-shelf instrument, low technical readiness, low relevance to science themes, or recommended by single group.

Table 4: Tiered Priority: Science Measurements

Tier 1	Tier 2	Tier 3
Phytoplankton imagery, species identification and particle counts **Turbidity (Tu)**, optical scattering **Near surface velocity (profile)**, near surface and near bottom mean current **Suspended particulates,** laser diffraction particle size & concentration	**Turbulent velocity**, high-freq 3D point velocity for turbulence **Methane,** detect methane seeps **Marine animal tags,** acoustic receiver for tagged animals (fish, sharks, turtles) **Passive acoustics,** detection/classification for marine mammals (whales) **Environmental Sampling**, in-situ sample analysis for microbes, algae, DNA **Turbidity and particulates on gliders** **POC/DOC/PIC/DIC**, particulate and dissolved organic carbon, inorganic carbon **Zooplankton imagery**, in-situ digital imagery of zooplankton **Phytoplankton primary productivity**, fluorescence-based sensor for ADP detection **Environmental DNA** (eDNA), DNA extraction from water samples	• Multibeam bathymetry/sub-bottom profiling • Sediment trap • Seismometer/OBS • Microstructure on gliders • Wet chemistry for nutrients (beyond nitrate) and other constituents • Surface met and flux on profiler moorings • Carbonate chemistry from DIC • Multibeam bathymetry in canyons • HF radar transmitter on buoys • Change all point velocity measurements to Aquadopp HR • LISST on WFP • Nitrate on WFP • pH on WFP • Radon for groundwater • LIDAR on surface buoy • FoSI (shadowgraph imaging) • bird tracking antenna on buoy • thermal imaging (whale blows) on buoy • methane on WFP

CGSN then performed a budgetary assessment of the procurement and refurbishment of the Tier 1 instruments. Based on the type and priority of measurement, the location of the measurement requested by the Innovations Lab #2 groups, and the cost impact assessment, CGSN recommended the instrument updates shown in Figure 20 through Figure 22. The phytoplankton imagery is proposed on a single surface mooring. This would be the Surface Mooring located in 30 m water depth co-located with a Shallow Water Mooring. All other instrumentation is planned for all moorings as noted in the figures.

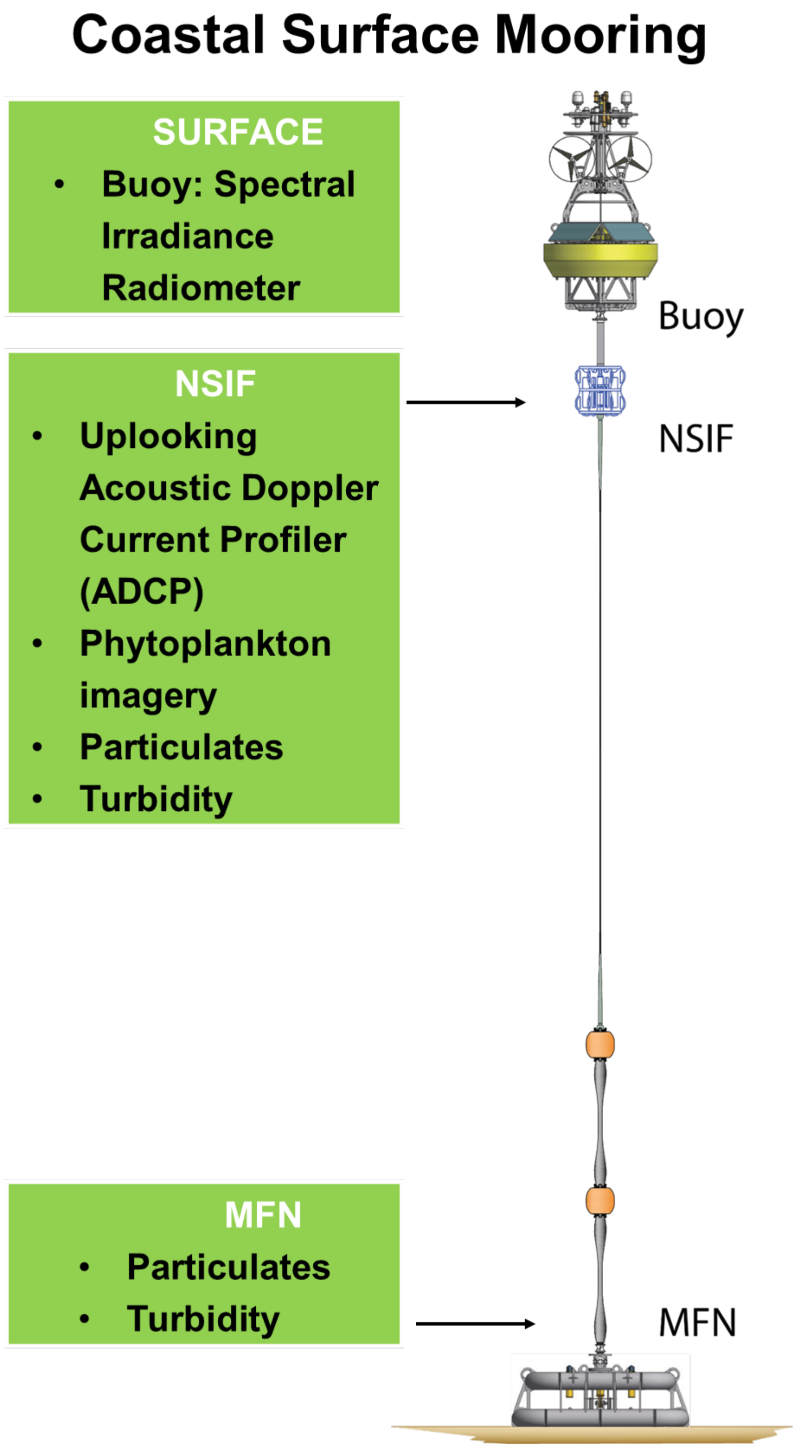

Figure 20: Additional Planned Instruments on Coastal Surface Mooring

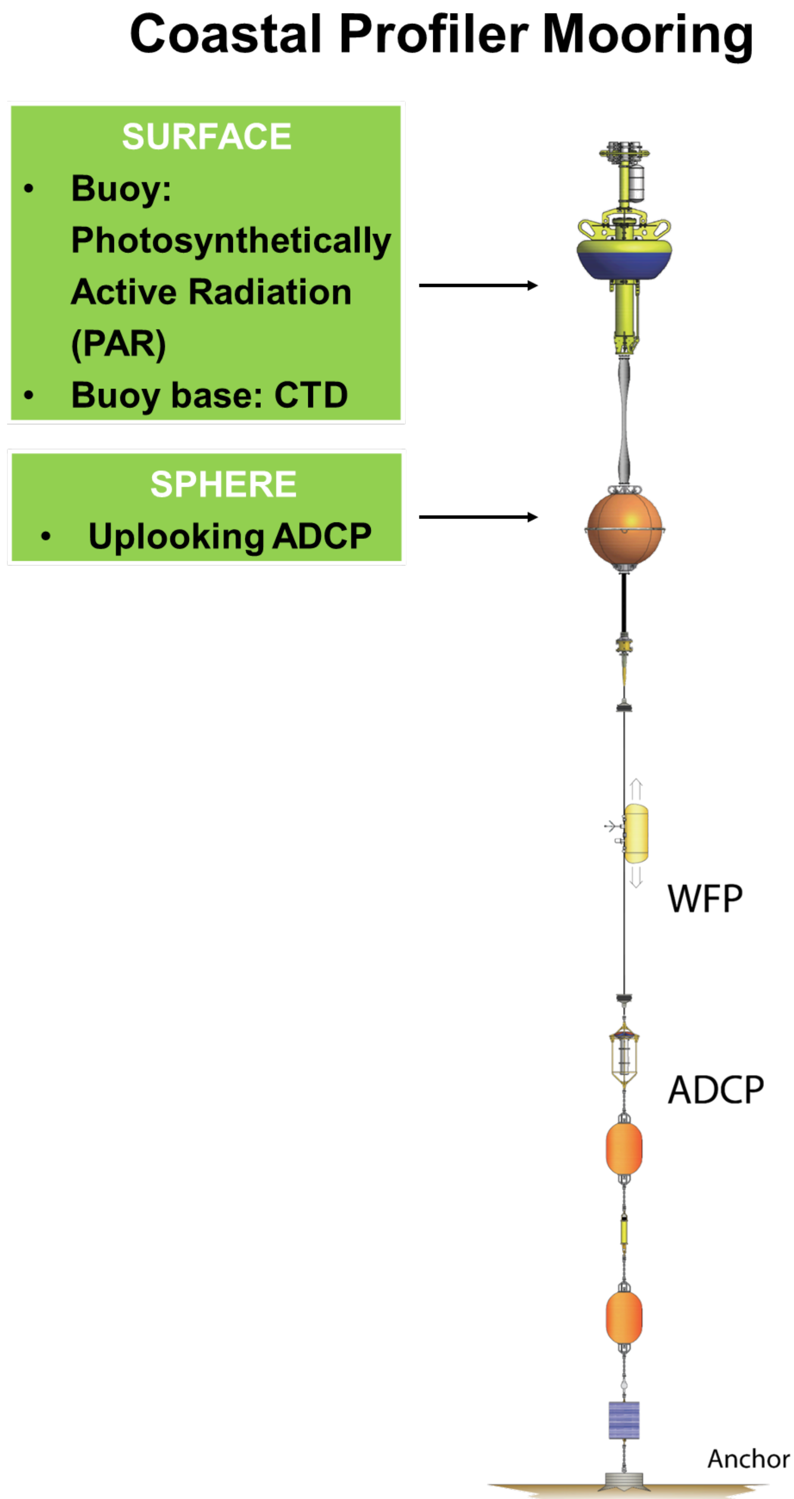

Figure 21: Additional Planned Instruments on Coastal Profiler Mooring

Shallow Water Mooring

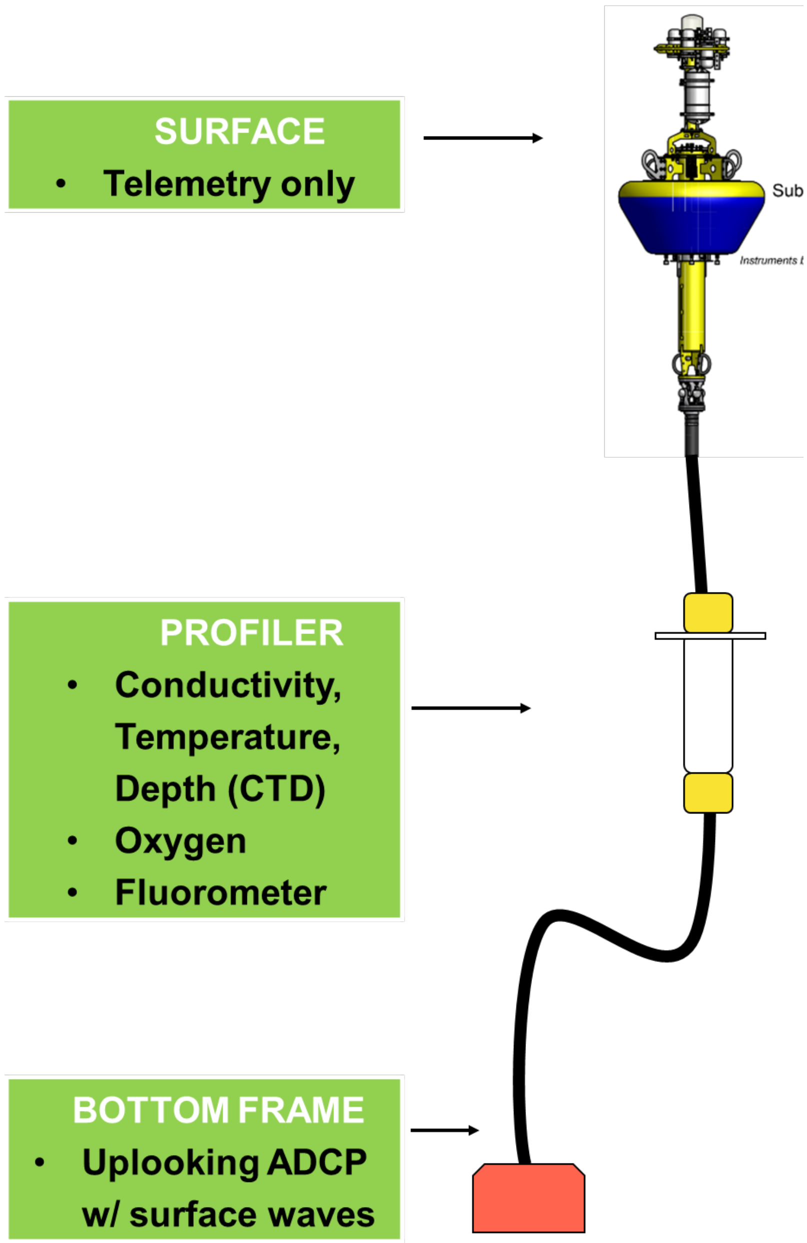

Figure 22: Instruments under Assessment for Shallow Mooring

Tier 1 measurements and instrument location plans were provided to the Focus Group for review in September 2022, no comments indicating significant alteration to the plan were received. Minor comments were incorporated into the planning process.

CGSN has implemented a RFI process to review instruments from multiple vendors, as well a comparison of existing instruments in OOI inventory for applicability. The RFI process will be completed and an assessment be undertaken in calendar Q1 of 2023. Test deployments of instruments will also be undertaken in Q1 2023 as part of the mooring test deployments at MAB.

13.0 Mobile Assets

During Innovations Lab #2, the groups were requested to review potential operating areas for mobile assets, as well as potential payloads. This applied to both gliders and autonomous undersea vehicles (AUVs).

The groups recommended the operational focus should be:

- Glider track lines and AUV missions designed to fill the spatial gaps between moorings
- Repeat glider and AUV transects oriented along-and across shelf
- Glider and AUV transects crossing the likely position of the shelf break front, ideally connecting the shelf and slope with a combination of shallow and deep gliders
- Glider and AUV sampling at Norfolk Canyon.

The groups also recommended that the measurements for mobile assets:

- Maintain current glider payloads
- Add nutrients to glider sampling
- Add methane, multibeam, sidescan, and sub-bottom to AUV payload.

CGSN reviewed the Innovations Lab #2 input and developed a preliminary Mobile Assets Plan (Table 5) which was presented to the Focus Group and subject matter experts in September and October 2022. This plan prioritized use of the existing gliders and AUV payloads to address the Innovations Lab priorities. Budgetary and operating constraints meant that no additional instrumentation would be included at this time.

Table 5: Mobile Assets Plan

Glider Plan	AUV Plan
• Retain current fleet level of 12 gliders • Deploy 4 gliders on 90-day intervals • Re-purpose existing profiling gliders on specific tracklines to provide nutrient measurements • Occupy 4 primary tracklines within the moored array providing across- and along-shelf measurements • Supplemental glider line from Norfolk Canyon to MAB could be occupied twice per year	• Maintain campaign mode operations with 2 x REMUS 600 AUVs • 4-6 missions per year • 1 x across-shelf box • 1 x along-shelf box • Boxes provide synoptic transects of the moored array and resolve the shelfbreak front

Table 6 and Table 7 lists the proposed glider and AUV lines as well as planned instruments and operational depths. Figure 23 and Figure 24 depict the geographical layout of the four proposed glider lines, and two proposed AUV lines.

Table 6: Glider Line Descriptions

Glider Line	Instruments	Operational Depths
Slope Sea Mesoscale	Conductivity, Temperature, Depth (CTD) Dissolved oxygen (DOSTA) Photosynthetically active radiation (PAR) Fluorometer (FLORT) Acoustic doppler current profile (ADCP)	100-1000 m
Slope Sea N-S	CTD, DOSTA, PAR, FLORT Nutrients (NUTNR)	1000 m isobath
Moored Array	CTD, DOSTA, PAR, FLORT, ADCP	30-100 m
Cross Shelf	CTD, DOSTA, PAR, FLORT, ADCP	30-100 m

The operational environment of the MAB is different from NES. CGSN is planning multiple test vehicle deployments in 2023 to assess:

1. Buoyancy engine and glider model effectiveness (shallower depths and sharper transition to deep areas, density changes due to freshwater outflow)
2. AUV operability, and
3. The impact of bio-fouling (warmer and shallower water).

Following field testing, the tracklines and glider payloads will be reviewed. Final trackline layout will be subject to review by the Focus Groups and a design review should design updates be required.

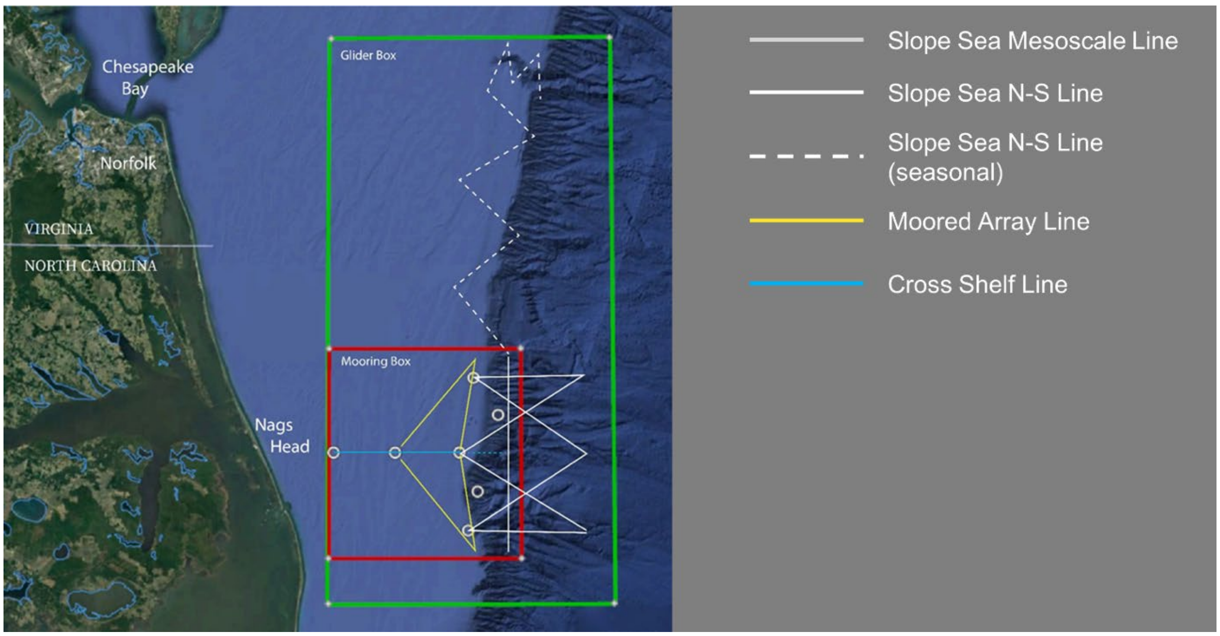

Figure 23: Proposed Glider Line Layout

Table 7: AUV Line Descriptions

AUV Line	Instruments	Operational Depths
AC-1 (across-shelf)	CTD, DOSTA, PAR, FLORT, NUTNR, ADCP	30-1000m
AL-1 (along-shelf)	CTD, DOSTA, PAR, FLORT, NUTNR, ADCP	30-100m

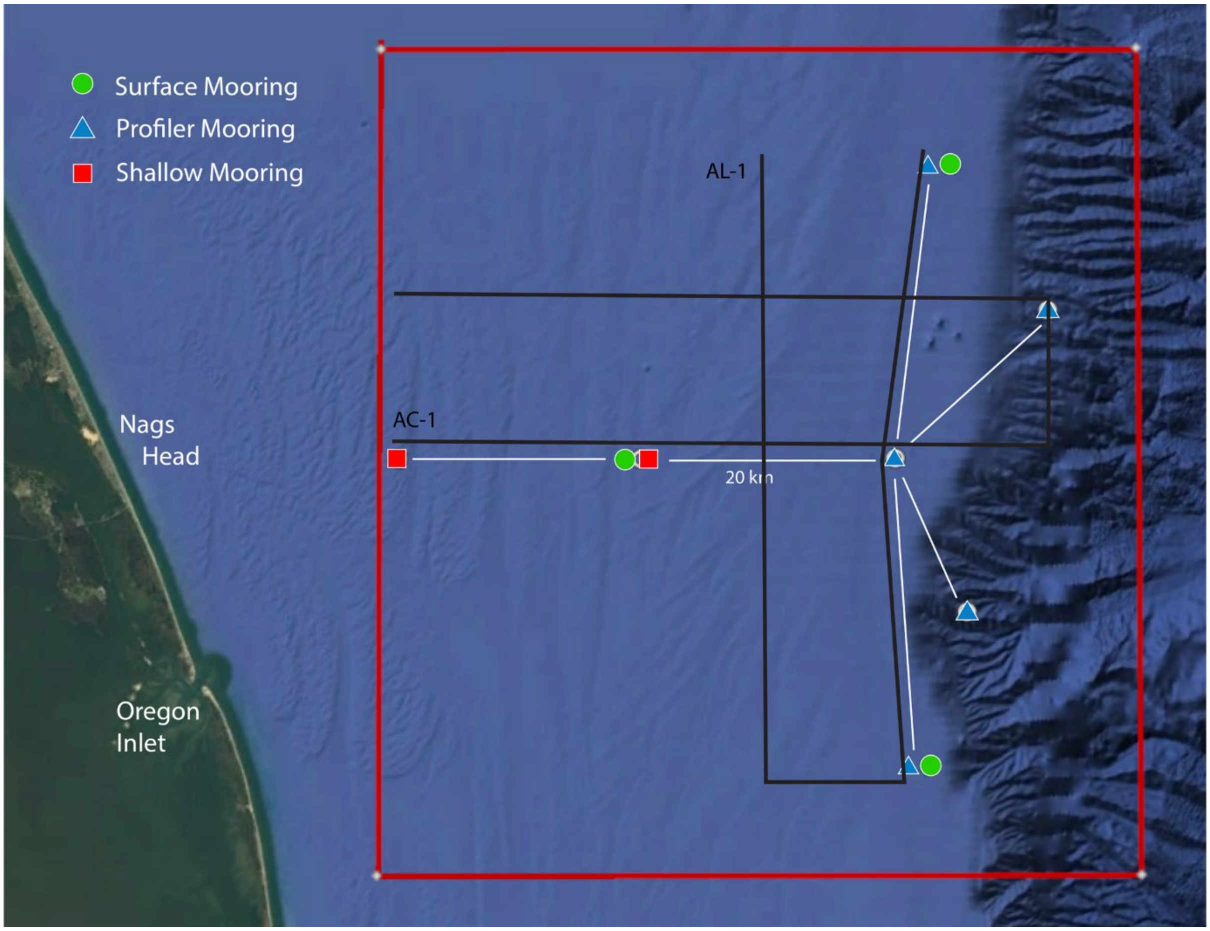

Figure 24: Proposed AUV Line Layout

14.0 Compliance with Themes

The Innovations Lab process resulted in a set of regionally-specific science themes that fit well within four of the six overarching OOI science themes (see Section 9.0). The consensus array design and mobile asset plan using existing Pioneer Array infrastructure is capable of addressing those themes.

However, the community input from the Innovations Lab, when overlaying the themes, indicated some measurement gaps within the CGSN infrastructure. Table 8 provides how CGSN plans to address these gaps based on a tiered prioritization of Innovations Lab input.

Table 8: Addressing Measurement Gaps

Measurement Gap	CGSN Infrastructure Update
Surface Radiation	• SPIKR on Surface Mooring towers • PAR on Profiler Mooring towers
Near surface water column gaps (temperature, salinity, velocity)	• Upward-looking ADCP on Surface Mooring NSIFs • CTD on Profiler Mooring buoy base • Upward-looking ADCP on Profiler Mooring 64" sphere
Turbidity	• Turbidity sensor on Surface Mooring NSIFs and MFNs
Suspended particulates	• Particulates sensor on Surface Mooring NSIFs and MFNs
Phytoplankton Imaging	• Phytoplankton imaging at shallow Surface Mooring location
Glider Nitrates	• Re-purpose profiling glilders to trackline duty (profiling glider payload includes NUTNR)

The Pioneer MAB location has specific features of interest addressed by the array layout and mobile asset plan. Table 9 shows the linkages between the MAB regional science themes and the CGSN infrastructure.

Table 9: Addressing MAB Specifics

MAB Regional Science Theme	CGSN Infrastructure Plan
Dynamics of shelf-slope exchange	Moorings are laid out as T-shape along and across shelf. Surface moorings are located at 30-100 m water depths and co-located with profiler or shallow moorings, further profiler moorings are located at 600 m water depth on shelf break, mobile assets fill gaps between moorings and provide repeat across- and along-shelf transects. Mooring spacing is ~20 km.
Biogeochemical cycling and transport	Existing instruments, some deployed at additional locations, and new instrumentation, increases ability of infrastructure to measure BGC properties.
Extreme events	Moorings are laid out to capture episodic events such as shelf intrusions, freshwater outflows, and hurricane events. New and relocated instruments improve the near-surface measurement capability. Modeling supports the proposed layout of the array to capture events.

Appendix B: Mid-Atlantic Bight Pioneer Array Regulatory Study

Mid-Atlantic Bight Pioneer Array Regulatory Study

Woods Hole Oceanographic Institution
Ocean Observatories Initiative
Coastal and Global Scale Nodes

June 2022

Prepared for

WOODS HOLE OCEANOGRAPHIC INSTITUTION

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Acronyms and Abbreviations

AUV	Autonomous Underwater Vehicle
AWOIS	Automated Wreck and Obstruction Information System
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
CGSN	Coastal and Global Scale Nodes
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DOI	U.S. Department of the Interior
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
ESA	Endangered Species Act
FR	*Federal Register*
HAPC	Habitat Areas of Particular Concern
IHA	Incidental Harassment Authorization
LNM	Local Notice to Mariners
LOA	Letter of Authorization
LOP	Letter of Permission
MAB	Mid-Atlantic Bight
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MMPA	Marine Mammal Protection Act of 1972
NAVSEA	Naval Sea Systems Command
NCDEQ	North Carolina Department of Environmental Quality
NCDCM	North Carolina Division of Coastal Management
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
nm	nautical mile
NMSA	National Marine Sanctuaries Act
NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	NOAA National Marine Fisheries Service
NSF	National Science Foundation
NWP	Nationwide Permit

OCS	Outer Continental Shelf
OOI	Ocean Observatories Initiative
PATON	Private Aids to Navigation
SHPO	State Historic Preservation Office
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
WHOI	Woods Hole Oceanographic Institution

1.0 INTRODUCTION

Woods Hole Oceanographic Institution (WHOI) was selected by the National Science Foundation (NSF) to support the development, installation, and initial operation of the coastal and global components of the NSF's Ocean Observatories Initiative (OOI). The OOI consists of a globally distributed and integrated network of marine observation systems that provides the United States ocean sciences research community with an advanced research infrastructure to support sustained, long-term, and adaptive measurements of the oceans across global, regional, and coastal scales.

WHOI is currently responsible for the implementation and operation of one coastal scale arrays and two global scale arrays collectively referred to as the Coastal and Global Scale Nodes (CGSN) portion of the OOI program. The CGSN includes a Coastal Array called the Pioneer Array currently located in the federal waters of the Middle Atlantic Bight off the coast of New England. In 2021, the NSF announced the relocation of the Pioneer Array from the New England Shelf to the Outer Continental Shelf (OCS) off the coast of North Carolina in the southern Mid-Atlantic Bight (MAB).

The following report evaluates the federal and state permits, licenses and approvals that will be required to successfully install and operate each component of the MAB Pioneer Array (henceforth the Pioneer Array) for the intended 5-year life of the project. This report specifically provides the following:

- A detailed assessment of the necessary permits, licenses, notices, consultations, and approvals required at the federal and state levels, as appropriate;
- A description of the specific project and/or environmental information required to support the permit or other regulatory compliance application process;
- An estimate of the time period for agency application review, final determination, and approval or renewal (as necessary);
- An estimate of the fees associated with the applications, registrations, reapplication/renewal (as necessary) and review of the permits or other regulatory requirements; and
- The point(s)-of-contact for each entity responsible for oversight and/or review of the necessary permit(s), license(s), and approval(s) application process(es).

The report provides a detailed permitting matrix highlighting the key aspects of the permitting process, integrated permitting schedules, and a complete record of all agency consultations regarding the requirements for the project.

2.0 PERMIT AND REGULATORY REQUIREMENTS – PIONEER ARRAY

The Pioneer Array is proposed to be relocated to the waters of the Atlantic Ocean off the coast of Nags Head, North Carolina. The planned array will be located approximately 13 nautical miles (nm) offshore on the OCS, to 45 nm at the shelf break and slope (Figure 1). The geographic footprint is the region of the Mid-Atlantic Bight between Cape Hatteras and Norfolk Canyon. The Pioneer Array will consist of the following:

- Three surface moorings with local power generation (wind turbines and solar panels), satellite communications capabilities, and benthic nodes;
- Five profiler moorings that would be internally powered (with primary and/or rechargeable batteries), three of the five would be located at the same site (within a few hundred meters) as a surface mooring;
- Two shallow-water moorings of a design similar to the surface moorings;
- Two autonomous underwater vehicles (AUVs) operated in campaign mode from ships; and
- Four to six buoyancy-driven ocean gliders.

The following sections evaluate the various federal and state permits that will be required to support the successful installation and operation of the Pioneer Array and its components. Records of agency consultations regarding Project permitting, licensing, and approval requirements as described in the following sections have been included in Appendix A to this report. A permits and approval matrix summarizing the requirements to support the installation and operation of the Pioneer Array has been included as Appendix B, and a permitting and approvals schedule has been included in Section 2.5.

2.1 Federal Permits, Licenses, and Approvals

2.1.1 U.S. Army Corps of Engineers

The U. S. Army Corps of Engineers (USACE) is responsible for issuing permits for the development of projects undertaken by other agencies or private entities that may affect the navigable waters of the United States. Navigable waters are defined as “those waters subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce” (33 Code of Federal Regulations [CFR] 329.4). As the Pioneer Array is proposed to be located in navigable waters, installation and operation of the Pioneer Array will require USACE authorization under Section 10 of the Rivers and Harbors Act of 1899 (33 United States Code [U.S.C.] 401 *et seq.*) and Section 404 of the Clean Water Act (CWA) (33 U.S.C. 1251 et seq.).

Section 10 of the Rivers and Harbors Act (33 U.S.C. 401 et seq.) regulates structures or work in or affecting navigable waters of the U.S. Structures include any pier, wharf, bulkhead, or other structure on the seabed. Work includes dredging, filling, excavation, or other modifications to waters of the U.S.

Section 404 of the CWA (33 U.S.C. 1251 et seq.) provides federal authority to issue permits for the discharge of dredged or fill material into waters of the United States at specified disposal sites (USACE n.d.a).

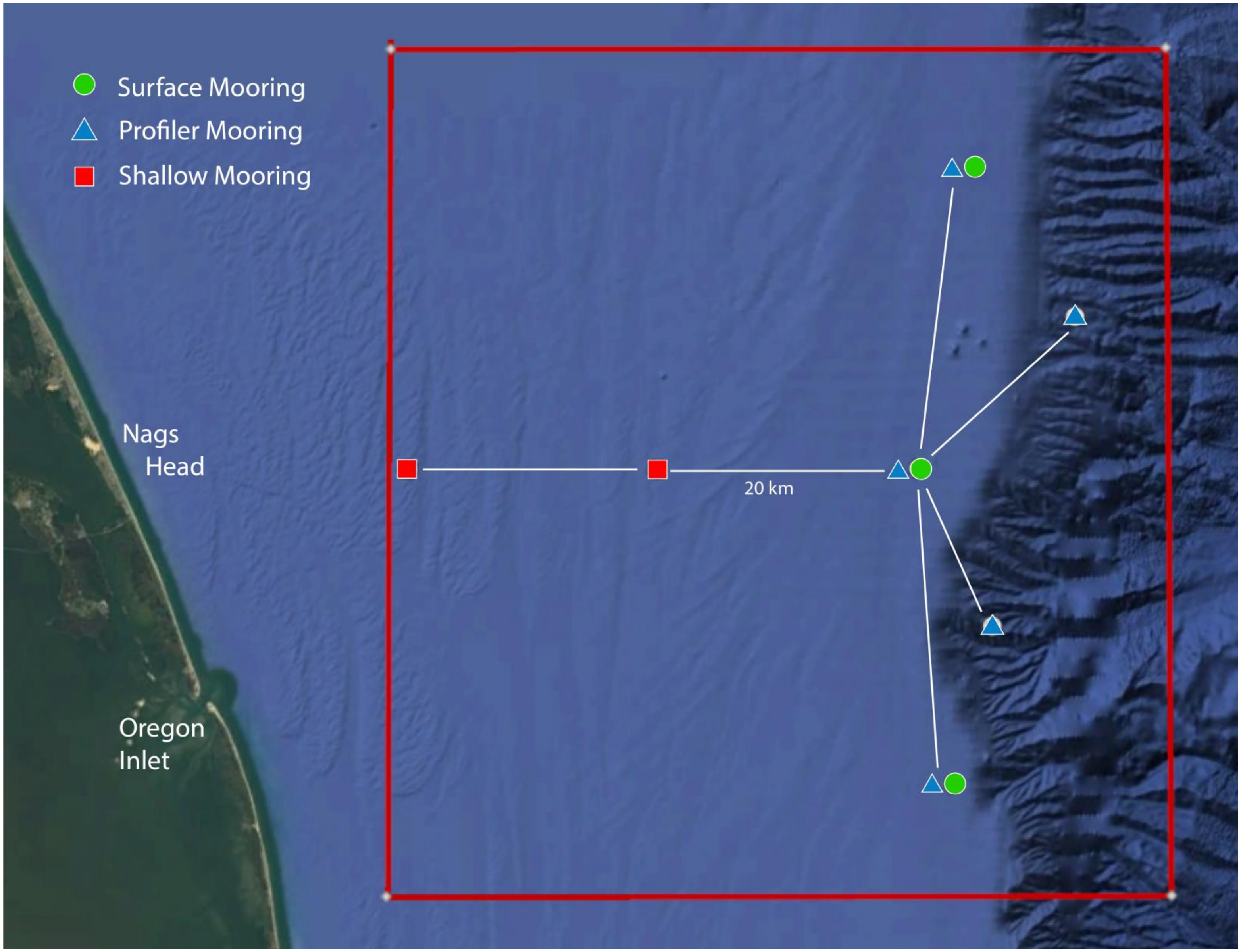

Figure 1. Pioneer Moored Array Location Overview – Preliminary Plan

Consultation with the USACE has determined that the anchoring of the Pioneer Array will qualify for Nationwide Permit (NWP) #5 Scientific Measuring Devices[1]. Based on a discussion with the USACE on March 17, 2022, submittal of a Pre-Construction Notification for the project will not be required for authorized use of NWP #5. NWPs are issued by the USACE to authorize activities under Section 10 and Section 404 that have been pre-determined to have minimal impacts to the environment. NWPs are issued for a period lasting no more than 5 years, at which point the USACE must modify, reissue, revoke, or suspend the permits based on the current guidelines and regulations for protection of aquatic resources, protected species, and cultural and historic resources as set forth by the Environmental Protection Agency (EPA) under Section 404 of the CWA and Section 10 Rivers and Harbors Act, the U.S. Fish and Wildlife Service (USFWS) Endangered Species Act, the National Historic Preservation Act of 1966, and other federal or state regulations to ensure those activities result in no more than minimal individual and cumulative adverse effects to the environment (86 *Federal Register* [FR] 73522). The latest NWP #5 was re-issued on February 25, 2022 and shall expire on March 14, 2026.

Deployment of the Pioneer Array is proposed for year 2024 and is expected to be in operations for five years. Maintenance of the moorings is anticipated to occur semi-annually over the five years to ensure the equipment is in good condition and properly functioning. The initial installment falls under the NWP conditions and is good for the life of the project. It is not required to renew for operations unless the scope changes with new installations. Due to maintenance needs, the placement of the mooring anchors may be readjusted, replaced and/or redeployed which may cause slight adjustments to the placement of the anchors on the sea floor. The USACE is expected to view these slight adjustments as re-occurring minor impacts. As such, compliance with all general and regional conditions of NWP #5 will need to be met during the life of the project. Based on the proposed timeline for the project it is highly likely that the latest NWP #5 will expire in 2026 while project operations are ongoing. However, should the USACE reissue NWP #5 and the project meets all general and regional conditions of the reissued permit, then no further action is required to maintain USACE approval.

In the unlikely event that NWP#5 has not been reissued, or the project does not meet all general and regional conditions of the permit, and no other NWP alternative exists, then the project may require approval of an USACE standard individual permit. To apply for a standard individual permit, a USACE ENG Form 4345 and the appropriate supplemental materials including a project description and engineering drawings must be submitted to the Wilmington District. Prior to developing the application, a pre-application meeting with the USACE is recommended to re-introduce the project and to discuss required information that should be included with the application. The pre-application meeting will help avoid the submittal of an incomplete application and subsequent permit processing delays (USACE n.d.b).

Upon receipt of a complete application, the USACE will begin the official review process. The USACE has 10 days to review and deem the application complete (or request additional information). Once deemed complete and if the USACE determines that the work is minor or routine with minimum impacts and objections are unlikely, the agency will issue a Letter of Permission (LOP) authorizing the project to proceed, usually within 30 days. During the pre-application meeting, eligibility for the more

[1] https://saw-reg.usace.army.mil/NWP2021/NWP-5.pdf

expedited LOP should be discussed with the USACE. A LOP is valid for a period of 3 years for construction activities. For operational activities the LOP is generally issued for the operational life of the project; however, it may contain certain restrictions and/or requirements based on the nature of the proposed activities. These specific restrictions and/or requirements will be determined during consultation and the permit application process.

If the USACE determines that the proposed project may have potential adverse effects, public input may be necessary. Should public involvement be required, the USACE will issue a public notice 15 days after receiving the complete application. The public notice begins the comment period, typically lasting 30 days, during which comments on the project are received from local, state, and federal agencies, as well as the general public, and interested groups and individuals. Upon completion of the comment period, the USACE will conduct a Public Interest Review to evaluate whether the issuance of the permit is in the public's interest. The USACE may ask the applicant to provide additional information during this time and may hold a public hearing, if necessary. Under this review scenario, the USACE would issue its decision as an individual standard permit (ENG Form 1721). For construction activities, an individual standard permit is valid for a period of 3 years, but can be issued for a period up to 10 years for maintenance dredging projects. For operational activities, an individual standard permit is generally issued and valid for the operational life of the project.

Fees are required for most USACE standard permits. The current fee is $10.00 for a noncommercial activity and $100.00 for a commercial or industrial activity. The final decision regarding the required fee (non-commercial versus commercial) is solely the responsibility of the USACE District Engineer. When the USACE issues a standard permit, they will provide notice concerning submission of the required fee. Fees are not charged for transferring a permit from one property owner to another, for nationwide or regional general permits, for LOPs, or for permits issued to governmental agencies.

The following individual has been designated as the USACE point-of-contact:

Billy Standridge
USACE Wilmington District
Phone: 910-251-4595
Email: Billy.w.standridge@usace.army.mil

2.1.2 National Environmental Policy Act Review

The National Environmental Policy Act (NEPA; 42 U.S.C. 4321 et seq*.)* requires federal agencies to take into consideration the potential environmental consequences of proposed actions in their decision-making process. The intent of NEPA is to consider impacts on the environment through informed federal decision making. As part of the reissuance of the NWPs, the USACE prepared a decision document which contains an Environmental Assessment, in compliance with the requirements of NEPA (86 FR 73522). Therefore, no further NEPA documentation is required for the Pioneer Array. In the event the project warrants an USACE individual permit, NEPA's procedural requirements will be met through the individual permitting process.

2.1.3 National Oceanic and Atmospheric Administration

The requirement to initiate consultations with the National Oceanic and Atmospheric Administration (NOAA) is triggered by a federal action (i.e., the issuance of the USACE authorization). As the Pioneer Array qualifies for the NWP #5, the requirements for these consultations were satisfied as a part of the USACE reissuance of these authorizations; therefore, no further action is required for the Pioneer Array. In the event the project warrants an USACE individual permit, the USACE will initiate consultation with NOAA and/or the USFWS to concur on any proposed impacts to living marine resources and to determine if any permits are required. Details regarding these consultations and the potential resulting permits are described in sections 2.1.3.1 and 2.1.3.2 below for reference.

2.1.3.1 NOAA National Marine Fisheries Service

The NOAA National Marine Fisheries Service (NOAA Fisheries), a division of the Department of Commerce, is the federal agency responsible for the management, conservation, and protection of living marine resources within the Exclusive Economic Zone (EEZ). This EEZ jurisdiction includes the area extending from the territorial sea baseline (the mean lower low water drawn across river mouths, bay openings and along the outer points of complex coastlines) out to 200 nm.

Endangered Species Act Section 7 Consultation

The Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531 *et seq.*) and subsequent amendments provide for the conservation of threatened and endangered species of animals (including some marine mammals) and plants, and the habitats in which they are found. The ESA prohibits jeopardizing threatened and endangered species or adversely modifying critical habitats essential to their survival. Section 7 of the ESA (with implementing regulations at 50 CFR 402) requires each federal agency to consult with NOAA Fisheries and the USFWS regarding any action they authorize, fund, or carry out to determine whether any threatened or endangered species under their jurisdiction may be affected by a proposed action (USFWS n.d.). Generally, the USFWS manages land and freshwater species, while NOAA Fisheries manages marine species, including anadromous salmon. However, the USFWS has responsibility for some marine animals such as nesting sea turtles, walruses, polar bears, sea otters, and manatees (see Section 2.1.4).

Marine Mammal Protection Act Incidental Harassment Authorization or Letter of Authorization

The Marine Mammal Protection Act of 1972 (MMPA) (16 U.S.C. 1361 et seq.) protects marine mammals by strictly limiting their "taking" in waters or on lands under U.S. jurisdiction, and on the high seas by vessels or persons under U.S. jurisdiction. The term "take," as defined in Section 3 (16 U.S.C. 1362) of the MMPA and its implementing regulations, means "to harass, hunt, capture, or kill, or attempt to harass, capture, or kill any marine mammal." The term "harassment" was further defined in the 1994 amendments to the MMPA as any act of pursuit, torment, or annoyance, at two distinct levels:

- Level A Harassment – potential to injure a marine mammal or marine stock in the wild.
- Level B Harassment – potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavior patterns including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering.

Should a project result in the “incidental take” of a marine mammal, a take authorization would be required, and a written request must be submitted to the NOAA Fisheries Office of Protected Resources. The application for the appropriate authorization must include a detailed description of the project, a list of potentially affected species, potential mitigation measures, and suggested means for monitoring and reporting impacts. This authorization, issued in the form of an Incidental Harassment Authorization (IHA) or Letter of Authorization (LOA), normally involve one public comment period and, depending on the issues and species involved, can take anywhere from 6 months to one year for issuance. Consultation with NOAA has determined that the anchoring of the Pioneer Array will not require an IHA or LOA; no further action is required at this time.

Consultation under the Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801-1882) established U.S. jurisdiction from the seaward boundary of the coastal states out to 200 nm for the purpose of managing fisheries resources. The MSA is the principal federal statute that provides for the management of marine fisheries in the U.S. The purposes of the MSA include (1) conservation and management of the fishery resources of the U.S.; (2) support and encouragement of the international fishery agreements; (3) promotion of domestic commercial and recreational fishing; (4) preparation and implementation of Fishery Management Plans; (5) establishment of Regional Fishery Management Councils; (6) development of fisheries which are underutilized or not utilized; and (7) protection of Essential Fish Habitat (EFH).

EFH is defined as those waters and substrate necessary to fish or invertebrates for spawning, breeding, feeding, or growth to maturity. Areas designated as EFH contain habitat essential to the long-term survival and health of U.S. fisheries. Under provisions of the MSA, eight Regional Management Fishery Councils were established for the New England, Mid-Atlantic, South Atlantic, Caribbean, Gulf of Mexico, Pacific, Western Pacific, and North Pacific regions.

Consultation under MSA also considers impacts to Habitat Areas of Particular Concern (HAPC). HAPCs are site-specific areas of EFH for managed species. The designation of HAPCs can provide focus for additional conservation efforts for habitat that is ecologically important, sensitive to disturbance, exposed to development activities, or rare. No HAPCs have been designated within the vicinity of the Pioneer Array.

2.1.3.2 NOAA Office of National Marine Sanctuaries

The NOAA Office of National Marine Sanctuaries manages the National Marine Sanctuary Program. The mission of the program is to identify, designate, and manage areas of the marine environment of special national, and in some cases international, significance due to their conservation, recreational, ecological, historical, research, educational, or aesthetic qualities (15 CFR 922.2). The NOAA Office of National Marine Sanctuaries is responsible for overseeing the implementation of sanctuary management plans and conservation activities and has the authority to issue permits to allow certain activities that would otherwise be prohibited by sanctuary regulations (National Marine Sanctuaries Office 2008).

National Marine Sanctuaries Act

The National Marine Sanctuaries Act (NMSA) (16 USC 1431 et seq.) authorizes the Secretary of Commerce to designate and protect areas of the marine environment with special national significance as national marine sanctuaries. Regulations at 15 CFR Part 922 further implement the NMSA and regulate the conduct of certain activities within the sanctuaries. Section 304(d) of the NMSA further requires federal agencies to consult with NOAA before taking actions, including authorization of private activities, “likely to destroy, cause the loss of, or injure a sanctuary resource.” In addition, federal agencies are required to consult on proposed actions that “may affect” the resources of a national marine sanctuary (Section 304[d]). Any activities prohibited by the aforementioned regulations can only be undertaken by obtaining a permit from the National Marine Sanctuary Program. No National Marine Sanctuaries have been identified within proximity to the proposed Pioneer Array; therefore, no further action is required at this time.

2.1.4 United States Fish and Wildlife Service

The USFWS within the U.S. Department of the Interior (DOI) is responsible for the conservation of terrestrial and freshwater fish and wildlife species and habitats. The USFWS activities include identification of threatened and endangered species, management of National Wildlife Refuges, and issuance of permits for activities affecting protected species and their habitats (50 CFR 1 through 100). The USFWS manages land and freshwater species, while NOAA Fisheries manages marine species, including anadromous salmon. The USFWS has responsibility for some marine animals such as nesting sea turtles, walruses, polar bears, sea otters, and manatees.

Consultations with the USFWS are also required under Section 7 of the ESA. The ESA defines “take” as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect any threatened or endangered species. Significant habitat modifications where listed species experience mortality or injury through impairment of essential behavior (e.g., nesting or reproduction) can be considered a “take” (USFWS 2016).

A desktop assessment of publicly available data and a protected species habitat assessment or survey will be needed to determine the potential for protected species to occupy or navigate the waters and aquatic habitats surrounding the proposed project location. Should results of the assessments determine protected species and/or their suitable habitat is present within the proposed project area, but the project is expected to have a “no effect” or “may affect, not likely to adversely affect” determination for protected species, request for informal consultation with the USFWS and NOAA (as detailed in Section 2.1.3) is recommended in order to comply with Section 7 of the ESA. Under an informal consultation, the applicant will submit a letter request to the USFWS and NOAA for concurrence that the proposed project will incur minimal to no adverse impacts to protected species. If the federal agencies agree that the action is not likely to adversely affect protected species (e.g., the effects are beneficial, insignificant, or discountable) the agencies will provide concurrence in writing and no formal consultation will be required.

However, should the USFWS or NOAA consider the project to be likely to adversely affect protected species within the area, formal consultation will be required. Formal consultation generally lasts up to 90 days where USFWS and NOAA coordinate with the federal permitting agency (USACE) to share information of the proposed project and the species likely to be affected. Following the 90 days, the USFWS has 45 days to prepare a Biological Opinion which analyzes the effects of the proposed actions to those species and may conclude on specific measures the project must take, including implementing conservative approaches or applying for an incidental take permit, to ensure its actions do not jeopardize the continued existence of the protected species.

It should be noted that documentation of all completed species assessments, surveys, and/or informal/formal consultations with the USFWS will be required for approval of a USACE permit.

2.1.5 United States Coast Guard

The United States Coast Guard (USCG) is a military branch of the United States, one of seven uniformed services and the smallest armed service of the United States. The USCG plays a role in homeland security, law enforcement, search and rescue, marine environmental pollution response, and the maintenance of river, intracoastal and offshore aids to navigation (USCG 2017). The USCG has jurisdiction over navigation safety on the high seas and navigable waters of the United States (33 CFR 1.01).

Based upon previous investigations and direct consultations with the USCG for the first deployment of the Pioneer Array as well as current experience with permitting the deployment of surface met buoys, it has been determined that USCG approved Private Aids to Navigation (PATON) and Local Notice to Mariners (LNM) will be required to support the installation and operation of the Pioneer Array.

2.1.5.1 Private Aids to Navigation and Local Notice to Mariners

A PATON is a buoy, light, or daybeacon owned and maintained by any individual or organization other than the USCG (33 CFR 66). The deployment of OOI's scientific buoys will require the submittal of an application for PATONs for each buoy deployed. To obtain PATON approval, a completed Aids to Navigation Application (CG-2554) must be submitted to the USCG District Commander for the district in which the PATON will be located (District 5 for the Mid-Atlantic Region including North Carolina). The applicant must provide information such as overall size, buoy color, light color and period (rate), latitude/longitude, depth, ownership/contact, mooring marking, and overall deployment duration. For the AUVs and gliders, the mission area boundaries must be clearly defined on a navigational chart and the outer-boundary coordinates of the "mission box" should be identified. Information provided in the Aids to Navigation Application will also be used by the USCG to develop an LNM that will inform mariners of the existence of the Project PATONs and areas where AUVs and gliders could be encountered.

As described in the Aids to Navigation Application (USCG 2018), the USCG District Commander will review the application for completeness and will assign the PATON one of the following classifications:

- Class I – Aids to navigation on marine structures of other works which the owners are legally obligated to establish, maintain, and operate as prescribed by the USCG.
- Class II – Aids to navigation exclusive of Class I located in waters used by general navigation.
- Class III – Aids to navigation exclusive of Class I located in waters not ordinarily used by general navigation.

PATON applications must be initiated through the following website: www.usharbormaster.com. To use the site, the applicant must first become a registered user, after which a username and password will be provided. Once initiated, three copies of the Aids to Navigation Application form must be forwarded to the USCG District Commander at least 30 days in advance of the proposed action.

As stated above, each of the 10 individual Pioneer Array buoys as well as the AUV and glider mission areas will require the submittal of separate Aids to Navigation Applications. There are no costs associated with application submittal or review. The general turnaround time from application submittal to issuance of the PATON and LNM is expected to be approximately 2 weeks. No buoy, AUV, or glider deployment will be permitted until the PATONs are authorized and the LNMs are issued. If an authorized PATON is not installed within one year of the approval date, the approved application will automatically be cancelled.

PATONs must be maintained and kept in working order. Any discrepancy in the operation of the aids at any time must be expediently reported to the USCG District Commander so that Notices to Mariners may be issued. A discrepancy exists whenever an aid is not operating or presenting itself as described in the approved permit (e.g., lack of signal or incorrect light characteristic). All classes of PATONs are subject to inspection by the USCG at any time and without prior notice. Also, removal, change in use, or discontinuance of use of Class I private aid to navigation will also require approval from the USCG District Commander. Class II and Class III private aids may be removed after 30 days' notice to the USCG District Commander who received the original request for authorization for the aid.

In addition to notifying mariners, the USCG will notify the U.S. Navy that a PATON has been issued. The USCG will also notify the National Oceanic and Atmospheric Administration (NOAA) to ensure that each PATON is included on new NOAA Navigational Charts.

It is important to note that, before a PATON consisting of a fixed structure is placed in the navigable waters of the United States, authorization must first be obtained from USACE and included within the PATON application.

The following individual has been designated as the USCG PATON and LNM point-of-contact for District 5:

Lieutenant Gregory C. Goetz
Commander Fifth Coast Guard District
Waterways Management
Private Aids to Navigation
431 Crawford Street
Portsmouth, Virginia 23704
Waterways Management Division: 910-772-2230
Phone: 757-398-6220
Email: gregory.c.goetz2@uscg.mil

2.1.6 U.S. Navy

The U.S. Navy requires notification of operation areas in accordance with Naval Sea Systems Command (NAVSEA) Instruction 4740.1A, referencing CNO ITR SER 02/6U385030 of April 1986. Because of the proximity of the Pioneer Array to naval submarine operations near Virginia Beach, Virginia, the

Pioneer Array may be of interest to the U.S. Navy and therefore the agency should be contacted to ensure that there are no conflicts between the proposed Project and current or future planned naval activities. The USCG has previously indicated that they will take responsibility for conducting this consultation during the PATON permitting process (Tetra Tech 2008). As such, WHOI will require no direct consultation with the U.S. Navy and no fees will be required to support the USCG's consultation with this agency.

The USCG will likely be contacting the following as part of their PATON consultations and notifications process:

FACSFAC VACAPES
601 Oceana Blvd
Virginia Beach, VA 23460
Phone: 757-433-1211

Commander, Naval Air Force Atlantic
1562 Mitscher Ave, Suite 300
Norfolk, VA 23551

2.1.7 Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) within the DOI manages alternative energy activities (wind, wave, and current) and mineral resources on the OCS and is responsible for granting leases for the use of the OCS for alternative energy production or mineral extraction (BOEM n.d.a). The OCS includes the submerged lands, subsoil, and seabed seaward of state territorial boundaries to the outer limit of the United States' EEZ (i.e., between 3 and 200 nm off the coast of all states except Texas, Louisiana, and the Gulf Coast of Florida) (BOEM n.d.b).

Although the Pioneer Array would be located on the OCS, the installation of scientific measurement devices does not fall under BOEM jurisdiction. However, because the Pioneer Array is located within proximity of existing and planned offshore wind lease areas, it is recommended that the BOEM be notified of the Project so that potential conflicts can be avoided.

The following individual has been designated as the BOEM point-of-contact:

Olivia Woods
Renewable Energy
Office of Public Affairs
1849 C Street, NW
Washington, D.C. 20240
Phone: 202-531-0667
Email: Olivia.woods@boem.gov

2.2 State Permits, Licenses and Approvals

The Submerged Lands Act of 1953 (43 U.S.C. 1301 et seq.) gives states jurisdiction over the natural resources of submerged lands out to 3 nm from shore (BOEM n.d.c). Environmental resources in North Carolina are protected under the North Carolina Administrative Code Title 15A Environmental Quality.

State agencies are required to lead and cooperate to manage the types of activities that require environmental documentation and compliance, including proposed construction on lands and waters owned or managed by any North Carolina Department of Environmental Quality (NCDEQ) agency. NCDEQ jurisdiction extends through state waters requiring the North Carolina Division of Coastal Management (NCDCM) to provide a federal consistency certification pursuant to the Federal Coastal Zone Management Act (CZMA) and compliance with the North Carolina Coastal Area Management Act.

Although the Pioneer Array is located outside of state waters, formal interagency consultation was undertaken with a consultation letter specifically sent to the NCDCM in the anticipation of the letter being circulated to appropriate North Carolina agencies. The NCDCM point of contact is:

Daniel Govoni
Policy Analyst & Federal Consistency Coordinator
North Carolina Department of Environmental Quality
Division of Coastal Management
400 Commerce Avenue
Morehead City, NC 28557-3421

Mr. Govoni followed up with a request of a map of the array with coordinates on a navigational chart, which was provided via email. As such, no further action by WHOI is anticipated for NCDCM to complete a CZMA federal consistency review. WHOI may consider forwarding the self-certification for NWP #5 to the NCDCM.

Applicability of the adjacent states' Water Quality Certification under Section 401 of the CWA and Section 106 Consultation under the National Historic Preservation Act of 1966 (NHPA) (16 U.S.C. 470 et seq.) were also evaluated for the Pioneer Array. Projects that require a federal permit or involve dredging or fill activities that may result in a discharge to U.S. surface waters and/or waters of the U.S. are required to obtain a CWA Section 401 Water Quality Certification to verify that the project activities would comply with state water quality standards. Although the Pioneer Array would require federal permits, given the location of the array several miles outside of state territorial water, the Project is not likely to affect state water quality; however, a Section 401 Water Quality Certification is automatically associated with NWPs, and therefore a separate authorization application and approval will not be required. A separate Water Quality Certification would only be required in the event an USACE individual permit is required.

Section 106 of the NHPA requires federal agencies to take into account the effects of their undertakings on historic properties that are potentially eligible for listing on the National Register of Historic Places. Section 106 compliance generally involves consultation with the State Historic Preservation Office (SHPO) of the state where the Project is located. Since the Pioneer Array is located outside of North Carolina state territorial waters and will not be visible from shore, compliance with the NHPA will require consultation with federal agencies (i.e., USACE) rather than with the SHPO. Survey data will be collected in the proposed project area with a review of the Automated Wreck and Obstruction Information System (AWOIS), and with appropriate siting, the installation of Pioneer Array's components would avoid impacts to cultural resources. Desktop survey data will be compiled for the NWP #5 self-certification to document proposed locations and avoidance of cultural resources, with a field survey to confirm siting will avoid impacts.

2.3 Local Permits, Licenses, and Approvals

The Pioneer Array is located approximately13 nm at its closest point from the town of Nags Head in North Carolina. The remainder of the array locations are planned further offshore, approximately 45 nm from the Outer Banks along the OCS, shelf break, and slope, and therefore well outside of theses states' territorial sea boundaries. At these distances from shore the Pioneer Array is well beyond the jurisdiction of local agencies and will not affect local resources.

2.4 International Permits, Licenses, and Approvals

The Pioneer Array does not extend past the EEZ; therefore, no international approvals or consultations will be required.

2.5 Pioneer Array Permits, Licenses, and Approvals Schedule

A project schedule specific to the requirements of the Pioneer Array has been included below. This schedule includes the anticipated surveys and permits to support the installation and operation of the Pioneer Array.

WHOI has indicated that the target date for installing the Pioneer Array is April 2024. Therefore, the surveys to support the permitting process could start in Spring 2023 to complete the self-certification documentation by September 2023 with PATON applications submitted to the USCG in January 2024.

Pioneer Array Proposed Schedule (Assuming approval under NWP #5)

- Desktop Analysis – Summer/Fall 2022
- Field Surveys – Spring 2023
- NWP #5 Self-Certification – Summer/Fall 2023
- PATON Applications – Winter 2023/2024

Pioneer Array Proposed Schedule (Assuming NWP #5 is not renewed in 2026 and approval is needed to maintain project under an IP)

- Desktop Analysis Update – Early 2026
- Field Surveys – Not planned for IP if array is already deployed, use previous survey results
- Submittal of IP – Spring 2026
    - Public Comment/Hearing Period (if warranted) – Summer/Fall (15 – 30 days)
- Agency approval of IP – Spring/Summer 2027
- PATON Applications – Winter 2023/2024

3.0 REFERENCES

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APPENDIX A: FEDERAL AND STATE RECORD OF AGENCY CORRESPONDENCES

Telephone Contact Log

Project Name: WHOI Pioneer Permit Analysis
Tetra Tech Caller: Mike Murphy
Conversation with: Daniel Govoni – North Carolina Division of Coastal Management
Subject: Pioneer Array required State permits or authorizations
Date and Time: March 8, 2022 – 9:15 AM

Summary of Conversation:

I spoke with Mr. Daniel Govoni, the Federal Consistency Coordinator with the North Carolina Division of Coastal Management. He informed me that he would require a brief, one-page memo summarizing the intent of the Project, that he would then review and distribute to the respective agencies that would have a regulatory interest in the proposed project.

He was very receptive during our discussion and seemed willing to facilitate the process.

Daniel Govoni's contact information:
Mr. Daniel Govoni, Policy Analyst & Federal Consistency Coordinator
NCDCM – Morehead City Headquarters
400 Commerce Ave.
Morehead City, NC 28557 Congress St. Suite 1100
Federal Consistency | NC DEQ
252-808-2808, ext. 233
daniel.govoni@ncdenr.gov

Telephone Contact Log

Project Name: WHOI Pioneer Permit Analysis
Tetra Tech Caller: Katherine Miller
Conversation with: Benjamin Laws - NOAA
Subject: Need for NOAA Authorization for Acoustic Emitting Equipment
Date and Time: March 15, 2022, 4:45 pm

Summary of Conversation:

Katherine Miller had a quick conversation with Benjamin Laws to confirm that an Incidental Harassment Authorization would not be required for the Project due to the following equipment:

- Acoustic doppler (ADCP);
- Singe point velocity;
- Bio-acoustic sonar; and
- Passive hydrophones.

Telephone Contact Log

Project Name: WHOI Pioneer Permit Analysis
Tetra Tech Caller: Katherine Miller
Conversation with: Bill Standridge (910-251-4595) - USACE
Subject: Applicability of the NWP #5
Date and Time: March 17, 2022, 12:50 pm

Summary of Conversation:

Katherine Miller had a quick conversation with Bill Standridge to confirm that the project qualifies for the Nationwide Permit #5 (NWP #5). Katherine provided an overview of the Project, including that up to 10 mooring will be deployed within federal waters, moored with weighted anchors. Bill noted that the Project sounds like it qualifies for the NWP #5, and as long as it follows and is in compliance with the General Conditions, then a Pre-Construction Notification (PCN) would not be required. Bill added that the USACE would prefer to not have to process a PCN, if not required. The USACE's main concern is with the USCG, and as long as a PATON is received, then there are no concerns from the USACE side.

TETRA TECH

MEMO

To:	Daniel Govoni – North Carolina Division of Coastal Management
From:	Michael Murphy and Jennifer Kraus, Tetra Tech, Inc.
CC:	Derek Buffitt and Albert Plueddemann, Woods Hole Oceanographic Institution
Date:	April 7, 2022
Subject:	Pioneer Array Relocation – Mid-Atlantic Bight

Summary

On behalf of the Ocean Observatories Initiative and the Woods Hole Oceanographic Institution, we would like to inform you of the proposed relocation of the Pioneer Array from the New England Shelf to the Outer Continental Shelf off the coast of North Carolina (Project). It is our intention to notify and inform all federal, state and local stakeholders of our intentions as to ensure that respective organizations have the opportunity to review and provide feedback regarding any permitting activities required of the Project.

Project Description

Woods Hole Oceanographic Institution (WHOI) was selected by the National Science Foundation (NSF) to support the development, installation and operation of the coastal and global components of the NSF's Ocean Observatories Initiative (OOI; https://oceanobservatories.org). The OOI consists of a globally distributed and integrated network of marine observation systems that provide the ocean sciences research community with an advanced research infrastructure to support sustained, long-term, and adaptive measurements of the oceans across global, regional, and coastal scales.

WHOI is currently responsible for the implementation and operation of one coastal scale array and two global scale arrays collectively referred to as the Coastal and Global Scale Nodes (CGSN) portion of the OOI program. The CGSN includes a Coastal Array called the Pioneer Array currently located in the federal waters of the Middle Atlantic Bight off the coast of New England (https://oceanobservatories.org/array/coastal-pioneer-array). In 2021, The NSF announced the re-location of the Pioneer Array from the New England Shelf to the Outer Continental Shelf (OCS) off the coast of North Carolina.

The Pioneer Array is proposed to be relocated in the Spring of 2024, in the waters of the Atlantic Ocean off the coast of Nags Head, North Carolina. The preliminary plan is for the moored array to be constituted in a sideways "T" shape, with seven mooring sites between about 13 nm and 45 nm offshore, outside of state waters.

The Pioneer Array will consist of:

- Three surface moorings with local power generation (wind turbines and solar panels), satellite communications capabilities, and benthic nodes;
- Five profiler moorings that would be internally powered (with primary and/or rechargeable batteries), three of the five would be located at the same site (within a few hundred meters) as a surface mooring;
- Two shallow-water moorings of a design similar to the surface moorings;

- Two autonomous underwater vehicles (AUVs) operated in campaign mode from ships; and
- Four to six buoyancy-driven ocean gliders.

We are seeking input as to the federal and state permits, licenses and approvals that will be required to successfully install and operate each component of the Pioneer Array for the intended 5-year life of the Project. The Unites States Army Corps of Engineers has confirmed that this Project will be permitted under Nationwide Permit #5. We have reviewed the States policies and concur that proposed activity is consistent (to the maximum extent practicable) with the enforceable policies of the State's coastal management program.

Please contact me at your convenience at Michael.Murphy@tetratech.com to discuss further details regarding the Project, as your support in this effort is greatly appreciated.

Attachments:

Figure 1 – Pioneer Array Overview

Figure 2 – Potential Mooring Types

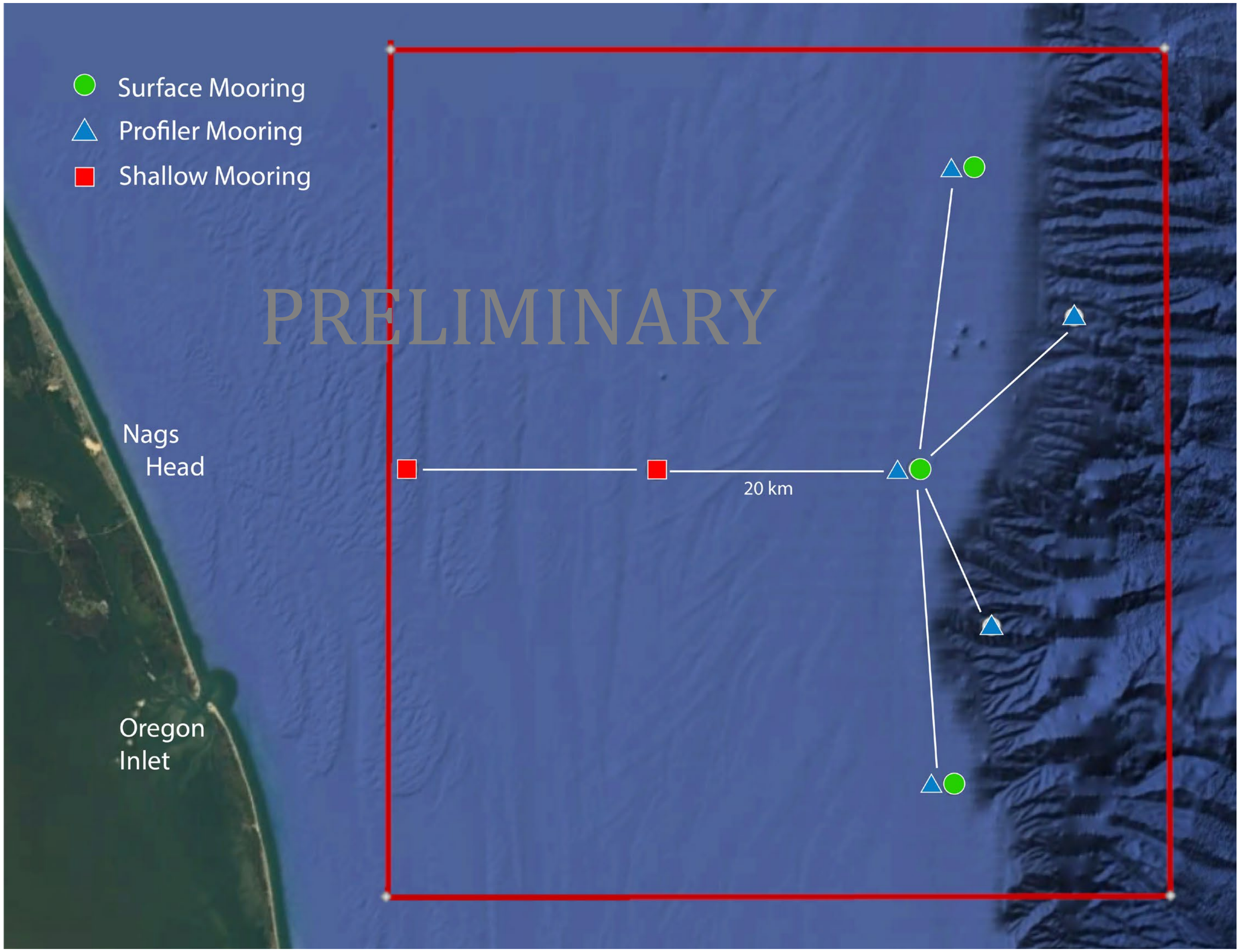


Figure 1- Pioneer Moored Array Location Overview – Preliminary plan.

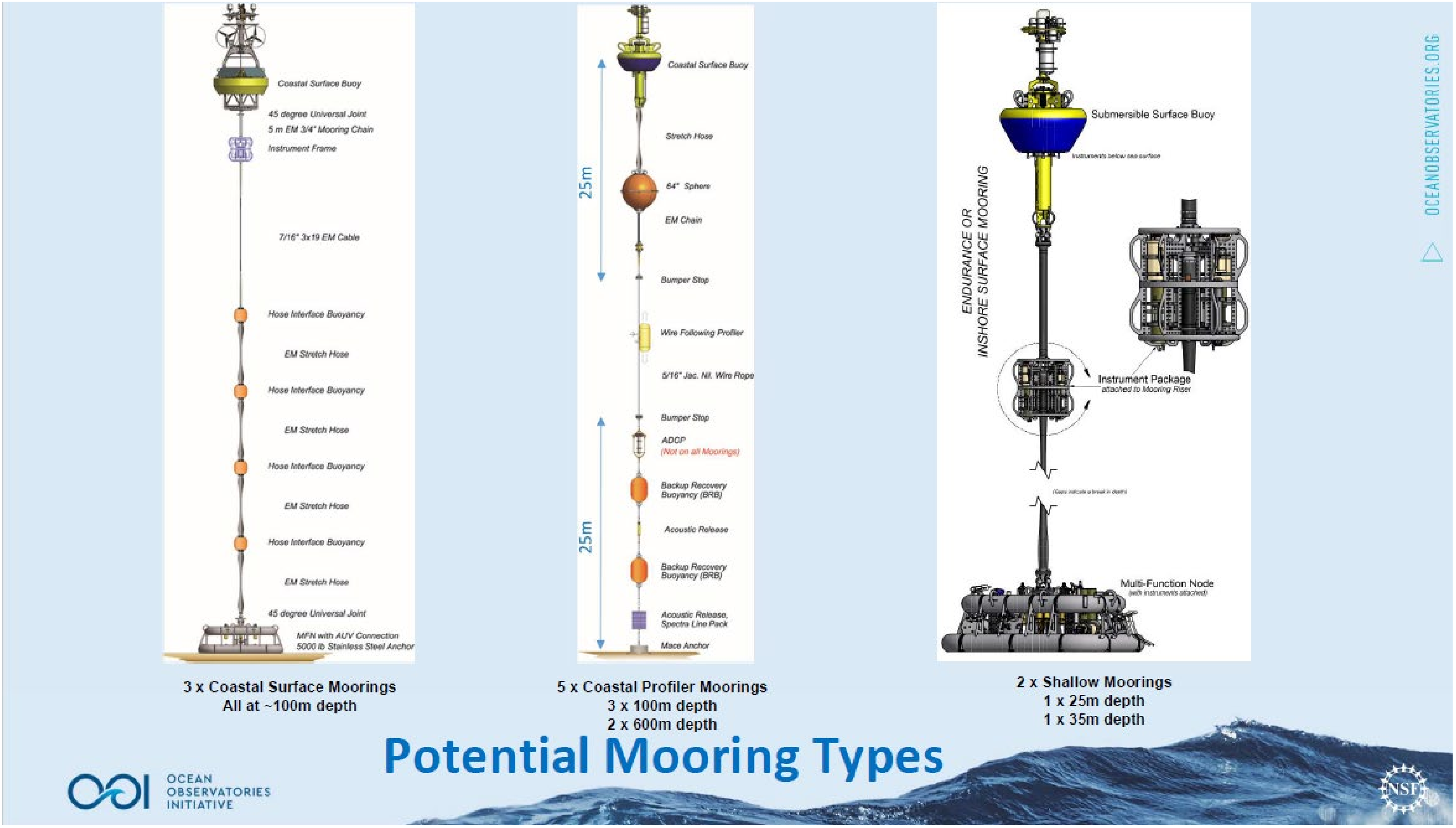


Figure 2 - Potential Mooring Types

Telephone Contact Log

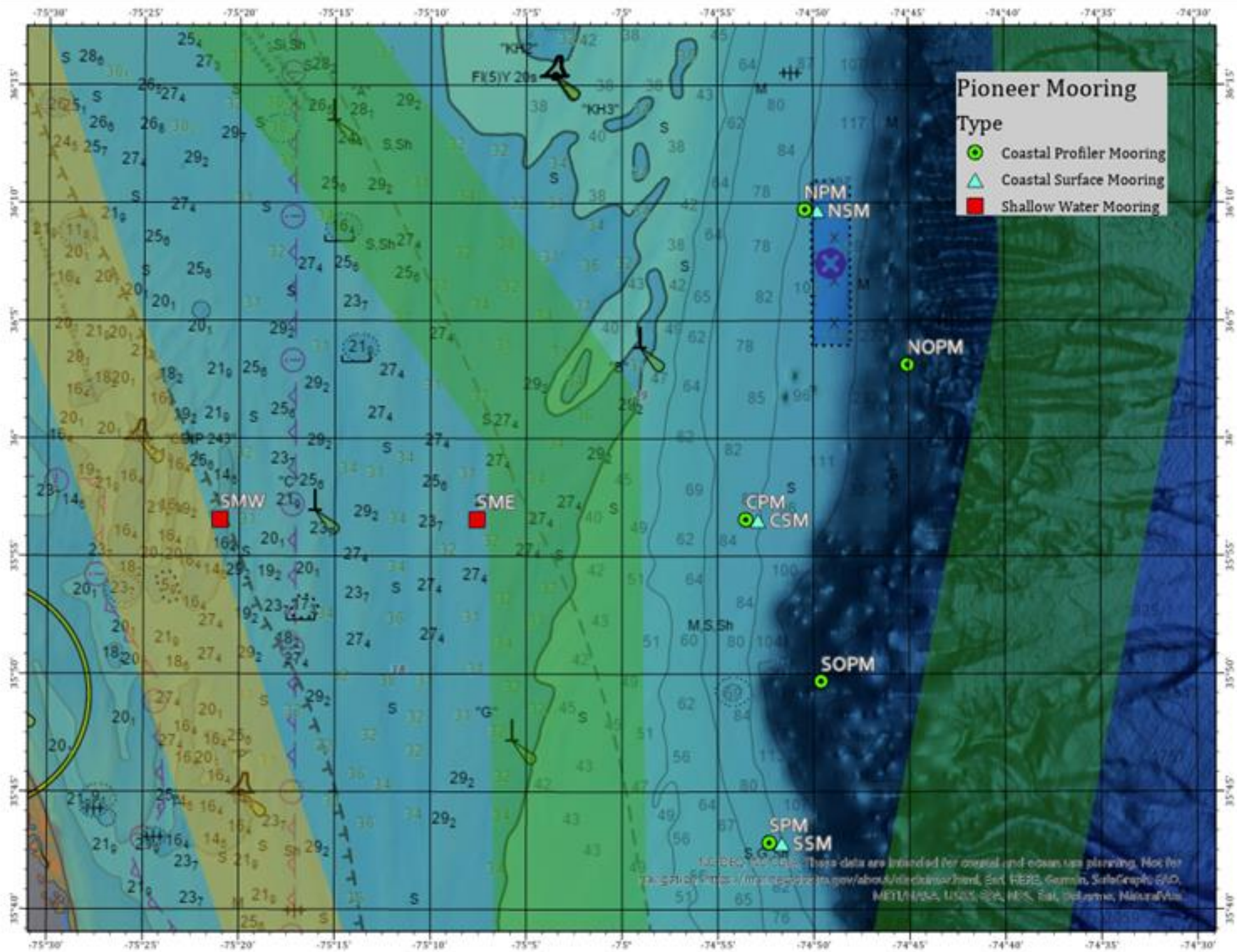
Project Name: WHOI Pioneer Permit Analysis
Tetra Tech Caller: Mike Murphy
Conversation with: Daniel Govoni – North Carolina Division of Coastal Management
Subject: Pioneer Array required State permits or authorizations
Date and Time: June 10, 2022 – 10:15 AM

Summary of Conversation:

I spoke with Mr. Daniel Govoni, the Federal Consistency Coordinator with the North Carolina Division of Coastal Management. He informed me that he would have the Pioneer Array memo review complete by June 17, 2022, as he was waiting on feedback from NC Marine Fisheries.

He was, again, very receptive during our discussion and seemed willing to facilitate the process. He requested a map of the array with coordinates on a navigational chart.
A new map was provided via email on June 15, 2022 (attached).

Daniel Govoni's contact information:
Mr. Daniel Govoni, Policy Analyst & Federal Consistency Coordinator
NCDCM – Morehead City Headquarters
400 Commerce Ave.
Morehead City, NC 28557 Congress St. Suite 1100
Federal Consistency | NC DEQ
252-808-2808, ext. 233
daniel.govoni@ncdenr.gov


Pioneer Mooring
Type
Coastal Profiler Mooring
Coastal Surface Mooring
Shallow Water Mooring
NPM
NSM
NOPM
CPM
CSM
SOPM
SPM
SSM
SMW
SME

APPENDIX B: PIONEER ARRAY PERMIT MATRIX

Required Approvals and/or Consultations

Permitting Agency	Name of Permit/ Regulatory Requirement	Jurisdiction	Point-of-Contact	Application Process Timeframe	Application Cost(s)	Permit/Regulatory Duration
FEDERAL						
U.S. Army Corp of Engineers (USACE)	Section 10 Individual Standard Permit under the Rivers and Harbors Act and Section 404 of the Clean Water Act	Navigable waters of the U.S.	Washington Regulatory Field Office U.S. Army Corps of Engineers 2407 West Fifth Street Washington, NC 27889 General Number: (910) 251-4610 Fax Number: (252) 975-1399 https://www.saw.usace.army.mil	Nationwide Permit #5 Scientific Measurement Devices[2] A Pre-Construction Notification Form would not be submitted.	N/A	The current Nationwide Permit authorizations are valid from February 25, 2022 through March 14, 2026.
Advisory Council on Historic Preservation	National Historic Preservation Act (NHPA) Section 106 Consultation	Historic properties in the United States	N/A	Section 106 consultation completed through the NWP. USACE to confirm the Project is compliant with Section 106.	N/A	Life of Project
U.S. Coast Guard (USCG)	Private Aid to Navigation Approval (PATON) and Local Notice to Mariners (LNM)	High seas and navigable waters of the U.S.	Gregory Goetz Commander Fifth Coast Guard District 431 Crawford Street Portsmouth, Virginia 23704 Portsmouth Federal Building Staff Status: 757-398-6441 or 800-334-8377 gregory.c.goetz2@uscg.mil (757) 398-6220 CGD5Waterways@uscg.mil	30 days prior to installation submit 3 copies of each application (separate application for each buoy, AUV, glider mission areas). Agency review period is approximately 2 - 4 weeks from application receipt.	N/A	PATON valid for life of project. PATON will expire after 1 year from the date of issuance if the project is not installed. Removal or change requires USCG approval.
U.S. Navy	FACSFAC VACAPES	High seas and navigable waters of the U.S.	FACSFAC VACAPES 601 Oceana Blvd Virginia Beach, VA 23460 Phone: 757-433-1211 Commander, Naval Air Force Atlantic 1562 Mitscher Ave, Suite 300 Norfolk, VA 23551	Courtesy notification recommended as the buoys will be located within the VACAPES.	N/A	Life of Project

[2] Tetra Tech confirmed that the NWP #5 is applicable for the Pioneer Array; USACE confirmed that a Pre-Construction Notification would not be needed, therefore a self-verification package would be prepared but not submitted to the USACE.

Permitting Agency	Name of Permit/ Regulatory Requirement	Jurisdiction	Point-of-Contact	Application Process Timeframe	Application Cost(s)	Permit/Regulatory Duration
U.S. Department of Interior Bureau of Ocean Energy Management (BOEM)	Courtesy Notification	Resources on the Outer Continental Shelf	Office of Public Affairs 1849 C Street, NW Washington, D.C. 20240 Phone: 202-208-6474 Olivia Woods Renewable Energy 202-531-0667 Olivia.Woods@Boem.gov	Courtesy notification recommended prior to the installation of the Project due to proximity to the Kitty Hawk Lease Area.	N/A	N/A
NOAA National Marine Fisheries Service (NOAA Fisheries)	Programmatic Level Consultation under Section 7 of the Endangered Species Act (ESA)	Exclusive Economic Zone (EEZ; 200 nautical miles from territorial sea baseline)	Southeast Regional Office 263 13th Ave South St. Petersburg, FL 33701 727-824-5301 David Bernhart Assistant Regional Administrator Protected Resources Division Email: David.bernhart@noaa.gov	Consultation conducted through the NWP (no further action required by WHOI)	N/A	Life of project.
	Programmatic Level Consultation under Marine Mammal Protection Act (MMPA)	EEZ (200 nautical miles from territorial sea baseline)	Southeast Regional Office 263 13th Ave South St. Petersburg, FL 33701 727-824-5301 David Bernhart Assistant Regional Administrator Protected Resources Division Email: David.bernhart@noaa.gov	Consultation conducted through the NWP (no further action required by WHOI)	N/A	Life of project.
	Programmatic Level Consultation under the Magnuson-Stevens Fishery Conservation Management Act (MSA)	The management of marine fisheries resources within the EEZ (200 nautical miles from territorial sea baseline)	Southeast Regional Office 263 13th Ave South St. Petersburg, FL 33701 727-824-5301 Virginia Fay Acting Deputy Regional Administrator Habitat Conservation Division Email: virginia.fay@noaa.gov	Consultation conducted through the NWP (no further action required by WHOI)	N/A	Life of project.

Permitting Agency	Name of Permit/ Regulatory Requirement	Jurisdiction	Point-of-Contact	Application Process Timeframe	Application Cost(s)	Permit/Regulatory Duration
U.S. Fish and Wildlife Service (USFWS)	Programmatic Level Consultation under Section 7 of the ESA	The conservation of terrestrial and freshwater species and habitats some marine mammal species including nesting sea turtles, walruses, polar bears, sea otter and manatees.	Southeast Regional Office U.S. Fish and Wildlife Service 1875 Century Boulevard Atlanta, GA 31830 (703) 358-2630	Consultation conducted through the NWP (no further action required by WHOI)	N/A	Life of project.
	Programmatic Level Consultation under the MMPA	Marine mammal species including walruses, polar bears, sea otter and manatees.	Southeast Regional Office U.S. Fish and Wildlife Service 1875 Century Boulevard Atlanta, GA 31830 (703) 358-2630	Consultation conducted through the NWP (no further action required by WHOI)	N/A	Life of project.
U.S. Environmental Protection Agency (EPA)	Spill Prevention Control and Countermeasures (SPCC) Plan	Regulation of pollutant discharges into U.S. waterways	Region 4 EPA Sum Nunn Atlanta Federal Center 61 Forsyth Street, SW Atlanta, GA 30303 Phone: 404-562-9900 Water Protection Division 404-562-9345	SPCC Plan not likely required, confirmation of liquids/oils/greases/etc. and amounts required to make final determination.	N/A	Life of project.
STATE						
North Carolina Division of Coastal Management	Courtesy Notification	3 nautical miles from shore	Daniel Govoni Federal Consistency Coordinator 400 Commerce Ave Morehead City, NC 28557 Phone: 252-515-5405 Email: daniel.govoni@ncdenr.gov	Approval through the NWP authorization. Courtesy notification recommended prior to the installation of the Project due to proximity to the Kitty Hawk Lease Area.	N/A	N/A
North Carolina Department of Environmental Quality - Division Water Resources	Section 401 Water Quality Certification	3 nautical miles from shore	N/A	Approval through the NWP authorization.	N/A	N/A

Appendix C: Desktop Study Mid-Atlantic Bight Pioneer Array

Desktop Study

Mid-Atlantic Bight Pioneer Array

December 2022

Prepared for

WOODS HOLE OCEANOGRAPHIC INSTITUTION
266 Woods Hole Road
Woods Hole, MA 02543-1050

Prepared by

TETRA TECH
117 Hearthstone Drive
Aiken, SC 29803

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Acronyms and Abbreviations

°C	degree Celsius
μPa	micropascal
ACPARS	Atlantic Coast Port Access Route Study
AIS	Automatic Identification System
AMAPPS	Atlantic Marine Assessment Program for Protected Species
ASMFC	Atlantic States Marine Fisheries Commission
AUV	autonomous underwater vehicle
AWOIS	Automated Wreck and Obstruction Information System
BMP	Best Management Practice
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
CGSN	Coastal and Global Scale Nodes
CWA	Clean Water Act
dB	decibels
DoD	Department of Defense
DPS	distinct population segment
EFH	essential fish habitat
EMF	electromagnetic fields
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FMC	Fishery Management Council
FMP	Fishery Management Plan
FR	Federal Register
GIS	geographic information system
GMFMC	Gulf of Mexico Fishery Management Council
GPS	Global Positioning System
HAPC	Habitat Areas of Particular Concern
HRG	high-resolution geophysical
Hz	hertz
IBA	Important Bird Area

kHz	kilohertz
km	kilometer
kV	kilovolts
L_{PK}	peak sound pressure levels
m	meter
m^2	square meter
MAFMC	Mid-Atlantic Fishery Management Council
mm	millimeter
MMPA	Marine Mammal Protection Act
MPA	Marine Protected Area
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NAAQS	National Ambient Air Quality Standards
NCDENR	North Carolina Department of Environment and Natural Resources
NCDEQ	North Carolina Department of Environmental Quality
NCDMF	North Carolina Division of Marine Fisheries
NCWRC	North Carolina Wildlife Resources Commission
nm	nautical mile
NOAA Fisheries	NOAA National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRHP	National Register of Historic Places
NSF	National Science Foundation
NWP	Nationwide Permit
OCS	Outer Continental Shelf
OOI	Ocean Observatories Initiative
OPAREA	at-sea Operating Area
PARS	Port Access Route Study
Project	the Pioneer Array coastal array currently located on the New England Shelf and proposed to be relocated to the Outer Continental Shelf off the coast of North Carolina in 2024
PTS	permanent threshold shift
RMS	root mean square
SAFMC	South Atlantic Fishery Management Council
SAV	submerged aquatic vegetation

SEL_{cum}	cumulative sound exposure levels
SMA	Seasonal Management Area
SPL RMS	root mean squared sound pressure level
Study Area	federal waters 13 nm to 45 nm offshore off the coast of Nags Head, North Carolina
Tetra Tech	Tetra Tech, Inc.
TTS	temporary threshold shift
U.S. Navy	U.S. Department of the Navy
U.S.C.	United States Code
UME	Unusual Mortality Event
USACE	U.S. Army Corps of Engineers
USCG	United States Coast Guard
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UXO	unexploded ordinances
WHOI	Woods Hole Oceanographic Institution

1.0 INTRODUCTION

Woods Hole Oceanographic Institution (WHOI) was selected by the National Science Foundation (NSF) to support the development, installation, and operation of the coastal and global components of the NSF's Ocean Observatories Initiative (OOI). The OOI consists of a globally distributed and integrated network of marine observation systems that provide the ocean sciences research community with an advanced research infrastructure to support sustained, long-term, and adaptive measurements of the oceans across global, regional, and coastal scales.

WHOI is currently responsible for the implementation and operation of one coastal scale array and two global scale arrays collectively referred to as the Coastal and Global Scale Nodes (CGSN) portion of the OOI program. The CGSN includes a coastal array called the Pioneer Array currently located in the federal waters of the Mid-Atlantic Bight off the coast of New England. In 2021, The NSF announced the relocation of the Pioneer Array from the New England Shelf to the Outer Continental Shelf (OCS) off the coast of North Carolina in the southern Mid-Atlantic Bight. The Pioneer Array is also referred to in this desktop study report as the Project.

The Pioneer Array is proposed to be relocated in the spring of 2024 to the shelf and slope offshore of the coast of Nags Head in North Carolina. The preliminary plan is for the moored array to be constituted in a sideways "T" shape, with seven mooring sites between about 13 nautical miles (nm) and 45 nm offshore, outside of state waters (**Figure 1-1 and Figure 1-2**).

The Pioneer Array will consist of:

- Three surface moorings (identified in Figure 1-1 as NSM, CSM, and SSM) with local power generation (wind turbines and solar panels), satellite communications capabilities, and benthic nodes;
- Five profiler moorings (identified in Figure 1-1 as NPM, NOPM, CPM, SOPM, and SPM) that would be internally powered (with primary and/or rechargeable batteries), three of the five would be located at the same site (within a few hundred meters) as a surface mooring;
- Two shallow-water moorings (identified in Figure 1-1 as SMW and SME) of a design similar to the surface moorings;
- Two autonomous underwater vehicles (AUVs) operated in campaign mode from ships; and
- Four to six buoyancy-driven ocean gliders.

The purpose of the desktop assessment is to document the existing conditions in the Study Area. This document will provide the existing conditions information for the Nationwide Permit (NWP) needed for the U.S. Army Corps of Engineers (USACE) NWP 5.

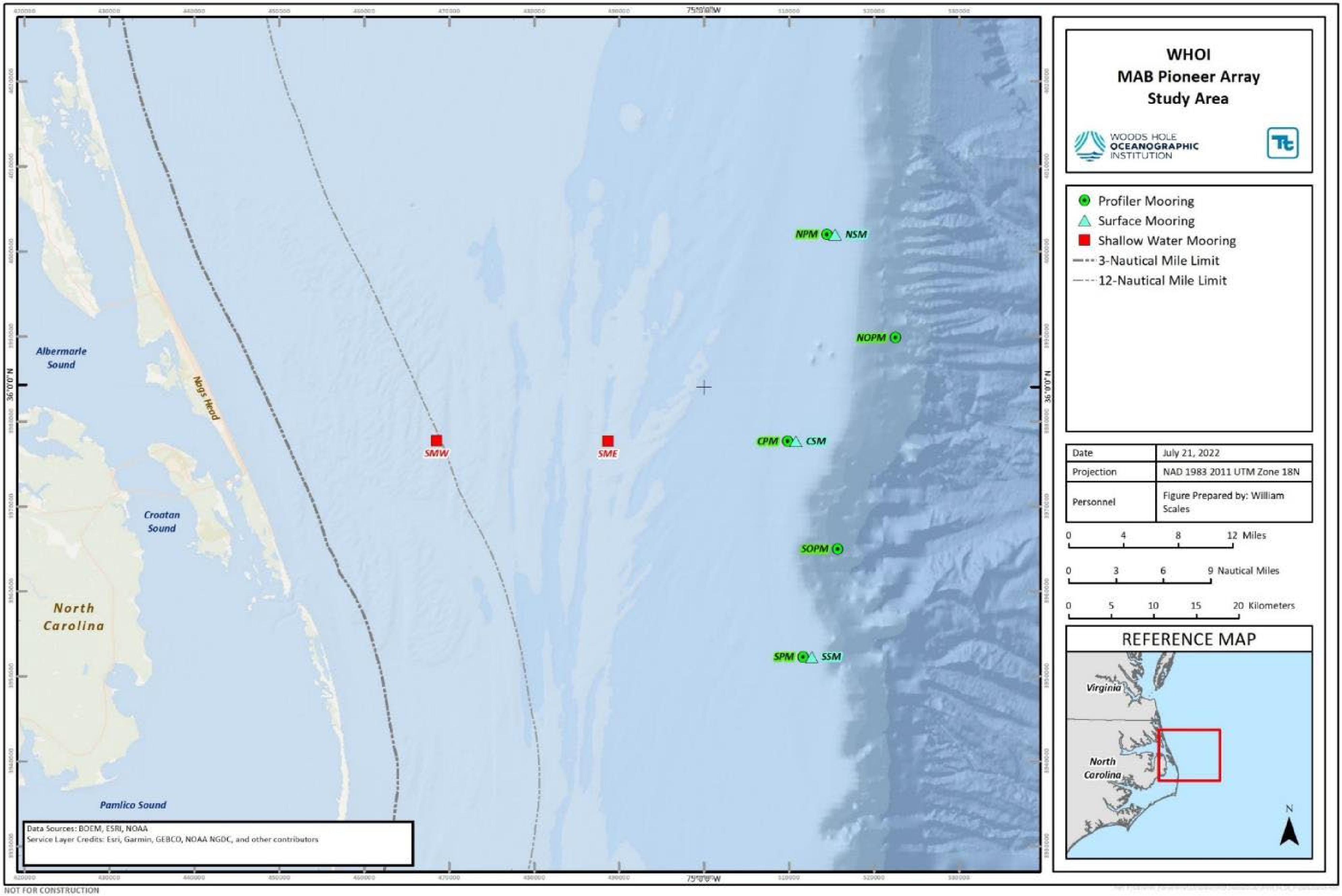

Figure 1-1. Study Area

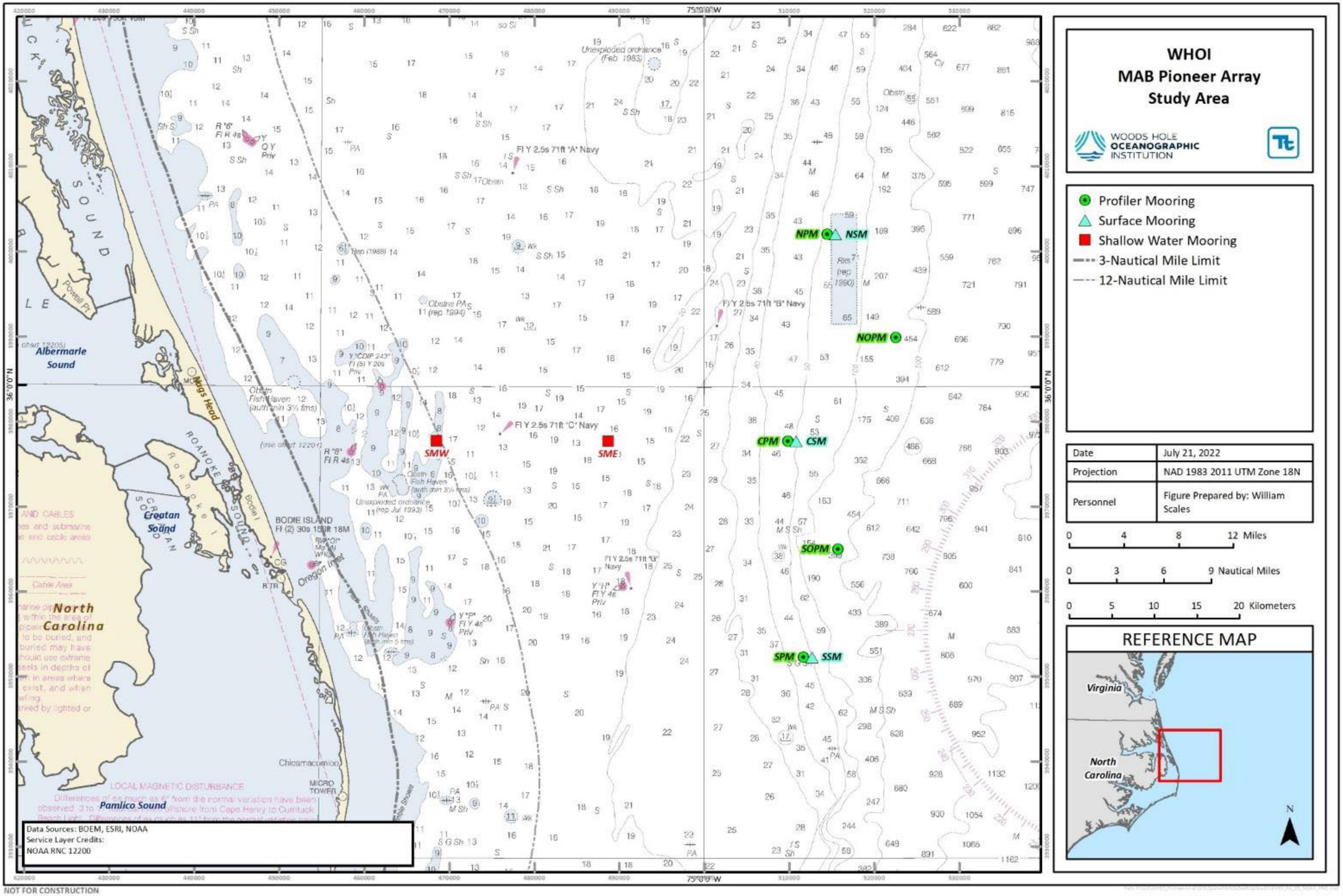

Figure 1-2. Pioneer Array on NOAA Chart

2.0 STUDY METHODOLOGY

Tetra Tech understands that WHOI is planning to relocate the Pioneer Array in the spring of 2024 between about 13 nm and 45 nm offshore off the coast of Nags Head, North Carolina (Study Area). Tetra Tech has evaluated this Study Area for the environmental resources and constraints based on publicly available data on topics and areas of concern. The purpose of the desktop environmental assessment is to document the existing conditions in the Study Area. This document will provide the existing conditions information for the USACE NWP 5 using desktop data, to be followed by a field study prior to deployment to confirm desktop findings. The following resources were used for the desktop study. Sources marked with ** were included in the figure setup but were not present in the data frame and were therefore left out of the map legend.

Biological:

- Artificial Reefs (NCDMF 2022a)
- Shell Bottom Habitat (NC OneMap)
- Submerged Aquatic Vegetation/Seagrass (Marine Cadastre (2019)
- Biologically Important Areas for Cetaceans (NOAA/Marine Cadastre 2015)
- Right Whale Seasonal Management Area (SMA) (NOAA/Marine Cadastre 2021)
- Critical Habitat (NOAA/ U.S. Fish and Wildlife Service [USFWS]/Marine Cadastre 2018)
- NAS/Important Bird Areas (National Audubon Society 2021)
- Coastal Critical Habitat (USFWS/Marine Cadastre 2018)**
- Wreck Diving Location (NC Wreck Diving)**

Military:

- Airports (BTS 2015) (includes Heliports)
- Danger Zones/Areas (NOAA/Marine Cadastre 2017)
- Operations Areas (U.S. Navy/Marine Cadastre 2019)
- Military Range Complex (Northeast Ocean Data 2016)
- Warning Area (Northeast Ocean Data 2016)
- Unexploded Ordinances (UXOs) (NOAA/Marine Cadastre 2018)
- Military Special Use Airspace (U.S. Navy/Marine Cadastre 2017)
- Military Coordinate Grid Area: Atlantic / Gulf of Mexico (U.S. Navy/Marine Cadastre 2017)
- Military Regulated Airspace (U.S. Navy/Marine Cadastre 2017)
- Unexploded Ordnance (FUDS) (NOAA/Marine Cadastre 2018)
- Department of Defense Exclusion Zone
- Submarine Transit Lane (U.S. Navy/Marine Cadastre 2018)**
- Radar Vector Area/Training Route Area/USMC Firing Area (NC Chapel Hill Study)**

Navigation:

- Ferry Routes (BTS 2022)
- Anchorage Area (NOAA/Marine Cadastre 2017)
- Maintained Channel (USACE/Marine Cadastre 2021)
- ACPARS Fairways (USCG 2022)
- Traffic Separation Schemes (TSS) (NOAA/Marine Cadastre 2015)**

Ocean Use:

- Ocean Disposal Sites (NOAA/Marine Cadastre 2022)
- Sand Borrow Areas/Sand Resources (USACE, BOEM, Florida Department of Environmental Protection's Regional Offshore Sand Source Inventory (ROSSI) 2021)
- BOEM Sand Lease Areas (BOEM 2021)
- Sand Resource Aliquots (BOEM 2021)
- Unexploded Ordnance Locations (NOAA/Marine Cadastre 2020)
- Unexploded Ordnance Areas (NOAA/Marine Cadastre 2020)**
- Anchorage Area (NOAA/Marine Cadastre 2017)**

Cultural Resources:

- Shipwrecks (Automated Wreck and Obstruction Information System [AWOIS]/Marine Cadastre 2009)
- Beach Access (NC DCM 2021) (Labeled "Beach" in map legend)
- Protected Areas Database of the United States (PAD-US 2.1 Data; USGS 2020)
- Historic Site (NCHPO 2021) (Labeled "Historic Resource" in map legend)
- Lighthouse (NCDCR 2021)
- NCHPO NR SL DOE Boundaries (NCHPO 2021)
- Wreck Diving Location (NC Wreck Diving)**
- Historic District (NCHPO 2021)**

Seafloor Sediment:

- USGS Seafloor Sediment (USGS 2005)
- US Submarine Canyons (BOEM 2019)
- World Seafloor Geomorphology (GRID Arendal 2015)
- Inlet Hazard Area (NC DCM 2019)**

Recreational Fishing:

- Artificial Reefs (NCDMF 2022a)
- Vessel Data (Northeast Ocean Data 2020)
- Fishing Pier (NCWRC 2021)**
- Wreck Diving Location (NC Wreck Diving)**

3.0 ENVIRONMENTAL RESOURCES

A summary of impacts to biological, physical, and human resources is provided below and includes a preliminary characterization of the resource within the Study Area.

3.1 Biological Resources

The following subsections provide an overview of the potential biological resources in the Study Area.

3.1.1 Benthic and Fisheries Resources

The benthic and fisheries resources discussion below includes, in some respects, commercial and recreational fisheries; however, desktop information is limited, and outreach to commercial and recreational fisheries entities has not been completed as part of this review. Some additional information regarding recreational fishing activities is also discussed in Section 3.3.6 Tourism and Recreation.

3.1.1.1 Preliminary Resource Characterization

The Study Area is located near the fluid boundary of the Mid-Atlantic Bight and the South Atlantic Bight at Cape Hatteras, North Carolina. The South Atlantic Bight extends from the Outer Banks of North Carolina south to the Florida Keys. The Mid-Atlantic Bight extends northward to Massachusetts. Benthic and fisheries species representative of both large ecosystem areas occur in the Project vicinity (Love and Chase 2007). Bottom habitat along the continental shelf is consistent with the Albemarle Self Valley Complex, with fine sand and mud overlaid with coarse sand that form surficial sand waves up to 3 meters (m) high (Swift et al. 1978). Depths along the Mid-Atlantic shelf averages approximately 25 m, becoming deeper eastward across the shelf to approximately 100 m before dropping dramatically across the slope break (Conley et al. 2017). The shelf is typically covered by a sheet of medium- to coarse-grained sands with occasional pockets of sand-shell and sand-gravel sediments (Wigley and Theroux 1981). Additional details on sediments are provided in Section 3.2.2, Geologic Conditions.

The softbottom macroinfaunal communities that dominate the Study Area have high species diversity but low densities because of unstable sediments, wide temperature fluctuations, and low nutrient and organic inputs. Many resident invertebrates are surface deposit or filter feeders with rapid generation times and high tolerances for intermittent and patchy nutrient inputs (BOEM 2014). Hardbottom substrates are heavily encrusted with sessile species (e.g., algae, barnacles, sponges, hydroids, anemones, bryozoans, bivalves, and tunicates) that provide structurally complex secondary habitat for resident invertebrate and finfish communities (BOEM 2014). Seagrass and shell bottom habitat, located well inshore of the Study Area, are shown in **Figure 3-1**. Details of artificial reefs are included in Section 3.1.4 Protected Habitats.

Across the North Carolina shelf, bottom water temperatures generally increase with depth, in contrast to the warm offshore waters that are influenced by the Gulf Stream. The maximum temperature gradient occurs from January to March when air temperatures are at their lowest. Water temperature throughout the North Carolina continental shelf are relatively uniform in the summer (Whitfield et al.

2014). Seasonal variations span up to 20 degrees Celsius (°C) at the surface and 12°C at the bottom of the water column (Guida et al. 2017). Thermal stratification begins in April, as ambient temperatures raise surface water temperatures, and increases until a maximum surface-to-bottom thermal gradient of up to 12°C is achieved in August (Guida et al. 2017). These fluctuations can trigger physiological and behavioral responses, such as inducing migratory behavior and gonadal development. As ocean temperatures increase, warm temperate species move in from the south. When water temperatures drop during winter, warm temperate species migrate southward and cold temperate species move northward (BOEM 2014).

Most marine organisms are neither wholly benthic nor wholly pelagic, but instead rely on the habitat continuum to support them throughout their lives. For example, Atlantic sea scallop eggs are fertilized in benthic habitats on the seafloor, then transform into planktonic larvae suspended in pelagic habitats. After drifting for 5 to 6 weeks and maturing from planktonic larvae into juveniles, these scallops settle back on benthic substrate to filter-feed on plankton, enrich the sediment with their waste, and release a new generation to repeat this cycle (Munroe et al. 2018). Together, benthic substrates and overlying pelagic waters provide supportive habitat for demersal and pelagic fish and invertebrates. These marine communities are supported by phytoplankton that thrive in the photic zone where nutrients are abundant. The coast of North Carolina is known for abundant phytoplankton sustained by nutrients drained into the region from river flow, tides, and currents, and carried to the surface by upwelling during seasonal turnover (Boicourt et al. 1987).

The demersal and pelagic habitats of North Carolina support approximately 600 fish species (BOEM 2014). BOEM and NOAA National Marine Fisheries Service (NOAA Fisheries) characterized fisheries resources within the Study Area as having few to no structure-forming fauna, notable differences in species assemblages and relative abundances between warm and cold seasons, and a relatively taxa-rich system (Guida et al. 2017). Dominant temperate reef fishes in this area include triggerfishes, jacks, grunts, wrasses, snapper/grouper, angelfishes, sea basses, porgies, and puffers (Bacheler et al. 2019).

Common fish families contributing to the demersal assemblages in the Mid-Atlantic Bight include drums, flounders, hakes, porgies, searobins, and skates. In the Study Area, managed demersal invertebrates and fish include the Atlantic surfclam, as well as the Atlantic croaker, black sea bass, flounders, hakes, searobins, scup, skates, smooth and spiny dogfish, and striped bass (NOAA Fisheries 2020a; Guida et al. 2017; BOEM 2014). Species aggregations form a gradient with respect to proximity to the coastline within the review area. Red and silver hakes, northern searobins, and summer and windowpane flounders may aggregate on the inner shelf (18 to 30 m); clearnose skates, little skates, and fourspot flounders may occur in intermediate shelf waters (30 to 50 m); and eels, hagfish, and pouts will likely be found on the outer shelf (50 to 100 m) (BOEM 2014; Love and Chase 2007).

Many coastal pelagic species in the Study Area (e.g., anchovies, bluefish, cobia, mullets, scup) are associated with structured bottom habitats but migrate in response to water column features (e.g., temperature, salinity, dissolved oxygen) and circulation. Atlantic menhaden, Atlantic mackerel, and small herrings are the dominant coastal pelagic forage species; these small shiny schooling fish tend to be short-lived, fast-maturing, and highly fecund, exhibiting wide variations in abundance (MAFMC 2017). Their species abundances may rise and fall asynchronously, and interannual variability in species recruitment can drive peaks in abundance for a given species unrelated to standing stock

(Bethony et al. 2016). Many species, including squid and butterfish, function as forage species while juveniles and as predators as adults.

Small coastal pelagic forage fish serve as an intermediate step to transfer energy from zooplankton to larger epipelagic predatory fish (e.g., jacks, sharks, swordfish, and tunas), which tend to be highly migratory (NOAA Fisheries 2017; BOEM 2014). These opportunistic predators are known to associate with natural and artificial flotsam, which provides foraging and nursery habitat. Yellowfin, blackfin, and skipjack tunas, for example, feed upon small fish attracted to *Sargassum* floats (Rudershausen et al. 2010; Casazza and Ross 2008; Moser et al. 1998). As many as 80 fish species, as well numerous invertebrates, are closely associated with floating *Sargassum* at some point in their life cycle. Floating *Sargassum* is designated as EFH for snappers, groupers, and coastal migratory pelagic species (68 Federal Register [FR] 192).

The Magnuson-Stevens Fishery Conservation Act (MSA) (16 U.S.C. §§ 1801-1882) established regional fishery management councils and mandated that Fishery Management Plan's (FMP) be developed to responsibly manage exploited fish and invertebrate species in U.S. federal waters. In the review area, species and stocks are managed by the North Carolina Marine Fisheries Commission, Atlantic States Marine Fisheries Commission (ASMFC), the South Atlantic Fishery Management Council (SAFMC), and the Mid-Atlantic Fishery Management Council (MAFMC). NOAA Fisheries' Highly Migratory Species Division is responsible for tunas, sharks, swordfish, and billfish (NOAA Fisheries 2017). Similarly, the SAFMC and the Gulf of Mexico Fishery Management Council (GMFMC) are responsible for coastal migratory pelagic species (e.g., king mackerel and Spanish mackerel).

Under the Sustainable Fisheries Act of 1996, Congress charged NOAA Fisheries with designating and conserving EFH for species managed under existing FMPs to minimize adverse effects and encourage conservation and enhancement of habitat caused by fishing or non-fishing activities (BOEM 2014). EFH may be defined as the waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity (16 U.S.C. § 1801(10)), where the term "necessary" indicates habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. Within the review area, EFH may be broadly typified as benthic habitat, including both seafloor habitats and the sediment-water interface, and pelagic habitat (NOAA Fisheries 2017; SAFMC 1998). In assigning specific substrate types, water depths, and foraging habitat as essential to managed species, EFH designations explicitly recognize the joint contributions of benthic and pelagic habitats.

Managed fish with designated EFH in the Study Area were identified using the online EFH Mapper (NOAA Fisheries 2022a). The 36 managed species that may occur seasonally or year-round in the review area are listed in **Table 3-1**.

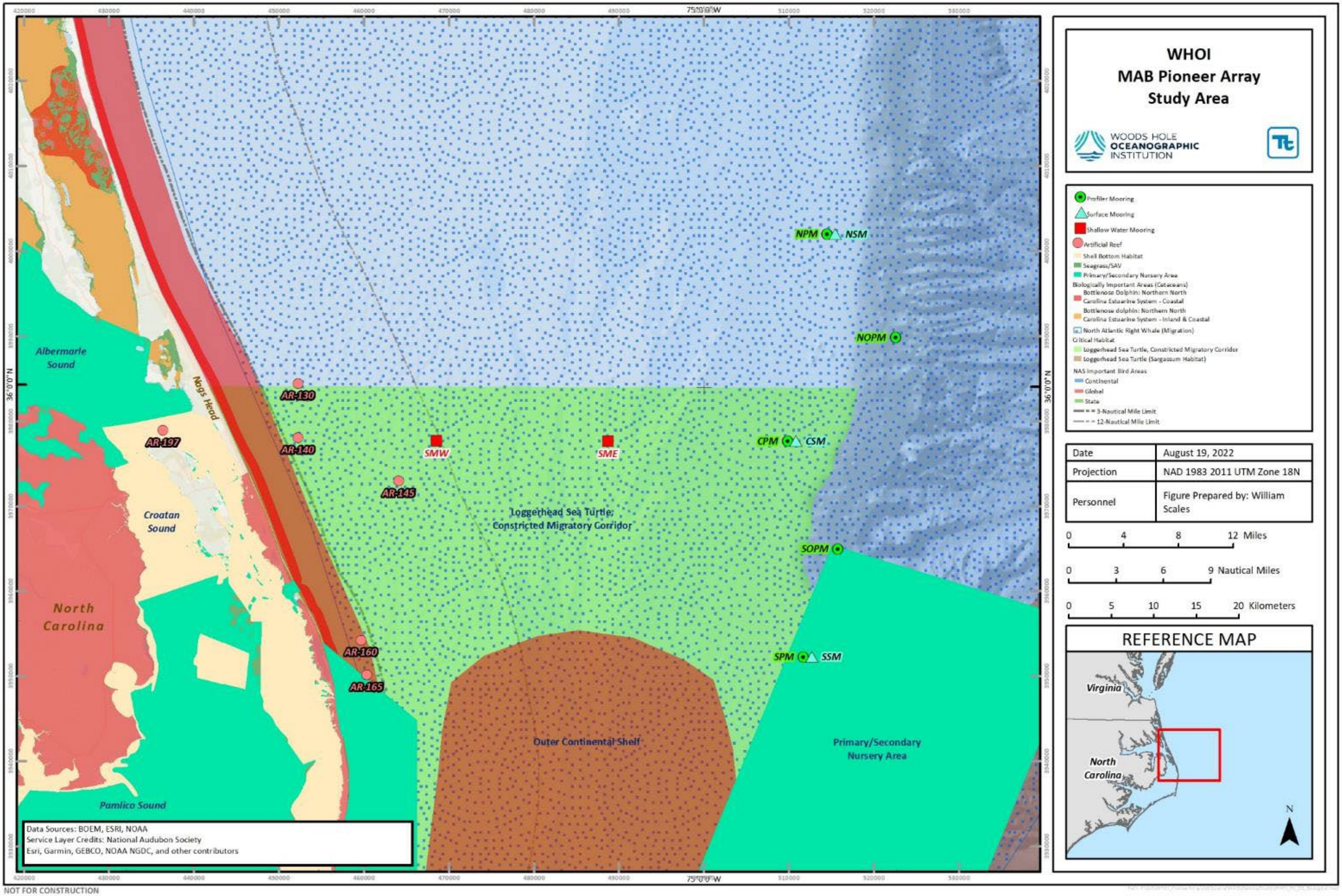

Figure 3-1. Biological Resources

Table 3-1. Managed Species with Designated EFH in the Study Area

Common Name	Scientific Name	Managing Fisheries Management Council	Lifestage(s) Found
Albacore Tuna	*Thunnus alalunga*	NOAA HMS	Adult, Juvenile
Atlantic Angel Shark	*Squatina dumeril*	NOAA HMS	All
Atlantic Butterfish	*Peprilus triacanthus*	MAFMC	Eggs, Adult, Juvenile
Atlantic Cod	*Gadus morhua*	NEFMC	Eggs, Larvae
Atlantic Mackerel	*Scomber scombrus*	MAFMC	Adult, Juvenile
Atlantic Sea Scallop	*Placopecten magellanicus*	NEFMC	All
Atlantic Sharpnose Shark	*Rhizoprionodon terraenovae*	NOAA HMS	Adult
Atlantic Surfclam	*Spisula solidissima*	MAFMC	Adult, Juvenile
Black Sea Bass	*Centropristis striata*	MAFMC	Adult, Juvenile, Larvae
Blue Shark	*Prionace glauca*	NOAA HMS	Adult, Juvenile
Bluefin Tuna	*Thunnus thynnus*	NOAA HMS	Adult, Juvenile, Spawning, Eggs, Larvae
Bluefish	*Pomatomus saltatrix*	MAFMC	Larvae
Clearnose Skate	*Raja eglanteria*	NEFMC	Juvenile
Common Thresher Shark	*Alopias vulpinus*	NOAA HMS	ALL
Dusky Shark	*Carcharhinus obscurus*	NOAA HMS	Adult, Juvenile
Longfin Inshore Squid	*Doryteuthis (Amerigo) pealeii*	MAFMC	Adult, Juvenile
Monkfish	*Lophius americanus*	NEFMC	Eggs/Larvae
Night Shark	*Carcharhinus signatus*	NOAA HMS	All
Northern Shortfin Squid	*Illex illecebrosus*	MAFMC	Adult, Juvenile
Sailfish	*Istiophorus albicans*	NOAA HMS	Adult, Juvenile
Sand Tiger Shark	*Carcharhinus taurus*	NOAA HMS	Adult
Sandbar Shark	*Carcharhinus plumbeus*	NOAA HMS	Adult, Juvenile, Neonate
Scalloped Hammerhead Shark	*Sphyrna lewini*	NOAA HMS	Adult, Juvenile
Scup	*Stenotomus chrysops*	MAFMC	Adult, Juvenile
Silky Shark	*Carcharhinus falciformis*	NOAA HMS	All
Skipjack Tuna	*Katsuwonus pelamis*	NOAA HMS	Adult, Juvenile
Smoothhound Shark Complex / Smooth Dogfish	*Mustelus canis*	NOAA HMS	All
Snapper Grouper	*Epinephelidae; Lutjanidae*	SAFMC	All
Spiny Dogfish	*Squalus acanthias*	MAFMC	Sub-Adult Female, Adult
Spiny Lobster	*Palinuridae*	SAFMC	All
Summer Flounder	*Paralichthys dentatus*	MAFMC	Adult, Juvenile
Tiger Shark	*Galeocerdo cuvier*	NOAA HMS	Adult, Juvenile, Neonate
Windowpane Flounder	*Scophthalmus aquosus*	NEFMC	All
Witch Flounder	*Glyptocephalus cynoglossus*	NEFMC	Larvae
Yellowfin Tuna	*Thunnus albacares*	NOAA HMS	Adult, Juvenile
Yellowtail Flounder	*Limanda ferruginea*	NEFMC	Larvae

The North Carolina Marine Fisheries Commission and the North Carolina Department of Environmental Quality (NCDEQ) Division of Marine Fisheries jointly manage fish and invertebrates within state waters, including shrimp and bay scallop. The North Carolina Fisheries Reform Act of 1997 requires the NCDEQ Division of Marine Fisheries to prepare FMPs for adoption by the North Carolina Marine Fisheries Commission for all marine and estuarine commercially and recreationally significant species. FMPs have been created for the bay scallop, blue crab, eastern oyster, estuarine striped bass, hard clam, kingfishes, red drum, river herring, sheepshead, shrimp, southern flounder, spotted sea trout, and striped mullet (NCDMF 2022b). No proposed Project structures are planned in state waters.

NOAA Fisheries has jurisdiction over two anadromous and three pelagic species federally protected under the Endangered Species Act (ESA) that may occur, but with no designated Critical Habitat, in the Study Area. The anadromous Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) is listed under the ESA as five distinct population segments (DPSs; one listed as threatened, the remaining four listed as endangered) (77 FR 24). Given its affinity for North Carolina waters, the Atlantic sturgeon is assumed to be present in the Study Area. Individuals from all DPSs migrate along the U.S. Atlantic Coast; therefore, all Atlantic sturgeon encountered in the Study Area are considered endangered. The anadromous shortnose sturgeon (*Acipenser brevirostrum*) is listed as endangered under the ESA (32 FR 48:4001). Since it rarely enters coastal waters beyond estuarine habitats, the shortnose sturgeon is not expected to occur in the Study Area. The pelagic giant manta ray (*Manta birostris*), oceanic whitetip shark (*Carcharhinus longimanus*), and Central and Southwest Atlantic DPSs of the scalloped hammerhead shark (*Sphyrna lewini*) are listed as threatened under the ESA (79 FR 128:38214-38242; 83 FR 14:2916-2931; 83 FR 20:4153-4165). While there is a low likelihood of these species transiting through the Study Area, it is virtually impossible to demonstrate absence of rare species within their historical ranges; therefore, these three species are assumed present in the Study Area.

3.1.1.2 Mitigation

As described above, the baseline characterization and assessment of potential impacts to benthic and finfish resources from installation and operation of a project in the Study Area may need to satisfy various federal requirements. No proposed Project structures are planned in state waters.

Existing and publicly available data sources do not provide sufficient site-specific coverage to adequately characterize baseline benthic, invertebrate, and finfish resources in the Study Area. Subsequent agency outreach and informal consultation is recommended to determine the need for site-specific benthic characterization surveys to identify sensitive habitats and fisheries resources in the Study Area in support of an Environmental Assessment. Tetra Tech recommends the following actions:

- Agency outreach via informal consultation with USFWS and NOAA Fisheries to establish formal written concurrence that Project activities will incur minimal to no adverse impacts to benthic and fisheries resources or habitats, and thus, the Project will not require more detailed site or species-specific studies or require agency consultation.
- Conduct communication and outreach with fishermen prior to siting as a courtesy in addition to the Local Notice to Mariners.

In addition to the above mitigations, resource agencies have established moratoria to protect species during critical life stages. These moratoria are from sampling data, known fish distribution, and known impacts to a fish or habitat from exposure to turbidity or sedimentation. NCDMF has regional moratoria for work in designated Primary Nursery Areas, or anadromous fish spawning and nursery areas. Similarly, the North Carolina Wildlife Resources Commission (NCWRC) has moratoria related to protected species like nesting sea turtles, and NOAA Fisheries has moratoria for anadromous fish. However, these do not apply as no Project moorings are located within state waters.

3.1.2 Marine Mammals and Sea Turtles

The following sections identify the resources present in the Study Area and mitigation needed to avoid and/or minimize impacts.

3.1.2.1 Preliminary Resource Characterization

The U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessment Reports (Hayes et al. 2021, 2022) provide a number of Atlantic species of marine mammals (whales, dolphins, porpoise, manatee, and seals) that may occur off the North Carolina coast. There are 36 species of marine mammals (7 large whales, 18 dolphins [including larger oceanic dolphin species], 1 porpoise, 5 beaked whales, 4 seals, and 1 manatee) that occur in the Southeast Atlantic OCS region, and all are protected by the Marine Mammal Protection Act (MMPA). Six of these species are additionally listed under the ESA as threatened or endangered and are known to be present, at least seasonally, in the Study Area.

NOAA Fisheries uses Marine Species Density Data Gap Assessments, developed by Roberts et al. (2021) and Duke/EC (2022), which built upon models originally developed by the U.S. Department of the Navy (U.S. Navy), to estimate marine mammal abundance (U.S. Navy 2007). The current estimates provided by Roberts et al. (2021) and Duke/EC (2022) are supplemented by data derived from several sources and independent studies and are used where feasible to update the species Stock Assessment Reports (Hayes et al. 2021, 2022). The Roberts et al. (2021) and Duke/EC (2022) data suggests that marine mammal density in the Mid-Atlantic region is patchy and seasonally variable. Currently, there are a number of Unusual Mortality Events (UMEs) that NOAA Fisheries has evaluated and declared (NOAA Fisheries 2022b). Under the MMPA, a UME is defined as "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response." Current UMEs include several of the species found in North Carolina including the North Atlantic right whale [right whale], humpback whale (*Megaptera novaeangliae)* minke whale (*Balaenoptera acutorostrata)*, harbor (*Phoca vitulina)* or gray seals (*Halichoerus grypus)* [nonactive, closure pending]) and West Indian manatee (*Trichechus manatus)*. Of these, the most relevant for this Study Area are UMEs affecting the right whale, minke whale, and humpback whale.

All 36 marine mammal species identified in **Table 3-2** are protected by the MMPA and some are also listed under the ESA. The six ESA-listed marine mammal species known to be present year-round or seasonally in the waters of the Mid-Atlantic are the right whale (*Eubalaena glacialis)*, fin whale (*Balaenoptera physalus),* sei whale (*Balaenoptera borealis*), blue whale (*Balaenoptera musculus)*, sperm whale (*Physeter macrocephalus)*, and the West Indian manatee. Four of the six ESA-listed species, the right, fin, sei, and sperm whale, have the likely potential to occur within the Study Area,

Table 3-2. Marine Mammals Known to Occur in the Marine Waters in Coastal Offshore North Carolina

Common Name	Scientific Name	Federal Status a/	Estimated Population	Stock	Likelihood of Occurrence/ Seasonality
Mysticetes (Baleen Whales)					
Balaenidae (Right and Bowhead Whales)					
North Atlantic Right Whale	*Eubalaena glacialis*	MMPA: Strategic ESA: Endangered	368	W. North Atlantic	Common/ Year-round
Humpback Whale	*Megaptera novaeangliae*	MMPA: Non-Strategic	1,396	Gulf of Maine	Common/ Year-round
Fin Whale	*Balaenoptera physalus*	MMPA: Strategic ESA: Endangered	6,802	W. North Atlantic	Common/ Year-round
Sei Whale	*Balaenoptera borealis*	MMPA: Strategic ESA: Endangered	6,292	Nova Scotia	Uncommon/ Winter/Spring/ Summer
Minke Whale	*Balaenoptera acutorostrata*	MMPA: Non-Strategic	21,968	Canadian East Coast	Common/ Year-round
Blue Whale	*Balaenoptera musculus*	MMPA: Strategic ESA: Endangered	Unknown	W. North Atlantic	Uncommon/ Year-round
Bryde's Whale	*Balaenoptera edeni*	MMPA Protected	Unknown	W. North Atlantic	Unknown
Odontocetes (Toothed Whales)					
Delphinidae (Dolphins)					
Atlantic Spotted Dolphin	*Stenella frontalis*	MMPA: Non-Strategic	39,921	W. North Atlantic	Common/ Year-round
Risso's Dolphin	*Grampus griseus*	MMPA: Non-Strategic	35,215	W. North Atlantic	Common/ Year-round
Long-Finned Pilot Whale	*Globicephala melas*	MMPA: Non-Strategic	39,215	W. North Atlantic	Common/ Year-round
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	MMPA: Non-Strategic	28,924	W. North Atlantic	Common/ Year-round
White-Sided Dolphin	*Lagenorhynchus acutus*	MMPA: Non-Strategic	93,233	W. North Atlantic	Uncommon/ Fall/Winter/Spring
White-Beaked Dolphin	*Lagenorhynchus albirostris*	MMPA: Non-strategic	536,016	W. North Atlantic	Uncommon/ Variable
Short- beaked Common Dolphin	*Delphinus delphis*	MMPA: Non-Strategic	172,974	W. North Atlantic	Common/ Year-round
Bottlenose Dolphin	*Tursiops truncatus*	MMPA: Non-Strategic	3,751	W. North Atlantic, Southern Migratory Coastal	Common/ Year-round
			62,851 b/	W. North Atlantic Offshore	Common/ Year-round
			823	N. North Carolina Estuarine System	Common/ Year-round
			Unknown	S. North Carolina Estuarine System Stock	Common/ Year-round
Clymene Dolphin	*Stenella clymene*	MMPA: Non-Strategic	4,237	W. North Atlantic	Extralimital/ Summer
Pan-Tropical Spotted Dolphin	*Stenella attenuata*	MMPA: Non-Strategic	6,593	W. North Atlantic	Uncommon/ Summer
Striped Dolphin	*Stenella coeruleoalba*	MMPA: Non-Strategic	67,036	W. North Atlantic	Uncommon/ Year-round

Common Name	Scientific Name	Federal Status a/	Estimated Population	Stock	Likelihood of Occurrence/ Seasonality
Spinner Dolphin	*Stenella longirostris*	MMPA: Non-Strategic	4,102	W. North Atlantic	Uncommon/ Year-round
Killer Whale	*Orcinus orca*	MMPA: Non-Strategic	Unknown	W. North Atlantic	Uncommon/ Year-round
False Killer Whale	*Pseudorca crassidens*	MMPA: Strategic	1,791	W. North Atlantic	Uncommon/ Variable
Melon-Headed whale	*Peponocephala electra*	MMPA: Non-Strategic	Unknown	W. North Atlantic	Uncommon/ Variable
Sperm Whale	*Physeter macrocephalus*	MMPA: Strategic ESA: Endangered	4,349	North Atlantic	Uncommon/ Year-round
Dwarf Sperm Whale	*Kogia sima*	MMPA: Non-Strategic	7,750 c/	W. North Atlantic	Uncommon/ Variable
Pygmy Sperm Whale	*Kogia breviceps*	MMPA: Non-Strategic	7,750 c/	W. North Atlantic	Uncommon/ Variable
Phocoenidae (Porpoises)					
Harbor Porpoise	*Phocoena phocoena*	MMPA: Non-Strategic	95,543	Gulf of Main/Bay of Fundy	Common/ Winter
Ziphiidae (Beaked Whales)					
Blainville's Beaked Whale	*Mesoplodon densirostris*	MMPA: Non-Strategic	10,107 d/	W. North Atlantic	Uncommon/ Spring/Summer
True's Beaked Whale	*Mesoplodon mirus*	MMPA: Non-Strategic	10,107 d/	W. North Atlantic	Uncommon/ Spring/Summer
Gervais' Beaked Whale	*Mesoplodon europaeus*	MMPA: Non-Strategic	10,107 d/	W. North Atlantic	Uncommon/ Spring/Summer
Cuvier's Beaked Whale	*Ziphius cavirostris*	MMPA: Non-Strategic	5,744	W. North Atlantic	Uncommon/ Spring/Summer
Sowerby's Beaked Whale	*Mesoplodon bidens*	MMPA: Non-Strategic	10,107 d/	W. North Atlantic	Uncommon/ Variable
Pinnipeds (Eared and Earless Seals)					
Phocidae (Earless Seals)					
Harbor Seal	*Phoca vitulina*	MMPA: Non-Strategic	61,336	W. North Atlantic	Common/ Fall/Winter/Spring
Gray Seal	*Halichoerus grypus*	MMPA: Non-Strategic	27,300	W. North Atlantic	Common/ Fall/Winter/Spring
Harp Seal	*Pagophilus groenlandicus*	MMPA: Non-Strategic	7,600,000	W. North Atlantic	Uncommon/ Winter/Spring
Hooded Seal	*Cystophora cristata*	MMPA: Non-Strategic	Unknown	W. North Atlantic	Extralimital/ Summer/Fall
Sirenia (Sea Cows)					
Trichechidae (Manatees)					
West Indian Manatee	*Trichechus manatus*	MMPA: Strategic ESA: Threatened	Unknown	Florida	Extralimital/ Variable

Notes:
a/ A strategic stock is defined as any marine mammal stock: 1) for which the level of direct human-caused mortality exceeds the potential biological removal level, 2) which is declining and likely to be listed as threatened under the ESA, or 3) which is listed as threatened or endangered under the ESA or as depleted under the MMPA (NOAA Fisheries 2019a).
b/ Estimates may include sightings of the coastal form.
c/ This estimate includes both the dwarf and pygmy sperm whales.
d/ This estimate includes Gervais' beaked whales and Blainville's beaked whales for the Gulf of Mexico stocks and all species of Mesoplodon in the Atlantic.
Sources: Hayes et al. 2021, 2022 (Draft NOAA Fisheries 2021 Stock Assessment Report (SAR); NOAA Fisheries 2022c, Pace et al. 2017, USFWS 2022b

based on the current knowledge of these species' occurrences and the overlap of project profiler and surface moorings within established Biologically Important Areas for cetaceans, **Figure 3-1**. The humpback whale is designated as non-strategic under the MMPA. The stock that inhabits the Mid-Atlantic region, which may occur year-round, was recently delisted as an endangered species (Hayes et al. 2021). Generally, many of these species are migratory, and as such, were historically thought to be present seasonally. However, they are increasingly seen foraging throughout the summer and fall months and in the winter during their migrations to warmer waters. Additionally, some individuals from the larger whale species (including right whales) are known to remain year-round (Hodge et al. 2015). Dolphins, especially bottlenose (*Tursiops truncatus)*, are known to be residents in estuarine regions (NOAA Fisheries 2014).

The Bryde's whale (*Balaenoptera edeni*) is not currently ESA-listed, and there is not enough information to estimate population trends for the Bryde's whale species as a whole. This species is designated as protected under the MMPA (Hayes et al. 2021). Other than a single stranding event in 2003, there are no confirmed NOAA Fisheries sightings of any type of Bryde's whale along the U.S. eastern seaboard between 1992 and 2019 (Rosel et al. 2021). Bryde's whales primarily have a restricted distribution with the majority of species sightings having occurred within the northeastern Gulf of Mexico (Waring et al. 2016). The West Indian manatee is listed as endangered under the ESA and is designated as strategic under the MMPA (Hayes et al. 2021). This manatee species has been sighted in North Carolina waters. However, such events are infrequent as this species cannot tolerate temperatures below 20°C for extended periods of time (USFWS 2022a), The potential for the Bryde's whale and West Indian manatee to occur within the Study Area is unlikely, therefore these species will not be described further in this analysis.

The offshore waters of North Carolina, including the Study Area, are primarily used as a migration corridor for many cetacean species, particularly by right whales, during seasonal movements north or south between important feeding and breeding grounds (Firestone et al. 2008; Knowlton et al. 2002). The right whale is considered one of the most critically endangered populations of large whales in the world and is listed as federally endangered under the ESA. The Western North Atlantic stock is considered strategic under the MMPA (Hayes et al. 2021). Right whales have been observed in coastal Atlantic waters year-round and have been acoustically detected off Georgia and North Carolina in 7 of 11 months monitored (Hodge et al. 2015). This species moves annually between high-latitude feeding grounds and low-latitude calving and breeding grounds. The current range of the western Atlantic right whale population includes two areas designated as Critical Habitat which are connected by a migratory corridor. As of January 26, 2016, NOAA Fisheries expanded the North Atlantic Right Whale Critical Habitat Southeastern U.S. Calving Area from below Cape Canaveral, Florida northward to Cape Fear, North Carolina; this Critical Habitat is utilized for wintering and calving (NOAA Fisheries 2019b, 2022d). The Critical Habitat Northeastern U.S. Foraging Area defines summer feeding and nursery grounds and is located between New England, the Bay of Fundy, and the Gulf of St. Lawrence (Kenney 2009; Hayes et al. 2021, NOAA Fisheries 2019b). The right whale migratory corridor connects the southern and northern Critical Habitat areas and there are additional zones along the coast that are designated as Seasonal Management Areas (SMAs) (NOAA Fisheries 2021). The Mid-Atlantic SMAs and designated Critical Habitat areas for right whales do not overlap with the Study Area. However, the offshore waters of North Carolina, including waters within the Study Area, are utilized by right whales, and are considered Biologically Important Areas for migration. Biologically Important Areas are designated by NOAA Fisheries with the input of specialists in order to identify areas where cetacean species or populations are known to concentrate for specific behaviors (NOAA Fisheries 2005; Hayes et al. 2021).

The fin whale is listed as endangered under the ESA and the Western North Atlantic stock is designated as strategic under the MMPA (Hayes et al. 2021). This species is the most commonly sighted large whale in continental shelf waters from the mid-Atlantic coast of the United States to Nova Scotia, principally from Cape Hatteras northward (NOAA Fisheries 2011). Fin whales are present in the Mid-Atlantic OCS region during all four seasons, although sighting data indicate that they are more prevalent during winter, spring, and summer (Hayes et al. 2021).

The sei whale is listed as endangered under the ESA, and the Nova Scotia stock is designated as strategic under the MMPA (Hayes et al. 2021). Sei whales occur in deep water characteristic of the continental shelf edge throughout their range (NOAA Fisheries 2012; Hayes et al. 2021). The sei whales' range is widespread encompassing the world's temperate, subpolar, subtropical, and tropical marine waters. NOAA Fisheries considers sei whales occurring from the U.S. East Coast to Cape Breton, Nova Scotia, and east to 42°W, as belonging to the "Nova Scotia stock" of sei whales (Hayes et al. 2021). Sei whales have been observed along the continental shelf and shelf edge waters around Cape Hatteras, North Carolina (NOAA Fisheries 2012).

The minke whale is not ESA-listed and the Canadian East Coast stock is listed by NOAA Fisheries as non-strategic under the MMPA (Hayes et al. 2021) Minke whales occur in the North Atlantic and North Pacific, from tropical to polar waters (Risch et al. 2019). Generally, they inhabit warmer waters during winter and travel north to colder regions in summer, while some animals migrate as far as the ice edge. They are frequently observed in coastal or shelf waters off the U.S. East Coast. Strandings of this species have been reported along the Cape Hatteras National Seashore (NOAA Fisheries 2022e).

The false killer whale (*Pseudorca crassidens*) is not ESA-listed and the Western North Atlantic stock is considered strategic under the MMPA (Hayes et al. 2021). False killer whales generally prefer offshore tropical to subtropical waters that are deeper than 3,300 feet. False killer whales have been sighted in U.S. Atlantic waters from southern Florida to Maine; however, these sightings are uncommon (NOAA Fisheries 2020b).

The Blainville's beaked whale (*Mesoplodon densirostris)*, True's beaked whale (*Mesoplodon mirus*), Gervais' beaked whale (*Mesoplodon europaeus)*, Cuvier's beaked whale (*Ziphius cavirostris)* and Sowerby's beaked whale (*Mesoplodon bidens)* are not ESA-listed and their Western North Atlantic stocks are designated as non-strategic under the MMPA (Hayes et al. 2021). For the relevant species of the *Mesoplodon* genus, sightings off the U.S. Atlantic coast have principally occurred along the shelf-edge and deeper oceanic waters including the continental shelf and shelf edge waters between Cape Hatteras, North Carolina and Nova Scotia (NOAA Fisheries 2004). The singular species of the *Ziphius* genus relevant to the Study Area is found worldwide in deep waters and have been sighted near the continental slope off the North Carolina coast. Particularly along the Gulf Stream area off Cape Hatteras which may potentially be year-round habitat for this genus (McLellan et al. 2018).

The blue whale is listed as endangered under the ESA and is designated as protected under the MMPA. Blue whales are considered an occasional visitor in U.S. Atlantic Exclusive Economic Zone waters, being generally more pelagic than most other whales (Hayes et al. 2021). A juvenile blue whale sighting from a survey vessel was the first photographic record of this species in the nearshore area (U.S. Navy Marine Species Monitoring 2018). It may be that prey availability, changing habitat from climate change, or other factors that are adjusting known distributions, are refining previous findings.

Sperm whales are listed as ESA endangered and the North Atlantic stock is designated as strategic by the MMPA. Sperm whales, including pygmy and dwarf species, are considered deep-water species. In the Northern Hemisphere, the peak breeding season occurs between March and June (NOAA Fisheries 2020c). Sperm whale distribution is typically associated with waters over the continental shelf break, the continental slope, and farther offshore, with higher concentrations near drop-offs and areas with strong currents and steep topography regardless of season (Whitehead et al. 1992; Jefferson et al. 2015; Hayes et al. 2021) Sperm whales have been known to concentrate off the North Carolina coast during winter months where calving grounds are believed to exist south of the Study Area around Cape Hatteras (NOAA Fisheries 2020c).

The harbor seal is not ESA-listed, and NOAA Fisheries considers the Western North Atlantic stock as non-strategic under the MMPA. Harbor seals are the most abundant seals in the waters of the eastern United States and are commonly found in all nearshore waters of the Atlantic Ocean from Newfoundland, Canada, southward to northern Florida. Winter haul-out sites for harbor seals have been identified within the Chesapeake Bay region and Outer Banks beaches; however, these seals are only occasionally sited as far south as the Carolinas (Hayes et al. 2021). The gray seal is not ESA-listed, and NOAA Fisheries considers the Western North Atlantic stock as non-strategic under the MMPA (Hayes et al. 2021). Until recently, coastal Virginia was thought to represent the southern extent of the habitat range for gray seals; however, rare sightings of gray seals have occurred along North Carolina beaches (Waring et al. 2016). Previously, data indicated that both harbor and gray seals prefer colder, northern waters; however, similar to shifts in cetacean occurrence, prey availability, or changing habitat from climate change or other factors could be driving changes in distribution of seals. More focused survey efforts for seals, such as the one presented in Jones and Dees (2020), are anticipated and may help refine and update previous findings. Both the harp and hooded seal are not ESA-listed, and NOAA Fisheries considers their Western North Atlantic stock as non-strategic under the MMPA. This stock of harp seal is generally found in more northern waters along the U.S. Atlantic coast; however, data suggests that abnormal environmental conditions likely account for the increase of sightings off North Carolina. The Western North Atlantic stock of hooded seals prefer deeper water and typically occurs farther offshore than harp seals with only extralimital strandings of this species reported off the southeast United States (Hayes et al. 2021).

The relevant stocks of harbor porpoises (*Phocoena phocoena*), Atlantic spotted dolphin (*Stenella frontalis)*, Risso's dolphin (*Grampus griseus*), long and short-finned pilot whale (*Globicephala spp.),* white-sided dolphin (*Lagenorhynchus acutus),* white-beaked dolphin (*Lagenorhynchus albirostris),* short-beaked common dolphin (*Delphinus delphis),* bottlenose dolphin, Clymene dolphin (*Stenella clymene)*, pan-tropical spotted dolphin (*Stenella attenuata),* striped dolphin (*Stenella coeruleoalba),* spinner dolphin (*Stenella longirostris),*killer whale (*Orcinus orca)* and melon-headed whale

(*Peponocephala electra)* are all non-ESA listed species with a non-strategic MMPA designation (Hayes et al. 2021).

The five species of sea turtle that have historically been reported to occur in Mid-Atlantic waters off the coast of North Carolina include the Atlantic hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*), Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), and loggerhead sea turtle (*Caretta caretta*). **Table 3-3** provides the known distributions within coastal North Carolina and the Study Area and a summary of key information for each species, all of which are listed as threatened or endangered under the ESA. Hawksbill sightings across North Carolina are rare, and since they are strongly affiliated with tropical environments, any occurrences in North Carolina should be considered extralimital (Finn et al. 2016; Sea Turtle.org 2022; STSSN 2022). Green, loggerhead, and Kemp's ridley turtles are the most abundant species to occur in North Carolina, while leatherbacks are observed annually in fewer numbers (Epperly et al. 1995; STSSN 2022). In 2014, NOAA Fisheries designated occupied marine areas within the Atlantic Ocean and the Gulf of Mexico as critical habitat for the Northwest Atlantic DPS of loggerhead turtle (**Figure 3-1**; 79 FR 128:38214-38242).

Table 3-3. Sea Turtles Known to Occur in the Marine Waters in Coastal Offshore North Carolina

Common Name	Scientific Name	Federal Status	Abundance a/	Known Distribution	Likelihood of Occurrence b/
Cheloniidae (Sea Turtles)					
Dermochelyidae (Leatherback Sea Turtles)					
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	34,00 – 94,000	Offshore, continental shelf and deeper	Uncommon/ Year-round
Cheloniidae (Hard-shelled Sea Turtles)					
Atlantic Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered	19,000	N/A	Extralimital/ Year-round
Green Sea Turtle (North Atlantic DPS)	*Chelonia mydas*	Threatened	215,000	Coastal, bays, estuaries, and inlets	Uncommon/ Year-round
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Endangered	248,300	Coastal, bays, estuaries, and inlets	Common/ Year-round
Loggerhead Sea Turtle (Northwest Atlantic DPS)	*Caretta caretta*	Threatened	588,000	Throughout: offshore, continental shelf and deeper; coastal, bays, estuaries, and inlets	Common/ Year-round

Sources: NOAA Fisheries 2015, 2019a, 2019c; NOAA Fisheries and USFWS 2009, 2013a, 2013b, 2015; TEWG 2007
Notes:
a/ Abundance estimates based on current nesting female and sex ratio estimates.
b/ Occurrence defined as: Common: occurrences are regularly documented, and the Study Area is generally considered within the typical range of the species.
Uncommon: occurrences are occasionally documented, and the Study Area is generally considered within the typical range of the species.
Extralimital: few occurrences have been documented and the Study Area is generally considered outside the typical range of the species; any occurrences would likely be of incidental individuals.

In North Carolina, sea turtles generally appear in late spring when water temperatures approach 20°C and leave in fall as water temperatures drop below 18°C (Barco and Lockhart 2016; Mansfield 2006). The Gulf Stream acts as a transportation vector for hatchlings that have departed their nesting beaches along the U.S. southeast coast (Putman et al. 2010). Juveniles use the Gulf Stream as overwintering habitat but may also occur nearshore in pursuit of macroalgae or submerged aquatic vegetation (SAV) and seagrass, as identified in **Figure 3-1**. North Carolina coastal and estuarine waters serve as important transitional foraging habitat for juvenile sea turtles in their migrations north to coastal developmental habitats or south to warmer water (Morreale and Standora 2005). The U.S. Mid-Atlantic Bight is prime foraging habitat for loggerhead sea turtles, one of North Carolina's most common sea turtle species, during the late-spring to summer months (NOAA Fisheries 2019c). The Study Area does not overlap with the loggerhead sea turtle Coastal Critical Habitat Designation (sargassum habitat), however, it does overlap with the loggerhead sea turtle Constricted Migratory Corridor encompassing profiler moorings CMP and SPM, surface moorings SSM and CSM and shallow-water moorings SME and SWM, as shown in **Figure 3-1**.

Sea turtles are found globally in tropical, sub-tropical, and temperate waters. They are long-lived, slow-growing reptiles that spend their lives in the ocean in two distinct life stages: a pelagic (offshore) stage and a neritic (nearshore to the continental shelf break) stage (Barco and Swingle 2014). Hatchlings begin their pelagic stage by drifting in convergence zones or sargassum rafts offshore and feeding on pelagic invertebrates (Witherington et al. 2012). As they mature into juveniles, they enter their neritic (relatively shallow, coastal waters) stage and transition from surface to benthic feeding and forage for crustaceans, mollusks, sponges, coelenterates, fish, and seagrasses. Adults migrate thousands of kilometers between nesting beaches, mating areas, nursery habitats, and feeding grounds to satisfy reproductive and foraging needs (Lohmann and Lohmann 2010). Cheloniid sea turtle (hard-shelled species that exclude leatherbacks) migrations are influenced by changes in ocean currents, food availability, reproductive requirements, and water temperatures (Musick and Limpus 1997). Water temperatures play a crucial role in dictating seasonal movements, since these species often become lethargic at temperatures below 10°C and risk becoming cold-stunned. Leatherbacks exhibit a wider geographic range and more variable movements due to their ability to maintain warm body temperatures in temperate waters and cool body temperatures in tropical waters (Barco and Swingle 2014).

Based on the known areas of occurrence, sea turtles are likely to occur in the offshore Study Area, but given the absence of terrestrial project parameters, no onshore impacts are expected for sea turtles. However, onshore strandings, particularly those associated with cold stunning, are initiated in offshore waters. Annual sea turtle strandings across North Carolina may number in the hundreds (Niemuth et al. 2020; STSSN 2022). Strandings are defined as events in which sea turtles wash ashore entangled, sick, injured, or dead; records of such events may be used to indicate seasonal trends in presence (NCWRC 2022a,b). Sea turtles may also strand due to cold stunning in winter months. Cold stunning is a hypothermic reaction that occurs in response to prolonged cold-water temperatures (typically under 10°C) and may manifest as decreased heart rate, decreased circulation, lethargy, shock, pneumonia, and possibly death. Juvenile loggerheads and Kemp's ridley turtles are most likely to suffer from such events in the Study Area (Barco and Lockhart 2016; Niemuth et al. 2020). Based on multi-decadal stranding data, green and Kemp's ridley turtles may be observed year-round in North Carolina. Loggerheads are present from May through October, while leatherbacks peak from May to July (STSSN 2022; NCWRC 2022a).

In North Carolina, loggerhead, green, leatherback, and Kemp's ridley sea turtle nest recordings are ongoing for 2022, with loggerhead nests being the most common (**.**

Table 3-4). Two nests were also laid by a hawksbill sea turtle in 2015 (Sea Turtle.org 2022; Finn et al. 2016). The two hawksbill sea turtle nests are unusual in that they are the only ones documented this far north.

Table 3-4. Sea Turtle Nests in North Carolina (January 1, 2022 – August 8, 2022)

Beach	Loggerhead	Green	Leatherback	Kemp's Ridley	Total
Atlantic Beach	4	1	0	0	**5**
Bald Head Island	132	0	0	0	**132**
Cape Hatteras National Seashore	334	10	1	1	**346**
Cape Lookout National Seashore	406	5	1	3	**415**
Carolina Beach	11	0	0	0	**11**
Caswell Beach	92	1	1	0	**94**
Emerald Isle	29	0	0	1	**30**
Figure 8 Island	9	0	0	0	**9**
Fort Fisher State Recreation Area	127	1	0	0	**128**
Fort Macon State Park	5	0	0	0	**5**
Hammocks Beach State Park	19	0	0	0	**19**
Holden Beach	62	0	0	0	**62**
Indiana Beach/Salter Path	9	0	0	0	**9**
Kure Beach	5	0	0	0	**5**
Lea-Hutaff Island	14	0	0	0	**14**
Masonboro	68	5	0	0	**73**
Northern Outer Banks	34	2	0	2	**38**
Oak Island	134	0	1	0	**135**
Ocean Isle Beach	36	0	0	0	**36**
Onslow Beach	87	0	0	0	**87**
Pea Island National Wildlife Refuge	46	2	0	0	**48**
Pine Knoll Shores	12	0	0	0	**12**
Sunset Beach plus Bird Island	20	0	0	0	**20**
Topsail Island	106	2	0	0	**108**
Wrightsville Beach	2	0	0	0	**2**
Total	**1,803**	**29**	**4**	**7**	**1843**

3.1.2.2 Mitigation

The potential impacts to marine mammal and sea turtle species from installation and operation of a project in the Study Area must fulfill federal requirements. Based on Tetra Tech's Pioneer Array Regulation Study (June 2022), consultation with the USACE determined that the Project is subject to NWP 5 for Scientific Measurement Devices. Authorization of the NWP 5 additionally satisfies NOAA consultation requirements including those outlined by NOAA Fisheries for living marine resources within the Exclusive Economic Zone. As such, no Incidental Harassment Authorization or Letter of Authorization is required for the anchoring and operating of the Pioneer Array (Laws 2022).

USFWS activities include the identification of threatened and endangered species and issuance of permits for activities affecting protected species and their habitats (50 CFR 1 through 100). The USFWS manages land and freshwater species, while NOAA Fisheries manages marine species; however, the USFWS has responsibility for some marine animals such as nesting sea turtles and manatees.

Based on this desktop study of publicly available data, there is potential for ESA-protected marine mammal and sea turtle species to occupy or navigate the waters and aquatic habitats surrounding the Study Area. Due to the small scale and temporary nature of the proposed Project activities, the limited use and speed (1 to 2 knots for mooring deployment) of vessels for array anchoring and maintenance (vessel strikes), the rigidity of the mooring cables (entanglement), and the slow speeds of the associated gliders (about 0.5 knot) and AUVs (about 3.5 knots), the proposed Project activities are not likely to adversely affect relevant marine mammal or turtle species.

A protected species habitat assessment or survey may be recommended by USFWS or NOAA Fisheries to further support the desktop study findings of marine mammals and sea turtles in the Study Area. Six of the Project's moorings are sited within the loggerhead sea turtle Constricted Migratory Corridor. NWP 5 does not authorize any activity that may directly or indirectly jeopardize the continued existence of an ESA threatened or endangered species or their habitat, or any activities that may affect a listed species or its critical habitat without Section 7 consultation. In order to comply with USFWS consultation under Section 7 of the ESA, Tetra Tech recommends subsequent agency outreach via informal consultation with USFWS and NOAA Fisheries to establish written concurrence that Project activities will incur minimal to no adverse impacts to protected marine species or their habitat, and thus, the Project will not require a more detailed protected species habitat assessment/survey or require formal agency consultation.

Furthermore, it is Tetra Tech's understanding that moorings, gliders, and AUVs employed by the Project pose little risk for entanglement or vessel strikes concerns to both marine mammals and sea turtles. Vessel transiting to and from the Study Area are responsible for adhering to the published NOAA Fisheries procedures outlined by the NOAA Vessel Strike Avoidance Guidelines.

3.1.3 Avian and Bat Species

The following sections identify the resource present in the Study Area and mitigation needed to avoid impacts.

3.1.3.1 Preliminary Resource Characterization

The Study Area is located along the Atlantic Coast of North Carolina and within the Marine Bird Conservation Region M19 (USFWS 2021a) where associated OCS waters support a large diversity of birds, including waterfowl, pelagic seabirds, shorebirds, wading birds, and raptors (**Table 3-5**).

The Study Area is located within the Atlantic Flyway, one of four major North American north-south migration routes for many species of seabirds, shorebirds, waterfowl, raptors, and songbirds (Audubon 2022a). The Atlantic Flyway essentially runs along the Atlantic Coast of North America and includes U.S. states and Canadian provinces that span the route from Canada to Central America, South America, and the Caribbean. Coastal and marine environments along the Atlantic Flyway provide important habitat and food resources for hundreds of avian species at stop-over sites, breeding locations, and wintering areas (Menza et al. 2012). Coastal habitats provide nesting and foraging habitats for seasonal and year-round residents. Some birds, such as shorebirds, are generally restricted to coastline margins except when migrating. Coastal and adjacent inland wetlands may

Table 3-5. Bird Species Likely to Occur Within the Study Area

Common Name	Scientific Name	Federal Status a/	State Status a/	Species-Habitat Associations b/	Likelihood of Occurrence c/
Dabblers, Geese, and Swans					
Blue-winged teal	*Anas discors*	MBTA	--	Coastal waters and freshwater wetlands	Unlikely
Grebes					
Pied-billed grebe		--	--	Coastal and freshwater wetlands	Unlikely
Rails					
King rail	*Rallus elegans*	BCC	--	Marshlands	Unlikely
Virginia rail	*Rallus limicola*	--	--	Marshlands	Unlikely
Black rail	*Laterallus jamaicensis*	T	SC	Marshlands	Unlikely
Shorebirds					
American oystercatcher	*Haematopus palliatus*	BCC, MBTA	SC	Coastal beaches, dunes, and saltwater marshlands	Unlikely
Wilson's plover	*Charadrius wilsonia*	BCC, MBTA	SC	Coastal beaches, dunes, and saltwater marshlands	Unlikely
Piping plover	*Charadrius melodus*	T, MBTA	E	Coastal beaches, dunes, and saltwater marshlands	Unlikely
Red knot	*Calidris canutus*	T, MBTA	ST	Migrant and rare winter resident; Coastal beaches, dunes, and saltwater marshlands	Unlikely
Auks					
Razorbill	*Alca torda*	--	--	Coastal and pelagic waters	Low
Terns					
Black skimmer	*Rynchops niger*	BCC	SC	Coastal waters and beaches	Moderate
Least tern	*Sternula antillarum*	BCC	SGCN, SC	Coastal waters and beaches	Moderate
Black tern	*Chlidonias niger*	--	--	Coastal and inlet bays; saltwater marshlands	Moderate
Sooty tern	*Onychoprion fuscatus*	--	--	Coastal waters and beaches	Moderate
Roseate tern	*Sterna dougallii*	E, MBTA	E	Coastal waters and beaches	Moderate
Common tern	*Sterna hirundo*	--	SGCN	Coastal waters and beaches	Moderate
Forster's tern	*Sterna forsteri*	--	SGCN	Coastal waters and beaches	Moderate
Gull-billed tern	*Gelochelidon nilotica*	BCC	T	Coastal waters and beaches	Moderate
Royal tern	*Thalasseus maximus*	--	SGCN	Coastal waters and beaches	Low

Common Name	Scientific Name	Federal Status a/	State Status a/	Species-Habitat Associations b/	Likelihood of Occurrence c/
Caspian tern	*Hydroprogne caspia*	--	--	Coastal waters and beaches	Low
Loons					
Red-throated loon	*Gavia stellata*	BCC	SGCN	Coastal and pelagic waters	Low
Common loon	*Gavia immer*	--	--	Coastal and pelagic waters	Low
Fulmars, Shearwaters, and Petrels					
Cory's shearwater	*Calonectris diomedea*	BCC	--	Coastal and pelagic waters	High
Manx shearwater	*Puffinus*	BCC	--	Pelagic waters	High
Audubon's shearwater	*Puffinus lherminieri*	BCC	--	Pelagic waters	High
Black-capped petrel	*Pterodroma hasitata*	BCC	--	Pelagic waters	High
Fea's petrel	*Pterodroma feae*	BCC	--	Pelagic waters	High
Storm-petrels					
Wilson's storm-petrel	*Oceanites oceanicus*	--	--	Pelagic waters	High
Band-rumped storm-petrel	*Oceanodroma castro*	BCC	--	Pelagic waters	High
Pelicans					
Brown pelican	*Pelecanus occidentalis*	--	--	Coastal waters	High
Raptors					
Bald eagle	*Haliaeetus leucocephalus*	BGEPA, MBTA	T, SGCN	Any saltwater and freshwater; woodland edges	Low

Sources: USFWS 2021a,b, 2022c, NCWRC 2015, 2020, NCNHP 2022
a/ E = Endangered; T = Threatened; SC = Special Concern, SGCN = Species of Greatest Conservation Need, BCC = Bird of Conservation Concern, BGEPA = Bad and Golden Eagle Protection Act, MBTA = Migratory Bird Treaty Act
b/ Habitat Association based on general species habitat preference for breeding and migration (NCWRC 2015).
c/ Likelihood of Occurrence: Unlikely– no species range overlap with Study Area or unsuitable habitat in Study Area or rare observation during migration; **Low**– species range overlaps with Study Area and marginally suitable habitat in PSN Area; Moderate– species range overlaps with Study Area and suitable habitat present in Study Area, or species known to occur in habitat similar to Study Area; High–highly suitable habitat present in Study Area, or known populations exist in Study Area.

serve as important habitats for overwintering, and as temporary feeding and resting habitats for migrating birds.

There are 17 species of bats known to occur in North Carolina, where 4 of those species are federally listed and 7 are state listed (**Table 3-6**). These species can be divided into two major groups based on their wintering strategy: cave-hibernating bats and migratory tree bats (Fleming 2019). Both groups of bats are nocturnal insectivores that use a variety of forested and open habitats for foraging during the summer (Barbour and Davis 1969). Cave-hibernating bats are generally not observed offshore (Dowling and O'Dell 2018); in the fall, these bats migrate from summer habitat to winter hibernacula in the mountain and foothill regions of the state (LeGrand et al. 2020). In contrast, migratory tree bats generally fly to southern parts of the United States to overwinter (Cryan 2003), with some present year-round in North Carolina (LeGrand et al. 2020, Timpone et al. 2011), and sightings have been documented offshore in the vicinity of the proposed project (Solick and Newman 2021; Peterson et al. 2016). Bat migration over the ocean has been documented to occur typically in the autumn months, with most sightings occurring during the day and where the migration route is observed to occur over a relatively wide area (Solick and Newman 2021; Peterson et al. 2016). There are records of migratory tree bats being observed offshore, and results of acoustic bat surveys completed near Bodie Island, North Carolina, and within proximity to the Study Area (Peterson et al. 2016), identified the presence of eastern red bats, tricolored bats, hoary bats, and silver-haired bats within 7.8 nm of the coast.

Table 3-6. Bat Species Likely to Occur in the Study Area

Common Name	Scientific Name	Federal Status a/	State Status a/	Species-Habitat Associations b/	Likelihood of Occurrence c/
Cave-Hibernating Bats					
Eastern small-footed bat	*Myotis leibii*	--	SC	Woodlands and forests	Unlikely
Little brown bat	*Myotis lucifugus*	--	--	Woodland and urban environments	Unlikely
Northern long-eared bat	*Myotis septentrionalis*	T	T	Woodlands and forest	Unlikely
Indiana bat	*Myotis sodalis*	E	E	Woodlands and forests	Unlikely
Gray bat	*Myotis grisescens*	E	E	Woodlands and forests	Unlikely
Southeastern myotis	*Myotis austroriparius*	--	SC	Woodlands and forests	Unlikely
Tri-colored bat	*Perimyotis subflavus*	--	--	Woodlands and forests	Unlikely
Big brown bat	*Eptesicus fuscus*	--	--	Woodland and urban environments	Unlikely
Rafinesque's big-eared bat	*Corynorhinus rafinesquii*	--	--	Woodland and urban environments	Unlikely
Virginia big-eared bat	*Corynorhinus townsendii virginianus*	E	E	Woodland and urban environments	Unlikely
Brazilian free-tailed bat	*Tadarida brasiliensis*	--	--	Woodland and urban environments	Unlikely
Migratory Tree Bats					
Evening bat	*Nycticeius humeralis*	--	--	Woodlands and forests	Unlikely
Eastern red bat	*Lasiurus borealis*	--	--	Woodlands and forests	Low
Seminole bat	*Lasiurus seminolus*	--	--	Woodlands and forests	Unlikely

Common Name	Scientific Name	Federal Status a/	State Status a/	Species-Habitat Associations b/	Likelihood of Occurrence c/
Hoary bat	*Lasiurus cinereus*	--	--	Woodlands and forests	Low
Silver-haired bat	*Lasionycteris noctivigans*	--	--	Coniferous woodlands and forests	Low
Northern yellow bat	*Lasiurus intermedius*	--	SC	Woodlands and forests	Unlikely

Sources: NCWRC 2015, 2020; LeGrand et al. 2020; USFWS 2021a
a/ E = Endangered; T = Threatened; SC = Special Concern
b/ Habitat Association based on general species habitat preference for breeding and migration (NCWRC 2015).
c/ Likelihood of Occurrence: Unlikely– no species range overlap with Study Area or unsuitable habitat in Study Area; Low– species range overlaps with Study Area and marginally suitable habitat in Study Area; Moderate– species range overlaps with Project area and suitable habitat present in Study Area, or species known to occur in habitat similar to Study Area; High–highly suitable habitat present in Study Area, or known populations exist in Study Area.

3.1.3.2 Mitigation

The Project is not anticipated to significantly affect avian and bat populations. Surface buoys will consist of buoyant, non-compressible materials with metal platforms to support sensors and satellite/radio transmitters that may provide roosting or stopover habitat for avian or bat species migrating through the area but are expected to pose little to no risks to the species, as compared to other large off-shore projects that have been documented to affect migratory birds and bats through noise and artificial lighting stressors, habitat alteration, displacement, and collisions (USFWS 2022d). The buoys will consist of a low profile on the water's surface with little to no noise emissions and will be constructed and operated in compliance with USCG requirements for lighting, while using lighting technology that minimizes impacts on avian and bat species to the extent practicable. Any dead or injured birds or bats found on or near the Project during array deployment operations or routine maintenance should be reported to the USFWS. Any birds found with federal bands should be reported to the United States Geological Survey (USGS) Bird Band Laboratory.

3.1.4 Protected Habitats

Protected coastal and marine habitats provide refuge for resident and transient species of fishes, invertebrates, marine mammals, sea turtles, and birds in North Carolina. The protected habitats identified in this section occur from the intertidal zone to open ocean and include marshes, estuaries, complex nearshore habitats, and offshore benthic and pelagic habitats within and in the vicinity of the Study Area.

Coastal protected habitats in tidal and state waters within 3 nm (5.6 kilometers [km]) of shore are under the jurisdiction of the State of North Carolina. NCDEQ manages coastal habitats such as wetlands and administers the Coastal Area Management Act under the Clean Water Act (CWA) (15A NCAC 07H .0100). NCDMF regulates fishing practices in coastal waters, including management of SAV (15A NCAC 03I .0101), artificial reefs (15A NCAC 03I .0109), and Fishery Nursery Areas (15A NCAC 03N .0104). NCDMF and the NCWRC jointly manage anadromous fish spawning (15A NCAC 10C .0603) and management areas (15A NCAC 03R .0201). The North Carolina Department of Environment and Natural Resources (NCDENR) manages Marine Protected Areas (MPAs) and may co-manage certain MPAs with NOAA Fisheries (MPA Executive Order 13158). However, no proposed Project structures are planned to be located in state waters.

At the federal level, impacts to protected habitats are regulated under various federal laws. Regional Fisheries Management Councils (FMCs) designate Habitat Areas of Particular Concern (HAPC) as sub-categories of EFH under the MSA. NOAA Fisheries establishes North Atlantic right whale SMAs and administers them under the ESA and MMPA. The National Audubon Society establishes and protects Important Bird Areas (IBAs) for species listed as threatened or endangered under the ESA.

The following sections identify the resource present in the Study Area and mitigation needed to avoid impacts.

3.1.4.1 Preliminary Resource Characterization

Artificial Reefs. Hard bottom is defined as exposed areas of rock or consolidated sediments, distinguished from surrounding unconsolidated sediments, which may or may not be characterized by a thin veneer of live or dead biota (NCDEQ 2016). In addition to areas of natural hard bottom, man-made structures, including artificial reefs and shipwrecks, provide substrata for the development of hard bottom communities. Artificial reef habitats are considered crucial spawning and foraging habitat for the state's commercially and recreationally important fisheries. NCDMF maintains 43 offshore and 25 estuarine artificial reefs. Due to their high habitat value, NCDMF may prohibit or restrict the use of any equipment in and around any artificial reef (15A NCAC 03I .0109; NCOAH 2022). Several artificial reefs are in the vicinity of the Study Area, including AR-130, -140, -145, -160, and -165 (**Figure 3-1;** NCDMF 2022a). Artificial reef AR-197 is located within Croatan Sound, where no Project structures will be located (NCDMF 2022a).

Fishery Nursery Areas. NCDMF administers the Fishery Nursery Area Program (15A NCAC 03N .0104; NCOAH 2022). Fishery Nursery Areas are defined as areas in which young finfish and crustaceans spend a major portion of their first growing season. Compared to other coastal habitats, Fishery Nursery Areas support greater contributions of juveniles to adult recruitment because they provide protection, foraging opportunities, and suitable environmental conditions for growth, development, and survival during early life history (NOAA Fisheries 2019d). Primary Nursery Areas are those areas in the estuarine system where initial post-larval development takes place. These are areas where populations are uniformly early juveniles. Secondary Nursery Areas are those areas in the estuarine system where later juvenile development takes place. Populations are composed of developing sub-adults of similar size that have migrated from upstream Primary Nursery Areas. The southern mooring locations for SOPM, SPM and SSM are sited within a Primary/Secondary Nursery Habitat east of Oregon Inlet (**Figure 3-1**). To protect sensitive life stages, NCDMF has established moratoria for coastal alteration projects in Nursery Areas. No excavation or filling activities are permitted between April 1 and September 30 within any designated Fishery Nursery Area, however, as no excavation or fill activities are associated with the Project, this restriction is not applicable.

Critical Habitat. Under 50 CFR § 226.223, Critical habitat has been established for the Northwest Atlantic Ocean DPS of the loggerhead sea turtle. Critical habitat is designated by the Secretary of Commerce, under Section 4 of the ESA, for endangered and threatened species. Critical habitat designations do not create preserves or refuges or affect land ownership, and only result in restrictions on human activities in situations where federal actions, funding or permitting are involved. In those cases, the federal agency concerned works with NOAA Fisheries or USFWS to avoid, reduce or mitigate potential impacts to the species' habitat. Critical habitat is only designated within U.S. jurisdiction. **Figure 3-1** identifies the loggerhead sea turtle Constricted Migratory Corridor, defined as a high use migratory corridor that is constricted (limited in width) by land on one side and the edge of the continental shelf and Gulf Stream on the other side (79 FR 39855). In addition, the area identifies conditions to allow for migration to and from nesting, breeding, and/or foraging areas. Six moorings, including profiler moorings CMP and SPM, surface moorings SSM and CSM and shallow-water moorings SME and SWM are sited within the loggerhead sea turtle Constricted Migratory Corridor. Loggerhead sea turtle Sargassum habitat is also identified in **Figure 3-1**, which is critical as developmental and foraging habitat for young loggerheads where surface waters form accumulations of floating material, especially Sargassum. Sargassum critical habitat is located east of the Constricted Migratory Corridor along the shelf break and out to the boundary of the Exclusive Economic Zone. The proposed Project activities are not likely to adversely affect relevant turtle species or their habitat. However, actions that may affect designated critical habitat or adversely modify or destroy proposed critical habitat are subject to the ESA section 7 consultation process and include Federal activities and non-Federal activities requiring a permit from a federal agency (e.g., a Clean Water Act, Section 404 dredge or fill permit from the USACE) or some other federal action, including funding (e.g., Federal Highway Administration funding for transportation projects). ESA section 7 consultation would not be required for federal actions that do not affect listed species or critical habitat and for non-federal activities or activities on non-federal and private lands that are not federally funded, authorized, or carried out.

Habitat Areas of Particular Concern. Under the MSA, HAPCs are defined as subsets of EFH that exhibit one or more of the following traits: rare, stressed by development, provide important ecological functions for federally managed species, or are especially vulnerable to anthropogenic degradation. While not relevant to project facilities, HAPCs are designated by regional FMCs, and while they do not convey additional restrictions or protections on an area, FMCs may include actions to restrict the use or possession of fishing gear or fishing equipment types within HAPCs. The Study Area intersects a joint Snapper-Grouper, Coral Reefs and Hardbottom, and Dolphin/Wahoo HAPC designated by the SAFMC, also coincident within the Primary/Secondary Nursery Area (sited east of Oregon Inlet [**Figure 3-1**]).

Important Bird Areas. IBAs are sites administered by the National Audubon Society that provide essential habitat to one or more species of birds during some portion of the year, including nesting, crucial migratory stop-over sites, or wintering grounds. Criteria for IBA designation includes occurrence of threatened and endangered species or species of conservation concern, and/or sites with substantial concentrations of birds or high species diversity. The Pioneer Array project will have no impact on IBAs, the existence of local IBAs is provided for inclusion purposes only as to fully evaluate protected habitats. The Outer Continental Shelf IBA is located in the vicinity of the Study Area eastward of the Oregon Inlet. This IBA is unique in that it is the open ocean of the Atlantic. This is a site where two major Atlantic currents mix, forming a very rich marine environment. Large mats of Sargassum form surface reefs and concentrate rare and endangered seabirds, marine mammals, marine turtles, and fish (Audubon 2022b). The site is an important commercial and sport fishing area, as well as an important commercial birdwatching area. The Outer Continental Shelf IBA has the greatest diversity of seabirds and marine mammals in the southeastern United States. For tropical species, the site probably has the greatest density of seabirds in the southeastern United States (Audubon 2022b). Bird species common in this area include the Atlantic puffin, Audubon's shearwater, band-rumped storm-petrel, black-capped petrel, black-legged kittiwake, sooty shearwater, South Polar skua, and Wilson's storm-petrel. (Audubon 2022b). This IBA is currently afforded no formal protection.

North Atlantic Right Whale Seasonal Management Areas. North Atlantic right whales (right whales) are protected under the ESA and MMPA. SMAs are established to reduce the likelihood of right whale deaths and serious injuries that could result from vessel collisions. Regulations implement speed restrictions of 10 knots or less on all vessels 19.8 m (65 feet) or longer transiting through any given SMA. Project installation and service vessels should be aware of the existence of SMAs for the Ports of Norfolk, Virginia, and Morehead City, North Carolina, depending on port of departure for Project activities (NOAA Fisheries 2022f).

3.1.4.2 Mitigation

The proximity of protected habitats does not preclude future development of the Study Area; however, these habitats should be considered refuges for certain protected species. A site-specific survey may be recommended by USFWS or NOAA Fisheries to ensure avoidance of any protected habitat.

- Delineate and avoid any artificial reefs.
- Observe any construction moratoria established in Fishery Nursery Areas, if applicable.
- In order to comply with USFWS consultation under Section 7 of the ESA, Tetra Tech recommends subsequent agency outreach via informal consultation with USFWS and NOAA Fisheries to establish written concurrence that Project activities will incur minimal to no adverse impacts to protected marine species, critical habitats, and HAPCs.

3.2 Physical Resources

Physical resources such as noise, geologic conditions, sediment and water quality, electromagnetic fields (EMF), and air quality require analysis in support of federal and state regulations. The following sections provide the preliminary resource characterization, and next steps.

3.2.1 Underwater Noise

The MMPA provides for the protection of all marine mammals and additionally regulates and provides protection for marine mammals sensitive to underwater noise. The MMPA prohibits, with certain exceptions, the "take" of marine mammals (NOAA Fisheries 2019a). NOAA Fisheries has jurisdiction for overseeing the MMPA regulations as they pertain to most marine mammals and sea turtles, while the USFWS has jurisdiction over a select group of marine mammals, including manatees.

Generally, NOAA Fisheries is responsible for issuing take permits under the MMPA, upon a request, for authorization of incidental but not intentional "taking" of small numbers of marine mammals by U.S. citizens or agencies who engage in a specified activity (other than commercial fishing) within a specified geographical region. The USFWS would issue a take permit for manatees, but the criteria for evaluating the potential acoustic impacts to manatees has not yet been developed by the agency. The term "take," as defined pursuant to the MMPA (16 U.S.C. § 1362[13]), means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." The term "harass" was then further defined in the 1994 amendments to the MMPA, with the designation of two levels of harassment: Level A and Level B.

By definition, Level A harassment is "any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock", while Level B harassment defined as "any act of pursuit, torment, or annoyance which has the potential to disturb (but not injure) a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering." In reference to the underwater acoustic environment, NOAA Fisheries defines the threshold level for Level B harassment at 160 decibels (dB) referenced at 1 micropascal (dB re 1 µPa) sound pressure level for impulsive sound, averaged over the duration of the signal, and at 120 dB re 1 µPa for non-impulsive sound, with no relevant acceptable distance specified.

In July of 2016, NOAA Fisheries finalized the Technical Guidance for Assessing the Effect of Anthropogenic Sound on Marine Mammals – Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. This guidance is reaffirmed in the 2018 Revision to the Technical Guidance (NOAA Fisheries 2016, 2018) NOAA Fisheries provided guidance for assessing the impacts of anthropogenic sound on marine mammals under their regulatory jurisdiction, including whales, dolphins, seals, and sea lions. The updated 2018 guidance (NOAA Fisheries 2018) specifically defines marine mammal hearing groups, develops auditory weighting functions, and identifies the received levels, or acoustic threshold levels, above which individual marine mammals are predicted to experience changes in their hearing sensitivity (permanent threshold shift [PTS] or temporary threshold shift [TTS]) for acute, incidental exposure to underwater sound. Under this guidance, any occurrence of PTS constitutes a Level A, or injury, "take". The sound emitted by man-made sources may induce TTS or PTS in an animal in two ways: 1) peak sound pressure levels (L_{PK}) expressed in dB re 1 µPa may cause damage to the inner ear, and 2) the accumulated sound energy that the animal is exposed to (cumulative sound exposure levels [SEL_{cum}], expressed in dB re 1 $\mu Pa^2 \cdot s$) over the entire duration of a discrete or repeated noise exposure has the potential to induce auditory damage if it exceeds the relevant threshold levels.

Research has demonstrated that the frequency content of the sound plays a role in causing damage. In other words, sounds that are outside of the hearing range of the animal would unlikely affect its hearing, while the sound energy within the hearing range could be harmful. Under the NOAA Fisheries 2018 guidance, recognizing that marine mammal species do not have equal hearing capabilities, five hearing groups of marine mammals are defined as follows: low-frequency, mid-frequency, high-frequency, phocid seals, and otariid seals.

For sea turtles, NOAA Fisheries has considered injury onset beginning at a root mean squared sound pressure level (SPL RMS) of 180 dB re 1 µPa to prevent mortalities, injuries, and most auditory impacts as well as behavioral responses from impulsive sources at 175 dB re 1 µPa SPL RMS, which has elicited avoidance behavior of sea turtles in the past (Blackstock et al. 2018). There is currently limited information available on the effects of noise on sea turtles and the hearing capabilities of sea turtles are still poorly understood. In a cooperative effort between federal and state agencies, interim criteria were developed to assess the potential for injury from elevated anthropogenic underwater noise to fish and sea turtles. These noise thresholds were established by the Fisheries Hydroacoustic Working Group, assembled by NOAA Fisheries and these thresholds have subsequently been adopted by NOAA Fisheries. Additionally, the Fisheries Hydroacoustic Working Group, under the American National Standards Institute, developed sound exposure guidelines for fish and sea turtles (Popper et al. 2014). They identified three types of fish according to how they could potentially be affected by underwater sound. These categories include fish with no swim bladder or other gas chamber (e.g., dab and other flatfish), fish with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g., salmonids), and fish with a swim bladder that is involved in hearing (e.g., channel catfish).

3.2.1.1 Preliminary Resource Characterization

Noise in the ocean associated with natural sources is generated by physical and biological processes as well as anthropogenic sources such as shipping. Examples of physical noise sources are tectonic seismic activity, wind, and waves; examples of biological noise sources are the vocalizations of marine mammals and fish. There can be a strong minute-to-minute, hour-to-hour, or seasonal variability in sounds from biological sources. The ambient noise for frequencies above one kilohertz (kHz) is due largely to waves, wind, and heavy precipitation (Simmonds et al. 2004). Surface wave interaction and breaking waves with spray have been identified as significant sources of noise. Wind-induced bubble oscillations and cavitation are also near-surface noise sources. At areas within distances of 8 to 10 km (4.3 to 5.4 nm) of the shoreline, surf noise will be prominent in the frequencies ranging up to a few hundred hertz (Hz) (Richardson et al. 2013).

A considerable amount of background noise may also be caused by biological activities. Aquatic animals generate sounds for communication, echolocation, prey manipulation, and as byproducts of other activities such as feeding and breeding. Biological sound production usually follows seasonal and diurnal patterns, dictated by variations in the activities and abundance of the vocal animals. The frequency content of underwater biological sounds ranges from less than 10 Hz to beyond 150 kHz. Source levels show a great variation, ranging from below 50 dB to more than 230 dB SPL RMS re 1 µPa at 1 m. Likewise, there is a significant variation in other source characteristics such as the duration, temporal amplitude, frequency patterns, and the rate at which sounds are repeated (Wahlberg 2012). Typical underwater noise levels show a frequency dependency in relation to different noise sources; the classic curves are given in Wenz (1962).

Anthropogenic noise sources can consist of contributions related to industrial development, offshore oil industry activities, naval or other military operations, and marine research. A predominant contributing anthropogenic noise source is generated by commercial ships and recreational watercraft. Noise from these vessels dominates coastal waters and emanates from the ships' propellers and other dynamic positioning propulsion devices such as thrusters. The sound generated from main engines, gearboxes, and generators transmitted through the hull of the vessel into the water column is considered a secondary sound source to that of vessel propulsion systems, as is the use of sonar and depth sounders, which occur at generally high frequencies and attenuate rapidly. Typically, shipping vessels produce frequencies below one kHz, although smaller vessels such as fishing, recreational, and leisure craft may generate sound at somewhat higher frequencies (Simmonds et al. 2004).

3.2.1.2 Mitigation

Measures are typically put in place to minimize and avoid exposure of marine mammals and sea turtles to potentially impactful noise levels. The anticipated underwater noise impacts associated with Project activities were evaluated against the criteria prescribed in the revised NOAA Fisheries (2018) Technical Guidance which establishes specific hearing criteria thresholds for each functional hearing group. Active acoustic sources for the Pioneer Array generally operate at frequencies higher than the auditory range of fish and marine mammals (greater than 180 kHz) with most equipment operating at greater than 200 kHz. Instruments operating at frequencies between 2 and 1200 kHz include acoustic dopplers, bioacoustics profilers, altimeters, acoustic modems and tracking pingers. However, these acoustic sources are limited in use due to the infrequent sampling method. Therefore, the generated underwater noise associated with Project activities, including the anchoring of the Pioneer Array and deployment of AUVs and gliders, would result in no significant impact to marine fauna. Consultation with NOAA Fisheries confirmed that neither a Letter of Authorization nor Incidental Harassment Authorization would be required due to the acoustic dopplers, single point velocity, bio-acoustic sonar and passive hydrophone equipment (Laws 2022). For an overview of general marine mammal and sea turtle mitigation measures, see Section 3.1.2.

3.2.2 Geologic Conditions

Understanding the geologic conditions, including bathymetry and seabed morphology, sediment type and distribution, and existence of natural hazards, is a key element of characterizing and evaluating important environmental resources and constraints in the Study Area. These factors have a direct impact on the siting of the project and inform other critical issues, such as benthic habitats, protected species, and the potential for cultural resources.

3.2.2.1 Preliminary Resource Characterization

The Pioneer Array is to be relocated on the Atlantic Outer Continental Shelf and Slope, off the coast of North Carolina's Outer Banks. The relevant stretch of continental shelf is commonly referred to as the Mid-Atlantic Bight. The Mid-Atlantic shelf averages 25 m in depth, growing deeper eastward until it reaches 100 m at the shelf edge and then drops to 1,000 m at the steep escarpment and deep canyons of the slope break. The topography of the Mid-Atlantic shelf is mostly flat, with low-relief features such as sandy shoals and swales, sand wedges and waves, and relict coastal features (Conley et al. 2017).

The Mid-Atlantic shelf is overlain by a mantle of sand approximately zero to 20 m thick along the OCS shelf off North Carolina. Linear sand ridges are also characteristic of the continental shelf in this region. In places where the sand cover is absent, the substrate is harder, consisting of exposures of cemented sand that can range from smooth outcrops to rough bottoms with relief up to 15 m (50 feet).

The Study Area located along the shelf is located at the southernmost part of the Baltimore Canyon Trough, a geological feature that extends along the Atlantic continental shelf from Cape Hatteras in the south up to Georges Bank in the north (Poag 1978). Off the coast of North Carolina, the Quaternary sediments are expected to be predominantly Quaternary fluviatile sands and silts, perhaps generally decreasing in grain size with increasing distance from the shore.

The seabed within the Study Area is predominantly composed of unconsolidated sediment. However, some areas of harder substrates are exposed at the seabed and within the shallow subsurface. Softbottom sediments in the Study Area are characteristic of Mid Atlantic Bight sediments and range from very fine to fine sands (0.065 to 0.25 millimeters [mm]), medium sands (0.25 to 0.5 mm), and coarse to very coarse sands (0.5 to 2 mm) (**Figure 3-2**; Conley et al. 2017).

There is also potential for sediment to be significantly thicker or absent in some locations. In general, the present-day continental shelf is starved of sediment due to sediment accumulation in coastal estuaries. Typically, seabed sands originating from the Appalachian Mountains have been transported by major rivers, deposited in coastal plains in the nearshore zone and subsequently reworked during the Holocene transgression (sea level rise).

The continental slope here is highly dissected by deep canyons and valleys. The canyons vary in size, shape, and morphological complexity; some were scoured by the flow of rivers during past low sea level periods, but most formed via other erosional processes, such as mudslides, debris flows, and turbidity currents. Sediments on the slope are highly variable but consist mainly of sandy silts on the upper slope and silts and clays on the lower slope (McGregor 1983).

Seabed Mobility Risk

The seabed along northeastern North Carolina is one of the more dynamic along the U.S. East Coast in terms of current-driven sedimentation patterns. The interplay between the northward flow of the Gulf Stream and seasonal wind and wave activity are overlaid with the impacts of extra-tropical and tropical storms, which can mobilize large amounts of sediments on the shallow shelf. Frying Pan Shoals off Cape Fear, Lookout Shoals off Cape Lookout, and Diamond Shoals off of Cape Hatteras are the most striking examples in terms of the scale of the area impacted, the size of the features, and the timeline of feature mobility.

This is supported by the data provided by the USGS in their Sea Floor Stress and Sediment Mobility Database for the South Atlantic Bight. This dataset spatially and temporally resolves seabed bottom stress and sediment movement recurrence intervals, using modelled currents and waves acting on measured seabed core data for sediment texture and grain size. The result is a gridded dataset with yearly and seasonal values for bed shear stress and seabed mobility event frequency and recurrence intervals for approximately 5-km cell size grids across the area.

Where available, the datasets indicate that the mooring locations avoid the regions of the very highest average annual seabed shear stress and the shortest mobility event recurrence interval; however, the values at the SMW location are higher due to the shallow depth at this location and its proximity to the coast. Recurrence intervals for seabed mobility events are on the order of days to weeks, indicative of a high potential for mobile seabed and seabed scour. The addition of structures on the seabed or changes to the seabed due to cable burial or cable protection may locally alter currents and enhance the risks of scour and mobility.

While the dataset does not extend further offshore to show seabed mobility recurrence intervals or average shear stress along the continental slope, the geomorphologic nature of the slope (e.g., escarpments, sediment gravity flow deposits) and the presence of mapped submarine canyons (The Point and Keller) indicate that seabed mobility may be a concern for the mooring locations (SOPM and NOPM) along and across the continental slope.

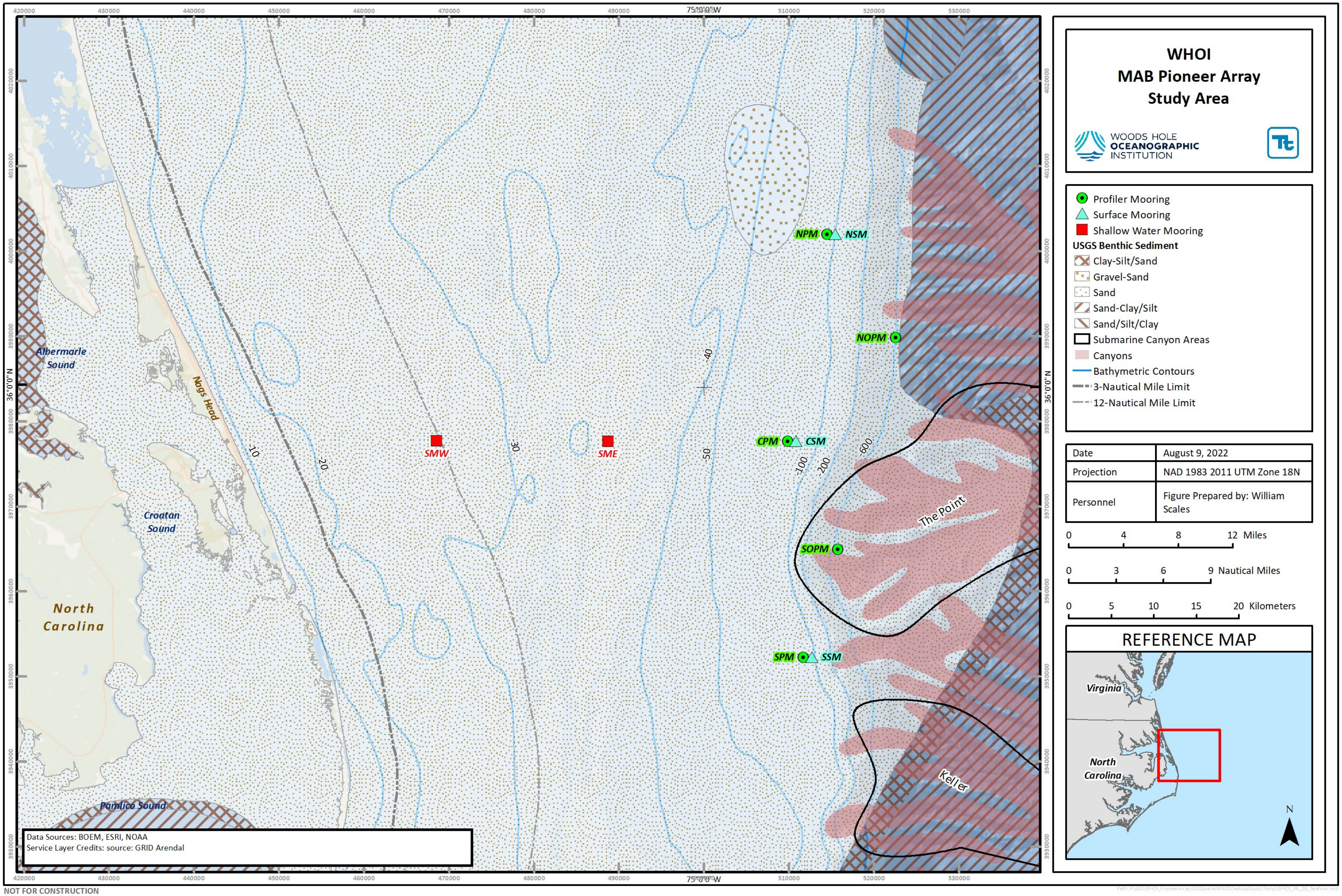

Figure 3-2. Seafloor Sediments

Seabed Character and Seafloor Sediments

The nature of the seafloor sediment will directly impact the suitability of offshore mooring locations. Generally, seabed sediments are coarse, composed of fine to coarse sands, with some areas of older, harder strata potentially exposed at the seabed, or encrusted with marine biota.

Areas of hardbottom can be outcropping rockier or harder seabed, or naturally occurring due to the presence of encrusting organism that colonize existing harder seabed or very coarse materials. These areas represent potential sensitive habitat to be avoided (see Section 3.1, Biological Resources). These areas are likely to be encountered within a particular mooring siting area, and special attention should be given to mapping and understanding potential hardground features during any reconnaissance survey to facilitate micrositing for avoidance and evaluation of other potential mitigations, if needed.

Exposed hard substrata are common in canyons and are generally found on the upper rims, where currents are elevated, and sometimes in the base of the axis, where boulders have been deposited. They may also occur on outcrops or relict shorelines along canyon walls, where currents keep substrata clear of sediment.

Submarine Canyons

Canyons vary in physical structure, hydrography and geological activity, and this variation creates complex patterns in oxygen, temperature, food, sedimentation, and substrata. Exposed hard substrata are common in canyons and are generally found on the upper rims, where currents are elevated, and sometimes in the base of the axis, where boulders have been deposited. They may also occur on outcrops or relict shorelines along canyon walls, where currents keep substrata clear of sediment (Ross and Brooke 2012).

The North Carolina canyons may be unique relative to those further north due to their location where strong current systems collide. The cold Labrador Current from the north meets the warm Gulf Stream and Virginia Currents from the south, where the latter currents are deflected offshore at Cape Hatteras. The colliding currents create a dynamic exchange of inshore and offshore waters as well as one of the sharpest thermal boundaries known in the world’s coastal oceans. Regional differences in fishes, invertebrates, and deep-sea corals have been documented north and south of Cape Hatteras, with origins likely related to the barrier created by steep temperature gradients and tolerances of organisms (Morrison 2019).

Two mooring sites are located along the continental slope off the coast of North Carolina, NOPM and SOPM. The most southerly of these sites, SOPM, occur in an extremely dynamic and productive area known as The Point. The Point has been characterized as one of the most productive fishing spots on the East Coast, apparently fueled by upwelling generated by the collision of several major currents over complex bottom topography (e.g., escarpment) (Ross and Brook 2012).

Sites SSM and SPM are located on the outer shelf, to the Northwest of Keller Canyon. Keller Canyon is the only one of the Carolina canyons that incises the shelf, but less so than the canyons further to the north.

3.2.2.2 Mitigation

The placement of the Pioneer Array anchors and sensors would result in short-term insignificant impacts to surface sediments in the immediate vicinity of the proposed Pioneer Array assets. The primary mitigations an offshore project can take regarding geologic conditions are 1) identification, delineation, and avoidance of sensitive or challenging conditions during project siting; and 2) survey the area to ensure the anchor locations minimize impacts and withstand potential geologic hazards.

A high-resolution geophysical (HRG) survey designed to understand site conditions at the proposed mooring anchor sites and respective surrounding areas of possible seabed disturbance, is considered the best practice to ensure geological conditions and hazards are adequately identified and evaluated, and to inform project siting. As a guide for siting studies within the OCS for renewable energy projects, BOEM has published documents capturing the recommended approaches for characterizing geological conditions and hazards through the collection of geophysical and geotechnical datasets in the document *Guidelines for Providing Geophysical, Geotechnical, and Geohazard Information Pursuant to 30 CFR Part 585* (BOEM2020a).

Currently, there are no specific survey requirements for the deployment and operation of scientific buoys, however the guidelines for HRG survey activities detail the recommended equipment and specifications inclusive of the following:

- Navigation and positioning
- Bathymetry
- Magnetometer
- Side-scan sonar
- Sub-bottom profiler
- Seabed imagery and/or sampling

Prior to installation of the Pioneer Array, HRG surveys are suggested at each location along a series of regularly-spaced parallel track lines to allow for adequate seabed evaluation and facility micrositing if necessary to avoid identified hazards or other features. Survey of approximately 200 m x 200 m area of seabed is anticipated to be adequate for each mooring site and can be adjusted for site-specific conditions and planned mooring geometry. Survey specifications and line spacing is dependent on a variety of factors such as water depth, equipment deployed and desired resolution, and different minimum line spacing based on the area and goals of the survey.

3.2.3 Sediment and Water Quality

Impacts to sediment and water quality are regulated under various federal and state laws including the CWA, National Environmental Policy Act, and North Carolina's Coastal Management Program under the Coastal Zone Management Act. State regulations apply to state waters including the waters of the Atlantic Ocean within 3 nm (5.6 km) from the coastline and all other tidal waters within the State of North Carolina. As the arrays will be deployed in OCS outside of the 3 nm limit and outside of state waters, the Project is not anticipated to be subject to state water quality standards.

3.2.3.1 Preliminary Resource Characterization

The Study Area is located in the Mid-Atlantic Bight where the topography is mostly flat with low-relief features such as sandy shoals and swales, sand wedges and waves, and relict coastal features (Conley et al. 2017). Sediments within the area consist of sand and sand-clay/silts with an approximate thickness of 20m (65 ft). In places where the sand cover is absent, the substrate is harder and consists of cemented sand that can range from smooth outcrops to rough bottoms with relief up to 15 m (50 ft). The disturbance of sediments during Project activities including surveys mooring deployment and placement on the sea floor, and potential adjustments to the mooring placement during routine maintenance has the potential to affect water quality and increase total suspended solids in the water column as well as release of contaminants that could affect surrounding marine habitat and aquatic life through dispersal, resuspension, and subsequent sedimentation. These impacts are typically short-term, and the disturbance area is often limited to the immediate vicinity of the moored array, although exact impacts are dependent on sediment type, extent of disturbance, and installation method. Accidental spills associated directly with the arrays are not anticipated as chemicals and petroleum products are not used on site in the marine environment to maintain the equipment. Impacts from accidental spills associated with marine vessels used during Project deployment and routine maintenance are expected to be negligible as they are of low probability and low magnitude, and appropriate spill control and response procedures will be developed based on industry best management practices (BMPs) to minimize potential impacts.

Transport of suspended sediment will be driven by existing currents throughout the Study Area. Ocean currents in the Study Area are dependent on the ocean floor currents, wind-generated near-surface currents, swell and surf-generated longshore currents, swell and surf-generated rip currents, and tidal currents.

Recent water quality data have not been collected in the Study Area. Review of the Environmental Protection Agency's (EPA) most recent National Coastal Condition Report IV (EPA 2012) summarizing coastal monitoring data collected between 2003-2006 identified the Project to be located within the South Atlantic Bight of the Southeast Coast Region assessment area with an overall ecological health rating of fair. The overall ecological health rating is determined based on the assessment of the following factors: water quality index, sediment quality index, benthic index, coastal habitat index, and fish tissue contaminants index. Data collected at several monitoring locations within the vicinity of the Study Area characterized water quality as fair to good and sediments were characterized as good (EPA 2012).

The National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management monitors water quality through the Integrated Ocean Observing System. However, there are no data available in the vicinity of the Study Area. The USGS, NOAA, and NCDEQ do not have surface water monitoring locations near the landfall areas, therefore, water quality data are not available for the Study Area.

The majority of pollutants to marine waters are sourced from shore-based activities. There are no federal Superfund sites or wastewater outfalls in the OCS within the vicinity of the Project that would contribute to contaminated sediments (Marine Cadastre National Viewer 2022). No oil and gas wells are off the coast of North Carolina. In the event of a spill, spills from vessels would be localized.

3.2.3.2 Mitigation

Potential but unlikely impacts on water quality would result from mooring deployment and placement on the sea floor, potential adjustments to the mooring placement during routine maintenance, and accidental spills associated with marine vessels. BMPs would be used to minimize impacts.

The deployment and anchoring of the array moorings would require use of USACE Nationwide Permit (NWP) 5 Scientific Measuring Devices (USACE 2022). Based on previous discussions with the USACE Wilmington District on March 17, 2022, submittal of a Pre-Construction Notification for the Project will not be required for authorized use of NWP 5. Projects that require a federal permit or involve dredging or fill activities that may result in a discharge to U.S. surface waters and/or waters of the U.S. are required to obtain a CWA Section 401 Water Quality Certification to verify that the project activities would comply with state water quality standards. Although the Project would require a federal permit, given the location of the Project several miles outside of state territorial waters, the Project is not likely to affect state water quality. As Section 401 Water Quality Certifications are automatically associated with NWPs, a separate authorization application and approval will not be required.

Based on these conditions, Tetra Tech recommends developing appropriate spill control and response plans in accordance with industry BMPs and agency recommendations.

3.2.4 Electric and Magnetic Fields

There are no federal regulations that limit human or environmental exposure to EMF. North Carolina does not have EMF threshold regulations listed by the North Carolina Utilities Commission and NCDEQ.

3.2.4.1 Preliminary Resource Characterization

There are three primary, natural sources of EMF in the marine environment: earth's geomagnetic field, electric fields induced by the movement of charged objects (e.g., marine currents and organisms) through this geomagnetic field, and bioelectric fields produced by marine organisms (Normandeau et al. 2011). Anthropogenic sources of magnetic and induced electric fields such as exhibited in some marine cabling, may generate additional EMF sources. The intensity of EMF depends on a combination of various factors which may include the type of current (alternating or direct), cable characteristics (if applicable), transmitted power, and ambient marine conditions (Gill and Desender 2020).

Elasmobranchs (rays, sharks, and skates), finfishes, invertebrates, marine mammals, and turtles are reported to exhibit sensitivity to EMF (Taormina et al. 2018). Sensitive taxa exhibit varying degrees of magnetosensitivity, electrosensitivity, or a combination of both. Magnetosensitive species use naturally occurring EMF for migration and foraging purposes. Electrosensitive species have specialized sensory organs called ampullae of Lorenzini that use ambient electric fields to locate prey or avoid predators; however, the range over which these species can detect electric fields is limited to centimeters (Snyder et al. 2019). Studies in the literature indicate the potential for anthropogenic EMF to interfere with ambient EMF and impact predator-prey interactions, orientation and migration behaviors, or physiological development of fishes (e.g., eels, elasmobranchs, salmonids), invertebrates (e.g., bivalves, crabs, lobsters, shrimp), marine mammals, and sea turtles (Taormina et al. 2018).

The Pioneer array consists of 10 uncabled moorings that are powered through surface buoys as well as internal battery packs, thus EMF impacts related to marine life are unlikely. Each surface mooring can contain multiple "nodes" that provide power and connectivity. Non-cabled nodes contain one or more computers and power converters, powered by batteries, wind or solar. Cabled instruments are plugged into the powered cable and their data are collected and transmitted to shore. These nodes also serve as distribution centers for extension cables that provide power and communication to sensors, instrument platforms, and moorings. Continuous, real-time flow of data allows interactive science experiments to be conducted at the seafloor and throughout the water column.

3.2.4.2 Mitigation

The potential EMF impacts to marine life for the Pioneer array are considered negligible due to the restricted potential of EMF output from the proposed Project equipment.

Project components including those associated with deployment of the proposed monitoring buoys, inductive mooring cables, or associated data collection instrumentation generate minimal EMF output there are no impacts, mitigation recommendations or additional analyses related to EMF required.

3.2.5 Air Quality

Impacts to air quality are regulated under various federal laws including the Clean Air Act, Outer Continental Shelf Lands Act, and National Environmental Policy Act, as well as federal regulations including the OCS Air Regulations under 40 CFR Part 55, and the General Conformity Regulations under 40 CFR Part 93.

EPA Region 4 is responsible for implementing and enforcing Clean Air Act requirements for OCS sources offshore the state seaward boundaries of North Carolina. If any air emissions from construction or operation of a project will be produced by equipment that can be considered part of an "OCS source," then they may be subject to submittal and approval of an OCS air permit application. Within state waters and onshore, the NCDEQ regulates air quality with the Department of Air Quality with the Wilmington Regional office covering Dare County. The Air Quality Rules and Regulations identify procedures for permits and approvals if there is a need for air pollution control requirements. The Project would not need a Title V Air Quality permit under Title 15A of the North Carolina Administrative Code because the Project is not located within state waters and there would be no air pollutant emissions during operations.

3.2.5.1 Preliminary Resource Characterization

The geographic area included in a National Ambient Air Quality Standards (NAAQS) designation is limited to areas that are either within a state or territory's actual area, or that are within 3 nm of a state or territory's seaward boundary. Since the entire Study Area is more than 3 nm from the seaward boundary of any state, 40 CFR Part 55 specifies that a Corresponding Onshore Area must be identified in order to determine what federal and state air quality regulations may apply to a project. In most cases, the Corresponding Onshore Area will be the nearest point of land to a proposed project.

The nearest point of land to the Study Area is Nags Head, in Dare County, North Carolina, located approximately 13 nm west of the nearest proposed mooring. Dare County is part of the “Northern Coastal Plain” Air Quality Control Region (40 CFR 81.149). This region is designated as unclassifiable or attainment for all NAAQS pollutants.

The Project would result in minor temporary emissions from surface vessels used during array installation and annual maintenance and would not represent a substantial increase above existing conditions. To protect human health, the EPA establishes NAAQS under authority of the Clean Air Act that apply for outdoor air throughout the country. For each NAAQS pollutant and averaging period, the EPA may designate a specified geographic area as being in attainment of the standard, as being in nonattainment of the standard, or as being a maintenance area, meaning that an area was previously in nonattainment but has since been re designated to attainment due to ongoing improvements in local air quality. Because the Project will occur in an attainment area, no further conformity analysis would likely be required pursuant to 40 CFR Part 93 for air emissions occurring within 3 nm from shore (and potentially as far as 25 nm from the state seaward boundary), both for construction of a project, and for any operational air emissions that will not be included in an OCS air permit.

3.2.5.2 Mitigation

No mitigation is needed for air quality. The Proposed Action is not located within the jurisdiction of any state. There are no emissions standards for vessels or activities operating beyond 12 nm of shore. Proposed activities would result in minor temporary emissions from surface vessels or surface buoys during installation and operation and maintenance activities of the Pioneer Array. However, these emissions would not represent a substantial increase above existing conditions because only a small number of vessels and surface buoys would be used.

3.3 Anthropogenic Resources

In support of the NWP and other federal and state regulations, the National Historic Preservation Act, and the Ports and Waterways Safety Act, anthropogenic resources including marine cultural resources, transportation and navigation, military operations, aviation and radar, humanmade hazards and obstructions, tourism and recreation, visual and aesthetic resources, and environmental justice require analysis. The following sections provide the preliminary resource characterization and recommendations for next steps.

3.3.1 Cultural Resources

Review of the marine cultural resources is assessed under separate cover (*Marine Cultural Resources Study)*. Review of terrestrial cultural resources present along the shoreline adjacent to the Study Area are included below. Historic properties that have been listed on or are eligible for listing on the National Register of Historic Places (NRHP) are considered significant cultural resources and may include properties of traditional, religious, and cultural importance to Native American Tribes.

3.3.1.1 Preliminary Resource Characterization

A review of recorded terrestrial cultural resources identified NRHP-listed, NRHP-eligible, and unevaluated properties within the Study Area (Figure 5). Although the vast majority of these recorded resources have at least a partial view of the Atlantic Ocean, none are expected to have views of the Pioneer Array given the distance of the array from the shoreline and the array's low height above the waterline (maximum 4.5 m above the water).

Publicly available shipwreck and obstruction data from NOAA Coast Survey's Automated Wreck and Obstruction Information System (AWOIS) was used to identify charted shipwrecks in the Study Area (**Figure 3-3**). Three charted shipwrecks were identified in the vicinity of planned moorings. However, these data are limited; therefore, a detailed desktop assessment was completed by a Qualified Marine Archeologist. It should be noted that uncharted shipwrecks and obstructions are commonly identified during HRS surveys, since full coverage surveys are typically not conducted on a regular basis to update shipwreck databases. An HRG survey will likely identify additional wrecks and obstructions. Note, however, that not all wrecks and obstructions identified in the Study Area will require a cultural avoidance buffer. If the wreck or obstruction is not identified as having cultural significance, there is potential for it to be removed from the Study Area.

3.3.1.2 Mitigation

With regard to terrestrial cultural resources, mitigation measures will not be required since adverse effects to these resources are not anticipated to occur.

It is recommended that an HRG survey of the mooring sites be completed. All wrecks, debris, obstructions, and potential paleolandscapes identified in HRG survey data will be reviewed for potential cultural significance. A project Qualified Marine Archeologist would evaluate this data and develop a Marine Archaeological Resources Assessment whereby shipwrecks and other submerged cultural resources will be identified and delineated. If site-specific survey confirms the presence of shipwrecks and/or other submerged cultural resources, avoidance is the preferred mitigation measure. A Qualified Marine Archeologist would make recommendations for avoidance. Avoidance buffers for shipwrecks are typically in the range of 50 m applied to the extent of identified acoustic targets and/or magnetic anomalies. These avoidance buffers will apply to both shipwrecks and obstructions identified on the seabed, as well as paleolandscapes identified below the seabed. Tetra Tech recommends collaboration and coordination with the North Carolina State Historic Preservation Office and the local tribes during the planning process.

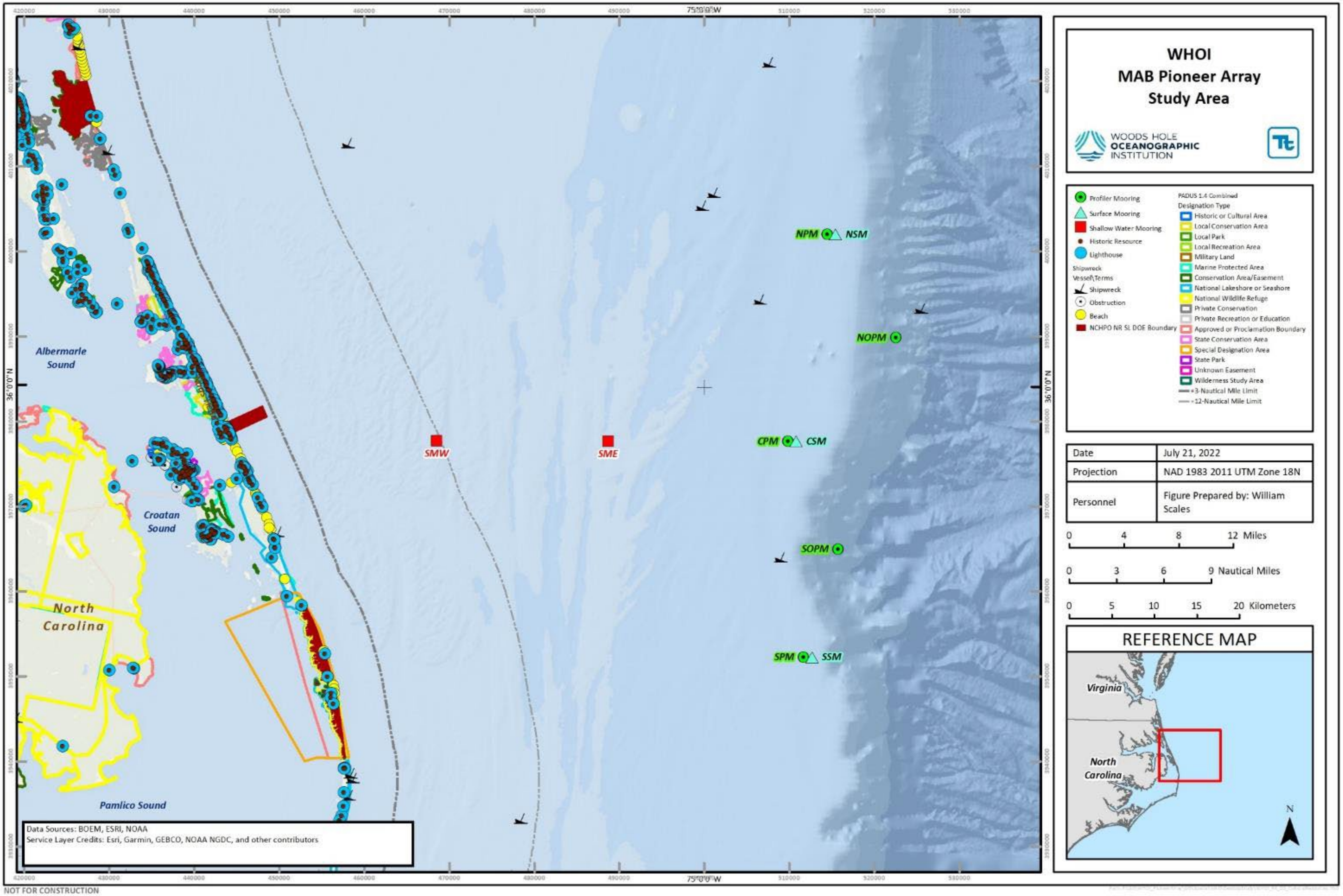

Figure 3-3. Cultural Resources and Restricted Land Use

3.3.2 Marine Transportation and Navigation

In 2011, the USCG began a Port Access Route Study (PARS) for the entire Atlantic Coast in order to develop reasonable routing measures (where required) to provide for the safe transit of vessels near offshore wind energy developments. To accomplish this, the final Atlantic Coast Port Access Route Study (ACPARS) established certain designated safety fairways running north and south along the coast. These fairways are designated as "nearshore" or "offshore" to be used at the preference of the vessel operator. The ACPARS study was published on July 8, 2015 (USCG 2015) and includes responses to comments from maritime stakeholders who were concerned about how the presence of offshore wind facilities may affect vessel navigation (USGS 2015).

The ACPARS study is primarily concerned with vessel traffic along the Atlantic coast that transits in a north-south direction. It was recognized that a study of vessel traffic transiting from these north-south routes to ports on the U.S. East Coast was necessary. On March 18, 2020, the USCG announced a new PARS for the Seacoast of North Carolina Including Offshore Approaches to the Cape Fear River and Beaufort Inlet, North Carolina. Results of this study were published by the USCG in 2021 (USCG 2021a).

In addition to the north and south navigational safety fairways discussed in the ACPARS study, a similar PARS study was conducted just for the Chesapeake Bay. Published in 2021, the study introduced two offshore routes for vessels transiting in the east-west to and from Chesapeake Bay. These new proposed fairways may impact local traffic, however they are located greater than 50 nm from the proposed Pioneer Array moorings and are considered to have no impact (USCG 2021b).

The Pioneer Array will have a total of 10 moorings, both surface moorings and subsurface. It is essential that vessel traffic in the vicinity of the array pass these buoys at a safe distance. Since offshore wind farms are developed along the East Coast in the Kitty Hawk Lease Areas, vessel traffic will also need to ensure that their routes pass offshore wind structures at a safe distance. An analysis of likely routing changes to vessel traffic due to the combined development of offshore wind and the Pioneer Array should be conducted to minimize any "funneling" effects and ensure buoys are not located within either the nearshore or offshore fairways.

Figure 3-4 shows the relative location of the proposed Pioneer Array, the Kitty Hawk lease areas, and the nearby St. Lucie-to-Chesapeake Bay Fairways (offshore and nearshore). The proposed distance from both SMW and SME has been calculated as less than 0.5 nm.

3.3.2.1 Preliminary Resource Characterization

The largest ports in the vicinity of the project are Norfolk, Virginia, the largest military port in the country to the north, and to the south, Morehead City with breakbulk facilities and Wilmington, with breakbulk and container facilities. Likely changes to vessel traffic patterns have been considered in the above-mentioned PARS studies, providing valuable background information for the placement of the Pioneer Array moorings.

The primary source of commercial vessel traffic data is AIS, which is required for most commercial vessels. AIS data received from vessels in the Study Area is considered to be at the limit for terrestrial AIS receivers as parts of the Pioneer Area are beyond 30 nm from the shore. AIS data received by satellite receivers may be used to fill any data gaps that are likely for the eastern extent of the Study Area. **Figure 3-5** and **Figure 3-6** show 1 year of AIS data for all vessel types in 2020 and 2019, respectively. Further examination of vessel traffic of all types may be used to inform the sighting of Pioneer Array elements.

3.3.2.2 Mitigation

USCG-approved Private Aids to Navigation (PATON) and Local Notice to Mariners (LNM) will be required to support the installation and operation of the Pioneer Array.

While all aspects of the array should be monitored to ensure buoys are on-station, extra care should be taken with SMW and SME due to their close proximity to the navigational fairways. The St. Lucie-to-Chesapeake Bay Nearshore Fairway is a designated tug and towing vessel fairway. These vessels are routinely operating with restricted maneuverability and may not be able to avoid collision should SMW become off-station.

It will be important for the Pioneer Array location to be routinely monitored to ensure any off-station buoys do not encroach or impede traffic in the nearby navigational fairways and to keep track of further mitigation measures as they are developed. It is Tetra Techs understanding that the Pioneer Array employs Global Positioning System (GPS) telemetry which monitors buoy location in real-time. The GPS telemetry combined with the Projects scheduled weekly Operations Team meetings are sufficient mitigation for monitoring buoy positioning.

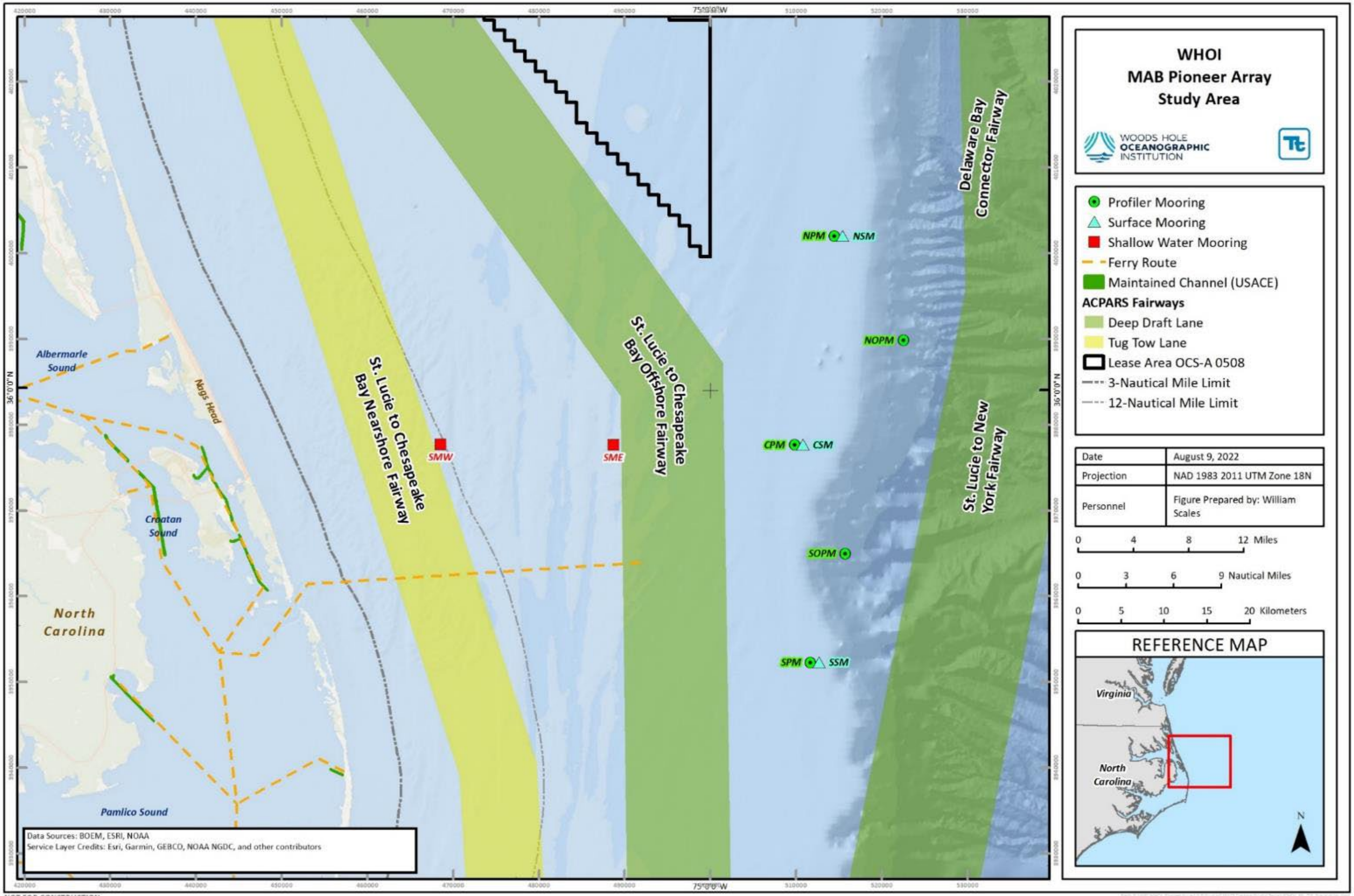

Figure 3-4. Navigation

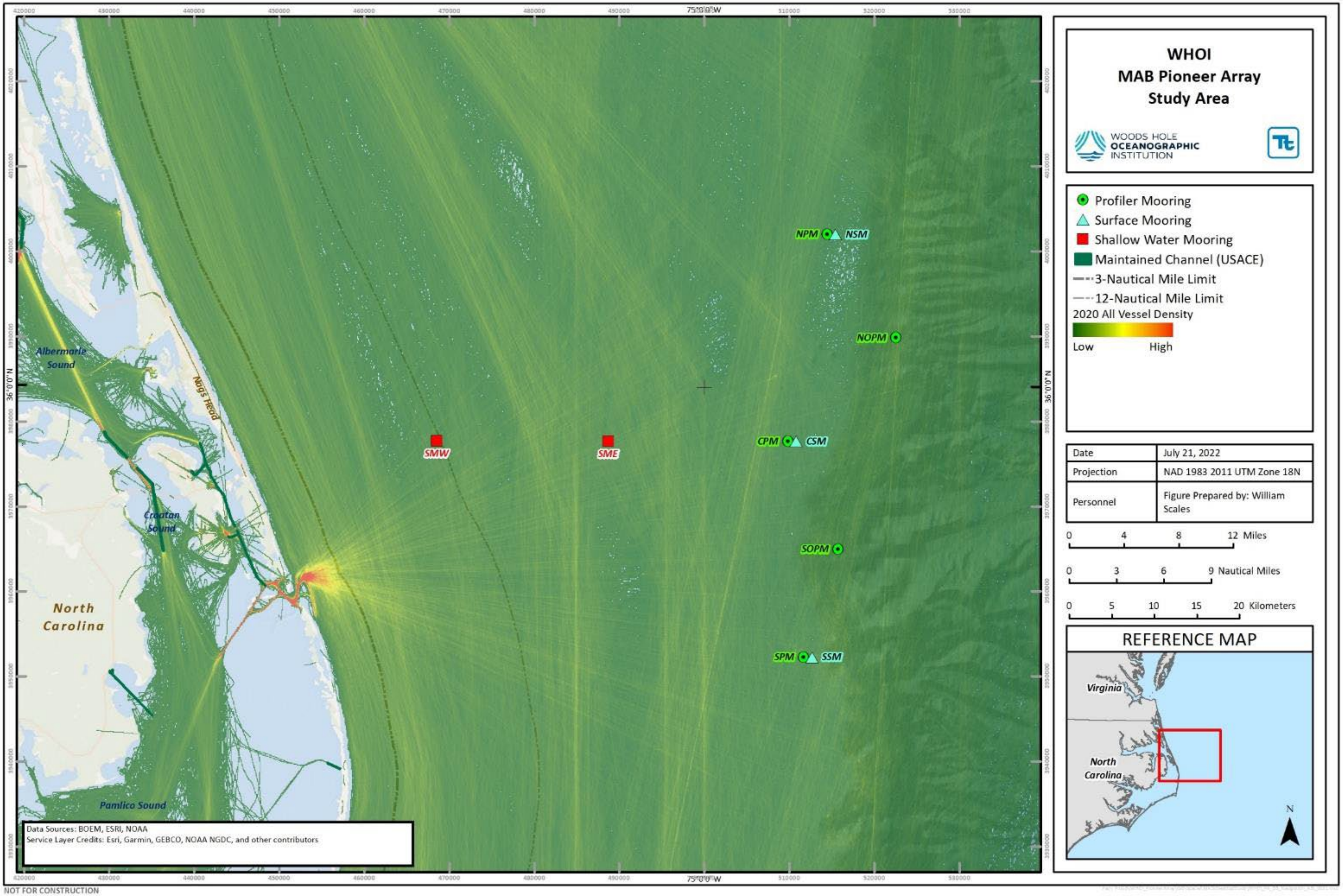

Figure 3-5. AIS Data for 2020

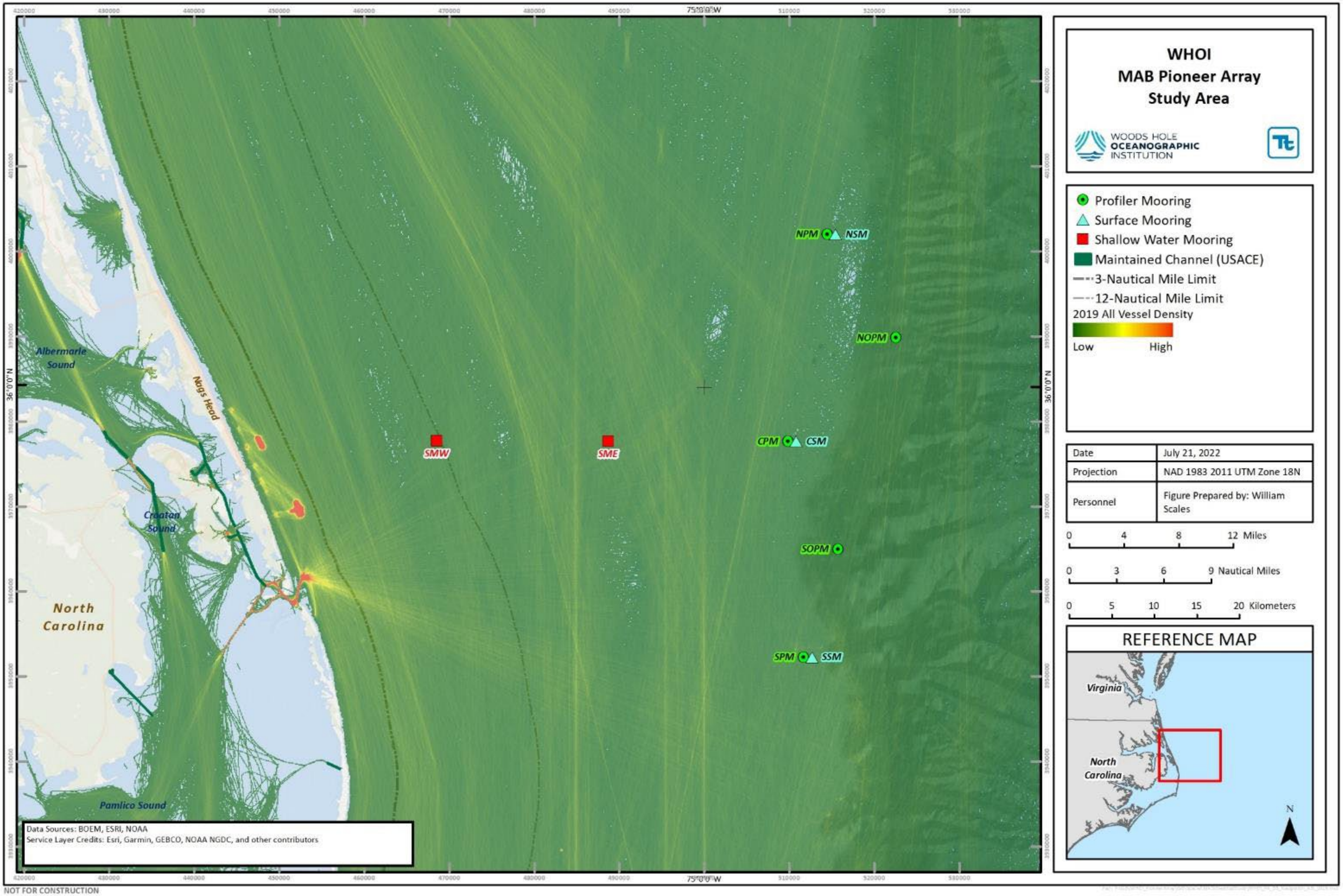

Figure 3-6. AIS Data for 2019

3.3.3 Military Operations

Under 49 U.S.C.§ 44718, the Department of Defense (DoD) was required to study the effects of new construction of obstructions on military installations and operations including radar and wind turbine generator interference and low-level flight operations. The act also established a “Clearinghouse” to provide a coordinated DoD review of renewable energy applications. The stated objective is “To ensure the robust development of renewable energy sources and the increased resiliency of the commercial electrical grid may move forward in the United States, while minimizing or mitigating any adverse impacts on military operations and readiness.”

The DoD is authorized under 10 U.S.C. § 2684a to enter into agreements to limit encroachments and other constraints on military training, testing, and operations in order to ensure training range sustainability. The DoD Clearinghouse is an important resource for the determination of impacts to DoD programs by the placement of Pioneer Array elements.

3.3.3.1 Preliminary Resource Characterization

The proposed location of the Pioneer Array is located within the Virginia Capes Range Complex and near the northern border of the Cherry Point Range Complex. A range complex is a designated set of specifically bounded geographic areas and encompasses a water component (above and below the surface), airspace, and may encompass a land component where training and testing of military platforms, tactics, munitions, explosives, and electronic warfare systems occur. Since the Pioneer Array is located near the border of both at-sea Operating Areas (OPAREA), this study references both.

The U.S. Navy Virginia Capes Range Complex has an area of more than 27,000 square nm extending from the Delaware-Maryland border down the coast through Virginia and ends approximately off the coast of Cape Fear, North Carolina. In addition to surface operations, the Virginia Capes Range Complex includes two submarine transit lanes (Whiskey and Echo), Special Use Airspace with designated Warning Areas (U.S. Navy 2018). The proposed location of the Pioneer Array within the VACAPES Range Complex is shown in **Figure 3-7**.

The U.S. Navy Cherry Point Range Complex has an area of more than 18,000 square nm extending from North Carolina to South Carolina. The U.S. Navy Cherry Point Range Complex includes special use airspace with associated warning areas and surface and subsurface sea space of the U.S. Navy Cherry Point. This Range Complex is adjacent to the U.S. Marine Corps Cherry Point and Camp Lejeune Range Complexes associated with U.S. Marine Corps Air Station Cherry Point and U.S, Marine Corps Base Camp Lejeune. (U.S. Navy 2018).

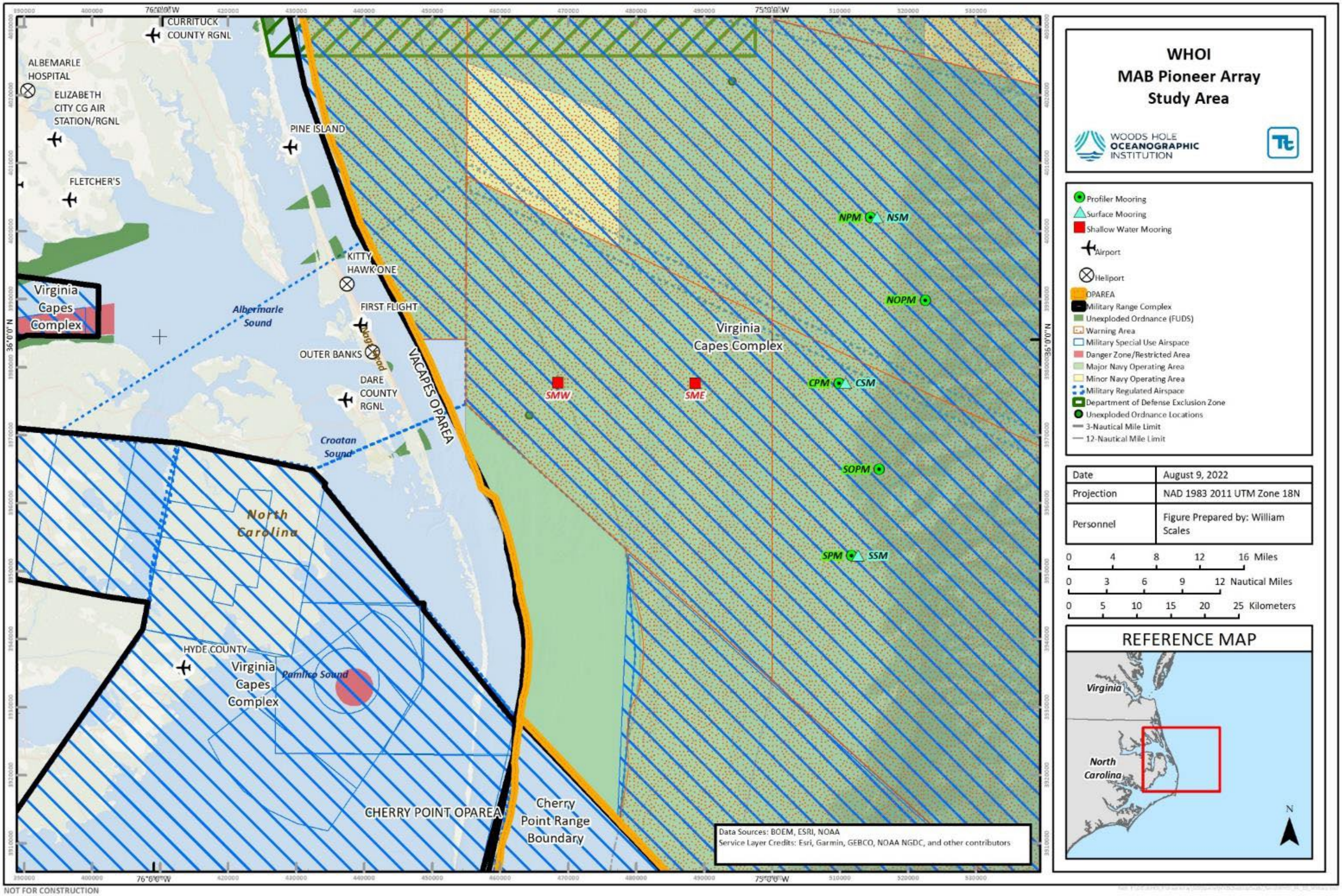

Figure 3-7. Military Areas

3.3.3.2 Mitigation

Consultation and engagement with USCG and DoD will provide further detail regarding ongoing and upcoming military use in the Study Area. To support the assessment of military operations off the coast of North Carolina, South Carolina, and Virginia as it pertains to Project siting and development, the following steps should then be taken:

- Establish communication and outreach with DoD and the USCG to confirm expectations regarding regulatory requirements.
- With the array being located near the border of both Virginia Capes and Cherry Point OPAREAS, engage the DoD Siting Clearinghouse to better understand how both areas are being used and any future area plans. Also determine if there are classified operations that may be impacted by the presence of the Project.

3.3.4 Aviation and Radar

The Federal Aviation Administration (FAA) regulates air safety and use of the navigable airspace (14 CFR Part 77). The FAA must be notified of any construction that may affect the National Airspace System under provisions 14 CFR Part 77. A Notice of Proposed Construction or Alteration (Form 7460-1) must be submitted to the FAA for structures over 200 feet (61 m) tall, or for structures less than 200 feet tall that extend into regulated air space near an airport, or as otherwise required under 14 CFR 77 Subpart B, Section 77.9.

No elements of the Pioneer Array meet this reporting standard so there are no concerns to aviation or land-based radar or mitigation factors.

3.3.5 Hazards and Obstructions

Shipwrecks and other charted obstructions are discussed in Section 3.3.1. Marine cultural resources are assessed under separate cover (*Marine Cultural Resources Study).*

There are currently no charted offshore cables or pipelines in the Study Area; however, due to the proximity of the Kitty Hawk Lease Area, there could be export cables in the vicinity of the Study Area by the time an offshore wind facility is built. In federal waters, the cable owner as well as other federal regulatory authorities should be consulted in the event a seabed use issue arises.

3.3.5.1 Preliminary Resource Characterization

Telecommunications and Power Cables

Subsea cables cross the continental shelf and connect coastal areas. In-Service and Out-of-Service, or retired, telecommunications cables occur across the world's oceans. Modern fiber optic cables carry voice and data, while many of the oldest telegraph cables, some installed more than 150 years ago, still lie on or below the seabed. Power transmission cables may also cross nearer to the shoreline as part of a nation's power infrastructure.

The National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey is responsible for updating and maintaining the NOAA Nautical Charts of the United States. As such, the relevant nautical charts have been consulted. On occasion, the USACE may have information regarding seabed assets that are not plotted on nautical charts; therefore, consultation with the USACE regarding seabed assets during the normal course of permitting is advisable.

There are currently no charted submarine cables in the vicinity of the Study Area.

A proposed offshore wind export cable planning effort is underway and includes cable routing options that may impact mooring sites along the OCS. However, the schedule for the Pioneer Array relocation would preclude any offshore wind project export cable installation.

Engineering, installation methodologies, and notification requirements for crossing telecommunications cables have been established by the International Cable Protection Committee (ICPC) and formalized in a series of best-practices guidelines. Additional information on cable location, ownership, and owner contact information may be available from federal and local agencies (e.g., U.S. Navy, USACE, and the North Carolina State Ports Authority), from commercial databases, and from cable maintenance authorities and cable operators. It must be noted that uncharted cables related to DoD activities or facilities may occur within the Study Area.

Additional review of existing and proposed telecommunications and power cables should be considered during mooring siting activities. Specifically, coordination with the Naval Seafloor Cable Protection Office (NSCPO), the North American Submarine Cable Association (NASCA), and International Cable Protection Committee is recommended, in addition to procurement of relevant GIS datasets for the management and analysis of geographically referenced cable data in the Study Area.

Pipelines

Pipelines, generally transporting water or petroleum liquid or gas products, may also cross coastal areas, along with outfall pipes that may be utilized to drain storm water or treated effluent from onshore locations. Charted "Pipeline Areas" are typically identified on NOAA Nautical Charts. More detailed nautical charts may show outfall pipes as these features typically only extend a few hundred feet from the shoreline.

There are currently no charted pipelines in the vicinity of the Study Area.

Sand Resource Areas

The BOEM Marine Minerals Program identifies Atlantic OCS sediment aliquots with sand resource areas identified in a block grid. These OCS blocks represent areas within the OCS protraction grid where sand resources have been identified through reconnaissance and/or design-level OCS studies. Access to and identification of potential OCS sand resources is crucial for the long-term management of coastal restoration, beach nourishment, and habitat reconstruction to mitigate future coastal erosion, land loss, flooding, and storm damage along the U.S. Atlantic Ocean.

These offshore sand resource areas occur in federal waters within the Study Area (**Figure 3-8**). As storm effects and storm-preparedness efforts have reached critical levels in recent years, identifying these resources has become a priority. BOEM maintains leased sand and gravel borrow areas on the OCS. These polygons define the areas where leaseholders can dredge sand, gravel, or shell material

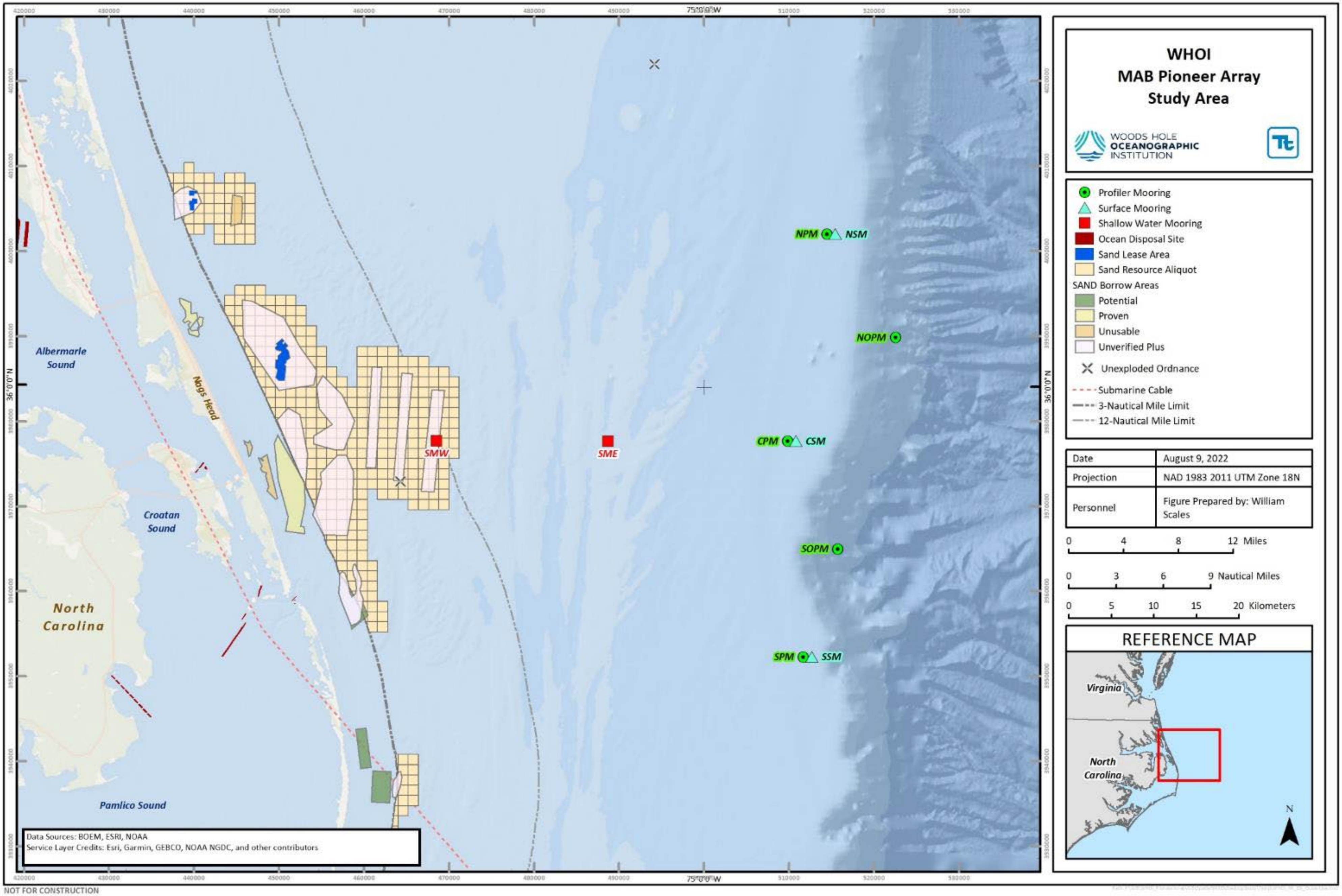

Figure 3-8. Ocean Uses.

from the OCS for use in beach and coastal restoration and protection projects undertaken by the federal government, or in a construction project funded in whole or in part by the federal government and should be carefully considered for avoidance by export cable routing.

Initial assessment indicates that site SMW is located within a sand resource aliquot (MT6014) and Borrow Area (NC_M14AC00009_91). The Borrow Area is classified as Unverified Plus, which are defined as those hypothesized to contain beach-quality sand based on limited geophysical or geotechnical data. Avoidance of these sand borrow areas should be considered.

Obstructions

Various obstructions are charted throughout the Study Area. These obstructions can include artificial reefs (Figure 3-1) and fish havens containing a variety of materials from debris to rocks, or even sunken vessels (Review of the marine cultural resources is assessed under separate cover (*Marine Cultural Resources Study*).

Obstructions, artificial reefs, fish havens, and submerged piles should all be avoided as a hazard to installation. The increased fishing efforts near these features may also pose an additional risk to mooring suitability from potential vessel activity and anchor impacts. Additional items of debris may be encountered during marine surveys and should be evaluated as potential hazards and avoided through micrositing or otherwise mitigated through further investigation, if necessary.

Sites NSM and NPM are located within a charted “rock” area and should be further evaluated during mooring siting activities.

Unexploded Ordinance

Munitions are present in U.S. waters as a result of live-fire testing and training (both ongoing and past); combat operations (acts of war through World War II); sea disposal (conducted through 1970); accidents (periodic); and disposal (e.g., jettisoning) during emergencies (Carton et al. 2017). Unexploded ordnance (UXO), which was either deployed in the marine environment during military activities but failed to initiate, or has been dumped at sea, can present a prospective threat.

The principal issue is that some activities, such as trawling, dredging of the installation, operation and maintenance, or decommissioning of marine infrastructure, may encounter UXO (Cooper and Cooke 2015). The closest location of potential UXO is charted 6.4 km southwest of mooring site SMW.

Areas of the seabed that will be disturbed during installation of oceanographic moorings should be investigated thoroughly prior to installation activities to the extent necessary for both human safety and environmental protection.

Dumping Areas

The EPA is responsible for designating and managing ocean dumping sites under the Marine Protection, Research and Sanctuaries Act. Many of these ocean disposal sites are located offshore of major ports and harbors nationwide. Designated ocean disposal sites are selected to minimize the risk of potentially adverse impacts of the disposed material on human health and the marine environment.

EPA Regional Offices conduct oceanographic surveys to monitor the impacts of regulated dumping at the ocean disposal sites. EPA Regional Offices often conduct site monitoring activities in coordination with the USACE because the vast majority of ocean sites are designated for the disposal of dredged material. Ocean disposal sites are monitored to ensure that dumping will not unreasonably degrade or endanger human health or the environment, to verify that unanticipated adverse effects are not occurring from past or continued use of the site, and to ensure that terms of the ocean dumping permit are met. Individual projects using the ocean disposal sites are also monitored for compliance with EPA site use conditions.

No USACE Ocean Dredged Material Disposal Site areas are located near the Study Area for current dredged material disposal.

3.3.5.2 Mitigation

To support the assessment of manmade hazards and obstructions within the Study Area pertaining to siting and development, the following actions are recommended:

- Project-specific field surveys beyond the geophysical studies necessary to support characterization of geologic and benthic resources are not yet recommended; however, consultation with federal agencies and other stakeholders is recommended as follows:
  - Commercial or Private owners of any utilities that may be identified during field surveys;
  - USACE and US EPA to identify existing and future sediment borrow/dumping areas;
  - Naval Seafloor Cable Protection Office to elucidate potentially unknown constraints and/or DoD assets that are unpublished; and
  - North American Submarine Cable Association and International Cable Protection Committee to advise on the location of the planned moorings and requesting feedback from their respective members as to any concerns of installed or planned cables in the area.

3.3.6 Tourism and Recreation

Review of the recreation and tourism resources within and around the Study Area indicate that recreational boating and fishing, charter fishing, shellfishing, sailboat races, sightseeing, bird and wildlife viewing (including whale watching), surfing, swimming, watersports, visiting beaches, hiking, and other activities are common to this part of coastal North Carolina (Visit North Carolina 2021; Outer Banks Visitors Bureau 2022a).

3.3.6.1 Preliminary Resource Characterization

The main resources associated with and around the Study Area for recreation and tourism include recreational boating and fishing, charter fishing, shellfishing, sailboat races, sightseeing, bird and wildlife viewing (including whale watching), swimming, visiting beaches, and hiking. Most of these activities occur nearshore or onshore in the towns of Nags Head, Kitty Hawk, and Kill Devil Hills, North Carolina, particularly during the summer months when tourism it as its highest. The south end of the Town of Nags Head borders the Cape Hatteras National Seashore, which extends more than 113 km from South Nags Head to Ocracoke Inlet encompassing 30,000 acres of shoreline (Outer Banks Visitors Bureau 2022b).

In 2021, visitors to North Carolina spent $28.9 billion, or just 1 percent below record 2019 spending levels and 45 percent more than 2020, when travel restrictions tied to the pandemic crippled the state's tourism industry (Visit North Carolina 2021). The towns of Nags Head, Kitty Hawk, and Kill Devil Hills are situated within Dare County, North Carolina. Located on the Outer Banks of North Carolina there are several attractions within the county that draw recreation and tourism activity, including parks, lighthouses, and beaches (Outer Banks Visitors Bureau 2022a). Tourism provides more than 13,880 jobs in Dare County, employing one out of three county residents. Annual Dare County tourism generates more than $130 million ($1,409 per resident) in state and local tax revenue. Visitor spending in Dare County surpassed $1.4 billion in 2020 and ranks the fifth-highest among counties for tourism expenditures in North Carolina, on average (Outer Banks of North Carolina 2022).

Kill Devil Hills is the largest town in Dare County with a population of 7,633 (U.S. Census Bureau 2021) and home of the Wright Brothers National Memorial. Located between Kill Devil Hills and Hatteras Island, Nags Head is an Outer Banks community known for its sand dunes and endless stretches of pristine shoreline. Nags Head is a well-known for its miles of sand dunes. Jockey's Ridge State Park covers 427 acres and includes the tallest active sand dune system in the eastern United States (NCDPR 2022). Given the offshore nature of the Project, no impacts are associated with any land-based recreation or tourism opportunities or nearshore water-based activities.

The recreation and tourism elements most pertinent to Project activities are associated with saltwater fishing as recreational angling is a major tourism activity and a significate contributor to North Carolina's tourism economy (Bumgarner and Hegyi 2006). The waters off the Outer Banks are renowned for the year-round fishing opportunities, particularly for species commonly considered ocean game or trophy fish. Referred to as the "The Billfish Capital of the World", more than 100 fishing tournaments were scheduled in North Carolina in 2020 (Fisherman's Post 2020). Fishing tourism is demonstrated through the use of privately owned vessels, chartered vessels, and head boats in the form of both pleasure and tournament-style fishing (Outer Banks Visitors Bureau 2022c). In 2020, recreational anglers took 16.4 million trips in North Carolina, with the majority shore fishing (5.5 million) followed by private (5.4 million) and manmade boat trips (5.2 million) and charter boats (215,000; NCDMF 2020). Figure

Recreational fishing is mainly associated with targeted fishing grounds and includes HMS species like tuna and sailfish. Due to the likely presence of highly sought-after game fish, the Study Area will be subject to vessels transiting and fishing within proximity. Established artificial reefs providing fish habitat essential to maintaining healthy fish stocks are located east of the Study Area and are maintained by the North Carolina Division of Marine Fisheries. State-wide data on recreational fishing efforts may serve as an indicator for fishing activity and is demonstrated by the density of recreational fishing vessel use in **Figure 3-9**.

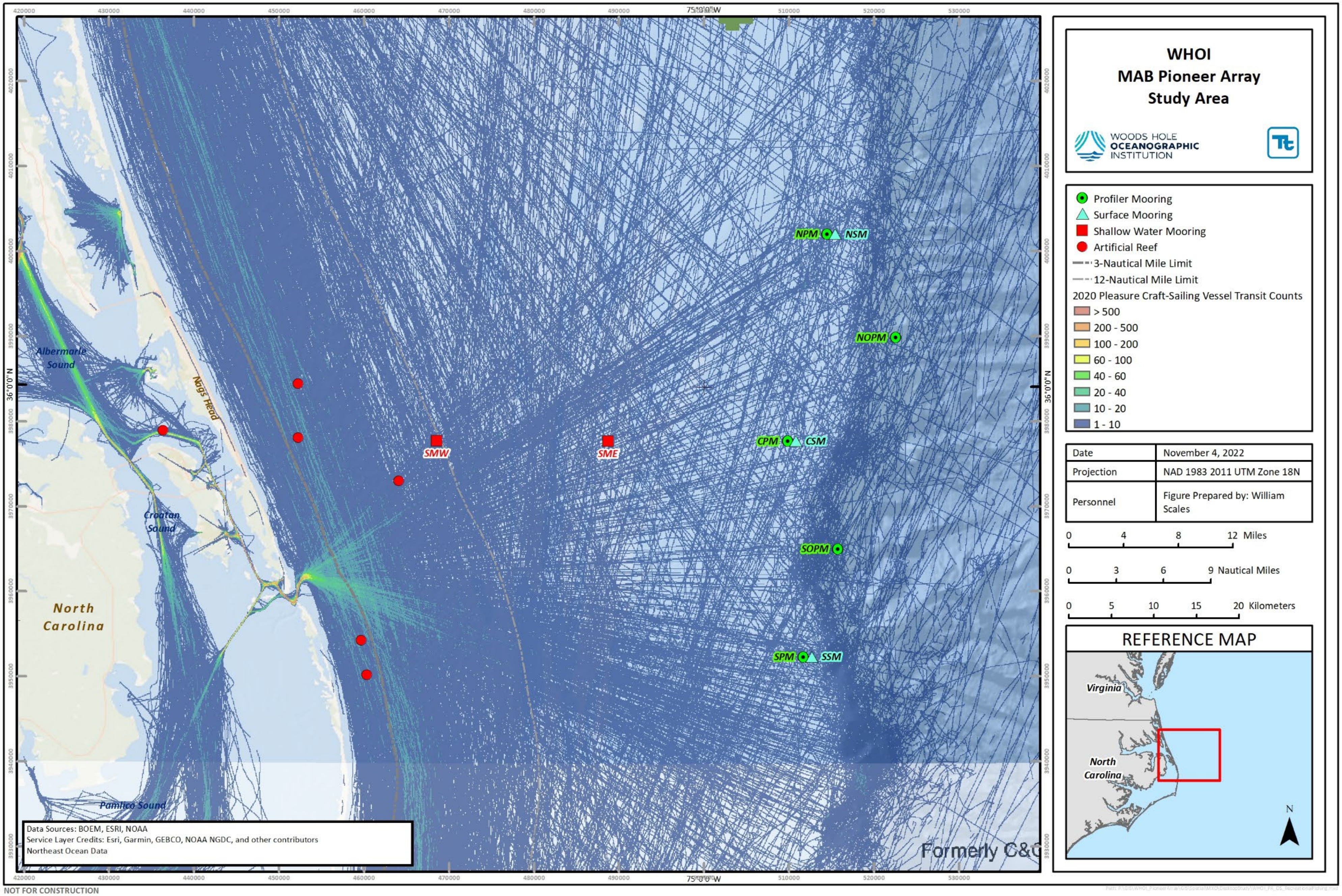

Figure 3-9. Recreational Fishing

Recreation and tourism opportunities associated with the Study Area are subject to minimal displacement due to the localized, short-term, temporary nature of the mooring installation and maintenance periods. Once installed, the micro-siting of the moorings will not significantly reduce access to pelagic fishing grounds; therefore, impacts would be considered discountable.

3.3.6.2 Mitigation

The impacts to recreation and tourism opportunities associated with the Study Area are anticipated to be minimal due to the localized, short-term, temporary nature of the Pioneer Array; no further mitigation is required. However, due to extent of the recreational fishing community, communication with the towns of Nags Head, Kitty Hawk, Kill Devil Hills and Caswell Beach, North Carolina is suggested as a courtesy and best practice above and beyond the Local Notice to Mariners required by the USCG.

3.3.7 Visual and Aesthetic

3.3.7.1 Regulatory Context

BOEM guidelines for assessing impacts to seascape, landscape, and visual resources apply to offshore renewable energy development in federal waters (BOEM 2020b). As such, there are no established visual impact regulatory requirements specific to scientific measurement devices; therefore, in this instance, the BOEM guidelines used comparatively established that the scale of the Pioneer Array Project does not meet the minimum threshold for a Visual Impact Assessment.

State and local plans or policies may additionally protect or manage views from specific publicly accessible areas. For example, the North Carolina Department of Transportation provides guidelines for preserving and protecting valued scenery surrounding designated state scenic byways.

3.3.7.2 Preliminary Resource Characterization

The Study Area is located approximately 13 nm and 45 nm offshore from the eastern shore of Nags Head, North Carolina. The adjacent shorelines and inland areas support a variety of open space, residential, recreational, and cultural uses. In addition to these uses, as noted in the preceding section, tourism associated with beaches and offshore recreational activities (i.e., water sports, sport fishing, etc.) is important to the local economy. The Project description and geographic scope, including the size and scale of changes to the existing visual conditions are critical to evaluating the potential for seascape, landscape, and visual impacts of proposed offshore projects. Applying the BOEM Visual Impact Assessment guidelines to access the Project scale for potential applicable visual impacts requiring regulations, Tetra Tech concluded that the cumulative potential impacts of Project components to the scenic value of the seascape, landscape, and the community are negligible due to the temporary nature of the Pioneer Array installation, the small-scale scope of operation and maintenance procedures, the overall distance from shore, the limited number of moorings, and the low height profile (less than 4.5 m) of the surface buoys. As mandated, the Project must comply with all USCG requirements for lighting; however, the impacts of the compulsory lighting to the scenic value of the seascape, landscape, and the community are also considered negligible.

3.3.7.3 Mitigation

The installed components of the Pioneer Array are primarily subsurface with only small-scale buoy towers extending visibly above the waterline; therefore, the potential impacts of the proposed Study Area's visual and aesthetic resources require no additional mitigation measures.

4.0 SUMMARY AND RECOMMENDATIONS

Based on the evaluated desktop data, the relocation of the Pioneer Array to the OCS off the coast of North Carolina is low risk of impacts to resources, but further site-specific field studies are recommended to comply with federal permitting guidelines.

The items detailed below may require the development of site-specific mitigation strategies:

- **Benthic and Fisheries Resources:** Species and EFH managed by the MAFMC, SAFMC, GMFMC, and NOAA HMS Division occur in the Study Area in federal waters. No proposed Study Area structures are planned to be located in state waters. Mitigation measures include informal consultation with cognizant agencies to determine the need for site-specific benthic characterization surveys to identify sensitive habitats and fisheries resources in the Study Area to avoid impacts due to placement of moorings.
- **Marine Mammals and Sea Turtles:** Marine mammals and sea turtles protected under the ESA are known to occur in the Study Area. Mitigation in the form of informal consultation with USFWS and NOAA Fisheries is recommended to document concurrence that no further steps will be necessary. Site-specific surveys may be conducted to ensure critical habitat is not present in the Study Area. Documentation from USFWS and NOAA Fisheries is required to accompany the NWP 5 certification to document that no formal agency consultation will be necessary, nor species-specific surveys are required.
- **Avian and Bat Species:** Species regulated under ESA, MBTA, and BGEPA are known to occur in the Study Area. From a mitigation standpoint, the Project is required to be constructed and operated in compliance with the USCG requirements for lighting, while using lighting technology that minimize impacts on avian and bat species to the extent practicable.
- **Protected Habitats:** Protected habitats are regulated by the NCDEQ, Coastal Area Management Act, NCDMF, NCWRC, NCDENR, and NOAA Fisheries. Project-specific protected habitats are limited to offshore benthic and pelagic habitats within and in the vicinity of the Study Area. The proximity of protected habitats does not preclude siting buoys; a site-specific survey may be recommended by USFWS or NOAA Fisheries to ensure avoidance of any protected habitat.
- **Underwater Noise:** MMPA regulates and provides protection for marine mammals sensitive to underwater noise, with USFWS having jurisdiction over a select group of marine mammals, and NOAA Fisheries responsible for issuing take permits under the MMPA. Previous consultation with NOAA regarding underwater acoustics outputs for the Pioneer Array confirmed that neither a Letter of Authorization or Incidental Harassment Authorization would be required. No further mitigation is required.
- **Geologic Conditions:** The risk of scour and seabed mobility should be considered in siting buoys. Site-specific HRG surveys are recommended as they are considered the best practice to access geological conditions for project implementation and hazard avoidance.
- **Sediment and Water Quality:** Impacts to sediment and water quality are regulated under the CWA. No existing issues with sediment and water quality were identified. Risk of impacts to

sediment and water quality would be from mooring deployment and operational maintenance of the project. Prior consultation with the USACE Wilmington District confirmed that a Pre-Construction Notification for the Project will not be required for authorized use of NWP 5. The issuance of the NWP 5 automatically authorizes the CWA Section 401 Water Quality Certification, no further mitigation is required.

- **Electric and Magnetic Fields:** Minimal EMF outputs are associated with the deployment of the proposed monitoring buoys, inductive mooring cables, or associated data collection instrumentation; there are no recommendations for additional analyses or mitigation.
- **Air Quality:** Dare County is part of the "Northern Coastal Plain" Air Quality Control Region. This region is designated as unclassifiable or attainment for all NAAQS pollutants. Emissions are restricted to installation and maintenance vessels and thus expected to be both minor and temporary with no air quality mitigation measures needed.
- **Cultural Resources:** Due to the offshore nature of this Project there are no mitigation measures or recommendations related to terrestrial cultural resources. Marine cultural resources are assessed under separate cover.
- **Marine Transportation and Navigation:** The two shallow water moorings are in close proximity to navigational fairways. The St. Lucie-to-Chesapeake Bay Nearshore Fairway is a designated tug and towing vessel fairway. These vessels are routinely operating with restricted maneuverability. Appropriate mitigation measures would include array monitoring to ensure inadvertent events such as off-station buoys do not encroach or impede traffic in the nearby navigational fairways.
- **Military Operations:** Military operations in the vicinity of the Study Area include Virginia Capes and Cherry Point OPAREAS. Mitigation measures in the form of consultation with USCG and DoD will provide further detail regarding ongoing and upcoming military use in the Study Area.
- **Aviation and Radar:** Mitigation measures are not necessary as there are no concerns to aviation or land-based radar systems.
- **Hazards and Obstructions:** There are currently no charted pipelines or USACE Ocean Dredged Material Disposal Sites in the vicinity of the Study Area. Mooring sites NSM and NPM are located within a charted "rock" area and should be further evaluated during mooring siting activities. Areas of the seabed that will be disturbed during installation of oceanographic moorings should be investigated prior to installation activities to the extent necessary for both human safety and environmental protection. Mitigation in the form of consultation with federal agencies is recommended to help identify existing utilities, existing and future sediment borrow/dumping areas and potentially unknown constraints and/or DoD assets.
- **Tourism and Recreation:** The installed components of the Pioneer Array are unlikely to interfere with tourism and recreation; therefore, potential impacts are considered negligible and no further mitigation measures are required. However, consultation with the towns of

Nags Head, Kitty Hawk, Kill Devil Hills and Caswell Beach, North Carolina, would be considered as a courtesy notice/best practice.

- **Visual and Aesthetic:** The installed components of the Pioneer Array are primarily subsurface with only small-scale buoy towers extending visibly above the waterline; impacts to visual and aesthetic resources are therefore considered negligible, and no additional mitigation measures are required.

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Appendix D: Marine Archeology Study, Moored Buoys for Scientific Data Collection, North Carolina, Outer Continental Shelf

MARITIME ARCHAEOLOGY DESKTOP STUDY
WOODS HOLE OCEANOGRAPHIC INSTITUTION
MOORED BUOYS FOR SCIENTIFIC DATA COLLECTION
NORTH CAROLINA, OUTER CONTINENTAL SHELF

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DATE:	November 2022

In September 2022, SEARCH completed a desktop analysis in support of a research project the Woods Hole Oceanographic Institution (WHOI) proposed for the deployment of 10 moored buoys for scientific data collection. The project area is in federal waters between 24 and 80 kilometers (km) (13 and 43 nautical miles [nm]) off Nags Head, North Carolina (**Figure 1**). The buoys will be moored by simple anchors measuring approximately 3.5 meters (m) (12 feet [ft]) in diameter. A high-resolution geophysical survey will be conducted in 2023 to microsite the locations prior to installation.

Tetra Tech, Inc., contracted SEARCH to evaluate the proposed buoy locations to identify known, reported, and potential submerged archaeological resources in the vicinity of the project area. This pre-survey review provides WHOI an archaeological study area encompassing 1.6 km (1 mi) of the proposed buoy locations. The results will assist WHOI planning under the United States Army Corps of Engineers *Nationwide Permit 5 Scientific Measurement Devices* permitting process. SEARCH reviewed numerous databases to locate any documented submerged cultural resources in the study area. These databases include:

- Bureau of Ocean Energy Management (BOEM) Archaeological Resource Information Database;
- Global GIS Data Services, LLC, Global Maritime Wrecks Database (GMWD);
- National Oceanic and Atmospheric Administration (NOAA) Automated Wreck and Obstruction Information System (AWOIS);
- NOAA Electronic Navigation Charts Database (ENC);
- 2006 NOAA Aids to Navigation (NavAids) and the 2007 US Coast Guard (USCG) Hazards to Navigation database;
- Secondary sources relative to shipwrecks off the North Carolina coast.

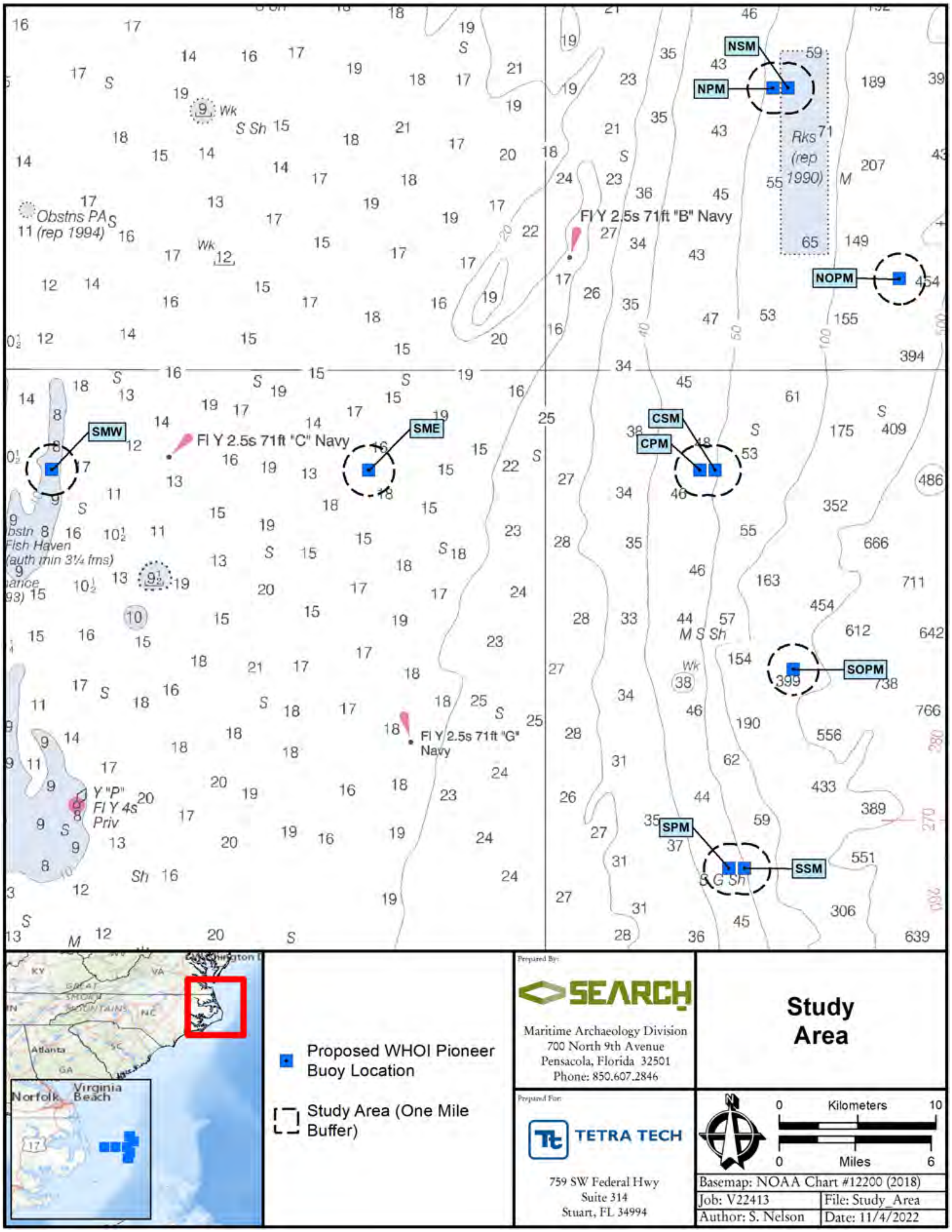

Figure 1. The proposed WHOI buoy locations.

ENVIRONMENTAL CONTEXT

To determine the likelihood of encountering archaeological sites in a particular region, archaeologists apply the knowledge that precontact peoples utilized specific landscape characteristics. Utilized landscapes include floodplains adjacent to river systems, due to their proximity to fresh water, and areas of higher elevation, which are ideal vantage points with dry soils. Evaluating the submerged coastal plains for these landscape features includes a review of regional climate, crustal geophysical shifts, sea-level changes, and shoreline migration. This analysis is essential for creating predictive models for human use of the offshore landscape (Merwin 2010).

The coastal plain of northeastern North Carolina is composed of surficial Quaternary sediments consisting of sand, clay, and gravel in a variety of fluvial and lacustrine environments overlaying a pre-Cambrian igneous basement. These deposits originate from the Eastern Slate Belt, which comprises the middle of the state, primarily metamorphic rocks with some igneous intrusions (Brown 1985). The easternmost of these belts are lower-grade metamorphic rock consisting of Greenschist facies with chlorite and biotite. Intermediate between the metamorphic belt and the coastal sediment plain are the Yorktown and Duplin Formations, which consist of fossiliferous clays interbedded with fine-grained, bluish-gray sand. The western margin of the Atlantic coastal sediment plain is known as the “Fall Line,” which is the boundary where the crystalline metamorphic rocks abut the younger sedimentary strata (Spangler 1950). Much of what is known about the stratigraphy of northeastern North Carolina is from initial oil exploration drilling by the Esso Standard Oil Company between 1945 and 1947.

The underlying basement dips from the Fall Line eastward to the coast and is directly overlain by undefined Lower Cretaceous sediments followed by the Upper Cretaceous Tuscaloosa Formation, which consists of gravelly sands and dark lignitic clays. The Eutaw Formation overlies this layer, consisting of variably colored sands and clay shales with lignite, pyrite, and glauconite. The Eocene is represented by glauconitic, clayey sands with shell limestones and coquinas and is well-dated due to the presence of foraminifera. However, the Oligocene was not represented in any drilled cores, likely because this period was an erosional environment offshore. The Miocene deposits are like those of the Eocene but with frequent phosphate nodules. These formations are overlain by Pleistocene and modern sediments (Spangler 1950).

The geological system of northern North Carolina’s Coastal Plain, from Cape Lookout to the Virginia border, consists of basal sediments of Pliocene age (about 5.3 to 1.8 million years in age) and surficial sediment deposits of Quaternary age (fewer than 1.8 million years in age) (Riggs et al. 1992). The proposed buoy locations are at the eastern edge of the Albemarle Shelf, a depositional basin characterized as an embayment on the central to southeast coast of the United States (Brown et al. 1972) (**Figure 2**). The basin is confined by the Norfolk Arch to the north and the Cape Lookout high on the northern flank of the Mid-Carolina Platform to the

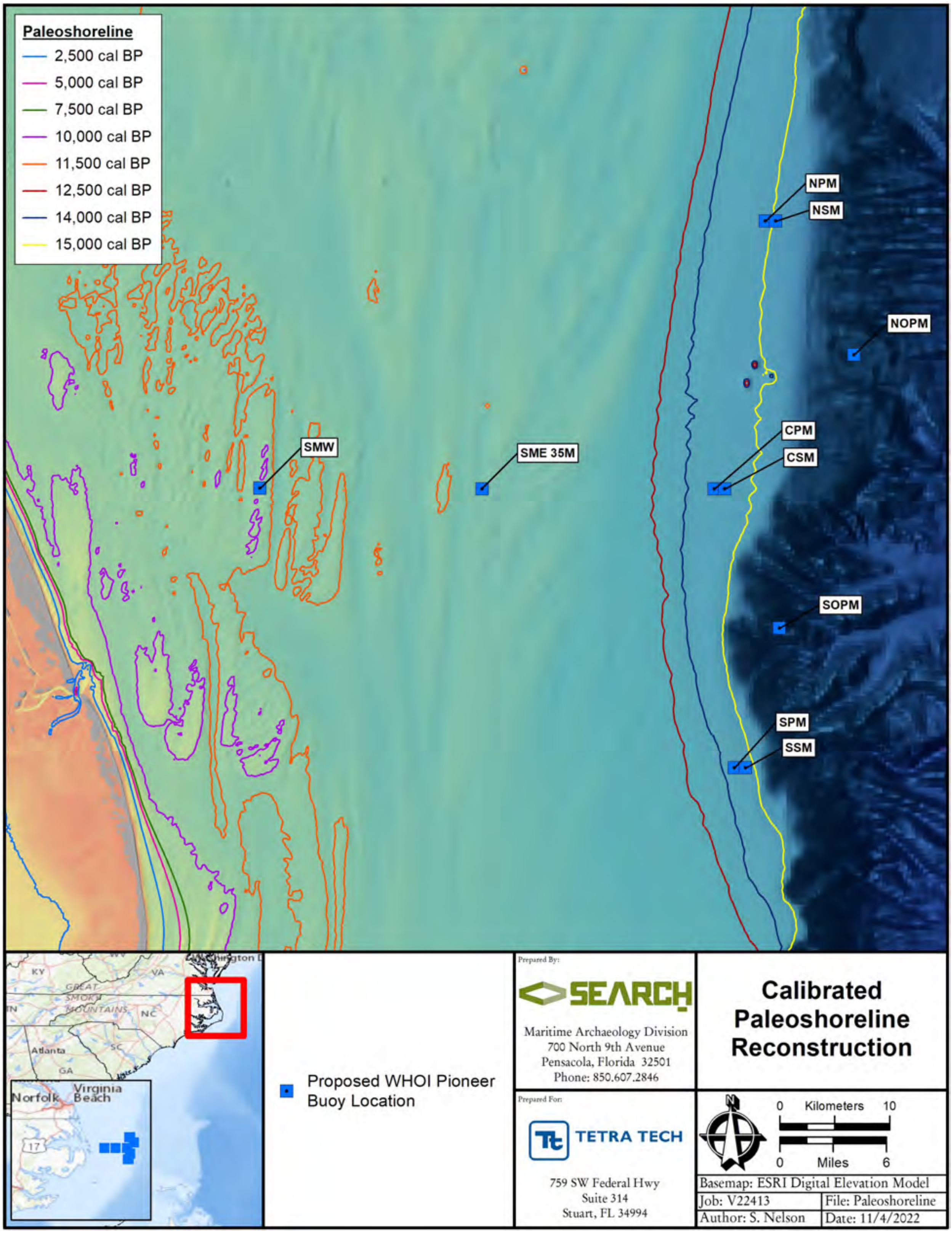

Figure 2. Paleoshoreline migration of the North Carolina Outer Continental Shelf.

south (Ward and Strickland 1985). The Pliocene sedimentary units are composed of several southward protruding sedimentary sequences, whereas the Quaternary deposits are mostly remnant beach features and paleo-channel fill from several fluctuations in sea levels during the past 1.8 million years (Riggs et al. 1992). Sediments that make up the Outer Banks, the formations on the offshore continental shelf and barrier islands east of terrestrial North Carolina, were supplied from three sources: paleo-fluvial channels, shoal complexes, and sand-rich Pleistocene sedimentary deposits (Thieler et al. 2014).

The overlying Quaternary sediments primarily consist of muds and slightly indurated muddy sand, sand, and peat that thicken northward to fill the subsiding Albemarle Embayment. The Quaternary deposits can be 70 to 90 m (229 to 295 ft) thick near major river drainages such as the Roanoke and Pamlico Rivers and Outer Banks barrier islands (Culver et al. 2011; Riggs et al. 1995). The northern embayment is dissected by a large fluvial drainage system incised during the last glacial maximum (LGM), around 24,000 calendar years before present (cal BP). A major paleo-fluvial valley, the Paleo-Roanoke River Valley, bisected the continental shelf and extended eastward from the region around Kitty Hawk, across the continental shelf, and toward the buoy locations. This now-submerged and -buried paleo-river valley was the sole Appalachian-sourced river drainage in the area (Thieler et al. 2014). The paleo-river valley is approximately 8 to 9 km (4.9 to 5.6 mi) wide and is incised to a depth of 57.3 m (188 ft) below sea level (Thieler et al. 2014). The Late Pleistocene to Holocene sediments associated with the LGM fill the paleo-Roanoke River valley (Mallinson et al. 2005; Sager and Riggs 1998). The more-recent late Pleistocene/early Holocene sediments are approximately 15 m (49 ft) thick (Culver et al. 2011) and tend to thin to less than 1.1 m (3.6 ft) below 12.8 m (42 ft) of water depth (Rice et al. 1998). The formation of the estuaries and barrier island system of North Carolina west of the project area began as early as 6000 cal BP as the rate of sea-level rise decreased and sea level approached present-day levels (Kopp et al. 2015; Mallinson et al. 2018).

During the LGM, approximately 24,000 cal BP, 5% of the Earth's water was locked within ice sheets in the northern and southern hemispheres. This caused the lowering of global sea levels by roughly 134.1 m (440 ft) (Lambeck et al. 2014). The reintroduction of fresh water into the oceans radically changed global sea levels and littoral (nearshore) landscapes. During the last 20,000 years, approximately 15–20 million km^2 (5.8–7.7 million mi^2) of coastal landscape has been submerged worldwide, roughly the area of South America (Faure et al. 2002). The introduction of fresh water into the oceans also had global climatic ramifications. Oscillations in climate, coupled with sea-level rise, radically changed the landscape and ecosystem. Arid conditions severely affected freshwater supplies during the climatic shifts, making sources of water such as springs, streams, and rivers focal points for human occupation during those periods (Thulman 2009). The water shortage lowered water tables within the region, limiting major water sources to the springs and deeply incised river valleys, such as the Paleo-Roanoke River (Faure et al. 2002).

The paleoenvironment and paleoecology for North Carolina's Coastal Plain from roughly 14,000 cal BP to present-day climate conditions established roughly 3,000 cal BP, has been reconstructed utilizing pollen analysis of sediment cores extracted from throughout the region. From the LGM to the end of the Younger Dryas, (23,000–11,600 cal BP), Coastal Plain forests were filled with cold weather fir (*Abies*), spruce (*Picea*), pine (*Pinus*), alder (*Alnus*), and a gradually increasing population of oak (*Quercus*) trees (Canuel et al. 2017; Spencer et al. 2017). The assemblage of pollen taxa indicate that the Late Pleistocene climate was much cooler and drier than present-day conditions (Sirkin et al. 1977). There also was an abundance of sedges (*Cyperaceae*) and grasses (*Poaceae*) on which megafauna such as mastodon (*Mammut*) and horse (*Equus* sp.) would have grazed upon (Eshelman et al. 2018). Evidence at sites across the Americas indicate that Paleoindian peoples frequently utilized mastodon and horse as a part of their subsistence strategy (Halligan et al. 2016; Waguespack and Surovell 2003; Waters et al. 2015).

By 14,000 cal BP, all but one of the buoy locations would have been inundated (**Figure 2**). During the Younger Dryas (12,900–11,600 cal BP) period, there was a marked increase in spruce and pine as climatic conditions became increasingly colder and drier (Carlson 2010). Sea levels were 60 to 65 m (197 to 213 ft) below present-day sea levels (Lambeck et al. 2014). The paleo-Atlantic coastline would have been approximately 39 km (24 mi) west of the easternmost project buoy. During this period, many of the megafauna, including mammoths and mastodons, became extinct (Perrotti 2018). The archaeological record also reflects major cultural changes that may have been a response to sudden climatic changes, as Clovis technology quickly spread throughout North America then abruptly disappeared (Waters and Stafford 2007). This abrupt climatic period was followed by warming temperatures and the replacement of spruce and fir by pine and hemlock by 9000 cal BP (Canuel et al. 2017). By this time, sea levels had rapidly increased to 18 m (59 ft) below modern levels (Engelhart et al. 2012). By 10,000 cal BP, the westernmost buoy location was inundated by sea level rise after the Younger Dryas.

From 9000 to 6000 cal BP, sedimentary and pollen data from lake sites in the southeastern United States indicate that the early to middle Holocene was significantly wetter than previously suggested (Grimm et al. 1993). Sea levels also had increased to 7.9 m (26 ft) below present-day levels (Engelhart et al. 2012). This period is characterized by high pollen percentages of tupelo (*Nyssa*) and oak (*Quercus*), but low percentages of pine (*Pinus*). Forests throughout the Southeast would have resembled those of swampy areas in present-day northern Florida. Additionally, 15 large flooding events were detected within sediment samples from the Little River in the upper North Carolina Coastal Plains. This rise in major floods increased fivefold as, on average, five floods were detected per 1,000 years compared to only six large flood events occurring since 6100 cal BP (one flood/1,000 years) (Goman and Leigh 2004). The increase in flooding events is associated with changes in atmospheric circulation related to shifts in the position of the Bermuda High, sea surface temperatures, and El Niño activity. The increase in tropical storms resulted in a greater than average precipitation for the surrounding region than is the case today (Goman and Leigh 2004). By 3500 cal BP, forests shifted to drier, deciduous forests, including oaks and members of the blueberry family, such as arrowwood (*Viburnum*) (Canuel et al. 2017), and sea levels had increased to present-day levels, submerging the study area (Engelhart et al. 2012).

In summary, the palynology data show changes across the Terminal Pleistocene/Early Holocene boundary from cooler and dryer climate species to a shift toward warmer and wetter species. All but one buoy location were fully inundated by sea-level rise by 14,000 cal BP. The westernmost buoy location was inundated by 10,000 cal BP. From 9000 to 6100 cal BP, temperatures ameliorated, and conditions were wetter than at present, with an increase in species such as tupelo, oak, cypress, and sedges. There is an abundance of charcoal in the sediments around 6000 cal BP when modern forest ecosystems emerged with drier climate conditions. The period of colonization is marked by a significant increase in ragweed (*Ambrosia*). Sediment cores collected from Jug Bay in the Chesapeake area span 1,500 years and show changes in trees and wetland taxa during the Medieval Warm period (approximately AD 950–1250). During that time, pollen of walnut (*Juglans*), a tree which grows in wet habitats, decreased dramatically while pollen of dry taxa, such as oak and holly (*Ilex*), increased. Similarly, there are large decreases in seeds of wetland plants such as wild rice (*Zizannia*) and pickerelweed (*Pontederia*). The initial slow increase in ragweed is accompanied by a rapid increase in pollen of the high marsh arrowhead (*Sagittaria*), suggesting drier conditions probably due to sediment infilling of the marsh (Canuel et al. 2017).

NATIVE AMERICAN CULTURAL HISTORY

There are no confirmed precontact archaeology sites within the study area; however, the known presence of Native Americans populations in North America before 13,000 cal BP offers the potential for undiscovered sites to exist. The traditional model for the peopling of the New World argues that Asian populations migrated to North America over the Bering land bridge that linked Siberia and Alaska. These peoples then travelled to southern North American via an ice-free corridor between the Laurentide and Cordilleran ice sheets just before 13,000 cal BP (Fiedel 2000; Waters and Stafford 2014). However, archaeologists continue to identify sites that show clear evidence for human presence in the Americas by 14,000 to 15,000 cal BP (Dillehay et al. 2008; Halligan et al. 2016; Jenkins et al. 2012; Waters et al. 2015). More recently, evidence of humans living on the continent as early as 23,000 cal BP has been presented (Bennett et al. 2021). Human occupation of the Americas prior to circa (ca.) 13,000 cal BP requires alternative models for entry because the ice-free corridor remained closed prior to 13,400 cal BP (Heintzman et al. 2016). An alternative hypothesis for pre-13,000 cal BP migration routes includes populations traveling along the Pacific and Atlantic coasts using boats and following exposed shorelines (Anderson and Gillam 2000; Braje et al. 2017; Bradley and Stanford 2004; Faught 2008; Fladmark 1979). If humans were in the Americas during the LGM by 23,000 cal BP, then other possible routes of entry are available, including over land during the last interglacial period. In the Atlantic, sites that could be associated with coastal migration or oceanic boat use before ca. 4000 cal BP would now be inundated due to increases in global sea levels since the LGM.

The North Carolina–Virginia shoreline is estimated to have migrated across the buoy locations between 15,000 and 10,000 cal BP (see **Figure 2**). The submersion of the buoy locations by approximately 10,000 years ago excludes Mid to Late Archaic-, Woodland-, and Contact-period occupation sites from being established on the associated paleolandscape (Engelhart et al. 2011). The following discussion highlights the precontact chronology for the buoy locations, including Paleoindian and Early Archaic period settlements and possible maritime use by later Archaic, Woodland, and Contact period populations.

Paleoindian Period (>14,500–10,000 cal BP)

Anderson (1995) has identified three Paleoindian periods: Early or Pre-Clovis (pre-15,000–13,250 cal BP); Middle Paleoindian (13,250–12,850 cal BP); and Late Paleoindian/Early Archaic (12,600–10,700 cal BP). The Paleoindian period is characterized by a distinctive set of fluted projectile points, including Clovis, Simpson, Suwannee, and Dalton Hardaway varieties. Paleoindian groups were mobile hunter-gatherers, likely organized in small bands or extended families. Most models suggest Paleoindian peoples were skilled hunters of big-game animals and utilized species such as mastodon and horse as part of their subsistence strategy (Halligan et al. 2016; Waguespack and Surovell 2003; Waters et al. 2015). Multiple sites and isolates in the region support this hypothesis for Paleoindian land use, mobility, and organization (Forman 2003; Lowery 2008; McAvoy and McAvoy 1997; Stanford et al. 2014).

The Cactus Hill site along the Nottoway River in Virginia and the Topper site on the terrace above the Savannah River in South Carolina are two potential examples of pre-Clovis sites regionally located near the buoy locations (Goodyear 2005; McAvoy et al. 2000; Miller 2010). These sites include Middle Paleoindian fluted Clovis points, lithic debitage, fire-cracked rocks, bone, charcoal, and pottery eroded along shorelines and in buried contexts. Lithic debitage and bifacial tools at Cactus Hill are present below the Clovis materials indicative of a pre-Clovis occupation (McAvoy et al. 2000). Broken chert material below the Clovis artifacts at Topper have been used to argue for a pre-Clovis occupation there (Goodyear 2005). Despite the presence of these artifacts, a pre-Clovis occupation at these sites is not commonly accepted. Most archaeologists attribute the pre-Clovis artifact ages and stratigraphic locations to relocation, poor dating contexts, and natural processes (Haynes 2015). Further offshore, a potential isolated Paleoindian biface was found. The Cinmar Isolated Find was located approximately 109.4 km (68 mi) off Virginia near the continental shelf break and approximately 63 km (39.1 mi) north of the northern buoy locations. Archaeologists associated the find with the Paleo-Susquehanna River (Lothrop et al. 2016). The biface and a mastodon skull were discovered by scallop fishermen in the 1970s. The mastodon skeleton was later directly dated to 27,000 cal BP (Stanford et al. 2014). The age of the remains and the loose contextual association with the mastodon skull have made this discovery highly disputed (Boulanger and Eren 2015; Eren et al. 2015; Haynes 2015). Yet, as there is building evidence for human presence in North America and the southeast by 15,000-14,000 cal BP (Halligan et al. 2016; Waters et al. 2018) it is likely that old sites are preserved on Virginia and North Carolina's continental shelves (Stanford et al. 2014).

Middle Paleoindian projectile point variants in the North Carolina Coastal Plain include Clovis points, Hardaway blade, and Hardaway-Dalton. Late Paleoindian variants include Hardaway side notched. Some archaeologists view the Hardaway complex as a manifestation of the Early Archaic period, suggesting that the Hardaway types are the result of synchronic tool modification as opposed to diachronic change. However, most archaeologists agree that the other tools found in association with Hardaway Complex points, such as side- and end-scrapers, are very similar to Paleoindian tool assemblages (Ward and Davis 1999:42). As such, the Hardaway Complex could be a transitional Late Paleoindian/Early Archaic assemblage.

Settlement models derived from data recovered in the Piedmont suggest a Paleoindian settlement system focused on high-quality lithic material (Gardner 1977). This model, however, may not be applicable to the lithic-deprived Coastal Plain. Reid and Simpson (1998:33) suggest that a settlement model proposed by Dent (1995) for the Chesapeake region, which includes the Coastal Plain of Virginia, Maryland, and Delaware, is more applicable to the Coastal Plain of North Carolina. The model proposes two site types: regional residential bases and resource extraction locations, reminiscent of Binford’s (1980) foraging system. The residential bases served as the “hub of subsistence activities,” while the resource extraction locations functioned as lithic procurement sites (Binford 1980:9).

Archaic Period (ca. 10,000–3000 cal BP)

Following the Paleoindian period, climate at the beginning of the Holocene became warmer but remained dry. This period is marked by an increase in population, sedentism, and a change in the environment. Climatic change resulted in the boreal forests occupied by Paleoindian peoples to be replaced with northern hardwoods. Technologically, the early Holocene was the beginning of the Early Archaic period (10,000–8500 cal BP). Little is known about Early Archaic subsistence. Based on the recovery of bone and antler tools, white-tailed deer appear to have been an important species, both for tools and diet (Reid and Simpson 1988). Based on the location of sites within different environmental niches, additional terrestrial and aquatic fauna, such as small mammals and fish, and available floral resources, such as nuts and seeds, are suggested dietary staples (Daniel 2001).

Early Archaic Period (10,000 to 8000 cal BP)

Early Archaic (10,000–8000 cal BP) sites, like Paleoindian sites, are typically identified by the presence of diagnostic projectile points. As noted, some archaeologists view the Hardaway complex as a transitional Late Paleoindian/Early Archaic lithic assemblage, a viewpoint that is open to debate (Ward and Davis 1999). However, there are a series of points, based on definitive stratigraphic context in the Piedmont, categorized as Early Archaic. These include Palmer Corner Notched and Kirk Corner Notched types. Other tools include end-scrapers, side-scrapers, blades, and drills along with various bone and antler tools (Reid and Simpson 1998:34). This general tool assemblage is also found at archaeological sites on the Coastal Plain (Phelps 1983:22).

Early Archaic sites are small with a settlement pattern indicating residential shifts between floodplain and upland ecosystems (Steponaitis 1986:371). Daniel (1998:194) suggests that this movement was most likely predicated on the availability of knappable stone as opposed to a drainage basin adaptation proposed by Anderson and Hanson (1988). However, Phelps (1983:24) suggests that Early Archaic site location in the lithic-poor Coastal Plain was based on stream accessibility.

Middle Archaic Period (8000 to 5000 cal BP)

The Middle Archaic (8000–5000 cal BP) is marked by the appearance of the Stanly Stemmed projectile point along with Morrow Mountain Stemmed and Guilford Lanceolate points (Ward and Davis 1999:73). Tool use also expanded to include atlatl weights, grooved axes, and notched pebbles. Middle Archaic settlement and subsistence patterns were very similar to the previous Early Archaic as groups continued to utilize local resources in the upland terraces and floodplains they occupied.

Numerous sites from the Middle Archaic period have been found along the eroded shorelines and ploughed fields of the region (Lowery 1999). These sites supported larger populations with increased regional dependency for materials and often bear evidence of the reuse of cemeteries, suggesting that the Middle Archaic was a time of higher territoriality and restricted mobility. During the Middle Archaic, modern coastal waterways and estuaries became inundated. Shellfish resources were available to the Middle Archaic cultures living throughout the Coastal Plain (Cronin 2000), although the archaeological procurement settings for shellfish and marine resources are now, for the most part, inundated and difficult to access. The use of marine resources also points to marine adaptations that may include the use of boats.

Late Archaic Period (5700 to 3200 cal BP)

The Late Archaic period is marked by a series of climatic changes from warm and wet conditions to warm and dry conditions to wet and cold conditions. At this time, sea levels increased to approximately 4 m (13.1 ft) lower than present conditions. Given this sea-level history, some Late Archaic sites surrounding the Coastal Plains may be buried below tidal marsh deposits in inundated upland settings (Lowery 2008).

Continued growth in population, regional differentiation, increased technological specialization, increased sedentism, the establishment of trade networks, and the intensified use of the forest and aquatic resources define the Late Archaic period (5700–3200 cal BP). Numerous Late Archaic sites along the Coastal Plain indicate the existence of long-distance trade and cultural influence from peoples living outside of the region. Artifacts, including ground slate knives, points, stone gouges, fishhooks, and old copper cultural items, were found at multiple sites throughout the region, indicating contact with eastern and western Great Lakes cultures (Lowery 2008).

Some of the earliest pottery and steatite vessels are from the Later Archaic. Fiber-tempered clay ceramics were produced at this time, predating steatite vessels in some areas (Sassaman 1993:180). The earliest expression of fiber-tempered ceramics in the Coastal Plain is the

Stallings series (Ward and Davis 1999:76). Exterior surface treatments included punctations, incising, and finger pinching. Stallings pottery is found throughout the southern Coastal Plain but is rare north of the Neuse River, leading Phelps (1983:26) to subdivide the Coastal Plain into north and south subregions. The Thom's Creek series, which is like the Stallings series in terms of exterior surface treatments, is a sand-tempered ceramic and associated with the Late Archaic. Late Archaic groups, however, did not abandon lithic technology. In the North Carolina Coastal Plain, the broad-bladed, broad-stemmed Savannah River type is the diagnostic projectile point of the period. Late Archaic groups also continued to use atlatl weights and grooved axes seen during the Middle Archaic.

During this period, settlements seem to shift from upland terraces and riverine valleys to estuaries and the mouths of major rivers (Ward and Davis 1999:75). In South Carolina, Georgia, and Florida, large coastal shell rings and shell sheet middens have been associated with the Late Archaic. These types of sites are rare along the North Carolina coast (Reid and Simpson 1998:39). Late Archaic sites in this area are reminiscent of earlier site types, including large, residential base camps and smaller resource extraction locations. The increased use of coastal locations also suggests a potential increase in boat use and on-water activities during the period.

Woodland and Contact Period (3200 cal BP–European Contact)

Woodland Period (3200 to 300 cal BP)

The Woodland period (3500–300 cal BP) is characterized by the widespread introduction of ceramics, the onset of maize cultivation, and the emergence of sedentary lifestyles and complex societies. There also was a continued population increase throughout the Coastal Plain region. The climate generally approached present-day conditions, which allowed subsistence resources to become more reliable as sea levels reached near-current levels. The cultural regionalization, typically reflected in ceramic assemblages, lead to a division of the Coastal Plain into northern and southern subregions. The northern Coastal Plain extends from the Neuse River north to the Virginia state line.

Early Woodland Period (3200 to 2400 cal BP)

The Early Woodland period (3200–2400 cal BP) is typically marked by pottery’s common usage and subsequent common archaeological occurrence. Early minority pottery types in the Coastal Plain represent a southeastern tradition and include the fiber-tempered Stallings wares and sand-tempered Thom's Creek series. More common wares recovered throughout the Coastal Plain reflect a Middle Atlantic influence as evidenced by the frequent recovery of sand-tempered, cord-marked, and fabric-impressed ceramic sherds (Phelps 1983).

In the northern Coast and Coastal Plain, the Early Woodland period is known as the Deep Creek phase and is identified by the recovery of Deep Creek ceramics. The series was named for a small tributary of the Tar River where the complex was first recognized at the Parker site

(31ED29) (Phelps 1983:29). The Deep Creek series contains medium to coarse sand tempering with, in order of frequency, cord-marked, net-impressed, fabric-impressed, simple-stamped, and plain surfaces.

The Hamp's Landing series, a limestone- or marl-tempered ceramic, also has been associated with Early Woodland contexts (Hargrove and Eastman 1997:92). Surfaces are typically plain, simple stamped, fabric impressed, or cord marked. Associated lithic tools are somewhat limited and include the Gypsy point, thought to be a derivation of the Savannah River type, and the Roanoke triangular point (Phelps 1983:29).

Little is known about Early Woodland settlement patterns on the Coastal Plain; however, Phelps (1983:32) speculates that it was like that of the Late Archaic period. Reid and Simpson (1998:41) suggest that the Woodland settlement pattern proposed by Gardner (1982) in the Virginia Coastal Plain may be applicable to the southern Coastal Plain of North Carolina. The settlement model included two site types: large base camps and smaller resource extraction camps. The largest known sites are in transition zones between fresh and salt water (Stewart 1992), while smaller sites along streams were occupied seasonally.

Middle Woodland Period (2400 to 1200 cal BP)

The Middle Woodland (2400–1200 cal BP) period is known as the Mount Pleasant phase in the north. Mount Pleasant ceramics are tempered with medium sand and include “an occasional large particle of quartz sand” (South 1976:18) or “larger clastic inclusions” (Phelps 1983:32). Surfaces are cord marked, fabric impressed, or net impressed. Hanover ceramics, also associated with Middle Woodland contexts throughout the Coastal Plain, are tempered with crushed sherds or lumps of fired clay. Exterior surfaces also were cord marked and fabric impressed. Roanoke points, biface blades, abraders, celts, shell pendants, and gorgets have been associated with the Mount Pleasant phase in the northern Coastal Plain (Phelps 1983:33). North of the Virginia border, during the Middle Woodland period after 1700 cal BP, Mockley ware became the dominant Coastal Plain ware (Stewart 1992). Mockley ceramics are characterized by a poorly paddled paste, 20 to 30%of which is composed of unburned, crushed shell, usually oyster.

Settlement patterns during the Middle Woodland have been described as “dispersed,” marked by “a relatively high rate of residential mobility...” (Herbert 2002:302). Loftfield (1976) notes a shift from upland areas to bottomland sites, perhaps in response to increased plant cultivation, and estuaries for resource procurement. The number of shell midden sites also increases during this period. In the north, subsistence reflects a greater dependence on estuarine resources than in previous periods. Phelps (1983:33) suggests that small camps in the estuaries were used as shellfish-collecting stations, with hunting and fishing relegated to minor activities. Despite these activities, heavy and continuous warm-season fishing and clamming were documented at the Addington site in Virginia Beach (Whyte 1988). Deposits at this site date approximately from 1800 to 400 cal BP.

Late Woodland Period (1200 to 300 cal BP)

By the Late Woodland, agriculture had developed into a major subsistence activity, ushering in significant changes in precontact settlement patterns. The growing human population inhabited larger, more sedentary villages, participated in a new range of activities, and developed complex forms of sociocultural interaction (Turner 1992). The Late Woodland/Contact period (1200—300 cal BP) is divided into the Colington phase along the northern Tidewater and the Cashie phase within the interior of North Carolina's northern Coastal Plain and associated with historically documented Algonquian-speaking and Iroquois-speaking tribes, respectively. Colington-phase sites along the northern coast are identified primarily by the recovery of shell-tempered ceramics. In order of popularity, surface treatments are fabric impressed, simple stamped, plain, and incised. Additional artifacts include small triangular points, abraders, celts, bone pins and awls, fishhooks, shell hoes and picks, freshwater pearls, and shell beads (Ward and Davis 1999:211).

Settlements have been identified archaeologically and historically; however, settlement patterns remain problematic. Post molds associated with two Colington-phase longhouses and a palisade were uncovered in 1985 at the Amity Site (31HY43) east of Lake Mattamuskeet in Hyde County, North Carolina. The use of longhouses is supported in a historic context from accounts of European explorers and with the help of drawings by John White in 1585. White's drawings provide a very different view of village organization. The village of Pomeiock on the north side of the Pamlico Sound is a palisaded, circular settlement with numerous longhouses in the interior, while Secoton on the south side of the Pamlico River appears to be more of an elongated village with nucleated and dispersed sets of longhouses (Ward and Davis 1999:214–215).

White's drawings also show the use of charnel houses (moturary vaults). Mass graves or ossuaries appear to have been a major part of the Algonquian burial complex; however, semi-flexed and bundle pit burials have been associated with Colington ceramics in Dare County, suggesting alternate burial practices (Ward and Davis 1999:216). Evidence for subsistence is also provided in the historic record. White's drawings of the village of Secoton show fields of corn in various stages of maturity (Ward and Davis 1999:215). In addition, Colington-phase site locations suggest the continued use of riverine, upland, and estuarine environments.

The Cashie phase is associated with the Iroquois-speaking Tuscarora in the northern, inner Coastal Plain. Most of the information on the Cashie phase comes from excavations at the Jordan's Landing site (31BR7) in Bertie County, North Carolina. Cashie ceramics are tempered with small pebbles that typically extrude through the interior and exterior surfaces. Surface treatments are fabric impressed, simple stamped, incised, and plain. Additional artifacts include numerous bone tools such as awls and perforators, shell beads, and small Roanoke and Clarksville triangular points.

Cashie burial practices were different than those along the coast. Cashie ossuaries typically contain two to five individuals, as opposed to the large number of individuals found in

Colington and White Oak ossuaries. Phelps (1983:43) suggests that the small number may reflect a sociopolitical organization focused at the village level. Based on the archaeological and historical record, Phelps (1983:43) defines the settlement pattern as small villages, farmsteads, and specialized camp sites. Subsistence data include hickory nuts, various species of mammals, turtles, turkey, mussels, and domesticates such as maize and beans (Phelps 1983:46). However, as of 1983, no complete Cashie structures had been identified (Phelps 1983:47).

Many Algonquian groups in the north were united under the rule of Chief Powhatan of the Chesapeake Bay region. By the beginning of the seventeenth century, the Powhatan chiefdom encompassed most of the Coastal Plain of Virginia and had a population of possibly 13,000 people. The first well-documented contact between Europeans and the Native American groups of the lower Chesapeake Bay occurred in 1570 (Strickland et al. 2016; Turner 1992).

POSTCONTACT CONTEXT

This section provides a maritime historic context of the proposed WHOI buoy project on the Outer Continental Shelf (OCS) off North Carolina. This context emphasizes the key events, people, places, and activities that have affected the maritime history of this region, from the period of European settlement in the early seventeenth century to present.

Contact Period

Bodie Island, a member of North Carolina's ever-evolving string of barrier islands known collectively as the Outer Banks, was first explored by Europeans during the mid-sixteenth century. In 1524, King Francis I of France commissioned Giovanni de Verrazano to discover the elusive Northwest Passage. Verrazano and his crew of the carrack *La Dauphine* departed Portugal on January 17, 1524. Following an arduous transatlantic crossing, the crew of *La Dauphine* made landfall on March 21 at a site dubbed "Selva di Lauri" (Forest of Laurels) in the locale of present-day Cape Fear, North Carolina. Verrazano initially turned south for approximately 225 mi before turning north to follow the Atlantic Coast to Newfoundland. On March 25, *La Dauphine* landed a party of 25 men to replenish the ship's dwindling supply of fresh water. Upon seeing an expansive body of water bordering the island's western shore, Verrazano determined that he was standing on the isthmus that divided the Atlantic Ocean from the long sought after "Oriental Sea" (Stick 1958:13). According to historians, Verrazano had in fact made landfall on North Carolina's Outer Banks within the vicinity of present-day Cape Lookout and Cape Hatteras. Thus, the Oriental Sea was in fact present-day Pamlico Sound. Verrazano would continue north, passing by the remaining islands of the Outer Banks before eventually reaching Newfoundland. Running low on supplies, Verrazano ordered his ship's helm turned east and back to European waters. He and the crew of *La Dauphine* returned to Dieppe, France, on July 8. Though his written observations would prove vital to subsequent explorers, his inaccuracy would haunt Europe for more than 150 years as many a resource would be spent endeavoring to find Verrazano's sea (Stick 1958:11–21).

Except for shipwrecked sailors in 1559 and 1564, the region of the Outer Banks remained devoid of foreign invaders in the succeeding years of 1524 (Stick 1958:14). That narrative was ended, however, in late summer 1566 with the arrival of the packet boat *La Trinidad* carrying two Dominican friars, 15 soldiers, and one baptized Virginia Native American named Don Luís. The expedition was the brainchild of Pedro Menéndez de Avilés, Spanish Governor of Florida, to further extend Spain's colonial reach into the Baya a de Santa Maria (present-day Chesapeake Bay). The proposal called for returning Don Luís, a native chieftain, to his homeland within the Chesapeake Bay region. Upon his safe return, it was expected that Luís would assume his place among his people and "champion the cause of Spain and Catholicism" (Vigneras 1969:403). The expedition sailed from San Mateo, Florida, on August 2 and arrived in present-day Chincoteague Bay on the August 14. However, strong winds forced *La Trindad* out to sea, and they did not reach the coast again for another 10 days. Unbeknownst to the Spanish, they were considerably further south than their initial landfall. The expedition entered what they believed to be a river but was in fact present-day Currituck Sound. The newly found "river" and its opposite banks were claimed for the King of Spain and dubbed San Bartolmé (Saint Bartholomew). The Spanish would spend the next three days exploring the river's banks, even going so far as venture seven leagues inland before Don Luís concluded the region was not the land of his people. *La Trindad* was provisioned and turned north before a hurricane forced the expedition to set sail for Spain. *La Trindad* arrived in Cádiz, Spain on October 23, 1566 (Vigneras 1969:398–414).

Despite continued Spanish interest in region, it was the English in 1584 that arrived with serious intentions to settle a permanent colony. On July 4, two English barks, *Bark Raleigh* and *Dorothy*, arrived under the combined command of Captain Phillip Amadas (*Bark Raleigh*) and Captain Arthur Barlowe (*Dorothy*). This expedition was seen as a preliminary step to exercising the power granted to Sir Walter Raleigh by Queen Elizabeth I on March 25, 1584 (Stick 1958:14). Under the proceeding Royal Charter of 1584, Raleigh was authorized to explore and establish dominion over any "remote, heathen and barbarous lands, countries and territories, not actually possessed of any Christian Prince or inhabited by Christian People [*sic*]" (Lillan Goldman Law Library 2008). The charter was not only viewed as potentially profitable entity for the budding British Empire, but also as a check to the growing Spanish presence in the New World. For Amadas and Barlowe's part, their collective mission was to explore the region and provide a detailed assessment regarding the area's potential for future colonization within the proceeding seven years (the length of the royal charter) (Stick 1958:14).

Upon sighting the coast on July 2, presumably within the vicinity of present-day Core Banks, the ships turned north and followed the shore approximately 120 mi. Two days later, the vessels reached a navigable inlet near present-day Jean Guite Creek, just north of present-day Kitty Hawk (Stick 1958:14). Upon navigating the treacherous inlet, the ships "cast anker about three harquebuz-shot within the havens mouth on the left hand of the same…and took possession of the land, in the right of the Queenes most excellent Majestie [*sic*]" (Barlowe 1584:2). After approximately six weeks of exploration and trade with local Native American tribes, the two vessels returned to Plymouth, England, in September 1584.

Upon reading the expedition's proceeding report, Raleigh decided to finance a second expedition to the North Carolina coast. Led by Raleigh's cousin, Sir Richard Grenville, the members of the expedition included approximately 600 men, 300 of which were soldiers, and various tradesmen, including carpenters, smiths, cooks, shoemakers, and at least one minister. Their collective mission was to establish a permanent settlement on the lands previously explored by Captains Amadas and Barlowe. On April 9, 1585, five vessels, including the refitted galleass *Tiger*, flyboat *Roebuck*, ship *Red Lion*, ship *Elizabeth*, and bark *Dorothy*, slipped their moorings at Plymouth, England, and arrived off present-day Ocracoke Island on June 26. Despite reaching their destination with most ships intact, the expedition experienced difficulties from the onset. Grenville's flagship, *Tiger*, had too deep a draft to navigate the narrow inlet leading to Pamlico Sound and subsequently ran aground on June 29. To further frustrate matters, much of the ship's cargo was destroyed in the crew's efforts to refloat the vessel, thus a years' worth of food was cut to roughly 20 days of rations. Following exploration of the county to the south and the west, Grenville and his party received permission from local Native American leaders to establish a settlement on the northern portion of present-day Roanoke Island (Stick 1958:16–17).

On August 25, Grenville departed the island with roughly 500 men aboard the *Tiger* and *Roebuck* with the intention of returning to England for additional men and much-needed supplies. He left command of the settlement and its 107 inhabitants to Sir Ralph Lane, who saw to the completion of a small fortification consisting of primitive lodgings within an earthen perimeter wall. Despite the colonists' perseverance, dwindling supplies and poor relations with local tribes plagued the colony for remainder of its short existence. On June 8, 1586, Sir Francis Drake arrived off the coast of the Outer Banks with an assorted fleet of 23 vessels following a successful cruise against Spanish shipping in the Spanish West Indies and Florida. Drake was prepared to offer assistance to the colony with whatever supplies and manpower the colonists required; but a three-day hurricane scattered the fleet and ultimately lead to Lane's decision to abandon his position on Roanoke Island. Lane and the remaining colonists boarded the *Bark Bonner* on June 19 and arrived in Plymouth, England, in July 1856. Ironically, a relief ship outfitted by Raleigh, and "fraighted with all maner of things [*sic*]," arrived off the coast of the Outer Banks in late June (Stick 1958:18). Upon finding Lane's fort abandoned, the ship was quickly repaired for England "with all the aforesaid provisions" (Stick 1958:18). Following in close succession, Sir Richard Grenville arrived with six ships boasting 200 colonists and supplies; however, he too found Lane's settlement abandoned. Unwilling to give up England's hard-fought position, he left 15 men behind with two years' worth of provisions (Stick 1958:19).

The following spring, Sir Walter Raleigh made a final attempt to capitalize on the Royal Charter of 1548. On May 8, 1587, the ship *Lyon* and her two consorts, a 20-ton flyboat and a 30-ton pinnace, departed Plymouth, England, with 150 colonists under the command of the artist John White. The small fleet arrived off the Outer Banks on July 22 with the intention of collecting the 15 men left behind by Sir Richard Grenville the previous summer and continuing to the Chesapeake Bay in the hopes of establishing the "Cittee of Raleigh [*sic*]" (Stick 1958:19). However, upon reaching the northern tip of Roanoke Island, White and his fellow colonists found Lane's fort demolished. Among the ruins lay the bare bones of a man believed to be one of the 15 men left behind by Grenville. Following much debate, White reluctantly ordered his colonists to establish themselves in the remnants of Lane's fort with the resolve to make their stay permanent. Despite rebuilt homes and improved relations with local tribes, the colony required additional manpower and supplies if it were to survive as intended by Raleigh. The colonists elected then-Governor James White to return to England to "encourage and accelerate plans to resupply and reinforce the colony" (Evans 2006). White departed the colony on the *Lyon* on August 27, 1587 (Stick 1958:20).

Three years would pass before White returned to the northern tip of Roanoke Island. He returned not as the leader of a relief expedition, but as a passenger onboard the ship *Hopewell*, the flagship of privateering fleet under the command of John Watts. On August 18, 1590, White, Watts, and their fellow privateers found the colony all but abandoned. Further examination of the immediate area turned up no trace of the 117 inhabitants save the word "CROATOAN" carved into a post that once made up the fort's outer fence and the letters "C-R-O" carved into a nearby tree (**Figure 3**). Designs to conduct an extensive search of the area were abandoned following the approach of severe storms, which forced Watt's weather-beaten ships to return to England for repairs. The fleet arrived in Plymouth, England, on October 24, 1587. To this day the fate of the so called "Lost Colony," remains a mystery (Stick 1958:21).

Figure 3. An 1876 sketch of John White returning to the Roanoke Colony after a three-year absence to find the colony mysteriously deserted (Bryant and Gay 1876).

Colonial Period

In the aftermath of the Lost Colony, King James I of England chartered the Virginia Company of London in 1606 and tasked investors with establishing a permeant settlement in North America. As a result, the Jamestown settlement was established on the northern bank of the present-day James River on May 14, 1607 (Rouse 1972). The physical boundaries of the settlement began to expand as early as 1611 as colonists (those newly arrived and preexisting) sought healthier places to settle and potentially prosper. Further fuel was added to the fire of those desiring to relocate following John Rolfe's successful cultivation of tobacco in 1612 (Salmon 2010). Suddenly, colonists were not only in need of land, but land that contained well-drained soil with good aeration, essential characteristics for tobacco cultivation. In the proceeding years, colonial expansion slowly began to spread south and east of Jamestown. By 1653, colonists reached the banks of the present-day Albemarle and Currituck Sounds. Known as the Albemarle region, this remote area of land and water was the stuff of legend prior to the mid-seventeenth century. Early explorers and hunters to the region returned to the Virginia settlements boasting of the country's "glories and riches" (Connor 1919:23). An early visitor to the region named John Pory reported the region was "very fruitful and pleasant county, yield[ing] two harvests in a year"

(Connor 1919:23). Another visitor named Edward Bland declared "tobacco will grow larger and more in quantity than in Virginia" (Connor 1919:23).

To instill order over competing territorial claims within the Albemarle region, King Charles II of England granted the Carolina Charter of 1663 to eight of his most loyal supporters. Known as the Lords Proprietors, this group of men gained board authority over the land between the Virginia Colony and Spanish Florida. On September 8, 1663, the Lords Proprietors issued the new colony's first land grant. The recipient was Sir John Colleton, a member of the Lords Proprietors, and the property deeded to him was an island known today as Colington Island. There, Colleton built a plantation that is widely considered the "first permanent settlement in the Banks area" (Stick 1958:22). In the proceeding years, the plantation would attempt to "grow tobacco, cultivate grapes and start a winery, and raise hogs." However, it appears none of the ventures took serious hold, largely due to the island's lack of soil development and instability. Colleton's experience, however, did not stop other like-minded individuals from following suit, and by the early 1720s, the entire Outer Banks was in private hands, though most of the population was composed of individuals and families of "modest circumstances, who either squatted on the large holdings or secured grants for small tracts of their own" (Stick 1958:23). Overall, island residences primarily relied on marine life, including fish, and water flow for sustenance and more than likely maintained a small garden for supplemental means (Stick 1958:22–25).

While the soil was unfavorable to support large-scale crop cultivation, the islands offered its diverse population other means to turn a profit. Dead whales routinely washed ashore, and from them, inhabitants extracted oil and bone. These humble beginnings turned into full-fledged industry following the influx of New England whalers to the region as early as 1715 (Stick 1958:24, 33). With them came the introduction of offshore whaling techniques, and by 1730, the Kingdom of Great Britain was importing on average roughly 656 imperial gallons of whale oil from Carolina (Reeves and Mitchell 1988:4). Additionally, the region's remoteness and inaccessibility to outsiders provided "excellent natural grazing lands without requiring fencing," thus stock raising quickly became an important occupation for early inhabitants. While this livelihood proved profitable, the introduction of animals such as "cattle, horses, hogs, and sheep" further contributed to the Outer Banks instability, thus accelerating the island's erosion via wind and water (Stick 1958:33).

In addition to providing natural boundaries for livestock, the islands' seemingly impassable barriers provided inhabitants with yet another occupation, though this one was potentially more lucrative albeit sporadic. Wrecking became synonymous with the Outer Banks in the years leading up the eighteenth century. This unsavory characteristic became a national reputation following the incident of the HMS *Hardy* in 1696. A swift frigate of the Royal Navy, *Hardy* was allegedly driven ashore between Roanoke Inlet and Currituck Inlet and looted by locals, "who got some of her guns ashore and shot into her sides and disabled her from getting off" (Stick 1958:23). Pirates, those known and otherwise, also took advantage of the region's natural asylum. In the waning years of the "Golden Age of Piracy" (roughly 1713 to 1718), notorious sea rogues such as John "Calico Jack" Rackham and Edward "Blackbeard" (**Figure 4**) each utilized the Outer Banks as a rendezvous from which to terrorize coastal shipping lanes. Practicing hit-and-run tactics, these raiders and their crews relied on captured merchantmen such as sloops and schooners to ply their trade. These sleek, shallow drafted vessels came equipped with ample cargo space and were easily modified to carry heavy armament, which the pirates used to deadly effect (Konstam 1999:7–77). The problem became so significant and far-reaching that Virginia Governor Alexander Spotswood was forced to intervene without the knowledge of North Carolina Governor Charles Eden. On November 17, 1718, Spotswood sent the provisional sloops *Ranger* and *Jane*, under the command of Lieutenant Robert Maynard and manned by Royal Navy sailors, to the Outer Banks. At dawn on November 22, Maynard engaged Blackbeard and the crew of the sloop *Adventure* off Ocracoke Island. The ensuing action resulted in the death of Blackbeard, whose severed head was suspended from the bowsprit of *Ranger* as a grisly trophy of Maynard's victory. The engagement, commonly referred to as the Battle of Ocracoke Inlet, ended both the "most notorious pirate of them all" and the golden age of piracy (Rankin 1994:55–61).

Figure 4. An eighteenth-century portrait of Captain Edward Teach, also known as Blackbeard. The ship in the background is believed to be his flagship *Queen Anne's Revenge* (Nicholls 1726–1765).

Albemarle policymakers, free from the burden of the pirate menace, were eager to establish permanent communities on the Outer Banks to facilitate greater regional commerce. However, many of the proposed settlements, such as the Town of Carteret on Roanoke Island in 1723 and the town of Portsmouth on Ocracoke Island in 1734, failed to physically materialize until the 1750s, if at all. Though these locations were hardly the foundation for a town, scanty accommodations were made to station experienced maritime pilots to assist incoming vessels to commercial hubs such as Edenton and Bath Town (Stick 1958:40–43).

While policymakers were busy laying the groundwork for anticipated communities, opportunistic individuals, both near and far, were buying up what remained of the available land on the Outer Banks. One of the more notable land grants was deeded to a resident of nearby Alligator River, Matthew Midget. In 1722, Midget purchased all 1,900 acres of Bodie Island, which at the time was a 9.5 mi strip of land bracketed by Roanoke Inlet to the north and Chickinacommock Inlet to the south. Later that year, Midget and his family moved to the island and established one of the first permeant settlements near the site of the Lost Colony in more than a century. Midget died at his residence on Bodie Island in 1734, but he left behind four sons to carry on his family name and ensure the survival of his investment for later years f(Stick 1958:277).

Further colonization of the Outer Banks stopped temporarily when war between the empires of Britain and Spain came to the area in the spring of 1741. Known collectively as the War of Jenkins' Ear (1739–1748), Spanish privateers arrived due the conflict, including a "large, high stern black sloop" in late April 1741 (Stick 1958:35). By early May, the Spanish vessels had "captured a total of six vessels, including two registered at Edenton" (Stick 1958:35). The Spanish would continue periodic raids of the Outer Banks and harassing English shipping along the coast until the cession of hostilities in 1748. Their final raid culminated in the burning of Brunswick Town on the western bank of the Cape Fear River, just south of present-day Wilmington, North Carolina (Stick 1958:37). Though the damage from the conflict was relatively minimal on the Outer Banks, North Carolina Governor Arthur Dobbs pushed forward plans to establish fortifications at Beaufort and Ocracoke Inlets. Fort Dobbs at Beaufort Inlet was never completed and thus was never garrisoned. Fort Granville at Ocracoke Inlet was completed in 1756 and garrisoned the following year. Though the fort was abandoned less than 10 years later, its garrison's need for local amenities and accommodations paved the way for the development of nearby towns Portsmouth and Pilot Town (also known as Ocracoke Village). These two villages were the largest communities on the Outer Banks on the eve of the American Revolution in 1775 (Stick 1958:35–43).

Revolutionary War

In the aftermath of the French and Indian War (1754–1763), the Kingdom of Great Britain made repeated attempts to levy taxes against its 13 American colonies to alleviate the heavy debt incurred during the conflict's campaigns. These policies coupled with the colony's overall attitude and various responses toward them resulted in the outbreak of war on Lexington green on April 19, 1775. At the commencement of hostilities, Britain's Royal Navy boasted approximately 150 ships and was considered to be the superior maritime fighting force in the world (Clodfelter 2017). Playing the role of David to the Royal Navy's Goliath was the newly created Continental Navy, which did not possess a single vessel at the outbreak of war. Thus, the Continental Navy was forced to purchase armed merchantmen while simultaneously launching frigates inferior in both design and armament to those of its adversary (Holland 2000).

As a result of the Royal Navy's overwhelming nautical superiority, the British Admiralty predictably responded with "a naval blockade–designed not only to cut off the colonies from Europe and the Caribbean but also to sever intercolonial commerce" (Davis and Engerman 2006:59). However, in the roughly eight and a half years of war, the Royal Navy could never fully accomplish either facet of its assignment. For one, the British commanders, which include the likes of Lord Richard Howe, never seemed to have enough ships to cover the entirety of the American coast. In fact, the largest contingent of vessels attached to the North American station at one time was 90 ships of various types. While this amount appears adequate to institute a formidable blockade, the actual number of ships at sea never equaled the number of ships available on paper. This discrepancy was largely due to the reality that wooden ships are forever in a state of decay, thus requiring constant repairs. The issue regarding a lack of ships on station was further compounded on March 18, 1775. On that date, the Continental Congress approved the commissioning of privateers and provincial naval vessels to harass British vessels. During the war, some 2,000 vessels were granted letters of mark and reprisal (Daughan 2016:37–43). It is estimated that American ships captured approximately 3,100 British merchantmen (Daughan 2016:37–43).

The colony of North Carolina, particularly the Albemarle region, quite possibly proved to be the greatest thorn in the side of the Royal Navy. As a whole, North Carolina was notorious for its liberal policies regarding privateering. Sailors of privateers fitting out in the colony were authorized to keep "one half of the goods taken from merchant ships" (Feyerabend 2019:5). In the event a privateering crew captured a British vessel, they could "split the bounty among themselves, minus a fee" (Feyerbend 2019:5). In addition to these appealing incentives, crews based in the Albemarle region had yet another reason to put to sea early and often: the Outer Banks, long cursed as a physical barrier responsible for stunting the development of a region, now acted as a natural seawall against opposing forces. This increased the odds of successful privateering activities against the brute strength of the Royal Navy. For the duration of the war, the ports of the Albemarle, Currituck, and Pamlico sounds remained open for commerce. Much-needed supplies and war material poured through the narrow inlets of the Outer Banks. Allied vessels running in and out of Ocracoke Inlet were considered the best hope for getting supplies to Washington's beleaguered army at Valley Forge during the winter of 1777 (Stick 1958:45).

Despite their precarious situation, the British did what they could to stifle American trade and discourage support for the patriotic cause among the Outer Banks' inhabitants. From 1775 to 1782, Royal Navy ships routinely took station off the various inlets of the Outer Banks, capturing numerous merchant craft in the process. In addition to the ships offshore, Royal Marines conducted frequent raids of the Outer Banks' settlements. Most of these activities involved livestock looting, much to the chagrin of the livestock's owners, but resistance was often met with violence and destruction of property. In response to these affronts, the North Carolina Provincial Congress recommended "six companies be stationed along the seacoast between Virginia and South Carolina" (Delaney 1959:4). By the end of 1776, five companies of provincial troops were sent to the Outer Banks and stationed at strategic locations: "one between Currituck and Roanoke Inlet, one at Ocracoke Inlet, one between Ocracoke and White Oaken Inlet, one between Bogue Inlet and new River Inlet, and the last to be stationed between New River and Deep Inlet" (Delaney 1959:4). In addition to the troops ashore, two row galleys were pledged to the defense of the Outer Banks by Virginia's General Assembly. Only one galley, the *Caswell*, was completed and sent to Ocracoke Inlet, where it served until it sank due to poor maintenance in 1780. The final defensive measure employed on the Outer Banks was the construction Fort Hancock at Cape Lookout in 1778. Erected using earth and logs, Fort Hancock boasted at least six cannons and included "barracks, powder house, and well" (Stick 1958:59). The fortification, however, never saw significant action, and its garrison was removed by the end of 1781. By that time, the British had met a disastrous defeat at the hands of American and French forces at Yorktown, Virginia. This long sought-after Allied victory effectively brought the British war effort in the 13 American colonies to a close (Grant 2008:171).

Figure 5 is a 1776 map of the North Carolina coast created by B. Romans of London, England. As described above, the waters off the coast of the Outer Banks was anything but quiet during the years of the American Revolution. During this time, Allied privateers and Royal Navy warships and auxiliary vessels would continuously traverse the project area. Despite leading raids and establishing a loose blockade, the British never completely closed the Outer Banks to the American war effort.

War of 1812

In the immediate aftermath of the Revolutionary War, approximately 1,000 people lived in the Outer Banks. While the islands remained scantly developed even by eighteenth-century standards, the foundations for present-day villages such as Kitty Hawk were very much in place in 1783. As for regional occupations, little had changed over the last century. Piloting remained the staple source of income for most inhabitants of Portsmouth and Ocracoke Village. Elsewhere on the Outer Banks, locals attached several occupational titles to themselves, including farmer, planter, stockmen, mariner, and whaler. Except for the pilot title, most residents assumed all occupational titles. Residents “raised garden stuff for the table, owned stock which grazed on the open Banks range, caught their own fish, dug their own oysters, and clams, put up their own houses, built and sailed their own boats” (Stick 1958:73). Even the old occupation of wrecking found its way into the late eighteenth century when locals became instant beachcombers upon learning an ill-fated ship was pounded to pieces on the island’s ocean side (Stick 1958:72–73).

In the waning years of the eighteenth century, the world around the Outer Banks once again descended into a state of war. In 1792, the French Revolutionary Wars commenced, and with them came a disruption in global trade as belligerent European nations attempted to disrupt each other’s supply chain. At the onset of hostilities, the United States remained neutral, but this policy soon drew the ire of both sides, and restrictions were placed on American maritime commerce (Lipsey 2000). By 1812, belligerent nations repeatedly violated the rights of US ships and sailors, even those of the American Navy (reestablished in 1794). America’s desire to protect its maritime prerogatives coupled with its western territorial expansion led to a declaration of war on the United Kingdom on June 18, 1812 (Springer 2017). Once again, America found itself badly outmatched in the maritime theater of war. Britain’s Royal Navy had approximately 800 warships in commission on the eve of hostilities, whereas the recently revived United States Navy had just 16 commissioned warships (Black 2008). What the US Navy lacked in quantity, however, it more than made up for in quality. Six of the warships were Joshua Humphreys’ famed six frigates: USS *United States*, USS *Constellation*, USS *Constitution*, USS *Chesapeake*, USS *Congress*, and USS *President*. Their unique construction and heavy armament allowed them to overpower the inferior frigates of the Royal Navy in ship-to-ship action. This disparity allowed the US Navy to enjoy relative success in the war’s first year (Toll 2008). American privateers, revived by act of Congress on June 26, 1812, also contributed

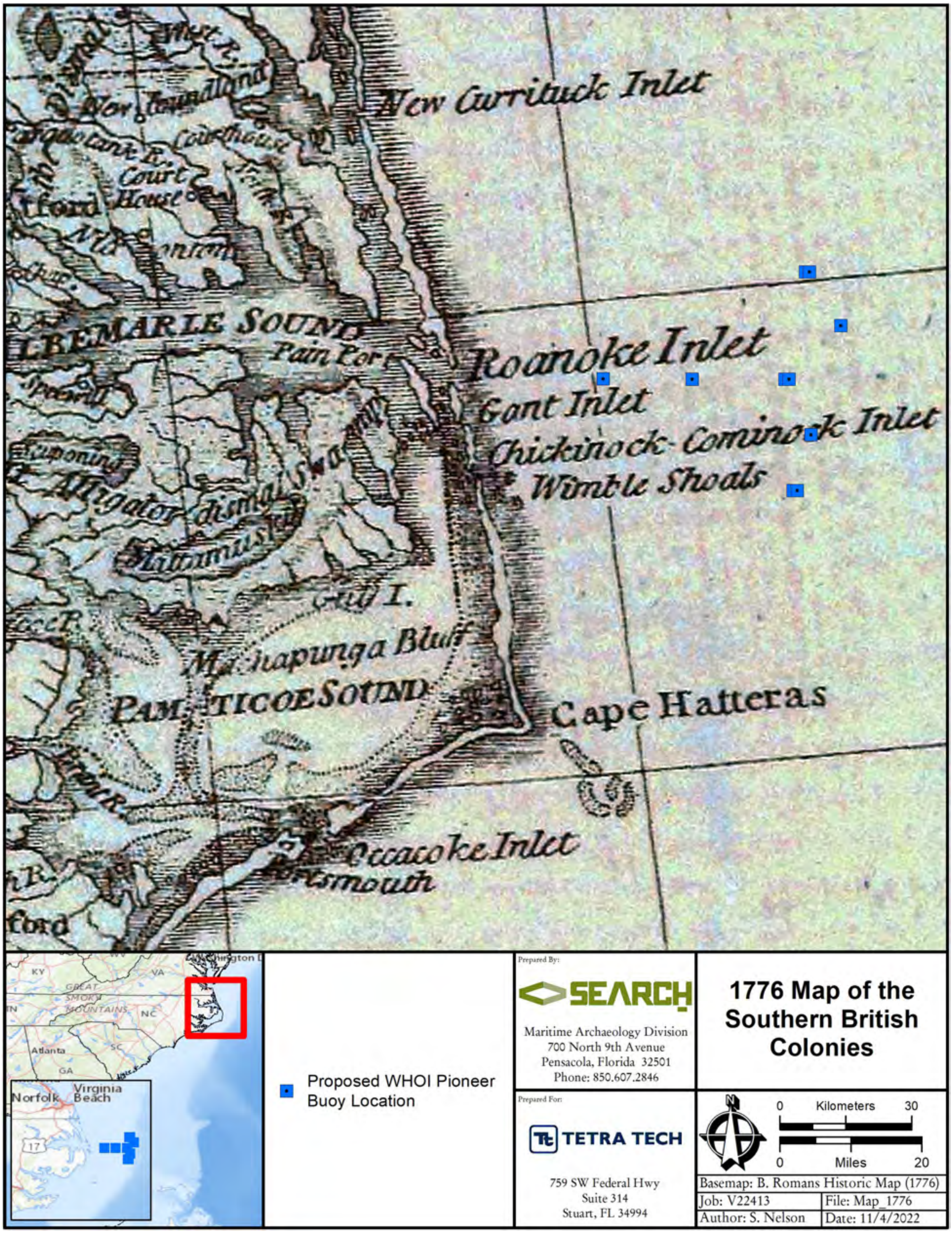

Figure 5. A 1776 historical map of North Carolina's barrier islands (Office of Coast Survey, NOAA 1776).

to these early blows to British morale (Leiner 2014). Bloodied but hardly beaten, the British Admiralty responded to these affronts by instituting a blockade of the American coast, specifically its major ports from Boston to New Orleans and the Chesapeake Bay (Toll 2008). Unlike their previous attempt, the British blockade during the War of 1812 was bolstered by significantly more ships; the North American Station alone was composed of 135 vessels by 1814 (Grodzinski 2014). Further aided by seasoned commanders of the Napoleonic Wars and substantial resources from the home islands, the British sealed the vaunted American frigates in their ports and brought maritime commerce to a screeching halt. Exports from the United States dropped from $45 million in 1811 to just $7 million in 1814 (Black 2008). It was during this strangle hold by the Royal Navy that American privateers once again took center stage and engaged in an all-too-familiar style of guerrilla naval warfare. While the exact damage done by American privateers is unknown, historians generally agree the number of British merchantmen captured during the war lies anywhere from 1,200 to 2,000 vessels (Leiner 2014).

Like the American Revolutionary War, the Outer Banks became an epicenter for privateering activity. The ports of the Albemarle region assumed critical importance as entry points from which supplies could be funneled to besieged American ground forces. One of the more impactful American privateer captains to operate out of the Outer Banks was Otway Burns. A native of Swansboro, North Carolina, Burns and his crew of the Baltimore clipper ship *Snap Dragon* operated chiefly out of Ocracoke and Beaufort Inlets (**Figure 6**). From 1812 to 1814, Burns made three separate cruises, resulting in the capture of 42 British ships and their cargo, the latter of which was valued at more than $4 million dollars (Tucker 2012). As for the blockading vessels of the Royal Navy, they managed to capture approximately 1,500 American vessels during roughly three years of war, including the notorious *Snap Dragon* in June 1814 (Grodzinski 2014; 1812privateers.org 2020). For all their nautical might and strategy, the British were never able to stomp out the privateering trade, particularly out of the Banks. Strikingly, the only notable attack on North Carolina's barrier islands by British amphibious forces occurred on July 12, 1813. At dawn, residents of Portsmouth and Ocracoke woke to the sight of 19 barges loaded with Royal marines heading for shore. Fortunately for the residents, little if any damage was done to the communities, though the invading marines captured "hundreds of cattle and sheep" (Stick 1958:84).

Figure 6. The luck of the notorious *Snap Dragon* finally ran out following an engagement with HMS Martin on June 30, 1814 (North Carolina Department of Natural and Cultural Resources 2020).

Antebellum Period

The hotly contested conflict came to end with the signing of the Treaty of Ghent on February 17, 1815. As a result, residents of the Outer Banks turned their attention to the region's worsening navigational issues and how to mitigate them. In the immediate years of the American Revolution, it became apparent that Roanoke Inlet was shoaling up at an alarming rate and would soon be impassable by vessels, even those of the shallowest draft. In 1787, the North Carolina General Assembly planned to build a canal in Roanoke Inlet's place and even went so far to incorporate The Raleigh Canal Company to "improve the navigation of the Albemarle Sound" (Stick 1958:75). However, the project never materialized, and by 1811, Roanoke Inlet was completely closed to seafaring traffic. The project was revitalized by English engineer Hamilton Fulton in 1820, but the State of North Carolina and the federal government were unprepared to bear the brunt of the estimated $2 to 3 million price tag. Subsequent government surveys (six in all) were performed in the area to ease public pressure and possibly find an agreeable alternative, but none could be found and the project collapsed. The situation for ports in the Albemarle region was made worse with the closure of Currituck Inlet in 1828, leaving Ocracoke Inlet as the region's single lifeline to the Atlantic. The closure of Currituck Inlet also came at a time when maritime commerce was reaching new heights. Thus, it was a common sight to see anywhere from "thirty to sixty vessels anchored in the roads at one time" (Stick 1958:88). Most of these vessels were sailing ships, but steamships or steamers were also becoming a common sight amongst the maritime world's rank and file. By 1840, the dual communities of Portsmouth and Ocracoke Village had grown extensively because of the increased burden put on the inlet. That same year, a post office, the first of the Outer Banks, was established in each of the towns, and a hospital would follow in six years later (Stick 1958:88–89). On September 7, 1846, a hurricane aptly named the "Gale of 1846" slammed into the North Carolina coast. Upon emerging from their place of shelter, inhabitants found two inlets had been cut through Bodie Island and Cape Hatteras Banks, respectively. The inlet on Cape Hatteras Banks assumed the name Hatteras Inlet and opened following the successful passage of the schooner *Asher C. Havens* on February 5, 1847. Meanwhile, the inlet on Bodie Island was given the name Oregon Inlet in June 1848 after the steamship SS *Oregon* became the first vessel to cross its narrows (Stick 1958:280; 297).

The hazards associated with the inlets of the Outer Banks were not the only concern shared by state and federal officials. Every year, the oceanic coastline of North Carolina's barrier islands was littered with the remains of ill-fated vessels of every size and shape. Furthermore, unless navigational aids were optimized, the issue was guaranteed to only get worse as coastal traffic increased year in and year out. Prior to the opening of Oregon Inlet in 1846, the Outer Banks was home to three lighthouses at Cape Hatteras, Ocracoke Inlet, and Cape Lookout. However, it was evident among policymakers that they needed to do more because the number of lives and property lost along the coast, particularly at Diamond Shoals, continued to reach staggering heights. As early as 1837, Congress appropriated approximately $5,000 for the construction of a new lighthouse on Pea Island to work in tandem with Cape Hatteras Lighthouse. However, the proposal was ill-received by local residents due to the site's location, and construction was delayed until the mid-1840s. The creation of Oregon Inlet in 1846 caused further delays.

Subsequently, the inlet's potential to become a new artery for maritime commerce entering Albemarle and Pamlico Sounds created the opportunity to compromise on the proposed lighthouse's location. On March 3, 1847, Congress appropriated $12,000 for the construction of a lighthouse on the southern tip of Oregon Inlet. The 56.5 ft structure known as Bodie Island Lighthouse was officially opened in the spring of 1848. However, the foundation on which the structure was built was of poor quality, so the tower began to lean as early as 1850. The Bodie Island lighthouse was declared unfit for service, prompting demolition in favor of new lighthouse in 1857. The second Bodie Island Lighthouse, also south of Oregon Inlet, was operational on July 1, 1859, at an appropriated cost of $25,000 (Stick 1958:73–106, 277–279, 302).

A final noteworthy addition to the safety of regional and national maritime traffic came out of the Outer Banks area in the wake of the Calypso Hurricane of 1837. The newly built passenger steamship SS *Home,* bound for Charleston, South Carolina, was heavily damaged because of the hurricane (**Figure 7**). With the steamship's condition growing worse by the minute, Captain Carleton White ordered the *Home* run aground on a reef roughly "a quart of a mile offshore," just north of the safety of Ocracoke Inlet. The vessel carried 135 passengers and crew onboard, but only three lifeboats and two life preservers. All three lifeboats were either smashed or capsized upon launching, and the two life preservers were taken by two men who quickly jumped overboard. The *Home* was pounded to pieces by the relentless surf, and approximately 90 people died, including women and children. The needlessness of the catastrophe garnered the attention of national headlines, increasing the pressure on Congress to intervene on behalf of the American public (Stick 1958:110–116). The result was the passage of the "Steamboat Act" in 1838, which required "all commercial vessels to carry enough life preservers for all passengers" (Neely 2019:106).

Figure 7. A mid-nineteenth-century lithograph of the sinking of the steam packet SS *Home*. This tragic episode contributed to Congress's decision to pass the Steamboat Act of 1838 (Currier 1837).

Civil War

On the morning of April 12, 1861, a 25-centimeter (10-inch) mortar battery from Fort Johnson opened the bombardment of Fort Sumter in Charleston Harbor and consequently touched off four years of bloodshed (Page 1994). On May 20, 1861, the State of North Carolina ratified the Provisional Constitution of the Confederate States of America, thus dissolving its union with the United States. Despite earning the distinction as the final state to join the Confederacy, North Carolina prepared better than most prior to succession. Local militia assumed control of the

Cape Fear River Fort Caswell and Fort Johnston immediately following secession (Moore 1999). Meanwhile, provisional troops occupied Fort Macon, a formidable third-system fortification located on Bogue Banks and responsible for guarding Beaufort Inlet. In addition to assuming control of the fortifications, Governor John Ellis authorized the creation of the North Carolina Navy, which consisted of the side-wheel steamer *Winslow* (2-guns) and the gunboats *Ellis* (2-guns), *Beaufort* (1-gun), and *Raleigh* (1-gun). Turned over to the Confederate States Navy in the wake of secession, these four warships were charged with overseeing the defense of the Albemarle region's sounds and tributaries. The CSS *Winslow* also served as a coastal raider and captured sixteen prizes in six weeks during the summer of 1861. Additional privateers and locally and foreign-owned blockade runners were also operating out of the Albemarle region.

Confederate officials were aware the latter two would eventually draw the ire of the United States Navy, and no one expected the former North Carolina Navy to defend the sounds against a fleet, much less a frigate. Thus, a series of earthen fortifications were hastily constructed at the inlets of the Outer Banks. By early August 1861, Fort Oregon stood on the south bank of Oregon Inlet, while Fort Morgan (also known as Fort Ocracoke) was positioned on Beacon Island inside Ocracoke Inlet. Concurrently, Hatteras Inlet, "the only inlet at the time…which could admit large ocean-going vessels," (Stick 1958:119) was guarded by two forts on its east bank, Fort Hatteras and Fort Clark (Kaufmann and Kaufmann 2004:251). Despite an initial lack of supplies and manpower, Fort Oregon and Fort Morgan were each garrisoned by a small detachment of provisional troops, while Forts Hatteras and Fort Clark received roughly 580 Confederate regulars under the command of Colonel William F. Martin. The forts at Hatteras Inlet received an additional commanding officer, Captain Samuel Barron, commander of coastal defenses of Virginia and North Carolina (Page 1994:58–59).

The first and last test of the fortifications on the Outer Banks came on August 28, 1861. At dawn, Confederate lookouts at Fort Clark spotted a newly arrived federal fleet under the command of Commodore Silas H. Stringham. The naval force comprised the USS *Minnesota* (44-guns), USS *Wabash* (46-guns), USS *Susquehanna* (15-guns), USS *Pawnee* (10-guns), USS *Monticello* (3-guns), USS *Cumberland* (24-guns), and revenue cutter *Harriet Lane* (6-guns). The warships were further supported by the steam tug USS *Fanny Cadwalader* (1-gun) and chartered steamers *Adelaide* and *George Peabody* (Page 1994:59–60). All told, the fleet boasted 149 guns. Their shore-based advisories at Fort Hatteras and Fort Clark mounted just 19, one of which, a 10-inch rifled cannon, had no ammunition. In addition to the Stringham's fleet, the federal government also sent General Benjamin F. Butler and a land force of approximately 880 federal troops and artillery (Kaufmann and Kaufmann 2004:251–252).

Following a 25-minute bombardment, the Confederates were persuaded to abandon Fort Clark, which became the possession of Butler's shore detachment roughly an hour later (**Figure 8**). Fort Hatteras survived the inevitable iron hailstorm until roughly 11 a.m. the following day. By that time, Barron hauled down the Confederate insignia in favor of the white flag of surrender. The price of victory was relatively light for federal forces; they suffered just three wounded men. By comparison, the fort's defenders were not so fortunate. Confederate casualties comprised roughly four men dead, 20 wounded, and 678 captured. On August 30, Butler and

Figure 8. An 1861 drawing of bombardment of Fort Hatteras and Fort Clark. Federal troops under the command of Colonel Max Weber can be seen landing in the foreground (Waud 1861).

Stringham received orders from Washington, D.C., to permanently occupy the forts at Hatteras Inlet, a reversal of the original plan which called for inlet to be obstructed and the forts destroyed. While the battle itself was comparatively anticlimactic, its repercussions reverberated for the remainder of war. Washington's decision to occupy Fort Hatteras and Fort Clark convinced Confederates forces to abandon Fort Oregon and Fort Morgan and thus control of their respective inlets for fear of suffering a similar fate (Page 1994:60–63). Furthermore, the federal Navy now had a base of operations from which to reprovision their ships and extend their reach of attack. The biggest blow, however, was absorbed by the Confederacy's maritime supply line. In the words of Union Admiral Dixon D. Porter, "It was a death-blow to blockade running in that vicinity, and ultimately proved one of the most important events of the war" (Page 1994:63).

Fueled by the thought of these scenarios coming to fruition, Confederate Colonel Ambrose R. Wright organized the remaining rebel forces in the area on Roanoke Island. Supported by ships of the former North Carolina Navy under the command of Commodore William F. Lynch, Colonel Wright moved to counter the federal offensive by fortifying the island, thus controlling access to the Albemarle Sound. Hampered with inadequate manpower, supplies, and just 34 pieces of artillery, one of which was a souvenir from the Mexican War, Confederate engineers chose to concentrate their efforts on the island's northwestern shore. There, they constructed three earthen fortifications. The southernmost position, named Fort Barlow, was at Pork Point and boasted 9-guns. Roughly 1,000 yards to the north along the coast sat the four-gun battery Fort Blanchard. Anchoring the line of defenses was Fort Huger at Weir Point, mounting 12-guns. The final defensive position, Fort Forest, was positioned on the mainland, across Croatan Sound from Fort Huger. Unlike the Roanoke defenses, Fort Forest comprised "two canal boats that had been beached…and armed with seven cannons" (Page 1994:65). The remaining two cannon were deployed in a battery constructed at Ballast Point overlooking the Roanoke Sound, its only line of defense (Page 1994:65–66).

Cognizant a Confederate stronghold on Roanoke Island could prove particularly troublesome to offensive operations against Richmond, Union Major General George B. McClellan dispatched Brigadier General Ambrose E. Burnside to the Outer Banks. Supported by the North Atlantic

Blockading Squadron under the command of Rear Admiral Louis M. Goldsborough, Burnside's orders were "to capture and fortify Roanoke Island" before moving on to Beaufort Inlet and Fort Macon (Page 1994:65). Eager to bolster Union moral with a decisive victory, Burnside spent the remaining months of 1861 assembling a force of 15,000 men and gathering a diverse collection of 20 shallow-drafted ships, including former passenger steamers, tugs, and "even a couple of garbage scows" (Page 1994:65).

Burnside's expedition arrived off the coast of Hatteras Inlet on January 13, 1862. Upon arrival, however, the armada was battered by storms and forced to take shelter inside Hatteras Inlet, further delaying operations until the following month. In the interim, the roughly 5,000 Confederate defenders of Roanoke Island experienced difficulties of their own. Recently appointed Brigadier General Henry A. Wise took ill, and command of the island's defenses fell to Colonel Henry M. Shaw of the 8th North Carolina Battalion (Page 1994:65–66). Forewarned of the federal armada en route to his location, Shaw added to his defenses by "driving piles and sink ships to obstruct the channel" between Fort Forrest and Fort Barlow (Page 1994:66). On the morning of February 7, Burnside's motley assortment of watercraft led by the former New York ferry turned gunboat USS *Southfield* entered Croatan Sound. There, they found Lynch's equally diverse fleet composed of nine vessels, including two aging side-wheel steamers, six screw-steamers, and an armed schooner. In total, Lynch's fleet could bring 9-guns to bear, while the federal gunboats could muster 40-guns. As the odds would suggest, the impending two-day battle did not begin or end well for the Confederate defenders. At 11:30 a.m., federal gunboats simultaneously engaged Fort Barlow and the vessels of Lynch's hapless fleet, silencing both by mid-afternoon. Their success allowed federal ground forces to reach the shore of Roanoke Island unopposed. By midnight, roughly 10,000 federal troops under the command of Brigadier General John G. Foster were encamped on the island's southern tip. The following day, Foster and his men advanced north, rolling up Shaw's 3,000 Confederates in the process. By nightfall on February 8, with his back to the Albemarle Sound, Shaw surrendered the remainder of his force to prevent further bloodshed. Federal causalities included 41 killed and 227 wounded, while the Confederates suffered 24 killed, 68 wounded, and 2,500 captured. Burnside's forces would remain in the vicinity Roanoke Island for roughly a month before capturing New Bern on March 15, 1862. Forty-two days later, Fort Macon would surrender following a devastating 30-day siege. The fort's capitulation ensured the last free inlet of the Outer Banks was closed, and with it, the war for the Albemarle Region and its barrier islands (Page 1994:66-77; Stern 1962:68–69).

The Civil War coastline of the Outer Banks is depicted in **Figure 9.** Though the region had been essentially knocked out of the conflict by 1863, its offshore waters remained turbulent with the bow waves of passing vessels. Most of these ships were vessel types belonging to the federal Navy, including wind-powered and steam-driven warships, ironclads, and troop transports. Occasionally, foreign and Confederate-owned blockade runners traversed the area, though by this time, many avoided the region completely and instead made for Confederate-held ports such Wilmington and Charleston.

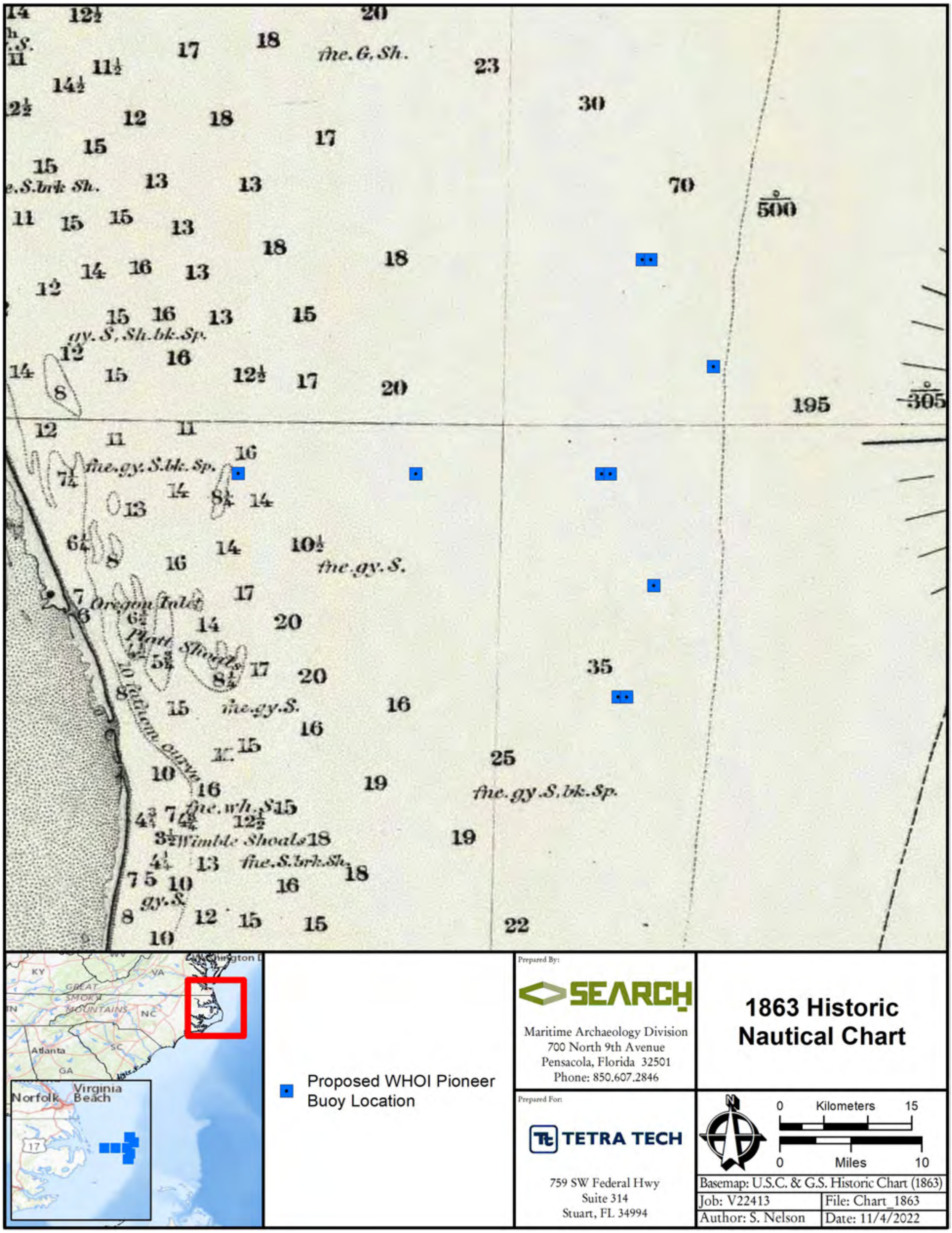

Figure 9. An 1863 US Coast and Geodetic Survey nautical chart of North Carolina's barrier islands (Office of Coast Survey, NOAA 1863).

Reconstruction to the Early Twentieth Century

Because the Outer Banks was knocked out early in the war and devoid of large-scale infrastructure worth destroying to prevent its use by enemy forces (save for aids to navigation), the Outer Banks' road to recovery was considerably brighter than the rest of the war-torn South. Prior to the Civil War, the barrier island's lighthouses were notorious for contributing little to the actual act of maritime navigation. In 1852, soon-to-be Admiral and Civil War veteran Lieutenant David D. Porter referred to the Outer Banks lighthouses as "the worst in the world," while Lieutenant H. J. Hartstene argued the lighthouses "if not improved…should be dispensed with, as a navigator is apt to run ashore looking for them" (Stick 1958:168). As fate would have it, the process of alleviating these criticisms and others like them began during the nation's four years of civil war.

On two known occasions, Confederate raiding parties landed on the barrier islands with the intent to blow up the Outer Banks lighthouses to ensure they could no longer aid the activities of the federal Navy. The Confederates succeeded in destroying the Bodie Island Lighthouse in 1862, but their second attempt in 1864 at Cape Hatteras and Lookout yielded no such results because both lighthouses remained standing. By 1870, Cape Lookout Lighthouse was fully repaired and received a new first order Fresnel lens, while Cape Hatteras Lighthouse was torn down in favor of the modern-day 198 ft tower. The new Cape Hatteras Lighthouse also received a new first order Fresnel lens, and at the time of its completion, it was the tallest brick lighthouse in the world. As for Bodie Island, its third and final lighthouse was completed in October 1872. Using material left over from the completed Cape Hatteras Lighthouse, the tower measured 156 ft tall and cost approximately $140,000 in US Government appropriated funds. Like Cape Hatteras and Lookout, Bodie Island Lighthouse received a first order Fresnel lens with an accepted range of 18 nm. To further prolong the life of the structure, engineers built the lighthouse on Oregon Inlet's north bank to avoid eventual complications with the south migrating inlet. The final addition to the Outer Banks coastal lighthouses was the 162 ft Currituck Beach Lighthouse in the community of Corolla, completed in December 1875 (Stick 1958:168–169).

In addition to lighthouses, the federal government also invested heavily in the region's ability "to protect life and property from shipwrecks" along the coast (Oppermann 2005:4). Under the supervision of the US Department of Treasury, seven US Life-Saving Stations were completed by December 1874 at "Jones's Hill, Caffrey's Inlet, Kitty Hawk Beach, Nag's Head, Bodie's Island, Chicamicomico, and Little Kinnakeet" (**Figure 10**; Stick 1958:169). Designed to house a crew of six surfmen four months out of the year (December through March), these early structures were minimalist and among the earliest examples of life-saving station standardization. The station's first floor housed the crew's surfboat and a common room/kitchen combination, while the second floor served as the crew's living quarters and storage room (Oppermann 2005:6). The presence of the Life-Saving Service contributed to a noticeable decline in the loss of life and property along the Outer Banks; however, by the winter of 1877 to 1878, it was clear more needed to be done. The tipping point came with the loss of 188 lives because of the wreck of the USS *Huron* and SS *Metropolis* on the North Banks in November 1877 and January 1878, respectively. In June, Congress authorized the construction 11 additional lifesaving stations, all of which were operational by the winter of 1878 to 1879. Located at Deal's Island, Old Currituck Inlet, Poyner s Hill, Paul Gamiels Hill, Kill Devil hills, Tommy's Hummock, Pea Island, Cedar Hummock, Big Kinnakeet, Creeds Hill, and Hatteras, these new stations were constructed in the image of the 1874 stations, but they were larger and included more amenities, including office space, bathrooms, and an observation tower. In the succeeding years, additional resources and procedures arrived in the form of a seventh surfman at each station, year-round employment for all crewmembers, and the establishment and coordination of a beach patrols. By 1883, North Carolina was home to 29 life-saving stations. Only four were in an area outside of the Outer Banks (Stick 1958:172–173).

Figure 10. An early twentieth-century photograph of Bodie Island Life-saving Station. The site's VIP quarters can be seen in the background (Library of Congress).

Several of the navigational aids and life-saving stations are apparent in an 1879 United States Coast and Geodetic Survey (U.S.C.&G.S.) chart (**Figure 11**). In an era devoid of modern technology, these structures proved critical to the safe passage of ships and minimal loss of life along the North Carolina coast. Despite the best efforts of their keepers and crews, maritime disasters still occurred offshore, as was the case for the schooner *Veto* in 1885. According to *The Meriden Daily Republican*, the vessel was en route to Boston before floundering in gale off Bodie Island on March 21. Fortunately for Captain J. L. Springer and his crew of six, the schooner *Genevieve* was nearby and provided assistance, and there was no loss of life (*The Meriden Daily Republican*, 27 March 1885:3).

The flow of Congressional funding did not stop with aids to navigation and search and rescue. A US Weather Bureau Station was established at the lighthouse keeper's quarters at Cape Hatteras in 1874, followed by additional stations at Kitty Hawk (1875), Cape Lookout (1876), Portsmouth (1876), Beaufort Inlet (1878), and Wash Woods (1878). Post offices were also widely established up and down the barrier islands. In 1865, the only post offices in the Outer Banks region could be found at the villages of Portsmouth, Ocracoke, and Hatteras, respectively. However, by 1939 the region was home to 23 post offices, all of which were within the boundaries of the Outer Bank's hamlets. Inevitably, the process of selecting a name to appear on the new post office led to a flurry of name changes for many historic Outer Banks communities to avoid duplicates and complications. Chicamacomico, for example, became the present-day community of Rodanthe in 1874, while Whales Head became present-day Corolla in 1895. Like the lighthouses, life-saving stations, and weather stations, the establishment of US

Post Offices brought much-needed employment to the Outer Banks (Stick 1958:174–175). Prior to this time, most inhabitants still relied on the trades of their ancestors for survival, most notably maritime trades, including "boatmen, mariners, pilots, and fishermen" (Stick 1958:212). However, these trades were largely seasonal and thus had to be paired with other ventures, such as raising livestock. The advent of full-time employment opportunities associated with the establishment of government-funded facilities at long last provided the residences of the Outer Banks with steady source of income. This economic foundation proved vital to the region's subsistence during the economic downturns of the early twentieth century (Stick 1958:175).

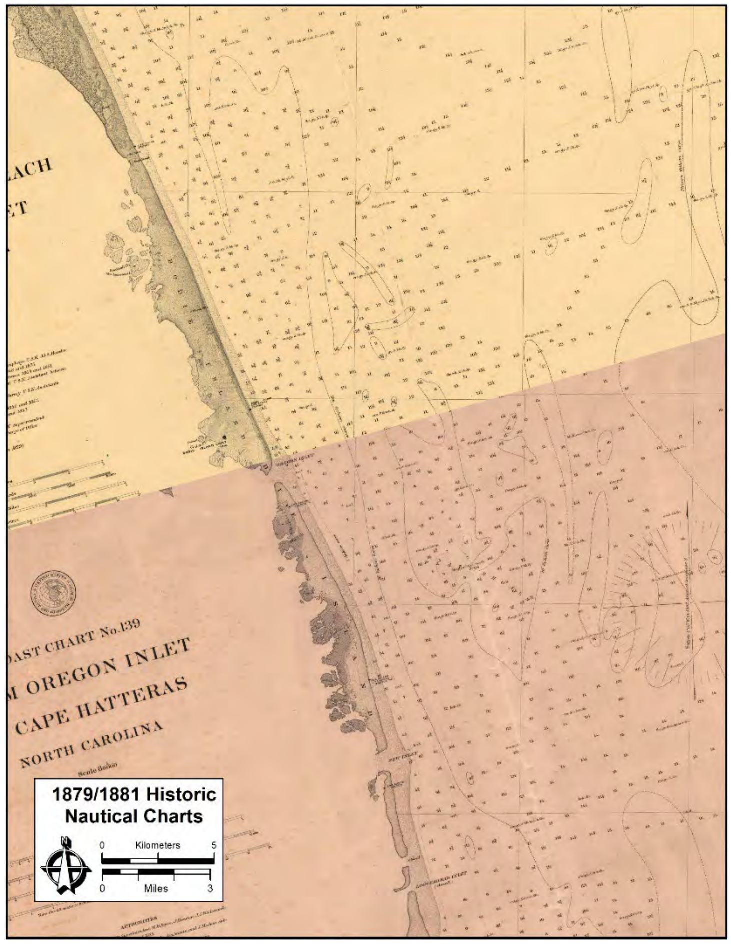

Figure 11. An 1879 United States Coast and Geodetic Survey nautical chart of North Carolina's barrier islands (Office of Coast Survey, NOAA 1879).

The Outer Banks, particularly the communities of Kitty Hawk and Kill Devil Hills, were thrust into the national spotlight with the successful flight of the Wright brothers' heavier-than-air aircraft, also known as the *Wright Flyer*, on December 17, 1903 (Stick 1958:195–211). The Outer Banks received further attention during the final months of the Great World War, but this attention stemmed from a place of concern rather than national pride. World War I, universally dubbed "the war to end all wars," had consumed the great powers of Europe and Asia since July 1914. Though a thinly veiled source of war material for the Allies, the United States remained neutral until joining the fray on the side of England and France in April 1917 (MacMillan 2014). The war came to the American coast, specifically the waters off the Outer Banks, the following spring. In May 1918, a succession of three German U-boats, beginning with *U-151*, followed by *U-140,* and ending with *U-117*, "sank a total of 10 vessels off North Carolina alone" (NOAA 2017). Their victims included the British steamships *Harpathian*, *Pinar Del Rio, Vindeggen,* and *Mirlo*; Norwegian steamships *Vinland* and *Hendrik Lund* and bark *Nordhav*; and the American steamship *Mera*, schooner *Stanely M. Seaman*, and US Lighthouse Services Light Vessel *LV-71* (NOAA 2017).

World War II and Post War Years

The end of the war came with Imperial Germany's acceptance of formal surrender on November 11, 1918. Almost immediately, residents of the Outer Banks region turned their attention from the threat of a foreign enemy to two seemingly unrelenting domestic forces, one of an environmental nature the other financial. Decades of open stock raising and subsequent failure to replace vegetation left the Outer Banks little more than bald beaches stuck in a state of rapid erosion by merciless tides, wind, and weather. As for the economy, tried and true trades of the past, such as stock raising, fishing, and whaling, were on the decline or near extinction due to poor resource management. The shoaling of the Outer Banks's various inlets due to erosion allowed for only vessels of the shallowest draft to enter. Thus, maritime traffic entering North Carolina's sounds via the Atlantic Ocean was brought to little more than a trickle, leaving little work for experienced pilots. The sharp decline of shipwrecks along the coast put life-saving operations, now under the direction of the US Coast Guard, at risk of downsizing (Stick 1958:242–243).

In addition to sand, the barrier islands were also bleeding their population as younger generations sought a livelihood elsewhere. In the latter half of the 1920s, regional policymakers under the direction of Wash F. Baum, Dare County Board of Commissioners, created a plan to stem the bleeding. Baum believed the solution to the woes of the Outer Banks was to increase the region's accessibility via roads and bridges connecting the barrier islands together and to the mainland. This in turn would allow the communities of the Outer Banks to take advantage of the nation's budding tourism industry, which had already given new life to once-struggling beach communities such as Atlantic City, New Jersey, and Virginia Beach, Virginia. By the eve of World War II, and in the face of the Great Depression, the Outer Banks was connected to the mainland by two bridges over Roanoke Sound and Currituck Sound, respectively. Furthermore, an 18 mi stretch of asphalt highway ran from the beaches of Kitty Hawk to Nags Head (Stick 1958:243–246). In addition to the "finest beaches…seen anywhere," local advocates and policymakers saw to the construction of the Wright Brothers National Memorial at Kill Devil Hill in 1932 and improvements to the Fort Raleigh National Historic Site in 1937 (Stick 1958:243–250). Three years later, conservation efforts and erosion control measures, debated upon and agreed to circa 1937, began to take shape. According to a National Park Service report dated July 1940, "southward from the Virginia State Line exendin got Hatteras Inlet a great barrier dune has been built for the protection of the Banks form the ocean…In all, one hundred and fifteen miles of barrier dune has been constructed." The report also states, "a total of 141,841,821 square feet of grassing has been planted…2,552,359 seedlings and shrubs were set out" (Stick 1958:250). By 1941, attendance at the historic sites were reaching an "all-time high," whilst Outer Banks communities, specifically Kitty Hawk and Nags Head, recently furnished new hotels and summer cottages were "doing big business" (Stick 1958:251). That same year, North Carolina officials, backed by funds from multimillionaire philanthropist Paul Mellon, received authorization to establish a national seashore on the battier islands (Vaughn and Cortner 2013:27). Large swaths of land, including those comprising the famed Cape Hatteras, were donated to the project. However, the Japanese attack on Pearl Harbor on December 7, 1941, brought all feelings and projects of good will to a screeching halt.

The Outer Banks, like the rest of America, was plunged back into a state of war the following day. Dozens of able-bodied Outer Banks residents, including "more than a hundred" members of the Midgett family (ancestors of Bodie Island's 1722 owner Matthew Midget), rushed to the nearest recruiting station to join all branches of the military (Stick 1958:251). By January of 1942, U-boats, now under the employ of Nazi Germany, reemerged from the watery depths to wreak havoc on the Outer Banks coast, which was soon to be known as "Torpedo Alley." Despite prior proof of U-boat capabilities during World War I, the American coast began the war devoid of resources dedicated to sub-hunting and merchant ship escort duties (NOAA 2017). As a result, the barrier island's saw the loss of more than 250 vessels in 1942, including the steam tankers *Olympic* (5,300-tons) and *China Arrow* (**Figure 12**; 8,400-tons). The latter vessels were lost in vicinity of Bodie Island in January and February, respectively. Ever-mounting merchant ship losses compelled American war planners to train their focus on U-boat countermeasures along the Outer Banks. By 1943, the U-boat terror was relatively under control and would remain so for the duration of the war. Residents of the Banks were will-versed in executing "black outs," a common coastal community practice of shutting off all the lights to avoid silhouetting Allied ships at sea. More direct measures included a coastal convoy system, long-range aircraft patrols, and an influx of anti-submarine vessels (Hickam, Jr. 2014; National Park Service 2016). The final German U-boat to be sunk off the Outer Banks was *U-548* in April 1945 (Branch and Barefoot 2006).

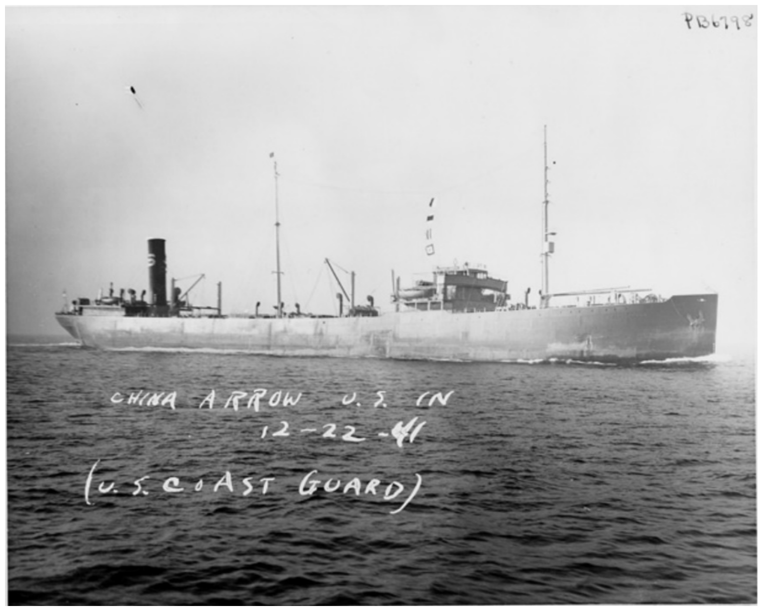

Figure 12. A photograph taken of the ill-fated steam tanker China Arrow in December 1941. The vessel was torpedoed and sunk off by Bodie Island by U-103 less than three months later(The Mariners' Museum and Park).

Figure 13 shows the project area against the backdrop of a 1945 U.S.C.&G.S. nautical chart. By this time, the U-boat threat was largely under control, though enemy incursions did occur, most notably *U-548* in the second to last month of the war. Allied merchantmen including steam tanks and freighters represented most maritime traffic passing by the Outer Banks. As mentioned above, these vessels typically traversed the shipping lanes under the cover of American aviators or under the escort of US Navy destroyers and US Coast Guard cutters. In the war's aftermath, the coastal waters of North Carolina remained turbulent with the wake of fleeting merchantmen moving up and down the American coast. That trend remains to this day.

The post-war years saw the Outer Banks become a hub of activity because the tourism industry was fully embraced as the region's primary economic staple. As early as the summer of 1946,

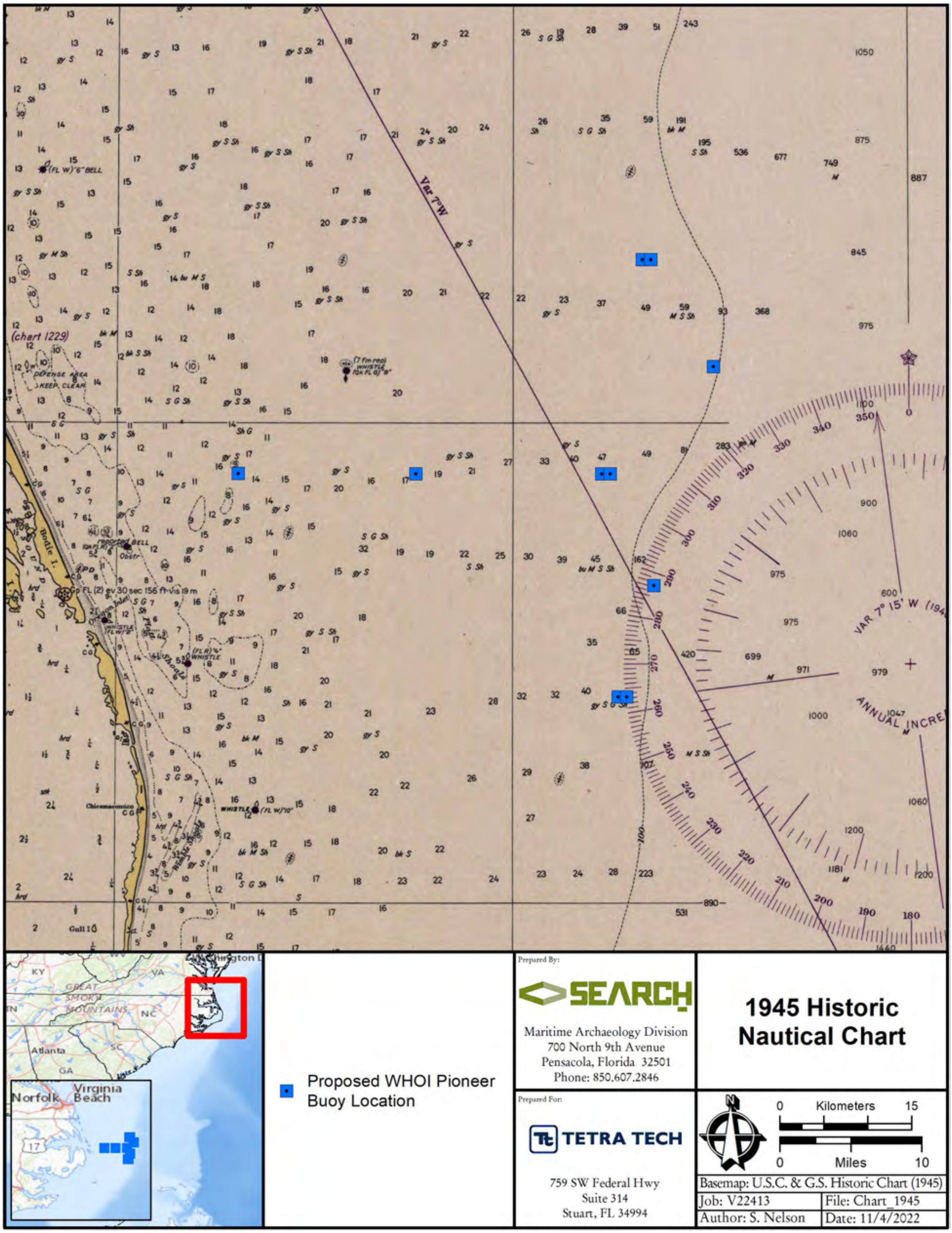

Figure 13. A 1945 U.S.C.&G.S. nautical chart of North Carolina's barrier islands (Office of Coast Survey, NOAA 1945).

land prices steadily began to climb, and real estate developers, eager to acquire land at the lowest price, pounced as soon as lots become available. By 1952, "new hotels, motels, restaurants, stores, and cottages were open for business" up down the Outer Banks, with the greatest concentration at Nags Head, Kill Devil Hills, and Kitty Hawk (Stick 1958:251). In June of that same year, the present-day Cape Hatteras National Seashore, considered a dead project in the immediate aftermath of the Second World War, became a reality. Thus, calls were amplified to increase automobile access to Cape Hatteras and beyond. By 1960, it was possible for tourists to travel from Nags Head to Ocracoke Village via a system of free highways and ferries. Today, tourism continues to be the industry on which the islands north of Ocracoke Inlet rely on to sustain their way of life. The same cannot be said of the lower Outer Banks composed of the islands of Portsmouth, Core Banks, and Shackleford Banks. These islands remain isolated, devoid of human life, and at the mercy of the wind, weather, and tides (Stick 1958:251–253).

POTENTIAL FOR SUBMERGED CULTURAL RESOURCES

SEARCH assessed the precontact through postcontact contexts to determine the potential for submerged archaeological resources to be within the area of potential effects (APE). The APE is the area of buoy impacts, while the project study area encompasses a 1.6 km (1 mi) radius around each buoy. The study area permits a broader context for analysis when assessing potential impacts to archaeological resources. Based on the precontact occupation of the once-exposed OCS, the historic maritime context of the area, and the small footprint of any one of the 10 buoys being deployed, SEARCH expects a low to moderate potential for precontact and postcontact submerged archaeological resources at any one buoy location, but a moderate to high potential for the entire project study area.

Low water levels during the late Pleistocene and evidence for human presence in the Americas by 15,000 to 14,000 cal BP support a moderate to high potential for submerged precontact deposits. While the research area is far offshore and was inundated between 14,000 and 10,000 cal BP, the importance of nearshore and coastal resources to human subsistence provides high potential for resource use. Additionally, the presence of potential stream systems near and through the buoy locations add potential for landscape use and site preservation.

The preservation potential for submerged archaeological resources on North Carolina's OCS varies and is highly dependent on the duration of exposure and unique resource composition. Marine transgression and seafloor sedimentation are the main environmental factors affecting preservation (TRC Environmental Corporation 2012). A low sedimentation rate along the continental margin within the last 10,000 years has created a seafloor that is highly exposed to erosional forces associated with marine transgression and bottom currents (Goff et al. 2005; Rice et al. 1998). For example, Native American dugout wooden canoes, used for fishing and open water transportation, are not likely to exist intact on the seafloor. This is because exposed wood tends to deteriorate in marine environments with high erosional force. The best chance of survival for such submerged cultural resources exists if the resources were buried within marine sediment. Burial is possible in instances of quick, large-scale flooding that produces rapid sediment accumulation (Uchupi et al. 2001).

For similar reasons, archaeologists expect a progressively higher preservation potential for historic submerged cultural resources because shipbuilding started to utilize materials with a lower susceptibility for deterioration in maritime environments. European exploration along the Outer Banks region in the mid-sixteenth century brought the first maritime transportation—sailing vessels. Increased maritime activity in the region during the seventeenth and eighteenth centuries included larger ocean-going ships and coastal traders. These larger wooden vessels are also likely to deteriorate; however, metal components, such as iron fastenings, may exist on or beneath the seafloor.

The introduction of steam vessels in the region in the nineteenth century presents a much higher preservation potential. Though the wooden hull of steam vessels is likely to deteriorate, any iron machinery may exist individually or as complex concentrations of components. The use of iron and steel in hull construction soon followed steam technology in the nineteenth century. Whether propelled by sail or steam, a vessel with an iron or steel hull is more likely to remain intact on the seafloor. The twentieth-century workboat is another category of shipwreck that should be expected to have high preservation potential. An iron or steel vessel propelled with a steam or gasoline engine would also likely survive relatively intact on the seafloor. The modern recreational vessel, although not considered a submerged cultural resource, could be another vessel type documented in the vicinity of the cable route. Vessels made of fiberglass utilizing modern aluminum marine motors will likely exist on the seafloor due to the recent deposition and durability of fiberglass and aluminum.

PREVIOUSLY RECORDED ARCHAEOLOGICAL SITES AND SURVEYS

SEARCH conducted a review of previous maritime archaeological investigations to determine whether submerged archaeological resources have been documented within or adjacent to the APE. The proposed APE is approximately 24 km (13 nm) from the shoreline of North Carolina at its closest point. This is outside state waters. Nevertheless, SEARCH archaeologists consulted North Carolina's Underwater Archaeology Branch, Office of State Archaeology, Department of Historic and Cultural Resources (NC DNCR). The NC DNCR did not have any additional information on previously recorded sites or surveys within the study area. Review of databases (GMWD, NOAA AWOIS, ENC, NavAids, and BOEM) within 1.6 km (1.0 mi) of the APE did not reveal any shipwrecks in the study area. **Figure 14** shows shipwrecks reported in the vicinity of the study area, and **Table 1** lists these wrecks.

It is important to note that positional accuracy for historic shipwrecks is typically tentative at best. Historic shipwrecks are generally plotted based on contemporary records, maps, or oral histories. Many shipwreck databases provide a range of positional accuracy or an accuracy reliability scale. It must be assumed, therefore, that the databases do not constitute an exhaustive list of reported shipwrecks potentially within the 1.6 km (1.0 mi) buffer zone around the proposed buoy positions, nor can it be assumed that every shipwreck truly resides where it is depicted.

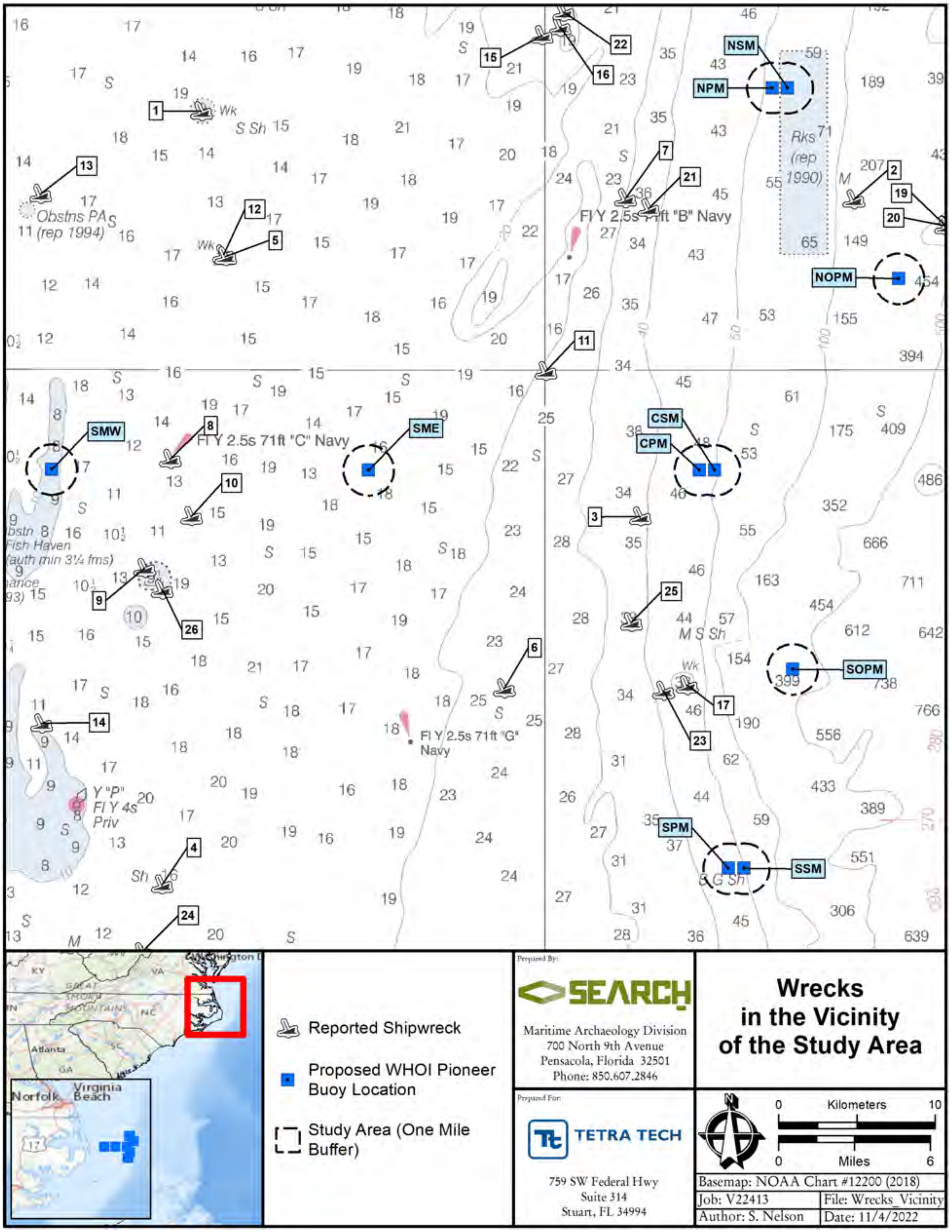

Figure 14. Wrecks in the vicinity of the study area.

Table 1. Wrecks in the Vicinity of the Study Area.

Map ID	Vessel Name	Year Lost	Source
1	Byron D. Benson (B.D. Benson)	1942	BOEM (6001, 8593); AWOIS (717); GMWD (22269, 39118, 259670); ENC (7261, 8221)
2	Cape Charles Wreck	Unknown	BOEM (4427)
3	China Arrow	1942	BOEM (2108)
4	City of Atlanta	1942	BOEM (14281)
5	Norvana	1942	BOEM (10192); GMWD (39117); ENC (4656)
6	P.T. Barnum	1906	BOEM (311)
7	Russian Trawler	Unknown	BOEM (948)
8	Tower	Unknown	BOEM (4425)
9	U-85	1942	BOEM (10318, 15968); AWOIS (700); GMWD (22468)
10	U-85 (second location)	1942	BOEM (14773)
11	Veto	1885	BOEM (5701)
12	York	1942	BOEM (8590); AWOIS (713); GMWD (22467); ENC (7579)
13	Unidentified	Unknown	BOEM (3122)
14	Unidentified	Unknown	BOEM (3180)
15	Unidentified	Unknown	BOEM (8594, 4428); AWOIS (719); GMWD (259671)
16	Unknown (150)	Unknown	BOEM (971, 4429)
17	Unknown	Unknown	BOEM (8587); AWOIS (698); GMWD (39204, 259512); ENC (4662)
18	Unknown	Unknown	BOEM (8591); AWOIS (714); GMWD (39378, 259668); ENC (5056)
19	Unknown	1918	BOEM (8852); GMWD (19966)
20	Unknown	1968	BOEM (9211); GMWD (20820); ENC (8360)
21	Unknown	Unknown	BOEM (8592); AWOIS (715); GMWD (259669)
22	Unknown	Unknown	BOEM (8595); AWOIS (721); GMWD (259672)
23	Unknown	Unknown	BOEM (9021); GMWD (23076)
24	Unknown	Unknown	GMWD (38487); ENC (1056, 6575, 7922)
25	Unknown	Unknown	ENC (7583)
26	Unknown	Unknown	ENC (8506)

Throughout history and up to the present day, the waters off northern North Carolina have been a crossroads of maritime traffic. Maritime accidents and shipwrecking events have included numerous vessels operating in the surrounding waterways, sailing vessels along the Outer Banks, cargo vessels moving goods and fuel out of and into Chesapeake Bay and north and south along the Atlantic seacoast, war time losses, and other maritime casualties. The strong weather events common in the Atlantic make maritime commerce hazardous. There exists the potential for yet undocumented archaeological resources to be revealed in a future survey.

CONCLUSION AND RECOMMENDATIONS

SEARCH conducted the current desktop analysis on behalf of Tetra Tech, Inc., to determine existing and potential submerged cultural resources within the proposed project area within US federal waters. This analysis, utilizing geological, precontact, and postcontact background research and a review of archaeological sites and shipwreck databases, indicates a moderate to high potential for submerged cultural resources to exist in the vicinity of the proposed buoy locations. Although SEARCH did not identify any documented archaeological sites, reported shipwrecks, or maritime obstructions within 1.6 km (1.0 mi) of the proposed buoys, a future high-resolution geophysical survey could locate archaeological sites. This analysis is intended for submittal to WHOI and will assist with planning of the 2023 remote-sensing survey and buoy placement.

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Appendix E: CGSN Site Characterization: Pioneer Mid-Atlantic Bight Array

CGSN Site Characterization: Pioneer Mid-Atlantic Bight Array

Control Number: 3210-00007
Version: 1-01
Date: 2023-07-19
Author: A. Plueddemann, A. Macdonald, A. Ramsey

Coastal and Global Scale Nodes
Ocean Observatories Initiative
Woods Hole Oceanographic Institution

Revision History

Version	Description	ECR No.	Release Date
0-01	Initial draft		
0-02	Review, edits		
1-00	Initial Release	ECR-947	2023-02-07
1-01	Addition of Reference list to Section 5.0		

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1.0 Introduction

1.1. Scope

This report describes sea surface, seafloor and ocean conditions in the vicinity of the Pioneer Mid-Atlantic Bight (MAB) Array. The configuration of moored and mobile assets for the Pioneer MAB Array are described in OOI document 3210-00008 CGSN Site Design: Pioneer Mid-Atlantic Bight Array. Seafloor conditions are described first - assessment of regional bathymetry was necessary in order to adjust the nominal mooring locations to obtain the desired geographic layout and water depths. Oceanographic conditions, focusing on currents, temperature-salinity (T-S) properties, and stratification, are described next. Finally, surface conditions, including wind, waves, storm events, and solar radiation are presented.

1.2. Background

The Pioneer Array is a multi-scale array utilizing fixed and mobile assets to provide observations spanning the continental shelf and slope. The Array was designed to be relocatable, suitable for moderate wind, wave and current conditions in water depths of approximately 100-600 m. After initial deployment on the New England Shelf (NES), the Pioneer Array will be relocated in the spring of 2024 to a location off the coast of North Carolina. The proposed site is in the southern part of the MAB, typically defined as encompassing the continental shelf and slope between Cape Hatteras, NC and Martha's Vineyard, MA.

A review of environmental conditions in the MAB region is necessary to refine the array layout, determine mooring locations and depths, assess mooring performance, provide the expected density range for ballasted elements (e.g. gliders, wire following profilers) and inform other aspects of array performance such as power generation by solar radiation.

The consensus concept for the Pioneer MAB array, developed from community input at NSF-sponsored Innovations Labs held during March and June of 2021, was for a moored array within a roughly 60 x 60 km box offshore of Nags Head, North Carolina. There was also a recommendation to extend the reach of observations by utilizing gliders in a larger domain. In order to assess regional environmental characteristics, three regions were defined: (Figure 1-1).

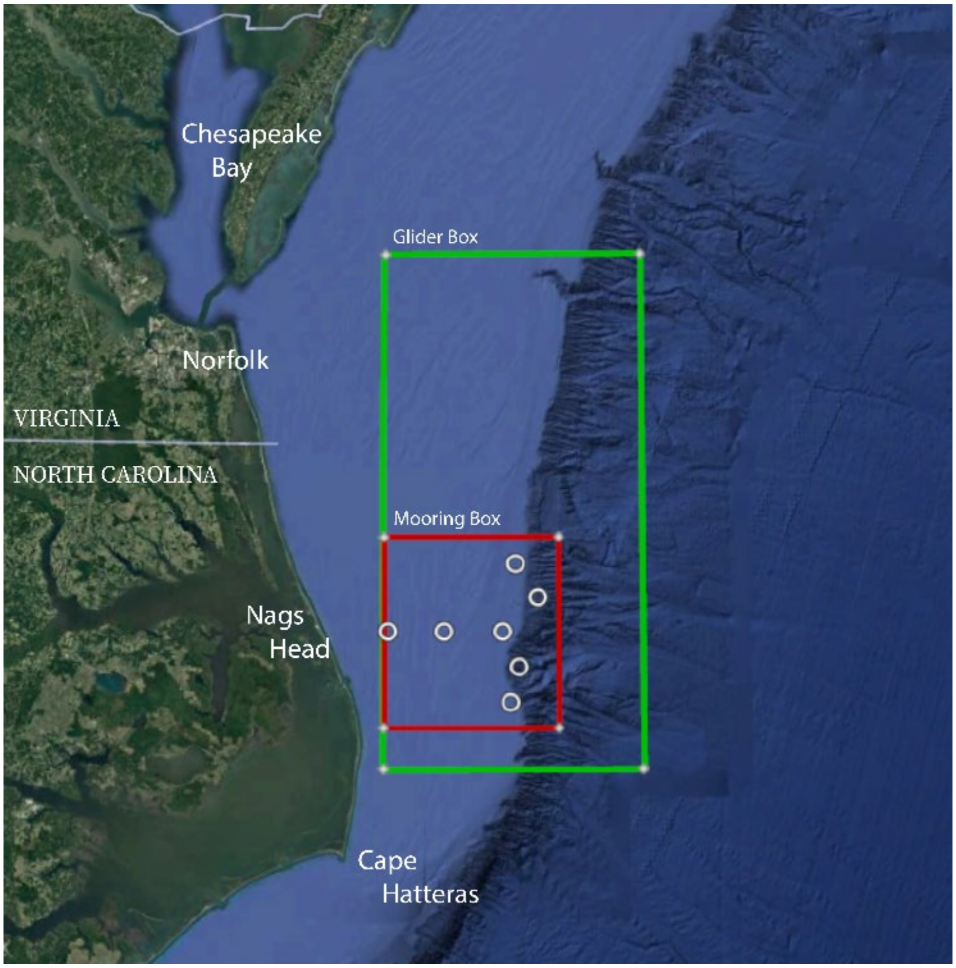


Figure 1-1 – Southern MAB Pioneer Array regions.
The red box indicates the region where moorings would be located, and the green box indicates where the mobile assets (gliders and AUVs) would operate.

The regional bounding box, or "Big Box" includes slightly more (< 1° latitude and longitude) area than that covered by the broadest reaching instrumentation. The Big Box is useful for extracting gridded data, e.g., from a bathymetry database, or a regional model, to ensure there is enough regional coverage and larger scale variability is visible. The Big Box runs from just north of Chincoteague, VA - off Assateague Island at the border between VA and MD. Big Box WESN = [-77.00 -73.00 34.83 38.00]

Big Box	Lat (°N)	Lon (°E)
NW corner	38.0000	-77.0000
NE corner	38.0000	-73.0000
SE corner	34.8333	-73.0000
SW corner	34.8333	-77.0000

The potential glider operations region, or "Glider Box" is contained within the Big Box, and is where we expect all the Array elements (moorings, gliders, AUVs) to be located. It runs from just north of Chesapeake Bay (Kiptopeke, VA) to just north of Cape Hatteras (CH) – Cedar Island NC. Glider Box WESN = [-75.37 -74.33 35.50 37.17]

Glider Box	Lat (°N)	Lon (°E)
NW corner	37.1667	-75.3667
NE corner	37.1667	-74.3333
SE corner	35.5000	-74.3333
SW corner	35.5000	-75.3667

The Mooring Box is contained within the Glider Box, and is the area in which we expect all the mooring sites to be located. Ideally site characterization information for the moored array would come from other observing assets (e.g. NDBC moorings, process study moorings) within the Mooring Box.

Mooring Box	Lat (°N)	Lon (°E)
NW corner	36.2500	-75.3667
NE corner	36.2500	-74.6667
SE corner	35.6333	-74.6667
SW corner	35.6333	-75.3667

The Pioneer MAB Moored Array will consist of ten elements: Three Surface Moorings located in 30 m and 100 m water depths, five Profiler Moorings located in 100 m and 600 m water depths, and two Shallow Water Moorings located in 30 m water depths. These elements will be arranged in a sideways “T” shape to capture both cross-shelf and along-shelf variability (Figure 1-2). An assessment of regional bathymetry (Section 2.0) was used to refine the nominal mooring sites and determine latitude, longitude and depth for each Site Center.

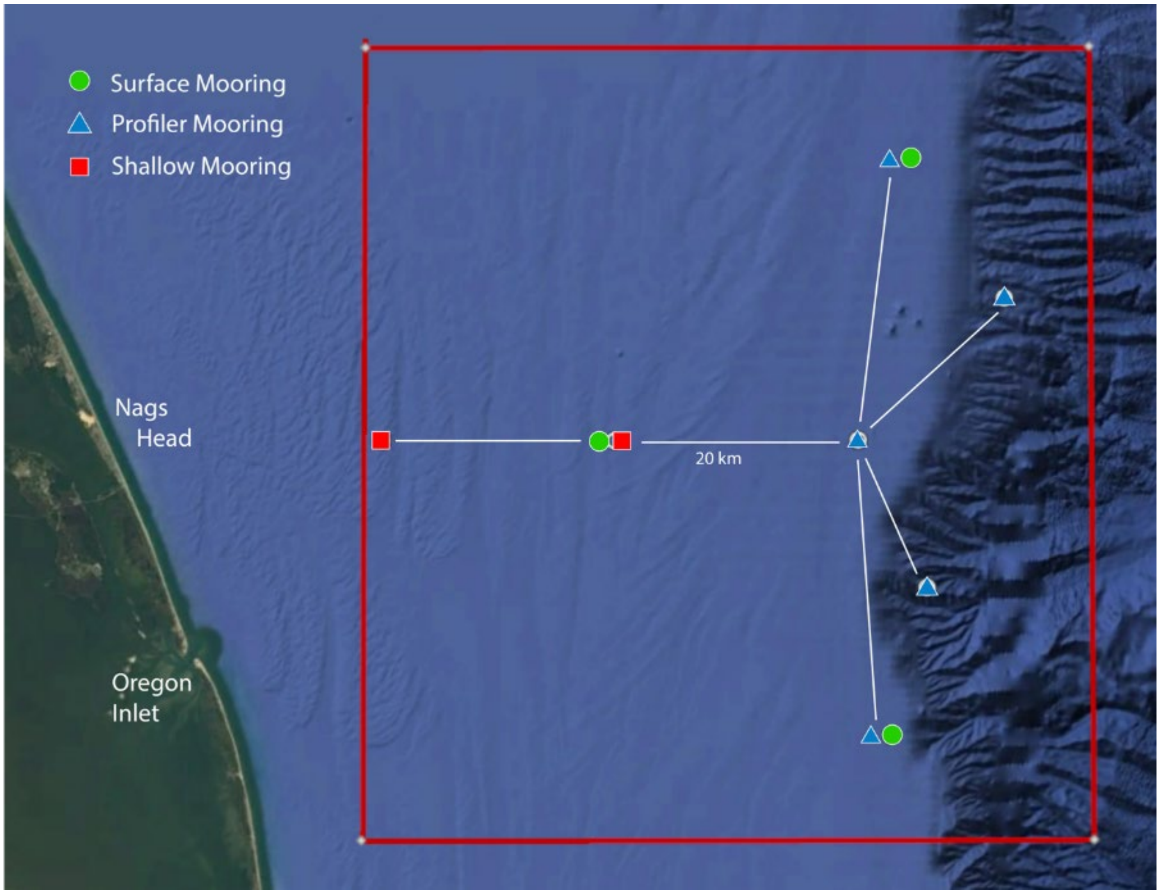


Figure 1-2 – Nominal mooring sites, and mooring types at each site, for the Pioneer MAB Array.

2.0 Seabed

2.1. Bathymetry

The investigation into the bathymetry in the region of the proposed mooring site is based on Volume 2 of National Centers for Environmental Information's (NCEI) U.S. Coastal Relief Model (CRM, 1999; henceforth NGDC referencing the former name of the NCEI, National Geophysical Data Center, https://www.ngdc.noaa.gov/mgg/coastal/crm.html). It covers the period from January 1999 to present and includes the following data sources: the U.S. National Ocean Service Hydrographic Database, the U.S. Geological Survey (USGS), the Monterey Bay Aquarium Research Institute, the U.S. Army Corps of Engineers. Topographic data are from the USGS and the Shuttle Radar Topography Mission. The NGDC CRM product has a grid cell size of 3 arc-seconds, or roughly 90 m. However, one should not assume that grid cell size equals horizontal resolution, at least not everywhere. The website suggests that one should assume a vertical accuracy of no better than 1 m. The data used here was downloaded as crm_vol2.nc on August 19, 2022. Volume 2 covers the region 31°-40°N, 68°-85°W (Figure 2-1).

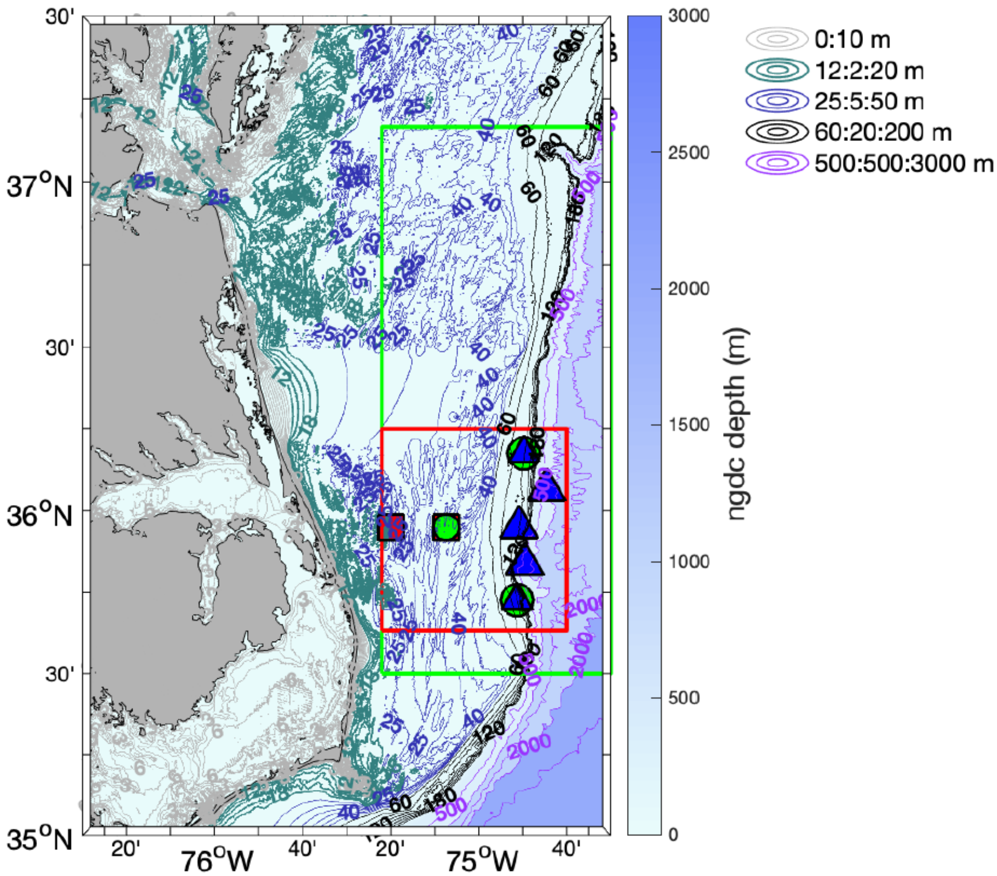


Figure 2-1 – NGDC 3-arc second bathymetry in the region of interest including the glider box (green) and mooring box (red). Bathymetry contour lines (grey, green blue, black, and cyan curves) are described in the legend and mooring symbols are defined in Figure 1-2.

Prior to choosing the NGDC model for examining the characteristics of the local bottom topography to determine "best" locations for the mooring deployments, several bathymetric products were considered. These included the NOAA soundings (Figure 2-2) as well as the 15 arc-second SRTM15+V2.1 and GEBCO-2022 products (Figure 2-3). Both SRTM15+

(https://doi.org/10.5069/G92R3PT9, https://topex.ucsd.edu/WWW_html/srtm15_plus.html) and GEBCO-2022 (https://www.gebco.net/data_and_products/gridded_bathymetry_data/gebco_2022/) have global extent. The former includes some 3.6 million ship soundings and more than 6 years of non-repeat altimetry measurements (Tozer et al., 2019). The latter begins with SRTM15+, uses predicted depths based on the V31 gravity model (Sandwell et al., 2019), and is augmented with multibeam data from the Seabed 2030 Regional Centers. Multibeam image mosaics are available from NCEI- https://www.ncei.noaa.gov/maps/bathymetry/ with output in the form of image (.tiff) files. A search of "NASA Bathymetry" – produces the NASA GEBCO page and https://earthobservatory.nasa.gov/images/148246/sounding-the-seafloor-with-light (Thomas et al., 2021) on mapping near-shore shallows to a horizontal scale of 10 m available in three specific areas However as of this writing this site did not include our area of interest.

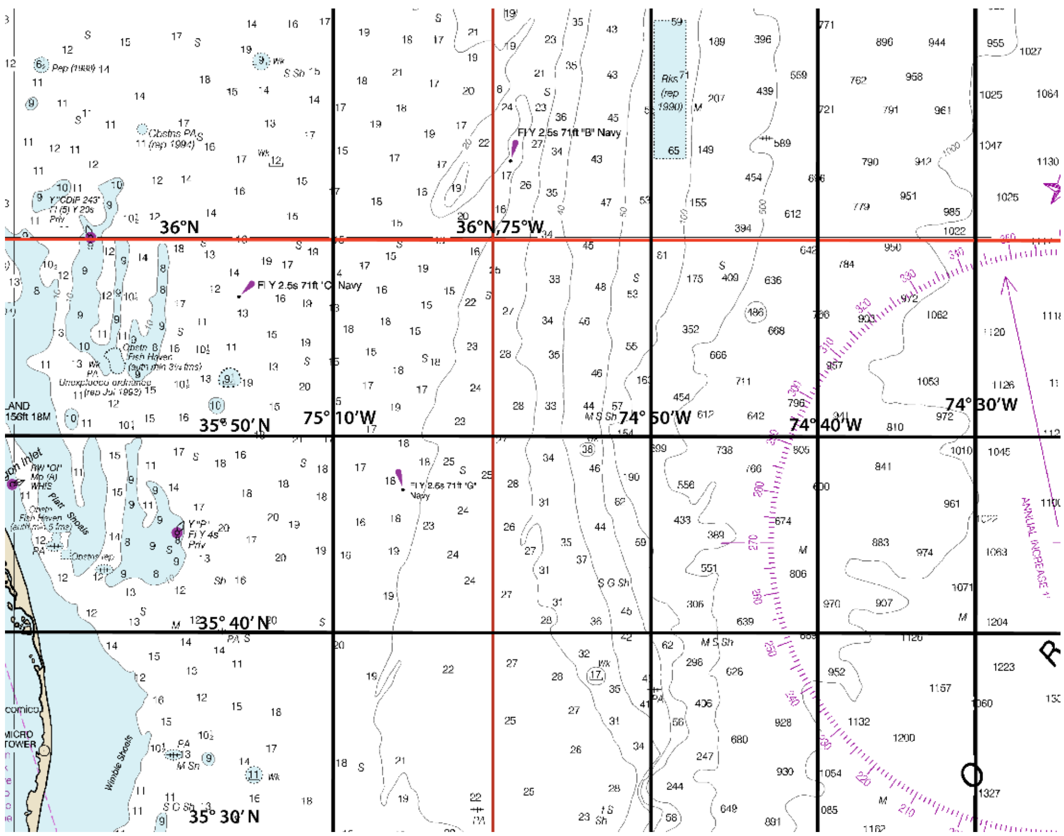


Figure 2-2 – A zoomed-in, cropped version of NOAA Soundings Chart 12200 in the region of the Mooring Box (https://charts.noaa.gov/InteractiveCatalog/nrnc.shtml#mapTabs-2). (Units meters).

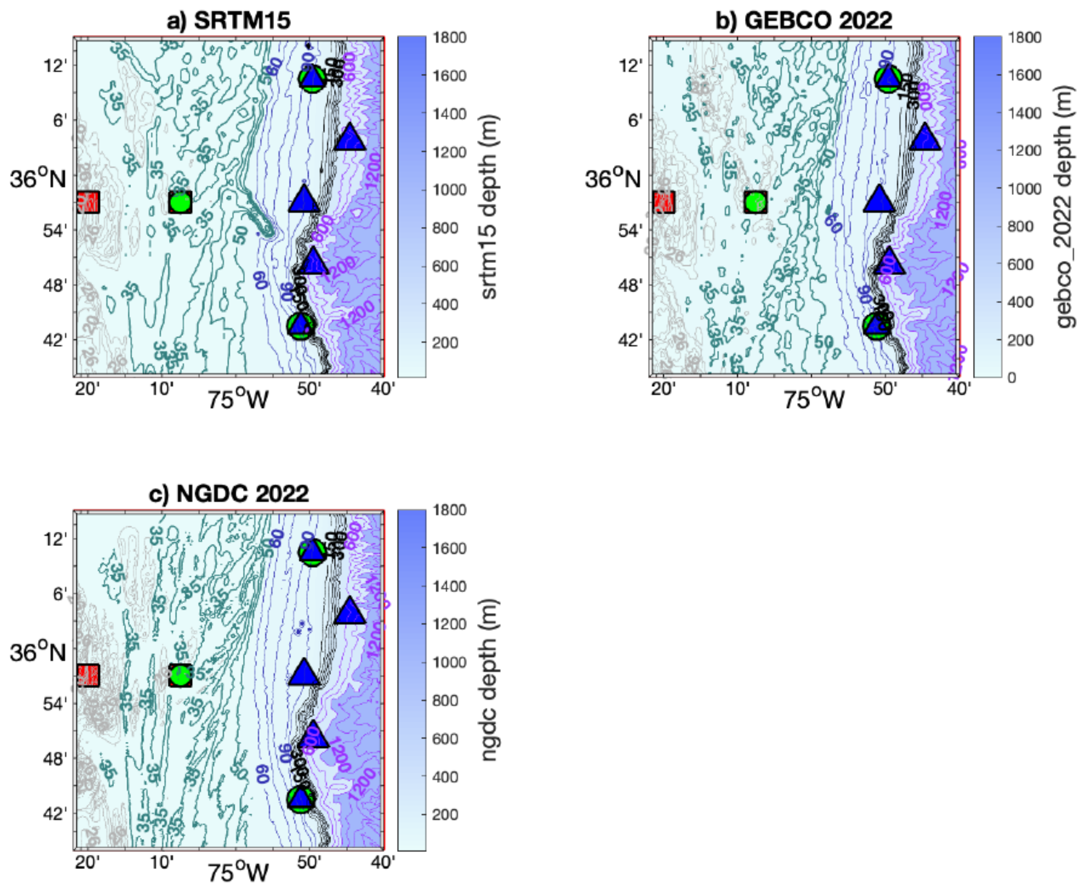


Figure 2-3 – Comparison of bathymetry products in region of the mooring box (red outline) with the preliminary mooring sites labeled as in Figure 1-2: a) SRTM15+V2.1 15 arc-second (Tozer et al., 2019); b) GEBCO-2022 15 arc-second (GEBCO Group, 2022); and c) NGDC-2022 3 arc-second. All panels have the same bathymetry contours (20:2:30 m grey, 35:5:50 green, 60:10:100 blue, 150:50:400 black, and 600:200:2000 purple).

Besides apparent resolution, the choice of bathymetric product was based on noting the peninsula-like feature running to the southeast of 35° 56'N, 75°W in SRTM15+ (Figure 2-3a) along what was determined to be a satellite track. In the GEBCO-2022 product (Figure 2-3b) that is an update of SRTM15+, this feature while still visible is less apparent, possibly because there is multibeam section that runs along this same track (https://www.ncei.noaa.gov/maps/bathymetry/). In the coastally focused NGDC product the peninsula is not seen at all (Figure 2-3c). We also note that while the resolution is low, the soundings in the region (Figure 2-2) do not indicate any such peninsula-like feature.

Determining the location of the moored array Site Centers was an iterative process starting from the schematic array drawing (Figure 1-2), and then considering the desired site separations and depths on the regional bathymetry maps, along with potential waterspace conflicts (e.g. military operating areas, ship traffic fairways, offshore wind lease blocks, submarine cables and potential coral habitats; see OOI document 3210-00008). The optimal east-west line for the sideways "T" shaped array was determined to be 35° 57'N. The longitudes of the WE and CN sites were constrained by marine navigation fairways; the site depths were determined from the NGDC depths at the desired latitude and longitude. The EA, NO and SO sites were planned to be along the 100 m isobath with a north-south separation of about 25 km. The site locations were determined from the location of the NGDC 100 m isobath at 35° 57.0'N, 36° 10.5'N and 35° 43.5'N, respectively. The NE and SE sites were planned to be along the 600 m isobath, with north-south separation of about 12.5 km from the moorings along the 100 m isobath. The site locations were determined from the location of the NGDC 600 m isobath at 36° 3.8'N and 35° 50.2'N, respectively.

The resulting proposed Site Centers are shown in the table below (final site locations are controlled in 3210-00008).

Table 2-1 – Proposed Mooring Site Center Locations

Mooring Site	Code	Lat (°N)	Lon (°E)
Western	WE	35.9500	-75.3333
Central	CN	35.9500	-75.1250
Eastern	EA	35.9500	-74.8457
North	NO	36.1750	-74.8267
Southern	SO	35.7250	-74.8530
Northeast	NE	36.0633	-74.7427
Southeast	SE	35.8367	-74.8242

The bathymetry in the region can be described as a broad coastal area with depths of less than 20 m, an inner shelf with depths to ~20 m, and a mid-shelf that extends depths of ~50 m. The shelf break is seen near 100 m with a precipitous drop to > 1000 m (Figure 2-4). The mooring box covers the region offshore of the inner shelf (25 – 30 m, moorings WE and CN) extending to the beginning of the slope (600 m, mooring NE and SE). Moorings NO, EA and SO are aligned along the 100 m isobath at the shelf break. For a sense of scale, the distance from WE to CN is about 19 km, from CN to EA about 25 km, and from NO to SO about 50 km.

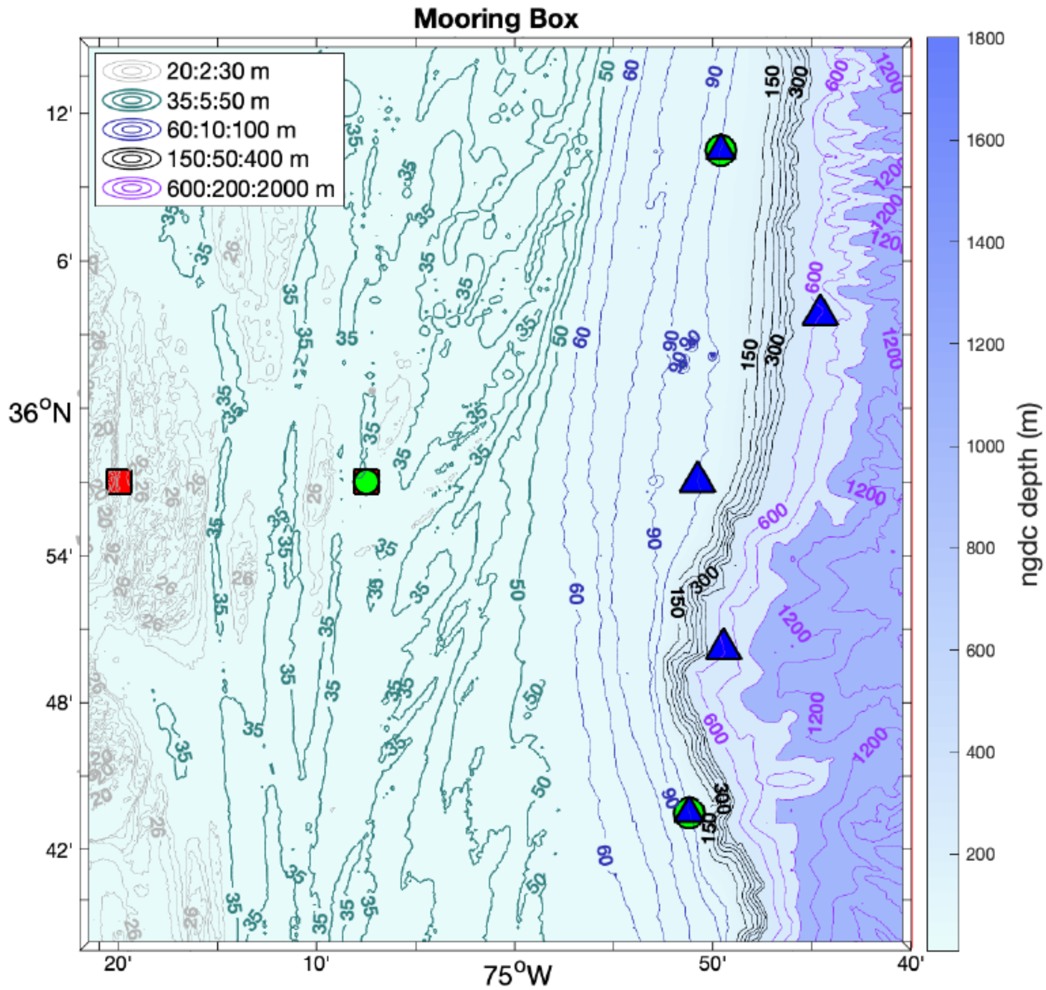
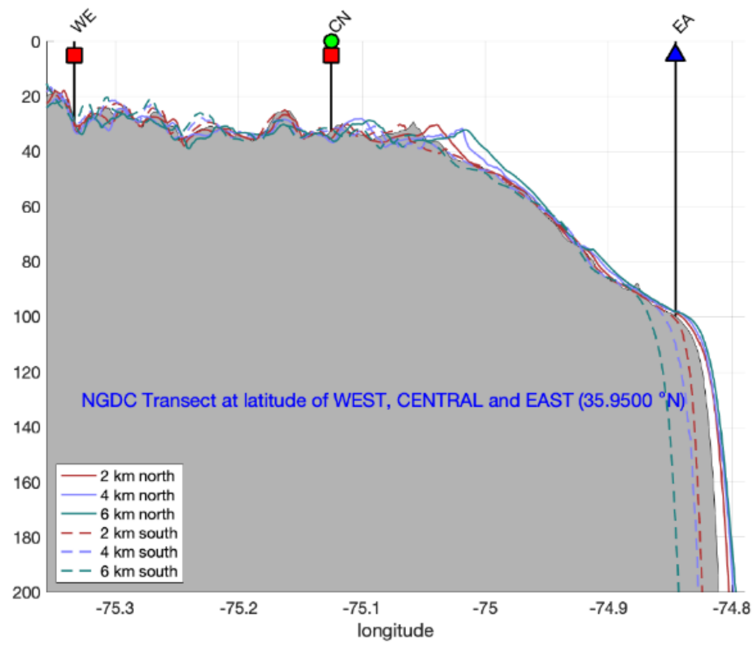


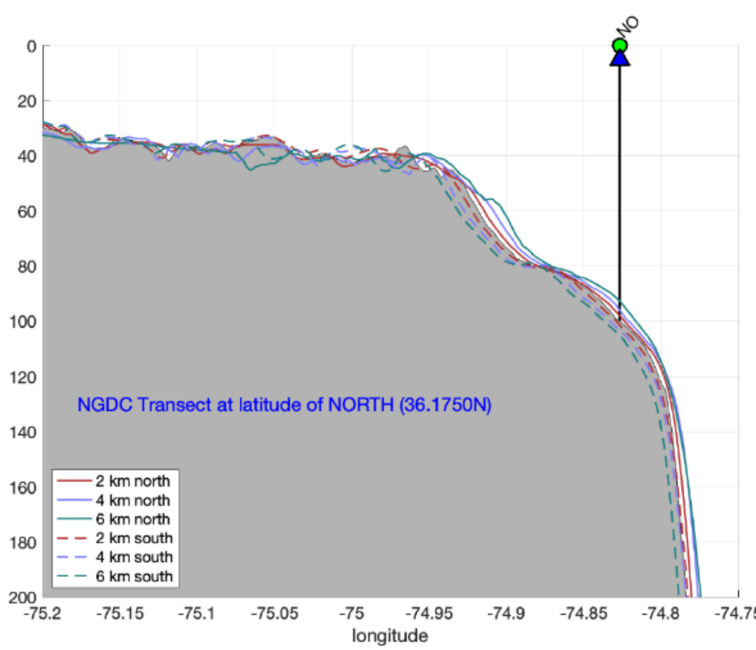
Figure 2-4 – The same as Figure 2-3c but zoomed in to provide a clearer illustration of the mooring box.

To visualize and compare the variability in bathymetry near the moorings (WE, CN, EA, NO, SO, NE and SE) as well as to determine longitudes to go with the latitudinal target positions assigned to all but the shallowest moorings (WE and CN), transects along the latitude of each mooring site were created using the NGDC database (Figures 2-5a-e).

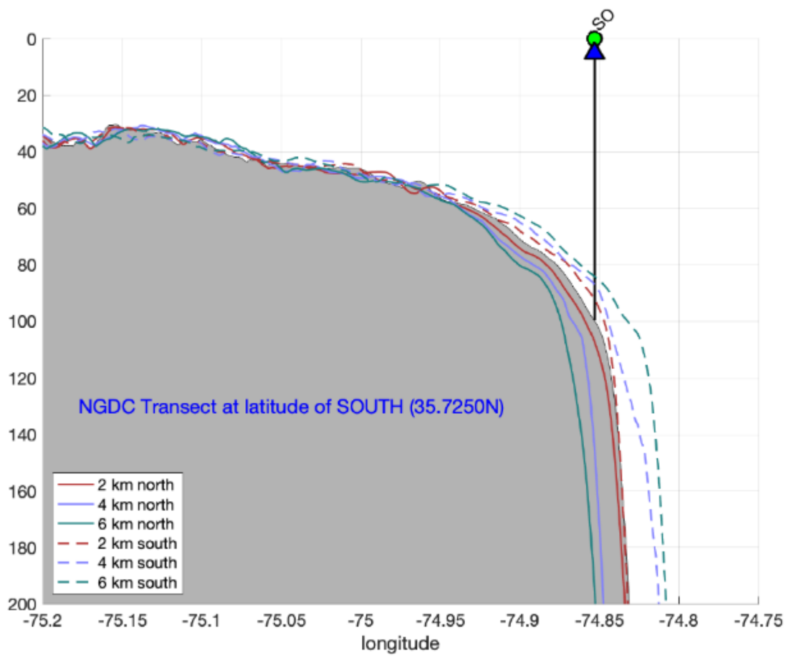
Figures 2-5 – East-West Transects across the mooring locations (a-e)



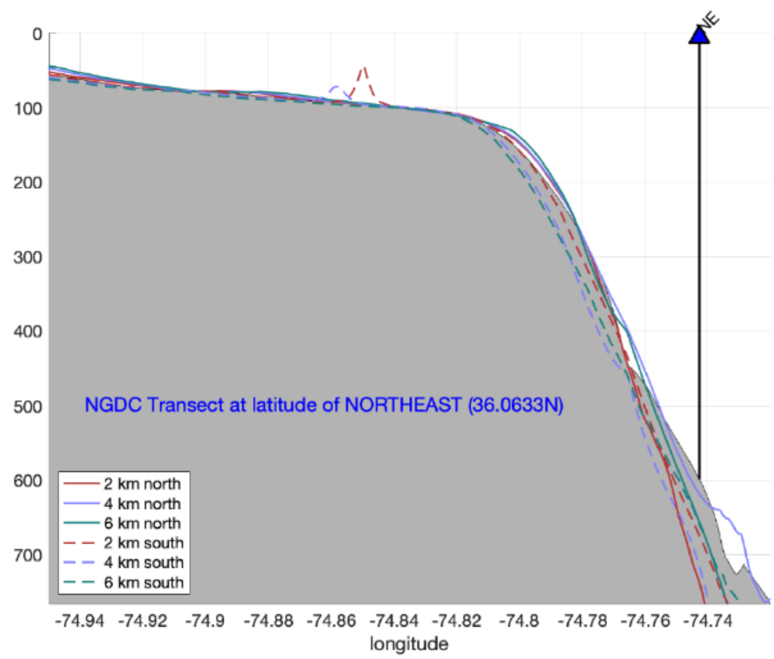
a) Transect along the latitude of the WE, CN and EA moorings (35° 57.00'N) based on NGDC 3-arcsecond bathymetry. The longitude of WE and EA sites were chosen based on waterspace usage considerations; the resulting depths were determined from the bathymetry. The longitude of EA was determined by finding the first instance of a grid cell along this zonal line greater than 100 m and then using linear interpolation to find the longitude at 100 m.



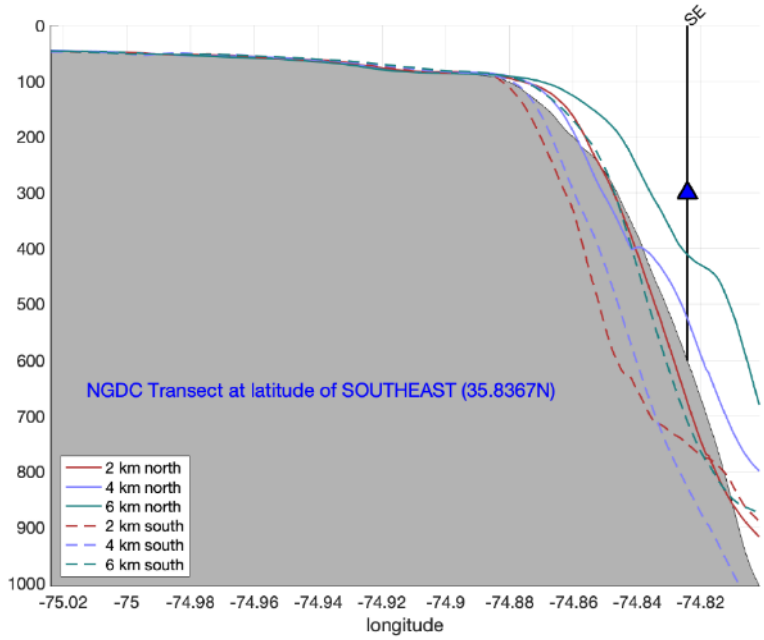
b) Transect along the latitude of the NO mooring (36° 10.50'N) based on NGDC 3-arscsecond bathymetry. The longitude of NO was determined by finding the first instance of a grid cell along this zonal line greater than 100 m and then using a linear interpolation to find the longitude at 100 m.



c) Transect along the latitude of the SO mooring (35° 43.50'N) based on NGDC 3-arscsecond bathymetry. The longitude of SO as determined by finding the first instance of a grid cell along this zonal line greater than 100 m and then using a linear interpolation to find the longitude at 100 m.



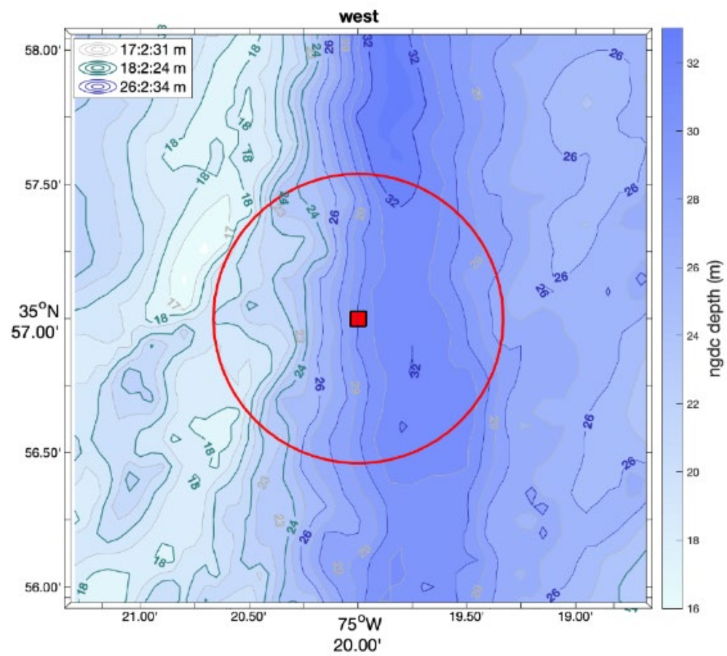
d) Transect along the latitude of the NE mooring (36° 3.798'N) based on NGDC 3-arscsecond bathymetry. The longitude of NE as determined by finding the first instance of a grid cell along this zonal line greater than 600 m and then using a linear interpolation to find the longitude at 600 m.



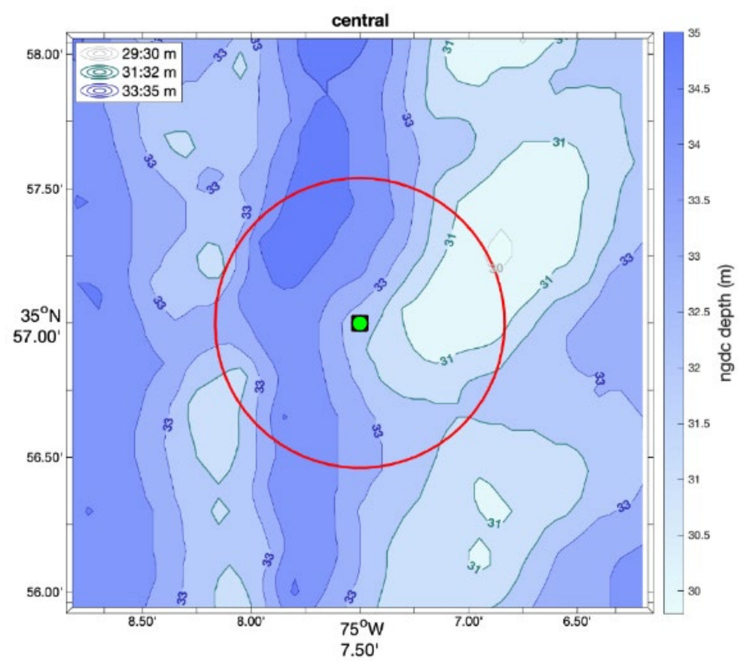
e) Transect along the latitude of the SE mooring (35° 50.2'N) based on NGDC 3-arscsecond bathymetry. The longitude of SE as determined by finding the first instance of a grid cell along this zonal line greater than 600 m and then using a linear interpolation to find the longitude at 600 m

Site Maps – regional bathymetric maps in the vicinity (±2 km in latitude and longitude) of each mooring site - were made to illustrate the local depth characteristics (Figures 2-6a-g). It is useful to define the Site Center and Site Radius. The Site Center is the central location for a given mooring site. The Site Center is listed in array location tables and plotted on maps. However, the moorings are not typically located at the Site Center (although they should be within the Site Radius). The Site Radius for the Pioneer Array is a circular region within a radius of 1 km from the Site Center. A region, rather than an exact location, is necessary to allow for local-scale bathymetric features unresolved on available maps, uncertainties in "anchor-over" position, anchor fall-back during deployment, and to allow space for a replacement mooring to be deployed before the deployed mooring is recovered. These plan-view maps are centered on the Site Center and show the depth ranges to be encountered within the Site Radius. The maps also provide information on the likely impact, in terms of depth variation, of deployment targets being missed. Maps were created using the NGDC database. (Figures 2-6a-e).

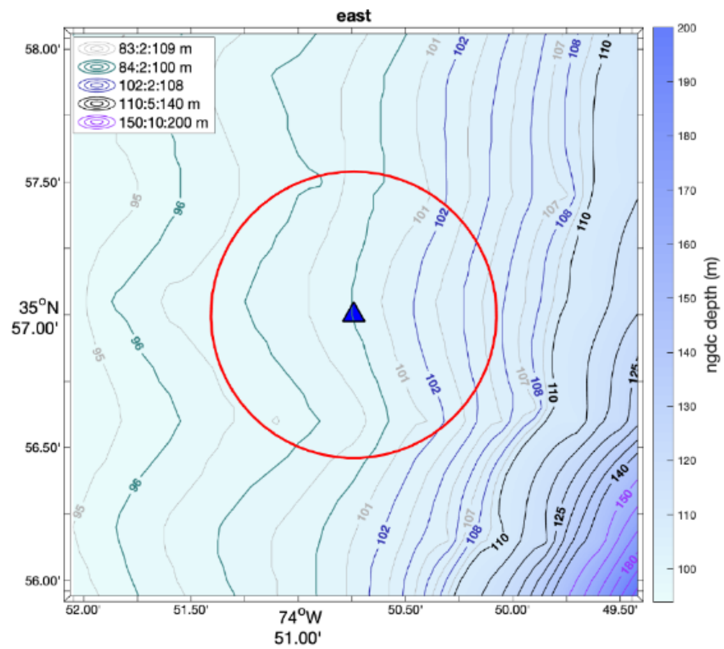
Figures 2-6 – Site Maps for each mooring location (a-g)



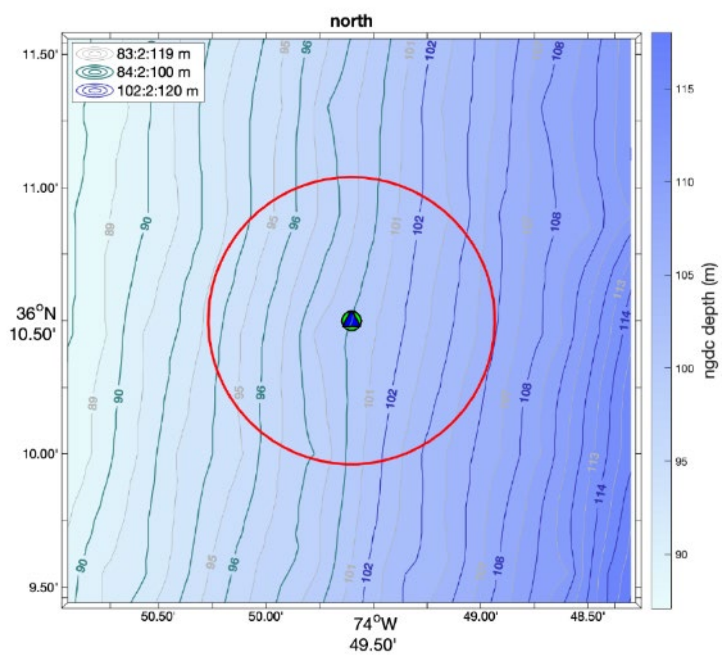
a) Map of the NGDC bathymetry in the mid-shelf region within ±2 km of the shallow (~30 m) westernmost mooring WE (red square). Red circle is the 1 km site radius from the site center. Bathymetric contour intervals are shown in the legend.



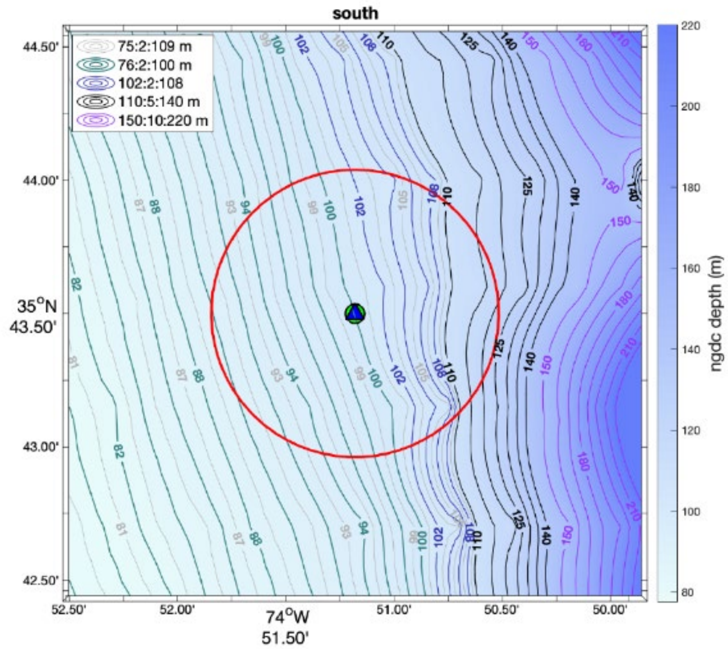
b) Map of the NGDC bathymetry in the mid-shelf region within ±2 km of shallow/surface mooring CN (red square/green circle). Red circle is the 1 km site radius from the site center. Bathymetric contour intervals are shown in the legend.



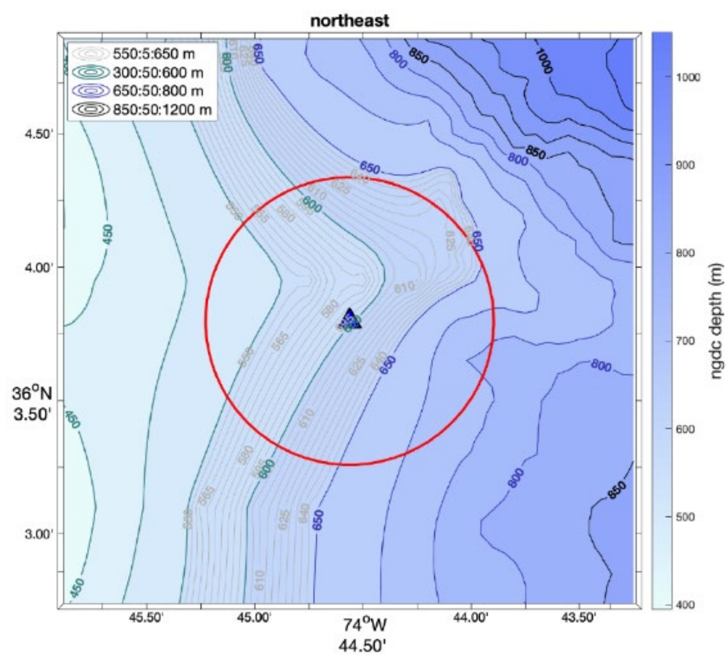
c) Map of the NGDC bathymetry in the shelf break region within ±2 km of the profiler mooring EA (blue triangle) located on the 100 m isobath. Red circle is the 1 km site radius from the site center. Bathymetric contour intervals are shown in the legend.



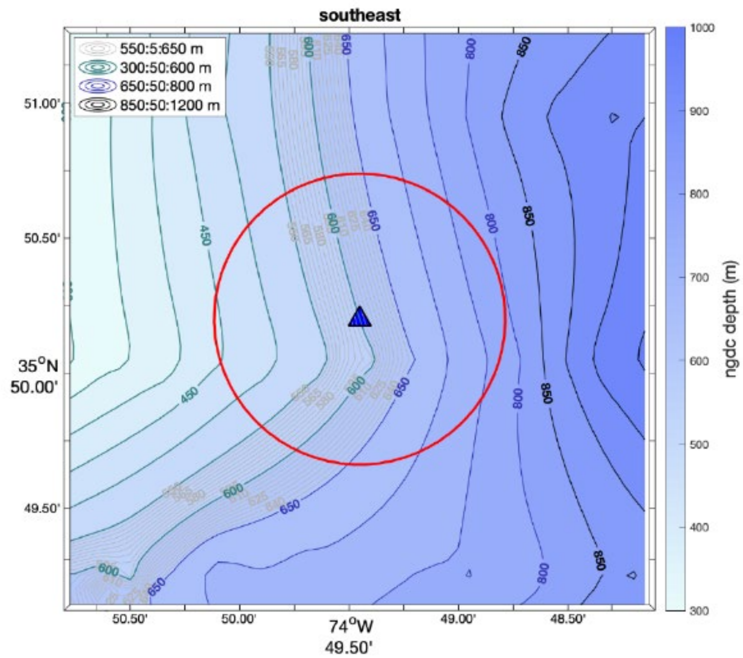
d) Map of the NGDC bathymetry in the shelf break region within ±2 km of the northern surface/profiler mooring NO (green circle/blue triangle) located on the 100 m isobath. Red circle is the 1 km site radius from the site center. Bathymetric contour intervals are shown in the legend.



e) Map of the NGDC bathymetry in the shelf break region within ±2 km of the southern surface/profiler mooring SO (green circle/blue triangle) located on the 100 m isobath. Red circle is the 1 km site radius from the site center. Bathymetric contour intervals are shown in the legend.



f) Map of the NGDC bathymetry in the slope region within ±2 km of the most northern and eastern profiler mooring NE (blue triangle) located on the 600 m isobath. Red circle is the 1 km site radius from the site center. Bathymetric contour intervals are shown in the legend.



g) Map of the NGDC bathymetry in the slope region within ±2 km of the most southern and eastern profiler mooring SE (blue triangle) located on the 600 m isobath. Red circle is the 1 km site radius from the site center. Bathymetric contour intervals are shown in the legend.

Mooring WE lies toward the eastern edge of the inner shelf. With isobaths running meridionally, WE (at ~30 m) appears to lie near the bottom of a short slope (22 to 32 m). The slope appears as a divot in the transect (Figure 2-5a) and is more clearly a slope in the site map (Figure 2-6a). Mooring CN (at ~32.5 m) lies well onto the mid-shelf where the isobaths to the west are oriented in the N/S direction, while those to east appear more as circular hillocks. CN lies half way up a short 35 to 30 m slope which is far more apparent in the site map (Figure 2-6b) than in the transect (Figure 2-5a). Neither WE nor CN would be greatly affected by a location choice to the north or south (Figure 2-5a).

Mooring EA (at 100 m) lies at the shelfbreak on the same line of latitude as WE and CN. Moving the target location for EA to north would require moving it further east to keep it at 100 m on and on the shelfbreak. As the 100 m isobath at this site center forms a shallow “<”, moorings placed to the north by any distance within 6 km, would require changing in the target longitude to a position further east to keep the 100 m depth. Placement to the south by less than ~1 km, would also require an eastward change in longitude, but any further south than 1 km, would require a compensating shift to westward (Figure 2-5a, Figure 2-6c).

At the location of Mooring NO, the isobaths are fairly regularly spaced and tilted slightly from northeast to southwest (Figure 2-5b). Therefore, NO placement to the north (south) of the site center would require a compensating westward (eastward) shift to remain on the 100 m isobath. Siting the mooring with 6 km without a compensation in longitude would change the target depth by ~10 m (Figure 2-6d). At Mooring SO, the isobaths are again quite regular, but are tilted in the opposite direction from northwest to southeast and are more tightly packed than at SO (Figure 2-5c). The opposite tilt means that placing SO to the north (south) of the site center would require a compensation eastward (westward) shift to remain on the 100 m isobath (Figure 2-6e), i.e., the opposite as the compensation at NO. The steeper gradient requires careful placement to avoid undesired change in depth.

The site centers for Moorings NE and SE at 600 m on the slope mean that small changes in position will have a noticeable effect on the resulting mooring depth. The isobaths within 2 km of Mooring NE form a “>” with the target location close to the vertex (Figure 2-5d). A small shift offshore by about 0.02 arc minute (30 m) by an almost equal shift northward, but for any further shift offshore there is no compensating shift to the north or south within 2 km that would result in a location on the 600 m isobath. Placement onshore (i.e. westward) of the site center on the other hand, can be compensated for by a shift either to the north or the south to retain the same depth (Figure 2-6f). Without compensation, a 30 m shift in longitude or latitude in either direction would result in a 15 to 20 m difference in depth (Figure 2-5d). Almost the same can be said for Mooring SE (Figure 2-5e, Figure 2-6g): an onshore placement can always be compensated for, while offshore placement will nearly always result in a deeper mooring. The slope however is steeper, so that a 30 m shift in any direction could result in a 30 to 50 m difference in depth.

It is assumed that prior to deployment, location specific multibeam surveys will be performed to determine at least two locations within the site radius of the site center for mooring location. Prioritizing this need in terms of importance to safe deployment, accurate multibeam surveys of the WE and CN sites will be useful, the NO, EA, and SO sites will be important, and the NE and SE site will be critical.

All maps were created using run_cre_all_smab_bathy_map_plots.m, which allows choice of bathymetric product and region. All transects for created using run_cre_all_smab_bathy_map_plots.m, which allows choice of bathymetric product, mooring and axis limits. Both these scripts call run_plot_bathy.m, which relies on three hardwired functions to define the regions and mooring locations, as well as transect and map specifics: define_smab_boxes.m , define_plot_bathy_region_numbers.m, and get_hardwired_plot_map_details.m.

2.2. Bottom types

The USGS sediment classification map (Figure 2-7) summarizes bottom characteristics along the Southern mid-Atlantic Bight and suggests that in OOI mooring region there is mainly a sandy bottom, with some gravelly sediment on the inshore shelf and possible sandy clay or silt on the slope. This figure provides a useful overview, but to zoom in and explore the seafloor types within the immediate area of the target Southern mid-Atlantic Bight moorings, we relied on information from the Conley et al. (2017) review.

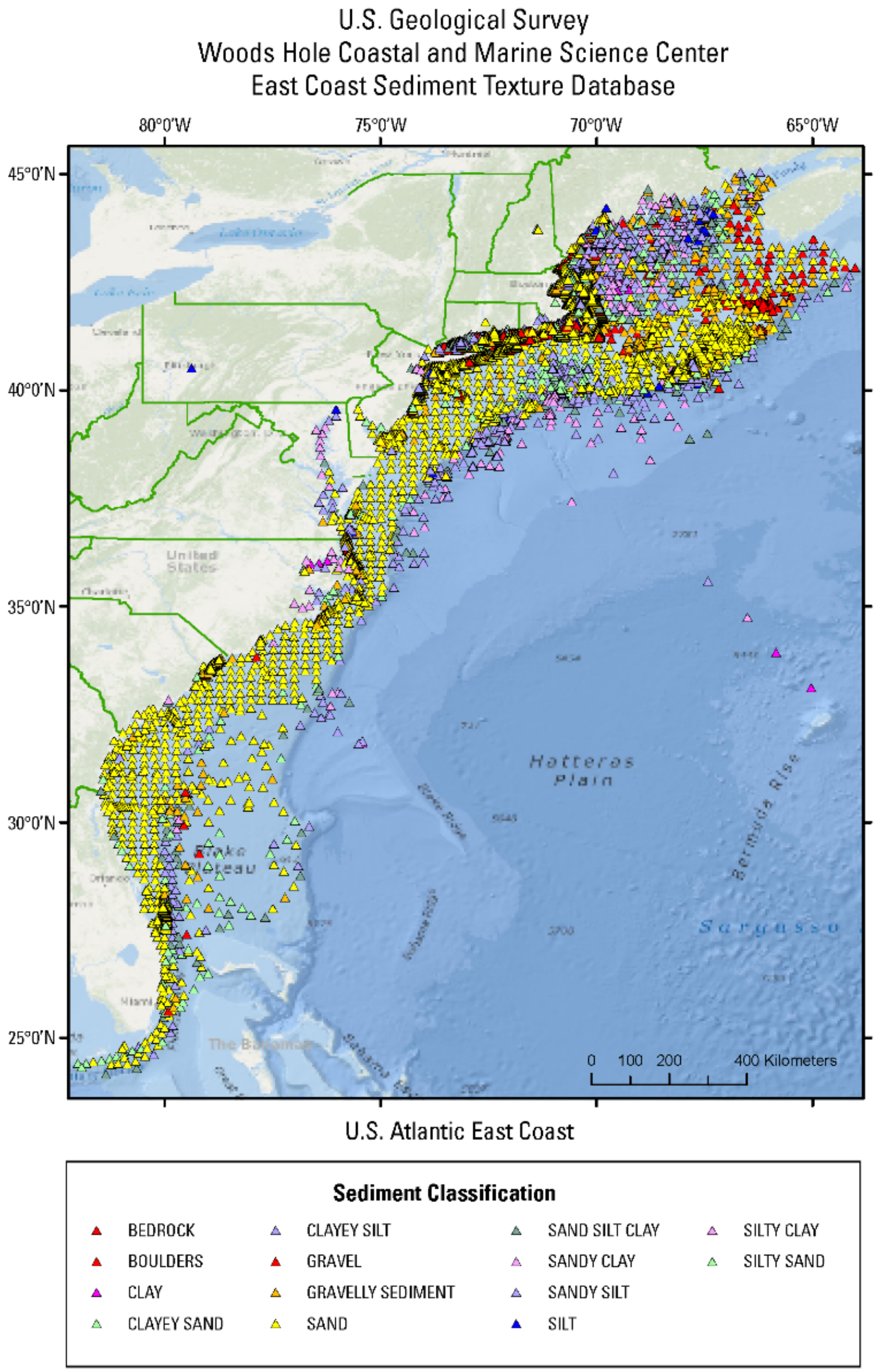


Figure 2-7 – USGS sediment classification map for the U.S. Atlantic East Coast. (Source: http://pubs.usgs.gov/of/2005/1001/)

Conley et al. (2017) characterized the structure of seafloor geophysics in terms of three variables: bathymetry (depth, which we have described in Section 2.1), seabed forms (topography), and substrate (texture and hardness). Like bathymetry, seabed forms and substrate are important to mooring location decisions. Conley et al. (2017) point out that these three variables are generally more stable than water column parameters which change on shorter timescales and “have been shown to correlate with the distribution and abundance of demersal fish and benthic organisms.” While OOI does not focus on the latter per se, disturbance of such environments may be a concern in determining mooring locations within the site radii.

Conley et al., (2017) define the varying depth regions in the mid-Atlantic Bight in term of six littoral zones, five of which concern the target mooring sites (Infralittoral 0-30 m, Shallow Circalittoral 30-70 m, Deep Circalittoral 70-200 m, Shallow Mesobenthic 200-600 m and Deep Mesobenthic 600 to 1000 m). See Conley et al. (2017) – their Table 3.1 for a review of the literature on the relationship between seafloor types and biota. Here, we present their figures covering the littoral zones themselves (Figure 2-8), seabed forms (Figure 2-9), soft sediment types (Figure 2-10), and hardbottom types (Figure 2-11) with the target SMAB mooring sites overlaid. Conley et al. also provide figures which combine these various seabed characteristics (their figure 3.34 combines depth zones with seabed and hardbottom types, and their figure 3.38 shows ecological marine units which combine depth zones with seabed, hardbottom and soft sediment types). However, these figures are somewhat redundant and are also difficult to use to explore the small scales in and around the mooring sites due to their inherent complexity. Further location-specific details may be available through the original databases used by Conley et al. (2017).

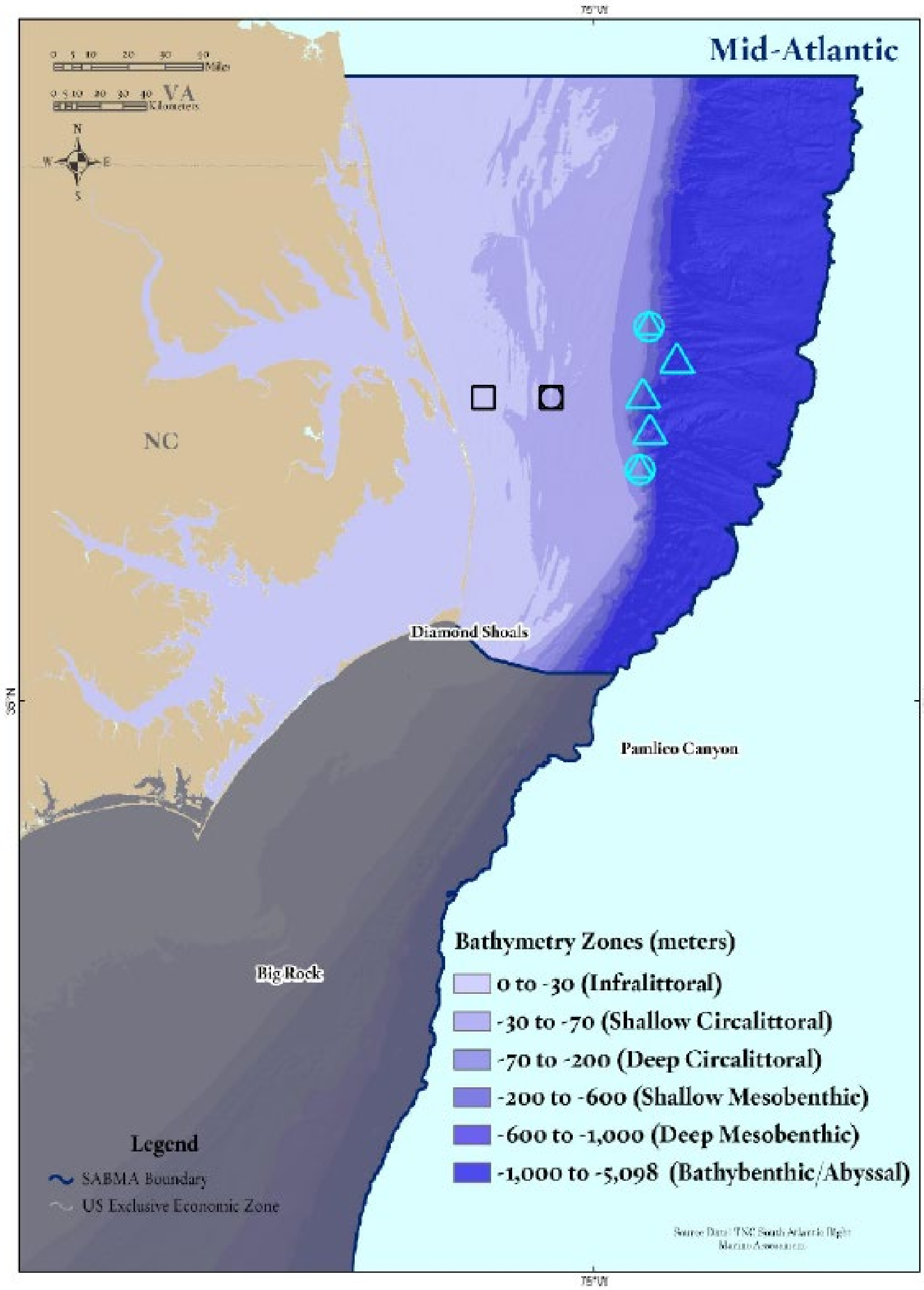


Figure 2-8 – The littoral (Depth) zones according to Conley et al. (2017) in the southern mid-Atlantic Bight. Symbols for target mooring locations as described in Figure 1-2, however the color coding has not been used to allow inspection of bottom characteristics at the site centers. The two symbol colors (black and cyan) have no inherent meaning and were chosen to stand out against all backgrounds in Figure 2-8 through Figure 2-11. (Adapted from Conley et al., 2017, their figure 3.4)

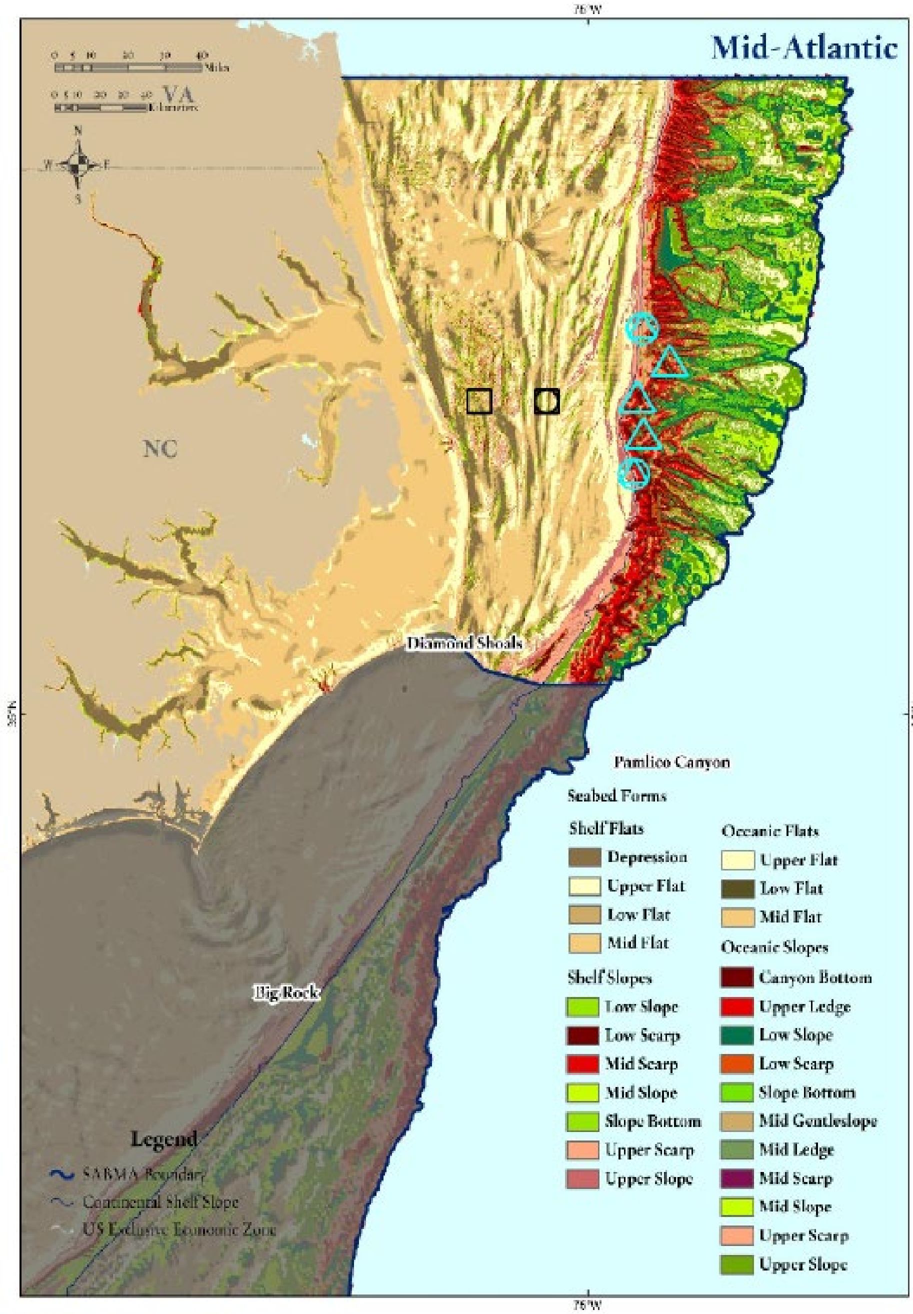


Figure 2-9 – Map of the seabed forms in same region and with same symbols as Figure 2-8. (Adapted from Conley at al., 2017, their figure 3.8)

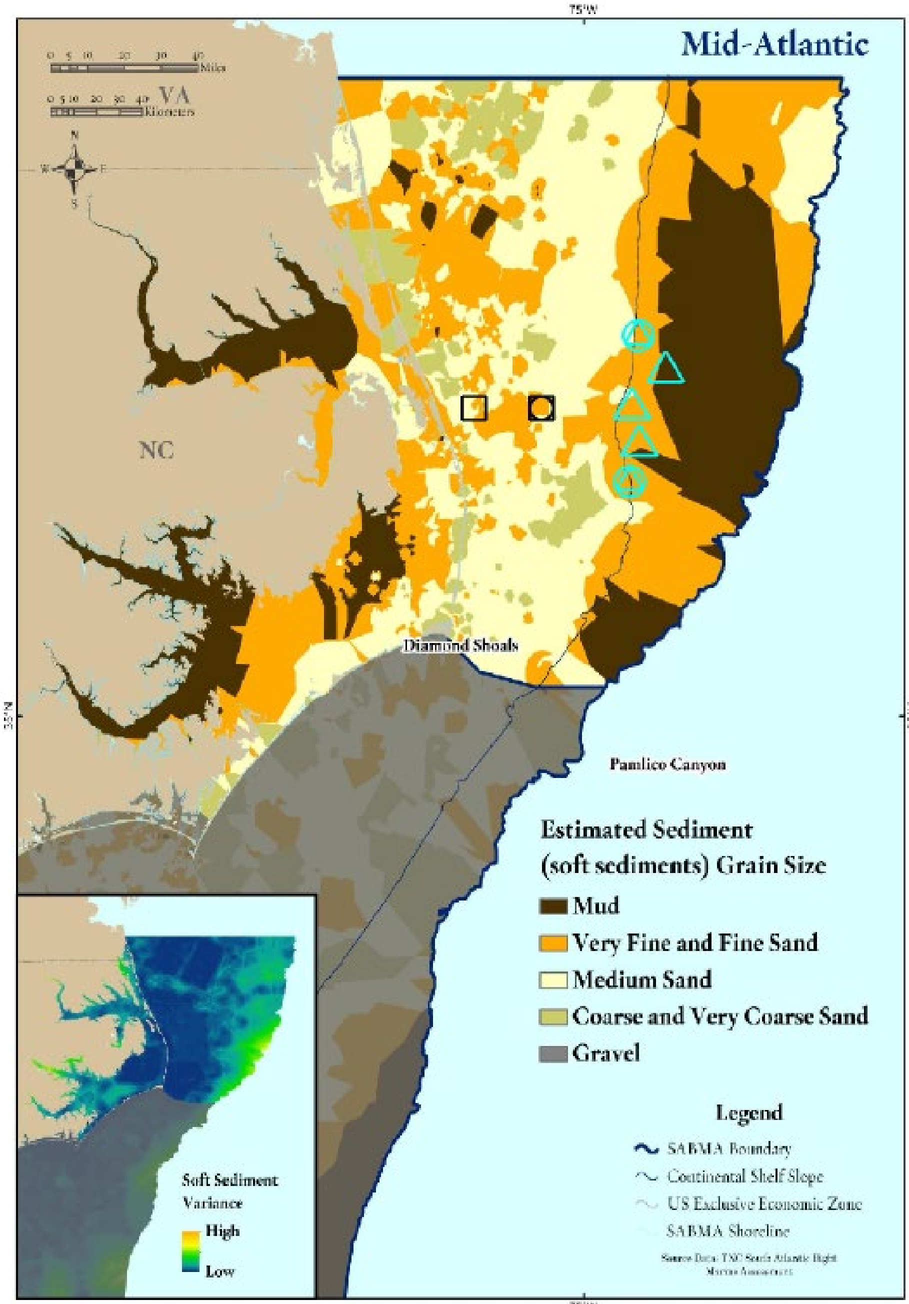


Figure 2-10 – Map of the soft sediment distribution in same region and with same symbols as Figure 2-8. (Adapted from Conley at al., 2017, their figure 3.20)

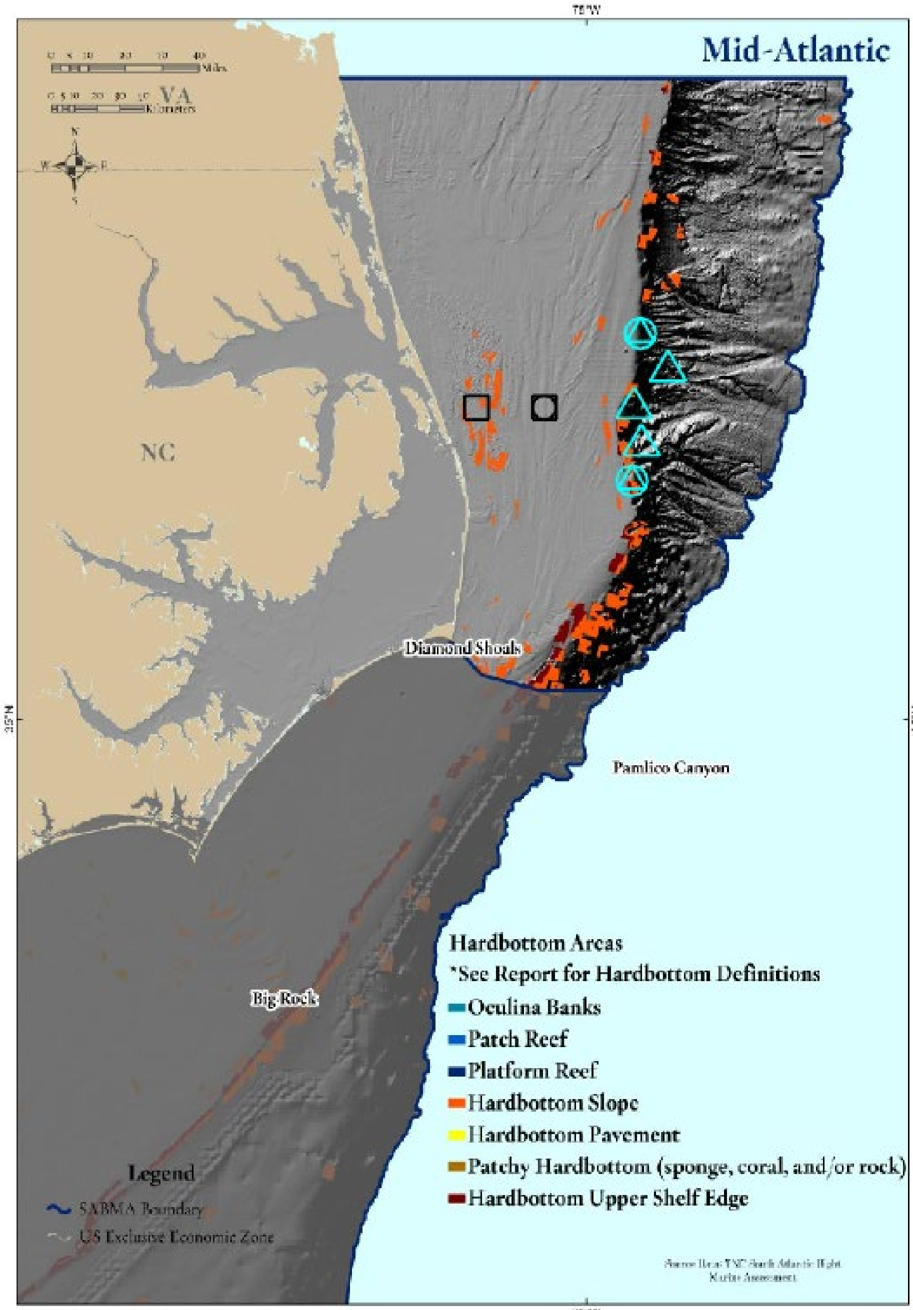


Figure 2-11 – Map of the hardbottom and corals overlaid on shaded topography in same region and with same symbols as Figure 2-8. (Adapted from Conley at al., 2017, their figure 3.25)

An examination of seabed characteristics near the target sites according to these figures is summarized in Table 2-2. We note that while Conley et al. (2017) divided the U.S. east coast area they studied into 7 regions of hardbottom types, only two of these exist in the OOI SMAB region; **Hardbottom Slope**: High relief hardbottom associated with ledges and slopes; **Hardbottom Upper Shelf Edge (HUSE)**: High relief hardbottom associated with the upper shelf edge to -100 m. In particular, the **Patchy Hardbottom (corals, sponges and/or rock)** only exists well south of the intended mooring sites. In addition, the Hardbottom Slope and HUSE regions appear to be patchy; in-situ site surveys will be necessary to augment the seabed characteristics suggested from the Conley et al. maps.

Table 2-2 – Summary of bottom characteristics in the region of the target mooring sites according to Figure 2-8 through Figure 2-11

Mooring Site	Littoral Zone (m)	Seabed Form	Soft Sediments	Hard Bottom
WE	Infralittoral (0-30)	Variable Shelf Slope	Medium Sand	none
CN	Bordering Infra- & Shallow Circalittoral (0-30-70)	Shelf Upper Flat	Very Fine & Fine Sand	none
EA	Deep Circalittoral (70-200)	Shelf Upper Scarp	Very Fine & Fine Sand	Hardbottom Slope
NO	Deep Circalittoral (70-200)	Shelf Upper Scarp	Very Fine & Fine Sand	none
SO	Deep Circalittoral (70-200)	Shelf Upper Scarp	Very Fine & Fine Sand	Hardbottom Slope/ HUSE
NE	Bordering Shallow & Deep Mesobenthic (200-600-1000)	Slope Upper Ledge	Mud	none
SE	Bordering Shallow & Deep Mesobenthic (200-600-1000)	Slope Upper Ledge	Mud to Very Fine & Fine Sand	Hardbottom Slope

The shallowest westernmost mooring WE target site lies well onto the shelf, but in a region with a variable seabed with rough topography (Figure 2-8). While the site center suggests a medium sand bottom, the intended locations within the site radius could place it in fine or very fine sand or on a hard bottom (but not corals or sponges). CN also lies on the shelf (near the depth break between infralittoral and shallow circa littoral). The site center for CN and the immediate surrounding area is all sand or very fine sand.

EA, NO and SO on the 100 m isobath lie solidly in the deep circalittoral depth zone and are associated with the Shelf Upper Scarp seabed form with fine to very fine sand at the bottom. That said, for SO, mooring placement within the site radius to the north could put it on Hardbottom and placement to south could put it on either Hardbottom or Hardbottom Shelf Edge. There is Hardbottom just to the north of the NO site center, but it is difficult to say whether this region lies within the site radius (Figure 2-11). In neither location (NO or SO) is there any indication of Patchy Hardbottom with corals or sponges.

At 600 m, moorings NE and SE also lie at the boundary between two of the defined depth zones, Shallow and Deep Mesobenthic. The NE site center appears to sit at the Slope Upper Ledge (bright red, Figure 2-9), and though scale is difficult to discern it appears that upper ledge and upper/mid-slope (bright/dull green, Figure 2-9) lie within the site radius. This interpretation is consistent with the bathymetric transect (Figure 2-5d). As noted elsewhere, the slope is extremely steep here. The SE site centers is on the Slope Upper Ledge but lies close to an Upper Scarp feature (light pink, Figure 2-9). The same is not illustrated in the transect (Figure 2-5e) possibly because that figure is zonal and it would require a meridional transect to see the scarp. The seabed sediments at NE are mud while at SE they sand/very fine sand, though just to the south of the site center there is again mud (Figure 2-10).

In summary, all target mooring locations except CN and NO lie in regions of patchy seabed characteristics, and it will take a bathymetric survey to be sure of both the depths and seafloor types in the immediate vicinity of each target site.

3.0 Oceanographic Conditions

3.1. Regional Circulation Patterns

The mean circulation patterns over the Mid-Atlantic Bight were analyzed by Lentz et al. (2008) using moored current observations with records exceeding 200 days. They found a consistent mean circulation pattern with the mean depth-averaged flow along-shelf, towards the equator, increasing linearly with depth (3 cm/s at the 15-meter isobath and 10 cm/s at the 100-meter isobath). The mean cross shelf circulation was weak but still showed a consistent cross-shelf and vertical structure. Near the surface, the flow was typically offshore, ranging between -2 to 4 cm/s. The “interior” cross-shelf flow was ~1 cm/s onshore and was found to be consistent. Mean flow in the near-bottom region increased with water depth from -1 cm/s (near the coast) to 4 cm/s (over the slope), switching from onshore to offshore around the 50-meter isobath. The inner shelf showed a two-layer structure, offshore near the top and onshore near the bottom. The mid- and outer shelf had a three-layer structure with offshore flows near the top and bottom and an onshore flow in the “interior”.

3.2. Surface currents

The Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) has been measuring hourly ocean surface currents (depths > 2.5 m) using High Frequency Radar between Cape Cod, MA and Cape Hatteras, NC, since 2007. Roarty et al. (2020) analyzed 10 years (2007-2016) of High Frequency Radar data in the Mid-Atlantic Bight resulting in a detailed evaluation on the effect of wind forcing and riverine discharge on surface flows over seasonal and annual time periods.

The HF Radar hourly averaged surface currents were de-tided, low-pass filtered using a 30-hour period, and gridded. Three-month seasonal means and 12-month annual means were calculated using only data from grids with more than 50% of measurements available. Decadal means for each season and full year were calculated by taking the mean of the 10 seasonal means so each year was equally weighted.

NOAA weather buoys and Coastal-Marine Automated Network (C-MAN) stations provided hourly wind data using only data with at least 50% coverage included in analysis. Mean seasonal, annual, and decadal wind was calculated using the same method as currents above. River discharge data was provided by the U.S. Geological Survey (USGS) with data from all the smaller tributaries flowing into Chesapeake combined into a single data set.

Results from the analysis found a strong coastal current which turns offshore south of the Chesapeake Bay and merges with Gulf Stream. Steady flow was found along the shelf and the most varied found near shore. As found by Lentz (2008), the mean along-shelf currents increased with distance offshore. The variability in mean flow was small from year to year but large within any given year, which may be influenced by the Gulf Stream. The largest variability was in fall and winter when the water-column changes from stratified to well mixed with strong winds and freshwater flow driving the variability.

An overview of findings by Roarty et al. (2020), broken down by season, is as follows. Winter: Strong cross shore winds (NW), strong freshwater flow, currents strongest across the entire shelf, mostly offshore (peak velocities 7-12 cm/s), largest along shore currents turning counterclockwise off shelf and into gulf stream, with a cross-shore wind and more mixed water column. Spring: Weak alongshore winds (SW), with nearshore winds from the west, strong freshwater flow, weaker currents nearshore (3-6 cm/s) and follow same pattern as winter, strongest at shelf break, currents reach similar highs to fall and winter but without wind forcing, and weakest along shore (opposed by wind). Summer: Wind speeds are midrange (1.0-1.9 m/s) and from SW, which is typical response from Bermuda high, weakest wind alongshore, weak freshwater flow, weakest currents overall (3-6 cm/s), weakest along shore (opposed by wind), strongest currents at shelf break, flowing in more cross-shelf direction, then southeast towards gulf stream. Fall: Strong cross shore winds (NW), weak freshwater flow, fastest seasonal currents, driven by wind and directing flow along shore, more mixed water column, coastal current flows to shelf and joins shelf break jet, flowing offshore into one current.

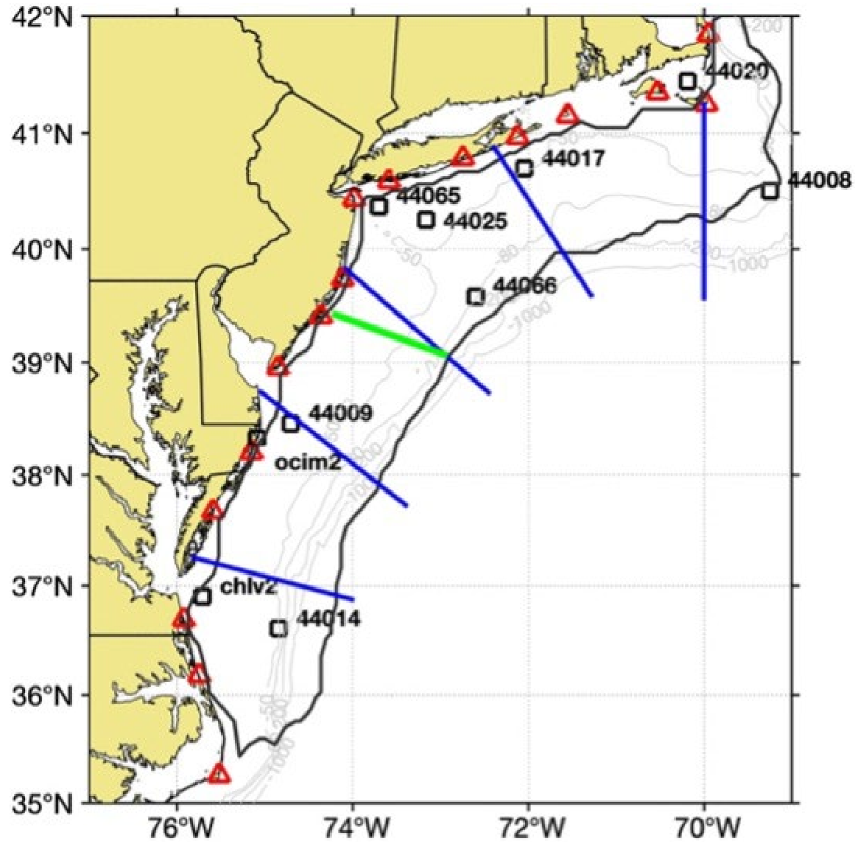


Figure 3-1 – From Roarty et al. (2020). NOAA NDBC stations are marked as black squares and labeled. The 50-, 80-, 200-, and 1,000-m isobaths are marked along with the total vector coverage for the study period shown as the thick black line. The Tuckerton endurance line is marked in green. The continental shelf was divided into six regions following definitions used by Wallace et al. (2018). From north to south, the regions are Eastern New England (ENE), Southern New England (SNE), New York Bight 1 (NYB1), New York Bight 2 (NYB2), Southern Shelf 1 (SS1), and Southern Shelf 2 (SS2).

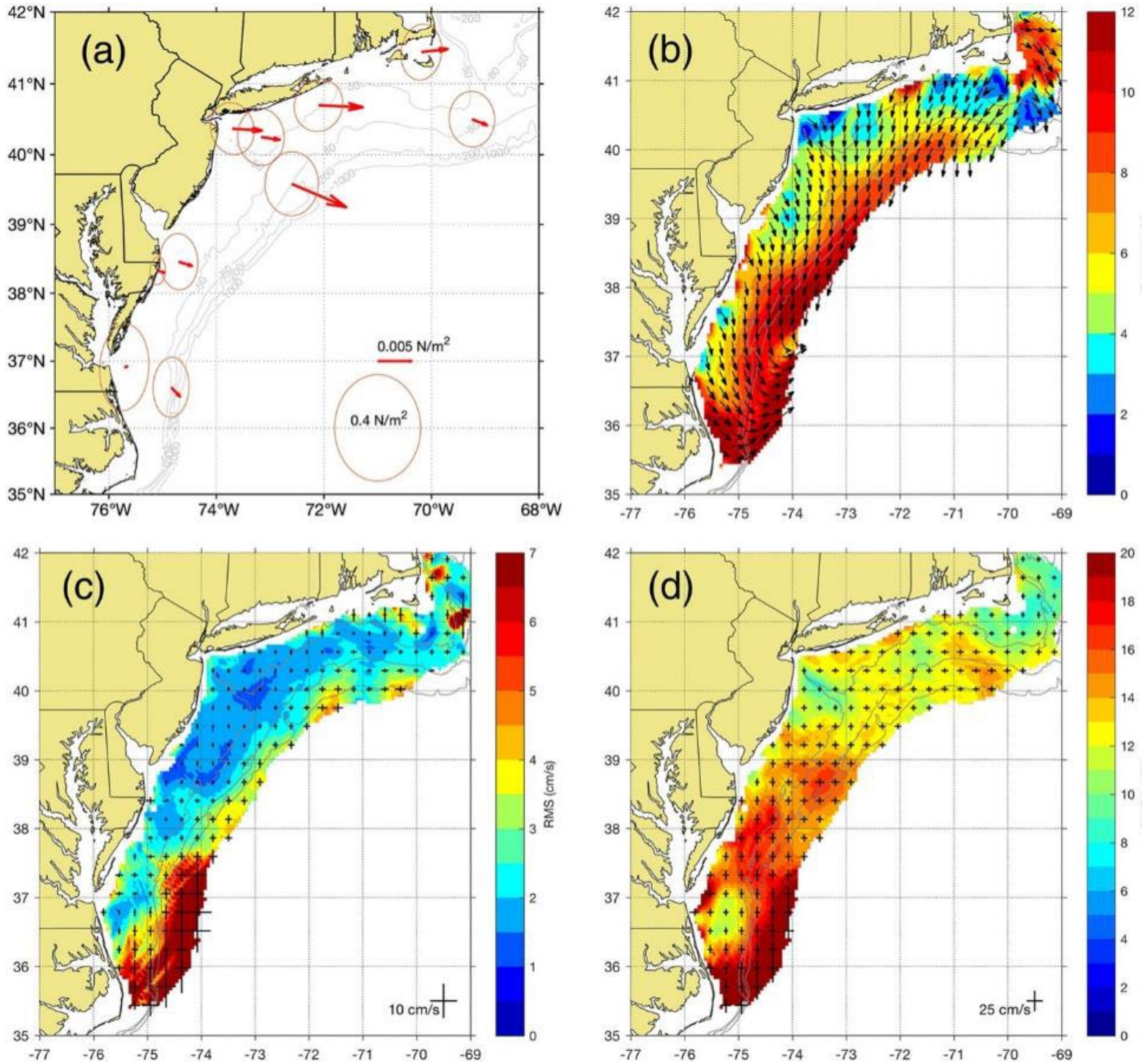


Figure 3-2 – From Roarty et al. (2020). (a) Mean and 95% data ellipse of wind stress (N/m^2) from NDBC stations for 2007–2016. The reference vector of 0.005 and 0.4 N/m^2 variability ellipse is given in the lower right. (b) Mean surface current for the Mid-Atlantic Bight (cm/s) colorbar indicates magnitude and vectors indicate direction toward of surface current. (c) Interannual standard deviation of the surface currents (cm/s). (d) Intra-annual standard deviation of the surface currents (cm/s).

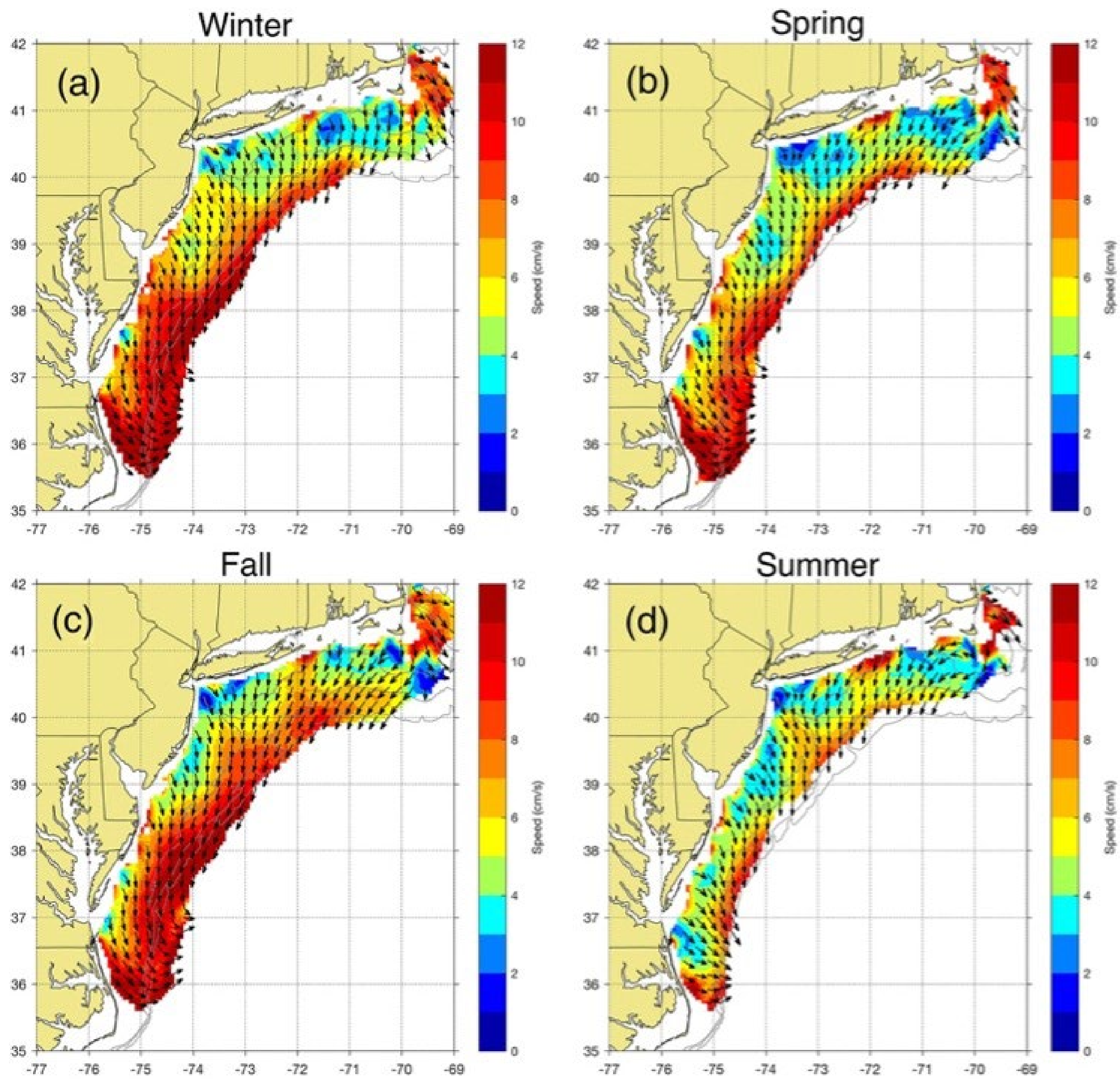


Figure 3-3 – From Roarty et al. (2020). Mean surface currents (2007-2016) broken down by season (a) winter, December–February; (b) spring, March–May; (c) fall, September– November; and (d) summer, June–August. indicates magnitude (cm/s) and vectors indicate direction-toward for surface current.

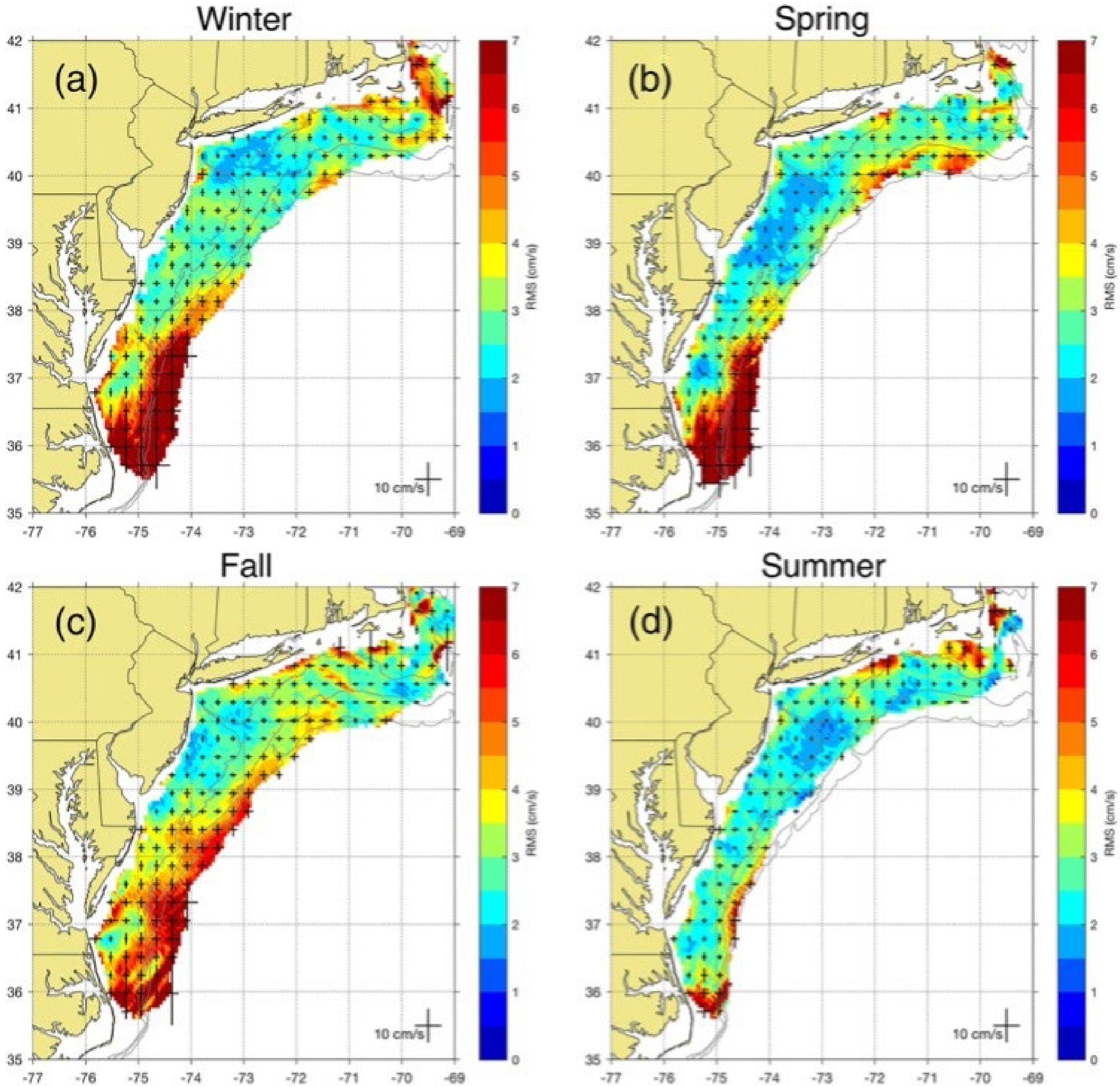


Figure 3-4 – From Roarty et al. (2020). Intraseasonal standard deviation of the surface current (cm/s) in the Mid-Atlantic from (a) winter, December–February; (b) spring, March–May; (c) fall, September–November; and (d) summer, June–August. One standard deviation marks in the east/west and north/south directions are shown for every fifth grid point (30-km spacing) with a reference scale of 25 cm/s in the lower right.

3.3. Subsurface Currents

As part of the **P**rocess driving **E**xchange **a**t **C**ape **H**atteras (PEACH) project, located in the Mid-Atlantic Bight and Southern Atlantic Bight, 10 moored upward looking ADCPs were deployed along the shelf and shelf-break (Haines et al., 2022; Seim et al., 2022). Of these, four ADCPs (A1, A2 A3, and B1) were located within the proposed bounds for the new Pioneer Array site (Figure 3-5) and along the same ~100 m isobath intended for OOI moorings NO, EA and SO. Moorings A1, A2, and A3 were deployed along the shelf break from April 2017 to November 2018; Mooring B1 was deployed on the shelf from April 2017 to December 2018 (Table 3-1). The ADCP data were hourly averaged and regridded to a uniform depth grid (Table 3-1), and the u- and v-velocity were depth-averaged and de-tided.

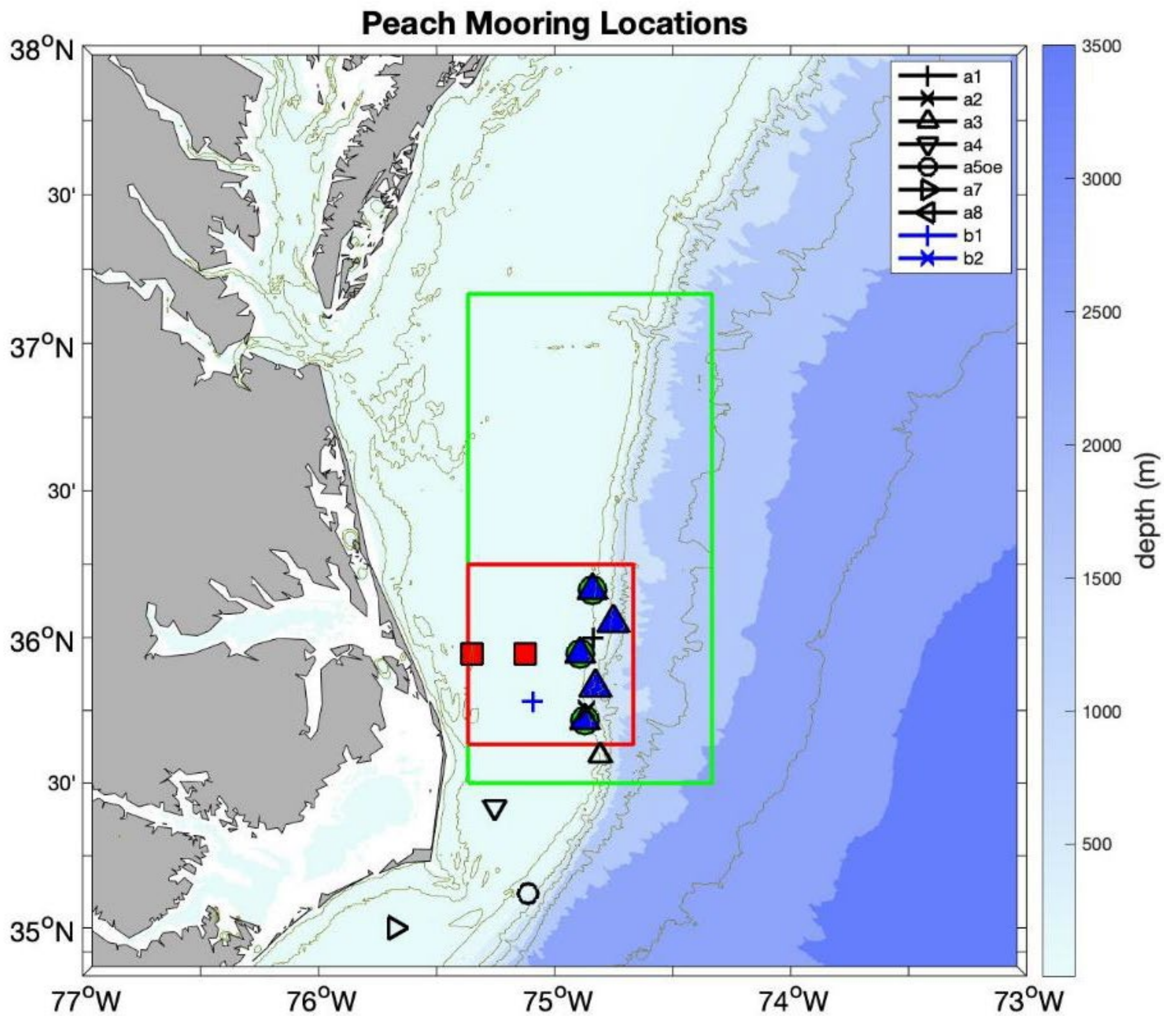


Figure 3-5 – PEACH mooring locations A1, A2, A3, and B1 with the OOI glider (green), and mooring array bounds (red), and shallow (red squares), surface (green circle), and profiler (blue triangles) mooring central locations.

Table 3-1 – PEACH moored ADCP data overview.

Mooring	Dates		Depth	Lon	Lat	Bin size	# of bins	Bin depths
A1 shelf break pod	Apr 18, 2017	Nov 23, 2018	100	-74.834	36.001	4	21	92-12
A2 shelf break pod	Apr 18, 2017	Nov 23, 2018	96	-74.863	35.752	4	20	88-12
A3 shelf break pod	Apr 18, 2017	Nov 19, 2018	97	-74.809	35.595	4	20	92-16
B1 Oregon Inlet bottom frame	Apr 20, 2017	Dec 31, 2018	36	-75.093	35.780	1	29	33-5

The percentage of ADCP current meter data recorded for each of the PEACH moorings are presented in Figure 3-6 as histograms. The histograms are all recorded data for all depth bins, grouped into months. The data return for Moorings A1, A2, and A3 were similar with the lowest return in January (~4%) and the highest returns between May and October (~10%). The data return for Mooring B1 was also lowest in January (~4%) but had fairly consistent data returns from May to December (~10%).

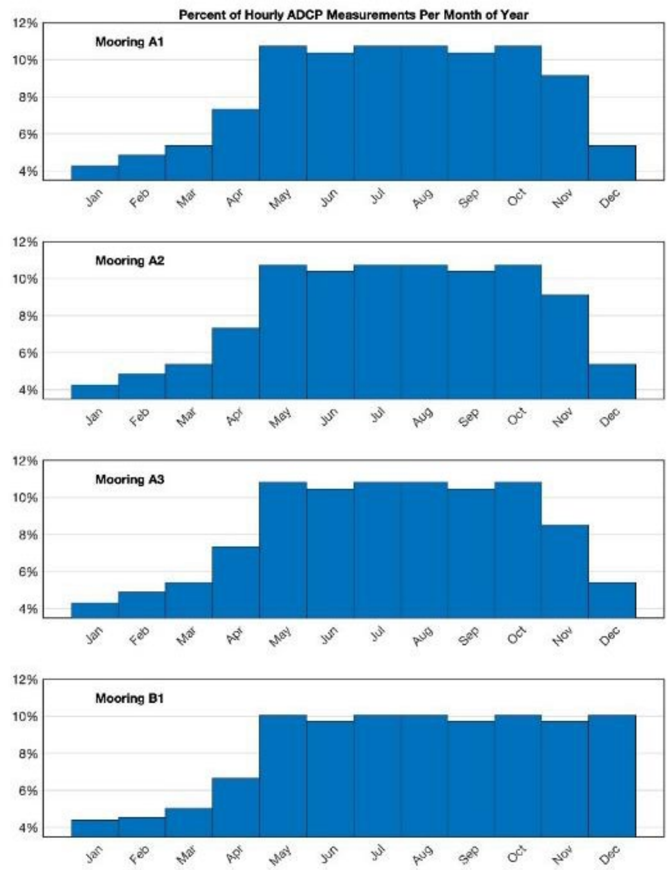


Figure 3-6 – Histograms of the hourly ADCP data from (top to bottom) PEACH moorings A1, A2, A3 and B1, showing percent of hourly current measurements for all depth bins available per month. July had 9.3% of the measurements while February had 7.4% of the measurements.

Evaluation of time-mean currents vs. depth show that the strongest currents were found at Mooring A3, ranging between 4.9 cm/s to 29.4 cm/s with the strongest flow at the surface (Figure 3-7). The predominant flow was to the northeast. The time-mean currents at Moorings A1, A2, and B1 were much weaker than at Mooring A3. The flow throughout the water column was uniform, with the highest percentage of flow to the south (Figure 3-7). The minimum, maximum, and mean of the time-mean flow and the predominant direction of flow for each mooring are listed in Table 3-2.

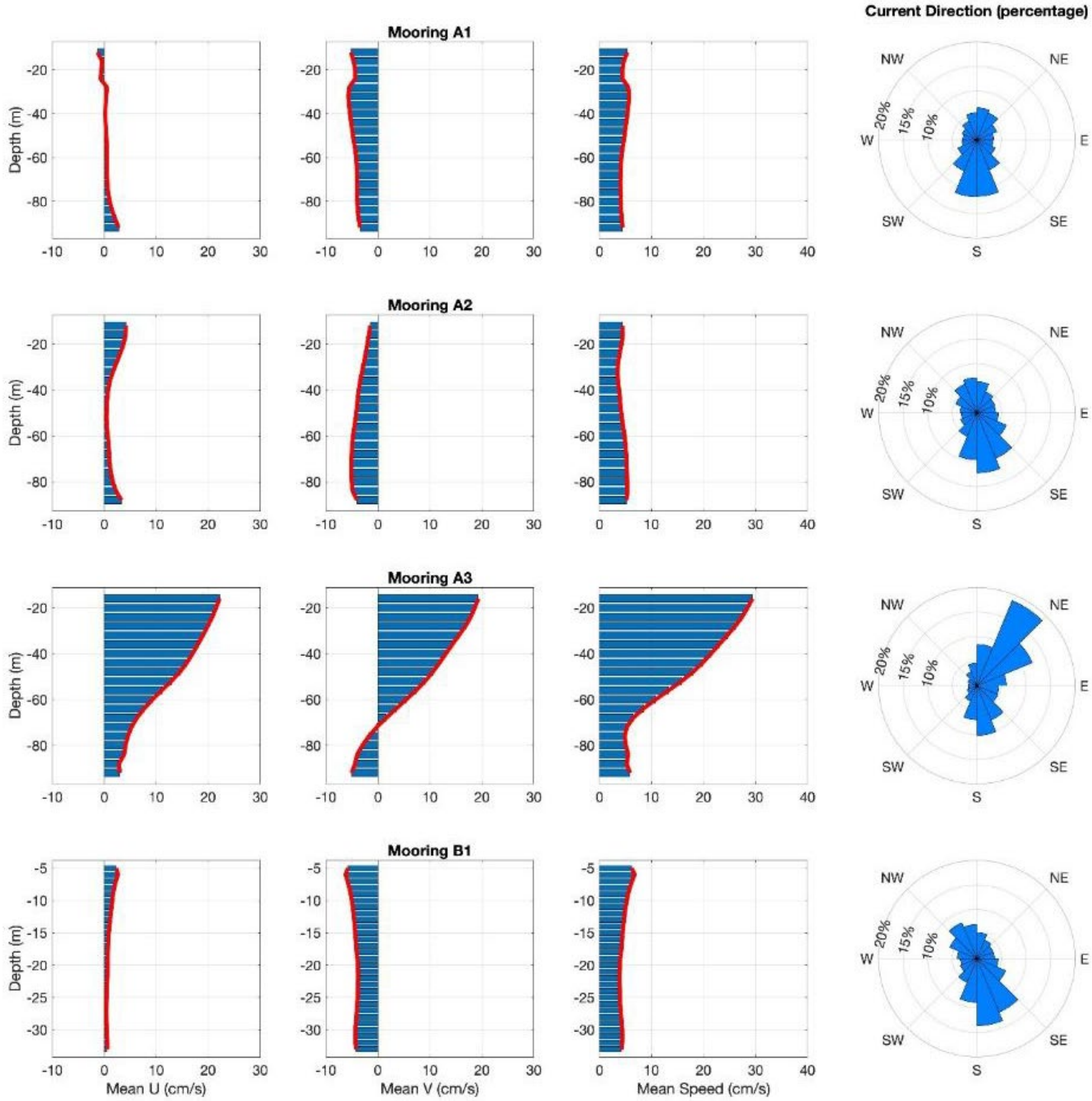


Figure 3-7 – Time-mean u-velocity (column 1), v-velocity (column 2), and speed (column 3). Current direction rose (column 4) for (top to bottom) mooring A1, A2, A3, and B1.

Table 3-2 – Minimum, maximum, and mean of time-mean flows for PEACH moorings and predominant direction.

Mooring	Min Speed (cm/s)	Max Speed (cm/s)	Mean Speed (cm/s)	Predominant direction
A1 shelf break pod	4.0	5.7	4.7	South
A2 shelf break pod	3.5	5.4	4.5	South
A3 shelf break pod	4.9	29.4	15.3	Northeast
B1 Oregon Inlet bottom frame	3.9	6.8	4.6	South

To provide a sense of the possible worst-case currents that might be encountered at a given site, a synthetic maximum current profile was created for moorings A1, A2 and B1 by extracting the maximum at each depth from the full time series (Figure 3-8). This showed surface-intensified currents (within the upper 40 m) of 120 - 135 cm/s and deeper currents (40-90 m depth) at A1 and A2 near 100 cm/s.

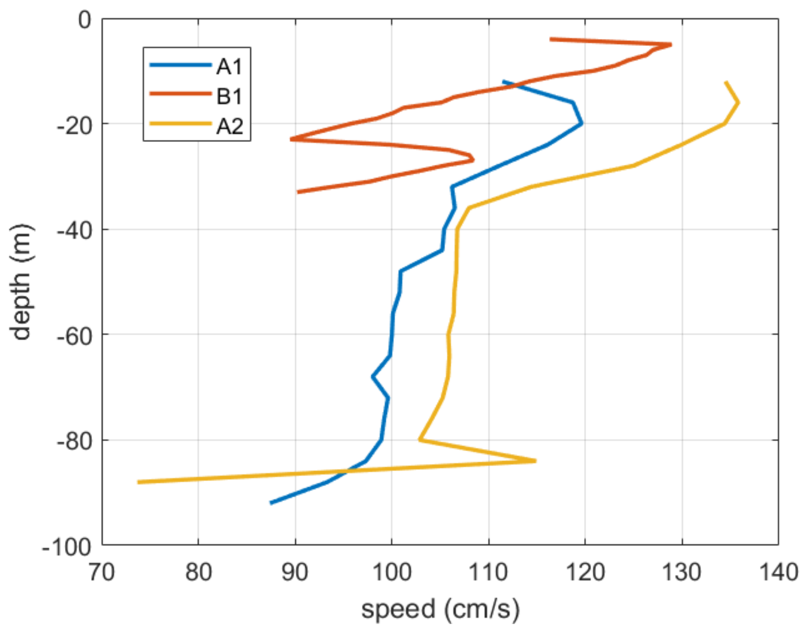


Figure 3-8 – Synthetic vertical current profiles at PEACH moorings A1, A2 and B1 created by selecting the maximum current speed for each depth bin from the full record.

In order to assess vertical current structure and timing for very strong and very weak conditions, two high-current events and two slack-current events were found for each of the four PEACH Moorings (Table 3-3). Features of interest from the high-current events include the following (Figure 3-9 - Figure 3-11):

- Mooring A1, Sep 2017: Surface intensified, southward flow at 100 cm/s, duration 2 days.
- Mooring A2, Mar 2018: Surface to bottom, southward flow at 100 cm/s, duration 3 days.
- Mooring A3, Oct 2017: Surface to bottom, oscillatory, up to 150 cm/s, duration 2.5 days.

Features of interest from the slack current events include (Figure 3-12 and Figure 3-13):

- Mooring A1: Jun 2017: Surface to bottom, <10 cm/s for 2 days, weak tides.
- Mooring A3: Mar 2018 Surface to bottom, <10 cm/s for 2.5 days, weak tides.

Table 3-3 – List high-current and slack-current events for each mooring.

Mooring	Date	Max/Min Speed (cm/s)	Depth of max/min Speed (m)	Comments
High-Current Events				
A1 shelf break	Sep 19, 2017	119.6	20	Hurricane Jose
	Mar 4, 2018	100.9	52	Winter storm Riley
A2 shelf break	Sep 20, 2017	135.8	16	Hurricane Jose
	Mar 4, 2018	111.8	12	Winter storm Riley
A3 shelf break	Dec 21, 2017	149.0	20	
	Sep 7, 2018	170.8	16	Hurricane Florence
B1 Oregon Inlet bottom frame	Aug 30, 2017	128.9	5	
	Oct 12, 2018	119.8	5	
Slack-Current Events				
A1 shelf break	Feb 14, 2018	0.05	40	
	Apr 22, 2018	0.02	56	
A2 shelf break	Aug 12, 2017	0.04	68	
	Jan 19, 2018	0.05	68	
A3 shelf break	Oct 31, 2017	0.09	16	
	Mar 28, 2018	0.09	36	

Figure 3-9 a)

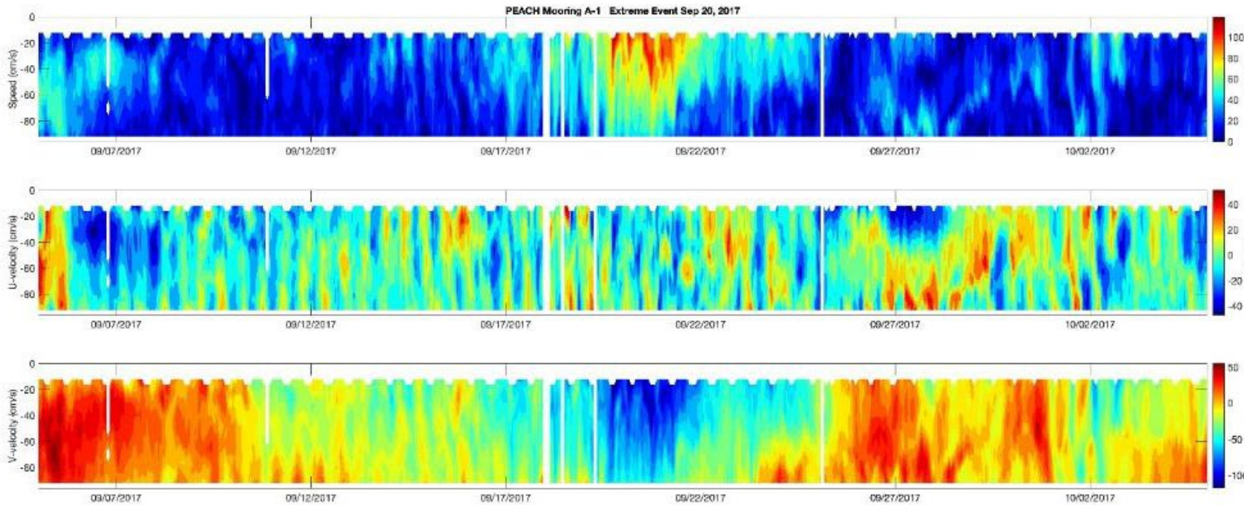


Figure 3-9 b)

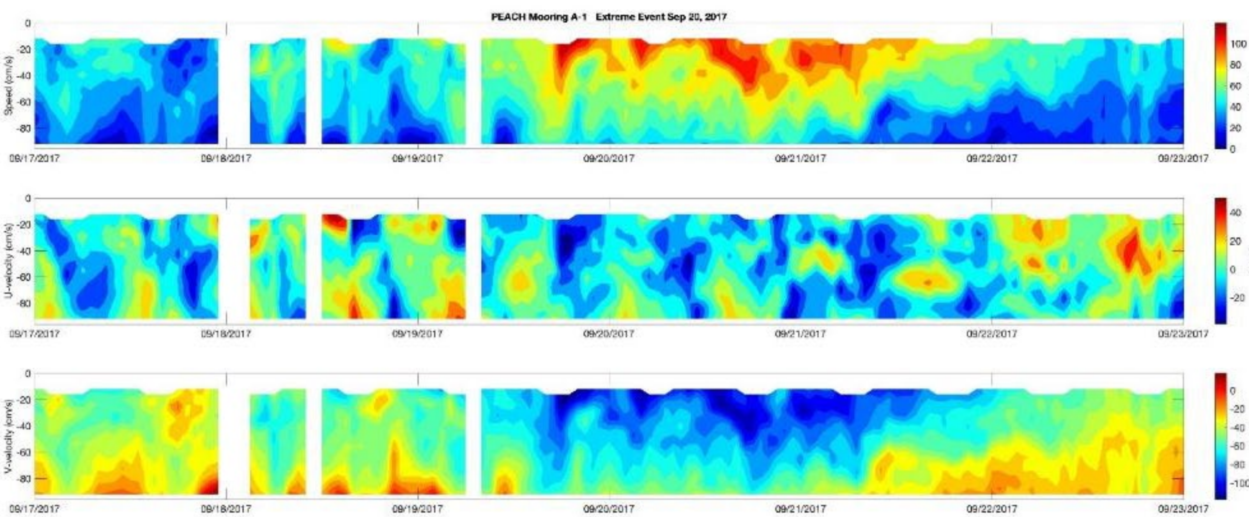


Figure 3-9 – Speed (upper) and east (middle), north (lower) velocities for a) a 30-day period surrounding a high-current event at PEACH mooring A1 during September 2017; and b) a 6-day period surrounding the event.

Figure 3-10 a)

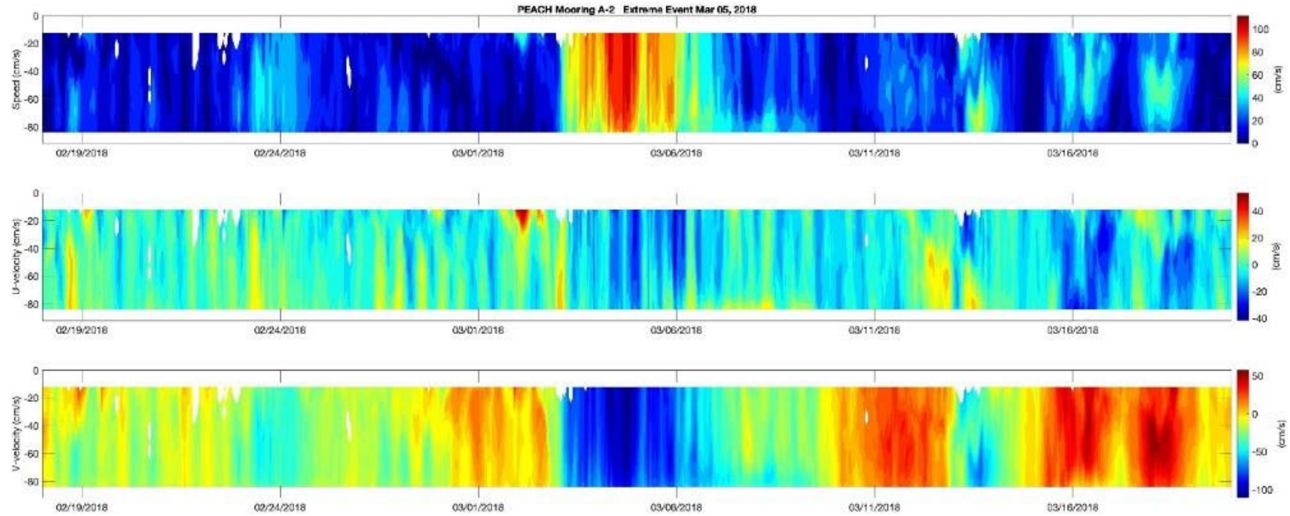


Figure 3-10 b)

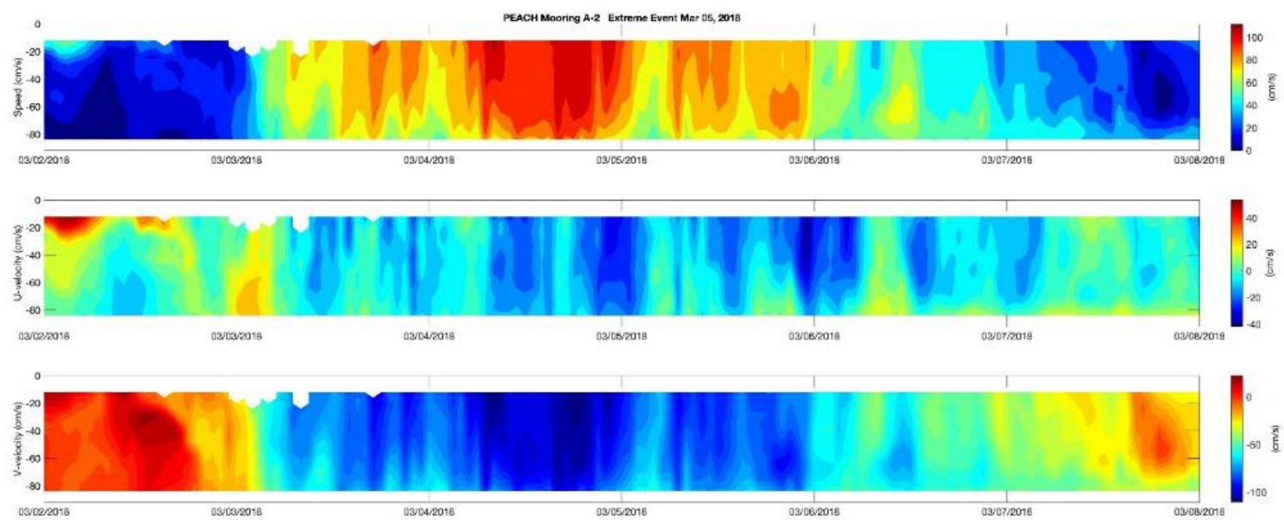


Figure 3-10 – Speed (upper) and east (middle), north (lower) velocities for a) a 30-day period surrounding a high-current event at PEACH mooring A2 during March 2018; and b) a 6-day period surrounding the event.

Figure 3-11 a)

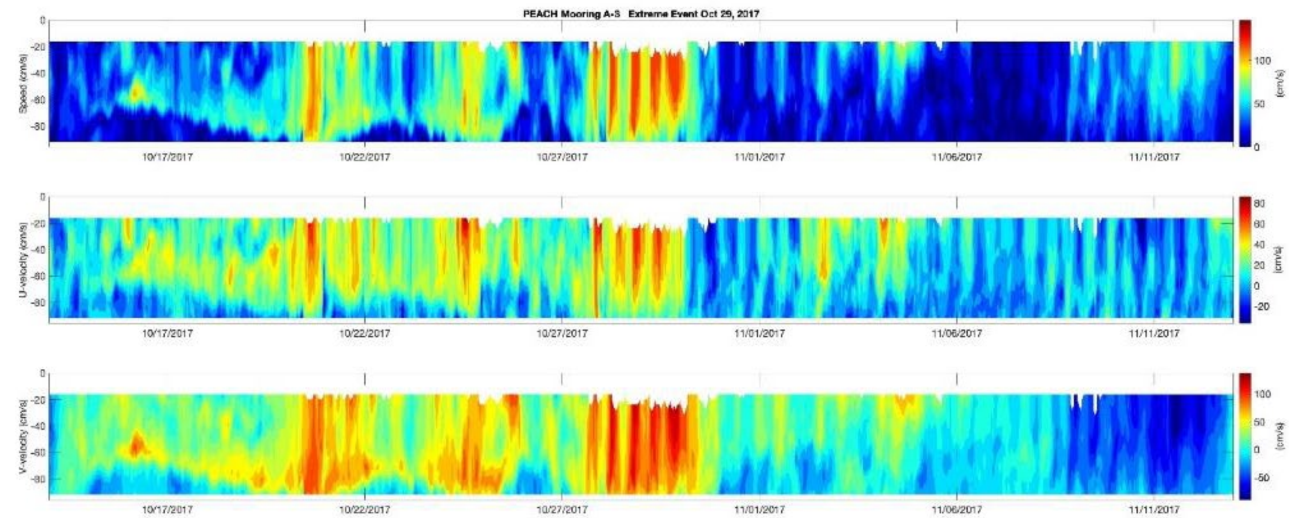


Figure 3-11 b)

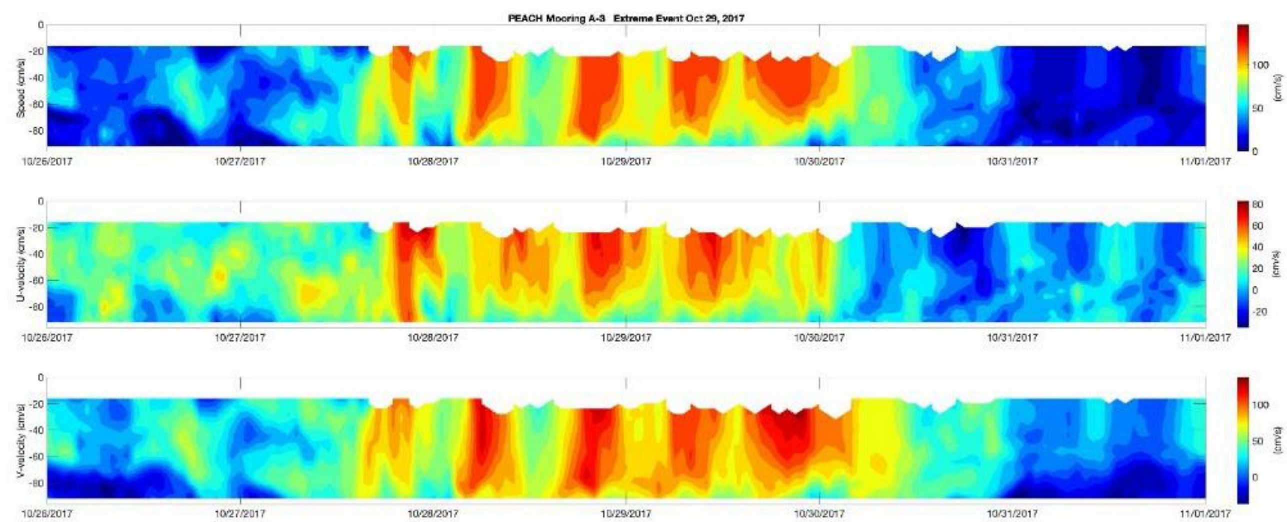


Figure 3-11 – Speed (upper) and east (middle), north (lower) velocities for a) a 30-day period surrounding a high-current event at PEACH mooring A3 during October 2017, and b) a 6-day period surrounding the event.

Figure 3-12 a)

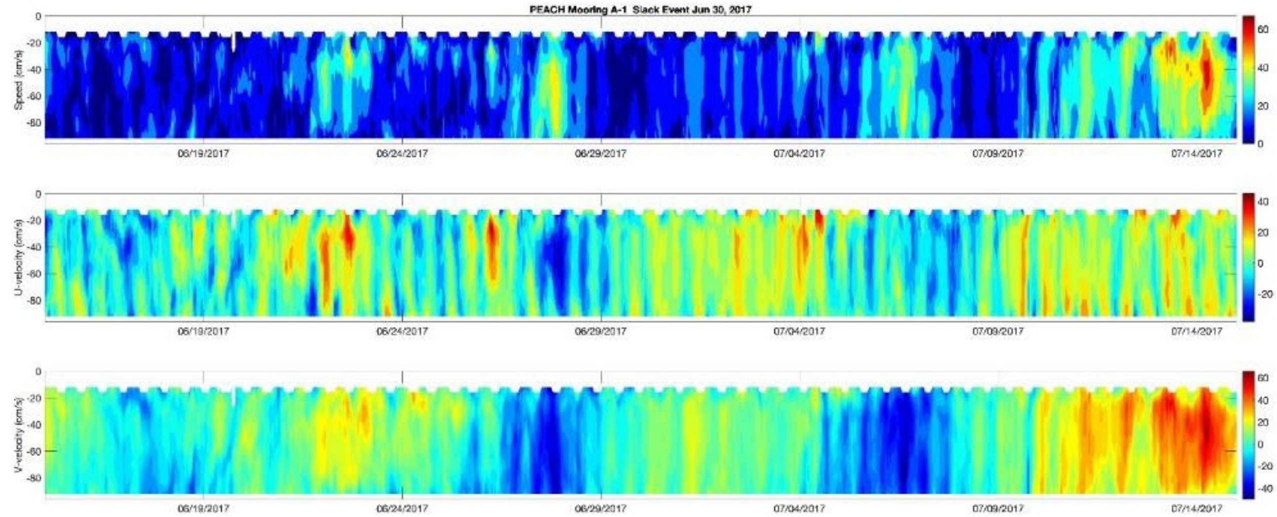


Figure 3-12 b)

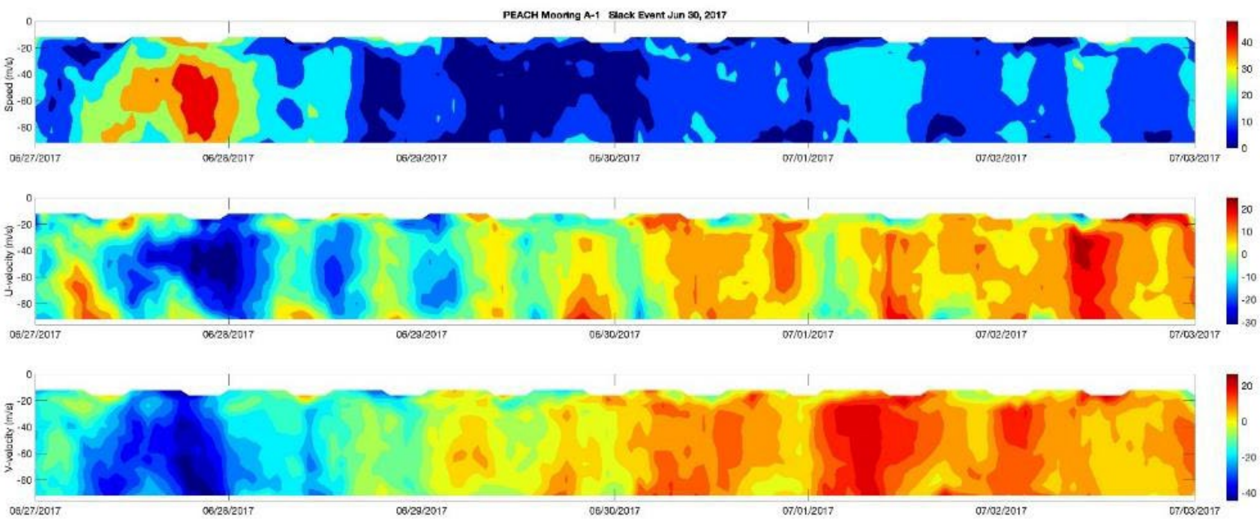


Figure 3-12 – Speed (upper) and east (middle), north (lower) velocities for a) a 30-day period surrounding a slack-current event at PEACH mooring A1 during June 2017; and b) a 6-day period surrounding the event.

Figure 3-13 a)

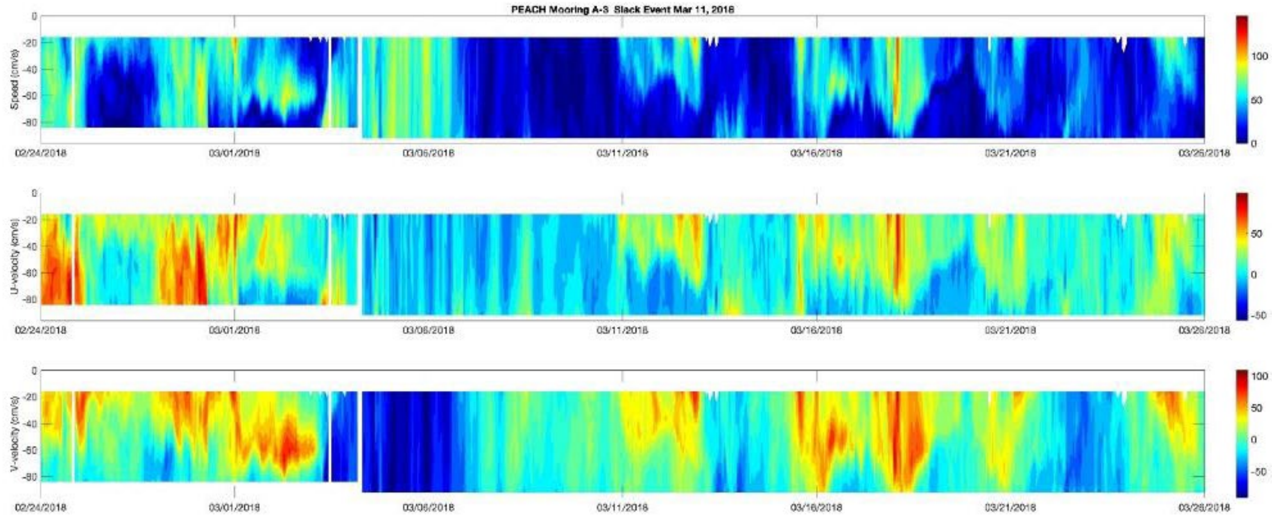


Figure 3-13 b)

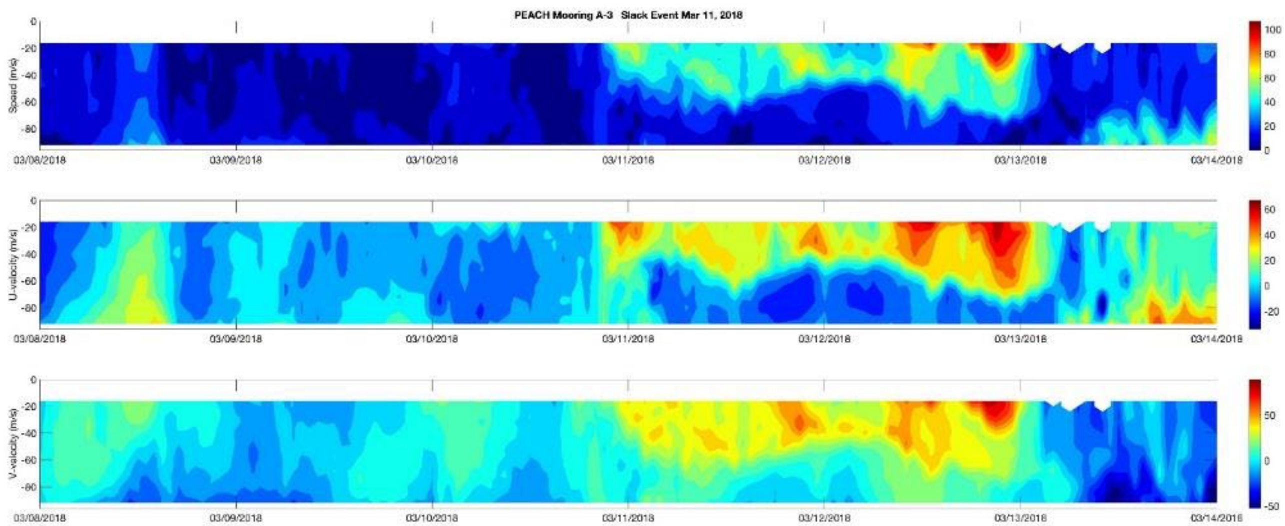


Figure 3-13 – Speed (upper) and east (middle), north (lower) velocities for a) a 30-day period surrounding a slack-current event at PEACH mooring A3 during March 2018; and b) a 6-day period surrounding the event.

3.4. Tides

The pressure record from PEACH moorings A1, A2, A3, and B1, shows the maximum tidal range to be approximately 1.5 meters. Lentz et al. (2001) analyzed the barotropic tide on the North Carolina Shelf using 18 near-bottom pressure sensors and eight current meter moorings between Chesapeake Bay and Cape Hatteras. They found the largest tidal constituents to be M_2, N_2, and S_2 semidiurnal tides and K_1/P_1 and O1 diurnal tides (Table 3-4).

Table 3-4 –Tidal constituents from Lentz et al. (2001)

Constituent	Sea level amplitude	Type	Tidal currents
M_2	47 cm	Semidiurnal	10 cm/s
N_2	11 cm	Semidiurnal	> 3 cm/s
S_2	10 cm	Semidiurnal	> 3 cm/s
K_1/P_1	7 cm	Diurnal	> 3 cm/s
O_1	5 cm	Diurnal	> 3 cm/s

3.5. Seasonal stratification - PEACH

In addition to ADCPs, the PEACH moorings also included CTDs: one at the bottom of Moorings A1, A2, and A3 (100 m, 96 m, 97 m respectively) and three on Mooring B1 (4 m, 16 m, and 36 m). The processed CTD data were hourly averaged. Sea surface temperatures from the Copernicus Climate Change Service (C3S) were downloaded and values nearest to each mooring were extrapolated. A 24-hourly running mean of the CTD temperature data were plotted with the extrapolated sea surface temperature values for each mooring (Figure 3-14 and Figure 3-15).

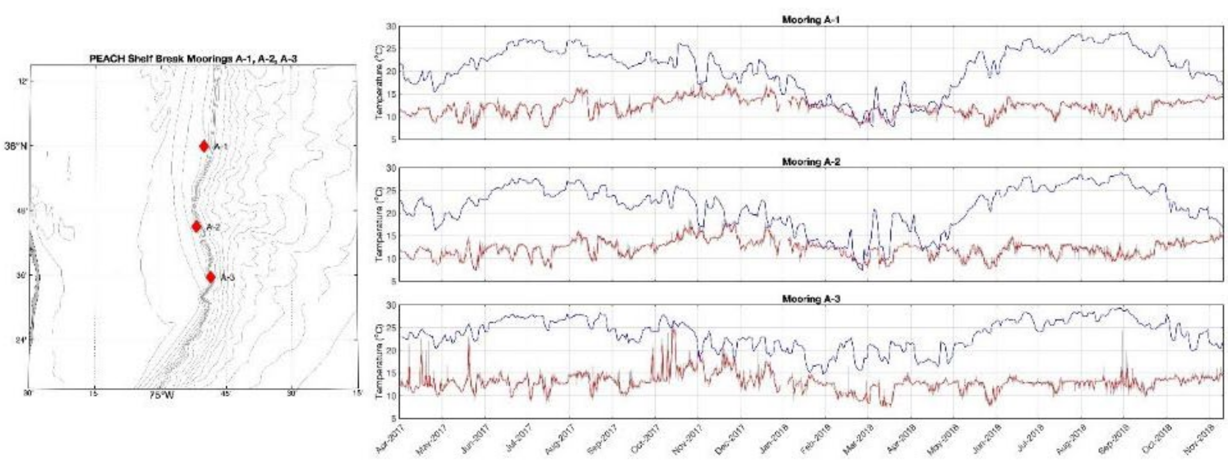


Figure 3-14 – Location map (left) and temperature (right) for moorings A1, A2, and A3. Hourly sea surface temperature from Copernicus Climate Change Service (blue), and hourly (gray) and 24-hour running mean (red) near bottom temperature from mooring A1 (top), Mooring A2 (middle), and Mooring A3 (bottom).

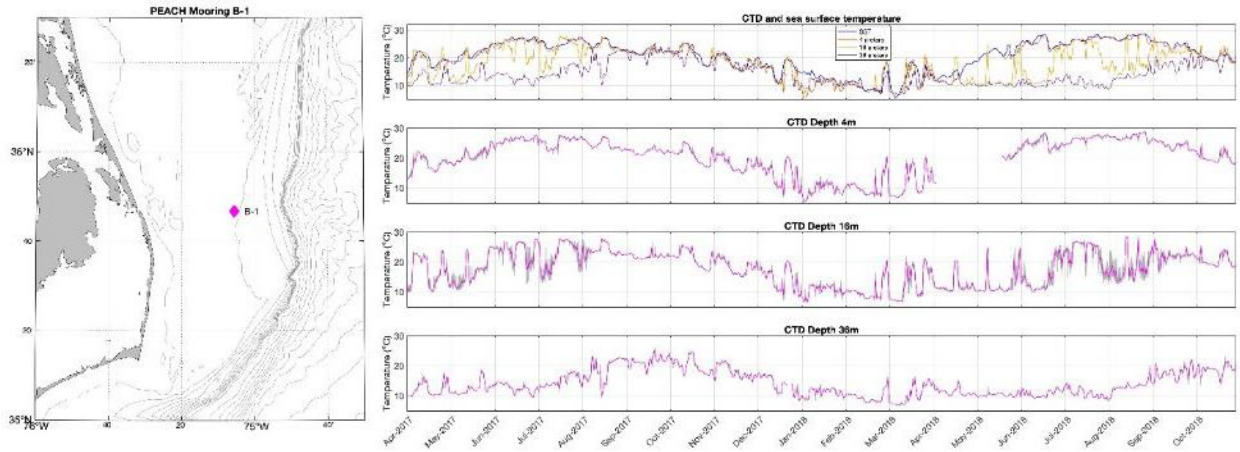


Figure 3-15 – Location map (left) and temperature (right) for mooring B1. Hourly sea surface temperature from Copernicus Climate Change Service (blue), and 24-hour running mean at 4 m (orange), 16 m (yellow) and 36 m (purple; upper panel). Hourly (gray) and 24-hour running mean temperature at 4, 16 and 36 m (second through fourth panels).

Mean, minimum, and maximum of the sea surface temperature and hourly CTD temperature are listed in Table 3-5. The sea surface temperatures at Moorings A1 and A2 display a strong seasonal cycle while the bottom CTD temperature remains consistent. The difference in the surface and bottom summer temperatures is approximately 10°C, while the difference in surface and bottom winter temperatures is within approximately 1°C. The sea surface temperatures at Mooring A3 are warmer than those at the other mooring sites throughout the year with winter temperatures staying above ~15°C. The CTD temperatures at mooring A3 are also noisier with episodes of warm water reaching ~29°C.

At Mooring B1, sea surface temperatures and the 4-meter CTD temperature have discernable seasonal cycles. The 36-meter CTD has a smaller annual range with warmer temperatures occurring in October 2017 and 2018. The temperature signal in the mid-water column is extremely noisy during the summer, which is likely due to instrumentation error. Haines et al. (2022) note that the primary cause of offsets in PEACH CTD salinity values was bubbles or debris being sucked into the conductivity sensors. in winter, sea surface and all CTD temperatures at Mooring B1 are within approximately 1.5°C of each other.

Table 3-5 – Mean, minimum, and maximum values for sea surface temperatures and hourly CTD temperatures at Moorings A1, A2, A3, and B1.

Mooring		Range (°C)	Min (°C)	Max (°C)	Mean (°C)
A1	SST	20.8	7.8	28.6	20.2
	CTD	9.6	7.6	17.2	12.1
A2	SST	21.7	7.4	29.1	20.9
	CTD	10.3	7.4	17.9	12.2
A3	SST	14.6	14.8	29.3	23.3
	CTD	16.7	7.9	24.6	13.0
B1	SST	23.4	5.4	28.8	20.0
	4 m CTD	23.7	5.3	29.0	20.3
	16 m CTD	22.2	6.3	28.5	17.8
	36 m CTD	19.7	6.6	26.3	14.1

The CTD salinity data from Moorings A1, A2, and A3 all exhibit similar signals, with Mooring A2 slightly fresher than Mooring A1 and Mooring A3 fresher than both Moorings A1 and A2 during 2017 only (Figure 3-16). At Mooring B1 (Figure 3-17), the 4-meter CTD and 16-meter CTD data are extremely noisy, especially in the spring and summer months. Salinity at the 36-meter CTD is less erratic, ranging between (~32-36 psu). A 7-day running mean was used to smooth the data (Figure 3-17). From the 7-day running mean, a 30-day cycle was apparent with stronger differences in summer than in winter. Mean, minimum, and maximum values of hourly CTD salinity for all moorings are listed in Table 3-6.

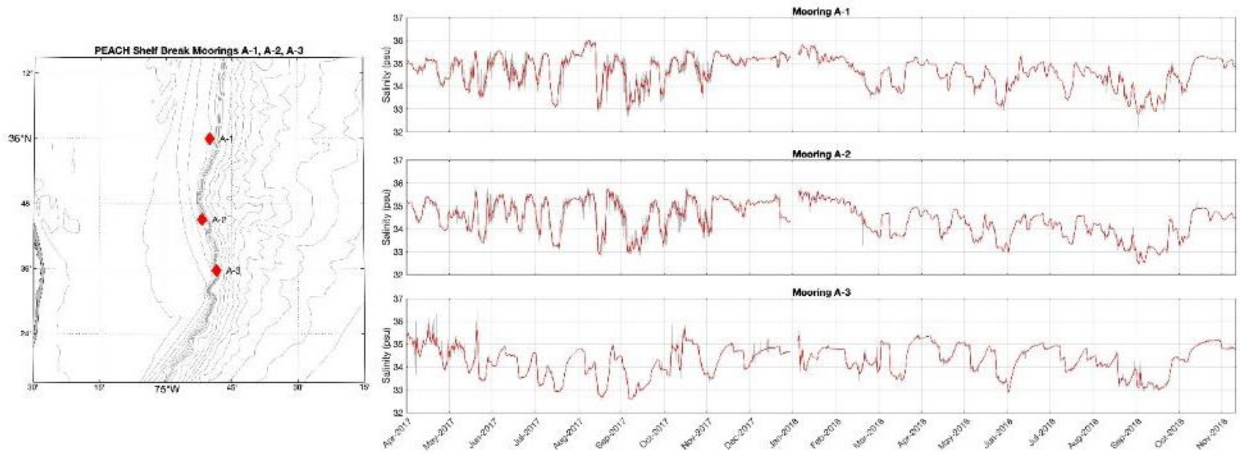


Figure 3-16 – Location map (left) and salinity (right) for moorings A1, A2, and A3. Hourly (gray) and 24-hour running mean (red) near bottom salinity from mooring A1 (upper), Mooring A2 (middle), and Mooring A3 (lower).

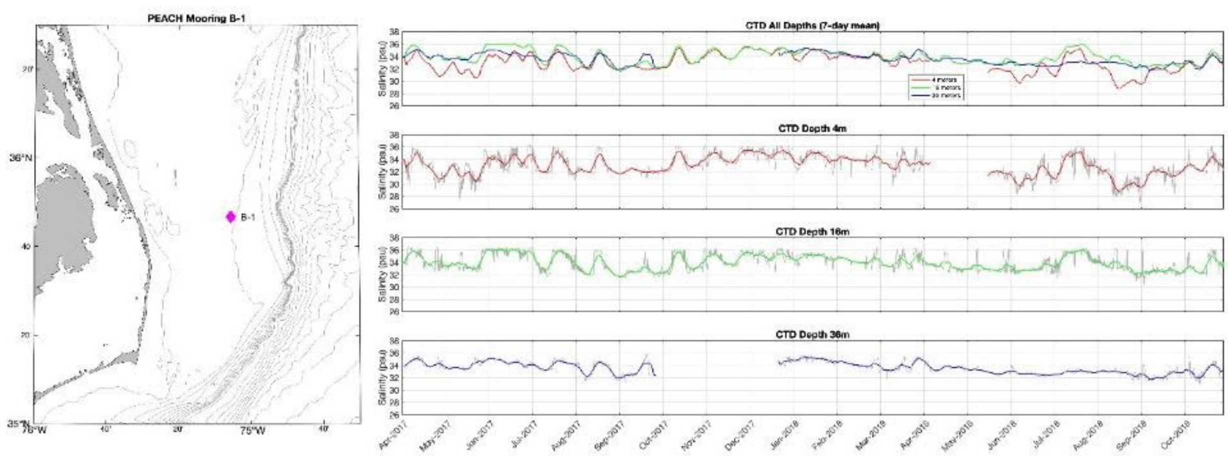


Figure 3-17 – Location map (left) and salinity (right) for mooring B1. Seven-day running mean salinity at 4 m (orange), 16 m (yellow) and 36 m (purple; upper panel). Hourly (gray) and 7-day running mean salinity at 4, 16 and 36 m (second through fourth panels).

Table 3-6 – Mean, minimum, and maximum values for hourly CTD salinity at Moorings A1, A2, A3, and B1.

Mooring	Range (psu)	Min (psu)	Max (psu)	Mean (psu)
A1	3.9	32.1	36.0	34.6
A2	3.4	32.4	35.8	34.4
A3	3.8	32.6	36.4	34.3
B1 4 m	9.4	26.9	36.3	33.0
B1 16 m	6.1	30.5	36.5	34.0
B1 36 m	5.1	30.8	36.0	33.6

3.6. Seasonal Stratification - World Ocean Database

To further explore the seasonal differences in temperature and salinity, CTD data were extracted from the World Ocean Database (https://www.ncei.noaa.gov/products/world-ocean-database) using instrument, variable, and location selection criteria. Only stations for which both temperature and salinity data were available were downloaded. Using ODV (Schlitzer, Reiner, Ocean Data View, odv.awi.de, 2021) these observations were subsequently divided into three regions defined as **Shelf**: 75.33°W to 75.00°W (75° 20' to 75° 00'), **Slope**: 75.00°W to 74.70°W (75° 00' to 74° 42'), and **Offshore**: 74.70°W to 74.00°W (74° 42' to 74° 00'), all with latitudinal limits describing the glider box 35.5°N to 37.25°N. The observations in each of these geographical regions were also divided into seasons defined as winter (December-February), spring (March-May), summer (June-August) and fall (September-November). The next subsections describe the resulting geographical and temporal distributions of the temperature and salinity observations and provide some basic statistics on the WOD data available.

Shelf Region (Figure 3-18 through Figure 3-22, Table 3-7)

In the shelf region, the mean depths are ~15.5±9 m regardless of season, while the mean temperature ranges from 9.1±2.8°C in winter to 20.7±3.8°C in fall. The spring mean temperature is similar to winter, while the summer mean is similar to fall. The extrema in the Tables include outliers. Therefore, without further statistical analysis, the expected ranges are best illustrated by the ranges of the Figure 3.6.1-3 axes. According to Figure 3-18 the minimum/maximum shelf region temperatures are ~4°C/30°C. This same figure suggests that temperatures are coldest in the January through March time frame (upper left panels). Warming begins in mid-April (note there are no data in early April) and continues through the fall with the highest temperatures and lightest densities occurring in July and mid-September. Note there are no December observations.

Winter Shelf (Figure 3-19): Winter sampling is sparse (3658 data points). There are no December observations and no observations in early January or late February (upper left panels). That said, there is no obvious pattern to the depth range sampled during the winters where there are observations (upper right panel). With slightly cooler temperatures in the later part of the record, densities are also greater in the late winter (upper left panels). There is a tendency for waters to be warmer and more saline on the offshore side, particularly south of 36.5°N (i.e., in the Mooring Box). There is an inshore fresh region to the south of 35.75°N just of barrier islands.

Spring Shelf (Figure 3-20): There are nearly twice as many spring observations compared to Winter or Summer (6783 data points). That said they are concentrated in March and late May with very few profiles between and the April/early May profiles tend to be shallower than the others (upper left panels). The coolest waters are the deepest and occur earlier in the years (upper right and center panels, respectively). The coldest and densest waters are seen before April and by May the waters appear to be more stratified with warmer lighter waters lying above the cooler denser waters (upper left panels). With slightly cooler temperatures in the later part of the record, densities are also greater in the late winter (upper left panels). As in winter, there is a tendency for waters to be warmer and more saline on the offshore side, again particularly south of 36.5°N (i.e., in the Mooring Box), but also further. Also as in winter, there is an inshore fresh region, but in spring it reaches to the north of 36°N.

Summer Shelf (Figure 3-21): There are more shallow observations in summer months than in any other season (2375 data points). June is well covered as is later July through August, but there is a gap in July (upper left panels). The coolest waters are the deepest and occur earlier in the years (upper right and center panels, respectively). As in the spring, the coolest but not the densest waters are seen earlier in the season and stratification strengthens throughout the summer (upper left panels). The densest waters occur deep in this shallow water column in early August, and it appears that salinification is contributing to the summer densification (upper center panel). There is a north-south gradient in surface salinities, with the largest values occurring to the south of 36°N (lower center panel) and there is an apparent surface cool patch just to the north of 36.5°N. This could be the result of the scatter sampling and relatively low number of observations.

Fall Shelf (Figure 3-22): There are 5660 shelf observations in the fall months and the only obvious gap occurs around the second week of October (upper left panels). The warmest waters in the entire shelf record are seen in September and it appears that stratification begins to weaken by late September/early October. Along with the weakening stratification, the spread in salinities and temperatures is reduced later in the season. Returning to the pattern seen earlier in the year, surface waters are freshest and warmest south of 36°N.

Table 3-7 – Shelf CTD statistics.
Overall (upper panel) and seasonal (successive panels) statistics for the MAB Shelf defined between 35.5-37.25°N and 73.3-75.0°W, Based on all available World Ocean Database. Statistics, including the mean, standard deviation, standard error, number of observations, and the minimum and maximum values for Conservative Temperature (°C), Absolute Salinity (g kg^{-1}), and depth (m). Mean, Stand. Dev., Stand. Err. and Count do not include outliers, but the extrema do include outliers (see caption of Figure 3-18 for definition). The table was created using ODV (right-click on T/S plot – summary statistics.

Shelf

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	14.204	6.456	0.0474	18544	3.830	29.333
Absolute Salinity SA [g/kg] :	33.3850	1.1898	0.00874	18544	22.6738	36.7863
Depth [m] :	15.5	9.0	0.07	18544	1.0	44.7

Shelf Winter: December – February (cf. Figure 3-19).

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	9.144	2.789	0.0461	3658	3.830	19.700
Absolute Salinity SA [g/kg] :	33.8050	1.1013	0.01821	3658	24.0424	36.5371
Depth [m] :	15.2	9.0	0.15	3658	1.0	43.7

Shelf Spring: March – May (cf. Figure 3-20).

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	10.092	3.741	0.0454	6783	4.547	22.496
Absolute Salinity SA [g/kg] :	33.5643	1.1450	0.01390	6783	22.6738	36.4728
Depth [m] :	15.5	9.0	0.11	6783	1.0	44.7

Shelf Summer: June – August (cf. Figure 3-21).

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	18.154	5.712	0.1172	2375	8.375	28.354
Absolute Salinity SA [g/kg] :	33.3954	1.3808	0.02833	2375	27.3158	36.7863
Depth [m] :	15.7	9.1	0.19	2375	1.0	42.7

Shelf Fall: September – November (cf. Figure 3-22).

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	20.720	3.842	0.0511	5660	9.639	29.333
Absolute Salinity SA [g/kg] :	32.9073	1.0388	0.01381	5660	28.6611	36.5854
Depth [m] :	15.6	9.0	0.12	5660	1.0	42.7

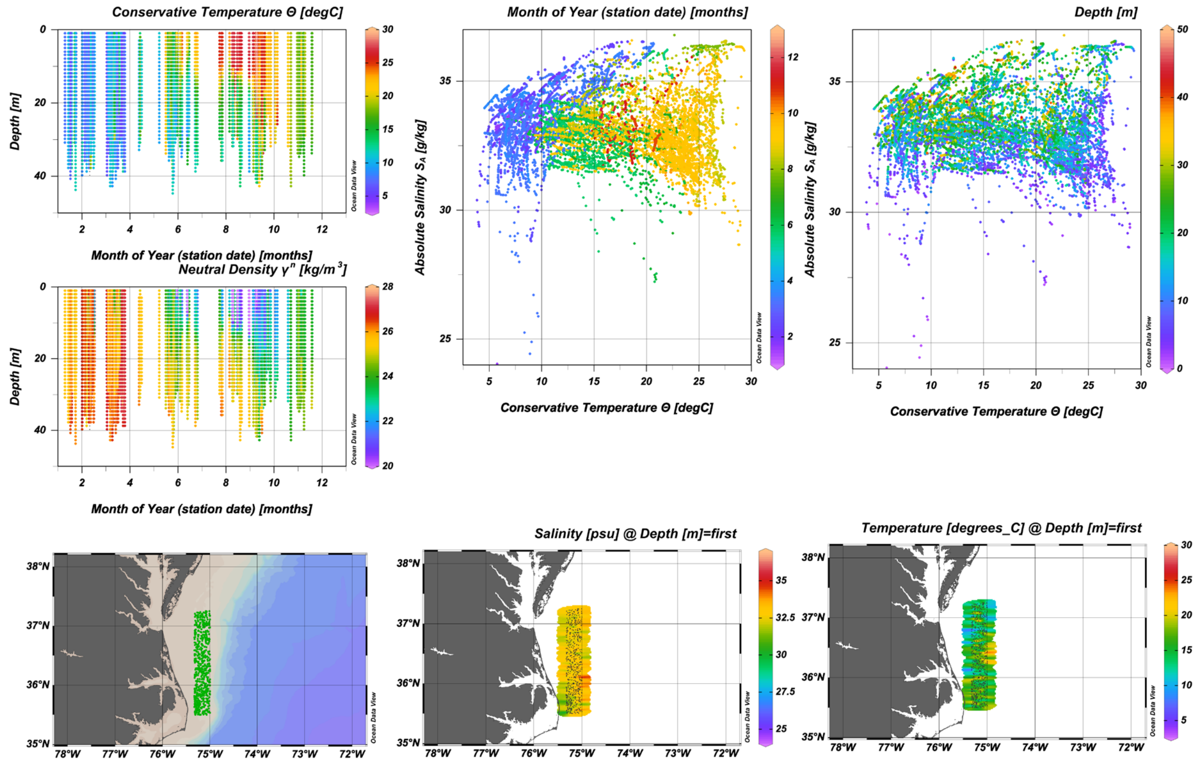


Figure 3-18 –Shelf CTD data for the MAB Shelf defined between 35.5-37.25°N (~latitudinal range of the glider box) and 75.33—75.0°W based on all available World Ocean Database: upper left profiles of month of the year vs. depth (m) with color shading indicating Conservative Temperature (CT,°C), and just below, the same with color shading representing Neutral Density (γ^n, kg m^{-3}); upper center T/S diagram (CT/SA) color-coded by month of the year; upper right the same color-coded by depth; lower left maps of station locations; lower center a weighted-average gridded field of SA; lower right the same for CT. Note, there is some extrapolation at the edges. The figure was created using an ODV (Schlitzer, Reiner, Ocean Data View, odv.awi.de, 2021) six-window layout. Outliers, defined as data values deviating from the mean of the field of values by more than 1.5 times the standard deviation (Schlitzer et al., 2021), have been removed.

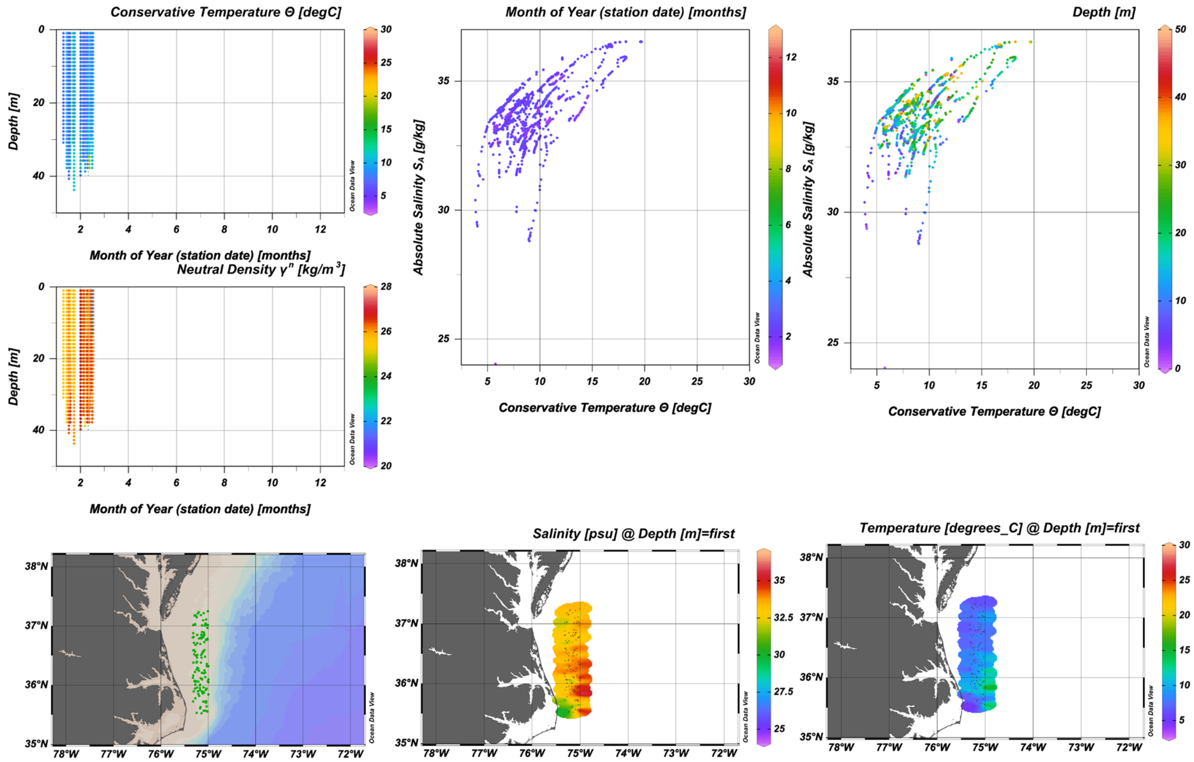


Figure 3-19 – Same as Figure 3-18, but just the winter months (December-February).

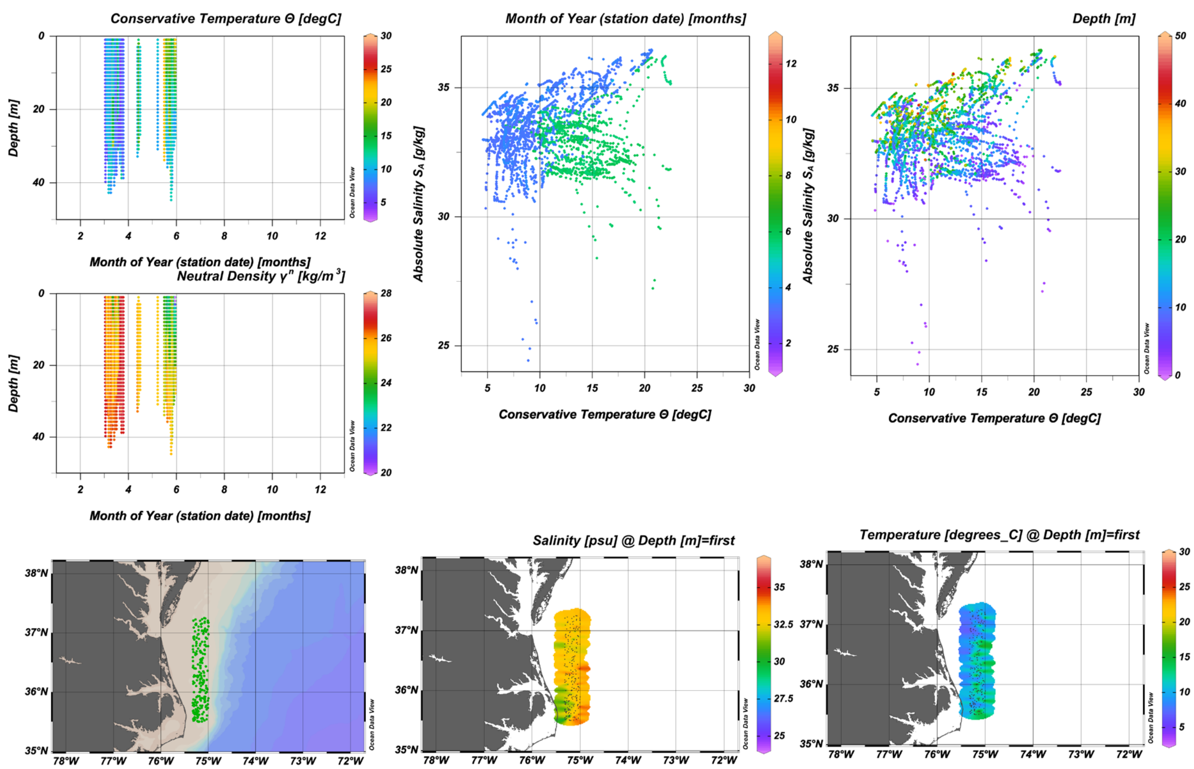


Figure 3-20 – Same as Figure 3-18, but just the spring months (March-May).

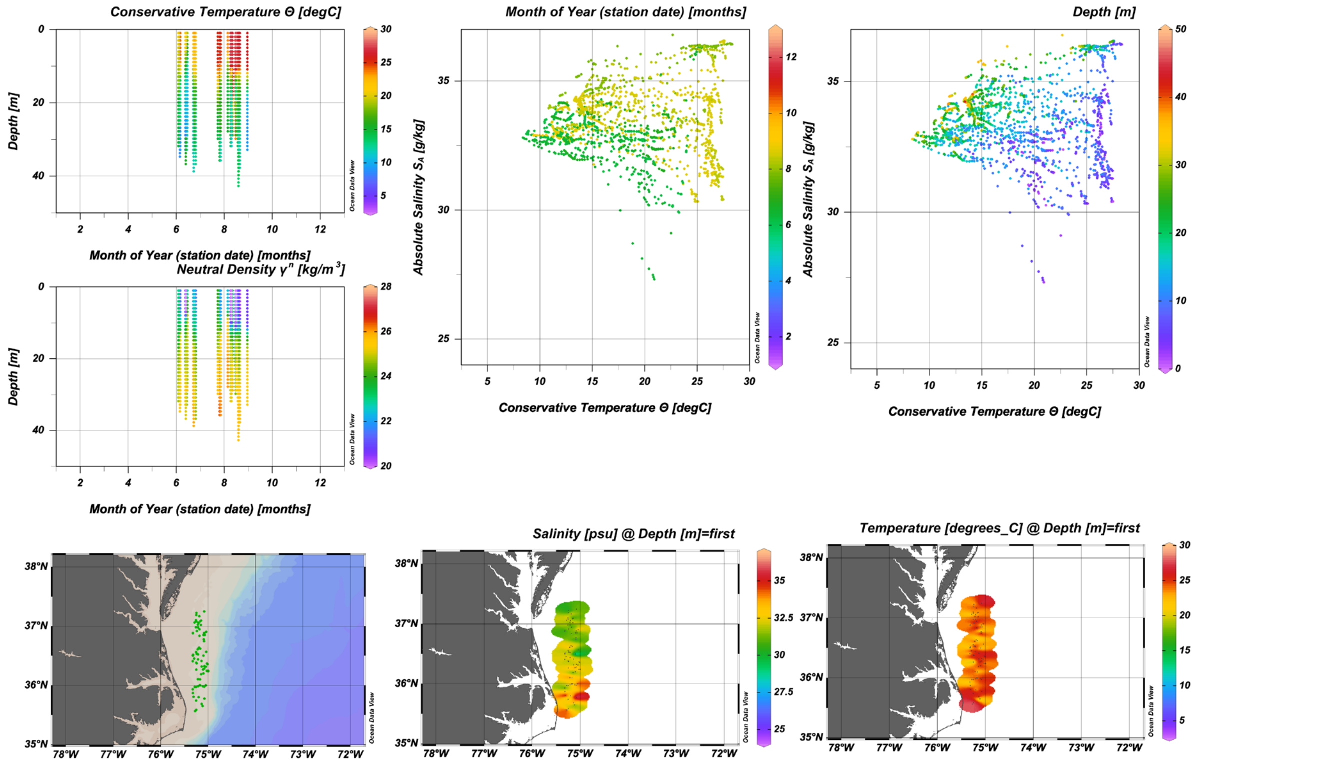


Figure 3-21 – Same as Figure 3-18, but just the summer months (June-August).

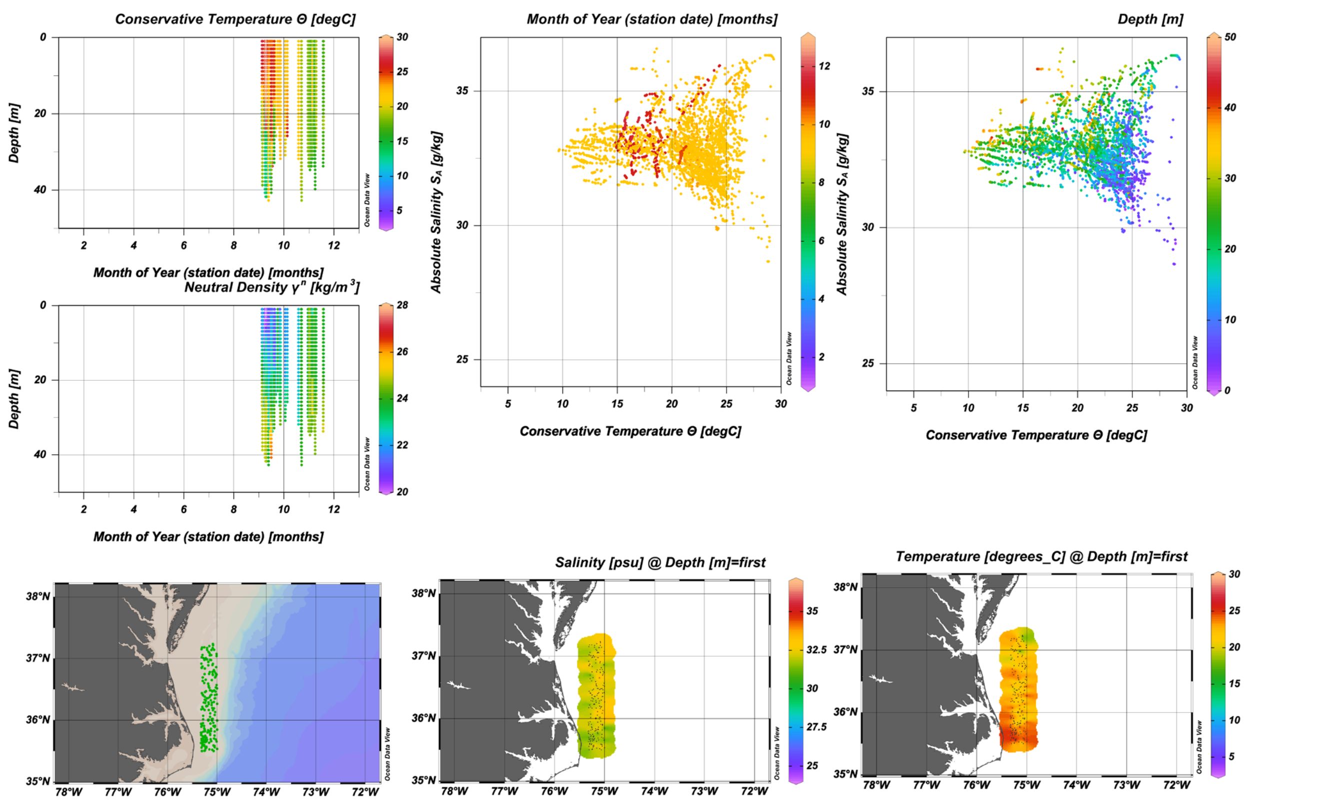


Figure 3-22 – Same as Figure 3-18, but just the fall months (September-November).

Slope Region (Figure 3-23 through Figure 3-27, Table 3-8)

In the slope region Figure 3-23, the mean depths of the observed data are similar, ranging from 91 - 103 m in the different seasons and having large variability are not significantly different from the overall mean of the data record (96±111 m). Mean temperature ranges from 11.5±2.9°C in spring to 15.1±5.3°C in fall. As on the shelf, the spring mean temperature is similar to winter, but here the average summer temperature is equally distant from the spring and fall values. The magnitude of the variability (σ_{CT} = 5.8°C) is more similar to that seen in the fall. While the extrema in Table 3-8 (3.8°C < T < 29.8°C, 28.06 g kg^{-1}< SA <41.19 g kg^{-1}) includes outliers, the figure axes suggest that it is only the maximum salinity which is likely an outlier. The largest salinities are ~38 g kg^{-1}. Full water column 0-50 m, coldest temperatures and densest waters are seen January through May, while below about 30 m, the lowest temperatures are seen from January through August (upper left panels). As on the shelf the warmest and lightest waters appear in the fall. Cool saline waters are seen early in early in the year (center top, blue shading), and the freshest waters are most prevalent in the May-June. Note, as on the shelf, there are no December observations.

Winter Slope (Figure 3-24): On the slope, Winter sampling is less sparse than on the shelf (~20,000 data points) - half what is measured in the spring and fall, but more than measurements than in the summer. There are no December observations and no observations in early January or late February (upper left panels). There is no obvious pattern to the depth range sampled during the winters where there are observations (upper right panel). As on the shelf, densities are greatest late in the winter, but not necessarily when the waters are coldest, suggesting the effect of greater salinities. There is a patch of higher winter salinities between 36-36.5°N - it is possible there is fresh water input to the south and north. This slope pattern is consistent with the fresh winter shelf region to the south of 35.75°N (Figure 3-19), but different from the tendency for waters to be warmer and more saline on the offshore side of the shelf.

Spring Slope (Figure 3-25): There are nearly two/three times as many spring observations (~38,000) compared to winter/summer. As on the shelf, these data are concentrated in March and mid-later May with fewer profiles between and the April/early May profiles. Like the shelf, spring observations on the slope tend to be in shallower waters in March and deeper in May (upper right and center panels). In May, the coolest waters are the deepest, but in March the water column is less stratified. (upper left panels). With slightly cooler temperatures in the early part of the record, densities are also greater in the early spring (upper left panels). Temperatures are generally lower to north of ~36.75°N, but salinities are quite patchy (lower right panels). There are fresher waters offshore of the various freshwater sources, but there are also some extremely low values (purple) which one should probably question without further investigation and it appears the contouring has perhaps smeared a few questionable data points.

Summer Slope (Figure 3-26): In spite of the lower number of observations (~13,000), there is good spatial and temporal spread in the slope summer data. The only gap is later June to early July (upper left panels). Summer slope waters are stratified. The coolest waters are the deepest and unlike on the shelf (where they occur earlier in the year), on the slope cool temperatures are seen throughout the summer period (upper right and center panels, respectively). The coolest, most saline, and densest waters are seen at depth, particularly below ~20-25 m (upper left panels, upper right panel). As on the shelf, there is a north-south gradient in surface salinities, with the largest values occurring to the south of 36°N (lower center panel) and an apparent surface cool patch just to the north of 36.5°N. While this could be real, we again note that this could be the result of the scatter sampling and relatively low number of observations, or a single cruise with uncalibrated salinities that ran from spring into summer. Further investigation would be required to better understand this pattern.

Fall Slope (Figure 3-27): There are ~36,000 slope observations in the fall months with more scattered sampling later in the season than earlier, but no obvious temporal gaps (upper left panels). Loss of stratification is seen throughout September. The deepest records are the most saline and coldest (upper right panels). Along with the weakening stratification, as on the shelf the spread in salinities and temperatures is reduced later in the season. As on the shelf, where there is a fall pattern of surface waters being warmest south of 36°N, but unlike the shelf pattern, here the most saline waters are also found in the south.

Table 3-8 – Slope CTD statistics. Overall (upper panel) and seasonal (successive panels) statistics for the MAB Slope defined between 35.5-37.25°N and 75.0—74.7°W. Data description same as for Table 3-7.

Slope

		Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (	:	13.046	4.536	0.0138	107601	3.841	29.802
Absolute Salinity SA [g/kg]	:	34.8125	1.1052	0.00337	107601	28.0643	41.1907
Depth [m]	:	96.4	111.2	0.34	107601	0.3	1427.9

Slope Winter: December – February (cf. Figure 3-24).

		Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (	:	11.975	2.793	0.0198	19818	5.198	21.248
Absolute Salinity SA [g/kg]	:	35.1487	0.8945	0.00635	19818	32.0721	36.7391
Depth [m]	:	91.1	89.8	0.64	19818	1.0	495.7

Slope Spring: March – May (cf. Figure 3-25).

		Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (	:	11.469	2.847	0.0146	38186	3.841	23.488
Absolute Salinity SA [g/kg]	:	34.9829	0.8161	0.00418	38186	29.5090	41.1907
Depth [m]	:	95.3	110.0	0.56	38186	1.0	1427.9

Slope Summer: June – August (cf. Figure 3-26).

		Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (	:	13.530	5.842	0.0511	13071	4.380	29.328
Absolute Salinity SA [g/kg]	:	34.1942	1.4597	0.01277	13071	28.0643	36.6195
Depth [m]	:	102.8	147.9	1.29	13071	1.0	874.7

Slope Fall: September – November (cf. Figure 3-27).

		Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (	:	15.101	5.308	0.0278	36526	3.924	29.802
Absolute Salinity SA [g/kg]	:	34.6733	1.2073	0.00632	36526	29.9330	36.7140
Depth [m]	:	98.1	107.3	0.56	36526	0.3	1208.2

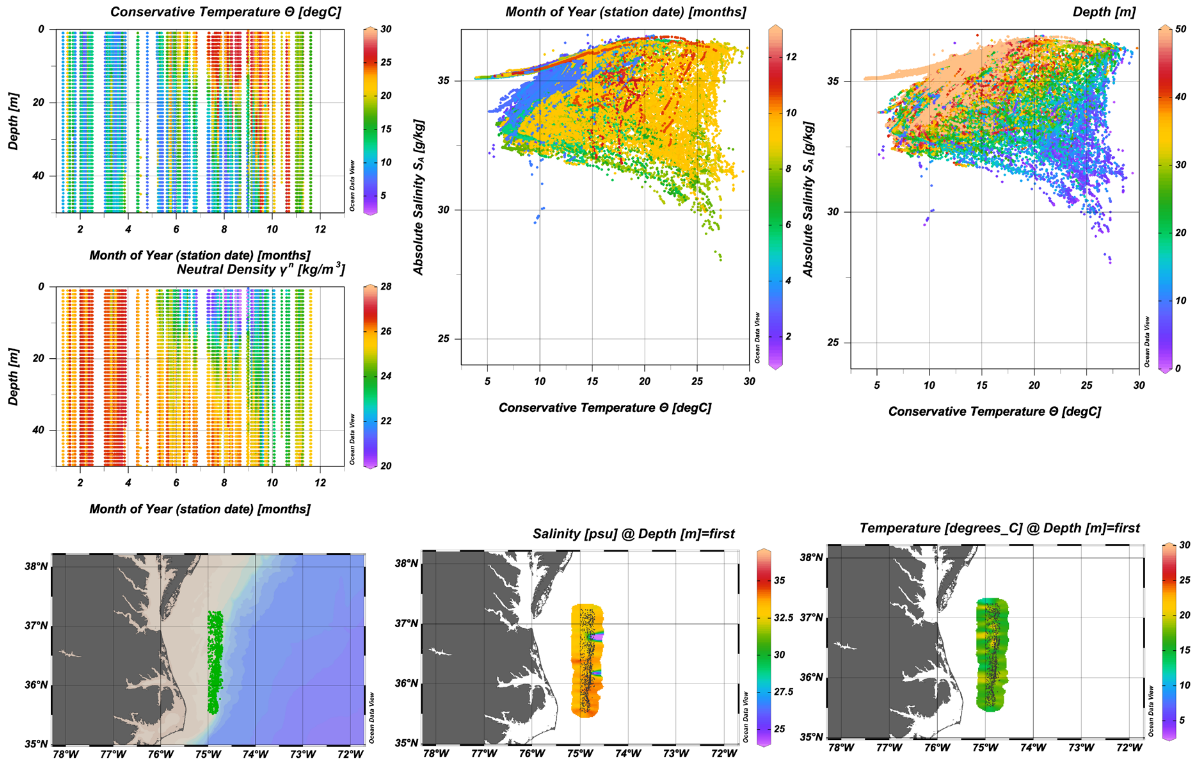


Figure 3-23 – Same as Figure 3-18, but for the slope region defined between 75.0–74.7° W

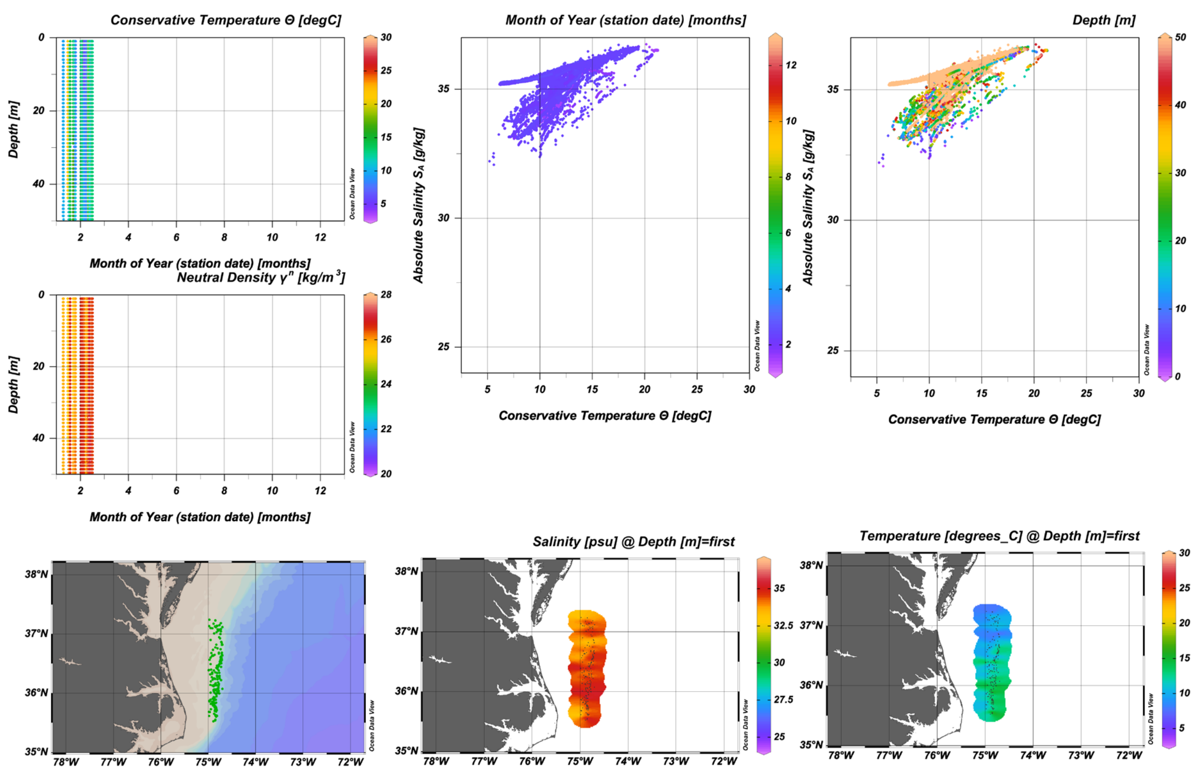


Figure 3-24 – Same as Figure 3-23, but just the winter months (December-February).

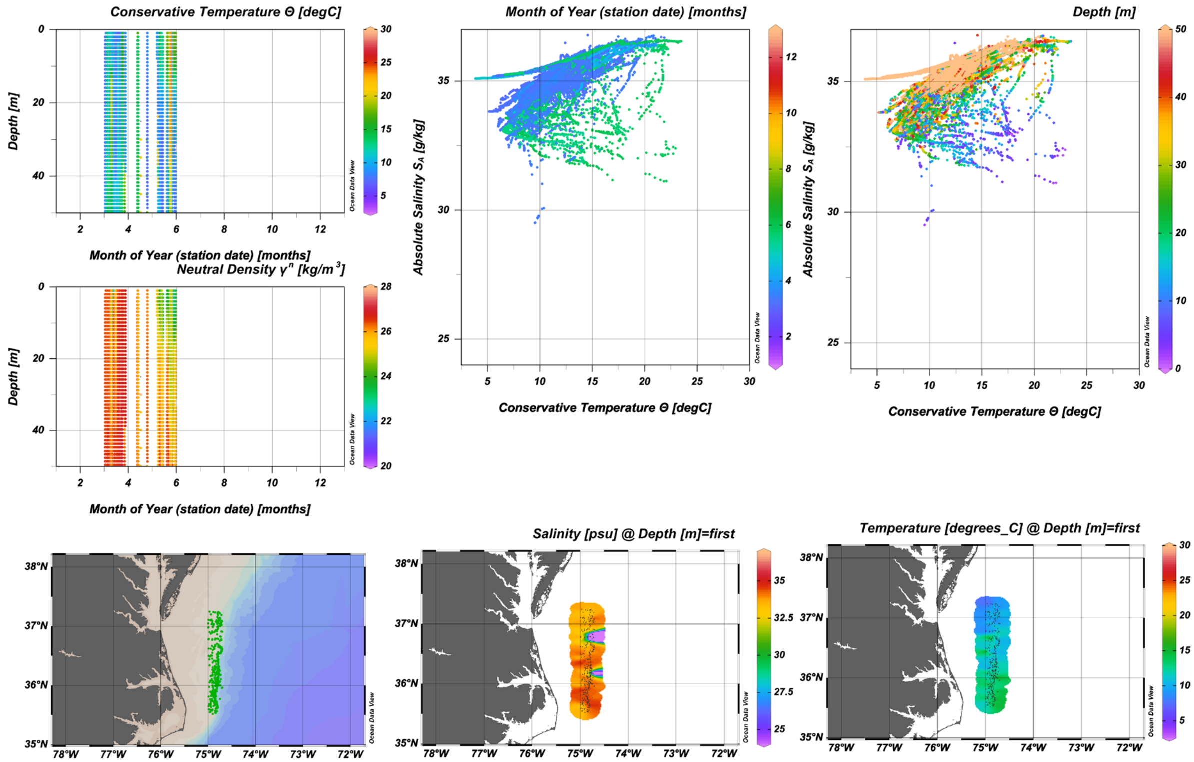


Figure 3-25 – Same as Figure 3-23, but just the spring months (March-May).

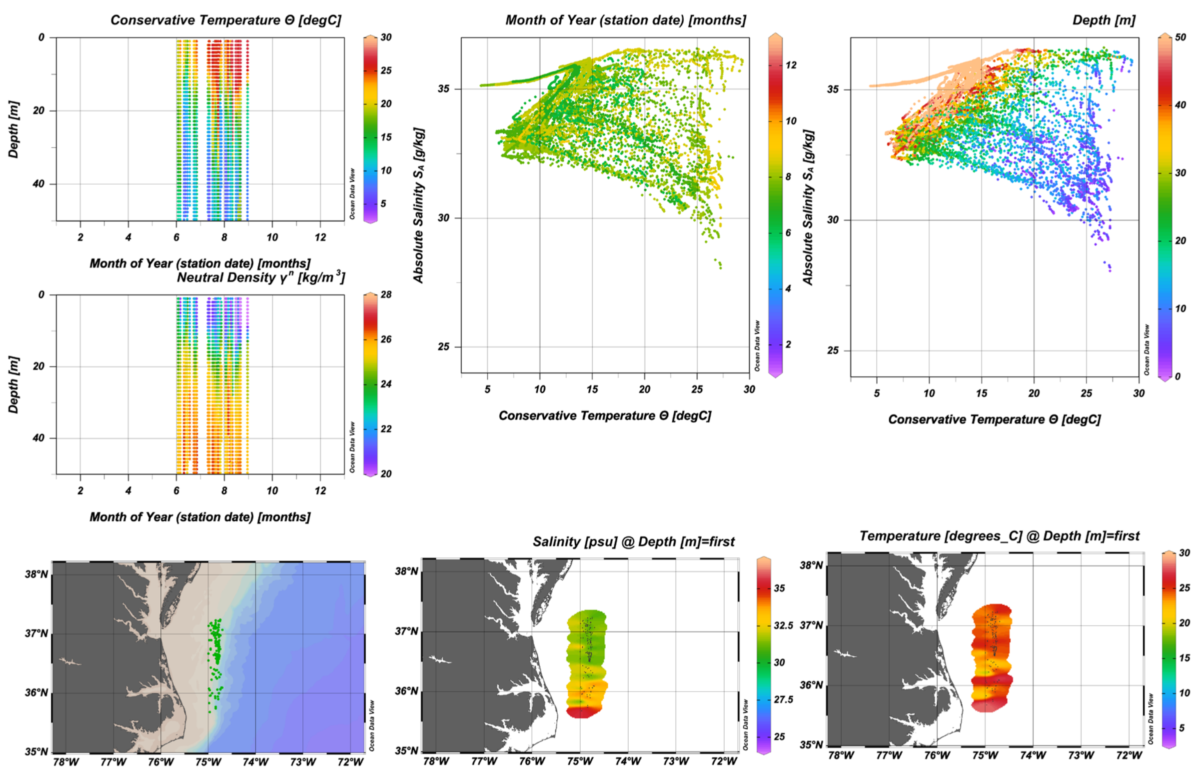


Figure 3-26 – Same as Figure 3-23, but just the summer months (June-August).

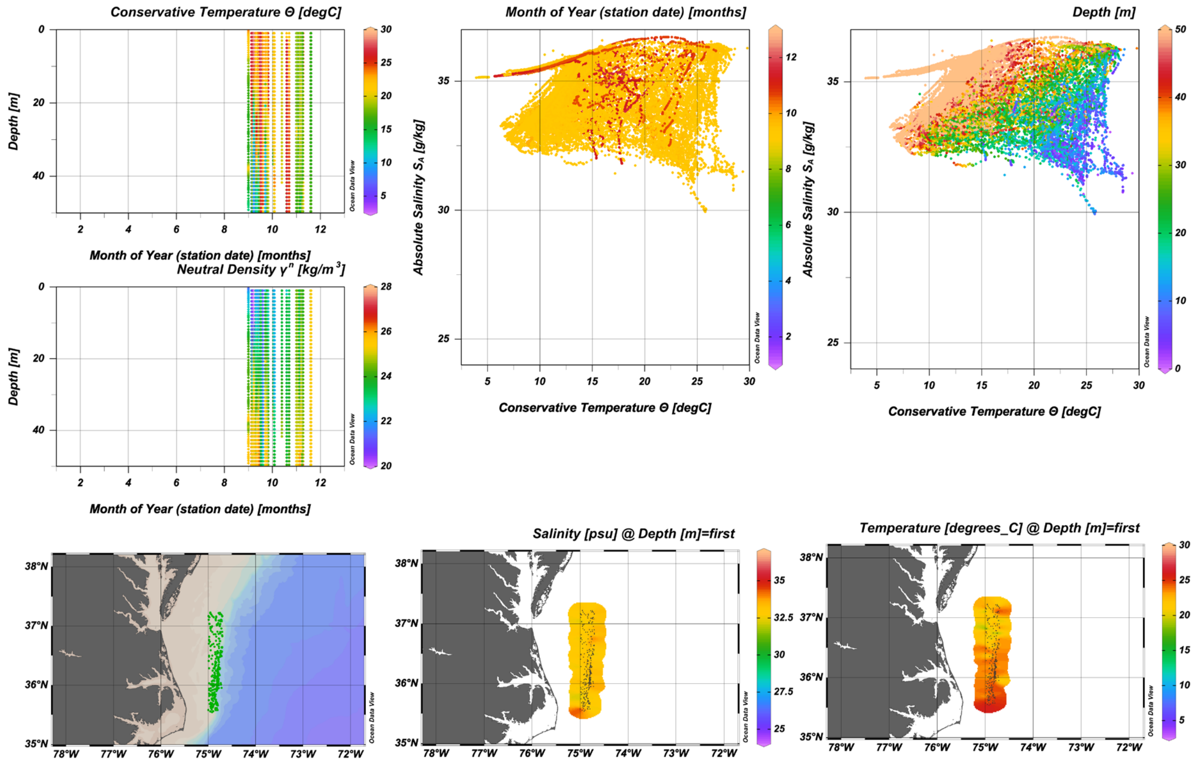


Figure 3-27 – Same as Figure 3-23, but just the fall months (September-November).

Offshore Region (Figure 3-28 through Figure 3-32, Table 3-9)

The offshore dataset includes almost 121,000 records with winter, spring, summer and fall containing 20%, 30%, 39% and 11% of the observations, respectively. In the offshore region, the mean depths of the observed data range from 122±102 m in the fall to 759±702 m in the summer creating a shallow/deep bias between these two seasons in particular, but also including the winter which has only one profile reaching below ~1000 m (upper left panels). This “deeper” profile happens to be the only December profile in the entire shelf/slope/offshore data collection. There is also a geographic bias, with most of the observations in the northwest corner of the region (lower right panels). The latter creates a diagonal surface pattern of cool-fresh to warm-saline from northwest to southeast (lower right panels). As the deepest waters are also the most saline, there is tail in the T/S diagrams (upper right panels) that is also seen on the slope (Figure 3-23 through Figure 3-27)

Offshore (Figure 3-28), ranges from 2.4°C to ~29°C, with the lowest values in the summer because they are deepest. Mean water column temperature is similar in the winter, spring and summer (8.5°C to 9.4°C), but is greater in the fall (~14.3) because these profiles are the shallowest. As in both the shelf and slope regions, average salinity is similar in the winter and spring (35.23 to 35.24±0.46 g kg^{-1}). Summer salinities are higher (35.42 g kg^{-1}) and fall lower (35.18 g kg^{-1}), but neither significantly so. The range is likely due to the different depth ranges in the two seasons. Regardless of the sampling biases, as would be expected, throughout the year in the offshore region there is stratification with a tendency for the greatest densities to occur in the late winter and early spring (upper left panels).

Winter Offshore (Figure 3-29): There are approximately the same number of offshore winter samples as on the slope (21,000) - here less than what is observed for in the spring and summer, but more than that measured in the fall. As previously mentioned, here we have the only December observations in the entire dataset, a single profile reaching to about 1200 m.

January sampling is particularly shallow (all < 1000 m) and with samples to 2000 m February provides the deepest sampling during the season (upper left panels). Stratification is apparent in all winter months, with the warmest surface temperatures in December and the clearest and deepest mixed layer (based on a likely color-biased visual inspection of the temperature and density gradients, upper left panels) later in the season. Above and below 50 m there is clear distinction between water masses in the T/S diagrams (upper right panels) suggesting an average mixed layer depth at around 200 m, though the temperature-density/depth plots (upper left panels) would suggest that the mixed layers could reach deeper. Further analysis is required. The cold/saline T/S tail is again apparent and is associated with the deeper samples. The one December profile produces its own high salinity/high temperature. With most samples congregated in the northwest corner, the geographic picture is difficult to unravel, but there appear to be lower surface salinities and temperatures to the north (lower center and right panels). There are distinctly different high salinity and temperatures to the south, particularly offshore. These are possibly associated with Gulf Stream intrusions or they could be single values whose quality should be considered in light of a larger (further offshore) region of WOD data. In either case, they are different from the shelf/slope patterns which both suggested fresher winter waters to the south of 35.75°N (Figure 3-19 and Figure 3-24).

Spring Offshore (Figure 3-30): There are more than 35,000 spring observations. There is a reasonable spread temporally with no obvious gaps. Again, the data locations are biased to the northwest corner of the region and while there are a good number of profiles reaching below 1000 m throughout the season, the mean depth is only about 350 m and none of the profiles are as deep as those obtained during the winter and summer. Therefore, one ought to assume a shallow bias for the spring observations. That said, the distinction between shallower and deeper values is again apparent in the T/S diagrams (upper right panels) with the visual (color) distinction noted at about 200 m. As in winter, the cold/saline tail is associated with deeper waters and is apparent throughout the season, and the T/S diagrams fill out in the direction of warm and fresh in the late spring. The upper tail of temperatures warmer than 15°C that was seen only in the December profile during the winter is also apparent throughout the spring, but especially in May. As in the winter, there are fresh colder waters to the north (lower right panels) with the same caveats as mentioned in the previous subsection. To the north of 36.5°N there is once again the tendency for waters further offshore to be warmer and more saline.

Summer Offshore (Figure 3-31): Unlike on the shelf and slope there are more summer data offshore than in any other season (~47,000 data points). The overall coverage depth-wise is decent with the deeper profiles available than in the other seasons (upper left panels). That said, the deep profiles are intermingled with much shallower sampling, particularly early in the summer and July to early August where there is a single deep profile. Very warm (> 25°C) light surface waters are scattered through the middle of the season (mid-June to mid-August). Warmer (> 26.5°C, visually red, upper left panel) waters reach below 500 m. This might be particularly so later in the season, but the sampling depth bias may be playing into this interpretation. The T/S diagrams (upper right panels) again show the cold/saline/deep tail and the area of warmer fresher upper waters is filled out compared to the spring. The warm/saline (upper right hand) edge of the T/S pattern is provided by the August data (upper center panel).

There is good spatial and temporal spread in the slope summer data. The only gap is later June to early July (upper left panels). Summer slope waters are stratified. The coolest waters are the deepest and unlike on the shelf (where they occur earlier in the year), on the slope cool temperatures are seen throughout the summer period (upper right and center panels, respectively). The coolest, most saline, and densest waters are seen at depth, particularly below ~20-25 m (upper left panels, upper right panel). As on the shelf, there is a north-south gradient in surface salinities, with the largest values occurring to the south of 36°N (lower center panel) and an apparent surface cool patch just to the north of 36.5°N. While this could be real, we again note that this could be the result of the scatter sampling and relatively low number of observations, or a single cruise with uncalibrated salinities that ran from spring into summer. Further investigation would be required to better understand this pattern.

Fall Offshore (Figure 3-32): There are ~13,500 fall offshore observations - far fewer than in any other season. As in the other seasons, the data are concentrated in the northwest corner. Contributing to the lack of fall observations is the fact that all the profiles are shallower than 500 m, and the ones that go this deep occur later in the season with most of the profiles concentrated in September (upper left panels). The saline/cold tail in the T/S diagrams is represented by late October/November observations, but so are some of the warmer (15-20°C)/fresher (<34 g kg^{-1}) values (upper center panel). The former are deep (closer 500 m) while the latter are shallower (closer to 100 m) and form the southernmost blob in the surface contour plots (lower right panels). The fresher, colder central blob in the surface contour plots represents early September data, while the elongated shape to north depicting somewhat warmer values is strongly influenced by the northwest concentration of data and span the entire season. There is no obvious on/offshore gradient, but there is some suggestion of higher temperatures along the eastern edge of the region of concentrated sampling. These higher values come from multiple cruises in multiple years, so although appearing somewhat unnatural are perhaps real (i.e. have a physical cause).

Table 3-9 – Offshore CTD statistics. Overall (upper panel) and seasonal (successive panels) statistics for the MAB Offshore region defined between 35.5–37.25°N and 74.7–74.0°W. Data description same as for Table 3-7.

Offshore

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	9.777	5.703	0.0164	120748	2.372	29.362
Absolute Salinity SA [g/kg] :	35.3073	0.6034	0.00174	120748	23.6586	39.1850
Depth [m] :	527.8	596.3	1.72	120748	0.1	2815.9

Offshore Winter: December – February (cf. Figure 3-29).

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	8.525	3.828	0.0264	21000	3.484	24.447
Absolute Salinity SA [g/kg] :	35.2404	0.4611	0.00318	21000	33.0820	36.6828
Depth [m] :	502.3	500.1	3.45	21000	1.0	1976.8

Offshore Spring: March – May (cf. Figure 3-30).

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	9.258	3.625	0.0193	35457	3.612	24.182
Absolute Salinity SA [g/kg] :	35.2331	0.4698	0.00250	35457	23.6586	36.7090
Depth [m] :	346.9	358.1	1.90	35457	1.0	1595.9

Offshore Summer: June – August (cf. Figure 3-31).

	Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (:	9.401	6.907	0.0319	46873	2.372	28.884
Absolute Salinity SA [g/kg] :	35.4187	0.5935	0.00274	46873	23.8545	36.9953
Depth [m] :	758.5	701.6	3.24	46873	1.0	2799.4

Offshore Fall: September – November (cf. Figure 3-32)

		Mean	Stand.Dev.	Stand.Err.	Count	Minimum	Maximum
Conservative Temperature (	:	14.283	4.702	0.0405	13502	5.739	28.881
Absolute Salinity SA [g/kg]	:	35.1777	0.9164	0.00789	13502	31.6673	36.7351
Depth [m]	:	122.2	102.1	0.88	13502	1.0	500.7

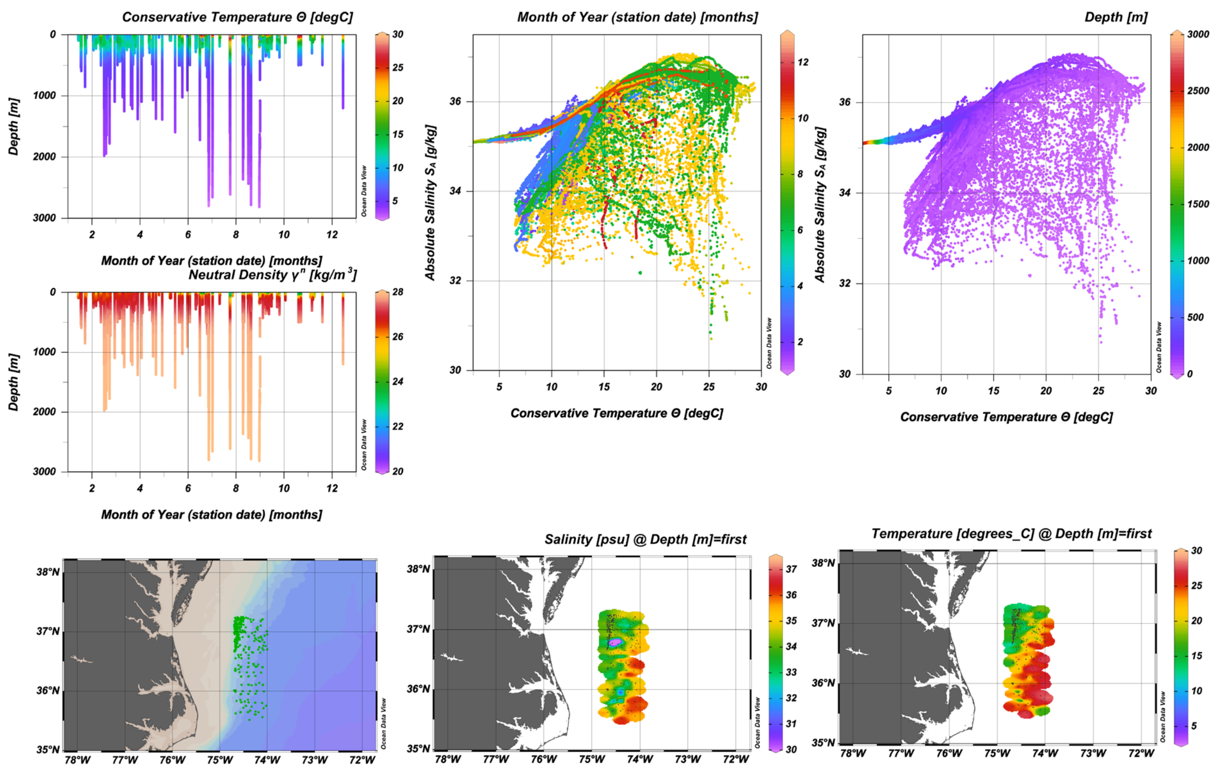


Figure 3-28 – Same as Figure 3-18, but for the offshore region defined between 74.7–74° W

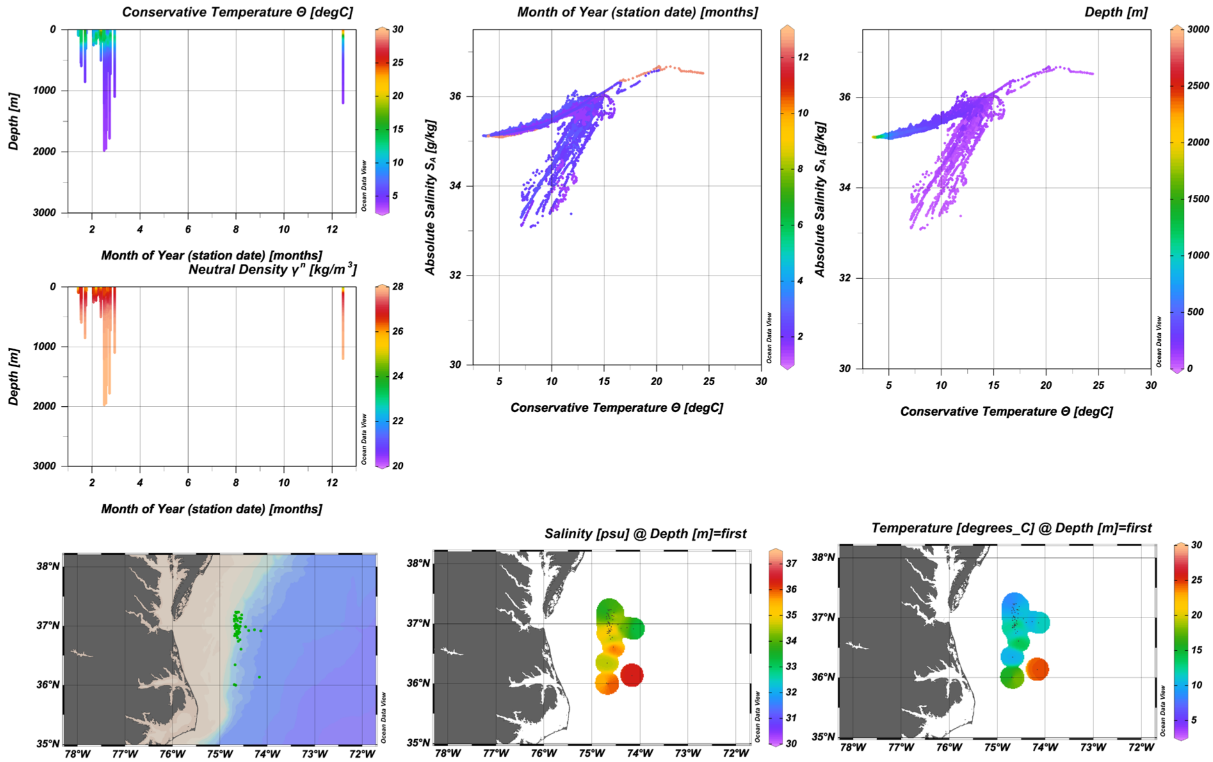


Figure 3-29 – Same as Figure 3-28, but just the winter months (December-February).

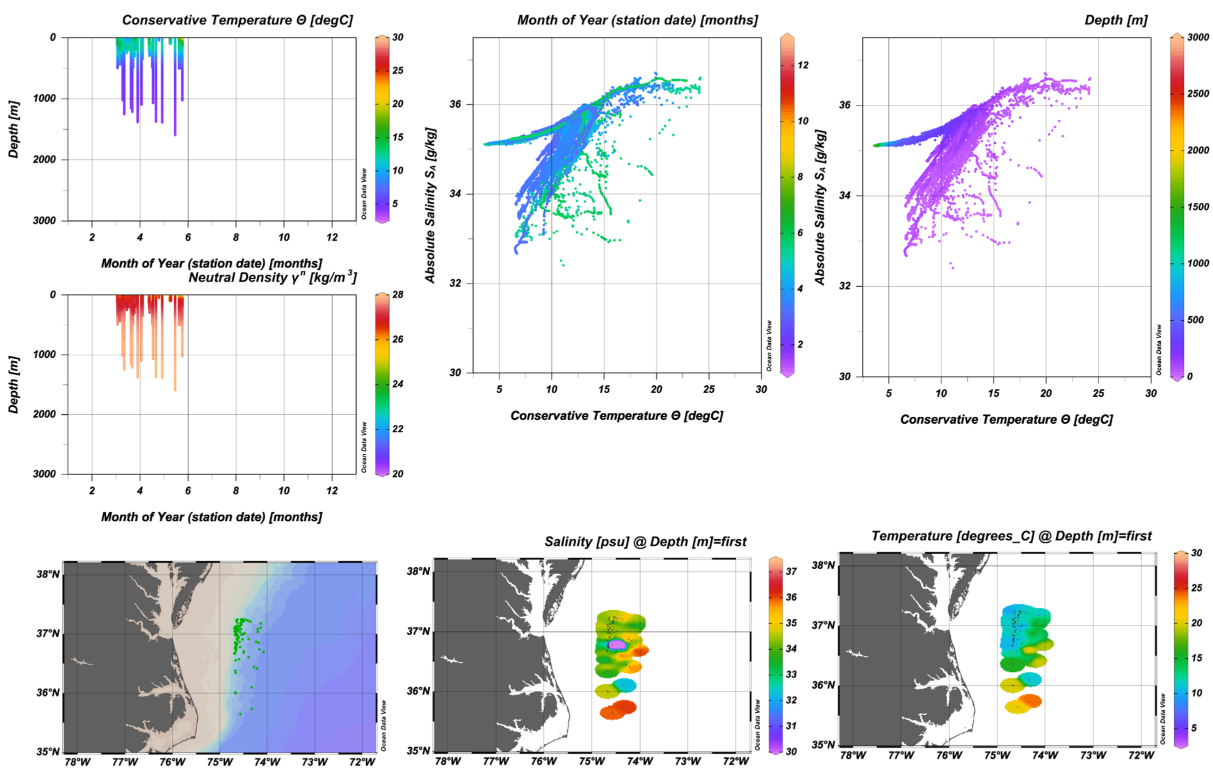


Figure 3-30 – Same as Figure 3-28, but just the spring months (March-May).

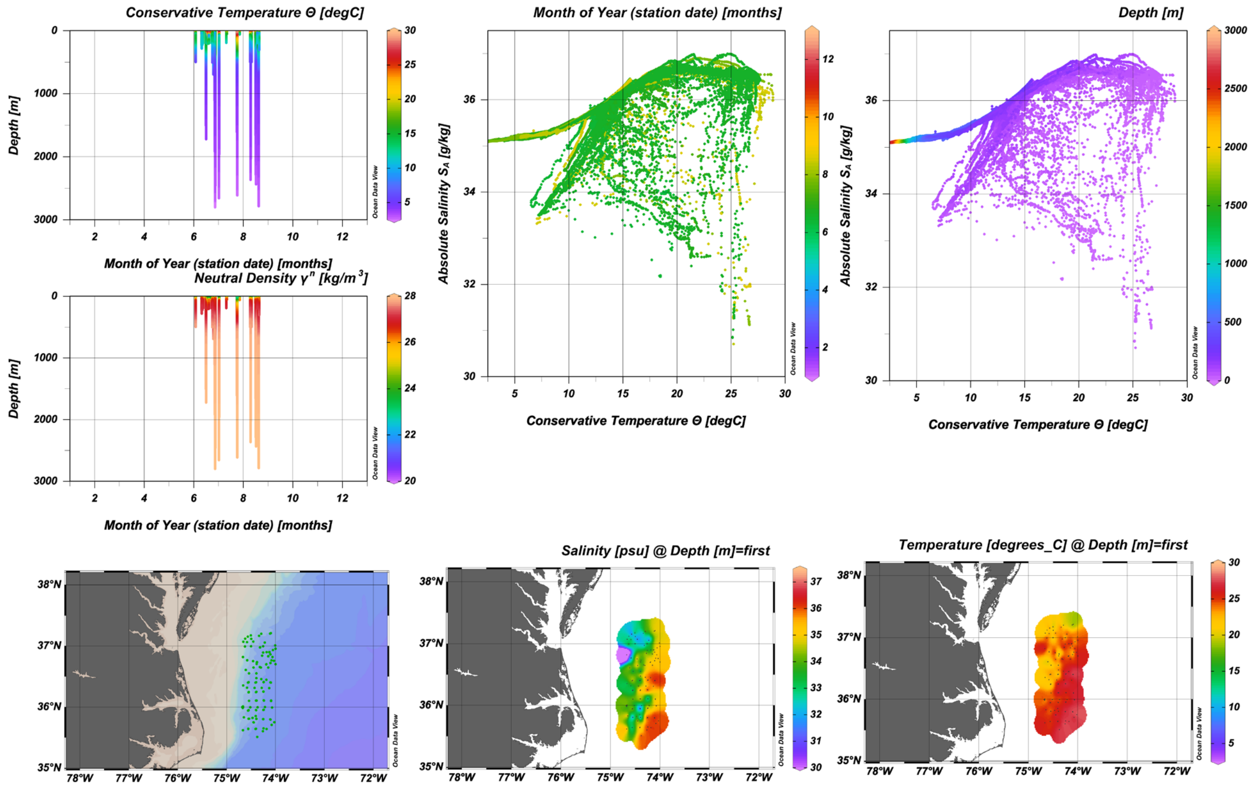


Figure 3-31 – Same as Figure 3-28, but just the summer months (June-August).

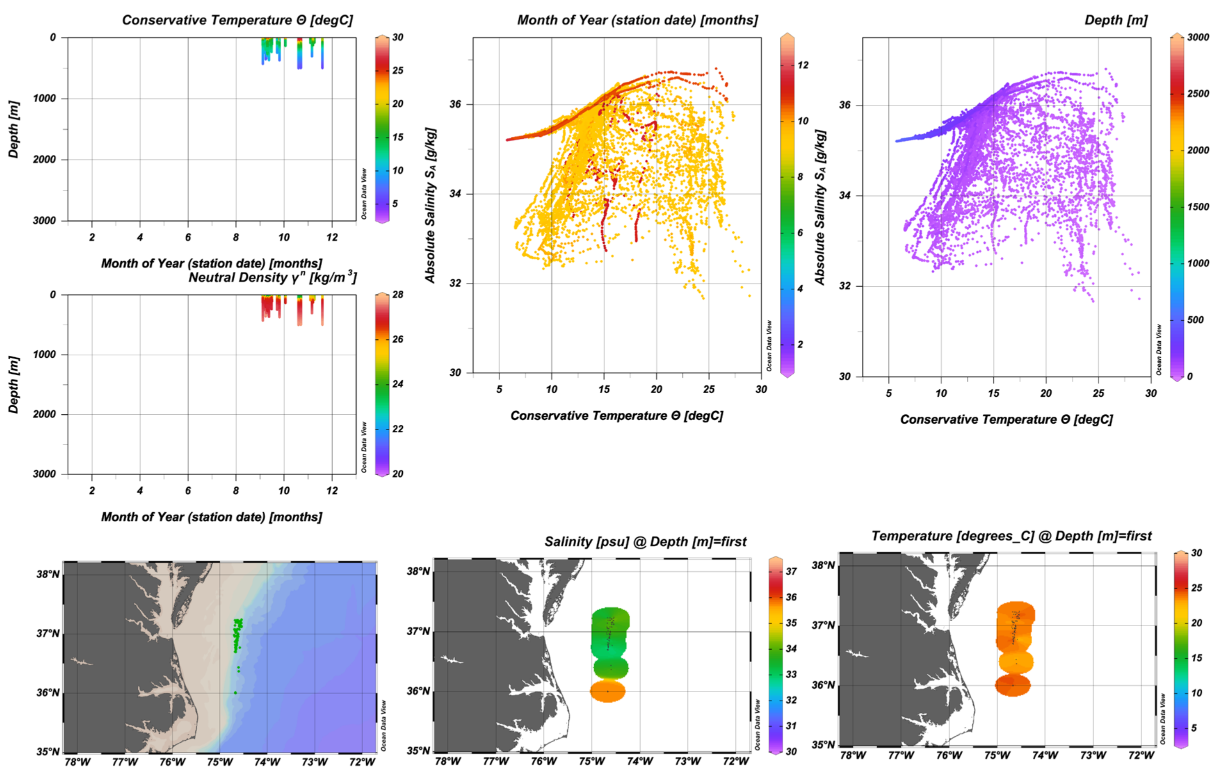


Figure 3-32 – Same as Figure 3-28, but just the fall months (September-November).

WOD Spatial Sampling Assessment

With 247,929 CTD observations in the defined shelf-slope-offshore regions, there are approximately 5-6 times fewer CTD data points on the shallow shelf(~18.5K, Table 3-7) compared to the deeper slope (~108K, Table 3-8) and offshore regions (~121K, Table 3-9). The WOD CTD dataset includes observations from 1982 to 2021, however, the 1980's data are sparse with records in 1982, and more regular sampling not beginning until 1987. With just a few early years with deeper records, until about 2010, most of the data are limited to the upper ~200 m (Figure 3-33). The offshore plots in particular should be interpreted with caution as there are seasonal biases in the depth range of the profiles and the majority of profiles are confined to the northwest corner of the region (see location maps in Figure 3-28 though Figure 3-32). Most of the offshore profiles deeper than 600 m are located to the north and/or west of the mooring box. There are 4 exceptions which might be useful references when considering bottom water conditions for the 600 m NE and SE moorings (Figure 3-34).

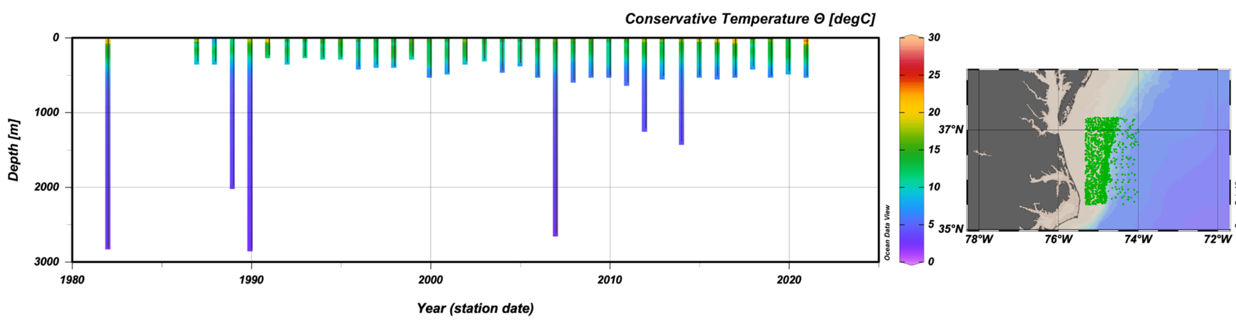


Figure 3-33 – CTD depth range and temperature by year (left) based on all available World Ocean Database CTD data for the SMAB shelf defined between 35.5-37.25°N and 75.33—75.0°W. Color shading indicates the overall average Conservative Temperature (CT,°C) for the individual year. CTD location map (right). Software credit as in Figure 3-18.

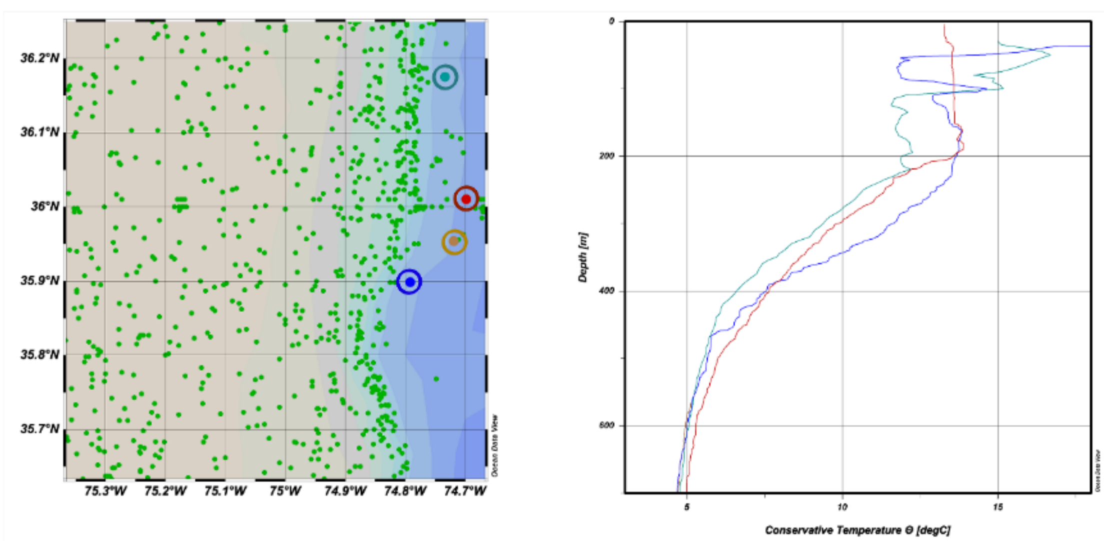


Figure 3-34 – CTD profiles near 600 m depth within the Mooring Box. Based on all available World Ocean Database CTD data within the mooring box. Right panel - Conservative Temperature (CT, °C)/Depth (m) profiles from the four stations in the Mooring Box with observations that reach 600 m (see Figure 3.6.4). These are: 1) WOD Station ID 10416495 from 04/24/1989 at 74.733°W, 36.175°N (teal dot); 2) WOD Station 11554728 from 09/01/1990 with partial profile crossing 600 m at 74.733°W, 36.175°N (orange dot); 3) WOD Station 11190264 from 07/23/2007 at 74.791°W, 35.898°N (blue dot); and 4) WOD Station 15808283 from 02/15/2012 at 74.698°W, 36.01°N (red dot). Left panel - map of the data points with the locations of profiles color coded to match the right panel. Software credit as in Figure 3-18.

Comparing WOD to PEACH

Comparing the WOD-based slope findings (1982-2022, mean depth ~96 m, Table 3-8) to the PEACH mooring A1, A2 and A3 results (April 2017-November 2018, mean CTD depth ~96, Table 3-5 and Table 3-6) we begin with the caveats: a) while for a general comparison it should not matter, be aware that the WOD values are TEOS-10 variables (CT and SA), while the PEACH variables are ITS-90 and Practical Salinity; b) the mooring data represent a little more than 1.5 years of data at single locations, while the WOD data represent a broader region and 4 decades of observations; and c) the mooring data have smaller temporal gaps than the WOD data and while not having obvious seasonal biases in gaps, they include two instances of April-November data and one instance of December-March data.

Full range of the bottom PEACH CTD sensors and SSTs from the Copernicus Climate Change Service, 7.4°C to 29.3°C. The WOD slope region data set includes a much lower minimum, 3.8°C and a similar maximum, 29.8°C. The colder WOD minimum is likely because WOD represents more winters than PEACH. The similarity in maxima is hard to judge without knowing details of what went into the Copernicus SST values. It may be that summer maximum temperatures are generally more consistent though that seems unlikely given climate change. It is more likely that the more recent summers (including 2017 and 2018) have been warmer and therefore better represent the maximum. This explanation would also provide a reason for the comparatively warm SST 14.8°C minimum at A3, which is not significantly different from the WOD mean slope temperature (13.1±4.5°C). The mean depth of all the WOD slope values that go into the temperature is approximately the same as the depth of PEACH A1 to A3 bottom CTDs. The PEACH 20-month mean temperatures range between 12.1°C and 13.0°C, which suggests that near the bottom this 2017-2018 record is representative of the longer-term mean.

In salinity, because the WOD tables include outliers, it is a little hard to judge ranges, but the maximum salinity seen in the full-record slope T/S diagrams (Figure 3-23, upper right panels) is 36.6 g kg^{-1}. This compares well with PEACH A1-A3 maximum salinity of 36.4. The minimum salinity seen in the WOD slope data is 28.06 g kg^{-1}. This is quite a bit less than the 32.1 minimum in PEACH. It seems unlikely that minimum salinities have become this more saline over time. Again, looking at the WOD T/S diagrams, it is apparent the minimum S is represented by a single profile. That said, there are multiple profiles in multiples in multiple locations that indicate minimum salinity of order 29 g kg^{-1}. This suggests that the four decades of WOD data saw more fresh events than the year and half of PEACH, i.e. the 2017-2018 time frame is not completely representative of possible extrema in salinity. That said, the mean salinity WOD slope salinity is 34.8±1.1 g kg^{-1}, which is consistent with the PEACH A1-A3 mean bottom salinity range of 34.3 to 34.6.

4.0 Surface Conditions

4.1. Wind speed and direction statistics

Mean hourly wind speed and direction data along with maximum hourly wind gusts were downloaded from NDBC Historical Standard Meteorological Data files for buoy stations 41062 and 44014 (Figure 4-1, Table 4-1) (www.ndbc/noaa.gov). Although the record was discontinuous, data for Station 44014 spanned Oct 1, 1990 to Oct 31, 2021, (Figure 4-2). Notable gaps include Nov to Dec 1993; Jan 1995; Nov 1997 to Mar 1998; Mar 1999; Oct 2003; Jan to Feb 2006; April to May 2006; Apr 2010 to Mar 2011; Mar to May 2012; Oct 2012 to Dec 2013; Mar to Apr 2020. The available wind record for Station 41062, approximately 100 km to the south, had only 19 months of continuous data and was not used for analysis in this report.

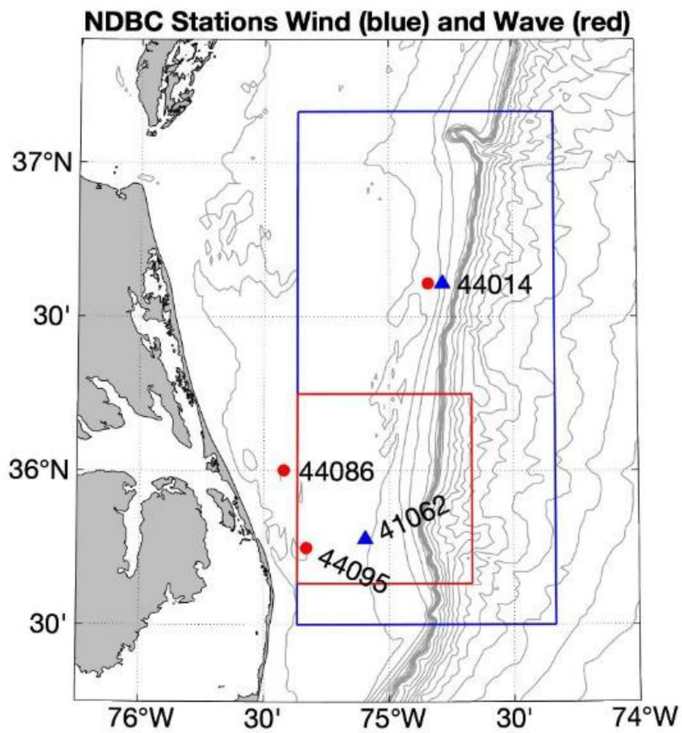


Figure 4-1 – NDBC buoy locations providing historical wind data (two blue triangles) and historical wave data (three red dots) shown with the glider bounds (blue) and mooring bounds (red). Bathymetric contours are every 20 m to 200 m and every 250 m from 250 to 3000 m.

Table 4-1 – NDBC Buoy station information for wind data. Only Buoy 44014 was used in this report, as Buoy 41062 had only 19 months of continuous data available.

NDBC Buoy	Name	Location	Height	Years
41062	Hatteras Bay (B1)	35.778 -75.095	3.5 m	2014, 2017-2018
44014	Virginia Beach offshore	36.609 -74.842	3.2 m	1990-2012, 2014-2021

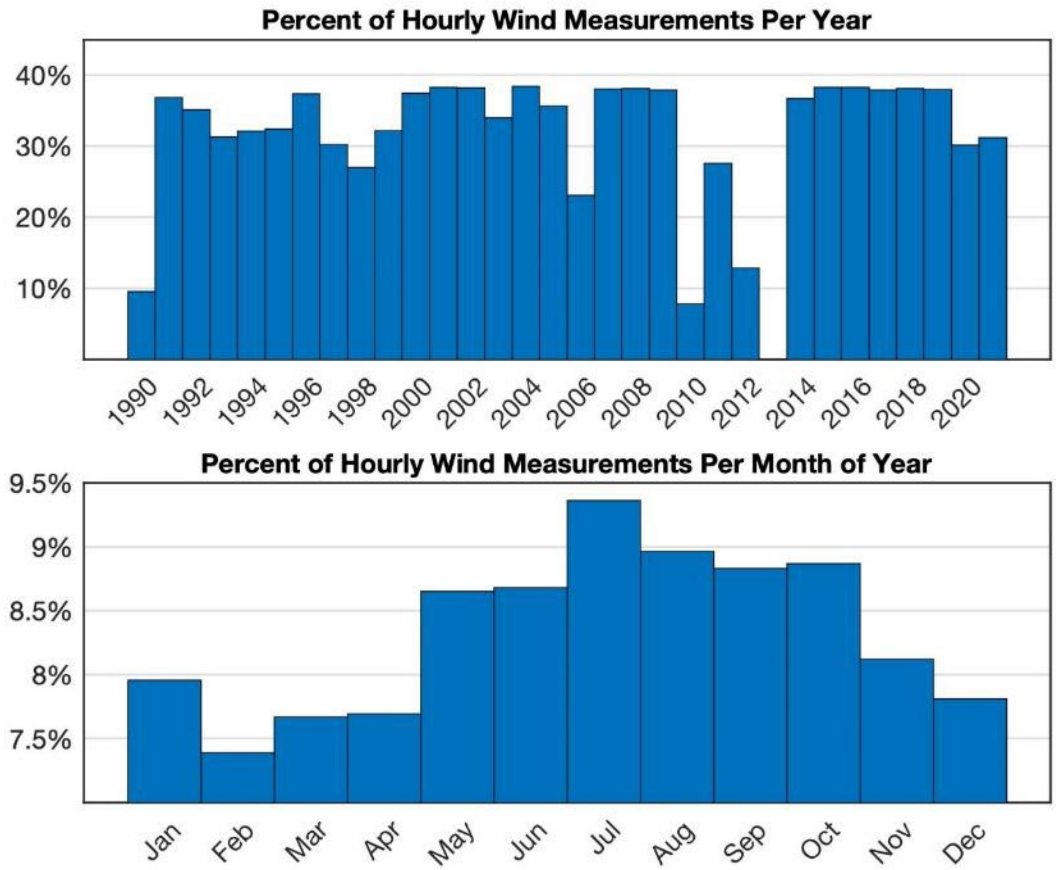


Figure 4-2 – Histogram of the hourly NDBC wind data for Buoy 44014. Top panel - percent of hourly wind measurements available for each year. Bottom panel - percent of hourly wind measurements available per month for all years. No data were available for 2013. Month with the maximum/minimum measurements was July/February, with 9.3%/7.4%.

NDBC wind speed (m s^{-1}) and wind direction are measured as eight-minute averages. These data are then hourly averaged and provided to the public via the website www.ndbc/noaa.gov. Wind gust values are taken as peak 5 to 8 second gust speed (m s^{-1}) measured during the same eight-minute time period as the wind speed, and then also averaged hourly. The one exception is for the 2021 data which are available at 10-minute intervals and not averaged hourly. For consistency, in this report, the 2021 data are averaged hourly before use.

To show the highest occurrence of winds speeds for all hourly wind speeds, the data were binned into 1 m s^{-1} bins for wind speeds between 0 to 17 m s^{-1} and wind speeds greater than 18 m s^{-1} were grouped together into one bin (Figure 4-3). Hourly wind speeds in the 5 m s^{-1} bin were the most common (12%). The cumulative occurrence for wind speeds less than or equal to 10 m/s was approximately 79%. Wind speeds greater than or equal to 18 m/s occurred less than 1% of the time.

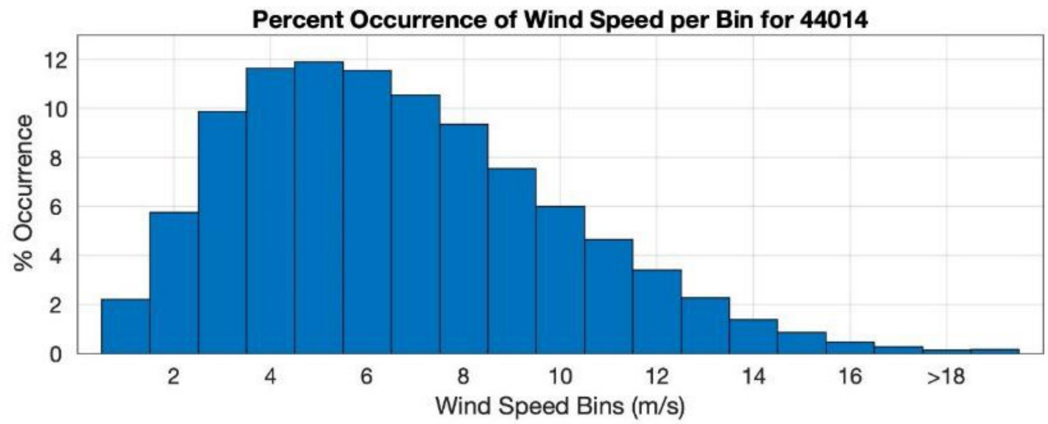


Figure 4-3 – Hourly wind speed data from Station 44014 showing the distribution of wind speeds for all data. The wind speeds were binned into 1 m s^{-1} bins between 0 to 17 m s^{-1}. All wind speeds greater than 18 m s^{-1}are binned together.

The hourly wind speed data was averaged daily for all available data at Station 44014 to identify trends in the data (Figure 4-4 and Figure 4-5). The wind speed has an annual trend with faster wind speeds in the winter and slower wind speeds in the summer. Binning the wind speed data by month of year and calculating the mean speed for each bin, January has the fastest wind speeds (~7.8 m s^{-1}), while the slowest wind speeds occur in June (~4.5 m s^{-1}) over the 31-year data record of hourly wind (Figure 4-6); September has the highest maximum wind speed (~28 m s^{-1}), while the June has the lowest maximum wind speed (~17 m s^{-1}) (Figure 4-6).

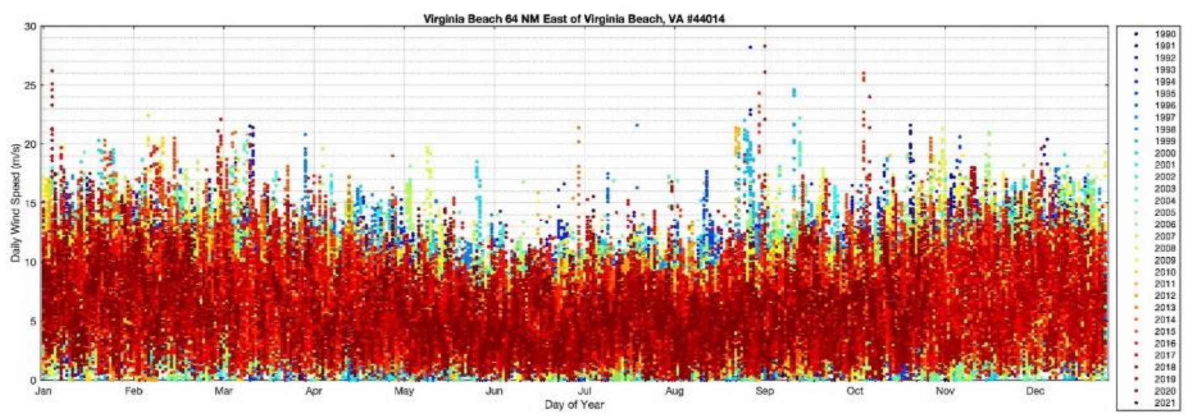


Figure 4-4 – Hourly wind speed data averaged daily versus day of year for Station 44014. Legend shows color for each year.

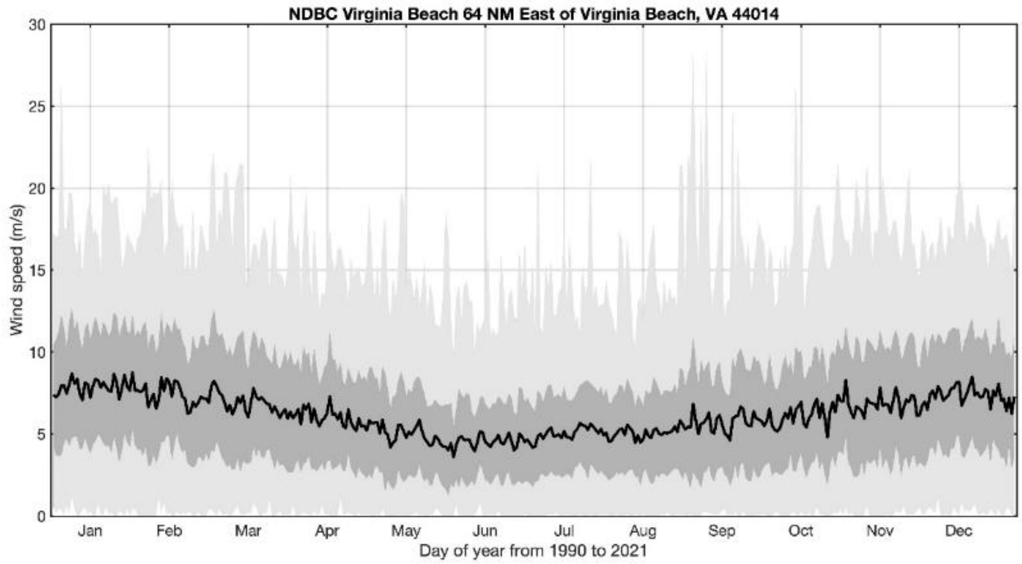


Figure 4-5 – Mean of hourly wind speed versus day of year (thick black line), minimum and maximum hourly wind speed versus day of year (dark shaded area), and standard deviation of hourly wind speed versus day of year (light shaded area) for Station 44014.

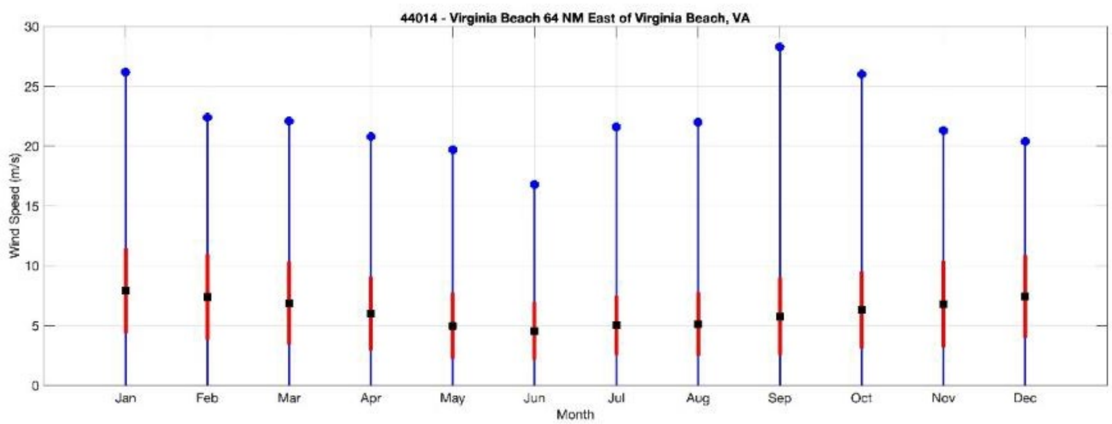


Figure 4-6 – Stem plot showing monthly statistics of hourly-average wind speed. Monthly mean (black square), maximum (blue circle), and standard deviation (red line) plotted year over year for Station 44014.

Percent occurrences of wind from different directions are presented in Figure 4-7. The data were divided into 16 equal compass segments of 22.5 deg. The predominant annual wind direction is SSW (~40%). The predominant spring and summer wind direction is also SSW (~27% and ~35% respectively). The winter wind direction is mostly SW to NNW with the strongest wind direction NNW (~12%). Most of the fall wind direction tends to be between NW and NE with the strongest direction being NNE (~11%) (Figure 4-8). Wind direction is further divided into months and shows that July has the strongest winds in the SSW direction (~20%) (Figure 4-9).

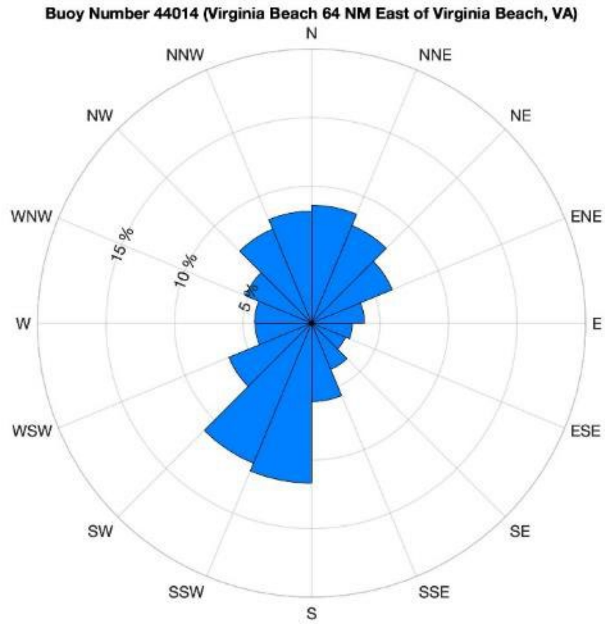


Figure 4-7 – Percent occurrence of wind direction for Station 44014.

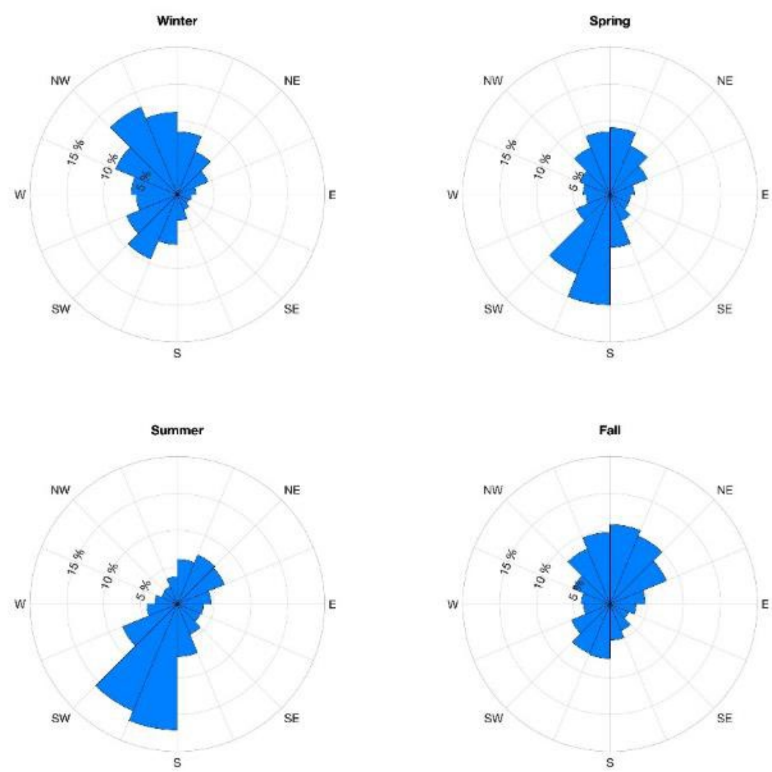


Figure 4-8 – Percent occurrence of wind direction for Station 44014 divided into seasons.

Figure 4-9 – Percent occurrence of wind direction for Station 44014 by month.

The weaker summer winds coming from the southwest are due to the Bermuda High, a semi-permanent, high-pressure system that migrates between the East Coast of North America (near Bermuda) in the summer and near the Azores in the winter and spring. The strong variable winds in the fall and winter are due to tropical storms, hurricanes, extratropical winter storms, and cold air outbreaks.

4.2. Wave statistics

Three NDBC buoys (Figure 4-1) providing historical, hourly wave data records measuring significant wave height, peak wave direction, peak wave period, and average wave period were downloaded from www.ndbc/noaa.gov and/or https://cdip.ucsd.edu. Table 4-2 lists the names, locations, depth, and years of available data.

Table 4-2 – NDBC Buoy information for wave data used in this report.

NDBC Buoy	Name	Location	Depth	Years
44014	Virginia Beach offshore	36.609 -74.842	47 m	1990-2022
44086	Nags Head, NC	36.001 -75.421	21 m	2018-2022
44095	Oregon Inlet, NC	35.750 -75.330	18 m	2012-2022

The number of days of available wave data downloaded from NDBC for Buoy 44014 is shown in Figure 4-10. No data was available for 2013 and fewer than 90 days were available in 1990. The bottom panel of Figure 4-10 shows the percent of hourly wave measurements available per month for all years. The highest percentage of measurements were in July (9.2%) while the lowest percentage of measurements were in February (7.7%).

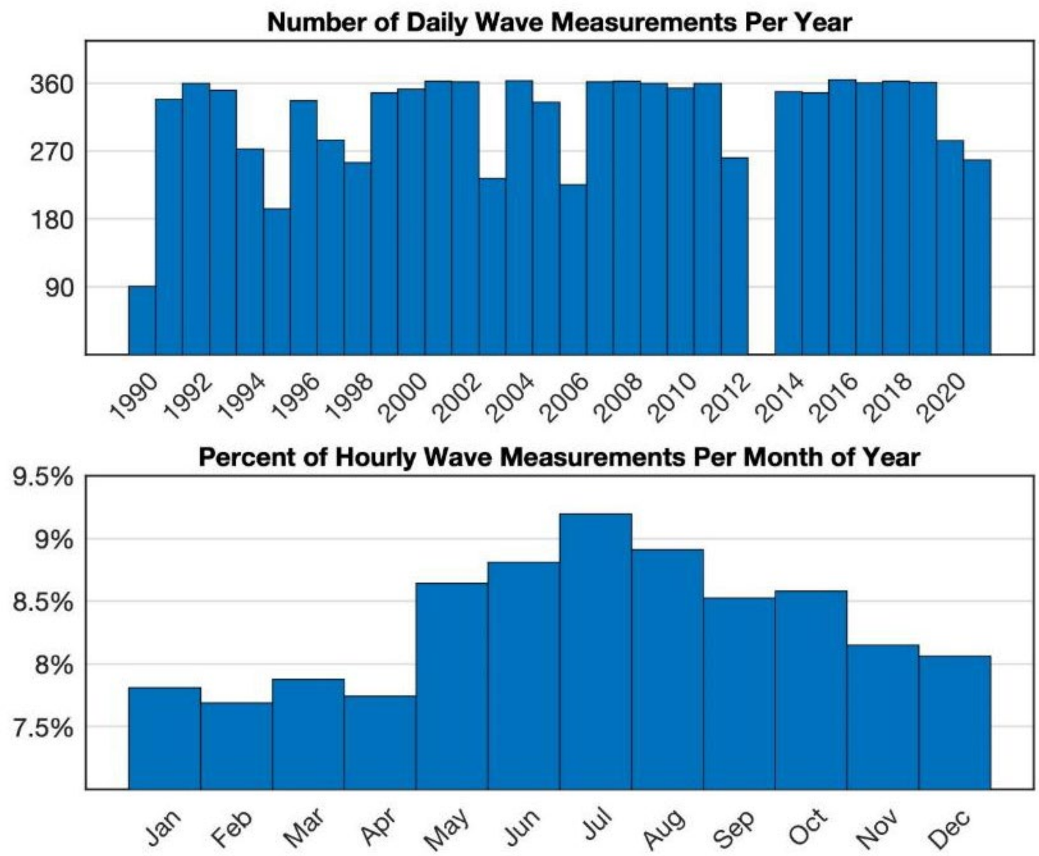


Figure 4-10 – Histogram of the available wave data downloaded from NDBC for Buoy 44014. Top panel shows the number of daily wave measurements available for each year. Bottom panel shows percent of hourly wave measurements available per month for all years. No data was available for 2013. The highest percentage of measurements were in July (9.2%) while the lowest percentage of measurements were in February (7.7%).

To show the highest occurrence of significant wave heights for all hourly wave data, the data were binned into 0.5 m bins between 0 to 4.0 m, and all significant wave heights greater than 4.5 m grouped together into one bin (Figure 4-11). The most common significant wave height was 1.0 m (33%). The cumulative occurrence for wave heights less than or equal to 3 m was approximately 93%. Wave heights greater than or equal to 4.5 occurred less than 2% of the time.

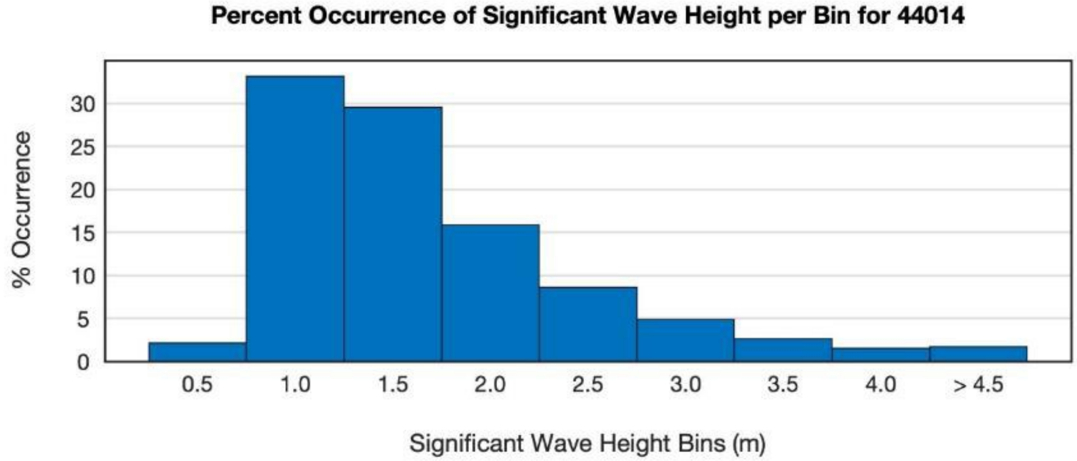


Figure 4-11 – Hourly significant wave height data from Station 44014 showing the distribution of significant wave heights for all data. The significant wave heights were binned into 0.5 m bins between 0 to 4.0 m, and all significant wave heights greater than 4.5 m were binned together.

Significant wave height (meters) is calculated by taking the mean of the one-third highest wave heights in a 20-minute sampling period. These data are hourly averaged and provided to the public on the NDBC website. The dominant wave period (seconds) the hourly maximum wave energy. The average wave period (seconds) is the mean of all waves in a 20-minute period, and then averaged hourly. The one exception is for the 2021 data which was available at 10-minute intervals and not averaged hourly. For consistency, the 2021 data was averaged hourly before any of the observations provided in this report were made.

Figure 4-12, Figure 4-13 and Figure 4-14 are day-of-year (x-axis) plotted with daily mean of hourly significant wave height (black line), daily minimum and maximum of hourly significant wave height (m) (light gray), and daily +/- standard deviation or hourly significant wave height (dark gray) (y-axis). Years are stacked on top of each other. Note the absence of data in March for Buoy 44086 which is evident in the standard deviation calculations over this time period. All figures are plotted with the same y-axis for direct comparison.

The Figure 4-15, Figure 4-16, and Figure 4-17 are the day-of-year (x-axis) plotted with daily average of the hourly significant wave height (m) values for that day (y-axis). Years are plotted on top of each other with the color bar denoting the year.

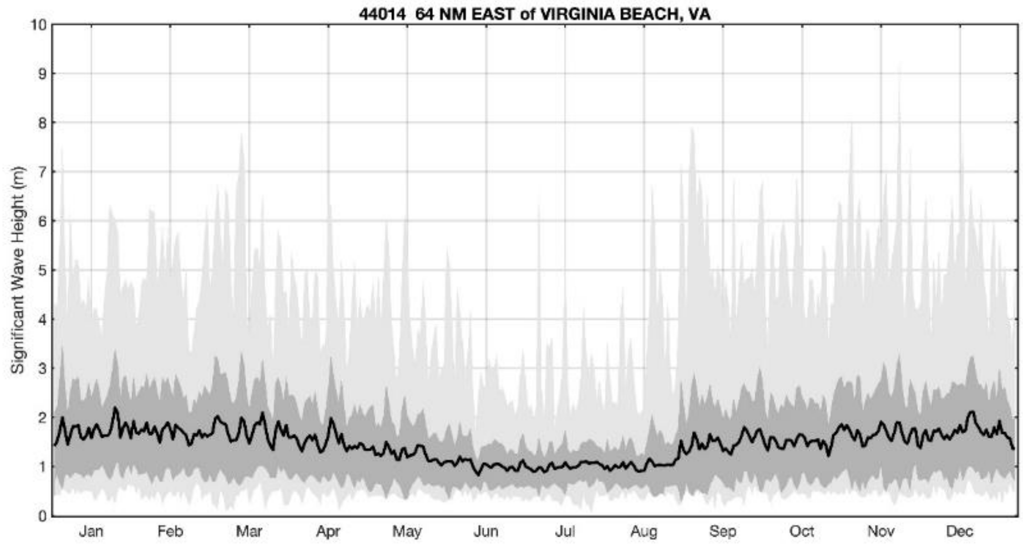


Figure 4-12 – Daily mean of hourly significant wave height versus day of year (thick black line), daily minimum and maximum of hourly significant wave height versus day of year (dark shaded area), and daily standard deviation of hourly significant wave height versus day of year (light shaded area) for Station 44014.

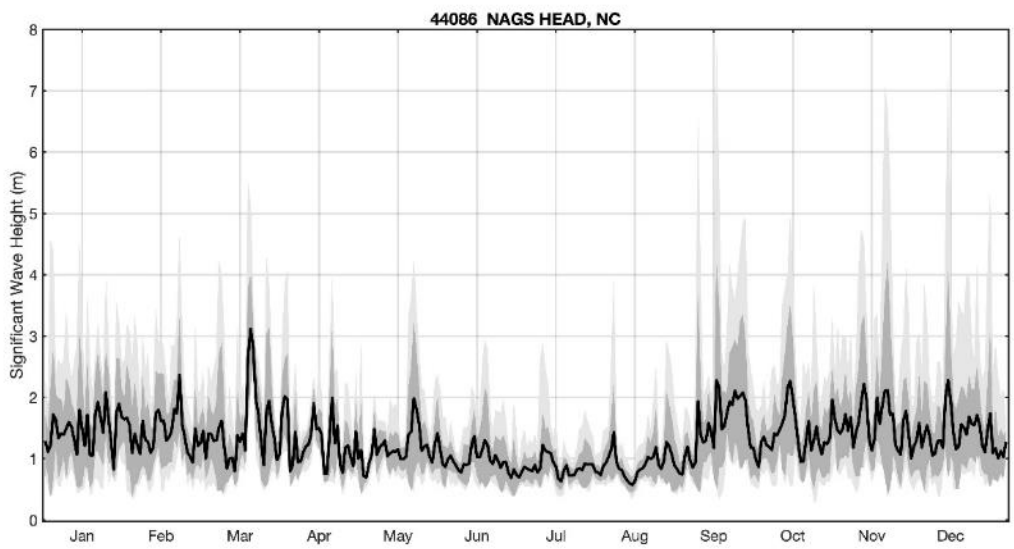


Figure 4-13 – Daily mean of hourly significant wave height versus day of year (thick black line), daily minimum and maximum of hourly significant wave height versus day of year (dark shaded area), and daily standard deviation of hourly significant wave height versus day of year (light shaded area) for Station 44086.

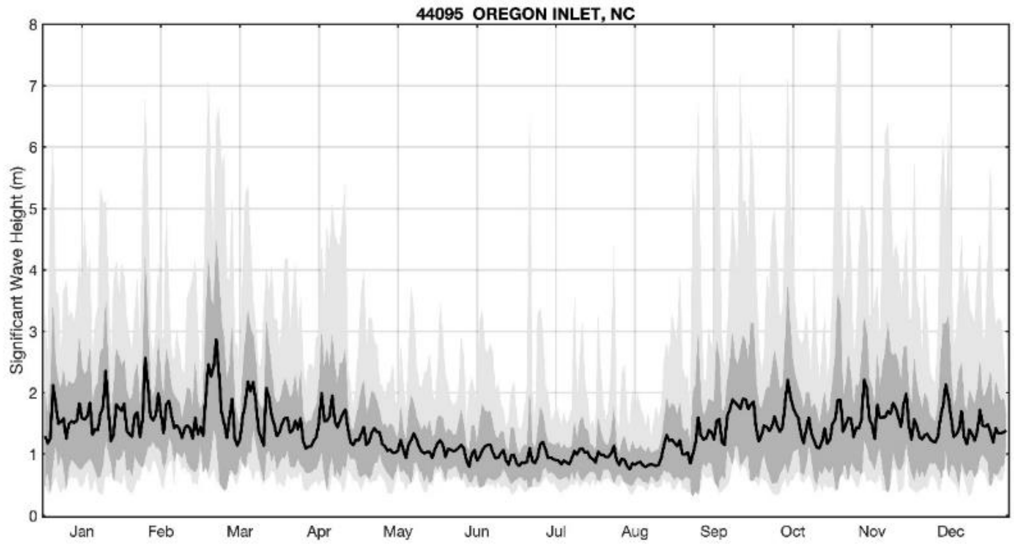


Figure 4-14 – Daily mean of hourly significant wave height versus day of year (thick black line), daily minimum and maximum of hourly significant wave height versus day of year (dark shaded area), and daily standard deviation of hourly significant wave height versus day of year (light shaded area) for Station 44095.

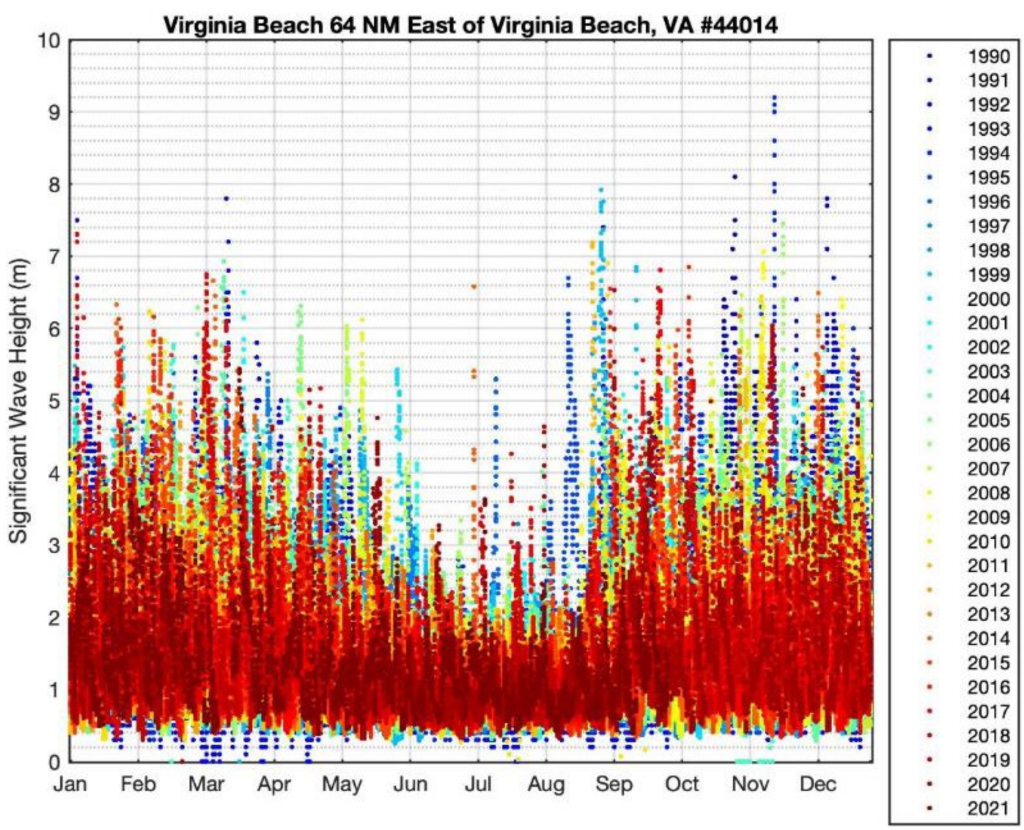


Figure 4-15 – Daily average of the hourly significant wave height (m) values for that day (y-axis) versus day of year for Station 44014. Years are plotted on top of each other with the color bar denoting the year.

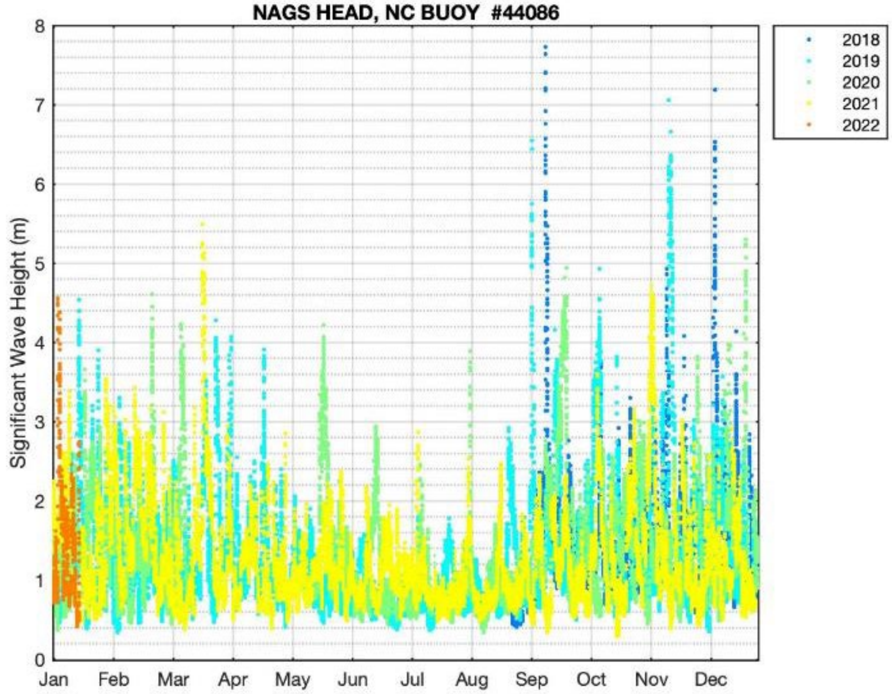


Figure 4-16 – Daily average of the hourly significant wave height (m) values for that day (y-axis) versus day of year for Station 44086. Years are plotted on top of each other with the color bar denoting the year.

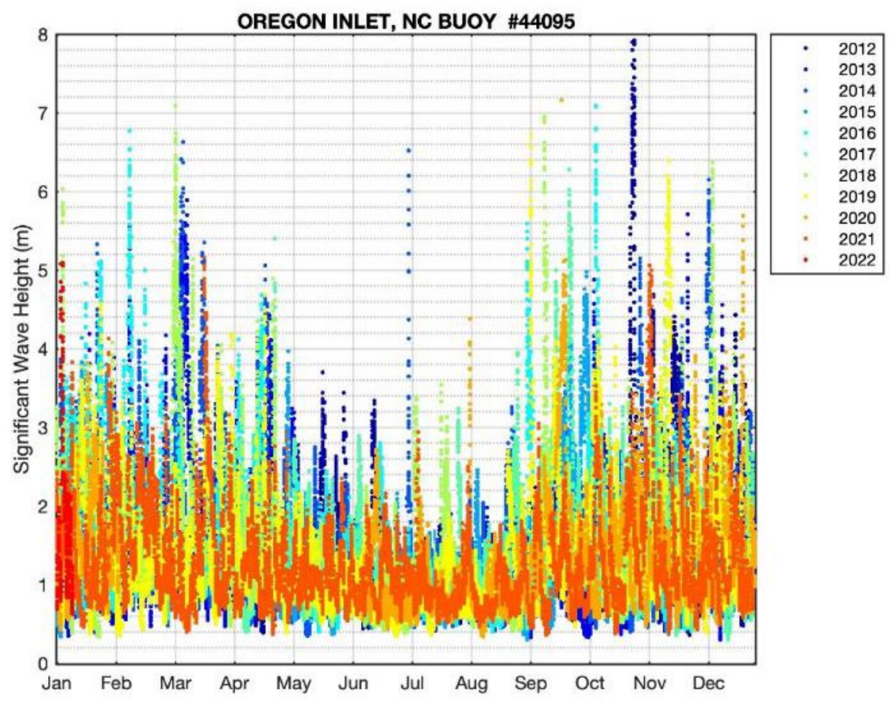


Figure 4-17 – Daily average of the hourly significant wave height (m) values for that day (y-axis) versus day of year for Station 44095. Years are plotted on top of each other with the color bar denoting the year.

Figure 4-18, Figure 4-19, and Figure 4-20 are the percent occurrence of waves from different directions. The data were divided into 16 equal compass segments of 22.5 deg. The dominant wave direction for all three sites was either ENE or E, as expected based on the orientation of the shoreline relative to the Atlantic Ocean.

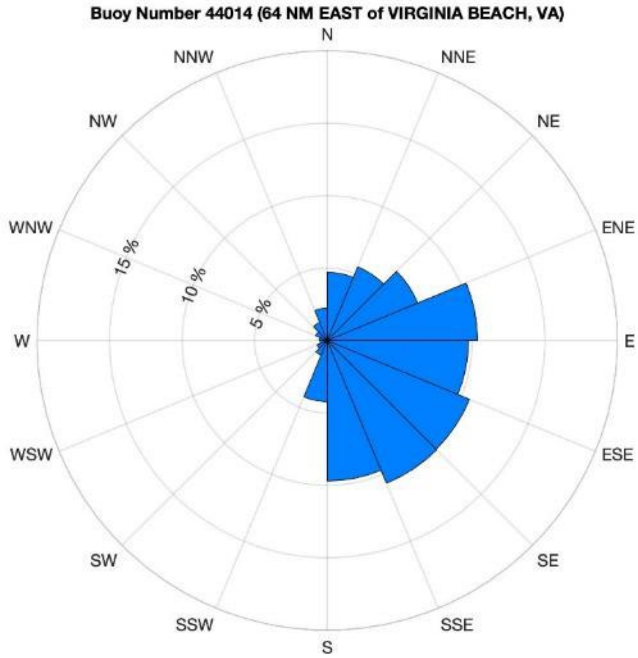


Figure 4-18 – Percent occurrence of wave direction for Station 44014.

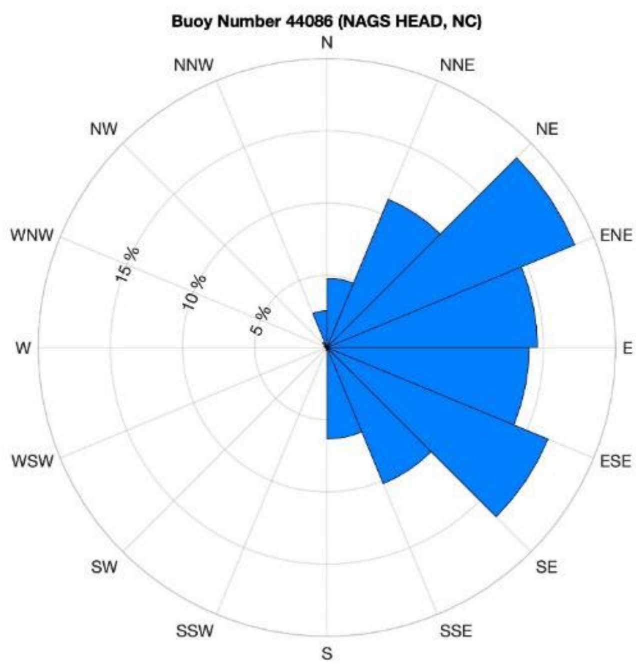


Figure 4-19 – Percent occurrence of wave direction for Station 44086.

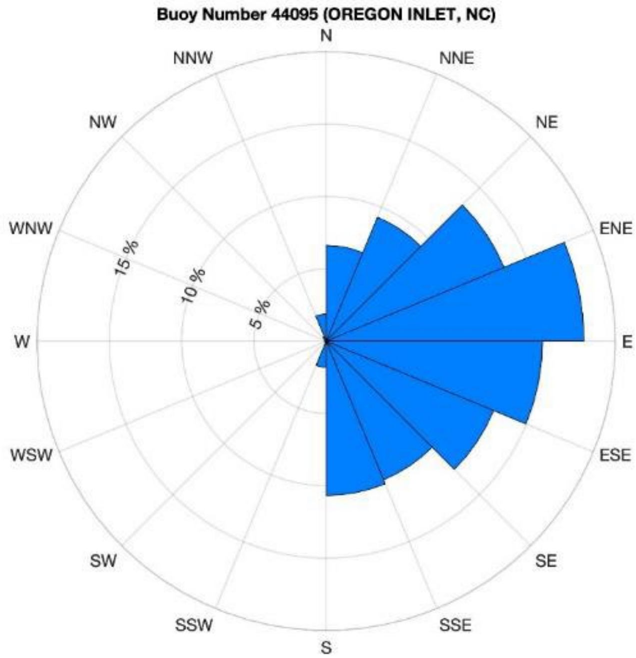


Figure 4-20 – Percent occurrence of wave direction for Station 44095.

Figure 4-21, Figure 4-22, and Figure 4-23 are the monthly maximum of the hourly significant wave height versus the associated wave period. As expected, there is significant variability in wave periods for storm events associated with energetic waves. However, there is generally a trend that indicates that longer period waves are associated with higher significant wave heights. Note the evidence of events that generate long period/ high energy waves from distant storm events as shown by high energy waves with periods greater than 12 seconds.

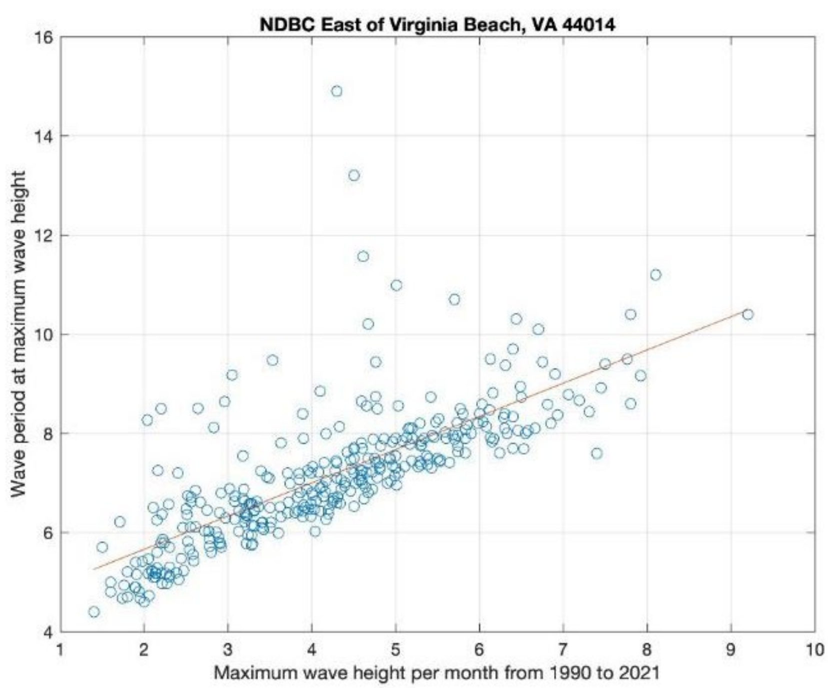


Figure 4-21 – Monthly maximum significant wave height from hourly averaged data plotted against the associated wave period for Station 44010.

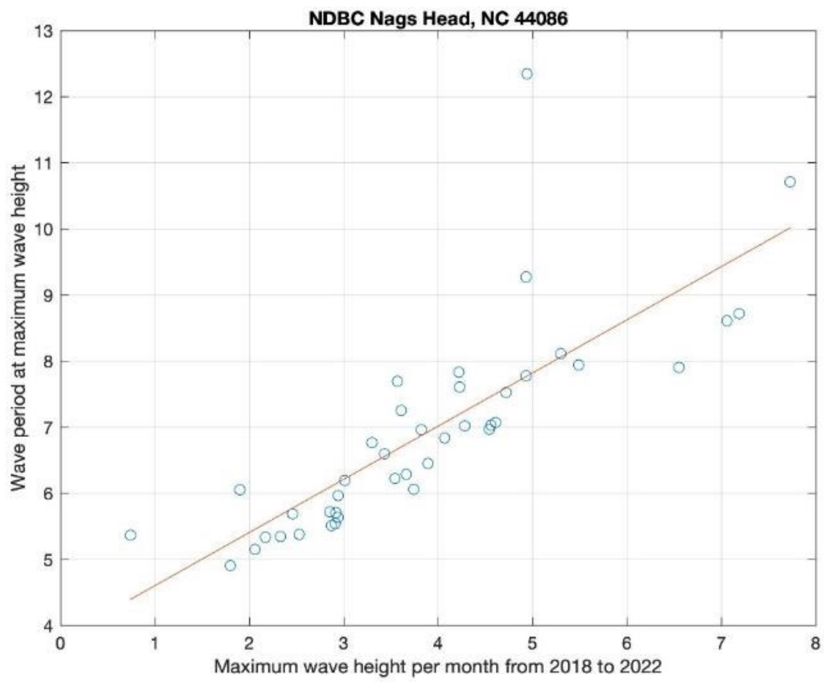


Figure 4-22 – Monthly maximum significant wave height from hourly averaged data plotted against the associated wave period for Station 44086.

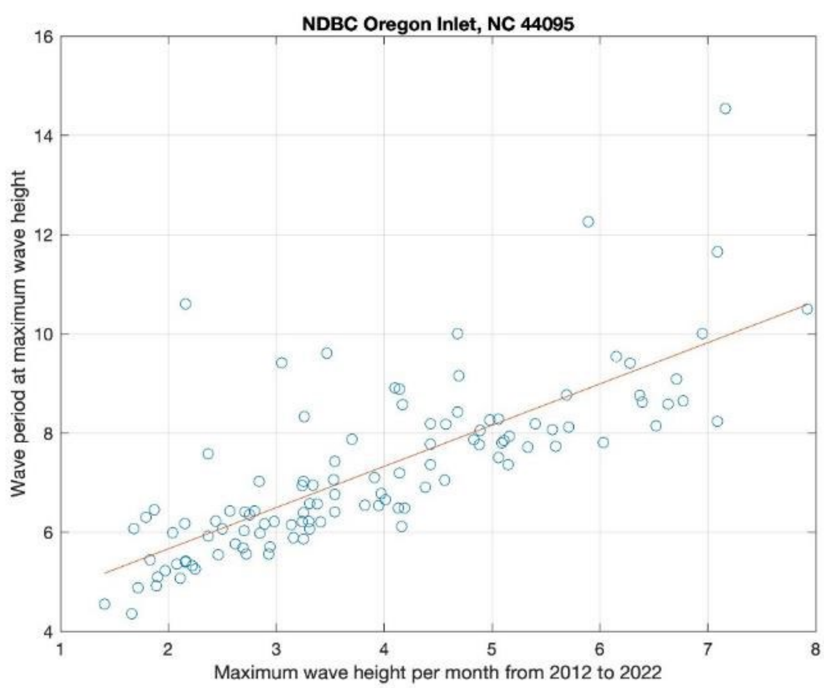


Figure 4-23 – Monthly maximum significant wave height from hourly averaged data plotted against the associated wave period for Station 44095.

The predicted return period for storm wave heights were calculated using the Fisher-Tippett Distribution (also known as the Extreme Value Distribution and the Log-Weibull Distribution), a statistical method for calculating the extreme values of an asymptotic distribution (Cole, 2001). The input data were the hourly significant wave height (m), hourly peak wave period (s), and hourly mean wave period (s) from the NDBC Buoys 44014, 44086, 44095, and the Wave Information Study hindcast model results for stations 44010 and 63257. Results are presented in Table 4-3. All NDBC Buoy data have similar storm wave characteristics, with a 10-year storm wave height of approximately 7.7 meters. The WIS hindcast model data tends to over predict the storm wave heights with results getting larger as time increases. This is especially true for WIS station 63257, which differs from the NDBC buoys ~4.5-meters in 100-years.

Table 4-3 – Return period (years) for extreme significant wave heights (m) using the Fisher-Tippett Distribution on NDBC buoy data and Wave Information Study hindcast model. Inputs were hourly significant wave height (m), peak wave period (s), and mean wave period (s).

Buoy	Years	1-year	5-year	10-year	25-year	50-year	100-year
44014 (offshore VA)	32	5.6	7.3	7.8	8.5	9.0	9.5
44086 (Nags Head, NC)	5	4.5	7.0	7.7	8.7	9.4	10.2
44095 (Oregon Inlet, NC)	11	5.3	7.1	7.6	8.4	8.9	9.4
WIS 44010	20	4.9	7.6	8.4	9.5	10.2	11.0
WIS 63257	20	5.0	9.3	10.6	12.3	13.5	14.8

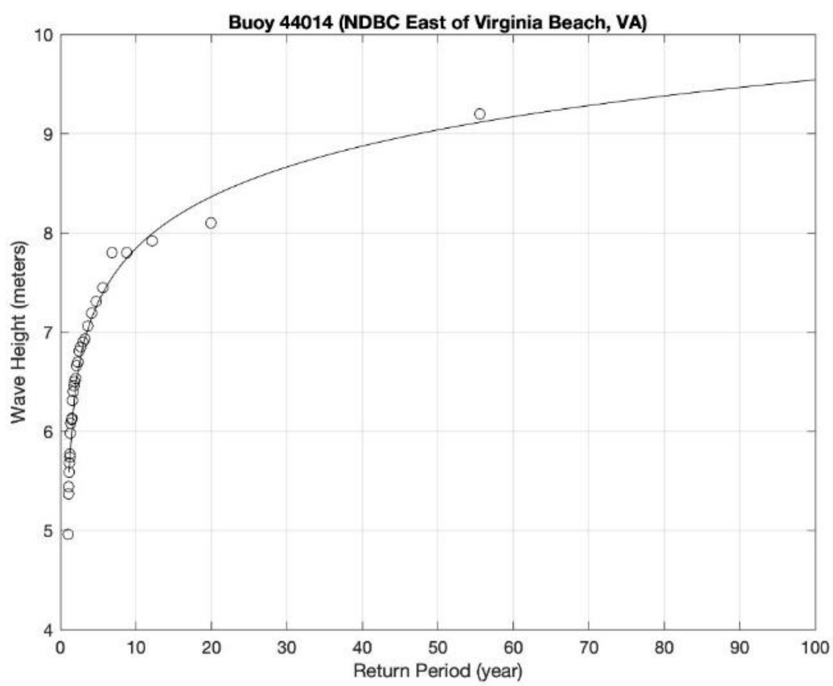


Figure 4-24 – Return period for extreme significant wave heights (m) using monthly average of the hourly significant wave height (m) data for Station 44014, east of Virginia Beach, VA. The black circles are the calculated storm wave heights; the black line is the line fitted to the output.

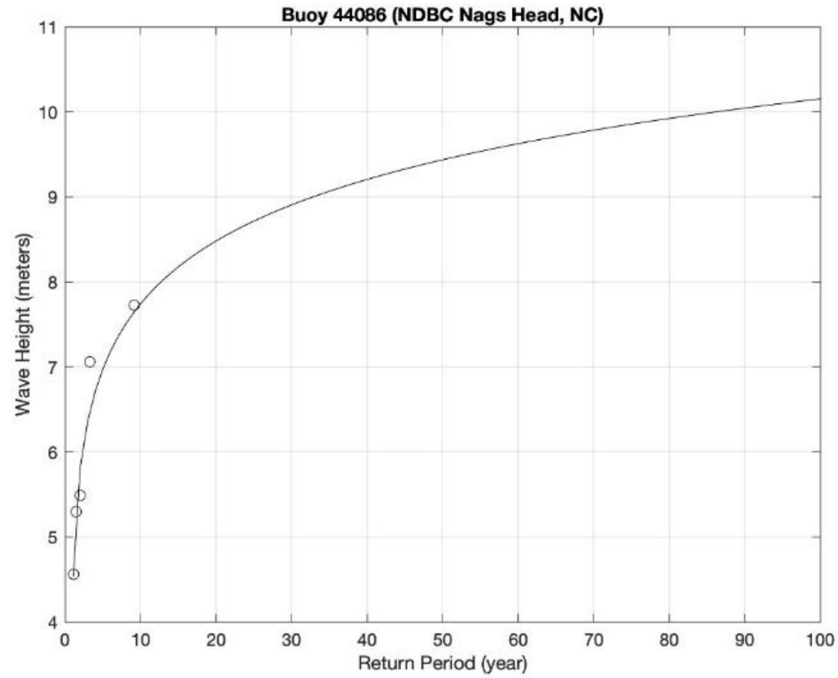


Figure 4-25 – Return period for extreme significant wave heights (m) using monthly average of the hourly significant wave height (m) data for Station 44086, Nags Head, NC. The black circles are the calculated storm wave heights; the black line is the line fitted to the output.

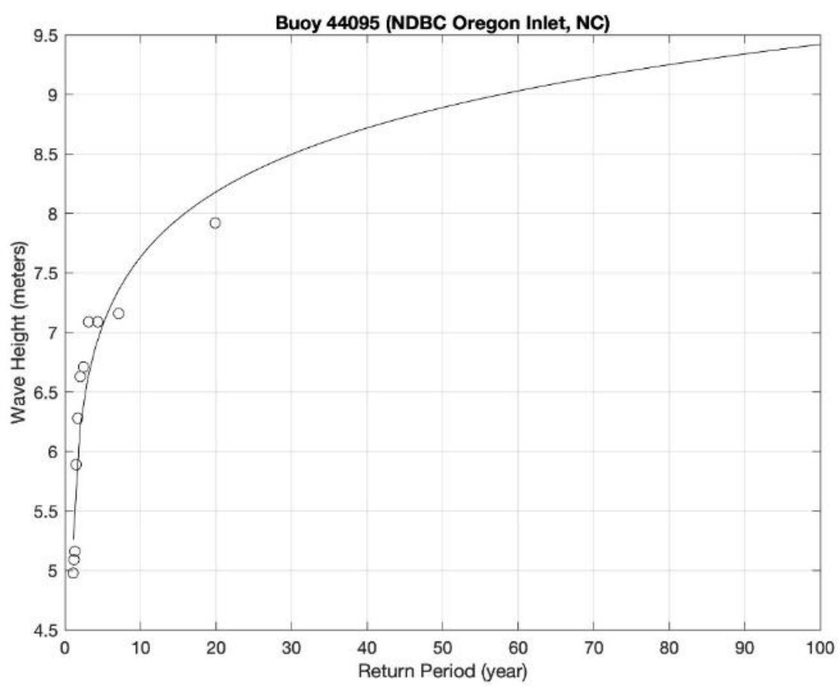


Figure 4-26 – Return period for extreme significant wave heights (m) using monthly average of the hourly significant wave height (m) data for Station 44095, Oregon Inlet, NC. The black circles are the calculated storm wave heights; the black line is the line fitted to the output.

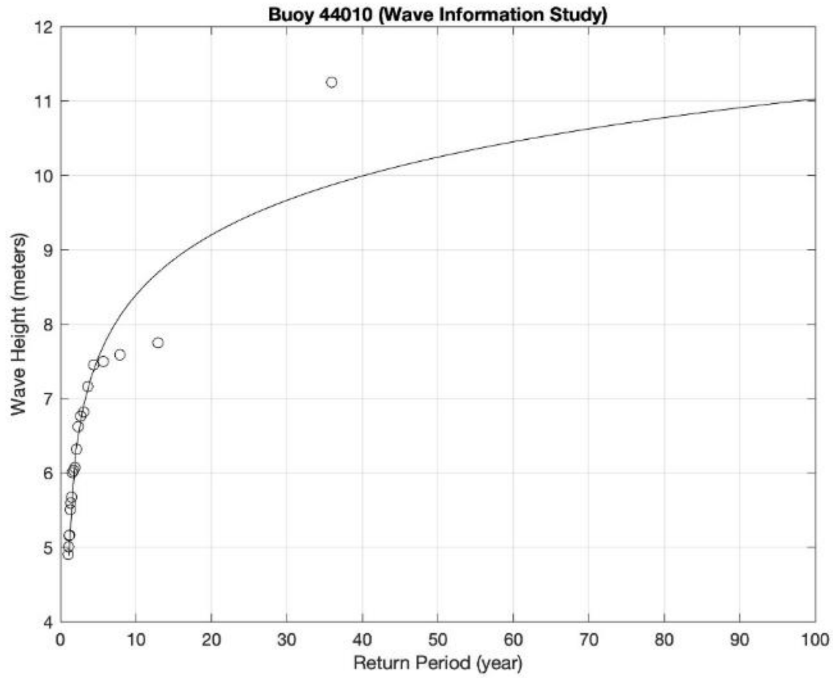


Figure 4-27 – Return period for extreme significant wave heights (m) using monthly average of the hourly significant wave height (m) data for WIS Station 44010. The black circles are the calculated storm wave heights; the black line is the line fitted to the output.

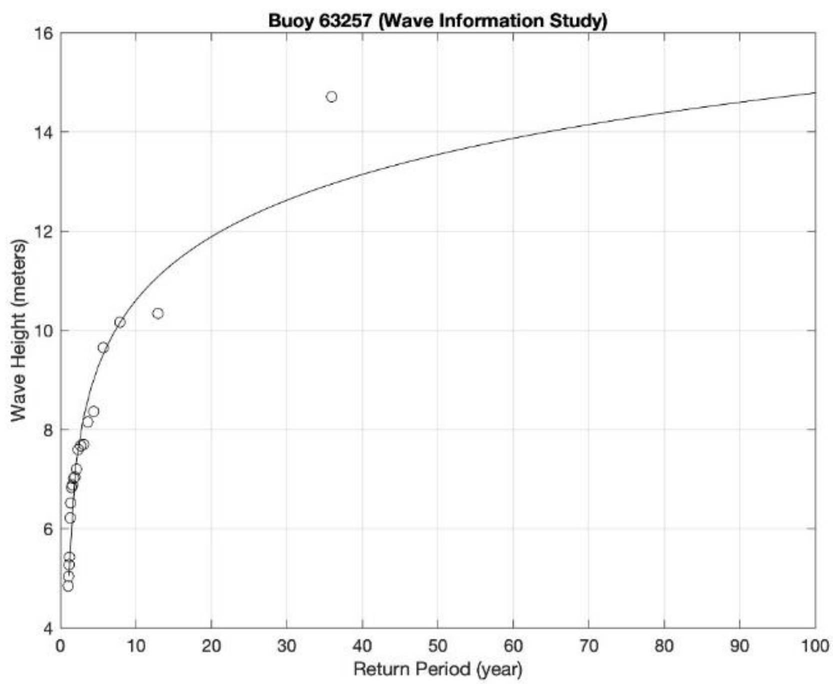


Figure 4-28 – Return period for extreme significant wave heights (m) using monthly average of the hourly significant wave height (m) data for WIS Station 63257. The black circles are the calculated storm wave heights; the black line is the line fitted to the output.

4.3. Major Storm Events

Major storms in the area of interest include tropical storms, hurricanes, major hurricanes, and nor’easters. Tropical storms and hurricanes are warm-core lows that usually occur between June and November and are categorized by the Saffir-Simpson Hurricane Wind Scale (Table 4-4). Storms with a defined circulation pattern and sustained winds greater than 38 mph are predetermined given names by the National Hurricane Center (www.law.cornell.edu/definitions). During hurricane events, wind and waves bring colder saltier waters up from below causing water temperatures to drop and salinity to rise. The increased salinity remains high and does not decrease as quickly as temperature, etc. The rainfall does not make the surface water fresher as one might expect.

Nor'easters are cold-core lows that form along the East Coast of North America and usually occur between October and April. Nor'easters are named after the strongest wind direction blows over the northeast states, including the Mid-Atlantic and New England regions (https://scijinks.gov/noreaster).

Table 4-4 – Saffir-Simpson Hurricane Wind Scale

Storm Type	Category	Sustained Wind Speed (mph)
Tropical Depression	0	<38
Tropical Storm		39-74
Hurricane	1	74-95
	2	96-110
Major Hurricane	3	111-129
	4	130-156
	5	>157

Tropical Storms and Hurricanes

The National Hurricane Center (NHC) has summarized the number of hurricanes and the number of named storms in the Atlantic Ocean for the months of August and September over the past 100 years (Figure 4-29, Figure 4-30, Figure 4-31, Figure 4-32). Cape Hatteras, which sits just to south of the Glider Box, touches the 35-49 hurricanes contour in both August and September (Figure 4-29, orange contour) while the Mooring Box region lies in the 20-34 hurricane contour for both months (Figure 4-30, green contour). While hard to tell at this scale, it looks as if the Mooring Box does lie wholly or partly within the 50-69 named storms region (Figure 4-31 and Figure 4-32, orange contour).

The National Hurricane Center has also summarized the Return Period (Years) for Hurricanes (Figure 4-33) and for Major Hurricanes (Figure 4-34). The Mooring Box return period for hurricanes lies in the 5-7 year range category (Figure 4-33), while for major hurricanes it lies somewhere in the 16–25-year range category (Figure 4-34).

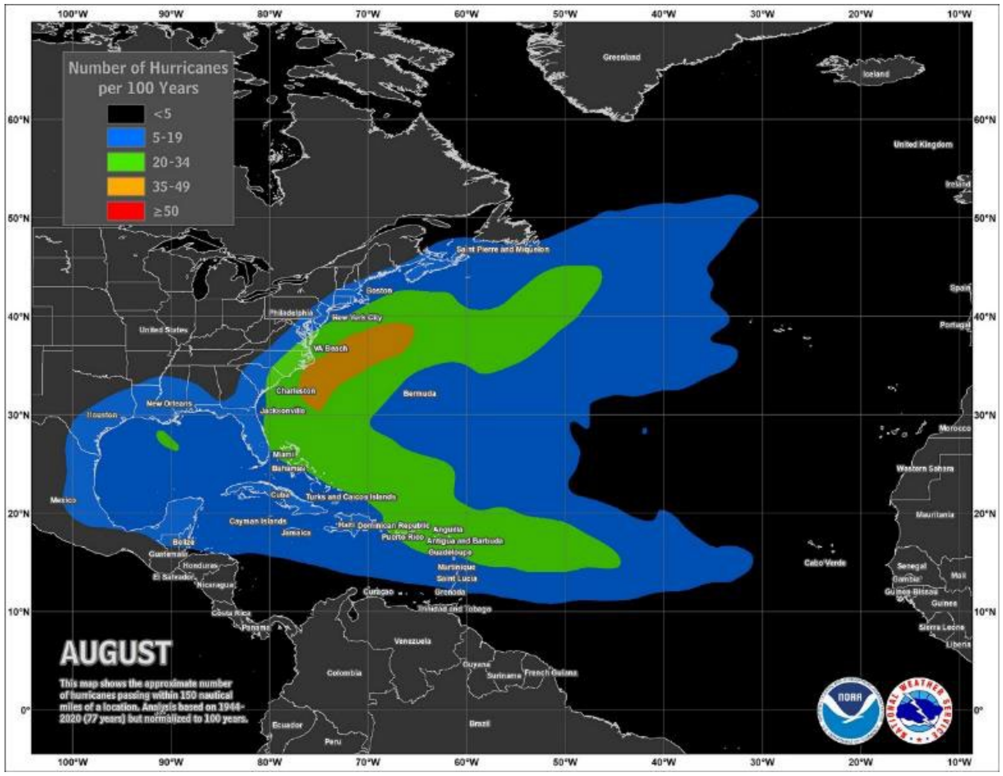


Figure 4-29 – Number of hurricanes per century during August (color shading). Colorbar shown in legend. Based on 77 years of data from 1944-2020 (NHC).

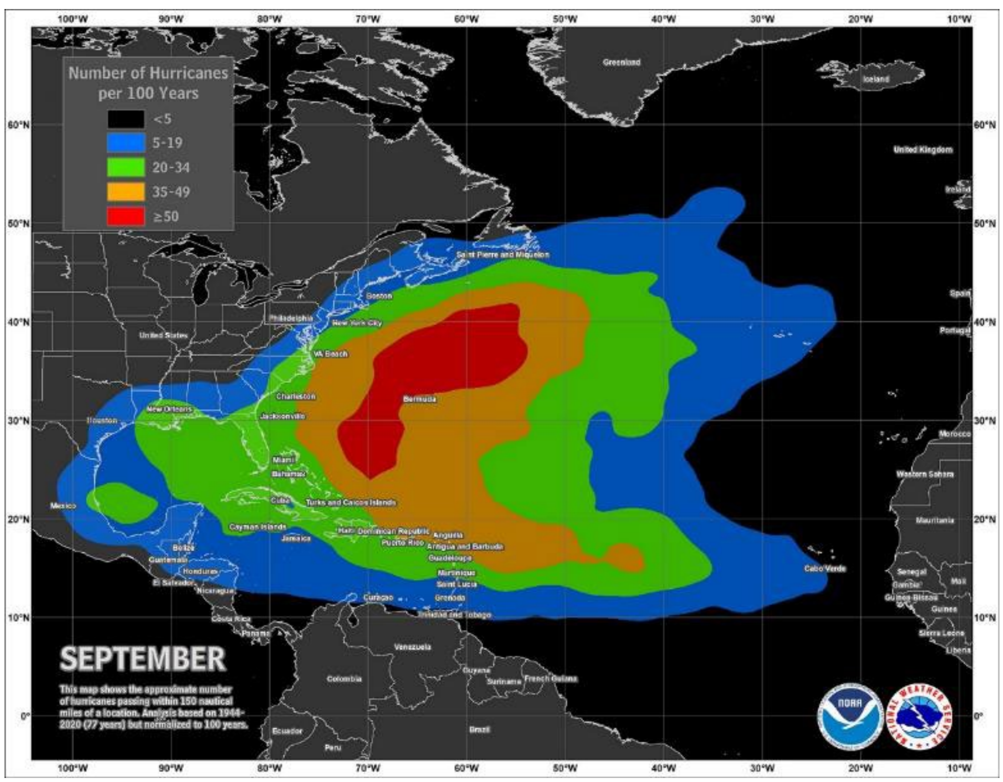


Figure 4-30 – Same as Figure 4-29, but for September (NHC).

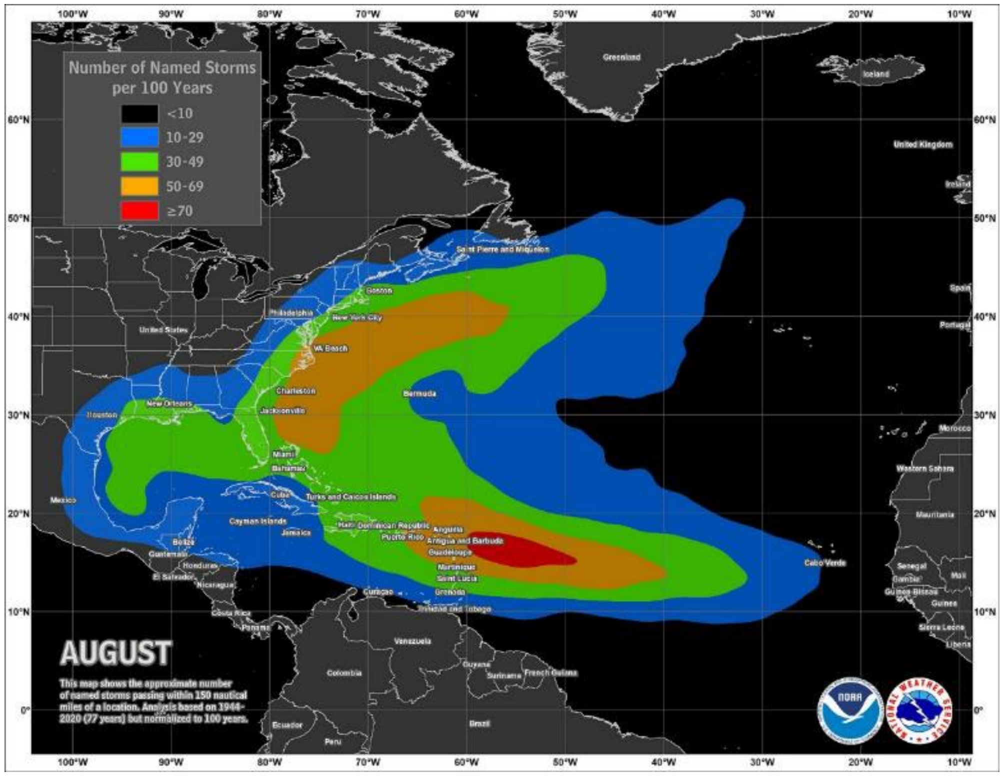


Figure 4-31 – Number of named storms per century during August (color shading). Colorbar shown in legend. Based on 77 years of data from 1944-2020 (NHC).

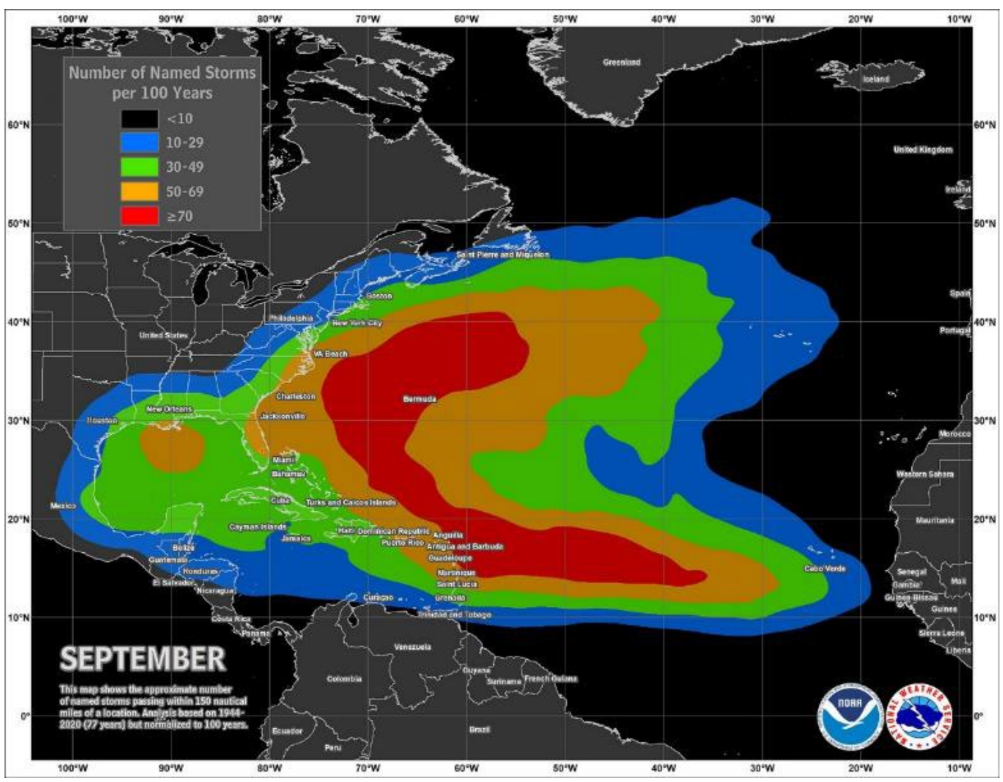


Figure 4-32 – Same as Figure 4-31, but for September (NHC).

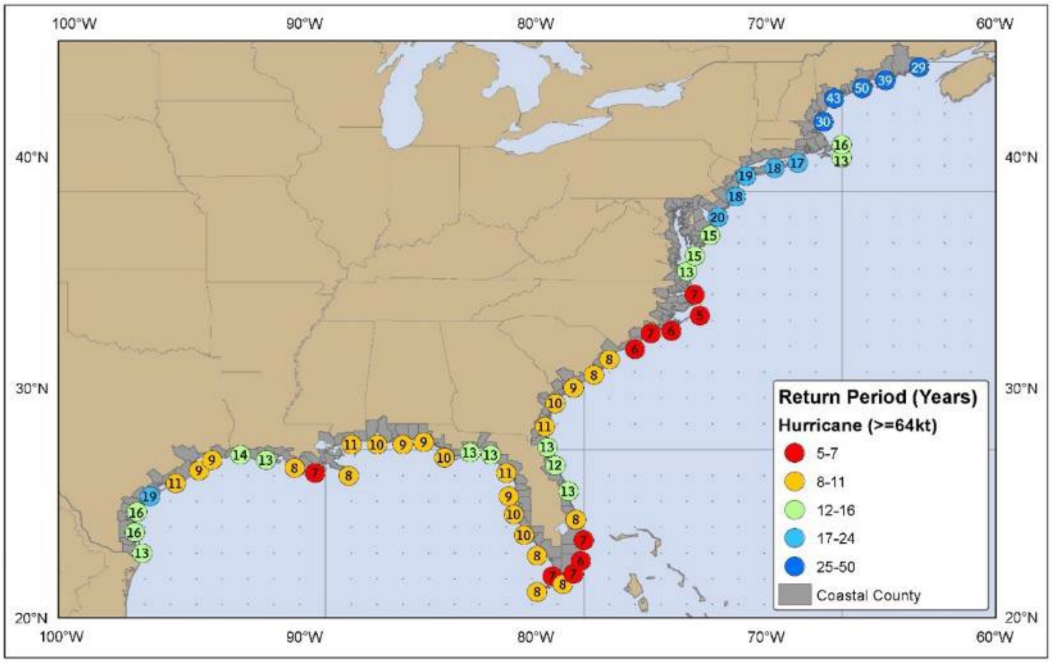


Figure 4-33 – Average number of years between hurricanes (storms with winds greater than 64 kts) along the gulf and east coasts of the United States (NHC).

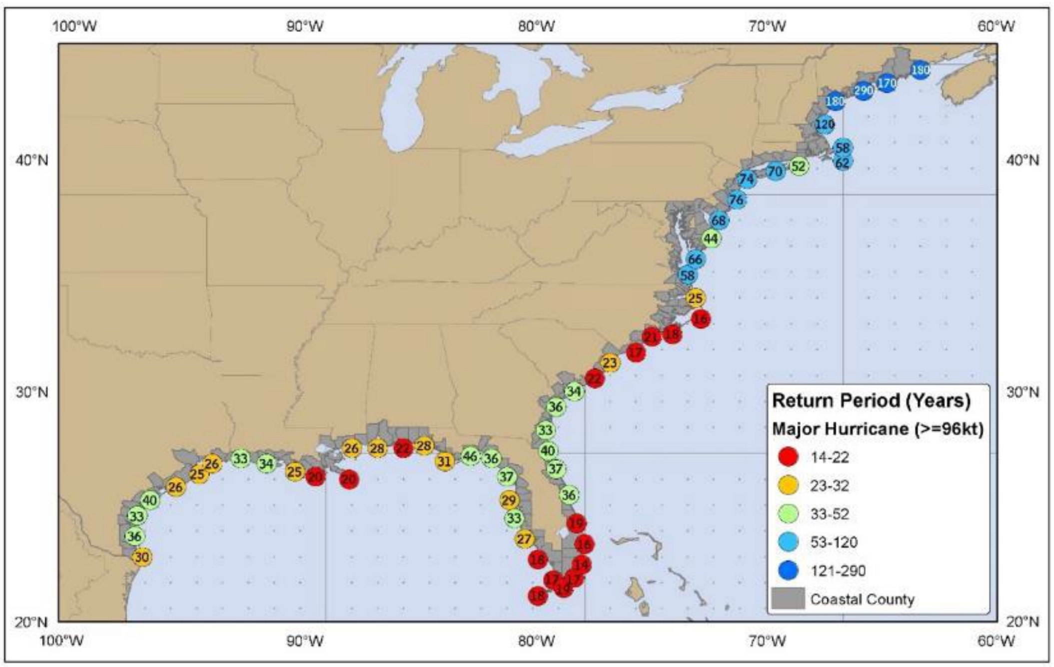


Figure 4-34 – Average number of years between major hurricanes (storms with winds greater than 96 kts) along the gulf and east coasts of the United States (NHC).

Between 2000-2021, 17 hurricanes occurred in the southern Mid-Atlantic Bight (Table 4-5 and Figure 4-35 through Figure 4-51). Of these, 11 made landfall and four were within 85, 140, 210, and 330 miles of the shore. The distance offshore was referenced to the southwest corner of the glider box [-75.3667, 35.5] since this was the closest point to shore within the box. Maximum wind speeds recorded at the NDBC Buoy 44095 never exceeded 70 mph. The maximum significant wave height for all storms was 7.2 meters (Hurricane Irene, 2011, Category 4) which is below the five-year event (return period) value of 7.3 meters. The maximum wave period (12.2 seconds) was during Hurricane Earl in 2010, which was a Category 3. The maximum wind speed occurred during Hurricane Dorian in 2019, which was a Category 2.

Table 4-5 – Hurricanes in the Mid-Atlantic Bight between 2000-2021 based on historical hurricane data from National Hurricane Data Center, WIS data, NDBC data (www.nhc.noaa.gov)

Year	Name	Date	Direction	Location	Category	Max Wind m/S	Peak Hs	Peak Ta	Storm event
2002	Gustav	Sep 10	NE	Within 10 miles of Outer banks, NC	TS to 1	18.1	5.08	7.85	>1
2003	Isabel	Sep 18	NW	Between Cape Lookout and Cape Hatteras, NC	2	22.2	N/A	N/A	n/a
2004	Alex	Aug 3	NNE	Within 10 miles of Outer banks, NC	1	17.3	4.01	7.12	>1
	Charley	Aug 15	NE	West of NC coast	1 to TS	15.8	2.72	7.12	>1
2005	Ophelia	Sep 15-16	NE	Stalled offshore Oregon Inlet, NC (~55 miles offshore)	1	13.1	3.95	8.44	>1
2010	Earl	Sept 3	NNW	~Offshore 85 miles	1 to2	N/A	6.90	12.24	3
2011	Irene	Aug 27	NNE	Near Cape Lookout, NC	1	21.4	7.19	8.94	4
2014	Arthur	Jul 3-4	NNE	Between Cape Lookout and Beaufort, NC	2	21.4	6.58	8.05	2
	Bertha	Aug 5	NE	~Offshore 140 miles	1 to TS	10.4	2.18	8.58	>1
2016	Hermine	Sep 6	NE	Nags Head, NC	TS	24.3	6.55	9.47	2
	Matthew	Oct 9	E	Turns eastward off Cedar Island	1	26.0	6.85	8.25	3
2017	Gert	Aug 15	NE	~Offshore 330 miles	1	10.5	2.43	9.52	>1
	Jose	Sep 19	N	~Offshore 210 miles	1	17.3	6.56	10.5	3
	Maria	Sep 27	E	~Offshore 140 miles	1	17.3	6.81	10.5	3
2018	Chris	Jul 9	NE	~Offshore 140 miles	2	13.8	3.5	8.1	>1
	Florence	Sep 13	NW	Landfall south of Morehead City, NC	2	13.0	4.78	10.75	3
2019	Dorian	Sep 6	NE	Landfall Outer banks, North Carolina	2	28.3	6.53	8.02	2

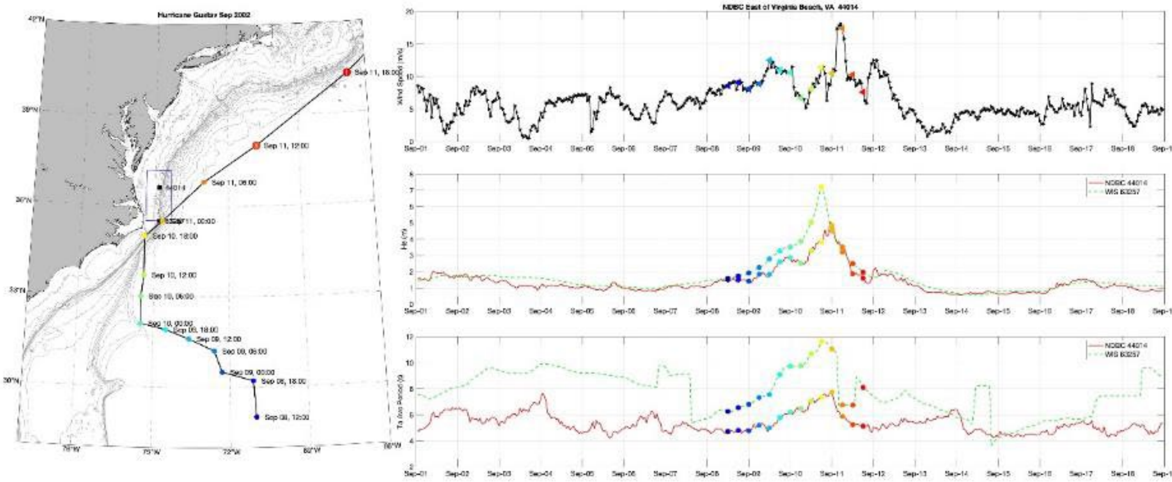


Figure 4-35 – September 2002 Hurricane Gustav map of storm path with dates and times of day (left panel); wind speed (m s^{-1}) versus date with colored dots indicate times shown in map on the left (top right panel); wave height (m) versus time (middle panel on right); average period (s) versus time (bottom panel on right panel). Time is 7-days before and 7-days after the storm. Wind and wave data is from NODC buoys (specified in legend) and WIS hindcast data. Blank panel indicates no data was available.

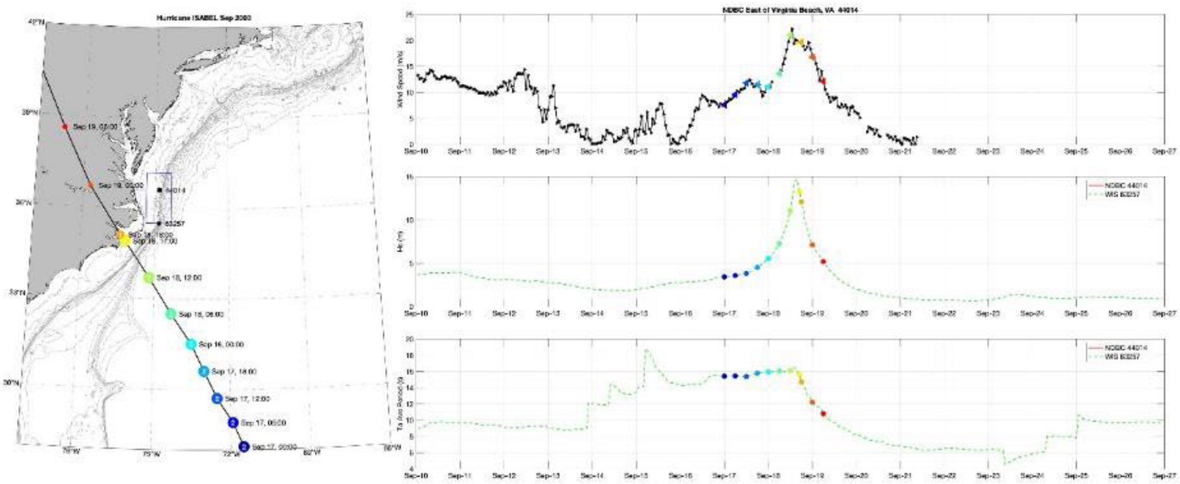


Figure 4-36 – Same as Figure 4-35 but for September 2003 Hurricane Isabel.

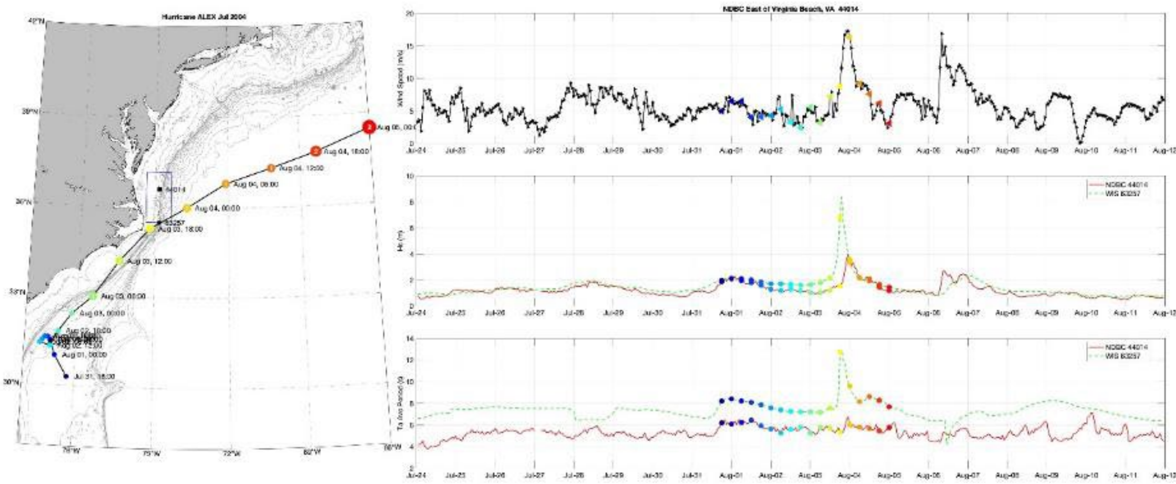


Figure 4-37 – Same Figure 4-35, but for August 2004 Hurricane Alex.

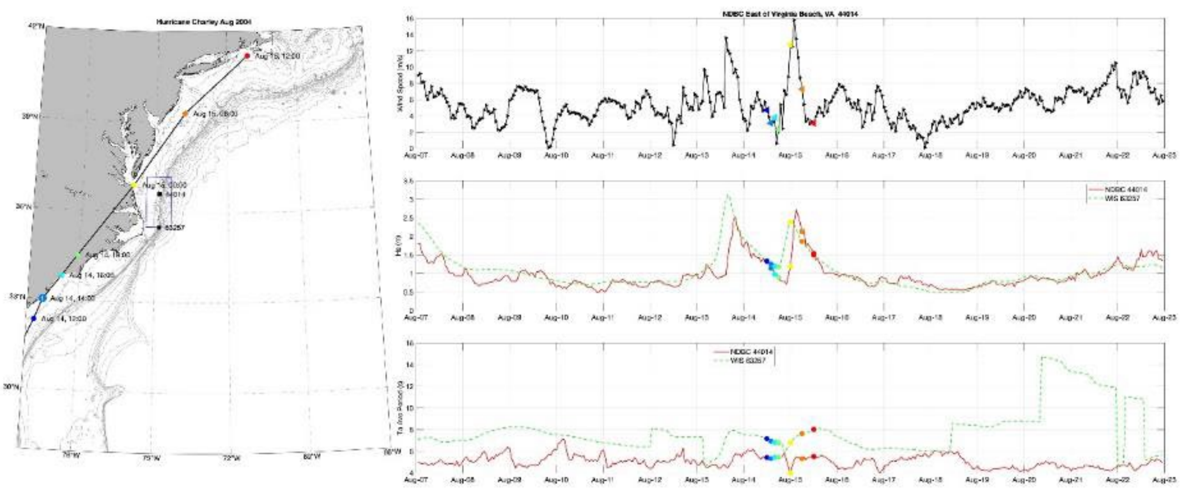


Figure 4-38 – Same Figure 4-35, but for August 2004 Hurricane Charley.

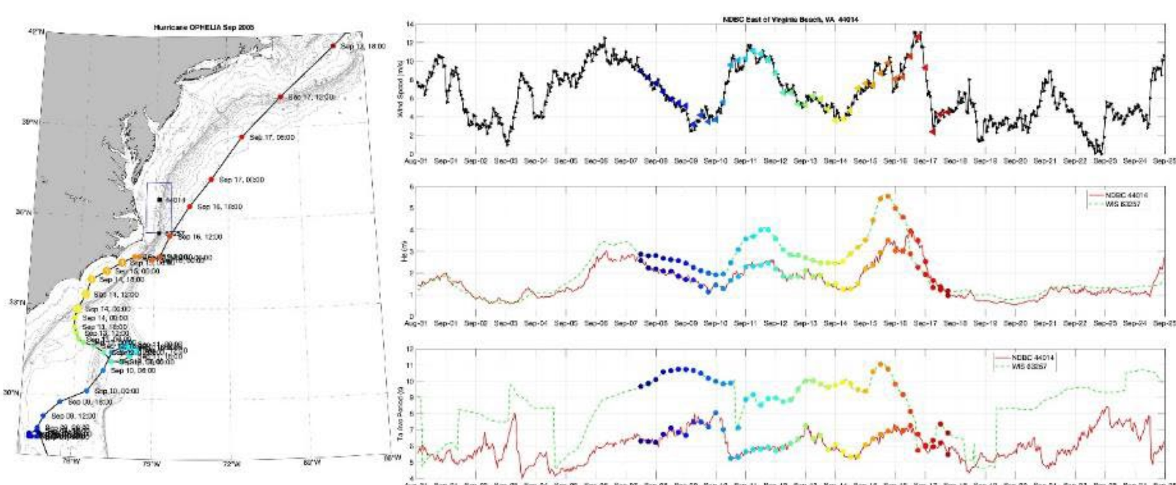


Figure 4-39 – Same Figure 4-35, but for September 2005 Hurricane Ophelia.

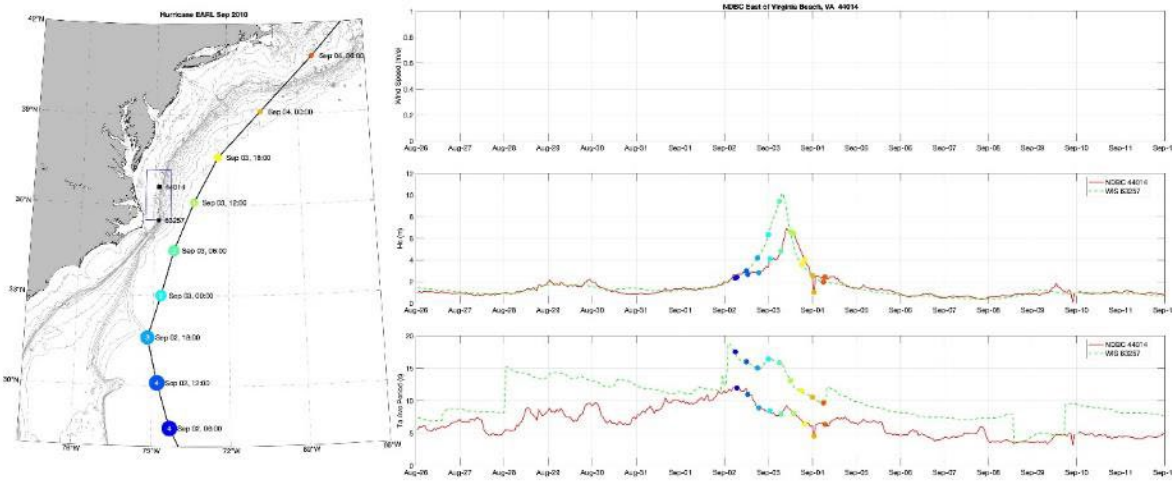


Figure 4-40 – Same Figure 4-35, but for September 2010 Hurricane Earl.

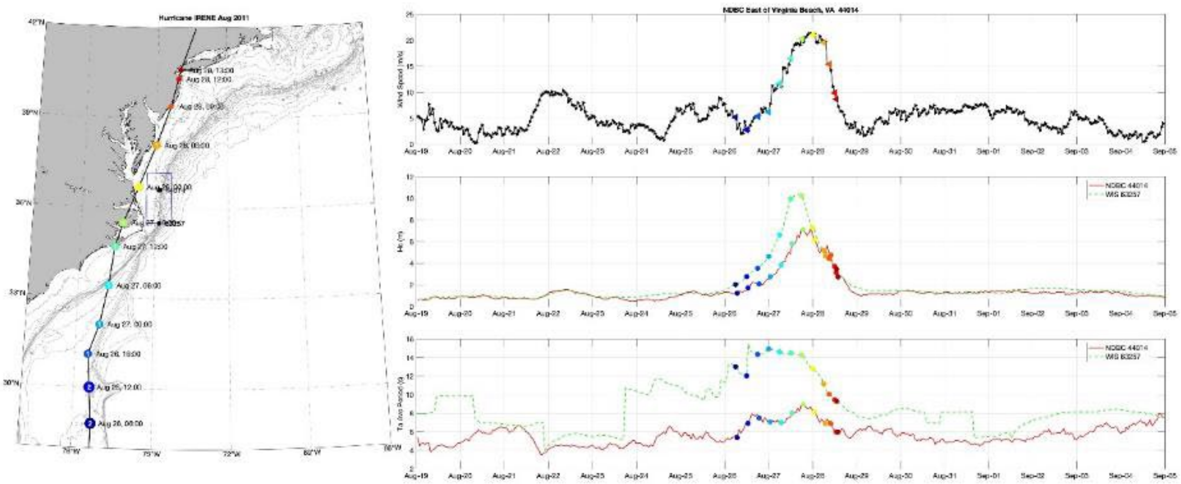


Figure 4-41 – Same Figure 4-35, but for August 2011 Hurricane Irene.

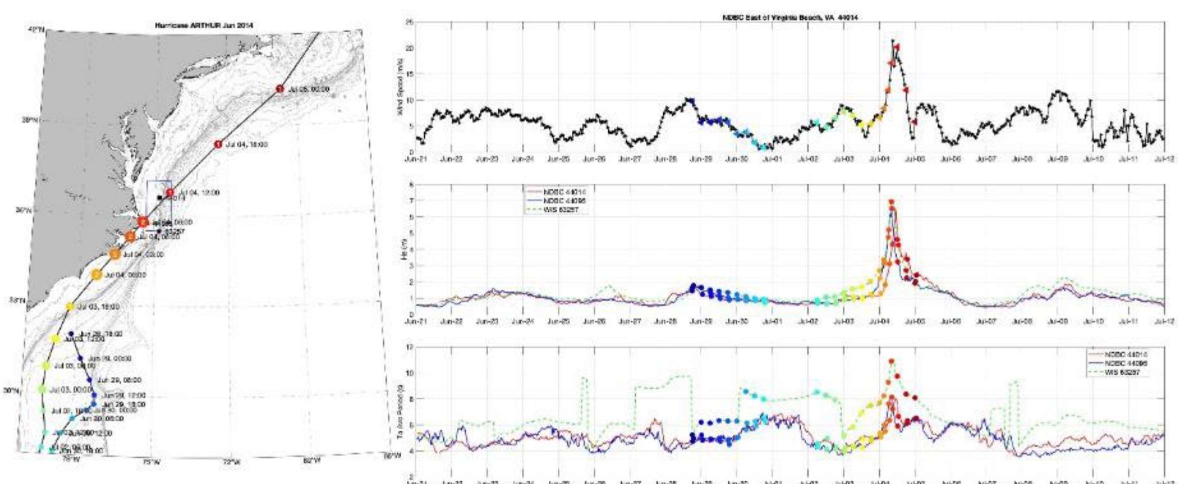


Figure 4-42 – Same Figure 4-35, but for June 2014 Hurricane Arthur.

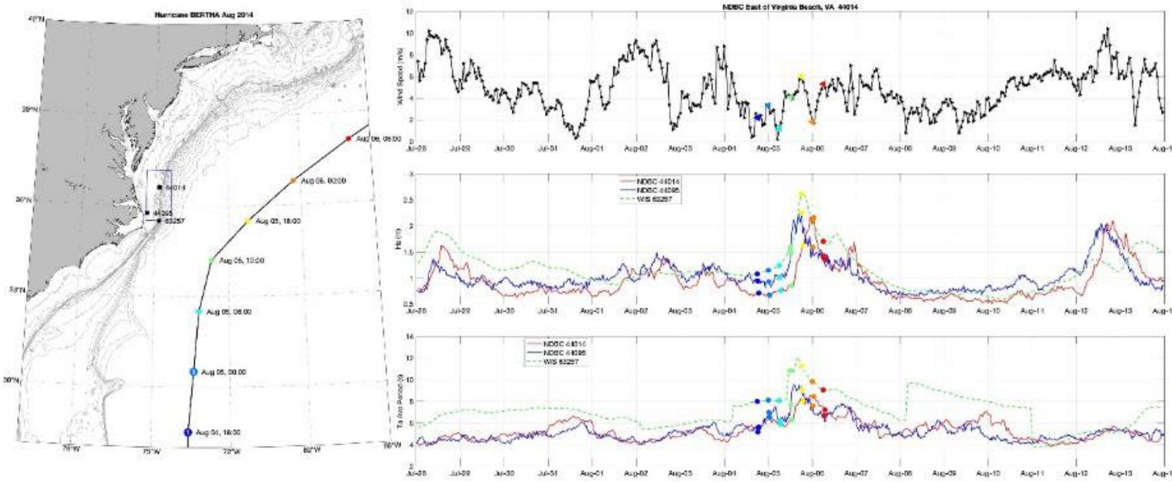


Figure 4-43 – Same Figure 4-35, but for August 2014 Hurricane Bertha.

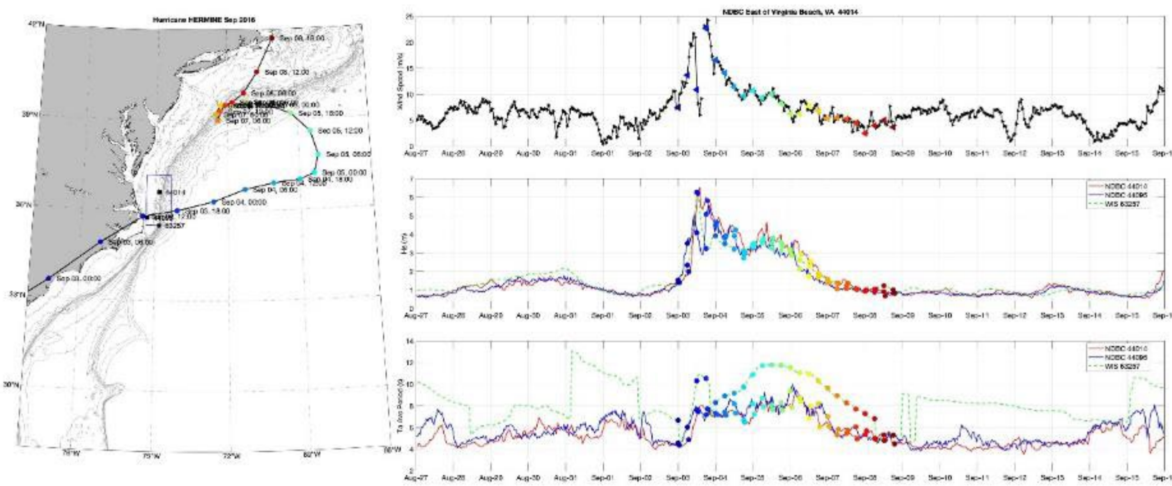


Figure 4-44 – Same Figure 4-35, but for September 2016 Hurricane Hermine.

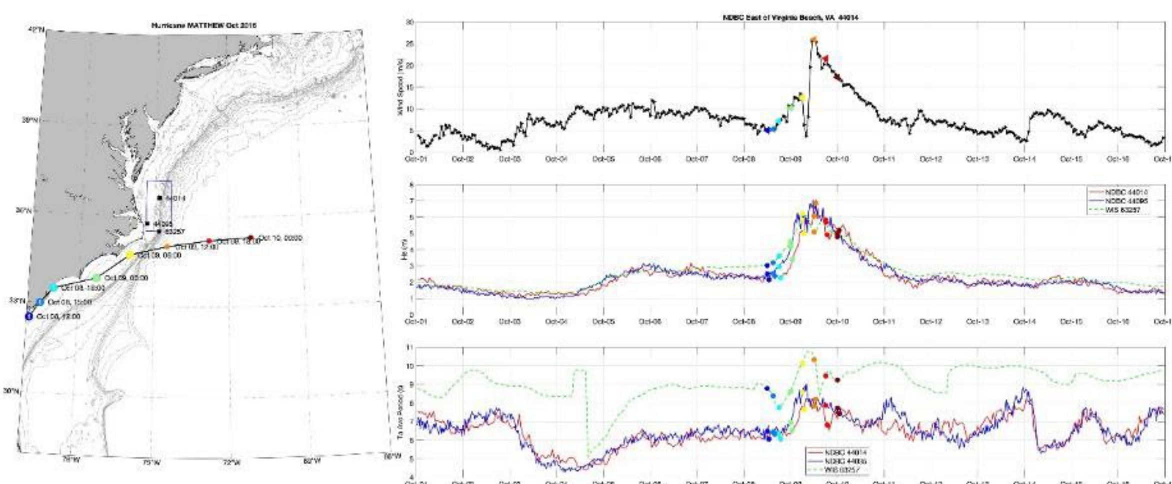


Figure 4-45 – Same Figure 4-35, but for October 2016 Hurricane Matthew.

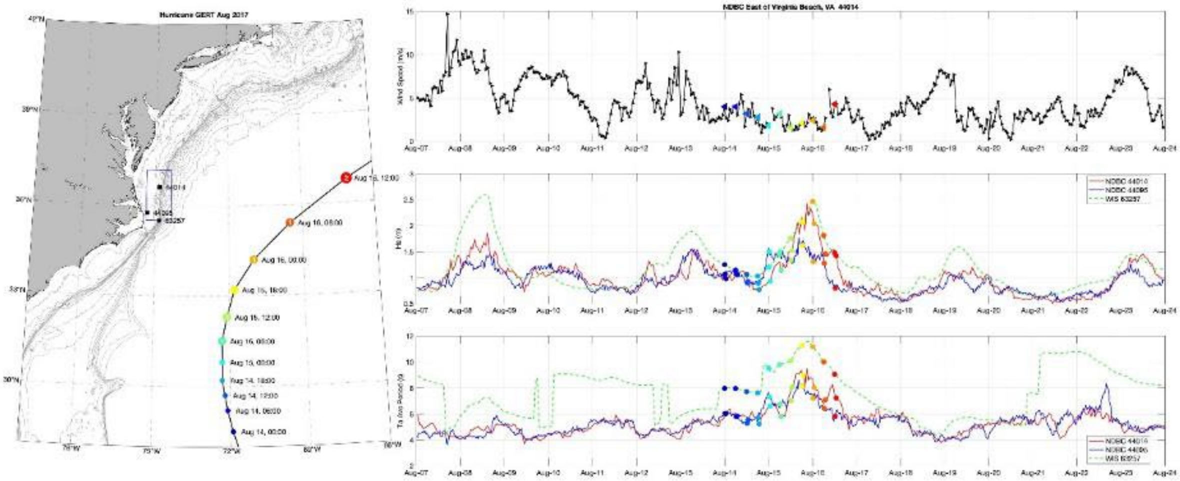


Figure 4-46 – Same Figure 4-35, but for August 2017 Hurricane Gert.

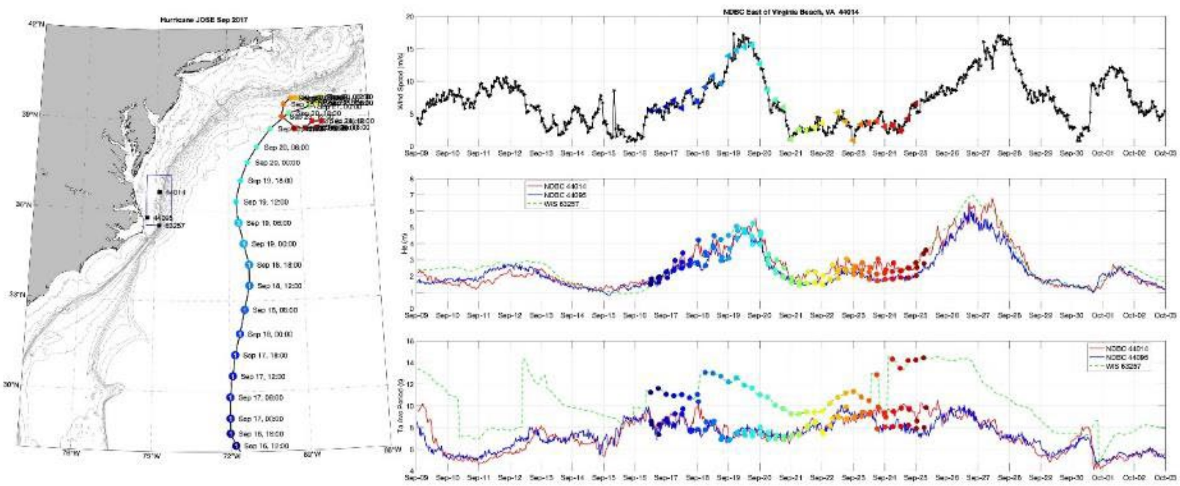


Figure 4-47 – Same Figure 4-35, but for September 2017 Hurricane Jose.

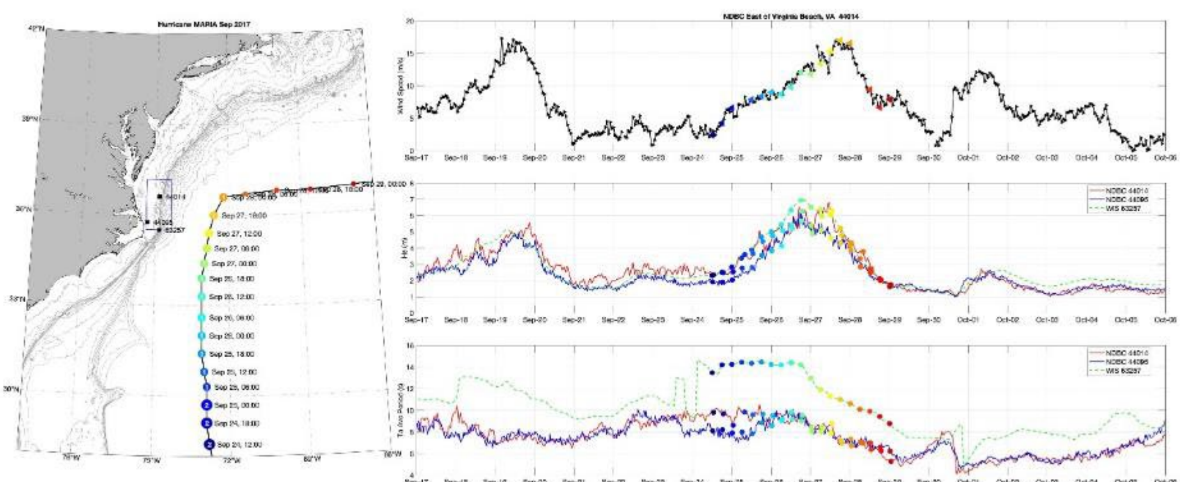


Figure 4-48 – Same Figure 4-35, but for September 2017 Hurricane Maria.

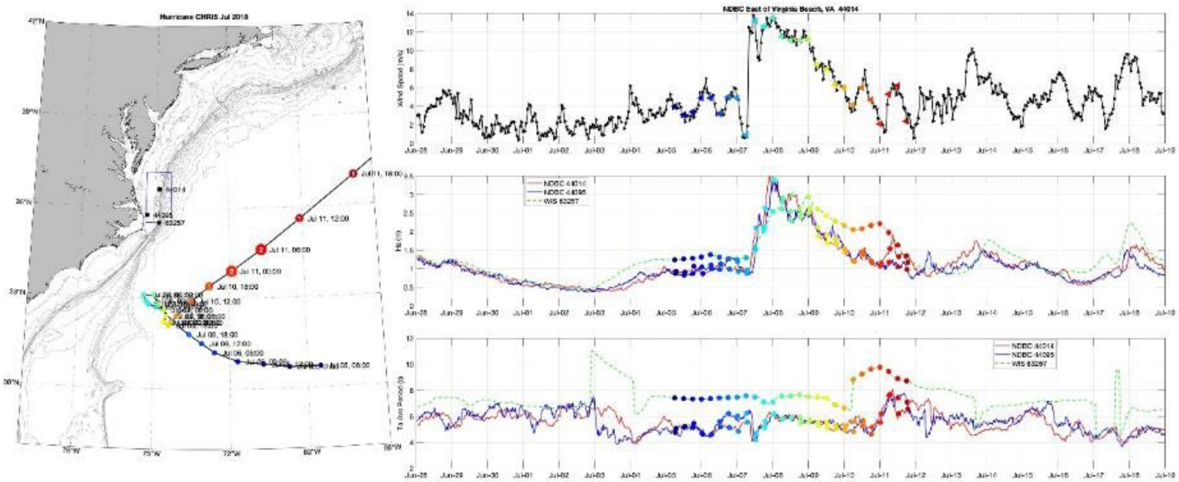


Figure 4-49 – Same Figure 4-35, but for July 2018 Hurricane Chris.

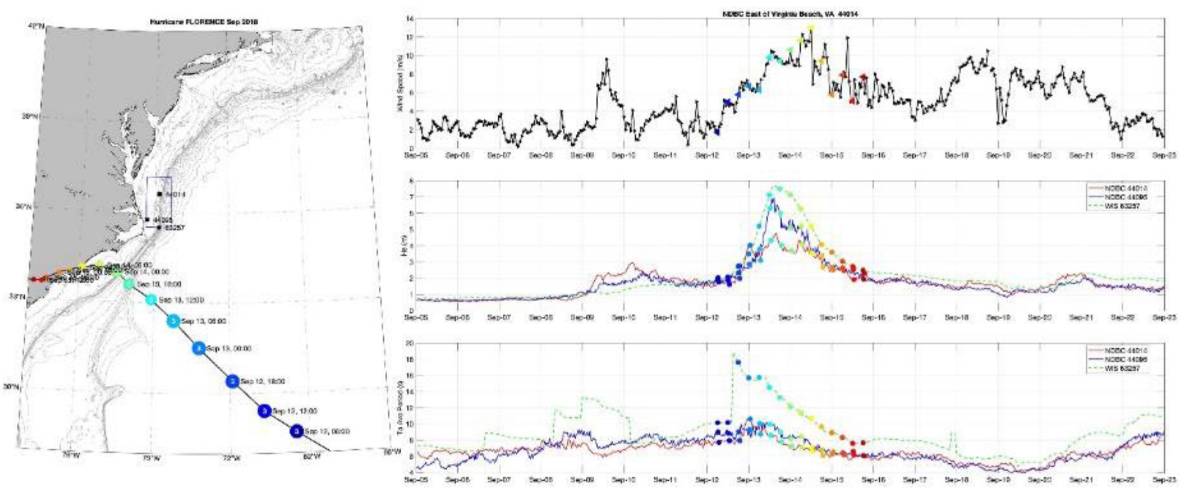


Figure 4-50 – Same Figure 4-35, but for September 2018 Hurricane Florence.

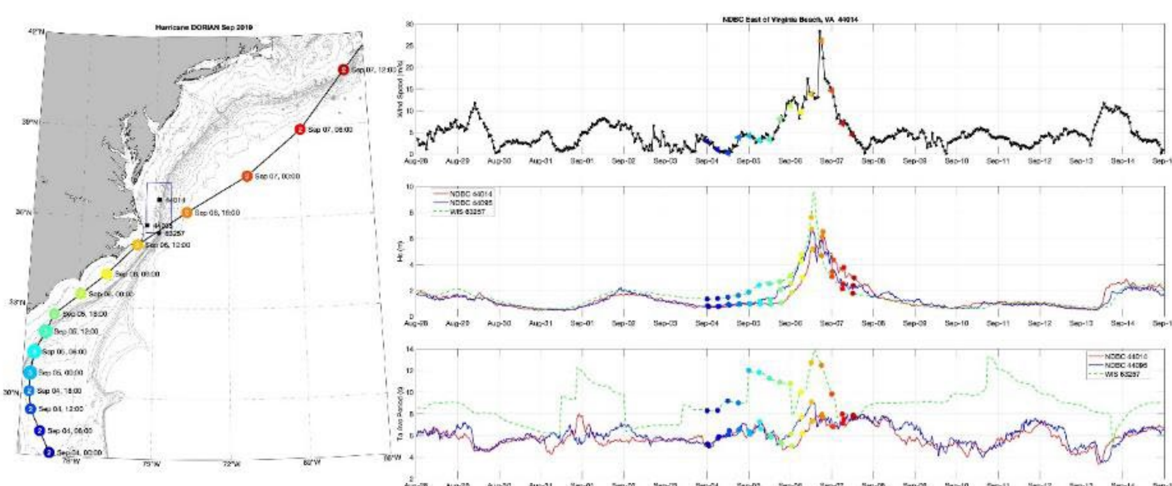


Figure 4-51 – Same Figure 4-35, but for September 2019 Hurricane Dorian.

Nor’easters

Nor’easters are massive storms generally without a clearly defined eye, but with a low pressure core and winds circling to the right (i.e. counterclockwise). The warm air from the storm interacts with the cold air as it moves northeast. As these storms move northward, wave periods tend to stay long as swell continues to be generated from Greenland. Nor’easters can cause severe snowstorms, heavy rain, gale force winds, and excessive flooding.

Between 2000-2017, there were nine major nor’easters in the Mid-Atlantic Bight (Table 4-6). The maximum significant wave height was 7.3 meters during Winter Storm Grayson in 2018. The maximum wave period was 11.7 seconds, during Winter Storm Riley. The blizzard of 2018 (Jan 2-6) was a five-year storm event; all other storms were less than a five-year storm event. Note that the two longest wave periods were associated with slow-moving winter storms (Riley, 2018; Jonas 2016). The largest wave heights were associated with a winter storm (Grayson, 2018) and a hurricane (Ida, 2009).

Table 4-6 – Noteworthy Nor’easters in the Mid-Atlantic Bight between 2000-2021 based on historical data records. Wind and wave data from NDBC Buoy (www.nhc.noaa.gov).

Year	Name	Date	Maximum wind speed m/a	Peak Hs	Peak Ta	Storm event
2003	President’s Day Storm II	Feb 14-19	16.3	5.77	8.6	1
2009	Nor’ Ida (remnants of Hurricane Ida in Gulf)	Nov 11-17	19	7.06	9.71	4
2010	Blizzard of 2010 (severe, long-lasting blizzard)	Dec 5-15	N/A	4.48	7.74	>1
2011	Blizzard of 2011 (first of two, back-to-back)	Jan 8-13	N/A	3.76	7.42	>1
2011	Blizzard of 2011 (second of two, back-to-back)	Jan 25-27	N/A	3.99	7.88	>1
2015	Blizzard of 2015	Jan 23-31	17.4	4.59	8.71	>1
2016	Winter Storm Jonas, Snowzilla, The Blizzard of 2016	Jan 19-29	19.3	6.13	10.32	2
2018	Winter Storm Grayson, Blizzard of 2018, Storm Brody	Jan 2-6	26.2	7.31	8.44	5
2018	Winter storm Riley (Nor’easter)	Mar 1-5	22.1	6.75	11.73	3

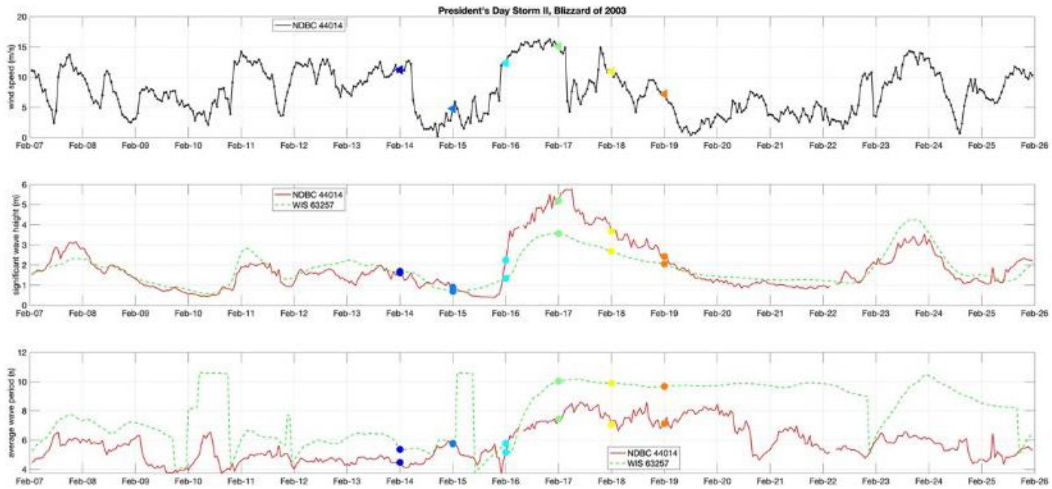


Figure 4-52 – 2003 President's Day Storm II Nor'easter wind speed (m s^{-1}) top panel; significant wave height (m) middle panel; wave period (sec) bottom panel. The figures span 7-days prior and 7-days post storm dates with colored markers marking the storm dates. The wind (black line) and wave (red line) data are from NDBC Station 44014. The green dashed line is hindcast data from the Wave Information Study (WIS). Blank panels indicate that no data were available.

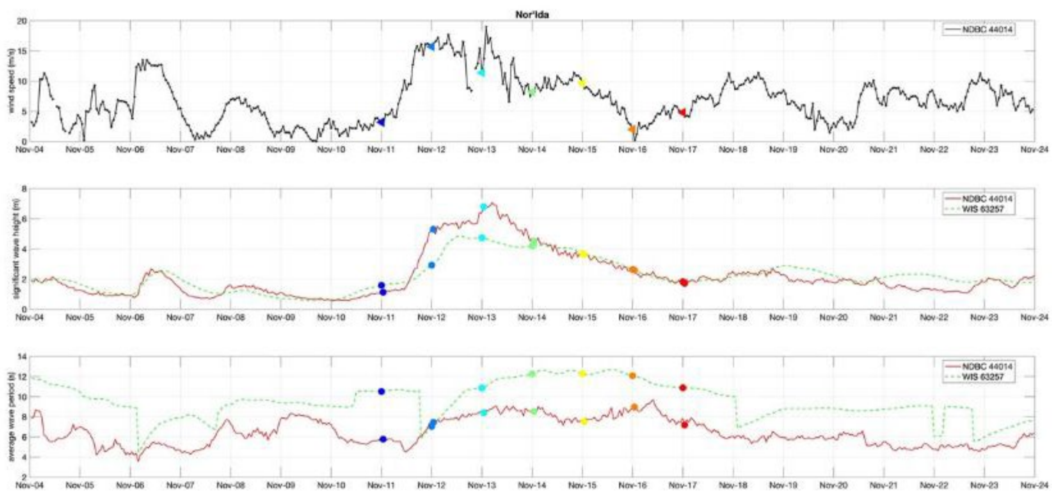


Figure 4-53 – Same as Figure 4-52, but for 2009 Ida Nor'easter.

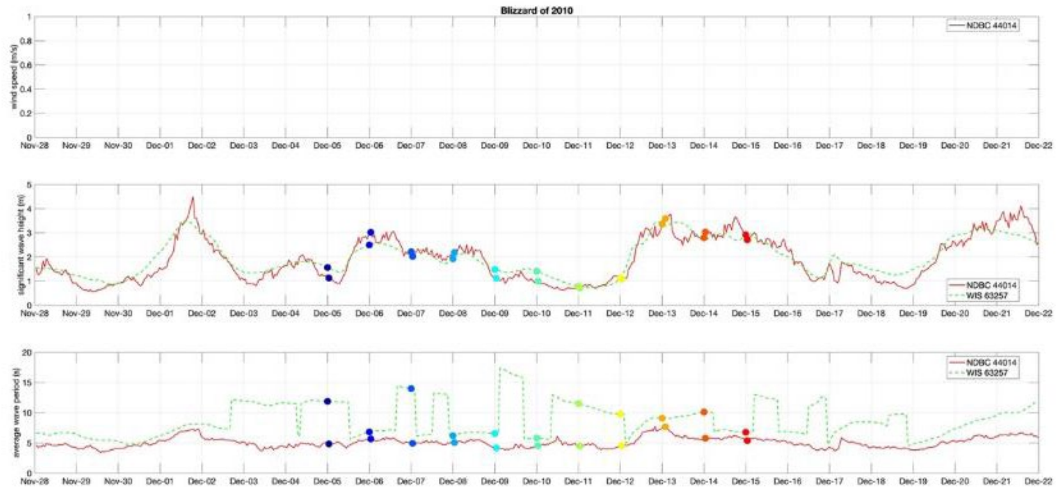


Figure 4-54 – Same as Figure 4-52, but for 2010 Blizzard.

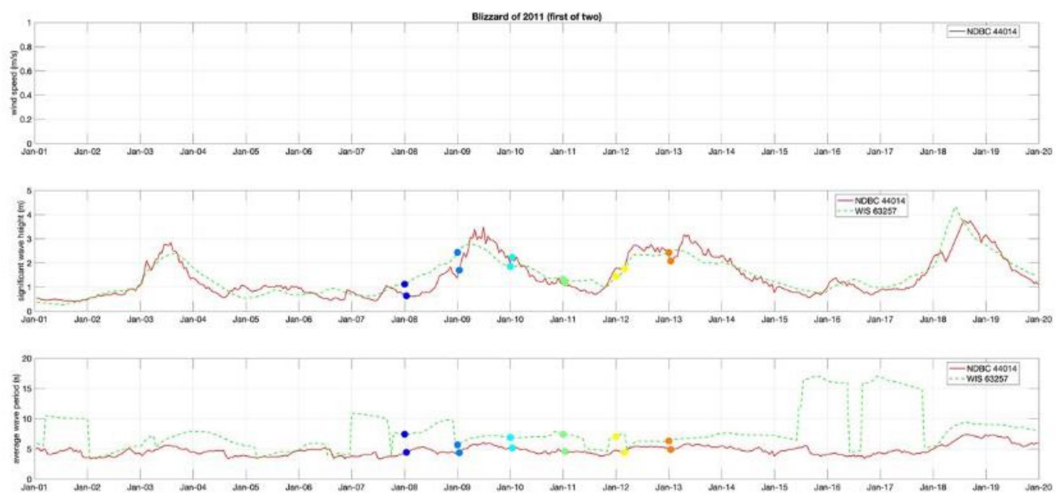


Figure 4-55 – Same as Figure 4-52, but for 2011 first Blizzard.

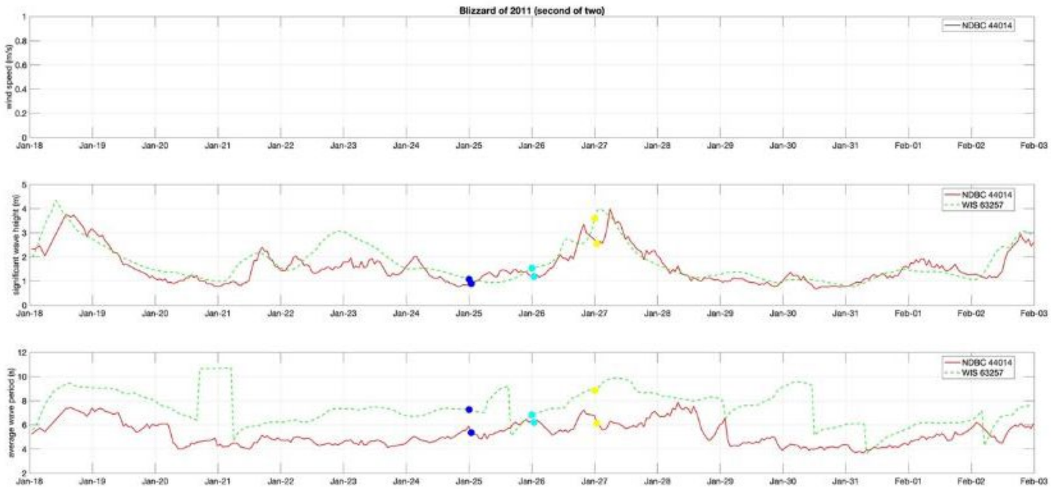


Figure 4-56 – Same as Figure 4-52, but for 2011 second Blizzard.

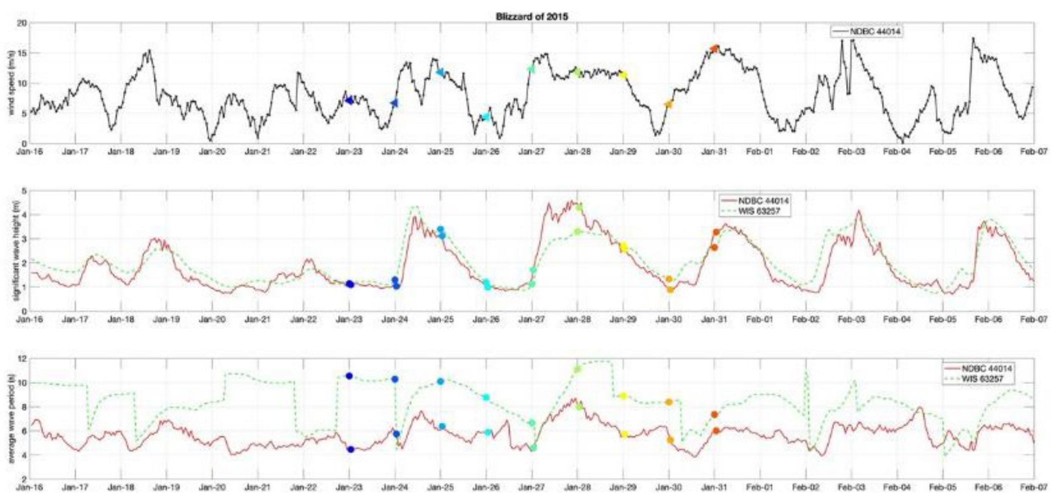


Figure 4-57 – Same as Figure 4-52, but for 2015 Blizzard.

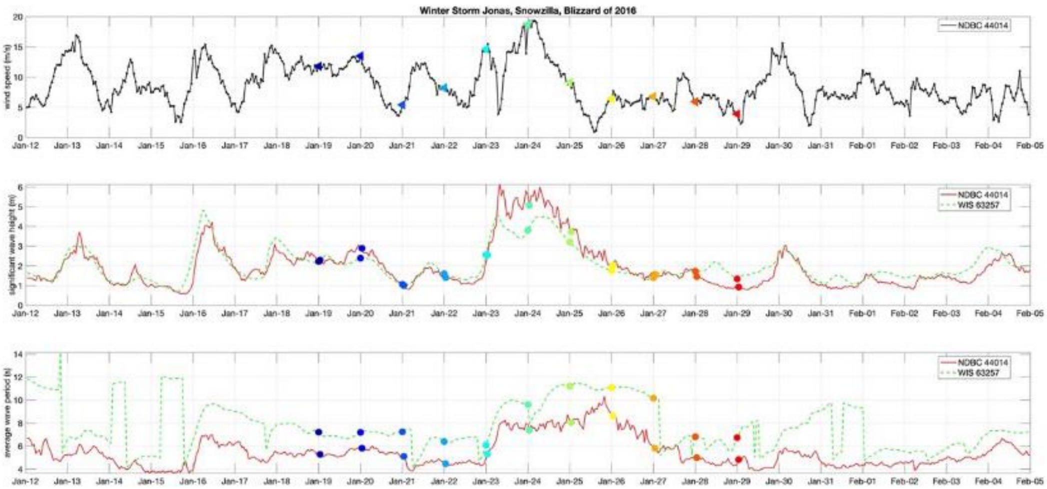


Figure 4-58 – Same as Figure 4-52, but for 2016 Winter Storm Jonas Blizzard, (also named Snowzilla).

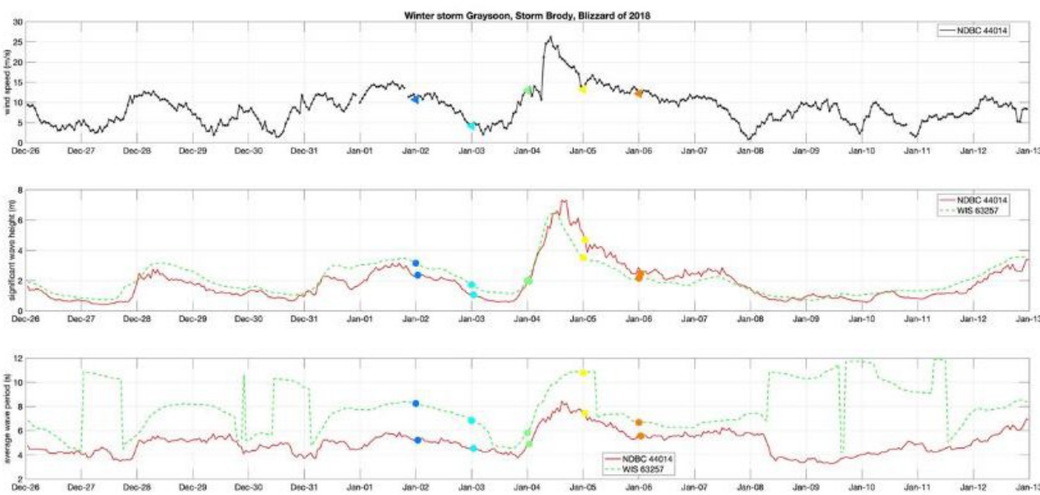


Figure 4-59 – Same as Figure 4-52, but for 2018 Blizzard Winter Storm Grayson (also named Storm Brody).

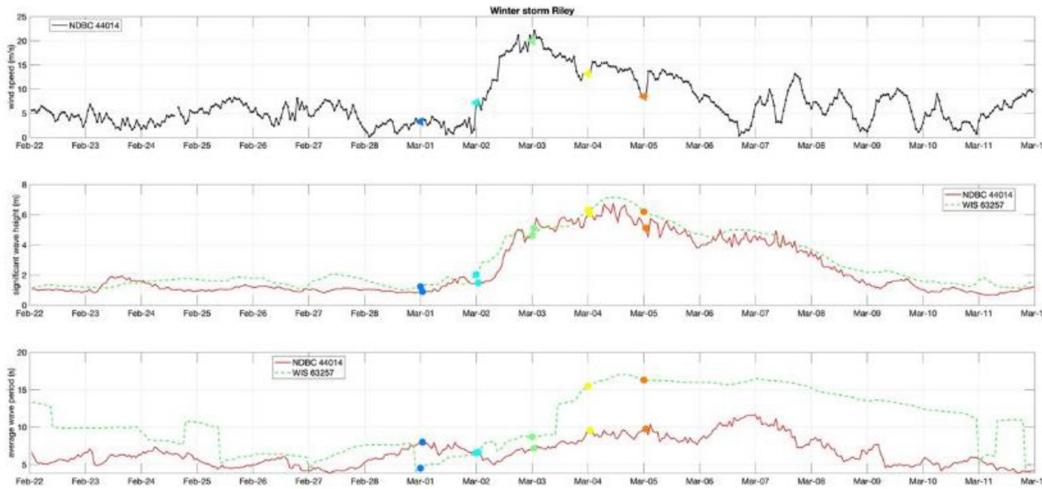


Figure 4-60 – Same as Figure 4-52, but for 2018 Nor'easter Winter Storm Riley.

It is worth noting that the PEACH Cruise Report (AR-33) stated that Buoys B1 and B2 were heavily damaged due to strong storms, particularly Winter Storm Riley (March 2018) and Hurricane Florence (September 2018), with a number of sensors damaged or missing. The PEACH Mooring report noted that mooring A3 moved downslope from 94 meters to 108 meters March 4, 2018 (during Winter Storm Riley). A disturbance in the bottom pressure of A1 also occurs March 4, 2018, although not as pronounced.

4.4. Solar radiation

Solar radiation (also known as shortwave radiation) data was available from NDBC Buoy #41035 located at inner Onslow Bay, NC, Figure 4-61 and Table 4-7. The data provided is the mean shortwave radiation (W/m^2) for the preceding hour with a sample frequency of 2Hz (https://www.ndbc.noaa.gov/). As expected, the highest daily averaged values are in May and June; the lowest are December and January (Figure 4-62).

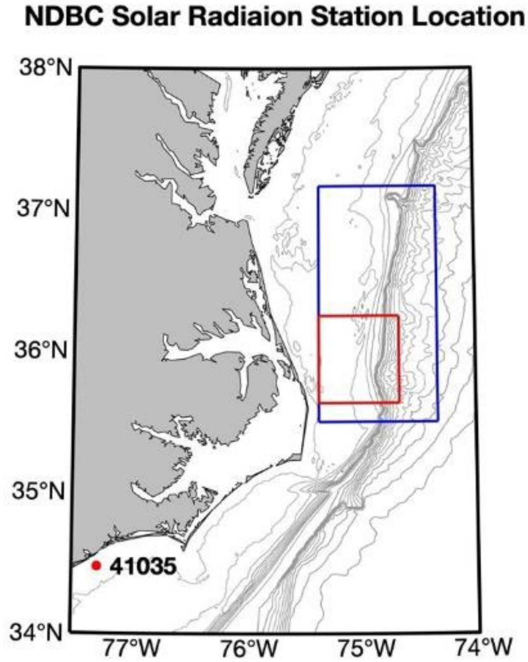


Figure 4-61 – NDBC Buoy 41035 location which provided shortwave solar radiation data for the site characterization.

Table 4-7 – Temporal and spatial information for NDBC Buoy 41035 and the reanalysis data from the Copernicus Climate Data Store used for the shortwave solar radiation data.

NDBC Buoy	Name	Location	Dates
41035	Onslow Bay Inner, NC	34.476 N, 77.280 W	Apr 1, 2006 - Sep 30, 2008 Apr 15, 2010 - Nov 30, 2010 Jan 1, 2011 - Aug 22, 2011
Reanalysis	Copernicus (CDS)	34.470 N, 77.300 W	Jan 1, 2006 - Dec 31, 2021

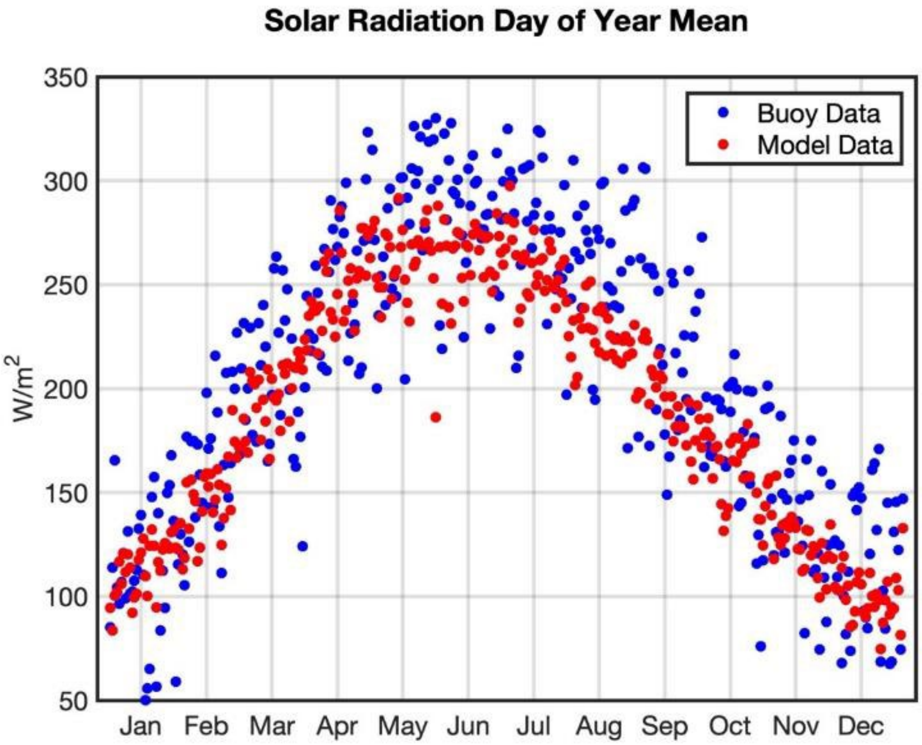


Figure 4-62 – Mean day of year for measured shortwave radiation (blue dots) and reanalysis shortwave radiation (red dots).

Mean one-hour surface downward shortwave radiation flux reanalysis data was downloaded from Copernicus Climate Data Store (Hersbach, et al., 2018). This parameter includes both direct and diffuse solar radiation. The reanalysis data has been mapped to a 0.25 deg x 0.25 deg grid. The data downloaded was from the closest location to Buoy Station 41035 (Table 4-7), starting January 1, 2006 until December 31, 2021. The model data follows the same trend of higher values in May and June and lowest values in December and January (Figure 4-63).

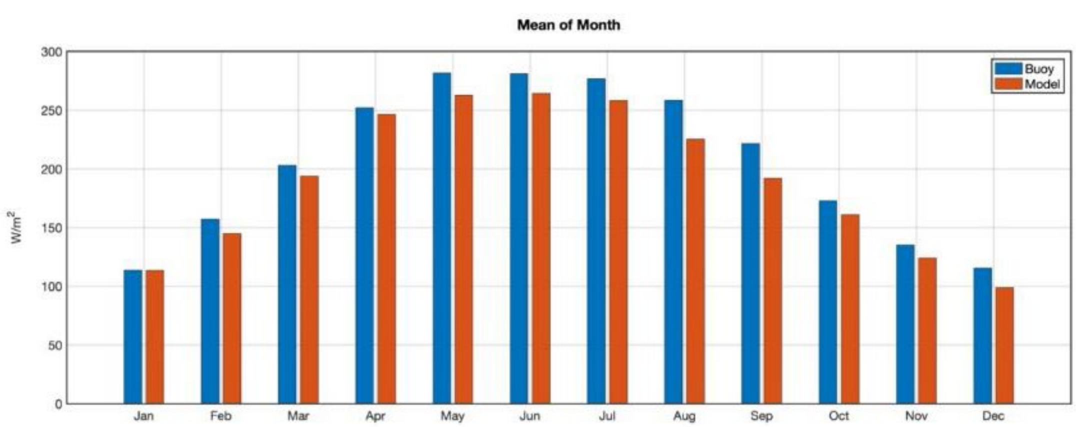


Figure 4-63 – Mean by month of year for measured shortwave radiation data (blue bars) and reanalysis shortwave radiation (red bars).

Directly comparing the measured data with the model data showed an 80% correlation between the two datasets (Figure 4-64). This high correlation supports using the reanalysis data for the site characterization. A sample of hourly data for the months of January and July of 2007 gives a sense of the good correspondence between measured and model radiation for shorter time scales (Figure 4-65).

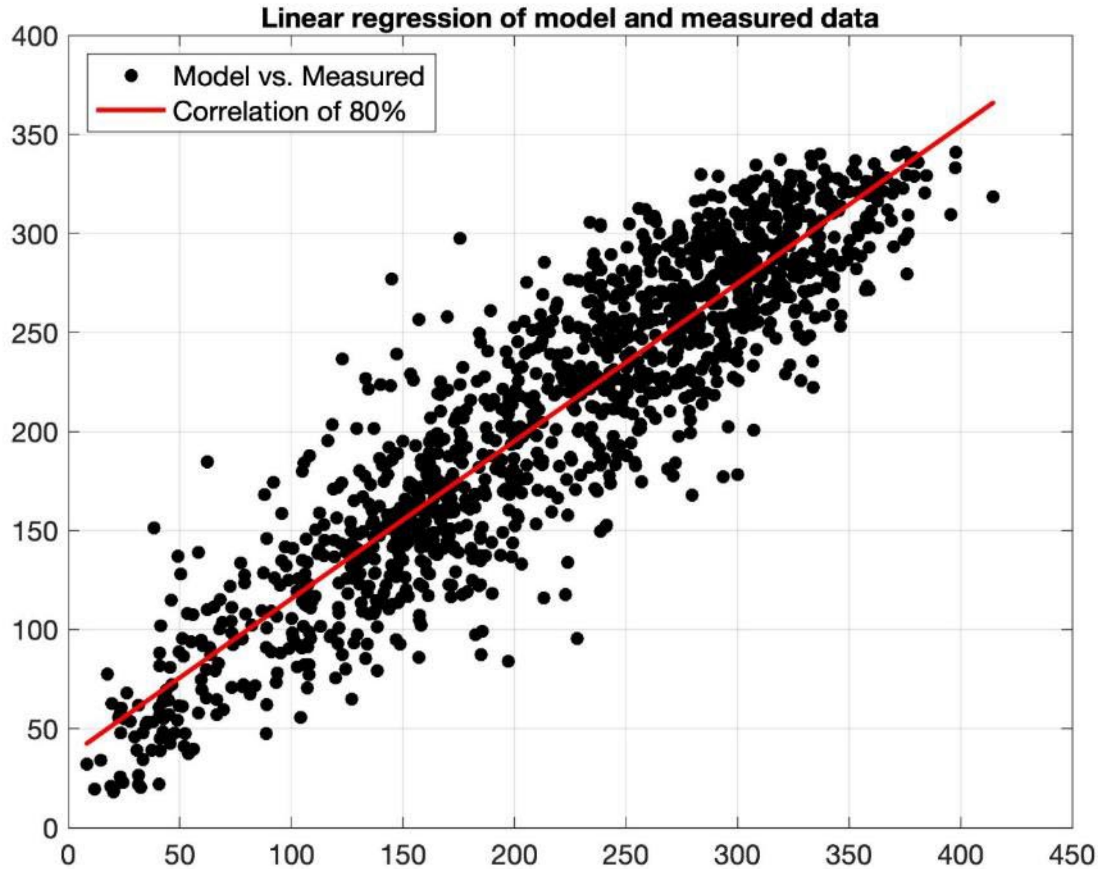


Figure 4-64 – Linear regression analysis comparing daily mean of measured shortwave radiation data from Buoy 41035 and daily mean of reanalysis shortwave radiation from the Copernicus CDS for the same days. The data show an 80% correlation.

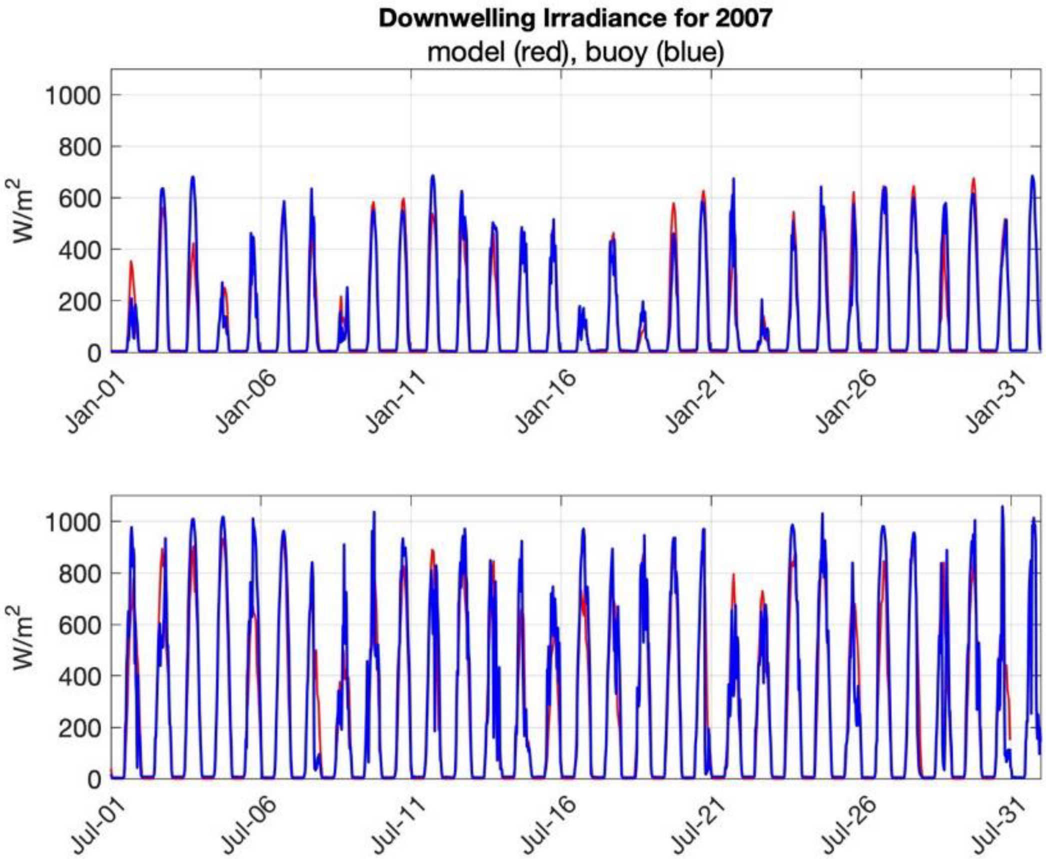


Figure 4-65 – Comparison of hourly downwelling solar irradiance for buoy data (blue) and reanalysis data (red) for the months of January 2007 and July 2007. As expected, the January values are lower on average than the July values.

5.0 References

Data Sources

Coastal Data Information Program, wave data, https://cdip.ucsd.edu

Copernicus Climate Change Service (C3S), https://climate.copernicus.eu/

GEBCO Compilation Group (2022) GEBCO_2022 Grid

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Appendix F: Pioneer MAB Seabed Survey and ROV Inspections

Pioneer MAB
Seabed Survey & ROV Inspections

Control Number: 3210-00004
Version: 0-04
Date: 2024-01-29
Author: Derek Buffitt, Al Plueddemann

Coastal and Global Scale Nodes
Ocean Observatories Initiative
Woods Hole Oceanographic Institution

Revision History

Version	Description	ECR No.	Release Date
0-02	Updated following NSF/OOI PMO comments	--	2023-06-01
0-03	Updated with survey results for Updated Northeastern and Southeastern mooring locations	--	2023-11-06
0-04	Updated based on NSF comments to SSSEA	--	2024-01-29

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1.0 PURPOSE

The purpose of this document is to provide the results of the seabed mapping survey and ROV inspection of the Pioneer Mid-Atlantic Bight (MAB) mooring sites. The initial surveys and ROV inspections were performed between 21 February – 1 March 2023 in conjunction with the deployment of test moorings at the Central site and Northeastern (Old) site. The surveys for updated Northeastern (NE) and updated Southeastern (SE) mooring locations were performed on the test mooring recovery cruise between 23 October – 4 November 2023.

The desktop planning performed by OOI and Tetra Tech provided a baseline for the layout and design of the proposed Pioneer MAB array. The surveys were performed to ground truth the results of the studies, including:

1. Establishing the actual water depth, seabed types, and slopes to inform the engineering of the mooring systems,
2. Confirming the avoidance of cultural and archeological resources, and
3. Assessing and avoiding any impacts to Essential Fish Habitats and Critical Habitats.

2.0 REFERENCE DOCUMENTS

Table 1: Reference Documents

Document ID / Source	Document Title
3210-00007	CGSN Site Characterization: Pioneer Mid-Atlantic Bight Array
3210-00008	CGSN Site Design: Pioneer Mid-Atlantic Bight Array
TetraTech, June 2021	Mid-Atlantic Bight Pioneer Array Regulatory Study
TetraTech, December 2022	Desktop Study: Mid-Atlantic Bight Pioneer Array
Search, November 2022	Maritime Archaeology Desktop Study

3.0 DEFINITIONS & ACRONYMS

Alt Alternate
BOEM Bureau of Ocean Energy Management
CGSN Coastal & Global Scale Nodes
CN Central Site
EA Eastern Site
EFH Essential Fish Habitat
IFREMER Institut Français de Recherche pour l'Exploitation de la MER
MFN Multi-Function Node
MAB Mid-Atlantic Bight
NDBC National Data Buoy Center
NE Northeastern Site
NEPA National Environmental Policy Act
NO Northern Site
NOAA National Oceanic and Atmospheric Administration
NSF National Science Foundation
NSIF Near Surface Instrument Frame
OOI Ocean Observatories Initiative
PI Principal Investigator

PM	Profiler Mooring
ROV	Remotely Operated Vehicle
SE	Southeastern Site
SEANOE	SEA scieNtific Open data Edition
SHOM	Service Hydrographique et Océanographique de la Marine
SIS	Seafloor Information System
SM	Surface Mooring
SO	Southern Site
SW	Shallow Water Mooring
VME	Vulnerable Marine Ecosystem
WE	Western Site

4.0 OVERVIEW

4.1. Site Summary

The Pioneer MAB Array is proposed to be relocated in the spring of 2024 to a region off the coast of Nags Head in North Carolina. The proposed plan is for the moored array to be constituted in a sideways "T" shape, with seven mooring sites between about 24 kilometers (km) and 84 km offshore, outside of state waters (Figure 1). The Pioneer MAB Array will consist of:

- Three surface moorings located in 30m and 100m water depths (CN, NO, SO)
- Five profiler moorings located in 100m and 300m water depths (NO, NE, EA, SE, SO)
- Two shallow-water moorings located in 30m water depths (WE, CN)
- The original NE and SE sites are shown for informational purposes (NE Old, SE Old)

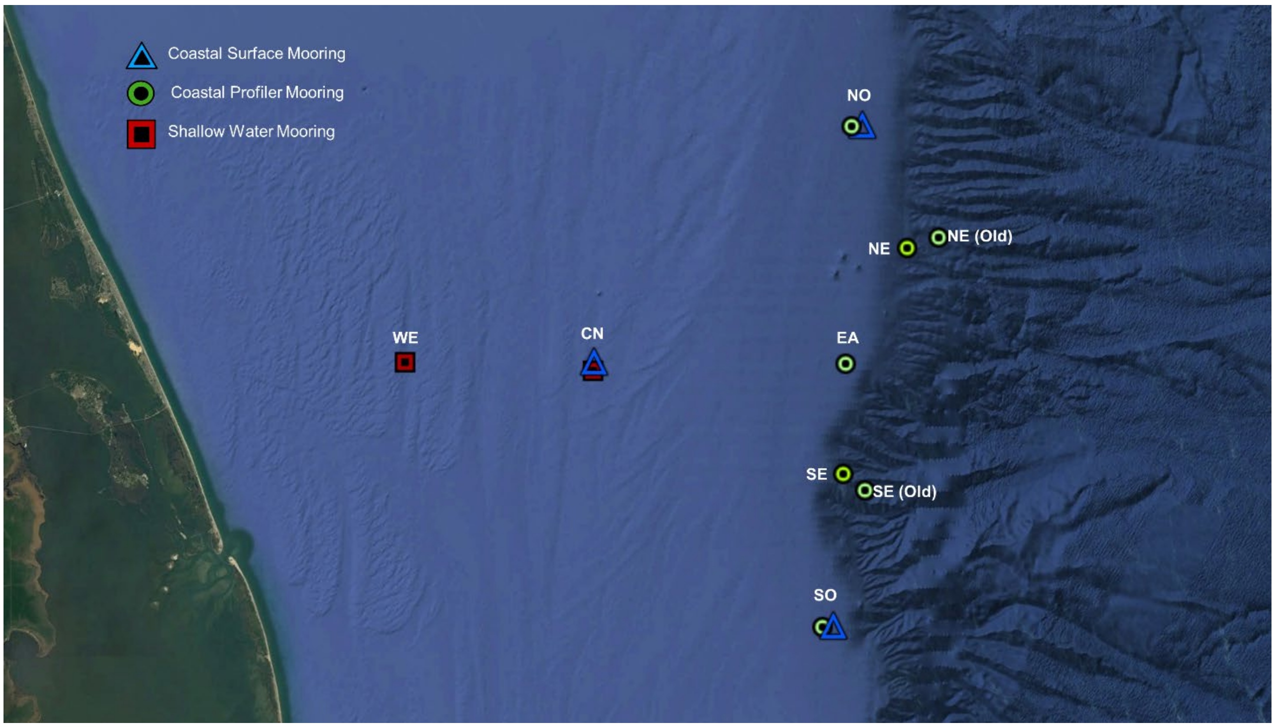

Figure 1: Pioneer MAB Proposed Array Layout

The individual site centers were initially selected during the National Science Foundation (NSF) Innovation Labs workshops based on input from the scientific community. The site centers were slightly adjusted based on information reviewed by OOI during the planning stages (*3210-00008 Site Design: Pioneer Mid-Atlantic Bight Array*) including data sourced from the Bureau of Ocean Energy Management (BOEM) and National Oceanic and Atmospheric Administration (NOAA) Marine Cadastre, as well as the desktop study (*Desktop Study, Mid-Atlantic Bight Pioneer Array, Prepared by Tetra Tech*) and regulatory study (*Mid-Atlantic Bight Pioneer Array Regulatory Study. Prepared by Tetra Tech*). A maritime archeology study (*Marine Archeology Study, Moored Buoys for Scientific Data Collection, North Carolina, Outer Continental Shelf. Prepared by SEARCH for Tetra Tech)* did not identify any documented archaeological sites, reported shipwrecks, or maritime obstructions within 1.6 km (1.0 mi) of the proposed site centers. The updated NE and SE sites were selected and surveyed based on feedback received during the 30-day public NEPA review. The original NE and SE sites (denoted as NE Old and SE Old) are shown for continuity purposes.

4.2. Vessel

The RV Neil Armstrong (Figure 2) performed the mapping and ROV inspection operations.

Figure 2: RV Neil Armstrong

- Propulsion: (x2) Siemens AC Electric Motors, 876 kW ea. (1175 hp ea.), 1752 kW total (2350 hp total)
- Bow Thruster (x1) White-Gill, 686 kW (920 hp)
- Stern Thruster: (x1) Schottel, 620 kW (831 hp)
- Main Generators: (x4) Cummings Diesels, 1044 kW ea. (1400 hp ea.), 4176 kW total (5600 hp total)
- Emergency Generator: (x1) MTU Diesel, 210 kW (282 hp)

4.3. Mapping Equipment

- Bathymetry and Backscatter: Kongsberg EM710 40-100kHz
- Subbottom: Knudsen 3260 3.5kHz
- Backup deepwater multibeam: Kongsberg EM122 12kHz (deepwater sites only)

4.4. ROV Equipment

- Saab SeaEye Falcon DR ROV with associated equipment, see Figure 3 and Table 2.

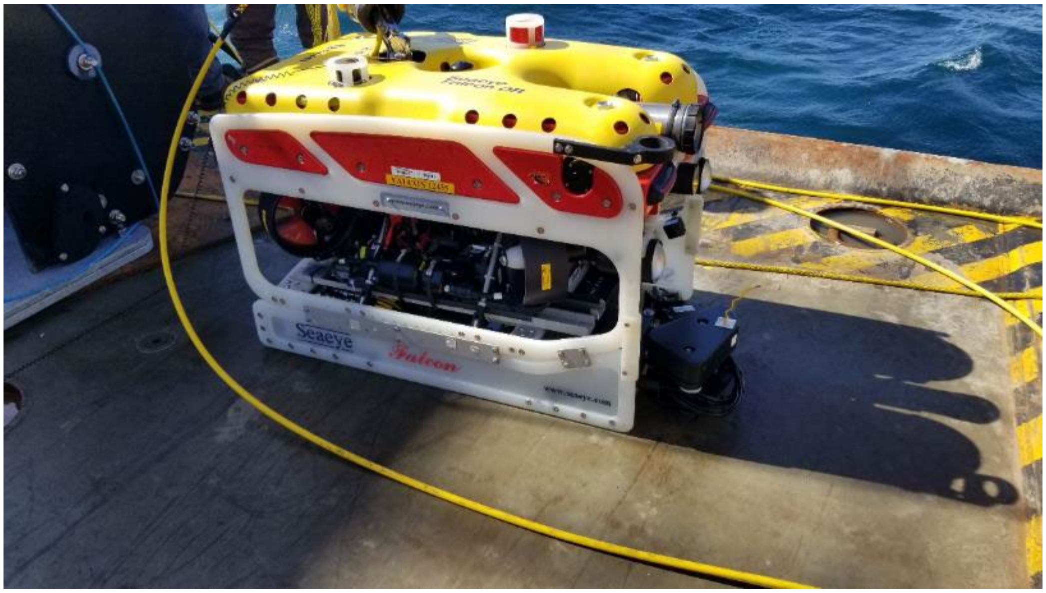

Figure 3: Saab SeaEye Falcon DR ROV

Table 2: ROV Specifications

Feature	Description
Dimensions (mm)	1055mm x 635mm x 600mm
Weight (kg)	100kg
Payload (kg)	15kg
Thrust	5 brushless (4 vectored H, 1 V); 50kgf forward, >3kts
Umbilical (m)	1100 525kg breaking strain Min dynamic bend radius 250mm Min static bend radius 165mm
Operating Depth (m)	850
Manipulator	Single function Gripstick02 plus skid mounted Hydro-Lek 5-function; cutter available as option, Gripstick02 includes soft line cutter
Navigation	PA500 altimeter Auto heading, Auto depth, Auto altitude Fluxgate compass, rate sensor
Acoustic Positioning	EasyTrak Alpha 2665 Portable USBL -1 x AAE 1310 mini-beacon (1000m rated), 1 x AAE 1015 mini-beacon (2000m rated) for use with EasyTrak -5 x Sonardyne Nano beacons (500m rating) with charger, for use with Sonardyne Mini-Ranger 2 USBL
Imaging	Imagenex gyro stabilized sonar 881A GS 310kHz 40d beam/675kHz 20d beam/1MHz 10d beam 1-4m resolution = 2mm, >5m = 10mm, 200m range
Camera	SEAEYE mini color camera, includes video recorder Kongsberg HD camera 1920 x 1080, 1080i/720p, 10x optical zoom; 1 x rear facing mini wide angle camera
Lights	2 x forward looking LEDs, 1 x rear looking LEDs

5.0 SITE MAPPING

Vessel hull-mounted multibeam and subbottom systems were used to map an approximate 2km x 2km box around each site center. Table 3 provides a list of coordinates denoting the site center for each of the nine surveyed mooring sites. Upon reviewing the survey data, the Chief Scientist selected the anchor target sites for ROV inspection. Table 4 provides the coordinates for the recommended anchor targets. During mooring service cruises, replacement moorings are typically deployed prior to recovery of the previously deployed mooring. Thus, two anchor targets are needed for a site with a single mooring. At sites where two moorings will be deployed (a surface mooring adjacent to a profiler mooring), four anchor targets are needed.

The ship's multibeam collected bathymetry and backscatter imagery. The bathymetry was used to generate digital terrain models (DTMs) and depth contour charts to assess/select anchor target locations. This data will also be used to finalize mooring designs based on improved estimates of water depth at the anchor sites. The backscatter, along with the subbottom data, was used to assess bottom types, hardness, and potential hazards. The multibeam and the subbottom frequencies do not conflict and were therefore run concurrently. Primary focus for the backscatter hazard assessment was ensuring clearance around each anchor target. Anchors are typically deployed within a 25m radius of the target.

Table 3: Site Center Coordinates

Mooring Center	Code	Lat (°N)	Lon (°W)
Western	WE	35.9500	75.3333
Central	CN	35.9500	75.1250
Eastern	EA	35.9500	74.8457
Northern	NO	36.1750	74.8267
Southern	SO	35.7250	74.853
Northeastern (Old)	NE old	36.0633	74.7427
Southeastern (Old)	SE old	35.8367	74.8242
Northeastern (Updated)	NE	36.0536	74.7776
Southeastern (Updated)	SE	35.8514	74.8482

Table 4: Anchor Target Coordinates

Anchor Target	Lat (°N)	Lon (°W)
WE N-tar	35.95442	75.3333
WE S-tar	35.94558	75.3333
CN N-tar	35.95362	75.1250
CN S-tar	35.94558	75.1250
CN E-tar	35.9503	75.1195
CN W-tar	35.9503	75.1311
NO N-tar	36.1794	74.8267
NO S-tar	36.17058	74.8267
NO E-tar	36.1750	74.8212
NO W-tar	36.1750	74.8321
EA N-tar	35.95442	74.8457

Anchor Target	Lat (°N)	Lon (°W)
EA S-tar	35.94558	74.8457
SO N-tar	35.72937	74.8530
SO S-tar	35.72062	74.8530
SO E-tar	35.7250	74.8476
SO W-tar	35.7250	74.8584
NE old N-tar	36.0675	74.7412
NE old S-tar	36.05972	74.7457
SE old N-tar	35.84083	74.8258
SE old S-tar	35.8325	74.8258
NE N-tar	36.0581	74.7773
NE S-tar	36.0492	74.7786
SE N-tar	35.8555	74.8506
SE S-tar	35.8473	74.8466

6.0 ROV INSPECTION

The ROV was tracked using the vessel Sonardyne USBL system. The position of the ROV, and ROV depressor weight, were collected in a Sonardyne log file. Targets were loaded into the USBL system to support vessel and ROV maneuvering.

The ROV performed a visual and forward looking sonar inspection of each anchor target site. Camera and sonar information were recorded to video files for each site. Forward looking sonar was set to a 50m range.

At dual mooring sites, the ROV was lowered to the initial anchor target. Once settled, the ROV performed a visual and sonar inspection surrounding the target, then transited to the next anchor target, continuing to collect camera and sonar data. Once at the next anchor target, the camera and sonar inspection was repeated. Four transects and four target inspections were completed at each dual mooring site (Figure 4).

Single mooring locations have two anchor target sites and a single survey transect. The ROV started at one anchor target and transited through the site center to the other target (Figure 4).

Procedures were in place to inspect seabed targets of interest, either visible in camera or in sonar, during the transects. However. no seabed targets were seen in the sonar during the transect lines. From camera imagery along the transect lines, away from the anchor target areas, there were some areas of benthic fauna noted. No OOI mooring deployments are planned in these areas, but they were considered areas of interest, in that they may be relevant to future, non-OOI deployments in the region. Appendix A provides an overview of these areas of interest.

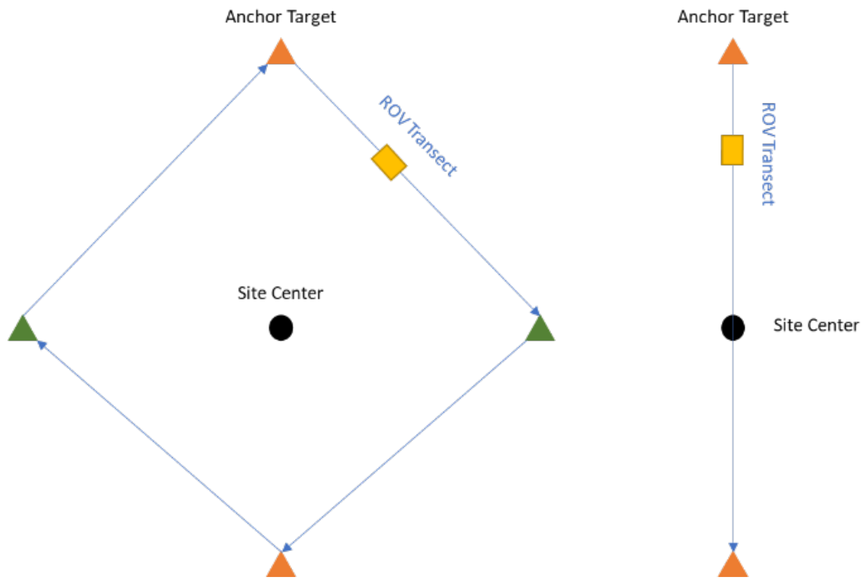

Figure 4: ROV Inspections & Transects. At sites with two moorings (left) four anchor targets are inspected with the ROV transects between targets creating a square pattern. At sites with one mooring (right) two targets are inspected with the ROV transect passing through the site center.

7.0 DATA PROCESSING

This section will provide a short introduction into the data processing and visualization performed to generate this report.

7.1. Sound Velocity

Conductivity, temperature, and depth (CTD) profiles were collected by the survey team at representative sites on the shelf and slope. These profiles were stored in *.cnv file formats. DORIS, a sound velocity visualization and processing tool, developed by IFREMER and SHOM, was used to inspect the profiles, remove duplicate soundings, and convert to *.vel files for use during the data processing step. (*Ifremer, Shom (2022). DORIS Software. SEANOE. https://doi.org/10.17882/90121*)

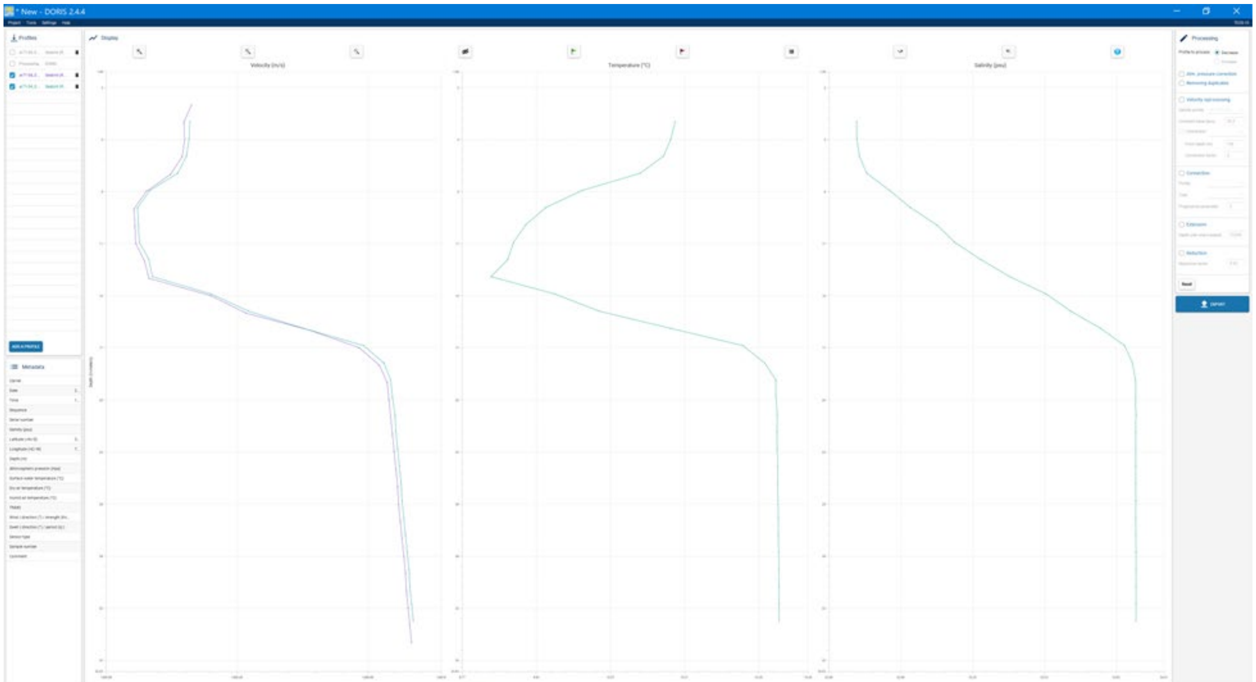

Figure 5: Example Sound Velocity Profile

7.2. Bathymetry & Backscatter

The EM710 bathymetry data was processed using the GLOBE data processing software developed by IFREMER. (*Poncelet Cyrille, Billant Gael, Corre Marie-Paule, Saunier Anthony (2023). Globe (GLobal Oceanographic Bathymetry Explorer) Software. SEANOE. https://doi.org/10.17882/70460*)

The following steps were performed:

1. Raw *.all files generated by the EM710 were loaded into the GLOBE environment.
2. Raw *.all files were then converted to *.mbg files.
3. Sound velocity profiles collected during the cruises were then loaded and applied to the sounder data.
4. A visual inspection of the soundings was performed including removal of minor errant soundings.
5. The sounding files were then filtered using the Delaunay Normal method.
6. Upon completion of the filtering, a digital terrain model (DTM) was generated using a 0.2m cell size.
7. Globe was then used to generate 1m, 2m, 10m, 20m contour files depending on location.
8. Backscatter images were also generated using GLOBE. The processed files from the bathymetry were used to generate grayscale images of the seabed strength returns.

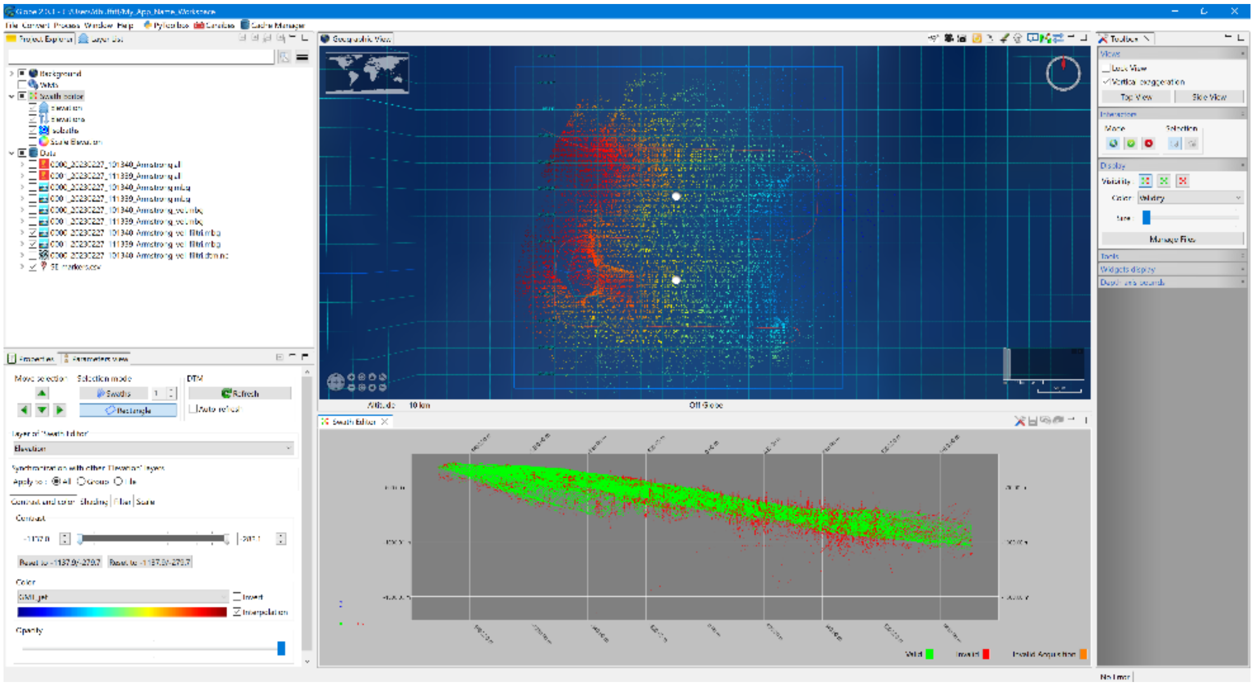

Figure 6: Example Bathymetry Processing

7.3. Subbottom

The Knudsen 3260 subbottom data (*.segy files) were loaded and visualized in the EchoPostSurvey software developed by Knudsen Engineering Limited. Visuals for each anchor target the full site survey were generated, no other processing was performed.

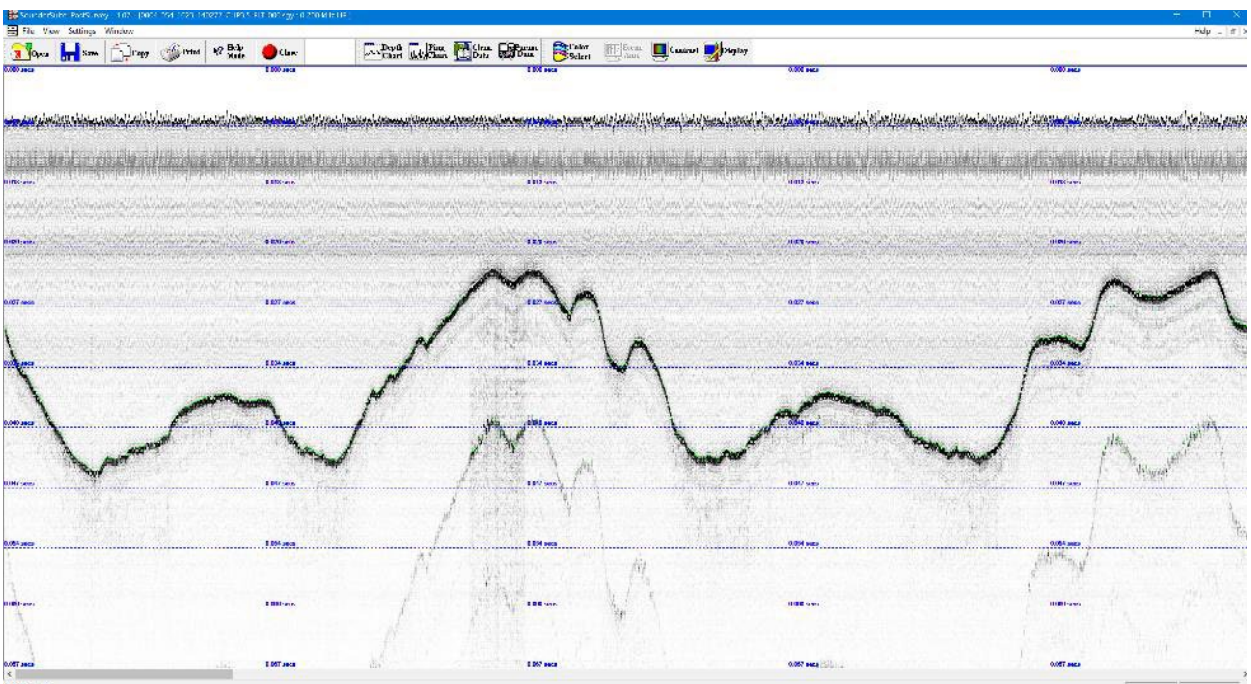

Figure 7: Example Subbottom Visualization

8.0 SURVEY RESULTS

This section provides an overview of the results of the survey and ROV inspections for each planned mooring site.

8.1. Western

Bathymetry

Moving west to east across the site (Figure 8), the water depth is at the shallowest ~17m, then deepens to ~28m in a somewhat flat north/south running channel, then rises slightly to 24m in the east. The data indicates several shallow banks to the west. As discussed in the Pioneer MAB desktop study, these shallow banks may consist of mobile sand and gravel sediments. The North and South anchor targets are at depths of ~25 m. Data collected over 2km x 2km area using 90m line spacing.

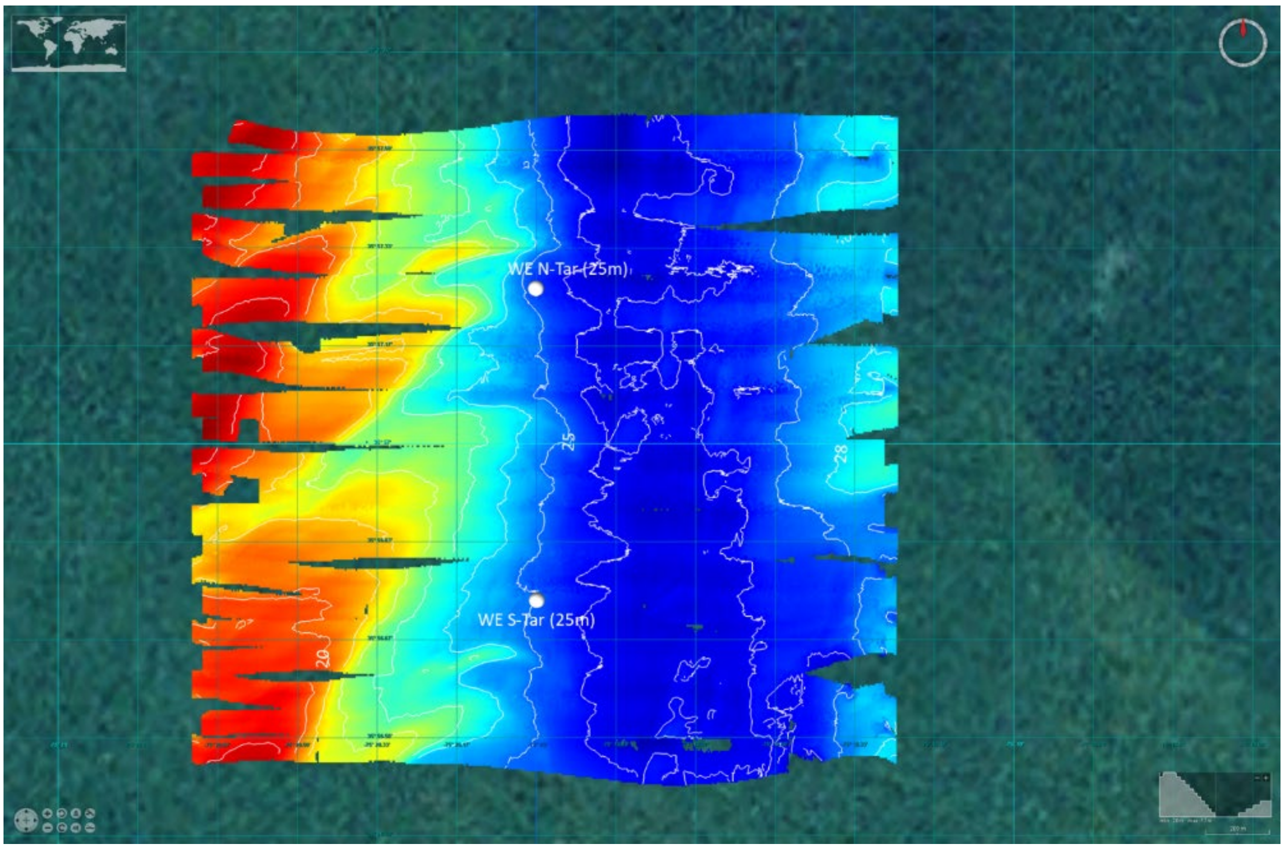

Figure 8: Western Site Digital Terrain Model (2m contours)

Backscatter

Backscatter imagery at both the north and south anchor target sites indicate a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figures 9 & 10).

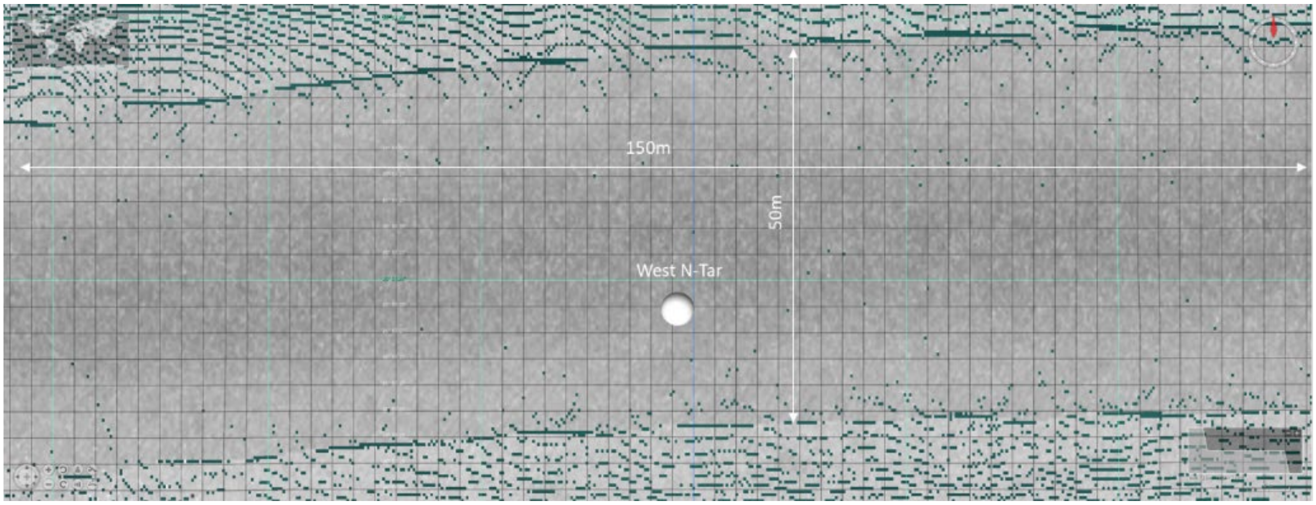

Figure 9: Western Site North Anchor Target (N-Tar) Backscatter

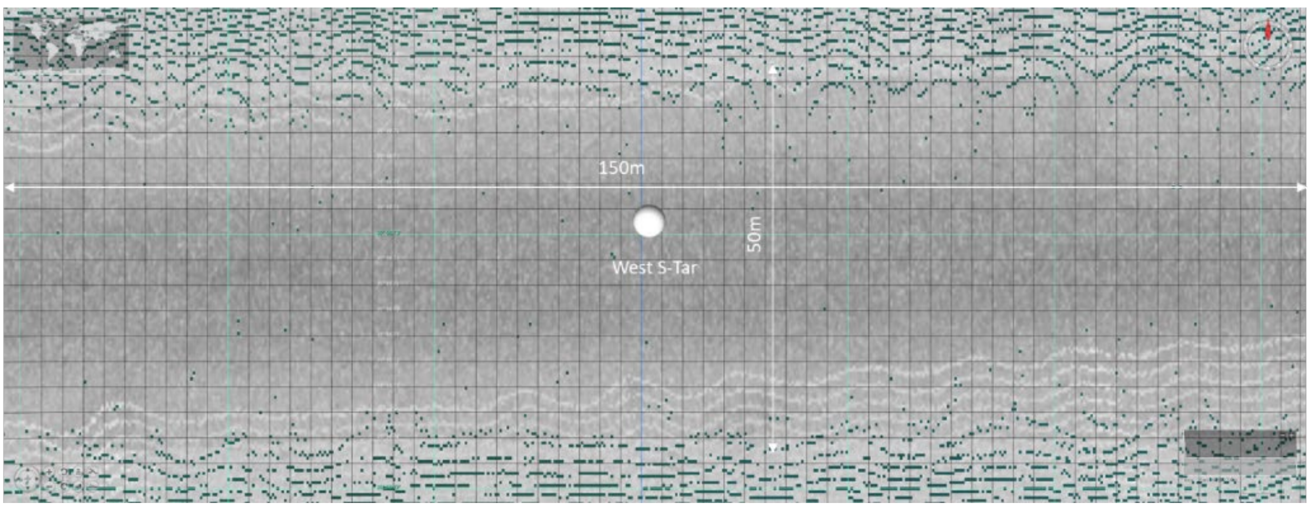

Figure 10: Western Site South Anchor Target (S-Tar) Backscatter

Subbottom

Subbottom profiles at both the north and south anchor target sites indicate a soft and homogeneous seabed with good penetration, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 11 & 12). Slopes are ~1.5-2°.

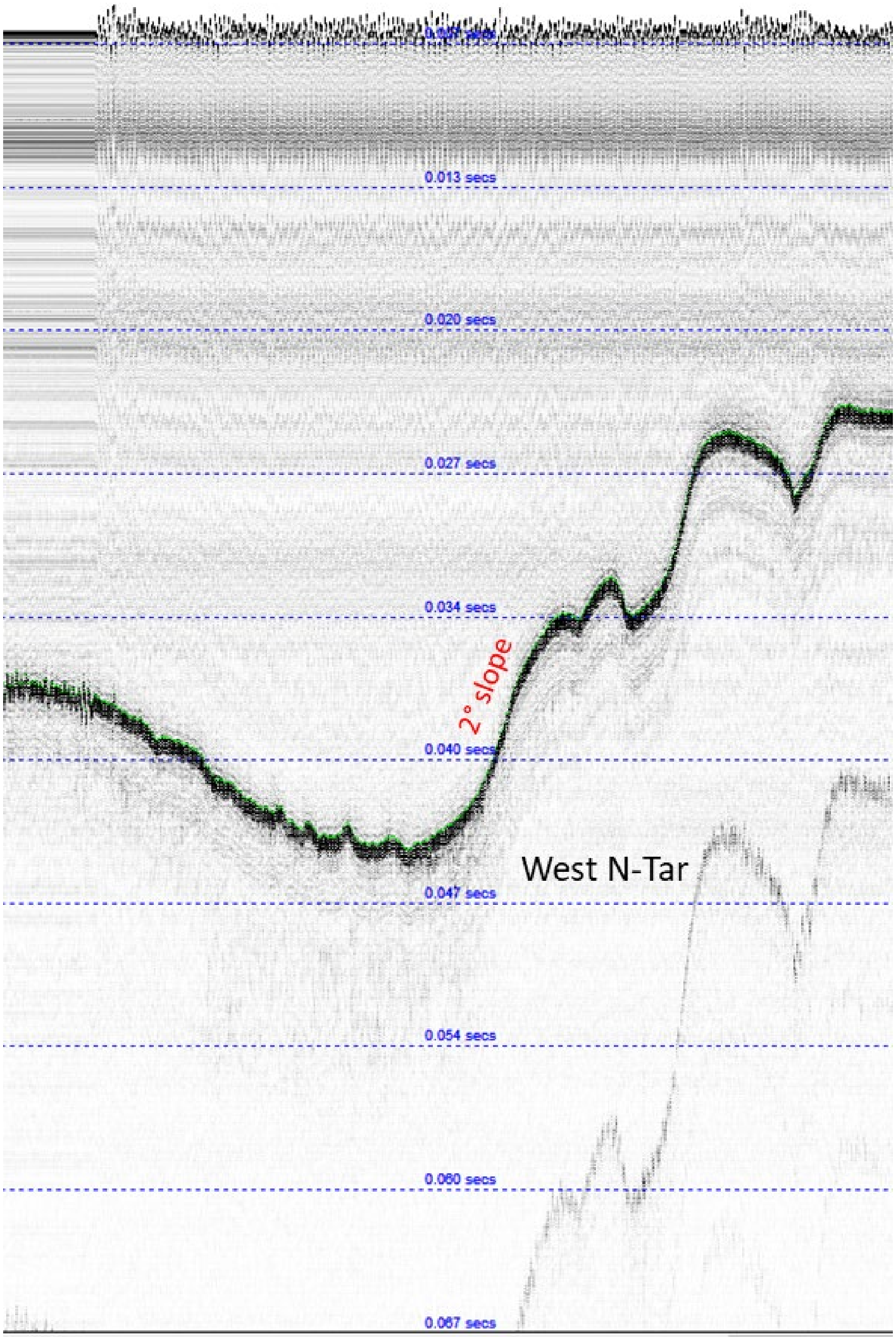

Figure 11: Western Site North Anchor Target (N-Tar) Subbottom

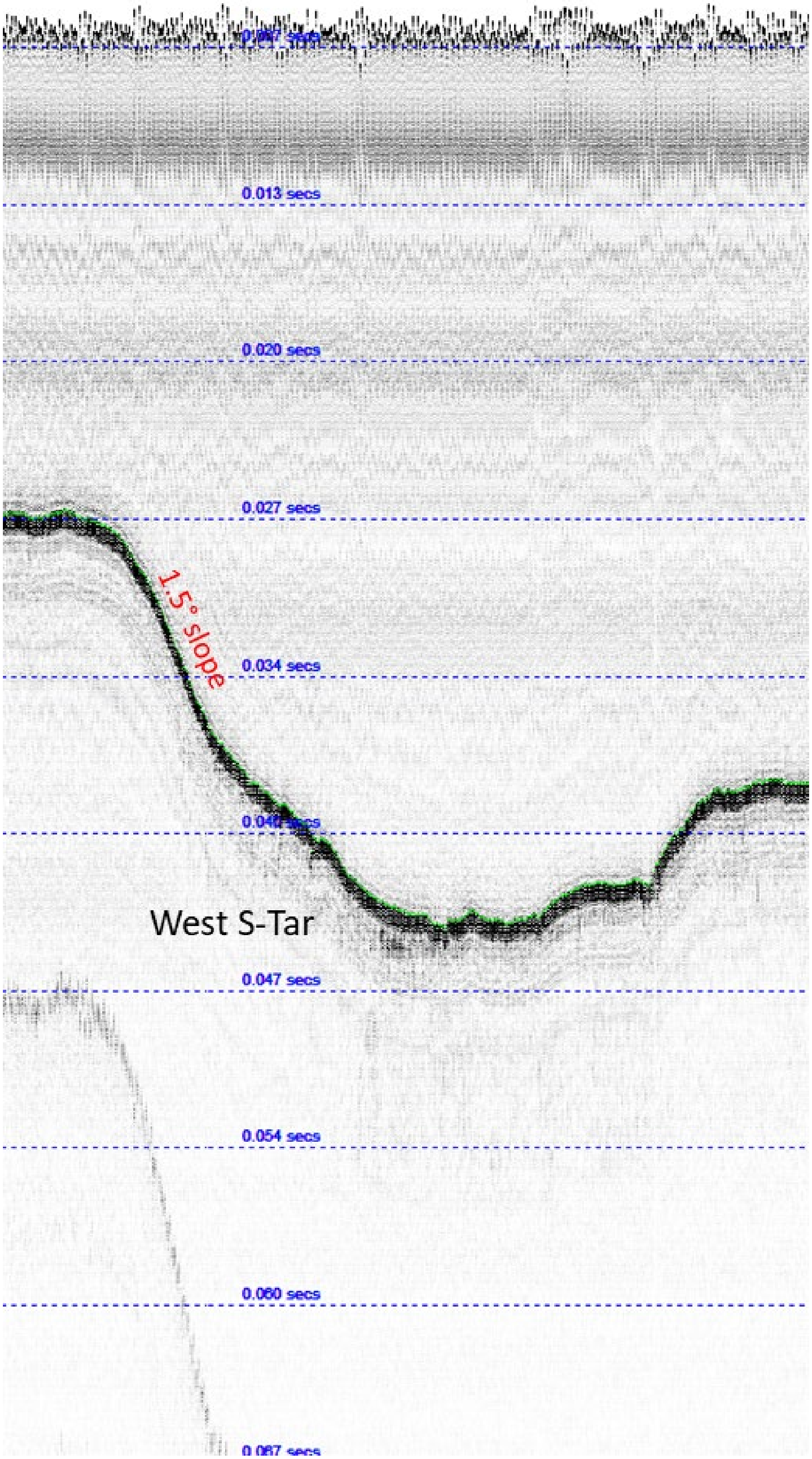

Figure 12: Western Site South Anchor Target (S-Tar) Subbottom

ROV Inspection

ROV inspection was completed at both anchor target sites, Figure 13 shows the ROV and depressor positions overlaid on the DTM. The camera data indicates a flat seabed at both sites consisting of sands and gravels (Figures 14-17). Wavy seabed also indicates some potential sediment movement. No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

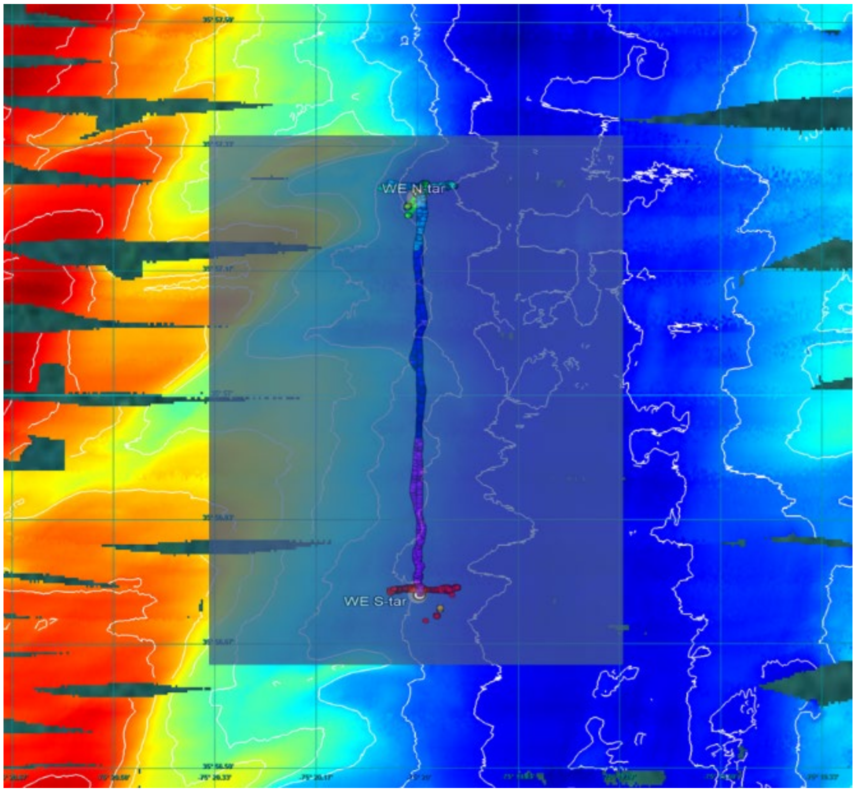

Figure 13: ROV Track at Western Site

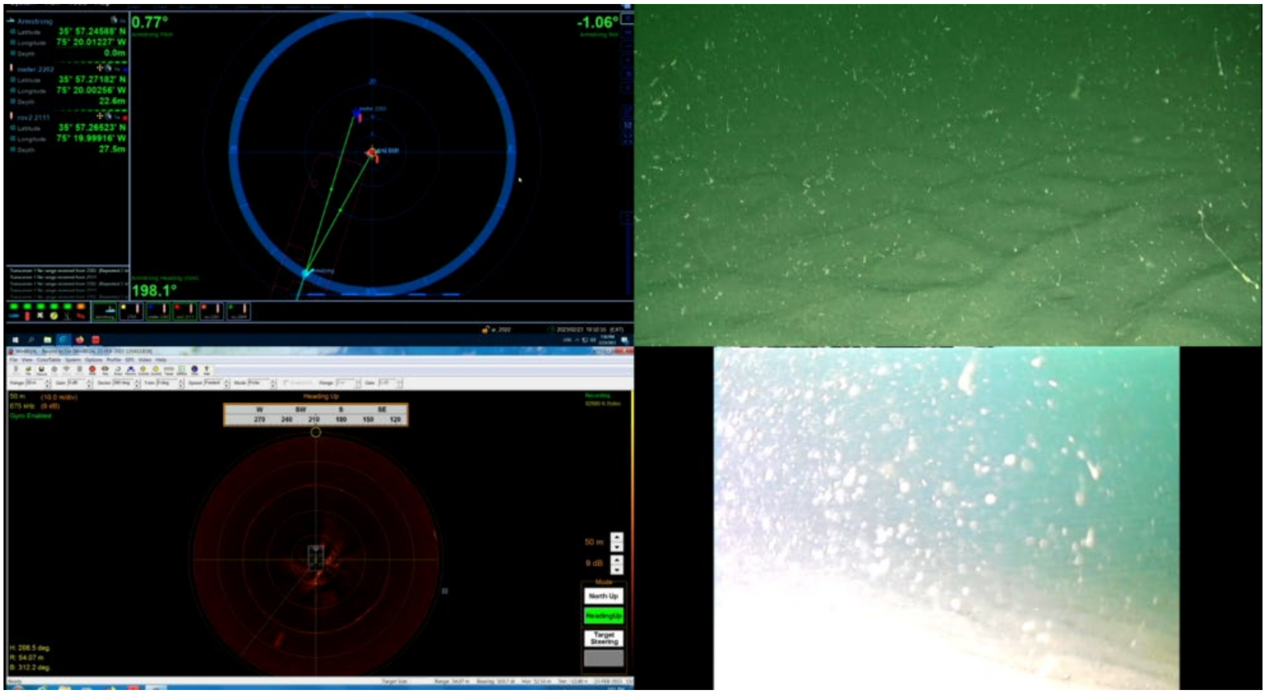

Figure 14: ROV Imagery at Western Site, North Anchor Target

Figure 15: Sandy Seabed Western Site, North Anchor Target

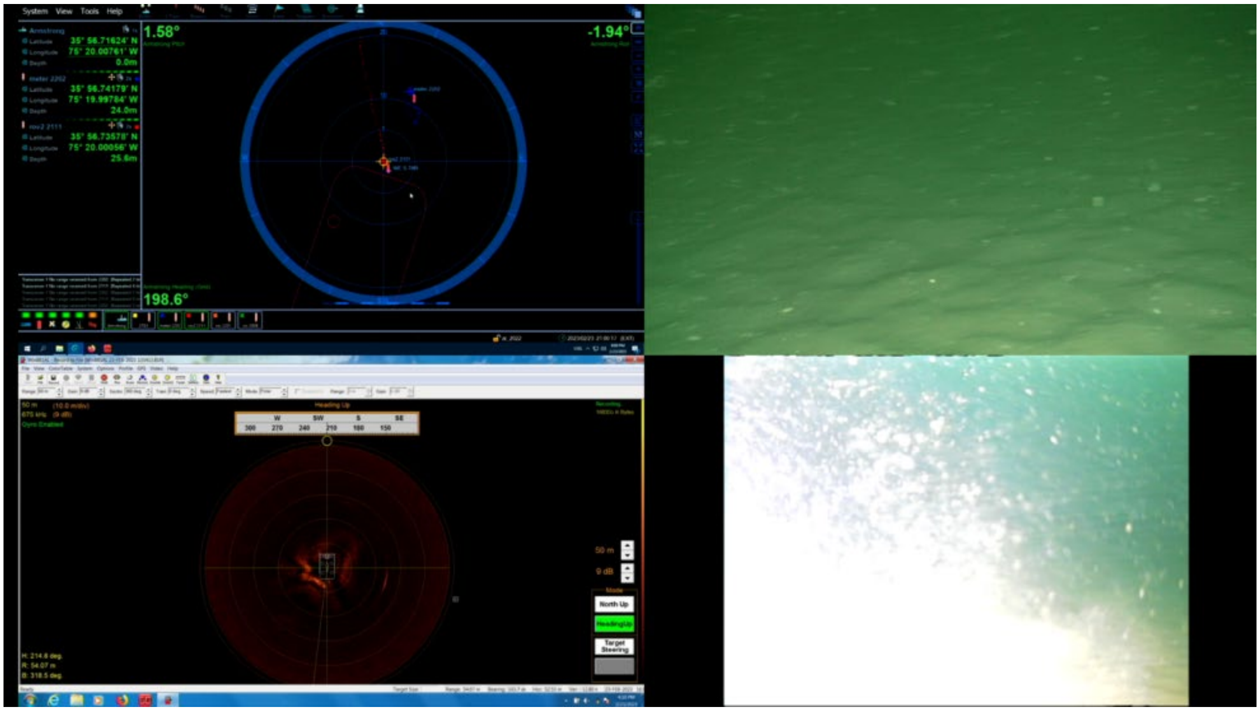

Figure 16: ROV Imagery at Western Site, South Anchor Target

Figure 17: Sandy Seabed Western Site, South Anchor Target

8.2. Central

Bathymetry
Moving west to east across Figure 18, the water depth is at the shallowest ~30m in the north and southwest corners, then deepens to ~33m in a somewhat flat north/south running channel, then rises to ~28m in the eastnortheast. The data indicates several shallow banks to the east and west. As discussed in the desktop study, these shallow banks may consist of mobile sand and gravel sediments. The North, South, East and West anchor targets are at depths of 32 m, 31 m, 28 m and 33 m, respectively. Data collected over 2km x 2km area using 90m line spacing.

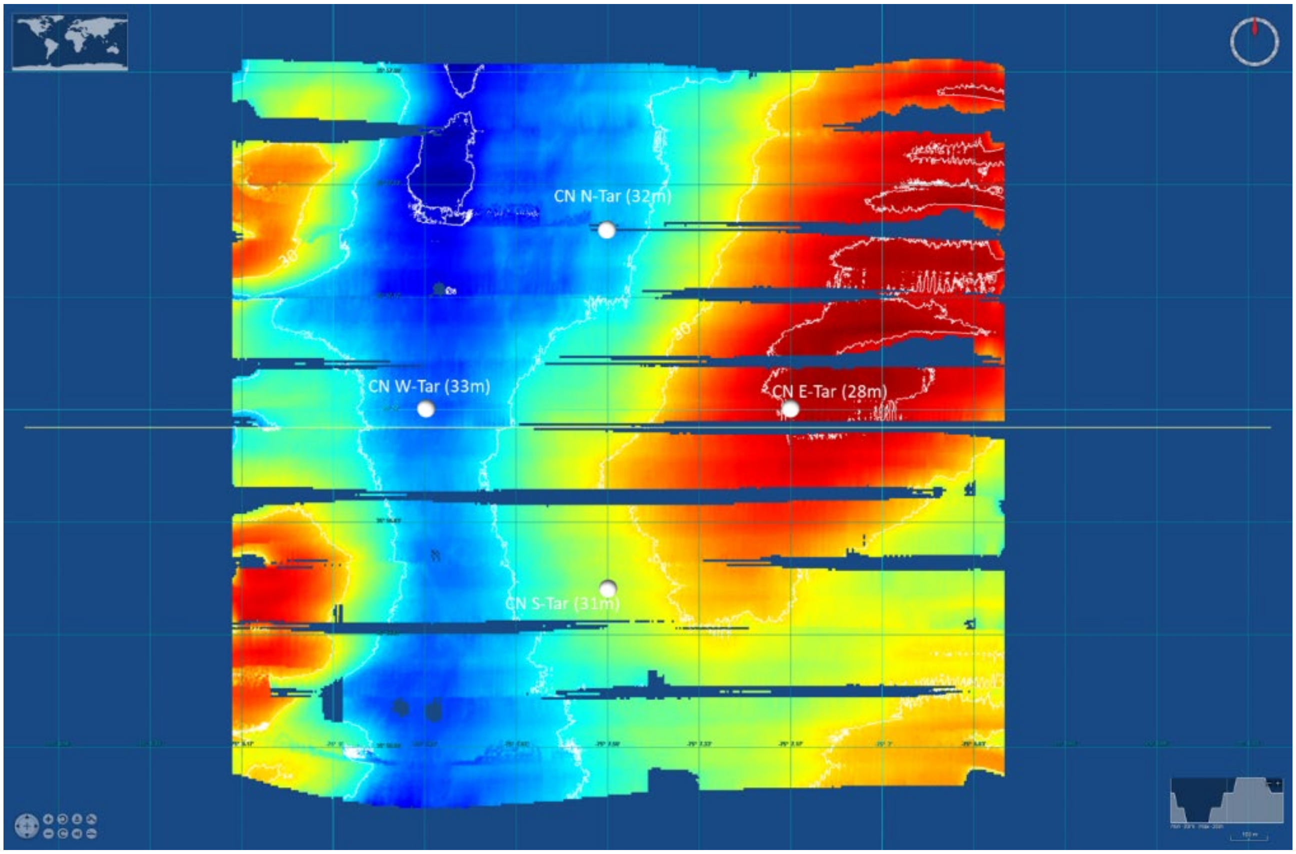

Figure 18: Central Site Digital Terrain Model (2m contours)

Backscatter

Backscatter imagery at all anchor target sites indicates a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figures 19 thru 22).

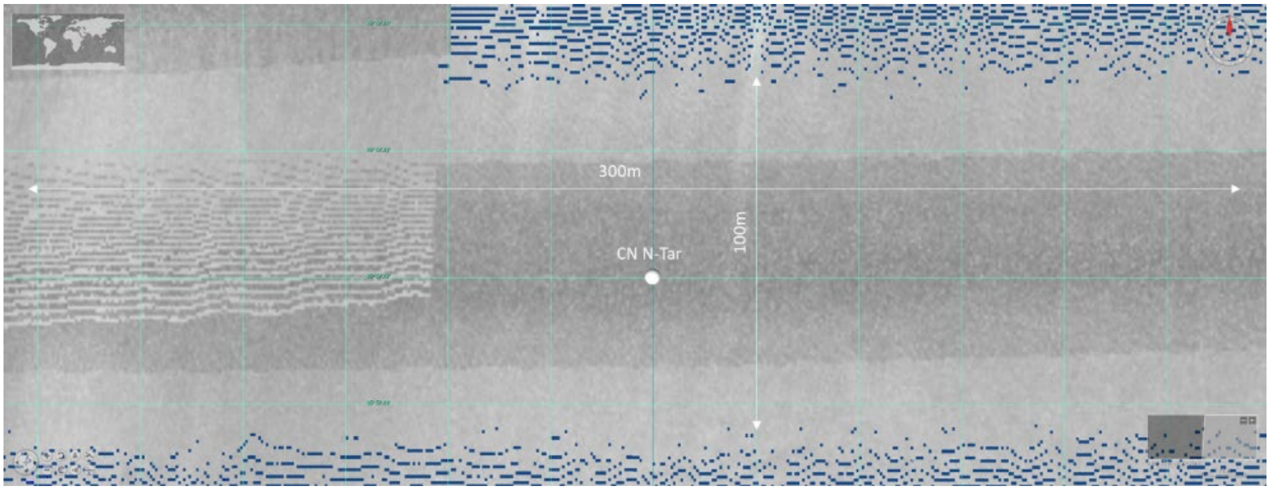

Figure 19: Central Site North Anchor Target (N-Tar) Backscatter

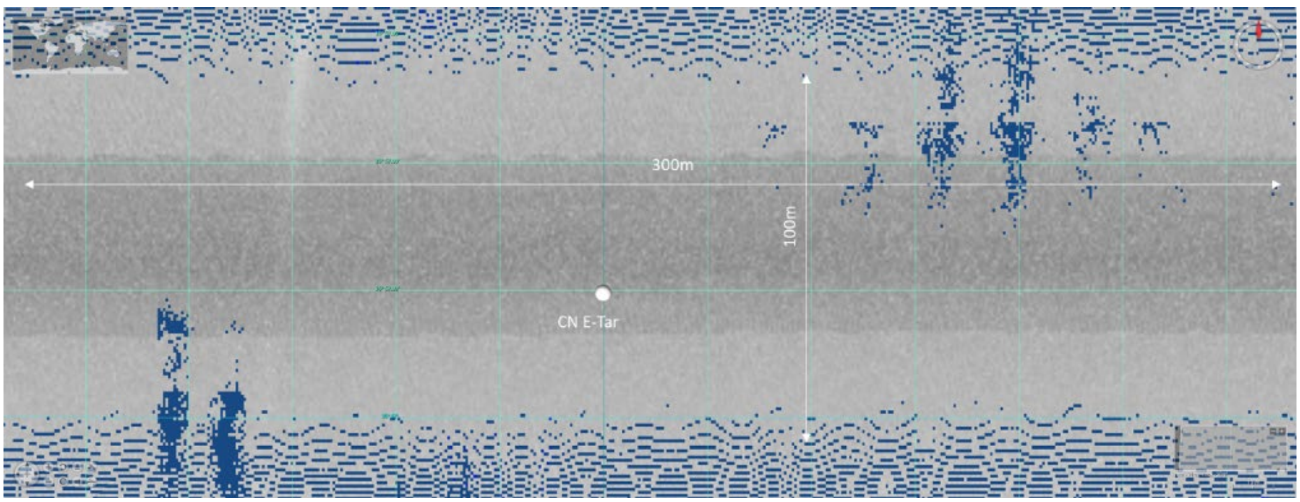

Figure 20: Central Site East Anchor Target (E-Tar) Backscatter

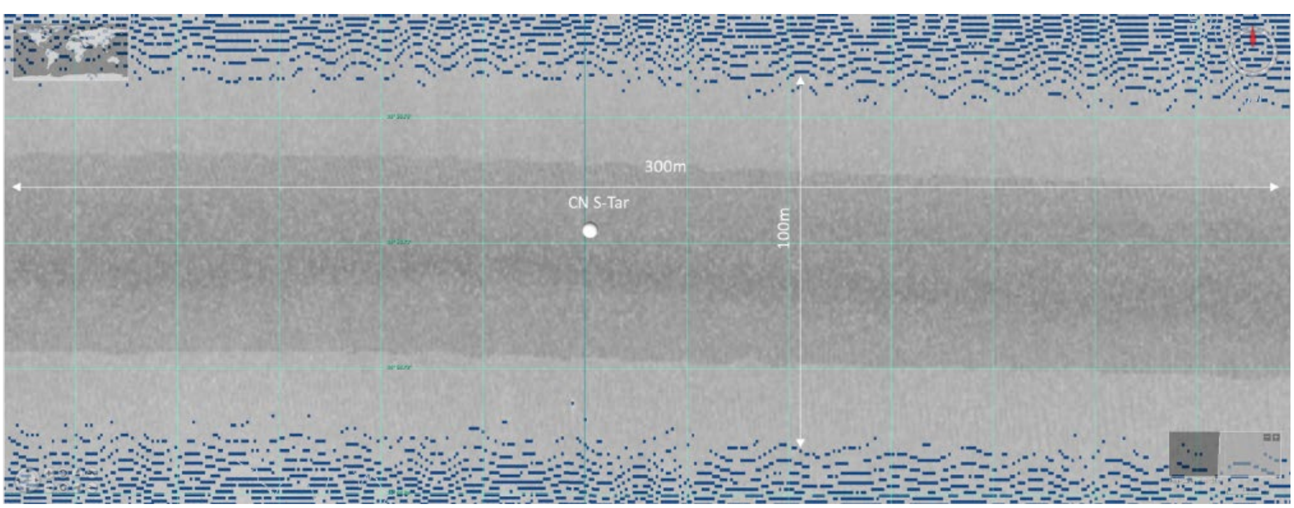

Figure 21: Central Site South Anchor Target (S-Tar) Backscatter

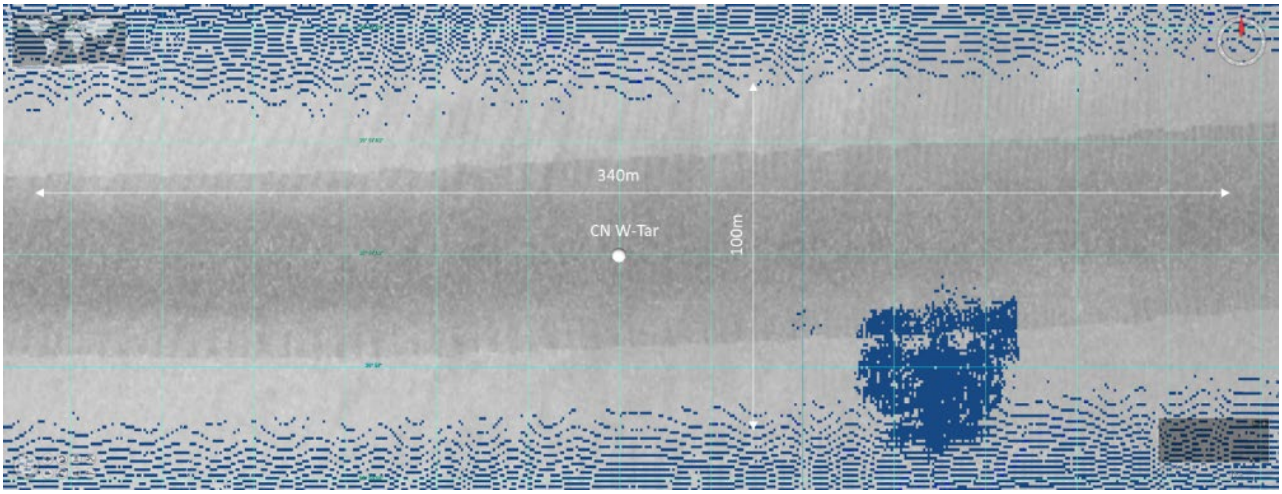

Figure 22: Central Site West Anchor Target (W-Tar) Backscatter

Subbottom

Subbottom profiles at all anchor target sites indicate a soft and homogeneous seabed with good penetration, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 23 thru 25). Slopes are ~0.5-1°.

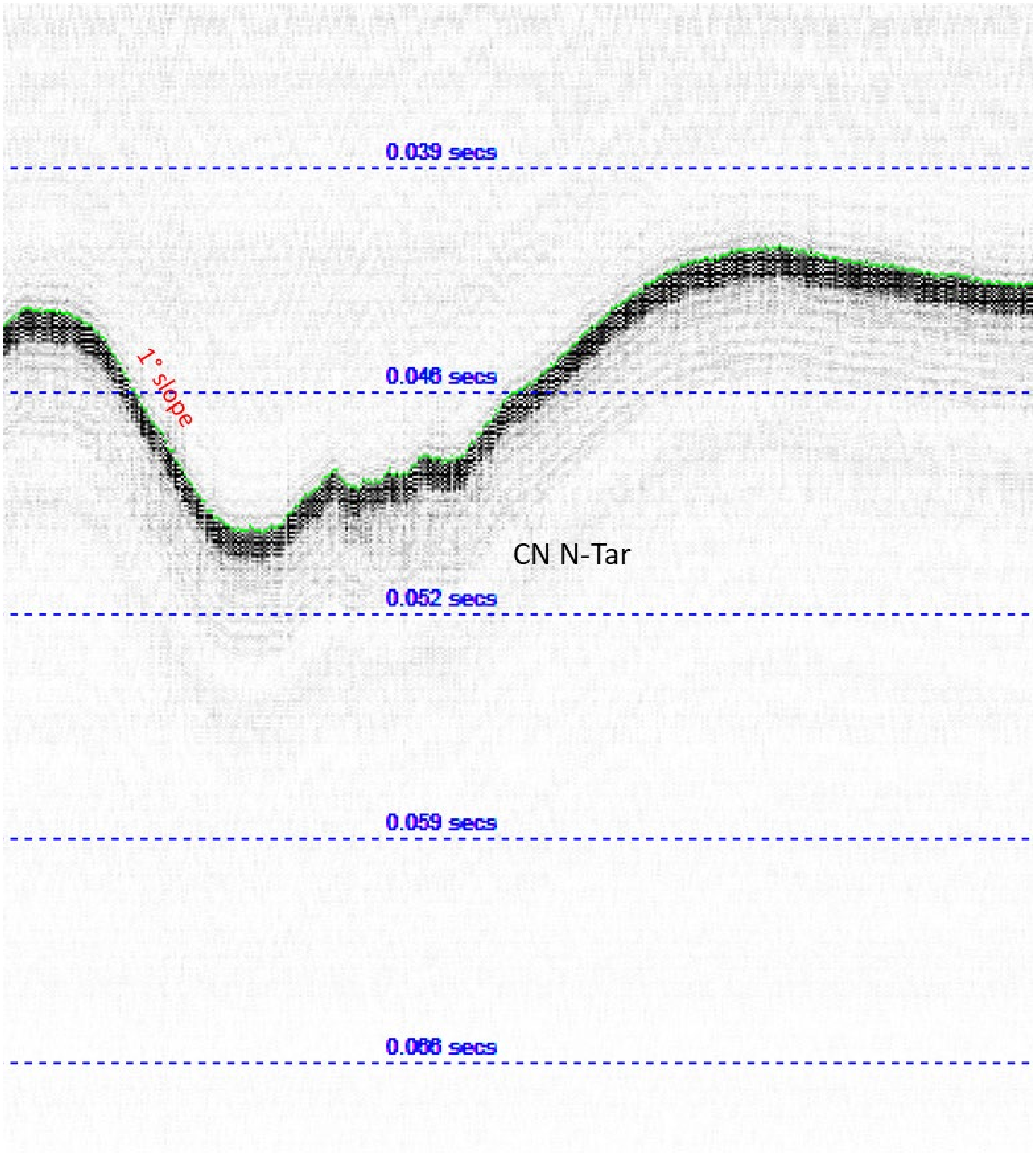

Figure 23: Central Site North Anchor Target (N-Tar) Subbottom

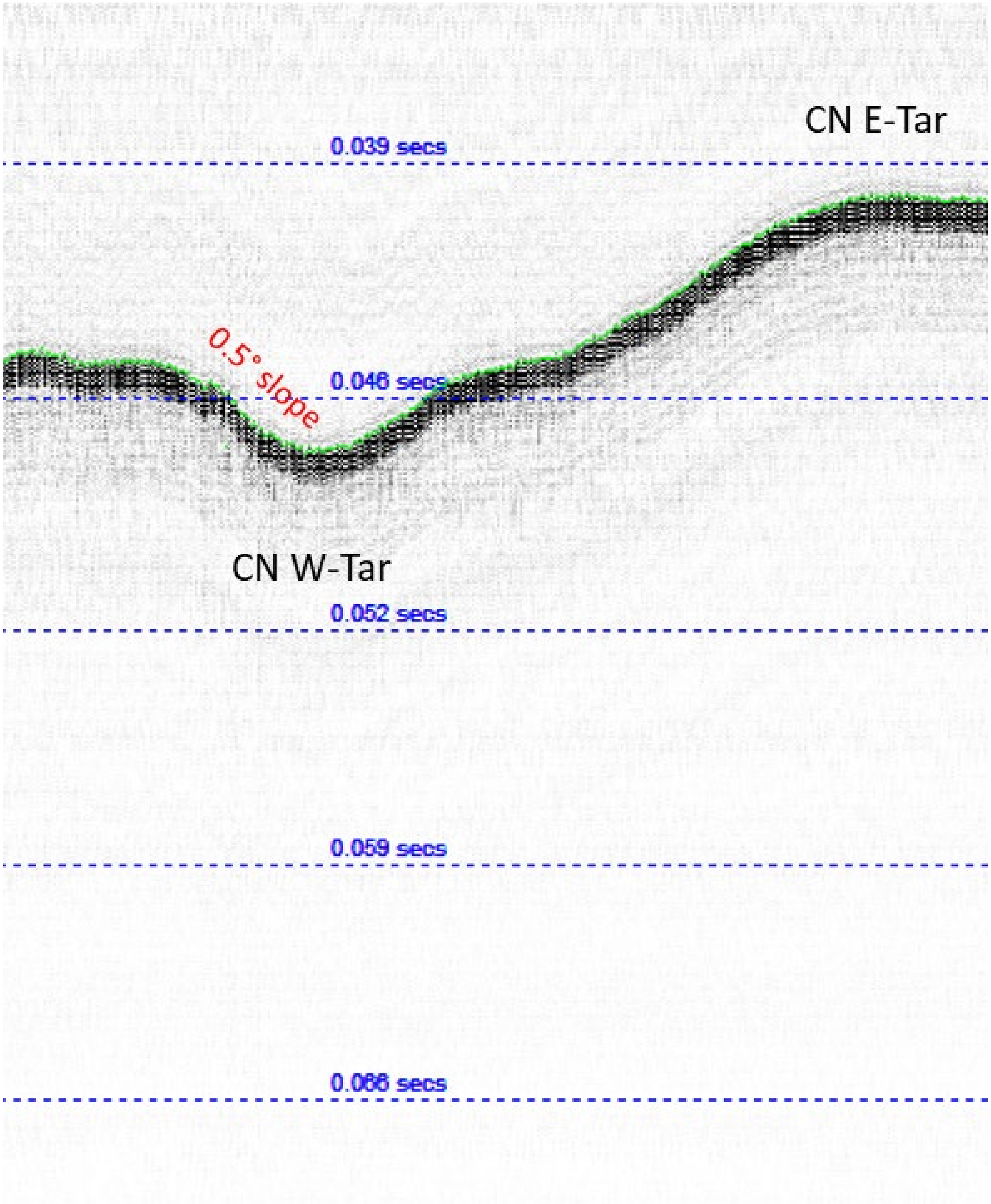

Figure 24: Central Site East & West Anchor Targets (E-Tar, W-Tar) Subbottom

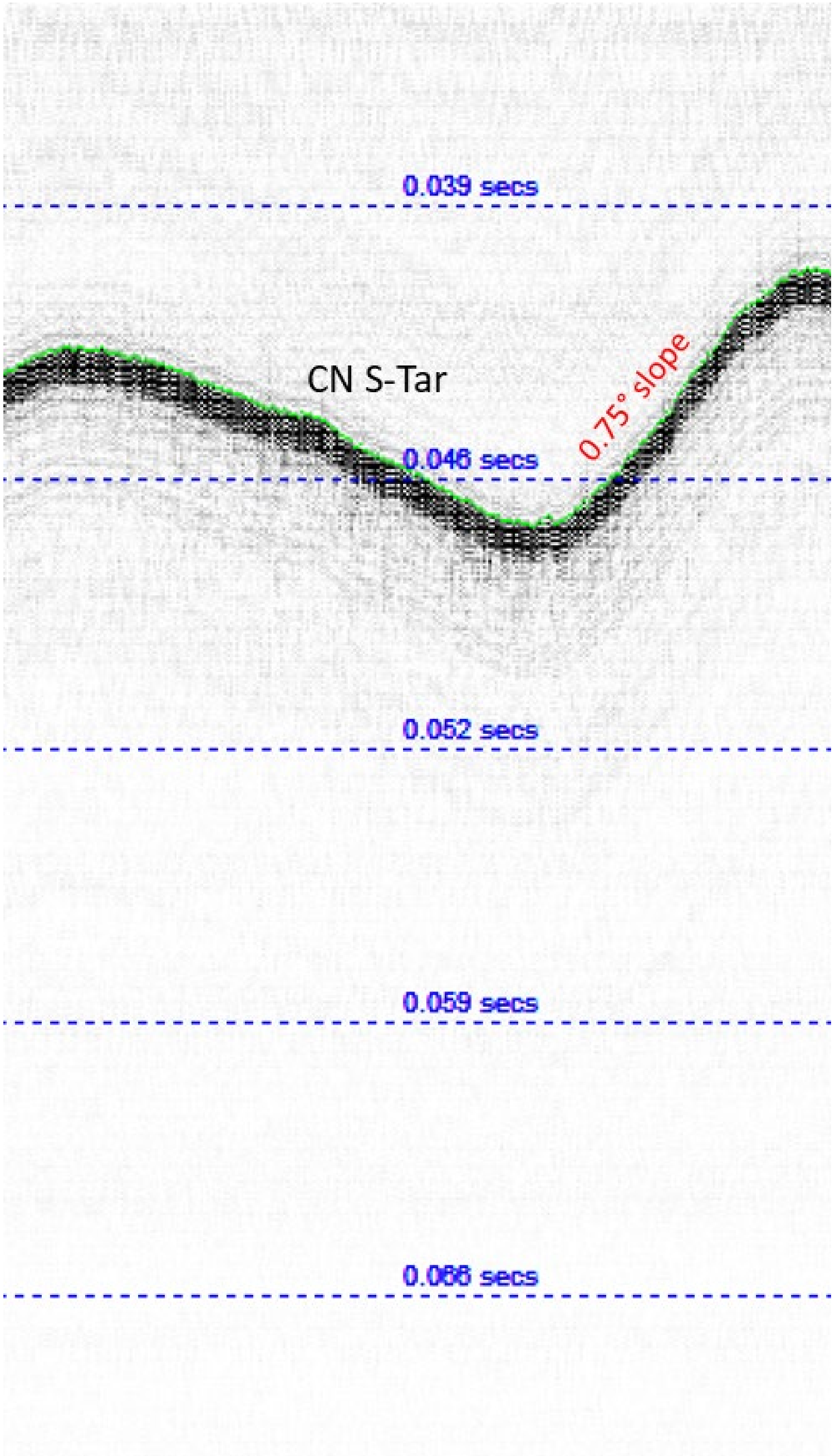

Figure 25: Central Site South Anchor Target (S-Tar) Subbottom

ROV Inspection

ROV inspection was completed at all anchor target sites, Figure 26 shows the ROV and depressor positions overlaid on the DTM. The camera data indicates a flat seabed at all sites consisting of sands, gravels, and shells (Figures 27-30). Wavy seabed also indicates some potential sediment movement. No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

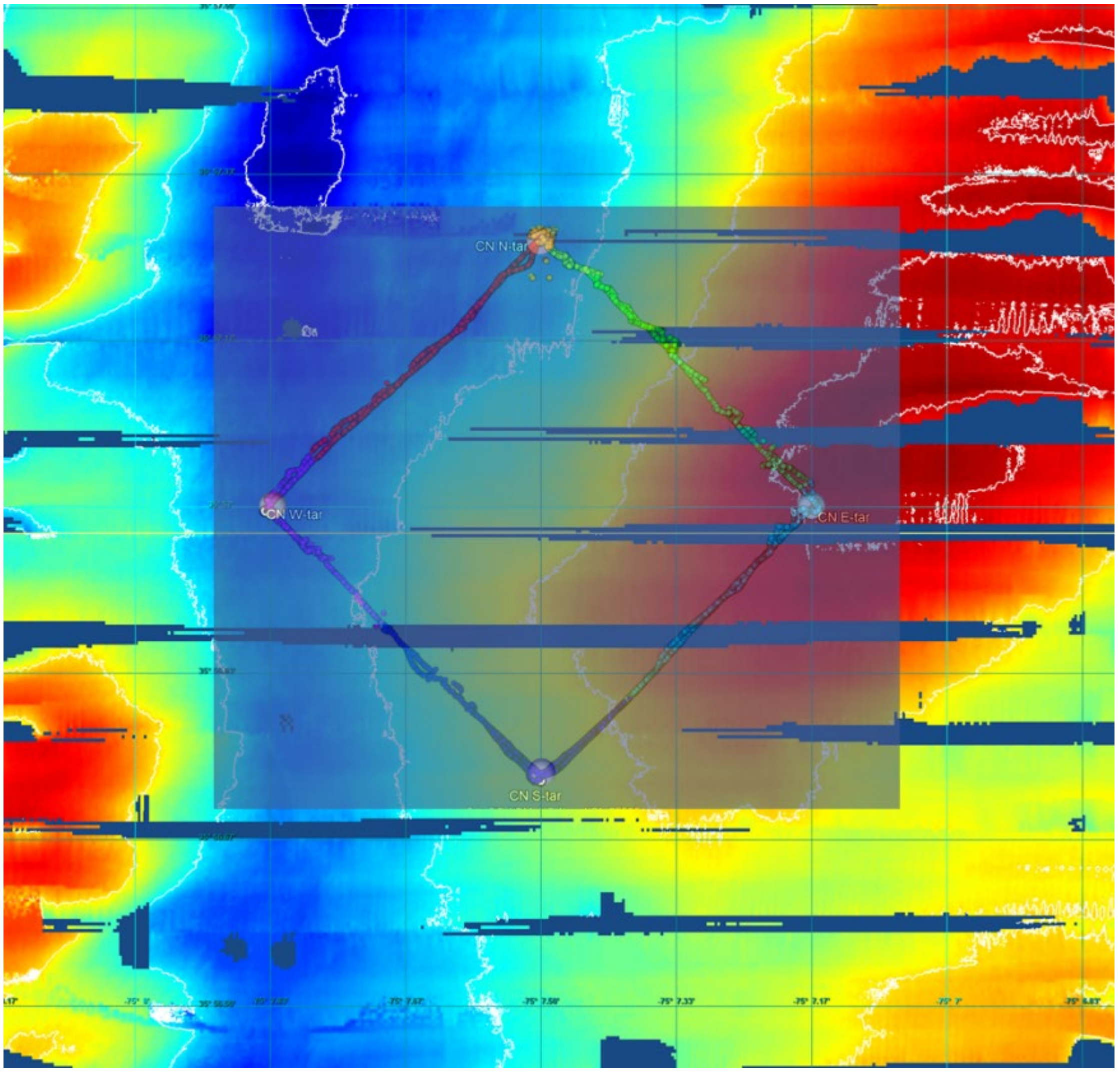

Figure 26: ROV Track at Central Site

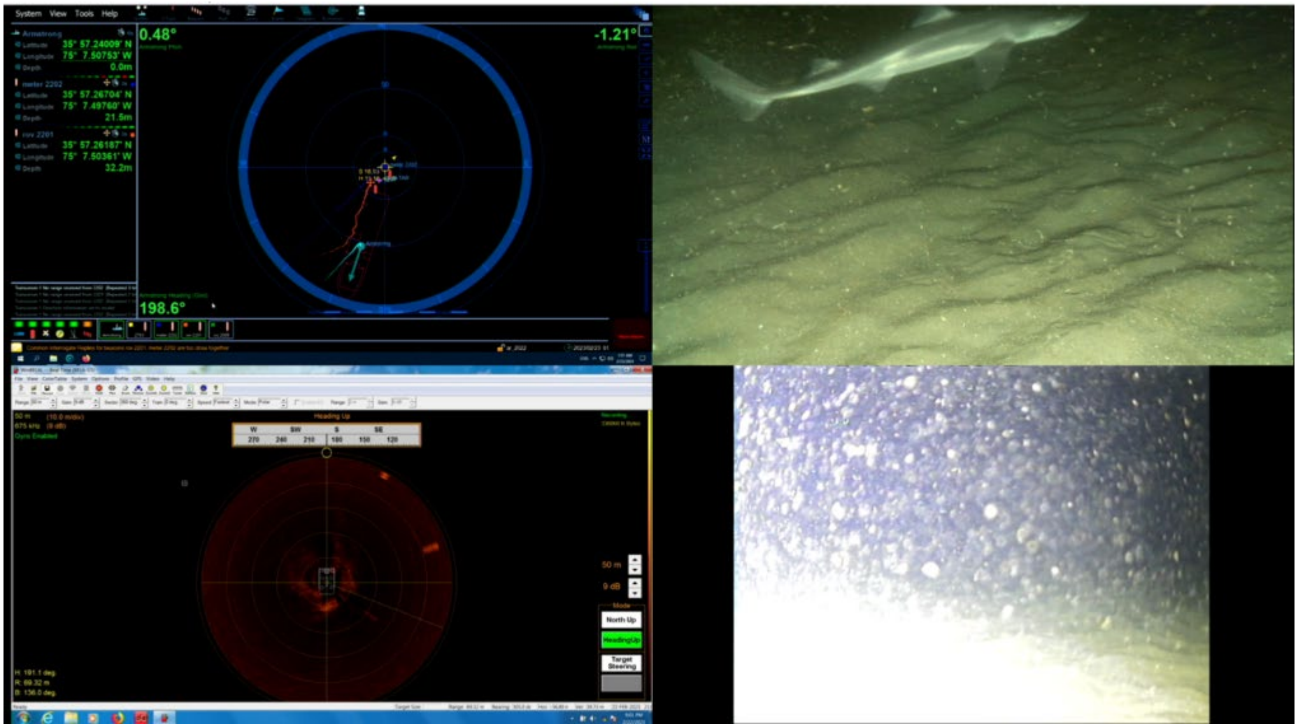

Figure 27: ROV Imagery at Central Site, North Anchor Target

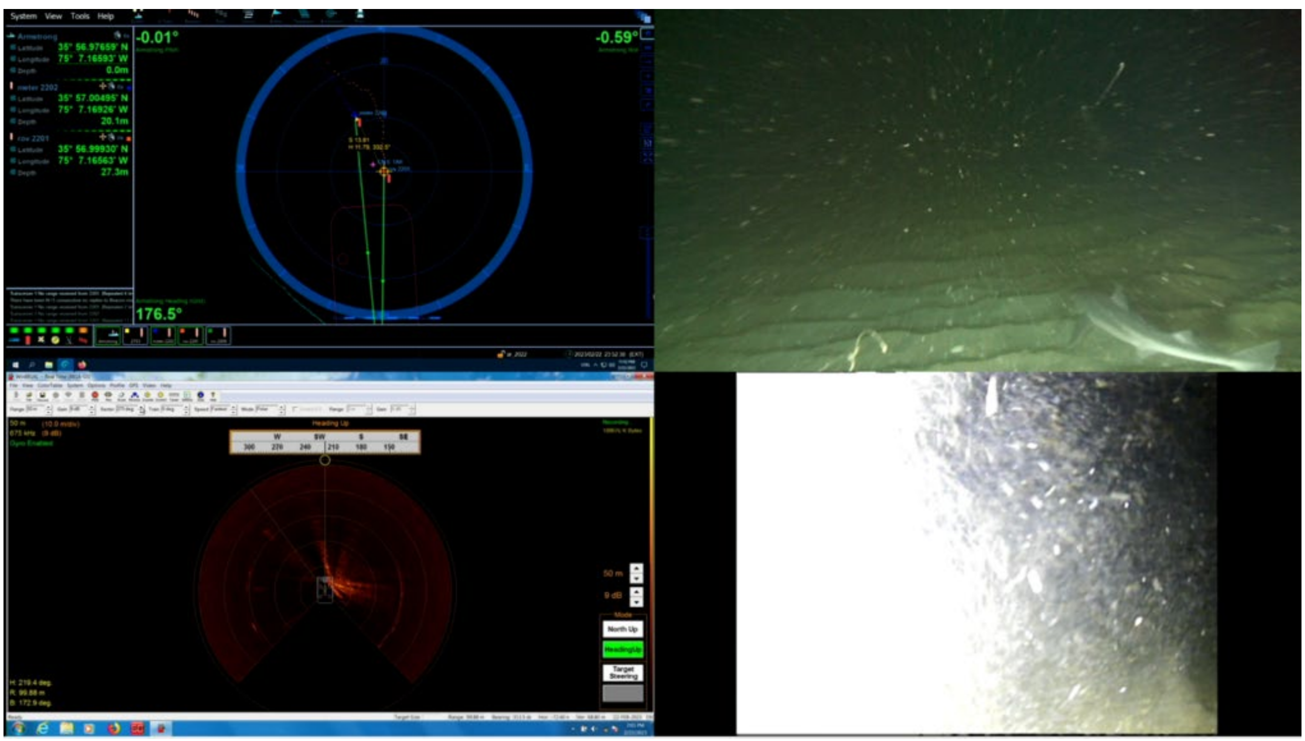

Figure 28: ROV Imagery at Central Site, East Anchor Target

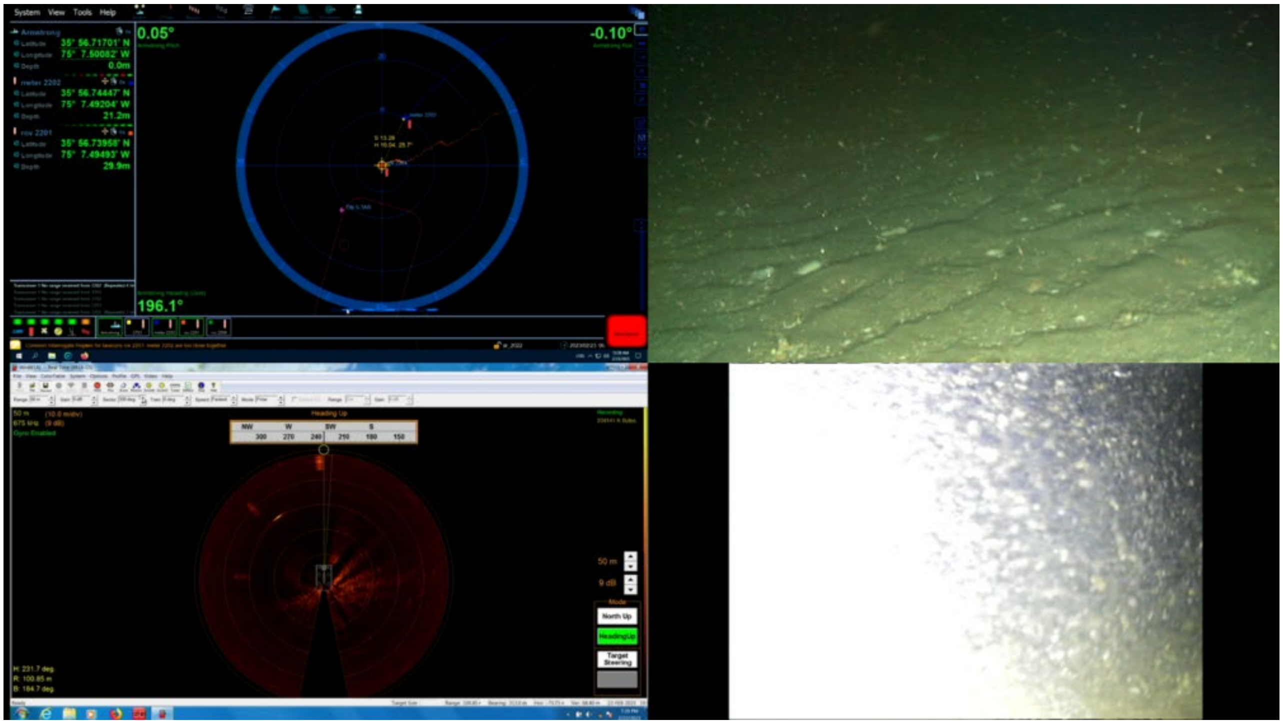

Figure 29: ROV Imagery at Central Site, South Anchor Target

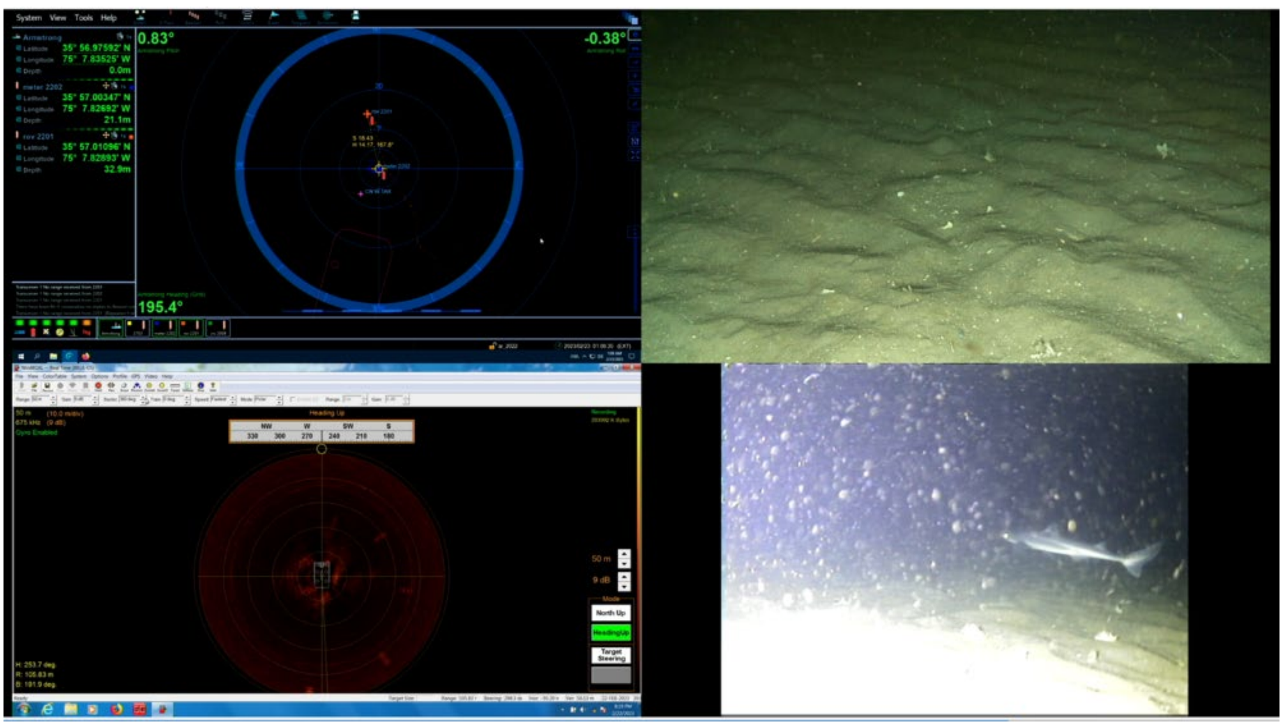

Figure 30: ROV Imagery at Central Site, West Anchor Target

8.3. Eastern

Bathymetry
Moving west to east across Figure 31, the water depth is at the shallowest ~95m, then gradually deepens to ~105m. The North and South anchor targets are at depths of 97 m and 97 m, respectively. Data collected over 2km x 2km area using 200m line spacing.

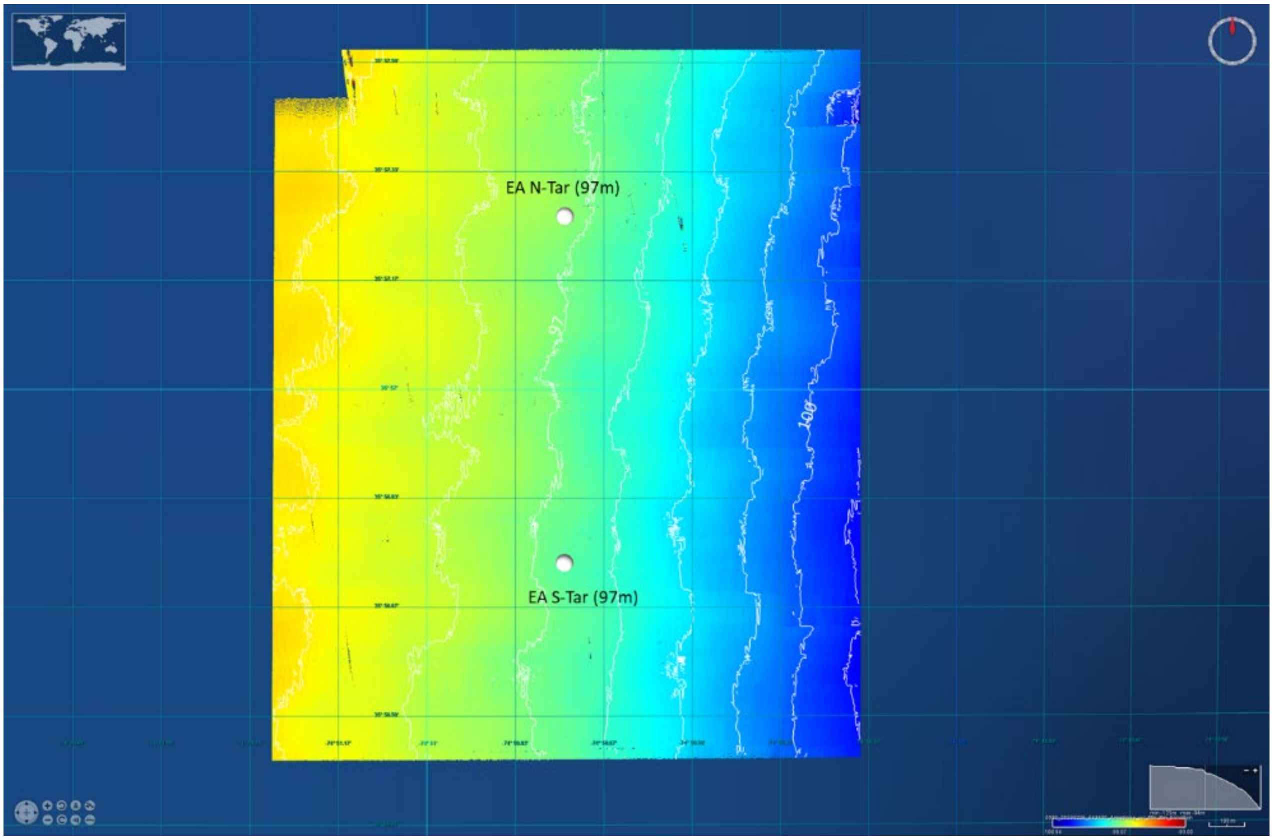

Figure 31: Eastern Site Digital Terrain Model (1m contours)

Backscatter

Backscatter imagery at both the north and south anchor target sites indicate a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figures 32 & 33).

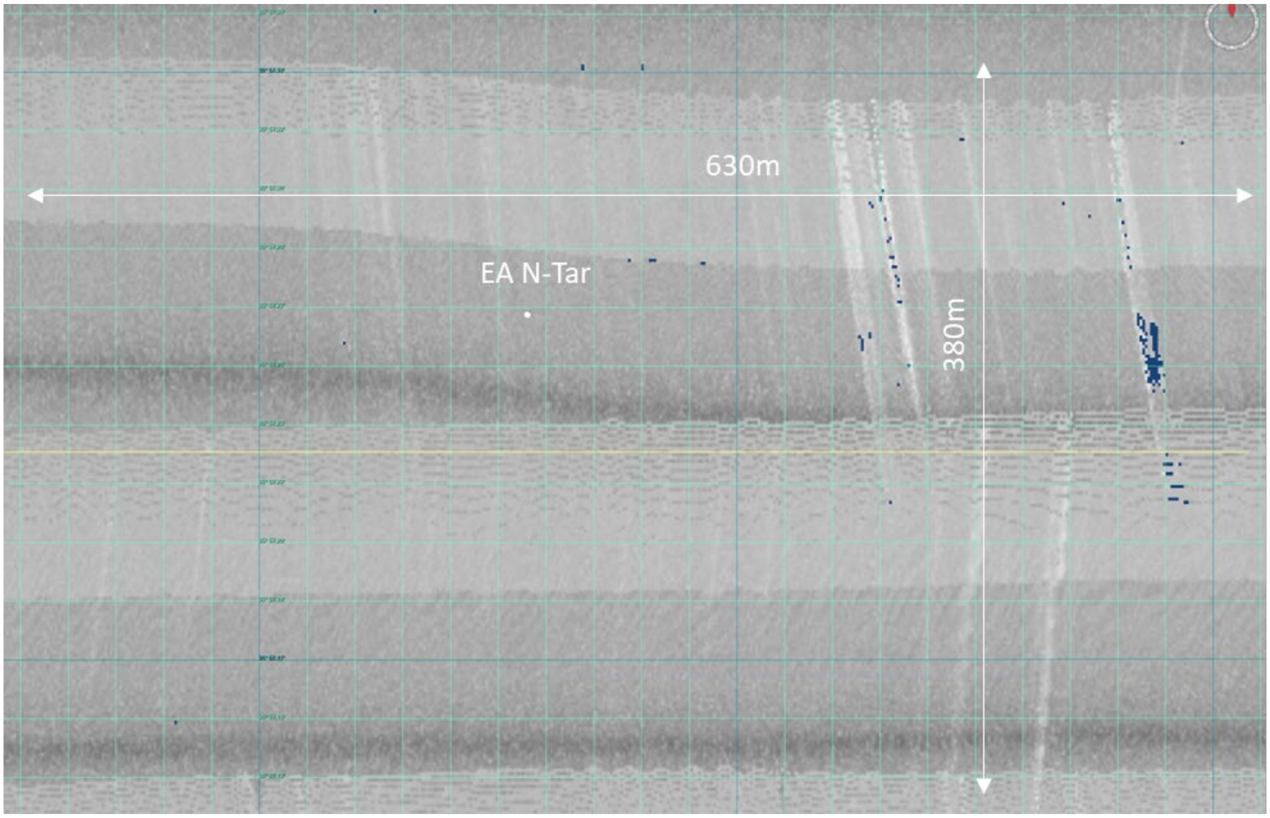

Figure 32: Eastern Site North Anchor Target (N-Tar) Backscatter

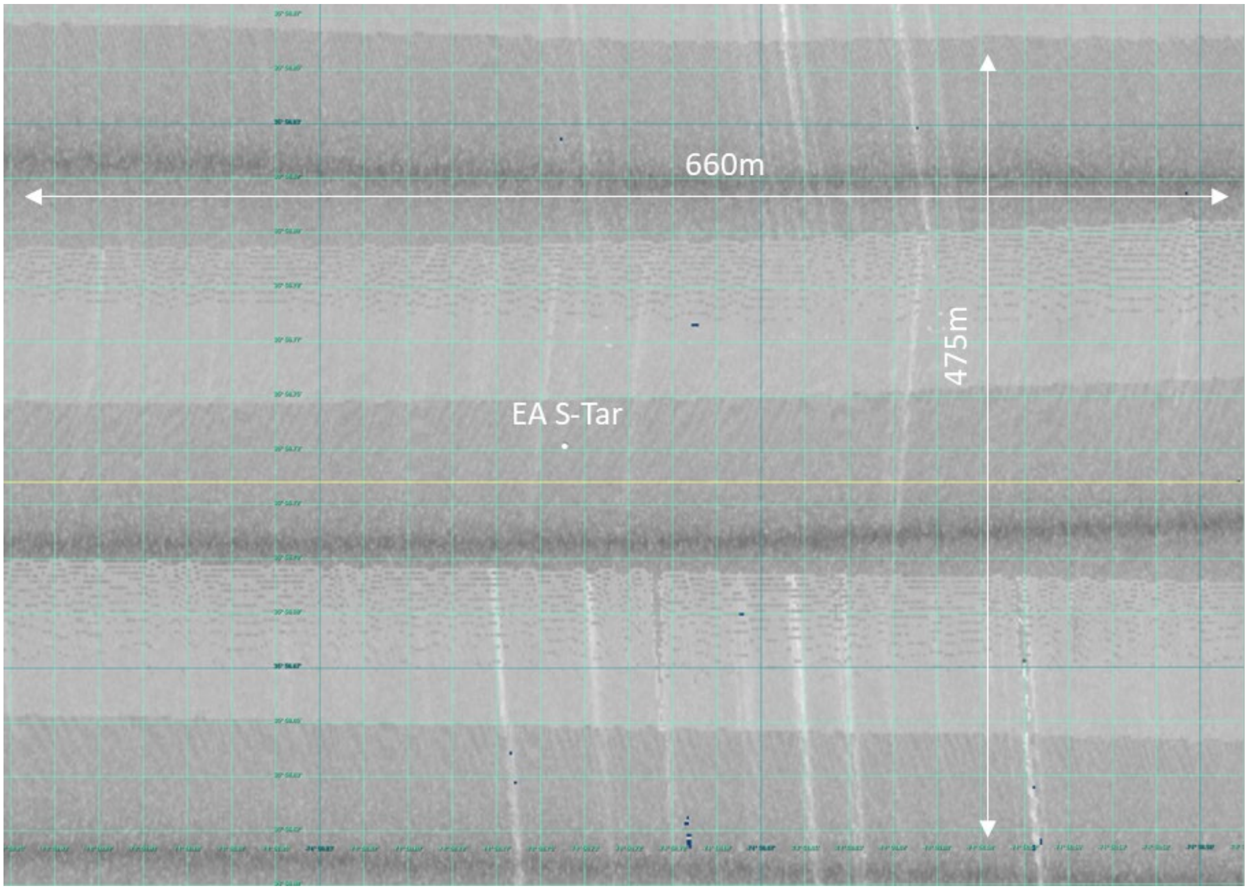

Figure 33: Eastern Site South Anchor Target (S-Tar) Backscatter

Subbottom

Subbottom profiles at both the north and south anchor target sites indicate a soft and homogeneous seabed with good penetration, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 34 & 35). Slopes are less than 0.5°.

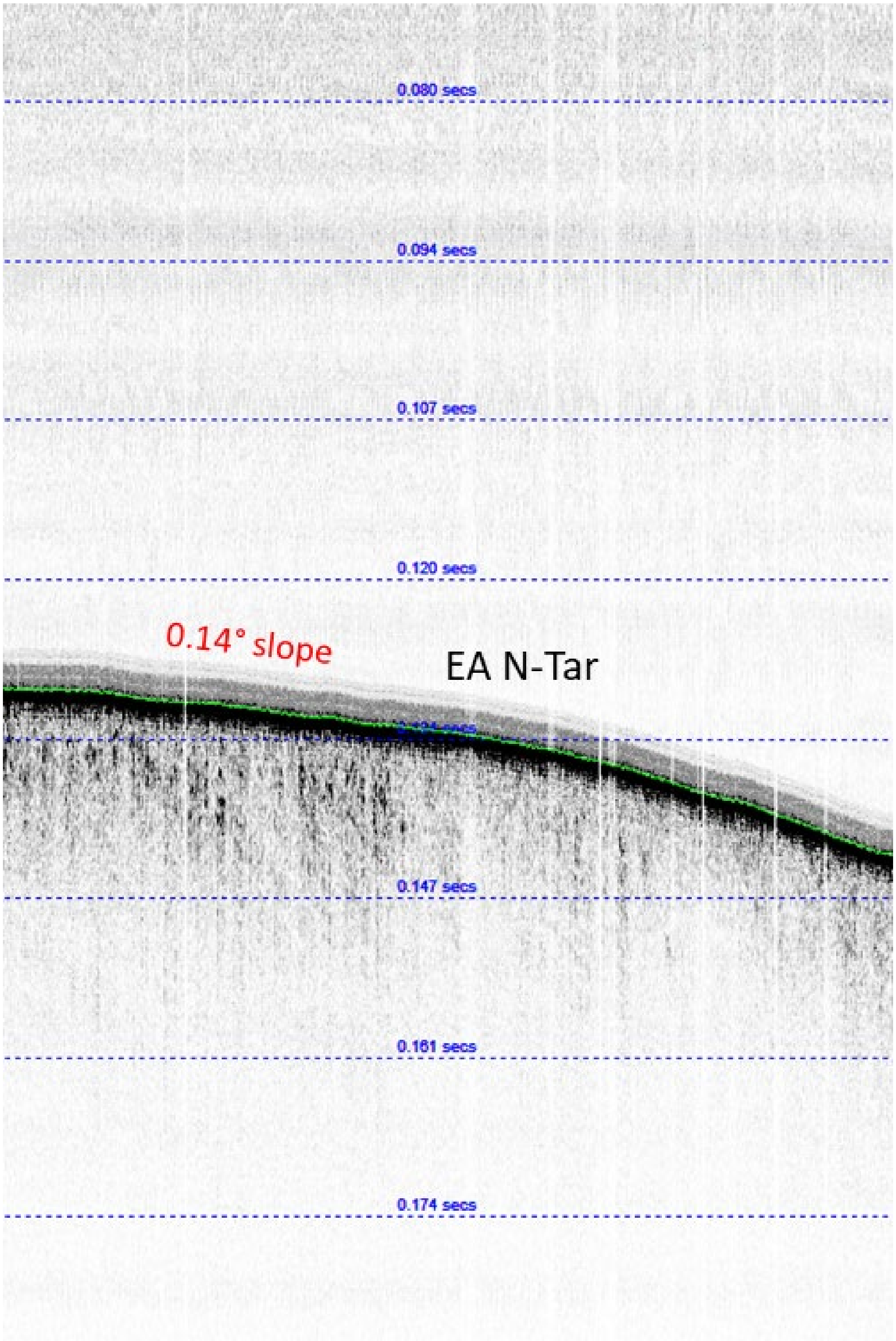

Figure 34: Eastern Site North Anchor Target (N-Tar) Subbottom

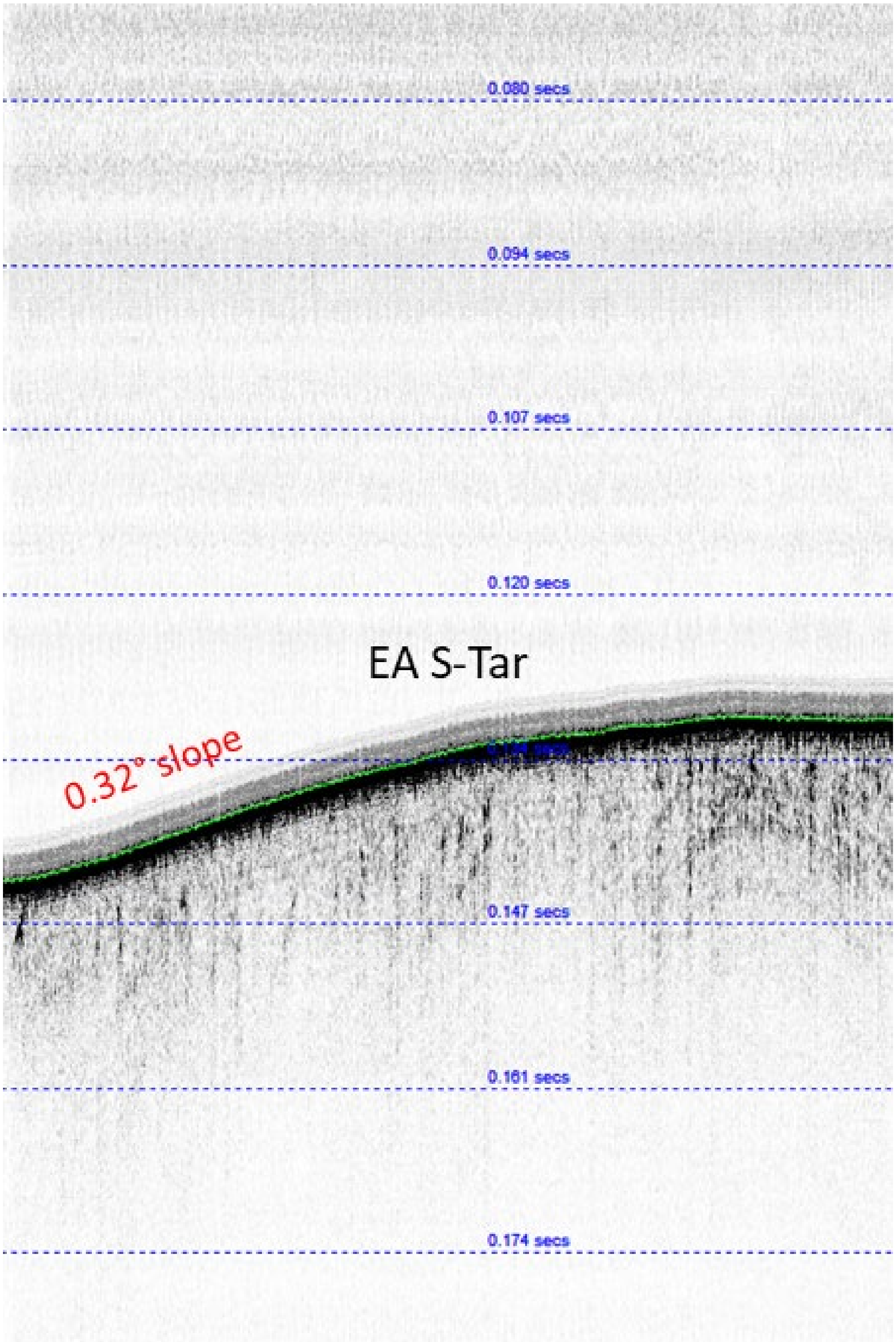

Figure 35: Eastern Site South Anchor Target (S-Tar) Subbottom

ROV Inspection

ROV inspection was completed at both anchor target sites, Figure 36 shows the ROV and depressor positions overlaid on the DTM. The camera data indicates a flat seabed at both sites consisting of sands, gravels, and shells (Figures 37 – 39). No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

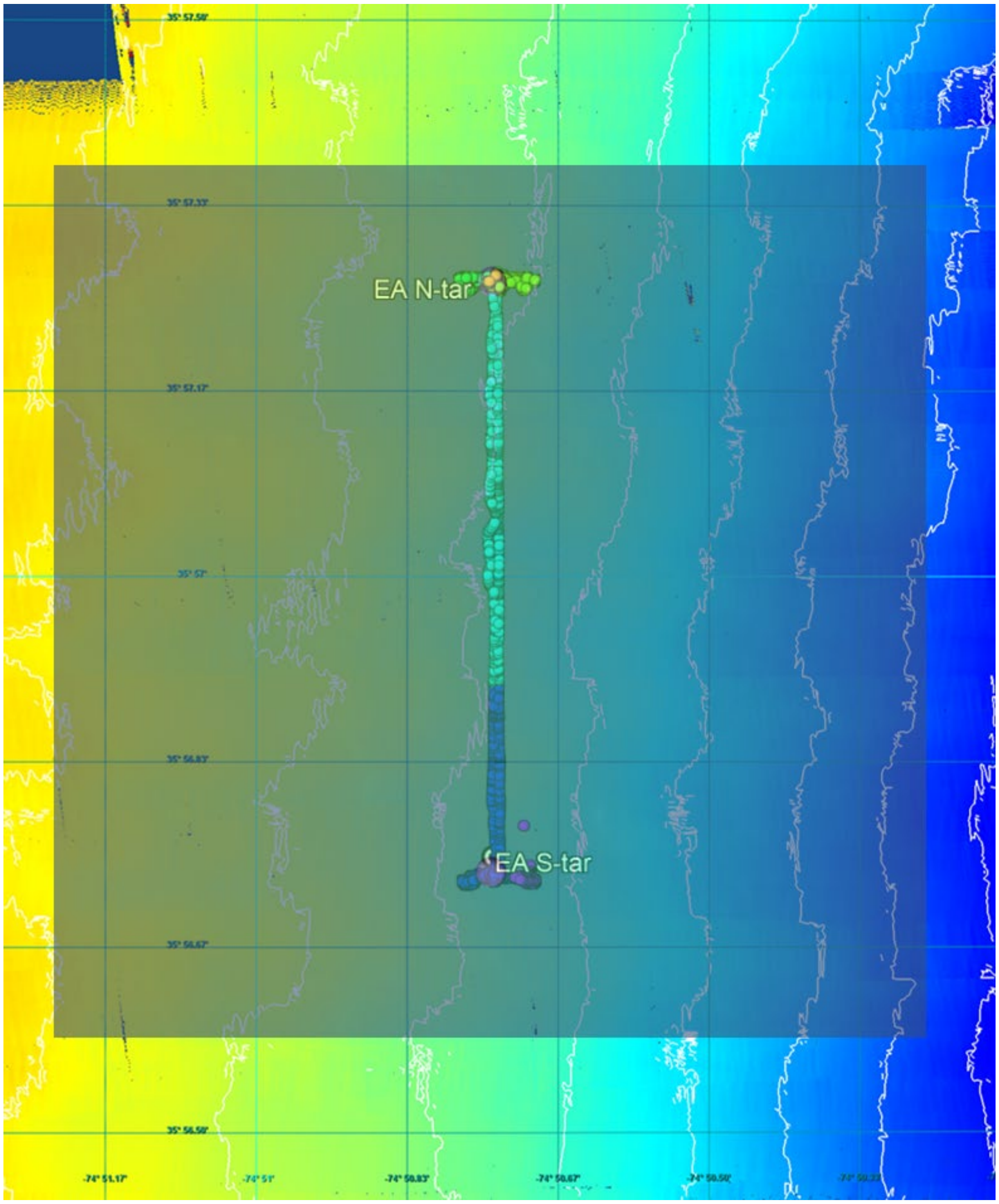

Figure 36: ROV Track at Eastern Site

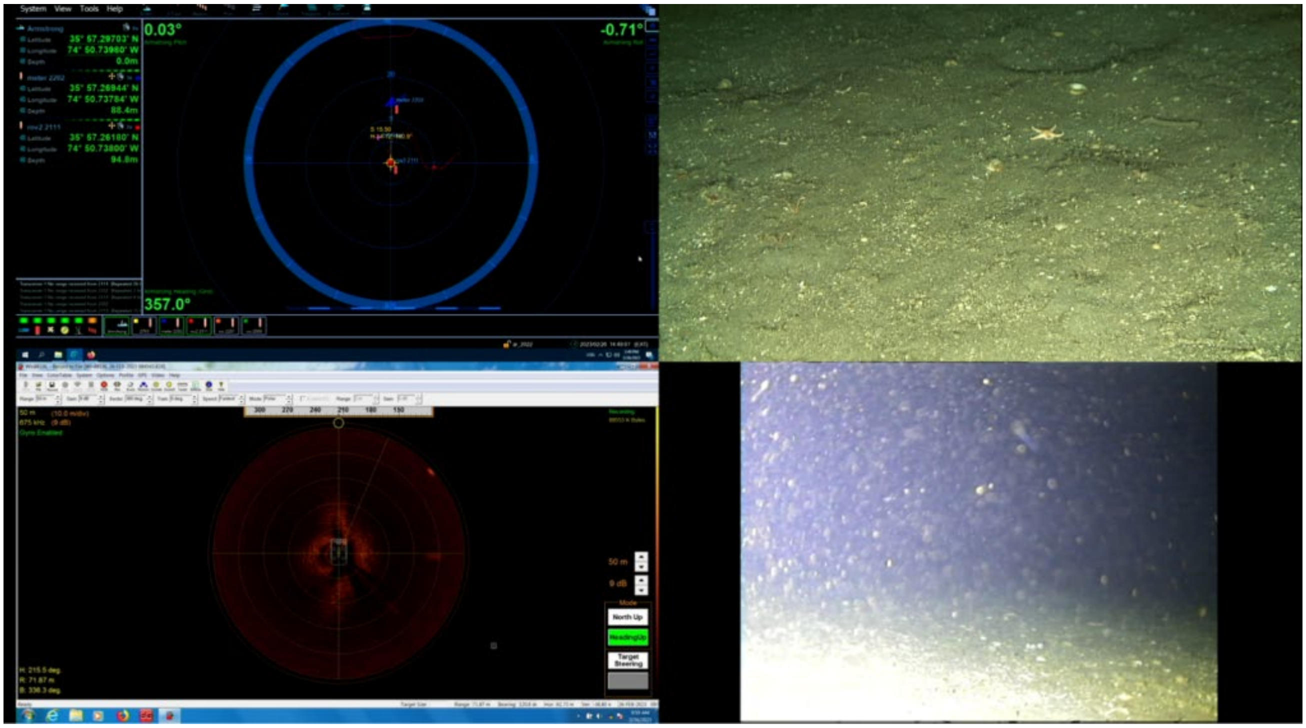

Figure 37: ROV Imagery at Eastern Site, North Anchor Target

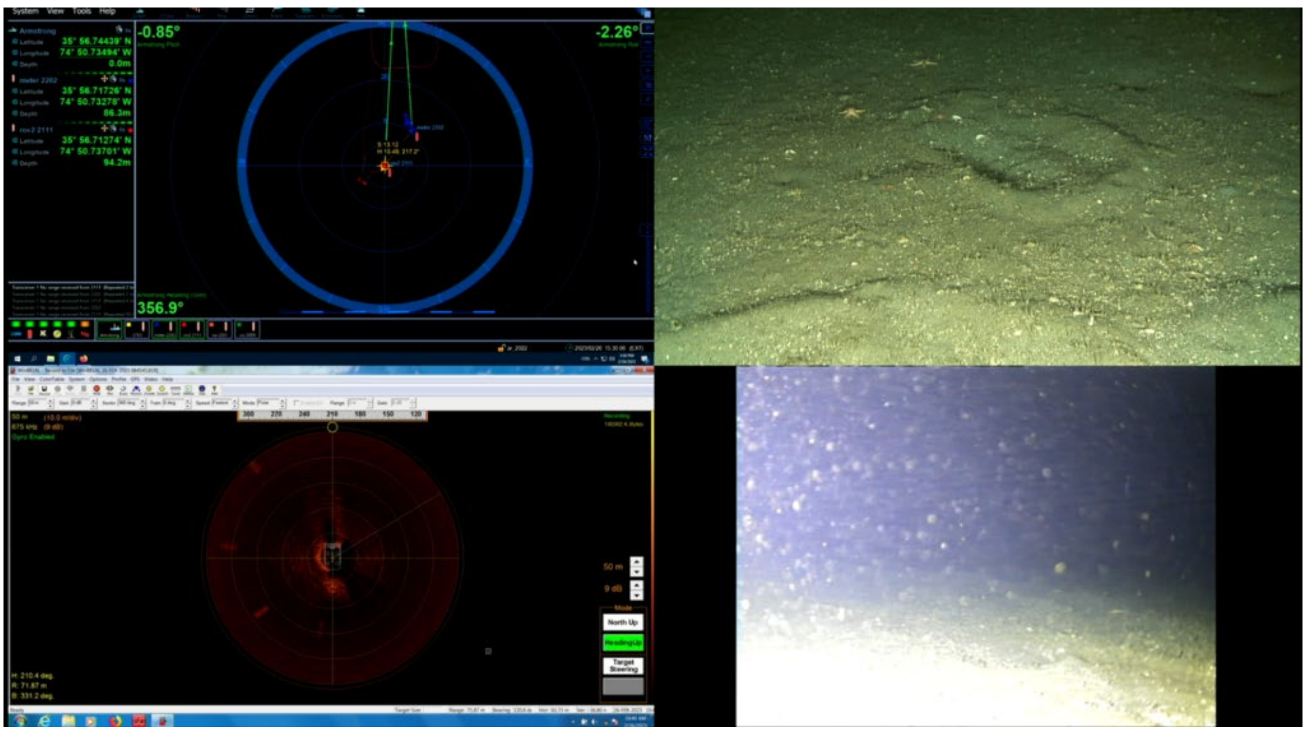

Figure 38: ROV Imagery at Eastern Site, South Anchor Target

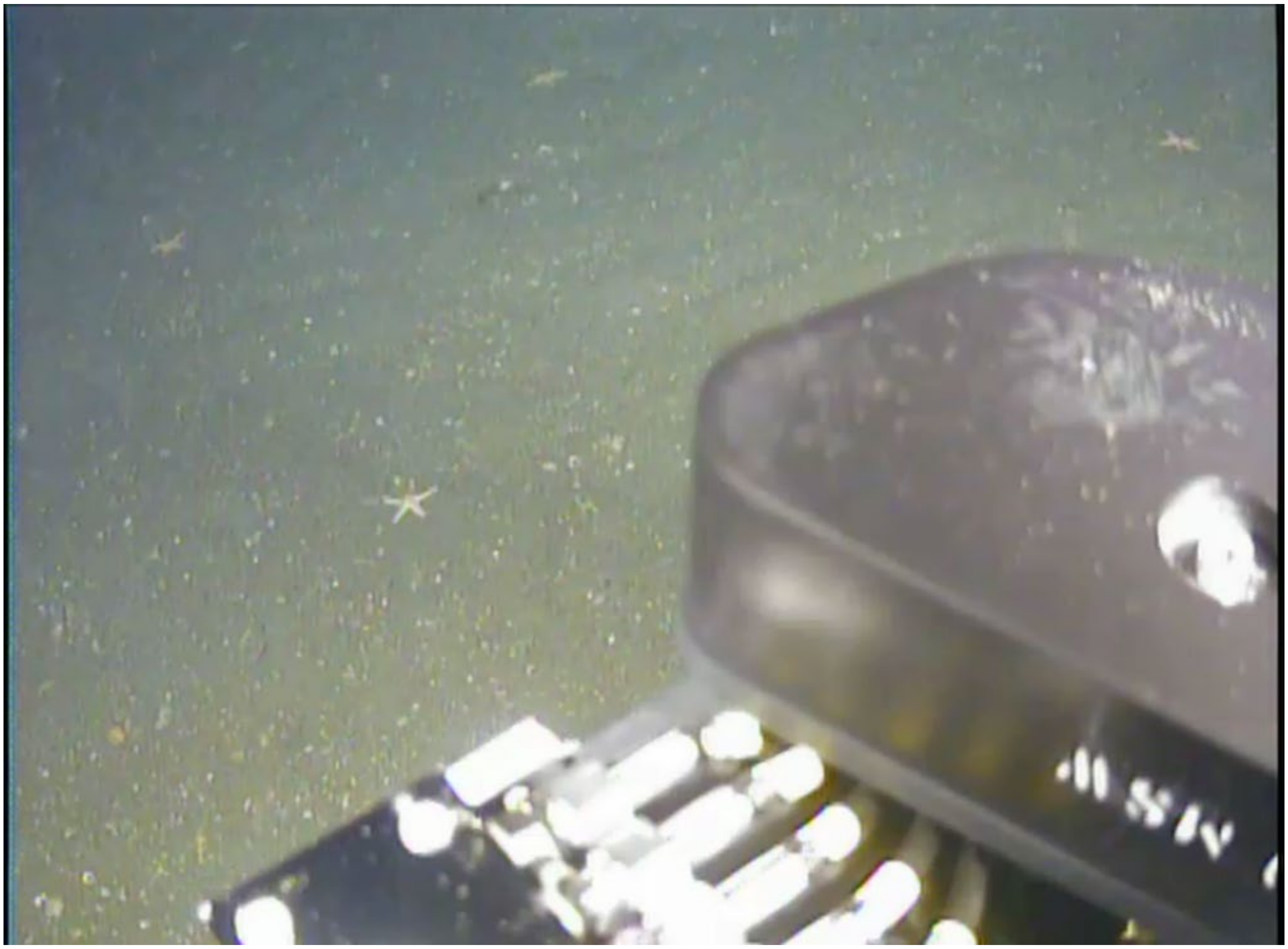

Figure 39: Sandy, Gravelly, Shelly Seabed Eastern Site, South Anchor Target

8.4. Northern

Bathymetry

Moving west to east across Figure 40, the water depth is at the shallowest ~92m, then gradually deepens to ~105m. The North, South, East and West anchor targets are at depths of 97 m, 99 m, 101 m and 95 m, respectively. Data collected over 2km x 2km area using 200m line spacing.

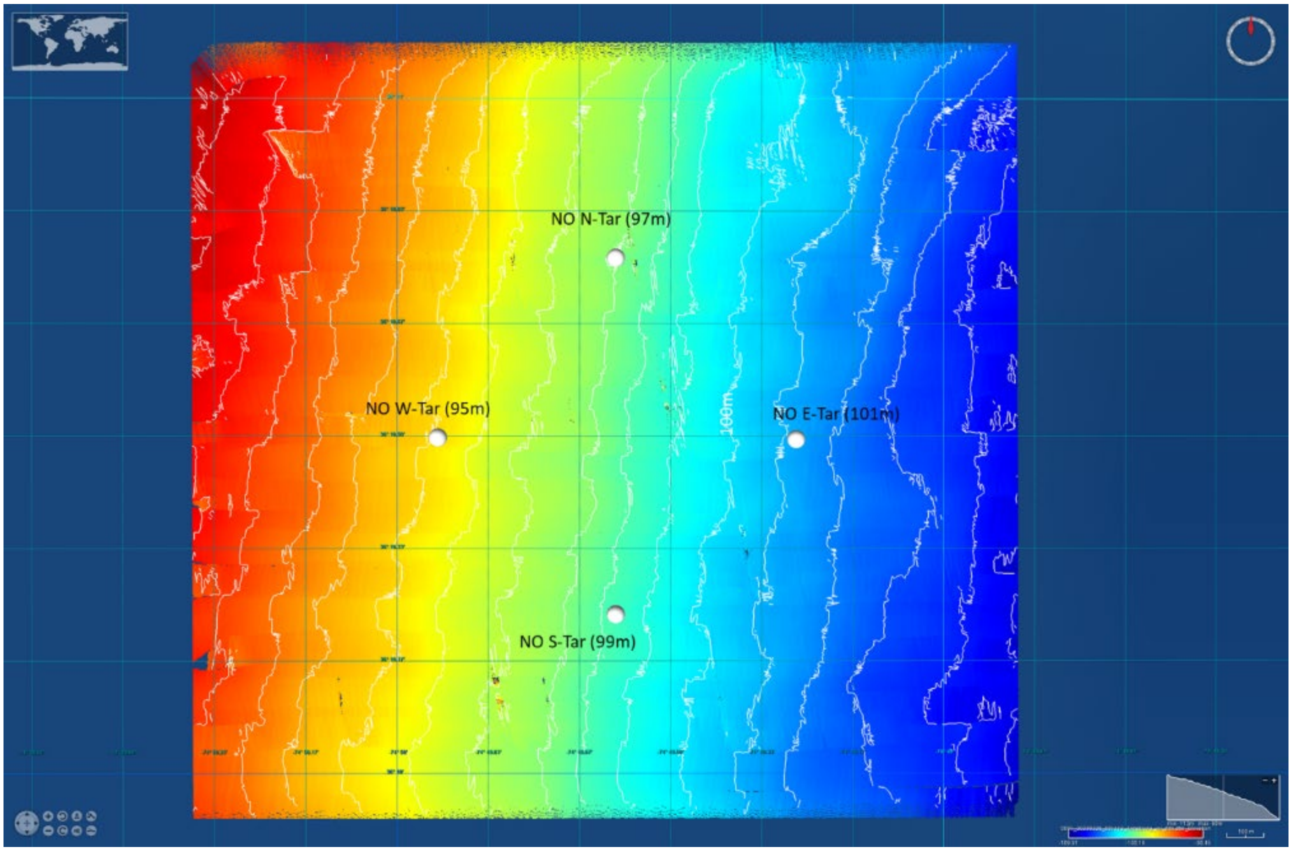

Figure 40: Northern Site Digital Terrain Model (1m contours)

Backscatter

Backscatter imagery at both the north and south anchor target sites indicate a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figures 41 thru 44).

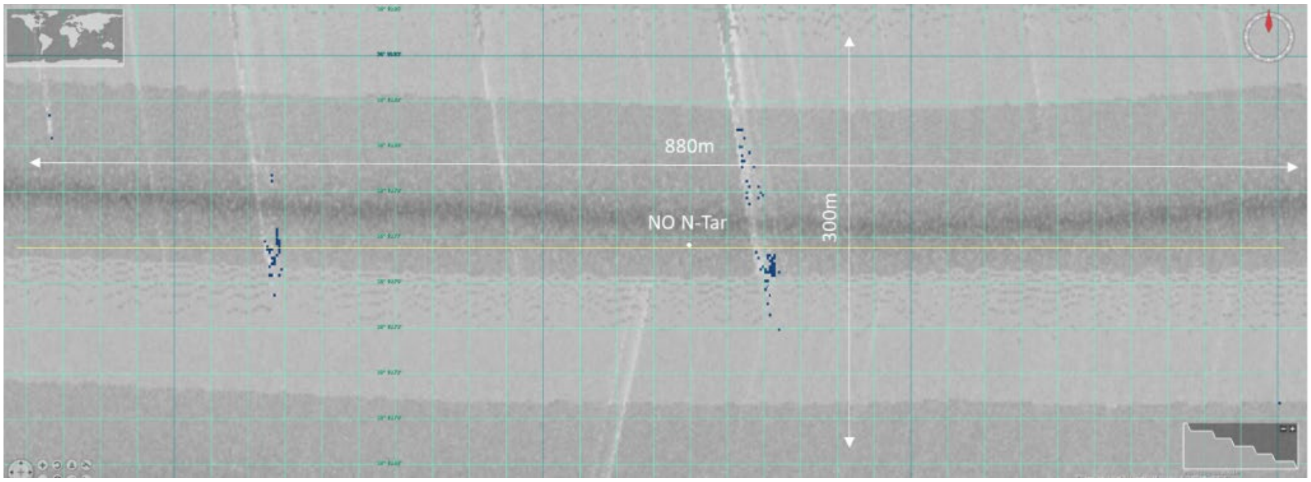

Figure 41: Northern Site North Anchor Target (N-Tar) Backscatter

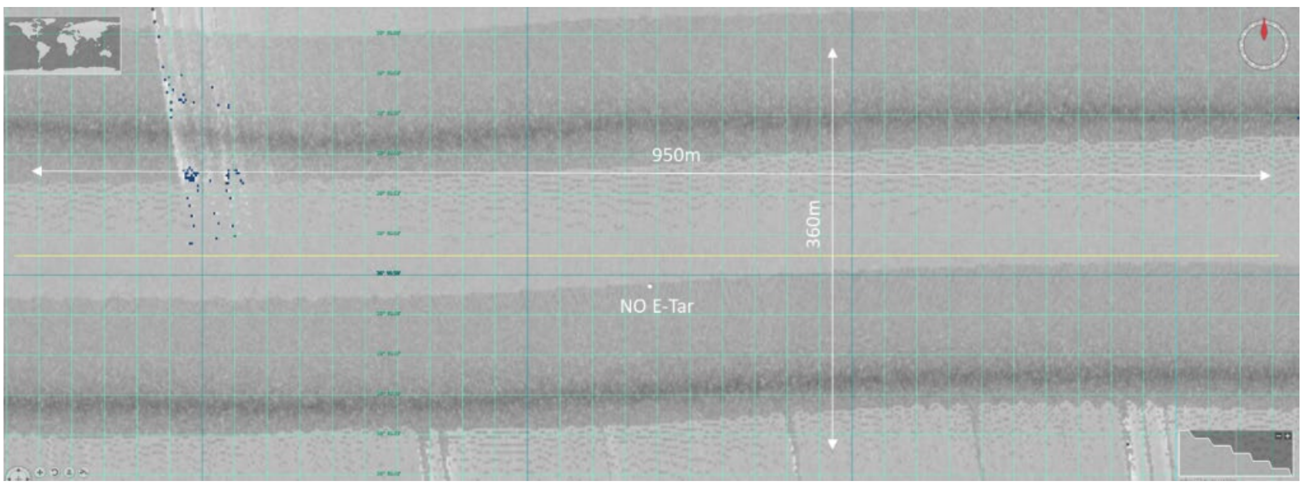

Figure 42: Northern Site East Anchor Target (E-Tar) Backscatter

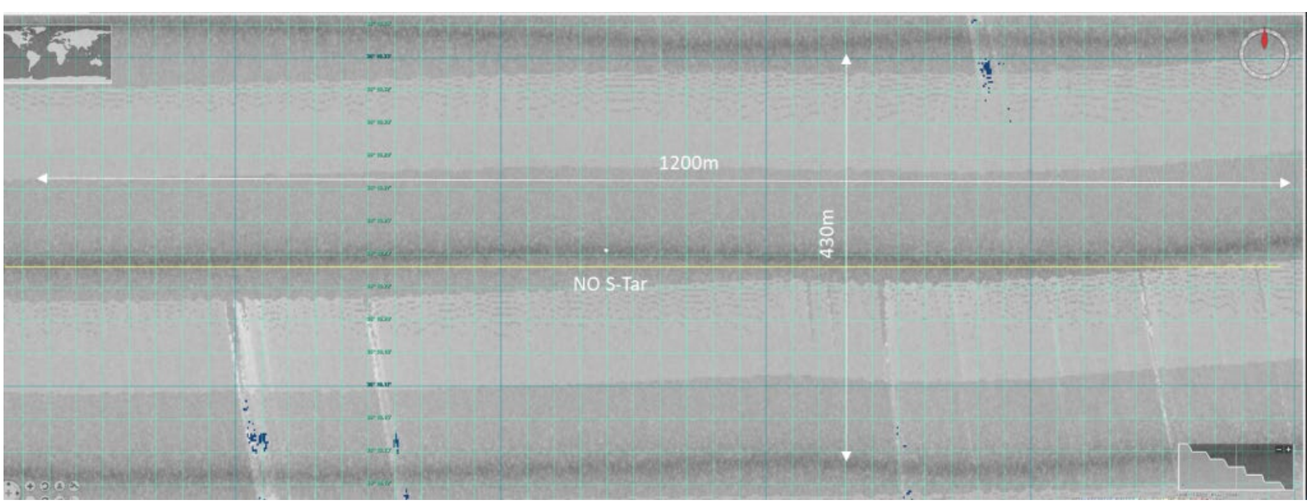

Figure 43: Northern Site South Anchor Target (S-Tar) Backscatter

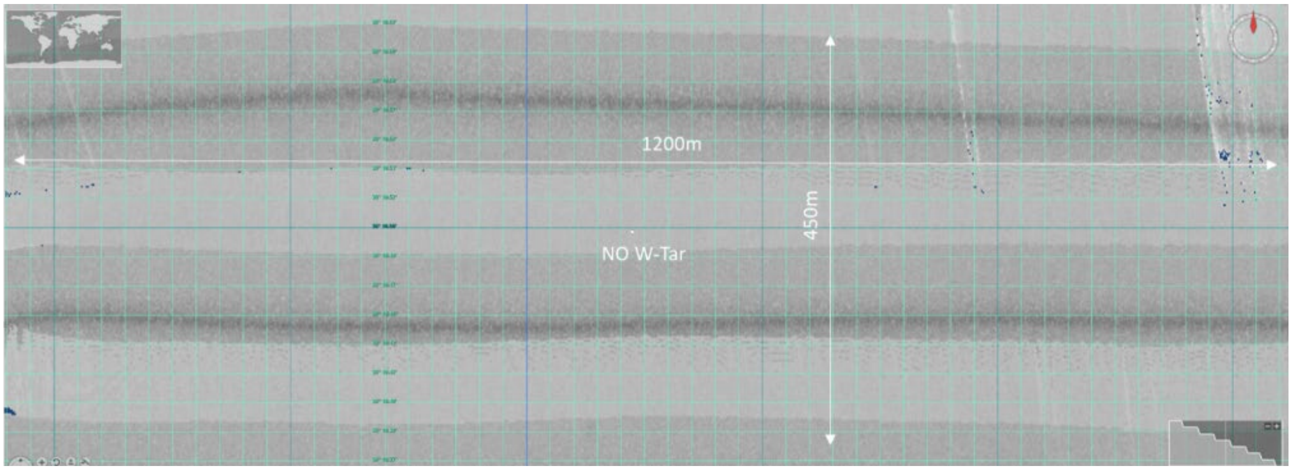

Figure 44: Northern Site West Anchor Target (W-Tar) Backscatter

Subbottom

Subbottom profiles at all anchor target sites indicate a soft and homogeneous seabed with good penetration, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 45 thru 47). Slopes are ~0.5°.

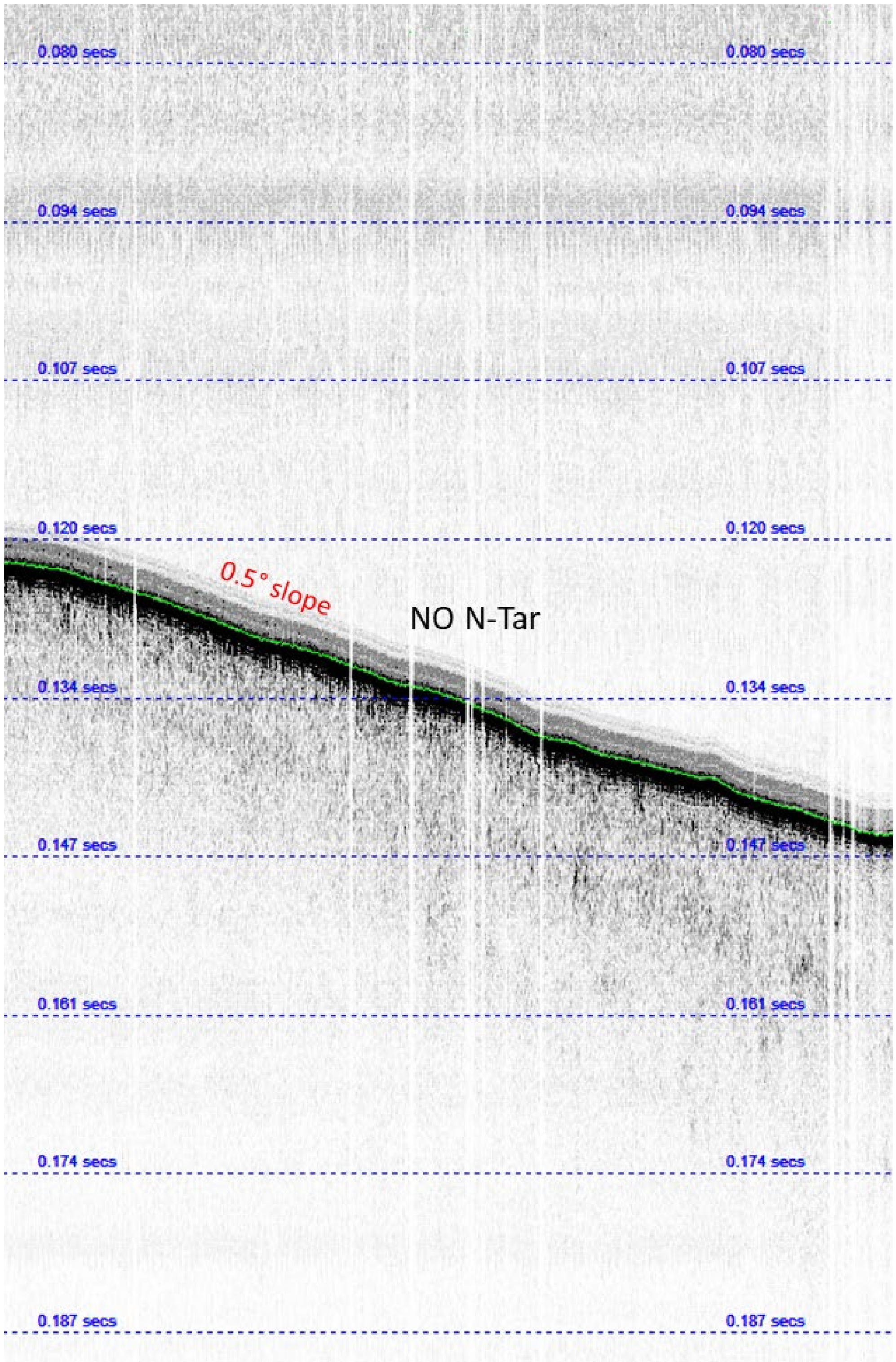

Figure 45: Northern Site North Anchor Target (N-Tar) Subbottom

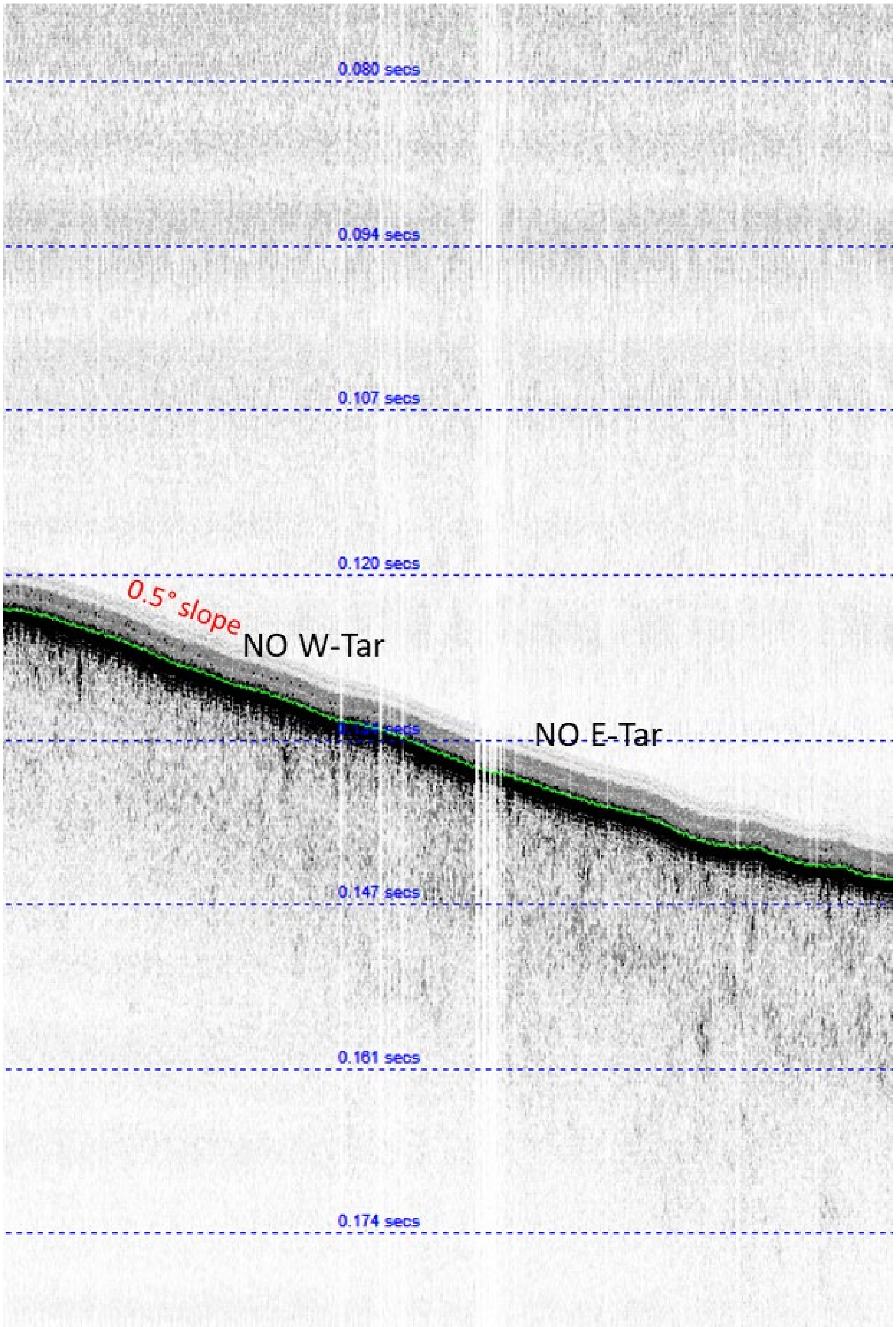

Figure 46: Northern Site East & West Anchor Targets (E-Tar, W-Tar) Subbottom

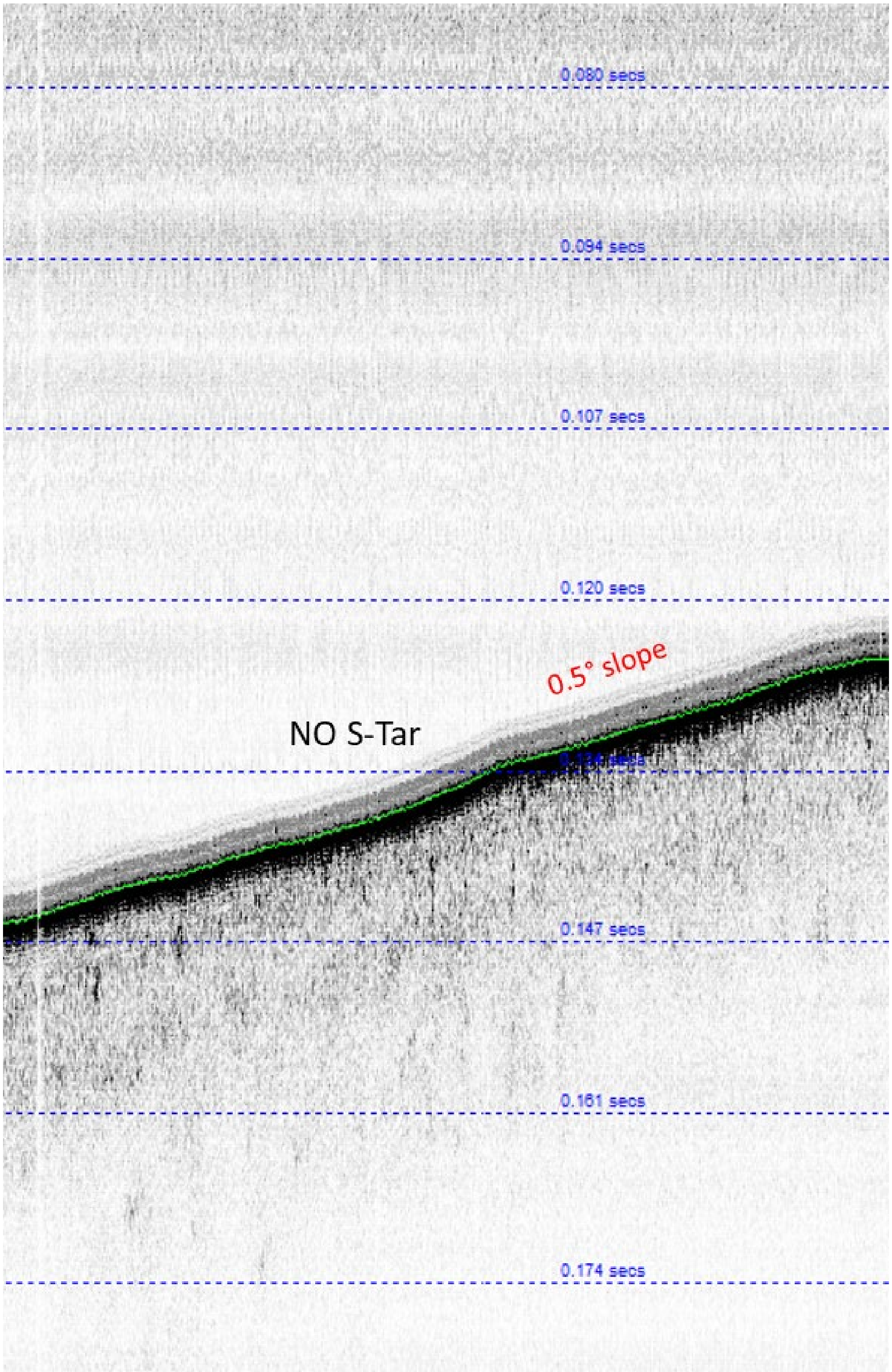

Figure 47: Northern Site South Anchor Targets (S-Tar) Subbottom

ROV Inspection

ROV inspection was completed at all anchor target sites, Figure 48 shows the ROV and depressor positions overlaid on the DTM. The camera data indicates a flat seabed at all sites consisting of sands, gravels, shells (Figures 49 thru 54). No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

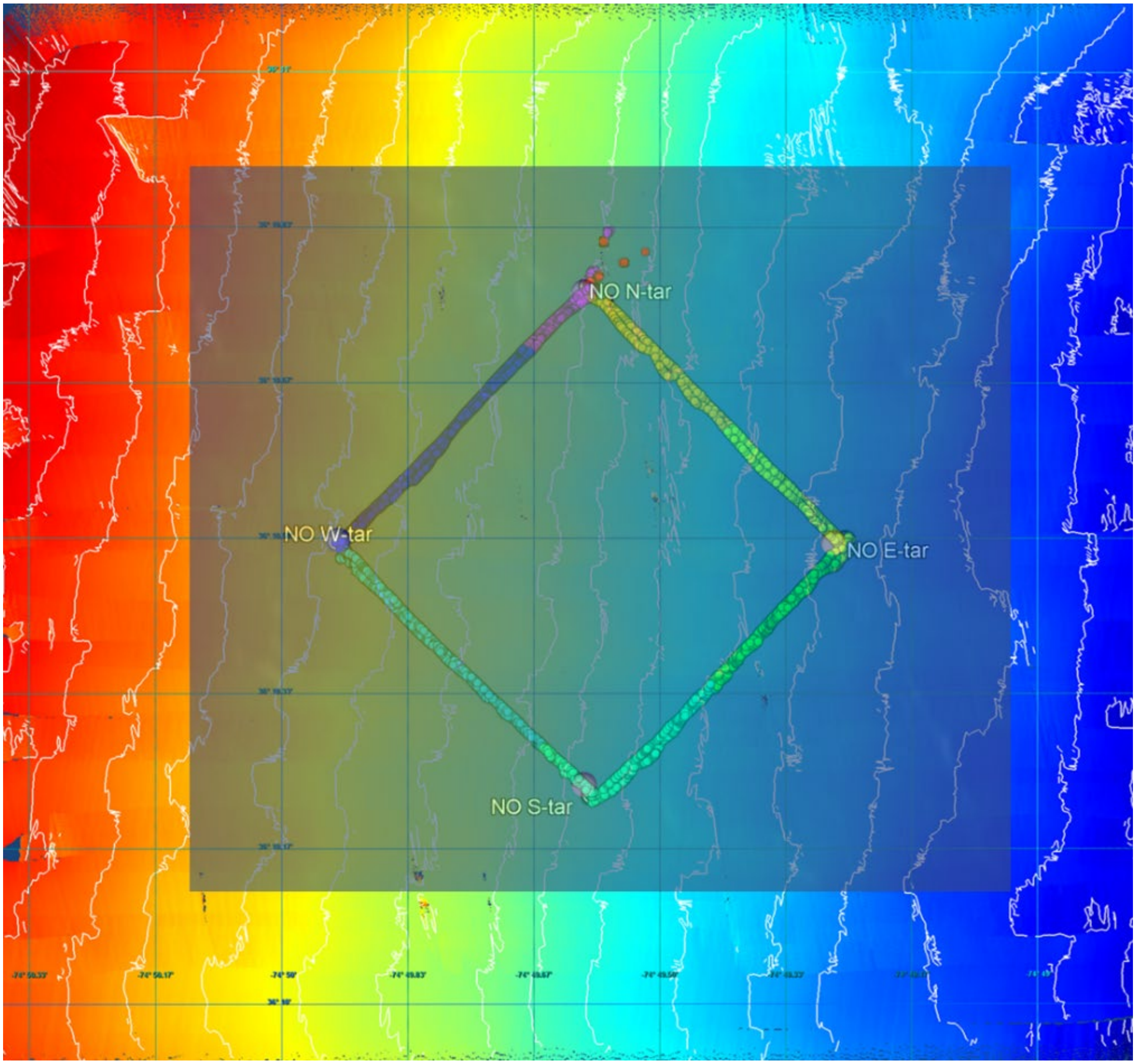

Figure 48: ROV Track at Northern Site

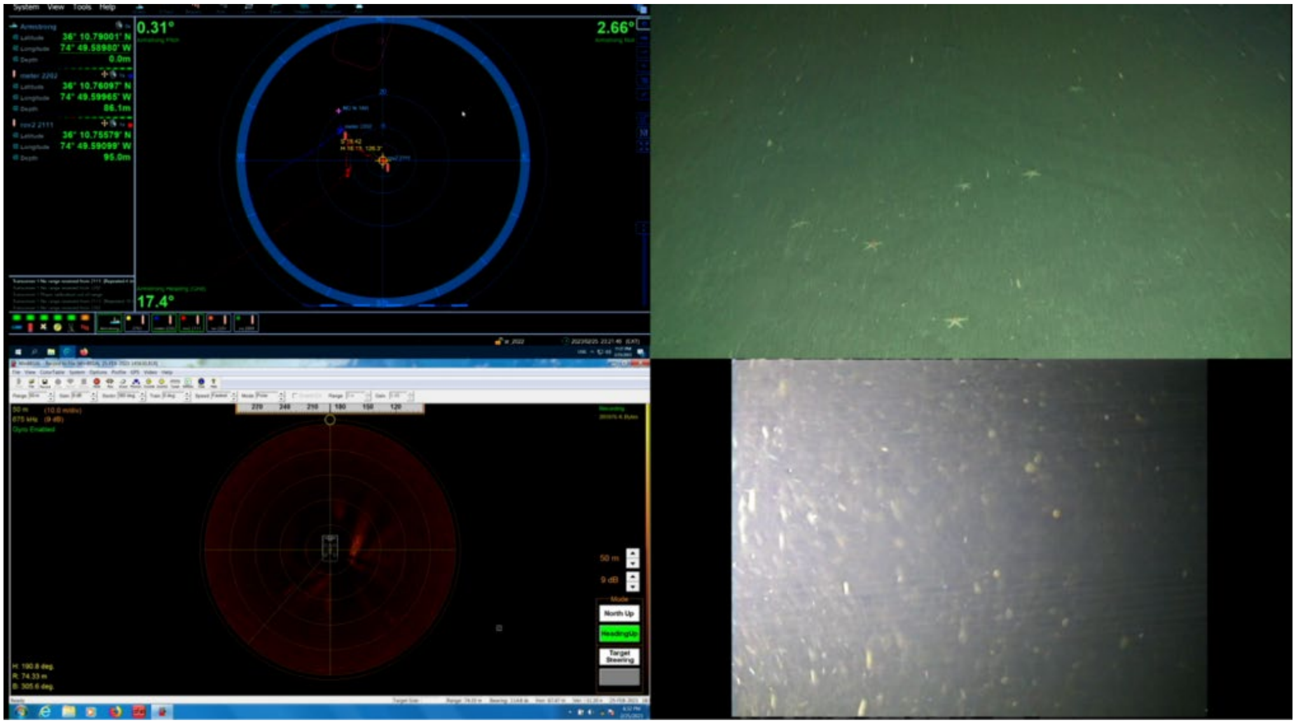

Figure 49: ROV Imagery at Northern Site, North Anchor Target

Figure 50: Sandy, Gravelly, Shelly Seabed Northern Site, North Anchor Target

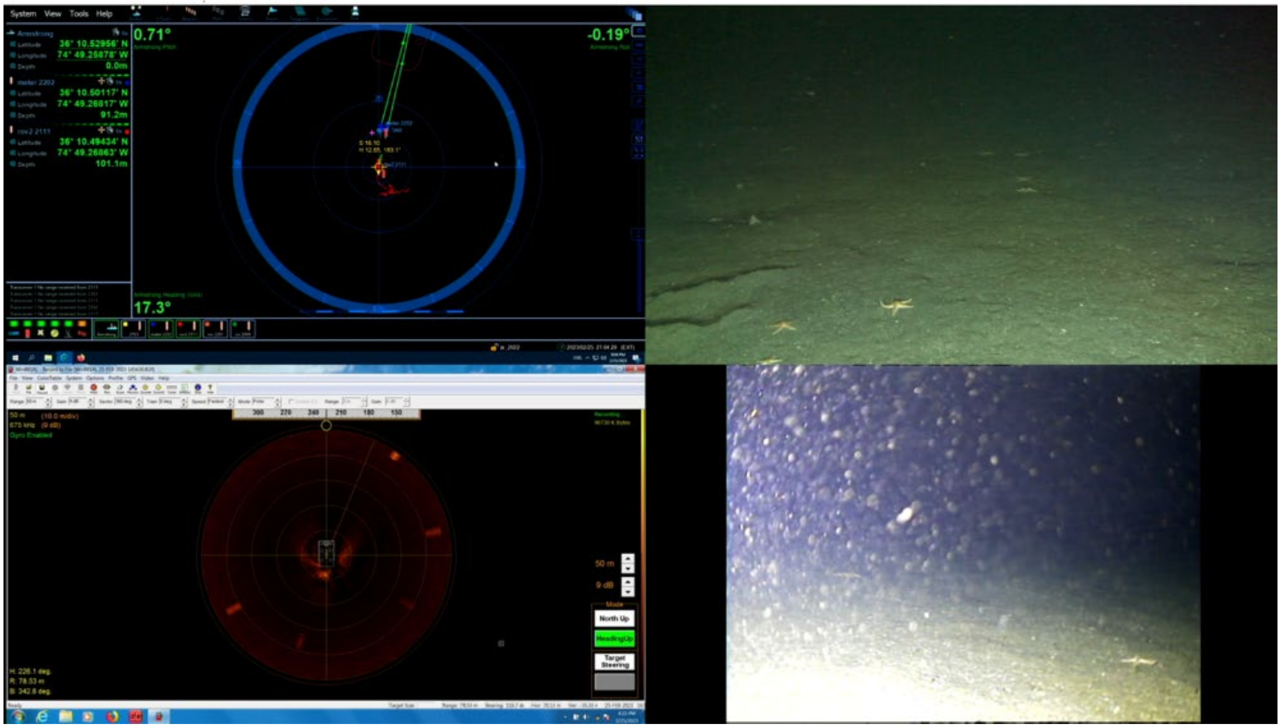

Figure 51: ROV Imagery at Northern Site, East Anchor Target

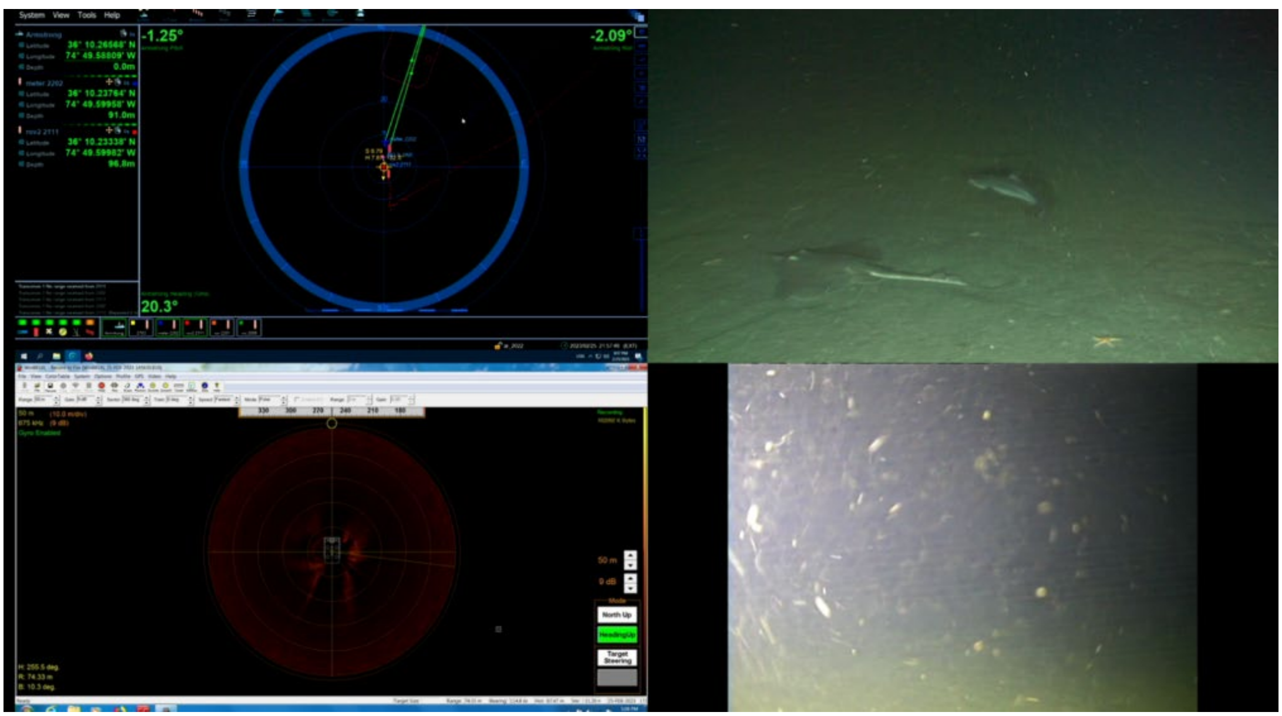

Figure 52: ROV Imagery at Northern Site, South Anchor Target

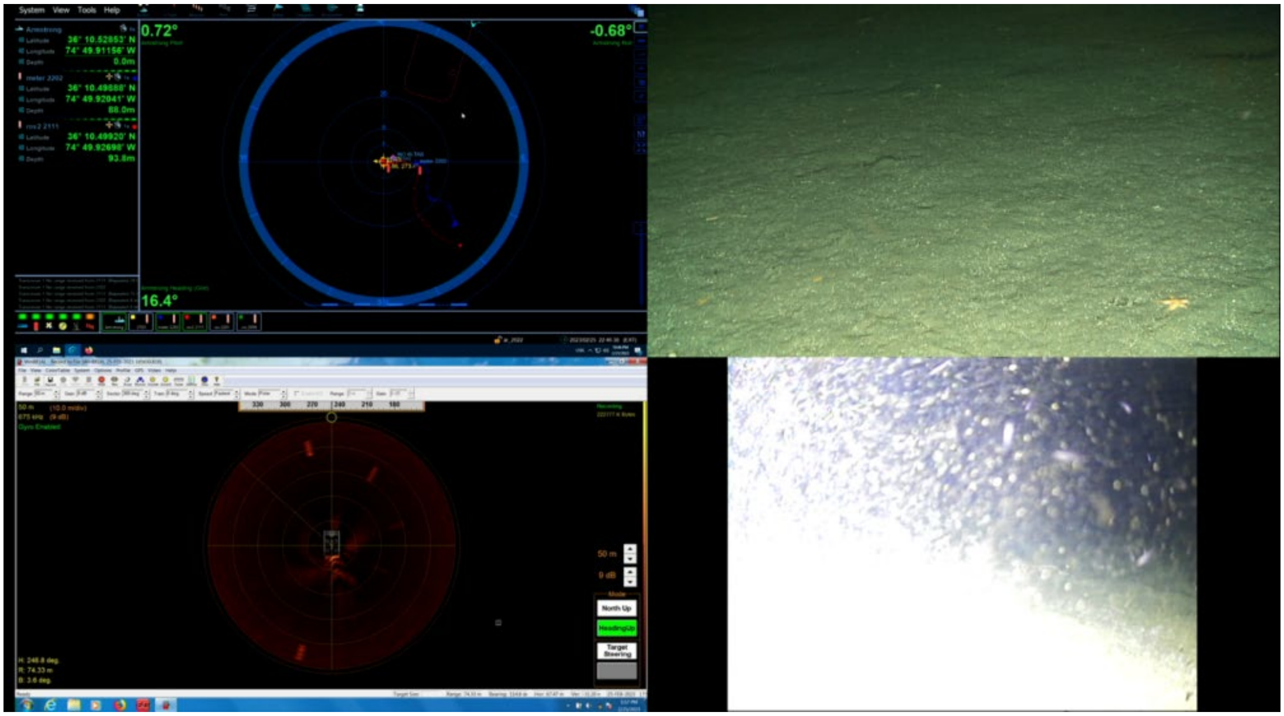

Figure 53: ROV Imagery at Northern Site, West Anchor Target

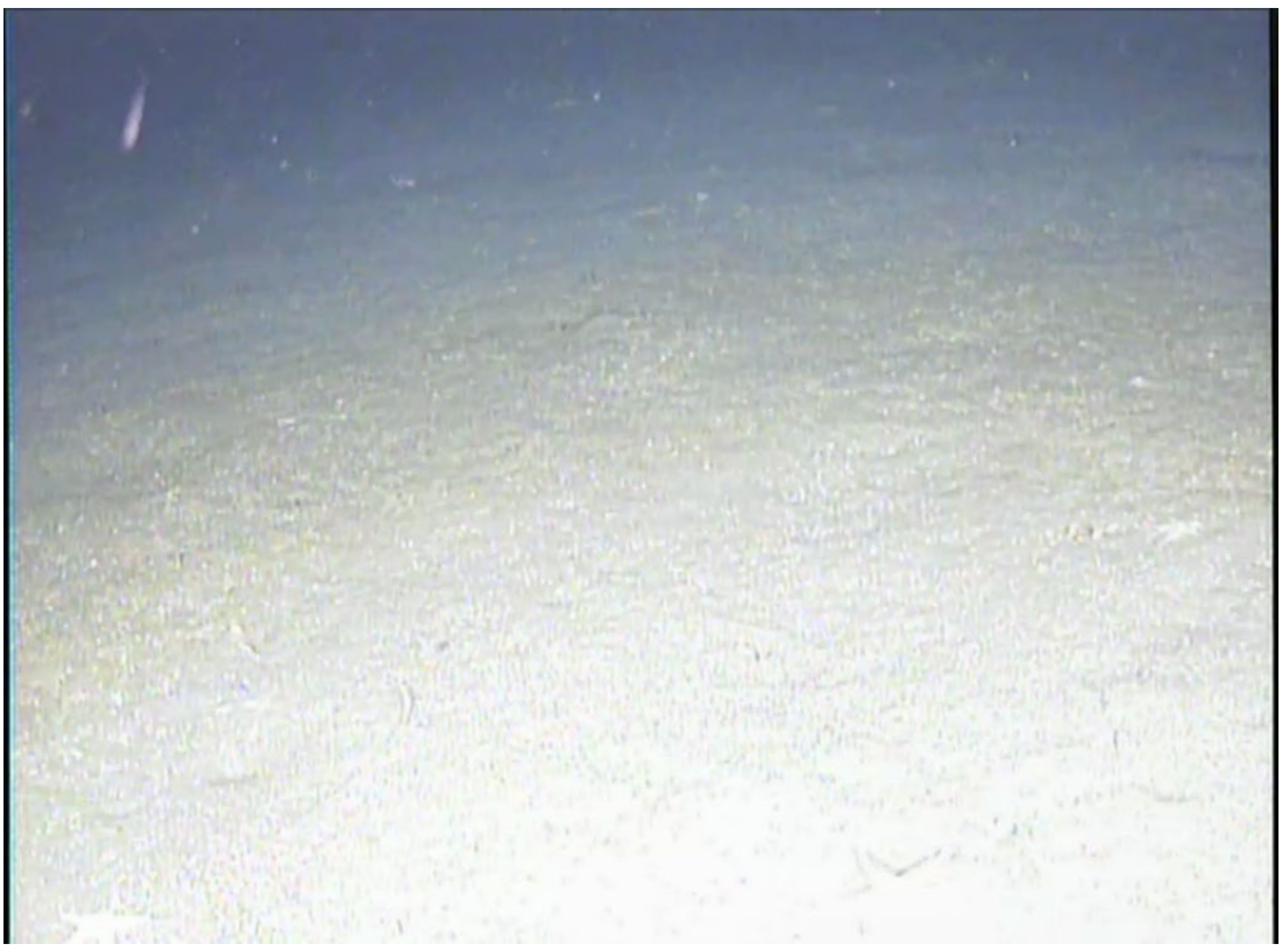

Figure 54: Sandy, Gravelly, Shelly Seabed Northern Site, West Anchor Target

8.5. Southern

Bathymetry

Moving west to east across Figure 55, the water depth is at the shallowest ~85m in the southwest corner, then deepens to the west with a steeper dropoff starting at the ~118m contour deepening again to ~140m to the west, with a steeper dropoff to ~144m in the southeast corner. The North, South, East and West anchor targets are at depths of 94 m, 92 m, 98 m and 88 m, respectively. Data collected over 2km x 2km area using 200m line spacing.

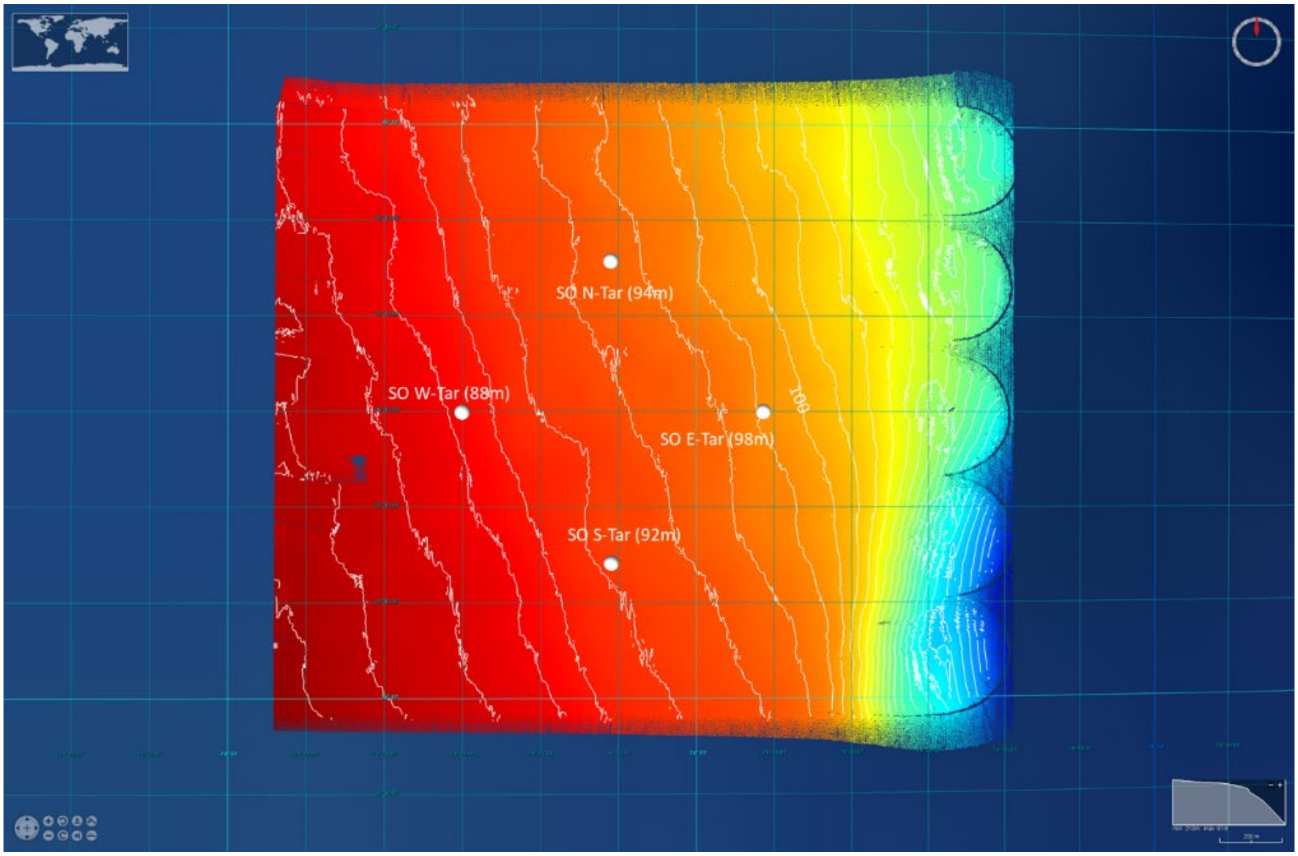

Figure 55: Southern Site Digital Terrain Model (2m contours)

Backscatter

Backscatter imagery at both the north and south anchor target sites indicate a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figures 56 thru 59).

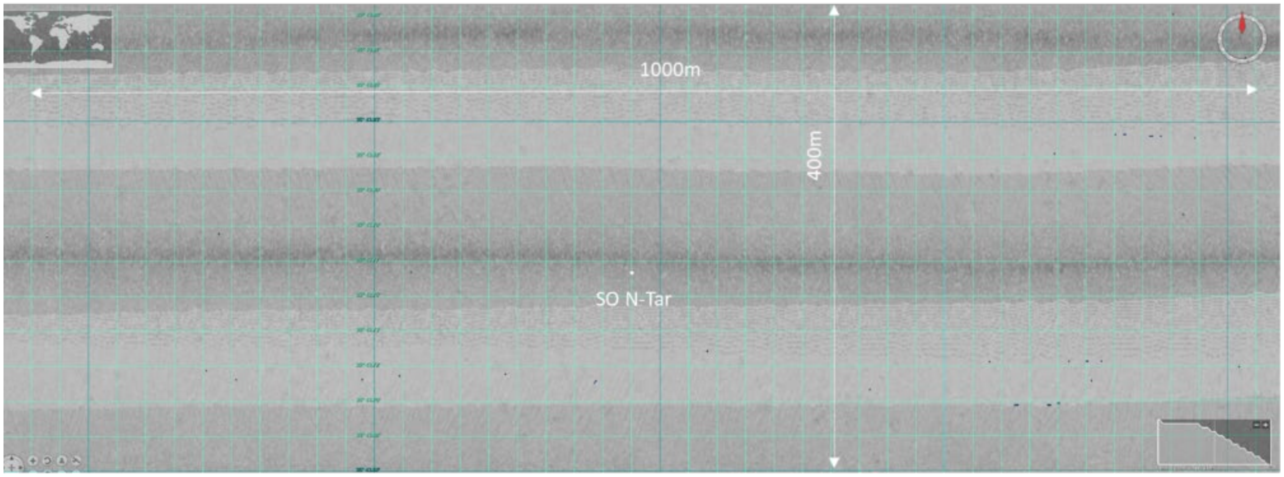

Figure 56: Southern Site North Anchor Target (N-Tar) Backscatter

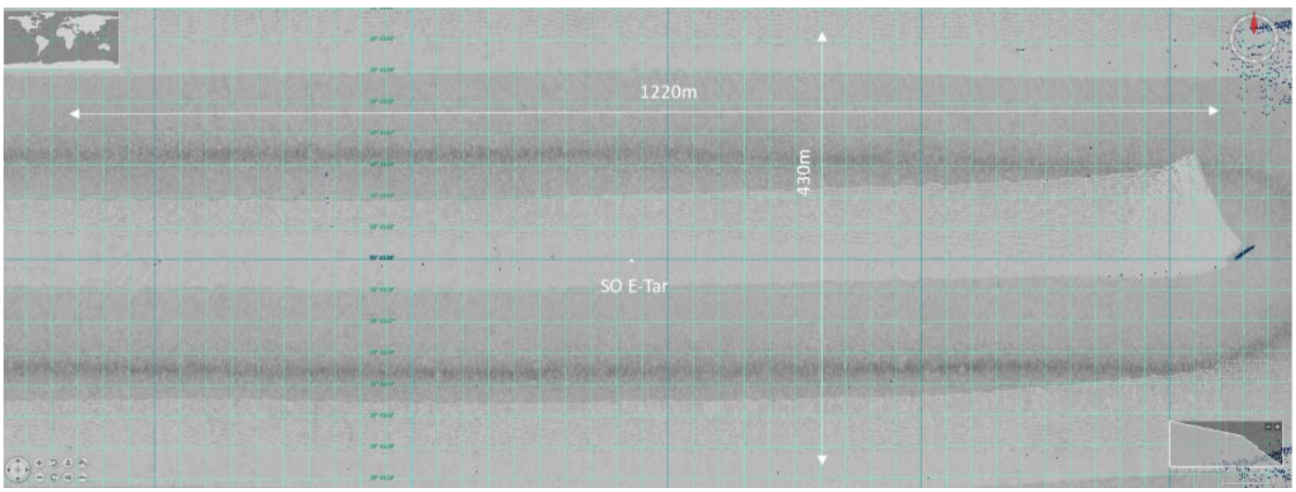

Figure 57: Southern Site East Anchor Target (E-Tar) Backscatter

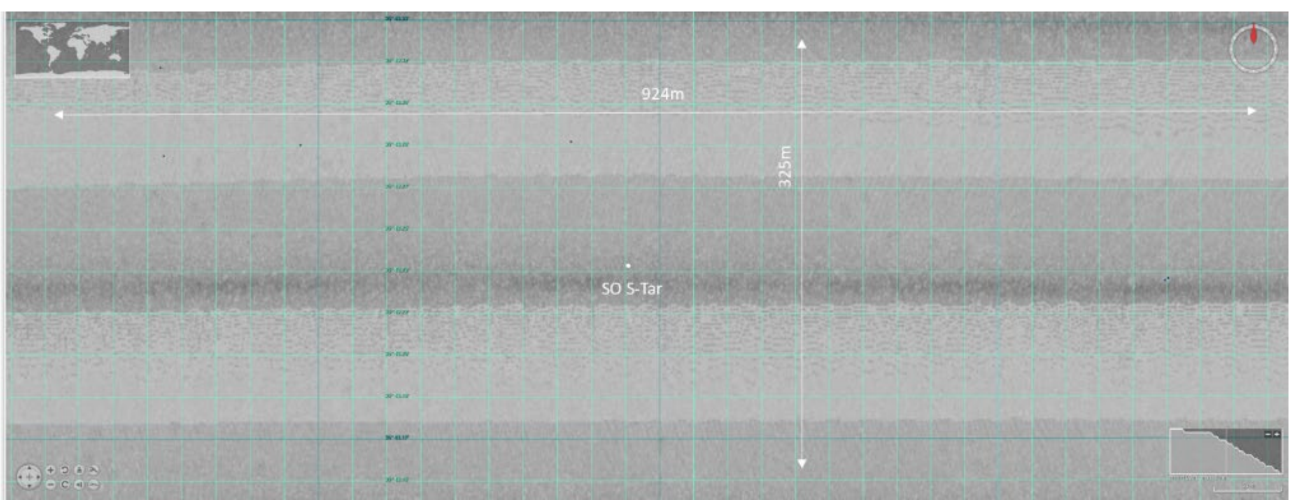

Figure 58: Southern Site South Anchor Target (S-Tar) Backscatter

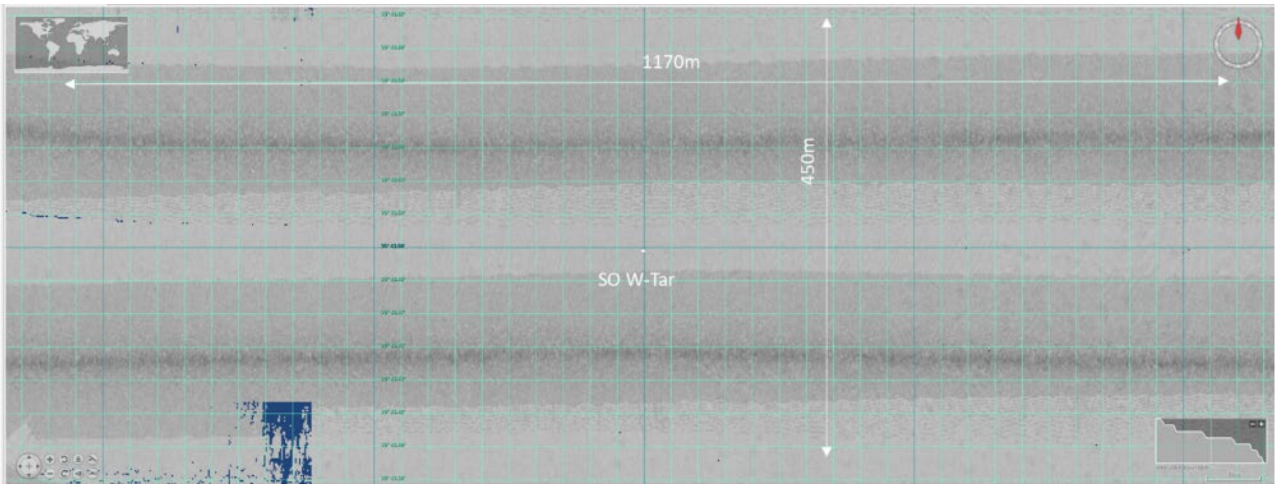

Figure 59: Southern Site West Anchor Target (W-Tar) Backscatter

<u>Subbottom</u>
Subbottom profiles at both the north and south anchor target sites indicate a soft and homogeneous seabed with good penetration, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 60 thru 62). Slopes range from 1-4°.

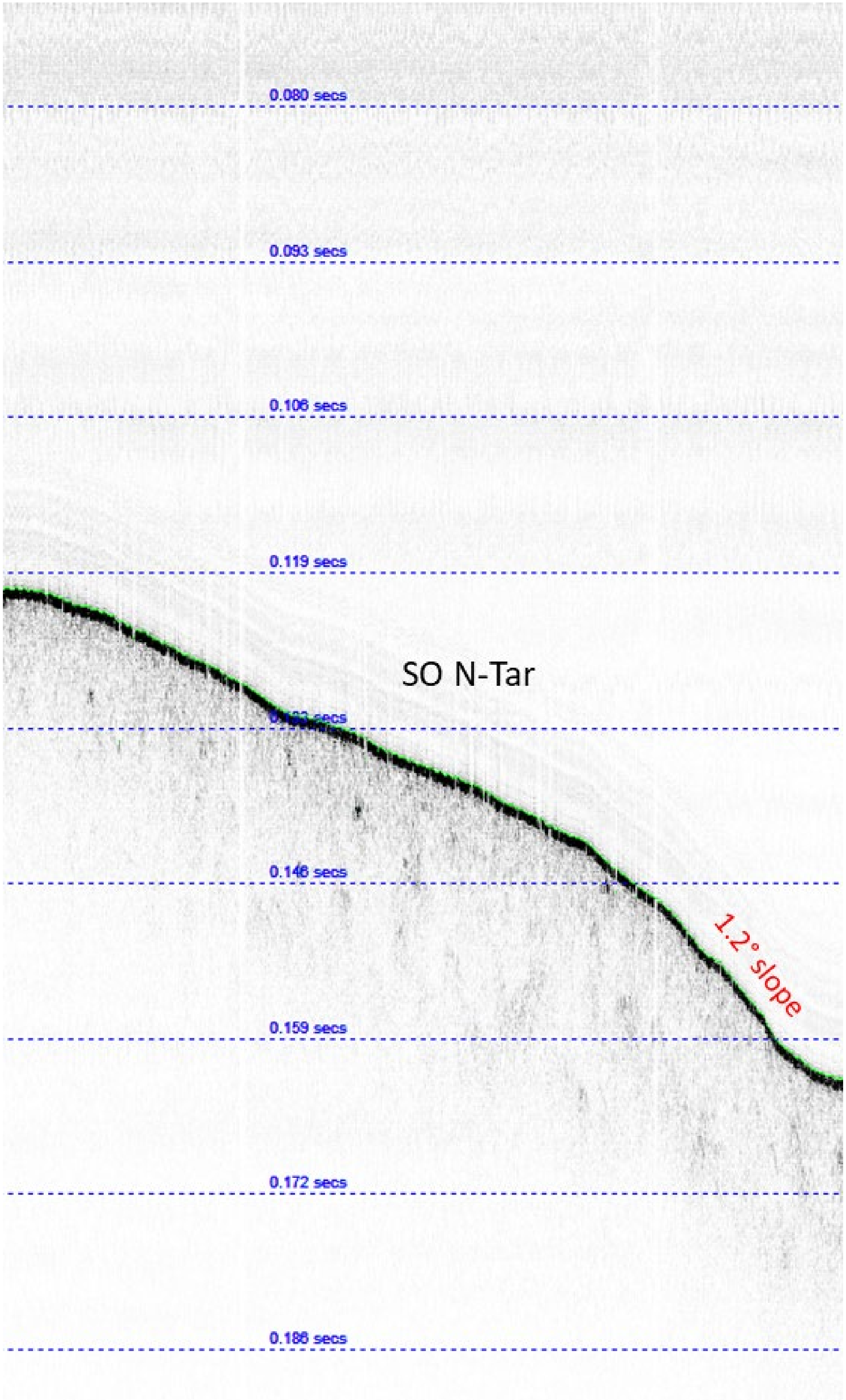

Figure 60: Southern Site North Anchor Target (N-Tar) Subbottom

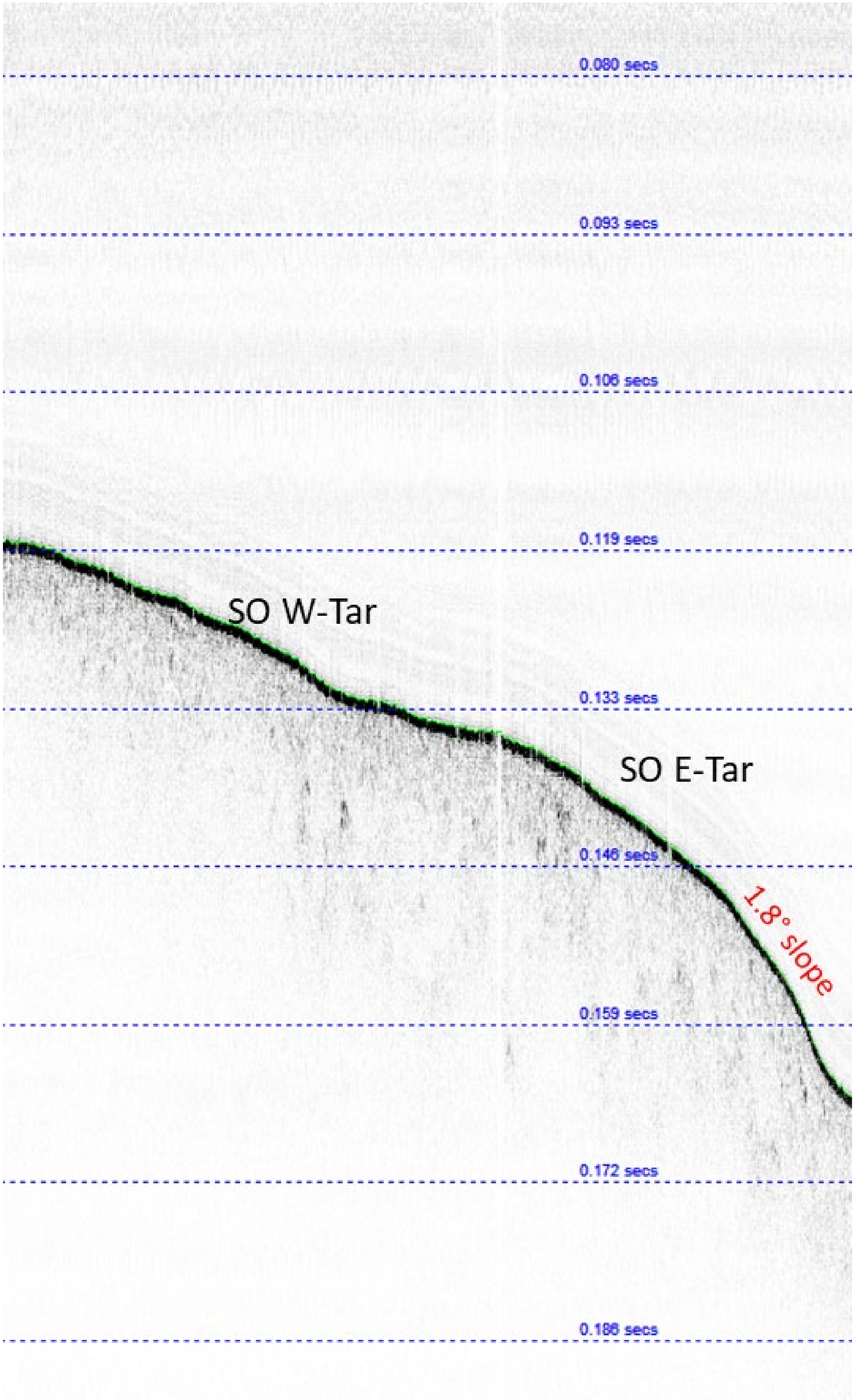

Figure 61: Southern Site East & West Anchor Targets (E-Tar, W-Tar) Subbottom

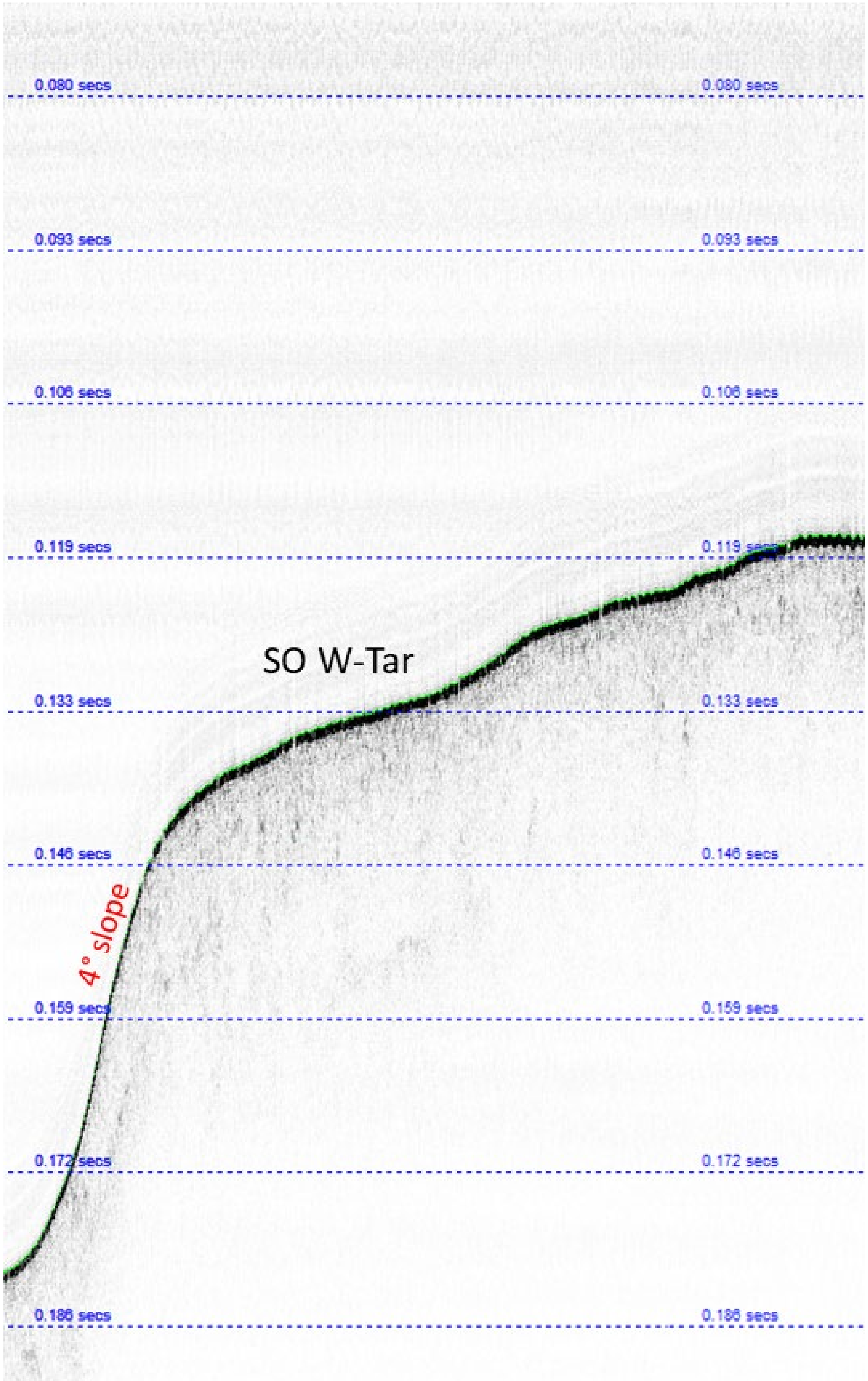

Figure 62: Southern Site West Anchor Target (W-Tar) Subbottom

ROV Inspection

ROV inspection was completed at all anchor target sites, Figure 63 shows the ROV and depressor positions overlaid on the DTM. The camera data indicates a flat seabed at both sites consisting of sands and gravels (Figures 64 thru 68). No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

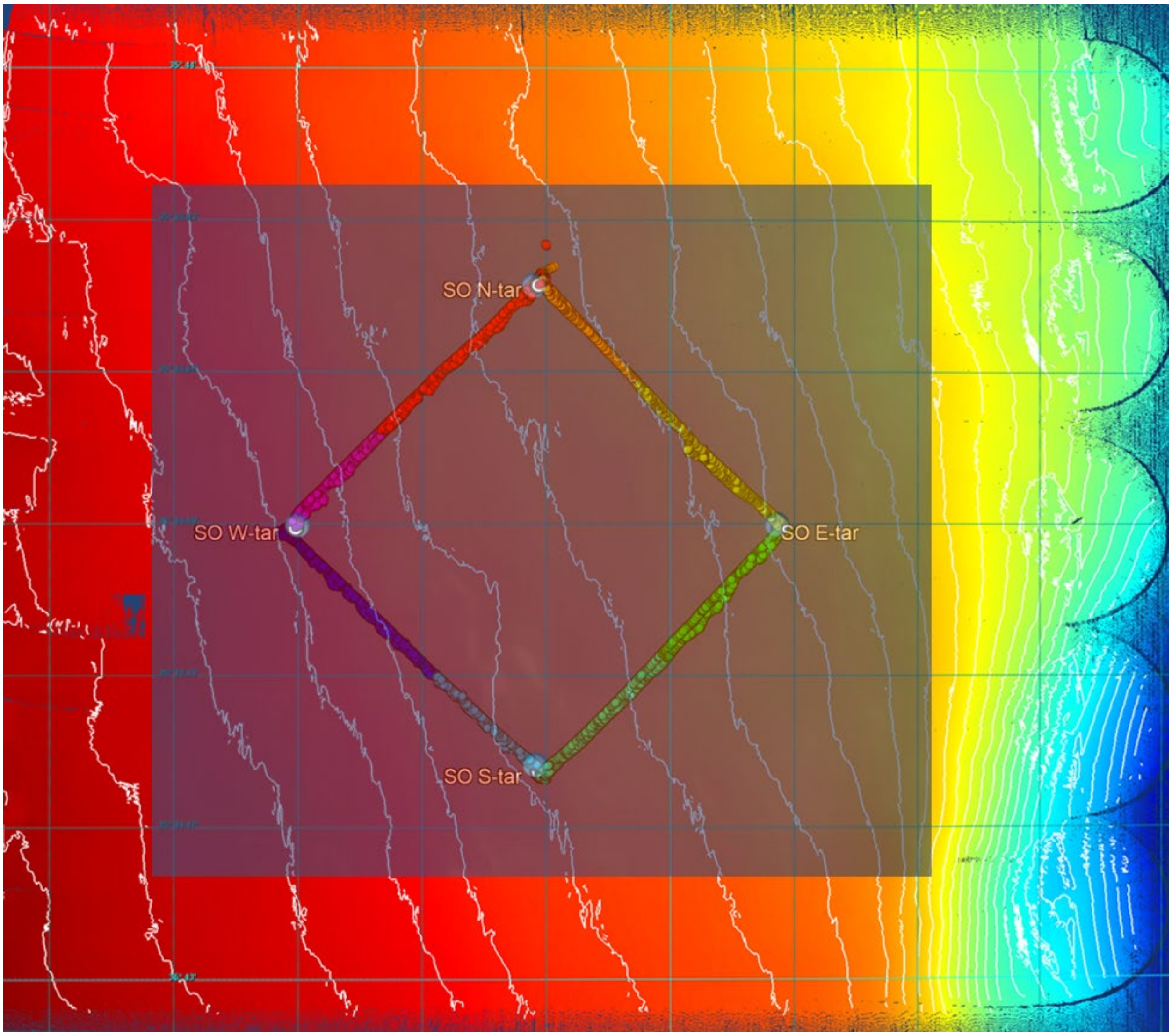

Figure 63: ROV Track at Southern Site

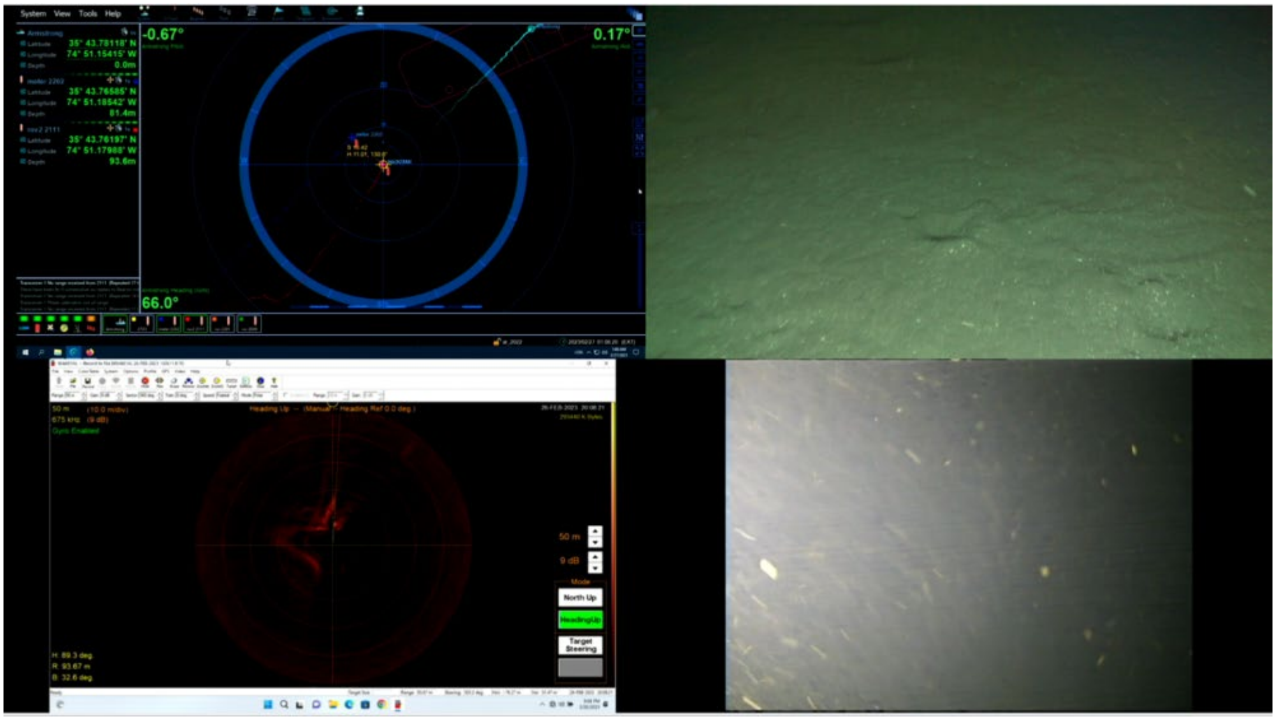

Figure 64: ROV Imagery at Southern Site, North Anchor Target

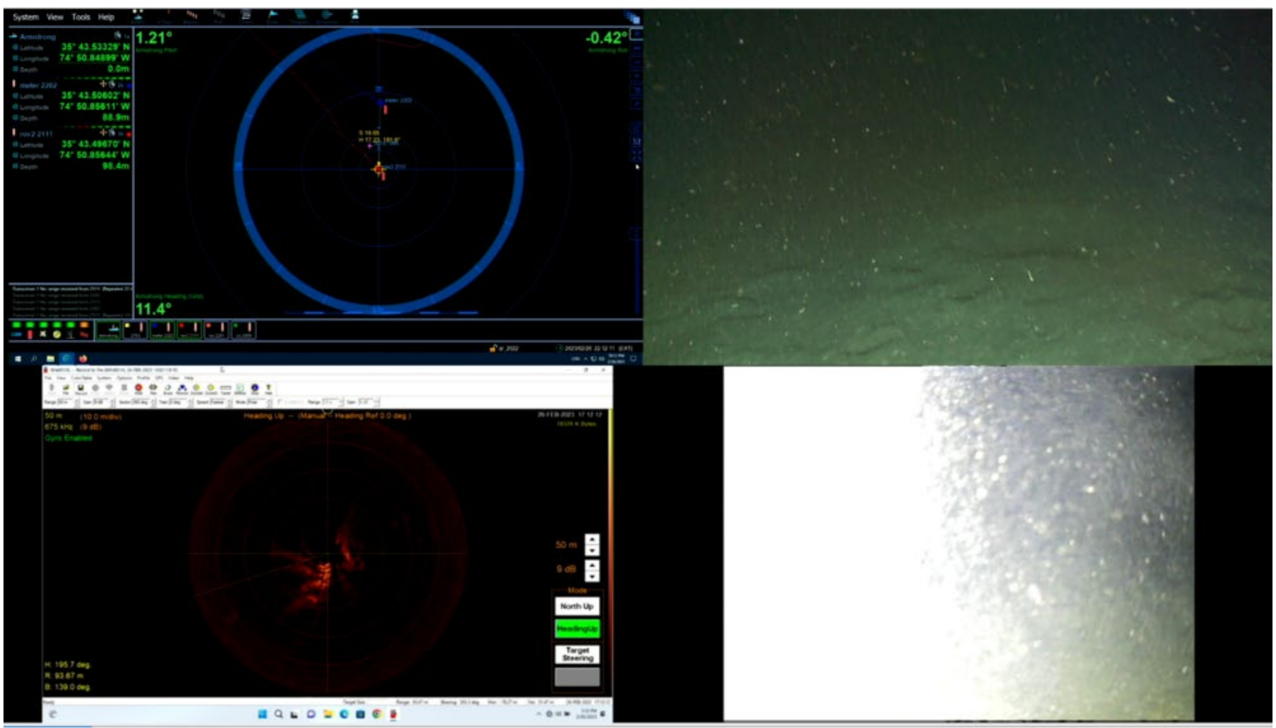

Figure 65: ROV Imagery at Southern Site, East Anchor Target

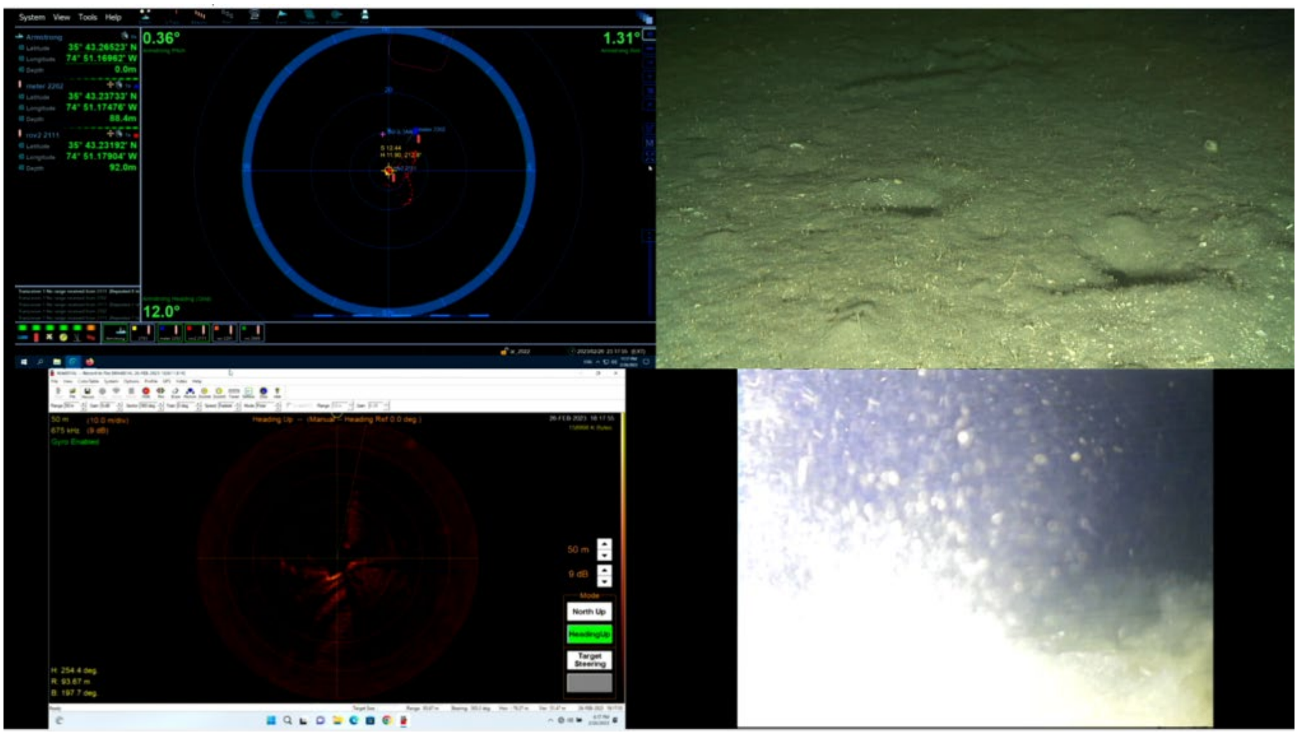

Figure 66: ROV Imagery at Southern Site, South Anchor Target


Figure 67: Sandy, Gravelly, Shelly Seabed Southern Site, South Anchor Target

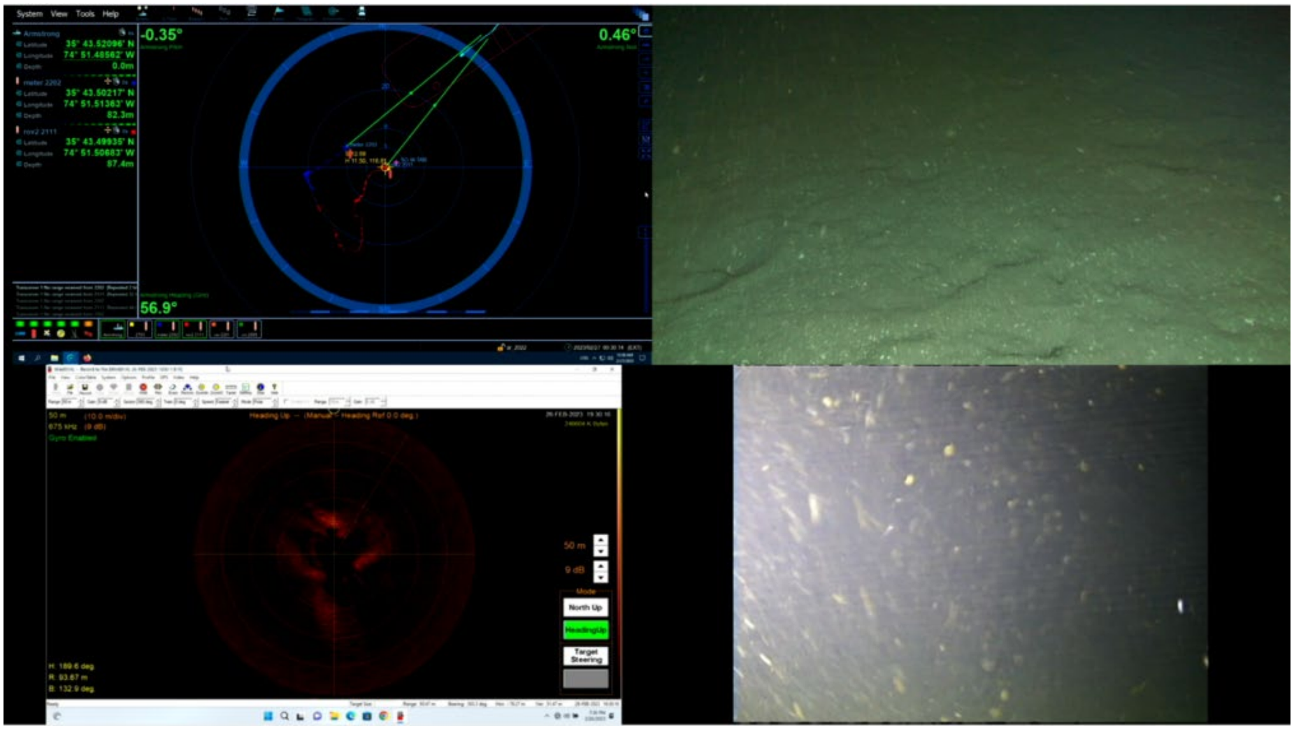

Figure 68: ROV Imagery at Southern Site, West Anchor Target

8.6. Northeastern (Old)

Bathymetry

Moving west to east across Figure 69, the water depth is at the shallowest ~450m in the northwest corner, following a ridge structure to the west, the seabed then deepens to ~930m. There is a steeper dropoff to the north of the ridge to a depth of ~950m. The slopes at the planned locations are ~11°. The North and South anchor targets are at depths of 560 m and 650 m, respectively. Data collected over ~6km x 4km area using 1km line spacing.

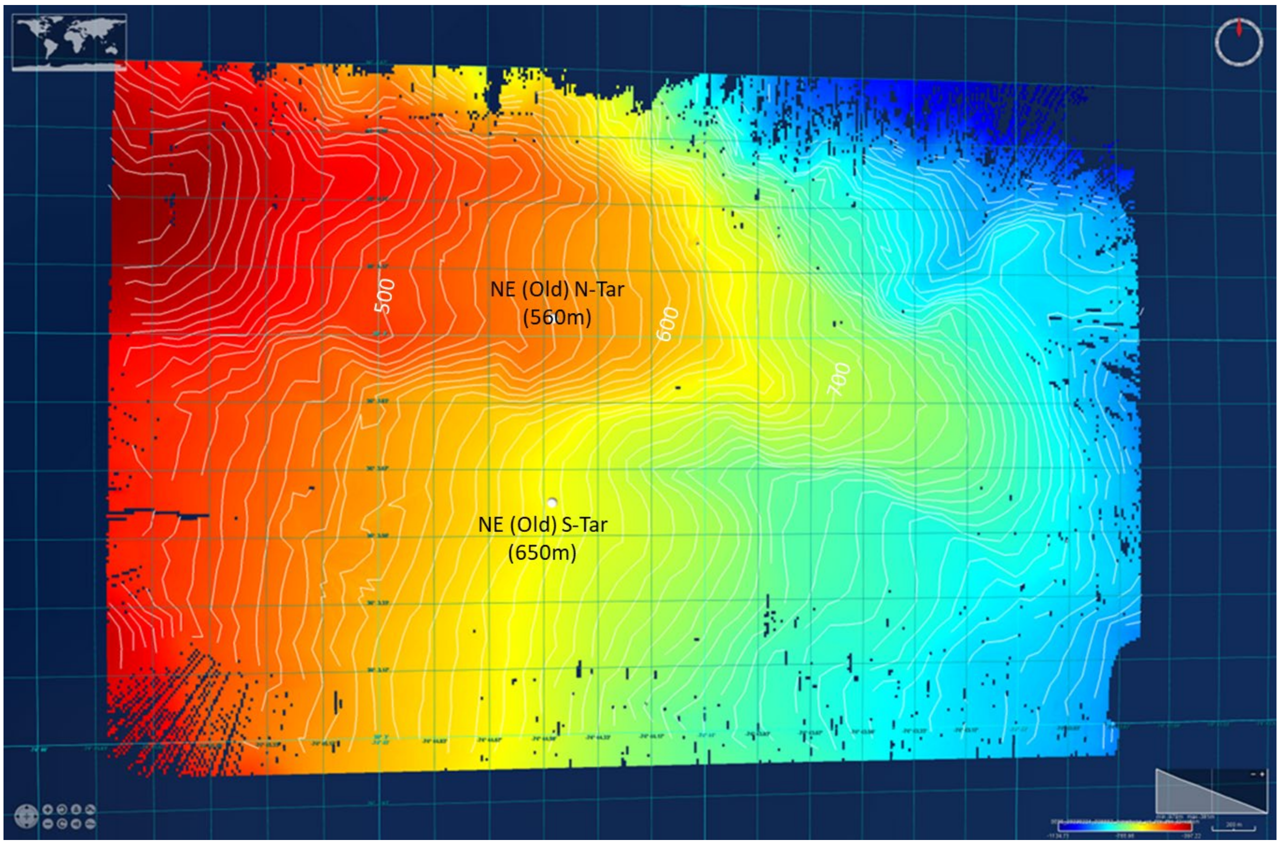

Figure 69: Northeastern (Old) Site Digital Terrain Model (10m contours)

Backscatter

Backscatter imagery at both the north and south anchor target sites indicate a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figure 70).

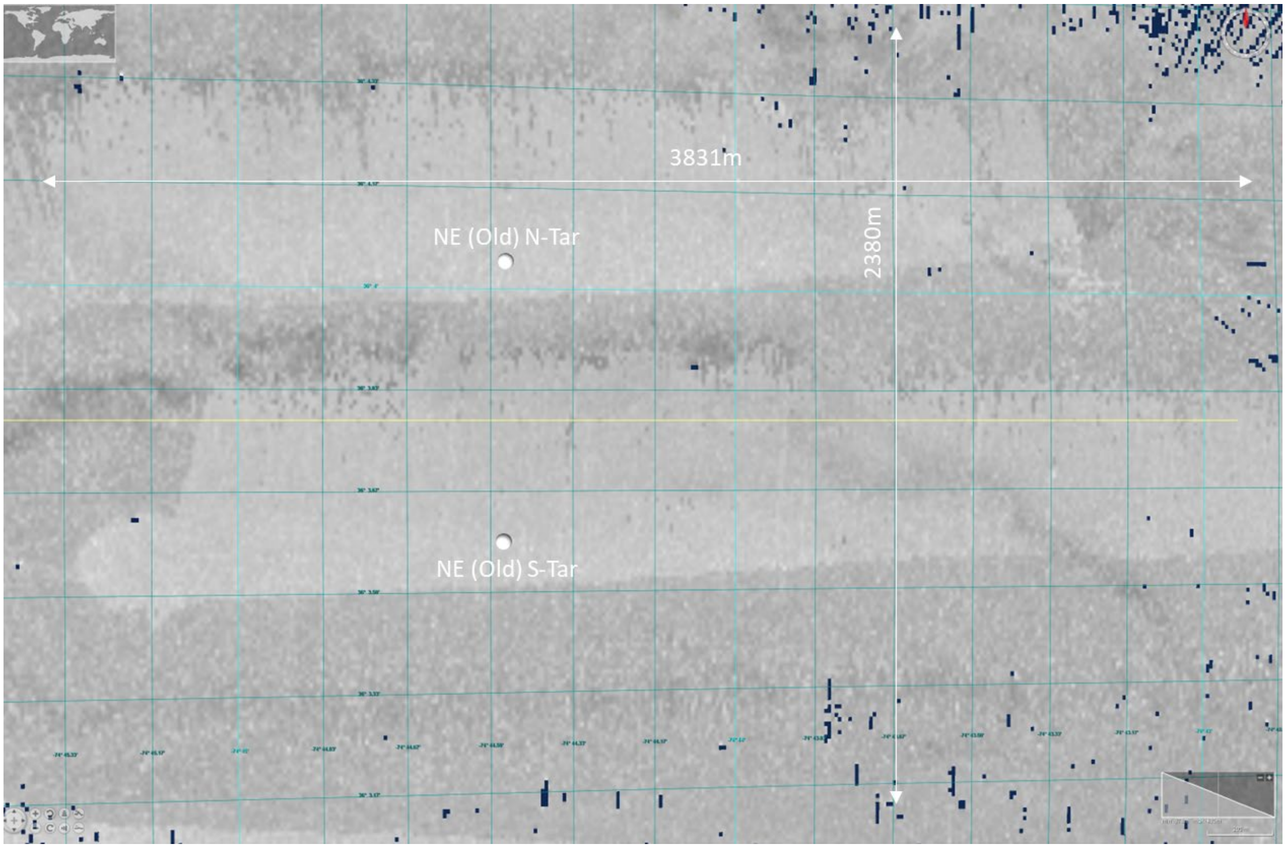

Figure 70: Northeastern (Old) Site North & South Anchor Targets (N-Tar, S-Tar) Backscatter

<u>Subbottom</u>
Subbottom profiles at both the north and south anchor target sites indicate a soft and homogeneous seabed with good penetration, some indication of harder sublayers that do not impact operations, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 71 & 72). As can be seen in the subbottom profile, this is a steeper site as the seabed crosses the shelfbreak. Slopes range from 5-15°, localized may be higher.

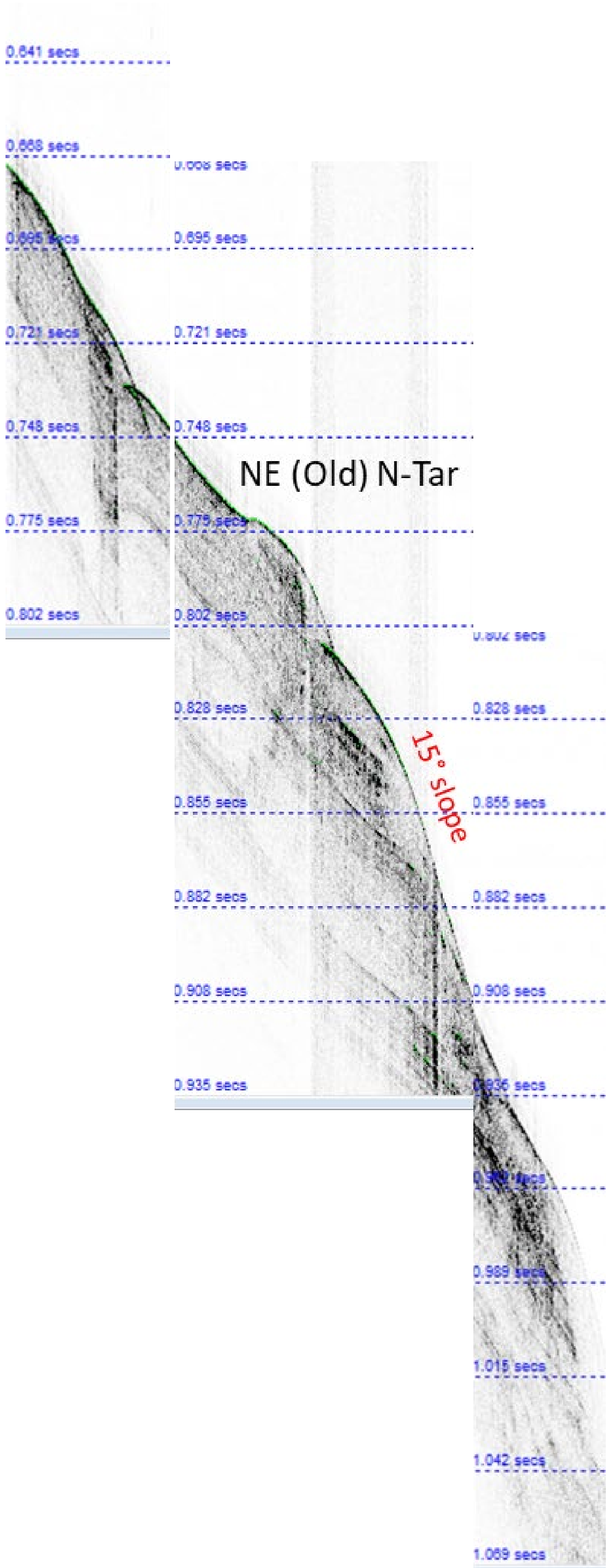

Figure 71: Northeastern (Old) Site North Anchor Target (N-Tar) Subbottom

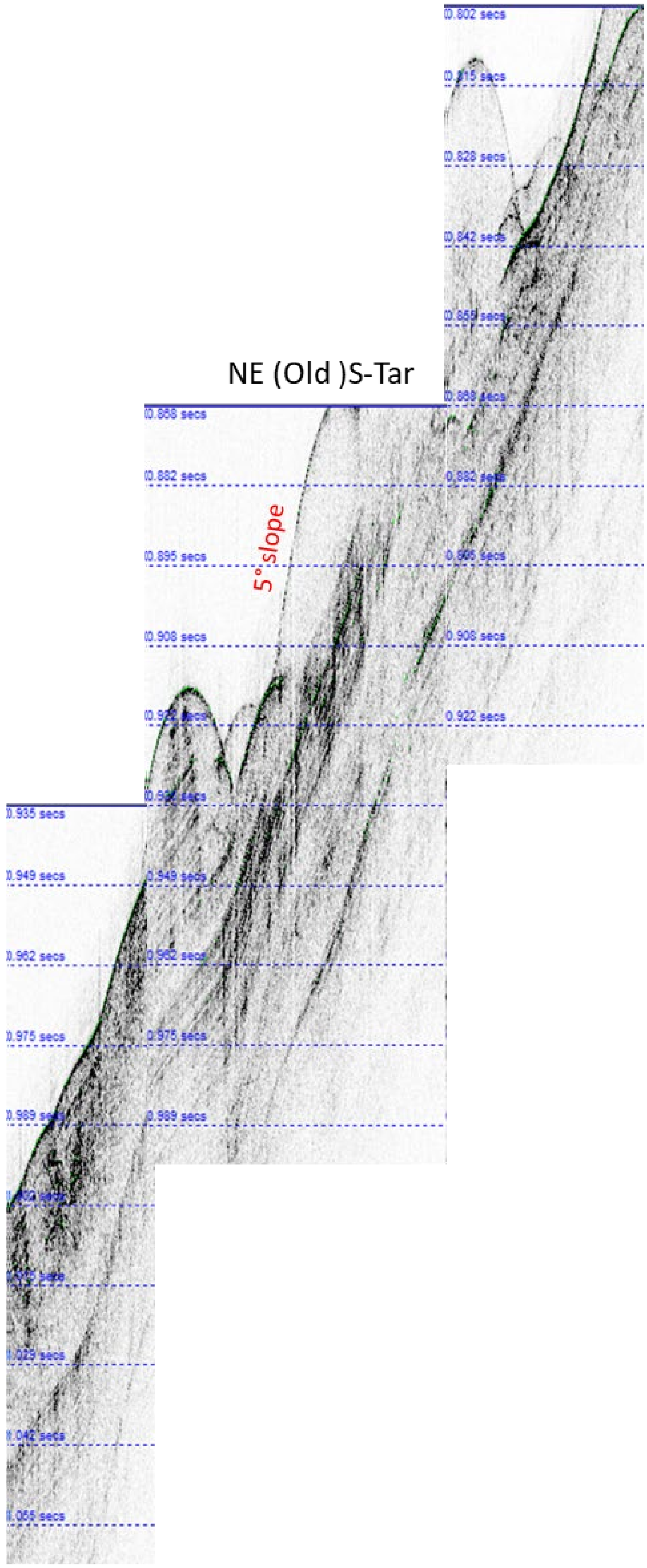

Figure 72: Northeastern (Old) Site South Anchor Target (S-Tar) Subbottom

ROV Inspection

ROV inspection was completed at the North anchor target only. Due to the risk of steep slopes and the need to maintain a constant depth, the ROV survey was halted after a depth discrepancy was found between the beacon and ROV depth sensor. Figure 73 shows the ROV and depressor positions overlaid on the DTM. The camera data indicates a flat seabed in the vicinity of the north anchor target consisting of a sandy seabed (Figures 74-75). No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

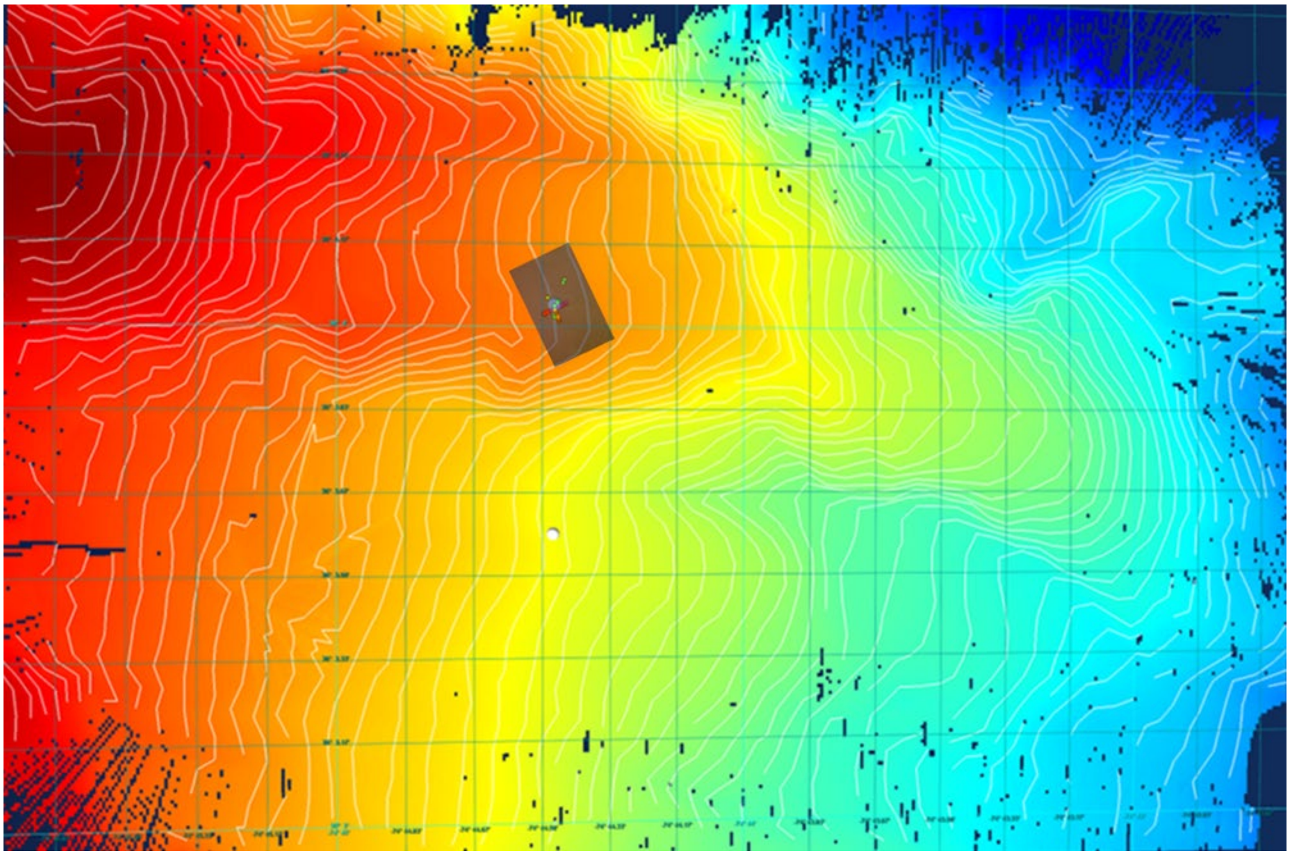

Figure 73: ROV Track at Northeastern (Old) Site

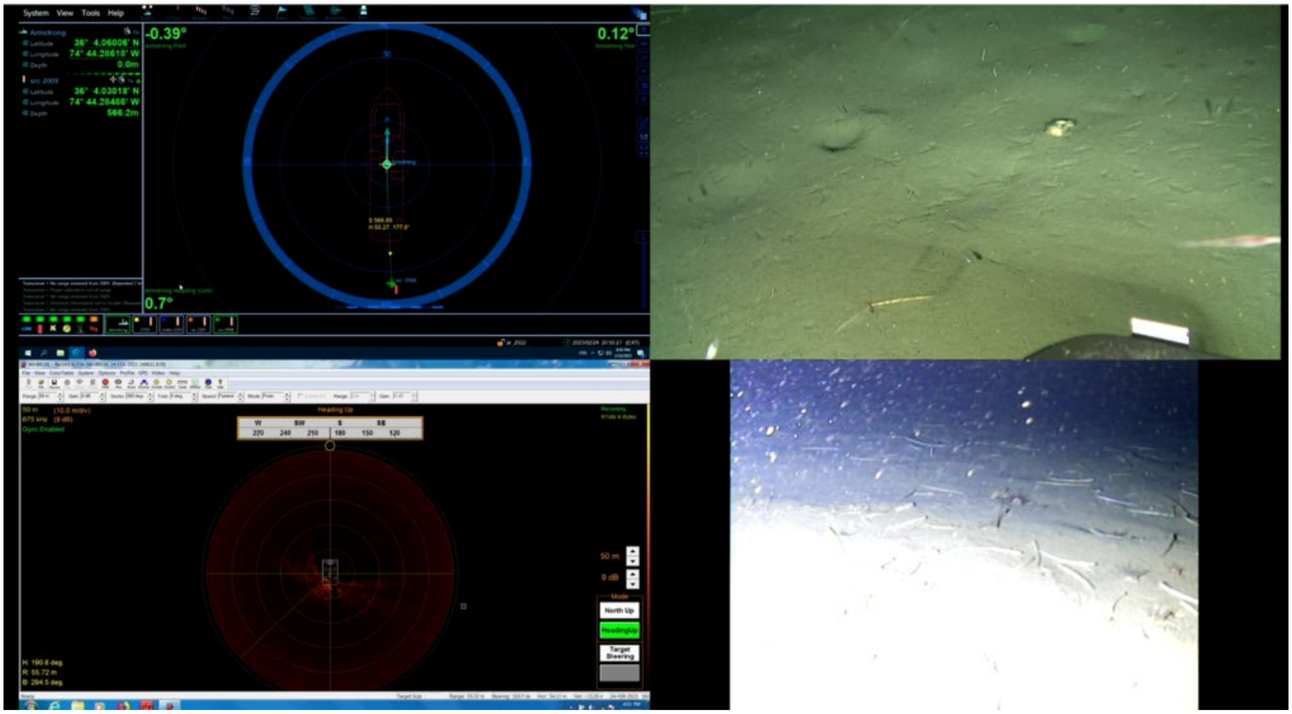

Figure 74: ROV Imagery at Northeastern (Old) Site, North Anchor Target

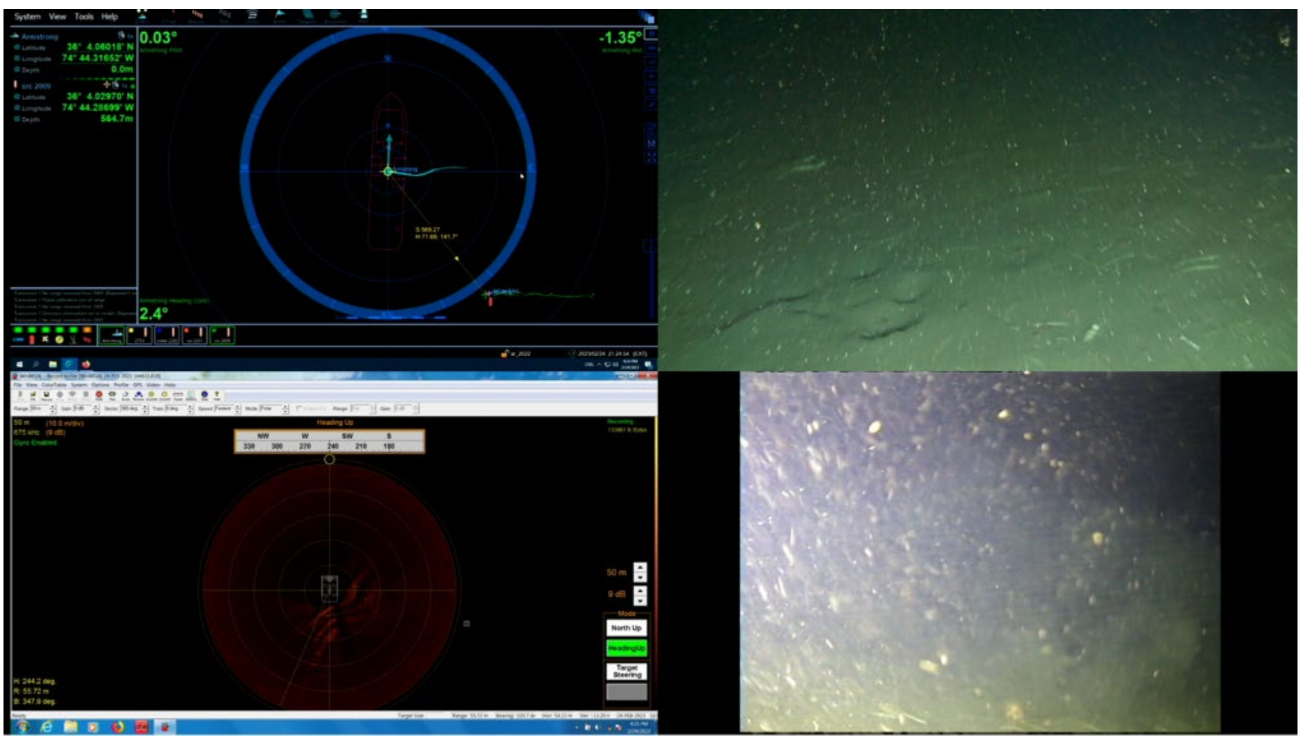

Figure 75: ROV Imagery at Northeastern (Old) Site, North Anchor Target

8.7. Southeastern (Old)

Bathymetry

Moving west to east across Figure 76, the water depth is at the shallowest ~290m, then deepens to ~1130m. There are several steep ridges and channels running west to east, the seabed is highly variable, and there is very little flat bottom. Slopes in the vicinity of the planned anchor locations can reach 15° with surrounding slopes of 30-45°. The North and South anchor targets are at depths of 570 m and 614 m, respectively. Data collected over ~5km x 4km area using 1km line spacing.

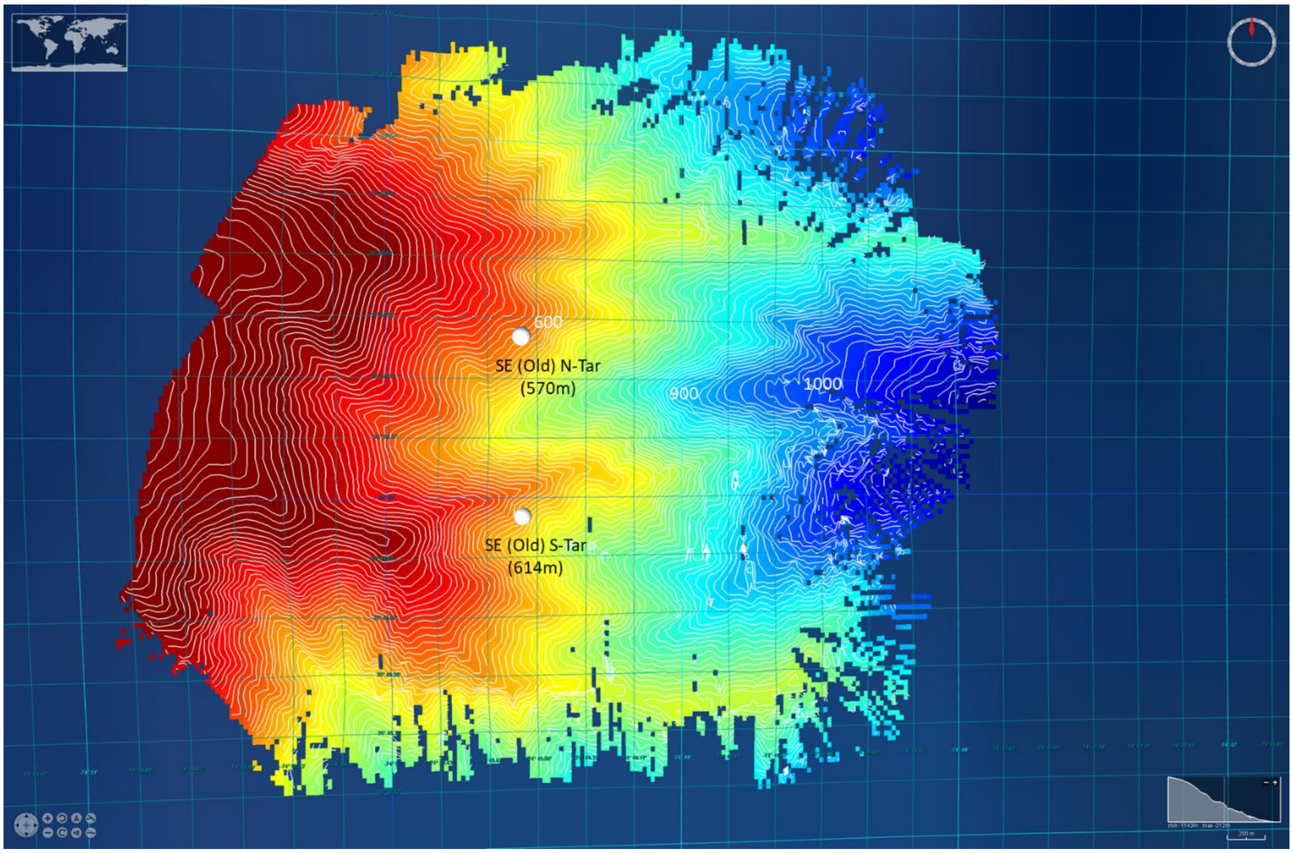

Figure 76: Southeastern (Old) Site Digital Terrain Model (10m contours)

Backscatter

Backscatter imagery at both the north and south anchor target sites indicate a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figure 77).

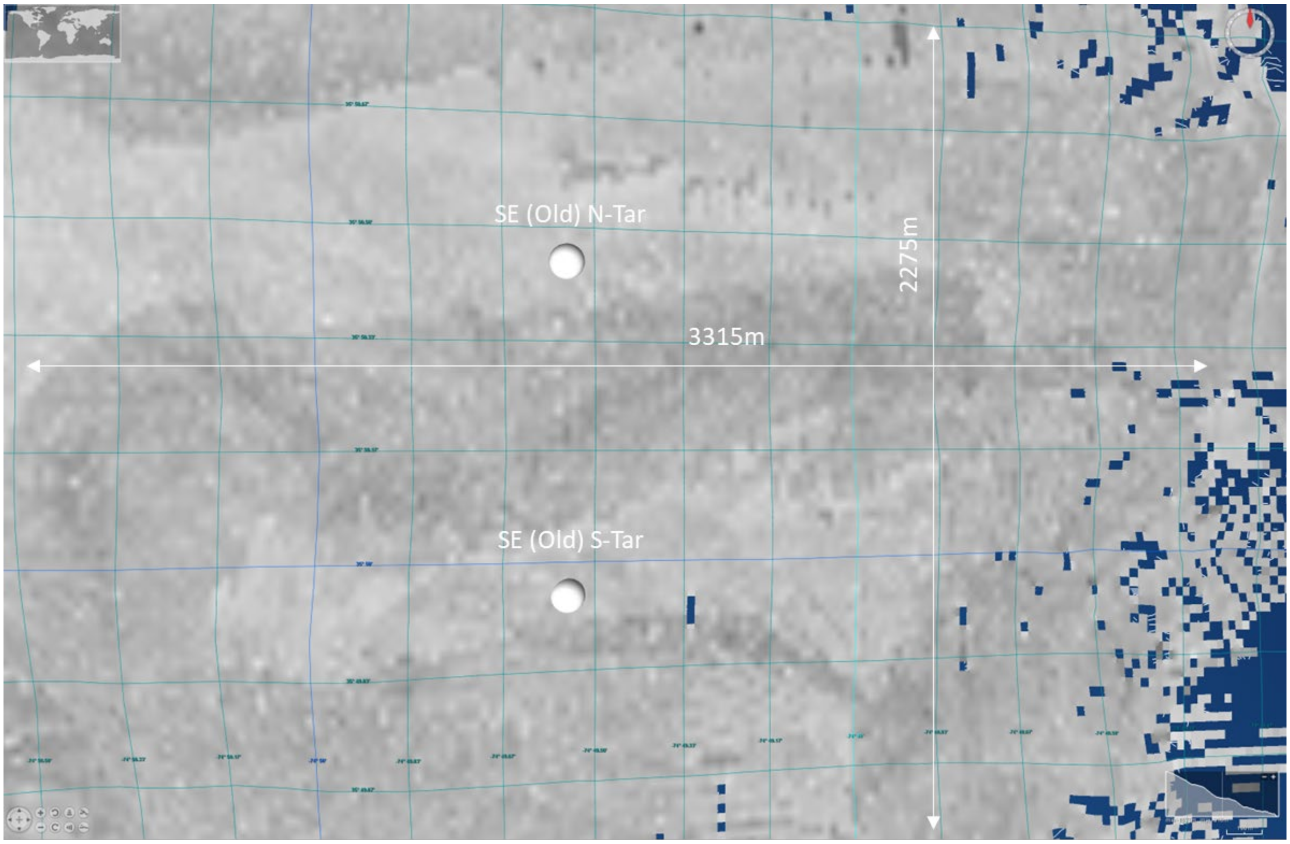

Figure 77: Southeastern (Old) Site North & South Anchor Targets (N-Tar, S-Tar) Backscatter

<u>Subbottom</u>
Subbottom profiles at both the north and south anchor target sites indicate a soft and homogeneous seabed with good penetration, some indication of harder sublayers that do not impact operations, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 78 & 79). As can be seen in the subbottom profile, this is a steeper site as the seabed crosses the shelfbreak. Slopes can range from 8-14°, localized will be higher.

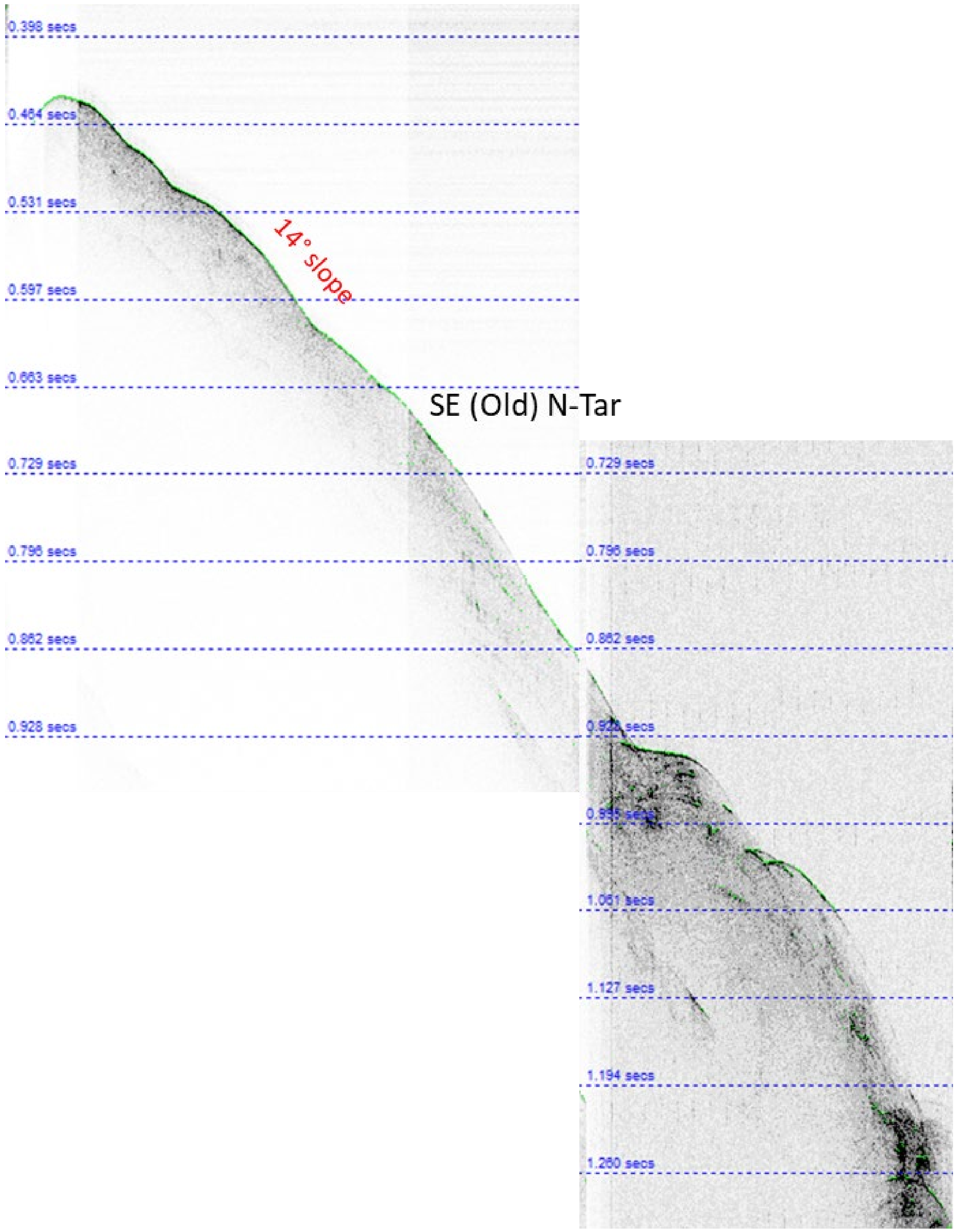

Figure 78: Southeastern (Old) Site North Anchor Target (N-Tar) Subbottom

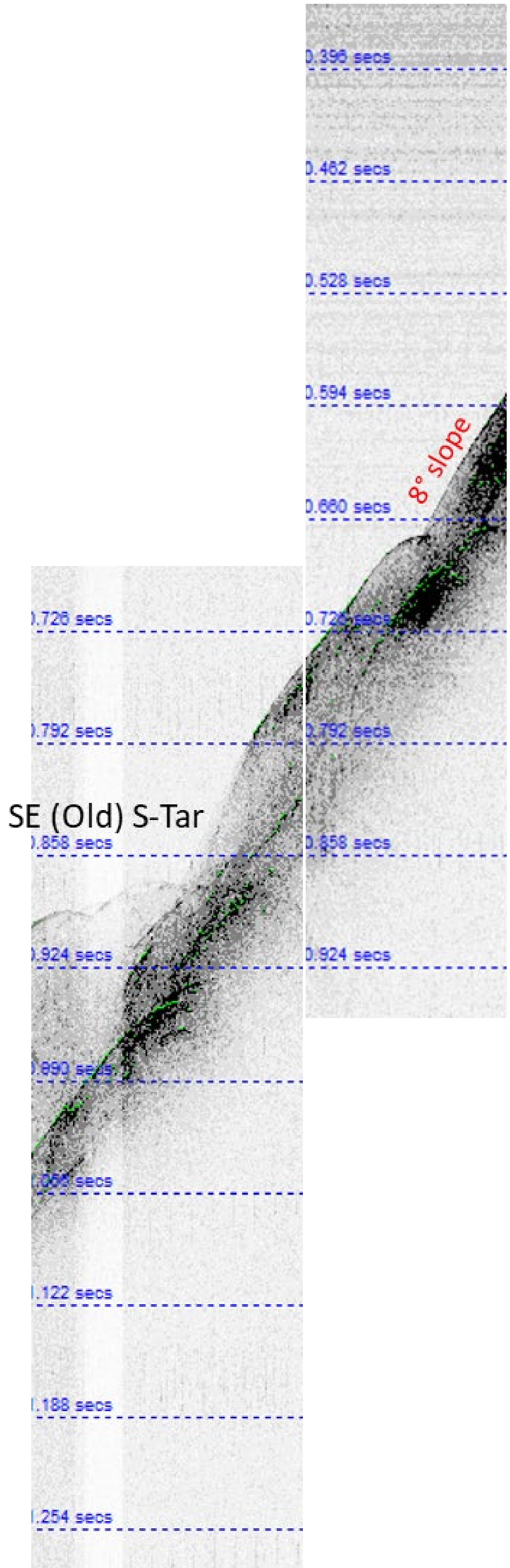

Figure 79: Southeastern (Old) Site South Anchor Target (S-Tar) Subbottom

ROV Inspection

ROV inspection was completed at the North anchor target only. Due to the risk of steep slopes and an inability to maintain a constant depth with good beacon tracking, the ROV survey was halted. Figure 80 shows the ROV and depressor positions overlaid on the DTM. The camera data indicates a flat seabed in the vicinity of the north anchor target consisting of sands and gravels (Figures 81-82). No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

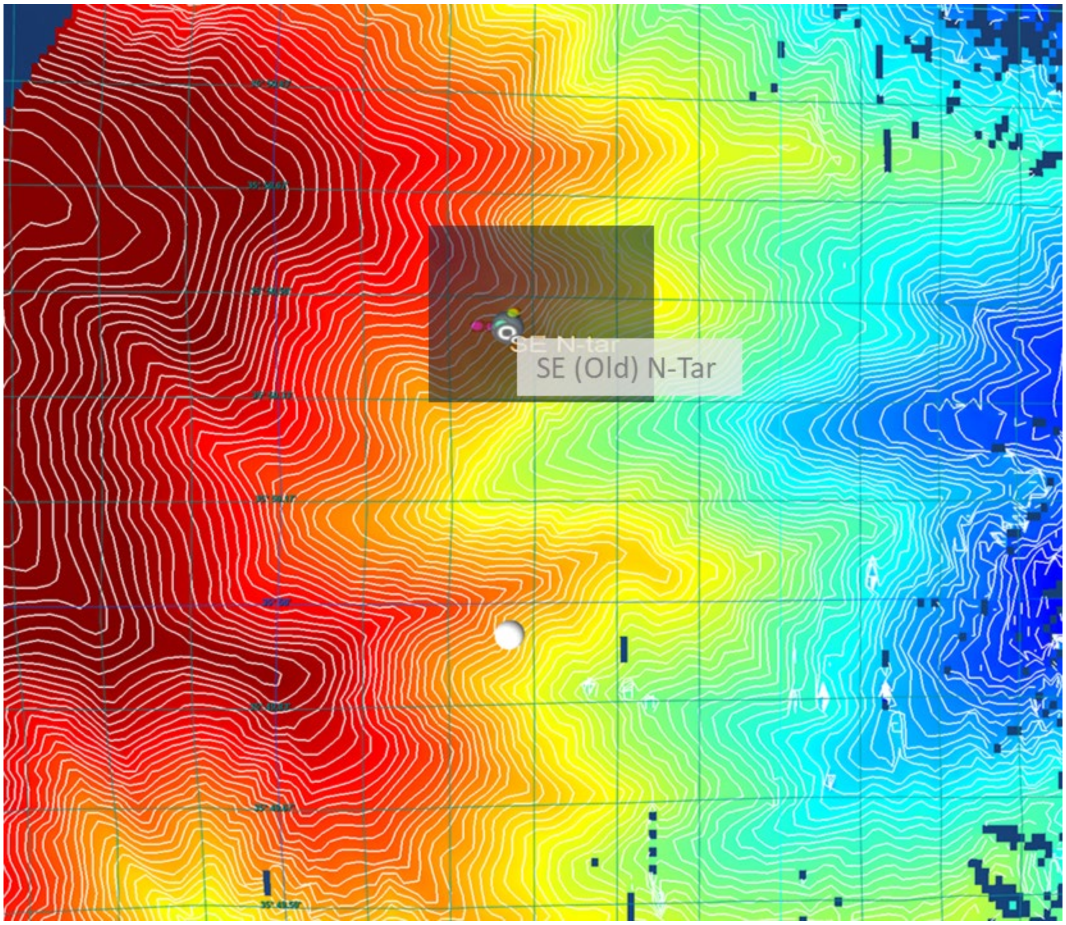

Figure 80: ROV Track at Southeastern (Old) Site

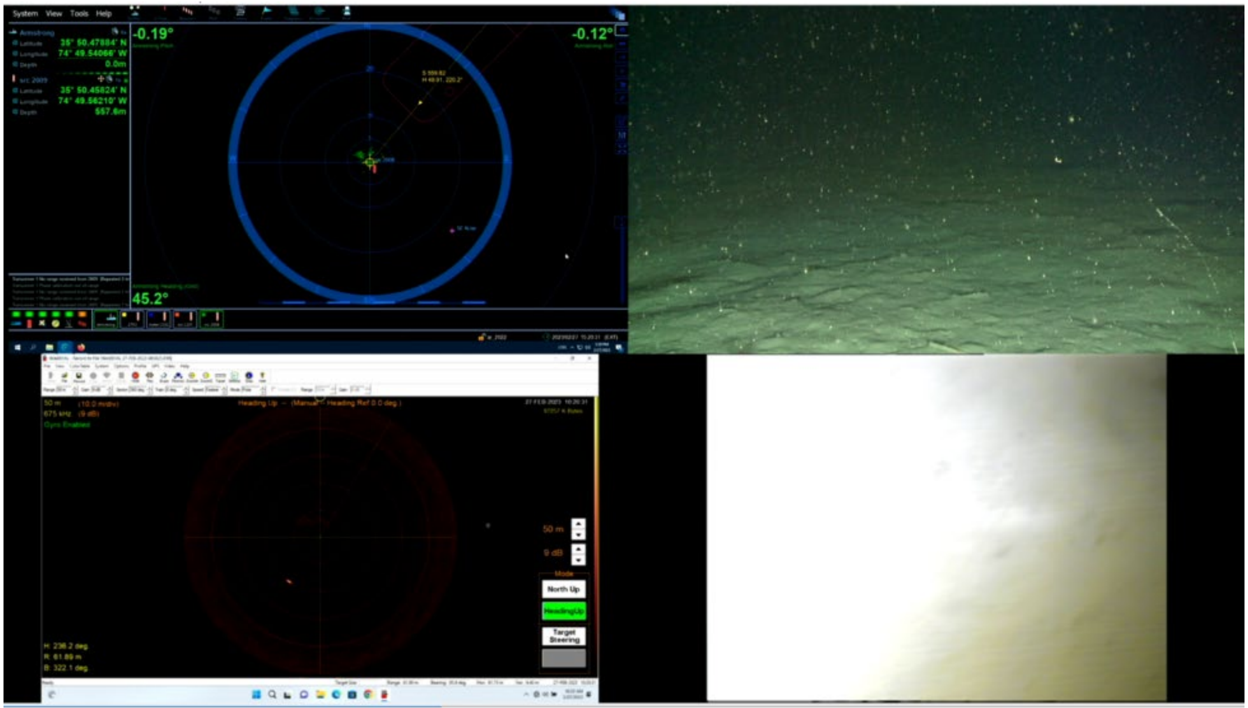

Figure 81: ROV Imagery at Southeastern (Old) Site, North Anchor Target

Figure 82: Sandy Seabed Southeastern (Old) Site, North Anchor Target

8.8. Northeastern (Updated)

Bathymetry

Moving west to east across Figure 83, the water depth is at the shallowest ~94m,moving eastward the seabed then deepens to ~500m. There is a ridge beyond the 300m depth with associated steeper slopes. The slopes at the planned locations are ~5°. The North and South anchor targets are located on the 300m contour. Data collected over ~8km x 3km area using 200m line spacing.

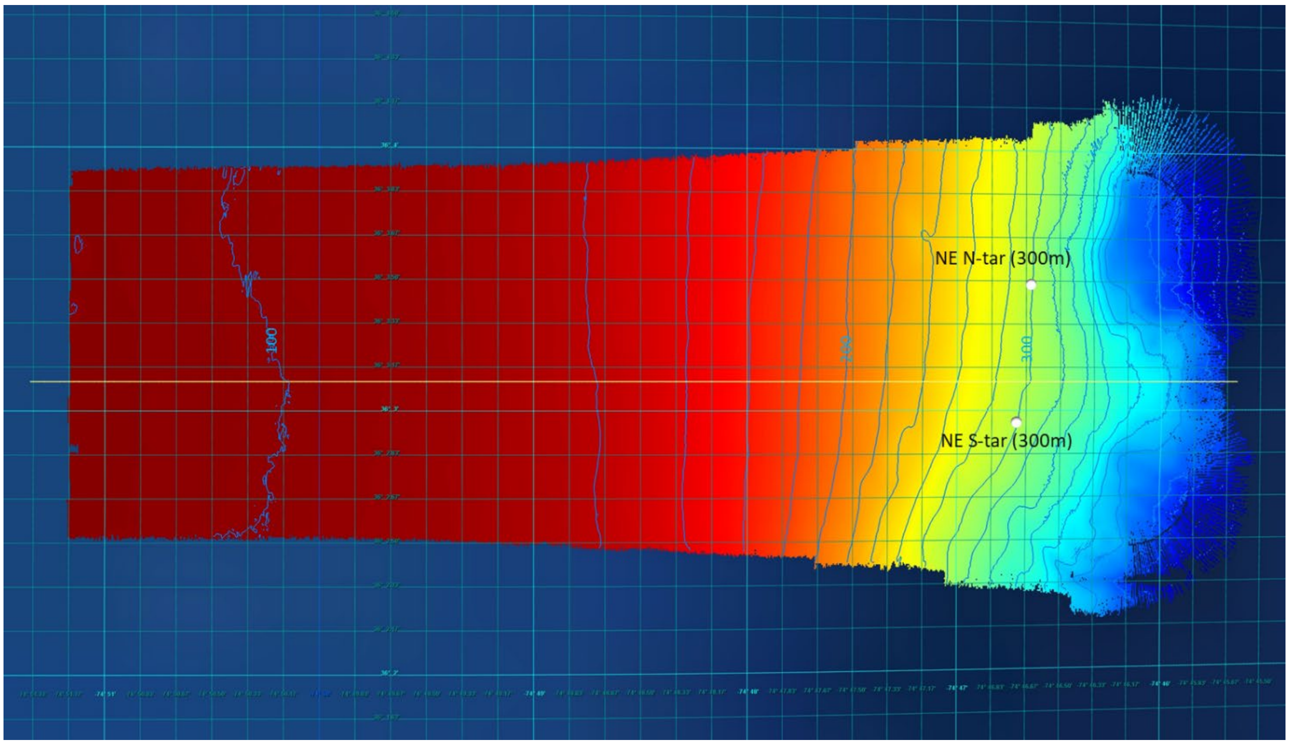

Figure 83: Northeastern (Updated) Site Digital Terrain Model (20m contours)

Backscatter

Backscatter imagery at both the north and south anchor target sites indicate a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figure 84).

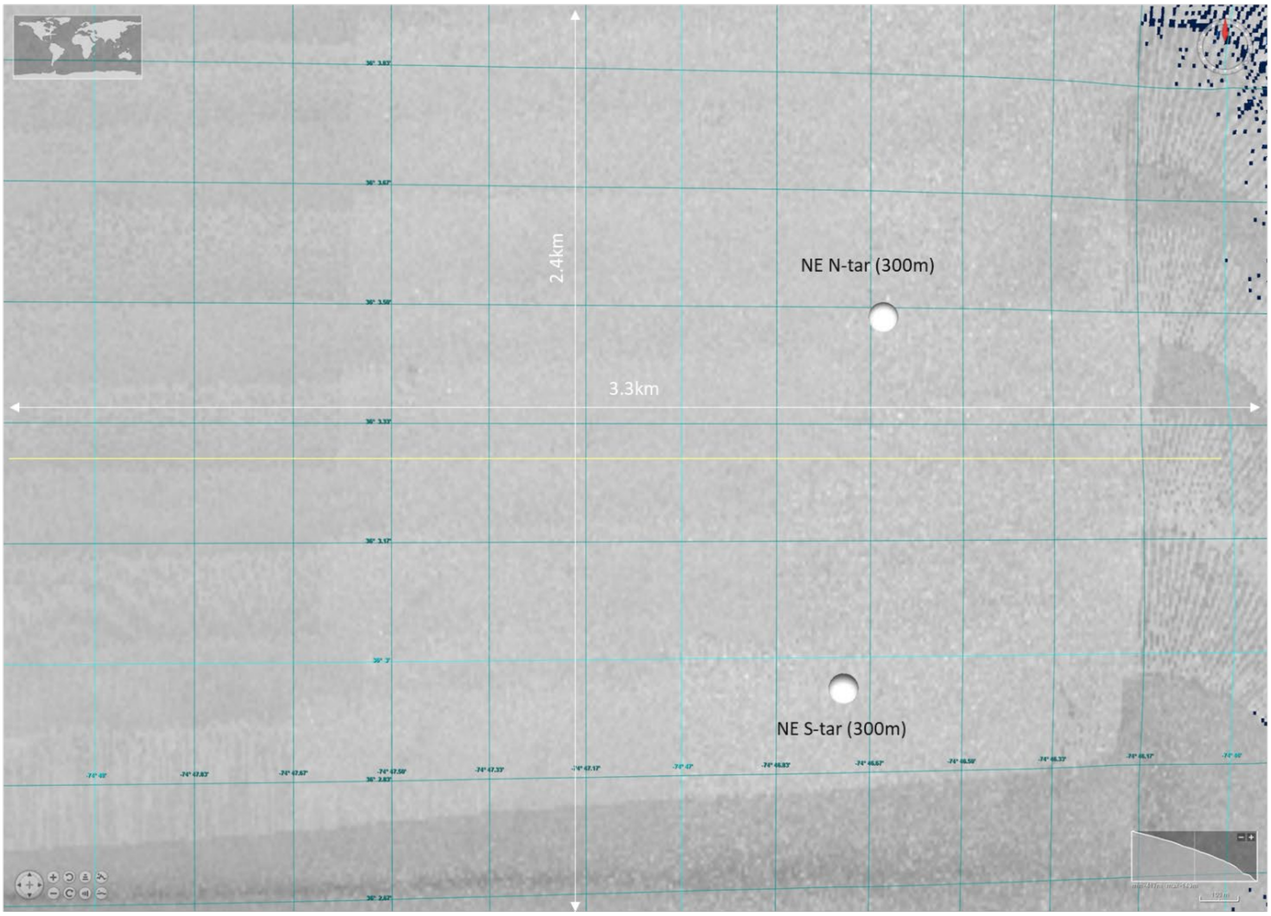

Figure 84: Northeastern (Updated) Site North & South Anchor Targets (N-Tar, S-Tar) Backscatter

Subbottom

Subbottom profiles at both the north and south anchor target sites indicate a soft and homogeneous seabed with good penetration, some indication of harder sublayers that do not impact operations, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 85 & 86). Slopes are approximately 5°, localized may be higher.

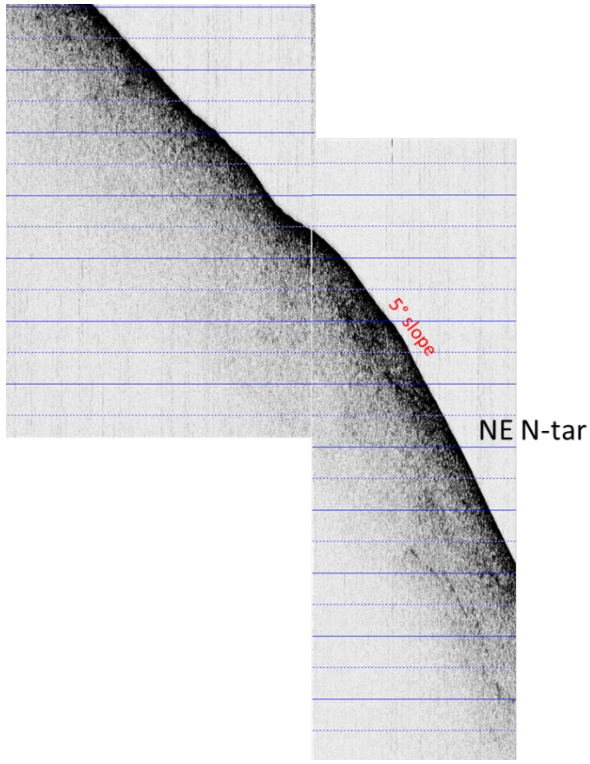

Figure 85: Northeastern (Updated) Site North Anchor Target (N-Tar) Subbottom

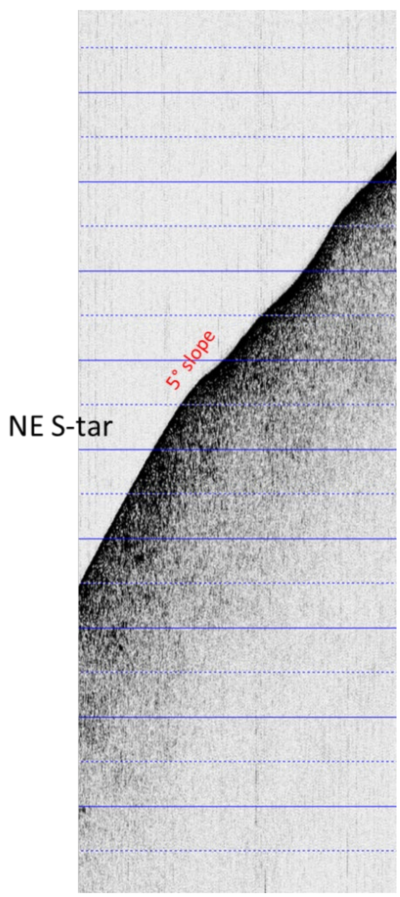

Figure 86: Northeastern (Updated) Site South Anchor Target (S-Tar) Subbottom

ROV Inspection

ROV inspection was completed at all anchor target sites, The camera data indicates a flat seabed at both sites consisting of sands and gravels (Figures 87 & 88). No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

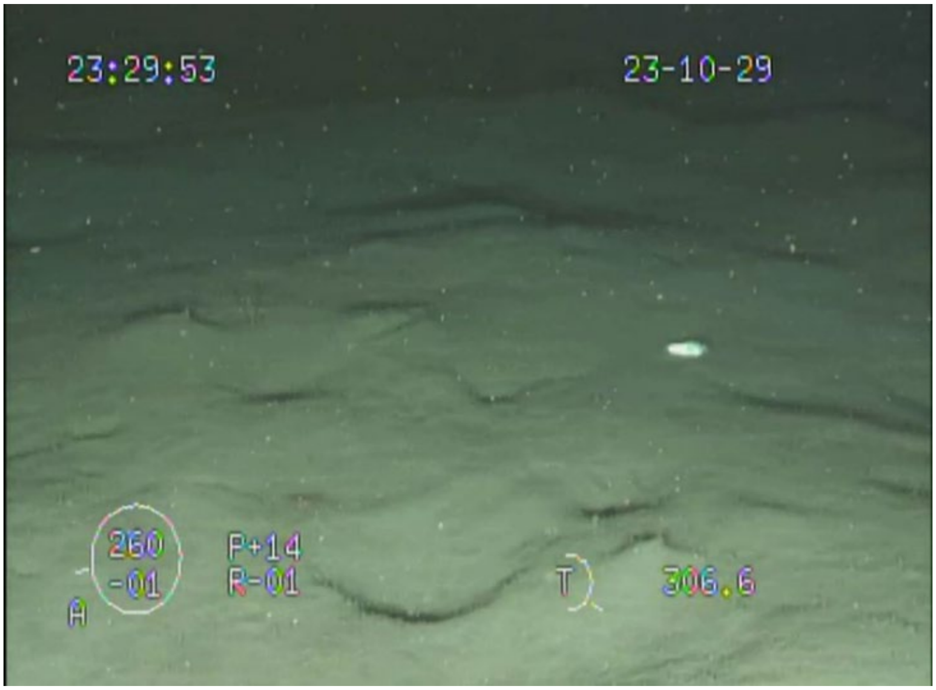

Figure 87: ROV Imagery at Northeastern (Updated) Site, North Anchor Target

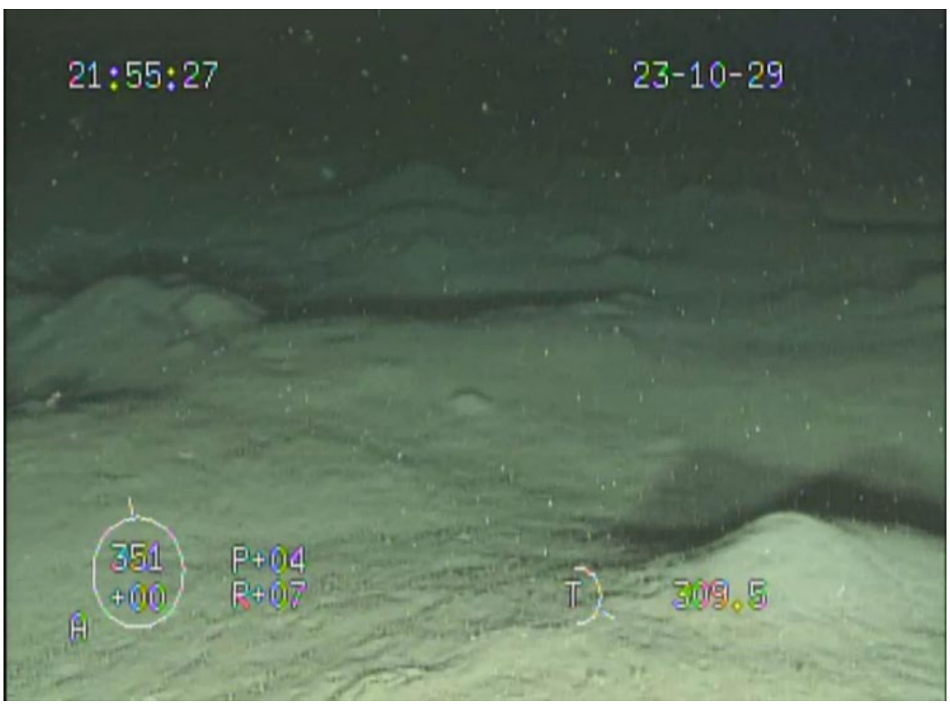

Figure 88: ROV Imagery at Northeastern (Updated) Site, South Anchor Target

8.9. Southeastern (Updated)

Bathymetry
Moving west to east across Figure 89, the water depth is at the shallowest ~84m, then deepens to ~650m. There are two channels starting at approximately the shelfbreak, running west to east. The seabed is highly variable beyond 300m water depth. Slopes in the vicinity of the planned anchor locations can reach 11° with some surrounding slopes higher. The North and South anchor targets are at the 300m depth. Data collected over ~5.5km x 3km area using 200m line spacing.

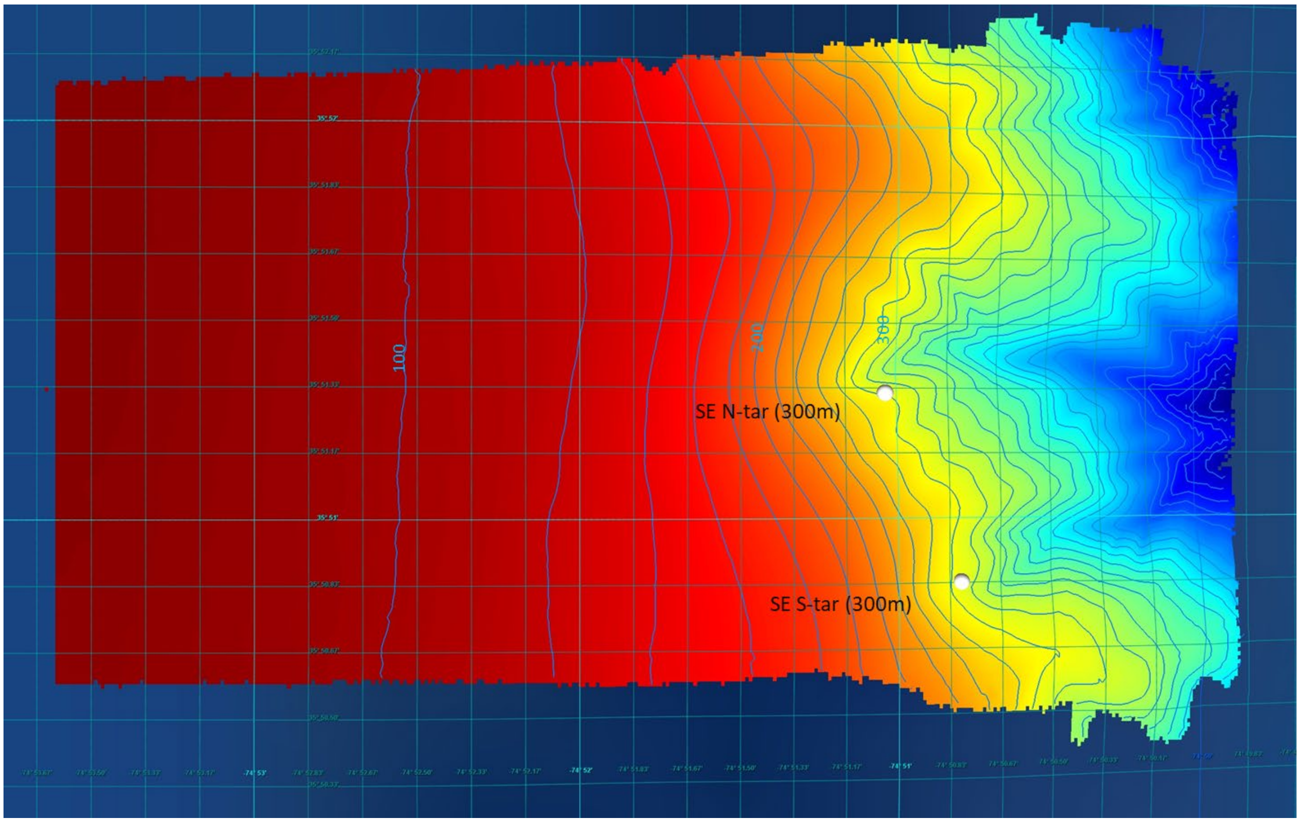

Figure 89: Southeastern (Updated) Site Digital Terrain Model (20m contours)

Backscatter

Backscatter imagery at both the north and south anchor target sites indicate a homogeneous seabed, no visible hazards such as hard bottom, cables, pipelines, wrecks, or debris (Figure 90).

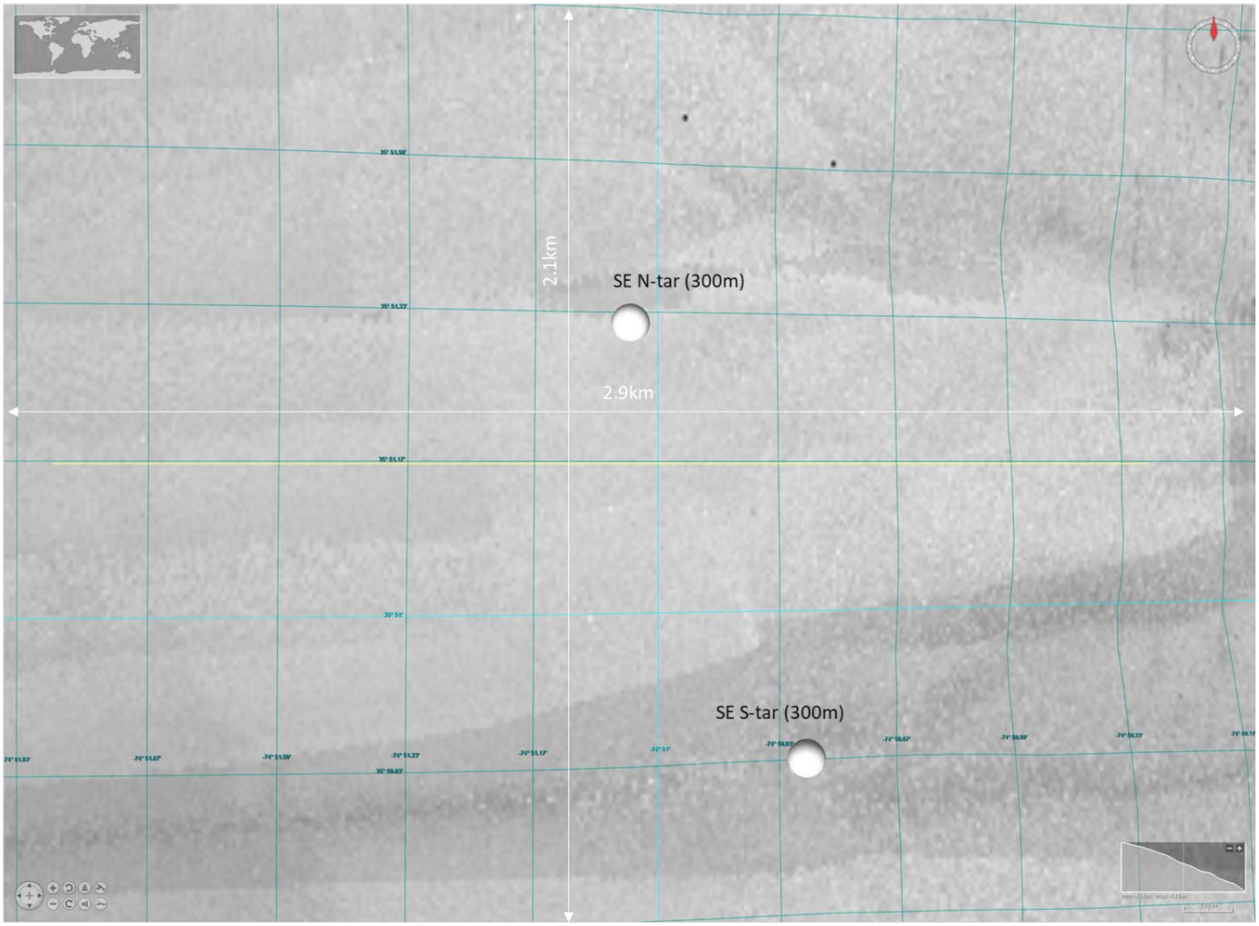

Figure 90: Southeastern (Updated) Site North & South Anchor Targets (N-Tar, S-Tar) Backscatter

Subbottom

Subbottom profiles at both the north and south anchor target sites indicate a soft and homogeneous seabed with good penetration, some indication of harder sublayers that do not impact operations, no indication of hard bottom or hazards such as cables, pipelines, debris, or wrecks (Figures 91 & 92). As can be seen in the subbottom profile, this is a steeper site as the seabed crosses the shelfbreak. Slopes are approximately 11°, localized will be higher.

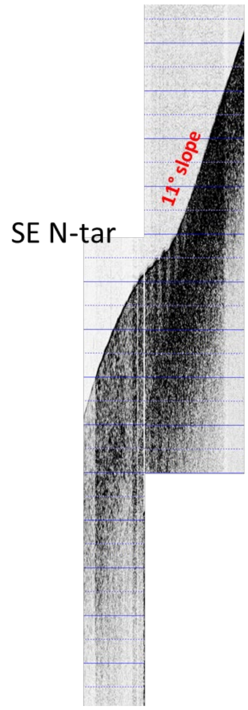

Figure 91: Southeastern (Updated) Site North Anchor Target (N-Tar) Subbottom

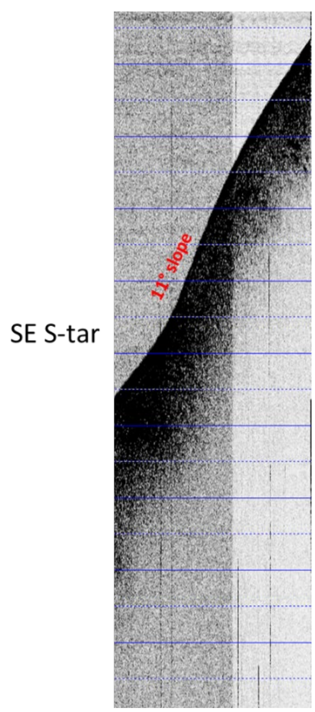

Figure 92: Southeastern (Updated) Site South Anchor Target (S-Tar) Subbottom

<u>ROV Inspection</u>
ROV inspection was completed at all anchor target sites, The camera data indicates a flat seabed at both sites consisting of sands and gravels (Figures 93 & 94). No areas or features of concern (hard bottom, debris, cables, pipelines, wrecks, artifacts, marine habitat) in ROV sonar or imagery in vicinity of anchor targets.

Figure 93: ROV Imagery at Southeastern (Updated) Site, North Anchor Target

Figure 94: Sandy Seabed Southeastern (Updated) Site, South Anchor Target

9.0 CONCLUSION & RECOMMENDATIONS

The survey and ROV inspection confirmed the results of the planning studies:

1. Primarily sandy seabed, suitable for anchoring and mooring deployments. Some evidence of sediment movement which should be monitored during mooring recoveries,
2. Steeper slopes at the deep mooring sites, with localized flat areas for deployment,
3. No indication of shipwrecks or cultural resources at the mooring sites, and
4. No indication of at-risk marine habitat.

The completed surveys provide sufficient information for environmental compliance at each mooring site. Additional anchor target surveys would be done as-needed to confirm seafloor characteristics prior to deployment. Table 5 and 6 provide engineering and compliance findings.

Table 5: ROV Inspection & Survey Findings

Site	Findings	Risks	Recommendations
WEST	Survey and ROV data indicate the anchor sites are suitable for the deployment of a single mooring.	Evidence of sediment mobility, risk of some burial of multifunction node (MFN)	Retain anchor targets as planned. ROV should always be available for inspection and recovery of MFN. If sediment movement impacts future recoveries, anchor targets could be moved east, further into bottom of channel.
CENTRAL	Survey and ROV data indicate the anchor sites are suitable for the deployment of dual moorings.	Minor risk of sediment mobility, and burial of MFNs.	Retain anchor targets as planned. ROV should always be available for inspection and recovery of MFN.
EAST	Survey and ROV data indicate the anchor sites are suitable for the deployment of single mooring.	Flat, sandy seabed, no minor/major risks	Retain anchor targets as planned.
NORTH	Survey and ROV data indicate the anchor sites are suitable for the deployment of dual moorings.	Flat, sandy seabed, no minor/major risks	Retain anchor targets as planned.
SOUTH	Survey and ROV data indicate the anchor sites are suitable for the deployment of dual moorings.	Flat, sandy seabed, no minor/major risks	Retain anchor targets as planned.
NORTHEASTERN (OLD)	Bathymetry and subbottom show steeper slopes, no indication of hazards in backscatter, ROV video shows sandy flat bottom in vicinity of anchor target.	South anchor target surveyed but not ROV inspected; steeper slopes greater than 30° could be found away from anchor target areas. Potential turbidity current risk. Public feedback indicates longline fishing in the area and that moorings could be a risk to longlining activities. Longlining is also a risk to mooring operations including fouling of profilers.	Assess Northeastern (Updated) site in area of less potential longlining activity. This also moves the mooring away from steep slopes and potential recovery/deployment risks.
SOUTHEASTERN (OLD)	Bathymetry and subbottom show significantly steeper slopes, no indication of hazards in backscatter, ROV video shows sandy flat bottom in vicinity of anchor target.	South anchor target surveyed but not ROV inspected; localized slopes steeper than 30° could be an anchor holding risk, slopes and channels could also be turbidity current risk leading to mooring loss. Public feedback indicates longline fishing in the area and that moorings could be a risk to longlining activities. Longlining is also a risk to mooring operations including fouling of profilers.	Assess Southeastern (Updated) site in area of less potential longlining activity. This also moves the mooring away from steep slopes and potential recovery/deployment risks.

Site	Findings	Risks	Recommendations
NORTHEASTERN (Updated)	Survey and ROV data indicate the anchor sites are suitable for the deployment of single mooring.	Flat, sandy seabed, no minor/major risks	Retain anchor targets as planned.
SOUTHEASTERN (Updated)	Survey and ROV data indicate the anchor sites are suitable for the deployment of single mooring.	Flat, sandy seabed, no minor/major risks	Retain anchor targets as planned.

Table 6: Compliance

Site	Findings	Risks	Recommendations
WEST	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks.	Retain anchor targets as planned. If anchor targets are moved in the future due to engineering concerns, re-perform ROV inspections.
CENTRAL	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks.	Retain anchor targets as planned.
EAST	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks.	Retain anchor targets as planned.
NORTH	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks.	Retain anchor targets as planned.
SOUTH	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks.	Retain anchor targets as planned.
NORTHEASTERN (OLD)	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks within survey data. Public feedback indicates longline fishing in the area and that moorings could be a risk to longlining activities. Longlining is also a risk to mooring operations including fouling of profilers.	Assess Northeastern (Updated) site in area of less potential longlining activity.

Site	Findings	Risks	Recommendations
SOUTHEASTERN (OLD)	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks within survey data. Public feedback indicates longline fishing in the area and that moorings could be a risk to longlining activities. Longlining is also a risk to mooring operations including fouling of profilers.	Assess Southeastern (Updated) site in area of less potential longlining activity.
NORTHEASTERN (Updated)	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks.	Retain anchor targets as planned.
SOUTHEASTERN (Updated)	No indication of wrecks or cultural artifacts. No visible risks to marine habitat. No identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs).	No identifiable risks.	Retain anchor targets as planned.

APPENDIX A: Areas of Interest

AREAS OF INTEREST

The following section describes areas of interest located during the ROV transects between sites. These areas of interest are outside of the anchor target areas (anchors can typically be deployed within a 25m radius of the target) and would not be impacted by the proposed action, including Pioneer MAB anchors and operations. Benthic organisms were found within these areas; organism identification was performed by Tim Shank, a WHOI Associate Scientist in Biology. Based on the review, there are no identifiable vulnerable marine ecosystems (VMEs) and no essential fish habitats (EFHs) in these images.

Table A-1: Areas of Interest

Area	Site	Distance from Nearest Anchor Target (m)	Water Depth (m)
1	Central	300	30
2	Southern	272	85.7
3	Southern	50	93.7
4	Northeastern (Old)	230	567
5	Southeastern (Old)	50	557

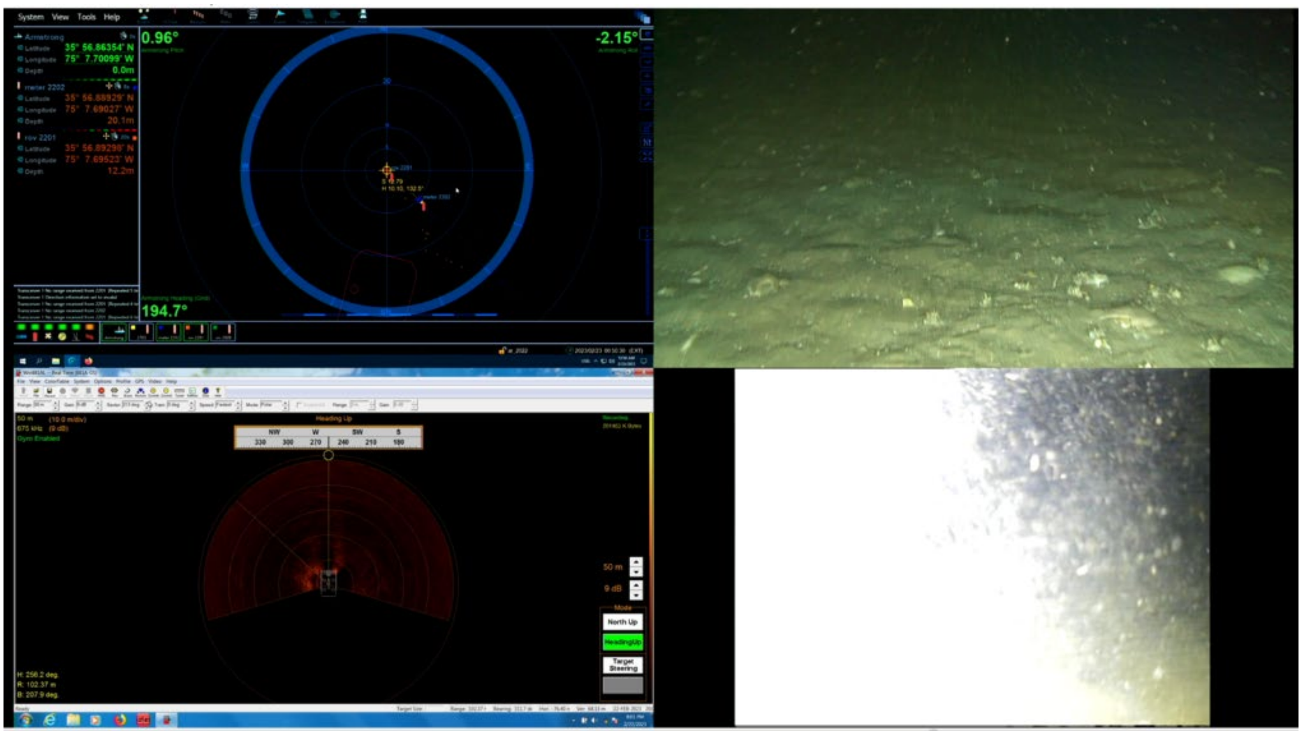

Figure A-1: Area of Interest #1, Central Site: Shell and skeleton debris, sea star, scattered vertical worm tubes

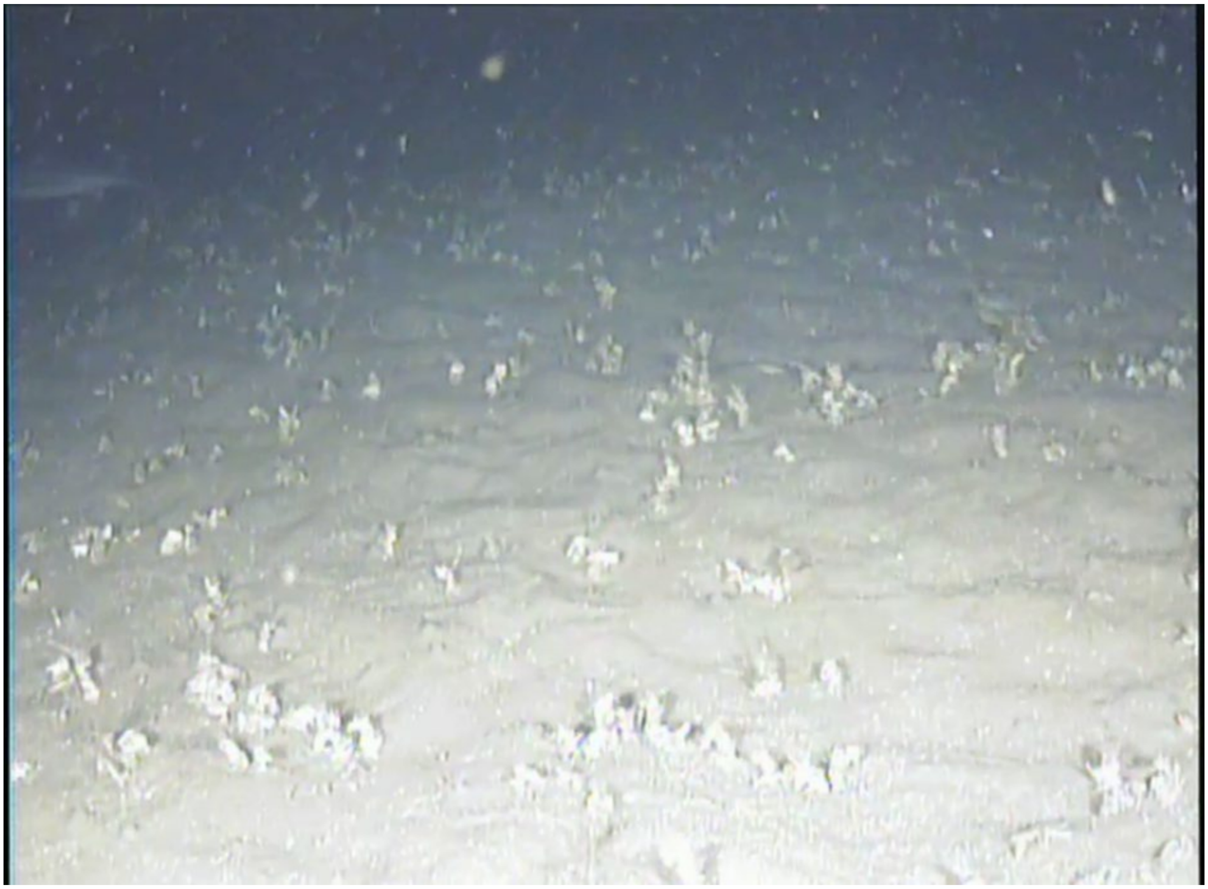

Figure A-2: Area of Interest #1, Central Site: Shell and skeleton debris, sponges

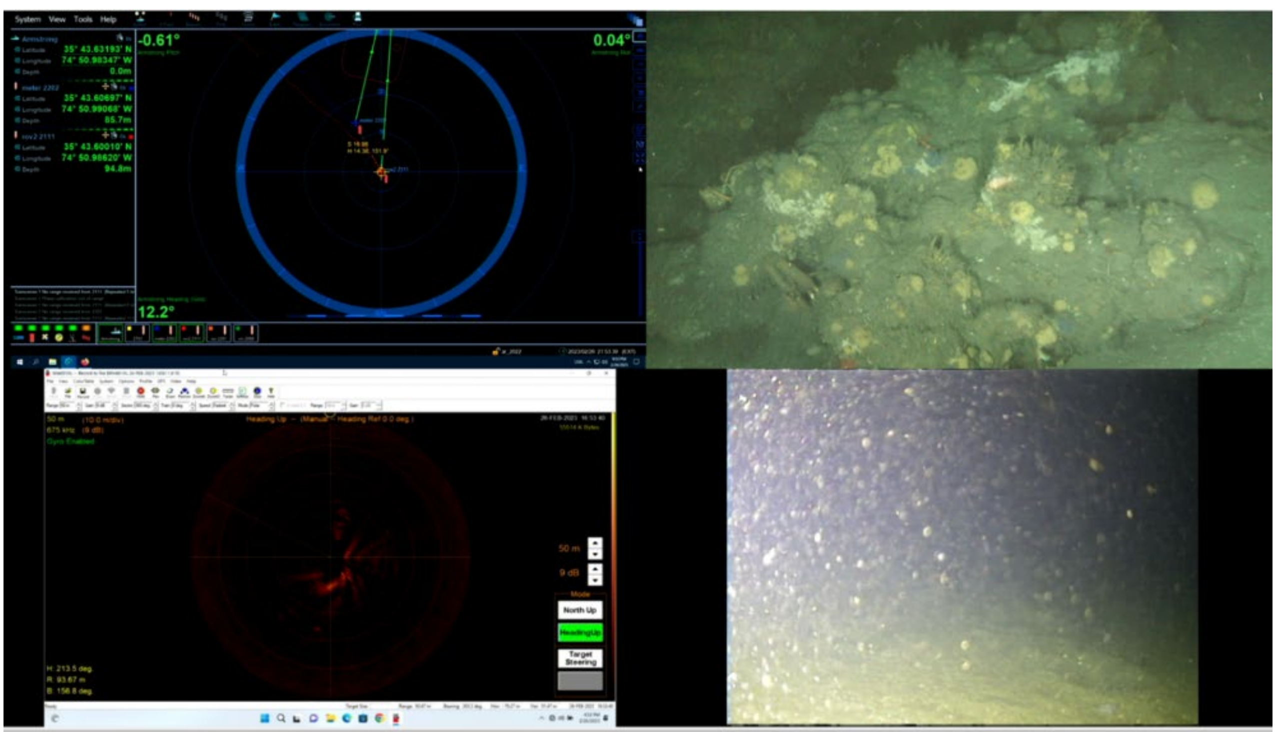

Figure A-3: Area of Interest #2, Southern Site: Lithotherm-like substrate, sponges, Galatheid crabs, Bryozoan-like animals

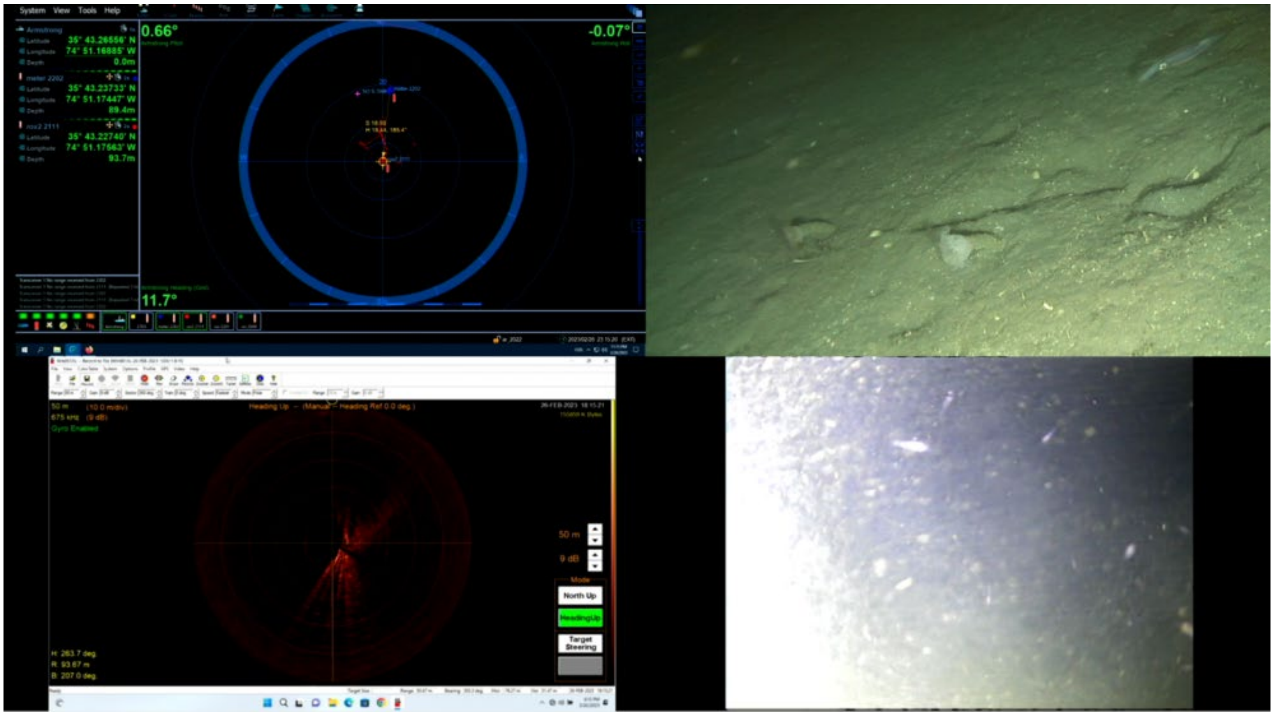

Figure A-4: Area of Interest #3, Southern Site: Anemones (solitary hydroids), shell debris, squid, small Polychaete Hyalinoecia worm tubes

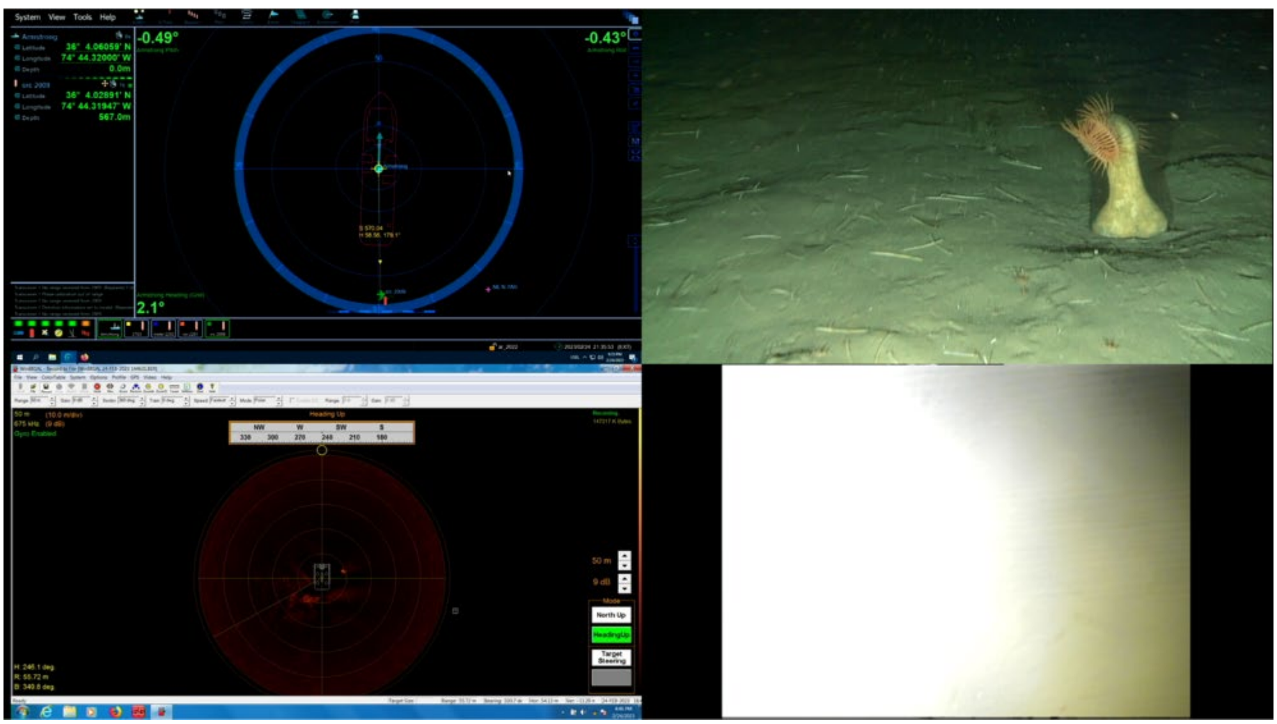

Figure A-5: Area of Interest #4, Northeastern (Old) Site: Actinoscyphia Venus Flytrab anemone, Polychaete Hyalinoecia worm tubes

Figure A-6: Area of Interest #4, Northeastern (Old) Site: Anemones, squid, Polychaete Hyalinoecia worm tubes

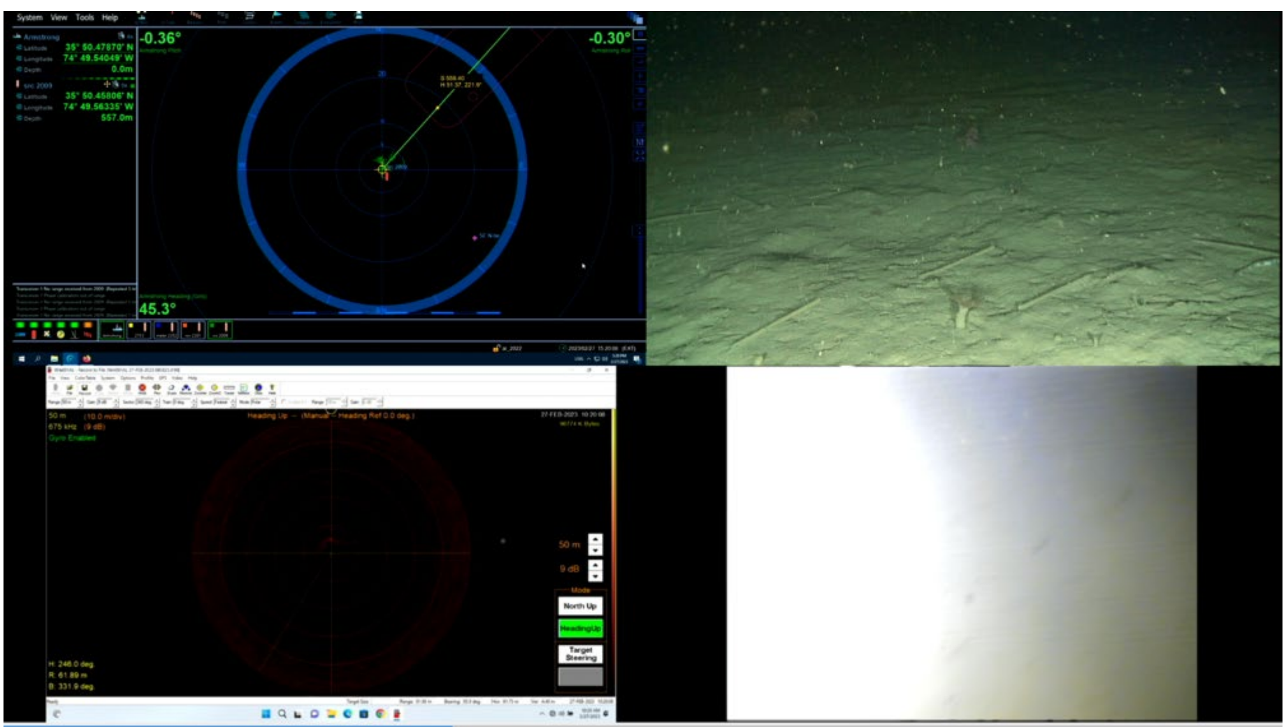

Figure A-7: Area of Interest #5, Southeastern (Old) Site: Polychaete Hyalinoecia worm tubes, tube anemones

Appendix G: Pioneer MAB Community Outreach

NATIONAL SCIENCE FOUNDATION
2415 Eisenhower Avenue
Alexandria, Virginia 22314

OFFICE OF THE
GENERAL COUNSEL

DATE: September 29, 2023

MEMORANDUM FOR: TRIBES, GOVERNMENT AGENCIES, ORGANIZATIONS, INDIVIDUALS, AND INTERESTED PARTIES

FROM: NATIONAL SCIENCE FOUNDATION (NSF)

RE: Notice of Availability of a Draft Supplemental Site-Specific Environmental Assessment for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight

The National Science Foundation (NSF) gives notice of the availability of the "Draft Supplemental Site-Specific Environmental Assessment for Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight" (Draft SSSEA) for review and public comment.

NSF proposes to fund the relocation, operation, and maintenance of the NSF Ocean Observatory Initiative's (OOI) Pioneer Array to the Mid-Atlantic Bight (MAB) off North Carolina in the Northwest Atlantic Ocean (Proposed Action). The OOI is a globally distributed, networked, ocean-focused research observatory with arrays of sophisticated instruments that utilize cutting-edge technologies to observe and study ocean processes. The Pioneer MAB Array would represent a Coastal Scale Node component of the OOI. The Pioneer MAB Array is designed to resolve transport processes and ecosystem dynamics in the vicinity of the shelf-break front, a region of high biological productivity and complex oceanographic dynamics that include intense mesoscale variability and episodic event disturbances (i.e., hurricanes). It would collect high-resolution, multidisciplinary, synoptic measurements spanning the shelf break on horizontal scales from a few kilometers to several hundred kilometers. The array is designed and planned to be relocatable approximately (~) every 5 years with new locations proposed by the NSF with input from the scientific community.

The Proposed Action would (1) relocate the Pioneer New England Shelf (Pioneer NES) Array to the southern MAB (Pioneer MAB Array, Figure 1); 2) modify the mooring designs for the new site water depths; and 3) include additional scientific instrumentation on the moorings. The Proposed Action would occur within the Exclusive Economic Zone (EEZ) of the U.S. but outside of state waters. The Pioneer MAB Array would be a T-shape array located off the coast of Nags Head, North Carolina, starting ~24 kilometers (km) (~13 nautical miles [nm]) offshore, extending ~59 km (~32 nm) east/west and ~49 km (~26 nm) north/south across the continental shelf, centered at the shelf-break front. The Project Area, including the surrounding area of potential effect, would consist of 10 moorings and a 2 km by 2 km (1 nm by 1 nm) square around the center point of each of the mooring locations. In addition, there would be mobile assets, such as autonomous underwater vehicles (AUVs) and gliders that would operate around the moorings. Gliders and AUVs would run underwater missions along tracks in the vicinity of the moored array. Two (2) AUVs and four (4) gliders would be used to provide underwater monitoring abilities along and across the shelf and within the waters of the continental slope. Gliders would be deployed on a 60-90-day rotation schedule and would be operated continuously along pre-determined paths, while the AUVs would be deployed for limited periods of ~4 days every 2 months.

The Pioneer MAB Array is proposed to be deployed in April 2024. The array and associated AUVs and gliders would be serviced primarily by vessels from the U.S. Academic Research Fleet (ARF) with support from local chartered vessels when needed; a proposed schedule for installation, operations, and maintenance is included in the Draft SSSEA. Installation, operations, and maintenance activities would use standard methods and procedures currently used by the ocean observing community. Like the Pioneer NES Array, the moorings deployed at Pioneer MAB would include anchors and benthic nodes designed to be fully recoverable, minimizing impact on the seabed.

Telephone (703) 292-8060 FAX (703) 292-9485

The Draft SSSEA evaluated the potential impacts of the Proposed Action on the human and natural environment, pursuant to the National Environmental Policy Act (NEPA) and tiers to existing OOI NEPA documentation[1]. The Draft SSSEA focused on activities and associated potential impacts on marine resources (e.g., geological, marine biological, socioeconomic, etc.) that were not previously assessed by existing OOI NEPA analyses. The conclusions from the Draft SSSEA were used to inform the NSF Division of Ocean Sciences (OCE) of potential environmental impacts of the Proposed Action.

Impacts from the placement of proposed mooring anchors or nodes on the seafloor would include temporary disturbance of soft sediments and coverage of relatively small areas of substrate by the anchors and scientific sensors (~37 m^2) for the deployment period. Over time, the natural movement of sediments by ocean currents and burrowing organisms would reestablish natural bottom topography. Upon conclusion of operations, the entire system, including anchors and nodes, would be removed from the MAB Project Area. A small amount of Essential Fish Habitat (EFH) may potentially be impacted during installation activities. The short-term and minor increases in turbidity and sedimentation resulting from system installation, operations, maintenance, and removal would not affect the ability of EFH to support healthy fish populations, and affected areas are expected to recover quickly. The vessels and activity associated with installation and maintenance of the moorings may cause marine species, such as Endangered Species Act (ESA)-listed marine mammals, to avoid the immediate vicinity of the proposed Pioneer MAB Array sites, but this impact would be brief and temporary due to the nature of the proposed activities (estimated time to deploy a mooring with one vessel is 12 to 24 hours). Entanglement and vessel strike/collision threats to marine mammals or sea turtles are not anticipated due to the equipment design, slow operational speed (0.5 to 2 knots), and use of NMFS standard oceanographic marine mammal vessel strike avoidance measures, including special measures for North Atlantic Right Whale. The use of gliders and AUVs is not expected to affect marine species, as the proposed gliders and AUVs are self-contained and move slowly within the water column similar to a dolphin or whale. Additional new scientific instrumentation sensors would be mounted on or incorporated into the existing mooring designs; however no adverse effects to marine species are anticipated from the new sensors. Mooring sites were selected to avoid historic and cultural resources (e.g., shipwrecks).

Specific sensitive areas were considered during early planning and siting of the Pioneer MAB Array. The array would not overlap with or be anticipated to impact artificial reefs or fishery nursery areas. Four of the Pioneer MAB Array moorings would be located within the loggerhead sea turtle Constricted Migratory Corridor; however, they are not anticipated to impede sea turtle migration. The Pioneer MAB Array would not overlap with loggerhead sea turtle Coastal Critical Habitat Designation (sargassum habitat). The Pioneer MAB Array's southernmost mooring would be located within a joint Snapper-grouper/Coral Reefs and Hardbottom/Dolphin and Wahoo Habit Areas of Particular Concern (HAPC) designated by the South Atlantic Fisheries Management Council (SAFMC). The small scale and temporary nature of the single mooring would have little to no impact on the HAPC. A survey conducted of the sites also did not indicate the existence of corals.

Due to the distance from shore, small footprint, localized and temporary nature (~5 years), interactions between the Proposed Action and other ocean users, including fishing operations, in the study area are expected to be limited. Other activities, including fisheries, could occur within the proposed project area; a safe distance, however, would need to be kept from Pioneer MAB Array individual moorings. Any potential space-use conflicts would be minimized through outreach and communication with ocean users. The USCG would be contacted prior to the deployment of moorings as part of the Private Aids To Navigation (PATON) approval process and the Pioneer MAB Array moorings would be easily visible and avoidable. All mooring locations and associated components of the Pioneer Array would be published in NOAA charts, Notice to Mariners and Local Notice to Mariners. Gliders and AUVs would be marked with the name of the owning organization and a contact telephone number that ocean users could call to report any encounters at sea.

The Draft SSSEA also assessed potential cumulative effects of the Proposed Action. Overall, the combination of the proposed activities with other activities occurring in the region is expected to produce only a negligible increase in overall disturbance effects on the marine environment. Given the distance from shore, small footprint, temporary nature, and experience with Pioneer NES, significant impacts from the Proposed Action are not anticipated on the

[1]OOI NEPA documents are available on the NSF website (https://www.nsf.gov/geo/oce/envcomp/index.jsp).

marine environment. While the Proposed Action may affect EFH and ESA-listed species, adverse effects are not likely. NSF will consult with federal regulatory agencies as applicable and appropriate.

Additional information about the proposed Pioneer MAB Array can be found in the Draft SSSEA and tiered OOI NEPA documentation, including details on relocation, operations, and maintenance; scientific instrumentation; potential effects, and diagrams of the array components.

After reviewing and considering all public comments received during the public comment period and regulatory processes, NSF will issue a Final Supplemental Site-Specific Environmental Assessment (Final SSSEA), accompanied by a decision document.

Public Comments:
The Draft SSSEA regarding the proposed action is posted for public comment on the NSF website at: http://www.nsf.gov/geo/oce/envcomp/index.jsp, closing on October 28, 2023. We welcome any comments you may have on the Draft SSSEA. Comments may be submitted via email to: nsfnepaooipioneer@nsf.gov. Comments received will be addressed in the Final SSSEA.

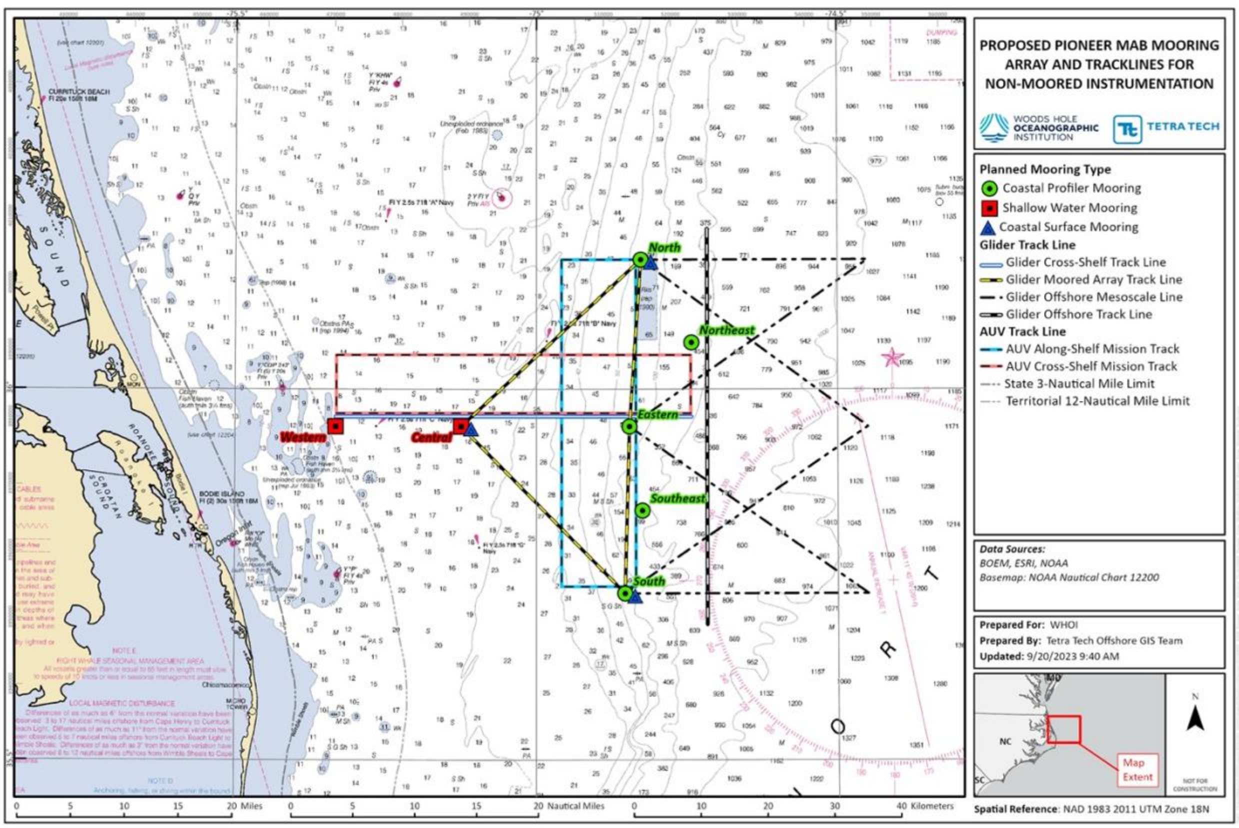

Figure 1. Proposed Pioneer MAB Array of Moorings and Surface Projection of Underwater Track lines for Mobile Assets

The Draft SSSEA was posted on September 29, 2023, for a 30-day public comment period. The following comments were received.

#	Date	Commentor	Comment	Response
1	3-Oct-2023	Michael Muglia	As an oceanographer working in the southern Mid Atlantic Bight and South Atlantic Bight, I am thrilled to have these observations planned for such a complicated area. The confluence of so many different water masses here, the cold pool in the MAB, the saltier warmer SAB that meets the cold pool at the Hatteras Front, and offshore, the profound influence of the Gulf Stream on this confluence and its influence on shelf/deep ocean exchange all make this an ideal site for the Pioneer Array. The combination of the Pioneer Array observations with the observations we currently support at ECU's Coastal Studies Institute, like the CDIP buoys off Nags Head/Pea Island/and Buxton as well as our land-based surface current observations from our HF radar network, will significantly enhance our understanding of the oceanography here. We greatly appreciate your significant efforts to relocate the array.	Thank you for your comment, no response or action required.
2	4-Oct-2023	Ryan Coe, PhD, Water Power Technologies, Sandia National Laboratories	The new Pioneer Array deployment at the Mid-Atlantic will provide an invaluable opportunity to study the application of a wave energy converter (WEC) system to power. This will be a truly novel test and could lead to the broader application of WECs in oceanographic sensing and autonomous ocean power, potentially reducing greenhouse gas emissions.	Thank you for your comment, no response or action required.
3	23-Oct-2023	Caroline Lowcher	As a Nags Head resident, I look forward to seeing the OOI Pioneer MAB Array deployed off of Nags Head because this region of the coastal ocean is scientifically rich and diverse. The observations collected from the Pioneer Array at this location would support invaluable science relevant for academia, industry, and societal sectors. I hope there will be an educational outreach component for the community to publicize the research efforts taking place adjacent to this part of North Carolina's coastline. I look forward to seeing a successful deployment in spring 2024 and am optimistic about the high-impact science that will occur afterwards.	Thank you for your comment, no response or action required.
4	28-Oct-2023	Dewey Hemilright	This comment here and email thread below is in opposing to the placement of the only northeastern offshore placement Pioneer Array Buoy in 300fathom+ depth of water, Reason for opposing is that placement of this Buoy is in direct path of the Pelagic longline fishing area, which are historical and productive fishing ground for over 20 vessels [PLL] vessel fishing in this area year around from Mass.to Florida fishing this area. Pelagic Long Line gear is free floating monofilament line free float, fished the water column from surface to deep in water column, given the free floating with length 15/32 miles in length movement with tide once set doesn't stay in same place. The proposed placement location of the Northeastern offshore buoy would basic cause a closed area inside the NE offshore buoy as there is probably at least 2 to 3 vessels lost sets inside of NE buoy because gear would entangle in Proposed NE buoy which fishermen couldn't fish inside, making it a closed area.not good As PLL can't afford to lose any more highly productive fishing grounds, I personally have spent a good amount of time tracking down and educating folks that are with WHOI, as why we can't have a NE offshore placed in productive fishing grounds. Inclosing please reconsider different location of placement of this NE offshore buoy, I've also included the PLL vessel tracks from 2012-2020 for your review as to where we fish. In the future it would be good to have early outreach to fishermen and community before any placement of Buoy's in fishing ground as the placement earlier this year that didn't happen, also included a PLL fishermen entangled in NE Offshore Buoy that was placed with fishermen knowledge which is in video below, Thank you for opportunity to comments and would welcome a comprise to NE offshore buoy placement.	Thank you for your comment. In response to the concerns raised, the originally planned 600-m locations (Northeastern and Southeastern moorings) would be moved westward to the 300-m contour. This new mooring position would reduce the likelihood of impacts to longline fishing activity
5	1-Nov-2023	North Carolina State Historic Preservation Office	Thank you for your submission of September 29, 2023, concerning the above project. We have conducted a review of the project and are aware of no historic resources which would be affected by the project. Therefore, we have no comment on the project as proposed. The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800.	Thank you for your comment, no response or action required. The NC State Environmental Review Clearing house distributed the SSSEA to all relevant state agencies for their review according to the State Environmental Policy Act. The relevant agencies reviewed the project and responded with no comments.
6	2-Nov-2023	North Carolina Department of Environmental Quality	The Department of Environment Quality has reviewed the proposal for the referenced project. The Department will continue to be available to assist the applicant with any questions or concerns. Thank you for the opportunity to respond. Attachments indicate No Comment.	Thank you for your comments, no response or action required. The NC State Environmental Review Clearing house distributed the SSSEA to all relevant state agencies for their review according to the State Environmental Policy Act. The relevant agencies reviewed the project and responded with no comments.

ROY COOPER
Governor
ELIZABETH S. BISER
Secretary

NORTH CAROLINA
Environmental Quality

To: Kadisha Molyneaux
State Clearinghouse
NC Department of Administration

From: Lyn Biles
Division of Environmental Assistance and Customer Service
Washington Regional Office

Re: 24-0110
Environmental Assessment - Proposal for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight. The Proposed Action would (1) relocate the Pioneer New England Shelf (Pioneer NAS) Array to the southern MAB (Pioneer MAB Array; 2) modify the mooring designs for the new site water depths; and 3) include additional scientific instrumentation on the moorings. The Proposed Action would occur within the Exclusive Economic Zone (EEZ) of the U.S. but outside of state waters.
Dare, Pender, Onslow and Carteret Counties

Date: November 2, 2023

The Department of Environment Quality has reviewed the proposal for the referenced project.

The Department will continue to be available to assist the applicant with any questions or concerns.

Thank you for the opportunity to respond.

Attachments

Department of Environmental Quality
Project Review

Project Number: 24-0110 | **County: Carteret, Dare, Onslow& Pender** | **Date Received: 10-2-2023**

Due Date: 10-27-2023

Project Description: *Environmental Assessment - Proposal is for the Draft Supplemental Site-Specific Environmental Assessment for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight. NSF proposes to fund the relocation, operation, and maintenance of the NSF Ocean Observatory Initiative's (OOI) Pioneer Array to the Mid-Atlantic Bight (MAB) off North Carolina in the Northwest Atlantic Ocean (Proposed Action). The Proposed Action would (1) relocate the Pioneer New England Shelf (Pioneer NES) Array to the southern MAB (Pioneer MAB Array, Figure 1); 2) modify the mooring designs for the new site water depths; and 3) include additional scientific instrumentation on the moorings. The Proposed Action would occur within the Exclusive Economic Zone (EEZ) of the U.S. but outside of state waters.*

This Project is being reviewed as indicated below:

Regional Office	Regional Office Area	In-House Review	
☐ Asheville	☐ Air	☐ Air Quality	☑ Coastal Management
☐ Fayetteville	☑ DWR	☑ Waste Mgmt	☑ Marine Fisheries
☐ Mooresville	☐ DWR - Public Water	☐ Water Resources Mgmt (Public Water, Planning & Water Quality Program)	☐ CC & PS Div. of Emergency Mgmt
☐ Raleigh	☐ DEMLR (LQ & SW)		☑ DMF-Shellfish Sanitation
☑ Washington	☐ DWM	☐ DWR-Transportation Unit	☑ Wildlife Maria
☑ Wilmington			☐ Wildlife/DOT
☐ Winston Salem			

Manager Sign-Off/Region:	Date:	In-House Reviewer/Agency:
	10-25-2023	[signature] /NCWRC

Response (check all applicable)

____ No objection to project as proposed. ✓ No Comment

____ Insufficient information to complete review ____ Other (specify or attach comments)

Department of Environmental Quality
Project Review

Project Number: 24-0110 | **County: Carteret, Dare, Onslow& Pender** | **Date Received: 10-2-2023**

Due Date: 10-27-2023

Project Description: *Environmental Assessment - Proposal is for the Draft Supplemental Site-Specific Environmental Assessment for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight. NSF proposes to fund the relocation, operation, and maintenance of the NSF Ocean Observatory Initiative's (OOI) Pioneer Array to the MId-Atlantic Bight (MAB) off North Carolina in the Northwest Atlantic Ocean (Proposed Action). The Proposed Action would (1) relocate the Pioneer New England Shelf (Pioneer NES) Array to the southern MAB (Pioneer MAB Array, Figure 1); 2) modify the mooring designs for the new site water depths; and 3) included additional scientific instrumentation on the moorings. The Proposed Action would occur within the Exclusive Economic Zone (EEZ) of the U.S. but outside of state waters.*

This Project is being reviewed as indicated below:

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☐ Mooresville	☐ DWR - Public Water	☐ Water Resources Mgmt (Public Water, Planning & Water Quality Program)	☐ CC & PS Div. of Emergency Mgmt
☐ Raleigh	☐ DEMLR (LQ & SW)	☐ DWR-Transportation Unit	☑ DMF-Shellfish Sanitation
☑ Washington	☐ DWM		☑ Wildlife Maria
☑ Wilmington			☐ Wildlife/DOT
☐ Winston Salem			

Manager Sign-Off/Region:	Date:	In House Reviewer/Agency:
	10/5/2023	Andrew Haines for Shannon Jenkins

Response (check all applicable)

____ No objection to project as proposed.

__X__ No Comment

____ Insufficient information to complete review

____ Other (specify or attach comments)

North Carolina Department of Natural and Cultural Resources

State Historic Preservation Office

Ramona M. Bartos, Administrator

Governor Roy Cooper
Secretary D. Reid Wilson

Office of Archives and History
Deputy Secretary, Darin J. Waters, Ph.D.

November 1, 2023

MEMORANDUM

TO: Kadisha Molyneaux — state.clearinghouse@doa.nc.gov
North Carolina State Clearinghouse
Department of Administration

FROM: Ramona M. Bartos, Deputy
State Historic Preservation Officer

RGE for Ramona M. Bartos

SUBJECT: NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight, Multiple Counties, 24-E-0000-0110, ER 23-2215

Thank you for your submission of September 29, 2023, concerning the above project.

We have conducted a review of the project and are aware of no historic resources which would be affected by the project. Therefore, we have no comment on the project as proposed.

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, environmental review coordinator, at 919-814-6579 or environmental.review@dncr.nc.gov. In all future communication concerning this project, please cite the above referenced tracking number.

Roy Cooper
Governor

Pamela B. Cashwell
Secretary

November 2, 2023

Holly Smith
National Science Foundation
Office of the General Counsel
2415 Eisenhower Avenue
Alexandria, NC 22314-

Re: SCH File # 24-E-0000-0110 Proposal is for the Draft Supplemental Site-Specific Environmental Assessment for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight. NSF proposes to fund the relocation, operation, and maintenance of the NSF Ocean Observatory Initiative's

Dear Holly Smith:

The above referenced environmental impact information has been submitted to the State Clearinghouse under the provisions of the National Environmental Policy Act. According to G.S. 113A-10, when a state agency is required to prepare an environmental document under the provisions of federal law, the environmental document meets the provisions of the State Environmental Policy Act.

Attached to this letter are comments made by the agencies in the review of this document. If any further environmental review documents are prepared for this project, they should be forwarded to this office for intergovernmental review.

If you have any questions, please do not hesitate to contact me at (984) 236-0000.

Sincerely,

KADISHA MOLYNEAUX
State Environmental Review Clearinghouse

Attachments

Control No.: 24-E-0000-0110

County.: DARE, PENDER, ONSLOW, CARTERET

Date Received: 10/2/2023

Agency Response: 11/1/2023

Review Closed: 11/1/2023

LYN BILES

CLEARINGHOUSE COORDINATOR

DEPT OF ENVIRONMENTAL QUALITY

Project Information

Type: National Environmental Policy Act ironmental Assessment

Applicant: National Science Foundation

Project Desc.: Proposal is for the Draft Supplemental Site-Specific Environmental Assessment for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight. NSF proposes to fund the relocation, operation, and maintenance of the NSF Ocean Observatory Initiative's (OOI) Pioneer Array to the Mid-Atlantic Bight (MAB) off North Carolina in the Northwest Atlantic Ocean (Proposed Action). The Proposed Action would (1) relocate the Pioneer New England Shelf (Pioneer NES) Array to the southern MAB (Pioneer MAB Array, Figure 1); 2) modify the mooring designs for the new site water depths; and 3) include additional scientific instrumentation on the moorings. The Proposed Action would occur within the Exclusive Economic Zone (EEZ) of the U.S. but outside of state waters.

As a result of this review the following is submitted:

☐ No Comment ☐ Comments Below ☑ Documents Attached

Reviewed By: LYN BILES

Date: 11/1/2023

Control No.: 24-E-0000-0110

County.: DARE, PENDER, ONSLOW, CARTERET

Date Received: 10/2/2023

Agency Response: 11/1/2023

Review Closed: 11/1/2023

JINTAO WEN

CLEARINGHOUSE COORDINATOR

DPS - DIV OF EMERGENCY MANAGEMENT

Project Information

Type: National Environmental Policy Act ironmental Assessment

Applicant: National Science Foundation

Project Desc.: Proposal is for the Draft Supplemental Site-Specific Environmental Assessment for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight. NSF proposes to fund the relocation, operation, and maintenance of the NSF Ocean Observatory Initiative's (OOI) Pioneer Array to the Mid-Atlantic Bight (MAB) off North Carolina in the Northwest Atlantic Ocean (Proposed Action). The Proposed Action would (1) relocate the Pioneer New England Shelf (Pioneer NES) Array to the southern MAB (Pioneer MAB Array, Figure 1); 2) modify the mooring designs for the new site water depths; and 3) include additional scientific instrumentation on the moorings. The Proposed Action would occur within the Exclusive Economic Zone (EEZ) of the U.S. but outside of state waters.

As a result of this review the following is submitted:

☑ No Comment ☐ Comments Below ☐ Documents Attached

Reviewed By: JINTAO WEN

Date: 10/30/2023

Control No.: 24-E-0000-0110

County.: DARE, PENDER, ONSLOW, CARTERET

Date Received: 10/2/2023

Agency Response: 11/1/2023

Review Closed: 11/1/2023

DEVON BORGARDT

CLEARINGHOUSE COORDINATOR

DEPT OF NATURAL & CULTURAL RESOURCE

Project Information

Type: National Environmental Policy Act ironmental Assessment

Applicant: National Science Foundation

Project Desc.: Proposal is for the Draft Supplemental Site-Specific Environmental Assessment for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight. NSF proposes to fund the relocation, operation, and maintenance of the NSF Ocean Observatory Initiative's (OOI) Pioneer Array to the Mid-Atlantic Bight (MAB) off North Carolina in the Northwest Atlantic Ocean (Proposed Action). The Proposed Action would (1) relocate the Pioneer New England Shelf (Pioneer NES) Array to the southern MAB (Pioneer MAB Array, Figure 1); 2) modify the mooring designs for the new site water depths; and 3) include additional scientific instrumentation on the moorings. The Proposed Action would occur within the Exclusive Economic Zone (EEZ) of the U.S. but outside of state waters.

As a result of this review the following is submitted:

☐ No Comment ☑ Comments Below ☑ Documents Attached

SHPO No Comment ER 23-2215

Reviewed By: DEVON BORGARDT

Date: 11/1/2023

Control No.: 24-E-0000-0110

County.: DARE, PENDER, ONSLOW, CARTERET

Date Received: 10/2/2023

Agency Response: 11/1/2023

Review Closed: 11/1/2023

JESSICA MOSLEY

CLEARINGHOUSE COORDINATOR

DEPT OF TRANSPORTATION

Project Information

Type: National Environmental Policy Act ironmental Assessment

Applicant: National Science Foundation

Project Desc.: Proposal is for the Draft Supplemental Site-Specific Environmental Assessment for the NSF Ocean Observatory Initiative (OOI) Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight. NSF proposes to fund the relocation, operation, and maintenance of the NSF Ocean Observatory Initiative's (OOI) Pioneer Array to the Mid-Atlantic Bight (MAB) off North Carolina in the Northwest Atlantic Ocean (Proposed Action). The Proposed Action would (1) relocate the Pioneer New England Shelf (Pioneer NES) Array to the southern MAB (Pioneer MAB Array, Figure 1); 2) modify the mooring designs for the new site water depths; and 3) include additional scientific instrumentation on the moorings. The Proposed Action would occur within the Exclusive Economic Zone (EEZ) of the U.S. but outside of state waters.

As a result of this review the following is submitted:

☑ No Comment ☐ Comments Below ☐ Documents Attached

Reviewed By: JESSICA MOSLEY

Date: 10/10/2023

From: Pace Federal <pace.wilber@noaa.gov>
Date: Wednesday, January 3, 2024 at 4:44 PM
To: "Smith, Holly E." <hesmith@nsf.gov>
Subject: [EXTERNAL] - Re: EFH Consultation Request - NSF OOI Pioneer Array

Dear Ms. Smith,

NMFS has reviewed your letter dated November 17, 2023, and *Draft Supplemental Site-specific Environmental Assessment for Pioneer Array Modifications and Relocation to the Mid-Atlantic Bight* dated September 28, 2023. NSF and partners propose to (1) relocate the Pioneer New England Shelf (Pioneer NES) Array to the southern Mid-Atlantic Bight (MAB) (Pioneer MAB Array); 2) modify the mooring designs; and 3) augment the array's scientific instrumentation. The Pioneer MAB Array would be located in federal waters offshore North Carolina and partly overlap an area known as "The Point," which the South Atlantic Fishery Management Council designates a Habitat Area of Particular Concern (HAPC) under several fishery management plans. NSF anticipates relocating the array every five years to new locations proposed by the scientific community, and those relocations may be subject to future EFH consultations if there is a federal nexus. NSF does not anticipate establishing and operating the Pioneer MAB Array will have adverse effects on EFH designated by the Mid-Atlantic Fishery Management Council, South Atlantic Fishery Management Council, or NMFS.

Appendices to the Environmental Assessment include detailed site characterizations, including ROV surveys, of the mooring locations for the Pioneer MAB Array. The mooring sites consist of unconsolidated sediments without deepwater coral and hardbottom habitats. The NMFS anticipates any adverse effects occurring from the Pioneer MAB Array to NOAA-trust resources would be minimal. Consequently, the NMFS offers no EFH conservation recommendations pursuant to the Magnuson-Stevens Fishery Conservation and Management Act. If further coordination on this action is needed, please let us know.

Sincerely,

Pace Wilber, Ph.D.
South Atlantic and Caribbean Branch Chief
Habitat Conservation Division
NOAA Fisheries Service
331 Ft Johnson Road
Charleston, SC 29412

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

12/7/23

Refer to NMFS No: OPR-2023-03040

Ms. Holly Smith
Environmental Policy Specialist
National Science Foundation
2415 Eisenhower Avenue
Alexandria, Virginia 22314

RE: Concurrence Letter for the National Science Foundation Ocean Observatory Initiative's Pioneer Mid-Atlantic Bight Array

Dear Ms. Smith:

On November 17, 2023, the National Marine Fisheries Service (NMFS) received your request for a written concurrence under the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.) that the National Science Foundation's (NSF) funding of the Ocean Observatory Initiative's Pioneer Mid-Atlantic Bight Array is not likely to adversely affect ESA-listed species or designated critical habitat. This response to your request was prepared by NMFS pursuant to section 7(a)(2) of the ESA, implementing regulations at (50 CFR §402), and agency guidance for preparation of letters of concurrence.

We reviewed the consultation request document and related materials submitted by your agency. Based on our knowledge, expertise, and the materials submitted in your request for informal consultation, we concur with the NSF's conclusions that the proposed action is not likely to adversely affect the NMFS ESA-listed species and designated critical habitat.

This concludes consultation under the ESA for species and designated critical habitat under NMFS's purview on NSF's funding of the Ocean Observatory Initiative's Pioneer Mid-Atlantic Bight Array.

Reinitiation of consultation is required and shall be requested by the NSF where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (a) take occurs; (b) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered in this consultation; (c) the action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not previously considered in this consultation; or (d) if a new species is listed or critical habitat designated that may be affected by the action (50 CFR §402.16).

We look forward to further cooperation with you on other projects to ensure the conservation of our threatened and endangered marine species and designated critical habitat. If you have any questions on this consultation, please contact Colette Cairns, Consultation Biologist at (301) 427-8414 or by email at colette.cairns@noaa.gov, or me at (240) 723-6321, or by email at Tanya.Dobrzynski@noaa.gov.

Sincerely,

Tanya Dobrzynski
Chief, ESA Interagency Cooperation Division
Office of Protected Resources

Pioneer MAB
Community Outreach Status

Control Number: 3210-00005
Version: 0-02
Date: 2023-05-30
Author: Derek Buffitt, Al Plueddemann

Coastal and Global Scale Nodes
Ocean Observatories Initiative
Woods Hole Oceanographic Institution

Revision History

Version	Description	ECR No.	Release Date
0-01	Initial Draft		29-Mar-2023
0-02	Updates to Sec. 4 table		30-May-2023

Table of Contents

2.0 Purpose

The purpose of this document is to provide an ongoing status of community outreach for the Pioneer Mid-Atlantic Bight (MAB) Relocation.

3.0 Definitions & Acronyms

AGU	American Geophysical Union
CFRF	Commercial Fisheries Research Foundation
CGSN	Coastal & Global Scale Nodes
CNO	Chief of Naval Operations
COMSUBLANT	Commander, Submarine Force Atlantic
ECU	East Carolina University
MFN	Multi-Function Node
MAB	Mid-Atlantic Bight
MABPOM	Middle Atlantic Bight Physical Oceanography and Meteorology Meeting
MAFMC	Mid-Atlantic Fishery Management Council
MARACOOS	Middle Atlantic Regional Association Coastal Ocean Observing System
MTS	Marine Technology Society
NCDCM	North Carolina Division of Coastal Management
NCSU	North Carolina State University
NDBC	National Data Buoy Center
NERACOOS	Northeastern Regional Association Coastal Ocean Observing System
NES	New England Shelf
NETC	Naval Education and Training Command
NOAA	National Oceanic & Atmospheric Administration
NSFCO	Naval Seafloor Cable Protection Office
NSFEXWC	NAVFAC Engineering & Expeditionary Warfare Center
NSIF	Near Surface Instrument Frame
NWP	Nationwide Permit
OOI	Ocean Observatories Initiative
OOIFB	Ocean Observatories Initiative Facilities Board
PM	Profiler Mooring
SECOORA	Southeast Coastal Ocean Observing Regional Association
SM	Surface Mooring
SWM	Shallow Water Mooring
UNC	University of North Carolina
USACE	US Army Corps of Engineers
USFFC	US Fleet Forces Command

4.0 Overview

4.1. Site Summary

The Pioneer MAB Array is proposed to be relocated in the spring of 2024 to the coast of Nags Head in North Carolina. The preliminary plan is for the moored array to be constituted in a sideways "T" shape, with seven mooring sites between about 13 nautical miles (nm) and 45 nm offshore, outside of state waters. The Pioneer MAB Array will consist of:

- Three surface moorings located in 30 m and 100 m water depths
- Five profiler moorings located in 100 m and 600 m water depths
- Two shallow-water moorings located in 30 m water depths

5.0 Science Community Outreach

Date	Outreach	Topic	OOI-CGSN Participant
20-Feb-2020	Public Announcement	NSF announces intent to relocate at Ocean Sciences Meeting Town Hall	
8-Dec-2020	Presentation at Fall American Geophysical Union meeting	Pioneer Relocation Update*	Plueddemann
15-19-Mar-2021	NSF sponsored Innovations Lab #1	Pioneer ReLocation, community discussion and input	Plueddemann, Buffitt
5-Mar-2021	Commercial Fisheries Research Foundation (CFRF), New England Fishers	Pioneer Relocation Update	Plueddemann
21-25-Jun-2021	NSF sponsored Innovations Lab #2	Pioneer ReLocation, community discussion and input	Plueddemann, Buffitt
13-Dec-2021	Presentation at Fall American Geophysical Union meeting	Pioneer Relocation Update	Plueddemann
21-Jul-2021	Presentation to MARACOOS board	Pioneer Relocation Update	Trowbridge
15-Oct-2021	Email OOIFB	CGSN establishes Pioneer Relocation Focus Group	OOIFB and Plueddemann
18-Feb-2022	Public Announcement	CGSN establishes Pioneer Relocation web pages on oceanobservatories.org	
24-Feb-2022	OOIFB	Pioneer Relocation Update	Plueddemann
25-Feb-2022	Ocean Sciences Meeting	Pioneer Relocation Update	Plueddemann
31-Mar-2022	OOIFB	Pioneer Relocation Update	Plueddemann
16-18-Jun-2022	Biogeochemical Sensor Workshop	Pioneer Relocation Update	Plueddemann
20-Sep-2022	MTS Buoy Workshop	Pioneer Relocation Update	Plueddemann
13-Oct-2022	MABPOM Meeting	Pioneer Relocation Update	Plueddemann
27-Oct-2022	OOIFB	Pioneer Relocation Update	Plueddemann

Date	Outreach	Topic	OOI-CGSN Participant
15-Nov-2022	Email Notification	CGSN notifies National Data Buoy Center (NDBC) of the Pioneer Array Relocation	Reed
12-Dec-2022	Presentation at Fall American Geophysical Union meeting	Pioneer Relocation Update	Plueddemann
20-Jan-2023	Presentation at OCB BGC Network workshop	Pioneer NES & MAB Status and Overview	Plueddemann
23-Jan-2023	Email Exchange	Pioneer Relocation overview and outreach coordination with Directors of NERACOOS, MARACOOS and SECOORA	Plueddemann
21-Feb-2023	Press Release	Pioneer Relocation press release, picked up by eight different media outlets	Plueddemann, Trew Crist
30-Mar-2023	OOIFB	Pioneer Relocation Update	Plueddemann
9-Mar-2023	Article	Pioneer Relocation article appears in WHOI's Oceanus Magazine	Plueddemann
7-Mar-2023	Phone Call with: Francis "Dewey" Hemilright MAFMC	Discussed longlining in the area of proposed Pioneer MAB location, indicated deepest moorings (600m) may conflict with fishing activities	Plueddemann
29-Mar-2023	Email Exchange Francis "Dewey" Hemilright, MAFMC Mike Muglia, ECU George Bonner, NCSU Lindsay Dubbs, UNC	Continued discussion concerning fishing activity in area of proposed Pioneer MAB	Plueddemann
18-Apr-2023	Presentation at North Carolina State University	Pioneer Relocation Update with telepresence to UNC Chapel Hill and Duke	Plueddemann
19-Apr-2023	Presentation at Cape Fear Community College	Pioneer Relocation Update with telepresence to UNC Wilmington	Plueddemann
20-Apr-2023	Presentation at Eastern Carolina University Coastal Studies Institute	Pioneer Relocation Update with live stream to public as part of ECU-CSI Science on the Sound series	Plueddemann
21-Apr-2023	Presentation at University of North Carolina Institute of Marine Sciences	Pioneer Relocation Update with telepresence at NCSU Center for Marine Science and Technology and Duke University Marine Lab	Plueddemann

6.0 Relocation Planning/Regulatory Outreach

Date	Outreach	Topic	OOI-CGSN Participant
08-Mar-2022	Phone call Daniel Govoni • NCDCM	Introduction of Pioneer MAB array and location, discussed need for a one page introduction to project for distribution	TetraTech – Mike Murphy
15-Mar-2022	Phone call Benjamin Laws • NOAA	Introduction of Pioneer MAB array and location, discussed whether Incidental Harassment Authorization required (not required)	TetraTech – Katherine Miller
17-Mar-2022	Phone call Bill Standridge • USACE	Introduction of Pioneer MAB array and location, project qualifies for Nationwide Permit #5 as long as it follows General Conditions, and no PCN required.	TetraTech – Katherine Miller
21-Mar-2022	Email Exchange Daniel Govoni NCDCM	Introduction memo delivered, one page description of Pioneer Array	TetraTech – Mike Murphy/Jennifer Kraus
07-Apr-2022	Email Exchange Daniel Govoni • NCDCM	Memo delivered to support federal consistency determination, one page description of Pioneer Array	TetraTech – Mike Murphy/Jennifer Kraus
10-June-2022	Phone Call Daniel Govoni • NCDCM	Confirmed receipt of memo, requested coordinates for moorings (delivered June 15), noted review would be complete by mid-June	TetraTech – Mike Murphy
24-June-2022	Email Exchange Daniel Govoni • NCDCM	Confirmed completion of review, no major issues, recommended review of two deepest offshore sites (600m profiler moorings), they are located in longlining areas	TetraTech – Mike Murphy
23-Aug-2022	Email Exchange Michael Mcginn • US Navy COMSUBLANT Beth Levy • US Navy CNO Paul Ling • US Navy Sean Locker • US Navy NETC Dan Hurley • US Navy Dustin Reddy • US Navy COMSUBLANT Anna Kathryn • US Navy COMSUBLANT Victor Hill • US Navy USFFC Greg Thomas • US Navy USFFC Michael Jones	Advised of final recovery of Pioneer NES 2022, planned move to Pioneer MAB 2024, overview of infrastructure and locations. Mcginn distributed to US Navy CNO, CTR, NETC, COMSUBLANT, USFFC No issues noted other than performing USCG PATONs and LNTMs	Emrich, Buffitt

Date	Outreach	Topic	OOI-CGSN Participant
	• US Navy USFFC		
28-Sept-2022	Email Exchange Michael Mcginn • US Navy COMSUBLANT	Verifying no other coordination contacts required for operations	Emrich
07-Dec-2022	Email Exchange Michael Mcginn • US Navy COMSUBLANT	Providing confirmation of Pioneer NES recovery, Pioneer MAB test deployment schedule, and approximate timing of first Pioneer MAB deployment	Emrich
13-Jan-2023	Email Exchange Catherine Creese • US Navy NSFCO NSFEXWC	Providing an overview of Pioneer MAB infrastructure and locations	Buffitt
06-Feb-2023	Email Exchange Michael Mcginn • US Navy COMSUBLANT	Provided PATON and LNTM for AST3 test deployment	Emrich
07-Feb-2023	Email Exchange Catherine Creese US Navy NSFCO NSFEXWC	Received confirmation, no conflicts with Navy infrastructure	Buffitt