## Technical Summary

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| Study Title | Deepwater Atlantic Habitats II: Continued Atlantic Research and Exploration in Deepwater Ecosystems with Focus on Coral, Canyon and Seep Communities – "Deep SEARCH - Deep Sea Exploration to Advance Research on Coral/Canyon/Cold seep Habitats" |
| Report Title | Deepwater Atlantic Habitats II: Continued Atlantic Research and Exploration in Deepwater Ecosystems with Focus on Coral, Canyon and Seep Communities – "Deep SEARCH - Deep Sea Exploration to Advance Research on Coral/Canyon/Cold seep Habitats" Final Report |
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**ABSTRACT:** Coral reefs are iconic ecosystems that support biodiverse, productive biological communities in both shallow and deep waters. Like their warm, shallow counterparts, cold-water coral

(CWC) reefs and mounds come in many forms, but unlike shallow water reefs, we have an incomplete knowledge of cold-water coral niche space. This limits scientific understanding of their distribution and the ecosystem services they provide. We present recent surveys of the CWC mound province on the Blake Plateau beneath the Gulf Stream. At one site (Richardson Reef Complex, 700–900-m water depth), the CWC mounds are arranged in lines that total over 150 km in length, making this one of the largest reef complexes ever documented in the deep ocean. This site experiences rapid shifts in temperature values between 4.3 and 10.7°C, with bottom current speeds approaching 1 m/s. This reef community cycles and sequesters carbon and nitrogen derived from interactions with mesopelagic species as well as sinking and resuspended particulate organic matter. Through these processes, the reef provides a previously unrecognized nitrate source that contributes to primary productivity in the Gulf Stream and North Atlantic gyre. Our new predictive models based on these recent surveys indicate broad geographic areas of highly suitable CWC habitat in the region. This study improved understanding of suitable habitat distribution and of deep coral reef carbon and nitrogen cycling and enables new analyses, including potential re-evaluation of the ecosystem services that CWCs provide to the global ocean and confirms the importance of appropriate conservation management of these systems.

**BACKGROUND**: Deep-sea ecosystems along the US continental margin provide numerous ecosystem services including enhancing local biodiversity, yet sensitive biological communities remain poorly understood. Substantial losses of deep-sea biodiversity could have long-term, damaging effects to large expanses of the deep seafloor and the overlying water column. Improving understanding of key ecosystem functions requires better characterizing the distributions of important fauna and habitats, the processes that shape patterns in population and community structure, and the linkages between physical, chemical, and biological processes. Such interdisciplinary datasets are essential for predicting organism and ecosystem-level responses to potential anthropogenic impacts and for assessing the potential severity and nature of different activity impact on sensitive deep-sea communities. Through this study, we fill in the data gaps for poorly known deepwater ecosystems in order to help inform decision-making and development of appropriate specific regional mitigation measures in the deep sea. Improved understanding of the habitats and communities in offshore areas of the Atlantic Large Marine Ecosystem will augment the scientific community's capacity to accurately and precisely predict the distribution of sensitive areas and support the Bureau of Ocean Energy Management's mission to manage development of US Outer Continental Shelf (OCS) energy and mineral resources in an environmentally and economically responsible way.

**OBJECTIVES:** The overarching goal for this project is to improve understanding of deepwater ecosystem biology and processes and improve the ability to accurately predict within the study area the location of seafloor communities that are potentially sensitive to natural and anthropogenic disturbances. The study area encompasses a variety of different habitat types, including canyons, hard-bottom substrates, CWC mounds, methane seeps, and soft sediments.

**METHODS**:

1. Explore and characterize the biological communities of the study area.
2. Examine the sensitivity of habitat-structuring fauna and associated communities to natural and anthropogenic disturbance.
3. Describe the oceanographic, geological, and geochemical conditions associated with each habitat type.
4. Model the distribution of habitats and fauna with respect to environmental conditions.

**RESULTS:** Deep-sea ecosystems along the US continental margin support enhanced biodiversity and sensitive biological communities, yet they remain poorly understood. The maintenance of biodiversity is critical to the function and sustainability of these deepwater ecosystems that provide numerous ecosystem services. Loss of deep-sea biodiversity could have long-term, damaging effects to large expanses of the

deep seafloor and the overlying water column. The data gathered throughout the Deep SEARCH project has been applied to improving predicting organism and ecosystem-level responses to potential anthropogenic impacts and for assessing the severity of different impact types on sensitive deep-sea communities. Through this study, we have filled major data gaps for poorly known deepwater ecosystems in order to refine regional mitigation measures in the deep sea. Improved understanding of the habitats and communities in offshore areas of the Atlantic Large Marine Ecosystem will augment the capacity to predict the distribution of areas likely to harbor sensitive seafloor communities.

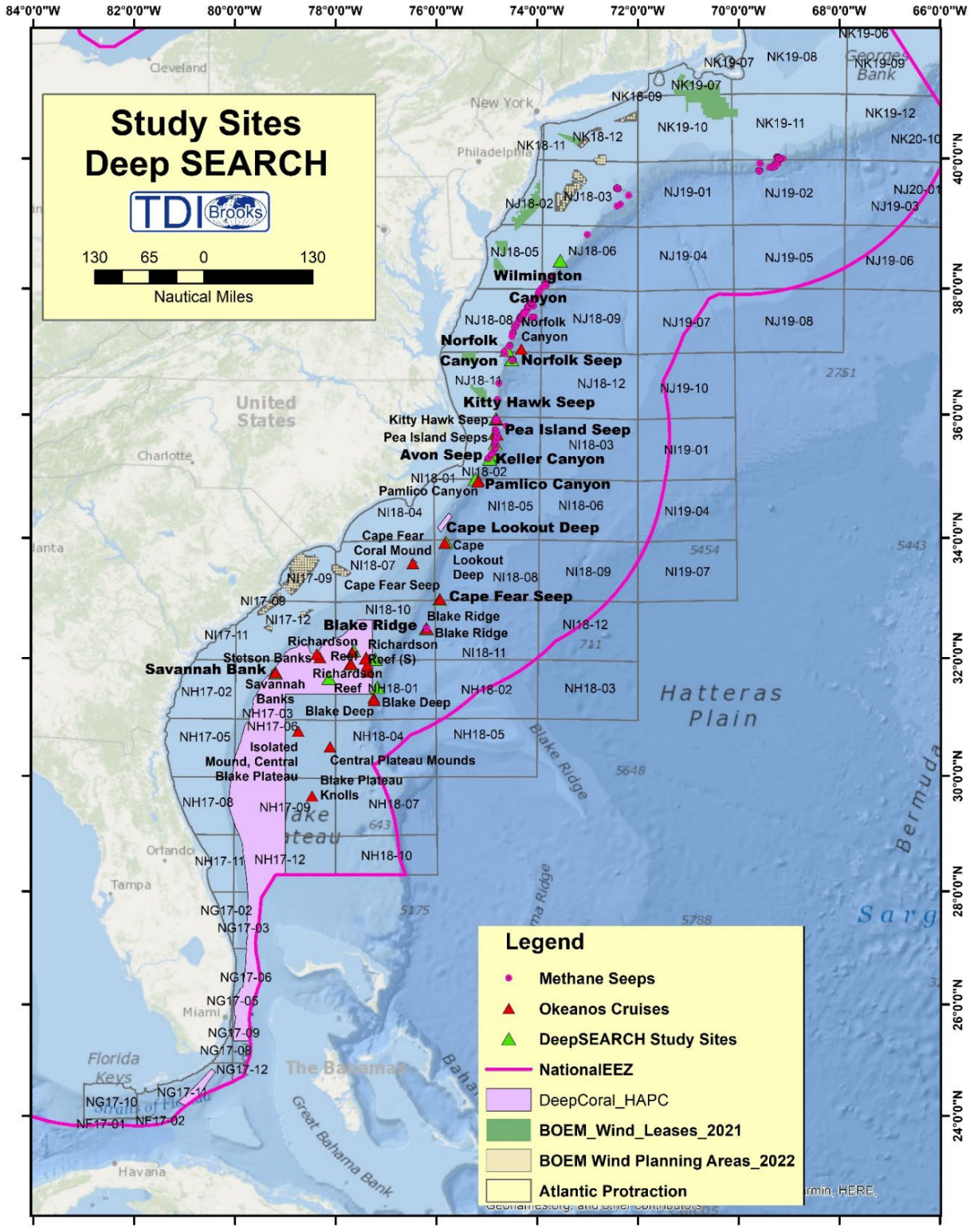
**CONCLUSIONS:** The habitats within the study area comprise a combination of hard and soft substrata inhabited by a fauna that can be generally characterized as sensitive to disturbance. Of course, there is a variety of specific habitat types that vary in their potential vulnerability to anthropogenic impacts. Certain areas of the Blake Plateau contain ferromanganese-encrusted phosphorite deposits that are sometimes occupied by habitat-forming octocorals, solitary corals, and sponges. This biodiversity has ecological value, as each species plays a specific role in the ecosystem. In addition, certain deepwater species (such as sponges) show promise of biopharmaceutical utility that may potentially lead to future commercial collection.

At depths below approximately 500 m, there are vast areas of CWC mounds created primarily by *Lophelia pertusa*, along with *Madrepora oculata*, *Enallopsammia rostrata*, and *Solenosmilia variabilis*, which host added biodiversity of associated fauna. Along the margin of the Blake Plateau are two influential hydrocarbon seep sites, the Blake Ridge and Cape Fear seeps, which are primarily inhabited by large mussel beds of *Bathymodiolus heckerae* and associated fauna. As the Blake Plateau drops off to the steep continental slope, there are diverse assemblages of octocorals, black corals, and sponges that can be hundreds to thousands of years old. Further to the north, the Blake Plateau gives way to a series of submarine canyons that incise the shelf break to different degrees and have limestone walls of varying composition and stability. On the walls of the canyons are numerous octocorals and cup corals that add to the heterogeneity of the substrate and the biodiversity of the coral assemblage in the region.

Along the shelf break in this area are numerous seeps that can be visualized by the acoustic opacity of the methane bubble streams that they are actively emitting. Those observed to date have been in fairly shallow water (200–300 m) and are very different in composition from the deeper seeps to the south. Together, these habitats contribute to a continental margin that is complex and heterogenous in both geology and biology.

Salient to the mission of the Bureau of Ocean Energy Management (BOEM) are the oil and gas (including gas hydrate) accumulations within the study area. These hydrocarbon reservoirs primarily lie beneath the seep sites investigated during this study but also overlap some of the coral sites and intersect some of the canyons. The large area of ferromanganese-encrusted phosphorite deposits, along with localized areas of manganese nodules on the Blake Plateau, are also within the jurisdiction of BOEM and may become of commercial interest in the future.

The majority of areas of interest for fixed platform wind power development are shallower and shoreward of the study area (below). It is conceivable that wind energy development could extend onto the Blake Plateau in the future if there are OCS spatial-use conflicts elsewhere, depending on what happens with the nascent development of floating wind turbines, which can be anchored to the seabed in regions of the OCS that are deeper than the current, fixed US OCS wind turbines. Any resource development activities discussed above would require additional, precise ecological surveys prior to activity implementation in order to avoid or minimize negative impacts to the coral, seep, and canyon habitats presented in this study.

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**Deep SEARCH area showing BOEM wind leases NOTE: along with protraction areas, methane seeps, *L. pertusa* sites and deep-sea coral Habitat Area of Particular Concern.**

The extensive mapping effort, sampling, visual surveys, and predictive modeling studies presented in this study revealed that the CWC mound province in the study area is one of the largest in the world. It extends from the Cape Lookout mounds (offshore Cape Fear, NC) in the north to the Million Mounds area (offshore Jacksonville, FL) in the south. These coral mounds are solitary in much of the Blake Plateau but are observed in high densities along the eastern edge of the plateau at the Savannah, Jacksonville, and Miami Terrace sites that have been studied for decades within the Million Mounds area. In the Richardson area, these mounds have coalesced into a continuous reef complex consisting of over 200 km of mounds and ridges. Our study focus on these habitats is already influencing regulation and management, with the addition of a "live hard-bottom" category of habitat in the *Protective Measures Assessment Protocol* used by the United States Navy (https://nwtteis.com/Environmental-Stewardship/Protective-Measures-Assessment-Protocol).

CWC mounds are internationally recognized as "ecologically and biologically sensitive habitats" (EBSAs), as defined by the U.N. Convention on Biological Diversity, and "vulnerable marine ecosystems" in the parlance of international fisheries management organizations. In the US, these features are considered essential fish habitat (EFH). Some specific EFH areas are further protected through their designation as Habitat Areas of Particular Concern (HAPCs) under the Magnuson-Stevens Fishery Conservation and Management Act. The coral mounds in the study area are known to harbor numerous fisheries species of potential commercial importance, including the swordfish, blackbelly rosefish, and golden crab; the South Atlantic Fishery Management Council designated the Stetson–Miami Terrace as an HAPC. Most of the coral mounds explored in this study are already within this HAPC, but many of the more isolated mounds in the central Blake Plateau had gone unnoticed in earlier, coarser resolution surveys.

The canyon sites within the study area—including Norfolk, Keller, Hatteras, and Pamlico—are similar to the canyon sites further north along the shelf break (including Wilmington Canyon, which we also visited during AT-41) in that they support coral communities on their walls, which in turn support elevated biomass at all levels from plankton up to marine mammals. During this program, an important achievement was the amount of data collected at Pamlico Canyon, which had not been previously visited by remotely operated vehicle (ROV) or other submersibles. This site has extremely high octocoral diversity and concentrations of mesopelagic fauna. Acoustic data obtained at all of the canyon sites demonstrated benthopelagic coupling (see **Chapter 4.2**), further supporting the significance of these areas to regional fisheries. The canyon sites to the north, including Norfolk and Wilmington Canyons, are designated as deep-sea coral HAPCs by the Mid-Atlantic Fishery Management Council. Any impactful activities permitted to occur near the heads of the canyons (where the coral assemblages are diverse, the seeps are nearby, and benthopelagic coupling is strong) would therefore need to be carefully assessed and managed.

At our shallower, inter-canyon seep sites, we discovered a visually apparent and unexpectedly high degree of benthopelagic coupling. These are some of the most active seeps ever directly measured (see **Chapter 3.3**), with methane fluxes highly elevated in the water column and occasionally measurable at the air-sea interface. This area is known to have one of the highest abundances of benthic infauna, carbon flux, and particulate sedimentation rates of anywhere along the US Atlantic margin. The seep sites exhibit localized areas of chemosynthetic productivity at the seafloor and in the water column and could augment the delivery of nutrients to the photic zone, as has been observed in the Gulf of Mexico.

Numerous species of demersal fishes and squid occupy the seep sites, further contributing to the linkage with the overlying pelagic communities. The full role of the seeps in the larger mid-Atlantic and southeast US seascape remains to be revealed, but this study has provided a wealth of data that begins to tell the story. Already, seeps are considered EFH on the US West Coast and should be considered for this fishery management designation both in the study area and further to the north. In the context of BOEM

management decisions, biodiverse seep sites could be considered “high density” benthic communities that should be avoided in the Gulf of Mexico.

These seep sites could be precisely located using seabed reflectivity anomalies in the industry-generated 3D seismic data housed at BOEM. However, in the Atlantic area considered in this study, there are insufficient seismic data to utilize such methods, but the detection of water-column bubble plumes by multibeam echosounder sonars could be another effective way to locate the active seeps. Additional ground-truthing data would be required to extend this methodology and ensure that other influential seep sites do not go undetected.

Considering the results of this study and looking ahead, we recommend that site-specific surveys provided to BOEM by operators include environmental baseline information necessary to accurately assess potential activity impacts and manage them appropriately through physical distancing or other mitigations via site-specific conditions of approval for permits. Methods and information requirements for these surveys would include some shared characteristics, whether they be conducted for oil and gas, marine mineral mining, or renewable energy (wind, wave, solar, and/or ocean thermal energy conversion) infrastructure installation. All these activities would include some disturbance of the seafloor. We recommend that high-resolution multibeam echosounder sonar bathymetric and backscatter data first be acquired from surface ships or vehicles (if not already available) and then at higher resolution over specific areas interest, likely using autonomous underwater vehicles (AUVs). The resolution of the site-specific data needs to approach 1 $m^2$ in order to reliably detect rugose topography and high backscatter features or areas that are most likely to represent hard substrata. During the bathymetric surveys, water-column data could be acquired by CTD (conductivity-temperature-depth) rosette to measure certain water-column conditions in the area, including particulate loads, trace metal abundance, hydrocarbon concentrations, and the composition of the microbial community. These data would provide the information needed to model potential impact of the proposed activity in the areas of focus.

After review of the mapping data and model results, benthic sampling is critical for providing information about the benthic community that may be impacted by the activity. Soft-sediment benthic sampling could be accomplished by multicore seafloor sediment sampling deployments from surface ships. These samples could be analyzed for both geological characteristics and biological community characterization to the macrofauna level (at a minimum). Any areas that are likely to contain hard substrate, as revealed by the bathymetric surveys or available 3D seismic data, should be surveyed visually by ROV and/or AUV. Random transect design can be employed but should be heavily stratified to include the vast majority, if not all, of the detected hard substrata within the zone predicted to be impacted by the proposed activity. If these surveys reveal any potentially sensitive habitats in the area, subsequent activities should avoid them by appropriate distancing of infrastructure.

Climate change is an ever-present concern that remains in focus in the southeast US. The Gulf Stream has a major influence on the oceanographic conditions at depth in the region, frequently bringing warm temperatures (> 12 to 15°C) to the depths under consideration in this study. Our predictive habitat modeling and projections indicate that the deeper sites will see less warming in the future, but the shallower coral sites in the western portion of Stetson Banks and Savannah Banks would be exposed to temperatures above their thermal limits (approximately 15°C for *L. pertusa*, see **Chapter 5**).

As global and ocean water temperatures continue to climb and is translated to depth, some gas hydrate accumulations along the shelf break may further destabilize, potentially releasing additional methane to the ocean and atmosphere (see **Chapter 3**) and causing localized benthic habitat disturbance. Global use of fossil fuels likely will continue to contribute to these ongoing ocean temperature, acidification, and other relevant global change trends. These factors must be analyzed and considered because they will impact the stability of the living resources investigated in this study.

**STUDY PRODUCTS:**

The following study products are presented in the final report.

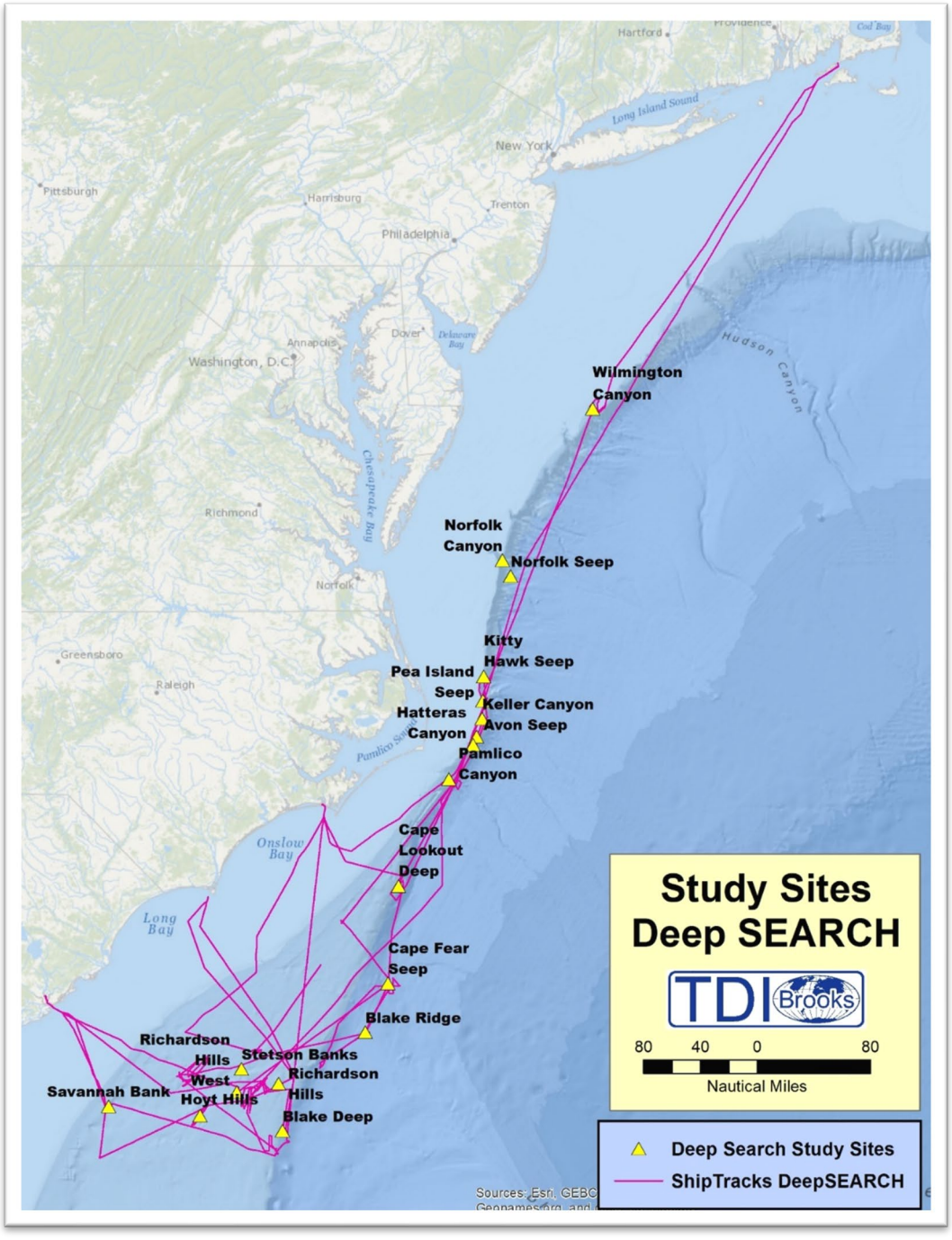
Project data has been submitted to following data repositories:

- OSF
- NOAA National Centers for Environmental Information
- NCBI Sequence Read Archive
- NCEI Ocean Archive
- USNM Specimen Data

**Publications and Presentations**
More than 60 publications and presentations have been produced to date.

**Cruise Reports**
Links to the following cruise reports are provided in final report.

- NOAA Ship *Pisces / Sentry*
- TDI-Brooks RV *Brooks McCall*
- WHOI – RV *Atlantis* / DSV *Alvin*
- NOAA Ship *Nancy Foster*
- NOAA Ship *Ron Brown* / ROV *JASON*




**Map of the study area**