WHITE PAPER

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From

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for

DEEP SEARCH
DEEP Sea **E**xploration to **A**dvance **R**esearch
on **C**oral/Canyon/Cold seep **H**abitats

Deepwater Atlantic Habitats II:
Continued Atlantic Research and Exploration
in Deepwater Ecosystems with Focus on
Coral, Canyon and Seep Communities

Study Background

The overarching goal for this project is to augment the ability to predict the location of seafloor communities off the coast of the Southeast US that are potentially sensitive to natural and anthropogenic disturbances. This area encompasses a variety of different habitat types, including submarine canyons, cold-water coral mounds and gardens, methane seeps, and soft sediments. Specifically, this project will explore and characterize the biological communities of the study area, examine the sensitivity of habitat-structuring fauna and associated communities to natural and anthropogenic disturbance, and describe the oceanographic, geological, geochemical, and acoustic conditions associated with each habitat type.

Deep-sea ecosystems along the U.S. 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, the overlying water column, and to human health. Thus, we need to better characterize faunal and habitat distributions, determine the processes that shape patterns in population and community structure, and determine the linkages between physical, chemical, and biological processes to better understand ecosystem function. Such interdisciplinary data sets are essential for predicting organism and ecosystem-level responses to human activities in the study area and for assessing the severity of different impact types on sensitive deep-sea communities. Through this study, we will improve our understanding of the habitats and communities in offshore areas of the Atlantic Large Marine Ecosystem, which will augment the capacity to predict the distribution of sensitive areas with respect to the potential development of energy and marine mineral resources.

Site Selection

The study region straddles the BOEM South Atlantic and Mid Atlantic Planning Areas (BOEM 2015). The area of interest to BOEM lies between Norfolk Canyon (~37.5^{o}N) and the Georgia-Florida border (~30^{o}N), from 50 miles offshore to the edge of the US exclusive economic zone (EEZ). Within that study area are three general habitat types: canyons, corals, and seeps. Of course these habitat types overlap and there are corals and seeps within the canyons and corals at some of the seeps that are not associated with canyons. Below is a brief description of the sites that are under consideration for visitation.

Seeps

Until recently, the only confirmed seeps with dense biological communities along the US Atlantic margin were those on the Blake Ridge and Cape Fear diapirs off North Carolina, plus a suspected site on the upper continental slope near Baltimore Canyon (Hecker et al 1983). Since then, the Baltimore Canyon seep and Norfolk seep have been discovered, and many more are suspected. Between the Norfolk seep and the Blake Ridge diapir, there are over 100 gas venting sites (50 m to 2650 m depth) discovered during USGS and NOAA Ship *Okeanos Explorer* cruises over the last few years. Some of these expulsion locations are comprised of clusters of seeps, and others (less common) are individual sites. Only a few have been visually surveyed.

Norfolk seep

Norfolk Seep was discovered in 2013 and is the most extensive of the known methane seeps in the North Atlantic. The seepage area is approximately 120 km off the coast of Virginia, just south of Norfolk Canyon in approximately 1600 m depth, and is comprised of two separate ridges, each ~ 1 km in length. Both ridges are almost completely covered in dense populations of Bathymodiolin chemosynthetic mussels, with endemic seep associates such as the seep cucumber (*Chiridota heheva*) and alvinocarid shrimp. Unlike other deep seeps in the region, there were no tubeworms or vesicomyid clams observed at this seep. Large boulders of authigenic carbonate, methane hydrate and streams of gas bubbles indicate long term and active seepage. Non-seep fauna were relatively scarce, but included echinoid urchins and fishes such as *Gaidropsaurus* sp. The Norfolk Seep also lies within the MAFMC protected area.

Cape Fear Seep

This site is the location of a persistent bubble plume observed in the multibeam surveys of the Okeanos Explorer, and three areas inhabited by clams and bacterial mats as detected by *Sentry* photographs. Unlike other seeps in the region, methane seep mussels have not yet been observed.

Blake Ridge Seep

This is the best known seep site off of the east coast. The Blake Ridge diapir was the subject of extensive geological surveys as part of the Ocean Drilling Program (Paull et al 1996, 2000). Gas hydrates and extensive methane seepage have been documented from this site (Brothers et al 2013). Chemosynthetic communities were initially described from visual surveys and collections (Van Dover et al 2003), and included seep mussels (*Bathymodiolus heckerae*) and vesicomyid clams (*Vesicomya venustus*) at depths of ~2155 m. More recent AUV surveys expanded the known extent of chemosynthetic communities to four discrete areas (Brothers et al 2013).

Canyons

Recent explorations and research have highlighted the resources associated with submarine canyons along the western Atlantic margin (Quattrini et al 2015, Ross et al 2015, Brooke et al 2017). These have primarily focused the area between Virginia and New England, with one expedition further south off North Carolina. There are three named canyons off the coast of North Carolina; Keller, Hatteras and Pamlico, the former is unexplored, but the Hatteras Canyon complex has been the focus of some geological and biological studies.

Norfolk Canyon

The head of Norfolk Canyon is approximately 90 km offshore from the mouth of Chesapeake Bay, Virginia, and is a long shelf-incised canyon that begins at ~ 200m on the shelf and ends on the abyssal plan at > 3000 m depth. The walls of Norfolk Canyon have extensive areas of exposed hard substrate, which provide habitat for dense communities of sessile benthic fauna such as corals and sponges. These communities have been documented from ~400m to 1300 m depth and support diverse assemblages of other invertebrates. Norfolk Canyon remains relatively unexplored, and recent studies have revealed new records of several coral species, including the structure-forming scleractinian, *Lophelia pertusa*. Commercial fishery species such as red crab, Hake and Monkfish are common on the sediment of the canyon slopes. Norfolk Canyon is part of the Deep Sea Coral protected area, implemented in 2015 through the Mid Atlantic Fishery Management Council.

Keller Canyon

Keller Canyon is the only one of the potential target canyons that incises the shelf, but much less so than those further north. The funneling effect of the shelf-incised canyons creates strong currents that remove sediment and allow development of hard-substrate benthic communities. Without accelerated currents, sediments cover all but the steepest slopes. Deep corals have been observed on steep walls so it is likely they will occur in Keller Canyon, but possibly with more restricted distribution than in those more deeply incised into the shelf. Soft sediment corals (e.g. Pennatulids) are likely to be encountered in the canyon. Several multibeam surveys have collected data as single transit swaths across Keller Canyon, but the most comprehensive surveys to date were by the Okeanos Explorer (NCEI Survey ID EX1106) and the R/V Henson (NCEI Survey ID: HEN04-3), which together cover the canyon head to the abyssal plain and reveal the rugged habitat along the head of Keller Canyon and adjacent shelf slope break. Recent visual surveys with AUV *Sentry* revealed some octocorals and anemones, but low abundance/occurrence overall. Multibeam surveys by NOAA-USGS in 2011 revealed >50 areas of diffuse gas venting near Keller Canyon, in depths ranging from 53-930 m depth. This site is lower priority than the other canyons in the region based on the previous observations at the site.

Hatteras Canyon

Hatteras Canyon and adjacent slope were the subject of earlier surveys of benthic megafauna using research submersibles (Rowe and Menzies 1969, Rowe 1971). Their observations were of mostly soft-sediment fauna, primarily sea pens, large holothurians, asteroids, quill-worms and Cerianthid anemones. They recorded differences in species composition between canyon and slope, which they attributed to higher sedimentation levels in the canyon that excluded many common slope invertebrates. They defined 'canyon indicator species' as the seastars *Dystaster* and *Benthopecten*, the sea pen *Kophobelemnon*, the holothurian *Peniagone*, the anemone *Ceriantheomorphe*. Rowe 1971 observed 'small white objects' on the Cerianthid tubes, which were probably small hexactinellid sponges. Outcrops of exposed hard substrates at 1500 m supported *Euplectella* sp (Hexactinellids) and *Anthomastus* sp. None of the records noted any scleractinians or gorgonian octocorals, but recent exploration of Hatteras Canyon (NOAA-OER) using the AUV Sentry (WHOI) produced images of octocorals on one of the steep canyon walls. Multibeam surveys by NOAA-USGS in 2012 revealed ~12 areas of diffuse gas venting near Hatteras Canyon, in depths ranging from 183-374 m depth.

Pamlico Canyon

Pamlico canyon only minimally impacts the shelf break approximately 20 miles off the North Carolina outer banks. The axis of the canyon on the continental slope is approximately 15 nautical miles long from approximately 400 m to over 3000 m depth, but then extends onto the seafloor for over 100 miles to over 5000 m depth. It has been mapped and was first explored visually on the AUV Sentry cruise in 2016, when octocorals were discovered on the canyon walls. Bubble plumes have not been observed in the vicinity of this canyon.

Corals

The narrow continental shelf off Cape Hatteras gradually widens to the south, particularly off South Carolina and Georgia, then becomes narrow again off the coast of Florida. Between the continental shelf and slope in this region, is a vast horizontal platform called the Blake Plateau. This feature is 228,000 km^2, has an average depth of ~850 m, and is one of the most rugged areas offshore of the southeastern US. Hundreds of hard-bottom features ranging from low relief ledges to massive conical peaks contribute to the rugged topography. Hard-bottom habitat includes areas of rocky outcrops and ledges, and large numbers of mounds, many of which are bioherms formed by the *Lophelia pertusa* and *Enallopsammia profunda* at depths from 600-900 m. Most of the platform is carbonate in origin, but fields of manganese oxide nodules and slabs of phosphoritic rock have also been observed. Some of these areas have

been the focus of significant research effort, whereas others have barely been explored. This is a rich area of potential study sites (detailed below), in a different biogeographic province and oceanographic regime from the northern part of the study area. All of the sites described below lie within Coral Habitat Areas of Particular Concern (C-HAPC), established in 2009 by the South Atlantic Fishery Management Council (SAFMC).

Cape Lookout

This site is located on the Blake Plateau in relatively shallow depths (320-550 m), and the series of topographic features that comprise this site are the most northerly known *Lophelia* bioherms on the US Atlantic coast. There are ~10 large and several small features at this location, with elevation up to 80 m and variable slopes. Multibeam bathymetry surveys have covered the full known extent of the mounds (NCEI Survey ID: NF-07-02-MPA and NF-08-01-MPA, and additional surveys by the *R/V Pelagia* in 2010). This site is relatively well studied, with habitat and community data collected using submersible and ROV surveys (Ross 2006, Partyka et al 2007, Ross and Nizinski 2007, Ross and Quattrini 2007, 2009, Quattrini et al. 2012), and detailed analysis of physical and geological conditions (Mienis et al 2014). Physical data indicate that this site is exposed to extreme environmental conditions of highly variable temperature and strong currents. Community data show extensive colonies of *Lophelia pertusa*, especially on the tops and current-facing aspects of the mounds, but with highly variable percentages (5-75%) of live coral. Other species of coral, which are common further south, were notably lacking (Partyka et al 2007), but coral-associated invertebrates and fishes were abundant and diverse (Partyka et al 2007). Because of the existing information at this site, it is not a high priority.

Cape Fear

This site comprises a single large (0.7 km^2) coral bioherm, in similar depths (360-500 m) to the Cape Lookout mounds. The mound is very steep, extremely rugged and rises 100 m above the seafloor. The mound is comprised of living and dead coral, and is surrounded by areas of dead coral rubble. Localized high abundances of orange cup corals and anemones were observed on the dead coral matrix, but large octocorals and other structure-forming scleractinians were absent. Multibeam bathymetry (NCEI Survey ID: NF-07-02-MPA) is available for this site and there are several publications that document the geology and biology of this feature (Ross 2006, Partyka et al 2007, Ross and Nizinski 2007, Quattrini et al 2012). As with Cape Lookout, this is one of the more well-known sites in the proposed study region.

Stetson Banks

Stetson Banks is a large area of rugged and varied habitat on the eastern Blake Plateau off of South Carolina at depths of ~550-850 m. It was first surveyed in the 1950s, and extensive coral communities were subsequently discovered during dredging, drop

camera and submersible surveys (Stetson et al. 1962, Milliman et al 1967, Pratt 1968, Ross and Nizinski 2007, Partyka et al 2007). Stetson estimated that more than 200 mounds, up to 150 m tall covered an area of 6000 km^2. Although this significant area of coral habitat was discovered several decades ago, it remains relatively unexplored. In addition to the 'hundreds of coral mounds' described by Stetson (1961), this area also contains complex ledges and slopes composed of consolidated rubble that has been undercut by currents. The sessile invertebrate fauna is much more diverse at this location than at the NC bioherms. In addition to the structure-forming stony corals (*Lophelia pertusa* and *Enallopsammia profunda*), several species of cup corals (*Bathypsammia* sp, *Caryophyllia* sp), Antipatharians (*Leiopathes* sp, *Bathypathes* sp.) and Octocorals (*Plumarella pourtalesii, Acanella* sp, *Keratoisis flexibilis*, Plexauridae) have also been documented in the Stetson Banks region. Sponges are also very abundant, with 18 different taxa observed by Reed et al (2006). In addition to the older geological surveys, modern multibeam bathymetry is also available for this region (NCEI Survey ID: PAT0503, EX1403, and the most recent Okeanos cruise EX1805). We have selected two dive targets based on this new information and the results of our predictive habitat models, but the entire area remains of interest.

Savannah Banks

The Savannah Banks (475-600 m) are part of the Blake Plateau north of the large Charleston Bump feature that deflects the Gulf Stream and is intensively scoured by currents, exposing hard substrate (Popenoe and Manheim 2001). This large, complex site contains extensive hard-bottom habitats that range in relief from flat to near vertical scarps and lithoherms which can rise up to 100 m off the seafloor (Reed et al 2006). Earlier work described coral mounds (up to 54 m tall) that had abundant thickets of *E. profunda* and *L. pertusa*, with the former being dominant (Milliman et al. 1967, Wenner and Barans 2001). This region is comprised of layers of hard limestone rock and soft mudstone, which is susceptible to erosion. The differential erosion of these two rock types has created a series of terraces and steep walls with overhanging ledges. Sessile benthic fauna, consisting of stony corals (*L. pertusa, M. oculata*), dense sponge communities (*Phakellia* spp., *Geodia* sp., Pachastrellidae and Hexactinellidae), octocorals (Isididae, Primnoidae), black corals (*Antipathes* spp.) and hydrocorals, were abundant on the limestone, but not the less stable mudstone. Broken phosphorite pavement was observed at this site but was colonized by a sparse and different sessile community from the limestone substrate. Benthic communities were often dense in this area, but composed of small colonies. Corals found in this area include the stony corals *Lophelia pertusa* and *Enallopsammia profunda* (as individual colonies rather than the large contiguous thickets observed in other locations) as well as *Madrepora oculata*. Octocorals (*Keratoisis* sp, *Paramuricea* sp, *Swiftia* sp, *Eunicella modesta*), Antipatharians (*Leiopathes* sp) and hydrocorals (*Stylaster* sp) were also observed (Partyka et al 2007, Reed et al 2006). The precious coral genus *Corallium* was also

reported from this site (Partyka et al 2007). This area was notable for the large numbers of wreckfish (*Polyprion americanus*) observed on the high relief rocky bottom during 2001 surveys (Sedberry 2001), although these were not observed by Reed et al (2006). Multibeam data for this site include NCEI Survey ID: PAT0503, EX1203. EW9702, RC2503, and EX1805.

Charleston Bump

Submersible surveys of this feature (513-608 m) revealed a similar geology to the Savannah Banks, with low relief exposed rock, erosional terraces, high relief scarps and undercut ledges. The high relief areas and ledges were colonized by dense assemblages of corals and sponges of similar composition to those found on the Savannah Banks. Two notable exceptions were observations of the octocoral *Paragorgia* sp., and a group of stalked crinoids (Partyka et al 2007), which have not been documented further north or west than the Bahamas (Messing pers. comm.). Fish fauna were similar to those observed on the Savannah Banks, with abundant populations of Wreckfish (*Polyprion americanus*) and Alfonsinos (*Beryx dedactylus*) observed in high relief rocky areas (Partyka et al 2007).

Blake Deep

This is in the area on the eastern edge of the Blake Plateau where it descends to the abyssal plain further offshore. It was mapped and first explored by the recent Okeanos Explorer cruise (EX1805 and 1806). There was a relatively high density of corals at this site, including the framework forming *Solenosmilia variabilis*.

Jacksonville

This rugged area has a diversity of habitats including low relief (<2 m) coral structures, rubble and pavement, and high relief rocky ledges and walls. These features were first identified as coral habitat in 1982 (Reed 2002) and several surveys have been conducted since then (Reed et al 2006, Partyka et al 2007) but this large area remains relatively unexplored. Acoustic surveys by Reed in 2002 and 2004 revealed a massive lithoherm (5.7 km in length with seven individual peaks with up to 60 m relief. The south-facing flank was composed of a series of terraces that were colonized by thickets of live and dead *L. pertusa* with *Madrepora oculata*. Other dominant sessile fauna included sponges (*Geodia* spp, *Phakellia* spp. *Spongosorites* spp, Petrosiidae, Pachastrelliadae, and Hexactinellidae), octocorals (*Placogorgia* sp, *Chrysogorgia* sp, Isididae, Plexuaridae, and the soft corals, Neptheidae), black corals (*Leiopathes* sp.), hydrocorals (*Stylaster* sp) and anemones (Reed et al 2006, Partyka et al 2007). The **Million Mounds North** dive (see below) is in this area.

Million Mounds

The *Okeanos Explorer* (EX1203, 1403, 1805) has added a large amount of additional bathymetry for this region from the Florida Platform to the south of the study area, through the Jacksonville area, and extending to the Savanna Banks sites. This mapping effort revealed the presence of large numbers of mounds extending nearly 200 miles through this area. Previous observations, mostly from the Johnson Sea-Link, along with a few dives on the most recent *Okeanos* cruise (EX1806) have verified that these mounds (at least those that have been observed) are cold-water coral mounds. Two sites have been selected (**Million Mounds N** and **Blake Mounds**) to examine areas of this mound province that have not been previously observed. If this entire area is in fact covered in coral mounds, this would be one of the largest cold-water coral mound provinces in the world.

date	site	latitude	longitude	depth	transit to next site
19-Aug	WHOI				33 hrs @ 10kt
20-Aug	Norfolk seep	36.883	-74.5	2600	12
21-Aug	Pamlico Canyon	34.9576	-75.2047	923	13
22-Aug	Cape Fear Seep	32.9790	-75.9270	2600	11
23-Aug	Stetson Deep	32.016	-77.401	825	5
24-Aug	Blake Deep	31.323	-77.243	1300	14
25-Aug	Blake Mounds	31.079	-79.492	680	12
26-Aug	Million Mounds N	30.569	-79.698	590	4
27-Aug	Stetson Shallow	32.018	-78.322	500	12
28-Aug	Blake Ridge	32.494	-76.191	2155	7
29-Aug	Cape Fear	33.567	-76.45	425	12
30-Aug	Hatteras Canyon	35.2854	-74.9054	933	10
31-Aug	Norfolk Canyon	37.03294	-74.3173	2000	33
1-Sep	transit				
2-Sep	WHOI