Summary Report for the Atlantic Seafloor Partnership for Integrated Research and Exploration Science Planning Workshop

November 15-16, 2018
Sheraton Silver Spring Hotel
Silver Spring, MD

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
Office of Oceanic and Atmospheric Research
Office of Ocean Exploration and Research

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Executive Summary

On November 15-16, 2018, over 50 experts in deep-sea exploration convened in Silver Spring, Maryland to discuss North Atlantic Ocean exploration interests and priorities as part of the NOAA Office of Ocean Exploration and Research (OER) Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE) Science Planning Workshop. ASPIRE, under the Galway Statement on Atlantic Ocean Cooperation, is a multi-year, multi-national collaborative campaign to explore and characterize the North Atlantic Ocean. Participants in the workshop consisted of a mix of early- to late-career professionals and represented diverse backgrounds and interests from academia, industry, and government from across the United States, European Union, Iceland, Russia, and Canada. The objectives of the workshop were to determine Atlantic Ocean-based mapping and characterization needs from a variety of deep-sea exploration interests. Workshop outputs will guide exploration in the North Atlantic Ocean in 2019-2021, both through the development and execution of NOAA Ship *Okeanos Explorer* field seasons and through external partnerships with government, academia, industry, and nongovernmental organizations. ASPIRE workshop results are also intended to be used to inform other projects and platforms active in the North Atlantic.

Fieldwork in support of ASPIRE objectives has included missions to explore the submarine canyons of the U.S. and Canadian Atlantic continental margins, characterize the sensitive habitats of the U.S. South and Mid-Atlantic, and map deepwater areas within international waters supporting the Atlantic Seabed Mapping International Working Group. NOAA Ship *Okeanos Explorer* began working in the region in 2018 and has so far completed six ASPIRE missions. While these efforts are coordinated at the project-level, the ASPIRE Workshop was convened to better facilitate collaborative planning and develop a cohesive set of exploration priorities to work toward for the remainder of the ASPIRE campaign.

In advance of the workshop, OER distributed a 'Call for White Papers' to the North Atlantic deep-sea community and received 47 submissions. In these two-page submissions, authors identified exploration targets across the North Atlantic and provided brief summaries of why each target was worthy of exploration. These submissions provided the framework for workshop discussions and will be made available with the final workshop report. All white paper authors were invited to participate in the workshop, along with additional experts in the ocean community, as established and potential future partners representing governments, academia, industry, and nonprofits.

Following a comprehensive overview on current North Atlantic exploration and research activities, participants dispersed into small groups for a series of breakout sessions, tasked with identifying and refining areas and features of interest for ocean exploration across the North Atlantic basin. Collaborative real-time geospatial tools were used to capture geospatial priorities generated from these discussions. The workshop built upon these discussions, which served as a guide for a subsequent breakout session on subject area interests to be prioritized for ASPIRE: benthic ecology, geology/minerals/mapping, water column, marine archaeology, and connectivity. Groups discussed assets, partners, challenges, and potential expedition plans within their regions and subject areas. Staff from OER's Expeditions & Exploration Division, Science & Technology Division, and Engagement Division captured this input in geospatially annotated notes that participants then used in their final breakout session to make recommendations.

Participants were asked to refine regional and subject area interests into two to three management-relevant (e.g. fisheries, offshore energy, marine protected areas) expedition-sized priority areas. The Northwestern, Southwestern, and Central Atlantic groups collectively identified eight priority areas for exploration, as noted in the list below:

Northwestern Atlantic Ocean

1. Bermuda, the New England Seamount Chain, and the Northeast Canyons and Seamounts Marine National Monument
2. New England and Canadian shelf break canyons to the Laurentian Fan
3. Davis Strait/Iceland Transect

Southwestern Atlantic Ocean

4. Blake Plateau
5. Southeastern U.S. continental margin and Bahamas

Central Atlantic Ocean

6. Azores Plateau
7. Northern Mid-Atlantic Ridge/Charlie-Gibbs Fracture Zone
8. Southern Mid-Atlantic Ridge

Further details on these recommendations are found in the full ASPIRE report and serve as the basis for expeditions being planned for 2019-2021.

Introduction

ASPIRE Campaign

The Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE) initiative under the Galway Statement on Atlantic Ocean Cooperation (Galway Statement) is a multi-year, multi-national collaborative ocean exploration campaign to explore and characterize the North Atlantic Ocean. Building upon the successes of the 2012-2013 NOAA-led Atlantic Canyons Undersea Mapping Expeditions (ACUMEN), the ASPIRE campaign broadens the geographic focus to include more of the U.S. Atlantic Ocean and high seas. ASPIRE also broadens the scope of partnerships to include federal agencies, such as the Bureau of Ocean Energy Management (BOEM) and United States Geological Survey (USGS), as well as international partners from the European Union (EU) and Canada. Fieldwork thus far has included missions to explore the submarine canyons of the U.S. and Canadian Atlantic continental margins, characterize the sensitive habitats of the U.S. South and Mid-Atlantic Ocean, and map deepwater areas within international waters supporting the Atlantic Seabed Mapping International Working Group. NOAA Ship *Okeanos Explorer* began working in the region in 2018 and, as of August 2019, has completed seven ASPIRE missions (**Fig. 1**). While these efforts are coordinated at the project level, the ASPIRE Workshop was convened to better facilitate collaborative planning and develop a cohesive set of exploration priorities to work toward for the remainder of the ASPIRE campaign.

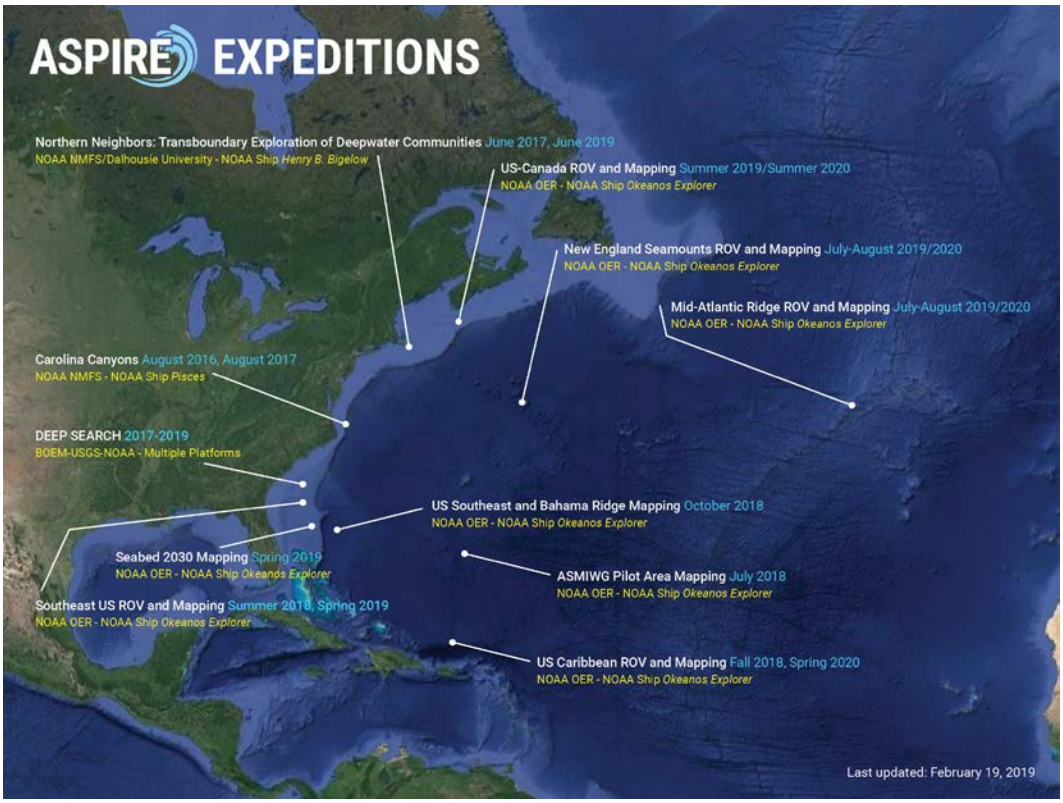

Figure 1. This map of the Northwestern Atlantic Ocean basin identifies all expeditions from 2016-2020 that fall under the auspices of the ASPIRE campaign. Expeditions for 2021 are in the early planning stages and are not shown in this figure.

The ASPIRE campaign will provide a foundation of publicly accessible baseline data and information to increase understanding of the North Atlantic Ocean. The effort will also provide critical information relevant to emerging Blue Economy priorities, including sustainable fisheries, offshore energy and marine minerals, coastal and offshore hazards, and marine tourism and recreation.

Specific goals are to:

- Improve knowledge of unexplored areas within the U.S. Exclusive Economic Zone (EEZ) and in deep-sea areas that have been mapped for the U.S. Extended Continental Shelf Project to inform management needs for sensitive habitats, geological features, maritime heritage sites, and potential resources;
- Locate and characterize deep-sea coral, sponge, and chemosynthetic communities;
- Characterize water column habitats throughout the Atlantic basin using acoustics, visual observations, and emerging technologies;
- Enhance predictive capabilities for vulnerable marine habitats and submarine geohazards;
- Extend bathymetric mapping coverage in the U.S. EEZ and international waters in support of Seabed 2030;
- Increase understanding of deep-sea ecosystem connectivity across the Atlantic basin;
- Improve international collaboration and serve as a major contribution to the Galway Statement and the Atlantic Ocean Research Alliance's deep-sea mapping and exploration efforts; and
- Leverage international partnerships and activities to conduct coordinated exploration and mapping of priority high seas areas of the North Atlantic, including the Mid-Atlantic Ridge (MAR).

International Context

The Galway Statement, signed in May 2013, provides a framework for furthering multilateral efforts to increase our knowledge of the Atlantic Ocean. Stemming from that agreement, the Atlantic Ocean Research Alliance (AORA) was formed to implement several priority research areas, including seabed and benthic habitat mapping, ocean health and stressors, ocean literacy, and aquaculture. AORA's Atlantic Seabed Mapping International Working Group (ASMIWG) is actively seeking input from the science and management communities to identify priority areas in international waters for future deepwater mapping activities. In addition to refining mapping priorities, ASPIRE will provide a means to align wider priorities, ensuring the optimization of available shiptime to cover multiple objectives, including oceanography, ecosystem function, and socioeconomic analysis.

The EU's Horizon 2020 research and innovation program is investing in a variety of interdisciplinary marine science and technology projects designed to characterize unknown areas across the Atlantic and improve understanding of ocean dynamics, habitats, and biodiversity. Two four-year projects—A Trans-Atlantic assessment and deepwater ecosystem-based spatial management plan for Europe (ATLAS) and Deep-sea Sponge Grounds Ecosystems of the North Atlantic (SponGES)—are currently underway. In line with the Galway Statement, both projects have direct U.S. and Canadian involvement through shared resources (technology development, equipment use, cruise participation) and training. The new Horizon 2020 Work Programme 2018-

2020 also promises exciting opportunities for collaboration in the coming years, with significant funding recently awarded through the European Commission's Blue Growth call.

Fisheries and Oceans Canada (DFO) supports a number of long-term field efforts, such as the Atlantic Zonal Offshore Monitoring Program, and academic partnerships like the Canadian Healthy Oceans Network (CHONe) and the Ocean Tracking Network that complement the Galway Statement. Canada partnered with the United States for a 2017 U.S.-Canadian transboundary cruise on NOAA Ship *Henry B. Bigelow* using the Canadian Scientific Submersible Facility's remotely operated vehicle (ROV) *ROPOS*.

Workshop Format

From November 15-16, 2018, over 50 experts in deep-sea exploration convened in Silver Spring, Maryland to discuss North Atlantic Ocean exploration interests and priorities as part of the NOAA Office of Ocean Exploration and Research (OER) ASPIRE Science Planning Workshop (**Fig. 2**). Participants consisted of a mix of early- to late-career professionals and represented diverse backgrounds and interests from academia, industry, and government from across the United States, European Union, Iceland, Russia, and Canada. The objectives of the workshop were to determine Atlantic Ocean-based mapping and characterization needs from a variety of deep-sea exploration interests. Workshop outputs will guide exploration in the North Atlantic Ocean in 2019-2021, both through the development and execution of NOAA Ship *Okeanos Explorer* field seasons and through external partnerships with government, academia, industry, and nongovernmental organizations.

Figure 2. The ASPIRE Science Planning Workshop in Silver Spring, MD, had over 50 attendees representing interests in Atlantic Ocean basin exploration and research from the United States, Canada, European Union, Iceland, and Russia.

In advance of the workshop, OER distributed a Call for White Papers to the North Atlantic deep-sea community and received 47 submissions (**Appendix C**). In these two-page submissions, authors identified exploration targets across the North Atlantic and provided brief summaries of why each target was worthy of exploration. These submissions provided the framework for workshop discussions and will be made available with the final workshop report. All white paper authors were invited to participate in the workshop, along with additional experts in the ocean community, as established and potential future partners representing governments, academia, industry, and nonprofits.

The workshop began with a welcome to participants from OER Director Alan Leonardi and former OER Deputy Director CAPT William Mowitt with an in-depth overview of the OER mission, past accomplishments, capabilities, and vision for ASPIRE—providing the framework for discussions. In addition, the workshop featured a live-streamed interaction with the science team aboard NOAA Ship *Okeanos Explorer*. Presentations by Terry Schaefer (NOAA, Office of Oceanic and Atmospheric Research, International Activities Office), Joana Xavier (University of Bergen), Marina Carreiro-Silva (University of the Azores), and Jennifer Higdon (DFO) provided insights into additional capabilities, assets, and exploration goals for ASPIRE partners, and highlighted projects currently underway in the North Atlantic Ocean, including the AORA, Horizon 2020 projects SponGES and ATLAS, and DFO programs.

Following the comprehensive overview on current North Atlantic exploration and research activities, participants dispersed into small groups for a series of three separate breakout sessions tasked with identifying and refining areas and features of interest for ocean exploration across the North Atlantic basin. Initially, groups were broken into regions of interest, as aligned with white paper submissions: Northwestern, Southwestern, Central, and Eastern Atlantic. The groups were each tasked with identifying areas lacking any or sufficient exploration. A fifth group was tasked with the same challenge but asked to consider a basin-wide assessment. Collaborative, real-time geospatial tools were used to capture geospatial priorities generated from these discussions. A second breakout session focused on subject area interests to be prioritized for ASPIRE: Benthic Ecology, Geology/Mapping/Minerals, Water Column exploration, Marine Archaeology, and Connectivity. During both sessions, groups discussed assets, partners, challenges, and potential expedition plans within their regions and subject areas. Staff from OER's Expeditions & Exploration, Science & Technology, and Engagement divisions captured this input in geospatially annotated notes that participants then used in their final breakout session to make recommendations.

Prior to reconvening for the third and final breakout session, OER leadership and expedition coordinators led a panel discussion to communicate the OER planning process and timelines associated with both the NOAA Ship *Okeanos Explorer* schedule development and the OER Federal Funding Opportunity process. This panel also served as a mechanism to further engage participants in NOAA and OER collaborative science programs while providing transparency regarding federal processes. The panel concluded with a modified charge for the final breakout session; returning to their original North Atlantic regional sections, participants were asked to refine regional and subject area interests into two to three management-relevant (e.g., fisheries, offshore energy, and protected areas), expedition-sized priority areas. What follows in this report are summaries of both the geographic and subject area breakout group discussions and an overview of the exploration priorities identified by the workshop.

Summary of Geographic Breakout Group Discussions

Northwestern Atlantic

For the purpose of the workshop, the Northwestern Atlantic was broadly defined as all waters west of the MAR (approximately 50° W), south of the Arctic Circle (66.5° N), and north of Cape Hatteras (approximately 35° N). Fifteen white papers focusing on the Northwestern Atlantic region were

submitted in response to the pre-workshop solicitation request. The discussion during the first breakout session started by going around the table to discuss submitted white paper ideas and other major interests in the region. These recommendations and interests were captured, and the group further discussed remaining data gaps, platforms for exploration, potential partners, and region-specific challenges. Priority regions identified during the first breakout session generally emphasized white paper submissions and areas with overlapping interests in need of further exploration. Participants also recommended focusing on collaborations to meet international interests and commitments, such as those in support of the Galway Statement through ATLAS and SponGES, among others.

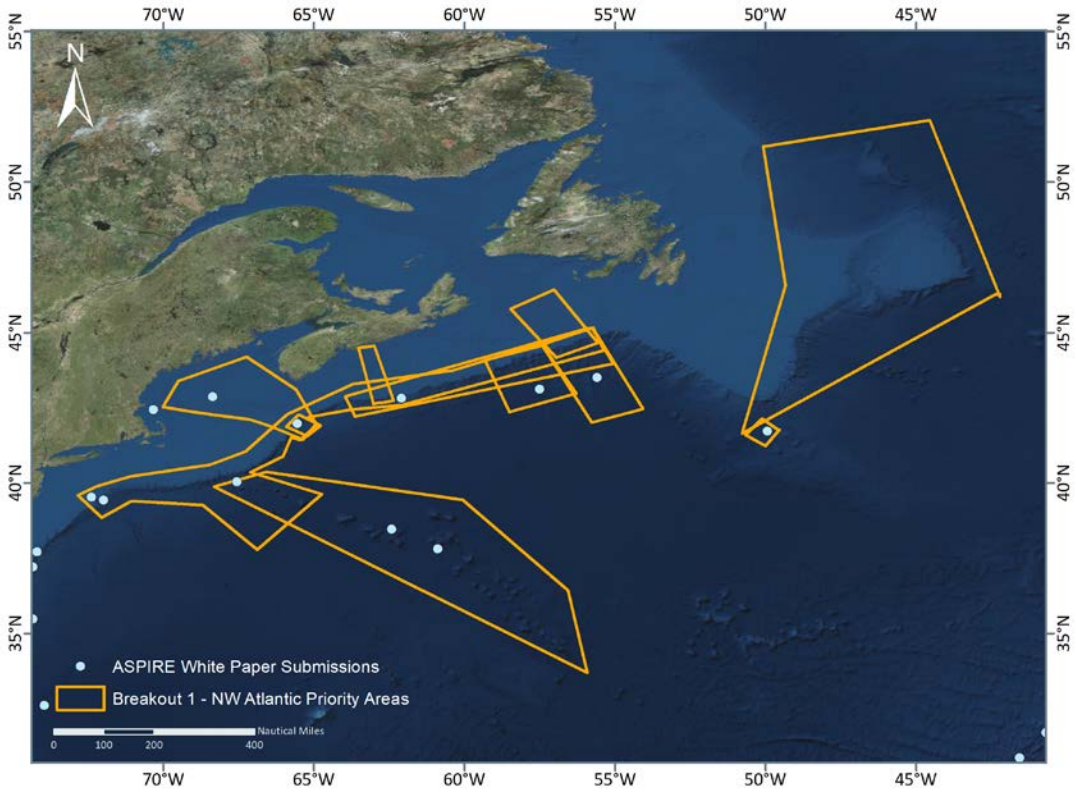

Figure 3. Map showing Northwestern Atlantic geographic priority areas identified during breakout session 1. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during workshop discussions.

Priority regions identified during the first breakout session were as follows:

1. **Outermost Shelf Break and Slopes**
   The outermost shelf break and slopes, offshore of New England and northeast to the Laurentian Fan in Canadian waters, contain a variety of features, habitats, and resources of interest to managers and the science community, including submarine canyons, seeps, deep-sea coral and sponge habitats, fisheries interests, and underwater cultural heritage (UCH) sites. The area encompasses existing marine protected areas (MPAs), potential MPAs, and potential MPA extensions (e.g., Northeast Canyons and Seamounts Marine National Monument (NCSMNM), Northeast Channel, DFO areas of interest). This region was

identified as the highest priority area for exploration in the Northwestern Atlantic due to high numbers of overlapping interests, management needs, and international collaboration. Overlapping interests include:

- **The Gully, canyons of interest to Canada:** See the Metaxas white paper (**Appendix C**). There is anticipation that there will be unique features and unique faunas in the unexplored canyons. The potential faunal connectivity among canyons is not understood at this time.
- **Laurentian Channel MPA:** This MPA was designated by the Government of Canada in April, 2019. It is an area where North Atlantic Right Whales transit—why are they here? How are the environmental conditions changing? See: http://dfo-mpo.gc.ca/oceans/aoi-si/laurentian-laurentien-eng.html
- **Laurentian Fan:** See the Mayer white paper (**Appendix C**). Unique submarine landslides stem from the landmark 1929 Grand Banks earthquake. There is an interest in seeps and seep communities in the area—this is the only seep explored this far north, aside from work the Norwegians have done. There is a strong interest in sampling the biology in the area. It is an ecologically and biologically significant area, and is a proposed marine park.
- **Halifax Line:** Benthic habitat and fisheries habitat assessments are needed in the area to complement oceanographic and animal tracking data. The maximum depth is around 200 m. The Halifax Line passes through the Vazella sponge grounds.
- **North Atlantic Margin Canyons, NCSMNM:** Workshop participants identified this as one of the highest priority areas, and a strong area of shared interest for both the United States and Canada, as well as AORA working groups in support of the Galway Statement. Exploration is needed to understand the differences and connectivity across the canyons, with particular interest in the study and characterization of minor canyons, and deep-sea coral and sponge communities. U.S. and Canadian canyons have very different geology, and the canyons off Nova Scotia are largely unexplored. Data are needed to support modelling efforts (deep-sea corals, geohazards) and MPA management and decisions (Northeast Channel Conservation Area; NCSMNM). The area surrounding the canyons unit of the NCSMNM encompass areas of interest to understand the beaked whale feeding grounds. Exploration for high-value shipwrecks, including the U.S. Coast Guard Cutter (USCGC) *Bear* (see Barr white paper, **Appendix C**), and shipwrecks offshore of Boston and New York.
- **New England Seamount Chain; NCSMNM:** Significant data gaps exist in understanding the New England Seamount Chain. Water column exploration here is desired for faunal exploration, specifically to investigate potential spawning grounds and bentho-pelagic interactions. Exploration and characterization of the Seamounts Unit of the NCSMNM are needed to provide sufficient data and information to meet regulatory requirements. POC: Michael Jech, NOAA Northeast Fisheries Science Center (NEFSC).
- **Cuvier Beaked Whales Feeding Grounds**: Whales seem to have very specific behaviors for diving related to the deep scattering layer. This is an area of interest to the Water Column group. There is also interest in understanding linkages between whale feeding grounds and the seep activity in the area (enhanced pelagic prey as a consequence of seep productivity). A beaked whale "core use area" near Keller

Canyon, not shown in **Figure 3** above, is listed in SeaSketch. Talk to Michael Jech (NEFSC) and Cindy Van Dover (Duke University) for more information.

- **Search for USCGC *Bear* in Northeast Channel:** High-resolution mapping (e.g., via an autonomous underwater vehicle (AUV)) is needed to identify potential targets of the USCGC *Bear.* A modelling output of likely resting areas has already been provided to OER. Ground-truthing and discovery of the site desired should be a NOAA Ship *Okeanos Explorer* target.

2. **Gulf of Maine**
   The Gulf of Maine and Northeast Channel is a heavily exploited area and there has been surprise and enthusiasm surrounding the discovery of unanticipated healthy, deep-sea communities. The area has been partially studied for deepwater corals. The coral populations here are genetically isolated and there is interest in understanding where other cold water coral communities are located. Groups of interest: University of Maine Ocean Observing System, Neil Pettigrew, and SponGES.

3. **Grand Banks, Flemish Cap, and Flemish Pass**
   This area contains a lot of management interest, and interest for oil and gas exploration. There are unmapped areas needing bathymetric data, unexplored canyons on the margin, and areas where the Gulf Stream tendrils flow through with uncertain impacts on fauna. Overwintering areas to the northern end of the box are locations for depressed cod stocks, and there are likely many shipwrecks in the area as well. The oil and gas industry has data in the region but they are proprietary—a suggestion is to partner with industry to leverage their data. DFO is working with industry to get the data in low-resolution. The wreck of the RMS *Titanic* is located here and has been recommended for resurvey using state-of-the-art archaeological methods for the first time.

Following a second breakout session by discipline, the Northwestern Atlantic group reconvened for a final session focused on synthesizing the input and priorities, heard during the first two breakout sessions, to identify top recommendations that could be addressed during two to three ocean exploration cruises. In each area, key managers and scientists with regional expertise were identified, logistical challenges discussed, and critical community data needs summarized. Below are the group's three recommendations to address the highest priority areas in need of exploration on the Northwestern Atlantic:

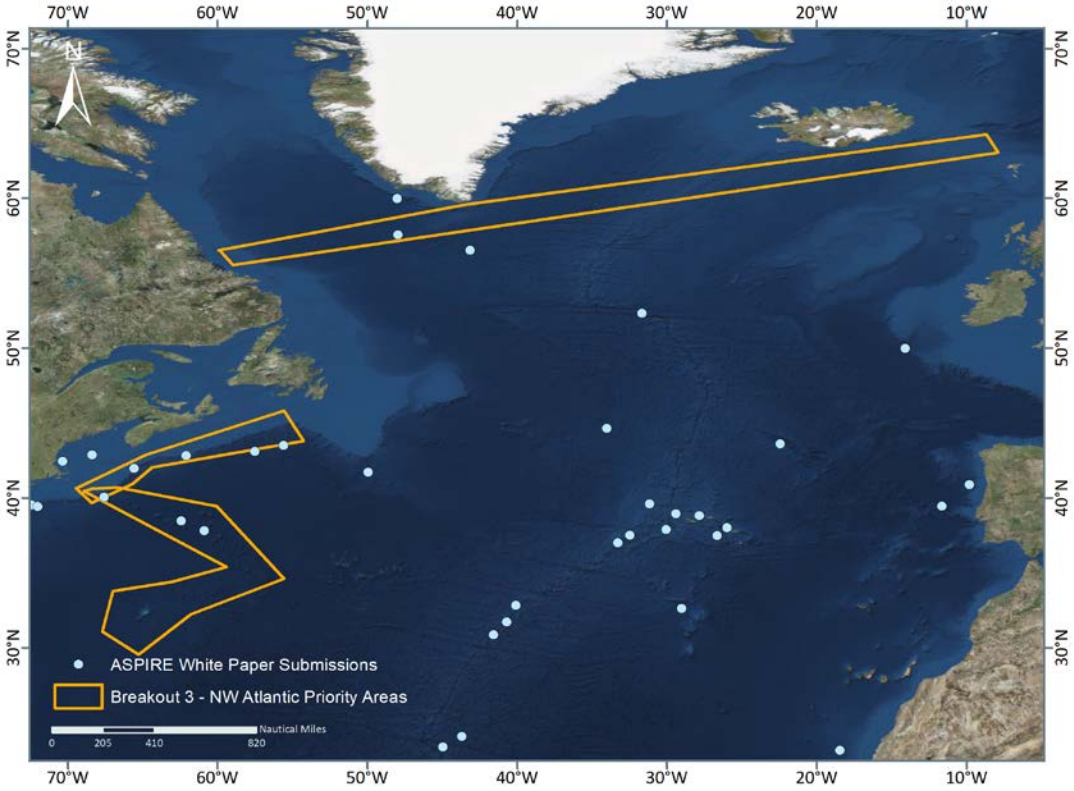

Figure 4. Maps showing Northwestern Atlantic priority areas identified during breakout session 3. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during workshop discussions.

1. **Bermuda to New England Seamount Chain to NCSMNM**
   Exploration of poorly known seamounts offshore Bermuda, potential shipwrecks off Bermuda, New England Seamount Chain exploration, data to support the NCSMNM managers, exploration of deep-sea coral and sponge grounds, connectivity, water column, deep-sea mining interests, and extensive fisheries interests (e.g., migration pathways for eels and sharks).

   Key Partners: Bermuda Department of Environment and Natural Resources, Fishery Management Councils, NCSMNM managers, NEFSC, Mystic Aquarium, New England Aquarium, New England Seamount scientists (Scott France, Les Watling, Rhian Waller, Peter Auster), Bermuda UCH contacts (Ed Harris, Philippe Rouja), and interested scientists (Dominique Rissolo, Rod Mather).

2. **New England and Canadian shelf break canyons to the Laurentian Fan**
   Exploration of unknown canyons and minor canyons, data to support MPAs and managers (e.g., NCSMNM, Northeast Channel Coral Conservation Area, Laurentian Channel MPA), critical marine mammal habitat, fisheries habitats and interests, seeps, corals, sponge grounds, water column exploration, connectivity studies, submarine landslide/geohazards, UCH surveys offshore of New England and Canada, and search for the USCGC *Bear*.

Key Partners: Ellen Kenchington (DFO), Canadian scientists (Anna Metaxas, Fred Whoriskey, Hal Whitehead, Paul Snelgrove), U.S. Canyons (Martha Nizinski, Peter Auster), Laurentian Fan/Seeps (Larry Mayer, Anna Metaxas, Cindy Van Dover), geology: see Mayer, Van Dover white papers in **Appendix C**, USCGC *Bear* (Brad Barr, NOAA Office of National Marine Sanctuaries; U.S. Coast Guard (USCG)), and U.S. Atlantic Margin UCH (Joe Hoyt, NOAA Marine Heritage Program).

3. **Davis Strait / Iceland Transect**
   Fisheries (shrimp, crab, salmon), coldwater corals, sponge grounds, whales (including potential North Atlantic Right Whale grounds), whaling ships, climate change and ocean acidification, shipwrecks (potential WWII convoy route wrecks, historic whaling groups), northern environment, connectivity, water column, seeps, and currents/Atlantic Meridional Overturning Circulation (AMOC). Note that there are ATLAS partnerships and efforts in the region, and 2019 is the International Year of the Salmon.

   Key Partners: NEFSC (Tim Sheehan and John Kocik), seeps (Emmelie Åström, Arctic University of Norway and Will Ambrose, Coastal Carolina University), DFO (Dave Cote, Pierre Pepin), water column (Doug Wallace, Dalhousie and Brad de Young, Memorial University), benthic (Paul Snelgrove, Memorial University), marine archaeology/whaling ships (Brad Barr, NOAA Office of National Marine Sanctuaries (ONMS)), SponGES (Ellen Kenchington, DFO), and corals (contact Tom Hourigan, NOAA Deep Sea Coral Research and Technology Program for contacts in Iceland).

Regional Data and Information Gaps
More seabed mapping is needed in the region, including higher-resolution mapping and improved mapping products; more water column data, including for detecting seep plumes; and data and observations to improve characterization of seamounts and benthos.

Platforms and Capabilities
Recommended platforms and technologies were identified by participants to facilitate exploration in these regions and include NOAA Ship *Okeanos Explorer;* NOAA Ship *Bigelow* (note a 2019 cruise is currently planned with ROPOS (pending)); Canadian research vessels; the Canadian ROV *Falcon* (500 m capable); R/V *Connecticut;* AUV surveys; and other high-resolution multibeam surveys and imaging.

Logistical Challenges
- Environmental challenges include limited weather windows, and working in and around the Gulf Stream, currents, cold, and ice.
- Securing funding and finding appropriate platforms and technologies (e.g. ROVs and deepwater AUVs outfitted with multibeam, imaging, and environmental sensors).
- Obtaining foreign vessel clearance, making port calls in Greenland, and working in areas with less established partnerships (which is both a challenge and an opportunity).
- Covering long distances during a cruise, and navigating fishing gear in areas with a strong fisheries presence (e.g., canyon heads).

Partnerships

Potential partners that could inform and benefit from ocean exploration in the region include relevant managers, ongoing collaborations and efforts, and scientists with expertise in the region. In particular: the Canadian Hydrographic Service, CHONe, DFO, the Geological Survey of Canada, Canada's Ocean Tracking Network, Canada's Ocean Supercluster, ATLAS, SponGES, USCG platforms, oil and gas surveys, fisheries managers, International Network for Scientific Investigations of Deep-Sea Ecosystems (INDEEP), Deep-Ocean Stewardship Initiative (DOSI), BOEM, and the USGS.

Southwestern Atlantic

For the purposes of this workshop, the Southwestern Atlantic Ocean was broadly defined as all waters west of the MAR (approximately 50° W), north of the Equator, and south of Cape Hatteras (approximately 35° N). With a wide-ranging group representing diverse interests in academia, U.S. federal government, and industry, the Southwestern Atlantic breakout group largely focused its discussions on the southeastern U.S. Atlantic continental margin (USAM), and some areas of connectivity in the Caribbean. There are large mapping gaps along the USAM, especially on the Blake Plateau. One of the biggest priorities for the Southwestern Atlantic is to fill the gaps in existing mapping data. The deep-sea community needs these data to:

- Improve understanding of seafloor habitat and hazard classification, characterization, and distribution;
- Understand population connectivity information for sensitive species; and
- Inform considerations for fisheries management, including establishing and refining coral habitat areas of particular concern (HAPCs), and offshore energy management.

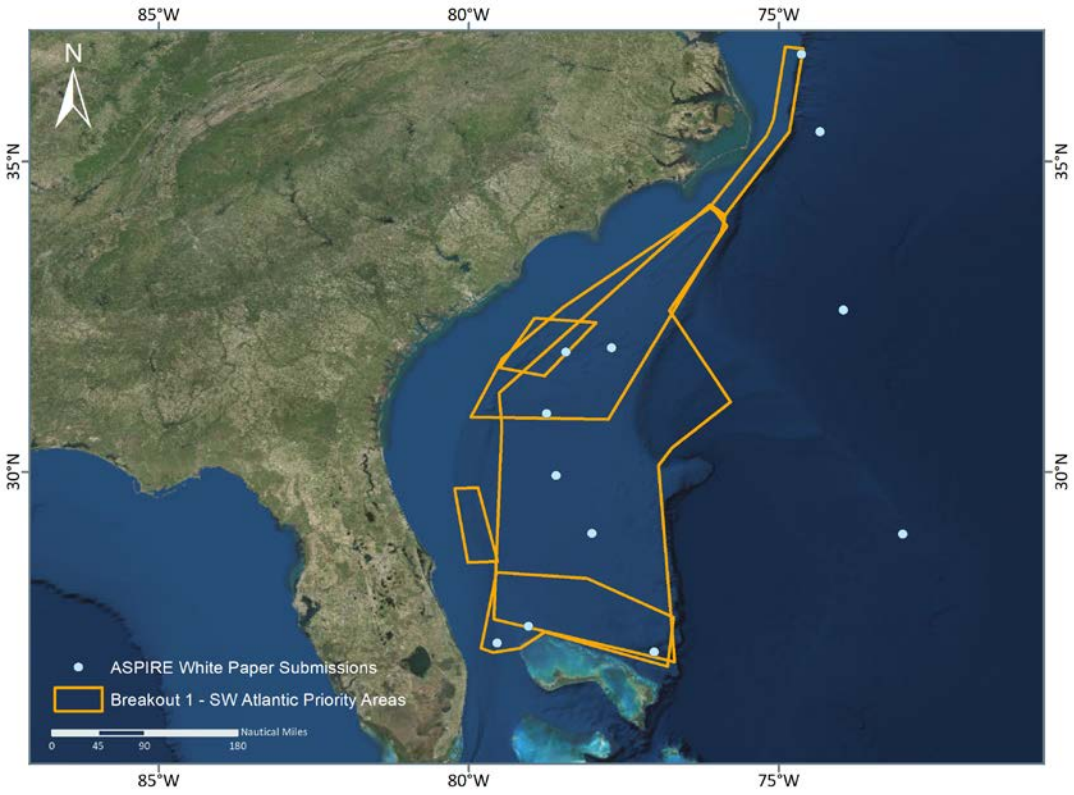

Figure 5. Map showing Southwestern Atlantic geographic priority areas identified during breakout session 1. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

Beyond this initial need for baseline multibeam, backscatter, and midwater mapping data, the group identified a number of exploration priorities during its first breakout session. These exploration priorities were as follows:

1. **Million Mounds coral habitats**
   This target was originally proposed by Chip Collier (South Atlantic Fishery Management Council (SAFMC)) in an ASPIRE white paper and was further endorsed by the group. These coral habitats appear extensive and require further study.

2. **SAFMC coral habitat**
   This is the second area submitted by the SAFMC as a white paper and endorsed by the entire breakout group. It is in need of additional mapping data, and there have been no NOAA Ship *Okeanos Explorer* dives in the area. In addition to being an area with potential golden crab fishery interests, other management considerations include possible seeps, potential oil and gas interests, and mineral resources.

3. **BOEM interest area**
   BOEM has a need to identify sensitive areas for avoidance, including coral and seep habitats, and identified this need in a white paper submission prior to the workshop. Deep Sea Exploration to Advance Research on Coral/Canyon/Cold Seep Habitats (DEEP SEARCH) is currently operating in this region, but BOEM is interested in additional work beyond the scope of that project, including focused multibeam mapping, geological studies, and connectivity.

4. **Northern Bahamas**
   First submitted by Sandra Brooke in an ASPIRE white paper (**Appendix C**), this area is largely unexplored and could be a key region for better understanding connectivity. There are a number of features to explore here, including Little Bahama Bank and Great Abaco Canyon. While there is a lot of mapping to be completed, it may prove to have challenging conditions for ROV operations.

5. **North Carolina canyons and seeps**
   There is current work in this region, but there is always a need for more study, given the diversity of canyon and seep habitats here. Most seeps still need to be ground-truthed. A better understanding of the connectivity between canyon habitats is needed. Submarine geohazards and shipwrecks represent additional focus areas in the region.

From these priorities, the group distilled its recommendations during the final breakout session into two expedition-sized polygons:

1. **Blake Plateau "Triangle"**
   a. Subject area relevance: benthic ecology, geology/mapping/minerals, marine archaeology.

b. Management connections: potential rare earth minerals and hydrocarbons, potentially polluting wrecks, Seabed 2030 mapping.

2. **Southeastern U.S. continental margin and Bahamas**
   a. Subject area relevance: benthic ecology, geology/mapping/minerals, connectivity.
   b. Management connections: fisheries, deep-sea coral HAPCs, offshore energy management.

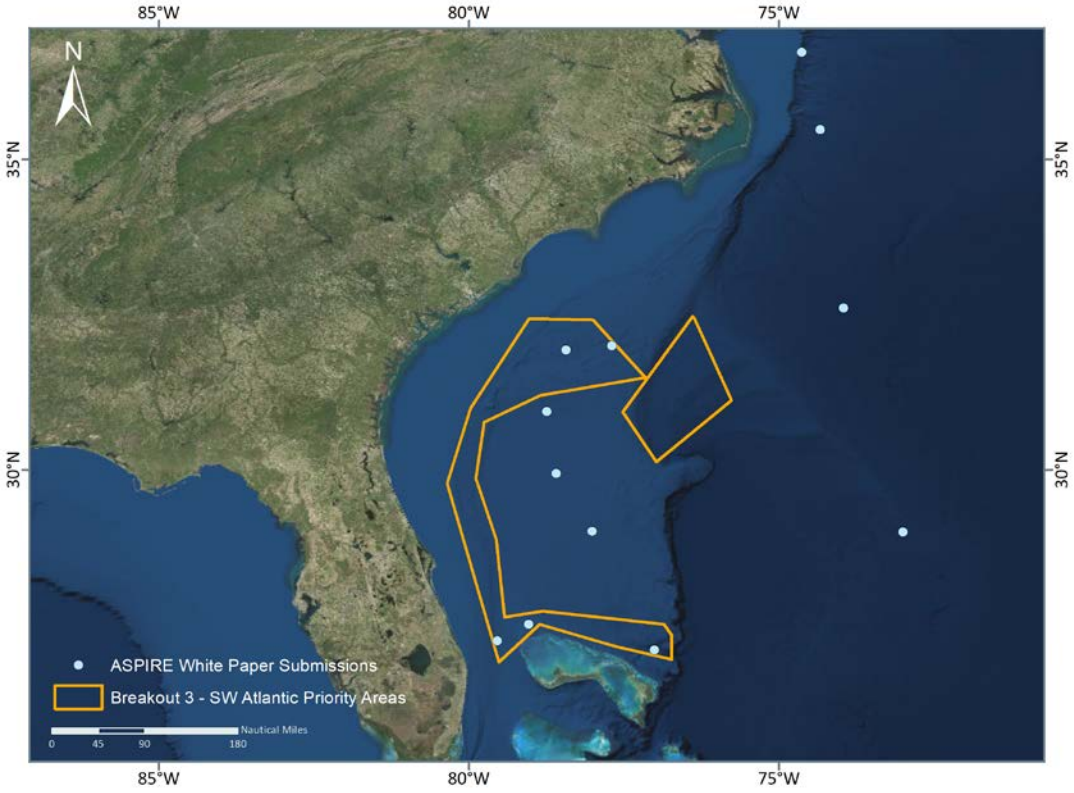

Figure 6. Map showing Southwestern Atlantic geographic priority areas identified during breakout session 3. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during workshop discussions.

Throughout their discussions, the Southwestern breakout group identified methods and capabilities for addressing identified priorities, as well as key partners in the region and potential logistical challenges.

Platforms and Capabilities

- Active vessels and projects in the area include DEEP SEARCH, Atlantic Deepwater Ecosystem Observatory Network (ADEON), NOAA ships (e.g., *Thomas Jefferson, Ferdinand Hassler, Pisces*, and *Nancy Foster*), University-National Oceanographic Laboratory System (UNOLS) vessels, and Fugro vessels.
- With a number of large, active ports in the southwestern Atlantic, crowdsourced bathymetry from ships could be possible.
- Beyond ships, autonomous platforms like AUVs, unmanned underwater vehicles, and autonomous surface vehicles are potential capabilities in the region.

Partnerships

- Current National Oceanographic Partnership Program studies: ADEON, DEEP SEARCH
- SAFMC
- U.S. federal agencies
- Industry: Fugro, potential oil and gas companies
- Caribbean states

Logistical Challenges

- Baseline mapping over vast, unmapped areas of the Southwestern Atlantic will take time, especially in the relatively shallow waters of the Blake Plateau.
- The Gulf Stream current is extremely strong throughout much of the region and will impact operations, especially ROV dives.
- Data access/sharing across regional partners can be challenging, especially with U.S. Navy activity in the region and with proprietary industry data.
- Weather patterns limit the work window in the region with both winter storms and hurricane seasons.

Central Atlantic

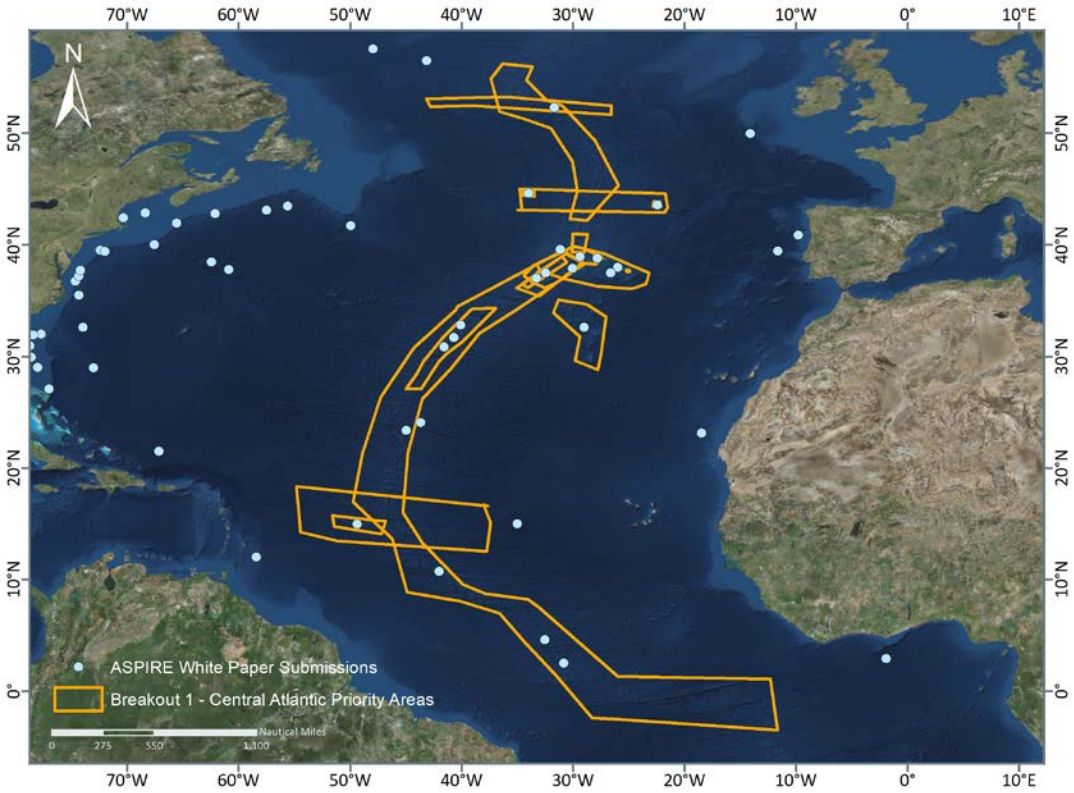

Figure 7. Map showing Central Atlantic geographic priority areas identified during breakout session 1. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

Early in the discussion of the Central Atlantic regional breakout group, the group honed in on three focal areas in need of further exploration: the Azores Plateau, areas north of the Azores in the vicinity of the MAR including nearby seamounts and the Charlie-Gibbs Fracture Zone, and the extent of the MAR south of the Azores. Each of these regions has unique drivers and exploration priorities. While these regions have had some level of focused exploration, there remain large gaps in our knowledge—as small areas have been the subject of studies with limited scope or geographical distribution.

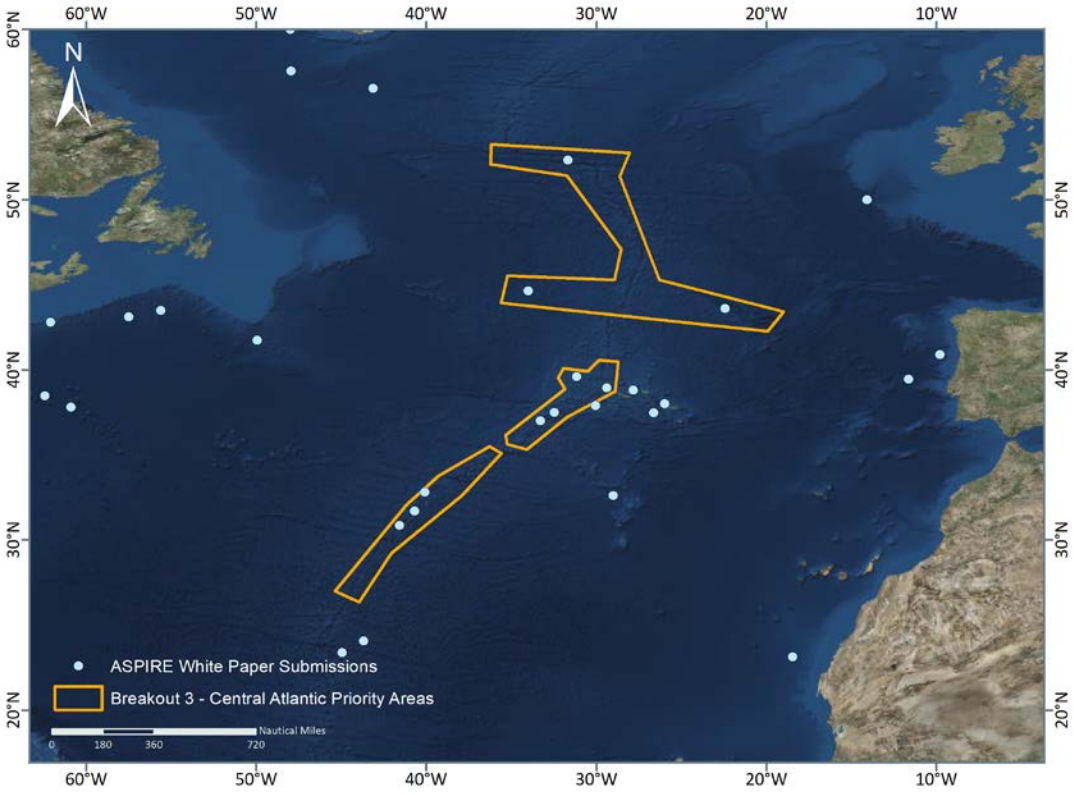

Figure 8. Map showing Central Atlantic geographic priority areas identified during breakout session 3. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during workshop discussions.

1. **Azores Plateau**
   Despite its proximity to one of the most fascinating features in the Atlantic Basin, there remain significant data holidays in multibeam coverage as well as knowledge gaps regarding the deepwater habitats in this region, including within local MPAs. As one of the shallowest areas in the Central Atlantic basin, this area is also very important for understanding basin-wide connectivity of depth-limited and highly migratory species (HMS). From a geological perspective, much remains unknown about the impact of tectonic activity on the Azores Plateau and other potential geohazards in the region. This region also offers a unique opportunity to learn about the geological history or island formation and subsidence in this dynamic environment. Additionally, as an area with a rich maritime history, it is likely that there are many undiscovered UCH sites in the region.

2. **Northern MAR/Charlie-Gibbs Fracture Zone**

A large portion of the MAR north of the Azores is unmapped and unexplored by deep submergence assets. While the same geophysical conditions—and hydrothermal vents—known to exist on the southern portion of the ridge may also exist in the north, there has been so little exploration here that this cannot yet be confirmed. Between the Azores and Charlie-Gibbs Fracture Zone, there has only been one confirmed vent, and two inferred by water chemistry that have not been ground-truthed. Over 300 linear miles of the MAR north of the Azores remain unmapped.

The Charlie-Gibbs Fracture Zone is a high seas MPA and a known corridor for HMS and pelagic species. The fracture zone is also believed to be a conduit for deep-sea fauna in general, as it connects the northwestern and northeastern Atlantic basin. Given the importance of this feature, it is surprising that so little in situ observation has been conducted here, and that there are large data holidays in multibeam coverage.

3. **Southern MAR**
   The southern portion of the MAR has some of the best multibeam coverage along the entire extent of the MAR. An area with abundant hydrothermal activity, this region has captured the imagination of the science community for years. However, many inferred sites of hydrothermal activity—through water chemistry analysis—have never been ground-truthed, few past cruises have ever explored beyond the boundaries of the hydrothermal sites for coral and sponge communities, and the farthest extents of the MAR are poorly characterized, as they are challenging to get to due to distance from shore and provisioning constraints. Operations in this area have a high likelihood of hydrothermal vent discoveries. Much of this area is within International Seabed Authority (ISA) lease areas.

Additionally, the areas south of Iceland, but north of the Charlie-Gibbs Fracture Zone were also an area of interest for exploration, but as little was known about this particular area among group members, not much time was spent delving into detail here.

Throughout the discussion, the group continued to come back to a challenge that was consistent among all three regions. As much of the region of interest lies in the high seas, there has been little done to synthesize past efforts. Much of the data from past expeditions lie in national repositories that may or may not sync with each other. In advance of an exploration expedition to this region, a gap analysis and synthesis of past data is needed to inform operating areas.

Eastern Atlantic

The Eastern Atlantic covers a large area from the more relatively known areas of Northern Europe to the southern areas offshore of Africa, where essentially little to no data exist. During the discussions, the group first focused on the white paper submissions and identified several priority areas that are important for multiple stakeholders. The group identified the areas highlighted in **Figure 9** as exploration priorities.

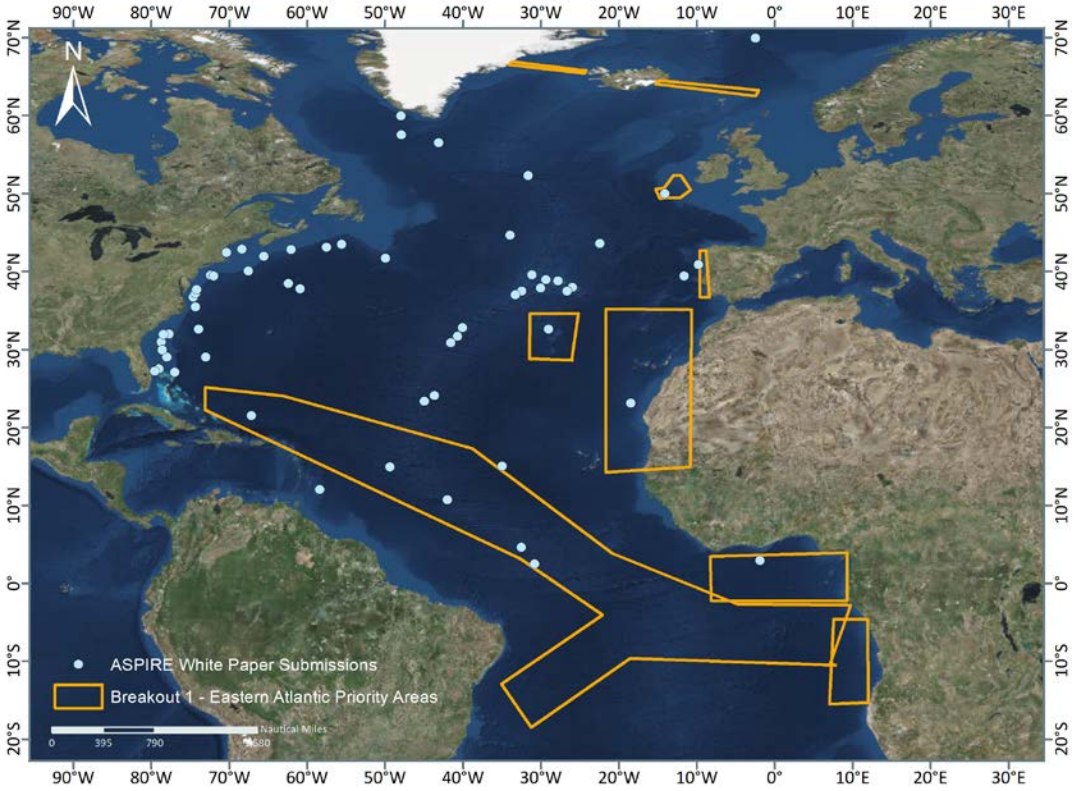

Figure 9. Map showing Eastern Atlantic geographic priority areas identified during breakout session 1. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

These priorities broadly included the following regions and themes:

1. **West Africa**
   This area was identified as the region that is least known in the Eastern Atlantic. Several smaller priority areas were identified based on white papers. The exploration data most critically needed in this region are bathymetric surveys along with the water column acoustics.
2. **Cross-Atlantic connectivity studies**
   Connectivity studies can benefit from a detailed characterization of the seafloor off of western Africa. Use of consistent, standardized surveys can help address connectivity questions. Similar connectivity questions exist for Iceland-Greenland-Scotland connectivity.
3. **Porcupine Seabight and coastal Portugal**
   The Porcupine Seabight, offshore southwestern Ireland, and coastal Portugal were also identified as priorities.
4. **Slave Trade Route**
   The historical Slave Trade Route extended from the Gulf of Guinea to the Caribbean and represents an important priority for marine archaeology.

The resources available for addressing these priorities are nearly non-existent in western Africa. It was argued that perhaps NOAA Ship *Okeanos Explorer* could partner with the United Nations to

address these resource limitations. Participants noted that working with EU partners can be a challenge as there is no central institution that coordinates exploration efforts within the EU. The data repositories and cruise planning contacts were shared as well, and it was recommended to rely more on AORA for coordination.

Basin-Wide

The Basin-Wide breakout group attempted to cover a large range of longitude and latitude, and focused the discussion around hitting high-interest areas and concepts, such as coral and sponge ecosystems, chemosynthetic ecosystems, midwater priorities, geohazards, submerged cultural resources, and Blue Economy priorities. The group met only during the first breakout session and instead self-assigned into one of the other regional groups during the third breakout session to facilitate discussion of more focused, regionally-based recommendations.

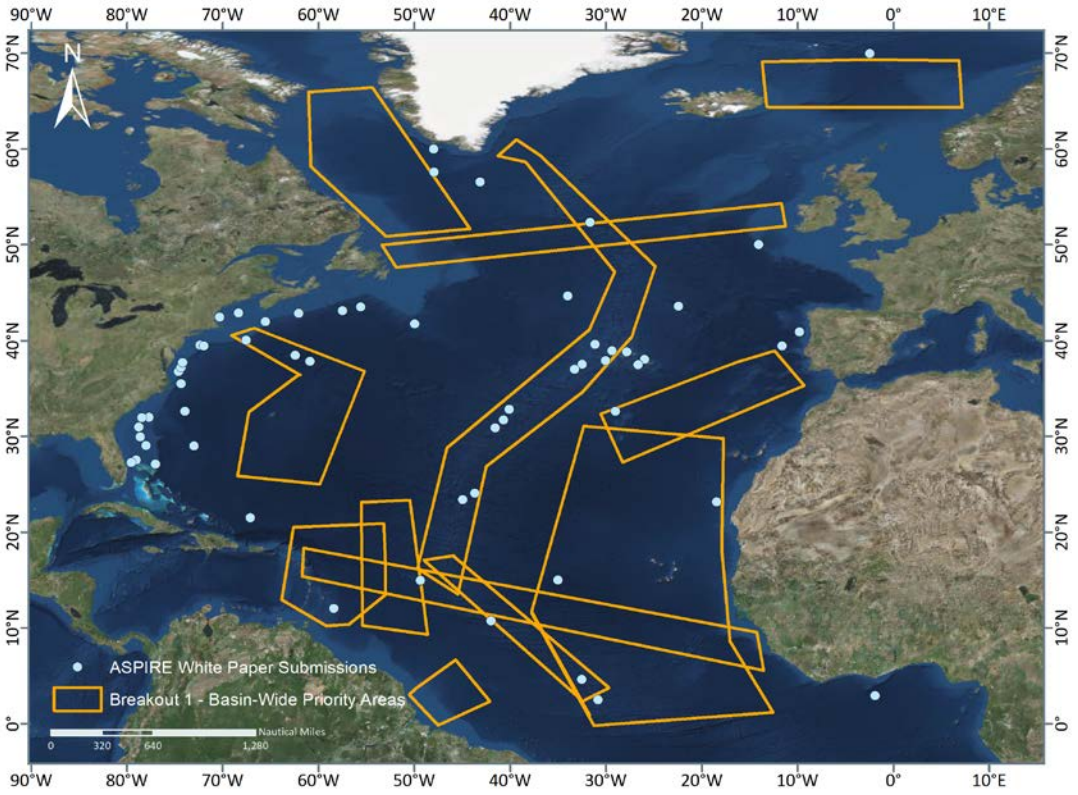

Figure 10. Map showing basin-wide geographic priority areas identified during breakout session 1. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

Several large, cross-basin regions were identified:

1. **Northern MAR**
   Inactive vents remain unexplored, the water column is poorly explored, and there are exploration ISA mining leases in the area (Blue Economy).
2. **Southern MAR**

This is a poorly explored area of the MAR near the equator. Interests include corals, sponges, and vents.

3. **Northern cross-Atlantic section**
   There is high interest from multiple nations (e.g., Ireland, Canada, and Norway), connectivity (corals and sponges), fisheries (Norway), seamounts, midwater column, and potential shipwrecks (Vikings, fisheries).
4. **Southern cross-Atlantic section**
   This region is poorly studied. There is the potential for significant archeological discoveries related to the Slave Trade Route. Other interests include seamounts, midwater column, connectivity (corals and sponges), and geohazards.

The following areas were identified as unexplored and underexplored areas with high potential for Blue Economy contributions:

1. **West Africa**
   This as a particularly poorly explored region. There are chemosynthetic systems, archeological sites, geohazards, and seamounts off West Africa with high potential for new discoveries. There are also shipwrecks and fisheries off this coast. The French did some work here in the 1980s.
2. **Mouth of the Amazon River**
   There are Blue Economy interests (e.g, gas/petroleum extraction, nodules, asphalt). There is some Extended Continental Shelf (ECS) mapping conducted here, however, the data may be proprietary.
3. **Caribbean**
   Interests include the Barbados accretionary prism as well as the Lesser and Greater Antilles (e.g., oil/gas, shipwrecks, and midwater column—particularly around seeps and topography).
4. **Meteor seamounts**
5. **Sargasso Sea to New England Seamounts**
   There are benthic and water column interests, including mapping, canyons, seamounts, connectivity, possible spawning grounds for bluefin tuna, and abyssal areas, which are particularly poorly explored.
6. **Davis Strait**
   This region is highly acidic and is important for fisheries, coral and sponge grounds, Arctic resources, and submerged cultural resources.
7. **Iceland**
   The Viking Trough is of particular interest, as there potentially are soft corals, which are useful to characterize before climate changes affects this habitat; additionally, there could be seeps.
8. **Abyssal plains between the coasts and the MAR**
   These are the least explored areas of the North Atlantic basin.

Partnerships

ATLAS, SponGES, DEEP SEARCH, NOAA National Marine Fisheries Service (NMFS), neighboring countries, NGOs (e.g., Sargasso Sea Alliance), ISA and leaseholders, L'Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), industry, U.S. Naval Research Laboratory (Brad Penta),

DFO, SEARCH Inc., Woods Hole Oceanographic Institution (WHOI) Advanced Imaging Lab, USGS, Bermuda-Atlantic Time-series Study (BATS), Bermuda Institute of Ocean Studies (BIOS), and Mareano.

Logistical Challenges

- Shiptime
- Access to proprietary information
- Weather
- Financial resources
- Permits
- Large area to cover
- Capacity

Summary of Subject Area Breakout Group Discussions

Benthic Ecology

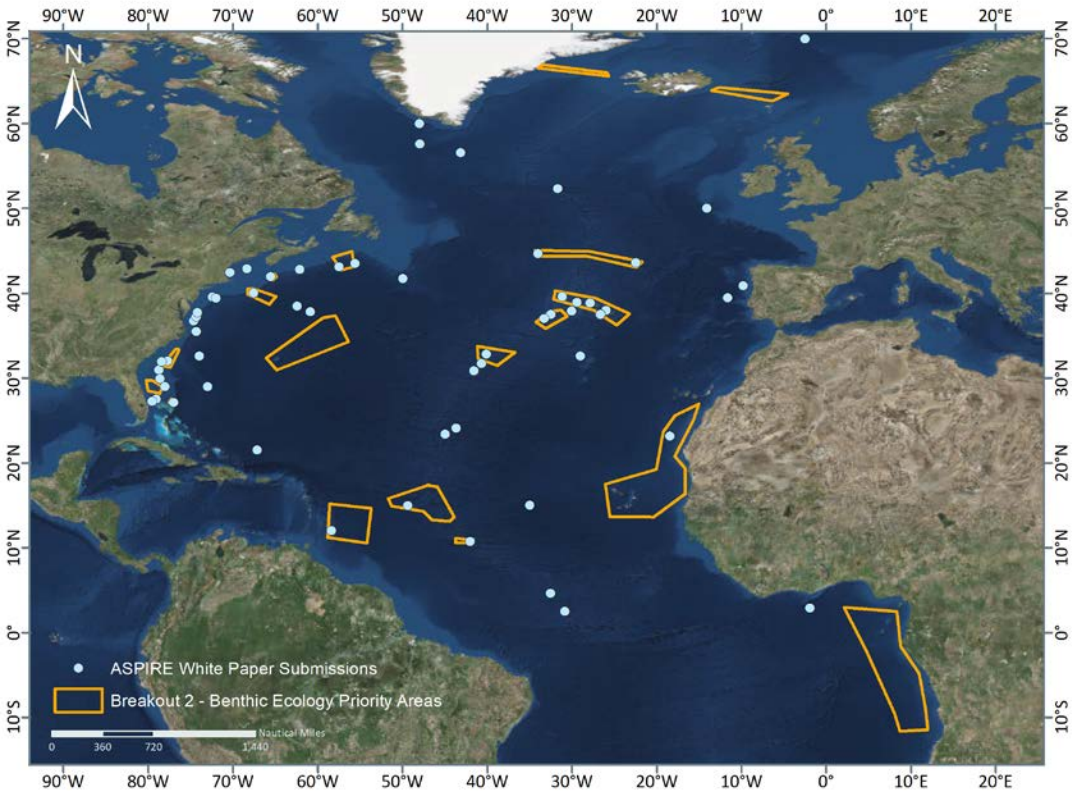

Figure 11. Map showing benthic ecology geographic priority areas identified during breakout session 2. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

The Benthic Ecology breakout group consisted of a diverse group of participants representing interests from across the Atlantic basin. Given the diversity of interests, the group first discussed benthic ecology needs on a holistic level, and then identified specific priority polygons on a regional scale, with only a subset of participants providing input for each area.

General data, samples, and/or measurements needed to characterize benthic ecology were identified as follows:

- Fine/large-scale spatial patterns (e.g., terrain, circulation, environmental factors—a/biotic)
- Migratory/resident species interactions with benthos (including economic fisheries relationships)
- Seasonality
- Community composition/assemblage structure (identifying comparative communities)
- Relationships between habitat and environment (including trophic dynamics)
- Macrofaunal communities (e.g., chemosynthetic communities, hard substrates, deep-sea mining)

While the group largely agreed that the platforms identified by the first regional breakout session had sufficient capability to meet benthic ecology exploration needs, they did note that eDNA sampling of both water and sediment is an emerging capacity that is still needed on many vessels, including NOAA Ship *Okeanos Explorer.*

Exploration priorities from the Benthic Ecology group were largely parsed out regionally, with the following targets identified:

1. **Southwestern Atlantic**
   Northern Bahamas, Richardson Hills reef complex, Million Mounds
2. **Northwestern Atlantic**
   NCSMNM, Northeast Channel, Laurentian Fan
3. **Eastern Atlantic**
   Icelandic coral and sponge grounds, Cape Verde, Angola Basin
4. **Central Atlantic**
   Researcher Ridge, Vema Fracture Zone, Altair Seamounts, Azores Plateau, and the central MAR

Data Gaps

- Non-active vent communities
- Unexplored seamounts and the ecological relationship across the MAR
- Many areas lack any data on benthic ecology

Partnerships

The group identified many potential partners in benthic ecological exploration, including: SponGES; ATLAS; Horizon 2020 partners; Merces; Food and Agriculture Organization of the United Nations (FAO); countries bordering target interests; regional fisheries management organizations; the ISA; NGOs such as Oceana, Pew, Blue Ocean Foundation, and the Sargasso Sea Alliance; Marine National Monument managers; and federal government agencies.

Geology, Mapping, Minerals

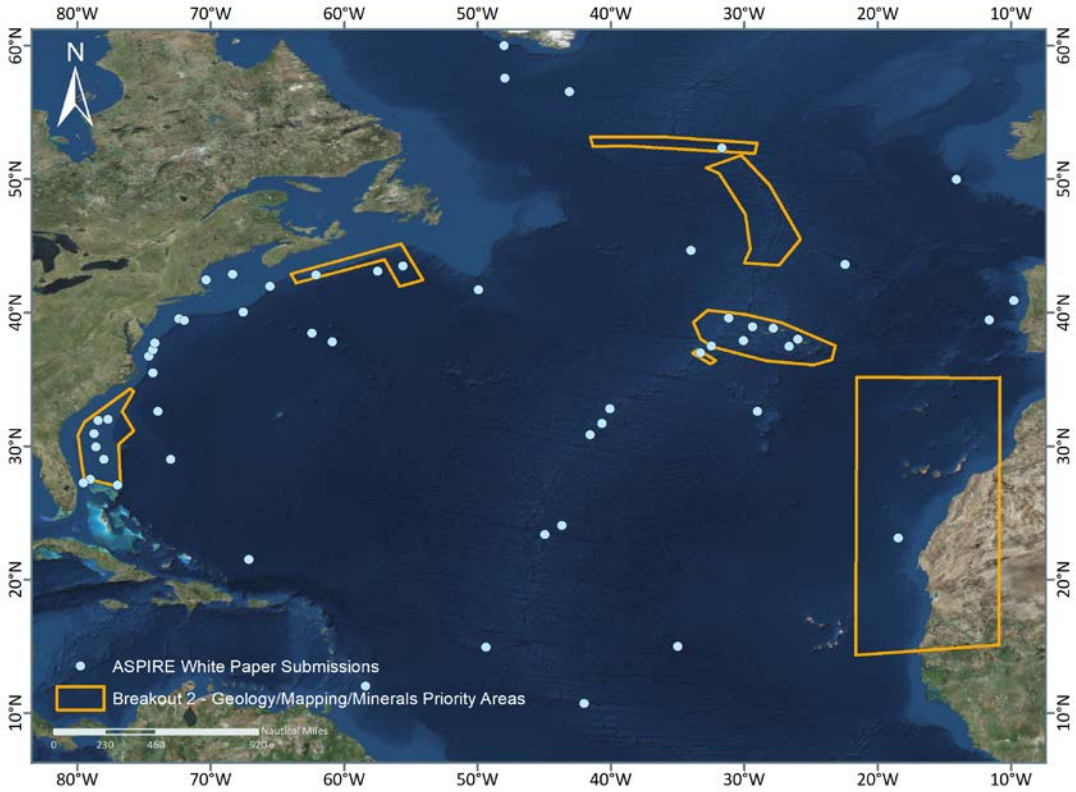

Figure 12. Map showing geology, mapping, and minerals geographic priority areas identified during breakout session 2. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

Because of the recent focus on the Blue Economy, countries have focused not only on their EEZs and ECSs but are also targeting the high seas. In particular, several permits have been obtained from the ISA for exploration in view of exploitation of benthic minerals by various countries. For effective geological characterization, a set of measurements was identified. These data sets include a full mapping suite of multibeam bathymetry, backscatter, water column, subbottom, and seismic data. These remotely-sensed data provide baseline information on the morphology of an area. To truly characterize an area geologically, however, it is necessary to also collect rock, sediment, gas, and water samples. A generalized guideline for sampling efforts cannot be provided, as the type and quantity of these samples will depend on the geological environment. Additional information obtained from CTD casts can also be very useful including pH, Eh, Fe, O_2, apart from temperature measurements. Finally, ROV video, images, and image mosaics can provide more details about the geomorphology of a site.

For the Atlantic Ocean, the two highest geological priorities were identified as the MAR and the Blake Plateau/Blake-Bahama Ridge. Lower priorities were identified to be the Laurentian Fan, Scotian Margin, and West Africa. Identifying where to go and what to do in these broad priority areas was identified as a challenge for ASPIRE. Within these broad regions however, ASPIRE could focus on smaller areas where an operational scenario could be developed and then applied to other areas. For example, for the MAR alone, there have been several initiatives to develop the foundation of geological understanding in a piecemeal way. However, these efforts can be supplemented by ASPIRE selecting a 50 km by 50 km area to work. The discussions concluded that the most interesting places to visit within the MAR will be the French-American Mid-Ocean Undersea Study (FAMOUS), Charlie-Gibbs, and the Azores Triple Junction. For the FAMOUS region, there could be two to four weeks of dedicated mapping one year, followed the next year by an AUV/ROV cruise. That would result in a better geological knowledge of the area and increased understanding of the impact of the geology on biota and benthic ecology, and, in particular, on the biological connectivity. The Charlie-Gibbs Fracture Zone is part of Iceland's ECS claim, and there is some mapping already completed by various groups (i.e., Ireland, Fugro, etc). These first studies led to the discovery of an abundant biota (e.g., sponges, skate nurseries, coral). There is also some evidence of venting, with a potential interest in the minerals. Along the western coast of the United States, the Blake Plateau and the Bahamas are of great interest, since the presence of rare earth elements and phosphorites in the sediments was recently identified. Because this area also has extensive and rich benthic habitats, the region is a very high mapping priority.

Data Gaps

Considering that vast sections within the high-priority areas are missing mapping data, an outside-the-box approach is needed to fulfill these data needs. Leveraging opportunistic, transit surveys could be a feasible option. In general, the abyssal plains, seamount chains, and the MAR are all areas that would benefit from more mapping efforts and support the Seabed 2030 project, environmental data acquisition, and geological sampling.

Partnerships

A host of potential partners were identified that could work in collaboration under the ASPIRE banner. Countries with EEZ and ECS claims and interests (e.g., France, Germany, Portugal, Russia, Poland, Canada) could be partners looking to extend the mapping coverage in the areas identified as geology priorities. Industry, defense organizations, and existing Atlantic partnerships were also identified as potential partners. In any case, it is of primary importance that the collected data be shared broadly.

Water Column

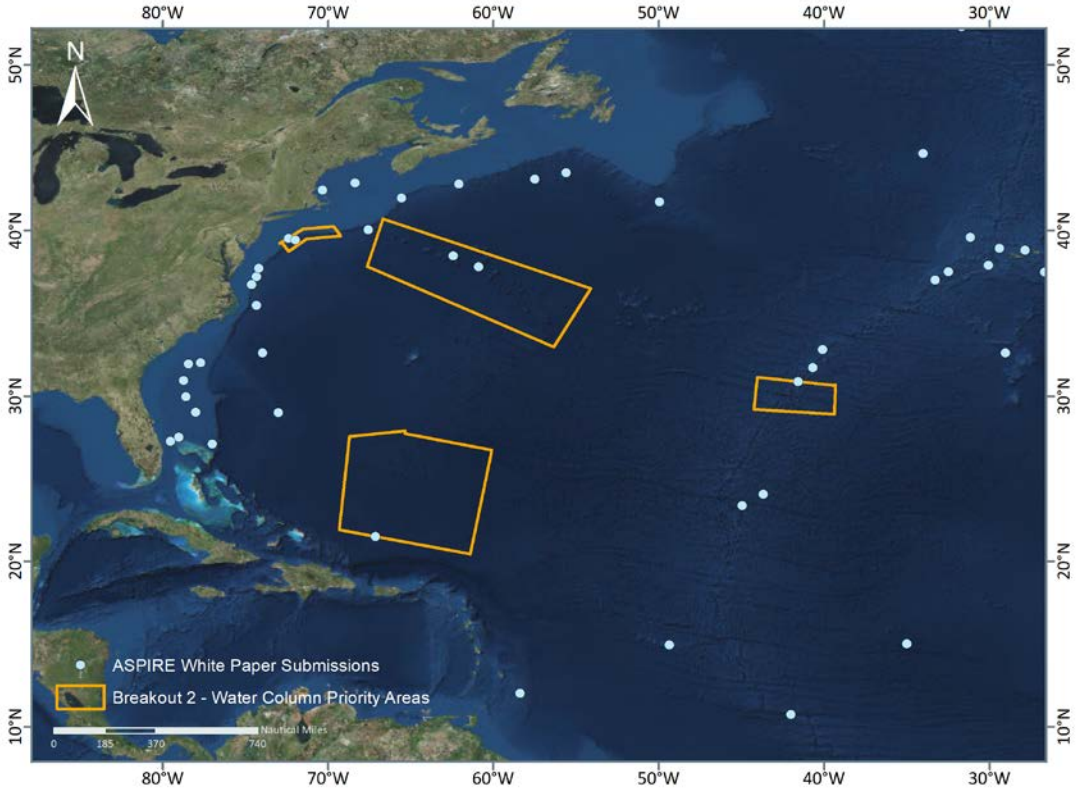

Figure 13. Map showing water column geographic priority areas identified during breakout session 2. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

Areas of particular interest for water column exploration included the New England seamounts and canyons, the MAR, and critical fish spawning grounds such as the western Sargasso Sea. As the water column throughout the global ocean remains poorly explored, the group expressed interest in conducting water column focused work throughout the entire North Atlantic basin as opportunities arise.

Data Gaps

Integrative studies that take into account multiple environments are often lacking in the exploratory context. Major gaps include documenting the midwater environment and organisms in the vicinity of notable features: (1) Seafloor—at the bentho-pelagic interface and near abrupt topography such as seamounts and canyons, (2) Open ocean—areas where large predators migrate (e.g., tuna spawning grounds), and (3) Areas of high chemical fluxes (e.g., hydrothermal vents). Basic habitat characterization—physical and chemical observations—is often lacking, even where imagery is collected of water column organisms. Connectivity studies are required to understand gene flow between water column regions (e.g., geographically, with depth). Because many mesopelagic organisms conduct diel vertical migration, it is critical to obtain nighttime, dawn, and dusk observations to understand the movement, behaviors, and interactions of this component of the deep-ocean ecosystem.

Data, samples, measurements
The participants highlighted the need to incorporate new technologies into NOAA Ship *Okeanos Explorer* operations in order to systematically survey the water column. Ideas included the use of plankton nets, acoustics, systematic CTD measurements (e.g., with tow-yo), and water collection (e.g., He^3). Such observations could be used to create water column "maps" to plan upcoming water column ROV work, similar to how seafloor mapping is used to plan benthic ROV operations. The group suggested that all or some of these systems be incorporated into NOAA Ship *Okeanos Explorer* mapping or transit legs. Another suggestion is that data collected by complementary assets such as drifters, moorings, satellites, and gliders could be better utilized for fieldwork planning.

In order to maximize limited time at sea, imaging systems could be deployed in tandem with ROV dives (e.g., ROV-mounted wirewalker, holographic camera) to collect water column data while the ROV is conducting seafloor operations. Water could be systematically sampled for eDNA to reveal the diversity and distributions of organisms in the water column.

A challenge for this community is to turn ROV dive video into scientific products, and the group suggested OER could convene groups in post-cruise data workshops to quality control annotations and identifications, and to work up the oceanographic data.

Partnerships
Partnerships were identified that would benefit the water column exploration component of ASPIRE and included working with physical oceanographers, hydrodynamic modelers, mooring and drifter networks, and EU and United Kingdom (UK) partners for the MAR component. The WHOI Ocean Twilight Zone initiative is a recently-funded, $35M project focused solely on water column exploration. Specific suggestions for partners included Cécile Cathalot, Valérie Chavagnac, and Ewan Pelleter from IFREMER (France); Wolfgang Bach and Nicole Dubilier from the University of Bremen (Germany); Rachel Mills, Blair Thornton, Jon Copley from the University of Southampton and Alessandro Tagliabue from the University of Liverpool (UK). Chris German from WHOI and Joe Warren from the State University of New York (SUNY) Stonybrook (U.S.) were also noted as researchers who may also be interested in this effort.

Marine Archaeology
Participants in the Marine Archaeology group started by explaining that there is a complete gap for high-resolution bathymetry data at sufficient resolution for UCH discovery in deep waters off the continental shelves, especially off the U.S. and Canadian east coast. The hull-mounted multibeam sonars of NOAA Ship *Okeanos Explorer* are not the best tool to find shipwrecks in deep water (generally below 1000 m). However, the sonar-derived bathymetry is critical for future AUV and ROV dive planning aimed at UCH. While mapping of new areas will support follow-on UCH surveys, higher resolution targeted surveys with other capabilities are still needed in most areas to discover and start inventorying UCH. Therefore, the findings from this workshop need to be used to support ocean exploration beyond NOAA Ship *Okeanos Explorer*.

Participants took a two-pronged approach to providing recommendations: (1) identifying considerations and improvements to expedition planning and data processing that maximize the

opportunity for UCH discovery and characterization, and (2) identifying broad geographic priority areas and the types of data and operations needed to support discovery of UCH, including key partners to engage to further identify and refine UCH priorities.

Expedition Planning and Data Processing Recommendations

- Broad geographic priority areas were identified during the workshop, but actual search boxes need to be a reasonable size. The group suggested follow-on meetings and workshops to engage region and subregion experts familiar with specific time periods, maritime traffic, etc., to narrow down search areas within a larger region.
- To maximize the opportunities for UCH discovery in OER- and ASPIRE-supported exploration, there is a need to identify multidisciplinary projects in marine archaeology priority areas that use the same tools as archaeology to acquire data to support multiple uses—note that tools vary with different UCH (e.g., shipwrecks, maritime cultural landscapes, paleoarchaeology).
- There is a need to raise awareness and identify opportunities for UCH investigations with other groups working in priority regions. It was suggested that OER have a protocol to take the lead to share and integrate archaeological priorities in other expeditions.
- Marine archaeology needs should be kept in mind during collection, processing, and analyses of mapping data. Ideally, mapping resolution should be adequate to address archaeology, keeping in mind the mantra “map once, use many times.”

Marine Archaeology Geographic Prioritization Strategy

- Prioritize coastal shelf and slope areas for approaches to harbors, battle areas, shipping channels, and paleo landforms.
- Identify landscape areas based on where high concentrations of UCH are likely to occur that require higher resolution mapping for inventory and discovery.
- Identify areas where higher resolution mapping, including subbottom data, are needed for paleo landform discoveries. Provide option of collecting deep sediment cores in these areas.
- Identify areas where multidisciplinary missions using appropriate tools could, and should, be leveraged to accomplish UCH priorities.
- In areas where no sonar bathymetry exists, coarser resolution bathymetry is a good first step for planning purposes.

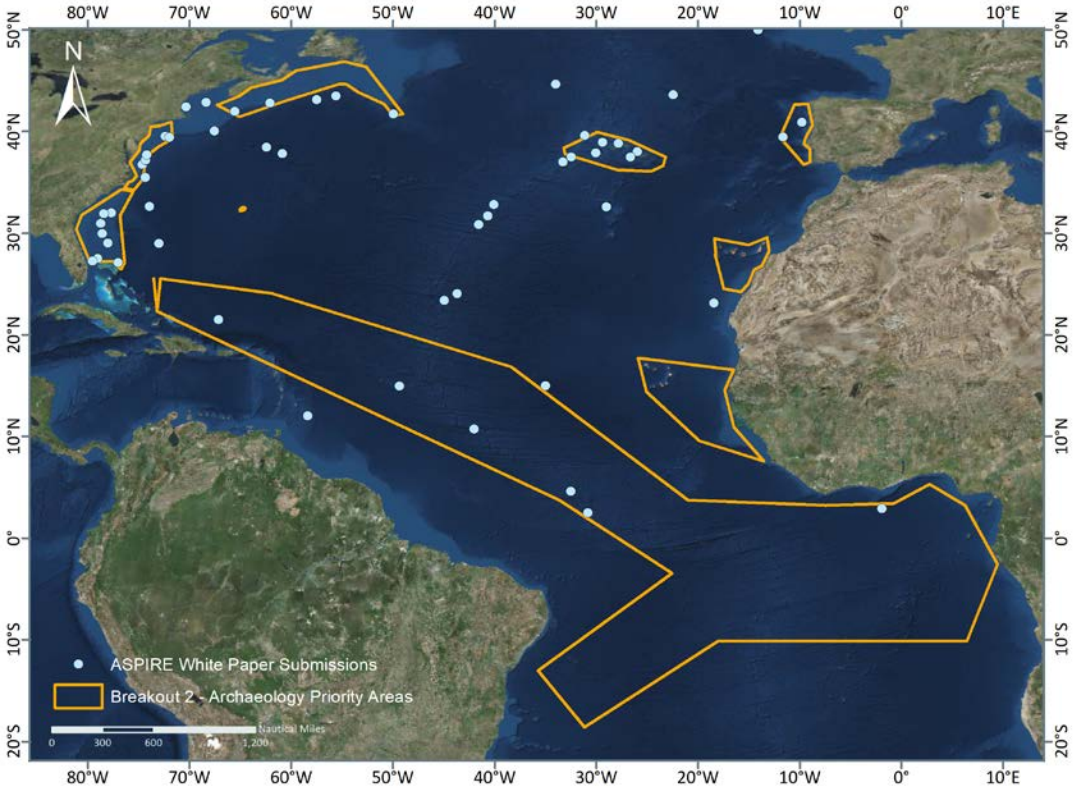

Figure 14. Map showing marine archaeology geographic priority areas identified during breakout session 2. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

The following broad geographic priority areas were identified for UCH investigation:

1. **Canadian Margin**
   High-resolution surveying is needed to identify UCH, including paleolandscapes, Canadian fishing wrecks, and high-priority targets such as the USCGC *Bear*. RMS *Titanic* is also located here and discussed in a white paper submission.
2. **Cape Hatteras to Long Island Sound**
   High-resolution surveying is needed for WWI, WWII, and potentially polluting wrecks. Battle of the Atlantic ships may also be in this area. Other priorities include the approaches to New York and Baltimore. Key partner/manager: Joe Hoyt, NOAA Maritime Heritage Program.
3. **Southeastern U.S. shelf wrecks**
   High-resolution mapping is needed to develop wreck site inventory. There are potentially polluting wrecks are in the area.
4. **Bermuda shipwrecks**
   There is interest in surveying wrecks offshore of Bermuda. Bermuda POCs: Ed Harris and Philippe Rouja. Scientists: Dominique Rissolo and Rod Mather.
5. **Slave Trade Route cultural heritage**

There is the potential to come across wrecks sunk in open water. The entire area requires additional mapping, especially deepwater high-resolution mapping, to discover possible wreck sites.

6. **Cape Verde**
   This area is currently completely unexplored. Surveying is needed for potential discovery of paleolandscapes and shipwrecks. There is the potential for discovery of Portuguese ships that were sunk while sailing around Cape Horn in southern Africa en route to India.
7. **Canary Islands**
   Surveying is needed for discovery of paleolandscapes and shipwrecks. Here, there is also the potential for discovery of Portuguese ships that were sunk while sailing around Cape Horn in southern Africa en route to India.
8. **Azores Platform**
   Interesting landscape work could be done here. Lost whaling ships could be in this area. Consult with Azores archaeologists for additional input.
9. **Wrecks off Portugal**
   There is the potential for discovery of shipwrecks of cultural value close to shore. See the Monteiro white paper (**Appendix C**) for detailed areas. Partners: Portugal government; Marine Protected Areas in the Atlantic Arc (MAIA).

Data Gaps

- There is a strong need for higher resolution mapping data. Most of the data currently acquired by the science community does not satisfy the resolution needed for identifying shipwrecks in deep water. Higher frequency subbottom data are also needed for paleolandscape studies and buried wrecks.
- There is a desire for diagnostic and high-priority samples, but NOAA Ship *Okeanos Explorer* currently conducts non-invasive surveying. There need to be procedures for high-priority samples.
- LiDAR should be used for coastal surveying.
- Characterization technologies that should be employed include laser scanners, 4K cameras, HD still cameras, and soft manipulators.
- The Marine Archaeology group recommended tighter line spacing and higher resolution grids in high-priority UCH areas.

Partnerships

- Areas without boxes may still have interest, they have just not yet been prioritized.
- Engage coastal state managers and archaeologists in identifying priority areas and planning surveys in foreign waters.
- Canadian partners: Canadian Hydrographic Service, Parks Canada.
- Nautical Archaeology Society.
- Engage tribal nations in paleolandscape surveys.
- State historic preservation offices and local and area university historians, archaeologists, relevant academics.
- U.S.: Naval History and Heritage Command, BOEM, private industry, USCG.
- Philanthropists: wealthy hobbyists who may be willing to support work.

General observations about the workshop and approach were also shared. Participants acknowledged a bias on the geographical recommendations based on the geographic areas represented or not represented by participants attending (this was true workshop-wide, not just for marine archaeology). It was suggested that future workshops include a meeting with the archaeology team in advance of the workshop to go over goals and objectives, and enable advance research to inform workshop input.

Connectivity

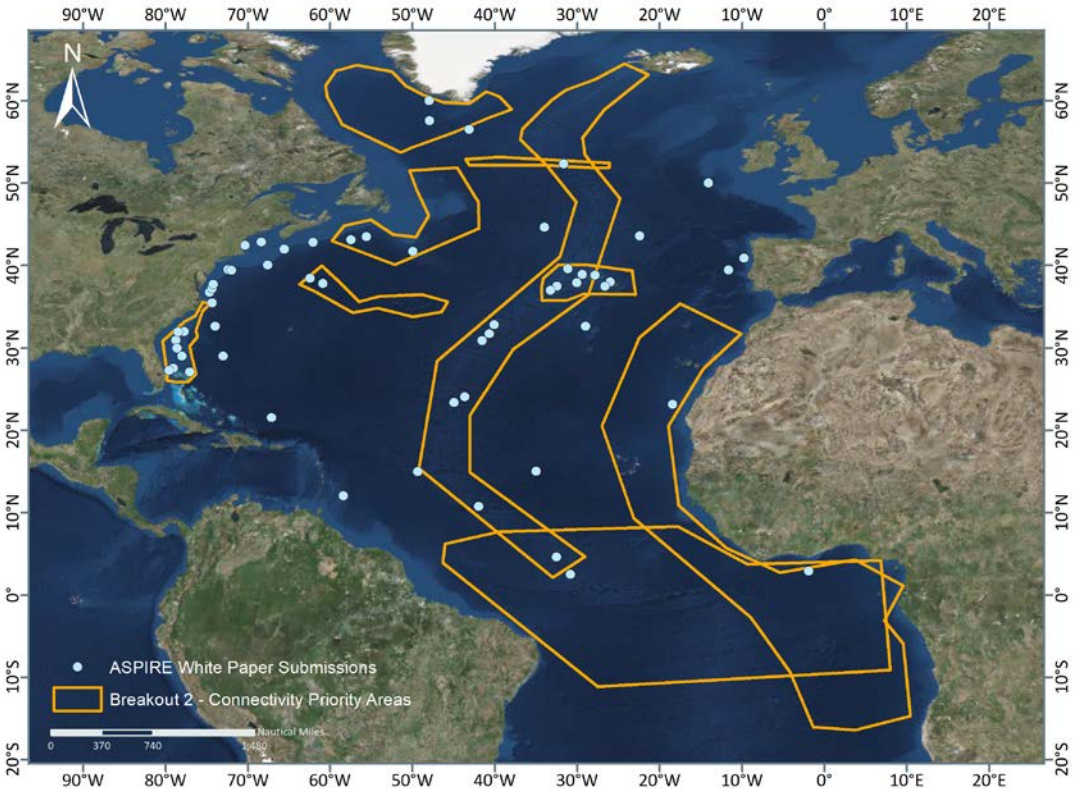

Figure15. Map showing connectivity geographic priority areas identified during breakout session 2. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

The deep sea is home to a diversity of ecosystems that, as a whole, are understudied. Of particular interest to this group was how these ecosystems interact and connect. Connectivity is the exchange and transport of individuals or genetic material among geographically-separated populations. Deep-sea connectivity studies often look across a large geographic area to determine how and at what rate populations are connected—from the larval dispersal stage to successful reproduction and successful recruitment in a new area.

Barriers, Conduits, and Stepping Stones

As the topic of connectivity is so broad and an emerging field, the Connectivity breakout group chose to focus on barriers, conduits, and stepping stones within the geographic regions. As discussed by the group, a barrier is something (e.g., a geological feature) that inhibits or prevents connectivity. A conduit is something (e.g., a current system) that promotes or enhances connectivity. Stepping stones are features that may help geographically-dispersed connectivity as they offer habitat, feeding grounds, or refugia for fauna or a population to aggregate around before either mobile fauna continue to a new location or sessile fauna release larvae into the water column for dispersal, contributing to connectivity. Exploring these dynamic drivers—and learning more about how each impacts regional communities—is critical to increasing our understanding of connectivity across the Atlantic Basin.

Table 1. Summary of the Regional Connectivity Discussion.

Geographic Region	Barriers	Conduits	Stepping Stones
Northwestern Atlantic	●Ice coverage ●Canyons ●Temperature ●Ocean acidification ●Carbonate compensation depth (CCD)	●Labrador Current ●Canyons	●New England seamounts ●Corner Rise seamounts
Southwestern Atlantic	●Canyons ●Gulf Stream ●Cape Hatteras/Gulf Stream offshoring	●Gulf Stream ●Canyon	●Blake Plateau ●Blake Escarpment ●Canyons ●*Lophelia* mounds ●Landslides/exposed heads of scarps
Central Atlantic	●Azores Platform ●MAR ●Currents	●Seamounts and ridges ●Fracture zones (particularly Charlie-Gibbs Fracture zone) ●Currents ●Gulf Stream	●Seamounts ●Azores Platform
Eastern Atlantic	●Canyons	●Canyons ●Landslides	●Seamounts

Data Gaps

- Standardized methods across sampling efforts
- Transport mechanisms
- Deepwater currents and the role they play in the deep sea
- Regional currents, particularly in poorly explored areas
- Complete understanding of the life cycle and life history of deep-sea biota systems
- Chemosynthetic/seep fauna connectivity

Data, samples, measurements
The biggest takeaway from the Connectivity group discussion was that there are fundamental data gaps that hinder our ability to fully understand connectivity across the Atlantic Basin. For example, a simple question like "What is invasive?" cannot currently be answered because we lack enough samples, data on population dynamics, and number of sites visited in the deep sea to determine if something is invasive or endemic. We are beginning to learn about pelagic and benthic connectivity, but pathogenic and microbial species connectivity is still largely unknown. Future connectivity studies should consider including these aspects as part of their sampling procedures. Additionally, connectivity studies are further hampered by proprietary and non-publicly-available samples from rarely visited sites that could help characterize the Atlantic Basin.

A recommended action from this group was to standardize sampling and data collections during transatlantic expeditions to better inform connectivity studies. As part of the ASPIRE campaign, and in response to community interest in connectivity across the Atlantic Basin, OER has added connectivity sampling to NOAA Ship *Okeanos Explorer* operations, specifically targeting a list of ASPIRE Target Species (**Appendix D**) identified by the community as important species that can contribute to basin-wide studies.

Next Steps and Conclusion

The Northwestern, Southwestern, and Central Atlantic groups collectively identified eight priority areas for exploration, as noted in the list below and geographically represented in **Figure 16**. The Eastern Atlantic group focused their recommendations on cruise planning processes and information gaps, given the diversity of stakeholder interests in the region. The Basin-Wide group did not provide final recommendations, as they did not meet during the final breakout session and instead joined any of the other regional groups. The priority area recommendations for exploration are as follows:

Northwestern Atlantic Ocean

1. Bermuda, the New England Seamount Chain, and the NCSMNM
    a. Subject area relevance: benthic ecology, water column, marine archaeology, connectivity
    b. Management connections: NCSMNM, deep-sea coral and sponge habitats, fisheries interests
2. New England and Canadian shelf break canyons to Laurentian Fan
    a. Subject area relevance: benthic ecology, geology/mapping/minerals, water column, marine archaeology, connectivity
    b. Management connections: U.S. and Canadian protected areas, deep-sea coral and sponge habitats, fisheries interests
3. Davis Strait/Iceland Transect
    a. Subject area relevance: benthic ecology, water column, marine archaeology, connectivity
    b. Management connections: fisheries, deep-sea coral and sponge habitats, ocean acidification

Southwestern Atlantic Ocean

4. Blake Plateau
    a. Subject area relevance: benthic ecology, geology/mapping/minerals, marine archaeology
    b. Management connections: potential rare earth minerals and hydrocarbons, potentially polluting wrecks, Seabed 2030 mapping
5. U.S. Southeastern Continental Margin and Bahamas
    a. Subject area relevance: benthic ecology, geology/mapping/minerals, connectivity
    b. Management connections: fisheries, deep-sea coral HAPCs, offshore energy management

Central Atlantic Ocean

6. Azores Plateau
    a. Subject area relevance: benthic ecology, geology/mapping/minerals, marine archaeology, connectivity
    b. Management connections: fisheries, deep-sea coral and sponge habitats, first deepwater exploration of MPAs, geohazards, global habitat models
7. Northern MAR/Charlie-Gibbs Fracture Zone
    a. Subject area relevance: benthic ecology, geology/mapping/minerals, connectivity
    b. Management connections: high seas MPAs (e.g., Charlie-Gibbs Fracture Zone MPA), global climate models, global seabed models, potential future minerals mining, Atlantic HMS
8. Southern MAR
    a. Subject area relevance: benthic ecology, geology/mapping/minerals, water column, connectivity
    b. Management connections: ISA lease areas, global climate models, deep-sea coral and sponge habitats, global seabed models, habitat suitability models

These recommendations serve as the basis for ASPIRE expeditions being planned for 2019-2021. All recommendations are now under consideration by OER and partners as outyear ASPIRE planning is completed. Relevant partners have or will be engaged in 2019-2021 NOAA Ship *Okeanos Explorer* expedition planning. This report provides additional details based on breakout group discussions and recommendations. The ASPIRE workshop was organized by OER and made possible with the organizational support of the University Corporation for Atmospheric Research (UCAR).

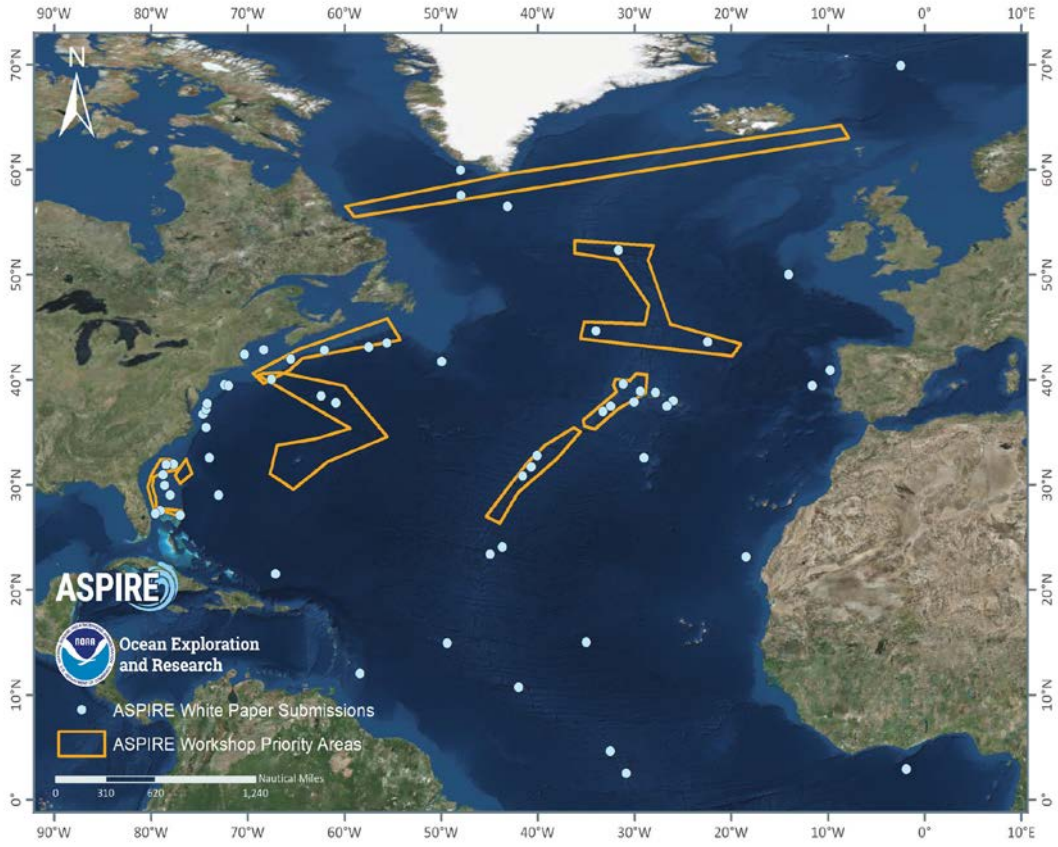

Figure 16. Map identifying final priority area recommendations received during the ASPIRE Science Planning Workshop. White dots are the general location of white paper submissions; orange polygons are priority areas for exploration identified during the workshop discussions.

Over the next two years, NOAA Ship *Okeanos Explorer* will conclude its time in the Atlantic and Caribbean Basins before transitioning to the Pacific in 2022. During the 2020-2021 field seasons, NOAA Ship *Okeanos Explorer* will incorporate feedback from the ASPIRE workshop to drive remaining expeditions while continuing to meet international commitments that align with the Galway Statement. OER is committed to meeting NOAA-wide initiatives to both map and characterize the U.S. EEZ by the year 2030. To achieve these goals, OER will be looking to capitalize on expeditions that satisfy these objectives. OER is also looking to incorporate innovative technologies that focus on autonomous systems for acquisition and processing of data. Based on these objectives, the community should expect to see a blended approach to meeting the objectives set forth in the ASPIRE workshop, U.S. EEZ 2030 goals, and the maturation of innovative technologies that address the optimization of mapping and characterizing the ocean. Additionally, a survey requesting additional input on potential areas of exploratory significance in the Atlantic will be released in August 2019. This survey will ask for feedback from the deep-ocean community based on the OER priorities, as mentioned in this paragraph that align with Atlantic-based ocean exploration, and results from this survey will be used to provide an additional layer of transparency to the community regarding expedition.

Appendices

ASPIRE

Atlantic Seafloor Partnership for Integrated Research and Exploration

SCIENCE PLANNING WORKSHOP · November 15-16, 2018

Sheraton Silver Spring Hotel · 8777 Georgia Ave., Silver Spring, MD · Fourth Floor Meeting Center - Cypress Ballroom

DAY ONE — NOVEMBER 15, 2018

8:30 AM	**Registration and Breakfast**
9:15 AM	**Welcome and Introductions** (Alan Leonardi, OER Director)
10:00 AM	**Background on OER and ASPIRE** OER 101 (Alan Leonardi, OER Director) ASPIRE Overview (CAPT Bill Mowitt, OER Deputy Director)
10:45 AM	**BREAK**
11:00 AM	**Galway Statement Presentation** (Terry Schaefer, International Activities Office, NOAA Office of Oceanic and Atmospheric Research)
11:15 AM	**EU Partnerships Presentation** (Joana Xavier, SponGES, University of Bergen; Marina Carreiro-Silva, ATLAS, University of the Azores)
11:30 AM	**Canada Partnerships Presentation** (Jennifer Higdon, DFO)
11:45 AM	**LUNCH**
12:45 PM	**NOAA SHIP *OKEANOS EXPLORER* LIVE INTERACTION / GROUP PHOTO**
1:30 PM	**Setting Stage for Breakout 1** Review group assignments, goals, questions, and timing
1:45 PM	**Breakout Round 1** See guidelines for breakout rounds below
3:45 PM	**BREAK**
4:00 PM	**Report Outs: Breakout 1** Q&A to follow each report out
5:00 PM	**Wrap Up Day 1**

HAPPY HOUR TO FOLLOW AT MCGINTY'S PUBLIC HOUSE
(911 Ellsworth Dr, Silver Spring, MD)

ASPIRE

Atlantic Seafloor Partnership for Integrated Research and Exploration

SCIENCE PLANNING WORKSHOP · November 15-16, 2018

Sheraton Silver Spring Hotel · 8777 Georgia Ave., Silver Spring, MD · Fourth Floor Meeting Center - Cypress Ballroom

DAY TWO — NOVEMBER 16, 2018

8:00 AM	**Breakfast**
8:30 AM	**Welcome and Review of Day 1**
8:45 AM	**Setting Stage for Breakout Round 2** Review group assignments, goals, questions, and timing
9:00 AM	**Breakout Round 2**
11:30 AM	**Report Outs: Breakout 2** Q&A to follow each report out
12:30 PM	**LUNCH**
1:30 PM	**Setting Stage for Synthesis Session** Review group assignments, goals, questions, and timing
1:45 PM	**Breakout Round 3**
3:15 PM	**BREAK**
3:30 PM	**Report Outs: Syntheses**
4:30 PM	**Wrap Up & Next Steps**
	MEETING TO CONCLUDE BY 5:00 PM

BREAKOUT ROUND 1: WHERE?

In the first breakout session, participants will be assigned to one of five regional groups. Each group will identify priority areas and features for exploration within the given region. These exploration priorities will be actively recorded into SeaSketch, an online collaborative GIS platform, by an OER staff member and will be made available to participants during and after the workshop. The goals and questions below should be used to guide the conversation. Each group should spend the last 10-15 minutes of the session assembling a brief report-out of their discussion using a pre-designed Google Slides template.

GEOGRAPHIC REGION BREAKOUT GROUPS

- **Northwestern Atlantic:** US EEZ north of Cape Hatteras, Canada
- **Southwestern Atlantic:** US EEZ south of Cape Hatteras, Caribbean
- **Central Atlantic:** Mid-Atlantic Ridge, Azores, Charlie-Gibbs Fracture Zone, High Seas
- **Eastern Atlantic:** Western Europe, West African Coast
- **Basin Wide:** Basin-scale interests that extend beyond regional boundaries

GOALS

- Identify exploration priorities in each region
- Identify methods and capabilities (i.e., assets and logistics) to address these priority areas
- Understand key individuals or players we should consider engaging
- Identify potential logistical challenges of working in this region

QUESTIONS

1. Based on the white paper submissions and your areas of interest/expertise, what areas or features do you recommend for exploration? Why?
2. Are there gaps beyond the areas identified in question 1?
3. How could these areas be explored? What platforms are available to reach these geographic areas? Partnerships and interested scientists/organizations in the region?

BREAKOUT ROUND 2: WHAT?

In the second breakout session, participants will be assigned to one of five subject area groups. Each group will review the summary map of regional priority areas and features created in breakout round 1 and identify those features most relevant to their subject area. If there are areas/features that were not identified on day one, subject area groups are encouraged to identify these as well. These thematic exploration priorities will also be incorporated into SeaSketch, and the goals and questions below should be used to guide the conversation. Each group should spend the last 10-15 minutes of the session assembling a brief report-out of their discussion using a pre-designed Google Slides template.

SUBJECT AREA BREAKOUT GROUPS

- Water Column
- Geology/Mapping/Benthic Minerals
- Archaeology
- Benthic Ecology
- Connectivity

GOALS

- Identify thematic exploration priorities within target areas from breakout 1
- Identify data, samples, methods, and capabilities (i.e., assets and logistics) to facilitate surveys, sampling, mapping, etc.
- Understand key individuals, players, and/or experts we should consider engaging
- Identify potential logistical challenges

QUESTIONS

1. Using the summary map from breakout 1, identify the most relevant features and areas for your subject in each geographic region. If there are areas/features that were not identified by the geographic breakout groups, what are they?
2. What information gaps exist and what data are required to address these needs for information? What are the broader research questions that could be addressed through exploration in this area?
3. What data, samples, and/or measurements need to be gathered to characterize these targets? Do the recommended platforms from breakout 1 have sufficient tools for meeting these exploration needs or are additional capabilities needed?
4. What partnerships and interested scientists/organizations are available or should be engaged for such work?

BREAKOUT ROUND 3: SYNTHESIZING THE WHERE, WHAT, AND HOW

Returning to the geographic breakout groups from Round 1, participants will summarize regional exploration targets and their relevance to subject area interests, as proposed in breakout round 2 groups. The SeaSketch input from both previous rounds will be displayed for reference, but this breakout is not focused on geospatial input. Instead, each group should develop synthesized exploration recommendations for their region, and give some thought to the overall weight of their assigned region in comparison to others. In addition to finalizing recommendations, each group should spend time considering next steps for the region and what is needed to accomplish the identified exploration goals. Each group should spend the last 10-15 minutes of the session assembling a brief report-out of their discussion using a pre-designed Google Slides template.

GOALS

- Identify and summarize critical community data/measurement needs
- Form regional exploration recommendations
- Summarize logistical challenges and identify next steps

QUESTIONS

1. What priority regions of interest were identified for exploration? Why?
2. What platforms and partners are available to support the execution of proposed exploration? What engagement opportunities are available?
3. What are the next steps needed to accomplish these prioritized exploration goals?

Science Planning Workshop
Sheraton Silver Spring Hotel, 8777 Georgia Ave, Silver Spring, MD
November 15-16, 2018

Remote attendees indicated in blue highlight. European and Canadian attendees indicated with bold text.

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2018 NOAA OER ASPIRE WHITE PAPER SUBMISSION

Contact Information
Primary Contact: Dr. Diva Amon
Home Institution: Natural History Museum, London, UK

Target Name
Seamounts, Abyssal Plains, The Deep Pelagic, Ridges and Hydrothermal Vent Fields

Geographic Area(s) of Interest within the North Atlantic Ocean
Southwest, South Central

Relevant Subject Areas
Biology, Geology, Chemistry

Description of Region Recommended for Exploration
Brief Overview of Area
The deep southwest and south central Atlantic Ocean, located approximately from 10° to 20°N and 40° to 56° E (Fig. 1), contains a variety of bathymetric features (seamounts, abyssal plains, ridges and hydrothermal vent fields). Few of these features have been well characterized despite many currently providing (or due to provide in the near future) living and non-living resources, e.g., fisheries, oil and gas, and minerals. Given the increased relevance of this region to the Blue Economy, both in international waters and in the national jurisdictions of many adjacent Small Island Developing States, as well as the interconnectedness of the our ocean, increasing our efforts to collect critical baseline data in order to understand, conserve, and manage effectively, is a priority.

Brief Summary of Current State of Knowledge and Rationale for Future Exploration
There is little existing knowledge of the seabed bathymetry, geology, and biological communities (including their connectivity) in the southwest and south central Atlantic Ocean. Given the increased use of this region, the need for exploration is great. Below, the current state of knowledge and rationale for exploration for the four main habitat types is given.

1) Seamounts
Hundreds of seamounts exist in this region with only a handful previously explored e.g. during the TROPICS expedition in 2013. Further exploration will likely reveal numerous deep-sea coral and sponge communities, including many that have the criteria of Vulnerable Marine Ecosystems (VMEs) or Ecologically and Biologically Significant Areas (EBSAs), similar to those discovered on the New England Seamounts. This is pertinent as the region has a productive longline fishery, which could have already impacted these sensitive habitats. Additionally, there are cobalt-rich crusts on several of the seamounts, a sought-after source of deep-ocean minerals, pointing to further potential impact.

2) Hydrothermal Vent Fields

The hydrothermal vent fields located on the Mid-Atlantic Ridge in this region (Ashadze 1-4, Krasnov, Logatchev 1 and 2, Irinovskoe, Semyonov 2, etc.) have been explored but are still not yet fully understood. These vent fields are amongst the deepest and hottest in the world and host chemosynthetic communities of anemones, shrimp, polychaetes, etc. Gaining a better understanding of these habitats is especially important given that they fall within the exploration contract area for polymetallic sulphides of the Government of the Russian Federation, and so are extremely vulnerable to human impact.

3) Abyssal Seafloor
Very little of the abyssal seafloor in this region has been explored. The limited surface productivity, depths and recent discovery of polymetallic nodules draw parallels to the Clarion Clipperton Zone, one of the most diverse areas of deep seafloor in the world, and also one of the most stable. The potential for new discoveries, both geological and biological, is very high, including of those relevant to the Blue Economy.

4) The Deep Pelagic
The deep pelagic realm is very poorly explored and any information gained will aid in its management.

NOAA OER's interest in pushing the boundaries of deep-ocean exploration and science is well suited to studying this poorly-known region of the ocean. This exploration also aligns itself with several of the specific goals of the ASPIRE Initiative. Additionally, the ROVs *Deep Discoverer* and *Seirios* are able to reach many of the deeper sites (4000-6500m) to document new finds and place them in ecological and oceanographic context. Finally, exploration of this region will ensure visually stunning and varied dives that will not only provide crucial baseline data that will enable further research effort, but also excellent outreach opportunities.

Relevant Partnerships
1) Natural History Museum, London, UK
2) National Oceanography Centre, Southampton, UK
3) University of the West Indies, Trinidad and Tobago

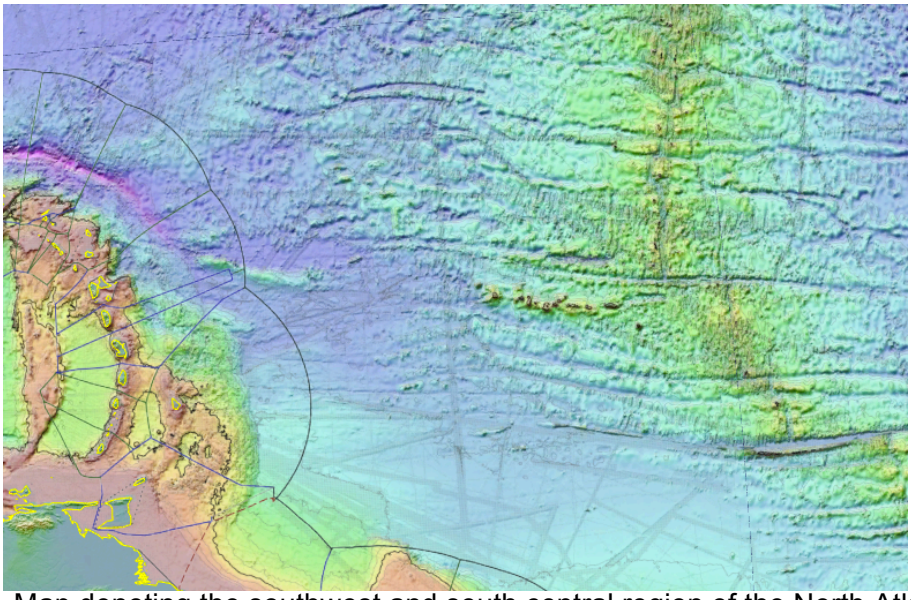


Figure 1. Map denoting the southwest and south central region of the North Atlantic.

Exploration of deep-seafloor communities along the Researcher Ridge seamounts

Contact Information

Steven Auscavitch, Temple University

Erik Cordes, Temple University

Target Name(s)

Research Ridge including, but not limited to, the following named seamounts: Gramberg Seamount, Molodezhnaya Seamount, Keldysh Seamount, Brekhovskih Seamount, Vayda Seamount

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

South West, South Central

Relevant Subject Area(s) (Indicate all that apply)

Biology
Geology
Oceanography

Description of Topic or Region Recommended for Exploration

Brief Overview of Feature

Researcher Ridge is the only high-profile seamount chain in the southern North Atlantic west of the Mid-Atlantic Ridge (MAR) (Fig. 1). The ridge consists of five named seamounts targeted as priorities for exploration along with many other lower profile features and knolls. Named features of Researcher Ridge are >3000m above surrounding seafloor and whose summits range in depth from 500m to 1200m water depth. The length of the ridge is approximately 180nmi from the westernmost (Gramberg Seamount) to easternmost feature (Vayda Seamount). Vayda seamount, is located approximately 75km due South of the Fifteen-Twenty Fracture Zone.

The potential for topographic diversity among these features is extremely high. These seamounts include cone-shaped peaks in addition to others that are composed of a more complex arrangement of ridge-crest topography along the entire breadth of Research Ridge. Brekhovskih Seamount, based on preliminary multibeam bathymetry, can be defined as a large guyot.

The existence of these seamounts is somewhat of a mystery as few published records on their formation exist. No records on the geologic age of this feature is available, however, there is an indication that these seamounts may have been formed by a tectonic hotspot (Epp & Smoot 1989) following a change in plate North and South American plate movement ~7Ma BP (Roest & Collette 1986). The location of these high-seas seamounts makes them an ideal target for geological, biological, and oceanographic exploration.

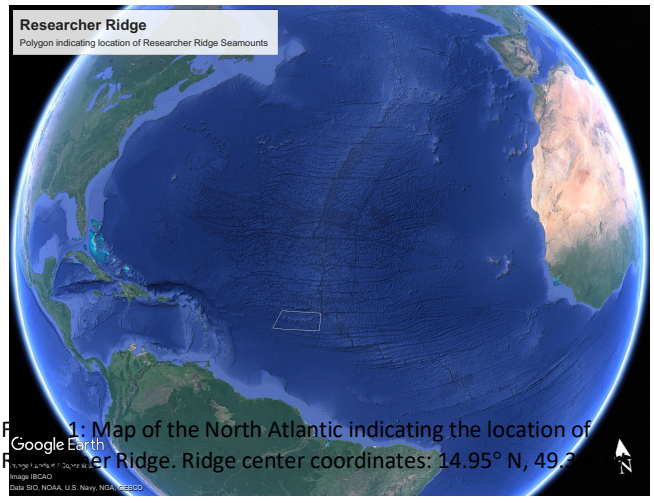


Figure 1: Map of the North Atlantic indicating the location of Researcher Ridge. Ridge center coordinates: 14.95° N, 49.2

Brief Summary of Current State of Knowledge

This area was partially mapped in 2014 by the R/V Knorr resulting in a base map for the ridge at a sufficient resolution for dive planning purposes (Fig. 2). Nevertheless, many gaps exist, particularly over several seamount summits, that would benefit from additional

mapping effort. The background on the geologic formation of these seamounts help to resolve changes to North and South American plate movement prior to 7 Ma BP (Pichot *et al.*, 2012 *Mar. Geo.*). There have been no remotely operated vehicle or human occupied vehicle surveys done on Researcher Ridge but DSV *Alvin* and the *Nautile* have operated immediately east on the MAR axis examining and collecting vent-associated faunas from bathyal and abyssal depths (Calder & Vervoort 1998).

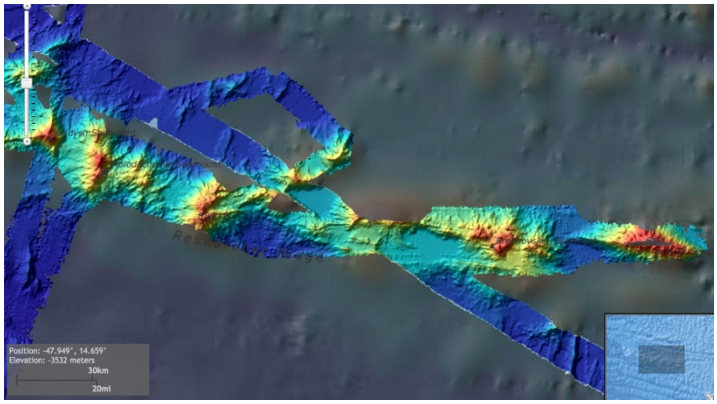


Figure 2: Existing multibeam bathymetry for seamounts of Research Ridge from a 2014 cruise on the R/V Knorr. Coverage is sparse from the central portion of the ridge and above several seamount summits.

Rationale for Future Exploration

Benthic structure-forming taxa, including deep-sea corals and sponges, dominate the megafauna of seamounts and generate habitat for associated seafloor organisms. Biogeographically, the oceanographic setting of these seamounts allows us to look more closely at the communities of benthic organisms inhabiting Antarctic Intermediate Water (700-1200m) as it moves northward into the north Atlantic Basin, as well as species inhabiting the North Atlantic Deep Water (>1200m) as it exits to the south. Water mass boundaries have been observed to be oceanographic transition zones where species turnover occurs (Victorero et al 2018 *Sci. Rep.*) and local and regional biodiversity is enhanced.

A comparison could be made of deep-water benthic communities at this latitude to similar features in the north Atlantic (Corner Rise and New England Seamounts) to explore patterns of species diversity among deep-sea corals and sponges and examine environmental filtering associated with changes in water mass structure over latitude in the North Atlantic Basin. An interesting oceanographic feature of this area specifically is a zone of low oxygen coincident with Atlantic central and intermediate water masses (Fig. 3). More intense low oxygen zones in the east of RR may harbor distinct species assemblages capable of tolerating oxygen-limitation.

Additionally, the location and depth range of the Research Ridge seamounts sets up an opportunity to examine the species relationships and connectivity between MAR hard-bottom non-vent faunas and those of adjacent seamounts at bathyal depths. Clarifying these relationships are exceptionally timely as parts of the MAR directly east of the Researcher Ridge complex are being considered for seafloor massive sulfide (SMS) exploration. In this case, off-axis seamounts in the area may act as population refugia for hard-bottom non-vent species in the event of SMS mining impacts. Finally, as Researcher Ridge is located entirely outside national jurisdictions, it is a potential target destructive activities including mineral crust mining and bottom-contact fishing which can result in permanent biodiversity loss and habitat destruction (Williams *et al.*, 2010 *Mar. Ecol.*; Van Dover *et al.*, 2017 *Nat. Geosci.*).

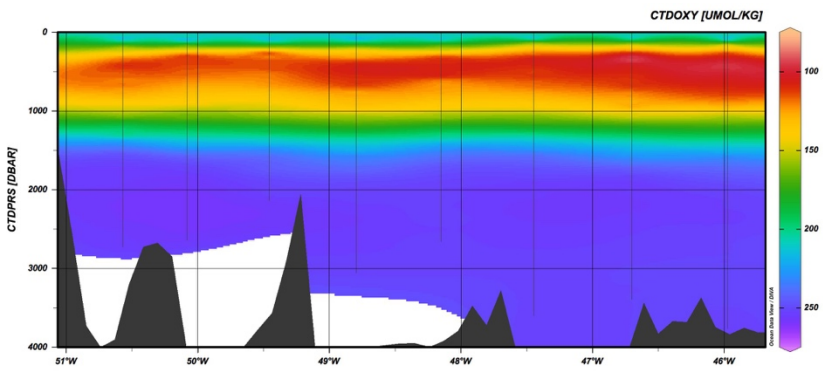


Figure 3: Longitudinal section of oxygen concentrations over 4000m depth along Researcher Ridge. The lowest oxygen concentrations of the water column are coincident with the summits of the Researcher Seamounts (500-1200m). Data obtained from CTD records via the CLIVAR & Carbon Hydrographic Data Office Database.

Proposed ASPIRE White Paper – "Search for the USS BEAR"

Contact Information Bradley W. Barr, Ph.D. ONMS Maritime Heritage Program
Bruce F. Buckley USCG Auxiliary

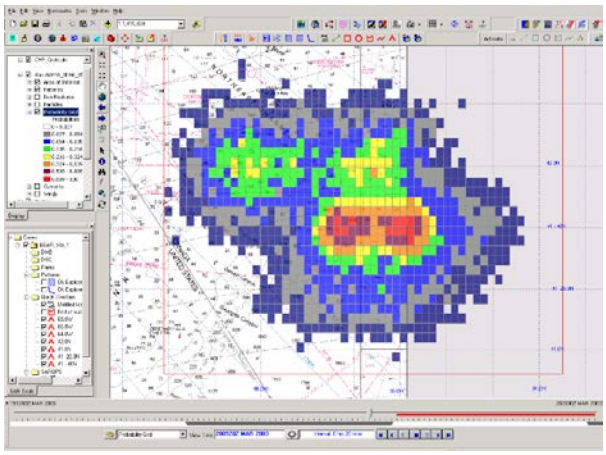
Target Name: Shipwreck of the US Revenue Cutter BEAR
Geographic Area of Interest: Northwest Atlantic
Relevant Subject Area: Maritime Archaeology

Description of Topic or Region Recommended for Exploration

Brief Overview of the Feature: In the entire maritime history of the United States, few ships have been routinely identified as "iconic" and "legendary", and none more historically-significant than the US Revenue Cutter BEAR. Largely associated with polar exploration, and particularly its Arctic service, the ship's history is a series of compelling stories of bravery in the face of peril, dedication to duty, and legendary exploits. Built in Scotland originally as a sealer in 1874, for the first ten years of service, she operated as part of the commercial sealing fleet off Newfoundland. Purchased by the US Government, it was put into service by the US Navy as part of the rescue fleet for the Greely Expedition to the Arctic in 1884, and first came to world-wide acclaim as the vessel that rescued the few survivors of that disastrous expedition. In 1885, the BEAR was transferred from the Treasury Department for service in the Arctic as a Revenue Cutter, and for an unprecedented 41 years ably patrolled the Arctic, saving lives and dispensing justice in this remote and often challenging region. Between 1886-1895, the captain of the BEAR was the legendary "Hell Roaring Mike" Healy, the first person of African-American descent to command a ship of the US Government. The CGC HEALY, commissioned in 1999 and routinely operating in Alaska, was named in his honor. Particularly notable was the so-called "Overland Rescue of 1897." Discovering that eight whaling ships were trapped in the ice off Barrow, the BEAR dispatched a small team from Nelson Island near the Bering Strait to drive a herd of 450 reindeer 1,600 miles in driving snow and perilous conditions to Barrow to provide food to the 275 men from the whaling ships stranded onshore. To this day, the US Coast Guard's highest honor for bravery is named for the leader of that expedition, Lt. David Jarvis. She stayed in meritorious service in the Arctic until 1917, when she was transferred back to the Navy during WWI, and after the war remained on patrol in Arctic waters. The BEAR was decommissioned by the US Government in 1929, and given to the City of Oakland, California, where she was repurposed as a maritime museum, and used as the movie set for the film of Jack London's "Sea Wolf." However, she was not long idle, as Admiral Richard Byrd purchased the still stout ship for his Second Antarctic Expedition. She was refit and performed admirably for both this successful expedition, in 1933-1935, and later for the US Antarctic Expedition of 1939-1941. During WWII, she again went into service for the US Navy in the Greenland Patrol, and notably participated in the capture of a German spy vessel, the trawler BUSKOE. Ending her service as a commissioned vessel in 1944, the BEAR was sold in 1948 to a Canadian steamship company to be re-converted to her original purpose as a sealer, but poor market conditions caused the company to abandon her on a beach in Nova Scotia. Saved from this fate

by an entrepreneur from Pennsylvania, who purchased the ship in the early 1960's to become a museum and restaurant near Philadelphia, Pennsylvania, she was lost while being towed to her new berth in 1963, and her final resting place lies, according to the position recorded at the time of the sinking, some 260 miles off Boston, approximately 90 miles South of Cape Sable, Nova Scotia. Some might characterize this was an ignominious end to such a storied ship that served so long and had such an extraordinary career.

Brief Summary of the Current State of Knowledge: While the general location of where the BEAR was lost was documented by the tug, IRVING BIRCH, that was towing her to Philadelphia, the precise location of the wreck is still unknown. Research has been conducted to attempt to better define a more discrete search area, most recently using the Search and Rescue Optimal Planning System (SAROPS) tool (see inset image) and the potential locations of the wreck have been narrowed down considerably since earlier work was conducted around 2010 related to a pre-proposal from the University of Connecticut to OER, which was ultimately not funded. There is an ongoing collaboration between OER and the USCG continuing the search for the BEAR, led by Bruce Buckley of the USCG Auxiliary with support from USCG Historian's Office and others. As part of this collaboration, work continues on refining potential search areas using existing data, as well as potentially employing the OKEANOS EXPLORER to visit these identified high-probability targets on a "ship of opportunity" basis, which will certainly advance this knowledge even further.



Rationale for Future Exploration: Clearly, this storied and historically-significant vessel is of great interest to the maritime heritage community, NOAA/ONMS Maritime Heritage Program, the US Coast Guard, and the University of Connecticut, who all have been consulted in the preparation of this white paper. It would be of considerably greater interest to the general public with the opportunity provided by continuing the search for the BEAR to frame the recounting of its Polar exploits. The history of the BEAR is compelling, and such an exploration would not only offer the opportunity to tell these significant stories of the ship's heritage to a wider audience, but the discovery of the final resting place of the BEAR would empower relevant agencies in the US and Canada (should the BEAR lie outside US waters) to insure the wreck is appropriately protected, preserved, and commemorated. With such a meritorious and notable history of service to the United States and the world, the BEAR deserves no less.

<u>Relevant Partnerships</u>

US Coast Guard; NOAA/ONMS Maritime Heritage Program; University of Connecticut; Government of Canada (if found in Canadian Waters). CCOM/JHC at UNH may be contacted to seek assistance in seabed mapping data acquisition and interpretation.

ASPIRE WHITE PAPER: GEOLOGY AND BIOLOGY OF THE AZORES SUBMARINE PLATEAU

CONTACT INFORMATION

Christoph Beier (marine geology, igneous petrology, geochemistry), *GeoZentrum Nordbayern, Friedrich-Alexander Universität Erlangen-Nürnberg*; Neil Mitchell (geophysics, tectonics, sedimentology), *Univ. Manchester, UK*

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DelWayne Bohnenstiehl (geophysics, seismology), *NC State University, USA*
Marine Carreiro-Silva (benthic community mapping, ecosystems), *Universidade dos Açores, Azores*
Eric Fielding (space geodesy, active tectonics, fault systems, landslides), *JPL, Caltech, Pasadena CA, USA*
Thor Hansteen (marine geology, petrology and volcanology), *GEOMAR Kiel, Germany*
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Paraskevi Nomikou (marine geomorphology, tectonics, volcanology), *University of Athens, Greece*
Telmo Morato (benthic community mapping, submarine ecosystem), *Universidade dos Açores, Azores*
José Pacheco (marine geology, volcanology), *Universidade dos Açores, Azores*
Rui Quartau (landslides, tectonics, marine geology), *Instituto Hidrográfico, Lisbon, Portugal*
Ricardo Ramalho (marine geology, tectonics, geochemistry), IDL *Universidade de Lisboa, Portugal*
Fernando Tempera (marine ecology), *MARE – Marine and Environmental Sciences Centre, Azores, Portugal*

TARGET NAME(S): Azores submarine Plateau

GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN: North Central Atlantic

RELEVANT SUBJECT AREA(S): Biology, Geology, Other: Geophysics, Oceanography

DESCRIPTION OF TOPIC OR REGION RECOMMENDED FOR EXPLORATION

Rising several kilometers above the surrounding ocean floor and intersecting water masses of multiple origins, the topographically-rich Azores Plateau is of exceptional geological and ecological interest. For decades, this enigmatic feature, which consist of a triple plate junction, hundreds of seamounts and 9 inhabited islands, has attracted groundbreaking marine geological and biological research. As important aspects on the origin of the magmatic rocks, the structural evolution and the biological distributions are still missing, detailed studies will have to continue. The lack of submarine samples and imagery from this unique geological and biological habitat and the interaction between volcanism, tectonic evolution and the biological communities here makes new exploration of great interest to a broad scientific community of biologists, oceanographers and geoscientists. Our white paper brings together exploration interests from a broad community of biologists, oceanographers and geoscientists working on three prominent issues: (i) the origin of magmatic eruptives at the Azores Plateau, (ii) the chronological and structural evolution of the edifices emplaced and (iii) the way the distinct and variably geomorphology regulates the distribution of biological assemblages.

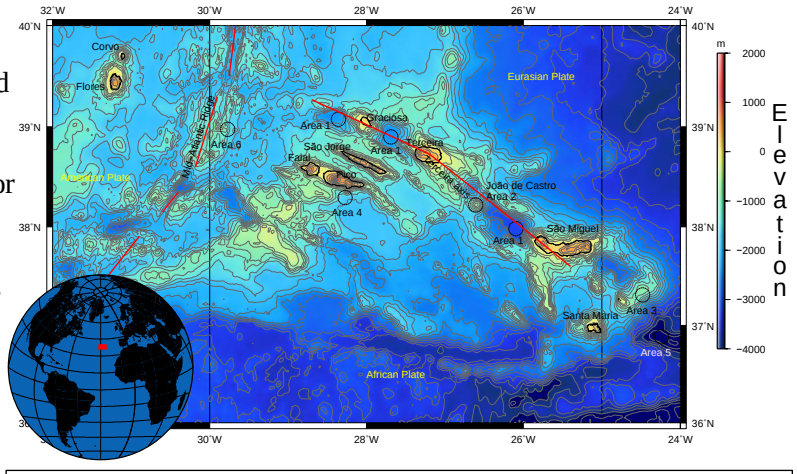


Fig. 1: Areas of interest for exploration in the Azores archipelago. Areas refer to hypotheses to be tested (see main text).

Filling these gaps is important for assessing critical hazards (e.g., landslides, volcanic eruptions, sea storms, ocean acidification and temperature changes, commercial fishing pressure and marine litter pollution), which may physically impact on human populations, the marine economy and ecology. Resolving these issues critically depends on further survey work across the full depth range and extent of the Azores Plateau. Using modern ROV technology to conduct image-supported collection of seafloor samples is instrumental, particularly in the poorly sampled deeper reaches of the Plateau,

which have been targeted by a limited number of expeditions (EMEPC/LUSO/AÇORES/G3 2008 and 2009 cruises and the RV Meteor M128 cruise in 2016).

We propose testing a number hypotheses in the course of an exploration cruise: a) do the deep basins along the northern Terceira Rift axis between the islands of São Miguel, Terceira and Graciosa show evidence for volcanic activity (Area 1 in Fig. 1), b) have the sedimentary deposits in these basins been influenced by hydrothermal venting and faulting in the past (Area 1), c) are biological vent communities in these areas similar to those in active intraplate hydrothermal systems, e.g., at João de Castro (Area 2), d) did faulting at the eastern Formigas bank influence the early igneous edifices in the Azores (Area 3), e) are both the eastern and western extensions of the Azores Plateau defined by volcanism that is chemically less enriched than that currently observed on the islands, f) can turbidites in the interisland basins be associated with recent earthquakes and, along with submarine fault breaks, assist earthquake hazard assessment (Area 4)?

The biological diversity of the Azores submarine plateau at deeper levels has barely been investigated. The interaction between geological structures and biological targets has rarely been studied, sampled or imaged during past cruises, but new exploration will allow a better understanding of the interaction between geological processes creating different substrates and the species settling in these environments.

The Azores archipelago is known to be highly active seismically and earthquakes can exceed M=6.0, as well as slope failure, volcanic eruptions and gas discharges. At present, the active lengths of faults and some of their recent offset histories are known from trenching and mapping on land, but there have been many earthquakes offshore between the islands, so it seems likely that the active lengths of faults are much larger, implying a risk of larger events. Imaging the structures of faults crossing the turbidite-floored basins between some islands could provide data on fault lengths, as well as data to constrain the timescale over which seabed breaks are preserved, before bioturbation and later turbidites destroy them, hence this problem requires biological input. The SE corner of the Azores Plateau, where the Terceira Ridge connects to the active Gloria transform Fault is also a source of seismicity that deserves attention (Area 5). In this place, strain partitioning makes earthquake focal mechanisms difficult to interpret and therefore more investigation is needed to better constrain active tectonics. Additionally, the area is key for our comprehension of the Azores Triple Junction, given that the onset of the Terceira Rift is linked to the deactivation of the East Azores Fault Zone, and the timing is poorly constrained. Samples and multibeam survey data would eventually shed light on this crucial moment in the evolution of the Azores (Area 5).

At shallower water depths (180-500 mbsl), multibeam surveys have recently provided evidence of past arrivals of icebergs to this remote mid-ocean mid-latitude area. Investigating the iceberg drag and bump marks on some Azores islands and seamounts will add a paleoclimatological aspect and also contribute to a better understanding of the forces shaping ocean island margins. ROV sediment push-core samples will be key to detecting stratigraphic discontinuities and estimating the age of these features (cf. Heinrich events?). Such information would contribute to timing extreme ocean climate episodes that likely explain the low levels of endemism of the fauna and flora currently present on the remote archipelago. ROV imaging of a selection of iceberg ploughmarks at >200m depth would further permit investigating whether the reshaped sediments exhibit vulnerable marine ecosystems (VMEs). Certain filter feeding assemblages of gorgonians, tall hydroids, scleractinian corals and sponges are known to colonize and exploit the ploughmark relief (levees, furrows) and form VMEs like corals gardens, coral reefs or sponge aggregations.

A new actively venting hydrothermal field named Luso has recently been discovered at the Gigante Seamount (Area 6), a few tens of km W of the mid-Atlantic Ridge and almost ~100 km W of the active Azores raises questions on its geological origin and whether other comparable vents exist in similar settings. The Luso site lies at only 570 mbsl and the geological, hydrothermal and biological characterization of its geomorphological context and water column imprint would greatly benefit from work with the multibeam, the echosounder and the Ocean Surveyor ADCP available onboard. Mapping the distribution and composition of fluid emissions, their hydrothermal deposits and the associated biological assemblages would benefit from further ROV surveys. The data will shed light on multidisciplinary topics such as a) the specific composition of biological vent assemblages sitting in upper bathyal grounds and what local physico-chemical conditions differ from those of deeper spreading-ridge sites and shallower hot springs, b) how off-axis magma dynamics function and what role the melt supply from the Azores melting anomaly has, c) how discharge relates to structural features and if those features are implicated in the formation and evolution of a new volcanic edifice, i.e. the position of Gigante Seamount in a E-W direction east of the mid-Atlantic Ridge may suggest that the off-axis magmas are focused into a transform fault system; this has rarely been observed in spreading axis systems globally and may be the result of the nearby placement of the Azores melting anomaly.

PARTNERSHIPS: InterRidge newly formed working group on mid-ocean ridge islands and seamounts

Exploring interactions between deep scattering layers and large-scale bathymetric features

Contact Information
Primary Contact: Kevin M. Boswell
Home Institution: Florida International University

Target Name(s): Continental slopes, canyons, and Mid Atlantic Ridge
Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)
Northwest, North Central, Northeast, Southwest
Relevant Subject Area(s) (Indicate all that apply)
Biology, Geology, Physical Oceanography, Other - Water column processes
Description of Topic or Region Recommended for Exploration
Brief Overview of Area or Feature
We are interested in the interactions between several large-scale bathymetric features (e.g., continental slope, submarine canyons, mid-oceanic ridge, seamounts) and the mesopelagic community (i.e. nekton and zooplankton), and in particular, we seek to use water column acoustic scattering data to measure deep scattering layers to better understand the processes that structure the vertical migration patterns of deep-sea organisms along a latitudinal gradient. Our primary request is for additional cross-shelf transects to be done over a 24-48 hour period (to capture migration events as well as day/night distributions) at a wide variety of latitudes (e.g., North Atlantic to at least the Caribbean) to increase the amount of available data regarding the movements of these features with respect to various bathymetries.

Brief Summary of Current State of Knowledge
The mesopelagic (200-1000 m) zone's spatial extent is approximately 60% of the area of the planet and constitutes nearly 20% of the volume of the world's oceans. The continental shelf margins bound the mesopelagic zone, abruptly transitioning into deeply sloping habitats leading to the abyssal plane. Mid-oceanic ridges also extend into the depths where migrating mesopelagics can interact with the benthic communities. The mesopelagic biological community is highly diverse consisting of fishes, crustaceans, cephalopods and gelatinous zooplankton, and aggregates in Deep Scattering Layers (DSL) that undergo daily vertical migration (DVM), transiting hundreds of meters between the meso- and epi-pelagic zones. These communities play a critical role in trophic pathways of the oceanic realm (Sutton 2013), and form one of the few connections between surface and abyssal waters. While migrating DSLs are ubiquitous across oceans, the patterns observed in DSLs are highly variable (Klevjer et al. 2016). Less well understood is the within basin variation, and in particular, how DSLs behave when encountering bathymetric features (Fig1).

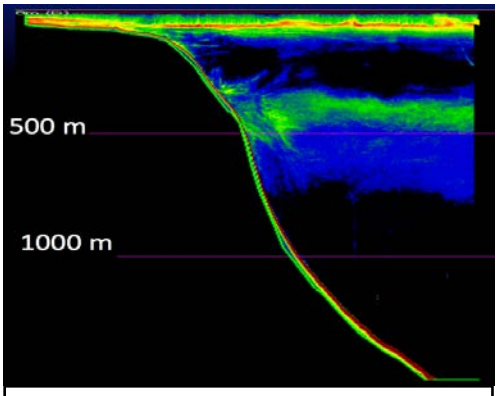


Figure 1. Example of DSLs detected at 38 kHz interacting with the continental shelf/slope at night in the Gulf of Mexico (Boswell unpub. data).

DSLs near a boundary can migrate both vertically and laterally (Fig 1) which can transfer carbon on or off shore as well as higher/lower in the water column with direct linkages between the migrating mesopelagic and the shelf communities. This vertical and lateral connectivity has important life-history and trophic implications, with direct consequences for material (i.e., carbon) flux in the ocean.

Rationale for Future Exploration
Recent estimates of the global mesopelagic fish biomass may be 10x greater than previously estimated (Irigoien et al., 2014, Proud et al. 2017). Given that many of these fish participate in DVM (Klevjer et al. 2016), the potential for fish alone to play a substantial role in active carbon transport in the World's oceans is immense (Davison et al. 2013).

There are few existing data sets that have broadband water column backscatter data providing multiple cross-shelf transects that capture the day-transition-night distribution and movement of the DSLs. The NOPP-funded ADEON program has suitable data at seven sites (ranging from VA to Northern FL) that were conducted in November 2017 and June 2018 (with another cruise scheduled for Nov 2018). There may be some additional data from NOAA NEFSC/SEFSC survey (such as AMAPPS), however these cruises do not focus on the shelf-break region and do not repeat transect lines over a 1-2 day period so they are not suitable for characterizing the diel movements at a particular location.

While not the focus of study, an evolving threat to the world's oceans is the impact of seafloor mining with potential to disrupt biological and ecological processes (Boschen et al. 2013). In particular, mid-oceanic ridges are known to contain an abundance of highly-valuable deposits (Hannington et al. 2011). Concerns of the associated sediment plumes within the water column hold unknow implications towards the mesopelagic community and in particular for those performing diel migrations and comprising the DSLs. More extensive datasets described herein will provide a working model on understanding broad-scale patterns in mesopelagic communities.

References

Boschen, R.E., Rowden, A.A., Clark, M.R. and Gardner, J.P.A., 2013. Mining of deep-sea seafloor massive sulfides: a review of the deposits, their benthic communities, impacts from mining, regulatory frameworks and management strategies. Ocean & coastal management, 8:54-67.

Davison, P.C., Checkley Jr, D.M., Koslow, J.A. and Barlow, J., 2013. Carbon export mediated by mesopelagic fishes in the northeast Pacific Ocean. Progress in Oceanography, 116:14-30.

Hannington, M. Jamieson, J., Monecke, T., Petersen, S., Beaulieu, S. 2011. The abundance of seafloor massive sulfide deposits Geology, 39:1155-1158.

Irigoien, X., Klevjer, T.A., Røstad, A., Martinez, U., Boyra, G., Acuña, J.L., Bode, A., Echevarria, F., González-Gordillo, J.I., Hernandez-Leon, S. and Agusti, S., 2014. Large mesopelagic fish biomass and trophic efficiency in the open ocean. Nature communications, 5, p.ncomms4271

Klevjer, T.A., Irigoien, X., Røstad, A., Fraile-Nuez, E., Benítez-Barrios, V.M. and Kaartvedt, S., 2016. Large scale patterns in vertical distribution and behaviour of mesopelagic scattering layers. Scientific reports, 6, p.19873.

Proud, R., Cox, M.J. and Brierley, A.S., 2017. Biogeography of the global ocean's mesopelagic zone. Current Biology, 27:113-119.

Sutton, T.T. 2013. Vertical ecology of the pelagic ocean: Classical patterns and new perspectives. Journal of Fish Biology 83:1508–1527.

Relevant Partnerships

Colleagues associated with existing deep sea programs have indicated interest in participating directly in this program: ***Joseph D. Warren***, Stony Brook University, associated with ADEON, DEEPSEARCH, and DEEPEND; ***Tracey T. Sutton***, College of Natural Sciences and Oceanography, Nova Southeastern University, associated with DEEPEND and DEEP SEARCH; Michael Vecchione, NOAA NMFS, assocated with DEEPEND; ***J. Christopher Taylor***: NOAA National Ocean Service; ***Ciaran O'Donnell***: Marine Institute, Ireland, associated with AORA; ***Nils Olav Handegard***: IMR, Norway, associated with MESOPP; ***Rudy Kloser***: CSIRO, Australia, associated with MESOPP.

2018 ASPIRE WHITE PAPER;

TARGET NAME, GEOGRAPHIC AREA: ***The SPAR offset at 69°N, Kolbeinsey Ridge, North Central Atlantic.*** SUBJECT AREA: ***Bathymetry, geology, geochemistry, rift-relocation, transform evolution, hydrothermal venting and biology.***

Contact information: Primary contact: Bryndís Brandsdóttir, Institute of Earth Sciences, Science Institute, University of Iceland
Other contacts: Neil Mitchell, Univ. Manchester, UK;
Carmen Gaina, University of Oslo, Norway;
Christoph Beier, GeoZentrum Nordbayern Erlangen, Germany;
Emilie Hooft, University of Oregon, USA;
Jeffrey A. Karson, Syracuse University, USA;
Isobel Yeo, National Oceanographic Centre, Southampton, UK;
Katrin Linse, British Antarctic Survey, Cambridge, UK;
Sæmundur A. Halldórsson, Inst. Earth Sciences, SI, Univ. Iceland.

Brief Overview of Area

The central Kolbeinsey Ridge (KR), north of Iceland, is the least explored region of the Northern Mid-Atlantic Ridge (MAR). The KR is of multidisciplinary importance, with fundamental seafloor spreading structures that deflect strong currents supplying nutrients to the biosphere. The central KR represents hot spot-influenced spreading that contrasts with the Reykjanes Ridge (RR) south of Iceland. The region also includes the SPAR offset or overlapping spreading center (OSC) at 69°N (Figure 1). The KR is of high importance to the blue economy, it is the feeding ground of newly hatched capelin (*Mallotus villosus*), currently the most important migrating fish stock in the N-Atlantic, and a key food of cod and other species. The region is closely monitored by the Meteorological Offices and Coast Guards of Iceland, Denmark and Norway (http://www.seaice.dk/) and is free of sea ice, except in late winter and early spring.

Brief Summary of Current State of Knowledge

Spreading along the KR was initiated at ~26 Ma following a westward ridge jump from the extinct Ægir Ridge [Brandsdóttir et al., *G3,* 2015 and references therein; Gaina et al., *Geol. Soc. London, Spec. Publ.,* 2017; Figures 1 and 2]. The slow-spreading (1.5-1.8 cm/yr) KR has since evolved through repeated axial reorganizations, the last at anomaly 3A time (~5.5 m.y.) when a sinuous ridge axis split into four segments with non-transform offsets (NTOs) and spreading segments more orthogonal to the spreading direction [Appelgate et al., *Geology,* 1997].

The influence of the Iceland hot spot on the adjacent ridges, has been recognized geophysically and geochemically since the 1970s. Bathymetry, magnetics and gravity data, suggests plume pulses with a 5 Myr periodicity extending hundreds of kilometers N and S from Iceland. Deeper pulses of the Iceland plume may explain the asymmetric crustal production between KR and RR [Abelson and Agnon, *EPSL*, 2001]. Relative to other Mid-Oceanic Ridges, basalts (MORBs) from the KR are highly depleted in trace elements, with low Na_8, suggesting relatively high degrees of melting, and high Fe_8, suggesting deep initiation of melting [Klein and Langmuir, *JGR,* 1987; Elkins et al., *Chem. Geol.*, 2016 and references therein]. Furthermore, major and trace element studies along the RR and KR support decreasing extent of mixing between plume and normal MORB sources and decreased melting with distance from the plume.

Seismic crustal thickness along Iceland's neovolcanic zones and the adjacent mid-ocean ridges also support a decreasing extent of melt production with distance from the center of the plume [Hooft et al., *G3*, 2006 and references therein; Figure 1]. At similar distances from the Iceland hot spot, crustal thickness along the KR is 2–2.5 km less than on the RR, consistent with the asymmetry in plume-ridge interaction inferred from their axial depth and geochemistry. The crustal structure and thickness along the southernmost 225 km of the KR decreases northwards, from 12-13 km next to Iceland to 9-10 km north of the Iceland shelf. A 140 km cross-axis profile at 68°N revealed significant undulations in Moho depth east of the ridge with a minimum of 6 km, beneath 7.5 Myr crust, 75 km from the ridge axis, increasing to 12 km in 10-12 Myr old crust [Furmall et al., *Eos Trans. AGU*,

2008]. Lower crustal high-velocity domes and corresponding gravity highs mark the location of active and extinct rift segments within Iceland and the southern KR. Volcanic seamounts (Figure 2a,c,d) represent locally enhanced magmatic productivity. Four prominent seamounts are located within the SPAR region, at variable distance from the active ridge axis (Figure 1 center). SPAR focal mechanisms reflect left-lateral movement along an E-W striking faults. Overlapping earthquake distributions suggest an overlapping spreading center, with the KR propagating southwards.

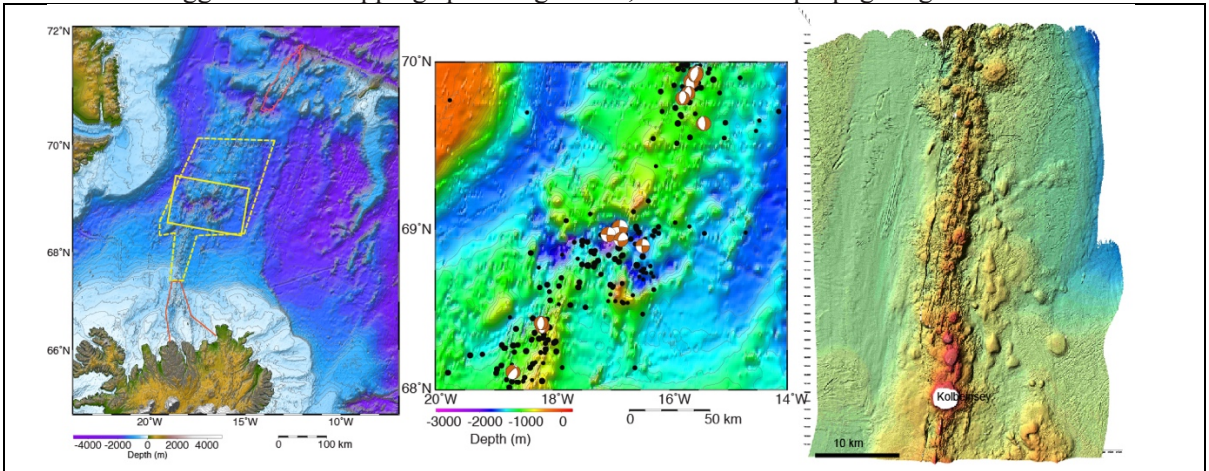


Figure 1, left: KR bathymetry based on ~100 m (30 arcsecond) grid from Smith and Sandwell, [2014]. Yellow dashed line delineates region to be explored, with emphasis on the SPAR offset at 69°N (yellow box). Red outlined regions have been mapped. Center: SPAR NEIC-earthquakes from 1970 (black dots) and CMT focal mechanisms 2005-2018. Right: EM300, 10 m gridded map of southernmost KR with segmented, left-stepping rift zones, along the plate boundary. Seamounts vary in size and distribution along the ridge axes. Sediment drape reflects relative age.

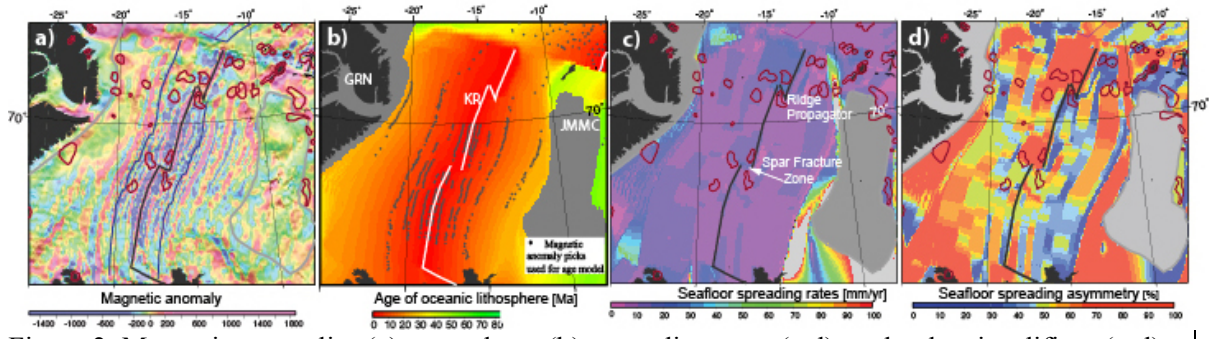


Figure 2. Magnetic anomalies (a), crustal age (b), spreading rates (c,d), and volcanic edifices (red) west of Jan Mayen Microcontinent, JMMC (Gaina et al., *Geol. Soc. London, spec. publ.,* 2017).

Rationale for Future Exploration:

Geology and geophysics: Mapping and sampling the KR and SPAR system will provide a contrasting view of hot spot-influenced spreading. The structure and timing of spreading processes can be contrasted for the KR and RR in the context of plume pulses. Further, as there are no comparable offsets on the RR, the evolution and migration of the SPAR offset can be assessed in the context of propagating rift zones and plume pulsations. Focusing on the young (<7 Myr) KR-SPAR offset at 69°N it will be possible to evaluate it as a migrating NTO, an OSC (rare on slow-spreading ridges) or some previously unknown type of structure. The glacial and post-glacial sedimentation drape along the KR is indicative of relative flow ages (Figure 1, right), using the distribution and backscatter intensity as a proxy for sediment thickness and hence age [Yeo et al., *EPSL*, 2016], will guide the identification and sampling of lava flows along the ridge axis. ***Geochemistry:*** Sampling the relatively steep fault scarps and volcanic edifices along the offset and adjacent KR can potentially provide the opportunity of sampling individual lava flows, in order to model the geological evolution of KR both in space and time. ***Hydrothermal and biological activity:*** Hydrothermal plumes have not been detected north of Kolbeinsey Island. Combined CTD and ROV surveys can search for hydrothermal venting and related biological activity in this poorly known spreading environment.

Relevant partnerships: ***The Marine Research Institute of Iceland; The Icelandic Coast Guard.***

CONTACT INFORMATION
CAPT. Richard Brennan, NOAA/OCS, Chief, Hydrographic Surveys Branch

TARGET NAME(S) [Main Feature(s)/Area(s) of Interest]: Outer Limits of Blake-Bahama Ridge

GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN (Indicate all that apply)
| Northwest | North Central | Northeast **X Southwest** | South Central | Southeast

RELEVANT SUBJECT AREA(S) (Indicate all that apply)
| Biology **X Geology** | Chemistry **X Physical Oceanography** | Marine Archaeology | Other

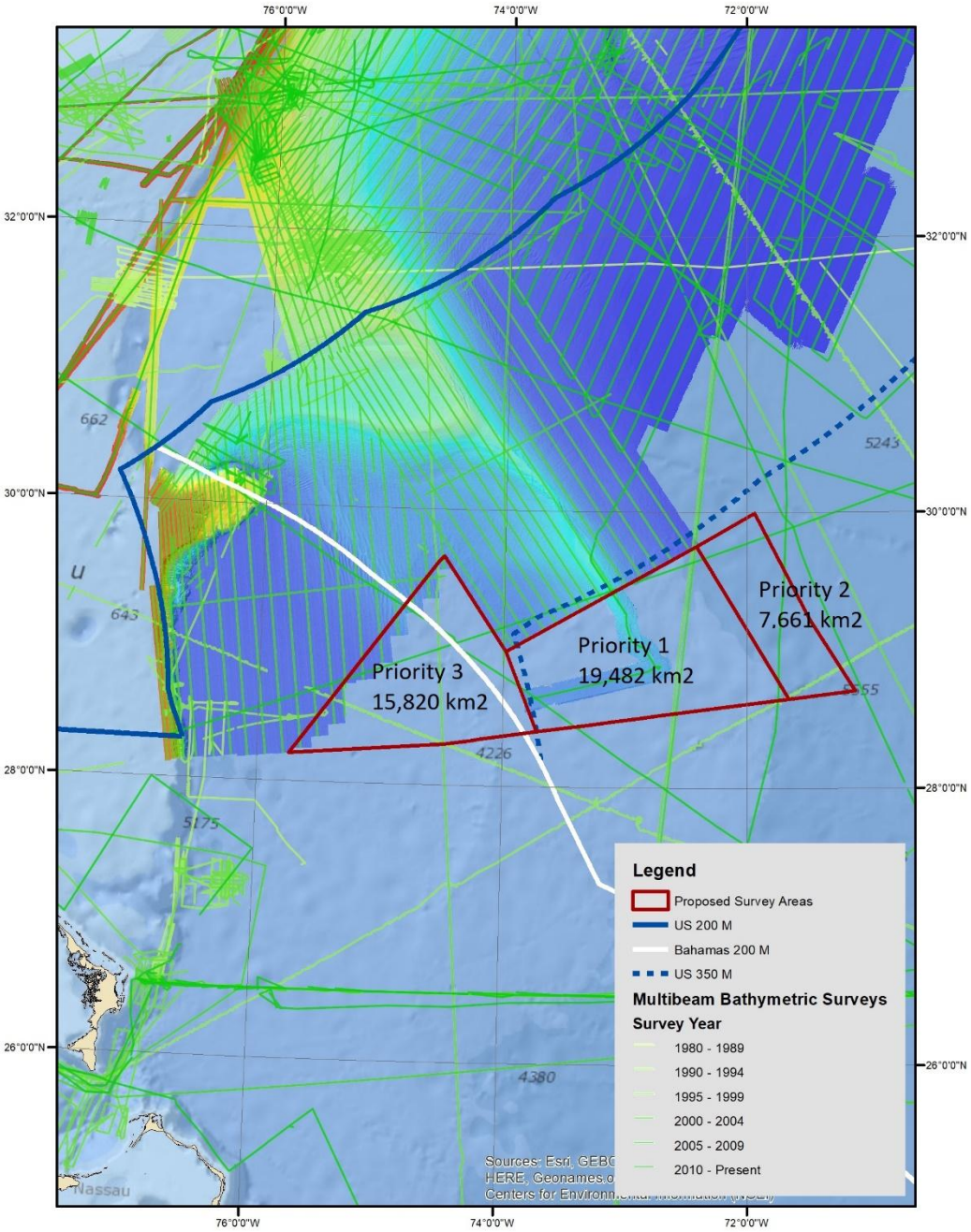
DESCRIPTION OF TOPIC OR REGION RECOMMENDED FOR EXPLORATION
Brief Overview of Area/Feature
The Blake-Bahama outer ridge is a complex sedimentary structure off the southeast coast of the U.S./southwest part of the North Atlantic Ocean, influenced by both underlying structure and regional currents along the margin.

Brief Summary of Current State of Knowledge
The seaward end of the Blake-Bahama Ridge is poorly defined, with only sparse bathymetric sounding lines crossing the area. The extensive literature in this area (see examples in URLs below) is limited by the lack of high resolution bathymetric information.
https://academic.oup.com/gji/article-pdf/195/3/1519/17052629/ggt327.pdf
http://www.whoi.edu/cms/files/Flood%26Giosan_45601.pdf
https://doi.org/10.1175/1520-0485(1997)027<2187:DFATWB>2.0.CO;2

Rationale for Future Exploration
Existing bathymetric data hints at subtle bathymetric detail that, if fully mapped, would provide much improved insight into the sedimentary and morphological processes of this important area of the continental margin. Additional bathymetry in the Blake-Bahama Ridge area would also assist the United States in convincingly establishing the outer limits of its continental shelf in this area. Moreover, the United States and the Commonwealth of The Bahamas are engaged in maritime boundary negotiations, including in the Blake-Bahama Ridge area. The two nations hold different views on several important matters, including the location of the base of the continental slope in this area. Thus, in addition to strengthening the U.S. documentation establishing the outer limits of the continental shelf, additional bathymetry would also help inform ongoing boundary negotiations.

RELEVANT PARTNERSHIPS (If applicable) (e.g. SponGES, ATLAS, Canada Healthy Oceans Network, etc.): The Atlantic Ocean Research Alliance Atlantic Seabed Mapping International Working Group SeaBed 2030, and US SeaBed 2030, Office of Coast Survey, USGS, Department of State.

Below is a figure (cut into priority sub-areas) and attached are shapefiles of the survey area we're interested in. The figure contains the survey area (outlined in red) and displays the MBS survey lines that currently reside in the NCEI repository. The proposed survey polygon is approximately 42,894 km2 and doesn't appear to have many overlapping MBS lines within it.



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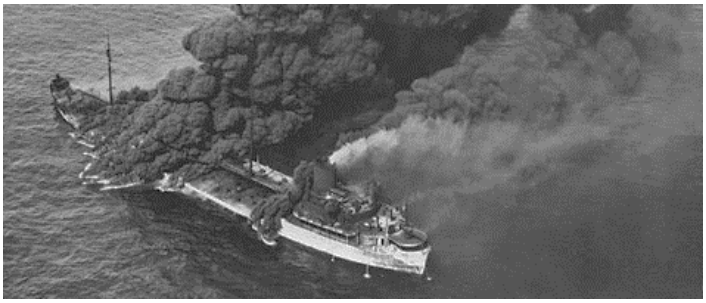


Figure 1. SS *Pennsylvania Sun* torpedoed by the German submarine U-571 in July 1942 (US Navy).

Target Name/Area of Interest
Potentially Polluting Shipwrecks (PPW)

Geographic Area of Interest
Southwest, Northwest

Relevant Subject Areas
Marine Archaeology
Chemistry
Biology

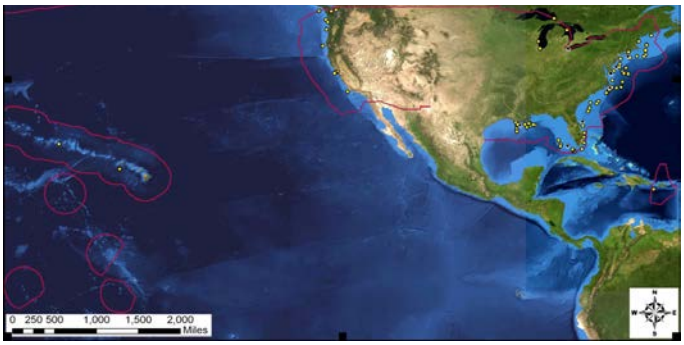


Figure 2. Location of 87 priority shipwrecks identified in NOAA's 2012 Potentially Polluting Wreck (PPW) study (NOAA).

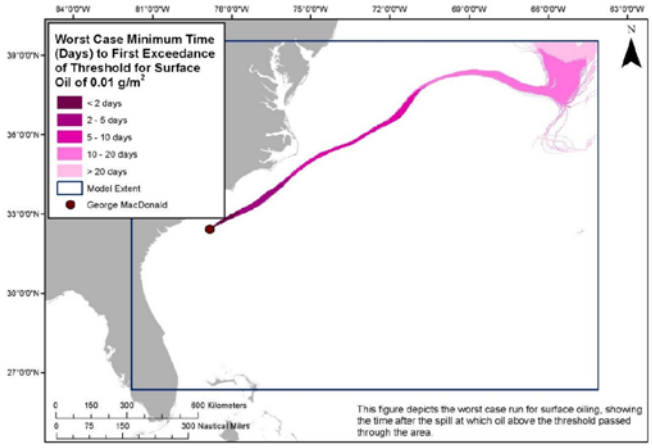
Description of Topic Recommended for Exploration

America's entrance into World War II awakened its industrial power as it sought to supply allies and its own fleets and armies in two oceans. Oil tankers and freighters transporting these supplies for the war effort became the targets of German and Japanese submarines seeking to interrupt the flow to the two fronts. Today, these sites represent a national maritime cultural landscape reflecting wartime maritime commerce. However, many of these wrecks still contain cargo and fuel and represent pollution hazards as corrosion in the marine environment weakens the hulls. Many of these shipwreck sites remain unlocated or undocumented yet are important historical sites as well as potential environmental hazards. Efforts to locate and characterize these World War II shipwrecks will assist with the determining their historical integrity and environmental condition.

The identification of 87 priority shipwrecks that pose a threat of oil or chemical spills in NOAA's 2012 Potentially Polluting Wreck (PPW) study was an essential first step at mitigating possible pollution events. However, five years after the study, only a minority of these wrecks have been investigated, while less than half of them have been located. A handful of shipwrecks have leaked oil, and the response has been to conduct large-scale remediation to remove fluids from the hulls and mitigate catastrophic leaks; however, the cost is too great, ranging from $25 million for the wreck of *Jacob Luckenbach* off San Francisco to more than $70 million for the wreck of USAT *Brigadier General M. G. Zalinski* in Canadian waters. In each of these instances, it was determined that the oil leaking out was due to shifting currents moving oil out of small overhead spaces in the shipwreck, and there was little to no oil remaining in the hulls.

In 2016, archaeologists from NOAA and SEARCH took advantage of a cruise of opportunity with E/V *Nautilus* to lead a dive remotely through telepresence from the Inner Space Center at the University of Rhode Island on the wreck of SS *Coast Trader* off Victoria, British Columbia. Through this one dive, it was able to be determined which bunker tanks survived the torpedo impact and that there was little corrosion present, effectively lowering this wreck's pollution risk factor. Such comprehensive assessments are able to characterize the wrecks' potential environmental impacts, hull or tank condition, and determine the overall site stability without the large cost of reactionary remediation.

During World War II, dozens of merchant tankers and freighters were sunk by German U-boats off the US east coast and in the Gulf of Mexico during the Battle of the Atlantic. A number of tankers and freighters on the PPW list have never been found or identified. Many PPW are potentially eligible for listing on the National Register and their identification will provide a greater understanding of the war's undersea maritime cultural landscape. U-boat activities during Operation Drumbeat in 1942 spanned the entire eastern seaboard of the United States resulting in merchant ship casualties from the Gulf of Maine to the Florida Keys and into the Gulf of Mexico. The potential impact of pollutant spills from these wrecks, however, is not limited to the western Atlantic. Modelling of oil movement from these wreck sites in the PPW study show much of the oil moving eastward throughout the Atlantic due to the influence of the Gulf Stream.



Water surface oiling from the most probable spill of 11,500 bbl of heavy fuel oil from *George MacDonald* shown as the area over which the oil spreads at different time intervals (NOAA 2012)

Support from the ASPIRE campaign can assist with mapping efforts to locate and characterize PPWs allowing scientists to determine level of risk to local communities, the environment, and sensitive marine resources resulting from a release event. The increased knowledge about PPWs will help better inform response managers to prioritize what sites are a hazard and warrant detailed assessments. Next steps could include an archaeological, biological, and hydrocarbon assessment, analysis of the hull stability and thickness, and oil type, quantity, and location. This information will ultimately result in recommendations for removal of polluting substances or stabilization.

Relevant Partnerships

National Oceanic and Atmospheric Administration (ONMS, OER, OR&R)
Bureau of Ocean Energy Management
Coast Guard

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Target Name/Area of Interest
Shipwrecks of the Slave Trade

Geographic Area of Interest
Southeast, South Central, Southwest

Relevant Subject Areas
Marine Archaeology
Biology

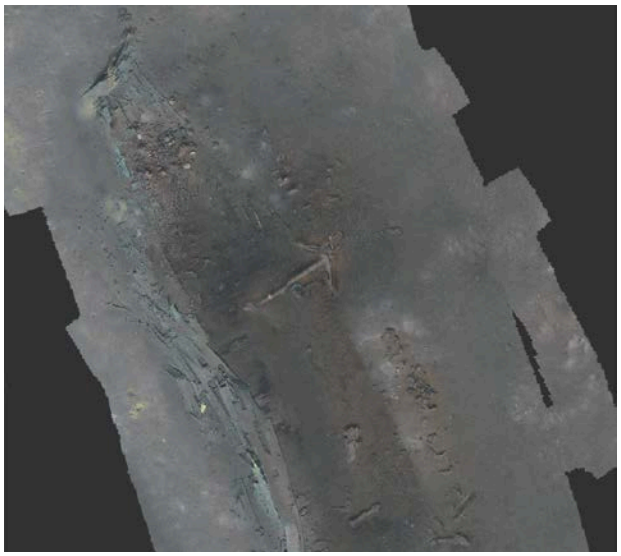


Figure 1. BOEM site Monterrey C may be connected to the Trans-Atlantic slave trade (BOEM).

Description of Topic Recommended for Exploration

In recent years, archaeologies of internment have viewed places of people in confinement as archaeological sites and documented the ways in which people modify space to make it habitable, even when imprisoned (Moshenska and Myers, 2011). While concentration camps from World War II and prisons have received attention, an area lacking in investigation are the slave ships that brought people from Africa to the Americas, largely due to the scarcity of sites. Between 1501 and 1867, an estimated 12.5 million Africans were captured, sold into slavery and forcibly transported to the New World (Eltis et al., 2010). During their passage (in total, more than 35,000 voyages) an estimated 1.8 million people died as a result of illness, suicide and in some cases, were murdered by throwing sick or rebellious persons overboard, at times chained together.

The oceanic route navigated by the slavers is relatively well known as an infamous highway marked on the maps as the “Middle Passage.” In the physical world, this route may be discerned by what lies underwater, either in the form of shipwrecks associated with the slave trade, or by the material that may survive from what was cast over from ships engaged in the trade. Other than shipwrecks, what may exist in the depths would be evidence of the throwing overboard of dead or dying slaves. One other possibility for maritime remains also exists on the routes of the transatlantic slavers. It reflects the practice of murdering slaves, in particular in the nineteenth century in order to evade prosecution as a slaver during the period when the slave trade (but not slavery) was banned and anti-slavery naval patrols were in effect on the route. In short, a physical record of this most infamous trade likely exists in the South Atlantic’s depths, discernible at its faintest traces perhaps as a section of anchor chain with shackles attached, in and by itself a chilling thought.

The Slave Wrecks Project (SWP) identifies over 590 vessels involved in the African slave trade that were lost between the sixteenth and nineteenth centuries. Archaeological evidence of

these sites is minimal and only consist of six known sites: *Sao Jose Paquete d'Africa* off South Africa, *Henrietta Marie* in the Florida Keys, *Wydah* off Massachusetts, *Fredensbourg* off Denmark, *James Matthews* off Australia, and Q*ueen Anne's Revenge off North Carolina.* Only one of these, *Sao Jose Paquete d'Africa*, was carrying slaves when lost. One hypothesis for the identity of the Monterrey C site (pictured above) in the Gulf of Mexico, is having been involved in the slave trade, as no other cargo is visible, and warrants further investigation after its initial assessment in 2013 with E/V *Nautilus*. Current efforts are underway to located the pirate slave ship *Guerrero* in the Florida Keys and the *Clotilda* near Mobile, Alabama, the last vessel to import slaves into the United States.

Support from the ASPIRE campaign can assist in deep-water mutibeam mapping and ROV operations to locate sites linked to the slave trade. The trade's shipping routes, known as the Triangle Trade, connected Africa with the Caribbean and New England through the Straits of Florida. These are the high probability places where slave ships might have sunk. More specifically, surveys between Senegal and Cape Verde Islands, along the Gold Coast, and South America's northeastern coast might also yield potential targets and could be areas where initial mapping operations are undertaken. Archaeological evidence of the slave trade might consist of an entire shipwreck site with a hull and evidence of human cargo or hard to detect manacles or shackles on the seafloor. While un-pleasant to consider, such archaeological evidence of these crimes would not only verify them, but bring the physical reality to light.

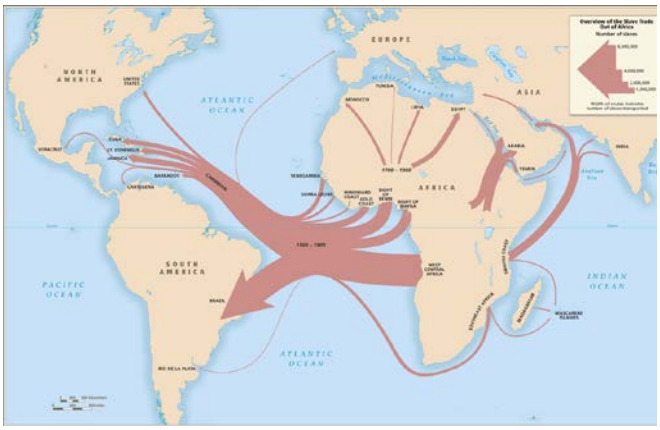


Figure 2. African Slave Trade Routes 1500-1900 (Trans-Atlantic Slave Trade Database)

Relevant Partnerships

Bureau of Ocean Energy Management (BOEM)
Slave Wrecks Project
Smithsonian Institution's National Museum of African American History and Culture
National Park Service
National Geographic Society
NOAA (ONMS, OER)

Eltis, D., D. Richardson, D. Blight, and D.B. Davis (2010) *Atlas of the Transatlantic Slave Trade*, Yale University Press, New Haven.

Moshenska, G. and A. Myers (2011) An Introduction to Archaeologies of Internment, in *Archaeologies of Internment*, Springer, New York, pp. 1-19.

2018 ASPIRE WHITE PAPER SUBMISSION

CONTACT INFORMATION

Primary Contact: Sandra Brooke Ph.D.
Home Institution: Florida State University Coastal and Marine Lab

TARGET NAME

Northern margin of the Little Bahama Bank: deep coral reefs and canyons.

GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN (Indicate all that apply)

Northwest North Central Northeast
Southwest South Central X Southeast

RELEVANT SUBJECT AREA(S) (Indicate all that apply)

X Biology X Geology Chemistry
X Physical Oceanography Marine Archaeology Other

DESCRIPTION OF TOPIC OR REGION RECOMMENDED FOR EXPLORATION

Over the past several decades, a large amount of information has been generated on the deep slopes of the southeastern US continental margin from the Carolinas to Florida. These studies described vast deep-water coral habitats that support diverse and abundant sessile fauna and their associates, including fisheries species such as golden crab, royal red shrimp, deep water groupers. Adjacent areas in Bahamian waters are understudied by comparison, but recent mapping efforts in the region have revealed large areas of potential deep sea coral mounds, canyons and other complex topography. The few areas of the deep Bahamian slope that have been explored, show different temperature-depth profiles and species assemblages from those reported in the continental US. The dominant oceanographic feature in this region is the Gulf Stream, which flows northwards between the western (continental US) and eastern (insular Bahamas) sides of the Florida Straits. The Gulf Stream waters create a sufficiently continuous environment from their origin in tropical latitudes, to sub-tropical latitudes further north, that many benthic and demersal organisms have ranges extending from northern South America to the southeastern US. The Gulf Stream flow could serve as a conduit for population connectivity among deep sea communities and fishery resources in the US and Bahamas. Alternatively, this powerful current could create a biogeographic barrier between communities on either side of the axis.

The proposed exploration region encompasses three general areas (described below) of the northern Little Bahama Bank (LBB), and addresses the ASPIRE program goals to 'explore and characterize physical, geological and biological features and processes across the North Atlantic, including international waters'. The primary physical feature in the proposed region is the Gulf Stream, which influences geomorphology, species distributions and population connectivity within the region and beyond. The proposal encompasses ecologically and economically valuable benthic habitats, many of which are unexplored, in a region of future energy development and

potentially expanding fisheries activity. The information collected will help understand links between US and Bahamian deep sea communities and optimally will lead to combined efforts at management and conservation of shared natural resources.

1)*Western LBB*. Distributional ranges of many deep-water benthic and demersal taxa extend north along the continental US side of the Florida Straits, often reaching biogeographic barriers at the Carolinas; whereas many on the eastern Bahamas side occur no further north than the western corner of the LBB (e.g. 21 Scleractinia, 11 Octocorallia, ~35 Decapoda, 13 Crinoidea, ~50 Asteroidea, and 5-10 fishes). This region may therefore represent the northern extent of deep-water tropical western Atlantic fauna, but species descriptions have been limited to scattered trawl and dredge surveys. Recent detailed mapping of a portion of this area has revealed major topographic features, including an escarpment in 275-460 m surrounding an ancient slump feature, an isolated 50 m tall pinnacle, and a field of smaller pinnacles, which may be coral mounds in 450-570 m. The biological communities associated with this unusual topography have not been investigated and this area coincides with the northern limit of many tropical deep-water taxa, making it an excellent candidate for exploration and investigations into biogeographic boundaries.

2) *Mullins' Reefs.* Mullins *et al.* (1981, 1984) reported an area of features described as coral mounds (1000-1300 m) patchily distributed across an area of at least 2,500 km² on the northern slope of LBB. These features are > 60 km east of the well-documented mounds of the western Blake Plateau in US waters, which support a diverse fauna of corals, sponges, octocorals, antipatharians, hydroids, and other invertebrates and fishes. Dredge samples of the Mullins reef area included eleven genera of scleractinian corals. The majority were solitary, but the branching coral *Solenosmilia variabilis* and the solitary *Bathypsammia* sp. were the dominant stony corals, whereas *L. pertusa* absent, probably due to the depth of the mounds. Much of the northern LBB slope was recently mapped, including the area of Mullins' *Solenosmilia* mounds. These maps show a complex area of shallow canyons and furrows, with a significant escarpment separating this zone from a flatter area to the north. Small dots scattered through the area might represent Mullins coral mounds. The combination of a possibly unique (to the western Atlantic) *Solenosmilia*-dominated reefs and the other complex seafloor structures make this area a fascinating target for exploration

3) *Great Abaco Canyon.* Canyon geomorphology causes currents to be funneled along the axis at sufficient speed to remove sediment and expose hard substrates. These are colonized by sessile benthic fauna (such as corals and sponges) that are not found on the sedimentary slopes, therefore canyon biodiversity is generally higher than surrounding slope areas. Numerous canyons dissect the outer margin of the US continental shelf from North Carolina northward. However, over 800 km separates the southernmost of these from three canyons on the Blake Escarpment north of the Bahamas. The geology of the largest, Great Abaco Canyon, was studied in 1975 and 1977, and one ROV dive in nearby Little Abaco Canyon documented the presence of deep corals and higher fish diversity than continental canyons further north. We propose to explore Great Abaco Canyon and collect baseline data on benthic faunal composition, zonation, and distributional limits, for comparison with continental canyons to the north and deep island margin faunas to the south.

RELEVANT PARTNERSHIPS

Dr. C. Messing, NOVA Southeastern University, Mr. J. Reed, Harbor Branch Oceanographic Institute, Cape Eleuthera Institute, Smithsonian Museum of Natural History, others TBD.

2018 ASPIRE WHITE PAPER SUBMISSION

Contact Information

Jamshid Gharib and Kelley Brumley

Fugro

Willing to Attend Workshop?

Yes

Target Name(s)

Atlantic Margin Cold Seeps

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

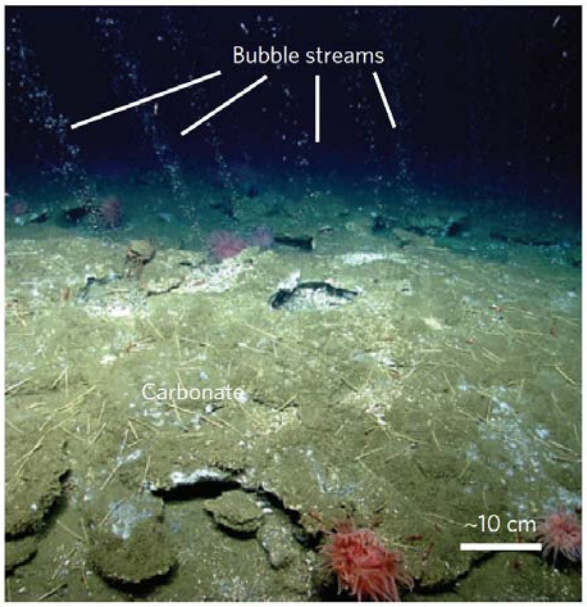
All

Relevant Subject Area(s) (Indicate all that apply)

Geology, Chemistry, Biology, Geophysics

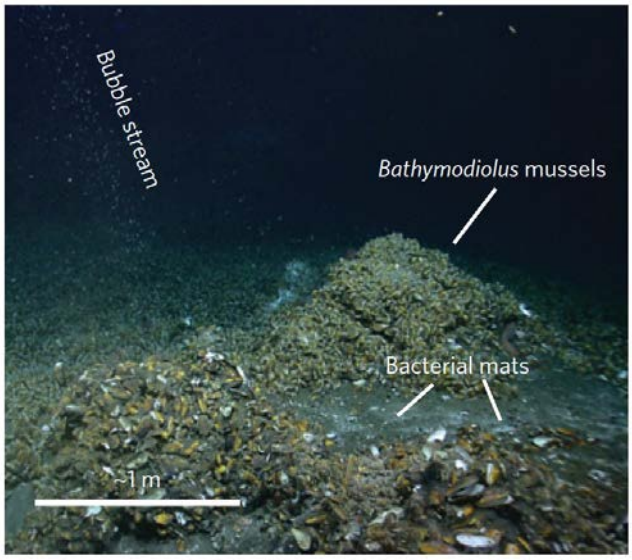
Description of Topic or Region Recommended for Exploration

The first evidence of widespread methane seeps on the Atlantic Margin was described by Brothers et al., (2013) during ACUMEN expeditions, and Skarke et al., (2014) utilized ACUMEN MBES data to report shallow seeps formed due to dissociation of solid methane hydrate. In this area, deeper seeps differ morphologically from shallower seeps, and support distinct chemosynthetic communities and authigenic carbonate mounds (Skarke et al., 2014; Brothers et al., 2013). These morphological differences suggest that geochemistry may be correlative with different habitats, which in turn, yield different MBES responses as suggested by Fisher et al., (2013) in the Gulf of Mexico. The ability to link characteristic seep geochemistry to MBES response along the Atlantic Margin will improve remote sensing methods for determining the extent of hydrocarbon seeps and allow for greater protection and avoidance of these important ecosystems.



ROV videos from 2013 *Okeanos Explorer* expeditions, showed shallow seeps (<600m mbsl) were associated with carbonate crusts, bubble streams, and pockmarks (left, Dive EX1302 no. 10 from Skarke et al., 2014). Thin carbonate crusts were common and benthic communities present at this type of seep typically consisted of small tube worms and bacterial mats. This type of seep is likely to predominantly consist of methane sourced from the dissociation of gas hydrates where seeps exist above the gas hydrate stability zone (Skarke et al., 2014; Brothers et al., 2013).

Seeps described at greater water depths in this area (>1000m mbsl) exist within the gas hydrate stability zone, which suggests gas hydrate dissociation is an unlikely primary source for methane release (Skarke et al., 2014). These seeps display characteristically distinct morphology with thriving benthic communities consisting of chemosynthetic clams, mussels, lobsters, shrimp, and tube worms, as well as massive authigenic carbonate mounds (right, Dive EX1302 no. 4 from Skarke et al., 2014). Skarke et al. also observed that these seeps appear in sublinear clusters (2014), which suggests structural control of seep locations, and may indicate faults are utilized here as migration pathways to the surface for a mixture hydrocarbon fluids from depth.



Although seeps have been identified along the Atlantic Margin, little is known about how different seep morphologies can be differentiated by their MBES response. Furthermore, because different sonar systems, even different settings of the same system, can yield vastly different images of the seafloor, it is necessary that calibration standards of MBES systems be implemented, specifically for backscatter, to improve interpretation of seep morphologies between datasets (Mitchell et al., 2018). If seep communities and their associated morphologies correlate to distinct sources of hydrocarbon seepage as illustrated in the images above, then MBES may be used to characterize the extent of different types of seep communities. This can have broader implications for the protection of ecologically sensitive benthic communities, optimizing resource planning, and providing input to global methane budgets.

To understand the correlation of remotely-sensed seep morphologies to hydrocarbon source, we suggest the following:

- Prioritize seep sites for future survey and dive locations
- Use publicly available MBES data to determine possible locations of cold seeps that can then be used by the *Okeanos Explorer* for future research consideration
- Partner with Fugro to calibrate MBES system so that new data collected during the ASPIRE campaign is specifically optimized for backscatter acquisition
- Collect water samples above seeps for geochemical analysis
    - Characterize seep geochemistry (with Fugro and Academic partners)

Relevant Partnerships (If Applicable)

Fugro, University of Houston, BOEM, University of Texas Institute of Geophysics, University of Alaska Fairbanks

Exploring pristine deep-sea walls to reveal hidden deep-sea biodiversity in the Azores

CONTACT INFORMATION

Primary Contact: Marina Carreiro-Silva
Home Institution: IMAR and OKEANUS, University of the Azores, Portugal
Other participants: Telmo Morato, Christopher K. Pham, Ana Colaço (IMAR, Universidade dos Açores, Portugal)

TARGET NAME: Deep-sea vertical walls (approximately 500m tall, from 200-1,000 m depth) around steep island slopes of the Azores

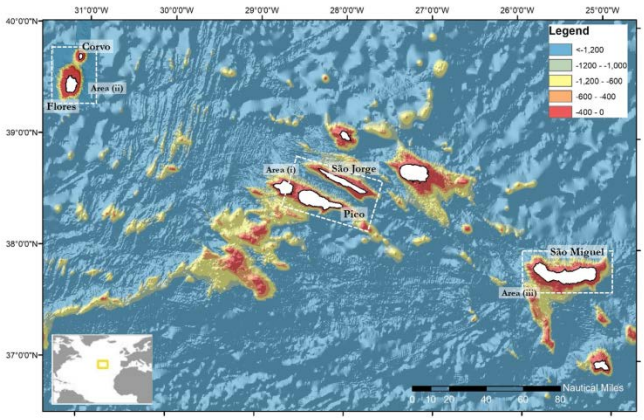
GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN: South Central (between 37°N and 41°N)

RELEVANT SUBJECT AREAS: Biology, Conservation, Geology, Chemistry, Physical Oceanography

DESCRIPTION OF TOPIC OR REGION RECOMMENDED FOR EXPLORATION

Brief Overview of the Area

The Azores volcanic archipelago located in the northeast Atlantic, sits above a tectonically active triple junction between the North American, Eurasian and African plates, surrounded by numerous seamounts, deep fracture zones, trenches, a considerable extension of the Mid-Atlantic Ridge and abyssal plains deeper than 5,00 m. This diverse geomorphology holds an extraordinary diversity of benthic organisms, making this area a cold-water coral hotspot in the NE Atlantic (1). Vertical walls, defined as seabed structures >70 º, are common geological structures associated with the steep submarine morphology of island slopes and seamounts in the Azores (2). They have been recognized as important areas of increased biodiversity, namely cold-water corals (3,4), but have been seldom studied.



The primary target areas to explore are the South of Pico and São Jorge Islands (Figure 1) in the central group of islands (Area 1), where the existence of communities of interest in vertical walls has been identified. Additional areas will target the island slopes of Flores and Corvo in the western group of islands (Area 2) and S. Miguel in the eastern group (Area 3).

Brief Summary of Current State of Knowledge

The heterogeneous and abrupt topography of vertical walls provides hard substrate for attachment of sessile species and creates complex hydrodynamic patterns (3), enhancing food availability for filter and suspension feeders such as bivalves, cold-water corals and sponges. These particular conditions have been hypothesized as responsible for their diverse communities some that may be unique, displaying not only singular species composition, such as large and long-lived bivalves and cold-water corals (1,4), but also specific life strategies (e.g. dispersal and reproductive strategies, and morphological accommodations). Furthermore, the natural refuge they can offer to anthropogenic impacts (e.g. fishing) may facilitate the persistence of vulnerable species at regional scales by providing habitat and larval sources to areas impacted by human activities elsewhere. Past studies have shown the occurrence of a unique 'living-fossil community' formed by a long-lived deep-sea oyster and a cyrtocrinid in vertical walls of the Faial Channel (5). More recent submersible expeditions by the Blue Azores deep-sea explorations around the Azores led by Telmo Morato and Marina Carreiro-Silva have found pristine cold-water coral communities associated with vertical walls around São Jorge and Pico Islands, not commonly found elsewhere in the region (Figure 1), such as tall black coral forests of the millenia-lived *Leiopathes* sp (6). The seemingly occurrence of these unique and fragile communities suggests the existence of vulnerable marine ecosystems (VMEs) of high biological and conservation importance on such vertical structures. These areas may constitute some of the last pristine areas of century to

millennia old deep-sea communities documented in historical records but that are hardly encountered in present times.

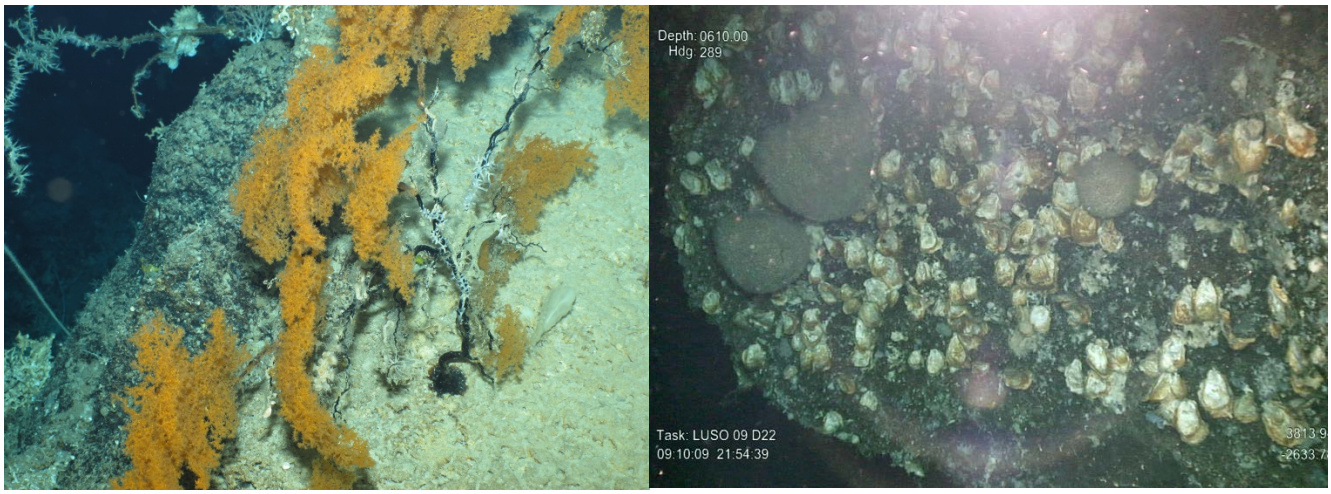


Fig 2. Examples of fauna associated with vertical walls (1) large black coral *Leiopathes* sp.; (2) deep-sea oyster *Neopycnodonte zibrowii*.

Rationale for Future Exploration

The proposed explorations in the Azores aim to (i) characterize and map the distribution of megafaunal communities associated with vertical walls in terms of species composition, diversity, abundance and size structure and to (ii) determine if these communities can be used as ecosystem reference sites to assess their good environmental status (GES). The results of this explorations will also contribute to identify the geomorphological and small-scale oceanographic variables that explain horizontal and vertical variation in ecological characteristics (such as abundance, number of species observed and diversity) of mega-benthic invertebrates and habitats in the deep-sea. Furthermore, it will greatly contribute to establish ecosystem approach and adaptive management frameworks by identifying areas that may constitute ecosystem reference sites to assess GES. Many ecosystems have experienced a long history of exploitation (e.g. fisheries) making it difficult, if not impossible, to know what the reference (a.k.a. baseline) conditions were. Vertical walls may thus constitute one of the few areas where pristine ecosystems may be found.

On each sampling location we suggest to collect multibeam data for mapping and ROV dive planning, ROV transects from the bottom to the top of the wall for a general characterization of the communities, with a subsequent fine-scale mapping based on video mosaicking construction on selected parts of the walls Water masses properties could also be characterized by sampling seawater and measuring physical-chemical parameters.

RELEVANT PARTNERSHIPS

This white paper is presented under IMAR plans for an improved mapping of vulnerable deep-sea benthic communities in the Azores. This line of research has been developed under relevant partnerships with H2020 international research project ATLAS, SPONGES and MERCES, and Azores funded research projects MapGES. Exploration of the areas proposed here may contribute to the Atlantic project currently submitted to the H2020 program. This white paper was also developed in close collaboration with papers being developed in the context of ATLAS and SPONGES projects and to Deep Ocean Observing Strategy (DOOS) initiative to integrate physical, biogeochemical, and biological/ecosystem-based investigations.

References: [1] Braga-Henriques et al. (2013) Biogeo. Disc. 10; 529–590; [2] Omira et al. (2016) Plate Boundaries and Natural Hazards 219: 271-287; [3] Huvenne et al. (2011) PloS one, 6(12): e28755; [4] Robert et al. (2015) Mar. Ecol 36: 1256-1276; [5] Puig et al. (2014) Ann. Rev Mar Sci 6: 5.1–5.25; [6] Wisshak, et al (2009) Palaeogeol, Palaeoclim, Palaeoecol, 271(1-2), pp.77-83; [7] Carreiro-Silva et al (2013). Mar Ecol Progr Ser, 473, pp.189-199.

SUBMARINE LANDSLIDES, TSUNAMI HAZARDS AND ASSOCIATED HABITATS FROM NORTH ATLANTIC CONTINENTAL MARGINS, OCEANIC ISLANDS AND SEAMOUNTS

Contact Information
Jason Chaytor, USGS Coastal and Marine Science Center, Woods Hole, USA; **Aggeliki Georgiopoulou**, University College Dublin, Ireland; **Sebastian Krastel**, Christian-Albrechts University of Kiel, Germany; **Uri ten Brink**, U.S. Geological Survey, Woods Hole, USA *Associated/Interested Parties*
Michael Clare - National Oceanography Center, Southampton, UK; **Amanda Demopoulos** - U.S. Geological Survey, Gainesville, USA; **Veerle Huvenne** - National Oceanography Center, Southampton, UK; **Finn Løvholt** - Norwegian Geotechnical Institute, Oslo, Norway; **Aaron Micallef** - University of Malta, Malta; **Katleen Robert** - Memorial University Newfoundland, Canada; **Roger Urgeles Esclasans** - Institut de Ciènciesdel Mar, Barcelona, Spain; **Morelia Urlaub** - GEOMAR Helmholtz Center for Ocean Research, Kiel, Germany; **Paraskevi Nomikou** – University of Athens, Greece

Target Names
Northern Caribbean/ West Africa continental margin/ Central Atlantic seamounts (Bermuda/Meteor) and ridges (spreading and fracture zone)
Geographic Areas of Interest
Southwest, East, Central
Relevant Subject Areas
Geology, Biology, Physical Oceanography

Description of Topic or Region Recommended for Exploration

Brief Overview of Area or Feature

Submarine landslides, and their associated potential for causing tsunamis, form some of the largest marine geohazards that can affect growing coastal populations, submarine infrastructure and the global economy. To document the location, magnitude and nature of failed seabed sections, tremendous efforts have been made to survey large portions of the continental margins on either side of the North Atlantic as well as around the oceanic islands off North Africa and southern Europe. Even with the decades of effort, many gaps remain where high-resolution mapping data necessary for assessment of submarine geohazards is not available. Large and potentially hazardous landslides have been partially or completely mapped offshore eastern Canada, Saharan North Africa, the Azores and Cape Verde Islands, offshore Western Europe from Portugal to Norway, yet it is expected that gaps in existing data hide vital details of known landslides and active seafloor structures or contain completely unknown landslide complexes. The collection of new data in these regions, especially offshore Western North Africa, the North Caribbean Margin and the Central North Atlantic Seamounts (e.g., Meteor Seamounts and Bermuda) and spreading and fracture zone ridges (examples shown in figure 1) presents an incredible opportunity to not only facilitate complete and more detailed geohazard assessment, but to push the boundaries of exploration into areas that have not been visited/mapped before.

Brief Summary of Current State of Knowledge

Accurate and actionable submarine geohazard assessment requires complete knowledge of the sources of the hazard and their characteristics. While some regions in the North Atlantic have been densely surveyed and are the focus of detailed evaluation, most have incomplete or no data on which to effectively evaluate current or past hazard potential. Although of lower frequency than the highly active margins of other ocean basins, hazards from earthquakes, landslides and tsunamis exist in the North Atlantic. But because of their very low-probability of occurrence over short-time scales and our limited understanding of the driving processes, they represent potentially high-risk events for which mitigation and management policies are not well developed.

Large earthquakes have occurred along the active continental plate boundaries (Cuba, Greater & Lesser Antilles, Gulf of Cadiz or west of the Tore-Madeira Rise, Charlie-Gibbs and Atlantis Fracture Zones), and

tsunamis they could possibly generate, and those resulting from submarine landslides, likely constitute one of largest hazards to the continental and oceanic island coastlines in the North Atlantic. That said, our ability to support such statements is limited by our current knowledge of the basic morphology, composition, structure, and geologic/ecologic processes of the seafloor in many of the areas where the hazards may be the greatest. Our current knowledge is limited to those areas where high-resolution bathymetry and seismic data allow us to identify landslides scars, canyons, mass transport deposits, and other structural features – low-resolution datasets are often incapable of capturing the often subtle seafloor morphologies that these features display.

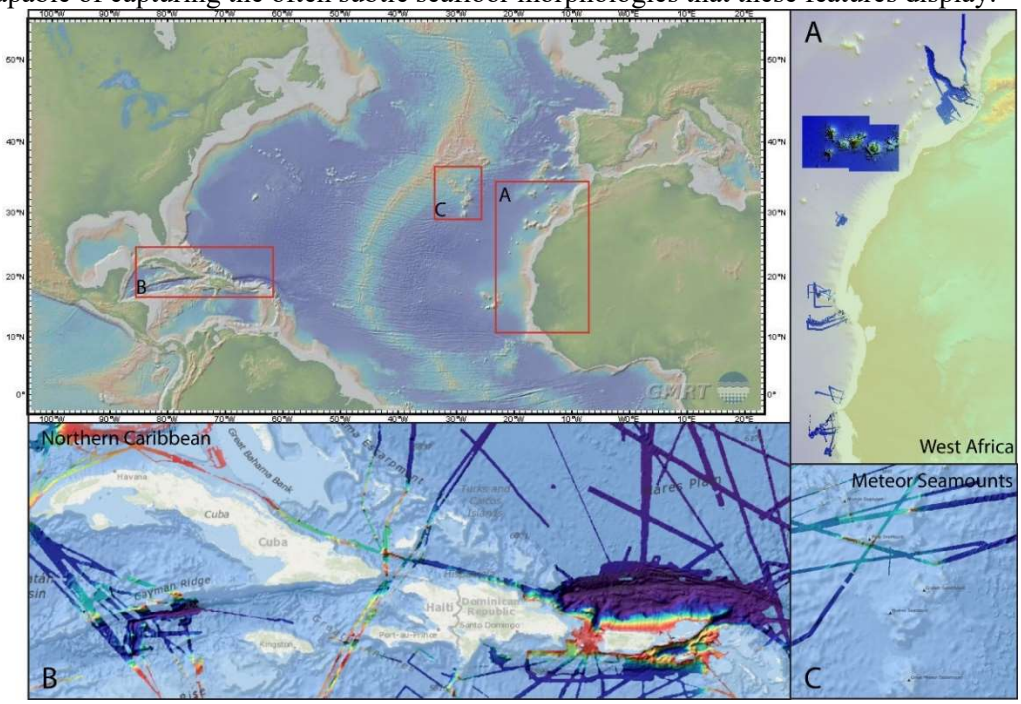


Figure 1. Examples of areas of known or suspected geohazards and extent of high-resolution data covering them (from NEIC and other sources)

Rationale for Future Exploration

The regions identified represent those where new data are expected to inform the community as to the presence, nature, and extent of submarine geohazards to countries bordering the North Atlantic Ocean and provide the information necessary to focus future efforts. While this is a primary goal, these areas also contain a wealth of basic geologic, biologic and physical oceanographic information that has not been documented. Submarine landslide headwall scarps have recently been demonstrated to provide substrate for specific faunal communities, creating unique habitats. In addition to filling gaps in existing data, exploratory surveys and baseline information are likely to facilitate new avenues of investigation across multiple disciplines which has been successfully demonstrated in past activities of this kind.

Surveys of the Caribbean region and western North Africa will support the infrastructure of developing nations, which do not have the means to carry out such work with hazards and resources assessments. All three regions provide unique geological and biological environments. Western North Africa borders the largest desert belt in the world with massive input of aeolian sedimentary deposits. The Caribbean region is a tropical region with majority of carbonate deposits and banks. The central Atlantic seamounts and ridges comprises of majority basaltic substrate and narrow valleys and topographic obstacles (seamounts), which direct oceanographic flow and species dispersal.

Relevant Partnerships

S4SLIDE (IGCP-640), ITN-SLATE, INSIGHT (CTM2015-70155-R), AtlantOS, ASTARTE, Commonwealth Marine Economies Programme, iAtlantic (H2020 project proposal, NERC Climatic Linked Atlantic Sector Science (CLASS), Global Tsunami Network (GTN), UNISDR Global Risk Assessment Framework

Proposal for an ASPIRE mission to the FAMOUS segment and Sarda seamount on the Mid-Atlantic Ridge

Contact Information

Primary Contact: Ana Colaço; (Marina Carreiro e Silva, Telmo Morato)
Home Institution: MARE – Marine and Environmental Sciences Centre and Okeanos - Univ. dos Açores (Portugal)

Target name(s)

Main Feature(s)/Area(s) of Interest: Mid-Atlantic-Ridge (MAR); benthic habitats such as hydrothermal vents (active and inactive) and mid ocean ridge (non vent), with corals, sponges and other structure-forming biota linked to seamounts and ridges

Geographic areas of interest within the North Atlantic Ocean

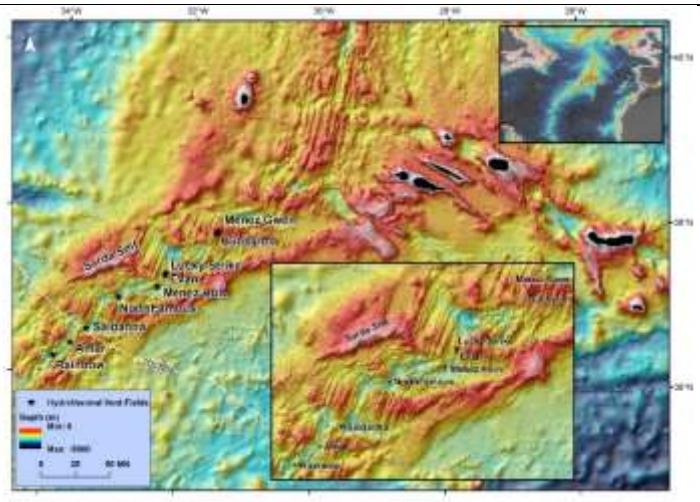
North Central

Relevant subject area(s)

Biology, Geology, Chemistry, Physical Oceanography, Ecosystem-based observation and management

Description of topic or region recommended for exploration

We propose missions to the FAMOUS segment and Sarda seamount on the Mid-Atlantic Ridge to address several specific science goals, and that will have repercussions on a Deep Ocean Observing Strategy (DOOS).



Bathymetry:
Amante, C., & B.W. Eakins, 2008. Escartin, J., et al., 2001. Lourenço, N., et al 1998. Morpho-tectonic analysis of the Azores volcanic plateau from a new bathymetric compilation of the area. Marine Geophysical Researches, 20: 141-156.

Figure 1 - Seafloor morphology of the southern part of the Azores region, with close up of the Interested region. The first goal is the area from the Lucky Strike segment at the periphery of the vent field to the Sarda seamount, and the second goal is on the Famous segment, from North Famous to the Saldanha mound. R.Medeiros © *Imag*DOP

(1) This first goal is to assess if the biotopes that exist in the large periphery of Atlantic active vents are similar to those on nearby inactive vents and seamounts slopes. Active hydrothermal vents in this region have been the subject of many studies in the past decades. Therefore, hydrothermal mega- and macrofaunal invertebrate communities are relatively well known (for the surveyed vent fields, e.g. Lucky Strike). The energy that fuels these hydrothermal systems is known to come from different types of microorganisms (either symbionts or free living) with different energy sources and chemical electron donors. When the hydrothermal activity ceases, chimneys become inactive, and may provide hard substrate for species that do not tolerate the harsh vent environments. Nevertheless, the ecology of the animals living on inactive vents remains poorly understood. What is known is that the non-vent suspension feeders that live close to the vents can benefit from the large number of suspended particles derived from the active vents (Eriksson et al 2009). However, the distribution patterns of the faunal assemblages colonising inactive vent sites close by or further away from active venting have not yet been studied. The degree to which fauna and nutritional resources are shared among inactive vents and seamounts remains unknown as well. To date, some work has been done on seamounts hosting vents (Boschen et al, 2015), but not on seamounts or inactive sites out of the influence of active vent fields. The first study area proposed is an east-to-west transect from the ridge valley where the well-known Lucky Strike Hydrothermal vent field ecosystem is present (and EMSO-observatory is in place, maintained by EMSO –France) towards Sarda seamount, placed at the west side of the ridge.

(2) The second area will be the exploration of the Famous segment from the North Famous inferred vent field location towards Saldanha vent (south of the Lucky Strike segment), in order to locate and characterise possible new vent field. This will take into account the previously inferred vent fields and the new hypothesis/knowledge on the 50-km larval dispersal potential limit for mussel larvae, which should mean that theoretically there should be an active vent field in that region.

The hypothesis that vent mussel larvae along the Mid-Atlantic Ridge cannot travel more than 50 km as stated by Breusing et al. (2016) will be tested. Within the scope of the MIDAS project (EU-FP7-603418), Colaço et al. (in prep) modelled the dispersal of Atlantic vent mussel larvae, showing that the origin of the larvae able to settle in Lucky Strike and Rainbow vent fields must be originated on the Famous segment. Hence, there are strong indications for the existence of intermediate vent fields facilitating dispersal. Up to now, two hydrothermal vent fields were discovered south of Lucky Strike and north of Rainbow. One of them is Saldanha (South of Famous segment), a low temperature vent field with no chimneys or endemic fauna, just diffusion and another site has been inferred at North Famous. Therefore, using the new technology available today, we would like to use it to explore the Famous segment in order to locate these and possibly other new vent fields, which could shed a new light on dispersal abilities of vent fauna.

Relevant partnerships

This campaign would benefit from (and leverage) the work in progress in scope of the H2020-SponGES project, Atlas and Merces, as also the recent submitted projects Azores fun and the DOOS initiative

The questions in this proposal align with DOOS objectives to integrate physical, biogeochemical, and biological/ecosystem-based investigations. Understanding the connectivity of species (bathymodiolin mussels) and of habitats (e.g., inactive vents and seamounts) in the North Atlantic requires combined knowledge of physical transport (current velocities), habitat suitability (heat fluxes from below, and biogeochemical conditions (oxygen, H2S and, POC fluxes) required for microbial and faunal support. With an end –to-end approach the data would become open access and syntheses would be available to the Portuguese governments, OSPAR; BBNJ; CBD to monitor and designate protected areas, design-mining regulations, develop EIS requirements, as examples.

Contact Information:
Chip Collier/Roger Pugliese
South Atlantic Fishery Management Council

Target Name(s):
Blake Plateau and South Atlantic Slope and Shelf Edge

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)
Southeast

Relevant Subject Area(s) (Indicate all that apply)
Biology, Physical Oceanography, Management

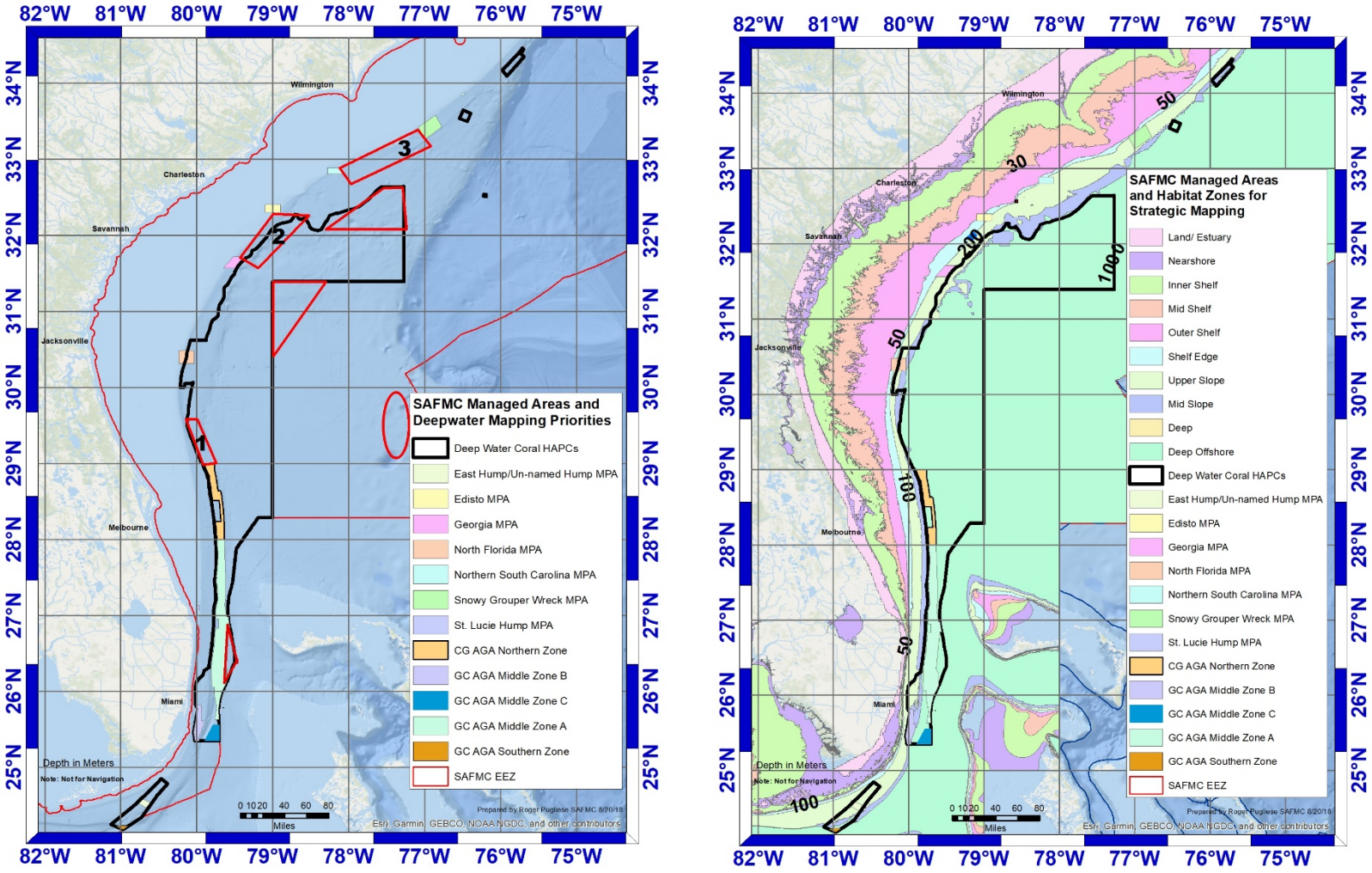
Description of Topic or Region Recommended for Exploration

The South Atlantic Fishery Management Council has a long history of protecting deep-water ecosystems including coral, coral reef and live hard bottom habitats in addressing Magnuson-Stevens Act mandates to prevent fishing impacts to sensitive habitats and provide policy guidance addressing impacts of non-fishing activities on these resources. The Council through the federal FMP prevents harvest or retention of coral and live hard bottom habitat resources and focuses additional conservation to protect these habitats through creation of Coral Habitat Areas of Particular Concern (CHAPC). Data gathered during previous Ocean Exploration and Okeanos mapping research cruises provided critical data in the establishment of or refined understanding associated with the detailed mapping and characterization of complex habitats making up these protected deep-water ecosystems. While some core areas have been mapped, much of the South Atlantic region is lacking high resolution mapping data and habitat characterization crucial to informing management decisions.

The South Atlantic Fishery Management Council is reviewing available mapping and habitat characterization information associated with the Stetson-Miami Terrace CHAPC as it relates to a request from the Golden Crab Fishery to consider adjusting allowable gear areas. EX 1806 explored some areas in the South Atlantic region and provided insight in the habitats that are in the region. This is extremely valuable information that will be provided to managers and fishermen as the fishery access area amendment is being developed. This is extremely important considering the Council manages these as deep-water ecosystems protecting the coral, coral reefs and live hard bottom habitat and providing policy guidance on all associated benthic and pelagic habitats essential to other Council manages species.

Continuing to map the area is critical to prevent fishing impacts to sensitive habitats and potential protect other unknown areas. Areas outside of the access area are currently open to fishing. It is unlikely that fishermen are currently using this area, but they could explore new fishing grounds. Areas in the Blake Plateau east of CHAPC are open to trap fishing and are in the depth range where fishermen have caught golden crab in the Southeast region (490 to 730 m). Mapping data have been extremely useful in protecting potential coral habitats. Below is a general target area for mapping in the region managed by the South Atlantic Fishery Management Council.

Relevant Partnerships (If Applicable)
South Atlantic LCC, SECOORA, SAFMC Digital Dashboard



SAFMC Mapping Priorities based on managed areas (left) and habitat zones (right). Areas outlined in red (right) are ranked for the top three priorities and other priorities are mapped for reference. Area 1 is a deep offshore habitat with little mapping data and highest interest from Golden Crab fishermen. This area is next to high density coral areas based on observations in EX 1806. Areas 2 and 3 would address deep offshore and upper slope habitats with little mapping information and will be useful in our understandings of connectivity ecosystems.

WHITE PAPER

ASPIRE Workshop

From

Erik Cordes, Temple University

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				

CONTACT INFORMATION

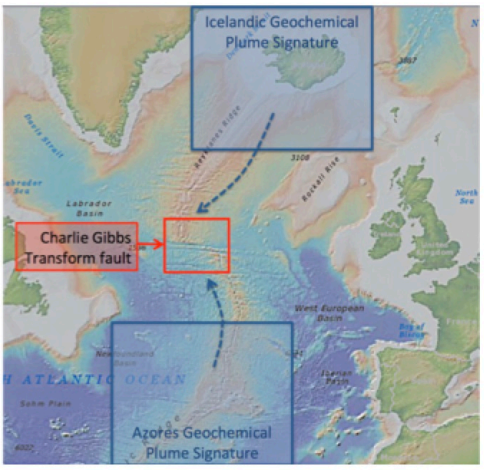
Primary Contact: Marie-Helene Cormier
Home Institution: University of Rhode Island, Graduate School of Oceanography

TARGET NAME

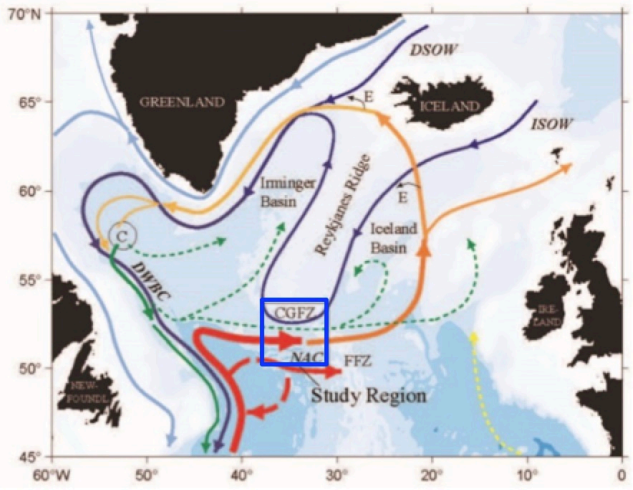
Charlie-Gibbs Fracture Zone, 52°-53°N

GEOGRAPHIC AREA OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN

North Central



The Charlie-Gibbs transform separates two regions of the Mid-Atlantic Ridge with contrasting morphology and mantle geochemistry.



The blue box outlines the position of the Charlie-Gibbs transform. At depth, the cold ISOW (blue) flows westward across the transform fault. Near the surface, the warm North Atlantic Current (NAC) flows eastward.

RELEVANT SUBJECT AREAS

Biology, Geology, Chemistry, and Physical Oceanography

DESCRIPTION OF REGION RECOMMENDED FOR EXPLORATION

Large oceanic transform faults are associated with valleys 10-20 km wide and >1,000m deeper than the ridge segments that abut them. As such, they provide strategic gateways across the mid-ocean ridge for bottom waters, and may also provide critical stepping-stones for the spread of bathyal ecosystems. The tectonic evolution of ocean basins is nicely recorded in the geometry and morphology of fracture zones (the fossil extensions of transform faults), their varying characteristics informing about former changes in plate motions and spreading rates. Furthermore, the largest (Mw > 6) earthquakes along the mid-ocean ridge system occur at transform faults – although the impacts at the seafloor of such earthquakes remain undocumented.

With a left-stepping offset of 340 km, the Charlie-Gibbs is the longest transform fault in the North Atlantic, its offset comparable to those of the prominent equatorial transform faults between 1°N and 2°S. It is centered at 52°-53°N and is the only significant transform fault between the Azores (38°N) and Iceland (63°N). It offers the deepest gateway (~3,600 m) between western and eastern ocean basins over a 2,800 km-long section of the northern Atlantic. Hydrographic surveys show that the transform valley is a crossroads for water masses comprising both the warm and cold branches of the Atlantic Meridional Overturning Circulation. The North Atlantic Current (NAC) transports eastward warm and relatively

nutrient-poor surface water as well as colder Labrador Sea Water between 1000 and 2000 m. Below 2000 m, the transform valley is mainly filled with sediment-laden Iceland-Scotland Overflow Water (ISOW), which, along with the Labrador Sea Water, is a component of the North Atlantic Deep Water. Because the different currents and water masses are squeezed through the narrow valleys of the transform fault, it is the site of a permanent but mobile front with a particularly high productivity and species richness. In turn, this enhanced biological productivity fertilizes the deep seafloor below. Numerous species of cold-water corals, cephalopods, demersal fishes, and cetaceans have recently been identified in that area.

The Charlie-Gibbs transform fault represents a key morphological and geochemical boundary between contrasting sections of the Mid-Atlantic Ridge. To the north, the ridge is shallow and "inflated", and rock samples reveal a marked influence of the Icelandic hot spot. To the south, the ridge has a morphology and geochemistry typical of slow-spreading ridges. Recent models suggest that large-offset transform faults may generate strong lateral flow and mixing between mantle reservoirs, possibly explaining the observations. In terms of morphology, the Charlie-Gibbs comprises two branches separated by a 40 km-long spreading segment. The northern branch is heavily sedimented, suggesting that the ISOW passes preferentially through that branch, moving westward at times when the eastward NAC transport slackens or retreats southward. Lastly, the Charlie-Gibbs transform fault displays a puzzling along-strike variation in seismic behavior: The northern branch has hosted several large earthquakes (M>6.5) since 1923 with a repeating interval of 20-40 years. In contrast, the southern (unsedimented) branch has not generated any large earthquakes and may slip mostly aseismically.

Yet, despite all its superlative characteristics and strategic location, the Charlie-Gibbs transform fault remains surprisingly under-investigated, with only a small fraction of its length mapped with multibeam bathymetric resolution. Possible exploration activities could include the acquisition of full multibeam bathymetric coverage, hull-mounted sub-bottom profiling data, hull-mounted ADCP data, as well as lowered ADCP on a rosette. The collection of full-depth water samples for standard hydrography (T,S), nutrients (PO4, NO3 + NO2, SiOH4), and carbon (DIC, total alkalinity) would also prove invaluable. Lastly, near-bottom investigations with a ROV equipped with a suite of sensors, cameras, and sampling tools, would provide unique data on bathyal ecosystems and geological processes.

RELEVANT PARTNERSHIPS

Physical oceanographers at the University of Rhode Island's Graduate School of Oceanography (GSO) have long investigated the Atlantic Meridional Overturning Circulation in the general area of the Charlie-Gibbs transform fault, and GSO's geoscientists are most interested in the study of oceanic transform faults and processes affecting their evolutions.

OSPAR (a mechanism by which 15 Governments and the EU cooperate to protect the marine environment of the North-East Atlantic) has created in 2010 the "*Charlie-Gibbs Marine Protected Area*" (http://www.charlie-gibbs.org/charlie). Because this Protected Area covers a large expanse, coordinating investigations from both sides of the Atlantic would be of great benefit. The Mar-Eco project, a project of the Census of Marine Life campaign, was launched in 2001. For 10 years, scientists from 16 countries deployed an array of methods to investigate how ocean currents influence the health of the ocean around the northern Mid-Atlantic Ridge. The follow-up project ECOMAR investigated the North-South and East-West differences in the ridge ecosystems around the Charlie-Gibbs fracture zone. Last year, the *R/V Celtic Explorer* from Ireland conducted a partial multibeam survey, and this year, the same team deployed the *ROV Holand-1* (depth rated to only 3,000 m depth) to image benthic ecosystems.

SAINT ANDRE, 1901 - PORTUGAL'S DEEP WATER UNDERWATER CULTURAL HERITAGE MANAGEMENT

Contact Information: Paulo Costa

Instituto de Arqueologia e Paleociências, Universidade NOVA de Lisboa

Target Name: *Saint Andre*

Geographic Areas of Interest within the North Atlantic Ocean: Portuguese coast, around the point 40.530717°; -9.802692°.

Relevant Subject Areas: Marine Archaeology, Art History, Modern History.

Brief Overview of Area: A small elliptical area, oriented north-south, around the point 40.530717°; -9.802692°, with depths between 100 and 300 meters.

Brief Summary of Current State of Knowledge: This steamship sunk in 1901 with part of the art collection presented in the Portuguese pavilion at the World Exhibition of Paris in 1900. This site has not been located by archaeologists.

Although perhaps the most important part of the cargo were paintings, which have long disappeared, we believe that this shipwreck can become a tremendously important learning center for the history of Portugal in the late 19th and early 20th century.

The beginning of the 20th century in Portugal – as in Europe – was a period of cultural and technological change, not very well known by the general public. The finding and studying of this shipwreck would entail an extensive research of the period and the history of the institutions involved in planning and designing the Portuguese pavilion.

…

Filipe Castro (TAMU); Joao Sousa (LSTS/FEUP); Alexandre Monteiro (IAP/UNL); Jose Pinto (LSTS/FEUP); Paulo Costa (IHC/UNL); Miguel Martins (DGPC); Goncalo Calado (ULHT); Clara Sarmento (CEI/ISCAP); Miguel San Claudio (IAP/UNL); Rebeca Alonso Galvan (ICAM).

Rationale for Future Exploration: Texas A&M ShipLAB, the Oporto University Underwater Systems and Technology Laboratory (LSTS) and the Lisbon NOVA University are now applying for permits with the Portuguese Heritage Agency (DGPC) for the survey and mapping of selected areas of the Portuguese coastline up to 100 m deep, the maximum range of the sensing equipment embarked on board LSTS AUV's.

Relevant Partnerships: We are a collaborative interdisciplinary scientific exploration group, that integrates Spanish and Portuguese nautical archaeologists, biologists, historians, maritime historians and lawyers, social scientists and underwater robotics specialists that collect input from management agencies, fishing and diving communities in order to identify unexplored areas of the ocean where new UCH discoveries are likely to be made.

We have MoU's with the Portuguese Mission for the Extension of the Continental Shelf (EMEPC), the Cultural Heritage General Directory (DGPC), the Portuguese Navy Hydrographical Institute (IH) and with the coastal counties of Esposende, Lagos, Grandola, Sines and Alcacer do Sal.

NOVA University of Lisbon's Instituto de Arqueologia e Paleociências has since 2011 positioned itself as a national and international leader on nautical archaeology studies, with increased participation in international European research programs. IAP-NOVA is also a leading institution in two sensitive topics concerning the safety of UCH: treasure hunting and trawler fishing activities, which are threatening the submerged heritage of Portugal, as well as that of many other countries such as Mozambique, Cape Verde and Uruguay.

The Underwater Systems and Technology Lab (LSTS) is an interdisciplinary research laboratory established in 1997. The LSTS specializes on the design, construction, and operation of unmanned underwater, surface and air vehicles and on the development of tools and technologies for the deployment of networked remotely operated vehicle systems. During the last 20 years, researchers from the LSTS have successfully fielded unmanned air, ground, surface and underwater vehicles in the Atlantic and Pacific oceans, and in the Mediterranean Sea.

Filipe Castro (TAMU); Joao Sousa (LSTS/FEUP); Alexandre Monteiro (IAP/UNL); Jose Pinto (LSTS/FEUP); Paulo Costa (IHC/UNL); Miguel Martins (DGPC); Goncalo Calado (ULHT); Clara Sarmento (CEI/ISCAP); Miguel San Claudio (IAP/UNL); Rebeca Alonso Galvan (ICAM).

Contact Information
James P. Delgado
Robert D. Ballard
Michael Arbuthnot
Michael L. Brennan

SEARCH, Inc.

Target Name/Area of Interest
RMS *Titanic*

Geographic Area of Interest
North Atlantic

Relevant Subject Areas
Marine Archaeology
Chemistry
Biology

Description of Topic Recommended for Exploration
Next year will mark nine years since the last mission to RMS *Titanic* and fifteen years since the last NOAA mission to *Titanic*. This is the longest gap in the history of missions to this significant deep ocean shipwreck since its discovery in 1985. A variety of questions can be posed that address the iconic site's condition, stability, and continued environmental processes active at the wreck:

- What are the changes to the site since 2010?
- What are the changes that have occurred because of *Titanic*'s bacteriological colonization and consumption?
- What other natural and anthropogenic processes have changed or impacted the wreck?
- Have there been undocumented, clandestine visits to the wreck, and if so, what impacts has such activity caused? and
- Are there changes in the surrounding terrain, and the physical and chemical oceanography since the 2004 mission measured them?

In addition to the scientific questions, there is also a compelling argument that NOAA undertake a mission to observe *Titanic* for legal and administrative reasons. Since the discovery of the wreck site in 1985, NOAA has been involved in protecting and preserving the site in some capacity, from participating in exploration and scientific missions to negotiating international agreements. In 1985, Congress recognized the shipwreck as a site of "national and international cultural and historical significance" in need of international protection and enacted the **R.M.S. Titanic Maritime Memorial Act of 1986** (1986 Act), signed by President Reagan. The 1986 Act encouraged NOAA and the United States Department of State to (1) negotiate an **international**

agreement (International Agreement) to protect *Titanic*; and (2) develop international **guidelines** (NOAA Guidelines) for exploration, research, and, if determined appropriate, salvage. The U.S. District Court for the Eastern District of Virginia recognized the public interest in *Titanic* and NOAA's role in overseeing activities of the salvor, R.M.S. Titanic, Inc. NOAA has designated its Office of General Counsel and its Office of National Marine Sanctuaries to implement the Court's directives. Today, the United States Departments of Justice, State, and Commerce (primarily through NOAA), and other interested federal agencies continue work to:

- Implement the International Agreement that the U.S. signed in 2004, subject to the enactment of domestic legislation, including the recognition of the wreck as an international maritime memorial and providing the authority to ensure that it continues to be respected as the resting place of those who lost their lives in its sinking;
- Prohibit potentially harmful activities directed at RMS *Titanic*, such as looting and unwanted salvage;
- Establish a permitting system to manage any research, exploration, recovery, or salvage of RMS *Titanic* in accordance with scientific rules;
- Require the application of current professional standards of scientific and archaeological resource management to ensure that RMS *Titanic* is properly preserved and conserved for present and future generations; and
- Create an advisory council to make recommendations to the United States Secretary of Commerce regarding the protection and long-term management of the wreck site, as well as the conservation and curation of any artifacts recovered.

The 100th Anniversary of the sinking of the RMS *Titanic* on April 15, 2012 triggered significant interest in the wreck site. On January 31, 2012, in response to a request from NOAA, the U.S. National Park Service, the U.S. Coast Guard, and the International Maritime Organization issued a circular on *Titanic*. The circular advised all vessels to refrain from discharging any garbage, waste, or effluent in a zone approximately 10 nm (34 km) above the wreck. It also requested that submersibles avoid landing on the *Titanic*'s deck and concentrate the release of any drop weights on ascent in specific areas away from the hull portions of the wreck. The circular also requested that visitors refrain from placing plaques or other permanent memorials on the wreck, however well-intentioned. As of April 15, 2012, the RMS *Titanic* wreck came under the 2001 UNESCO Convention on the Protection of Underwater Cultural Heritage**.**

On May 5, 2017, the Consolidated Appropriations Act, 2017 (Public Law 115-31) was signed into law. Section 113 of the Act provides:

For fiscal year 2017 and each fiscal year thereafter, no person shall conduct any research, exploration, salvage, or other activity that would physically alter or disturb the wreck or wreck site of the RMS *Titanic* unless authorized by the Secretary of Commerce per the provisions of

the Agreement Concerning the Shipwrecked Vessel RMS *Titanic*. The Secretary of Commerce shall take appropriate actions to carry out this section consistent with the Agreement.

Under Article 4 of the Agreement, each party is to take "appropriate actions" to enforce measures taken pursuant to the Agreement against it nationals and vessels flying its flag and to prohibit activities in its territory including its maritime ports, territorial sea, and offshore terminals, that are inconsistent with the Agreement.

With this as background, and with ongoing Congressionally-mandated responsibilities, and NOAA's role in leading and participating in three scientific expeditions to *Titanic*, a 2019 mission is recommended, in addition to scientific observation and documentation, to:

1. Conduct an oversight inspection of the wreck;
2. Conduct a telepresence-enabled mission to make the first live inspection of the wreck by the United States District Court, which exercises authority and oversight on *Titanic* through Admiralty, and also to provide a live inspection and briefing to Congress.
3. To conduct a NOAA-led inspection for the public in what would be the first telepresence-enabled mission to *Titanic*, and involve both Dr. Robert Ballard, as discoverer of the wreck and leader of the 1986 mission and as chief scientist for the 2004 mission, as well as the SEARCH, Inc. team, which includes Dr. Delgado as the chief scientist for the last (2010) mission to the wreck.

In addition to Dr. Ballard and Dr. Delgado, the team, which could take the science lead ashore, include Mr. Arbuthnot, who led the documentation dives to the wreck and into the wreck for James Cameron, and Dr. Brennan, who was the archaeological lead and expedition coordinator for Dr. Ballard's Ocean Exploration Trust.

The mission to *Titanic* would take one to two days of ROV operations to assess the bow, stern and the intermediate artifact field. It would yield new observations, demonstrate ongoing NOAA and U.S. Government involvement as laid out by Congress and the courts, and be an exciting mission with broad appeal to demonstrate the role of telepresence-enabled exploration of arguably the world's best-known shipwreck and NOAA's role and leadership in deep ocean exploration to what could well be the largest telepresence audience in the history of NOAA's ocean exploration missions.

Relevant Partnerships
National Oceanic and Atmospheric Administration (OER, ONMS MHP, GCIL)
Ocean Exploration Trust
University of Rhode Island GSO
Department of Justice

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Target Names

New England Seamounts and Mid-Atlantic Ridge, ASMWG Pilot Area Mapping

Geographic Areas(s) of Interest within the North Atlantic Ocean

Northwest, North Central, Southwest

Relevant Subject Area(s)

Biology, Geology, Physical Oceanography

Relevant Partnerships

Canada Healthy Oceans Network, SponGES

Description of Topic or Region Recommended for Exploration

We are writing in response to the NOAA call for white papers from the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean Exploration and Research under the Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE). Deep-sea coral and sponge communities significantly enhance biodiversity, contribute to habitat complexity and provide biogenic substrate for associated invertebrate and fish species. Morphology of deep-sea megafauna increases the surface area of available substrate through provision of secondary substrate for species such as brittle stars, gastropods, and others (Beaulieu, 2001; Buhl-Mortensen et al., 2010), enable sessile organisms to reach bottom currents (Edwards et al., 2012), and provide areas of protection for communal fauna (Roark et al., 2009). These associations can benefit their host species. Girard et al. (2016) demonstrated that brittle stars improve the health and resilience of corals by keeping them free of sediment and other epifauna. Previous studies report enhanced fish diversity with certain Lophelia reefs (Ross and Quattrini 2007), however, it is unclear whether this relationship can be generalized to all deep water Lophelia or deep water coral habitats and their associated fishes (Quattrini et al. 2015). There is a need to better characterize fauna and their distributions, provide mechanisms that shape their distribution, and examine the linkages between abiotic factors and biological processes. Understanding these linkages and how associated species use deep-sea reefs will help to predict how the loss of coral communities may add to current pressures on commercially important fishes. While deep sea coral reefs habitats in the North Atlantic appear to enhance invertebrate and fish biodiversity, they still remain poorly explored or understood.

Corals and reef building sponges can be found in aggregations, and are often patchily distributed on and across seamounts and outcrops. Quality and availability of food, suitable substrate, and oceanographic factors such as temperature and currents among others are drivers/constrainers of their distribution (Buhl-Mortensen et al., 2010). Substrate type is also a strong contributor for species distribution as many corals, sponges and other sessile species require hard substrate for attachment. These parameters have been integrated into species distribution models for the prediction of deep-water coral communities. However, these coral communities are not present on hard bottom seafloor, even in areas that appear to be have optimal conditions. Current patterns, re-suspension, variable recruitment, mortality, and predation are factors that contribute to dispersal and population connectivity, and consequently determine spatial and temporal distribution of deep-water coral and sponge communities on seafloor features. Factors that regulate deep-water reef communities are still poorly understood, yet critical to the stability and function of these ecosystems.

Geomorphic features such as seamounts and mid-ocean ridges are considered to be environmentally complex with a variety of hard bottom substrates, and water column properties. These features influence the distribution and abundance of organisms, including many of commercial importance, while increasing both local and regional biodiversity. It is estimated that 25 million seamounts >100m height exist on the seafloor, however, due to the difficulty of mapping small outcrops by means of echo-sounders and satellite altimetry, they are often overlooked (Wessel et al., 2010). The ASPIRE 2019-2020 planning region covers many topographically complex and rugged hard bottom seafloor features, including the Mid-Atlantic Ridge and potentially many not-yet discovered seamounts. These areas can act as “stepping stones” for dispersal, hubs of refugia and speciation for deep-sea populations. The North Atlantic is ideal for examining similarities in overall benthic habitats, especially across the ASPIRE planning sites. These sites provide a setting to determine the influence of geomorphic structures on the composition and diversity of deep-sea fauna, the influence of environmental variables for the maintenance of invertebrate and fish biodiversity, and to examine linkages in deep-sea population connectivity. Improved understanding of the habitats in these off-shore areas will expand the capacity to predict the distribution of benthic habitats with respect to management in response to environmental change and exploration and exploitation of natural resources such as minerals and oil.

Broad-scale benthic habitat characterization of the 'Million Mound' province in the Southeast United States using submersibles, remotely operated vehicles, and AUVs

Peter Etnoyer, Derek Sowers

Contact Information
Peter Etnoyer, PhD. Marine Biologist, NOAA National Centers for Coastal Ocean Science

Target Names
Blake Plateau, Million Mounds, Stetson Banks, Savannah Banks

Geographic Areas of Interest within the North Atlantic Ocean
Southeast United States

Relevant Subject Areas
Geology, biology, habitat mapping

Description of Topic

One of the challenges for deep-sea exploration is the mismatch in coverage between acoustic surveys like multibeam, which can reveal very large areas of terrain, and visual surveys by AUV or ROV, which can reveal relatively small areas of the seafloor or water column. This white paper aims to address this challenge through a pilot study of coordinated, systematic explorations in the Million Mounds province, a large extent of mound features of the Southeast United States. The mound province lies within a marine protected area established by the South Atlantic Fishery Management Council in called the Coral Habitat Area of Particular Concern (C-HAPC, Fig 1). Previous observations, mostly from Johnson Sea-Link, along with a few dives on the most recent *Okeanos* cruise (EX1806) have verified that some of the mounds (those that were observed) are cold-water coral mounds. If the area is indeed covered in coral mounds, this would be one of the largest coral mound provinces in the world (E. Cordes, pers. comm.).

We propose to use multibeam data previously collected by the NOAA ship *Okeanos Explorer* (EX1403, EX1806) to guide a new series of systematic visual explorations by multiple assets. These coordinated explorations will yield a robust sample size of images and other data to permit extrapolation from small areas to larger areas. The pilot project will provide a case study and research design for broad scale habitat characterization, consistent with the goals of Seabed 2030. The proposal would deploy ROVs and AUVs in different ways, using a simple stratified, random design distributed over a large extent to determine whether there are gradients in coral cover and condition, such as latitudinal (north/south) gradients, related to mound orientation, or longitudinal (depth related, east/west) gradients in mound structure, coral cover, and associated species. This information would help to understand whether the mapped area is a more or less homogenous or heterogenous extent.

A second dilemma for broad scale habitat characterization is the choice of vehicle – ROV or AUV for a survey. AUVs can cover large areas, moving relatively quickly high over the bottom (~ 3 m), using down looking still cameras for visual samples. The video imagery collected with ROVs has more detail because it is typically closer to the bottom (~ 1-2 m), with forward-oblique and down-looking cameras. One solution is to use both of these platforms at the same time, and to deploy them simultaneously in a type of effort known as 'coordinated robotics' (Schmidt Ocean Institute, 2016). For example, two AUVs can fly parallel lines adjacent to an ROV transit line, at the same time, or offset in time. The end result would be a larger survey extent, and broader habitat characterization. If this effort were repeated in a systematic research design, the ability to characterize large areas would increase substantially.

Recent investigations have indicated that Coastal and Marine Ecological Classification Standard (CMECS) can be applied to image data to further enhance its value to the ocean research and management (Ruby, 2017; Etnoyer et al, 2018). CMECS is a comprehensive framework of common terminology developed for the classification of biological species, water column properties, and seafloor morphology as well as composition in all lacustrine and marine environments including the deep sea (Bassett et al, 2017). CMECS has been adopted by governmental agencies and other organizations since 2012. Because CMECS has seen wide adoption, annotating *Deep Discoverer* ROV video data and AUV imagery with CMECS compliant terminology would improve its accessibility and compatibility with other substrate classification approaches currently employed by the deep-sea research community. NOAA has developed image annotation tools (MADBAT) to codify data standards and an online data platform to share these data with the public. All imagery data from the proposed surveys would be codified using CMECS standards and distributed to the public through NOAA and BOEM websites.

References

Bassett, RD, M Finkbeiner, and PJ Etnoyer. 2017. Application of the Coastal and Marine Ecological Classification Standard (CMECS) to Deep-Sea Benthic Surveys in the Northeast Pacific: Lessons from Field Tests in 2015. NOAA Technical Memorandum NOS NCCOS 228, NOAA National Ocean Service, Charleston, SC 29412. 49 pp.

Etnoyer, PJ et al. (2018), Working with Video to Improve Deep-Sea Habitat Characterization, *Oceanography*, *31*:*1*, *Supp*, 64–67.

Ruby, C. (2017), Application of Coastal and Marine Ecological Classification Standard (CMECS) to remotely operated vehicle video data for enhanced geospatial analysis of deep sea environments. M.S. thesis, 266 pp., Mississippi State University.

Relevant Partnerships

NOAA National Centers for Environmental Information, Deep Sea Coral Research and Technology Program, NOAA National Centers for Coastal Ocean Science, Bureau of Ocean and Energy Management, DeepSEARCH

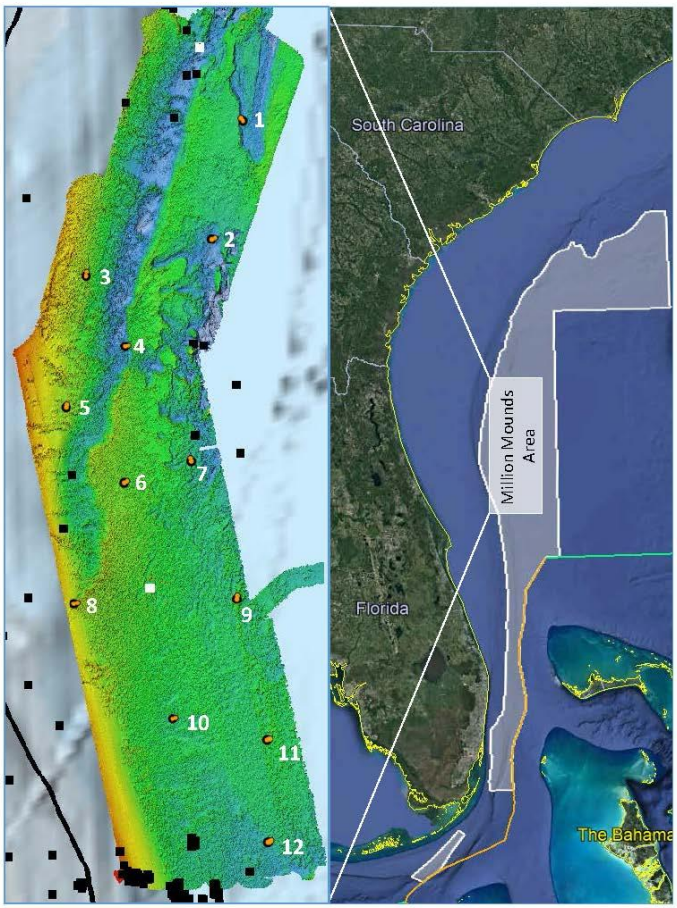

Figure 1: Location map of the Million Mounds province in the Southeast U.S. EEZ. The inset shows 30m resolution multibeam bathymetry collected by NOAA *Okeanos Explorer* during EX1403 and EX1806 expeditions. Black boxes represent the location of previous dives. White boxes represent the two ROV dives completed within the province during EX1806.

Proposed potential locations for future deep submergence dives are numbered 1-12 covering a diversity of depth, Gulf Stream current, and compass direction gradients. Dive site locations also sample a variety of geomorphological features (distinct mounds, ridge features, and mound/ridge complexes). Image created by Derek Sowers, NOAA OER.

ASPIRE White Paper, August 14, 2018

Contact Information

Primary Contact: VADM Paul Gaffney and Professor Jesse Ausubel
Home Institutions: Monmouth University and The Rockefeller University

Target Name(s)

Soundscapes and lifescapes of areas where anthropogenic noise (commercial shipping principally) and marine life interact continually or during key migratory periods.

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

Northwest Atlantic/US EEZ: A discrete pilot area(s); top priority is greater deep water areas of NY-NJ Bight and maritime approaches to NY, Hudson Canyon

- One would expect to position passive listening sites and general ocean data collection shoreward of the NEPAN instrument suite
- Data analyses would include information from long time-series collections by NEPAN sites
- Physics of sound within the Hudson Canyon would be an area to discuss

Relevant Subject Area(s)

Passive acoustics, ambient noise, bio-acoustics, combined with general physical oceanography and depth/bottom composition information.

- One would expect to run transmission loss calculations/diagrams to best select passive listening device locations and depths.
- Opportunities for eDNA collection in and around the "listening area" of passive moorings add to the pilot's importance.

Description of Topic or Region Recommended for Exploration

While the US operates several passive acoustic instrument sites offshore from NY Bight to Georges Bank, these NEPAN sites may not be designed effectively to monitor shipping and marine life noise at the same time and interactions of sound and life. Designs benefitting from new technologies could, e.g., better assist choices of maritime traffic routes and speeds at critical migratory times. Uninterrupted shipping may be the major Blue Economy revenue producer for the region. The maritime transport community aims to be as environmentally responsible as is practical. Leveraging ASPIRE ship, talent and technology assets, NOAA OER should consider leading design of pilot experiments in deeper water where sound channels and convergence zones can occur but shallow enough that they overlay ship route convergence areas. Start of systematic regional collection of eDNA samples, as recently in the ADEON 2018 cruise, is a bonus.

Relevant Partnerships (If Applicable)

NOAA NMFS/NEFSC **NEPAN**; NOPP ADEON Project; Navy (ONR, NRL, N-45 and NAVOCEANO); NOAA OER, Marine Sanctuaries, Marine Mammals; BOEM Marine bioacoustics program; Marine Mammal Commission

2018 ASPIRE WHITE PAPER FOR THE EXPLORATION OF THE CHARLIE-GIBBS FRACTURE ZONE, CENTRAL ATLANTIC

CONTACT INFORMATION

Aggeliki Georgiopoulou (marine geology, sedimentology and geophysics), University College Dublin, Ireland
Bramley Murton (marine geology, igneous petrology and geochemistry), National Oceanography Centre, Southampton, UK

Co-proponents (in alphabetical order)
Jason Chaytor (marine geology, sedimentology, geophysics), US Geological Survey, Woods Hole
Patrick Collins (marine ecology), Queen's University Belfast
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Sebastian Krastel (marine geology and geophysics), Christian-Albrechts University of Kiel
Paraskevi Nomikou (marine geology, tectonics and geophysics), University of Athens, Greece
Katleen Robert (marine ecology and habitat mapping), Memorial University Newfoundland
Isobel Yeo (marine geology, igneous petrology), National Oceanography Centre

TARGET NAME: Charlie-Gibbs Fracture Zone
GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN: North Central
RELEVANT SUBJECT AREAS: Geology, Biology, Chemistry, Physical Oceanography

DESCRIPTION OF TOPIC OR REGION RECOMMENDED FOR EXPLORATION

Brief Overview of Area or Feature

Oceanic crust covers 72% of the Earth's surface, and is continuously regenerated along 75,000 km of mid-ocean ridges (MOR) worldwide. These spreading centres are interrupted along their length by deep and linear fracture zones that host major strike-slip plate boundaries. While there have been substantial advances in our understanding of oceanic spreading ridges, their volcanic, tectonic and hydrothermal activity, and their role in the evolution of the Earth, relatively little work has been done on oceanic fracture zones and their bounding transform faults. Recent developments have identified oceanic fracture zones as playing important roles in the chemical interaction between the Ocean and Earth's interior; hosting important marine mineral deposits; controlling the evolution of passive margin basins; providing insights into the role of serpentinisation on reducing seismic activity and hazards at strike-slip plate boundaries; providing important pathways for deep-ocean circulation; and fostering high degrees of biodiversity and benthic population connectivity.

The Charlie-Gibbs Fracture Zone (CGFZ) is one of the most spectacular and significant examples of an oceanic fracture zone intersecting a MOR. It forms a major transform fault complex that has been active since continental break-up. It offsets the Mid Atlantic Ridge (MAR) approximately 370 km left-laterally, between Iceland and the Azores (52^{o} to 53^{o} N) (Figure 1). It is thought to have initiated on a continental plate and continued to evolve with the opening of the N Atlantic. The CGFZ provides a major pathway for the flow of deep, cold and oxygenated Atlantic Deep Water. The supply of nutrient-rich water at the convergence between the Polar and Atlantic Ocean fronts supports a rich ecosystem. So rich is the biodiversity here that the area of the CGFZ was declared one of the first Marine Protected Areas in the high-sea. Baseline and geological investigations will contribute to environmental protection measures.

Brief Summary of Current State of Knowledge

The CGFZ comprises two seismically active E-W transform-fault valleys separated by a short ridge. The width of the ridge spreading centre is 40 km. Hence the central rift is simultaneously an inside corner, a slow spreading centre, and a cold low-magma supplied system. The median ridge between the double transform faults was first studied in the 60's and 70's. More recent opportunistic AORA backed transit high resolution multibeam data, acquired by the Irish lead AORA transatlantic expeditions of 2015, 2016 and 2017 have provided greater detail of

the area of spreading between the double transform faults. Following these expeditions, the Irish lead TOSCA expedition (CE18008) May-June 2018, surveyed and sampled a portion of the median ridge, using high resolution multibeam swath sonar and multichannel seismic reflection profiles, dredge, gravity core and ROV sampling. Alpine scale corrugated dome-shaped massifs to the east and west of the central spreading centre confirm the presence of a series of OCCs between the fracture zones. Cyclical OCC formation with no obvious localised volcanism indicates spreading is accommodated by movement of upper crustal and lower mantle rocks along deep detachment faults exclusively.

The varying and abrupt topography of the CGFZ has had a demonstrable effect on North Atlantic current circulation and the Atlantic overturning (i.e. North Atlantic Current). Dramatic topographic relief and deep parallel transform fault valleys create flow paths across the MAR, these are known to be responsible for generating surface eddies and stimulating a hotspot of biodiversity here.

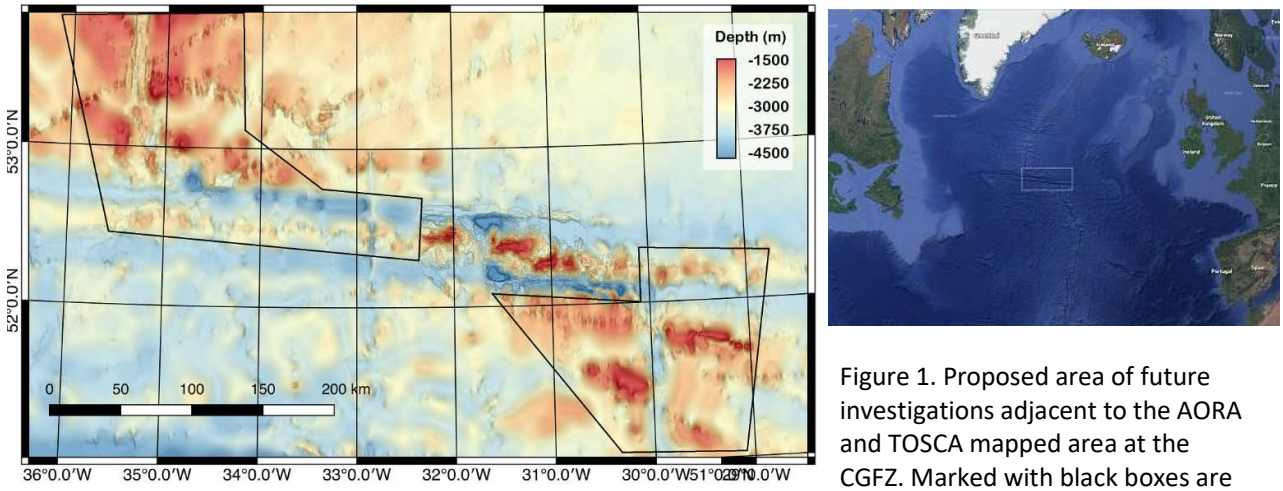

Figure 1. Proposed area of future investigations adjacent to the AORA and TOSCA mapped area at the CGFZ. Marked with black boxes are areas of priority interest.

Rationale for Future Exploration

Data collected from the area to date testify to the significance of this site in the Central North Atlantic in terms of geological processes, plate tectonics, geohazards, biological activity and physical oceanography. Additional high resolution imaging in this region would significantly increase our understanding of the unique spreading history in a region of the Atlantic where there is least influence of the Icelandic Hotspot and the Azores hotspot. The spreading axis between the Charlie Gibbs Fracture zones, has yet to be sampled. Sampling here is of particular interest considering a lack of basaltic samples yet retrieved in previous sampling champagnes... During the TOSCA expedition, ROV dives retrieved geological samples and some Eh anomalies which may indicate the presence of hydrothermal activity, but as yet no active venting has been recorded here.

The CGFZ presents a unique opportunity to study the effects of a long-lived asymmetric spreading and associated hydrothermal venting and to establish the extent of volcanism, investigate the landslide-generated tsunami hazard associated with these edifices and analyse the biodiversity hosted in these environments.

Relevant partnerships

ECOMAR, MAR-ECO, AORA, Blue Mining, MarineE-tech, InterRidge newly formed working group on mid-ocean ridge islands and seamounts

2018 ASPIRE WHITE PAPER: Missing Venting of the Mid-Atlantic Ridge, 35°-39°N

Contact Information

Christopher R German
Woods Hole Oceanographic Institution

Target Name(s)

Mid-Atlantic Ridge, 35°-39°N

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

North Central

Relevant Subject Area(s) (Indicate all that apply)

Biology
Chemistry
Geology
Physical Oceanography

Relevant Partnerships

U. Bremen (Germany) Cluster of Excellence: The Ocean Crust – Earth's Uncharted Interface
InterRidge, GEOTRACES, INDEEP

Description of Topic or Region Recommended for Exploration

Overview

The Mid Atlantic Ridge (MAR) between 35°N and 39°N is already known to host abundant, geologically diverse styles of hydrothermal venting and these sites give rise to a broad variety of vent-fluid compositions and habitats for life that, in turn, host a broad spectrum of chemosynthetic organisms with metabolisms that reflect, and are presumably controlled by, that geologic diversity. Twenty-five years on from the original discoveries of the Rainbow, Lucky Strike and Menez Gwen hydrothermal fields, however, many of the plume signals identified during the initial exploration of this region have still never been tracked to source while ROV-based geological transects have encountered unexpected additional diffuse flow sites (Fig.A1).

Over the same time-period, our ability to explore for seafloor fluid flow has been revolutionized in three important ways:

- the power of CTD tow-yo techniques has been vastly expanded with the addition of *in situ* redox (ORP) sensors as well as optical back-scatter sensors for plume detection and characterization.
- AUVs have been demonstrated to be particularly effective at tracking hydrothermal plumes to source and locating them precisely, to guide ROV-based investigations.
- In suitably shallow/gas-rich systems (primarily at ocean margins, but also on shallow ridges) it has been shown that water-column surveys using shipboard multibeam sonars can be used to detect gas-rich flares rising from the seafloor and trace them back to their source.

This white paper proposes a plan of campaign to return to the Mid Atlantic Ridge south of the Azores, informed by the latest scientific understanding *and* technological approaches, to complete a program of systematic hydrothermal exploration. The approach proposed would not only be anticipated to find new seafloor vents but also new *styles* of seafloor venting and associated chemosynthetic habitats.

Current State of Knowledge

Hydrothermal research and, more specifically, hydrothermal plume based exploration and discovery has been revolutionized in the past few years. First, it has been demonstrated that fluxes of metals from hydrothermal systems extend much farther out into the global deep ocean than can be traced by *in situ* sensors mounted on a CTD rosette. Such trace metal distributions, as revealed by the international GEOTRACES program, have now been identified in every ocean basin on Earth. Indeed, it is now predicted that stabilized dissolved Fe release through seafloor venting can persist so far that it can be upwelled into the surface ocean at high latitudes where, as an essential micro-nutrient, it can control 10-30% of CO_2 uptake and primary productivity in the Arctic and Antarctic regions, respectively. Second, theoretical modelling undertaken by SCOR Working Group 135 has predicted that the vast majority of this stabilized dissolved Fe dispersed through hydrothermal plumes may not be sourced by the high-temperature "black-smoker" venting that has been the focus of much past seafloor hydrothermal studies. Rather, it may be sourced via diffuse hydrothermal flow associated with these high temperature systems, where abundant life may lead to a ready supply of organic binding ligands. Finally, extension to the use of ORP sensors alongside traditional optical back-scatter sensors has led to a realization – based, to date, on just one study site on the northern East Pacific Rise (EPR) - that traditional CTD tow-yo surveys used routinely for hydrothermal exploration since the 1980s may have only detected a subset of all the diversity of seafloor fluid flow present. Consequently, the global-scale impact of seafloor venting may until now have remained grossly under-estimated.

Rationale for Future Exploration

New work to address the relative importance of diffuse rather than focused hydrothermal flow is now planned for the fast-spreading EPR, using the Sentry AUV and updated tow-yo techniques equipped with ORP sensors. However, slow spreading ridges such as the MAR make up more than 50% of the global ridge crest and express a much wider pattern of geologic diversity. Consequently, this white paper proposes to take the current state of the art technology for vent exploration (also including bubble mapping for shallow ± gas-rich vent-sources) and complete a more comprehensive survey for hydrothermal venting than has ever previously been achieved in this natural laboratory, known to be one of the most geologically-diverse and vent-rich sections of slow-spreading ridge-crest world-wide.

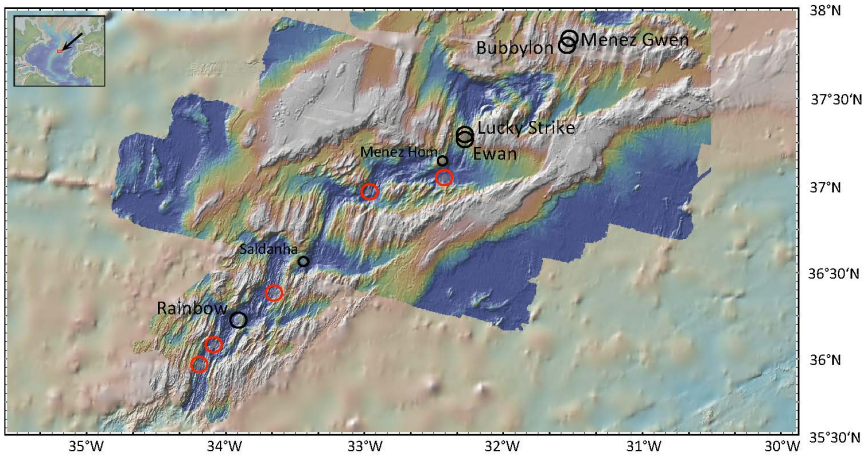

Fig.1 Map of MAR south of the Azores showing (black circles) known locations of high-T and low-T venting already known (likely a subset of everything present) plus (in red circles) the locations of additional plume signals that were first detected in 1992-1994 but which have never yet been tracked to source.

2018 ASPIRE WHITE PAPER Deepwater Archaeological Exploration

Contact Information
Jack B. Irion, Ph.D.
Bureau of Ocean Energy Management

Target Name(s)
Deepwater approaches to the ports of Baltimore and New York
Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)
Northwest
Southwest
Relevant Subject Area(s) (Indicate all that apply)
Marine Archaeology, Benthic Biology

Description of Topic or Region Recommended for Exploration
The United States owes its very existence to the sea and to its well-situated ports, through which flowed goods and people and from which flowed the bounty of a young nation. The three preeminent ports of the young Republic were New York, Baltimore, and New Orleans. Associated with each of these ports are the physical remains of shipwrecks on the seafloor that document the lives of the sailors, immigrants, enslaved Africans, traders, and pirates that wove their stories into the fabric of America. Of the three primary port cities, New Orleans is favorably situated as the entrepôt for the rich oil and gas fields of the Gulf of Mexico. As a result, the waters off its coast, up to the edge of federal jurisdiction 200 miles offshore, have been the subject of high resolution geophysical survey undertaken by the oil and gas industry at the behest of the federal agency that regulates it, the Bureau of Ocean Energy Management. These surveys, magnetometry, sidescan sonar, and multibeam bathymetry, have discovered dozens of historic shipwrecks in water depths as much as 7,500 feet. Undisturbed by man, too deep to be effected by even the most ferocious of storms, and only reduced by the marine organisms that feed on the organic remains, these wrecks lie on the seafloor in a remarkable state of preservation. Surprisingly fragile artifacts have been observed intact on Gulf shipwrecks that preserve their original placement aboard

Figure 1. Partial photomosaic of Wreck 15377

the ship and help to interpret the ship and its contents to modern researchers. Most importantly, vessels such as the large mid-19th century three-masted wreck known solely by its BOEM designation of Wreck 15377 (Fig. 1) are documented only through their archaeological remains. Despite years of archival searching for shipping losses in the Gulf, no written record of loss of this vessel has come to light. Other similar vessels from the 17th, 18th and 19th centuries have been found through oil and gas surveys with many clustering within 15 to 85 miles of the approach to the Mississippi River. These ships were simply "lost at sea" with no survivors to record their passing. They are arguably among the most significant submerged cultural resources in the US for the information they undoubtedly contain relating to the endeavors, hopes, aspirations, and travails of a young nation. However, the deep water approaches to America's two wealthiest and busiest historic seaports, Baltimore and New York City, remain unsurveyed between the shelf edge at 400 feet to 8,000 feet with the kind of equipment needed to detect historic shipwrecks.

Summary of Current State of Knowledge

At present the deep water areas off the Outer Continental Shelf remain largely unexplored using high resolution sonar or any equipment capable of detecting the deflated remains of an historic wooden-hulled shipwreck on the seafloor. The hull-mounted multibeam surveys conducted by NOAA lack the resolution to find even large, modern vessels in more than one- or two hundred feet of water. As a result, the depths outside the Shelf towards the edge of America's Exclusive Economic Zone are undescribed for the sorts of rich archaeological remains they may preserve. Yet, it is likely that scores, if not hundreds, of ships were lost in these depths on the approaches to the busiest harbors of colonial America and the Early Republic as the result of Atlantic storms, on-board fires, pirates, or mishap.

Rationale for Future Exploration

The recent accidental discovery of the Blake Ridge wreck by Woods Hole Oceanographic Institute, almost 140 miles off the coast of North Carolina, argues for the likely presence of shipwrecks in deep water along other parts of the U.S. coastline. If the example of New Orleans serves, these would lie on the approaches to the two most active historic ports along the Eastern Seaboard, Baltimore and New York. Furthermore, if the examples of the Gulf of Mexico hold, these sites from the earliest history of European contact with North America are likely well-preserved and intact and could contribute substantially to our understanding of colonial settlement and exploration. In addition, shipwrecks function as artificial reefs in the deep ocean and recruit a wide variety of organisms, and yet the role of randomly situated shipwrecks within the natural environment remains poorly understood. Thus any study of shipwrecks should incorporate a biological analysis of the species attracted to them.

Relevant Partnerships (If Applicable)

Bureau of Ocean Energy Management, Bureau of Safety and Environmental Enforcement, NOAA Office of National Marine Sanctuaries

Exploration of the mesopelagic community using nets, acoustics, optics, and DNA
White paper to NOAA Ocean Exploration and Research (OER)

Contact Information

Primary Contact: Michael Jech
Home Institution: NOAA Northeast Fisheries Science Center, Woods Hole, MA

Target Name(s)

Main Feature(s)/Area(s) of Interest: Our primary interest is exploring and quantifying the community of animals that live in the deep scattering layers (DSL) from 400 m to 2000 m depths using nets and acoustical, optical, environmental, and genetic sensors. The DSL is ubiquitous throughout the North Atlantic, but topographic features such as the New England Seamounts (Fig. 1) and mid-Atlantic ridge can modulate the spatial structure of the DSL.

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

Northwest: primary interest
North Central: secondary interest
Northeast: secondary interest
Southwest: NA
South Central: NA
Southeast: NA

Relevant Subject Area(s) (Indicate all that apply)

Biology: primary interest
Geology: NA
Chemistry: NA
Physical Oceanography: primary interest
Marine Archaeology: NA
Other: acoustical oceanography

Description of Topic or Region Recommended for Exploration

Brief Overview of Area or Feature: “The DSL” is an overarching term for a layer apparent in acoustic echograms that is present in the mesopelagic regions in all of the world’s oceans. This layer was extensively studied using acoustics, optics, and nets during and after WWII to characterize the DSL’s biological community. That interest waned until recently when commercial exploitation of the DSL as a source of protein is becoming technologically feasible and economically viable.
Brief Summary of Current State of Knowledge: Technological advances in acoustic and optical instrumentation have provided high resolution views of the DSL that upon close examination reveal a spatial structure that is vertically complex while remaining horizontally extensive (e.g., Fig. 1). The vertical migration of some of the layers in the DSL transports biomass from deep waters to the sea surface providing an additional food source for predators (e.g., birds, small cetaceans) in low-nutrient pelagic regions. Recent estimates of the abundance and biomass in these layers have suggested an order of magnitude greater biomass than original estimates, suggesting that these layers may contain enough biomass for human exploitation. Genetic

techniques and tagging technology (e.g., DTAGS) are beginning to elucidate the trophic dynamics of the DSL as food for apex predators such as beaked whales, tuna, and sharks.
Rationale for Future Exploration: The “layers within layers” of the DSL are coarsely visible using hull-mounted acoustic systems and little is known about the species composition of these layers. Broadband acoustic systems, cameras, and eDNA samplers that can be towed in these layers will be critical for understanding migratory (or lack of) behavior and how the mesopelagic community is spatially structured. Acoustic diversity (i.e., acoustic backscattering patterns and features) may be an indicator of biological diversity, which can only be verified by nets, optical systems, and genetic samplers that directly sample the layers.
We just completed a successful test and evaluation of the Deep-See system in August 2018 on the NOAA ship HB Bigelow. Deep-See is an acoustical, optical, environmental, and eDNA system that is towed at the depths of the DSL. With the newly installed 0.681 fiber optic cable, the Bigelow has the capability to tow an advanced system like Deep-See as well as sample the DSL with nets and water samples.

Relevant Partnerships (If Applicable)

Deep-See (Woods Hole Oceanographic Institution); Ocean Twilight Zone (Woods Hole Oceanographic Institution);

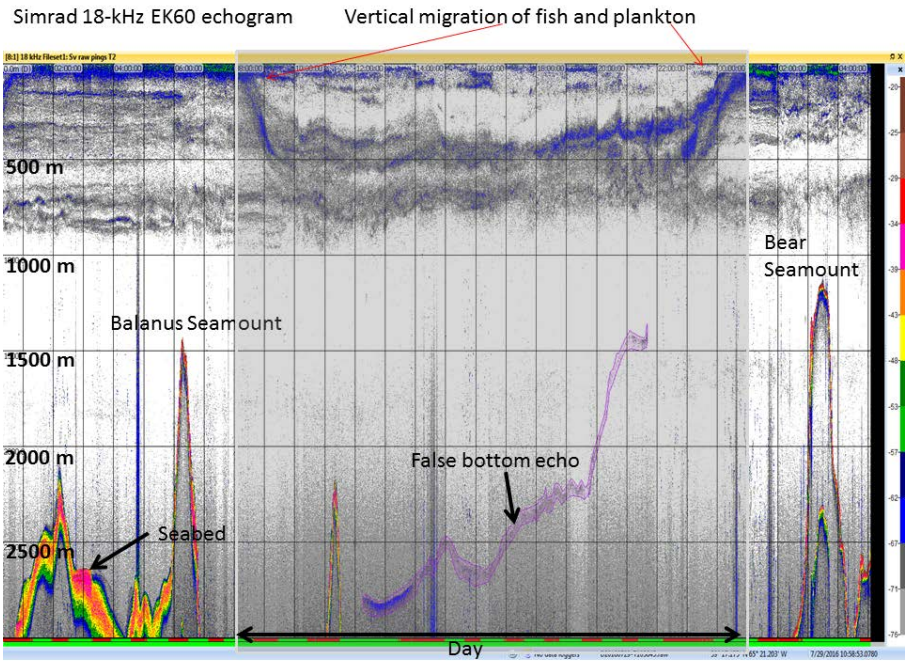

Figure 1. 18-kHz echogram along a transect from Balanus to Bear Seamounts on 28-29 July 2016. The seabed echo is the rainbow color feature near the bottom of the echogram and a false (aka “ghost”) echo is highlighted in purple. The acoustic scattering from about 400 to 1000 m is the DSL.

Contact Information

Primary Contact:	**Larry Mayer**	**Cindy Van Dover**
Home Institution:	Center for Coastal and Ocean Mapping, UNH	Duke Univ. Marine Lab

Target Name: Exploration of Western North Atlantic Shelf-Break Ecoregions and the Laurentian Fan

Geographic Area(s) of Interest within the North Atlantic Ocean: Northern shelf break ecoregions and the Laurentian Fan

Relevant Subject Area(s) Biology, Geology, Chemistry, Habitat Mapping

Description of Region and Topic Recommended for Exploration

REGION: Northern shelf-break ecoregions. Based on published databases of biophysical proxies (temperature, pH, particulate organic carbon flux, dissolved oxygen, sediment granulometry) and K-neighborhood clustering methods (spatial autocorrelation), the shelf break extending from Cape Hatteras to the Gulf of Maine is predicted to include 5 ecoregions (Fig 1), with additional ecoregions accumulating to the north (i.e., beyond the geographic scope of the effort that generated Fig 1). **TOPIC: Shelf-break biogeography.** Seeps and the surrounding seafloor environment provide targets for testing whether the ecoregions identified using biophysical proxies are reflected in measurable differences in the benthic faunas. Mapping of water column acoustic anomalies associated with methane release from seeps could be strategically focused within unexplored northern ecoregions, ideally extending as far north as the Laurentian Fan (Fig 2), where there is a seep that has not been visited since 1986.

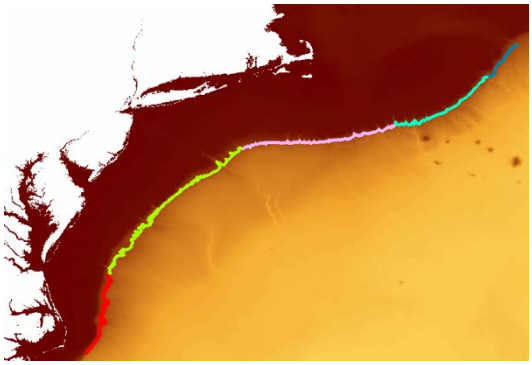

Figure 1. Color-coded ecoregions of the NW Atlantic shelf break (Van Dover laboratory).

The Laurentian Fan – North Atlantic –centered on 43°33'N, 55°37'W, 3878 m. On 18 November 1929, a magnitude 7.2 earthquake occurred in the region of the Eastern Valley of the Laurentian Fan south of Newfoundland. This earthquake generated a turbidity current that sequentially destroyed submarine telegraph cables across the Atlantic and repaved the floor of the Eastern Valley creating fields of giant, transverse, gravel-wave bedforms. Exploration of this remarkable seabed geomorphology with the submersible *Alvin* in 1986 led to the totally unexpected discovery of dense biological communities (vesicomyid and thyasirid clams, gastropods, pogonophoran tubes, galatheids, and unidentified branched organisms; Mayer et al. 1988) located on the crests of gravel waves and presumed to be associated with a methane cold-seep system (Figure 2). These communities may represent one of the largest cold-seep systems ever discovered.

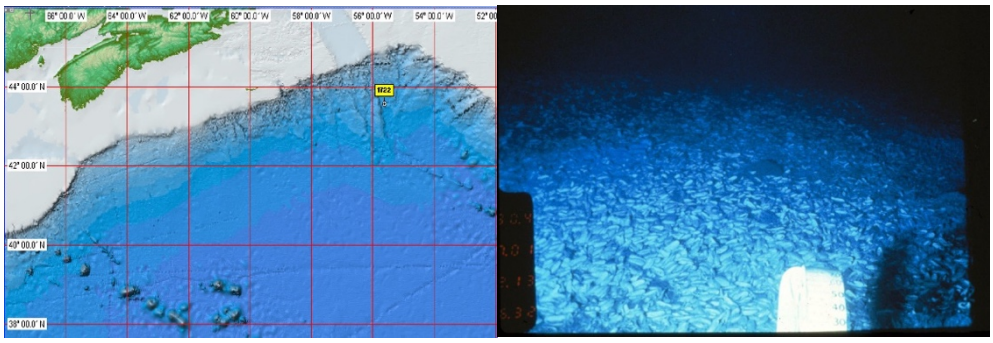

Figure 2. Left - Location of large chemosynthetic communities on the Laurentian Fan (yellow); right – example of clam communities seen from Alvin.

Brief Summary of Current State of Knowledge: Shelf-Break Ecoregions. Skarke et al. (2014) identified more than 500 seeps along the US Atlantic margin and set the stage for follow-on characterization of shelf-break seep

ecosystems (e.g., Bourque et al. 2016). Global data sets of biophysical proxies enable spatial analyses that explore potential eco- and biogeographic regions and that can be used strategically to identify priority areas for exploration and characterization of seafloor ecosystems (Watling et al. 2013, Dunn et al. 2018). Detailed analysis of seep faunas extending from Cape Hatteras to Cape Cod documents shifts in community characteristics consistent with an ecoregion structure (P Turner, Duke PhD dissertation, in progress).

Brief Summary of Current State of Knowledge: The Laurentia Fan. The classic work of Heezen and Ewing (1952) that demonstrated the existence of deep-sea turbidity currents triggered by the 1929 Grand Banks earthquake, this region of the Laurentian Fan has been subject to a number of geological studies focused on the impact of the turbidity current. The discovery chemosynthetic communities in 1986 was accidental and unexpected. Faunal and biophysical characteristics seemingly places these communities in a different biogeographic/ecoregion from those of the Skarke et al. seeps on the US Atlantic coast shelf break and those recently discovered off Svalbard (Astrom et al. 2016).

Rationale for Future Exploration: Shelf-Break Ecoregions and the Laurentian Fan. Extending the exploration and characterization of seep sites further north than the Skarke et al. (2014) observations will open a new frontier for developing an understanding of the distribution of seep and other seabed faunas relative to biophysical proxies. The *Okeanos Explorer*'s ROV and mapping systems enable localization and characterization of study sites and faunas within a detailed morphologic context. The relationship of communities to the shelf break, and, in the case of the Laurentian Fan, to canyon walls, gravel waves, and turbidity-current deposits, will provide insight into the nature of the methane sources. Sampling and analysis of the fauna will also address the extent of population connectivity between the Laurentian Fan seep fauna and other seeps in the North Atlantic. This will allow Laurentian Fan invertebrates to be placed within a global biogeographic context and provide a basis for the understanding of the relationship of benthic populations to ecoregions defined by biophysical proxies, and to local and regional seafloor processes and fluid flow. Stable isotope analyses of animal tissues will help to resolve whether there is a deep source of thermogenic methane at Laurentian Fan seeps. Finally, because the seafloor was stripped clear by the Laurentian Fan turbidity current in 1929, the 1929 event established a "time zero" benchmark against which the development of the seep community can be assessed (Mayer et al. 1988). A re-visit to the sites visited by ALVIN in 1986 will document changes in the community 33 years after the first dives and nearly a century after the initiating event. The proposed expedition will address fundamental biological and geological questions including the nature of chemosynthetic communities, how they are established, and how they are sustained, and will image and sample environments that are beautiful and exotic -- a key to engaging the public.

Potential Partnerships ATLAS, SponGES, Canada Healthy Oceans Network, Geological Survey Canada (esp. David Mosher, David Piper, Alexandre Normandeau), University Kiel (esp. Sebastian Krastel), InDeep

References **Astrom EKL** et al. (2016) Arctic cold seeps in marine methane hydrate environments: Impacts on shelf macrobenthic community structure offshore Svalbard. Mar Ecol Prog Ser 552:1–18. **Bourque JR** et al. (2016) Macrofaunal communities associated with chemosynthetic habitats from the U.S. Atlantic margin: A comparison among depth and habitat types. Deep Res Part II Top Stud Oceanogr 137:42–55. **Dunn DC** et al. (2018) A strategy for the conservation of biodiversity on mid-ocean ridges from deep-sea mining. :1–16. **Heezen, B.**, W. M., Ewing, (1952), Turbidity currents and submarine slumps, and the Grand Banks earthquake, Amer. Journ. of Science, v. 250, p. 849-873. **Mayer LA** et al. (1988) Dense biological communities at 3850 m on the Laurentian Fan and their relationship to the deposits of the 1929 Grand Banks earthquake. Deep-Sea Research A 35:1235-1246. **Skarke A** et al., (2014) Widespread methane leakage from the sea floor on the northern US Atlantic margin. Nat Geosci:1–5. **Watling L** et al. (2013) A proposed biogeography of the deep ocean floor. Prog Oceanogr 111:91–112.

TITLE Exploring the Canadian continental slope and inactive vents on the Mid Atlantic Ridge

CONTACT PERSON Anna Metaxas, Dalhousie University, Canada

TARGET NAMES (1) Canadian Continental Slope (Eastern Canyons and Laurentian Fan cold seeps); (2) Mid Atlantic Ridge (inactive hydrothermal vents) (all, at depths >> 200 m)

GEOGRAPHIC AREA OF INTEREST Northwest, North Central

RELEVANT SUBJECT AREAS Biology, Geology

DESCRIPTION OF THE REGION RECOMMENDED FOR EXPLORATION

One region of interest is the continental slope off Nova Scotia Canada, in the northwest Atlantic (Fig. 1). In the last 6 years, we have had a long-standing successful US-Canada collaboration during which we have been collecting data on the ecological assemblages of the Gulf of Maine and submarine canyons and fans along the US and Canadian continental slopes. We propose to continue extending this coverage to the northeast (Fig. 1 in green shading), in an effort to generate a mechanistic understanding of faunal distributions, and particularly the role of connectivity in generating these distributions. This area contains highly complex ridge formations and is expected to contain cold seeps. The shallow (<1000 m) depths of the canyons and slope have been surveyed, including in 2018. However, the deeper sections of the canyons and the adjacent waters to the EEZ remain largely unexplored by ecologists. The "Laurentian Fan Cold Seeps" Ecologically and Biologically Significant Area (EBSA) (Fig. 1, shaded in orange) includes several cold seep communities at ~ 4000 m depth that were discovered by geologists and only surveyed photographically and cursorily once (Mayer et al. 1988. Deep-Sea Res, Part A 35: 1235-1246). The extent and composition of the chemosynthetic communities remains unknown, but it has been proposed that this location may serve as a critical node of connectivity of cold seeps between the two sides of the north Atlantic Ocean.

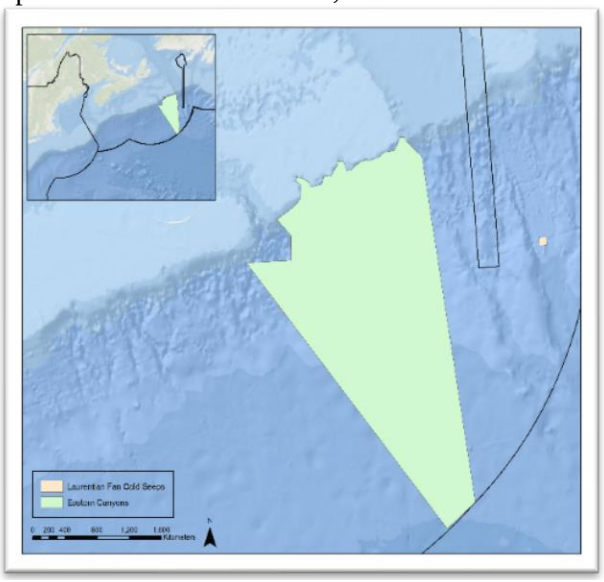

Figure 1: Proposed locations on the Canadian continental slope.

In March 2018, Fisheries and Oceans Canada announced plans to advance a new fishery closure (Marine Refuge) for a large deep-water area encompassing the two large canyons and extended out to the Exclusive Economic Zone. In addition to the known aggregations of corals along the slope, the area was selected because it encompasses representative examples of canyon, slope, continental rise, and abyssal plain habitats and associated biological communities. Knowledge of the dominant biological assemblages, as well as evidence of connectivity among deep sea systems from the "shallow" (shelf edge) to the deepest extent of the planning region, will inform management measures being designed for that area. The Laurentian Fan cold seeps EBSA is included in the draft Marine Protected Area Network Design for the Scotian Shelf Bioregion to be released in 2018, as it is currently the only confirmed seep community in the region. Again, baseline data on the biological communities are needed to better inform its inclusion in the overall design.

Another area of interest focusses on inactive vents on the Mid Atlantic Ridge (MAR). The precise location is not critical because it is the feature that is of interest and may be combined with any other research effort that focusses on active hydrothermal vents or the general geographic region of the ridge. [InterRidge Vents Database ver. 3.4 (http://vents-data.interridge.org/) includes all known locations of hydrothermal vent fields, all at depths > 800 m; the most logistically convenient can be selected, e.g. near Iceland or the Azores.]

Most ecological research done on hydrothermal vent ecosystems globally has focused on active vents because of the unique and spectacular fauna that inhabits them. Active vents eventually become inactive and the flow of hydrothermal fluids permitting chemosynthesis to occur ceases. The hard substratum at most hydrothermal vents may become partially covered with sediment, altering the types (and diversity) of habitats available for colonization. These physical and chemical changes will lead to inevitable changes in the biological assemblages from those based on chemosynthesis to ones that rely on an allochthonous food supply. Suspension feeders that require hard substratum, such as deep-water corals and sponges, are likely members of the new assemblages, although their ability to colonize will depend on proximity to adult populations. Over time and with increasing sedimentation, fauna that typically occupy soft sediments may also begin to colonize. To date, the patterns and rates of the ecological succession that occurs when active hydrothermal vents transition to inactive ones remain unknown. Here, I propose to survey a series of inactive hydrothermal vents at increasing distances (starting at 100 m) from the active vent field to begin to describe their biological assemblages and shed some initial light on the rates of colonization and succession.

This research is not only novel scientifically, but it is also very timely in light of the accelerated development of deep-sea mining. In a publication earlier this year, we proposed that active hydrothermal vents should not be mined at all (Van Dover et al. 2018. Marine Policy 90: 20-28). This proposal appears to be gaining at least partial support from the International Seabed Authority and the mining industry. Although inactive vents will most likely be the target of mining activities, we made no explicit recommendations with respect to mining those because of the lack of data on their ecological assemblages. Thus, a pressing need exists to, at least, describe the assemblages that occupy inactive vents in order to make recommendations on the best approaches for managing the mining activities.

RELEVANT PARTNERSHIPS

The research on the Canadian continental slope will benefit from a number of existing partnerships. I am a member of the leadership of the ***Canadian Healthy Oceans Network (CHONe)*** and lead research on the role of population connectivity in the design of Marine Protected Areas. The proposed work closely aligns with CHONe's interests and the priorities of the Science and Ocean Management branches of the ***Department of Fisheries and Oceans Canada*** and extends the work we have been doing with Dr. Martha Nizinski at ***NOAA*** (and that she is proposing as part of this same program). Additionally, it closely links with the research that Snelgrove is proposing for 2018 ASPIRE because of the hydrodynamic connection between the Labrador Sea and Nova Scotia current. CHONe also has a partnership with ***ATLAS*** and our research on deep-water corals and sponges will directly inform the overall objectives of ATLAS to improve our understanding of complex deep-sea ecosystems, and in particular the role of connectivity. Our research will also be relevant to ***SponGES***, which aims to develop an integrated ecosystem-based approach to preserve and sustainably use deep-sea sponge ecosystems of the North Atlantic**.** In fact, Dr. Kenchington (one of the co-coordinators of SponGES) is a member of DFO-Science mentioned above and one of the proposed focus areas for 2018 ASPIRE by her and Whoriskey of the ***Ocean Tracking Network*** is the Scotian Shelf.

The research on inactive vents has been developed from the many coordinated efforts of the ***Deep Ocean Stewardship Initiative*** (DOSI) to propose management solutions for deep-sea mining. We will collaborate closely with the 2018 ASPIRE proposal by ***ATLAS*** in the northeast Atlantic (e.g. south of Iceland or by researchers Carreiro Silva and Morato focused on describing the diversity of deep-sea ecosystems in the Azores region).

Contact Information
Primary Contact: Rosanna Milligan
Home Institution: Nova Southeastern University, FL

Target Name(s)
Porcupine Seabight / Porcupine Abyssal Plain. Biomass estimation concepts also apply generally.

Main Feature(s)/Area(s) of Interest
Porcupine Seabight

Geographic Area(s) of Interest within the North Atlantic Ocean
North East

Relevant Subject Area(s)
Biology, Geology, Chemistry and Physical Oceanography

Description of Topic or Region Recommended for Exploration
Brief Overview of Area or Feature.
The Porcupine Seabight is a broad, canyon-like oceanic basin in the NE Atlantic, extending from approximately 400 – 3000 m depth on the continental margin off SW Ireland. Within this region, a number of distinct seafloor habitats have been identified, including: three major carbonate mound provinces (Belgica, Hovland and Magellan Mounds) in the north that support cold-water coral frameworks (e.g. Huvenne *et al.* 2005); canyons to the east; and hexactinellid sponge beds between 1000 and 1300 m depth (Rice *et al.* 1990), with new data showing evidence of trawling damage. The Gollum Canyon System extends from the Irish continental shelf, along the axis of the Porcupine Seabight, and ultimately connects the Porcupine Seabight to the Porcupine Abyssal Plain to the west. The Porcupine Abyssal Plain – Sustained Observatory provides a long-term ecological research dataset from 1989-present for understanding change and pelagic benthic coupling processes that help shape seafloor communities (Hartman et al. 2012; Durden et al. 2017).

Brief Summary of Current State of Knowledge
The Porcupine Seabight has been subject to extensive seafloor mapping efforts (e.g. Dorschel et al, 2010). and the demersal and benthic megafauna were well surveyed, primarily by trawling, during the 1970s – early 2000s (e.g. Rice et al, 1991; Priede et al, 2010). The majority of these studies focused on the bathymetric and regional-scale distributions (i.e. 10s – 100s km) of deep-living fauna. As a result, we have a good taxonomic knowledge of the benthic and demersal fauna occurring within the Porcupine Seabight (and wider NE Atlantic), as well as on the regional oceanographic and biogeochemical setting (e.g. Carney, 2005). More recently, ROV video surveys of the biota have been conducted, but these have been focused mainly on the coral mound provinces. However, the region is subject to anthropogenic influences, the most notable of which is commercial fishing, which has extensive impacts on both target and non-target fishes and habitat-forming species such as cold-water corals and sponges. More generally, global to regional scale seafloor biomass can be estimated with valuable skill (see Wei et al. 2010), but there is an important challenge left revise such model estimates to better account for attributes like seafloor shape and composition in driving seafloor ecology. Models with such regional to local focus will be valuable in managing natural resources across a range of uses including fishing, energy extraction and mining. This program provides an opportunity to collect data to help drive data collection suitable to address this challenge.

Rationale for Future Exploration.
The Porcupine Seabight make it a highly desirable location in which to conduct high-resolution photographic, video and acoustic surveys that build upon the existing knowledge base. As interest in

spatial approaches to seafloor management increases within Europe and beyond (e.g. by designating Marine Protected Areas and identifying Vulnerable Marine Ecosystems), there is a clear need to better understand how the spatial distributions of deep-sea fauna relate to seafloor heterogeneity, and how they are affected by overlying oceanographic and biogeochemical processes in the water column. This includes the need to collect data suitable for estimating size specific biomass to help form and revise theories of how regional scale surface ocean and local scale seafloor features interact to influence the distribution and abundance of deep sea life. These management requirements feed into a growing interest in understanding the landscape ecology of marine organisms in general, and the role of the deep sea as a comparative environment in which to examine general ecological principles relating to space and habitat use.

In the present study, we propose a series of visual (video / photographic) ROV surveys conducted across different substrate / habitat types, conducted at different depths along the axis of the Porcupine Seabight, with the aim of examining the fine-scale spatial distributions of mobile invertebrate megafauna and demersal fishes at the seafloor. Acoustic and CTD surveys of the overlying water column (if feasible) would also allow connections between the benthic and pelagic realm to be examined and provide far more comprehensive, and high-resolution exploration of the Porcupine Seabight region than has been achieved to date.

Relevant Partnerships
The following colleagues have expressed interest in participating:
David M. Bailey, University of Glasgow, UK; Henry A. Ruhl, National Oceanography Centre, UK; Monterey Bay Aquarium Research Institute, CA, USA

The data collected from these surveys could be used to revise the estimates of Priede et al., 2010, Wei et al. 2010 and augment the NOC National Capability Project Climate Linked Atlantic Sector Science (CLASS) efforts.

Key References

1. Carney, R. S. (2005). Zonation of deep biota on continental margins. In Oceanography and Marine Biology - an Annual Review, Vol. 43, pp. 211-+. Ed. by R. N. Gibson, R. J. A. Atkinson, and J. D. M. Gordon.
2. Dorschel B. et al. (2010) Porcupine Seabight. In: Atlas of the Deep-Water Seabed. Springer, Dordrecht
3. Durden, JM, HA Ruhl, C Pebody, SJ Blackbird, D van Oevelen, 2017. Differences in the carbon flows in the benthic food webs of abyssal hill and plain habitats. Limnology and Oceanography: doi: 10.1002/lno.10532.
4. Hartman, SE et al. (2012). The Porcupine Abyssal Plain fixed-point sustained observatory (PAP-SO): variations and trends from the Northeast Atlantic fixed-point time-series. ICES Journal of Marine Science 69: 776-783.
5. Huvenne V.A.I. et al. (2005). The seabed appearance of different coral bank provinces in the Porcupine Seabight, NE Atlantic: results from sidescan sonar and ROV seabed mapping. In: Freiwald A., Roberts J.M. (eds) Cold-Water Corals and Ecosystems. Erlangen Earth Conference Series. Springer, Berlin, Heidelberg
6. Priede, I. G., et al. (2010). Deep-sea demersal fish species richness in the Porcupine Seabight, NE Atlantic Ocean: global and regional patterns. Marine Ecology-an Evolutionary Perspective, 31: 247-260.
7. Rice, A.L. et al. (1991). The Institute of Oceanographic Sciences Biology Programme In The Porcupine Seabight: Background And General Introduction. *Journal of the Marine Biological Association of the UK* 71(02):281 – 310
8. Wei C-L, et al. (2010) Global Patterns and Predictions of Seafloor Biomass Using Random Forests. PLoS ONE 5(12): e15323. doi:10.1371/journal.pone.0015323

Contact Information:
Primary Contact: Calvin Mires; Home Institution: Bridgewater State University

Target Names: Main Features/Areas of Interest: Exploration for sites and features that have maritime heritage significance *and* biological phenomena associated with deep-sea cultural and natural resources.
Geographic Areas of Interest: Northwest / North Central / North East / Southwest
Relevant Subject Areas: Biology, Marine Archaeology, Underwater Photogrammetry, UHDTV Video Documentation; Machine Learning
Description of Topic or Region Recommended for Exploration

The North Atlantic is one of the most historically significant regions on Earth. Upon its waters ships explored, fought, fished, traded, and connected cultures with indelible consequences. From Viking explorers through the mid-20th century, these ships representing more than 1000 of years of society, technology, and industry, were the primary tools of globalization. Not every journey ended well, however, and the waters of the North Atlantic hold the remains of ships that tragically never made their destination. These shipwrecks hold a wealth of information, but are resources that remain largely understudied, underserved, and untapped in part due to the difficulty in locating them in the deep-sea.

We are an interdisciplinary group of researchers from Woods Hole Oceanographic Institution, Marine Image Technologies, and Bridgewater State University, representing fields in marine archaeology, biology, deep-sea exploration and advanced imaging, and machine learning. We seek to explore for sites and features that have maritime heritage significance by leveraging cutting-edge underwater survey methods and documentation technology. We offer multiple approaches for seafloor characterization ranging from deep water renavigation, magnetometer data, and sidescan surveys to machine learning-based seafloor anomaly detection to prioritize survey areas of the seafloor where marine heritage targets are likely to be, localize these sites, and provide preliminary characterization. Using underwater imaging technologies developed at WHOI's Advanced Imaging and Visualization Laboratory and Marine Imaging Technologies, our goal is to be platform agnostic while producing the following outcomes in North Atlantic's deep-sea: 1) to map and archaeologically document known and newly discovered shipwreck sites; and 2) to investigate biological colonization of shipwrecks.

Shipwrecks are tangible connections to the past that allow us to explore and understand this human experience in a way not possible in history books or archives. They can represent a time capsule since they occur in a discrete moment in time, but they are multi-faceted, dynamic databases that may be studied as artifacts themselves, a carrier of artifacts, a microcosm of maritime cultures and associated systems, or a combination of all the above[1]. The depth of cultural information that can be learned from shipwreck sites is considerable, but it is first necessary to acquire the baseline data, such as location, current conditions, and possible identity to develop further research for maritime scholars. This is information is lacking for maritime heritage resources in deep water.

Shipwrecks are also part of an environmental system that provide habitats for obligate hard-bottom organisms, such as algae and sessile invertebrates, but do not directly replicate natural hard-bottom communities, because wrecks are isolated, island-like systems, especially at greater depths. Studying shipwreck communities can provide numerous insights into the process of community assembly, which includes larval dispersal, recruitment, interspecific interactions, and succession[2]. Wrecks may be colonized by different species than natural hard-bottom habitats and augment the biodiversity of a region. Shipwrecks typically have lower diversity than natural communities, allowing pairwise species interactions to be examined in detail[3]. Wrecks can also show the process by which a community develops over time, especially if the sinking date is known[4].

[1] Gould, RA 1983. *Shipwreck Anthropology*
[2] Meyer KS. 2017. Islands in a sea of mud. Adv Mar Biol 76: 1 – 41.
[3] Pawlik JR, et al. 2008. Patterns of sponge recruitment. Mar Ecol Prog Ser 368: 137 – 143.
[4] Perkol-Finkel S, et al. 2005. Fouling reefal communities on artificial reefs. Biofouling 21: 127 – 140

The major impediment to studying new shipwrecks and other isolated, island-like habitats is finding them. This problem offers us an excellent opportunity to leverage different methods of seabed characterization to accommodate different possible platforms used depending on collaborators and partnering agencies. WHOI has decades of experience working with deep-towed sonars, ROVs, and submersibles to survey, find, and record submerged and cultural resources. Furthermore, depending on goals and needs of national and international collaborators, we can contribute to the development and testing of artificial intelligence technologies for seafloor characterization. Anomaly detection techniques that operate in the context provided by automated seafloor characterization have the potential to fundamentally transform how we perform and interpret searches for targets whose exact appearance is not known *a priori*. Ideally, such techniques can be used *in situ* in combination with an autonomous underwater vehicle, to enable higher resolution data collection around potential locations of interest. The anomaly detection technique developed by Girdhar et al.[5] would enable the localization and preliminary interpretation and investigation of shipwreck sites in the deep North Atlantic, using sidescan sonar and image collection in a 2-tiered search method. The autonomous vehicle would begin with a high-altitude sidescan sonar survey and identify points of interest; these areas would then be investigated at higher resolution using sonar or image collection at lower altitude. Machine learning allows for faster exploration and focused data collection, by combining in a single dive what might otherwise take two or three.

For exploring new sites or re-investigating known wrecks, we will utilize some of the most cutting-edge underwater technology available to date. WHOI's Advanced Imaging and Visualization Laboratory and Marine Imaging Technologies have developed a suite of precision underwater imaging systems capable of conducting ultra-high-resolution close-up optical inspection, 3D photogrammetric volumetric imaging and methods for high resolution optical documentation of each research site. Data from these precision-imaging systems can be used to create interactive 3D volumetric models with near millimeter accuracy. Additionally, the team has developed and tested several observation class ROVs with advanced imaging capabilities for shallow water wrecks and developed imaging systems capable of easy integration to work-class ROVs and Human Occupied Vehicles to water depths of 7000 meters. A prototype penetration ROV was also recently developed in collaboration with the National Park Service Submerged Resources Group and successfully tested inside the USS *Arizona* in 2017. These imaging technologies and methods have been successfully used to document iconic shipwrecks including the RMS *Titanic*, and USS *Arizona.*

We propose baseline exploration of historical shipwrecks in the deep North Atlantic. Currently, we are collaborating with the staff at Stellwagen Bank National Marine Sanctuary (SBNMS) to explore, the Sanctuary's historic shipwrecks and want to expand our investigations and explorations further offshore. The deep North Atlantic serves as a rich repository for shipwrecks that provide a treasure trove of cultural information and a golden opportunity for biological investigations, but wrecks in the deep sea are severely underexplored. One possible region to begin investigations is the deep ocean surrounding the Azores. These volcanic islands have steep slopes that reach great depths in short distances offshore and are home to numerous U-boats sunk during the second World War as well as other vessels targeted by U-boats. They also were the last stop before ships sailed across the Atlantic to the "New World," and famous for the first global maritime industry, whaling. Further, deep-sea habitats that are easily accessible from shore will allow a preliminary test of machine learning technologies and baseline investigation of historically-important shipwrecks. Similar investigations could then be applied to other areas of the North Atlantic. Additional regions of interest include the eastern seaboard of the U.S., waters west of Ireland, and the waters around Greenland and Iceland, areas rich in fishing and maritime disasters. All of these regions are understudied, and the current state of knowledge is limited at best. We have the expertise to provide essential knowledge to begin to better understand the breadth and scope of human's activity and relationship with and on the North Atlantic for more than a thousand years.

[5] Girdhar Y, et al. 2016. Anomaly detection in unstructured environments. IEEE 2651 – 2656

2018 ASPIRE WHITE PAPER SUBMISSIONS TEMPLATE

Contact Information

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Home Institution; P.P. Shirshov Institute of Oceanology RAS (Moscow, Russia)

Target Name(s)

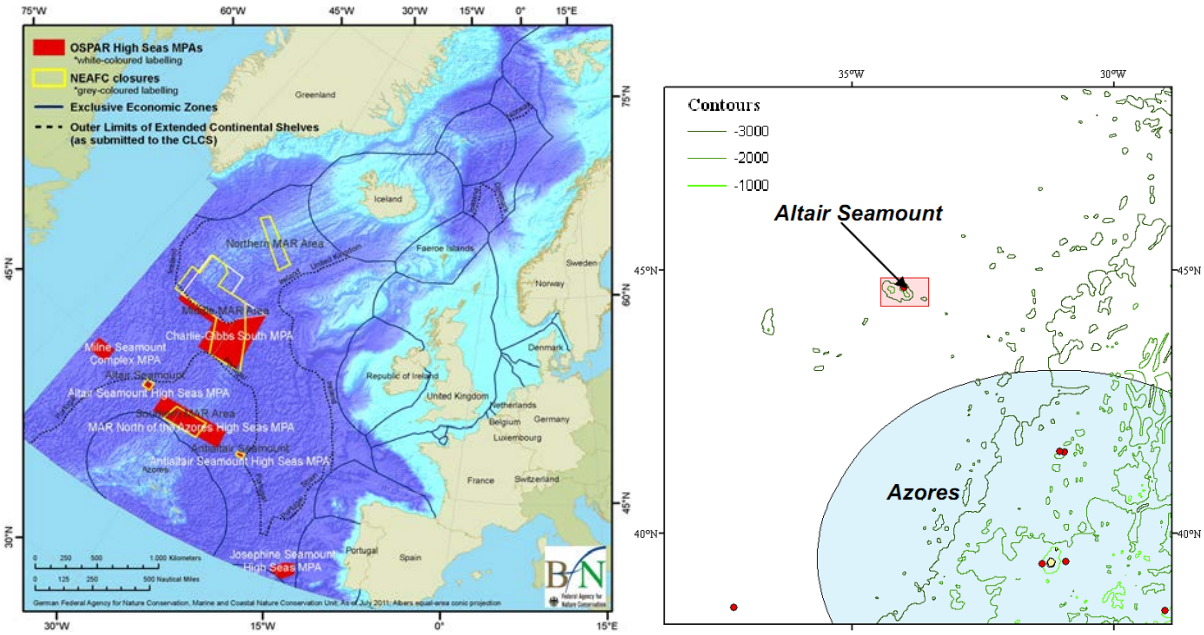
Main Feature(s)/Area(s) of Interest: Altair seamount

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

North Central

Relevant Subject Area(s) (Indicate all that apply)

Biology: X
Geology: X
Chemistry
Physical Oceanography
Marine Archaeology
Other



Description of Topic or Region Recommended for Exploration

Brief Overview of Area or Feature:

Altair seamount located in the North Atlantic just north west of the Azores (44° 40' 00" N 34° 00' 00" W) and min depth 975 m. The seamount has very steep topography Altair seabed is encompassed by a Portuguese submission to the Commission on the Limits of the Continental Shelf (CLCS). It was designated by both OSPAR (for the waters overlying the seabed) and Portugal (for the seabed) as MPAs. Altair seamount has been protected by a NEAFC fishery closure since 2005.

Brief Summary of Current State of Knowledge

Altair seamount is one of the less studied seamounts. Few scientific studies have been conducted on Altair before its closure, therefore very little is known about its biodiversity and

ecology. Study conducted using a Spanish freezer trawler did perform three experimental trawls (1.8 h total) over Altair seamount at depth 975-1382 m (Durán Muńoz et al, 2000). The main fish species that were caught in just under 2 hours of trawling on Altair were Black scabbardfish (*Aphanopus carbo*) and Lantern shark (*Etmopterus princeps*) (Durán Muńoz et al, 2000).

Rationale for Future Exploration

Altair seamount has been protected by a NEAFC fishery closure and no bottom trawling is apparently being conducted on this seamount since 2005. It believed to be extremely rich on both vulnerable marine ecosystems and fish resources, but no studies on VME were performed. This seamount is appearing to be extremely useful for transatlantic studies and for understanding the biodiversity, biography and connectivity in the both sides of the Atlantic.

Relevant Partnerships (If Applicable)

SponGES, ATLAS

Literature

Durán Muńoz, P., Román, E. & González, F. (2000) Results of deep-water experimental fishing in the North Atlantic: An example of co-operative research with the fishing industry. ICES CM 2000/W:04.

2018 ASPIRE WHITE PAPER SUBMISSIONS TEMPLATE

Contact Information

Primary Contact: Tina Molodtsova
Home Institution; P.P. Shirshov Institute of Oceanology RAS (Moscow, Russia)

Target Name(s)

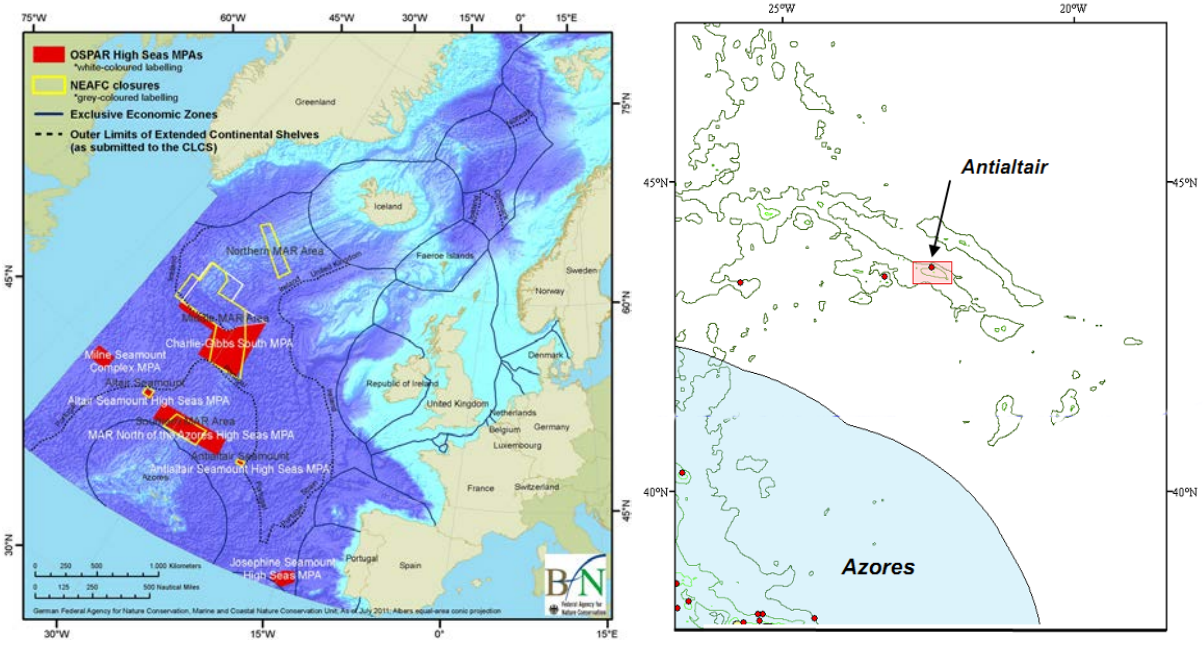
Main Feature(s)/Area(s) of Interest:
Antialtair seamount

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

North Central

Relevant Subject Area(s) (Indicate all that apply)

Biology: X
Geology: X
Chemistry
Physical Oceanography
Marine Archaeology
Other



Description of Topic or Region Recommended for Exploration

Brief Overview of Area or Feature:

Antialtair seamount located in the North Atlantic just north east of the Azores (43° 37' 00" N 22° 27' 00" W) with minimum depth ~900m. Antialtair seabed is encompassed by a Portuguese submission to the Commission on the Limits of the Continental Shelf (CLCS). It was designated by both OSPAR (for the waters overlying the seabed) and Portugal (for the seabed) as MPAs. Antialtair seamount has been protected by a NEAFC fishery closure since 2005.

Brief Summary of Current State of Knowledge:

Very little information is available on Antialtair seamount. Before the closure in 2005 three dredges were realized during SEAMOUNT2 program of MNHN (Paris) at depths 900 m and 1175-1210 m with very few animals recovered (Gofas, 1993) and one hawl (0.6 h) conducted using a Spanish freezer trawler specially adapted for trawling along rough terrain at depth range 889-1080 m. This last survey has found that the main fish species caught over Antialtair was Orange roughy (*Hoplostethus atlanticus*) (Durán Muńoz et al, 2000). No ROV dives were ever conducted at Antialtair seamount.

Rationale for Future Exploration

Antialtair seamount has been protected by a NEAFC fishery closure and no bottom trawling is apparently being conducted on this seamount since 2005. It is believed to be extremely rich on both vulnerable marine ecosystems and fish resources, but no studies were performed since the closure. This seamount is appearing to be extremely useful for transatlantic studies and for understanding the biodiversity, biography and connectivity in the both sides of the Atlantic and expected to potentially support more endemics than the younger seamounts of the Mid-Atlantic Ridge.

Relevant Partnerships (If Applicable)

SponGES, ATLAS

Literature

Gofas, S. (1993) *Mission Océanographique Seamount 2. Compte-rendu et liste des stations.* [unpublished report].Paris: Muséum National d'Histoire Naturelle. 30 p.

Durán Muńoz, P., Román, E. & González, F. (2000) Results of deep-water experimental fishing in the North Atlantic: An example of co-operative research with the fishing industry. ICES CM 2000/W:04.

PORTUGAL'S DEEP WATER UNDERWATER CULTURAL HERITAGE MANAGEMENT

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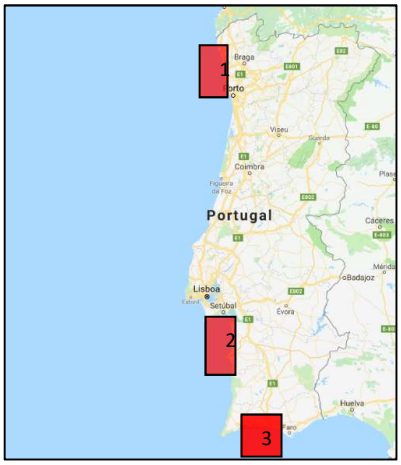
Target Name: Portuguese Coastline.

Geographic Areas of Interest within the North Atlantic Ocean: North Central and Northeast.

Relevant Subject Areas: Marine Archaeology, Biology, Geology, Physical Oceanography.

Brief Overview of Areas: Study areas are the *Esposende Area* (1), the *Sines Area* (2) and the *Lagos Area* (3), with depths ranging from 50 to 500 meters.



Brief Summary of Current State of Knowledge: Serving as an interface between the Mediterranean and the Northern Atlantic seas, Portugal's ocean facing position on the Iberian Peninsula has played a crucial role in Europe's maritime world over the last three millenia. Phoenicians, Romans, Goths, Arab Muslims, Crusaders, all have exploited it's coastal resources, leaving behind a tangible (buildings, structures, landscapes, etc.) and an intangible (performing arts, social practises, etc.) heritage.

During the Age of Discoveries, as Atlantic trade winds forced ships coming from the New World, Africa or Asia to sail to the Azores and then straight ahead towards Lisbon, Sevilla or Cádiz, storms, pirate and corsair attacks and navigational errors have sent to the bottom of the Portuguese territorial waters more than 225 treasure carrying ships, a shinning beacon still attracting modern day looters and treasure hunters that see those sites as auctionable goods instead of cultural heritage.

criminalizing treasure hunting, recognizing the value of cultural heritage of coastal and maritime regions and being aware of its vulnerability, Portugal ratified the UNESCO Convention for the Protection of Underwater Cultural Heritage. The economic benefits of Underwater Cultural Heritage (UCH) study and protection are now widely recognised not only in terms of tourism, but also as an innovative stimulant for growth and employment in a wide range of traditional and new industries - cultural heritage being one of the four pillars of Europe's sustainable development, with heritage being a strategic resource and a major contributor to social cohesion.

As UCH is a non-renewable resource that is forever lost if destroyed, it is therefore crucial to locate, preserve and record submerged sites before they are impacted - either by erosion or by looting, deep trawling or other human activities. For this to happen, shipwreck databases have to be built and UCH sites have to be pinpointed and identified.

For the past 20 years, Portuguese nautical archaeologists have been colecting information from the fish trawling activities regarding sites once impacted by fishing nets, where amphorae, cannons, olive jars, human bones and bullion have surfaced. Maps have been produced with this data, with depths and coordinates/transits recorded.

Filipe Castro (TAMU); **Joao Sousa** (LSTS/FEUP); **Alexandre Monteiro** (IAP/UNL); **Jose Pinto** (LSTS/FEUP); **Paulo Costa** (IHC/UNL); **Miguel Martins** (DGPC); **Goncalo Calado** (ULHT); **Clara Sarmento** (CEI/ISCAP); **Miguel San Claudio** (IAP/UNL); **Rebeca Alonso Galvan** (ICAM).

The research process in now on the desk-based assessment (DBA) phase, with existing archaeological, geological and oceanographic databases being consulted in order to study the nature and potential of UCH sites. Sources used include historical archives, published literature, maps, charts, aerial and satellite photographs, sites and monuments data, wrecks data, geophysical and geotechnical data.

Rationale for Future Exploration: Texas A&M ShipLAB, the Oporto University Underwater Systems and Technology Laboratory (LSTS) and the Lisbon NOVA University are now applying for permits with the Portuguese Heritage Agency (DGPC) for the survey and mapping of selected areas of the Portuguese coastline up to 100 m deep, the maximum range of the sensing equipment embarked on board LSTS AUV's.

Data interpretation will be based on a combination of geophysical data (eg. magnetometer data with side scan sonar and multibeam imagery) coupled with geological, geomorphological and archaeological data compiled on the DBA phase.

If detected, UCH remains will be evaluated according to their intrinsic value and degree of significance. Criteria used to determine the intrinsic value of detected UCH sites will be: potential to yield important information; association with important events or people; distinctive characteristics of a period; representativeness; social or spiritual significance; and economic value in the present time and future/looting potential. Criteria used to evaluate the degree of significance will be: provenance; representativeness; rarity/uniqueness; condition/completeness; interpretive potential; and capacity to inform us about the past

As the most promising deep water UCH suspected sites –as recorded by trawling masters – are situated in between 200 and 500 m deep, a future colaboration with an ASPIRE campaign mission would be of paramount importance for strengthening research activities on the documentation, mapping, monitoring, preservation, protection and valorisation of Portugal's UCH in deep water.

Relevant Partnerships: We are a collaborative interdisciplinary scientific exploration group, that integrates Spanish and Portuguese nautical archaeologists, biologists, maritime historian and lawyers, social scientists and underwater robotics specialists that collect input from management agencies, fishing and diving communities in order to identify unexplored areas of the ocean where new UCH discoveries are likely to be made.

We have MoU's with the Portuguese Mission for the Extension of the Continental Shelf (EMEPC), the Cultural Heritage General Directory (DGPC), the Portuguese Navy Hydrographical Institute (IH) and with the coastal counties of Esposende, Lagos, Grandola, Sines and Alcacer do Sal.

NOVA University of Lisbon's Instituto de Arqueologia e Paleociências has since 2011 positioned itself as a national and international leader on nautical archaeology studies, with increased participation in international European research programs. IAP-NOVA is also a leading institution in two sensitive topics concerning the safety of UCH: treasure hunting and trawler fishing activities, which are threatening the submerged heritage of Portugal, as well as that of many other countries such as Mozambique, Cape Verde and Uruguay.

The Underwater Systems and Technology Lab (LSTS) is an interdisciplinary research laboratory established in 1997. The LSTS specializes on the design, construction, and operation of unmanned underwater, surface and air vehicles and on the development of tools and technologies for the deployment of networked remotely operated vehicle systems. During the last 20 years, researchers from the LSTS have successfully fielded unmanned air, ground, surface and underwater vehicles in the Atlantic and Pacific oceans, and in the Mediterranean Sea.

Filipe Castro (TAMU); **Joao Sousa** (LSTS/FEUP); **Alexandre Monteiro** (IAP/UNL); **Jose Pinto** (LSTS/FEUP); **Paulo Costa** (IHC/UNL); **Miguel Martins** (DGPC); **Goncalo Calado** (ULHT); **Clara Sarmento** (CEI/ISCAP); **Miguel San Claudio** (IAP/UNL); **Rebeca Alonso Galvan** (ICAM).

Exploring pristine Vulnerable Marine Ecosystem along the MAR in the Azores

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Primary Contact: Telmo Morato

Home Institution: IMAR and OKEANUS, University of the Azores, Portugal

Other participants: Marina Carreiro-Silva, Christopher K. Pham, Ana Colaço (IMAR, Universidade dos Açores, Portugal)

WILLING TO ATTEND WORKSHOP? YES

TARGET NAME: The Mid-Atlantic Ridge, seamounts and valleys between Pico and the Kurchatov fracture zones

GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN: South Central (between 37°N and 41°N)

RELEVANT SUBJECT AREAS: Biology, Conservation, Geology, Chemistry, Physical Oceanography

DESCRIPTION OF TOPIC OR REGION RECOMMENDED FOR EXPLORATION

Brief Overview of the Area

The most prominent ocean floor feature in the Atlantic Ocean (AO) is the Mid-Atlantic Ridge (MAR), dividing the ocean into eastern and western deep basins[1]. In the Azores region, the MAR intersects the Terceira Rift, separating three tectonically active plates: the North American plate, the Euro-Asian plate and the African plate (Fig. 1). This unique setting of the Azores at the triple junction of tectonic plates and close proximity to the ridge, offers an exceptional opportunity to survey the role of the MAR in shaping connectivity patterns and assemblages of deep-sea megafauna communities in the East and West Atlantic. The diverse geomorphology surrounding the Azores (island slopes, seamounts, hydrothermal vents, and abyssal plains exceeding 5,000m depth) hold an extraordinary diversity of benthic organisms, making this area a cold-water coral hotspot in the NE Atlantic[2].

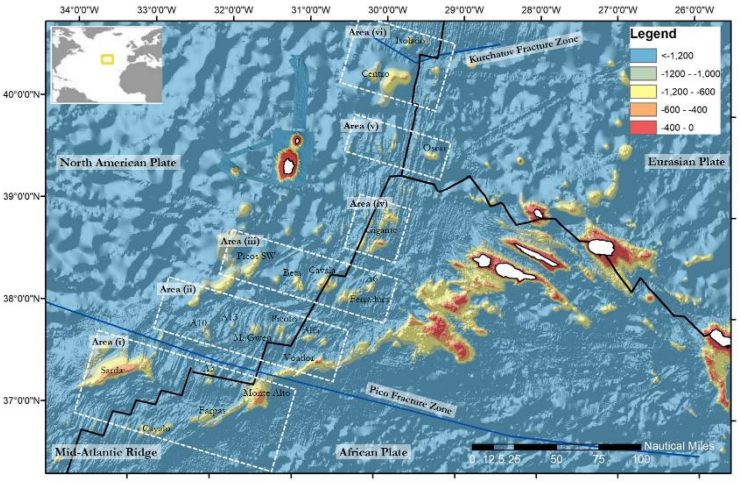

Fig.1 Targeted geographical region and exploration locations on the MAR

Tentative areas to explore (Fig. 1) include from S to N: (i) Monte Alto, Farpas, Espadarte, Cavalo, A3 and Sarda seamounts and ridges; (ii) Voador, Alfa, Picoto, MenezGwen, A13, and A10; (iii) A6, Ferradura, Cavala, Beta, and Picos SW Flores; (iv) Gigante Seamount Complex; (v) Oscar, and 3 unnamed features, and (vi) Centro, Isolado, 4 unnamed features, and the Hard-Rock Café seamount.

Brief Summary of Current State of Knowledge

Biogeographic studies indicate that deep-sea coral species in the Azores region showed mixed biogeographic affinities; greater to the Lusitanian-Mediterranean biogeographic region than to the NW Atlantic[2]. Dissimilarities between the deep-water coral fauna on both sides of the MAR were noted at local and wider scale studies[3], raising the question on whether the Mid Atlantic Ridge can effectively represent a boundary for the genetic connectivity between the east and west Atlantic[4]. However, there has been considerably few explorations on seamounts, ridges and other topographic features along the MAR, since most scientific research in the region has focused on known hydrothermal vent field such as Lucky Strike, Rainbow, or Menez Gwen. The recent Blue Azores deep-sea explorations to the MAR around the Azores led by Telmo Morato and Marina Carreiro-Silva have discovered many new deep-sea coral and sponge areas that fit the FAO vulnerable marine ecosystems (VME) definition, a new hydrothermal vent[5] (Fig. 2), and many new species, biotopes and habitats.

Fig 2. The new hydrothermal vent field discovered on June 16th 2018; named "Luso" and the new VME area discovered in Gigante area with exuberant Paragorgia johnsoni which forming dense coral gardens.

Rationale for Future Exploration

Future exploration in the MAR will aim to use the most recent technology to understand the role of the MAR in shaping trans-Atlantic deep-sea biogeography, connectivity patterns and assemblages of deep-sea megafauna. Additionally, the exploration strategy aimed to (i) map, locate and characterize deep-sea coral and sponge communities inhabiting unexplored seamounts and ridges in the MAR in the Azores Region, (ii) explore new hydrothermal vent fields in the Gigante seamount complex area, (iii) identify new areas that fit the FAO vulnerable marine ecosystems definition; and (iii) determine distribution patterns of deep-sea benthic biodiversity in the Azores. The results of this explorations will also contribute to identify the environmental drivers that determine the spatial distribution of deep-sea benthic biodiversity in the Azores region, evaluating at the same time the role played by the Mid-Atlantic Ridge as a barrier between the western and the eastern parts. It will also provide valuable information to enhance the predictive capabilities for VMEs, and to inform Good Environmental Status (GES), Marine Spatial Planning (MSP) and provide new insights on how to sustainably manage deep-sea ecosystems.

Comparative exploration could be conducted on both sides of the MAR, and along its fault scarps and rift valleys of such as those close to the Pico Fracture Zone, and the Kurchatov fracture zone (Fig. 1), where plume signals have been detected, potentially indicating the presence of active hydrothermal fields[6]. Here, we suggest to explore under-visited portions of the MAR and associated seamounts between 400 and 1200m deep. Exploration could focused both potentially pristine and non-pristine areas as evaluated by local Vessel Monitoring System data that holds much better resolution than the recently launched Global Fishing Watch dataset[7]. On each sampling location we suggest to collect multibeam data for seabed mapping and ROV dive planning, fishery research ecosounding transects for detection of fish aggregations, ROV transects to survey deep-sea coral and sponges megafauna communities and to collect biological, water and sediment samples for biodiversity analyses, metagenomics and connectivity studies. Water masses properties could also be characterized by sampling seawater and measuring physical-chemical parameters.

RELEVANT PARTNERSHIPS

This white paper is presented under IMAR plans for an improved mapping of vulnerable deep-sea benthic communities in the Azores. This line of research has been developed under relevant partnerships with H2020 international research project ATLAS, SPONGES and MERCES, and Azores funded research projects MapGES. Exploration of the areas proposed here may contribute to the Atlantic project currently submitted to the H2020 program. This white paper was also developed in close collaboration with papers being developed in the context of ATKAS and SPONGES projects.

References: [1] Priede et al. (2013) Mar. Biol. Res. 9: 624–628; [2] Braga-Henriques et al. (2013) Biogeo. Disc. 10; 529–590; [3] Watling & Auster (2005) Cold-water Corals and Ecosystems, Springer, p. 279-296; [4] Mironov et al. (2006) KMK Scientific Press, Moscow; [5] https://phys.org/news/2018-06-extraordinary-hydrothermal-vent-discovery-mid-atlantic.html; [6] Chin et al. (1998) Earth Planet. Sci. Lett.162:1-13; [7] Kroodsma et al. (2018) Science, 359: 904-908.

2018 ASPIRE WHITE PAPER SUBMISSION: DEEP SEARCH CONNECTIVITY

Contact Information

Primary Contact: Cheryl Morrison
Home Institution: U.S. Geological Survey, Leetown Science Center

Target Name(s)

Main Feature(s)/Area(s) of Interest:

- The Atlantic Equatorial Belt: Cold seep/chemosynthetic communities at the Barbados accretion prism, the Mid-Atlantic Ridge, and the West African Seeps
- The Coral Circle: Deep-sea coral habitats on the Angolan margin and Orenoque

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

Northwest
North Central* (Mid-Atlantic Ridge)
Northeast
Southwest* (Barbados accretionary prism, Orenoque)
South Central
Southeast* (West African cold seeps)

Relevant Subject Area(s) (Indicate all that apply)

Biology*
Geology
Chemistry
Physical Oceanography
Marine Archaeology
Other

Description of Topic or Region Recommended for Exploration

Brief Overview of Area or Feature: To investigate the presence of stepping stone and/or preferred pathways explaining the present-day connectivity across the Atlantic, deep-sea coral and cold seep habitats that lie within the Atlantic Equatorial Belt that are potentially influenced by the AMOC current are proposed for targeted characterization. Key deep-sea coral habitats include Orenoque in the Southwest and Regab and Anna Ridge in the Southeast Atlantic off Angola. Cold seep and vent communities at the Barbados accretionary prism, the mid-Atlantic Ridge (MAR; Lucky Strike, Snake Pit, and Logachev), and the Angolan margin (Worm Hole, Lobes, and Regab) are also suggested for exploration, allowing for complete amphi-Atlantic species connectivity assessment for multiple habitat types and species, enhancing regional analyses that are ongoing in the U.S. and Europe.

Brief Summary of Current State of Knowledge:

A high-priority goal of ASPIRE is to, “increase understanding of deep-sea ecosystem connectivity across the Atlantic basin.” To meet this goal, good representation from both sides of the Atlantic is required for robust connectivity analyses, yet specimens are often available for one side or the other, and to date, most connectivity studies have been regional in scope. Mechanisms of larval dispersal remain poorly characterized across the Atlantic in part due to a lack of information for individual species regarding larval development time and behavior, unknown potential stepping stone habitats across the Atlantic, and the influence of major currents such as the Atlantic Meridional Overturning Circulation (AMOC), the

"conveyor belt". Major initiatives in the Eastern Atlantic (ATLAS) and Western Atlantic (DEEP SEARCH) are adding to regional connectivity studies. However, several pivotal locations do not fall within the study areas for these projects. Therefore, we propose key areas for exploration under ASPIRE that would fill sampling and data gaps for trans-Atlantic cold seep and deep-sea coral species, allowing for a robust and comprehensive analysis of connectivity.

Large overlap in the dominant cold seep genera and species, such as *Bathymodiolus* mussels, *Alvinocaris* shrimps, vesicomyid clams, and *Escarpia* tube worms, led to the hypothesis of the existence of recent or contemporary faunal linkages across an "Atlantic Equatorial Belt" connecting fauna originally described from the western Atlantic, Gulf of Mexico, West Florida Escarpment and the Barbados accretionary prism and the West African seeps from the eastern side of the Atlantic basin. Sunken wood, vertebrate carcasses and other organic matter were thought to be stepping stones allowing gene flow and maintaining species commonality from the western and eastern Atlantic, but molecular work has suggested that the Mid-Atlantic Ridge (MAR) may be an important a stepping stone as well. Collections of target amphi-Atlantic species from the Barbados and West African seeps and the MAR would complement those obtained through DEEP SEARCH and previous research efforts.

Many cold-water corals are widely distributed in the Atlantic, with corals occurring in the "coral circle" from Canada to Argentina in the west and from Norway to southern Africa in the east. Reefs are often dominated by a limited set of structure-forming scleractinian species, including *Lophelia pertusa*, *Madrepora oculata*, and less frequently *Solenosmilia variabilis*. Octocorals, such as *Acanella arbuscula*, *Primnoa resedaeformis*, *Paragorgia arborea*, and *Anthomastus* sp., as well as the black corals *Leiopathes* and *Bathypathes* species are present on both sides of the Atlantic and are targets for connectivity studies. Genomic RADseq methodologies are being standardized between partners and offer expanded possibilities to test hypotheses regarding ancient (geological time) versus present (ecological time) larval exchanges to explain present day patterns of connectivity.

Rationale for Future Exploration: Dominant ocean circulation patterns have likely affected distributions of widely distributed deep-sea corals and seep species. However, species-specific patterns of past connectivity, refuge areas and recolonization pathways are still uncertain. Collections from the proposed areas will fill gaps in sampling, allowing for robust connectivity analyses that estimate past and present trans-Atlantic dispersal as inferred from genomic analyses. As threats from global habitat loss, rapid climate change and ocean acidification increase, an improved understanding of extinction risks is imperative for effective predictions and ecosystem-based spatial management plans.

Relevant Partnerships (If Applicable)

The areas proposed for exploration will optimize two major initiatives, including two in the United States (e.g. the BOEM/NOAA/USGS and others, and the NOAA Deep Sea Coral Research and Technology Program Southeastern Initiative), plus the European ATLAS project (Sophie Arnaud-Haond). The cold seep and coral communities proposed for exploration were chosen by members of these campaigns to capitalize on existing transatlantic connectivity research efforts in the western and eastern Atlantic, catalyzing and stimulating interactions and providing crucial samples to be utilized in a comprehensive analysis of both taxonomy and connectivity across the Atlantic Basin.

ASPIRE 2018 WHITE PAPER SUBMISSION

CONTACT INFORMATION

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Division of Environmental Sciences
Bureau of Ocean Energy Management

TARGET NAME(S)

See Tables 1 and 2 and Figure 1AK, below.

GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN

The general area of greatest biological interest to BOEM for future baseline exploration lies between Norfolk Canyon (~37.5°N) and the Georgia-Florida border (~30°N), from 25 nmi offshore to the edge of the US exclusive economic zone. A subset of that general area of particular interest for additional exploration is this polygon:

32.6, -78.8
30.6, -80.3
30.6, -77.0
32.6, -76.0

RELEVANT SUBJECT AREA(S)

Biology, Geology, Physical Oceanography

DESCRIPTION OF TOPIC OR REGION RECOMMENDED FOR EXPLORATION

Within the general areas of interest are found three general, sometimes overlapping habitat types: canyons, corals, and seeps. BOEM's NEPA documents (Environmental Impact Statements) must accurately describe the Affected Environment and projected routine, accidental, and cumulative impacts of potential/proposed leasing activities, including to what it terms "deepwater benthic communities": deep sea corals, sponges and chemosynthetic organisms and associated habitat features and associated communities. Therefore, there is a management need to better understand the basic biology and ecology of these communities, especially as relates to potential impacts and recovery.

Drivers for BOEM interest in future exploration and improved baseline understanding of this region:

- 2019-2024 Oil and Gas Leasing Draft Proposed Program
- Collection of baseline data prior to offshore development
- Better understand Atlantic chemosynthetic communities and supporting seep habitats
- Understanding of resilience of particular habitats to disturbance
- Renewable Energy expansion and likely future operations
- Understanding connections between water column & benthic communities (benthic / pelagic coupling)
- Connectivity along the shelf (biogeography/connections and dispersal among canyons)
- Informing Essential Fish Habitat consultations

BOEM priorities for future exploration and improved baseline understanding of this region:

- Identify sensitive communities in advance of offshore development
- Characterization of Atlantic chemosynthetic communities and associated coral/sessile benthic species
- >200m (biology); >100 m (geohazards and shallow water processes)
- Identifying areas of 'dense' coral, sponge, chemosynthetic communities
- Understanding how deep sea communities will respond to change and how will they recover/adapt
- Slope stability/instability as it could potentially impact future development (geohazards)

RELEVANT PARTNERSHIPS

- Deep SEARCH team: Deep Sea Exploration and Research of Coral/Canyon/Seep Habitats. BOEM-funded (and National Oceanographic Partnership Program-sponsored) study led by TDI Brooks, with Erik Cordes as PI; ongoing field work results should serve as input to NOAA OER future planning; representatives of this team should be invited to the November workshop (we suggest Erik and/or Sandra Brooke). Per E. Cordes regarding rationale for these areas: *"…relevant to BOEM, I think that there is a good deal of mapping that still needs to be done in the southern part of our study area, particularly in the Stetson Banks area and south of the Savannah Banks. This is a really complex area with a lot of different geomorphologies, and presumably biological habitats. It is also relevant to offshore gas exploration. We have a few "postage stamps" of good multibeam in these areas, but there is a lot more to do. This is especially relevant after the Okeanos cruise where they seemed to have found an area of Lophelia mounds extending from Florida up to the Carolinas."*
    - As a follow-on to a previous Atlantic canyons study, one of the focus areas of this study will include submarine canyons south of Norfolk Canyon. A larger portion of the study will focus on other sensitive deepwater ecosystems in the region, including chemosynthetic communities related to hydrocarbon seeps, areas with known presence of deepwater corals, and previously unexplored areas deemed likely to possess deepwater coral ecosystems. Additional exploration of areas with known or likely hard bottom is needed to better understand the distribution and disturbance sensitivity of associated biological communities. The resulting information will be used to develop appropriate protective measures designed to prevent, minimize, and/or mitigate impacts.

- NOAA NCCOS benthic coral/sponge suitability modeling team in Silver Spring: Matthew Poti, Arliss Winship and associated "Data Rescue" team in Charleston (led by Peter Etnoyer). The predicted habitat suitability outputs from this ongoing BOEM-funded study "Data Synthesis and Advanced Predictive Modeling of Deep Coral and Hardbottom Habitats in the Southeast Atlantic" should be useful in showing general areas with high likelihood of coral/sponge presences.

APPENDIX

Table 1 and Figure 1. Sites planned for survey/sampling by 2018 R/V Atlantis / DSV Alvin Expedition AT41 (E. Cordes)

date	site	latitude	longitude	depth
19-Aug	WHOI			
20-Aug	Norfolk seep	36.8654	-74.4929	1600
21-Aug	Pamlico Canyon	34.9576	-75.2047	923
22-Aug	Cape Fear Seep	32.9790	-75.9270	2600
23-Aug	Stetson Deep	32.016	-77.401	825
24-Aug	Blake Deep	31.323	-77.243	1300
25-Aug	Blake Mounds	31.079	-79.492	680
26-Aug	Million Mounds N	30.569	-79.698	590
27-Aug	Stetson Shallow	32.018	-78.322	500
28-Aug	Blake Ridge	32.494	-76.191	2155
29-Aug	Cape Fear	33.567	-76.45	425
30-Aug	Hatteras Canyon	35.2854	-74.9054	933
31-Aug	Norfolk Canyon	37.03294	-74.3173	2000

Table 2. Additional sites of interest to BOEM, that are *not* planned to be surveyed and sampled by Expedition AT41

site	latitude	longitude	depth
Norfolk Canyon deep	37.03294	-74.3173	2000
Norfolk Canyon shallow	37.04607	-74.51171	1400
Norfolk seep	36.883	-74.5	200-1500
Pea Island Seep	35.706	-74.826	500
Keller Cyn	35.533	-74.833	200-1500
Hatteras Cyn	35.283	-74.933	200-1500
Pamlico Cyn	34.95	-75.217	200-1500
Cape Lookout A	34.317	-75.783	400
Cape Lookout B	34.183	-75.883	400
Cape Fear*	33.567	-76.45	425
Cape Fear Seep	32.9790	-75.9270	2600
Blake Ridge	32.494	-76.191	2155
Stetson Banks S	32.033	-77.667	600
Savanna Shallow	32.018	-78.322	500
Savanna Deep	32.016	-77.401	825
Stetson Banks N	31.817	-77.6	600
Savanna W	31.733	-79.167	550
Savanna E	31.7	-78.8	550
Charleston Bump	31.4	-78.833	600
Blake Deep	31.323	-77.243	1300
Blake Mounds	31.079	-79.492	680
Million Mounds N	30.569	-79.698	590

2018 ASPIRE WHITE PAPER SUBMISSION

CONTACT INFORMATION

Primary Contact Martha Nizinski
Home Institution NOAA/NMFS National Systematics Lab

WILLING TO ATTEND WORKSHOP?

(Yes/No) Yes

TARGET NAME(S)

Canyons, Seamounts, Seeps, Deep-Sea Coral and Sponge Habitats/
Northeast Channel, Northeast Canyons and Seamounts National Marine Monument

GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN (Indicate all that apply)

☐ Northwest ☐ North Central ☒ Northeast
☐ Southwest ☐ South Central ☐ Southeast

RELEVANT SUBJECT AREA(S) (Indicate all that apply)

x Biology ☒ Geology ☐ Chemistry
x Physical Oceanography ☐Marine Archaeology ☐Other

DESCRIPTION OF TOPIC OR REGION RECOMMENDED FOR EXPLORATION

Submarine canyons are prominent and important features along the Atlantic continental margin. They provide important connections between the shallow continental shelf and the deep sea by creating pathways for land-based sediments, organic matter, and unfortunately, marine debris. The focused water currents and steep walls of submarine canyons make them optimal habitat for deep-sea coral and sponge communities. Generally, canyons are biodiversity hotspots, harboring sensitive marine habitats (e.g., deep-sea coral and sponge communities and chemosynthetic habitats) and a variety of organisms, including commercially, recreationally, and ecologically important species.

Seamounts, like canyons are also highly productive ecosystems. High currents, reduced sedimentation, upwelling of nutrient-rich water, and habitat heterogeneity contribute to seamounts being characterized as biodiversity hotspots as well. Their steep walls provide good substrate for deep-sea corals to anchor onto, which form the basis for thriving ecosystems.Thus, it is not surprising that canyons and seamounts have become a priority for resource managers and scientists.

Prior to an extensive program of fieldwork dedicated to deep-sea coral habitats and submarine canyons off the Northeast Region (2012-2015), limited deep-sea exploration and research had been conducted recently in U.S. waters of the western Atlantic. But as the potential increased for fisheries and exploitation of other resources to move offshore, it became apparent that data gaps needed to be addressed.

Living marine resources have no geopolitical boundaries. It is this sentiment that brought together U.S. and Canadian research teams in 2011. Two successful transboundary missions (2014, 2017) have been conducted to date. Our primary objective was to explore and survey deep-sea coral habitats in submarine canyons off the coast of the Northeast U.S. and Atlantic Canada, as well as several locations in the northern Gulf of Maine.

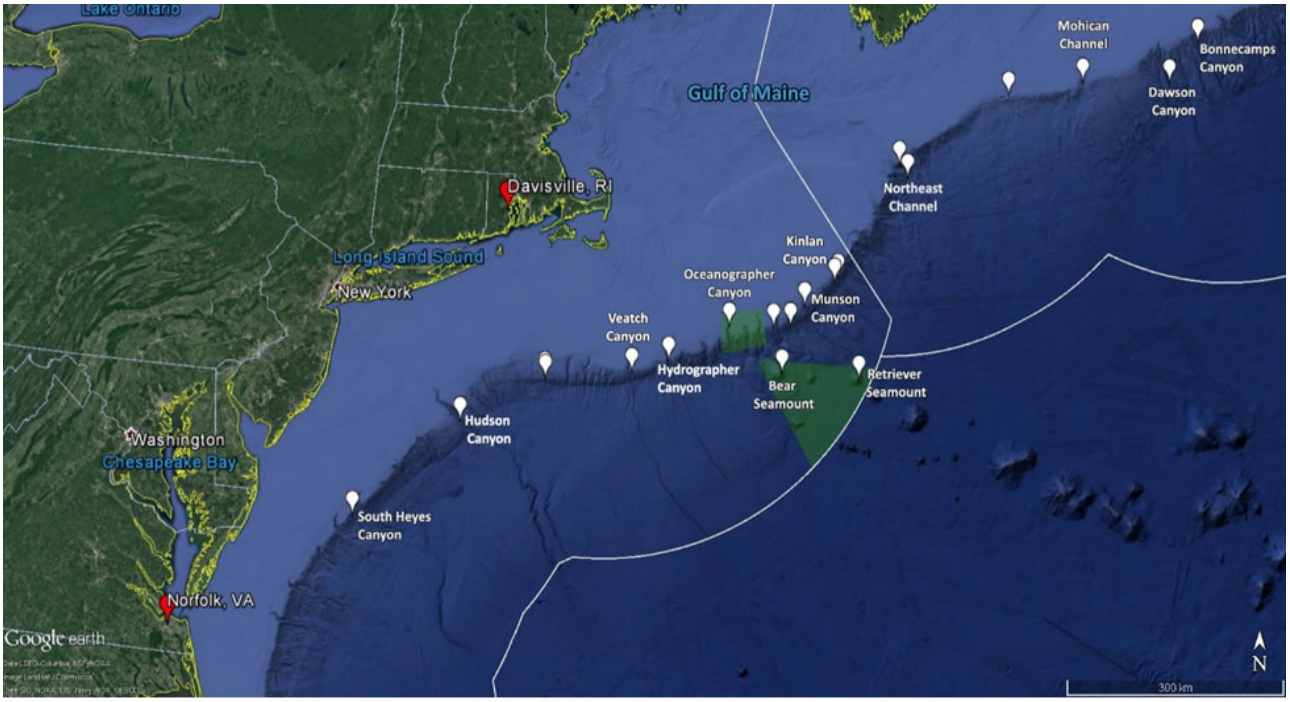
Although these missions were highly successful, data gaps were identified as well as need the to address additional questions such as connectivity between habitats and between regions throughout the North Atlantic. An international team of government and academic scientists, resource managers, and representatives from conservation organizations were solicited for recommendations on priority areas in need of further research. Submarine canyons and seamounts, with a particular emphasis on deep sea coral habitats, were identified as priority targets.

The Northeast Canyons and Seamounts Marine National Monument and the Northeast Channel Coral Conservation Area were identified as the highest priority areas within the region. Additional data are needed to (1) support the designation of these conservation areas and (2) determine if the boundaries currently set for these areas are the most appropriate.

During a series of conference calls, the team selected a number of potential dive targets that would meet the needs of the international community as a whole. Specifically, South Hayes, Hudson, Veatch, Hydrographer, Munson, Kinlan, and several minor canyons in U.S. waters; and Bonnecamps, Dawson, and Mohican canyons in Canadian waters as well as several locations in marine conservation areas on both sides of the border. See figure below.

Previous work suggests that canyons have their own biological and geological signature. But we can't effectively manage and conserve what we don't know. Filling in knowledge gaps provides us the opportunity to better understand species distributions, the processes influencing the structure of these sensitive deep-sea communities, and connectivity between canyons. Further work will help us gain a better understanding of coral diversity, abundance, and distribution; inform habitat suitability models; collect samples for taxonomy, coral aging, and reproduction; refine estimates of coral recruitment; and examine the relationship between biodiversity and ecosystem function. Work proposed here will address science themes and priority areas put forward by scientists and managers from the U.S. and Canada and international working groups supporting the Atlantic Ocean Research Alliance and the European Union's Horizon 2020 program. Given that organisms don't stop at the border and that the western Atlantic is not isolated from the eastern Atlantic, transatlantic cooperation between research initiatives in Europe, Canada, and the United States will provide a better understanding of the North Atlantic as a whole.

RELEVANT PARTNERSHIPS: SponGES, ATLAS, DFO Canada, New England and Mid-Atlantic Fishery Management Councils, Dalhousie University, Memorial University, University of Connecticut, University of Maine, NOAA (NMFS, NOS, Deep Sea Coral Research and Technology Program), USGS.



Overview map showing the proposed survey locations. New England Canyons and Seamounts National Marine Monument is highlighted in green.

Collaborations between NOAA and the UK and France

Contact Information:

Joseph Resing; University of Washington

Target Name(s)

Mid Atlantic Ridge and areas of submarine volcanism and hydrothermal activity.

Geographic area(s) of interest within the North Atlantic Ocean:

North Central; South Central

Relevant Subject Area: Chemistry

Description of Topic or Region Recommended for Exploration

The resource potential of hydrothermal systems along MAR makes them of significant interest to European nations, most notably England and France. As a result, French and English scientists have conducted many studies along the MAR in recent years and have made numerous discoveries. The Earth Ocean Interactions program at PMEL and in collaboration with OER has been in collaboration with scientists from both countries and together they have worked on understanding the chemical impacts of the MAR on ocean biogeochemical cycles.

While the driving force for much of the European research funding is the presence of mineral deposits, the scientists that we are collaborating with are more interested in hydrothermal sources of iron to the ocean. Hydrothermal vents produce Fe-rich plumes that persist for 1000's of kilometers. We seek to understand how this iron impacts the ocean carbon cycle. This impact depends on the abundance of hydrothermal venting, the lifetime of vented iron, and the mixing of this Fe into surface ocean. These aspects are poorly constrained and thus our understanding the ocean iron cycle is incomplete. This is important, because iron availability over large parts of the ocean controls the biological pump and thus influences oceanic productivity and ocean-atmosphere carbon dioxide exchanges. Our studies suggest that ridge-driven Fe supply can enhance the flux of Fe to surface waters and is a significant contributor to regional Fe budgets and our collaborations look to quantify the lifetime of this Fe and its vertical transport from mid ocean ridges to the ocean surface. Our work suggests that Fe-binding ligands control the longevity of Fe exported from the ridge and thus the ultimate impact on the carbon cycle.

The MAR is a slow-spreading ridge crest with a lower frequency of intense hydrothermal activity compared to the more continuous activity on faster spreading ridge crests like the South East Pacific Rise. Work with UK colleague Tagliabue (University of Liverpool) shows that when we model the impact of hydrothermal activity solely in the light of the primordial tracer ^{3}He, that the model suggests that the MAR is not an important source of Fe to Fe-deplete regions of the ocean. However we think that this model may overlook the importance of both the ambient ligand pool and low-temperature diffuse flow along the ridge crest. We expect diffuse sites to host microbial activity and thus produce organic-rich effluent containing a wide range of organic compounds including Fe-binding ligands. This should result in a greater percentage of Fe being stabilized from diffuse flow than from focused high-temperature flow where most of the Fe is deposited onto the sea-floor close to where it is vented. In fact, our recent OER-EOI-SOI collaborative project to the slow spreading Mariana Back Arc shows this to be true. We suggest that the MAR may have abundant low-temperature venting along most of the Ridge crest which suggests that the MAR might be a more important source of Fe than suggested by the results of our model.

ASPIRE presents a great opportunity for NOAA through Ocean Exploration and Earth Ocean Interactions to continue its leadership in understanding the global impact of hydrothermalism on ocean chemistry and productivity by further extending our collaborations with our French (IFREMER; University of Brest, University of Paris, and LEGOS0) and British (University of Liverpool, Southampton University, University of Plymouth) colleagues on MAR research and exploration. There remain many under-explored regions along the MAR and it is essential to better understand the incidence of hydrothermal activity to inform future research along the MAR and to properly model and understand the impacts of hydrothermal activity on the ocean. Prior to attending the ASPIRE meeting I will discuss unexplored targets with my European colleagues so as to identify sites of interest along the MAR for the ASPIRE campaign. Our collaborations fall within the Aspire goal to leverage international partnerships to conduct coordinated exploration and mapping of priority high-seas areas of the North Atlantic, including the Mid-Atlantic Ridge.

RELEVANT PARTNERSHIPS

IFREMER; University of Brest, LEGOS, University of Liverpool, Southampton University, University of Plymouth

Exploration and documentation of the spawning grounds of oceanic top predators

Contact Information
David Earl Richardson
Northeast Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Organization

Target Name(s)
Open Ocean-General

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)
All Areas within North Atlantic Ocean

Relevant Subject Area(s) (Indicate all that apply)
Biology

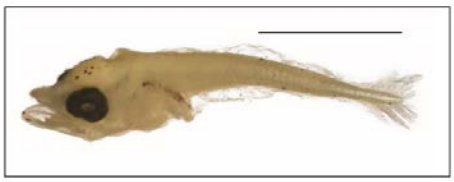
Description of Topic or Region Recommended for Exploration

In 1920 Johannes Schmidt undertook his famous expedition to determine the spawning grounds of European eels. The discovery that this species spawn in the Sargasso Sea, thousands of miles from their adult habitat, was remarkable in its own right and continues to have practical implications for how to manage this vulnerable species. Importantly, the approach used in making this discovery, plankton tows in an oceanic environment to collect eggs and early stage larvae, still has relevance today.

Atlantic spawning grounds for numerous high-profile migratory species still have yet to be determined, as is the case for giant squid, or are incompletely known as is the case for many economically valuable species of tunas and billfish. As an example, in 2013 opportunistic plankton collections made during a marine mammal cruise into the Slope Sea, between the Gulf Stream and Northeast U.S. continental shelf, revealed the presence of early stage Atlantic bluefin tuna larvae. These collections overturned the long-standing paradigm that Atlantic bluefin tuna only spawn in the Mediterranean Sea and Gulf of Mexico. As with the exploratory work with eels, the discovery of an additional bluefin tuna spawning ground has practical implications for how to manage this iconic and economically valuable species. Notably, the discovery also highlighted how little plankton sampling has occurred in the open Atlantic Ocean, and of this sampling, how little has been analyzed with the taxonomic expertise or genetic techniques necessary to resolve spawning by these highly migratory top predators. In other words, aside from a number of well sampled areas on the U.S. continental shelfs and in the Gulf of Mexico, we lack even the most basic understanding of which top predators are spawning in different locations within the Atlantic Ocean.

Exploratory work focused on resolving open-ocean spawning grounds of highly migratory species can occur through directed sampling guided by additional information that suggests the presence of spawning in a place and time (e.g. electronic tagging data, habitat modelling, reports from the fishing industry) or by opportunistic sampling done on cruises with alternate primary objectives. The latter approach is particularly suitable to adding onto to established exploratory cruises in the open ocean environment. Individual plankton stations can be sampled quite rapidly (about 15 minutes), with limited personnel requirements, and during weather and sea state conditions that may not be suitable for other types of operations. The early life stages of most pelagic teleost and squid species co-occur in the upper water columns and can be simultaneously sampled using the same gear. During most dedicated plankton cruises, a large portion of the ship time is spent in transit between stations, an issue that is magnified when sampling the vast expanses of the open ocean. Piggy-backing plankton sampling on already scheduled ship transits is thus a highly efficient approach to evaluating the spawning of highly migratory top predators in space and time.

Larval slender sunfish (*Razania laevis*), Atlantic sailfish (*Istiophorus albicans*) and Atlantic bluefin tuna (*Thunnus thynnus*) collected during plankton sampling operations. Photos by C. Guigand and K. Marancik



Plankton sampling and processing procedures are well established and have been standardized across the two National Marine Fisheries Service Science Centers that operate in the Atlantic. Advances in genetic techniques over the past decade have also allowed for the species-level identification of larvae and eggs that in the past could only be identified at higher taxonomic levels. The technical know-how and the capacity to process samples are both available if plankton sampling were to be integrated into the Atlantic exploratory cruises.

Relevant Partnerships (If Applicable)

National Marine Fisheries Service

2018 ASPIRE WHITE PAPER SUBMISSION

Contact Information

J. Murray Roberts, ATLAS coordinator, University of Edinburgh

Target Name(s) Hydrothermal vents, cold-water coral and sponge grounds, submarine canyon ecosystems, deep-sea mining areas, transatlantic cold-water coral genetic connectivity

Geographic Area(s) of Interest within the North Atlantic Ocean

Northwest, North, North Central

Relevant Subject Area(s) (Indicate all that apply) Biology, Ecology, Geology, Genetics, Connectivity

Description of Topic or Region Recommended for Exploration

As Atlantic climate shifts towards generally warmer conditions with less sea ice and complex changes in overturning circulation[1], the northern parts of the Atlantic are predicted to experience great changes in productivity and faunal diversity. We therefore propose a series of sites along the northwest Atlantic (US continental slope, Northern Canada, Greenland, Iceland) and the mid-Atlantic ridge area (Azores, Brazil). The expeditions would focus on the discovery and description of cold-water coral and sponge ecosystems, hydrothermal vent fields, potential Areas of Particular Environmental Interest for seabed mining and on collecting samples to study basin-scale genetic connectivity of key taxa.

The **US continental slope** region from off Cape Lookout, North Carolina to off Cape Cod, Massachusetts, contains a remarkable diversity of physical and biological attributes. These include the Gulf Stream system, major submarine canyons composed of hard substrates and consolidated muds, hundreds of active methane seeps, extensive cold-water coral ecosystems, a major zoogeographic transition zone, extremely productive fisheries, and perhaps the richest biodiversity in the Western Atlantic. **Further exploration** in this region is important as a western Atlantic anchor point for more Atlantic basin-wide research that includes similar habitats and fauna to the north (off Canada) and to the east (off Greenland and the mid-Atlantic Ridge). Given the predominant focus of ATLAS and SponGES has been in the NE Atlantic, targeting central and western Atlantic regions also gives a more balanced geographical spread for these AORA projects and for future projects funded through the All Atlantic Ocean Research Alliance Flagship (BG-08-2018-19) to which iAtlantic is applying[2].

In the central Atlantic, the first living sample of the cold-water coral *Lophelia pertusa* from **Greenland** waters was recently discovered at 60°N, 48°W. This cold-water coral community is the only known reef in the northwest Atlantic north of 44°. Travelling south, *Lophelia* reefs are not known from Canadian waters until reaching Nova Scotia. Reef-like structures formed by living and dead *Lophelia* were identified from photographs taken in summer 2018 (CCGS *Amundsen*) at four sites 886-932 m depth, but strong currents made the area difficult to survey with a drop camera and this biogeographically important coral habitat has not been mapped. Returning to this site for **further exploration, mapping and genetic sampling** will lead to a better understanding of their connectivity at oceanic scales. We do not currently know if this site is related to western or eastern Atlantic populations, and can incorporate this analysis into ATLAS workpackage 4 'Connected Resources' led by Ifremer (France).

The **Mid Atlantic Ridge (MAR)** remains very poorly explored and there are great opportunities for new scientific discoveries building upon the 2018 discovery by ATLAS partners at the University of the Azores of the Luso vent field. Only a fraction of this area was surveyed in 2018 and samples for geology, chemistry (fluids and gases), biology and microbiology are all needed for a **complete description of this the newest active vent discovered on the MAR**. Close-by are important seamount habitats including Vulnerable Marine Ecosystems (VMEs) formed of cold-water coral gardens and sponges. Key target areas include Sarda, Farpas, Monte Alto, Voador, Cavala and Ferradura seamounts and ridges, see details in the White Paper from IMAR & OKEANUS.

[1] Thornalley et al. (2018) Anomalously weak Labrador Sea convection and Atlantic overturning during the past 150 years. Nature 556: 227-230

[2] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/bg-08-2018-2019.html

In addition, beyond national jurisdiction the International Seabed Authority (ISA) has issued three **exploration contracts for deep-sea mining** for polymetallic sulphides PMS along the MAR[3]. To manage exploration contracts, the ISA has listed the MAR as a priority area for developing Regional Environmental Management Plans (REMPs)[4]. For a REMP to have effective conservation measures as part of the spatial planning for deep-sea mining, there needs to be sufficient environmental baseline information. The section of the MAR immediately south of the current block of exploration contracts (extending from Vema Transform Fault at 10°N to the Brazilian EEZ around Saint Peter and Saint Paul Archipelago) has been little explored and the environmental baseline here is poorly characterised. Understanding the faunal communities along this section of the MAR and their connectivity to the rest of the MAR would provide vital context for the potential impact of deep-sea mining between 10°N and the Azores EEZ. One of the conservation measures used in ISA REMPs are **Areas of Particular Environmental Interest** (APEIs). Suggestions have recently been made for optimal APEI placement along the MAR, with the network of proposed APEIs being centred on APEIs placed at the Romanche Transform Fault and the Vema Transform Fault[5]. Exploration around the Vema Transform Fault heading south along the MAR towards the Brazilian Saint Peter and Saint Paul Archipelago would help to confirm Vema as an anchor for APEI placement. Exploration here would also **identify further areas with special fauna and habitats** along the MAR that could be considered for inclusion in APEIs.

Studying the **genetic connectivity** of widespread reef framework-forming corals *Lophelia pertusa* and *Madrepora oculata* is necessary to reveal patterns of genetic connectivity at the North Atlantic scale. This work is grounded in larval distribution modelling and connectivity analyses completed through the ATLAS project. The underlying VIKING20 hydrographic model outputs, Lagrangian particle tracking modelling and connectivity analysis approach can be developed with other species to create testable hypotheses on population relatedness, co-evolution, speciation etc. For example, it is presently unclear whether *L. pertusa* and *M. oculata* species are actually the same species since recent genome scan analysis point toward the possible occurrence of several taxa of *Madrepora* in the Eastern Atlantic. Important stepping stones may be coral habitats from Iceland, Greenland and the Azores, although our knowledge of their distribution on Atlantic seamounts and abyssal plains is much less advanced that on margins and canyons. Thus, sampling in Northern Canada, Greenland as well as along the MAR, would allow examination of hypotheses of (1) ongoing or resolved **speciation** among taxa present on both sides of the Atlantic and (2) if common taxa are confirmed, the present-day **connectivity** of populations distributed along ridge and across the Atlantic.

Relevant Partnerships (If Applicable)

This white paper has been prepared by the University of Edinburgh drawing primarily on discussions within the ATLAS (2016-2020) and iAtlantic consortia and the team writing the IMAR & OKEANUS white paper at the University of the Azores, Portugal[6]. During its preparation email discussions were also held between the ATLAS, SponGES, CHONe and DEEPSEARCH communities and we look forward to developing collaborations to maximise the benefits of any ASPIRE partnerships that arise from these White Papers. At the time of writing the iAtlantic consortium was finalising its bid for a €10.6M project to produce an integrated assessment of Atlantic marine ecosystems. If funded, iAtlantic would run 2019-2023 and would complete a programme of work in both North and South Atlantic including several focal regions addressed in this White Paper. iAtlantic also includes an extensive **capacity building plan** that would greatly benefit from telepresence expeditions allowing collaborators across Argentina, Brazil, South Africa, Namibia, Angola, Senegal, Canada, the USA and Europe to be engaged with the work offshore and participate actively in the missions. Both the ATLAS and iAtlantic consortia include significant partnerships with offshore industries and we would look to capitalise on this to make any baseline research directly relevant to economic activities in the Atlantic (e.g. via ATLAS WP5 'socioeconomics' and WP6 'maritime spatial planning).

[3] https://www.isa.org.jm/deep-seabed-minerals-contractors?qt-contractors_tabs_alt=1#qt-contractors_tabs_alt
[4] International Seabed Authority (2018) Preliminary strategy for the development of regional environmental management plans for the Area. *ISBA/24/C/3*.
[5] Dunn DC & Van Dover CL *et al.* (2018) A strategy for the conservation of biodiversity on mid-ocean ridges from deep-sea mining. *Science Advances* 4:eaar4313
[6] Contributions to this White Paper were received from Sophie Arnaud-Haond (Ifremer), Rachel Boschen-Rose (Seascape), Lea-Anne Henry (UEDIN), Ellen Kenchinton (DFO), Steve Ross (UNCW), Telmo Morato (IMAR-UAz), J Murray Roberts (UEDIN) and Bodil Wesenberg Lauridsen (Geo Survey Denmark)

Enhancing the value of ROV Deep Discoverer video data through application of the Coastal and Marine Ecological Classification Standard (CMECS)

Adam Skarke, Peter Etnoyer, Scott Cross, Caitlin Ruby, Kathryn Rose

Contact Information
Adam Skarke
Mississippi State University

Target Names
All Seafloor Habitats (particularly seeps, sandy, and hard-bottom habitats with deep corals and sponges)

Geographic Areas of Interest within the North Atlantic Ocean
Southwest (Southeast United States and Caribbean Sea)

Relevant Subject Areas
Geology, Biology, Habitat Mapping

Description of Topic

Video imagery collected with remotely operated vehicles (ROV) is a hard-to-obtain and highly valuable source of oceanographic data that supports a wide array of scientific, archaeological, and management objectives. High-definition video collected and live-streamed from the ROV Deep Discoverer is a hallmark data product of the NOAA Okeanos Explorer Program, which has continually increased its value through proactive video data management policies focused on accessibility, improved scientific annotation, and development of species identification guides. Recent investigations have indicated that Coastal and Marine Ecological Classification Standard (CMECS) can be applied to ROV video data to further enhance its value to the ocean research and management communities by temporally indexing and geospatially referencing observed environmental features and organisms
(Ruby, 2017; Etnoyer et al, 2018). This would allow investigators to rapidly identify features of interest within the very large video data sets and cartographically represent the spatial relationships between identified features, a key factor in understanding fundamental biological, chemical, physical, and geological processes in the ocean. Here, we suggest further enhancement of ROV video data through the systematic application of the Coastal and Marine Ecological Classification Standard (CMECS) to Deep Discoverer video data collected during the ASPIRE Campaign, particularly the ongoing efforts in the Southeastern US and Caribbean Sea. Specifically, we encourage NOAA OER to support and enable telepresence-based integration of CMECS classification into the existing Deep Discoverer video data annotation and processing workflow, including the SeaScribe and SeaTube annotation systems.

CMECS is a comprehensive framework of common terminology developed for the classification of biological species, water column properties, and seafloor morphology as well as composition in all lacustrine and marine environments including the deep sea (Bassett et al, 2017). It is organized in a hierarchal structure that allows users to select a set of common terms to fully describe a marine environment observed in video data. CMECS was endorsed as a national data standard by the Federal Geographic Data Commission in 2012 (USGS, 2012) with the goal of standardizing marine environmental feature classification across a wide range of geographic locations, and spatiotemporal scales. It has subsequently been adopted by a number of governmental agencies, organizations, and partnerships, notably the Renewable Energy and Marine Minerals Program with the Bureau of Ocean Energy Management. Because CMECS has seen wide adoption, annotating Deep Discoverer video data with CMECS compliant terminology would improve its accessibility and compatibility with other marine data

sets. The effort serves as an example for the unification of the wide variety of habitat and substrate classification approaches currently employed by the deep-sea research community (Etnoyer, 2018).

Notable benefits of the application of CMECS to Deep Discoverer video data, beyond compatibility and standardization include enhanced video indexing and geospatial representation as demonstrated by Ruby (2017). Video indexing is an important aspect of data accessibility that allows investigators to query the location of particular CMECS defined environmental characteristics (e.g. seafloor composition, substrate) or biological attributes (e.g. squat lobsters, corals) of interest within voluminous video data sets. This reduces the need for individual investigators to scan through many hours of video data to potentially find observations relevant to their work, saving substantial amounts of time and removing a barrier to wider ROV video data use. A related data access tool enabled by CMECS is the geospatial representation of ROV Video observations. Ruby (2017) developed an automated geographical information system tool that produces maps of CMECS classified environmental features based upon the navigational and environmental sensor data recorded during ROV dives as well as the view angle geometry of the ROV camera system (Fig 1). The resulting visualizations of ROV video data enable researchers to rapidly understand the spatial distribution and relationships of classified features, which will promote discovery and accelerate ROV video data use among the ocean research and management communities.

Substantial efforts have been made to consider how to best implement CMECS with the existing Deep Discover video data workflow. Ruby (2017) presented a detailed analysis of the feasibility of CMECS application to ROV Deep Discover video data and guidelines for implementation. Additionally, the use remote application of CMECS to video data via telepresence and the existing SeaScribe annotation system was successfully demonstrated by the Etnoyer Lab during Okeanos Explorer ROV expeditions in 2017 and 2018. As OER seeks geographic locations of broad community interest for exploration during the ASPIRE campaign, we would suggest that it is equally important to consider exploring new data processes and products of value to a broad cross section of the ocean research and management community as well. Accordingly, we suggest the ASPIRE campaign as an ideal opportunity to test, optimize, and operationalize CMECS as a classification standard for Deep Discoverer video data.

Bassett, RD, M Finkbeiner, and PJ Etnoyer. 2017. Application of the Coastal and Marine Ecological Classification Standard (CMECS) to Deep-Sea Benthic Surveys in the Northeast Pacific: Lessons from Field Tests in 2015. NOAATechnical Memorandum NOS NCCOS 228,NOAA National Ocean Service, Charleston, SC 29412. 49 pp.

Etnoyer, PJ et al. (2018), Working with Video to Improve Deep-Sea Habitat Characterization, *Oceanography*, *31*:*1*, *Supp*, 64–67.

Ruby, C. (2017), Application of Coastal and Marine Ecological Classification Standard (CMECS) to remotely operated vehicle video data for enhanced geospatial analysis of deep sea environments. M.S. thesis, 266 pp., Mississippi State University.

U.S. Geological Survey (2012), Coastal and Marine Ecological Classification Standard, Fed. Regist., 77(170), 53224–53225.

Relevant Partnerships

NOAA National Centers for Environmental Information, Deep Sea Coral Research and Technology Program, NOAA National Centers for Coastal Ocean Science, Bureau of Ocean and Energy Management

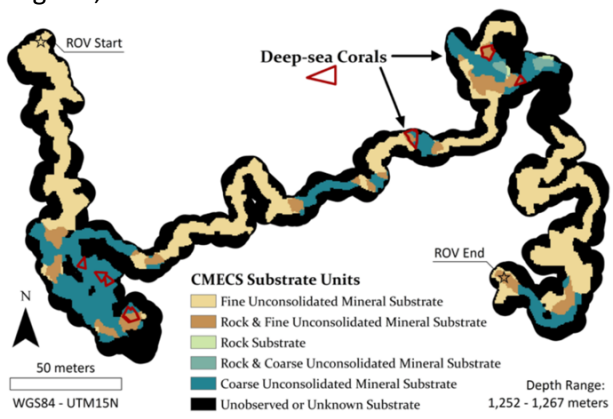


Figure 1: A map of CMECS classified seafloor substrate and deep-sea corals, observed during a dive of the ROV Deep Discoverer. The map visually indicates the spatial relationship between deep-sea corals and rock as well as coarse unconsolidated mineral substrate. Image created by Caitlin Ruby (NOAA) and adapted from Etnoyer et al. (2018).

CONTACT:
Paul Snelgrove
Memorial University of Newfoundland
St. John's, NL Canada

TARGET NAMES: Labrador Sea - Global "hotspot" for climate change and carbon/heat export, production & deep water corals

GEOGRAPHIC AREA(S) OF INTEREST WITHIN THE NORTH ATLANTIC OCEAN: Northwest Atlantic

RELEVANT SUBJECT AREA(S): Biology, geology, chemistry physical oceanography

Labrador Sea Ecosystem Dynamics

Description of Region

Virtually nothing is known about the biota in the deep ocean. For example, Canadian scientific trawl surveys do not extend deeper than 750 m depth, and targeted deep ocean mapping and seabed and fish surveys have only just begun (Canadian ISECOLD project and EU ATLAS project). Such knowledge is critical to understanding how these unique oceanographic processes link to the biota; specifically whether we might expect enhanced productivity in deep ocean areas of convection and how ocean acidification will affect vulnerable biota. Deep-water convection sites also might be expected to be the 'ground zero' of climate change effects in the deep ocean because these areas will experience the most pronounced rate of ocean acidification and potential changes in food delivery.

Rationale for Future Exploration

The Labrador Sea has attracted numerous been research studies over the past forty years, particularly researchers from Canada, the United States, and from the European Union. The Labrador Sea is one of the few places where the deep ocean exchanges gases such as oxygen and carbon dioxide directly with the atmosphere. Transport out of the Labrador Sea carries oxygen and anthropogenic CO_2 into the North Atlantic interior, oxygenating the subsurface layers and slowing the accumulation of CO_2 in the atmosphere, but exacerbating ocean acidification along Canada's eastern margin. While much has been learned about convection, transport, and water property formation in this region, many fundamental questions remain unanswered: what is the

relationship between convection and the Meridional Overturning Circulation (MOC)? How is the uptake of CO_2 changing with the possible slowdown of the MOC? Why is there a decline in nutrient concentrations and what are the implications for deep-sea biota as well as fisheries resources vital to Indigenous groups? How will the Labrador Sea respond to changes in the cryosphere (e.g. Greenland and other high latitude glaciers) and changing sea-ice conditions in the Arctic Ocean? These natural science questions are globally important, and can dovetail into timely social science questions on how coastal communities, scientists and governments can cooperate to analyze and mitigate risk in order to protect and enhance livelihoods in the face of rapid climate change and human development.

RELEVANT PARTNERSHIPS (If applicable)

The Ocean Frontier Institute, led by Dalhousie and Memorial universities, is a major initiative to examine key aspects of atmosphere-ocean interaction, resulting ocean dynamics and shifting ecosystems in the Northwest Atlantic. This partnership focuses on effective approaches to resource development that are sustainable, globally competitive, societally acceptable and resilient to change. Several of the major research modules in the Ocean Frontier Institute focus on this region and bring in researchers from GEOMAR and AWI in Germany. D. Wallace is leading the module studying biogeochemical processes in the Northwest Atlantic; P. Snelgrove is leading the module studying ecosystem indicators and B. DeYoung is leading the module to develop new observational technology for application in the Labrador Sea. We are partners in the international, meridional overturning circulation program, OSNAP, that has been active for several years and has plans to continue. We are developing a partnership with the TERIFIC program led by Eleanor Frajka-Williams from the National Oceanographic Center in Southampton. We are partners with U. Send of SIO who is building a new SeaCycler mooring system for deployment in the Labrador Sea. Through LabSea2020, Wallace and DeYoung, are developing an international, transdisciplinary program to bring together scientists and social scientists with a focus on the Northwest Atlantic including the natural systems and the coastal communities that rely on ecosystem services from the Labrador Sea. A nascent program led by Fisheries and Oceans Canada (ISECOLD) has collected limited deep-water data from the CGS Amundsen, in collaboration with the EU programs SponGES and ATLAS, which focus on deep-water ecosystems in the region. MEOPAR has also conducted Labrador Sea research cruises. Data from this effort can feed into newly developing data focused efforts such as CIOOS (Canadian Integrated Ocean Observation System) and DeepSense. In short, this region offers an ideal opportunity to deliver on the Galway Statement promises by capitalizing on international interests that already prioritize the Labrador Sea as a globally critical research site.

Canadian Team: Paul Snelgrove, Brad deYoung and Evan Edinger (Memorial) Doug Wallace and Eric Oliver (Dalhousie) David Cote (Fisheries and Oceans Canada), Kent Moore (University of Toronto)

European Potential Collaborators: Murray Roberts (ATLAS), Hans Tore Rapp SPONGeS, Johannes Karstensen (GEOMAR) Eleanor Frajka-Williams (NOC)

U.S. Potential Collaborators: U. Send (SIO), B.Pickart (WHOI)

Note that we collaborate with leaders of parallel ASPIRE LOIs including Metaxas, Roberts, and Morato and envision our effort as part of a broader geographic effort.

Exploration of the Vema Fracture Zone, tropical Mid-Atlantic Ridge.

Contact Information
Primary Contact: Michael Vecchione
Home Institution: NOAA National Systematics Lab, National Museum of Natural History
Target Name(s): Mid-Atlantic Ridge
Main Feature(s)/Area(s) of Interest: Vema Fracture Zone
Geographic Area(s) of Interest within the North Atlantic Ocean: South Central
Relevant Subject Area(s)
Biology, Geology, Chemistry, and Physical Oceanography
Description of Topic or Region Recommended for Exploration
Brief Overview of Area or Feature.

The Mid-Ocean Ridge system is the largest continuous geological feature on the planet. The Vema Fracture Zone (VFZ), centered at about 11° N, 42° W, is one of the largest transform faults of the Mid-Atlantic Ridge (MAR) in the North Atlantic. It displaces the axis of the ridge by 320 km. The fault has a prominent valley, up to 5200 m deep. The fracture zone appears to be a major deep-sea corridor connecting the abyssal West and East Atlantic Basins. Its role in north-south biogeography has not been investigated, nor has small-scale biological and geological variability in the VFZ.

Brief Summary of Current State of Knowledge.

The Dec 2014-Jan 2015 Vema-TRANSIT expedition of the German RV Sonne examined bathymetry and benthic macrofauna at a few stations within the VMZ during a trans-Atlantic passage (Figure 1). Methods included multi-beam bathymetry and biological sampling using a camera-epibenthic sledge. The primary goal was consideration of the VFZ as a biogeographic conduit between the abyssal basins to the east and west. A recent special issue of Deep-Sea Research II included 16 papers on a variety of fauna and habitat characteristics, plus a general overview of the expedition. The 2018 Deep-Sea Biology meeting in September, Monterrey CA includes four additional presentations.

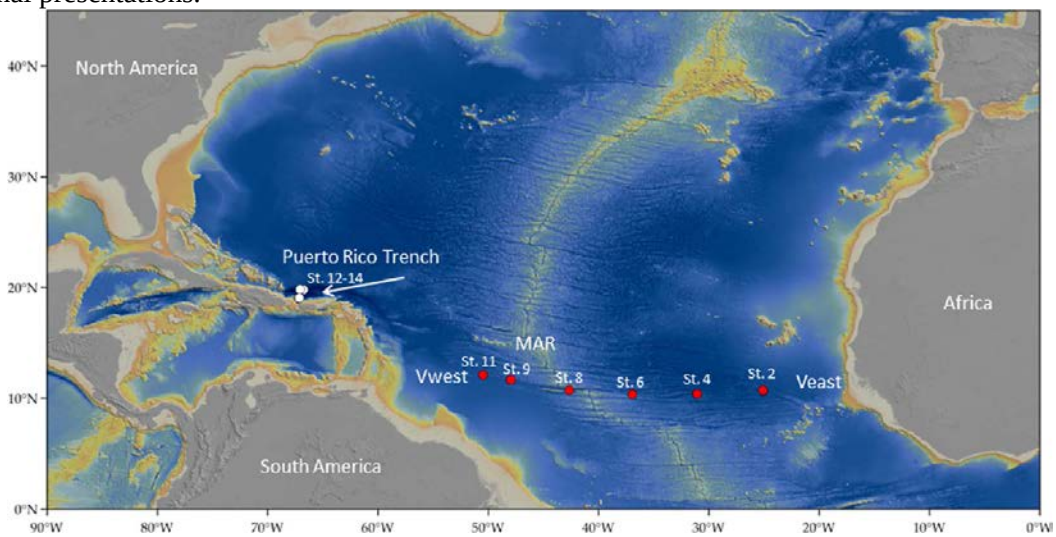


Figure 1. RV Sonne stations during the Vema-TRANSIT expedition (Brandt et al., 2018)

Additionally, published records of vesicomyid clams *A. southwardae* in the VFZ suggest the presence of reducing habitats in this area. The off-axis position of these records may indicate a new type of reducing habitats. Also, discrete-depth midwater sampling for zooplankton and micronekton was conducted east and west of the VFZ by the Census of Marine Zooplankton project of the Census of Marine Life.

Rationale for Future Exploration.

Recently, ecosystems of the Mid-Atlantic Ridge (MAR) have received increasing attention. On the MAR between the Azores and the VFZ, the International Seabed Authority (ISA) has approved 15-year exploration contracts for polymetalic sulphide deposits to Russia, France, and Poland

(https://www.isa.org.jm/contractors/exploration-areas). Protection of the marine environment on the MAR under regulations of the ISA has therefore become a priority. The ISA works with experts on deep-sea ecology toward a Strategic Environmental Management Plan (SEMP) for the MAR based on the principles applied for the SEMP for manganese nodule fields of the Clarion-Clipperton Fracture Zone (ISBA/18/C/22). These include the principle that the network of protected areas should capture the full range of habitats and communities in the region. The northern MAR is predominantly a soft-sediment environment, ~94% of the ridge is flat or gentle slope (5°-30°). Fracture zones are not only important elements of the ridge structure, but they apparently provide a bulk of hard substrate habitats on the ridge. Biota of these habitats in tropical regions have never been explored in detail

In contrast with the very large-scale trans-Atlantic focus of the Vema-TRANSIT expedition, we propose to examine smaller-scale patterns using a strategy similar to that of the ECOMAR project on the Charlie-Gibbs Fracture Zone of the northern MAR. We want to examine locations north and south of the VFZ, both east and west of the MAR axis, in addition to comparative dives in the deep central valley of the VFZ. The project is aimed at revealing faunal changes and connectivity of benthic populations at the MAR segments offset by the VFZ. Specific objectives include (1) examination of hard substrate and soft sediment faunas inside the Vema transform fault and adjacent ridge areas, (2) detailed bathymetric mapping and investigation of the seafloor in the area of the Vema fault with assumed reducing habitats, and (3) exploration of the ridge structure in the tropical part of the MAR. As an adjunct to the primary benthic focus of this exploration, we propose to conduct standardized Okeanos midwater transects at the ends of some or all dives.

Relevant Partnerships

The following colleagues have expressed interest in participating:

Andrey Gebruk, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences.

Louise Allcock, School of Natural Sciences and Ryan Institute, NUI Galway.

Tracey T. Sutton, Rosanna Milligan, and Tamara Frank, College of Natural Sciences and Oceanography, Nova Southeastern University.

Kevin Boswell, Department of Biological Sciences, Florida International University

Additionally, Louise indicated that NERC might be interested. The German Ministry for Science and Education might also be interested as a follow-up to their Vema TRANSIT expedition and the International Seabed Authority may be interested for defining representative habitats for protection.

References

Brandt, A., S. Kaiser, and T. Riehl (eds.) 2018. Bathymetry of the Vema-Fracture Zone and Puerto Rico TRench Abyssal AtlaNtic BiodiverSITy Study (Vema-TRANSIT). Deep Sea Research Part II: Topical Studies in Oceanography 148:1-260.

Koslow, J. A., P. Auster, O. A. Bergstad, J. M. Roberts, A. Rogers, M. Vecchione, P. Harris, J. Rice, and P. Bernal. 2016. Biological communities on seamounts and other submarine features potentially threatened by disturbance. Chapter 51. *In:* Inniss, L. and A. Simcock (joint coordinators). *First Global Integrated Marine Assessment, World Ocean Assessment I.* United Nations, New York. 26 pp.

Priede I.G., O.A. Bergstad, P.I. Miller, M. Vecchione, A. Gebruk, et al. 2013. Does presence of a mid-ocean ridge enhance biomass and biodiversity? *PLoS ONE* 8(5): e61550. doi:10.1371/journal.pone.0061550

Ramirez-Llodra, E., A. Brandt, R. Danovaro, B. De Mol, E. Escobar, C.R. German, L.A. Levin, P. Martinez Arbizu, L. Menot, P. Buhl-Mortensen, B.E. Narayanaswamy, C.R. Smith, D.P. Tittensor, P.A. Tyler, A. Vanreusel, and M. Vecchione. 2010. Deep, diverse and definitely different: unique attributes of the world's largest ecosystem. *Biogeosciences* 7, 2851–2899.

Vecchione, M., O.A. Bergstad, I. Byrkjedal, T. Falkenhaug, A.V. Gebruk, O.R. Godø, A. Gislason, M. Heino, Å.S. Høines, G.M.M. Menezes, U. Piatkowski, I.G. Priede, H. Skov, H. Søiland, T. Sutton, and T. de L. Wenneck. 2010. Biodiversity Patterns and Processes on the Mid-Atlantic Ridge. pp 103-121 *In:* McIntyre, A.D. (ed.) *Life in the World's Oceans.* Blackwell Publishing Ltd.

ASPIRE: Coral Gardens in the Gulf of Maine

Contact Information
Primary Contact: Rhian G. Waller, Ph.D.
Home Institution: University of Maine, Darling Marine Center

Target Name(s): Gulf of Maine (200m+ depth) – e.g. Schoodic Ridges, Northeast Channel, Western Jordan Basin.

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)
Northeast

Relevant Subject Area(s) (Indicate all that apply)
Biology
Chemistry
Physical Oceanography

Description of Topic or Region Recommended for Exploration
Brief Overview of Area or Feature: Though it was originally thought that extensive coral and sponge habitats would not exist in the Gulf of Maine due to intensive fishing pressure, a series of four cruises from 2013 – 2017 using towed cameras and ROV systems (ISIS 2, Kraken II and ROPOS) demonstrated this was not the case. Though fishermen had frequently pulled up corals as bycatch, it wasn't until this series of cruises that coral gardens were visualized, identified and sampled. Extensive coral ecosystems were located from 170-250m depths in three major locations within the Gulf of Maine (Schoodic Ridge, Western Jordan Basin and Central Jordan Basin). Coral and sponge ecosystems are also well known from the Northeast Passage, where cold nutrient rich deep water feeds into the Gulf of Maine, as well as canyons on the outer continental shelf edge. This area is one of the fastest warming bodies of water in the world, and this year has seen a large influx of abnormally warm water, leading to unknown consequences for these ecosystems.

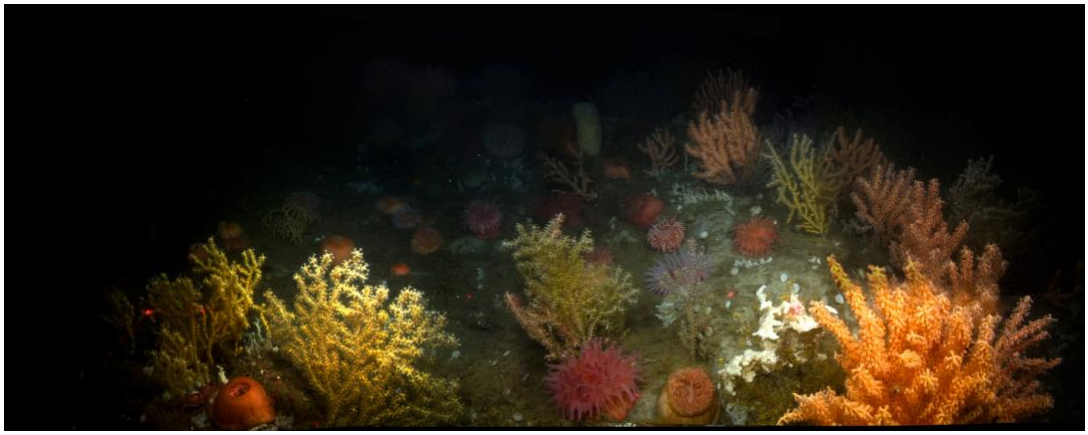


Fig. 1. Coral ecosystem within the Gulf of Maine (Central Jordan Basin). Courtesy of NOAA, UConn., Mystic Aquarium, UMaine.

Brief Summary of Current State of Knowledge: Four cruises identified three major areas of coral growth within the Gulf of Maine – Schoodic Ridges (a large ridge following the coastline from Mt. Desert Rock northwest towards Canadian waters. Two of these cruises used an ROV (Kraken II and ROPOS) to sample these three areas. Samples were split between identification, genetics and reproduction. Genetics (Morrison (USGS) pers. Com.) show the populations within the Gulf of Maine to be isolated from coral populations outside the Gulf (with crossover seen in the Northeast channel). Reproductive work shows the Schoodic Ridge population to be critically important to the Gulf of Maine as a whole, as it produces significantly more larvae than the other two sampled populations (Fountain et. al. in review). The other two populations have smaller coral colonies, indicating either a younger, or more disturbed, community.

Exploration for corals occurred only on two towed camera cruises and did locate some other coral colonies along points on Schoodic Ridges. The towed camera proved inefficient at examining coral areas thoroughly however due to topography. ROV cruises were focused on collections of corals.

Rationale for Future Exploration: This region is an important region in the US (and Canadian) economies in terms of intensive fisheries areas. Benthic communities are important to the overall health of the ocean ecosystem and many species of corals observed in the area potentially provide habitat for commercially viable species. We know little of the extent of coral communities in this area, and it was notable that despite records of corals within the Gulf of Maine extending back into the 1800's, and numerous submersible and ROV dives in the region in the 1990's, it wasn't until 4 years ago that extensive communities were finally discovered – there are likely more pockets of perseverance within Gulf waters awaiting discovery.

Fig. 2. Seastar predation. Courtesy of NOAA, UConn., Mystic Aquarium, UMaine

The Gulf of Maine is also one of the fastest warming bodies of water on this planet, and the effects of this ocean warming are already being felt in commercial species (e.g. lobster, clams etc.). This year a core of warm water entered the Gulf of Maine through the Northeast passage, warming waters at around 200m depth to up to 11C warmer than usual averages. This water is still sitting in the Gulf of Maine, at depths where we find these critical coral and sponge communities, and will move out in a few months time.

This is a unique opportunity to not only explore for more populations of corals within the Gulf of Maine, an urgent need in itself given fisheries pressures in this region, but also to explore the effects of ocean warming on populations that have already been fairly well documented and examined. We know from other studies warming waters can have detrimental effects in terms of reproduction and eventual colony death, though these studies are all done within laboratory settings. To explore these effects in a natural setting would be unique and exciting.

Relevant Partnerships (If Applicable)

ATLAS: Fits with ATLAS Work Packages 2, 3 and 5 – examining ecosystem function, biodiversity and biogeography and has consequences for ocean and fisheries health.

SponGES: Many species of sponge were observed in the first cruises that would be of interest to the SponGES group.

Canada Healthy Oceans Network: The Gulf of Maine extends into Canadian waters and is an important resource to both the US and Canada in terms of fisheries.

Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE)

Charleston Bump "4D Ocean Cube" Exploration Program

Primary Contact: Dr. Scott White
Home Institution: University of South Carolina

Target Names: Charleston Bump, a deepwater (2,300 feet with over 400 feet of vertical relief) bottom feature located 80 to 100 miles southeast of Charleston, SC

Geographic Area of Interest within the North Atlantic Ocean: Southwest Atlantic

Relevant Subject Areas: Biology, Geology, Chemistry, Physical Oceanography, Ocean Engineering including satellite and hyper-spectral remote sensing, underwater communications, modeling, Big Data analysis and autonomous vehicles.

Description of Topic or Region Recommended for Exploration:

In the 2016 National Ocean Exploration Forum Final Report "Beyond the Ships 2010-2025" Paul Gaffney (Vice Admiral, USN retired) and Jesse Ausubel (The Rockefeller University) put forth a vision for ocean exploration campaigns defined as "a strategically planned set of activities to characterize a yet-to-be-explored or underexplored geographic area, selected to meet sponsor requirements and maximize potential scientific opportunity, and often spanning several years and involving multi sponsors and performers. Rather than limiting observation to a single subject or sense, campaigns can characterize an area or volume of ocean in terms of marine life, chemistry, geology and geophysics, history and archeology, and bathymetry include dynamic measurements and sample collection, and record observations using a broad range of methods of perception, including hearing, smell, touch, taste, and sight, as extended by advanced technologies. Necessity as well as opportunity favors movement to campaigns beyond ships." This idea is atypical for NOAA Ocean Exploration, as an OE expedition would be an initial phase of this broader activity as it is envisioned. However, this kickoff expedition for a future campaign would be both broadening and compelling within the Ocean Exploration portfolio, as a science-led but engineering/technology-focused exploration.

Considering the above, the University of South Carolina (USC) recommends ASPIRE consider a "4D Ocean Cube" approach to the ocean campaign model as a means for addressing the need for understanding and sustaining an "energy and ecological balance" within a 4D Ocean Cube of the three spatial dimensions along with time. The spatial extent of Ocean Cube encompasses a surface area (we propose 25x25 mile square for the Charleston Bump) and a depth dimension that includes air-sea interaction, the water column, as well as the subsurface geology and groundwater hydrology of the seabed. Basically, taking the idea of Ocean Observatories Initiative coastal array (e.g. Coastal Pioneer) and expanding it to include the seafloor subsurface geology and atmosphere with a series of wells, moorings, and meteorological sensors.

Specifically, USC is proposing conducting a campaign for exploring the Charleston Bump region aimed at a complete atmosphere-to-lithosphere characterization of an ocean region of interest.

The Charleston Bump is a unique feature, deflecting the flow of the Gulf Stream and setting up the Charleston Gyre, bringing warmer Gulf Stream water close to shore to meet cooler shelf water potential application of "Horizontal Ocean Thermal Energy Conversion?) and causing upwelling of nutrient-rich water that supports the rich fishery in this region. Also, the Charleston Bump includes a series of steep scarps with rocky cliffs, ridges, overhangs and caves that support populations of deep reef fishes, the only known spawning site for wreckfish in the western North Atlantic, and spawning ground for swordfish. In the broader region this is an area expecting increased shipping traffic from Post/New PANAMAX deep draft ships, poorly known marine mineral reserves, and potential deep biological communities.

An example of a Charleston Bump R&D collaborative effort, according to the NOAA website "Increased research efforts are needed on the U.S. continental slope as fisheries expend into deeper water…The fauna of the Charleston Bump and the Blake Plateau has been poorly studied because of the difficulties in deploying nets and other traditional fish sampling gear in deep water under the Gulf Stream. Visual observations from submersible are needed to describe the deep water fish assemblages, their preferred habitats, and their ecological roles."

Our proposed initiative is aimed at measuring fluxes of water, nutrients, sediments and involves a multi-stage, multi-year effort. Fluxes, direct measurements of changes in volume or mass over time, have been difficult if not impossible to capture data for with present technology. Initial data from ship-based observations could constrain a set of numerical models. Such models could predict the best locations for infrastructure such as vertical profiler moorings, seabed wells, and meterological platforms. Autonomous technology would be employed to dynamically collect dense spatial data with UUV's, AUV's and wave gliders, and also UAV's doing atmosphere and surface ocean work. This autonomous network could be repositioned as needed based on near real-time feedback from the static sensors and data provided to run numerical models of oceanographic processes. Data from this area are essential toward to the smart growth of the rising Blue Economy in the U.S. Southeast EEZ, and addressing the need to more comprehensively understand the ocean dynamics and biology in the Southeast U.S. shelf.

Relevant Partnerships: NOAA's Office of Coastal Services, the National Ocean Service, NOAA NERRS SWMP and our NOAA IOOS.

2018 ASPIRE WHITE PAPER SUBMISSION
An ASPIRE mission in Support of Sponge Grounds and Animal Tacking Research I: NW Atlantic Continental Shelf

Contact Information

Primary Contact: Ellen Kenchington
Home Institution: Bedford Institution of Oceanography, Department of Fisheries and Oceans, Nova Scotia, Canada

Primary Contact: Fred Whoriskey
Home Institution: Ocean Tracking Network, Dalhousie University, Halifax, Nova Scotia, Canada

Target Name(s)

Main Feature(s)/Area(s) of Interest: Continental shelf/slope; sponge grounds; benthic habitats

Geographic Area(s) of Interest within the North Atlantic Ocean (Indicate all that apply)

Northwest Atlantic/ Scotian Shelf

Relevant Subject Area(s) (Indicate all that apply)

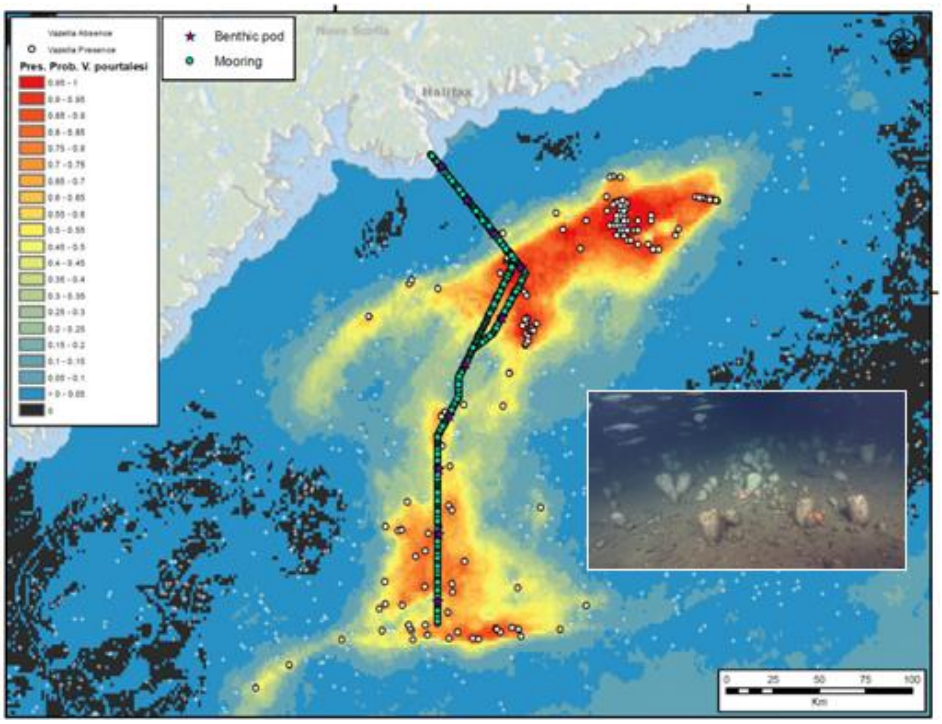
Biology, Geology, Chemistry, Physical Oceanography

Description of Topic or Region Recommended for Exploration

The continental shelf and slope of the Northwest Atlantic Ocean is an area of complex biology, topography, chemistry and ocean currents. The area is the boundary between the southern flowing cold current of the Atlantic Meridional Overturning Circulation (Labrador current) and the Northward driven Gulf stream, and exhibits pronounced season productivity cycles that drive long-distance migration to the area by highly valued marine species (e.g., Bluefin tuna, striped bass, white sharks). The resources of the shelf support the socio-economic well-being of a vast number of North American communities. The shelf off Halifax, Nova Scotia currently hosts major research efforts by two international networks. The Horizon 2020 SponGES program is providing desperately needed information about the biology of poorly known sponges in the Atlantic Ocean, the role of sponge grounds in the ecology and productivity of NW Atlantic ecosystems, and the linkages of the sponge grounds to pelagic and offshore ecosystems (benthic production exported to other food webs, rearing grounds for larvae of other species, carbon sequestration, etc.). The SponGES team from the Bedford Institution of Oceanography hosts the North American node of this project with E. Kenchington as a project so-coordinator. This is a case study area for SponGES (CS7).

Also based in Halifax is the headquarters of the global Ocean Tracking Network (OTN), an international research infrastructure and science network that uses electronic telemetry to document the movements and survival of marine animals, and to link them to environmental conditions in the face of a changing

ocean. Off Halifax, the OTN maintains a line of acoustic receivers that spans from the nearshore across the width of the continental shelf (> 100 nautical miles). This array is documenting the seasonal movements of species from overwinter habitats in southern (US) waters, into northern (Canadian) summer habitats, and providing information on the three dimensional use of the water column by these species. It also passes through important sponge grounds, and the OTN is currently a member of the SponGES consortium supporting the SponGES researchers through providing access to this valuable infrastructure. Our animal telemetry work has shown that a number of species that move into the area become resident along specific portions of the shelf for the spring-autumn period. Yet, we do not understand why these areas are so highly attractive and used by these species.



Location of OTN acoustic receivers (black and green dots) on the Scotian Shelf, in relation to the predicted distribution (red and yellow shading) of a globally unique population of glass sponge, Vazella pourtalesi (blue and black areas indicate low and zero probability of occurrence respectively). White circles and crosses indicate presence and absence of Vazella in research vessel surveys with the crosses indicating no Vazella. The sponge is currently protected from bottom contact fishing in parts of this range. This is a Case Study Area (CS7) for the SponGES project.

In establishing formal linkages, the research of the SponGES and OTN projects have become mutually supporting in attempting to understand the production and use of shelf areas by both sessile and mobile animals. We are integrating sampling missions and sharing equipment to ensure efficient and sustainable research, however, we lack a detailed description of the habitats within the sponge grounds and along the Halifax electronic telemetry array that could be used to inform our understanding of the ecology of species while they are using these areas, and modelling to predict the presence and or absence of animals in association with environmental conditions.

We propose an ASPIRE mission to help describe the habitats of the continental shelf from the inshore to the continental slope along the path of the Halifax line (average depth 202 m). Through a combination of high resolution mapping at night, and selective ROV dives during the day, quantitative descriptions can be provided of the benthic landscape and habitats that can be compared to the abundance of sponges and the residency patterns of electronically tagged fish to help determine the factors that make this area so important to these species.

Proposal for an ASPIRE mission to the Azores archipelago and the Mid-Atlantic Ridge

Contact Information

Primary Contact: Joana Xavier
Home Institution: CIIMAR - Interdisciplinary Centre of Marine and Environmental Research of the University of Porto (Portugal); KG Jebsen Centre for Deep-Sea Research and Department of Biological Sciences, University of Bergen (Norway)

Primary Contact: Ana Colaço/Christopher Pham (SponGES), Telmo Morato/Marina Carreiro-Silva (ATLAS)
Home Institution: MARE – Marine and Environmental Sciences Centre and Okeanos - Univ. dos Açores (Portugal)

Target name(s): Azores EEZ - oceanic islands slopes; seamounts; Mid-Atlantic-Ridge (MAR); benthic habitats (particularly sponge grounds).

Geographic areas of interest within the North Atlantic Ocean: North Central

Relevant subject area(s): Biology, Geology, Chemistry, Physical Oceanography

Description of topic or region recommended for exploration

The Azores archipelago is a key region in the North Central Atlantic, due to its geographic and oceanographic setting and its complex geological history. It lays on the triple-junction of the North American, Eurasian and African plates, on either side of the Mid-Atlantic-Ridge (MAR), a key topographic feature of the Atlantic. Oceanography in the region is influenced by two eastward currents branching from the Gulf Stream, the North Atlantic Current in the north and the Azores Current to the south, resulting in a complex circulation, high salinity and temperature, and a low nutrient regime that typifies the Azores. The region has a spatial, seasonal and inter-annual variability typical of mid-latitudes, influenced by the Atlantic Meridional Overturning (AMOC). It comprises nine islands, numerous islets and over 60 large seamounts. Over relatively short distances from the islands' shorelines, deep-sea and open ocean conditions are found, with a variety of shelf/slope/ridge/ seamount features being home to a diversity of species and habitats of conservation priority such as cold-water coral gardens, sponge grounds and hydrothermal vents (Fig. 1).

Despite ongoing deep-sea research in the area by various national and international teams in recent years, its wide expanse (an EEZ of nearly a million km^2) makes of the Azores a yet largely unexplored region, especially west of the MAR, on the North American plate. We propose an ASPIRE mission to map, describe and characterize the benthic habitats of the shelf and slopes of Faial/Pico (E of the MAR) and Flores/Corvo (W of the MAR) islands, as well as two seamounts (Cavala and Ferradura), and the section of the Mid-Atlantic-Ridge separating these islands' pairs (Fig. 1).

The campaign could comprise high resolution multibeam mapping of target features at night, alternated with: 1) exploration dives in areas never visited before, but where vulnerable marine habitats are expected to occur (e.g. Cavala/Ferradura seamounts and the MAR section); and 2) characterization dives in sites where sponge grounds and coral gardens have been reported but await detailed characterization (e.g. the *Pheronema* sponge grounds and *Narella* sp. coral gardens on the slope of Pico island).

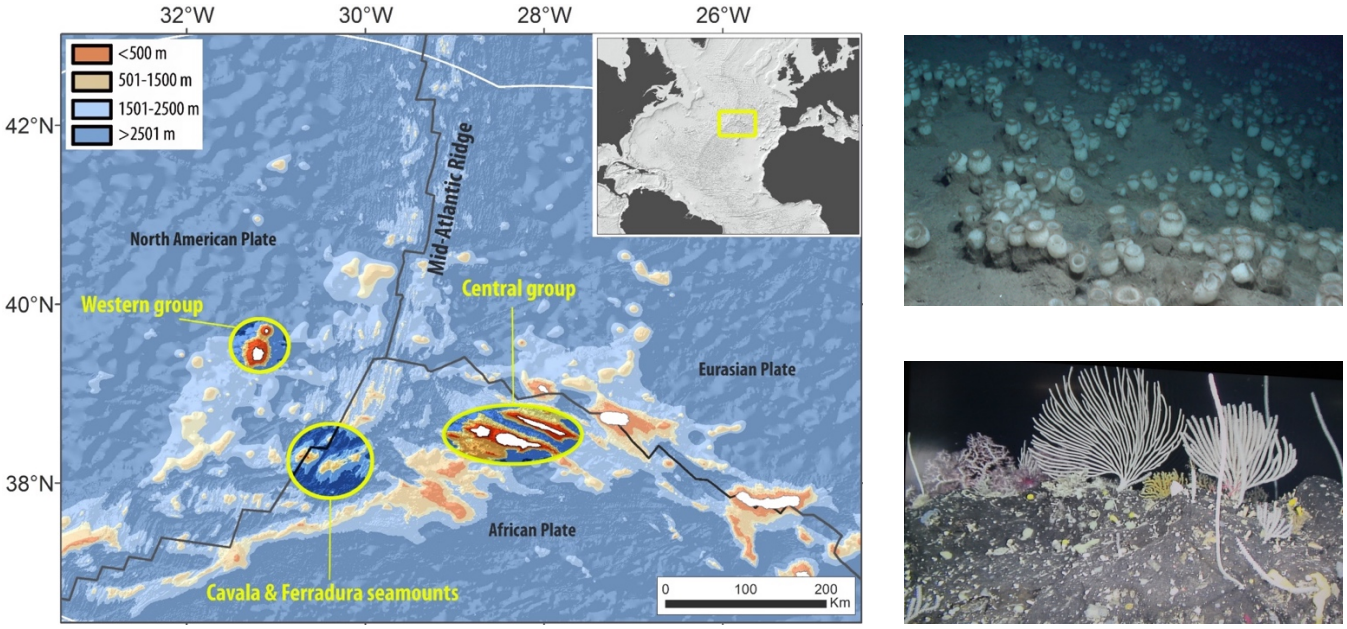


Figure 1. Map of the area proposed for exploration under an ASPIRE campaign, and examples of some benthic habitats to be characterized (sponge grounds and coral gardens). Circles highlight the main target features: Western group (Flores and Corvo islands); the Cavala and Ferradura seamounts (and the MAR section); Central group (Pico, Faial and São Jorge).

Recorded species and habitats will contribute to studies aimed at understanding regional to basin scale biodiversity and biogeographic patterns, as well as validate distribution models under development. Targeted sampling will allow us to assess the patterns of genetic diversity and connectivity across the North Atlantic, by complementing ongoing population genomics studies of key structuring species (e.g. the sponges *Pheronema carpenteri, Aphrocallistes beatrix, Acanella arbuscula*); and Gulf Stream mediated connectivity (e.g. the sponges *Vazella pourtalesi* and *Geodia* spp.) with the eastern seaboard of the US, the Canadian Scotian Shelf and even the NAFO high seas areas on Flemish Cap (see sister proposal submitted by Ellen Kenchington and Fred Whoriskey).
As bottom fishing in the area is mostly of small-scale and artisanal characteristics using bottom longline and handline (trawling is banned in the region) we expect to find pristine habitats which will provide baseline data (community composition and structure, density, extent, etc.) for comparative assessments of the environmental and ecological status of such habitats.

Relevant partnerships

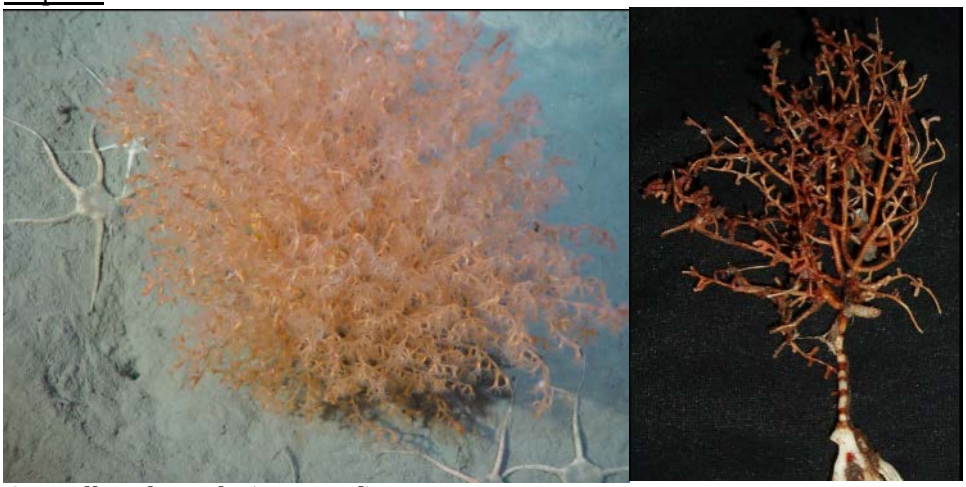
This campaign would benefit from (and leverage) the work in progress in scope of two large Horizon 2020 projects (SponGES – www.deepseasponges.org and ATLAS - https://www.eu-atlas.org, grant agreements nos. 679849 and 678760) funded by the European Union under the Blue Growth call aimed at "Improving the preservation and sustainable exploitation of Atlantic marine ecosystems". Both projects are undertaking in-depth characterization of deep-sea benthic ecosystems, as well as biodiversity, biogeographic and connectivity assessments across the North Atlantic, and include Case Study areas in the Azores region. The global Ocean Tracking Network (OTN), a partner in the SponGES project also manages an acoustic receiver line in the area – the Azores Array - which supports work on migratory and resident species over the MAR. The proposed ASPIRE work in the Azores will provide information that will inform current OTN telemetry studies on the valued species that use the area's seamounts and slopes.

ASPIRE Target Species for Connectivity Sampling

The following list of species is based on expert input from: Scott France, Shirley Pomponi, Murray Roberts (in consultation with the ATLAS Project Steering Committee), Tina Molodtsova, and Andrea Quattrini, and edited to account for feasibility (likelihood of finding the organisms in multiple locations, ability to collect using current capabilities on ROV Deep Discoverer, etc.) and likely value of the samples to contributing new scientific knowledge about dispersal dynamics in the Northern Atlantic ocean.

Corals

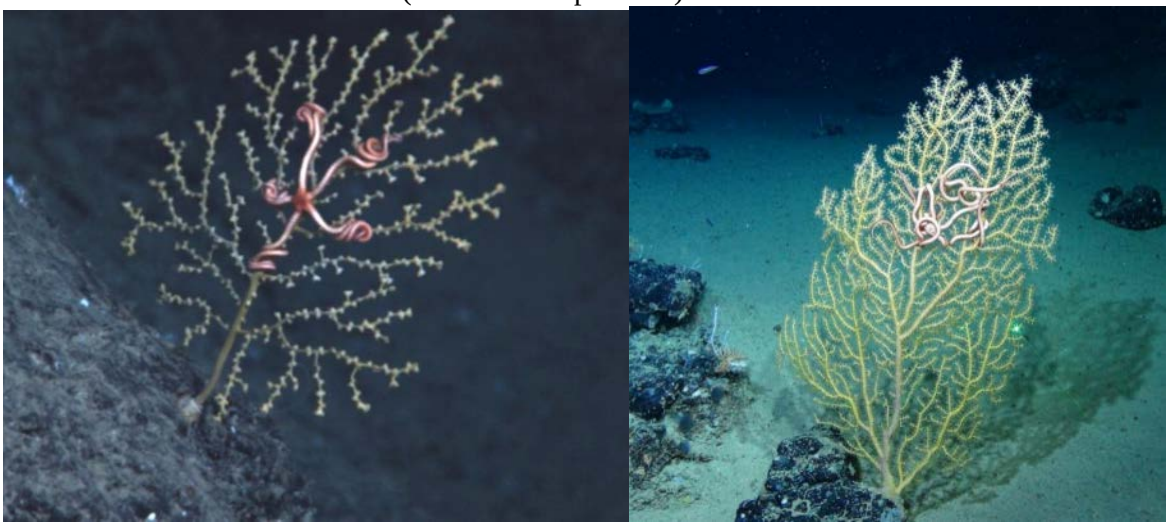
Top tier



Acanella arbuscula (octocoral)

[Images: http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=125371&pic=41867; http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=125371&pic=41883]

Paramuricea with *Asteroschema* (octocoral & ophiuroid)



http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=125385&pic=125705; http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=125311&pic=127186]

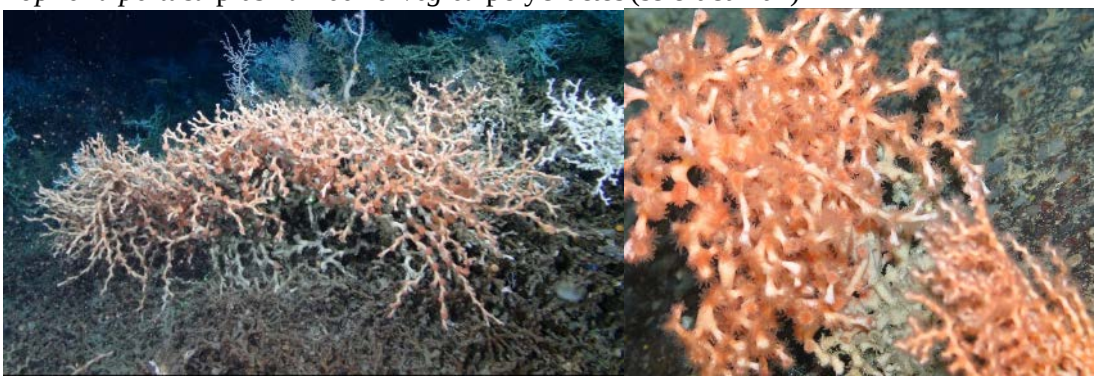
Leiopathes spp. (black coral)

[Images: https://oceanexplorer.noaa.gov/explorations/05stepstones/logs/aug14/media/leiopathes.html;]

Bathypathes "*alternata*" (black coral) [Images:

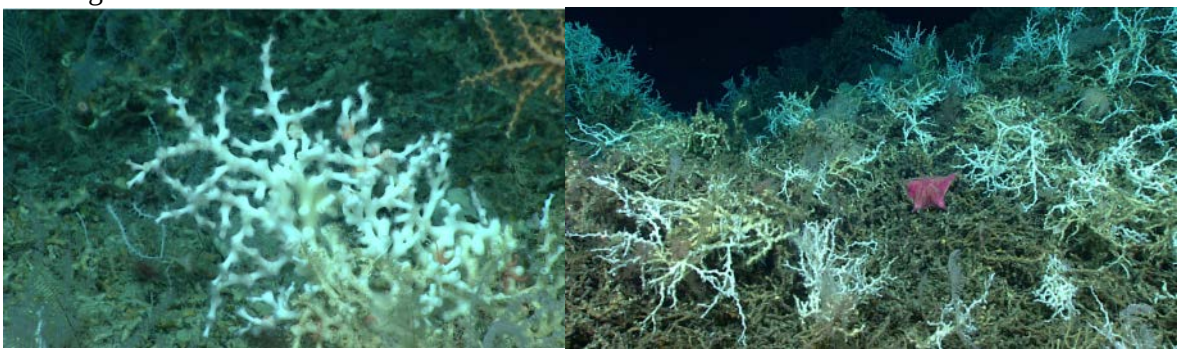
https://oceanexplorer.noaa.gov/okeanos/explorations/ex1404/logs/oct4/media/black.html; http://www.marinespecies.org/aphia.php?p=image&tid=103304&pic=41523; http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=103304&pic=129092]

Lophelia pertusa plus *Eunice norvegica* polychaetes (scleractinian)

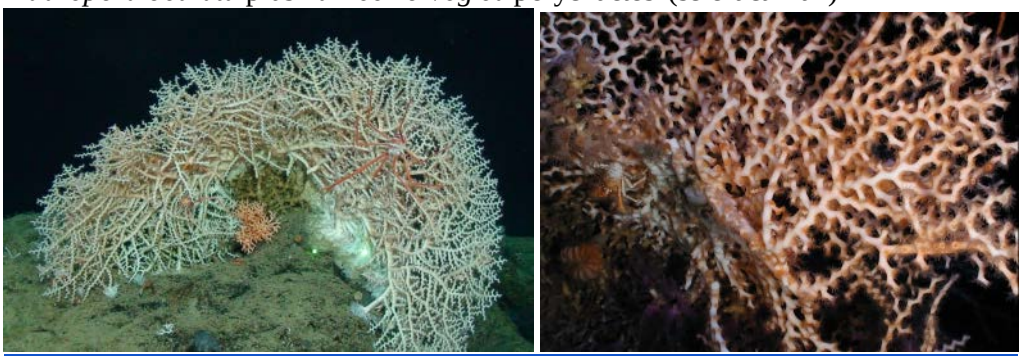


http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=135161&pic=127184;
http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=135161&pic=17587

Or images from EX1806:



Madrepora oculata plus *Eunice norvegica* polychaetes (scleractinian)



http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=135209&pic=127284;
http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=135209&pic=64163

Secondary targets

Primnoa resedaeformis (octocoral)

[Images: https://coastal.er.usgs.gov/coral-microbes/discovre/images/PrimnoaLG.jpg;
https://oceanexplorer.noaa.gov/explorations/17gulfofmaine/background/ca-conservation/media/jordan-hires.jpg]

Desmophyllum dianthus (scleractinian)

http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=135159&pic=41536; https://www.whoi.edu/cms/images/oceanus/2006/10/coral1en_32348.jpg]

Paragorgia arborea (octocoral)

[http://www.seawater.no/fauna/cnidaria/arborea.html; https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/img/20171127-paragorgia-arborea-mbari-1000.jpg]

Dendrophyllia cornigera (scleractinian)[Images: https://inpn.mnhn.fr/espece/cd_nom/361085?lg=en]

Tertiary

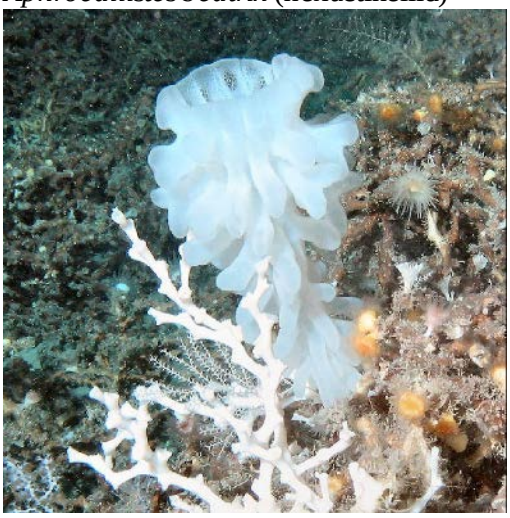
Anthomastus group (octocoral)

http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=125285&pic=64153; http://www.marinespecies.org/deepsea/aphia.php?p=image&tid=125285&pic=127634

Sponges

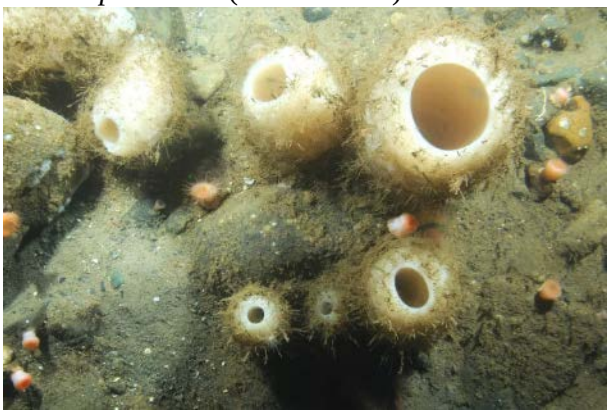
Geodia pachydermata (demosponge)[Images:]

Aphrocallistes beatrix (hexactinellid)



[Images: https://cnso.nova.edu/messing/strait-of-florida/images/deep-reefs/porifera/200511102_aphrocallistes.jpg]

Vazella pourtalesi (hexactinellid)



[Images: http://www.deepseasponges.org/?attachment_id=578]

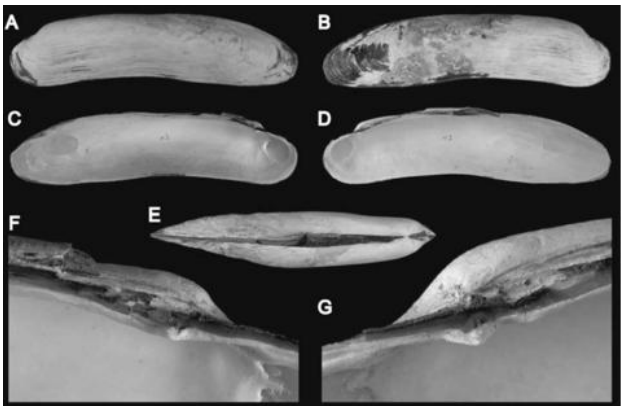
Pheronema carpenteri (hexactinellid)

https://deepseacru.files.wordpress.com/2013/11/pheronema-carpenteri-fields.jpg

Chemosynthetic-associated
Bathymodiolus (mussel)

http://www.deepseaspy.com/var/storage/images/medias-ifremer/medias-deepseaspy/faune/mar/mouliere-lucky-strike/1506679-1-fre-FR/Mouliere-Lucky-Strike_fullsize.JPG; http://chess.myspecies.info/taxonomy/term/33246/media

Abyssogena sp. (clam)[Images: http://chess.myspecies.info/taxonomy/term/30963/media]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Appendix E. Acronyms

ACUMEN—Atlantic Canyons Undersea Mapping Expeditions
ADEON—Atlantic Deepwater Ecosystem Observatory Network
AMOC—Atlantic meridional overturning circulation
AORA—Atlantic Ocean Research Alliance
ASMIWG—Atlantic Seabed Mapping International Working Group
ASPIRE—Atlantic Seafloor Partnership for Integrated Research and Exploration
ATLAS— A Trans-Atlantic assessment and deepwater ecosystem-based spatial management plan for Europe
AUV—Autonomous underwater vehicle
BATS—Bermuda-Atlantic Time-series Study
BIOS—Bermuda Institute of Ocean Studies
BOEM—Bureau of Ocean Energy Management
CCD—Carbonate compensation depth
CHONe—Canadian Healthy Oceans Network
CTD—Conductivity, temperature, and depth
DEEP SEARCH— Deep Sea Exploration to Advance Research on Coral/Canyon/Cold Seep Habitats
DFO—Fisheries and Oceans Canada
DNA—Deoxyribonucleic acid
DOSI—Deep-Ocean Stewardship Initiative
ECS—Extended Continental Shelf
eDNA—Environmental DNA
EEZ—Exclusive Economic Zone
EU—European Union
FAMOUS—French-American Mid-Ocean Undersea Study
FAO—Food and Agriculture Organization of the United Nations
Galway Statement—Galway Statement on Atlantic Ocean Cooperation
HAPC—Habitat area of particular concern
HD—High-definition
HMS—Highly migratory species
IFREMER—L'Institut Français de Recherche pour l'Exploitation de la Mer
INDEEP—International Network for Scientific Investigations of Deep-Sea Ecosystems
ISA—International Seabed Authority
LiDAR—Light Detection and Ranging
MAIA—Marine Protected Areas in the Atlantic Arc
MAR—Mid-Atlantic Ridge
MPA—Marine protected area
NCSMNM—Northeast Canyons and Seamounts Marine National Monument
NEFSC—NOAA's Northeast Fisheries Science Center
NGO—Non-governmental organization
NMFS—National Marine Fisheries Service

NOAA—National Oceanic and Atmospheric Administration
OER—NOAA's Office of Ocean Exploration and Research
POC—Point of contact
RMS—Royal Mail Ship
ROPOS—Remotely Operated Platform for Ocean Sciences
ROV—Remotely operated vehicle
SAFMC—South Atlantic Fishery Management Council
SponGES—Deep-sea Sponge Grounds Ecosystems of the North Atlantic
SUNY—State University of New York
UCAR—University Corporation for Atmospheric Research
UCH—Underwater Cultural Heritage
UK—United Kingdom
UNOLS—University-National Oceanographic Laboratory System
USAM—U.S. Atlantic Margin
USCG— U.S. Coast Guard
USCGC—U.S. Coast Guard Cutter
USGS—United States Geological Survey
WHOI—Woods Hole Oceanographic Institute