**Contact Information:**
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**Willing to Attend Workshop?** Yes
**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].

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[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