Atlantic Deepwater Ecosystem Observatory Network (ADEON) - An Integrated System for Long-Term Monitoring of Ecological and Human Factors on the Outer Continental Shelf

Reporting Timeframe: October 1, 2016 to September 30, 2017

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Project Website: https://adeon.unh.edu

LONG-TERM GOALS

The ultimate goal of ADEON is to generate multi-year measurements of the natural and human factors that describe the ecology and soundscape of the U.S. east coast Outer Continental Shelf (OCS). We aim to develop standardized tools for comparing soundscapes across regions and predictive models for the soundscape and overall ecology of the southeast OCS in water depths between 100-1000 m.

OBJECTIVES

1) Establish an ecosystem observation network that provides baseline monitoring and supports predictive modeling of the soundscape and its relationship to marine life and the environment of the Mid- and South Atlantic Planning Areas.
2) Develop standardized measurement and processing methods and visualization metrics for comparing ADEON observations with data from other monitoring networks.
3) Assess baseline soundscape and ecosystem conditions in support of predictive environmental modeling and trend analyses in the planning areas.
    - How do soundscape and ecosystem components vary with water depth across the OCS?
    - How do the soundscape and ecosystem components vary with latitude along the OCS?
    - Where are the hot spots of human activity for consideration in ecosystem/habitat health impacts?
4) Assess the spatial and temporal distribution of the soundscape and biological scatterers, including their expected variation and correlation with distance from the lander locations.
    - What are the environmental factors that define and constrain the horizontal range of appropriate extrapolation of observations measured at the stationary lander sites?
5) Develop and apply new methods for the effective visualization of five-dimensional (5D – time, latitude, longitude, frequency, and depth) soundscape data to interactive visual analysis tools that enable users to explore, analyze, and integrate ancillary ecosystem data streams with the 5D soundscape.
6) Develop a robust data management system that archives and provides public access to multiple data streams to encourage future development of ecological models targeted at questions beyond the scope of this study.

APPROACH

ADEON combines acoustic information with contextual data from space-based remote sensing, hydrographic sensors, and mobile platforms to fully comprehend how human, biologic, and natural abiotic components create the soundscape and influence ecosystem dynamics of the OCS. The program effort goes beyond basic ocean measurements and derived data products related to ecosystem components. Unique and innovative attributes of the ADEON work scope include 1) a standardization task aimed at developing and implementing acoustic metrics and

practices across ADEON components and recommending these approaches to other international monitoring programs, 2) network design to identify the appropriate range of extrapolation for bottom lander point samples, 3) ecological and soundscape modeling to predict potential influence of long-term change on the marine ecosystems, and 4) web-based tools to access and visualize multi-dimensional data streams.

To achieve the objectives, a four-phase research program was developed: I) Network Design, Procurement, and Deployment, II) Data Acquisition and Network Maintenance, III) Data Processing, and IV) Data Integration and Visualization (Fig. 1). These are complimented by overarching tasks that weave through all phases to manage data and standardize measurement, processing, and visualization metrics for the acoustic data sets. The network was designed to generate the baseline time-series of acoustic and supporting data using stationary bottom landers, space-based remote sensing, towed array missions, and vessel-based measurements (Fig. 2). Seven ocean bottom landers will be deployed along the OCS from VA to FL (Fig. 3). The outputs of the standardization effort will allow effective comparison of acoustic results between locations and research groups. Baseline assessment of the soundscape and contributing environmental components is critical to assessing long-term patterns and trends of individual ecosystem components and synergistic relationships, as well as providing the input parameters in support of the development of predictive models that integrate multiple data streams to determine future soundscapes and impacts resulting from environmental changes related to human activity, climate change, or other identified factors.

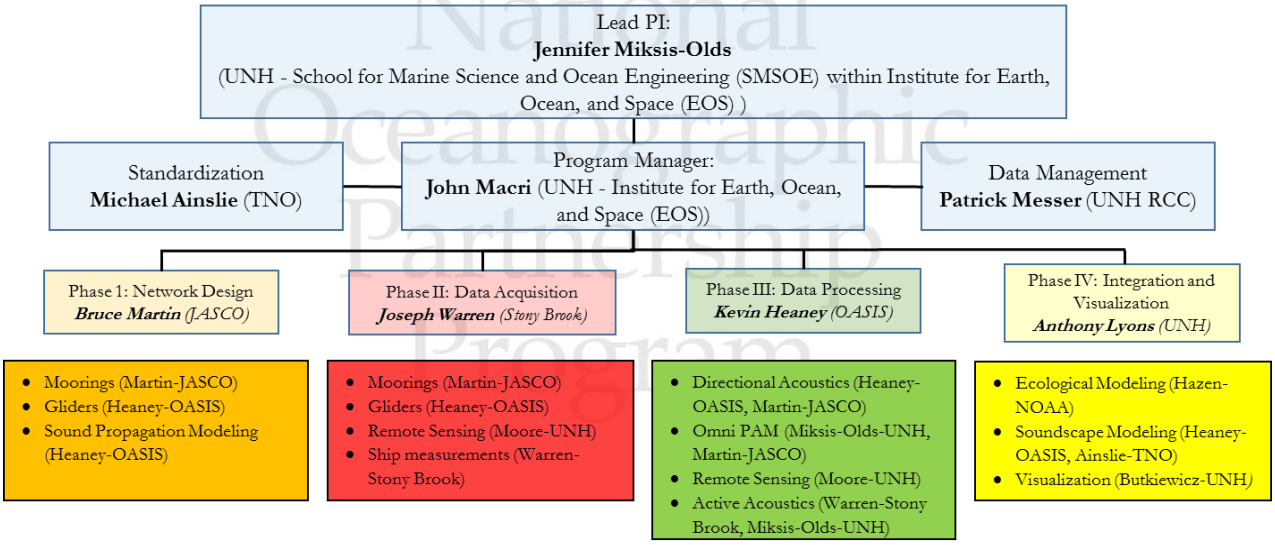

Figure 1. The ADEON team includes world leaders in collecting and managing acoustic, oceanographic, and remote sensing data.

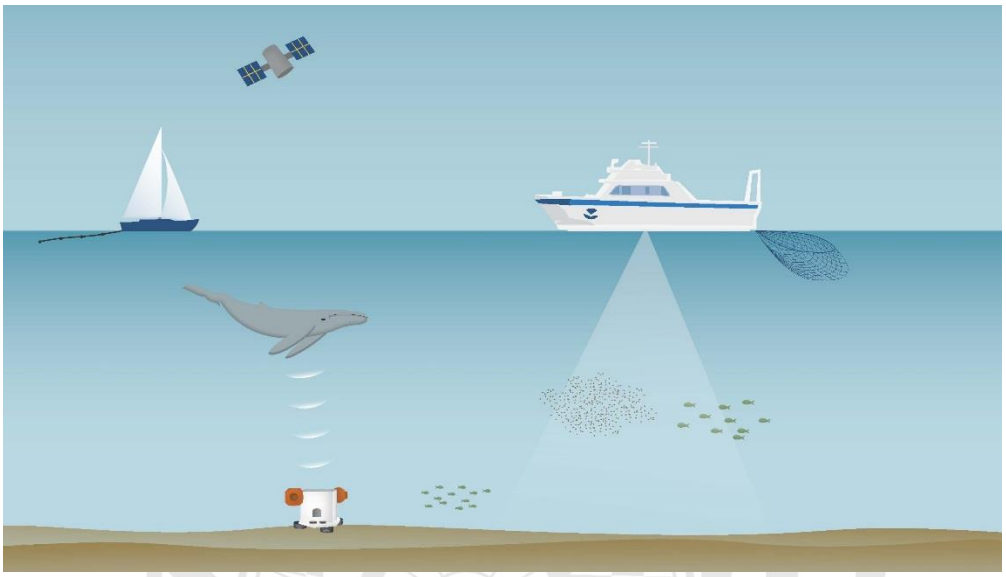

Figure 2. Overview of ADEON's network design including ocean bottom landers, mobile (ship and sailboat) platforms, and remote sensing satellites for data collection.

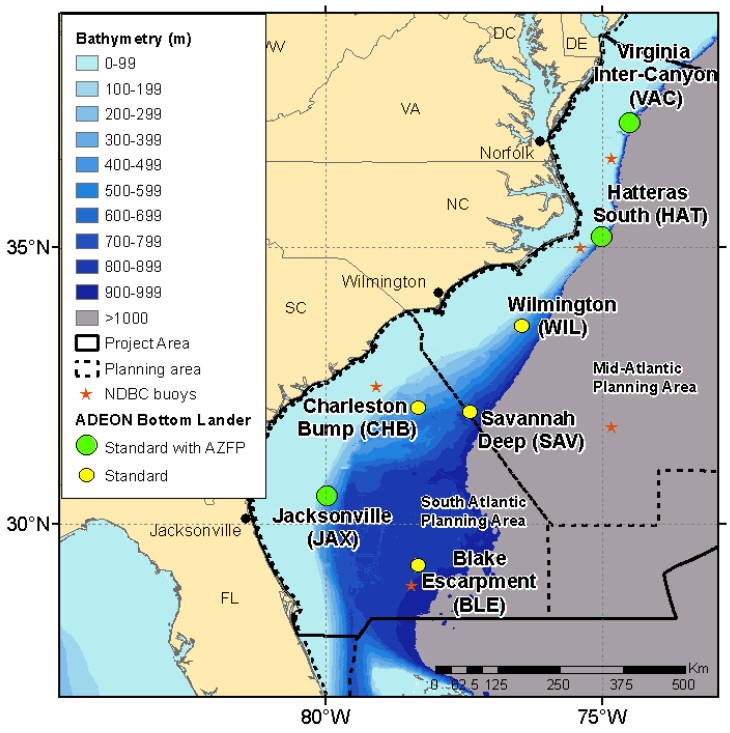

Figure 3. ADEON lander locations along the U.S. east coast OCS. Three shallow locations (green dots) will be equipped with active Acoustic Zooplankton Fish Profilers (AZFPs) in addition to passive acoustic and physicochemical sensors. The deeper (yellow dot) locations have only passive acoustic and physiochemical sensors.

WORK COMPLETED

Phase I

The primary objectives of the Phase I – Network Design, were selection of the static recording locations (Fig. 3) and finalization of the ADEON sensor suite (Fig. 4). Considerations for site selection included distribution throughout the 100-1000 m waters of the mid-and-south Atlantic planning areas, proximity to other known passive recorders in the region for analysis of the distance that soundscapes remain similar, proximity to National Data Buoy Center (NDBC) buoys that will provide sea surface condition data (which affects ambient noise), and selection of locations near known deep-water coral sites to assess the differences in soundscape between these biologically diverse sites. The final sites were approved by the US Navy, BOEM, and NOAA.

Many of the selected recording locations are within the Gulf Stream. To maximize the quality of acoustic data collected, the effects of water moving over the hydrophones must be minimized, which is most easily achieved by locating the sensors at the seabed. Acoustic propagation modeling confirmed that the seabed is an acceptable location for recording surface activity since the sound speed profile is downward refracting for most of the year. A novel free-fall lander was designed that integrated the sensors at the seabed and simplified deployments (Figure 4). Three trial deployments of the lander were performed to optimize the design, test the ease of deployment, retrieval, and acoustic data quality.

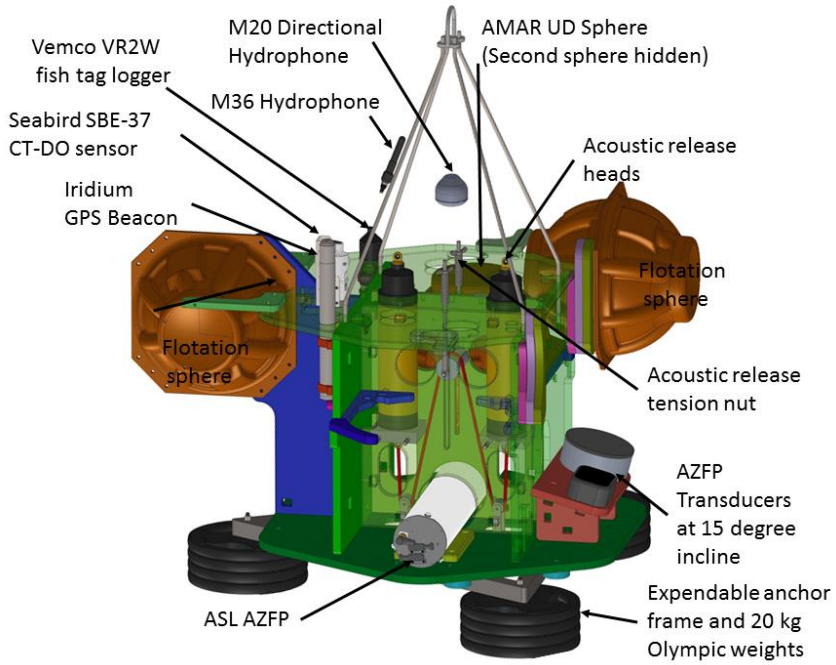

Figure 4. ADEON lander system diagram.

Phase II

Most of the Phase II activities this year were in preparation for the upcoming first equipment deployment cruise (taking place Nov 19 – Dec 15, 2017 on the RV Armstrong). In addition to procuring equipment and supplies necessary for completing the cruise objectives, the primary task was the design of the cruise plan and associated sampling operations. The other major accomplishment was the completion of the draft Calibration and Deployment Good Practice Guide detailing the procedures that we will be using during the cruise to deploy and collect the various data sets. Successful field tests have occurred for the bottom lander design, and other lander instruments (i.e. AZFP active acoustic sensors) have been calibrated in the lab prior to deployment. Discussions with the Data Processing and Data Management teams have determined the procedures for delivering data products collected during the cruise to the appropriate team members for archiving and analysis purposes. Cruise personnel have been (or will be) trained in proper procedures for Marine Mammal Observations following the Marine Species Awareness Training video protocol.

Phase III

With the ADEON deployment cruise scheduled for Fall 2017, the primary effort for Phase III (Data Analysis) this year was to develop a catalogue of data, which will be collected both at-sea and via remote-sensing, and to prepare for data analysis and archiving. Our remote sensing team selected a robust set of satellite measurements to use as covariates in the ecosystem and soundscape data analysis. They include automated-identification-system ship tracks, hydrodynamic forecasts of the ocean volume (temperature/salinity), sea surface temperature, chlorophyll-a concentration, net primary productivity, mixed layer depth, wind speed and direction as well as surface current speed and direction. An automated download and archiving of the remote sensing data was established.

Phase IV

In FY2017, Phase IV completed several key elements of the Visualization component, including: 1) surveying existing rapid, interactive web-based visualization tools that will allow data to be explored by researchers both within and outside the ADEON project and, 2) creating methods to display the long time series of ADEON data using sample datasets provided by JASCO. Part of the work begun by the Visualization component in 2017 involved the investigation of alternative methods for spectrogram compression, which will allow users to better find information present in data that spans large ranges in frequency. A PhD student, Brian Powell, who will be involved in the development of web-based tools and the integration of data into these tools, began his work at UNH in September 2017.

The Soundscape Modeling component of Phase IV performed setup and testing of the Peregrine parabolic equation model for the ADEON region of interest. Studies intended to help in the development of strategies for dealing with the large spatial and temporal scales involved in modeling soundscapes over the study area were initiated. The Ecological Modeling component of Phase IV worked in conjunction with other phases to help ensure that relevant

data is collected and processed for ecosystem modeling. A post-doctoral researcher, Gemma Carroll, will be working on ecological modeling as part of this Phase IV component was hired in September 2017.

Standardization

Drafts of four ADEON standardization documents were completed and are available for comment on the ADEON website: 1) Soundscape and Modeling Metadata Standard, 2) Equipment Specification, 3) Calibration and Deployment Good Practice Guide, and 4) Data Processing Standard.

Data Management

An Intergroup Access Framework has been established for the ADEON project (Fig. 5). The project's data server is housed within the Lenharth Data Center, a secure, climate controlled facility located on the UNH campus. The data served includes raw data from the ADEON network and products created through data analysis. An additional collaboration venue for the team has been set up via "Box"; a secure, cloud-based, collaboration and storage application. Team members can work on documents (e.g. word, excel) individually or simultaneously as a team. Both venues can be accessed anytime from anywhere.

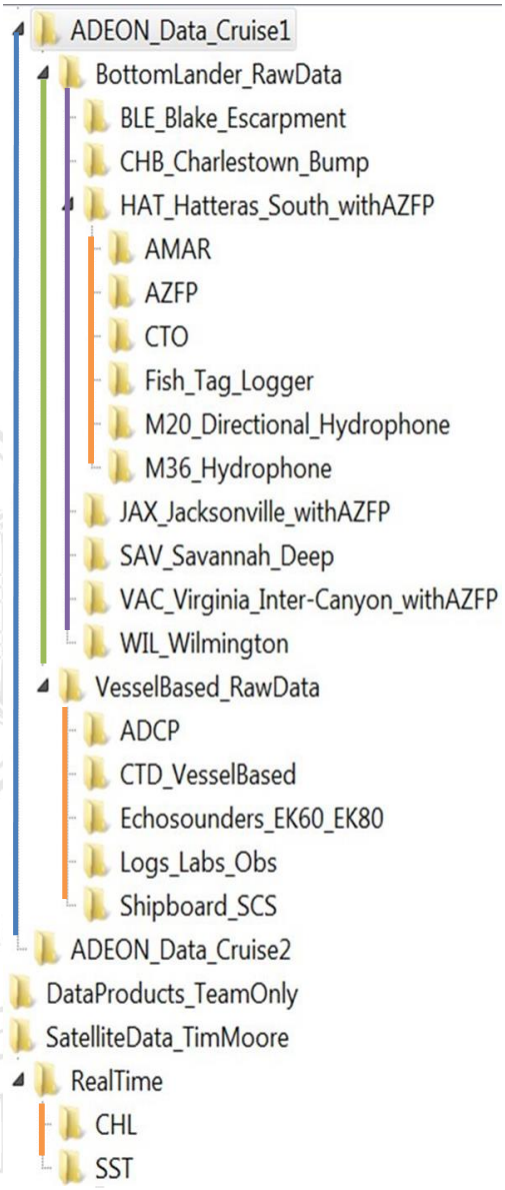

Figure 5. Data Collection and Storage Schema on the ADEON server. Data is stored and searchable by cruise, location, and collection instrument name.

ADEON's soundscape data collection employs two methods; active (ping/echo) and passive (hydrophone) listening of the underwater soundscape. ADEON is collaborating with the NOAA National Centers for Environmental Information (NCEI) on *Archival Processes* for this data. The ADEON data server is configured to facilitate NCEI's raw data packaging software for Passive Acoustic data (*Passive Packer*) and Water Column Sonar or Active Acoustics data (*WCSD Packager*). This software also facilitates the generation of ISO 19-115 compliant metadata that is packaged with the archived raw data.

RESULTS

As a first test of the soundscape modeling framework, the sound field was computed for a large set of shipping, wind, and biologic sound source positions in the Atlantic OCS. The acoustic field for over 3,300 source positions was computed with each source position requiring approximately 1,500 parabolic approximation (PE) acoustic propagation runs. An example of the modeled soundscape at 20 m depth for a 50 Hz signal produced by the surface wind field over the Atlantic OCS at one instant in time is shown in Fig. 6.

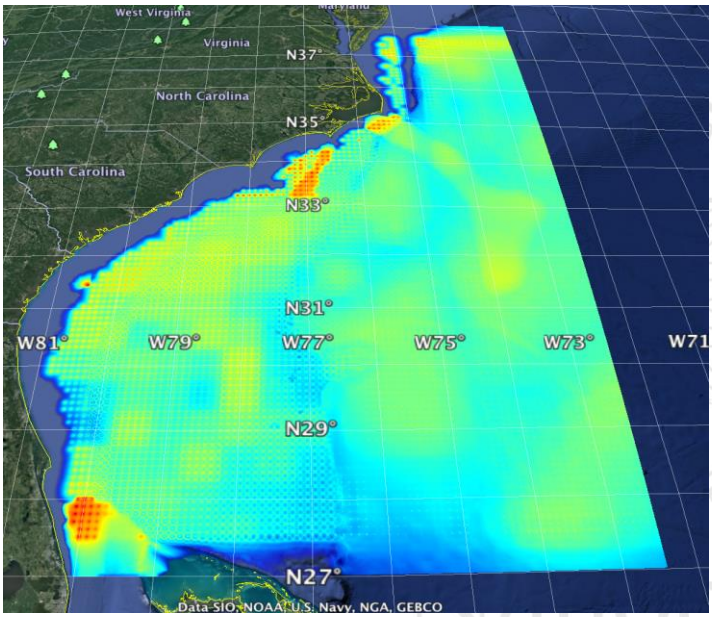

Figure 6. Modeled surface wind component of the soundscape at 20 m depth and 50 Hz across the ADEON region.

The ADEON project team came to agreement and has adopted the terminology of ISO 18405 Underwater Acoustics – Terminology for use in all ADEON documents to facilitate technical discussion, processing, and reporting of soundscape measurements that will be consistent across an international community. The ADEON team has also come to agreement on the standard frequency bands from IEC 61260-1:2014 Electroacoustics - Octave-band and fractional-octave-band filters - Part 1: Specifications to be used in ADEON measurements, processing, and reporting to produce results comparable with other regions.

DELIVERABLES/DATA TRANSMISSIONS

1. **National Security**

BOEM's mission related to offshore energy development contributes to the national security by managing and providing access to energy resources. The ADEON program is providing new data to inform potential offshore energy development in an environmentally responsible manner.

The United States Navy (USN), in order to support our national interests and maintain freedom of navigation of the seas, must be able to operate in all international waters. This places a requirement on the fleet of detecting and localizing possible hostile submarines. The detection of quiet submarines is critically dependent upon the local ocean ambient noise field (soundscape). An understanding of the temporal-spatial characteristics of the noise field is critical to planning and executing naval operations. The ADEON project will collect long-term measurements in the Atlantic Outer Continental Shelf (OCS), helping the USN understand and characterize sonar system performance in this important region. In addition, soundscape analysis by ADEON researchers is expected to improve our understanding of the sources and structure of ocean noise.

2. **Economic Development (e.g., new product lines, businesses, practices, increased efficiency, new manufacturing techniques)**
   BOEM's mission related to offshore energy development also contributes to national economic development. The ADEON program is providing information to allow for development in an environmentally responsible manner. Information will also inform sustainable fisheries management in the region with fisheries playing an important economic role.

3. **Quality of Life (e.g., public health, ecosystem health, coastal resource management)**
   Data collected by ADEON, and made available to the public, will provide a regional set of baseline measurements critical to 1) informing decisions about future ocean use of the Atlantic OCS, and 2) for comparison in assessing environmental conditions over time.

4. **Science Education and Communication**
   ADEON team members communicated the technical aspects, network design, and standards developments at the following national and international conferences:
   Miksis-Olds, JL, Ridgeway, T (2017). ADEON: Atlantic Deepwater Ecosystem Observatory Network – Data Management. NCEI Passive Acoustic Data Workshop. September 14-15, 2017. Boulder, CO.
   Miksis-Olds, JL, Ainslie, MA, Martin, B, Warren, J, Heaney, K, Lyons, AP (2017). Atlantic Deepwater Ecosystem Observatory Network: An integrated system. OCEANOISE 2017. May 8-12, 2017. Vilanova, Spain.
   Heaney, KD, Ainslie MA (2017). High fidelity soundscape modeling of the Atlantic Outer Continental Shelf (OCS). OCEANOISE 2017. May 8-12, 2017. Vilanova, Spain.

Ainslie, MA (2016). Introduction of Atlantic Deepwater Ecosystem Observatory Network (ADEON) project. Meeting of the EU Technical Group on Underwater Noise (EU TG-NOISE), October 19-20, 2016. Ministry for the Sea, Lisbon, Portugal.

Miksis-Olds, JL (2016). ADEON: Atlantic Deepwater Ecosystem Observatory Network – an integrated system. Center for Coastal and Ocean Engineering/ NOAA-UNH Joint Hydrographic Center Seminar Series. September 30, 2016. Durham, NH.

IMPACTS AND APPLICATIONS

1. **National Security**
   Information collected by the ADEON program will ensure that appropriate mitigations are in place for potential offshore energy development activities, which serve the national security interest.

2. **Economic Development (e.g., new product lines, businesses, practices, increased efficiency, new manufacturing techniques)**
   Information collected by the ADEON program will ensure that appropriate mitigations are in place for offshore energy development activities, which also contribute to national economic development. Mitigations for sustainable fisheries may also be informed by the program, with Atlantic fisheries having important economic value.

   Appropriate standardization leads to increased cost-effectiveness both by reducing costs of duplication and by increasing effectiveness through improved compatibility (e.g., through use of international standard frequency bands) of ocean sound measurements across U.S. projects and programs. Further, harmonization with the European Union's Technical Subgroup (TG) Noise and ISO increases the likelihood that standards proposed by ADEON will be adopted internationally, thus decreasing the risk of having to change later.

3. **Quality of Life (e.g., public health, ecosystem health, coastal resource management)**
   The modeling and visualization tools developed as part of ADEON's Phase IV will certainly be useful for monitoring and predicting noise fields in (almost) real time which will be of interest to regulators and researchers. The ecological modeling tools will be useful for understanding the relationship of the ecology to the present soundscape conditions and hopefully offer a capability for predicting future ecological effects.

4. **Science Education and Communication**
   Each ADEON research cruise will include 4 or more graduate students, expanding their at-sea abilities and skills for future workforce development.

   A PhD student and postdoctoral student as part of Phase IV are being supported on this effort which is a contribution to workforce development in this technical area.

The web-based visualization tools developed in Phase IV will prove useful for quickly communicating information related specifically to data collected and modeled as part of ADEON and will also serve goal of informing the public on soundscapes.

RELATED PROJECTS

ADEON is collaborating with NCEI–Boulder (facilitators Carrie Wall Bell and Charles Anderson of the Cooperative Institute for Research in Environmental Sciences) for archiving the raw data from this project. NCEI is providing data packaging software (jointly developed by NCEI and the National Marine Fisheries Service) that will package our raw data for archiving at the NCEI. The NCEI web page provides a searchable map of raw data collected at specific sites within the world's oceans. All of the ADEON raw data will be archived and served out to the public here. ADEON and the data managers at NCEI will work in collaboration to ensure QA/QC of the data transfer during the archival process. In addition, we will work in collaboration to ensure compliance to the ISO 19-115 metadata standards.
https://www.ngdc.noaa.gov/

ADEON and the NOAA Noise Recording Stations (NRS) program have agreed to use common frequency bands and averaging times as specified in the ADEON DRAFT Soundscape and Modeling Metadata Standard.
https://www.nefsc.noaa.gov/psb/acoustics/psbAcousticsNRS.html

The EU Marine Strategy Framework Directive (MSFD) requires EU Member States to achieve or maintain Good Environmental Status[1], requiring in turn that "Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment" in Member States' coastal waters. An MFSD requirement for regional coordination leads to the need for multiple regionally organized sound monitoring projects (e.g., BIAS[2]). Rather than entering a discussion with each regional project separately, ADEON's approach is to liaise with TG Noise. Dr. Ainslie is a member of TG Noise and in October 2016 introduced the ADEON project to TG Noise. Dr. Ainslie has further requested feedback from TG Noise on the ADEON DRAFT Soundscape and Modeling Metadata Standard.
http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-11/index_en.htm

The E&P Sound and Marine Life Joint Industry Programme (JIP) runs a project dedicated to the standardization of underwater sound processing and reporting. A second phase of this project, with its focus in the measurement of underwater sound and the characterization of underwater sound sources is presently the subject of discussion. The terminology for this JIP project is based on ISO 18405, making the JIP standards of interest to ADEON. Permission has been

[1] http://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm
[2] https://biasproject.wordpress.com/

requested and obtained to use draft JIP terminology, data processing and reporting standards in the ADEON DRAFT Data Processing Standard. http://www.soundandmarinelife.org/

ADEON is collaborating with another federally-funded research NOPP program (DEEP SEARCH, PI: Erik Cordes) investigating deep sea and continental shelfbreak habitats. Personnel from DEEP SEARCH and ADEON will be participating in the other project's cruises to assist with activities ranging from processing of deep sea biological specimens, identifying deep sea mesopelagic fish layers, and identification of critical habitat regions along the continental shelfbreak slope.

Thomas Butkiewicz is a Co-PI on NOAA Grant No: NA15NOS4000200 which funds the Center for Coastal and Ocean Mapping at the University of New Hampshire. Within the overall project, Tom is tasked with those that involve improvement in the visualization, presentation, and display of hydrographic and ocean and coastal mapping data, including four-dimensional high resolution visualization. http://ccom.unh.edu/vislab/

Dr. Heaney (OASIS), is involved with a US Navy (funded by NAVSEA) project tasked with predicting the spatial and temporal structure of the ocean soundscape (ambient noise, in Navy terms). The ADEON project will provide long term measurements across the United States Atlantic Outer Continental Shelf which will help characterize the temporal (and frequency content) variability of the ocean noise field.

PUBLICATIONS
N/A

PATENTS
N/A

WORK PLAN
The major endeavors of the upcoming year are the first and second ADEON cruises. The first cruise will be the initial deployment of the 7 bottom landers from mid-November to mid-December 2017 aboard the R/V Armstrong. The second cruise will recover, refurbish, and redeploy the 7 bottom landers in June 2018 onboard the R/V Endeavor. All ADEON cruises will also conduct systematic vessel transects in the region of each lander to capture marine mammal presence, echosounder surveys, and standard CTD casts.

Final document delivery of three of the five ADEON Standardization products will occur over the next year: 1) Soundscape Modeling and Metadata Standard, 2) ADEON Hardware Specification, and 3) ADEON Calibration and Deployment Good Practices Guide. By the conclusion of the next contracted year, the prototype visualizations for historical and/or limited ADEON data will be available.

OUTREACH MATERIALS

Three videos (to be downloaded from Box link):

1) Soundscape modeling results integrating wind data over the ADEON region. (wind_ambient_noise.mp4)
   Caption: In order to compute the wind component of the ocean soundscape, the propagation loss (PL) from a large set of positions (used as sources in the model) was computed to a very dense set of field positions covering the Atlantic OCS. The PL was computed along all required radials (to satisfy the output grid spacing) out to 400km. This was the maximum range considered to effect the wind noise level. The European Commission Medium Weather Forecast (ECMWF) fields for the predicted wind at 10m was used as the local source term for the surface source level. The wind surface source level was combined with all of the PL runs and the power for each patch of wind was added for each receiver position. This leads to the predicted level of wind induced ocean noise. The observable features are the sensitivity to local bathymetry and geo-acoustics as well as the time-variability as storms pass over the ocean.

2) ADEON bottom lander prototype acoustic release test in evaluation tank. (ADEON release.mov)
   Caption: Testing a release mechanism and stability of the ADEON lander prototype at the Sea Survival Systems training tank in Dartmouth, NS, Canada in March 2017.

3) ADEON bottom lander prototype deployment in waters of Halifax, Canada. (adeonDeployment4April2017.mov)
   Caption: In this movie clip the first prototype of the ADEON lander is lowered to the seabed in 50 m of water outside of Halifax NS, Canada on 4 April 2017. Two types of omni-directional hydrophone flow-shields were evaluated (clear polycarbonate sleeve and yellow spandex cover – which did not remain attached during the deployment). The lander remained in place for 4 hours and was then retrieved. Improved versions were deployed by free-fall in June 2017 and July 2017.

ADEON Program blog highlighting the first ADEON cruise from mid-November to mid-December 2017 can be found on the ADEON website.