Measuring changes in ambient noise levels from the installation and operation of a surge wave energy converter in the coastal ocean

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LONG-TERM GOALS

Ecosystem impacts resulting from elevated underwater noise levels generated by anthropogenic activities in the coastal ocean are poorly understood. Ambient noise levels are an important habitat component for marine mammals and fish that use sound for essential functions such as communication, navigation, and foraging. Questions surrounding the amplitude and frequency distribution of noise emissions from renewable wave energy conversion (WEC) projects during their construction and operation present concerns for long-term consequences in marine habitats. Goals of this project are to provide new information and a framework for measuring and assessing the potential impacts of acoustic emissions associated with shallow water WEC projects in a high energy, nearshore environment. This research will assist future marine renewable energy projects in permitting and licensing efforts providing background noise levels where knowledge gaps exist as well as measured noise levels from an operational surgeWEC device. Furthermore, this project provides guidance for techniques and approaches for making sound level measurements surrounding WEC projects in challenging shallow water marine environments.

OBJECTIVES

Scientific and technological objectives of the project include: 1) quantitative measurements of broadband (10Hz – 13 kHz) sound pressure levels before and during the installation and operation of a surge type wave energy conversion (WEC) device in the shallow coastal waters off the north Oregon coast; 2) time/frequency characterizations of noise emissions surrounding the project through a variety of environmental conditions; 3) evaluation of ambient noise levels measured during WEC construction and operation within the framework of baseline recordings taken in the area; 4) quantitative comparisons of WEC generated noise emissions with natural and anthropogenic acoustic sources found near the project site.

APPROACH AND WORK PLAN

1) Approach and Methods

Passive acoustic data will be collected using two approaches in order to address temporal and spatial variability in the surge WEC noise emissions.

1) Bottom-mounted hydrophone lander frames

Two, passive acoustic seafloor hydrophone mooring platforms will be deployed at the project site in 10 m and 15 m water depths separated by a cross-shore distance of roughly 500 m, and 300 m and 800 m from the surgeWEC™ device from Resolute Marine Energy, Inc. once it is deployed. Each hydrophone lander frame will be outfitted with 2 identical hydrophone sensors horizontally separated by a distance of 1 m, enabling coherence measurements to assist in identify periods and frequencies contaminated with wave induced flow noise. The semi-trawl protected lander frames consist of hollow aluminum tubing weighted with lead ballast and an estimated circular seafloor footprint of roughly 3 square meters ($r \approx 1$ m) and a vertical extent of nearly 2 m. In addition, an acoustic release recovery system will allow the entire instrument package and frame to remain fully submerged with no surface expression during the deployment period. During recovery operations, an acoustic command will initiate the release of a messenger float to the surface, enabling the lander frame and all components to be lifted and recovered from the seafloor. The 10 m depth contour is chosen as a shoreward deployment limit to reduce potential damage from breaking wave action and to avoid data contamination and burial rates encountered inside of the estimated sediment transport closure depth of 10-12 m found along the Pacific Northwest coast.

2) Acoustic drifting underwater hydrophone (ADUH)

A series of short-term “snap shot” type acoustic recordings will be carried out using an autonomous drifting underwater hydrophone (ADUH) system deployed as near to the device as possible, (conditions permitting) to provide range dependent characterizations and ambient noise level measurements of acoustic energy radiated during project activities. Similar to the fixed hydrophones, ADUH based acoustic recordings will be collected before and during the surgeWEC™ demonstration project. The ADUH system consists of a 3 m long spar buoy with GPS logger, shock cord, static line, damping disc and a hydrophone instrument suspended 7 m below the sea surface. A free drifting approach will be used to avoid “pseudo-sound” contamination of the recordings resulting from non-propagating acoustic fluctuations at the hydrophone typical of cabled systems tethered to a floating vessel. The drifter is designed to decouple surface wave motion from the hydrophone and has limited surface area above the waterline to reduce “sail” effects that cause the hydrophone system to move faster through the water than the mean current. This design therefore minimizes data contamination from flow noise generated by wind induced lateral movement of the hydrophone and/or vertical motion resulting from surface waves. The ADUH will be deployed ~ 500 m seaward of the MHK device, moving shoreward with wave motions and will eventually be recovered as near to the surgeWEC™ paddles as possible (~ 50-100 m). In the case that the drift is too slow or currents unpredictable to “aim” the ADUH system toward the WEC from 500 m, it will be recovered and redeployed allowing for additional shorter drifts and more near field measurements prior to recovery (50-100 m distance from the WEC).

2) Key personnel for the project include:

- Joe Haxel – Cooperative Institute for Marine Resources Studies Oregon State University – Principle Investigator Acoustics Program Coordination of ship logistics, deployment/recovery operations, drifting hydrophone measurements, data analysis and reporting
- Haru Matsumoto - Cooperative Institute for Marine Resources Studies Oregon State University – Chief Engineer Acoustics Program
  Build and test hydrophone instrumentation and data acquisition systems

3) Work Plans for upcoming year

WEC installation/ construction acoustic measurements, (2017)

Data analysis of background levels recorded in 2016 will continue in 2017, providing robust estimates of noise levels in a variety of environmental conditions and nearby vessel traffic activity.

Dependent upon the RME, Inc.'s schedule for deployment of the SurgeWEC™ device(s) at Camp Rilea in 2017, we will deploy the seafloor landers using the methodology described previously and record acoustic data during the entirety of the installation activities as RME prepares the site and executes the deployment of their device(s). Additionally, we will coordinate with RME to deploy the ADUH free drifting hydrophone during ship and amphibious based operations of the surgeWEC™ installation.

Seafloor hydrophone lander deployments will occur over 6-8 week time periods during periods of SurgeWEC™ testing and operations. Upon recovery, the hydrophone data will be returned to Newport, OR and backed up on data servers at CIMRS-OSU and NOAA/PMEL Acoustics Program facilities. The data will be screened to insure systems are operating as designed. Hydrophone systems will be checked and then outfitted for the next deployment.

Depending on weather, ADUH drifting hydrophone recordings will occur after ship based seafloor lander operations and therefore will follow the same data acquisition schedule as deployment and recovery of the lander units.

WORK COMPLETED

In a paragraph, please describe the tasks or technical accomplishments completed.

Permitting and licensing application of this acoustic study was done with U.S. Army Corps of Engineers, Clatsop County, and the U.S. Coast Guard with Oregon Department of State Lands leading the regulatory process. The hydrophone lander systems were designed, fabricated, tested and built in January-March 2016 including a short 1 day test deployment off Newport, OR. At the Camp Rilea project site, pre-WEC acoustic baseline recordings from fixed seafloor lander platforms and a mobile drifting platform (ADUH) were carried out in a campaign style for the scheduled spring, summer, and fall seasons totaling 84 days of continuous passive acoustic measurements at 32kHz sample rate. The landers were deployed at target depths (10m/13m) with positions based on the planned location of the SurgeWEC™ installation. Additionally, drifting hydrophone acoustic surveys were carried out on days during the months of July, August and September.

RESULTS

As concisely as possible, please describe any meaningful scientific and/or technical results achieved during FY15, making significance clear. This should be a short summary of significant results and conclusions. If including figures/tables, please include a caption in the report text and not embedded within the graphic. This is necessary to meet accessibility requirements.

A significant gap in knowledge exists for measured noise levels in Oregon's high-energy, shallow coastal water environment. Measurements reported here, represent the some of the first recordings specific to the Oregon coast at these shallow depths. Acoustic recordings using the mobile ADUH platform were collected in environmental conditions with significant wave heights ranging from 0.7-1.4 m, dominant periods 10-17 sec, and wind speeds 1-2 m/sec. Analysis reveals surf generated noise from nearby breaking waves in the surf zone is a dominant sound source in frequencies ranging from ~ 1kHz to 9 kHz. Meanwhile, flow noise associated with wave motions appears to influence low frequency noise levels (f < 50 Hz) throughout the drifting recordings. During particular periods discrete spectral peaks are observed in frequencies between 100 Hz - 1 kHz are observed as continuous bands in spectrogram display and identified as vessel noise. Spatial distributions of root mean square sound pressure levels (SPL_{rms}) averaged over 30 second periods and high pass filtered with a corner frequency f_c = 50 Hz to remove the influence of flow noise show variability associated with vessel traffic (higher noise periods) (Fig. 1). The drift velocity dependence on wave and wind driven alongshore current is readily observed in the distance covered by the drifter despite nearly equal drifting periods for each deployment. Measurements reveal a range of expected noise levels based on calm environmental conditions and light to medium vessel traffic experienced during the drifting recordings.

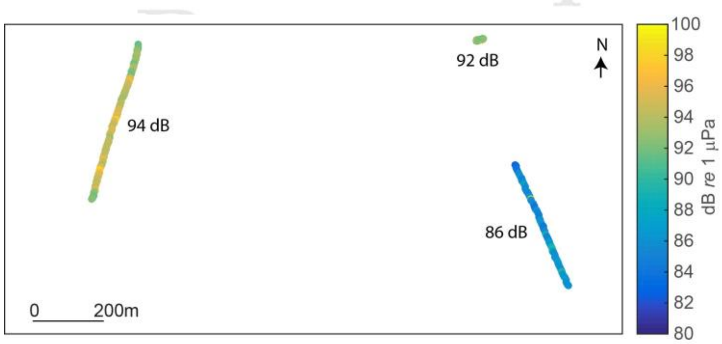

Figure 1. The spatial distribution of drifter SPL_{rms} measurements within the project site calculated from 30 second data windows and high pass filtered at 50 Hz to avoid low frequency flow noise contamination. Median noise levels adjacent to each drift represent typical acoustic conditions for that time period.

Analysis of pre-WEC installation, hydrophone lander recordings is ongoing and results will be used to characterize "typical" sound levels associated with a range of environmental conditions and vessel traffic. Preliminary results from long-term spectral averages of 1-minute data windows (Fig. 2) illuminate the time dependent variability in broadband noise levels up to 13 kHz. Periods of increased energy levels are associated with elevated wave heights and sounds generated by incident wave energy dissipation and wave breaking in the nearby surf zone, the dominant sound source in the area. Percentile distributions of background spectral levels averaged over 1 minute periods at 1 Hz frequency resolution will provide a robust, quantitative characterization of sound levels recorded during the spring, summer and fall seasons in the high energy nearshore environment of the Oregon coast. These results will provide significant, new information that can be used to inform coastal managers and regulatory agencies about the range of expected noise levels and affected frequencies from future marine renewable energy projects.

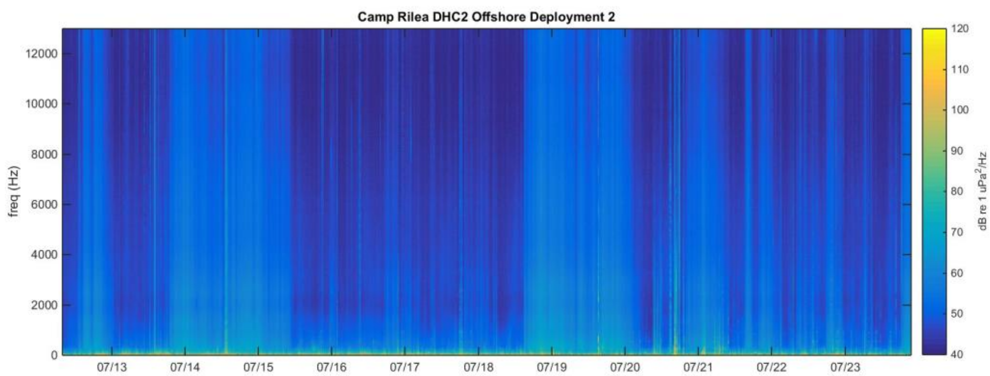

Figure 9 A long-term spectrogram calculated from 1-minute data windows from a portion of the second deployment of hydrophone landers showing the time dependent, broadband noise level variability associated with changes in incident wave energy conditions.

IMPACT AND APPLICATIONS (*Please note N/A for sections not applicable*)
Please describe the potential future impact and application of the effort with regard to the following four factors.

1. **National Security**
   Results from this study will assist future marine renewable energy testing and development projects in similar environments by providing valuable information relevant to permit and licensing that fills existing knowledge gaps. In turn, marine renewable energy projects will become easier to pass through the environmental regulatory framework, furthering the MHK energy industry and easing the U.S. reliance on foreign oil.

2. **Economic Development**
   This study will help to alleviate uncertainties associated with environmental concerns surrounding wave energy converters in the coastal ocean. These concerns have created significant financial burden in the regulatory process for WEC device developers. Results here will assist regulatory agencies and WEC developers in permitting and licensing reducing project costs overall and assisting the economic development of the WEC industry.

3. **Quality of Life**
   Results from this project will be used to help inform coastal resource managers and regulatory agencies on changes in underwater ambient noise levels that can be associated with WEC installation and operation activities in the coastal zone. This study provides a framework for assessing potential changes in ecosystem health related to noise level variability.

4. **Science Education and Communication**
   This project includes an outreach component with local students at Waldport High School. As part of a Career and Technical Education program, students fabricated the lander frames from aluminum stock and participated in a number of the deployment cruises. These students are now actively involved in data analysis of the acoustic time series identifying periods of marine mammal vocalizations, ship noise and weather generated signals. Additionally, all of the lander deployment and recovery operations are performed from the *M/V Forerunner*, a Clatsop Community College Marine and Environmental Research Training Station vessel with maritime sciences students as crew. This project has provided students ranging from the high school level through community college opportunities to engage in oceanographic research and technology development.

TRANSMISSIONS *(Please note N/A in sections that are not applicable)*
Please describe how the results (hardware, software, knowledge) are being incorporated into other work or programs or otherwise carried further. Please describe any transmissions directly related to any of the following four factors.

1. **National Security**
   N/A

2. **Economic Development**
   N/A

3. **Quality of Life**
   The drifting hydrophone hardware and analysis techniques developed for this project are being implemented on a larger spatial scale for a gray whale noise exposure study

on the central and southern Oregon coast. The ADUH drifter has been used extensively to record the spatial distribution of ambient noise levels surrounding critical marine habitat for seasonally resident and migrating gray whales along the Oregon coast. These recordings will be used to inform future long term hydrophone mooring installations in Oregon's marine reserves.

4. **Science Education and Communication**
   Acoustic recordings from this study have been shared with Oregon Sea Grant to include in public presentations focused toward marine underwater acoustic phenomena.

RELATED PROJECTS

The Northwest National Renewable Energy Center's (NNRMEC) Pacific Marine Energy Center facilities offshore of Newport, Oregon are aimed at providing fully supported testing facilities for WEC developers. Technologies developed for this project have roots in acoustic technologies and applications from previous work at NNMREC. As NNMREC collaborators since 2009, Haxel and Matsumoto have developed acoustic expertise and capabilities that have benefited this project.
http://nnmrec.oregonstate.edu/

OUTREACH MATERIALS ***(Delete this section if not applicable)***

Waldport High School (WHS) senior Etosha Golden participating in a hydrophone lander deployment cruise off the Oregon coast. Etosha led the WHS component of the lander frame fabrication effort as part of her senior project. Etosha presented a poster on the building and design of the lander units at the Marine Technology Society Oregon Chapter Summit October 11-12, 2016. She is now an undergraduate student in Engineering at Oregon State University.