

STUDY TITLE: Propagation Characteristics of High-Frequency Sounds Emitted During High-Resolution Geophysical Surveys: Acoustic Modeling Effort

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ABSTRACT: Marine geophysical data is critical for industry and BOEM to make informed leasing decisions. High-frequency marine acoustic sources are commonly used to acquire this data for infrastructure siting, geological or environmental characterization, and shallow hazard or archaeological cultural surveys. The acoustic sources currently in use include boomers; sparkers; subbottom (chirp or other) profilers; side-scan sonar; and single, swath, and multi-beam bathymetric fathometers. This report is the third of related reports designed to characterize and predict the sound fields of these sources in shallow water. The first report, BOEM 2016-044, detailed the source measurement of 17 sources by the Naval Undersea Warfare Center, Newport, Rhode Island, at their facilities and in controlled environments. The second report, BOEM 2018-052, detailed the at-sea measurement of those same sources (plus several hull-mounted sonars) in the shallow water (10-, 30-, and 100-m deep) off Virginia and Maryland. This report recommends an acoustic modeling approach for sources in other shallow water areas and conditions.

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APPLICABLE PLANNING AREA(S): U.S. Mid-Atlantic Coast Planning area out to 100-m water depth.

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COMPLETION DATE OF REPORT:

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KEY WORDS: High-Resolution Geophysical survey systems, HRG sound sources, sound exposure level, sound pressure level, SEL, SPL, rms, received level, boomer, sparker, airgun, chirp, multibeam, echosounder, underwater noise, side-scan sonar, subbottom profiling, seafloor mapping, hydrographic survey, propagation.

BACKGROUND: Geophysical surveys are integral to many marine activities that support the marine energy sector (e.g., oil and gas, renewable) and infrastructure (e.g., ports, cabling), restoration, environmental characterization and monitoring, identification of hazards, and detection of archaeological resources. Given the scientific uncertainty regarding potential acoustic impacts on marine life, many regulatory requirements include precautionary mitigation strategies to lower the acoustic energy of geophysical surveys, even for surveys of a short duration and limited geographic extent.

Contributing to the challenges of understanding shallow-water propagation are the limitations in the amount and quality of in-field or laboratory data regarding acoustic propagation characteristics (e.g., pulse structure, beam directionality, transmission loss, power spectra, and frequency spectra) from air gun and high-resolution geophysical (HRG) sources, despite their wide use by industry. The propagation characteristics are especially poorly understood in shallow to intermediate waters (e.g., 10 to <100 m), where propagation and transmission loss are affected by many factors (e.g., bathymetric interaction, sediment composition, shallow-water processes).

OBJECTIVES: CSA Ocean Sciences Inc. (CSA) was contracted by BOEM to use the field-measured sound field produced by 17 commonly used HRG sources to model and predict the exposure levels from each source in shallow water depths ranging from 10 to 100 m. The study objective was to provide reliable predicted sound field acoustic levels for the HRG sources to better assess potential acoustic impacts to marine fauna.

The goals of this Phase III modeling effort were to recommend an acoustic modeling approach, to best predict the acoustic sound field produced in shallow water during operation of the sound sources used during HRG surveys, and to compare the adjusted data from Phase II to these models for validation purposes.

DESCRIPTION: Overall, the study was accomplished by a number of steps including reviewing the two previous and related technical reports by Crocker and Fratantonio (2016) and Halvorsen and Heaney (2018); identifying the positional locations of each functional acoustic buoy (for each source) at all five test sites; estimating corrected ranges between sources and functional acoustic buoys; acquiring a best estimate of the measured *in situ* received level (thus generating an adjusted data set); comparing the adjusted measured data results to the simulated results from the most appropriate acoustic propagation model(s) (e.g., Peregrine, ray theory, parabolic equation [PE], normal mode, range-dependent acoustic model [RAM]) for 40 representative HRG sources at the five test sites; determining acoustic propagation model(s), supporting environmental parameter databases, and other model inputs for modeling the HRG source propagations that produce reasonably accurate predictions at the five test sites; recommending the most appropriate propagation model(s) for HRG sources in shallow-water conditions (<100 m); and documenting the analytical methods, results, and acoustic propagation model recommendations in a final report that is understandable by both experts and non-experts.

This approach yielded recommendations for propagation models that best predict HRG output signal propagation in shallow-water settings. Recommendations include the site-specific environmental parameters that influence acoustic propagation. To meet the project objectives, buoy positioning was rectified using Phase II data and compared to those with predictive modeling outputs. After the acoustic buoys were localized, the measured received levels were adjusted.

The results of the model to data comparisons provide a scientifically defensible way forward for environmental agencies and contractors working with HRG sources to confidently predict acoustic propagation for these sources under similar environmental conditions.

SIGNIFICANT CONCLUSIONS: The data documented in this study needs to be carefully interpreted given the layers of complexity involved in the collection, troubleshooting, and modeling phases. This report is intended to be transparent to both the troubleshooting solutions employed in processing *in situ* data and the presence of noise in the data when compared to models. Uncertainty was incorporated into the models as much as possible to reflect realities like environmental conditions constantly changing in the ocean and positions of receivers changing with the current strength. With these uncertainties and troubleshooting methods in mind, the data and modeling reported here apply only to these five sites during summer conditions in calm seas. Extrapolation to other sites in different seasons and under different weather conditions should only be performed in collaboration with an underwater acoustician to incorporate the influence of environmental parameters and how the variety of signals could most likely propagate in said environments.

SIGNIFICANT RESULTS: This study presented the measured data overlayed on modeled percentile predictions and 10logR and 20logR curves. The layering of this information is needed by the user to determine which modeling is most appropriate for a source within the particular environmental parameters.

STUDY PRODUCT(S): Final report, simple script tool for graphic image lookup, user's manual, and calibrated data.