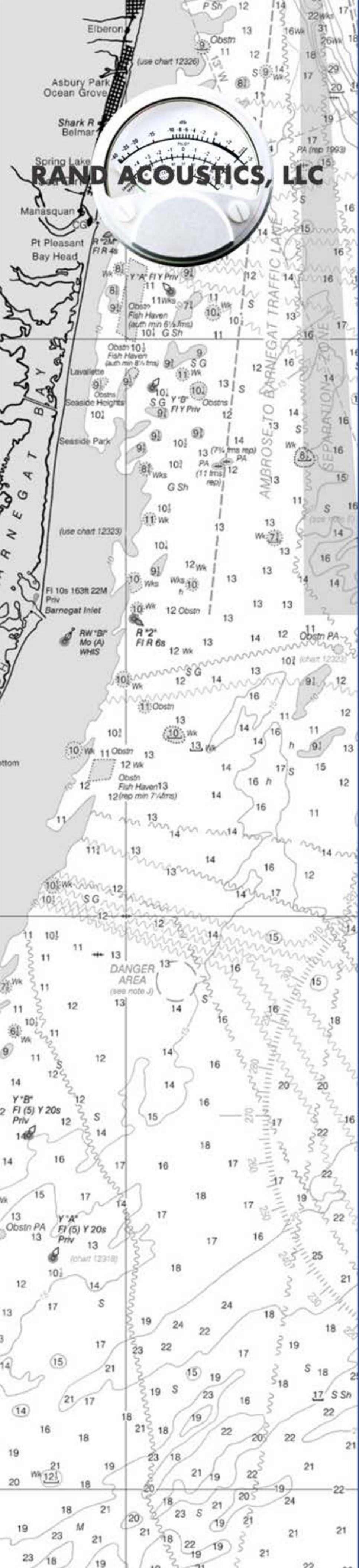

SONAR VESSEL NOISE SURVEY
Technical Report

Survey Date:
May 8, 2023

Report Date:
September 22, 2023

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Abstract

This technical report presents the methodology, analysis and results of a brief independent investigation of underwater noise levels from a sonar survey vessel, conducted offshore New Jersey on May 8, 2023.

Keywords: noise, offshore, survey, vessel, hydrophone, sonar, sparker, threshold, transmission loss, SEL, thermocline

Foreword

This technical report serves as a comprehensive document intended to provide valuable insights, analysis, and information pertaining to geophysical sonar vessel operational noise. It has been prepared to support understanding of vessel and sonar noise emissions for a diverse audience, including professionals, researchers, policymakers, and interested stakeholders. The primary purpose of this report is to facilitate informed decision-making, foster discussion, contribute to the advancement of knowledge in this field, and improve noise control protections for the critically endangered North Atlantic right whale and other ESA-listed mammals and marine species.

Disclaimer

The information contained in this technical report is presented in good faith and based on the best available data and analysis at the time of publication. However, it is important to note that the content is subject to change as new research, developments, or circumstances emerge. The author makes no representations or warranties, either express or implied, regarding the accuracy, completeness, or suitability of the information provided. Users of this report are encouraged to verify the information independently and consider consulting relevant experts when making decisions based on its content.

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EXECUTIVE SUMMARY

Reports of recent whale and dolphin deaths on and near the New York and New Jersey shores, and public concerns of marine noise impacts from offshore wind development activities, prompted an investigation into the sonar noise levels produced by exploratory survey vessels working in ocean areas leased by the Bureau of Ocean Energy Management (BOEM). This technical report presents the methodology, analysis and results of a brief independent investigation of underwater noise levels from a sonar survey vessel, conducted offshore New Jersey on May 8, 2023. Underwater acoustic recordings were acquired between 8:09 and 9:40 am, approximately 43 nautical miles (NM) east of Barnegat Light, Long Beach Island, NJ, near a mobile geophysical survey vessel, the Miss Emma McCall (vessel). A "sparker" sub-bottom profiler (SBP) and several mid-frequency (MF) positioning system sonars (USBL) were measured including two impulsive, intermittent USBLs at 19.5 and 20 KHz, and two FM swept-sine USBLs at 21 to 32 KHz. An SBP listed for the vessel operating above 85 KHz was not measured as it was above instrumentation range. Transmission loss (TL) was larger at higher frequencies generally above 3000 Hz due to excess attenuation which is expected for the distances measured and shallow-water acoustic conditions.

Peak sound levels were controlled by the sparker and measured 151.6 dB,peak re 1uPA at 0.5 NM. The sparker source level (SL) was estimated at 224 dB,peak re 1uPa@1m, consistent with the sparker manufacturer's published SL of 2 Bars/m (226 dB,peak re 1uPa). Using NOAA National Marine Fisheries Service (NOAA Fisheries or NMFS) 2020 guidelines based on Crocker and Fratantonio (2016), the sparker RMS level is estimated at 219 dB,rms re 1uPA@1m.

Vessel continuous noise included propulsion and dynamic positioning (DP) thruster noise emissions. Vessel noise was tonal, containing multiple cyclical/rotational tonal noise components from 9.5 Hz to several kilohertz, and was highly audible at 0.5, 1 and 2 NM. Vessel tonal noise was audible and measurable at 4 NM. Vessel continuous noise measured 126.5 dB,rms re 1uPA at 0.5 NM. Total vessel continuous noise with sparker was 128.5 dB,rms re 1uPA at 0.5 NM.

The vessel's Incidental Harassment Application (IHA) was reviewed. The USBLs are impulsive yet were not listed or analyzed in the vessel IHA application. Vessel propulsion and DP thruster noise were also not listed or analyzed in the IHA application. The sparker proxy SL,rms used in the IHA application was cited as 16 dB quieter than expected based on manufacturer published levels harmonized with NMFS guidance for RMS noise levels. The IHA listed a 160 dB,rms Level B Behavioral Harassment threshold of 141 meters for the sparker impulsive noise, whereas the threshold using the NMFS Level B spreadsheet tool for calculating the distance to the Level B threshold with manufacturer data returned a distance of 890 meters.

To meet the NMFS 120 dB,rms behavioral harassment limit for continuous noise, the distance required is approximately 1 nautical mile (1852 meters). However, the vessel was operating with a vessel separation distance of 500 meters for the North American right whale (NARW) and other ESA-listed mammals and 50 or 100 meters for all other marine mammals. The IHA is silent regarding the 120 dB,rms Level B behavioral harassment threshold.

The data acquired during the survey and subsequent review of the IHA application raise concerns of sufficient NOAA review and mitigation distances to protect the critically endangered NARW and other marine species from behavioral harassment and temporary threshold shift (TTS) impacts.

1 Introduction

1.1 Background

Reports of recent whale and dolphin deaths on and near the New York and New Jersey shores, and public concerns of marine noise impacts from offshore wind development activities, prompted an investigation into the sonar noise levels produced by exploratory survey vessels working in ocean areas leased by the Bureau of Ocean Energy Management (BOEM).

In April 2023 the highly mobile exploratory sonar vessel R/V Miss Emma McCall (IMO: 9289659) was identified working off the New Jersey coast within BOEM wind lease area OCS-A 0538. The area is leased to Attentive Energy LLC.

Miss Emma McCall is an offshore tug/supply ship registered and sailing under the U.S. flag (vessel)[1]. It is equipped with 2x CAT 3508TA w/twin disk MG6690-OOSC 3.21 ratio main engines and a CAT 3406, MARPROP 300hp dynamic positioning (DP) bow tunnel thruster. The vessel is understood to have replaced a sister boat (the R/V Brooks McCall) tasked with marine site characterization surveys using high resolution geophysical (HRG) equipment and geotechnical sampling off the coasts of New York and New Jersey in the New York Bight area in the Atlantic Ocean (Attentive IHA Application [2]).

Figure 1. The Miss Emma McCall viewed through binoculars at 0.5 nm distance (May 8, 2023 840 am EDT from investigator boat) while operating approximately 43 nautical miles east of Long Beach Island, New Jersey.

The sonar equipment on board the vessel is generally described in the IHA application as consisting of a multibeam echosounder, side scan sonar, gradiometer, and shallow and deep sub-bottom profiler. A "sparker" is a device that creates an acoustic expansion pulse and possible repetitive or

1 Miss Emma McCall specifications at https://www.tdi-bi.com/wp-content/uploads/2022/03/2021-Miss-Emma-McCall-Flyer_030222.pdf accessed 7/8/23.

2 NOAA.gov https://media.fisheries.noaa.gov/2022-06/AttentiveEnergyNYBight_2022IHA_App_OPR1.pdf.pdf accessed 5/22/23. "To conduct the HRG survey, TOI-Brooks has proposed the use of a purpose-built survey vessel, the R/V Brooks McCall (Figure 1-2) (or equivalent vessel) for the program."

spurious pulses [3]. The IHA application used proxy sparker SL data from Crocker and Fratantonio, 2016 [4], much lower than manufacturer-provided data. A list of the equipment specified in the IHA application is provided in Attachment A of this report. The manufacturer sparker data sheet is included in Attachment B and reviewed in Attachment E.

The IHA application states its requirements to comply with Level B harassment thresholds as follows, "*NMFS has defined the threshold level for Level B harassment at 120 Decibel (dB) Root Mean Square (RMS) referenced to (re) 1 microPascal (μPa) for continuous noise and 160 dB RMS re 1 μPa for impulsive and non-continuous pulsed noise. The Zone of Influence (ZOI) is the area that is ensonified to those levels and constitutes the area in which take of marine mammals could occur.*"

Section 6 of the IHA application reports the marine mammal "take" estimates by species. Therein the application states, "*The only anticipated potential exposures to Level B take for marine mammals is associated with noise and is limited to the use of the Dual Geo-Spark 2000X (400 tip) during HRG surveys*", which utilized the NMFS 160-dB,rms threshold for impulsive sources.

Of concern is that 1) sparker sonar levels listed in the IHA application were much lower than actual, and 2) the IHA application treated the vessel as if it were silent.

As a result it appears the issued IHA permit imposed insufficient noise mitigations. The only protective mitigation imposed by NMFS is covered under the exclusion zones NMFS established, generally defined as 500 meters for the North American right whale (NARW) and other ESA-listed mammals and 50 or 100 meters for all other marine mammals [5].

1.2 Acoustic Terminology

Acoustic waves in water have sound pressure and particle motion components. Mammal hearing is based on sound pressure detection. Sound pressure in water is quantified for level using decibels referenced to 1 microPascal (uPa). Underwater sound pressure levels differ from those in air by 26 dB (the difference in the reference levels of 1 uPA in water versus 20 uPA in air), plus 36 dB (the difference in acoustic impedance between water and air). The differential is roughly 62 dB. For example, a sound pressure level of 160 dB re 1 uPA in water would equate roughly to 98 dB re 20 uPA in air.

Water is compressible like air (although denser) thus longitudinal pressure waves occur in the water fluid medium as they do in air: Particles vibrate in the direction the sound is moving. Sound speed in water is about 1500 m/s, nearly 5 times faster than the sound speed in air (343 m/s). Underwater sound "source level" (SL) is referenced at 1 meter and derived in practice from sound pressure measurements calculated back to 1 meter. Sound pressure level (SPL, dB re 1 uPA) at a distance beyond 1 meter is lower than the SL due to attenuation with distance and is affected by underwater acoustic factors including winter vs summer sound speed gradients and thermocline

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3 Silvano Buogo, Giovanni B. Cannelli; Implosion of an underwater spark-generated bubble and acoustic energy evaluation using the Rayleigh model. J Acoust Soc Am 1 June 2002; 111 (6): 2594–2600. https://doi.org/10.1121/1.1476919, accessed 8/19/23.

4 Crocker, S., Fratantonio, F., Characteristics of Sounds Emitted During High-Resolution Marine Geophysical Surveys, NUWC-NPT Technical Report 12,203 24 March 2016, accessed 8/6/23.

5 Incidental Harassment Authorization, National Marine Fisheries Service, 8/16/2022.

strength. A first-order estimate of SPL using spherical spreading, ignoring absorption in the medium vs frequency, seabed topography and other factors, is:

SPL, dB at r, meters = SL – 20log10(r), dB (spherical)

The drop in sound pressure level with distance using this equation is 20 dB per decade, or 6 dB per doubling of distance. NOAA applies spherical spreading for shallow water conditions. For near-shore conditions, NOAA recommends a "practical spreading" loss model to estimate transmission loss (TL) in the near shore. Using the practical spreading loss model, TL in dB units is defined by,

SPL, dB at r, meters = SL – 15log10(r), dB "practical spreading" (NMFS)

The drop in sound pressure level with distance using this equation is 15 dB per decade or roughly 4.5 dB per doubling of distance.

In a shallow confine, the water surface and sea bottom channel acoustic energy horizontally, with possible cylindrical propagation. Temperature gradients, thermoclines, sea bottom and water surface interactions, shoaling and focusing can lead to deviations from ideal cylindrical spreading. Cylindrical propagation can be estimated ideally using a transmission loss (TL) coefficient α as in αlog10(r) of 10 such as in the equation,

SPL, dB at r, meters = SL – 10log10(r), dB (cylindrical)

The drop in sound pressure level with distance using this equation is 10 dB per decade or roughly 3 dB per doubling of distance.

1.3 Metrics

Underwater sound levels are reported here using peak, peak-to-peak, root-mean-square "RMS" amplitude, and sound exposure level (SEL) metrics to be consistent with NOAA metrics used for regulatory limits of marine sound levels. The relationship of peak, peak-to-peak and RMS is illustrated in Figure 2. SEL is expressed in dB re 1 $\mu Pa^2 s$ as a quantity of exposure over time (the time period must be provided). In the context of this report, NMFS applies cumulative SEL for Level A harassment, e.g. the onset of permanent threshold shift (PTS, hearing loss).

$$SEL = 10 \cdot \log_{10}\left(\frac{1}{T}\sum_{i=1}^{N} p_i^2\right)$$

Where:

- T is the time duration over which the sound levels are integrated (in seconds).
- N is the total number of pressure samples in the given time interval.
- p is the sound pressure value at the i-th sample, usually given in Pascals.

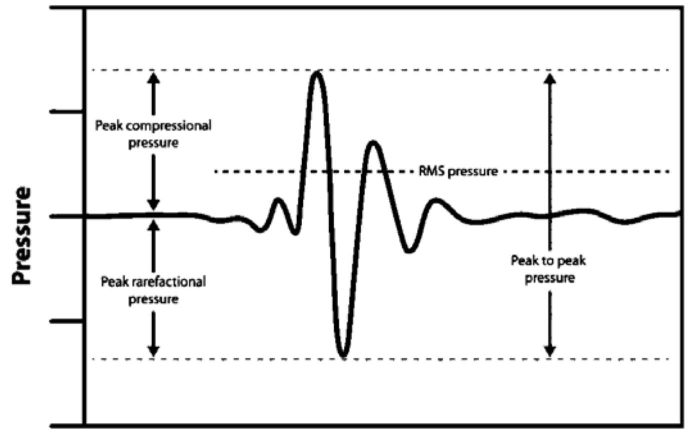

Figure 2. Sound pressure relationship of impulse waveform peak, peak-to-peak, and rms levels.

In Figure 2, the "RMS pressure" is shown as the level integrated over the time period of the pulse, and is always lower than the peak pressure level. The peak sound pressure level is the highest sound pressure measured or "held" by the instrumentation depending on its circuitry. The sound pressure level (defined by ANSI as "rms" pressure) has no restrictions on the RMS integration time period. The integration time period should always be provided with the sound pressure level when it is reported as RMS.

The RMS amplitude value may adequately characterize slow-changing or continuous, non-impulsive noise [6,7]. However, the RMS value of an impulsive sound does not reflect the peak energy in the signal. Peak sound pressure values are preferred over RMS for measuring, characterizing and evaluating the impact of impulse sounds. Depending on the rapidity of the pressure change in impulsive sound, regulation of impulsive sound using RMS values may provide little protection from peak pressures [7].

The disparity between RMS and peak pressures underscores long-standing professional acoustic concerns about the suitability of using RMS levels for protection from impulsive noise sources. The RMS value does not track the impulsivity associated with startle and sudden hearing loss. As Madsen [7] summarized in 2005, "*Current mitigation levels for noise transients impinging on marine mammals are specified by rms pressures. The rms measure critically relies upon choosing the size of averaging window for the squared pressures. Derivation of this window is not standardized, which can lead to 2–12 dB differences in rms sound pressure for the same wave forms. rms pressure does not represent the energy of the noise pulse and it does not prevent exposure to high peak pressures. Safety levels for transients should therefore be given by received peak–peak sound pressure and energy flux density instead of rms sound pressure levels.*" For

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6 National Research Council (US) Committ.ee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals. Ocean Noise and Marine Mammals. Washington (DC): National Academies Press (US); 2003. Appendix E, Glossary of Terms. https://www.ncbi.nlm.nih.gov/books/NBK221261/ accessed 6/5/23.

7 Madsen PT (2005), Marine mammals and noise: Problems with root mean square sound pressure levels for transients. The Journal of the Acoustical Society of America (JASA), 117(6), 3952–3957. https://doi.org/10.1121/1.1921508, accessed 6/28/23.

reference, in-air impulsive sound limits for hearing damage are not assessed with RMS but rather with peak and peak-to-peak levels [8].

1.4 Underwater Thresholds for Noise Impact Assessment

NOAA Fisheries or NMFS is an office of the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce. NMFS is charged with protecting marine species and their habitats in the United States. NMFS published guidance related to underwater noise and the potential impacts on marine mammals in a document titled "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing." This document, often referred to as the "NOAA Technical Guidance," was published in 2016, 2018 v 2.0, and again in 2020 v 2.2.

NOAA defines impulsive and non-impulsive (continuous) noise as follows [9]:

> *Continuous sound: A sound whose sound pressure level remains above ambient sound during the observation period (ANSI 2005).*
>
> *Impulsive sound: Sound sources that produce sounds that are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay (ANSI 1986; NIOSH 1998; ANSI 2005). They can occur in repetition or as a single event. Examples of impulsive sound sources include: explosives, seismic airguns, and impact pile drivers.*
>
> *Non-impulsive sound: Sound sources that produce sounds that can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent) and typically do not have a high peak sound pressure with rapid rise time that impulsive sounds do. Examples of non-impulsive sound sources include: marine vessels, machinery operations/ construction (e.g., drilling), certain active sonar (e.g. tactical), and vibratory pile drivers.*

The NMFS Summary of Marine Mammal Acoustic Thresholds [10] states the following with respect to behavioral harassment,

> "*Marine mammals are considered harassed when exposed to elevated sound levels that may lead to mortality, temporary or permanent hearing impairment (threshold shift), non-auditory physical or physiological effects, and behavioral disturbance. Using the best available science, NMFS has developed acoustic thresholds that identify the received level of underwater sound*

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8 Impulse peak limits defined in US law at 140 dB,peak by MSHA standards for mines [30 CFR 56.5050; 30 CFR 57.5050], this exposure limit is enforceable; in the OSHA standards [29 CFR 1910.95; 29 CFR 1926.52], it is nonenforceable. https://www.nonoise.org/hearing/criteria/criteria.htm accessed 7/13/23.

9 National Marine Fisheries Service. 2018. 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p. https://www.fisheries.noaa.gov/action/2018-revision-technical-guidance-assessing-effects-anthropogenic-sound-marine-mammal-hearing accessed 6/30/23.

10 NMFS Summary of Marine Mammal Acoustic Thresholds, https://www.fisheries.noaa.gov/s3/2023-02/MMAcousticThresholds_secureFEB2023_OPR1.pdf, 2/24/23, accessed 8/11/23.

from explosive and non-explosive sources above which exposed marine mammals would be expected to:

- *be behaviorally disturbed or incur a temporary threshold shift (TTS), both of which qualify as Level B harassment under the Marine Mammal Protection Act (MMPA), or*
- *incur a permanent threshold shift (PTS) of some degree or lung or gastrointestinal (g.i.) tract injury, both of which qualify as Level A harassment.*"

February 2023

Underwater Level B Harassment Acoustic Thresholds (NOAA 2005)

Source type	Threshold
Continuous	$L_{p,\text{RMS,flat}}$: 120 dB re 1 μPa
Non-explosive impulsive or intermittent	$L_{p,\text{RMS,flat}}$: 160 dB re 1 μPa

For in-air sounds, NMFS predicts that harbor seals exposed to RMS received levels ≥90 dB re 20 μPa will be behaviorally harassed, and other pinnipeds will be harassed when exposed to RMS received levels ≥100 dB re 20 μPa.

In-Air Level B Harassment Acoustic Thresholds (Southall et al. 2007; NOAA 2009)

Species/Group	Threshold*
Harbor seal	$L_{p,\text{RMS,flat}}$: 90 dB re 20 μPa
All other pinnipeds	$L_{p,\text{RMS,flat}}$: 100 dB re 20 μPa

* A cumulative sound exposure level threshold of 100 dB re 20 μPa (DoN 2017) has been used for Navy military readiness activities. NMFS is currently in the process of re-evaluating the Navy's threshold.

NMFS defines the threshold level for Level B Behavioral Harassment as follows [2]:

"*120 Decibel (dB) Root Mean Square (RMS) referenced to (re) 1 microPascal (μPa) for continuous noise and 160 dB RMS re 1 μPa for impulsive and non-continuous pulsed noise. The Zone of Influence (ZOI) is the area that is ensonified to those levels and constitutes the area in which take of marine mammals could occur*".

Sound exposures leading to PTS and TTS may be assessed with the cumulative sound exposure over a period of time ("cSEL" in this report).

1.5 Auditory Weightings for Sound Exposure

Auditory weightings are considered important for assessing marine species *noise exposure* and susceptibility to noise-induced hearing loss [11]. Hearing auditory weighting coefficients for marine mammal species are summarized in the 2018 NMFS guidance document [12].

11 Jakob Tougaard, Michael Dähne; Why is auditory frequency weighting so important in regulation of underwater noise? J Acoust Soc Am 1 October 2017; 142 (4): EL415–EL420. https://doi.org/10.1121/1.5008901 accessed 6/29/23.

12 National Marine Fisheries Service. 2018. 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent

Weightings for analysis of this survey's data were selected for the species listed in Tables ES1 and ES2 of the Attentive IHA application, shown below. Highlighting in the table denotes the species evaluated by "Functional Hearing Group" listed in the IHA application [2].

Table ES1: Marine mammal hearing groups.

Hearing Group	Generalized Hearing Range*
Low-frequency (LF) cetaceans (baleen whales)	7 Hz to 35 kHz
Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz
High-frequency (HF) cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*)	275 Hz to 160 kHz
Phocid pinnipeds (PW) (underwater) (true seals)	50 Hz to 86 kHz
Otariid pinnipeds (OW) (underwater) (sea lions and fur seals)	60 Hz to 39 kHz

* Represents the generalized hearing range for the entire group as a composite (i.e., all species within the group), where individual species' hearing ranges are typically not as broad. Generalized hearing range chosen based on ~65 dB threshold from normalized composite audiogram, with the exception for lower limits for LF cetaceans (Southall et al. 2007) and PW pinniped (approximation).

Table ES2: Summary of auditory weighting and exposure function parameters.*

Hearing Group	*a*	*b*	f_1 (kHz)	f_2 (kHz)	*C* (dB)	*K* (dB)
Low-frequency (LF) cetaceans	1.0	2	0.2	19	0.13	179
Mid-frequency (MF) cetaceans	1.6	2	8.8	110	1.20	177
High-frequency (HF) cetaceans	1.8	2	12	140	1.36	152
Phocid pinnipeds (PW) (underwater)	1.0	2	1.9	30	0.75	180
Otariid pinnipeds (OW) (underwater)	2.0	2	0.94	25	0.64	198

* Equations associated with Technical Guidance's auditory weighting ($W_{aud}(f)$) and exposure functions ($E_{aud}(f)$):

$$W_{aud}(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\} \text{ dB}$$

$$E_{aud}(f) = K - 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{\left[1+(f/f_1)^2\right]^a\left[1+(f/f_2)^2\right]^b}\right\} \text{ dB}$$

Hearing auditory weightings consistent with the species evaluated for take estimates in the Attentive Energy application for incidental harassment authorization (IHA) Section 4 are shown in Figure 3. During this survey's post-survey analysis, NMFS 2018 auditory weightings were computed and applied to the unweighted audio recording acquired at 0.5 nautical miles (NM) to obtain weighted overall and one-third octave band sound pressure levels at that distance for the species shown in Figure 3.

and Temporary Threshold Shifts. U.S. Dept. of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p. accessed 6/5/23.

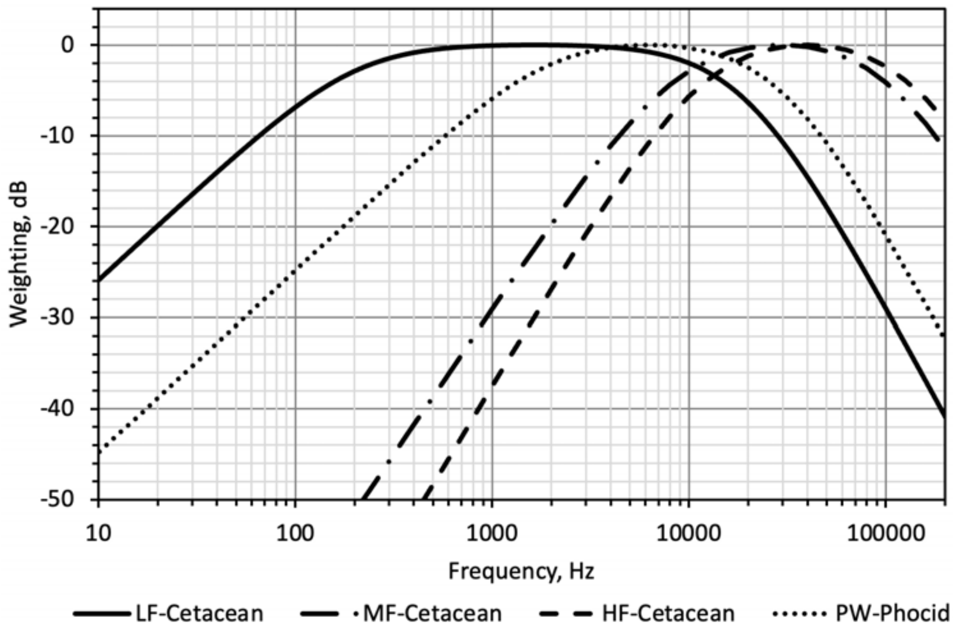

Figure 3. Bode diagram, marine species auditory weightings, NMFS 2018.

While this analysis utilized the 2018 NMFS auditory weightings, it should be noted that Southall et al. 2019 [13] published a set of modifications to the 2018 NMFS auditory weightings for consideration that are less flattened and closer to audiograms. It appears the Southall 2019 weightings are still under consideration.

13 Southall et al., "Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects", Aquatic Mammals 2019, 45(2), 125-232, DOI 10.1578/AM.45.2.2019.125. accessed 6/26/23.

2 Methodology

2.1 Survey location

Underwater acoustic recordings were acquired on May 8, 2023 between 8:09 and 9:40 am, approximately 43 nautical miles east of Barnegat Light, Long Beach Island, NJ (see Figure 4). Passive acoustic monitoring (PAM) was conducted with a hydrophone dipped by hand to a 15m depth from the side of a 32-foot center-console sport-fishing boat ("investigator boat") at 0.5, 1, 2, and 4 NM from the vessel.

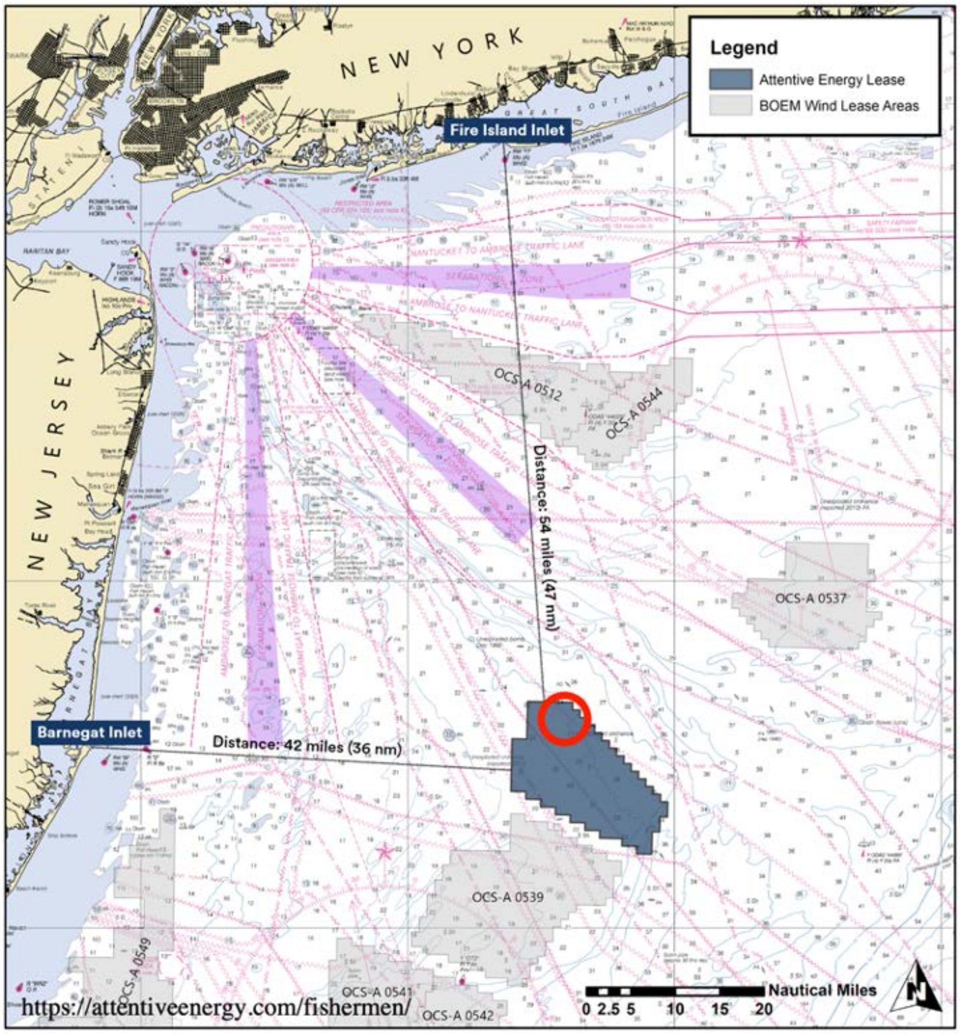

Figure 4. Survey location area marked with red circle, 43 nautical miles from Barnegat Light, NJ.

Distance to the vessel was determined using the investigator boat's onboard Furuno marine radar prior to shutting off systems for acoustic recording. During data recordings, precise source-receiver distances were unavailable. A position uncertainty of ±100 m (+/- 1 dB at 0.5 NM over 120 seconds) is assumed based on a vessel transit speed of 3 knots or less relative to the investigator boat. Sound measurements were acquired forward of the vessel's transit path. No other vessels were within visible range or heard during measurements.

Weather conditions were sunny, with unlimited visibility, thin high clouds, air temperature 63 degrees F (18 C) with very light winds from the NW, and waters at Beaufort sea state 1, water smooth, ~1-foot swells. Water depth at 8:40 am (at 0.5 NM from the vessel) was approximately 45 meters (150 ft) Water temperature at the surface was 55 degrees F (13 C). A seasonal thermocline was visible on the onboard Funuro fishing sonar at 18 to 23 meters (60 to 75 feet). Two sea anchors were deployed during recording which minimized boat drift and successfully prevented hydrophone cable strumming and flow noise.

The survey was conducted in a manner consistent with the NOAA issued guidelines for hydrophone measurements including selection of a "far range" location of at least 20 times the water depth, and hydrophone depth at least 5 meters [14].

The first data acquisition was conducted starting at 8:09 am near the eastern edge of the lease area, in front of and slightly to one side of the vessel transit line at 2 NM (39.79N,73.22W). Upon lowering the hydrophone 15 meters into the water (above the thermocline), vessel and sonar noise was immediately audible on headphones, with repetitive pounding sonar noise and oscillating tonal noise from vessel propulsion, DP thruster and possibly other equipment.

After recording at 2 NM, the investigator boat was steered to a 1 NM distance from the vessel and stopped at 8:30 am (lat/long not recorded). Vessel and sonar noise at the 1 NM distance was notably louder and more prominent. After recording at 1 nm, the investigator boat was then steered to a 0.5 NM distance from the vessel and stopped at 8:40 am, where vessel noise and sonar was dominating the ocean acoustic environment (39.82N,73.20W).

The investigator boat was then steered slowly to a 4 NM distance from the vessel and stopped at 9:30 am (39.79N,73.25W). At 4 NM the vessel propulsion noise was clearly audible but the sparker was not operating. Wind and Beaufort sea state had increased somewhat during transit to the 4 NM distance, resulting in occasional water slap on the investigator boat hull. Two 2-minute recordings were acquired but the sparker remained off except for a few seconds, not enough for sparker analysis. Vessel noise was evaluated in post analysis.

As previously noted, NOAA defines *continuous* sound as a sound whose sound pressure level *remains above ambient* sound during the observation period (ANSI 2005). Sounds observed during this survey were above the ambient during the survey period. In the absence of nearby shipping and marine species noise, ambient ocean noise is primarily a function of wind speed. Winds were light or absent during measurements at 0.5, 1 and 2 NM. Noise from the vessel including sparker pulses, vessel propulsion and DP thrusters dominated the ocean acoustic environment out to 2 NM, clearly above the ambient background. Post analysis confirmed that sparker and MF USBL sonar levels were tens of decibels above ambient levels observed between sonar pulses.

The combined vessel and sonar activity prevented direct measurement of ambient sound levels during the survey, however, a previous survey conducted in similar water depths and distances offshore Ocean City, MD about 105 NM south is informative [15]. Monitoring in that survey found background broadband (1-1000 Hz) ambient sound levels with distant vessel noise were 107

14 NMFS Northwest Region and Northwest Fisheries Science Center, Guidance Document: Sound Propagation Modeling to Characterize Pile Driving Sounds Relevant to Marine Mammals, January 1, 2012.

15 Marine Acoustics, Inc., Underwater Acoustic Assessment of Pile Driving during Construction at the Maryland Offshore Wind Project, for US Wind, report version 2.3 date 13 May 2022.

dB,rms re 1uPa. Background sound levels were modestly affected by the proximity to shipping lanes into the Philadelphia area. Those results suggest ambient sound levels in the absence of traffic would be lower, in the range of 100 dB re 1uPa, consistent with NOAA determinations in 2019 [16]. These are well below noise levels measured during this survey.

2.2 Instrumentation

Underwater sound pressure levels were acquired with a Cetacean Research C75 research-grade pre-amplified omnidirectional hydrophone. The pre-amplified C75 has an effective sensitivity of -180 dB re 1V/1uPA, an equivalent self-noise of 51 dB re 1uPA/√Hz, and a linear frequency response range of +/-1 dB from 25 Hz to 10 KHz and +/-3 dB from 10 Hz to 170 KHz (see Attachment C). The hydrophone output was routed to a SINUS Messtechnik GmbH Apollo Sound & Vibration Analyzer sn7800 operated with Samurai software Version 2.8.3 running on a Lenovo Windows 10 laptop. Data acquisition was set to 120 seconds, 51.2 KHz, 24-bit resolution, AC coupled, 10 Hz high pass filter. The Sinus Apollo provides digital Class 1 sound level meters meeting Standard IEC 61672-1 and Class 0 octave filtering according to IEC 61260. One-third octaves were stored at a rate of 10 per second. FFT windows were computed with 12800 FFT frame at 0.08 second intervals with Hanning weighting.

The hydrophone signal was split (Y'd) to a Tascam X8 digital audio recorder set to record digital audio files at 96 KHz, 24-bit resolution. The Tascam X8 has a frequency response of 20Hz – 40 kHz at 96 kHz of +0/-0.4dB (JEITA).

The C75 hydrophone, Sinus analyzer and Tascam recorder were calibrated end-to-end with a GRAS 42AG acoustic calibrator at a sound pressure level in air of 114 dB re 20 uPA at 251.2 Hz (equivalent sound pressure in water, 140 dB re 1uPA) using a custom machined hydrophone calibrator adapter Model HADP42AG-C75 from BRC Engineering of Sonoma, CA, with calibration current and certified traceable to NIST (see Attachment D). Recordings were run concurrently on the Tascam X8. Post-survey analysis was conducted with Sinus Samurai software version 2.8.3 and Spectraplus-SC software version 5.3.0.12C (Pioneer Hill Software, LLC). Excel and custom Python scripts were utilized for data and waveform review, analysis and plotting.

The acquired recordings had high signal to noise in the frequency ranges of interest and sufficient headroom to prevent digital signal clipping.

Particle motion was not acquired during this survey.

For sparker RMS computation, Crocker and Fratantonio, 2016 [4] based their RMS time "window" on that part of the acoustic waveform containing 90% of the total radiated energy during the sparker pulse. Their testing was performed close-in within a couple of meters of the devices under test. In contrast, this survey's far-field measurement locations were 0.5 NM (926 meters) and farther, with multipath propagation over distance, reflections, scattering, and distinct sound speeds above and below the ocean thermocline resulting in echo/reflection groups and overlapping recurring peaks especially at the larger distances. The RMS calculation method used in this analysis is the same,

16 National Oceanic and Atmospheric Administration, 84 FR 52464 October 2, 2019 stating: "Ambient ocean noise levels generally do not exceed 100 dB in the Atlantic waters of the Northeast United States (Haver et al., 2018)." https://www.govinfo.gov/content/pkg/FR-2019-10-02/pdf/2019-21458.pdf accessed 9/10/23.

but the time window is significant, as outlined by Sertlek et al 2012 [17], and importantly, captures the total sound received in the reflective ocean environment during sparker, sonar, and vessel operations.

2.3 Measurement Uncertainty

Uncertainties for the acoustic parameters presented in this report were considered in general accordance with United States and international standards [18,19]. Uncertainty considerations apply to the probability of replicating measured sound pressure levels at the same distances at the same location under the same conditions. Acoustic survey measurements can be affected by acoustic propagation and environmental conditions occurring during the survey. Utmost care was taken to minimize environmental effects by selecting a day with the calmest weather conditions available within the weather forecast, using a standardized depth of the dipped hydrophone, and minimizing handling noise of the dipped hydrophone.

System end-to-end calibration before and after the survey found calibration constant within 0.5 dB. Class 1 digital sound meters have an intrinsic standard uncertainty of +/- 0.5 dB (ISO 1996-2). The remainder of the uncertainty was allocated to the distance to the source being measured, estimated at +/-1 dB. From ANSI 1996-2, the expanded uncertainty (2σ or coverage probability 95%) of effects on short-term measurements with Class 1 instrumentation (the type used during this survey) is +/-1.6 dB. No uncertainty was introduced by residual sound levels as they were well below measured levels. All reported uncertainties are in the category of Type B evaluation or analysis other than a statistical analysis of repeated observations. While a precise total uncertainty for the offshore measurement survey is not known, the expanded uncertainty is unlikely to exceed +/-4 dB.

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17 H. Ozkan Sertlek, Hans Slabbekoorn, Carel J. Ten Cate, Michael A. Ainslie; Insights into the calculation of metrics for transient sounds in shallow water. Proc. Mtgs. Acoust 2 July 2012; 17 (1): 070076. https://doi.org/10.1121/1.4789476 accessed 8/21/23.

18 B.N. Taylor and C. E. Kuyatt, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results,” National Institute of Standards and Technology, Gaithersburg, MD, NIST Technical Note 1297, 1994. [Online]. Available http://www.nist.gov/pml/pubs/tn1297/ accessed 8/16/23.

19 ISO/FDIS 1996-2 "Acoustics — Description, measurement and assessment of environmental noise — Part 2: Determination of sound pressure levels", ISO/TC 43/SC 1-2017.

3 Results

3.1 Sound pressure data (Pa) versus distance

Time-series sound pressure data are shown in Figures 5, 6 and 7 at 2, 1 and 0.5 NM with 0.005 second linear sampling. The sound pressures in each figure include total vessel propulsion, DP thruster, and other machinery noise (all *continuous*), a sparker and mid frequency (MF) positioning sonar signals firing at different rates and frequencies. The y-axis amplitude scales reflect higher sound levels with closer distance. Of the three measurement distances, the 0.5 NM record provides the highest detail and captured an apparent startup of the sparker. Section 3.2 focuses on the sound pressure levels at 0.5 NM.

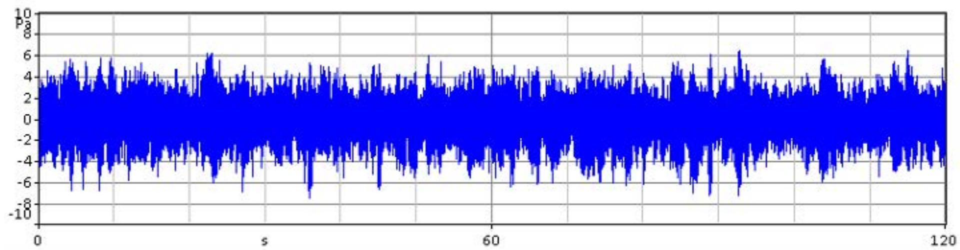

Figure 5. Time series sound pressure, Pa 8:09 am, 2 NM (3704 meters). Vessel continuous noise and sparker and SBP noise were present. Sparker was firing twice per second.

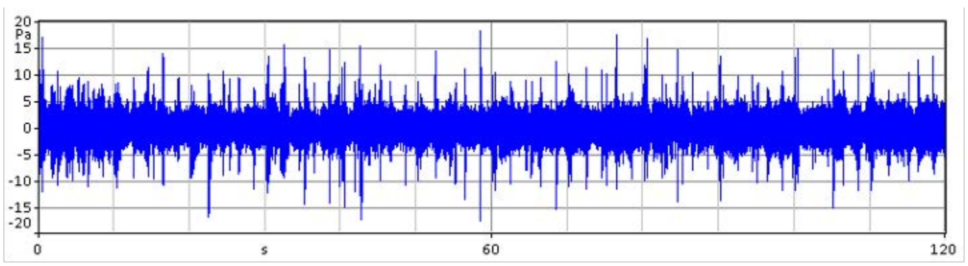

Figure 6. Time series sound pressure, Pa 8:35 am, 1 NM (1852 meters). Vessel continuous noise and sparker and SBP noise were present. Sparker was firing once every 5 seconds.

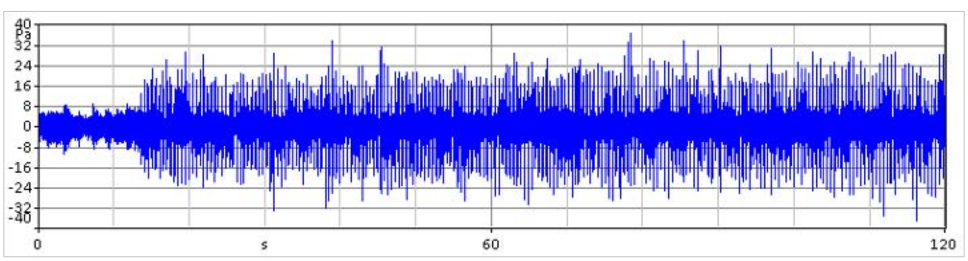

Figure 7. Time series sound pressure, Pa 8:41, am 0.5 NM (926 meters). Vessel continuous noise was present at start of data acquisition. Sparker startup occurred at 14 seconds, then firing twice per second.

Peak sound pressures (Pa) during sparker firing were identified with a custom Python script and plotted in Figures 8, 9 and 10 for the data acquired at 2, 1, and 0.5 NM. Brickwall filtering (48 dB/octave, Butterworth) was applied from 315 to 12000 Hz to remove low and high frequency sound outside the sparker's frequency range.

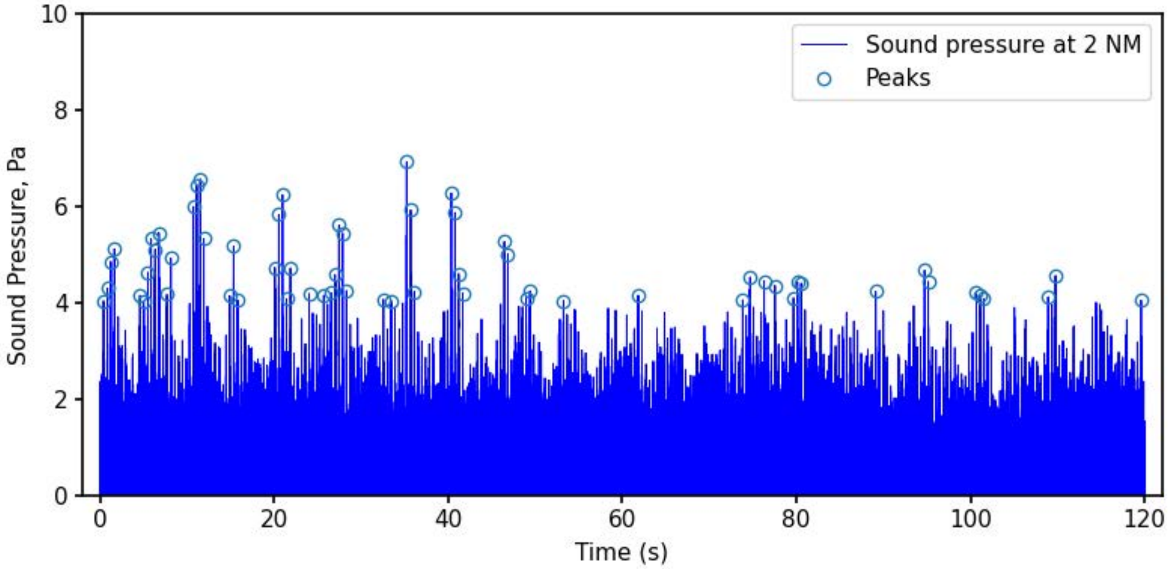

Figure 8. Time series sound pressure, Pa 8:09 am, 2 NM (3704 meters). Vessel continuous noise and sparker noise were present. Sparker peaks are circled. During this data acquisition, the sparker was firing off twice per second. Peaks were acquired for sound pressures above 4 Pa to avoid fluctuating vessel noise.

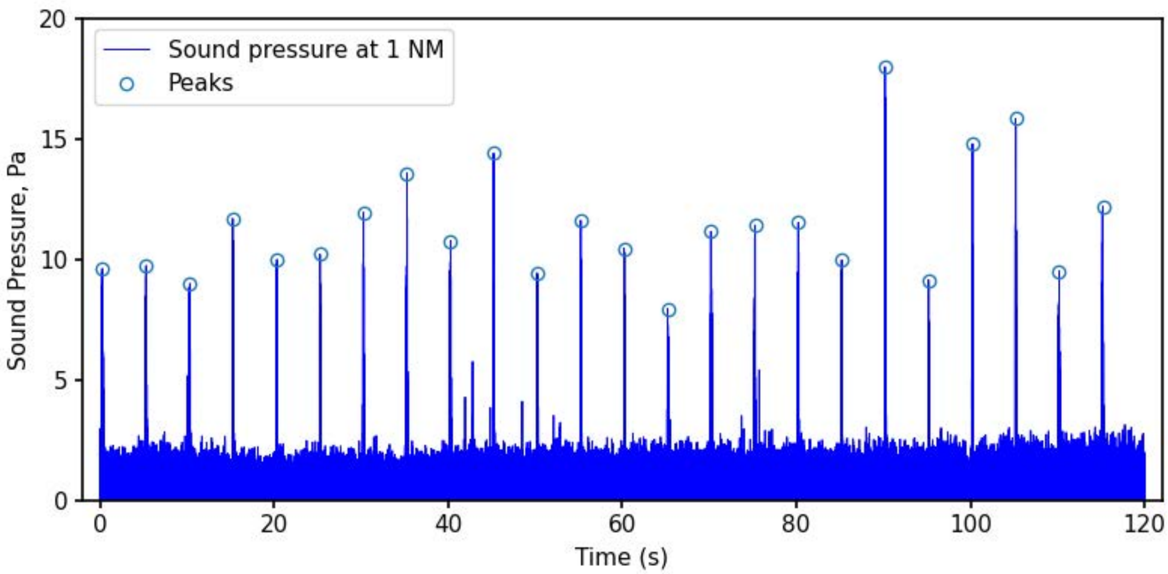

Figure 9. Time series sound pressure, Pa 8:35 am, 1 NM (1852 meters). Vessel continuous noise and sparker noise were present. Sparker peaks are circled. During this data acquisition, the sparker was firing off only one every 5 seconds..

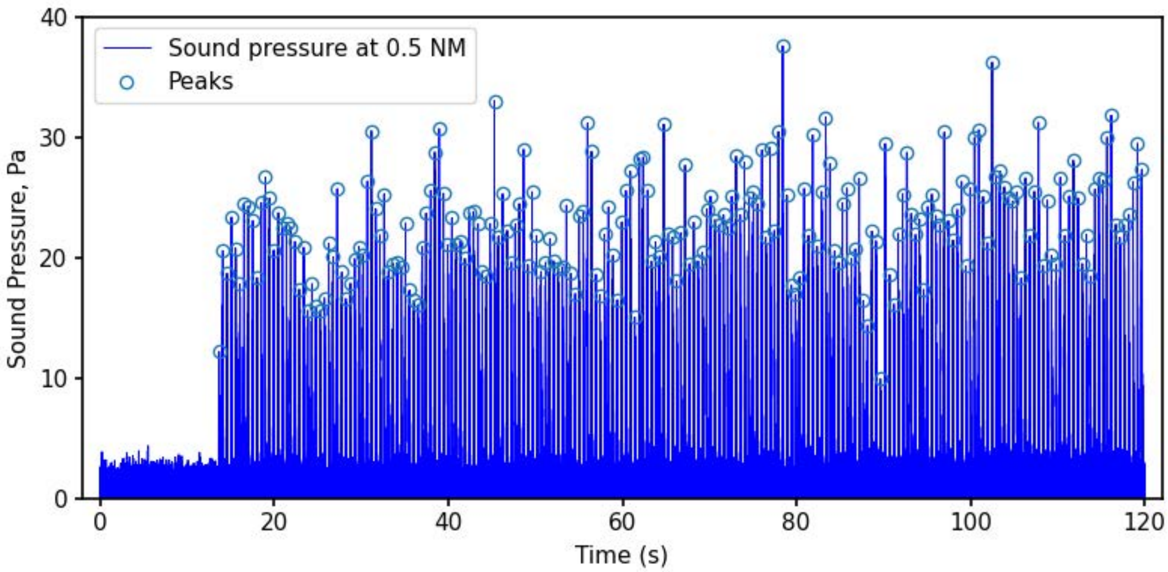

Figure 10. Time series sound pressure, Pa 8:41, am 0.5 NM (926 meters). Vessel continuous noise only was present at start of data acquisition. Sparker startup occurred at 14 seconds. Sparker peaks are circled. Sparker startup occurred without a 30-second ramp.

The data revealed acoustic features which are not accounted for in simple spherical spreading acoustic models such as used for the IHA. In Figures 11, an exemplar sparker pulse plot at 0.5 NM shows not one clean pulse as would be assumed from near-field manufacturer data or Crocker and Fratantonio (2016), but pulse groups.

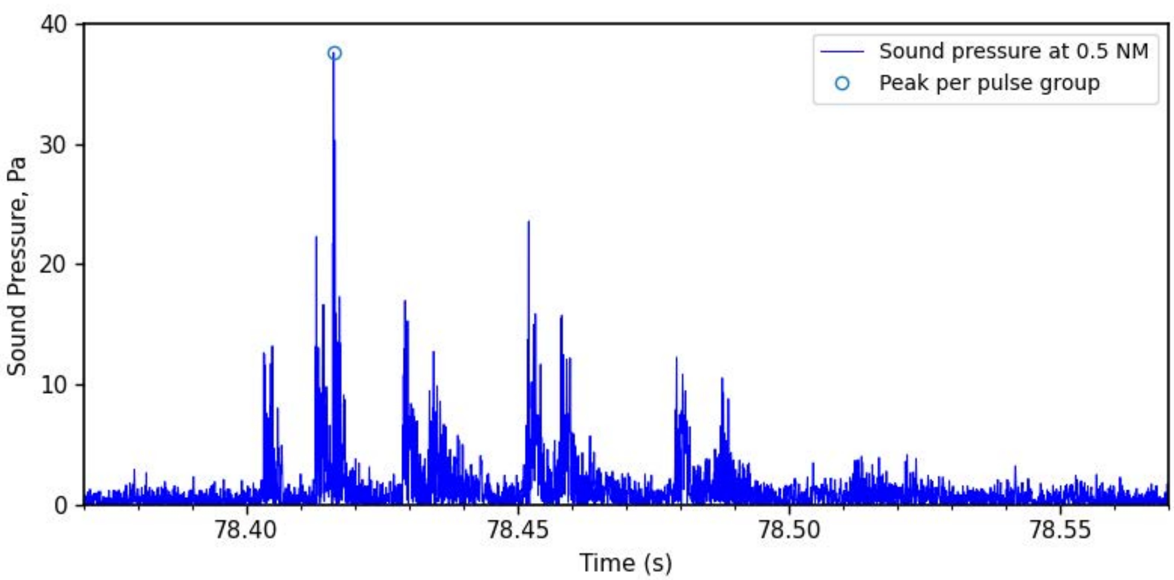

Figure 11. Time series sound pressure, Pa 8:41, am 0.5 NM (926 meters). Sparker pulse shows echo/reflection groups and dual sound speed paths characteristic of reflections off bottom and surface and differing sound speed above and below thermocline.

The data show a series of echo/reflection groups with different time arrivals consistent with acoustic path time and strength modifiers:

- Direct path from sparker to hydrophone
- Primary reflections off the water surface and the ocean bottom
- Two sound speed paths, likely one above and one below the thermocline
- Focusing and horizontal refraction
- Scattering

The waters in the survey area are shallow (approximately 45 to 50 meters) compared to the distances of the measurements (926, 1852, and 3704 meters). The diagram below illustrates the ratio of 50 meter water depth to the survey measurement range radii at 0.5, 1, 2 and 4 nm.

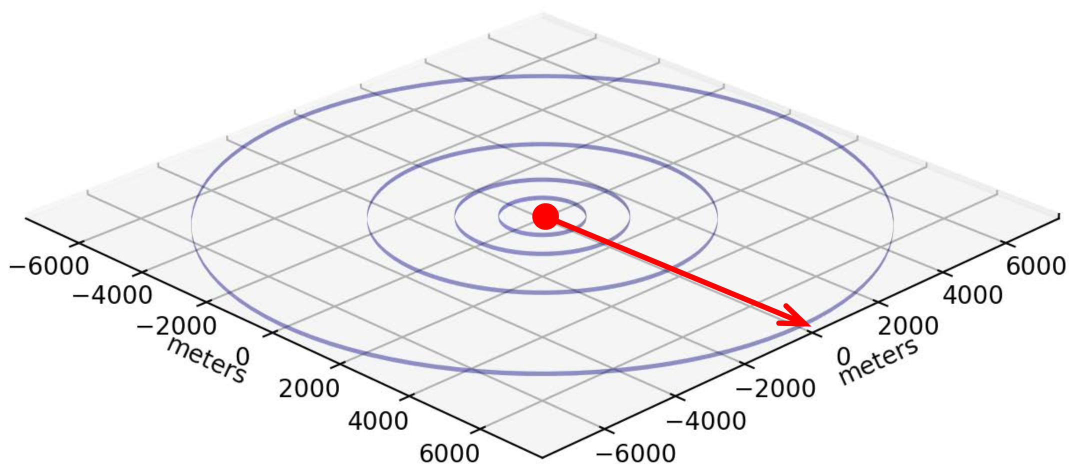

Figure 12. Illustration of water depth to sound radius ratios for offshore shallow littoral waters in the survey area. This diagram shows radii at 0.5, 1 and 2 nautical miles (926, 1852, and 3704 meters) from a sound source located at 0,0. Radii height is 50 meters. An arrow is shown indicating sound propagation outward from the source to receiver radii.

The water surface and sea bottom channel the acoustic energy horizontally, acting as containing surfaces with varying degrees of reflectivity and absorption from location to location between source (at 0,0) and receiver.

This is consistent with Oliveira et al [20], "*Three-dimensional (3D) effects can profoundly influence underwater sound propagation and hence soundscape at different scales in the ocean ... In the particular case of coastal seas, a range of physical oceanographic and geological features can cause horizontal reflection, refraction, and diffraction of sound.*" The 50 meter ocean depth evaluated by Oliveira et al was similar to the water depths for this survey.

20 Oliveira, T., Lin Y.T., Porter, M., Underwater Sound Propagation Modeling in a Complex Shallow Water Environment, Front. Mar. Sci., 15 October 2021.

3.2 Sound level data at 0.5 nm

Table 1 provides overall and one-third-octave unweighted and weighted sound pressure levels, cumulative SEL (cSEL), and SEL per sparker pulse interval including all vessel operations noise emissions, at 0.5 NM. Marine species weightings are described in Section 1.5.

Level, dB re 1uPa	Unweighted	LF	MF	HF	PW
SPL,rms(120s)	128.5	127.1	118.4	117.1	122.9
peak (highest)	151.6	151.1	147.7	146.8	150.3
peak (negative)	-151.6	-150.9	-147.7	-146.8	-150.4
peak-to-peak	157.6	157.0	153.7	152.8	156.4
cSEL,120s (~2 pps) re 1uPa^{2}s	147.9	147.9	138.4	137.9	143.7
SEL per sonar pulse re 1uPa^{2}s	124.1	124.1	114.6	114.1	119.9
ANSI 1/3 Octaves, Hz	dB,rms re 1uPa				
40	100.9	99.3	11.3	56.8	90.3
50	98.1	96.5	8.8	54.1	87.5
63	97.8	96.2	8.8	53.8	87.2
80	95.7	94.1	7.2	51.7	85.1
100	96.0	94.4	8.3	52.1	85.5
125	96.1	94.5	9.4	52.3	85.6
160	96.5	94.9	11.3	52.8	86.1
200	104.3	102.7	21.9	61.0	94.0
250	114.6	113.1	33.2	71.4	104.4
315	102.4	100.9	24.2	59.8	92.4
400	104.0	102.6	29.6	62.2	94.3
500	112.8	111.5	42.4	72.2	103.6
630	113.1	111.9	47.7	74.1	104.7
800	116.4	115.4	55.0	79.0	108.7
1000	113.4	112.6	56.9	78.2	106.8
1250	112.5	112.0	61.8	80.0	107.2
1600	113.7	113.5	69.2	84.5	110.0
2000	115.4	115.4	77.0	89.4	113.0
2500	114.9	114.9	81.8	91.9	113.4
3150	111.8	111.7	83.9	91.8	110.9
4000	110.6	110.3	88.5	94.0	110.2
5000	111.0	110.5	93.9	97.5	110.8
6300	110.6	109.8	98.0	100.0	110.6
8000	104.9	103.7	95.8	96.8	104.8
10000	103.0	101.0	97.1	97.2	102.7
12500	102.3	99.2	98.9	98.5	101.5
16000	101.4	97.0	99.6	99.0	99.9
20000	117.5	111.3	116.8	116.2	115.0
25000	106.8	98.2	106.7	106.3	102.8
31500	100.7	90.2	100.7	100.5	95.5
40000	89.5	75.3	89.2	89.5	81.7
Octave band sum 40 Hz-40KHz	125.7	124.5	117.6	117.1	122.2

Table 1. Data compiled in Spectraplus-SE over a 120-second period with vessel propulsion, DP thruster and general operations noise, and the vessel's sparker operating at a rate of 2 firings per second and USBL sonars (19.5 to 32 KHz) firing every 2 seconds [21].

21 The Sinus Apollo and Spectraplus-SE analysis systems provided comparable data results, within 1 dB over comparable source data. The Spectraplus-SE was used during analysis of audio data acquired at 96 KHz providing analysis bandwidth for the high frequency sub bottom profilers observed at 19.5 to 32 KHz.

3.3 Multiple sonars

Digital recordings at 0.5 NM acquired on the Tascam X8 at 96 KHz were imported into Spectraplus SE and plotted as a spectrogram shown below in units of power spectral density Pa2/Hz.

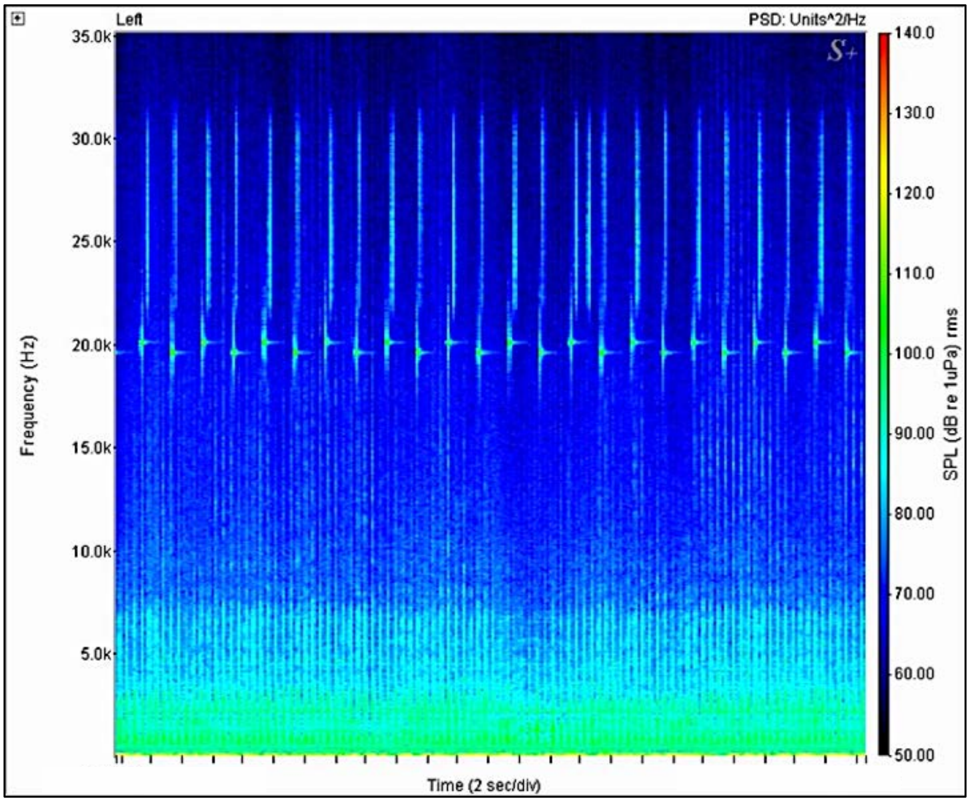

Figure 13. Spectrogram at 0.5nm (926 meters). Signal includes total vessel propulsion, DP thruster, and other equipment noise below 3 KHz, closely spaced sparker pulses filling the frequency range (vertically), and high frequency underwater positioning (USBL) sonars from 19.5 to 32 KHz.

The vessel sonar emissions are complex, consisting of a sparker with a dominant range from approximately 400-5000 Hz and several mid frequency (MF) positioning sonar signals at 19.5 to 32 KHz.

Sparker pulses were observed at a rate of 2 pulses per second and were dominant from 400 to 5000 Hz (thin green vertical lines) with pulse energy observed out beyond 20 KHz.

Sonars in the 19.5 to 32 KHz frequency range appears consistent with the ixBlue Gaps Medium frequency (MF) Ultra-Short Baseline (USBL) positioning system. The Attentive IHA did not list or evaluate USBL sonar noise.

According to the Attentive Energy IHA application, a high frequency (HF) sub bottom profiler (SBP) operating above 85 KHz was proposed for use that produces sound levels at frequencies above the limits of the monitoring equipment in use on this survey.

The two pulsed MF USBL sonars were observed at 19.5 KHz and 20 KHz. Those sonar signals exhibited impulsive characteristics [22]. Two MF swept-frequency (FM) USBL sonars were observed from 21 to 32 KHz. The two FM USBLs appeared to be sequenced with the 19.5 and 20 KHz pulsed USBLs. One FM USBL sweep intensity was more dominant in the range of 21 to 27 KHz, while the other was dominant in the 27 to 32 KHz range. Occasional misfires or rapid repeat firing of the FM USBLs were observed and can be seen in Figure 13 as out-of-step vertical streaks from 22 to 32 KHz.

Peak unweighted sound pressure levels at 0.5 NM for the 19.5 KHz and 20 KHz pulsed MF USBL signals were approximately 131 dB,peak re 1uPA, and for the FM USBL signals in the range of 21 to 32 KHz, 124 dB,peak re 1uPA.

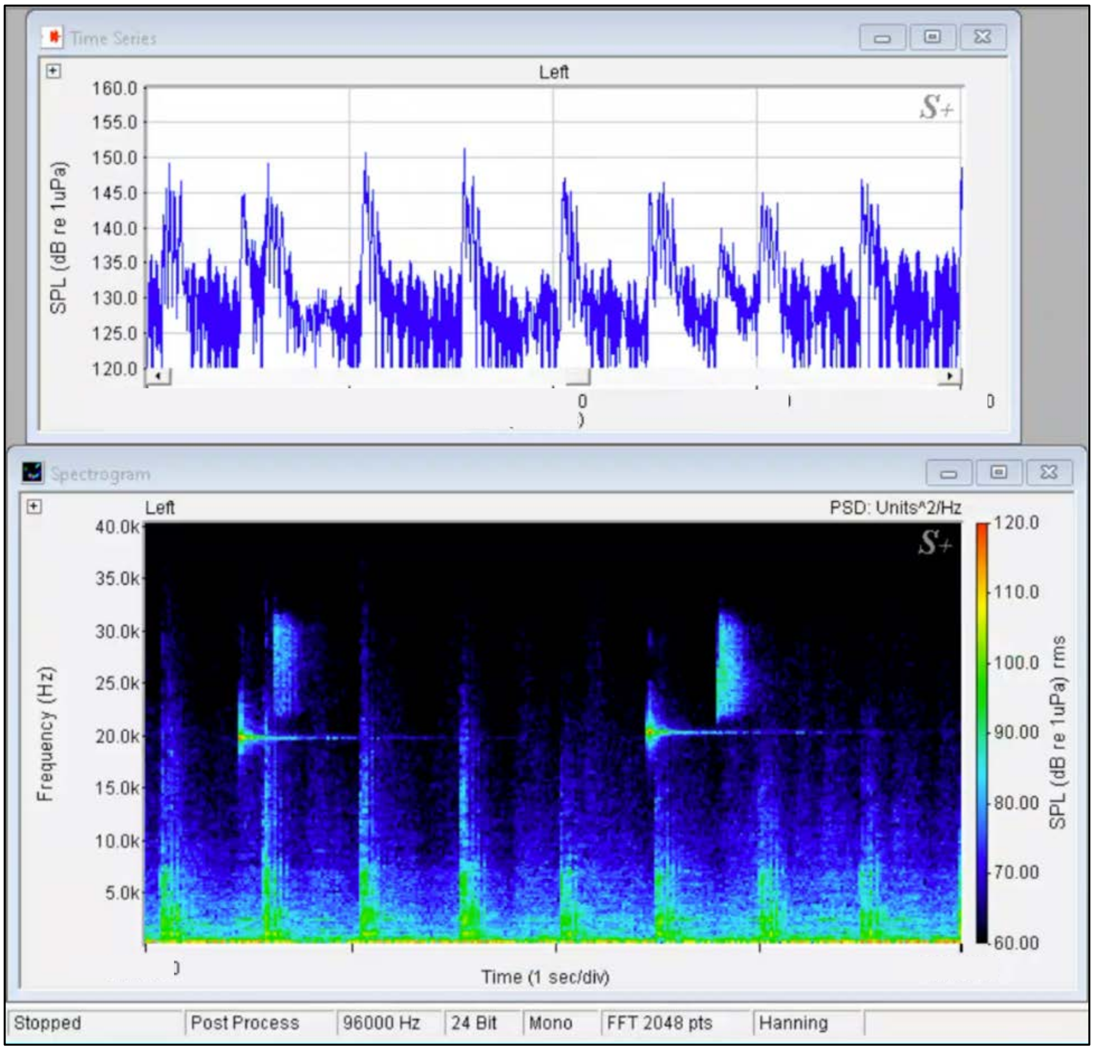

Figure 14. Sound pressure and spectrogram at 0.5nm (926 meters). Signal includes total vessel propulsion, DP thruster, and other equipment noise below 3 KHz, regularly spaced sparker pulses (vertical stripes), and alternating USBL sonar signals at 19.5, 20, and 22 to 32 KHz.

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22 Southall et al, Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations, Aquatic Mammals, Volume 33, Number 4, 2007 ISSN 0167-5427, accessed 9/5/2023. Table 1, Single or Multiple pulses, > 3-dB difference between received level using impulse vs equivalent continuous time constant. Examples include sparkers pulses, single ping of certain sonars, and pingers.

RMS levels for the impulsive MF USBLs are estimated at 125 dB,rms at 0.5 NM, utilizing the NMFS 2020 guideline defining the difference between SPL,peak and SPL,rms as 6 dB for the Single Frequency sonar, listed in Table 1 of the guidelines issued by NMFS in 2020 [23]. Survey RMS levels in the 20 KHz band were 117.5 dB,rms, a ratio of 14 dB below USBL SPL,peak levels.

Figure 14 shows an expanded 4-second time section at 0.5 NM with a times-series sound pressure chart at top and a 2048-point FFT spectrogram underneath lined up in time [24]. The pulsed MF USBLs are clearly visible at 19.5 and 20 KHz, occurring every 2 seconds.

Similarly, the repetitive sparker pulses are easily observed occurring twice per second. Multiple reflections were observed for each sparker pulse. Sound pressures between pulses are dominated by vessel continuous noise and influenced by scattering and reverberation.

3.4 Vessel continuous noise

Vessel noise was observed to be continuous, tonal and highly audible at all measurement locations. As shown in Figures 15 and 16, vessel noise contains numerous tonal components from below 20 Hz to several kilohertz. Noise levels are discussed here for two ranges, 40 Hz up and below 40 Hz. Above 40 Hz, vessel noise is observed to be tonal from multiple propulsion and machinery noise emissions.

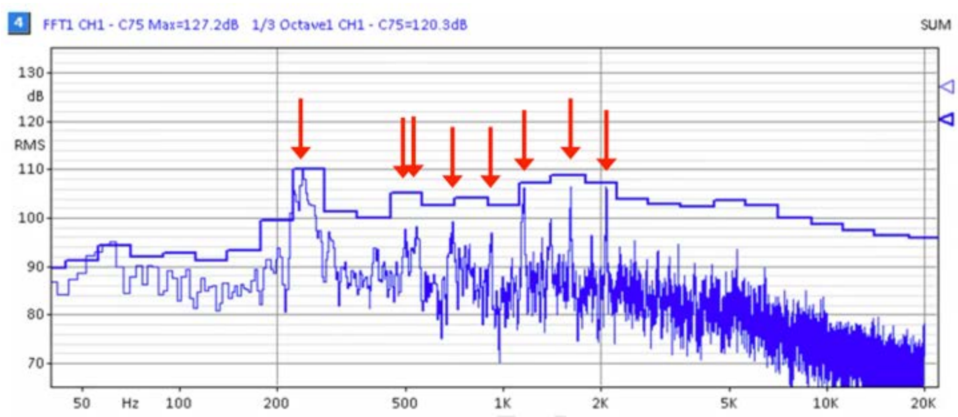

Figure 15. Spectrum chart of one-third-octave and narrow-band 12800 FFT at 0.5nm (926 meters), 4 second span between sonar pulses 841 am. Vessel continuous tones highlighted.

23 Guan, S., Recommendation For Sound Source Level And Propagation Analysis For High Resolution Geophysical (HRG) Sources, National Marine Fisheries Service, Version 4.0, April 2, 2020.

24 The spectrogram's PSD computations employed a 2048-point FFT which displays fractional sound levels per bin due to FFT division of the total received sound pressure at each moment in time shown in the top time series chart, normalized to a 1-Hz bandwidth.

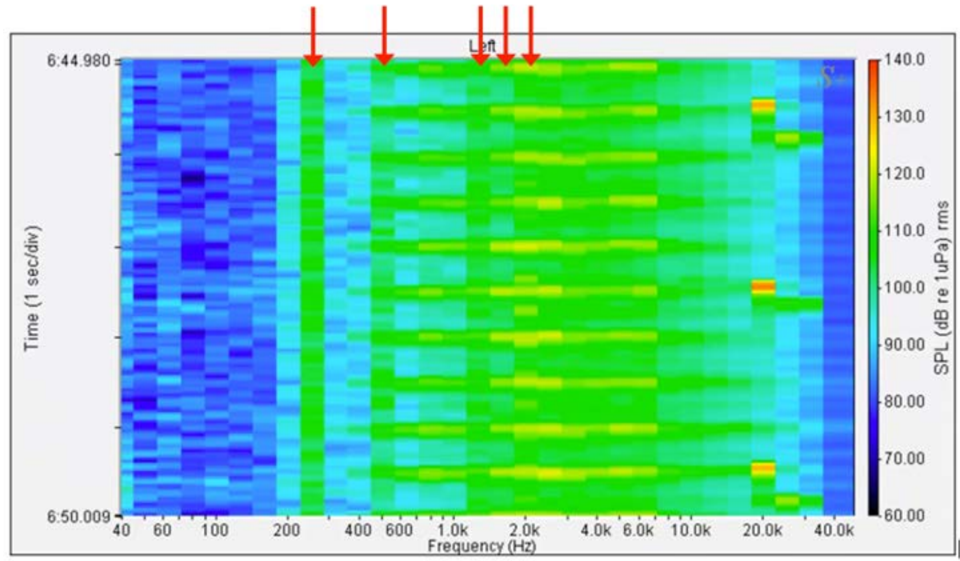

Figure 16. Spectrogram of one-third octave bands, rms at 0.5nm (926 meters), 5 second span. One-third octave bands controlled by vessel tonal noise are highlighted with red arrows. Ultrasonic SBP pulses are observable in the 20, 25 and 31.5 KHz one-third octave bands.

Continuous vessel noise above 40 Hz is observed in the one-third-octave band spectra between sparker pulses, including prominent audible tones in the 250, 500, 630, 800, 1000, 1250, 1600, and 2000 Hz bands. The vessel noise level from 40 Hz to 40 KHz (without sparker and MF USBL positioning sonars) totals approximately 120 dB,rms unweighted.

The frequency range below 40 Hz is an important sonic range for LF cetacean long-range communications. The hydrophone recording at 0.5 NM (926m, approximately 1 kilometer) was decimated 50x with 8192 FFT to analyze vessel-radiated noise below 40 Hz. Vessel noise emissions were assessed with one-third octave band analysis. Vessel noise levels below 40 Hz total 125.4 dB,rms at 0.5 NM (120s). Noise emissions are dominant in the 10 and 12 Hz one-third octave bands as highlighted in Figure 17. These are below human pitch detection range but within the range of data collected.

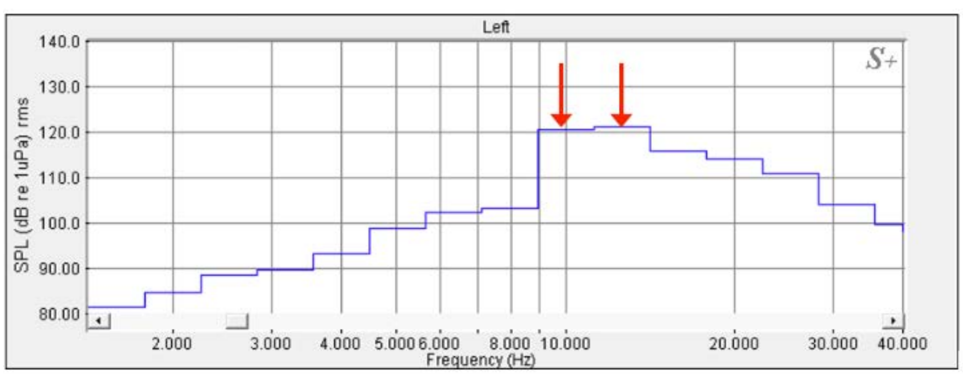

Figure 17. Spectrum of one-third octave bands, rms at 0.5nm (926 meters), 120s span.

To obtain a better picture of vessel emissions at low frequencies with FFT analysis, the recording at 0.5 NM was sped up 10x. Figure 18 shows a 120-second spectrogram at 10x playback speed. Frequencies listed are 10x actual.

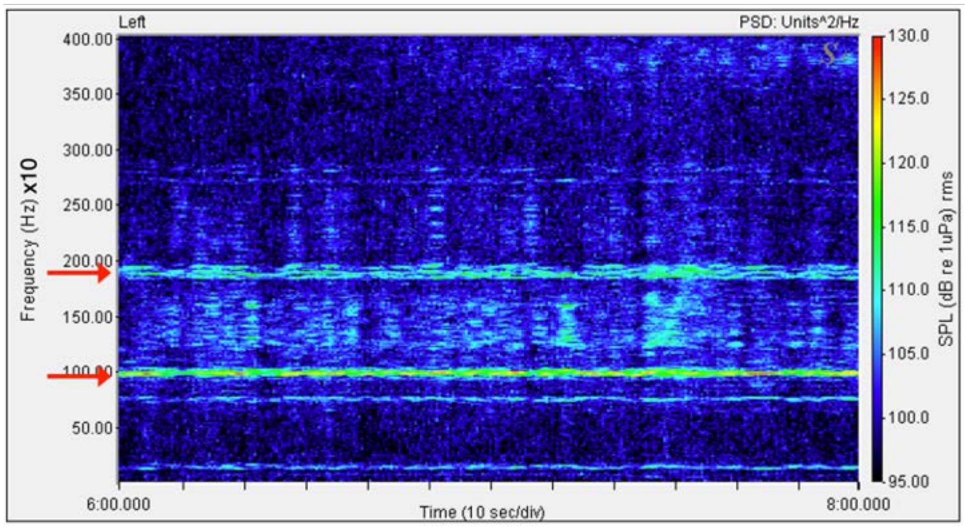

Figure 18. Spectrogram at 0.5nm (926 meters), 120s span, 10x frequency, power spectral density dB re 1uPa²/Hz. Vessel machinery, possible DP thruster noise or propeller cavitation at 9.5 Hz and 19 Hz. Secondary machinery noise observed at 7.3 and 1.2 Hz. Noise at 19 Hz exhibits apparent multiple harmonics.

Noise emissions in this frequency range exhibit fundamentals and harmonics located at approximately 9.5 and 19 Hz. The 9.5 Hz range is consistent with a rotational rate close to 600 RPM. Multiple frequencies at 19 Hz (190 Hz in this 10x chart) are distinct when the 9.5 Hz noise (95 Hz in this 10x chart) is more concentrated. Harmonics in the 19 Hz range shift slightly up and down in frequency over time. Secondary machinery continuous frequencies are observed at 7.3 and 1.2 Hz. By inspection, the noise emissions below 40 Hz are man-made and continuous.

Summary of vessel noise analysis: The vessel noise was *continuous* with no discernible impulsivity. Vessel noise included numerous tonal components from propulsion, DP thruster and other machinery, with a strong cyclical grating sound. Combining the noise emissions below 40 Hz (125.4 dB,rms) with the vessel noise above 40 Hz observed between sparker pulses (120 dB,rms), the total vessel *continuous* noise is estimated at 126.5 dB,rms at 0.5 NM. Vessel continuous noise levels remained above the ambient sound level at 0.5, 1 and 2 NM.

3.5 Reverberation

Reverberation time in the shallow littoral waters at the measurement location (depth 45 meters) was estimated with T20 decay estimation and Schroeder backward integration on selected portions of the audio recording at 0.5 NM, employing the vessel's sparker and MF USBL positioning impulsive sonars as test source. Reverberation was estimated at approximately 1 seconds at 400 Hz and 0.75 seconds at 20 KHz. Total operational noise between sparker firings appears elevated some 10 dB compared to the continuous noise observed from vessel operations prior to sparker firings. This observation is consistent with the well-known acoustic property of reverberation sustaining noise levels between acoustic pulses.

3.6 Sparker Sound Levels

Peak pressure levels controlled by the sparker at 0.5, 1, and 2 NM (shown in Figures 8, 9, and 10) were tabulated and plotted relative to equivalent distance in meters. Peak data acquisition at 1 NM (1852 meters, n=24) was thinned by the sparker firing only once every 5 seconds, as compared to the nominal 2 times per second at 926 and 3704 meters. Peak data selection threshold at 3704 meters was set to 4 Pa to avoid including vessel noise. Figure 19 shows sparker peak pressure levels and calculated transmission loss (TL) trends.

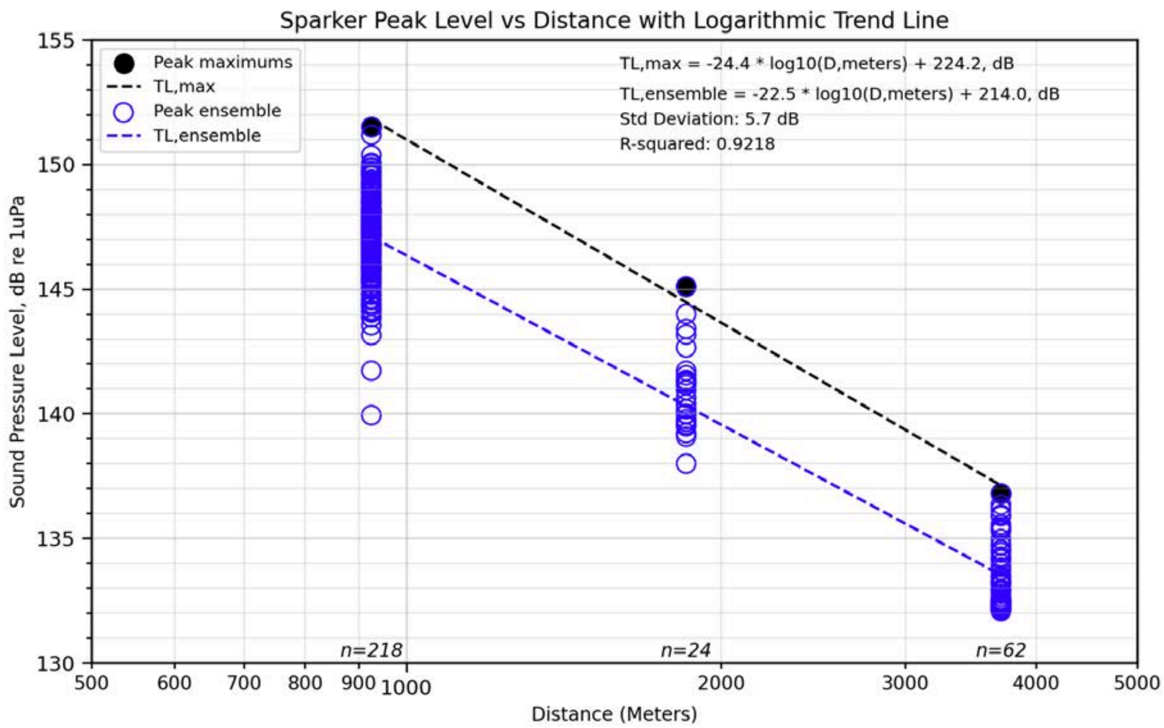

Figure 19. Transmission loss (TL) simple model estimation for peak sound pressure of pulsed sparker, acquired at 0.5, 1, and 2 NM (blue data points), scaled in meters. Trend means for maximum and ensemble peak levels shown as dashed lines..

The sparker SL,peak is conservatively estimated from the top peaks as 224 dB,peak re 1uPA@1m. A second upper prediction limit (UPL) for SL,peak was derived from ensemble peaks variously exhibiting excess attenuation by scattering and interference, employing the trend mean constant (214.0 dB) plus SDx1.96 for 95% confidence (1.96 * 5.7 or 11.2 dB) arriving at 225.2 dB,peak re 1uPA@1m. As discussed further on, both conservative SL,peak estimates are in line with the manufacturer listed typical SL,peak of 2 Bars/m or 226 dB re 1uPA@1m.

The 'max' peaks TL coefficient is estimated at 24.4 dB per decade, approximately 7 dB per doubling of distance. The 'ensemble' peaks TL is 22.5 dB per decade, somewhat closer to spherical spreading. The differential suggests spectra were dynamically attenuated at higher frequencies by phase interference, scattering and shallow-water propagation conditions generally above 3000 Hz in the roughly 50-meter depth at the relatively long distances to the survey measurement locations. The 'ensemble' peaks TL slope appears constrained slightly by the reduced data range at 1 NM and the upward compression of the data at 2 NM (from selecting peaks only above 4 Pa to avoid introducing vessel noise into the data set). It is possible the sparker SL,peak computed from 'ensemble' peaks understates the sparker peak level.

3.7 Transmission Loss

Transmission loss describes the rate of change in sound level versus distance. Transmission loss (TL) coefficients over distance were estimated using the values for SPL,peak(10-24000 Hz) shown in Figure 20, plus TL for one-third octave band rms levels from 400 to 5000 Hz, and the average transmission loss for those bands (SUM). The results were scaled to propagation spreading coefficient α as in αlog10(r) and the results shown in Figure 20.

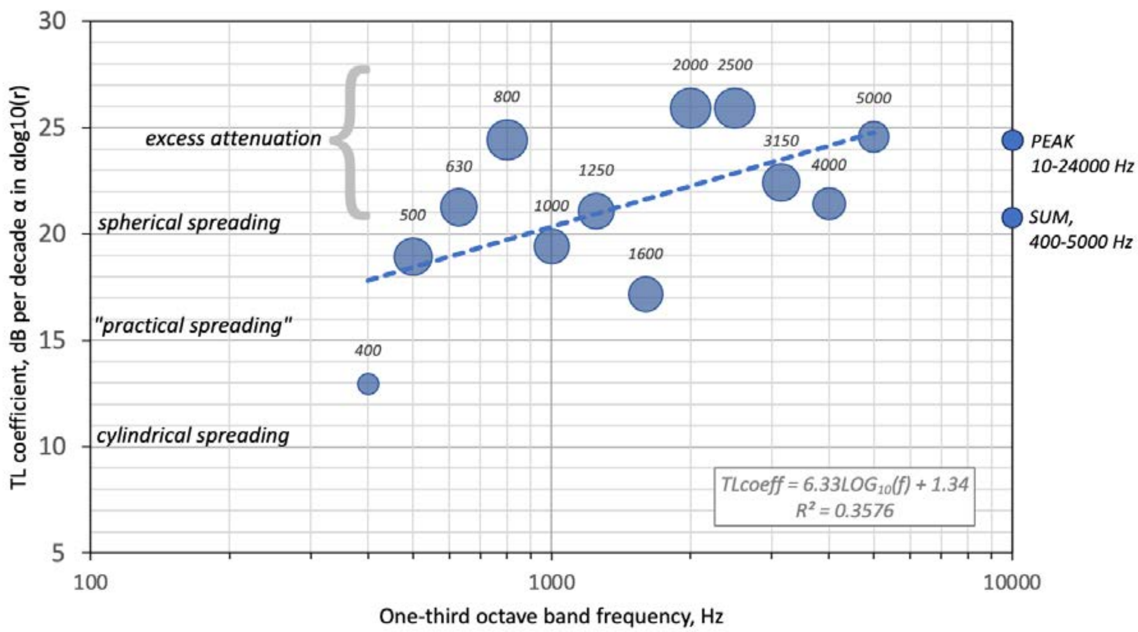

Figure 20. Illustration of attenuation with distance for one-third-octave bands, summation of those bands, and peak. The 1600 Hz band was controlled by vessel tonal noise and was evaluated from 0.5 to 4 NM. All other data were evaluated from 0.5 to 2 NM. The plotted one-third octave band data points are labelled by frequency and scaled visually to measured decibel levels at 0.5 NM. Larger on-third octave band points contain more operations noise.

The one-third octave bands from 500 to 2500 Hz contained vessel continuous operational tonal noise and were strongly influenced by repetitive sparker impulsive noise. The 1600 Hz one-third octave band rms sound level was controlled by continuous vessel tonal noise. Evaluated from 0.5 to 4 NM, the 1600 Hz band level dropped more slowly with distance, with attenuation closer to "practical spreading". The remaining one-third octave bands were evaluated from 0.5 to 2 NM. Overall, sparker peak levels dropped with distance at a faster rate than vessel propulsion and DP thruster noise.

Transmission loss (TL) propagation rates exhibit the effects of excess attenuation notably in the 800, 2000, 2500 and 5000 Hz one-third octave bands where sparker impulse energy is prominent (refer to Figure 16). The TL best fit slope is upward with increasing frequency, consistent with increased excess attenuation at higher frequencies. Several bands exhibit transmission loss slower than spherical spreading; 400, 500, 1000 and 1600 Hz.

These results underscore challenges of accurately estimating SL and far-field SPL sound levels for differing frequency ranges from a single transmission loss coefficient.

3.8 Sparker Level B Harassment Acoustic Threshold Review

NMFS regulates impulsive noise sources based on the impulsive source level SL,rms, including determination of mitigation requirements and methods using a 160 dB,rms isopleth for Level B Harassment. Sparker devices produce impulsive sounds that are subject to NMFS' 160 dB,rms limit and are a primary focus of this survey analysis.

NMFS' guidance for determining sparker source peak and RMS levels directs applicants to use source levels provided by Crocker and Fratantonio (2016). In cases where Crocker and Fratantonio (2016) does not provide source peak and RMS levels for the proposed configuration, NMFS recommends applicants use the manufacturer's specification. Finally, if only peak source levels are available, NMFS allows for approximating the source level RMS by subtracting a certain number of decibels from the reported peak values (Table I, S. Labak, pers. comm., 16 August 2019). Figure 21 shows the NMFS 2020 Table I.

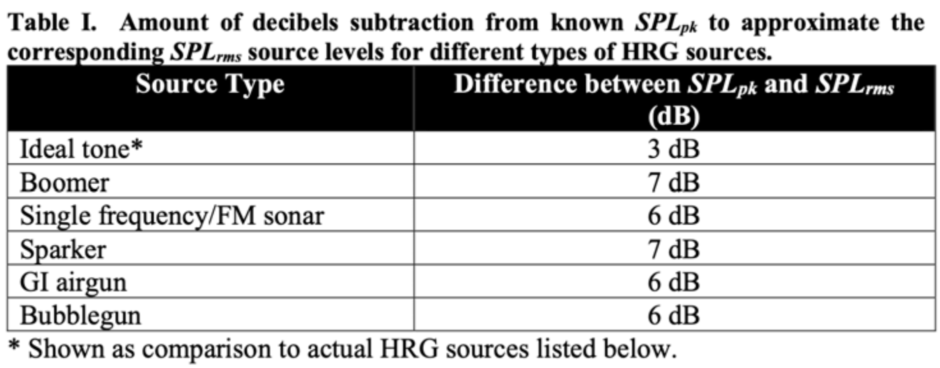

Table I. Amount of decibels subtraction from known SPL_{pk} to approximate the corresponding SPL_{rms} source levels for different types of HRG sources.

Source Type	Difference between SPL_{pk} and SPL_{rms} (dB)
Ideal tone*	3 dB
Boomer	7 dB
Single frequency/FM sonar	6 dB
Sparker	7 dB
GI airgun	6 dB
Bubblegun	6 dB

* Shown as comparison to actual HRG sources listed below.

Figure 21. NMFS 2020, Amount of decibels subtraction from known SPLpk to approximate the corresponding SPLrms source levels for different types of HRG sources.

The IHA application proposed using the Geo-Marine sparker with 400 tips to be energized at 800 Joules. With no equivalent unit defined in Crocker and Fratantonio (2016), the manufacturer's data sheet for the sparker was consulted which showed an acoustic waveform with a peak of 2 Bars/m at 800 Joules [25] (see Attachment B). Applying a standard Bars to decibel conversion, this equates to a SL peak of 226 dB which is consistent with sparker source levels determined from survey measurements (i.e. 224 to 225.2 dB,peak re 1uPa@1m). Applying the NMFS Table I for RMS, the sparker RMS level is 226 – 7 = 219 dB,rms re 1uPa.

The IHA did not follow NMFS' guidance, and instead selected a proxy source from Crocker and Fratantonio (2016) listed at 211 dB,peak and 203 dB,rms which are substantially lower than test data of 2 Bars/m (226 dB re 1uPA@1m) published by manufacturer Geo-Marine for the Geo-Source 400 at 800 Joules.

25 Geo-Marine Geo-Source 400, https://ww2.geosys.nl/products/sparkers/geo-source-400, accessed 9/2/2023.

Nothing in the Geo-Marine data sheets (see Attachment E for analysis) suggests that an SL of 211 dB,peak re 1uPa would be appropriate for a Geo-Source 400 Tips sparker energized at 800 Joules. Similarly, data sheets for the competitor model Applied Acoustics Dura Spark 400 Tips at 600 Joules list an SL,peak of 225.1 dB [26], consistent with the Geo-Marine sparker data.

The difference in SL,rms between the IHA "proxy" sparker and the Geo-Marine sparker prompted review below of the IHA Level B Harassment thresholds for the sparker.

The IHA listed a threshold distance of ***141*** meters for the SL of 203 dB,rms re 1uPa@1m. The IHA spreadsheet is included in Attachment F and copied below in Figure 22.

INPUT VALUES (LEVEL B)		COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
Threshold Level	*160*	alpha (dB/km)	0.00882342
Source Level (dBrms)	*203*	TL coefficient	20
Frequency (kH)	*1*	Slant distance of threshold (m)	**141**
Beamwidth (degree)	*180*	Vertical depth of threshold (m)	8.63376E-15
Water depth (m)	*60*	Horizontal Threshold Range (m)	**141**

Figure 22. IHA application spreadsheet calculation for impulsive Level B harassment threshold isopleth for the IHA listing of the Dual Geo-Spark 2000X 400 Tip, 800 Joule.

Using the same spreadsheet, an input value for 'Source Level (dBrms)' of 219 dB,rms determined previously from the Geo-Marine Geo-Source 400 data sheet (400 tip, 800 Joules) peak rating of 2 Bars/m (226 dB,peak re 1uPa@1m), and the decibel ratio of peak to rms recommended by NMFS rule (7 dB), the resulting Level B harassment threshold isopleth distance is ***890*** meters shown in Figure 23.

INPUT VALUES (LEVEL B)		COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
Threshold Level	*160*	alpha (dB/km)	0.00882342
Source Level (dBrms)	*219*	TL coefficient	20
Frequency (kH)	*1*	Slant distance of threshold (m)	**890**
Beamwidth (degree)	*180*	Vertical depth of threshold (m)	5.44968E-14
Water depth (m)	*60*	Horizontal Threshold Range (m)	**890**

Figure 23. NOAA/NMFS spreadsheet calculation for impulsive Level B harassment threshold isopleth with the Geo-Marine Geo-Source 400 data sheet (400 tip, 800 Joules) and NMFS recommendations of decibel ratio of peak to rms for sparkers, NMFS 2020.

This 160 dB,rms isopleth analysis suggests that the Level B Harassment threshold distances calculated in the IHA application are underestimated. Note: Using a lower RMS level has a direct effect on the distances and methods of acoustic mitigation for protecting marine life.

26 Applied Acoustics Dura Spark UHD Operation Manual, SPK-DURA-8003/1, Lower Deck Typical Dura Spark Pulse Signature at 600J with 400 tips. https://www.subseatechnologies.com/files/2849/ accessed 9/4/23.

3.9 Sparker SEL and Distances to Level B and Level A Thresholds

From professional experience with industrial noise pollution impacts and statistical audio noise dosimetry in power plant environments [27], questions arose during analysis as to the length of time required to breach NOAA/NMFS Level B and Level A thresholds associated to temporary and permanent threshold shifts (TTS and PTS). The cumulative sound exposure level (cSEL) is computed by summation of sound exposure over time exposed to sound level, expressed in dB re 1 µPa2s. The longer the time, the higher the exposure. Two methods were used to estimate the sparker SEL for a 1-second period which is then extrapolated to longer time periods and assessed against distance using NOAA spherical spreading 20log(r).

SEL from manufacturer data: The peak level for the Geo-Marine 400 Tips 800 Joules sparker is 226 dB re 1uPa. The NMFS RMS rule for sparkers subtracts 7 dB from the peak level to obtain the RMS level, 226 – 7 = 219 dB re 1 uPa. The SEL is the SPL,rms + 10log(t), t in seconds. The manufacturer data suggest a pulse width of 2 milliseconds, yielding 291 – 10log(0.002) = 219 – 27 = 192 dB re 1 uPa^2s for one pulse. At a rate of two pulses per second, the 1-second sparker SEL is 192 + 10log(2) = 192 + 3 = 195 dB re 1uPa^s. This value is derived from two clean sparker pulses per second without reflections or reverberation.

SEL from survey data: The sparker SEL level at 0.5 NM (926 meters) was calculated from RMS data at 124.1 dB re 1uPa^2 for one sparker pulse. At a rate of two pulses per second, the 1-second sparker SEL is 124 + 10log(2) = 124 + 3 = 127 dB re 1uPa^2s at 926 meters. It is assumed that the sparker impulsive RMS level follows the sparker peak level and the sparker impulsive transmission loss (TL) coefficient which measured 24.4 dB per decade. The effective sparker source level SEL in the reflective ocean environment, operating at two sparks per second, is estimated at 127 + 24.4log(926) = 127 + 72 = 199 dB re 1uPa^2s.

Reflections and reverberation add energy and increase sound exposure level compared to the close-in, single-pulse test measurement. The increase for the survey-derived sparker source 1-second SEL, dB re 1uPa^2s,1m in the reflective ocean environment compared to the manufacturer-derived clean-pulse, near-field sparker SEL, dB re 1uPa^2s,1m is 199 – 195 = +4 dB. This increase in the reflective ocean environment is in good agreement and consistent with the presence of multiple reflection groups arriving at survey locations.

By contrast, the IHA application for this vessel used a proxy SEL for a single sparker pulse of 173.4 dB, 19 dB lower than the manufacturer-sourced SEL and 23 dB lower than survey measurements for a single sparker pulse SEL.

Using the 1-second SEL of 195 dB re 1 uPa2s developed from manufacturer data and the NMFS peak-to-RMS guidelines, cSEL was estimated for a range of distances and times assuming fixed source and receiver distances. Figure 24 provides a log plot showing exposure times for the LF Cetacean marine species at Level B (TTS) and Level A (PTS) thresholds, 168 dB and 183 dB re 1uPa^2s, respectively. NOAA's spherical spreading 20log(r) is used for plotting exposure times

[27] Teplitsky, AM, Bradley, WE, Rand, RW and Suuronen, DE, "Statistical Audio Dosimetry Methodology", American Speech-Language-Hearing Association, November 1984. Research and work products were developed under contract with the New York Empire State Electric Energy Corporation (ESEERCO).

versus distance. The results match calculations using the NMFS User Spreadsheet Version 2.2 (2020) Tab 'E' (Stationary).

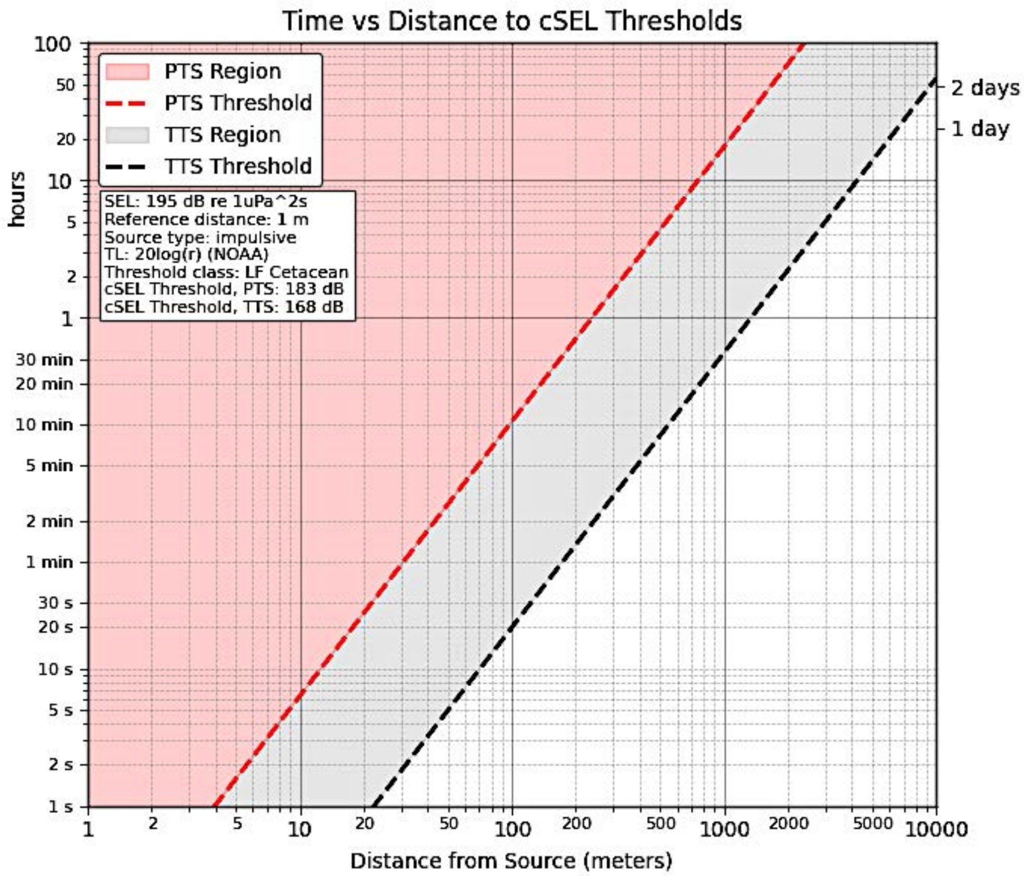

Figure 24. Log plot showing exposure times associated to Level B (TTS) and Level A (PTS) thresholds for the LF Cetacean marine species, 168 dB and 183 dB re 1uPa^2s, respectively, assuming exposure at a fixed position.

Figure 24 illustrates the range of cumulative sound exposure (cSEL) versus distance and time for the 400 Tips/800J sparker operating at 2 pulses per second. For example, a sound exposure of ten minutes at 500 meters yields a cSEL exceeding the TTS threshold (temporary threshold shift, hearing impaired). A sound exposure of five hours at 500 meters yields a cSEL exceeding the Level A PTS threshold (onset of permanent hearing loss). A sound exposure of roughly 25 minutes at the IHA Level B threshold of 141 meters could cause the onset of PTS.

4 Conclusions

This paper presents the methodology, analysis and results of a brief independent investigation of underwater noise levels from a sonar survey vessel, conducted offshore New Jersey on May 8, 2023. The survey results find elevated continuous sound levels at large distances, note disparities between measured sound and IHA equipment listings, and raise concerns about federal acoustic monitoring, noise mitigation, and project oversight.

1. Technical data sheets for the Geo-Marine sub-bottom profiler Geo-Source 400 tip, 800 Joule sparker list 2 Bar/m peak pressure, which is 226 dB,peak re 1uPa@1m, 15 dB higher than the 'proxy' sparker source level (SL) peak of 211 dB re 1uPA taken from Crocker and Fratantonio (2016) for the IHA application.

2. This survey analysis conservatively estimates vessel sparker SL,peak at 224 dB,peak re 1uPa@1m, consistent with Geo-Marine's published SL data.

3. Geo-Marine data sheets don't list the RMS source level. Where sparker SL,peak is available and SL,rms is not available, NFMS recommends using a decibel ratio (peak minus rms) of 7 dB, yielding a sparker SL,rms level of 219 dB re 1uPa@1m.

4. The Level B harassment threshold distance for a sparker SL of 219 dB,rms is 890 meters. Whereas the IHA application used a proxy sparker SL.rms of 203 dB,rms and calculated a Level B harassment threshold distance of 141 meters.

5. Sparker sound exposure level (SEL) determined from Geo-Marine data and NMFS methods was 19 dB higher than the 'proxy' SEL listed in the project IHA application. Survey analysis found measured sparker SEL in the ocean environment another 4 dB above SEL determined from Geo-Marine data. The increase is consistent with multiple sparker echo/reflection groups found in the analysis. Sparker pulse reflections from sea bottom and surface are not factored in NOAA analysis. Cumulative SEL for TTS and PTS impact was plotted for time vs distance for the LF Cetacean (including the critically endangered North Atlantic Right Whale).

6. Several mid-frequency (MF) positioning system sonars (USBL) were measured including two impulsive, intermittent USBLs at 19.5 and 20 KHz, and two FM swept-sine USBLs at 21 to 32 KHz. The four MF USBLs were prominent in their frequency range at 0.5 NM, tens of decibels above the background. Their frequencies are at or near the top hearing sensitivity of cetaceans and phocids. The impulsive MF USBLs measured 131 dB,peak and 117.5 dB,rms at 0.5 NM. The USBLs were not listed or analyzed in the IHA application. USBLs are necessary components for geophysical surveying towing a hydrophone array. It is unclear why NMFS did not require impulse analysis for these sonars.

7. HF sub bottom profilers (SBPs) operating above 85 KHz, if any, could not be acquired during this survey.

8. The IHA application spreadsheets did not show calculations of a Zone of Influence (ZOI) for the 120-dB Level B harassment threshold for continuous noise. The IHA application did not evaluate vessel propulsion, DP thruster or combined continuous noise levels by vessel operations in the lease area. The IHA application treated the vessel as if it were silent.

9. Vessel-only *continuous* noise at 0.5 NM (126.5 dB,rms unweighted) exceeds the NMFS behavioral harassment threshold of 120 dB,rms for continuous noise. DP thruster noise appears to be a significant, even primary contributor to overall vessel noise levels. Total operations noise including sparker was 128.5 dB,rms re 1uPA at 0.5 NM (120s sample).

10. In order to meet the NMFS 120 dB,rms behavioral harassment limit for *continuous* noise, the distance required is approximately 1 nautical mile.

11. NMFS appears to have abandoned evaluation of Level B behavioral harassment at 120 dB,rms.

12. Level A harassment due to cumulative SEL appears feasible depending on time periods occupied at various distances to the sparker. It is unclear that the mitigation methods set in place are adequate to protect the NARW and other ESA-listed mammals and marine species.

13. The results from the survey underscore that absent continuous near-field acoustic monitoring and operations monitoring, NMFS cannot know what noise emissions are occurring during vessel operations. Disparities between IHA application data and the equipment acoustic signatures detected during the survey are concerning. The results suggest a need for comprehensive acoustic monitoring and management of survey equipment prior to and during survey operations.

Limitations

Sonar equipment in the project IHA application was listed as "Proposed". The vessel surveyed (a sister-vessel substitute for the vessel listed in the IHA application) may be outfitted with sonars from different manufacturers and models, with noise levels emissions at other frequencies and levels, than reviewed and approved in the IHA permit.

Geophysical sonar equipment listed for the vessel operating above 85 KHz, if present, was not measured as it was above instrumentation range.

Survey recordings at 4 NM were set aside generally due to increased sea state and wave slap on the investigator boat hull at the time of the 4-nm data acquisition. Vessel tonal noise in the 1600 Hz one third octave band was usable.

Source Level SL estimations from far field measurements can differ significantly depending on the sound attenuation versus distance. Sound attenuation with distance underwater could differ from the results found during this survey depending on factors including absorption and scattering, winter versus summer sound speed gradients, thermocline strength, sea state, and sea bottom absorption and reflectivity. Increased TL at upper frequencies are generally due to increased excess attenuation at higher frequencies, which is expected for the distances measured and shallow-water acoustic conditions above 3000 Hz. The May time of year, the presence of a shallow seasonal thermocline at 18 to 23 meters, and the measured attenuation of 24.4 dB per decade that is steeper than the standard 20 dB per decade all suggest sound attenuation measured during the survey is closer to a summer condition than a winter condition.

Declaration of Conflicting Interests

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this report. INCE Members are required by professional ethics to ensure compliance with regulatory requirements and hold paramount the safety, health and welfare of the public. The author extends the same professional commitments to marine species.

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Acknowledgements

Many thanks to investigator boat captain Brian and trip coordinator Greg for a safe and successful voyage out of Barnegat Light, NJ. Many thanks to Adam Sniff P.E. of Cetacean Research Technology and Richard Craig at BRC Engineering for consultation and support with system design and calibration, and John Pattee of Pioneer Software LLC for review of rms calculations. Many thanks to the anonymous reviewer who provided invaluable proofreading and helpful comments.

5 Attachments

Attachment A: Vessel acoustic equipment proposed in project IHA application.

Table 1-3 Proposed Acoustic Equipment for HRG Surveys for the Project

Equipment Type	Equipment Make/Model	Operating Frequency (kHz)	Source Level (RMS dB re 1 µPa @1m)	Source Level (Peak dB re 1 µPa @1m)	Sound Exposure Level (dB re 1µPa²-s; NR=not reported)	Reference for Source Level	Pulse Duration (milliseconds)	Repetition Rate (Hz)	Beam Width (degrees)
Mobile, Non-impulsive, Intermittent									
Side-Scan Sonar	EdgeTech 4205	300/600 or 300/900	NR	NR	NR	NR	NR	NR	50
Multi-beam Echosounder	Dual head Norbit Winghead	400	NR	NR	NR	NR	NR	60	NR
Gradiometer/ Altimeter*	Geometrics G882	200	190	192	NR	Crocker and Fratantonio 2016†	1.13	50	7
Shallow SBP	Innomar SES-2000	85-115	241	247	NR	Manufacturer	2	40	2
Mobile, Impulsive									
Deep SBP	Dual Geo-Spark 2000X (400 tip/800 J)	0.3–1.2	203	211	174	Crocker and Fratantonio 2016‡	1.1	4	180

*Acoustic specification applies to the optional altimeter on the gradiometer.

†Odom Echo Trac Proxy

‡Applied Acoustics Dura-spark 500 J to 2,000 J Proxy

Key:

NR – Not reported

SBP – sub-bottom profiler

Hz – hertz

kHz – kilohertz

µPa – microPascal

RMS – root mean square

dB – decibel

re – referenced at

m – meters

s – seconds

Table 1-4 Level A and Level B Threshold Distances for the Proposed Sub-Bottom Profilers

Equipment Make/Model	Distance to 160 dB (m)	Horizontal Distance to 160 dB (m)	Distance to Level A Isopleth (m)				Distance to Level B Isopleth (m)
			Low Frequency	Mid Frequency	High Frequency	Pinnipeds	All
Innomar SES-2000	116	1.05	<1	<1	135.9	<1	1.05
Dual Geo-Spark 2000X (400 tip/800 J)	141	141	<1	<1	2.8*	<1	141

Level A distances are based on the SELcum threshold unless denoted with *, in which case it is based on the Peak threshold (higher of the two values is shown).

Key:

m – meters

J - joules

dB – decibels

Attachment B. Geo-Marine Geo-Source 400 sparker data sheet

GEO
MARINE SURVEY SYSTEMS

Geo-Source 400

MARINE MULTI-TIP SPARKER SYSTEM

Versatile maintenance free negative discharge sparker designed for small and larger operations.

Description

INNOVATIVE PRESERVING ELECTRODE MODE
The Geo-Source 400 is designed to operate with the 2000 X Geo-Spark Pulsed Power Supply or higher. It uses the the "Preserving Electrode Mode", a patented concept that consists of using a NEGATIVE electric discharge pulse, instead of positive.

Note that working with a negative pulse is NOT the same thing as reversing the polarity of an antique power supply, which is generating a positive pulse.

MAINTENANCE FREE ELECTRODES 5 YEAR GUARANTEE
The Preserving Electrode Mode reduces the tip wear to practically zero. You can shoot day after day, week after week, month after month with practically NO tip maintenance.

OPTIMUM ACOUSTIC REPEATABILITY
Zero tip wear is essential for the repeatability of the acoustic pulse, which depends largely on a constant, unaltered electrode surface.

Operational Features

→ Water depths from 2 to 1500 m.

→ Penetration higher than 400 ms below seabed depending on geology.

→ Vertical resolution of 10 - 30 cm.

→ You don't need to trim tips during the survey - electrodes do NOT burn off.

→ Successfully employed in wind farm surveying, coastal engineering, sand search, site and route surveys and many others.

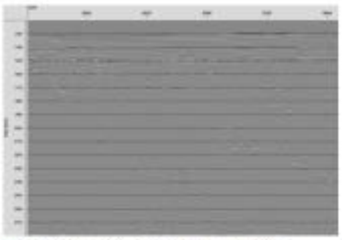
geo-spark.com

Attachment B (cont.) Geo-Marine Geo-Source 400 sparker data sheet

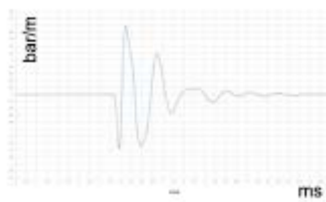
MARINE SURVEY SYSTEMS

Geo-Source 400

MARINE MULTI-TIP SPARKER SYSTEM



Geo Spark 400 with a 48 ch Multi-channel streamer - see more examples at our gallery.



signal spectrum at 800 J and source 30 cm deep.

No wear of the tips even after 3 years of use.

Additional Features

CONTROL OF ALL SPARKER PARAMETERS
The effective source depth is 15-20 cm. A constant source depth at 1/4 of the wavelength is essential in order to optimize the constructive interference between the primary pulse and surface ghost. But this can be easily customized by the user with the use of extensions, for instance, in situations where penetration should be a priority.

SOURCE GEOMETRY AND CONFIGURATION OF THE TIPS
The electrode modules are evenly spaced in a planar array of 0.50 m x 1.00 m. This geometry not only enhances the downward projection of the acoustic energy, it also reduces the primary pulse length, since all tips are perfectly in phase. Each tip has an exposed surface of 1.4 mm, suitable for maximum 10 Joules per tip and with this configuration it gives an excellent pulse over the 400 - 2000 Joule power range.

FLEXIBLE AND FLOATING HV TOW CABLE
The Geo-Source 400 is towed by a very high quality, Kevlar reinforced, coaxial power/tow cable with stainless steel kellum grip. This dedicated high voltage (HV) cable contains 4 × 10 mm^2 cores (negative) plus a 40 mm braiding (ground-referenced). It is designed to have a very low self inductance to preserve the high dI/dt pulse output of the Geo-Spark 2000 PPS. The coaxial structure of the HV cable reduces the electromagnetic interference to the absolute minimum.

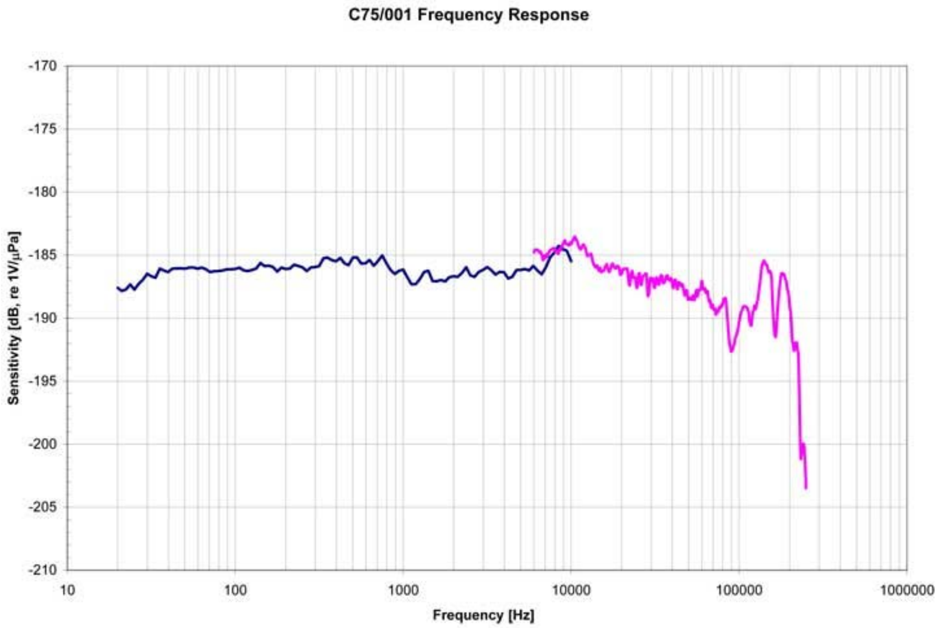
Specification

Dimensions (cm) & Weight	110 (L) x 120 (W) x 60 (H) for 80 kg
Number of Tips	400
Operation Depth (m)	2 - 1500
Dominant Frequencies	1000 - 1500 Hz (at 800 J)
Better if used with	Geo-Spark 2000, 8E single-channel Streamer, multi-channel streamer
Recommended interface system	Mini-Trace II or Multi-Trace Server
Power Requirements	5kVA generator (for the Power Supply)

We are always pushing for improvements, so equipment specifications can change without notice. Please keep in contact with support to stay in tune with the developments.

geo-spark.com

Attachment C. Cetacean Research hydrophone frequency response (manufacturer test).



Attachment D. GRAS Model 42AG Acoustic Calibrator calibration certificate.

Calibration Chart

GRAS 42AG Multifunction Sound Calibrator, Class 1

Serial No. 281474

Calibration date 14. Feb, 2023

Operator ZBA

Environmental calibration conditions
Temperature 23 °C
Relative humidity 44 %
Barometric pressure 1030 hPa

	Nominal Frequency [Hz]	Measured SPL [dB re. 20 uPa]	Measured Frequency [Hz]	Measured THD [%]	Measured THD + Noise [%]	Status
Tolerance		±0.20	±0.30	1.5	2.0	
Uncertainty		±0.08	±0.02	±0.1	±0.1	
94 dB	251.19	94.00	251.20	0.08	1.03	Pass
114 dB	251.19	114.02	251.20	0.13	0.23	Pass
94 dB	1000	94.02	1000.00	0.01	1.47	Pass
114 dB	1000	114.02	1000.00	0.02	0.13	Pass

Calibration
The performed tests refer to the sections 5.2, 5.3 and 5.5 in IEC 60942 (2003): Electroacoustics - Sound Calibrators. The calibrator has been tested ad described in Annex B of the IEC 60942 standard.

Approved by

Quality Manager

14. Feb, 2023
Date

GRAS Sound & Vibration

GRAS Sound & Vibration A/S
Skovlytoften 33, 2840 Holte, Denmark
Email support@gras.dk · gras.dk

Attachment D (continued). BRC hydrophone adapter calibration certificate.

BRC Engineering

21870 Eighth St. E.
Unit # C-4
Sonoma, CA 95476

Tel: 707-226-3332
Fax: 707-236-8964
E-Mail: brcnorcal@aol.com

Specialists in Noise & Vibration Measurement & Analysis

CALIBRATION CHART for TYPE HADP42AG-C75 S/N: 65506

Hydrophone Adapter for Calibrator Type # 42AG used to

Calibrate CETACEAN Hydrophone Type # C75

Pressure Correction Factor: +0 dB +/- 0.5 dB at reference conditions

Nominal Frequency: 250 Hz

There is no pressure correction factor for the HADP42AG-C75. The sound pressure level inside the adapter is determined by the pressure level chosen on the G.R.A.S. 42AG, either:

1 Pa or 94 dB re 20 microPa or 120 dB re 1 microPa

or

10 Pa or 114 dB re 20 microPa or 140 dB re 1 microPa

Note: 250 Hz preferred for best accuracy.

Reference Conditions:

Ambient Temperature: 14.7 C
Ambient Static Pressure: 101.0 kPa
Relative Humidity: 64%

Reference Equipment:

Calibrator Type: G.R.A.S. # 42AG
Microphone Type: LD Type 377B02
Hydrophone Type: C-75

Approved by: Richard Craig

Signature

Date: May 3, 2023

Attachment E. Sparker Data Review

The IHA application listed the "Geo-Marine Dual Geo-Spark 2000X" (400 tip/800 J) in the sparker identification field. The model 2000X is the power supply for the sparker. The power supply doesn't emit sound underwater. It's housed in a weather-proof work shed on deck and supplies voltage to the sparker. The sparker (Geo-Source 400 Tips) is towed behind the vessel in a sled with a strong tow cable and is connected to the power supply with electrical cable. The sparker is energized at the listed Joules level. Figure E-1 shows the Geo-Marine 2000X power supply (left) and the Geo-Marine 400 sparker (right).

Figure E-1. Geo-Marine Dual Geo-Spark 2000X Power Supply (left) and Geo-Source 400 sparker sled (right).

The Geo-Marine Geo-Source 400 data sheet shows an acoustic waveform with a peak of 2 Bars/m at 800 Joules [28]. This is the configuration listed in the IHA application (400 tip / 800 Joules). Determining SL in dB re 1uPA requires conversion from Bars to pascals (1 Bar = 100,000 Pa) and then to decibels re 1uPA, that is, 20 * log10(2* 100,000/0.000001) = **226** dB re 1uPa@1m. This report's sparker SL estimates of 224 to 225.2 dB,peak re 1uPa@1m are consistent with the manufacturer's published data.

Bracketing the Geo-Source 400, the smaller Geo-Marine Geo-Source 200 data sheet (200 tip) shows a test waveform with a peak of 0.91 Bars/m at 300 Joules, equivalent to **219.2** dB,peak re 1uPa@1m [29]. The larger Geo-Marine Geo-Source 800 data sheet (800 tip) shows a test waveform with a peak of 2.2 Bars/m at 6000 Joules, equivalent to **226.8** dB,peak re 1uPa@1m [30].

Nothing in the Geo-Marine data sheets suggests that an SL of 211 dB,peak re 1uPa would be appropriate for a Geo-Source 400 Tips sparker energized at 800 Joules. Similarly, data sheets for

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28 Geo-Marine Geo-Source 400, https://ww2.geosys.nl/products/sparkers/geo-source-400, accessed 9/2/2023.
29 Geo-Marine Geo-Source 200, https://ww2.geosys.nl/products/sparkers/geo-source-200, accessed 9/2/2023.
30 Geo-Marine Geo-Source 800, https://ww2.geosys.nl/products/sparkers/geo-source-800, accessed 9/2/2023.

the competitor model Applied Acoustics Dura Spark 400 Tips at 600 Joules list an SL,peak of 225.1 dB, consistent with the Geo-Marine sparker data.

Figure E-2 shows sparker SL,peak sound level output by input in Joules for 1) the Geo-Marine and Applied Acoustics Dura-Spark manufacturer data sheets, and 2) the test data in Crocker and Fratantonio (2016) Table 10.

The Geo-Marine manufacturer's data for the Geo-Source 400 Tips at 800 Joules is shown with blue dot. The Applied Acoustics manufacturer's data for the Dura-Spark 400 Tips at 600 Joules (lower sled) is shown with orange dot.

By inspection, the 'proxy' sparker source peak sound level selected for the IHA application is much lower than the manufacturer data, and lower than most data in Crocker and Fratantonio (2016) Table 10.

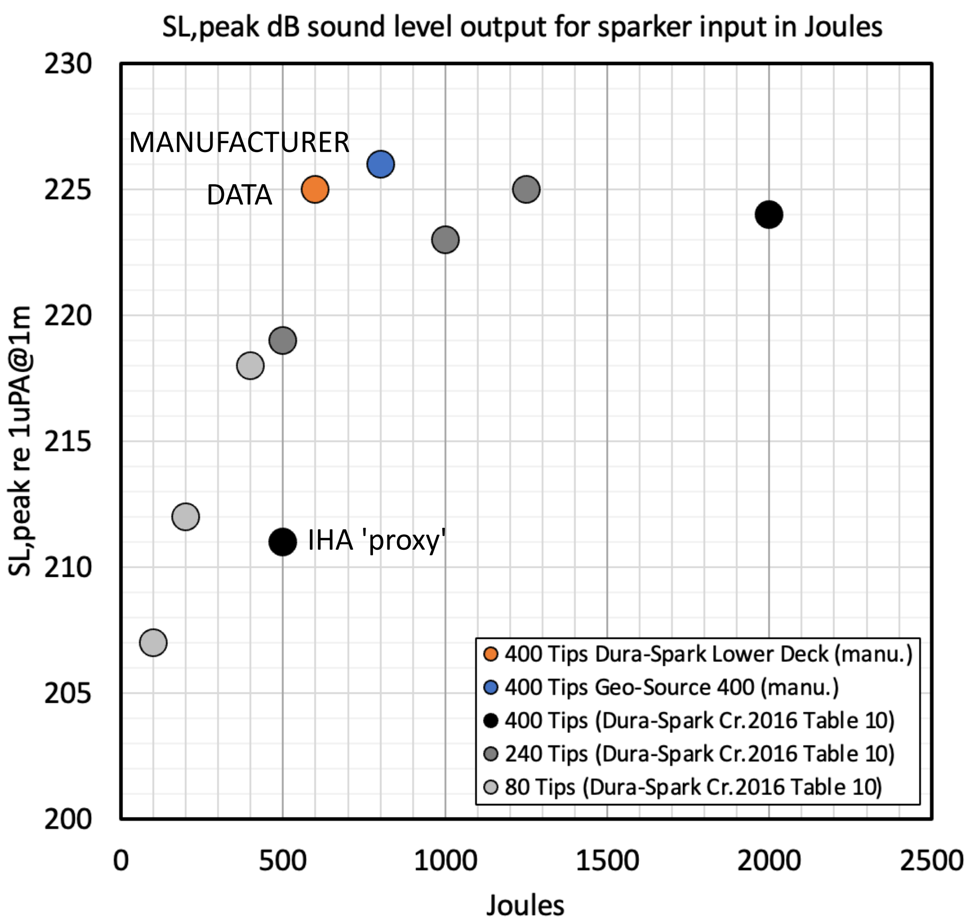

Figure E-2. Sparker SL,peak sound level output by input in Joules for 1) the Geo-Marine and Applied Acoustics Dura-Spark manufacturer data sheets, and 2) the test data in Crocker and Fratantonio (2016) Table 10.

Attachment F. IHA Appendix B Spreadsheet Results

Application for Incidental Harassment Authorization for the Non-Lethal Taking of Marine Mammals during a Site Characterization Survey

F: MOBILE SOURCE: Impulsive, Intermittent ("SAFE DISTANCE" METHODOLOGY)

VERSION 2.2: 2020

KEY

- Action Proponent Provided Information
- NMFS Provided Information (Technical Guidance)
- Resultant Isopleth

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Attentive Energy HRG Surveys
PROJECT/SOURCE INFORMATION	Dual Geo-Spark 2000X (400 tip/800J)
Please include any assumptions	
PROJECT CONTACT	Sarah Courbis/Melissa Snover

STEP 2: WEIGHTING FACTOR ADJUSTMENT

		Specify if relying on source-specific
Weighting Factor Adjustment (kHz)¥	1	NMFS recommended

¥ Broadband: 95% frequency contour percentile (kHz); For appropriate default WFA: See INTRODUCTION tab

CONVERSIONS

Source Level ($L_{p,pk-pk}$)			
Source Level ($L_{p,0-pk}$)	-6	Source Level ($L_{p,0-pk}$)	
Source Level (L_{rms})	-12	Source Level (L_{rms})	-6
Source Level ($L_{E,p, single shot}$)	-22	Source Level ($L_{E,p, single shot}$)	-16

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 68), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: METHOD F1 is PREFERRED method when SEL-based source levels are available (because pulse duration is not required). Only use method F2 if SEL-based source levels are not available.

F1: METHOD† TO CALCULATE PK and SEL_{cum} (SINGLE SHOT/PULSE EQUIVALENT) **PREFERRED METHOD (pulse duration not needed)**

SEL_{cum}

Source Level ($L_{E,p, single ping/pulse/shot}$)	173.4
Source Velocity (meters/second)	2.06
1/Repetition rate^ (seconds)	0.25
Source Factor	8.75105E+17

loss of 20 log R; Activity duration (time)

^Time between onset of successive pulses (inverse of repetition rate or inter-pulse interval)

PK

Source Level ($L_{p,0-pk}$)		211

NOTE: The User Spreadsheet tool provides a means to estimates distances associated with the Technical Guidance's PTS onset thresholds. Mitigation and monitoring requirements associated with a Marine Mammal Protection Act (MMPA) authorization or an Endangered Species Act (ESA) consultation or permit are independent management decisions made in the context of the proposed activity and comprehensive effects analysis, and are beyond the scope of the Technical Guidance and the User Spreadsheet tool.

RESULTANT ISOPLETHS*

*Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	0.7	0.0	0.1	0.1	0.0
PK Threshold	219	230	202	218	232
PTS PK Isopleth to threshold (meters)	NA	NA	2.8	NA	NA

"NA": PK source level is ≤ to the threshold for that marine mammal hearing group.

Application for Incidental Harassment Authorization for the Non-Lethal Taking of Marine Mammals during a Site Characterization Survey

	A	B	C
1	Slant Distance	TL	RL
2	1	8.82E-06	203
3	2	6.020618	196.9794
4	3	9.542452	193.4575
5	4	12.04124	190.9588
6	5	13.97944	189.0206
7	6	15.56308	187.4369
8	7	16.90202	186.098
9	8	18.06187	184.9381
10	9	19.08493	183.9151
11	10	20.00009	182.9999
12	11	20.82795	182.172
13	12	21.58373	181.4163
14	13	22.27898	180.721
15	14	22.92268	180.0773
16	15	23.52196	179.478
17	16	24.08254	178.9175
18	17	24.60913	178.3909
19	18	25.10561	177.8944
20	19	25.57524	177.4248

Source Name:

INPUT VALUES (LEVEL B)	
Threshold Level	160
Source Level (dBrms)	203
Frequency (kH)	1
Beamwidth (degree)	180
Water depth (m)	60

COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
alpha (dB/km)	0.00882342
TL coefficient	20
Slant distance of threshold (m)	**141**
Vertical depth of threshold (m)	8.6373E-15
Horizontal threshold range (m)	**141**

Level B

Ready

Attachment F (continued). IHA Appendix B Spreadsheet Results

D: MOBILE SOURCE: Non-Impulsive, Intermittent ("SAFE DISTANCE" METHODOLOGY)

VERSION 2.2: 2020

KEY

(green)	Action Proponent Provided Information
(pink)	NMFS Provided Information (Technical Guidance)
(blue)	Resultant Isopleth

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Attentive Energy HRG Survey
PROJECT/SOURCE INFORMATION	Innomar Sub-Bottom Profiler

Please include any assumptions

PROJECT CONTACT	Sarah Courbis/Melissa Snover

STEP 2: WEIGHTING FACTOR ADJUSTMENT

Weighting Factor Adjustment (kHz)¥	85	Lower end of source-specific operation frequeny range

alternative weighting/dB adjustment, or if

¥ Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 61), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: METHOD D1 is PREFERRED method when SEL-based source levels are available (because pulse duration is not required). Only use method D2 if SEL-based source levels are not available.

D1: METHOD† (SINGLE PING/PULSE EQUIVALENT) PREFERRED METHOD (pulse duration not required)

Source Level ($L_{E,p,\text{ single ping/pulse}}$)	178
Source Velocity (meters/second)	2.06
1/Repetition rate* (seconds)	0.025
Source Factor	2.52383E+19

†Methodology assumes propagation loss of 20 log R; Activity duration (time) independent
* Time between onset of successive pulses (inverse of repetition rate or inter-pulse interval).

NOTE: The User Spreadsheet tool provides a means to estimates distances associated with the Technical Guidance's PTS onset thresholds. Mitigation and monitoring requirements associated with a Marine Mammal Protection Act (MMPA) authorization or an Endangered Species Act (ESA) consultation or permit are independent management decisions made in the context of the proposed activity and comprehensive effects analysis, and are beyond the scope of the Technical Guidance and the User Spreadsheet tool.

RESULTANT ISOPLETHS

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	199	198	173	201	219
PTS Isopleth to threshold (meters)	0.0	0.3	135.9	0.0	0.0