Cumulative and Chronic Effects in the Gulf of Mexico

Addendum: Estimating Reduction of Listening Area and Communication Space due to Seismic Activities in Support of the BOEM Geological and Geophysical Activities Draft Programmatic Environmental Impact Statement

Submitted to:

Jolie Harrison
National Oceanic and Atmospheric Association

Authors:

Marie-Noël R. Matthews
Héloïse Frouin-Mouy
David G. Zeddies

29 November 2017

P001367-002
Document 01510
Version 1.0

JASCO Applied Sciences (Canada) Ltd
Suite 202, 32 Troop Ave.
Dartmouth, NS B3B 1Z1 Canada
Tel: +1-902-405-3336
Fax: +1-902-405-3337
www.jasco.com

Suggested citation:

Matthews, M-N.R., H. Frouin-Mouy, and D. Zeddies. 2017. *Cumulative and Chronic Effects in the Gulf of Mexico: Addendum: Estimating Reduction of Listening Area and Communication Space due to Seismic Activities in Support of the BOEM Geological and Geophysical Activities Draft Programmatic Environmental Impact Statement*. Document 01510, Version 1.0. Technical report by JASCO Applied Sciences for National Oceanic and Atmospheric Association.

Disclaimer:

Contents

Figures

Tables

1. Introduction

This addendum study evaluates potential chronic and cumulative effects to marine mammals from noise exposures caused by oil and gas exploration activities in the Gulf of Mexico, in support of the Bureau of Ocean Energy Management (BOEM) Geological and Geophysical Activities Draft Programmatic Environmental Impact Statement (G&G EIS). In this addendum, the methods for calculating a change in communication space by Clark et al. (2009) are applied to sperm whales (*Physeter macrocephalus*).

In the previous assessment, JASCO presented a framework to calculate cumulative sound exposure levels (SEL) produced by large numbers of geographically distributed acoustic sources, such as seismic pulses from multiple seismic surveys using airgun arrays (Matthews et al. 2015). SEL were calculated for several scenarios for one full year of exploration activities in the Gulf at ten receiver sites (Table 1, Figure 1). Several species were considered, with a variety of hearing acuities and frequency-dependent sensitivities. Twenty-one cetacean species are listed in Appendix D of the G&G EIS (BOEM 2016), including low-, mid-, and high-frequency cetaceans, and the corresponding M-weighting filters defined by Southall et al. (2007) were applied to assess changes in listening areas. Bryde's whales, the most common mysticete in the Gulf, was previously selected for a communication space assessment. This addendum study focuses on sperm whales, the only endangered cetacean in the Gulf of Mexico. Sperm whales are mid-frequency cetaceans, and changes in listening area for mid-frequency cetaceans were presented in the associated report (Matthews et al. 2015). Here, we estimate changes in communication space based on male sperm whale slow-clicks (Madsen et al. 2002).

Table 1. Modeled receiver site locations and water depths.

Site	Receiver site	Latitude	Longitude	Water depth (m)
1	Western Gulf	27.01606	−95.7405	842
2	Florida Escarpment	25.95807	−84.6956	693
3	Midwestern Gulf	27.43300	−92.1200	830
4	Sperm Whale Site	24.34771	−83.7727	1053
5	Deep Offshore	27.64026	−87.0285	3050
6	Mississippi Canyon	28.15455	−89.3971	1106
7	Bryde's Whale Site	28.74043	−85.7302	212
8	De Soto Canyon	29.14145	−87.1762	919
9	Flower Garden Banks National Marine Sanctuary	27.86713	−93.8259	88
10	Bottlenose Dolphin Site	29.40526	−93.3247	12

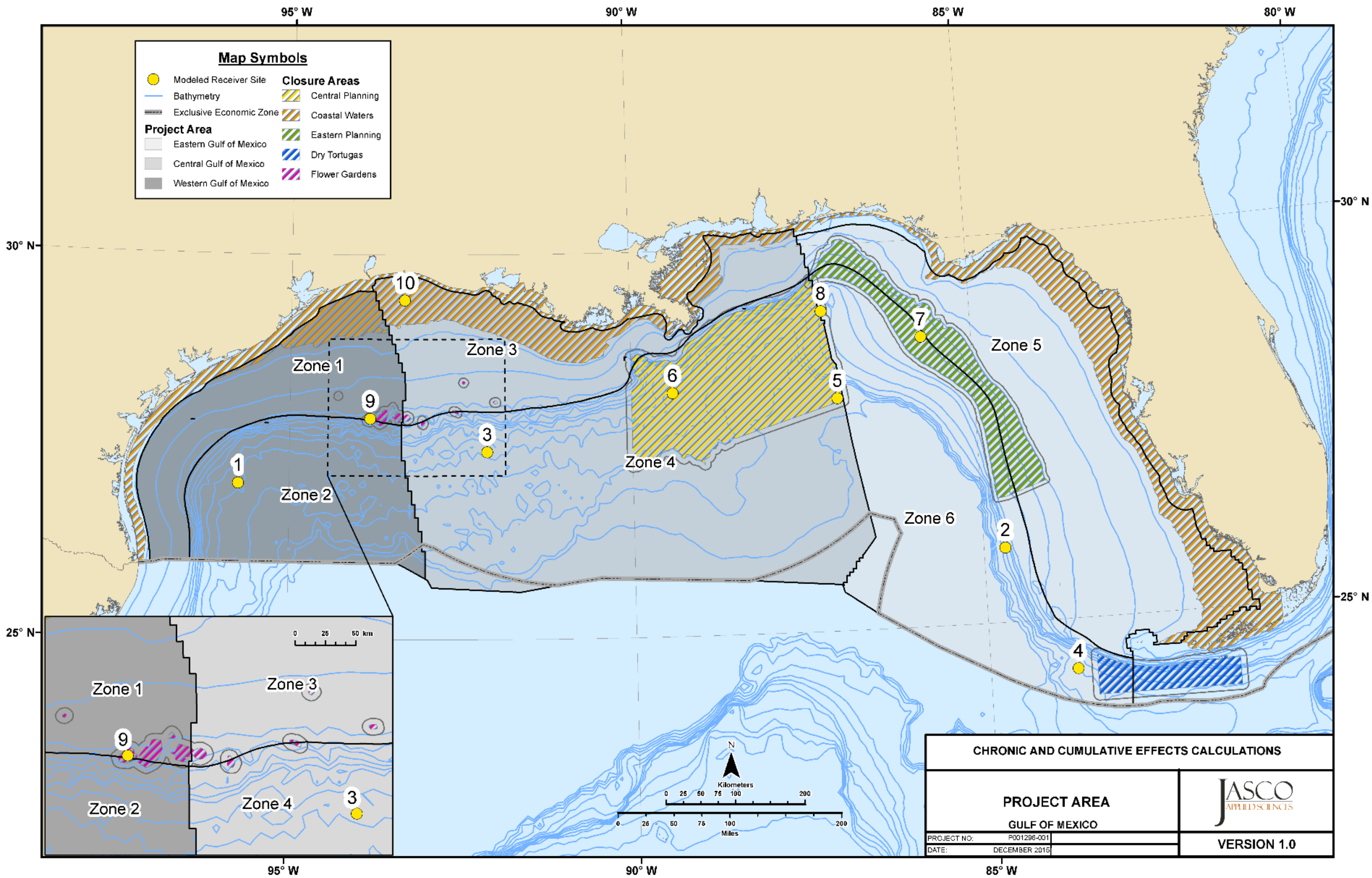

Figure 1. G&G EIS project area with ten modeled receiver sites (yellow dots), project management zones (grey shaded areas), activity zones (1–6), and closure areas (hashed areas). The inset shows a close up of the Flower Gardens closure area.

2. Methodology

2.1. Sperm Whale Communication Space

A communication space assessment considers the region of ocean within which marine fauna can detect calls from conspecifics. Masking can be defined as a reduction in communication space that an individual experiences due to an increase in background noise in the frequency bands relevant for communicating. Reduction in communication space due to anthropogenic sound cannot be determined based on broadband SEL because the effect depends on the noise levels within each frequency band of the vocalizations, and these noise levels vary with receiver distance from the noise source. To estimate the communication space quantitatively, it is necessary to account for parameters such as call source levels, detection thresholds (based on the receiver perception capabilities), signal directivity, band-specific (spectral) noise levels, noise duration, and signal duration.

The communication space for sperm whales is estimated using a similar approach to that employed by Clark et al. (2009). This approach calculates the horizontal area in square kilometers over which a call can be detected, recognizing that the true call could originate within a 3-D volume of ocean. The primary difference between our approach and Clark et al.'s is that we apply the analysis in a single representative 1/3-octave-band rather than to broadband levels. This approach is based on a form of the sonar equation that considers the maximum distance an animal can detect a signal in the presence of masking noise. The form of the sonar equation employed here is:

$$SE = SL - TL - NL - DT + DI + SG \ . \tag{1}$$

The signal excess (*SE*) is the signal excess above detectability. The source level (*SL*) is the source level of the animal call. *TL* is the acoustic transmission loss between the calling sperm whale and the that is listening (a function of the distance of their separation). *NL* is the noise level in the same frequency band as the source level. *DT* is the detection threshold of the animal, representing the amount above ambient level the sound must be in order for it to be detected. The directivity index (*DI*) represents the animal's ability to discriminate sounds coming from a specific direction, in the presence of masking noise arriving uniformly from all directions. *SG* is the signal gain that indicates the ability of the animal to use its knowledge of the time-frequency structure of the call to differentiate it from background noise.

2.2. Baseline Levels

To estimate changes in communication space for various levels of seismic activities, we calculate a baseline noise level containing mainly commercial shipping noise and natural sounds produced mostly by wind and breaking waves. The commercial shipping noise levels were obtained from the SoundMap mapping tool (SoundMap Working Group 2011). SoundMap provides commercial shipping noise levels in the Gulf of Mexico in 1/3-octave frequency bands between 50 and 800 Hz. Natural levels are calculated from the formulas of Wenz (1962) and Cato (2008) for a wind speed of 8.5 knots. The natural noise levels are added to all available vessel noise levels to generate composite 1/3-octave-band baseline levels between 10 Hz and 5000 Hz. Since no data for commercial shipping noise were available outside the frequency range of the SoundMap results, shipping noise outside the 50–800 Hz bands is excluded (Figures 2–4).

One-third-octave-band baseline levels vary between 75.6 and 94.1 dB re 1 µPa, depending on the receiver location, the receiver depth, and the frequency. Baseline levels in the 3150 Hz 1/3-octave-band, estimated at 82.0 dB re 1 µPa across the study area, are used to calculate sperm whale communication space under Alternative A (Baseline: no seismic survey activities).

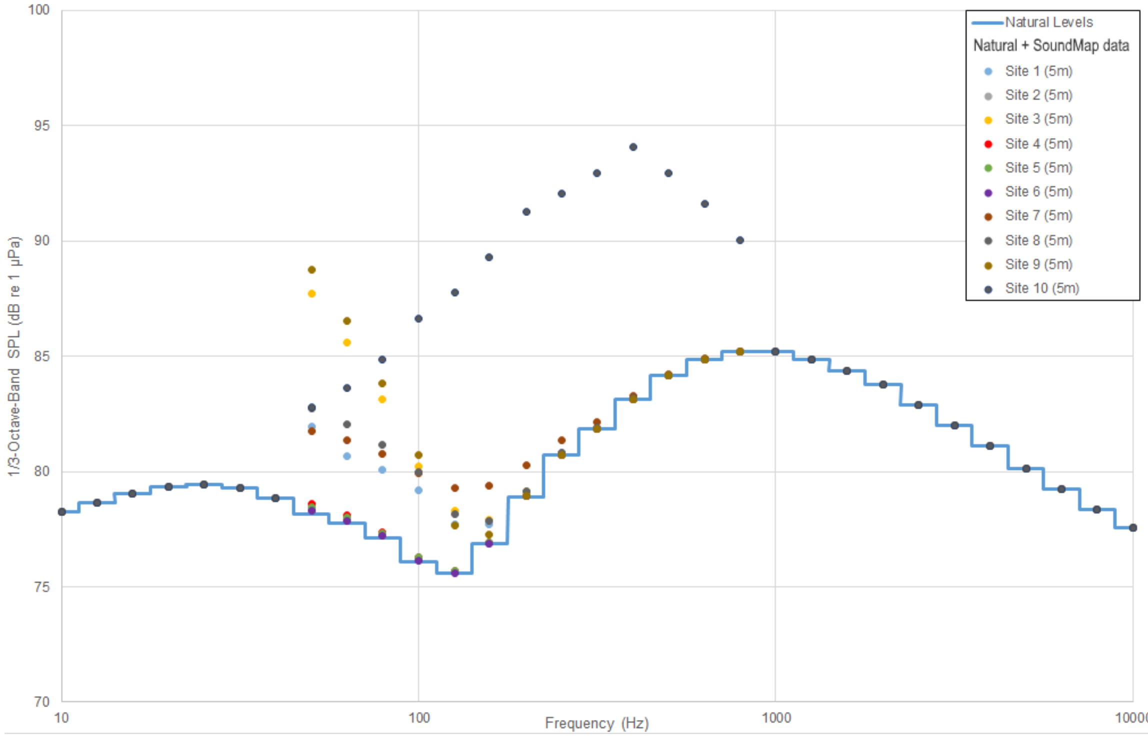

Figure 2. Receiver depth of 5 m: 1/3-octave-band baseline noise levels at each site. The natural interpolated sound levels (blue line; Wenz 1962, Cato 2008) and SoundMap data were summed for frequency bands between 50 and 800 Hz. Beyond these limits the interpolated natural levels were used.

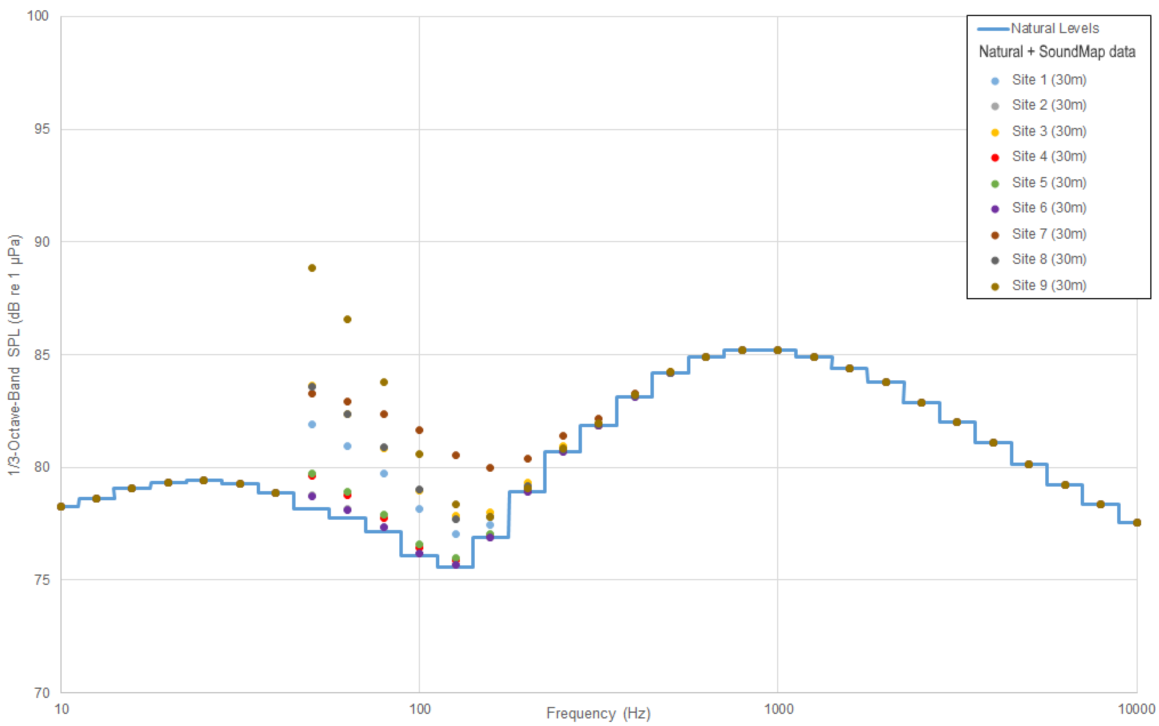

Figure 3. Receiver depth of 30 m: 1/3-octave-band baseline noise levels at each site. The natural interpolated sound levels (blue line; Wenz 1962, Cato 2008) and SoundMap data were summed for frequency bands between 50 and 800 Hz. Beyond these limits the interpolated natural levels were used. Note that not all sites have a water depth reaching this receiver depth.

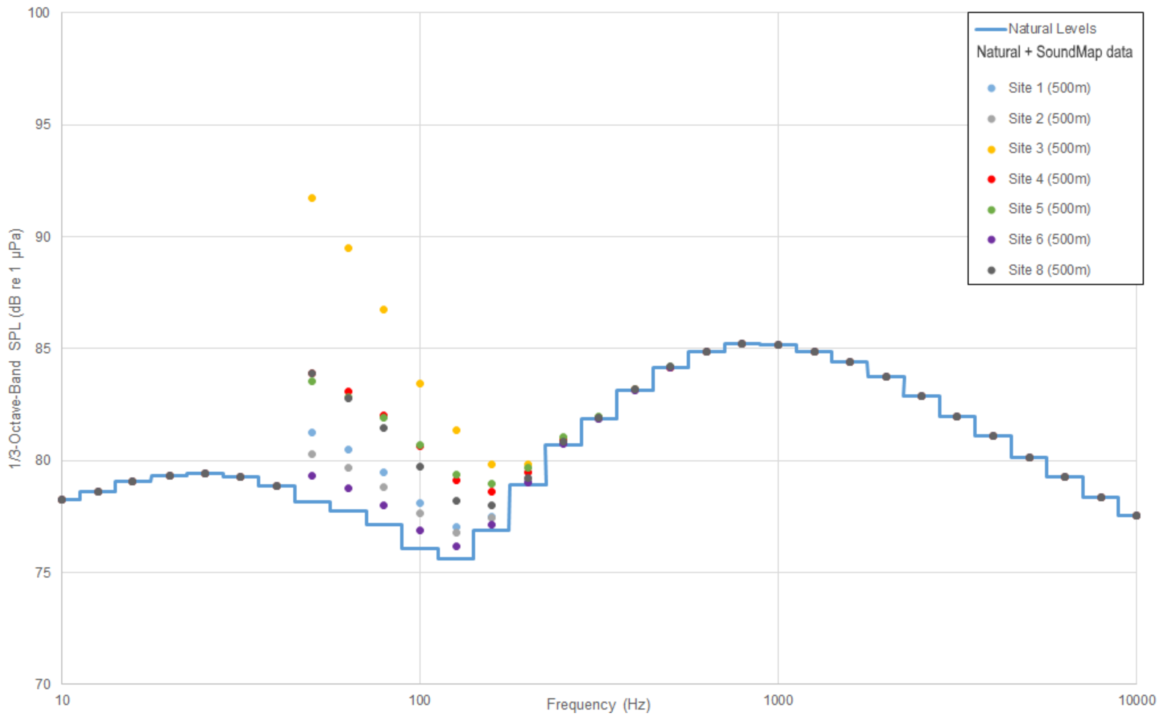

Figure 4. Receiver depth of 500 m: 1/3-octave-band baseline noise levels at each site. The natural interpolated sound levels (blue line; Wenz 1962, Cato 2008) and SoundMap data were summed for frequency bands between 50 and 800 Hz. Beyond these limits the interpolated natural levels were used. Note that not all sites have a water depth reaching this receiver depth.

3. Modeled Parameters

Sperm whales produce at least four types of clicks: usual clicks, buzzes (also called creaks), codas (patterns of 3–20 clicks), and slow-clicks (or clangs). Oliveira et al. (2013) demonstrates that sperm whales on feeding grounds emit slow-clicks in seemingly repetitive temporal patterns. This supports the hypothesis that their function is long range communication between males, possibly relaying information about individual identity or behavioral states.

A representative source level is estimated from male sperm whale slow-clicks reported by (Madsen et al. 2002). These calls have an estimated bandwidth of 4 kHz, centered at 3 kHz, and broadband source levels between 175 and 190 dB re 1 µPa at 1 m. These calls were chosen for this analysis since they have a lower frequency emphasis and longer duration than other sperm whale clicks (the center frequency of usual clicks and buzzes is 15 kHz; Madsen et al. 2002). Since the frequency band of slow-clicks is closest to that of the seismic activity, these calls are the most affected in the context of this study. In addition, low-frequency sounds generally propagate farther than high-frequency ones. Thus, low-frequency communication is generally more affected by distant noise sources than high-frequency communication.

All communication space calculations were performed in the single 1/3-octave frequency band centered at 3150 Hz. Assuming that the energy of a call is equally distributed over the call's bandwidth, a source level of 181 dB re 1 µPa at 1 m was specified for the 1/3-octace-band centered at 3150 Hz.

A 1/3-octave-band analysis is often used to approximate the critical bandwidth of the mammalian ear and is used here to assess the audibility of a signal. We used a signal excess of $SE = 0$ to represent the onset of detectability. Transmission loss was obtained at each receiver site from the transmission loss model results (Section 2.2; Matthews et al. 2015). The noise levels were calculated with the Cumulative and Chronic Exposure (CCE) calculator (Section 2.3; Matthews et al. 2015). The detection threshold was assumed to be 10 dB, and the detection index was assumed to be zero (Clark et al. 2009). The signal processing gain ($SG = 10\log(TW)$), which accounts for an animal's ability to detect and recognize a signal from conspecifics, was estimated to 3.0 dB, based on a median frequency bandwidth (W) of 4 kHz and call length (T) of 500 µs (Madsen et al. 2002).

4. Results

In the 3150 Hz band, noise contribution from seismic survey activities in the Gulf of Mexico was estimated between 82.0 and 82.1 dB for all sites and all alternatives. These levels are similar to the estimated baseline levels of 82.0 dB at all site. Therefore, it is estimated that the seismic survey activities, as modeled for alternatives C, E, F1, and F2 (Matthews et al. 2015), do not significantly contribute to the soundscape in the 3150 Hz band, and that there will be no significant change in communication space under the modeled alternatives.

This ≤0.1 dB difference between baseline levels in Alternative A and noise levels in Alternative C, E, F1, and F2 results in:

- A 1% decrease in communication space at site 1, receiver depth of 5 m for Alternatives C, F1, and F2;
- A 2% decrease in communication space at site 1, receiver depth of 5 m for Alternative E;
- A 1% decrease in communication space at site 9, receiver depth of 5 m for all Alternatives; and
- No change in communication space at all other sites and receiver depths.

The estimated areas (in km^2) for sperm whale communication space under baseline conditions (Alternative A) are presented in Table 2.

Table 2. Sperm whale communication space at all receiver sites.

Site	Receiver depth (m)	Alternative A Area (km^2)	Site	Receiver depth (m)	Alternative A Area (km^2)
1	5	21,672	6	5	13,643
	30	5,639		30	1,244
	500	804		500	1,277
2	5	2,571	7*	5	2,517
	30	774		30	454
	500	1,016		n/a	n/a
3	5	13,662	8	5	17,967
	30	1,798		30	1,577
	500	1,867		500	1,747
4	5	2,537	9*	5	21,157
	30	790		30	5,398
	500	1,117		n/a	n/a
5	5	342	10*	5	17,967
	30	336		n/a	n/a
	500	362		n/a	n/a

* Sites 7, 9, and 10 are located in areas too shallow to place a receiver at the 500 m depth. Site 10 is located in an area too shallow to place a receiver at the 30 or 500 m depths.

5. Discussion and Conclusion

This assessment applied acoustic modeling to determine changes to sperm whale communication space caused by introducing various seismic survey activities in the Gulf of Mexico. Ten receiver sites were modeled (Table 1, Figure 1) for five alternatives of seismic survey activity (Matthews et al. 2015), representing possible levels of annual survey activity across six geographic activity zones comprising the project area (Figure 1). The key finding is that, at all sites, communication space for sperm whales is minimally affected or unaffected for all alternatives relative to no-activity (Alternative A).

This analysis is based on sperm whale slow-clicks, which are estimated to represent the lower frequency range of sperm whale calls. Since low-frequency calls are more affected than high-frequency calls by noise sources such as those present in Alternatives C, E, F1, and F2, we expect no decrease in sperm whale communication space for other known calls.

A feature of underwater sound propagation is that nearby sources generally contribute substantially more sound exposure levels (SEL) than more distant sources of the same type because exposure levels decay approximately with the square of distance from a source. This causes cumulative SEL received from spatially distributed and moving seismic sources to be dominated by the source pulses generated closest to a receiver. The period of exposures from nearby sources is typically short. Exposures from these sources are important for assessing acute effects, but need to be excluded from the chronic effects assessment (Section 2.3.2; Matthews et al. 2015). Although chronic effects from seismic activities on sperm whale communication space is negligible, there may be short-term acute effects from nearby sources.

Literature Cited

[BOEM] Bureau of Ocean Energy Management, [BSEE] Bureau of Safety and Environmental Enforcement, and [NOAA] National Oceanic and Atmospheric Administration. 2016. *Geological and Geophysical Draft Programmatic Environmental Impact Statement*. Prepared by the Bureau of Ocean Energy Management.

[SoundMap Working Group] Underwater Sound-field Mapping Working Group. 2011. *Annual Average Ambient Noise Modeling Methodology: Global Shipping*. By National Oceanic and Atmospheric Administration. https://cetsound.noaa.gov/sound_data#tabs-2.

Cato, D.H. 2008. Ocean ambient noise: Its measurement and its significance to marine animals. *Proceedings of the Institute of Acoustics* 30(5): 1-9.

Clark, C.W., W.T. Ellison, B.L. Southall, L. Hatch, S.M. Van Parijs, A. Frankel, and D. Ponirakis. 2009. Acoustic masking in marine ecosystems: Intuitions, analysis, and implication. *Marine Ecology Progress Series* 395: 201-222. http://www.int-res.com/abstracts/meps/v395/p201-222/

Madsen, P., M. Wahlberg, and B. Møhl. 2002. Male sperm whale (*Physeter macrocephalus*) acoustics in a high-latitude habitat: implications for echolocation and communication. *Behavioral Ecology and Sociobiology* 53(1): 31-41. https://doi.org/10.1007/s00265-002-0548-1.

Matthews, M.-N.R., A. Schlesinger, and D. Hannay. 2015. *Cumulative and Chronic Effects in the Gulf of Mexico: Estimating Reduction of Listening Area and Communication Space due to Seismic Activities in Support of the BOEM Geological and Geophysical Activities Draft Programmatic Environmental Impact Statement.* Document Number 01073, Version 1.0. Technical report by JASCO Applied Sciences for National Marine Fisheries Service.

Oliveira, C., M. Wahlberg, M. Johnson, P.J.O. Miller, and P.T. Madsen. 2013. The function of male sperm whale slow clicks in a high latitude habitat: communication, echolocation, or prey debilitation? *Journal of Acoustic Society of America* 133(5): 3135-3144. https://doi.org/10.1121/1.4795798.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, et al. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals* 33(4): 411-521.

Wenz, G.M. 1962. Acoustic ambient noise in the ocean: Spectra and sources. *Journal of the Acoustical Society of America* 34(12): 1936-1956.