



Addendum to Acoustic Propagation and Marine Mammal Exposure Modeling of Geological and Geophysical Sources in the Gulf of Mexico

Exposure Estimates for Seismic Surveys Using NOAA Technical Memorandum NMFS-OPR-55 For Estimating Injury

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1. Addendum

As cooperating agencies, the Bureau of Ocean Energy Management (BOEM), the National Oceanic and Atmospheric Administration’s (NOAA) National Marine Fisheries Service (NMFS), and the Bureau of Safety and Environmental Enforcement (BSEE) developed a Draft Programmatic Environmental Impact Statement (PEIS). This document evaluates the potential significant environmental impacts of multiple geological and geophysical (G&G) activities within federal waters of the Gulf of Mexico’s (GOM) Outer Continental Shelf (OCS) and adjacent state waters (BOEM 2016). Potential injurious impacts to marine mammals due to acoustic exposure to seismic surveys in the GOM were investigated for the PEIS. As feed-in data for the impact assessment (Appendix D of the Draft PEIS in BOEM 2016; Zeddies et al. 2015), JASCO estimated the exposure probability for the various species through a modeling process that simulated animals moving in sound fields generated by defined sources in specific environments. As part of this modeling process and exposure estimate analysis, the sound fields were filtered (frequency weighted) to account for the hearing range and sensitivity of different marine mammal hearing groups. Threshold levels of exposure, over which injury may occur, were associated with the hearing groups.

After the draft PEIS was developed, NOAA released technical guidance *NMFS-OPR-55* (NMFS 2016) for frequency-weighting functions and associated thresholds. This addendum conveys, as Excel Workbooks, the updated 24-hr injury-exposure probability estimates using the Technical Guidance (NMFS 2016) for predicted G&G airgun array survey activity in the GOM between 2016–2025. All other aspects of the modeling remained the same as described in Appendix D of the Draft PEIS. Table 1 shows the threshold levels used to estimate exposure probability. Section 1.1 explains the weighting functions used.

Notes:

- (1) While the work in this addendum updates the peak SPL and SEL injury estimates, the Excel Workbooks contain the (unchanged) exposure probability estimates for potential behavioral disruption and prior NMFS criteria so that all the current data are located together.
- (2) Animal movement was identically replicated in most cases, but it was found that for most species in Box 1 (beaked whales, bottlenose dolphins, clymene dolphins, false killer whales, killer whales, pantropical spotted dolphins, Risso’s dolphins, and rough toothed dolphins) and some species in Box 5 (pantropical spotted dolphins, Risso’s dolphins, rough toothed dolphins, and killer whales) the initial seeding was lost. These species represent new animal movement modelling runs and, therefore, a statistical comparison to the prior work instead of an exact replication.

Table 1. Summary of relevant permanent threshold shift (PTS) onset acoustic thresholds (NMFS 2016).

Hearing group	Threshold
Low-frequency (LF) cetaceans	^{peak} SPL, flat: 219 dB SEL, 24h: 183 dB
Mid-frequency (MF) cetaceans	^{peak} SPL, flat: 230 dB SEL, 24h: 185 dB
High-frequency (HF) cetaceans	^{peak} SPL, flat: 202 dB SEL, 24h: 155 dB

Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

^{peak} SPL, flat–peak sound pressure is flat weighted or unweighted and has a reference value of 1 μ Pa.

SEL denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 μ Pa²s.

The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting.

1.1. Marine Mammal Weighting Functions

The potential for anthropogenic sounds to impact marine mammals is largely dependent on whether the sound occurs at frequencies that an animal can hear well, unless the sound pressure level is so high that it can cause physical tissue damage regardless of frequency. Weighting functions reflect an animal’s ability to hear a sound. Sound spectra are weighted at particular frequencies in a manner that reflects an animal’s sensitivity to those frequencies (Nedwell and Turnpenney 1998, Nedwell et al. 2007). Auditory weighting functions have been proposed for marine mammals, specifically associated with PTS acoustic thresholds expressed in metrics that consider what is known about marine mammal hearing (e.g., SEL) (Southall et al. 2007, Erbe et al. 2016, Finneran 2016). Marine mammal auditory weighting functions published by Finneran (2016) are included in the NMFS 2016 Technical Guidance for use in conjunction with corresponding SEL PTS (injury) onset acoustic criteria (Table 1).

1.1.1. Type III marine mammal frequency weighting functions

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10 \log_{10} \left[\frac{(f/f_{lo})^{2a}}{\left[1 + (f/f_{lo})^2\right]^a \left[1 + (f/f_{hi})^2\right]^b} \right]$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA’s technical guidance that assesses noise impacts on marine mammals (NMFS 2016). Table 2 lists the frequency-weighting parameters for each hearing group. Figure 1 shows the resulting frequency-weighting curves.

Table 2. Parameters for the auditory weighting functions recommended by NMFS (2016).

Hearing group	a	b	f _{lo} (Hz)	f _{hi} (kHz)	K (dB)
Low-frequency cetaceans	1.0	2	200	19,000	0.13
Mid-frequency cetaceans	1.6	2	8,800	110,000	1.20
High-frequency cetaceans	1.8	2	12,000	140,000	1.36
Phocid pinnipeds in water	1.0	2	1,900	30,000	0.75
Otariid pinnipeds in water	2.0	2	940	25,000	0.64

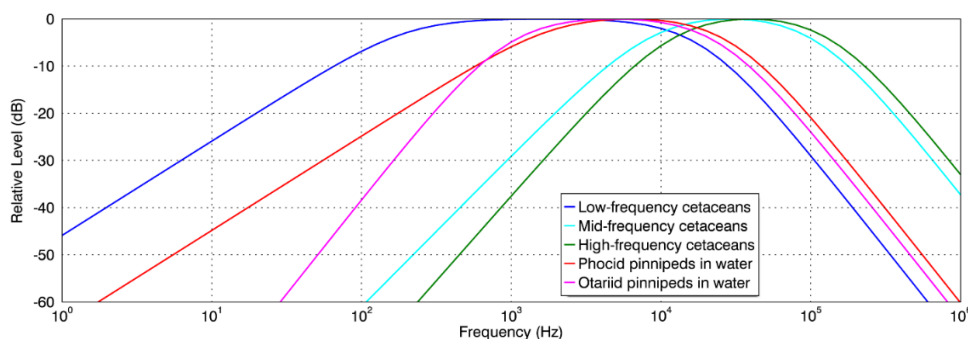


Figure 1. Auditory weighting functions for functional marine mammal hearing groups recommended by NMFS (2016).

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