

## National Marine Fisheries Service: Summary of Marine Mammal Protection Act Acoustic Thresholds<sup>1</sup>

This document serves as a summary of NMFS's current marine mammal acoustic thresholds.

### SOURCE CHARACTERIZATION (NMFS 2024)

To determine which threshold is appropriate, NMFS characterizes sound sources as impulsive/non-impulsive (AUD INJ/TTS) and intermittent/continuous (behavioral harassment):

- Continuous sound sources: emit sound with a sound pressure level that remains above ambient sound during the entire observation period. Examples of continuous sound sources include drilling and vibratory pile driving.
- Intermittent sound sources: have interrupted levels of low or no sound or bursts of sound separated by silent periods. Typically, intermittent sounds have a more regular (predictable) pattern of bursts of sounds and silent periods (i.e., duty cycle). Examples of intermittent sound sources include scientific sonar, high-resolution geophysical survey equipment (i.e., sub-bottom profilers), and impact pile driving.
- Impulsive sound sources: produce sounds that are typically transient, brief (less than one second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay. Impulsive sounds can occur in repetition (e.g., seismic airguns, impact pile driving) or as a single event (e.g., explosives).
- Non-impulsive sound sources: can be continuous or intermittent, and produce sounds that can be broadband, narrowband or tonal, and brief or prolonged. Non-impulsive sources do not have the high peak sound pressure with rapid rise time typical of impulsive sounds. Examples of non-impulsive sources include drilling, vibratory pile driving, and certain active sonars.

### MARINE MAMMAL HEARING GROUPS

The application of marine mammal hearing groups occurs in two ways. First, thresholds are designated by hearing group to acknowledge that not all marine mammal species have identical hearing or susceptibility to noise-induced hearing loss. Second, marine mammal hearing groups are used to establish marine mammal auditory weighting functions.

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**Marine Mammal Hearing Groups (NMFS 2024)**

Hearing Group <sup>^</sup>	Generalized Hearing Range*
<b>UNDERWATER</b>	
Low-frequency (LF) cetaceans (baleen whales)	7 Hz to 36 kHz
High-frequency (HF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz
Very High-frequency (VHF) cetaceans (true porpoises, <i>Kogia</i> , river dolphins, cephalorhynchid, <i>Lagenorhynchus cruciger</i> & <i>L. australis</i> )	200 Hz to 165 kHz
Phocid pinnipeds (PW) (true seals)	40 Hz to 90 kHz
Otariid pinnipeds (OW) (sea lions and fur seals)	60 Hz to 68 kHz
<b>IN-AIR</b>	
Phocid pinnipeds (PA) (true seals)	42 Hz to 52 kHz
Otariid pinnipeds (OA) (sea lions and fur seals)	90 Hz to 40 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).

**LEVEL A HARASSMENT**

NMFS's 2024 Updated Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (NOAA Technical Memorandum NMFS-OPR-71) identifies criteria to assess auditory injury (Level A harassment) to different marine mammal groups (based on hearing sensitivity) as a result of exposure to sound from impulsive and non-impulsive sources.

### Onset of Auditory Injury (AUD INJ) (NMFS 2024)

	AUD INJ Onset Criteria* (Received Level) <b>PLEASE SEE TABLE NOTES TO FULLY UNDERSTAND SYMBOL MEANING</b>	
Hearing Group	Impulsive	Non-impulsive
<b>UNDERWATER</b>		
<b>Low-Frequency (LF) Cetaceans</b>	Cell 1 $L_{p,0-pk,flat}$ : 222 dB $L_{E,p,LF,24h}$ : 183 dB	Cell 2 $L_{E,p,LF,24h}$ : 197 dB
<b>High-Frequency (HF) Cetaceans</b>	Cell 3 $L_{p,0-pk,flat}$ : 230 dB $L_{E,p,HF,24h}$ : 193 dB	Cell 4 $L_{E,p,HF,24h}$ : 201 dB
<b>Very High-Frequency (VHF) Cetaceans</b>	Cell 5 $L_{p,0-pk,flat}$ : 202 dB $L_{E,p,VHF,24h}$ : 159 dB	Cell 6 $L_{E,p,VHF,24h}$ : 181 dB
<b>Phocid Pinnipeds (PW)</b>	Cell 7 $L_{p,0-pk,flat}$ : 223 dB $L_{E,p,PW,24h}$ : 183 dB	Cell 8 $L_{E,p,PW,24h}$ : 195 dB
<b>Otariid Pinnipeds (OW)</b>	Cell 9 $L_{p,0-pk,flat}$ : 230 dB $L_{E,p,OW,24h}$ : 185 dB	Cell 10 $L_{E,p,OW,24h}$ : 199 dB
<b>IN-AIR</b>		
<b>Phocid Pinnipeds (PA)</b>	Cell 11 $L_{p,0-pk,flat}$ : 162 dB $L_{E,p,PA,24h}$ : 140 dB	Cell 12 $L_{E,p,PA,24h}$ : 154 dB
<b>Otariid Pinnipeds (OA)</b>	Cell 13 $L_{p,0-pk,flat}$ : 177 dB $L_{E,p,OA,24h}$ : 163 dB	Cell 14 $L_{E,p,OA,24h}$ : 177 dB

\* Dual metric criteria for impulsive sounds: Use whichever criteria results in the larger isopleth for calculating AUD INJ onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level criteria associated with impulsive sounds, the PK SPL criteria are recommended for consideration for non-impulsive sources.

Note: Peak sound pressure level ( $L_{p,0-pk}$ ) has a reference value of 1  $\mu$ Pa (underwater) and 20  $\mu$ Pa (in air), and weighted cumulative sound exposure level ( $L_{E,p}$ ) has a reference value of 1  $\mu$ Pa<sup>2</sup>s (underwater) and (20  $\mu$ Pa)<sup>2</sup>s (in air). In this Table, criteria are abbreviated to be more reflective of International Organization for Standardization standards (ISO 2017; ISO 2020). The subscript “flat” is being included to indicate peak sound pressure are flat weighted or unweighted within the generalized hearing range of marine mammals underwater (i.e., 7 Hz to 165 kHz) or in air (i.e., 42 Hz to 52 kHz). The subscript associated with cumulative sound exposure level criteria indicates the designated marine mammal auditory weighting function (LF, HF, and VHF cetaceans, and PW, OW, PA, and OA pinnipeds) and that the recommended accumulation period is 24 hours. The weighted cumulative sound exposure level criteria could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these criteria will be exceeded.

### LEVEL B HARASSMENT

NMFS predicts that marine mammals are likely to be behaviorally harassed in a manner that qualifies as Level B harassment when exposed to underwater noise *above* root-mean-square (RMS) received levels of 120 dB re 1  $\mu$ Pa for continuous (e.g., vibratory pile driving, drilling) and 160 dB re 1  $\mu$ Pa for non-explosive, impulsive (e.g., seismic airguns, impact pile driving) or intermittent

(e.g., scientific, non-tactical sonar) sources.

### Underwater Level B Harassment Acoustic Thresholds (NOAA 2005)

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

For in-air sounds, NMFS predicts that harbor seals exposed to RMS received levels  $\geq 90$  dB re 20  $\mu$ Pa will be behaviorally harassed, and other pinnipeds will be harassed when exposed to RMS received levels  $\geq 100$  dB re 20  $\mu$ Pa. These in-air behavioral thresholds apply to all sound sources, including airborne detonations.

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

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

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

Note: Sound levels underwater (re: 1  $\mu$ Pa) have a different reference pressure compared to in-air sounds (re: 20  $\mu$ Pa). Thus, it is not appropriate to compare sound levels in-air to those underwater.

### UNDERWATER EXPLOSIVES

NMFS uses the acoustic and pressure thresholds below to predict the onset of behavioral harassment and TTS as well as AUD INJ, tissue damage (i.e., lung and g.i. tract), and mortality from the use of underwater explosives.

Note: For a single detonation (within a 24-h period), NMFS relies on the TTS onset threshold to assess Level B harassment. For multiple detonations (within a 24-h period), NMFS relies on a behavioral thresholds that is -5 dB from TTS onset (see Table below).

**AUD INJ Onset, TTS Onset, and Behavioral Thresholds (Multiple Detonations) for Underwater Explosives (NMFS 2024)**

<b>Hearing Group</b>	<b>AUD INJ Impulsive Thresholds</b>	<b>TTS Impulsive Thresholds</b>	<b>Behavioral Threshold (multiple detonations)</b>
<b>Low-Frequency (LF) Cetaceans</b>	<i>Cell 1</i> $L_{p,0-pk,flat}$ : 222 dB $L_{E,LF,24h}$ : 183 dB	<i>Cell 2</i> $L_{p,0-pk,flat}$ : 216 dB $L_{E,LF,24h}$ : 168 dB	<i>Cell 3</i> $L_{E,LF,24h}$ : 163 dB
<b>High-Frequency (HF) Cetaceans</b>	<i>Cell 4</i> $L_{p,0-pk,flat}$ : 230 dB $L_{E,HF,24h}$ : 193 dB	<i>Cell 5</i> $L_{p,0-pk,flat}$ : 224 dB $L_{E,HF,24h}$ : 178 dB	<i>Cell 6</i> $L_{E,HF,24h}$ : 173 dB
<b>Very High-Frequency (VHF) Cetaceans</b>	<i>Cell 7</i> $L_{p,0-pk,flat}$ : 202 dB $L_{E,VHF,24h}$ : 159 dB	<i>Cell 8</i> $L_{p,0-pk,flat}$ : 196 dB $L_{E,VHF,24h}$ : 144 dB	<i>Cell 9</i> $L_{E,VHF,24h}$ : 139 dB
<b>Phocid Pinnipeds (PW) (Underwater)</b>	<i>Cell 10</i> $L_{p,0-pk,flat}$ : 223 dB $L_{E,PW,24h}$ : 183 dB	<i>Cell 11</i> $L_{p,0-pk,flat}$ : 217 dB $L_{E,PW,24h}$ : 168 dB	<i>Cell 12</i> $L_{E,PW,24h}$ : 163 dB
<b>Otariid Pinnipeds (OW) (Underwater)</b>	<i>Cell 13</i> $L_{p,0-pk,flat}$ : 230 dB $L_{E,OW,24h}$ : 185 dB	<i>Cell 14</i> $L_{p,0-pk,flat}$ : 224 dB $L_{E,OW,24h}$ : 170 dB	<i>Cell 15</i> $L_{E,OW,24h}$ : 165 dB

\* Dual metric criteria for impulsive sounds: Use whichever criteria results in the larger isopleth for calculating AUD INJ onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level criteria associated with impulsive sounds, the PK SPL criteria are recommended for consideration for non-impulsive sources.

Note: Peak sound pressure level ( $L_{p,0-pk}$ ) has a reference value of 1  $\mu\text{Pa}$ , and weighted cumulative sound exposure level ( $L_{E,p}$ ) has a reference value of 1  $\mu\text{Pa}^2\text{s}$ . In this Table, criteria are abbreviated to be more reflective of International Organization for Standardization standards (ISO 2017; ISO 2020). The subscript “flat” is being included to indicate peak sound pressure are flat weighted or unweighted within the generalized hearing range of marine mammals underwater (i.e., 7 Hz to 165 kHz). The subscript associated with cumulative sound exposure level criteria indicates the designated marine mammal auditory weighting function (LF, HF, and VHF cetaceans, and PW and OW pinnipeds) and that the recommended accumulation period is 24 hours. The weighted cumulative sound exposure level criteria could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these criteria will be exceeded.

### Lung and G.I. Tract Injury Thresholds (DoN 2017)

Hearing Group	Mortality (Severe lung injury)*	Slight Lung Injury*	G.I. Tract Injury
All Marine Mammals	Cell 1 Modified Goertner model; Equation 1	Cell 2 Modified Goertner model; Equation 2	Cell 3 $L_{p,0-pk,flat}$ : 237 dB

\* Lung injury (severe and slight) thresholds are dependent on animal mass (Recommendation: Table C.9 from DON 2017 based on adult and/or calf/pup mass by species).

Note: Peak sound pressure ( $L_{pk}$ ) has a reference value of 1  $\mu$ Pa. In this Table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, ANSI defines peak sound pressure as incorporating frequency weighting, which is not the intent for this Technical Guidance. Hence, the subscript “flat” is being included to indicate peak sound pressure should be flat weighted or unweighted within the overall marine mammal generalized hearing range.

#### Modified Goertner Equations for severe and slight lung injury (pascal-second)

$$\text{Equation 1: } 103M^{1/3}(1 + D/10.1)^{1/6} \text{ Pa-s}$$

$$\text{Equation 2: } 47.5M^{1/3}(1 + D/10.1)^{1/6} \text{ Pa-s}$$

$M$  animal (adult and/or calf/pup) mass (kg) (Table C.9 in DoN 2017)

$D$  animal depth (meters)

#### LITERATURE CITED

- ANSI (American National Standards Institute). 2013. Acoustic Terminology (ANSI S1.1-2013). New York: Acoustical Society of America.
- DoN (Department of the Navy). 2017. Technical Report: Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). San Diego, California: SSC Pacific.
- NMFS (National Marine Fisheries Service). 2024. Update to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 3.0): Underwater and In-Air Criteria for Onset of Auditory Injury and Temporary Threshold Shifts. U.S. Dept. of Commerce. NOAA. NOAA Technical Memorandum NMFS-OPR-71, 182 p.
- NOAA (National Oceanic and Atmospheric Administration). 2005. Endangered Fish and Wildlife; Notice of Intent to Prepare an Environmental Impact Statement. Federal Register 70: 1871-1875.
- NOAA (National Oceanic and Atmospheric Administration). 2009. Small Takes of Marine Mammals Incidental to Specified Activities; Dumbarton Bridge Seismic Retrofit Project, California. Federal Register 74: 63724-63731.
- 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, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L.

Tyack. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals* 33:411-521.