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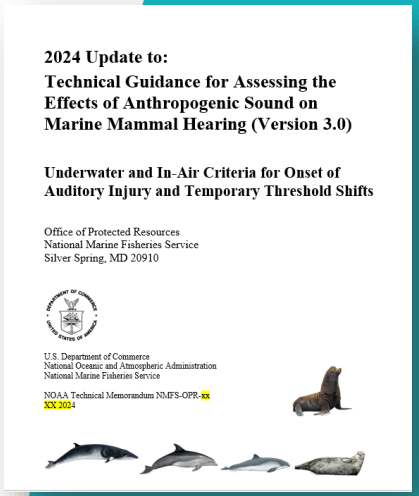
Update to:

Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 3.0):

Underwater and In-Air Thresholds for Onset of Auditory Injury/Permanent and Temporary Threshold Shifts



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

Office of Protected Resources
National Marine Fisheries Service
Silver Spring, MD 20910

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OPR-xx
XX 2024

Changes: Updated Technical Guidance (2024) vs. Technical Guidance (2018)

- Adoption of marine mammal hearing group terminology from Southall et al. 2019
- Addition of in-air thresholds for pinnipeds
- Change of term “auditory injury” from term “PTS”
- Lower TTS & AUD INJ thresholds for HF cetaceans (*former MF cetaceans*), below 10 kHz, based on new data (Finneran data)
- Significantly lower TTS & AUD INJ thresholds (SEL_{24h} metric) for OW pinnipeds based on new data (Kastelein data)
- New PW pinniped impulsive TTS onset data (Sills data), which affected the extrapolation (SEL_{24h} metric) for species without impulsive data

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What is the same….

- Basic methodology for deriving thresholds & weighting functions is very similar between NMFS 2018 & NMFS 2024 Technical Guidance
  - Some tweaks
- Changes in thresholds/weighting functions primarily a result of new audiogram & TTS data
- No new data for LF cetaceans included (minke whale data coming…will be include in *next* update)
- As with previous versions of Technical Guidance, the document is divided into 2 parts:
  - Main Document (summary): ~35 pages
  - More detailed Appendices (A. Navy documents; B: Research Recommend.; C: Review; D: Glossary)

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Southall et al. 2019 Hearing Groups

What we use in Updated Technical Guidance

Family/Genera/Species Included	Southall et al. 2019 Hearing Group	NOAA 2018 Hearing Group	NOAA 2018 Weighting Function
Balaena mysticetus; *Balaenoptera musculus*; *Balaenoptera physalus*; *Eubalaenidae* spp.	LF[+] cetaceans	**LF Cetacean**	**LF Cetacean**
All other baleen whales	LF Cetaceans	**LF Cetacean**	**LF Cetacean**
Physeter macrocephalis; *Orcinus orca*; Ziphiidae	HF[^] Cetaceans	**MF Cetaceans**	**MF Cetaceans**
Other members of Delphinidae; Monodontidae; Plantanistidae*	HF Cetaceans	**MF Cetaceans**	**MF Cetaceans**
Phocoenidae; Iniidae; Kogiidae, Lipotidae; Pontoporiidae; *Cephalorhynchus* spp.; *Lagenorhynchus cruciger*; *Lagenorhynchus australis*	Very High-Frequency (VHF) Cetaceans	**HF Cetaceans**	**HF Cetaceans**
Phocidae	Phocid Carnivores in Water (PCW)	**PW Pinnipeds**	**PW Pinniped**
Otariidae[‡]	Other Marine Carnivores in Water (OCW)	**OW Pinnipeds**	**OW Pinnipeds**

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Change of term: PTS to AUD INJ

- Various studies with terrestrial mammals have reported recoverable noise-induced thresholds shifts that result in neuropathy (e.g., Kujawa and Liberman 2009; Lin et al. 2011).
  - Destruction of auditory tissue has occurred in terrestrial mammals, where threshold shifts were 30–50 dB measured 24 h after the exposure
  - There is no evidence that an exposure resulting in < 40 dB TTS measured a few minutes after exposure can produce AUD INJ
- Therefore, there are circumstances where auditory injury (AUD INJ) can occur, which may or may not result in PTS.
- Thus, the Updated Technical Guidance acknowledges that AUD INJ can occur, which includes but is not limit to PTS

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NEW: Audiogram data (*italics*) since 2016

Hearing Group	Species (number of individuals)	References (new references added for Updated Technical Guidance are in italics)
UNDERWATER		
High-Frequency (HF) Cetaceans	Beluga (9)	White et al. 1978; Awbrey et al. 1988; Johnson et 1989; Ridgway et al. 2001; Finneran et al. 2005b
	Bottlenose dolphin (3)	Johnson 1967;-Lemonds 1999; Finneran et al. 20
	False killer whale (1)	Thomas et al. 1988
	Killer whale (8)	Szymanski et al. 1999; *Branstetter et al. 2017*
	Pacific white-sided dolphin (1)	Tremel et al. 1996
	Striped dolphin (1)	Kastelein et al. 2003
	Tucuxi (1)	Sauerland and Dehnhardt 1998
Very High-Frequency (VHF) Cetaceans	Amazon River dolphin (1)	Jacobs and Hall 1972
	Harbor porpoise (5)	Kastelein et al. 2010; Kastelein et al. 2015c; *Kast et al. 2017a*
Phocid Pinnipeds (PW)	Harbor seal (5)	Terhune 1988; Kastelein et al. 2009b; Reichmuth al. 2013; *Cunningham and Reichmuth 2016*
	Bearded sealed (2)	*Sills et al. 2020a*
	Hawaiian monk seal (1)	*Sills et al. 2021*
	Harp seal (1)	*Terhune et al. 1972*
	Northern elephant seal (1)	Kastak and Schusterman 1999
	Ringed seal (1)	Sills et al. 2015
	Spotted seal (3)	Sills et al. 2014; *Cunningham and Reichmuth 201*
Otariid Pinnipeds* (OW)	California sea lion (4)	Mulsow et al. 2012; Reichmuth and Southall 2012 Reichmuth et al. 2013; *Cunningham and Reichmu 2016*
	Northern fur seal (3)	Moore and Schusterman 1987; Babushina et al. 1
	Steller sea lion (2)	Kastelein et al. 2005a
IN-AIR		
Phocid Pinnipeds (PA)	Harbor seal (1)	*Reichmuth et al. 2013*
	Spotted seal (2)	*Sills et al. 2014*
	Ringed seal (1)	*Sills et al. 2015*
Otariid Pinnipeds* (OA)	California sea lion (4)	*Moore and Schustrman 1987; Mulsow et al. 2011 Reichmuth et al. 2013; Reichmuth et al. 2017*
	Steller sea lion (1)	*Mulsow et al. 2010*
	Northern fur seal (3)	*Moore and Schusterman 1987; Babushina et al. 1*

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NEW: Underwater TTS data since 2016

Reichmuth et al. 2016	Single airgun (impulsive)*	Ringed seals (2); Spotted seals (2)
Popov et al. 2017	½ octave band noise (non-impulsive)	Beluga (1)
Kastelein et al. 2017b	Simultaneous airguns producing multiple shots (impulsive)*	Harbor porpoise (1)
Kastelein et al. 2017c	3.5-4.1 kHz sonar (non-impulsive)	Harbor porpoise (2)
Kastelein et al. 2018	Impact pile driving (impulsive)*	Harbor seal (2)
Kastelein et al. 2019a	6.5 kHz tone (non-impulsive)	Harbor seal (2)
Kastelein et al. 2019b	1/6 octave noise at 16 kHz (non-impulsive)	Harbor porpoise (2)
Kastelein et al. 2019c	1/6 octave noise at 32 kHz (non-impulsive)	Harbor porpoise (2)
Reichmuth et al. 2019	4.1 kHz tone (non-impulsive)+	Harbor seal (1)
Kastelein et al. 2019d	1/6 octave noise at 16 kHz (non-impulsive)	Harbor seal (2)
Schaffeld et al. 2019	Artificial ADD with peak at 14 kHz (non-impulsive)	Harbor porpoise (1)
Kastelein et al. 2020a	1/6 octave noise at 63 kHz (non-impulsive)	Harbor porpoise (2)
Kastelein et al. 2020b	1/6 octave noise at 32 kHz (non-impulsive)	Harbor seal (2)
Kastelein et al. 2020c	1/6 octave noise at 40 kHz (non-impulsive)	Harbor seal (2)
Kastelein et al. 2020d	1/6 octave noise at 88.4 kHz (non-impulsive)	Harbor porpoise (1)
Kastelein et al. 2020e	1/6 octave noise at 1.5 kHz and 6.5 kHz (non-impulsive)	Harbor porpoise (1)
Kastelein et al. 2020f	Simultaneous airguns producing multiple shots (impulsive)*	Harbor porpoise (1)
Kastelein et al. 2020g	1/6 octave noise at 0.5, 1, and 2 kHz (non-impulsive)	Harbor seal (2)
Sills et al. 2020b	Single airgun producing single and multiple shots (impulsive)	Bearded seal (1)
Kastelein et al. 2021a	1/6 octave noise at 0.5 (non-impulsive)	Harbor porpoise (1)
Kastelein et al. 2021b	1/6 octave noise at 2 and 4 kHz (non-impulsive)	California sea lion (2)
Kastelein et al. 2022a	1/6 octave noise at 8 and 16 kHz (non-impulsive)	California sea lion (2)
Kastelein et al. 2022b	1/6 octave noise at 0.6 and 1 kHz (non-impulsive)	California sea lion (2)
Kastelein et al. 2022c	1/6 octave noise at 32 and 40 kHz (non-impulsive)	California sea lion (2)
Finneran et al. 2022	Tones (non-impulsive)	Bottlenose dolphin (2)
Mulsow et al. 2022	Narrowband (1/6-octave), 10-ms noisebursts at 8 kHz (impulsive)	Bottlenose dolphin (3)

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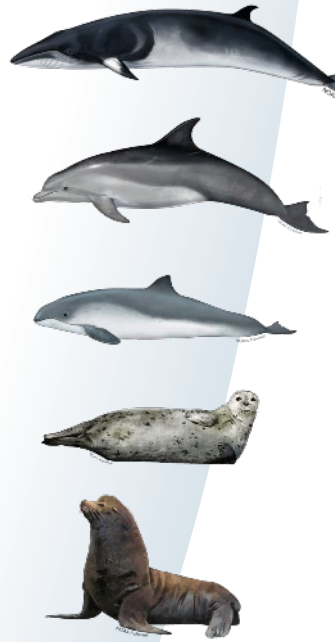
Updated: AUD INJ Criteria

Red: lower threshold in 2024
Green: higher threshold in 2024
Blue: no change

	AUD INJ Onset Thresholds* (Received Level)	
Hearing Group	**Impulsive**	**Non-impulsive**
UNDERWATER		
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{p,0\text{-pk,flat}}$: 222 dB +3 $L_{E,p,\text{LF,24h}}$: 183 dB 0	*Cell 2* $L_{E,p,\text{LF,24h}}$: 197 dB -2
High-Frequency (HF) Cetaceans	*Cell 3* $L_{p,0\text{-pk,flat}}$: 230 dB 0 $L_{E,p,\text{HF,24h}}$: 193 dB +8	*Cell 4* $L_{E,p,\text{HF,24h}}$: 201 dB +3
Very High-Frequency (VHF) Cetaceans	*Cell 5* $L_{p,0\text{-pk,flat}}$: 202 dB 0 $L_{E,p,\text{VHF,24h}}$: 159 dB +4	*Cell 6* $L_{E,p,\text{VHF,24h}}$: 181 dB +8
Phocid Pinnipeds (PW)	*Cell 7* $L_{p,0\text{-pk,flat}}$: 223 dB +5 $L_{E,p,\text{PW,24h}}$: 183 dB -2	*Cell 8* $L_{E,p,\text{PW,24h}}$: 195 dB -6
Otariid Pinnipeds (OW)	*Cell 9* $L_{p,0\text{-pk,flat}}$: 230 dB -2 $L_{E,p,\text{OW,24h}}$: 185 dB -18	*Cell 10* $L_{E,p,\text{OW,24h}}$: 199 dB -20
IN-AIR		
Phocid Pinnipeds (PA)	*Cell 11* $L_{p,0\text{-pk,flat}}$: 162 dB $L_{E,p,\text{PA,24h}}$: 140 dB	*Cell 12* $L_{E,p,\text{PA,24h}}$: 154 dB
Otariid Pinnipeds (OA)	*Cell 13* $L_{p,0\text{-pk,flat}}$: 177 dB $L_{E,p,\text{OA,24h}}$: 163 dB	*Cell 14* $L_{E,p,\text{OA,24h}}$: 177 dB



Remember only seeing "½" of criteria. Also need to consider weighting functions!!

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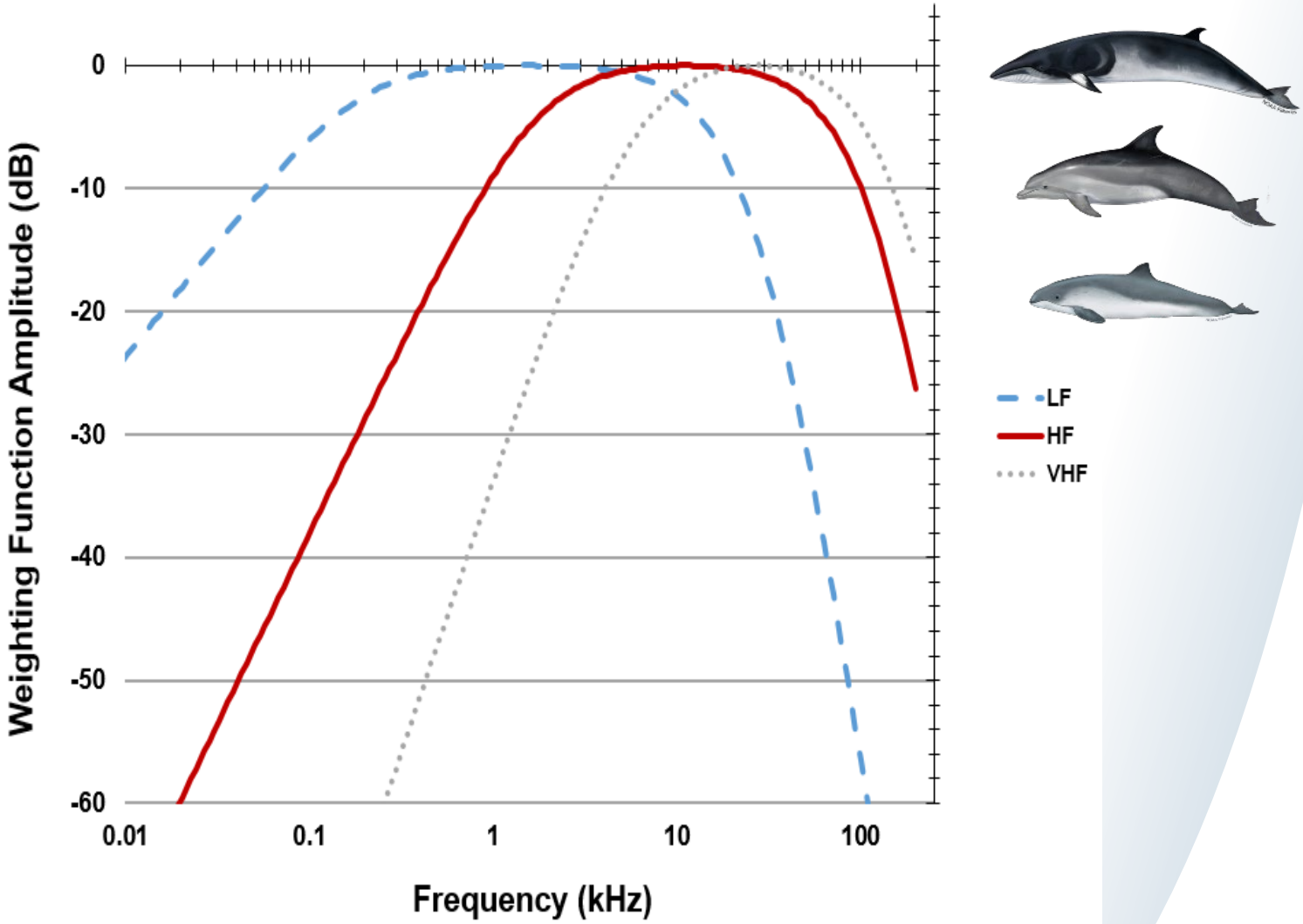
Updated: Cetacean Weighting Functions



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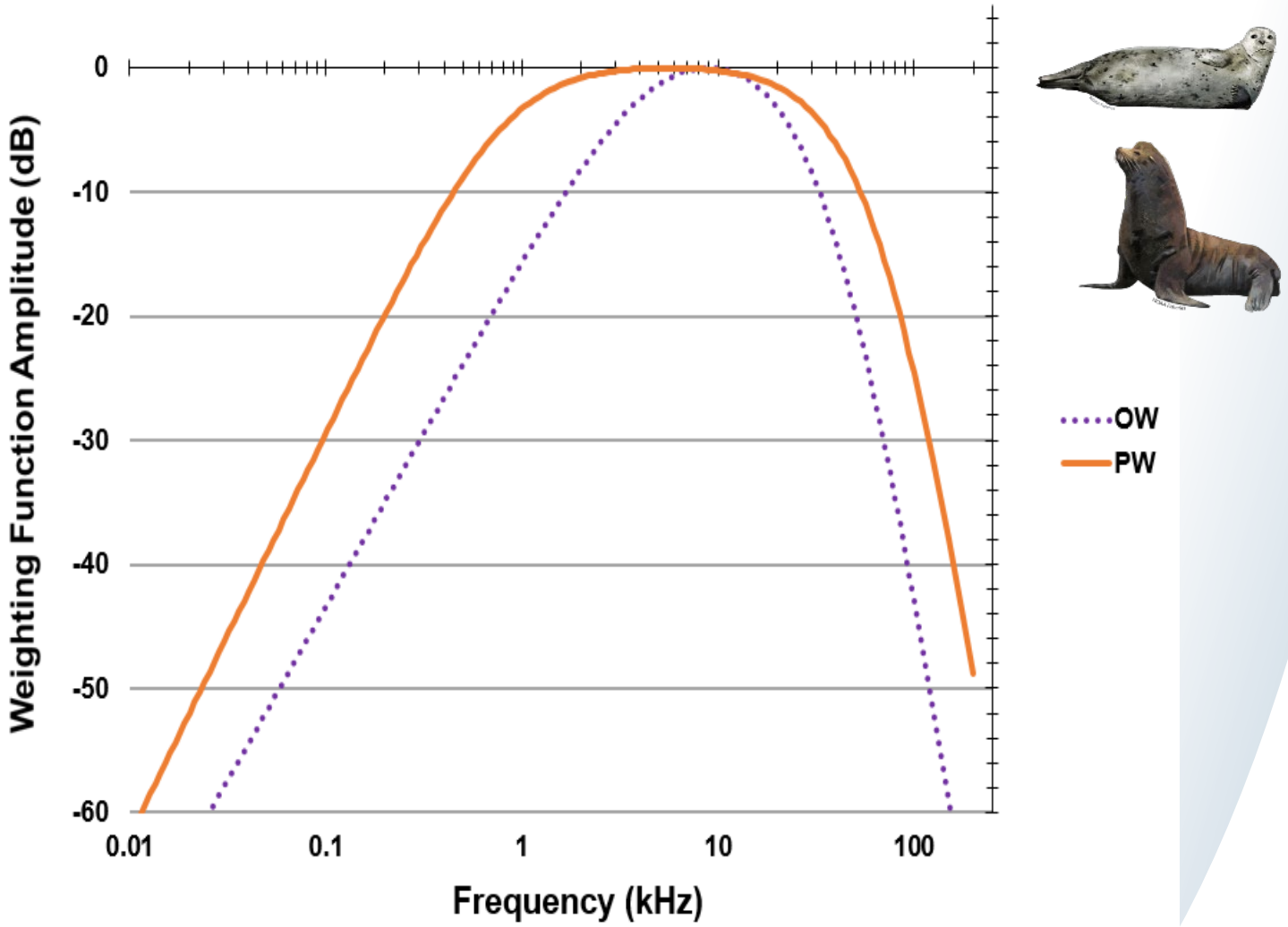
Updated: Pinniped$_{H20}$ Weighting Functions



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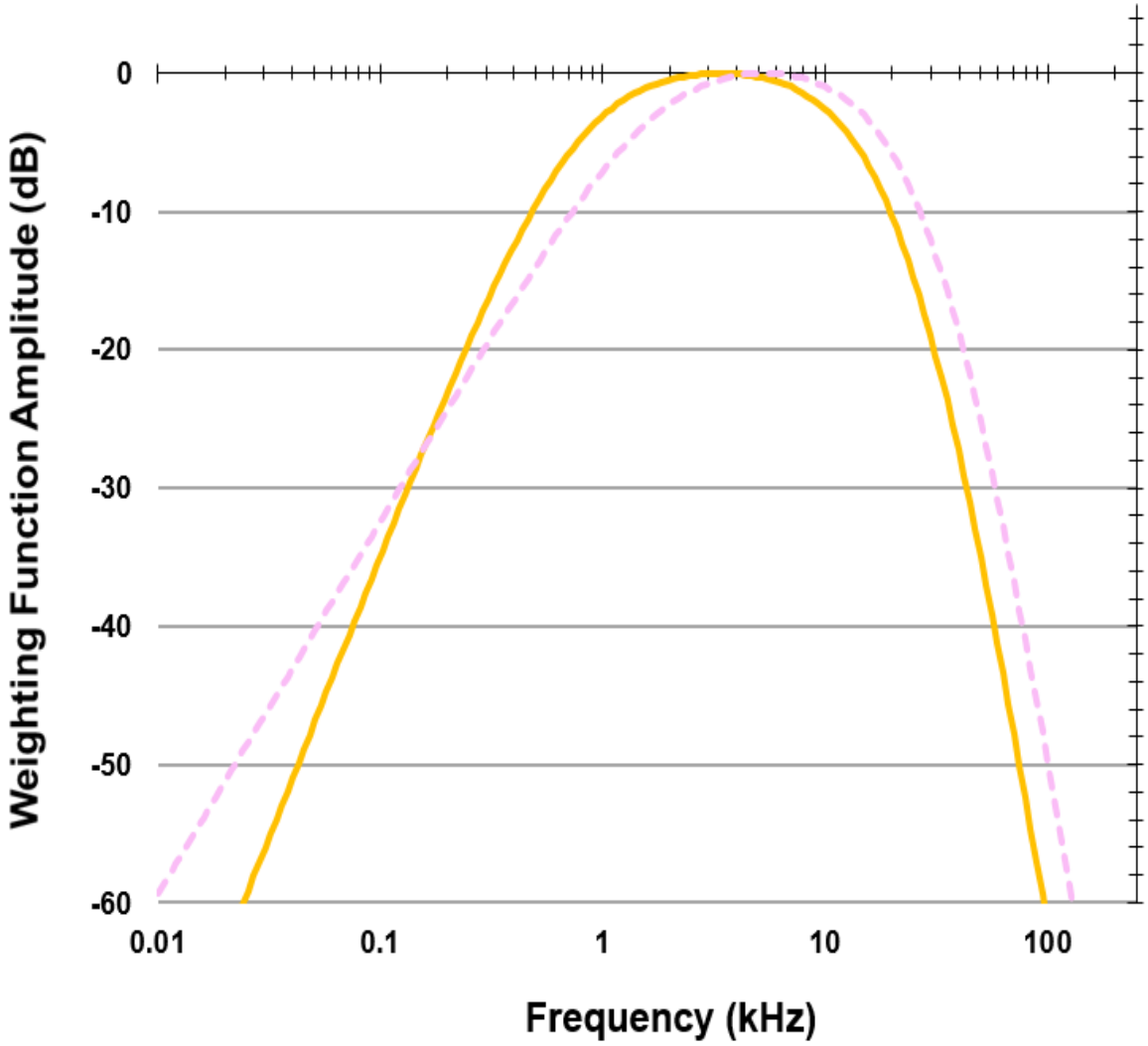
Updated: Pinniped$_{air}$ Weighting Functions



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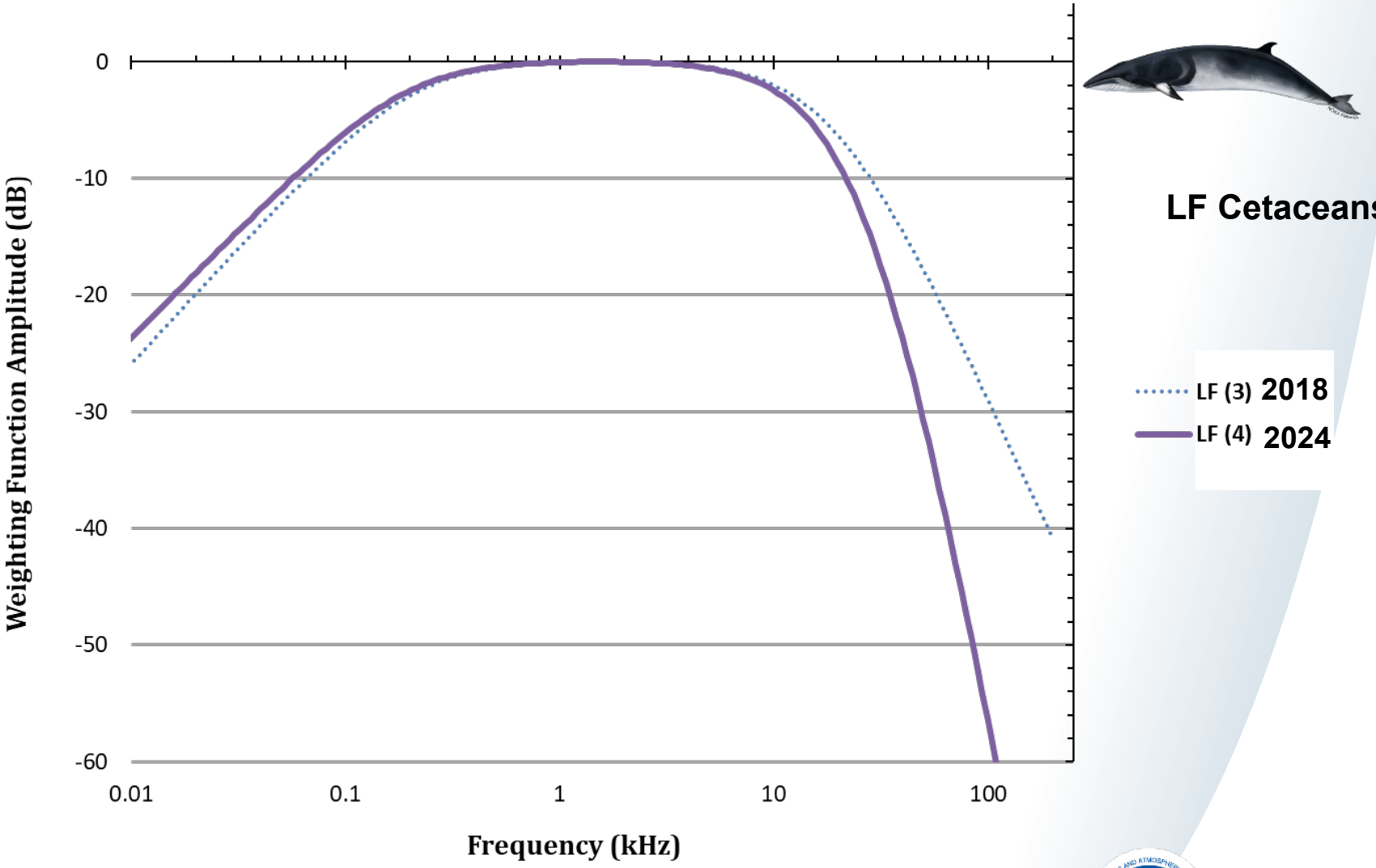
2024 Update vs. 2018 Technical Guidance



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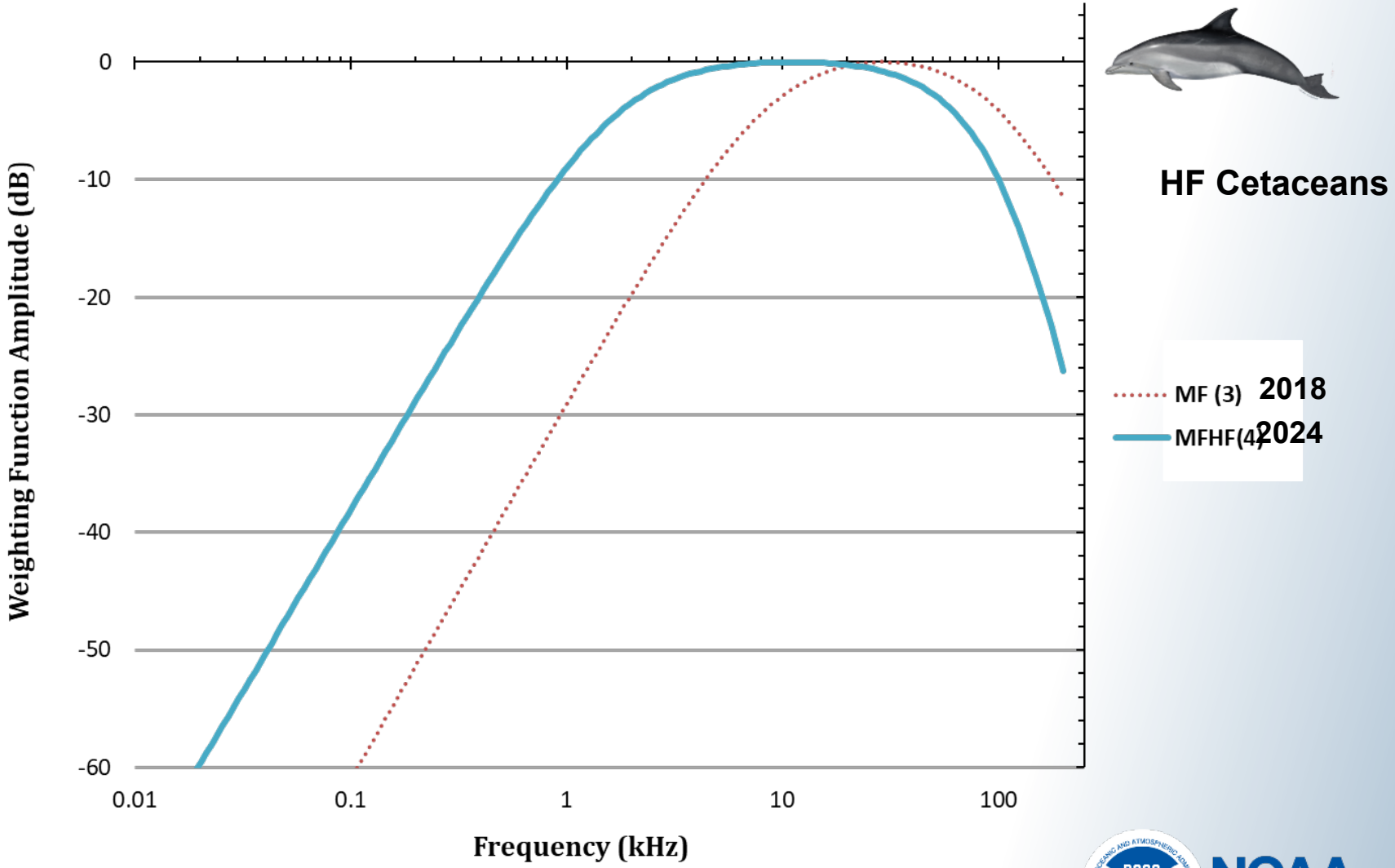

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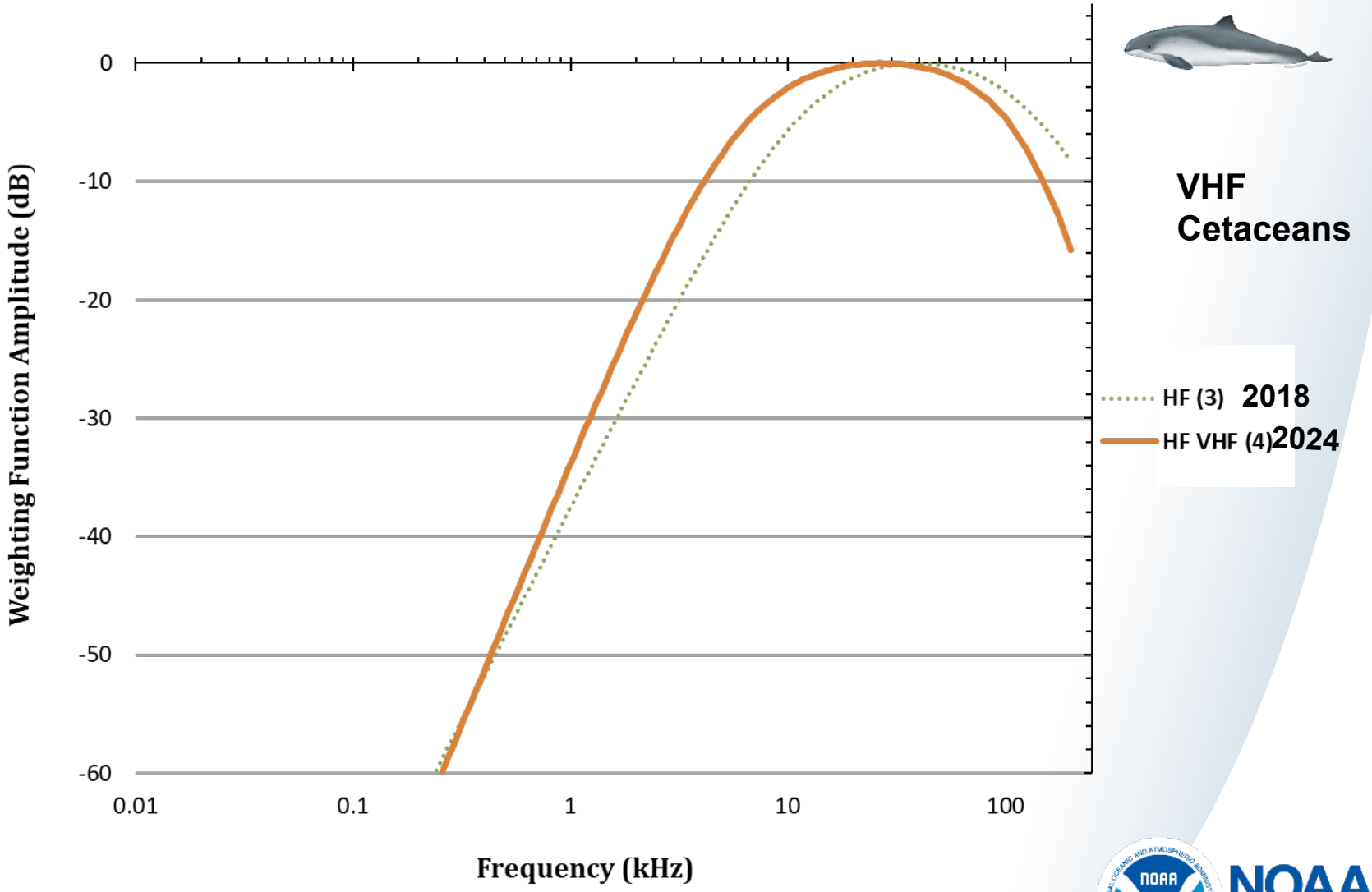

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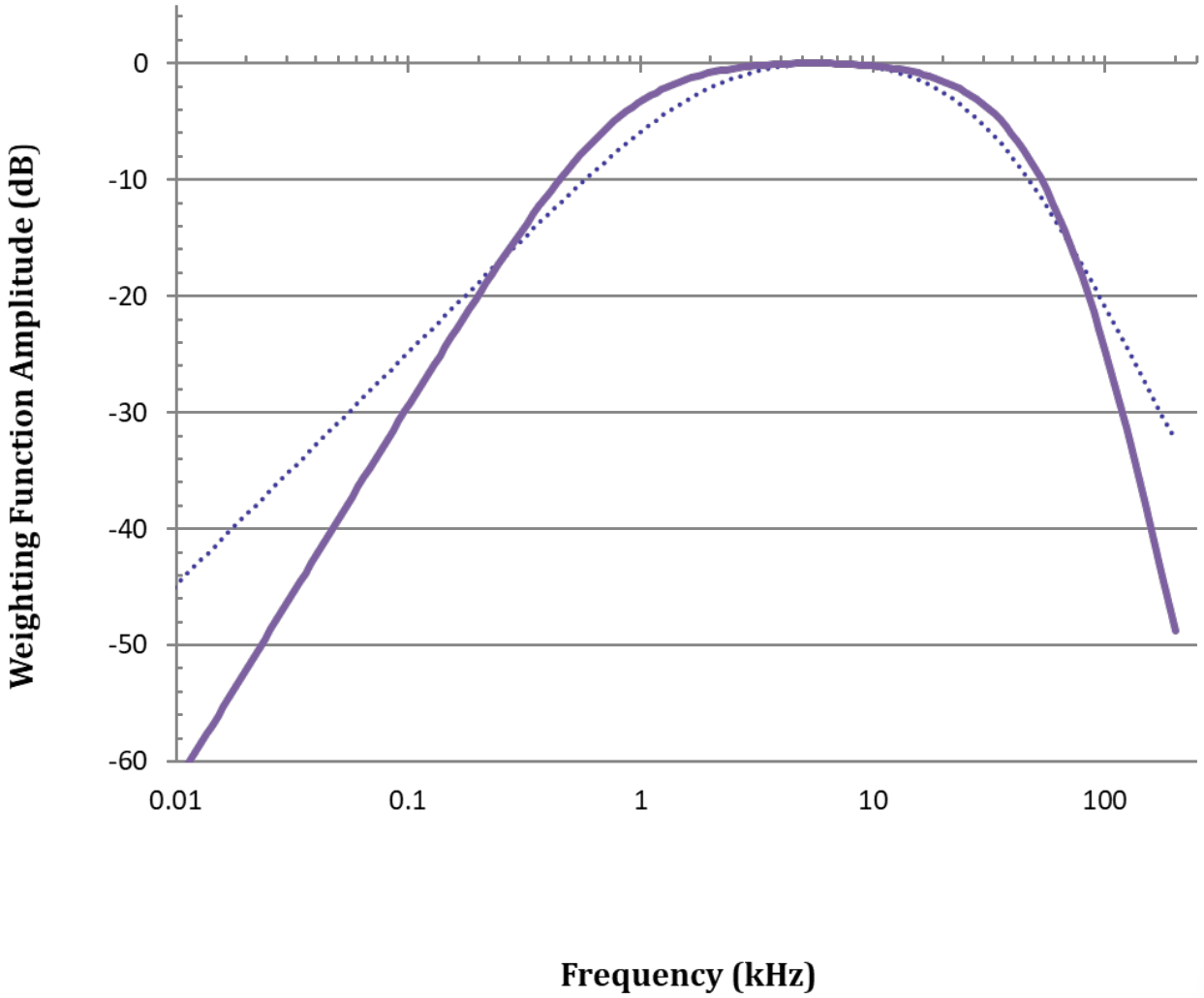

PW Pinnipeds

Phocid (3) **2018**

Phocid (4) **2024**

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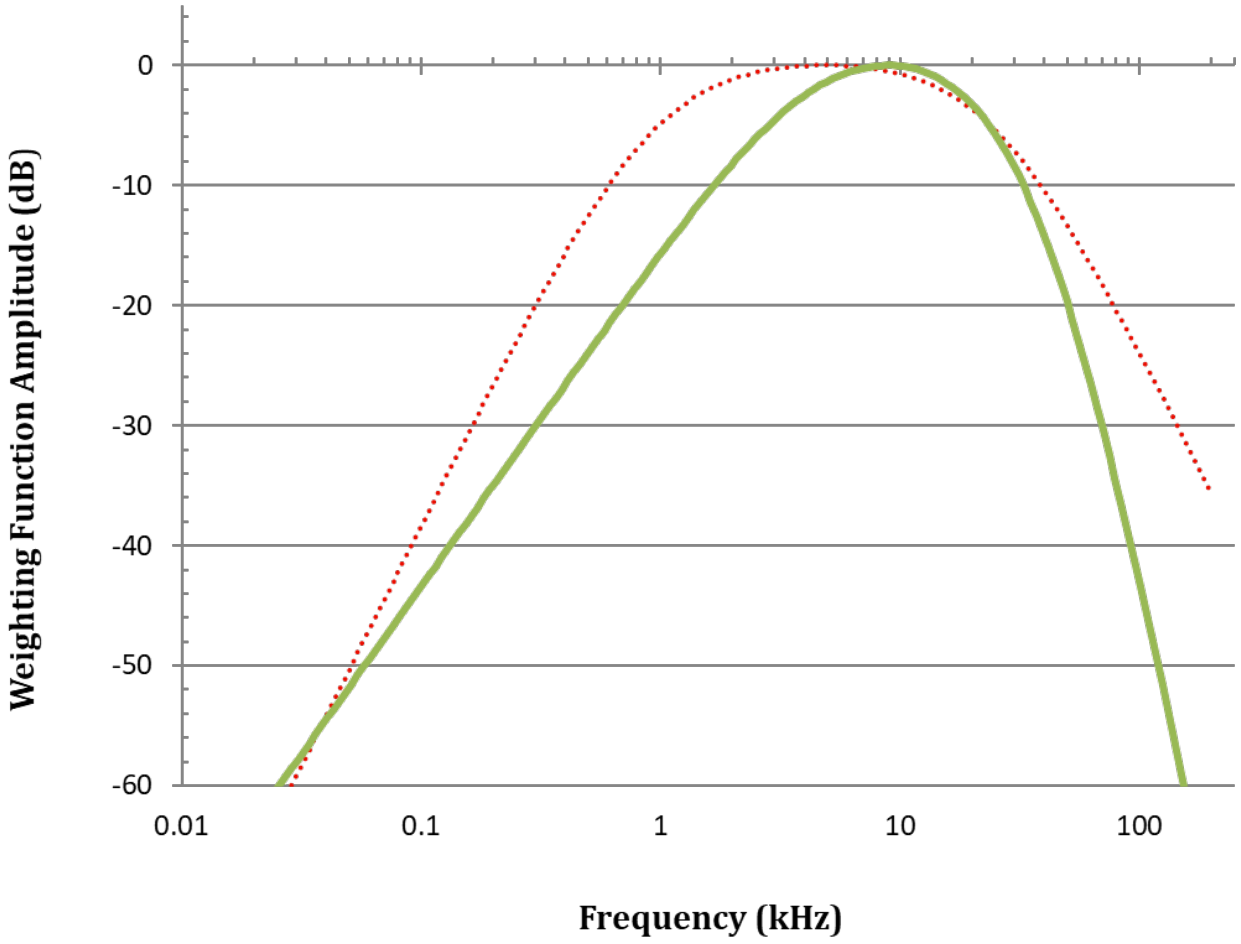
2024 Update vs. 2018 Technical Guidance



OW Pinnipeds

Otariid (3) **2018**

Otariid (4) **2024**

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