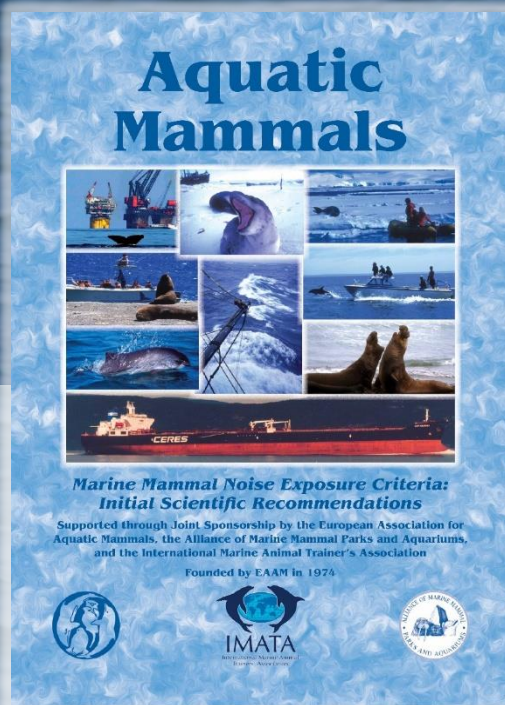


Differences arising from the application of the Southall and NOAA criteria to risk assessment of permanent auditory injury in marine mammals



Rebecca Faulkner
Adrian Farcas
Nathan Merchant
Cefas Noise & Bioacoustics Team

Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing

Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts



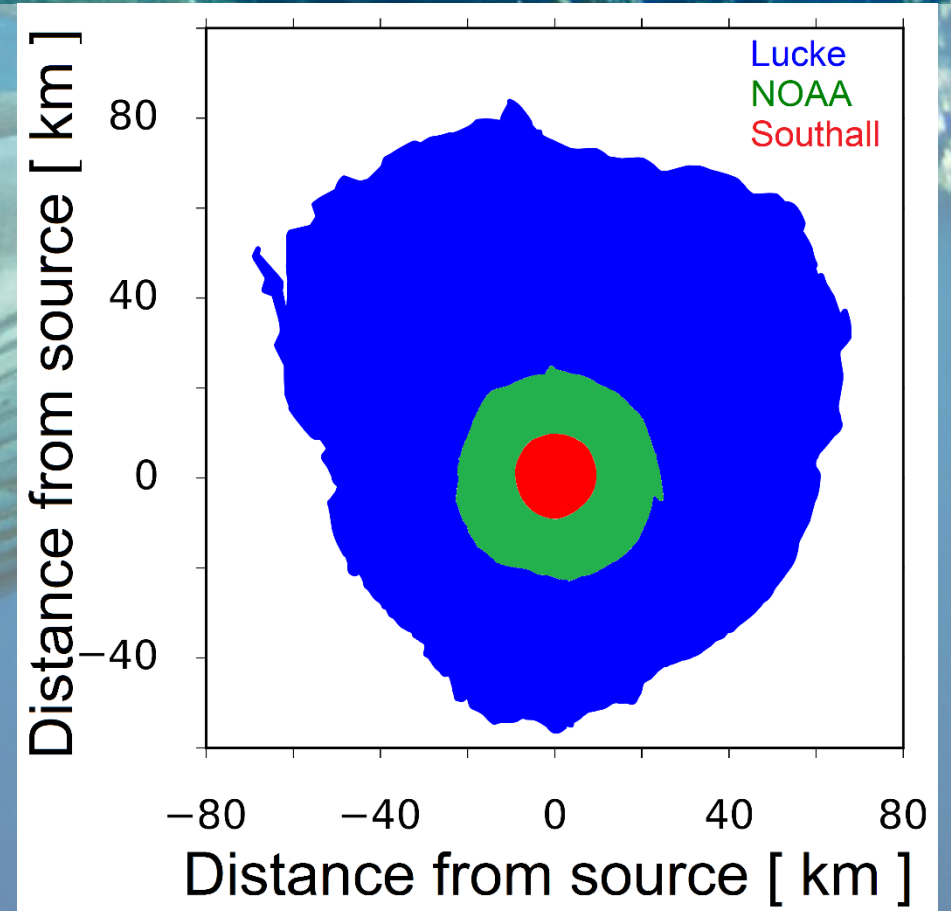
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OPR-55
July 2016



Context

- First thresholds defined by NOAA in late 1990s: 180 dB re 1 μ Pa (RMS SPL) for pinnipeds and 190 dB re 1 μ Pa for cetaceans
- First major marine mammal noise exposure criteria published by Southall et al. (2007)
- In 2016, the US National Marine Fisheries Service (part of NOAA) issued updated guidance based on an extensive peer-review exercise
- 'NOAA criteria' apply to temporary or permanent loss in hearing sensitivity in marine mammals exposed to acute noise exposure
- Uncertainty among regulators and SNCBs over differences between criteria and implications for EIA
- In 2018, Marine Scotland commissioned Cefas to undertake further work to investigate differences in representative UK contexts. Scottish Natural Heritage also on steering group.



Faulkner et al. 2018 Journal of Applied Ecology

Overview

The background of the slide is a photograph of two seals swimming underwater. The water is clear and blue, with sunlight filtering through, creating a bright, shimmering effect. The seals are dark-colored and appear to be looking towards the camera. One seal is in the upper left, and the other is in the lower right.

- **Context**
- **5 functional hearing groups**
- **Dual criteria**
- **Thresholds and weightings**
- **Modelling scenarios**
- **Differences by source type**
- **Differences with propagation from source**

Key differences between Southall and NOAA

Southall et al (2007)

4 functional marine mammal hearing groups:

- LF cetaceans
- MF cetaceans
- HF cetaceans
- Pinnipeds in water
[*Pinnipeds in air*]

NOAA (2016)

5 functional marine mammal hearing groups:

- LF cetaceans
- MF cetaceans
- HF cetaceans
- **Phocid Pinnipeds underwater**
(true seals)
- **Otariid Pinnipeds underwater**
(sea lions and fur seals)



Dual PTS criteria: peak and cumulative sound levels

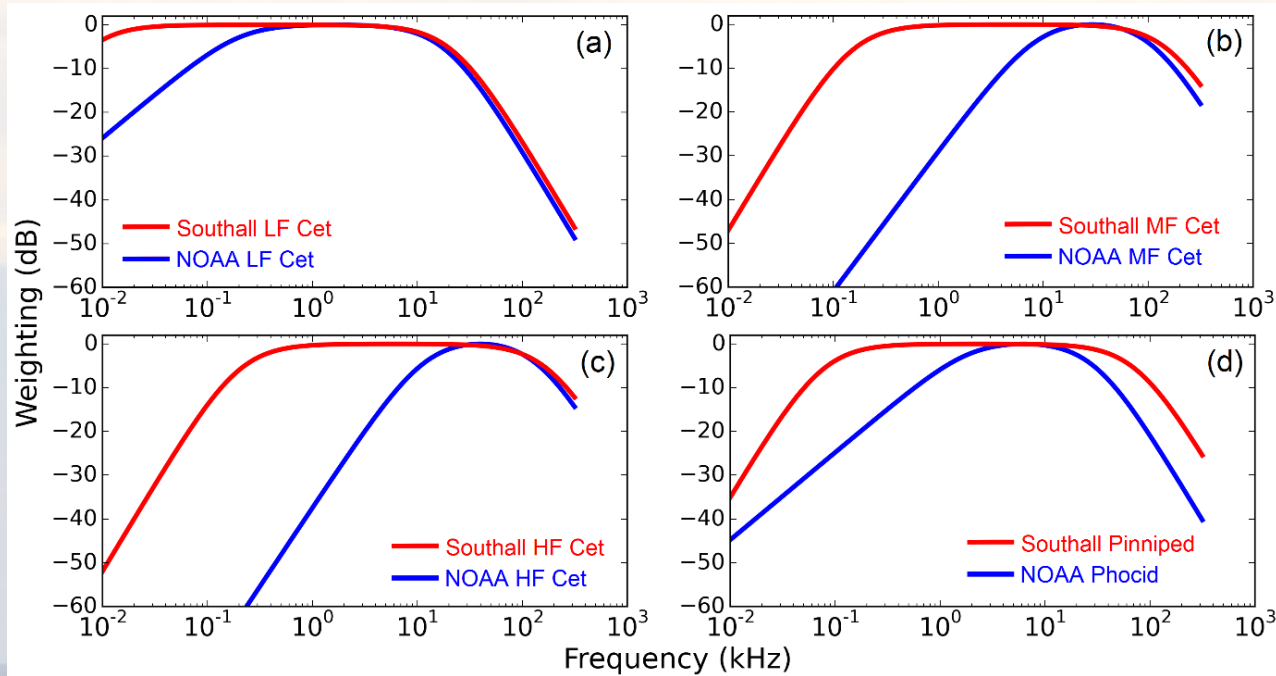
1. **Peak sound level thresholds (unweighted)**
2. **Cumulative sound exposure criteria (weighted for functional hearing group); different thresholds for pulse and non-pulse sound**

Peak sound level thresholds: Southall vs. NOAA

Hearing group	Southall 2007	NOAA 2016
LF cetacean	230	219
MF cetacean	230	230
HF cetacean	230	202
Phocid	218	218
Otariid	218	232

Units: dB re 1 μ Pa (peak ; unweighted)

Cumulative exposure: Thresholds and weightings



If weighting removes less sound from spectrum, criteria are more conservative

If threshold is lower, criteria are more conservative

Both factors influence predictions
Dependent on spectral distribution of received sound level

Cumulative sound exposure criteria have two components:

1. Weightings for each functional hearing group

Subtract sound from spectrum according to hearing sensitivity of functional hearing group

2. Sound level thresholds (weighted)

Define weighted sound level at which effect (e.g. permanent threshold shift; PTS) is predicted to occur, e.g. 198 dB re $1 \mu\text{Pa}^2 \text{s}$ (weighted)

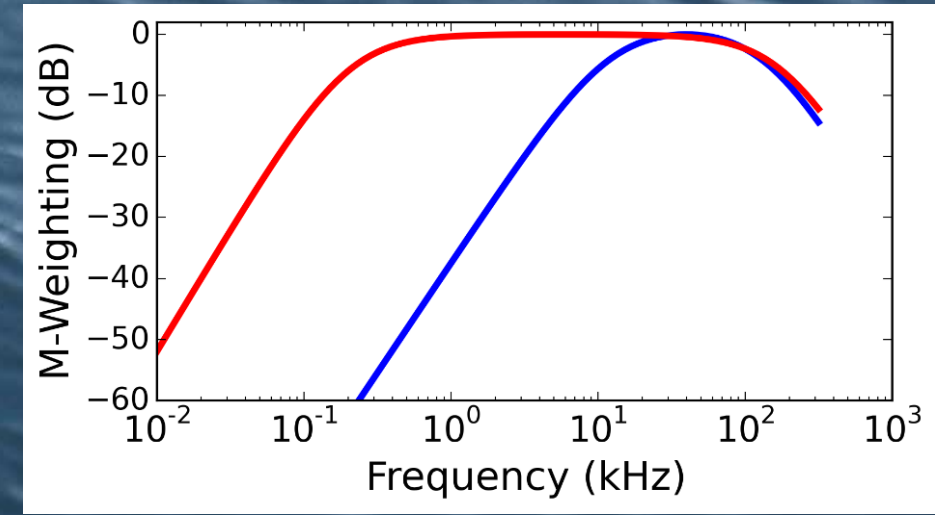
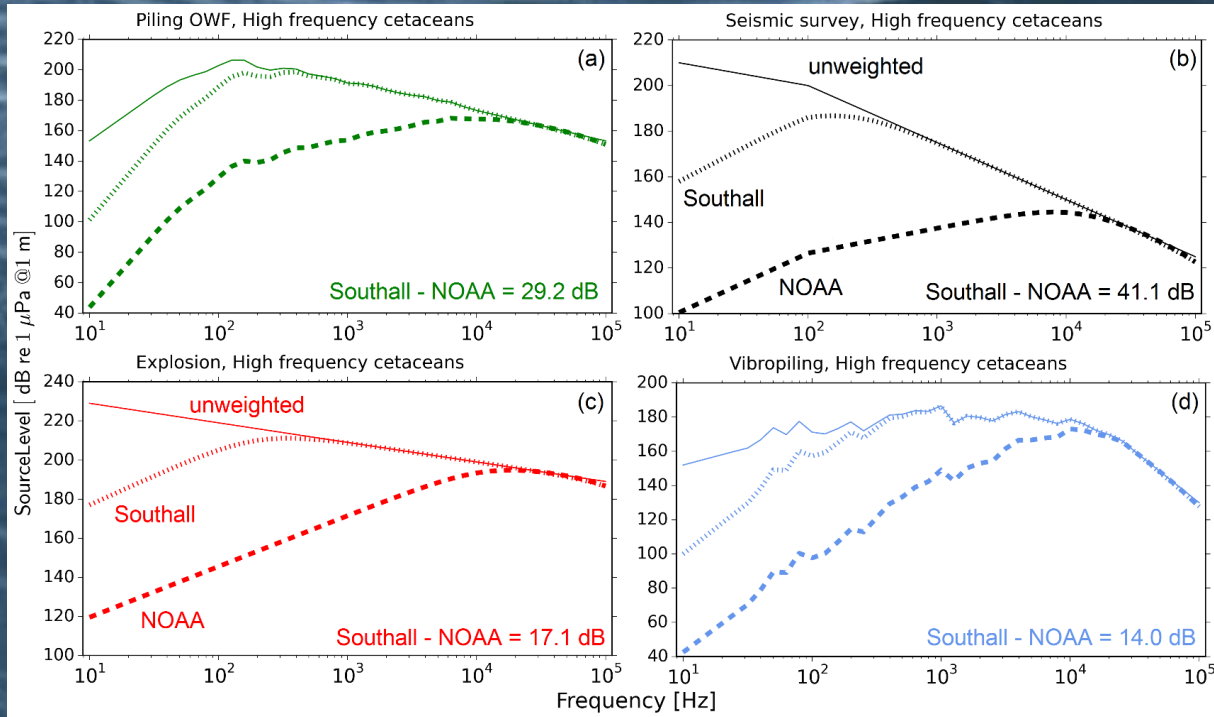
Modelling scenarios

Scenario	Source Type	Source Data	Temporal Properties for 24-h SEL _{cum}	Typical Location	Water Depth	Sediment Type	Season	Scenario Number
Pile driving Offshore Wind Farm (OWF)	Percussive pile driving hammer 3,000 kJ	Source model (validated by Cefas in Scottish waters): Ainslie et al. (2012)	Typical monopile hammer energy profile including ramp-up, 2 piles in 24-h	Northern North Sea	50 m at source, sloping to 100 m at 100 km	Sand	Year round	1
				Southern North Sea	30 m flat bottom	Sand	Year round	2
Pile driving inshore port works	Percussive pile driving (200 kJ inferred by Nigg piling study; 200 dB @1m) Vibratory pile driving	Source model (validated by Cefas in Scottish waters): Ainslie et al. (2012) Measurements on Scottish coast: Graham et al. (2017)	Four hours of piling (during daylight), repetition rate: 1 strike per second (from Nigg study) Four hours of piling (during daylight)	Scottish coast	10 m at source, sloping to 70 m at 100km range	Gravelly sand	Year round	3
				Scottish coast	10 m at source, sloping to 70 m at 100km range	Gravelly sand	Year round	4
Unexploded Ordnance (UXO) detonation	Exploding charge mass; 250 kg	Empirical source model: Soloway & Dahl (2014)	One event in 24 hours	Northern North Sea	60 m, flat bottom	Sand	Year round	5
				Southern North Sea	30 m flat bottom	Sand	Year round	6
Seismic survey	Seismic airgun array	Source model: Erbe & King (2009)	24-h operation, 8-second shot interval	Northern North Sea	80 m, flat bottom	Sand	Year round	7
				North-East Atlantic	150 m, flat bottom	Gravelly sand	Year round	8

Results

- Differences by **source type**
- Differences due to **sound propagation**

High-frequency cetaceans



— Southall — NOAA

Weightings differ substantially at **low frequencies**

Weightings differ by **17.1 to 41.1 dB** (impulsive) and **14 dB** (vibropiling; Graham et al 2017)



High-frequency cetaceans

NOAA criteria are **more precautionary** for HF cet for both impulsive and non-impulsive sounds

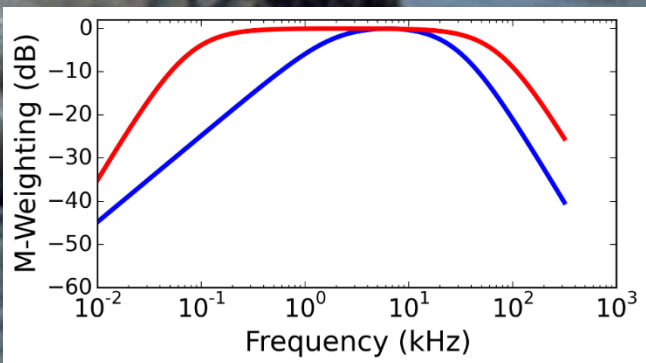
Criterion	Southall	NOAA	Difference (dB)
Peak SPL, PTS	230	202	-28
<i>Cumulative SEL PTS Threshold Impulsive</i>	198	155	-43
<i>Cumulative SEL Weighting</i>			17.1 to 41.1
Cumulative SEL Difference Impulsive			-25.9 to -1.9
<i>Cumulative SEL PTS Threshold Non-Impulsive</i>	215	173	-42
<i>Cumulative SEL Weighting</i>			14.0
Cumulative SEL Difference Non-Impulsive			-28.0

Phocid seals

NOAA criteria are **less precautionary** for phocid seals for both impulsive and non-impulsive sounds

Criterion	Southall	NOAA	Difference (dB)
Peak SPL, PTS	218	218	0
<i>Cumulative SEL PTS Threshold Impulsive</i>	186	185	-1
<i>Cumulative SEL Weighting</i>			10.7 to 18.4
Cumulative SEL Difference Impulsive			9.7 to 17.4
<i>Cumulative SEL PTS Threshold Non-Impulsive</i>	203	201	-2
<i>Cumulative SEL Weighting</i>			3.5
Cumulative SEL Difference Non-Impulsive			1.5

— Southall — NOAA



Differences by source type: Summary

- NOAA **more precautionary** than Southall for LF Cet and HF Cet
- Phocid seals are either the same or **less conservative**
- MF Cet are either the same or **less conservative**

	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid seal
Peak SPL threshold for PTS	-11	0	-28	0
Cumulative SEL Impulsive	-11.6 to -1.8	3.6 to 25.3	-25.9 to -1.9	9.7 to 17.4
Cumulative SEL Non-Impulsive	-15.5	-5.8	-28.0	1.5

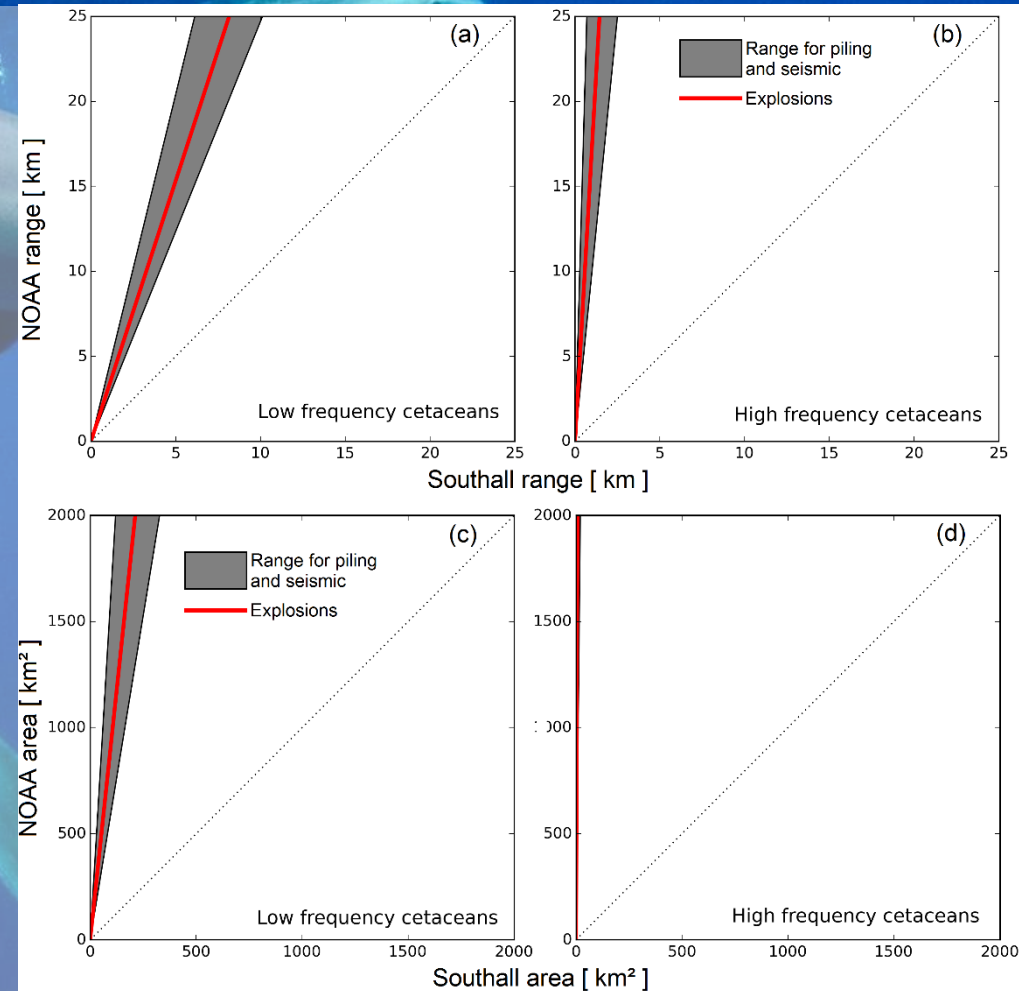
Results

- Differences by **source type**
- Differences due to **sound propagation**



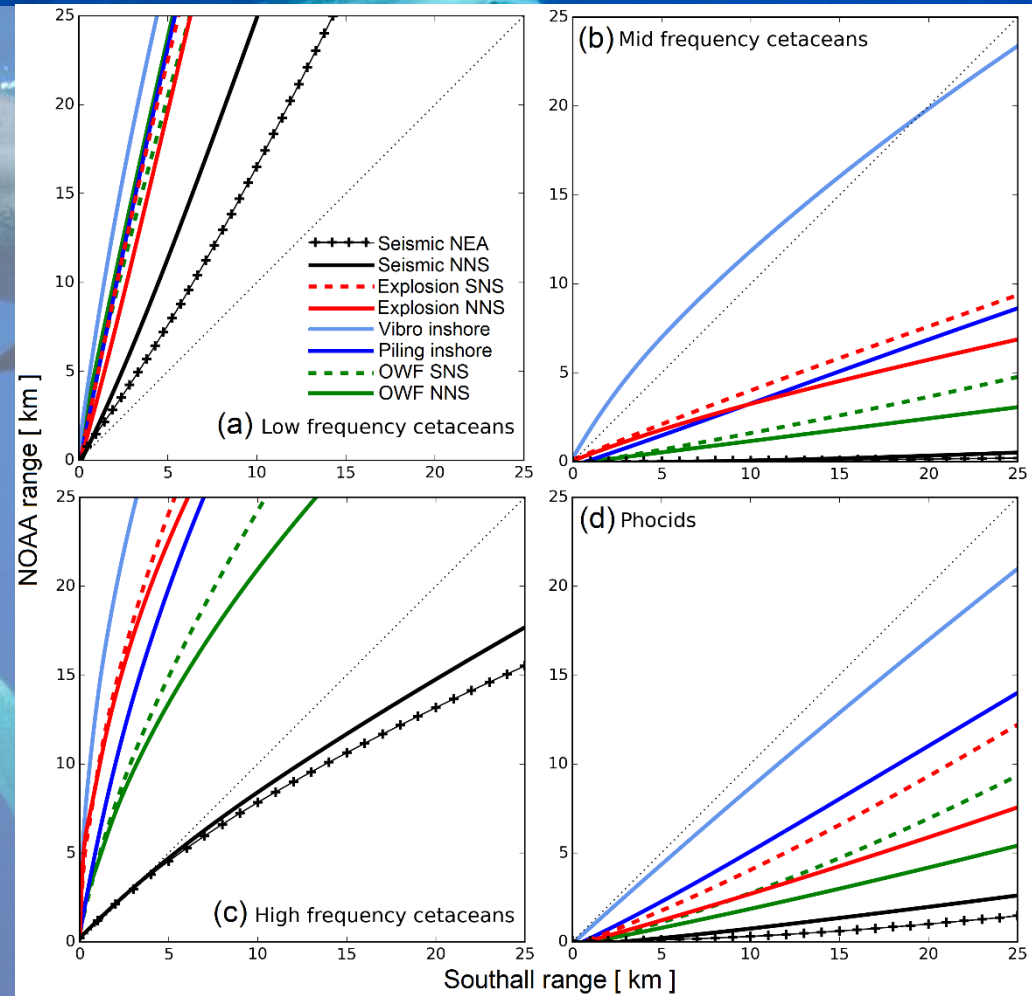
Differences with propagation distance: **peak SPL**

- **Peak SPL criterion**
- Only **low- and high-frequency** cetaceans have difference peak SPL criterion
- Plots show how **range** predicted with one criterion approximately **translates** to range with the **other criterion**
- **Area** is the more relevant than **range** when considering **number of animals affected**



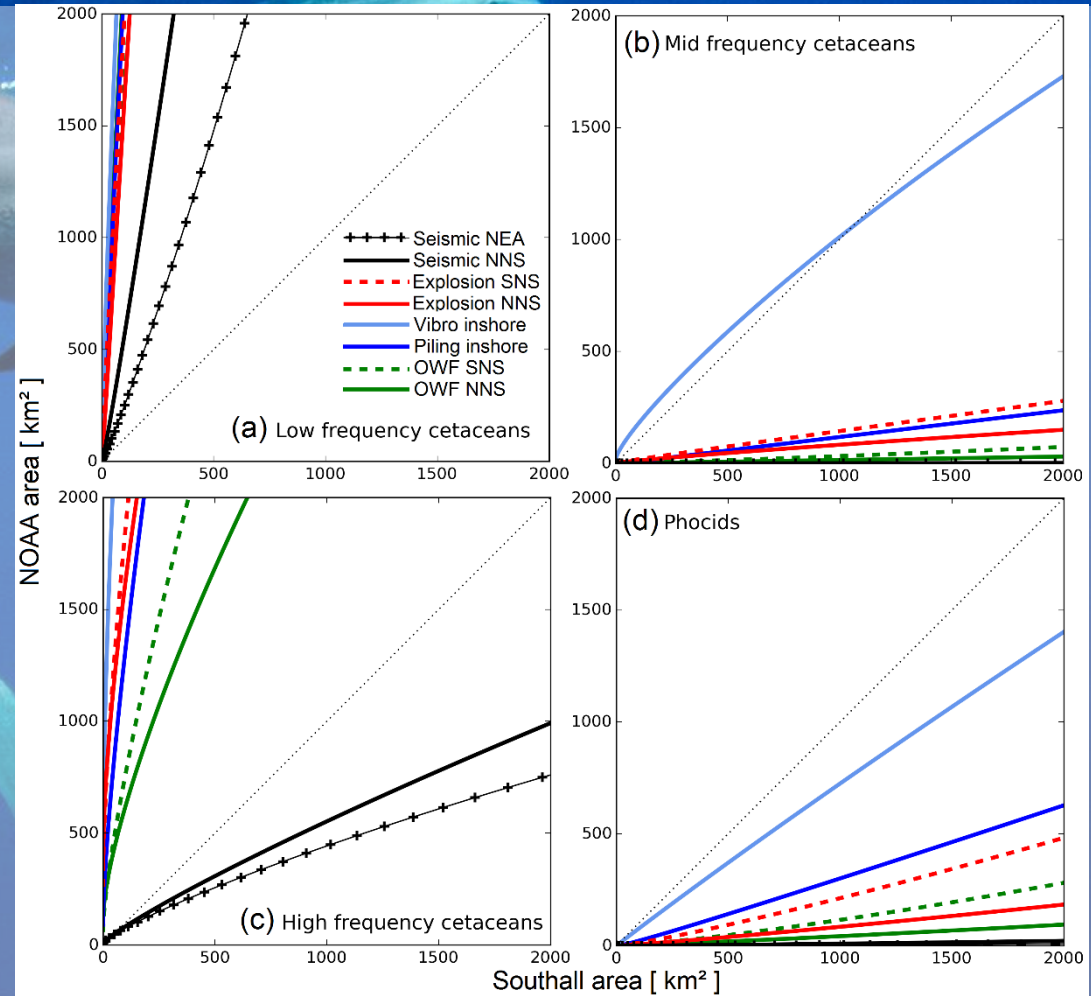
Differences with propagation distance: SEL_{cum}

- Cumulative SEL criterion
- Plots show how range predicted with one criterion approximately translates to range with the other criterion



Differences with propagation distance: SEL_{cum}

- **Cumulative SEL criterion**
- Plots show how **area predicted with one criterion approximately translates to area with the other criterion**
- **Area is the more relevant than range when considering number of animals affected**



Conclusions

- NOAA **more precautionary** than Southall for LF Cet and HF Cet
- Phocid seals are either the same or **less conservative**
- MF Cet are either the same or **less conservative**

	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid seal
Peak SPL threshold for PTS	-11	0	-28	0
Cumulative SEL Impulsive	-11.6 to -1.8	3.6 to 25.3	-25.9 to -1.9	9.7 to 17.4
Cumulative SEL Non-Impulsive	-15.5	-5.8	-28.0	1.5

Disclaimer: Caution should be exercised to avoid applying these results too widely or with unwarranted precision: the absolute decibel differences reported for the criteria should be broadly similar for other similar environments and sources, but variability should be expected according to the specifics of any particular modelling scenario assessed.