

Presentation from The Journal of the Acoustical
Society of America 141(5):3603-3603 · May 2017
DOI: 10.1121/1.4987709. Session 2pAB05.



Cumulative Sound Exposure Levels – Insights from long-term measurements

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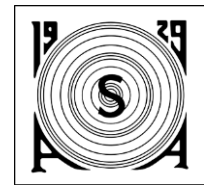
⁴Shell Global Solutions

⁵Groningen Institute for Evolutionary Life Sciences, University of Groningen

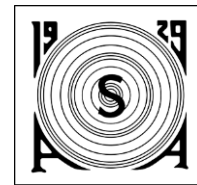
⁶Deep Water Wind

⁷Saint Mary's University, Electrical Engineering.

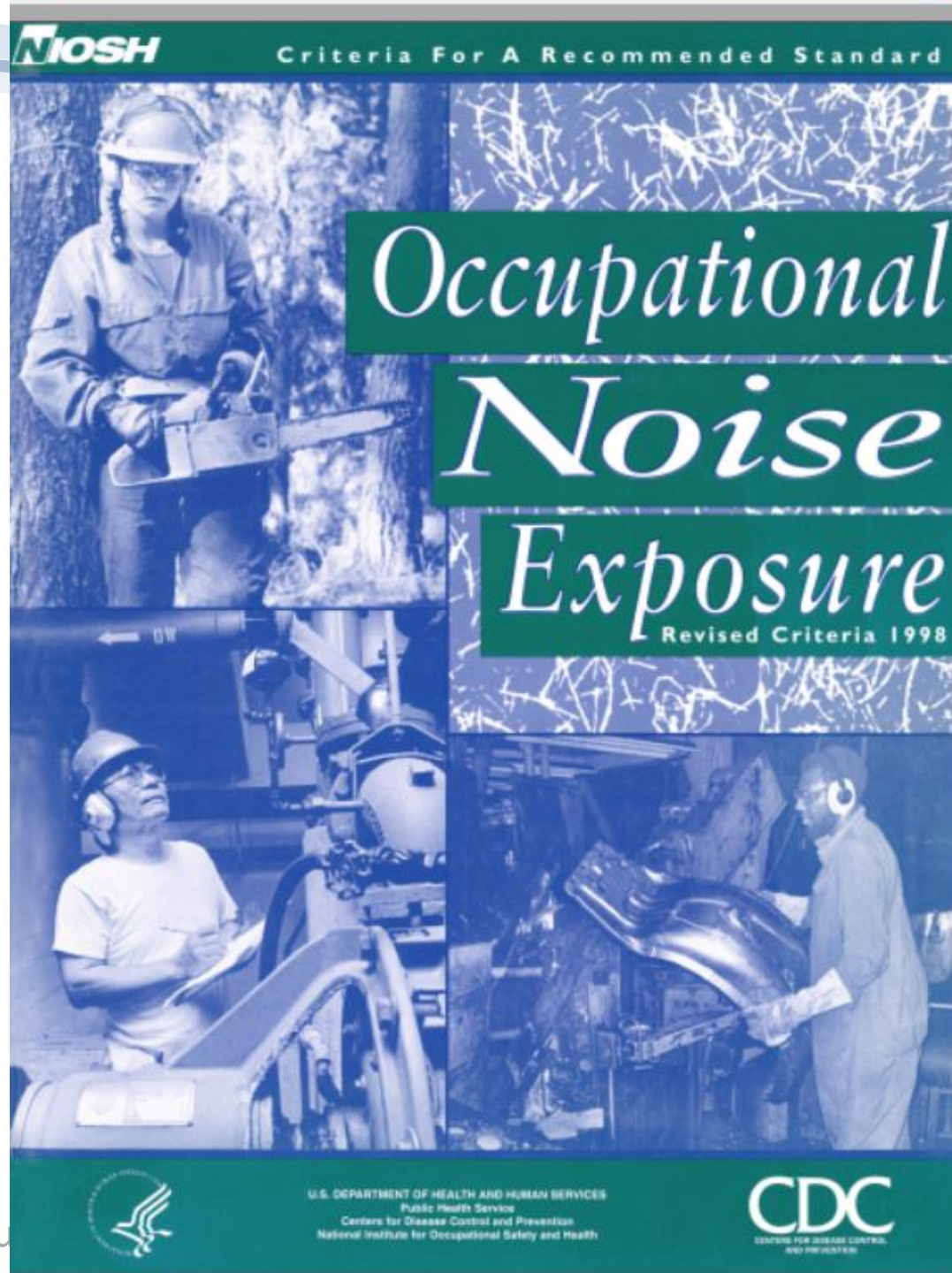
Martin et al, SEL Insights, 26 June 2017, Acoustic 2017, Boston.



- Context: what are human hearing loss recommendations from NIOSH? How does that compare to the Technical Guidance?
- What is normal? How does it depend on mammal hearing group?
- How does SEL accumulate?



Human Sound Exposure

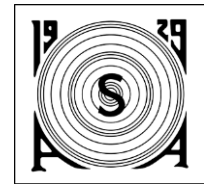


NIOSH → Recommended Exposure Level

$REL = 85$ dBA, 8 hour time weighted average

$$SEL = (L_{eq,8hr} + 10 \log(8hr)) \text{ dB}$$

$$SEL = \int_{8hr} (L_p * w_f) dt$$



DECIBEL - dB(A)

EQUIPMENT

Double protection
recommended
above 105 dB(A)

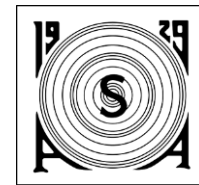
112	Pile driver
110	Air arcing gouging
108	Impact wrench
107	Bulldozer - no muffle
102-104	Air grinder
102	Crane - uninsulated cab
101-103	Bulldozer - no cab
97	Chipping concrete
96	Circular saw and hammering
96	Jack hammer
96	Quick-cut saw
95	Masonry saw
94	Compactor - no cab
90	Crane - insulated cab
87	Loader/backhoe - insulated cab
86	Grinder
85-90	Welding machine
85	Bulldozer - insulated cab
60-70	Speaking voice

Hearing protection
recommended
above 85 dB(A)

NIOSH permissible
exposure : 85 dBA
for 8 hours → SEL =
130 dB re 20 $\mu\text{Pa}^2 \cdot \text{s}$

Uses Equal Energy
Hypothesis:
As level goes up
maximum time
goes down.

Table 1: Some typical noise levels found on construction sites

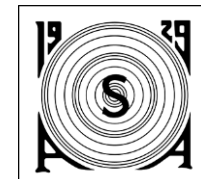


Time to REL*TWA = Noise Dose

DECIBEL - dB(A)	EQUIPMENT
112	Pile driver
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60-70	Speaking voice

Some typical noise levels found on construction sites

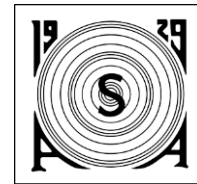
SPL (dBA re 20 µPa)	Source	Time to Noise Dose
139	Manowar	< 1 sec
136	KISS	<1 sec
112	Pile Driver	56 sec
103	Bulldozer	7.5 min
96	Jackhammer	35 min



Recall – NOAA 2016 SEL Limits

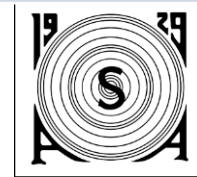
Hearing Group	PTS Onset Thresholds* (Received Level)	
	Impulsive	Non-impulsive
Low-Frequency (LF) Cetaceans	<i>Cell 1</i> $L_{pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	<i>Cell 2</i> $L_{E,LF,24h}$: 199 dB
Mid-Frequency (MF) Cetaceans	<i>Cell 3</i> $L_{pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	<i>Cell 4</i> $L_{E,MF,24h}$: 198 dB
High-Frequency (HF) Cetaceans	<i>Cell 5</i> $L_{pk,flat}$: 202 dB $L_{E,HF,24h}$: 155 dB	<i>Cell 6</i> $L_{E,HF,24h}$: 173 dB
Phocid Pinnipeds (PW) (Underwater)	<i>Cell 7</i> $L_{pk,flat}$: 218 dB $L_{E,PW,24h}$: 185 dB	<i>Cell 8</i> $L_{E,PW,24h}$: 201 dB
Otariid Pinnipeds (OW) (Underwater)	<i>Cell 9</i> $L_{pk,flat}$: 232 dB $L_{E,OW,24h}$: 203 dB	<i>Cell 10</i> $L_{E,OW,24h}$: 219 dB

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for

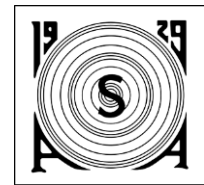


The 8 hour Marine Mammal Work Day

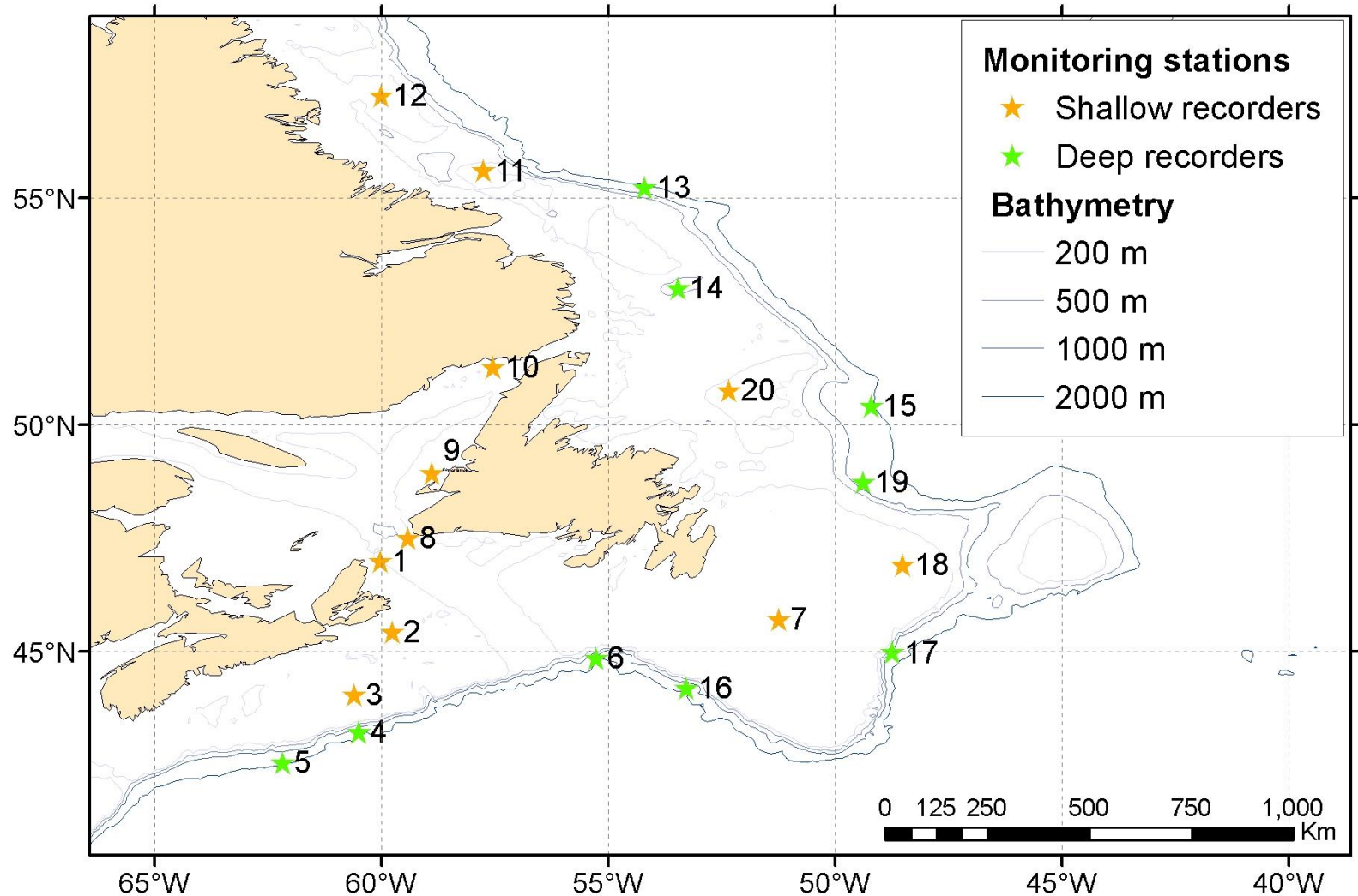
Species Group	PTS Onset Threshold (continuous, weighted, 24 hours, dB re 1 $\mu\text{Pa}^2\cdot\text{s}$)	$L_{\text{eq},8\text{hr}}$ (Weighted, dB re 1 μPa)
Low Frequency Cetaceans	199	154
Mid Frequency Cetaceans	198	153
High Frequency Cetaceans	173	128
Otariid Seals	203	158
Phocid Seals	185	140



What is 'normal' Ocean 24-hour SEL?



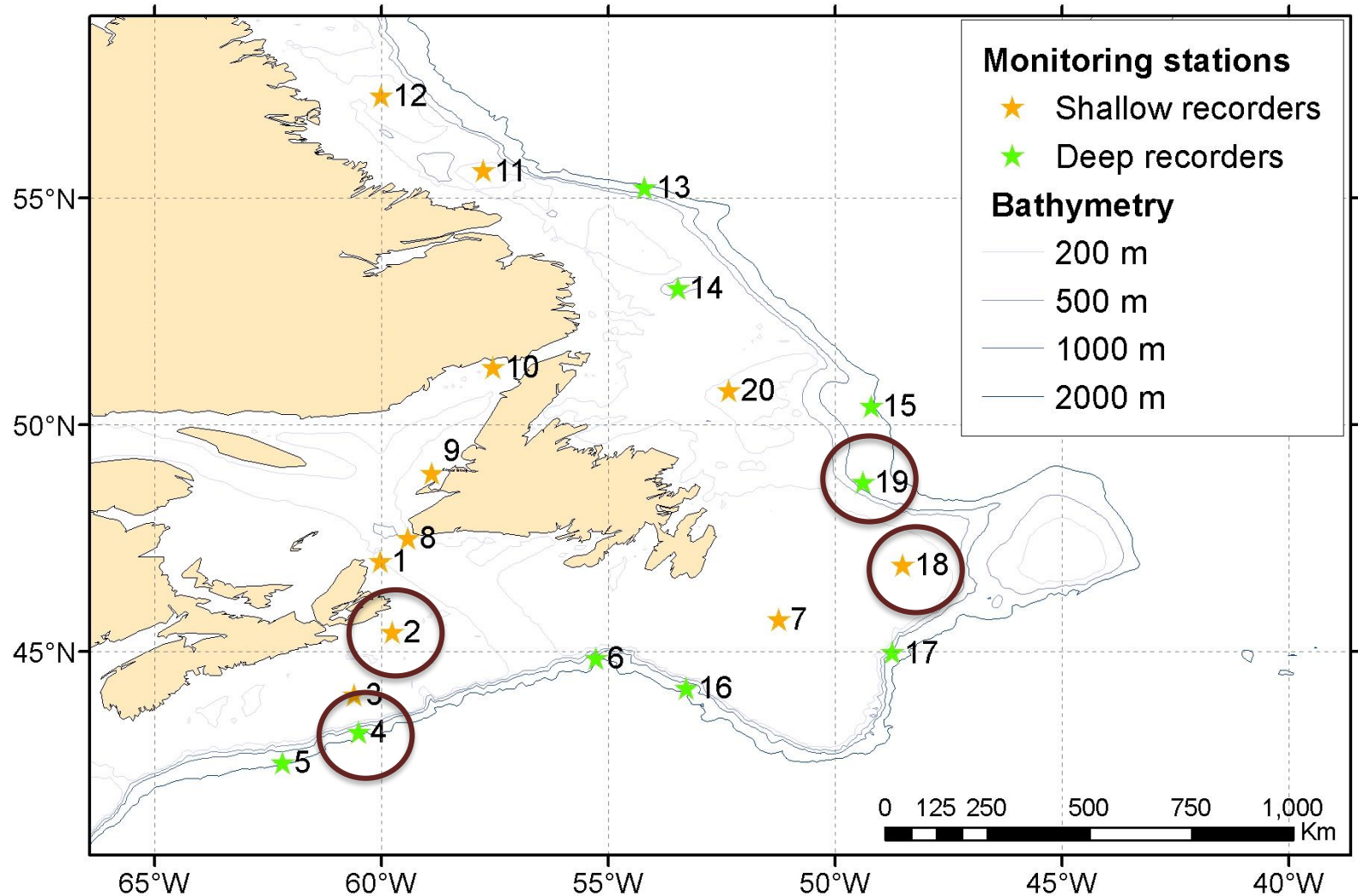
Atlantic Canada Monitoring Program



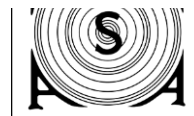
Martin et al, SEL Insights, 26 June 2017, Acoustic 2017, Boston.



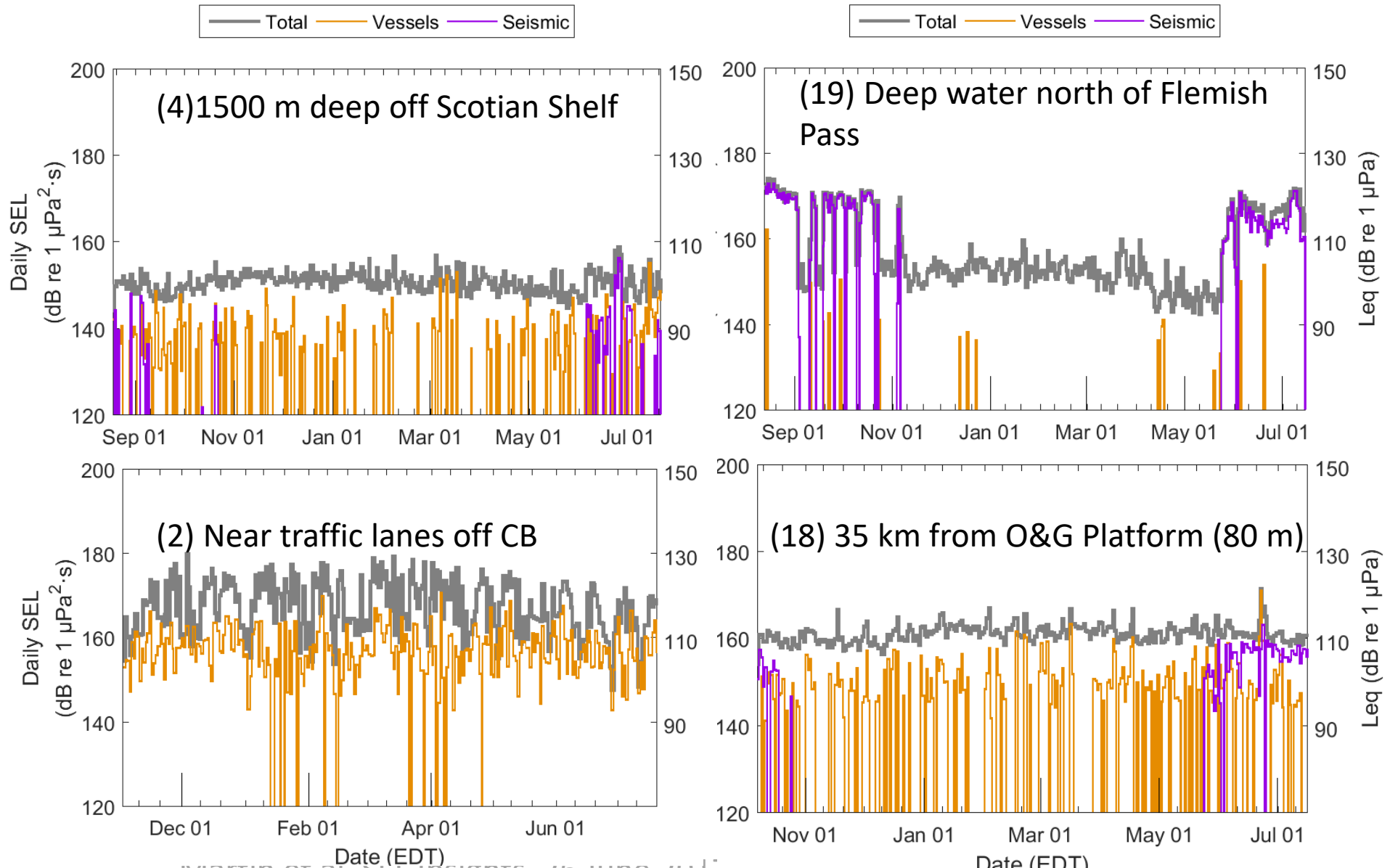
Atlantic Canada Monitoring Program



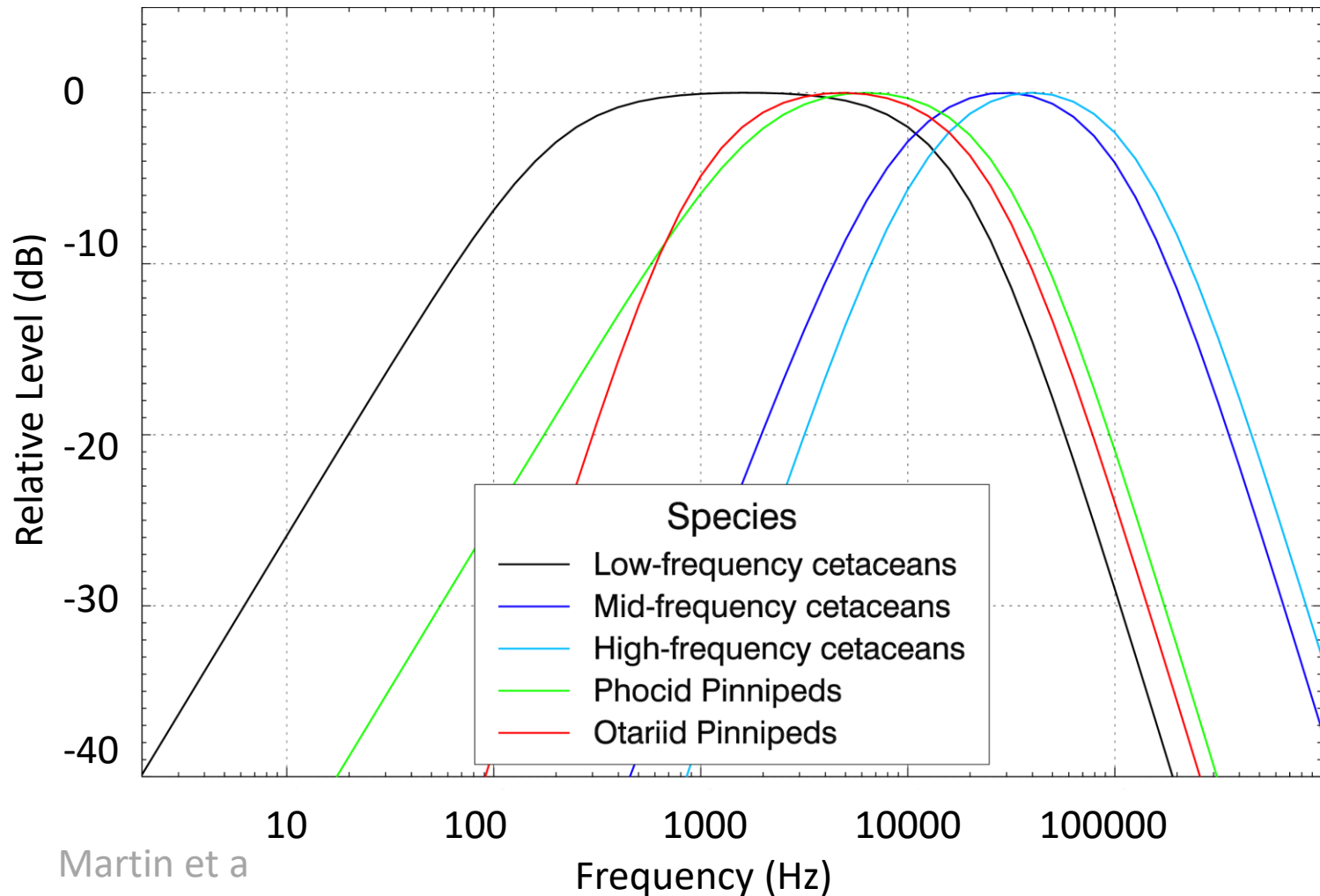
Martin et al, SEL Insights, 26 June 2017, Acoustic 2017, Boston.



SEL – What is Normal?



Weighting functions

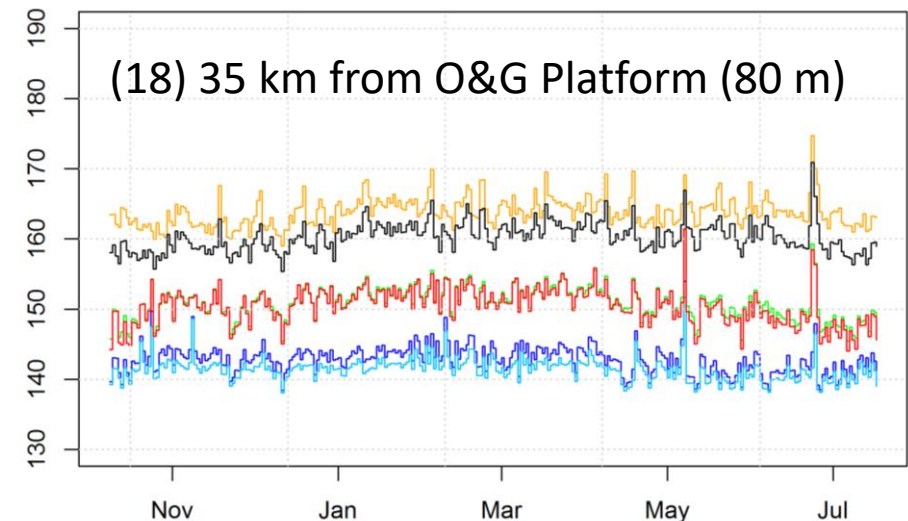
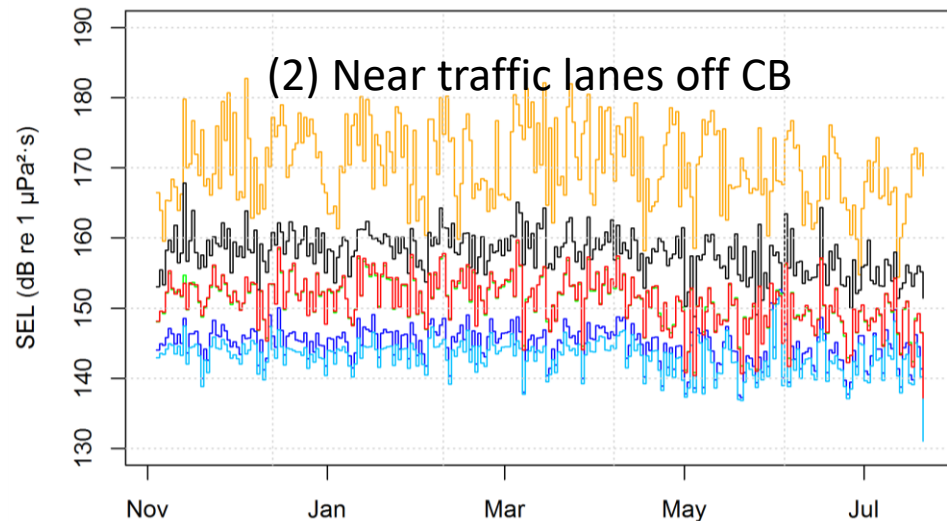
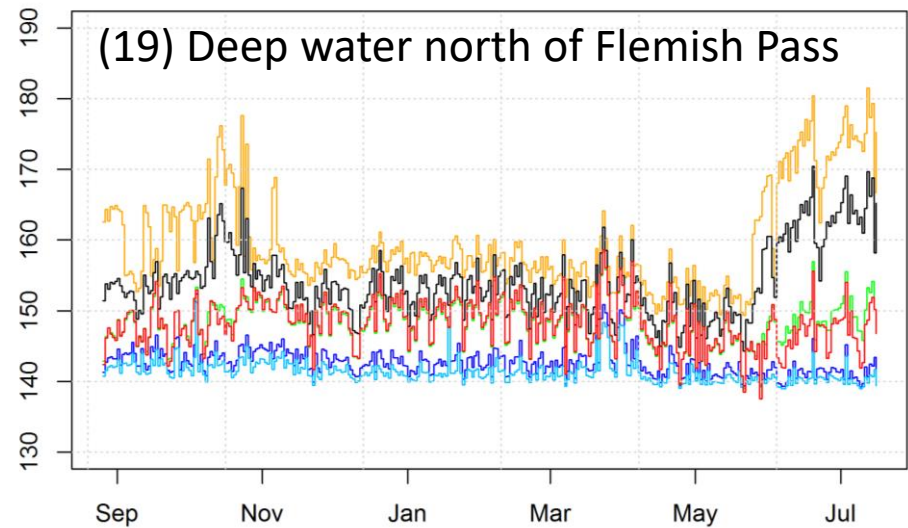
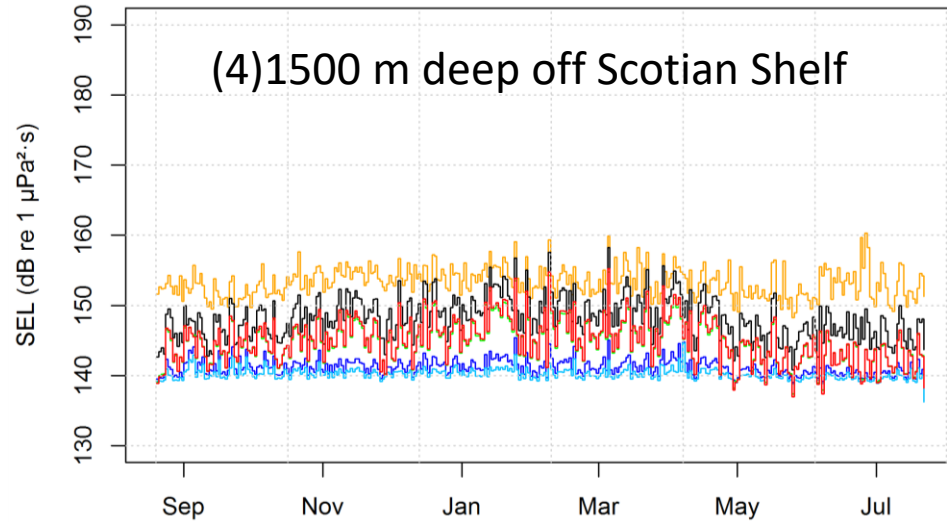


Martin et al

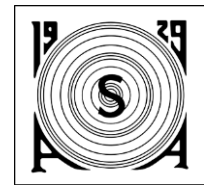


What is normal – weighted?

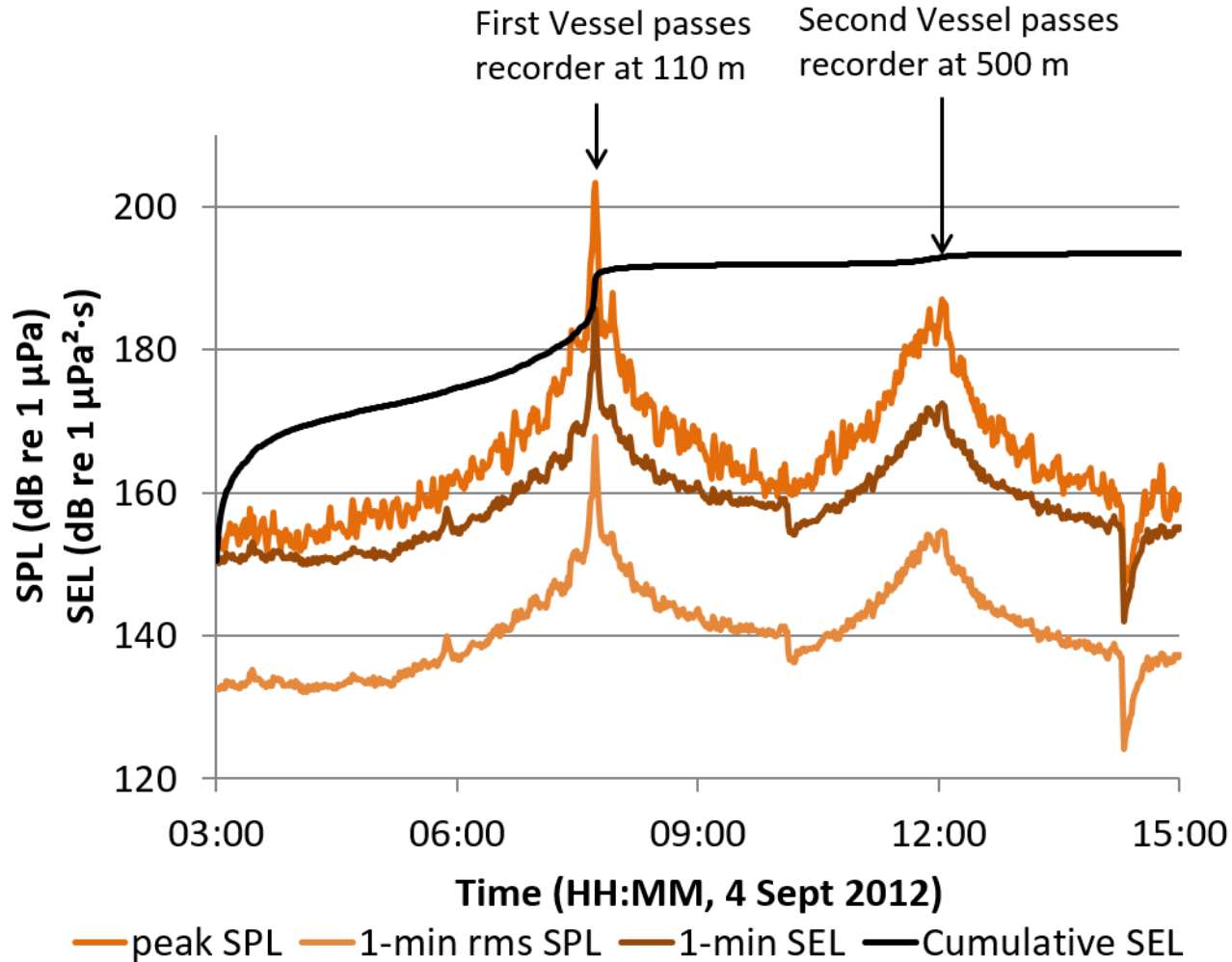
- Unweighted
- Low Frequency Cetaceans
- Mid-Frequency Cetaceans
- High Frequency Cetaceans
- Otariid Seals
- Phocid Seals



How does SEL accumulate?

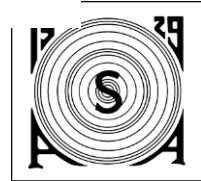


Accumulation of SEL: Seismic Surveys

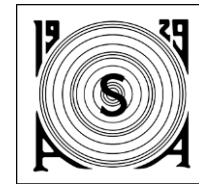
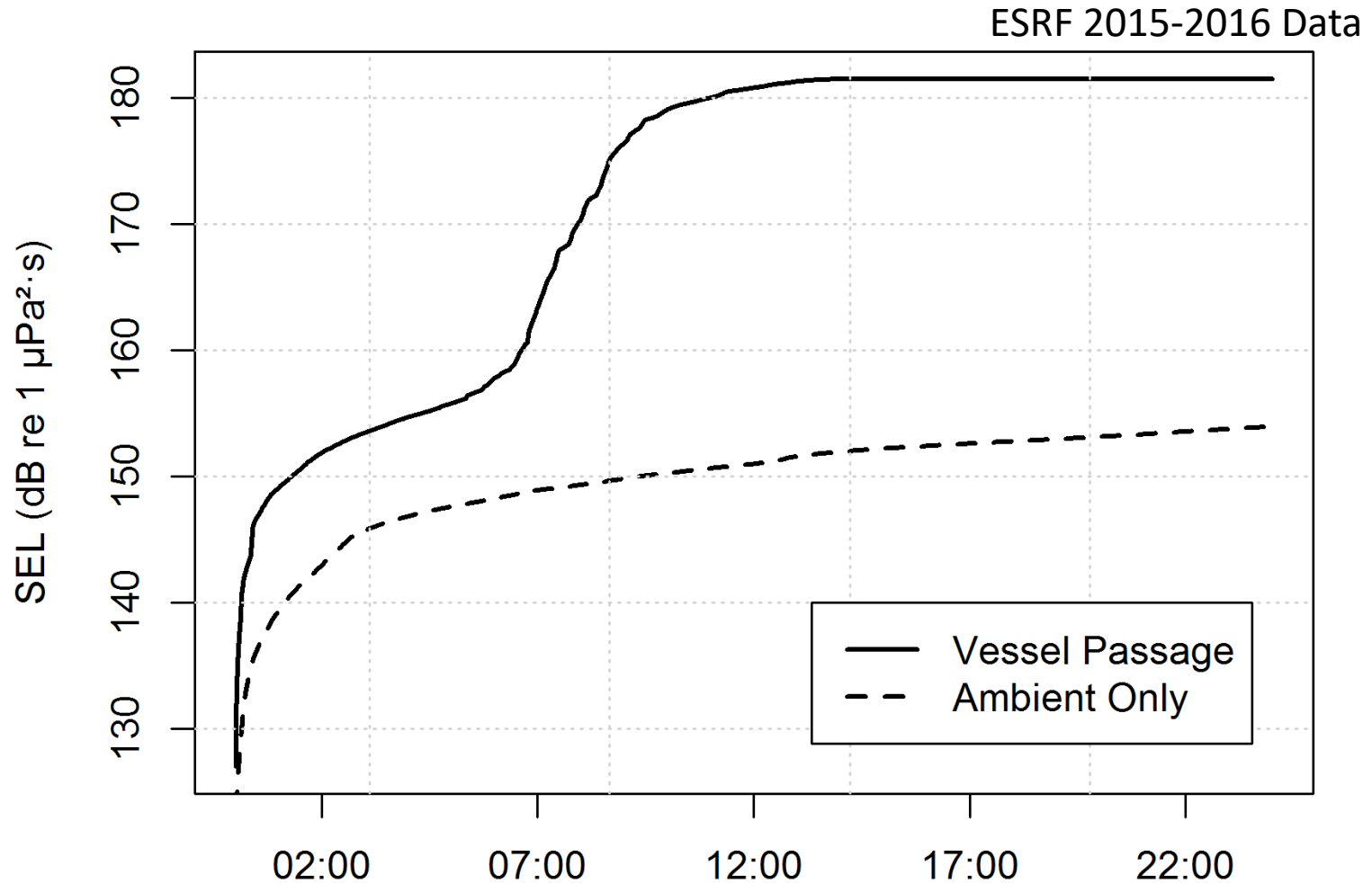


Shell Greenland 2012 Seismic Survey

Martin et al, SEL Insights, 26 June 2017, Acoustic 2017, Boston.



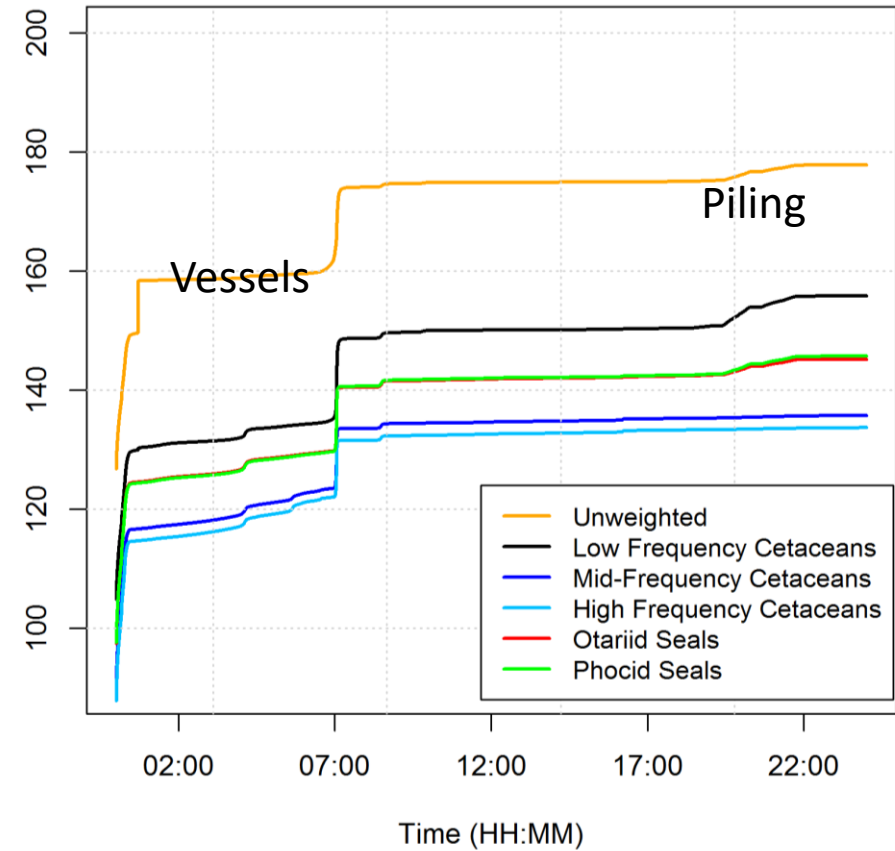
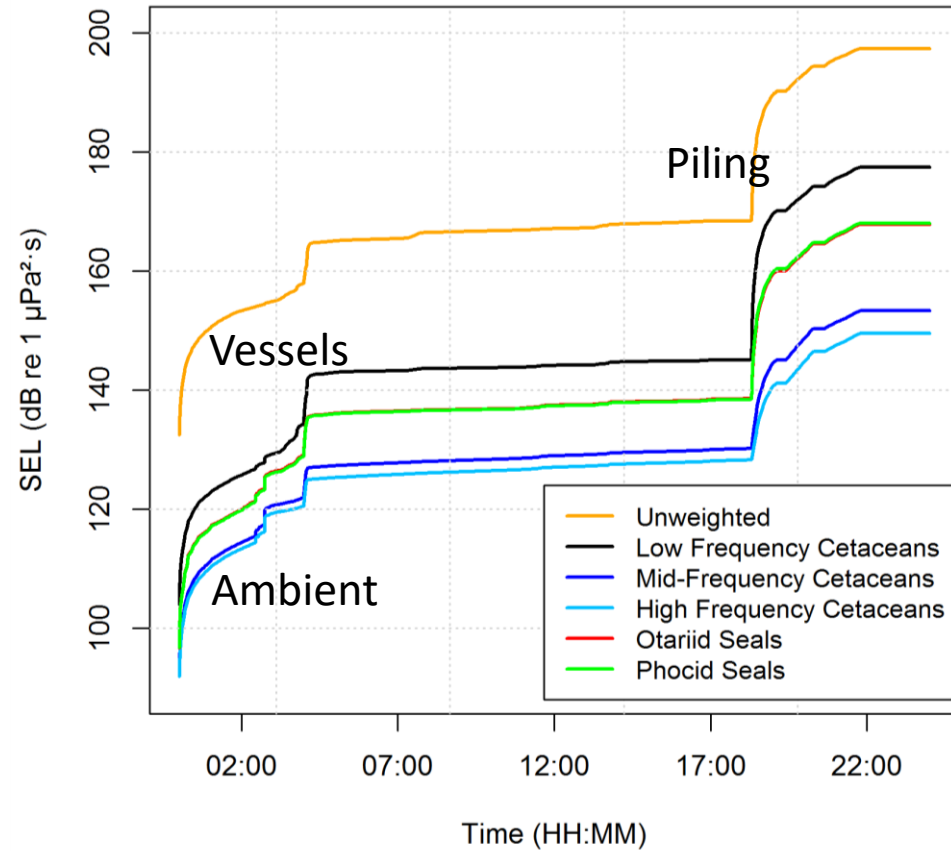
Accumulation of SEL: Ambient / Shipping



SEL: Pile Driving @Block Island F4 25 Oct

850 m

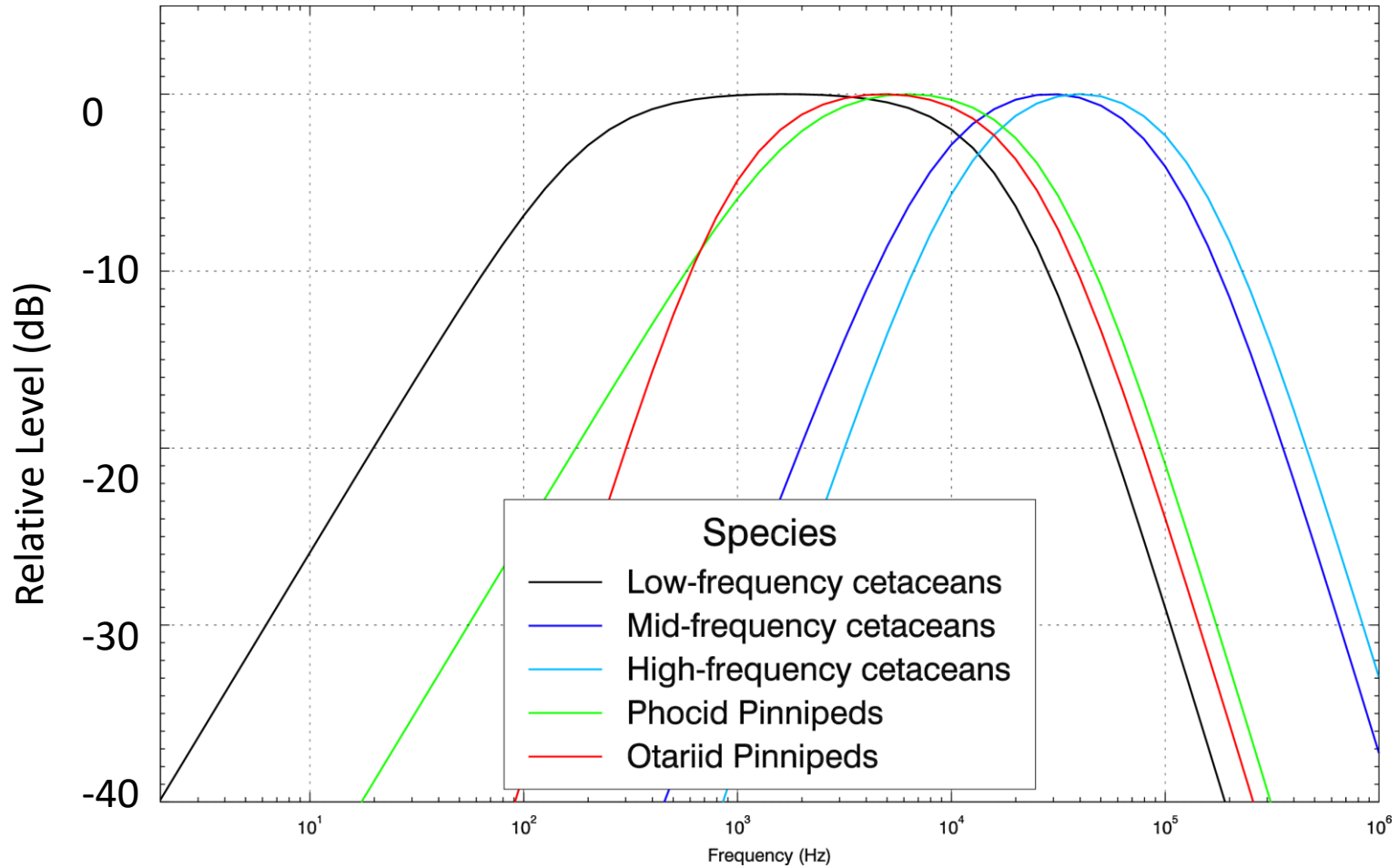
9100 m



Deep Water Wind Block Island 2015

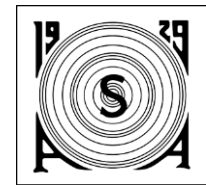
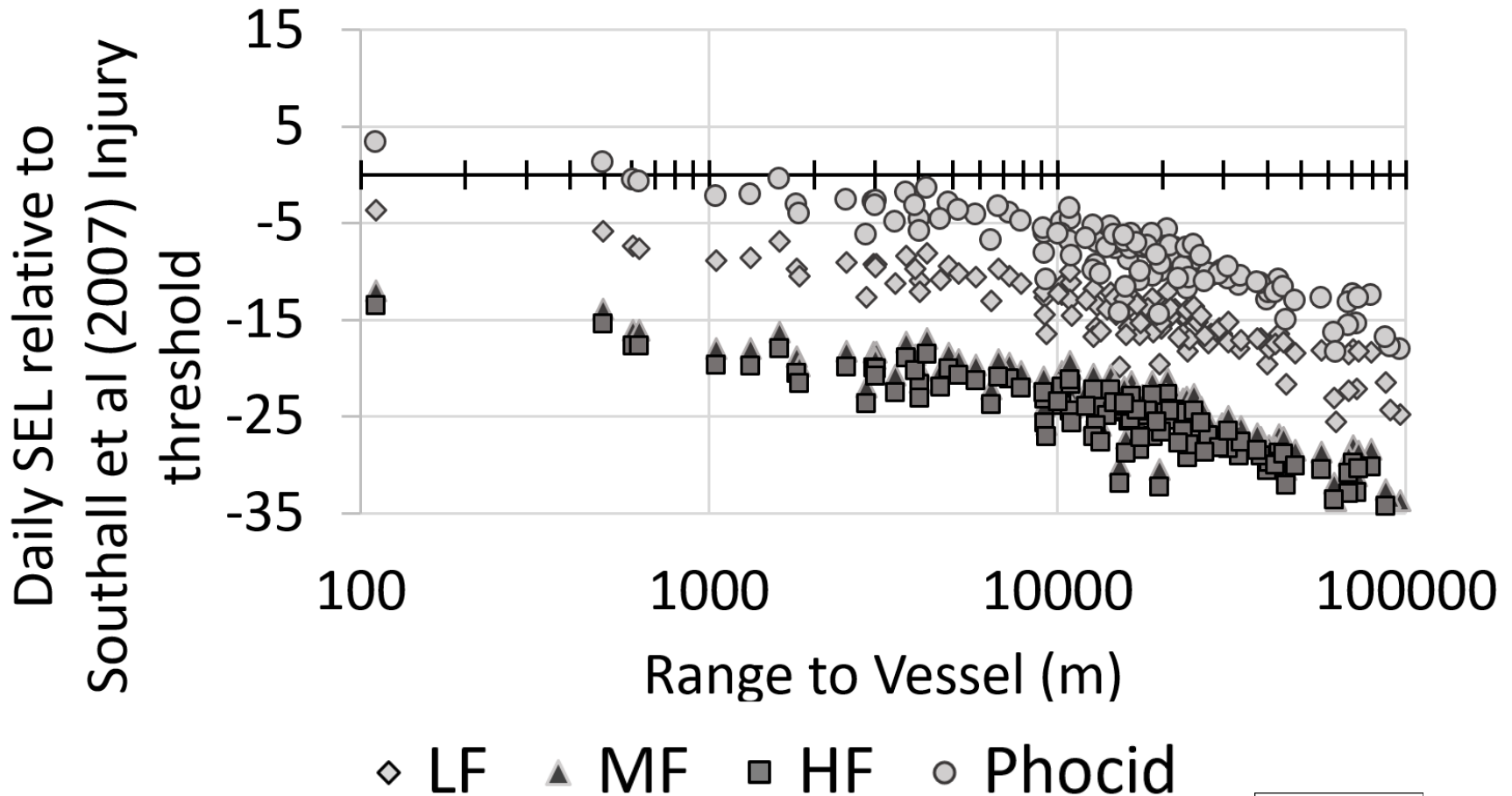


Weighting functions



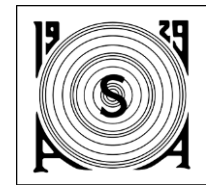
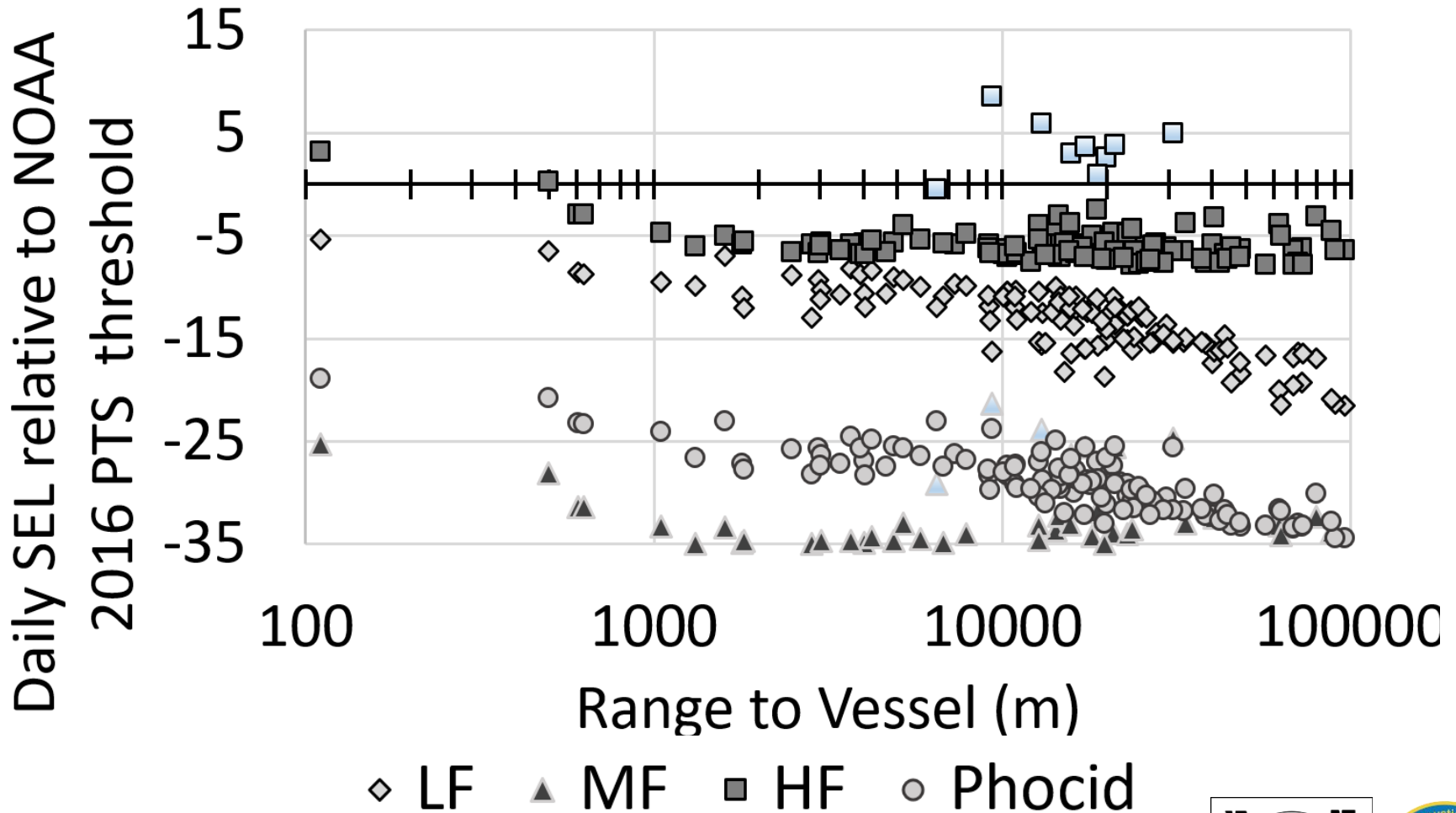
Weighted Daily SELs - Southall et al (2007)

Shell Greenland 2012 Seismic Survey



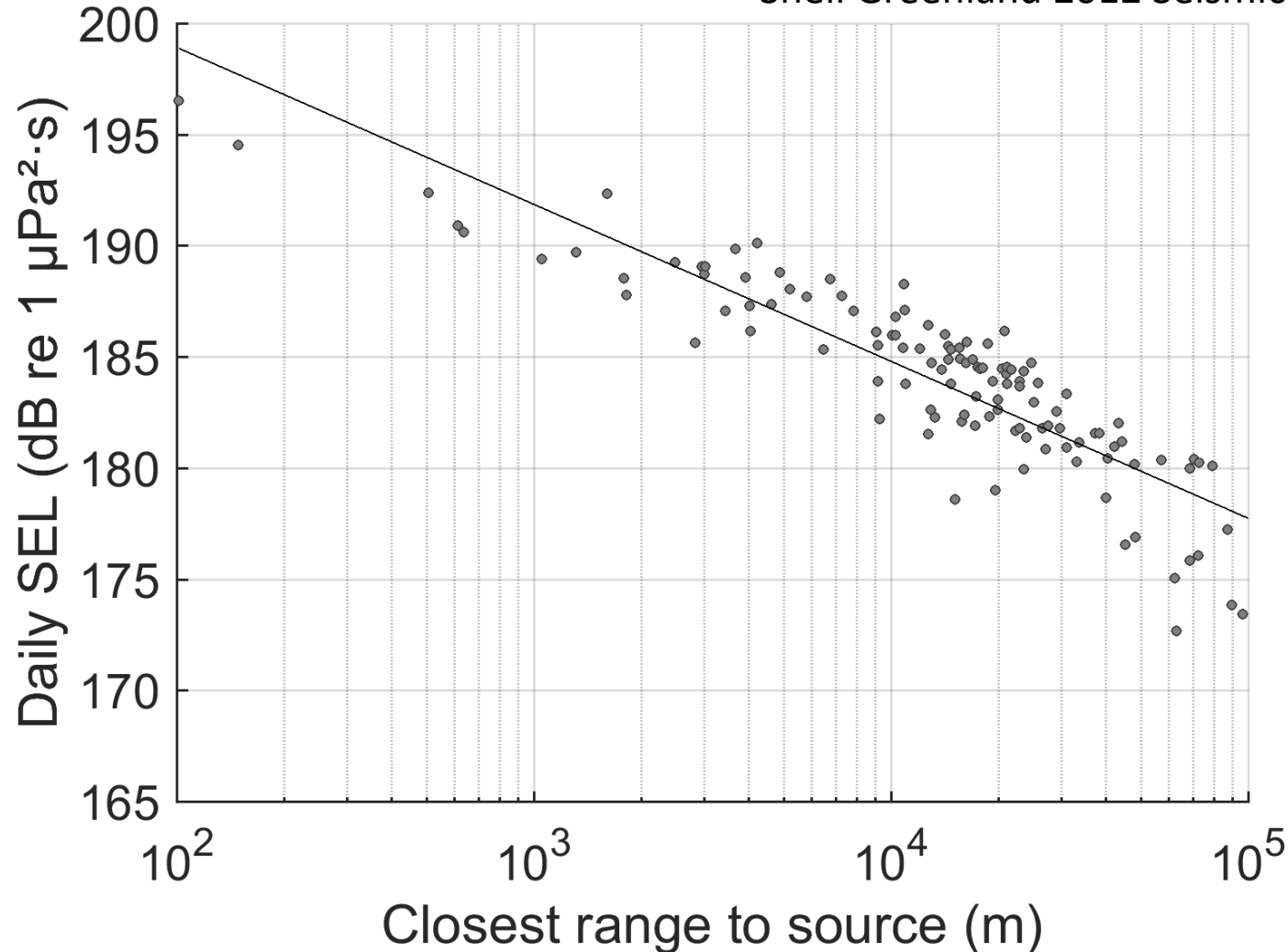
Weighted Daily SELs - NOAA (2016)

Shell Greenland 2012 Seismic Survey

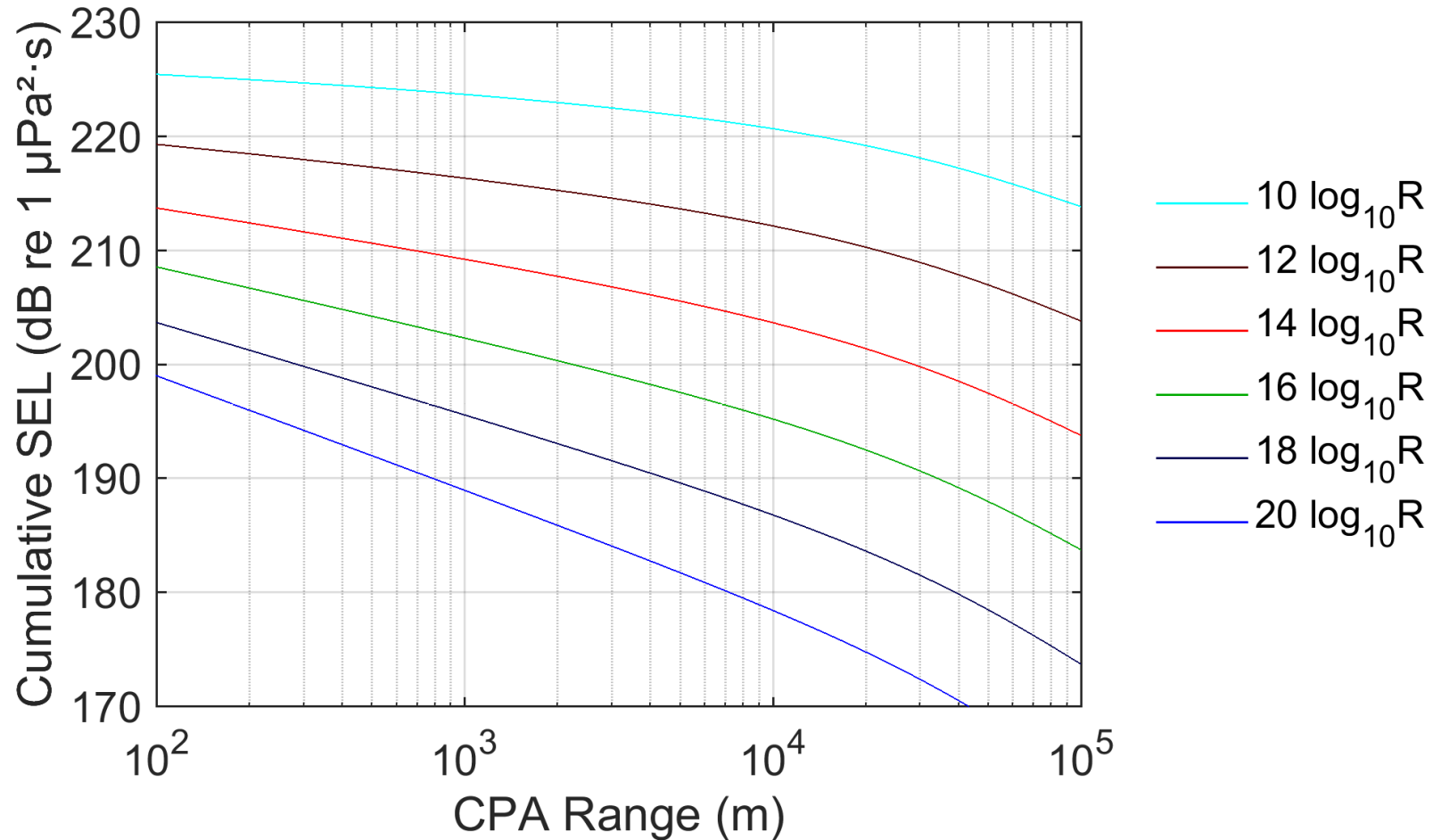


Daily SEL Vs Closest Range to Vessel

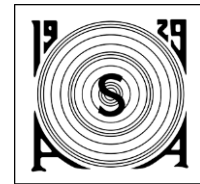
Shell Greenland 2012 Seismic Survey



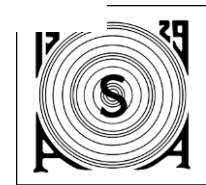
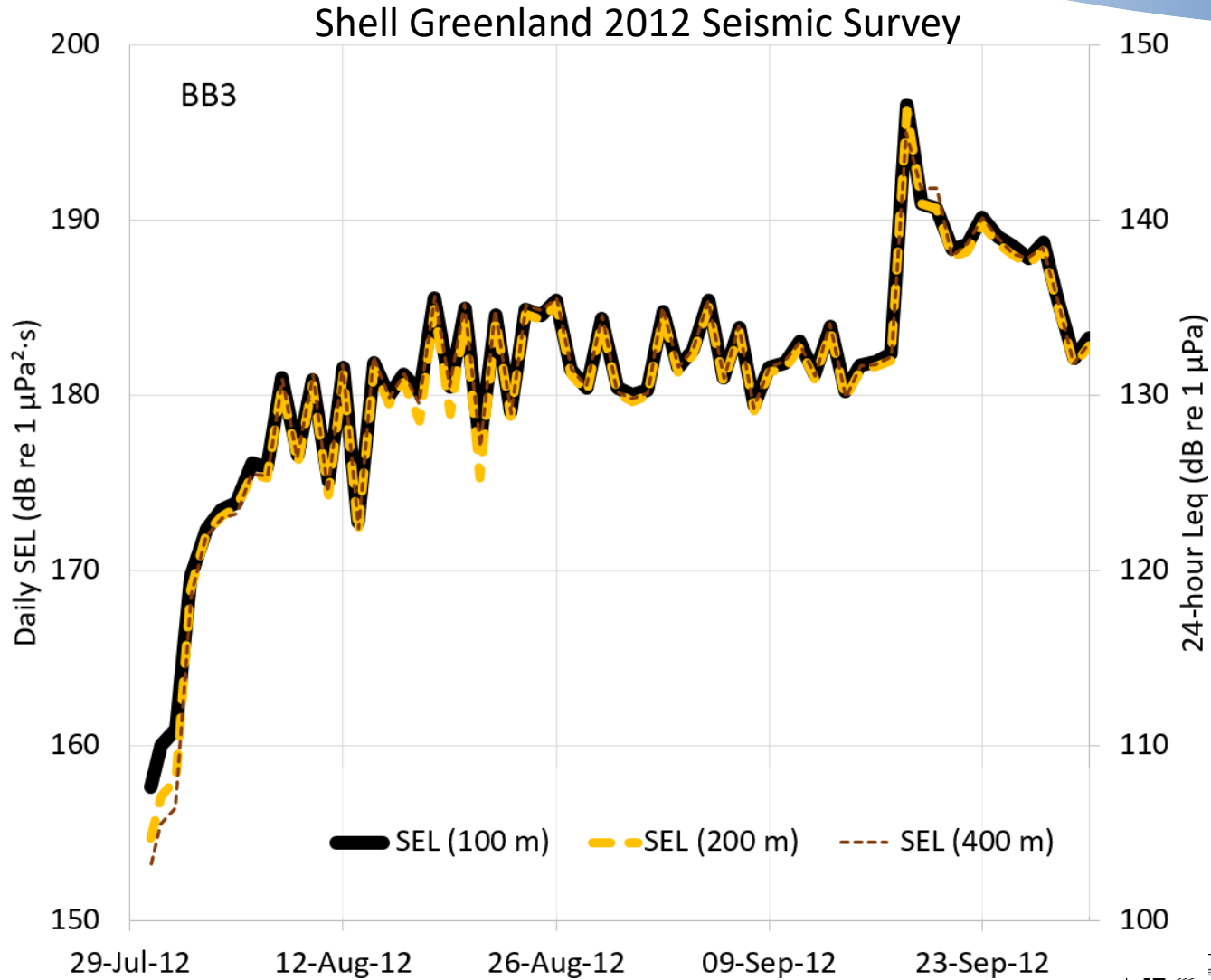
Simulating seismic SEL accumulation



228 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ per pulse SEL, 2.25 m/s, 10 sec IPI



Daily unweighted SEL vs Depth - Seismic



Alternate Method - Seismic

MMSpreadsheet.xlsx - Excel

File Home Insert Page Layout Formulas Data Review View Tell me what you want to do

Clipboard Font Alignment Number Styles Cells

B39

	A	B	C	D	E	F	G	H	I	
39										
40	F2: ALTERNATIVE METHOD (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)									
41	Source Level (Single strike/shot/pulse SEL)	228								
42	Source Velocity (meters/second)	2.25								
43	1/Repetition rate^ (seconds)	10								
44	Source Factor	6.30957E+21								
45	†Methodology assumes propagation of 20 log R; Activity duration (time) independent									
46	^Time between onset of successive pulses.									
47										
48	RESULTANT ISOPLETHS*	* Note: For impulsive sounds, action proponent must also consider isopleths peak sound pressure level (PK) thresholds (dual thresholds).								
49		Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds			
50		SEL _{cum} Threshold	183	185	155	185	203			
51		PTS Isopleth to threshold (meters)	4,416.4	18.0	3,235.0	1,462.7	29.7			
52										
53										

Marine Mammal Hearing Group

Low-frequency (LF) cetaceans: baleen whales

Mid-frequency (MF) cetaceans: dolphins, toothed whales, beaked whales, bottlenose whales

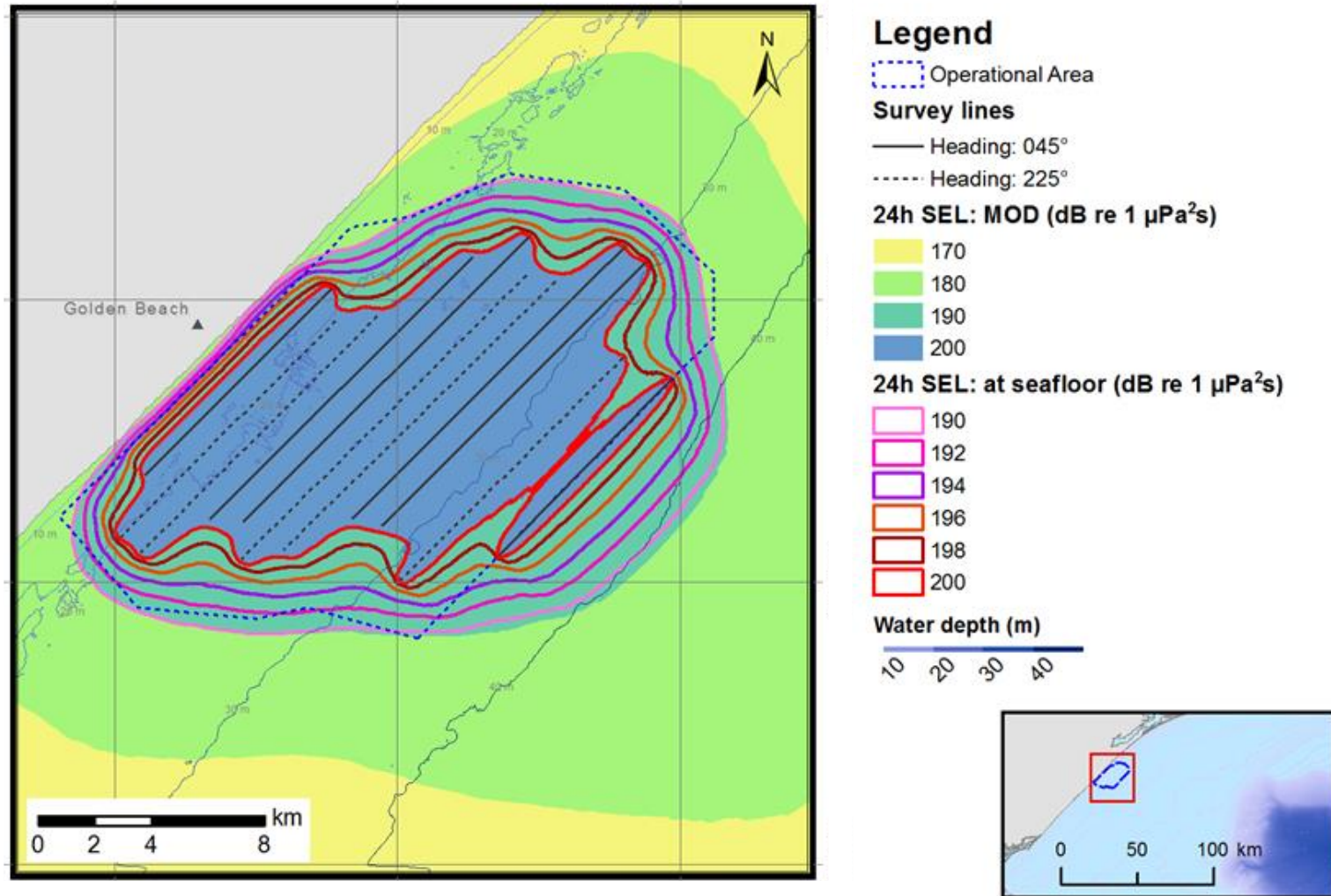
High-frequency (HF) cetaceans: true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*

Phocid pinnipeds (PW): true seals

Otariid pinnipeds (OW): sea lions and fur seals

E.1) IMPACT Pile Driving F) IMPULSIVE-MOBILE WEIGHTING FACTOR ADJUSTMENT WFA

24-hr SEL – complex operations



Scenario 1: 24 hr SEL for 4380 in³ array.

Acknowledgements

- **Shell Global Solutions** for permission to present the Greenland Seismic data.
- **Deep Water Wind** for permission to present the Block Island pile driving data.
- **Environmental Studies Research Fund** for permission to present the East Coast Canada data.
- JASCO's field teams & the Masters and crews of all the vessels used in these programs.

