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Quick Summary of RODEO Measurements of BIWF Construction and Operations

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RODEO

Environmental Studies Program: Ongoing Studies

Study Area(s): North, Mid-, and South Atlantic

Administered By: Office of Renewable Energy Programs

Title: Real-time Opportunity for Development Environmental Observations (RODEO)

BOEM Information Need(s) to be Addressed: BOEM is responsible for the approval of a construction and operations plan submitted by developers for wind facilities on the Outer Continental Shelf. The approval process includes the analysis of the environmental effects from the construction, operation, and decommissioning of these facilities. Real-time measurements of the construction and operation of the first facilities to be built will allow for more accurate assessments of the actual environmental effects. Without real time observations of the activities, best estimates based on perceived activities are used to make these determinations.

Mary Boatman BOEM

Study concept, oversight, and funding were provided by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, DC under Contract Number M16PD00025.

Anwar Khan Randy Gallien

HDR

https://www.boem.gov/Real-time-Opportunity-for-Development-Environmental-Observations/

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Monitoring Pile Driving

- Pile driving operations carried out in 2015 generated intense sound, impulsive in nature at close range, which radiated into the surrounding air, water and sediment.
- Our team deployed a number of instruments to monitor this noise at several locations from 500 m to 15 km from the pile driving.
- Note the piles are driven at a angle of 13.27^{o} with the vertical.

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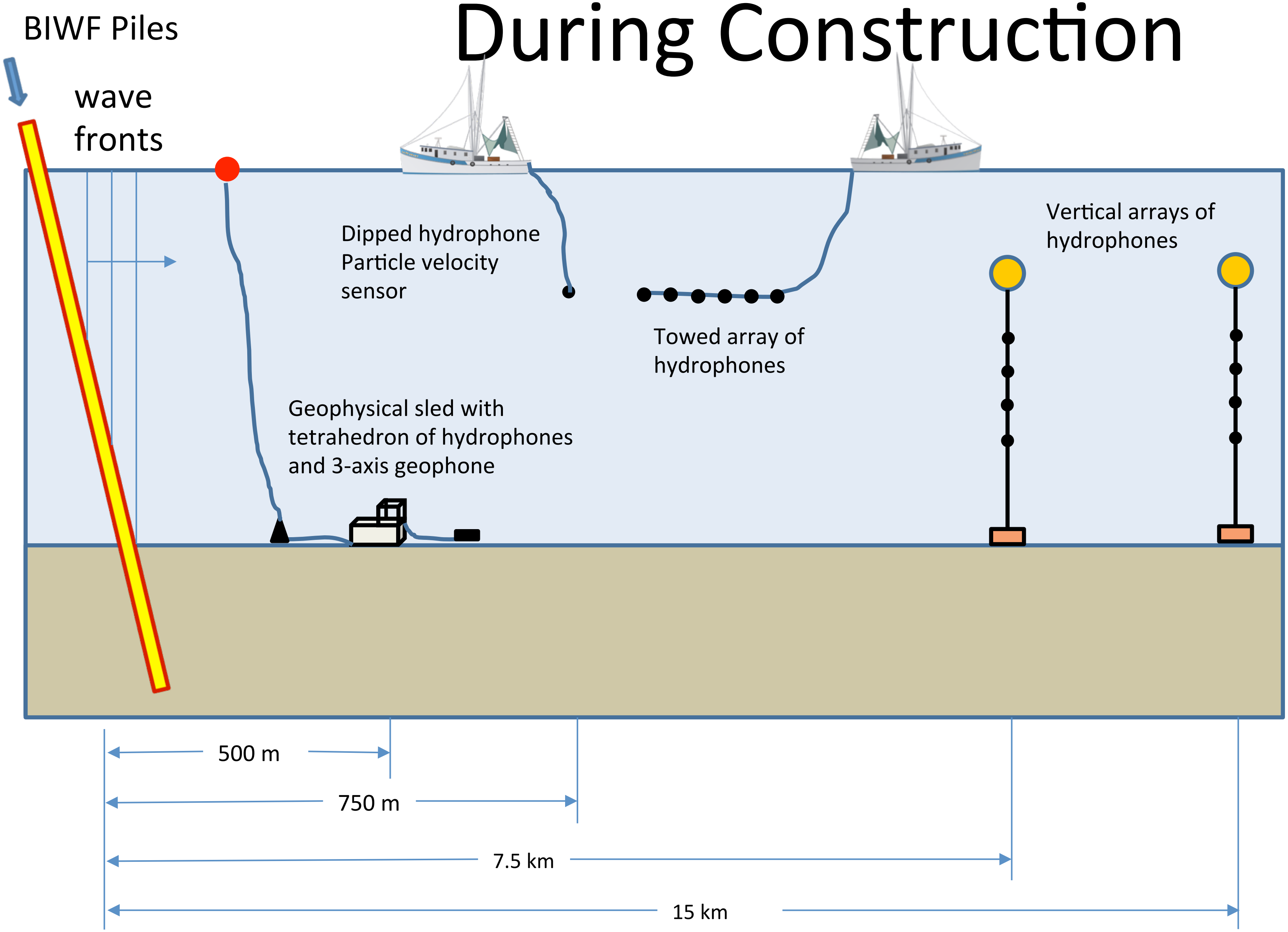
Overview of Measurements During Construction

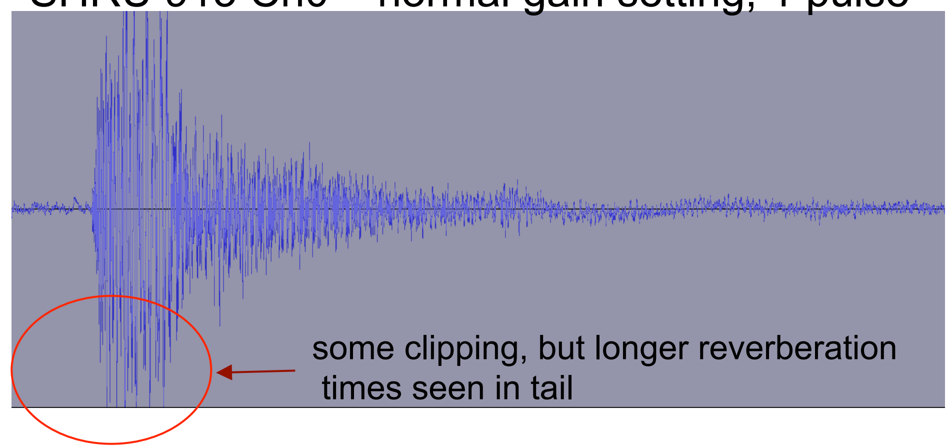


Impact Pile Driving Signals

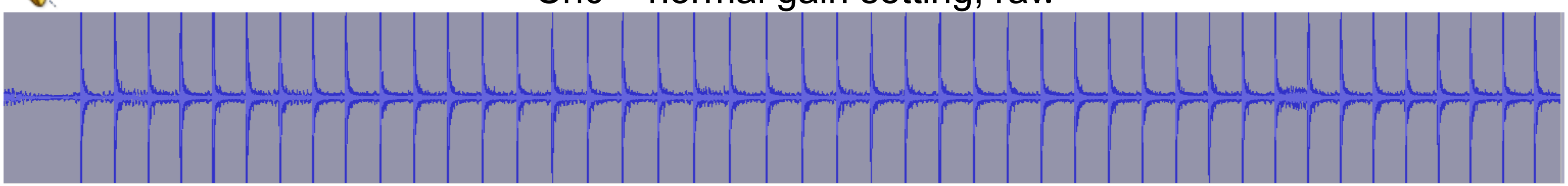
WHOI SHRU was set for alternating channels at different gains

Small amount of clipping for both SHRUs at normal gain

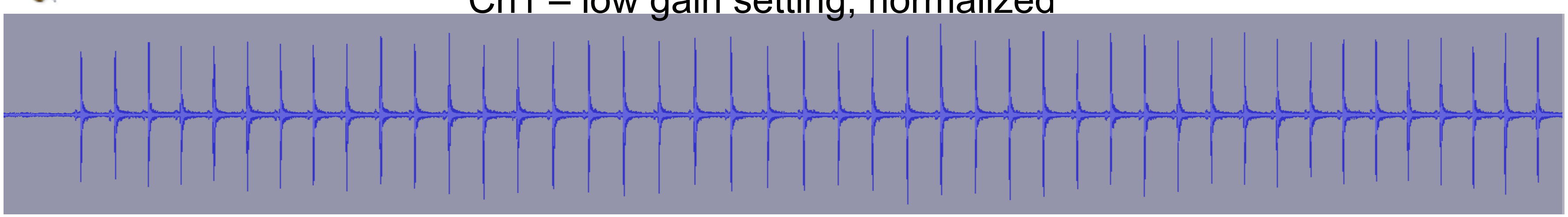
SHRU 913 Ch0 – normal gain setting, 1 pulse



Ch0 – normal gain setting, raw



Ch1 – low gain setting, normalized



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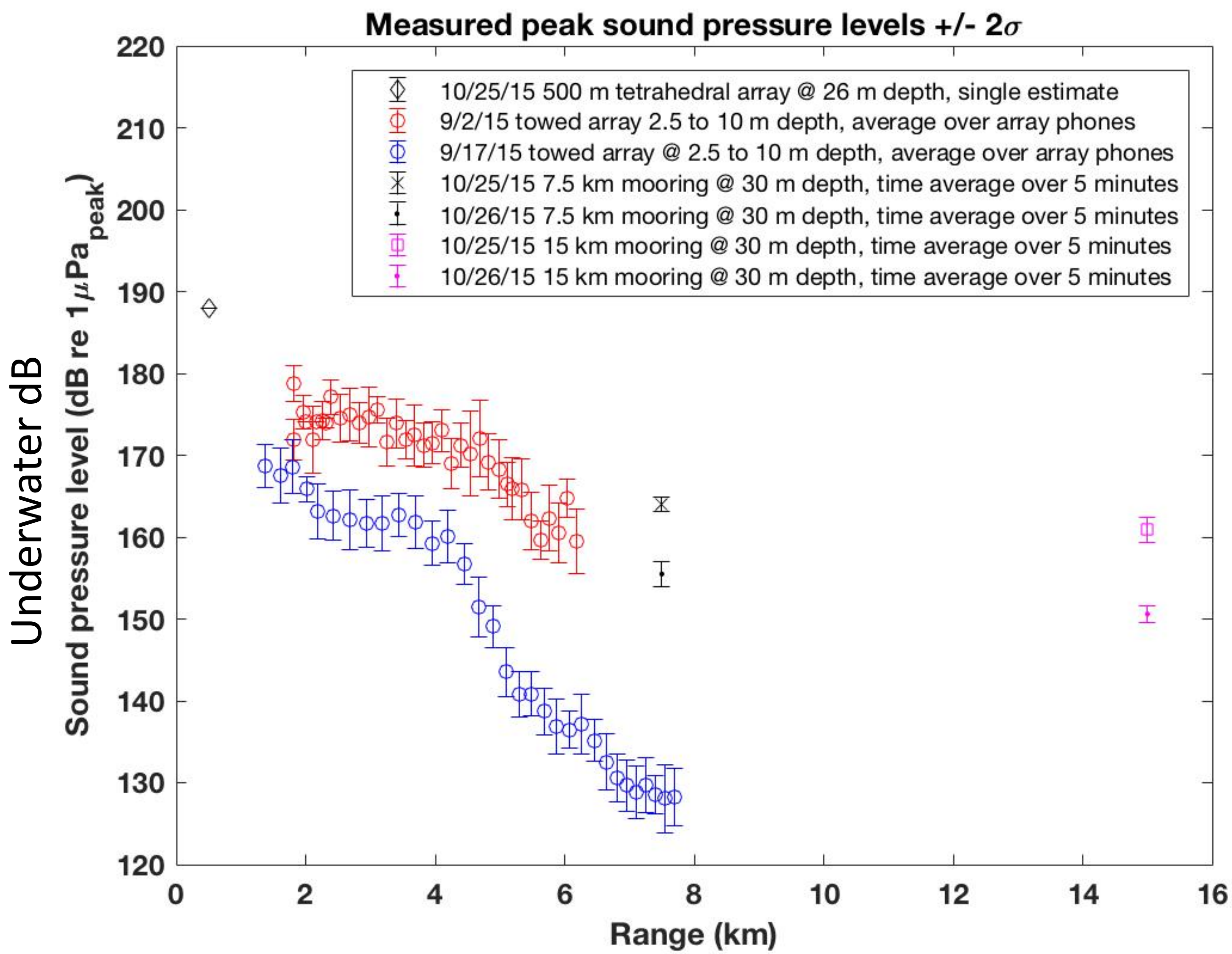
Summary of measurements during construction



Data show variation in levels probably due to the angle at which the piles are being driven.

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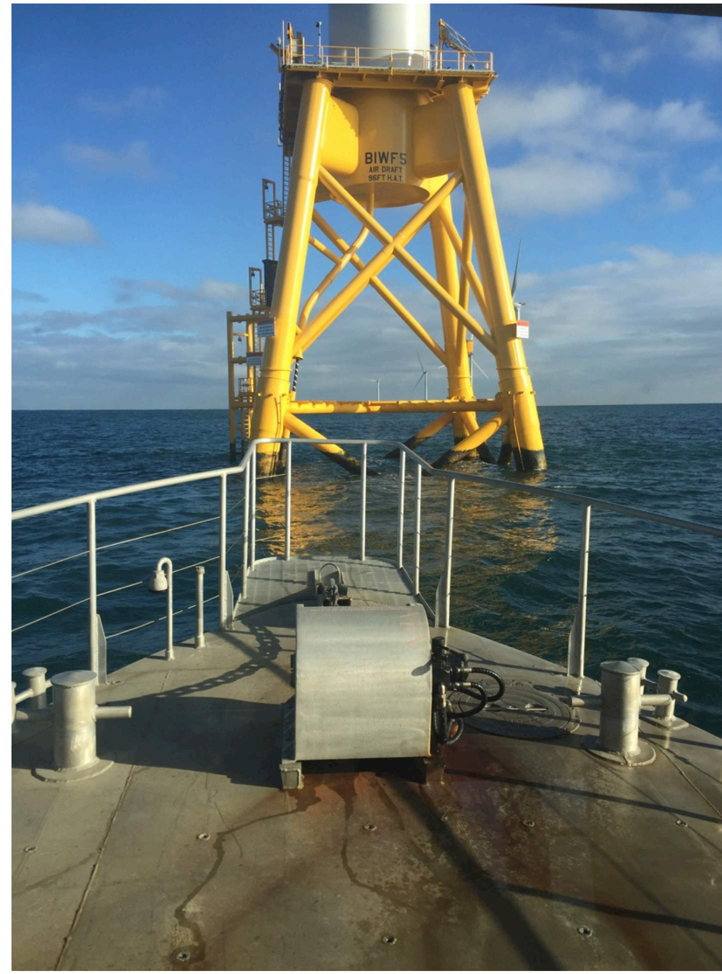
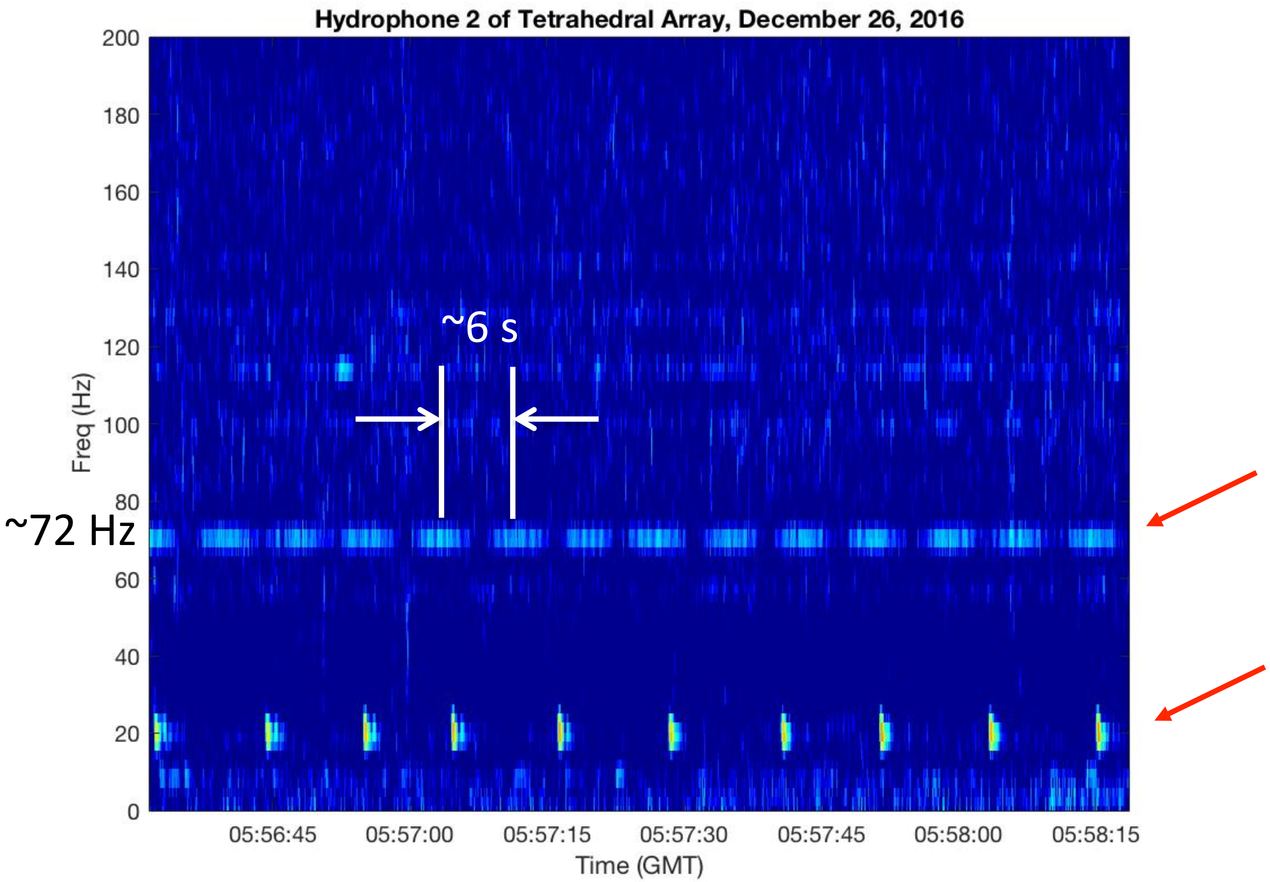
Monitoring Operations

- We deployed a similar suite of sensors to monitor operations of the wind farm from December 20, 2016 to January 14, 2017.
- Equipment included the tetrahedral hydrophone array/3-axis geophone (~50 meters from WTG #5), and two vertical hydrophone arrays (~100 m and 7.5 km from WTG #5).



Spectrogram taken 50 meters from WTG#5



- Spectrogram of underwater signals near WTG#5 up to 200 Hz.
- Probable turbine noise is evident at about 71 Hz, ~90 dB re 1 microPa rms
- Relatively intense signal near 20 Hz is a vocalizing fin whale, ~125 dB re 1 microPa peak

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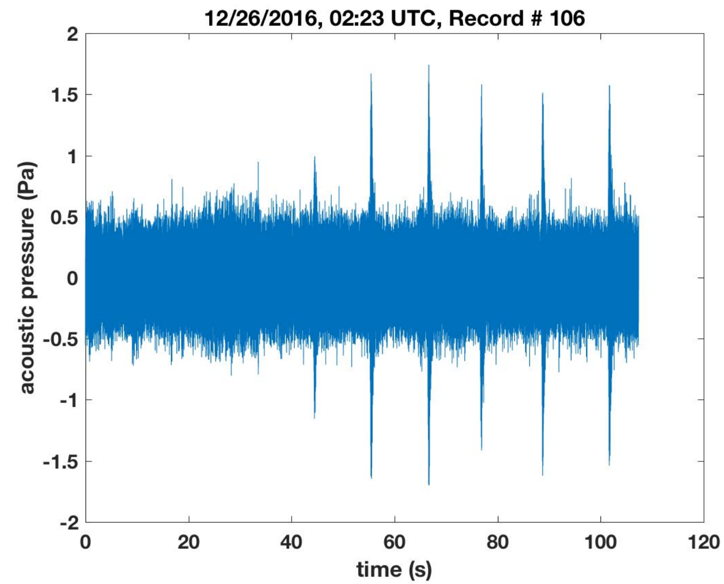
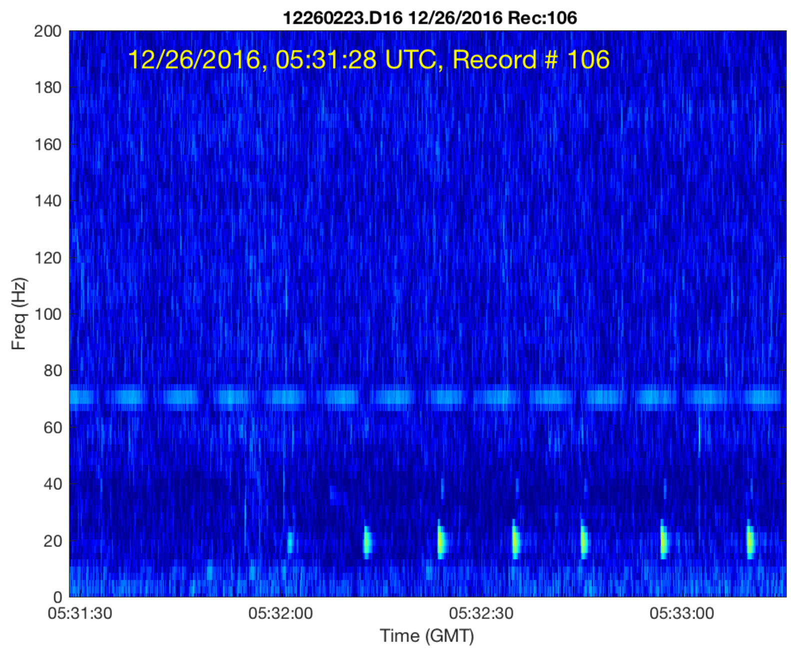
A spectrogram, time series and audio





Wind turbine noise at beating at 71 Hz

Fin whale vocalizations starting up at 20 Hz

Audio played at 10x original rate.

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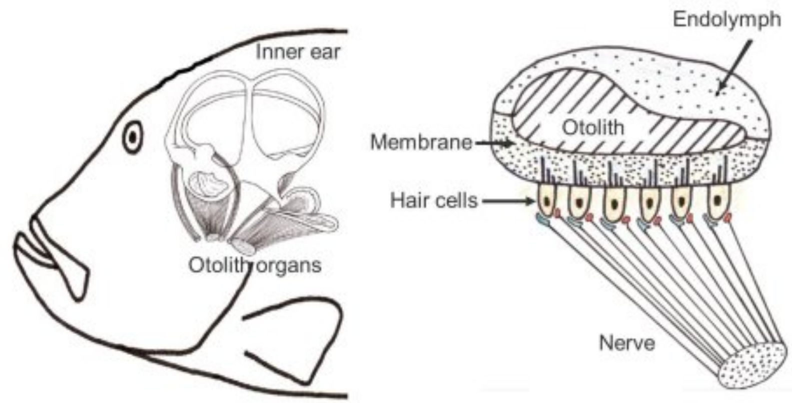
Fish Hearing

- Auditory portions of the fish ears are the “otolithic organs”
- Otolithic organs of all fishes respond to particle motion of the surrounding fluid.
- Many fishes are also able to detect sound pressure via the gas bladder or other gas-filled structures that re-radiate energy, in the form of particle motion, to the otolithic organs



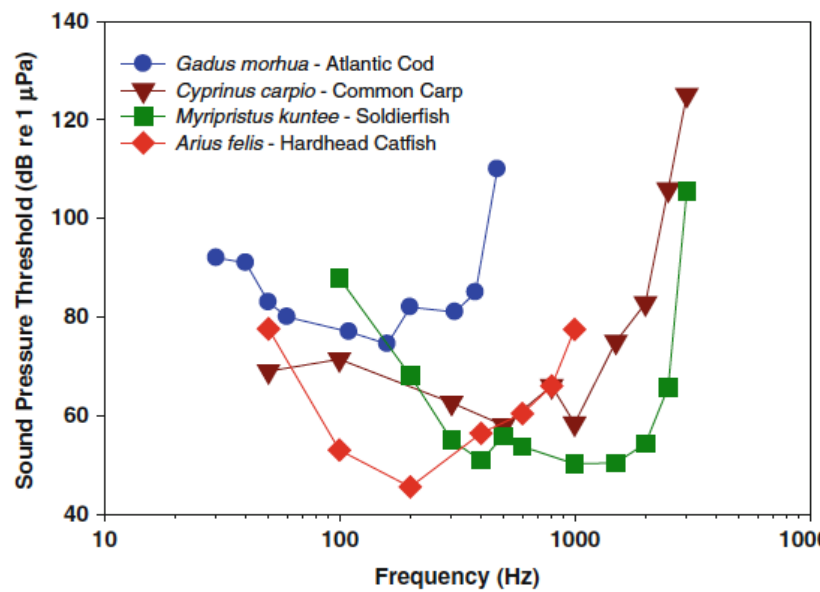


Fig. 3.2 Sound pressure behavioral audiograms for four species that are sound pressure-sensitive in the frequency regions plotted. Common carp (*Cyprinus carpio*, Popper 1972); Atlantic cod (*Gadus morhua*, Chapman and Hawkins 1973); soldierfish (*Myripristus kuntee*, Coombs and Popper 1979); hardhead catfish (*Arius felis*, Popper and Tavolga 1981)

Particle motion sensitivity

Hearing range and sensitivity varies considerably among species

Behavioral audiograms have been published for only a few species of fish and there are concerns about the usefulness of many of these

Poorly monitored acoustic conditions and it is difficult to determine whether the fish were responding to sound pressure or particle motion

Noise can result in the audiograms being masked so that the full hearing sensitivity of the animal cannot be determined.

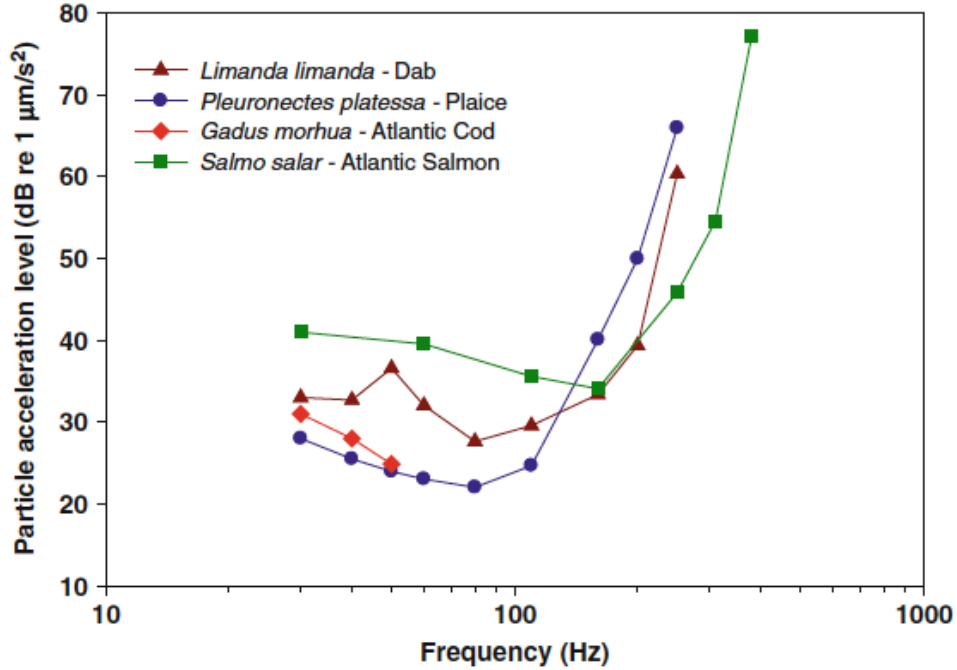


Fig. 3.1 Particle motion behavioral audiograms for four species that are particle motion-sensitive, or where sensitivity to particle motion is dominant at the frequencies plotted. Atlantic salmon (*Salmo salar*, Hawkins and Johnstone 1978); plaice (*Pleuronectes platessa*, Chapman and Sand 1974); dab (*Limanda limanda*, Chapman and Sand 1974); Atlantic cod (*Gadus morhua*, Chapman and Hawkins 1973)

Auditory evoked potentials may not fully reflect the hearing capabilities of animals - do not include signal processing by the brain

Particle Acceleration on the seabed and in water (Construction)

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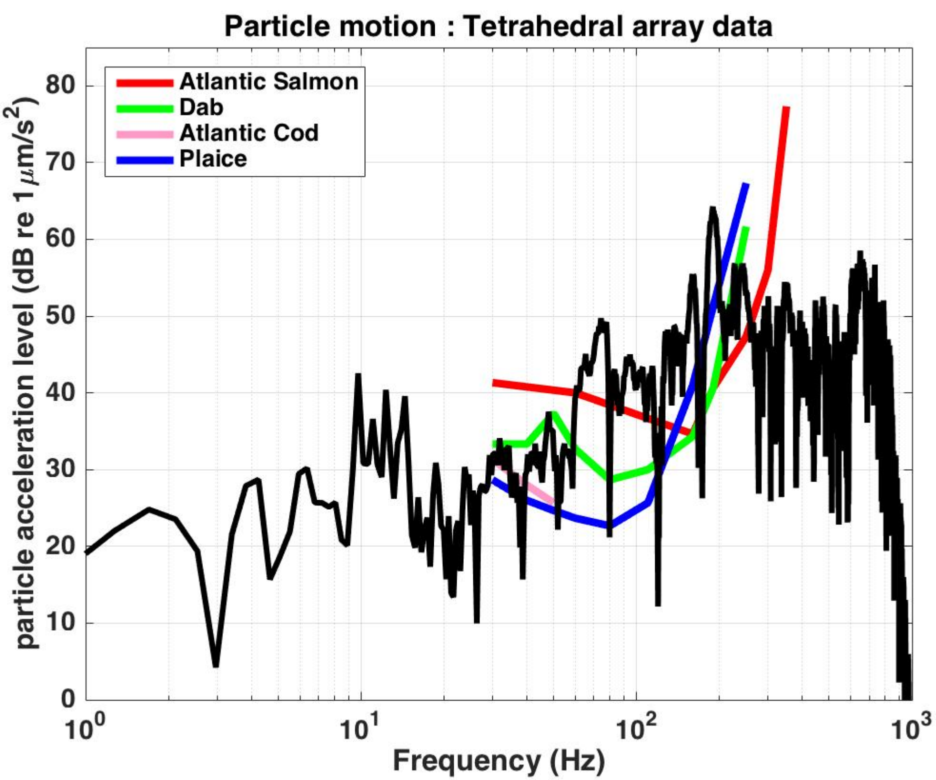
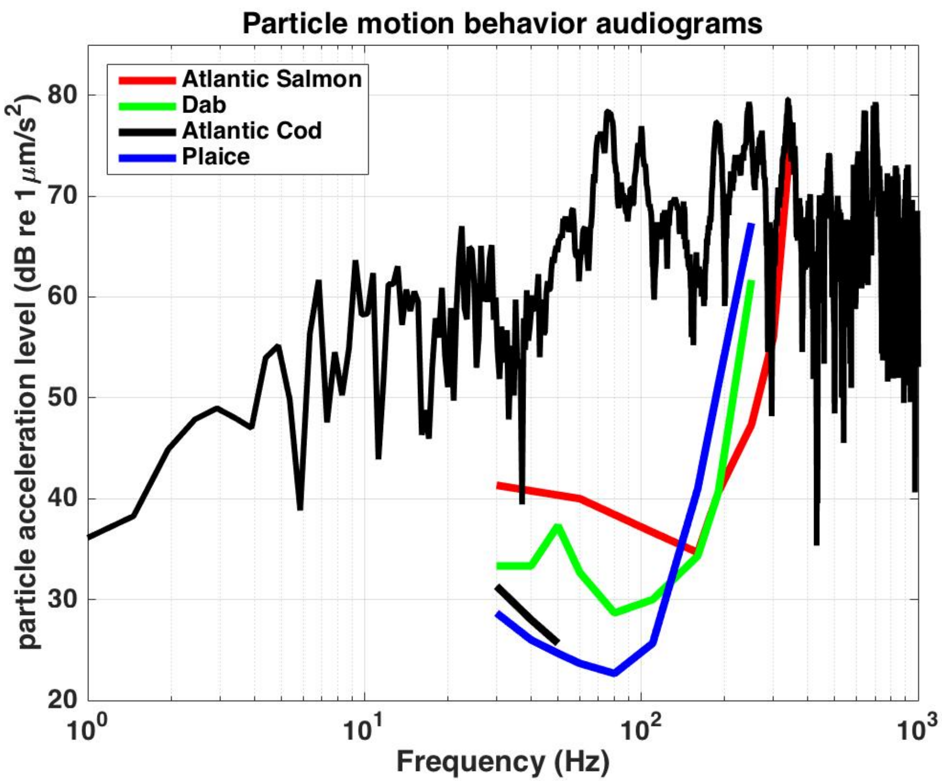
Frequency distribution of acceleration for one hammer strike calculated from geophone and tetrahedral array data at 500 m from the turbine

October 25, 2015; UTC 19 58

Tetrahedral Array data



Geophone data



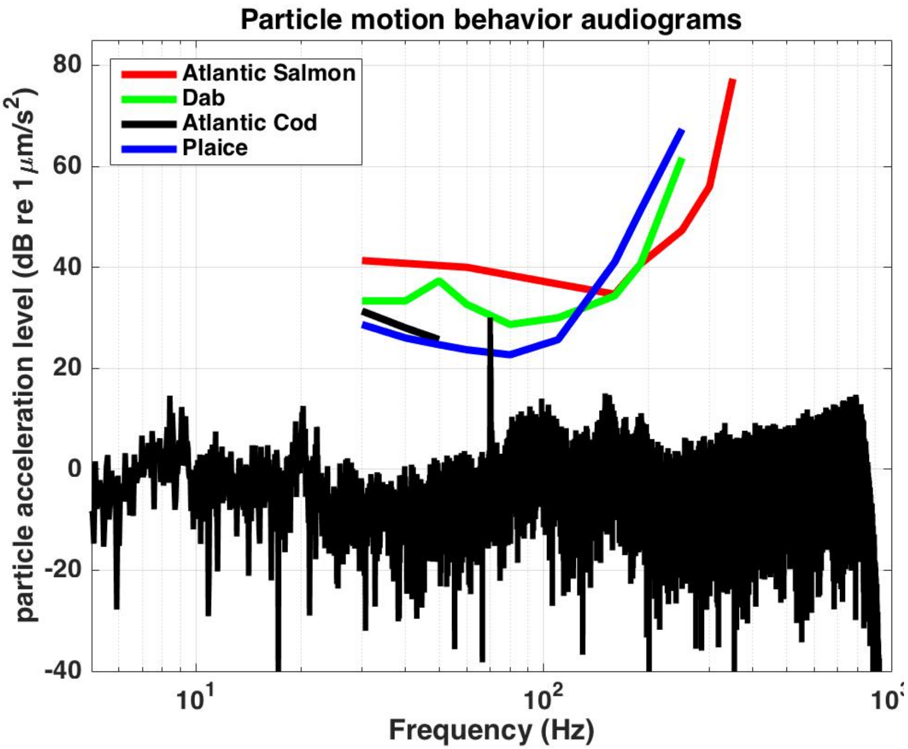
Atlantic salmon (Hawkins & Johnstone, 1978)
Plaice & Dab (Chapman and Sand, 1974)
Atlantic cod (Chapman & Hawkins, 1973)

- **Levels are slightly above the behavioral sensitivity for most fishes in water and on the seabed at 500 m**
- **Effect more pronounced along the seabed**

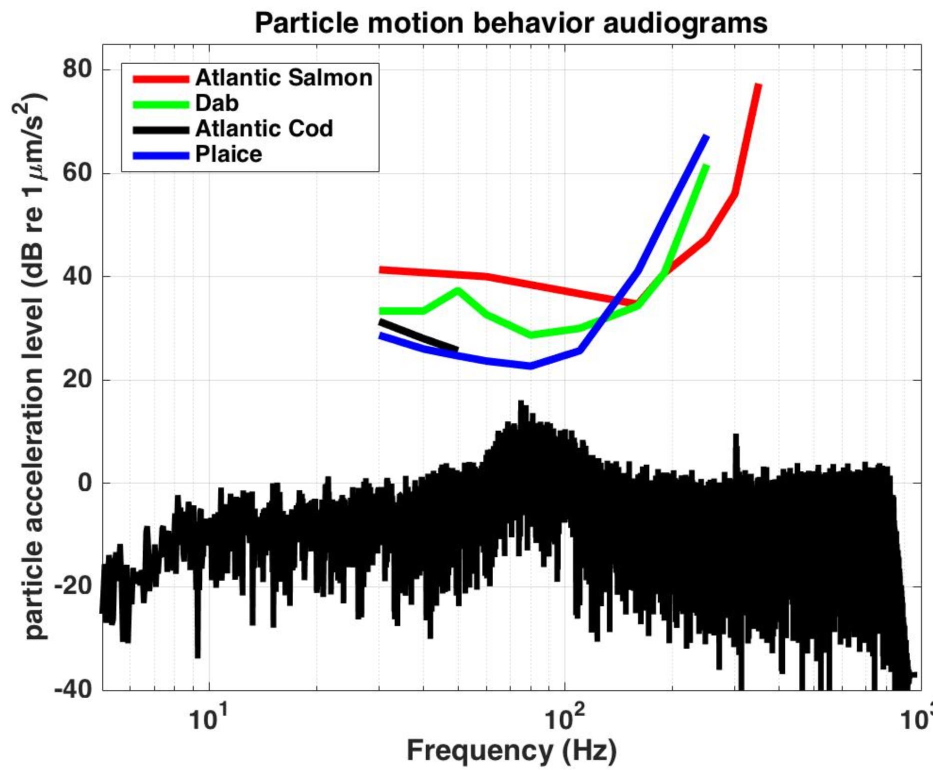
Particle Acceleration on the seabed and in water (Operation)

Frequency distribution of acceleration calculated from geophone and tetrahedral array data at 50 m from the turbine during operation

Tetrahedral Array data



Geophone data



Atlantic salmon (Hawkins & Johnstone, 1978)
Plaice & Dab (Chapman and Sand, 1974)
Atlantic cod (Chapman & Hawkins, 1973)

- **Levels are slightly above the behavioral sensitivity for some fishes in water**
- **Some fishes will 'hear' the operational noise@ 50 m.**

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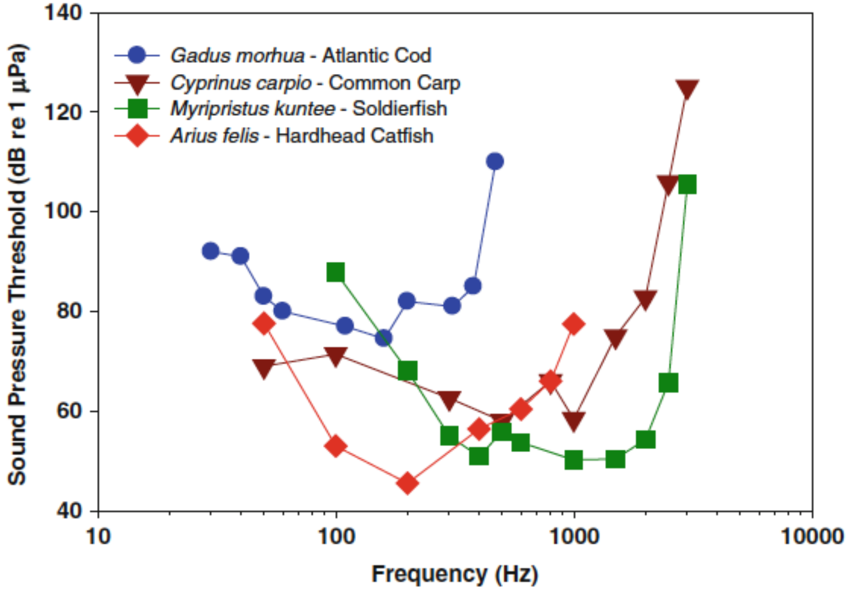
Fish hearing sensitivity



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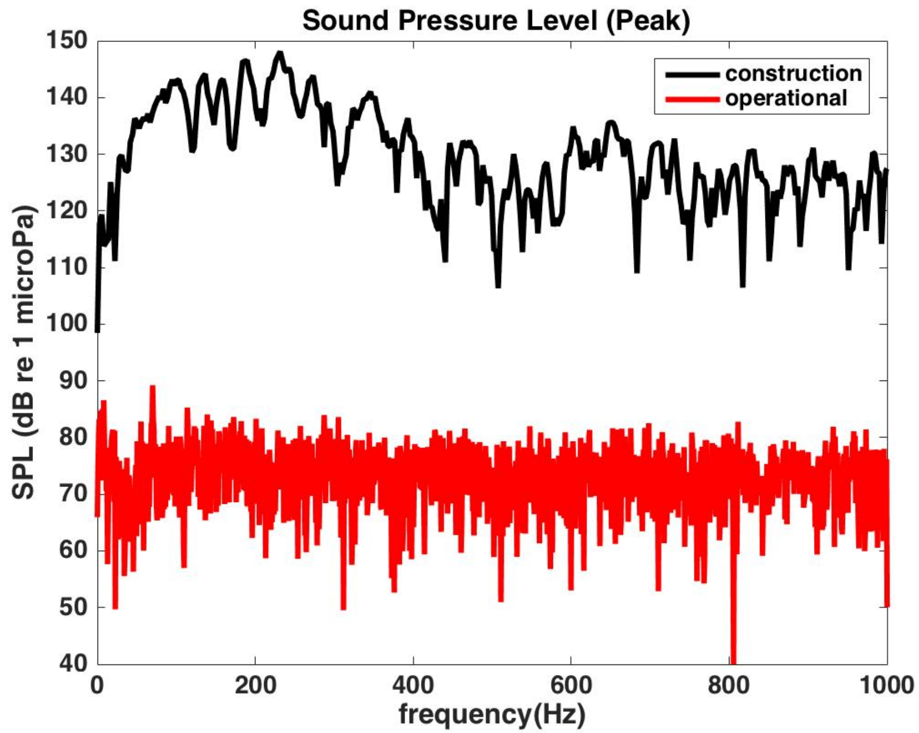


Construction

- Levels are above the behavioral sensitivity
- Fishes will 'hear' the construction noise @ 500 m.
- Peak levels are well below mortality & injury

Operation

- Levels are slightly above the behavioral sensitivity for some fishes
- Some fishes will 'hear' the operational noise@ 50 m.
- Peak levels are well below mortality & injury

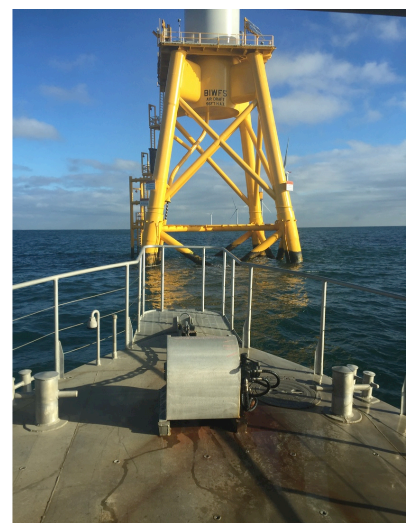
Conclusions

Construction

- Pile driving caused high sound and particle velocity levels.
- Peak pressure levels were measured at 188 underwater dB at a range of 500 meters.
- Zone of influence was azimuthally dependent due to the pile driving angle and 3D bathymetry.

Operation

- Operational noise levels are barely detectable at a range of 50 meters.
- We don't expect any effects on marine life from operational noise.



- BACKUP SLIDES

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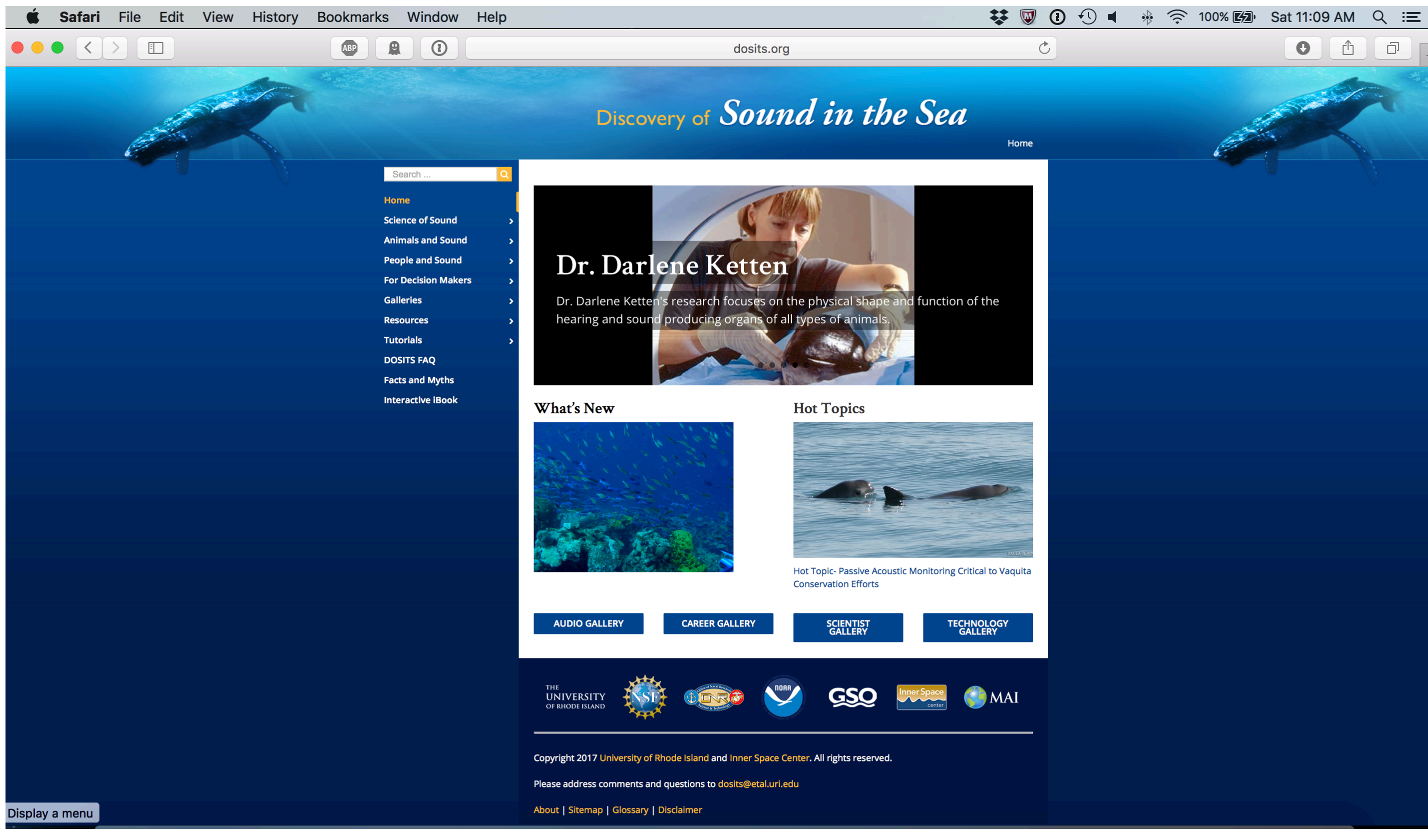
For more information

- Go to the Discovery of Sound in the Sea web site: dosits.org



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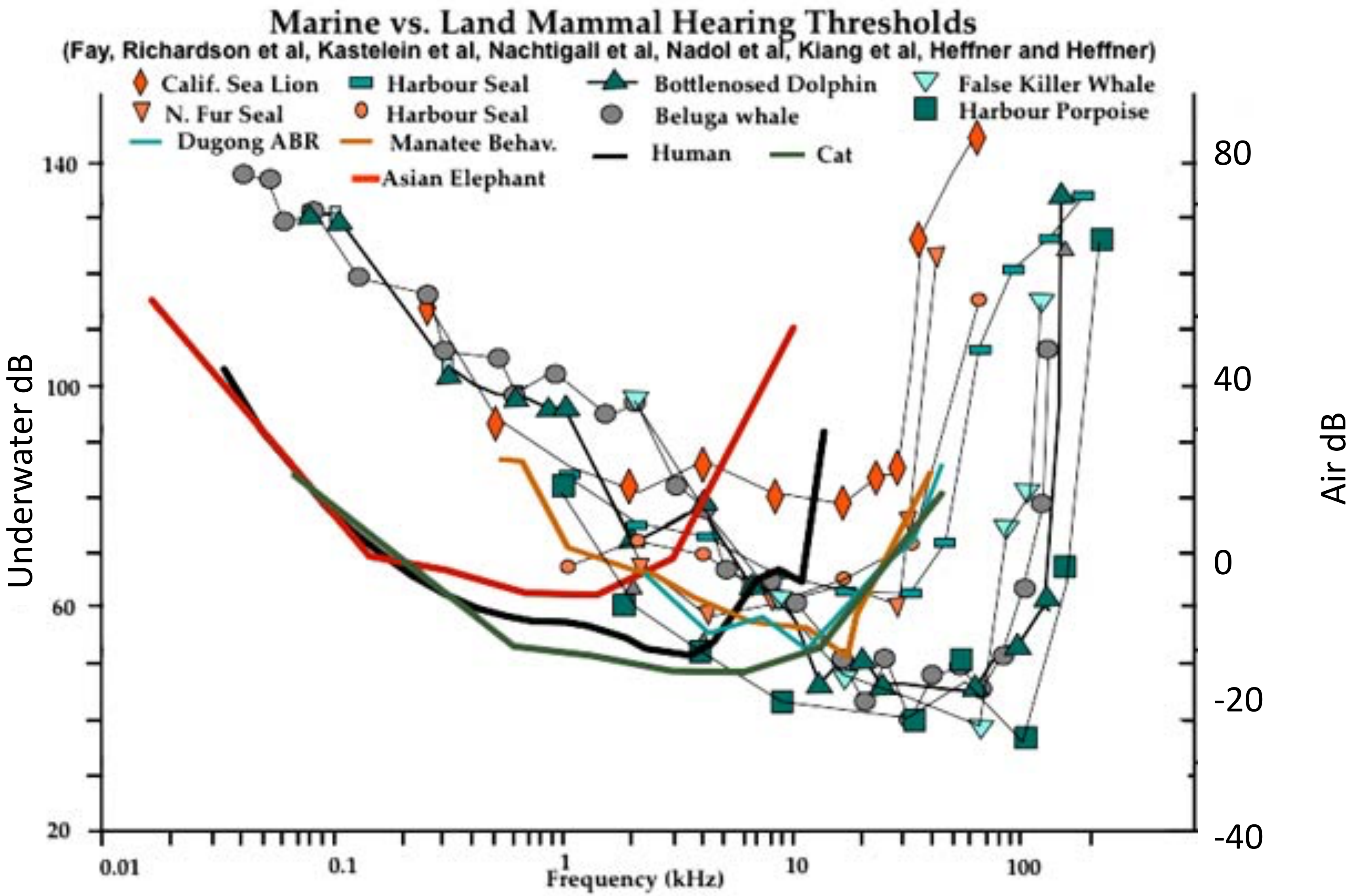
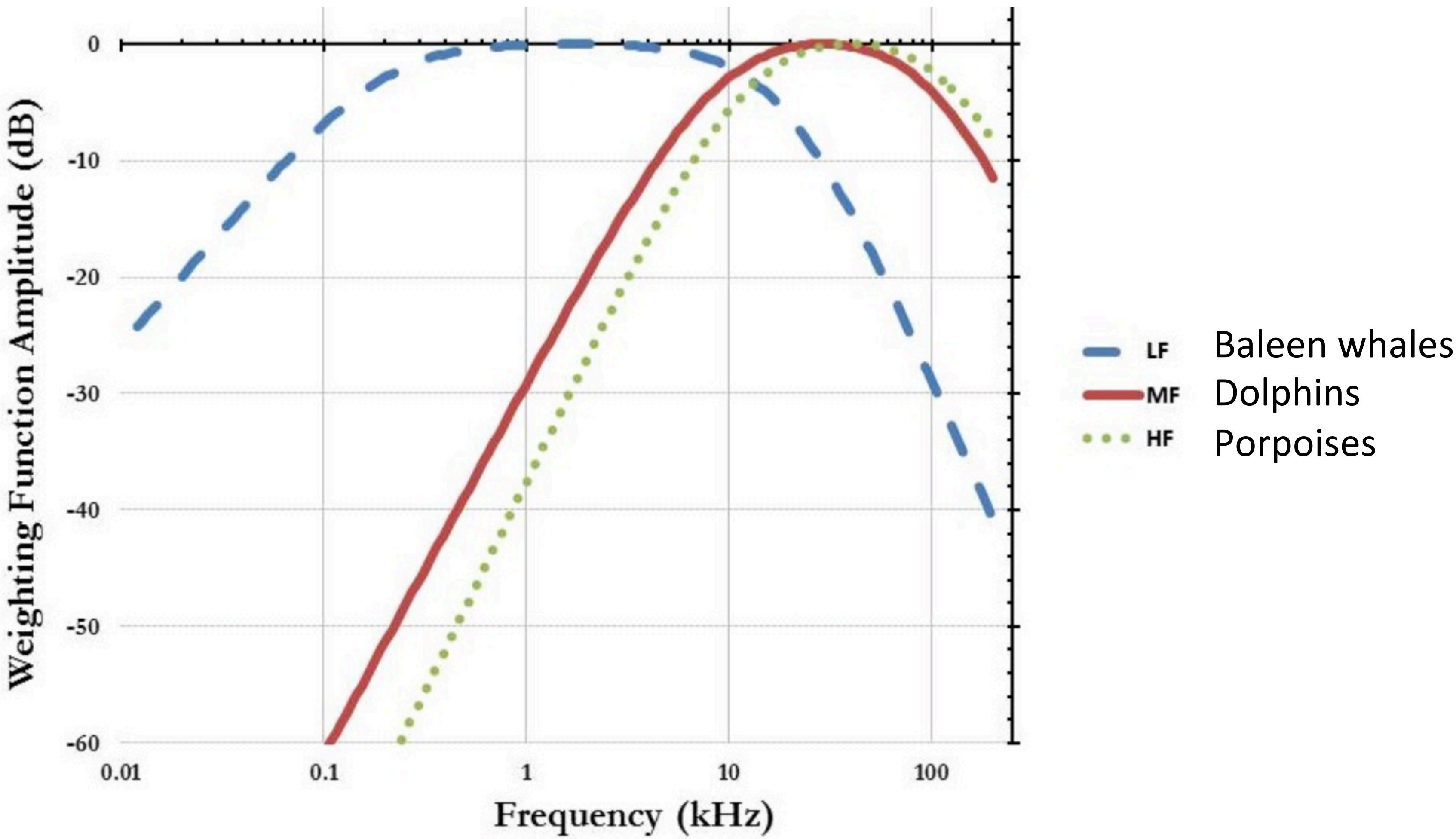
Marine mammal hearing



Darlene Ketten, http://dosits.org/science/measurement/what-sounds-can-we-hear/

Marine Mammal Weighting Functions



http://www.nmfs.noaa.gov/pr/acoustics/Acoustic%20Guidance%20Files/opr-55_acoustic_guidance_tech_memo.pdf

Injury Criteria

Hearing Group	Peak
Baleen Whales	219 underwater dB
Dolphins	230 underwater dB
Porpoises	202 underwater dB

Note: These single impulse levels are unweighted. The weighting functions are applied to the cumulative levels not shown here. Guidance is to use the the more conservative levels.

http://www.nmfs.noaa.gov/pr/acoustics/Acoustic%20Guidance%20Files/opr-55_acoustic_guidance_tech_memo.pdf

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Guidelines: Pile Driving (Popper et al., Sound exposure guidelines for fishes and sea turtles, 2014.)

Type of fish	Mortality	Recoverable Injury	TTS	Masking/behavior
No swim bladder	>213 dB peak >219 dB SEL_{cum}	>213 dB peak >216 dB SEL_{cum}	>>186 dB SEL_{cum}	High (N) Moderate (I) Low (F)
With swim bladder but not involved in hearing	207 dB peak >210 dB SEL_{cum}	207 dB peak >203 dB SEL_{cum}	>>186 dB SEL_{cum}	High (N) Moderate (I) Low (F)
Pressure detection	207 dB peak >207 dB SEL_{cum}	207 dB peak >203 dB SEL_{cum}	>>186 dB SEL_{cum}	High (N) Moderate (I) Low (F)

N – near the source; F – far from the source; I – intermediate distance