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Marine Acoustics Issues Related to Floating Windfarm Development

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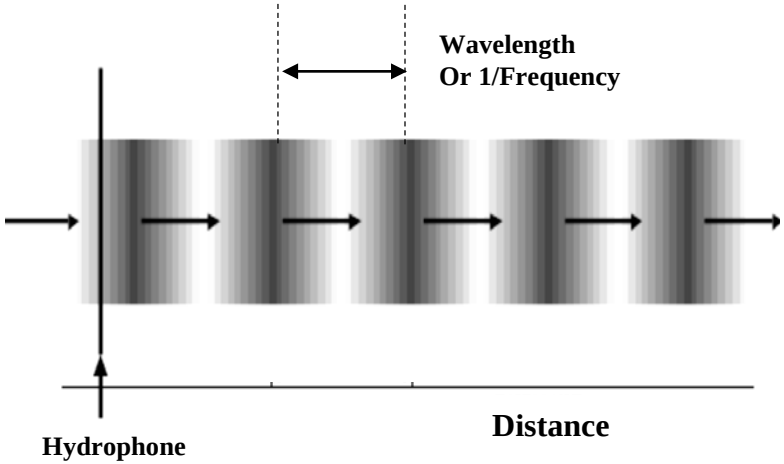
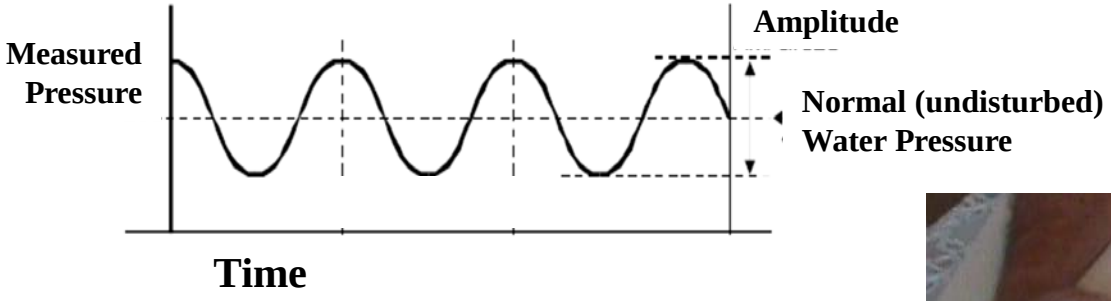
Acoustic Energy Propagates as a Compressional Wave in Water





Sources of "Noise" in the Ocean:

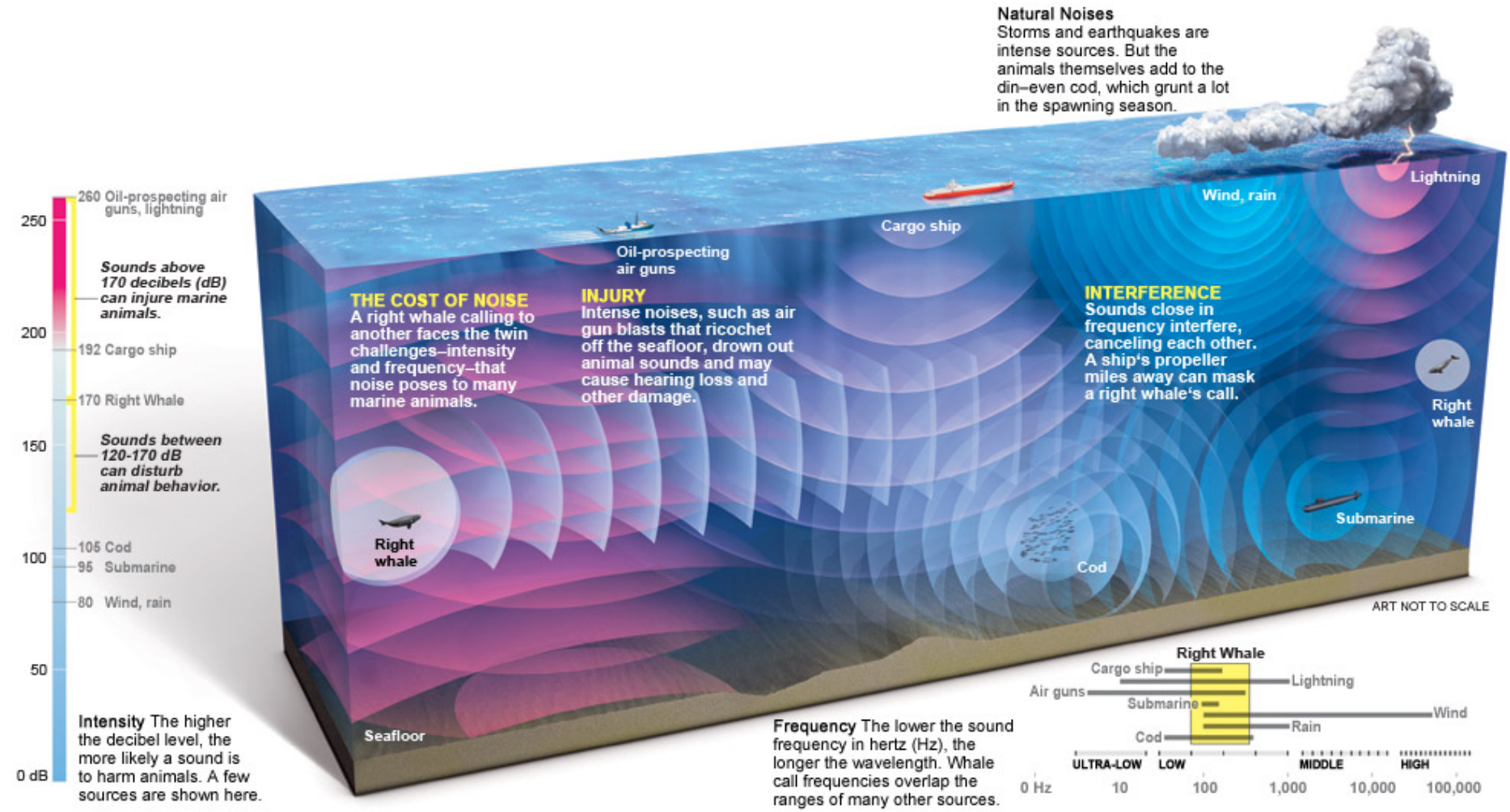


Image: National Geographic, 2011

Issues with Acoustic Energy in the Ocean:

- **Very large range of Received Level (RL) values**
  - Quietest to Loudest sound a human can hear in water is
    - 100 to about 31,600,000,000,000 µ Pa (3 billion times as large)
  - Use Decibel Scale to address this
  - Typical Received Level: 160 dB re 1 µ Pa (RMS)
    - "dB" means a dB scale is used (i.e., factor of 10 for every 20 dB)
    - "re" mean reference a standard unit of pressure – here 1 µ Pa
    - (RMS) implies a Broadband signal which is observed over all frequencies

- **Strong dependency of impacts on range from source**
  - Source level isn't enough.

- **Frequency content of signal is critical and often broad**
  - Humans only use a small portion (~10%) of the frequency spectrum
  - Other species use and are sensitive to much larger spectrum

- **Most underwater acoustic properties are not linear**
  - Sound generally does not travel in a straight line
  - Sound absorption, reflection, etc. are not linear to key parameters

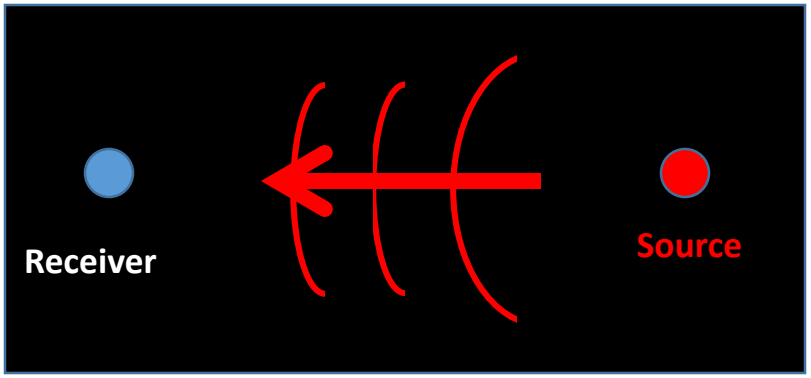
Terminology: Basics Types of Sonars

- Passive Sonar :

RL = SL - TL

Where :

RL = Received Level
SL = Source Level
TL = Transmission Loss

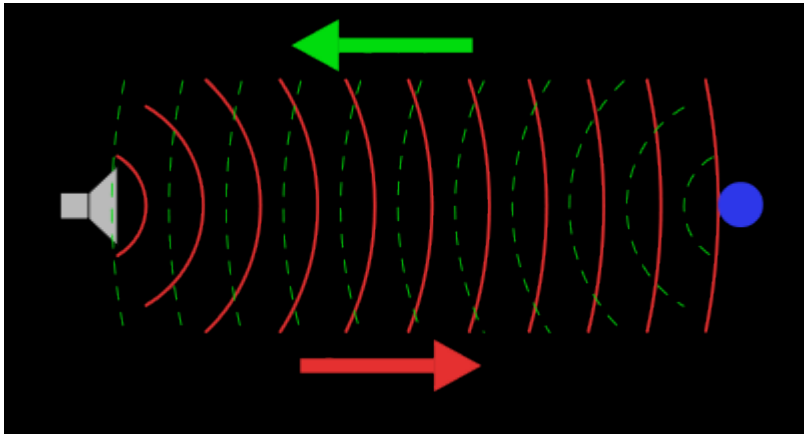


- Active Sonar :

RL = SL – TL1 + TS - TL2

Where :

RL = Received Level
SL = Source Level
TL1 = Outbound Transmission Loss
TS = Target Strength
TL2 = Inbound Transmission Loss



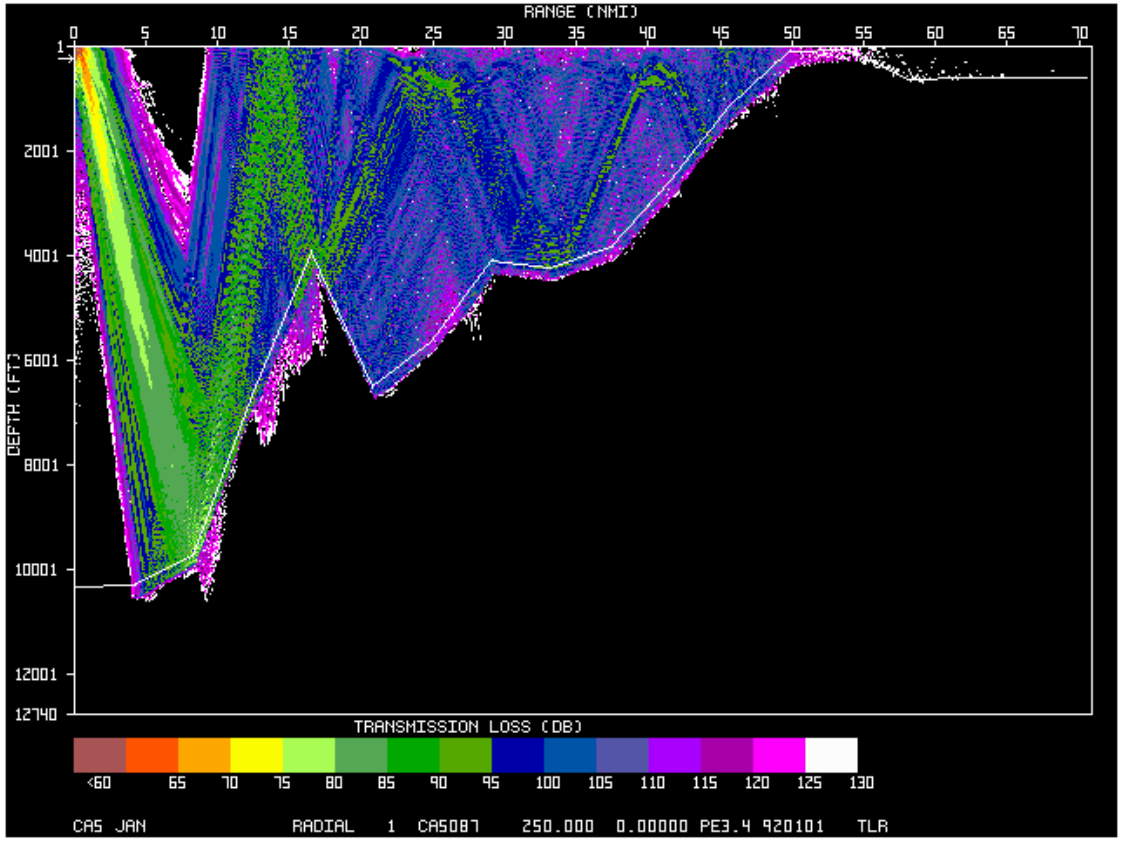
Transmission Loss (TL):

- Transmission (or propagation) Loss (TL) is the most variable of the terms in the sonar equation.
- Highly dependent on frequency, range from the source, depth of the source, depth of the receiver, duration of the signal, etc.

Typical TL "field plot"

- RAM Parabolic Equation Model
- TL for Range & depth
- For 1 location (SoCal)
- Along 1 azimuth (090, due east)
- For 1 frequency (250 Hz)
- For 1 source depth
- For 1 source array configuration

- Note penetration of the bottom



Noise Source from Floating Windfarms:

The dominant noise sources can be grouped by purpose as:

- **Site Assessment Plan (SAP) & High Resolution Geophysical (HRG) Surveys**
  - Sonar systems used during the surveys
  - Tow vessel noise
- **Construction / Installation**
  - Anchor & mooring system installation
  - Tow vessel noise
- **Operations**
  - Turbine blade, bearing and mechanical noise
  - Possible pump or other mechanical noise
  - Vessel noise from visits to the platform

For each of these sources, analysis will need to consider:

- The source characteristics (level, frequency& duration) and location,
- The pathway by which that noise is propagated into the ocean, and
- The shape and extent of the resulting sound field.

SAP and HRG Surveys

This category of sources consists of the commercially available and well understood scientific /oceanographic sonar system or the vessel towing/deploying them, which map the ocean floor and sub-bottom. They are used to site the project and to find and avoid:

- **Hazards**
- **Archaeological sites**
- **Cables**
- **Shipwrecks**

Nominally, most of this work is done before construction begins, but occasionally additional survey may be needed.

Sub-Bottom Profiling Systems

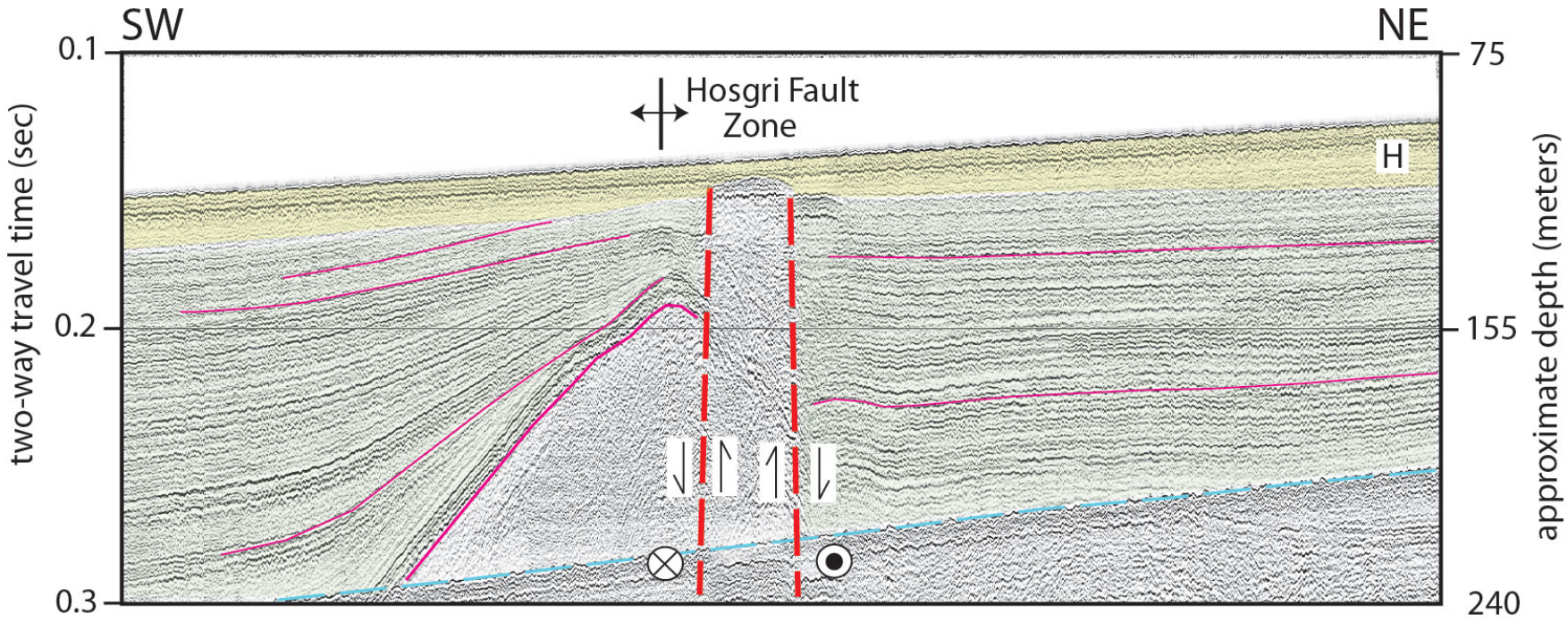
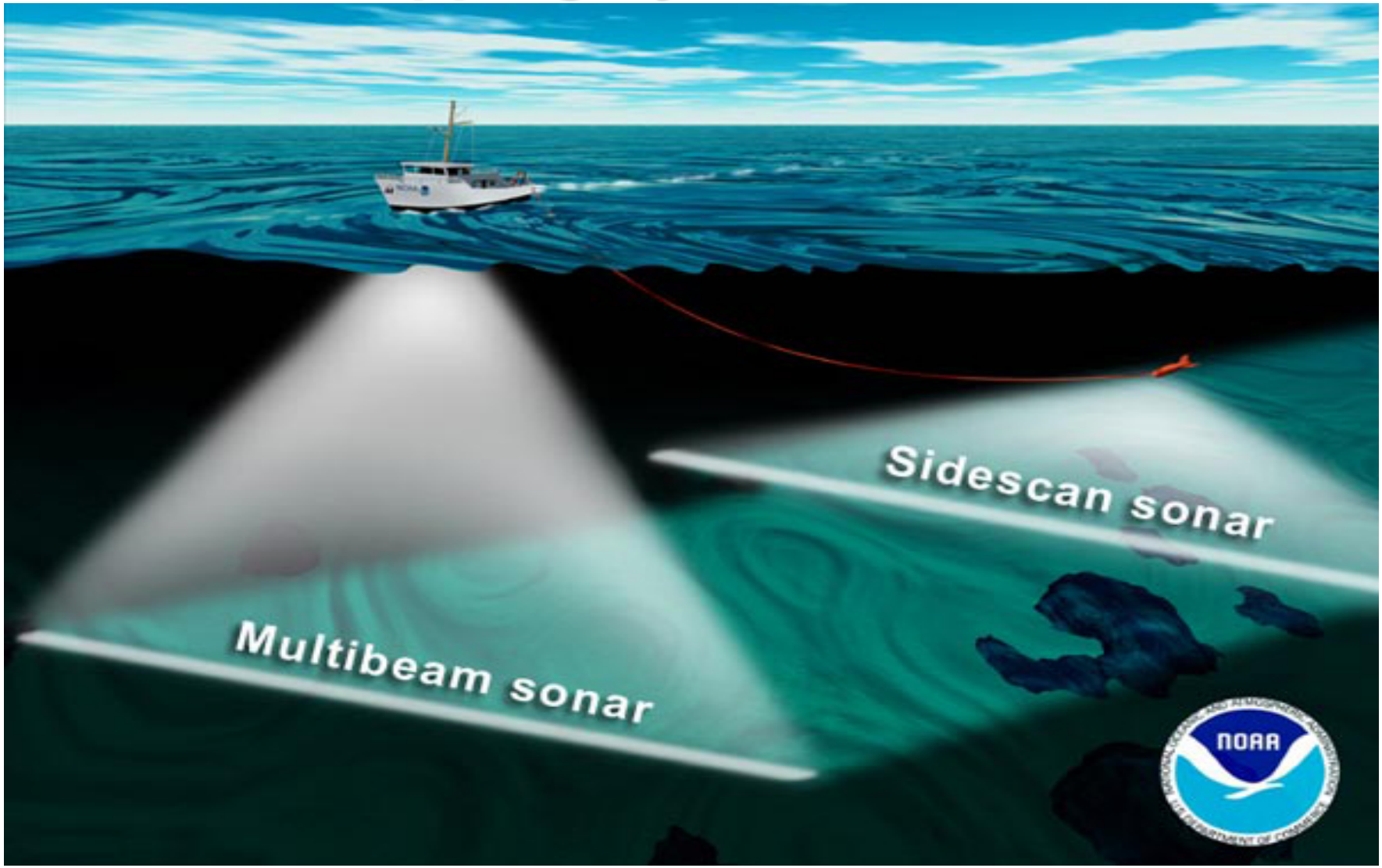


Image: United States Geological Survey

Applied Acoustic S-Boom Sub-Bottom Profiler

EdgeTech 512i Sub-Bottom Profiler

Bottom Mapping Systems



Multibeam Sonar

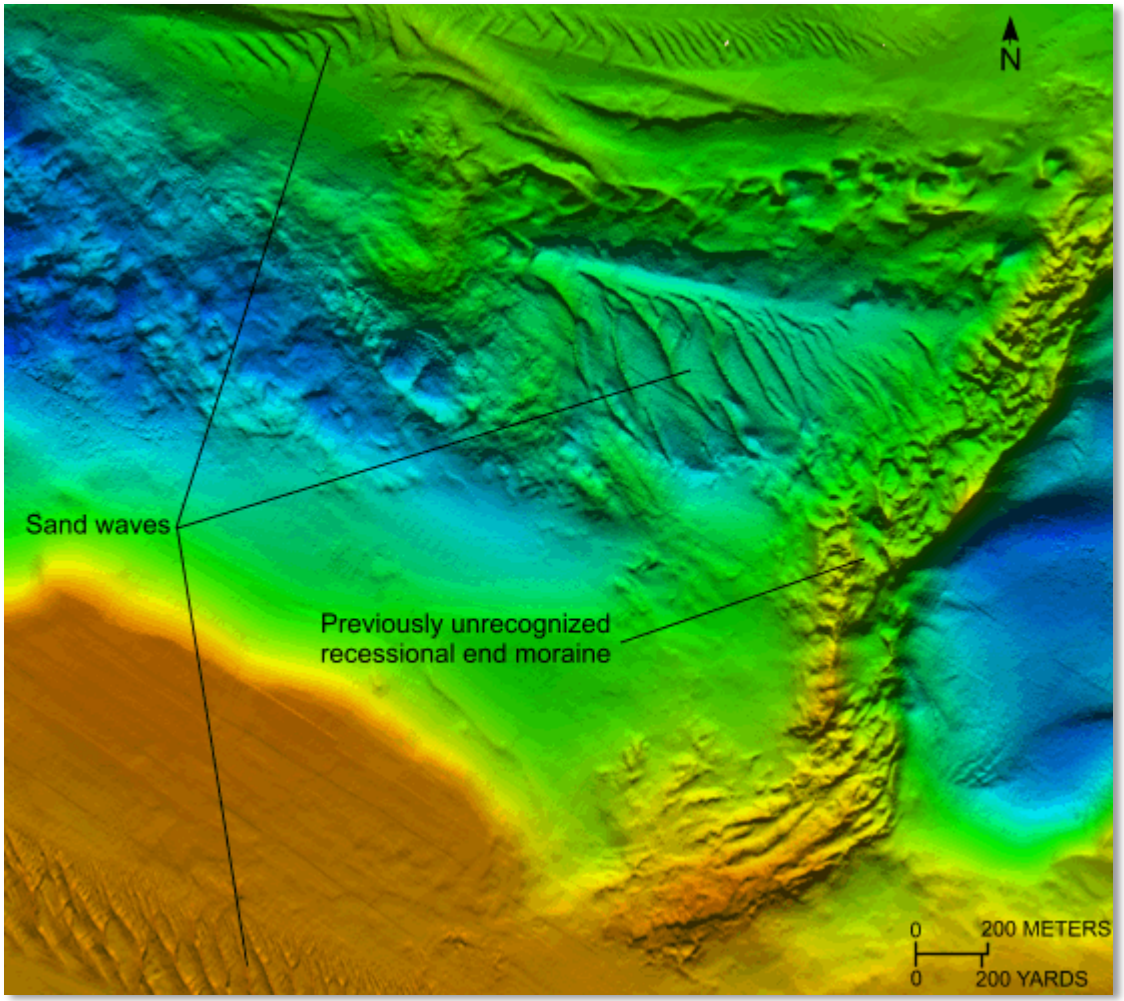


Image: United States Geological Survey

T20P Multibeam Fathometer

Image: Teledyne Reson

Side Scan Sonar

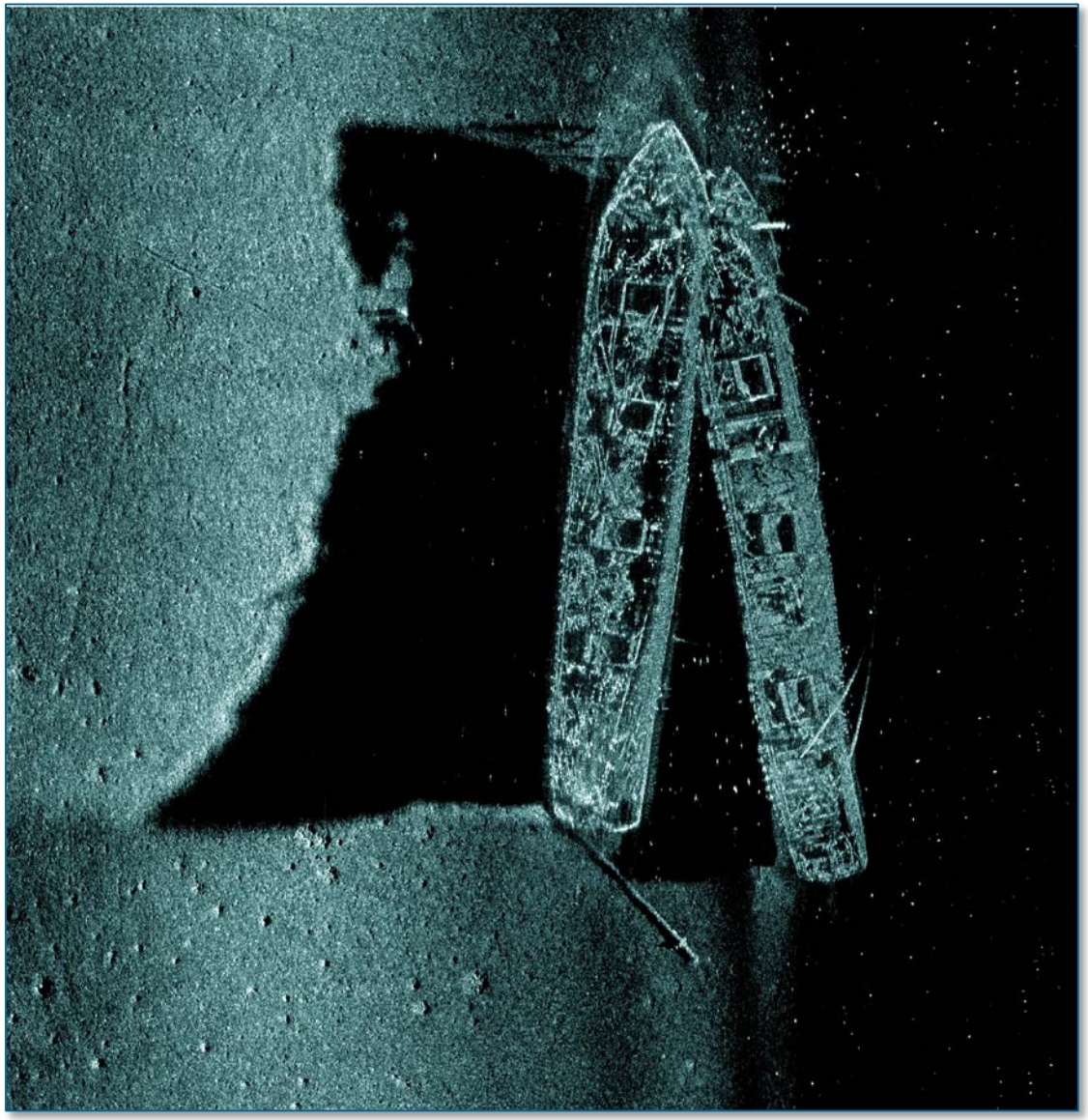


Image: National Oceanic and Atmospheric Administration (USA)

Klein 3000 Side Scan Sonar

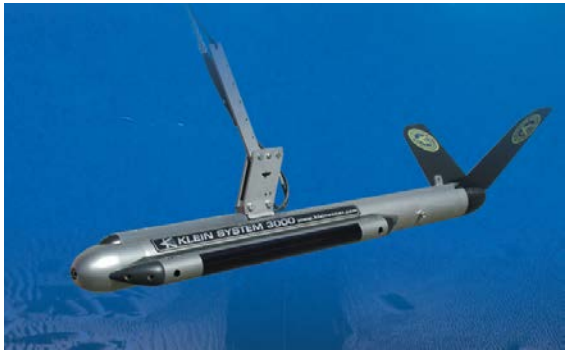
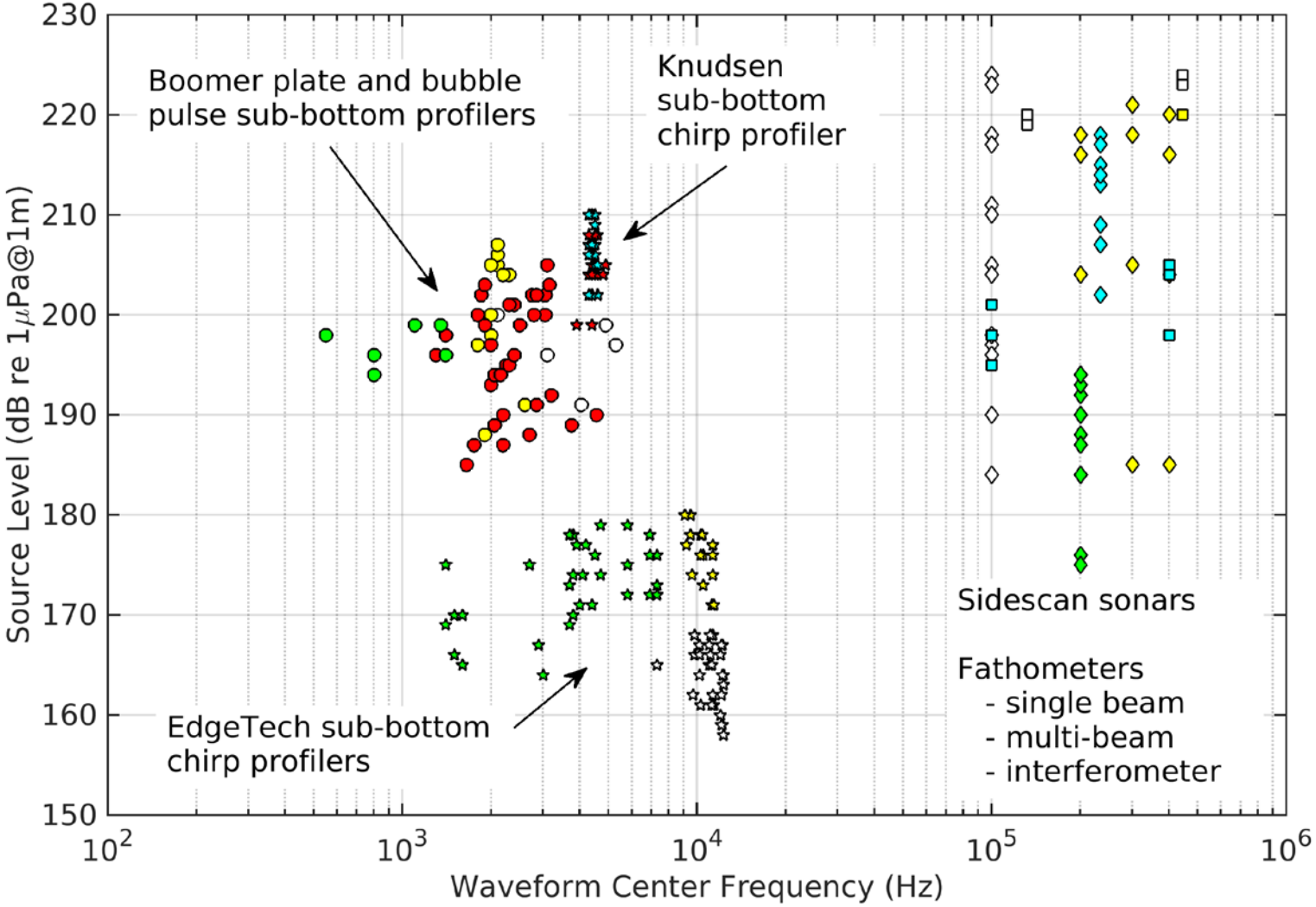


Image: Klein

Measurement Summary



From BOEM ESPIS Report at URL: http://www.data.boem.gov/PI/PDFImages/ESPIS/5/5551.pdf

Construction / Installation Noise

This category of sources consists of the mechanical noise created during the construction/installation process or the vessel used for towing or deploying equipment such as anchor and chains/cables.

Generally, these activities are perceived as a one time only event, but maintenance/repair activities or decommissioning of floating windfarm will also produce similar levels of noise as the initial construction.

Vessel Noise – Transiting	130 – 160 dB(RMS) @ 1m	10- 500 Hz
Vessel Towing or DP	150 – 170 dB (RMS) @ 1m	10 – 1000 Hz
Dredging, Setting Anchors	168 – 186 dB (RMS) @ 1m	100 – 500 Hz

Example of Potential Mooring Anchors

Source: Principle Power Inc.

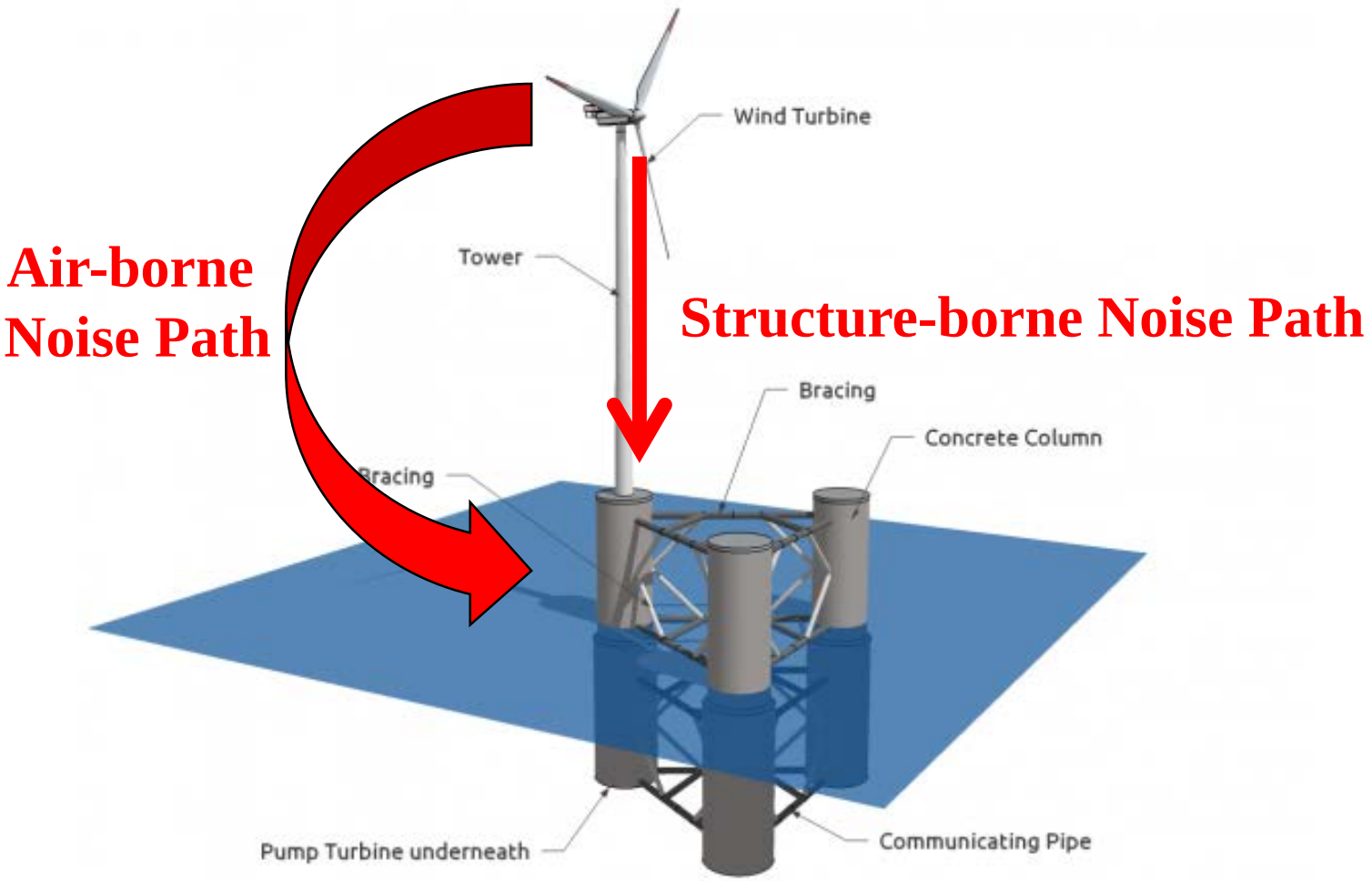
Operational Noise

This category of sources consists of the mechanical noise created during operations or the vessel used visit the platform.

Generally, most these activities are perceived as "continuous" sources by NOAA/NMFS.

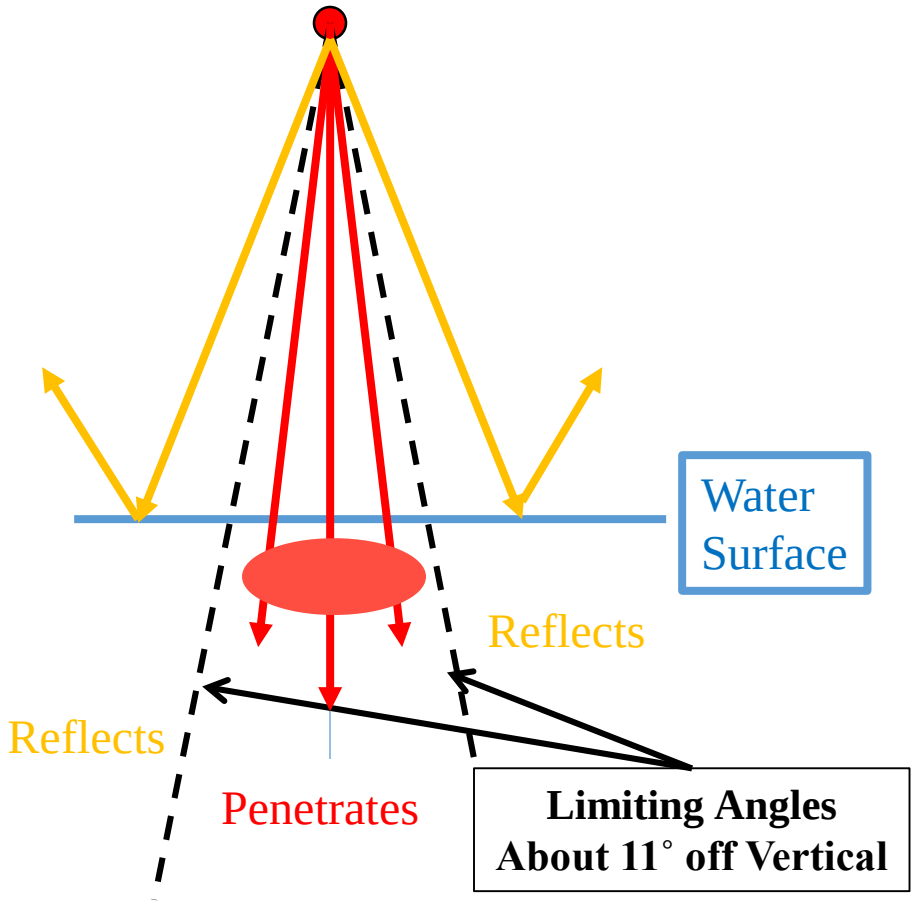
Wind Turbine (on concrete)	130 – 150 dB(RMS) @1m	30 - 200 Hz
Wind turbine (monopiles)	140 – 160 dB (RMS) @ 1m	10 – 500 Hz
Wind turbine (monopiles)	135 – 165 dB (RMS) @1m	10 – 800 Hz

Paths from Sources to Water for Operational Noise

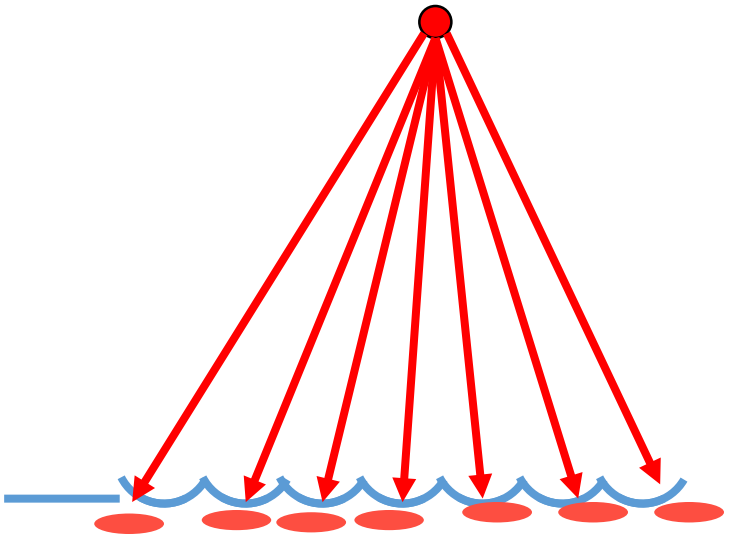


Physics Considerations for Air-borne Sources

Ideal Case



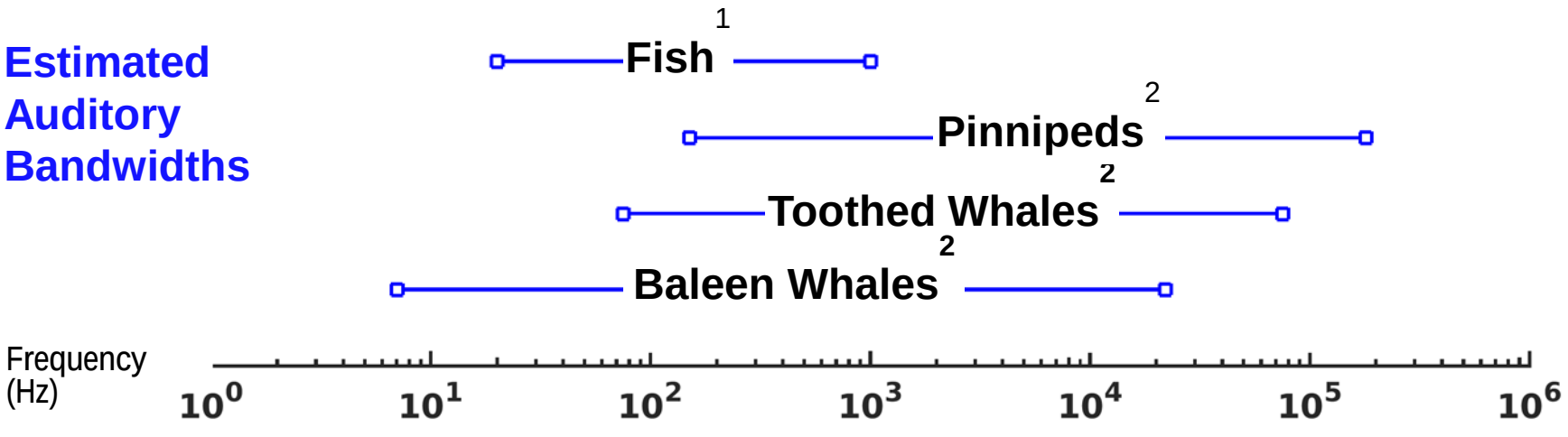
Realistic Case



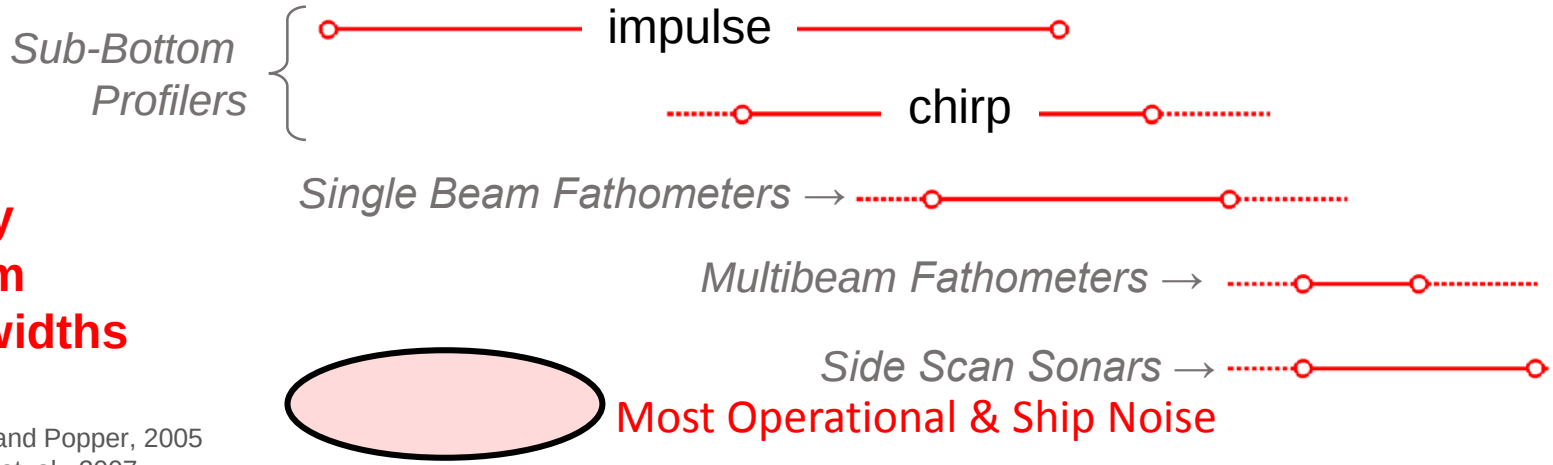
A more distributed
Sound Field

Acoustic Spectrum Usage

Estimated Auditory Bandwidths



Survey System Bandwidths



1) Hastings and Popper, 2005
2) Southhall et. al., 2007

Conclusion

This afternoon, Greg Sanders from the BOEM Pacific Region Office, will continue and expand this discussion with his talk on the Potential Interactions of Offshore Renewable Energy Activities with marine Mammals and Sea Turtles.

Questions??

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BACK-UP
Slides

Background

Marine Mammal Protection Act

The MMPA prohibits, with certain exceptions, the **"take"** of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S.

Definitions

Take: To harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.

Harass: Any act of pursuit, torment, or annoyance which - (i) has the potential to injure a marine mammal or marine mammal stock in the wild [Level A]; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering [Level B].

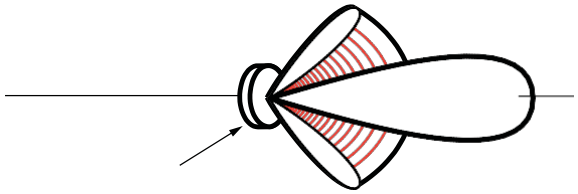
Sources: Marine Mammal Protection Act (MMPA) Sec. 3 (18); http://www.nmfs.noaa.gov/pr/laws/mmpa/; http://www.boem.gov/BOEM-Science-Note-March-2015/

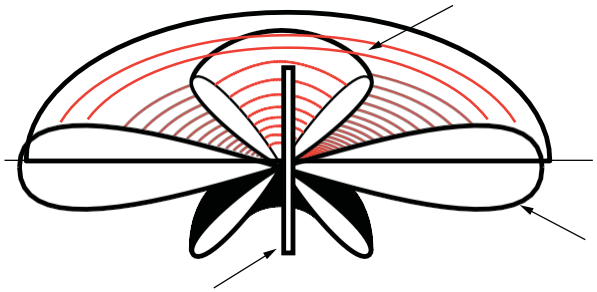
Source Level (SL):

RL = SL -TL

RL = SL – TL1 + TS – TL2

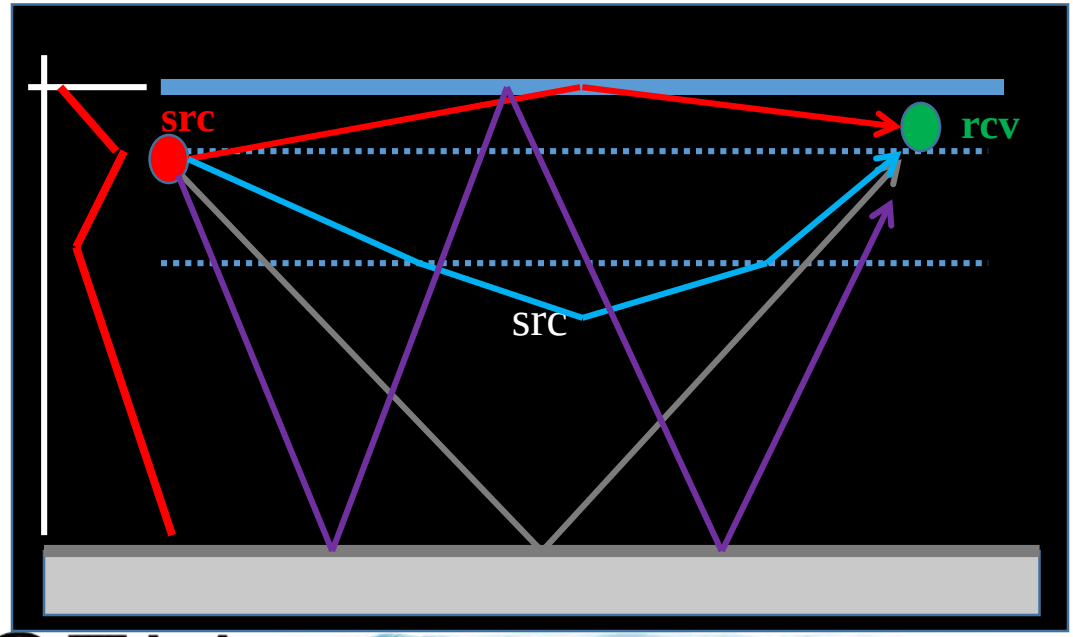
- Beam Patterns





  - Both sources and receivers
  - Frequency dependent

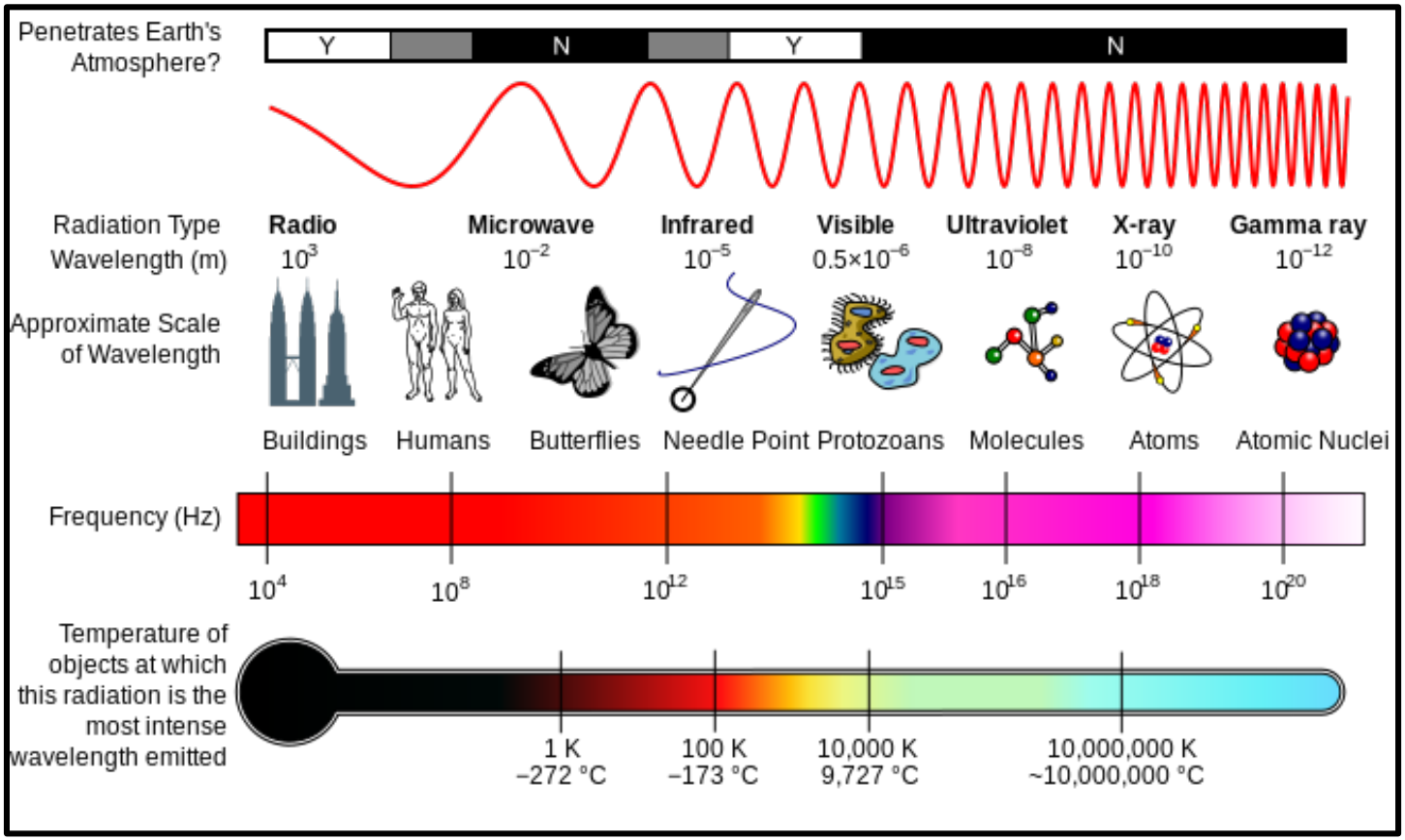
- Multipath/Signal Spreading



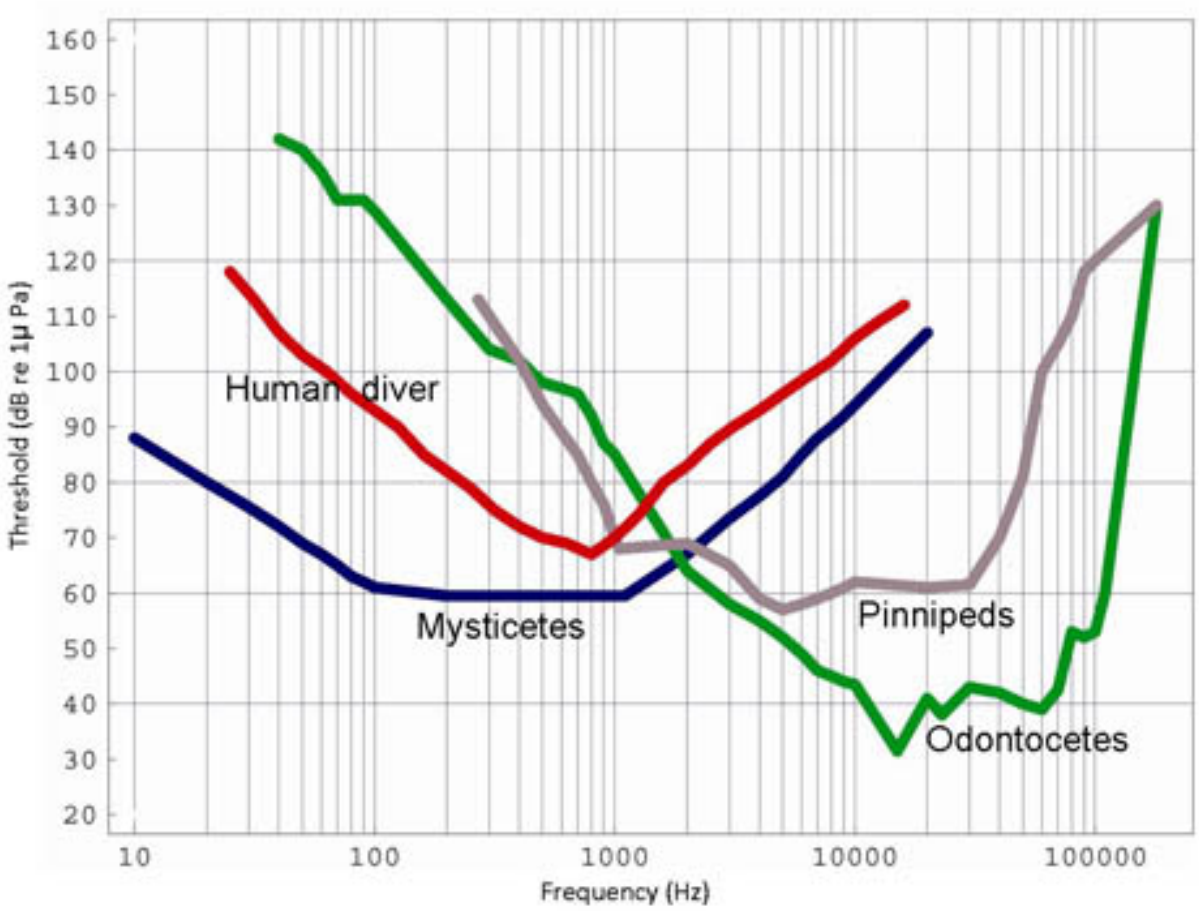
- Signal is spread in:
  - Time
  - Frequency
  - Duration

Addressing the Issues #3

- Frequency content of signal is critical and often broad



Cetacean & Human Underwater Hearing



Underwater Frequencies

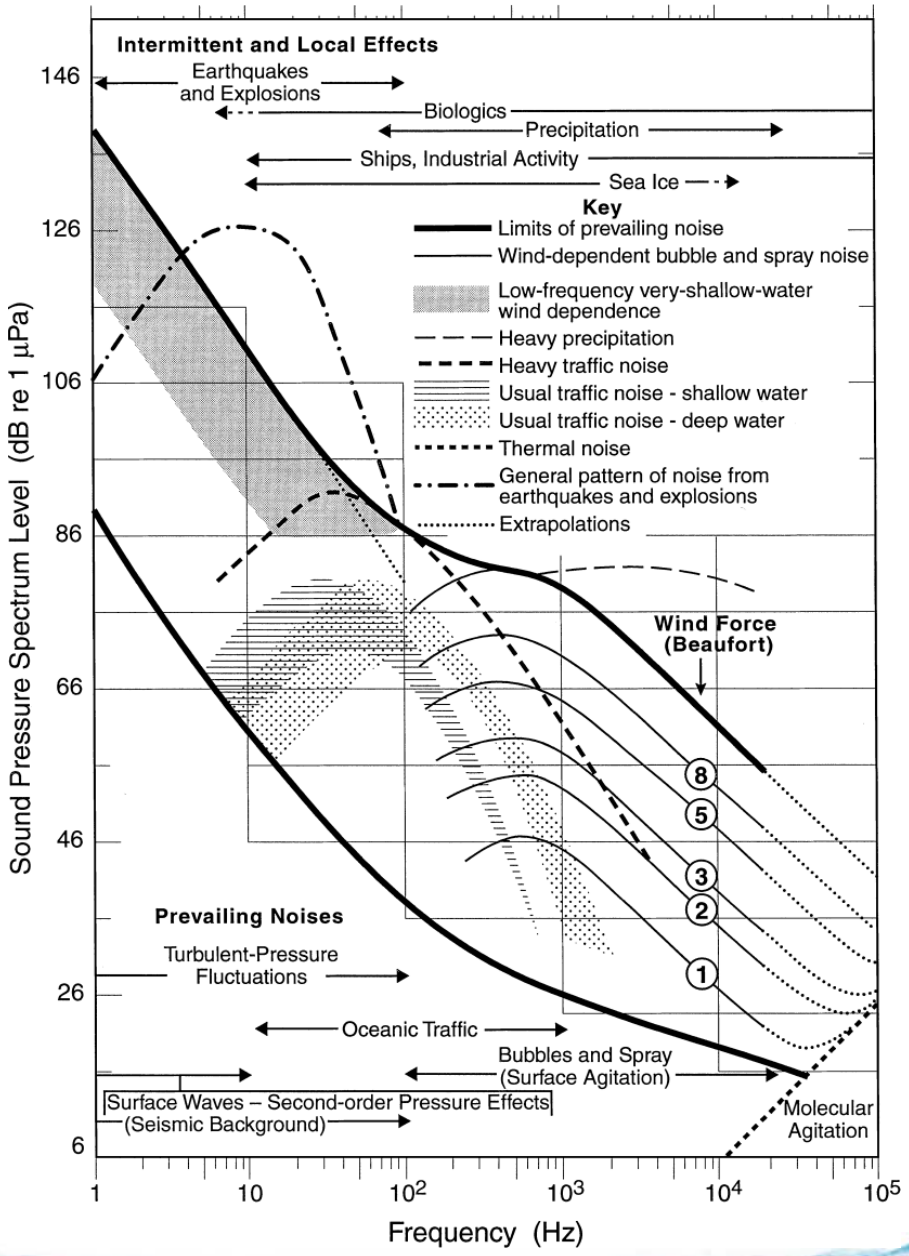
Human: 20 – 20, 000 Hz, Baleen Whales ~7 – 30,000 Hz, Odonocetes 200 – 180,000 Hz

Sonars 20 Hz – 1 MHz +, Seismic 5 – 10,000 Hz, Shipping 500 -2,000 Hz

Note: in Underwater Acoustics a 1 Hz wide band is generally assumed unless otherwise stated!

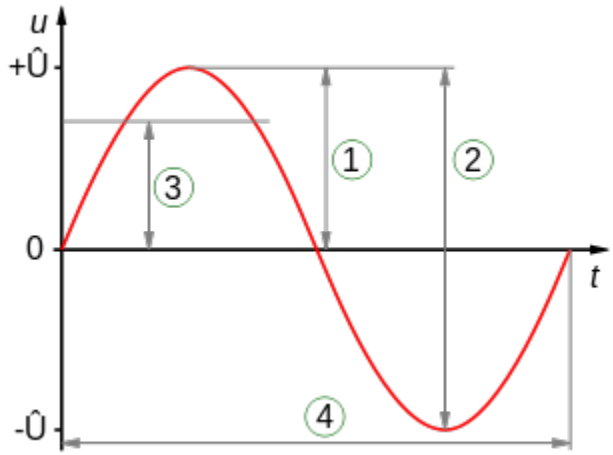
Ambient Noise (AN):

Wenz Curve:



Relationship of Various Acoustic Signal Metrics

For a sinusoidal curve
1 = Peak amplitude (U),
2 = Peak-to-peak amplitude (2 U),
3 = Root mean square amplitude (U/2^(1/2)) (~.7 U),
4 = Wave period (not an amplitude)



Abbreviations

Peak = Pk or Zero to Peak or 0-Pk
Peak to Peak = Pk-Pk or pk-pk
Root Means Squared = RMS or rms

Relationship in dB

Peak = Peak to Peak - 6 dB
RMS = Peak - 3 dB = Peak to Peak - 9 dB

Note: For a signal with multiple frequencies (e.g., an airgun) the RMS relationship is not this simple and it may be as much as 15 dB less than the Peak to peak signal.