



UNDERWATER SOUND PROPAGATION

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SOUND WAVES ARE VARIATIONS IN PRESSURE



- Equilibrium/background pressure depends on location
 - Atmospheric pressure at sea level
 - $1 \text{ atm} = 1 \times 10^5 \text{ Pa}$
 - Water pressure
 - For every 10 m in additional depth, water pressure increases 1 atm
- Sound waves are fluctuations in pressure about the equilibrium pressure
 - Talking: $1 \times 10^{-4} \text{ Pa}$ fluctuations

SOUND WAVES ARE DETECTED BY ACOUSTIC RECEIVERS

- Air-borne
 - Ears
 - Microphones
- Water-borne
 - Hydrophones





SOUND
WAVES ARE
GENERATED
BY ACOUSTIC
SOURCES

SOUND LEVELS ARE MEASURED IN DECIBELS

Sound pressure waves are measured in Pascals

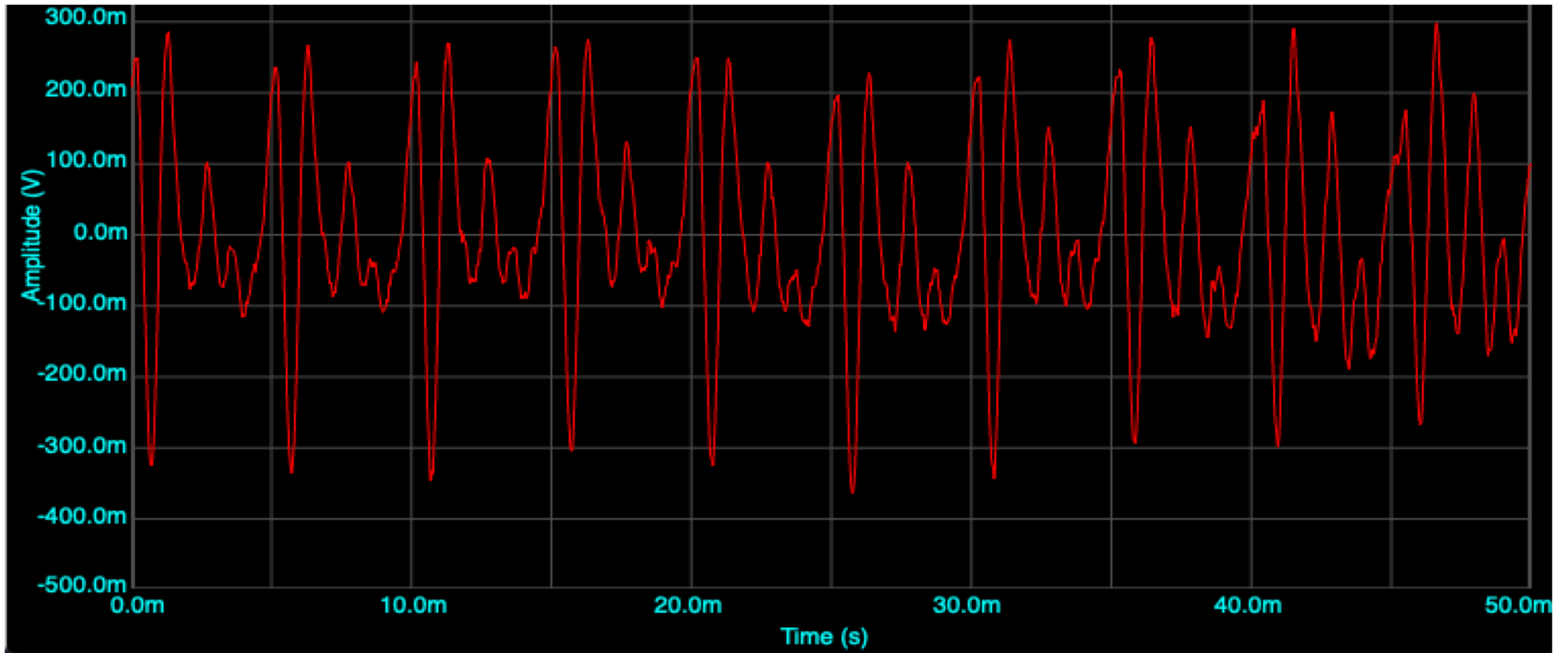
Sound Levels are on a logarithmic scale

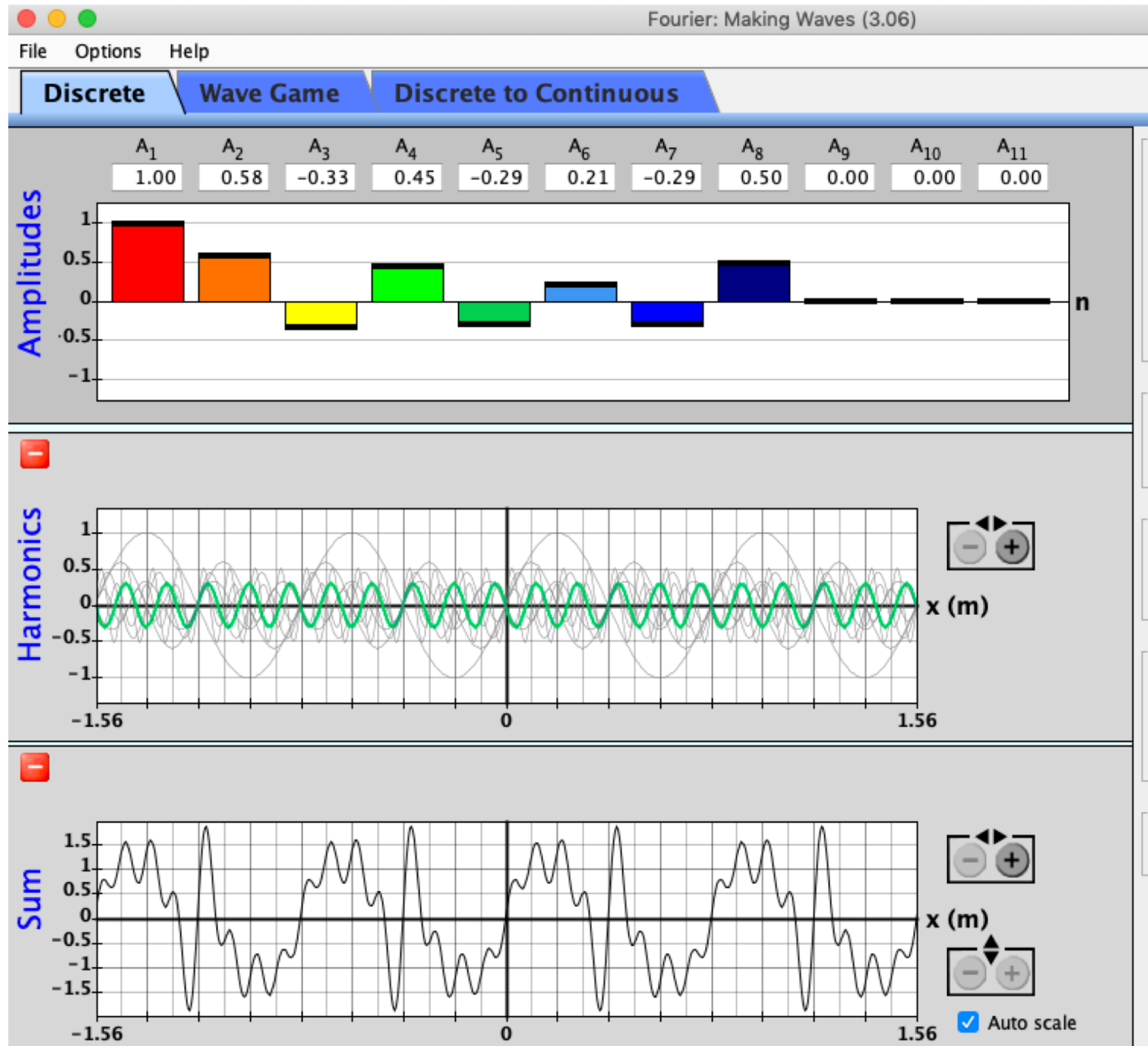
- $\text{Level} = 20 * \log_{10}[\text{abs}(\text{pressure})/(\text{reference pressure})]$
- Air-borne sounds:
 - reference pressure = 20 microPa ($20 \times 10^{-6} \text{ Pa}$)
- Water-borne sounds:
 - reference pressure = 1 microPa ($1 \times 10^{-6} \text{ Pa}$)

Comparisons

- Levels are 26 dB greater in the water because of the different reference pressure

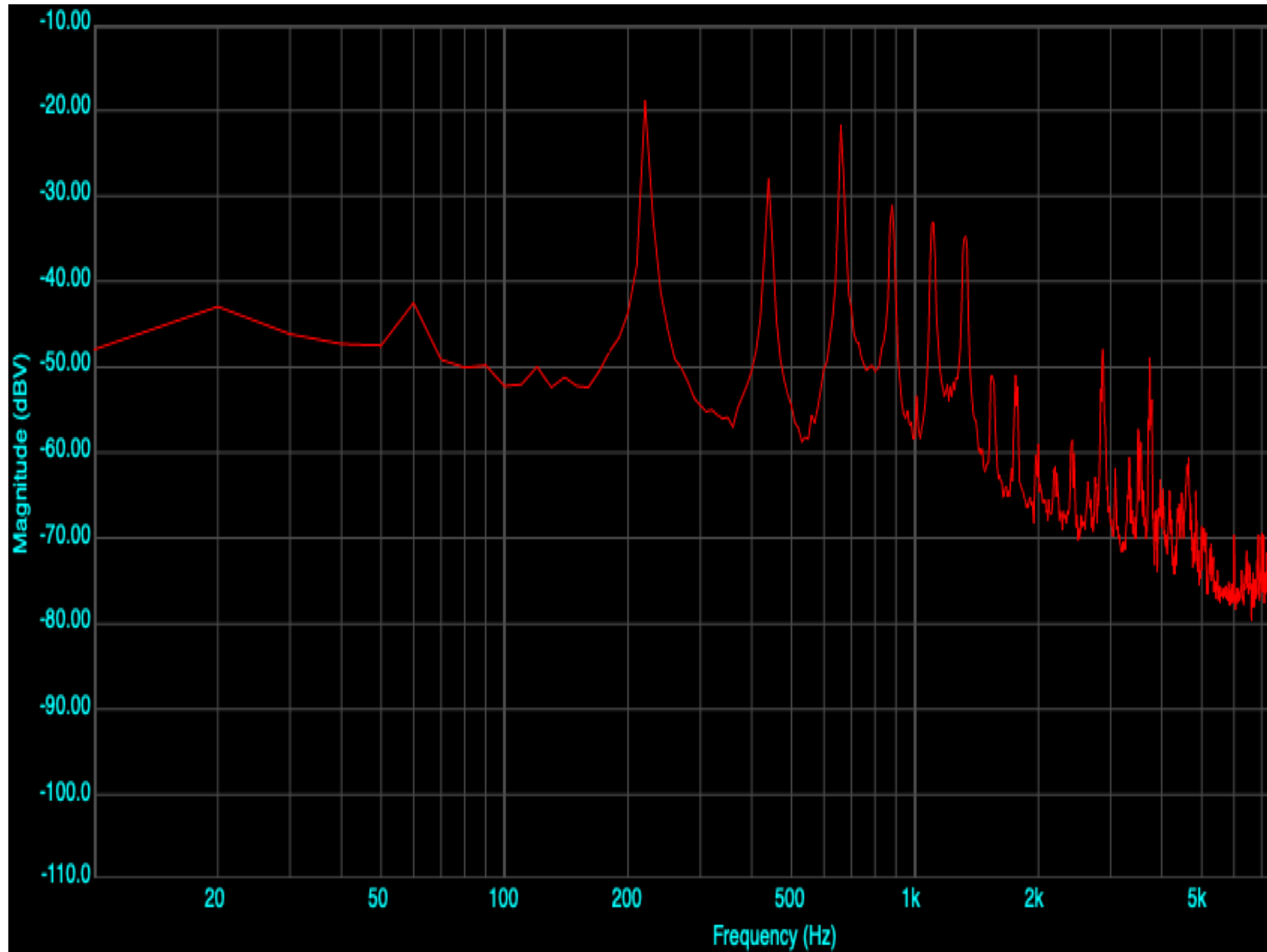
PRESSURE WAVEFORMS SHOW HOW A SOUND CHANGES WITH TIME



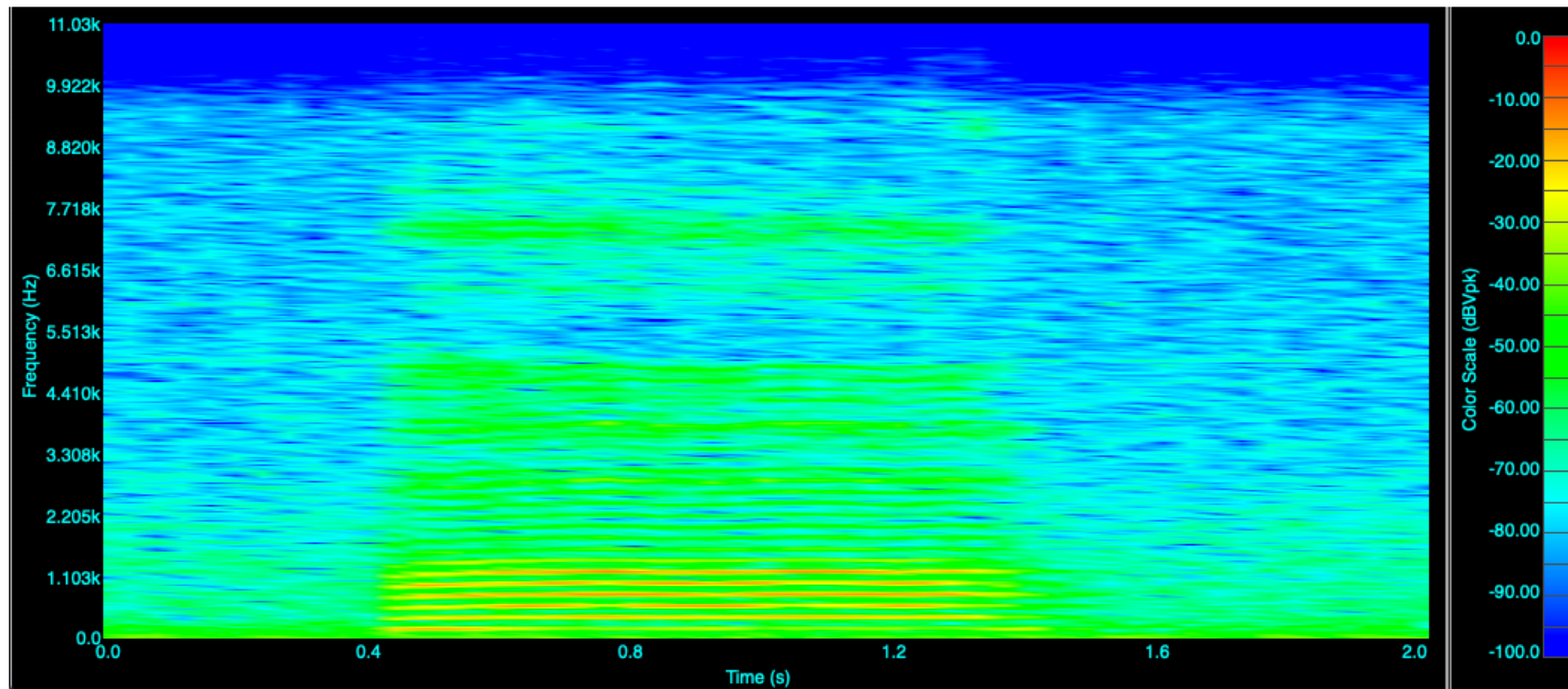


A SOUND WAVE IS
MADE OF DIFFERENT
FREQUENCIES

THE FREQUENCY
RECIPE FOR A
SOUND IS CALLED
THE SPECTRUM



A SPECTRUM
SHOWS THE
FREQUENCY
CONTENT
OF A SOUND
FOR A SINGLE
SNAPSHOT IN
TIME



SPECTROGRAMS SHOW HOW THE FREQUENCY CONTENT OF THE SOUND CHANGES IN TIME

DIFFERENT
ACOUSTIC
SOURCES HAVE
DISTINCT
SIGNATURES

THESE
SIGNATURES
ARE EASIER TO
DISCERN IN
SPECTROGRAMS

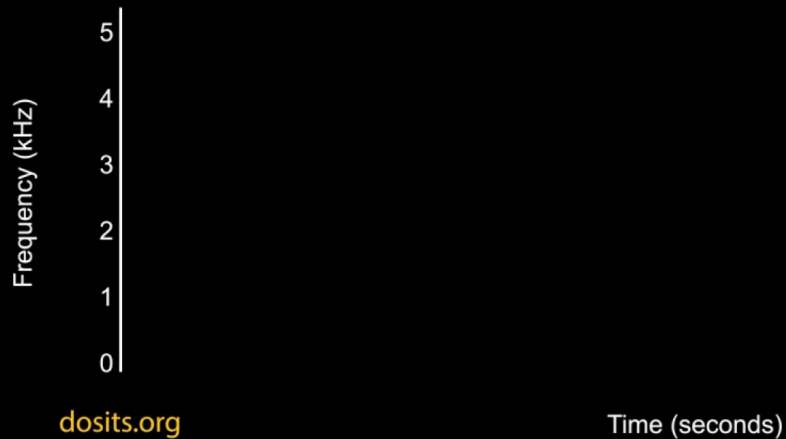


- Examples:
 - Different vessels have different acoustic signatures because of blade-rate
 - Scientists use the differences in acoustic signatures to identify marine species from each other (e.g., blue whale, fin whale, sei whale)
- DOSITS Audio gallery
 - <https://dosits.org/science/measurement/how-are-sounds-viewed-and-analyzed/>

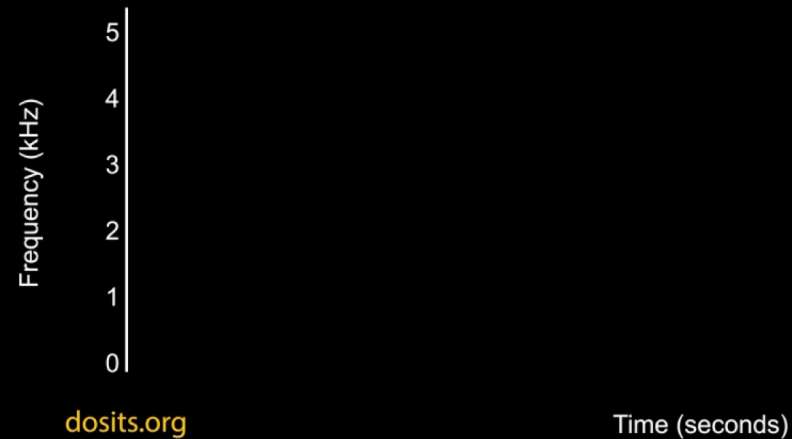
ANIMALS CAN BE IDENTIFIED BY SPECTROGRAMS



Discovery of *Sound*



Discovery of *Sound in the Sea*



ANIMALS CAN BE IDENTIFIED BY SPECTROGRAMS



Discovery of *Sound in the Sea*

Frequency (kHz)

21.2
15.9
10.6
5.3
0

dosits.org

Time (seconds)



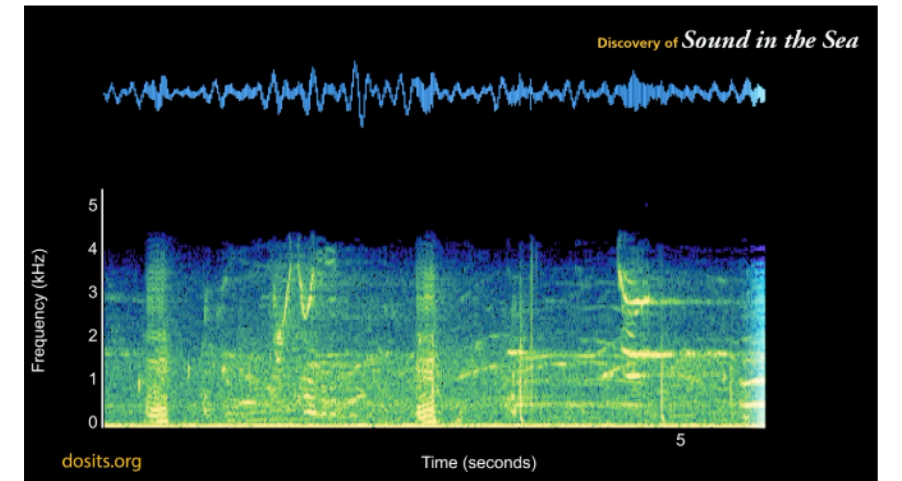
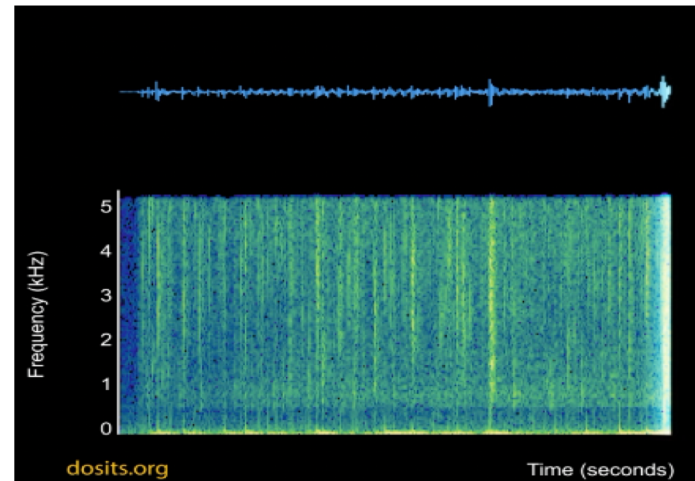
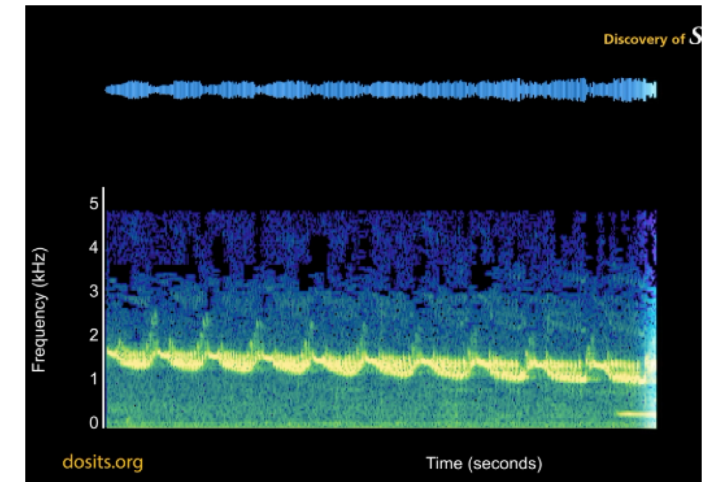
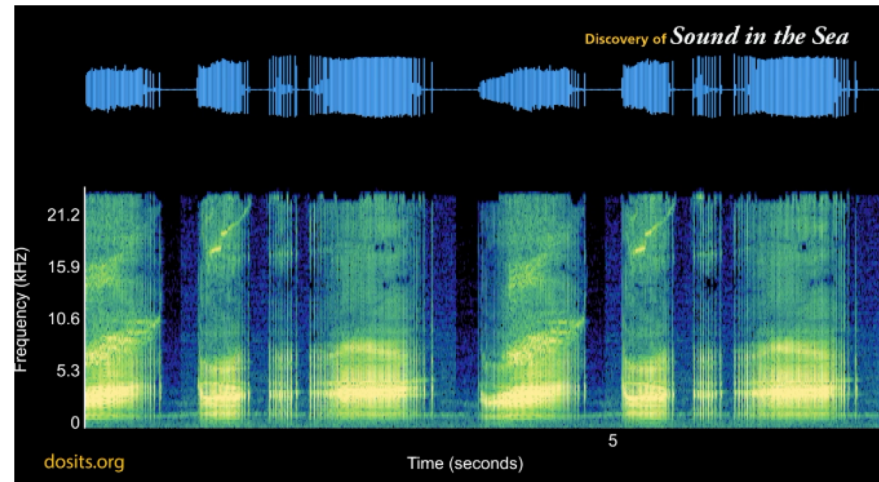
Frequency (kHz)

5
4
3
2
1
0

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Time (seconds)

WHICH ANIMAL PRODUCED WHICH SOUND?



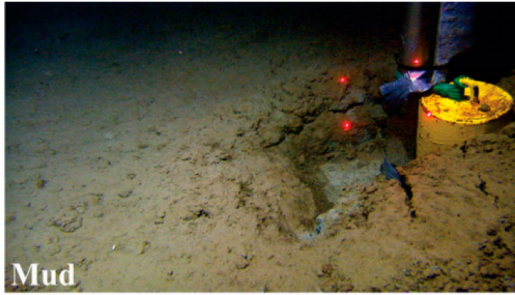
Discovery of *Sound in the Sea*

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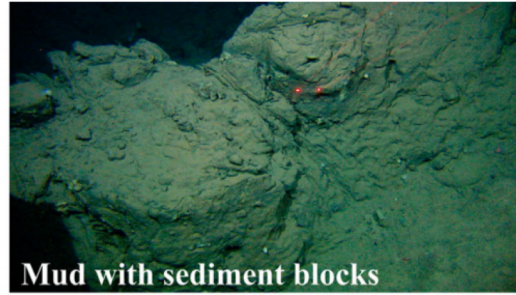
dosits.org

Time (seconds)

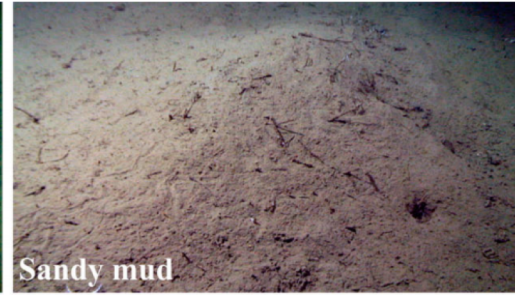
JET SKI ON A SPECTROGRAM



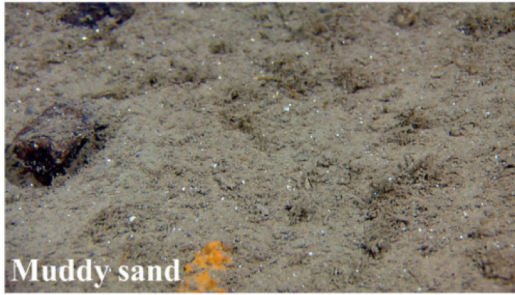
Mud



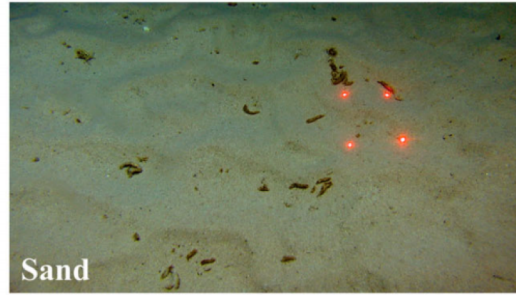
Mud with sediment blocks



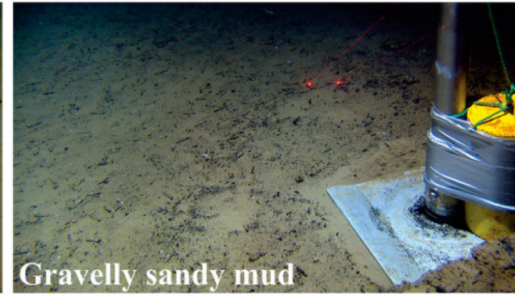
Sandy mud



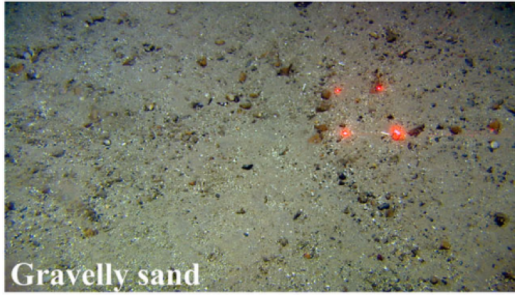
Muddy sand



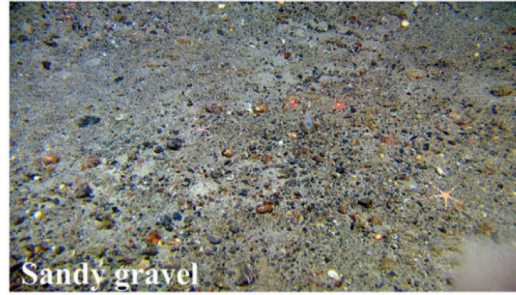
Sand



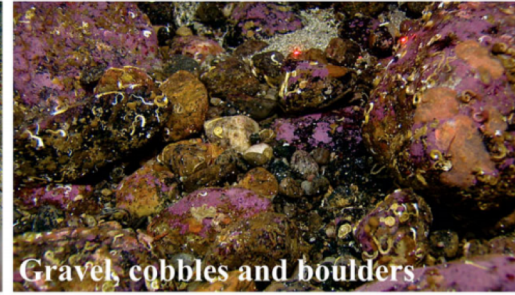
Gravelly sandy mud



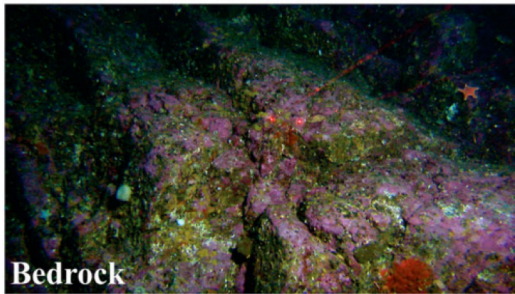
Gravelly sand



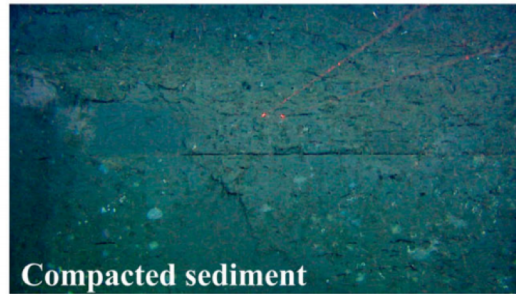
Sandy gravel



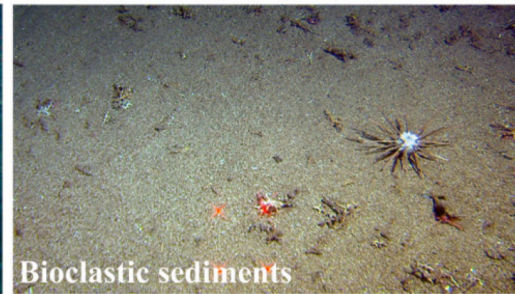
Gravel, cobbles and boulders



Bedrock



Compacted sediment

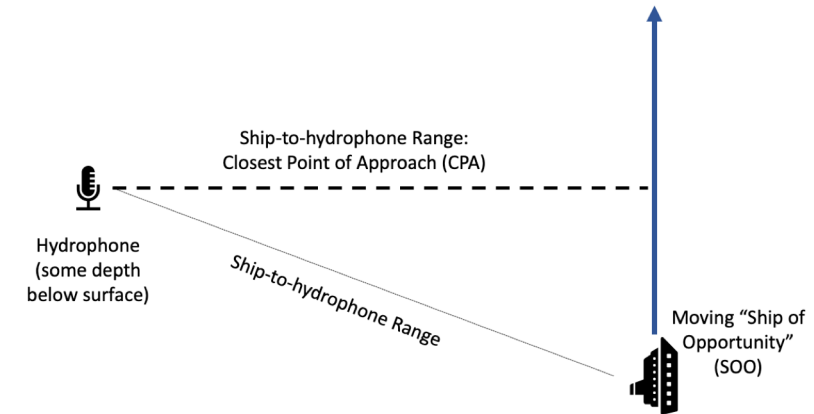


Bioclastic sediments

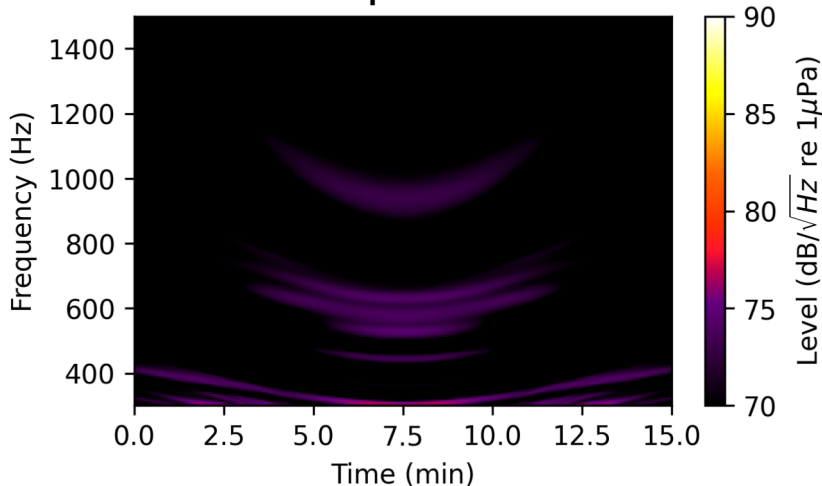
THE OCEAN ENVIRONMENT VARIES WITH LOCATION

THE RECEIVED SOUND DEPENDS ON THE OCEAN ENVIRONMENT

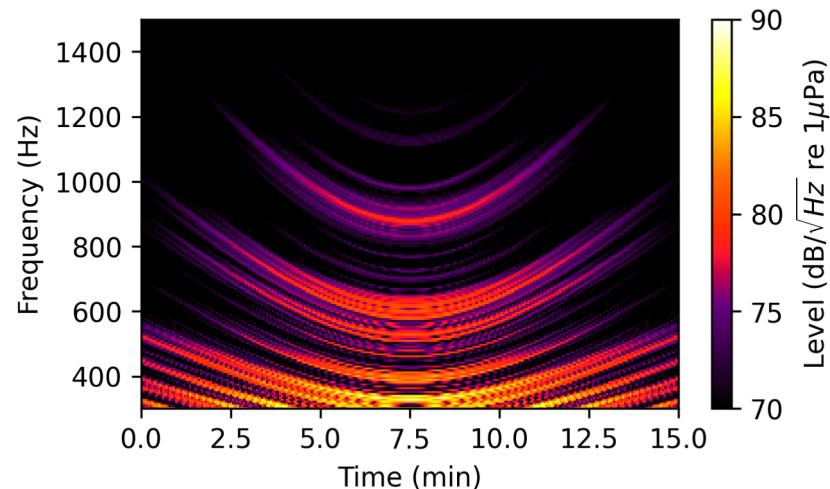
- Example from my research
 - A surface ship is passing by a hydrophone
 - A computer model of how the sound travels produces simulated spectrograms for different environments



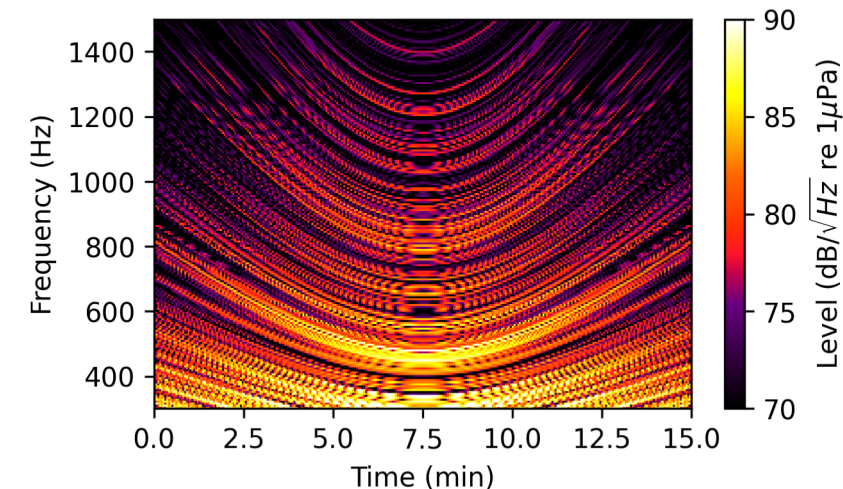
Deep mud



Mud over Sand

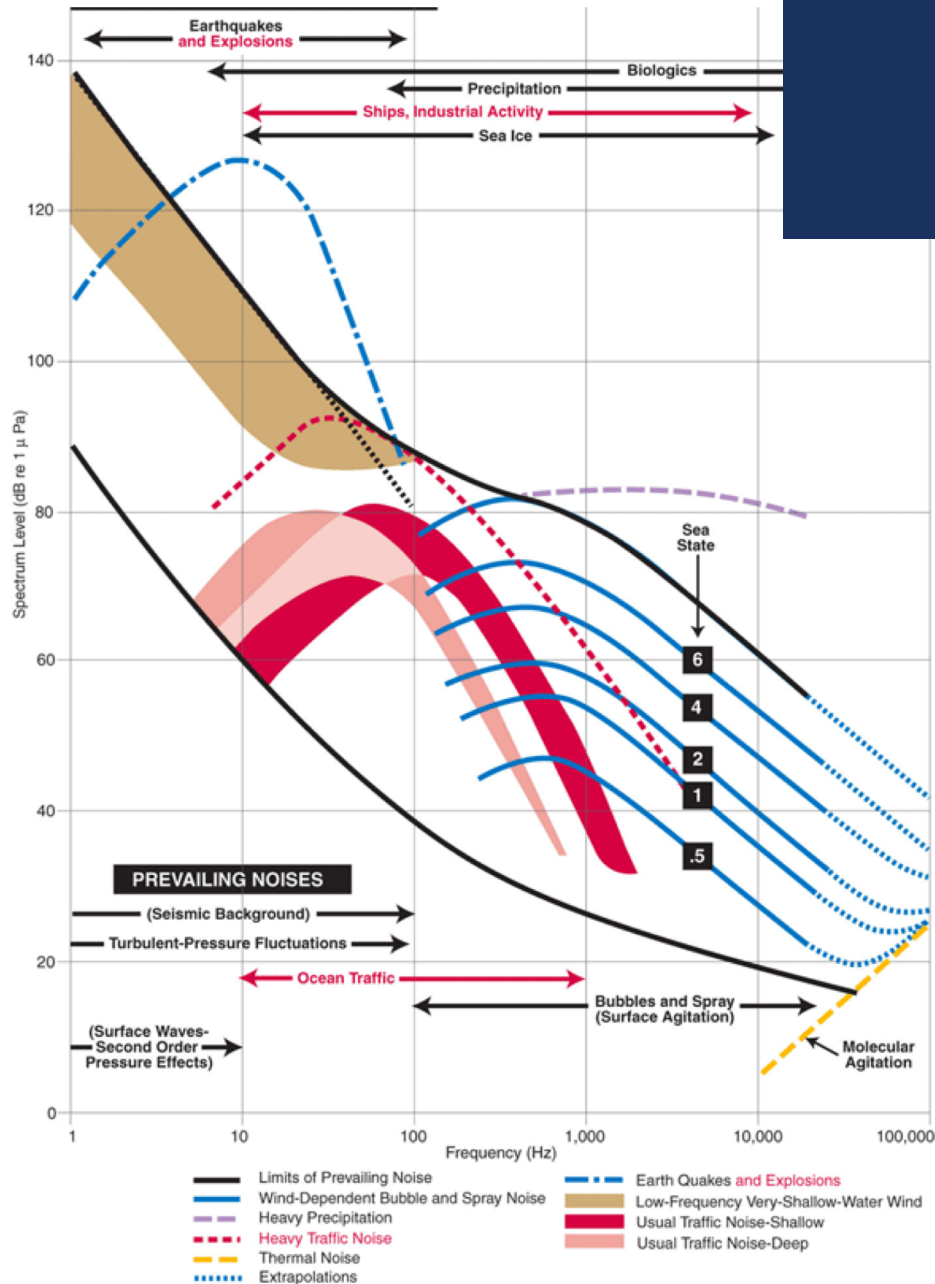


Sand



THE RECEIVED SOUND CONTAINS BACKGROUND NOISE

- Noise is often easier to discern in spectrograms
- Air-borne example
 - Talking on the phone with noise where you are/or where other person is
- Ocean example
 - Wind, waves, rain
 - Ships



<https://dosits.org/science/sounds-in-the-sea/what-are-common-underwater-sounds/>

KEY POINTS

- Sounds can be viewed either as pressure waves or as spectrograms
- Signatures of acoustic sources and background noise are easier to identify on spectrograms
- Sounds in the ocean depend not only on the acoustic source but also on the ocean environment
- Sound levels in the ocean have a different reference pressure than that used for in-air sound levels

