



Global Lessons Learned: Marine Acoustics

Agenda

Marine Acoustics: Lessons Learned, Pitfall to Avoid on the Path to Success

We are helping shape the U.S. offshore wind industry, as well as contributing to marine acoustic impact analyses. We share some lessons we have learned to help pave your path to success.

- **Lessons Learned**
 1. Stakeholder Engagement
 2. Baseline Underwater Sound Measurements
 3. Flexible Modeling Structure
- **Pitfall to Avoid**
 1. Underestimating the Complexity of Evaluating Potential Effects



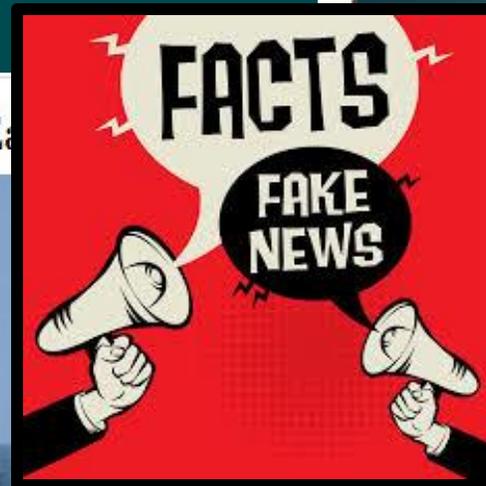
I. Stakeholder Engagement

Crucial conversations: State the Facts

A MASS STRANDING OF CETACEANS CAUSED BY

The New York Times

A Rising Tide of Noise Is Now Eating



TAKE ACTION TAKE A STAND AGAINST OCEAN NOISE



Every day, whales, dolphins, fish and other marine life are threatened by a cacophony of industrial noise from shipping, seismic exploration for oil and gas and naval sonar used for routine training exercises.

From the Atlantic to the Pacific to the wild Arctic, this endless barrage of noise impairs the ability of our planet's vulnerable marine life to communicate, find food, navigate and breed. Ocean noise is harming and even killing whales, dolphins and other creatures in water bodies all around the world.

We can make a difference, compelling industry and the government to chart a more responsible course to protect countless marine animals — if we rise up together now and demand change.

Discovery of Sound in the Sea

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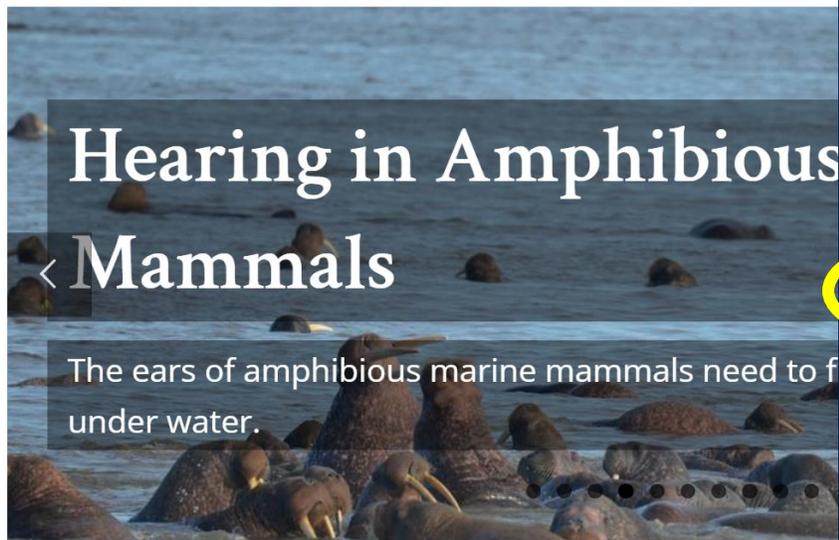


Discovery of *Sound in the Sea*

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Hearing in Amphibious Mammals

The ears of amphibious marine mammals need to function under water.



What's New



Hot Topics

Ultrasonic Ant...

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- Effects of Sound
 - Determine if a sound affects a marine animal
 - Considerations for "Contained" Studies in Laboratory
 - Potential effects of sound on marine mammals
 - Behavioral Changes in Mammals
 - Masking in Mammals
 - Hearing Loss in Mammals
 - Strandings
 - Impacts of Impulsive Sound
 - Potential effects of sound on marine fishes
 - Behavioral Changes in Fishes
 - Masking in Fishes
 - Hearing Loss in Fishes
 - Physiological Stress
 - Acoustic Issues Related to Diadromous Fishes
 - Criteria for Effects of Anthropogenic Sound on Fishes
 - Potential effects of sound on marine invertebrates
 - Measure marine mammal's reaction to sound
 - Hearing Sensitivity Studies
 - Visual Observations
 - Acoustic Monitoring
 - Tagging Studies
 - Controlled Exposure Experiments
 - Moderate or eliminate the effects of human activities
 - Ship Quieting Technologies
 - Anthropogenic Sound Sources
 - Commercial Vessel Traffic
 - Small Vessels
 - Single Deep Fish Sounders

Discovery of Sound in the Sea

Discovery of *Sound in the Sea*

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Facts and Myths

Hot Topics

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Videos

- Science of Sound Video
- Marine Mammal Hearing
- Hearing in Marine Fishes
- Determining Mitigation and Mon

Anthropogenic Sound Sources

- Commercial Vessel Traffic
- Echosounders
- Pile driving
- Seismic Airguns
- Sonar
- Wind Turbine

Decision Maker Tutorials

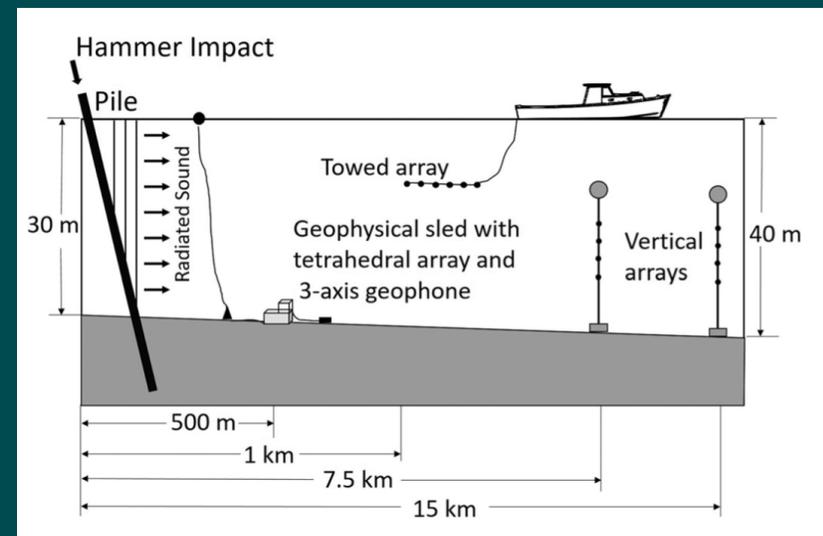
- Decision Makers Effects of Sound Tutorial Introduction
- Determine if a Sound Affects a Marine Animal Tutorial Introduction
- Decision Makers Science of Sound Tutorial Introduction
- Decision Makers Sound Source Tutorial Introduction

- FAQs
- Facts and Myths
- Stranding Fact Sheet
- Seismic Airgun Fact Sheet
- Media Backgrounder – How do animal hear underwater?
- DOSITS Webinars

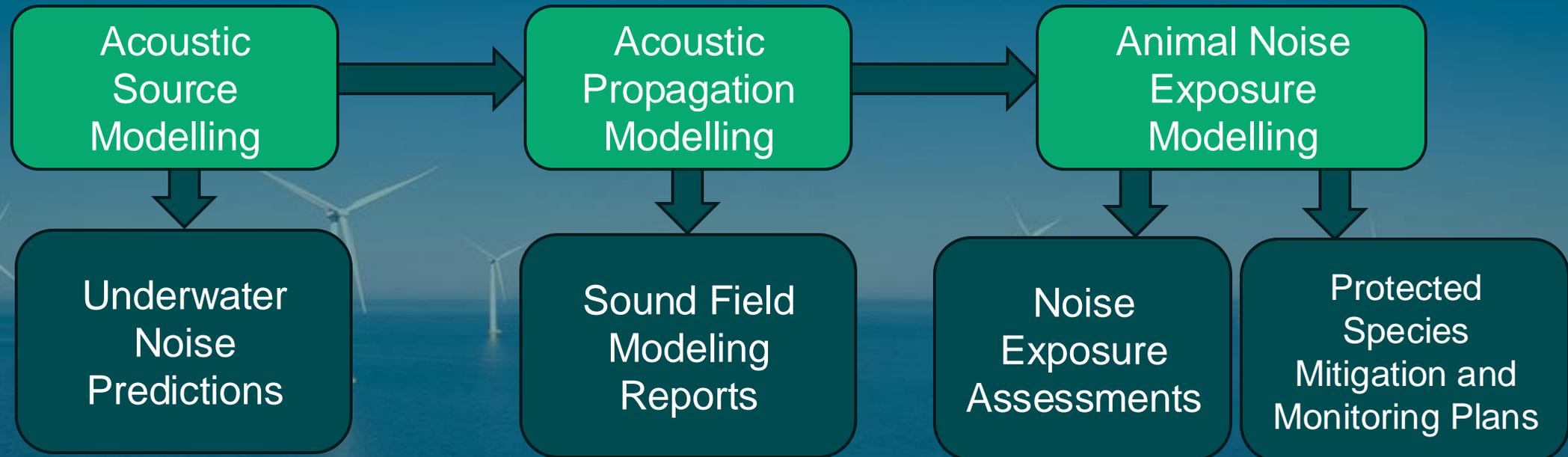
II. Baseline Underwater Sound Measurements

Lessons Learned

- Amaral et al. 2020: Identified need for 3D modelling of raked piles at Block Island Wind Farm
- Lin et al. 2019: 3D propagation model of operational wind farm sounds
- Potty et al. 2023: Particle motion as part of acoustic energy



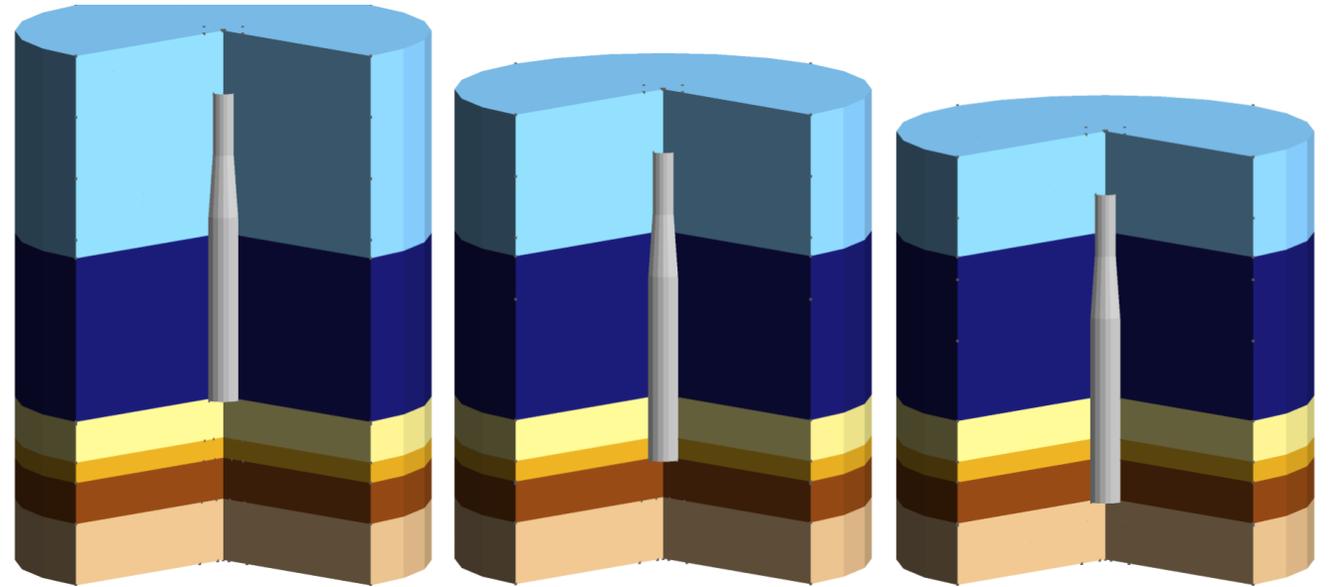
III. Flexible Modelling Structure



Pile Driving Acoustic Source Model

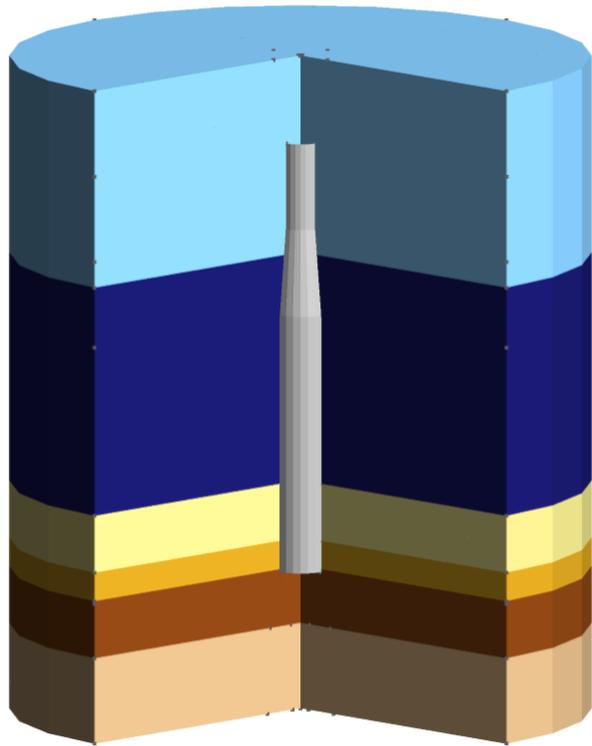
State-of-the-art numerical wave + 3D modelling provides sound field predictions accounting for:

- Pile length, diameter, thickness, and taper
- Pile penetration depth
- Hammer type and force
- Sound speed and shear speed profiles for solid and porous substrates



3D renders of a common XXL monopile in a stratified substrate

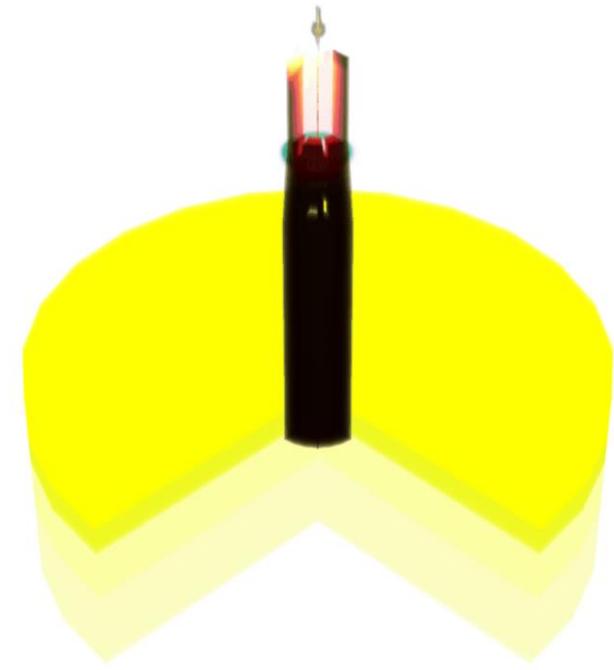
Pile Driving Model: 3D Sound



3D Render



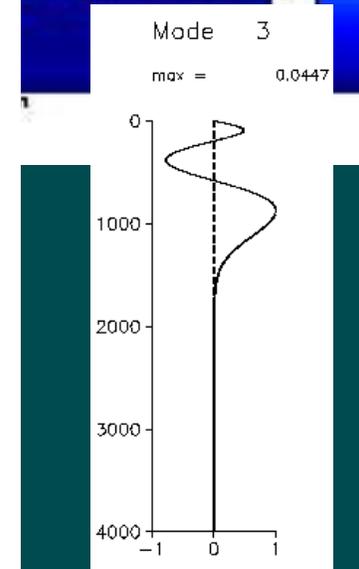
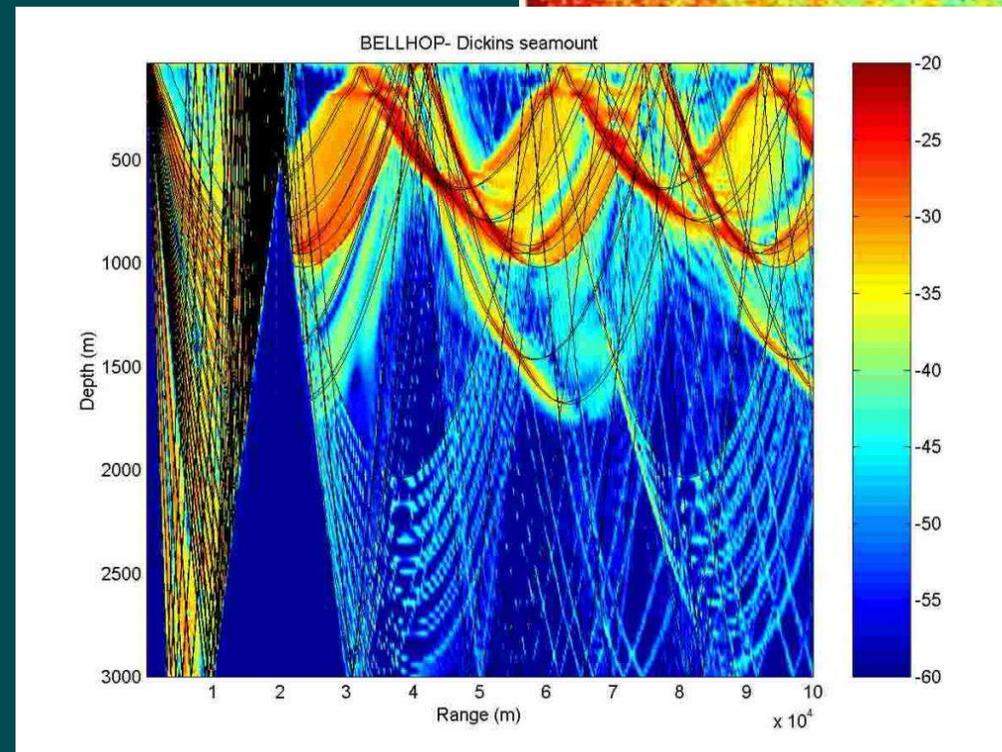
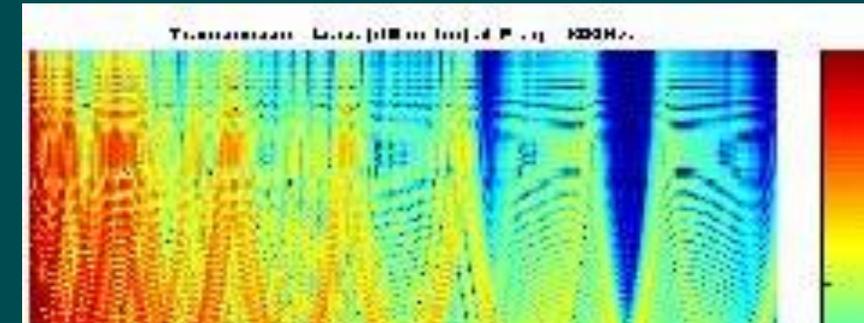
Impact Pile Driving



Vibratory Pile Driving

Acoustic Propagation Modelling

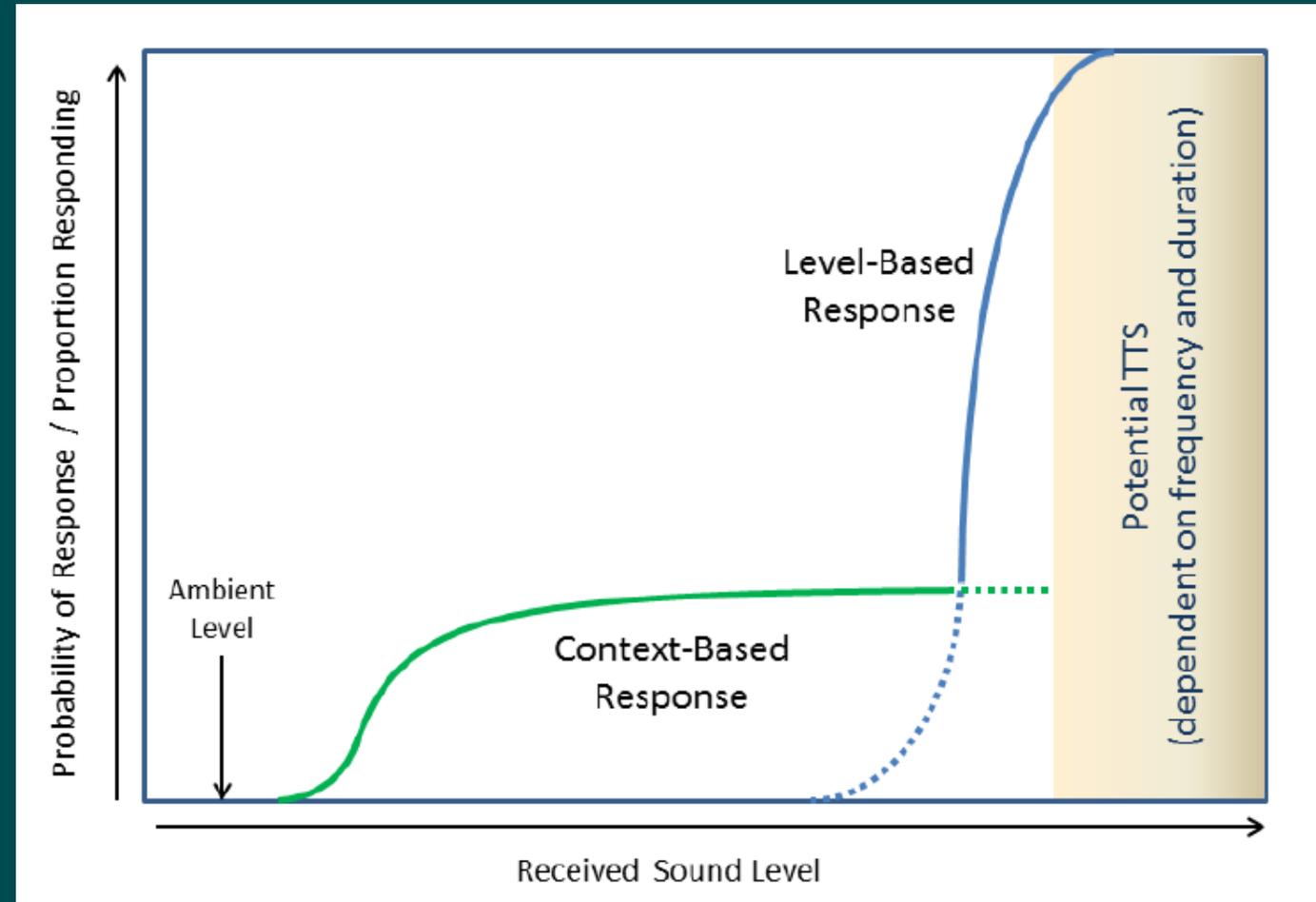
- Incorporates environmental conditions (bathymetry, water column profiles, sediment properties)
- Acoustic propagation models:
 - Parabolic Equation (PE)
 - RAMGeo: acoustic-elastic bottom with multiple sediment layers
 - 3D PE: horizontal refraction out of range-depth plane
 - Ray modelling: Bellhop
 - Normal mode: KRAKEN



Pitfall to Avoid: Underestimating the Complexity of Evaluating Potential Effects

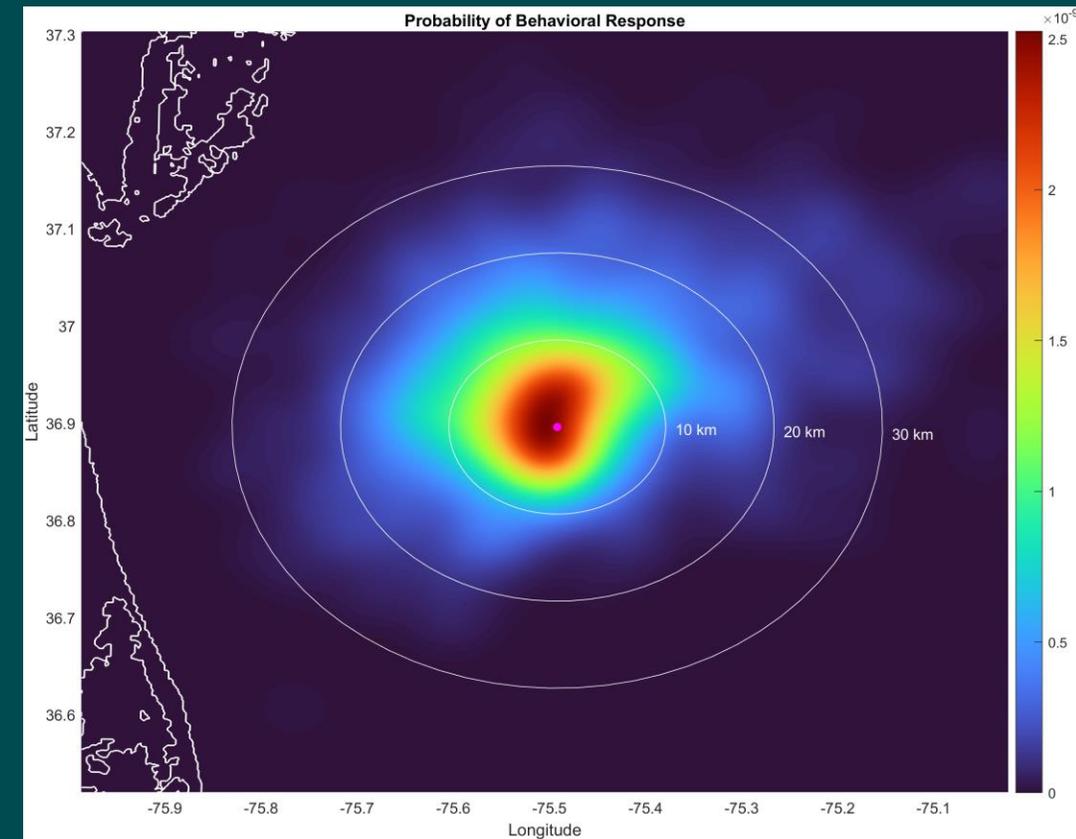
Develop meaningful thresholds

- One value does not reflect the science that shows animals react based on the context under which they are exposed
- At a certain level, almost all animals begin to have a response



Animal Exposure Modelling

- The source and propagation modelling produce a sound field (a pressure timeseries at points in a 3D volume).
- Monte Carlo simulations of animals moving through the sound field, accumulating energy
- Output: 2D maps showing the probability density of a chosen animal species exceeding a selected threshold, accounting for species specific information such as
 - Historical population density (monthly)
 - Diving behaviour and swim speed
 - Hearing sensitivity and aversion to sound levels



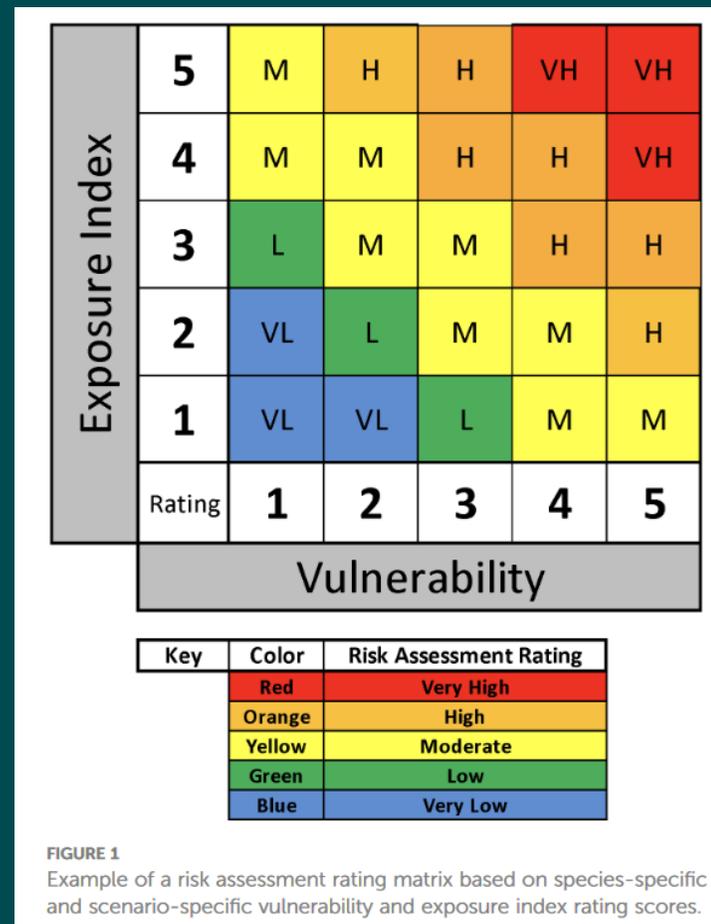
Possibility with Few Data: Biologically Relevant Risk Assessment Framework

Vulnerability Score

- Population status, trend, size
- Habitat, temporal overlap
- Masking overlap
- Other environmental stressors

Exposure Index

- Activity index
- Spectral index

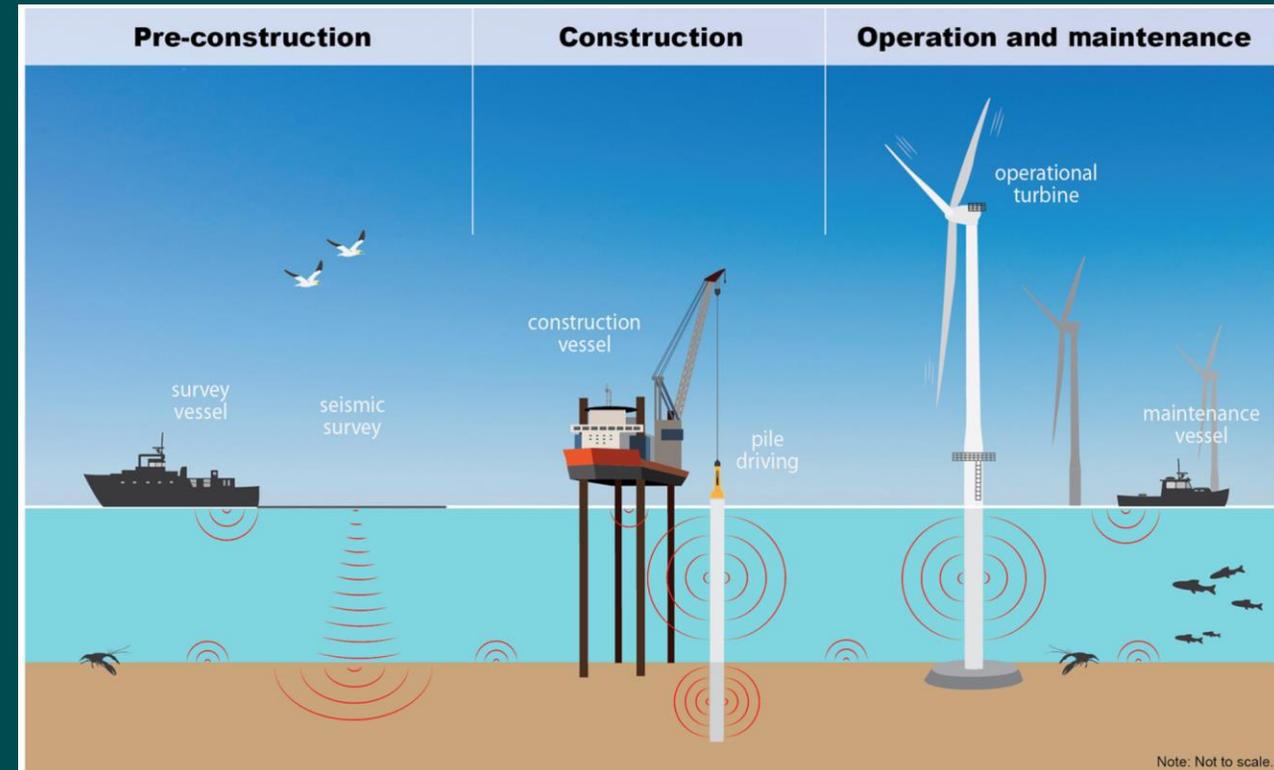


Cumulative Effects Analysis

Across Life Cycle of Each Wind Farm

- Multibeam Echosounder (MBES)
- Sub-bottom profilers
- Vessels
- Operational noise
- Explosives, UXO removal

Across Region, Time



Popper et al. 2022, Williams et al. 2023

Get in touch

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