



# Global Lessons Learned: Marine Acoustics

27 February 2025

# Agenda

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

We helped shape the U.S. offshore wind industry, as well as contributing to the 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

**The New York Times**

A Rising Tide of Noise Is Now Eating



## A MASS STRANDING OF CETACEANS CAUSED BY

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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- Home
- Science of Sound >
- Animals and Sound >
- People and Sound
- For Decision Makers >
- DOSITS Webinars >
- Galleries >
- Resources >
- Tutorials >
- DOSITS FAQ
- Facts and Myths
- Hot Topics
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- Home
- Science of Sound >
- Animals and Sound >
- People and Sound >
- For Decision Makers >
- DOSITS Webinars >
- Galleries >
- Resources >
- Tutorials >
- DOSITS FAQ
- Facts and Myths
- Hot Topics

- 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-Beam Echo Sounders

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Animals and Sound >

People and Sound >

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Resources >

Tutorials >

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Hot Topics

## *DOSITS Resources for Decision Makers*

**[dosits.org/decision-makers/resources/](https://dosits.org/decision-makers/resources/)**

### 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

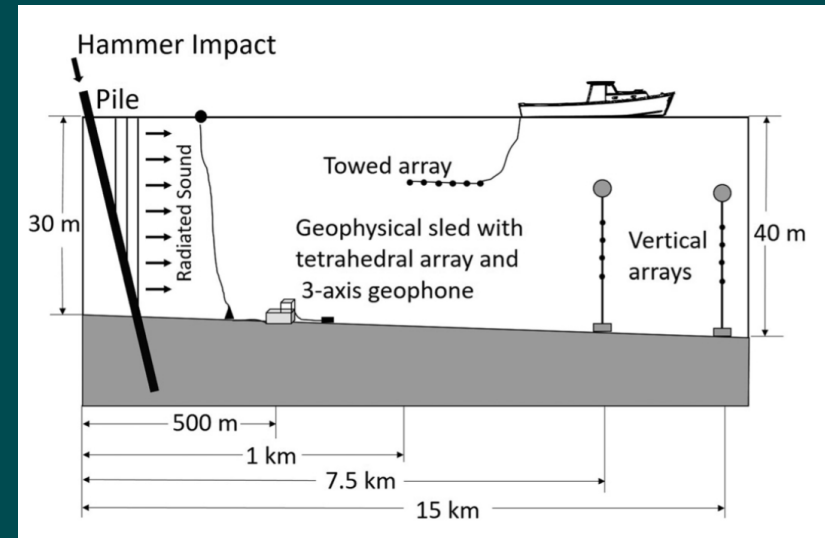
- Decision Makers Effects of Sound Tutorial Introduction
- Determine if a Sound Affects a Marine Animal Tutorial Introduction
- Decision Makers Science of Sound Tutorial Introduction
- Decision Makers Sound Source Tutorial Introduction

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

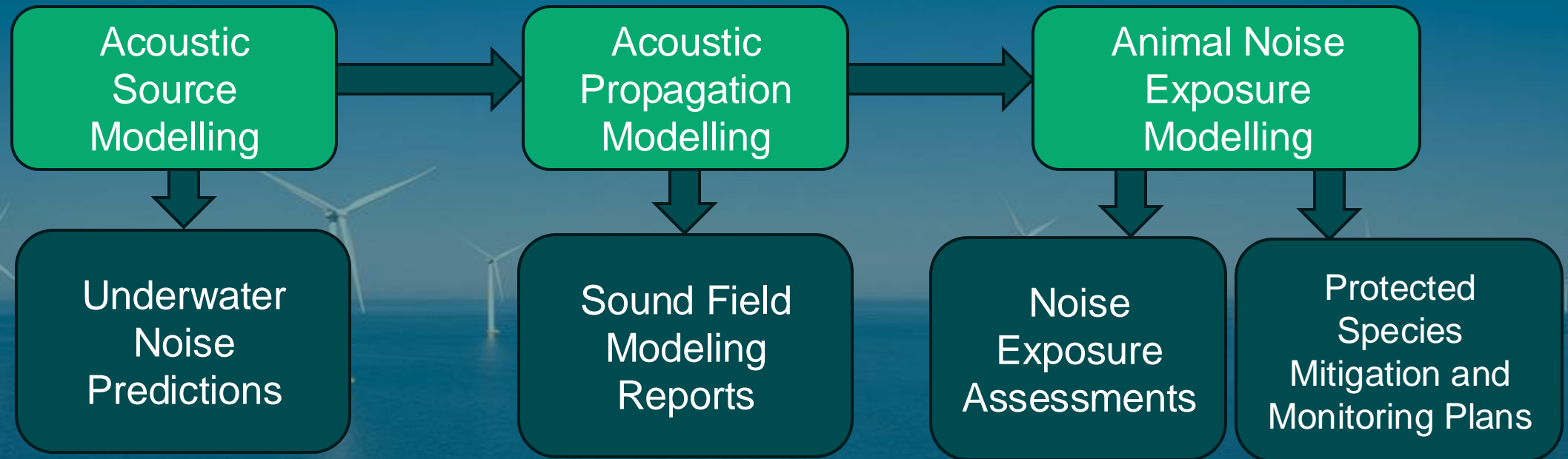
# II. Baseline Underwater Sound Measurements

## 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

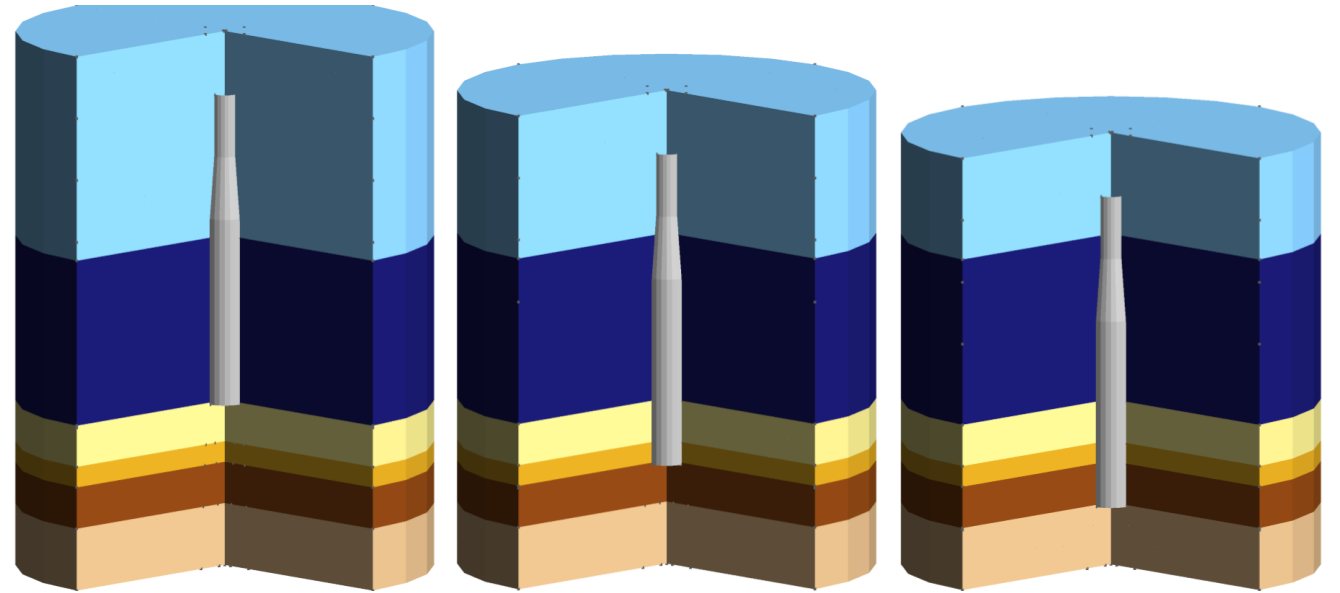




# Pile Driving Acoustic Source Model

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

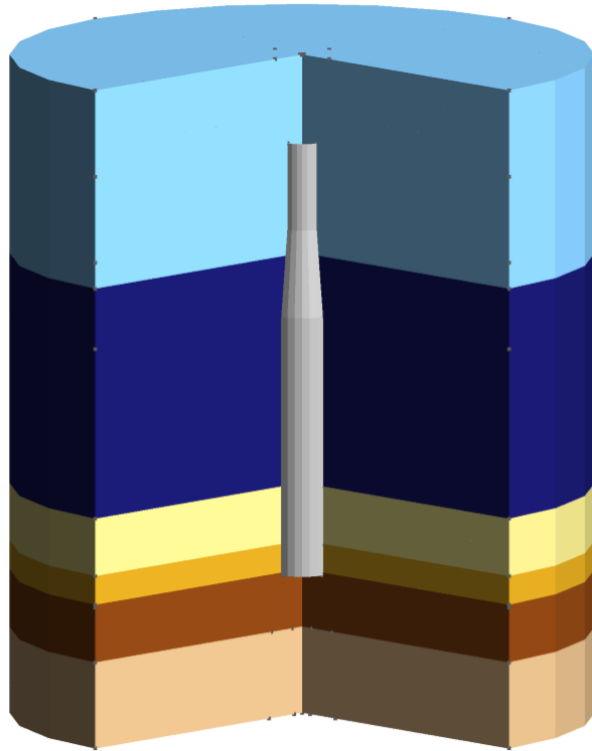
- Pile length, diameter, thickness, and taper
- Pile penetration depth
- Hammer type and force
- Sound speed and shear speed profiles for solid and porous substrates



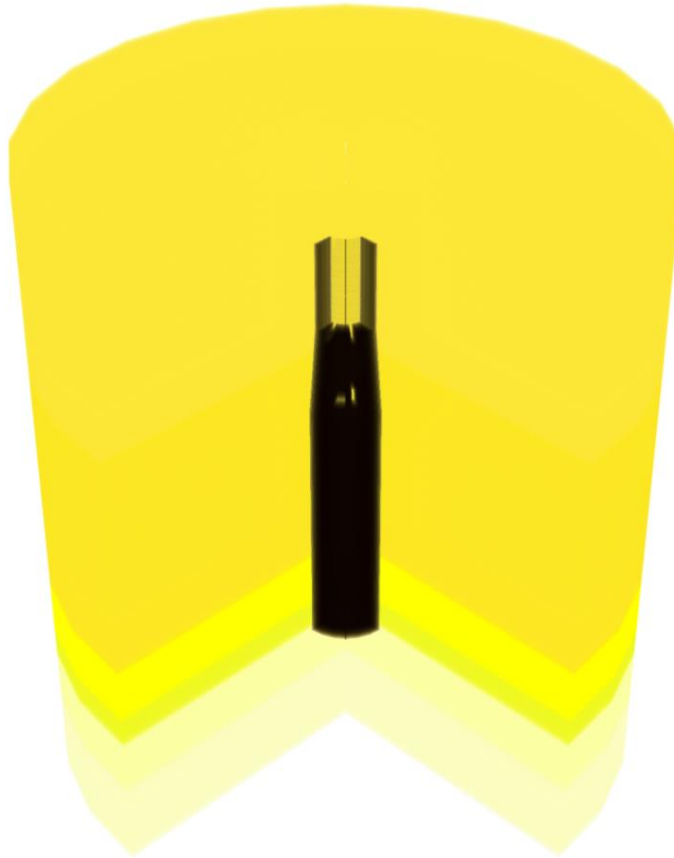
3D renders of a common XXL monopile in a stratified substrate



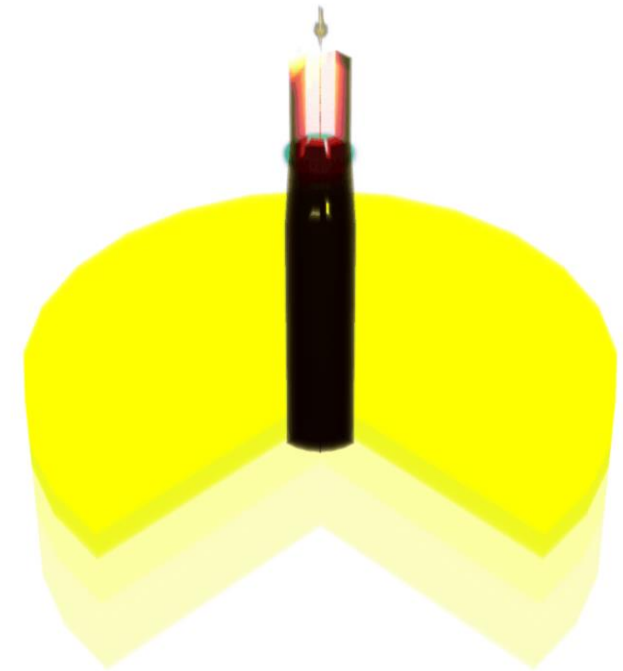
# Pile Driving Model: 3D Sound



3D Render

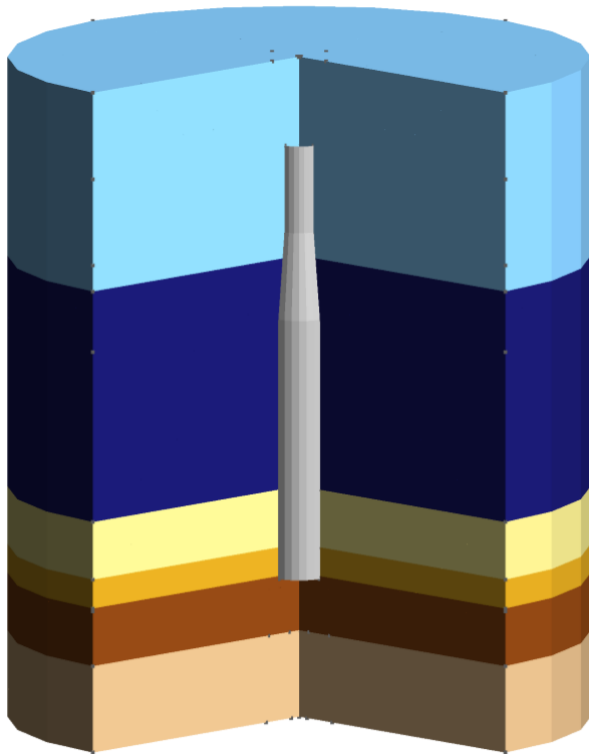


Impact Pile Driving



Vibratory Pile Driving

# Pile Driving Model: 3D Sound Field



3D Render



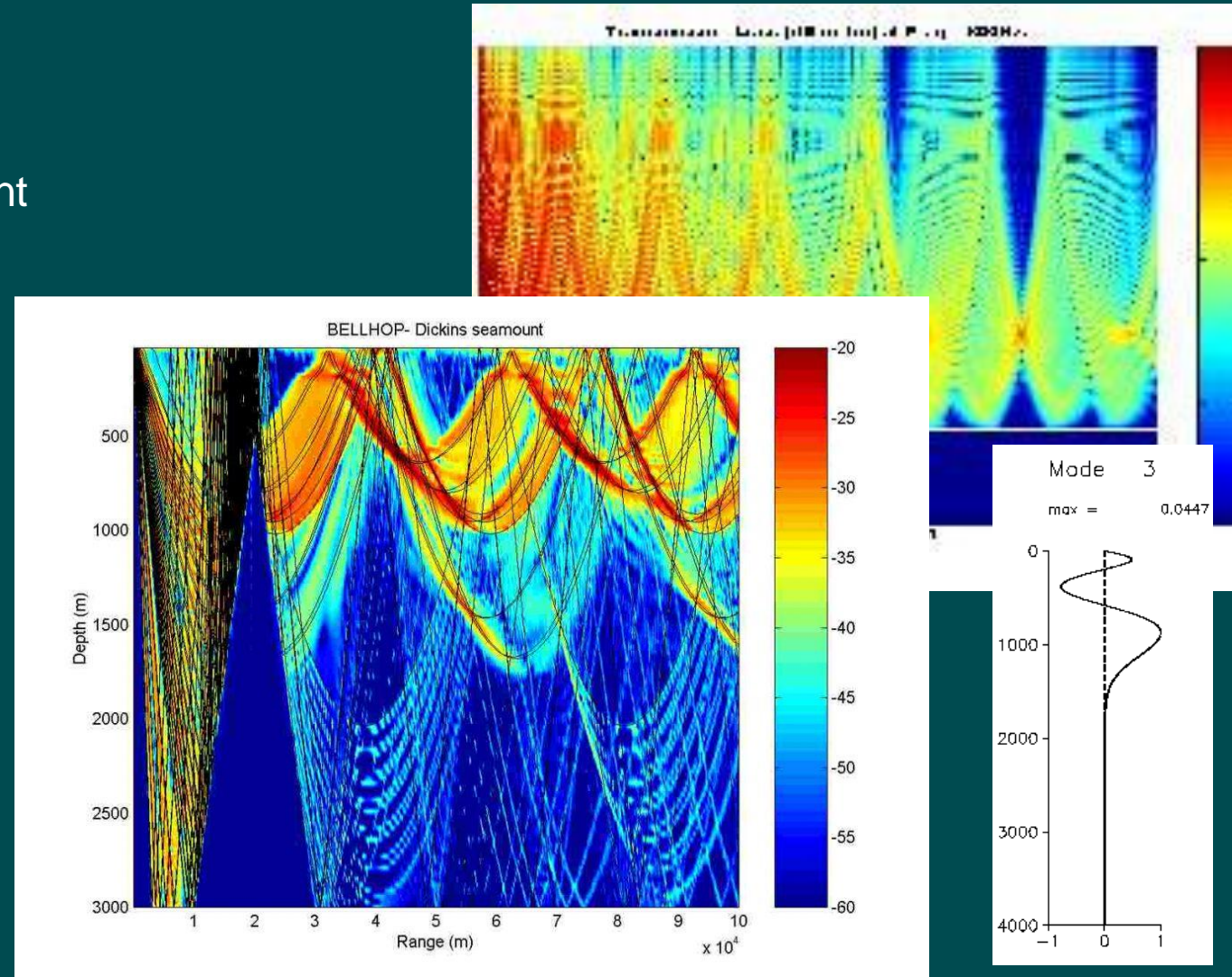
Front View



Back View

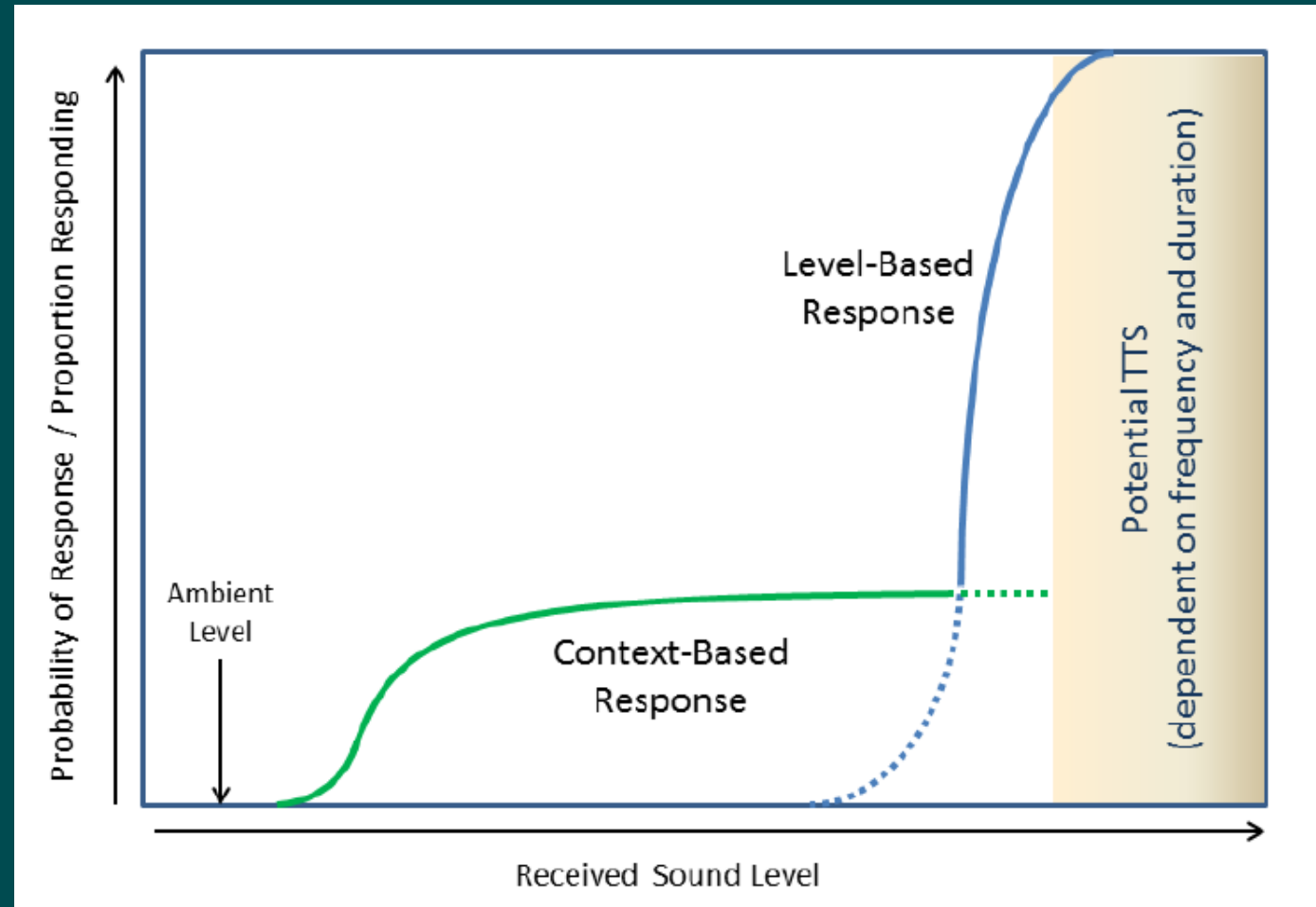
# Acoustic Propagation Modelling

- 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

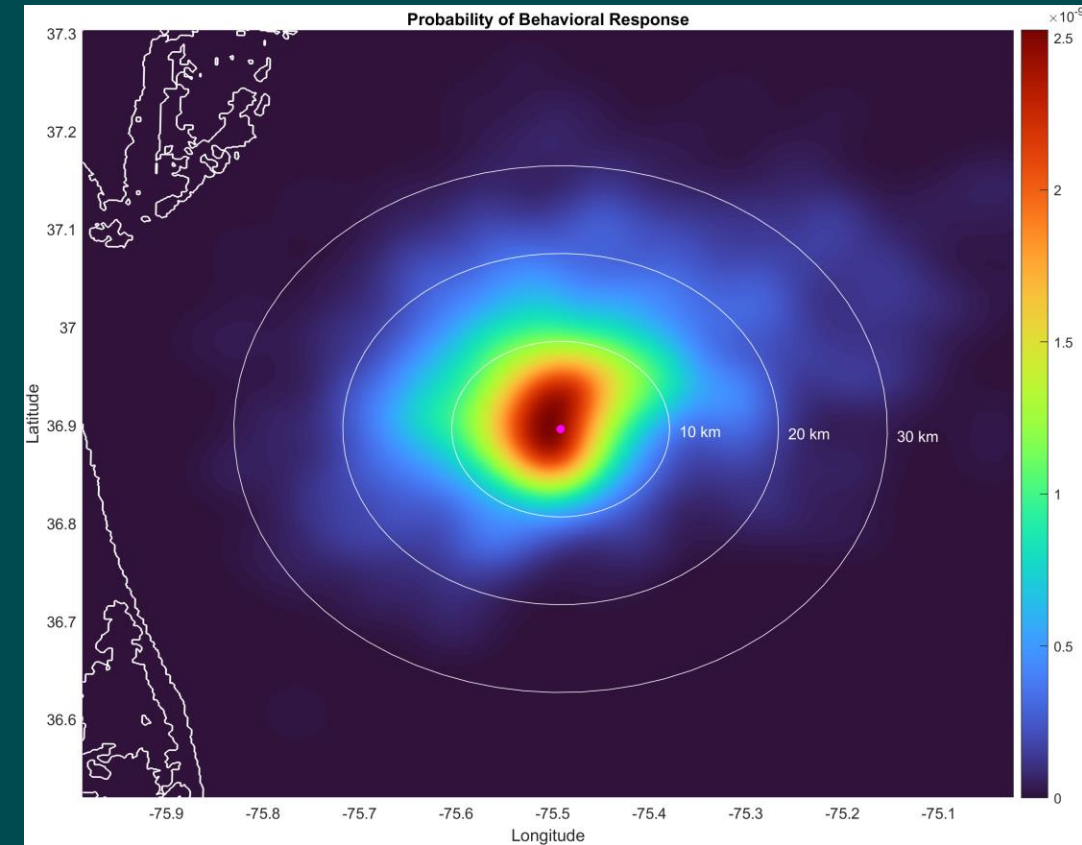
Develop meaningful thresholds





# 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



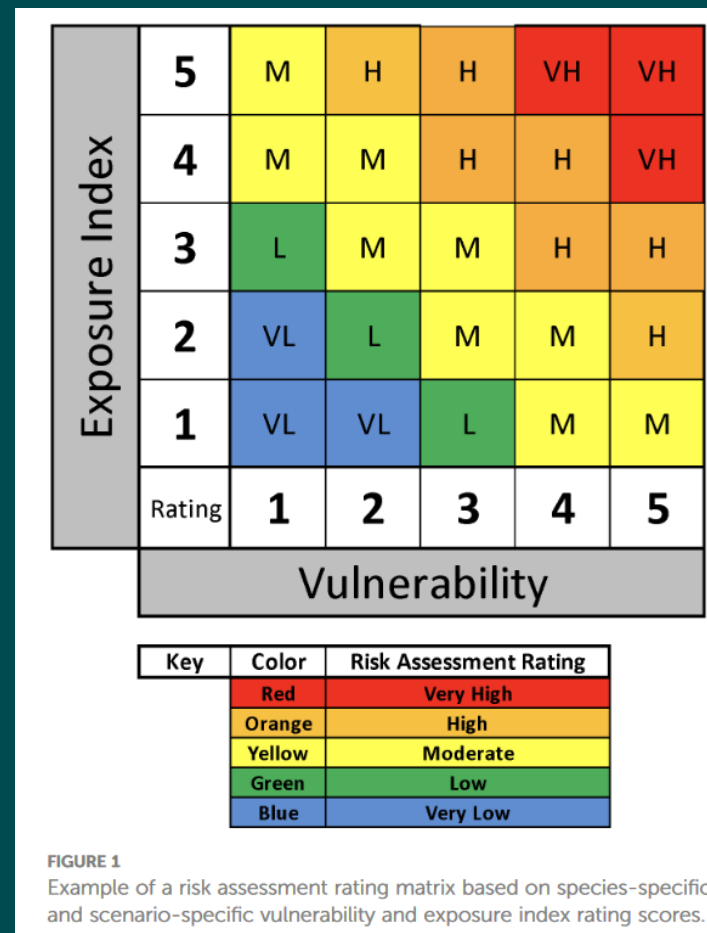
# Biologically Relevant Risk Assessment Framework

## Vulnerability Score

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

## Exposure Index

- Activity index
- Spectral index

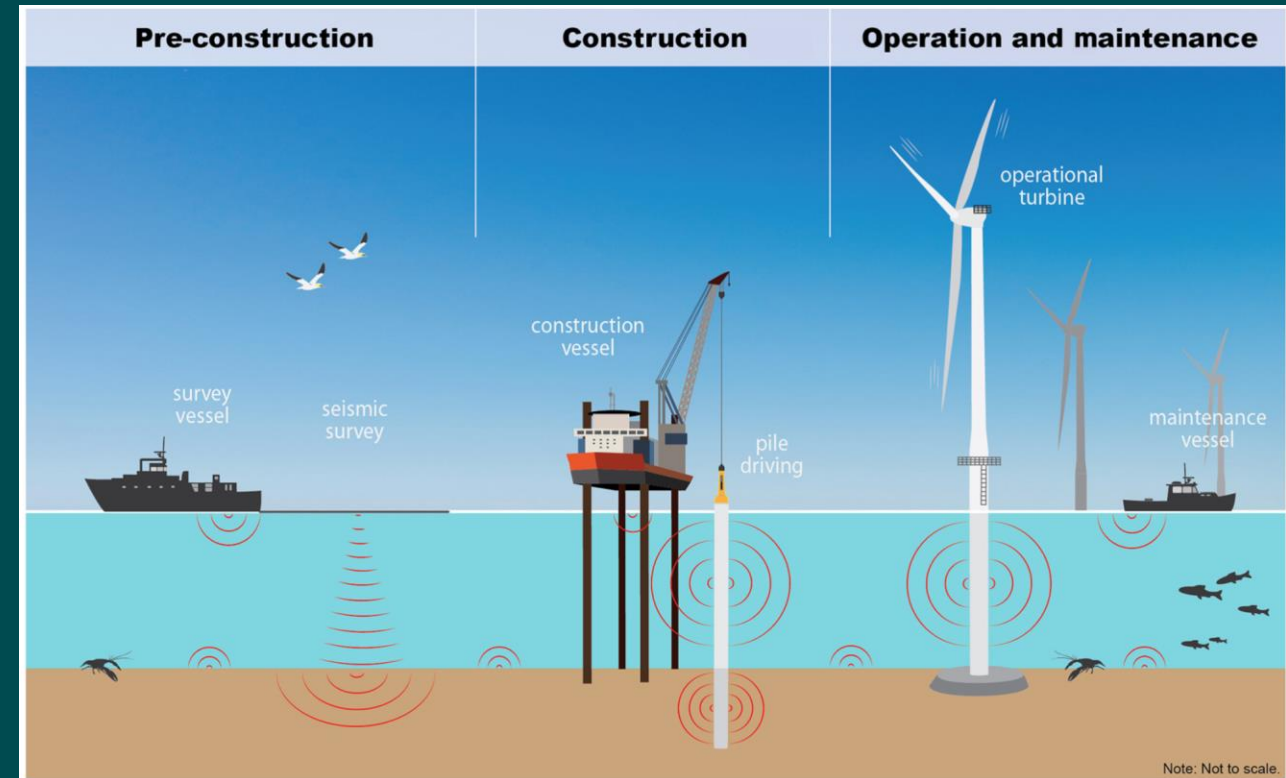


# Cumulative Effects Analysis

## 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

Contact:

Kathleen J. Vigness-Raposa, Ph.D.  
VP of Technical Services, Venterra Environmental  
[Kathy.VignessRaposa@venterra-group.com](mailto:Kathy.VignessRaposa@venterra-group.com)



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# DOSITS Jeopardy Game