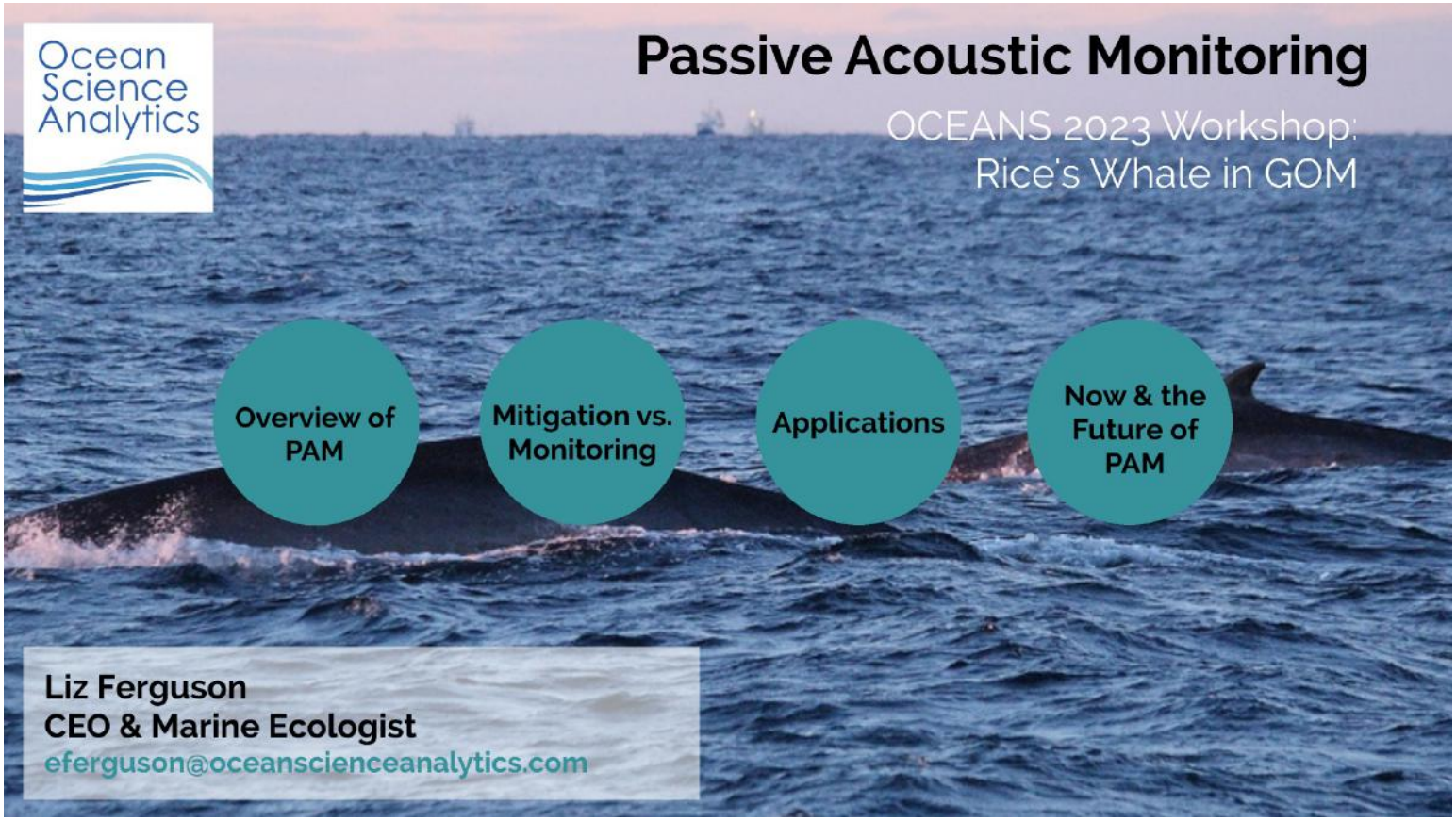
Ocean Science Analytics
Passive Acoustic Monitoring
OCEANS 2023 Workshop:
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Liz Ferguson
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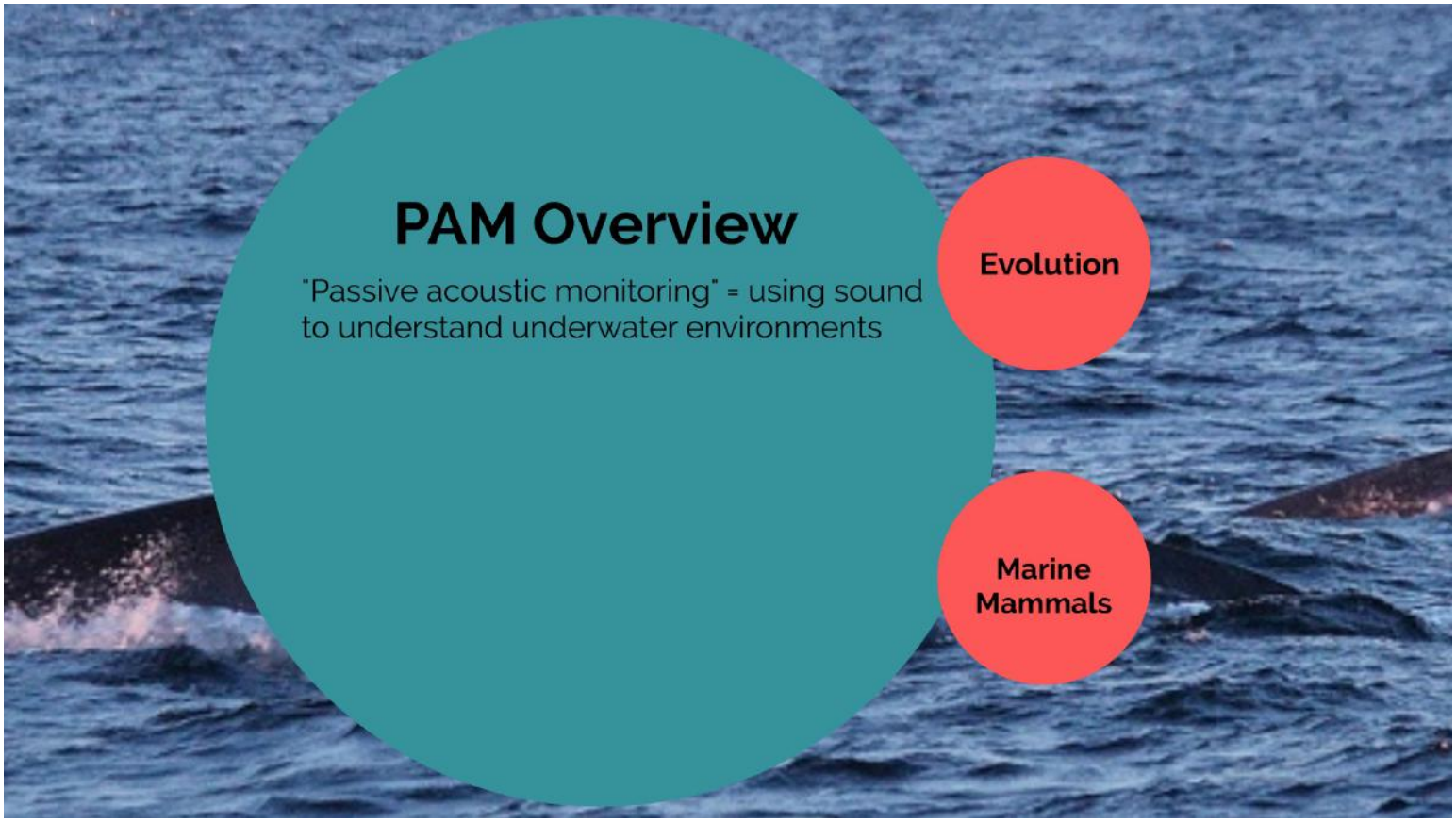
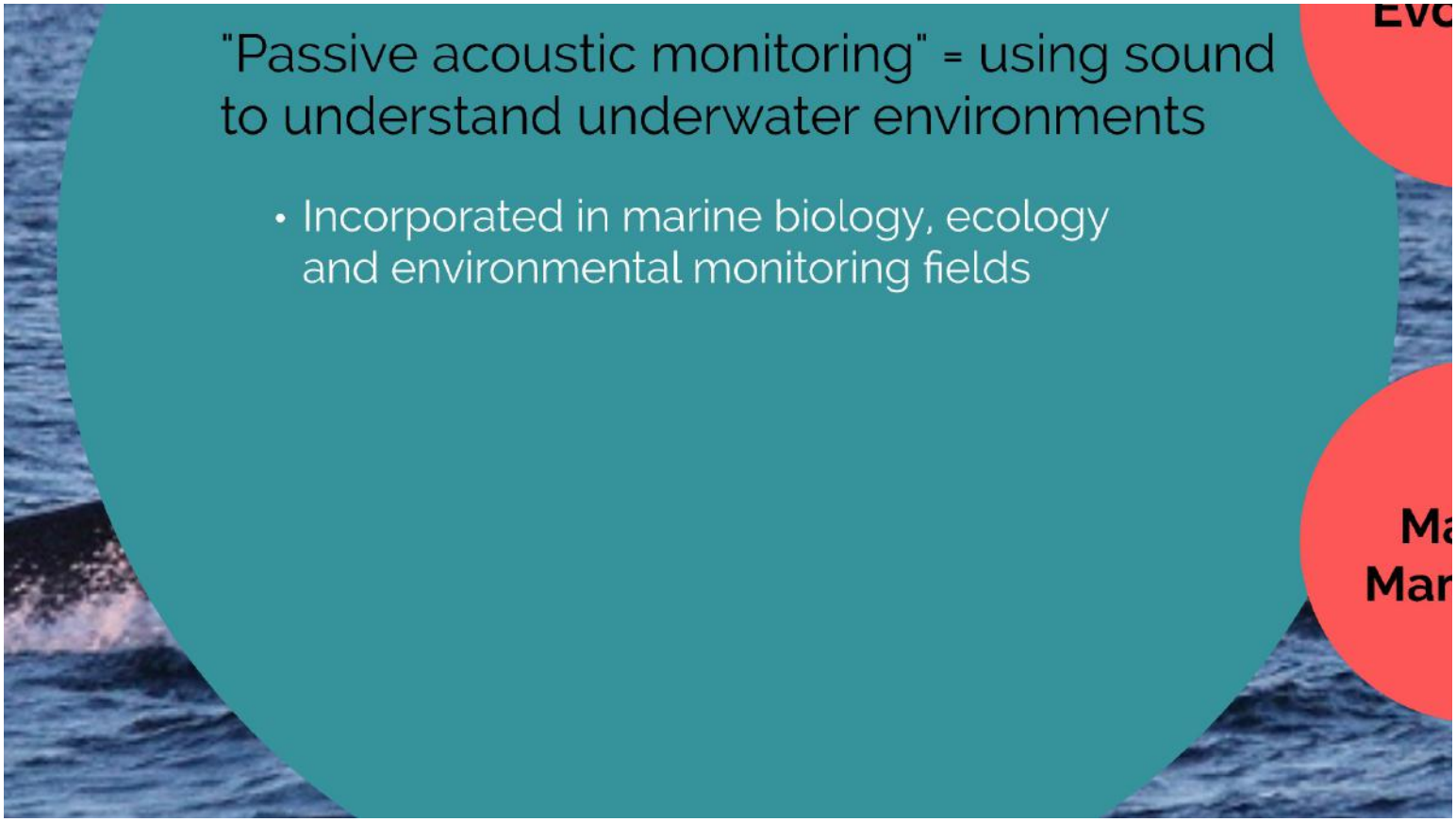

PAM Overview
"Passive acoustic monitoring" = using sound to understand underwater environments
Evolution
Marine Mammals


"Passive acoustic monitoring" = using sound
to understand underwater environments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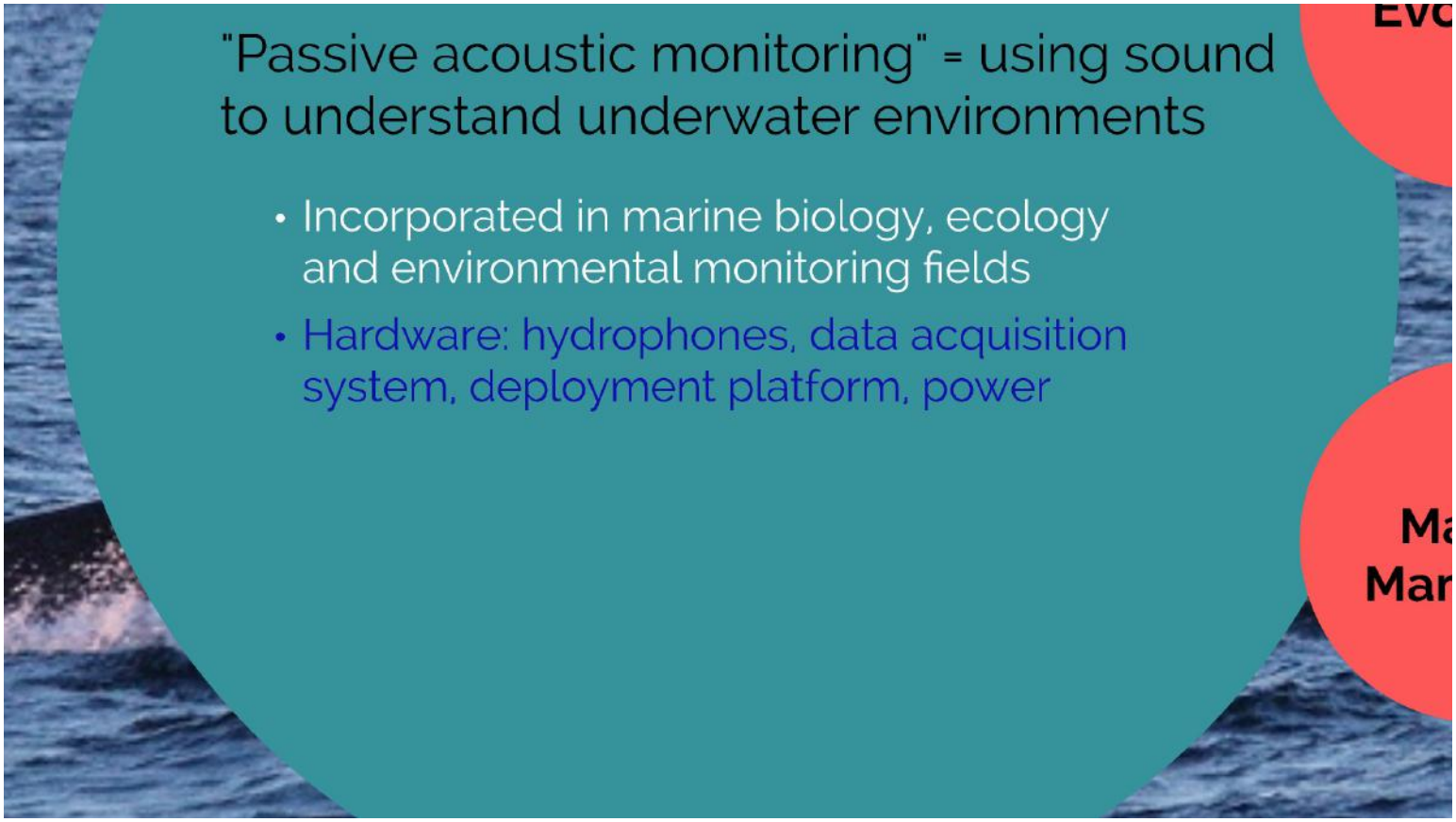
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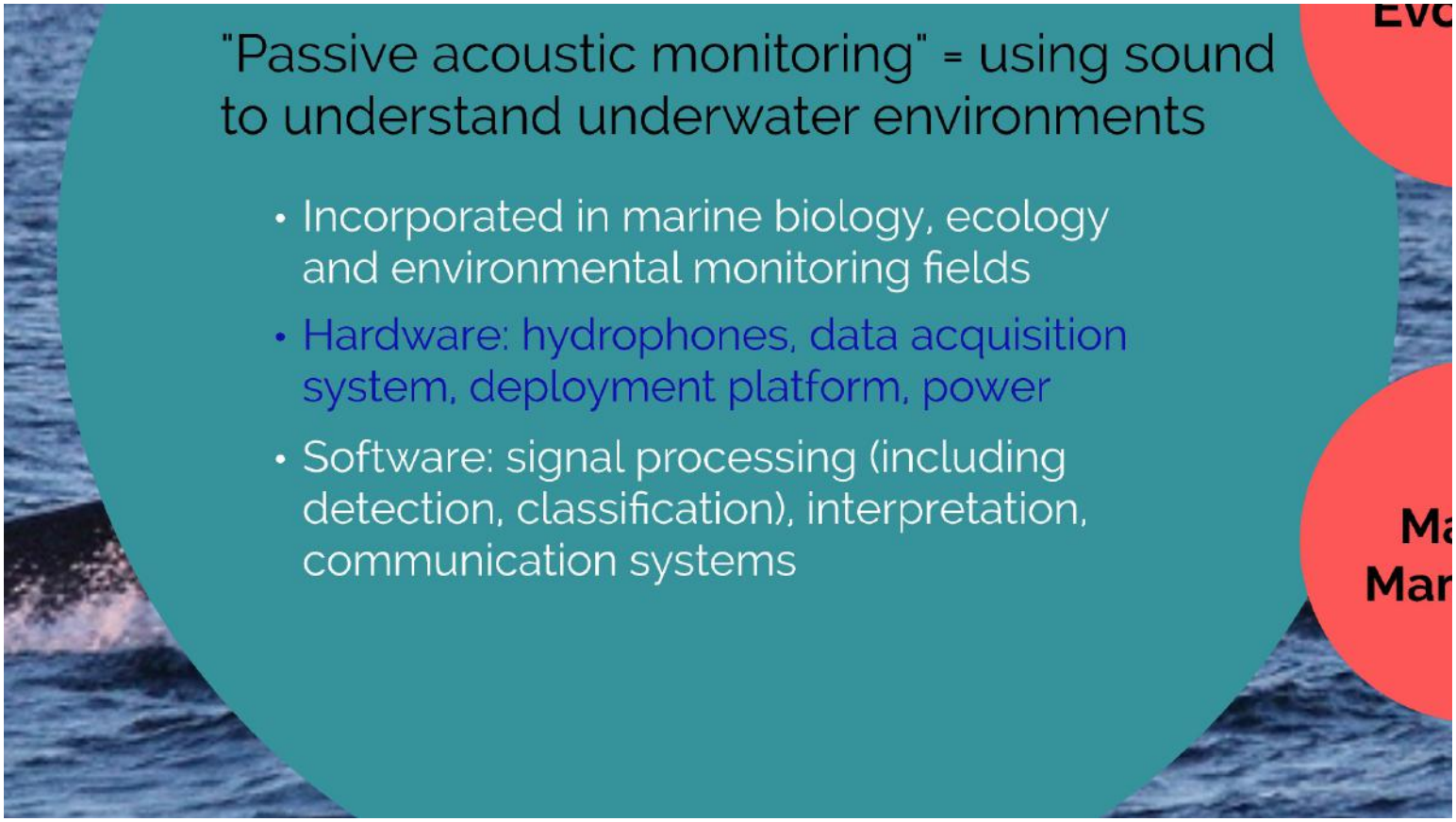
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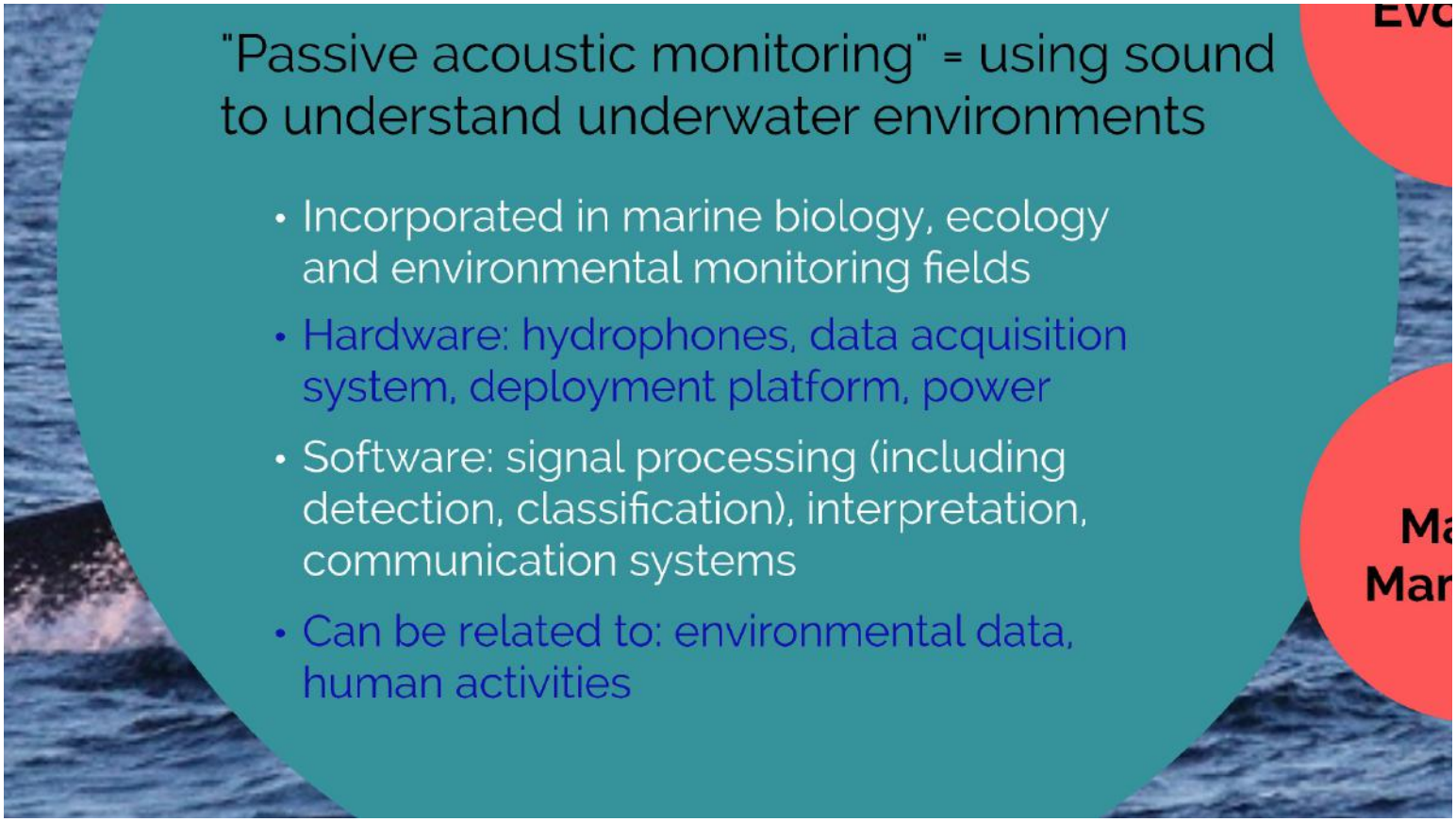
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• Can be related to: environmental data, human activities

PAM Evolution

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Earliest observations of marine mammal sounds underwater

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2000s-present
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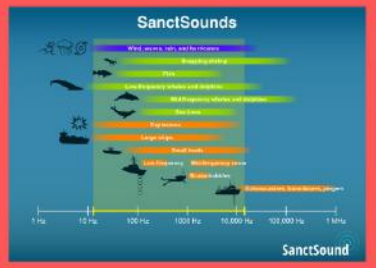
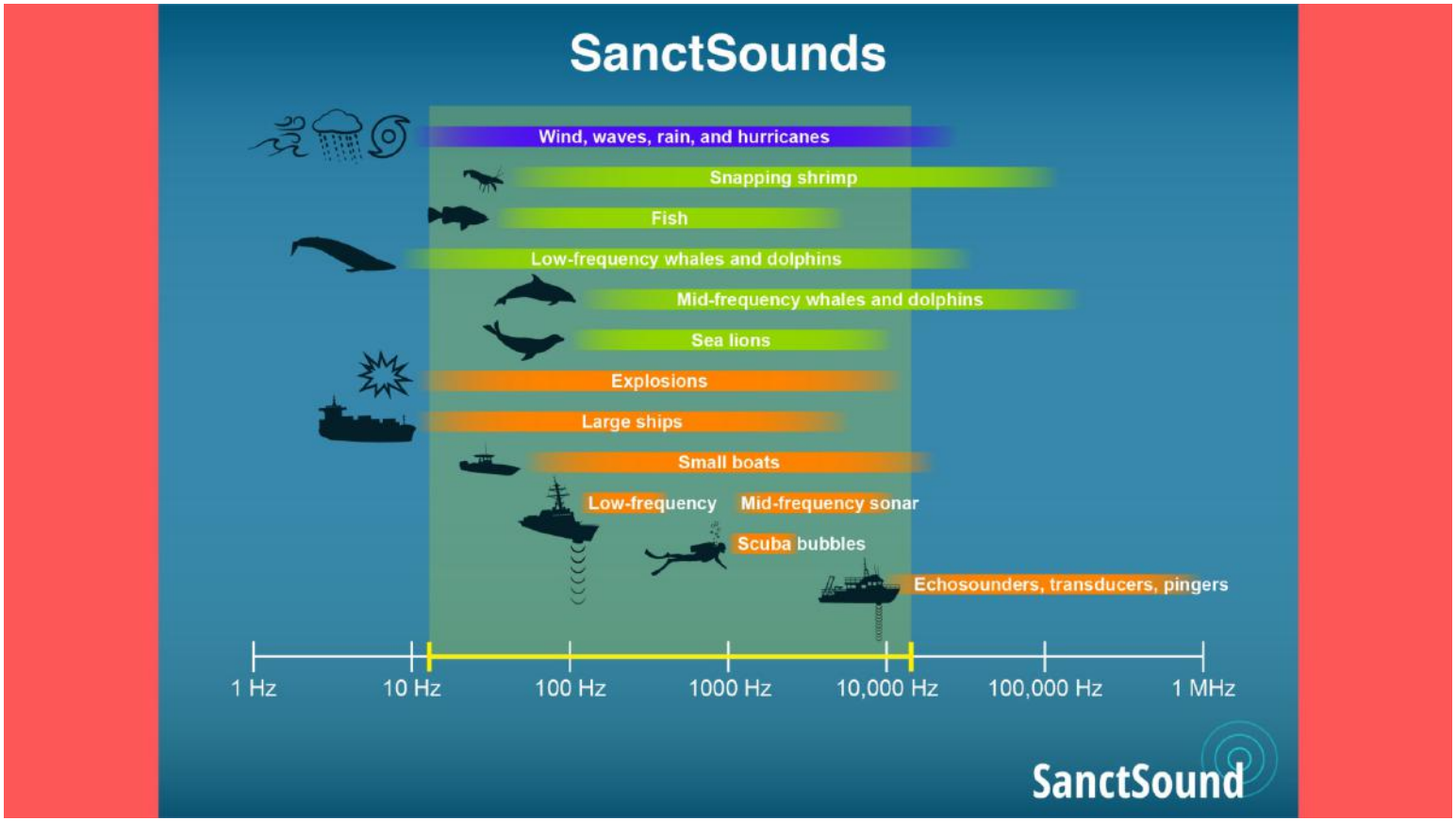
Recent Years
Advancement of equipment and data storage & increased use

Figure source: https://www.fisheries.noaa.gov/new-england-mid-atlantic/endangered-species-conservation/passive-acoustic-research-atlantic-ocean

Marine Mammal Sounds



Baleen Whales


SanctSounds
Wind, waves, rain, and hurricanes
Snapping shrimp
Fish
Low-frequency whales and dolphins
Mid-frequency whales and dolphins
Sea lions
Explosions
Large ships
Small boats
Low-frequency
Mid-frequency sonar
Scuba bubbles
Echosounders, transducers, pingers
1 Hz
10 Hz
100 Hz
1000 Hz
10,000 Hz
100,000 Hz
1 MHz
SanctSound

Baleen Whales

Baleen Whales

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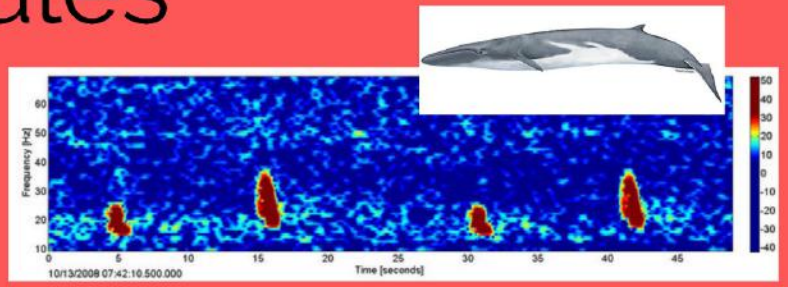
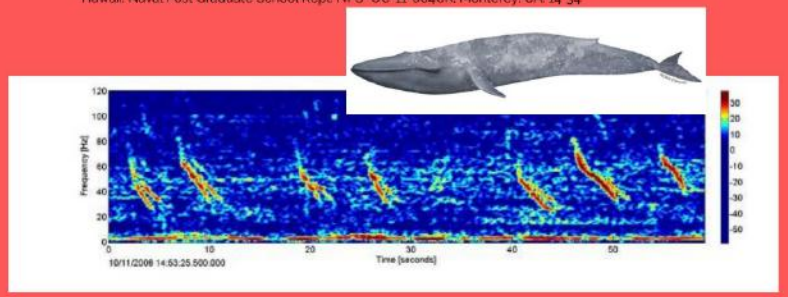
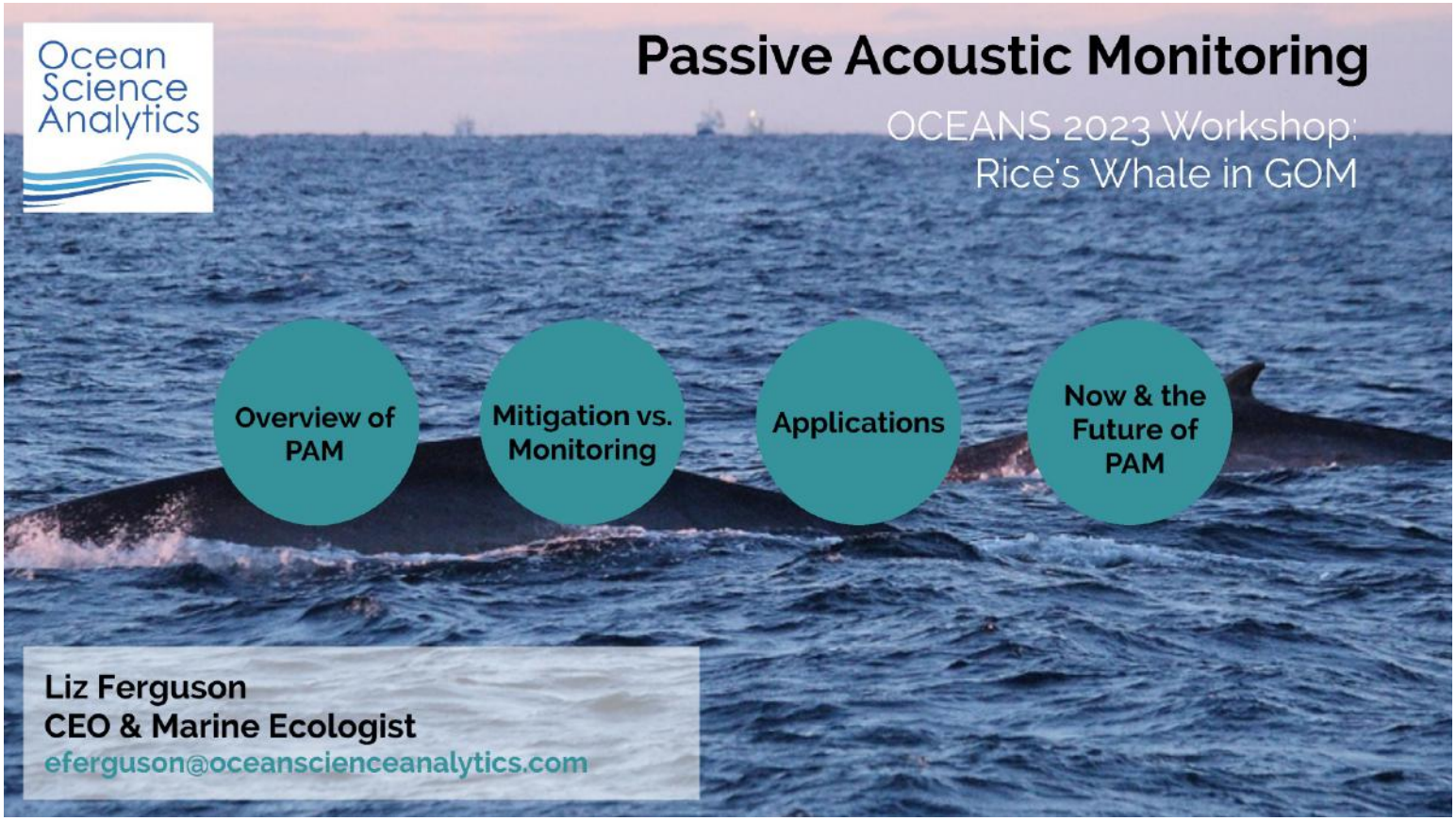


Širović, A., Oleson, E. M., Calambokidis, J., Baumann-Pickering, S., Cummins, A., Kerosky, S., ... & Hildebrand, J. A. (2011). Marine mammal demographics of the outer Washington coast during 2008–2009. Oleson, E. and Hildebrand, J., Marine mammal demographics off the outer Washington coast and near Hawaii, Naval Post Graduate School Rept. NPS-OC-11-004CR, Monterey, CA, 14-34.

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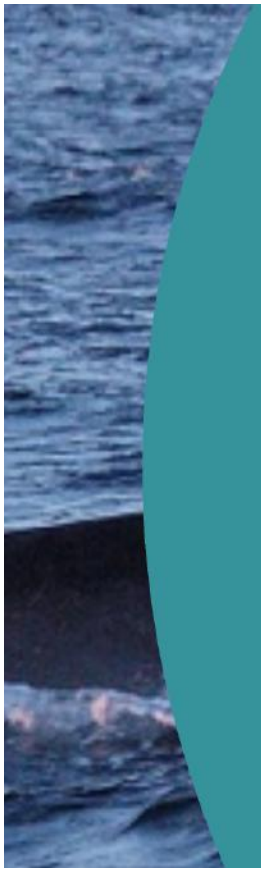
Mitigation vs. Monitoring

Mitigation Methods

Controlled Activities

Monitoring Methods



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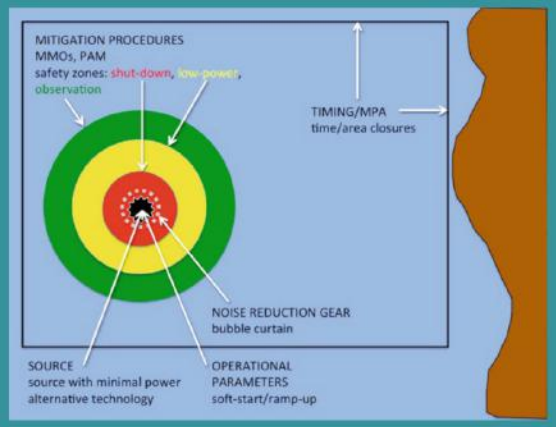
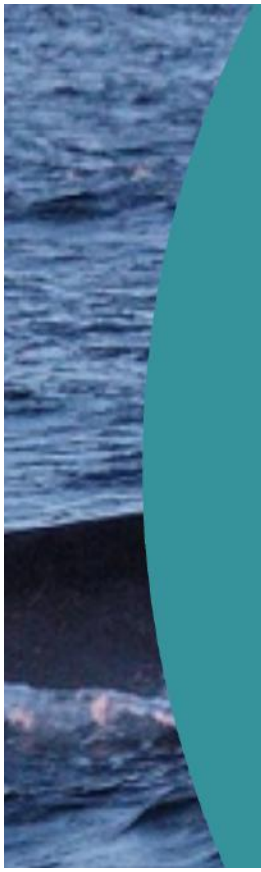
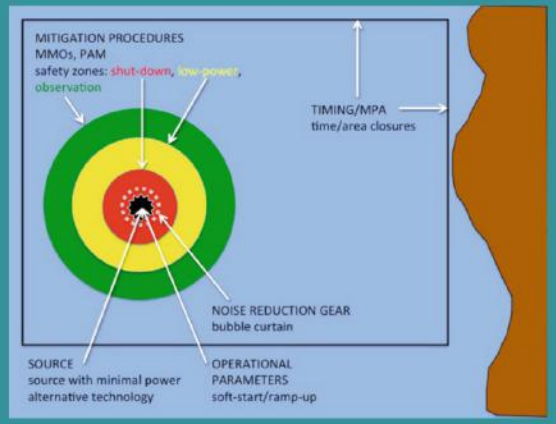


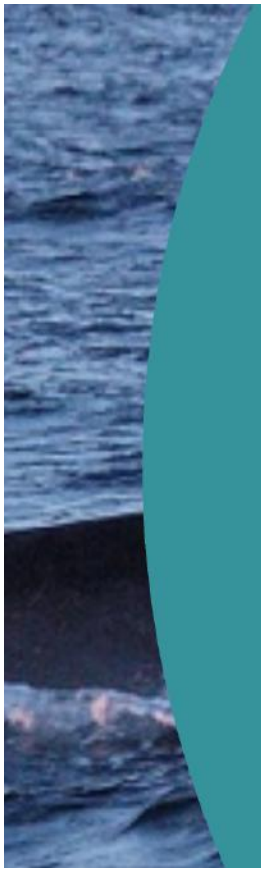


Mitigation Methods

Controlled Activities

Procedures defined by governing agencies



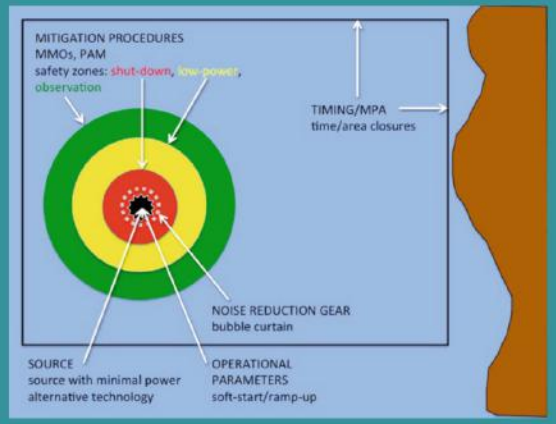


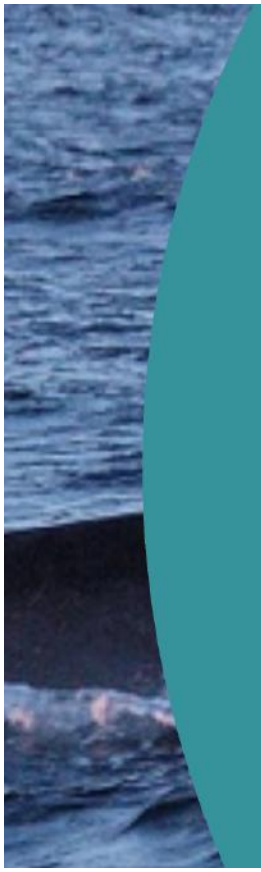
Mitigation Methods

Controlled Activities

Procedures defined by governing agencies

Equipment involves real-time buoys, towed arrays, single hydrophone





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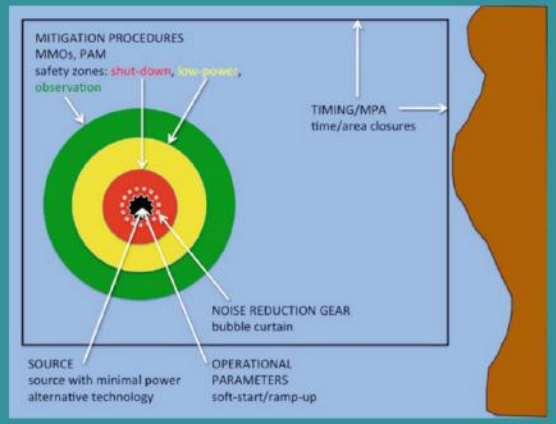
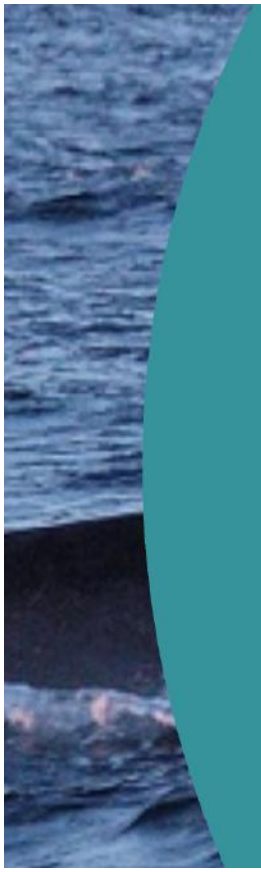




Mitigation Methods

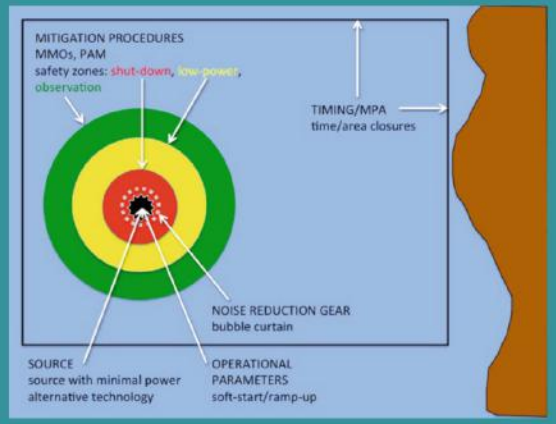
Controlled Activities

Procedures defined by governing agencies

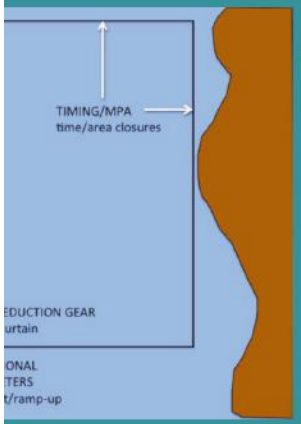
Equipment involves real-time buoys, towed arrays, single hydrophone

Methods for mitigation include:

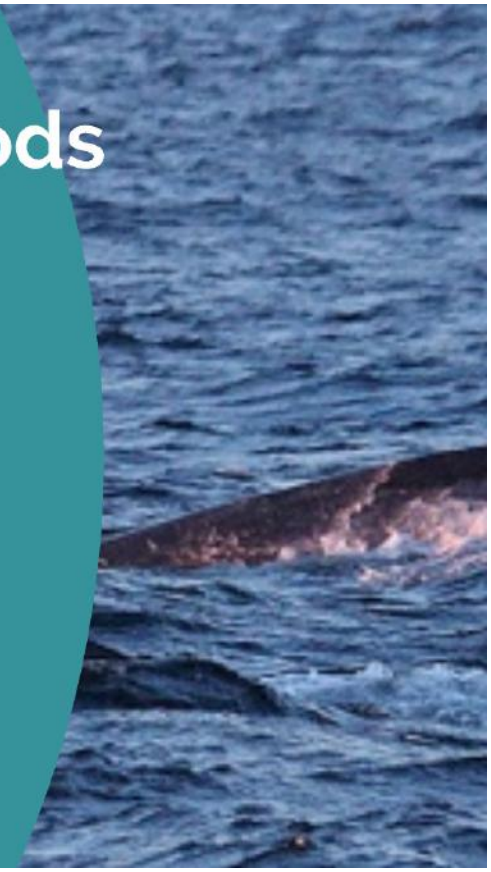
- area closures
- increase mitigation zone during seasonal activity
- noise reduction with bubble curtains (pile driving)
- noise source/operational modifications ("soft start")



Monitoring Methods

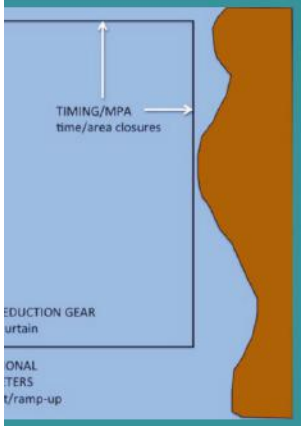


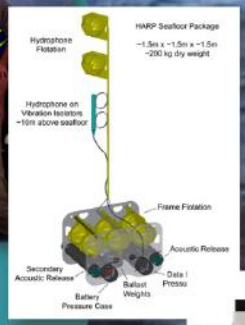
www.mnh.si.edu

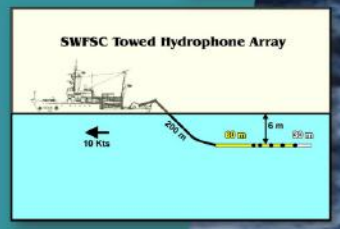


Monitoring Methods

Wide range of fixed, mobile equipment options







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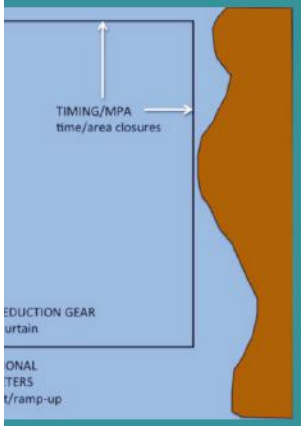
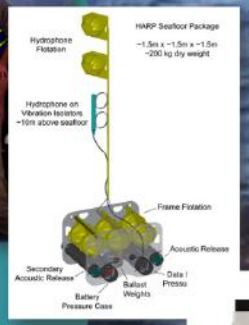
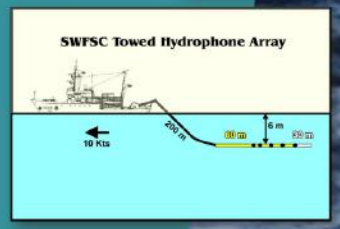


Wide range of fixed, mobile equipment options

Defines occurrence of marine mammals in a region





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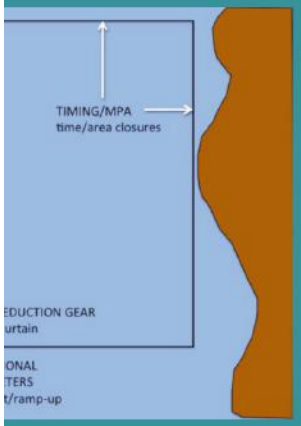

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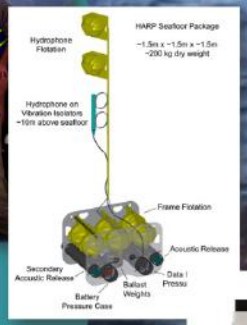
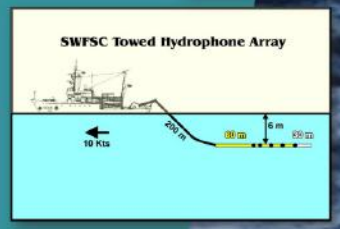
Defines occurrence of marine mammals in a region

Can incorporate localization for directing visuals or density/ abundance estimation





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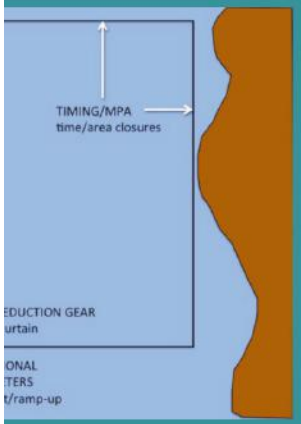
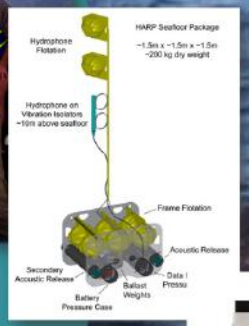


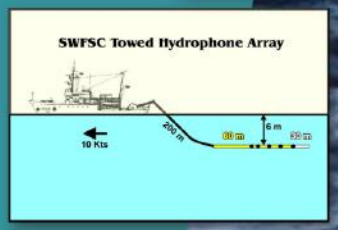
Wide range of fixed, mobile equipment options

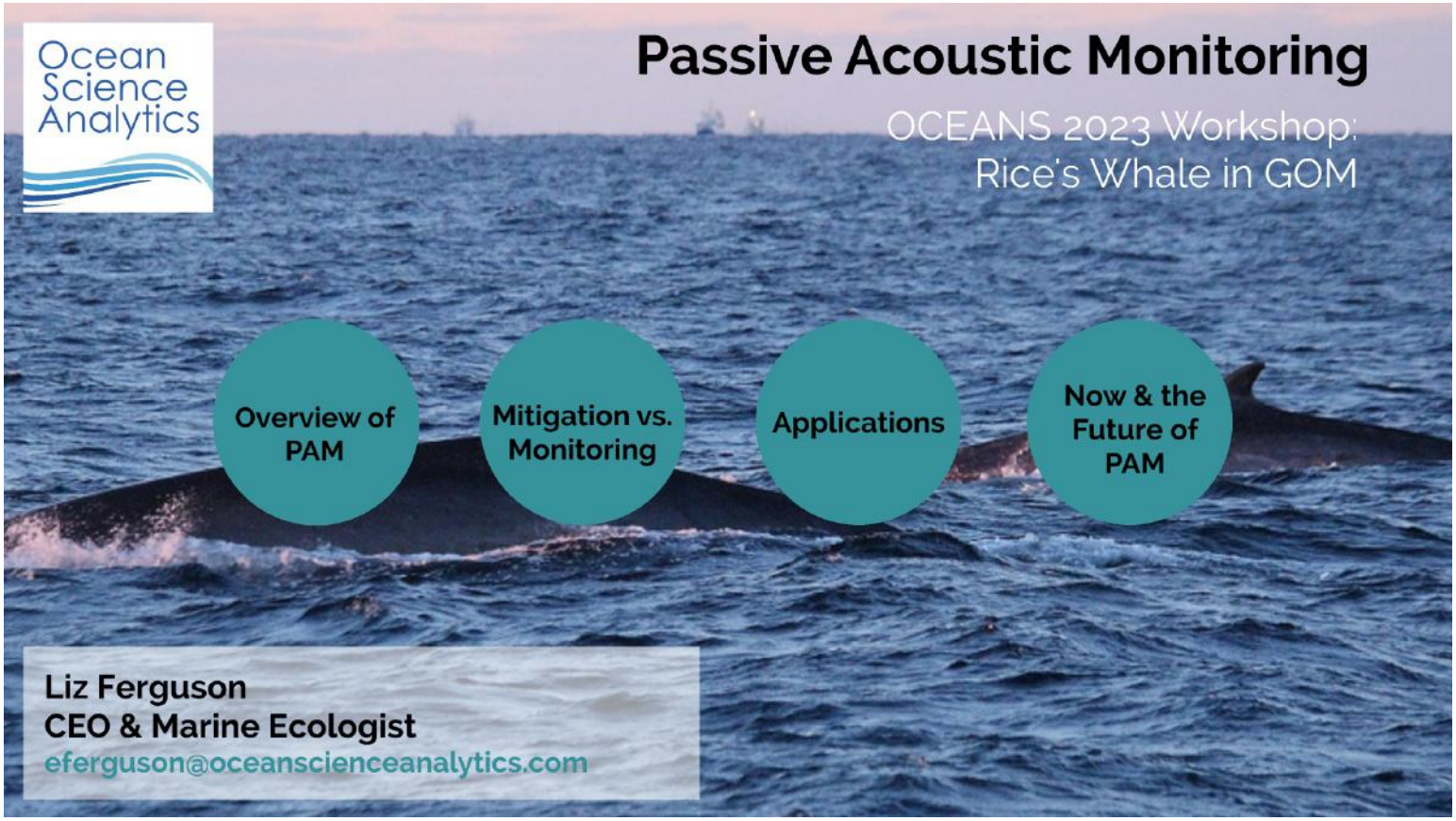
Defines occurrence of marine mammals in a region

Can incorporate localization for directing visuals or density/ abundance estimation

Useful in regions where occurrence is infrequent/ unknown, or extreme/remote locations



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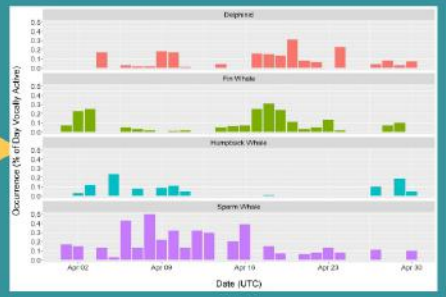
PAM Applications

Distribution & Abundance

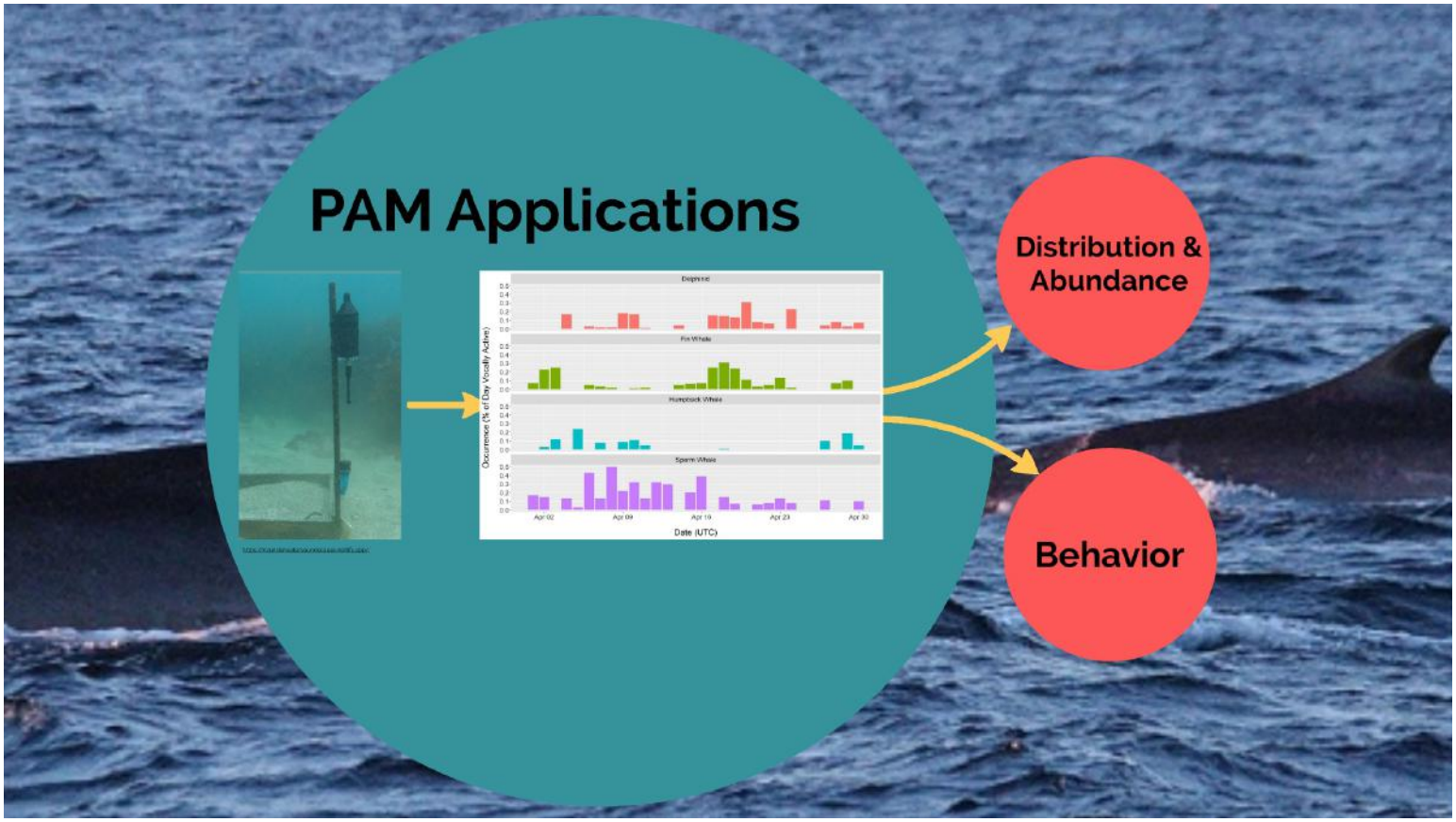
Behavior

PAM Applications



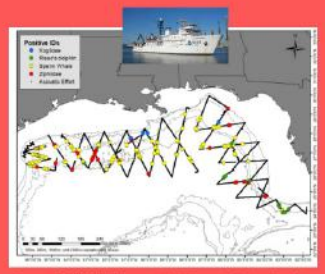
Distribution & Abundance

Behavior


PAM Applications
Distribution & Abundance
Behavior
Occurrence (% of Day Vocally Active)
Date (UTC)

Distribution & Abundance

Distribution



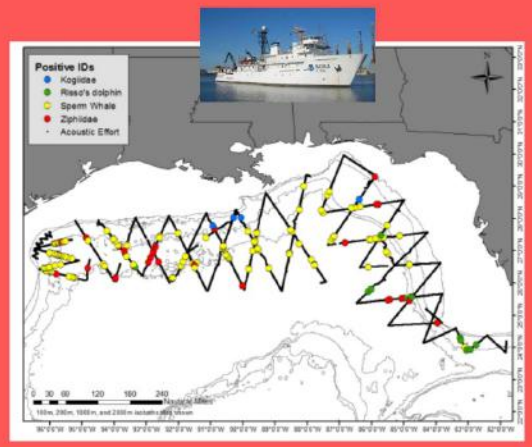
Source: GoMMAPPS Summer 2017 Research Cruise Report

Source: Fixed recorders from Ocean Observatories Initiative Coastal Endurance Array

Source: https://www.fisheries.noaa.gov/science-blog/sound-bytes-adventures-drifting-buoy

Density/Abundance

Distribution



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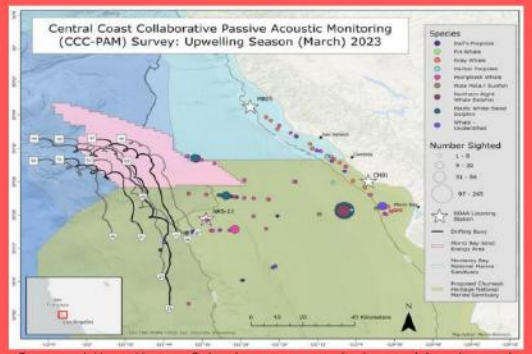
Source: Fixed recorders from Ocean Observatories Initiative, Coastal Endurance Array



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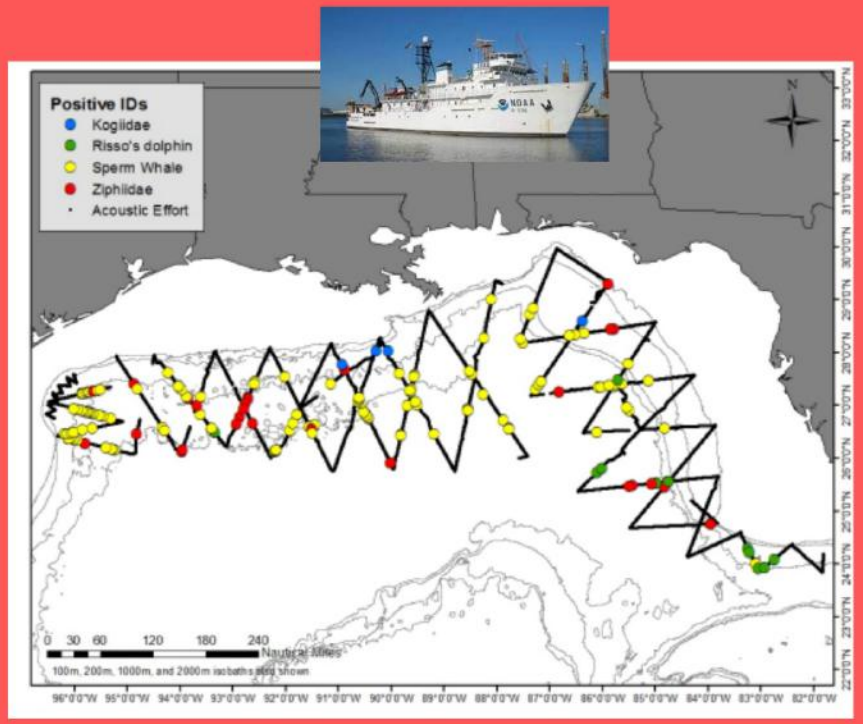

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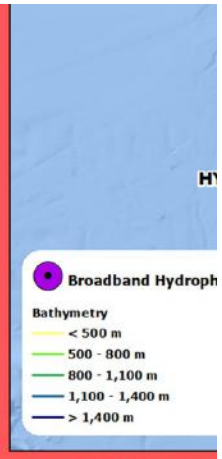
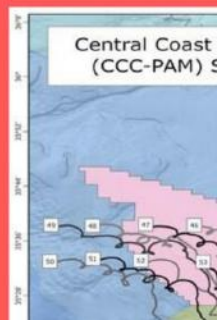
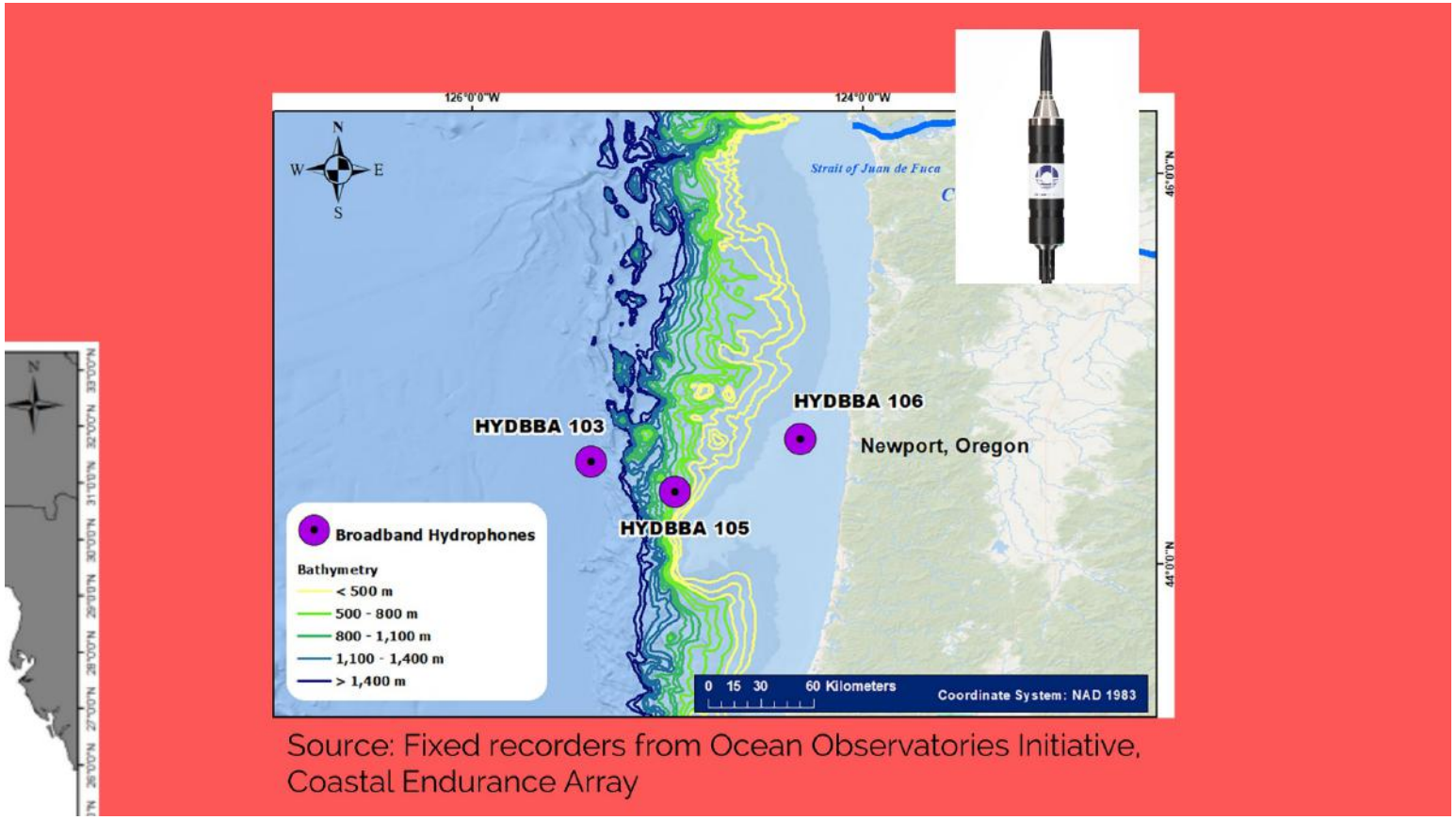
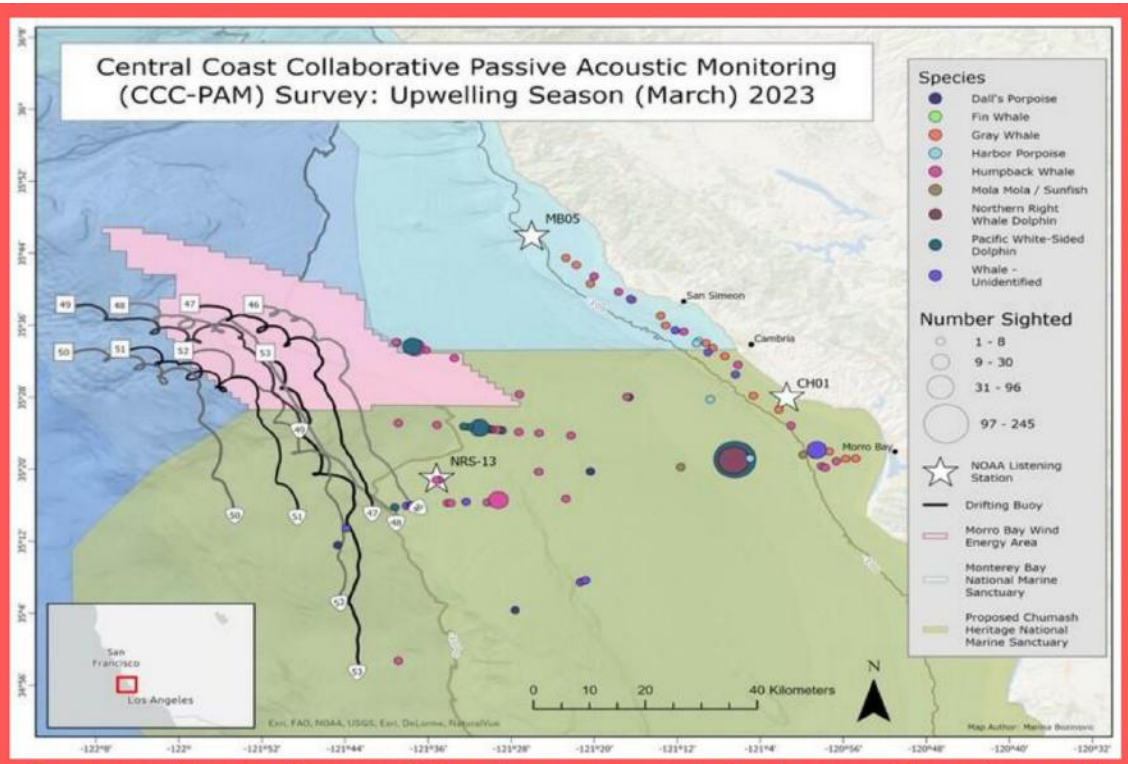


Source: Fixed
Coastal Endura





Source: Fixed recorders from Ocean Observatories Initiative, Coastal Endurance Array



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Density/Abundance

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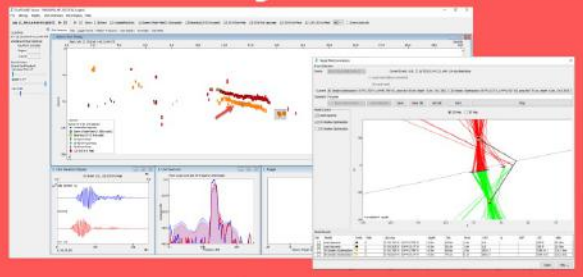
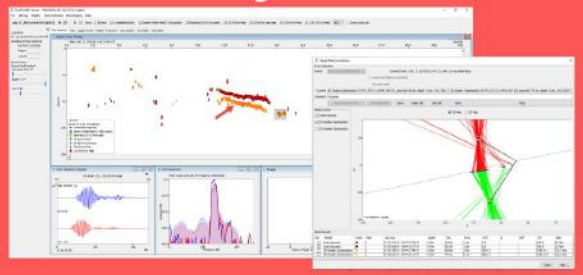
Density/Abundance



Adaption of Distance Sampling methods used with visual survey data

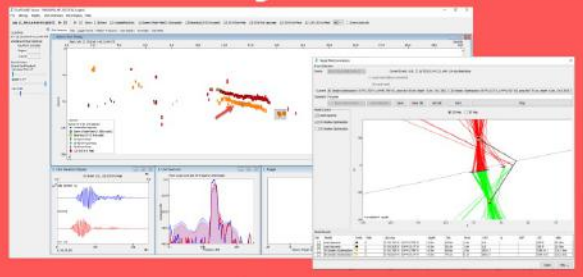
Density/Abundance



Sigourney et al. (2023): combined incorporating PAM localizations with visual line transect data reduced bias by >90%

Adaption of Distance Sampling methods used with visual survey data

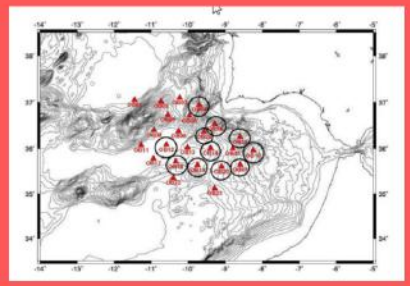
Density/Abundance



Sigourney et al. (2023): combined incorporating PAM localizations with visual line transect data reduced bias by >90%

Adaption of Distance Sampling methods used with visual survey data

Harris et al. (2013): Point transect sampling using cue counts = estimate the average probability of detecting fin whale calls



Behavior Applications

Changes in Behavior

Behavior & Environment

Changes in Behavior

Changes in Behavior

Example: Beaked whale behavioral response to ultrasonic antifouling gear

Trickey, J. S., Cárdenas-Hinojosa, G., Rojas-Bracho, L., Schorr, G. S., Rone, B. K., Hidalgo-Pla, E., ... & Baumann-Pickering, S. (2022). Ultrasonic antifouling devices negatively impact Cuvier's beaked whales near Guadalupe Island, México. Communications biology, 5(1), 1-9.

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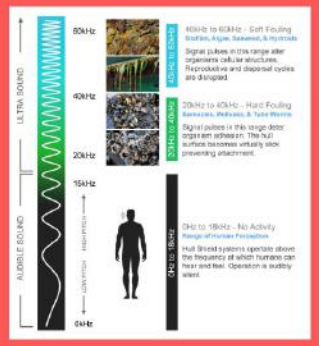

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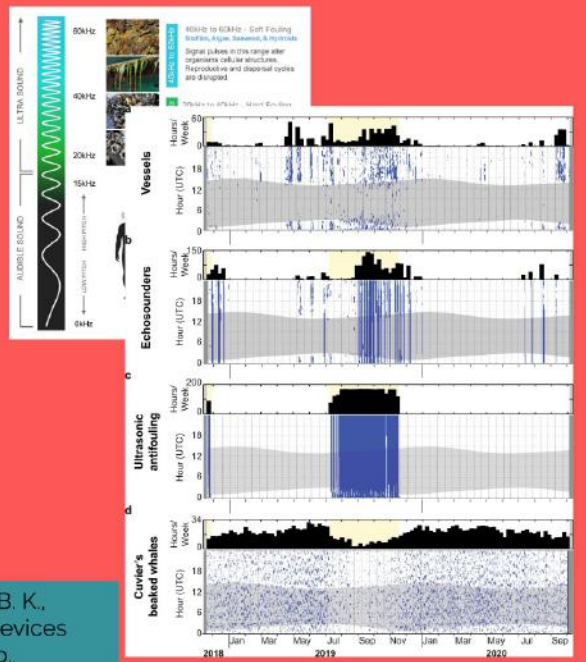
- Clear picture of habitat displacement off Guadalupe Island for this unregulated noise



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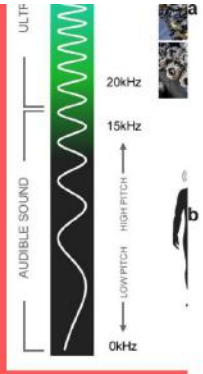
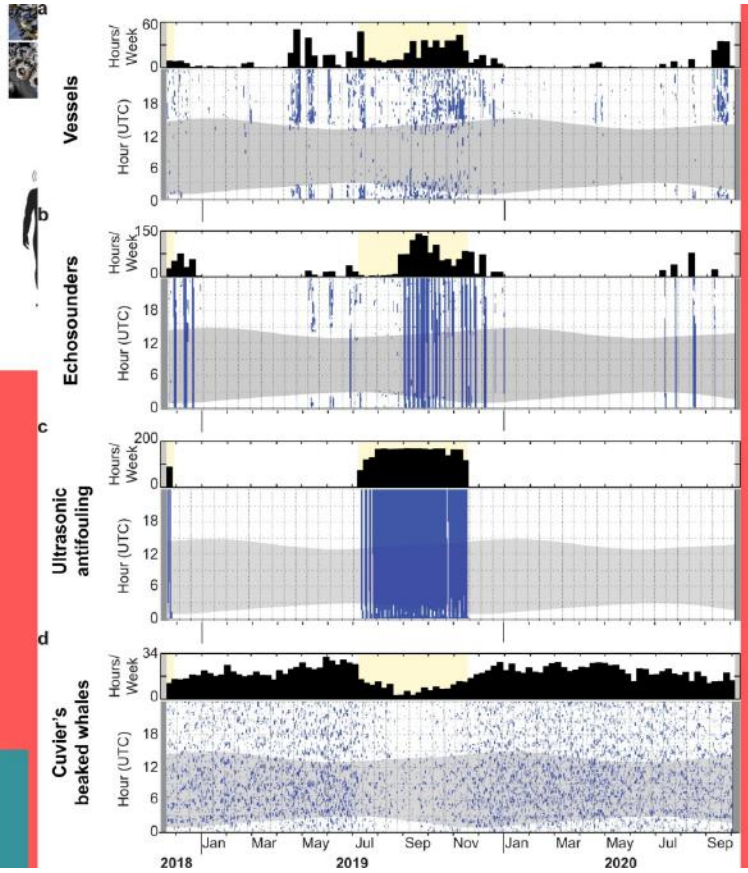
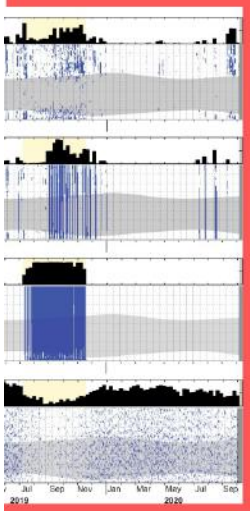


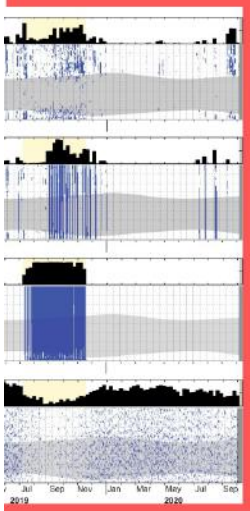


Behavior & Environment



Behavior & Environment

Example: Environmental conditions influence blue whale calls



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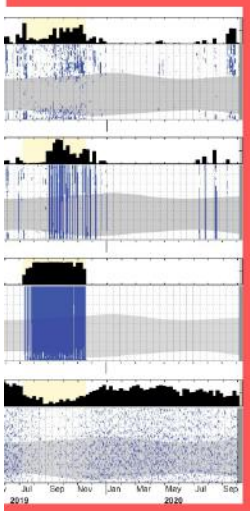
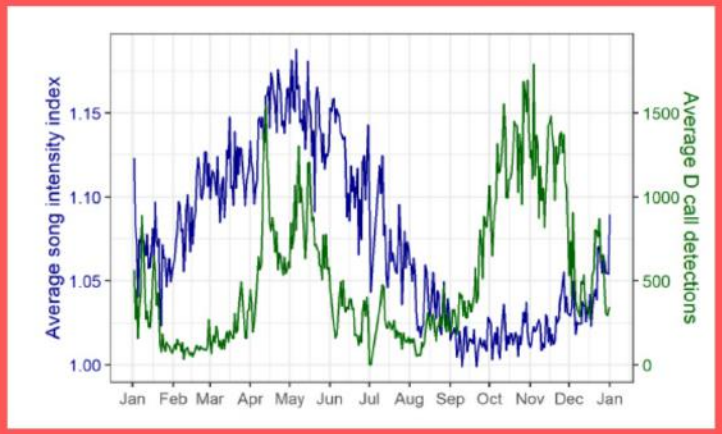


- Environmental correlates of call types vary



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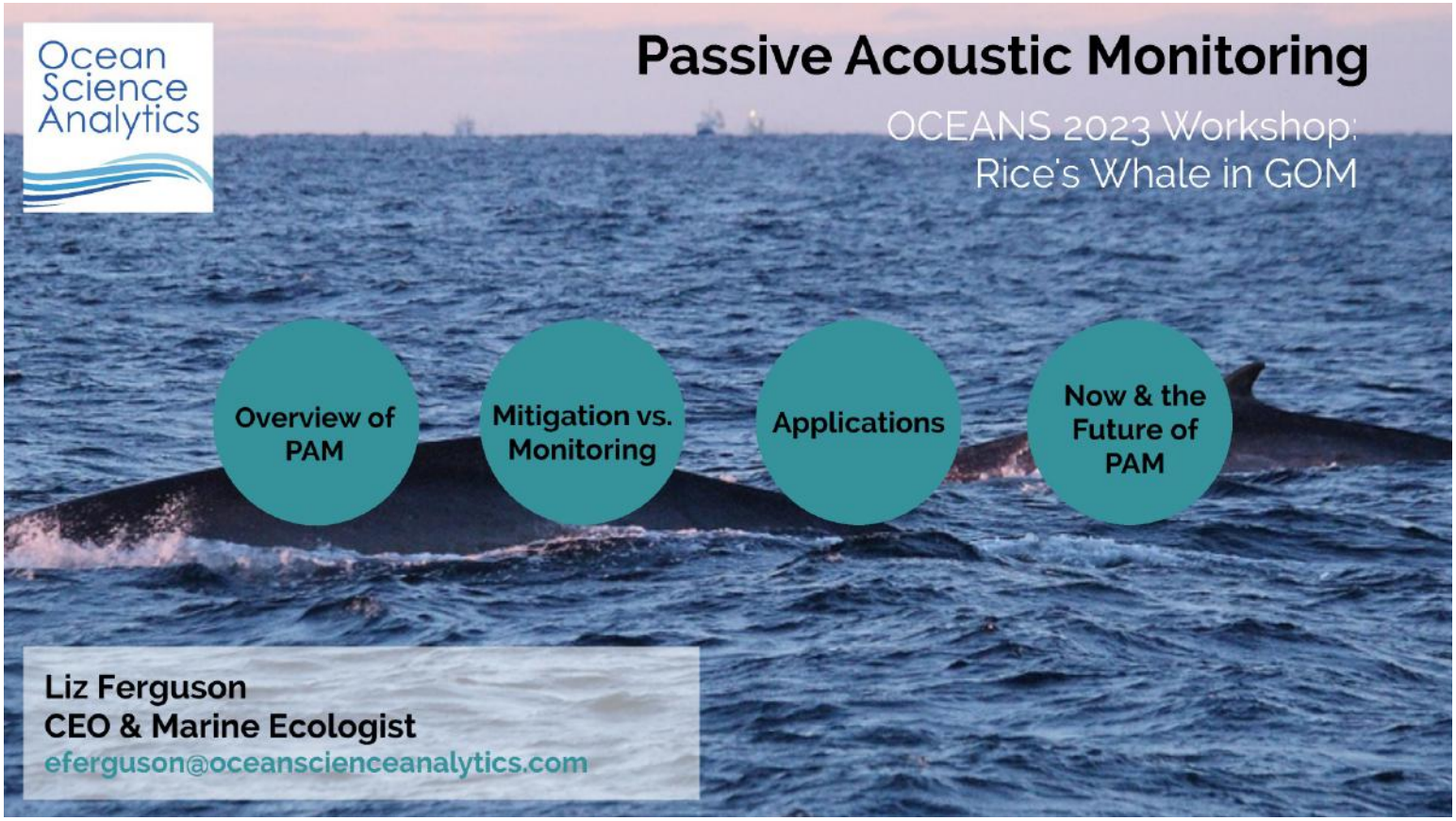
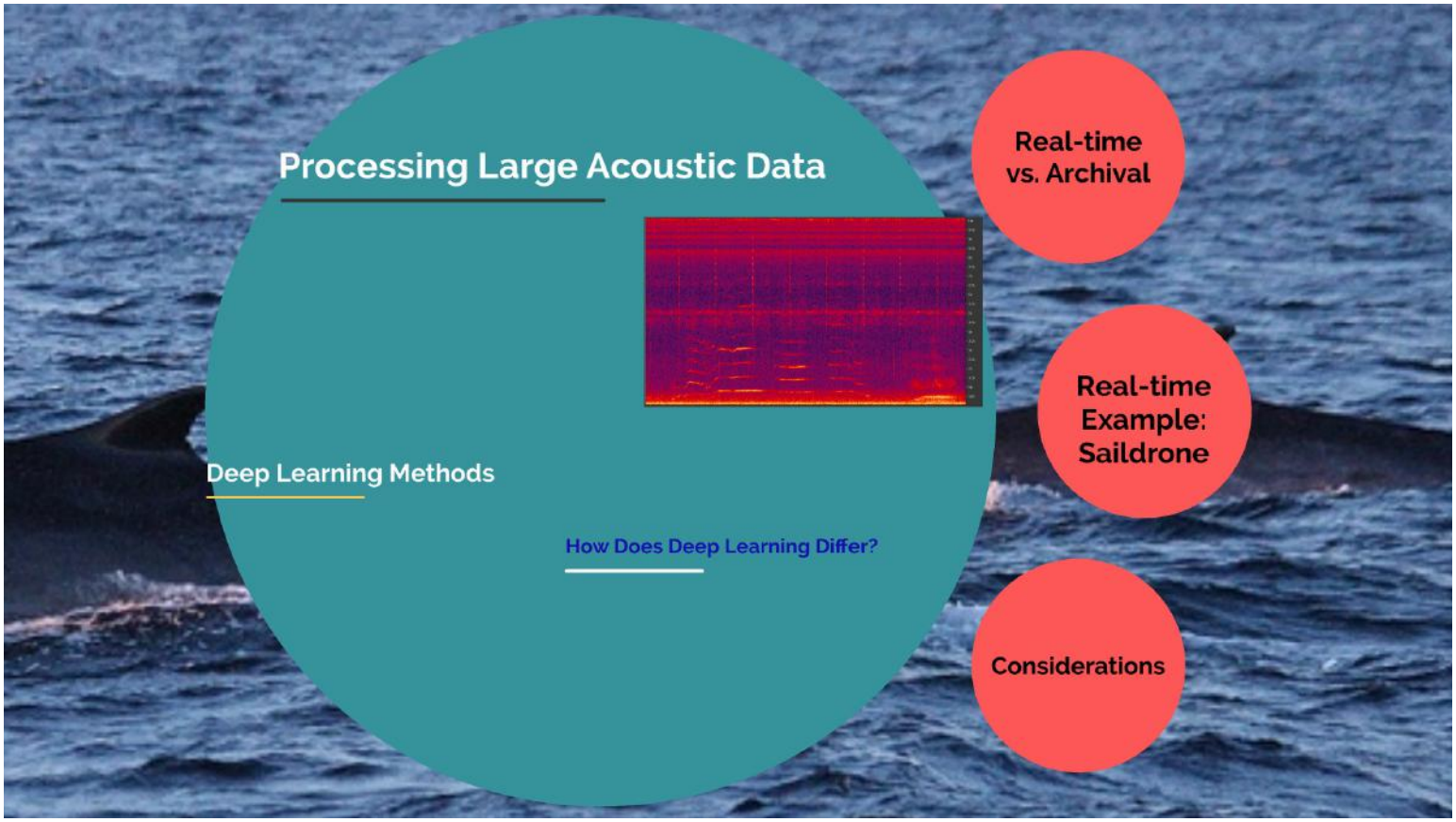
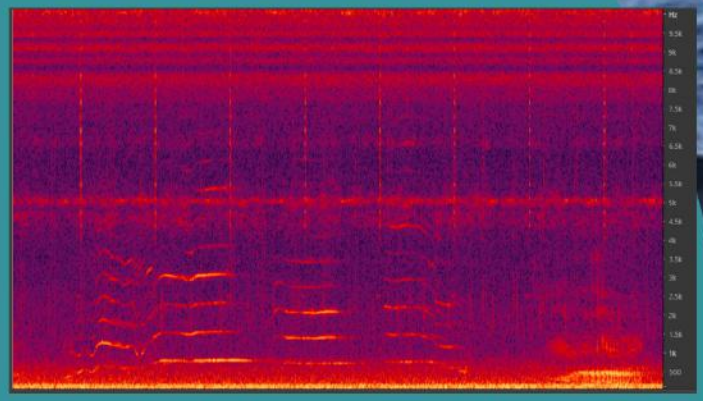

Ocean Science Analytics
Passive Acoustic Monitoring
OCEANS 2023 Workshop:
Rice's Whale in GOM
Overview of PAM
Mitigation vs. Monitoring
Applications
Now & the Future of PAM
Liz Ferguson
CEO & Marine Ecologist
eferguson@oceanscienceanalytics.com


Processing Large Acoustic Data
Deep Learning Methods
How Does Deep Learning Differ?
Real-time vs. Archival
Real-time Example: Saildrone
Considerations

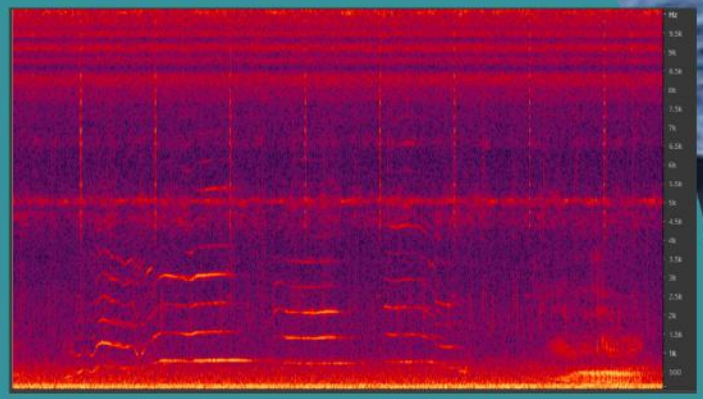
Processing Large Acoustic Data



ep Learning Methods

Processing Large Acoustic Data

- Data collection & storage allows for terabytes of information
- Manual methods not feasible with large acoustic datasets
- Machine learning methods expedite that process



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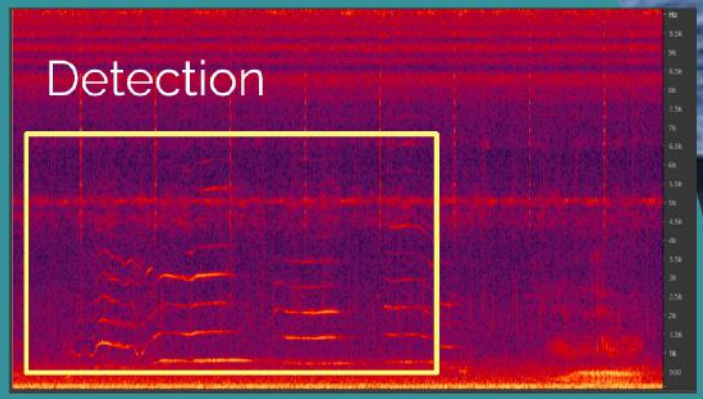

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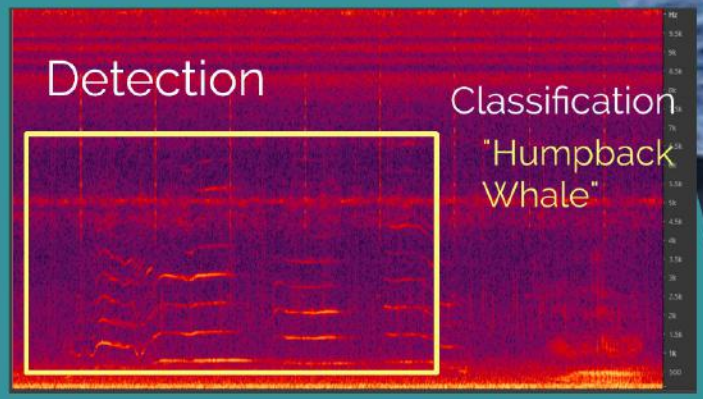

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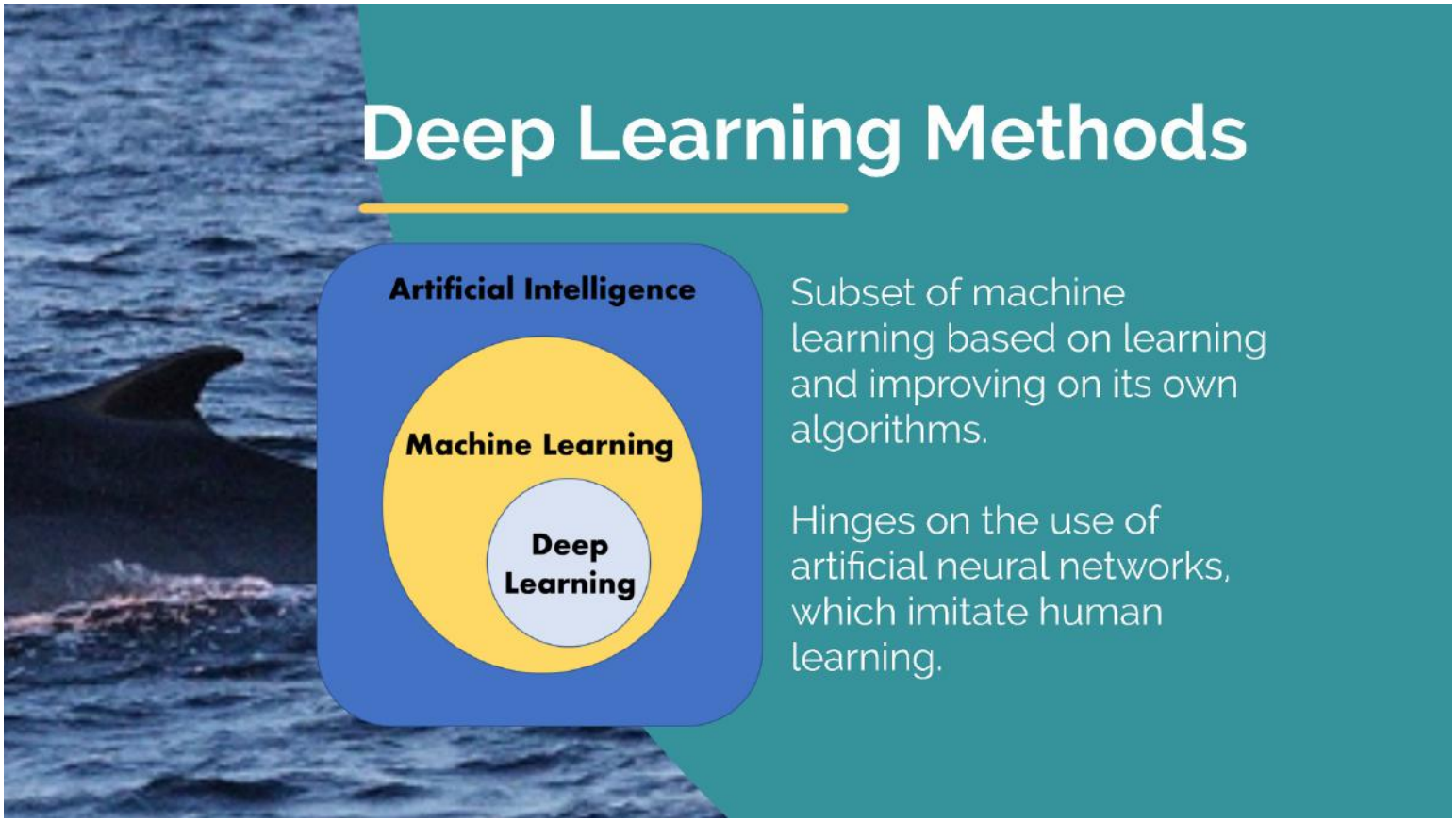
Deep Learning Methods
Artificial Intelligence
Machine Learning
Deep Learning
Subset of machine learning based on learning and improving on its own algorithms.
Hinges on the use of artificial neural networks, which imitate human learning.

How Does Deep Learning Differ?

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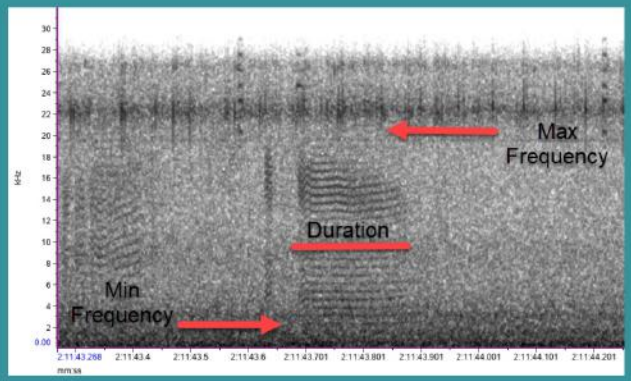
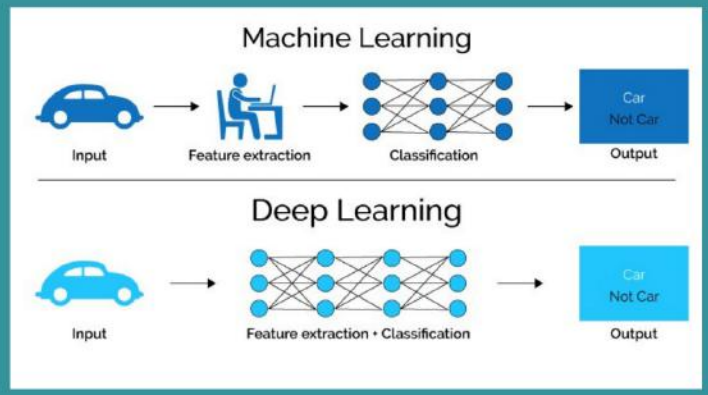
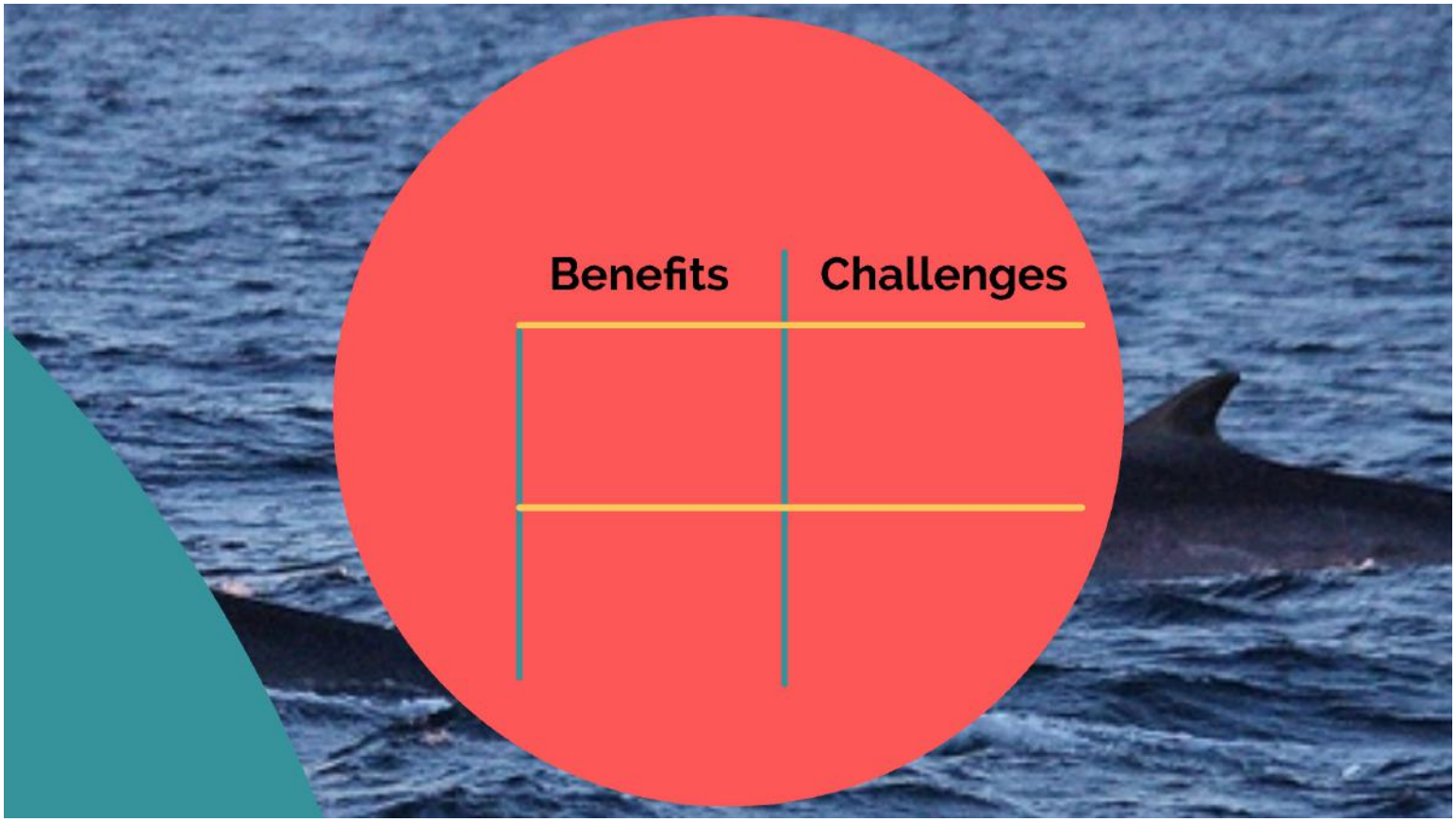




https://www.analyticsvidhya.com/blog/2020/02/cnn-vs-rnn-vs-mlp-analyzing-3-types-of-neural-networks-in-deep-learning/


Benefits
Challenges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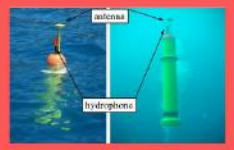
	Benefits	Challenges
 Real-time		
 Archival Analysis		

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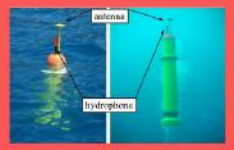 Real-time	• Timely results = faster reporting • Satellite transmission = lower cost	
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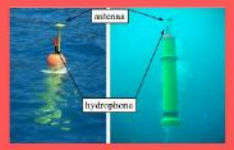 Real-time	• Timely results = faster reporting • Satellite transmission = lower cost	• Subject to higher rate of false positives • Data: onboard processing & transmission
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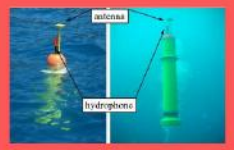 Real-time	• Timely results = faster reporting • Satellite transmission = lower cost	• Subject to higher rate of false positives • Data: onboard processing & transmission
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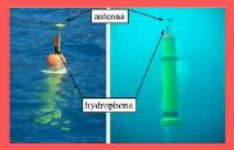 Real-time	• Timely results = faster reporting • Satellite transmission = lower cost	• Subject to higher rate of false positives • Data: onboard processing & transmission
 Archival Analysis	• Access to full bandwidth • Validation more accurrate	• Delay in results, all species is time consuming • Lost recorders = no data

Real-time PAM Example: Saildrone

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Automated processing and remote transmission of marine mammal detections

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"Neptune" algorithm detects and classifies signals

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Cloud-based data hosting

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Cloud-based data hosting

Deployed in windfarm for monitoring vetted by remote-based operator

Considerations for Rice's Whale

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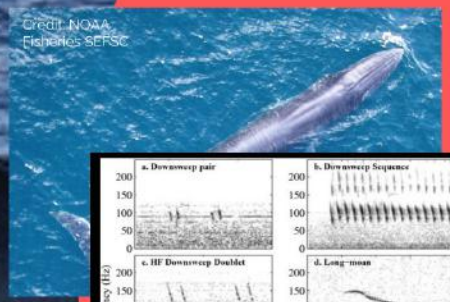
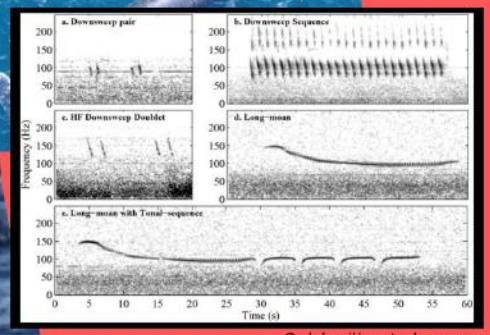
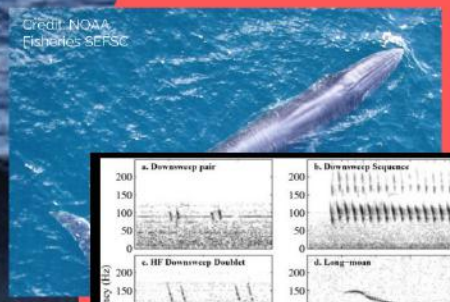


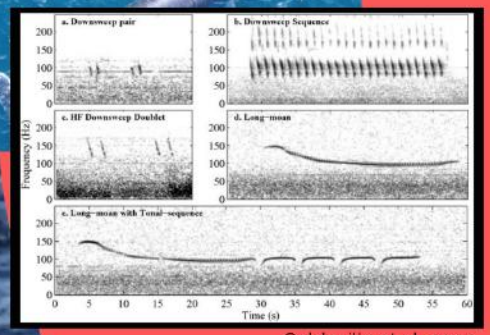
Soldevilla et al., 2022 confirmed call types attributable to Rice's Whale



Soldevilla et al., 2022

Considerations for Rice's Whale





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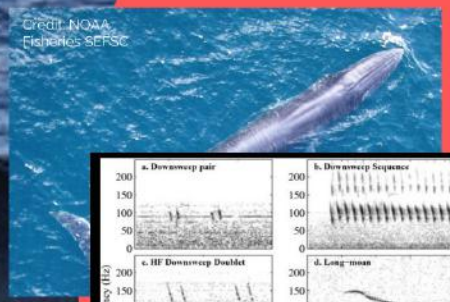
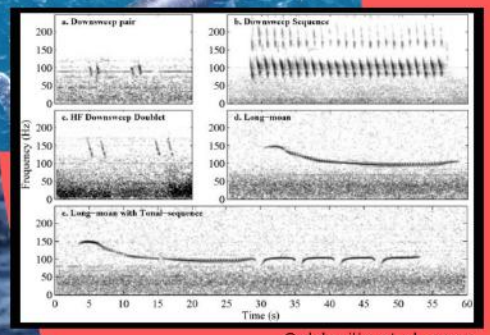
Large spatial coverage of acoustic instrumentation + AI analysis methods = Comprehensive distribution

Considerations for Rice's Whale





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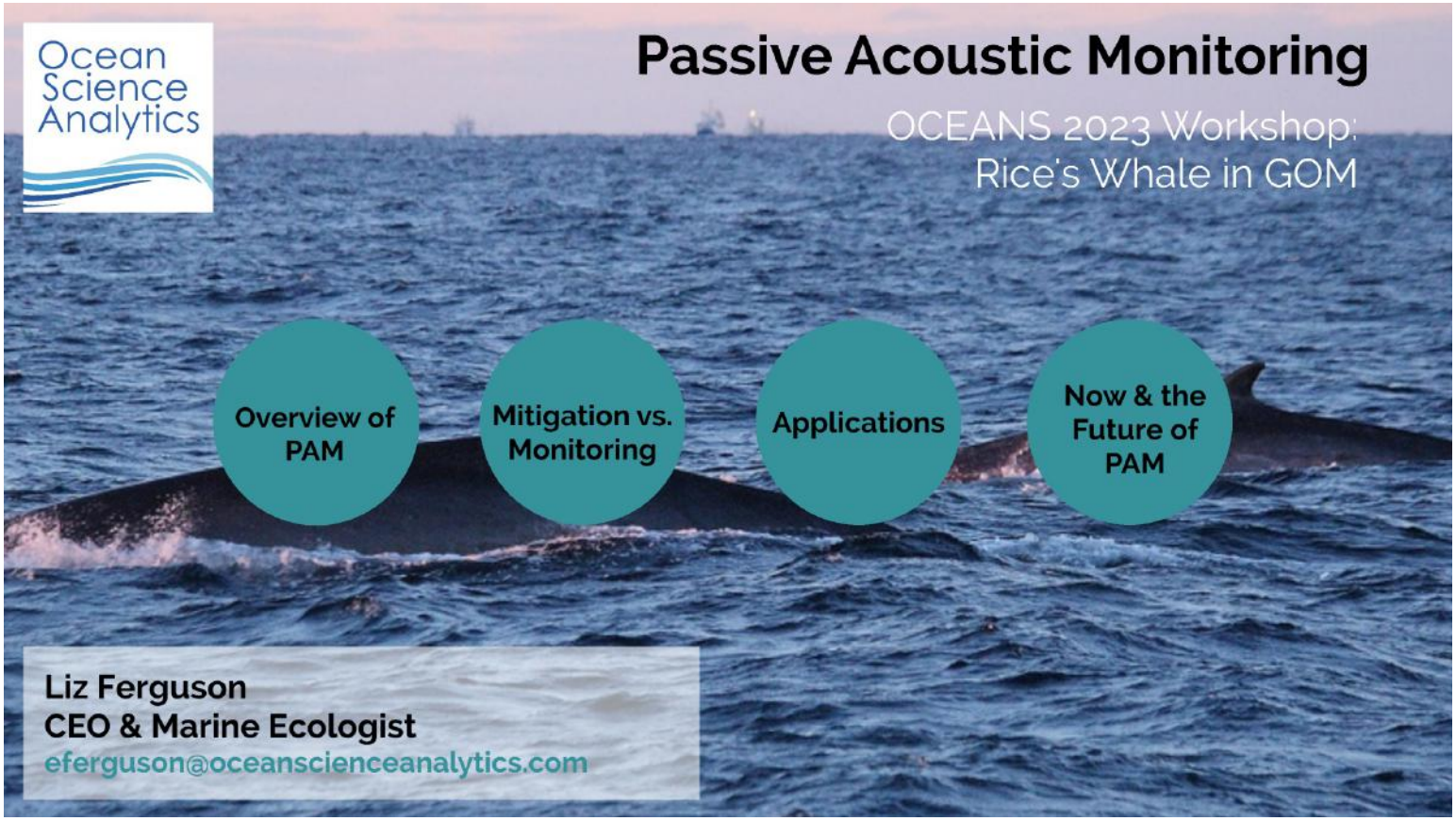
PAM offers opportunity to better understand Rice's Whale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Liz Ferguson
CEO & Marine Ecologist
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