Data Transferability and Data Collection Consistency for Marine Renewable Energy Development

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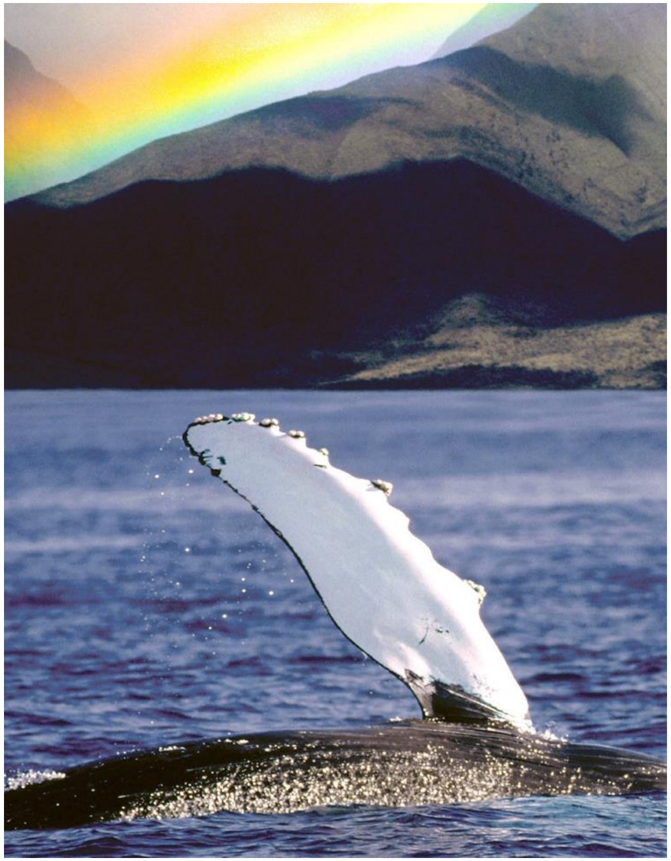
Pacific Northwest National Laboratory

Online Workshops
March - April 2018

Why are we here today?

- What do we mean by “data transferability”?
- What about “data collection consistency”?
- What do we hope to get out of today?



Today’s workshop:

- Introductions
  - Purpose of the workshop
  - Introduction to the topics
- Data set and information exploration
- Data transferability framework
- Next steps

Who are we? Why are we here?

- Work for PNNL, DOE national lab
- DOE Water Power Technology Office (WPTO), part of EERE
  - Responsible for marine renewable energy (MRE, MHK), and hydropower

- Here representing Annex IV:
  - Collaborative task under IEA Ocean Energy Systems
  - 12 countries part of Annex IV
  - Environmental effects of MRE
  - This year's major theme: Data Transferability & Collection Consistency

OES OCEAN ENERGY SYSTEMS

ANNEX IV

Background

- The MRE industry perceives:
  - Long time to get projects in the water
  - Permitting is long and complicated
  - Asked to provide extensive
    - Baseline/pre-installation data
    - Post-installation monitoring requests
  - Mitigation looms as a possible additional need

- We perceive that the regulatory community:
  - Face challenges due to
    - Lack of deployed devices
    - Novelty of technologies
    - Uncertainty of environmental effects
  - Mandated to
    - Protect the marine environment
    - Follow the federal or state regulations and statues
    - Make decisions on applications for MRE projects
- And that the regulatory process is key for getting devices deployed
  - Learning more as we go

Data Transferability and Collection Consistency

- Our hypothesis is that:
  - Data/information collected through research studies and monitoring from other projects should inform new projects.
  - Site specific data will be needed for all new projects.
  - But – the data from established projects may reduce site specific data collection needs.
  - And, similarities to other industries may inform new MRE projects.
  - These data that might be "transferred" need to be collected consistently for comparison.

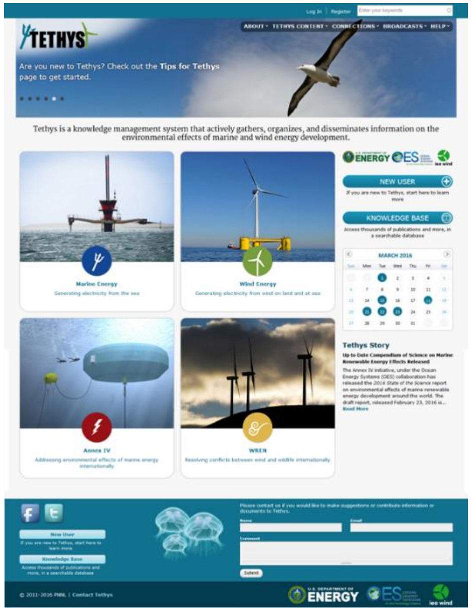
Some Definitions, Resources

- Marine Renewable Energy (MRE)
  - Mostly wave and tidal development
  - Also includes ocean current, river current, OTEC, salinity gradients

- For MRE resources: *Tethys* (https://tethys.pnnl.gov)

- What do we mean by "data"?
  - We really mean data and information:

    Could be raw or quality controlled data but *more likely* analyzed data, synthesized data to reach some conclusion, reports, etc.



What about today?

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- Walk through types of information that represent the major interactions of concern:
  - Collision risk – tidal
  - Underwater noise effects
  - Electromagnetic fields (EMF) effects
  - Habitat changes
  - Changes to physical systems

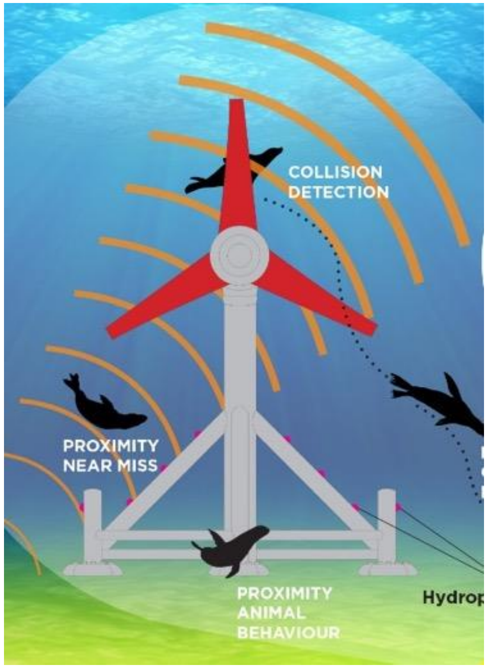
- Present our framework on data transferability, want your thoughts

Information on Collision Risk from MRE Devices

Videos and some data courtesy of:
Brian Polagye and PMEC partners; Voith and Aquatera Limited; Ocean Renewable Power Company

Collision Risk

- Concern with rotating blades of tidal turbine causing injury or death to marine mammals, fish, and diving seabirds
- Concern with effect on populations
- Impacts projected less than those of conventional hydropower turbines and ship propellers
- Animals may come into contact through:
  - Normal movements
  - Attraction to device for shelter, feeding, or out of curiosity
  - Inability to avoid device (strong tidal currents)



https://censis.org.uk/censis_projects/tidal-turbine-collision-detection/

Atlantis Andritz turbine

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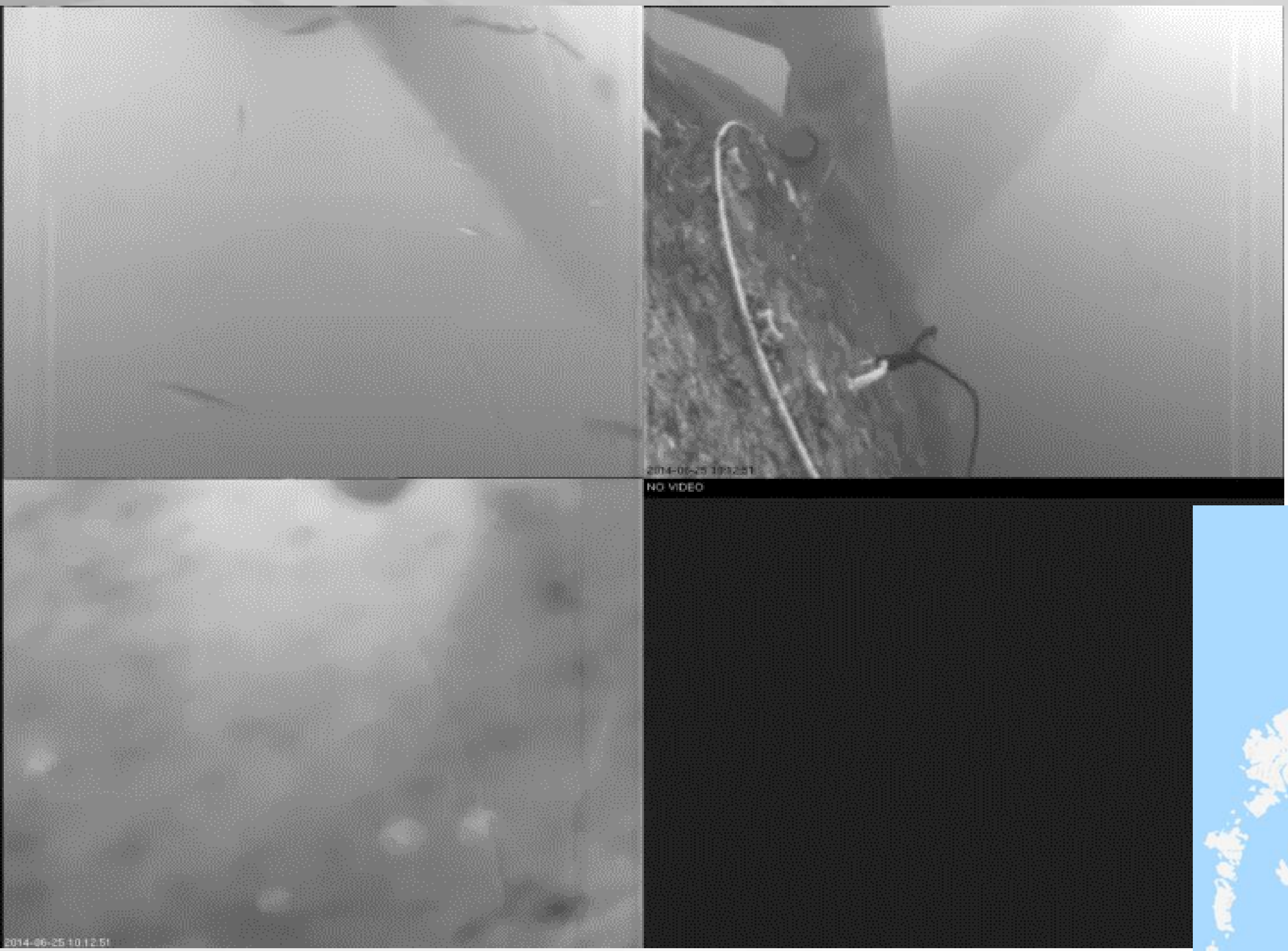
- Pentland Firth, Scotland

- 1.5 MW
- Depth: 35-100 m
- Blade length: 8 m
- Speed: 10 rpm

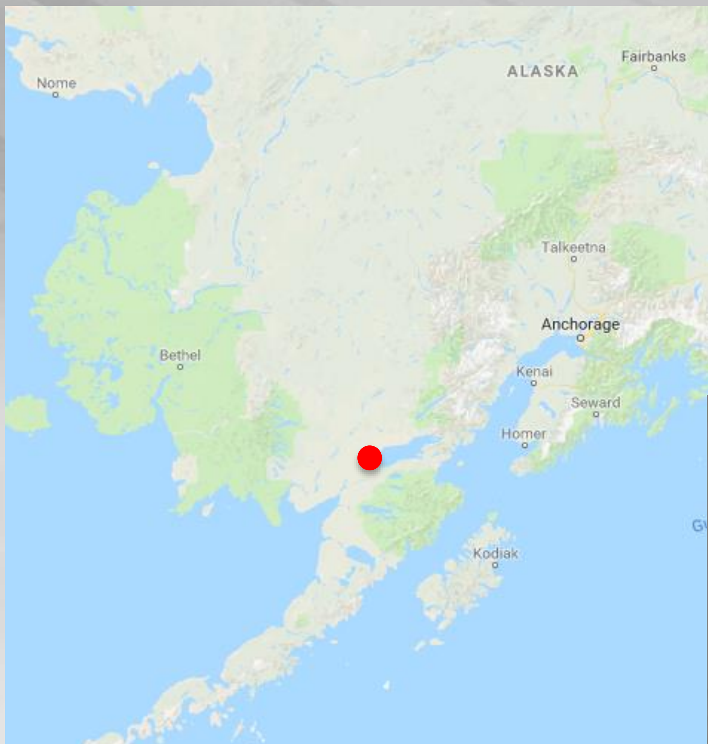
Voith turbine at EMEC



- 1 MW
- Depth: 35 m
- Blade length: 6 m

ORPC in-stream river turbine

- Igiugig, Alaska



- ORPC Riv-Gen
- Cross-flow, horizontal axis turbine
- 50 kW

ORPC in-stream river turbine

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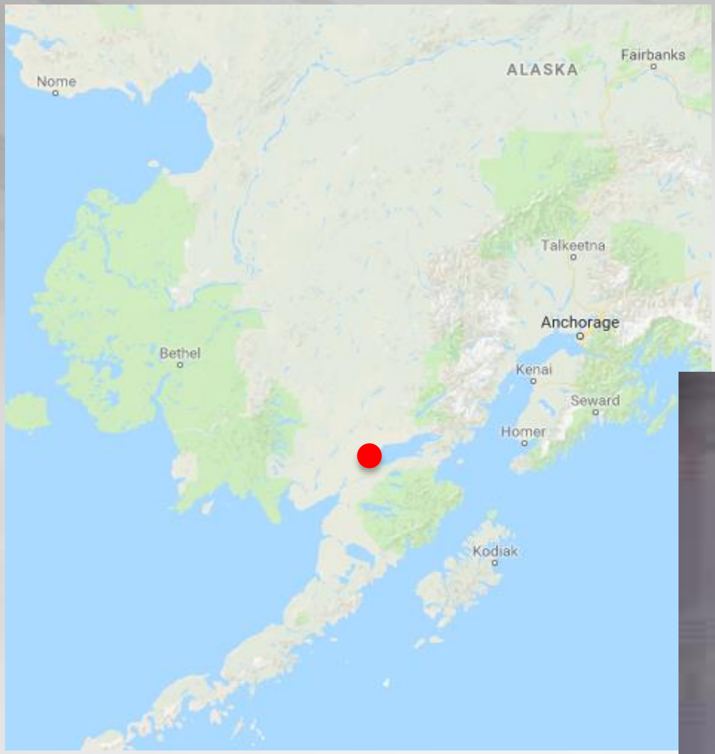
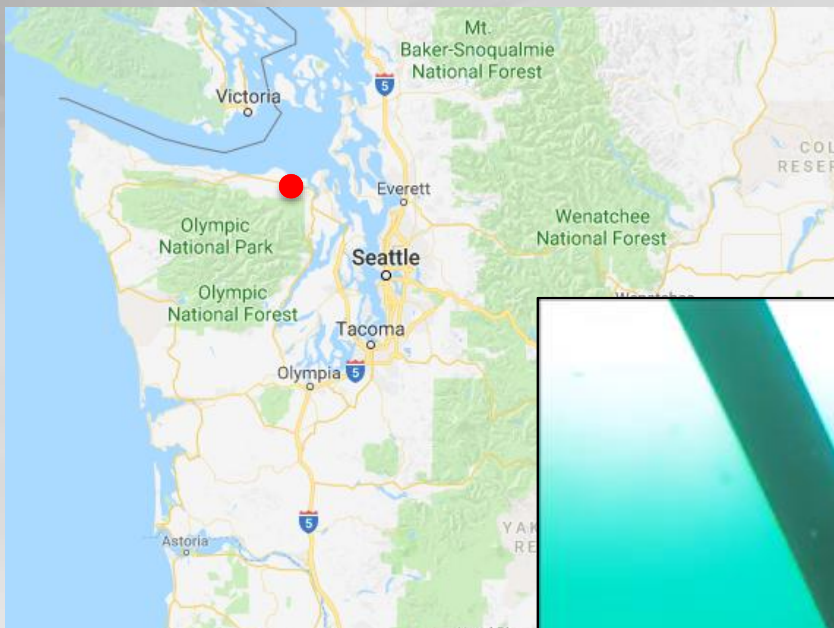
- Igiugig, Alaska



- ORPC Riv-Gen
- Cross-flow, horizontal axis turbine
- 50 kW

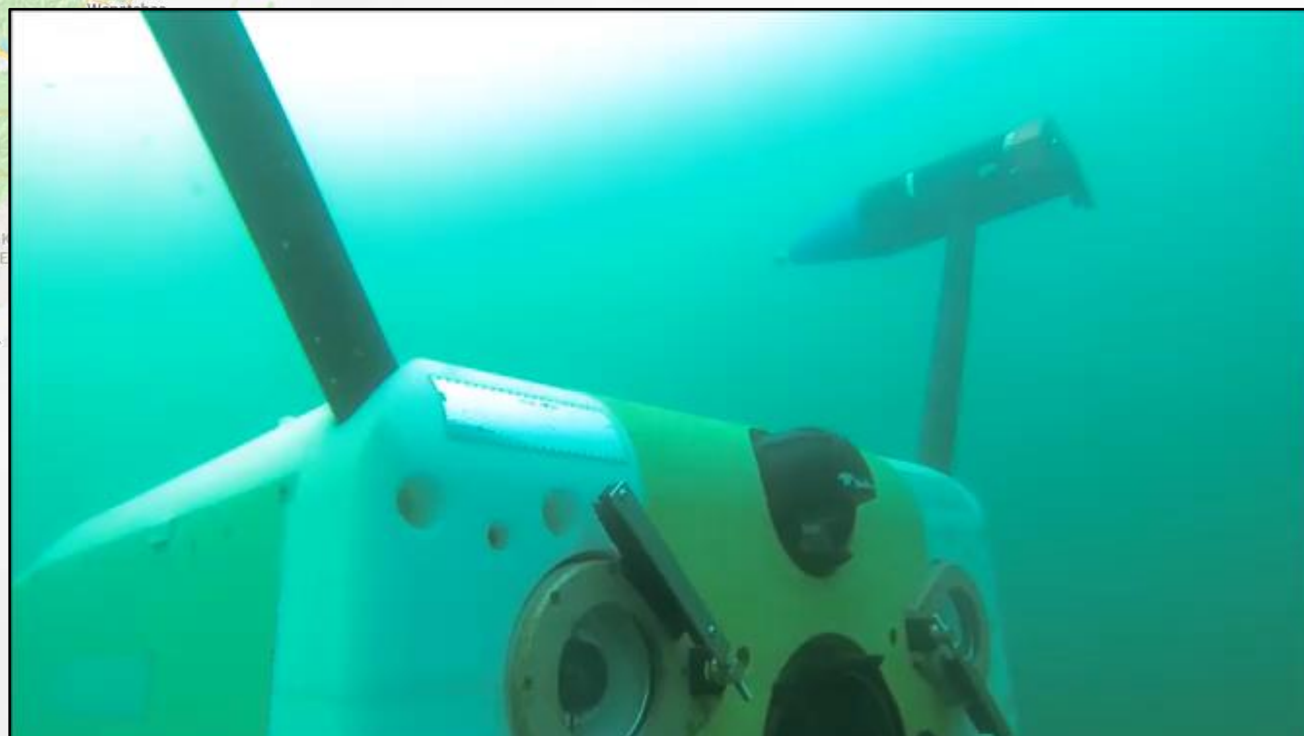
Adaptable Monitoring Package (AMP) NNMREC

- Sequim Bay, WA



- AMP = platform for multiple sensors, data acquisition
- Depth: 12 m
- In lieu of a turbine

Diver inspection of AMP



Active acoustic monitoring multi-beam sonar

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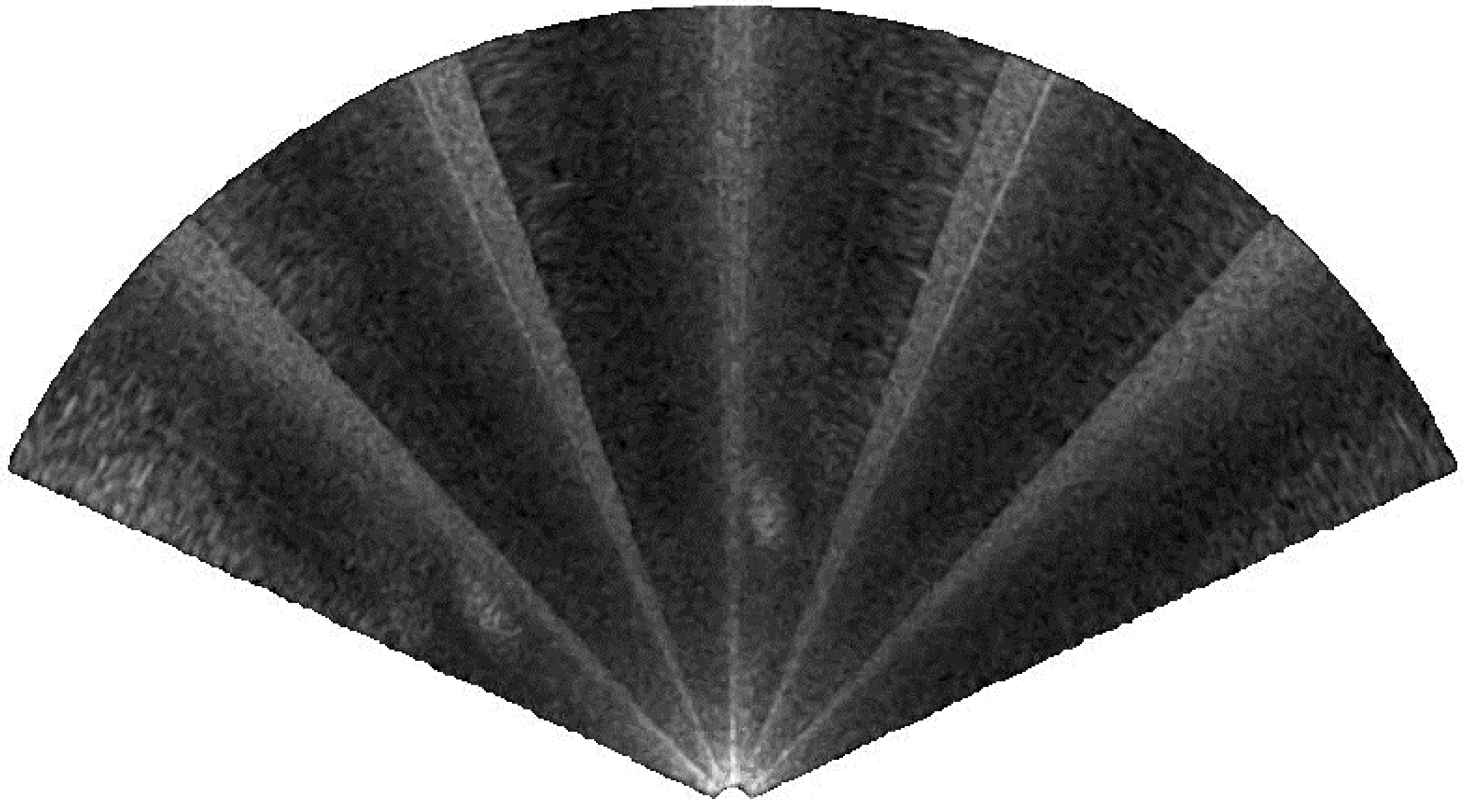
Target tracking example (seal)



Active acoustic monitoring multi-beam sonar

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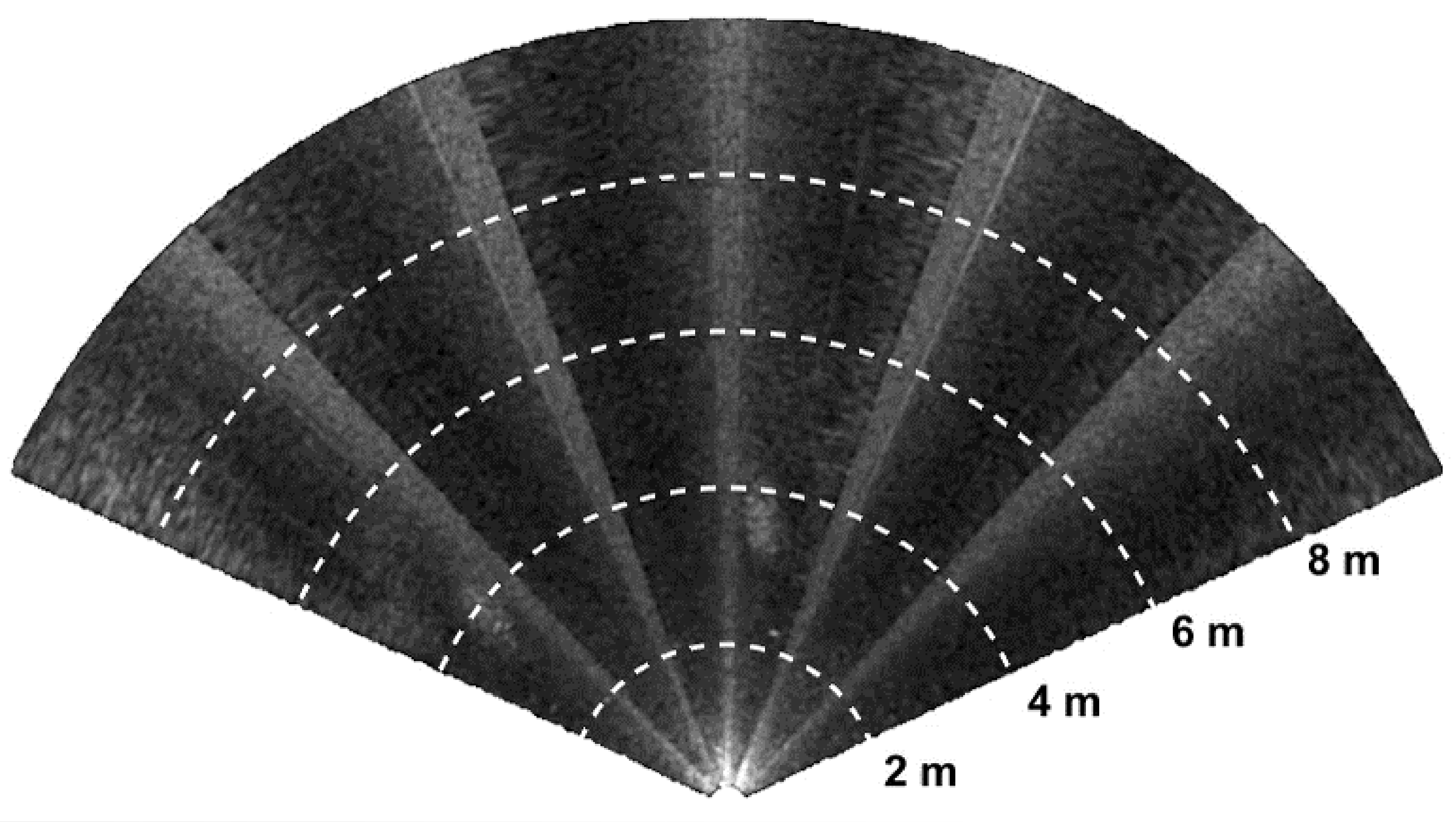
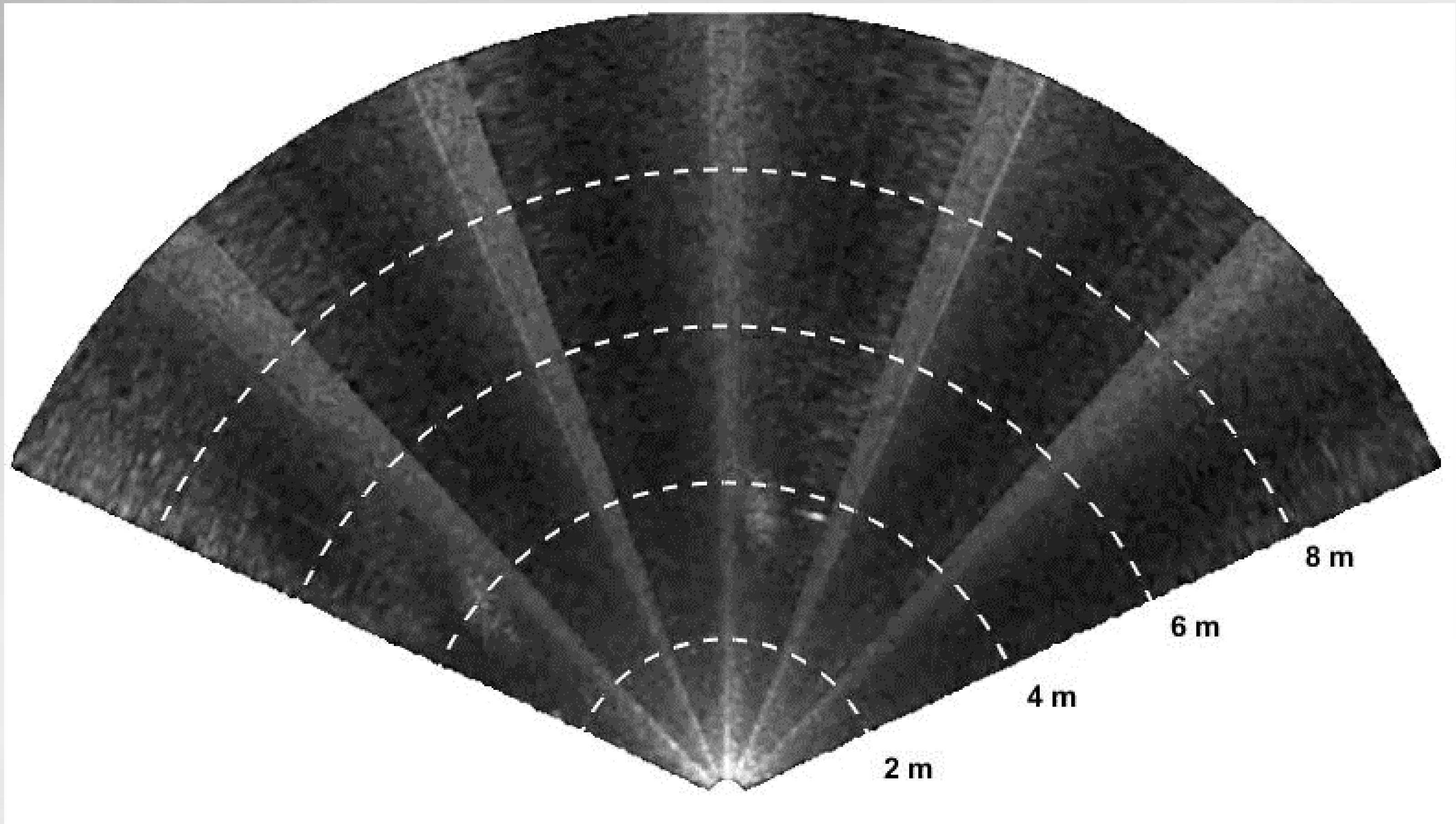
Fish scattering observed on acoustic camera when strobe lights are illuminated



Active acoustic monitoring multi-beam sonar

Interaction between fish and seal observed on acoustic camera



Active acoustic monitoring multi-beam sonar

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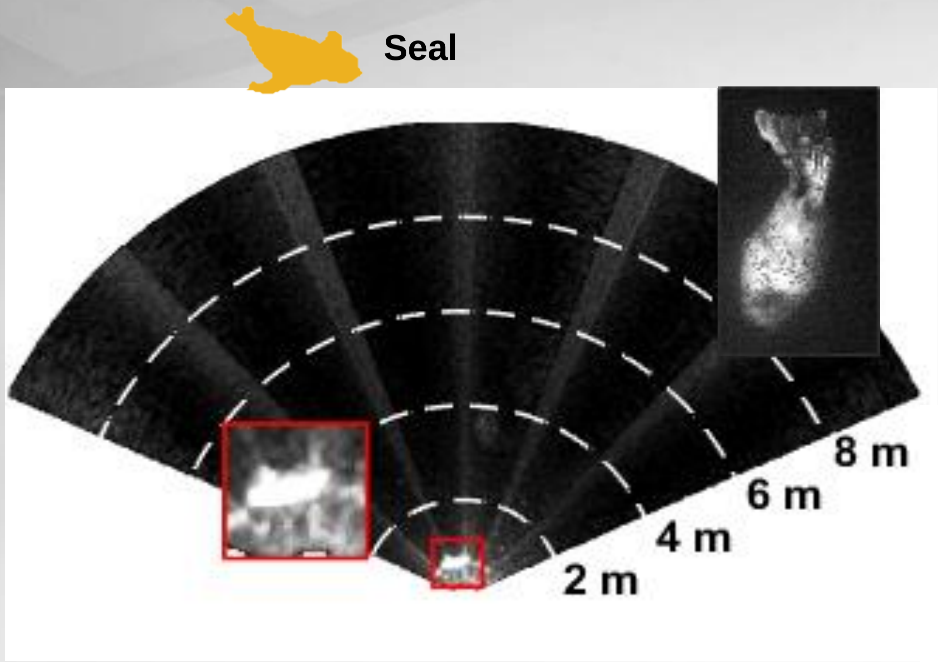
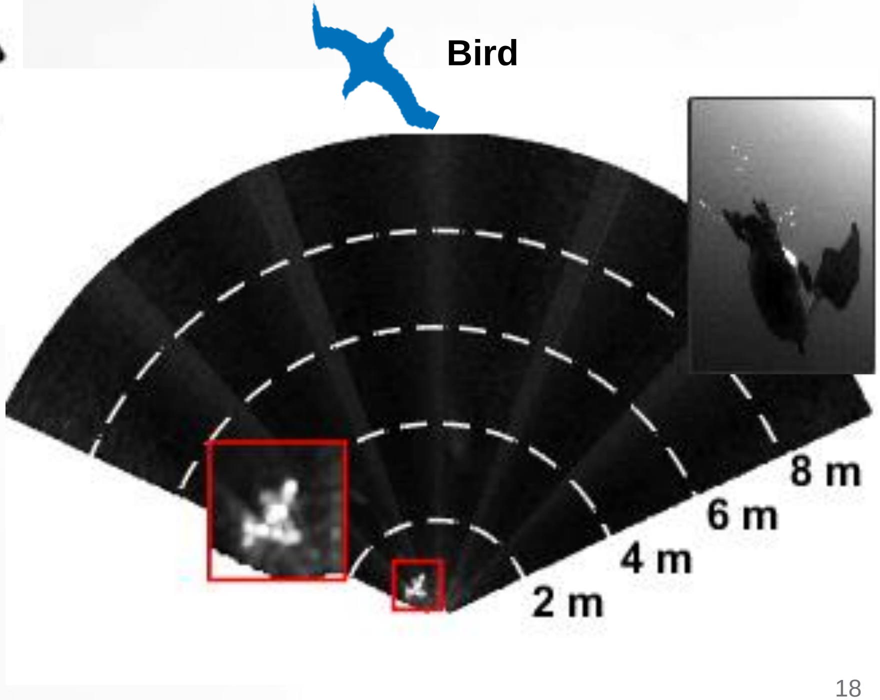
Triggered optical camera detections of a seal and a diving bird





Discussion

- What do the data tell you?
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Information on Underwater Noise from MRE Devices

Videos and data courtesy of
Brian Polagye, UW/PMEC and partners

Underwater Noise from MRE

- Anthropogenic noise from a variety of sources can:
  - Induce behavioral changes (i.e., avoidance/attraction)
  - Cause physical harm
- Shipping and other industry noises much louder than MRE
- Offshore renewables: noise concerns from construction; operational noise likely to be much lower
- Unlikely for noise from MRE to cause harm to marine animals



OpenHydro turbine at EMEC

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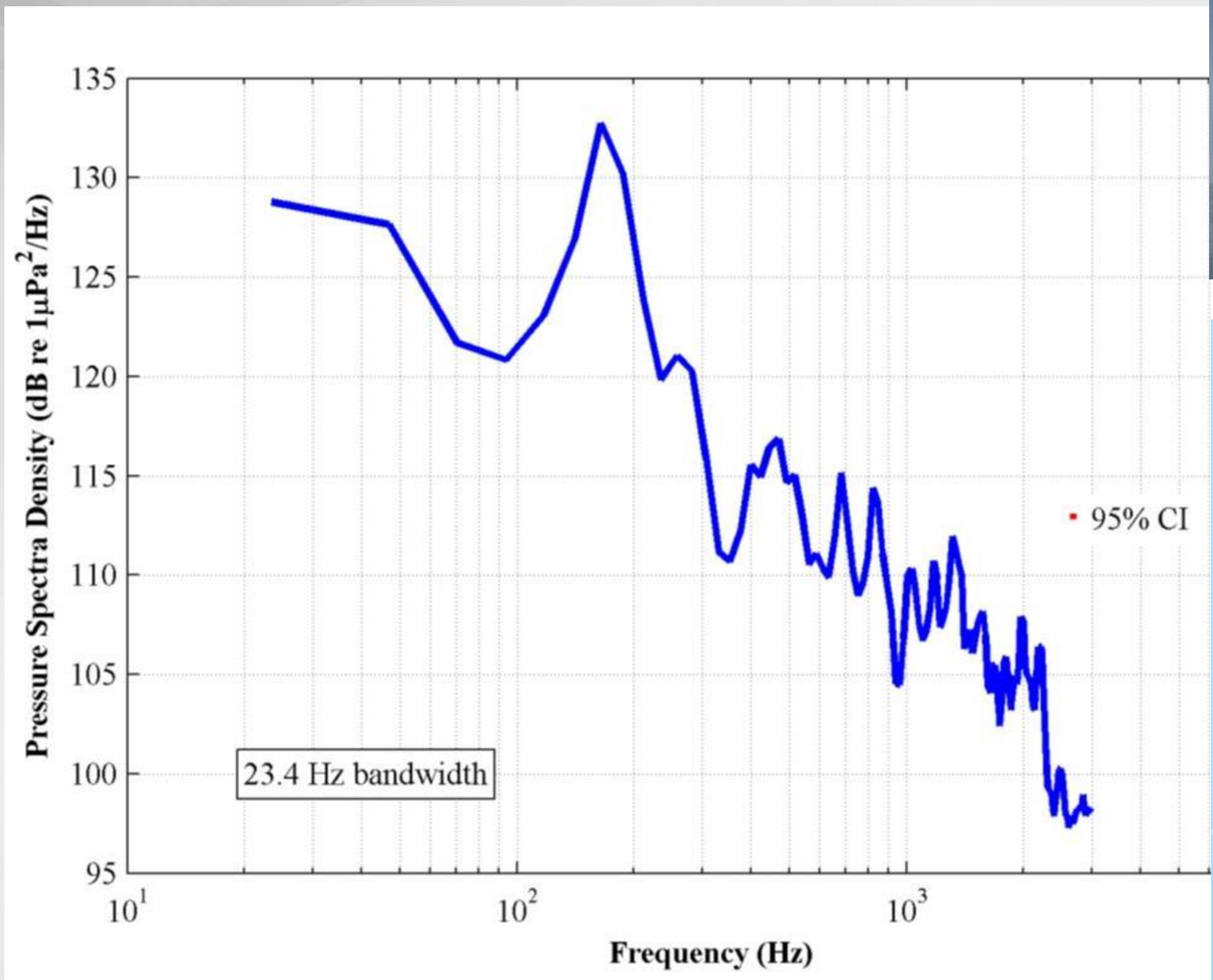
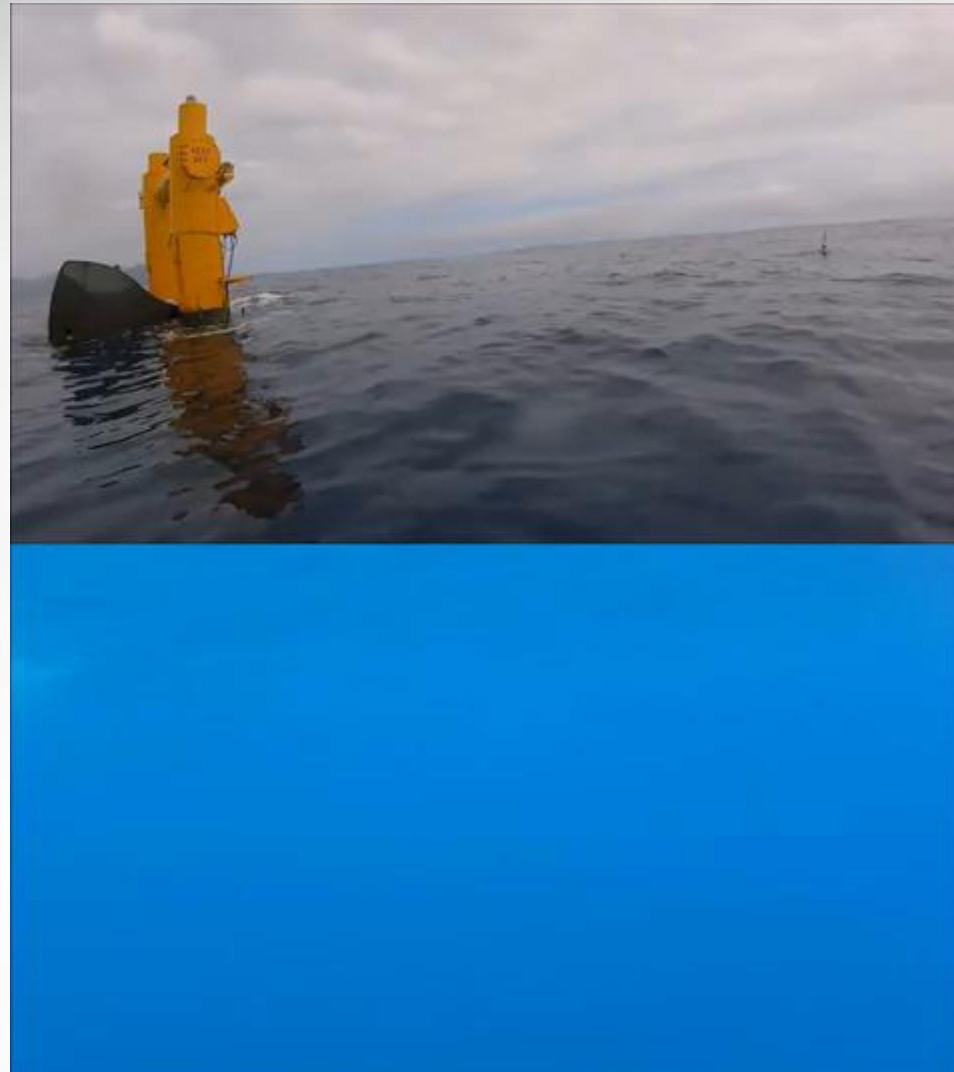
- Noise from rotor, power take off, within ~2 m
- Shipping noise generally 150-180 dB



NEWI Azura at Hawaii WETS

- “Point absorber”
- Sub-surface hydraulic power take-off



Acoustic Characteristics

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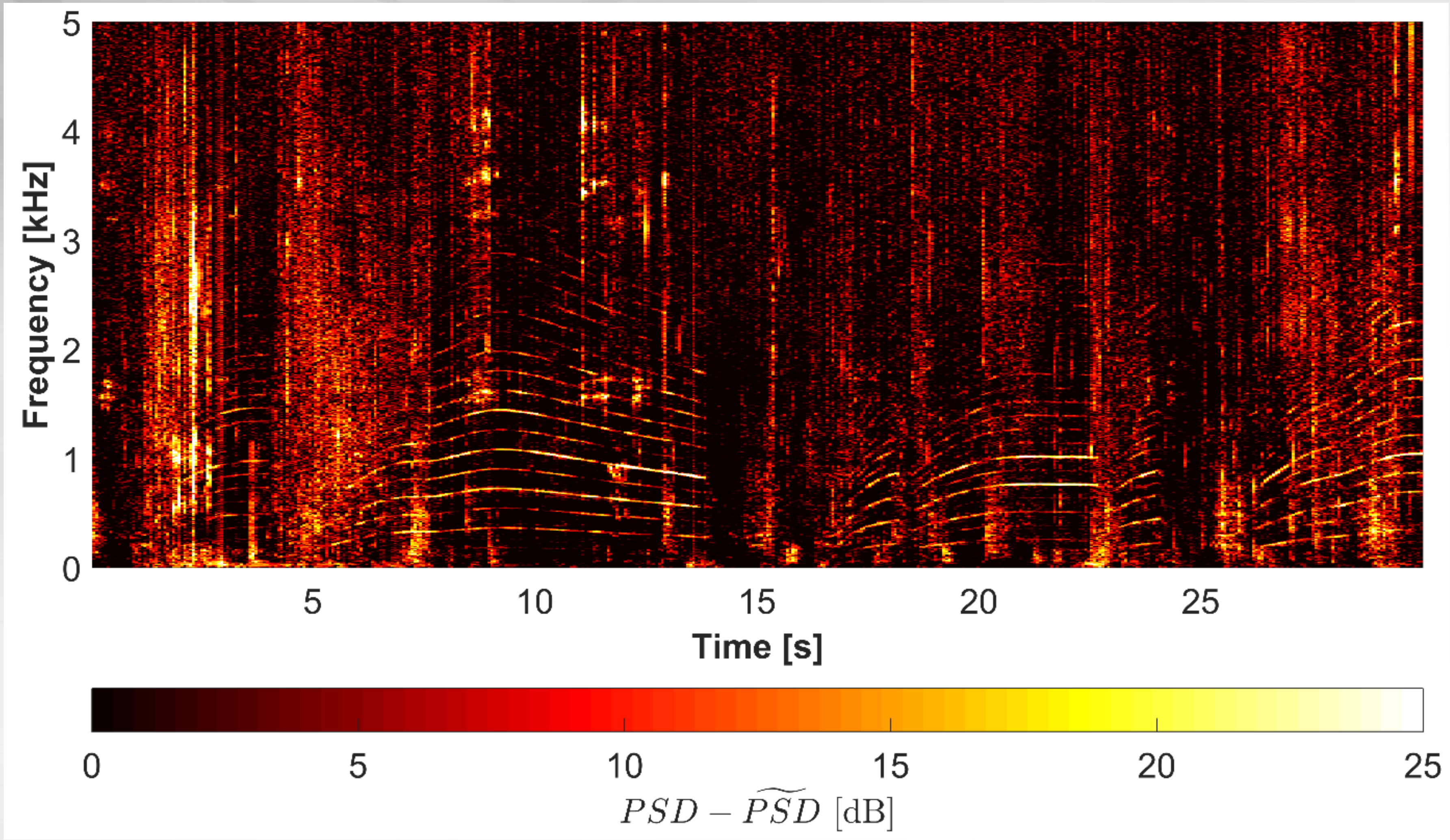
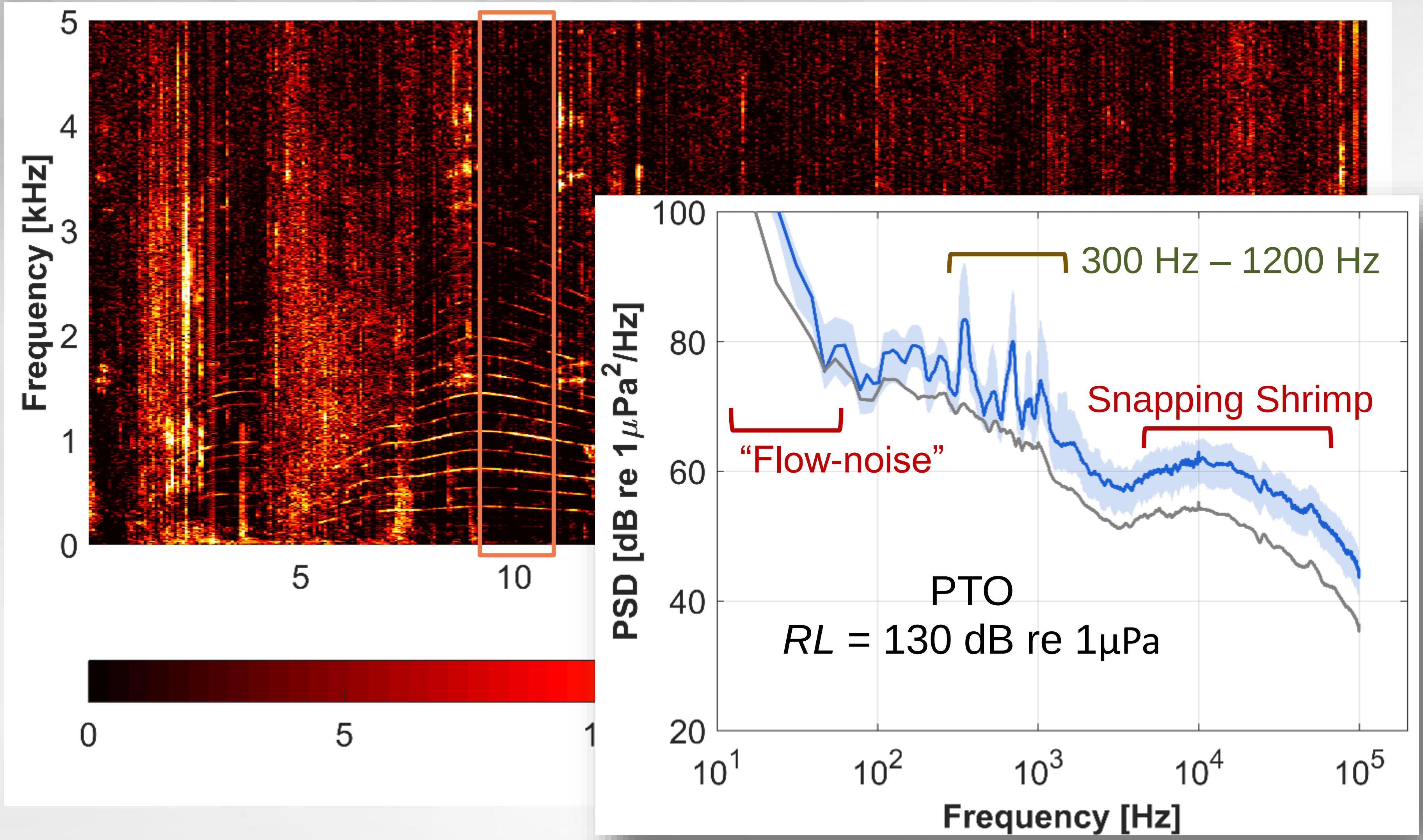


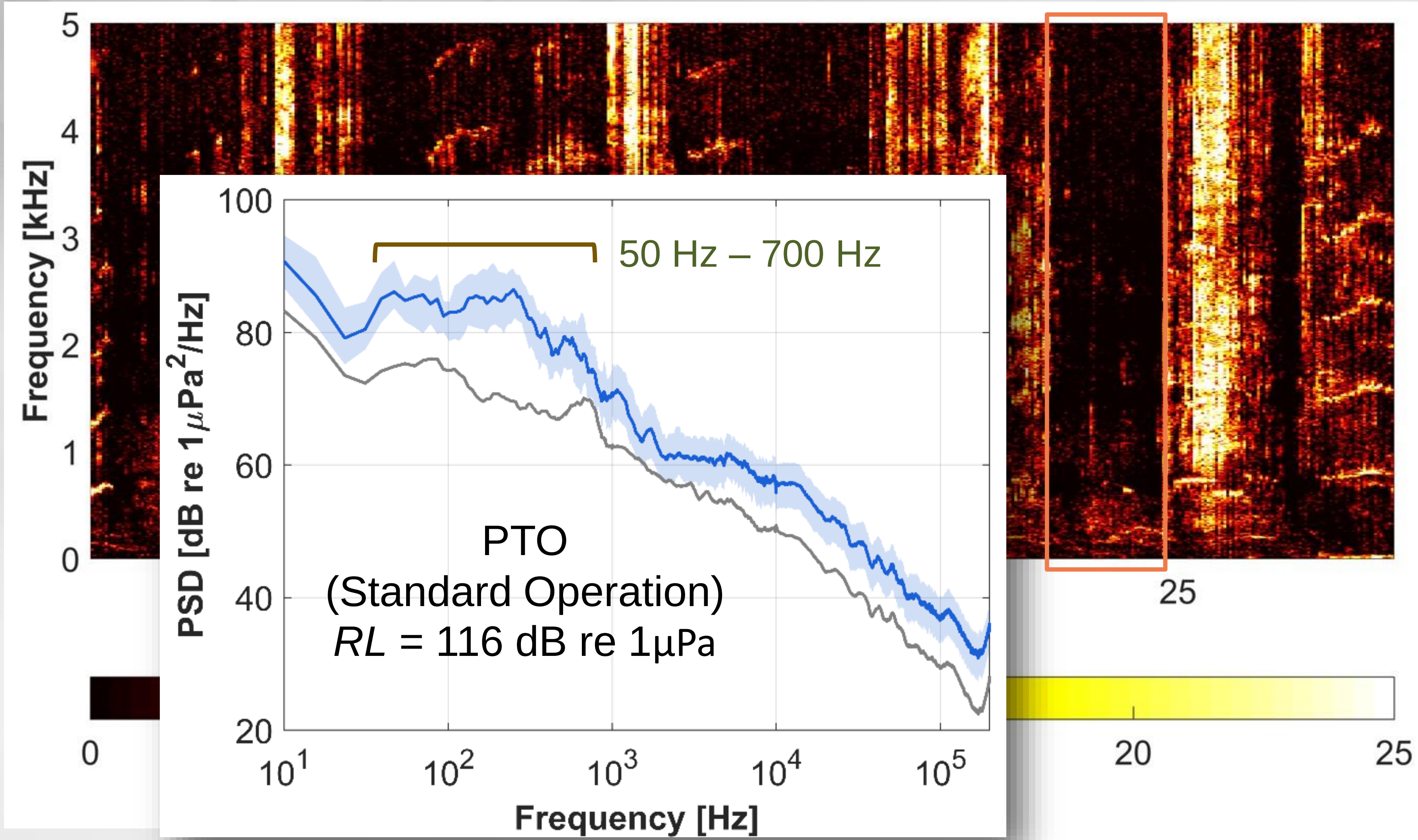
Acoustic Characteristics



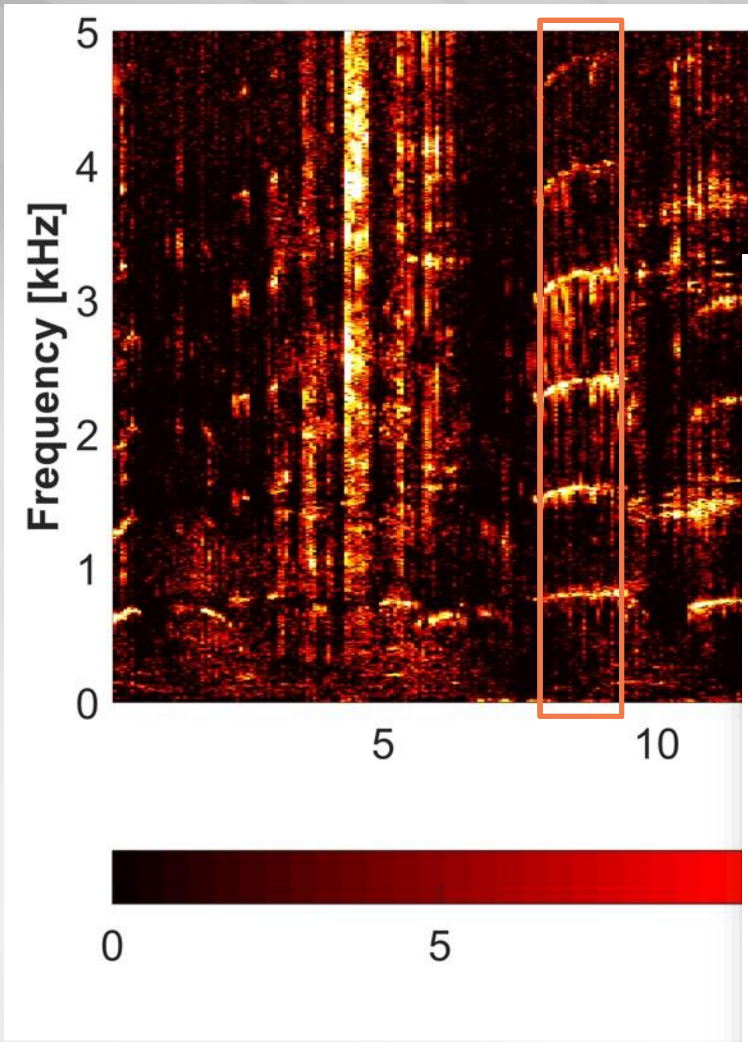
Fred Olsen Lifesaver at Hawaii WETS

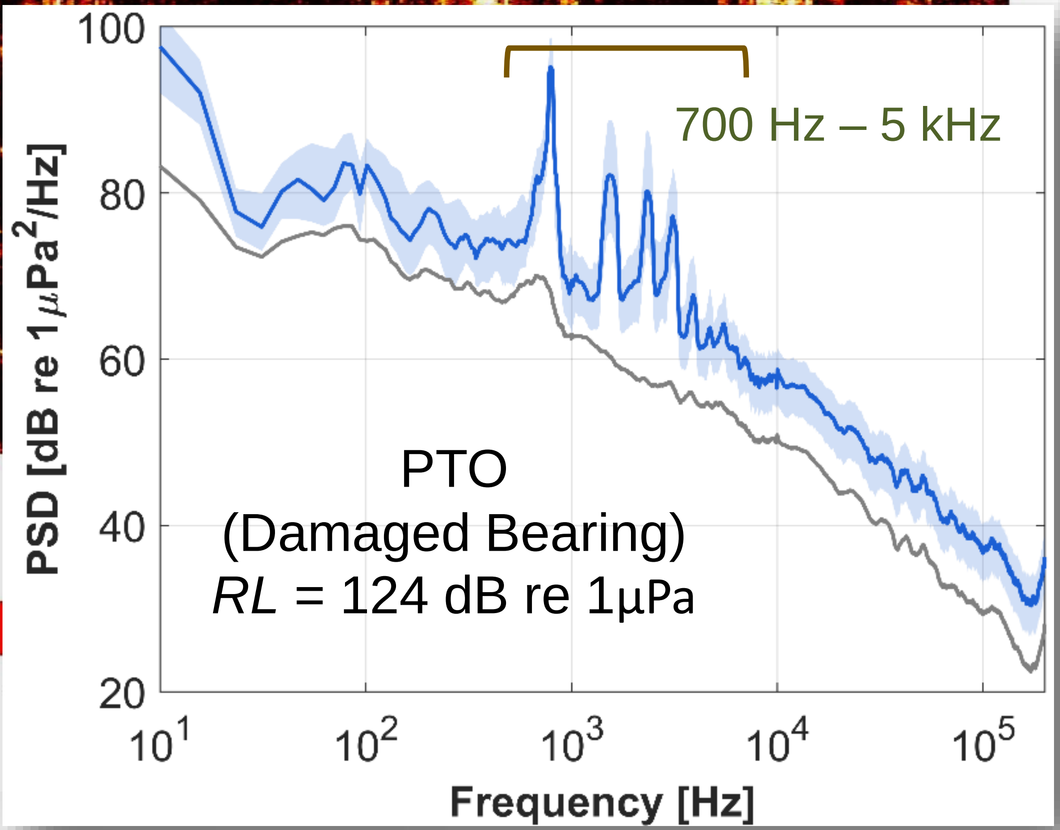
- Oscillating water column
- Air-side hydraulic power take-off
- Shallow draft (0.5 m)

Acoustic Characteristics



Acoustic Characteristics





Regulatory Thresholds

- Marine Mammals
  - NOAA Technical Guidance (2016)

Table 6: TTS onset auditory acoustic thresholds for non-impulsive sounds.

Hearing Group	*K* (dB)	*C* (dB)	Weighted TTS onset acoustic threshold (SEL_{cum})
Low-frequency (LF) cetaceans	179	0.13	179 dB
Mid-frequency (MF) cetaceans	177	1.20	178 dB
High-frequency (HF) cetaceans	152	1.36	153 dB
Phocid pinnipeds (underwater)	180	0.75	181 dB
Otariid pinnipeds (underwater)	198	0.64	199 dB

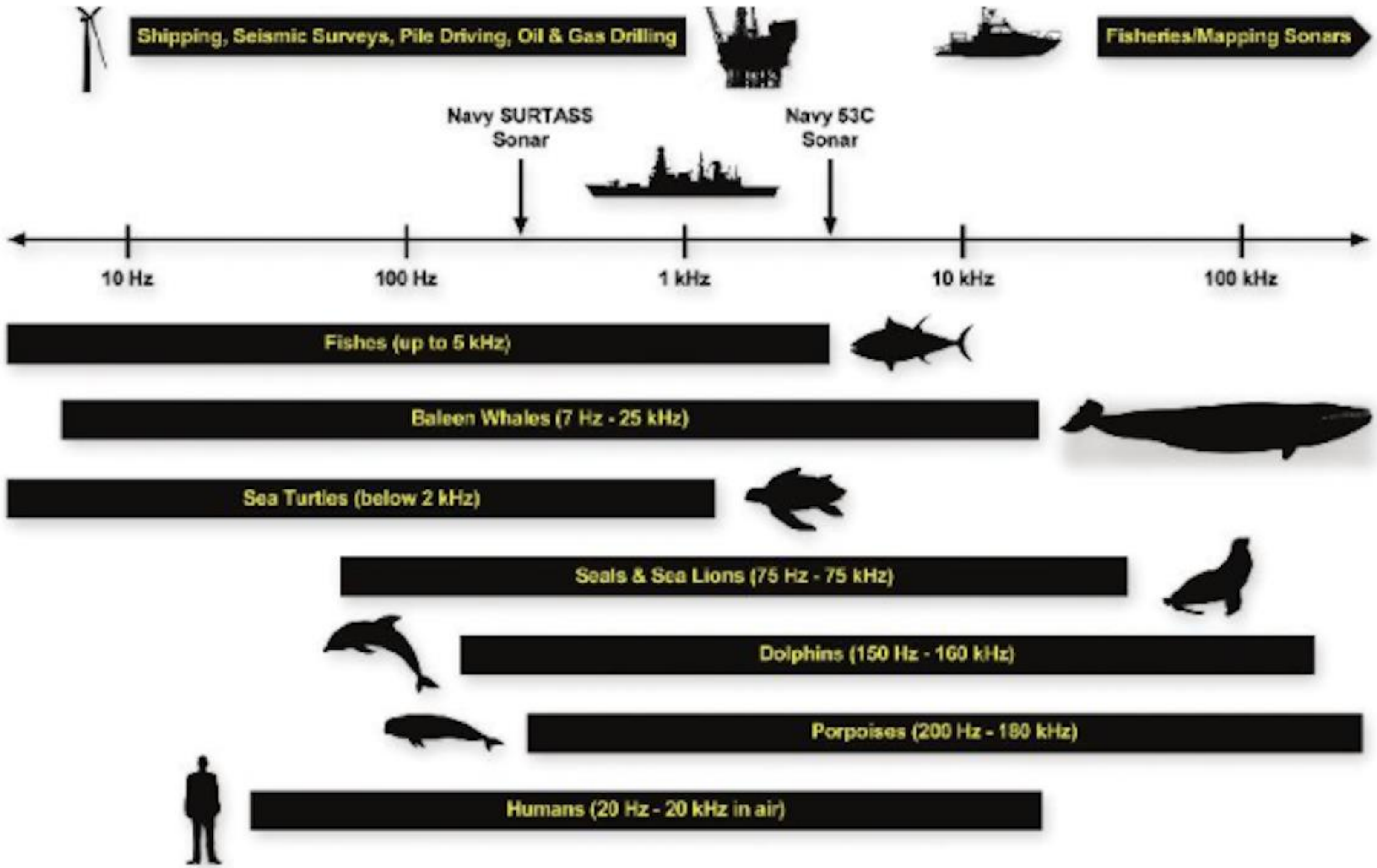
Table ES3: Summary of PTS onset acoustic thresholds.

	PTS Onset Acoustic Thresholds* (Received Level)	
Hearing Group	**Impulsive**	**Non-impulsive**
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	*Cell 2* $L_{E,LF,24h}$: 199 dB
Mid-Frequency (MF) Cetaceans	*Cell 3* $L_{pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	*Cell 4* $L_{E,MF,24h}$: 198 dB
High-Frequency (HF) Cetaceans	*Cell 5* $L_{pk,flat}$: 202 dB $L_{E,HF,24h}$: 155 dB	*Cell 6* $L_{E,HF,24h}$: 173 dB
Phocid Pinnipeds (PW) (Underwater)	*Cell 7* $L_{pk,flat}$: 218 dB $L_{E,PW,24h}$: 185 dB	*Cell 8* $L_{E,PW,24h}$: 201 dB
Otariid Pinnipeds (OW) (Underwater)	*Cell 9* $L_{pk,flat}$: 232 dB $L_{E,OW,24h}$: 203 dB	*Cell 10* $L_{E,OW,24h}$: 219 dB

- Fish
  - NOAA Fisheries
  - BOEM Underwater Acoustic Modeling Report (2013)

Table 3. Interim Fisheries Cause and Effect Guidelines

	Criteria Level	Type
Physiological Effects	206 dBL re 1 µPa	Absolute Peak SPL
	187 dBL re 1 µPa²s	SEL_{cum}, For fishes above 2 grams (0.07 ounces)
	183 dBL re 1 µPa²s	SEL_{cum}, For fishes below 2 grams (0.07 ounces)
Behavioral Effects	150 dBL re 1 µPa (RMS)	Absolute



Shipping, Seismic Surveys, Pile Driving, Oil & Gas Drilling
Fisheries/Mapping Sonars
Navy SURTASS Sonar
Navy 53C Sonar
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz
Fishes (up to 5 kHz)
Baleen Whales (7 Hz - 25 kHz)
Sea Turtles (below 2 kHz)
Seals & Sea Lions (75 Hz - 75 kHz)
Dolphins (150 Hz - 160 kHz)
Porpoises (200 Hz - 180 kHz)
Humans (20 Hz - 20 kHz in air)

Shipping noise

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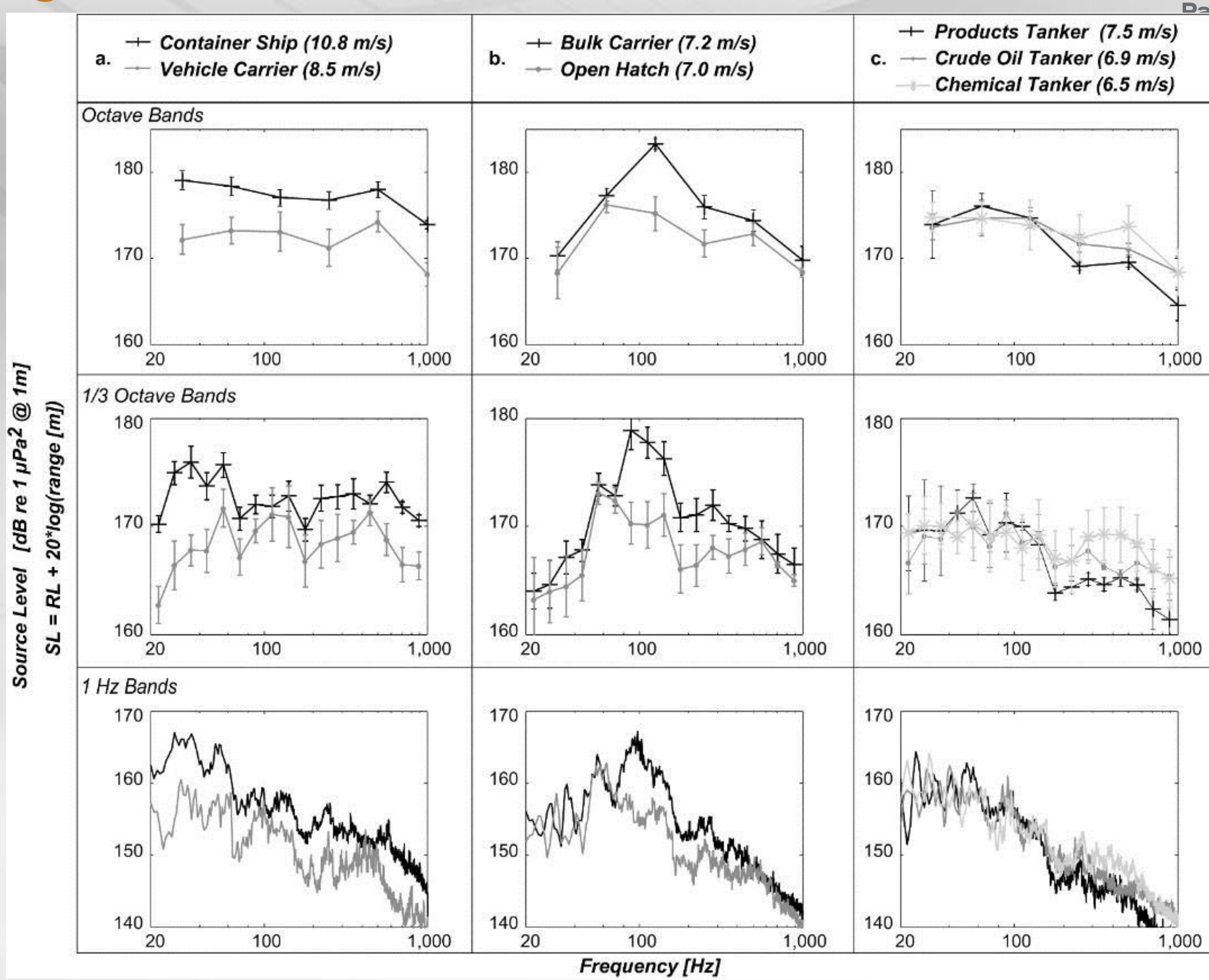

FIG. 4. Ship source levels for (a) container ships and vehicle carriers, (b) bulk carriers and open hatch cargos, and (c) three types of tankers. Top two series of figures show one-octave and 1/3 octave bands, with mean and standard errors. Bottom series shows the 1 Hz band levels.

Published in: Megan F. McKenna; ; Published in: Donald Ross; ; Published in: Sean M. Wiggins; John A. Hildebrand; ; *The Journal of the Acoustical Society of America* **2012,** 131, 92-103.
DOI: 10.1121/1.3664100

Discussion

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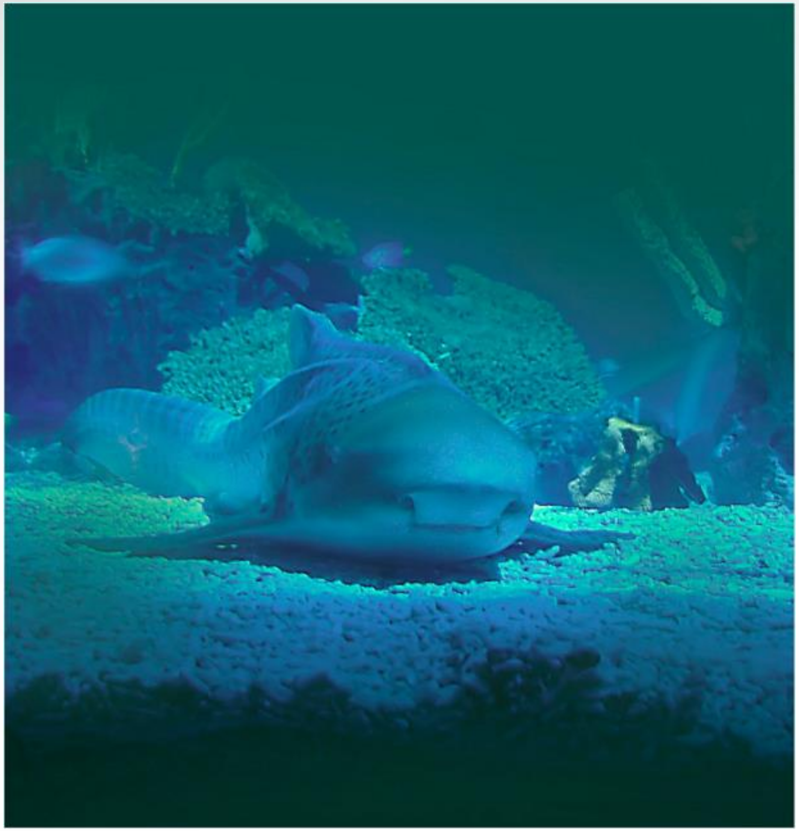
Information on EMF Impacts on Marine Animals from Export Power Cables



Credit to Ann Bull, BOEM for many of the slides

And many many researchers

U.S. DEPARTMENT OF ENERGY

OES OCEAN ENERGY SYSTEMS

ANNEX IV

Electromagnetic Fields

- Anthropogenic EMF signatures come from a variety of marine infrastructure (subsea cables, bridges, tunnels, etc.)
- MRE emits EMF signatures from power cables, moving parts of devices, and underwater substations or transformers
- May affect organisms that use natural magnetic field for orientation, navigation, and hunting
  - Includes elasmobranchs, marine mammals, crustaceans, sea turtles, some fish species
- EMF-sensitive species are attracted to/or avoid sources
  - But no demonstrable impact of EMF related to MRE devices on any sensitive marine species

Electromagnetic Fields from AC and DC Power Cables

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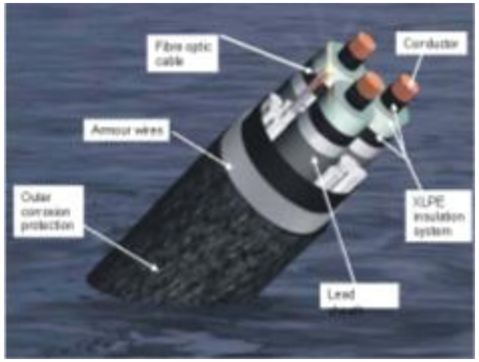
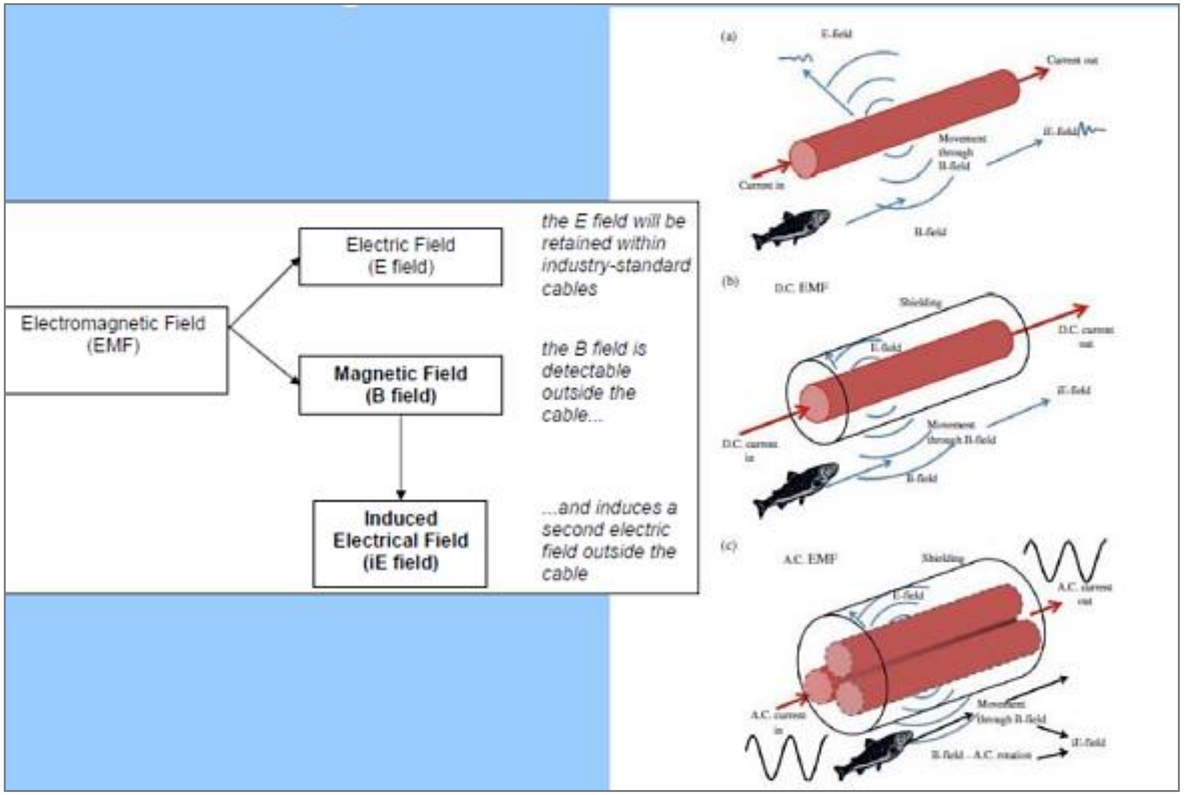
- Similar to any underwater cables

DC Cable

AC Cable

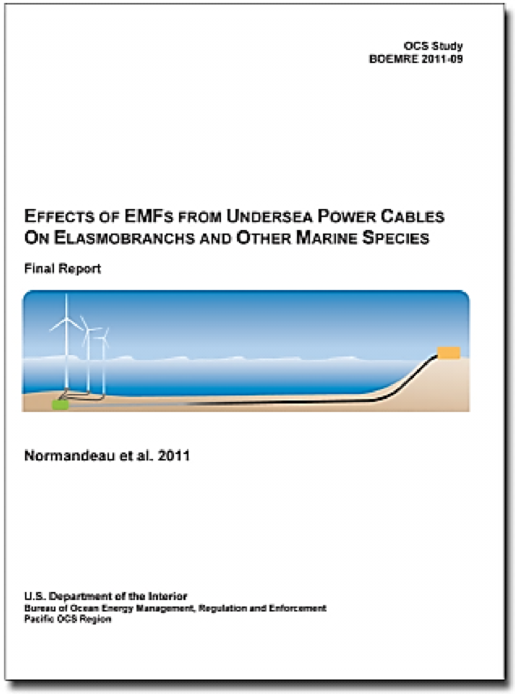




EMF Literature Studies

- EMFs from power cables can be modeled if specific information is available:
  - Cable design
  - Anticipated burial depth and layout
  - Magnetic permeability of the sheathing
  - Anticipated electrical loading range

- Behavioral responses of animals to EMF are known for only a few species


OCS Study
BOEMRE 2011-09

EFFECTS OF EMFS FROM UNDERSEA POWER CABLES ON ELASMOBRANCHS AND OTHER MARINE SPECIES

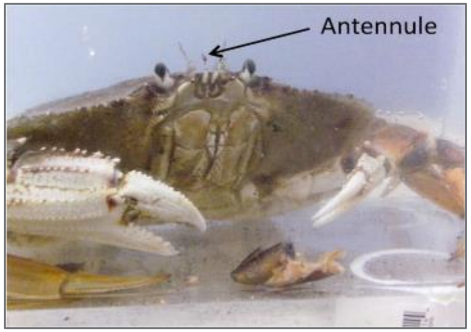
Final Report

Normandeau et al. 2011

U.S. Department of the Interior
Bureau of Ocean Energy Management, Regulation and Enforcement
Pacific OCS Region

Laboratory studies for response to EMF:

- Little evidence to indicate distinct or extreme behavioral responses in the presence of elevated EMF at 3 mT (3000 µT) for the species tested
- Several developmental and physiological responses were observed in the fish exposures, although most were not statistically significant
- Several movement and activity responses were observed in the crab experiments
- There may be possible developmental and behavioral responses to even small environmental effects; however, further replication is needed in the laboratory as well as field verification



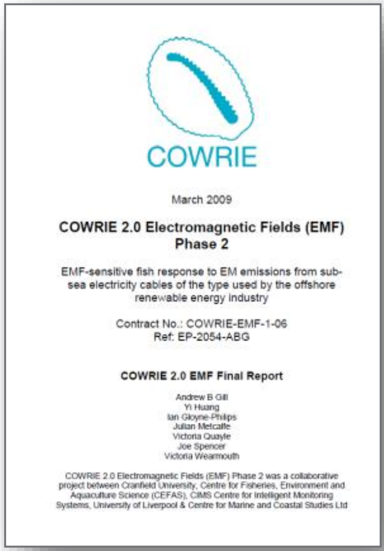
(Schultz et al. 2010; Wilson and Woodruff 2011; Woodruff et al. 2013)

EMF Fields Studies

EMF-Sensitive Fish Response to EM Emissions from Subsea Electricity Cables

- Mesocosms with energized and control cables
- No evidence of positive or negative effect on catsharks (dogfish)
- Benthic elasmobranchs (skates) responded to EMF in cable

(Gill et al. 2009)


COWRIE

March 2009

COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2

EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry

Contract No.: COWRIE-EMF-1-06
Ref: EP-2054-ABG

COWRIE 2.0 EMF Final Report

Andrew B Gill
Yi Huang
Ian Gloyne-Philips
Julian Metcalfe
Victoria Quayle
Joe Spencer
Victoria Wearmouth

COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2 was a collaborative project between Cranfield University, Centre for Fisheries, Environment and Aquaculture Science (CEFAS), CIMS Centre for Intelligent Monitoring Systems, University of Liverpool & Centre for Marine and Coastal Studies Ltd


Fisheries Management and Ecology

Sub-sea power cables and the migration behaviour of the European eel

H. WESTERBERG & I. LAGENFELT

Sub-sea Power Cables and the Migration Behaviour of the European Eel

- Used acoustic tags to track small movements of eels across energized cable
- Eels swam more slowly over energized cable
- Effect was small, no evidence of barrier effect

(Westerberg and Lagenfelt 2008)

EMF Fields Studies

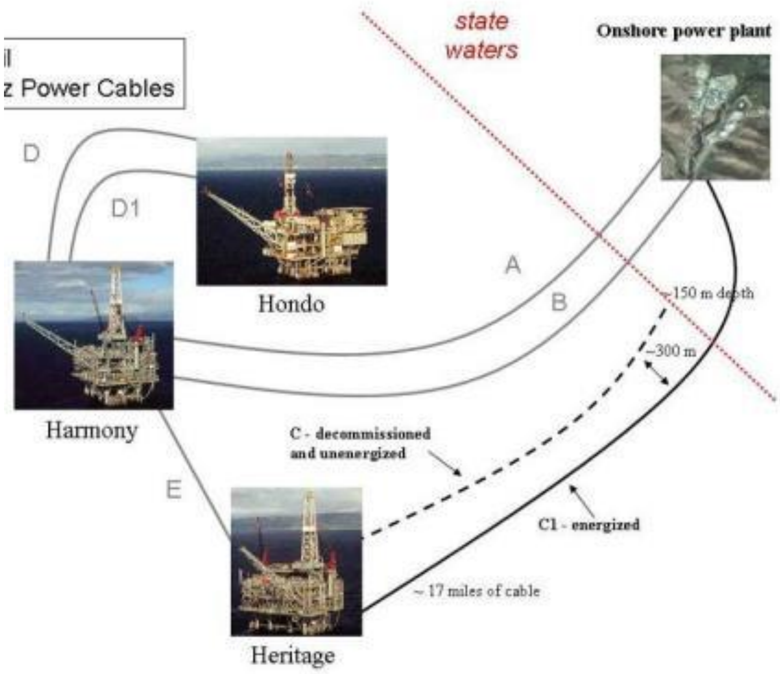
Renewable Energy *in situ* Power Cable Observation

- Measure EMF for energized and unenergized cables; determine attraction/avoidance of fish and invertebrates to the EMF; examine mitigation effectiveness for buried cable

- No response from fish or macroinvertebrates to EMF from a 35 kV AC *in situ* power transmission cable

(Love et al. 2016)

- Measured EMF fit modeling results



(Normandeau 2011)

EMF Fields Studies

MaRVEN – Environmental Impacts of Noise, Vibrations and Electromagnetic Emissions from MRE

- EMF from offshore wind turbine and export cables measurable during power generation
  - Wind turbine EMF considerably weaker
  - EMF higher for export cables to shore (compared to inter-turbine cables)
- EMF from AC cable within range of detection by sensitive receptor species
  - Magnetic field at the lower end, potentially outside detectable range
- Methods used showed EMF at biologically relevant levels can be observed

(Thompsen et al. 2015)

EMF Fields Studies

Electromagnetic Field Impacts on Elasmobranch and American Lobster Movement and Migration from Direct Current Cables

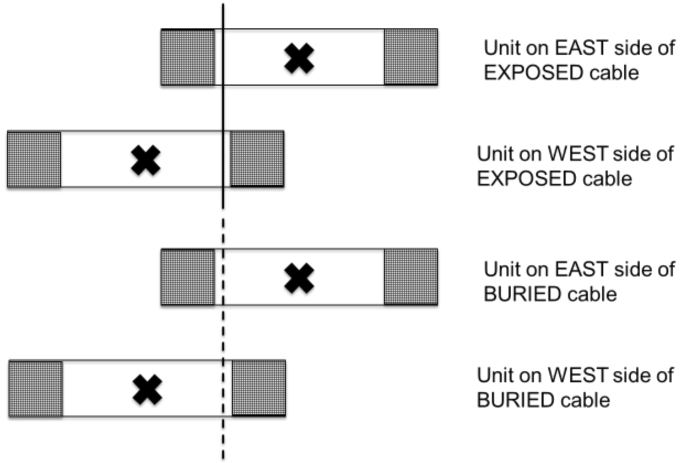
- Determine if EMF-sensitive animals react to HVDC cable, Long Island Sound
- Enclosures, acoustic tags
- Ongoing study

Potential Impacts of Submarine Power Cables on Crab Harvest

- Will rock crab (Santa Barbara channel) and Dungeness crab (Puget Sound) cross a power cable?
- Rock crabs cross an unburied 35 kV AC power cable
- Dungeness crabs will cross an unburied 69 kV AC power cable to enter baited commercial traps

EXPERIMENTAL SET UP IN BOTH STUDY AREAS

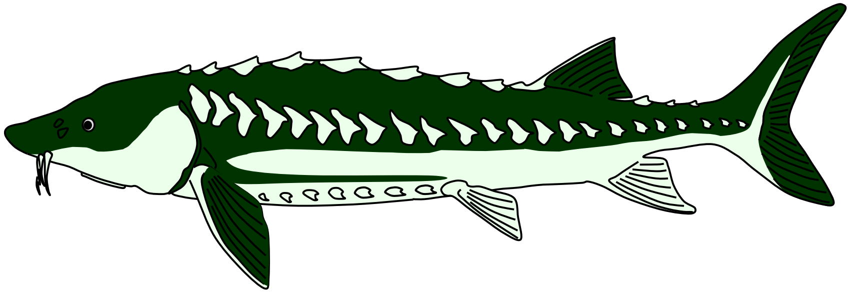
12 units, 3 replicates of each of 4 test conditions, were randomly placed along the cable



EMF Fields Studies

Assessment of Potential Impact of Electromagnetic Fields (EMF) from Undersea Cable on Migratory Fish Behavior

- HVDC cable in San Francisco Bay, parallel or perpendicular to green & white sturgeon, salmon, steelhead smolt migrations
- Tagged fish, magnetometer surveys
- Outcome – such large magnetic signatures from bridges, other infrastructure, could not distinguish cable!
- Fish did not appear to be affected



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Information on Benthic Habitat Changes from MRE Devices

Videos and data courtesy of Sarah Henkel, OSU/PMEC; Brian Polagye, UW/PMEC

Benthic Habitat Changes from MRE devices

- Presence of devices and parts (anchor lines, cables, etc.) on the seafloor and in the water column may alter marine habitats

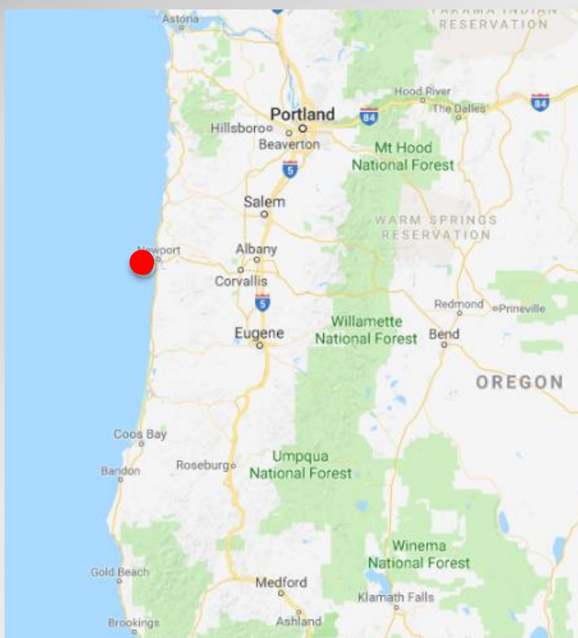
- Might affect marine organisms by:
  - Changing behavior or attracting organisms
  - Modifying/eliminating species in a localized area
  - Providing new opportunities for colonization
  - Altering patterns of species succession

- Analogous to other industries
  - Answer is to avoid rare and important habitats

Photo: Donna Schroeder, BOEM

West Coast Bottom Habitat

- Pacific Marine Energy Center, OR (OSU test center)
- 50 m deep
- Continental shelf, soft bottom



West Coast Bottom Habitat

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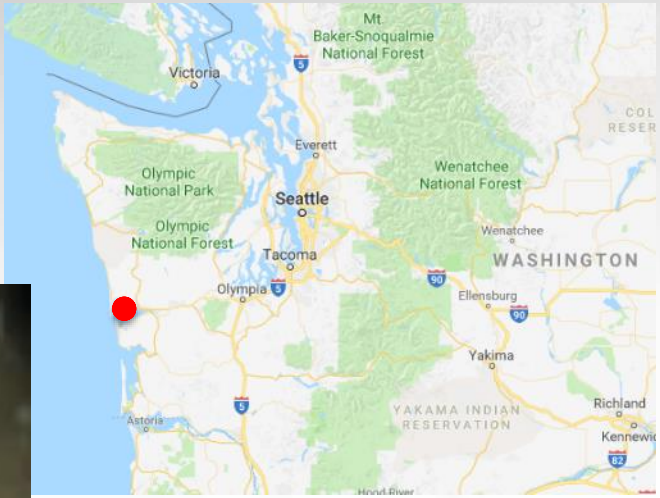
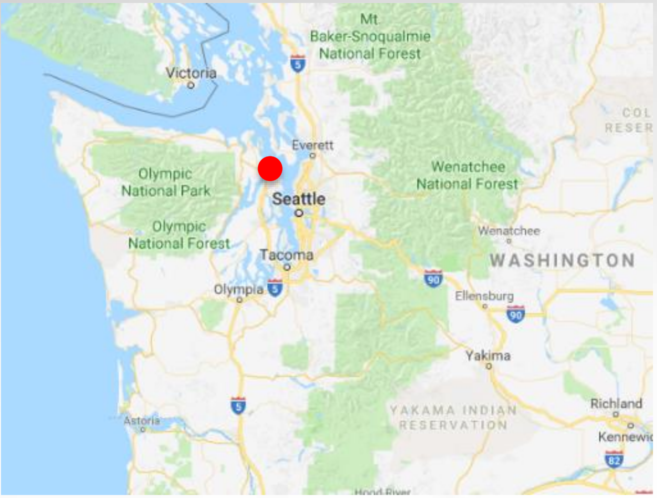
- Grays Harbor, WA
- 70 m deep
- Continental shelf, soft bottom



West Coast Bottom Habitat

- Admiralty Inlet, Puget Sound, WA
- 50-60 m deep
- Cobble bottom, fast current



Discussion

- What do the data tell you?
- What portions of these data are applicable in your jurisdiction/what could you use? Could you use these data for locations in your jurisdiction?
- What is lacking/missing from the data? What else would you need to satisfy monitoring data requirements (for this interaction)?
- What background information (metadata) would you need to see to set the context for your use of these data?

Information on Physical Systems Changes from MRE Devices

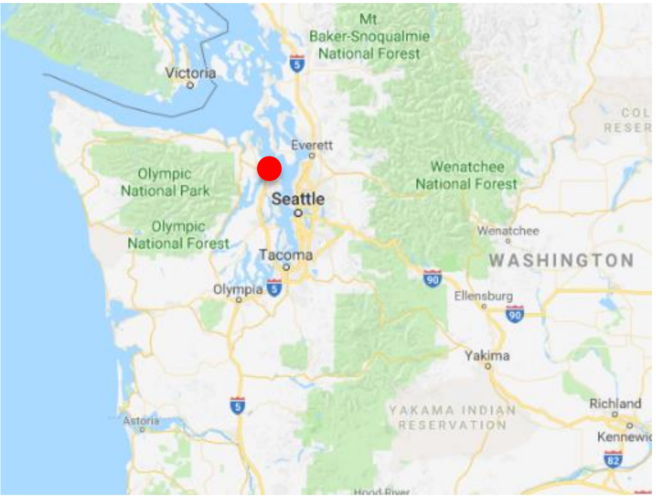
Data courtesy of
Zhaoqing Yang and Taiping Wang, PNNL

Effects of Physical Systems

- Changes in water flow, wave heights
- Effects from single MRE devices too small to measure
- Might need to look at effects of arrays in future
- Rely on numerical modeling

Modeling Example for Tidal Development

- Tidal turbines in Puget Sound
- Potential environmental impacts
  - Water circulation, sediment transport and water quality
- Placing realistic turbine number in model
- Lack of validation data

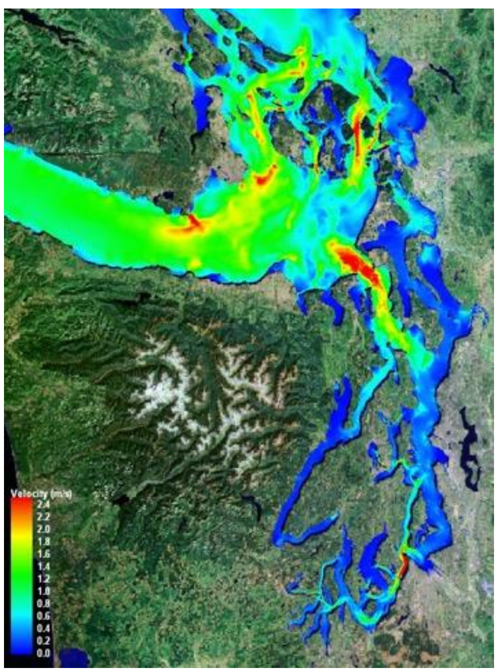


(Yang and Wang 2016)

Turbines in Tacoma Narrows

- Identify array location (high power density) and determine grid resolution
- Turbine diameter: 10 m; Turbine hub height: 10 m from seabed
- Local effect of energy extraction are measurable even with the 20-turbine farm

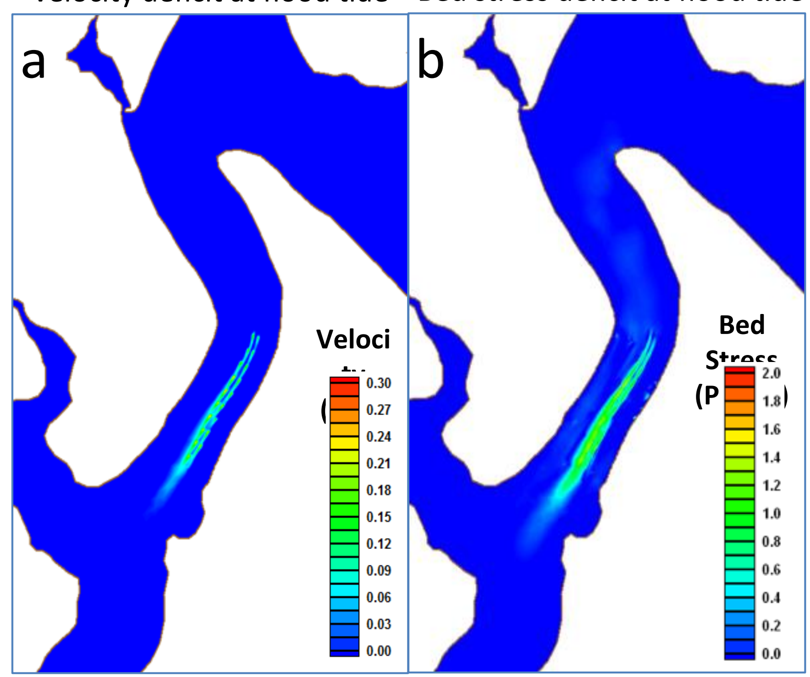
Max Velocity in Puget Sound



Modelling 20 turbines

Local effects near tidal farm

Velocity deficit at flood tide | Bed stress deficit at flood tide



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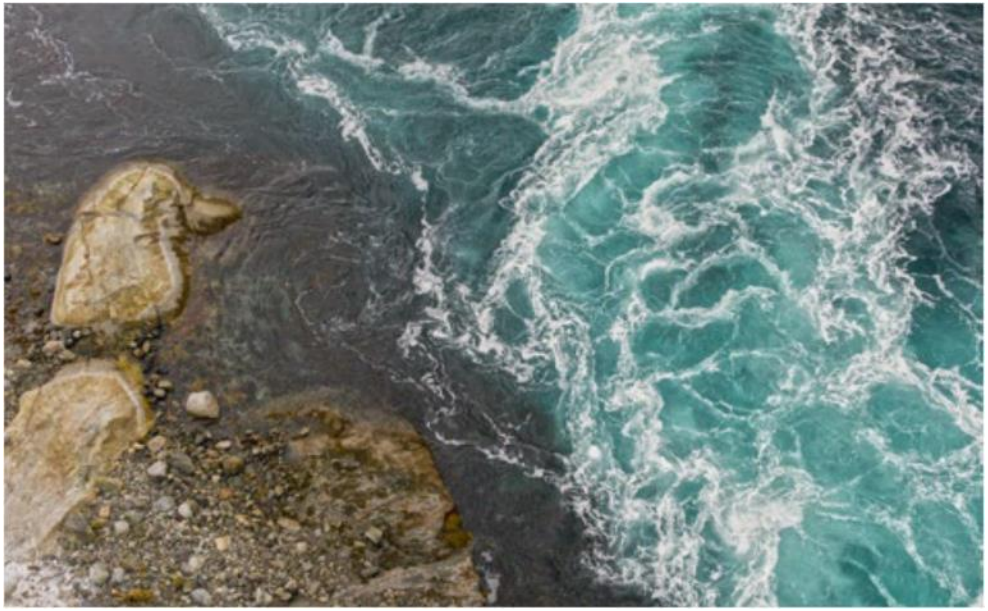

Framework for Data Transferability Annex IV proposes:

Data Transferability Framework

Framework must:

- Develop common understanding of data types and parameters to address potential effects of MRE development.
- Create best practices for consistent collection of data.
- Engage regulators to test framework, solicit input on acceptance for data transfer.
- Guide implementation of best practices for siting, permitting, post-installation monitoring, and mitigation.

Framework will consist of:

1. Method for describing environment, evaluating the comparability of data sets (MRE project archetypes);
2. Description for applying framework; and
3. Method for implementing framework, to support regulatory processes

Interactions (Stressors) for Data Transferability

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Stressors	MRE Technology
Collision Risk	Tidal
Underwater Noise	Wave and tidal
EMF	Wave and tidal
Changes in Benthic Habitat	Wave and tidal
Physical Systems	Wave and tidal

Marine Renewable Energy Project Archetypes

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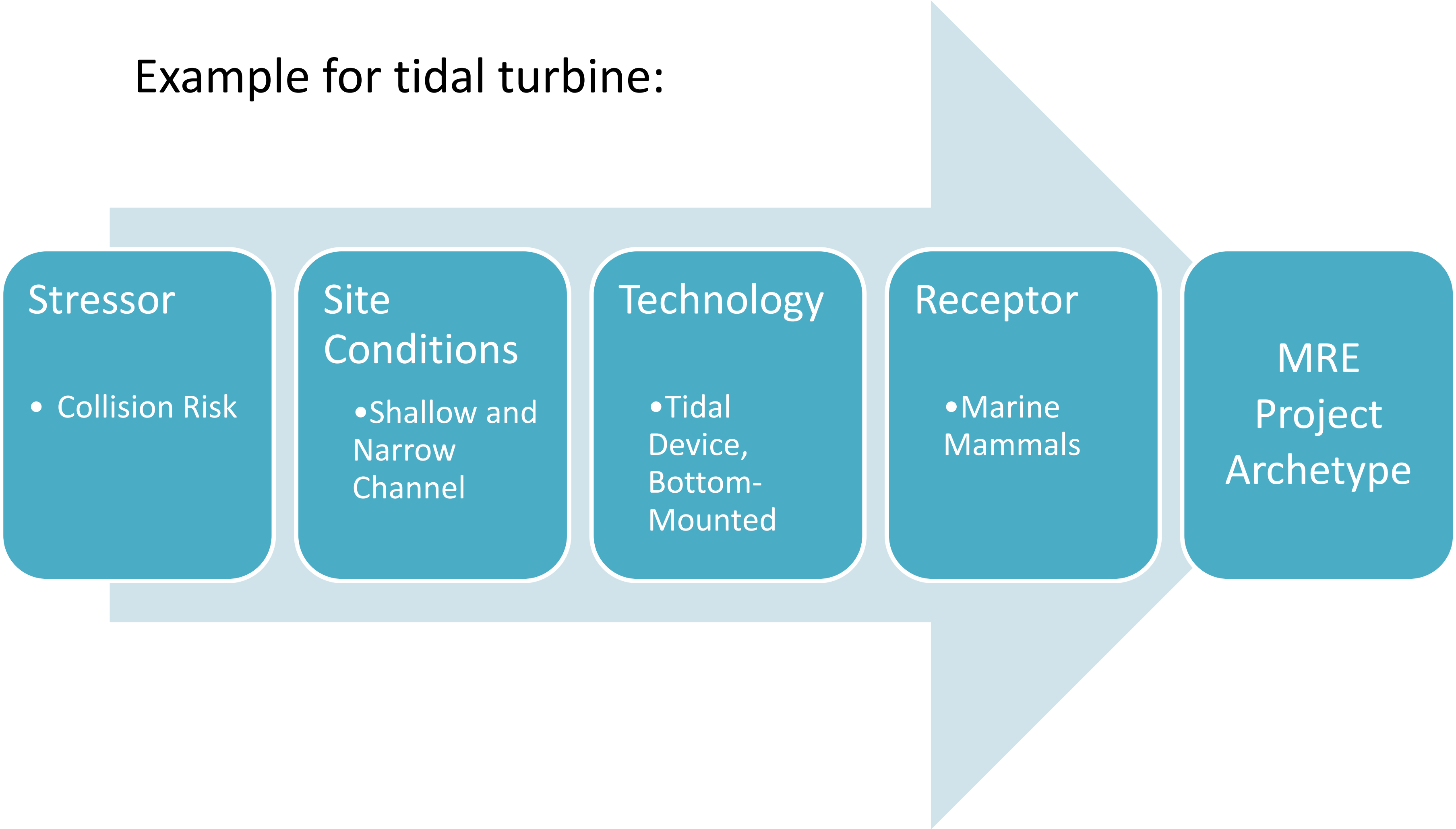
- Archetypes =
  - a very typical example
  - imitation of an original
- Learned from other industries - economics, transportation, ecology, and land system science

- Marine Renewable Energy Project Archetypes = MREPA
- “Like” MREPAs have highest potential for data transferability
- MREPA defined by 4 variables:
  - Stressor
  - Site conditions
  - MRE technology types
  - Receptor groups

Collision Risk MREPA for Origin Project Site

Example for tidal turbine:



Collision Risk MREPAs (22 archetypes)

Site Condition	Technology	Receptors
Shallow and Narrow Channels	Tidal Device, Bottom-Mounted	Marine Mammals
		Fish
		Diving Birds
	Tidal Device in the Water Column	Marine Mammals
		Fish
		Diving Birds
Shallow and Wide Channels	Tidal Device, Bottom-Mounted	Marine Mammals
		Fish
		Diving Birds
	Tidal Device in the Water Column	Marine Mammals
		Fish
		Diving Birds
Deep and Wide Channels	Tidal Device, Bottom-Mounted	Marine Mammals
		Fish
	Tidal Device in the Water Column	Marine Mammals
		Fish
		Diving Birds
Deep and Narrow Channels	Tidal Device, Bottom-Mounted	Marine Mammals
		Fish
	Tidal Device in the Water Column	Marine Mammals
		Fish
		Diving Birds

Shallow channels < 40m; Deep channels > 40 m; Narrow < 2 km; Wide > 2 km

Underwater Noise MREPAs (8 archetypes)

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Site Condition	Technology	Receptors
Isolated/Quiet Environment	Tidal Device	Marine Mammals
		Fish
	Wave Device	Marine Mammals
		Fish
Noisy Environment	Tidal Device	Marine Mammals
		Fish
	Wave Device	Marine Mammals
		Fish

Isolated/Quiet < 80 db; Noisy > 80 db

Electromagnetic Fields MREPAs (10 archetypes)

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Site Condition	Technology	Receptors
Buried Cables	Seafloor Cables	Elasmobranchs
		Mobile/Sedentary Invertebrates
Cables Laid on Seafloor	Seafloor Cables	Elasmobranchs
		Mobile/Sedentary Invertebrates
Shielded Cables	Seafloor Cables	Elasmobranchs
		Mobile/Sedentary Invertebrates
Unshielded Cables	Seafloor Cables	Elasmobranchs
		Mobile/Sedentary Invertebrates
	Draped cables	Elasmobranchs
		Mobile/Sedentary Invertebrates

Habitat Change MREPAs (9 archetypes)

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Site Condition	Technology	Receptors
Hard Bottom Habitat	Foundation/Anchors	Benthic Invertebrates
		Demersal Fish
		Shoaling Fish
Soft-Bottom Habitat	Foundation/Anchors	Benthic Invertebrates
		Demersal Fish
		Shoaling Fish
Water Column	Floats/Mooring Lines	Marine Mammals and Sea Turtles
		Demersal Fish
		Shoaling Fish

Physical Systems MREPAs (4 archetypes)

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Site Condition	Technology	Receptors
Enclosed Basin	Tidal Device	Sediment Transport
		Water Quality/Food Web
Open Coast	Wave Device	Sediment Transport
		Water Quality/Food Web

Transferability potential

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Necessary

- Same MREPA
- Same receptor species (or closely related)

Preferred

- Similar technology
- Similar wave/tidal resource

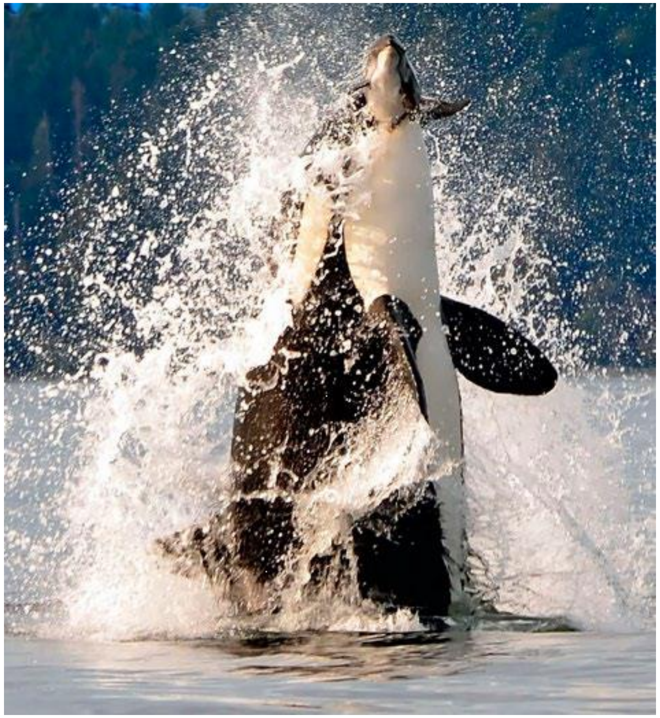
Optional

- Close geographical proximity

Feedback

- Does the framework make sense?
- Is the hierarchy useful to you?
- Could you make use of this framework?
- Can you suggest other groups of regulators who might be interested?

Next Steps



- Series of meetings/workshops with regulators in US and abroad
- Gather together feedback, modify framework, use of information
- International workshop in June with industry and researchers
  - Share input from regulators, framework
  - Develop best practices
- Culminate in report late 2018
- Web-based tool for MREPAs possible

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Thank you!

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U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

OES OCEAN ENERGY SYSTEMS

ANNEX IV