Data Transferability and Data Collection Consistency for Marine Renewable Energy Development

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Pacific Northwest National Laboratory

Online Workshops
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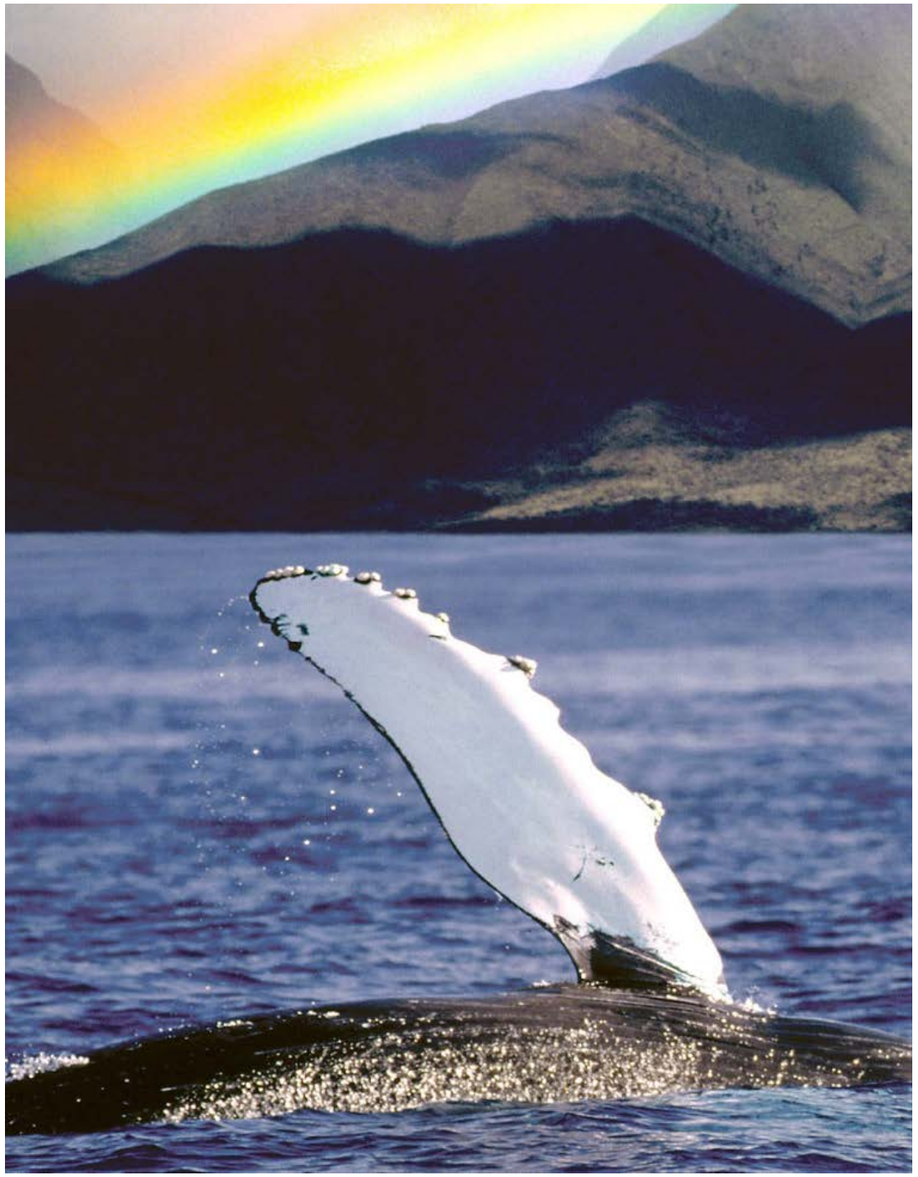
Today's workshop

- Why are we here and what do we hope to get out of today?

Agenda:

- Introductions
  - Purpose of the workshop
  - Introduction to the topics
- Dataset and information exploration
- Data Transferability Process
- Next steps



Who are we? Why are we here?

- Work for PNNL, DOE national lab
- DOE Water Power Technology Office (WPTO), part of the Office of Energy Efficiency and Renewable Energy
  - Responsible for marine renewable energy (MRE, MHK), and hydropower
- Here representing Annex IV:
  - Collaborative task under IEA Ocean Energy Systems
  - 15 countries part of Annex IV
  - Environmental effects of MRE
  - Continued major theme: Data Transferability & Collection Consistency

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 statutes
    - Make decisions on applications for MRE projects
- And that the regulatory process is key for getting devices deployed
  - Learning more as we go

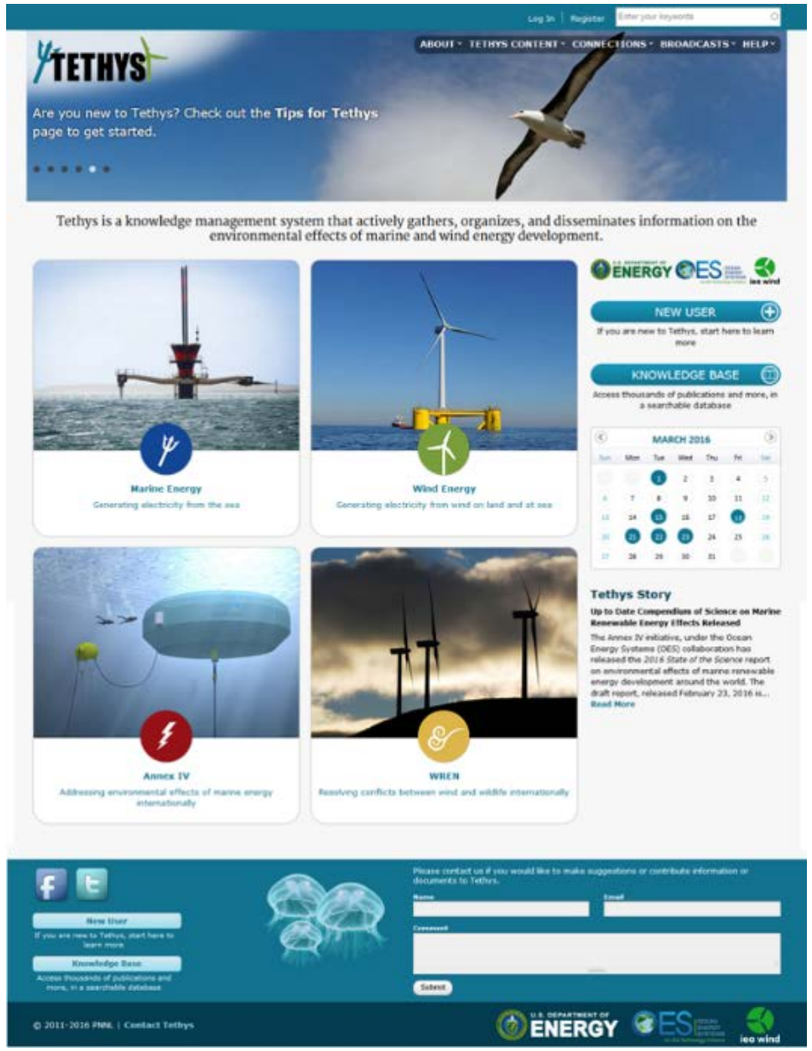
Data Transferability and Collection Consistency

- What do we mean by “data transferability”?
- What about “data 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, ocean thermal energy conversion, and 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?

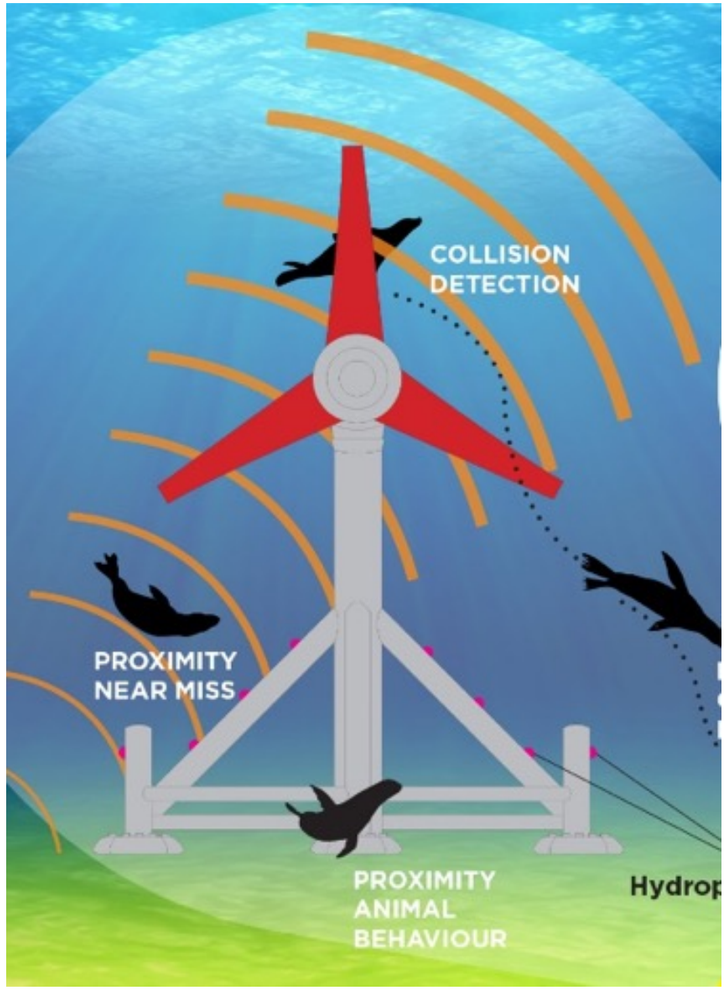
- Walk through types of information that represent the major interactions of concern:
  - Collision risk
  - Underwater noise effects
  - Electromagnetic fields (EMF) effects
  - Habitat changes
  - Changes to physical systems
  - Barrier effects
- Present our Data Transferability Process
  - We want your thoughts!
- Next Steps

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)



(ORE Catapult, 2016)

Atlantis Andritz turbine

- EMEC (Pentland Firth, Scotland)
- 1.5 MW
- Depth: 35 – 100 m
- Blade length: 8 m
- Speed: 10 rpm

Voith turbine at EMEC

- EMEC (Pentland Firth, Scotland)
- 1 MW
- Depth: 35 m
- Blade length: 6 m

ORPC In-stream River Turbine

- Igiugig, Alaska
- 50 kW
- ORPC RivGen
- Cross-flow, horizontal axis turbine

ORPC In-stream River Turbine

- Igiugig, Alaska
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- ORPC RivGen
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Adaptable Monitoring Package (AMP) PMEC

- Sequim Bay, WA
- Platform for multiple sensors, data acquisition
- Depth: 12 m
- In lieu of a turbine

Diver inspection of AMP

Active acoustic monitoring multi-beam sonar:
Interaction between fish and seal observed on acoustic camera

Active acoustic monitoring multi-beam sonar

Target tracking example (seal)

Active acoustic monitoring multi-beam sonar

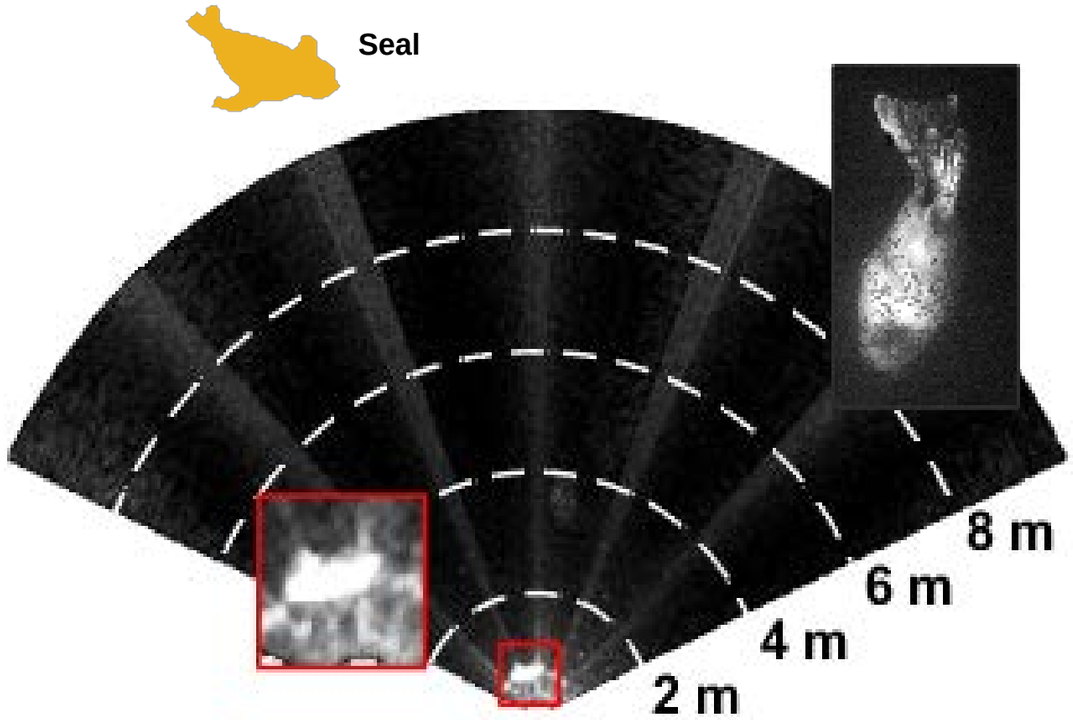
Fish scattering observed on acoustic camera when strobe lights are illuminated

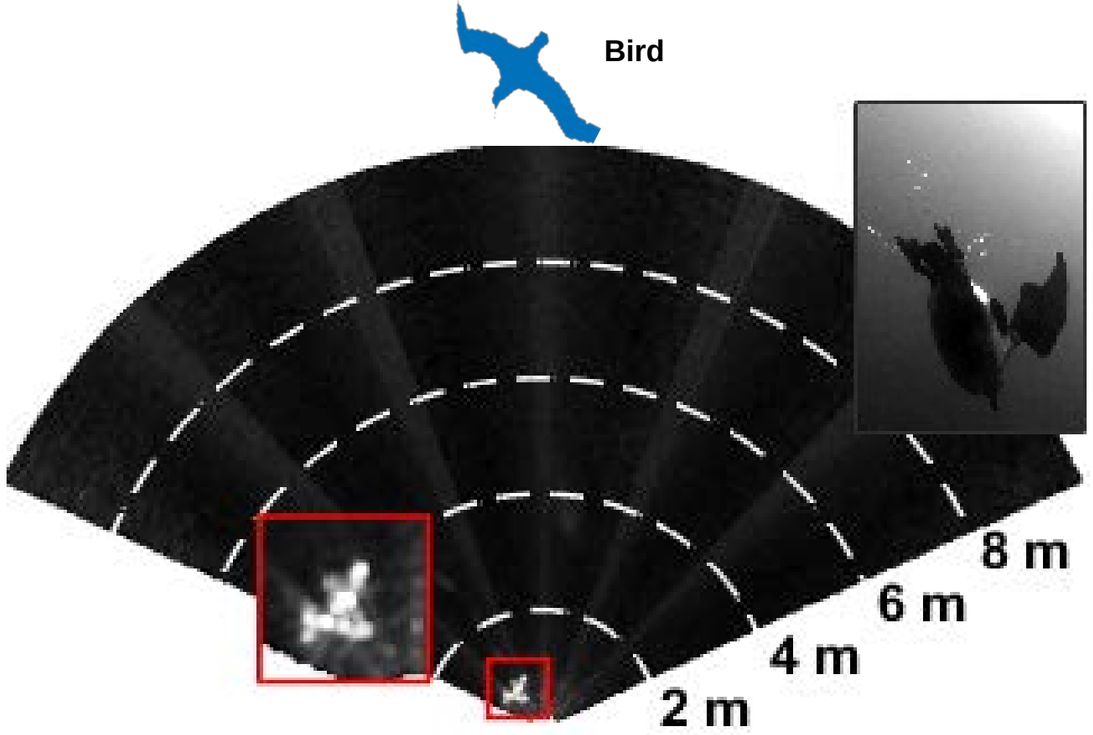
Active acoustic monitoring multi-beam sonar

Interaction between fish and seal observed on acoustic camera

Active acoustic monitoring multi-beam sonar

Triggered optical camera detections of a seal and a diving bird





Discussion and Feedback

- 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)?
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Information on Underwater Noise from MRE Devices

Videos and data courtesy of
Brian Polagye, UW/PacWave 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

Regulatory Thresholds

- Marine Mammals
  - NOAA Technical Guidance (2018)

Table 6: TTS onset 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 thresholds.

	PTS Onset Thresholds* (Received Level)	
Hearing Group	**Impulsive**	**Non-impulsive**
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{p,0\text{-pk,flat}}$: 219 dB $L_{E,p,\,LF,24h}$: 183 dB	*Cell 2* $L_{E,p,\,LF,24h}$: 199 dB
Mid-Frequency (MF) Cetaceans	*Cell 3* $L_{p,0\text{-pk,flat}}$: 230 dB $L_{E,p,\,MF,24h}$: 185 dB	*Cell 4* $L_{E,p,\,MF,24h}$: 198 dB
High-Frequency (HF) Cetaceans	*Cell 5* $L_{p,0\text{-pk,flat}}$: 202 dB $L_{E,p,HF,24h}$: 155 dB	*Cell 6* $L_{E,p,\,HF,24h}$: 173 dB
Phocid Pinnipeds (PW) (Underwater)	*Cell 7* $L_{p,0\text{-pk.flat}}$: 218 dB $L_{E,p,PW,24h}$: 185 dB	*Cell 8* $L_{E,p,PW,24h}$: 201 dB
Otariid Pinnipeds (OW) (Underwater)	*Cell 9* $L_{p,0\text{-pk,flat}}$: 232 dB $L_{E,p,OW,24h}$: 203 dB	*Cell 10* $L_{E,p,OW,24h}$: 219 dB

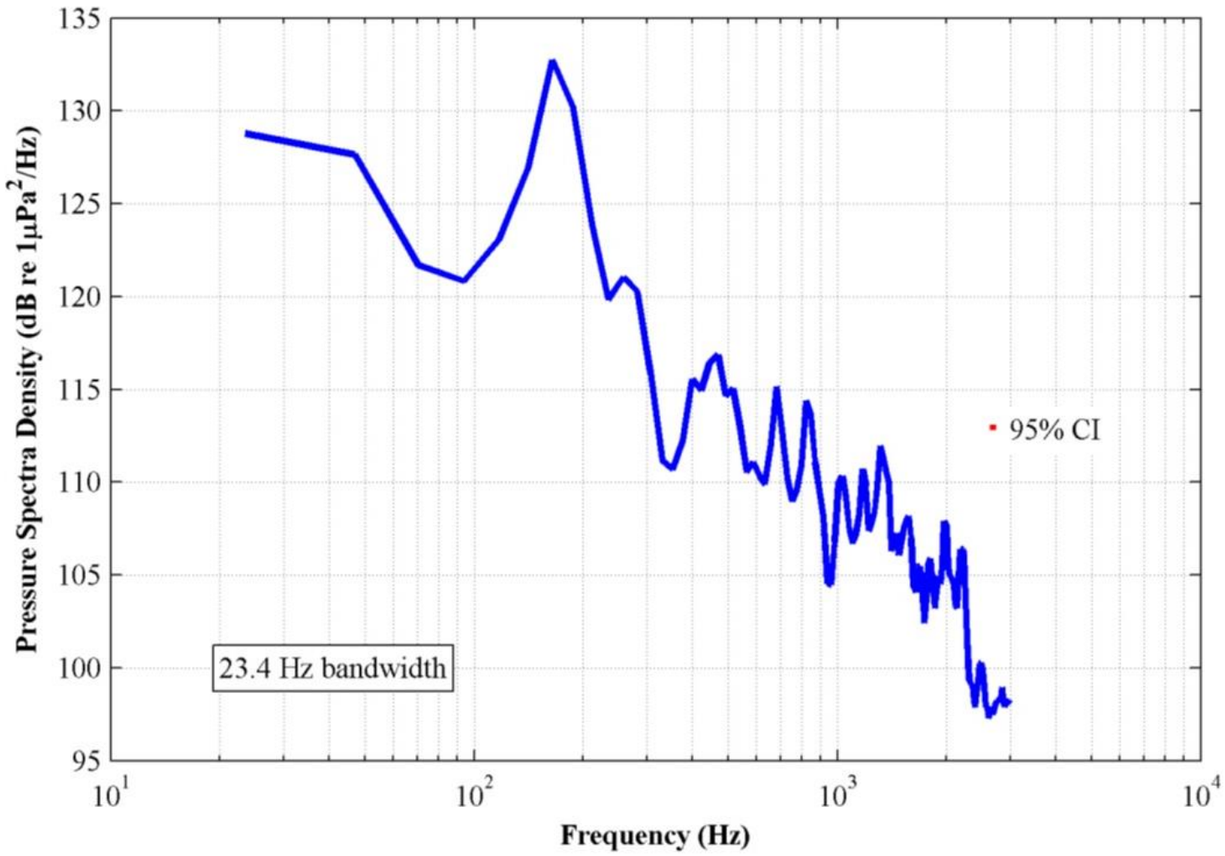
- Fish
  - NOAA Fisheries (Salmon & Bull Trout)
  - BOEM Underwater Acoustic Modeling Report (2013)

Table 3. Interim Fisheries Cause and Effect Guidelines

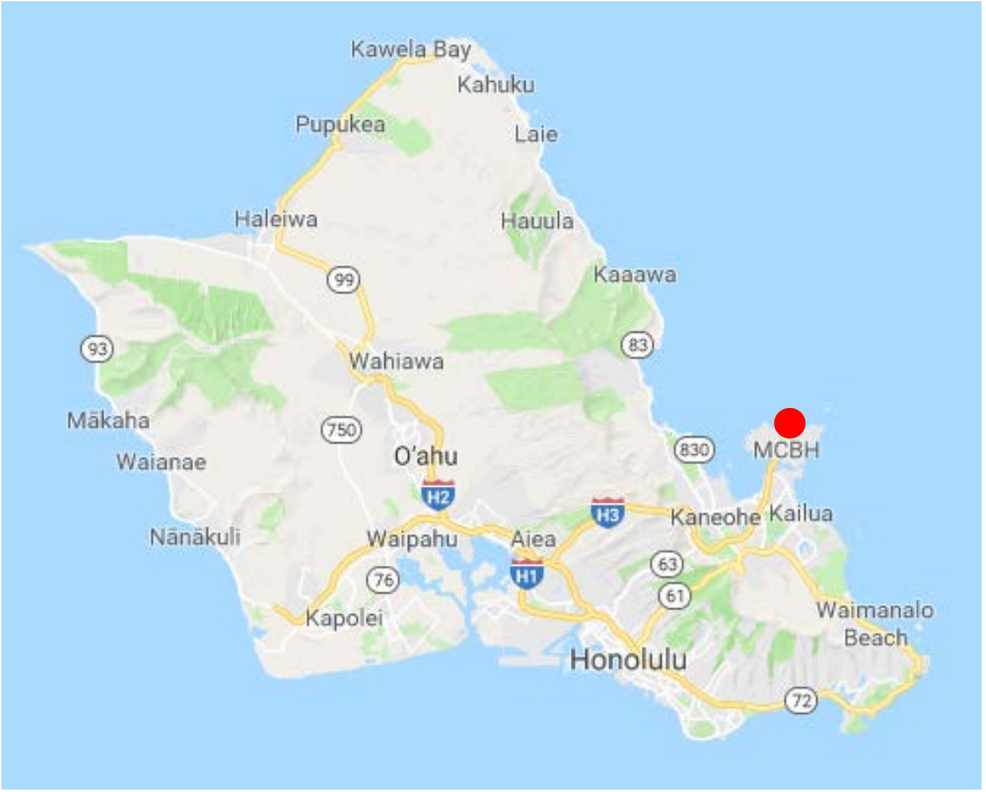
	Criteria Level	Type
Physiological Effects	206 dBL re 1 μPa	Absolute Peak SPL
	187 dBL re 1 μPa²s	SEL_{cum}, For fishes above 2 grams (0.07 ounces)
	183 dBL re 1 μPa²s	SEL_{cum}, For fishes below 2 grams (0.07 ounces)
Behavioral Effects	150 dBL re 1 μPa (RMS)	Absolute
Reference: U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM). Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities, Literature Synthesis, 2012		

OpenHydro turbine at EMEC

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

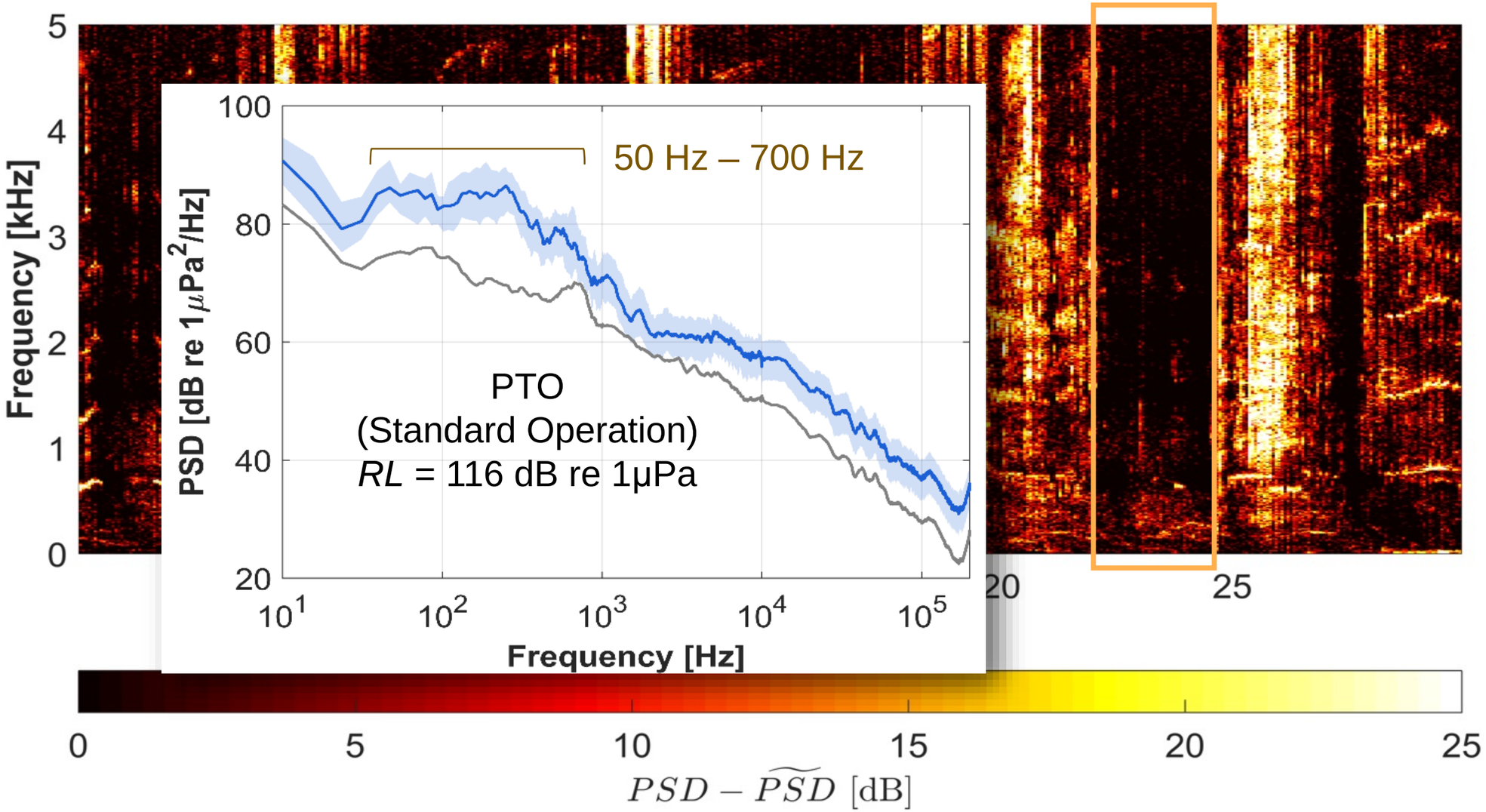


Fred Olsen Lifesaver

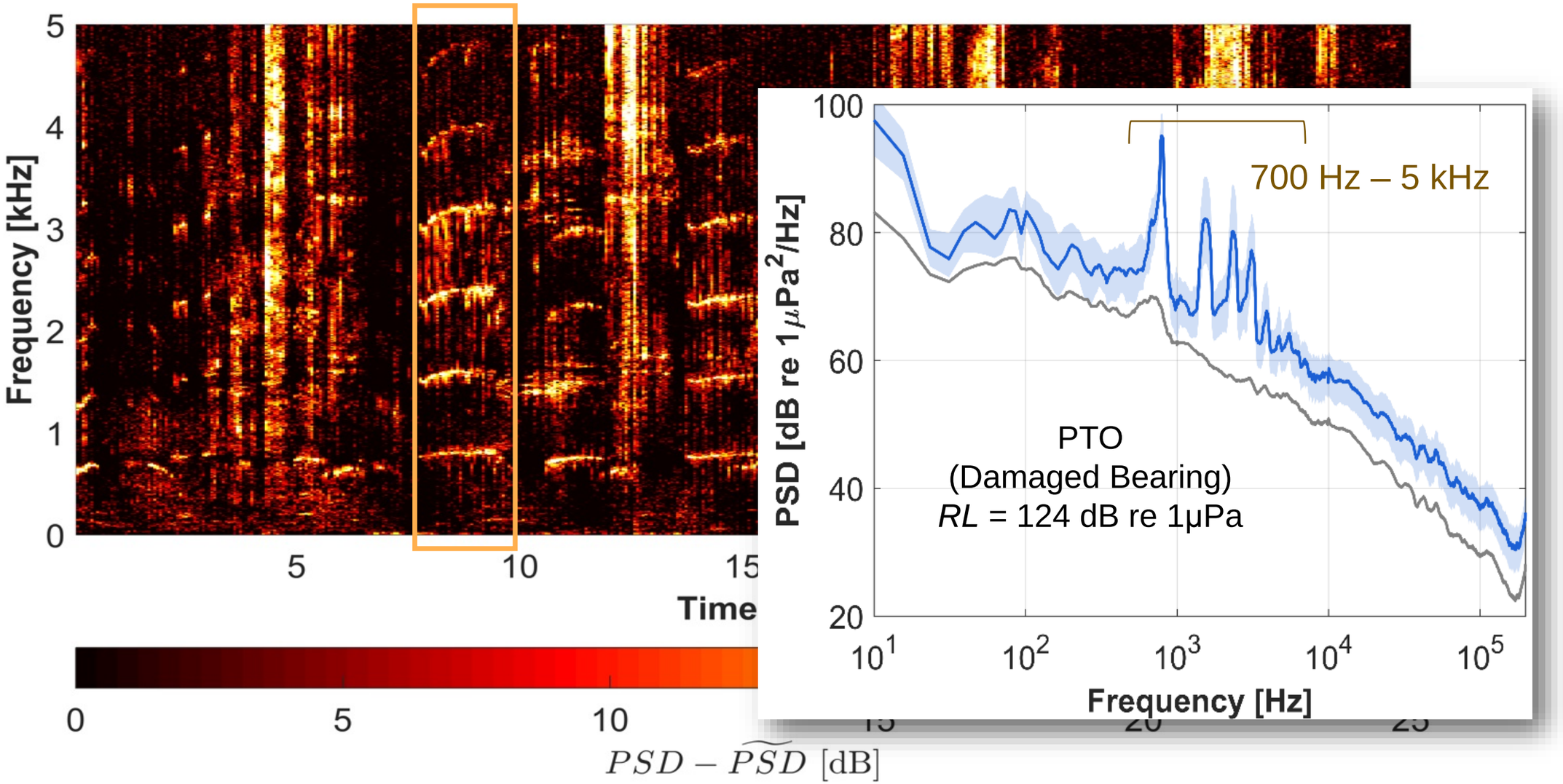


- Hawai'i WETS
- Point absorber
- Shallow draft (0.5 m)

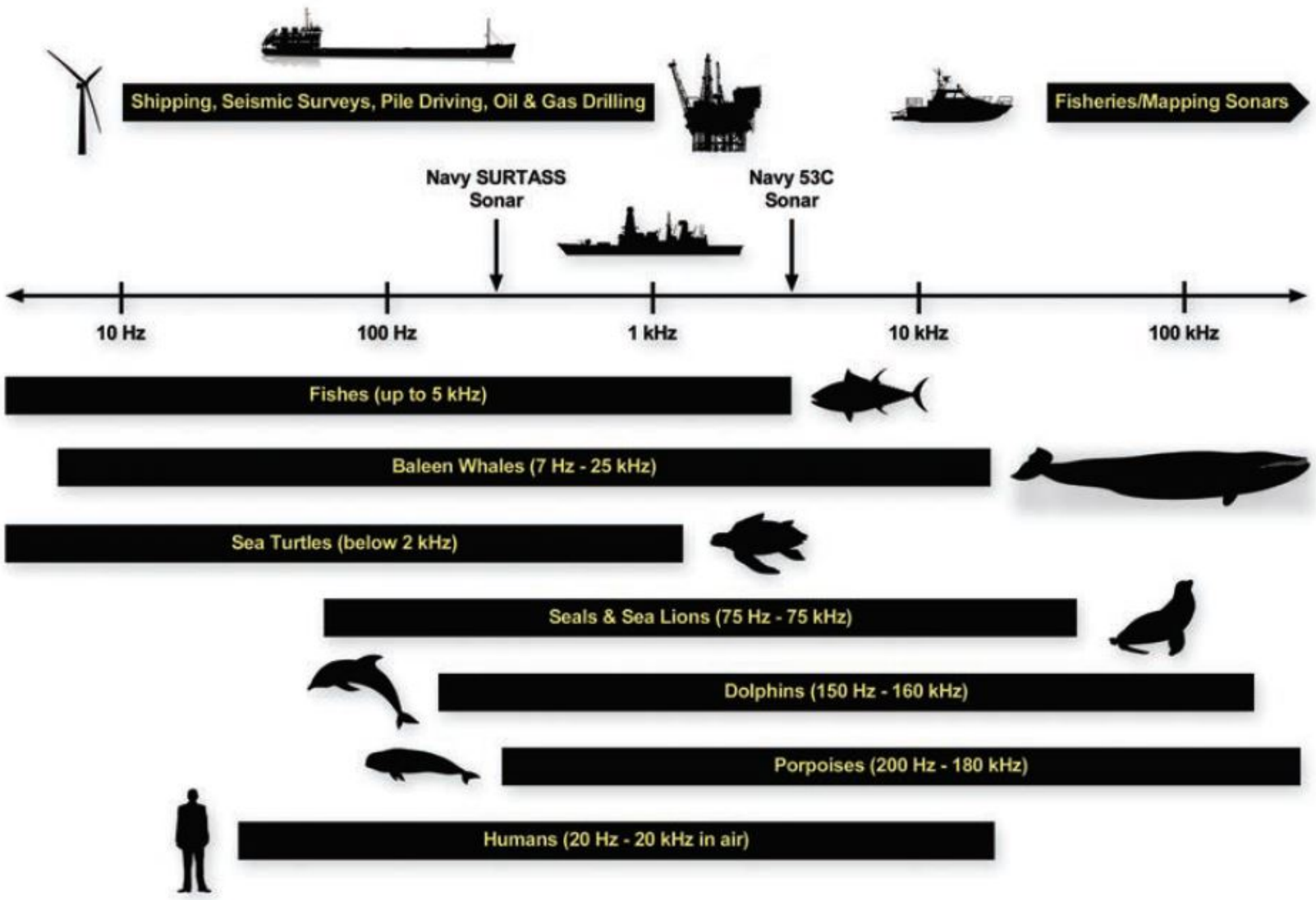
Acoustic Characteristics



Acoustic Characteristics



Hearing thresholds for marine animals and anthropogenic noise levels



(Scholik-Schlomer 2015)

Discussion and Feedback

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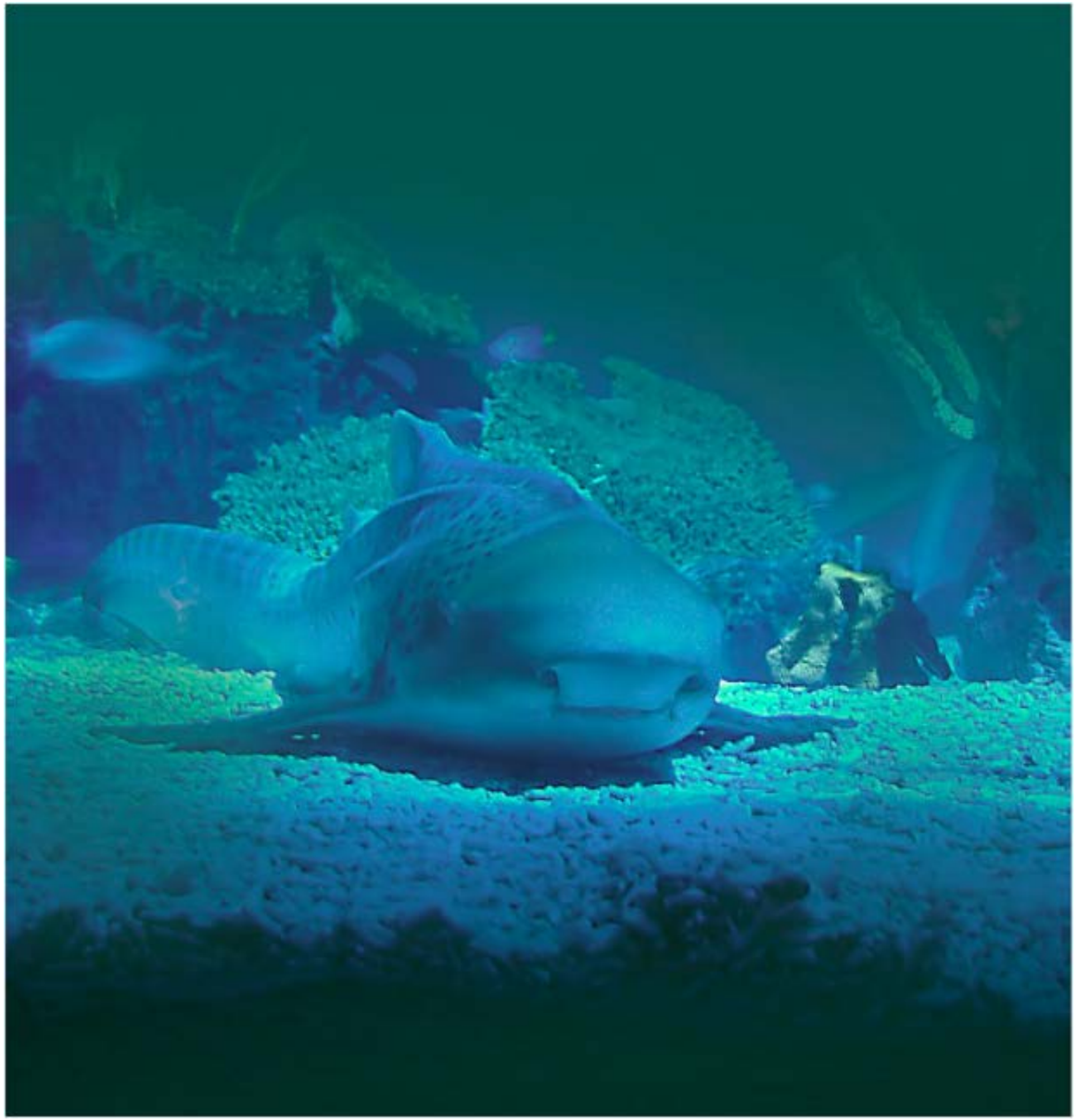
Information on EMF Impacts on Marine Animals from Exports Power Cables

Credit to Ann Bull, BOEM for many of the slides
And many many researchers

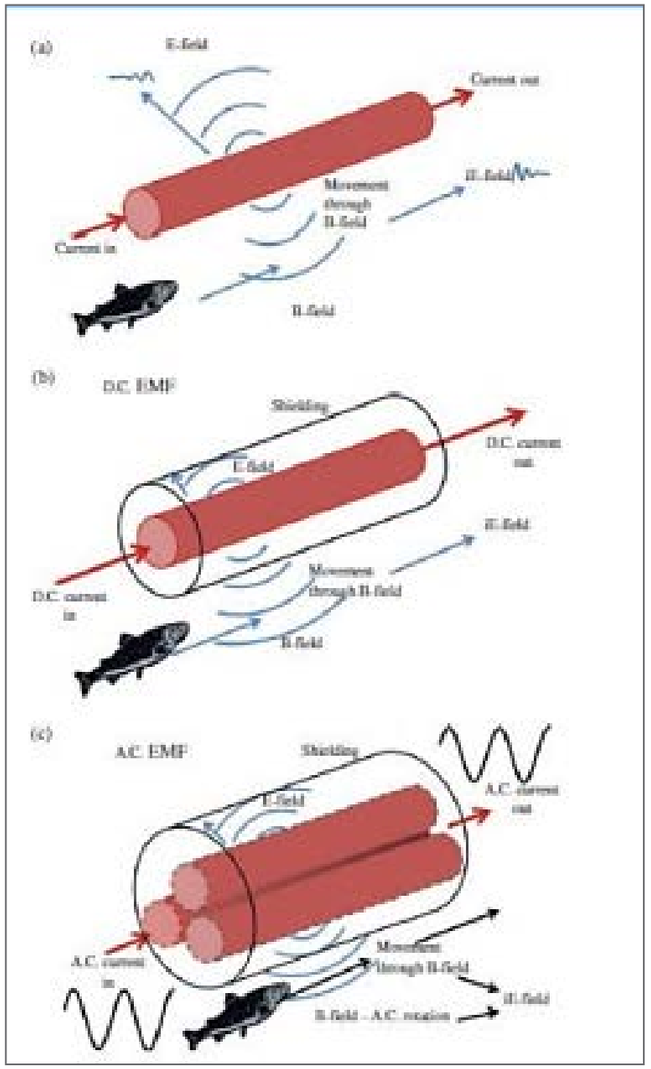


Electromagnetic Fields

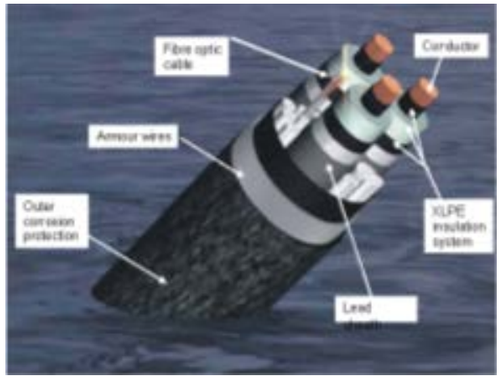
- Anthropogenic EMF signatures come from a variety of marine infrastructure (subsea cables, bridges, tunnels, etc.)
- MRE emits EMF signatures from power cables, moving parts of devices, and underwater substations or transformers
- May affect organisms that use natural magnetic field for orientation, 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

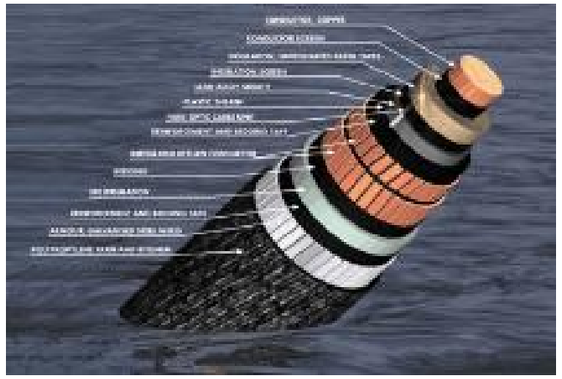
Electromagnetic Fields From AC and DC Power Cables

- Similar to cables used in the offshore wind industry
  - Export cable is typically 13kV AC cable capable of up to 250MW
  - Inter-array cables are typically 33kV AC cables
  - Where possible, cables are buried to 1-3m depth
  - Industry starting to use large DC cables for distances greater than 80km (less transmission loss)
- Cables used by MRE projects
  - Size varies by project, but all smaller than typical wind
  - Most common cable is 11kV AC, buried to 1m depth
- All cables are electrically shielded
  - But the magnetic field is not blocked and generates an induced electric field



AC Cable



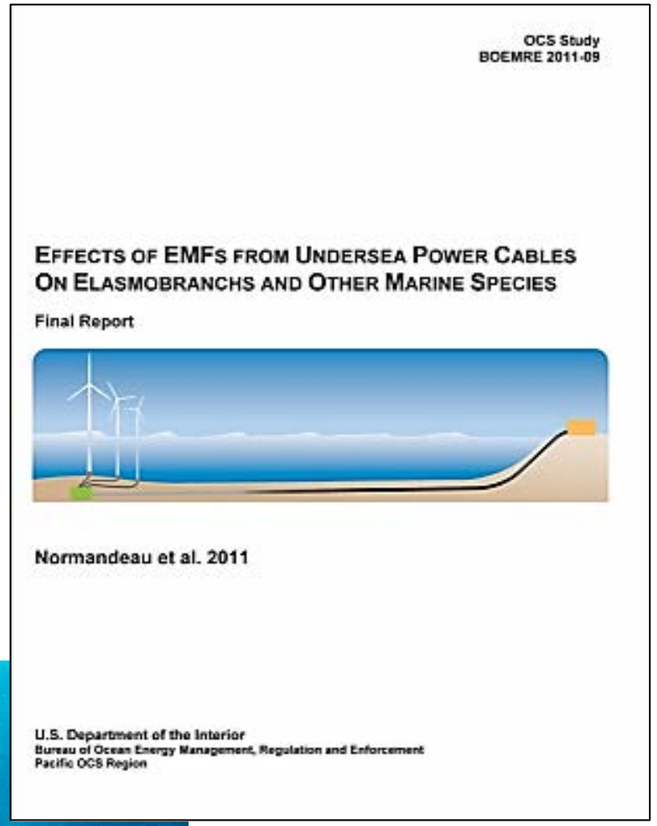


DC Cable

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

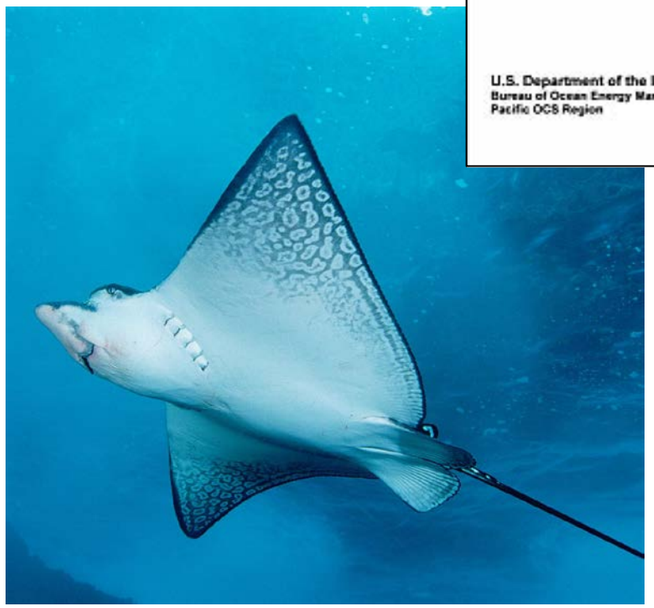

OCS Study
BOEMRE 2011-09

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

Final Report

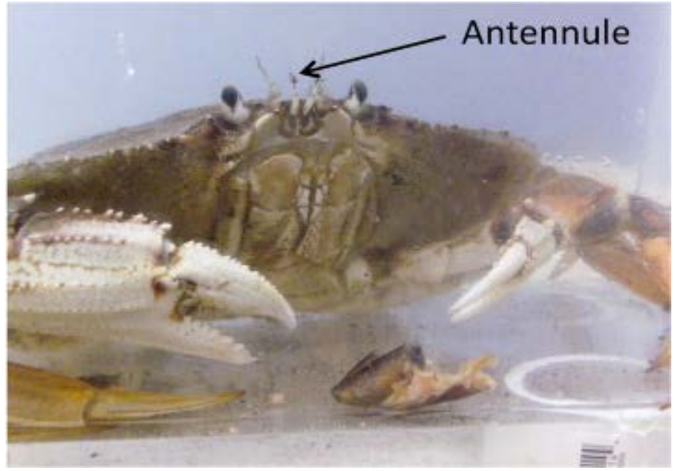
Normandeau et al. 2011

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



EMF Laboratory Studies

- 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



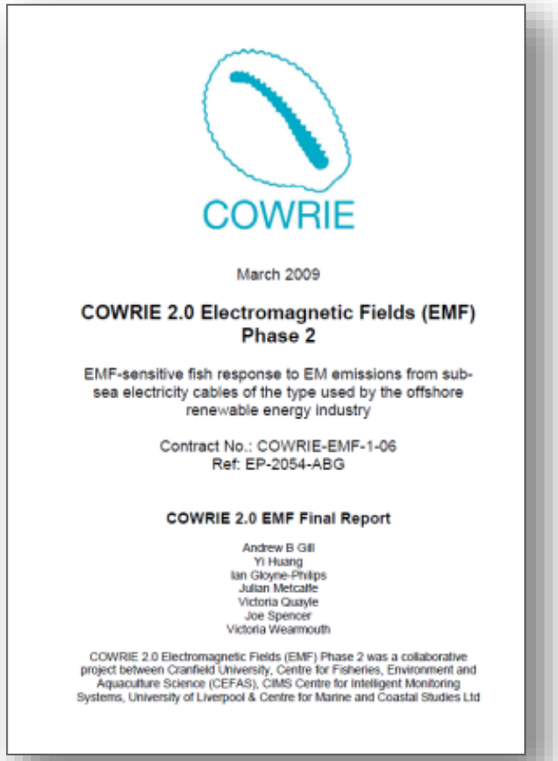
(Schultz et al. 2010; Woodruff et al. 2013)

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

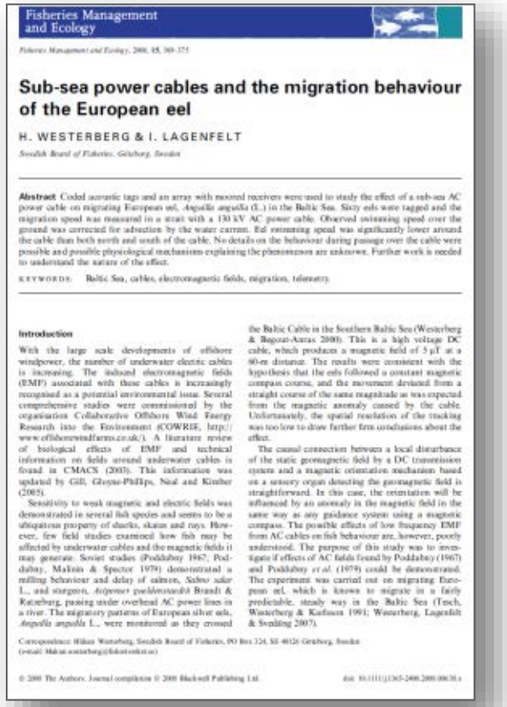
EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry

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

Fisheries Management and Ecology, 2008, 15, 369–375

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

H. WESTERBERG & I. LAGENFELT

Swedish Board of Fisheries, Göteborg, Sweden

Abstract Codel acoustic tags and an array with moored receivers were used to study the effect of a sub-sea AC power cable on migrating European eel, *Anguilla anguilla* (L.) in the Baltic Sea. Sixty eels were tagged and the migration speed was measured in a strait with a 130 kV AC power cable. Observed swimming speed over the ground was corrected for advection by the water current. Eel swimming speed was significantly lower around the cable than both north and south of the cable. No details on the behaviour during passage over the cable were possible and possible physiological mechanisms explaining the phenomenon are unknown. Further work is needed to understand the nature of the effect.

KEYWORDS: Baltic Sea, cables, electromagnetic fields, migration, telemetry.

Introduction

With the large scale developments of offshore windpower, the number of underwater electric cables is increasing. The induced electromagnetic fields (EMF) associated with these cables is increasingly recognised as a potential environmental issue. Several comprehensive studies were commissioned by the organisation Collaborative Offshore Wind Energy Research into the Environment (COWRIE, http://www.offshorewindfarms.co.uk/). A literature review of biological effects of EMF and technical information on fields around underwater cables is found in CMACS (2003). This information was updated by Gill, Gloyne-Phillips, Neal and Kimber (2005).

Sensitivity to weak magnetic and electric fields was demonstrated in several fish species and seems to be a ubiquitous property of sharks, skates and rays. However, few field studies examined how fish may be affected by underwater cables and the magnetic fields it may generate. Soviet studies (Poddubny 1967; Poddubny, Malkin & Spector 1979) demonstrated a milling behaviour and delay of salmon, *Salmo salar* L., and sturgeon, *Acipenser gueldenstaedtii* Brandt & Ratzeburg, passing under overhead AC power lines in a river. The migratory patterns of European silver eels, *Anguilla anguilla* L., were monitored as they crossed the Baltic Cable in the Southern Baltic Sea (Westerberg & Begout-Anras 2000). This is a high voltage DC cable, which produces a magnetic field of 5 μT at a 60-m distance. The results were consistent with the hypothesis that the eels followed a constant magnetic compass course, and the movement deviated from a straight course of the same magnitude as was expected from the magnetic anomaly caused by the cable. Unfortunately, the spatial resolution of the tracking was too low to draw further firm conclusions about the effect.

The causal connection between a local disturbance of the static geomagnetic field by a DC transmission system and a magnetic orientation mechanism based on a sensory organ detecting the geomagnetic field is straightforward. In this case, the orientation will be influenced by an anomaly in the magnetic field in the same way as any guidance system using a magnetic compass. The possible effects of low frequency EMF from AC cables on fish behaviour are, however, poorly understood. The purpose of this study was to investigate if effects of AC fields found by Poddubny (1967) and Poddubny *et al.* (1979) could be demonstrated. The experiment was carried out on migrating European eel, which is known to migrate in a fairly predictable, steady way in the Baltic Sea (Tesch, Westerberg & Karlsson 1981; Westerberg, Lagenfelt & Svedäng 2007).

Correspondence: Håkan Westerberg, Swedish Board of Fisheries, PO Box 324, SE 40126 Göteborg, Sweden (e-mail: Hakan.westerberg@fiskeriverket.se)

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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)

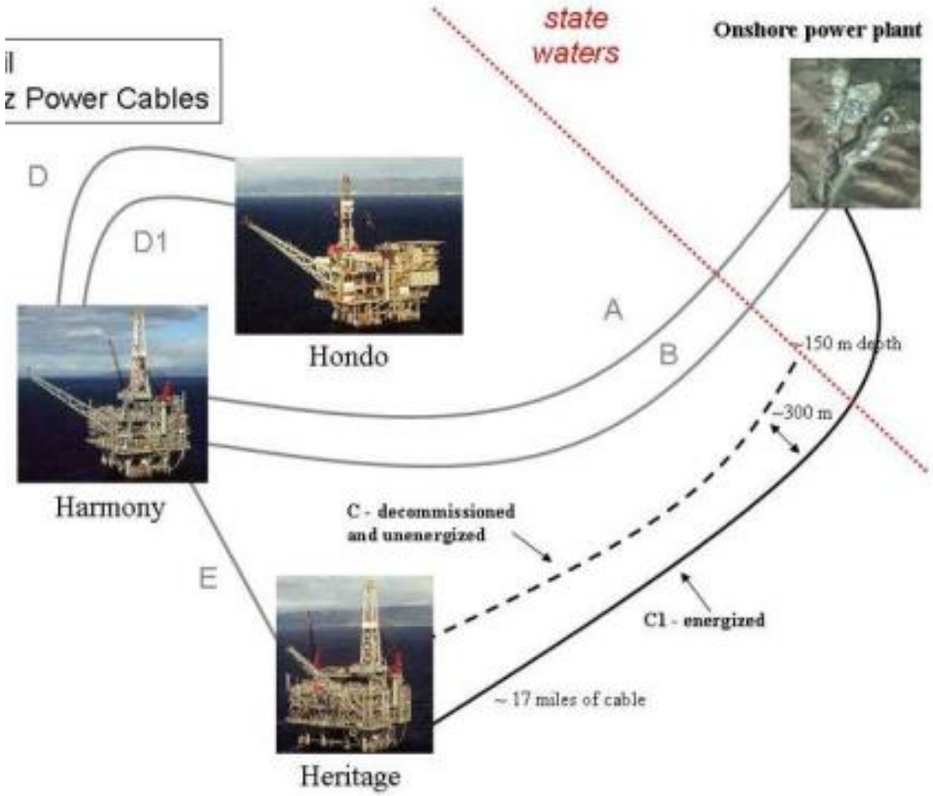
EMF Fields Studies

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 et al. 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

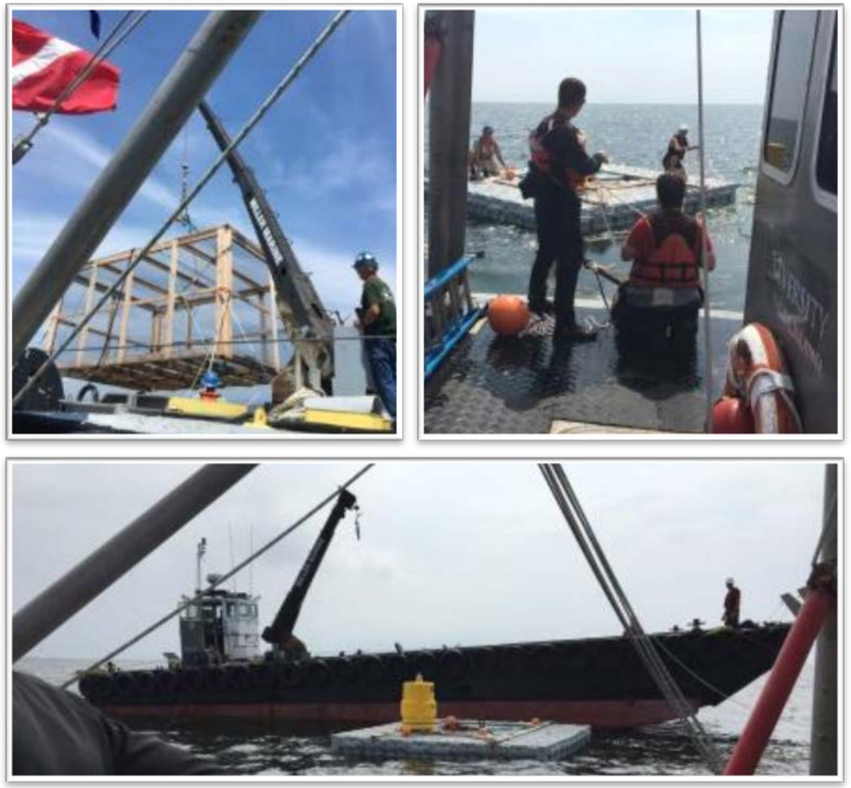
(Thomsen et al. 2015)

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 with animals using acoustic telemetry tags
- AC components measured from DC cable
- Lobster – statistically significant, but subtle change in behavior
- Skate – strong behavioral response, results suggested an increase in exploratory activity and/or area restricted foraging behavior with EMF
- EMF from cable didn't act as a barrier to movement for either species

(Hutchison et al., 2018)



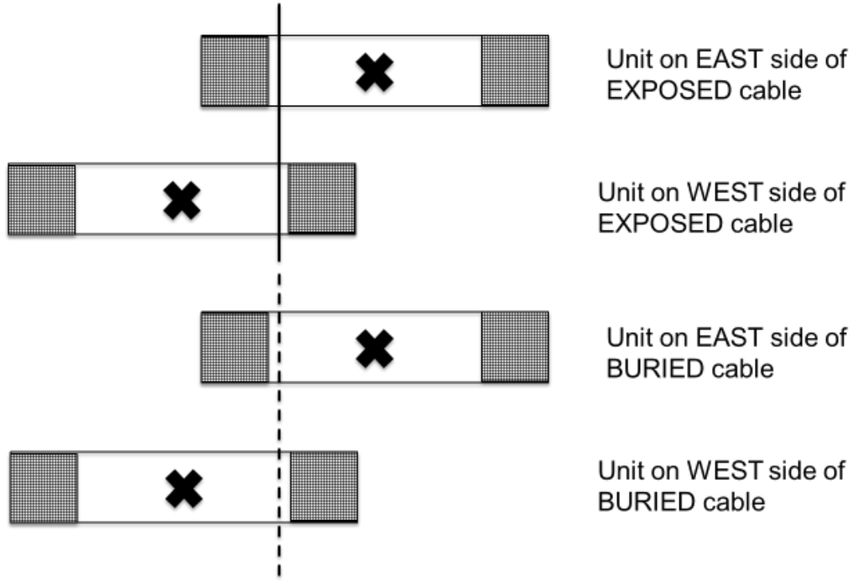
EMF Fields Studies

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 (Love et al., 2017)

EXPERIMENTAL SET UP IN BOTH STUDY AREAS

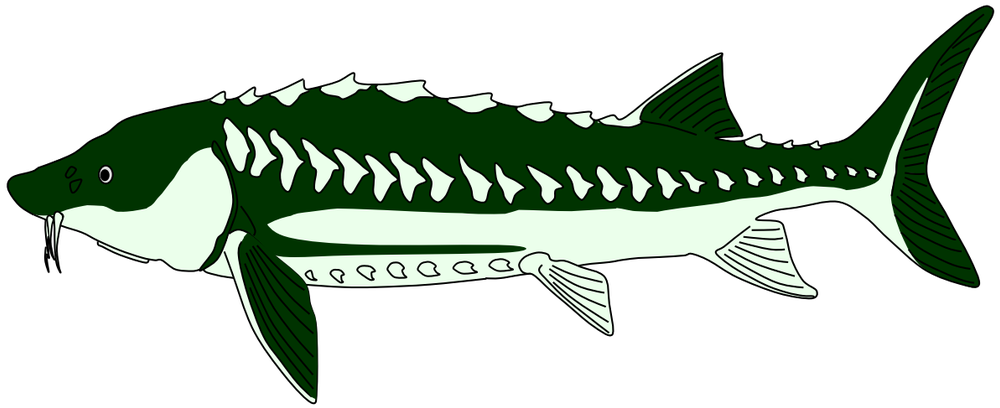
12 units, 3 replicates of each of 4 test conditions, were randomly placed along the cable



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 (Kavet et al., 2016)



Discussion and Feedback

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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

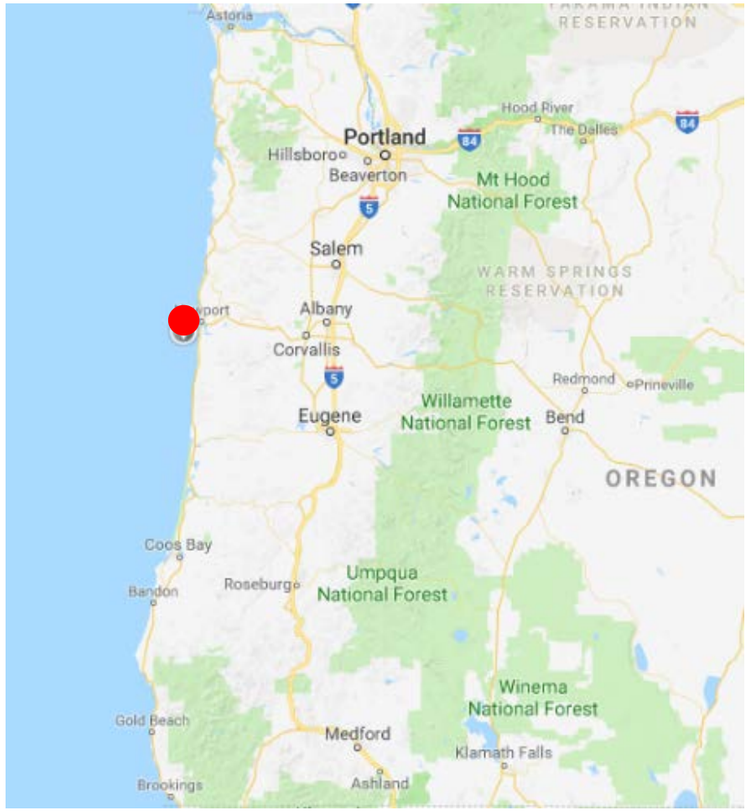
- Might affect marine organisms by:
  - Changing behavior or attracting organisms
  - Modifying/eliminating species in a localized area
  - Providing new opportunities for colonization
  - Altering patterns of species succession

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

Photo: Donna Schroeder, BOEM

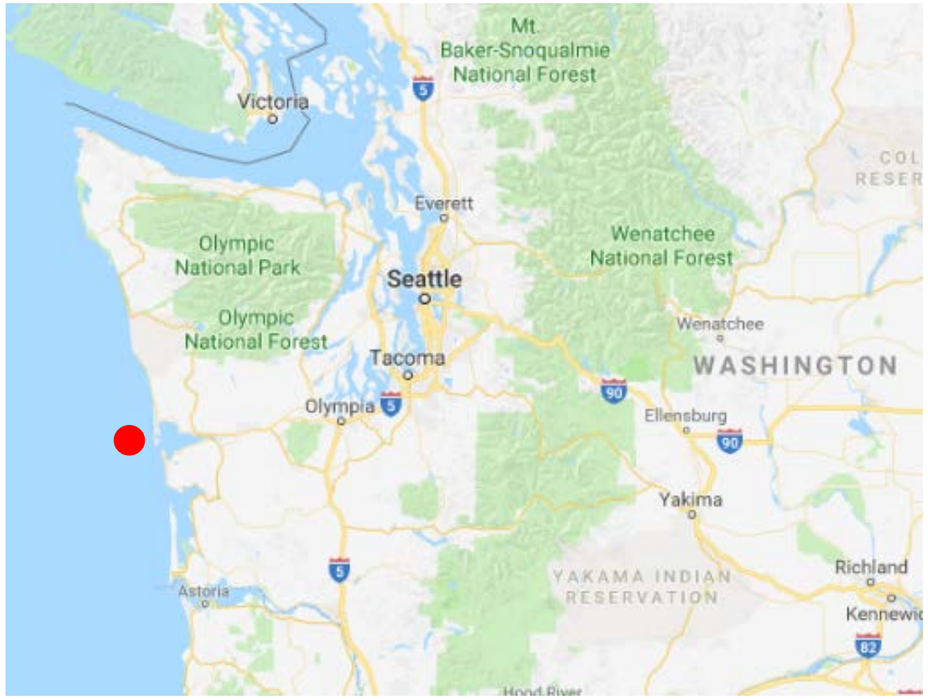
West Coast Bottom Habitat

- PacWave, OR (OSU test center)
- 50 m deep
- Continental shelf, soft bottom



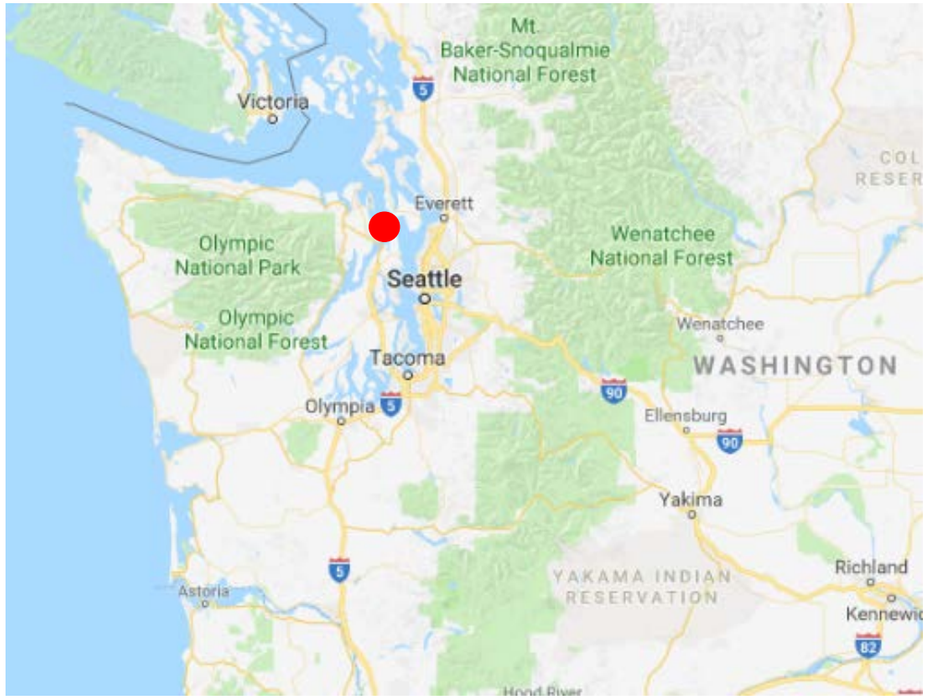
West Coast Bottom Habitat

- 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 and Feedback

- 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

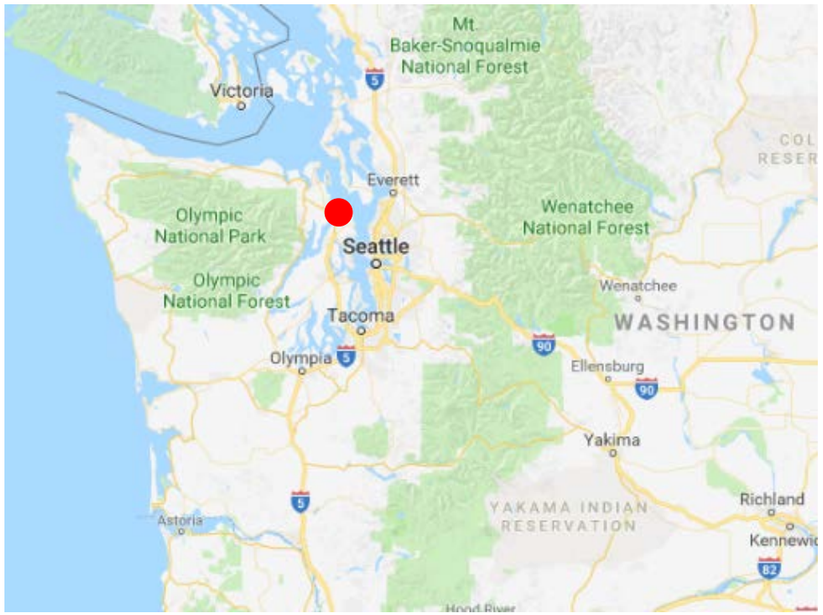
Data courtesy of
Zhaoqing Yang and Taiping Wang, PNNL

Effect 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

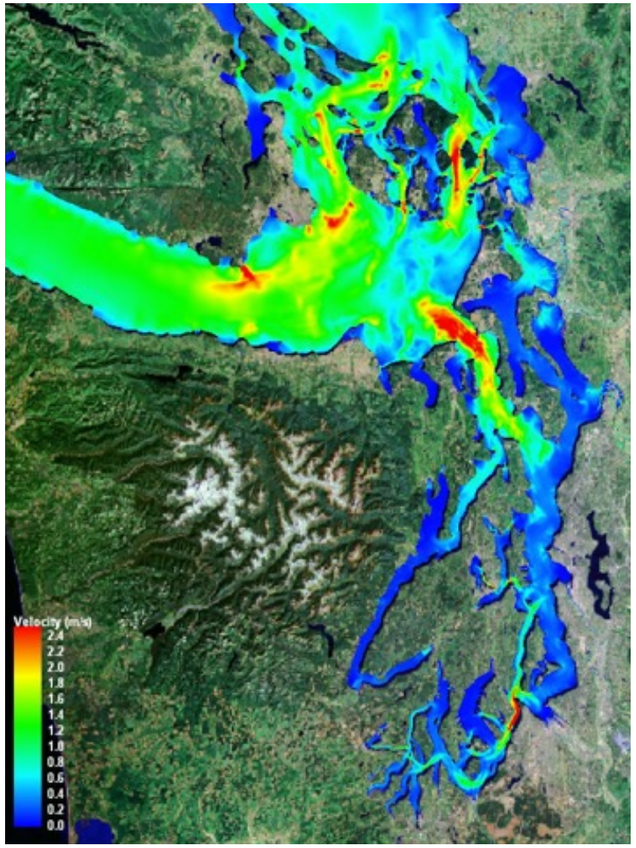


(Yang and Wang 2016)

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

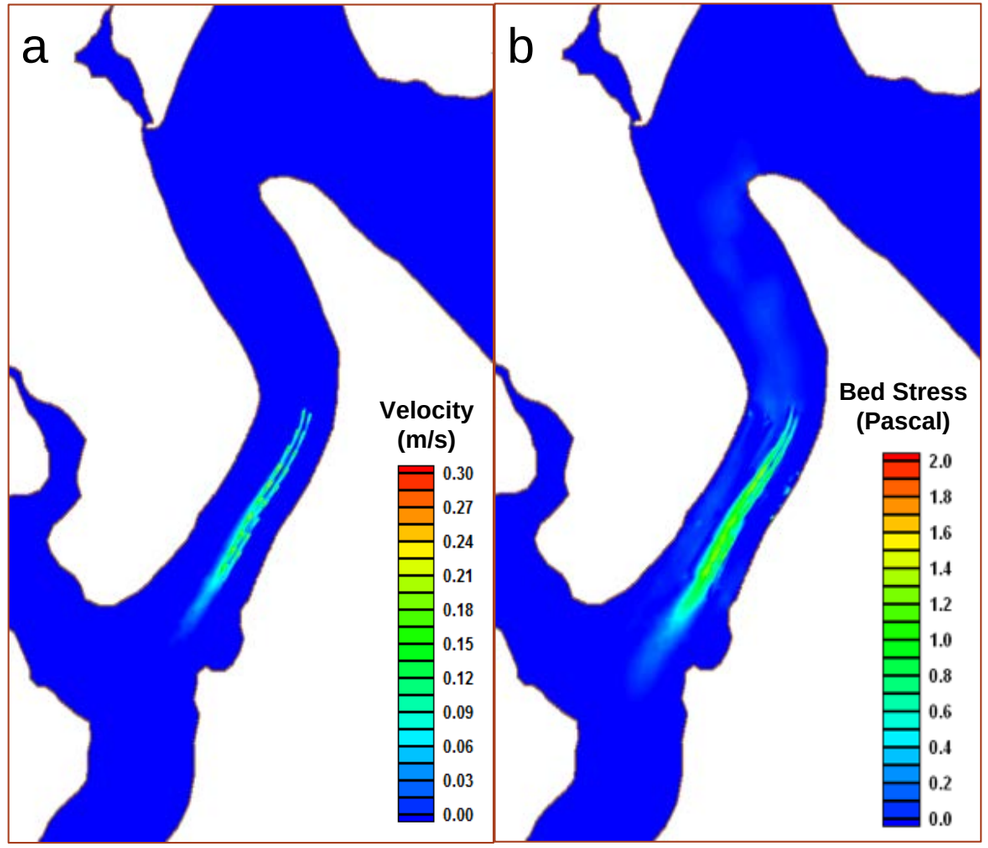


Modelling 20 turbines

Local effects near tidal farm

Velocity deficit at flood tide

Bed stress deficit at flood tide



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Information on Barrier Effect from MRE Devices

Barrier Effect from MRE devices

- Concern with animals being displaced from critical habitats (mating, foraging, resting)
- Concern with animals not being able to cross or move around MRE devices
- Impacts are more likely to happen when larger arrays or multiple devices are deployed
- As of now, no information/data is available
  - May improve as the industry moves from single devices to arrays

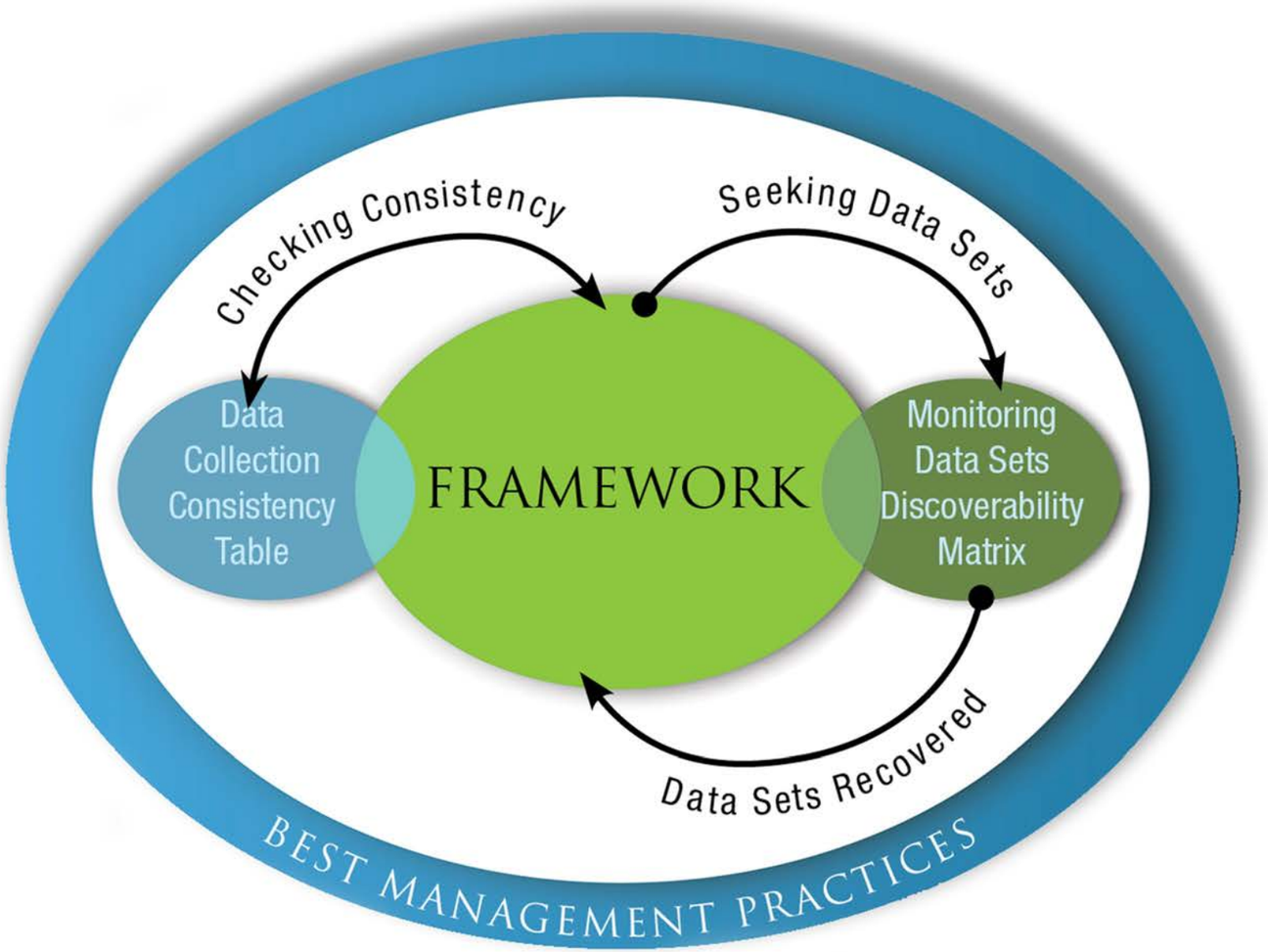
APEM (2016)

Previous Regulator Feedback Summary

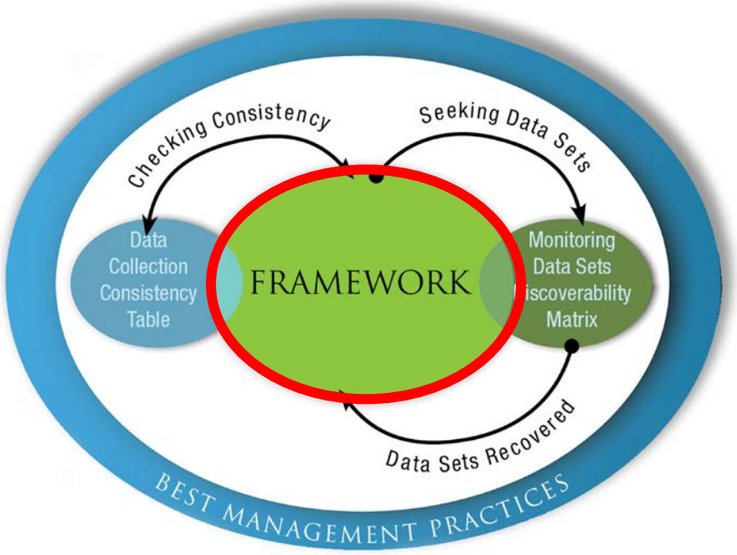
- 24 state and federal regulators
  - State: California (DFW and CA Energy Commission), Delaware (DFW), Hawaii (Energy Office), Maine (DEP), Massachusetts (DFG), Oregon (DLCD)
  - Federal: ACOE, BOEM, FERC, NOAA
- Regulators not looking for raw data
- Valued videos, audio clips and other data/information
  - Help increase understanding of potential impacts
- Overall, positive feedback
  - Would help to find data/information easier
  - Liked the idea of having data that is compatible with one another

Data Transferability Process

Data Transferability Process

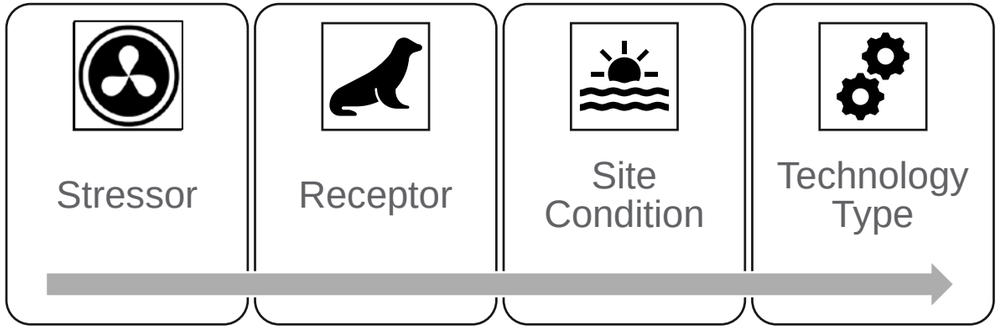


Framework for Data Transferability



1. Brings together datasets from already permitted/consented projects in an organized fashion
2. Compares the applicability of each dataset for use in permitting/consenting future projects
3. Assures data collection consistency through preferred measurement methods or processes
4. Guides the process for data transfer

- Uses stressors to categorize Framework:
  - Collision risk
  - Underwater noise
  - EMF
  - Habitat changes
  - Changes to physical systems
  - Barrier effects
- Four variables to define an interaction



Guidelines for Transferability

Necessary

- Interaction defined by same 4 variables and data collected consistently

- Same project size (single or array)

Important

- Same receptor species (or closely related)

- Similar technology

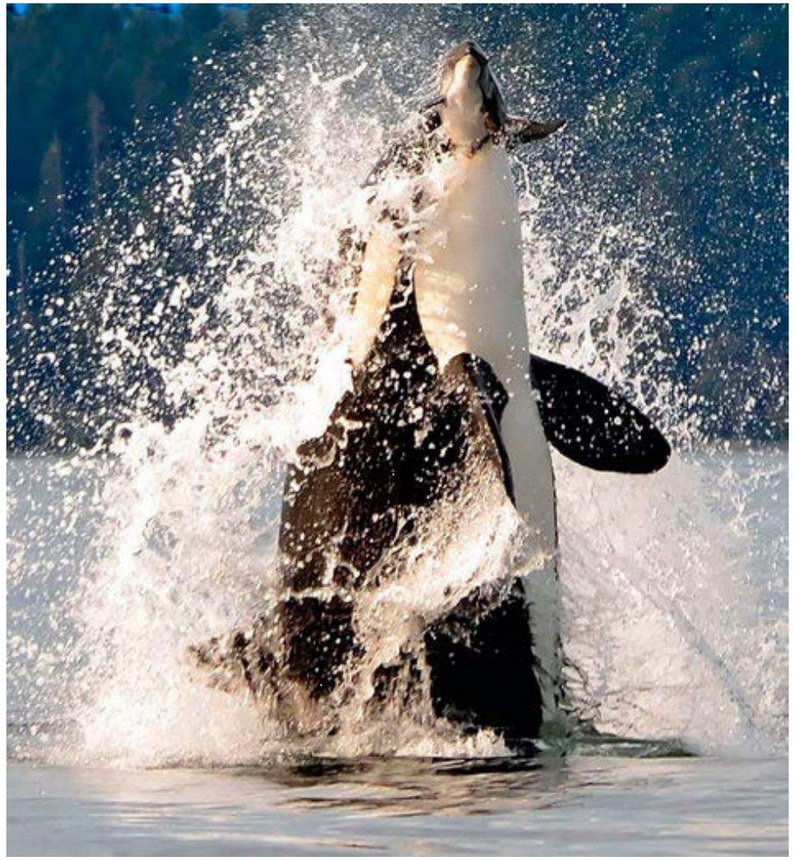
Desirable

- Similar wave/tidal resource

Discussion and Feedback

- Does the Framework make sense?
- Are the Guidelines for Transferability useful to you?
- Could you make use of this Framework?
- Can you suggest other groups of regulators who might be interested?

Next Steps



- May 28th and 30th workshops to discuss Data Transferability and Retiring Risk
  - Will send information and log-on instructions shortly
- Continue to seek input from US and other Annex IV country regulators
- Extend process to other Annex IV countries
- Present process via web-based tool on *Tethys*

Data Transferability Process Links

- *Tethys*:

  https://tethys.pnnl.gov/

- Data Transferability Process:
  - Regulator webinars on environmental effects
  - Data Transferability White Paper
  - Regulator online workshop recording
  - Annex IV workshop documents and report
  - *Will host today's presentation and recording*

  https://tethys.pnnl.gov/data-transferability

Thank you!

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