Environmental Effects and Risk Retirement for Marine Renewable Energy

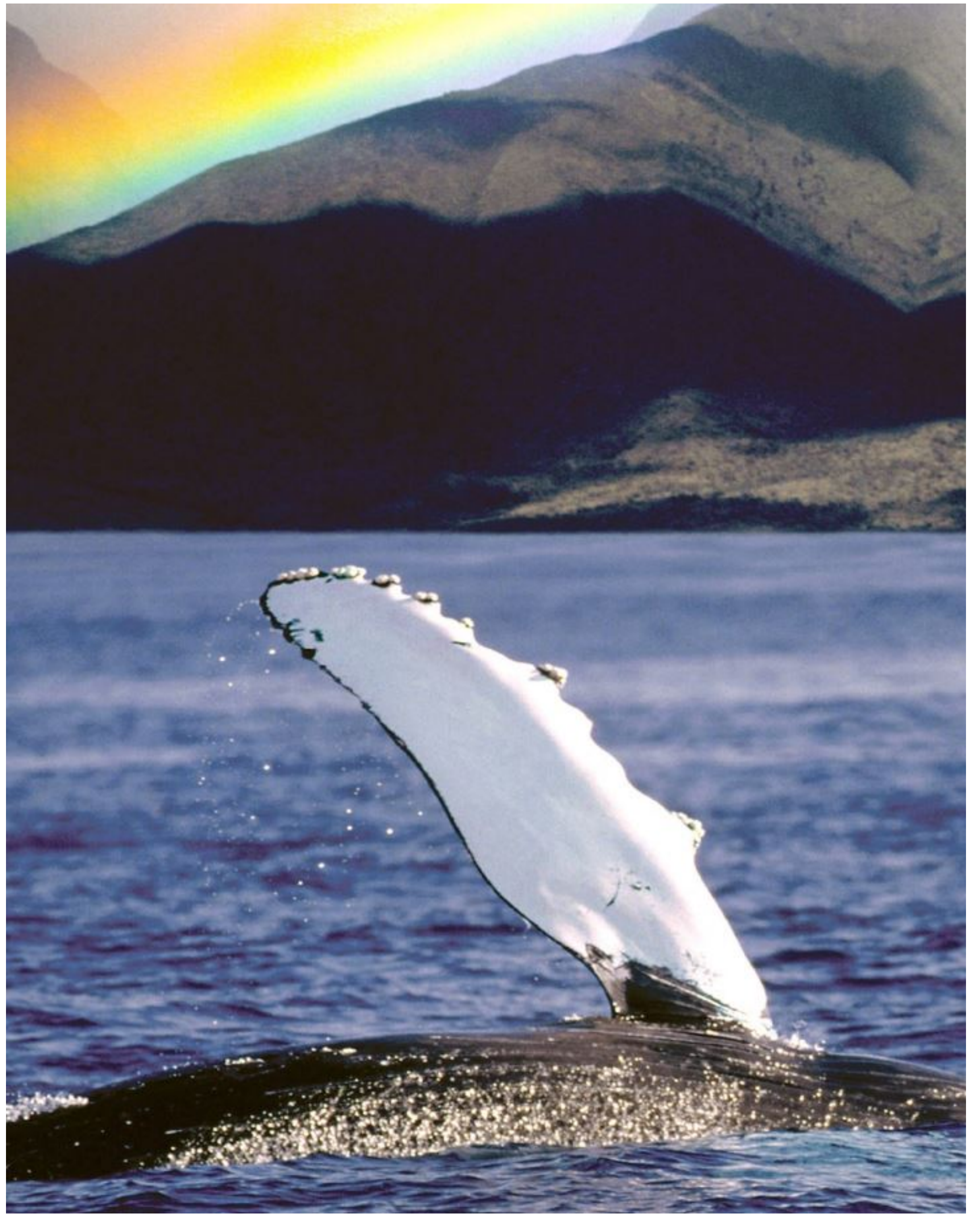
Sydney, Australia
December 4, 2019

Andrea Copping, Mikaela Freeman
Pacific Northwest National Laboratory

Ian Hutchison, Jennifer Fox
Aquatera, Limited

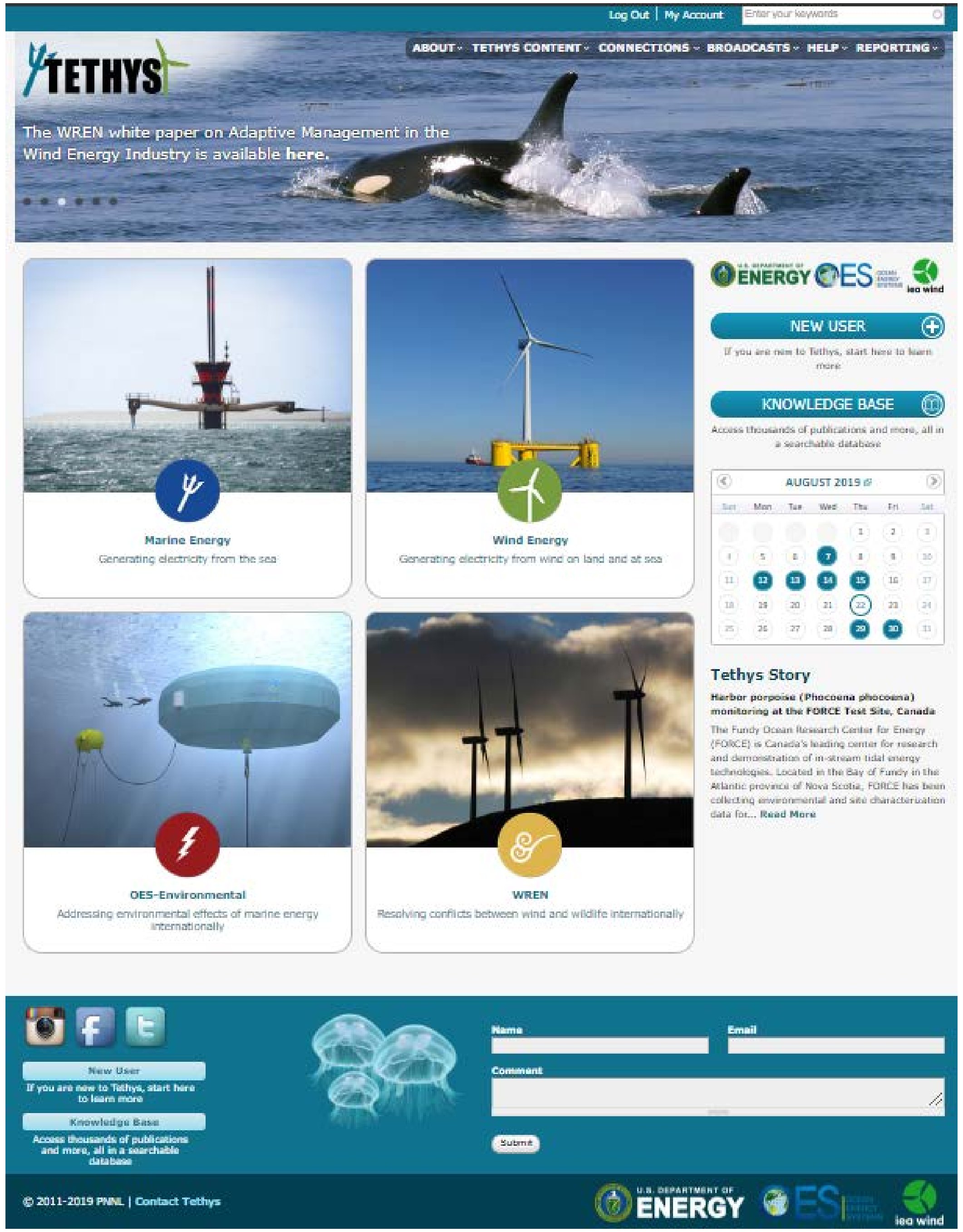
OES-Environmental

- Established by the International Energy Agency (IEA) Ocean Energy Systems (OES)
- 15 countries
- Examines the environmental effects of marine renewable energy (MRE) development
- Activities coordinated and recorded on *Tethys*



Pacific Northwest
NATIONAL LABORATORY

tethys.pnnl.gov



- *Tethys* knowledge management system on environmental effects of MRE
- Publicly available, constantly curated and updated
- Contains 5400+ documents (papers, reports, etc.)
- Viewable on Knowledge Base (searchable database) or Map Viewer
- Supports outreach activities (webinar archives, expert forums, events calendar, *Tethys* Stories, contact list, organizations, etc.)
- *Tethys Blast* biweekly, mailing lists of 1800+, webinar notices, etc.
- Join our mailing list!

Pacific Northwest
NATIONAL LABORATORY

OES ENVIRONMENTAL

OES-E nations:

Australia	India	South Africa
Canada	Ireland	Sweden
China	Japan	UK
Denmark	Norway	US
France	Portugal	

PNNL project team:

Andrea Copping
andrea.copping@pnnl.gov

Mikaela Freeman
mikaela.freeman@pnnl.gov

Lenaïg Hemery
lenaig.hemery@pnnl.gov

Alicia Gorton
alicia.gorton@pnnl.gov

ORJIP Ocean Energy

04 December 2019

Sponsors

Secretariat

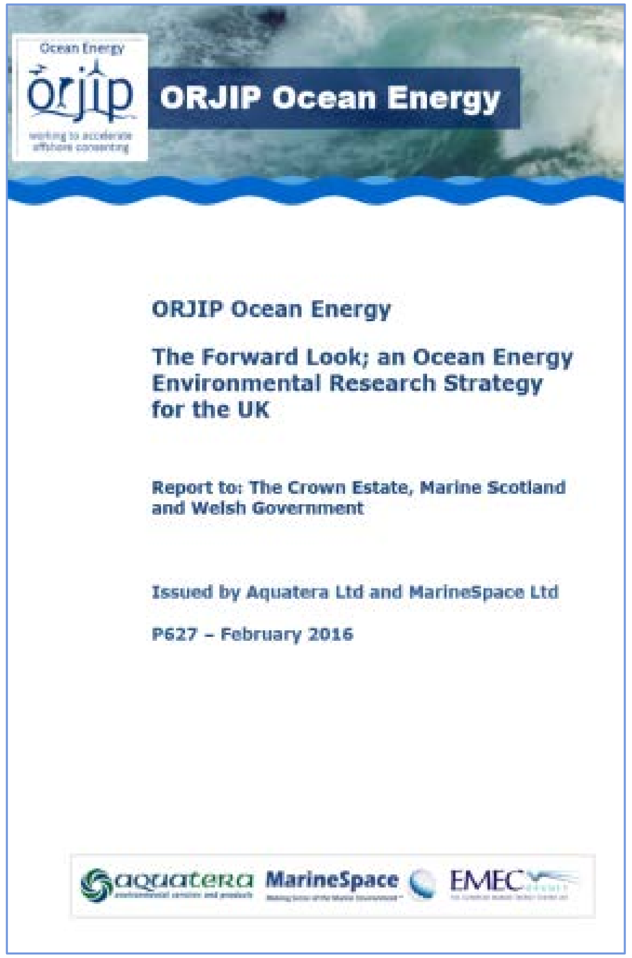
ORJIP Ocean Energy

- UK-wide collaborative **environmental research programme** with aim of reducing consenting risks for wave, tidal stream and tidal range projects.
- UK-led but globally recognised - **International Network with 62 active organisations from 26 countries**
- **Objectives**:
  - Bring together knowledge and expertise
  - Make knowledge available
  - Coordinate research and monitoring
  - Ultimately reduce the uncertainty around the environmental effects of wave and tidal energy projects

www.orjip.org.uk

The Forward Look

- **The Forward Look** identifies key evidence gaps and research projects required to address them.
- Prioritised list of strategic research projects to address key EIA/HRA issues
- Sets out the purpose, required timing and broad scope of these projects
- Three iterations of this document
- Next Forward Look will review global progress to date and present global priorities for research


ORJIP Ocean Energy

ORJIP Ocean Energy

The Forward Look; an Ocean Energy Environmental Research Strategy for the UK

Report to: The Crown Estate, Marine Scotland and Welsh Government

Issued by Aquatera Ltd and MarineSpace Ltd

P627 – February 2016

Contact details

Jennifer.fox@aquatera.co.uk
Ian.hutchison@aquatera.co.uk
Kate.smith@Aquatera.co.uk
Tel: 01856 850 088

Jonny.Lewis@marinespace.co.uk
Rhianna.Roberts@marinespace.co.uk

www.orjip.org.uk

Agenda

10:00 – 10:20	Introductions & Purpose of the Day
10:20 – 10:45	Consenting Challenges for MRE in Australia
10:45 – 11:15	Environmental Effects of MRE Developments
11:15 – 11:30	Break
11:30 – 11:50	Risk Retirement & Data Transferability Pathway
11:50 – 12:20	Evidence for Risk Retirement & Data Transferability
12:20 – 12:30	Instructions for Working Sessions
12:30 - 13:30	Lunch
13:30 – 14:30	Working Session • Case Study on EMF Risks • Case Study on Underwater Noise Risks
14:30 – 14:45	Break
14:45 – 15:15	Brainstorm: Next Steps
15:15 – 15:30	Summarize & Wrap-Up

Consenting Challenges in Australia

- Are environmental risks around MRE considered a challenge for consenting?
- What are the key challenges around wave energy?
- What are the key challenges around tidal energy?
- Is there a strategic approach to solving these challenges?
- Who are the key stakeholders?
- What large gaps remain?

State of the Science on Environmental Effects of MRE

Andrea Copping & Mikaela Freeman
Pacific Northwest National Laboratory

OES ENVIRONMENTAL

Ocean Energy orjip working to accelerate offshore consenting

Environmental Effects of Marine Renewable Energy (MRE)

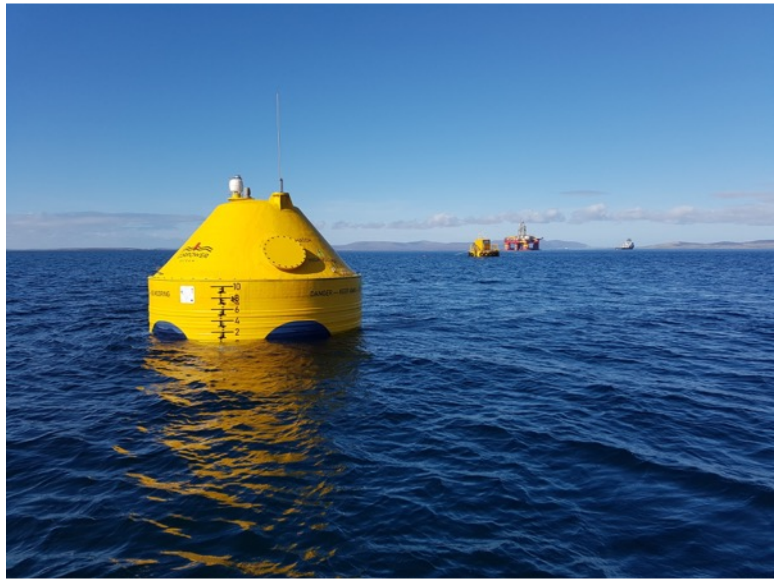
- Drivers for MRE are clear, but
  - Stakeholders and regulators have concerns about potential environmental impacts
  - Regulatory (permitting/consenting) processes are not well established

- These concerns are driven by:
  - New, largely unknown technologies with unknown potential for harm
  - New use of ocean space and many other uses
  - Insufficient knowledge of ocean environment in high energy areas
  - Concerns about marine species already under stress

- Improved information can:
  - Simplify/shorten time to permit deployment of devices and arrays
  - Decrease scientific uncertainty

Permitting MRE Developments

- As MRE is in early stages of development, deployment, and commercialization there is a need to streamline siting and permitting
- Barriers to Permitting
  - MRE industry perceptions
  - Perceptions of regulatory community
  - Environmental concerns



Current State of Knowledge

MRE Environmental Stressors

- Collision risk
- Underwater noise effects
- Electromagnetic fields (EMF) effects
- Habitat changes
- Changes to physical systems
- Displacement/barrier effects

2020 State of the Science

- to be released in May 2020

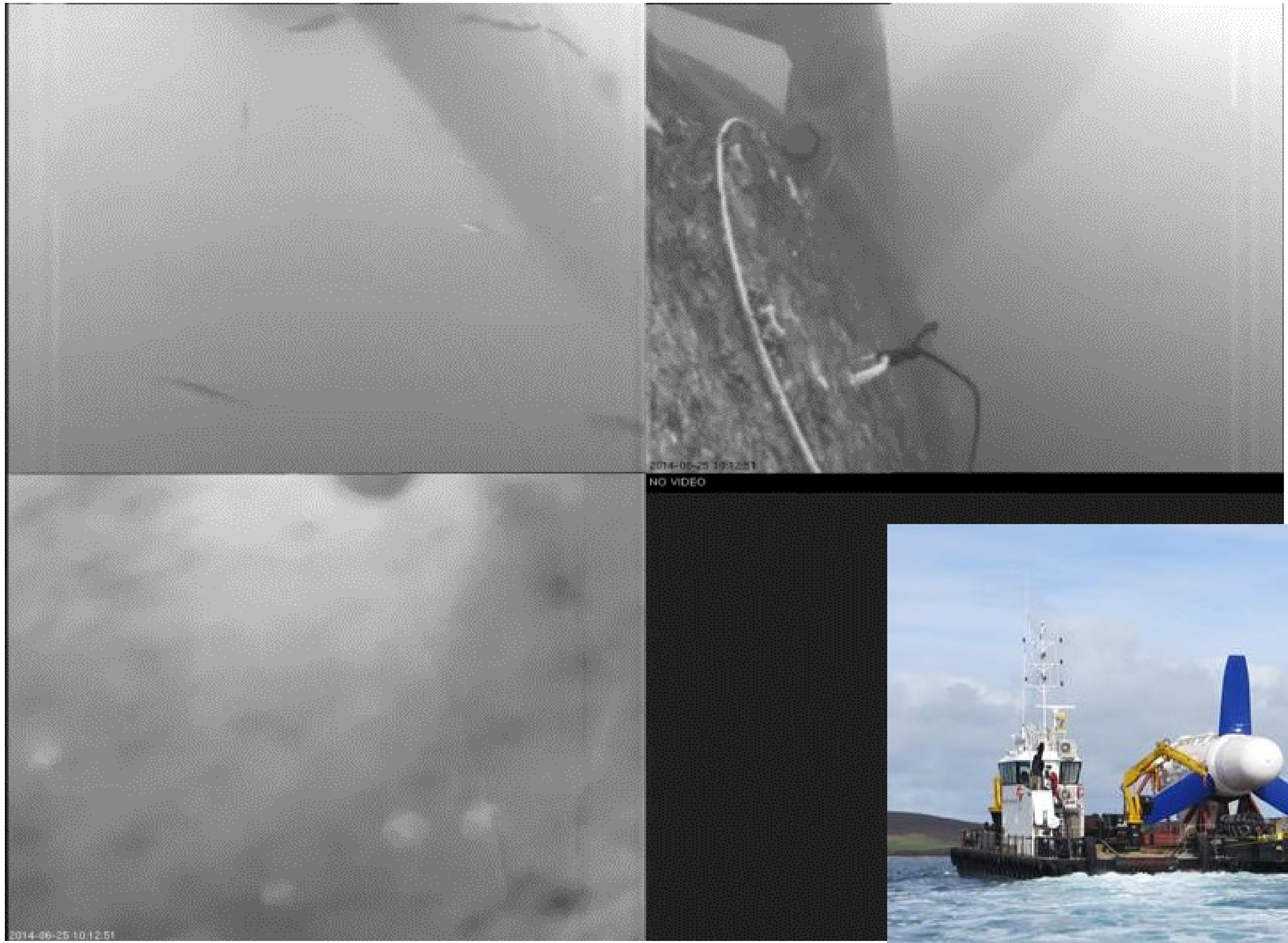
Interactions around MRE Devices

- Scientific uncertainty drives much of the perceived risk
- More data collection and research can help reduce uncertainty
- Most important and potentially highest risk interactions include:
  - Collision of animals with tidal turbines,
  - Underwater noise from MRE devices on animals,
  - EMF impacts from cables and devices
- Generally little impact expected from single devices; larger arrays will require more investigation

Collision Risk

- Concerns for tidal turbines' rotating blades causing injury and/or death to marine mammals, fish, and diving seabirds
- Animals may come into contact through normal movement, attraction to device (for shelter, feeding, or out of curiosity), or an inability to avoid device (due to strong tidal currents)
- Collision risk typically examined on individual level but results must be put in context of risk to populations
- No observations of collision of a marine mammal or seabird with a MRE device
- Observations of fish interactions have shown no harm

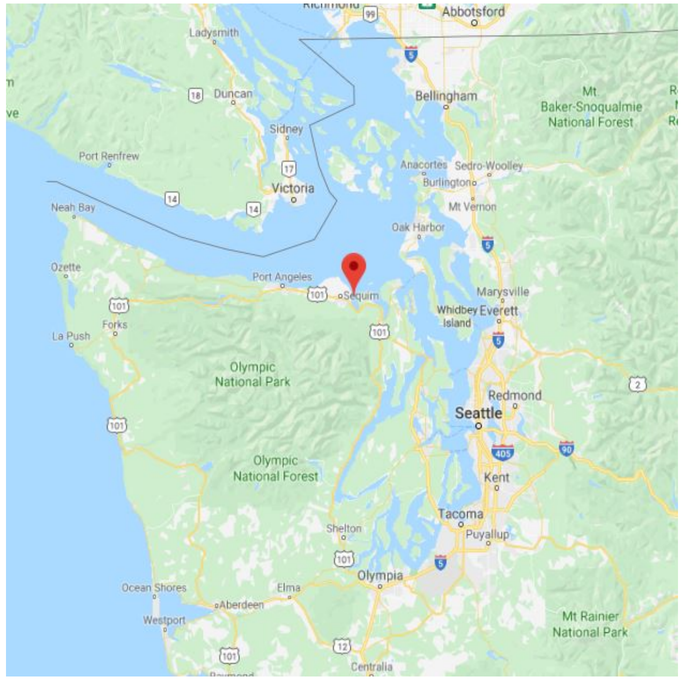
Voith Turbine at EMEC



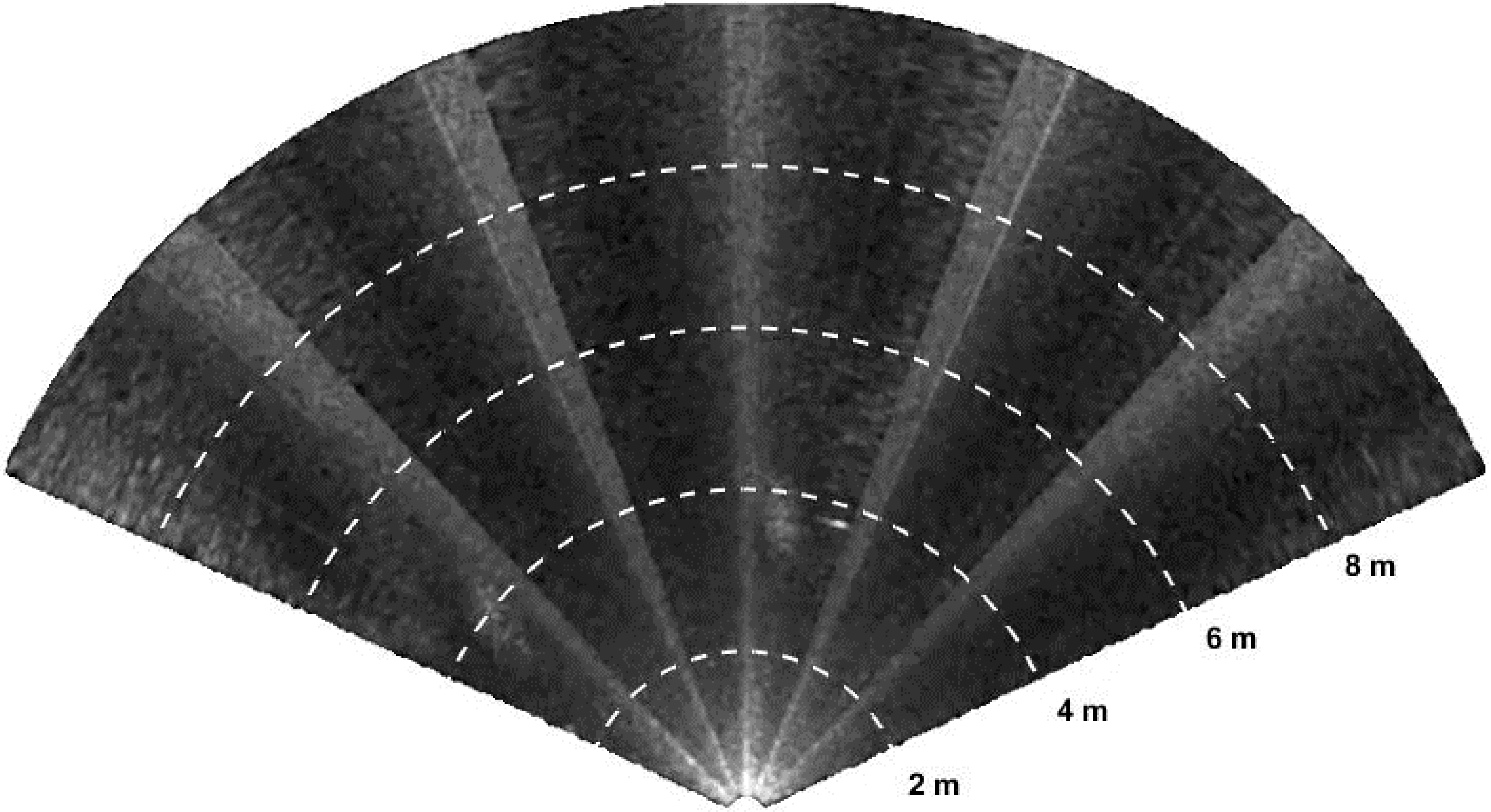
- EMEC (Pentland Firth, Scotland)
- 1 MW
- Depth: 35 m
- Blade length: 6 m

Video courtesy of Voith and Aquatera Limited

Adaptable Monitoring Package



Active Acoustic Monitoring Multi-Beam Sonar:
Interaction between fish and seal observed on acoustic camera



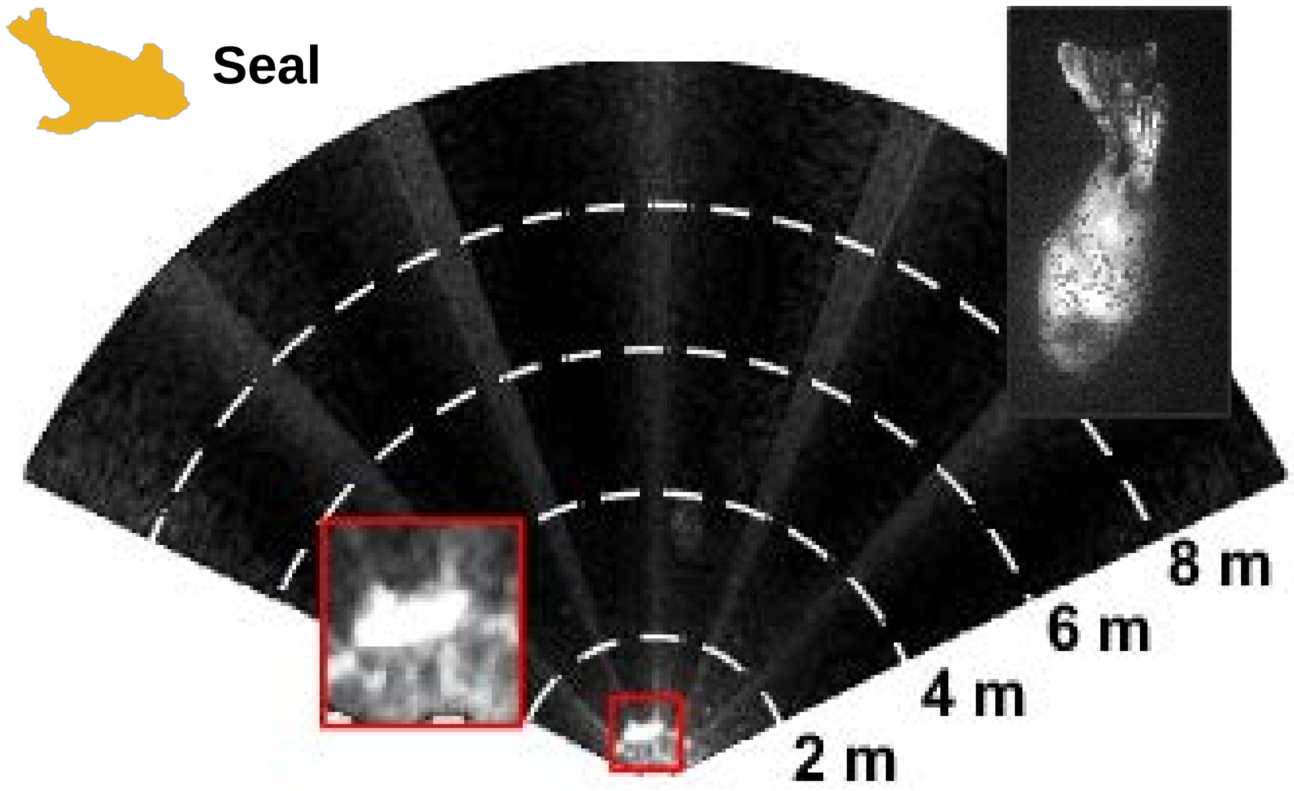
Video and data courtesy of Brian Polagye (PMEC)

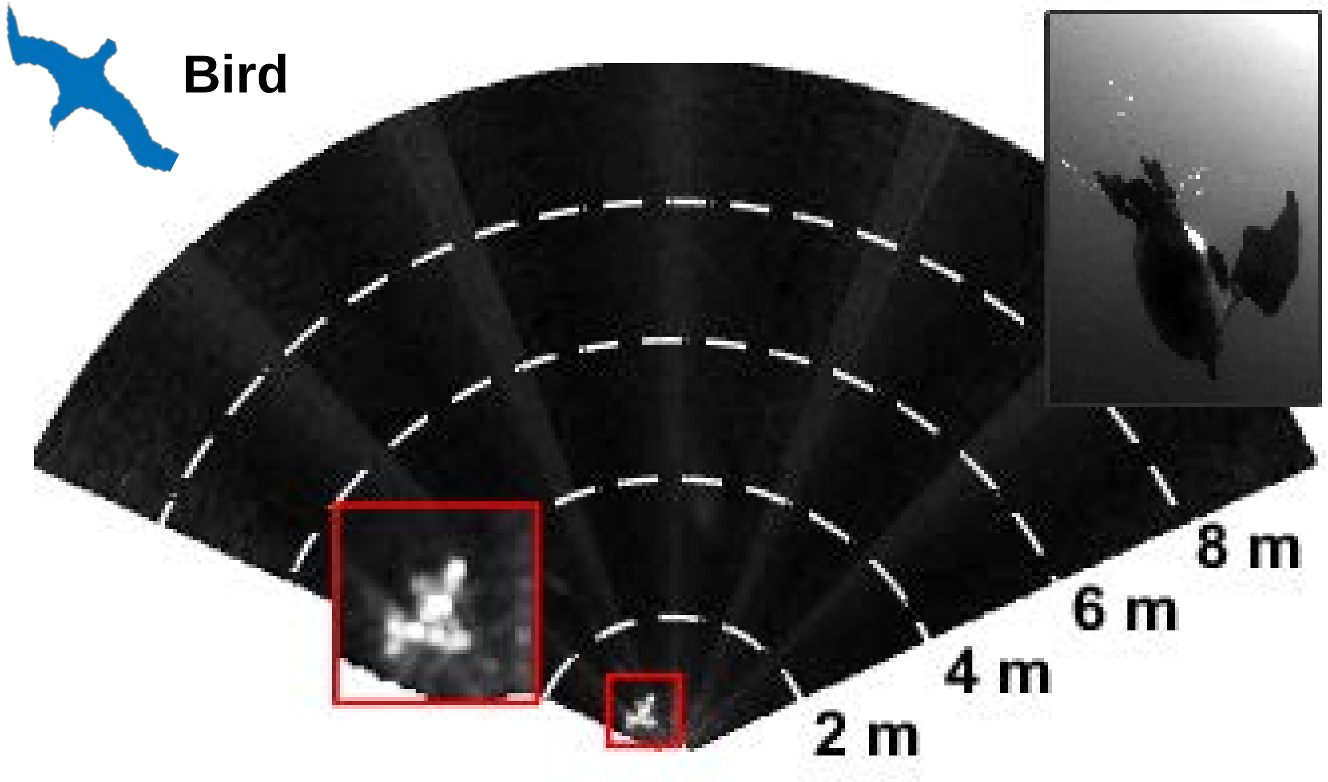
- Sequim Bay, WA, U.S.
- Platform for multiple sensors, data acquisition
- Depth: 12 m
- In lieu of a turbine

Applied Physics Laboratory, UW

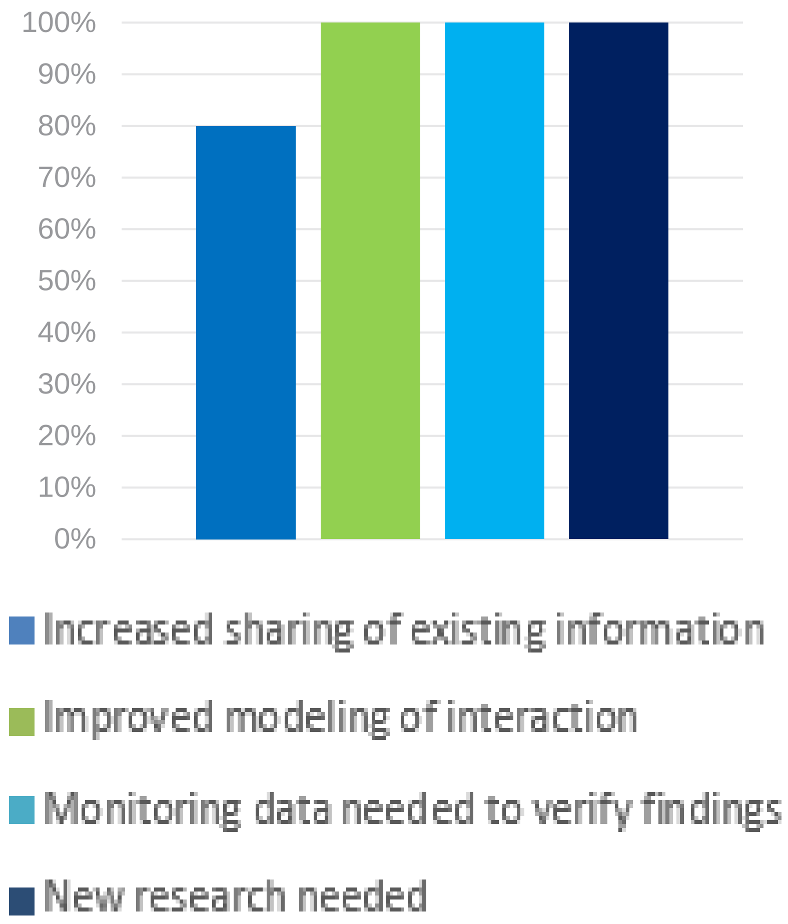
Adaptable Monitoring Package

Active Acoustic Monitoring Multi-Beam Sonar:
Triggered optical camera detections of a seal and a diving bird





Collision Risk (tidal) – Dashboard

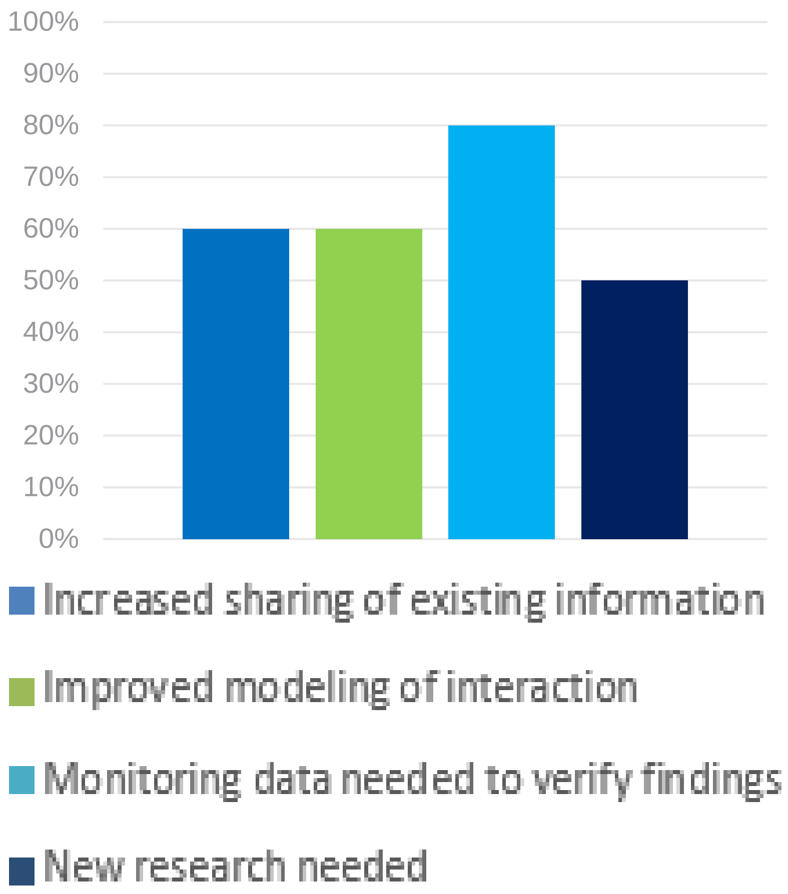


Copping, A.; Kramer, S.; Sather, N.; Nelson, P. (2017) Pacific Region Marine Renewables Environmental Regulatory Workshop Report.

Underwater Noise Effects

- Concerns for noise from MRE devices causing harm or injury to marine mammals or fish
- Marine animals use underwater sound for navigation and communication
- Noise from MRE devices may add to other anthropogenic sounds
  - Concerns for noise effects from construction, but operational noise is likely to be much lower
- Noise from single devices are being measured; predictions can be made about what arrays may sound like
- Unlikely for noise from MRE to cause harm to marine animals
  - But additional data are needed to fully understand how sounds many impact animals

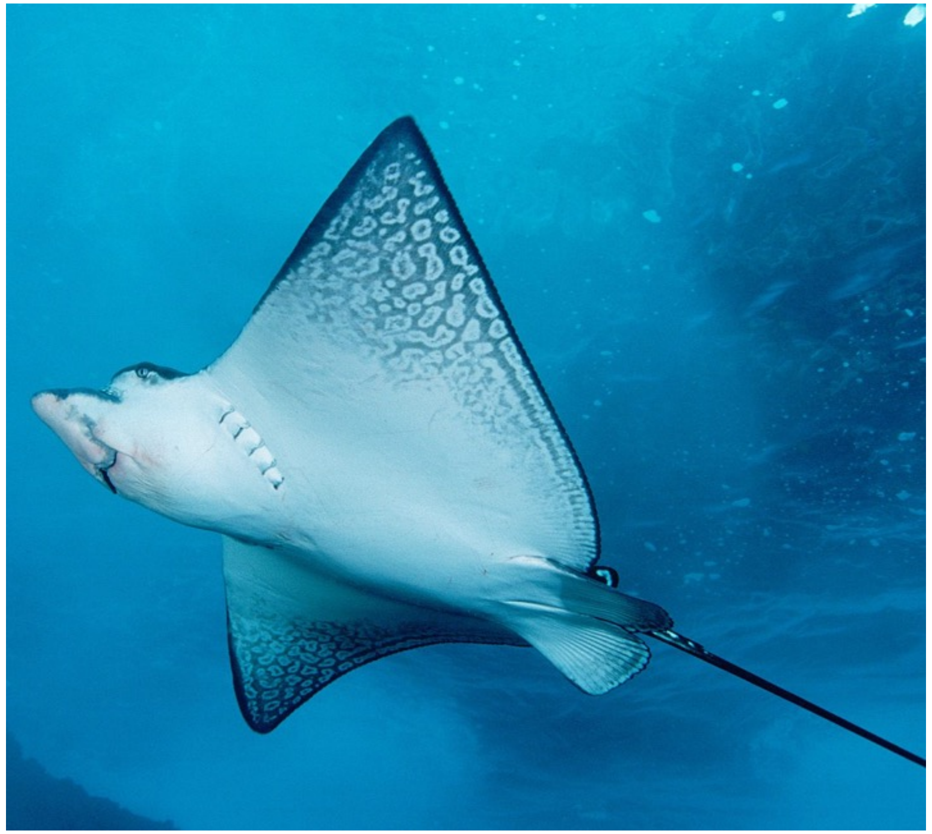
Underwater noise – Dashboard



Copping, A.; Kramer, S.; Sather, N.; Nelson, P. (2017) Pacific Region Marine Renewables Environmental Regulatory Workshop Report.

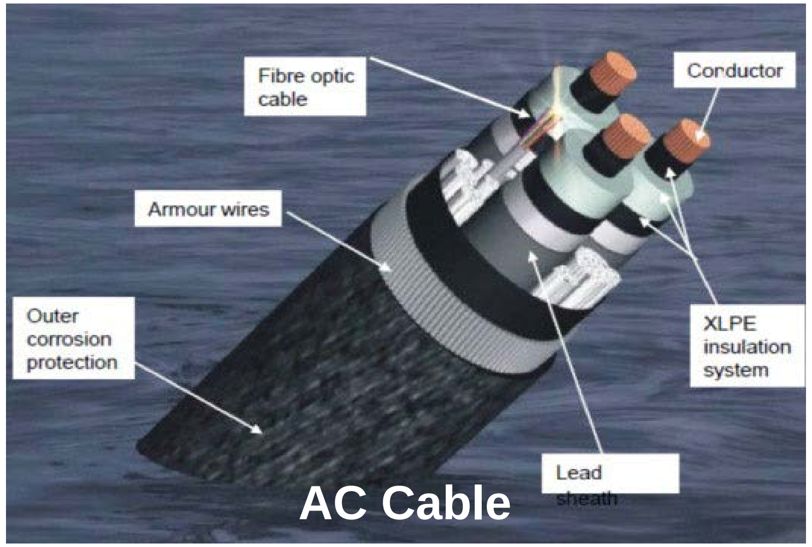
Electromagnetic Fields (EMF) Effects

- Concerns that EMF may affect organisms that use natural magnetic fields for orientation, navigation, and/or hunting
  - Elasmobranchs, marine mammals, crustaceans, sea turtles, and some fish species
- MRE emits EMF from power cables, devices' moving parts, and substations/transformers
- Most studies to date have focused on behavioral responses to EMF
- Lab and field studies have shown no evidence of effect on any species

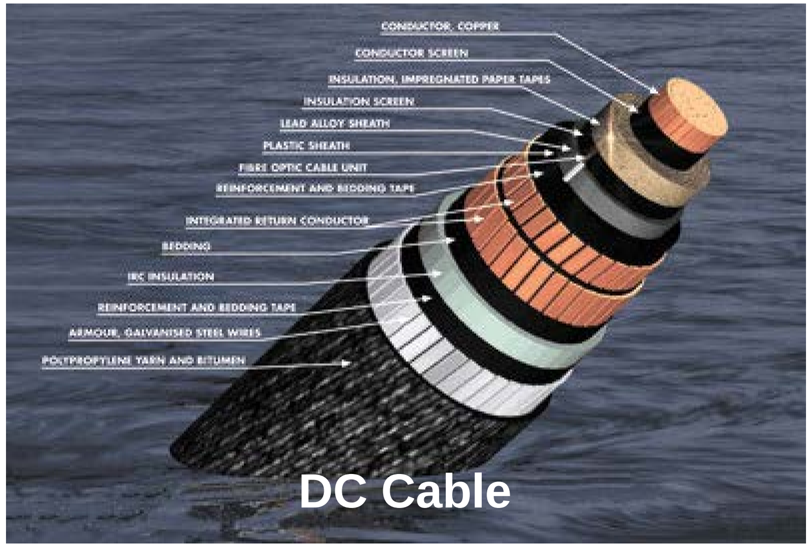


EMF from AC and DC Power Cables

- Similar to cables used in the offshore wind industry:
  - Export cable is typically 132 kV AC cable (up to 250 MW)
  - Inter-array cables are typically 33 kV AC cables
  - Where possible, cables are buried 1-3 m deep
  - Industry starting to use large DC cables for distances greater than 80 km (less transmission loss)
- Cables used by MRE projects:
  - Size varies by project, but all smaller than typical wind
  - Most common cable is 11 kV AC, buried to 1 m depth
- All cables are electrically shielded, but the magnetic field is not blocked and generates an induced electric field

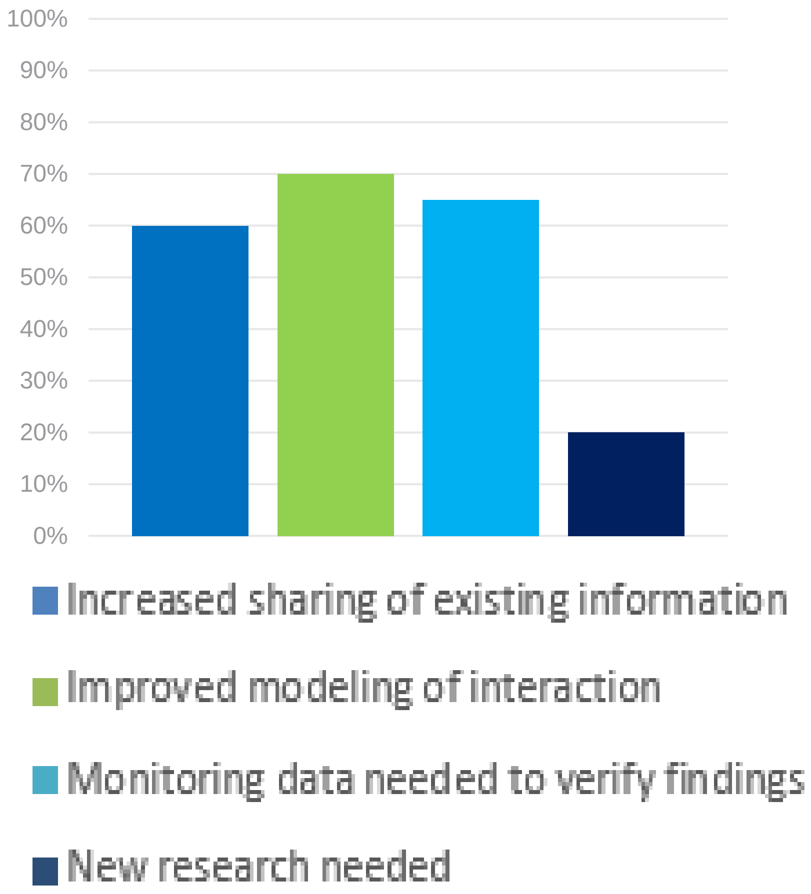


AC Cable



DC Cable

EMF – Dashboard

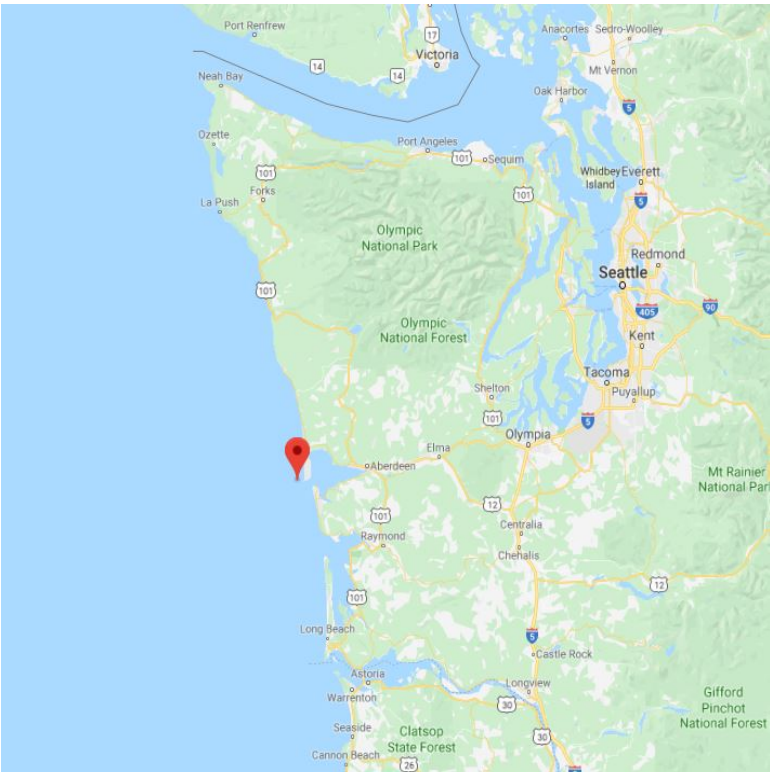


Copping, A.; Kramer, S.; Sather, N.; Nelson, P. (2017) Pacific Region Marine Renewables Environmental Regulatory Workshop Report.

Habitat Changes

- Concerns that presence of devices and parts (e.g., moorings, cables) 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 important habitats
- No evidence to date of significant negative effects occurring to benthic areas around MRE developments, or that marine animals reefing around devices will harm fish populations

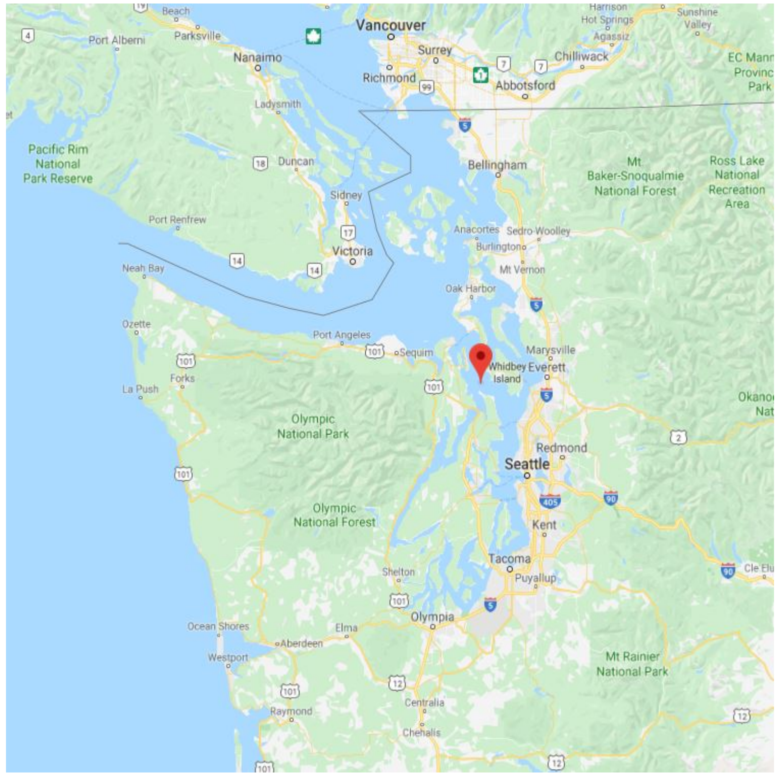
U.S. West Coast Bottom Habitat



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

Videos courtesy of Sarah Henkel (OSU/PMEC) and Brian Polagye (UW/PMEC)

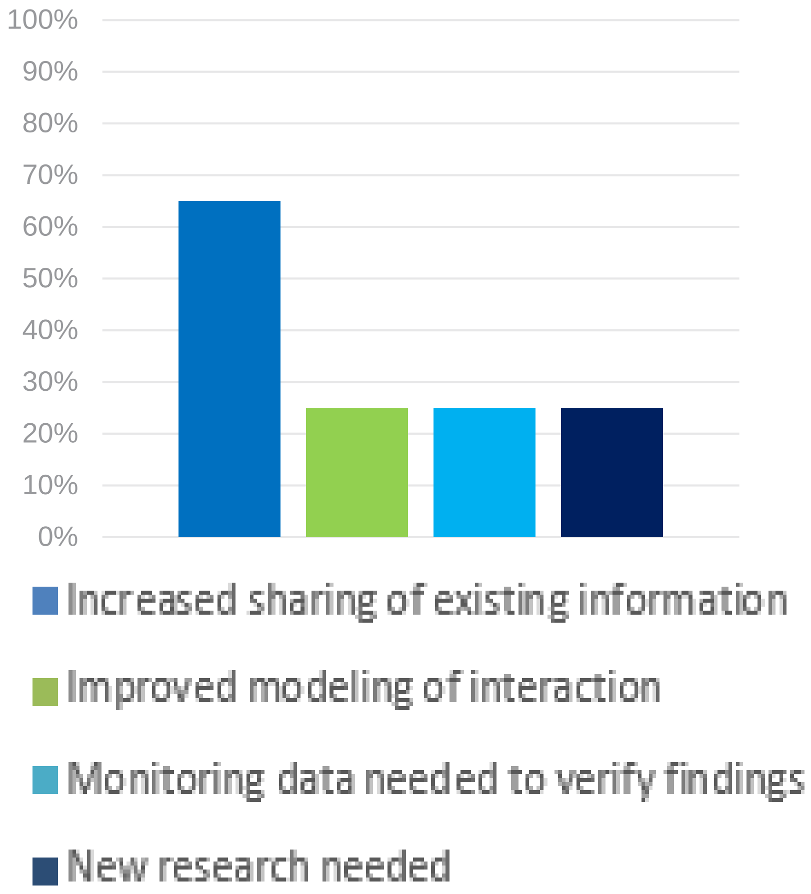
U.S. West Coast Bottom Habitat



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

Videos courtesy of Sarah Henkel (OSU/PMEC) and Brian Polagye (UW/PMEC)

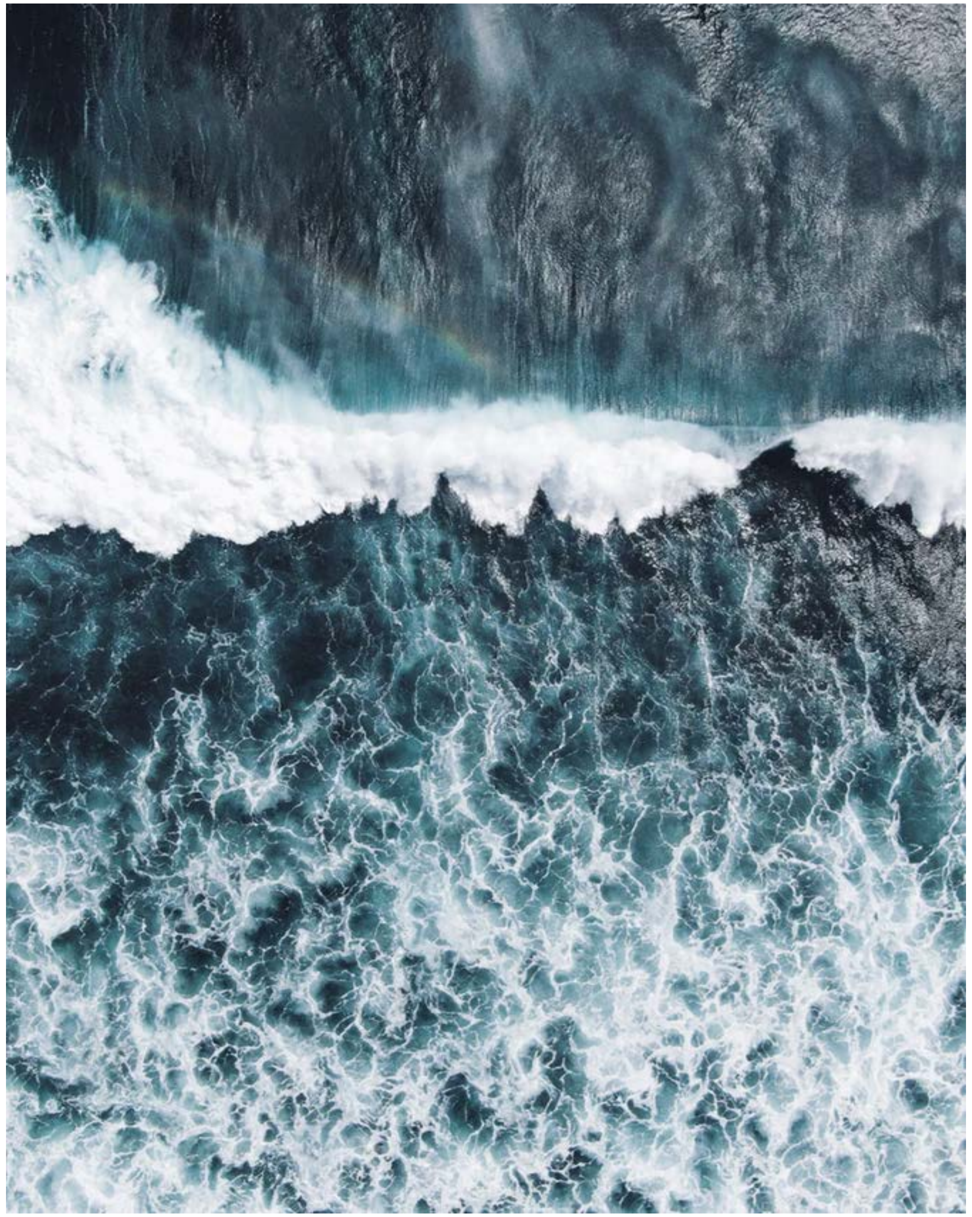
Habitat Changes – Dashboard



Copping, A.; Kramer, S.; Sather, N.; Nelson, P. (2017) Pacific Region Marine Renewables Environmental Regulatory Workshop Report.

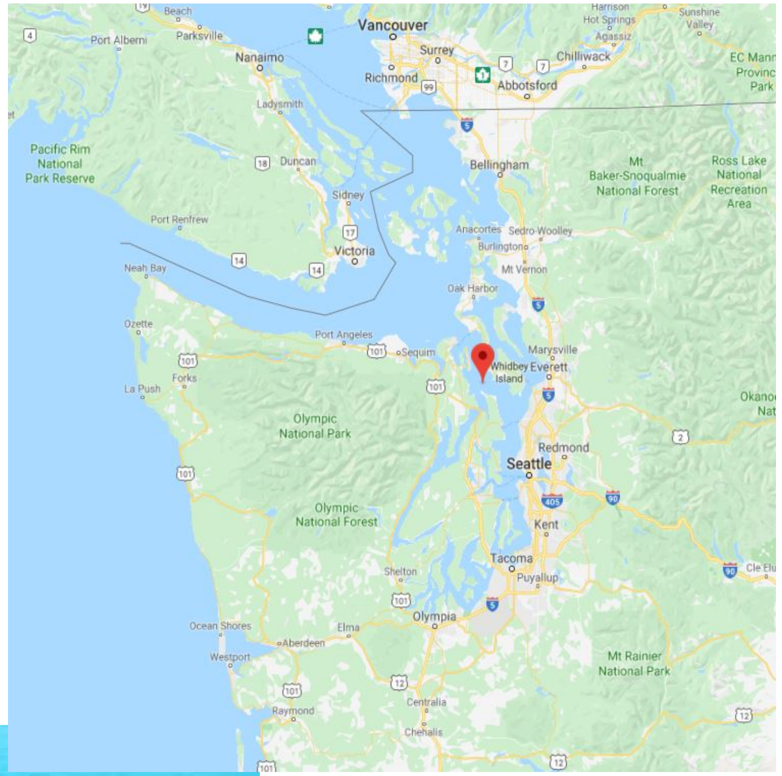
Changes to Physical Systems

- Concerns that placement of MRE devices may cause changes in circulation and flushing, as well as sediment transport and distribution
- Effects from single MRE devices are likely too small to measure
- Effects might be measurable in future, at the large array scale
- Scarcity of field data from high-energy environments and the small number of device deployments have slowed validation of models



Modeling for Tidal Development

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

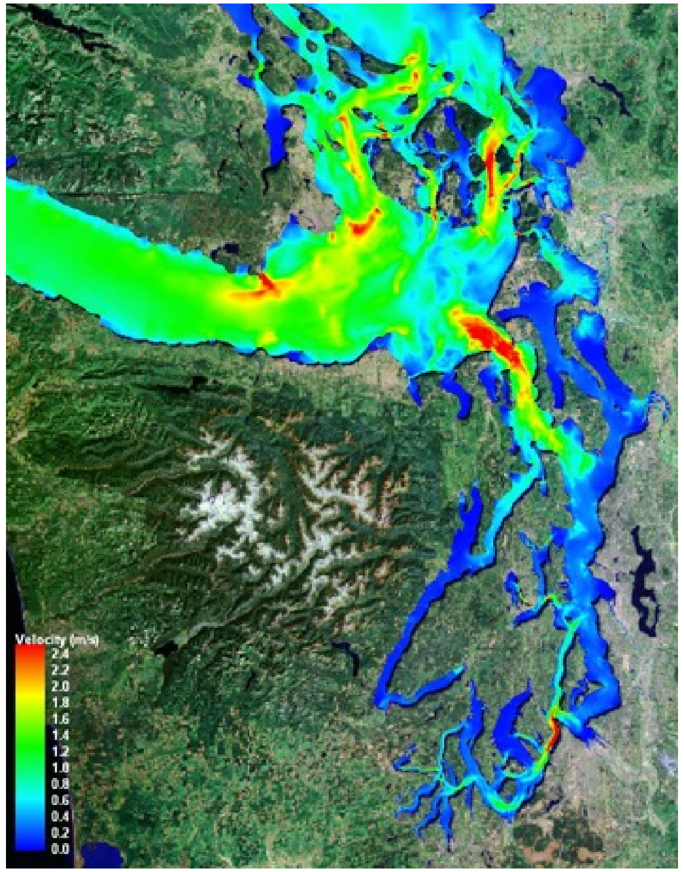


Data courtesy of Zhaoqing Yang and Taiping Wang (PNNL)

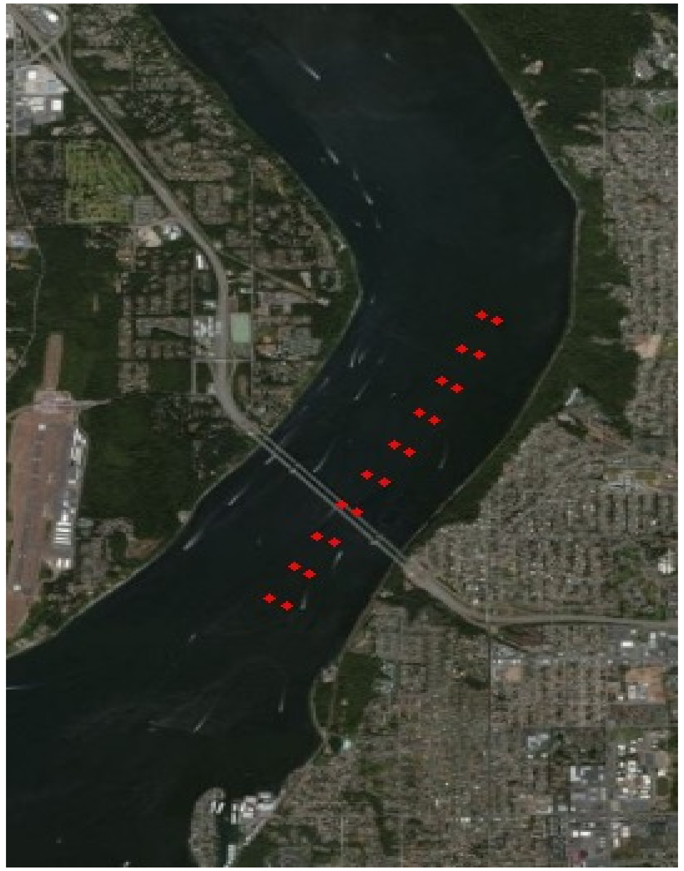
Turbines in Tacoma Narrows

- Identify array location (high power density) and determine grid resolution
- Local effect of energy extraction are measurable even with the 20-turbine farm

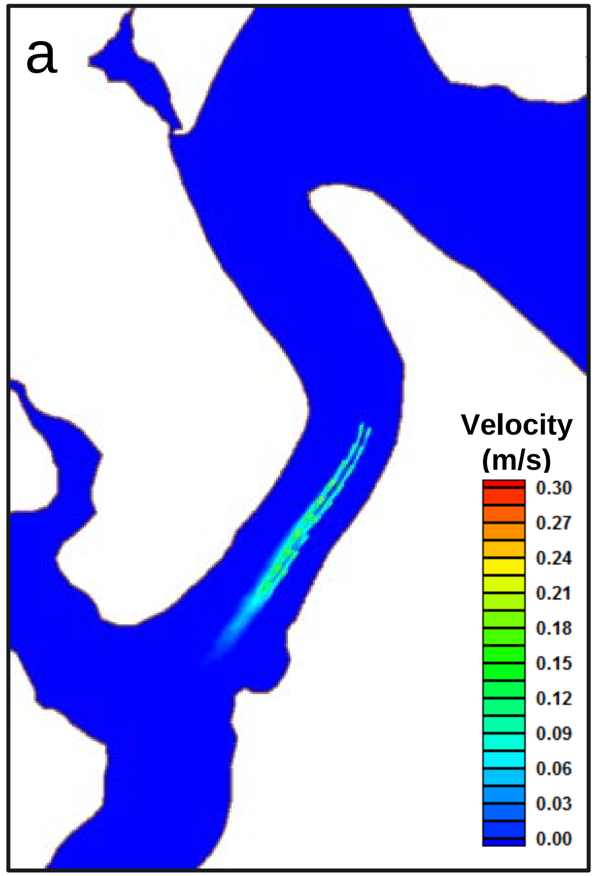
Max Velocity in Puget Sound



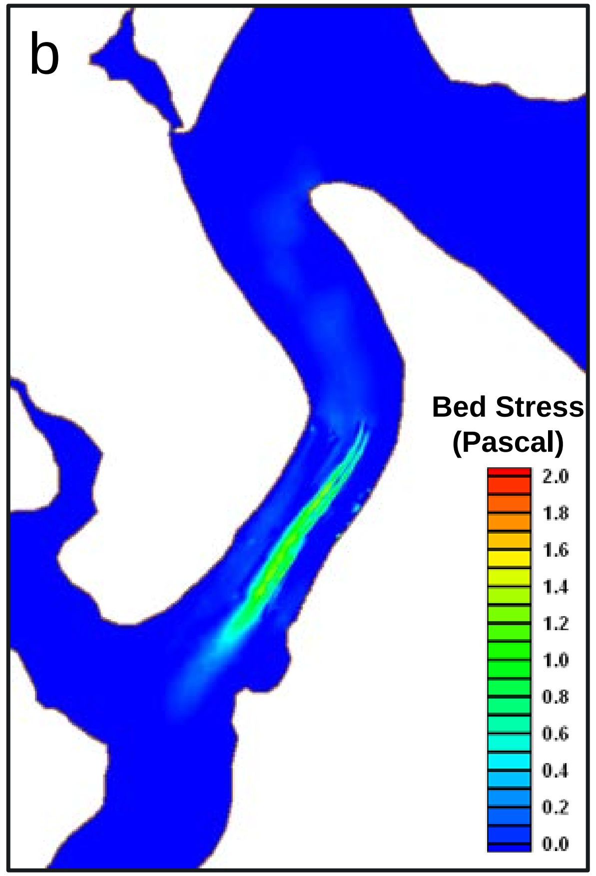
Modelling 20 turbines



Velocity deficit at flood tide



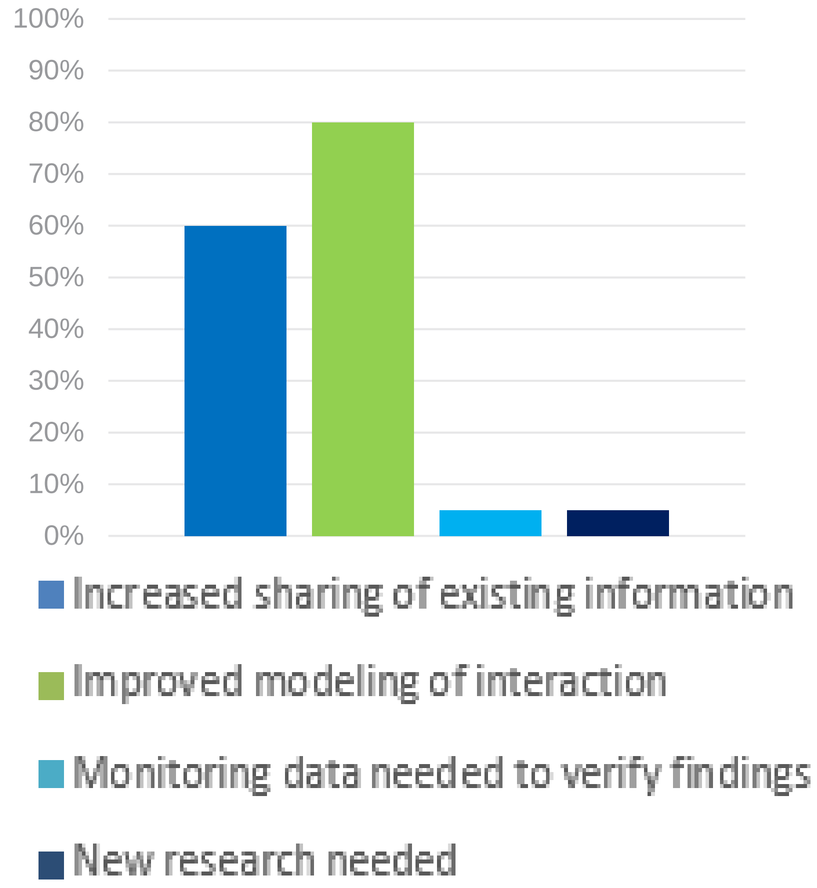
Bed stress deficit at flood tide



Data courtesy of Zhaoqing Yang and Taiping Wang (PNNL)

(Yang and Wang 2016)

Changes in Physical Systems – Dashboard

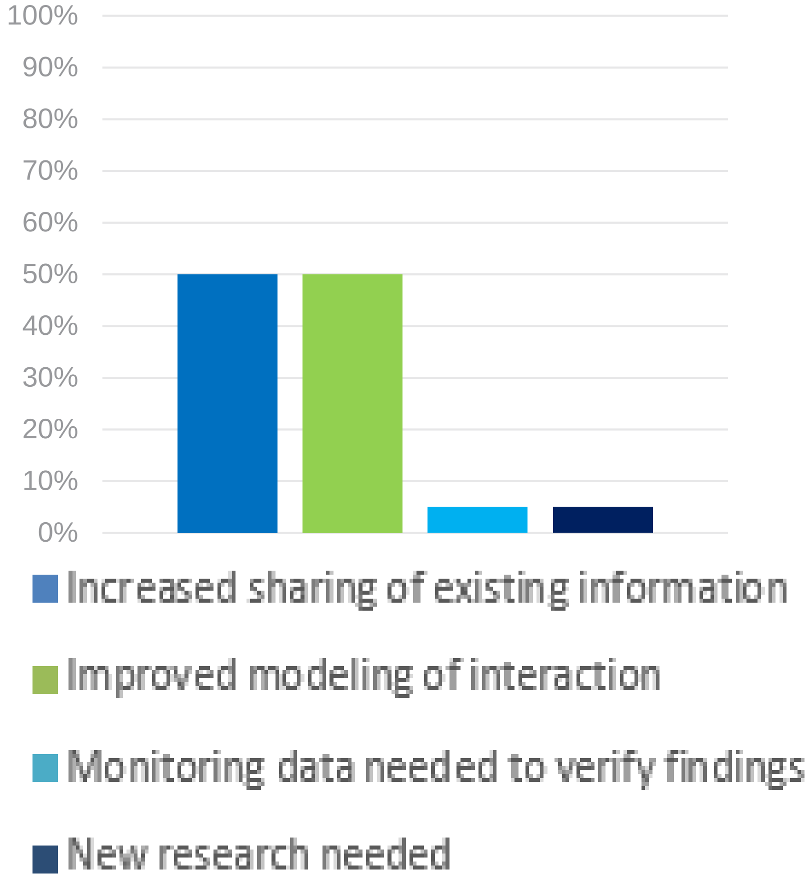


Copping, A.; Kramer, S.; Sather, N.; Nelson, P. (2017) Pacific Region Marine Renewables Environmental Regulatory Workshop Report.

Displacement/Barrier Effects

- Concern with animals being displaced from critical habitats (for mating, foraging, or 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

Displacement/Barrier Effect – Dashboard



Copping, A.; Kramer, S.; Sather, N.; Nelson, P. (2017) Pacific Region Marine Renewables Environmental Regulatory Workshop Report.

Path Forward

- Interactions with MRE devices are perceived to be risky largely due to uncertainty
- Additional information will help retire insignificant risks, while other risks may be determined to need mitigation
  - Monitoring requirements will be reduced as we learn more
- There are no methods for monitoring certain interactions now
  - These require strategic research investments to proceed

Processes of Risk Retirement and Data Transferability

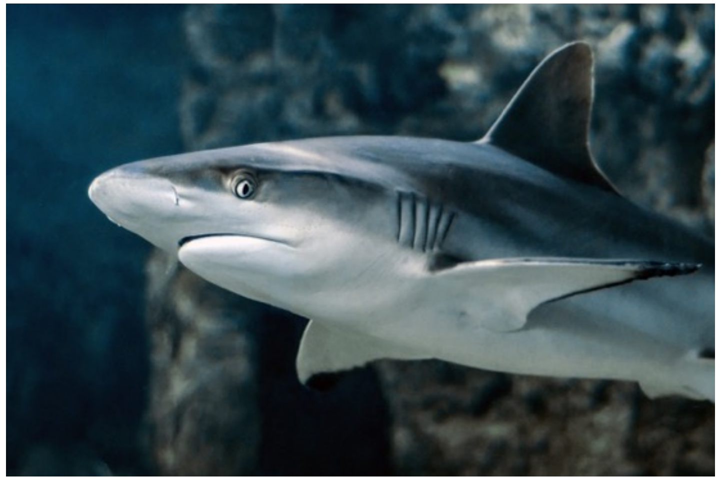
Mikaela Freeman & Andrea Copping

Pacific Northwest National Laboratory

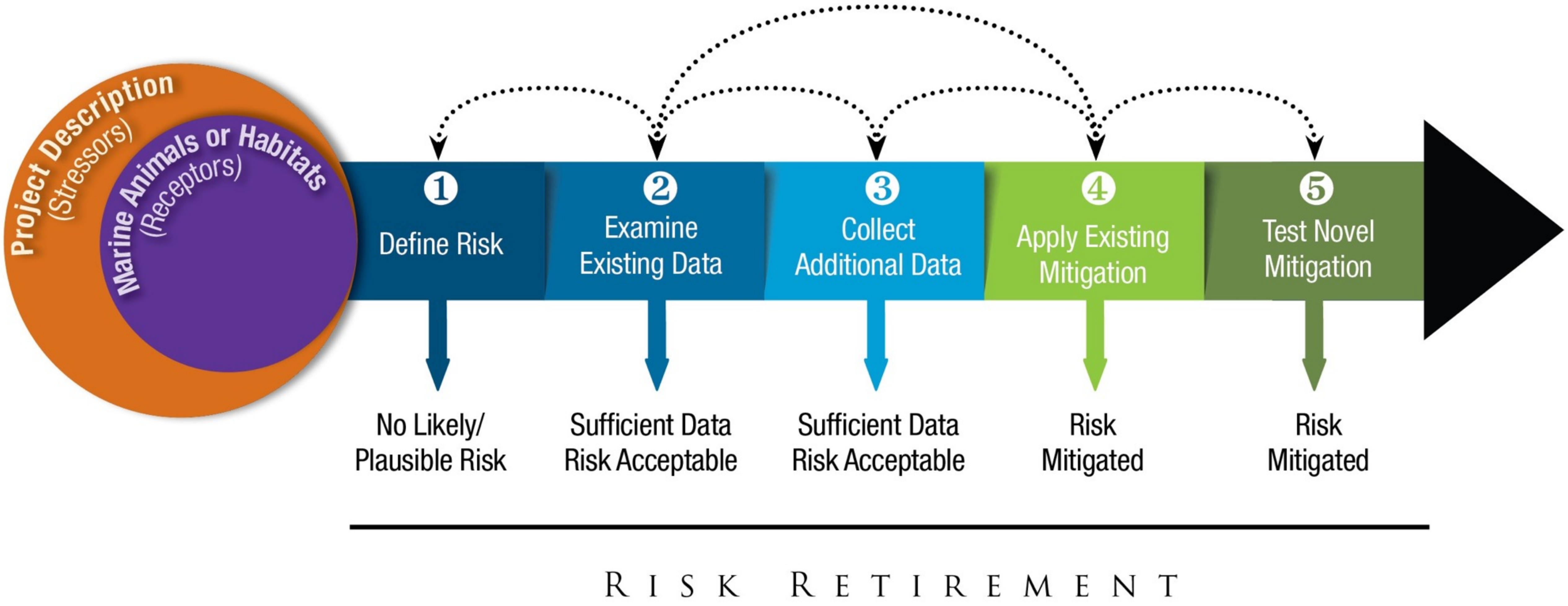
Risk Retirement

What is "risk retirement"?

- For certain interactions, potential risks need not be fully investigated for every project for small developments (1-2 devices).
- Rely on what is already known – already consented/permitted projects, research, or analogous industries.
- A "retired risk" is not dead, and can be revived in the future as more information becomes available for larger arrays.



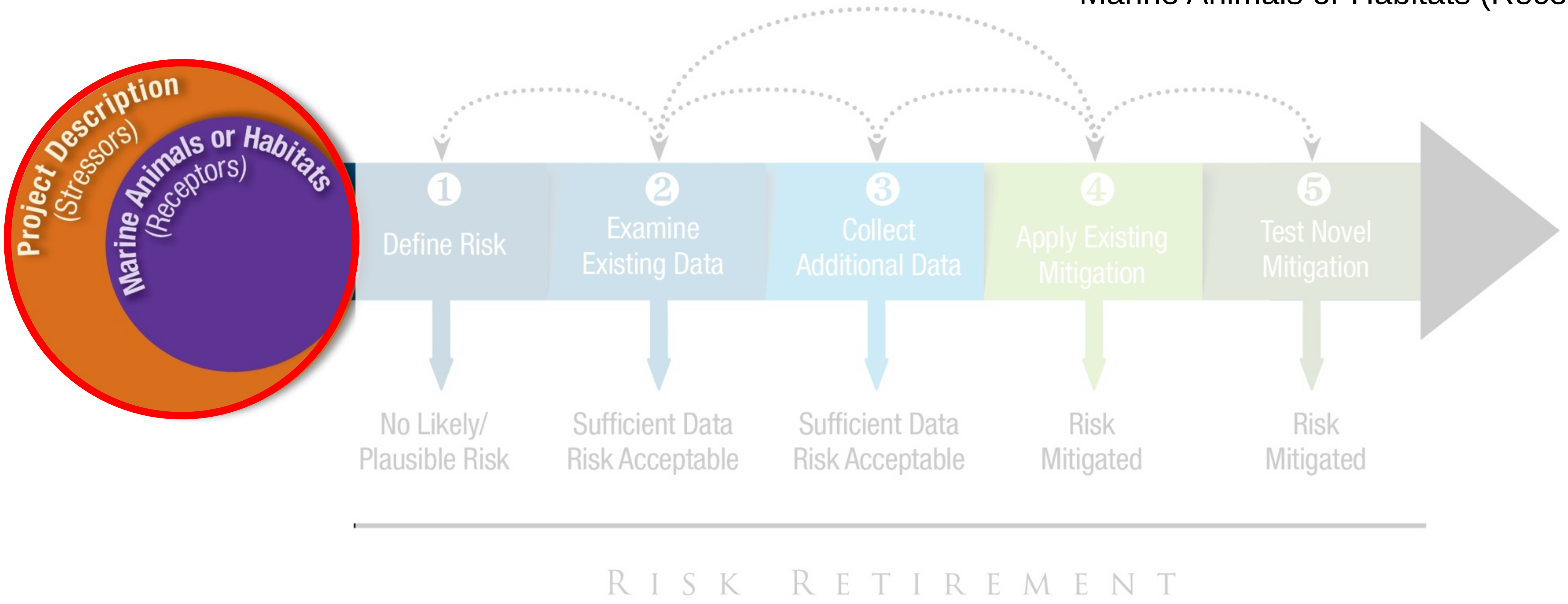
Pathway to Risk Retirement



Pathway to Risk Retirement

Define Interaction

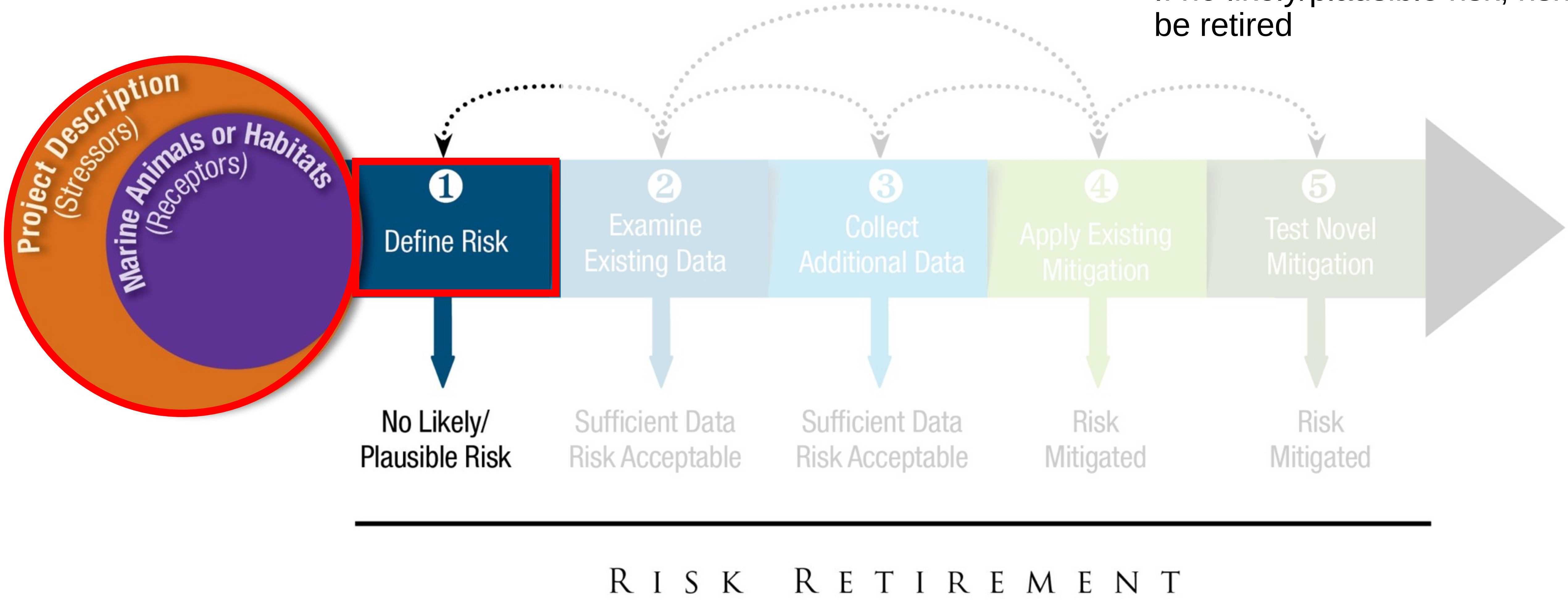
- Project Description (Stressors)
- Marine Animals or Habitats (Receptors)



Pathway to Risk Retirement

Stage Gate 1

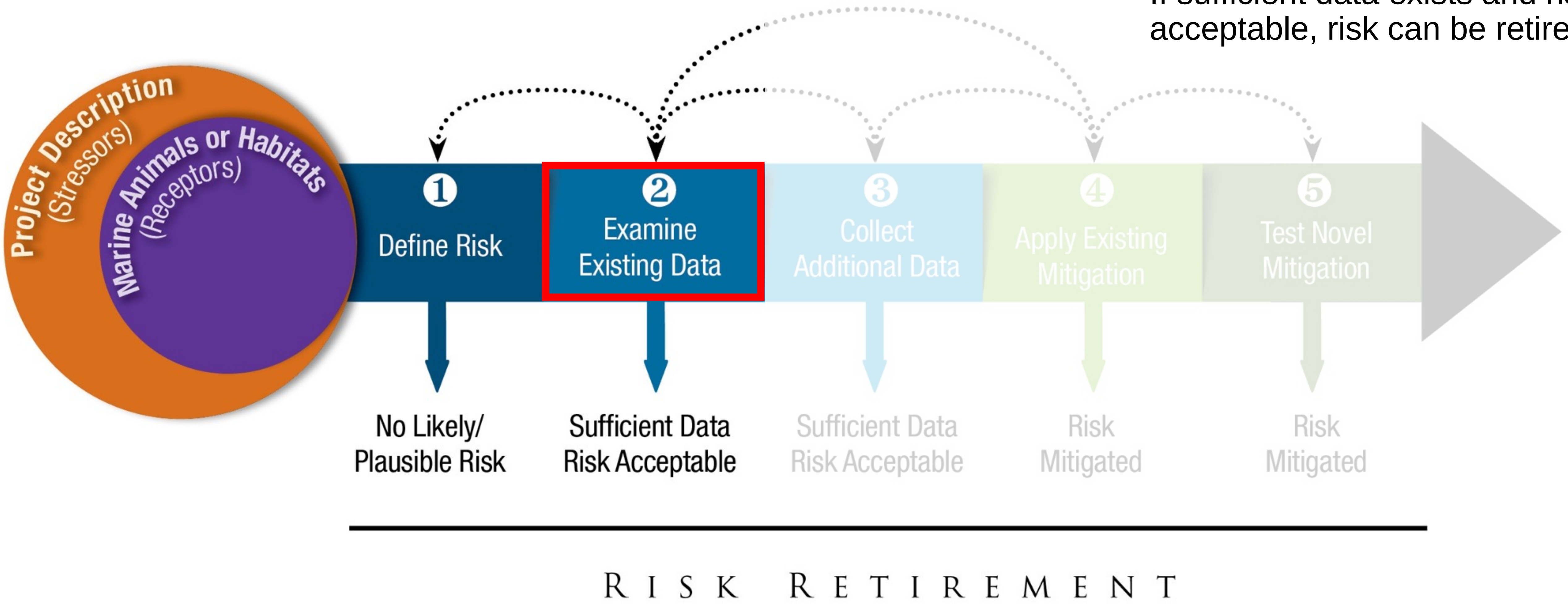
- Define Risk
  - If no likely/plausible risk, risk can be retired



Pathway to Risk Retirement

Stage Gate 2

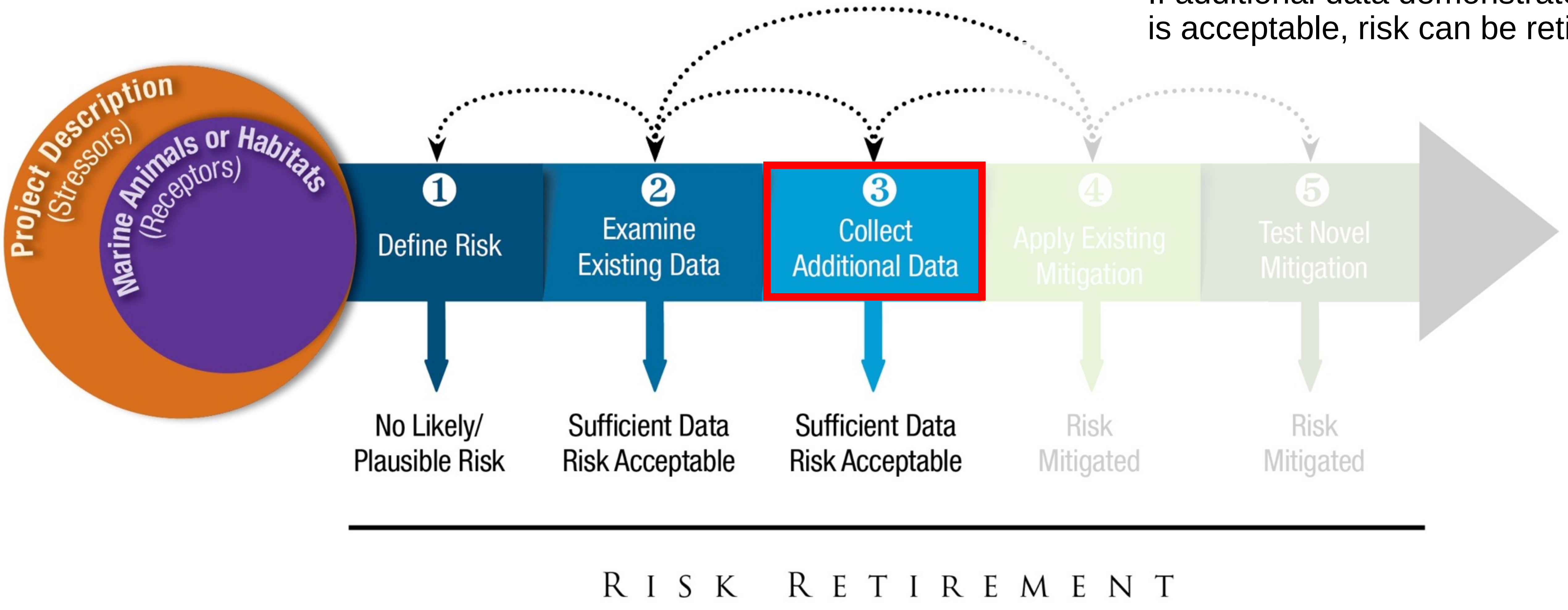
- Examine Existing Data
  - If sufficient data exists and risk is acceptable, risk can be retired



Pathway to Risk Retirement

Stage Gate 3

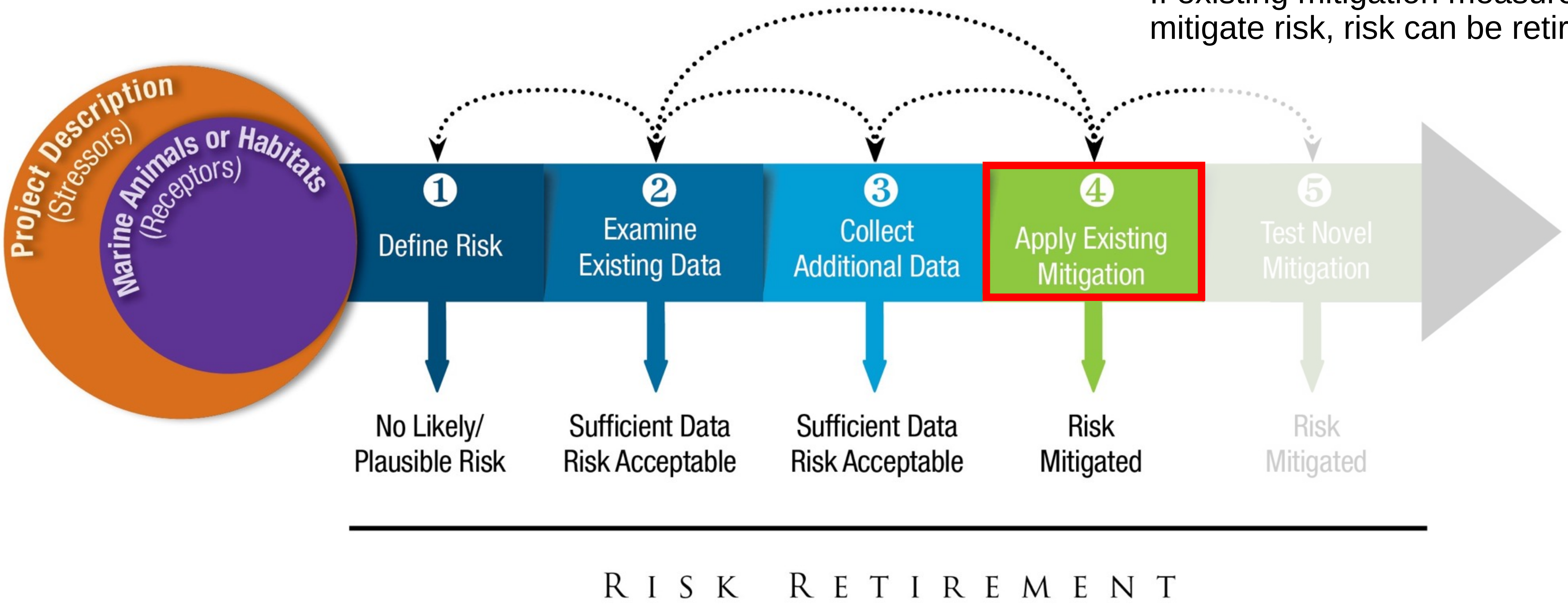
- Collect Additional Data
  - If additional data demonstrates risk is acceptable, risk can be retired



Pathway to Risk Retirement

Stage Gate 4

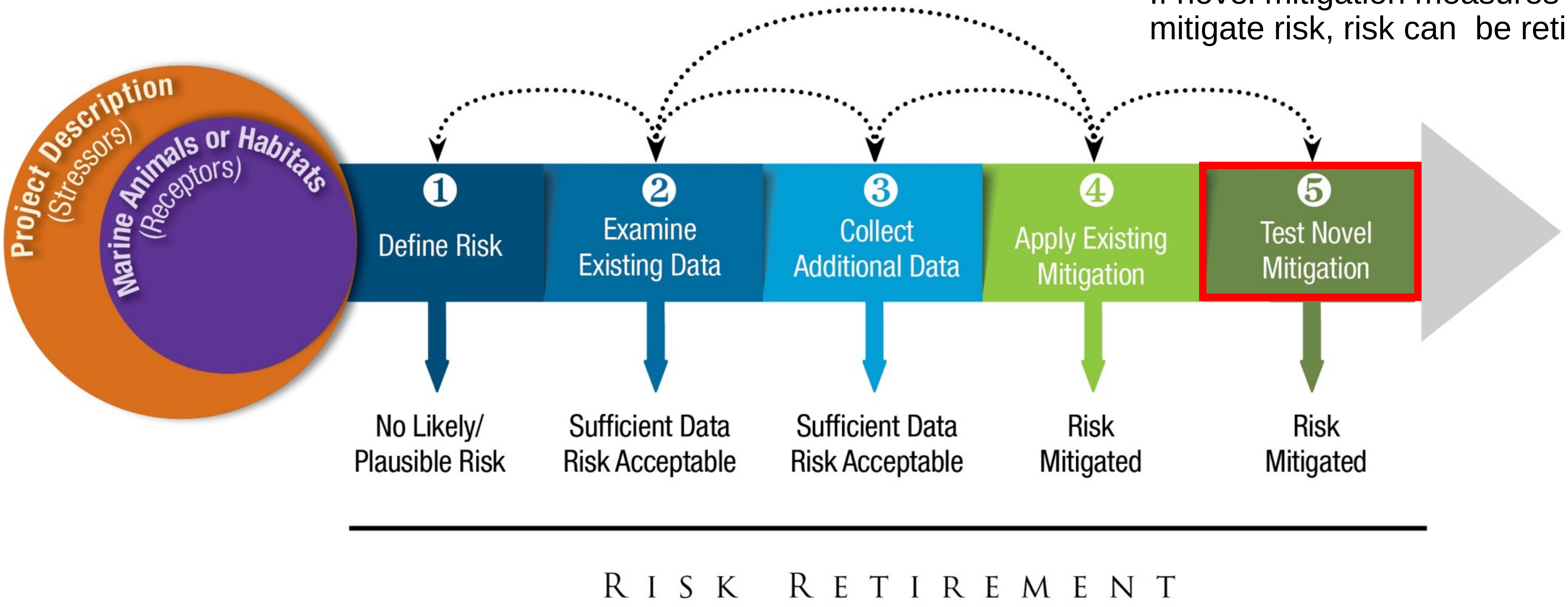
- Apply Existing Mitigation
  - If existing mitigation measures mitigate risk, risk can be retired



Pathway to Risk Retirement

Stage Gate 5

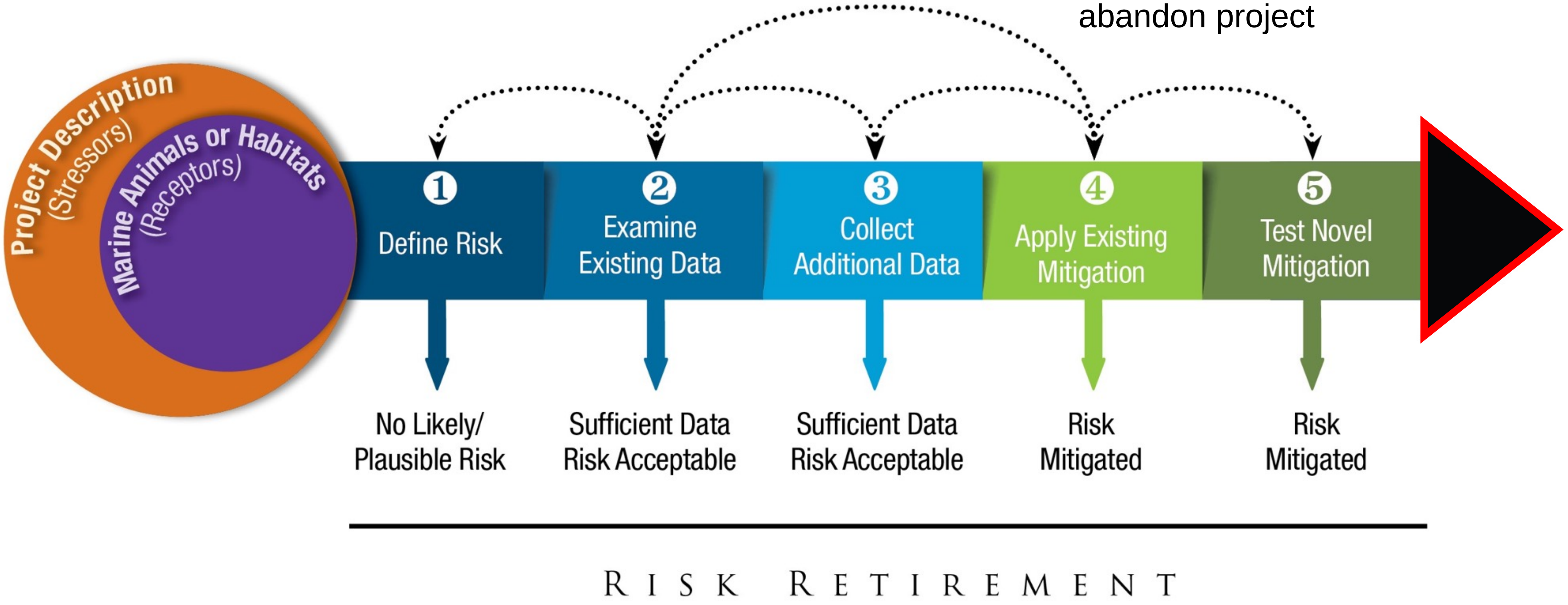
- Test Novel Mitigation
  - If novel mitigation measures mitigate risk, risk can be retired



Pathway to Risk Retirement

End of Pathway

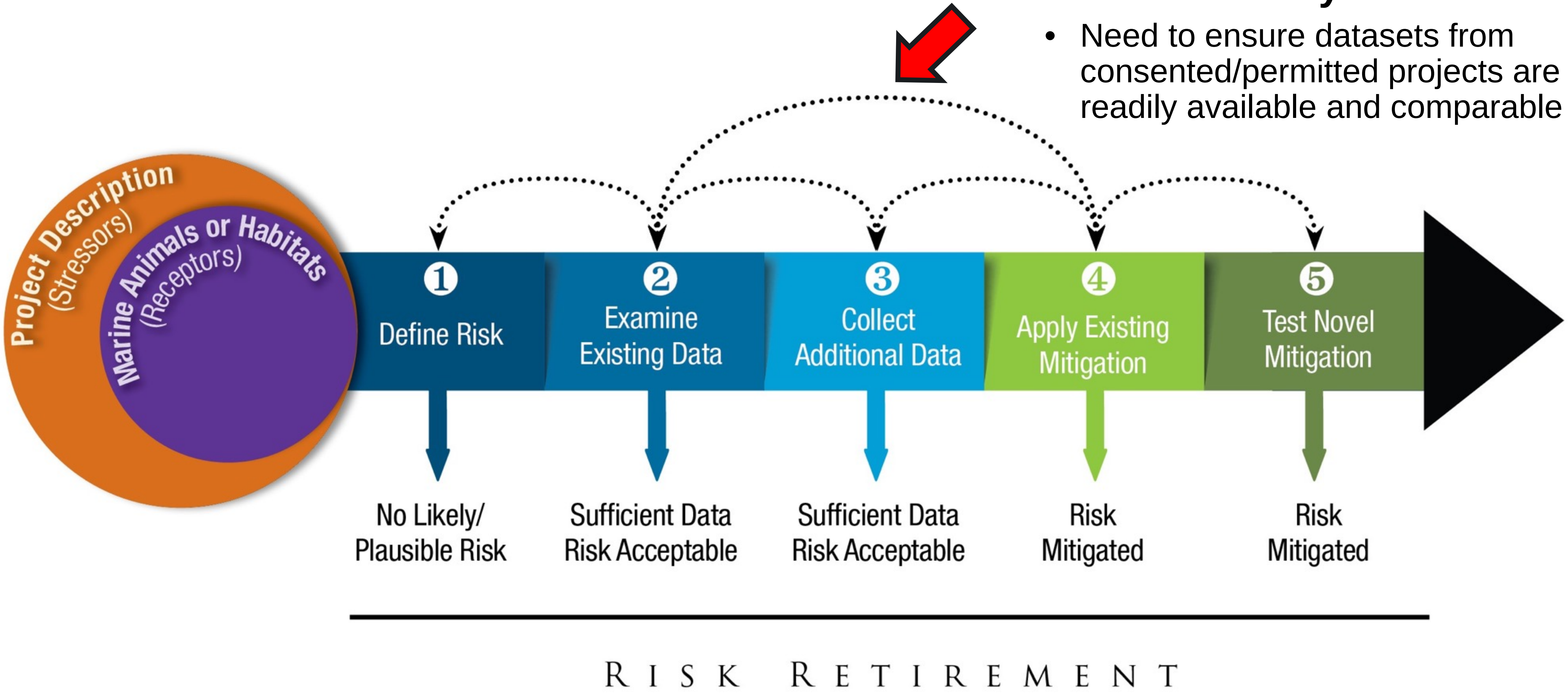
- If risk is significant and cannot be mitigated, redesign or possibly abandon project



Pathway to Risk Retirement

Data Transferability Process

- Need to ensure datasets from consented/permitted projects are readily available and comparable

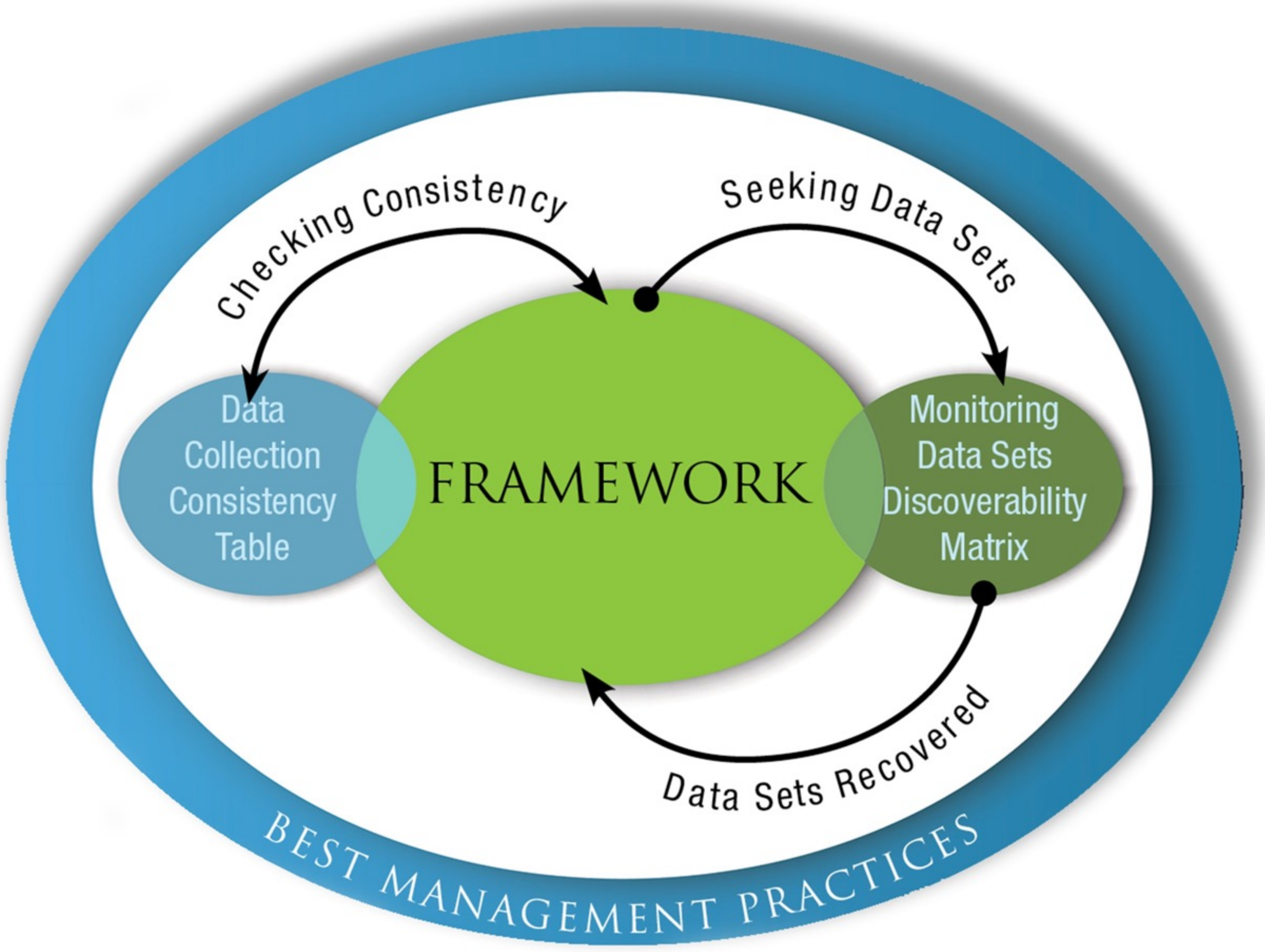


Data Transferability and Collection Consistency

What do we mean by "data transferability" and "data collection consistency"?

- 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 sets that might be "transferred" need to be collected consistently for comparison.

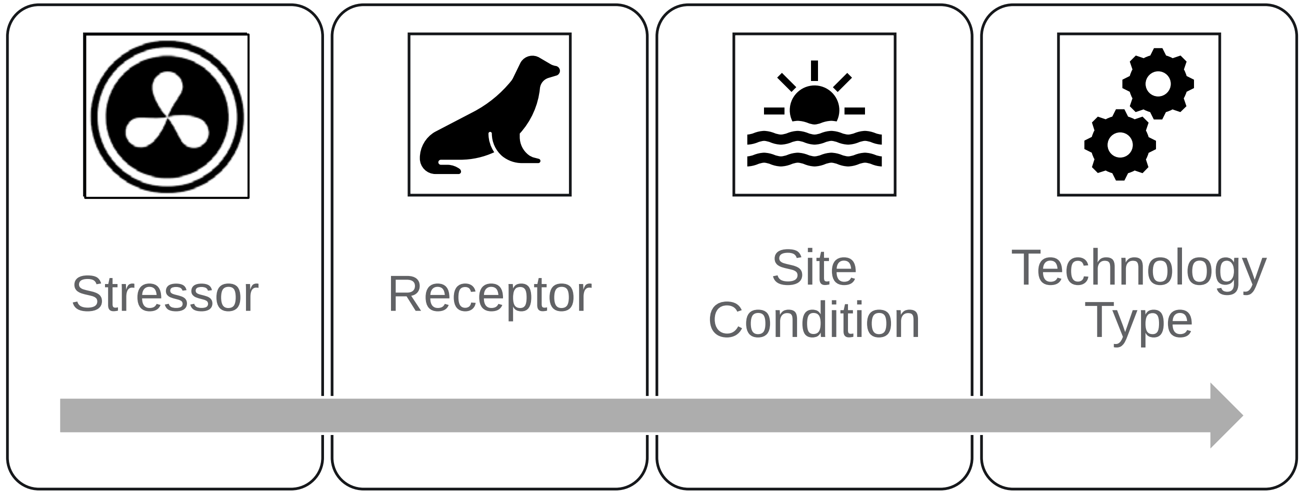
Data Transferability Process



Data Transferability Framework

What does the Data Transferability Framework do?

- Brings together data sets from already permitted/consented projects
- Compares the applicability of each data set for transfer
- Assures data collection consistency through preferred measurement methods
- Guides the process of data transfer



Pacific Northwest NATIONAL LABORATORY

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

Risk Retirement for Underwater Noise and EMF

Andrea Copping & Mikaela Freeman

Pacific Northwest National Laboratory

OES ENVIRONMENTAL

Ocean Energy ORJIP working to accelerate offshore consenting

Information on Underwater Noise from MRE Devices

Sound recordings and data courtesy of
Brian Polagye (PMEC), Teresa Simas, (WavEc),
Juan Bald (BIMEP) and partners

Underwater Noise Effects

- Anthropogenic noise from a variety of sources can:
  - Induce behavioral changes (i.e., avoidance/attraction)
  - Cause physical harm
- Shipping and other industries produce higher-amplitude noise (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



U.S. 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 4: Summary of PTS onset thresholds.

	PTS Onset 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

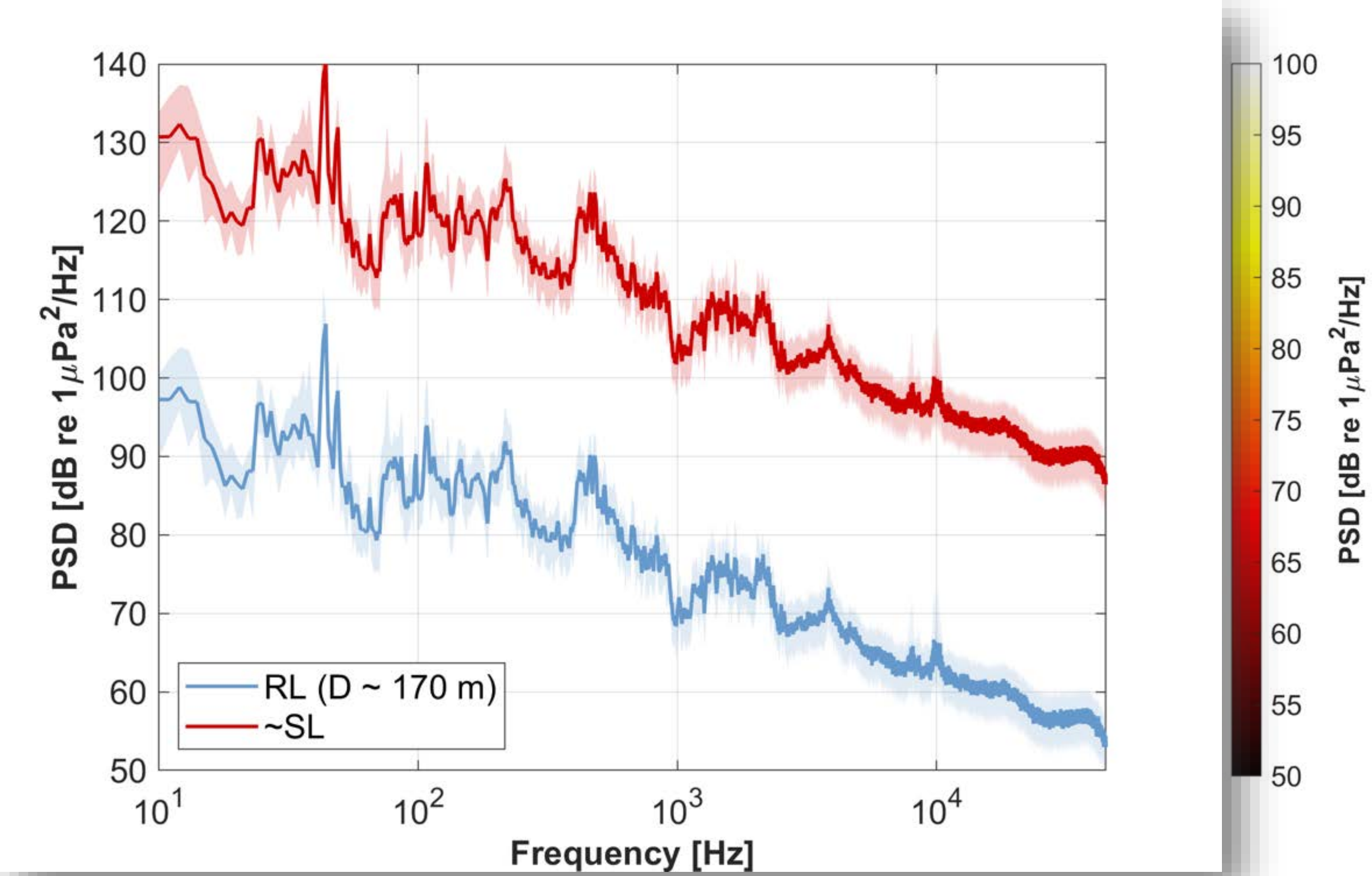
- NOAA Fisheries (salmon & bull trout)
- BOEM Underwater Acoustic Modeling Report (2013)

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 $\mu Pa^2 s$	SEL_{cum}, For fishes above 2 grams (0.07 ounces)
	183 dBL re 1 $\mu Pa^2 s$	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

- European Marine Energy Centre (EMEC), Fall of Warness
- Noise from rotor, power take off, and “seal scarer”
- Broadband (10 Hz – 45 kHz) SL = 150 dB



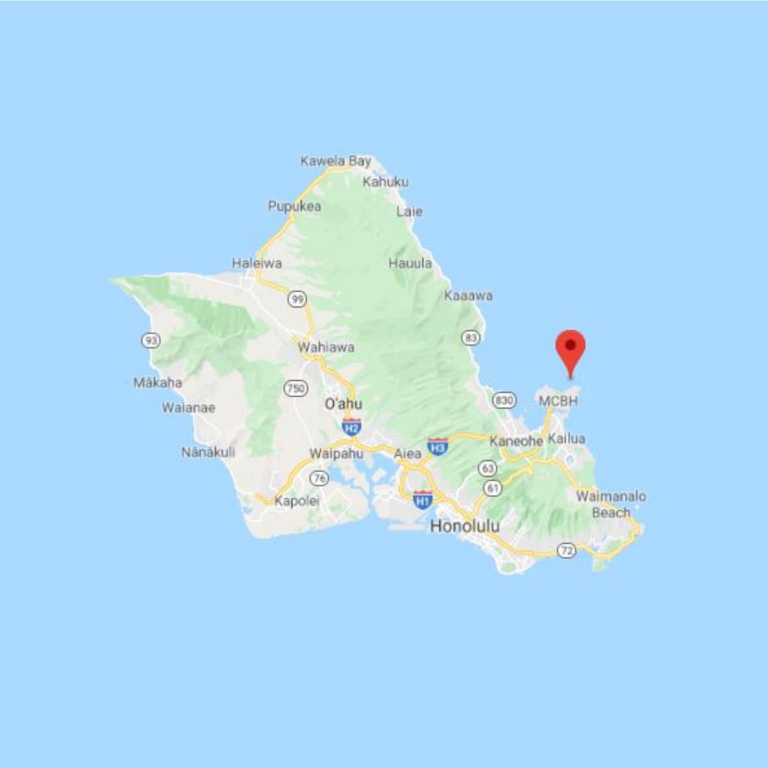
(Polagye et al. 2017, pers. com.)

ORPC In-stream River Turbine

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

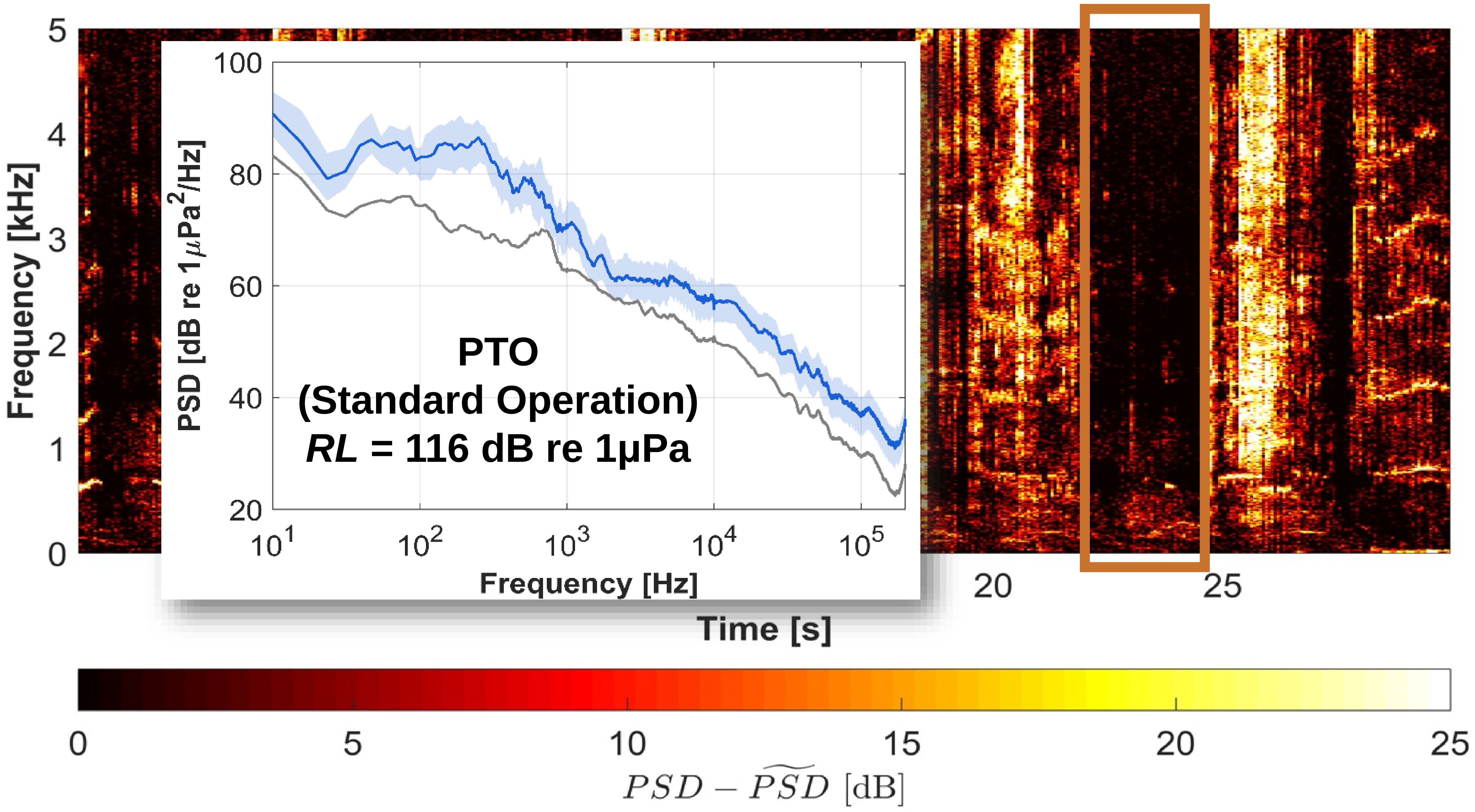
Fred. Olsen Lifesaver at WETS

- Hawai'i Wave Energy Test Site (WETS), Oahu, HW, U.S.
- Floating point absorber
- Shallow draft (0.5 m)
- Noise measurements (2016):
  - 3 seabed-mounted hydrophones (3 months)
  - 2 drifting hydrophones (3 drifts)



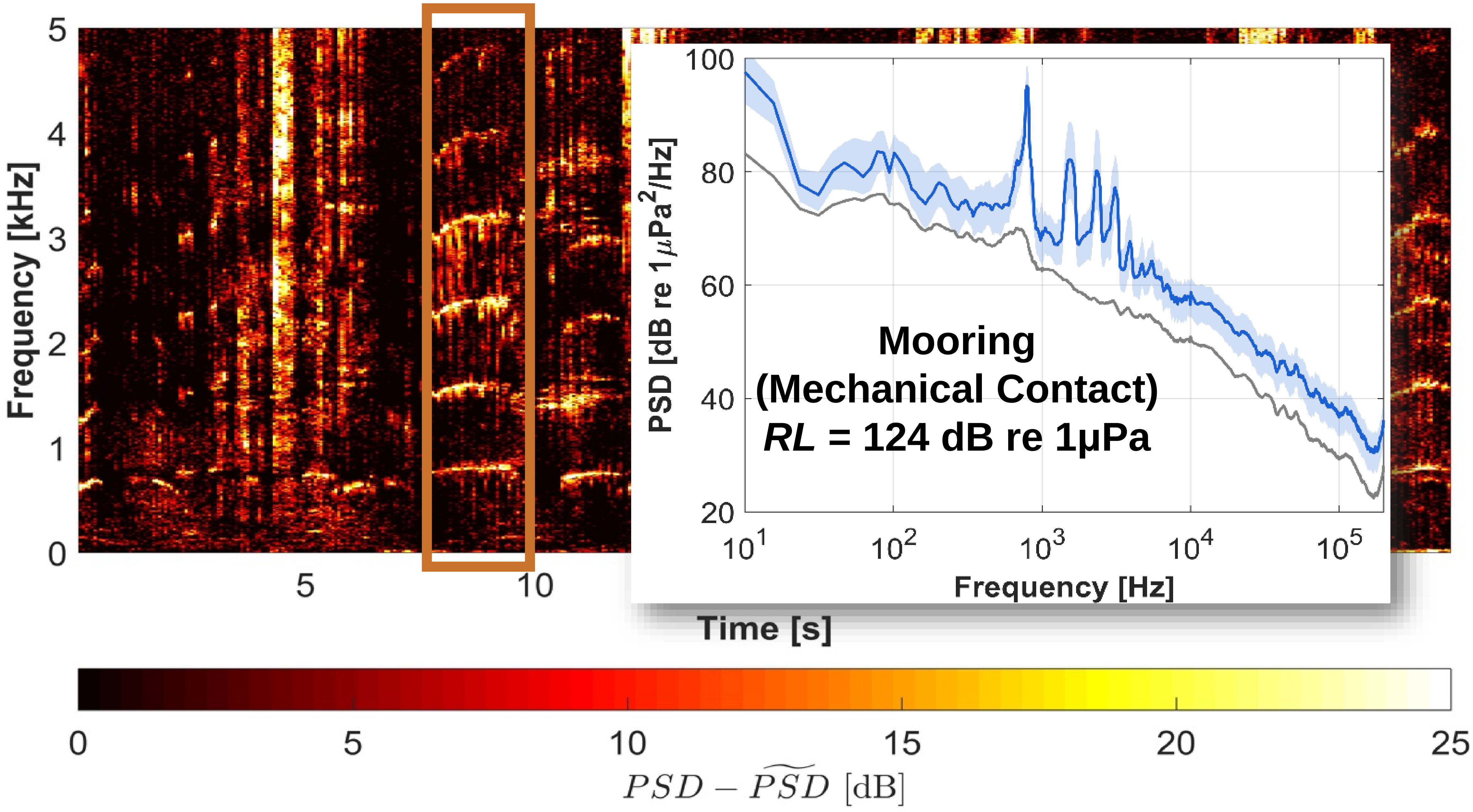
(Polagye et al. 2017, EWTEC)

Fred. Olsen Lifesaver at WETS



(Polagye et al. 2017, EWTEC)

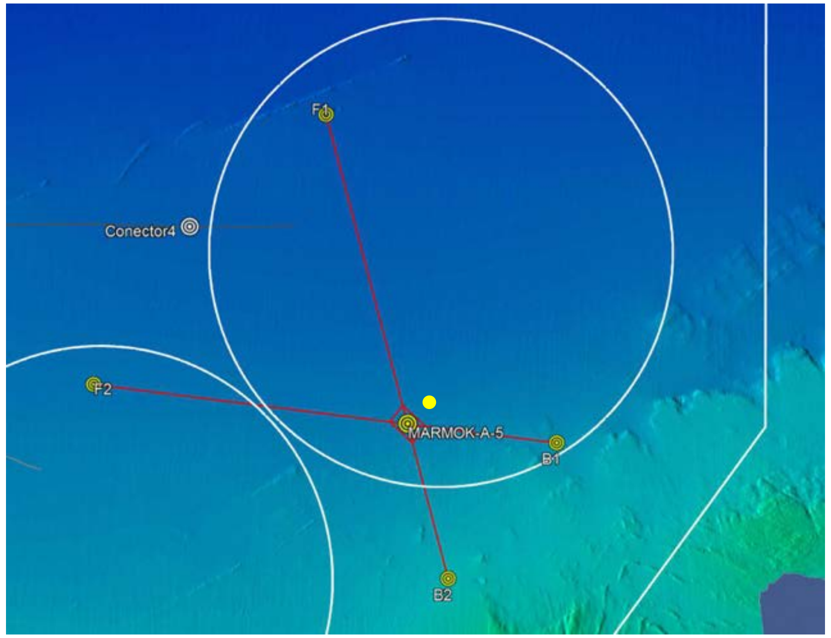
Fred. Olsen Lifesaver at WETS



(Polagye et al. 2017, EWTEC)

IDOM's MARMOK-A-5 at BiMEP

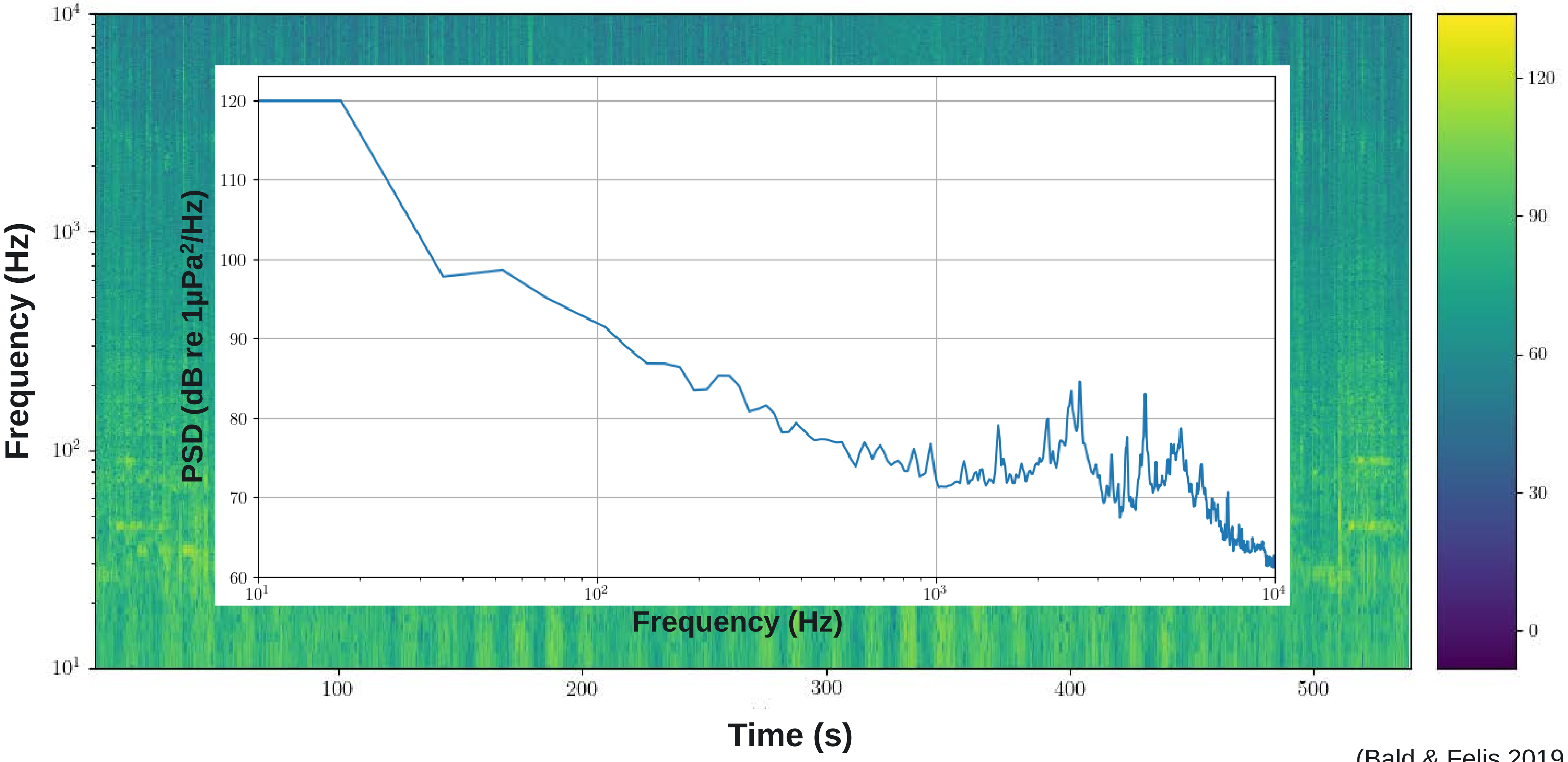
- Biscay Marine Energy Platform, Armintza Test Site, Spain
- Oscillating water column
- Noise measurements (WESE Project, 2019):
  - 1 seabed-mounted hydrophone at ≈ 100 m from device
  - Continuous recording for 44 days



(Bald 2019, pers. com.)

IDOM’s MARMOK-A-5 at BiMEP

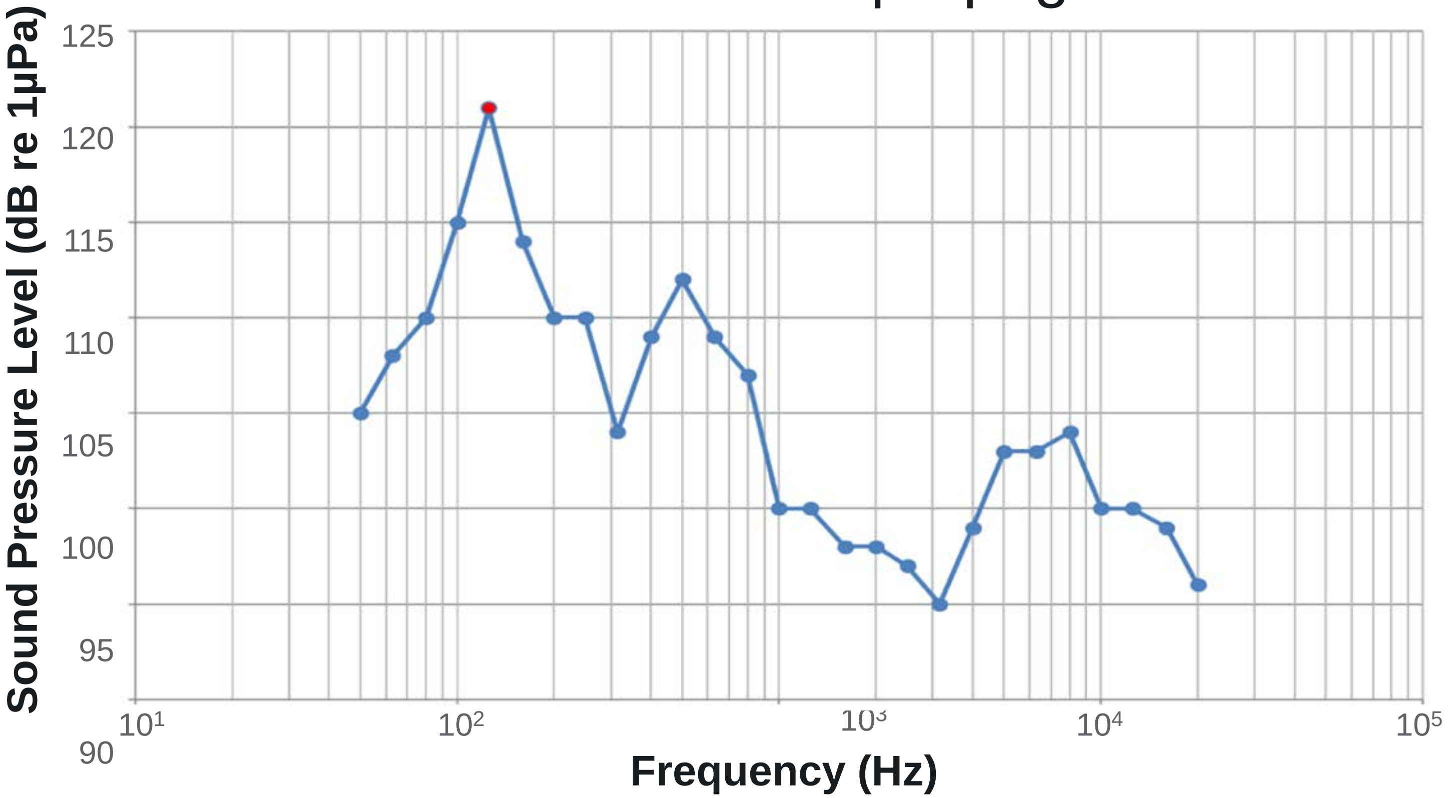
- Mooring line is dominant noise in 5 m wave height



(Bald & Felis 2019, pers. com.)

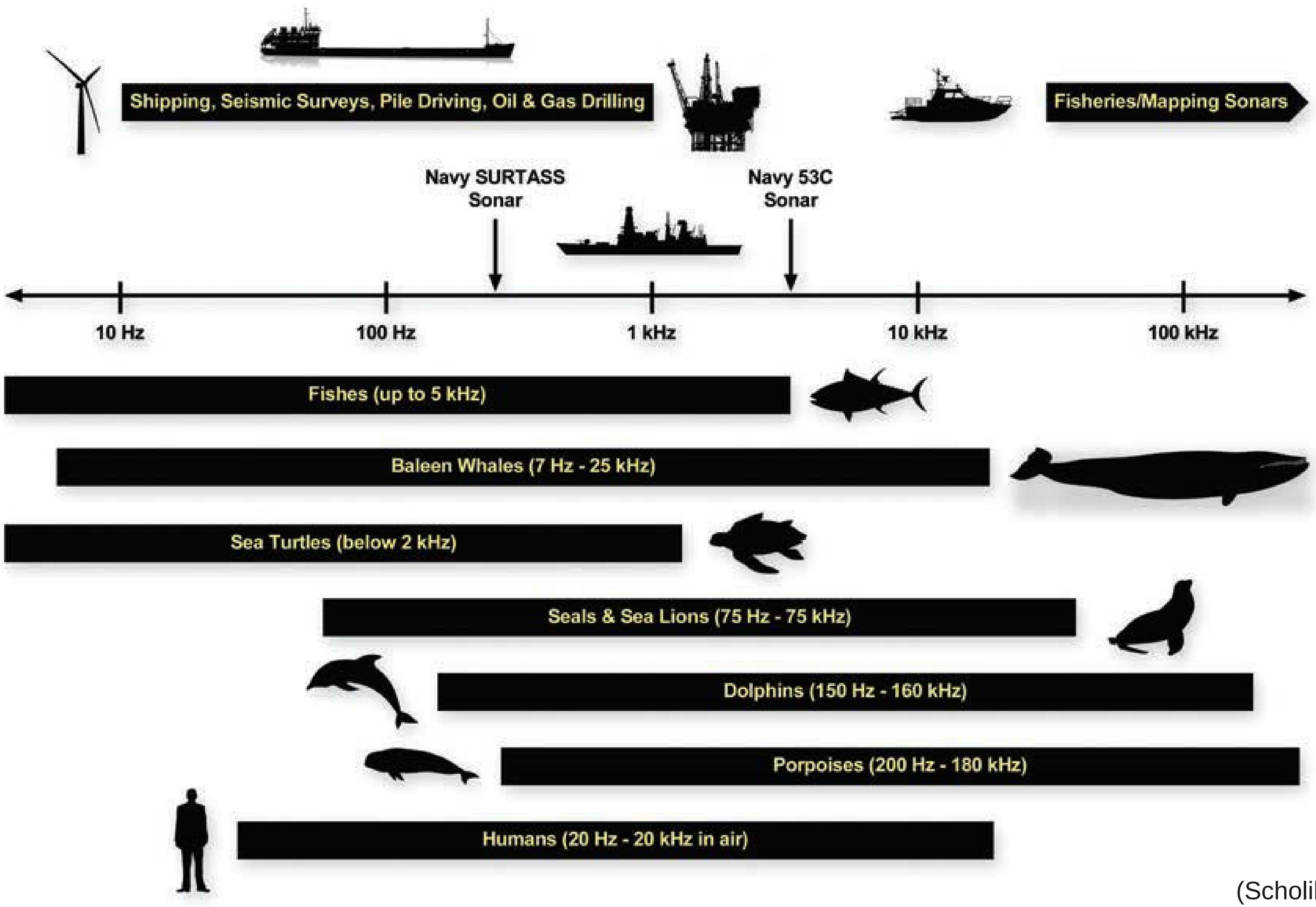
WaveRoller at WavEc

- WavEc Offshore Energy Test Site, Peniche, Portugal
- Oscillating wave surge converter, bottom-mounted
- Noise measurements (2014):
  - 2 seabed-mounted hydrophones (24 h)
  - Sound characterization & propagation measurements



(Cruz et al. 2015, EWTEC)

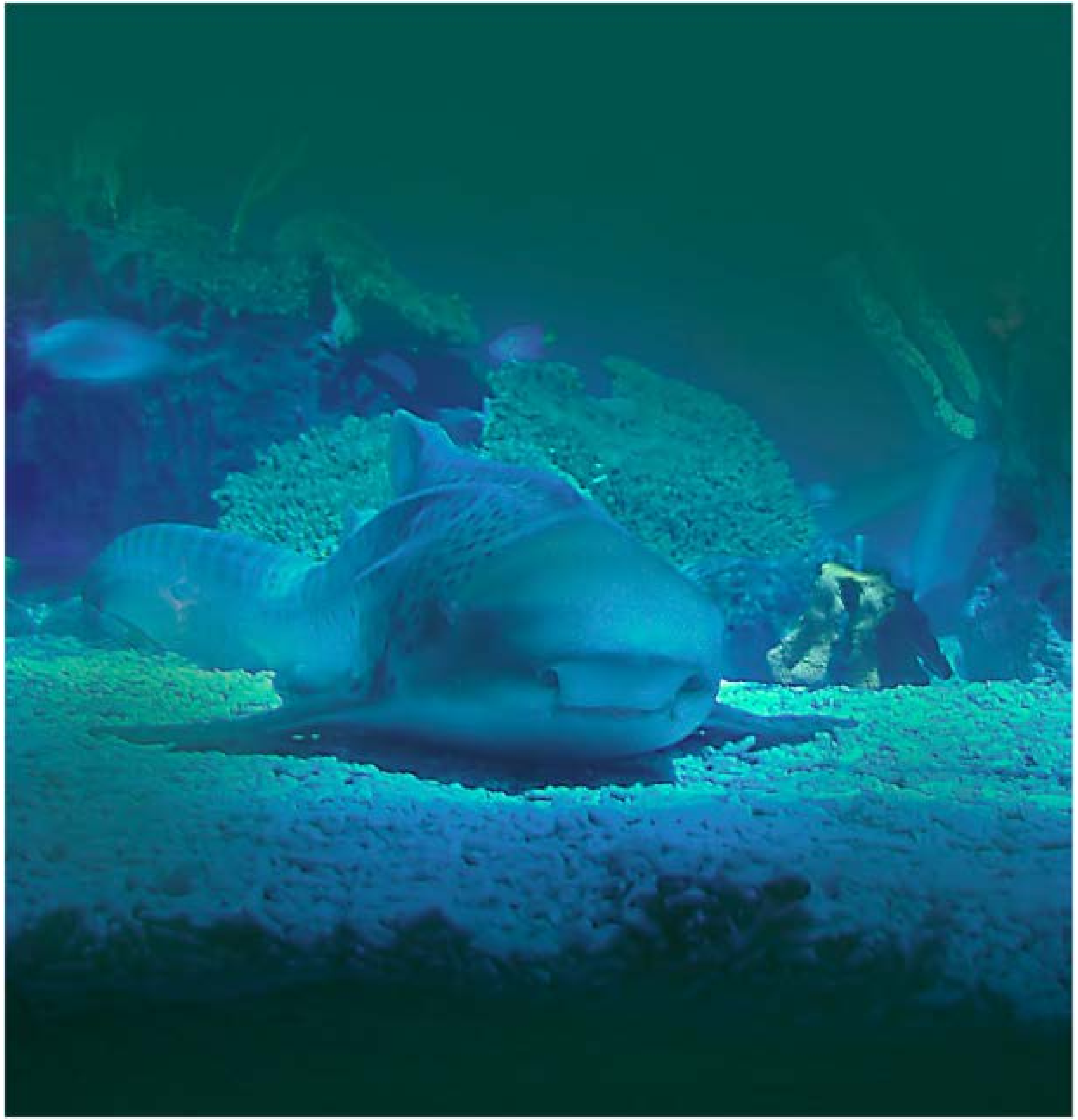
Hearing Thresholds vs. Underwater Noise Levels



(Scholik-Schlomer 2015)

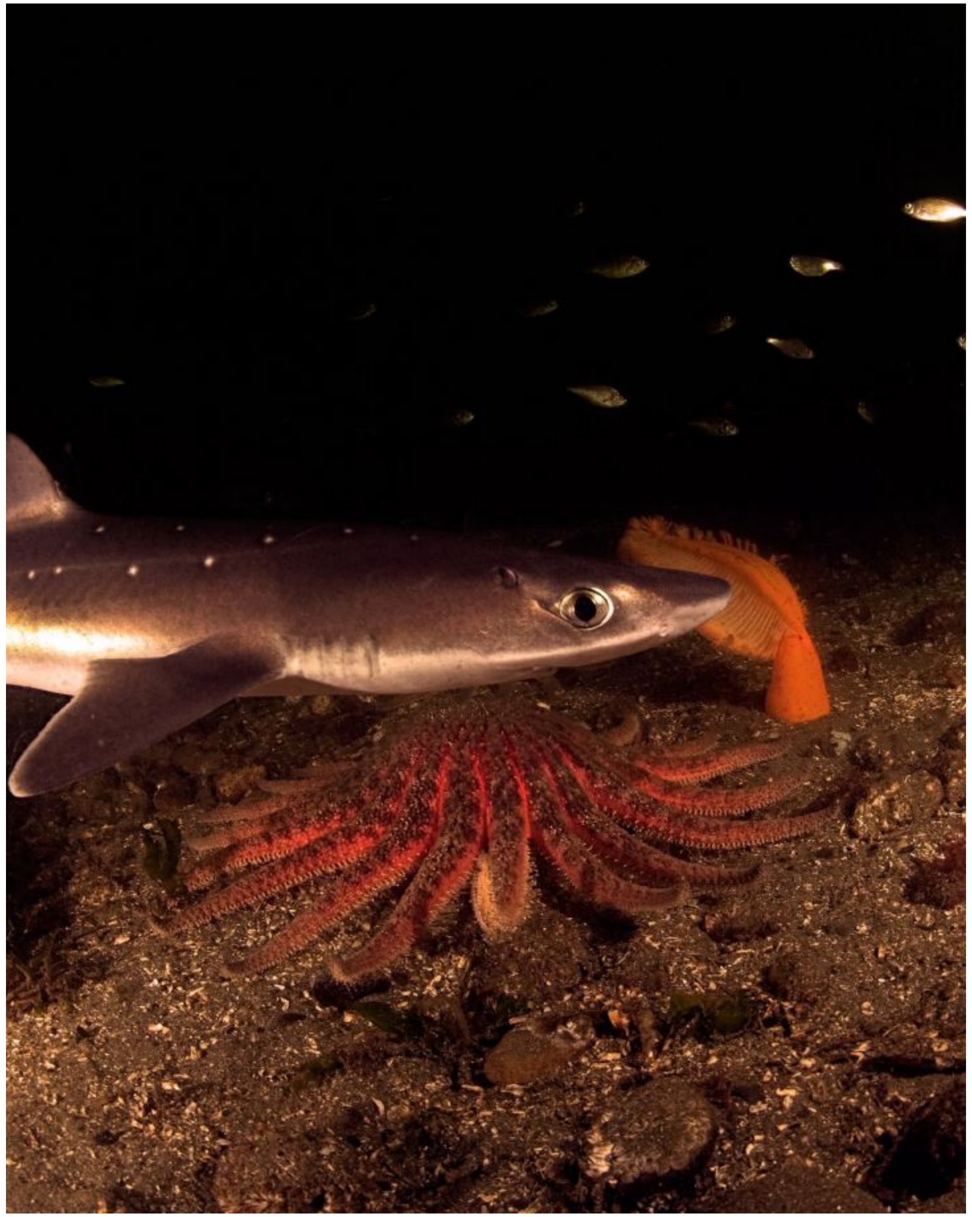
Information on EMF Impacts on Marine Animals from Exports Power Cables

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



Electromagnetic Fields (EMF) Effects

- Anthropogenic EMF come from a variety of infrastructure in marine environment (e.g., subsea cables, bridges, tunnels)
- MRE emits EMF from power cables, devices' moving parts, and substations/transformers
- EMF-sensitive species may be attracted to or avoid sources of EMF
- Concern that EMF emissions may interfere with natural magnetic fields used for orientation, navigation, and/or hunting
- No demonstratable impact of EMF related to MRE devices on any sensitive species



EMF Fields Studies

EMF-sensitive fish response to EM emissions from subsea electricity cables (Gill et al. 2009)

- Scotland, 2007. 125 kV AC cable buried 0.5-1 m
- Mesocosms with energized and control cables (3 trials)
- No evidence of positive or negative effect on catsharks (dogfish)
- Benthic elasmobranchs (skates) responded to EMF from cable


COWRIE

March 2009

COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2

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 (Westerberg and Lagenfelt 2008)

- Sweden, 2006, unburied 130 kV AC cable
- Used acoustic tags to track movements of 60 eels
- Eels swam more slowly over energized cable
- Effect was small, no evidence of barrier effect

EMF Fields Studies

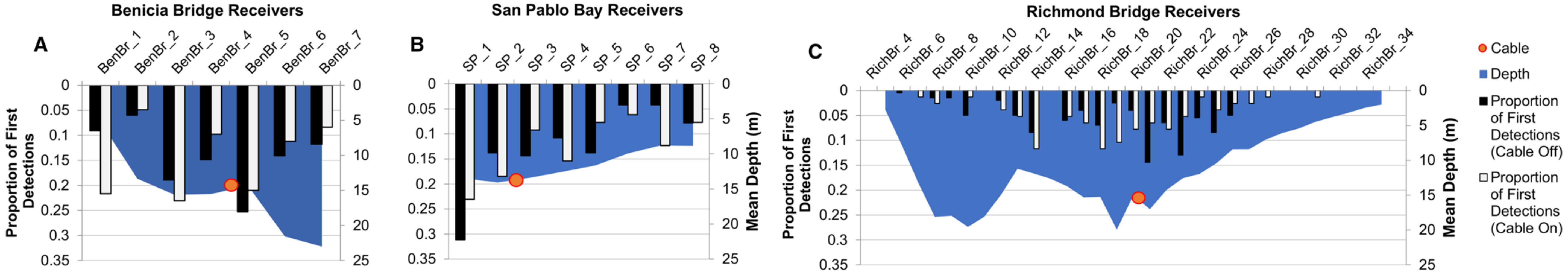
Assessment of potential impact of electromagnetic fields (EMF) from undersea cable on migratory fish behavior (Kavet et al. 2016)

- San Francisco Bay, U.S. 2014. Buried 200 kV DC cable
- HVDC cable parallel and perpendicular to green & white sturgeon, salmon, and steelhead smolt migrations
- Tagged fish, magnetometer surveys
- Outcome – such large magnetic signatures from bridges, other infrastructure, could not distinguish cable!
- Fish migration did not appear to be affected

EMF Fields Studies

Behavioral responses by migrating juvenile salmonids to a subsea high-voltage DC power cable (Wyman et al. 2018)

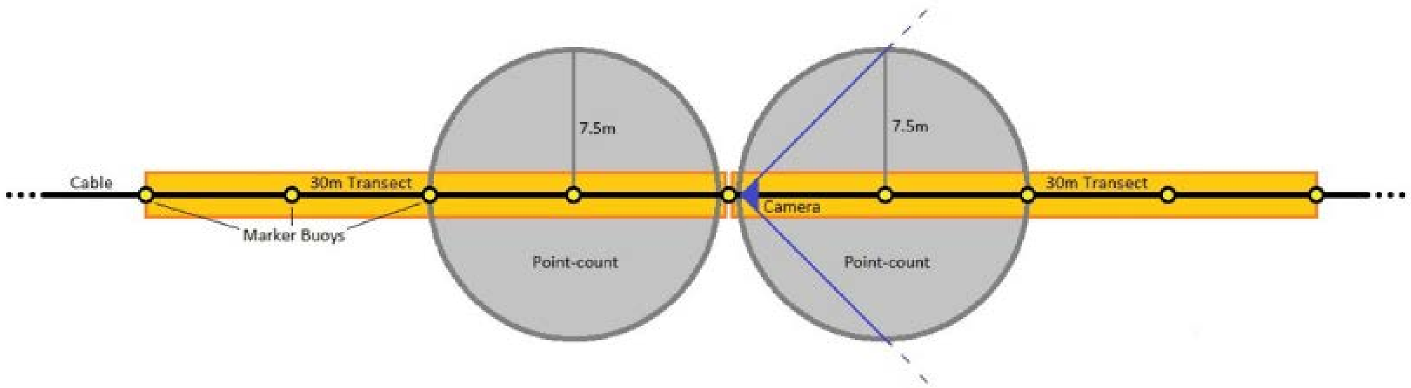
- Same U.S. study, 2014.
- Before and after energizing Trans Bay Cable
- Tagged Chinook salmon smolts successfully migrated through the bay before and after cable energized without significant difference
- Cable activity not associated with the probability of successfully exiting the system, or crossing the cable location

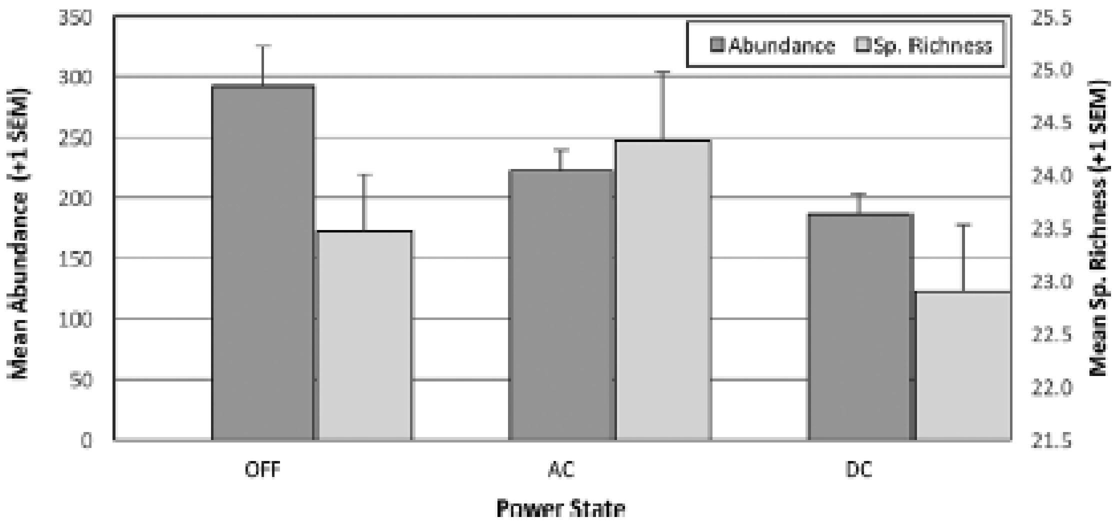


EMF Fields Studies

Effects of EMF emissions from undersea electric cables on coral reef fish (Kilfoyle et al. 2018)

- Florida U.S., 2014. 5-15 m deep, unburied cables
- Blind randomized sequence of ambient and energized AC and DC cable power states
- *In situ* observations of fish abundance and behavior ("unusual" or unexpected movements or reaction)
- No behavioral changes were noted in immediate responses to alterations in EMF
- No statistical differences in fish abundance between the power states





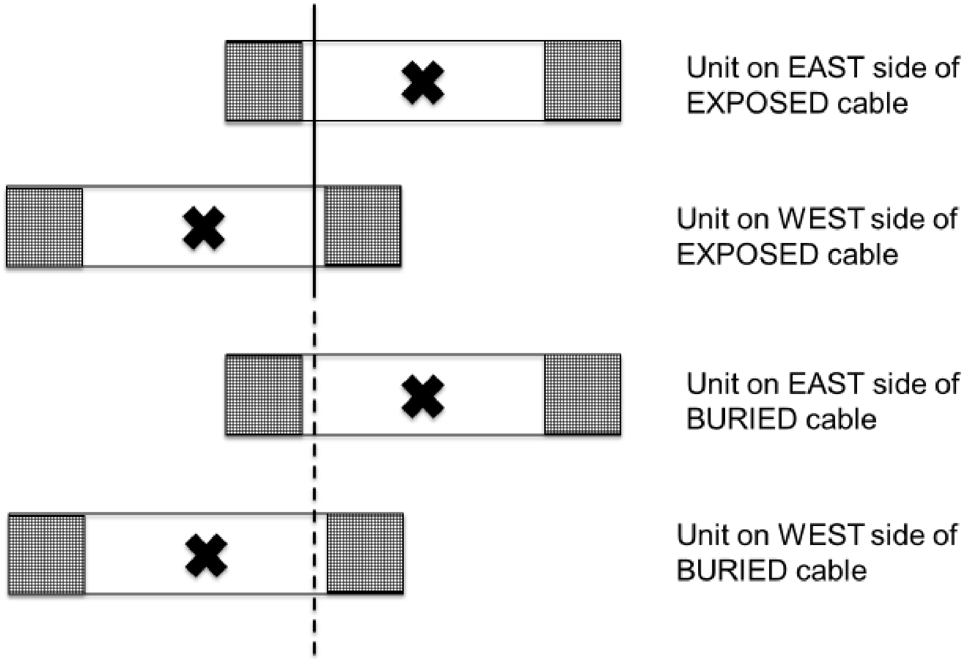
EMF Fields Studies

Potential impacts of submarine power cables on crab harvest (Love et al. 2017)

- Puget Sound and California, U.S, 2015. 10-13 m deep, unburied power cables
- Dungeness crab (Puget Sound) and red rock crab (Santa Barbara channel) – will they cross cable?
- Using baited cages across power line.
- Both crab species crossed cables, different voltages, power.

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

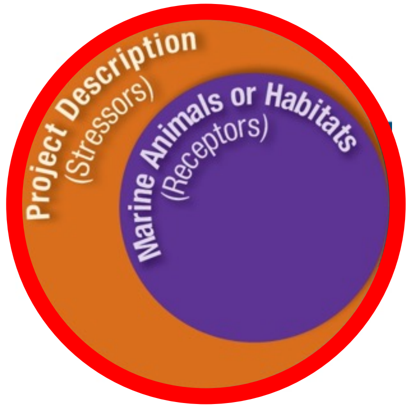
Electromagnetic field impacts on elasmobranchs and American lobster movement and migration from direct current cables (Hutchison et al. 2018)

- Rhode Island/Massachusetts, U.S., 2016. 10 m deep, buried 300 kV DC cable
- Determine if EMF-sensitive animals react to HVDC cable:
  - Enclosures with animals using acoustic telemetry tags
- 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

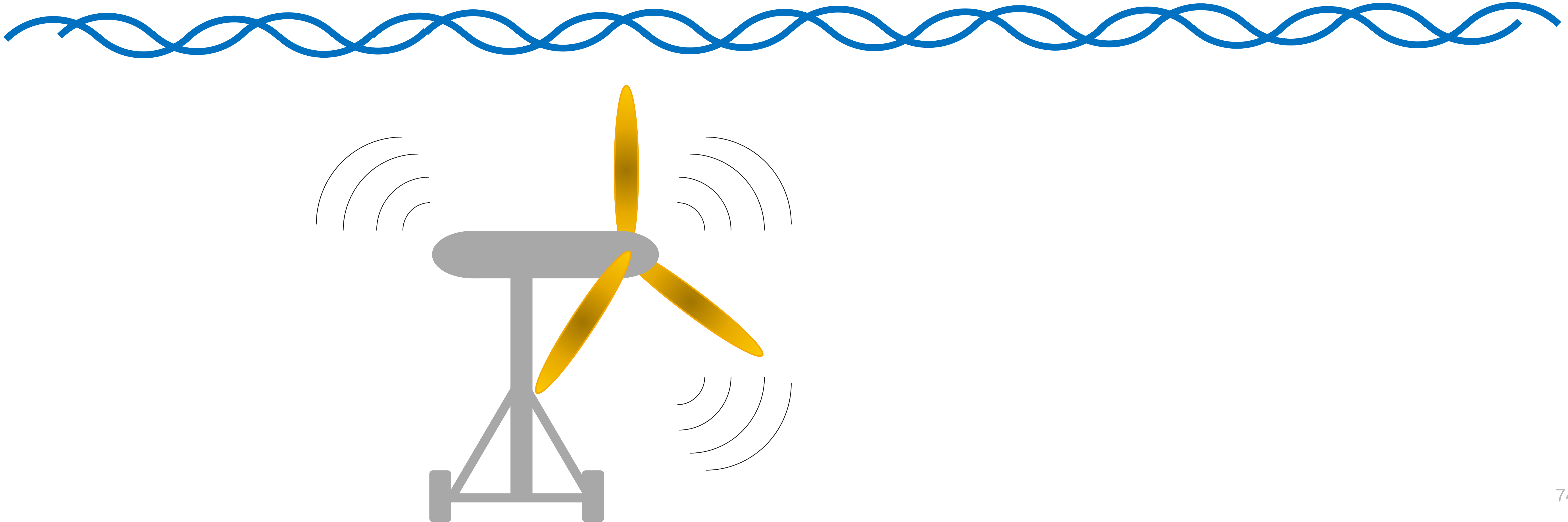
Case Study: Risk Retirement for Underwater Noise

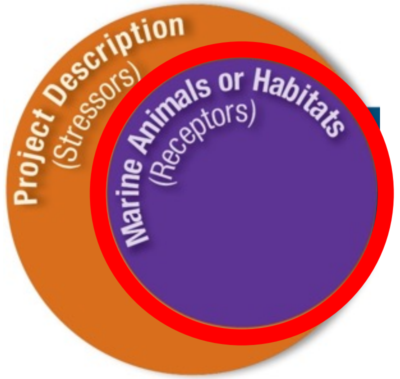
Ocean Energy
working to accelerate offshore consenting

Hypothetical example

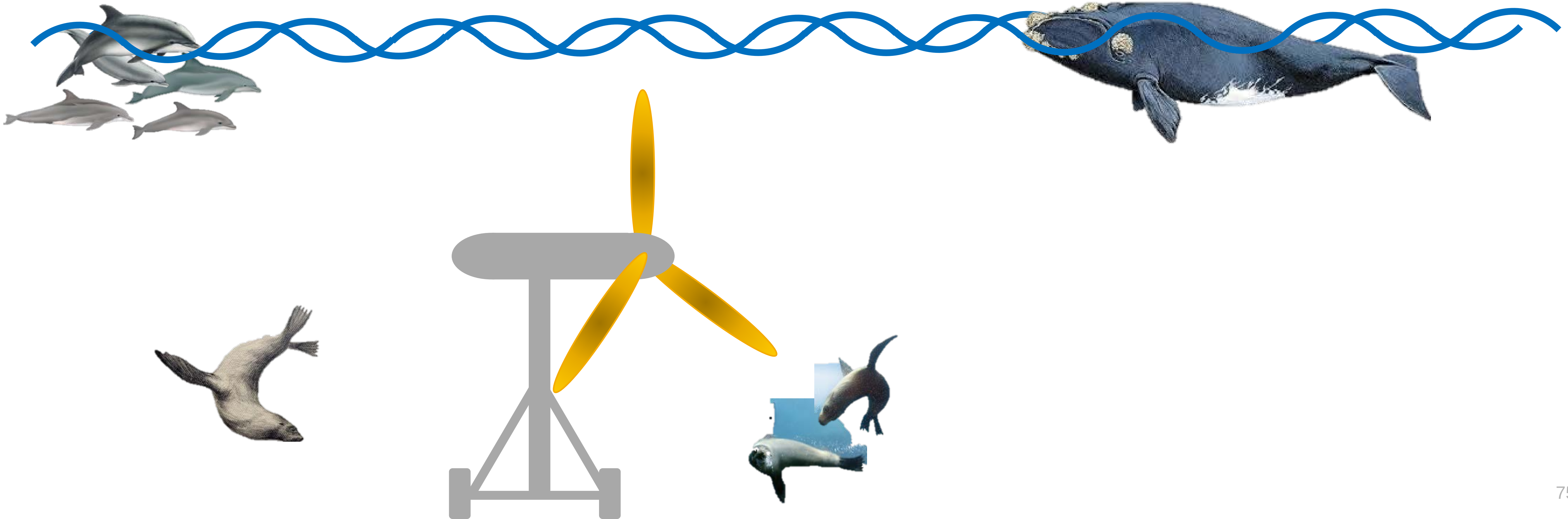


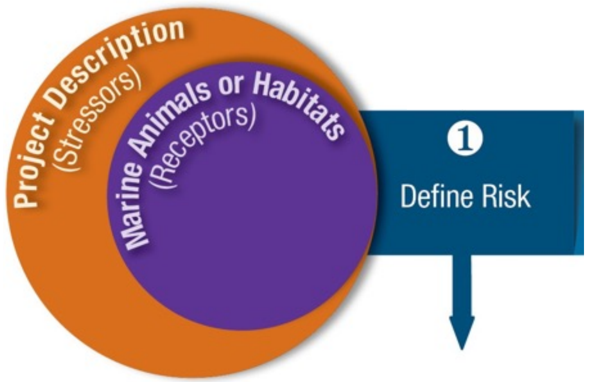
- ✓ 1 bottom-mounted tidal turbine.
- ✓ Sound generated by the rotating blades and the power take-off: 118 to 152 dB re 1 µPa at 1m, in the range 40 Hz to 8 kHz.



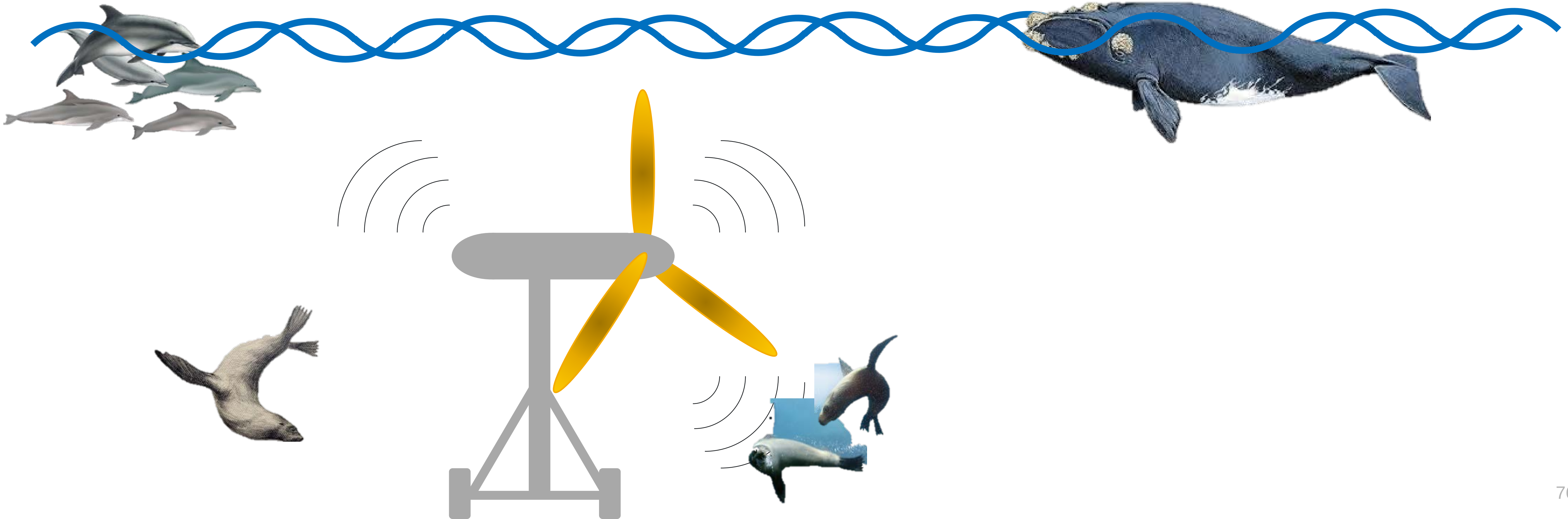


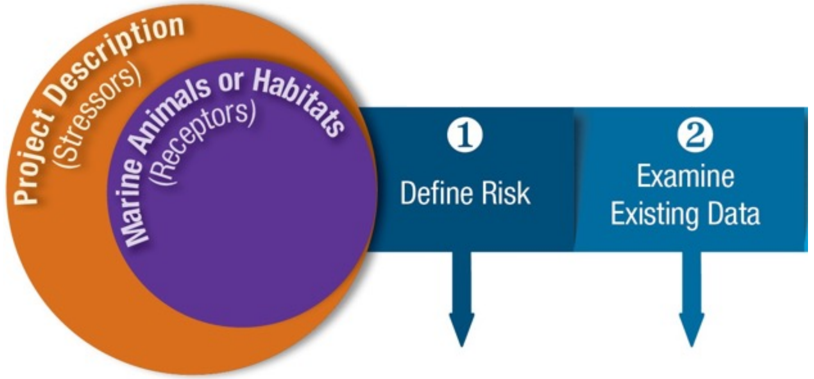
- ✓ 1 bottom-mounted tidal turbine.
- ✓ Sound generated by the rotating blades and the power take-off: 118 to 152 dB re 1 µPa at 1m, in the range 40 Hz to 8 kHz.
- ✓ Bass Strait: southern right whales, common dolphins, sea lions, fur seals.



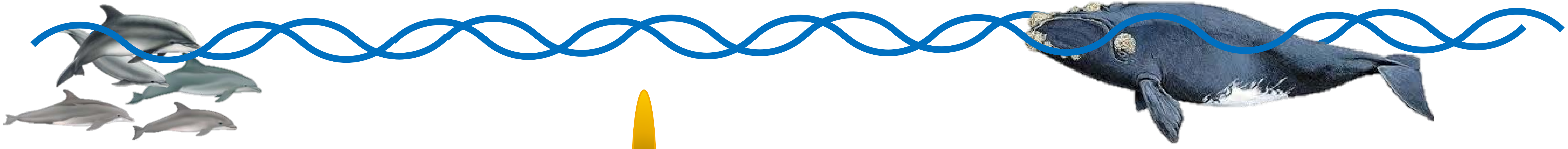


- ✓ Potential risk of underwater noise interfering with echolocation, may injure animals (ear trauma).





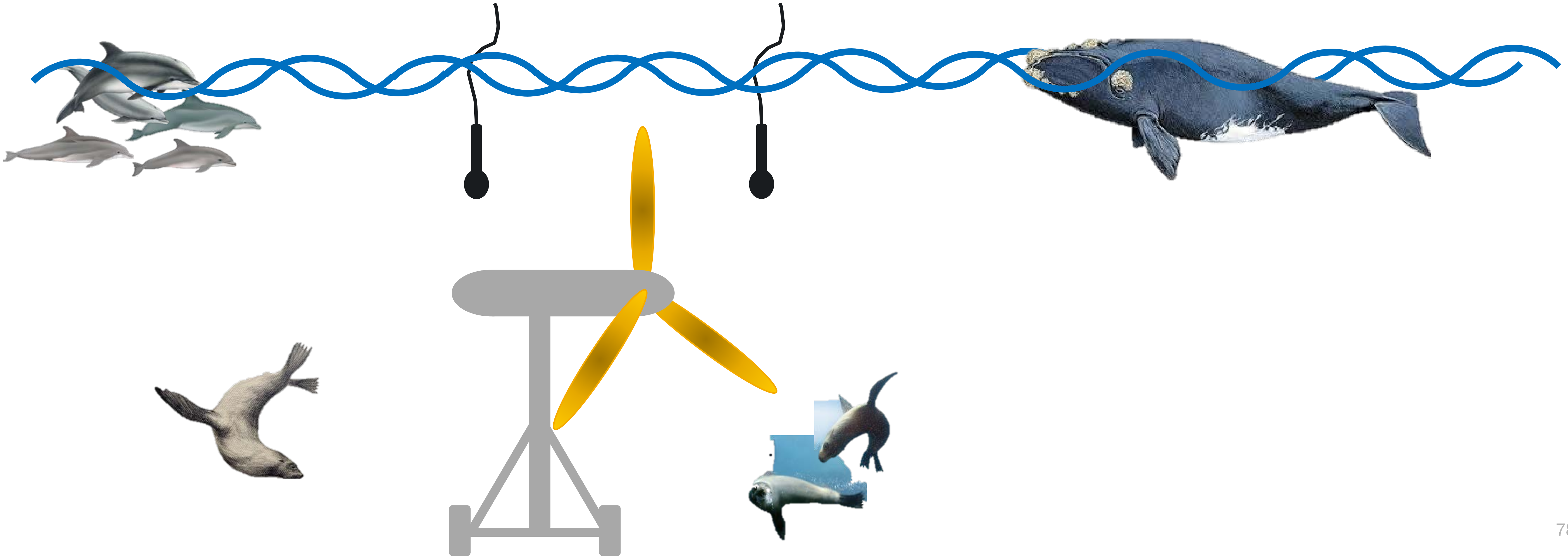
- ✓ Based on data (SEL = 150 dB re 1uPa^2-s):
  - ✓ Are sounds generated below regulatory thresholds?
  - ✓ How does it compare to noise generated by other industries?
  - ✓ Can we detect the noise of a mechanical defect?
- ➢ Risk retired except in case of mechanical failure.



TTS onset thresholds for non-impulsive sounds.

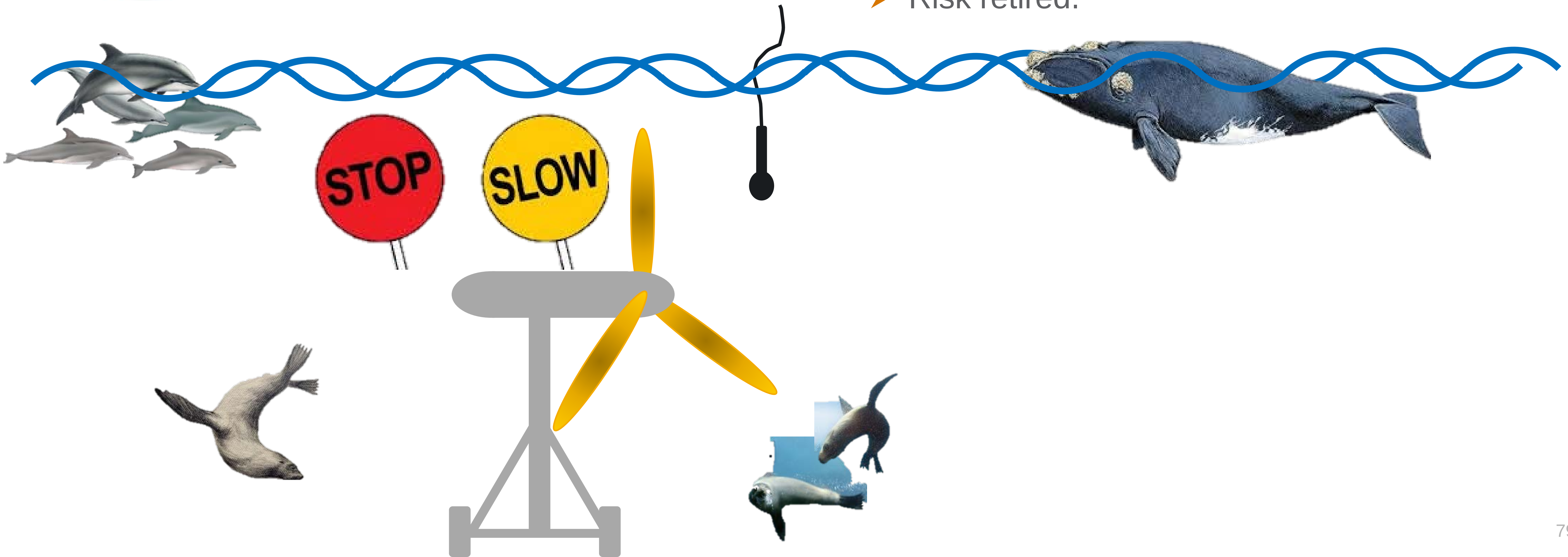
Hearing Group	*K* (dB)	*C* (dB)	Weighted TTS onset acoustic threshold (SEL_{cum})
Low-frequency (LF) cetaceans	179	0.13	179 dB
Mid-frequency (MF) cetaceans	177	1.20	178 dB
High-frequency (HF) cetaceans	152	1.36	153 dB
Phocid pinnipeds (underwater)	180	0.75	181 dB
Otariid pinnipeds (underwater)	198	0.64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

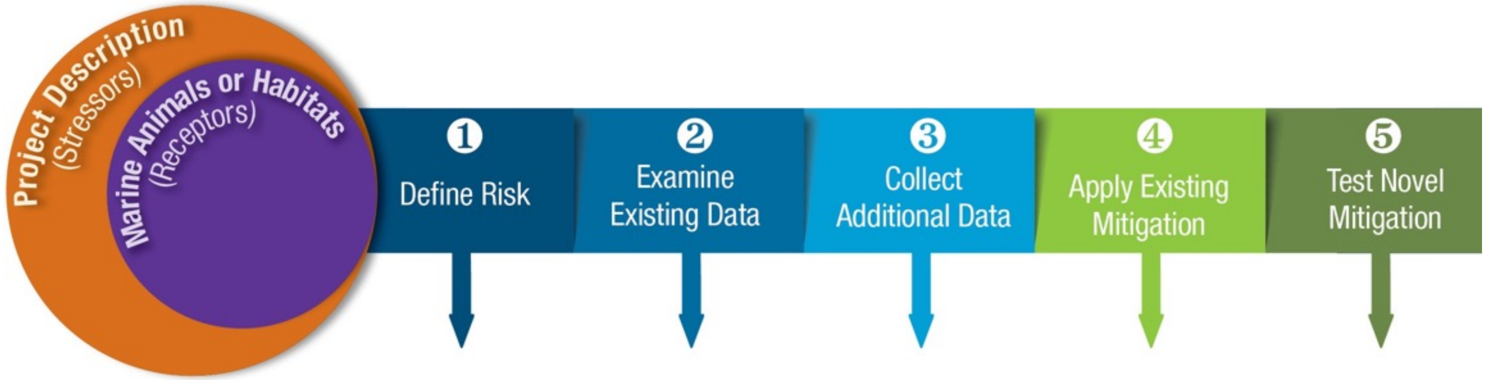
- ✓ Must have in-situ noise measurements to characterize overall sound levels.
- ➢ With this, risk may be retired.



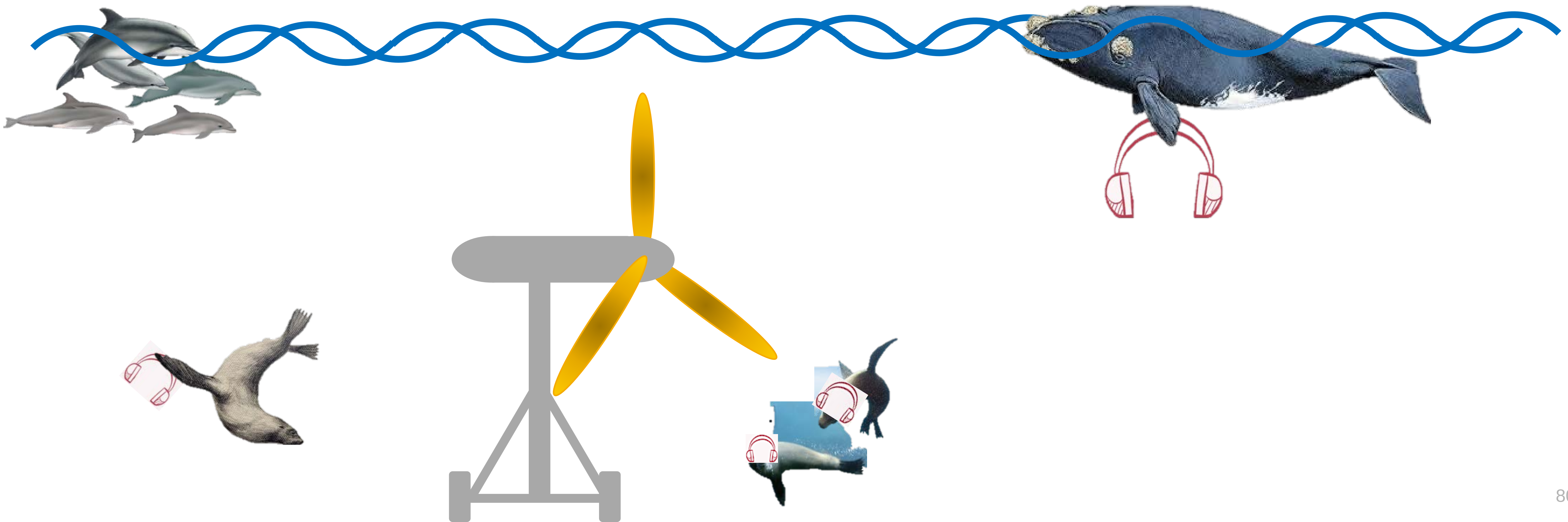
Pacific Northwest
NATIONAL LABORATORY

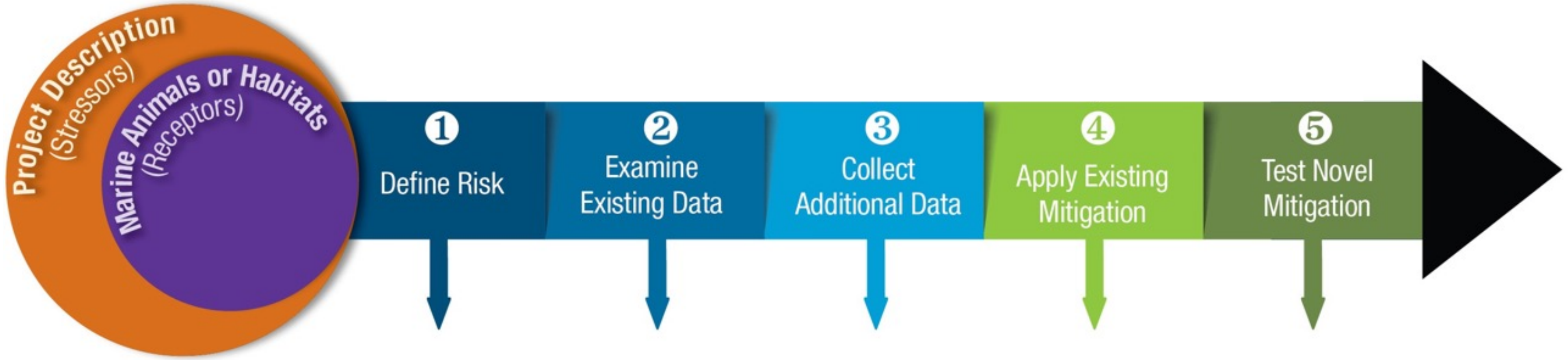
- ✓ Potential mitigation measures:
  - ✓ Monitor operational noise for mechanical failure;
  - ✓ Slow down or stop device when sound detected is above thresholds.
- ➢ Risk retired.



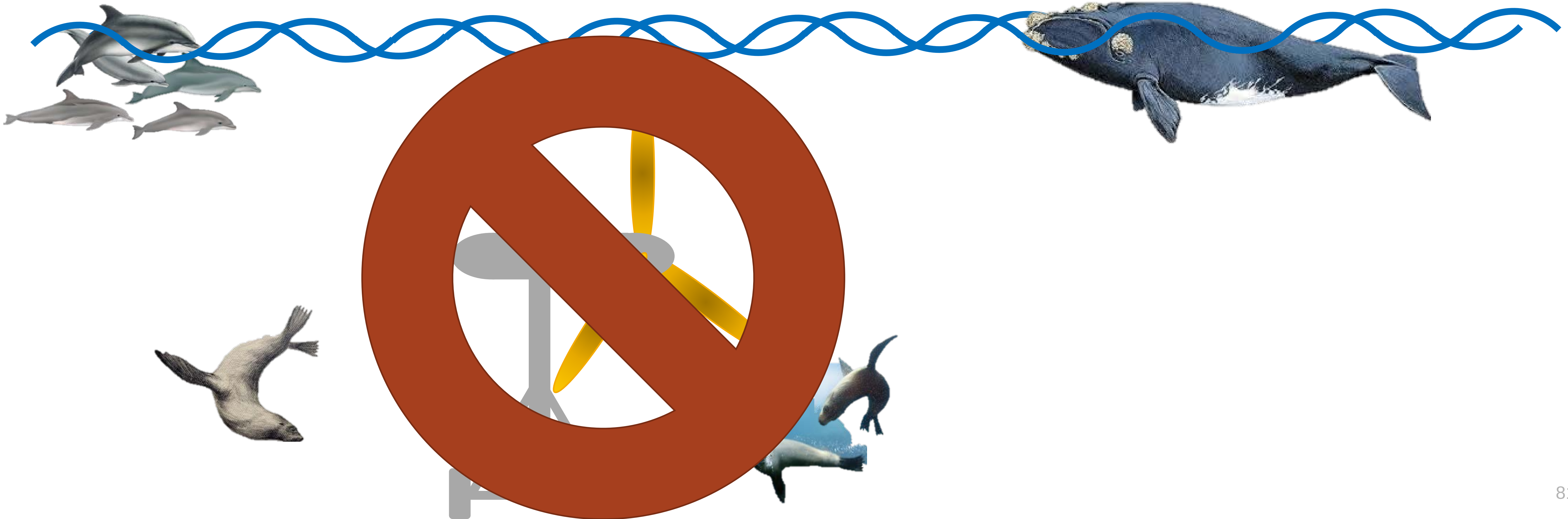


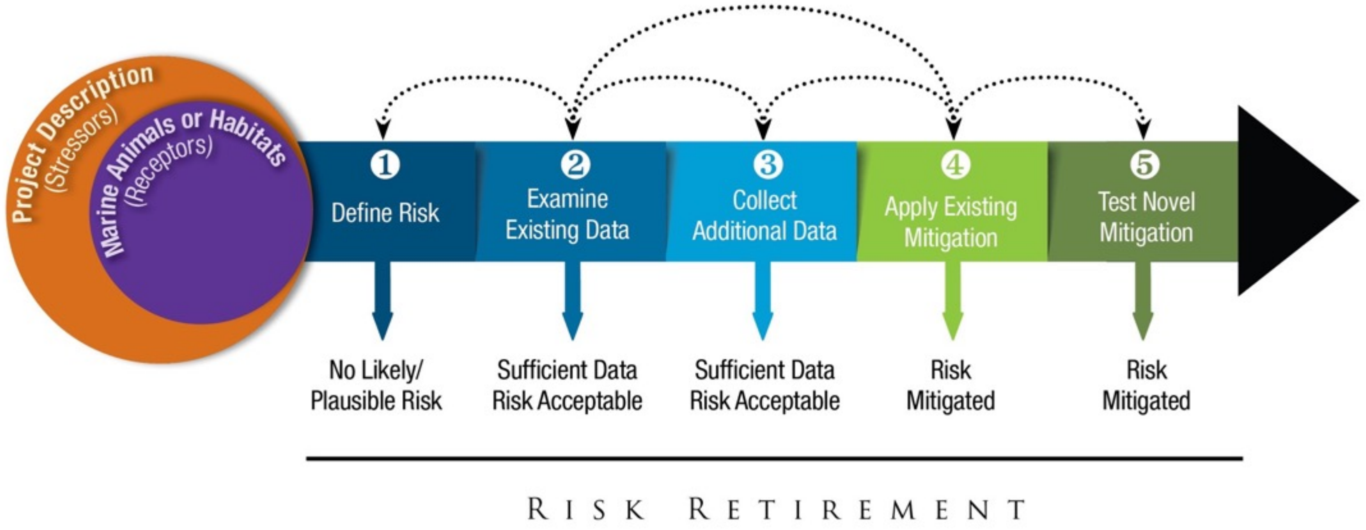
- ✓ Provide headphones to marine animals….?
- ➢ Risk retired.





- ✓ No mitigation possible?
- ➢ Redesign or abandon project.





Underwater Noise

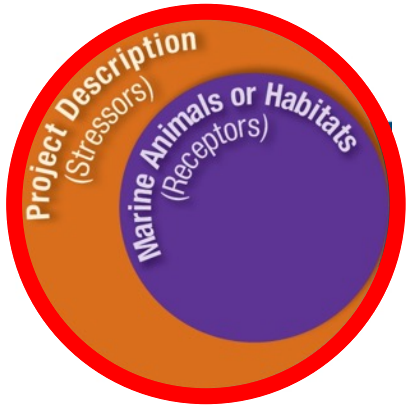
- We might consider underwater noise to be retired for small numbers of devices
- Should only have to proceed through steps 2 or 3 of pathway
- Need to collect sound signatures for each type of tidal or wave device
- Models and information from single MRE devices will inform effects of arrays

Case Study: Risk Retirement for Electromagnetic Fields

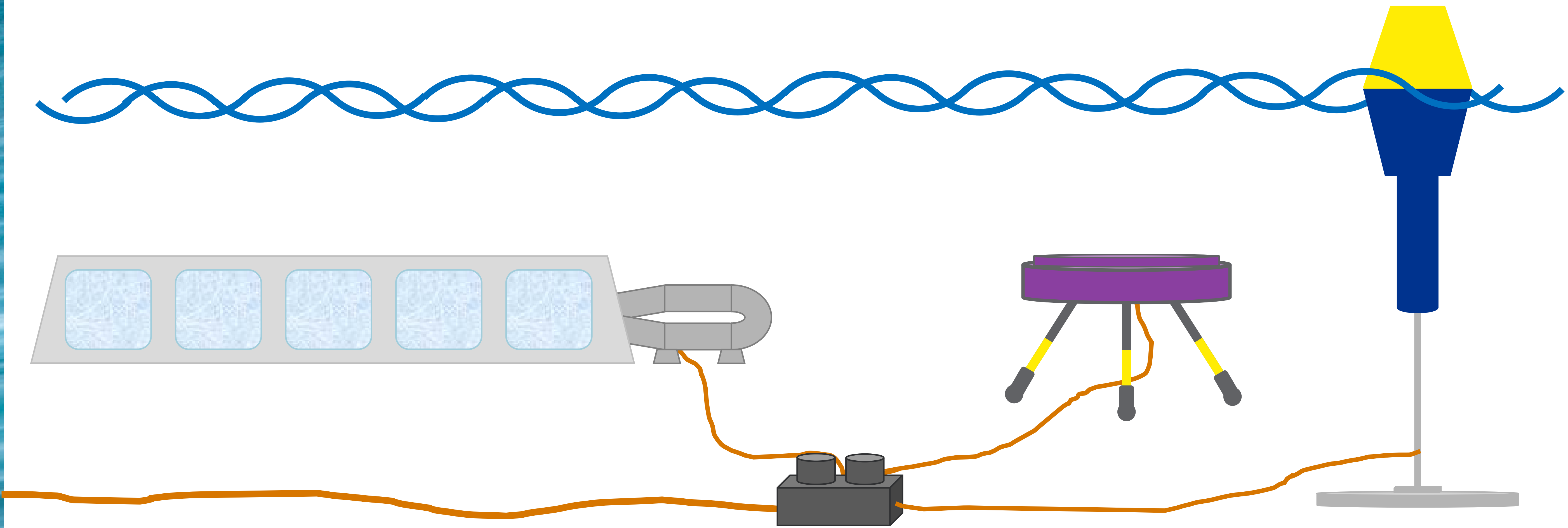
OES ENVIRONMENTAL

Ocean Energy ORJIP working to accelerate offshore consenting

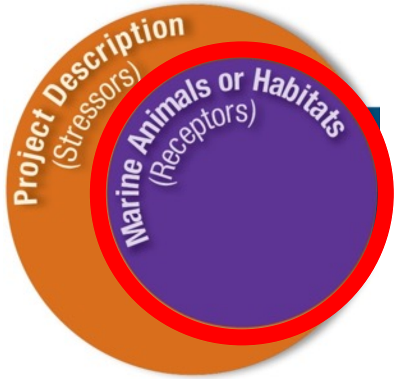
Hypothetical example



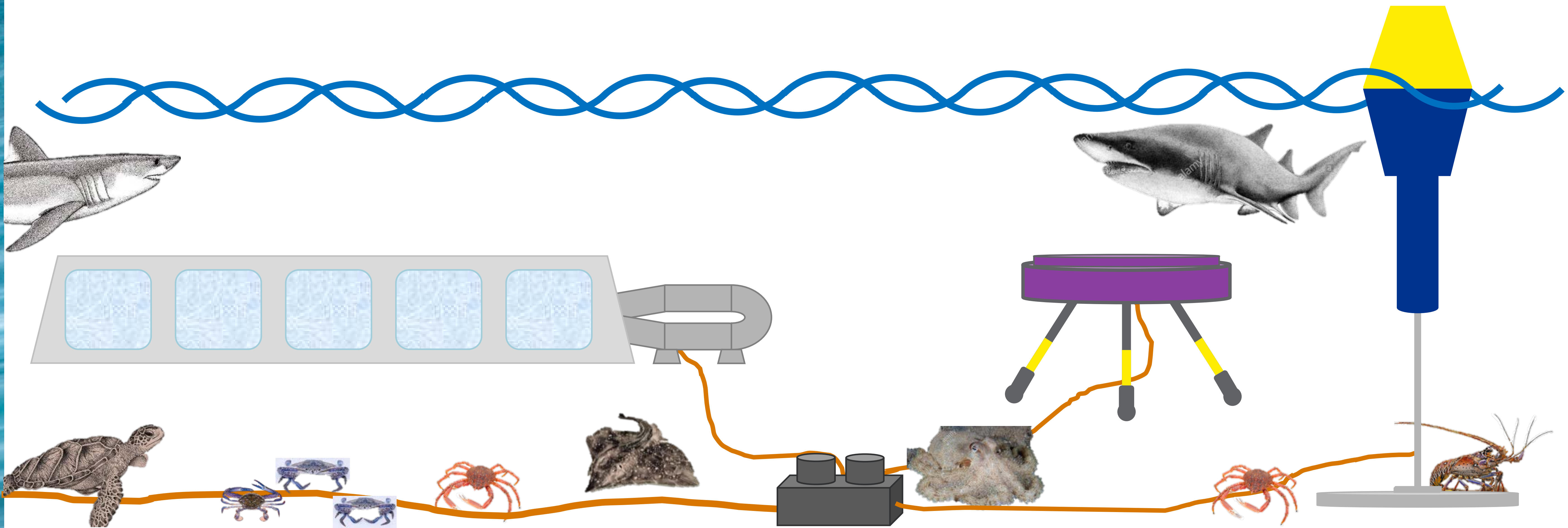
- ✓ Bottom-mounted point absorber WEC with heaving buoy;
- ✓ Submerged point absorber WEC;
- ✓ Bottom-mounted flexible membrane WEC;
- ✓ 3 seafloor cables from WECs to an offshore substation;
- ✓ 1 export cable from offshore to onshore substation, laid on the seafloor.

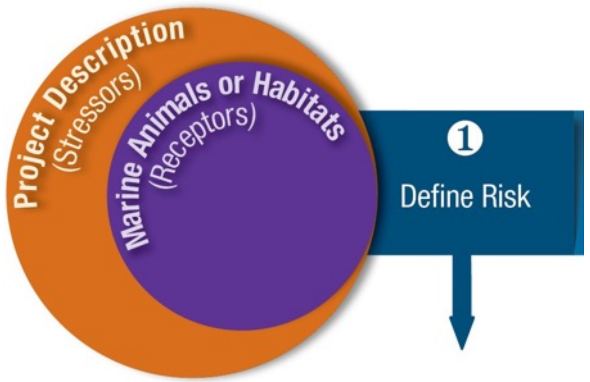


Pacific Northwest
NATIONAL LABORATORY

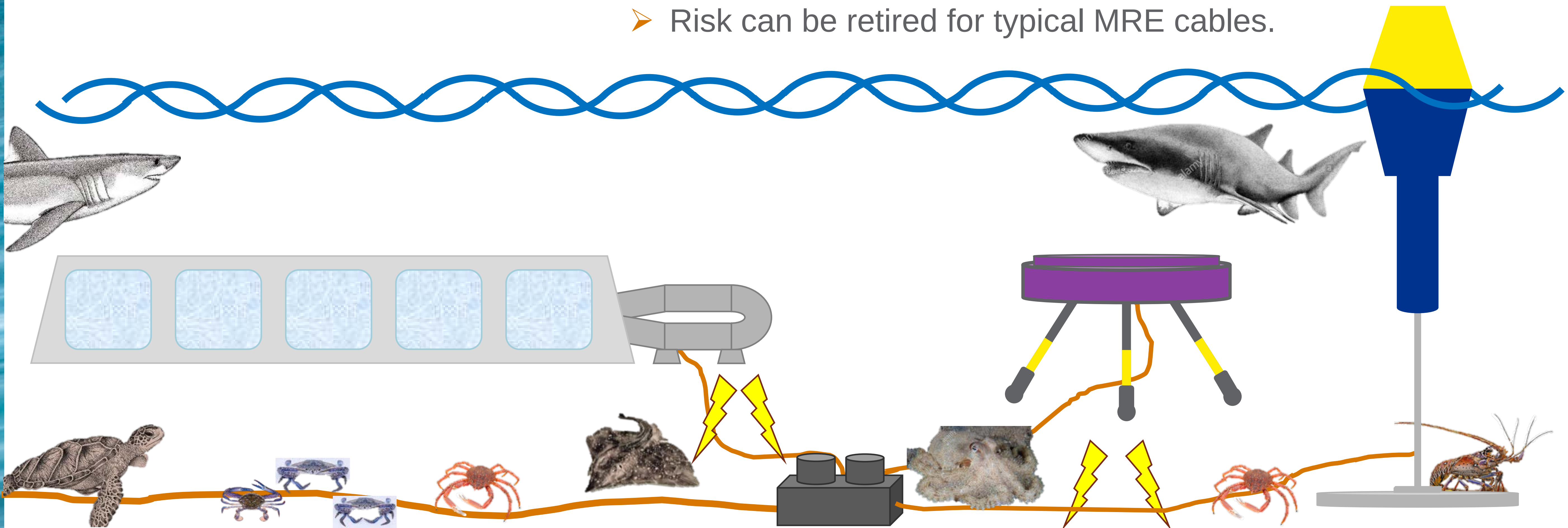


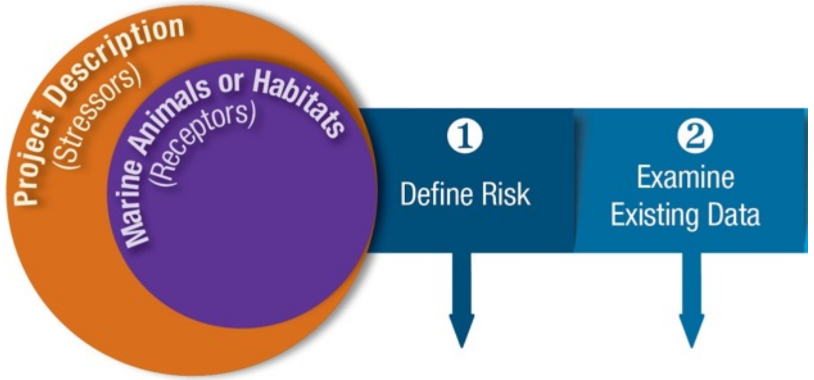
- ✓ 3 bottom-mounted WECs with seafloor cables;
- ✓ Southwest Australia marine organisms: sea turtles, various sharks, skates, lobsters, crabs, and other invertebrates.



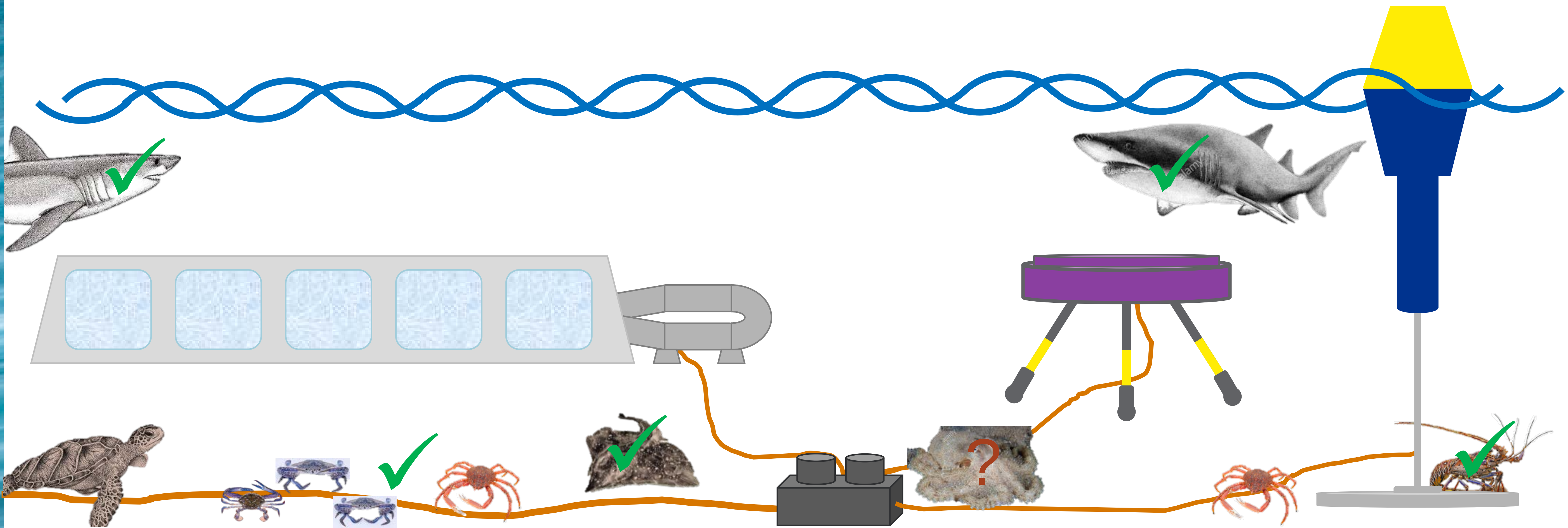


- ✓ Electromagnetic fields of various intensity emitted from each cable, predicted by modeling studies.
- ✓ Potential risk for some of these animals on foraging behavior, navigation, migration, physiological processes.
- ✓ Levels of EMF much lower than for OSW, other marine industries
- ➢ Risk can be retired for typical MRE cables.

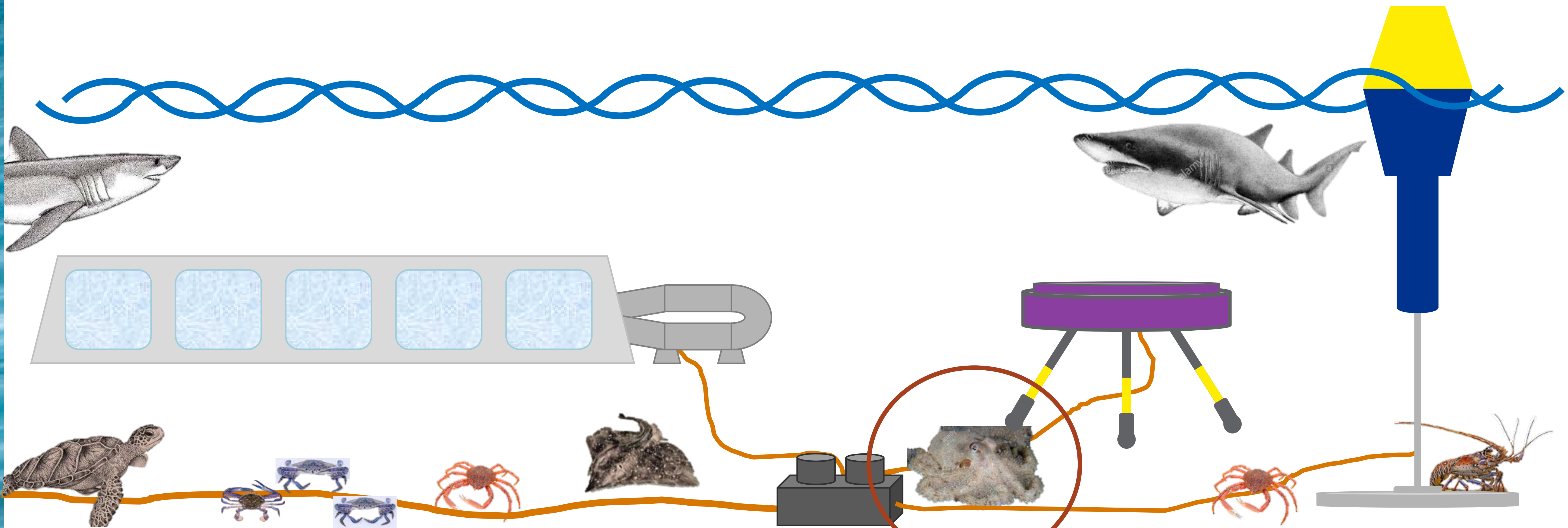




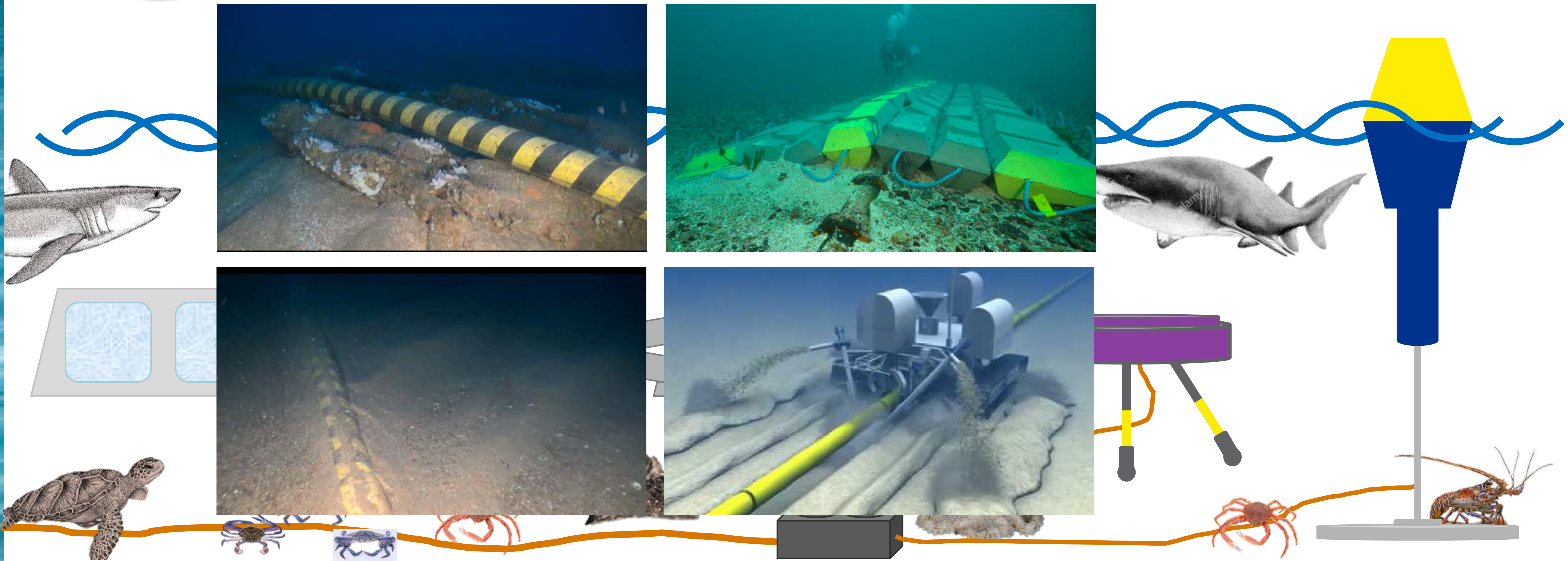
- ✓ Based on data:
  - ✓ Any statistical difference observed for crabs, sharks?
  - ✓ Skate more active around cables, is there any barrier effect?
  - ✓ Any data on invertebrates other than crustaceans?
- ➢ Risk retired for all but “other invertebrates”.



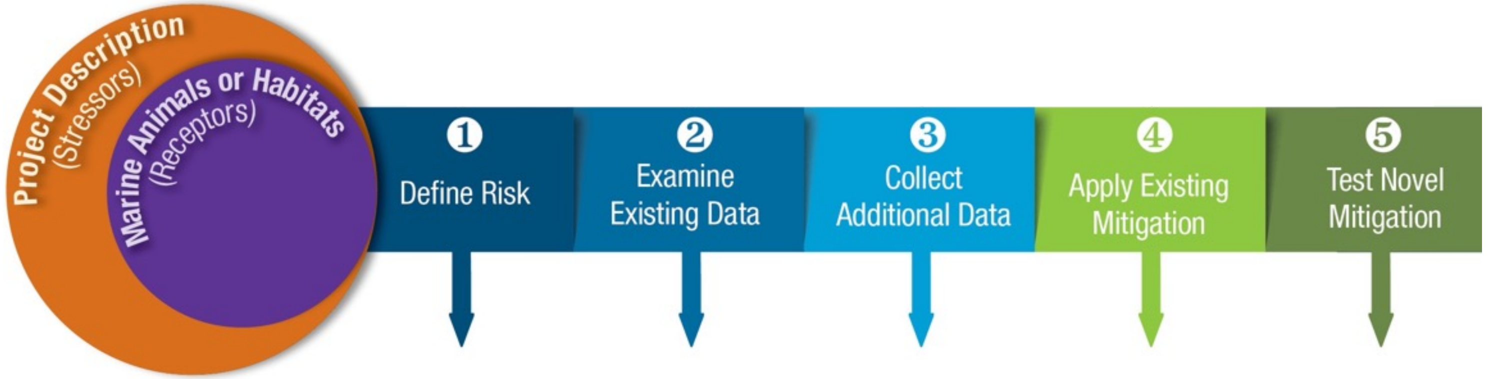
- ✓ Collect experimental data on other invertebrates and eggs;
- ✓ Little chance of being addressed if no commercial value or not a listed species.
- ➢ Risk is very close to being retired.



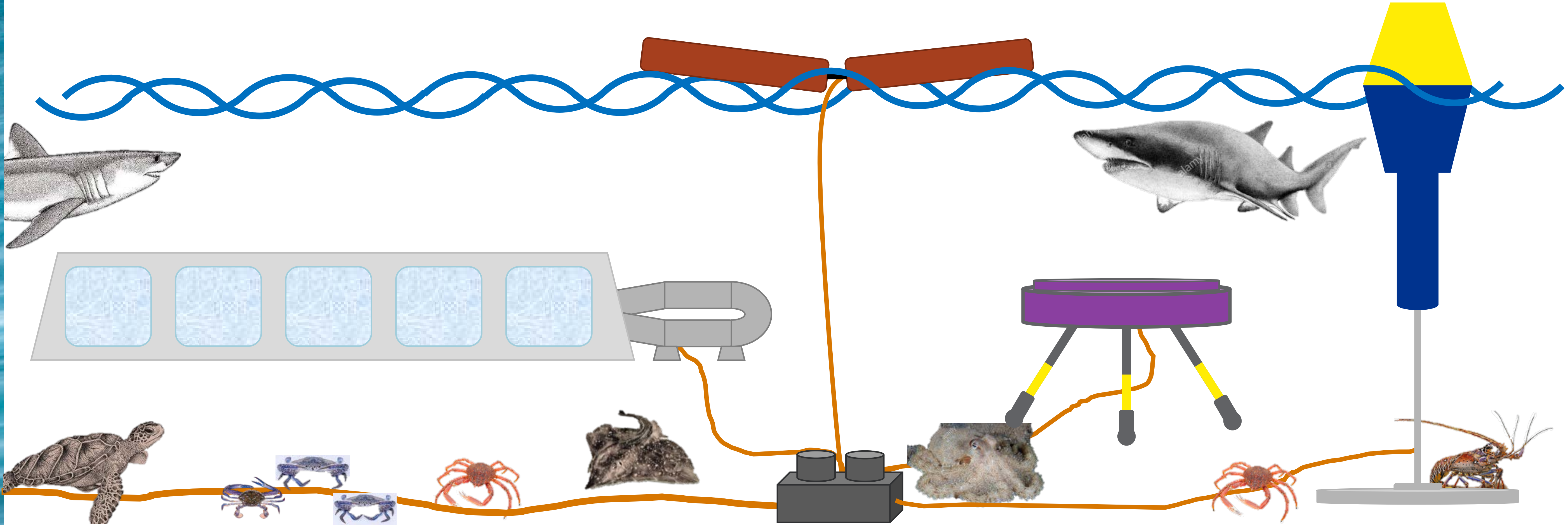
- ✓ Potential mitigation measures if needed:
  - ✓ Bury / protect cables;
  - ✓ Modify cable design.
- ➢ Risk retired for seafloor cables.

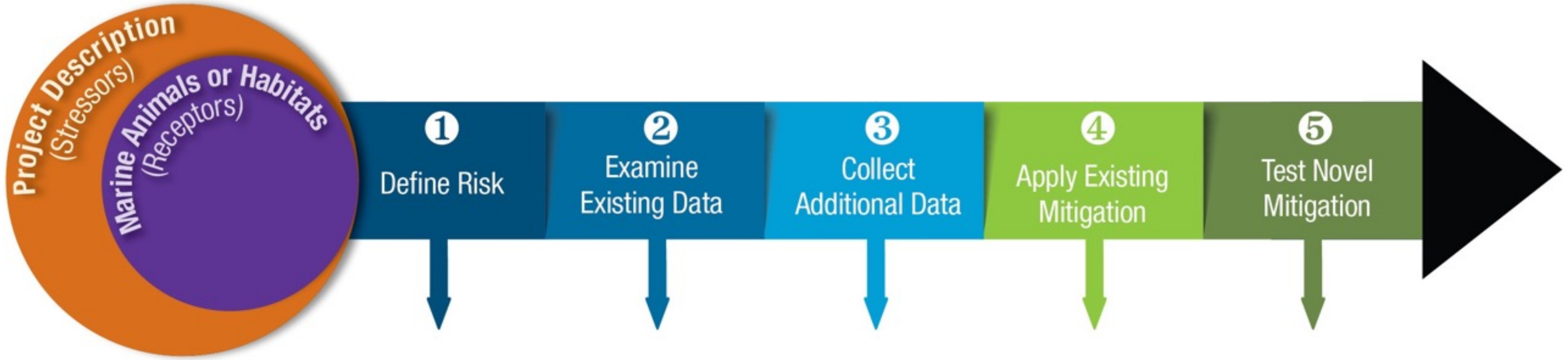


Pacific Northwest
NATIONAL LABORATORY

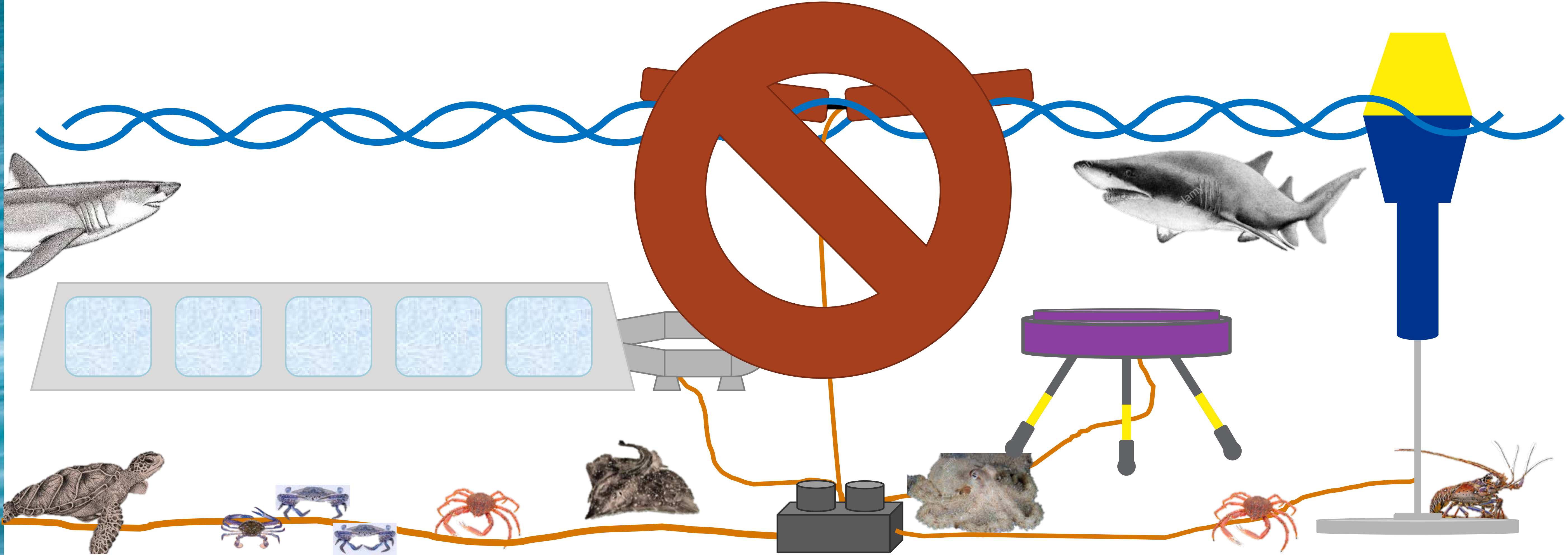


- ✓ Design mitigation measures for vertical and/or draped cables.
- ➢ Risk retired.

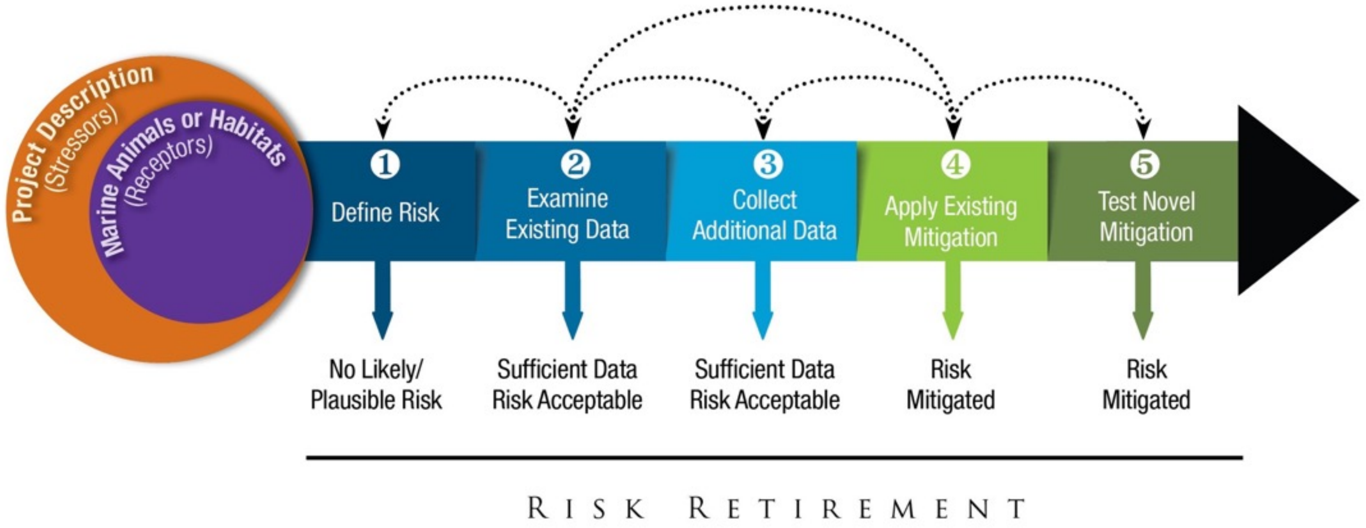




- ✓ No mitigation possible?
- ➢ Redesign or abandon project.



Electromagnetic fields (EMF)



- Risk from EMF should be considered retired for small numbers of devices/cables
- Should only have to proceed through steps 2 of pathway
- Need to collect data on different cable configurations and their EMF signatures for future build out

Instructions for Working Session

- Will address each stressor in turn (EMF, underwater noise)
- Group will have a technical lead, facilitator, and note taker
- Overarching questions:
  1. Are you convinced by the weight of evidence that the stressor should be retired for single or small numbers of devices?
  2. What additional data should be collected, processes modeled, or analyses performed (whether you are convinced or not)
  3. How does this information for small numbers of devices inform potential effects of arrays?

Thank you!

Andrea Copping
Pacific Northwest National Laboratory
andrea.copping@pnnl.gov

Mikaela Freeman
Pacific Northwest National Laboratory
mikaela.freeman@pnnl.gov

Ian Hutchison
Aquatera
ian.hutchison@aquatera.co.uk

Jennifer Fox
Aquatera
jennifer.fox@aquatera.co.uk