Pacific Northwest NATIONAL LABORATORY

OES ENVIRONMENTAL

# 2024 State of the Science Report on Environmental Effects of Marine Renewable Energy

October 2, 2024

U.S. DEPARTMENT OF ENERGY BATTELLE

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# Agenda

- Introduce OES-Environmental
- 2024 State of the Science Report overview

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| 2 | Progress in Understanding Environmental Effects of Marine Renewable Energy |
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- Q&A

# OES-Environmental

- Established by the International Energy Agency-Ocean Energy Systems in 2010
- Examines environmental effects of marine renewable energy (MRE) development to advance the industry in a responsible manner
- Led by the U.S. Department of Energy Water Power Technologies Office and implemented by Pacific Northwest National Laboratory
- Phase 4: 16 member countries

# 2024 State of the Science Report

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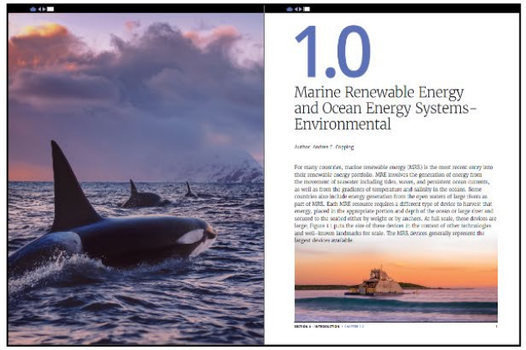
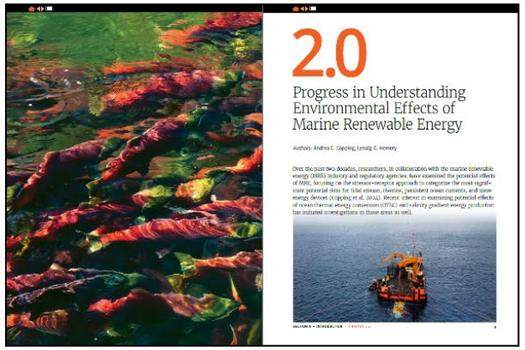
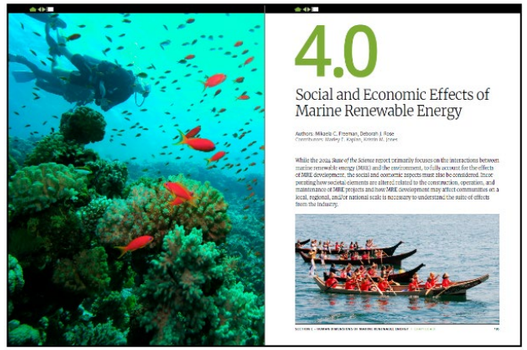
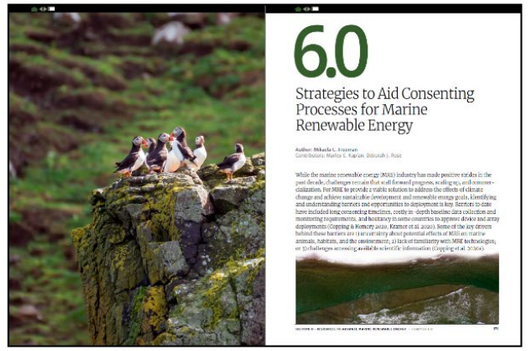


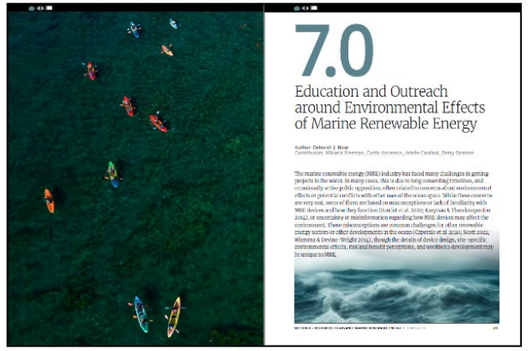



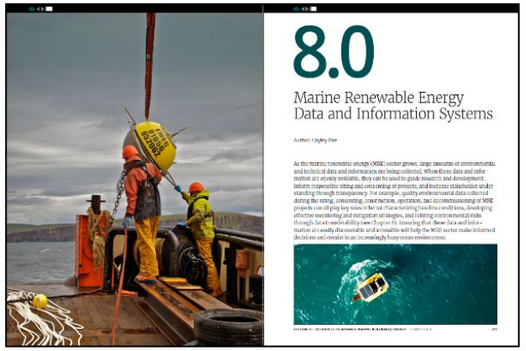




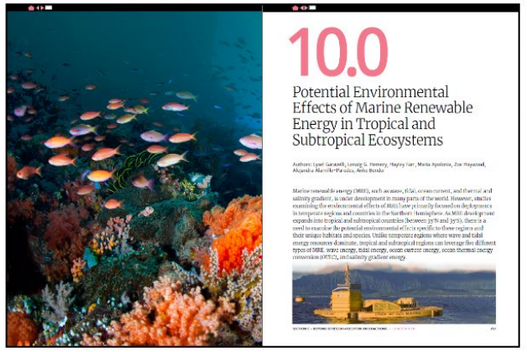


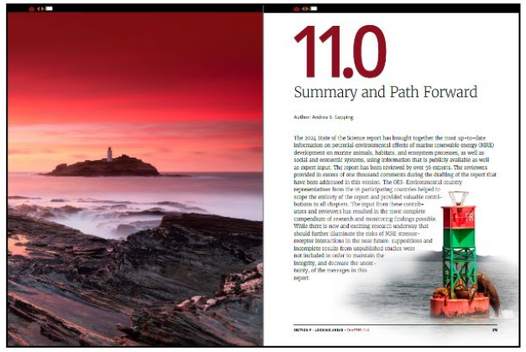






# 1.0

# Marine Renewable Energy and Ocean Energy Systems–Environmental

Author: Andrea E. Copping

# Status of Knowledge

Understanding environmental effects of MRE will support responsible development of the industry, and help accelerate consenting and deployment

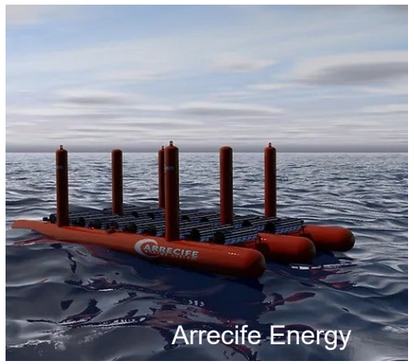
## Benefits of MRE

- Sustainable, predictable, low-carbon energy
- New source of power at sea
- Employment and development
- MRE sites may act as refuges

## Challenges to Measuring Environmental Effects

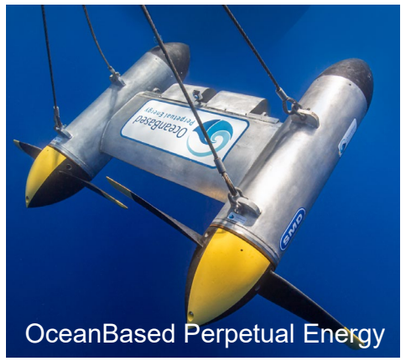
- Energetic, poorly understood areas of the oceans
- Uncertainty driving concerns for animals, habitats
- Need more devices in the water to learn
- Scaling to arrays less understood


Nova Innovation



Arrecife Energy

Ocean Renewable Power Company


OceanBased Perpetual Energy

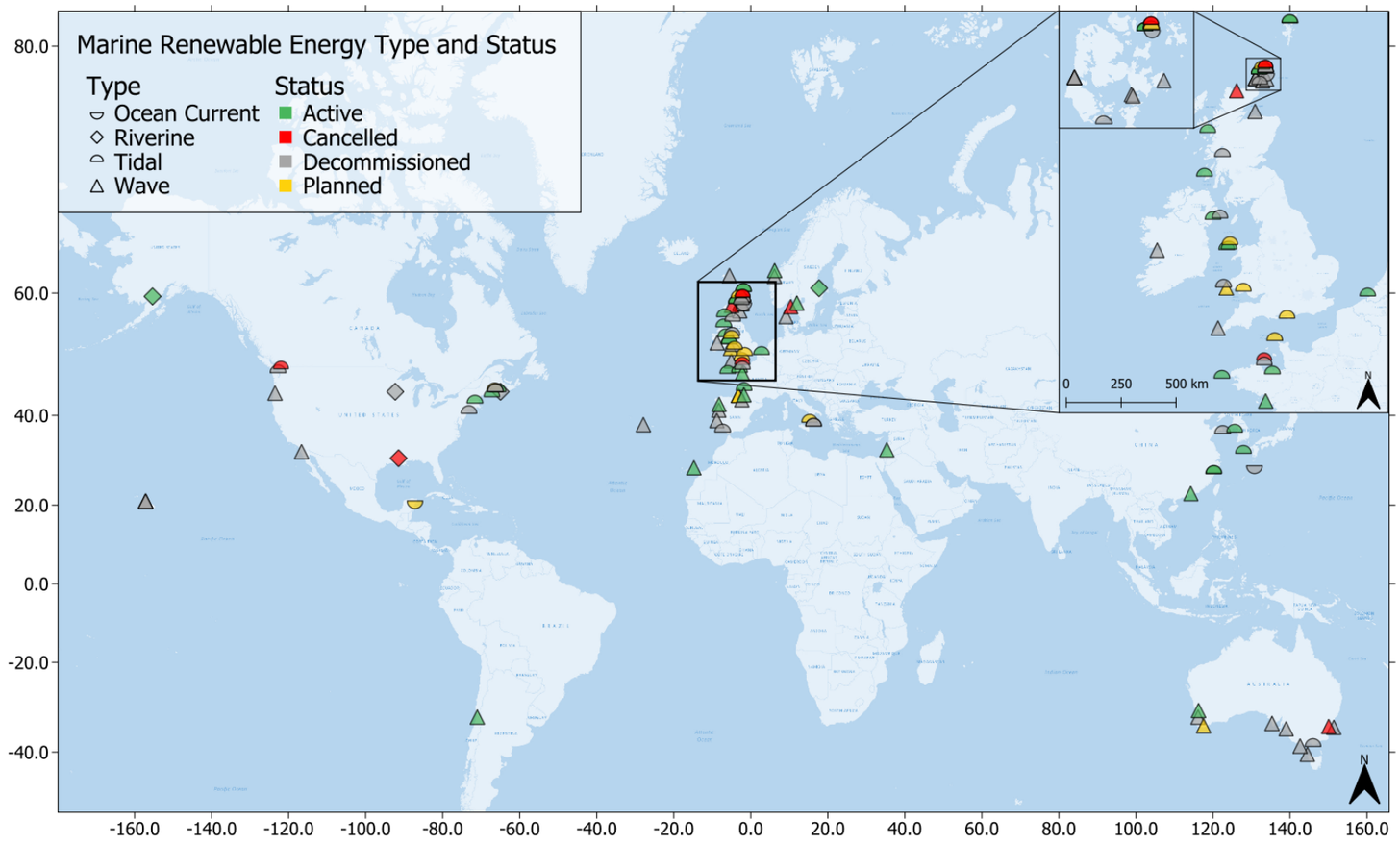
# 2.0

# Progress in Understanding Environmental Effects of Marine Renewable Energy

Authors: Andrea E. Copping, Lenaïg G. Hemery

# Status of Knowledge

- Mostly single devices, small arrays of four to six devices
- UK, Europe, Americas, Australia
- Mostly test sites or demonstration projects, some grid connected
- Environmental research on:
  - Collision risk
  - Underwater noise
  - Effects of electromagnetic fields (EMF)
  - Changes in habitats
- Most assessments occur where there are:
  - Species of concern
  - Other marine users are active



# Case Studies of MRE Projects

Five case studies to evaluate quality and outcome of environmental assessment and monitoring:

Table 2.2. Summary of examples of deployment sites where environmental monitoring has taken place.

| Project | Year of setup | Type of energy | Country | Environmental studies | Results |
|---|---|---|---|---|---|
| MeyGen Tidal Stream Energy Project | 2007 | Tidal | Scotland, United Kingdom (UK) | Collision risk marine mammals and diving seabirds; noise; EMF, sediment transport. | Marine mammals avoid the operational turbine; some seals swam nearby; EMF and noise not significant; no significant changes in sediment transport. |
| Nova Innovation Shetland Tidal Array | 2016 | Tidal | Shetland Islands, Scotland, UK | Collision risk marine mammals and diving seabirds; seabed surveys. Surveys carried out for marine mammals and seabirds and noise. Noise and disturbance considered not significant. | When turbine not moving: harbor seals, diving seabirds and fish swimming in close proximity; with blades rotating, they move away or are not present. |
| IDOM's Marmok Wave Energy Converter | 2016 | Wave | Spain | Underwater noise, EMF emissions, changes in seafloor integrity | No EMF emissions; no significant changes in seafloor integrity; noise lower than normal underwater noise. |
| Lysekil Wave Energy Test and Deployment site | 2006 | Wave | Sweden | Changes in habitats; underwater noise; displacement | Little change in the seafloor; new habitats; noise levels were deemed not likely to trigger behavioral responses. |
| Igiugig Riverine Turbine Project | 2014 | Riverine | Alaska, United States | Impact on sockeye salmon population | Adult salmon not affected; some smolts swam through the turbine and were disoriented. |

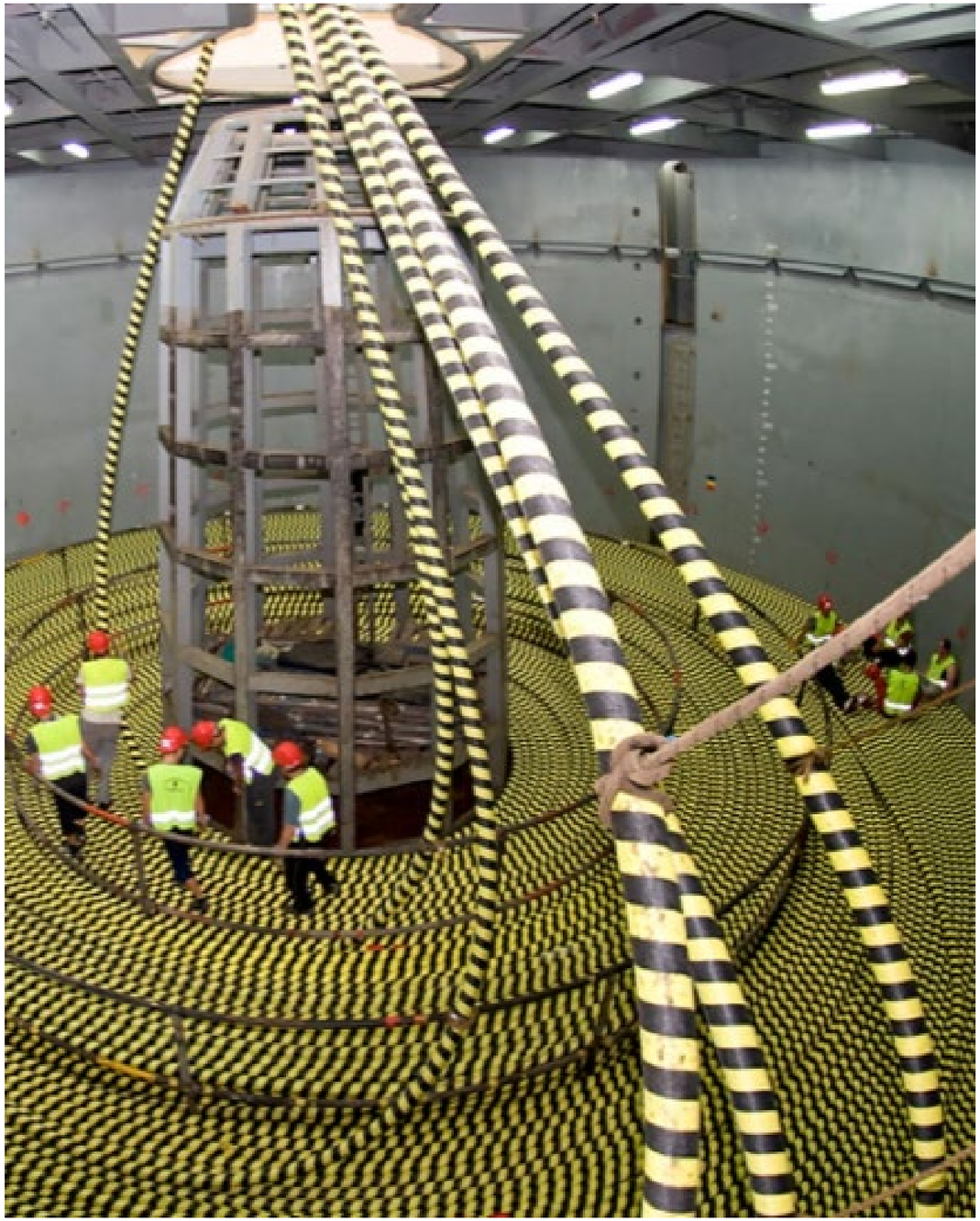
# Recommendations

- Baseline assessments almost always needed
- Potential risks should be identified to design post-installation monitoring plans
- Collaboration needed with industry, research, regulators, and other stakeholders
- Open accessible data supports transparency, improved decision-making
- Many tools and guidance available: OES-Environmental, Tethys, ORJIP
- Engage early with local communities
- Accepted methods needed for comparability


# 3.0

# Marine Renewable Energy: Stressor–Receptor Interactions

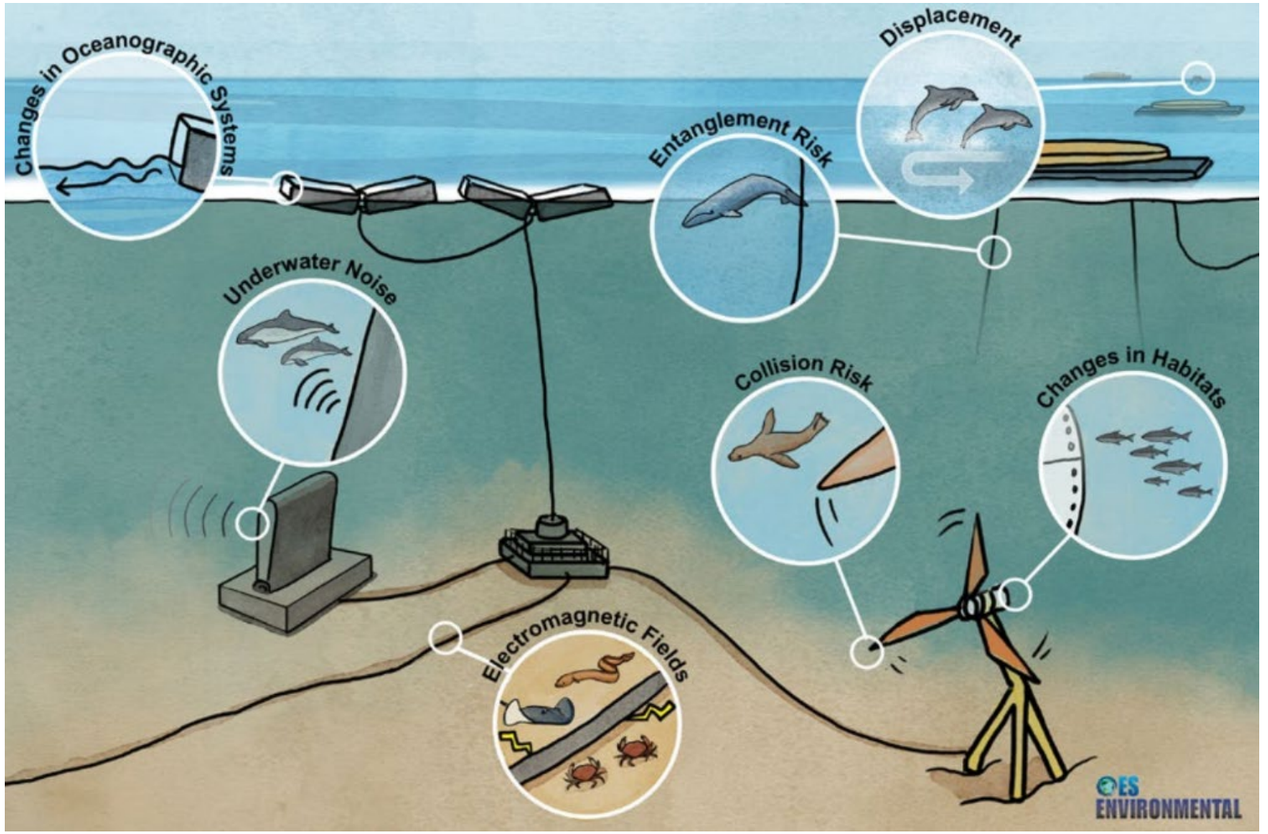
Authors: Lysel Garavelli, Lenaïg G. Hemery, Deborah J. Rose, Hayley Farr, Jonathan M. Whiting, Andrea E. Copping



# Stressor-receptor interactions

- Stressors – Marine energy devices, systems that may cause harm
- Receptors – Marine animals, habitats, ecosystem processes

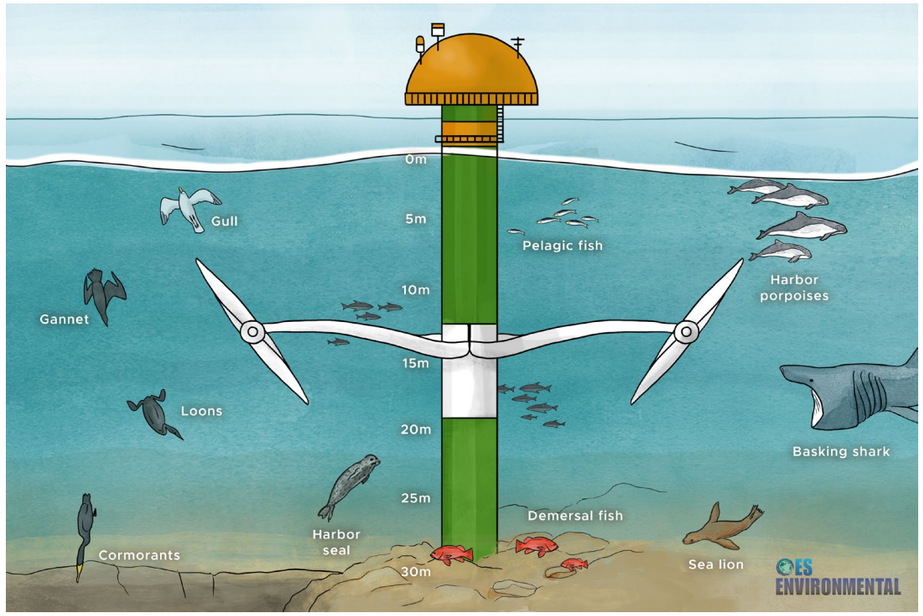
## Key stressor-receptor interactions:



# Status of Knowledge

3.1.
## COLLISION RISK FOR MARINE ANIMALS AROUND TURBINES

Authors: Lysel Garavelli, Deborah J. Rose, Andrea E. Copping




- Avoidance behavior more often documented than evasion
  - Limitations of monitoring technologies
  - Mainly observed during turbine operations for fish and marine mammals
- Collision
  - Fish: rarely observed during operations of riverine turbines
  - Marine mammals & seabirds: no observed contacts
- Numerical models to estimate the probability of encounter and collision
  - Sensitive to animals' behavior parameters
  - Dependent on data availability
- Probabilistic approach
  - Framework to move toward quantification of the likelihood of collision risk

# Pathway to Risk Retirement & Recommendations

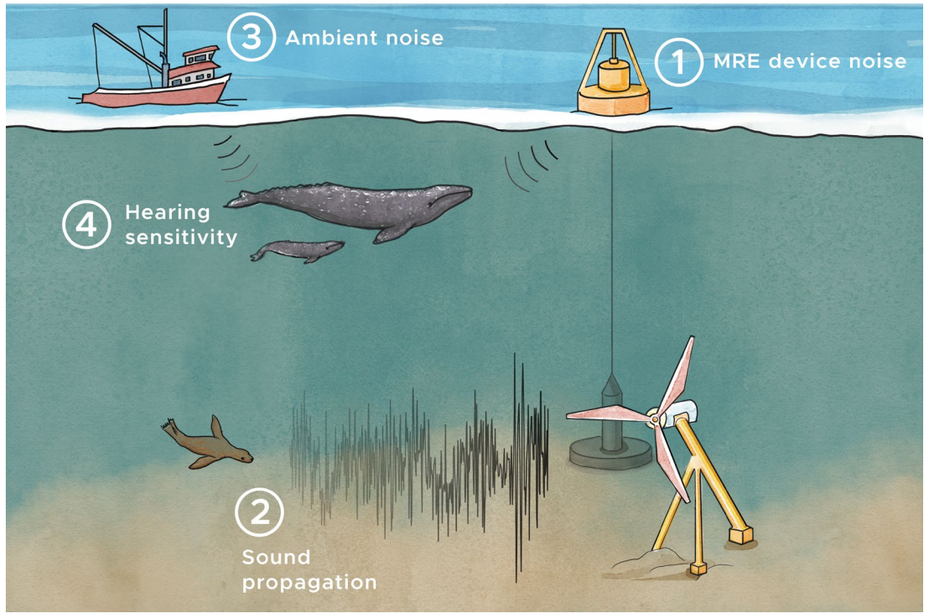
- Low number of deployments and challenges to observe collision risk events
  - Potential consequences of even rare events for the animal and associated populations remain uncertain
- Examining and processing all existing video datasets
- Designing research projects geared toward collecting appropriate data for parameterizing and validating models

- Ensuring that monitoring is focused on reducing uncertainty of collision risk
- Documenting and disseminating information on the most appropriate set of methods that will provide accurate observations of collision risk
- Continuing to update the MRE community on the state of the science on collision risk and encouraging developers to participate in data collection

# Status of Knowledge

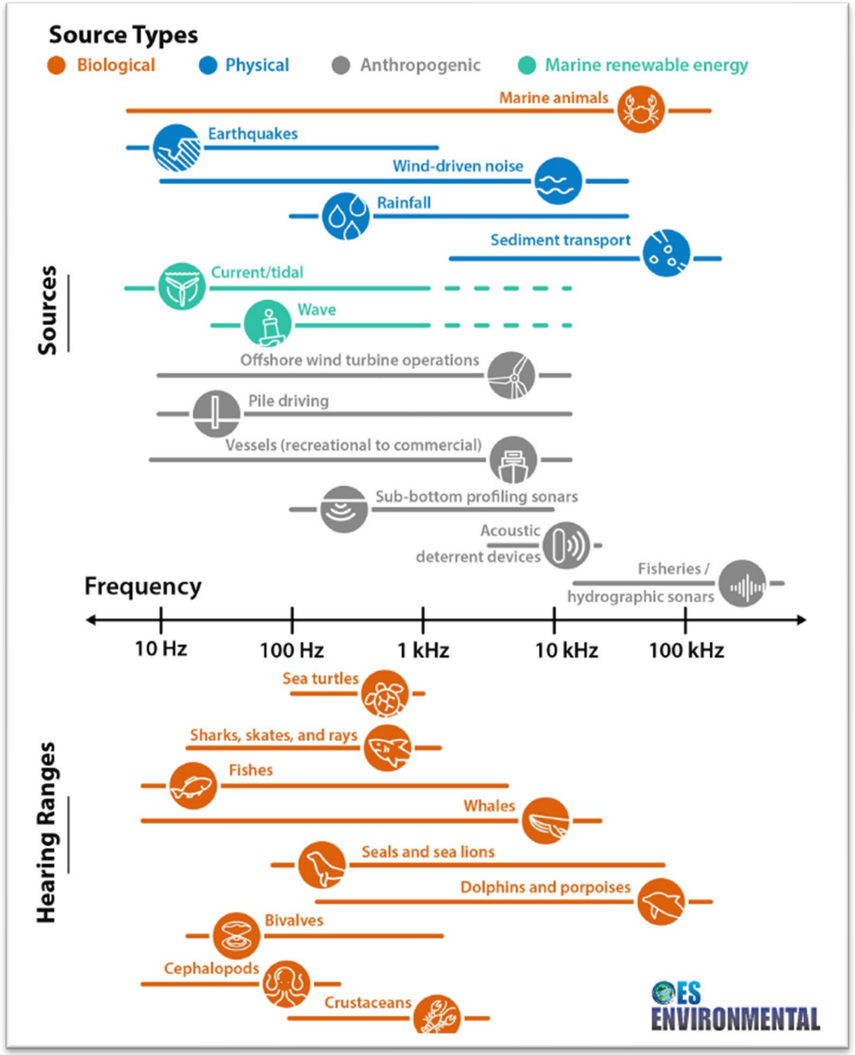
3.2.
RISKS TO MARINE ANIMALS FROM UNDERWATER NOISE GENERATED BY MARINE RENEWABLE ENERGY DEVICES

Author: Deborah J. Rose
Contributors: Joseph Haxel, Brian Polagye, Chris Bassett




- Operating MRE devices generate relatively low frequency noise (up to 1000 Hz)
- Main receptors:
  - Marine mammals
  - Sea turtles
  - Some fish and invertebrates that have sensory capabilities for detecting sound or particle motion
- Many new research studies on underwater noise generated by devices or at MRE project sites completed since 2020
  - Examples: ISWEC (Italy), MARMOK A-5 at BiMEP and Mutriku (Spain), CalWave (US), PacWave South (US)

# Pathway to Risk Retirement & Recommendations

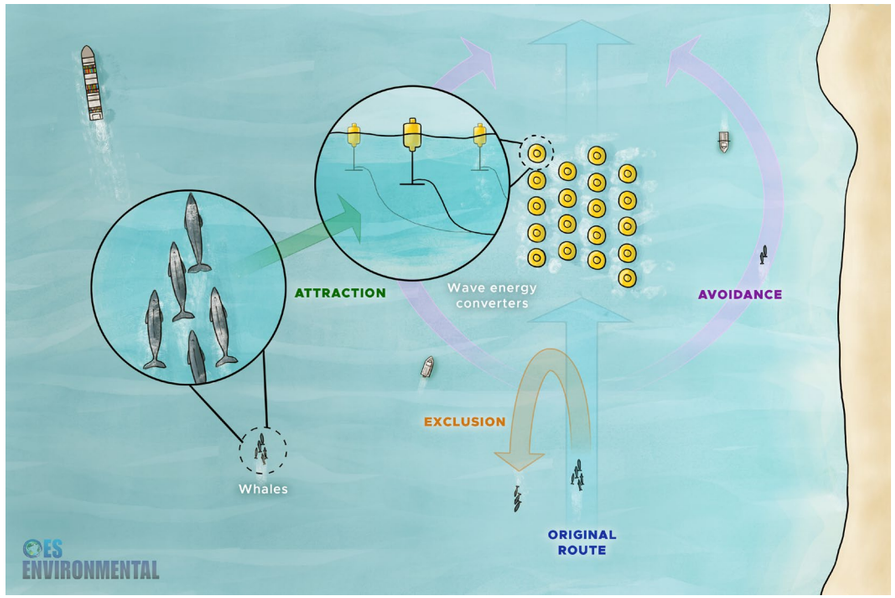



- Noise levels of MRE devices generally fall below those likely to cause injury or harm
- Behavioral changes are unlikely to be attributed solely to MRE devices
- Underwater noise from operational devices within small-scale MRE developments can be retired
- Each new MRE device design should be characterized (IEC TC 114 Technical Specification)
- Resolving remaining research needs (e.g., effects from particle motion) is not necessary for consenting processes to move forward

# Status of Knowledge

3.7.
## DISPLACEMENT OF ANIMALS FROM MARINE RENEWABLE ENERGY DEVELOPMENT

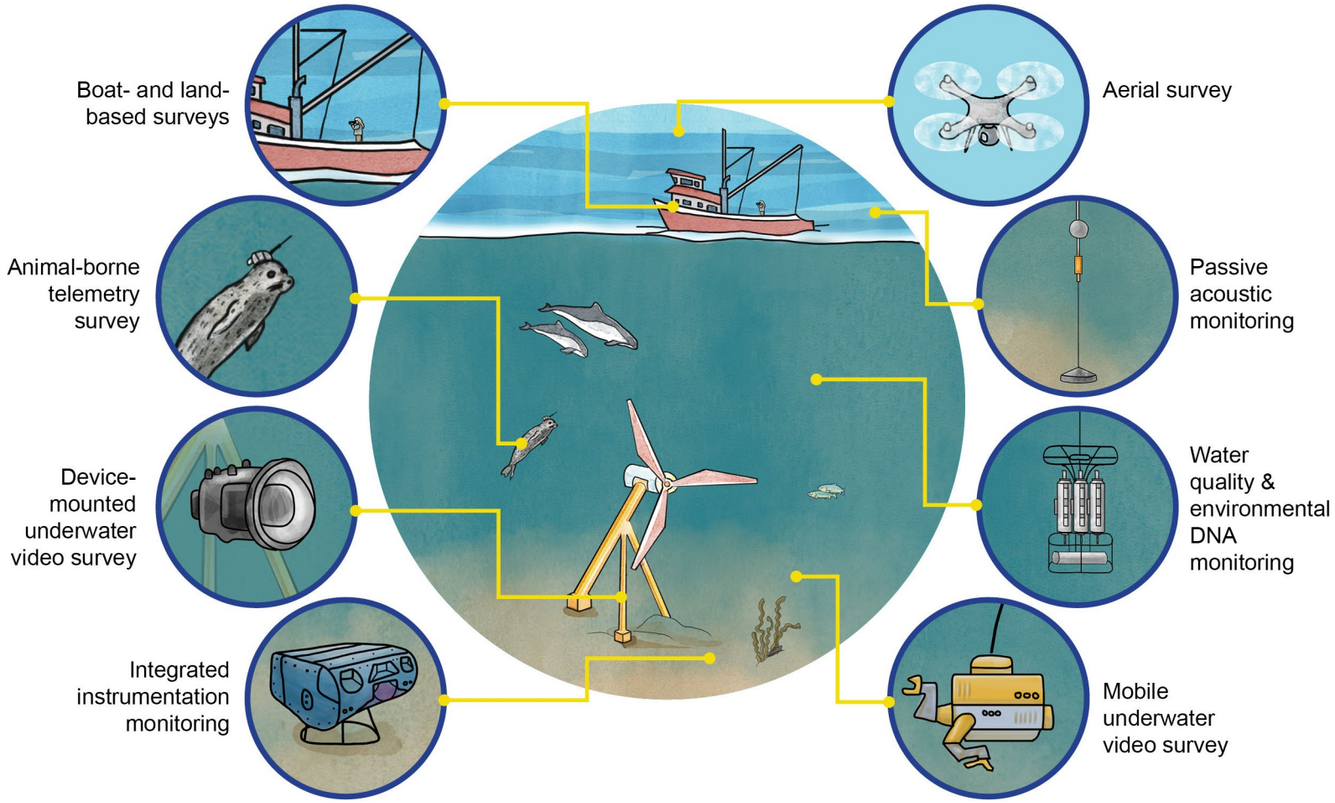
Author: Lenaïg G. Hemery




- Need for field observations
  - Understanding causes, responses, and consequences of displacement
  - For each species potentially affected
- Hypotheses generated for functional groups of species
- Knowledge gaps addressed by combining numerical models and field-based approaches
  - Field observations limited in the absence of large arrays of MRE devices
  - Numerical models or analytical frameworks help assess risks and consequences of displacement

# Pathway to Risk Retirement & Recommendations

- Not an issue for small MRE projects (one to six devices)
- Need to understand mechanisms and significance of animal displacement as larger projects are planned
- Recommendations:
  - Understand potential mechanisms that cause displacement and possible consequences to marine animals
  - Generate realistic models of such consequences, in combination with stressor-specific models
  - Identify how to best monitor and mitigate these changes
  - Initiate monitoring and collection of meaningful field data with the deployment of MRE arrays in mind

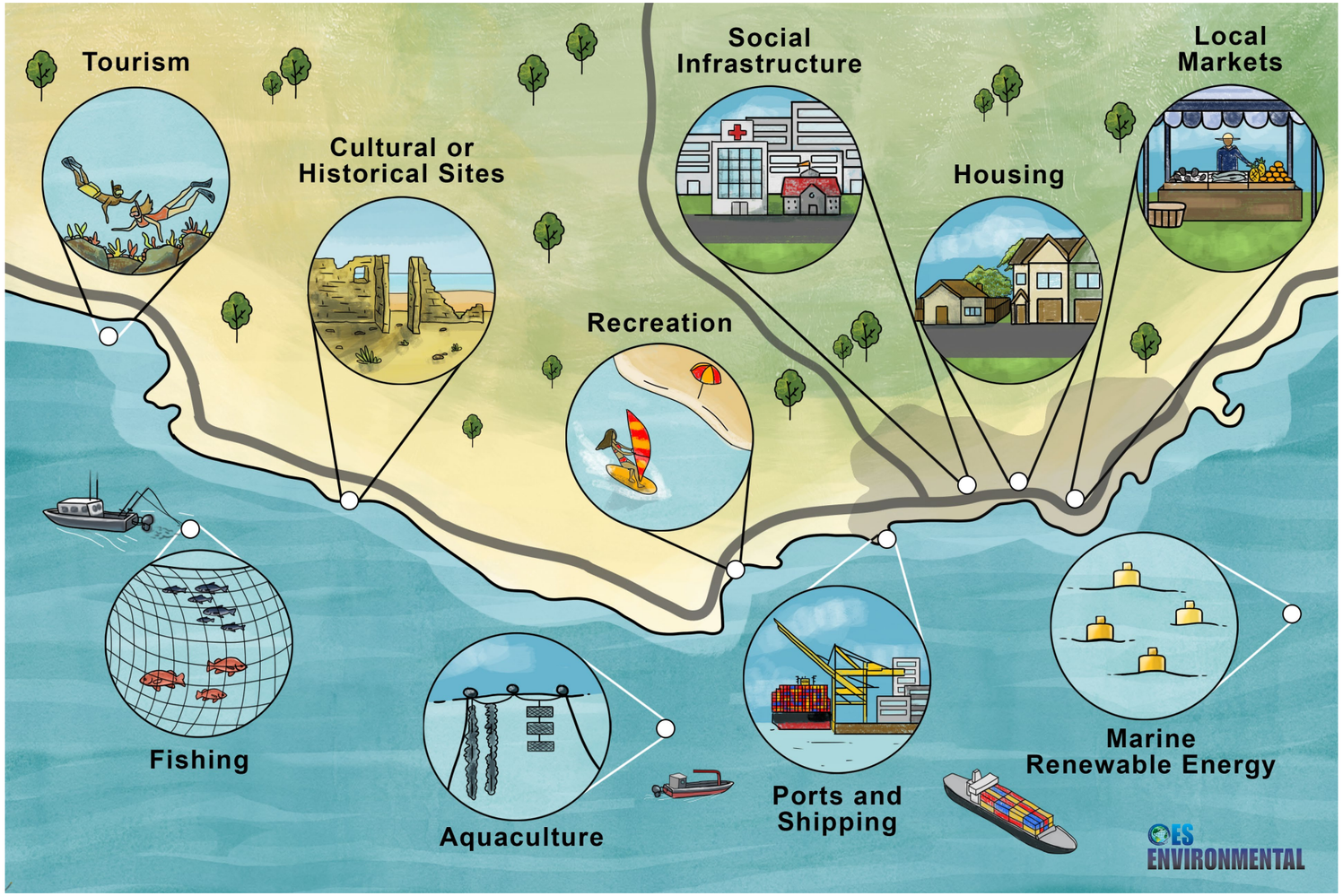


# 4.0

# Social and Economic Effects of Marine Renewable Energy

Authors: Mikaela C. Freeman, Deborah J. Rose
Contributors: Marley E. Kaplan, Kristin M. Jones

# Status of Knowledge

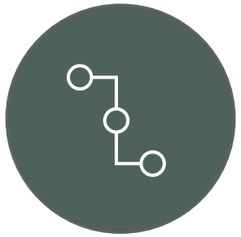



To fully account for the effects of MRE development, the social and economic aspects must also be considered in addition to environmental interactions.

# Groups Affected by or Involved in MRE

- Highlight effects on various groups documented for MRE
- Identify remaining knowledge gaps

*fisheries*



*supply chain*

*communities*

*conservation*

*ports*

*workforce*

*tourism*

*energy end users*

# Recommendations

## Strategic needs:

- Develop consistency in requirements and regulations for data collection
- Conduct/fund long-term assessments and monitoring at a broad spatial scale
- Coordinate to increase cumulative effects understanding

## Research needs:

- Use transdisciplinary methods
- Increase understanding of indicators for MRE-specific effects
- Apply quality checks for data collection
- Standardize methods for data collection that can be applied internationally

## MRE project/industry needs:

- Apply lessons learned from other industries
- Improve approaches to address social and economic effects, incorporating justice, equity, and diverse perspectives
- Bring together marine activities to comprehensively address social and economic effects

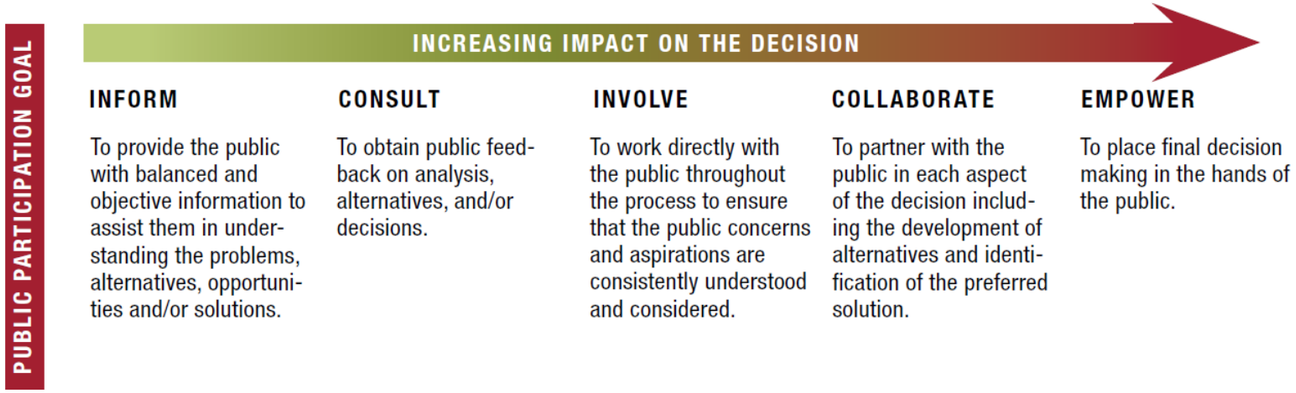
# 5.0

# Stakeholder Engagement for Marine Renewable Energy

Authors: Deborah J. Rose, Mikaela C. Freeman
Contributors: Kristin M. Jones, Marley E. Kaplan

# Status of Knowledge

- Stakeholder engagement critical for any new development project
- Key aspects:
  - Who is responsible, who are the stakeholders, and what approaches are best
  - Share information, but must listen to stakeholders and understand opportunities or barriers for MRE
  - Opportunity to advance social justice, avoid pitfalls of previous energy transitions or infrastructure projects




- Legal and regulatory frameworks exist, but lack of clear guidance for comprehensive stakeholder engagement for MRE projects
- Knowledge base of successful MRE engagement growing, but gap in the literature describing post-deployment efforts and ongoing assessments

# Recommendations

- Need to plan for and design a comprehensive approach:
  - Tailor based on defined context, community, and/or location
  - Clarify responsibility and set expectations
  - Conduct activities early and regularly
  - Move beyond ‘inform’ to participatory approaches
  - Include equity and social and energy justice considerations throughout engagement and all project phases

- Apply existing guidance from MRE and other industries on stakeholder engagement

- Develop regulatory-based guidance for MRE that goes beyond consultation and can be revisited as the industry moves toward larger-scale deployments

- Increase knowledge base for MRE and share lessons learned, especially around ongoing and post-engagement activities

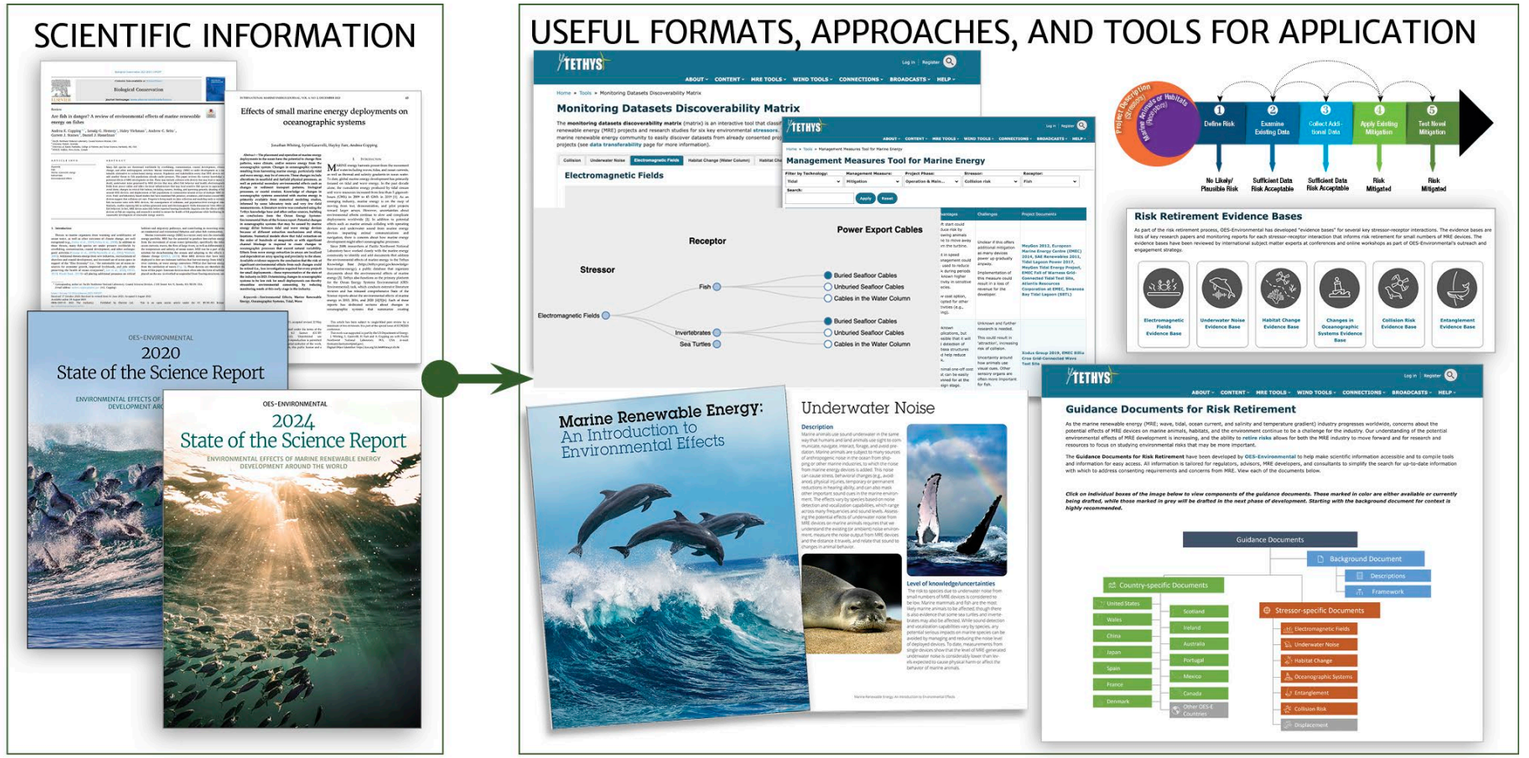
# 6.0

# Strategies to Aid Consenting Processes for Marine Renewable Energy

Author: Mikaela C. Freeman
Contributors: Marley E. Kaplan, Deborah J. Rose

# Approaches to Aid Consenting

- Numerous strategies implemented globally for consenting MRE projects
  - Create pathways for responsible development of MRE
  - Consenting to be proportionate to level of uncertainty and risk under consideration
  - Reduce duplication of efforts and resources by applying wider evidence base
- **Risk retirement**, adaptive management, and marine spatial planning



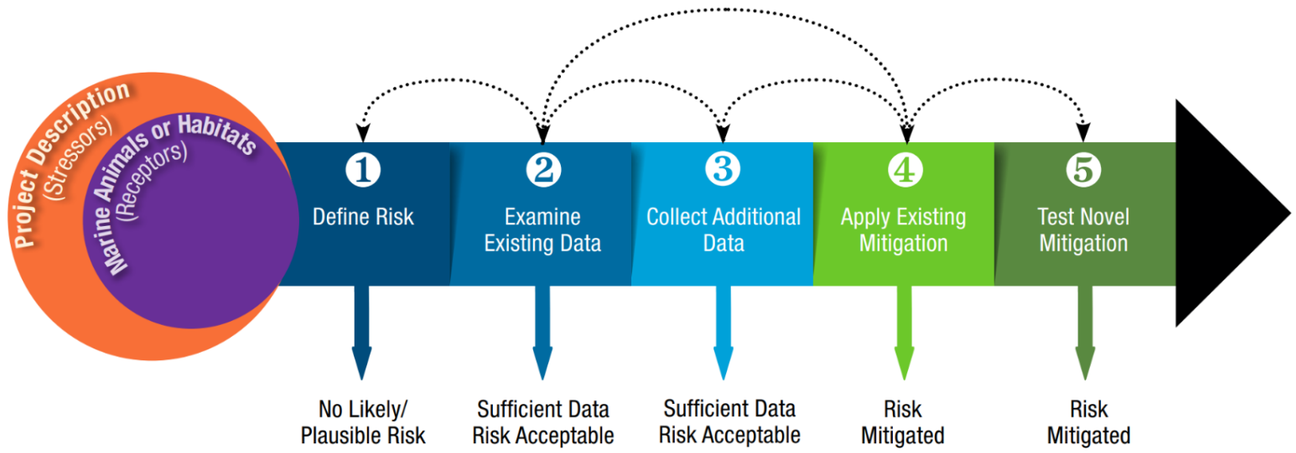
https://tethys.pnnl.gov/risk-retirement

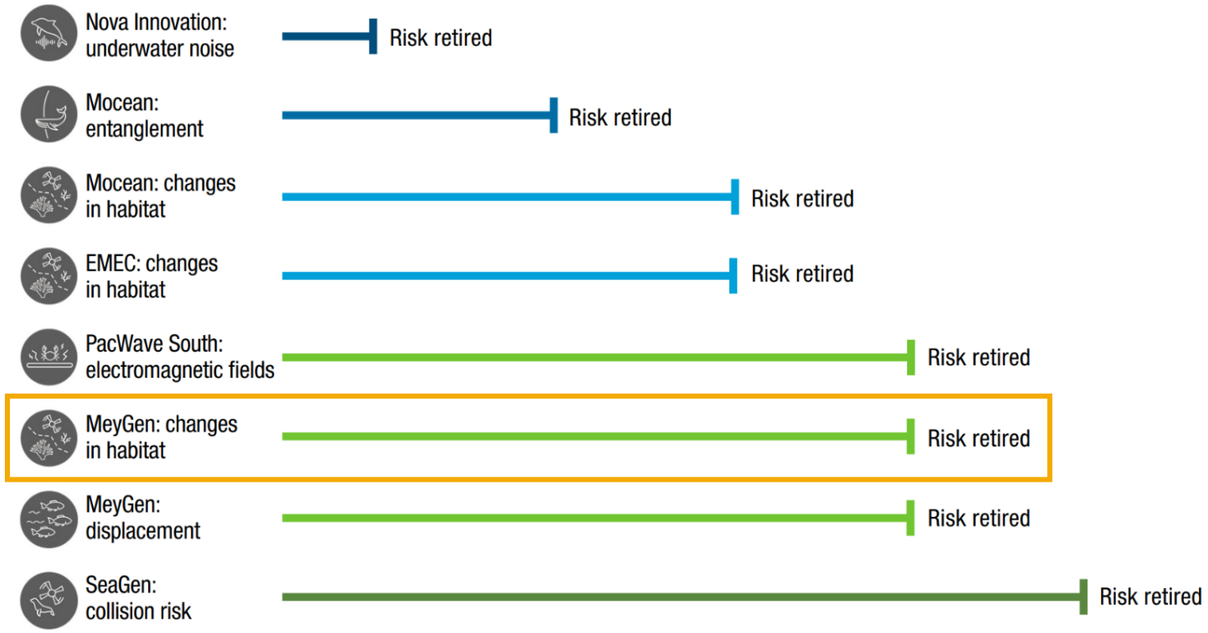
# Risk Retirement & Data Transferability

- **Risk retirement:** For certain interactions, potential risks may need not be fully investigated for every project
  - New MRE projects informed by what is already known (**data transferability**)
  - Aimed for use during consenting processes by regulators, advisors, developers, and consultants
    - ✓ Guidance documents to bridge from scientific evidence to regulatory use and make information easily accessible
  - OES-Environmental has explored the ability to retire risk for key stressor-receptor interactions

| | STRESSOR-RECEPTOR INTERACTION | READINESS FOR RISK RETIREMENT |
|---|---|---|
|  | Collision risk | Need more information. |
|  | Underwater noise | Retired for small numbers of devices. May need to revisit as the industry moves to larger-scale arrays. |
|  | Electromagnetic fields | Retired for small numbers of devices. May need to revisit as the industry moves to larger-scale arrays. |
|  | Changes in habitat | Retired for small numbers of devices. May need to revisit as the industry moves to larger-scale arrays. |
|  | Oceanographic systems | Retired for small numbers of devices. May need to revisit as the industry moves to larger-scale arrays. |
|  | Entanglement | Need more information as the industry moves to larger-scale arrays. |
|  | Displacement | Need more information as the industry moves to larger-scale arrays. |

# Risk Retirement Case Studies




## MeyGen Tidal Energy Project
Changes in Habitat

**DEFINE RISK**

- Potential risk of impact to benthic habitats and the animals that reside within that habitat.

**EXAMINE EXISTING DATA**

- Existing benthic habitat data were examined as part of the EIA process.

**COLLECT ADDITIONAL DATA**

- Benthic seabed surveys were carried out to determine the benthic habitats and species present and the biotope classification. These data were then examined during the EIA, the conclusions of which informed the development of the PEMP.
- Monitoring of benthic habitats and species was not required for the operational stage.

**APPLY EXISTING MITIGATION**

- No mitigation required during the operational stage.
- Design features and mitigation measures for the construction stage were built into the project to mitigate potential impacts.

# Recommendations

## Risk retirement and data transferability:

- Willingness to apply and transfer data from MRE projects, research studies, or analogous industries to inform projects and consenting processes, and to retire risks
- Share examples of successes and lessons learned; help develop best management practices
- Fund and support research on remaining risks not yet ripe for retirement, and larger-scale arrays

## Adaptive management:

- Identify available resources (time, funding, etc.) and minimize undue financial risks for developers, while balancing environmental protections
- MRE-specific implementation guidance: best approaches for application (including for larger-scale arrays) and reducing uncertainty

## Marine spatial planning:

- Incentives for including MRE in energy policies and renewable energy goals
- Clear objectives for MRE as part of MSP: practical measures to streamline consenting, available data and tools, and future needs for MRE development based on scale and applications

# 7.0

# Education and Outreach around Environmental Effects of Marine Renewable Energy

Author: Deborah J. Rose
Contributors: Mikaela Freeman, Curtis Anderson, Arielle Cardinal, Betsy Stratton

# Status of Knowledge

- Education and outreach can:
  - Improve understanding of risk to focus research efforts associated with new projects and
  - Maximize benefits to local communities while achieving clean energy goals

- Training needed to support development of a new workforce for the MRE industry

- Many outreach and educational materials available, developed by OES-Environmental and others
  - Includes workforce development activities

*https://tethys.pnnl.gov/educational-workforce-training-resources-mre*

# Recommendations

- Plans for communicating and disseminating information about MRE should be embedded in the research process
  - Accurate, current, and appropriate messaging to keep audiences properly informed
- Outreach efforts should be creative, with content developed for specific and diverse audiences
- Workforce development efforts will need to leverage resources and lessons learned internationally, and from offshore wind
  - Include programs at all education levels to increase awareness of MRE and develop skills

EMEC

# 8.0

# Marine Renewable Energy Data and Information Systems

Author: Hayley Farr

# MRE Data & Information Systems

https://primre.org/

- Large amounts of environmental and technical MRE data and information being collected
- Assuring data and information are easily findable and accessible to help make informed decisions
- Several national and international data and information systems
  - Host and disseminate data and information in a variety of formats
  - **Portal and Repository for Information on Marine Renewable Energy (PRIMRE):** central system for MRE data, information, and resources in the U.S.

# TETHYS

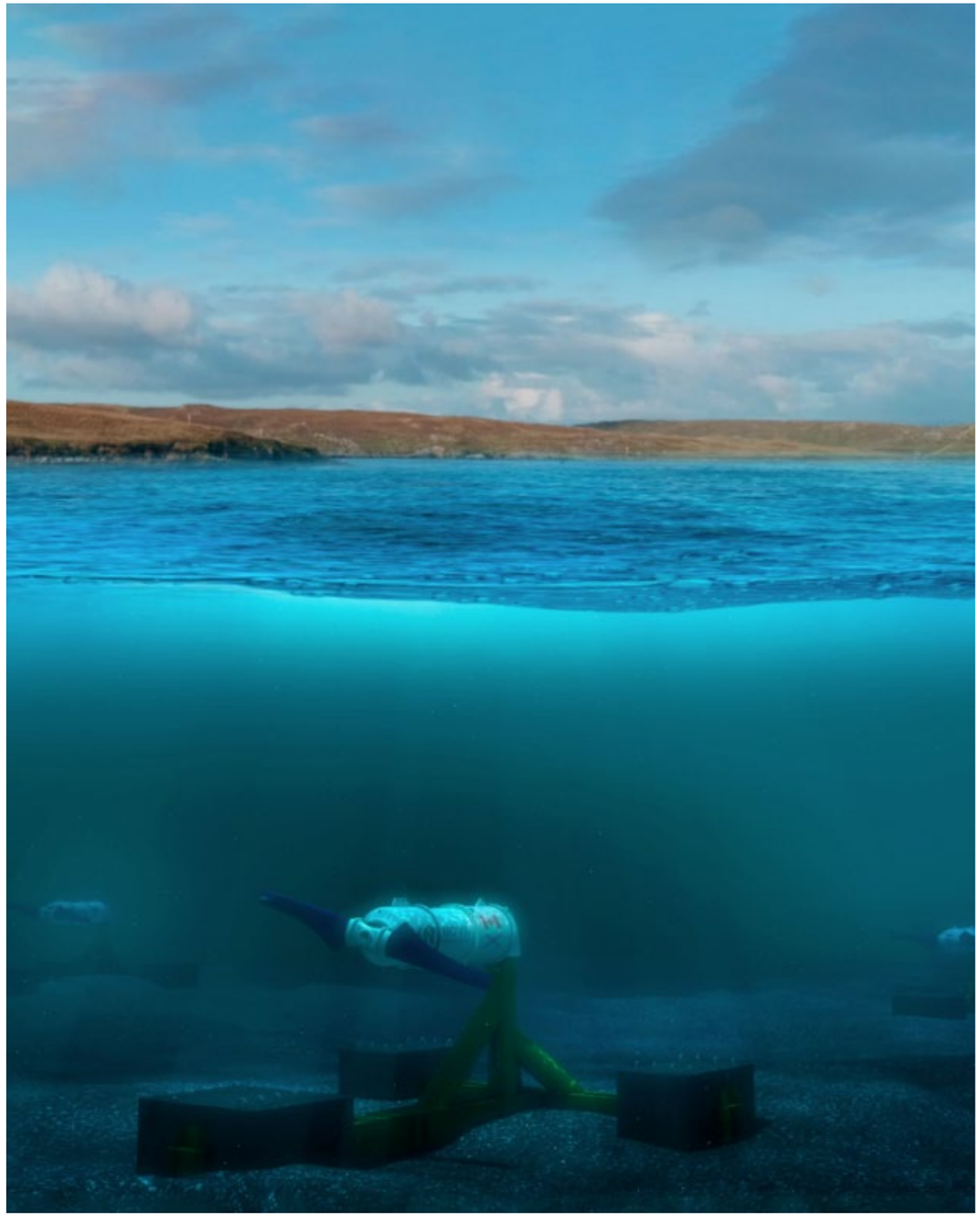
*Visit https://tethys.pnnl.gov/ to learn more and subscribe!*

- Within PRIMRE, **Tethys** hosts information and resources on the environmental effects of MRE and wind energy around the world
- Over 9,000 journal articles, conference papers, and reports
- Outreach and engagement platform for OES-Environmental
- Additional content and tools:
  - Events calendar
  - Archived webinars
  - Educational resources
  - Environmental metadata
  - Tethys Blast newsletter

# 9.0

# Beyond Single Marine Renewable Energy Devices: A System-wide Effects Approach

Authors: Lenaïg G. Hemery, Daniel J. Hasselman, Marie Le Marchand, Georges Safi, Elizabeth A. Fulton, Andrea E. Copping



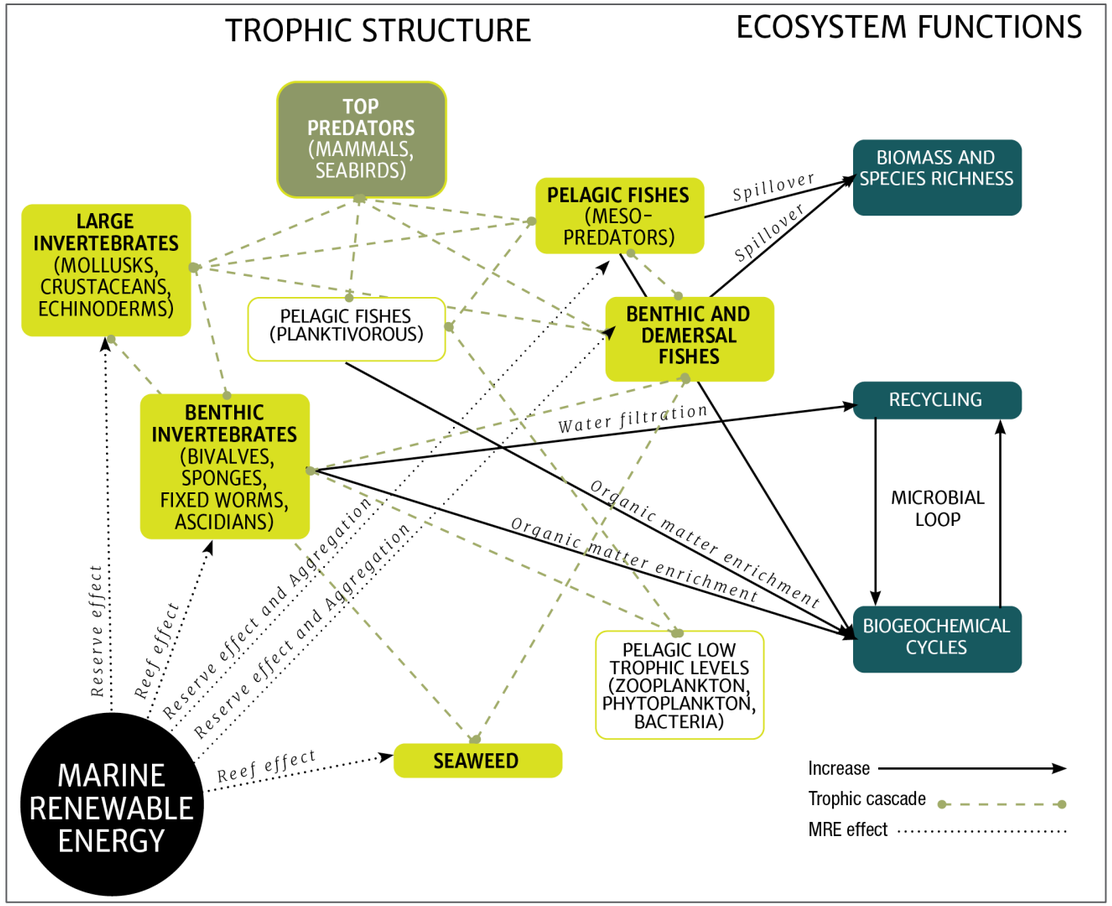
# Status of Knowledge

- **Scaling** environmental effects knowledge from single MRE devices to arrays
  - Investigations of MRE interactions to date on small numbers of devices, little known about effects of arrays
  - Array defined as 10-30 devices (depending on device size, array geometry, and ambient environment)
  - How to apply the knowledge of stressor-receptor interactions learned for single devices to arrays?

| Stressor-receptor Interactions | Environmental Effects | | | |
|---|---|---|---|---|
| | Dominance | Additive | Antagonistic | Synergistic |
| Collision risk | | × | × | × |
| Underwater noise | | × | | × |
| Electromagnetic fields | × | × | × | |
| Changes in habitats | | × | × | × |
| Changes in oceanographic systems | | × | × | × |
| Entanglement | | × | × | |
| Displacement | | × | | × |

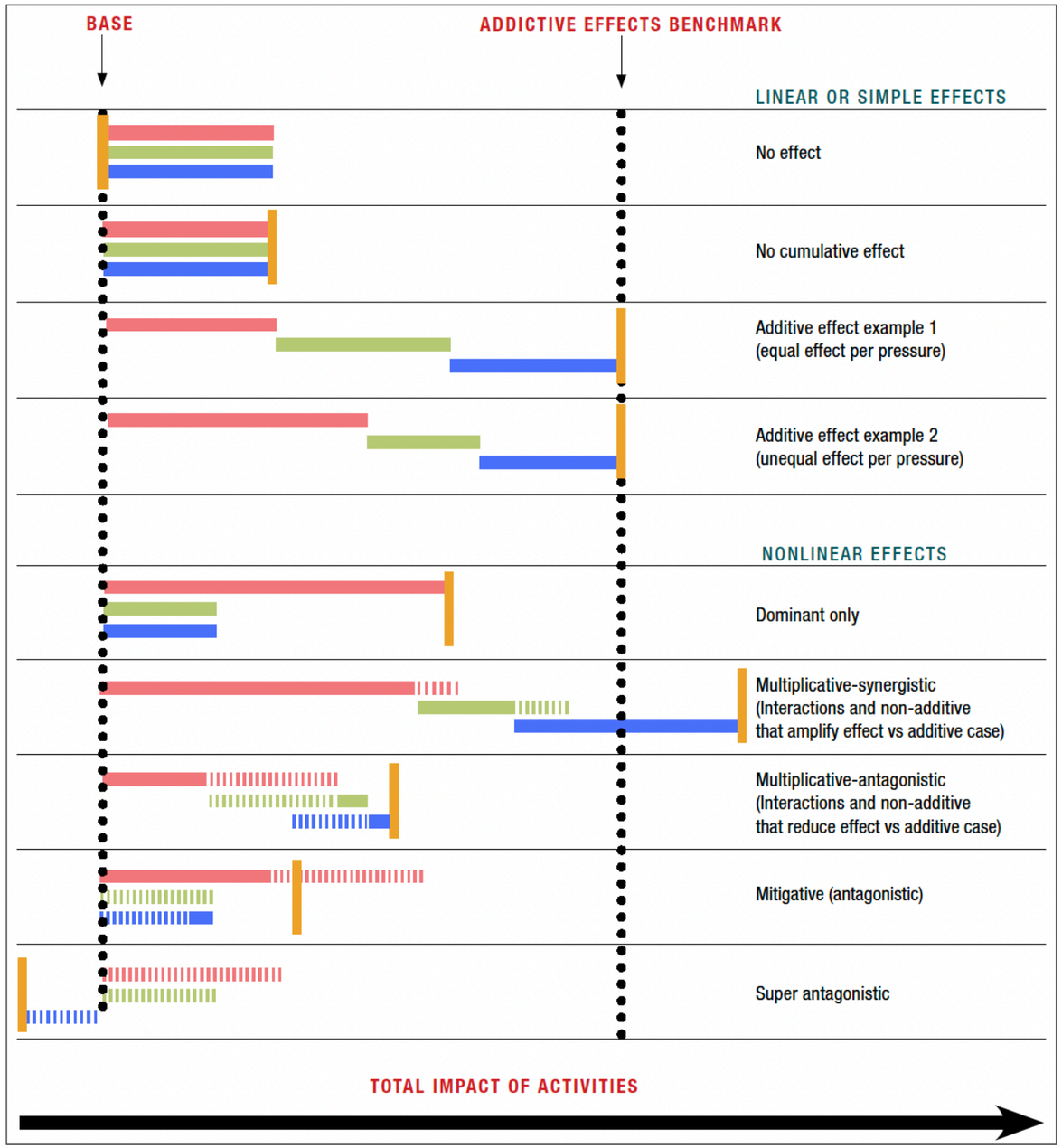
# Status of Knowledge

- Adding MRE to **ecosystem approach** to understand system-wide effects
  - How do MRE development and operation affect the ecosystem into which it is deployed?
  - Conceptual frameworks for global qualitative analysis describing interactions between ecosystem components and MRE systems
  - Assessment of existing models and indicators for applicability to MRE



# Status of Knowledge

- Adding MRE to **cumulative effects** of other human activities at sea
  - Direct and indirect effects from the variety of activities that occur within a region over time (e.g., MRE, fishing, shipping, climate change)
  - What are the cumulative effects of MRE developments?
  - Different forms of cumulative effects
  - Various means of investigation



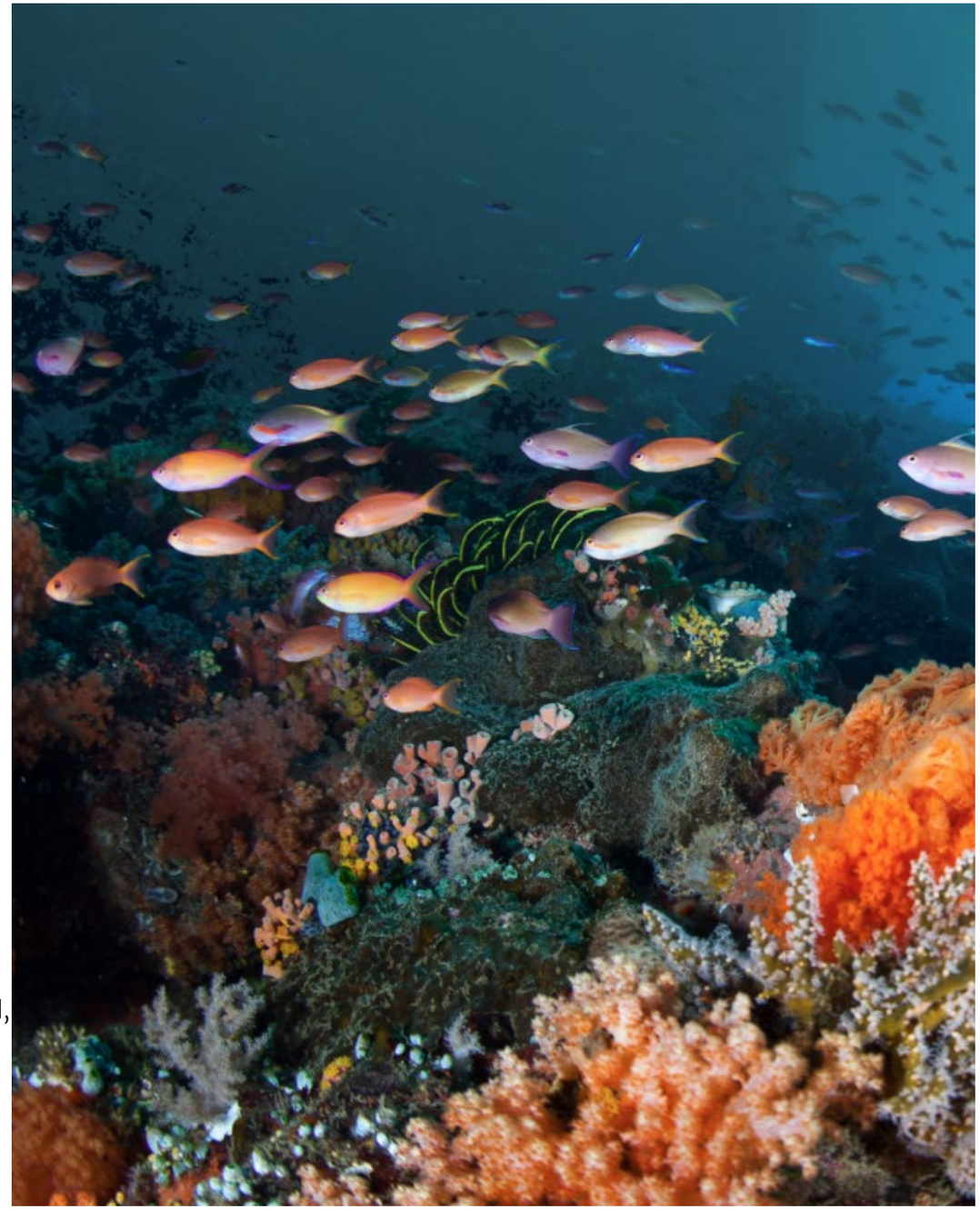
# Recommendations

- Improving understanding of physical and biological processes, ecosystems' characteristics, and socioeconomic factors in MRE development areas
- Identifying MRE-specific data gaps that prevent applying a system-wide approach
- Considering uncertainty in all modeling efforts for management
- Adapting system-wide investigations to MRE projects' lifecycle stages
- Identifying thresholds in responses to the stressor-receptor interactions

# 10.0

# Potential Environmental Effects of Marine Renewable Energy in Tropical and Subtropical Ecosystems

Authors: Lysel Garavelli, Lenaïg G. Hemery, Hayley Farr, Maria Apolonia, Zoe Haywood, Alejandra Alamillo-Paredes, Anke Bender



# Status of Knowledge

## Environmental concerns

- Need to better understand how environmental effects may differ between tropical/subtropical and temperate regions
- MRE resources in tropical regions often overlap with biodiversity hotspots
- Developments may affect unique habitats already experiencing the impacts of climate change (e.g., coral reefs, mangrove forests, seagrass beds)
- Most important concerns: effects on biodiversity and ecosystem functions

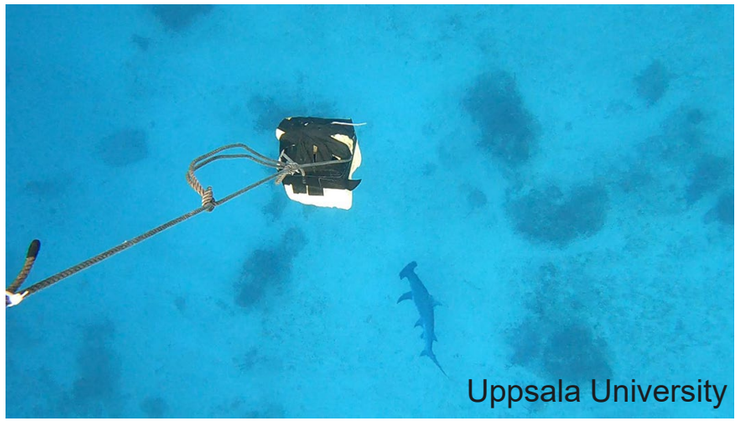
## Socioeconomic concerns

- Emphasis on social acceptance and economic impacts of MRE
- Examples:
  - Local and Indigenous communities (e.g., Chile)
  - Fisheries (e.g., Japan)
  - Tourism (e.g., Indonesia)

BOLT Sea Power

# Recommendations

- Identify priority and vulnerable habitats of tropical and subtropical ecosystems
- Combine long-term baseline monitoring and modeling studies
- Apply a system-effects approach (cumulative effects)
- Engage with local government bodies and non-governmental organizations to identify concerns early
- Collaborate with local stakeholders to collect environmental data
- Develop MRE technologies that are environmentally friendly and adapted to extreme events



# 11.0

# Summary and Path Forward

Author: Andrea E. Copping

# New Phase of OES-Environmental 2024-2028

## Continue with collection, analysis, dissemination of information

### Environmental acceptability

- Existing knowledge to be used for proactive developer guidance on design, deployment, operations, maintenance, and decommissioning

### Environmental effects of off-grid MRE applications

- Examining differences between potential effects of grid scale and off grid devices, generally smaller and fewer

### System-wide effects

- Continue to examine effects of scaling to arrays, effects on ecosystems, cumulative effects with other human activities, in face of climate change, and effects in tropical and subtropical ecosystems

### Social and economic effects of MRE

- Inextricably linked to environmental effects; needs standardized methods

# Conclusions

- Understanding potential MRE environmental effects is more complex than anticipated
- Many countries lack regulatory pathways for MRE deployment, including monitoring and mitigation of environmental effects
- Extensive insight has been gained on interactions of MRE with animals, habitats, ecosystem processes, but more to learn
- A global network of researchers, developers, regulators, and other stakeholders has been established
- OES-Environmental acts as a collaboration to assist with development of a sustainable MRE industry


Eco Wave


Azura Wave Energy

# Thank you

**Lysel Garavelli**
lysel.garavelli@pnnl.gov

Andrea Copping,
Lenaïg Hemery, Mikaela Freeman

Deborah Rose, Hayley Farr, Kristin Jones,
Marley Kaplan, Jonathan Whiting

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**Read the 2024 State of the Science report here:**

**https://tethys.pnnl.gov/2024-sos**

**Webinar survey**

**https://www.surveymonkey.com/r/M2G3PTK**