# Taking a Broader Look at Environmental and Ecological Effects of Marine Energy Development


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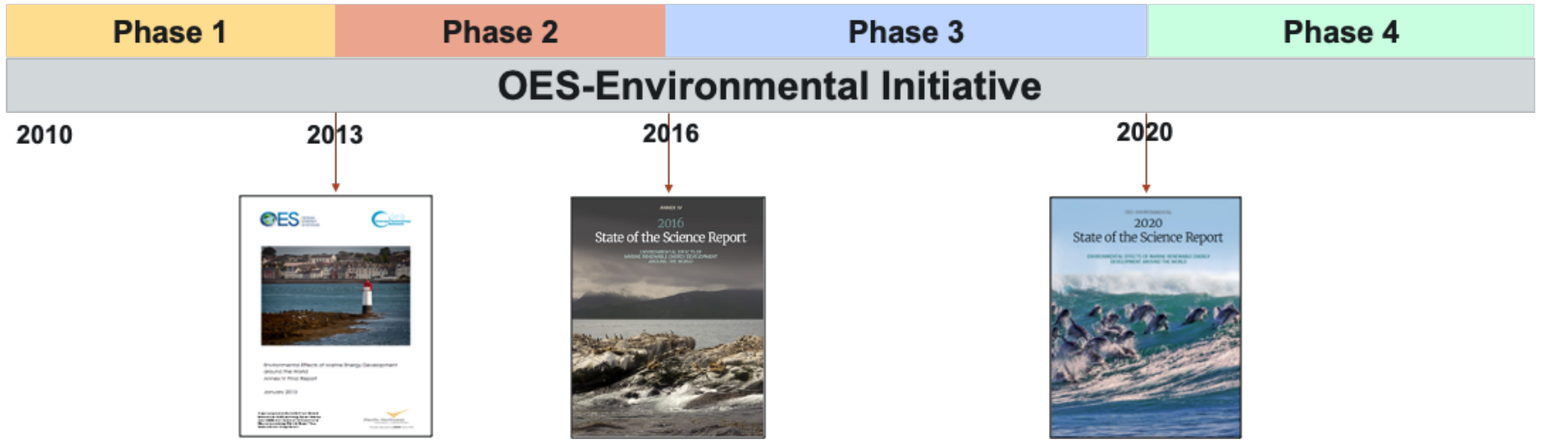
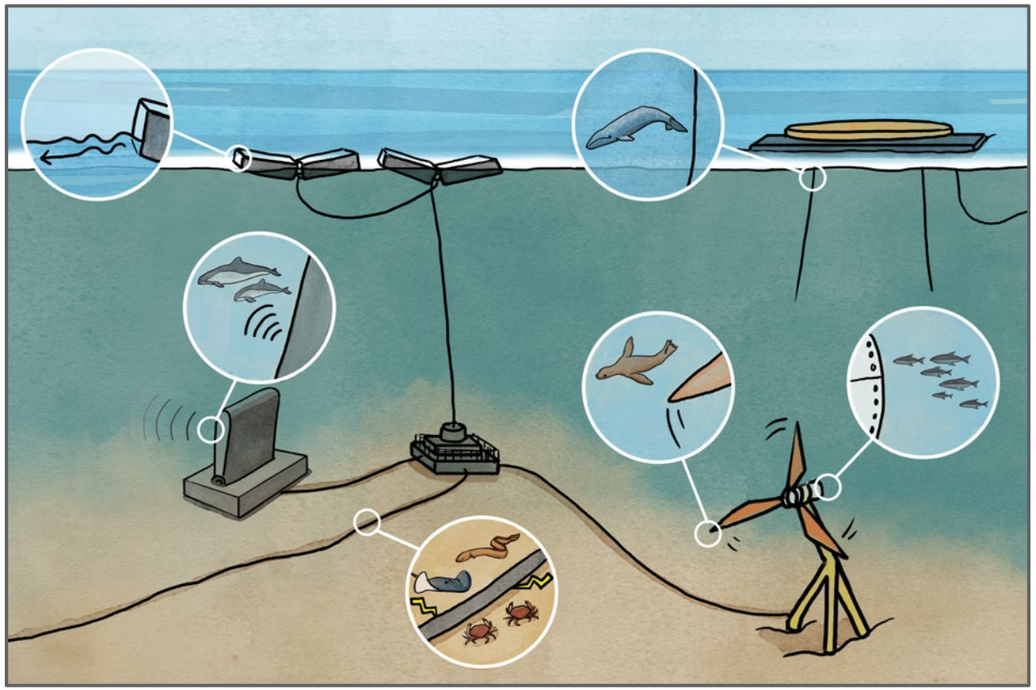
# OES-Environmental

- International initiative coordinating research and information to progress the marine energy industry in an environmentally responsible manner
- 16 OES nations currently participating
  - Australia, Canada, China, Denmark, France, India, Ireland, Japan, Mexico, Monaco, Portugal, Singapore, Spain, Sweden, United Kingdom, United States
- Led by the U.S. DOE Water Power Technologies Office and implemented by Pacific Northwest National Laboratory (PNNL)
- Publishes syntheses of the current available knowledge about environmental effects



# Environmental Effects of Marine Energy: Stressors and Receptors

- **Stressors:** marine energy devices and systems that may cause harm
- **Receptors:** marine animals, habitats, ecosystem processes



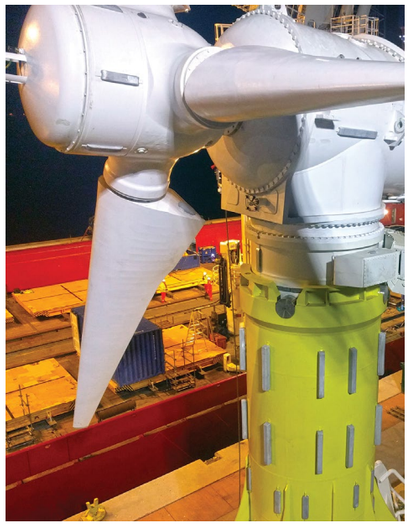
## Priority stressor-receptor interactions:

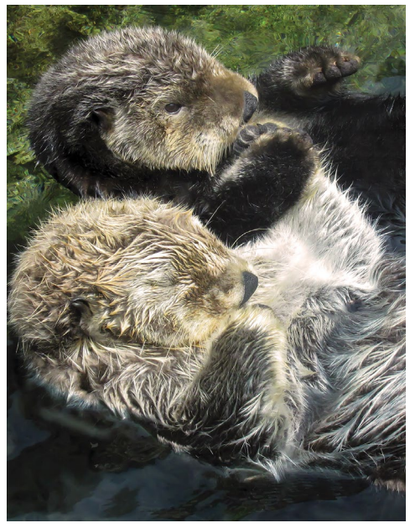
- Collision risk
- Underwater noise
- Electromagnetic fields
- Habitat changes
- Mooring line encounter
- Changes in oceanographic systems
- Displacement

# Moving Towards a Systems Perspective

Holistic approach, looking ahead to potential system effects, particularly as numbers of devices in the ocean increase:

- Cumulative effects of marine energy with other anthropogenic stressors
- Ecosystem effects of marine energy, including ecosystem services
- Scaling effects of marine energy from single devices to large arrays





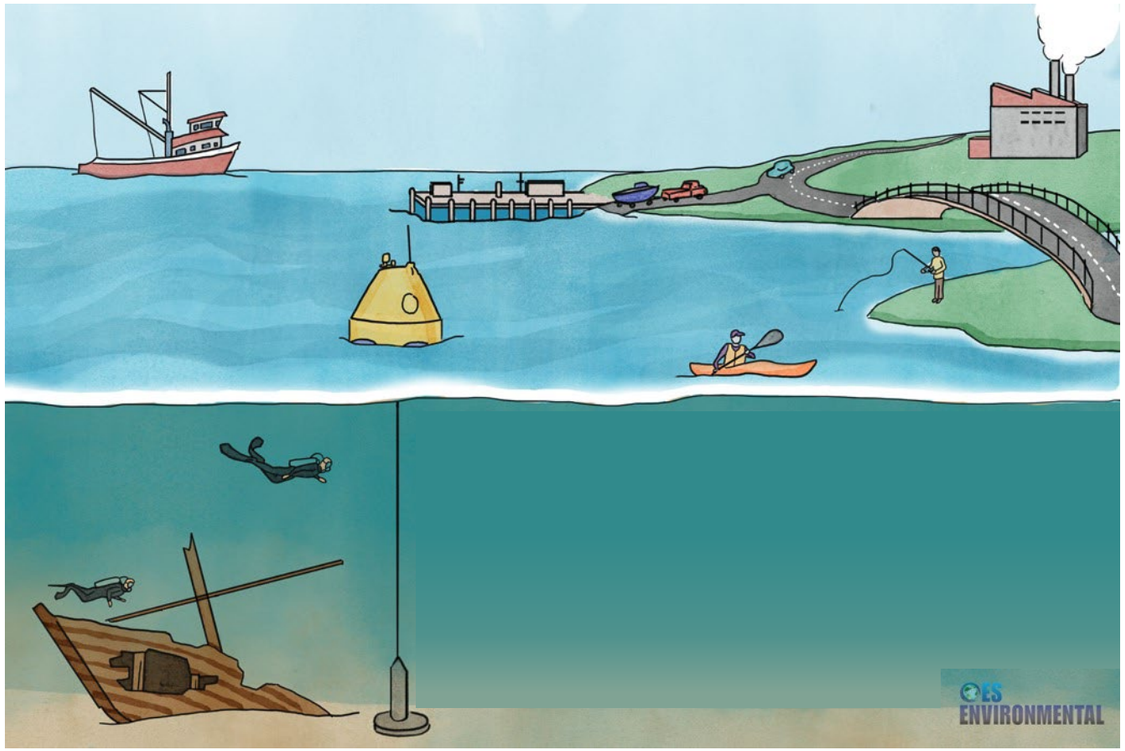
# Cumulative Effects of Marine Energy with Other Anthropogenic Activities at Sea

Led by Commonwealth Scientific and Industrial Research Organisation, Australia

**Cumulative Effects:** direct and indirect effects from the variety of activities that occur within a region over time (e.g., marine energy, fishing, shipping, climate change)

Questions that drive this inquiry:

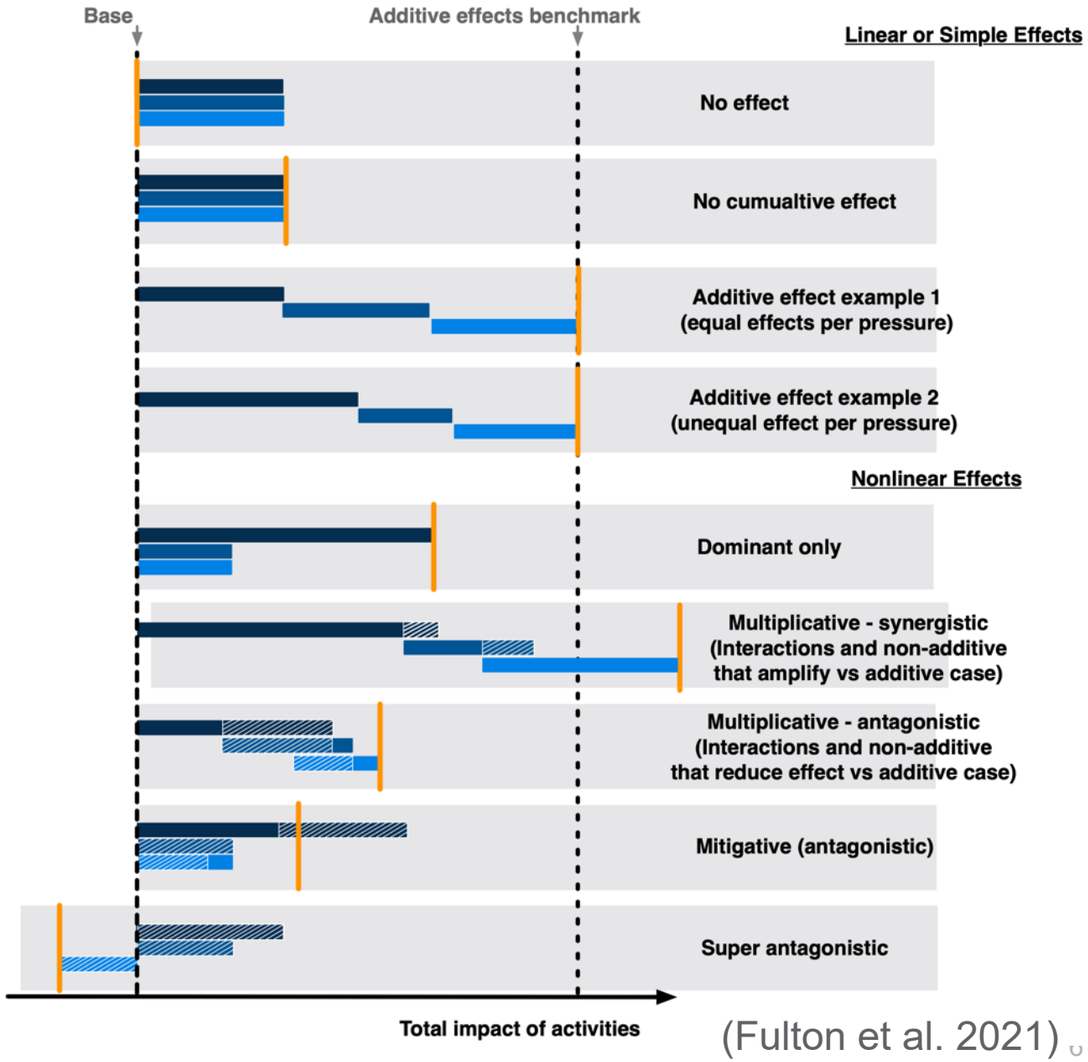
- What are the cumulative effects of marine energy developments?
- How do these effects combine with or affect other human uses of the ocean?
- What tools and research studies can be used to best assess these effects?



# Cumulative Effects of Marine Energy with Other Anthropogenic Activities at Sea

- Different forms of cumulative effects:
  - **Additive**: sum of individual effects is equal to the sum of each effect alone
  - **Masking**: one stressor dominates the signal, masking the effects of other stressors
  - **Synergistic**: interaction of multiple stressors is greater than the sum of the individual effects
  - **Antagonistic**: interaction of multiple stressors is less than the sum of the effects

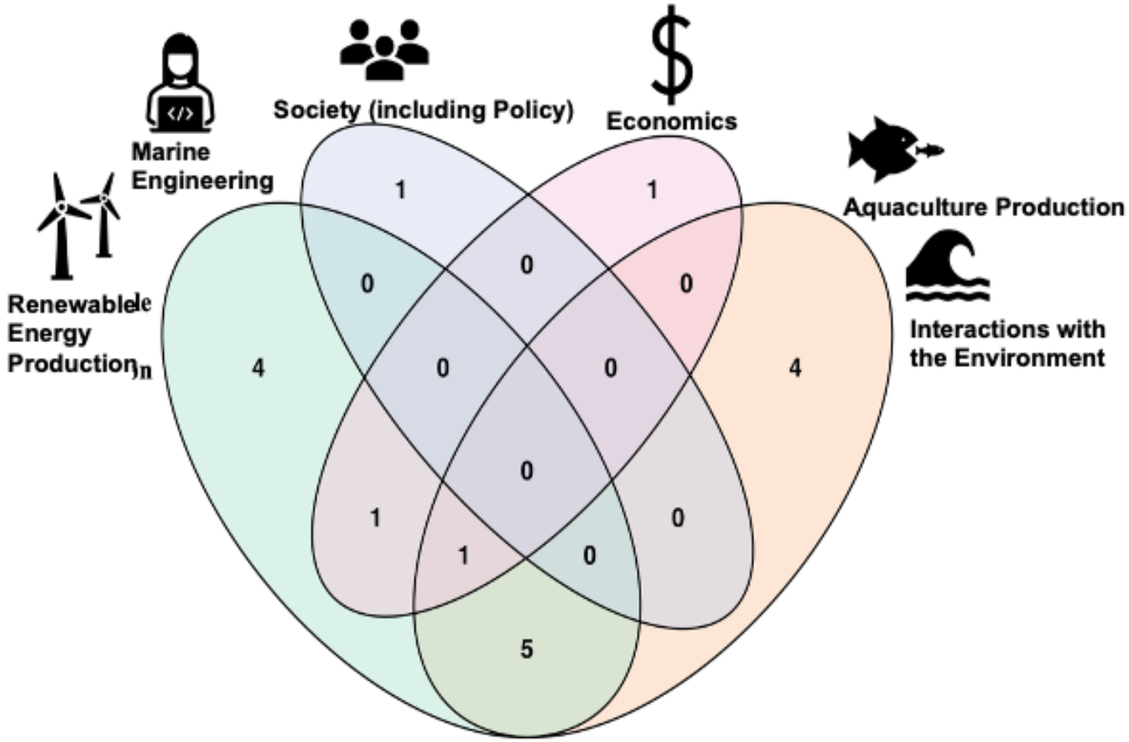
- Common approaches to cumulative effects assessments assume effects are additive
- Often struggle with non-linearities, and lack of readily accessible data
- Model-based outcomes




(Fulton et al. 2021)

# Cumulative Effects of Marine Energy with Other Anthropogenic Activities at Sea

- Many cumulative effects assessment methods available and based on:
  - GIS or marine spatial planning tools
  - Expert knowledge
  - Numerical modeling
  - Mixed approaches
- Assessments start with hazard identification, with limited cross-domain methods
- Few marine energy assessments (if any) go beyond the hazard identification stage




Crossover of hazard identification methods among domains (Turschwell et al., in prep.).

# Ecosystem Approach of Marine Energy

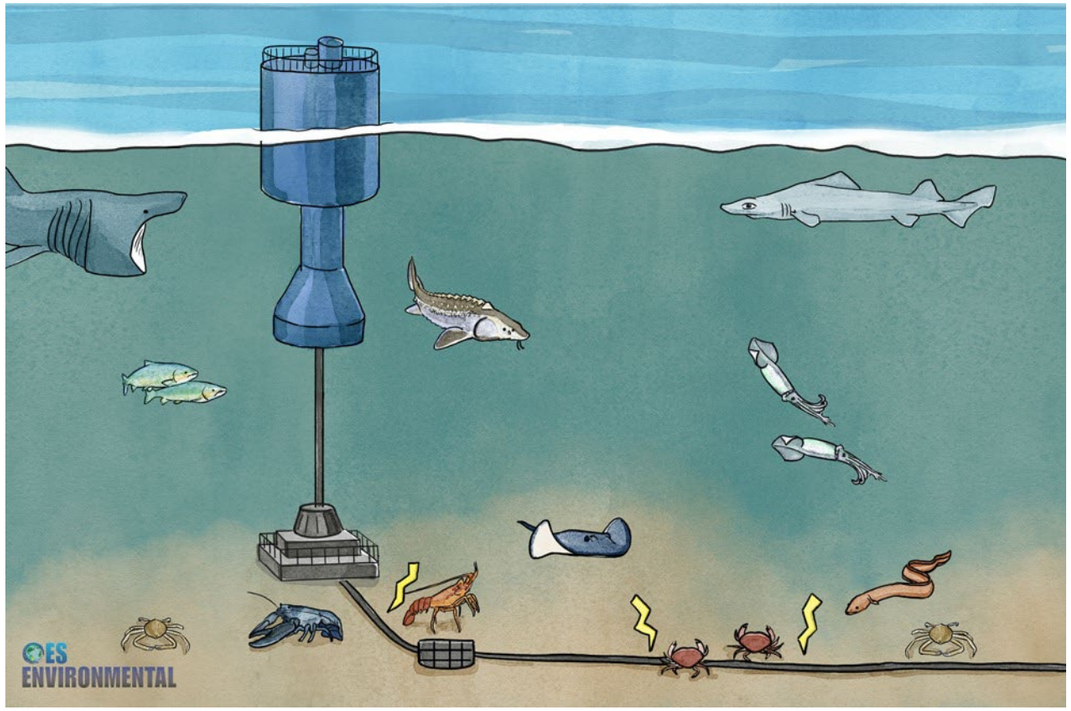
Led by France Energies Marines, France

**Ecosystem Approach** defined by the Convention on Biological Diversity, no mention to marine energy:

- Integrated management strategy that promotes equitable conservation and sustainable use of resources and spaces
- Scientific methodologies that encompass processes, functions and interactions among organisms and their environment

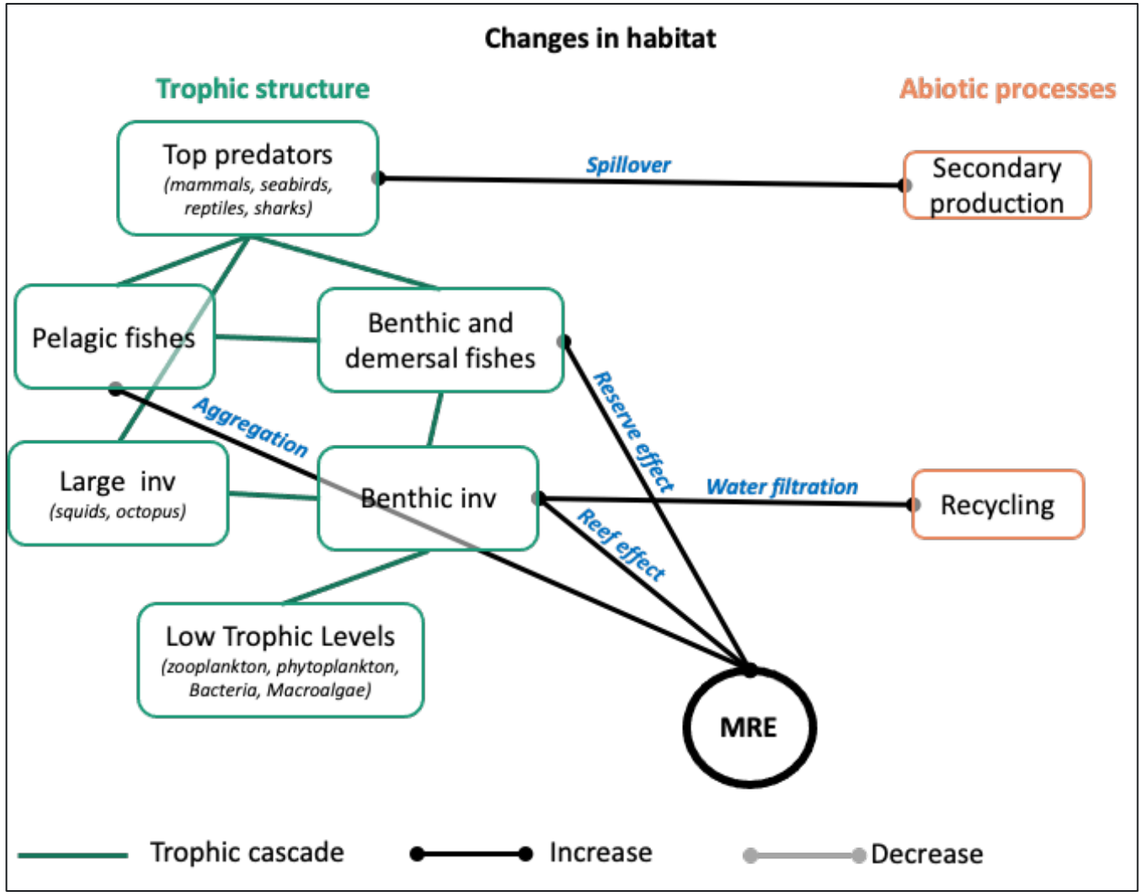
Questions that drive this inquiry:

- How do marine energy development and operation affect the ecosystem into which it is deployed?
- How are ecosystem services affected and/or assisted by marine energy?



# Ecosystem Approach of Marine Energy

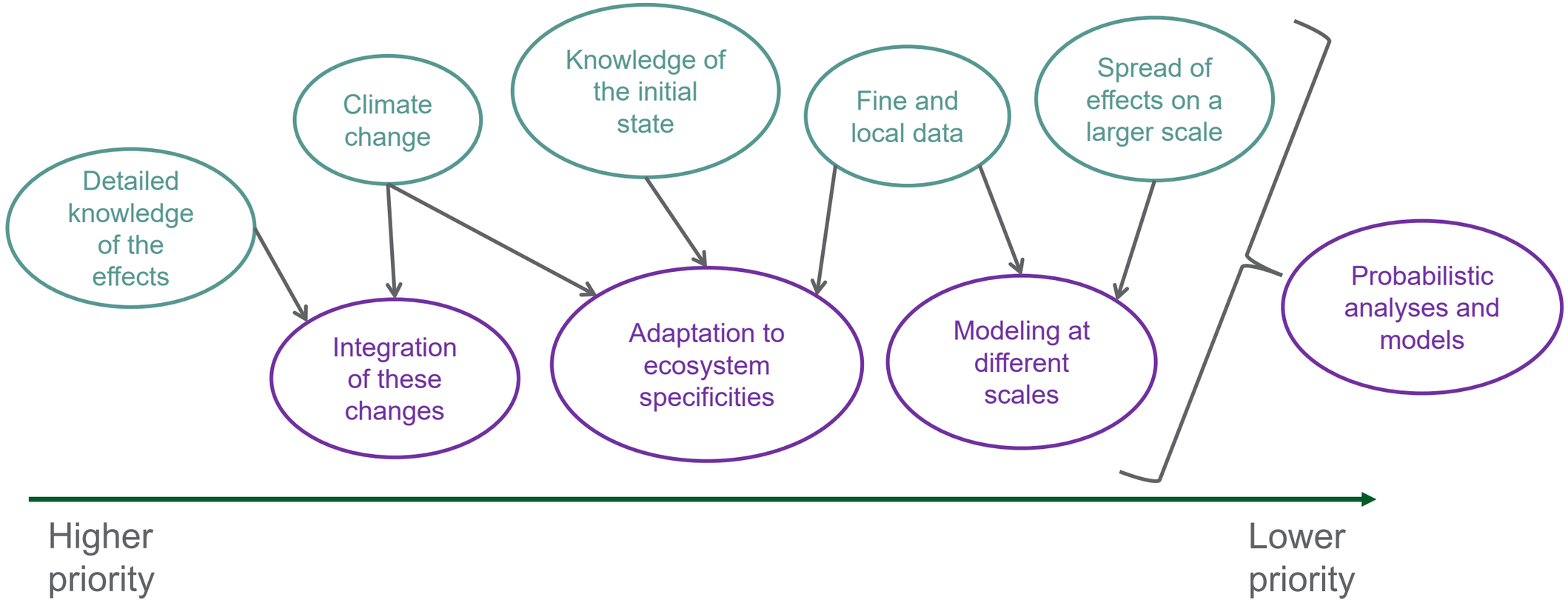
- Conceptual framework underway for global qualitative analysis describing interactions between ecosystem components and marine energy systems
- Current models under review, assessment for applicability for marine energy
- Survey of experts to refine the definition of ecosystem approach, conduct these assessments, and identify knowledge gaps specific to ecosystems for marine energy




Draft conceptual framework of the ecosystem-wide effects changes in habitats caused by marine energy developments.

# Ecosystem Approach of Marine Energy

Much improvement is needed in current knowledge and model quality:



# Scaling up our Understanding of Environmental Effects from Single Devices to Arrays

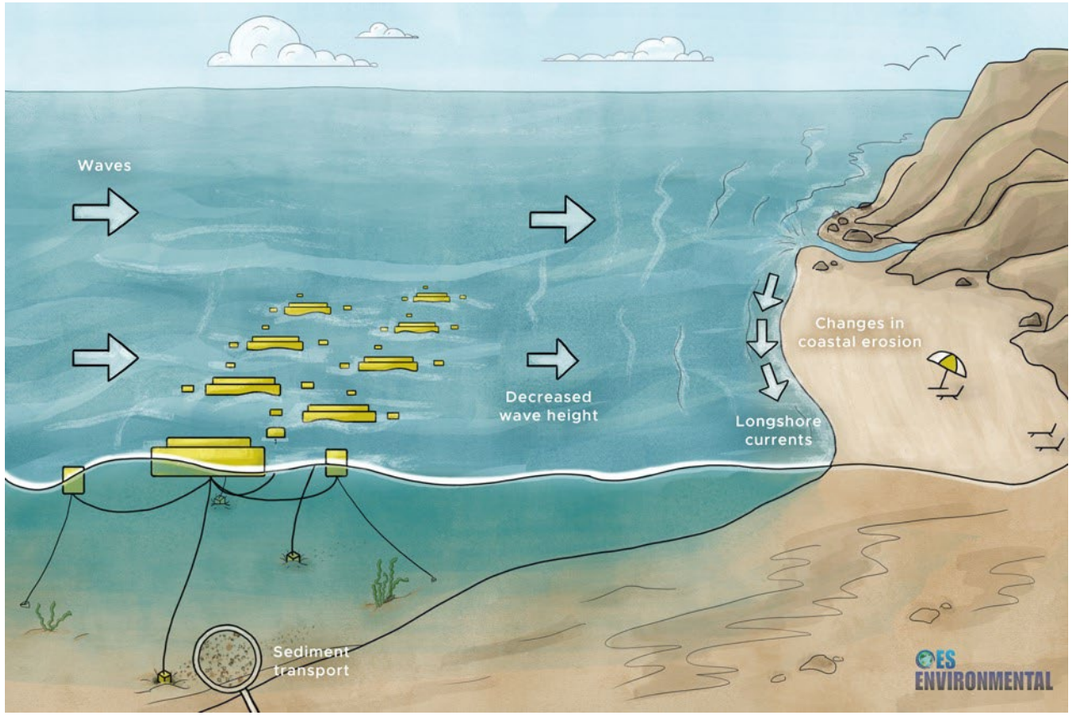
Led by Fundy Ocean Research Centre for Energy, Canada

**Scaling to Arrays**:

- Investigations of marine energy interactions to date on small numbers of devices. Little is known about effects of arrays
- Define array for this purpose of 10-30 devices (depending on device size, array geometry, and ambient environment)

Questions that drive this inquiry:

- How do we apply the knowledge of stressor-receptor interactions we have learned for single devices to effects from arrays?
- How should we examine interactions that are not significant around single devices when arrays are in the water?



# Scaling up our Understanding of Environmental Effects from Single Devices to Arrays

Level of Understanding for Single Devices

Knowledge Applicable to Arrays

- Effects of single devices not understood
- No collision with turbine ever observed
- Risk very site- and species-specific

Collision Risk

- No effect with single devices
- Investigation needs arrays in the water
- Numerical models need validation

Oceanographic Systems

Displacement

- Effects measurable and understandable
- Relatable to other marine industries
- Likely additive with the size of arrays

Electromagnetic Fields

Underwater Noise

Entanglement

- Similar effects to other industries
- Ecosystem-wide effects possible
- Increase in areal effects with array size

Habitat Change

# Scaling up our Understanding of Environmental Effects from Single Devices to Arrays

Remaining major caveats & knowledge gaps:

**Collision risk**

- animals' perception of tidal turbine arrays
- potential limits to behavioral responses
- animals' avoidance ability

**Oceanographic systems**

- lack of validated numerical models
- array size for measurable effects

**Displacement**

- animals' perception of arrays
- triggering stimuli
- array size thresholds

# Scaling up our Understanding of Environmental Effects from Single Devices to Arrays

Remaining major caveats & knowledge gaps:

**Electromagnetic fields**

- responses and adaptation of sensitive species
- reaction to multiple cables

**Underwater noise**

- lack of propagation models adapted to high-energy sites

**Entanglement**

- lack of empirical data
- animal behavior around mooring lines

**Habitat change**

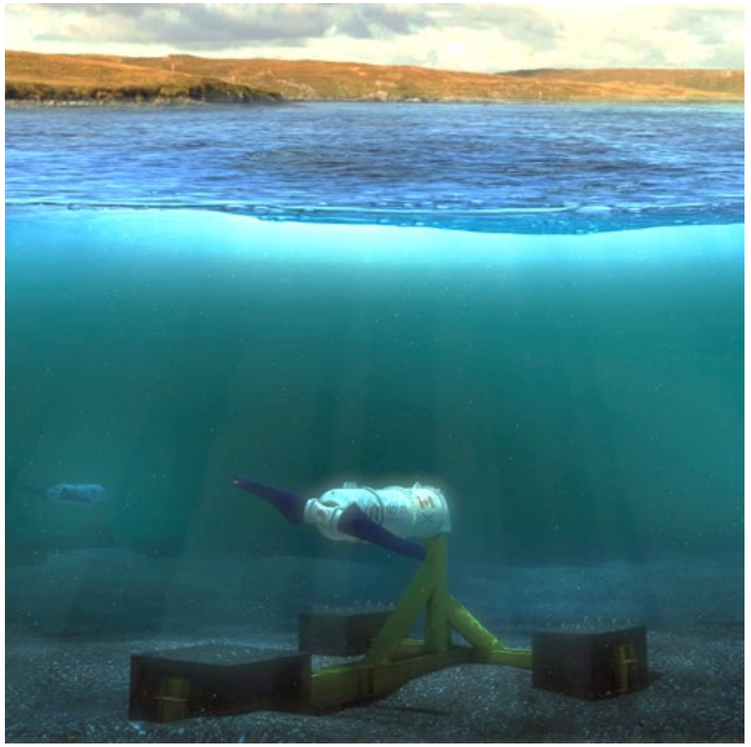
- wide range of spatiotemporal scales
- lack of standardized methods for data collection

# Conclusion, Next steps

- Investigations in the three topics continue
- Looking for input from knowledgeable partners
- Each will result in a white paper for release in late 2022

Path Forward:

1. Cumulative effects models under development
2. Ecosystem models expanding to include marine energy interactions
3. Scaling up to arrays will focus on what is known about single device interactions, based on physics and biology of regions



Pacific Northwest
NATIONAL LABORATORY

# Thank you for listening

# We are looking forward to your questions!

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