



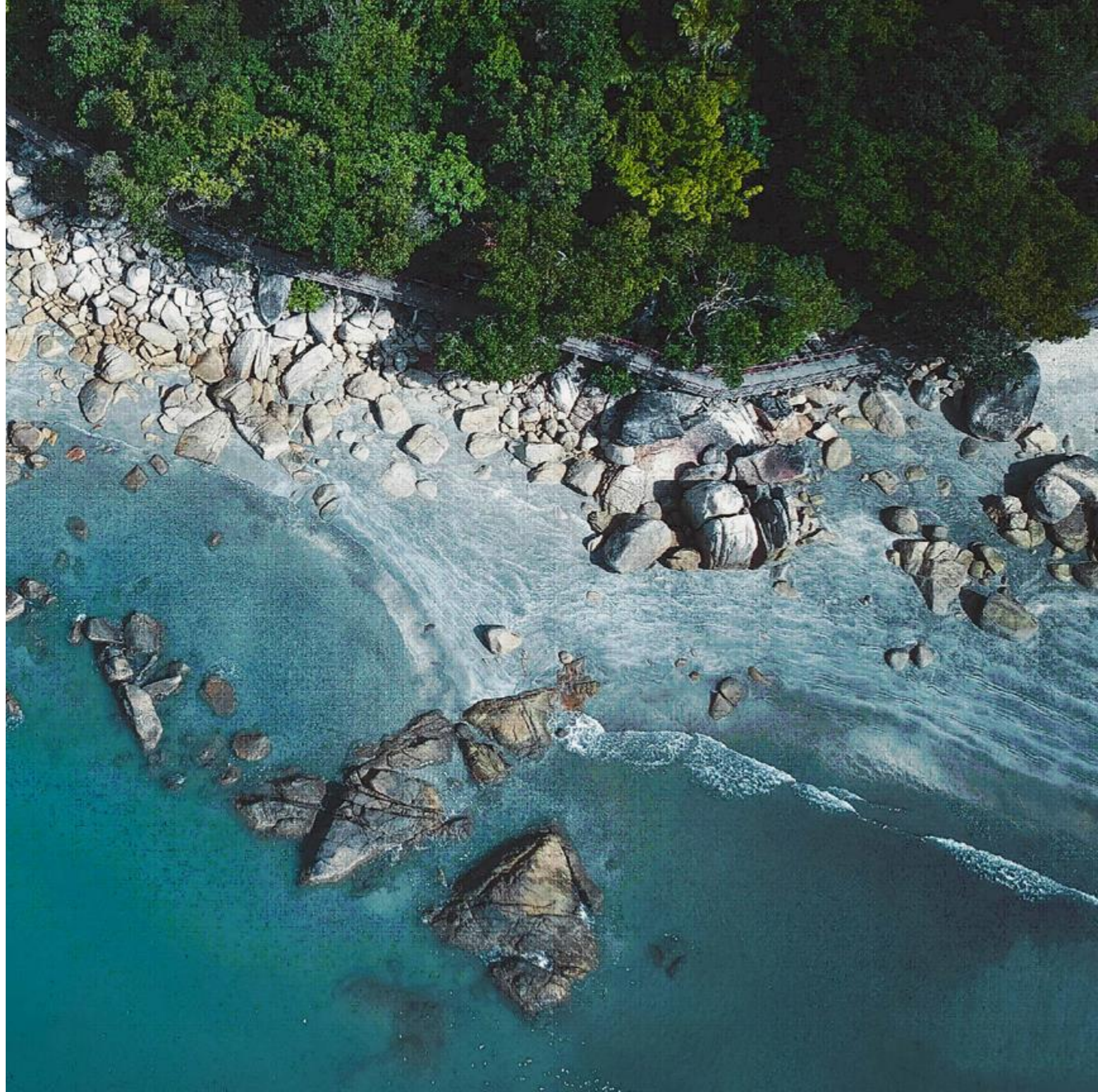
Environmental effects of marine renewable energy in tropical and subtropical ecosystems

January 24, 2024

Lysel Garavelli, Hayley Farr,
Lenaig Hemery, Andrea Copping,
Maria Apolonia, Alejandra Alamillo-Paredes



PNNL is operated by Battelle for the U.S. Department of Energy

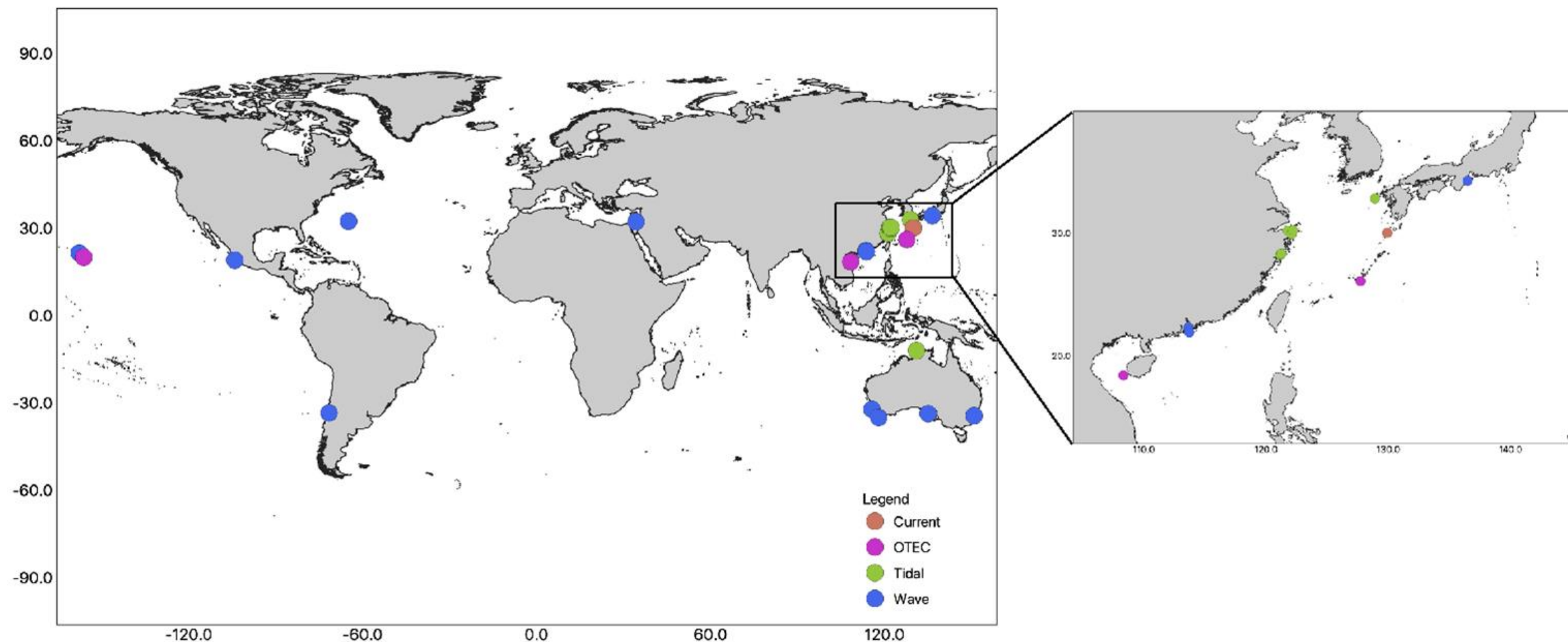


MRE Development in Tropical and Subtropical Countries

- Research on environmental effects of marine renewable energy (MRE) has primarily occurred in temperate regions and countries in the Northern Hemisphere
- Tropical/subtropical ecosystems: Species and habitats highly impacted by anthropogenic activities and climate change
 - MRE can present additional risks (reduce biodiversity and ecosystem resilience)



MRE Development in Tropical and Subtropical Countries



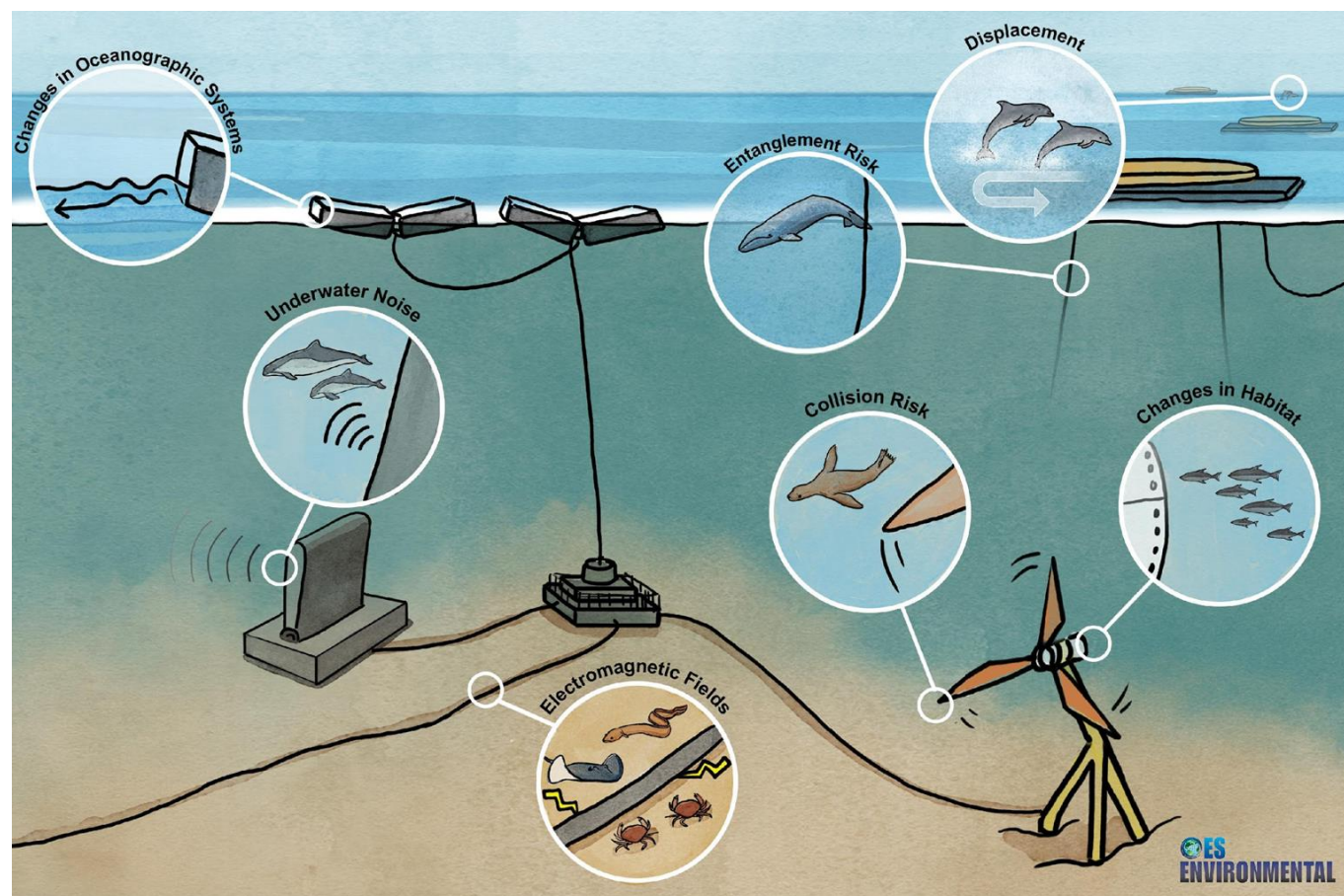
- Need to better understand how environmental effects may differ between tropical/subtropical and temperate regions, to adapt, if necessary, device deployments, monitoring methods, and mitigation measures



ENVIRONMENTAL

Specific Stressor-receptor Interactions?

- Similar to those identified in temperate regions
- Prevalence and perceived importance may differ in tropical/subtropical regions, likely due to unique receptors



- Specifically relevant for wave, tidal, and ocean current energy
- What about OTEC?

By Stephanie King (Pacific Northwest National Laboratory)

Environmental Effects of Ocean Thermal Energy Conversion (OTEC)

- Cold water return may disturb ecosystem processes
- Entrainment of deep marine life in pipe
- Chemical discharges and water quality effects
 - Potential for ammonia leaks (for closed systems onshore)
- Effects on nearshore intertidal habitats (e.g., coral reefs)
- At scale, offshore OTEC could alter pelagic habitat and potentially disrupt marine animal migrations





ENVIRONMENTAL Receptors of Concern

- MRE resources in tropical regions often overlap with biodiversity hotspots
- Developments may affect unique habitats already experiencing the impacts of climate change such as:
 - Coral reefs
 - Mangrove forests
 - Seagrass beds
- Most important concerns: effects on biodiversity and ecosystem functions
 - **Need to consider all the species of an ecosystem, the interactions between species**





ENVIRONMENTAL Receptors of Concern

South America (Mexico, Chile, Brazil): endangered marine mammals (sperm whale *Physeter macrocephalus*)

- Underwater noise
- Displacement
- Collision
- Entanglement



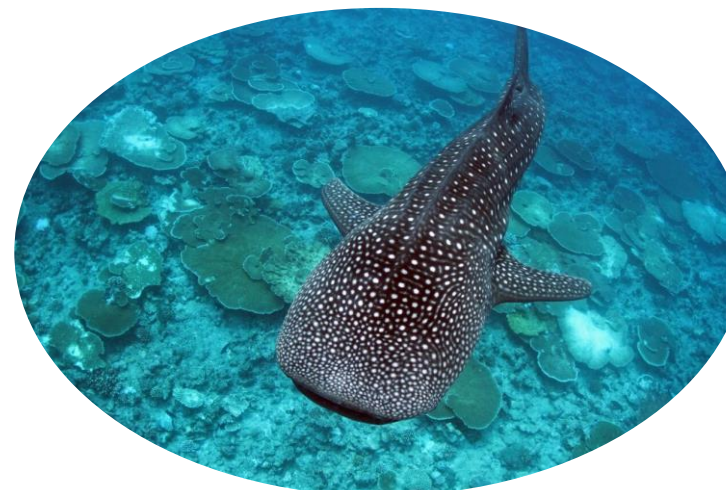
Indonesia: vulnerable fish species (ocean sunfish *Mola mola*)

- Displacement



Maldives: whale sharks (*Rhincodon typus*)

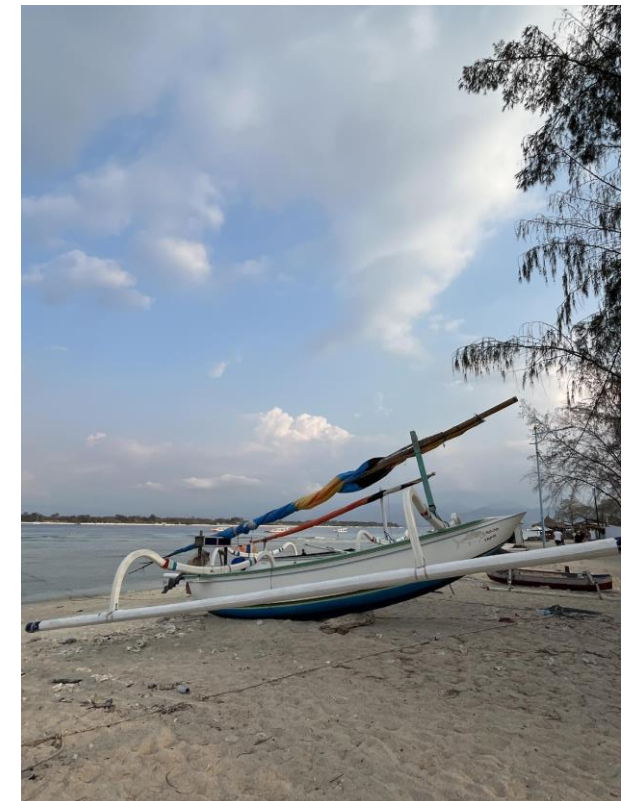
- Displacement





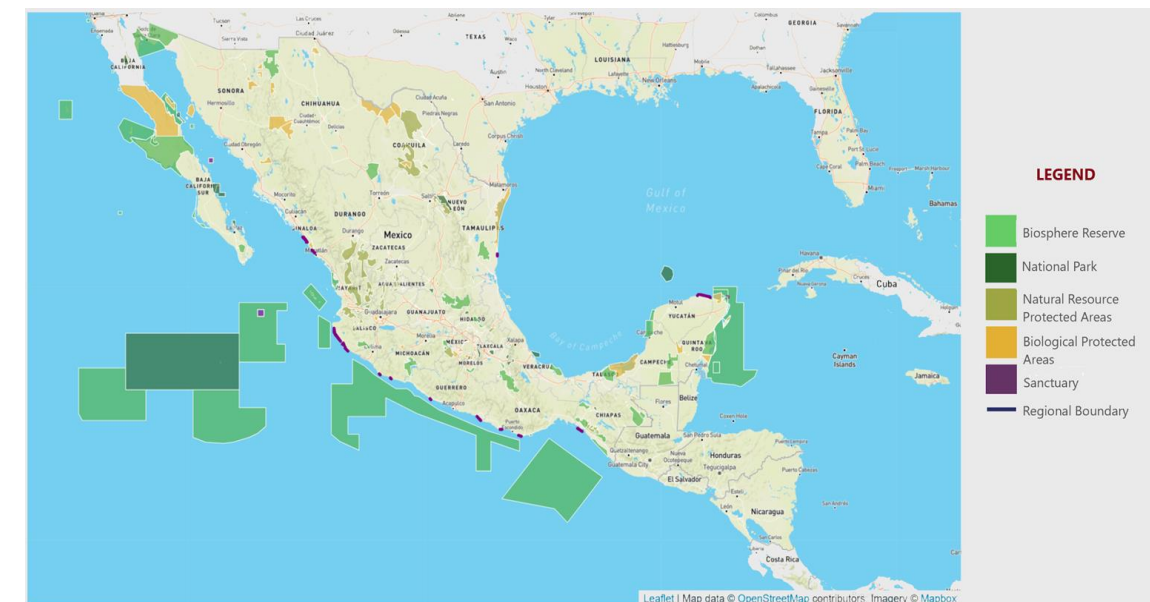
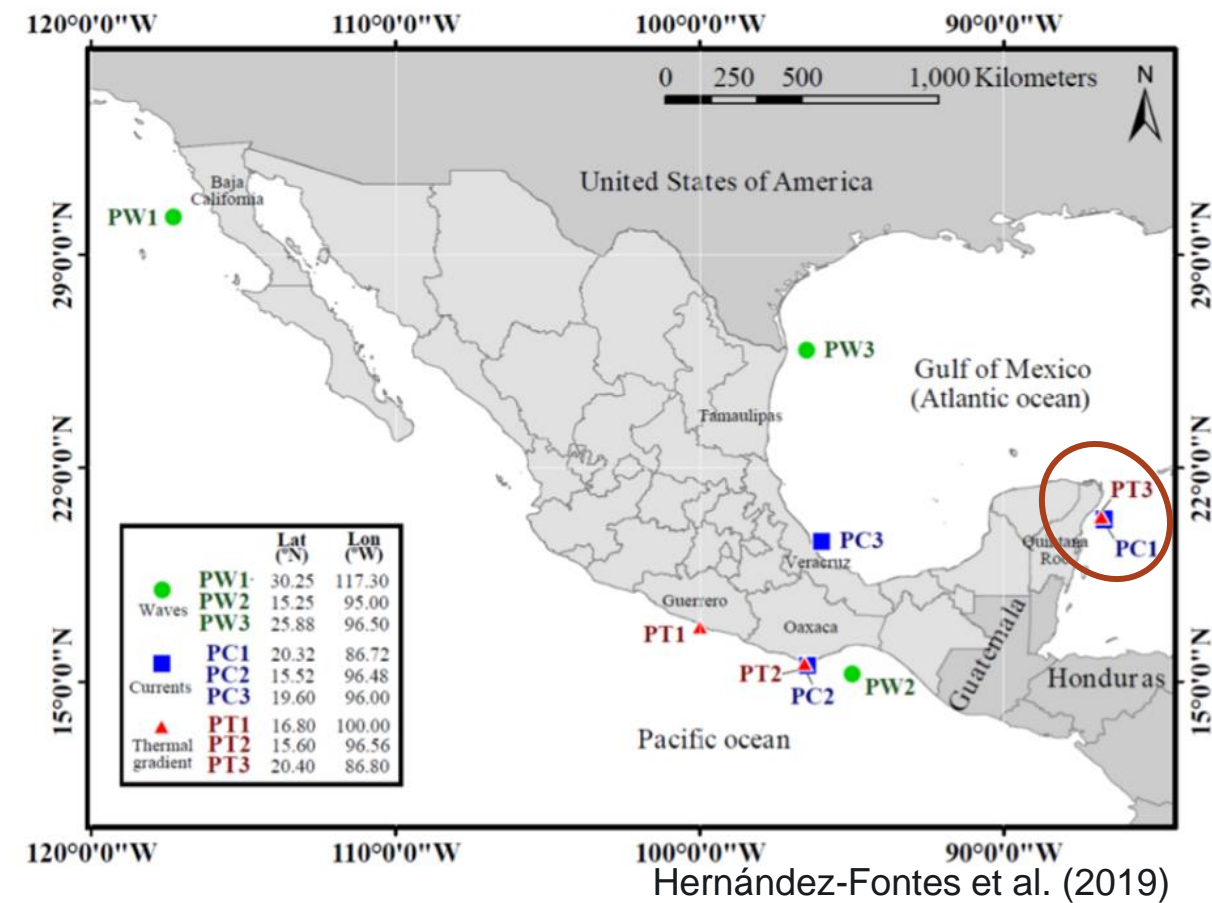
ENVIRONMENTAL Socioeconomic Concerns

- Emphasis on social acceptance and economic impacts of MRE (Adesanya et al. 2020; Fadzil et al. 2022)
- Concerns:
 - Local and indigenous communities
 - Chile: Lafkenche law - exclusive access rights to coastal areas and resources to indigenous communities (González-Poblete et al. 2020)
 - Fisheries
 - Japan: need agreement between fishers and MRE developers for project leasing
 - Tourism
 - Indonesia: displacement of ocean sunfish could disrupt scuba diving
 - Viewshed (“not in my backyard” effect)
 - Australia: perceived as impactful to tourism
- Residents may express these concerns in terms of environmental concerns (insufficient information)



ENVIRONMENTAL OTEC in Mexico

- High marine biodiversity (protected areas) and access to several MRE resources
 - Co-occurrence
 - Government and federal organizations involved in MRE development (stakeholder engagement)
- Suitable regions for OTEC: Pacific and Caribbean Sea coastlines (Garduño-Ruiz et al. 2021)
- Most significant potential effects – Cozumel Island (Garduño-Ruiz et al. 2021)
 - Dragging nutrients to the surface
 - Redistribution of ocean water bodies
 - Impacts from antifouling chemicals
 - Brine discharge

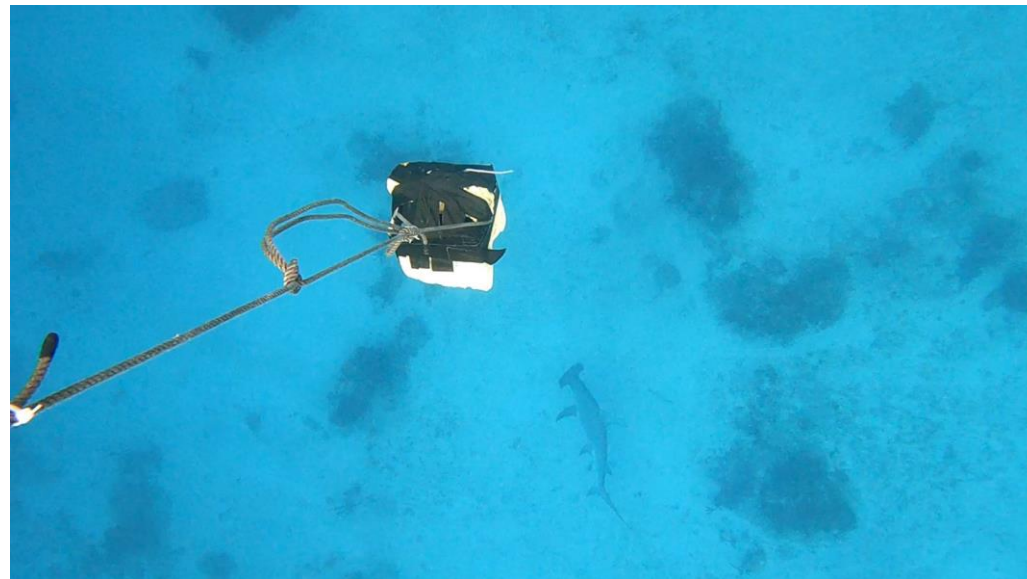




ENVIRONMENTAL Tidal Energy in Bahamas

Uppsala University, Octopus Ink Research & Analysis,
Chalmers University of Technology, and Swedish University
of Agricultural Sciences
Point of contact: Anke Bender anke.bender@angstrom.uu.se

- Effects of underwater noise from tidal devices on sharks
- Emissions of noise: similar to small and big tidal kites, other low frequency or loud sound
- Preliminary results:
 - Reef, nurse, and bull sharks not attracted to the noise
 - Avoidance and habituation seem to happen
 - Attraction to low-frequency noise but habituation with time
 - Sudden loud noise startled the sharks, effects wearing off rapidly



Hammerhead shark in Bahamas
(Photo courtesy of Anke Bender)





ENVIRONMENTAL Knowledge Gaps & Research Needs

- Slow MRE development: lack of investment & environmental and social concerns
- Lack of information about potential environmental effects
 - Need environmental regulations and standardization around environmental assessment
 - Need long-term baseline data
- No stressor-receptor interactions specific to tropical and subtropical regions
 - Need to consider the whole ecosystem and the linkages between species
- Heterogeneous social issues within a country
 - Need community involvement from the conception of a project
 - Need education on MRE





ENVIRONMENTAL Recommendations

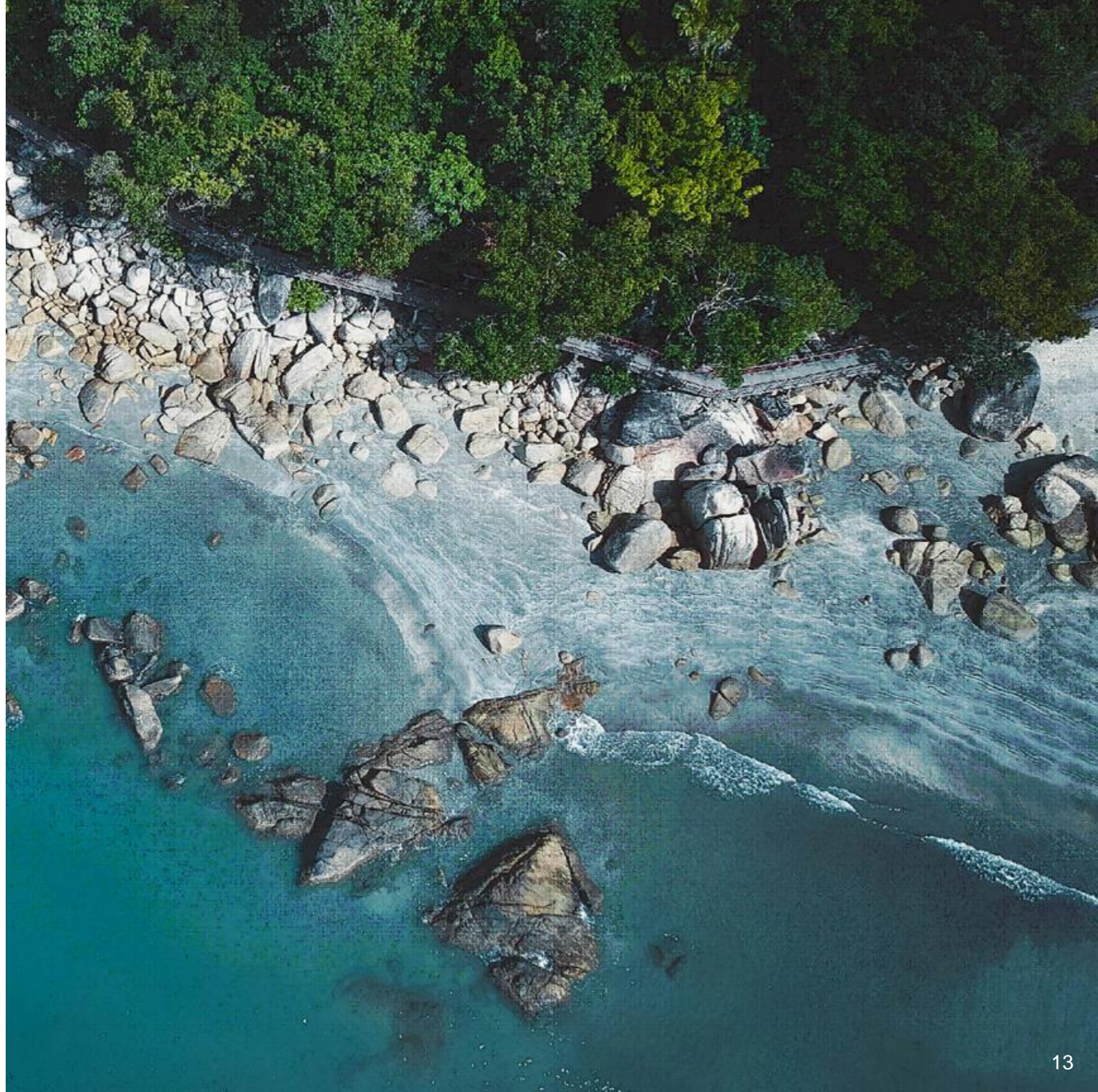
- Identify priority and vulnerable habitats
- Combine long-term baseline monitoring and modeling studies
- Apply a system effects approach (cumulative effects)
- Engage with local government bodies and non-governmental organizations to identify concerns early
- Collaborate with local stakeholders to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





Thank you!

Lysel Garavelli, PhD
lysel.garavelli@pnnl.gov



Methods

- Literature review
- Online survey (English & Spanish; 22 respondents)
- Workshops:
 - Chile Riding the Blue Wave International Conference – 2021
 - PAMEC 2022
- Interviews with experts (31 experts from 15 countries)

