PAMEC 2024

Pan American Marine Energy Conference

Barranquilla, Colombia Jan 22-24, 2024

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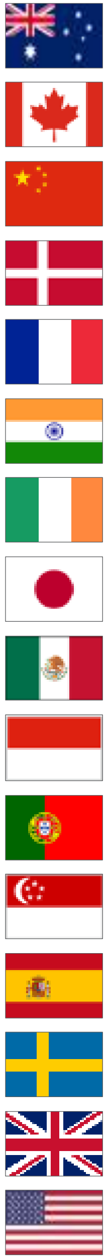
Improving Understanding of Environmental Effects from Single MRE Devices to Arrays

Daniel J. Hasselman, Science Director
Fundy Ocean Research Centre for Energy

Co-authors: L.G. Hemery, A.E. Copping, E.A. Fulton, J. Fox., A.B. Gill, and B. Polagye

January 24, 2024

ACKNOWLEDGEMENTS & RELEVANT INFORMATION



- Various contributors (OES-E staff, country representatives, others):
  - C Briggs, M. Freeman, M. Richlen, C. Long, A.M O'Hagan, I. Machado, A. Vishwanath, S. Narasimalu, C. Bassett, I. Hutchison, L. McGarry
  - Funding: US Dept. of Energy (WPTO)

- Synopsis will be included in OES-E 2024 State of the Science Report and integrated with other recent work on 'system-level' effects:
  - ecosystem approach
  - cumulative environmental effects
  - displacement

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

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'Scaling up' our understanding of environmental effects of marine renewable energy development from single devices to large-scale commercial arrays

Daniel J. Hasselman[a,*], Lenaïg G. Hemery[b], Andrea E. Copping[c], Elizabeth A. Fulton[d,e], Jennifer Fox[f], Andrew B. Gill[g], Brian Polagye[h]

Scaling up to arrays: Context

- MRE development is important to address impacts of climate change (IPCC 2019, 2022)
- Amount of potentially harvestable wave & tidal stream energy can meet global energy demand (IRENA 2020)
    - small, demonstration-scale deployments falls short of this potential
- Large-scale commercial arrays needed for a sustainable energy transition
- Obstacles: high capital costs, insufficient infrastructure, uncertain environmental effects

Source: NOAA

Source: TCD

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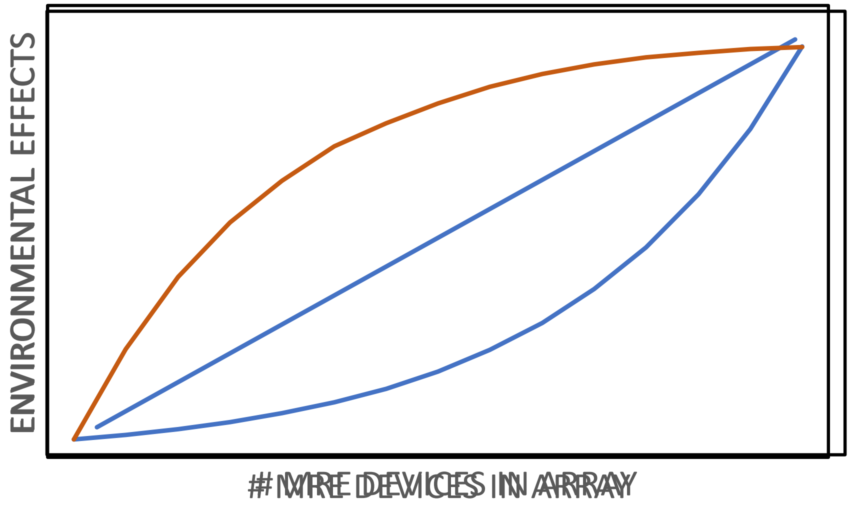
SCALING UP TO ARRAYS: ASSESSING ENVIRONMENTAL EFFECTS

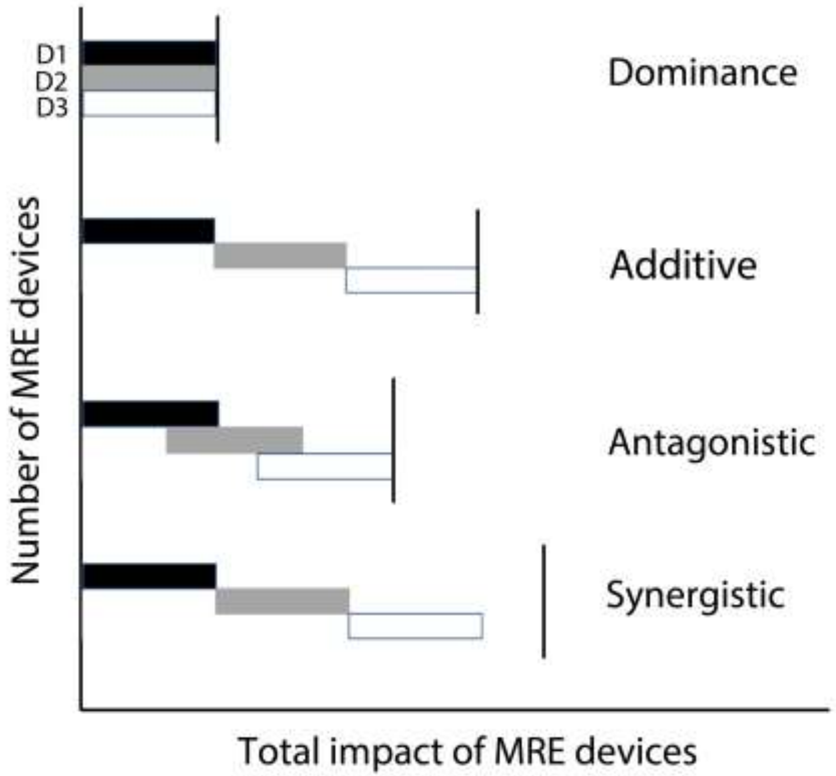
- Seven priority stressor-receptor interactions (Copping and Hemery 2020)
- Environmental effects of single MRE devices provides evidence base for understanding effects of arrays, but…
    - effects unlikely to scale linearly with number of MRE devices
    - likely complex & nuanced, conditional, site-specific, curvilinear responses
- Establishing general concepts for environmental effects of MRE arrays provides a foundation for hypotheses development & testing
    - facilitates application of a robust scientific approach for understanding how effects 'scale up'



SCALING UP TO ARRAYS: DEFINITIONS & TERMINOLOGY

- 'Large-scale commercial array': 10-30 devices
  - based on the number of individual devices that independently contribute to increasing the magnitude of effect for a given stressor

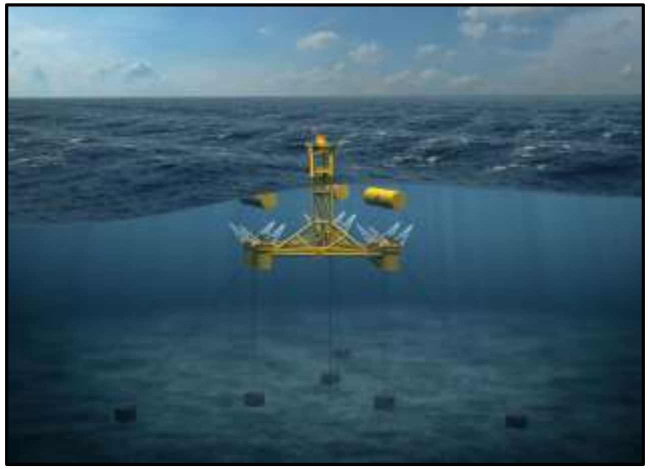
- Environmental effects terminology adapted from cumulative environmental effects literature:
  i. Dominance – effect of stressor does not increase with number of devices
  ii. Additive – effect is equal to sum of individual effects from each device
  iii. Antagonistic – overall effect is adjusted by a scalar as number of devices increases
  iv. Synergistic – effect of stressor from multiple devices significantly exceeds sum of their individual effects



SCALING UP TO ARRAYS: OBJECTIVES AND APPROACH

- Develop generalized concepts for each stressor-receptor interaction so that a robust scientific approach can be applied to improve our understanding of the environmental effects for arrays

- Framework for each stressor-receptor interaction:
  i. Describe each stressor in relation to a single device
  ii. Summarize existing knowledge of effects based on single devices
  iii. Define the nature of scaling-up for the stressor-receptor interaction and identify caveats
  iv. Identify the types of studies needed to understand the effects of scaling up for each stressor



Source: www.offshore-energy.biz

Source: www.maritime-executive.com

SCALING UP TO ARRAYS: EXAMPLE – COLLISON RISK

- Perceived as greatest risk – focus of research around single MRE devices
- Expected to be rare, no observations of collisions to date
    - evidence for avoidance/evasion (e.g., Gillespie et al. 2021)
- Environmental effects of array may vary based on location & configuration:
    - in-parallel: additive or synergistic effects
    - in-series: antagonistic effects
    - depends on technology type, specific location, species
- Additional research required:
    - simulations/modeling incorporating avoidance behavior and using realistic array layouts

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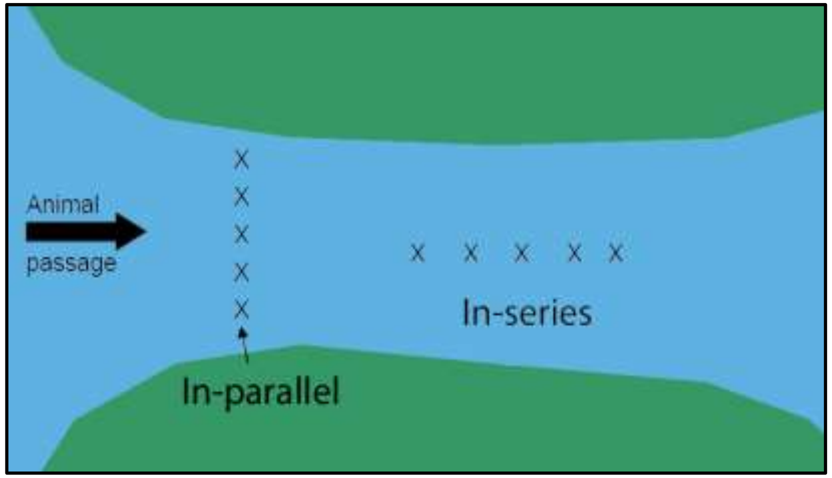
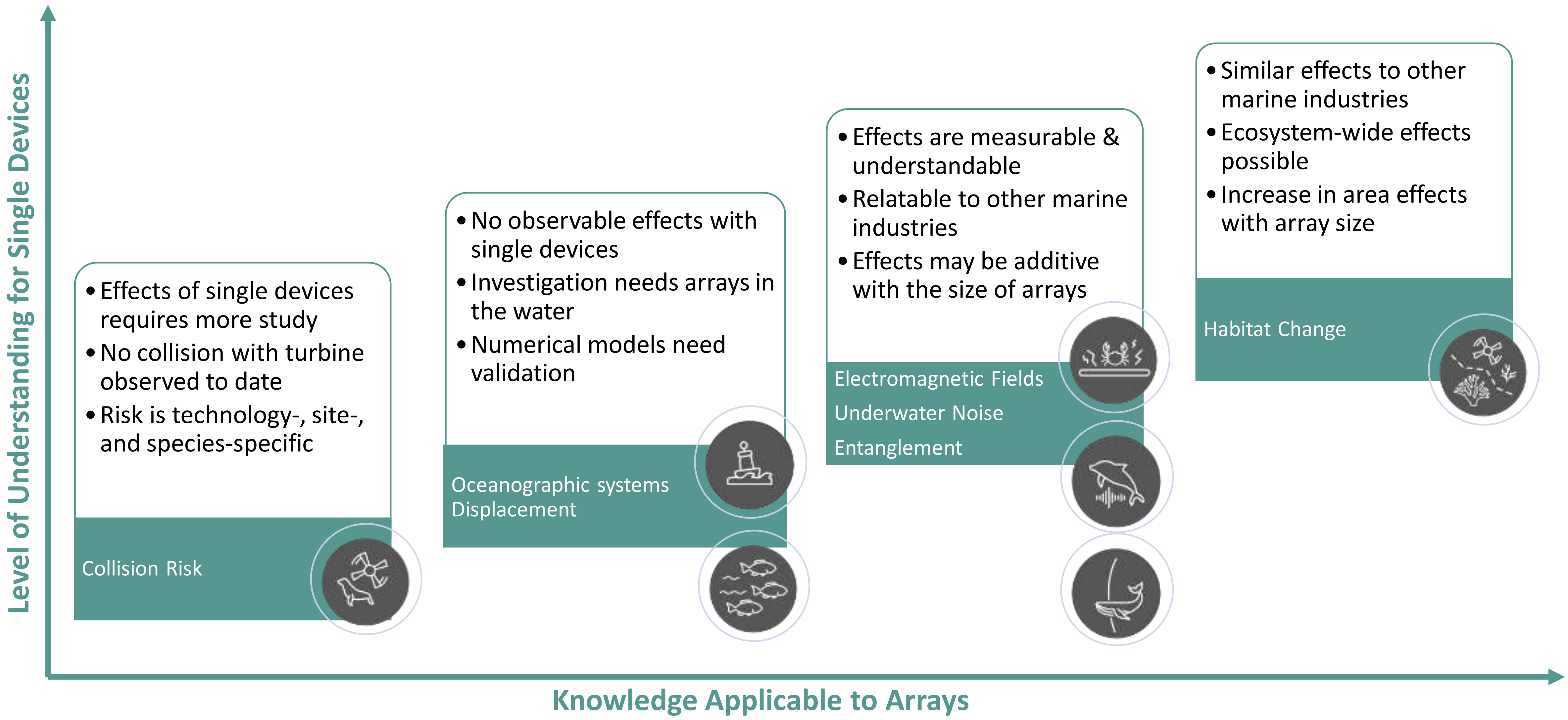


Modified from Wilson et al. (2006)

Scaling up to arrays:
Hypothesized environmental effects

Stressor-receptor interaction	Environmental Effects				
	Dominance	**Additive**	**Antagonistic**	**Synergistic**	**Notes**
Collision risk		✓	✓	✓	Dependent on array layout, technology type, location, species
Underwater noise		✓			Area of impact increases with array size; non-linear increases in received levels
Electromagnetic fields	✓	✓	✓		Increases linearly with additional electrical current; dependent on array cable layout
Habitat change		✓	✓	✓	May vary across spatiotemporal scales and with array configuration
Displacement		✓		✓	Effects observed at some threshold number of MRE devices
Entanglement		✓	✓		Dependent on configuration of mooring lines, animal behavior
Oceanographic systems		✓	✓	✓	Dependent on technology type, array layout, hydrodynamics

SCALING UP TO ARRAYS: CURRENT KNOWLEDGE



Scaling up to arrays: What is needed now

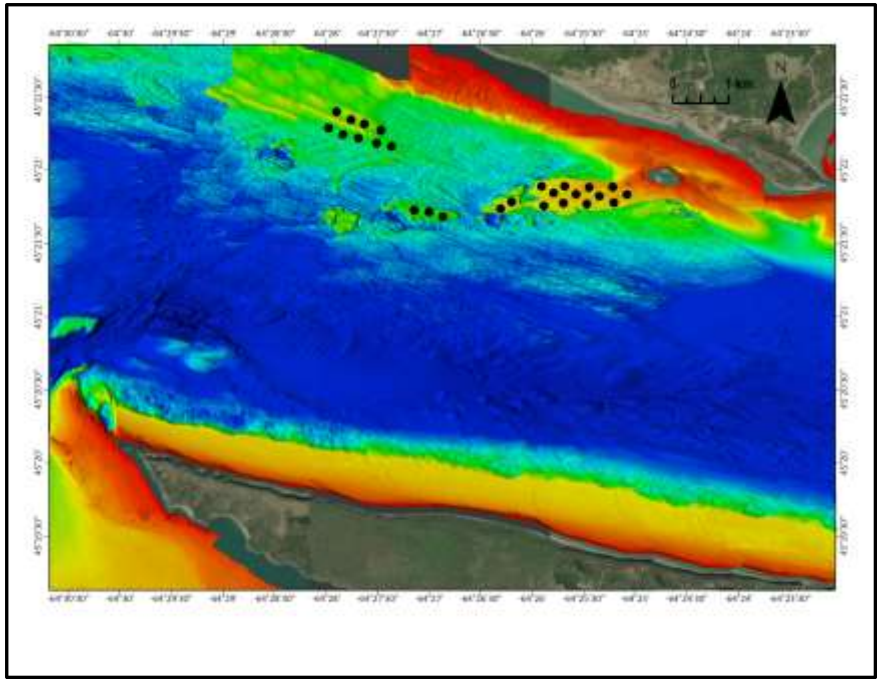
- numerical modeling and simulations using realistic array layouts and incorporating avoidance and evasion behavior
- *in situ* characterization of noise using standardized protocols (TC114-40) to validate acoustic propagation models
- systematic measurements with reliable sensors; controlled laboratory & field studies of behavioral responses for EMF sensitive species
- Consistent collection of high-quality baseline data prior to device installations for habitat suitability and ecosystem-wide model simulations
- Agent-based models to simulate animal movement around arrays; model validation using empirical observations
- agent-based models to simulate the risk of entanglement with array size and species spatiotemporal use of array site; model validation using empirical observations
- Improvements to numerical and physical models using accurate resource characterization data, bathymetry, hydrodynamics, and incorporating realistic MRE device operations

Scaling up to arrays: Array simulations

- Work on arrays focused on optimizing device spacing for wake reduction and device efficiency
  - flume tanks – actuator disks to simulate array configurations
  - computer simulations using hypothetical rectilinear and staggered grid array configurations

Source: Myers and Bahaj (2012)

- Array layouts limited by physical constraints of the environment (depth, bathymetry, hydrodynamics, etc.)
  - established as clusters of devices
  - simulations need to be based on realistic array configurations



- Ultimately, we need MRE devices in the water to test hypotheses about environmental effects of arrays

SCALING UP TO ARRAYS: REFERENCES

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THANK YOU