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Northwest National Marine Renewable Energy Center

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U.S. Department of Energy Environmental Research Webinar Series:

Instrumentation for Monitoring around Marine Renewable Energy Converters: Outcomes of an Experts' Workshop

Sponsored by Annex IV

U.S. DEPARTMENT OF ENERGY

OES OCEAN ENERGY SYSTEMS

ANNEX IV - ENVIRONMENTAL RESEARCH WEBINAR SERIES

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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In support of: U.S. Department of Energy
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Annex IV: International Ocean Energy Environmental Data Sharing Effort

- Goals:
  - Compile information from monitoring and mitigation efforts around deployed renewable energy devices from around the world;
  - Develop and populate a publicly accessible database to house this information; and
  - Disseminate information and metadata to marine energy researchers, developers, and regulators.

- Member Nations:
  - Canada, Ireland, Spain, New Zealand, Norway, South Korea, and United States

- Outcome:
  - 2 international scientific workshops held in Dublin, Ireland
  - The publicly accessible *Tethys* knowledge base
  - Final Annex IV report

Tethys: Ocean Energy Environmental Research Database

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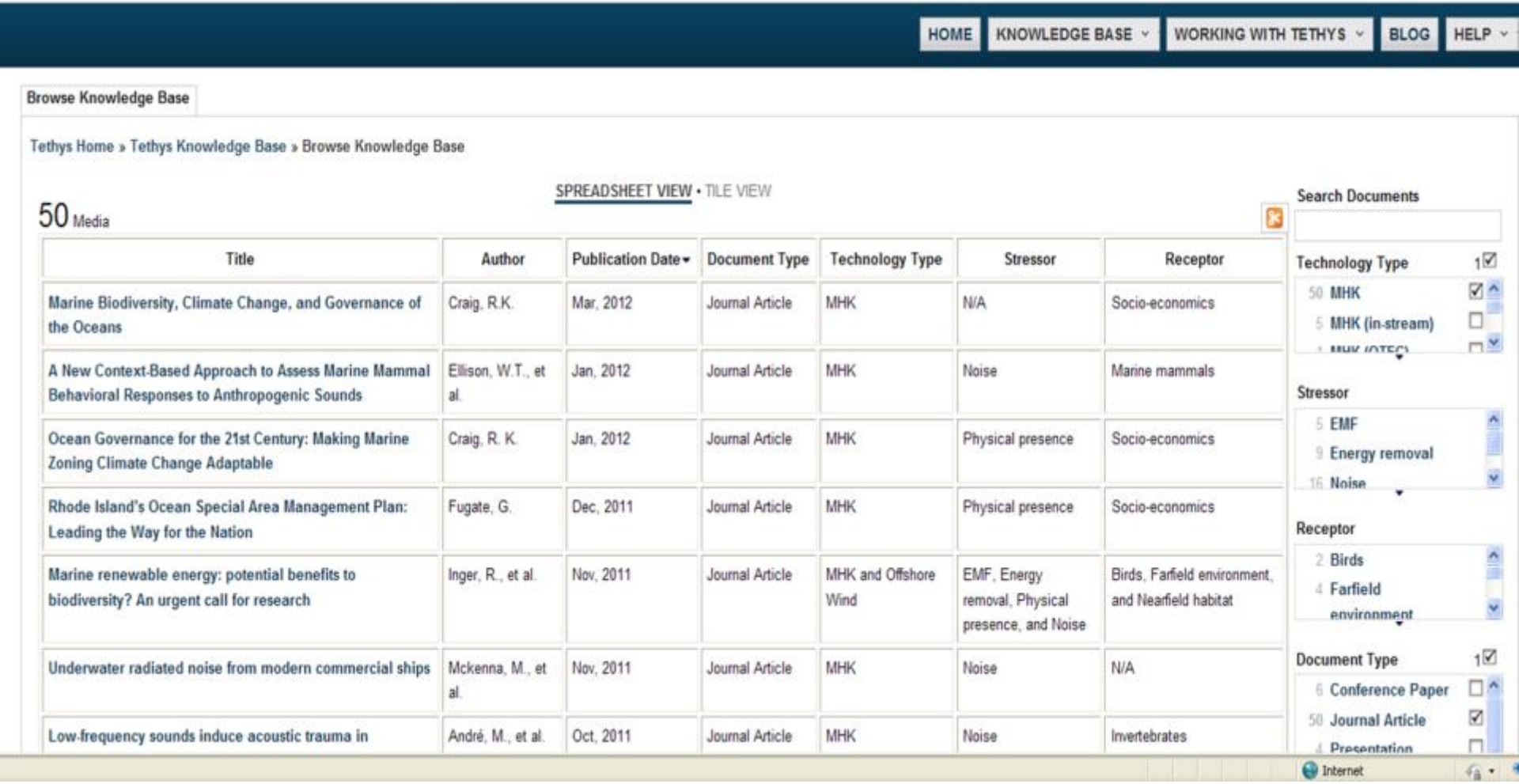
http://mhk.pnnl.gov/wiki/index.php/Tethys_Home



Title	Author	Publication Date	Document Type	Technology Type	Stressor	Receptor
Marine Biodiversity, Climate Change, and Governance of the Oceans	Craig, R.K.	Mar, 2012	Journal Article	MHK	N/A	Socio-economics
A New Context-Based Approach to Assess Marine Mammal Behavioral Responses to Anthropogenic Sounds	Ellison, W.T., et al.	Jan, 2012	Journal Article	MHK	Noise	Marine mammals
Ocean Governance for the 21st Century: Making Marine Zoning Climate Change Adaptable	Craig, R. K.	Jan, 2012	Journal Article	MHK	Physical presence	Socio-economics
Rhode Island's Ocean Special Area Management Plan: Leading the Way for the Nation	Fugate, G.	Dec, 2011	Journal Article	MHK	Physical presence	Socio-economics
Marine renewable energy: potential benefits to biodiversity? An urgent call for research	Inger, R., et al.	Nov, 2011	Journal Article	MHK and Offshore Wind	EMF, Energy removal, Physical presence, and Noise	Birds, Farfield environment, and Nearfield habitat
Underwater radiated noise from modern commercial ships	Mckenna, M., et al.	Nov, 2011	Journal Article	MHK	Noise	N/A
Low-frequency sounds induce acoustic trauma in	André, M., et al.	Oct, 2011	Journal Article	MHK	Noise	Invertebrates

Tethys: Ocean Energy Environmental Research Database

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Vision for Annex IV: Phase 2 2013-2016

- Annex IV becomes:
  - The international program in marine energy that provides new and reliable information and insights into research and monitoring of environmental effects; and
  - A expanding program that facilitates collaboration among the marine energy community to increase understanding of environmental effects and the role they play in marine energy project development.

Annex IV: Phase 2 Activities

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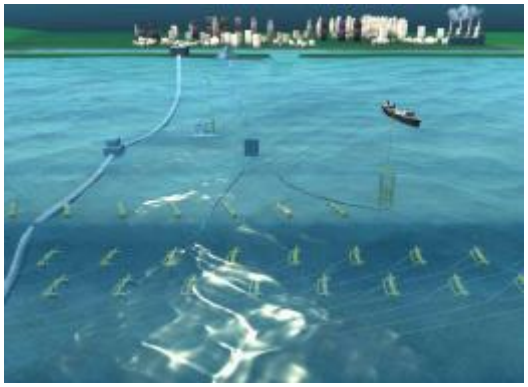
- **Update and collect metadata forms**
  - Project Sites and Research Studies
  - To contribute, please see: http://mhk.pnnl.gov/wiki/index.php/About_Annex_IV
- **Workshops**
- **Online meetings with research community**
- **Enhanced *Tethys* capabilities**
  - Build commons through user profiles, rating documents, social media, blog, webinars, etc.
  - Ongoing process through life of project
- **State of the Science Report**
  - 2016
- **International Annex IV Conference**
  - Planning begins this year, conference date TBD
- **Quarterly webinars**

Water Power Program Mission

The **mission** of the Water Power Program is to perform research and testing, and develop innovative technologies capable of generating renewable, environmentally responsible, and cost-effective electricity from water resources.



<u>This includes efforts related to:</u>

- *Marine and Hydrokinetics*
  - waves, tides, and currents in oceans, estuaries, and tidal areas;
  - free flowing water in rivers, lakes, and streams;
  - free flowing water in man-made channels; and
  - differentials in ocean temperature (ocean thermal energy conversion).

US DOE Water Power Program: Areas of Environmental Research Focus

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① Data Collection and Experimentation

- Research on effects on aquatic organisms
- Research on effects on physical systems

Through field monitoring, laboratory experimentation, and the development of models scientists are working to reduce uncertainty regarding environmental impacts.

② Monitoring and Mitigation Technologies and Techniques

- Development of new monitoring technologies
- Development of monitoring best practices

Scientists working to develop and tailor monitoring technologies and techniques to enable the gathering of data that will help reduce uncertainty regarding impacts.

③ Information Sharing and International Collaboration

- Data Compilation and Dissemination
- International partnerships

Data replication and synthesis are critical to informing understanding of impacts on an industry-wide basis. Efforts are underway to aggregate, disseminate, and analyze data.

US DOE Notice of Intent

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Environmental Stewardship for Renewable Energy Technologies: Marine and Hydrokinetic (MHK) Environmental and Resource Characterization Instrumentation

- The Office of Energy Efficiency and Renewable Energy (EERE) intends to issue a Funding Opportunity Announcement (FOA) on behalf of the Wind and Water Power Technologies Office
- This FOA will support the development of instrumentation, associated processing tools, and integration of instrumentation packages for monitoring the environmental impacts of marine and hydrokinetic technologies.
- It will also support the development and testing of sensors, instrumentation, or processing techniques to collect physical data on ocean waves (e.g., height, period, directionality, steepness) and characterize the available resources.
- It is anticipated that the FOA may include the following Topic Areas:
  Topic Area 1 – MHK Environmental Instrumentation Development
  Topic Area 2 - Development and Integration of Instrumentation Packages
  Topic Area 3 - Wave Resource Characterization

http://www1.eere.energy.gov/water/financial_opportunities.html

Please Note: This Notice is issued so that interested parties are aware of the EERE's intention to issue this FOA in the near term. All of the information contained in this Notice is subject to change. EERE will not respond to questions concerning this Notice. Once the FOA has been released, EERE will provide an avenue for potential Applicants to submit questions.

Instrumentation for Monitoring around Marine Renewable Energy Converters:

Outcomes of an Experts' Workshop

Andrea Copping, Pacific Northwest National Laboratory

Brian Polagye, Northwest National Marine Renewable Energy Center, University of Washington

Environmental Webinar sponsored by Annex IV
January 23rd 2014

Motivation for the Workshop

- **Environmental studies on small pilot projects conducted to date have:**
  - Been expensive in relation to overall project costs
  - Demonstrated that small projects are unlikely to have biologically significant environmental impacts.
- **Extrapolation to larger commercial projects:**
  - Limited acceptance of results to reduce uncertainty for large commercial scale developments.
- ***Paradox* for Commercial scale MRE development:**
  - At current rate, environmental monitoring costs are crippling to industry;
  - However, if early projects cause environmental harm, the industry may also be crippled.

Expectations versus Outcomes

- **What we expected to hear:**
  - "There is only one way to measure this parameter…only my instrument will do the task properly…"
- **What we actually heard:**
  - "There are many paths to the same objective…"

- **What we expected to hear:**
  - "We need to build new shiny expensive instruments…"
- **What we actually heard:**
  - "The real challenges are integration of instruments and development of software to interpret the data."

Workshop Objectives

Objective 1:

To enhance the understanding of the state of instrumentation readiness to answer important environmental questions for marine renewable energy (MRE) development.

Objective 2:

To develop a consensus among experts on methods for applying instrumentation to meet high-priority monitoring needs for MRE projects.

Objective 3:

To provide a forum to foster new and continuing collaboration around monitoring the environmental effects of MRE.

Scope and Organization of Workshop

Technology: MECs = marine energy converters. In this case, only wave and tidal current converters.

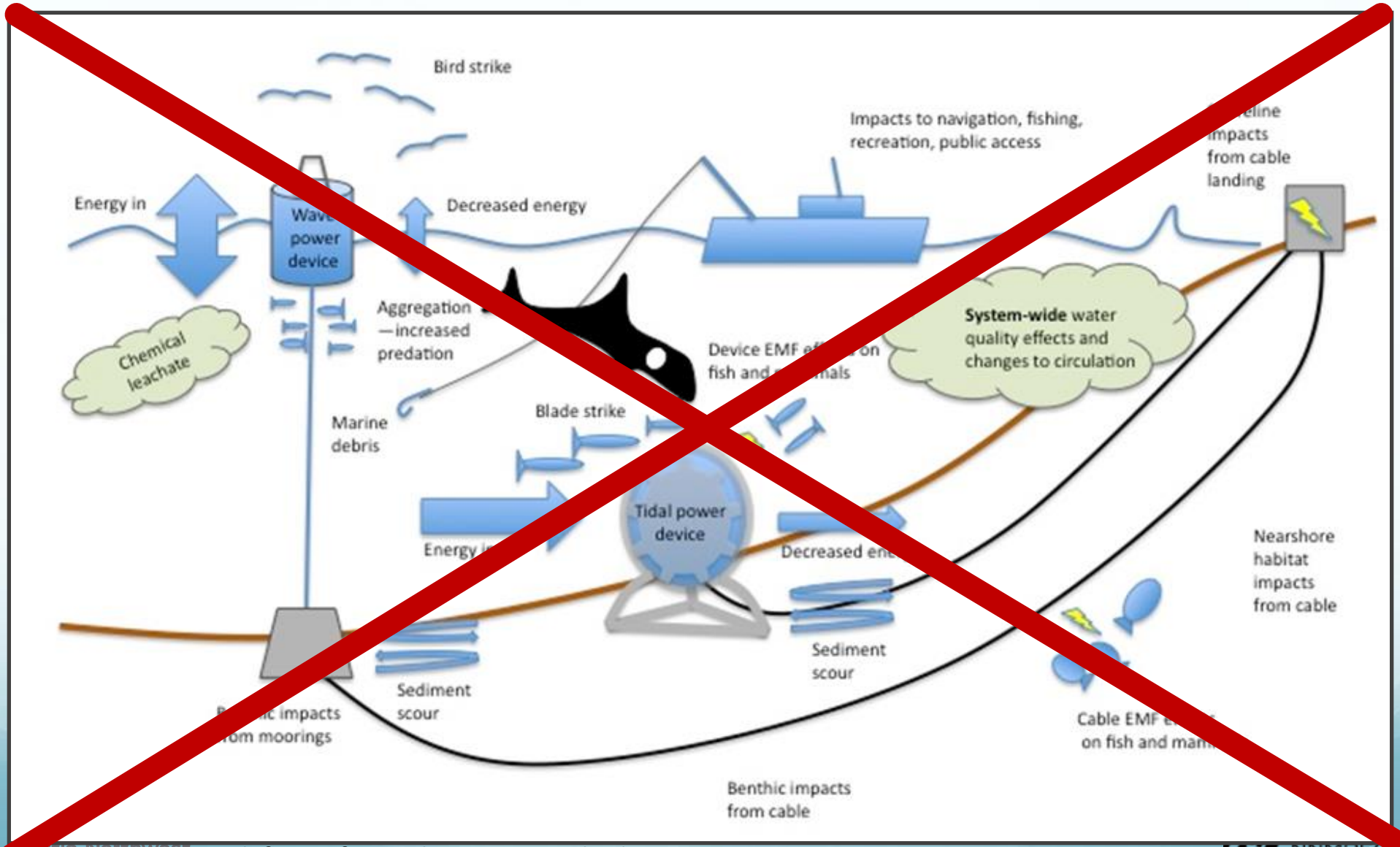
Environments: Water column and air-sea interface.

Geography: Worldwide, strongest emphasis on UK and US, also Canada.

Plenaries: Presentations on existing projects, monitoring, data synthesis.

Breakouts: Majority of time and hard work of the event.

Scope



Source: Simon Geerlofs, Pacific Northwest National Laboratory

Three specific interactions examined:

Nearfield: Direct interaction of marine mammals, fish, sea turtles, and birds with MECs (collision, abrasion, strike)

Distribution: Changes in the distribution and use of habitats by marine animals in very high energy areas

Sound: Characteristics of the sound produced by marine energy converters

Discussion Structure

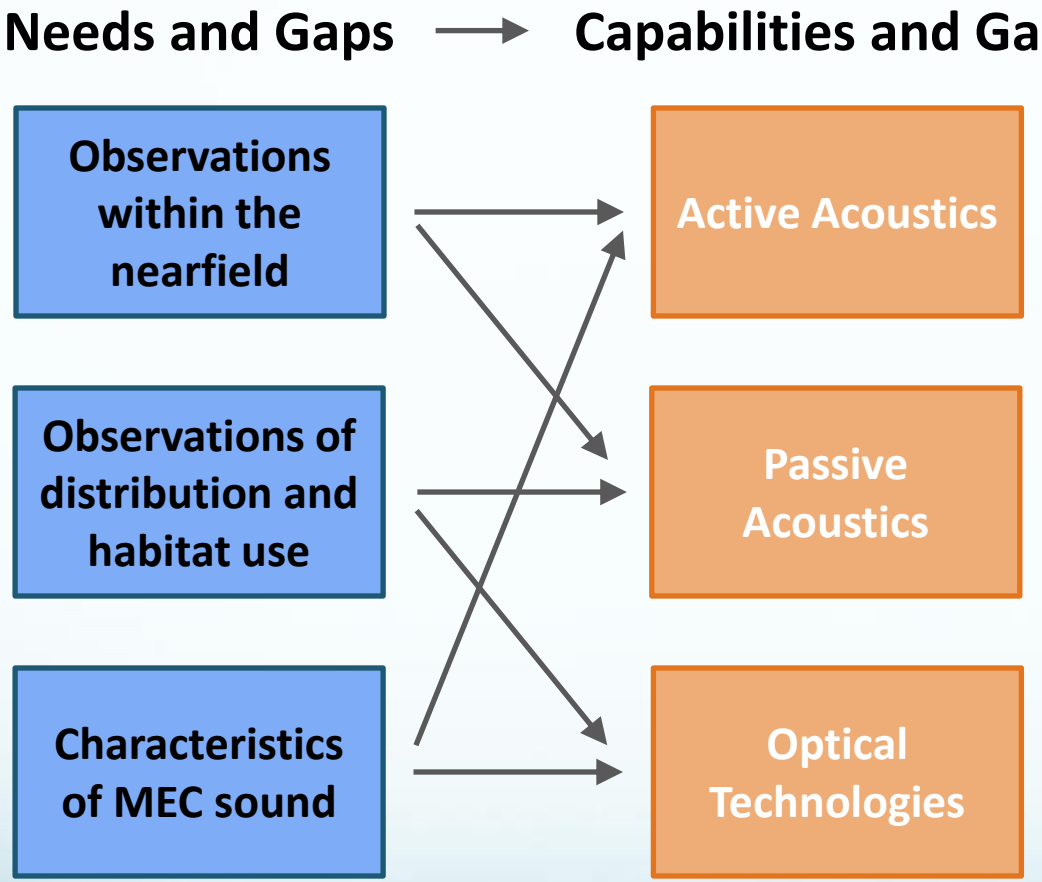
Needs and Gaps

Observations within the nearfield

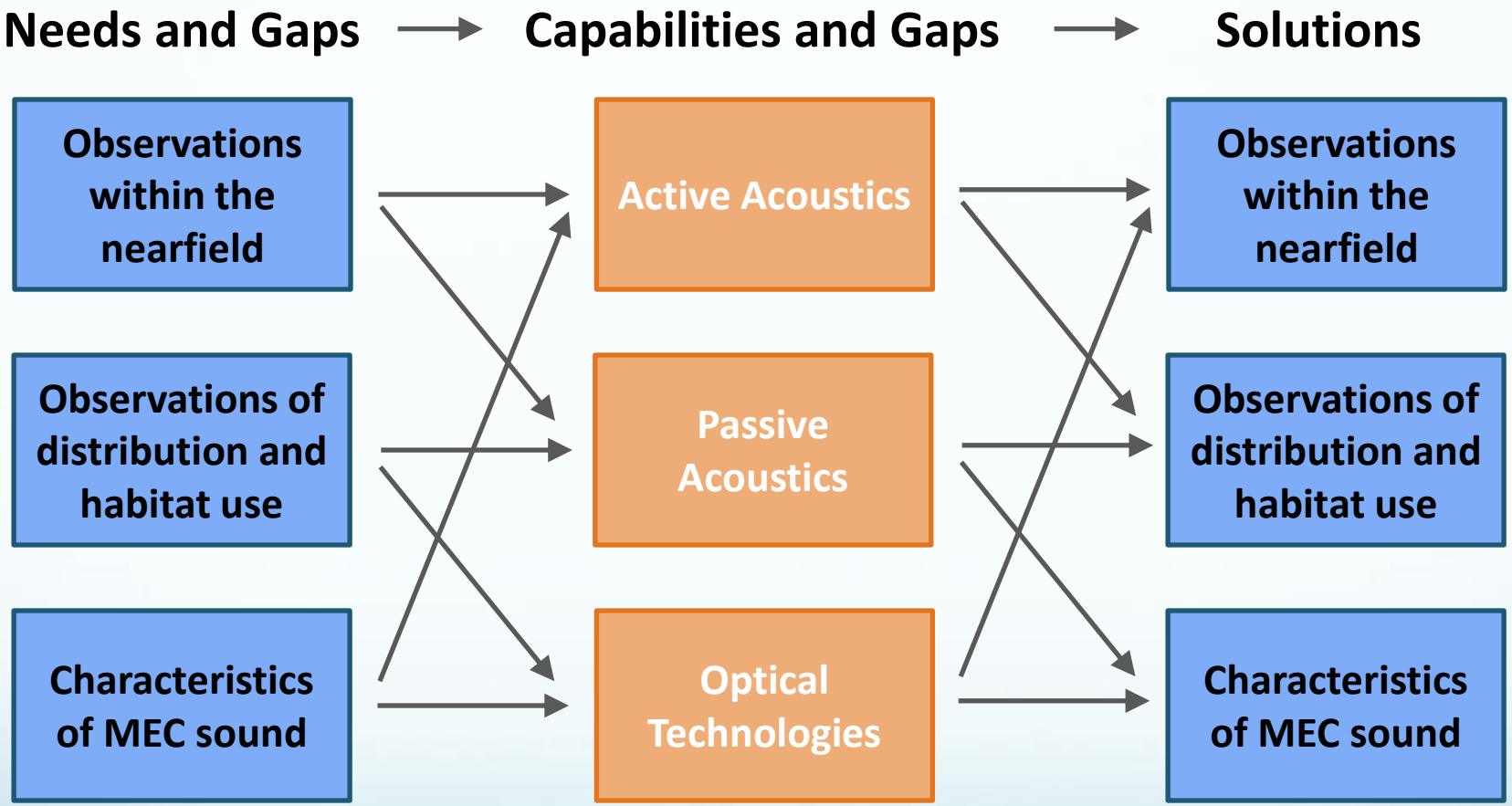
Observations of distribution and habitat use

Characteristics of MEC sound

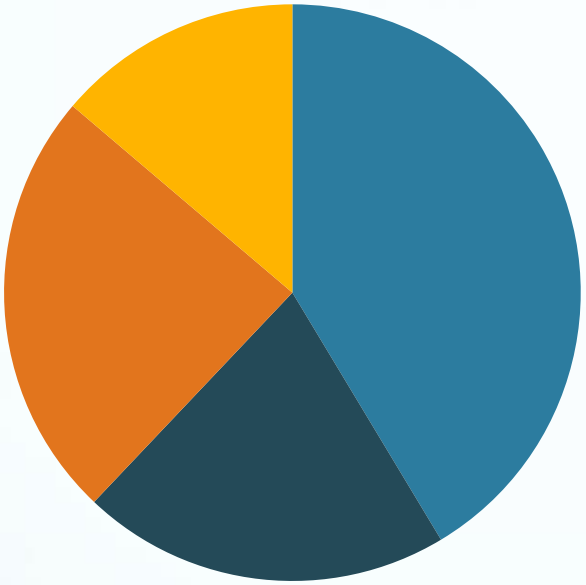
Discussion Structure



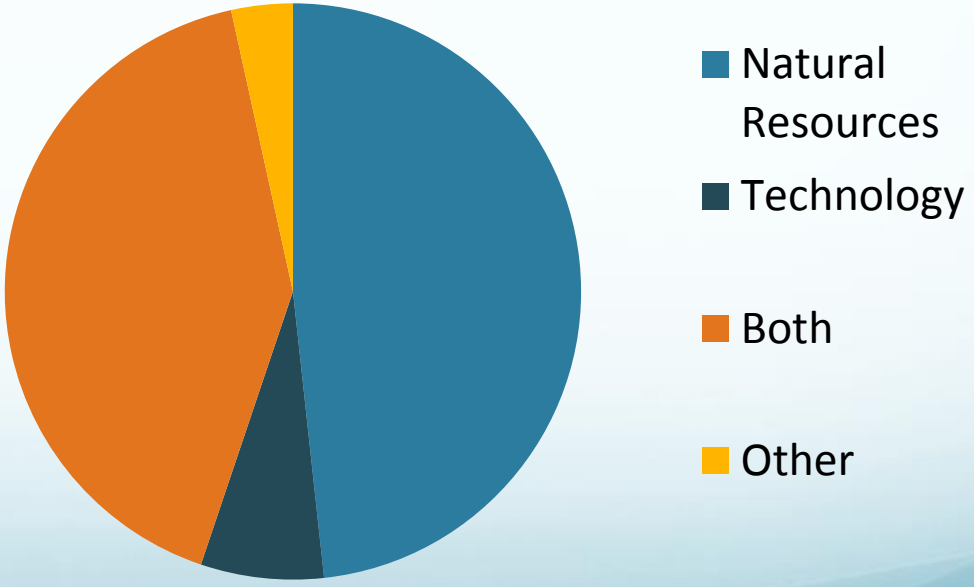
Discussion Structure



Participants



36 participants from 4 countries (US, Canada, UK, Chile)

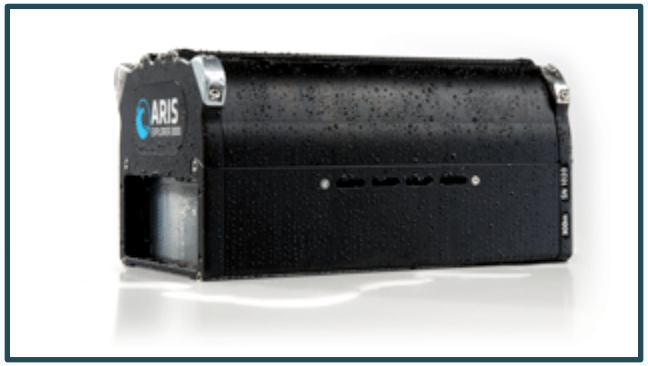


Questions for Capabilities Breakout

- **What are the primary challenges to achieving the desired instrument accuracy?**
  - Cost of operating the instruments, capital costs
  - Power-supply requirements
  - Required bandwidth for acquisition of data
  - Required processing time and algorithms
- **What are the challenges to getting instruments in the water and maintaining them?**
  - Limits to the durability or survivability of instruments in the harsh marine environment
  - Deployment challenges associated with moorings or platforms and deployment techniques
- **What are the instrument challenges for measuring animals in the marine environment?**
  - Limitations due to size or speed of organisms of interest?
  - Limitations due to climate seasonality (turbidity for example)?
  - Safety of instrument operation for sensitive marine animals

Active Acoustics: Instruments

- **Sonars**
  - Single-beam, split-beam, multibeam, broadband multibeam
  - Imaging sonars (2D and scanning)
- **Radar**
- **Acoustic tags**



Sound Metrics ARIS (imaging)

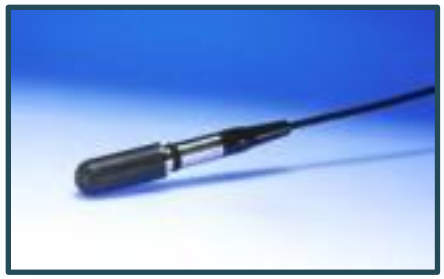
BioSonics DTX (split-beam) Autonomous Deployment

Active Acoustics: Outcomes

- Direct interactions with a MEC is not currently observable with most active acoustic technologies
  - 2D imaging sonars most promising, but lacks automation (mirrors optical technologies)
- Data processing and automation needs development
  - High data intensity requires automated pre- or post-processing
  - Not available for several types of active acoustic instruments (e.g., acoustic cameras)
- Integrated packages are likely to be necessary
  - No silver bullets - each active acoustic instrument has its own strengths and weaknesses
- Deployment and survival at MRE sites is challenging

Passive Acoustics: Instruments

- **Hydrophones**
  - Sensitive to acoustic pressure
  - Susceptible to flow noise at MRE sites
- **Vector Sensors**
  - Sensitive to acoustic pressure and acoustic particle velocity
  - Unproven in MRE applications



Teledyne Reson TC4014 (cabled)

JASCO AMAR (recorder)

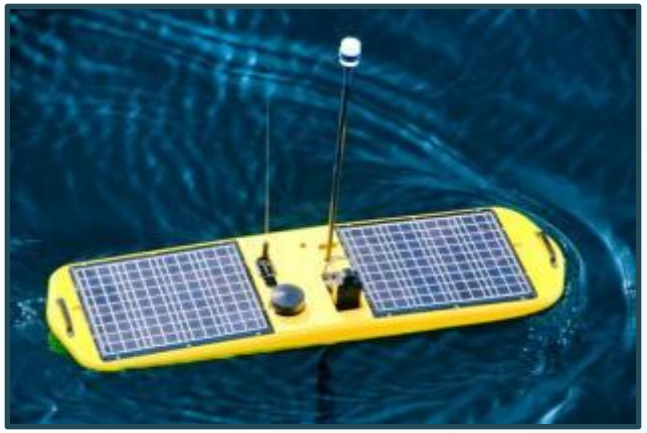
Chelonia C-POD (click detector)

Passive Acoustics: Outcomes

- Hydrophones work well, but room for improvement exists in high energy environments
  - Flow noise problematic for moored instrumentation at current energy sites
- Integrated packages are likely to be necessary
  - Concurrent monitoring of biological signals, ambient noise, and sound produced by MECs may be possible
- Data processing and automation needs development
  - High data intensity requires automated pre- or post-processing

Optical Technologies: Discussions

- **Emphasis on platforms for optical technology deployment, rather than underlying technology – relevance to all technologies**
  - Remotely operated vehicles
  - Manned submersibles
  - Surface vessels
  - Landers and sleds
  - Autonomous underwater vehicles (AUVs)
  - Animal-borne “critter cams”
  - Fixed, cable vantage points (submerged and above surface)
  - Aerial vehicles, including unmanned aerial vehicles (UAVs/drones)



Liquid Robotics WaveGlider (AUV)

Optical Technologies: Outcomes

	Tidal Energy Converter (TEC)	Wave Energy Converter (WEC)
Observations within the "nearfield"	Potential to integrate optical technologies with MEC	
Observations of distribution and habitat use	No viable platforms identified	Autonomous vehicles identified as potential "game-changers"

- Optical technologies have limited range and are not uniformly effective
- Data processing and automation needs development
  - High data intensity requires automated pre- or post-processing

Nearfield: Priorities

- Desire to monitor every interaction between marine animals and MECs (or a least, those under special protection)
  - However concerns about quantity of data generated
  - Need for integrated package of instruments, with triggers from acoustic to optical (for example)
- Transparent approaches to risk assessment needed to set monitoring program priorities
- Data processing and automation
  - Need for algorithms to detect animals (or classes of animals
  - Automated pre- or post-processing to avoid “data mortgages”
- Deployment, maintenance and survival at MRE sites is challenging

Distribution and Habitat Use: Priorities

- Generally, have necessary instruments, but advances in platforms sorely needed:
  - Autonomous vehicles need increased endurance
  - Animal born tags need to be reduced in weight and cost
- Integrated packages important, but:
  - No one-size-fits-all
  - Need access to toolbox for different receptors, technologies, questions
- Data processing and automation
  - Need for algorithms to detect animals (or classes of animals
  - Automated pre- or post-processing to avoid “data mortgages”
- Belief that the onus of determining population distributions at the on governments; site-based onus on developers

Sound: Priorities

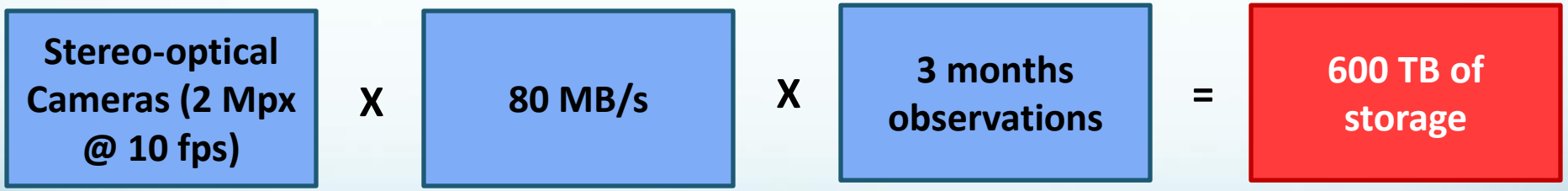
- Measurement of sound depends on MEC technology:
  - Tidal converters best measured using drifting hydrophones
  - Wave converters best measured using fixed hydrophones
- Engineering approaches are needed to increase signal to noise ratios for measurements
  - From tidal converters: flow noise
  - From wave converters: breaking waves and surf
- Obvious area for development of international standards for MEC sound measurement
- Low-cost drifting packages needed to avoid interference of MEC operation
- Use of accelerometers for low-cost, long-term study

Synthesis of Common Themes: *Risk*

- **Often, the objective of monitoring is to collect information that allows discussions of environmental risk**
- ***Ideally*, over time:**
  - Significant risks can be recognized and mitigated through converter design or operation
  - Insignificant risks can be selectively "retired" from monitoring programs
- **For topics discussed in this workshop, no agreed upon framework for reaching either of these end states**

Synthesis: *Potential for Data Mortgages*

- **Often, highest priority risks are for low probability events**
- **Spatial *comprehensive* and temporally *continuous* monitoring of converters requires the least time to resolve risk**
- **Data bandwidth for "brute force" approaches to this is problematic – "data mortgages"**



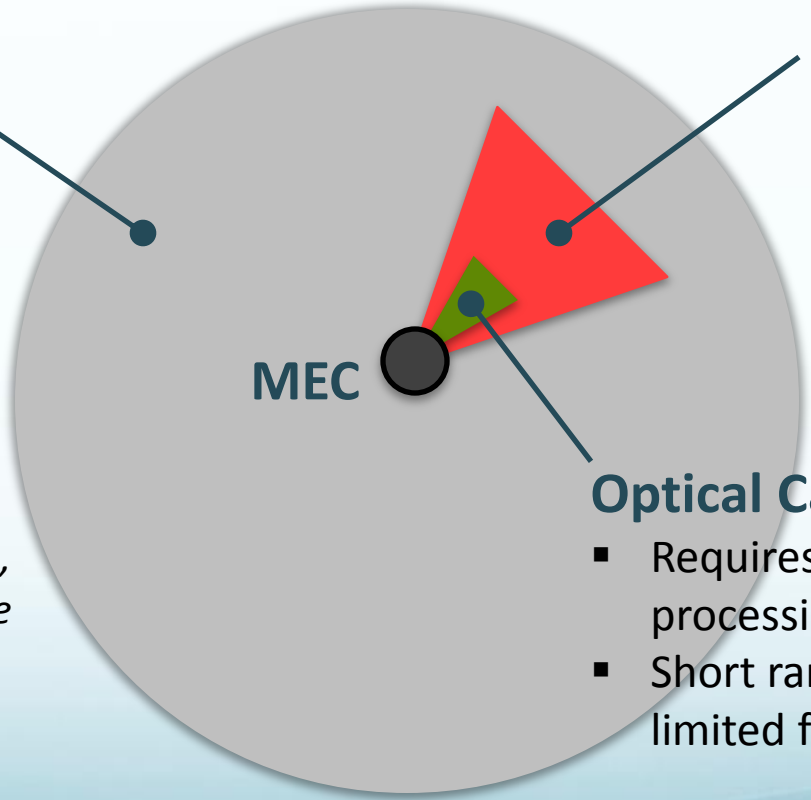
***Example**: Continuous stereo-optical monitoring for a single system. Comprehensive monitoring would require multiple systems.*

Synthesis: *Preventing Data Mortgages*

- **Instruments that intrinsically produce information**
  - *Example*: recording and transponding tags
  - Tend to be expensive to deploy in large numbers
- **Automated processing that mines data for information**
  - *Example*: split-beam echosounders
  - Requires ability to "trash" raw data
- **Is it reasonable to expect a "silver bullet" processing solution for all instruments?**

Synthesis: *Integrated Packages*

- **Integrated instrumentation packages may offer an intermediate option to pure hardware or software solutions**



Passive Acoustic Detection

- Processing in near real-time
- Omni-directional coverage at ranges on the order of 1 km

Split-beam Echosounder

- Processing in near real-time
- Tracking capability at ranges beyond 100 m

Optical Camera

- Requires archival processing
- Short range and limited field of view

***Example**: Detection, tracking, and identification of a marine mammal approach a MEC*

Synthesis: *Instrumentation Deployment*

- **Participants felt that survivability and reliability of instrumentation was too low**
  - Greater concerns with infrastructure than instrumentation
- **For "nearfield" observations, integrate with MEC**
  - Make use of power and data capabilities in MEC export cable
  - Develop a standardized "science port" to reduce integration cost
- **For distribution and use, autonomous platform development needed**

Synthesis: *Collaboration*

- **Greater collaboration between research and industry is needed**
  - MEC developers for integration of instrumentation with converters
  - Instrumentation developers for integrated packages and processing
- **Greater collaboration with regulatory agencies required to understand potential and limitation of monitoring data to inform risk discussions**

Near-term Recommendations

Standardize and Collaborate

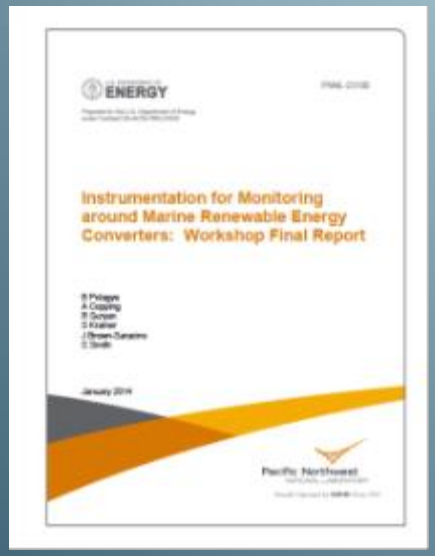
- Move towards more standardization, best practices, for environmental monitoring; perhaps international standards.
- More funding needed for instrument development, algorithms, deployment strategies, and international scientific collaboration.
- Hold another workshop to continue the dialogue, and organize an international conference.

Overarching Conclusions of the Workshop

- **Most gaps not specific to wave or tidal technologies**
  - Advancing instrumentation will serve the entire MRE industry
- **Pre and post -processing of data streams is a high priority need, including development of species-specific identification algorithms**
- **Instrumentation survivability and deployment strategies are important**
  - Many of the challenges are similar for the MECs themselves
- **Instruments need to be integrated into packages to meet objectives cost-effectively**

Acknowledgements

We gratefully acknowledge the assistance of the breakout session chairs: Rob Suryan, Sharon Kramer, Hoyt Battey, Jocelyn Brown-Saracino, as well as additional assistance by Simon Geerlofs, Jim Dawson, Courtney Smith, Rob Cavagnaro, Hayley Harguth, James Joslin, Danny Sale, Brit Sojka, Britta Timpane-Padgham, Lara Aston, and Nicole Faghin.



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depts.washington.edu/nnmrec/instrumentation/report.html

mhk.pnnl.gov/wiki/index.php/Instrumentation_for_Monitoring_around_Marine_Renewable_Energy_Converters

Thank You!

- A video of this webinar will be posted on Tethys at: http://tethys.pnnl.gov/wiki/index.php/Broadcasts
- Please stay tuned for the next environmental webinar announcement in late March or early April