SWAN Model Output Locations

WEC device array

Advances in Research to Understand the Impacts of Wave and Tidal Energy Devices in the United States

Jocelyn Brown-Saracino
New West Tech. LLC in support of:
US Department of Energy
Wind and Water Power Technologies Office

Wind and Water Power Technologies Office

- Increase the development and deployment of reliable, affordable, and environmentally sustainable wind and water technologies, including offshore wind and marine energy technologies

## Strategic Environmental Research Plan

- Developed based on an analysis of regulatory drivers, environmental risk, feasibility of reducing risk, and a gap analysis.

Research Areas

- Research and modeling to assess environmental impacts
- Advance monitoring technologies
- Analysis and dissemination of research findings
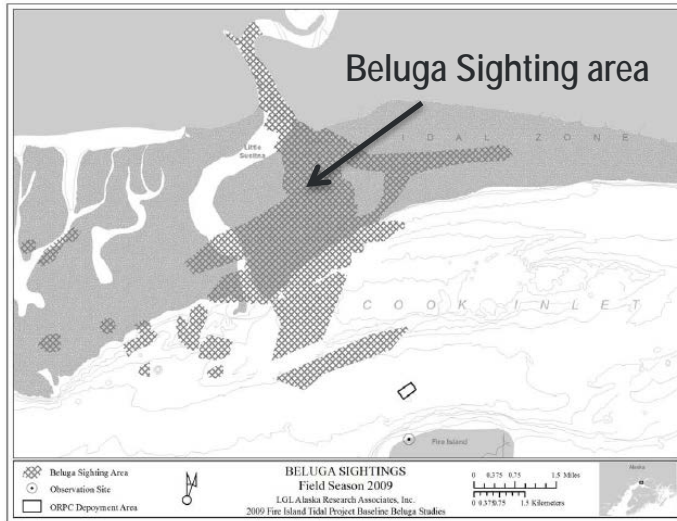
Talk Focus

- Understanding effects of operational noise
- Understanding the probability and effects of blade strike events
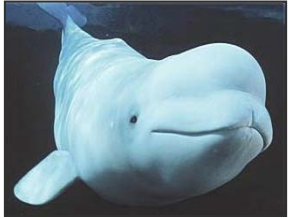
Determine where animals are located

❖ Acoustic Monitoring of Beluga Whales in Cook Inlet, AK (Ocean Renewable Power Company)

http://mhk.pnl.gov/sites/default/files/publications/ORPC%20Beluga%20Whale%202014_0.pdf

Beluga Sighting area

BELUGA SIGHTINGS
Field Season 2009
LGL Alaska Research Associates, Inc.
2009 Fire Island Tidal Project Baseline Beluga Studies

Beluga Sighting Area
Observation Site
ORPC Deoyment Area

Determine potential noise-level exposure

❖ Underwater Noise Measurements of a 1/7th Scale Wave Energy Converter (University of Washington, Columbia Power Technologies)

http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6107283&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D6107283

❖ Measuring Changes in Ambient Noise Levels from the Installation and Operation of a Wave Energy Converter in the Coastal Ocean (Oregon State University)

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Physiological Effects – Lab Experimentation

❖ Effects of Tidal Turbine Noise on Fish (Pacific Northwest National Laboratory)

- Juvenile Chinook salmon and largemouth bass exposed to tidal turbine noise (155-164 dB re 1 µPa rms) for 24 hours
  - Tested hearing sensitivity of salmon
  - Assessed tissue damage between control and treatment for salmon and bass

  http://mhk.pnl.gov/sites/default/files/publications/Effects_of_Tidal_Turbine_Noise_on_Fish.pdf

Organism	Hearing Sensitivity	Tissue Damage
Juvenile Chinook Salmon	No significant impact	No significant impact
Largemouth Bass	Not tested	No significant impact

Behavioral Effects – Controlled Setting

❖ Effects of Noise from Hydrokinetic Devices on Fish Behavior: Exposure Studies (Oak Ridge National Laboratory)

- Monitored behavioral response of transmitter-tagged fish to recorded hydrokinetic device sounds
  - Largemouth bass, paddlefish & pallid sturgeon
- No consistent trends of attraction or avoidance or changes in activity level to hydrokinetic device sounds at any volume


Underwater Speaker
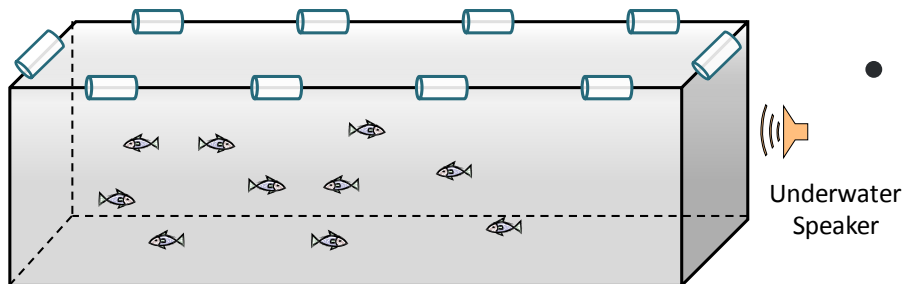
Floating Net Pen (6m wide x 20m long x 1.5m deep)

Characterization of Sound & Organismal Response In-Situ

❖ Acoustic Effects of Tidal Power Turbines (University of Washington)

  http://mhk.pnl.gov/sites/default/files/publications/SnoPUD_Acoustic_Effects_final_report.pdf

❖ Marine Mammal Behavioral Response to Tidal Power Turbines (University of Washington)

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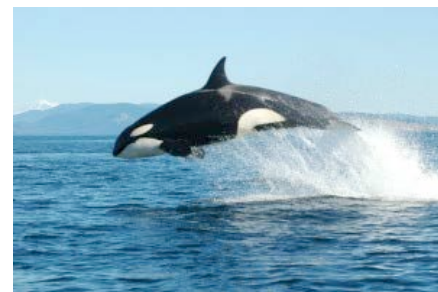
Development and Adaptation of Flexible Noise Models

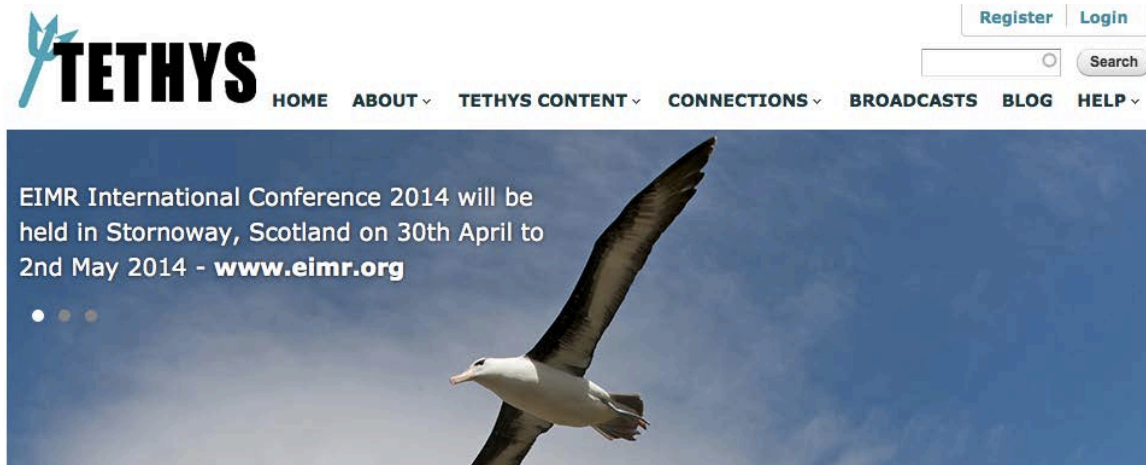Sound generation and propagation models (Sandia National Lab)

- Predict device-specific noise outputs based on design
- Predict noise propagation at project site
- Integrate into flexible modeling tools, including EFDC
- Proactively address concerns regarding noise effects

Development of Monitoring Tools

❖ Marine and Hydrokinetic Environmental and Resource Characterization Instrumentation Funding Opportunity
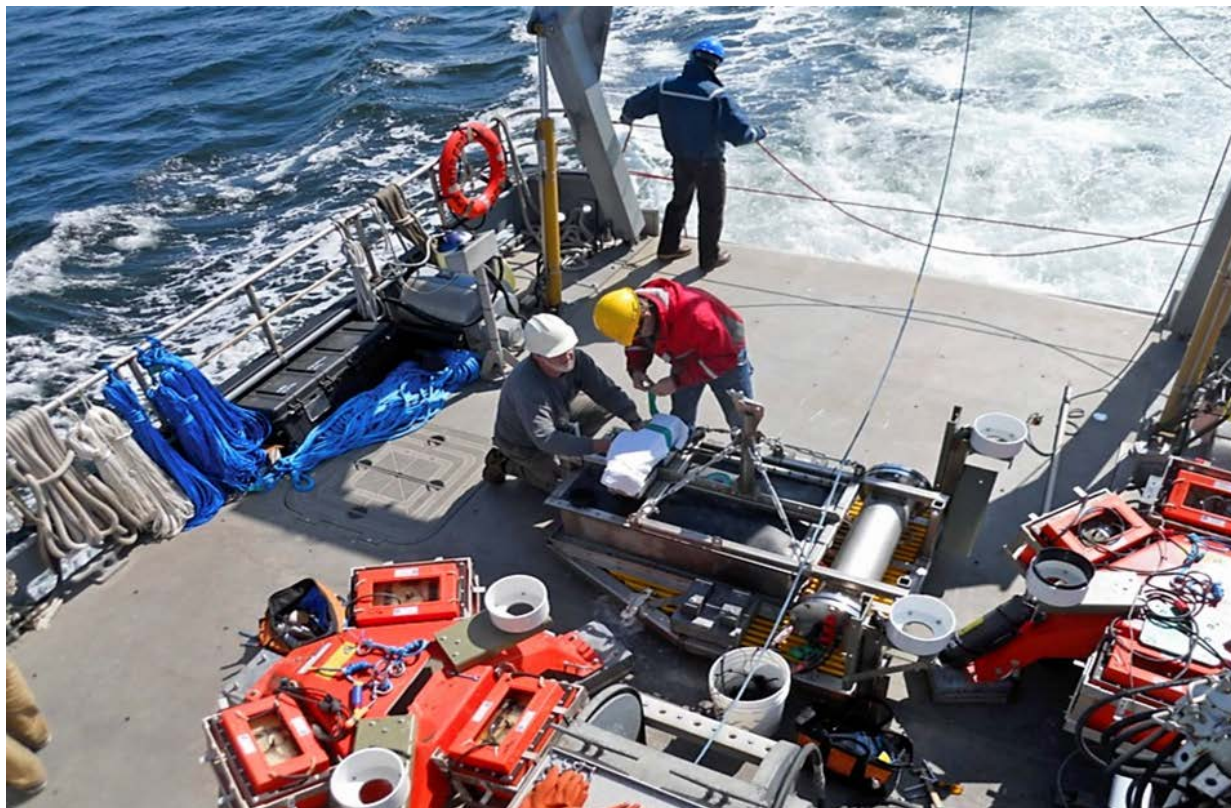
- Aggregate, analyze and distribute data to understand trends and increase the impacts of research
- Tethys online database

  http://tethys.pnnl.gov/
- Annex IV Final Report
  - Chapter devoted to effects of MHK acoustic output

    http://mhk.pnl.gov/sites/default/files/publications/Final%20Annex%20IV%20Report%202013%20v2.pdf

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Flume Studies

❖ Evaluation of Behavior and Survival of Fish Exposed to an Axial Flow Turbine (Electric Power Research Institute, ONRL, Alden)

http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003911

– Avoidance in both light and dark conditions

Species	% Avoidance	
	Day	Night
Rainbow Trout (small)	>86%	>98%
Rainbow Trout (large)	>95%	>98%
Hybrid Striped Bass	>32%	>65%
White Sturgeon	>87%	>87%

Strike: Establishing Probability of Encounter

Field Data Informing Predictive Models

❖ BACI study around the ORPC project (University of Maine)

❖ Eulerian - Lagrangian Agent Method (ELAM) For Modeling Fish Interactions with a Tidal Turbine (Argonne National Laboratory, University of Maine, SNL, Army Corps of Engineers)
  – Utilizes mobile hydroacoustic data to predict fish behavior in flow fields around MHK devices

❖ Informing Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response Using Multibeam Sonar Output (ORNL)
  – Incorporates video footage of fish behavior around full scale tidal turbine into analysis to estimate encounter and injury probability

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❖ Environmental Effects of Hydrokinetic turbines on Fish: Desktop and Laboratory Flume Studies (EPRI, Conte, Alden)

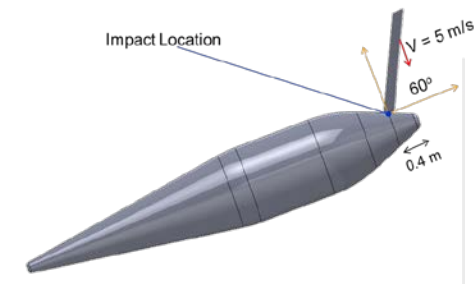http://mhk.pnl.gov/sites/default/files/publications/Jacobson_et_al_2012.pdf

❖ Evaluation of Behavior and Survival of Fish Exposed to an Axial Flow Turbine (EPRI, ONRL, Alden)

http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003911

Species	FFP Ducted Axial Flow	Lucid Spherical	Welka Axial Flow	Encurrent Vertical Axis
Rainbow Trout	>97%	>98%	>99%	-
Hybrid Striped Bass	>91%*	-	-	-
White Sturgeon	100%	-	-	-
Largemouth Bass	-	-	>99%	-
Juvenile Atlantic Salmon	-	-	-	Same as control
American Shad	-	-	-	Same as control

*Potential experimental artifact – one trial with lower mortality than others

❖ Assessment of Strike of Adult Killer Whales by an OpenHydro Tidal Turbine Blade (SNL, PNNL)

– Provided estimate of worst-case scenario results of blade strike

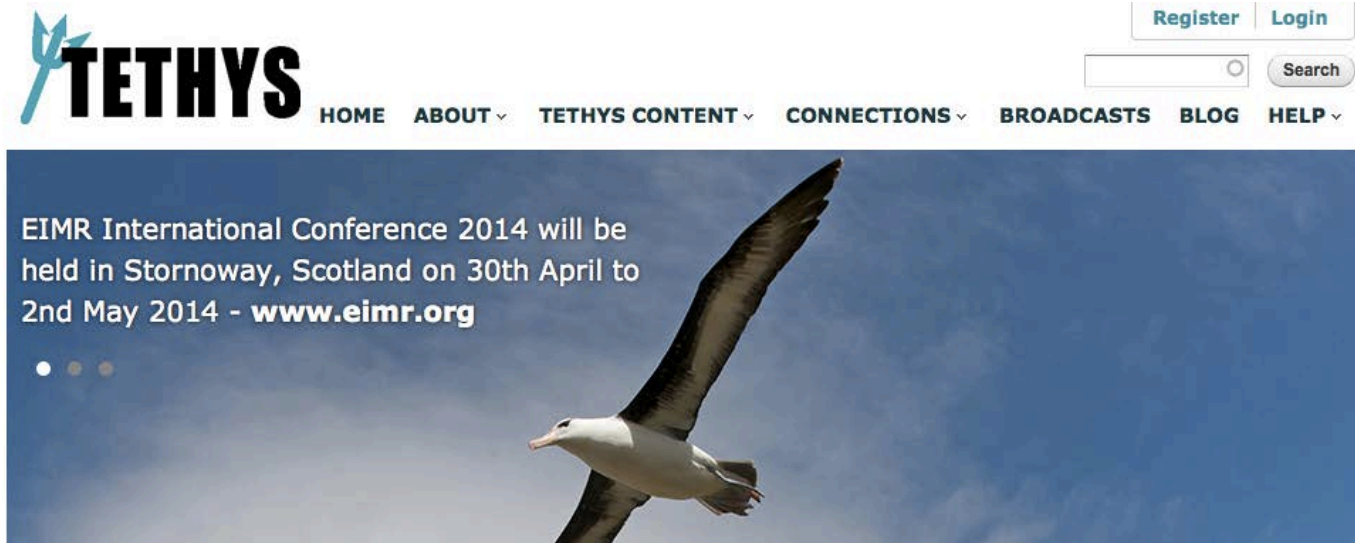http://mhk.pnl.gov/sites/default/files/publications/OpenHydro_Whale_Strike_Assessment_Final.pdf

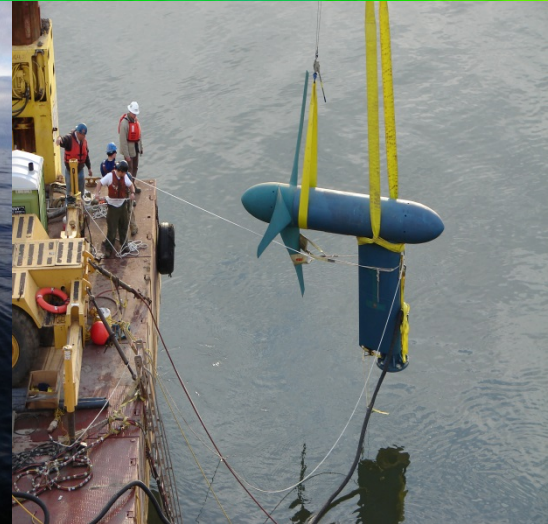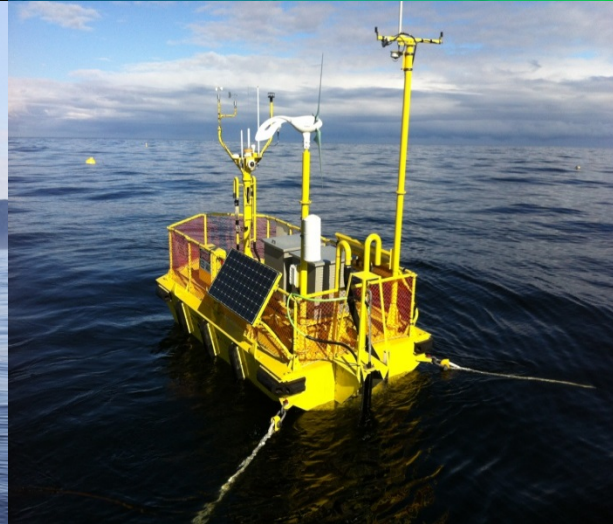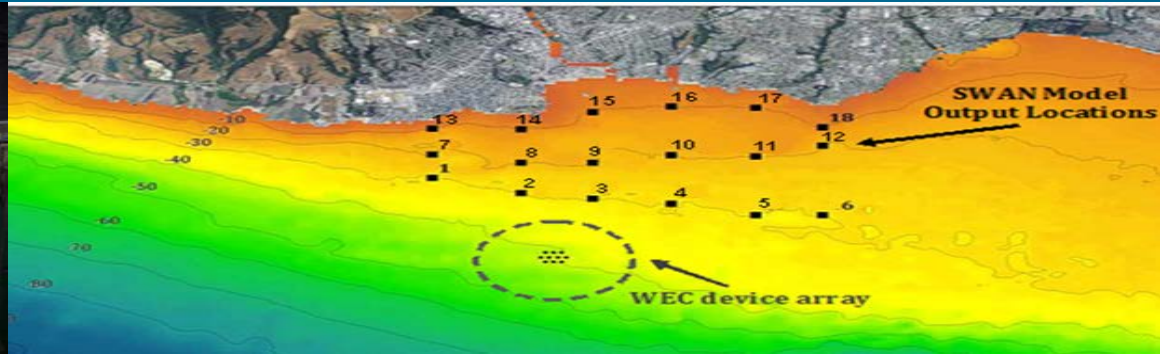U.S. DEPARTMENT OF **ENERGY** | Energy Efficiency & Renewable Energy

❖ Marine Animal Alert System (Pacific Northwest National Laboratory)

- Marine mammal monitoring using passive and active acoustics
  http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20812.pdf

❖ Underwater Active Acoustic Monitoring Network for Marine and Hydrokinetic Energy Projects (Scientific Solutions Inc.)

- Active acoustics tracking tool for marine mammals near MHK projects
  http://www.osti.gov/scitech/servlets/purl/1113677

❖ Development of the AMP for the Admiralty Inlet project (University of Washington/SnohomishPUD)

❖ MHK Environmental and Resource Characterization Instrumentation Funding Opportunity

Meta-Analysis and Dissemination

- Aggregate, analyze, and distribute data to understand trends and increase the impacts of research

- Tethys & Annex IV

- Annex IV Final Report
  - Chapter devoted to interactions of marine animals with turbine blades

    http://mhk.pnl.gov/sites/default/files/publications/Final%20Annex%20IV%20Report%202013%20v2.pdf

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Many thanks to the researchers involved in these studies.

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