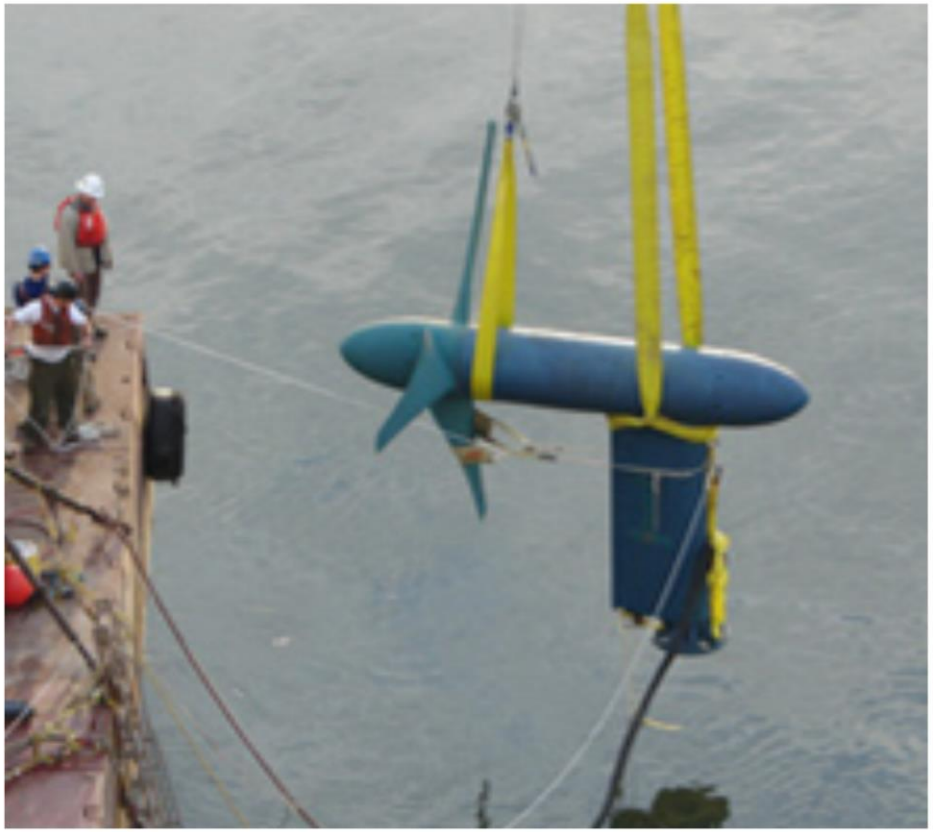

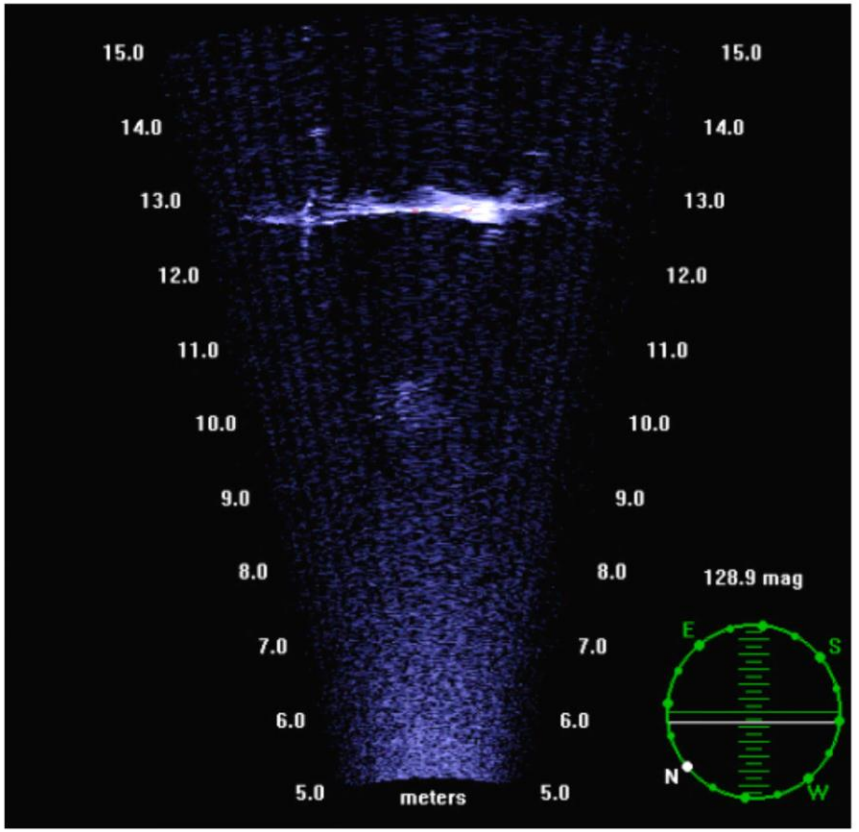

Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output

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Project Overview

Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output

FOA Number: OE DE-FOA-0000816

The Challenge:

- Concern of impacts to aquatic organisms by turbine interactions has slowed the licensing and deployment of MHK devices
- The potential for an operating tidal turbine to injure fish or affect their behavior (e.g., by interrupting normal movement patterns) is largely unknown and difficult to assess in high-energy environments where turbines are deployed
- Active sites with operating hydrokinetic turbines for testing have been rare
- Most standard fish assessment technologies are inadequate

The Solution:

- Advances in sonar (i.e., hydroacoustics) technology and associated analytical software present new opportunities for assessing fish interactions with turbines

Partners:

- Verdant Power – provided splitbeam and multibeam sonar data from Roosevelt Island Tidal Energy site; conducted strike model simulations with revised input parameters; contributed to final report
- Kleinschmidt Associates – Assisted with model simulations

Program Strategic Priorities

Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- Conduct R&D for innovative MHK systems & components
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- **Support research focused on retiring or mitigating environmental risks and reducing costs**
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

Market Development

- Support project demonstrations to reduce risk and build investor confidence
- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets
- Exchange of data information and expertise

Program Strategic Priorities

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- **Support research focused on retiring or mitigating environmental risks and reducing costs**
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

The Impact

- Developers will likely have difficulty getting licenses to deploy if they are unable to convince regulators that turbine interactions (including blade strike) will not significantly affect aquatic organisms.
- Knowledge of how different species of fish respond to turbine interactions will help developers:
  - Inform project siting
  - Assess impact mitigation
  - Reduce impact uncertainty
  - Focus environmental studies
  - Reduce mitigation costs
  - Speed licensing
- Experimental results to be published in peer-reviewed journals and made known to stakeholders via inclusion in Pacific Northwest National Laboratory's Tethys knowledgebase.

Technical Approach - 1

I. Analysis of Multi-beam Sonar Data

Turbine testing in 2012 provided opportunity for fish interaction study with DIDSON system

Conditions

- Tide (ebb vs. flood)
- Turbine (absent vs. stationary vs. rotating)
- Distance from turbine

35,000+ fish tracks evaluated for:

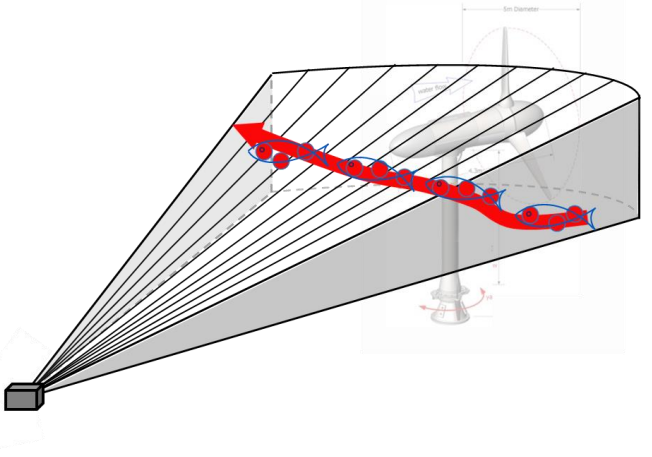
- Direction
- Change in direction (linearity of track)
- Velocity

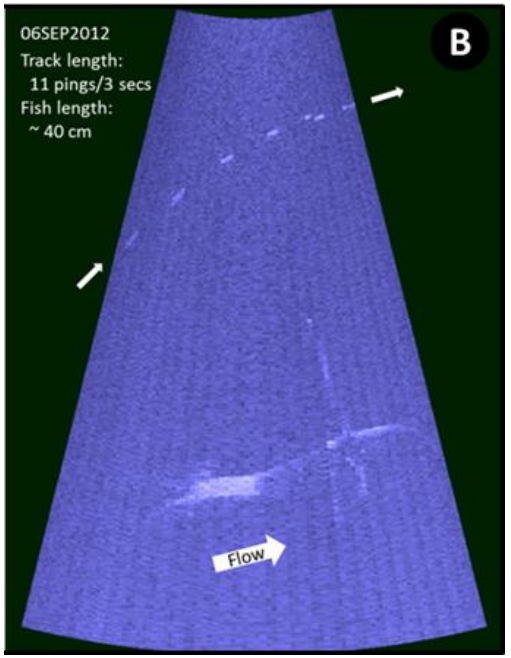
II. Split-beam data analysis from 2009 data

- Larger coverage area but lower resolution

III. Fish Interaction Model – probabilistic model of fish encounter and strike

IV. Multi-turbine Array Monitoring – assessment of applicability of DIDSON and other technologies for monitoring turbine arrays





Technical Approach - 2

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MULTI-BEAM Results

Univariate analysis found some differences in behavior (see figures →)

- Reduced swimming velocity near the turbine when present
- More downward movement near the turbine when present

Multivariate analysis (canonical discriminant analysis) found significant differences in collective behavior when turbine was present and when operating

SPLIT-BEAM Results

Abundance in the turbine swept area is naturally lower during periods of high water velocity reducing the probability of direct interaction between turbines and fish

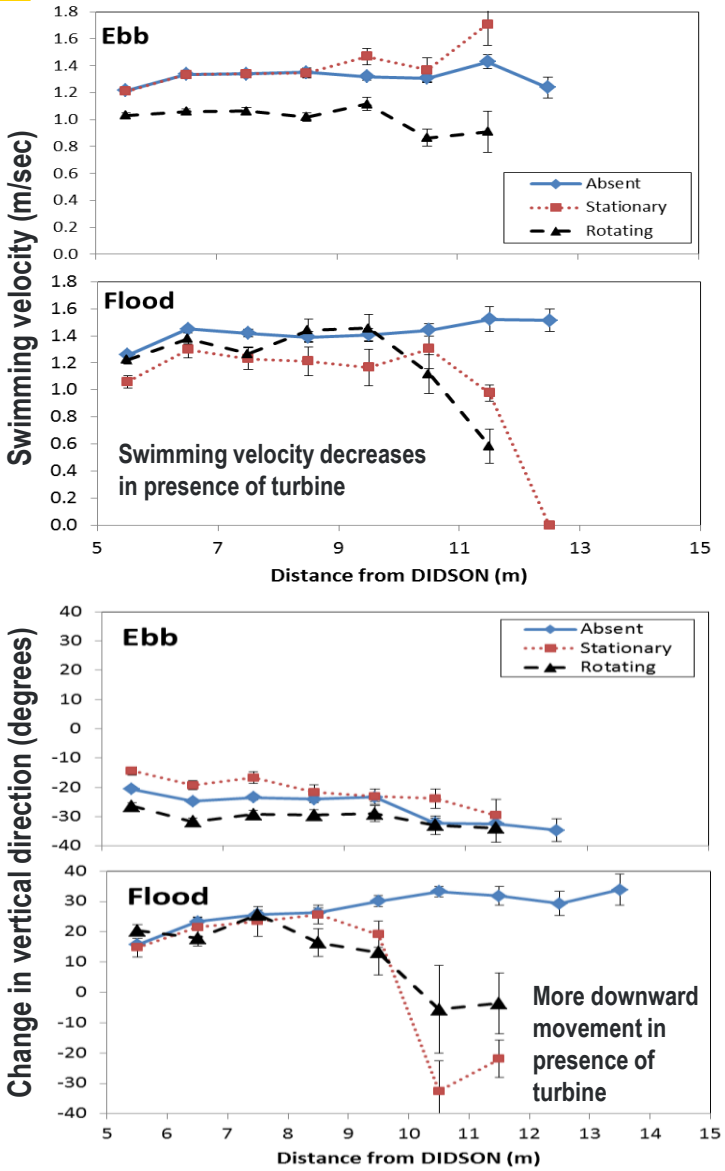
FISH INTERACTION MODEL

Revisions lowered the predicted strike probability by almost six-fold compared to previous model predictions for single turbines and arrays

CONCLUSIONS

Some fish appear to make small adjustments to swimming direction and velocity as they passed near an operating turbine.

However, large adjustments in swimming direction or velocity were not observed. The conclusion is that the presence of the turbine does not interrupt in any significant way the normal movements of fish through the area. Based on this analysis, it appears the risk of actual contact with the rotor is extremely small.



Accomplishments and Progress

Completed analysis of ~35,000 fish tracks

Completed near-field and far-field assessment

Collaborated with industry partner to use results to re-parameterize Fish Interaction Model

Evaluated monitoring options for multi-turbine arrays

Published comprehensive technical report on entire study

Bevelhimer, Colby, Adonizio, Tomichek, and Scherelis. 2016. Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output. ORNL TM-2016/219. 66 pages.

Submitted article on DIDSON analysis for journal publication

Bevelhimer, Scherelis, Colby, and Adonizio. (in review) Hydroacoustic Assessment of Behavioral Responses by Fish upon Encountering an Operating Tidal Turbine in the East River, New York. Transactions of the American Fisheries Society.

Project Plan & Schedule

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FY-Q	Initial Milestones
FY14-Q1	Conduct kickoff meeting with collaborators and acquire data files: hydroacoustic and hydrologic from Verdant Power
FY14-Q2	Complete analysis of tidal flow data and link tidal periods (with regards to direction and velocities) to hydroacoustics data to define stratified sampling periods.
FY14-Q3	Complete analysis of DIDSON acoustic files describing frequency of fish encounters with Verdant turbine and frequency and types of behavioral responses
FY14-Q4	Submit ORNL technical memorandum describing results of near-field analysis of DIDSON data for internal review
FY15-Q1	Host webinar for partners and DOE project managers to present the results of DIDSON and split-beam hydroacoustics data analysis.
FY15-Q2	Complete revised parameterization of fish interaction model complete new model simulations
FY15-Q3	Submit to HQ Technical Lead for review a manuscript that describes the results of hydroacoustics analysis
FY15-Q4	

- Project started off about one quarter behind schedule due to delay in initial funding (received at end of FY14-Q1) which caused delay in sub-contract with Verdant (completed FY14-Q2) and data acquisition
- The final report was delivered to DOE about two quarters late at end of FY16-Q1

Go/No-Go decision in FY15:

- FY15-Q1: Overcoming obstacles in automated data analysis due to turbine movement
- ORNL developed protocol for addressing analytical challenge with combination of software procedures and manual validation

Project Budget

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Budget History (New BA)					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$150k	$37k*	--	--	--	--

*** Cost-share from Verdant Power (in-kind funding)**

- No variances from planned budget
- Budget has been expended

Research Integration & Collaboration

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Partners, Subcontractors, and Collaborators:

Partner (subcontractor): Verdant Power—This work was conducted in collaboration with Verdant Power, who provided in-kind funding in terms of their previously collected hydroacoustics and hydrologic data. They also assisted with data interpretation and led re-parameterization of the existing fish interaction model for the Roosevelt Island Tidal Energy (RITE) project.

Student Technician: Oak Ridge Associated Universities/University of Tennessee

Communications and Technology Transfer:

Collaborator Verdant Power currently holds a 10-year U.S. pilot license for installation of up to 30 turbines in the East River. They intend to use the results from this study and the revised fish interaction model as evidence in on-going discussions with regulators about the possibility of environmental impacts due to turbine encounters by fish.

Technical report

Bevelhimer, Colby, Adonizio, Tomichek, and Scherelis. 2016. Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output. ORNL TM-2016/219. 66 pages.

Publications

Bevelhimer, Scherelis, Colby, and Adonizio. (in review) Hydroacoustic Assessment of Behavioral Responses by Fish upon Encountering an Operating Tidal Turbine in the East River, New York. Trans. Am. Fish. Soc.

Bevelhimer, Scherelis, Colby, Adonizo, and Tomicek. Fish Behavioral Response during Hydrokinetic Turbine Encounters: Applying Multi-Beam Hydroacoustics Results To A Fish-Turbine Interaction Model. Proceedings of the 3rd Marine Energy Technology Symposium (METS2015). April 27-29, 2015, Washington, D.C. (also a presentation)

Presentations

Tomicek, Colby, Bevelhimer, and Adonizo. 2016. Parameter Updates to Probabilistic Tidal Turbine-Fish Interaction Model. Poster presentation at METS 2016. April 27-29, 2015, Washington, DC.

Bevelhimer M.S. and C. Scherelis. “Assessing Hydrokinetic Turbine Avoidance and Strike Probability by Fish with a Multi-beam Sonar System”, Presentation at Hydrovision International, Portland, OR, July 2015.

Next Steps and Future Research

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FY17/Current research:

No project plans for FY17

Project has been completed

Proposed future research:

No official proposals for future research