VERDANT POWER

PO Box 282
Roosevelt Island
New York, NY 10044
www.verdantpower.com

July 3, 2019

Kimberly D. Bose, Secretary
Nathaniel J. Davis, Sr., Deputy Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

SUBMITTED ELECTRONICALLY

RE: Request for Approval of Modifications to Article 401 Roosevelt Island Tidal Energy (RITE) Project Monitoring of Environmental Effects (RMEE) Plans under FERC Pilot Project License No. P-12611

Dear Secretary Bose and Deputy Secretary Davis:

Attached please find a document package representing a request for Commission Approval of modifications to Article 401 of the Pilot Project License for the Roosevelt Island Tidal Energy (RITE) Project (No. P-12611). These proposed modifications have been provided to RITE resource agency stakeholders for review, comment, and concurrence, and are now being submitted for Commission review and approval as outlined in the License.

Under Article 401 of the License, Verdant Power will conduct a series of environmental monitoring activities, termed the RITE Monitoring of Environmental Effects (RMEE) Plans. However, since the 2012 issuance of the RITE Pilot Project License, Verdant Power has conducted a number of pre-installation activities that have provided key information on the design and implementation of the RMEE Plans. Based on these activities and resulting data, Verdant Power requests modifications to the RMEE Plans for implementation during the planned 2020 installation at RITE (Install B-1). These proposed modifications, which are summarized in the table below and further detailed in the attached package, will improve the information being collected, monitored, and analyzed in accordance with the key biologic questions related to Verdant Power's hydrokinetic energy system.

Prior to this submission, the proposed modifications were provided to RITE Project resource agency stakeholders for consultation. Meetings were also held with these agencies to introduce and discuss the proposed modifications, followed by a comment period. A chronology of this agency consultation is also provided in the attached documents, which include related supporting documents including an agency-requested updated review of existing fisheries data that provides a comprehensive list of the juvenile and adult fish assemblage in the area of the RITE Project. Also included are comments received from agency stakeholders, including concurrence with the proposed modifications from the New York State Department of Environmental Conservation.

Specifically, Verdant Power seeks the following amendments to the RMEE Plans outlined in the RITE License order (page 41).

New York State DEC Condition No.	Description	*Requested Modification*
11	RMEE-2 Seasonal DIDSON Observation	*Suspend*
12	RMEE-3 Seasonal Species Characterization Netting	*Suspend*
13	RMEE-4 Tagged Species Detection	*Execute with an additional receiver in East Channel*
15	RMEE-6 Underwater Sound Monitoring and Evaluation	*Modify to two far-field locations*

The biological rationales for these modifications are provided in detail in the attached and the studies that are proposed to be suspended are based on additional analysis and information that has been collected over the term of the License.

Should the Commission have any questions or require any additional information on this request, please do not hesitate to contact me. Thank you for your time and consideration.

Sincerely,

Ronald F. Smith

Ronald F. Smith
President & Chief Operating Officer

ATTACHMENT: Roosevelt Island Tidal Energy Project FERC No. P-12611 Article 401 RMEE Plan Amendments (July 2019) - with Agency Consultation Log (Appendix A) and Agency Comments (Appendix B)

ROOSEVELT ISLAND TIDAL ENERGY PROJECT
FERC No. P-12611

Article 401 RMEE Plan Amendments

July 2019

Verdant Power, LLC

Overview and Consultation on Proposed Amendments

a. Commission Approval of Plans

Article 401 of the Pilot Project License for the Roosevelt Island Tidal Energy (RITE) Project (FERC No. P-12611) specifically approved the six RITE Monitoring of Environmental Effects (RMEE) plans as shown on Table 1, and notes that they cannot be amended without Commission approval.

Following review and adaptive management consultation (see Appendix A), and agency concurrence (see Appendix B), Verdant requests Commission approval of the proposed modifications to the RMEE plans described in this document for implementation during the RITE Install B-1 Pilot Project in 2020.

b. Requirement to File Reports

During the period following the issuance of the RITE Pilot License (2012 - 18), Verdant has conducted monitoring and filed regular reports with agencies and the Commission in accordance with the Article 401 requirements. The body of filed information, including the P-12611-Addendum to Verdant Power RITE Draft License Application (August 2018) and the 2016 ORNL report[1], suggests that changes be made to improve the information being collected, monitored, and analyzed on the operating turbines in accordance with the intent of the key biologic questions addressed in the RMEE plans, which were established in 2010.

Verdant has been actively engaged in the continued study of the turbines, advancing the understanding since the license issuance and respectfully submits that the proposed changes will result in more robust monitoring of the turbines and updated information on the parameters for the KHPS-Fish Interaction Model (KFIM), which is the basis for the evaluation of species federally listed under the Endangered Species Act (ESA) and essential fish habitat (EFH) species interactions. A summary of this information was provided in August 2018.

c. Requirement to File Amendment Application

In accordance with Article 401 of the Pilot License, changes to the RMEE plans require Commission authorization granted after the filing of an application to amend the license.

Specifically, Verdant Power requests authorization for the following proposed changes, which are further outlined in Table 1 below. Justification for each of these changes is also discussed further in this document:

- Agreement to suspend RMEE-2 Seasonal DIDSON Monitoring
- Agreement to suspend RMEE-3 Seasonal Species Characterization
- Agreement to enhance RMEE-4 Tagged Species Detection
- Agreement to modify RMEE-6 Underwater Sound Monitoring

The remaining approved RMEE plans (5 and 7) will be executed as planned.

---

[1] Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output", Bevelhimer, M., Colby, J., Adonizio M.A., Tomichek, C., Scheleris, C., ORNL/TM-2016-219, July 2016.

Prior to submission of this request to the Commission, Verdant conducted agency consultation (see Appendix A) and received concurrence on these proposed modifications (see Appendix B).

Based on this, Verdant hereby submits this for Article 401 License amendment for Install B-1.

Table 1. Summary of RMEE Plans (Install B-1) and Proposed Changes (*red italics*)

Plan	Name	Scale	Operational Monitoring Objectives	RITE Install B-1 (2020) 3 Gen5 Turbines on 1 TriFrame	Proposed Changes
RMEE-2	Seasonal DIDSON Observation	Micro	KHPS-Fish Interaction	3 weeks during Sept - Dec	*Suspend*
RMEE-3	Seasonal Species Characterization Netting	Macro	Species Netting	Six days during Spring and Fall	*Suspend*
RMEE-4	Tagged Species Detection	Macro	Detection of ESA and other tagged species	April - November *Revised to year-round*	*Execute with enhancements*[2]
RMEE-5	Seasonal Bird Observation	Meso and Macro	Bird population interaction with and reaction to KHPS	11 days seasonal during Spring and Fall	None (execute as planned)
RMEE-6	Underwater Sound Monitoring and Evaluation	Micro, Meso, and Macro	KHPS Noise Signature and effects on aquatic species	Stationary: 1 near-field location (1 month); 3 far-field locations (1 week)	*Modify to two far-field locations*
RMEE-7	Recreational Observation	Macro	Recreation impacts of field	1 year after deployment	None (execute as planned)

As shown in Figure 1, under an adaptive management framework, and consistent with the Pilot License requirements:

- Monitoring is conducted;
- Adjustments or modifications (including suspending studies) are to be considered as the project advances;
- Operations can be adjusted if warranted; and
- As required, "*the project can be shut-down at any time*" should environmental effects be observed.

This fundamental concept underlies the Pilot project operation and has been the consistent application since the 2006 implementation of the RITE Project.

---

[2] At the January 2019 Joint Agency Meeting, Verdant was optimistic that an RMEE-4T triangulation concept could be implemented, however it was subsequently discovered that the fish tags used by researchers are not compatible with the receivers necessary to achieve triangulation, and therefore Verdant offers an enhanced RMEE-4 plan to provide additional detections in the East Channel of the East River.

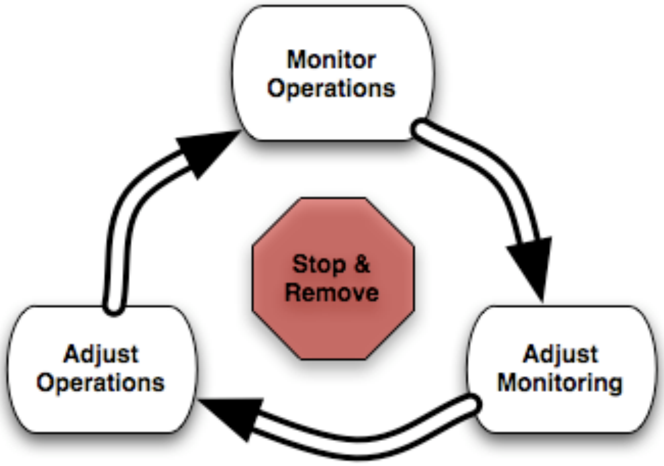


Figure 1. Schematic of Adaptive Management Framework

As approved in the RITE Pilot License, the fundamental questions respective to these plans are as follows:

- *RMEE-2: How do fish behave around an operating turbine?*
- *RMEE-3: What is the species characterization at RITE?*
- *RMEE-4: What is the detected presence, distribution and frequency of tagged fish?*
- *RMEE-5: What is the seasonal presence, and abundance of birds?*
- *RMEE-6: What is the operating noise signature of the turbines and will it affect fish?*
- *RMEE-7: What is the recreational usage at RITE?*

Therefore, in consultation with the agencies, we approached this review of the suite of RMEE plans as to how best to implement the monitoring of the Gen5 turbines and TriFrame. Fundamentally, we seek to provide the best solutions to provide the most complete understanding of the fundamental questions of each RMEE plan, given the body of information developed since project inception. A review of each plan follows.

RMEE-2 – Seasonal DIDSON Observation (NYSDEC WQC 11)

a. Background and Objectives

A full overview of the body of information developed under this plan was provided to the agencies under the P-12611- Addendum to Verdant Power RITE Draft License Application (August 2018).

As shown in Figure RMEE-2A, Verdant, during a 2012 In-Water Test (IWT) of the Gen5b KHPS turbine rotor, installed and operated a remotely aimable DIDSON (RAD) unit near the operating dynamometer turbine at RITE (this $175K effort was supported by co-funding from NYSERDA). A significant data set was collected over 2+ weeks with and without turbine operation. In conjunction with Oak Ridge National Laboratory (ORNL) and with co-funding support from the US Department of Energy, Verdant and ORNL re-evaluated the 2012 DIDSON data using automated data processing techniques conducted by a Ph.D. researcher. Their findings[3] included the following [emphasis added]:

> *In conclusion, we found <u>no evidence that fish were regularly struck by turbine blades</u> at the RITE site, and we believe that the likelihood is quite low based on several lines of evidence: the low probability that fish would directly encounter a turbine (Wilson et al. 2007), the apparent long range avoidance seen in this study and another study (Viehman and Zydlewski 2015), the apparent ability of most fish to avoid rotor blades when they are encountered at close range (Amaral et al. 2010, 2015), and the paucity of evidence for direct blade strikes. However, based on the relative <u>number of fish tracks identified</u> under the different turbine conditions, the results of this study do suggest that avoidance might be occurring at a distance beyond the 10–15-m range of the DIDSON system.*

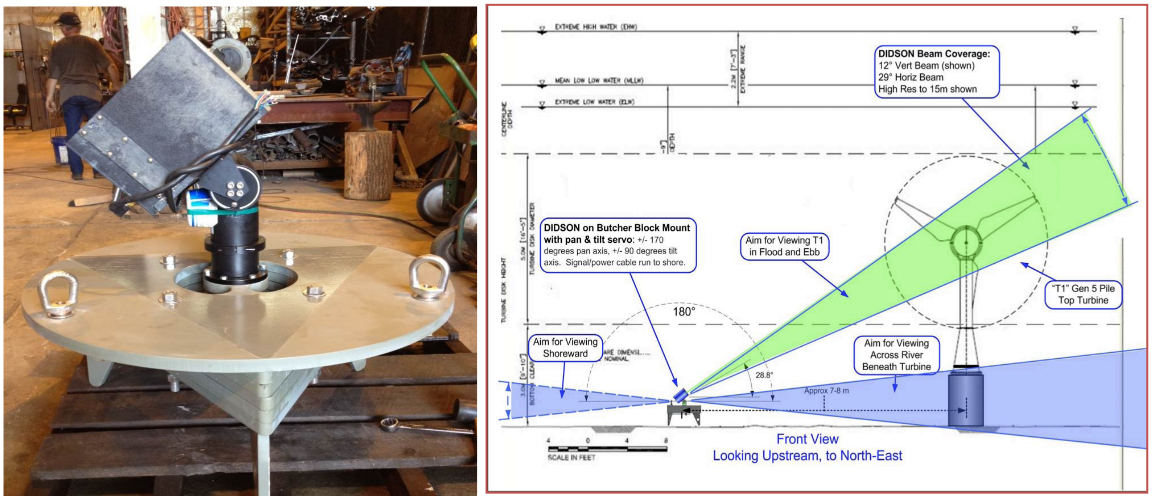


Figure RMEE-2A. DIDSON as deployed at RITE in 2012

---

[3] Taken from Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output", Bevelhimer, M., Colby, J., Adonizio M.A., Tomichek, C., Scheleris, C., ORNL/TM-2016-219, July 2016

The following outlines the objective of the RMEE-2 plan under the RITE Pilot License, as annotated by Verdant *(red italics)*:

> *The objective of the seasonal DIDSON observation is to:*
>
> 1. *Provide real-time observation of fish behavior near operating KHPS during a seasonal period of known fish abundance. Specifically, the goal is to provide imaging of any fish/KHPS interaction, both spatial and temporal, at the micro scale around a rotating turbine. Parameters that can be observed from the DIDSON will include:*
>   - *fish swimming location and direction relative to the turbine blades Achieved*
>   - *fish passage through or around the turbine Achieved*
>   - *for fish passing through the turbine, it will be possible in most cases, especially for larger fish, to determine if the fish avoided the blades or was struck Achieved*
>   - *fish size and shape with potentially some species identification, especially for larger individuals (e.g., Atlantic sturgeon, turtles, marine mammals) none observed; species identification not achievable*
>
> 2. *Add value to the body of collected data on fish presence, abundance, movement pattern and species in and around the operating KHPS machine by providing micro-scale details of the fish seen at the meso scale by the SBTs. Achieved*

b. Planning for Install B-1

Verdant has reviewed the conclusions and recommendations of Bevelhimer et al. (2016), which are provided below. In addition, Verdant has examined a possible deployment of the DIDSON on the RAD (see Figure RMEE-2B) and determined that this configuration is unable to insonify all three turbines. Further, as discussed in the ORNL report, the turbulence generated during operation limits the effectiveness of the DIDSON in observing the TriFrame. Based on this, Verdant proposes to suspend the RMEE-2 plan during Install B-1 and instead enhance detection of tagged species under the RMEE-4 plan.

Conclusions and Recommendations from Bevelhimer et al. (2016)

- The objectives of the RMEE-2 plan were achieved in the 2012 observation.

- It is doubtful that further RAD deployments to observe multiple operating turbines is a useful technique at RITE or that it would yield further data. Verdant will probably pursue an adaptive management conclusion of the RMEE-2 effort.

- The review of 239 hours of DIDSON video collected in September 2012 in the presence of an operating Gen5 KHPS turbine revealed no drastic changes in swimming behavior as a result of exposure to the turbine.

- Automated data analysis was a challenge because of the rotating turbine.

- This monitoring protocol is focused as discussed on the observation of a single (or few) operating KHPS turbines at the micro scale. It is likely not applicable for multiple turbines in an array condition. Moving toward such studies, it is recommended that research and development funding for alternative techniques or algorithms be undertaken to address the array condition.

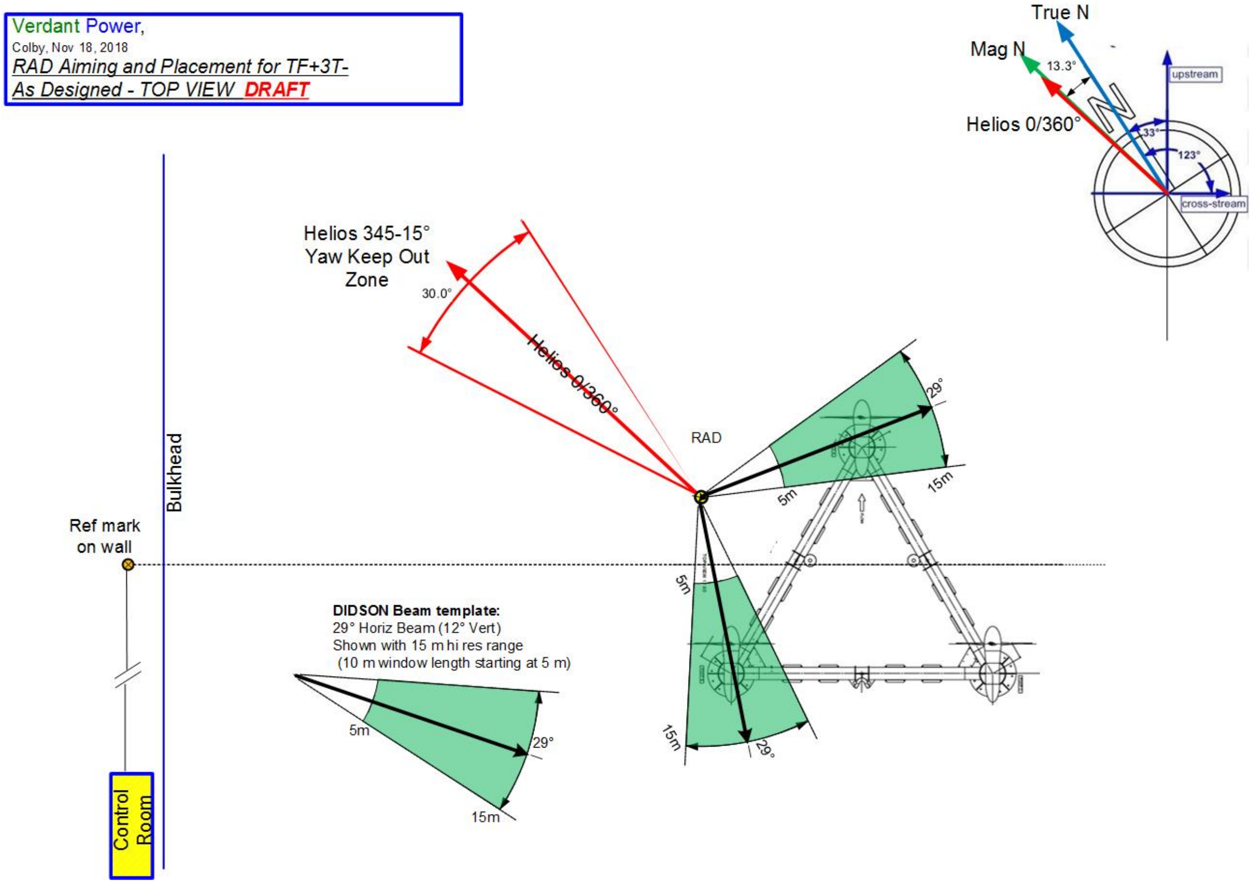


Figure RMEE-2B. DIDSON observing the TriFrame at RITE

c. Verdant Recommendations for RMEE -2

Based on the analysis conducted, it is clear that the DIDSON was a useful tool in imaging the micro-scale impact (or lack thereof) and confirmed the micro-scale absence (and likely avoidance) of fish around an operating turbine.

Further DIDSON data collection and analysis is unlikely to be useful during the RITE Install B-1 as the micro-scale interaction and fish impact has been shown to be de minimis. Additionally, since the biological objectives of the DIDSON observation were achieved in the 2012-2016 analysis, and the focus of the 2019 concerns is for the larger-species EFH and ESA designated fish, ***Verdant proposes the suspension of the RMEE-2 Seasonal DIDSON Observation plan for Install B-1 in favor of enhanced RMEE-4 plan activities.***

RMEE-3 – Seasonal Species Characterization Netting (NYSDEC WQC 12)

a. Background and Objectives

A full overview of the body of information developed under this plan was provided to the agencies under the P-12611- Addendum to Verdant Power RITE Draft License Application (August 2018). This includes a netting effort conducted in May 2013, under both NYS Scientific Collection and Endangered Species Collection permits.

The 2013 netting was conducted in conjunction with Normandeau, using a net designed and acquired by Verdant and analysis by Kleinschmidt (this $20K effort was supported by co-funding from NYSERDA) (see Figure RMEE-3).

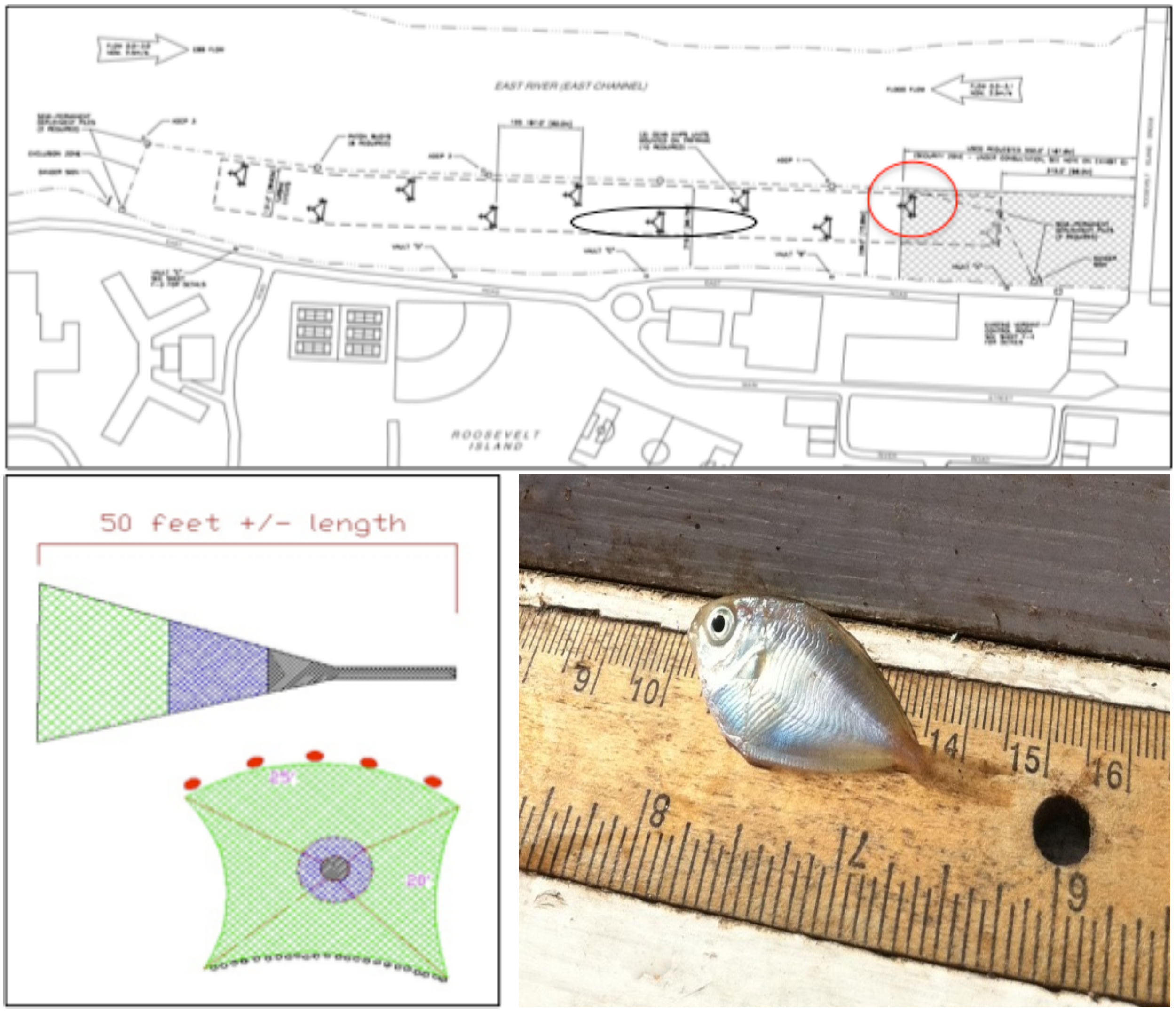


Figure RMEE-3. Stationary Netting at RITE

The following outlines the objective of the RMEE-3 plan under the RITE Pilot License, as annotated by Verdant *(red italics)*:

> *The objective of netting is to provide a set of net capture data, during May through December with more effort during the seasonal period (mid-September through mid-December) of elevated fish abundance in the project vicinity to provide: May 2013 effort provided no information*
>
> 1. *Species characterization information, that combined with the 2006 RITE trawling, and the Ravenswood historical impingement data collected in 1991, 1992, 1993, 1994, 2006 and 2007 provides characterization of the fish assemblage (72 aquatic species identified) in the East Channel, no additional information*
> 2. *Provide species characterization in the immediate vicinity of the turbines that can be used to support the interpretation of the past and future DIDSON monitoring and hydroacoustic evaluations, and no additional information*
> 3. *Potentially provide some observation and/or data for interpretation on potential fish injury due to turbine blade contact in a field of operating KHPS turbines. Very doubtful*

b. Planning for Install B-1

In preparing for the execution of the RMEE-3 plan during Install B-1, Verdant notes the following limitations:

- Review of 2013 effort yielded little knowledge (2 total fish < 50mm) (see Figure RMEE-3)
- Data assemblage, including Ravenswood data, is sufficient
- Execution of netting is dangerous in close proximity to operating turbines in a high energy tidal site
- Renewal of both permits would be required

c. Recommendations for RMEE-3 during Install B-1

Based on the 2013 netting effort, species characterization netting near the RITE Project Area is unlikely to yield meaningful results given the difficulty of netting in strong tidal currents and the general absence of fish in the mid-river. However, extensive fish assemblage data is available from aquatic organism samples collected at Ravenswood Generating Station, which is in close proximity to the RITE Project site. This information was also used in the RITE pilot license application.

After consultation with resource agencies, Verdant provided an update on the Ravenswood impingement data that has been collected recently (2013-2015). This information (contained in Appendix A) provides a comprehensive list of the juvenile and adult fish assemblage in the east channel of the East River in the area of the RITE Project. Considering this available information and the lack of data collected via trawl netting in the project area, ***Verdant proposes the suspension of RMEE-3 plan Seasonal Species Characterization Netting during Install B-1.***

RMEE-4 – Tagged Species Detection (NYSDEC WQC 13)

a. Background and Objectives

A full overview of the body of information developed under this plan was provided to the agencies under P-12611 - Addendum to Verdant Power RITE Draft License Application (August 2018). This includes all the RMEE information collected since license issuance, through 2018.

The following outlines the objective of the RMEE-4 plan under the RITE Pilot License:

> *The objective of this plan is to provide new and unique detections on the potential presence of the proposed ESA listed Atlantic sturgeon, ESA listed shortnose sturgeon, along with striped bass, bluefish, winter flounder and other species that have been acoustically tagged. Detection would occur in both the east and west channels of the East River, proximate to the RITE Pilot project boundary. Once that is achieved, based on collected data, revision and updated evaluation of species with respect to Installs B-1, B-2 and C will occur.*

Verdant acknowledged the importance of this study and beginning in 2011 and through 2018 voluntarily installed VEMCO tagged species detection hydrophones (VR2W - 69kHz) in both the East and West Channels of the East River to gain information on fish passing near the KHPS at RITE (see Figure RMEE-4-Rev 2010). Under the Pilot License, the RMEE-4 plan required detection active during April to November; however, Verdant has voluntarily extended this to year-round collection where possible, and as limited by battery life.

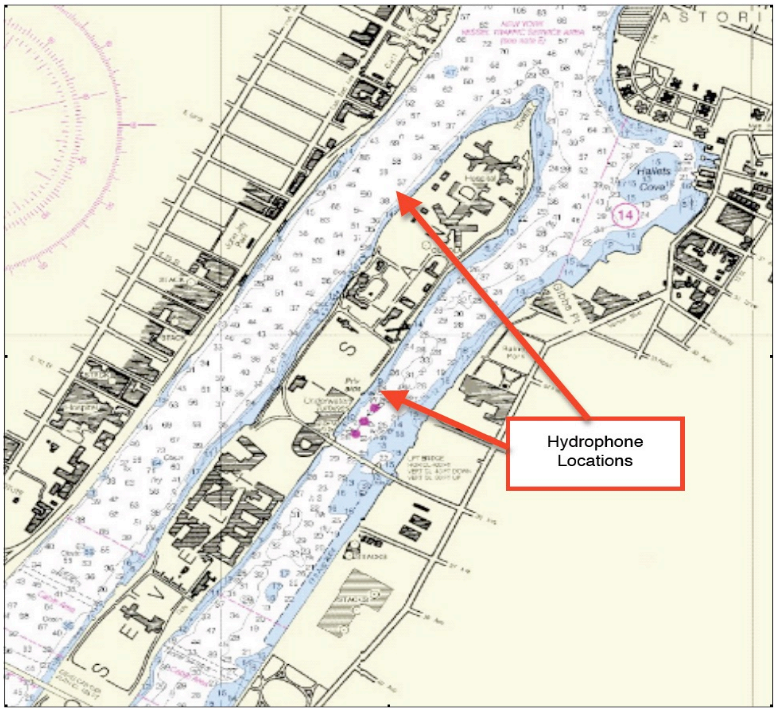


Figure RMEE-4-Rev 2010. RMEE-4 Tagged Species Detection - Hydrophone locations at RITE

Two acknowledged limitations of this plan are as follows:

- Effective only if researchers tagging fish participate in mutual data exchange
- The single platform as deployed in the East Channel detects presence (within 400m) but not specific location in relationship to the KHPS

Nonetheless the RMEE-4 plan has provided significant data informing the KHPS-Fish Interaction Model (KFIM), as described in the August 2018 document.

b. Planning for Install B-1

In examining options for the planned Install B-1 deployment, Verdant explored improvements to the RMEE-4 protocol. One option would be to deploy additional VEMCO receivers and tags and conduct analysis on the triangulation of detected tags to spatially locate, in 3-D, a tagged fish and its track as it passes by multiple KHPS turbines.

At a January 2019 Joint Agency Meeting, Verdant was optimistic that a RMEE-4 Triangulation concept could be implemented, however, it was later determined that the fish tags used by researchers are not compatible with this change and therefore Verdant cannot suggest such a modification to this RMEE plan.

While it is possible for Verdant to deploy VEMCO 180 kHz hydrophones in a triangulated platform proximate to the operating Verdant Power TriFrame + 3 turbines during Install B-1, in order to achieve an x-y-z location of a tagged fish, the tags deployed by the researchers are not compatible for this study as they only ping once per minute and do not measure depth.

Fish would need to be tagged with the 180 kHz tag (HR2 with a 5-second ping rate) and also be outfitted with a depth sensor in order to obtain the z (depth) parameter. Unfortunately, Verdant's informal survey of active researchers has indicated that most are only using the 69 kHz tag (ping rate 60 seconds) without depth sensors.

c. Recommendations for RMEE-4 for Install B-1

Based on the above, Verdant will continue the multi-year VEMCO 69 kHz tag detection effort of previously tagged species in both the East and West Channels to provide input to parameters in the assessment of the risk of fish-turbine interaction at the RITE Project. In place of triangulation, Verdant proposes to deploy additional receivers in and around the RITE Project area, as an enhancement to the RMEE-4 plan (see Figure RMEE-4-Rev 2019).

This effort requires cooperation for continued tagging by researchers and data sharing with many organizations, which does pose a potential hurdle to the success of the protocol for both striped bass recovery efforts and the tagging and identification of the ESA species Atlantic sturgeon[4]. Verdant will continue to work with the researchers and believes this ongoing body of information on macro and meso movement of detected species provides important biological information on target species.

---

[4] In 2018 Verdant provided NYSDEC and the researchers all of the raw data (VRL files) collected form the RITE VEMCO receivers, and agreed not to publish any scientific papers, in exchange for identification of tags, solely for the purpose of complying with this FERC license Article 401 plan. To date ~ 15% of the tags detected remain unidentified.

In June 2019, the resource agencies provided concurrence with this enhancement of the RMEE -4 Plan during the Install B-1 effort.

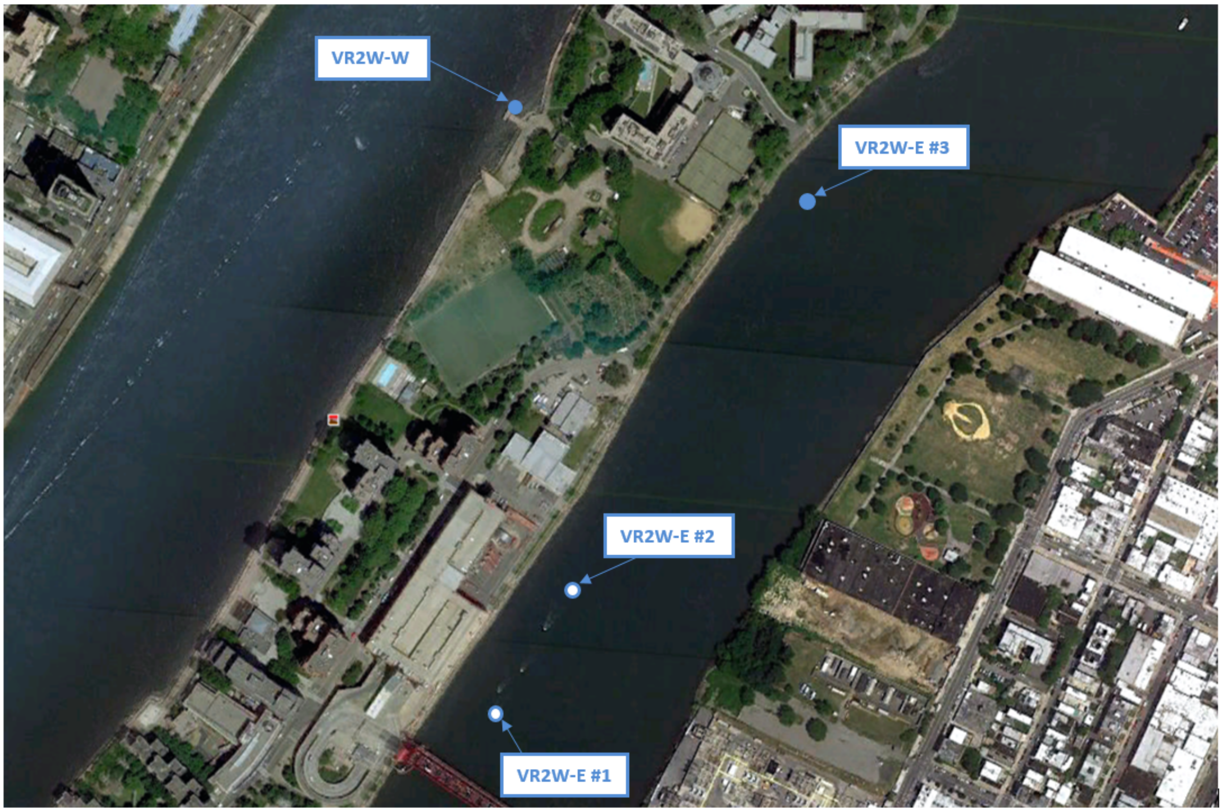


Figure RMEE-4-Rev 2019. RMEE-4 Tagged Species Detection - Proposed hydrophone locations at RITE

RMEE-6 – Underwater Noise Monitoring and Observation (NYSDEC WQC 16)

a. Background and Objectives

While no additional studies have been conducted since the Pilot License issuance on underwater noise, Verdant has explored practical hydrophone applications for accomplishing the RMEE-6 study, including consultation with researchers active in this area and consistency with evolving International standards[5]. The following outlines the objective of the RMEE-6 plan under the RITE Pilot License, as annotated by Verdant:

> *The objective of this study is to:*
>
> - *Determine the noise signature from 6-30 operating Gen5 KHPS turbines and use this information to verify or refute the initial finding that the machines do not emit noise at levels that would cause harm to aquatic resources. This task will include a review of the data on representative species and the physics of sound propagation in shallow water to establish the appropriate spatial and frequency limits for monitoring.*

The approved RMEE-6 hydrophone plan is shown on the Figure RMEE-6-Rev 2010 and includes the following:

- A stationary deployment at the TriFrame site for 1 month
- Three far-field deployments for one week

Figure RMEE-6-Rev 2010. Underwater Noise Monitoring and Observation at RITE

---

[5] The International Electrotechnical Commission (IEC) under Technical Committee (TC) 114: Marine energy – Wave, tidal and other water current converters has progressed the development of IEC Technical Specification (TS) 62600-40, "Acoustic characterization of marine energy converters." Approved 2019-03-09, publication pending.

b. Planning for Install B-1

In preparing for the execution of the RMEE-6 plan during Install B-1, Verdant has developed a tentative design of a stationary hydrophone application for deployment in proximity to the Verdant TriFrame as shown in Figure RMEE-6-Rev 2019. Verdant believes this effort will allow for the answering of the fundamental questions outlined above.

The planned “Snap” Loggerhead Instruments hydrophone will be deployed 100 meters north (as recommended by IEC evolving standard for underwater noise measurements) of the TriFrame to collect 30 days of data in the presence of operating turbines utilizing a battery system.

For far-field noise analysis a similar one-week deployment at two locations as shown in Figure RMEE-6-Rev 2019 will provide far-field noise evaluation. Verdant suggests a modification to the RMEE-6 plan to two rather than 3 locations due to the recent operation of a commuter ferry (Hornblower) in the Hallets Cove location. Analysis of data will be used to answer the fundamental biologic questions.

c. Recommendations for RMEE-6 for Install B-1

In Verdant’s opinion, the plan as written can be executed and recommends a modification to two far-field locations based on the recent addition of a ferry terminal in Hallets Cove and the likelihood that data collected in the existing third location provides little information relative to the underwater noise of the turbines.

Therefore, Verdant proposes the modification of RMEE-6 Underwater Noise Monitoring plan during Install B-1 to two far-field locations.

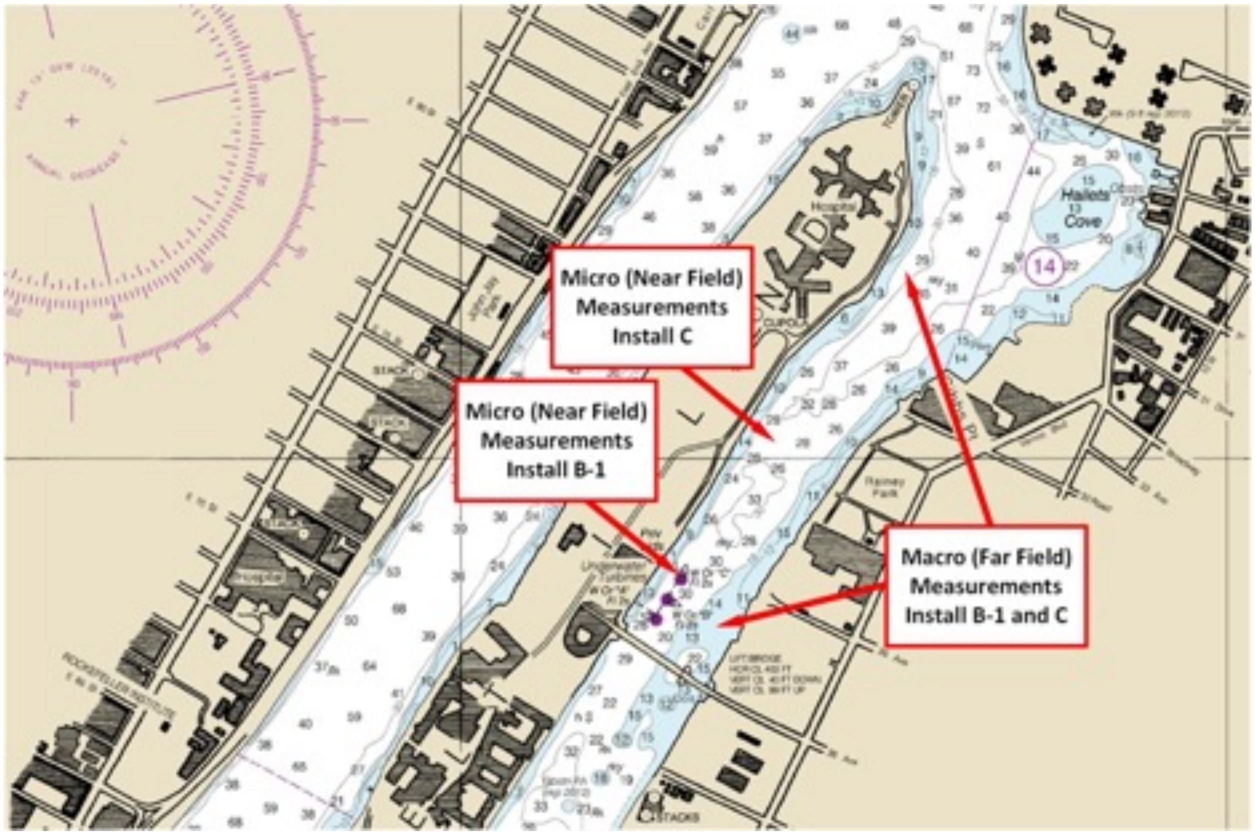


Figure RMEE-6-Rev 2019. Underwater Noise Monitoring and Observation at RITE

APPENDIX A:
Agency Consultation on Proposed RMEE Plan Amendments

The following table provides a chronology of consultation with RITE agency stakeholders on the proposed modifications to the RMEE Plans. Associated documents are provided in the pages that follow in the order they are listed in the table.

Table 1. Agency Consultation on Proposed Modifications to RMEE Plans

Date	**Action**	**Recipients**	**Related Documents**
March 05, 2019	**Invitation to Agency Review Meeting**[1]	**RITE Agency Working Group: USEPA, NYSDEC, USACE, USFWS, NOAA-NMFS, NYSERDA, NYSDOS**	**Letter of Invitation to Review Meeting (via email)**
March 15, 2019	**Provision of Proposed Modification and other Meeting Documents**	**RITE Agency Working Group (same as above)**	**Cover Email; Cover Letter; Proposed RMEE Plans Amendments Package; Meeting PPT; Background Report: "*Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output*"**
March 20, 2019	**Meeting held with agencies (Webinar)**		
March 22, 2019	**Make-up Meeting held with agencies (Webinar)**		
April 19, 2019	**Follow-up correspondence and documents**	**RITE Agency Working Group**	**Cover letter; Minutes of 03/20/19 & 03/22/19 Meetings; 2019 Review of Species Characterization Data (RMEE-3) *[Agencies provided 30-day comment period]***
May 24, 2019	**Follow-up correspondence requesting agency comments**	**RITE Agency Working Group**	**Cover email (04/19/19 document package re-sent for reference); *[comment period extended to 05/29]***

---

[1] The meeting was scheduled for March 20, 2019. An additional make-up meeting was also scheduled for March 22, 2019 based on agency feedback.

March 05, 2019 Consultation Documents:
-Letter of Invitation to Review Meeting (via email)

Subject: Environmental Monitoring Plans for Verdant Pilot License Install B-1
Date: Tuesday, March 5, 2019 at 2:05:03 PM Eastern Standard Time
From: Chris Tomichek
To: knutson.lingard@epa.gov, rudyard.edick@dec.ny.gov, Ronald.R.Pinzon@usace.army.mil, Steve_Sinkevich@fws.gov, David.bean@noaa.gov, Karen.Greene@noaa.gov, Matthew.Maraglio@dos.ny.gov, lisa.bonacci@dec.ny.gov, Julie.Crocker@noaa.gov, Gregory.lampman@nyserda.ny.gov, Mary Ann Adonizio, Jonathan Colby, Ronald Smith, Aaron Hernandez

Good Afternoon

Verdant Power is getting ready to implement the environmental monitoring plans approved in the 2012 RITE Pilot license for Install B-1 in 2020. This call is being held to discuss these environmental monitoring plans and proposed modifications to the plans with the you as the adaptive management group of agencies in a hosted call on **Wednesday March 20, 2019 at 1PM to 2:30PM.** Shortly you will receive a document with an overview of the proposed changes and a PDF copy of the PowerPoint we will present during the call for those of you that cannot log into Skype. However we are sending this invite now as we want to get this date and time reserved on your calendar. Hope you can all join us.

....

Join Skype Meeting

Trouble Joining? Try Skype Web App

Join by phone

DETAILS REDACTED

Toll number: English (United States)

Find a local number

Conference ID: Forgot your dial-in PIN? | Help

....

March 15, 2019 Consultation Documents:
-Cover Email
-Cover Letter
-Proposed RMEE Plans Amendments Package
-Meeting PPT
-Background Report: "*Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output*"

Subject: Environmental Monitoring Plans for Verdant Pilot License Install B-1
Date: Friday, March 15, 2019 at 3:48:38 PM Eastern Daylight Time
From: Chris Tomichek
To: knutson.lingard@epa.gov, rudyard.edick@dec.ny.gov, Ronald.R.Pinzon@usace.army.mil, Steve_Sinkevich@fws.gov, Karen.Greene@noaa.gov, Matthew.Maraglio@dos.ny.gov, lisa.bonacci@dec.ny.gov, Gregory.lampman@nyserda.ny.gov, Tracy Maynard, McLean, Laura (DOS), Binder, Jonathan A (DEC), Bauer, Cassandra L (DEC), Cain, Nicole E (DEC)
CC: Ron Smith, 'Mary Ann Adonizio', Jonathan Colby, Aaron Hernandez, Tim Oakes
Attachments: P12611-Article401-Proposed-RMEE-Amend_03-15-19.pdf, P12611-Article401-Proposed-RMEE-Amend-PPT_Mar2019.pdf, ORNL-VP Final Rpt JUL16.pdf

Good Afternoon

To facilitate our call next **Wednesday March 20, 2019 at 1PM to 2:30PM** to discuss Verdant Power's environmental monitoring plans approved in the 2012 RITE Pilot license for Install B-1 in 2020, three PDF's are attached. The first PDF is a document with an overview of Verdant Power's proposed changes, second is a PDF copy of the PowerPoint we will present during the call for those of you that cannot log into Skype. In addition, we attached a DOE report*, Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output*, Bevelhimer, M., Colby, J., Adonizio M.A., Tomichek, C., Scheleris, C. Published in July 2016, the report includes an extensive analysis of multi-beam sonar data collected at the RITE site which we will discuss on the call. Talk to you next Wednesday.
Regards,
Chris

Chris Tomichek
Senior Manager
Fisheries and Aquatic Resources
Office: 860.718-0296
www.KleinschmidtGroup.comAs

*Providing **practical** solutions for **complex** problems*
affecting energy, water, and the environment.

VERDANT POWER

PO Box 282
Roosevelt Island
New York, NY 10044
www.verdantpower.com

March 15, 2019

Sent via Email to:
Lingard Knutson, EPA (knutson.lingard@epa.gov)
Rudyard Edick, NYSDEC (rudyard.edick@dec.ny.gov)
Ron Pinzon, USACE (Ronald.R.Pinzon@usace.army.mil)
Steve Sinkevich, USFWS (Steve_Sinkevich@fws.gov)
Karen Greene, NOAA (Karen.Greene@noaa.gov)
David Bean, NOAA (David.bean@noaa.gov)

RE: P-12611 Article 401 Proposal for Modification of Roosevelt Island Tidal Energy (RITE) Project Monitoring of Environmental Effects (RMEE) Plans 2, 3, 4, and 6; and NYSDEC WQC conditions 11, 12, 13, and 16

Since the 2012 issuance of the FERC Pilot License for the RITE Project, Verdant Power has conducted a number of pre-installation activities that have provided information on the approved Article 401 RITE Monitoring of Environmental Effects (RMEE) Plans. This body of information was filed with FERC in August 2018 and provided to you as well.

As Verdant prepares to implement the RMEE Plans at RITE in 2020 (under Install B-1) and as previewed at the January 8, 2019 RITE Relicensing Joint Agency Meeting, we propose to discuss these plans and proposed amendments jointly with you as the RITE adaptive management group of agencies in a hosted call on **Wednesday, March 20, 2019 at 1 PM EDT.** Notice of this meeting was sent previously to you by Verdant's regulatory partner, Kleinschmidt.

As background for the call, we provide the attached document, **P-12611 – Article 401 Proposed RMEE Plan Amendments**. We encourage the productive review of this material within an adaptive management framework to best monitor Verdant's Gen5 kinetic hydropower turbines in the environment of the East River, and the advancements in knowledge that have occurred since 2010, when the plans were first proposed.

As required by the license, any amendments to these plans require Commission approval and as such this information is provided as part of a consultation process, and the discussions during the meeting will be confirmed in writing after the call. Thank you for your time and consideration.

Sincerely,

Ronald F. Smith

Ronald F. Smith
President & Chief Operating Officer

CC: Matthew.Maraglio@dos.ny.gov, lisa.bonacci@dec.ny.gov, Julie.Crocker@noaa.gov, Gregory.lampman@nyserda.ny.gov, John_Wiley@fws.gov

Attachment: P-12611 – Article 401 Proposed RMEE Plan Amendments (March 2019)

ROOSEVELT ISLAND TIDAL ENERGY PROJECT
FERC No. P-12611

Article 401 Proposed RMEE Plan Amendments

March 2019

Verdant Power, LLC

Overview and Consultation on Proposed Amendments

a. Commission Approval of Plans

Article 401 of the subject Pilot License specifically approved the six RITE Monitoring of Environmental Effects (RMEE) plans as shown on Table 1, and notes that they cannot be amended without Commission approval.

Verdant seeks a review and adaptive management consultation on the following changes to the RMEE plans for implementation during the RITE Install B-1 Pilot Project in 2020.

b. Requirement to File Reports

Over the course of the RITE Pilot License period (2012 - 2018), Verdant has conducted monitoring and filed regular reports with agencies and the Commission in accordance with the Article 401 requirements. The body of filed information, including the P-12611- Addendum to Verdant Power RITE Draft License Application (August 2018) and the 2016 ORNL report[1], suggests that changes be made to improve the information being collected, monitored, and analyzed on the operating turbines in accordance with the intent of the key biologic questions addressed in the 2010 RMEE plans.

Verdant has been actively engaged in the continued study of the turbines, advancing the understanding since the license issuance and respectfully submits that the proposed changes will result in more robust monitoring of the turbines and updated information on the parameters for the KHPS-Fish Interaction Model (KFIM), which is the basis for the evaluation of species federally listed under the Endangered Species Act (ESA) and essential fish habitat (EFH) species interactions. A summary of this information was provided in August 2018.

c. Requirement to File Amendment Application

In accordance with Article 401 of the Pilot License, changes to the RMEE plans require Commission authorization granted after the filing of an application to amend the license.

Specifically, Verdant seeks agency consultation on the following proposed changes as outlined in Table 1 below. Justification for each of these changes is discussed further in this document:

- Agreement to suspend RMEE-2 Seasonal DIDSON Monitoring
- Agreement to suspend RMEE-3 Seasonal Species Characterization
- Agreement to enhance RMEE-4 Tagged Species Detection
- Agreement to modify RMEE-6 Underwater Sound Monitoring

The remaining approved RMEE plans – 5 and 7 – will be executed as planned.

Following consultation, Verdant hopes to arrive at concurrence with the resource agencies on these proposed modifications and submit a License amendment for Install B-1.

---

[1] Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output", Bevelhimer, M., Colby, J., Adonizio M.A., Tomichek, C., Scheleris, C., ORNL/TM-2016-219, July 2016.

Table 1. Summary of RMEE Plans (Install B-1) and Proposed Changes

Plan	Name	Scale	Operational Monitoring Objectives	RITE Install B-1 (2020) 3 Gen5 Turbines on 1 TriFrame	Proposed Changes
RMEE-2	Seasonal DIDSON Observation	Micro	KHPS-Fish Interaction	3 weeks during Sept - Dec	*Suspend*
RMEE-3	Seasonal Species Characterization Netting	Macro	Species Netting	Six days during Spring and Fall	*Suspend*
RMEE-4	Tagged Species Detection	Macro	Detection of ESA and other tagged species	April - November *Revised to year-round*	*Execute with enhancements*[2]
RMEE-5	Seasonal Bird Observation	Meso and Macro	Bird population interaction with and reaction to KHPS	11 days seasonal during Spring and Fall	None (execute as planned)
RMEE-6	Underwater Sound Monitoring and Evaluation	Micro, Meso, and Macro	KHPS Noise Signature and effects on aquatic species	Stationary: 1 near-field location (1 month); 3 far-field locations (1 week)	*Modify to two far-field locations*
RMEE-7	Recreational Observation	Macro	Recreation impacts of field	1 year after deployment	None (execute as planned)

As shown in Figure 1, under an adaptive management framework, and consistent with the Pilot License requirements:

- Monitoring is conducted;
- Adjustments or modifications (including suspending studies) are to be considered as the project advances;
- Operations can be adjusted if warranted; and
- As required, "*the project can be shut-down at any time*" should environmental effects be observed.

This fundamental concept underlies the Pilot project operation and has been the consistent application since the 2006 implementation of the RITE Project.

---

[2] At the January 2019 Joint Agency Meeting, Verdant was optimistic that an RMEE-4T triangulation concept could be implemented, however it was subsequently discovered that the fish tags used by researchers are not compatible with the receivers necessary to achieve triangulation, and therefore Verdant offers an enhanced RMEE-4 plan to provide additional detections in the East Channel of the East River.

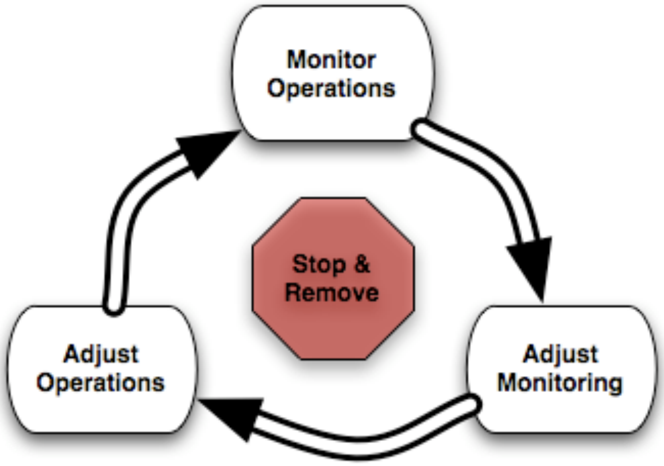


Figure 1. Schematic of Adaptive Management Framework

As approved in the RITE Pilot License, the fundamental questions respective to these plans are as follows:

- *RMEE-2: How do fish behave around an operating turbine?*
- *RMEE-3: What is the species characterization at RITE?*
- *RMEE-4: What is the detected presence, distribution and frequency of tagged fish?*
- *RMEE-5: What is the seasonal presence, and abundance of birds?*
- *RMEE-6: What is the operating noise signature of the turbines and will it affect fish?*
- *RMEE-7: What is the recreational usage at RITE?*

Therefore, as we approach this review of the suite of RMEE plans and how best to implement the monitoring of the Gen5 turbines and TriFrame, we seek to provide the best solutions to provide the most complete understanding of the fundamental questions of each RMEE plan, given the body of information developed since the project inception.

RMEE-2 – Seasonal DIDSON Observation (NYSDEC WQC 11)

a. Background and Objectives

A full overview of the body of information developed under this plan was provided to the agencies in 2018 under the P-12611- Addendum to Verdant Power RITE Draft License Application (August 2018).

As shown in Figure RMEE-2A, Verdant, during the 2012 In-Water Test (IWT) of the Gen5b KHPS turbine rotor, installed and operated a remotely aimable DIDSON (RAD) unit near the operating dynamometer turbine at RITE (this $175K effort was supported by co-funding from NYSERDA). A significant data set was collected over 2+ weeks with and without turbine operation. In conjunction with Oak Ridge National Laboratory (ORNL) and with co-funding support from the US Department of Energy, Verdant and ORNL re-evaluated the 2012 DIDSON data using automated data processing techniques conducted by a Ph.D. researcher. Their findings[3] included the following [emphasis added]:

> *In conclusion, we found <u>no evidence that fish were regularly struck by turbine blades</u> at the RITE site, and we believe that the likelihood is quite low based on several lines of evidence: the low probability that fish would directly encounter a turbine (Wilson et al. 2007), the apparent long range avoidance seen in this study and another study (Viehman and Zydlewski 2015), the apparent ability of most fish to avoid rotor blades when they are encountered at close range (Amaral et al. 2010, 2015), and the paucity of evidence for direct blade strikes. However, based on the relative <u>number of fish tracks identified</u> under the different turbine conditions, the results of this study do suggest that avoidance might be occurring at a distance beyond the 10–15-m range of the DIDSON system.*

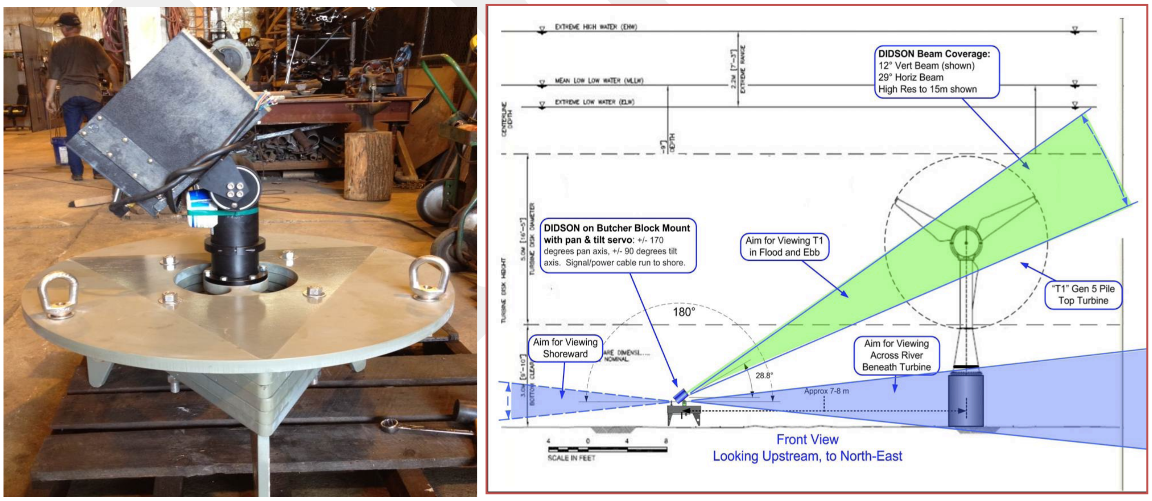


Figure RMEE-2A. DIDSON as deployed at RITE in 2012

---

[3] Taken from Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output", Bevelhimer, M., Colby, J., Adonizio M.A., Tomichek, C., Scheleris, C., ORNL/TM-2016-219, July 2016

The following outlines the objective of the RMEE-2 plan under the RITE Pilot License, as annotated by Verdant *(red italics)*:

> *The objective of the seasonal DIDSON observation is to:*
>
> 1. *Provide real-time observation of fish behavior near operating KHPS during a seasonal period of known fish abundance. Specifically, the goal is to provide imaging of any fish/KHPS interaction, both spatial and temporal, at the micro scale around a rotating turbine. Parameters that can be observed from the DIDSON will include:*
>   - *fish swimming location and direction relative to the turbine blades Achieved*
>   - *fish passage through or around the turbine Achieved*
>   - *for fish passing through the turbine, it will be possible in most cases, especially for larger fish, to determine if the fish avoided the blades or was struck Achieved*
>   - *fish size and shape with potentially some species identification, especially for larger individuals (e.g., Atlantic sturgeon, turtles, marine mammals) none observed; species identification not achievable*
>
> 2. *Add value to the body of collected data on fish presence, abundance, movement pattern and species in and around the operating KHPS machine by providing micro-scale details of the fish seen at the meso scale by the SBTs. Achieved*

b. Planning for Install B-1

Verdant has reviewed the conclusions and recommendations of Bevelhimer et al. (2016), which are provided below. In addition, Verdant has examined a possible deployment of the DIDSON on the RAD (see Figure RMEE-2B) and determined that this configuration is unable to insonify all three turbines. Further, as discussed in the ORNL report, the turbulence generated during operation limits the effectiveness of the DIDSON in observing the TriFrame. Based on this, Verdant proposes to suspend the RMEE-2 plan during Install B-1 and instead enhance detection of tagged species under the RMEE-4 plan.

Conclusions and Recommendations from Bevelhimer et al. (2016)

- The objectives of the RMEE-2 plan were achieved in the 2012 observation.

- It is doubtful that further RAD deployments to observe multiple operating turbines is a useful technique at RITE or that it would yield further data. Verdant will probably pursue an adaptive management conclusion of the RMEE-2 effort.

- The review of 239 hours of DIDSON video collected in September 2012 in the presence of an operating Gen5 KHPS turbine revealed no drastic changes in swimming behavior as a result of exposure to the turbine.

- Automated data analysis was a challenge because of the rotating turbine.

- This monitoring protocol is focused as discussed on the observation of a single (or few) operating KHPS turbines at the micro scale. It is likely not applicable for multiple turbines in an array condition. Moving toward such studies, it is recommended that research and development funding for alternative techniques or algorithms be undertaken to address the array condition.

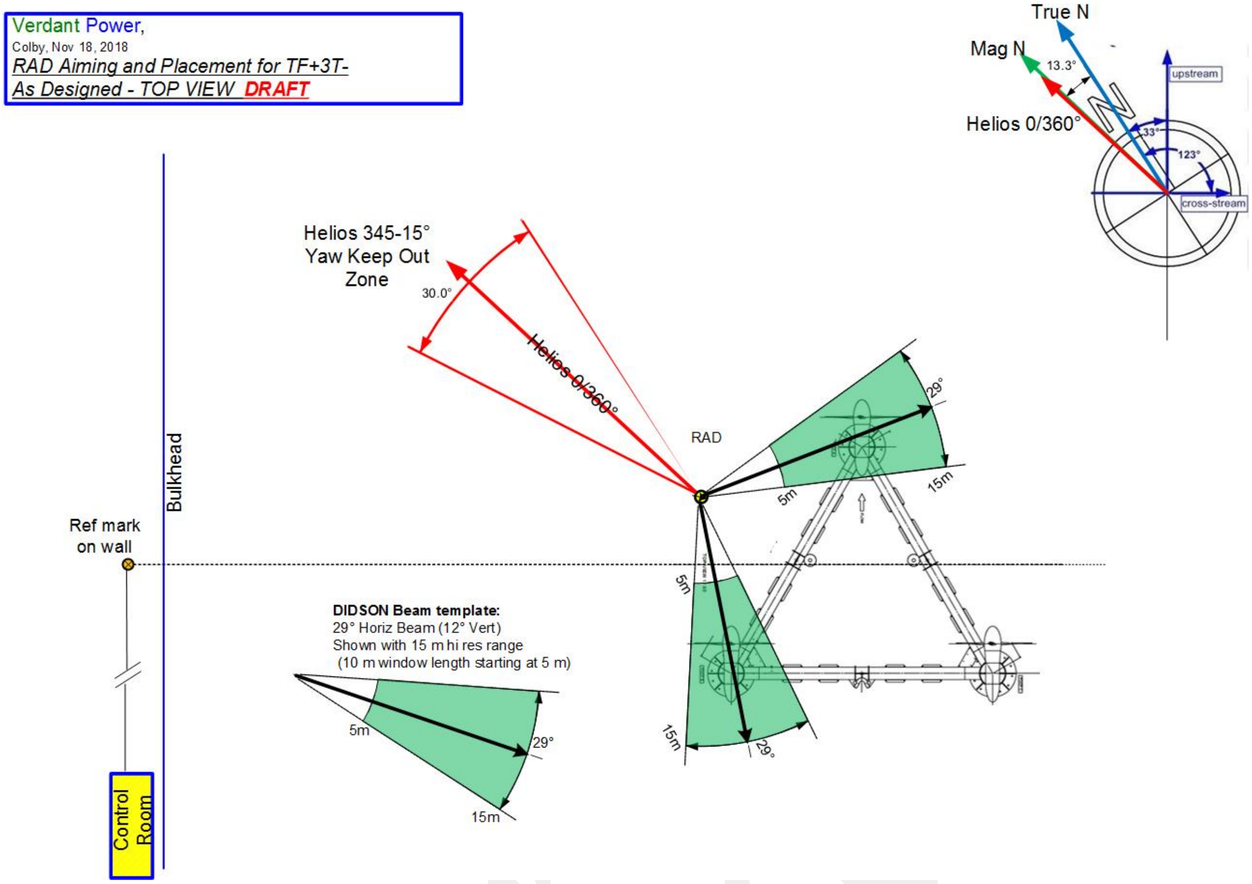


Figure RMEE-2B. DIDSON observing the TriFrame at RITE

c. Verdant Recommendations for RMEE -2

Based on the analysis conducted, it is clear that the DIDSON was a useful tool in imaging the micro-scale impact (or lack thereof) and confirmed the micro-scale absence (and likely avoidance) of fish around an operating turbine.

Further DIDSON data collection and analysis is unlikely to be useful during the RITE Install B-1 as the micro-scale interaction and fish impact has been shown to be de minimis. Additionally, since the biological objectives of the DIDSON observation were achieved in the 2012-2016 analysis, and the focus of the 2019 concerns is for the larger-species EFH and ESA designated fish, ***Verdant recommends the suspension of the RMEE-2 Seasonal DIDSON Observation plan for Install B-1 in favor of enhanced RMEE-4 plan activities, and seeks concurrence from the resource agencies.***

RMEE-3 – Seasonal Species Characterization Netting (NYSDEC WQC 12)

a. Background and Objectives

A full overview of the body of information developed under this plan was provided to the agencies in 2018 under the P-12611- Addendum to Verdant Power RITE Draft License Application (August 2018). This includes a netting effort conducted in May 2013, under both NYS Scientific Collection and Endangered Species Collection permits.

The 2013 netting was conducted in conjunction with Normandeau, using a net designed and acquired by Verdant and analysis by Kleinschmidt (this $20K effort was supported by co-funding from NYSERDA) (see Figure RMEE-3).

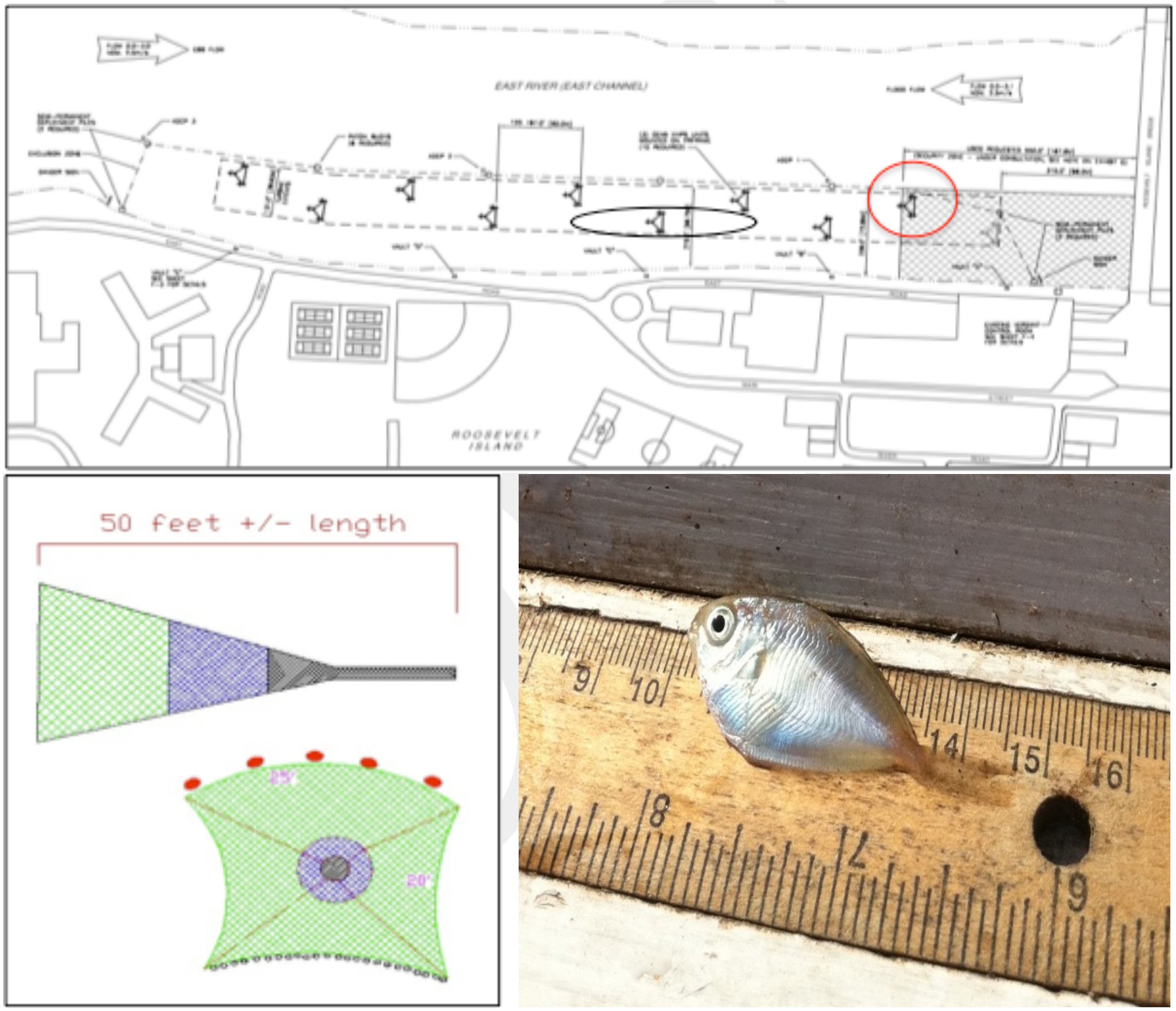


Figure RMEE-3. Stationary Netting at RITE

The following outlines the objective of the RMEE-3 plan under the RITE Pilot License, as annotated by Verdant *(red italics)*:

> *The objective of netting is to provide a set of net capture data, during May through December with more effort during the seasonal period (mid-September through mid-December) of elevated fish abundance in the project vicinity to provide: May 2013 effort provided no information*
>
> 1. *Species characterization information, that combined with the 2006 RITE trawling, and the Ravenswood historical impingement data collected in 1991, 1992, 1993, 1994, 2006 and 2007 provides characterization of the fish assemblage (72 aquatic species identified) in the East Channel, no additional information*
> 2. *Provide species characterization in the immediate vicinity of the turbines that can be used to support the interpretation of the past and future DIDSON monitoring and hydroacoustic evaluations, and no additional information*
> 3. *Potentially provide some observation and/or data for interpretation on potential fish injury due to turbine blade contact in a field of operating KHPS turbines. Very doubtful*

b. Planning for Install B-1

In preparing for the execution of the RMEE-3 plan during Install B-1, Verdant notes the following limitations:

- Review of 2013 effort yielded little knowledge (2 total fish < 50mm) (see Figure RMEE-3)
- Data assemblage, including Ravenswood data, is sufficient
- Execution of netting is dangerous in close proximity to operating turbines in a high energy tidal site
- Renewal of both permits would be required

c. Recommendations for RMEE-3 during Install B-1

Based on the 2013 netting effort, species characterization netting near the RITE Project Area is unlikely to yield meaningful results given the difficulty of netting in strong tidal currents and the general absence of fish in the mid-river. However, extensive fish assemblage data is available from aquatic organism samples collected at Ravenswood Generating Station, which is in close proximity to the RITE Project site. This information was also used in the RITE pilot license application.

In Verdant's opinion, given the level of effort yielding very little relevant information on target species or fish size, it is unlikely that this study will provide any additional information.

Therefore, Verdant recommends the suspension or conclusion of RMEE-3 plan Seasonal Species Characterization Netting during Install B-1 and seeks concurrence from the resource agencies.

RMEE-4 – Tagged Species Detection (NYSDEC WQC 13)

a. Background and Objectives

A full overview of the body of information developed under this plan was provided to the agencies in 2018 under P-12611- Addendum to Verdant Power RITE Draft License Application (August 2018). This includes all the RMEE information collected since license issuance, through 2018.

The following outlines the objective of the RMEE-4 plan under the RITE Pilot License:

> *The objective of this plan is to provide new and unique detections on the potential presence of the proposed ESA listed Atlantic sturgeon, ESA listed shortnose sturgeon, along with striped bass, bluefish, winter flounder and other species that have been acoustically tagged. Detection would occur in both the east and west channels of the East River, proximate to the RITE Pilot project boundary. Once that is achieved, based on collected data, revision and updated evaluation of species with respect to Installs B-1, B-2 and C will occur.*

Verdant acknowledged the importance of this study and beginning in 2011 and through 2018 voluntarily installed VEMCO tagged species detection hydrophones (VR2W - 69kHz) in both the East and West Channels of the East River to gain information on fish passing near the KHPS at RITE (see Figure RMEE-4-Rev 2010). Under the Pilot License, the RMEE-4 plan required detection active during April to November; however, Verdant has voluntarily extended this to year-round collection where possible, and as limited by battery life.

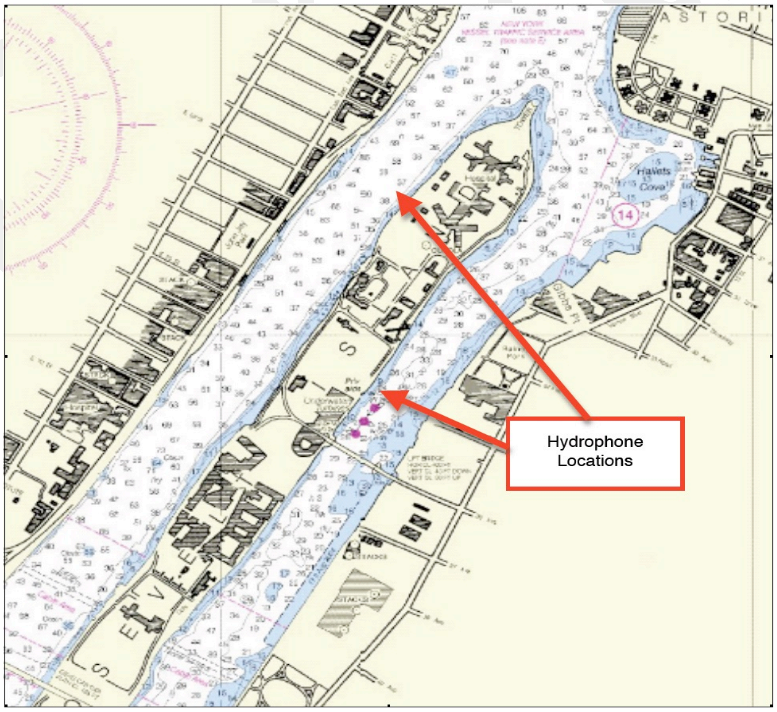


Figure RMEE-4-Rev 2010. RMEE-4 Tagged Species Detection - Hydrophone locations at RITE

Two acknowledged limitations of this plan are as follows:

- Effective only if researchers tagging fish participate in mutual data exchange
- The single platform as deployed in the East Channel detects presence (within 400m) but not specific location in relationship to the KHPS

Nonetheless the RMEE-4 plan has provided significant data informing the KHPS-Fish Interaction Model (KFIM), as described in the August 2018 document.

b. Planning for Install B-1

In examining options for the planned Install B-1 deployment, Verdant explored improvements to the RMEE-4 protocol. One option would be to deploy additional VEMCO receivers and tags and conduct analysis on the triangulation of detected tags to spatially locate, in 3-D, a tagged fish and its track as it passes by multiple KHPS turbines.

At the January 2019 Joint Agency Meeting, Verdant was optimistic that a RMEE-4 Triangulation concept could be implemented, however, it was later determined that the fish tags used by researchers are not compatible with this change and therefore Verdant cannot suggest such a modification to this RMEE plan.

While it is possible for Verdant to deploy VEMCO 180 kHz hydrophones in a triangulated platform proximate to the operating Verdant Power TriFrame + 3 turbines during Install B-1, in order to achieve an x-y-z location of a tagged fish, the tags deployed by the researchers are not compatible for this study as they only ping once per minute and do not measure depth.

Fish would need to be tagged with the 180 kHz tag (HR2 with a 5-second ping rate) and also be outfitted with a depth sensor in order to obtain the z (depth) parameter. Unfortunately, Verdant's informal survey of active researchers has indicated that most are only using the 69 kHz tag (ping rate 60 seconds) without depth sensors.

c. Recommendations for RMEE-4 for Install B-1

Based on the above, Verdant will continue the multi-year VEMCO 69 kHz tag detection effort of previously tagged species in both the East and West Channels to provide input to parameters in the assessment of the risk of fish-turbine interaction at the RITE Project. In place of triangulation, Verdant proposes to deploy additional receivers in and around the RITE Project area, as an enhancement to the RMEE-4 plan (see Figure RMEE-4-Rev 2019).

This effort requires cooperation for continued tagging by researchers and data sharing with many organizations, which does pose a potential hurdle to the success of the protocol for both striped bass recovery efforts and the tagging and identification of the ESA species Atlantic sturgeon[4]. Verdant will continue to work with the researchers and believes this ongoing body of information on macro and meso movement of detected species provides important biological information on target species.

---

[4] In 2018 Verdant provided NYSDEC and the researchers all of the raw data (VRL files) collected form the RITE VEMCO receivers, and agreed not to publish any scientific papers, in exchange for identification of tags, solely for the purpose of complying with this FERC license Article 401 plan. To date ~ 15% of the tags detected remain unidentified.

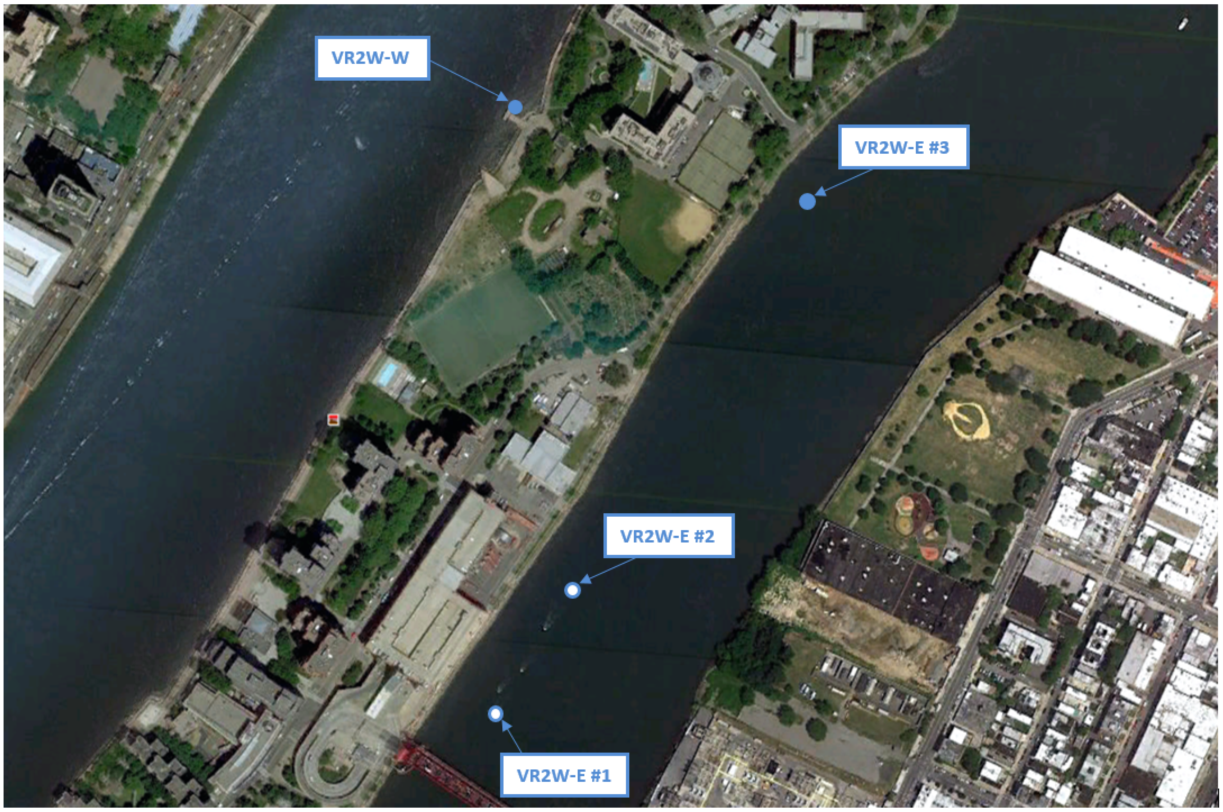


Figure RMEE-4-Rev 2019. RMEE-4 Tagged Species Detection - Proposed hydrophone locations at RITE

RMEE-6 – Underwater Noise Monitoring and Observation (NYSDEC WQC 16)

a. Background and Objectives

While no additional studies have been conducted since the Pilot License issuance on underwater noise, Verdant has explored practical hydrophone applications for accomplishing the RMEE-6 study, including consultation with researchers active in this area and consistency with evolving International standards[5].

The following outlines the objective of the RMEE-6 plan under the RITE Pilot License, as annotated by Verdant:

> *The objective of this study is to:*
>
> - *Determine the noise signature from 6-30 operating Gen5 KHPS turbines and use this information to verify or refute the initial finding that the machines do not emit noise at levels that would cause harm to aquatic resources. This task will include a review of the data on representative species and the physics of sound propagation in shallow water to establish the appropriate spatial and frequency limits for monitoring.*

The approved RMEE-6 hydrophone plan is shown on the Figure RMEE-6-Rev 2010 and includes the following:

- A stationary deployment at the TriFrame site for 1 month
- Three far-field deployments for one week

Figure RMEE-6-Rev 2010. Underwater Noise Monitoring and Observation at RITE

---

[5] The International Electrotechnical Commission (IEC) under Technical Committee (TC) 114: Marine energy – Wave, tidal and other water current converters has progressed the development of IEC Technical Specification (TS) 62600-40, "Acoustic characterization of marine energy converters." Approved 2019-03-09, publication pending.

b. Planning for Install B-1

In preparing for the execution of the RMEE-6 plan during Install B-1, Verdant has developed a tentative design of a stationary hydrophone application for deployment in proximity to the Verdant TriFrame as shown in Figure RMEE-6-Rev 2019. Verdant believes this effort will allow for the answering of the fundamental questions outlined above.

The planned "Snap" Loggerhead Instruments hydrophone will be deployed 100 meters north (as recommended by IEC evolving standard for underwater noise measurements) of the TriFrame to collect 30 days of data in the presence of operating turbines utilizing a battery system.

For far-field noise analysis a similar one-week deployment at two locations as shown in Figure RMEE-6-Rev 2019 will provide far-field noise evaluation. Verdant suggests a modification to the RMEE-6 plan to two rather than 3 locations due to the recent operation of a commuter ferry (Hornblower) in the Hallets Cove location. Analysis of data will be used to answer the fundamental biologic questions.

c. Recommendations for RMEE-6 for Install B-1

In Verdant's opinion, the plan as written can be executed and recommends a modification to two far-field locations based on the recent addition of a ferry terminal in Hallets cove and the likelihood that data collected in the existing third location provides little information relative to the underwater noise of the turbines.

Therefore, Verdant recommends the modification of RMEE-6 Underwater Noise Monitoring plan during Install B-1 to two far-field locations and seeks concurrence from the resource agencies.

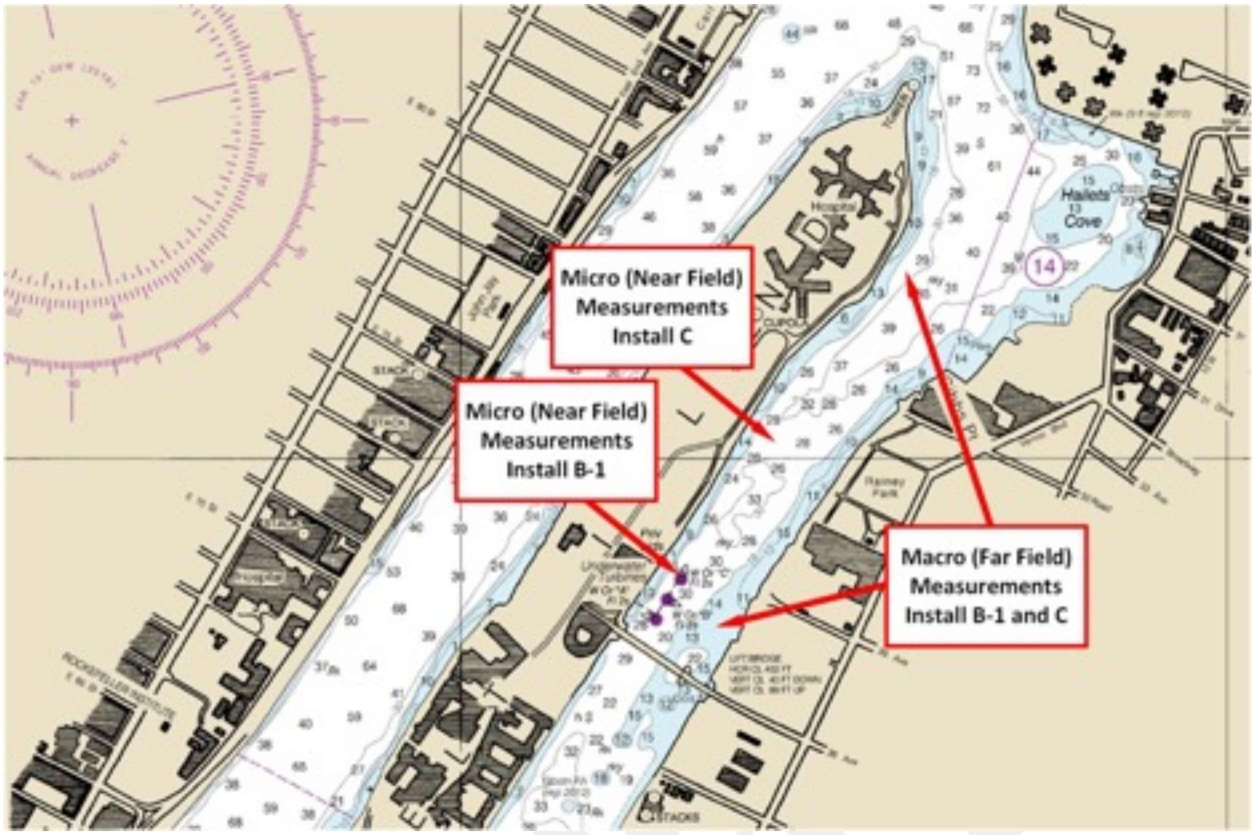


Figure RMEE-6-Rev 2019. Underwater Noise Monitoring and Observation at RITE

Appendix A *[below to be added following occurrence]*

- **Minutes of consultation meetings held March 20 and 22, 2019 with agencies**
- **Correspondence following**

VERDANT POWER

Adaptive Management Review of RMEE Plans for Install B-1 - Roosevelt Island Tidal Energy (RITE) Project
FERC Project No. P-12611

Wednesday, March 20, 2019
1:00 PM EDT

Agenda

VERDANT POWER

1. **Welcome and Verdant Power Perspective: *Ron Smith, Co-Founder & President, Verdant Power***
   - RITE Timeline and Key Moments (2002 - 2019):
     - Regulatory meeting in 2007 - *AHA!*
     - License awarded in 2012 - *First!*
     - DIDSON, ORNL, and KFIM through 2016
     - Data collection from 2006 into 2018

2. **RITE Key Biological Findings: *Chris Tomichek, Kleinschmidt Associates***
   - KHPS-Fish Interaction Model (KFIM) Answers

3. **Adaptive Management Review of Data Collected and Proposed Changes: *Jonathan Colby, Director of Technology Performance, Verdant Power***
   - Data collected
   - Proposed changes to approved RITE Monitoring of Environmental Effects (RMEE) Plans for Pilot Project
   - Next steps - Project Plans & Relicensing (2019 - 2021)

RITE Project Partners

VERDANT POWER

RITE Project Site

nyserda
Energy. Innovation. Solutions.

MRI MANUFACTURING RESOURCES INC.

RAMBOLL

Kleinschmidt

James Fisher and Sons plc
Marine Services Worldwide
Fisher

DONJON MARINE CO., INC.

Ken's Marine services

K-T Marine, Inc.

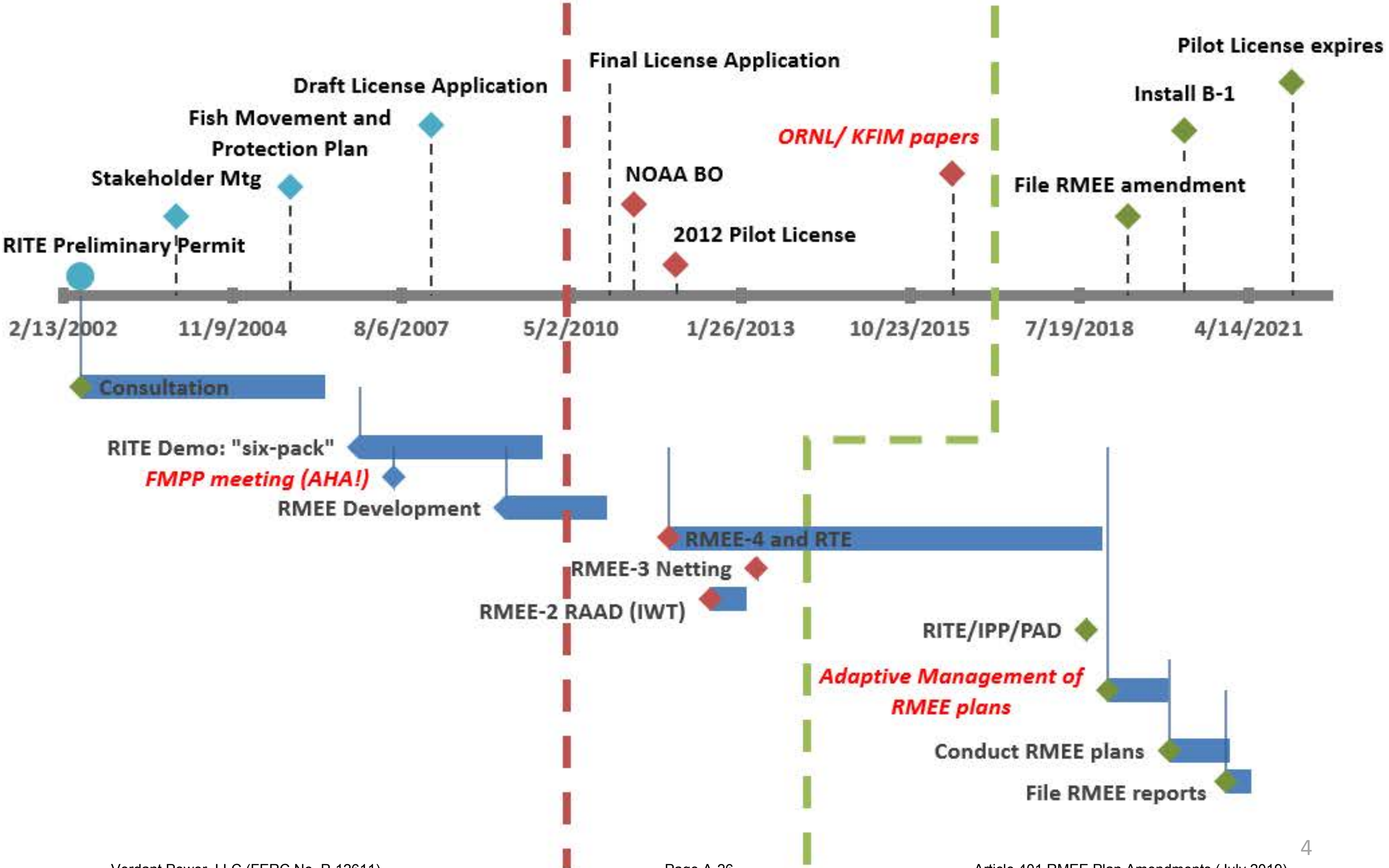
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

CORNELL UNIVERSITY FOUNDED A.D. 1865

conEdison

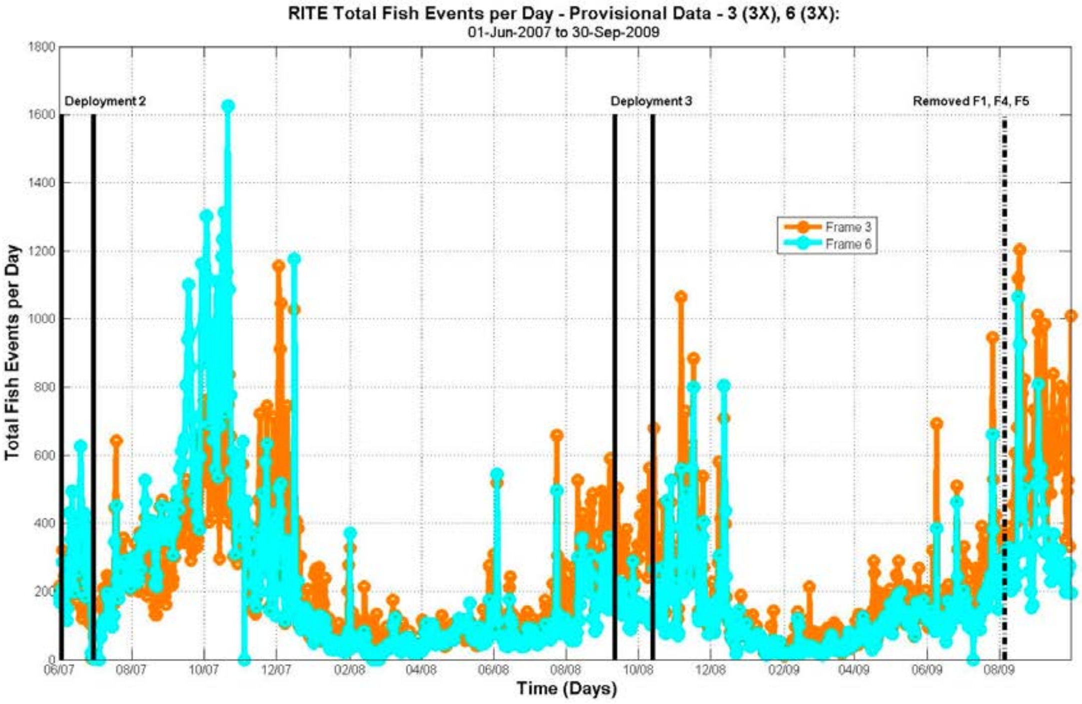
U.S. DEPARTMENT OF ENERGY

RITE Project Timeline

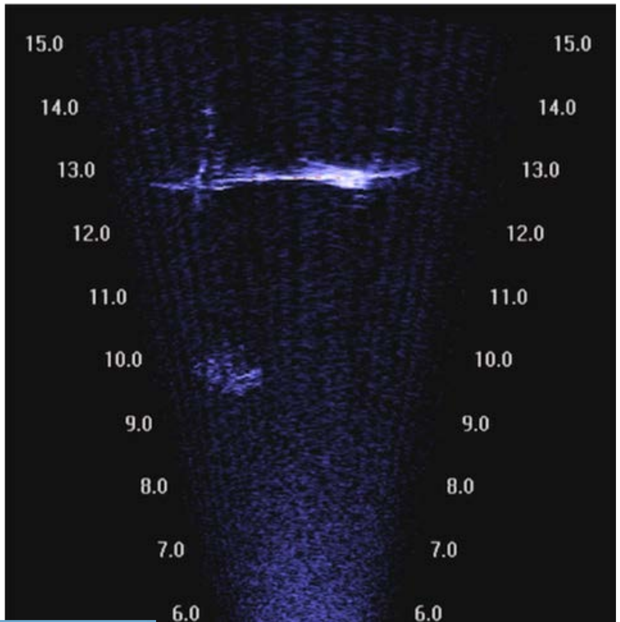


RITE Project: 2002 - 2012
Environmental Study History

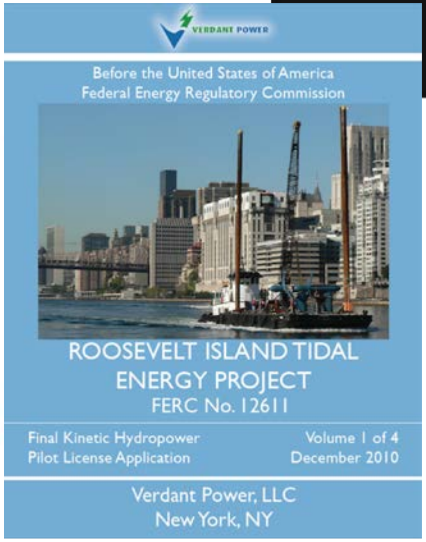
- $3M+ program of environmental studies: Fish, Avian, Noise
- DIDSON, SBT on Fish Frames
- Mobile DIDSON, RAD



SBT Results



DIDSON



VERDANT POWER

Before the United States of America
Federal Energy Regulatory Commission

ROOSEVELT ISLAND TIDAL
ENERGY PROJECT
FERC No. 12611

Final Kinetic Hydropower
Pilot License Application

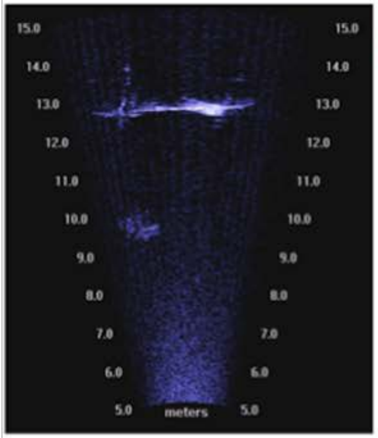
Volume 1 of 4
December 2010

Verdant Power, LLC
New York, NY

FERC FLA

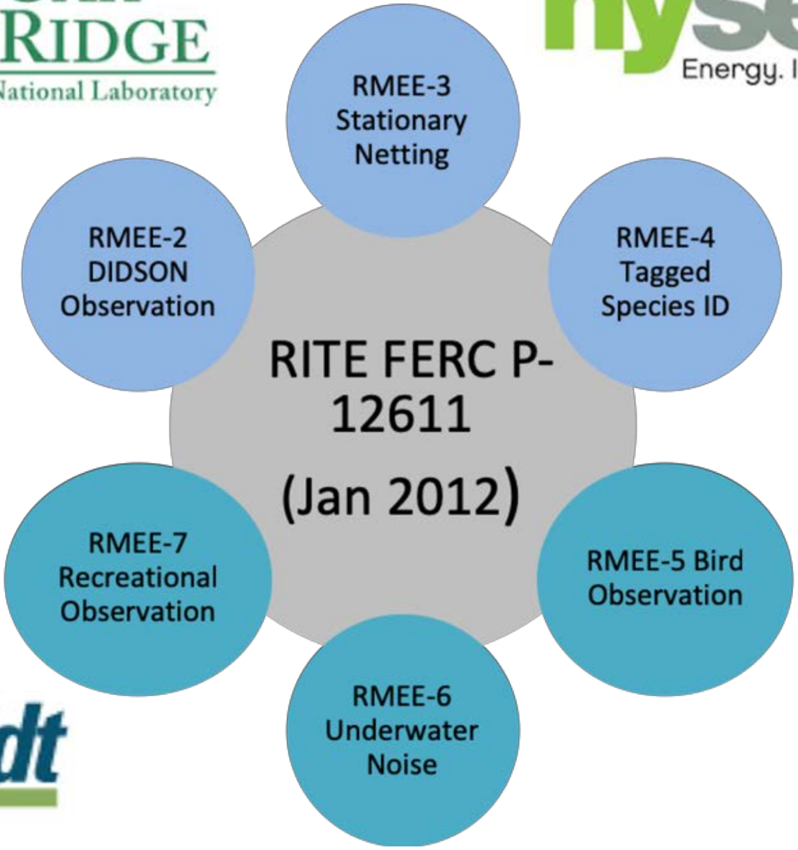
RMEE Plans

RITE Monitoring of Environmental Effects (RMEE) Plans



Oak Ridge National Laboratory

nyserda Energy. Innovation. Solutions.



RITE FERC P-12611 (Jan 2012)

- RMEE-2 DIDSON Observation
- RMEE-3 Stationary Netting
- RMEE-4 Tagged Species ID
- RMEE-5 Bird Observation
- RMEE-6 Underwater Noise
- RMEE-7 Recreational Observation

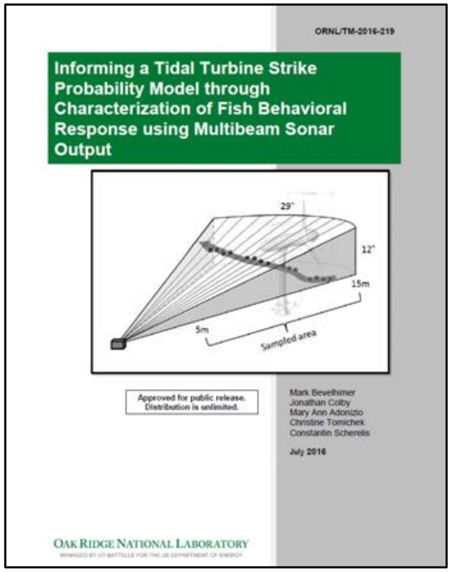
vemco

Kleinschmidt

Cornell University Founded A.D. 1865

RITE Project: 2012 - 2019 Environmental Study History

- RMEE-2: DIDSON video analysis by ORNL
- RMEE-3: Netting (May 2013)
- RMEE-4: VEMCO tagged species ID (>2500 days)
- KHPS-Fish Interaction Model (KFIM) parameter updates
- RTE filings 2012 - 2018


ORNL/TM-2016-219

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

Approved for public release.
Distribution is unlimited.

Mark Bevelhimer
Jonathan Colby
Mary Ann Adonizio
Christine Tomichek
Constantin Scherelis

July 2016

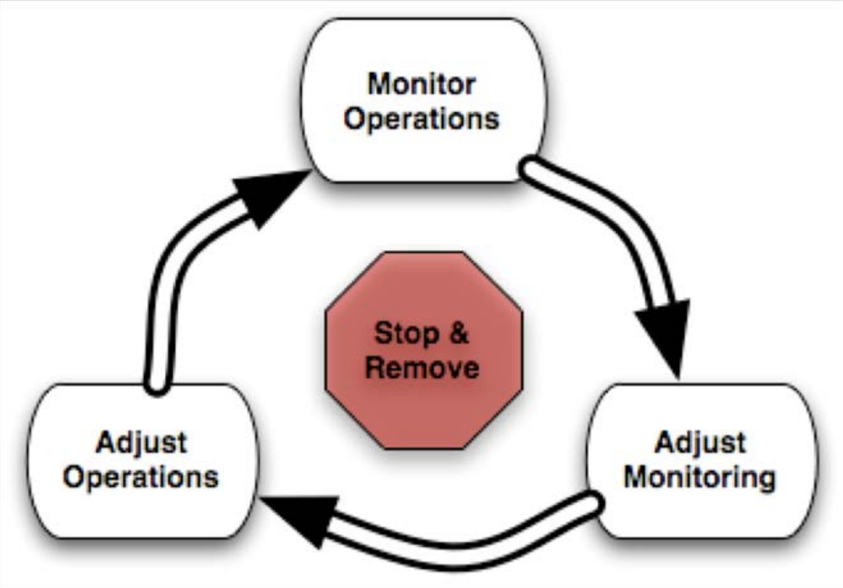
OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

ORNL Report (2016)

RMEE-3 at RITE (2013)

Adaptive Management of the RITE Project - Fundamentals

- Safety Net: Pilot License
  - Biological Opinion on ESA
  - Stop and remove
- RMEE Plans:
  - Established and executed and reviewed
  - Continue, adjust or suspend
- Principles:
  - Match ***prioritized biological issues*** to monitoring scales
  - ***Develop monitoring methods & protocols*** to answer uncertainties
- Methods:
  - Data from the RMEE studies
  - ***KHPS-Fish Interaction Model (KFIM) update parameters***



KHPS-Fish Interaction Model (KFIM)

- **Model Parameters:**

  P1: Probability of Blade Rotation

  P2: Distribution of Water Velocity over the Tidal Cycle

  P3: Fish Distribution (East vs. West Channel)

  P4: Turbine Rotor Area

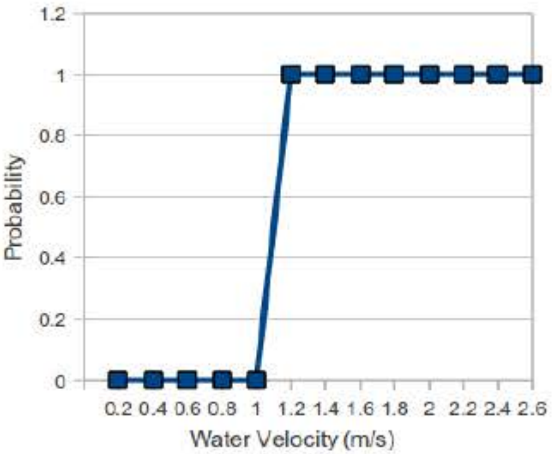
  P5: Blade Interaction with Fish

  P6: Fish Distribution (At Different Velocities)

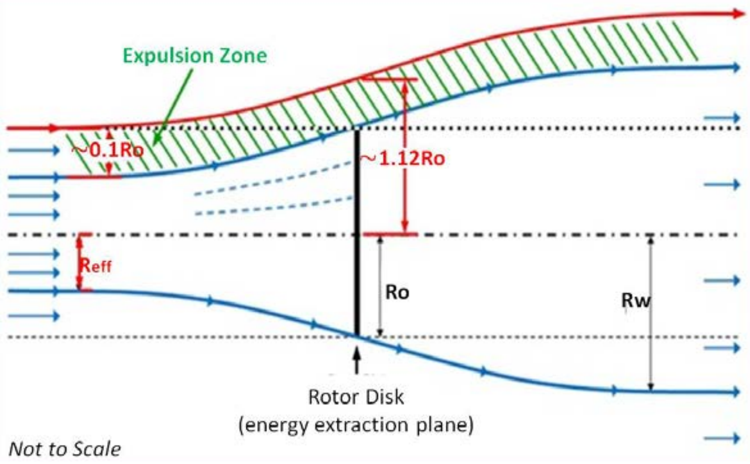
  P7: Avoidance Behavior

$$P_{Strike} = \sum_{V_W=0}^{V_{W,Max}} P1 \cdot P2 \cdot P3 \cdot P4 \cdot P5 \cdot P6 \cdot P7$$

RITE KFIM Model – Key Parameters



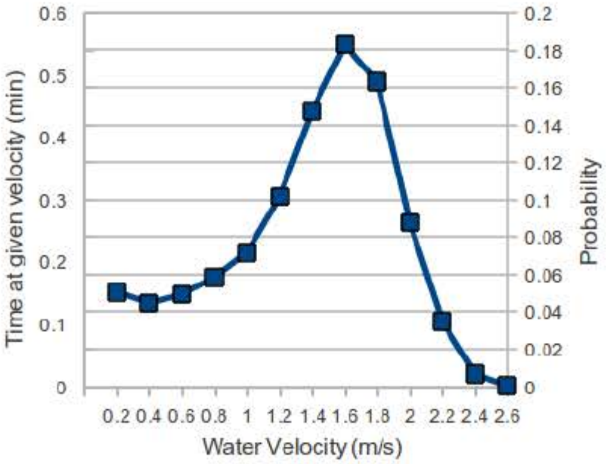
P1: Probability of Blade Rotation



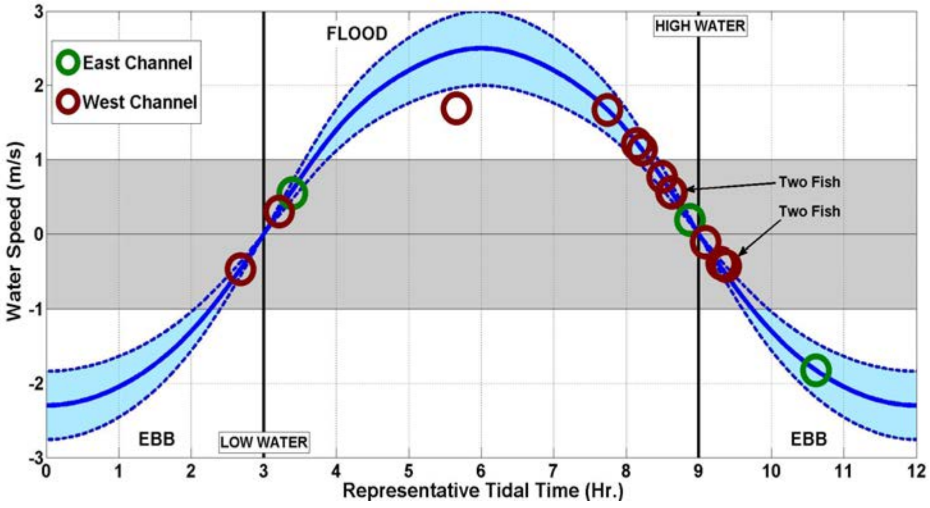
P4: Turbine Rotor Area

$$P5 = nR \times \left(\frac{L \sin(\theta)}{V_w + (V_b \sin(\theta))} \right)$$

P5: Blade Interaction with Fish



P2: Distribution of V_W over the Tidal Cycle



P6: Fish Distribution (At Different V_W)

KFIM Parameter Improvements

All work since 2011 has shown SIGNIFICANT REDUCTION in Risk of ESA and EFH Species Effects

Term	Parameter Description	Relevance	RITE 2010 KFIM	Proposed changes- 2018
P1	Probability of blade rotation	Specific to the KHPS at water velocity Vw of > 1 m/s; varies with tidal site	P1 = 1 at flows greater than 1 m/s, 0 for all flows less than 1 m/s	No change
P2	Distribution of water velocity over the tidal cycle	V_W as measured by ADCPs; varies with tidal site	See measured RITE Vw probability distribution	No change
P3	Fish distribution between east and west channel	An assumed distribution in the configuration of the RITE project	P3 = 0.5	P3 50/50 rule: Concurrent RMEE-4 observations from 2011–2018 suggests 23% use the East Channel. P3 = 0.25
P4	Effective KHPS turbine rotor area	A constant for a 5 m blade	P4 = 0.0066	No change
P5	Blade interaction with fish passing through turbine disk	Varies with shape of rotor, the Vw and presence of the subject of investigation, and the approach angle	P5 follows formulae discussed below. Two major parameters: (1) 80/20 rule: assumes 80% of fish swim with current, 20% against, for Vw less than or equal to the endurance velocity (Ve) (2) Angle of incidence: assumes all fish approach blade from all angles within 180° uniformly	P5 80/20 rule: ORNL work indicates a stronger case for 84%/16% as a setting for P5 P5 Angle of incidence: ORNL work strongly indicates a more narrow angel of incidence of +/- 15 degrees P5 = See modified distribution*
P6	Fish distribution	ESA fish presence in RITE East Channel variation with Vw	P6 = 1 equal likelihood that ESA fish are in east channel	DIDSON and SBT analysis confirms P6 can be lowered. P6 = See modified distribution*
P7	Fish avoidance behavior	Do fish avoid zones of operating turbine	P7 = 1 conservative, no avoidance	DIDSON data seems to show some avoidance. No change

* See detailed reference (2016) next slide

KFIM Results 2010 v. 2016

All work since 2011 has shown SIGNIFICANT REDUCTION in Risk of ESA and EFH Species Effects

Atlantic sturgeon (L = 104cm)

Case	2010 Model	Updated Results
1 Turbine (T)	0.09%	0.006%
2 T	0.17%	0.01%
3 T	0.26%	0.02%
12 T	1.03%	0.07%
30 T	2.59%	0.17%

Black sea bass (L = 25cm)

Case	2010 Model	Updated Results
1 Turbine (T)	0.03%	0.002%
2 T	0.07%	0.003%
3 T	0.10%	0.005%
12 T	0.39%	0.02%
30 T	0.98%	0.05%

"Parameter Updates to Probabilistic Tidal Turbine – Fish Interaction Model"
Tomichek, C., Colby, J., Bevelhimer, M., Adonizio, M.A.
Proceedings of the 4th Marine Energy Technology Symposium (METS), April 2016

Where Are We Today?

Evaluation and Recommendation:

- The body of data collected on fish < 25cm by the DIDSON indicates no adverse effects
- The 2011 NOAA Biological Opinion was acceptable for fish > 25cm and all efforts from the KFIM indicate a much lower risk evaluation
- The biological questions of the RMEE plans are being addressed
- Verdant recommends the following potential amendments be considered:
  - ***Suspend RMEE-2 DIDSON in favor of an enhanced RMEE-4***
  - ***Conclude RMEE-3 Netting in favor of an enhanced RMEE-4***
  - ***Adjust RMEE-4 Tagged Species to an enhanced RMEE-4***
  - ***Adjust RMEE-6 Noise to monitor in 2 rather than 3 locations***

RMEE-2: Seasonal DIDSON Monitoring

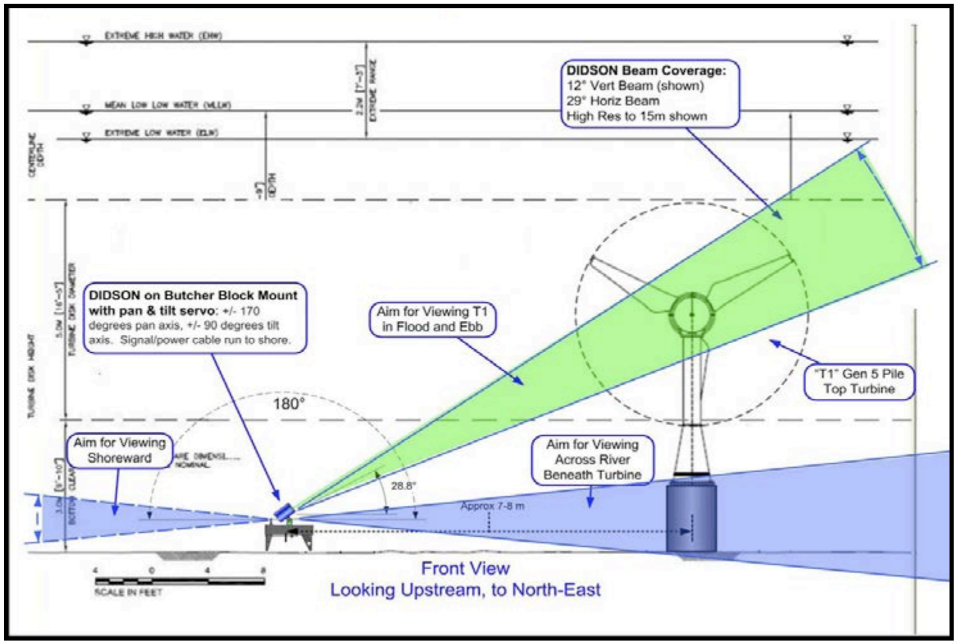
Purpose:
How do fish behave around an operating turbine?

B-1 License Requirements:

- 3 weeks after deployment
- Sept. 15 - Dec. 1
- Agency review and comments

Evaluation:

- How do fish behave around operating turbines?
- Do the observations provide meaning to the body of knowledge and input to the KFIM parameters?



DIDSON Coverage: Single Turbine

RMEE-2: Seasonal DIDSON Monitoring

Studies conducted in Fall 2012 were analyzed by: Oak Ridge National Laboratory

239 hours of DIDSON data with an operating unit was analyzed which equaled approximately 35,000 individual fish tracks.

Direct observations of DIDSON videos found that most individual fish and schools headed toward rotating blades avoided the blades by adjusting their horizontal swimming direction slightly; fewer fish disappeared just before encountering the rotor which would indicate change in vertical position.

A direct contact with the rotor by a large fish (>50 cm) would have been apparent if it had occurred.

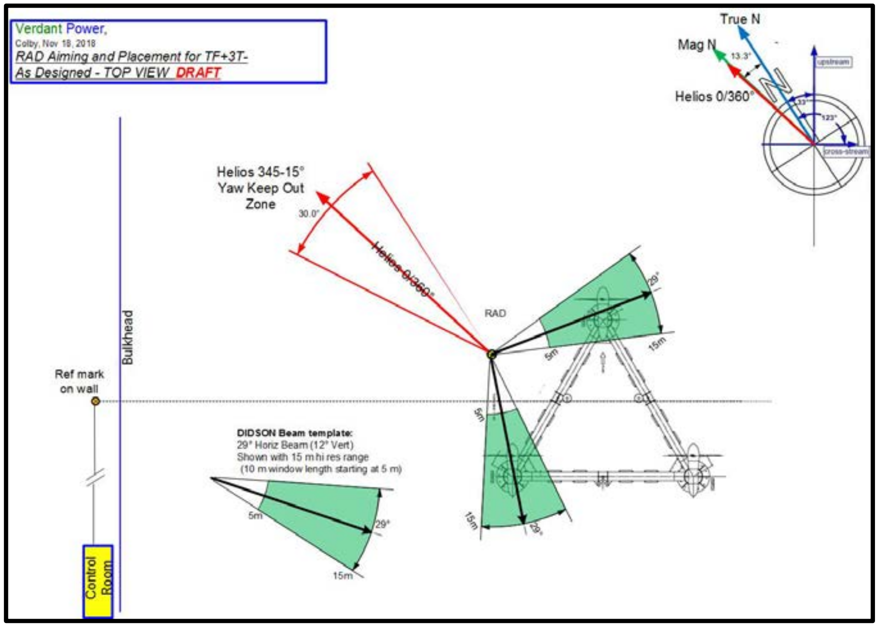
The DIDSON data provide some information about far-field avoidance. Results:
"In conclusion, we found no evidence that fish were regularly struck by turbine blades at the RITE site, and we believe that the likelihood is quite low based on several lines of evidence"

"*Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output*", Bevelhimer, M., Colby, J., Adonizio M.A., Tomichek, C., Scheleris, C., ORNL/TM-2016-219, July 2016

Proposed RMEE-2 Amendment

Evaluation and Recommendation:

- 2012 effort yielded extensive knowledge of operating turbine interaction.
- The study was complex to conduct and analyze e.g. turbulence from a single turbine required filtering of data.
- Data as reported (2016) is appropriate for the model.
- Verdant recommends not repeating this study, instead refocus effort on an enhanced RMEE-4.



DIDSON Coverage: Install B-1

RMEE-3: Seasonal Species Characterization Netting

Purpose:

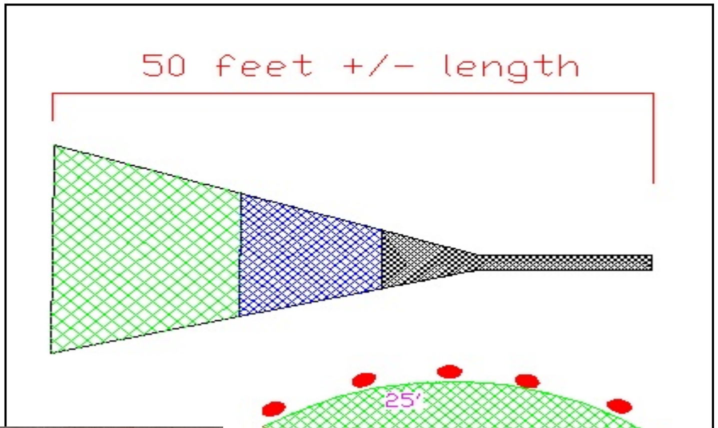
What aquatic species are found at the Project?

B-1 License Requirements:

- 1 day May - June
- 1 day July - August
- 6 days Sept - Dec

Studies Conducted:

Netting conducted in May 2013



RMEE-3 Net

RMEE-3 Butterfish

Results:

Caught during 3 tows:

- 1 *Callinectes sapidus*, blue crab (44 mm); alive; returned unharmed
- 1 *Peprilus triacanthus*, butterfish (37 mm); alive; returned unharmed

Proposed RMEE-3 Amendment

Evaluation and Recommendation:

- 2013 netting effort yielded little data.
- Ravenswood Data was used in FLA to characterize species:
    - Data collected in 1991, 1992, 1993, 1994, 2006 & 2007
    - Total of 72 aquatic species were identified
    - Of those, the top 10 species accounted for almost 75% of the total fish collected
    - 16 of the 72 species identified over all 6 sampling years were only seen one time
- Note that the Ravenswood Data represent the typical species in the New York Bight
- Verdant recommends concluding this study and instead refocusing effort on an enhanced RMEE-4

Top 10 Species Collected in the East River (Ravenswood Data):

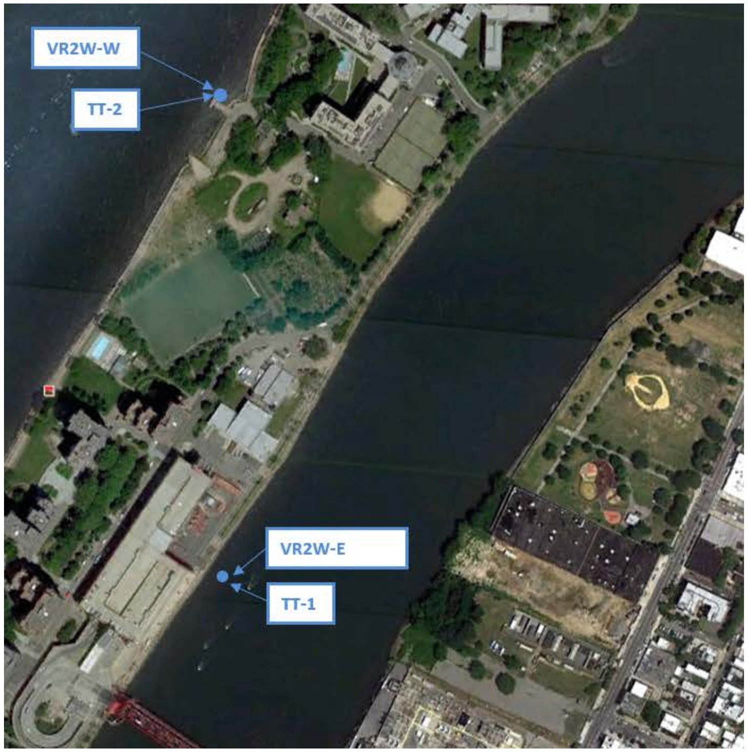
Winter flounder
Blueback herring
Grubby
Northern pipefish
Sea horse
Smallmouth flounder
Atlantic herring
Atlantic silverside
Northern searobin
Bay anchovy

RMEE-4: Tagged Species Detection

Purpose:
What is the detected presence, distribution and frequency of tagged fish?

B-1 License Requirements:
- VEMCO in West Channel and East Channel (where project is located)
- Revised to year-round data collection
- Tag ID and reporting in cooperation with researchers and agencies

Evaluation:
- What is the detected presence, distribution, and frequency of tagged fish in the East River?
- What can be postulated from this data as to the potential interaction of these species with operating turbines?



RMEE-4 Locations: 2017-2018

RMEE-4: What We Know

What we did:

- 2400+ days of data collection in East and West channels (6.5+ years of data)
- Voluntary (not required yet)
- 334 tagged fish events
- 143 unique ID detections
- 29 Atlantic sturgeon (ESA) (~108 cm)
- 252 stripped bass (> 50cm)
- 50 unknown species

Results:

- 23% of all detections are in the East Channel (77% in west)
- 12 total fish detections per year in the East Channel v. 40 in the West
- 19% of all Atlantic Sturgeon detections are in the East Channel (81% in West)
- 0.86 Atlantic Sturgeon detections per year in the East Channel v. 3.61 in the West

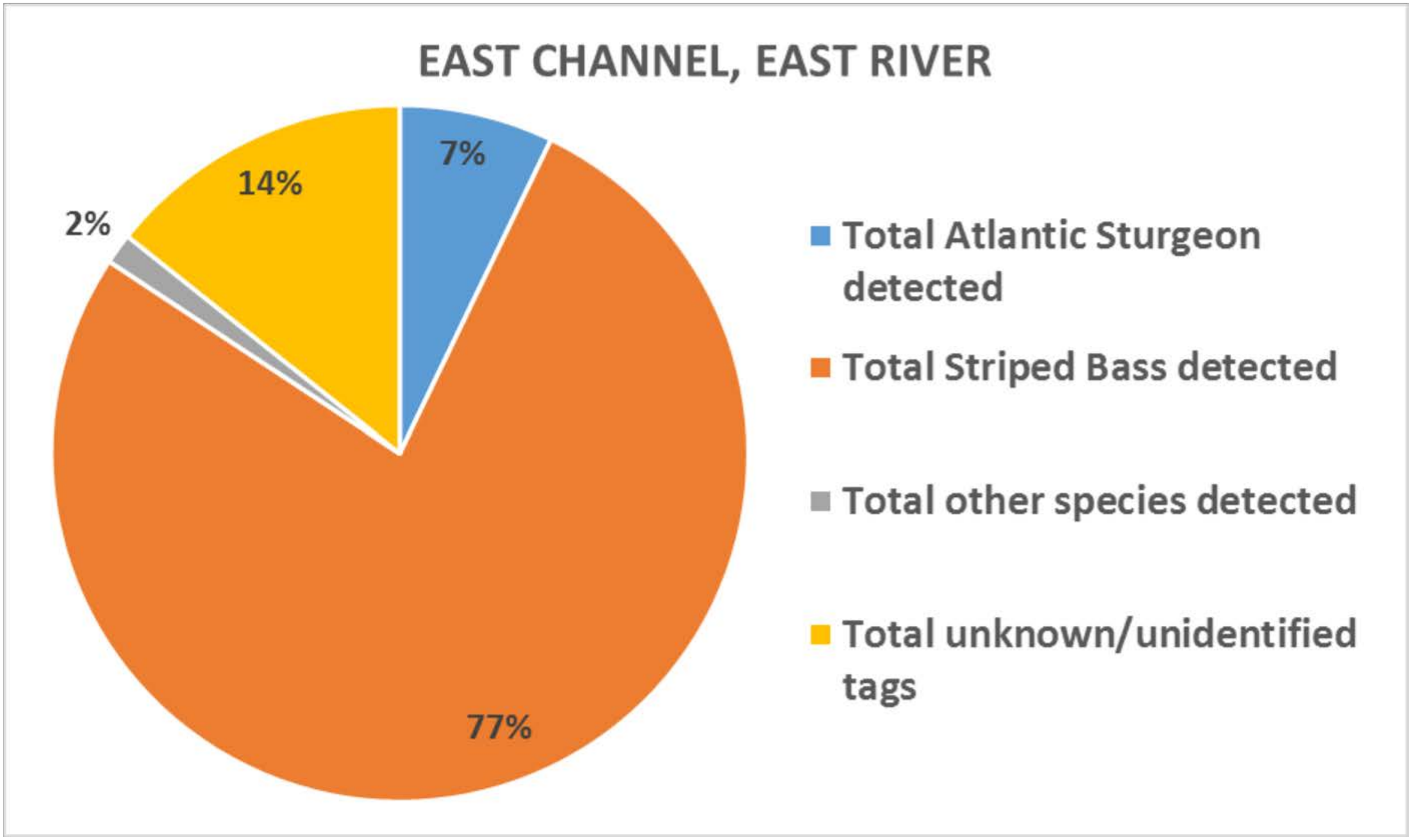
Knowledge:

- Know that a tagged fished passed within 400m from receiver
- Know the time, cross-reference to the tide
- Know the unique tag ID
- Simple, robust equipment functions in both channels

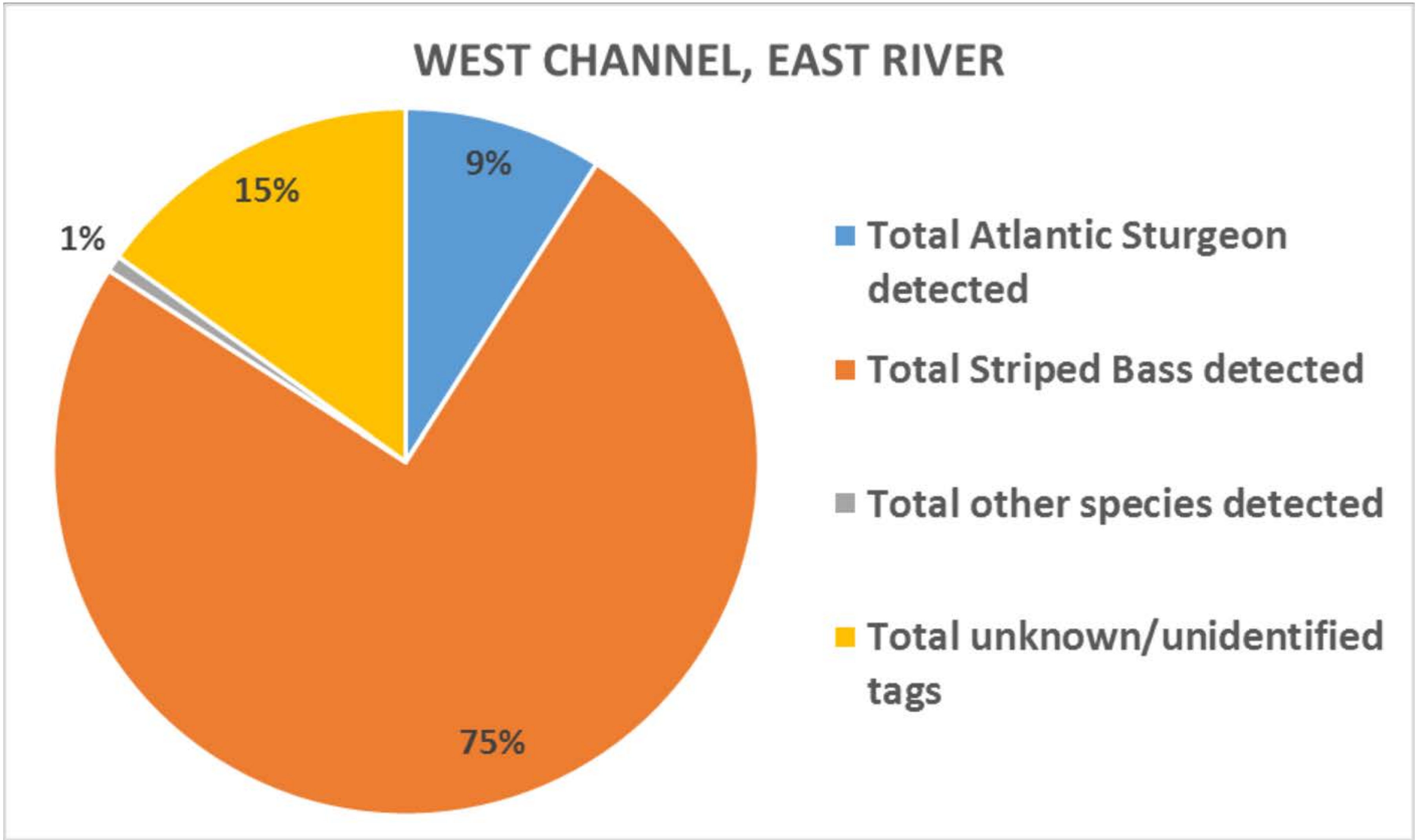
Limitations:

- Don’t know the location relative to receiver
- Don’t know track of fish
- Don’t know species without collaboration with researchers
- Don’t know total number of tagged fish

RMEE-4: What We Know



RMEE-4: What We Know



Proposed RMEE-4 Amendment

Studies Conducted:

2011 - 2018 (2400+ days = 6.5+ years of data)

Results:

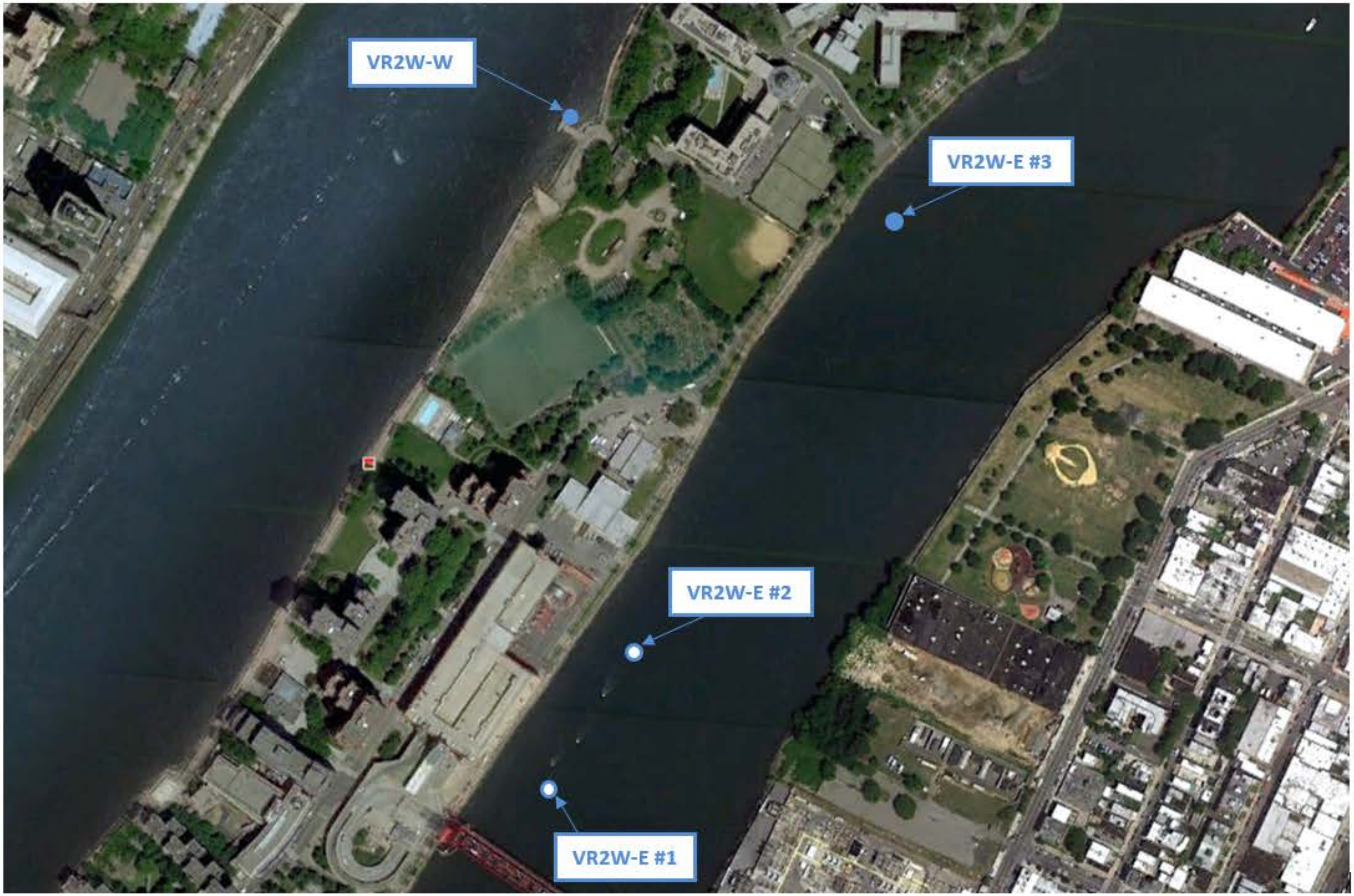
- Confirmed/improved KFIM parameters
- Robust equipment

Evaluation and Recommendation:

- Replace RMEE-2 and RMEE-3 with enhanced RMEE-4
- RMEE-2 complex to conduct and the 2012 effort yielded extensive knowledge of operating turbine interaction
- RMEE-3 Ravenswood Data provides a good characterization of fish in Project area
- Verdant recommends enhancing the RMEE-4 study with additional receivers in the East Channel (3 TOTAL) if RMEE-2 and RMEE-3 are waived

VEMCO VR2W

Proposed Enhanced RMEE-4 Amendment



RMEE-4 Locations: As Proposed

RMEE-5: Seasonal Bird Observation

Purpose:

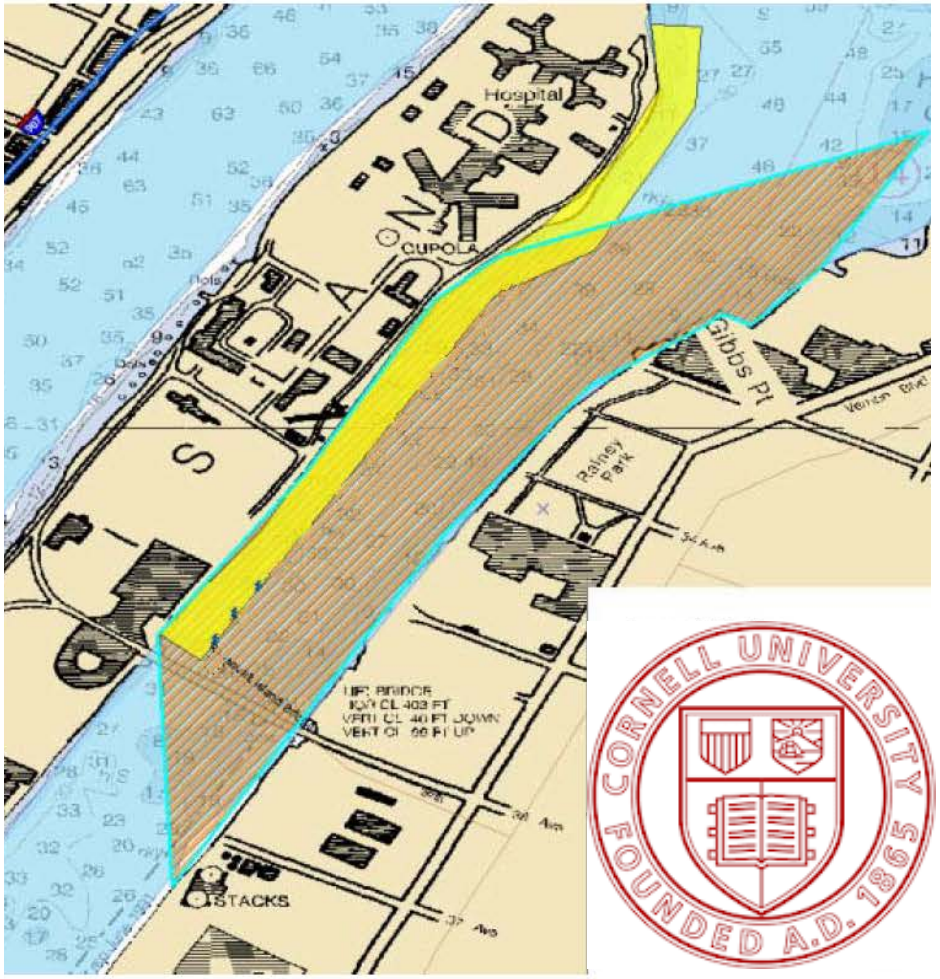
What is the seasonal presence, and abundance of birds?

License Requirements:

- 11 days seasonal Spring and Fall near operating turbines

Evaluation:

- Analyze seasonal presence abundance and activity of bird populations with operating KHPS turbines



Bird Observation Range

RMEE-6: Underwater Noise Monitoring and Evaluation

Purpose:

What is the operating noise signature of the turbines and will it affect fish?

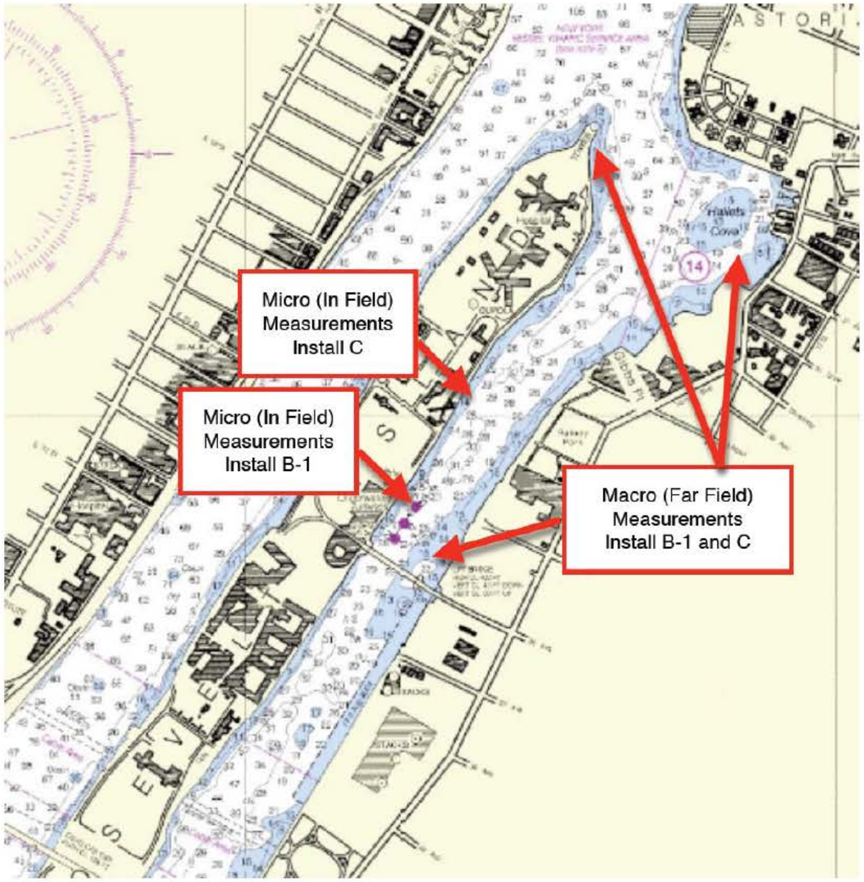
License Requirements:

Place Hydrophone monitoring at:

- 1 month near operating turbines
- One week at three (3) far-field locations

Evaluation:

- Analyze data to confirm Pilot understanding that the additional, if any, underwater noise from operating Gen5 turbines does not increase the ambient noise present in the East Channel



RMEE-6 Locations: As Licensed

Proposed RMEE-6 Amendment

Studies Conducted:

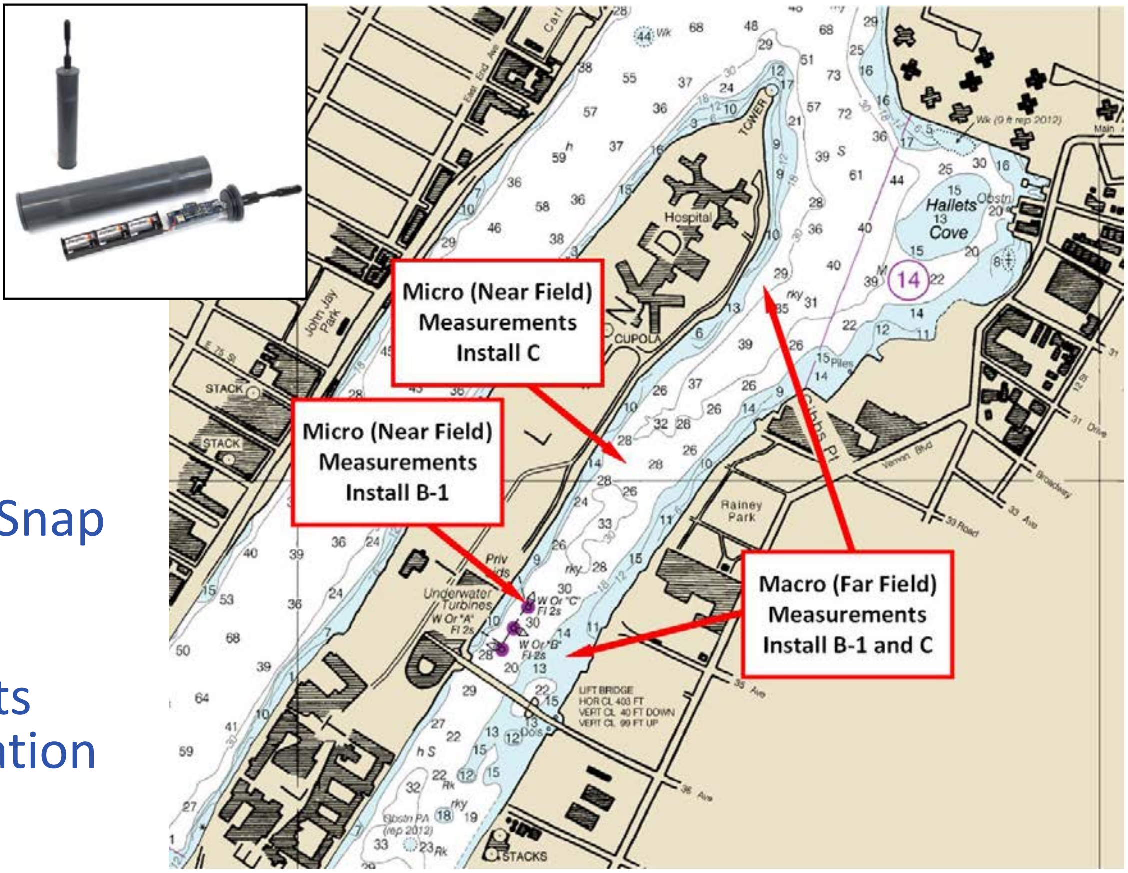
- None to date

Results:

- None to date

Evaluation and Recommendation:

- Conduct effort as planned using Snap Loggerhead Instruments hydrophones
- Modify location to remove Hallets point location due to Ferry operation



Micro (Near Field) Measurements Install C

Micro (Near Field) Measurements Install B-1

Macro (Far Field) Measurements Install B-1 and C

RMEE-6 Locations: As Proposed

RMEE-7: Recreation Monitoring

Purpose:

What is the recreational usage at RITE?

License/WQC #17 Requirements:

- 1-year after deployment
- Annual recreation use figures
- Methodology
- Agency review and comments

Evaluation:

- Is the Project exclusion zone affecting recreational use?

RMEE-7 Locations: As Licensed

Potential Amendment Answers to Biological Questions

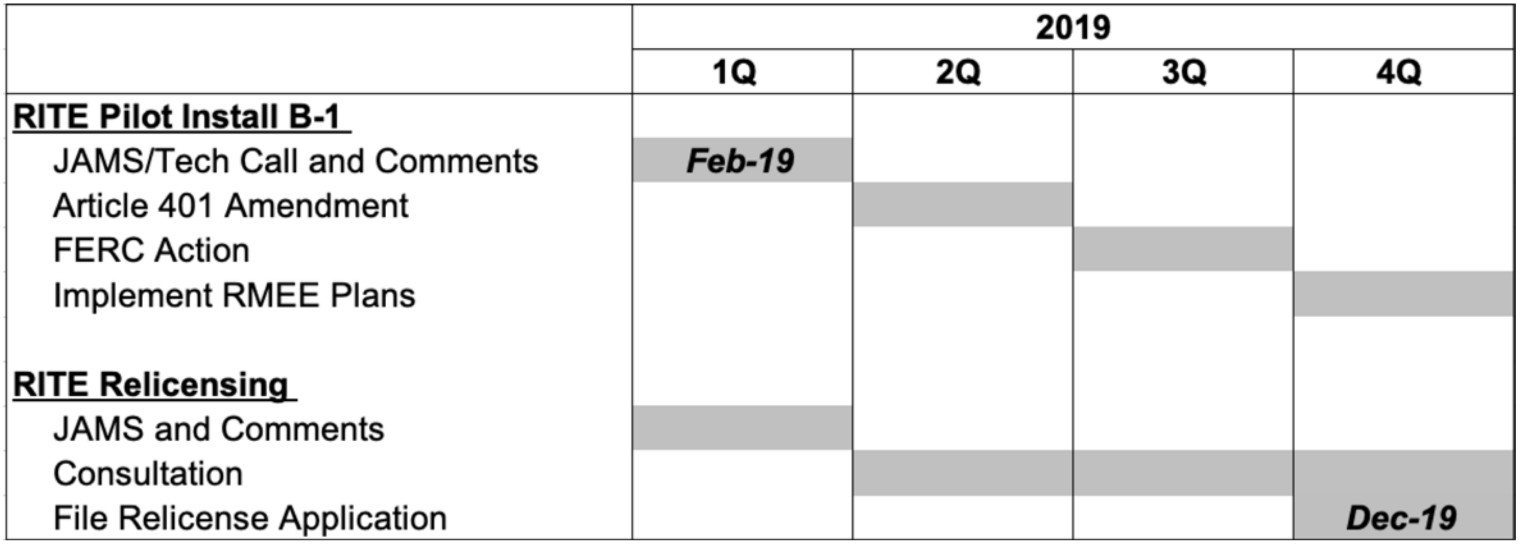
- **RMEE-2: How do fish behave around an operating turbine?**
  - Enhanced RMEE-4 will continue to answer this and further inform KFIM.
- **RMEE-3: What is the species characterization at RITE?**
  - We know from Ravenswood; Enhanced RMEE-4 will provide information on the species of striped bass and Atlantic sturgeon.
- **RMEE-4: What is the detected presence, distribution, and frequency of tagged fish?**
  - Enhanced RMEE-4 will provide additional information on key species.
- **RMEE-5: What is the seasonal presence and abundance of birds?**
  - Study to be conducted with Cornell University will enhance understanding.
- **RMEE-6: What is the operating noise signature of the turbines and will it affect fish?**
  - Study will quantify noise signature around three turbines on TriFrame.
- **RMEE-7: What is the recreational usage at RITE?**
  - Observations will start in 2019 – limited shoreline, mostly kayaks and jet skis.

Discussion and Reaction?

Plan	Name	Scale	Operational Monitoring Objectives	Install B-1 2020 3 Gen5 Turbines on 1 TriFrame	Proposed Changes
RMEE-2	Seasonal DIDSON Observation	Micro	KHPS-Fish Interaction	3 weeks during Sept-Dec	***Suspend***
RMEE-3	Seasonal Species Characterization Netting	Macro	Species Netting	Six days - Spring and Fall	***Suspend***
RMEE-4	Tagged Species Detection	Macro;	Detection of ESA and other tagged species	April to November - ***Revised to year-round***	***Execute with enhancements***
RMEE-5	Seasonal Bird Observation	Meso and Macro	Bird population interaction with and reaction to KHPS	11 days seasonal - Spring and Fall	None (Execute as planned)
RMEE-6	Underwater Sound Monitoring and Evaluation	Micro, Meso and Macro	Gen5 KHPS Noise Signature and effects on aquatic species	Stationary: 1 near-field location (1 month) 3 far-field locations (1 week)	***Modify to two far-field locations***
RMEE-7	Recreational Observation	Macro	Recreation impacts of field	1 year after deployment	None (Execute as planned)

P-12611 Pilot Project Article 401 RMEE Amendment – Next Steps

- File agreed amendment to FERC May 2019 and FERC action
- Implement Revised RMEE Plans during 2020 Install B-1, which *informs relicensing*



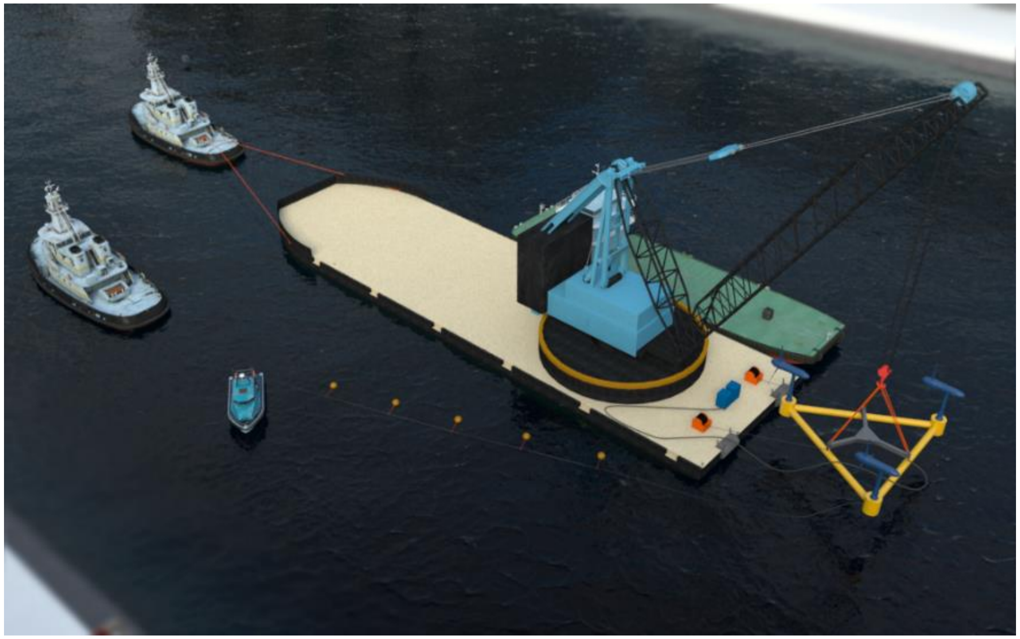
	2019			
	1Q	**2Q**	**3Q**	**4Q**
RITE Pilot Install B-1				
JAMS/Tech Call and Comments	▨ ***Feb-19***			
Article 401 Amendment		▨		
FERC Action			▨	
Implement RMEE Plans				▨
RITE Relicensing				
JAMS and Comments	▨			
Consultation		▨	▨	▨
File Relicense Application				▨ ***Dec-19***

Thank You

Comments via E-Mail:

riteproject@verdantpower.com

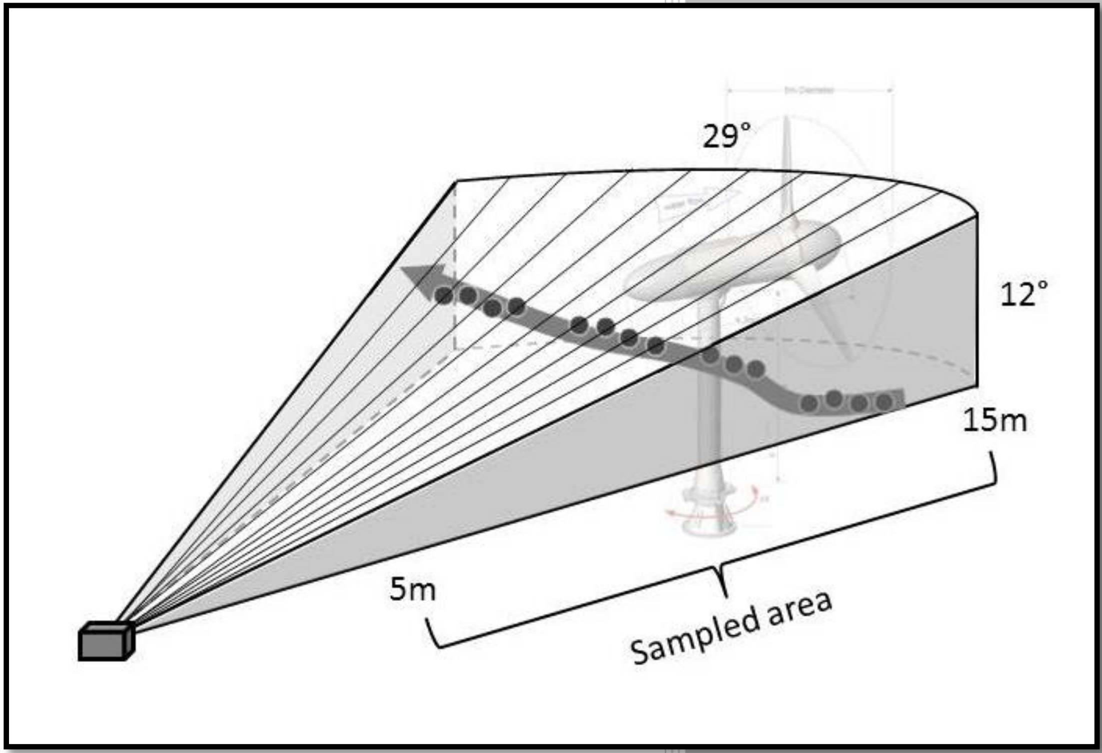
Gen4 KHPS RITE Deployment



Gen5 KHPS RITE Deployment - Schematic

ORNL/TM-2016-219

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



Mark Bevelhimer
Jonathan Colby
Mary Ann Adonizio
Christine Tomichek
Constantin Scherelis

July 2016

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

DOCUMENT AVAILABILITY

Reports produced after January 1, 1996, are generally available free via US Department of Energy (DOE) SciTech Connect.

Website http://www.osti.gov/scitech/

Reports produced before January 1, 1996, may be purchased by members of the public from the following source:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone 703-605-6000 (1-800-553-6847)
TDD 703-487-4639
Fax 703-605-6900
E-mail info@ntis.gov
Website http://www.ntis.gov/help/ordermethods.aspx

Reports are available to DOE employees, DOE contractors, Energy Technology Data Exchange representatives, and International Nuclear Information System representatives from the following source:

Office of Scientific and Technical Information
PO Box 62
Oak Ridge, TN 37831
Telephone 865-576-8401
Fax 865-576-5728
E-mail reports@osti.gov
Website http://www.osti.gov/contact.html

ORNL/TM-2016/219

Environmental Sciences Division

INFORMING A TIDAL TURBINE STRIKE PROBABILITY MODEL THROUGH CHARACTERIZATION OF FISH BEHAVIORAL RESPONSE USING MULTIBEAM SONAR OUTPUT

ORNL/Verdant

Mark Bevelhimer, Oak Ridge National Laboratory
Jonathan Colby, Verdant Power
Mary Ann Adonizio, Verdant Power
Christine Tomichek, Kleinschmidt Associates
Constantin Scherelis, Oak Ridge National Laboratory

Date Published: July 2016

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831-6283
managed by
UT-BATTELLE, LLC
for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 PHYSICAL INTERACTIONS WITH HYDROKINETIC TURBINES

1.1.1 What Is the Issue?

One of the most important biological questions facing the marine and hydrokinetic (MHK) energy industry is whether fish and marine mammals that encounter MHK devices are likely to be struck by moving components. For hydrokinetic[1] (HK) devices, i.e., those that generate energy from flowing water, this concern is greatest for large organisms because their increased length increases the probability that they will be struck as they pass through the area of blade sweep and because their increased mass means that the force absorbed if struck is greater and potentially more damaging (Amaral et al. 2015). Key to answering this question is understanding whether aquatic organisms change their swimming behavior as they encounter a device in a way that decreases their likelihood of being struck and possibly injured by the device. Whether near-field or far-field behavior results in general avoidance of or attraction to HK devices is a significant factor in the possible risk of physical contact with rotating turbine blades (Cada and Bevelhimer 2011).

Although numerous hydrokinetic device designs are under development (see DOE 2009 for a description of the technologies and their potential environmental effects), the ultimate goal for most developers is to deploy multiple devices in a large array positioned in high-velocity (high-energy) zones of rivers or tidal channels. The diverse designs imply a diversity of environmental impacts (Čada et al. 2010), but a potential impact common to most is the risk of blades striking aquatic organisms. Only a limited number of studies have been conducted to examine the risk of blade strike from HK technologies to freshwater fish (Turnpenny et al. 1992; NAI 2009; Schweizer et al. 2011; EPRI 2011; Amaral et al. 2015; Castro-Santos and Haro 2015).

Recent federal licensing requirements (e.g., see projects by Verdant Power in New York, New York and Ocean Renewable Power Company in Eastport, Maine) have included evaluation of possible interactions by fish and marine mammals with devices and additional monitoring as pilot arrays are deployed. Until it is demonstrated that these devices provide little risk of injury to aquatic organisms, this concern will likely persist for all device types and aquatic environments. These concerns are officially addressed by regulators under several regulatory statutes. For example, Section 7(a)(2) of the Endangered Species Act (ESA) requires federal agencies to ensure that their actions are not likely to jeopardize the continued existence of federally listed threatened and endangered species, or result in the destruction or adverse modification of their designated critical habitat. The Marine Mammal Protection Act (MMPA) prohibits, with certain exceptions, the “take” (defined under the statute as actions that are or may be lethal, injurious, or harassing) of marine mammals in US waters and the high seas. Section 10(j) of the Federal Power Act requires the Federal Energy Regulatory Commission (FERC), when issuing a license, to include conditions based on recommendations by federal and state fish and wildlife agencies, submitted pursuant to the Fish and Wildlife Coordination Act, to “adequately and equitably protect, mitigate damages to, and enhance fish and wildlife (including related spawning grounds and habitat)” affected by the project.

---

[1] The International Electrotechnical Commission (IEC) created a Technical Committee (TC114) to develop standards for the MHK industry, including a technical specification on common industry terminology, such as marine energy converters and hydrokinetic. This committee (IEC TC114) and the MHK industry at large include wave, current (tidal, river, ocean) and ocean thermal technologies; hydrokinetic energy refers to those that generate energy from flowing water.

1.1.2 Existing Tools for Addressing Fish Interactions with Hydrokinetic Turbines

Field observations and studies—Because this technology is so new and because so few devices have been in the water for extended periods of time, there are very few field studies on the interactions of fish with HK devices. Balloon tag studies performed with fish released into a ducted axial flow turbine in Hastings, Minnesota, found survival rates for many species of 99% or greater (NAI 2009). Researchers from the University of Maine partnered with Ocean Renewable Power Company have been collecting hydroacoustics (i.e., sonar) data at both a barge-mounted and a bottom-deployed horizontal axis turbine in Cobscook Bay, Maine. Among other findings, these studies found that (1) fish seemed to avoid an operating turbine more than a still one, (2) avoidance increased during the day and with fish size, and (3) avoidance of an operating turbine was detectable up to 140 m upstream of the turbine (Shen et al. 2015; Viehman and Zydlewski 2015). Hammar et al. (2013) monitored fish interactions with a vertical axis turbine of the coast of Mozambique using a video camera system and found near-field avoidance by fish and no collisions by the few fish that passed through the rotors. Verdant Power has monitored a horizontal axis turbine at its test site in the East River, New York, off and on for several years (Verdant 2008, 2010). As described above, Verdant Power undertook studies on presence, abundance, and species interaction with operating full-scale KHPS turbines at the Roosevelt Island Tidal Energy (RITE) project and most recently collected dual-frequency identification sonar (DIDSON, Sound Metrics Corporation, Bellevue, Washington) video data during a deployment of a single Gen5 KHPS turbine for a period of 2 weeks in August–September 2012.

Lab studies—Only a handful of laboratory studies have evaluated the effects on fish of passage through an HK turbine. Alden Engineering Lab and the Electric Power Research Institute (EPRI) collaborated on studies using a Lucid spherical (cross flow) turbine and the Welka UPG (axial flow propeller) turbine; they found that survival rates normally exceeded 98% for two species tested (EPRI 2011). When allowed time to respond behaviorally before being entrained in the turbine, most of the fish avoided passage through the turbine. Alden, EPRI, and Oak Ridge National Laboratory (ORNL) recently completed similar tests with a Free Flow Power half-scale ducted horizontal axis turbine and found survival rates above 95% for the three species tested, but a high incidence of de-scaling or injury for one species when entrained (Amaral et al. 2015). Recent studies conducted at Conte Anadromous Fish Research Center in Turners Falls, Massachusetts, exposed Atlantic salmon smolts and adult American shad to a full-scale vertical axis turbine in a large open-channel flume (Castro-Santos and Haro 2015). They found no sign of injury caused by passing through the turbine and a 48 h survival rate that did not differ from control fish.

Modeling—Several investigators have attempted to model interactions between aquatic organisms and HK turbines.

Wilson Probability Model—Wilson et al. (2007) described a simple model to estimate the probability that aquatic animals will enter the path of a marine turbine. The model is based on the density of the animals and the water volume swept by the rotor. The volume swept by the turbine can be estimated from the radius of the rotor and the velocity of the animals and the turbine blades. The researchers emphasized that their model predicts the probability that an animal will enter the region swept by a rotor, not collisions. Entry into the path toward the rotor may lead to a collision, but only if the animal does not take evasive action or has not already sensed the presence of the turbine and avoided the encounter. Applying this simplified model (no avoidance or evasive action) to a hypothetical field of 100 turbines, each with a 2-bladed rotor 16 m in diameter, they predicted that 2% of the herring population and 3.6 to 10.7% of the porpoise population near the Scottish coast would encounter a rotating blade. At this time, there is little information about the degree to which marine animals may sense the presence of turbines, take appropriate evasive maneuvers, or suffer injury in response to a collision. Wilson et al. (2007) suggested that marine vertebrates may see or hear the device at some distance and avoid the area, or they may evade the structure by dodging or swerving when in closer range.

ORNL Strike Model—Researchers at ORNL combined ideas from Wilson et al. (2007) with similar models for conventional hydropower turbines to construct a model that accounted for probabilities of encounter, turbine entrainment, and blade strike (Schweizer et al. 2011). Their model included a behavioral component that would account for avoidance, evasion, and fish swimming speed; but they had no real-world data to parameterize these features of the model.

Verdant Power/Kleinschmidt Fish Interaction Model—As part of the FERC licensing process, Verdant Power, in collaboration with Kleinschmidt Associates, developed a Kinetic Hydropower System – Fish Interaction Model (KHPS-KFIM) specifically to address the probabilities of endangered species interacting with a pilot project array of up to 30 KHPS turbines operating in the east channel of the East River (FERC 2012; NOAA 2012). Although the model was developed for sturgeon species it is applicable to other species simply by changing species-specific input parameter values. The model does not make any assumptions about fish behavior; that is, it does not incorporate any likelihood that if a fish detected the presence of the turbines, it would avoid an interaction. As adult shortnose sturgeon are highly mobile, it is likely that the model presents a very conservative estimate of the likelihood of interactions between an individual fish and the turbines. The model uses nine parameters (water velocity distribution; channel geometry; physical and operation characteristics of the turbines; and specific fish characteristics, such as size, burst swimming speed, and swimming velocity and endurance) and was applied to calculate the strike probability for a single turbine, as well as for an array of up to 30 turbines.

University of Maine Model – In collaboration with Ocean Renewable Power Company’s testing of a tidal turbine in Cobscook Bay (Eastport, Maine), researchers at the University of Maine developed a turbine interaction model based on fish density data that they collected onsite (Shen et al. 2015). The model includes three primary parameters: the probability of fish being at the device depth; the probability of fish behavior changing to avoid the device in the far-field; and the probability of fish behavior changing to avoid the device in the near-field.

1.2 ROOSEVELT ISLAND TIDAL ENERGY PROJECT

1.2.1 Background to 2012

Since its inception in 2000, Verdant Power has advanced the state of the art in kinetic hydropower research and demonstrated the utility and efficiency of a water-to-wire turbine system in converting the kinetic energy in flowing water into electric power, with concurrent environmental permitting and assessment. During 2006–2008, Verdant Power conducted a demonstration of its patented system, the KHPS, at its RITE project, located in the East River in New York City (Figure 1-1). During the RITE demonstration, the KHPS met expectations, showing a turbine peak efficiency of 38 to 44% in water current speeds of 0.9 to 2.1 m/s (1.8 to 4.2 knots) while delivering emission-free, renewable electricity to two commercial end users.

When Verdant Power first embarked on the development of the RITE project in 2002, with the filing of a FERC Preliminary Permit for the RITE site in the East River in New York, there was no precedent for the process in the United States, neither regulatory nor environmental, to evaluate this new type of project and tidal technology. Verdant proceeded within the federal context of a FERC hydropower process, which requires the development of an Initial Consultation Document (ICD) under the FERC Traditional Licensing Process. Therefore, when in October 2003 Verdant issued its ICD, the discussion of the potential environmental effects of KHPS technology was new to both resource agencies and stakeholders.

Figure 1-1. Verdant Power Roosevelt Island Tidal Energy project site—New York, east channel, East River.

In general, the opportunity for a new source of clean energy was well received during scoping meetings held in 2004; but it also raised significant concerns regarding the regulatory scheme for the grid-connected generation of such technology, as well as the potential environmental impacts of operation. In 2005, to demonstrate its technology and gather data that could begin to address these concerns, Verdant Power sought permission from FERC to test a six-turbine array of KHPS in the RITE project site in the east channel of the East River (RITE demonstration). In a precedent-setting declaratory order, the "Verdant Order," FERC ruled that this activity did not require a license under the Federal Power Act, as it was consistent with the following findings:

1) The technology in question is experimental

2) The proposed facilities are to be utilized for a short period for the purpose of conducting studies necessary to prepare a license application, and

3) Power generated from the test project will not be transmitted into, or displace power from, the national electric grid.[2]

As such, the RITE demonstration project could proceed to begin to examine many of the environmental issues. Subsequent to this, the FERC issued its April 2007 rules regarding Pilot Licenses.

---

[2] 111 FERC 61, 024 – April 14, 2005; the "Verdant Order"

During the RITE demonstration, Verdant Power conducted environmental monitoring efforts, including a specific *Fish Monitoring and Mitigation Plan* (FMMP) required under project permits, to advance the understanding of fish presence, abundance, species characterization, and fish interaction with operating kinetic hydropower turbines. This monitoring involved various applications of hydroacoustic detection devices in an effort to understand fish interaction with HK devices.[3] A third deployment of operating turbines in the fall of 2008 included the collection of additional information (as discussed later in this report). The results of this effort culminated in the December 2010 filing of a hydrokinetic pilot license application with the FERC for pilot development of the RITE project (FERC No. P-12611). Included in the draft license application were a set of environmental monitoring plans for RITE, termed the RITE Monitoring of Environmental Effects (RMEE) plans, as well as a KFIM for the Biological Assessment. The RMEE plans and KFIM are available at http://www.theriteproject.com as Volume 4 of the Final RITE Pilot License Application; they are further discussed in the context of this study.

1.2.2 RITE Project Moving Forward Beyond2012

In January 2012, FERC issued the first 10 year US pilot license to Verdant Power for the installation of up to 30 KHPS turbines in the east channel of the East River, accepting the results of the KFIM for both Endangered Species Act species and Essential Fish Habitat and incorporating a suite of seven RMEE plans in a staged monitoring strategy with adaptive management. Implementing this suite of monitoring plans was projected to cost more than $2.3 million over the course of the pilot license. Of importance in this project are RMEE-2, “Seasonal DIDSON Observation,” and to a lesser extent RMEE-4, “Tagged Species Detection.”

As part of the start of construction and the final technology development—with partial funding from the New York State Energy Research and Development Authority (NYSERDA)[4] and the US Department of Energy[5] (DOE) — following a year of preparatory work in September 2012, Verdant successfully completed an in-water test of an updated KHPS turbine rotor including composite blades and concurrently deployed a remotely aimed DIDSON (RAD) system (Figure 1-2). The RAD incorporates a DIDSON, a ROS PT25 2-axis servo, a ROS 400 ft underwater cable, a custom-designed river bottom gravity mount, and an executive program for control and data collection of an operating KHPS turbine in the East River under the RMEE-2 plan as a beta test of the monitoring equipment. The results of the data collection effort—over 370 hours of DIDSON RMEE-2 RAD video with and without the operation of a KHPS turbine—were initially shared with the agencies for their review as follows:

- Fish abundance varies significantly with the seasonal migration at the site (April–May and September–December).
- Equivalent abundance is seen day and night.
- The greatest movement is seen by fish observed moving in the direction of the tides or at slack tide (when KHPS turbines are not operating).
- Fish zonal location is near shore, not in the zones of the operating turbines.
- DIDSON technology did show “some signs” of avoidance behavior and showed promise for future monitoring—hence the development (and adoption) of the RMEE-2 plans.

---

[3] The efficacy of splitbeam transducers, various DIDSON mounts (stationary, mobile, and RAD), and netting is discussed later in this report.

[4] NYSERDA Grant 20802.

[5] DOE Grant DE-FG36-08GO18168, “Improved Structure and Fabrication of Large, High-Power KHPS Rotors.”

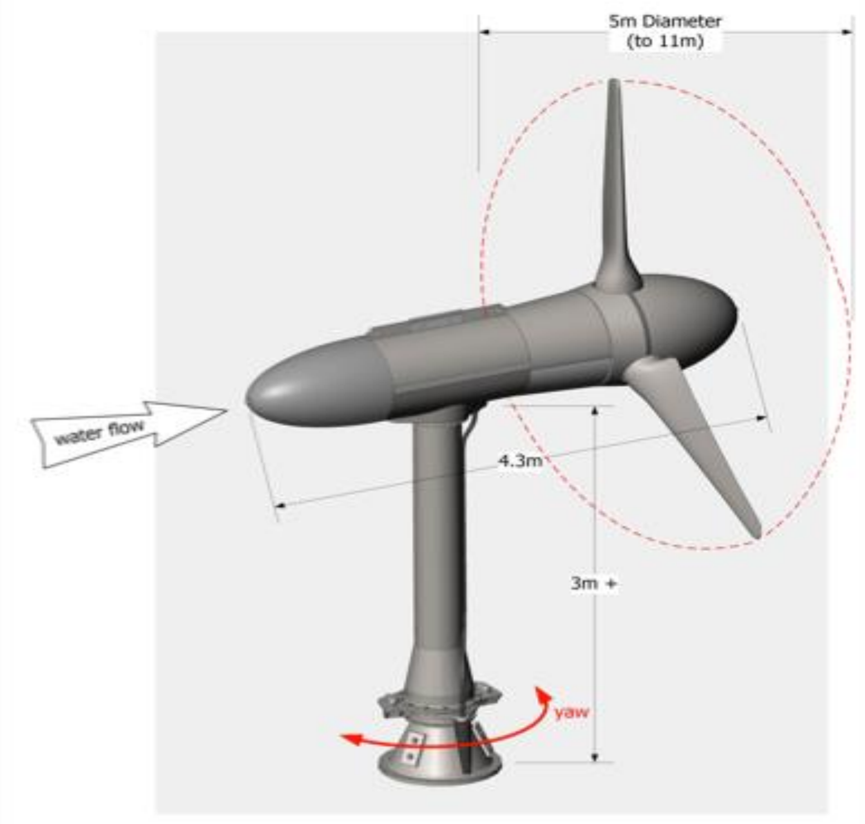


Figure 1-2. Verdant Power kinetic hydropower system Gen5 turbine.

The RAD hydroacoustics data are the subject data that are further analyzed in this report. As required by the FERC license, the actual deployment and operation of a full-scale kinetic hydropower device and the concurrent deployment of a DIDSON provided the unique opportunity to observe and address the questions most important to aquatic resource managers and regulators:

1. How do fish behave around operating KHPS turbines?
2. Can fish behavior be inferred by tracking a fish's swimming location and direction or its reaction in relation to the rotating blades?
3. Do the DIDSON observations provide some added meaning and value (correlation) to the body of collected data on fish presence, abundance, movement pattern, and species in and around the operating KHPS turbine?
4. What, if anything should be changed in the DIDSON operating protocol to improve evaluation of the effects of operating KHPS turbines?

These questions and answers will be addressed in Section 6 of this report, the summary.

1.3 STUDY OBJECTIVES AND REPORTING

The project objectives are as follows:

1. Quantify near-field (i.e., within 12 m) behavioral response and swimming trajectories of fish encountering an operating HK turbine using 373 hours of video from a deployed DIDSON multibeam hydroacoustics system. This is discussed in Section 2.

2. Quantify the far-field normal swimming trajectories and distribution of fish in the vicinity of the deployment site using previously collected data from a splitbeam hydroacoustics system during the same seasonal period. This is discussed in Section 3.1.

3. Characterize the relationship between flow dynamics and changes in behavior and distribution (near- and far-field) with correlation of concurrently collected acoustic Doppler current profiler (ADCP) data. This is discussed in Sections 2 and 3.1.

    a. Near-turbine fish trajectories, avoidance behavior, and general distribution relative to near-field hydraulics (i.e., water velocity and tide direction) with and without the influence of a turbine.

    b. Far-field vertical and horizontal distributions and trajectories of fish relative to water velocity and tide stage (ebb, flood and slack tide) with and without the influence of a turbine.

4. Update parameterization of existing fish interaction model developed for the East River and the RITE Project. This is discussed in Sections 3.2 and 4.2.

5. Use study results to assess which approaches (e.g., field observation, experimentation, models) will be most effective for predicting or monitoring the effects of turbine arrays. This is discussed in Section 5.

1.4 ORIENTATION TO THE KHPS OPERATION

Three fundamental understandings of the operation of the Verdant Power KHPS form the basis for this study. This section orients the reader to these elements: the KHPS turbine, operation in the tidal cycle, and the orientation of RMEE-2 seasonal DIDSON operation in September 2012 to the operating Gen5 KHPS.

1.4.1 The Gen5 KHPS

The KHPS turbine is a three-bladed horizontal-axis turbine (Figure 1-2) with four major assemblies:

- A rotor with three fixed blades that rotate at the relatively slow and constant speed of approximately 40 revolutions per minute (rpm) with tip-speeds of 35 feet per second. This is well below normal water vessel propeller speeds and conventional hydropower turbine blade speeds. The blade movement “self starts-stops” at flow speeds of approximately 1.0 m/s.

- A sealed nacelle, pylon, and passive yaw mechanism that are hydrodynamically designed to allow the turbine to self-yaw into the prevailing current flow when in the flood tide position like a weathervane, so that the blades are optimally aligned to generate energy. In the 180° opposite direction, the ebb tide position, the yaw stop holds the turbine in a stationary position preventing it from self-seeking a variable flow orientation. Note that this feature will be important in the DIDSON analysis that follows.

- An enclosed generator and drivetrain within the nacelle serve as a horizontal-axis custom-designed drivetrain unit that integrates the bearing housing with a special long-life planetary gearbox with mechanical shaft seals and a minimum of sealed lubricants.

- A streambed mounting system, which can vary depending on site conditions, as a single monopile, tri-frame mount (holds three turbines), or single concrete gravity-based structure.

For the effort completed in 2012— which generated the DIDSON data— a modified Gen5 KHPS turbine was used on an existing in-river monopile for the period August 29, 2012 through and including September 10, 2012 (Figure 1-3).

Figure 1-3. Gen5 KHPS turbine deployment with DIDSON (RAD) system being deployed (August 2012).

The multibeam hydroacoustics data analyzed in this study were collected using the RAD system deployed in the east channel of the East River in New York in September 2012. Figure 1-4 shows the orientation beam of the DIDSON relative to the operating Gen5 KHPS turbine.

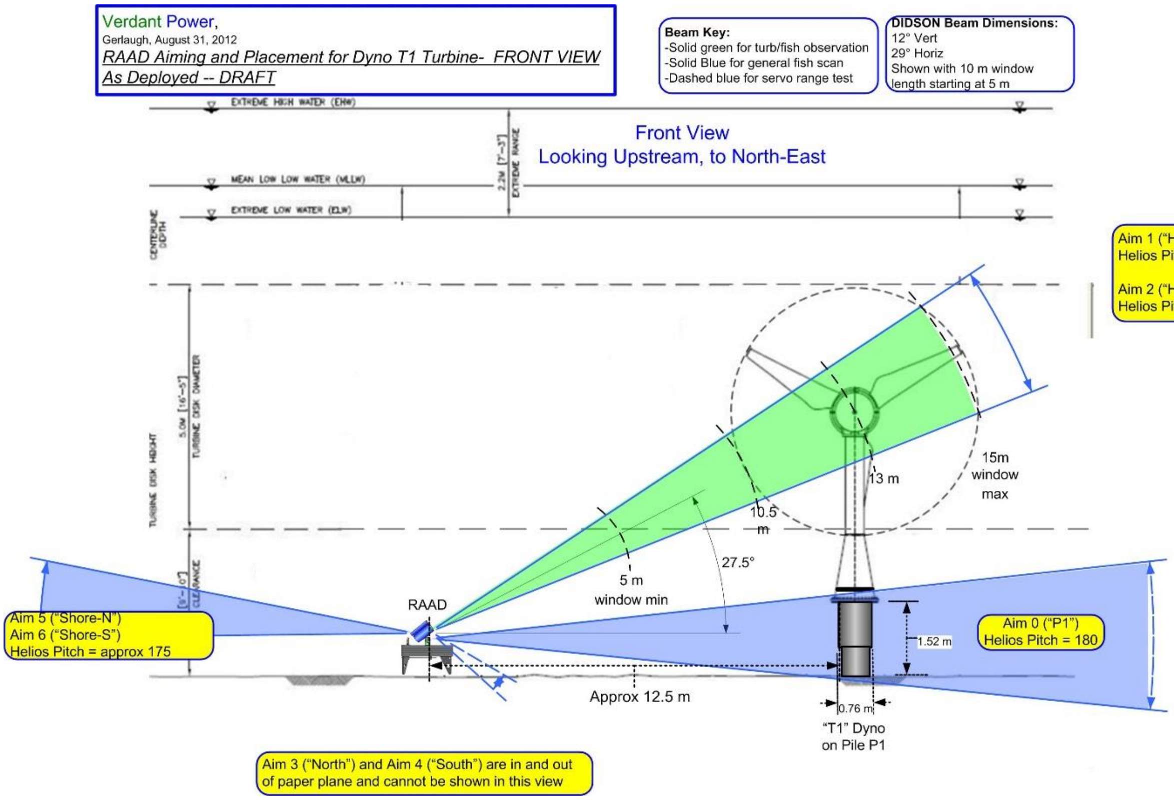


Figure 1-4. Deployed RAD system at RITE, September 2012.

2. DIDSON MULTIBEAM ANALYSIS

2.1 INTRODUCTION

During 2012 construction testing of its Gen5 KHPS turbine at the RITE site (P-12611) in the East River, Verdant Power used a RAD system to collect images of passing fish in the vicinity of the turbine. In addition to the DIDSON, the RAD consisted of a ROS PT25 2-axis servo, a ROS underwater cable, a river bottom gravity mount, and a custom execution program that integrated the DIDSON aim and data collection. Concurrent stationary ADCPs also collected detailed tidal velocity measurements as the Gen5 horizontal axial turbine operated. These data were collected continuously for 19 days (August 30–September 18, 2012) through multiple tidal cycles, including periods with and without the turbine in place and periods (according to water velocity conditions and video observation) when the turbine rotor was turning and when it was stationary. From August 29 through September 3, the RAD was put through various tests to ensure proper data collection and operation of the remote-control aiming system. Data were collected during this time, and the turbine was allowed to operate only during flood tides. Turbine operation began during ebb tides as well as flood tides on September 4 and continued through September 7. On September 8, the turbine testing was terminated, and turbine removal was completed on September 11. The DIDSON continued to collect data aimed at where the turbine had been located through September 14.

2.1.1 Objectives

The primary objective of this task was to analyze the multibeam hydroacoustics data to quantify near-field fish behavior, such as a change in water-column position, swimming direction, and velocity, in response to encountering an operating full-scale HK turbine. Specifically, we wanted to determine whether fish actively avoided the operating turbine and, if not, whether there was any indication of actual contact with the rotating blades. The results of this analysis were used to augment the fish interaction model (see Section 3) and to assess whether multibeam acoustics is an effective approach for future monitoring of the effects of turbine arrays on fish behavior.

2.1.2 Approach

The DIDSON unit consists of 90 individual transducers lined up side to side (Figure 2-1), each of which sends out an acoustic ping approximately eight times per second. The effective sampling range from the DIDSON is 5 to 15 m from the unit. The column on which the turbine with 5 m diameter blades rotates is located at approximately 12.5 m from the DIDSON; but depending on the flow direction effect on the turbine position, the blade tips can be as close as 9.7 m. The DIDSON data can be viewed as individual snapshots in time (Figure 2-2) or in the form of a video (this is why this technology is often referred to as an “acoustic camera”). These videos can be analyzed manually, but the results are only semi-quantitative; and for the amount of data collected in this study, manual analysis would not have been practical. Therefore, we chose to analyze the data in an automated fashion using Echoview software (v5, Myriax Software Pty Ltd, Hobart, Tasmania, Australia).

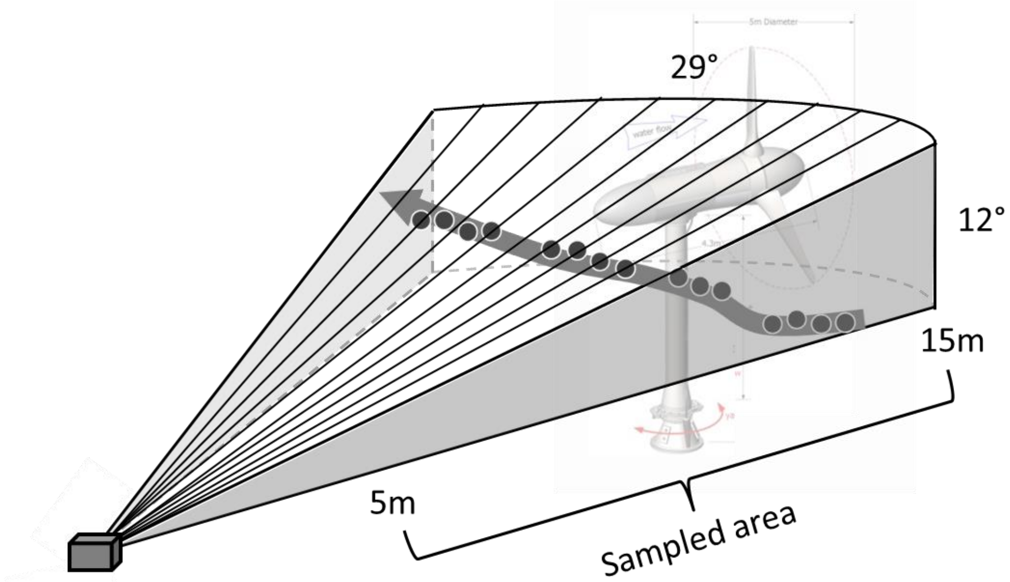


Figure 2-1. Dimensions of the surveyed field of the DIDSON multibeam hydroacoustics system with an example of a fish track (arrow) through the field constructed from individual signal returns (circles) of the same fish four times through time. This illustration shows only ten individual transducer fields, whereas in reality there are 90.

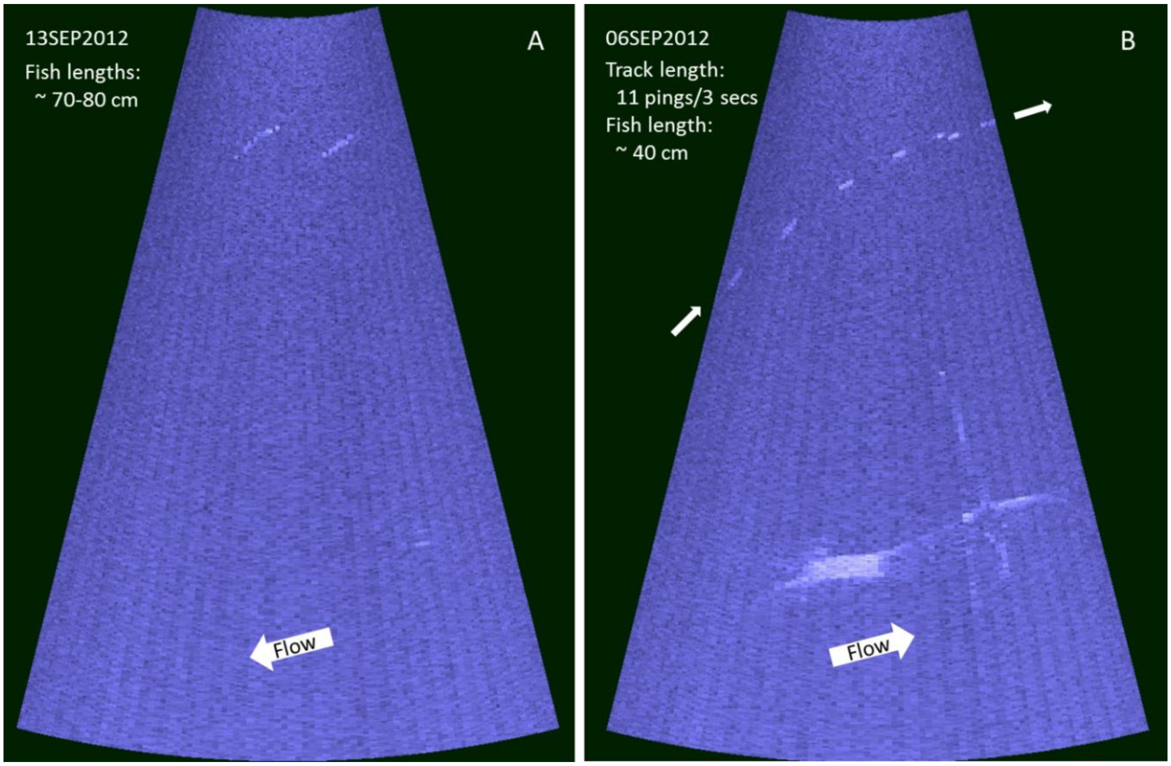


Figure 2-2. Plan view of the DIDSON acoustic camera field (5 to 15 m from DIDSON unit) with the DIDSON unit located 5 m above the field showing (A) two individual fish at a single point in time when the turbine was absent during ebb tide and (B) a composite image of every other ping of a single fish track over a 3-s interval during flood tide. In panel B, the turbine is at the bottom of the figure with the blades at the right end.

An echo that returns after bouncing off a fish target (henceforth referred to as a target) to any of the 90 transducers includes information on the xyz location of the target within a particular transducer's field of view. A single fish is typically picked up by two or more transducers depending on the size and orientation, and through data processing, pings returned to adjacent transducers can be joined together as a single target, based on pre-defined time and distance thresholds for categorization as the same fish. The Echoview analysis assigns the joined target an estimate of target strength (a surrogate for size) and an xyz location within the DIDSON field. Targets identified in successive pings within a predefined distance of each other can be linked to create a track of an individual fish as it passes through the DIDSON sampling area (Figure 2-1). Analysis of individual tracks can provide information on direction of travel and swimming velocity.

We hypothesized that active avoidance might be detected in one or more metrics that measure direction and speed of travel, and we structured our automated analysis so that we could compare changes in fish behavior as a result of turbine presence or operation. We analyzed the data to provide comparisons of the metrics among the three modes of operation (turbine absent, turbine present but not rotating, and turbine rotating) during periods of the same tidal cycle (i.e., ebb or flood), and comparisons of differences in metrics based on nearness to turbine within each of the same operation modes individually.

2.2 METHODS

2.2.1 Data Coverage

The data sets were filtered to address normal operating conditions of a tidal turbine, including the signature associated with rotating blades, self-seeking flow orientation in the opposite direction (flood) instead of the firm position at the yaw stop (ebb), and the normal change of turbine orientation four times daily with tidal flow. Not all periods of data collection provided useful data for analysis, since some periods included turbine maintenance, RAD aimed away from the turbine, and turbine removal. Of 373 hours of useful DIDSON data, we analyzed 239 (64%) distributed across ebb and flood tides, operation modes, and velocity classes (Figure 2-3). Note that since the turbine rotor would rotate only at velocities greater than 1 m/s, there were no observations for the low-velocity, turbine operating category.

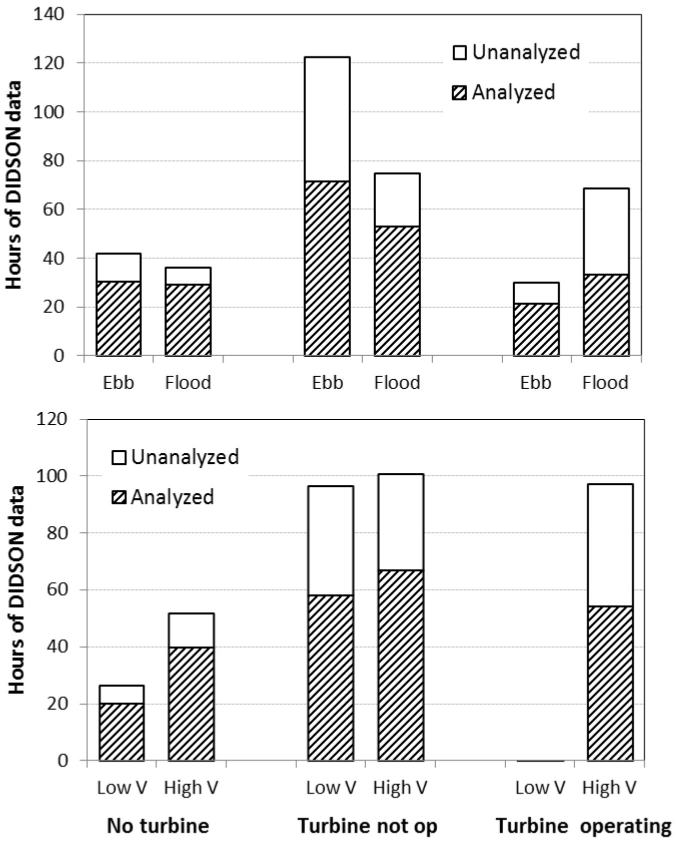


Figure 2-3. (Top) Number of hours of DIDSON data collection (analyzed and unanalyzed) by tide cycle and turbine operation mode. (Bottom) Number of hours of DIDSON data collection (analyzed and unanalyzed) by water velocity class and turbine operation mode.

2.2.2 Echoview Analytical Details

The raw DIDSON data files were divided into subsets by RAD aim and turbine position and operation. Each subset was processed with a series of filtering techniques to remove noise, interference, and the echo from stationary objects (e.g., the non-rotating turbine) so that all that remained were echoes of a signal strength greater than the smallest fish of interest. These data were then processed as described earlier to identify first fish targets at each point in time and then fish tracks from individual targets that were joined based on signal strength and distance.

Stationary objects, such as the locked turbine in the ebb position, are relatively easy to filter from the analysis, leaving the rest of the field open for analysis of fish targets. However, the moving rotor was difficult to filter from the DIDSON field, especially when the turbine was in the flood position and not locked in place but allowed to reposition itself to seek the optimal position for rotor rotation. Therefore, when the turbine was operating, we had to set an exclusion line across the DIDSON field at the point where the turbine was closest to the DIDSON unit. The exclusion zone for the different data subsets ranged from 9.7 to 12.1 m from the DIDSON depending on turbine rotor location, which depended on operation mode and tide direction. Fish movements in the area beyond the exclusion zone were analyzed manually for a subset of the period when the turbine was operating. Because the flow moves across the DIDSON beam, we used the surface area of the vertical side of the ensonified region to standardize among groups of analyses that excluded different amounts of the DIDSON sampled region. Without any exclusion, the sampled vertical area was 21.0 m^2. With a still turbine, the vertical area sampled was 12.8

m^2 during ebb tide and 12.3 m^2 during flood tide. With an operating turbine, the vertical area sampled was 12.5 m^2 during ebb tide and 9.8 m^2 during flood tide.

We used Echoview to generate two types of output files. The first was a csv file of every fish track along with associated information for over 20 descriptive variables. The second was a csv file of individual targets that included information on each fish each time it was identified, including an estimate of body length based on the distance between the two echoes most distant from each other that comprised the fish. For the best estimate of the body length of a fish in a track we searched the individual target data set and extracted the maximum length of those individual targets with a ping number that corresponded to the range of pings defined for a fish track.

2.2.3 Echoview Validation

Correct identification of fish targets is primarily based on establishing a signal strength threshold that captures fish of the size of interest while at the same time excluding fish smaller than the size of interest. Because the fish orientation, its distance from the transducer, and other factors affect the strength of a returned signal, the range of signal strengths for fish of a given size can be quite variable. In other words, it is impossible for automated analysis to capture every fish of a desired size that passes through the acoustic field. Therefore, we performed a validation exercise to determine the efficiency of our calibrated analysis.

We observed 112 min of DIDSON data in video form from September 1 and September 5 and, without knowledge of the automated processing results, noted the time, ping numbers, minimum and maximum range (i.e., distance from DIDSON), and length of each fish target that appeared to be roughly >10 cm. These data were compared with the automated results for the same periods. Of the 181 unique tracks (individual and schools) observed by the two methods, 74% were captured via the automated analysis. Of those not captured by the automated analysis, nearly all were small in size (based on visual observation) and likely just below the signal strength threshold established for inclusion; a few were larger but were seen only for two consecutive pings. Based on our validation, we believe that the automated method provided an accurate accounting of fish of the size range of interest that passed through the DIDSON beam during the sampling period.

During validation of the Echoview analysis, and while performing other visual assessments of the data, we used the measuring tool in Echoview to hand measure more than 100 individual fish of all sizes. These measurements were made on the clearest image of a track sequence and should be accurate within 10–20% in most cases. The manual measurements were compared with the estimated maximum size for the same individual generated through analysis of the Echoview output, and unfortunately, we found poor agreement between the two estimates. Therefore, we did not include size as a variable in further analysis of the automated data collection. We did, however, use the signal strength to identify likely large fish for our manual analysis of fish passing near the rotating turbine blades.

2.2.4 Metrics Evaluated

Output from the Echoview analysis included location, heading, and velocity of each fish as it passed through the multibeam field. Each track included information about the beginning and ending xyz location in the beam, time in the beam, and returned signal strength, from which direction of movement, velocity, track linearity, and fish size could be estimated. Fish avoiding the turbine might be expected to change depth, swim faster, swim in a direction away from the turbine, or deviate from a straight course. Key dependent variables that were evaluated included:

- Horizontal direction (degrees): The linear direction (or compass heading) of a fish track in the plane roughly parallel to the surface of the water. This value ranged from 0 to 360°, with the ebb current running at a heading of approximately 40–55° and flood at approximately 219–236° depending on the aim of the DIDSON relative to the turbine location.

- Vertical direction (degrees: The linear direction of a fish track in the vertical plane (i.e., depth) with +90° being straight up and –90° being straight down.

- Lateral movement (m): The amount of change in position of a fish track relative to a straight line between the DIDSON and the turbine, ranging from 0 to 10 m.

- Tortuosity (unitless): A measure of straightness of a track based on the xyz position of each point in time that makes up a track. It is calculated as the sum of the distances between adjacent targets in a track (that is, the total distance traveled) divided by the straight line distance between the first and last targets in a track (Johnson and Moursund, 2000). A value of 1 refers to a straight line, while the value of a crooked line is theoretically boundless.

- Swimming velocity (m/s): Calculated as the total distance covered by a track divided by the duration of the track.

These behavioral responses were evaluated as a function of:

- Turbine presence or absence: The turbine was present from August 29 to September 8 and absent from September 11 to September 14.

- Turbine operation (rotating or not): When in place, the turbine rotor generally rotated at water velocities in excess of 1 m/s except from August 29 through September 3, when the rotor was allowed to rotate only during flood tides for testing purposes.

- Tide (ebb or flood): A complete tidal cycle in the East River during the period of analysis was estimated at 12 h 24 min, with flood tide leading up to a high tide averaging about 6 h 24 min in duration, and an ebb tide leading up to a low tide averaging about 6 h.

- Current velocity (low, medium, high): Each fish track observation was associated with one of three current velocity classes based on the tidal cycle time. The first sixth of a tide (1 h for ebb and 1 h 4 min for flood) was classified as low velocity, the second sixth as medium, the third and fourth sixths as high, the fifth sixth as medium, and the last sixth as low. Although this did not provide a specific velocity cutoff for each category, it did provide bins of equal duration, which we believe provided for a better analysis given that velocities vary a little from day to day. On average, this meant that the low-velocity-class velocities were approximately 0 to 1.5 m/s, the medium class approximately 1.5–2.1 m/s, and the high class approximately 2.1 to 2.5 m/s.

- Relative direction (with or against): Whether a fish was swimming with the current or against it was determined by comparing the horizontal direction output from Echoview with the direction of the tide for each fish track observation. Based on the distribution of horizontal direction data for two different RAD aims, directions between 145 and 325° were considered to be traveling in the flood direction, and directions between 0 and 145° and >325° were considered to be in the ebb direction. A fish swimming in the ebb direction during a flood tide was considered to be traveling against the current, and so forth.

- Distance from the DIDSON (or conversely from the turbine): Data were collected within a range of 5 to 15 m from the DIDSON unit. The mean distance from the DIDSON for each track as it passed through the field was included in the analysis. For reference, the turbine body was located at about 11.5 m from the DIDSON and the turbine rotor from 10 to 15 m distance when present.

2.2.5 Direct Observation of Turbine Interactions

To minimize false detections caused by the moving rotor, we established an exclusion depth at the tips of the rotor blades for many analyses (typically 10–11 m from the DIDSON during ebb tides and 11–12 m during flood tides) beyond which signals were excluded from automated analysis. Therefore, since we were unable to automatically assess fish that might encounter the rotor directly, we used the output data to identify fish tracks that were most likely to cross the exclusion line and encounter the rotor; we evaluated those tracks manually. Such occurrences were most likely during ebb tides when the direction of the flow, which was not perpendicular to the DIDSON beam, was at an angle that would take fish across the exclusion zone if they were within a meter of the excluded area near the turbine. We filtered the 34,705 fish tracks based on tide (ebb), turbine operation (rotating), fish length (Echoview estimated >15 cm), and maximum target depth (>9 m). Alone, these three criteria were met by 69, 10, 16, and 18% of the tracks; but in combination, they were met by only ~0.1% (36 tracks). Each of these tracks was evaluated manually to determine if any culminated in turbine interaction or active avoidance.

During the previously described validation exercise that included 112 min of data, we also noted every fish that passed near the turbine that was not captured by the automated analysis. As well, during the processing of other subsets of the data, we noted anecdotally fish targets that had close encounters with the turbine.

2.3 RESULTS

2.3.1 Fish Tracks Count

Our analysis resulted in the identification of 34,705 fish tracks, distributed as 11,641 and 4,049 during ebb and flood tides, respectively, without a turbine in place; 10,490 and 5,076 during ebb and flood tides with a non-rotating turbine; and 1,734 and 1,715 during ebb and flood tides with a rotating turbine. Subsequent review of a subset of the tracks indicated that many of these tracks were actually schools of tens to hundreds of small fish and not individual fish. On a per-hour basis, more tracks were observed when the turbine was not in place than when it was (Table 2-1). These numbers were also evaluated after accounting for the smaller area analyzed when the turbine was rotating as described earlier, and, even with that correction, the rate of fish passing by the turbine was lowest when the turbine was operating.

Parsing the count of fish tracks by turbine operation mode, tide, and velocity revealed differences associated with each category (Table 2-2). The number of tracks per hour observed was generally higher during ebb tides than during flood tides and generally increased with increasing current velocity. The count per hour was highest when the turbine was absent and lowest when the turbine was rotating.

Table 2-1. Number of fish tracks observed per hour of data analyzed during three turbine operation modes for ebb and flood tide directions. Hours of data analyzed are shown in parentheses. The grand average (total counts/total time) was standardized by the vertical area sampled, as determined by the location of the exclusion line necessary to avoid moving blades in analysis

	No turbine		Turbine not rotating		Turbine rotating		Grand Total
Date	**Ebb**	**Flood**	**Ebb**	**Flood**	**Ebb**	**Flood**	
20120829	–	–	776.6 (1.9)	–	–	–	**776.6**
20120830	–	–	310.8 (3.6)	135.7 (6.0)	–	–	**201.4**
20120831	–	–	116.7 (3.4)	314.6 (1.9)	–	–	**109.2**
20120901	–	–	152.9 (11)	365.8 (3.4)	–	21.7 (3.8)	**138.4**
20120902	–	–	294.9 (5.3)	133.3 (1.7)	–	44.8 (7.9)	**210.2**
20120903	–	–	59.3 (6.5)	16.0 (1.4)	–	74.8 (1.9)	**59.6**
20120904	–	–	143.0 (7.0)	32.1 (1.7)	112.3 (4.3)	93.6 (4.3)	**113.0**
20120905	–	–	28.2 (4.1)	136.2 (3.8)	78.8 (8.2)	69.4 (7.2)	**76.5**
20120906	–	–	29.2 (2.6)	47.6 (2.9)	83.6 (4.3)	74.0 (3.8)	**62.8**
20120907	–	–	7.3 (1.0)	–	60.0 (4.1)	18.1 (0.7)	**46.0**
20120908	–	–	153.9 (6.5)	40.6 (3.6)	–	–	**113.4**
20120909	–	–	70.4 (12.7)	32.5 (11.3)	–	–	**52.6**
20120910	–	–	122.6 (6.2)	57.6 (9.6)	–	–	**83.2**
20120911	216.7 (0.5)	–	80.0 (0.1)	69.8 (5.8)	–	–	**81.1**
20120912	589.5 (12.0)	173.6 (12.0)	–	–	–	–	**381.5**
20120913	302.9 (12.0)	145.8 (11.3)	–	–	–	–	**226.8**
20120914	138.0 (6.0)	53.5 (6.0)	–	–	–	–	**95.8**
Grand average	**381.9**	**138.3**	**146.2**	**95.7**	**83.0**	**51.4**	
Standardized to no turbine	**381.9**	**138.3**	**239.8**	**163.6**	**140.3**	**110.0**	

Table 2-2. Number of fish tracks observed per hour of data analyzed during three turbine operation modes for ebb and flood tide direction and three velocity classes. Each of the three velocity classes was equal to approximately 2 h of a 6 h tide cycle with low velocity generally equivalent to 0–1.5 m/s, medium velocity to 1.5–2.1 m/s, and high velocity to 2.1–2.5m/s

Velocity	No turbine		Turbine not rotating		Turbine rotating		Row mean
	Ebb	Flood	Ebb	Flood	Ebb	Flood	
Low	217	104	79	93	78	83	**105**
Medium	350	116	166	100	70	40	**133**
High	589	194	223	98	88	52	**193**
Column mean	**382**	**138**	**146**	**96**	**79**	**49**	**143**

2.3.2 Spatial Distribution

In addition to consideration of operation mode, tide, and current velocity, the number of fish tracks—specifically the number per hour—can also be viewed relative to the nearness to the turbine (or distance from the DIDSON unit; Figure 2-4). In all cases, the greatest number of tracks occurred in the nearshore region, i.e., farthest from the turbine. For the different categories (e.g., high velocity, no turbine) 65–80% of the tracks were in the region of 5–8 m from the DIDSON unit even though this portion of the beam has the smallest cross-sectional area and sampling volume. The observation we noted earlier that the number of tracks with no turbine present is greater than when the turbine is present but not operating which is in turn greater than when turbine is present and operating is consistent for all distances from the turbine.

2.3.3 General Swimming Direction

An evaluation of fish swimming direction relative to current direction revealed that overall 16% of the fish tracks were in a direction against the current (Table 2-3). Among velocity classes, swimming against the current at low velocity was roughly twice as frequent as at higher velocities. Differences among operations were small, but fewer fish swam against the current when the turbine was operating than when it was absent. Differences between ebb and flood tides were minimal when the turbine was absent but were markedly different with a non-operating turbine (higher against the current during flood tide) and even more different when the turbine was operating.

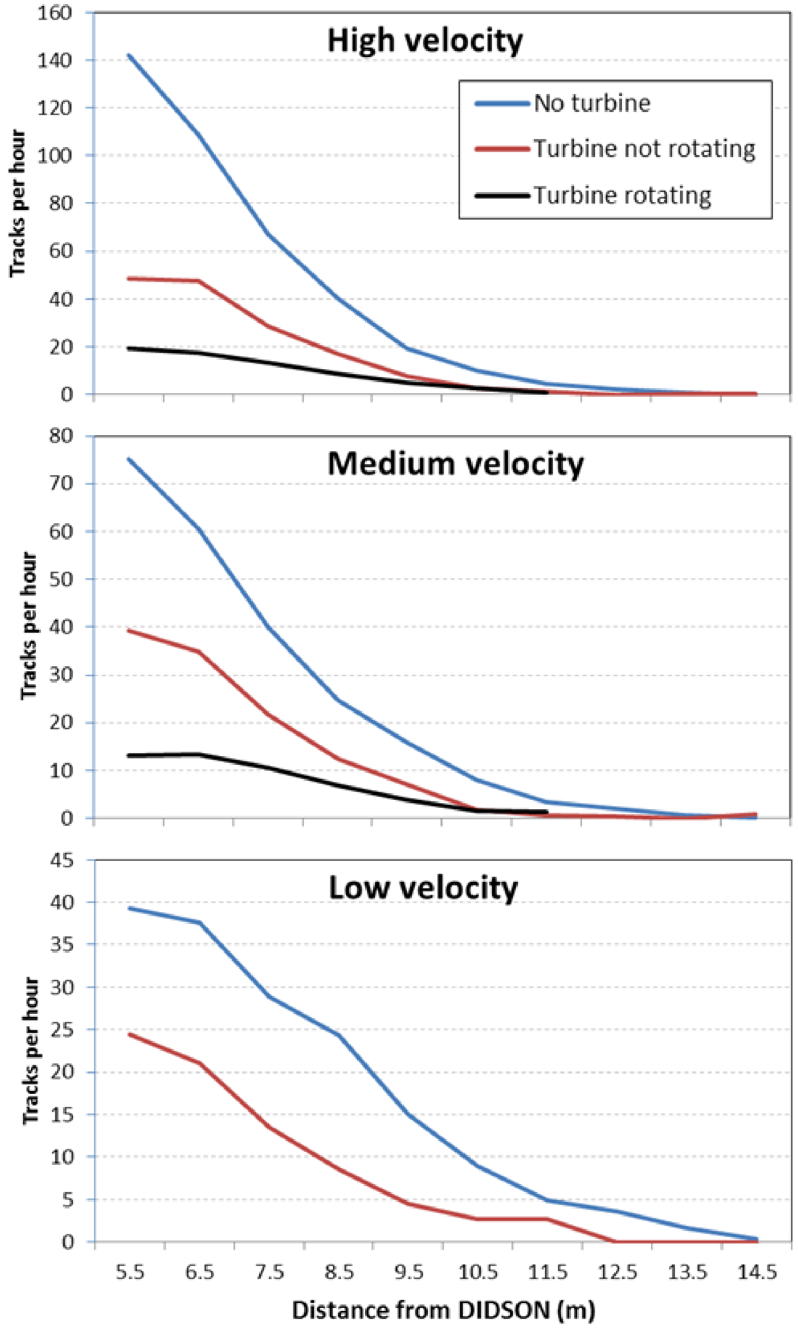


Figure 2-4. Number of fish tracks per hour during three operation modes (no turbine, turbine not rotating, and turbine rotating) summarized by distance from the DIDSON unit (1 m blocks) and by three current velocity classes (high, medium, and low). The low-velocity/turbine rotating class was not included, as there was less than an hour of data for this group because the turbine does not rotate below 1m/s.

Table 2-3. Summary of distribution of fish tracks against the current (%) for three operating conditions, ebb and flood tides and three current velocity classes

Velocity class	No turbine			Turbine not rotating			Turbine rotating			Row mean
	Ebb	Flood	All	Ebb	Flood	All	Ebb	Flood	All	
Low	32.2	22.1	29.2	21.1	30.4	25.9	4.8	19.0	14.6	**26.9**
Medium	10.8	9.4	10.4	10.4	11.0	10.6	4.0	15.1	9.4	**10.4**
High	14.9	17.2	15.5	12.3	10.9	12.0	8.2	18.8	13.3	**13.9**
Mean	**17.2**	**16.1**	**16.9**	**13.7**	**20.9**	**16.0**	**6.3**	**17.4**	**11.8**	**16.0**

2.3.4 Change in Range

Change in range refers to whether a fish moves closer to the turbine (positive values) or farther from it (negative values) during the time when it crosses through the DIDSON beam. Because the DIDSON position relative to the turbine is not perpendicular to the flow, the modes of the distributions for ebb and flood tides do not center around 0 (Figure 2-5). Both distributions suggest there is little difference between no turbine and a rotating turbine; however, during ebb tide, fish observed with a non-rotating turbine seemed to move away from the turbine location more than fish observed when the turbine was absent. The general direction of flow during ebb tides is in a direction that is angled slightly away from the DIDSON and toward the turbine, and vice versa for the flood tide. Change in range can also be evaluated as a function of nearness to the turbine (Figure 2-6). During flood tides, fish exposed to the turbine (operating or not) seemed to maintain a heading alongside the turbine as they got closer to it instead of moving away as when the turbine was absent.

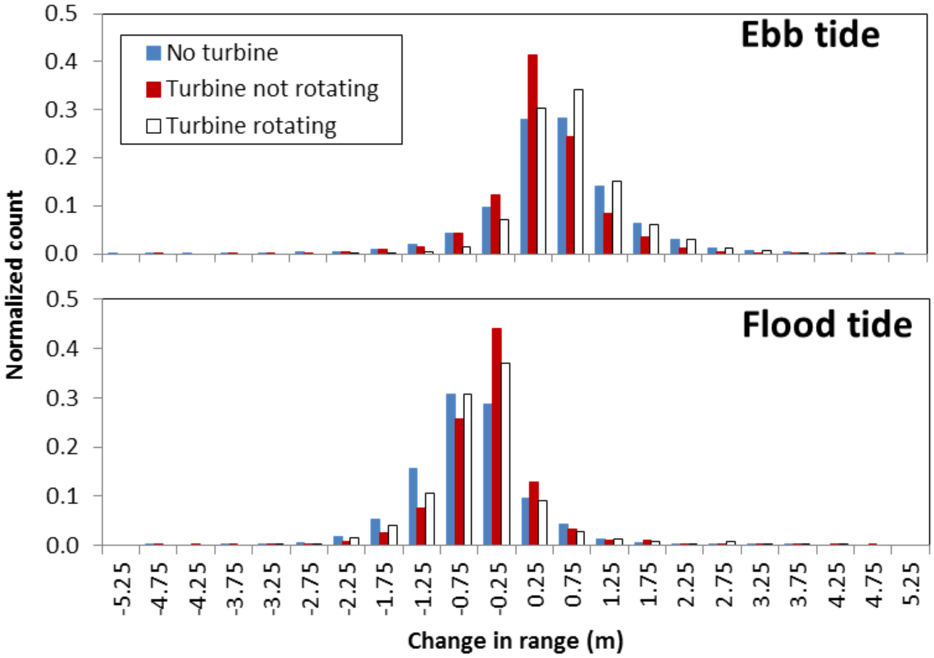


Figure 2-5. The distribution (normalized to the total tracks for any operating mode and tide combination) of lateral movement distance, i.e., moving toward [+] or away from [-] turbine for three turbine operation modes and ebb and flood tides. Each x-axis value is the midpoint of a 0.5 m bin.

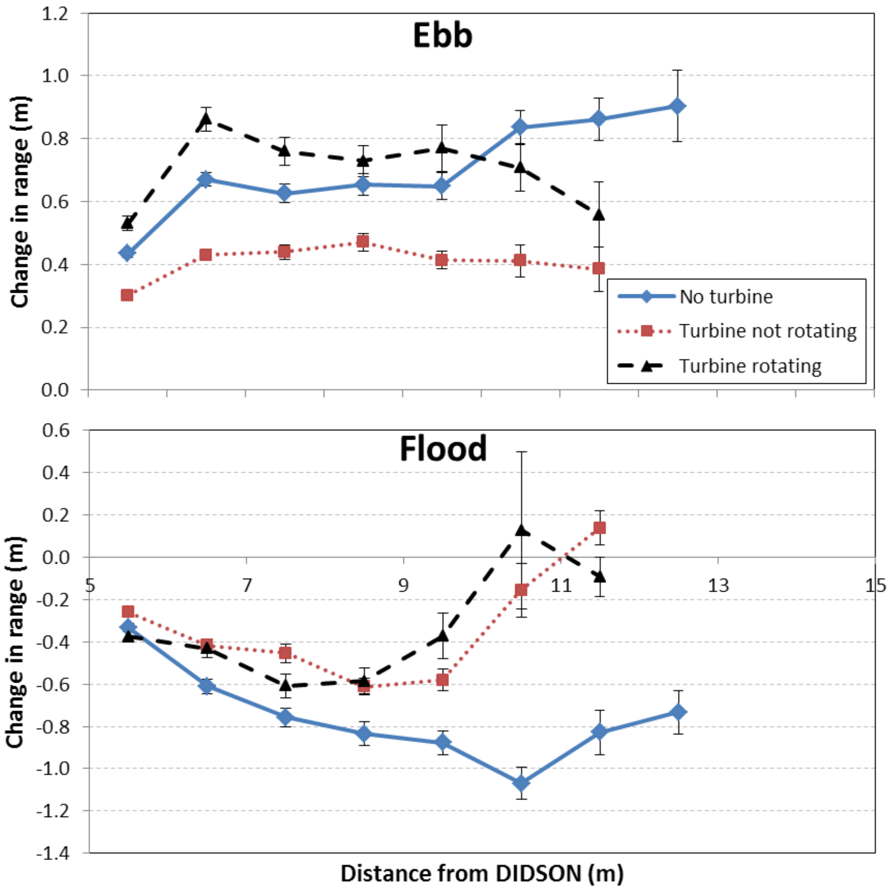


Figure 2-6. Mean (±1 SE) change in range (m) for each fish track as a function of the mean distance from the DIDSON acoustic unit. Note that the DIDSON is located at 0 m and the turbine between 11 and 15, depending on orientation and operation.

2.3.5 Vertical Direction

Vertical movement was analyzed as either upward (0 to +90° angle) or downward movement (0 to -90° angle) irrespective of what depth the track originated from with +90 indicating movement straight up and with –90 being straight down. An analysis of the distributions of vertical direction data for the three operating modes and two tides revealed that neither ebb nor flood tide distributions are centered on 0 (Figure 2-7), probably for a combination of two reasons: (1) the DIDSON was not aimed completely parallel to the surface, and (2) the bottom topography creates prevailing currents that most fish ride that also are not parallel to the surface. For both tides, the distributions for the no turbine case and the operating turbine case are similar; but for both tides, the non-rotating turbine case produced tracks with less vertical slope, meaning less upward or downward movement over the course of the track. Analysis of vertical direction as a function of nearness to the turbine produced mixed results but also showed that the non-rotating turbine often resulted in tracks with less change in vertical position (Figure 2-8). The rotating-turbine tracks differed the most from the no-turbine tracks (1) during ebb tides, and (2) during flood tides when the tracks were close to the turbine for downward tracking fish. During flood tide there was a large increase in downward movement near the stationary (not rotating) turbine at 10-12 m range but there were not enough observations when the turbine was absent or when rotating for a comparison.

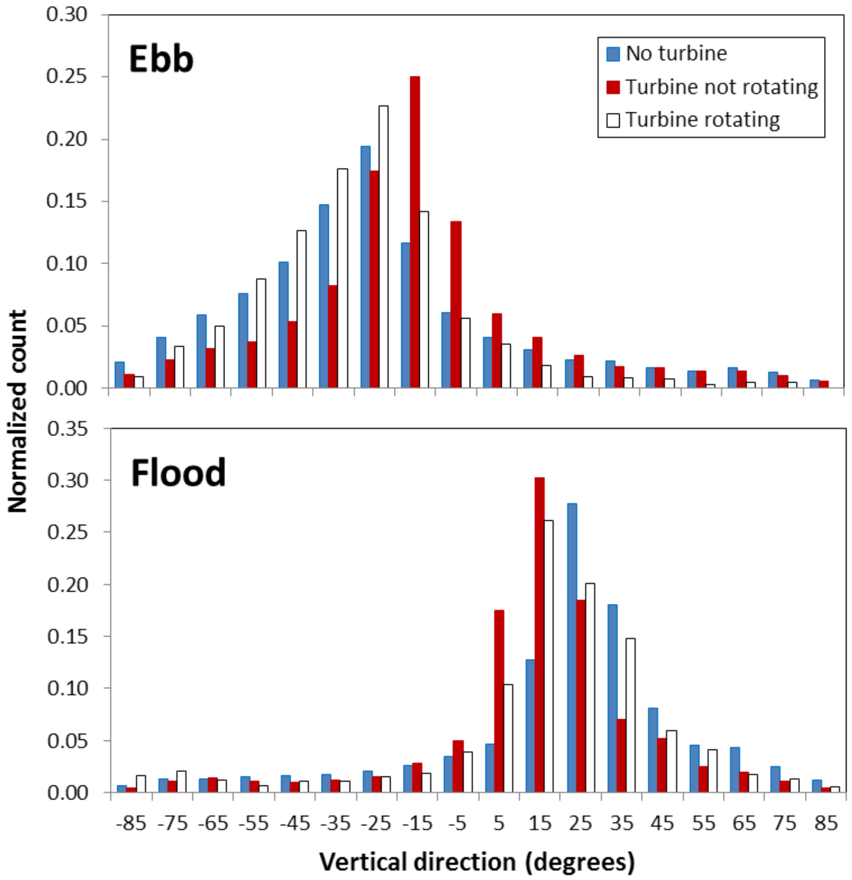


Figure 2-7. The distribution (normalized to the total tracks for any operating mode and tide combination) of vertical direction of fish tracks in degrees for three turbine operation modes and ebb and flood tides. Each x-axis value is the midpoint of a 10° bin.

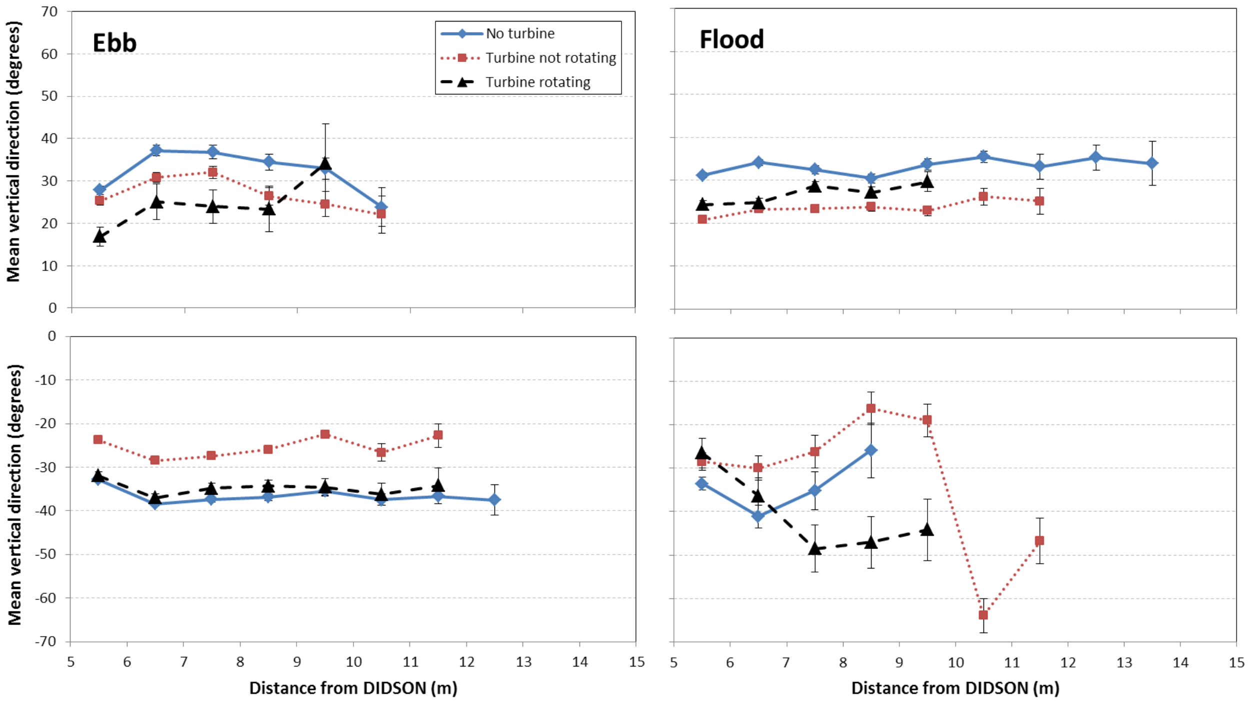


Figure 2-8. Mean (± 1SE) vertical direction (°) for each fish track during ebb and flood tides as a function of the mean distance from the DIDSON acoustic unit. Upward and downward moving tracks are presented separately in the top and bottom panels, respectively. Note that the DIDSON is located at 0 m and the turbine between 11 and 15, depending on orientation and operation.

2.3.6 Horizontal Direction

The prevailing current direction was a function of the tide direction and the camera aim selected. In addition, fish direction also had to be parsed by whether the fish were swimming with or against the current. Only one combination of tide (ebb) and RAD aim (1) provided enough tracks over two different 4 day periods for a comparison of no turbine (September 11–14) versus operating turbine (September 04–07) (Figure 2-9). For both operation modes, the variation around the central tendency was greater for fish swimming against the current than for those swimming with the current. For both operating modes, the horizontal direction for 95% of the tracks was within a 2° range. There is little indication of any effect of the operating turbine on horizontal direction for fish swimming with or against the current.

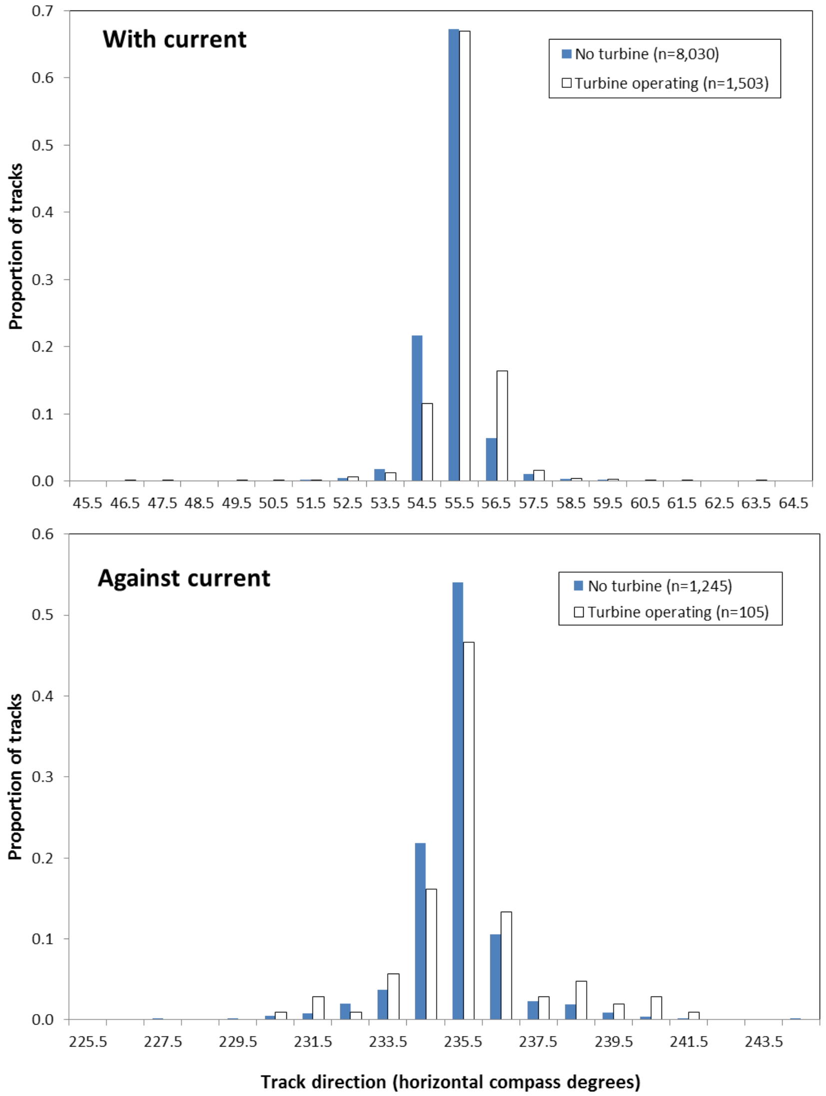


Figure 2-9. The distribution of horizontal direction of fish tracks in degrees (normalized to the total tracks for these two cases, 9,533 and 1,350) for fish swimming with and against the current during ebb tide with a RAD aim of 1 and when no turbine was present versus an operating turbine. The non-operating turbine case was not included in the figure because of the low sample size. Each x-axis value is the midpoint of a 2° bin.

2.3.7 Tortuosity

A fish track through the DIDSON field that is a straight line has a tortuosity value of 1; the larger the tortuosity value, the more crooked the path is. Most of the tracks were relatively straight, and there is only a slight indication of differences among the three operation modes based on the distribution of tortuosity values (Figure 2-10). Evaluation relative to the distance from the turbine showed that tortuosity gradually decreased (i.e., became straighter) as tracks neared the turbine location when the turbine was absent (Figure 2-11). Conversely, when the turbine was in place, either rotating or not rotating, tortuosity increased for tracks nearer the turbine.

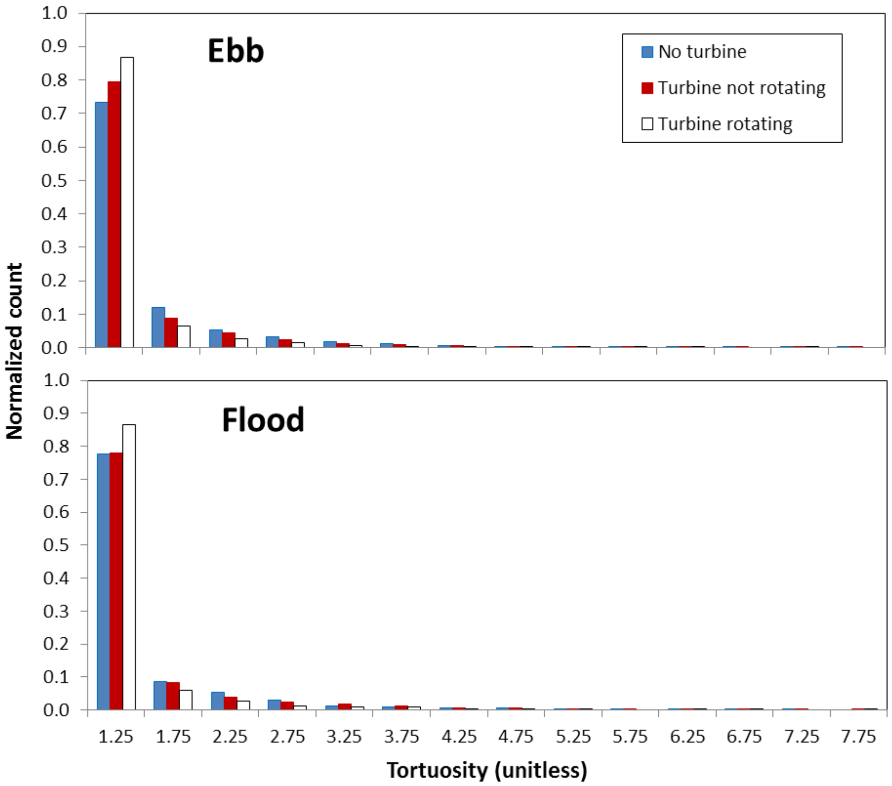


Figure 2-10. The distribution (normalized to the total tracks for each operating mode and tide combination) of tortuosity of fish tracks for three turbine operation modes during ebb and flood tides. Each x-axis value is the midpoint of a 0.5 bin.

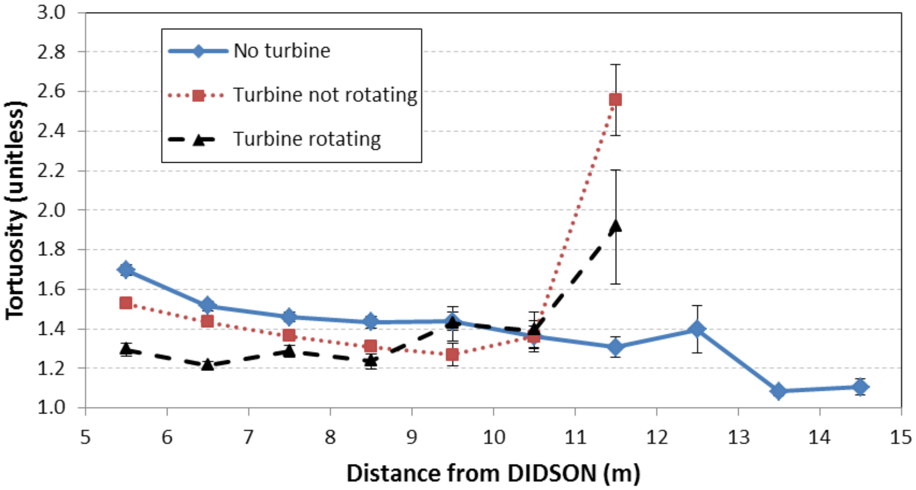


Figure 2-11. Mean (± 1SE) tortuosity for each fish track during three turbine modes as a function of the mean distance from the DIDSON acoustic unit. Note that the DIDSON is located at 0 m and the turbine between 11 and 15, depending on orientation and operation.

2.3.8 Swimming Velocity

During ebb tides, the mean (±1SE) swimming velocity of fish in the presence of a rotating turbine (1.03 ± 0.01 m/s) was slower than when the turbine was absent (1.29±0.01 m/s), as can be seen in the frequency distribution (Figure 2-12). The difference was similar but less pronounced during flood tides (1.28±0.01 m/s when the turbine was rotating versus 1.36±0.01 m/s when it was absent). However, viewed in relation to distance from the turbine, the possible effect of the turbine on swimming velocity is much more noticable during flood tides than during ebb tides for both rotating and stopped turbines (Figure 2-13).

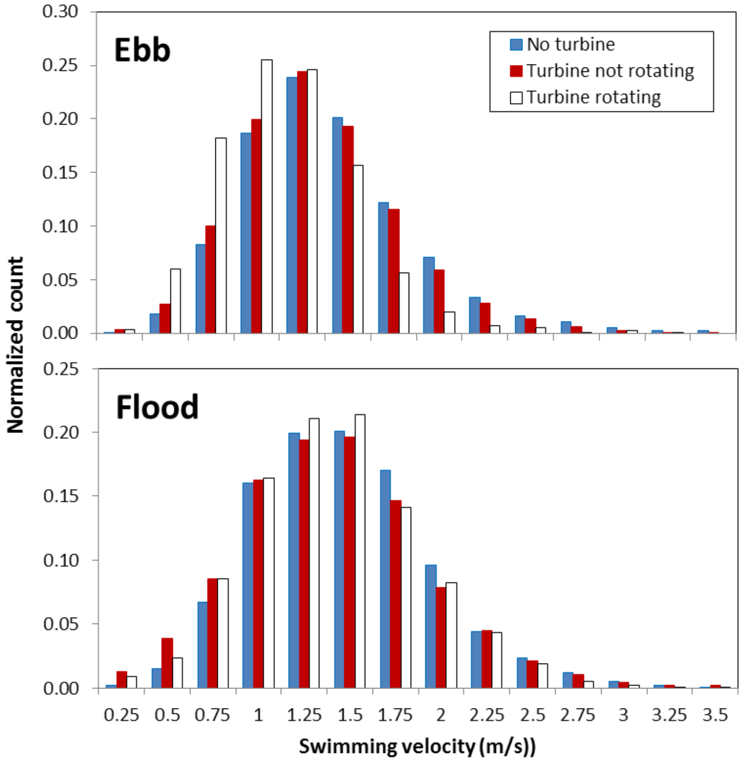


Figure 2-12. The distribution (normalized to the total tracks for each operating mode and tide combination) of fish track swimming velocities (m/s) for three turbine operation modes and ebb and flood tides.

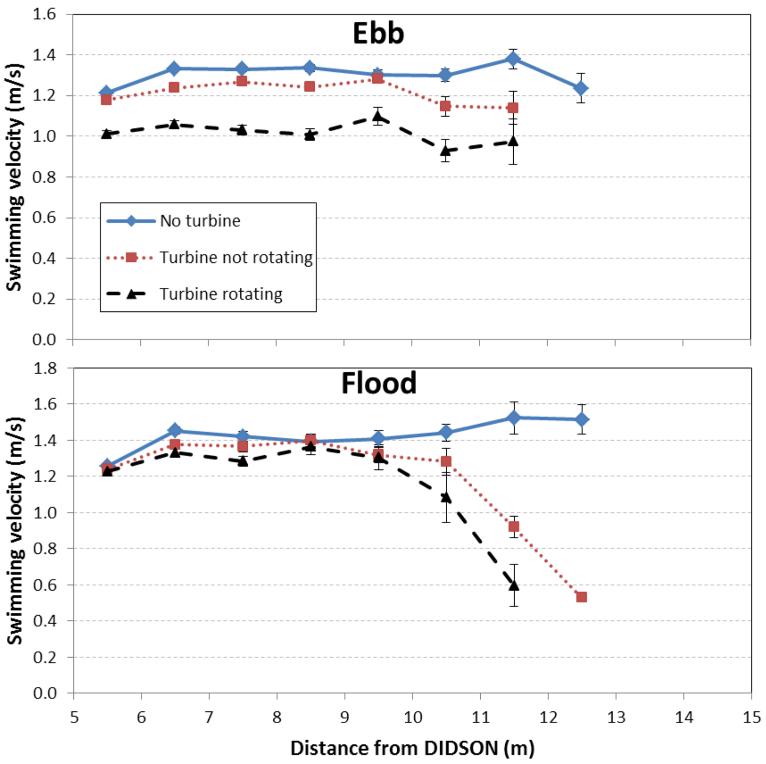


Figure 2-13. Mean (± 1SE) swimming velocity (m/s) for each fish track during ebb and flood tides as a function of the mean distance from the DIDSON acoustic unit. Note that the DIDSON is located at 0 m and the turbine between 11 and 15, depending on orientation and operation.

2.3.9 Direct Observation of Fish–Turbine Interactions

An analysis of 36 tracks with a possibility of a close encounter with the turbine based on their nearness to the turbine and the direction of the flow revealed fish exhibiting three different behaviors. They either exhibited no change in direction (two schools and two individuals), avoided the turbine by angling away from it (two schools and eight individuals), or swam at the moving blades and then disappeared from the DIDSON view either just before or as encountering the turbine (four schools and two individuals). Some of the tracks were multiple tracks associated with the same school; therefore, the total did not sum to the original 36 tracks. There was no evidence of any fish being struck by the rotor.

During the validation exercise described earlier, we observed 38 schools and 82 individual fish during 112 min of video when the turbine was rotating. Only five (4%) of these had what appeared to be direct encounters with the rotor blade. One individual and one school avoided the rotor by angling away from it, two individuals disappeared as they encountered the rotor, and one individual (~20 cm in length) might have contacted the rotor. The fish that possibly came in contact with the rotor originated at the blade tip and swam in a direction rarely seen (i.e., directly toward the DIDSON and perpendicular to the flow). However, the swimming direction prior to its appearance could not be determined and actual contact with the blade was not observed.

2.4 DISCUSSION

2.4.1 Summary of DIDSON Results

The automated data analysis we performed identified 34,708 fish tracks, which included both individual fish and schools. The number of tracks per hour of observation was generally higher during ebb tides than during flood tides and generally increased with increasing current velocity (Table 2-2). The count per hour was highest when the turbine was absent and lowest when the turbine was installed and rotating. The increase in rate with current velocity is probably more a function of the fact that more water passes by the DIDSON during increased flow, carrying with it more fish, and not a result of there being more fish in the water column during higher velocity. However, the latter is a possibility during some seasons for some migratory species that might be taking advantage of the currents to move in a particular direction. The most likely explanation for why more fish were observed during ebb tides than flood tides is that the seasonal migration patterns of many species is outward bound or southward during the fall. Because we could not alternate days of turbine presence and absence it is possible that the increased number of fish seen when the turbine was absent was a result of a natural change in abundance in the system. However, given that the change was a by factor of 3 or 4 and occurred in a single day (from 11 Sept to 12 Sept) suggests that it was most likely a response to turbine removal (Table 2-2).

In the near-field within the 10 m window viewed by the DIDSON, the number of tracks observed decreased sharply from near the DIDSON (away from the turbine location) to near the turbine location (away from the DIDSON) regardless of whether the turbine was absent, in place but not rotating, or in place and rotating (Figure 2-4). Because of the shape of the volume sampled by the DIDSON unit (see Figure 2-1), a correction by either volume sampled or vertical cross-sectional area sampled would make this difference between near-shore and offshore densities even larger. Given that the offshore decline is similar with and without a turbine in place, it does not appear that this particular observation is a result of turbine avoidance.

The best indications of near-field avoidance come from tracking the direction that fish move as they approach a turbine. The results we presented were specifically designed to compare the tracks of fish (1) in different turbine environments— i.e., absent, present but not rotating, and rotating—to see if turbine presence had an effect and (2) at different distances from the turbine to see if turbine proximity had an effect. Track direction was evaluated in one-dimensional space (change in range between the DIDSON and the turbine, two-dimensional space (change in vertical or horizontal direction), and three-dimensional space (path tortuosity).

Looking just at change in range (Figures 2-5 and 2-6), there are some differences between the no-turbine and operating-turbine conditions, but there is little evidence of fish moving away from the turbine. Change in vertical direction was evaluated for four cases (ebb and flood tide by upward and downward movement). Most of the tracks fit into either the flood-tide upward-movement category or the ebb-tide downward-movement category, and there is no evidence of any change in behavior relative to vertical direction for these two cases (Figure 2-8). For change in horizontal direction, we evaluated the case with the largest sample size, i.e., ebb tide with RAD position 1, and found no evidence of any change in horizontal direction relative to turbine presence or operation (Figure 2-9). Note that the horizontal direction was very consistent, and nearly 87% of the tracks going with the current were within ±1° of the mode and 99% within ±5° of the mode. We did see differences in tortuosity that might be in response to the deployed turbine. Without the turbine in place, fish tracks became straighter as distance from shore increased. However, when the turbine was present, rotating or not, the tracks of fish nearest the turbine (i.e., most offshore) were the most crooked (Figure 2-11), suggesting that fish made evasive moves.

The last metric evaluated for change in behavior was swimming velocity, which we found to be slower in the presence of the operating turbine (Figures 2-12), especially within 2 m of the turbine during flood tide (Figure 2-13).

One might expect that, if fish were responding to the turbine, the case of the non-rotating turbine would fall somewhere between no turbine and an operating turbine; but for some metrics (see Figures 2-5, 2-6, and 2-7), this does not appear to be the case. It is possible that when the turbine is not rotating and thus its signature is smaller (wake and noise), the fish are not alerted to the presence of the turbine until later (i.e., closer to the turbine). Fish seem to react to the rotating turbine well before they reach the turbine, so they might not sense the non-rotating turbine and therefore don’t avoid the stationary object until they are much closer (i.e., within a few m). Fish may have changed direction much earlier in their approach to the rotating turbine, if its presence was felt earlier.

From our direct observations of small subsets of the DIDSON videos, we found that individual fish and schools that were headed toward rotating blades usually avoided the blades by adjusting their horizontal swimming direction slightly and angling away. Others disappeared just before encountering the rotor (i.e., within 1 m), which we assume to have happened because the fish changed vertical direction, swimming either above or below the turbine and therefore out of view of the DIDSON beam. The automated analysis did not detect this change in vertical direction, but that analysis was not able to assess movements by fish that approached the swept area directly because of the interference created by the moving blades. A direct contact with the rotor by a large fish (>50 cm) would likely have been apparent if it had occurred, but the DIDSON resolution makes it difficult to observe actual contact for fish smaller than 50 cm. We occasionally saw some abrupt changes in direction, but we never confirmed contact with a rotor blade or observed fish swimming directly through the swept area and out the back side.

In addition to the intended analysis of near-field effects, the DIDSON data also provide some information about possible far-field avoidance. For example, the density of fish in the DIDSON sample area when the turbine was absent was roughly twice what it was when the turbine was in place, for both rotating and not rotating. This suggests that some avoidance may be occurring before fish are close enough to the turbine to be observed by the DIDSON. This response is similar to that observed by Shen et al. (2015) at a tidal energy site in Cobscook Bay, Maine, where they found evidence of general fish avoidance of a tidal energy device at up to 140 m from the device.

Some results of this analysis were used as input values for the fish interaction model discussed elsewhere in this report. Most notably, the distribution of the horizontal direction of fish tracks was used to inform the angle-of-incidence parameter. The angle at which a fish encounters the rotor has a significant effect on its probability of being struck by a blade. We presumed that the body of a fish is in a direct line with the direction in which it is swimming, and used the distribution of swimming direction to inform angle of incidence. Since there is so little variation in the direction in which fish swim relative to the direction of the flow, and therefore the position of the turbine, this parameter was revised in the fish interaction model so that nearly all the fish have an angle of incidence perpendicular to the direction of the rotor blades.

The use of multibeam acoustics proved to be a useful tool for evaluating the near-field interactions of fish with an operating KHPS turbine. However, because of its limited range and the size of the turbine, the position and aim of the DIDSON unit was critical for capturing the most useful information. This poses a particular challenge in tidal environments with turbines that change orientation with the direction of flow. The movement of the turbine (nacelle and rotor) also presented a challenge in automating data analysis, which was necessary because weeks of continuous data are required to adequately capture fish interactions under all conditions of flow and turbine operation. Manual analysis would take longer than data collection itself. Future advances in data analysis techniques should make dealing with operating turbines more feasible.

Although some investigators are starting to be successful in identifying fish by species with multibeam systems, doing so was not practical in this study. However, from previous fish sampling in the East River in the vicinity of RITE, we know that common species include winter flounder (*Pseudopleuronectes americanus*), Atlantic tomcod (*Microgadus tomcod*), striped bass (*Morone saxatilis*), grubby (*Myoxocephalus aenaeus*), bay anchovy (*Anchoa mitchilli*), Atlantic silversides (*Menidia menidia*), blueback herring (*Alosa aestivalis*), northern pipefish (*Syngnathus fuscus*), and Atlantic menhaden (*Brevoortia tyrannus*) (Verdant Power 2011). Atlantic silverside and northern pipefish are regular residents of the area, while the other species are seasonally abundant depending on species-specific migratory patterns. Other, less common species that likely migrate through the area on the way to and from spawning grounds include American eel (*Anguilla rostrata*), alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), Atlantic sturgeon (*Acipenser oxyrinchus*), rainbow smelt (*Osmerus mordax*), and shortnose sturgeon (*Acipenser brevirostrum*). As multibeam system hardware and software improve, the capability for species identification are likely to become more accurate.

Although we found some evidence that the presence of an operating turbine affected the swimming behavior of fish, resulting in apparent avoidance in some cases, we were not able to accurately estimate the frequency or rate of avoidance. We are confident, however, that the likelihood of fish being struck and injured by an KHPS turbine at the RITE site is relatively low, based on the apparent long-range avoidance seen in another study and supported by this study, the apparent ability of most fish to avoid rotor blades when they are encountered at close range, and the paucity of evidence of direct blade strikes.

3. INTEGRATION

3.1 SPLITBEAM DATA

3.1.1 Introduction

Little is known about the far-field behavioral response of fish to HK devices, although recent work by Shen et al. (2015) suggests that fish might exhibit avoidance as far away as 140 m. The objective of this task was to quantify the distribution and trajectory of fish throughout the vicinity of the RITE site using a representative sample of hydroacoustics data collected with an array of BioSonics splitbeam transducers (SBTs) mounted at the RITE site from June 2007 to October 2009 during testing of an array of six tidal turbines. Significant data analysis of fish presence and abundance using these data was previously accomplished by Verdant Power in support of its FERC license application; however, an analysis of the swimming direction, trajectory, and velocity was not fully undertaken. For this task, we analyzed data collected from nine SBTs while up to two Verdant Power Gen4 KHPS turbines were operating in the array. These data were collected at virtually the same location and during the same time of year (September 1–14, 2008), but not the same year, as the DIDSON data described in Section 2 earlier. Our analysis focused on the effects of proximity to turbine, tide cycle, and current speed on fish distribution, swimming direction (with or against the flow), and swimming velocity.

3.1.2 Methods

Because of the amount of data collected over the 2 year period, we chose a manageable subset to accomplish our objectives. Three frames were chosen (frames 1, 2, and 3, Figure 3-1) for which nine transducers were fully functional through the period of interest and that represented locations both away from the turbines (approximately 100 ft; frame 1) and in close proximity to operating turbines (immediately in front of and behind; frames 2 and 3). Each frame supported three transducers, one aimed at the top third of the water column, a second at mid-column, and a third at the bottom third of the water column (Figure 3-2).

We analyzed output from a prior analysis of the raw splitbeam data that included observations of 18,077 fish targets for the 2 week period and 9 transducers and included the following data:

- Date and time
- Target strength (dB; an indicator of fish size)
- XYZ coordinates within splitbeam sampling cone
- Location by zone (1 to 18; see Figure 3-2)
- Fish track speed (m/s)
- Fish track direction (north or south)
- Current speed (m/s), with positive numbers indicating northward direction and negative numbers southward

From the final two variables, we calculated an additional variable of swimming with (+1) or against (−1) the current.

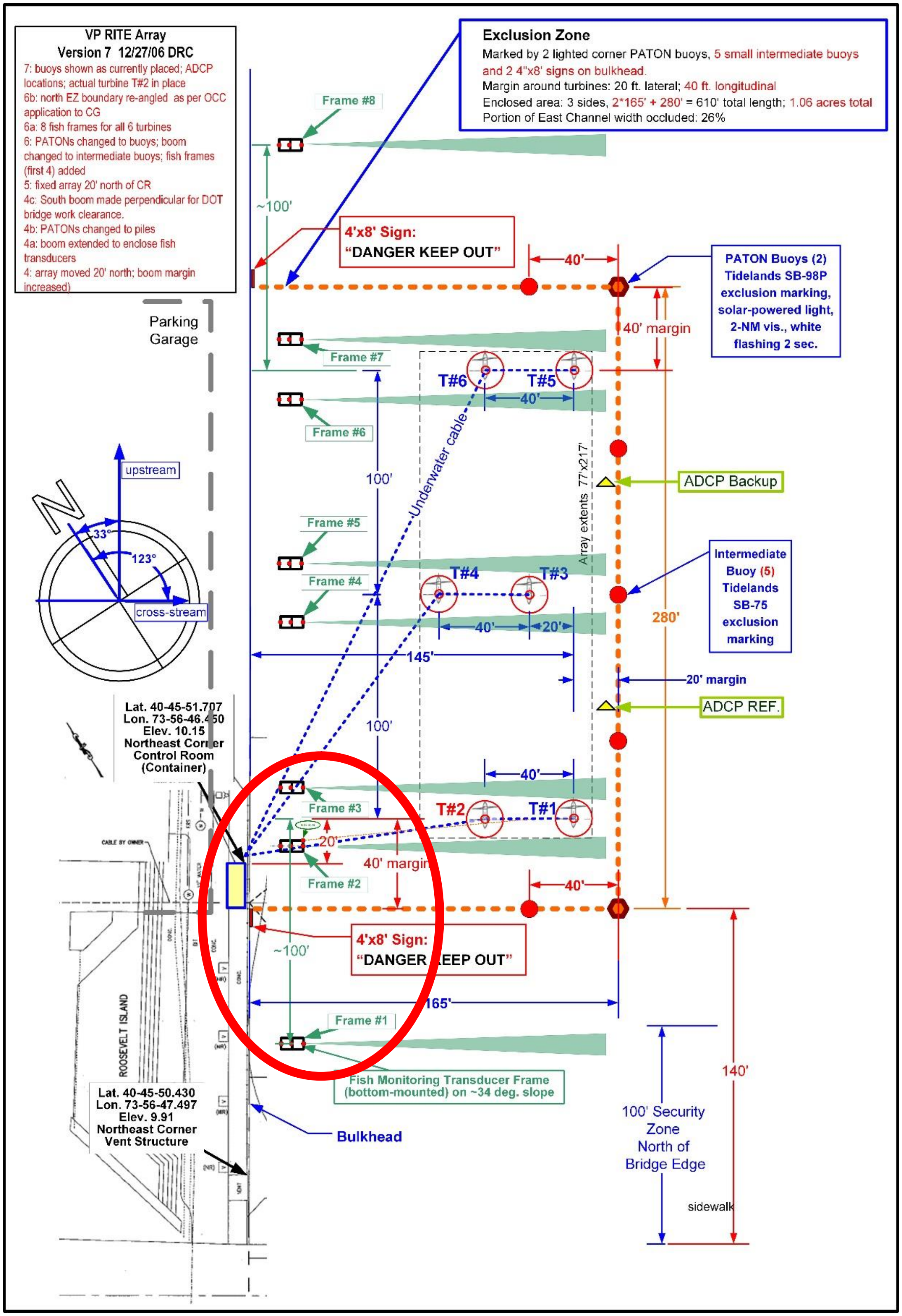


Figure 3-1. Overhead view of eight frames, three splitbeam transducers each, at the RITE site. Transducers were aimed in an offshore direction (toward right of figure). The analysis in this report was based on data from frames 1-3 circled in red. Source: FERC Draft License Application, Volume 4.

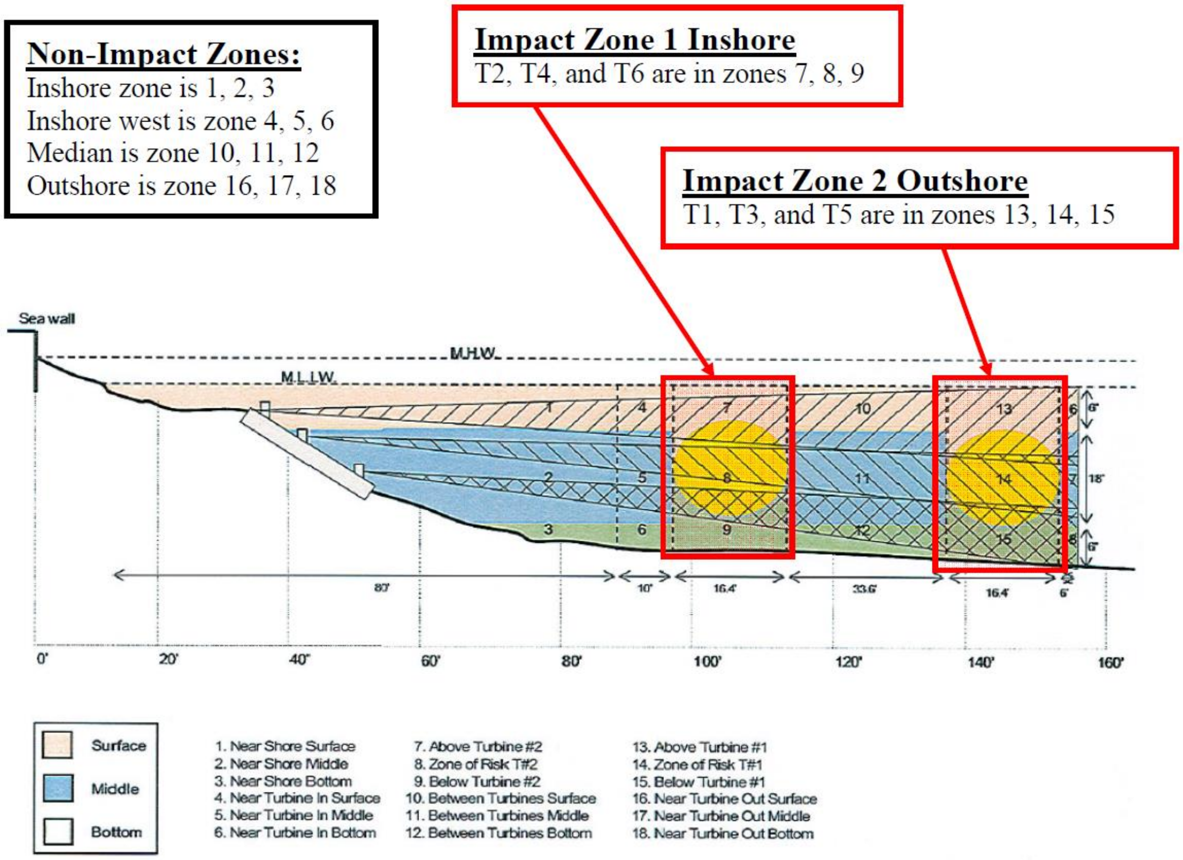


Figure 3-2. Cross-sectional view of field of view of three splitbeam transducers on a single frame relative to location of two turbines. The rotor-swept area for two turbines is indicated by yellow circles. The x-axis is in feet. Source: FERC Draft License Application - Volume 4.

Targets with a signal strength of greater than –20 dB were filtered from the original set to eliminate tracks that were unlikely to be fish targets, i.e., too large, based on Love's equation relating fish length to signal strength (Love 1977). Most of these filtered data came from one of the frames that sampled nearest the turbines, and these spurious observations were likely part of the turbine structure. This reduced the original number of tracks for the 14 day data set by 2,436, leaving a sample size of 15,641 fish targets for our analyses.

We summarized abundance (distribution), swimming direction relative to river current, and swimming velocity based on size, location, current speed, and tide. We defined two size categories, less than and greater than 76 cm (30 in.) as defined by signal strengths less than or greater than –30 dB. Location was categorized using the original 18 zones and also as 6 larger combined zones which were identified as near shore (zones 1–3), near turbine inshore (4–6), inshore impact zone (7–9), between turbines (10–12), offshore impact zone (13–15), and near turbine offshore (16–18). River current speed was categorized into 26 bins of 0.2 m/s ranges from –2.6 to 2.6 m/s; this resolution was chosen to match variables used in the fish interaction model. Tide direction was defined in three categories: ebb tide (current speed less than –1 m/s), flood tide (current speed greater than +1 m/s), and slack tide (–1 m/s > current speed < +1 m/s). The –1 and +1 m/s thresholds correspond to the speeds below and above which the turbine rotors would rotate.

We performed a standard analysis of variance (ANOVA) on the swimming velocity data to determine if there was a significant effect of current velocity, fish size (i.e., target strength) and proximity to turbine (frame 1 versus frames 2 and 3).

3.1.3 Results

After filtering the original data for the 14 days and three frames, we compiled 15,641 fish targets for further summarization. Total counts varied by about a factor of two among days within the data for a single frame and varied by a factor of 3 to 4 among frames with the greatest number of fish observed by the frame 1 transducers and the least by the frame 2 transducers (Figure 3-3).

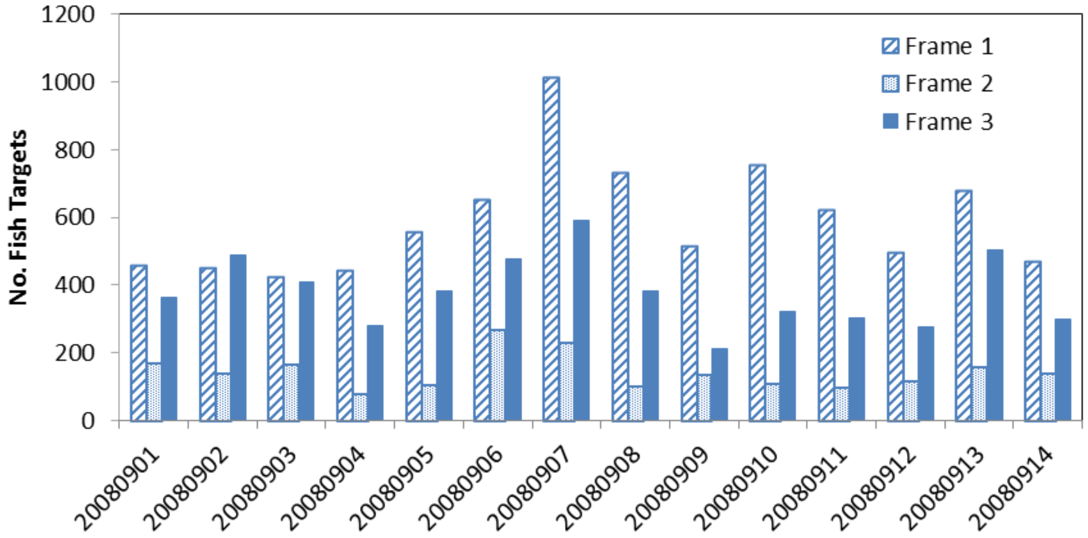


Figure 3-3. Counts of fish by date and splitbeam frame (total n=15,641).

3.1.3.1 Distribution

Parsing the distribution by tide (ebb, slack, or flood) and frame (1, 2, or 3) reveals that most of the fish are near shore; and nearly twice as many fish were observed at frame 1, which was away from the turbines, than at the other two frames (Figure 3-4). In addition, many more fish were seen during slack tide (with no turbine operating) than ebb and flood tides, but the differences were largely at the inshore zones and not at the turbine locations.

Ebb Tide

Frame 1	surface	19.14	4.93	1.21	0.00	0.00	0.00
	mid	48.29	11.29	3.57	2.07	0.00	0.14
	bottom	0.00	0.29	0.00	0.00	0.00	0.00
Frame 2	surf	0.00	0.00	0.00	0.00	0.00	0.00
	mid	31.93	6.00	2.86	1.36	0.07	0.00
	bottom	0.00	0.14	1.07	0.00	0.00	0.00
Frame 3	surf	0.57	2.43	4.00	0.07	0.00	0.00
	mid	39.29	13.64	8.64	2.79	0.00	0.00
	bottom	0.00	0.00	0.00	0.00	0.00	0.00

Slack Tide

Frame 1	surf	47.21	14.64	5.93	0.14	0.00	0.00
	mid	250.86	25.14	6.93	6.86	1.71	6.86
	bottom	0.00	0.21	0.43	0.29	0.00	0.00
Frame 2	surf	0.00	0.00	0.00	0.00	0.00	0.00
	mid	50.71	4.14	6.29	7.43	0.36	0.00
	bottom	0.00	0.00	0.00	0.14	0.00	0.00
Frame 3	surf	1.07	4.57	6.00	0.57	0.00	0.00
	mid	155.64	44.36	19.79	5.14	0.00	0.21
	bottom	0.00	0.00	0.00	0.00	0.00	0.00

Flood Tide

Frame 1	surf	52.29	4.07	1.21	0.00	0.00	0.00
	mid	49.07	12.86	4.93	6.21	2.71	0.79
	bottom	0.00	0.07	0.21	0.00	0.00	0.00
Frame 2	surf	0.00	0.00	0.00	0.00	0.00	0.00
	mid	21.07	3.93	4.64	4.14	0.00	0.00
	bottom	0.00	0.00	0.36	0.14	0.07	0.07
Frame 3	surf	1.64	1.00	3.79	0.71	0.00	0.00
	mid	27.43	21.36	9.36	3.57	0.00	0.07
	bottom	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3-4. Distribution of fish (mean number per day) in 18 zones (see Figure 3-2) as determined by splitbeam hydroacoustics systems at three frames during ebb, slack and flood tides. The relative locations of turbine rotor swept areas are indicated with yellow circles. Shades of red indicate relative density with dark red being greatest. Note that the two bottom cells from 0–50 feet were almost entirely out of range of the SBT beams.

3.1.3.2 Swimming direction

For the entire data set, we found that 23% of the fish were swimming against the current and 77% with. However, many of these observations were at velocities <1 m/s around slack tide at a time when the turbines were not rotating. Considering only the time when the turbines would have been rotating, i.e., when current velocity exceeded 1 m/s, the proportion of fish swimming against the current was about 7%. When the data were further subdivided by size class (above and below –30 dB target strength or about 76 cm), we found that at slow current (i.e., slack tide), smaller fish are more likely to swim against the current than large fish; but at faster current speeds, nearly all of the small fish swam with the current.

3.1.3.3 Swimming velocity

As expected, there is a large difference in the swimming velocity of fish swimming with the current as opposed to those against (Figure 3-5). Few fish swimming against the current swam at a velocity >1 m/s. On the other hand, fish swimming with the current (which could be as high as 2.5 m/s) regularly swam faster than 1 m/s and some nearly as fast as twice the current speed.

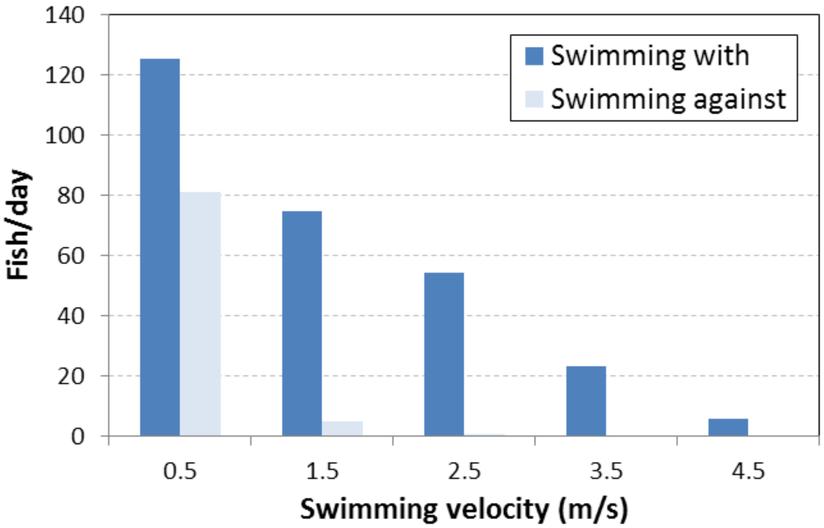


Figure 3-5. Distribution of swimming velocities of fish swimming with and against the current. X-axis values represent the mid-point of 1 m/s ranges.

Results of the ANOVA indicate that swimming velocity is dependent on current speed and fish size and also differs among the three frames (Table 3-2). Figures 3-6 indicates that differences in swimming velocities among the frames are mostly apparent at the highest current speeds.

Table 3-1. Results of analysis of variance testing the effects of current speed, target strength (i.e., fish size), and transducer frame on swimming velocity.

Variable	Sum of squares	DF	F value	Pr(>F)
Current speed	5915.2	1	8953.4	< 0.0001
Target strength	481.2	1	728.4	< 0.0001
Frame	33.0	2	25.0	< 0.0001

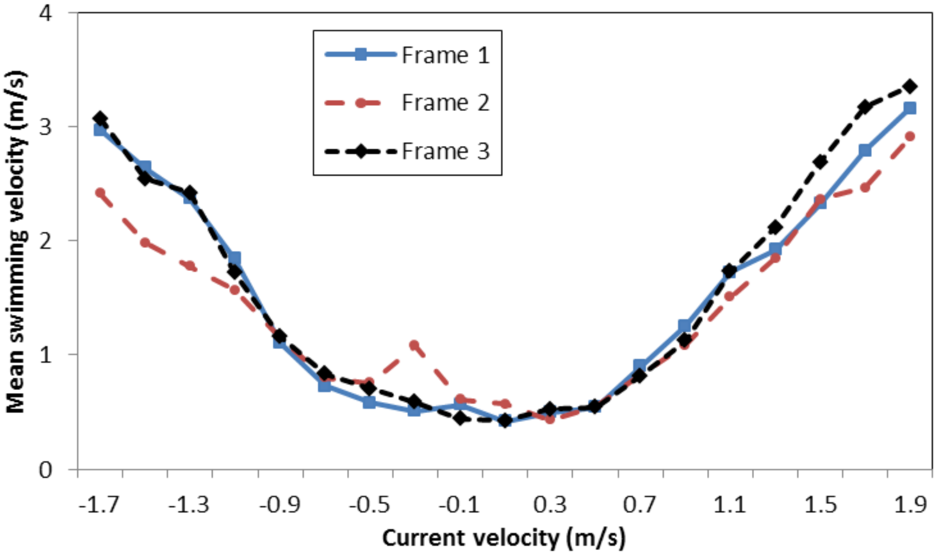


Figure 3-6. Mean swimming velocity by 0.2 m/s current velocity bins for fish swimming with the current for each of the three splitbeam transducer frames. Positive current velocity values indicate that flow is in the flood tide direction and negative values indicate the ebb tide direction.

3.1.4 Discussion

Splitbeam hydroacoustics data collected in September 2008 were re-analyzed to evaluate the effects of turbine proximity and tide cycle (i.e., current velocity and direction) on the distribution and swimming direction and velocity of fish. The ultimate intent of this analysis was to update parameters in an existing KFIM that predicts the likelihood of KHPS encounter and injury by fish in the East River. We found the distribution of fish in the vicinity of the RITE project during the period of sampling to be heavily skewed to near shore areas and to periods of slack tide when water current velocities are the lowest. This is consistent with previous analysis done for Verdant’s FERC license application. During high-velocity conditions, many fish probably move to the bottom or move further inshore than the splitbeam system sampled. Most fish observed during this sampling swam with the current, especially when current velocities were high. This observation might vary during seasons when fish are migrating in a particular direction (either upriver or downriver), but even then, for energetic reasons, most fish probably travel in their intended directions in the main channel and then move to low-velocity areas near the bottom or shore when traveling against the current. Of the three frames of transducers, the one farthest from the turbines produced the greatest number of fish track observations, suggesting that fish might be avoiding the waters nearest the turbines. This frame is also the closest frame to the Roosevelt Bridge, whose pilings often attract fish.

A change in velocity by fish close to an operating turbine might suggest some form of avoidance. We found some difference in swimming velocity among the three locations sampled, but the swimming velocity of fish at the site 100 ft away was intermediate between those at the two locations on either side of the turbines. That finding suggests that the swimming velocity was a function of fish size and water velocity, as might be expected with larger fish and fish in faster currents swimming at higher velocities.

3.2 KHPS–FISH INTERACTION MODEL

3.2.1 Description

In response to a request from the National Marine Fisheries Service (NMFS), Verdant and Kleinschmidt developed an in-stream KFIM for the East River. The overall intention of this model was to quantify the risk that Verdant's KHPS turbines present to fish at the proposed RITE project. Table 3-5 summarizes the parameters of the KFIM model and initial settings that were used by Verdant in assessing the KHPS-fish interaction in 2010.

Table 3-2. Parameters for the KFIM

Term	Parameter Description	Relevance	RITE 2010 KFIM
P1	Probability of blade rotation	Specific to the KHPS at water velocity Vw of >1 m/s; varies with tidal site	P1 = 1 at flows greater than 1 m/s, 0 for all flows less than 1 m/s
P2	Distribution of water velocity over the tidal cycle	Vw as measured by ADCPs; varies with tidal site	See measured RITE Vw probability distribution
P3	Fish distribution between east and west channel	An assumed distribution in the configuration of the RITE project	P3 = 0.5
P4	Effective KHPS turbine rotor area	A constant for a 5 m blade	P4 = 0.0066
P5	Blade interaction with fish passing through turbine disk	Varies with shape of rotor , the Vw and presence of the subject of investigation, and the approach angle	P5 follows formulae discussed below. Two major parameters: (1) 80/20 rule: assumes 80 % of fish swim with current, 20 % against, for Vw less than or equal to the endurance velocity (Ve) (2) Angle of incidence: assumes all fish approach blade from all angles within 180° uniformly
P6	Fish distribution	Are ESA fish present in RITE east channel?	P6 = 1 equal likelihood that ESA fish are in east channel
P7	Fish avoidance behavior	Do fish avoid zones of operating turbine	P7 = 1 conservative—no avoidance

ESA = Endangered Species Act

This is a spreadsheet, probability-based model that determines the overall risk of a turbine blade striking a fish (blade strike). The intent of the model was to initially concentrate on the turbine interaction with the shortnose sturgeon and Atlantic sturgeon, as these are protected species of interest at the RITE site However, comparative results were also generated for species identified in the Essential Fish Habitat Assessment that was performed as part of Verdant's Final Pilot License Application.

The National Oceanic and Atmospheric Administration/National Marine Fisheries Service, in its September 2012 Biological Opinion (Opinion) (REF3) concludes

> .. Opinion of the effects of Verdant Power's Roosevelt Island Tidal Energy (RITE) Project including the Seasonal Species Characterization Netting plan as required by Article 401 of the Pilot License issued on January 23, 2012. In this Opinion, we conclude

> that the proposed action is likely to adversely affect, but not likely to jeopardize the continued existence of the threatened Gulf of Maine Distinct Population Segment (DPS) of Atlantic sturgeon or the endangered New York Bight, Chesapeake Bay, South Atlantic or Carolina DPSs of Atlantic sturgeon. We also conclude that the proposed action may affect but is not likely to adversely affect shortnose sturgeon or the Northwest Atlantic DPS of loggerhead sea turtles, or Kemp's ridley, green or leatherback sea turtles.

Thus the acceptance of the application and results of the RITE 2010 KFIM was affirmed.

3.2.2 Parameters under Study

Since the acceptance of the KFIM model for FERC licensing, and with the opportunity provided by this DOE grant, the objective of this task as described in Section 1.3 was to update parameterization of existing fish interaction model developed for the East River and the RITE Project. Two specific parameters can be examined as a result of the ORNL DIDSON/SBT data review: P5, the probability of a blade impacting the fish and its subparameter assumptions; and P6, Fish Distribution, as observed in the DIDSON and SBT data. New model simulations using the revised P5 and P6 parameters will be referred to in this report as the ORNL 2015 case. Additionally, as a result of concurrent efforts by Verdant on other RITE monitoring and as a model sensitivity exercise, two other parameters, P3 and P7, can also be updated. Those model results will be referred to as the Verdant P-12611 case. Table 3.2 and the text that follows discuss the KFIM parameter updates and the revised model results.

ORNL 2015 Case

P5: Probability of the blade impacting the fish

For fish that will be incident upon the rotor, parameter P5 provides the probability of the blade impacting the fish (at any point on its body). This quantity is determined only by the following:

- The speed of the fish approaching the turbine (a function of species burst speed AND direction—the 80/20 rule as defined below;
- the length of the fish, generally grouped as native species size: Essential Fish Habitat Species L < 45 cm and ESA Species L = 88 cm and L = 104 cm
- the rotational speed of the turbine blades (a known constant)
- the angle at which the fish is approaching the turbine (angle of incidence)

i. P5 Subcomponent: 80/20 rule

The primary assumption included in this parameter is that a fish will move through the turbine blades by swimming at its maximum burst speed through the rotor. Based upon the body of data collected during the RITE demonstration, it may be possible to justify some additional spatial or zonal avoidance behavior. However, because no specific data are available for the sturgeon species of interest, no additional avoidance behavior is accounted for in the present model. The speed of the fish through the rotor will therefore be given only by the species' maximum burst speed plus the water velocity.

At RITE, fish likely swim through the east channel in both directions. However, over the course of the RITE demonstration, Verdant collected information on fish movements at the RITE east channel site that support the assumption that fish will typically be swimming with the current, especially at times of high velocity. From these data we made the assumption that when the water velocity is less than the regular endurance speed for a particular species, then 80% of fish will be swimming with the current and 20% against. For times when the water velocity is greater than the regular endurance speed, all fish will be swimming with the current. We term this assumption the 80/20 rule and postulate that this parameter could be examined as part of the ORNL work discussed in this report.

ii. P5 Subcomponent: Angle of Incidence

In the 2010 KFIM model runs , the angle at which the fish will approach the turbine disk was not known; therefore, it was assumed that fish will be incident upon the rotor disk from an even distribution of angles (±90°) centered on the direction of transit (upstream or downstream). As the angle of incidence for the fish moves away from the perpendicular, the effective length of the fish decreases; however, its velocity through the rotor is also reduced.

For a given water velocity and fish species, the probability of a strike for a fish incident on the turbine disk can be given by the following:

$$V_{apparent} = V_w + (V_b \sin(\theta))$$
$$L_{apparent} = L \sin(\theta)$$

where:

Parameter	RITE 2010	ORNL case	VP 12611 case
Vw = Water velocity	From ADCP	No change	No change
Vb = Species burst speed	See below	Modified	Same as ORNL case
L = Species nominal length	See below	No change	No change
n = number of blades	3–Gen5 KHPS 5m	No change	No change
R = Rotational speed (revolutions per second)	40 rpm – Gen5 KHPS	No change	No change
θ = Angle of incidence	Uniform 180°	Modified	Same as ORNL case

This equation is highly dependent upon species-specific parameters, such as swim speed and overall length. Unfortunately, swim speeds for these species are less well determined, although burst swim speed may be taken as 4 times the nominal length per second. Endurance swim speed can typically be seen as being half of the burst swim speed [REF - Wardle, C.S. 1975. Limit of fish swimming speed. Nature 255, 725-727 (26 June 1975) doi:10.1038/255725a0]. For the species of interest at RITE the following parameters were assumed.

Species	Common length (cm)	Endurance swim speed (Ve) (m/s)	Burst swim speed (Vb) (m/s)
Shortnose sturgeon	88	1.76	3.52
Atlantic sturgeon	104	2.08	4.16
EFH Fish	20–45	0.40–0.90	0.80–1.80

Given these assumptions and a uniform distribution of fish incident angles (θ), P5 can be seen for Atlantic and Shortnose sturgeon in Figure 3-8.

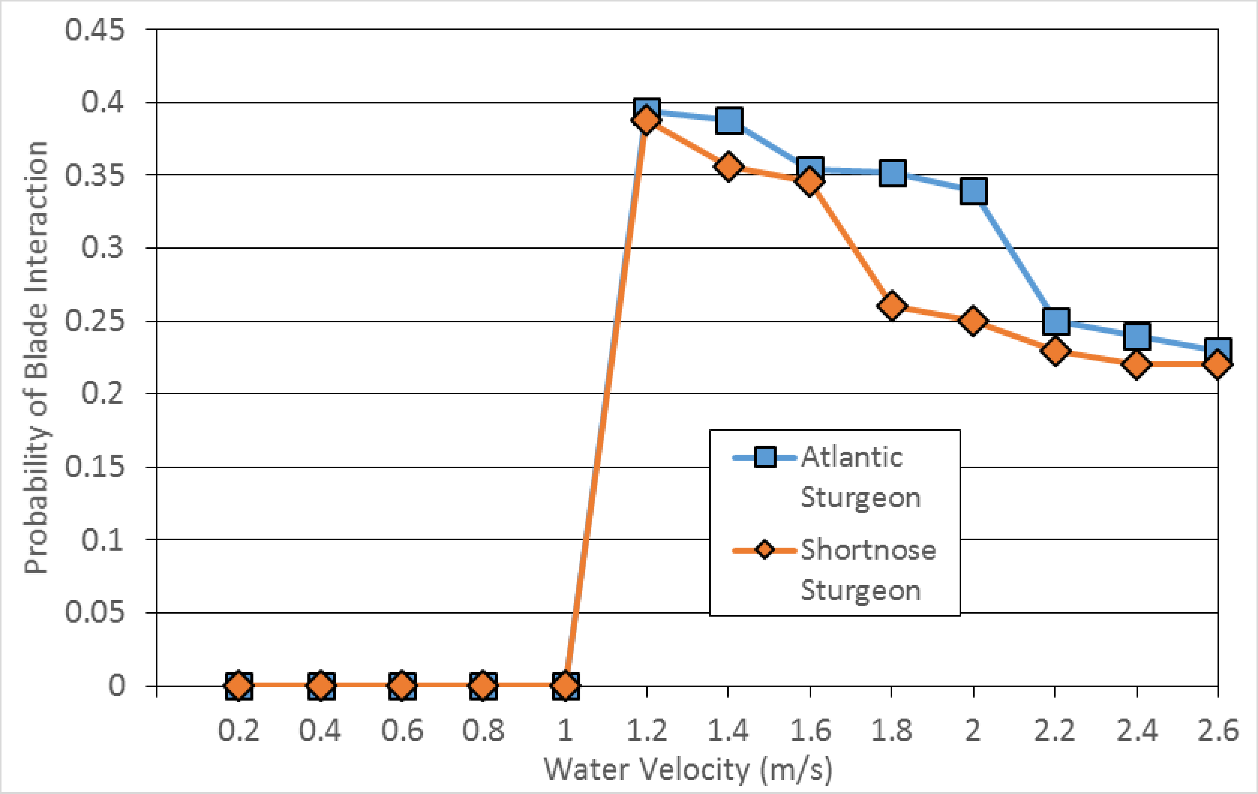


Figure 3-7. The probability of the blade impacting an Atlantic sturgeon and shortnose sturgeon as a function of water velocity.

Therefore, we postulate that the ORNL DIDSON video analysis could provide some new information on both the angel of incidence and the common length of fish that approach the rotor disk.

P6: ESA Fish Distribution

The ESA parameter was included in the KFIM for RITE to account for the transit of ESA species within the configuration at RITE, as described earlier. For the 2010 RITE KFIM cases, in the absence of further information on ESA fish species, the model assumed an even distribution of ESA fish in the East River. Therefore, P6=1 for all velocities. As information is gained from the proposed monitoring plans, this parameter can potentially be modified; it has been updated in the cases discussed in Section 4.

On further review, this parameter set at 1 for each velocity was applied as an extremely conservative value, rather than representing a uniform probability of 0.08 per velocity bin. The modification of this assumption will be reflected in the results.

Verdant P-12611 Case

Additionally, although it is outside the scope of this project, since the 2010 promulgation and 2012 acceptance of the KFIM model results, some additional new field data have been collected by Verdant under the RMEE-4 Tagged Species Detection Plan that might provide updated data for P3. As a result of the DIDSON and SBT results presented in this report, we also can postulate some adjustment to P7 fish avoidance behavior as a model sensitivity analysis. These details are the subject of a papers presented at the 2015 and 2016 Marine Energy Technical Symposium (Tomichek et al. 2015, 2016). The results of this are presented as a model sensitivity analysis in addition to the ORNL case discussed in Section 4.

P3: Fish Distribution

Unique to the RITE project, the East River bifurcates flow around Roosevelt Island, forming the east and west channels. The RITE project is located in the east channel. The cross sectional areas of the channels are roughly equal; both channels have a similar width of approximately 240 m and depth of 10 m. The west channel has a slightly higher average flow speed, and the volume of water passing through both channels is equal to within approximately 5%. Combined with the even fish distribution assumption explained earlier, it reasonably follows that half of any fish present will transit via the west channel and will therefore not be affected by the turbines present in the east channel.

The KFIM runs initially included a probability of 0.5 (50%) to represent the equal likelihood that fish will take the east channel (and be at risk) over the west channel (and have no risk). This probability is fixed and is not dependent upon the water velocity.

For other project sites, this parameter could be used to reflect 100% probability that a fish would encounter a field, or array, of kinetic hydropower devices or reflect some cross sectional distribution less than 100%.

P7: Fish Avoidance Behavior

In the KFIM, it was acknowledged that fish could indeed avoid the turbine blade; however, for the sake of completeness, the initial model runs took a conservative approach and assumed no avoidance behavior other than assuming that fish will speed up to avoid being struck. This increase in velocity was included in parameter P5. Thus for the 2010 model, P7=1, i.e., no fish avoidance behavior, was used for the Biological Assessment. It was noted that “as information is learned from the proposed monitoring plans this parameter can potentially be modified.”

4. DISCUSSION

4.1 INTERPRETATION OF DIDSON RESULTS

The automated data analysis we performed identified 34,708 fish tracks, which included both individual fish and schools. Various metrics that might indicate a behavioral response to the operating turbine (i.e., attraction or avoidance) were grouped into classes based on tidal cycle, current velocity, and swimming direction and evaluated with respect to turbine presence and operation and with respect to distance from the turbine. Significant findings from the automated analysis included:

- The density of fish in the DIDSON sample area when the turbine was absent was roughly twice what it was when the turbine was in place, both when rotating and when not rotating. This suggests that some avoidance may be occurring before fish are close enough to the turbine to be observed by the DIDSON.

- In the near-field within the 10 m window viewed by the DIDSON, the number of tracks observed decreased sharply from near shore (away from) to offshore (near to the turbine location) regardless of whether the turbine was in place and rotating or not.

- For fish swimming past the turbine, there were no changes in vertical, horizontal, or lateral trajectories of fish when the turbine was present or operating.

- Turbine presence, whether operating or not, resulted in more crooked tracks for fish near the turbine than for fish in the same location when the turbine was absent, suggesting that normal swimming behavior is disrupted.

- The last metric evaluated for change in behavior was swimming velocity which we found to be significantly slower in the presence of the operating turbine versus an absent turbine condition.

To supplement the automated analysis of fish tracks, we also conducted visual observations of the video output for subsets of the data. From these direct observations, we found that individual fish and schools that were headed toward rotating blades usually avoided the blades by adjusting horizontal swimming direction slightly and angling away. Others disappeared just before encountering the rotor (i.e., within 1 m), which we assume to have happened because the fish changed vertical direction, swimming either above or below the turbine and therefore moving out of view of the DIDSON beam. A direct contact with the rotor by a large fish (>50 cm) would likely have been apparent if it had occurred, but the DIDSON resolution makes it difficult to observe actual contact for fish smaller than 50 cm.

4.2 INTERPRETATION OF FISH INTERACTION MODEL

As discussed in Section 3, the integration of the results of the DIDSON and SBT analysis into the KFIM was a key result of this effort. The changes to the model parameters under the two cases are summarized in Table 4-1 and a biological discussion follows.

Table 4-1. KFIM parameters as updated—2015

Term	Parameter description	RITE 2010 KFIM	ORNL base case	Verdant P-12611 case
P1	Probability of blade rotation	P1 = 1 for flows greater than 1 m/s	No change	No change
P2	Distribution of water velocity over the tidal cycle	See RITE Vw probability distribution	No change	No change
P3	Fish distribution between east and west channels	P3 = 0.5	No change	Modified to P3= 0.25 based on concurrent RMEE-4 observation 2012–2015
P4	Effective KHPS turbine rotor area	P4=0.0066	No change	No change
P5	Blade interaction with fish passing through turbine disk	P5 follows formulae discussed below. Two major parameters: (1) 80/20 rule: assumes 80% of fish swim with current, 20 % against	P5 80/20 rule—ORNL work indicates a stronger case for 84%/16% as a setting for P5	Same as ORNL case
		(2) Angle of incidence—assumes all fish approach blade from all angles within 180° uniformly	P5 Angle of incidence—ORNL work strongly indicates a more narrow angle of incidence of 90^o +/- 15^o degrees	Same as ORNL case
P6	ESA fish distribution	P6=1 Equal likelihood that ESA fish are in east channel	DIDSON and SBT analysis confirms P6 could be lowered. P6= see revised distribution (Table 4-4)	Same as ORNL case
P7	Fish avoidance behavior	P7=1 conservative—no avoidance	No change	DIDSON data seems to show some avoidance. Assume P7=0.98

4.2.1 ORNL Base Case

The KFIM can be adjusted for two significant parameters, P5 and P6.

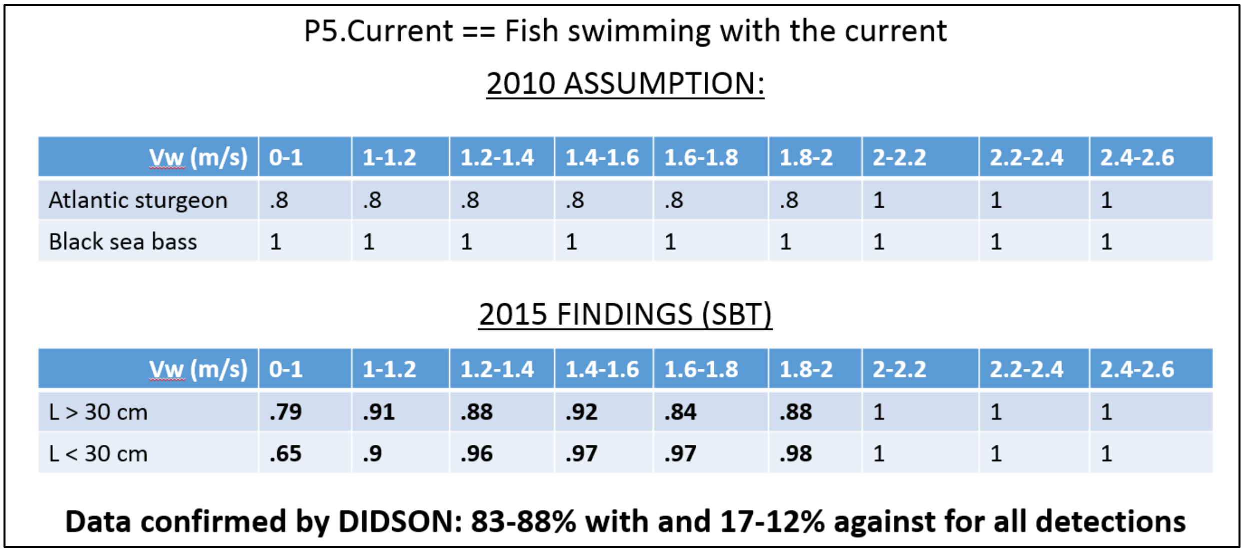
4.2.1.1 P5: Blade interaction with fish passing through turbine disk

Many factors make up parameter P5, including fish length, L; fish-incident angle, θ; fish burst and endurance velocity, Vb and Ve; water velocity, Vw; and rotor geometry. The following three changes can be made based on the ORNL analysis:

(1) P5 (Fish swimming with/against the current; 80/20 rule)

A review of the 2012 DIDSON data as well as the 2009 SBT data showed a confirmation and reduction of this parameter over a range of water velocities, as shown in Table 4-2, representing 83–88% with the current and 17–12% against the current, which was incorporated in the KFIM.

Table 4-2. Parameter P5-Ve



P5.Current == Fish swimming with the current

2010 ASSUMPTION:

Vw (m/s)	0-1	1-1.2	1.2-1.4	1.4-1.6	1.6-1.8	1.8-2	2-2.2	2.2-2.4	2.4-2.6
Atlantic sturgeon	.8	.8	.8	.8	.8	.8	1	1	1
Black sea bass	1	1	1	1	1	1	1	1	1

2015 FINDINGS (SBT)

Vw (m/s)	0-1	1-1.2	1.2-1.4	1.4-1.6	1.6-1.8	1.8-2	2-2.2	2.2-2.4	2.4-2.6
L > 30 cm	**.79**	**.91**	**.88**	**.92**	**.84**	**.88**	1	1	1
L < 30 cm	**.65**	**.9**	**.96**	**.97**	**.97**	**.98**	1	1	1

Data confirmed by DIDSON: 83-88% with and 17-12% against for all detections

The original model (RITE 2010 KFIM) parameter P5 assumes 80% of the fish swim with the current and 20% swim against it. The recent ORNL work indicates a stronger case for 84%/16% as a setting for model parameter P5. Fish are able to adjust swim speed and timing of activity during migration to changes in current velocity to minimize energy use (Brodersen et al. 2008). As migration requires energy, the timing of migration may depend on changes in current velocity for migrating fish. Fish can take advantage of changing environmental conditions to minimize their energy expenditure (Brodersen et al. 2008). Swimming with the current or swimming at slack tide requires less expenditure of energy and is a strategy often used in high current energy environments (Brodersen et al. 2008).

(2) P5 (incident angle change)

Θ = fish incident angle to the rotor disk

As shown in Table 4-3, the angle of incidence for any fish on the blades was assumed to be an even probability over 180° in 15° bins. As shown in the DIDSON analysis, the concentration of the angle of incidence observed was much more compact over a range of ± 15°, increasing the risk of impact should a fish encounter a blade. Therefore, this increased density of angle of incidence on the blade was used in the ORNL 2015 case run.

Table 4-3. Parameter P5-angle of incidence

Degree	2010 KFIM assumptions	2015 Findings DIDSON
7.5	0.08	**0**
22.5	0.08	**0**
37.5	0.08	**0**
52.5	0.08	**0**
67.5	0.08	**0.01**
82.5	0.08	**0.49**
97.5	0.08	**0.49**
112.5	0.08	**0.01**
127.5	0.08	**0**
142.5	0.08	**0**
157.5	0.08	**0**
172.5	0.08	**0**

(3) P6 (ESA fish distribution)

This parameter was included in the KFIM for RITE to account for the transit of ESA species within the configuration at RITE. For the 2010 RITE KFIM cases, in the absence of further information on ESA fish species, the model assumed an even distribution of ESA fish in the East River. Therefore, P6 = 1 for all velocities.

On further review, this parameter set at 1 for each velocity was applied in 2010 as an extremely conservative value, rather than representing a uniform probability of 0.08 per velocity bin. Table 4-4 shows the original 2010 assumption, now considered inappropriate; a uniform distribution that would be applicable in the absence of data; and a hybrid DIDSON–SBT distribution of fish size over water velocity based on the data of in excess of 40,000 fish targets.

Table 4-4. KFIM parameter P6 fish distribution 1—2015 update

Vw	0-1	1.0-1.2	1.2-1.4	1.4-1.6	1.6-1.8	1.8-2.0	2.0-2.2	2.2-2.4	2.4-2.6
2010	1	1	1	1	1	1	1	1	1
2010 revised	0.38	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
2015 ESA	0.30	0.12	0.12	0.14	0.11	0.08	0.05	0.04	0.04
2015 EFH	0.38	0.08	0.08	0.10	0.08	0.07	0.07	0.07	0.07

Figure 4-1 shows the resulting model run for the ORNL 2015 case using the modified P5 and P6 values resulting from this analysis. It reduces the probability of a blade strike to below 0.50% for all arrays up to 30 turbines.

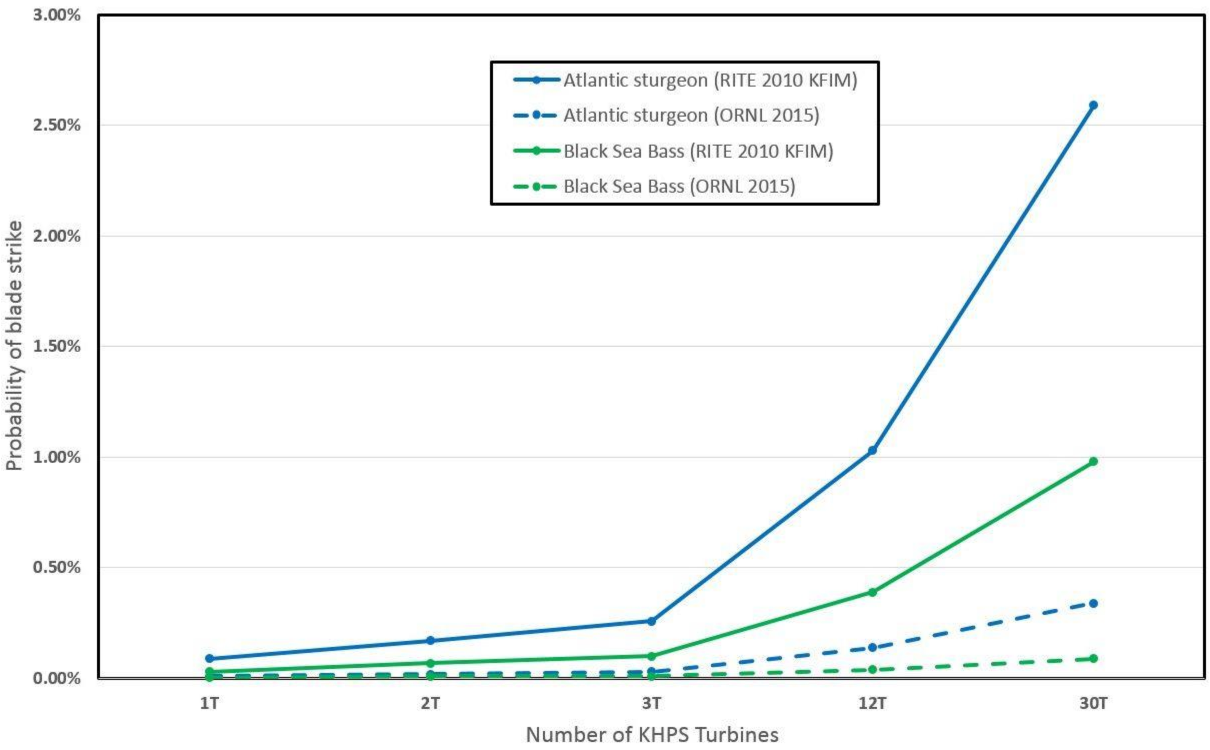


Figure 4-1. ORNL 2015 case—modification to P5 and P6; comparative KHPS–fish strike probabilities, RITE project.

4.2.2 Verdant P-12611 Case

For the Verdant case, in addition to the modifications described in the ORNL case, two other parameters can be modified.

P3 Fish Distribution—East/West Channel

The 2010 KFIM runs initially included a probability of 0.5 (50%) to represent the equal likelihood that fish will take the east channel (and be at risk) over the west channel (and have no risk). This probability is fixed and is not dependent upon the water velocity. Based on concurrent RMEE-4 work, discussed in the referenced papers, the value for this parameter can be reduced to 0.25% based on evidence of tagged fish, using the west channel over the east channel where the RITE project is located.

P7 Fish Avoidance Behavior

In the KFIM, it was acknowledged that fish could indeed avoid the turbine blade; however, for the sake of completeness, the initial model runs took a conservative approach and assumed no avoidance behavior other than assuming the fish will speed up to avoid being struck. Thus for the 2010 model, P7=1, no fish avoidance behavior was used for the Biological Assessment.

As a result of the further examination of the DIDSON video evidence, we found:

- Not enough data to allow for quantification of avoidance by fish approaching the turbine blade–swept area, because so few fish were seen in this area.

- Not enough evidence to quantify differences in behavior of fish within a few meters of the turbine compared to those further away (i.e., closer to the DIDSON) or when a turbine was absent or not operating. That is, there was little difference in swimming velocity or direction of track.

- However, the number of fish in the vicinity of the turbine decreased noticeably when the turbine was present versus absent, and even more when the turbine was operating. This is true at all distances from the turbine.

So while it is difficult to suggest a quantification metric for reduction of the P7 parameter (as shown in the video evidence), the researchers generally acknowledge that the parameter could be modified to P=0.98. Doing so would practically result in no change to the overall results but would account for the effort of observing some fish movement as a result of the presence of an operating KHPS. Figure 4-2 shows the resulting model run of changes to both P3 and P7, along with the previous changes to P5 and P6. As shown on Figure 4-2, additional modification to P3 distribution and allowance for a slight reduction to account for fish avoidance behavior reduces the results further below 0.50% with 30 turbines.

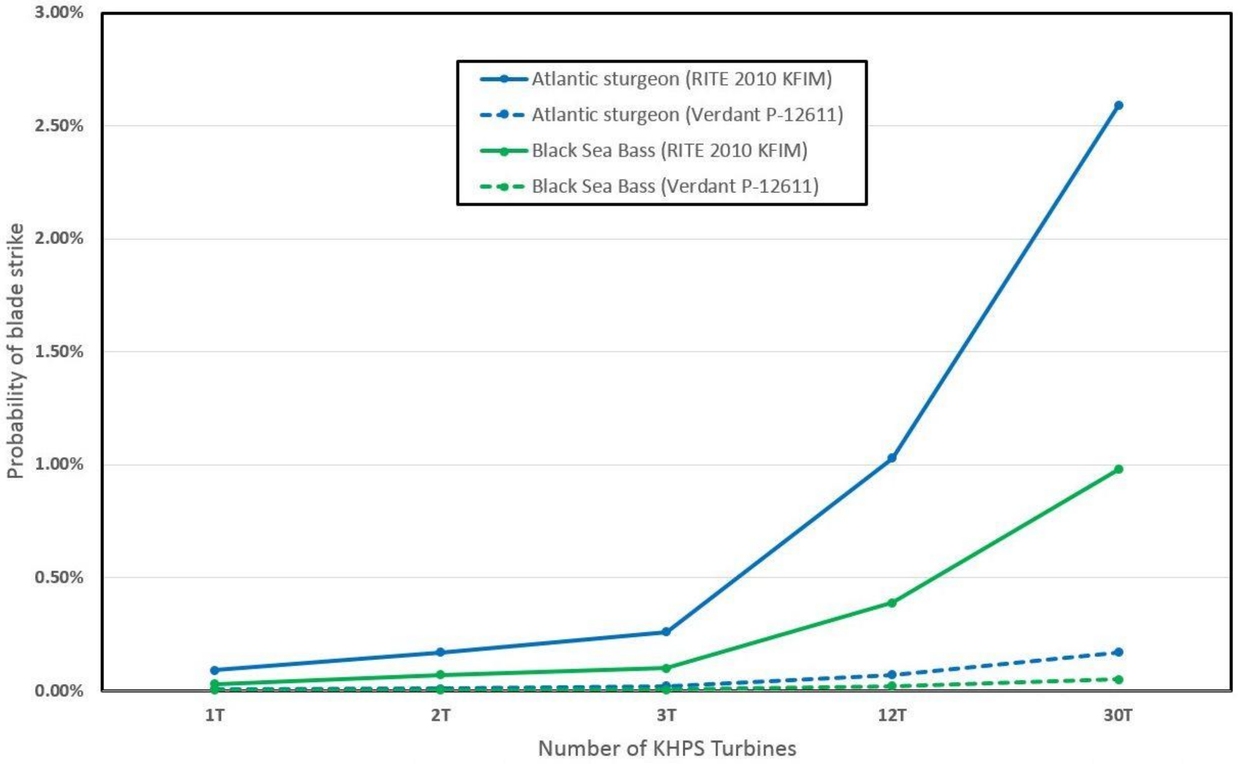


Figure 4-2. P-12611 case—modification to P3, P5, P6 and P7; comparative KHPS–fish strike probabilities, RITE project.

4.3 RESULTS OF UPDATE TO THE KHPS-FISH INTERACTION MODEL

The model determines the probability that a fish entering the East River will be struck by a turbine. Structurally, the model determines this strike likelihood by combining various parameters, including the water velocity distribution, the channel geometry, the KHPS physical and operating characteristics, and the specific fish characteristics (e.g., length, burst speed, and swimming velocity in relationship to water velocity). The model is designed to be customizable and incorporate elements of various parameters as they become known. For example, Verdant's sampling at the RITE site has demonstrated that fish move with the tide in the east channel and are most abundant at slack tide. Since the turbines do not operate in currents slower than 1 m/s, there is no risk to fish during the period of their highest abundance, which occurs over 27% of the tidal cycle. This type of site-specific knowledge is incorporated as parameters in the model.

The original model assumed very little fish behavior. Unknowns include temporal and spatial distribution throughout the river and the directions, shapes, and timing of their paths in the East River. The RITE RMEE plans were designed to improve site-specific knowledge, which can then be incorporated into the model.

The model uses nine parameters and is applied to calculate the strike probability for 1–30 turbines. For a multi-turbine array, another probability parameter is added to reflect the number of turbines, and their spacing in the turbine field. The turbines in the field are treated as if the fish had an equal opportunity to go through all 30. In reality, because the turbines would be grouped together in threes on a TriFrame, it would be likely that a fish going through one turbine in a Triframe would not be lined up to pass through either of the other two turbines. However, it is difficult to quantify this interaction, so the simple but worst case of treating the turbines as independent is modeled. The strike probability for one TriFrame is simply the strike probability for a single turbine multiplied by the three turbines in the single TriFrame.

The model determines only the probability of a strike by a turbine blade, not the probability of mortality. The model does differentiate between a strike that is determined to be too slow to cause any injury and one that could cause injury or mortality. Strikes that are deemed too slow to cause any injury are treated as non-strikes. While there are some early injury and mortality studies of turbine blades on smaller fish (Amaral et al. 2008), predictions of mortality for the larger fish are left out of the model at present. Thus the output of the model is a strike probability, not an injury or mortality probability.

The results of the modifications to the KFIM are shown for comparison with the 2010 KFIM results in Figure 4.3. The comparative results of the 2010 model results at RITE and the two cases examined in this report act to reduce the conclusions for a potential array of up to 30 KHPS turbines at the RITE pilot site.

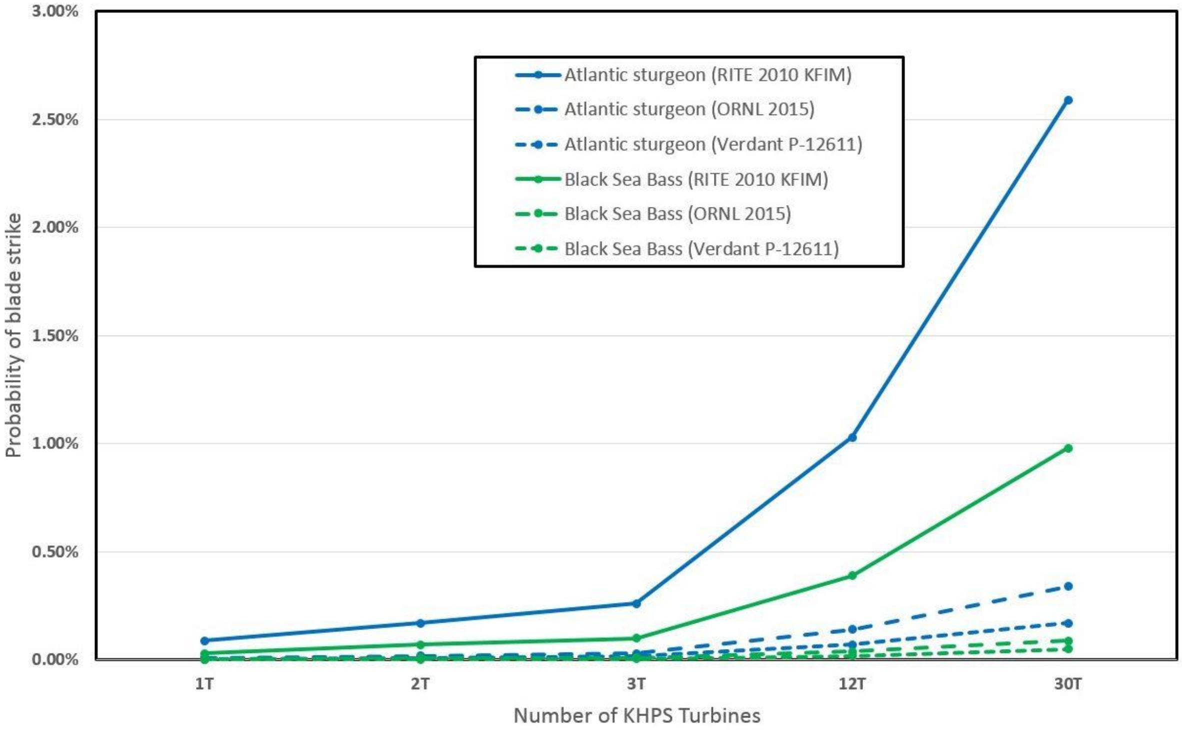


Figure 4-3. RITE project KFIM model output comparisons.

5. MONITORING TOOLS FOR TURBINE ARRAYS

The last objective of this task was to

> Use study results to assess which approaches (i.e., field observation, experimentation, models, etc.) will be most effective for predicting or monitoring the effects of a turbine array.

This section discusses the scale of monitoring and our perspective on scaled-up monitoring for arrays. Additionally, a review of opportunities for field observation, experimentation and modeling is provided.

5.1 MICRO-MESO-MACRO SCALE

A key aspect of the 2006–2008 RITE demonstration (six turbines, 2006–08) was to assess the interactions of Verdant Power's KHPS with the environment. Verdant worked with regulatory agencies and other key local stakeholders to develop and execute a number of study plans that have served as the basis for understanding the interactions and importance of moving forward with pilot and commercial-scale projects. During the demonstration, Verdant conducted a number of first-time fish interaction studies to examine biological issues regarding the operation of the KHPS in fast waters.

Verdant Power's experience is that it is useful to consider the following terminology in developing relevant monitoring methods and protocols for its KHPS projects. This process includes examining key biological parameters (e.g. fish movement, migration) and matching monitoring protocols at three different scales:

- Micro scale: In and around an individual turbine (1 diameter (1D) = 5m at RITE), rotating at <40 rpm and only during high-velocity periods over 1 m/s. At this scale, resident and migratory fish interactions, as well as micro hydrodynamics are being studied. The DIDSON data discussed in this report were collected at this scale.

- Meso scale: In front/back of the turbine TriFrame

- [6]. Here the reaction around a TriFrame of three turbines is being studied, as well as the interdependencies and recovery distance to the next TriFrame in the array—generally 12D (at RITE) to 20D (other sites) in distance. The splitbeam data discussed in this report were collected at this scale.

- Macro scale: Well beyond the TriFrame (and the fully developed array) extending to points where organisms first sense/encounter the minor hydrodynamic presence of the KHPS array. This is a broader-scale study conducted for longer-term deployments.

In developing the RITE RMEE plans for the licensed pilot project array of up to 30 KHPS turbines, this perspective was particularly challenging. Therefore, as the work conducted under this grant agreement is focused on observing the micro- and mesoscale impacts around a single turbine (or closely spaced operating turbines), how does one examine an array of up to 30 or more turbines in a commercial setting at the macro scale?

---

[6] The TriFrame is a riverbed foundation structure that will mount three turbines in a triangular configuration. When installed on the frame, the 5 m Gen5 turbines will each be spaced approximately 2 diameters apart.

5.2 ARRAY AND FULL FIELD EFFECTS

In licensing the RITE site, Verdant had to address the issue of potential full-field effects of a multiple-turbine array. Despite a lack of clear empirical data or robust monitoring techniques, it was necessary to provide an adaptive management monitoring plan for observing a full array of operating KHPS turbines, within the context of possible fish interactions. The approach taken was twofold:

1. Extending the KFIM to conservatively account for increasing the number of installed turbines to increase the probability of strike and evaluating the probability of strike under this macro circumstance.

2. Providing a longer-term macro observational monitoring plan, the RMEE-1 Seasonal Fixed Hydroacoustics, to attempt to observe these effects when multiple turbines are operating.

These efforts, in conjunction with the other RMEE plans through the adaptive management process, provide for opportunity to continue to refine at the micro, meso, and macro scale the understanding of fish interaction and risk within an array setting.

5.2.1 KFIM Model to Array

The most conservative estimate for the impact of the full field of 30 KHPS turbines is to multiply the single unit probability by the number of installed units.

However, this assumption does not take into account the physical location of the KHPS turbines. This is a worst-case assumption that may be overly conservative. As the KHPS turbines will be clustered in a single location, any fish entering the full array would likely try to leave the area once passing close to or through a small number of units. Nevertheless, there is little validated or published data to support this assumption; as a result, this model assumes no inherent avoidance of the array.

Using this conservative parameter that assumes that once a fish encounters the array it never leaves, results for the strike probabilities are as shown in Table 5-1. For comparison, the model was run for an essential fish habitat (EFH) species of smaller length as well. As a result of the 2015 work, the fish strike probability in an array was reduced and was further reduced when parameters P3 and P6 are incorporated.

Table 5-1. Overall KHPS-fish strike probabilities for proposed RITE project

Species	Single KHPS turbine	Array (30 turbines) 2010	Array—2015 ORNL case
Atlantic sturgeon	0.09%	2.59%	0.34%
EFH–25	0.03%	0.98%	0.09%

RMEE-1 Seasonal Fixed Hydroacoustic Plan

As part of the RITE FERC licensing, and to gain insight into the meso and macro behavior of fish in an array condition, Verdant proposed a seasonal deployment of two bottom-mounted SBTs within the array, with attendant software improvements to attempt to gain insight on presence, abundance, and trajectory behavior of fish encountering multiple KHPS turbines. Optimistically, this system was geared to actually follow a fish as it approached the array and, using proprietary BioSonics software, link its track potential through multiple KHPS turbines. This is a costly system, however, and at the time of the license application, it was considered a ‘potential’ technique for addressing the array-scale effects of fish behavior in the presence of an operating KHPS and was included in the requirements of the FERC license for the RITE Project. Under the adaptive management process for environmental monitoring to be implemented during the phased build-out at the RITE Project, the details of RMEE-1 and the deployment of SBTs will be re-evaluated to ensure effective data collection to increase the understanding of fish interaction and risk within an array.

5.3 OPPORTUNITIES FOR FIELD OBSERVATION

5.3.1 Methods and Limitations

Conducting a real-time field observation of an operating KHPS—or any HK device—involves a significant commitment of time and effort. The available equipment, be it a DIDSON, SBT, or other sensitive fish detection device, involves not only the equipment but also the mount, cabling or battery data recording system, and the considerations of in-water time and replacement. Almost as important is the cost and time associated with post-processing. Therefore, it is relevant to consider these costs and risks in proportion to the data and the biological questions that can be answered.

Verdant has had significant experience with monitoring device deployments and efficacy since 2006, as discussed in the licensing documents and other reports (NYSERDA 2012). For example, the 24-SBT array first deployed at RITE cost over $1.4 million. The most recent 2012 DIDSON video, the subject of this study, represented nearly $250,000 of effort plus this DOE-funded post processing. To put this in context, the power production of a 1MW array (30-turbine KHPS) is expected to generate revenues of approximately $350,000 per year.

5.3.2 Opportunities

Even given the high costs, field observation does have substantial merit. At the RITE project, both the RMEE-2 DIDSON program and some modification of the RMEE-1 protocol for arrays will be undertaken as the project progresses.

In conducting field observation of individual devices or field arrays, lessons learned include:

- Deploy monitoring in periods of seasonal abundance of fish. This was the case in the 2012 DIDSON deployment; however, as indicated by our analysis, a low number of large fish resulted despite best efforts.
- Simplify the in-water recording to facilitate post-processing. This became apparent in the most recent case with multiple DIDSON aims and several repositioning movements complicating the analysis.
- Limit in-water duration to match the functionality of the equipment. Practically, for a DIDSON, 3–4 weeks is the maximum for uninterrupted service due to bio-fouling.

5.4 OPPORTUNITIES FOR EXPERIMENTATION

5.4.1 Methods and Limitations

Direct experimentation—as conducted by EPRI/Alden (Amaral et al. 2015) on fish behavior and encounters—is useful to the industry and contributes to the microscale body of knowledge as the industry progresses, in conjunction with other methods discussed. It is recognized that these efforts are generally device-specific and controlled, to the extent that proxy size fish are directly controlled into the device strike without accounting for avoidance behavior, which is a key parameter. In addition, laboratory cost can be a significant factor in these controlled efforts. For arrays, laboratory experimentation is probably not a viable option.

5.4.2 Opportunities

In moving toward array monitoring and prediction, two experimental possibilities that might provide insight into fish behavior in the presence of multiple KHPS at RITE are:

1) Use a triangulated network of passive acoustic transmitters and receivers to create 3-D tracks of fish movement through the array of previously tagged species.

2) Release of fish tagged with a combination of an acoustic transmitter and a balloon-tag in front of a turbine array during full operation followed by retrieval downstream of the array.

Tagged Species Detection—triangulation in arrays

As discussed in Sections 3 and 4, Verdant has established a VEMCO tagged species detection platform to gain information on fish passing near the KHPS at RITE which is effective only if researchers tagging fish participate in mutual data exchange. A further limitation of this approach is that the current technology as deployed detects presence but not specific location in relationship to the KHPS. An improvement to this protocol, in the presence of multiple operating KHPS turbines, would be to deploy additional VEMCO receivers and conduct triangulation analyses of detected tags to XYZ locate a tagged fish and its track as it passes by multiple KHPS turbines. Verdant has unsuccessfully attempted to gain funding for this research but considers this a significant opportunity to begin to determine fish behavior within an array.

Tagged Species Controlled Release—arrays

Similarly, at RITE, because of the narrow channel configuration, an opportunity for a controlled release of balloon-tagged fish in open water upstream of the operating KHPS turbines could be accomplished, with immediate recovery and tracking downstream. Again, a coordinated field effort could be accomplished, which might provide significant new information on multiple turbine encounter behavior, albeit with the limitations of size, species, and recovery of tagged fish. As detection technology improves for passive integrated transponder tags, this technology also holds promise for detecting fine-scaled behavioral responses during turbine encounters.

5.5 OPPORTUNITIES FOR MODELING

5.5.1 Methods and Limitations

The KFIM proved to be a useful tool for evaluating conditions at RITE for a single turbine, as well as extending to arrays. The 2010 model, in the absence of data, used conservative assumptions to arrive at a fish-strike probability acceptable for obtaining a license. The 2015 work described in this report better defined certain parameters to refine the application of the model. Clearly, we believe this is a useful tool not only for the Verdant Gen5 KHPS but also for other HK device applications.

It is interesting to note that the United Kingdom’s Marine Mammal Scientific Support Research Programme (2015) uses a similar type of model to predict marine mammal encounters; therefore, this method of array modeling will likely be useful to the industry.

Although the actual development and running of models is probably a cost-effective solution, acquiring and adapting useful field and experimental data to support the model remains the costly limitation. However, as demonstrated in this DOE-funded project, the effort and results significantly enhance the understanding of the biological impact of HK devices in the environment.

5.5.2 Opportunities

Given the effort and results reported here, the following opportunities for array modeling can be recommended:

- Continued population of existing models with new data: As was done with the RITE KFIM in this project, the updating of parameters with monitoring data improves the understanding of fish strike risk. For arrays, implementing monitoring protocols that would support array extension would additionally improve the efficacy.

- Adaptation and development of models for different device types and array sites: Since the parameters in a model are very specific to a device and site conditions, efforts should be made to continue to apply models at different sites to improve quality, transferability, and acceptance.

- Ongoing collaborative research to incorporate model similarities with marine mammal models: For arrays in open water, this issue will continue to be a significant effort, and ongoing research to develop tools and models for marine mammal risk should benefit predictions of fish risk.

The different options for monitoring turbine arrays as described above are summarized in Table 5-2.

Table 5-2. Summary matrix of monitoring tools useful for monitoring turbine arrays.

Technique	Monitoring scale	Efficacy + to +++	Limitations & relative cost $-$$$	Opportunities
		Field Observation		
RMEE-2* RAD- DIDSON at RITE, New York	Micro/meso	+++	Short duration Post-processing costs $$$	Detect near-field responses during turbine encounters
RMEE-1* SBT deployment	Meso/macro	Unknown	Short duration Algorithms unproven $$$	Detect far-field responses during turbine encounters
		Experimentation		
Tagged species detection—triangulation**	Macro	Likely +++	$	Improves understanding of fish tracks in relation to KHPS
Controlled release of tagged species**	Macro	Likely ++ to +++ for fish behavior	$$	Observes fish tracks in presence of multiple turbines
		Modeling		
Verdant KFIM	Micro/macro	+++ conservative values	Device- and site-specific Limited data $	Continue to refine parameters with other techniques and data

*required by FERC Pilot License **possible enhancements at RITE

6. CONCLUSIONS AND OPPORTUNITIES FOR FUTURE RESEARCH

6.1 HYDROACOUSTICS ANALYSIS

The automated analysis of nearly three weeks of multibeam hydroacoustics data identified nearly 35,000 fish tracks for further analysis. These tracks included both individual fish and schools during periods with the KHPS turbine absent and present, operating and not operating, and during all phases of the tidal cycle, ebb, flood, and slack.

Various metrics of location, and swimming direction and velocity were evaluated for indication of behavioral responses to the operating turbine (i.e., attraction or avoidance). These metrics were grouped into classes based on tidal cycle, current velocity, and swimming direction and evaluated with respect to turbine presence and operation and with respect to distance from the turbine. Significant findings from the automated analysis included:

- The density of fish in the DIDSON sample area when the turbine was absent was roughly twice what it was when the turbine was in place, both when rotating and when not rotating. This suggests that some avoidance may be occurring before fish are close enough to the turbine to be observed by the DIDSON.

- In the near-field within the 10 m window viewed by the DIDSON, the number of tracks observed decreased sharply from a maximum near the DIDSON (away from the turbine) to near the turbine location (away from the DISON) regardless of whether the turbine was in place and rotating or not.

- For fish swimming past the turbine, there were no significant changes in vertical, horizontal, or lateral trajectories of fish when the turbine was present or operating but some differences were noted that suggested hints of avoidance.

- Turbine presence, however, whether operating or not, resulted in more crooked tracks for fish near the turbine than for fish in the same location when the turbine was absent, suggesting that normal swimming behavior was affected.

- The last metric evaluated for change in behavior was swimming velocity which we found to be slower in the presence of the operating turbine versus an absent turbine condition.

From our direct observations of small subsets of the DIDSON videos, we found that individual fish and schools that were headed toward rotating blades usually avoided the blades by adjusting their horizontal swimming direction slightly and angling away. Others disappeared just before encountering the rotor (i.e., within 1 m), which we assume to have happened because the fish changed vertical direction, swimming either above or below the turbine and therefore out of view of the DIDSON beam. Close encounters that might result in blade contact were practically non-existent.

In summary, our analysis suggests that fish might be making small adjustments to swimming direction and velocity as they pass near an operating turbine. However, large adjustments in swimming direction or velocity were not observed, and we do not believe that the presence of the turbine interrupts in any significant way the normal movements of fish through the area. We also believe based on our analysis that the risk of actual contact with the rotor is extremely small.

6.2 CONCLUSIONS AT RITE

As required in the RITE Pilot License (P-12611) RMEE-2 Plan (V3.2 December 2010) and Article 401 of the WQC11 Water Quality Certification (WQC) Permit, Verdant is required to address specific questions relative to the RMEE-2 DIDSON observations. As a result of the analyses presented in this report, we can add the following responses to these questions and to the evolving body of knowledge.

1. How do fish behave around operating KHPS turbines, and are they injured through direct contact with the blades?

    - The review of 239 hours of DIDSON video (September 2012) in the presence of an operating Gen5 KHPS turbine revealed no drastic changes in swimming behavior as a result of exposure to the turbine.

    - Fish tend to behave as generally is assumed in the KFIM model, confirming the 80% movement with current; but movement is now shown to be ~84% favoring the current

    - The angle of incidence to the blades was the most significant fish observation, narrowing the angle at which a fish approaches the blade to approximately ±15° from the original 180°. This has the effect of increasing the likelihood of strike for a fish approaching the KHPS.

    - A few occasional instances were recorded of avoidance behavior by large fish (>80 cm) as discussed in KFIM Parameter 7, but it is not possible to put a precise estimate on the probability that a fish will avoid the turbine.

    - From our direct observations of small subsets of the DIDSON videos, we found that individual fish and schools that were headed toward rotating blades usually avoided the blades by adjusting their horizontal swimming direction slightly and angling away.

2. Can fish behavior be inferred by tracking a fish's swimming location and direction in the visualization and fish reaction in relation to the rotating blades?

    - The techniques for review of 239 hours of DIDSON video (September 2012) in the presence of an operating Gen5 KHPS have been significantly advanced through the methods developed in this study. However, this post-processing (as described in Section 2) requires significant skill and effort to reveal the conclusions noted.

    - Generally, if a fish track can be isolated (a process that includes both filtering operating turbine blade ***signature*** and time-stamp tracking of water velocity and location), a visualization of the fish track in XYZ plane can be observed relative to the operating KHPS (videos to be posted and referenced later).

    - The DIDSON observational technique is useful, recognizing the limited observations in real time at RITE (e.g., due to low densities of fish in proximity to an operating turbine or low densities in general, even though September was considered to be a peak density season from prior baseline monitoring).

    - However, as was determined during the preliminary RMEE-2 on-water testing in September, 2012, the deployment of this remotely aimed DIDSON (RAD) system requires expertise and expense associated with accurate placement near an operating KHPS. Also, based on manufacturing recommendations and in-water experience, the RAD can be in-water only for 3–4 weeks without loss of acuity.

- In conjunction with the expense of post-processing video, the use of RAD monitoring of fish tracks should be considered a short-term, micro-observation technique likely used within an adaptive management framework for confirmation of expected KHPS fish interaction.

3. Do the DIDSON observations provide some added meaning and value (correlation) to the body of collected data on fish presence, abundance, movement pattern and species in and around the operating KHPS turbine?

- Yes, as discussed in Sections 3 and 4 the body of work accomplished under the ORNL effort supports, confirms, and expands the understanding of fish presence, abundance, movement, and (to a limited extent) species identification in the presence of the operating turbine.

- As discussed in Section 4, the 2015 analysis allows us to modify the KFIM with additional information on parameters that were previously conservatively set because of lack of knowledge. This is a significant advancement as the result of this work.

- From a biological point of view, the 2015 DIDSON analysis work supports, confirms, and expands the understanding outlined in the December 2010 Final License Application and the 2011 Biological Assessment /Opinion. This study confirms the following:

  - Most fish swim with the tide, especially at times of high current.
  - Fish are most abundant at slack tide when the turbines are not operating.
  - Large fish species such as sturgeon do not occur in high numbers in the East River.
  - Fish are transiting through the project area rather than residing there.
  - The overall probability of a fish–turbine interaction is low.

4. What, if anything should be changed in the DIDSON operating protocol to improve evaluation of the effects of operating a KHPS?

- Based on the 2012 DIDSON effort at RITE and the ORNL analysis, we remain confident that a single seasonal deployment for 3–4 weeks maximum is possible to observe KHPS–fish interactions at the micro scale. This field effort (~$75,000 using existing equipment) and the required post-processing (on the order of $100,000) should serve to confirm these findings in the operation of a single KHPS.

- Some improvements stemming from the DIDSON analysis could include the following.

  - Position the RAD so that the DIDSON field maximizes the amount of sampled area upstream of the rotors; that is, so that the rotors are at the very edge of the field.
  - Limit the number of DIDSON aims to two, one each for ebb and flood tides.
  - Collect data with the turbine removed (as in this study) or in a nearby control location.

Beyond this RMEE-2 effort, it is doubtful that further RAD deployments to observe multiple operating turbines is a useful technique at RITE or that it would yield further data. Verdant will probably pursue an adaptive management conclusion of the RMEE-2 effort, if appropriate.

6.3 RECOMMENDATIONS

From a biological and research study aspect:

- Whereas multibeam hydroacoustics provides the best opportunity to 'visually' assess fish interactions with turbines in low visibility systems, the limited range of this technique and the post-processing requirements make this technique less than ideal. For example, the diameter of the KHPS rotor is about twice the vertical range of the DIDSON field so that we were not able to capture the entire swept area.

- Precise positioning and strategic aiming of the RAD are crucial to capturing fish interactions with the turbine. Given the current range and width of field of the DIDSON unit, it would be beneficial to position two DIDSON units in tandem to fully capture fish entering and leaving the blade swept zone, although this option is quite likely cost prohibitive.

- Automated data analysis was a challenge because of the rotating turbine, however, analytical software and techniques continue to improve and this obstacle can likely be overcome in the near future.

- In the case of the RITE project, the ability to couple the multibeam results with those from a splitbeam hydroacoustics analysis and from netting studies provides valuable insight into fish behavior at the RITE project.

From the perspective of an HK developer:

- Although we were confident that the 2012 data confirmed the conservative assumptions regarding fish interaction, the added analysis and scientific third-party effort by ORNL to quantify these parameters with the significant video post-processing significantly enhances and advances the understanding of KHPS interaction.

- Pending the deployment of more Verdant Power Gen5 KHPS turbines at RITE, the post-processing expertise will be valuable to streamline the RMEE-2 study effort. Funding for this deployment and analysis should benefit the HK industry at large and RITE in particular.

- This monitoring protocol is focused as discussed on the observation of a single (or few) operating KHPS turbines at the micro scale. It is likely not applicable for multiple turbines in an array condition. Moving toward such studies, it is recommended that research and development funding for alternative techniques or algorithms be undertaken to address the array condition.

- Another supportive recommendation would be to fund a field tagging experiment when multiple KHPS turbines are operating at RITE (as discussed in Section 5).

- Ongoing research and development at various sites and for other HK developers along these lines is warranted. The model development and parameterization may be useful for others in the HK industry.

7. ACKNOWLEDGMENTS

This research was funded by the US DOE Office of Energy Efficiency and Renewable Energy, Wind and Water Power Program, and by Verdant Power. Verdant Power provided the hydroacoustics and flow data that were collected during turbine testing that was partially funded by NYSERDA. We appreciate the program management provided by J. Brown-Saracino of the DOE Wind and Water Power Program. M. Schramm (ORNL) assisted with analysis of the splitbeam data. S. Curd Hetrick (ORNL) provided valuable project management and contracting services. ORNL is managed by UT–Battelle, LLC, for DOE under contract DEAC0500OR22725.

8. REFERENCES

Amaral, S., G. Hecker, P. Stacy, and D. Dixon. 2008. Effects of Leading Edge Turbine Blade Thickness on Fish Strike Survival and Injury. Proceedings of Hydrovision International 2008. HCI Publications, St. Louis, Missouri.

Amaral, S., N. Perkins, G. Allen, G. Hecker, D. Dixon, and P. Jacobson. 2010. Evaluation of the Effects of Hydrokinetic Turbines on Fish. Proceedings of Hydrovision International 2010. PennWell Corporation, Tulsa, Oklahoma.

Amaral, S. V., M. S. Bevelhimer, G. F. Čada, D. J. Giza, P. T. Jacobson, B. J. McMahon, and B. M. Pracheil. 2015. Evaluation of Behavior and Survival of Fish Exposed to an Axial-Flow Hydrokinetic Turbine. N. Am. J. Fish. Mgmt. 35(1): 97–113.

Brodersen, J., P. Nilsson, J. Ammitzbøll, L. Hansson, C. Skov, and C. Brönmark. 2008. Optimal Swimming Speed in Head Currents and Effects on Distance Movement of Winter-Migrating Fish**.** PLoS ONE. 2008; 3(5): e2156. Published online May 14.

Cada, G. F., and M.S. Bevelhimer. 2011. *Attraction To and Avoidance of Instream Hydrokinetic Turbines by Freshwater Aquatic Organisms*. Prepared for the Wind and Water Power Program Office of Energy Efficiency and Renewable Energy. US Department of Energy. Washington, D.C. ORNL/TM-2011/131.

Castro-Santos, T., and A. Haro. 2015. Survival and behavioral effects of exposure to a hydrokinetic turbine on juvenile Atlantic salmon and adult American shad. Estuaries and Coasts 38 (Suppl 1), pp. 203–214.

DOE (US Department of Energy). 2009. *Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies*. Prepared in response to the Energy Independence and Security Act of 2007, Section 633(b). Wind and Water Power Technologies Program, US Department of Energy, Washington, DC. 89 p. + appendices.

EPRI (Electric Power Research Institute). 2011. *Evaluation of Fish Injury and Mortality Associated with Hydrokinetic Turbines*. EPRI report 1024569.

FERC (Federal Energy Regulatory Commission). 2012. Order Issuing Pilot License P- 12611 (Verdant's RITE project). January 23,.

Hammar, L., S. Andersson, L. Eggertsen, J. Haglund, M. Gullstrom, J. Ehnberg, and S. Molander. 2013. Hydrokinetic Turbine Effects on Fish Swimming Behaviour. PLoS ONE, 8(12), e84141, doi: 10.1371/journal.pone. 0084141.

Johnson, R. L., and R. A. Moursund. 2000. Evaluation of Juvenile Salmon Behavior at Bonneville Dam, Columbia River, Using a Multibeam Technique. Aquat. Living Resour. 13:313−318.

Love, R.H. 1977. Target strength of an individual fish at any aspect. Journal of the Acoustical Society of America 62:1397–1403.

Marine Mammal Scientific Support Research Programme. 2015. *Collision Risk and Impact Study: Examination of Models for Estimating the Risk of Collisions between Seals and Tidal Turbines.* MMSS/001/11 MR 7.2.2 Report .Available at www.smru.st-andrews.ac.uk/. Accessed December 2015.

National Marine Fisheries Service. 2012. Comments on the Biological Opinion re Verdant Power's Roosevelt Island Tidal Energy (RITE) Project Required by Article 401 under P-12611. September 28, 2012. NYSERDA New York State Energy Research and Development Authority. *Marine and Hydrokinetic Environmental Policy Workshop: Marine and Hydrokinetic Technology Background* *and Perspective for New York State* and 12-27c *A Review of Regulatory and Policy Requirements for Hydrokinetic Power Projects in New York State*. Report: 12-27b. May 2012. Available at http://www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/review-regulatory-policy-requirements.pdf. Accessed January 2016.

NAI (Normandeau Associates Inc.). 2009. An Estimation of Survival and Injury of Fish Passed through the Hydro Green Energy Hydrokinetic System, and a Characterization of Fish Entrainment Potential at the Mississippi Lock and Dam No. 2 Hydroelectric Project (P-4306), Hastings, Minnesota. Prepared for Hydro Green Energy LLC, Houston, Texas.

NOAA (National Oceanic and Atmospheric Administration). 2012. NOAA Biological Opinion. October.

Schweizer, P., G. Čada, and M. Bevelhimer. 2011. Estimation of the Risks of Collision or Strike to Freshwater Aquatic Organisms Resulting from Operation of Instream Hydrokinetic Turbines. ORNL/TM-2011/133, Oak Ridge National Laboratory.

Shen, H., G. B. Zydlewski, H. A. Viehman, and G. Staines. 2015. Estimating the Probability of Fish Encountering a Marine Hydrokinetic Device. Proceedings of the 3rd Marine Energy Technology Symposium. April 27–29, 2015, Washington, DC.

Tomichek, C., J. Colby, and M.A. Adonizio. 2015. Improvements to Probabilistic Tidal Turbine-Fish Interaction Model Parameters. Marine Energy Technical Symposium. Washington, D.C.

Tomichek, C., J. Colby, M. Bevelhimer, and M.A. Adonizio. 2016. Parameter Updates to Probabilistic Tidal Turbine-fish Interaction Model. Proceedings of the 4th Marine Energy Technology Symposium. Washington, D.C.

Turnpenny, A.W.H., M. H. Davis, J. M. Fleming, and J. K. Davies. 1992. Experimental Studies Relating to the Passage of Fish And Shrimps through Tidal Power Turbines. Marine and Freshwater Biology Unit, National Power, Fawley, Southhampton, Hampshire, England.

Verdant Power, LLC. 2008. Draft License Application Roosevelt Island Tidal Energy Project. November.

Verdant Power, LLC. 2010. Final License Application, Roosevelt Tidal Energy Project. December.

Verdant Power. 2011. Roosevelt Island Tidal Energy (Rite) Environmental Assessment Project: Final Report. NYSERDA report 11-04. Prepared for the New York State Energy Research and Development Authority, Albany, N.Y.

Viehman, H. A., and G. B. Zydlewski. 2015. Fish Interactions with a Commercial-Scale Tidal Energy Device in the Natural Environment. Estuaries Coasts 38 (Suppl 1): 241–252.

Wilson, B., R. S. Batty, F. Daunt, and C. Carter. 2007. Collision Risks between Marine Renewable Energy Devices and Mammals, Fish and Diving Birds. Report to the Scottish Executive. Scottish Association for Marine Science, Oban, Scotland. PA25 1QA. 110 p.

April 19, 2019 Consultation Documents:
-Cover Letter
-Minutes of 03/20/19 & 03/22/19 Meetings
-2019 Review of Species Characterization Data (RMEE-3)

VERDANT POWER

PO Box 282
Roosevelt Island
New York, NY 10044
www.verdantpower.com

April 19, 2019

Sent via Email to:
EPA: Lingard Knutson
NYSDEC: Rudyard Edick, Lisa Bonacci, Nicole Cain, Cassandra Bauer
USACE: Ron Pinzon
USFWS: John Wiley, Steve Sinkevich
NOAA/NMFS: Julie Crocker, Mike Johnson, Karen Greene, David Bean

RE: P-12611 Article 401 Proposal for Modification of Roosevelt Island Tidal Energy (RITE) Project Monitoring of Environmental Effects (RMEE) Plans 2, 3, 4, and 6; and NYSDEC WQC conditions 11, 12, 13, and 16

Dear Agency Stakeholders,

As noted in correspondence sent to you on March 15, 2019, Verdant Power is seeking to modify the Roosevelt Island Tidal Energy (RITE) Project Monitoring of Environmental Effects (RMEE) Plans 2, 3, 4, and 6; and corresponding NYSDEC WQC conditions 11, 12, 13, and 16. These plans are part of the Federal Energy Regulatory Commission (FERC) issued Pilot License for the RITE Project (FERC Project No. 12611) under Article 401. As required by the License, any amendments to these plans require FERC approval.

Further information on these modifications was presented and discussed during meetings with agency stakeholders on March 20 and March 22, 2019 (see Attachments A&B for respective meeting minutes). During these meetings, Verdant also agreed to review and update the East River species characterization data, which is provided here as Attachment C, and also finalize the RMEE-4 2018 data reports, which have been finalized and sent for agency review on April 15.

Based on information provided and discussions to date, Verdant requests any further questions or comments on the proposed amendments to the RMEE Plans be submitted to Verdant in writing so that we can file the proposed amendments for FERC approval. Specifically, Verdant is seeking agency affirmation of the proposed amendments as discussed, namely:

- Agreement to suspend RMEE-2 Seasonal DIDSON Monitoring
- Agreement to suspend RMEE-3 Seasonal Species Characterization
- Agreement to enhance RMEE-4 Tagged Species Detection (in lieu of the above plans)
- Agreement to modify RMEE-6 Underwater Sound Monitoring to two locations

Verdant respectfully requests agencies provide such questions, comments or affirmations within 30 days from the date of this letter via email to riteproject@verdantpower.com.

We greatly appreciate the time and effort put forth by agency stakeholders to conduct a productive review of this material within an adaptive management framework to best monitor Verdant's kinetic hydropower system in the environment of the East River.

Sincerely,

Ronald F. Smith

Ronald F. Smith
President & Chief Operating Officer

Cc: NYSDOS: Matthew Maraglio
NYSERDA: Greg Lampman

Attachment A: Minutes of March 20, 2019 Agency Review Meeting
Attachment B: Minutes of March 22, 2019 Agency Review Meeting
Attachment C: P-12611 – 2019 Review of Species Characterization Data (RMEE-3)

ATTACHMENT A: Minutes of March 20, 2019 Agency Review Meeting

Environmental Monitoring Plans for Verdant Pilot License Install B-1
Agency Review Meeting
Wednesday, March 20, 2019, 1:00 p.m. – 2:30 p.m. (ET)

Attendees:
Ron Smith (Verdant), Mary Ann Adonizio (Verdant), Jonathan Colby (Verdant), Aaron Hernandez (Verdant), Chris Tomichek (Kleinschmidt), and Tracy Maynard (Kleinschmidt)

Ronald Pinzon (USACE), Nicole Cain (NYSDEC), Matt Maraglio (NYSDOS), Laura McClean (NYSDOS), Greg Lampman (NYSERDA), Cassie Bauer (NYSDEC), Mike Johnson (NMFS), and Rudyard Edick (NYSDEC)

I Introductions

Ron Smith introduced Verdant and Kleinschmidt personnel, then agency staff introduced themselves.

II Purpose

Ron S. began by explaining the purpose of the meeting was to review the previous environmental monitoring that has occurred since the original license and to discuss Verdant’s proposed changes to the RMEEs (RITE Monitoring of Environmental Effects).

III Overview of Requirements and Monitoring Results

Jonathan Colby described his role and history with the project and provided an overview of the environmental monitoring requirements. Chris Tomichek continued to describe the individual RMEEs, data that were collected.

Ron S. confirmed that 6 turbines were installed in 2006 and removed in 2008.

Mike Johnson asked Chris about the source of the Ravenswood data, which she indicated was based on impingement sampling that was conducted at the station. Entrainment data were also available and reflected the same species assemblage as impingement data.

IV Proposed Changes to RMEEs

Based on the evaluation of data gathered to-date, Jonathan discussed Verdant’s 4 proposed amendments to the RMEE plans for the agencies to consider:

1. Suspend RMEE-2 DIDSON in favor of an enhanced RMEE-4
2. Conclude RMEE-3 Netting in favor of an enhanced RMEE-4 (add 3 receivers)
3. Adjust RMEE-4 Tagged Species to an enhanced RMEE-4
4. Adjust RMEE-6 Noise to monitor in 2 rather than 3 locations

V Questions/Answers

After Jonathan, Chris reviewed the questions that are intended to be answered by the amended RMEEs, and then opened up the discussion to all for input. A summary of the discussion is as follows.

Nicole Cain (assumed Mark Woythal's role) asked if more recent data from Ravenswood are available as the latest impingement data were collected in 2007. If no more recent data is available, she suggested reaching out to the current owners to see if they had plans for collecting any additional information and potentially working cooperatively to collect additional data. Chris answered that we could check with Ravenswood staff to see if they have plans for additional sampling.

Mike Johnson indicated that he agreed with Nicole since the most recent data are from 2007. He also said that the impingement data reflected eggs and larvae, so information lacks for juveniles and adults. Chris clarified that her assessment was based on the recent impingement data, which reflects juveniles and adults that become entrapped on the facility's traveling water screens, whereas entrainment at steam electric facilities refers to the eggs and larvae that are drawn into the station with the cooling water flow. Mike said he was surprised that many adults could be impinged and asked if we had any length data. Chris said she thought they did provide length data in the report and would summarize the information for submission to the agencies. Mike said he preferred a summary of the length data by species (mean, min, max). Jonathan offered to help Chris with that task.

Laura McClean asked about DIDSON data and whether the collected data were representative of different times of the year, for example, during extreme temperature periods or storm events. Jonathan explained that data were collected during Fall 2012 because we knew that was when the most fish would be in the vicinity of the site. In terms of temperatures, the East River water temperature doesn't vary as much as other rivers due to higher velocities and mixing effects. Also, there are not many fish present in the area during winter, so impacts are likely minimal. In terms of storm events, Jonathan explained that fish likely sense the movement of the turbines, rather than physically seeing them with their eyes, so they would still be able to sense that pressure generated by the moving turbines during storms as they don't rely on sight.

Cassie Bauer asked that since the turbines were removed in 2008, did the DIDSON data collection effort in Fall 2012 occur without turbines in the water? Jonathan explained that there was a 4-week trial period in 2012 in which the turbines were deployed to test a new blade design and that coincided with the DIDSON data collection.

Cassie indicated that Lisa Bonacci (NYSDEC) was not able to make the call, but they did discuss some concerns previously. In terms of obtaining species identifications for the acoustic detections at the receivers, some researchers suggested provided funding or for Verdant to tag some fish in the future. Jonathan analyzed the data Lisa sent to him about a week ago, which he has some questions about, so he will plan to call her to discuss their concerns.

VI Next Steps

Moving forward, Verdant plans to file the agreed-upon Article 401 amendment in May 2019, and assuming a FERC response in Q3 2019, then the revised RMEEs will be implemented later in Fall 2019. As of now, Verdant plans to deploy turbines in Spring 2020 and the information collected next year will inform relicensing (current FERC license expires in 2021).

Mike Johnson asked about relicensing and whether Verdant plans to reapply for another pilot license. Jonathan said no, rather Verdant is planning to use FERC's Traditional License Process for a longer-term license, but the design of the geometric array will remain unchanged.

Ron Pinzon asked if the existing Army Corps permit would cover the planned activities for 2019. Ron S. indicated that the Army Corps permit remained effective for the duration of the FERC license. Ron P. said he would verify. May Ann stated that the work falls under Nationwide (NW) Permit 52 and she will check if new paperwork needs to be filed. She reminded everyone that NW Permit 52 did not come into existence until 2012, so all prior work was conducted under an individual permit, but the 2020 turbine installation will be covered under NW 52. Mary Ann said they plan to initiate the paperwork in fall. Ron P. said the earlier the better. Laura McClean indicated that NYSDOS should be copied or provided a copy of the permit application submittals to Army Corps.

VII Adjourn

The call ended at 2:19 p.m.

ATTACHMENT B: Minutes of March 22, 2019 Agency Review Meeting

Environmental Monitoring Plans for Verdant Pilot License Install B-1
Agency Review Meeting *[Repeat meeting for those that could not attend on 3/20/19]*
Friday, March 22, 2019, 9:00 a.m. – 11:30 a.m. (ET)

Attendees:
Jonathan Colby (Verdant), Chris Tomichek (Kleinschmidt), David Bean (NMFS-Protected Species)

I Purpose

The purpose of the meeting was to review the previous environmental monitoring that has occurred since the original license and to discuss Verdant's proposed changes to the RMEEs (RITE Monitoring of Environmental Effects).

II Overview of Requirements and Monitoring Results

Jonathan Colby described his role and history with the project and provided an overview of the environmental monitoring requirements. Chris Tomichek continued to describe the individual RMEEs, data that were collected.

III Proposed Changes to RMEEs

Based on the evaluation of data gathered to-date, Jonathan discussed Verdant's 4 proposed amendments to the RMEE plans for the agencies to consider:

1. Suspend RMEE-2 DIDSON in favor of an enhanced RMEE-4
2. Conclude RMEE-3 Netting in favor of an enhanced RMEE-4 (add 3 receivers)
3. Adjust RMEE-4 Tagged Species to an enhanced RMEE-4
4. Adjust RMEE-6 Noise to monitor in 2 rather than 3 locations

IV Discussion

After Jonathan, Chris reviewed the questions that are intended to be answered by the amended RMEEs, and then opened up the discussion.

David Bean asked if more recent data from Ravenswood are available as the latest impingement data were collected in 2007. He also said that the data reflected eggs and larvae, so information lacks for juveniles and adults. Chris clarified that the assessment was based on the recent impingement data, which reflects juveniles and adults that become entrapped on the facility's traveling water screens, whereas entrainment at steam electric facilities refers to the eggs and larvae that are drawn into the station with the cooling water flow. Chris indicated that a similar discussion occurred during the March 20th agency meeting and she was tasked with finding more recent data from Ravenswood. She indicated that she would summarize the length data by species (mean, min, max).

VI Next Steps

David Bean indicated that he thought that RMEE-4 provided good information and would like to see the effort originally allocated to RMEE-2 and RMEE-3 be used to enhance RMEE-4. Chris indicated that she would look into getting more recent Ravenswood impingement data and provide a summary of the information including the lengths of juvenile and adult fish that Verdant proposes to use to characterize the East River fish assemblage.

VII Adjourn

The call ended at 11:30 a.m.

ATTACHMENT C: P-12611 – 2019 Review of Species Characterization Data (RMEE-3)

Background

The adaptive management component of Verdant Power's RITE Monitoring of Environmental Effects (RMEE) plans envisioned executing the monitoring plans, then reviewing the usefulness of the information and adjusting or suspending the monitoring, as needed. In the case of RMEE-3, Seasonal Species Characterization Netting, Verdant executed the plan in 2013 which yielded little information (1 fish and 1 crab). Since the objective of the plan is to characterize the fish assemblage in the project area and there is extensive fish assemblage data from impingement samples collected at the Ravenswood Generating Station (Ravenswood), Verdant proposed to use the Ravenswood impingement data to characterize the fish assemblage in the project area.

During a March 20, 2019 stakeholder meeting held to discuss the Adaptive Management Review of RMEE Plans for RITE Install B-1 which will occur in 2020, Verdant presented data collected in 2005 and 2006 to demonstrate the fish species' composition and abundance in the RITE Project area. Agency stakeholders requested that Verdant determine if more recently collected data are available from Ravenswood and also include the minimum, maximum, and mean lengths of the collected fish by species.

Ravenswood collected additional impingement data during 2 recent years (February 2013-January 2014 and February 2014-January 2015). These data are similar to the historic Ravenswood data and depict a fish assemblage in the east channel of the East River that is typical of species in the New York bight.

There was concern expressed by some agency stakeholders that the data from Ravenswood was comprised of egg and larval life stages and not juvenile and adult fish. However, the Ravenswood data includes egg and larval data, collected in entrainment samples, as well as juvenile and adult fish data collected from impingement samples.

- Entrainment at a steam electric facility occurs when small organisms such as ichthyoplankton and zooplankton pass through screens designed to keep larger material out of the cooling water, travel through the facility and are returned to the waterbody in the discharged water.

- Impingement at a steam electric facility is a process where aquatic organisms (juvenile and adult fish and macroinvertebrates) that cannot fit through the typical 3/8-inch mesh traveling screens become trapped on the screens.

For the purpose of determining the fish assemblage composition for the Verdant RITE Project, the Ravenswood juvenile and adult impingement dataset was used. As requested by agency stakeholders, the minimum, maximum and mean lengths are listed by species and life stage (young-of-the-year (YOY) and older fish), and the number of fish that were measured is provided.

The Ravenswood Generating Station is located opposite of the Verdant RITE Project Boundary in Long Island City, Queens County, New York and is situated along the east bank of the lower East River (Figure 1). The East River is a tidal strait separating Long Island from Manhattan and connecting the western end of Long Island Sound to New York Harbor. Ravenswood consists of three oil-fired, steam-electric generating units which utilize a non-contact, once through cooling water system. The operating units – Units 10, 20, and 30 – have a combined nominal rated capacity of 1,742 MWe and a design flow of 964,000 gpm (5,255,000 m^3/day). Cooling water is withdrawn from the East River into the intake structures. The intake structures are screened by wooden debris skimmers and conventional vertical traveling screens incorporating screen panels of 3/8-inch square opening vertical mesh.

Data Collection and Analysis

Impingement data collected in 1991, 1992, 1993, 1994, 2005, and 2006 (historic data) were compared to data collected during one 24-hour period each week from February 2013 through January 2014 (Year 1) and February 2014 through January 2015 (Year 2). In total, 72 aquatic species were collected in the historic impingement samples. During the 2013-2015 study, 65 species of fish were collected. The top 10 species historically collected were compared to recently collected data (Table 1). Seven (Winter Flounder, Blueback Herring, Northern Pipefish, Smallmouth Flounder, Atlantic Silverside, Northern Searobin, and Bay Anchovy) of the top 10 species collected were the same in the historic and the more recent impingement collections.

Figure 1. Location of the Ravenswood Generating Station and the Verdant RITE Project in the East Channel of the East River; New York, New York.

Table 1. The top ten species in the Ravenswood impingement collections historically compared to recently collected data (listed in order of descending abundance)

Historic Impingement Collections	Recent Impingement Collections
Winter Flounder	Winter Flounder
Blueback Herring	Oyster Toadfish
Grubby	Northern Searobin
Northern Pipefish	Smallmouth Flounder
Lined Seahorse	Bay Anchovy
Smallmouth Flounder	Spotted Hake
Atlantic Herring	Blueback Herring
Atlantic Silverside	Atlantic Silverside
Northern Searobin	Alewife
Bay Anchovy	Northern Pipefish

The minimum, maximum, and mean lengths of the fish in impingement collections at Ravenswood in Year 1 (2013-2014) and Year 2 (2014-2015) are listed by species in Tables 2 and 3. The length data was split into Year 1 and Year 2 and also into young-of-the-year (YOY) and older juvenile and adult fish. The number of fish that were measured for each length category is also included in Tables 2 and 3.

Table 2. The number of fish measured and the minimum, maximum, and mean lengths (mm) of young-of-the-year (YOY) and older fish in impingement collections at Ravenswood in Year 1 (2013-2014).

		Lengths		
Species	**n**	**Min**	**Mean**	**Max**
Winter Flounder YOY	489	30	50	79
Oyster Toadfish	453	30	114	310
Northern Searobin	385	42	87	212
Smallmouth Flounder	249	38	60	115
Bay Anchovy	226	46	73	97
Spotted Hake	126	48	75	347
Atlantic Herring	98	190	234	281
Atlantic Croaker YOY	88	33	36	51
Striped Searobin	80	41	76	107
Northern Pipefish	77	67	133	199
Atlantic Silverside	63	73	97	126
Blueback Herring	63	69	82	100
Winter Flounder	61	41	101	343
Bluefish YOY	51	38	61	87

Species	n	Lengths		
		Min	**Mean**	**Max**
Lined Seahorse	51	50	70	151
Summer Flounder	49	39	79	257
Black Sea Bass	47	61	82	165
American Eel	46	213	331	641
Striped Bass	40	65	94	410
Butterfish	37	40	51	88
Skilletfish	37	39	52	73
Silver Hake	36	52	85	154
Windowpane	34	30	62	159
Butterfish YOY	22	28	39	59
Naked Goby	20	30	47	59
Northern Searobin YOY	20	40	66	140
Silver Hake YOY	19	55	75	95
Cunner	18	58	91	174
White Perch	15	57	141	217
Black Sea Bass YOY	13	49	54	59
Smallmouth Flounder YOY	12	43	60	76
Threespine Stickleback	11	43	60	65
Bay Anchovy YOY	10	38	58	88
Atlantic Menhaden YOY	8	43	61	147
Atlantic Menhaden	8	82	102	127
Rock Gunnel	8	120	131	145
Striped Searobin YOY	8	55	104	145
Tautog	8	65	124	266
Alewife YOY	7	60	75	101
Atlantic Herring YOY	7	47	62	76
Hogchoker	7	72	90	113
Oyster Toadfish YOY	7	29	36	39
Striped Cusk Eel	7	53	124	227
Pollock	6	53	61	78
Spot	6	147	156	163
Atlantic Croaker	5	58	88	110
Atlantic Silverside YOY	5	65	88	97
Windowpane YOY	5	28	41	63
Feather Blenny	4	72	81	86
Northern Pipefish YOY	4	15	18	21
Atlantic Tomcod YOY	3	45	60	83
Gizzard Shad	3	139	238	350
Northern Puffer	3	164	190	209

Species	n	Lengths		
		Min	Mean	Max
Alewife	2	86	88	89
American Sand Lance	2	147	160	172
Atlantic Moonfish YOY	2	50	54	57
Blueback Herring YOY	2	62	89	115
White Perch YOY	2	76	77	78
Atlantic Moonfish	1	65	65	65
Conger Eel	1	232	232	232
Crevalle Jack	1	40	40	40
Gizzard Shad YOY	1	77	77	77
Grubby	1	93	93	93
Little Skate	1	426	426	426
Lookdown YOY	1	58	58	58
Lookdown	1	117	117	117
Pinfish	1	61	61	61
Scup	1	138	138	138
Seaboard Goby	1	44	44	44
Spot YOY	1	61	61	61
Spotfin Butterflyfish	1	51	51	51
Spotted Hake YOY	1	58	58	58
Striped Bass YOY	1	39	39	39
Summer Flounder YOY	1	94	94	94
Weakfish YOY	1	47	47	47

Table 3. The number of fish measured and the minimum, maximum, and mean lengths (mm) of young-of-the-year (YOY) and older of the fish in impingement collections at Ravenswood in Year 2 (2014-2015).

Species	n	Lengths		
		Min	Mean	Max
Oyster Toadfish	542	34	105	246
Smallmouth Flounder	436	33	56	114
Winter Founder YOY	415	30	51	95
Northern Searobin YOY	309	32	53	114
Bay Anchovy	307	52	78	95
Butterfish YOY	197	21	37	59
Spotted Hake	170	47	78	308
Alewife YOY	167	47	76	140
Scup YOY	165	25	50	79
Blueback Herring YOY	155	47	64	107
Threespine Stickleback	118	36	57	71

Species	n	Lengths		
		Min	**Mean**	**Max**
Windowpane	111	28	44	94
Northern Searobin	106	43	79	340
Atlantic Tomcod YOY	102	32	54	149
Lined Seahorse	87	50	75	107
Atlantic Silverside YOY	83	64	85	100
Bay Anchovy YOY	74	31	77	94
Black Sea Bass	69	51	77	115
Oyster Toadfish YOY	68	29	36	40
Atlantic Menhaden	61	50	236	358
Atlantic Silverside	55	72	96	112
Atlantic Menhaden YOY	53	38	62	85
Cunner	53	44	86	178
Striped Searobin YOY	52	40	71	124
Silver Hake	42	38	73	131
Weakfish YOY	38	32	53	83
Striped Bass	37	68	90	224
Atlantic Croaker YOY	31	36	52	76
White Perch YOY	29	48	57	72
Windowpane YOY	26	28	48	70
Butterfish	25	41	54	81
Blueback Herring	24	56	94	196
Smallmouth Flounder YOY	22	38	57	90
Atlantic Moonfish YOY	21	47	68	95
Striped Bass YOY	20	37	60	89
Bluefish YOY	18	43	102	256
Northern Puffer YOY	16	31	48	69
Grubby	14	42	70	96
Naked Goby	14	28	43	53
Winter Flounder	14	63	128	242
Alewife	12	66	96	274
Rock Gunnel	12	78	129	160
American Eel	10	165	303	345
Cunner YOY	10	43	54	59
Scup	10	78	92	146
Feather Blenny	8	55	78	97
Grubby YOY	8	42	46	49
Gizzard Shad	7	173	222	387
Silver Hake YOY	7	55	68	82
Spotted Hake YOY	7	70	58	58

Species	**n**	**Lengths**		
		Min	**Mean**	**Max**
White Perch	7	74	89	109
American Shad YOY	5	88	95	106
Silver Perch YOY	5	53	63	79
Striped Cusk eel	5	114	141	174
Black Sea Bass YOY	4	49	53	56
Hogchoker	4	84	104	135
Lookdown YOY	4	36	58	86
Summer Flounder YOY	4	59	66	73
Atlantic Herring YOY	3	46	49	53
Northern Pipefish YOY	3	91	95	102
Striped Butterfish YOY	3	25	30	39
Black Drum	2	31	33	35
Fourspot Flounder	2	115	142	168
Gizzard Shad YOY	2	93	102	110
Inshore Lizardfish	2	193	256	318
Little Skate	2	443	447	451
Northern Kingfish YOY	2	40	45	50
Northern Pipefish	2	150	153	156
Northern Puffer	2	107	161	214
Northern Stargazer YOY	2	38	41	44
Northern Stargazer	2	93	117	140
Seaboard Goby	2	48	54	60
Striped Anchovy	2	98	98	99
Striped Searobin	2	64	97	130
American Sand Lance	1	158	158	158
Atlantic Moonfish	1	101	101	101
Atlantic Tomcod	1	185	185	185
Banded Killifish	1	44	44	44
Bigeye Scad	1	54	54	54
Bluespotted Cornetfish	1	357	357	357
Fourspot Flounder YOY	1	77	77	77
Northern Kingfish	1	46	46	46
Silver Perch	1	93	93	93
Striped Butterfish	1	44	44	44
Striped Cusk Eel YOY	1	32	32	32
Striped Killifish	1	91	91	91
Summer Flounder	1	300	300	300
Tautog	1	143	143	143

Conclusions Regarding Species Characterization at Verdant RITE Project

The Ravenswood impingement data has been recently collected (2013-2015) and provides a comprehensive list of the juvenile and adult fish assemblage in the east channel of the East River in the area of the RITE Project. Considering this available information and the lack of data collected via trawl netting in the project area, Verdant proposes to discontinue the RMEE-3 Seasonal Species Characterization Netting Plan. Additionally, Verdant plans to redirect its monitoring efforts by enhancing the RMEE-4 Tagged Species Detection Plan with additional receivers deployed in the east channel of the East River.

May 24, 2019 Consultation Documents:
- Cover Email
(04/19/19 document package re-sent for reference)

Subject: RITE Project Environmental Monitoring Plans - Follow-up on Proposed Modifications
Date: Friday, May 24, 2019 at 3:03:20 PM Eastern Daylight Time
From: Verdant Power
To: Verdant Power
Attachments: P12611-Article401-Proposed-RMEE-Amend_Follow-Up-Comments_04-19-19.pdf

Dear Agency Stakeholder,

We are writing to follow up on the email below and attached correspondence to collect your questions, comments or affirmations on proposed modifications to the RITE Project RMEE Plans.

If you can please provide your input by **next Wednesday (5/29),** we will finalize and file the proposed modifications accordingly.

Verdant Power
New York, NY

From: Verdant Power <notices@verdantpower.com>
Date: Friday, April 19, 2019 at 12:00 PM
To: Verdant Power <notices@verdantpower.com>
Subject: RITE Project Environmental Monitoring Plans - Follow-up on Proposed Modifications

Attached please find follow-up correspondence and information regarding the discussed Article 401 proposal for modification of the Roosevelt Island Tidal Energy (RITE) Project Monitoring of Environmental Effects (RMEE) Plans.

Verdant Power, Inc.
New York, NY

APPENDIX B:
Agency Comments Received

Subject: RE: RITE Project Environmental Monitoring Plans - Follow-up on Proposed Modifications
Date: Friday, May 24, 2019 at 3:21:09 PM Eastern Daylight Time
From: Knutson, Lingard
To: Verdant Power

I'm sending this email to let you know I've looked at the RMEE changes, but I don't have the fisheries expertise to provide any detailed feedback. I'll have to defer to my natural resources colleagues.

Thanks!

Lingard

Lingard Knutson
Environmental Scientist
US EPA, Region 2
290 Broadway, 25th floor
New York, NY 10007
212 – 637-3747

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Environmental Permits
625 Broadway, 4th Floor, Albany, New York 12233-1750
P: (518) 402-9167 | F: (518) 402-9168 | deppermitting@dec.ny.gov
www.dec.ny.gov

June 14, 2019

Verdant Power
PO Box 282
Roosevelt Island
New York, NY 10044

To: Verdant Power and Other Agency Stakeholders

The New York State Department of Environmental Conservation (NYSDEC) is in concurrence with the proposals for modification of your RITE Monitoring of Environmental Effects (RMEE) per the April 19, 2019 letter addressed to the EPA, NYSDEC, USACE, USFWS, and NOAA/NMFS with subject line "P-12611 Article 401 Proposal for Modification of RITE Project Monitoring of Environmental Effects Plans 2,3,4 and 6; and NYSDEC WQC conditions 11,12,13, and 16".

If you have any questions, please contact me at 518.402.9150 or at Rudyard.edick@dec.ny.gov.

Sincerely,

Rudyard G Edick

Rudyard G. Edick
Project Manager, NYS DEC

Cc:

Lingard Knutson, EPA
Ron Pinzon, USACE
John Wiley, USFW
Steve Sinkevich, USFW
Julie Crocker, NOAA/NMFS
Mike Johnson, NOAA/NMFS
Karen Greene, NOAA/NMFS
David Bean, NOAA/NMFS

NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

Document Content(s)