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FISH BEHAVIORAL RESPONSE DURING HYDROKINETIC TURBINE ENCOUNTERS BASED ON MULTI-BEAM HYDROACOUSTICS RESULTS

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INTRODUCTION

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 devices 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 [1]. 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 or injured by the device.

OBJECTIVES

The primary objective of this project was to use multi-beam hydroacoustics to quantify near-field fish behavior (i.e., changes in water-column position and swimming direction and velocity) in response to encountering an operating full-scale hydrokinetic turbine. The results of this analysis will be used to augment an existing fish interaction model and also used to assess which approaches (e.g., hydroacoustics, telemetry, or modeling) will be most effective for monitoring the effects of turbine arrays on fish interactions.

During testing of their Gen5 turbine (Figure 1) at the Roosevelt Island site in the East River (New York), the Verdant Power Company used a remote-controlled, bottom-mounted, DIDSON multi-beam acoustic camera to collect images of passing fish in the vicinity of the turbine. These data were collected continuously for 19 days (30Aug-18Sep2012) through multiple tidal cycles and included periods when the turbine was operational, when it was in position but the turbine was stopped, and after the turbine had been removed.

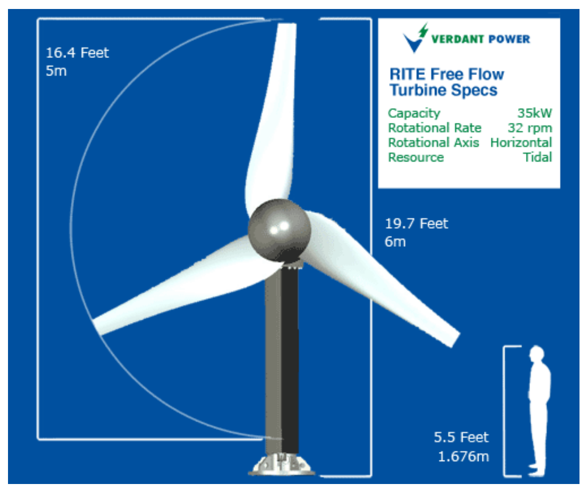

FIGURE 1. VERDANT POWER'S KINETIC HYDROPOWER SYSTEM (KHPS) TURBINE AS DEPLOYED IN THE EAST RIVER, NEW YORK CITY.

METHODS

We used Echoview v5 software (Echoview Software Pty Ltd) to analyze the DIDSON data to quantify near-field behavioral response and swimming trajectories of fish encountering the tidal turbine (Figure 2). The DIDSON unit is comprised of 90 individual transducers that each send out an acoustic ping eight times per second.

Successive pings returned from a fish target in a nearby location were joined to create tracks of individual fish as they passed through the DIDSON sampling area.

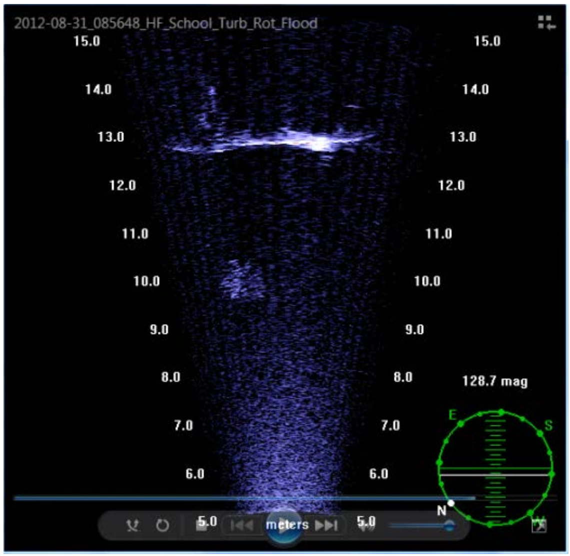

FIGURE 2. PLAN VIEW OF THE DIDSON ACOUSTIC CAMERA FIELD WITH TURBINE AT THE TOP OF THE FIGURE (BLADES AT LEFT END), DIDSON UNIT AT THE BOTTOM, AND A PASSING SCHOOL OF FISH IN THE MIDDLE. RIVER FLOW WAS RIGHT TO LEFT.

Automated analysis of the DIDSON data presented several challenges, including rotating blades, periodic turbine wobble, and changing turbine orientation four times daily with tidal flow.

Our analysis revealed the location, heading, and velocity of each fish as it passed through the multi-beam field. Each track included information about beginning and ending 3D 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. Behavioral responses (i.e., changes in swimming direction or velocity) were evaluated as a function of turbine presence and operation, time of day, tide cycle, water velocity, distance from turbine, and fish size.

Specific analyses were conducted to determine if fish closer to the operating turbine changed behavior relative to those further from the turbine or those sampled after the turbine was removed. For example, fish avoiding the turbine might be expected to change depth, swim faster, swim in a direction away from the turbine, or veer off of a straight course.

RESULTS

Most of the fish targets observed were less than 20 cm in length (Figure 3). The general understanding based on laboratory studies is that the effects of blade strike are typically more severe for larger fish [1] which is where we focused this analysis.

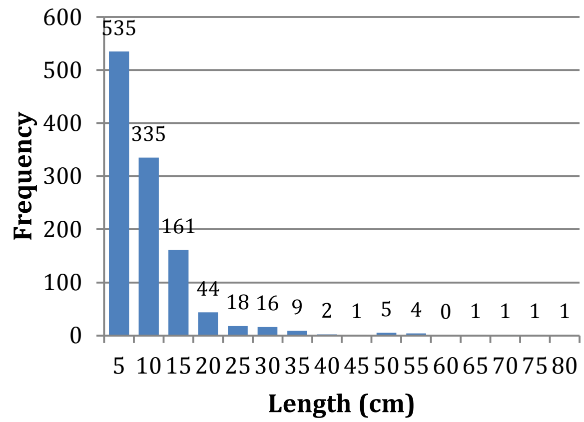

FIGURE 3. SIZE DISTRIBUTION OF FISH TARGETS OBSERVED ON 05SEP12 (07:30-08:20) DURING PEAK EBB TIDE.

We structured our analysis such that comparisons of turbine presence versus turbine absence or turbine operating versus turbine stationary were made during periods of the same tidal cycle (i.e., ebb or flood). For example, Figure 4 compares the direction of fish moving through the DIDSON field during a 2.5 hour period of peak ebb tide on September 8 when the turbine was operating to the same time period and tide conditions on September 13 after the turbine had been removed.

In this example, most fish traveled in the same direction as the current (220-240° compass heading relative to the DIDSON) with some moving against the current (40-60°). Preliminary analysis suggests that there is no indication of an effect of nearness to the turbine which was located at 14-15 m from the DIDSON or a difference between when the turbine is operating versus when absent.

In a comparison of data collected over several tidal cycles with an operating turbine (28 hours of data) and with the turbine absent (25 hours), we found evidence of a change in vertical location that suggests that fish in the presence of an operating turbine are more likely to move deeper than those when the turbine is absent (Figure 5).

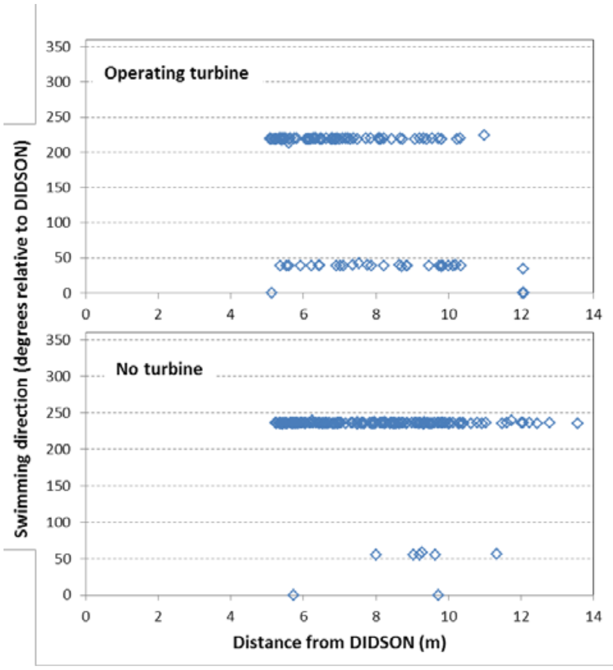

FIGURE 4. SWIMMING DIRECTION OF 175 FISH TRACKS WHEN TURBINE OPERATING (TOP) AND 115 TRACKS WHEN REMOVED (BOTTOM). TURBINE LOCATION IS AT 15 M FROM DIDSON.

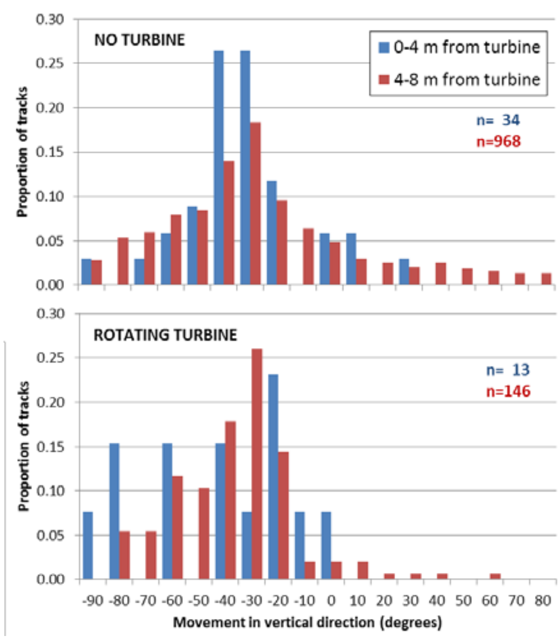

FIGURE 5. DISTRIBUTION OF CHANGE IN VERTICAL LOCATION FOR FISH TRACKS WITH NO TURBINE PRESENT VERSUS AN OPERATING TURBINE DURING THE SAME TIDAL CONDITIONS.

Preliminary results suggest no change in swimming velocity or in movement away from the turbine in the horizontal plane. There was some evidence that the tracks of fish swimming by the operating turbine were straighter than those swimming through the same space when the turbine was absent.

DISCUSSION

The use of multi-beam acoustics proved to be a useful way to evaluate the near-field interactions of fish with an operating turbine. The position and aim of the DIDSON unit is critical to capturing the most information. This is a particular challenge in tidal environments with turbines that change orientation with the direction of flow. The movement of the turbine also presents a challenge in automating data analysis, which is crucial since weeks of continuous data are necessary to adequately capture fish interactions under all conditions of flow and turbine operation.

Although we found some evidence that the presence of an operating turbine affected the swimming trajectories of fish, for the most part there was little evidence that individual fish made drastic changes in direction, location, or swimming speed in response to an operating turbine.

We did find a large difference I the number of fish in the area after the turbine was removed so an area-wide avoidance is possible.

Data for this study were collected in late summer which is not a peak migratory time for some of the key species of concern such as striped bass and Atlantic sturgeon, and our analysis indicated that the size range of fish near the turbine was heavily skewed toward smaller fish. The timing of the deployment in this case was dictated by the need for mechanical testing of the turbine and not environmental drivers. In the future, similar monitoring of fish interactions with an operating turbine during spring migration periods would be very informative.

These results will be used to parameterize an existing strike interaction model produced specifically for the Roosevelt Island project to better understand the potential impact of single and multiple hydrokinetic turbines on resident and migratory fish.

ACKNOWLEDGEMENTS

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REFERENCES

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