

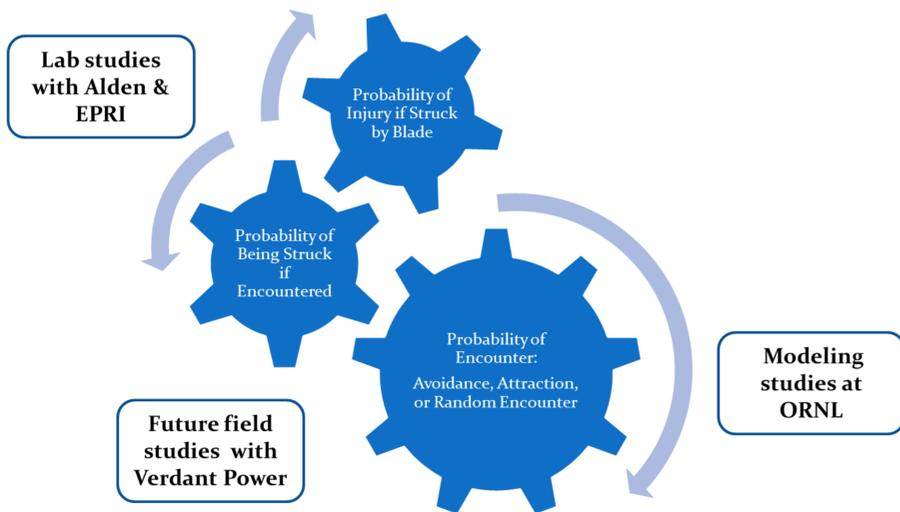
Physical Interactions of Aquatic Organisms with Hydrokinetic Turbines

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Background

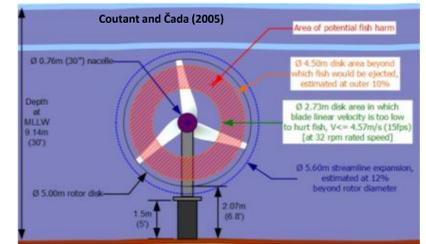
- Physical interaction of migratory and resident fish with hydrokinetic (HK) devices is a significant concern of regulators.
- Negative impact due to physical interactions is a product of probability of encounter, probability of strike if encountered, and probability of injury if struck.
- Injury or mortality is dependent on various turbine characteristics (e.g., blade speed, shape) and fish characteristics (e.g., size, skin covering, etc.).
- Studies are needed in all areas to reduce uncertainty in the effects of physical interactions with HK devices.



Methods

ORNL HK Turbine Encounter Modeling (FY10-11)

- Model framework developed to predict probability of encounter, strike, and injury for fish moving past a river-deployed HK device.
- Model designed to account for river dimensions and hydrodynamics, species distributions, and turbine characteristics.



ORNL Lab Studies of Larval Fish Survival (FY11-12)

- Early life stage fish were released directly upstream of a stationary blade in circulating flume to evaluate effects of strike and turbulent shear on a fragile life stage.
- Fish were retrieved from the flume immediately after passing the blade and survival was evaluated immediately and at 3 and 24 hours post-release.
- Three species tested (striped bass, walleyeXsauger hybrid, crappie; 1-45 days in age)
- Three blade profiles tested; three velocities (0.5, 0.85, 1.2 m/sec)

Alden/ORNL Flume Studies of Avoidance and Injury (FY12-13)

- Half-scale ducted HK turbine in recirculating flume operated at two velocities
- Injury/mortality trials with fish forced to pass through turbine
- Behavioral trials with fish given opportunity to avoid turbine (light and dark conditions)
- Three species tested (white sturgeon, rainbow trout, hybrid striped bass)

ORNL/Verdant Field Study of Avoidance (FY14-15)

- Fish occurrence and movements tracked continuously with bottom-mounted hydroacoustics system during hydrokinetic turbine testing in East River, New York.
- Data analysis will quantify swimming direction and velocity of fish relative to proximity to turbine, tide stage and direction (ebb, flood, slack), and time of day.
- Results will be incorporated into existing fish interaction model.

Results

ORNL HK Turbine Encounter Modeling

- Encounter and strike probabilities are very low under the rather simple conditions modeled (i.e., uniform fish distribution and no behaviorally directed movements).
- As behavior and other unknown relationships are better defined, they can easily be added into the model framework.

ORNL Lab Studies of Larval Fish Survival

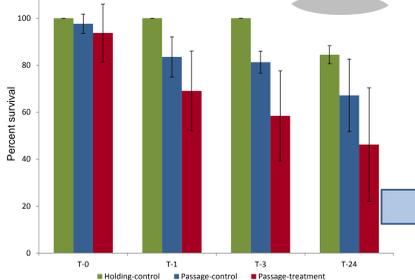
- Visual observation revealed that test fish rarely made contact with the blade but were swept along the boundary layer near the blade.
- Mortality did not differ significantly between treatment and control releases
- Mortality decreased with increasing age and decreasing velocity

ALDEN/ORNL Flume Studies of Avoidance and Injury

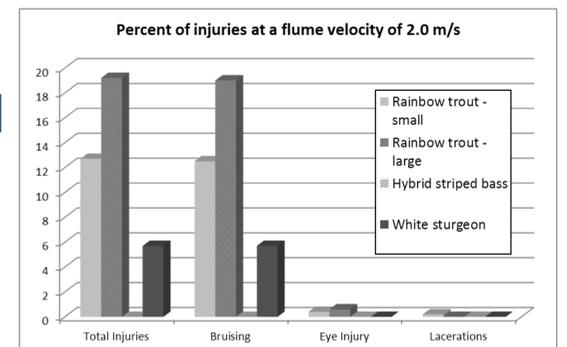
- High survival rates for the species and size groups evaluated (typically 98 to 100%).
- Injury/descaling ranged from 0-27% depending on size and species.
- Behavioral tests demonstrated a high degree of turbine avoidance (86 to 100%) for trout and sturgeon and moderate rates of avoidance for striped bass (32 to 65%).
- Avoidance was the same during night and day conditions
- Total passage survival estimates (function of mortality rate and avoidance rate) were typically very high (99-100%).

ORNL/Verdant Field Study of Avoidance

- New project; no results yet



Percent survival for striped bass at age 11-14 days post-hatching after exposure to a pointed blade profile in a 1.15 m/sec current.



Conclusions

ORNL HK Turbine Encounter Modeling -

ORNL Lab Studies of Larval Fish Survival - Our results suggest that blade strike mortalities of early life stages may not be large at the velocities tested, and that developmental stage, current velocity, and blade shape all influence mortality rates.

ALDEN/ORNL Flume Studies of Avoidance and Injury - During behavioral trials, active avoidance of turbine entrainment was noted for trout and bass, but sturgeon drifted passively and made little or no attempts to avoid entrainment. High turbine survival rates were observed for fish that passed through the turbine. Total passage survival (combining survival and avoidance probabilities) was essentially 100% for all but one test conditions. These results should not be extrapolated to larger fish which have a higher probability of strike when passing through a turbine.

PUBLICATIONS:

Cada and Bevelhimer. 2011. Attraction to and Avoidance of Instream Hydrokinetic Turbines by Freshwater Aquatic Organisms. ORNL/TM-2011/131

Schweizer et al. 2012. Effects of hydrokinetic turbine blade strike on fish early life stages - laboratory studies and projections to large river developments. In Mader & Kraml (eds.) 9th International Symposium on Ecohydraulics 2012 Proceedings, ISBN:978-3-200-02862-3.

Schweizer et al. 2012. Laboratory Experiments on the Effects of Blade Strike from Hydrokinetic Energy Technologies on Larval and Juvenile Freshwater Fishes. ORNL/TM-2012/108.

Amaral et al. 2014. Evaluation of Survival and Behavior of Fish Exposed to an Axial-flow Hydrokinetic Turbine, EPRI, Palo Alto, CA.; 2011. XXXXXXX.