Blade Strike Survival And Hydrokinetic Turbine Passage: Results Of Testing With White Sturgeon

Paul T. Jacobson, Electric Power Research Institute, Stephen V. Amaral, Alden Research Laboratory, Inc.

The installation and operation of hydrokinetic turbines in riverine habitats may impact local and migratory fish populations. One of the primary concerns associated with hydrokinetic projects is the potential for fish to be struck and injured or killed by turbine blades. To address this issue, we conducted laboratory evaluations of turbine blade strike mortality and fish entrainment through hydrokinetic turbines. The blade strike studies were conducted with trout and sturgeon and evaluated survival and injury for various fish lengths, blade leading edge thicknesses, and strike velocities. The resulting data set allows for blade strike mortality rates to be estimated for most teleost species and sturgeons for a wide range of turbine designs and operating conditions for both conventional hydro and hydrokinetic units.

Flume testing with three hydrokinetic turbine designs provided survival and behavioral data for fish approaching and passing through the blade sweep of each unit. These tests included an evaluation of white sturgeon juveniles with an axial-flow, ducted turbine. The results of these studies have produced valuable data that can be used to assess the potential for sturgeon to be entrained and injured when encountering hydrokinetic turbines in the field.

Dr. Jacobson is a Senior Project Manager in EPRI’s Waterpower Program, which encompasses conventional hydropower as well as marine and hydrokinetic technologies. His professional work over the past 25 years has focused on environmental assessment in aquatic ecosystems. Prior to joining EPRI in September, 2009, he worked in the environmental consulting arena, most recently for 13 years as the founder and principal scientist of Langhe Ecology, LLC. Dr. Jacobson’s specialty is design, analysis, and interpretation of monitoring and assessment programs to support environmental decision-making. Since 1998, Dr. Jacobson has been a faculty member of the Johns Hopkins University, Krieger School of Arts and Sciences, where he teaches a graduate course on ecological assessment. He holds Ph.D. and M.S. degrees in oceanography and limnology from the University of Wisconsin-Madison, and a B.A. degree in biology from Cornell University.

Development And Status Of Downstream Passage Technologies Designed For Sturgeon

Stephen V. Amaral, Alden Research Laboratory, Inc.

Fish passing downstream at hydro projects are often subjected to turbine entrainment and mortality, particularly at sites without downstream passage facilities or during periods of no spill. Although many downstream fish passage technologies designed to reduce turbine entrainment have been evaluated with a wide variety of freshwater and diadromous fishes, relatively few studies have been conducted with sturgeon species. Because sturgeons are very unique with respect to morphology, size, life history, and behavior, results from previous fish passage studies with other species generally are not directly applicable to sturgeon. However, development of upstream and downstream passage facilities for sturgeon has been receiving more attention, with recent studies focusing on the development of design criteria for effectively and safely passing various sturgeon species up and downstream at hydro dams. In particular, for downstream passage, several laboratory studies have investigated various guidance structure and bypass designs for reducing turbine entrainment. Also, some studies have examined the survival of sturgeon passing through turbines, including factors that affect mortality from blade strike. An overview of these downstream passage studies conducted with sturgeon will be presented. Based on the results of these studies, fisheries managers and scientists can begin to focus future their research efforts on specific downstream passage technologies that have the greatest potential for successfully protecting sturgeon.

Steve Amaral is a Principal Fisheries Biologist with Alden Research Laboratory, Inc. Steve has more than 20 years of experience in the development and evaluation of fish passage and protection technologies designed for application at all types of water intakes. He also has extensive experience in the assessment of injury and mortality of fish passing through conventional and hydrokinetic turbines. Steve has B.S. and M.S. degrees in fisheries biology, both from the University of Massachusetts.
The Importance Of Intake Bar Spacing For Protecting Sturgeon At Hydropower Projects

Stephen V. Amaral, Alden Research Laboratory, Inc.

Narrow bar spacings (less than or equal to 2 inches) have been installed at many hydro project intakes to reduce entrainment of fish through turbines and, when combined with angled structures, to guide them to downstream bypasses. The ability of narrow bar spacings to prevent entrainment is dependent on fish size and behavior and approach velocities. Even when fish are small enough to pass through a given bar spacing, many fish will actively avoid entrainment through intake racks as long as approach velocities are low enough for them to escape. Additionally, the relatively small size (less than 8 inches in length) of most fish that are entrained at hydro projects (with and without narrow bar spacing) usually results in high turbine survival rates. Therefore, determining appropriate bar spacings for any species or life stage should include estimation of physical and behavioral exclusion associated with proposed intake modifications, as well as estimates of turbine passage survival for fish that are entrained. These parameters can be estimated using existing data describing bar rack exclusion efficiencies and theoretical models developed for predicting turbine passage survival. When combined with the proportion of fish expected to pass over spillways for the expected river flows during a migration season, the bar rack exclusion and turbine survival estimates can be used to calculate total downstream passage survival for several bar spacings and a range of fish lengths in order to assess relative effectiveness. A dataset developed for shortnose sturgeon at a hydro project in the Northeast will be presented to demonstrate how such an analysis can be used for determining appropriate bar spacings for effectively protecting sturgeon species at any project.

Steve Amaral is a Principal Fisheries Biologist with Alden Research Laboratory, Inc. Steve has more than 20 years of experience in the development and evaluation of fish passage and protection technologies designed for application at all types of water intakes. He also has extensive experience in the assessment of injury and mortality of fish passing through conventional and hydrokinetic turbines. Steve has B.S. and M.S. degrees in fisheries biology, both from the University of Massachusetts.

Evaluation Of Burst Speed In Sturgeon Based On Photographic Images And Deficiencies Of Simple Methods

Michael Chelminski, David Huntress, Stantec, ASCE-EWRI, American Fisheries Society, Sea Run Brook Trout Coalition, Downeast Salmon Federation, Atlantic Salmon Federation

This paper presents a simple method for calculation of burst speeds of Atlantic sturgeon (Acipenser oxyrinchus) and shortnose sturgeon (Acipenser brevirostrum) based on field observations of leaping sturgeon in the waters of the Kennebec and Androscoggin Rivers in Maine, USA. The applied method for calculation of burst speeds is based on equivalence of kinetic and potential energy and results in calculated burst speeds expressed in body-lengths-per-second (BLS) that exceed published swimming speeds for other sturgeon. The applied method has been discussed with fish passage professionals, including biologists and engineers, and while the applied method may be described as reasonably sound, the results must be considered with due caution when considering their application to evaluation of the potential for sturgeon to successfully negotiate fish passage systems.

The intent of this talk is to present and dissect the applied method and to emphasize the potential deficiencies of deterministic analyses and evaluation of species-specific swimming speeds.

Michael Chelminski is an environmental consultant and Principal at Stantec Consulting Services Inc. The focus of his work is on fisheries habitat restoration through improved upstream fish passage. The current focus of his work is decommissioning of legacy infrastructure (i.e., dam removal) as a means to improve access for indigenous fish to their historic habitats. Michael also scopes, evaluates, and designs upstream and downstream fish passage projects in the United States and Canada. He is a charter member of the ASCE-EWRI/AFS-BES Ad Hoc Committee on Fish Passage, a fisherman, has a MS in engineering from Utah State University and a BS in engineering from the University of Connecticut, and is a licensed professional engineer.
Glendale Water Supply Improvement Project; Design Case Study

Michael Wilkin, P.E., Stantec

Description

Stantec Consulting designed the Glendale Water Supply Improvement Project to replace an antiquated diversion weir constructed of rock and rubble with a reliable diversion and screened intake to supply potable water for the community. Stantec’s goals for the project were: (1) design the diversion and intake improvements to ensure a reliable water supply to the Glendale WTP; (2) receive public input into evaluation criteria and design concepts for the diversion; and (3) complete the project construction in an environmentally sensitive manner. The project was completed in 2011, and won the 2011 ENR Southwest Region Civil Infrastructure Project of the Year.

Components

1. Provide a reliable water supply to the Glendale WTP and the community over a broad range of river flow conditions, including 100% capture of stored water that is released for TMWA customers in drought years
2. Provide a design supported by the community
3. Provide an environmentally-sensitive design and improve the biological connectivity and fish passage for the river
4. Design the diversion to work within the flood control efforts being actively pursued
5. Construct a facility that allows for safe boat passage and promotes the community’s goal of improving recreational opportunities along the Truckee River corridor
6. Provide an aesthetically pleasing appearance with low visual impact

Challenges

- Permitting and public process spanned a four year-period.
- River work area had to be dewatered for construction; activity was completed within a six month window.

Community Benefit

This project was essential to provide a reliable and safe drinking water supply to the community. River recreational opportunities and biological habitat were also improved.

Mike Wilkin, P.E., Project Manager

Mike Wilkin is a licensed engineer in Nevada and California, and has 30 years of experience in the design, operation, maintenance, and planning of all phases of water treatment and distribution facilities. His past project experiences include water facilities planning, surface and ground water resource planning, river diversions and intakes, river and stream bank restorations, well production designs, groundwater treatment and surface water treatment plant designs, distribution system improvements, and reclaimed water pumping and distribution systems. In addition to the Truckee River, Mike has recently designed fish passage, screening, and/or pumping facilities on the Shasta River, Little Shasta River, and the Sacramento River.

Glendale Water Supply Improvement Project; Owner Perspective

Ron Penrose, P.E., MS, Truckee Meadows Water Authority

The Glendale Diversion Dam provides municipal water for the Truckee Meadows Water Authority (TMWA), Reno, NV. TMWA had a need to improve the aging diversion structure, while improving fish passage upstream and provide downstream protection to native fishes in the Truckee River. The following will be discussed from the owners perspective;

- Multidiscipline approach
- Community involvement
- Trust in your designers
- Worked closely with the Permitting Agency USFWS
- Monitored and Evaluated closely with the Agencies involvement
- A success story

TMWA Glendale Water Supply Improvement Project Case Study; Fish Monitoring and Evaluation Results

Jay S. Kidder, P. E. and Fisheries Biologist, Chinook Engineering

Truckee Meadows Water Authority’s Glendale Water Supply Improvement Project was needed primarily to continue the supply of municipal drinking water to the Reno and Sparks Nevada area. The failing rubble diversion structure was inefficient for diverting water flow, fish passage, and boating and recreation activities. TMWA initiated the improvement project to repair the diversions inefficiencies. This was a multidiscipline design and implementation process. TMWA worked very hard to include the community and the agencies involved in the project to help form the design and the subsequent use of the diversion. The diversion needed to function for the TMWA goal for providing dependable water while at the same time allowing for river connectivity, fish passage and intake protection, and boater passage.

This discussion will present the results of the evaluation and monitoring that TMWA completed not only to meet permit requirements, but to establish an understanding
of the methods of assessment and to record the success of fish passage across the diversion. The diversion is designed as an eleven foot high hydraulic impoundment with a full river width roughened channel to provide fish passage. The roughened streambed slope is 4%. It also provides the primary goal of diverting approximately 60 cfs of water through a system of fine plate vertical fish screens, and allows for boater and recreation access as well. Three phases of fish passage measurement methods were completed. The pilot phase, pre-construction and post-construction results will be presented and the methods used to complete these shown and compared. Results indicate excellent fish passage for the full river width roughened channel structure for approval of the Monitoring and Evaluation requirements and nicely provide a great data set for fish passage through a roughened channel of many of the Truckee River native fish species. This may be the first rigorous evaluation and measurement of fish passage across a large full river width roughened channel fish pass. The results show the usefulness of this type of fish passage and the effectiveness for its application at other locations. As the costs to complete these types of solutions become lower as compared to other methods of fish passage, we now have a clear measured understanding of their excellent performance to go into the future.

**Jay Kidder** is a Professional Civil Engineer and Fisheries Biologist and is the Owner of Chinook Engineering. He focuses all of his work on the aspects of fisheries engineering and has been involved in the design and construction of many fish passage, fish screens, fishery management, and fish facilities throughout his 30 year career. Mr. Kidder started his career working beside the late Milo C. Bell in the 80’s and 90’s and has never looked back on the business of solving fish passage problems for clients around the West, Alaska, and the Great Basin. Chinook Engineering is celebrating its 24th year anniversary.

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Fish Passage - The Current State of Affairs in British Columbia

Craig Mount, Richard Thompson, British Columbia Ministry of Environment

With an area of almost 1 million square kilometres (or 365,000 square miles), the Canadian province of British Columbia (BC) is larger than California, Oregon and Washington combined. BC has traditionally been a resource-based economy and the result of over 100 years of resource extraction and development is a massive legacy of roads (>550,000 km) on the landscape. Conservative estimates place the number of culverted crossings on these roads at more than 430,000 - many of which represent a barrier to fish passage. As a result, improperly designed / installed / maintained closed-bottom culverts and the resultant isolation of thousands of kilometres of fish habitat are one of the greatest threats facing the significant number of native BC fish species which have a migratory component to their life cycle (anadramous and otherwise).

Since 2007, a multi-agency Provincial / Federal Fish Passage Technical Working group has been working on this problem. The group has been systematically assessing and prioritizing culverts for remediation to ensure the greatest habitat returns given limited resources. This prioritization exercise is based primarily on fish values and the amount of potential habitat upstream of each culvert. This has been modeled using a Geographic Information System (GIS) and incorporates known fish observations, upstream length, channel gradient, and other natural barriers to fish passage.

This presentation is an update to one given at the inaugural Engineering and Ecohydrology for Fish Passage conference in 2011. The BC Fish Passage Program program has now carried out over 10,000 assessments and while this is a small percentage of the total number of crossings on the landscape, it does give us a reasonable sample size from which to draw some meaningful observations. This presentation will provide summary statistics from the data collected to date and highlight some interesting relationships between roads, streams and crossings which fail to pass fish.

**Craig Mount** is the Aquatic Habitat Geomorphologist with the British Columbia Ministry of Environment. He obtained his M.Sc. in Physical Geography from the University of Western Ontario in 1995. He has worked in the Environmental Management / Geoscience field in BC since that time with experience in both consulting and varying levels of government. Craig has sat on the Culvert Fish Passage Technical Working group since its inception in 2007 and provides spatial modelling and data management expertise in addition to his main role as fluvial geomorphologist.

Development of Fish Passage In China--History And Future

Xiaotao Shi, Engineering Research Center of Eco-environment in Three Gorges Reservoir Region, Ministry of Education, Qiuwen Chen, China Three Gorges University, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences
Fish passage has garnered the attention of worldwide researchers for hundreds of years. However, China developed fish passage only since 1960s and almost vacant research and application since 1980s, until 2000s. Fish passage research and application became popular in China in the late 10 years mainly because the law regulation. There is a large gap between the willing to protect fish and actual fish passage efficiency, due to many reasons including the understanding of fish protection from stakeholder, limited knowledge on fish biology, concept update of fish passage design, and management. Even though, researchers and engineers are enthusiastic to develop fish passage. Future development should mainly focus on 1. Reinforce the acknowledgement of ecological protection. 2. Clarify parties responsible for fish passage construction, operation and management in laws. 3. Cultivate professional experts. 4. Develop global intelligence consultation. 5. Strengthen fundamental research related to fish biology and hydraulics. 6. Enact the standards for fish passage construction in China. 7. Optimize operation management on fish passage. 8. Establish the fish passage effectiveness assessment mechanism, and connect assessment to the project’s benefit and the builder’s credit.

Dr. Xiaotao Shi has been involved in fish research for more than ten years and started fish behavior study for years. He is now interested in fish habitat preference, swimming performance against velocity barriers, hydraulics, attraction/repelling techniques and computer modelling.

Fish Passage at Large Dams in California

Randy Beckwith, California Department of Water Resources, Alice Berg, NOAA Fisheries, John Hannon, U.S. Bureau of Reclamation

Historically, returns of around 2 million adult Chinook salmon were common in the Central Valley of California. However, the large dams built around the rim of the Central Valley do not have fish passage and have cut off access to more than 80% of the historical habitat for spring-run Chinook and steelhead, and almost 100% of the historical habitat for winter-run Chinook. Due to potential climate change effects on Central Valley streams, many researchers and agencies have recommended evaluating opportunities to reintroduce salmonid species into this historical habitat. In addition, NOAA Fisheries has stated in two biological opinions that fish passage needs to be implemented at several Central Valley rim dams. As a result, multiple agencies are working to examine the feasibility of providing passage at these dams. The California Department of Water Resources has developed a white paper, Technologies for Passing Fish at Large Dams. The Yuba Salmon Forum and NOAA Fisheries are investigating reintroduction options above Englebright Dam on the Yuba River. The Central Valley Project Interagency Steering Committee is investigating fish reintroduction above Shasta, Folsom, and New Melones dams. Additionally, several agency personnel have participated in site visits at fish passage projects in Oregon and Washington to gather important information to help determine the feasibility of implementing fish passage at large rim dams. California can learn much from the many successful fish passage projects that have been completed in the Pacific Northwest. However, we have many difficult issues to resolve. Characteristics of the reservoirs, such as high reservoir temperatures, large fluctuations in reservoir water surface elevation, and long reservoir tributary arm distances, make designing a passage project challenging. In addition, the need for flood control, water storage, power generation, and recreation adds to the complexity. Ideally, we can overcome these hurdles and begin implementing these important projects.

Randy Beckwith is a Senior Engineer with 17 years of Department experience on fisheries engineering issues. He has spent the last 7 years in the Fish Passage Improvement Program, leading an engineering unit that has developed designs to improve fish passage in the Calaveras River system and Yolo Bypass. He has also led the development of a draft white paper, Technologies for Passing Fish at Large Dams, and is the Department’s engineering lead on an interagency team that is examining the feasibility of providing anadromous salmonid passage at Shasta Dam.
Recent river rehabilitation measures in Swedish rivers

Olle Calles, Stina Gustafsson, Martin Österling, Larry Greenberg, Karlstad University, Sweden, Paolo Vezza, Claudio Comoglio, Politecnico di Torino, Italy

River rehabilitation in Europe has increased during the last decade, and in countries like Sweden the activities have moved from mainly addressing salmonid upstream passage and habitat rehabilitation, to also incorporating e.g. creating artificial habitat (nature-like design) to compensate for destroyed habitat and technical solutions for improved downstream passage. Nature-like design and downstream passage rehabilitation have quickly become hot topics in Northern Europe, and so there is a growing interest for finding similar successful projects in other countries. Transferring knowledge from rehabilitation projects from other parts of the world, to your own, is challenging since the solutions in most cases have to be adapted to the species composition, climate, and budget in question. I will present examples of rehabilitation projects from Swedish rivers dealing with nature-like design and downstream passage. The first example is on exploring the potential of nature-like design, moving from nature-like fishways as upstream passage routes for adult salmonids, to multipurpose channels. We investigated if increasing habitat heterogeneity in a nature-like fishway had a positive effect on the overall aquatic biodiversity. The other examples are on the design and evaluation of technical solutions to improved downstream passage for several fish species, in particular the critically endangered European eel (Anguilla anguilla). The solutions for improved downstream passage have until now consisted of low-sloping (35°) intake iron racks guiding fish to the surface. A recently completed collection facility is equipped with composite racks with adjustable angles, and during 2013 the first rack guiding fish to a lateral bypass will be built and evaluated. The current ideas and problems with design are presented and discussed.

Olle Calles is Associate Professor with the research group Management and Ecology of River Resources at Karlstad University, Sweden. He works on design, implementation and evaluation of rehabilitation techniques for fish in regulated rivers.

Massive Weir And Fishway Construction As A "National River Restoration Project" In Korean Government And The Fish Movement Evaluations Using Various Monitoring Methodologies

Kwang-Guk An and Ji-Woong Choi, Chungnam National University

The major objective of the research was to evaluate integrative impacts of fish movements and migrations after the constructions of weirs and fishways as a part of the "National River Restoration (NRR) Project" in Korean government. In the presentation, we introduce some plans and scales of the "National River Restoration Project" in Korea, and discuss some ecological problems on fish passage along with chemical water quality. The specific targets of our research are summarized as follows. First, fish species distribution and compositions were evaluated in the tributaries and mainstem sites of Yeongsan-River watershed after the completion of the fishway and weir constructions in 2011. Second, we analyzed the impacts of fish migrations and fish passage in fishways and weirs. Third, we traced the passage of migratory and non-migratory fishes using various fish tracking methodologies including Passive Integrated Transpondents (PITs) tags, ultrasonic telemetry, video recording, trap-setting, and ultra eco-sounder monitoring approaches, and evaluated some impacts of the weir/fishway constructions. Lastly, we are trying to establish a "national protocol of fish monitoring methodology" for the surveys of the weirs and fishways in Korea. Currently, this study is on-going project in 2013 and will be continued until 2014. Our outcomes are preliminary results now, but will contribute to the ecological conservation of national rivers in Korea after the completion of our research.