Development and Status of Downstream Passage Technologies Designed for Sturgeon

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Extended Abstract

There are nine sturgeon species inhabiting coastal and freshwater systems in North America. Most of these species have experienced seriously declines and some have been federally-listed as threatened or endangered throughout all or part of their range. Several of these species are also being protected at the state level. For sturgeon populations that utilize riverine habitats, hydroelectric dams can fragment populations and limit or prevent access to critical habitats used for spawning, rearing, feeding, and/or overwintering. Attempts have been made to minimize these impacts by providing upstream and downstream fish passage, but very few fishways have been designed specifically for sturgeon and those installed for other species (e.g., salmonids) are often ineffective. Consequently, fish passage 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, several laboratory studies have investigated various guidance structure and bypass designs for reducing turbine entrainment. Additionally, some studies have examined the survival of sturgeon passing through turbines, including factors that affect mortality from blade strike.

Laboratory studies that have evaluated downstream passage technologies for sturgeons have generally focused on physical structures that prevent turbine entrainment and guide fish to a bypass. Flume tests conducted with bar racks and louvers angled at 15 and 45 degrees to approach flow and with 1 or 2-inch clear bar spacing demonstrated poor guidance for young-of-the-year lake sturgeon (mean lengths of about 130 to 150 mm), with bypass efficiencies of about 10 to 37% at approach flow velocities of 1 to 3 ft/s (EPRI 2001; Amaral et al. 2002). Larger lake and shortnose sturgeon (mean lengths of 345 and 319, respectively) also were tested with the 15 degree structures and exhibited much higher guidance rates (85 to 100%) compared to the smaller fish. In a similar study, Kynard and Horgan (2001) reported guidance efficiencies of 58 to 80% for shortnose (275 mm mean length) and pallid sturgeon (216 mm mean length) exposed to a bar rack angled at 45 degrees to the flow with 1.5-inch clear bar spacing and an approach velocity of 1 ft/s. The lowest efficiencies for both species were observed during night testing. In the same study, guidance efficiencies of shortnose and pallid sturgeon were 96 to 100% for nighttime tests with a 20-degree louver array and 1.5 and 3.5-inch clear bar spacing. In general, the results of these laboratory studies suggest that guidance efficiencies of angled structures will be higher at lower velocities (1 to 2 ft/s) and that guidance of sturgeon greater than 200 mm in length will be higher than it is for smaller (younger) fish. Also, structures angled at 20 degrees and less to the flow will provide better guidance than structures angled at 45 degrees. The results from a field study conducted with shortnose sturgeon and a 400-ft louver array angled 15 degrees to the flow with 2-inch clear spacing verified the laboratory results, demonstrating guidance efficiencies of 100% at approach velocities of about 1 to 2 ft/s (EPRI 2006).

More recently, a series of laboratory studies was conducted specifically for developing downstream passage design criteria for shortnose sturgeon at the Hadley Falls Hydroelectric Project on the Connecticut River in Massachusetts. These studies were conducted in large flume test facilities at the USGS Conte Anadromous Fish Research Center (Kynard et al. 2005, 2006) and Alden Research Laboratory, Inc. (Alden 2007, 2008, 2009; Hogan et al. 2008). The Conte Center studies evaluated exclusion for three age groups of shortnose sturgeon (yearlings less than 500 mm in length and juveniles and adults greater than 500 mm) exposed to a 20-ft wide bar rack structure with 2-inch clear spacing and approach velocities of 1 to 3 ft/s. Entrainment was 0% for all three life stages at a velocity of 1 ft/s and for the two older life stages at 2 and 3 ft/s. Combined entrainment and impingement rates increased with velocity for yearlings to about 16% at 2 ft/s and 74% at 3 ft/s. Tests conducted at Alden evaluated a similar bar rack structure (10 ft wide, 2.0 to 2.3 ft/s approach velocity, 2-inch clear spacing) to determine exclusion rates and bypass efficiencies associated with various bypass entrance sizes, locations, and entrance velocities. Bypass efficiencies ranged from 0 to 74% and increased with fish length (range tested: about 200 to 425 mm) and entrance velocity (range tested: 1 to 6.2 ft/s). The results of these studies indicate that a bar rack with 2-inch clear spacing and approach velocities of about 2 ft/s and less should effectively exclude most shortnose sturgeon from entrainment at Hadley Falls, and that a bypass with an entrance velocity of about 5 ft/s would be the most effective at attracting and passing fish downstream.

Extensive research examining injury and mortality of fish passing through hydro turbines has been conducted over the past 50 years. However, most studies have focused on anadromous salmonids and more typical riverine species, with very little information being collected for sturgeons. Additionally, field evaluations of turbine passage survival have been conducted at more than 50 hydroelectric projects (EPRI 1997; Winchell et al. 2000), but none of these have included tests with sturgeon. The only turbine passage survival study that has investigated injury and mortality to sturgeon was a pilot-scale laboratory evaluation conducted with the Alden fish-friendly turbine (Cook et al. 2003; Amaral et al. 2003). The results of this study demonstrated that white sturgeon (about 103 mm mean length) had immediate (1-hr) and total (96-hr) survival rates of 98.3 and 97.0%, respectively. These survival rates were statistically greater than those of teleost (boney) species that were also tested (alewife, smallmouth bass, rainbow trout, and coho salmon). It is likely that the cartilaginous skeleton and tough integument (with no scales) of white sturgeon contributed to less blade strike injury and mortality compared the other species, which all have true bones and are prone to scale loss when struck by turbine blades. These results were confirmed by a follow-up study that examined the primary parameters influencing blade strike mortality (i.e., fish length, leading edge thickness, and strike velocity) (EPRI 2008, 2011; Amaral et al. 2008, 2011). The results of blade strike testing demonstrated that white sturgeon struck with thinner leading edges at higher strike velocities suffered less mortality than trout tested with thicker blades and lower velocities.

Upstream and downstream passage is an important issue for fisheries managers attempting to protect and restore sturgeon populations throughout North America. However, for downstream passage, information on effective designs is limited. Angled bar racks and louvers have potential to effectively guide sturgeon away from turbines and to bypasses at hydro projects if slat spacing and approach velocities are selected based life stages targeted for protection (e.g., clear bar spacing of 2 inches or less and approach velocities no greater than 2 ft/s for young-of-year fish). Also, bypass entrance velocities should be about 5 ft/s or higher to ensure fish are attracted and retained if they approach and enter a bypass. Although angled structures typically provide better guidance to bypasses, existing intake racks perpendicular to approach flows may be sufficient for preventing turbine entrainment and allowing sturgeon to find a downstream bypass if the bar spacing and approach velocities are appropriate for the smallest fish expected to encounter the structure. However, because sturgeon are less susceptible to blade strike injury and mortality during turbine passage, total passage survival may be high (greater than 90%) even when large numbers of smaller fish may be susceptible to entrainment.

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