Development and evaluation of the first fish ladder in N. America designed for migratory riverine fishes

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Donovan Henry – US Fish & Wildlife Service
Four Entity Partnership started in 2015

1. **Stockwell Mill Foundation** (owner of Stockwell Mill Dam) -- approval for a ladder at dam

2. **Donovan Henry, Carterville USFWS Conservation Office** – provide funds for ladder installation & evaluation

3. **Boyd & Brian Kynard, BK-Riverfish,llc** – built hydraulic lab, provided funds/2+ years to design ladder, design layout at dam, fabricate ladder, ship ladder to dam, and assist with installation

4. **Jerry Sweeten & staff, Manchester Univ.** – Assist with site layout, ladder installation, and monitor ladder performance & operation (fish ascent, debris, etc)
Ichthyomechanic/ Velocity Goals for ladder to pass upstream fish migrants in Eel River

• **Fish size/species**: pass all species 2-24 inch long
• **Max. Velocity**: burst swimming data on 2 inch long fish is poor; During ladder design, we rejected baffle designs with fast current > 30-40 cm/s (12-16 inches/sec). Field observations indicated a 2-4 “ long fish (minnows) could swim 6 inches or more in 30-40 cm/sec velocity.
• **Ascent Time**: pass fish quickly (few minutes per 10 ft of ladder)
• **Damage**: Cause no damage to fish moving up- or downstream in ladder
Ladder Design/River Flow/ Fish Habitat Goals

• Ladder must attract fish at low and high river flows
• Velocities to pass small fish must exist when water flow in ladder is low (6 inch depth) and at 24 inches (full depth)
• Ladder must create eddies for resting at short distance intervals (estimated, 5-6 inches apart) or small fish may not be able to ascend a long ladder
With advice from Brazilian hydraulic engineer, Ricardo Junco, PhD, Designed and constructed a hydraulic lab with a 14ft long sloped run
Trial and error tests with 9 baffle configurations in a ½ scale model ladder (1 ft wide x 1 ft high) was used to design the prototype 2ft x 2ft ladder for Eel River

Design Name:
Alternating Side-Baffle Ladder (ASBL)
Measured hydraulics between baffles 4 - 6
Video shows target velocity in slot & 5 inch swim distance between eddies on 8% slope
Presently: ½ scale model ladder (3 ft wide x 1ft high) tests to design a 6ft wide x 2ft high ladder for sturgeon and small riverine fishes found similar hydraulics and eddy habitats as in smaller ASBLs.
Stockdale Mill Dam with elevation contour lines
Ladder layout at Stockdale Mill Dam
Fabrication drawing of prototype 2ft x 2 ft ladder with 56 side baffles; 73 ft long in 11 sections; on 8% slope
11 Sections of ladder (3/16 inch painted steel)
Ladder sections on shipping truck
Martin Duffy, Site Engineer, making 8% ground slope for ladder
Assembly of ladder sections
Completed Ladder anchored to ground and bolted together: Assembled in 10 hours by 4 people + excavator to move sections
Finished ladder with entrance & exit concrete walls, rock fill + 6 inch thick concrete topping + stainless steel grate
Performance: ice damage, flooding, debris problems

- **Ice damage**: none in winter 2017-2018
- **Erosion**: 3 floods in winter 2018 with water depth 5-8 ft over ladder --- no erosion damage
- **Debris blocking ladder**: no daily problem; after high river discharge events -- remove debris (tree limbs) from top of ladder (water entrance)
Performance: fish passage (Preliminary Data)

- **~ 10,000 fish ascended ladder:** May-September 2018
- **Size of fish passed:** 1.5 to 16 inches (large fish size estimated as they escape trap at top of ladder)
- **Fish Species Passed:** 40 of 52 species in Eel River or 77% of all species migrated upstream in the ladder (passed 5 of 6 darter species)
- **Fish ascent speed to top:** Estimated 30 min/73 ft for 2-4 inch fish (details yet analyzed using PIT tagged fish)
- **Fish ascent in low & high flows:** fish passed @ 6-8 inch depth and @ 24 inch depth (details yet analyzed; ladder designed to operate over 80% of annual flows)
- **Fish migration season:** spring, summer, and fall (details yet analyzed)
Conclusions

• The ASBL passes diverse riverine fish species of small to large size in spring, summer, and fall during a range of river flows (details yet analyzed).

• About 80% of the fish species in the Eel River have innate upstream (and likely innate downstream migrations).

• Stockdale Mill Dam blocked upstream fish migrations after 1867 for ~150 years (and many fish generations)

• Diverse fish migrated upstream of the dam the first year after the fish ladder was installed at the dam, indicating the upstream migration drive is innate, just like the migration of diadromous fishes at a dam after passage is provided.
Riverine Fish Restoration has a New Tool - The ASBL to allow natural upstream migrations of riverine fishes at Dams and Road Culverts

20th Century: Fish Passage For only Diadromous Fish

The End