Coarse Fish Passage Screening Tool for Culverts in Maine

Data Inputs:
Inputs from NAACC survey data, USGS Streamstats Flow Regressions equations and NHD plus provided the relevant data for Flow, Slope, Culvert Geometry, Substrate coverage and Culvert Material/Corrugations needed to calculate roughness, flow depth, velocity and from manning's equation.

Input Variables	Usage
Structure Type	Logic parameter used to select the correct geometry calculation for pipes, boxes
Total Crossing Span	Measurement of Diameter or Width for X-sectional Area calculations
Crossing Height	Measurement of Diameter or Height for X-sectional Area calculations
Inlet Water Depth	Measurement of Water Depth in Culvert for back calculation of flow from manning's equation
Corrugations	Binary Classification of culvert Corrugation for estimate of manning's N Roughness coefficient
Number Of Culverts	Logic parameter to divide Flow and Span by to control for Multiple Culverts
Latitude & Longitude of Crossing Point	Grid location of crossing snapped to NHD flowline for StreamStats regression calculations
Q2 & Mean& day Low Flow from Stream Stats	Used to model average low flow conditions
Observed Flow during Survey	Classification of flow as High, Moderate or Low based on crew observations at time of NAACC survey.
Slope from NHD PLUS	Slope of Reach passing through culvert for Calculation of Velocity

Fish Flow:
Streamstats outputs for Q2 & Mean 10 day 7 year low flows were used to create a range of flows to bound the upper and lower limit of possible flows that fish would be most likely to experience. By filtering crossings by the observed low flow and solving manning's equation solved for flow in the crossings based on geometry, slope and measured inlet water depth, we derived a rough, quantitative estimate of the distribution of actual flows in culverts at typical low flows. Assuming that fish are most likely to be moving during these typical low flows, we divided the range of flows defined by Streamstats into increasingly smaller fractions and compared these results to the calculated low flow metric we derived, until we arrived at the denominator that minimized error between these two distributions. We used this denominator to calculate the "Fish Flow" from the range of Streamstats flows for all crossings.

We found that by dividing the range of flows from Streamstats by 8, we were able to most closely match our calculated flow we derived from our measured water depths at observed low flows.

Froude Number:

The Froude ratio defines the relationship between inertia and gravity in a flowing fluid. When the Froude number(Fr) is equal to 1, velocity is equivalent the force of gravity acting upon the volume of water, and the water is flowing at the critical depth(d_c) where its energy state is balanced. Slower velocities relative to gravity result in deeper, backwatered conditions (actual water depth > critical depth(d_c)) with high potential energy and actual water depth > critical depth(d_c) . High velocities relative to gravity result in shallow flows (actual water depth < critical depth(d_c)), fast flows with high kinetic energy. Froude numbers > 1 indicate velocities in culverts that are likely more difficult for fish to navigate, Froude number < 1 indicates velocities more likely to be conducive to fish movement. The Froude number was converted to pass-ability by assigning all barriers with Froude numbers higher than 3 (outliers) a value of 3. The Froude numbers were then scaled on a 0-1 range and inverted so that 0= full barrier and 1= fully passable.

Pass-ability score:

A numerical score from 0-1 that indicates how passable a barrier is likely to be, where 0=complete barrier and 1=fully passable. All dams are considered complete barriers, unless there is known fish passage facilities at a dam. Dams with fish passage were reviewed by J. Royte and E. Martin from The Nature Conservancy and assigned a pass-ability score based on the efficacy of passage at the dam. Pass-ability for road-stream crossings is first assigned based on Maine's crossing assessment protocol which splits crossings into barriers, potential barriers, and no barrier. Barriers were assigned a value of 0 and no barriers were assigned a value of 1. Potential barriers were further refined based on Froude number which is a proxy for the relationship between velocity and depth that can be utilized as a screening metric to identify crossings that have a high probability of being velocity barrier to fish passage. Pass-ability score of 0.66 correlates directly to a Froude number of 1, so only potential barriers with a score of < 0.66 were prioritized in the final result.

Important Notes:

This analysis contains compounded error vectors from the StreamStats Inputs, remote sensing of reach slope from NHD and qualitative field assessments methods. This method should not be used for anything other than a course screening method to identify the highest priority sites, and these errors should be assessed carefully when drawing conclusions from the model outputs. For the comprehensive methodology, please contact Benjamin.matthews@tnc.org for python I/O scripts, hydraulic geometry equations and model assumptions.