Improving Downstream Passage: Using Fish Morphological Characteristics to Re-Design Hydroelectric Turbines

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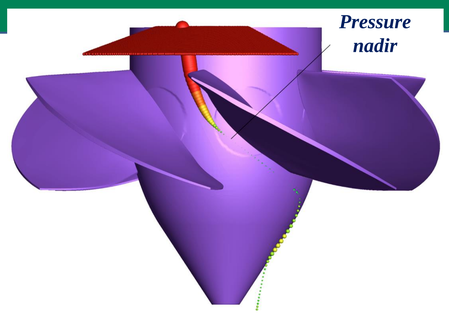
Background

- One of the most widespread environmental constraints to the development of hydropower in the U.S. is the provision of adequate fish passage.
- Mortality of downstream migrating fish, particularly as a result of passing through hydropower turbines, remains a serious problem at many sites.
- It is not possible to quantify turbine passage survival for every species that inhabits or passes through a hydropower reservoir – there may hundreds of species at a particular site.
- The fish passage task focuses on refining our understanding of turbine and reservoir passage stresses and predicting the responses of a wide range of fish species to those stresses.

ORNL's Task Objective: Develop an approach for predicting likelihood of injury/mortality among untested fish species using traits-based assessment techniques. (Note: this task was part of a larger study led by PNNL which included complementary objectives between the two labs.)



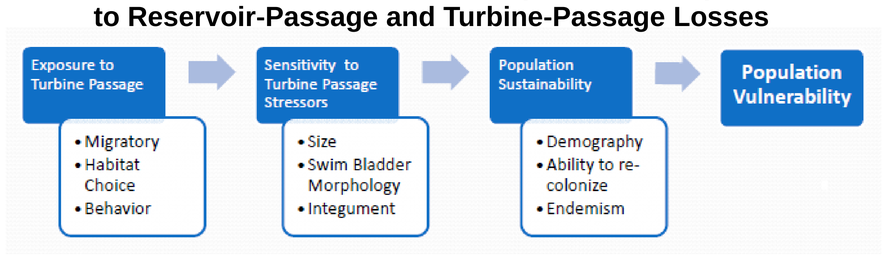
Schematic of a turbine runner that depicts the drop in water pressures to low values (nadirs) that are injurious to fish.

Methods

Traits-Based Assessment (TBA)

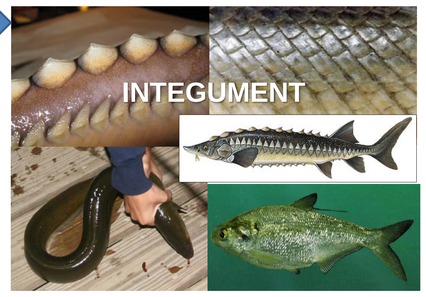
- Traits – Measureable properties of an organism
  - Ecological traits – environmental preferences, behaviors
  - Biological traits – body size, shape, physiology, life history characteristics
- Similar traits may lead to similar risk of turbine passage and similar turbine passage survival
- Traits may be more useful than taxonomy for predicting turbine passage survival.
- FishTraits database described in Frimpong & Angermeier 2009. Fisheries 34(10):487-495.

Traits that Influence the Vulnerability of a Fish Population to Reservoir-Passage and Turbine-Passage Losses

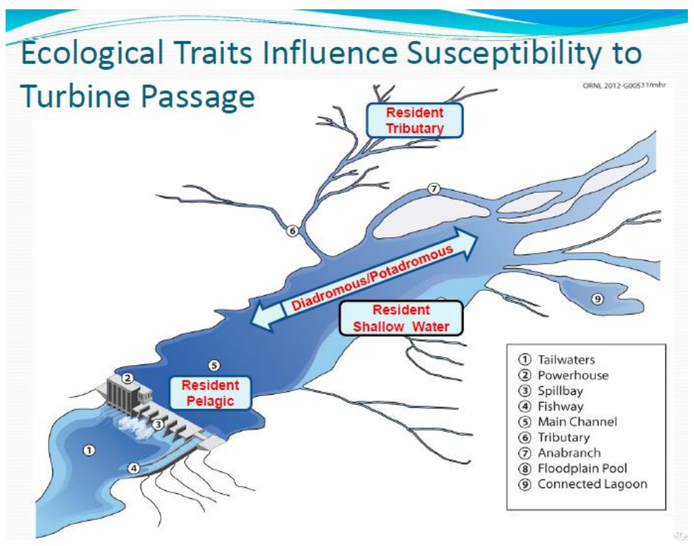


Biological Traits

Trait	Description	Turbine Passage Stressor-Trait Linkage
Swim bladder morphology	The swim bladder can be rapidly filled or emptied by means of the pneumatic duct (physostomous) or can only be slowly filled/emptied by diffusion (physoclistous)	Rapid decompression that occurs downstream from the turbine runner may cause damaging expansion of the swim bladder unless the expanding gases can be vented through the pneumatic duct
Size	Total length (TL)	Large (long) fish are more likely than small fish to be struck while passing through the space between the rotor blades
Integument	Thickness of protective mucous coating on surface of the fish and/or the resistance of scales to being dislodged	Abrasion from contact with hard structures or fluid forces (shear stresses) can cause loss of protective mucous coating, descaling, or damage to the skin



Ecological Traits



Results

- Hierarchical clustering analysis was performed on the traits for fish from 4 river basins as an example of the approach
- Original lists of 22 to 91 species were narrowed to more manageable lists of 5 to 7 species that should be considered for further study (see table)
- Species of concern identified by the TBA typically included long fish, highly migratory species, and fish that have an old age at first maturity.

Application of TBA to hypothetical hydroelectric power projects in four river basins.

River basin	Total number of fish species in basin	Number of species to consider for further study	TBA-derived list of species for further analysis		Primary clustering (selection) criteria
Roanoke (Virginia)	91	7	Shortnose sturgeon American eel Longnose gar Striped bass	Shad sp. Sucker sp. Minnow sp.	Longevity Age at maturity Habitat diversity
Deschutes (Oregon)	22	≤7	White sturgeon Coho salmon Chinook salmon Mountain whitefish	Sockeye salmon Steelhead trout Bull trout	Maximum total length Age at maturity Potamodromy
Canadian (Texas)	25	≤6	Gizzard shad White crappie White bass	Largemouth bass Walleye Rainbow trout	Potamodromy Physoclistous Cycloid scales
Seine (France)	33	≤5	European eel Common dace Common nase	Brown trout Common barbel	River habitat River order Potamodromy Longevity

Conclusions

Traits-Based Assessment

- considers environmental, biological, behavioral, and life history characteristics of fish including:
  - Identification of species most susceptible to turbine passage
  - Identification of species sharing similar sensitivities to turbine passage stressors
  - Evaluation of population sustainability in event of downstream passage losses
- TBA is transferable to fish communities from different bio-geographic regions
- TBA is useful for assessing impacts of new hydropower development, developing mitigation measures, and identifying representative test species

Publications:

Cada and Schweizer. 2012. The application of traits-based assessment approaches to estimate the effects of hydroelectric turbine passage on fish populations. ORNL/TM-2012/110.

Cada and Schweizer. (in review). The use of traits-based assessments to evaluate the effects of hydroelectric power projects on downstream fish passage.

U.S. DEPARTMENT OF ENERGY

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