Concurrent Sessions B: Integrating Fish Physiology or Behavior With Passage - A Predictive Model of Swimming Performance for Small-Bodied Fishes

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Can We Predict Swimming Performance of Small-Bodied Fishes?

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Overview

- Quick introduction to western Great Plains streams
- Stream alterations in these systems
  - Fragmentation
- Improving fish passage for small, nonsalmonid fishes
  - Predictive swimming model
  - Review of swimming abilities
  - Field study of existing rock ramps
  - Lab study using experimental rock ramps

Photo: Matt Kondratieff
Western Great Plains Streams

- Many semi-arid systems
  - Some have mountain headwaters
  - Large inter- and intra-annual flow variability
  - Large range of physicochemical conditions
- Many of these streams are highly fragmented
Western Great Plains Fishes

- Many small-bodied fishes
  - Adult TL ~ 100 – 150 mm
- Movement essential part of life history for most species

Photo: Jon Wardell
Photo: Shai Kamin
Photo: Matt Kondratieff

http://outdoornebraska.ne.gov
Facilitating Fish Passage

- Typically accomplished with fishways
- Multiple fishway types
- Incorporating swimming data into design is ideal
- Many questions remain
  - Swimming ability quantified for few species
  - Collection of swimming ability data requires expensive, long-term studies
Facilitating Fish Passage: Goal

- Develop a predictive model of swimming performance for small-bodied North American fishes.
  - Predictor variables = simple to collect
  - Combination of shape and physiological measurements
Methods: A Predictive Swimming Model

- Aerobic and sprint swimming as a function of...
- Morphology
  - Landmark Analyses
- Physiology
  - Hematocrit, Hb⁺
  - Percent red muscle
  - Percent white muscle
Dependent Variables: Swimming Abilities

- Loligo Model 32 & Model 90 swim tunnels
  - Constant acceleration tests (CATs)
  - Start velocity = 11 cm/s
  - Increments = 5 cm/s every 5 s
- Measurements
  - Aerobic ability = gait transition speed
  - Sprint ability = speed at “exhaustion”
Independent Variables: Morphology

- **Total length**
- **Landmark analysis**
  - 15 landmarks per fish
  - Procrustes analysis provides “typical shape” for species
  - PCA converts \((x, y)\) coordinates to scores
  - Scores can be used in statistical analyses
Independent Variables: Morphology
Independent Variables: Physiology

- Hematocrit
  - Hematocrit tubes centrifuged
  - Packed cell volume read
- Hemoglobin concentration
  - Quantichrom Hemoglobin Assay
- Red and white muscle
  - Percent @ 50% of TL
  - Preserved & stained cross sections analyzed with ArcGIS
Integrated Analysis

- Boosted regression trees
  - Strong predictive power

- Two analyses
  - Aerobic swimming ability
  - Sprint swimming ability

- Independent variables for both analyses:
  - Total length
  - Average body shape scores (PCA scores) for each species
  - Hematocrit
  - Hemoglobin concentration
  - Red and white muscle percentages
Results: Swimming Performance

[Graph showing swimming performance data for different species]
Results: Morphology
Effects on Swimming Performance

- **Aerobic**
  - Total length
  - Red Muscle
  - PC1 and PC2

- **Sprint**
  - PC1
  - Total length
  - HCT and Hb+ (Hemoglobin)
  - PC3
Partition for Aerobic

**Length**
- RedMuscle50<0.7265093266
- RedMuscle50>0.7265093266
- TL<75
- TL>75

**Musculature**
- RedMuscle50<0.062859362
- RedMuscle50>0.062859362

**Shape**
- PC1<0.000921832
- PC1>0.000921832

**LogWorth Difference**
- Mean
- Std Dev

**RSquare**
- 0.321

**RMSE**
- 11.246575

**N**
- 269

**Number of Splits**
- 5

**Imputes**
- 13

**AICc**
- 2070.81
Effects on Swimming Performance

- **Aerobic**
  - Total length
  - Red Muscle
  - PC1 and PC2

- **Sprint**
  - PC1
  - Total length
  - HCT and Hb$^+$
  - PC3
Effects on Sprint Performance

- Anaerobic
  - PC1
  - Total length
  - HCT and Hb
  - PC3

Effects on Sprint Performance

- Aerobic
  - Total length
  - Red muscle
  - PC1 and PC2

Hematology

- HCT<0.5416666667
  - Count 45
  - LogWorth Difference 1.1368124
  - Mean 62.977778
  - Std Dev 14.019431
- PC1>0.062859362
  - Count 215
  - LogWorth Difference 6.2468667
  - Mean 90.030233
  - Std Dev 22.088401

Length

- TL<95
  - Count 188
  - LogWorth Difference 1.9872
  - Mean 87.199468
  - Std Dev 20.748658
- PC3>0.022796916
  - Count 171
  - LogWorth Difference 20.731988
  - Mean 85.72807
  - Std Dev 14.452508

Shape

- PC3<0.022796916
  - Count 17
  - LogWorth Difference 14.452508
  - Mean 102
  - Std Dev 14.452508

Candidates
Results: Morphology
Conclusions

- Different factors may affect aerobic and anaerobic ability
  - We remain confident that we can produce a predictive model
- Integrating physiology and morphology important
- Important but unmeasured...
  - Behaviors (station-holding, searching)
  - Fin area and morphology (to be continued...)
- Estimating ability of untested fish will improve fishway efficacy
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