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Metrics to identify fishway passage bottlenecks in the multi-species Columbia River

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Metrics to identify fishway passage bottlenecks in the multi-species Columbia River

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Introduction

- Fishways at Columbia River dams
  - Large, hydraulically complex
- ESA-driven need to identify and address fish passage problems
- Metric development
  - Passage failures, turn-arounds
  - Route-related effects
  - Accounting for diverse behaviors
- Remediation planning
  - Prioritization
  - ‘Do no harm’: making fixes in a multi-species environment
Introduction: ‘inside the concrete’

- Attraction efficiency
  - Turbines, spill, fishways
  - Plume detection
  - Seasonal variation
  - Predator avoidance
Bonneville Dam case study

- Powerhouse 2 (1981)
- Spillway
- Powerhouse 1 (1938)
- New lock (1993)

Washington

Oregon
Bonneville Dam case study

- First dam, most complex fishways, high fish abundance and species diversity

- Sockeye ~190,000 / year
- American shad ~2,800,000
- Coho ~110,000
- Steelhead ~350,000
- Pacific lamprey ~25,000 – 80,000? nocturnal
- Chinook salmon ~640,000 adults ~110,000 jacks
Methods: Radiotelemetry

► Extensive, multi-objective research effort from 1996 to present
► > 22,000 adult migrants radio-tagged
Monitoring: Bradford Island fishway
Passage metric development

1) Event-based approach

- Assemble passage attempts (i.e., ‘fishway entries’)
- Score outcomes: ‘Pass dam’ or ‘Exit to tailrace’
- Infer turn-around location for all exit events

2) ‘Traditional’ individual-based metrics

- ‘Fishway passage efficiency’

Keefer et al. 2013 (CJFAS)
Distribution of fishway entries

Attraction broadly similar among species

- Lamprey: 2171
- Sockeye: 385
- Chinook-J: 273
- Chinook-A: 571
- Steelhead: 285

$n = 2171, 385, 273, 571, 285$
Event-based ‘efficiency’: survival curves

Route = PH1-S

\[ n = 361 \text{ entry events} \]

\[ E_{S1} = 0.69 \]
\[ E_{S2} = 0.92 \]
\[ E_{S3} = 0.91 \]
\[ E_{S4} = 0.89 \]
\[ E_{S5} = 0.95 \]
\[ E_{S6} = 0.80 \]

141 past dam

\[ \text{Eff} = (0.39) \]

Keefer et al. 2013 (CJFAS)
Event-based ‘efficiency’

Route = PH1-S

4-fold difference among species

Not to scale
Event-based ‘efficiency’

Least efficient route = PH2-S-DS

Efficiency differs widely among routes & species (& seasonally)
Event-based ‘efficiency’

Least efficient route = PH2-S-DS

Efficiency differs widely among routes & species (& seasonally)

Lamprey
Sockeye
Chinook-J
Chinook-A
Steelhead
Segment transition probabilities

Pacific lamprey

Keefer et al. *in press* (TAFS)
Bottleneck metric: Turn-arounds/fish

Turn-arounds / Fish

0.0
0.5
1.0
1.5
2.0

Lamprey

Spillway

PH1

PH2

~250 m

Not to scale
Bottleneck metric: Turn-arounds/fish

Variation among species, but also some common problem areas
Bottleneck metric: Passage failures/fish

High lamprey failure rates at a variety of sites
Junction pool

Transition to overflow weirs

Top-of-ladder Vertical slot weirs
Ultimately, what happens?

Dam-wide fishway passage efficiency

1.5 (jack Chinook) to 3.4 (steelhead) passage attempts per fish, on average. . . . Some make 20+ attempts.
Ultimately, what happens?
Dam-wide fishway passage efficiency

Almost all salmonids eventually pass Bonneville
But only ~50% of Pacific lamprey
Conclusions

• Pacific lamprey: passage failure = reduced access to historic habitat

Dramatically lower abundance in interior Columbia River and Snake River basins

Extensive fishway retrofit and remediation projects: making ‘salmonid-style’ fishway work for non-salmonids

Close et al. 1995
Conclusions

• Salmon & steelhead: fishway exit = passage delay of hours to days (sometimes weeks) and increased predation risk

• Some passage ‘bottlenecks’ affect all species
  – Priority sites for remediation
  – Transition areas
  – Junction pools
Conclusions

- Metric development has facilitated evaluation of environmental and operational effects.

Fishway passage probability (logistic regression)
Conclusions

- Metric-based models are being used to prioritize sites to maximize passage efficiency.
What is the dam problem?

Questions?