Jun 26th, 11:00 AM - 11:20 AM

Concurrent Sessions B: Fish Physiology and Fishway Passage Success - Olfactory Gene Regulation in a Regulated River: Understanding the Effects of Altered Flow Patterns on Sockeye Salmon Homing

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Sex-specific differences in adult salmon migration and passage success

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Outline of Presentation

1. Background
2. An emerging pattern – high female mortality during stressful migratory conditions
3. Potential physiological mechanisms
4. Implications for passage assessments
Graduate students / Postdocs


Collaborators / Colleagues

- Steve Cooke, David Patterson, Tony Farrell

Thanks to those who collected the data and generated ideas....
Fraser River and its tributaries

- Fraser River flows 1,375 km
- drains 1/3rd of British Columbia
- is 4th largest river solely within Canada
- largest producer of salmon in Canada
- no dams on mainstem, a few of the small tributaries have dams
- Fraser River is the largest producer of sockeye in Canada
- second most numerically abundant Pacific salmon species
- most commercially valuable salmon and fastest growing recreational fishery in Canada
- important component of First Nations culture, economy and environment
over past 15 years we have studied the behaviour, physiology and movement of homeward migrating adults from several populations.

- telemetry and laboratory investigations
Radio tagging and freshwater tracking studies

- Tagging sites
- Detection stations

Pacific Ocean

B.C.
Purse seining used for ocean tagging
Biosampling

- blood sample to examine range of plasma ions, and osmoregulatory, reproductive and stress hormones

Cooke et al. 2005 Journal of Fish Biology. 67: 1-17
Biosampling

- tissue removed from first gill arch to assess ionoregulatory function and for functional genomics assessments
- muscle plug taken for functional genomics
- adipose fin tissue taken for DNA stock assessment
Biosampling

- Gross somatic energy assessed by microwave energy meter
Transmitter insertion

- Transmitters normally inserted down throat into stomach on migrating adults
Survival rates (+/- CI) to natal rivers of fish with transmitters in relation to encountered Fraser River temperature 2002-2007, n=1500

Key findings
- for most stocks, 18°C is a tipping point
- thermal migration survival is stock-specific

Martins et al. 2011 Global Change Biology 17: 99-114
Where are the fish dying?

- Late Shuswap sockeye (n=437: 100 females, 84 males, 253 ?)
Fish die in upper river, when thermally stressed

Survival rate (83 km)

Overall survival: 0.92±0.05

Fish die in upper river, when thermally stressed

Female: 0.86±0.11 \textsuperscript{a}
Male: 0.95±0.07 \textsuperscript{a}

Female: 0.50±0.11 \textsuperscript{b}
Male: 0.79±0.09 \textsuperscript{b}

Do migrating females suffer high mortality when stressed and approaching spawning areas?

- most anadromous fish telemetry studies don’t assess sex as part of ocean or riverine migration tagging studies

- many do not focus on just final stages of migration

- migration conditions not extremely ‘stressful’ in some years

- is this phenomenon part of a larger pattern that is not well understood?
Energy Depletion Experiments – captivity can be stressful

- Early Stuart sockeye captured 1 week into their 4 week migration and held in tanks at cool temperatures for 25 days till maturation

Mortality
- female 50%, male 25%

Energy Depletion Experiments – captivity can be stressful

- Weaver sockeye captured en-route to spawning grounds and held in fast or slow raceways at cool temperatures for 21 days till maturation

Mortality
- female 50%, male 10%

Thermal Stress Experiments

- Harrison sockeye captured near spawning grounds, 4 weeks from full maturation, held in tanks at high (19 C) or low (13 C) temperatures for 10 days

Mortality
- 13 C female 80%, male 50%
- 19 C female 100%, male 53%

Thermal Stress Experiment and Field Study

- Weaver sockeye captured near spawning grounds 3 weeks from maturation, held in tanks at either warm (18 C) or cool (10 C) temperatures for 3 weeks

Mortality
- 10 C female 24%, male 14%
- 18 C female 44%, male 22%

Survivors tagged, released 80 km downriver of capture site, and tracked to spawning grounds
Thermal Stress Experiment and Field Study

- mortality low for both temperature treatments until they enter final 10 km

**Mortality**
- 10 C females and males 30%
- 18 C females 90%, males 45%
Fishway passage studies

- Seton Dam Fishway, southern BC
Fishway passage studies

- Gates Creek sockeye captured at fishway, tagged, released downstream, tracked to upstream spawning area (**1 week further migration**)

**Mortality**

- **2012** – females 62%, males 29%  (Burnett et al. in prep – 4th presentation from now)
Hypotheses for high female mortality during challenging migrations

- energy depletion
- ion imbalance (acidosis)
- immuno-compromised (increasing cortisol, advanced maturation)
- metabolic / cardiac collapse
Swim tunnels used for metabolic and cardiac performance
Aerobic scope & changing temperature

Aerobic scope = $O_2$ available for activities other than routine and is temperature-dependant.
Females have a 20-25% lower metabolic scope

• Also, sexually mature female salmon have ~13% smaller hearts than males

Working Hypothesis
• poorer cardiac performance

The ability to move oxygenated blood around the body is reduced in migrating females, and is further reduced later in the migration.

This will cause reductions in:

• aerobic scope (swim performance)
• stress tolerance
• disease resistance
• thermal tolerance

• cardiac performance further reduced by diversions of blood to gonads to maintain and grow eggs as females mature

Why would females die at higher levels than males?
Conclusions

• high female mortality evident across several populations of sockeye

• lab and field studies

• common elements were that the studies examined fish during the final few weeks of their life

• migrants exposed to challenging conditions: captivity, high temperature, capture-release fishing (data not shown), fishway passage

Take Home Point
• highlights the importance of knowing fish sex for passage assessments and effectiveness monitoring (helps understand ‘motivation’ and life-stage risk)

Food for Thought
• how general is this phenomenon across other species and systems?
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