

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



Thanks to those who collected the data and generated ideas....

Graduate students / Postdocs

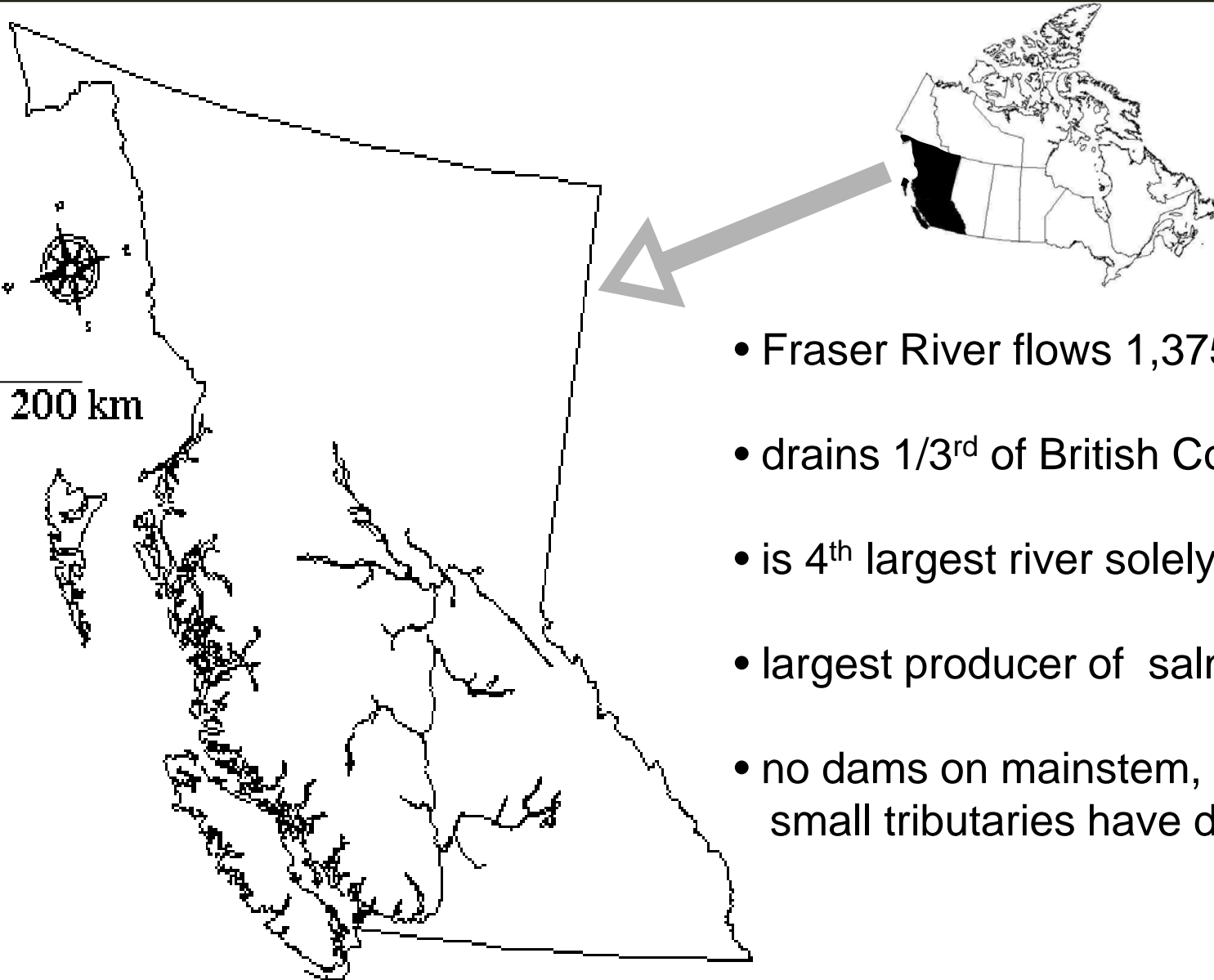
- Glenn Crossin, Ken Jeffries, Erika Eliason, Tim Clark, Kendra Robinson, Pat Nadeau, David Roscoe, Lucas Pon, Nich Burnett, Eduardo Martins

Collaborators / Colleagues

- Steve Cooke, David Patterson, Tony Farrell

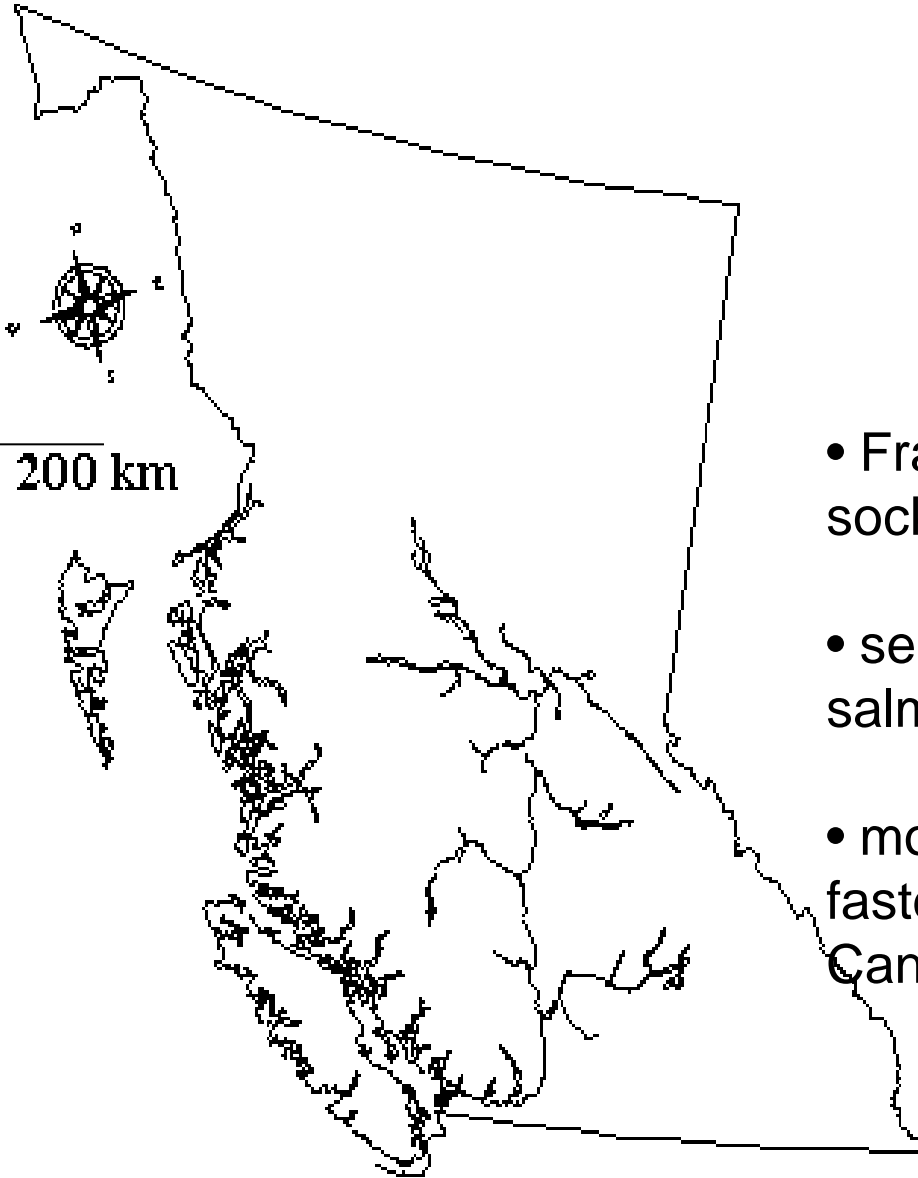


Fraser River and its tributaries



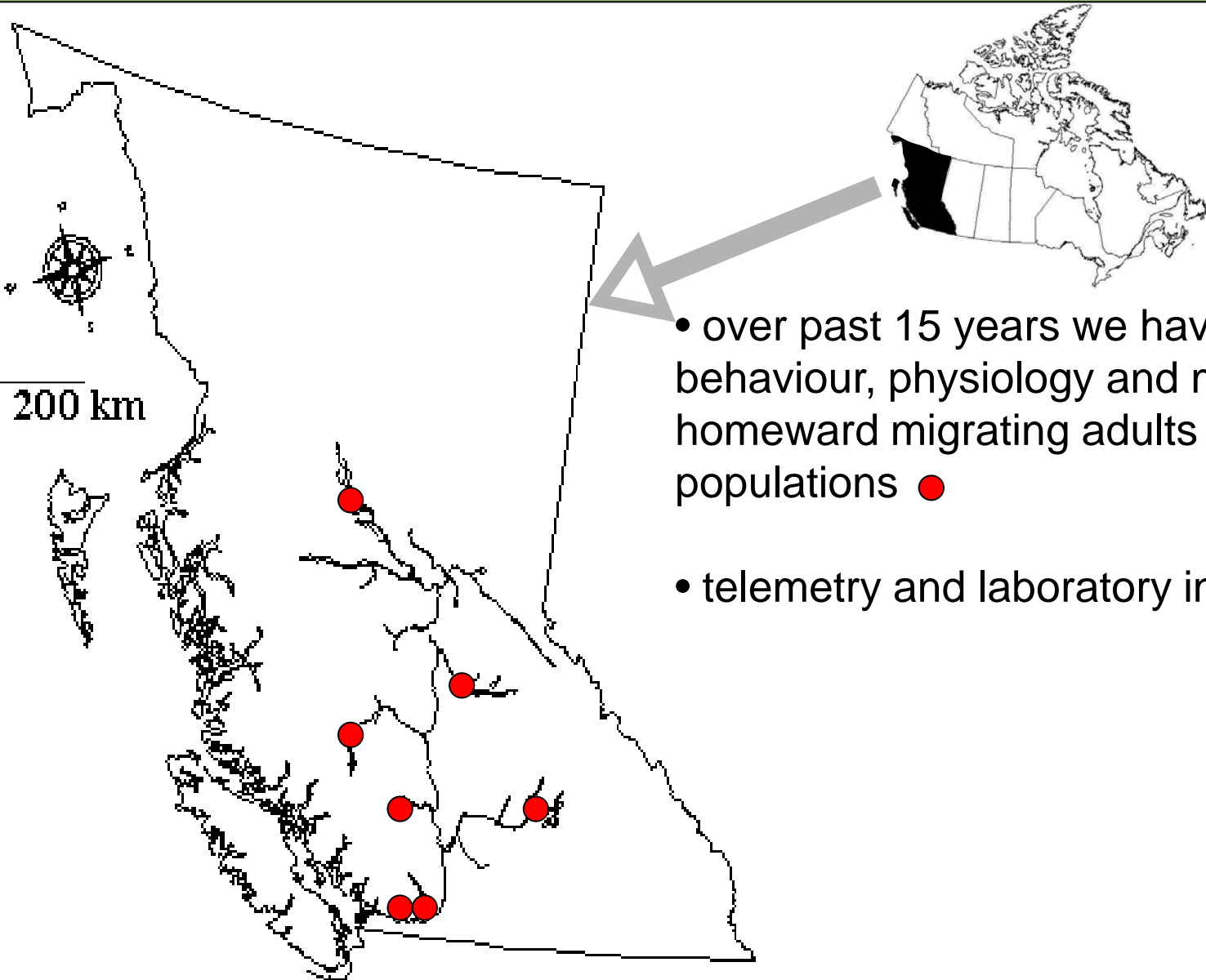
- Fraser River flows 1,375 km
- drains 1/3rd of British Columbia
- is 4th largest river solely within Canada
- largest producer of salmon in Canada
- no dams on mainstem, a few of the small tributaries have dams

Fraser River sockeye salmon



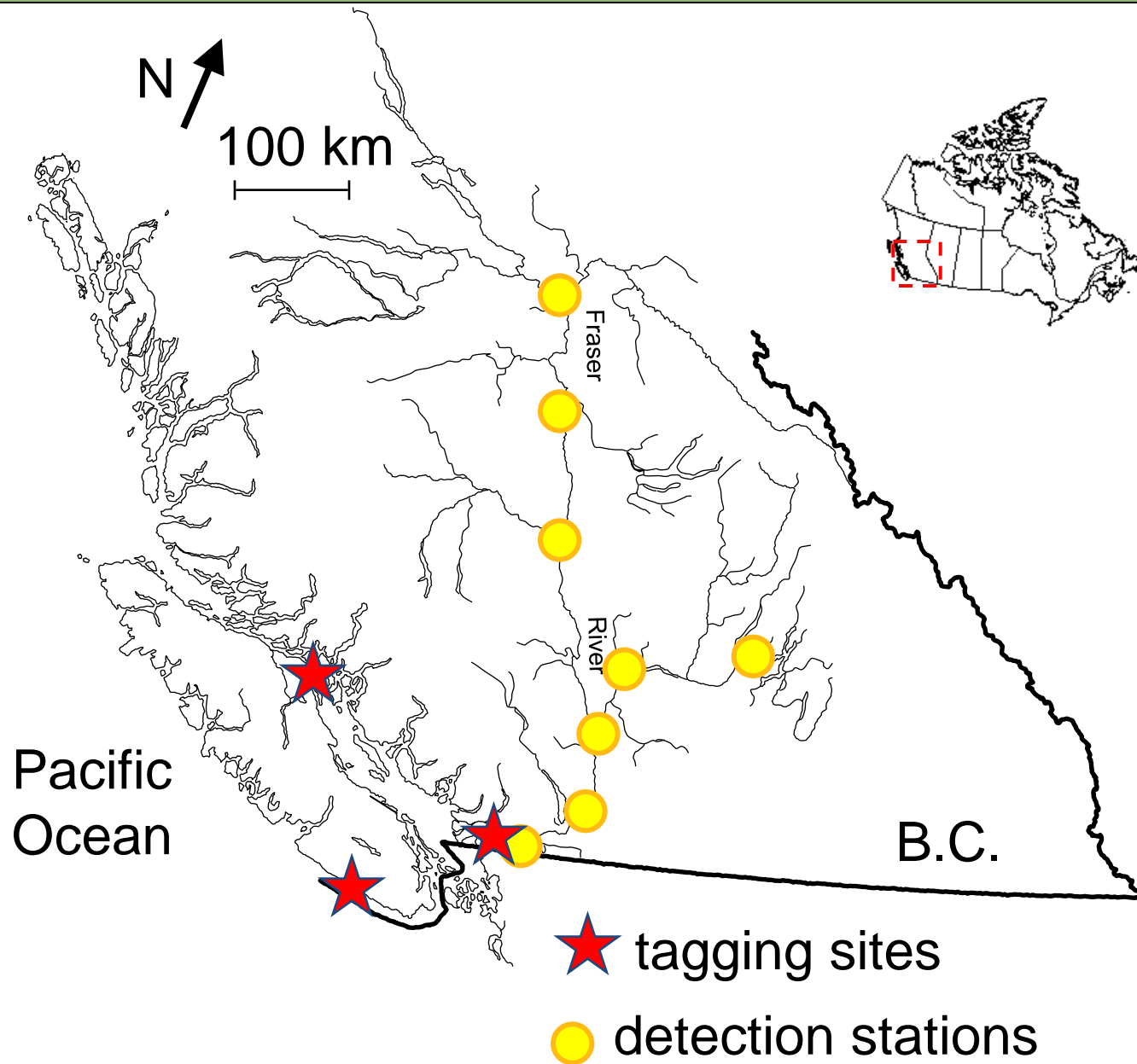
- Fraser River is the largest producer of sockeye in Canada
- second most numerically abundant Pacific salmon species
- most commercially valuable salmon and fastest growing recreational fishery in Canada
- important component of First Nations culture, economy and environment

Fraser River sockeye salmon



- 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



Purse seining used for ocean tagging



Biosampling



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

Cooke et al. 2008. Fisheries 33:321-338

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



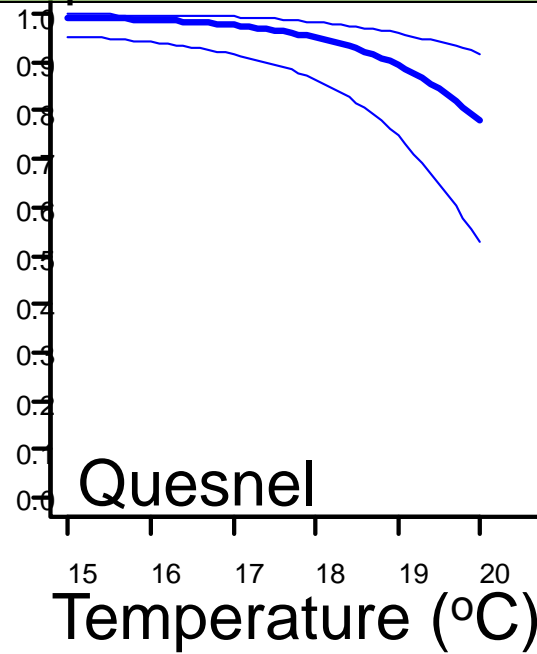
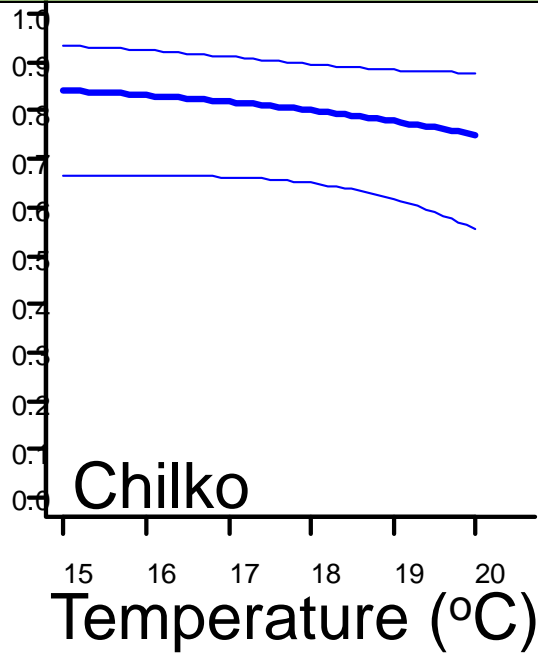
Transmitter insertion

- Transmitters normally inserted down throat into stomach on migrating adults

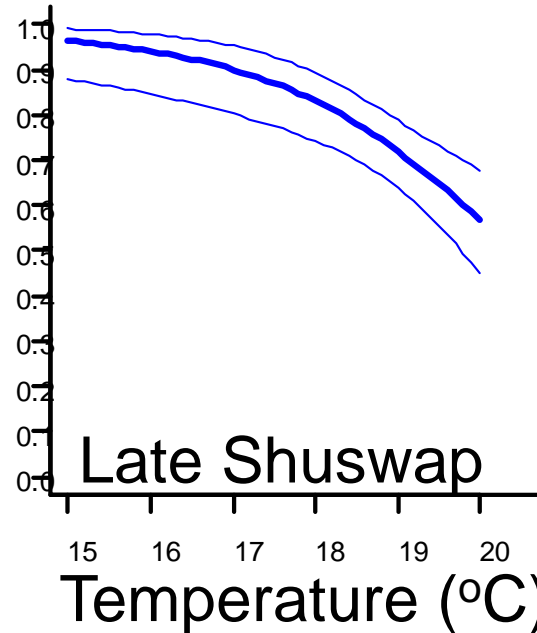
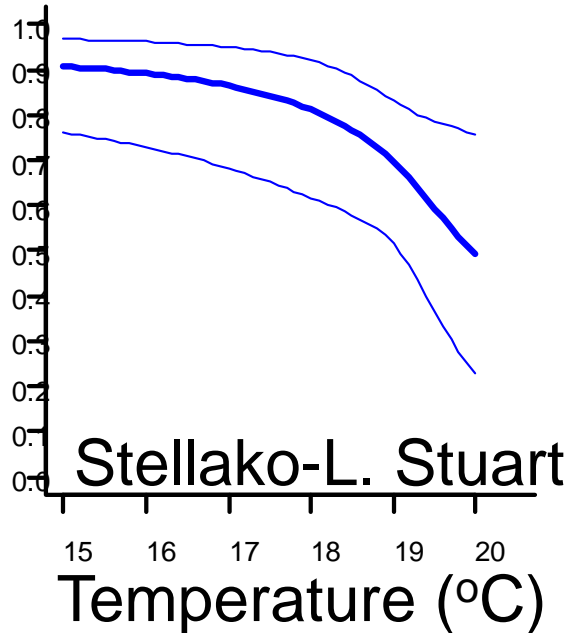


Survival rates (+/- CI) to natal rivers of fish with transmitters in relation to encountered Fraser River temperature 2002-2007, n=1500

Survival rate



Survival rate



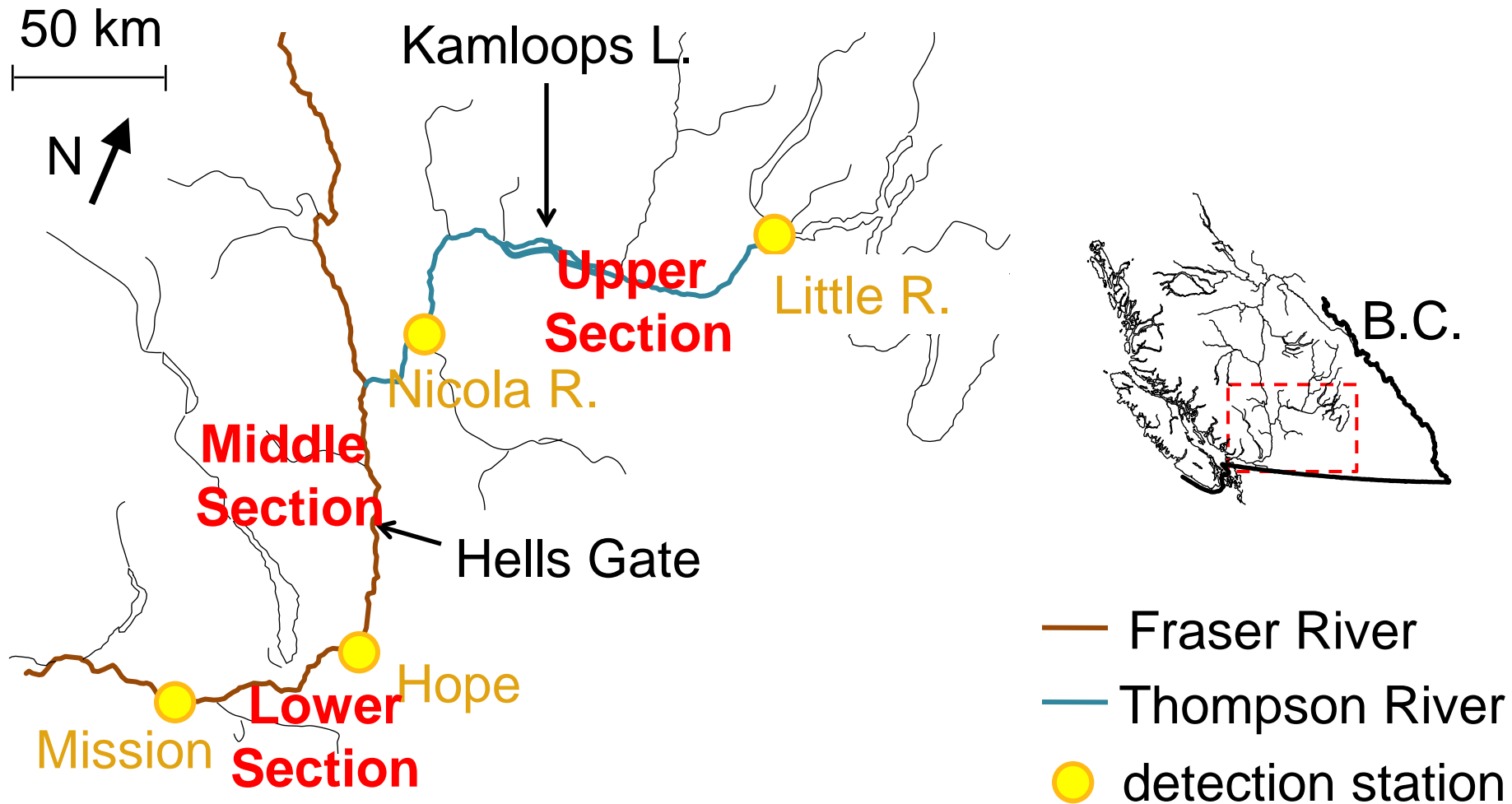
Key findings

- for most stocks, 18°C is a tipping point

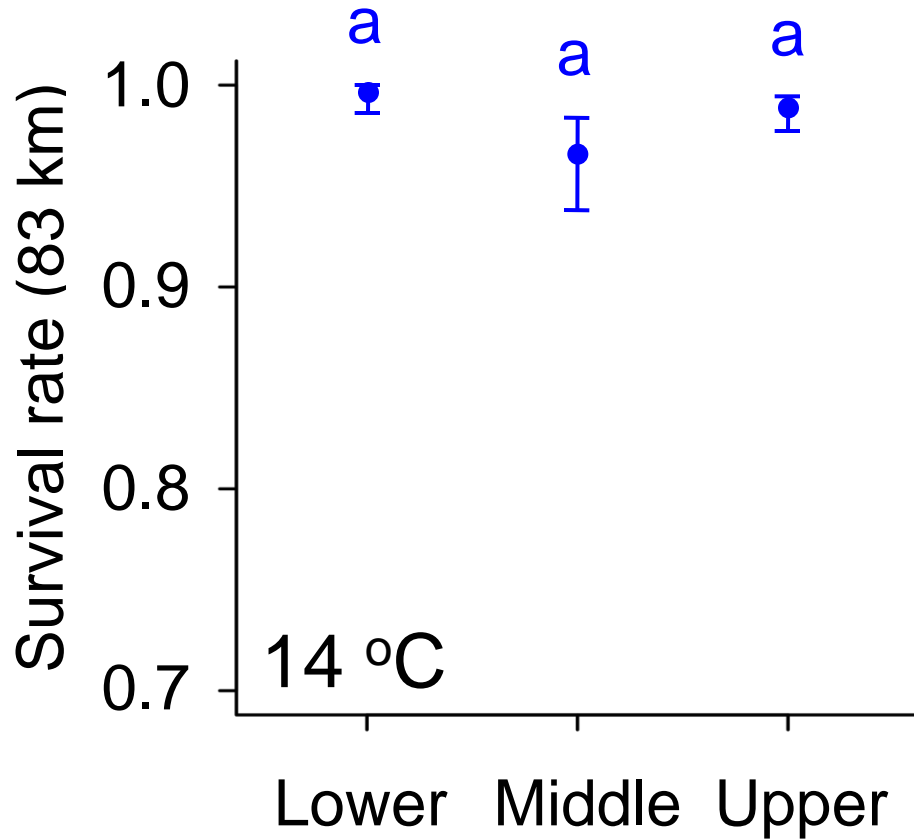
- thermal migration survival is stock-specific

Where are the fish dying?

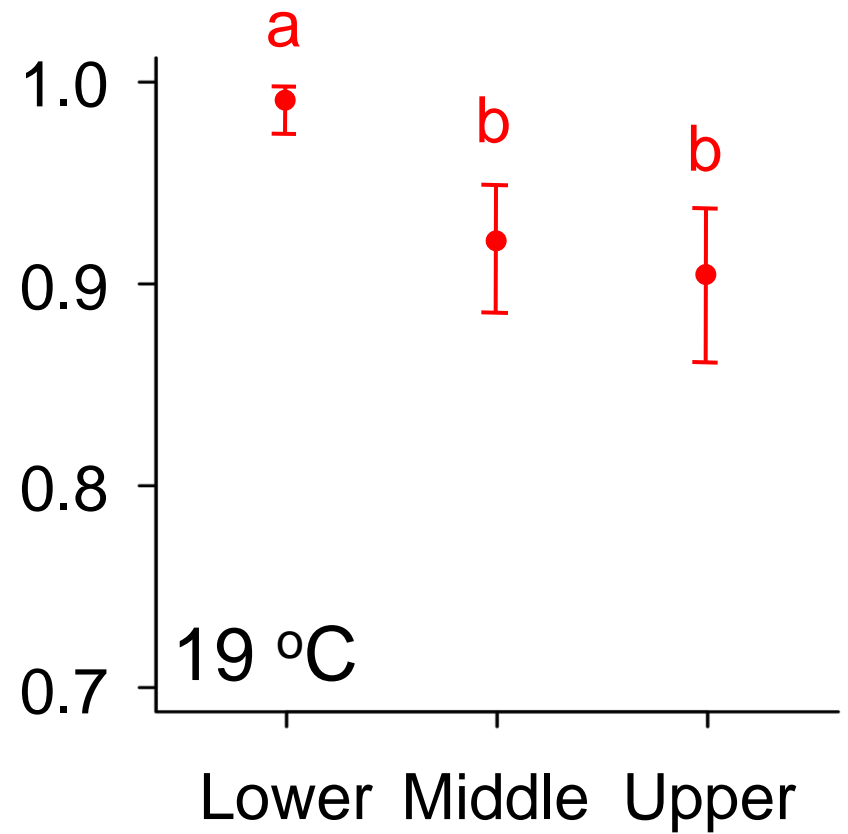
- Late Shuswap sockeye (n=437: 100 females, 84 males, 253 ?)



Fish die in upper river, when thermally stressed

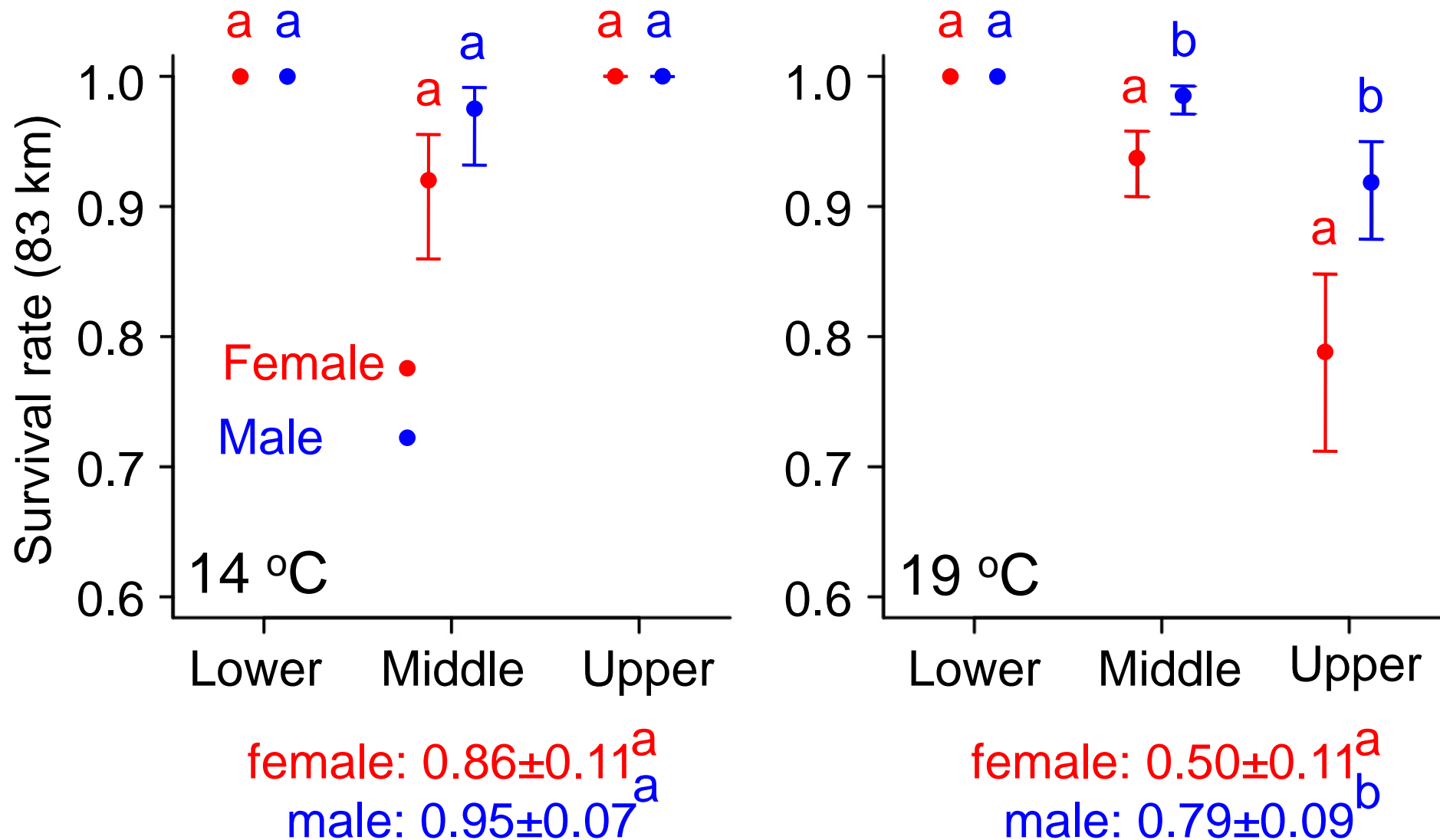


overall survival: 0.92 ± 0.05



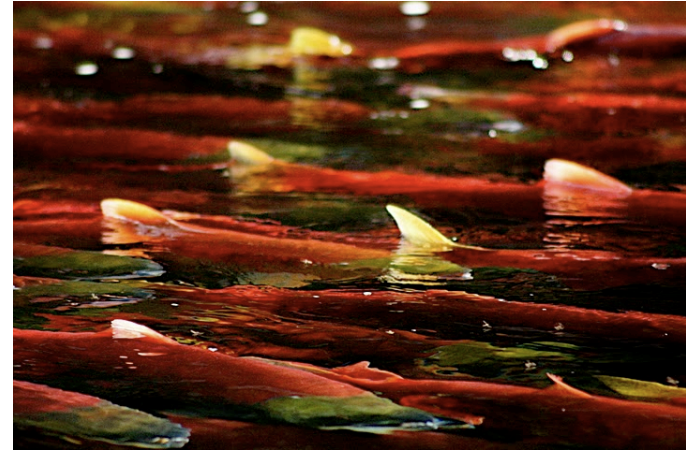
overall survival: 0.69 ± 0.10

Much higher female mortality in upper river



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%

Patterson, et al. (2004) Journal of Fish Biology 64: 1-21



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%

Nadeau, et al. 2010. Environmental Biology of Fish 88: 241-251



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%

Jeffries et al. 2012. *Physiological and Biochemical Zoology* 85: 62-73.



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

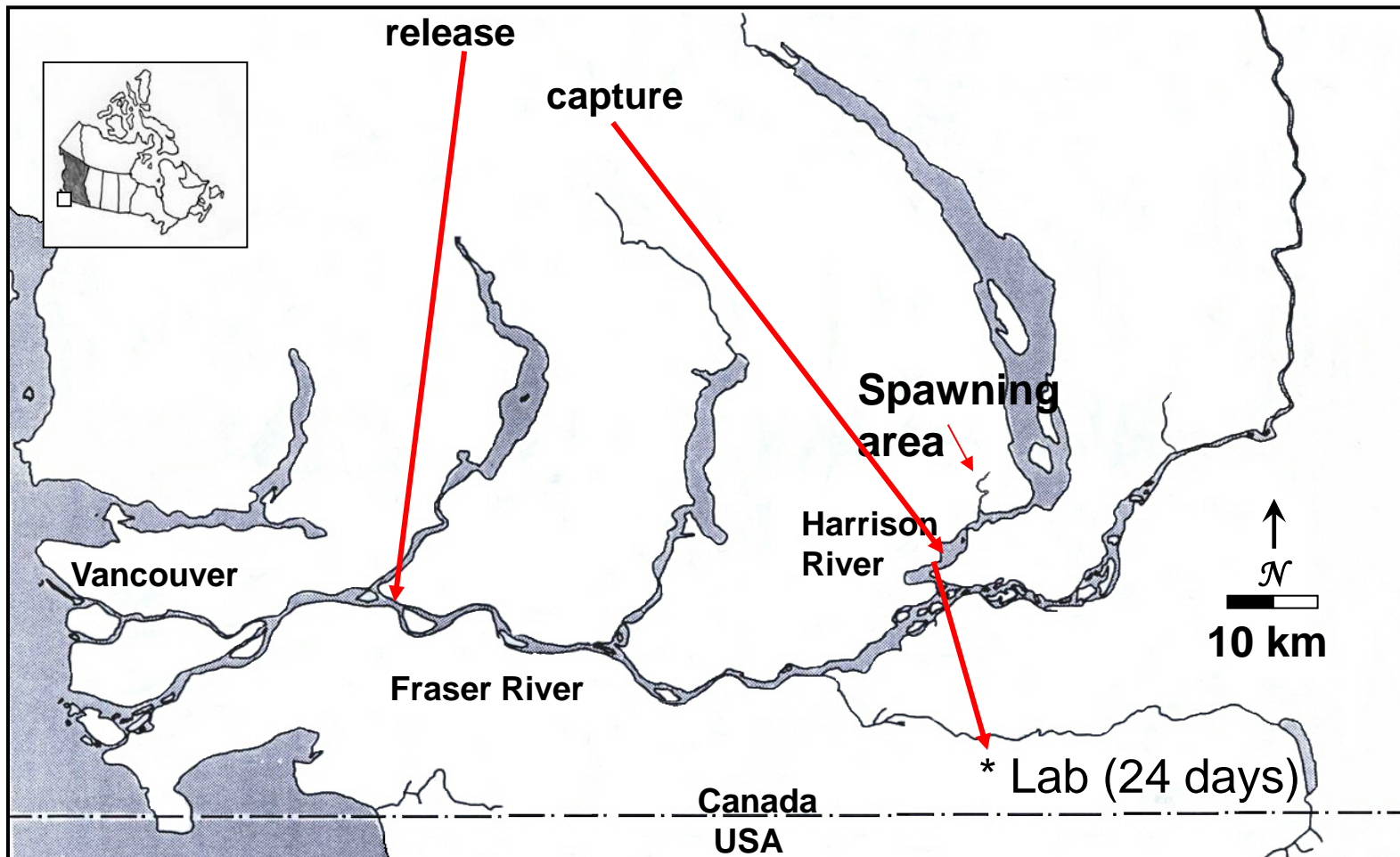
- 10 C female 24%, male 14%
- 18 C female 44 %, male 22%

Crossin et al. (2008). Canadian Journal of Zoology 86: 127-140.



Thermal Stress Experiment and Field Study

- Survivors tagged, released 80 km downriver of capture site, and tracked to spawning grounds

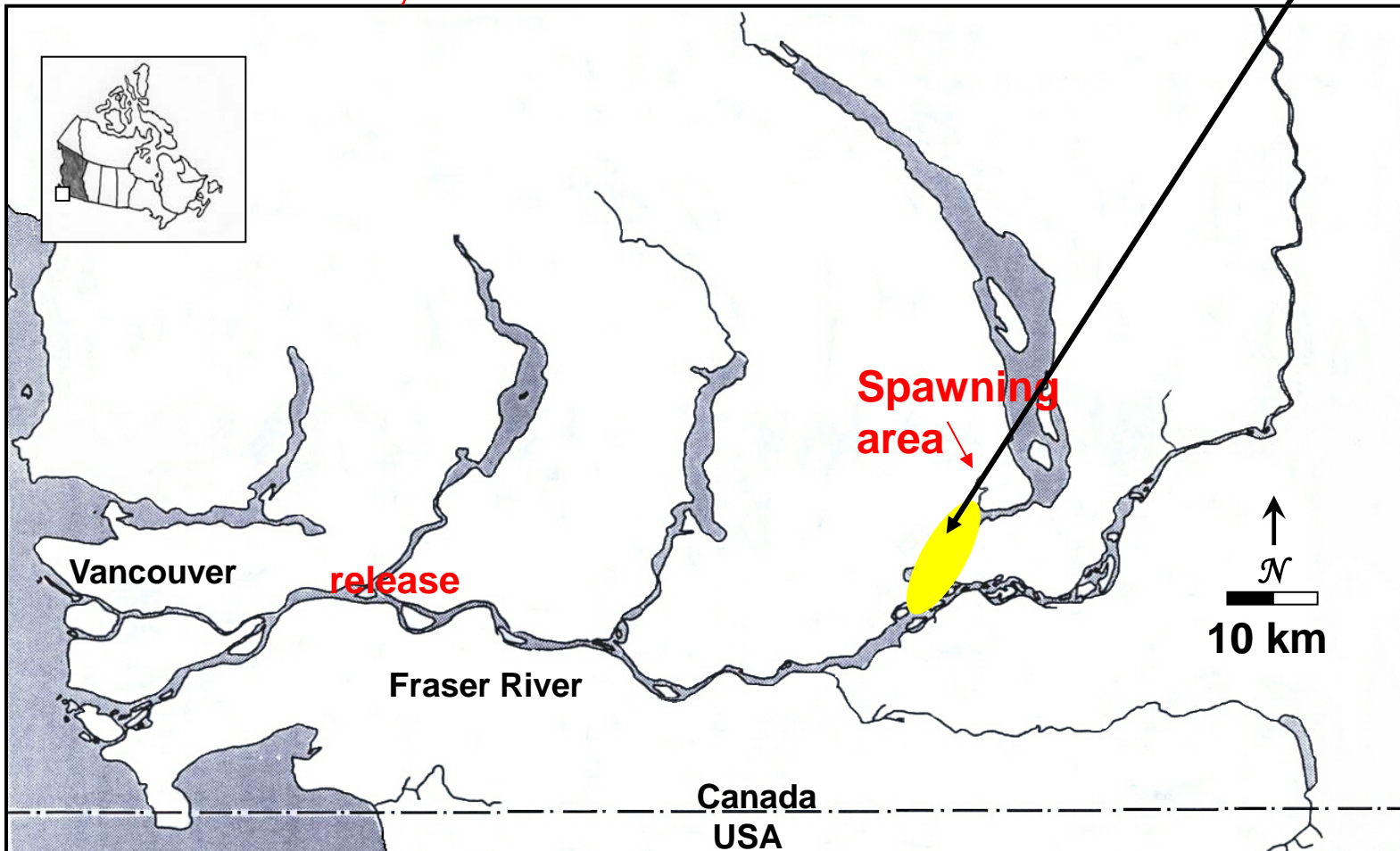


Thermal Stress Experiment and Field Study

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

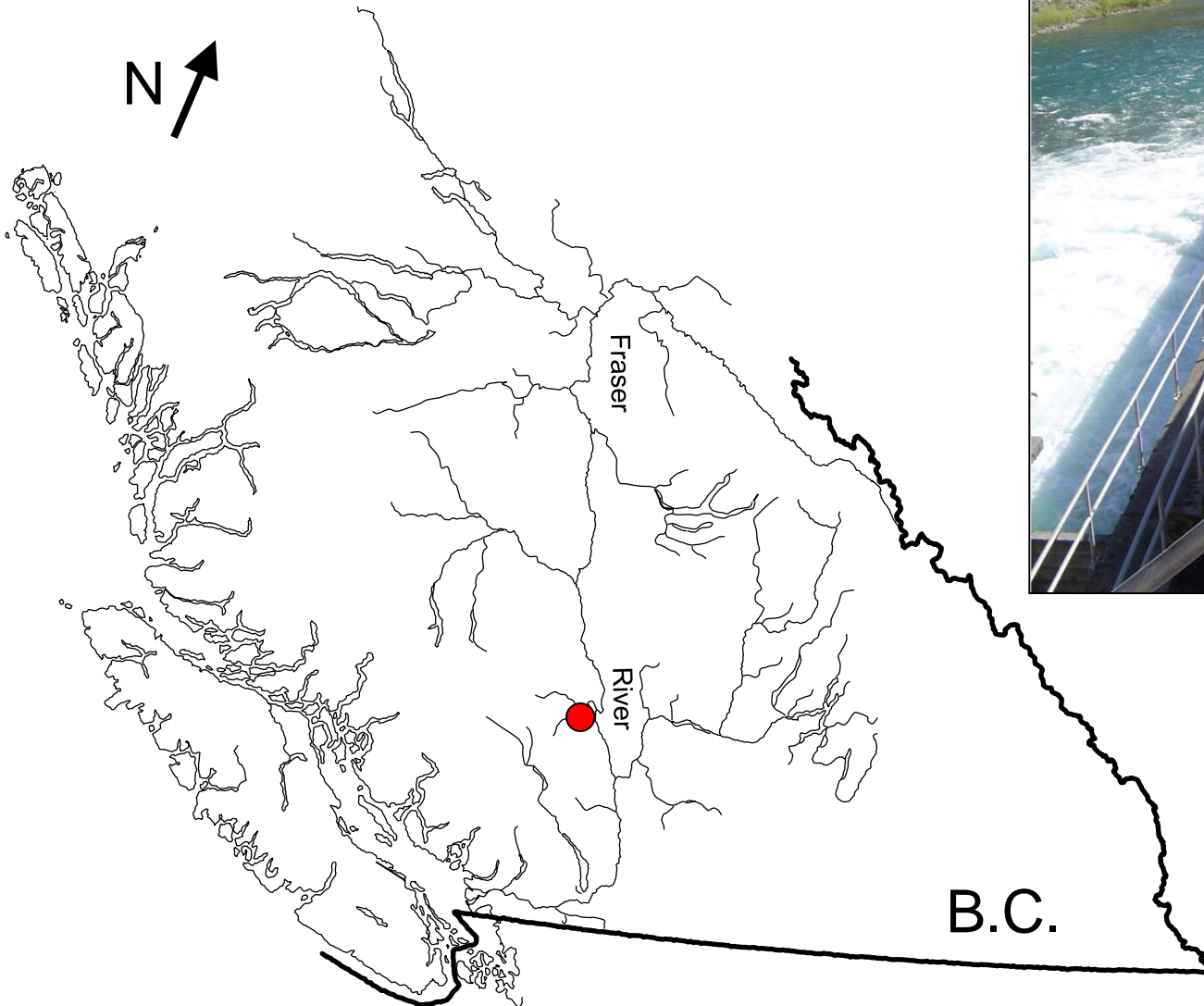
Mortality

- 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

- **2007 – females 60%, males 29%** (Roscoe et al. 2011. River Res. Applic. 27: 693–705.)
- **2012 – females 62%, males 29%** (Burnett et al. in prep – 4th presentation from now)



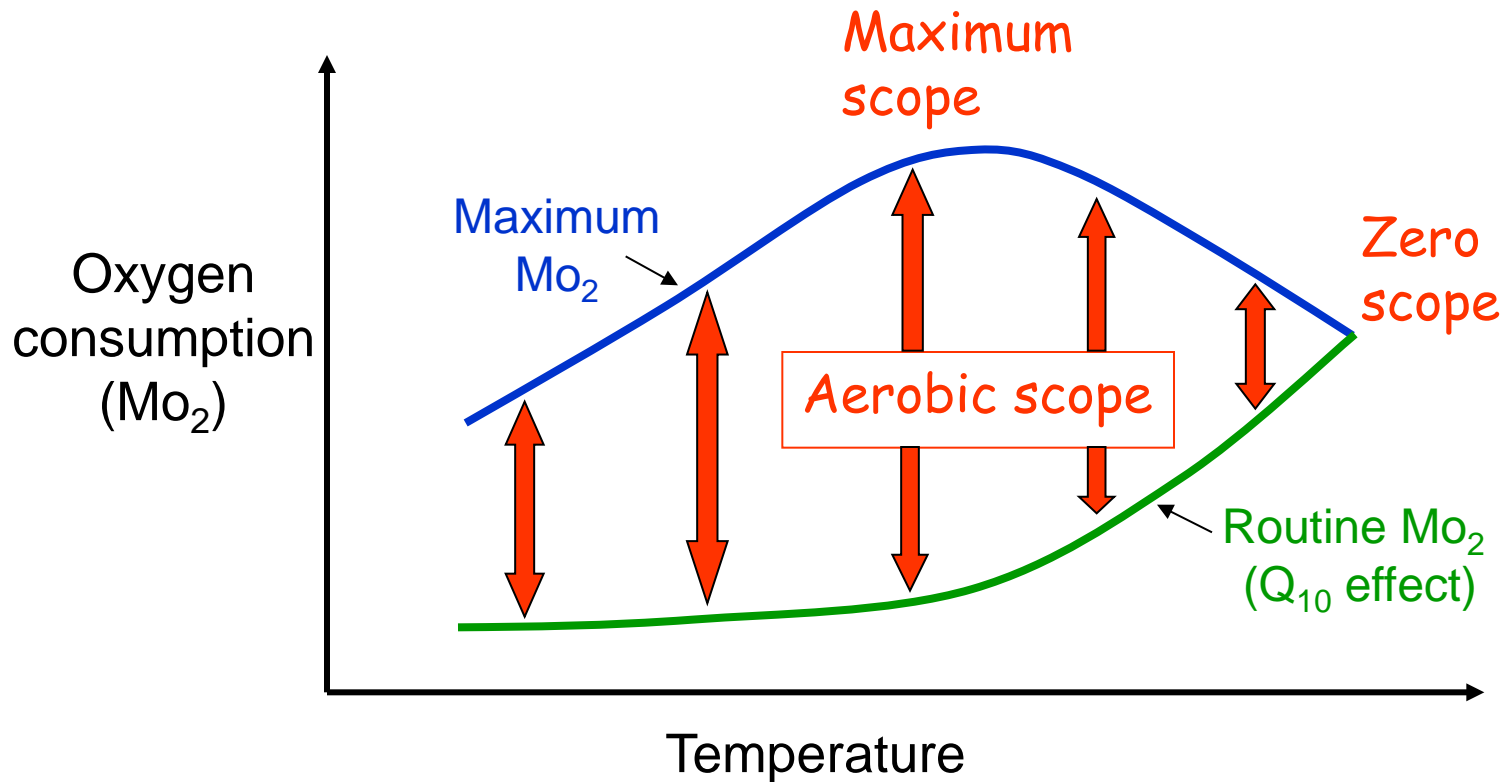
Hypotheses for high female mortality during challenging migrations

- energy depletion
- ion imbalance (acidosis)
- immuno-compromised (increasing cortisol, advanced maturation)
- metabolic / cardiac collapse

Swim tunnels used for metabolic and cardiac performance

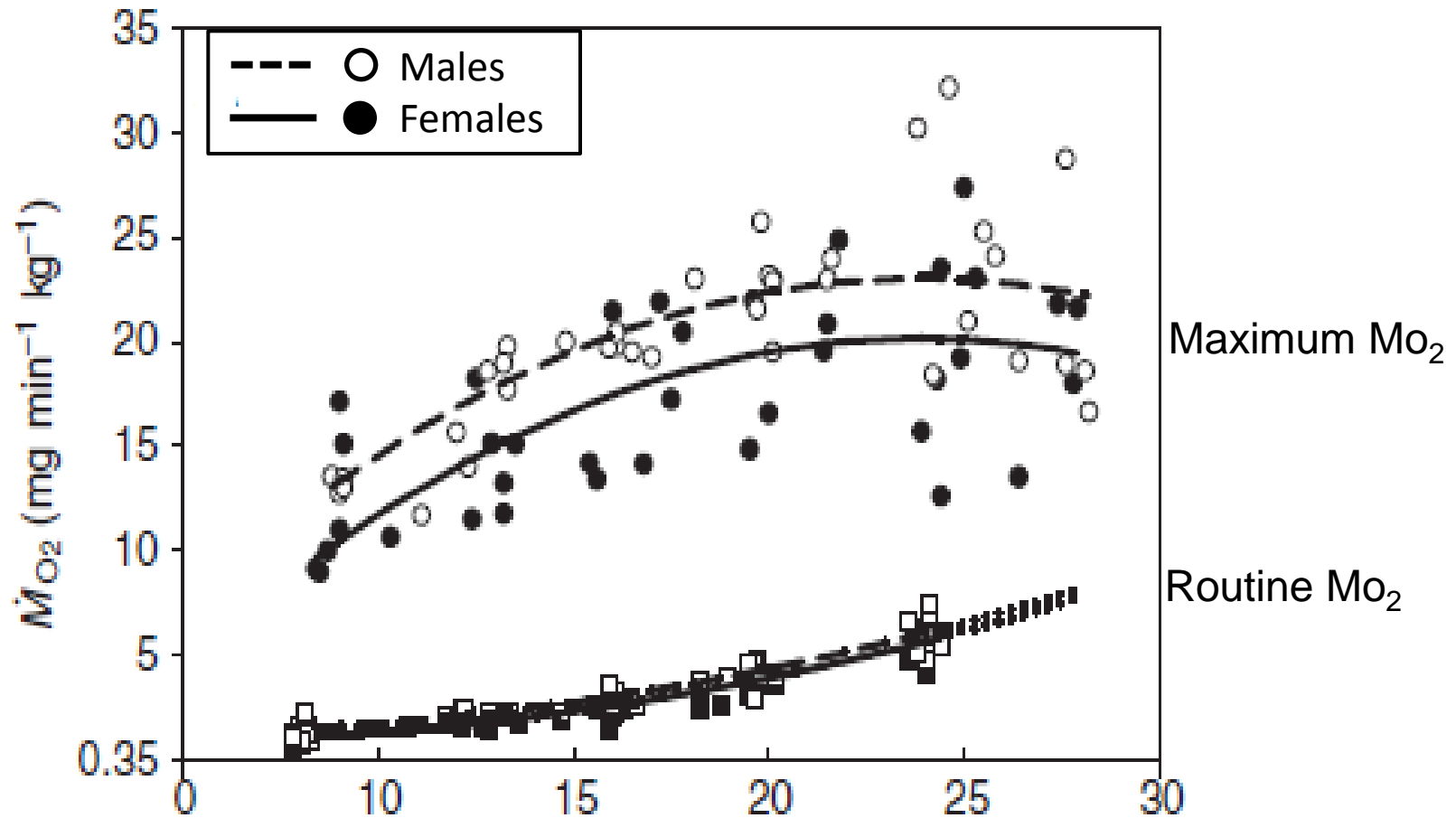


Aerobic scope & changing temperature

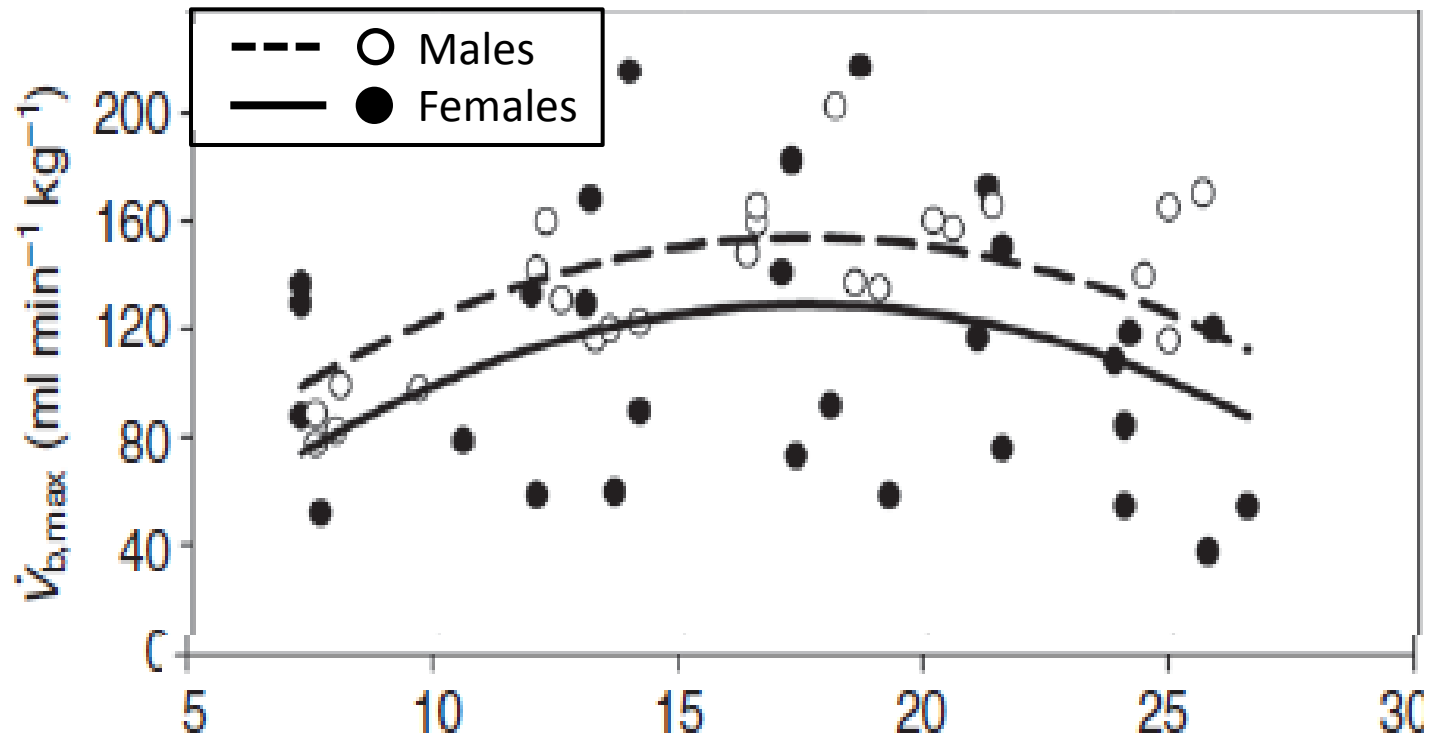


Aerobic scope = O₂ available for activities other than routine and is temperature-dependant

Females have a 20-25% lower metabolic scope



Females have lower maximum cardiac (venous) output



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

Why would females die at higher levels 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

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?

Thanks to our supporting organizations

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