ADAPTATION TO MINIMIZE THE JOINT IMPACTS OF CLIMATE CHANGE AND THE MANAGEMENT OF HYDRAULIC INFRASTRUCTURES ON FISH AND FISH HABITAT:

THE EFFECT OF ELEVATED TEMPERATURE ON METABOLIC PERFORMANCE AND POTENTIAL SURVIVAL OF PACIFIC SALMON AND WHITE STURGEON

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Outline of Talk

I) Salmon Thermal Tolerance Studies

II) Juvenile White Sturgeon Thermal Tolerance Studies

III) Future Research Directions

Acknowledgments

-research was a very large collaborative team effort

-Dr. Erika Eliason (Assist. Prof. University of California, Santa Barbara)

-Dr. Andreas Ekstrom (Postdoctoral Fellow, University of Gothenburg)

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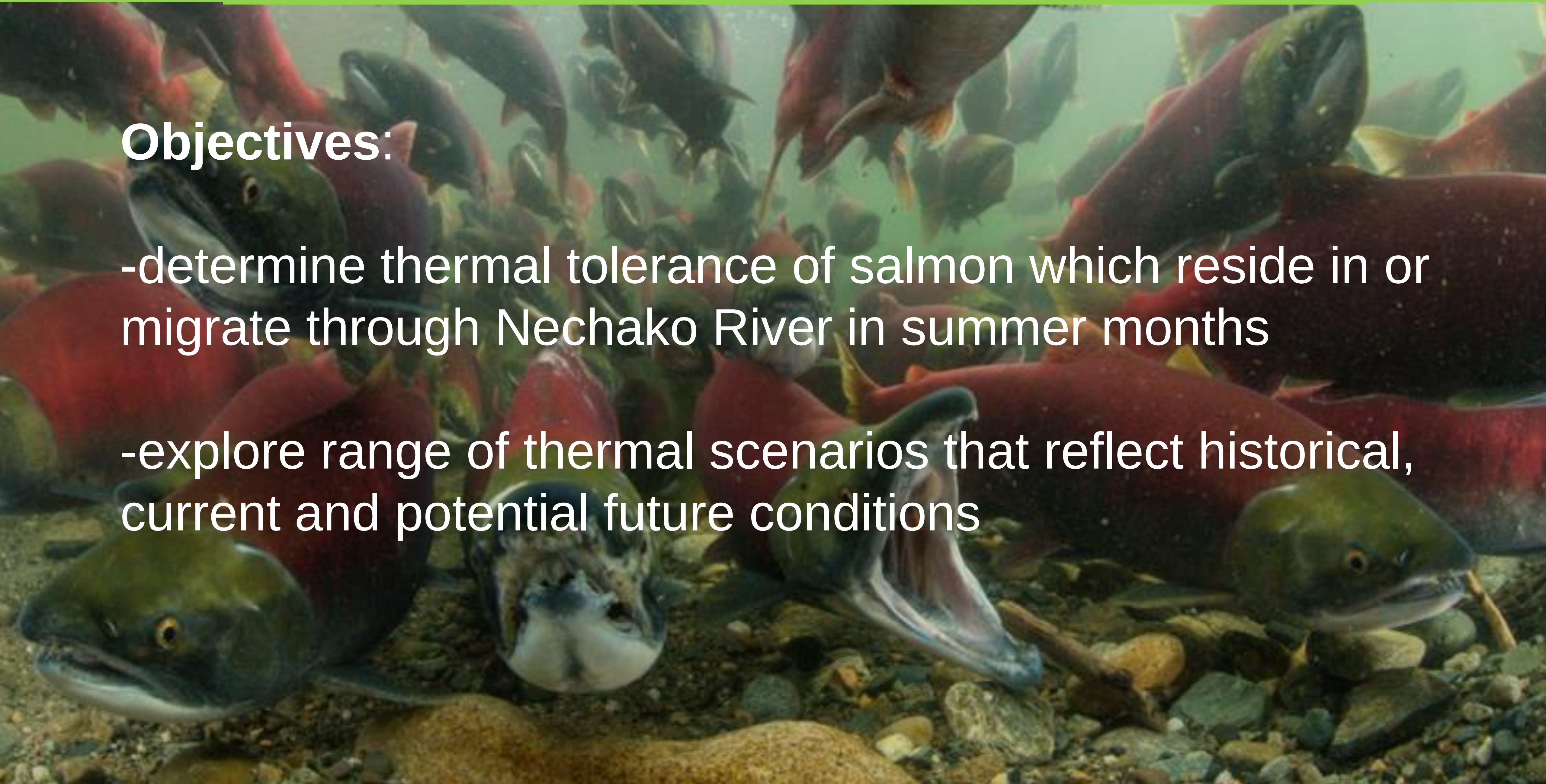
-Andrew Lotto (Senior Technician, UBC)

-and several other graduate and undergraduate students/techs

I) Salmon thermal tolerance studies



Objectives:

-determine thermal tolerance of salmon which reside in or migrate through Nechako River in summer months

-explore range of thermal scenarios that reflect historical, current and potential future conditions

Life stages that spend time in summer in Nechako River

Chinook salmon (adults)
- spends up to several weeks in Nechako River

Sockeye salmon (adults)
- spends few days to a week in Nechako River

Chinook salmon (juveniles)
- spends up to a year in Nechako River

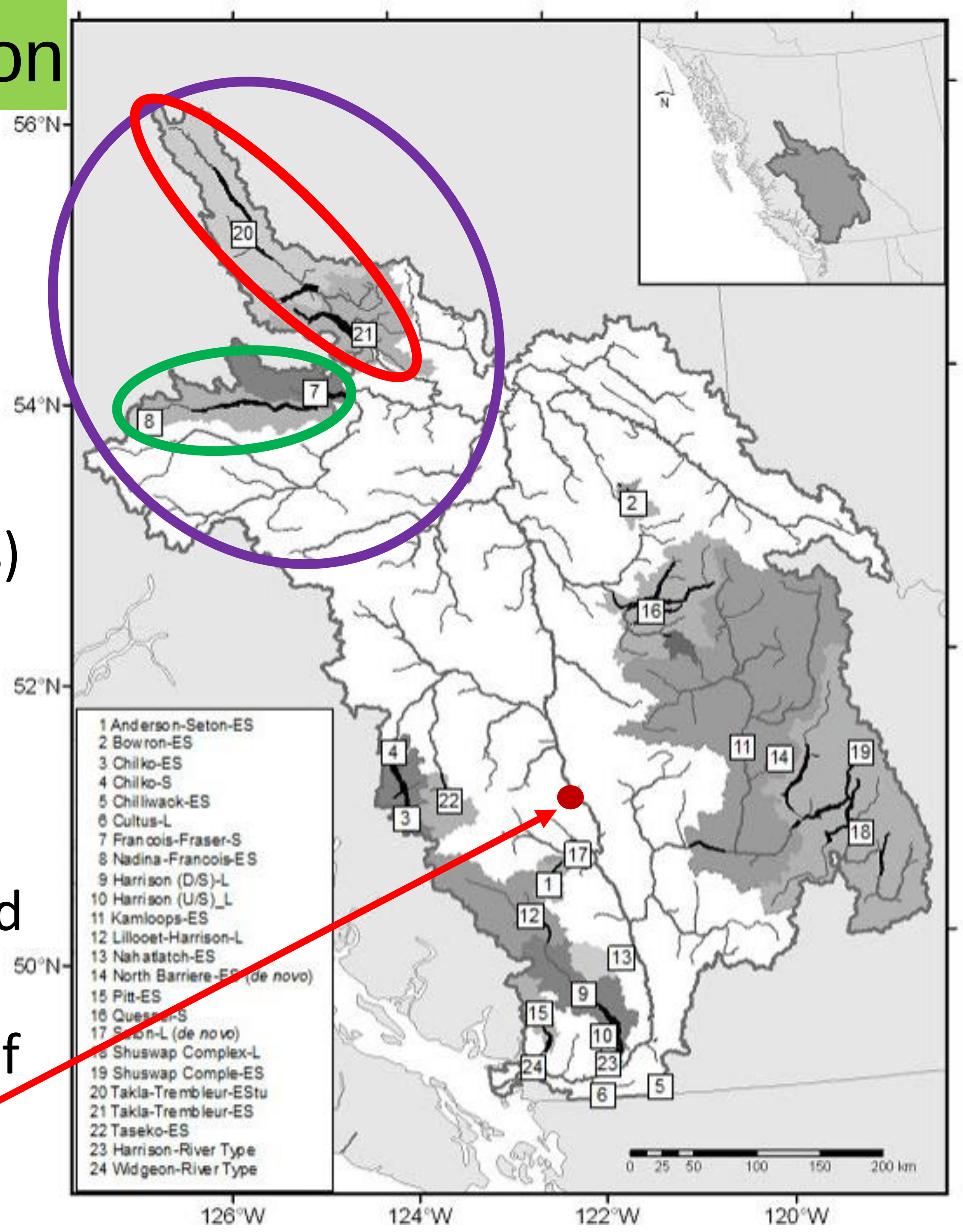
Current issues for Fraser River Salmon

- **COSEWIC Designations** (updated 2018):
  Endangered/threatened groups
  Chinook – 13, Sockeye – 11, Coho – 1

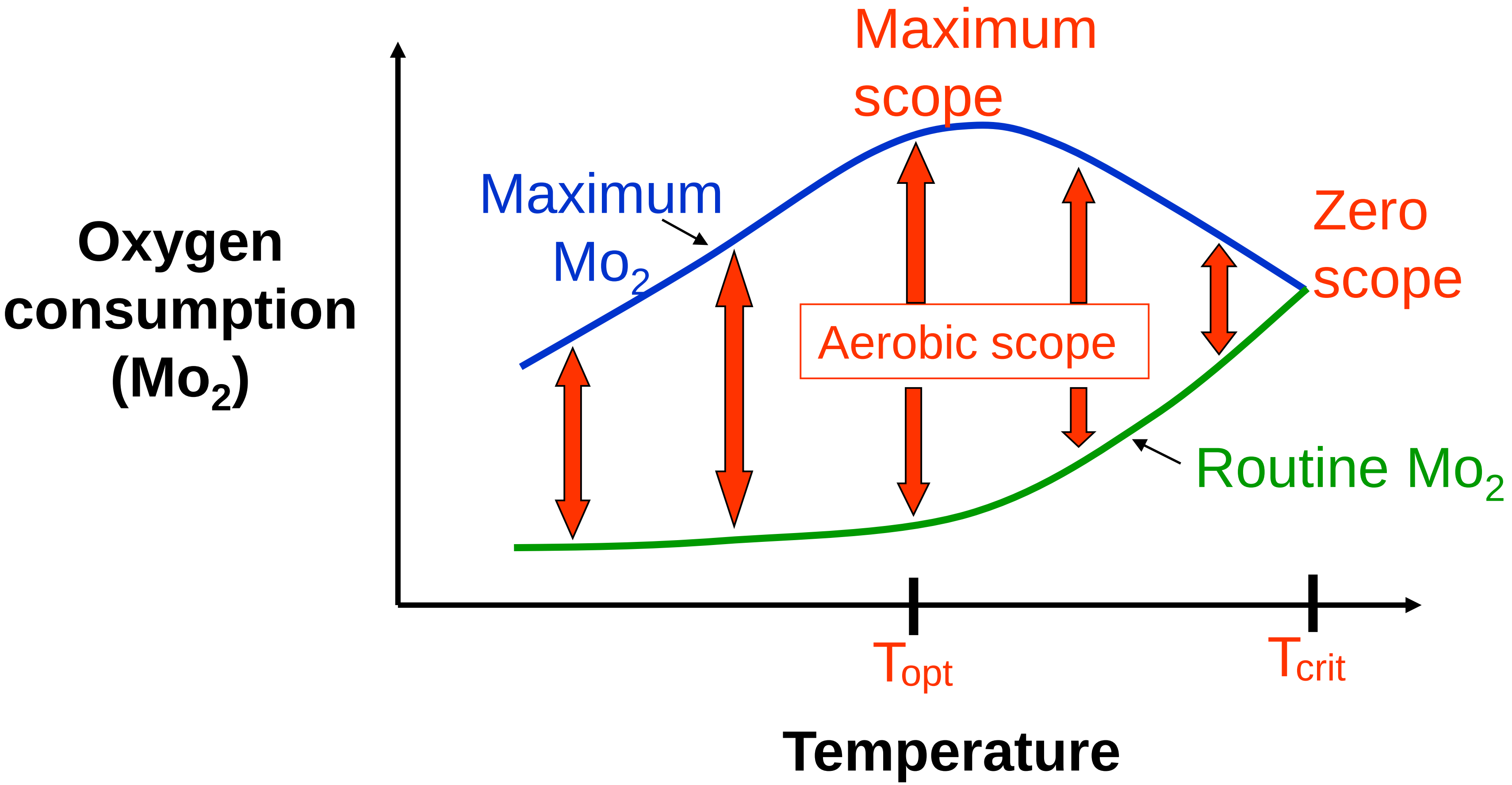
- **Chinook** - includes middle Fraser summer runs (Nechako, Stellako, Stuart River systems)
  -Nechako population ~ 588 adults (2017)

- **Sockeye** - includes Takla, Trembleur, Stuart populations
  -Francois and Nadina pops not threatened

- **Big Bar Landslide** (2019) – affected all runs of Chinook and Sockeye migrating towards central/northern Fraser River



Aerobic scope and temperature



Aerobic scope = O_2 available for fish swimming and migrating and is temperature-dependent

Optimum and Critical Temperatures

- Temperature where scope is greatest (T_{opt}) enables fish to most efficiently use energy and swim their fastest for prolonged periods of time

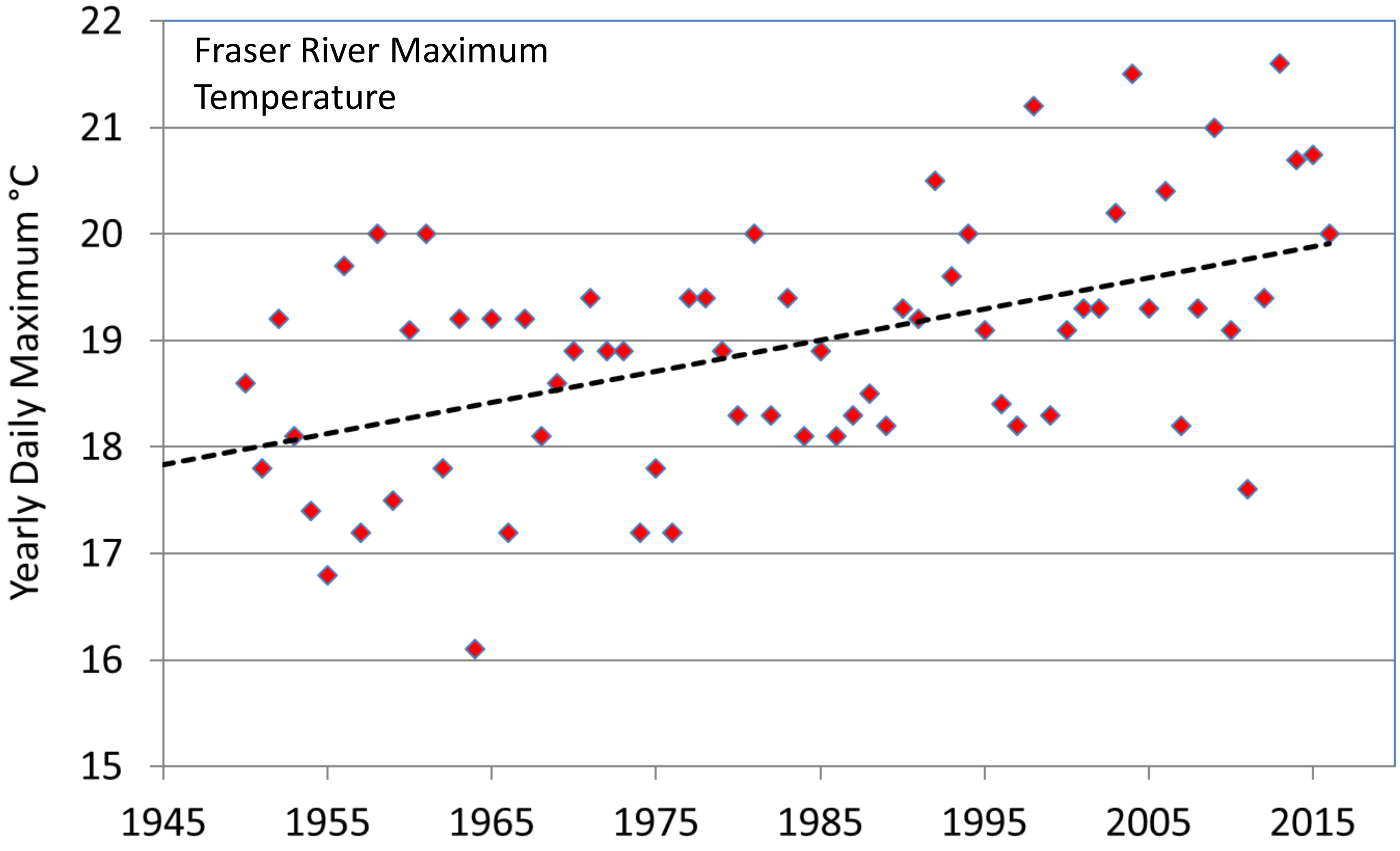
- Often fish survive and grow best at these temperatures because it is most efficient for pursuing prey and escaping predators

- Fish will die when metabolic rates are continually out of the scope range (approaching or at ‘critical temperatures’ - T_{crit})

- Aerobic scope is a physiological basis for understanding temperature limits

River temperatures are warming

- 2°C increase over past 65 years
- Additional 1 - 1.5ºC warming expected by 2050



DFO Environmental Watch Program

Thermal maximum results from other studies

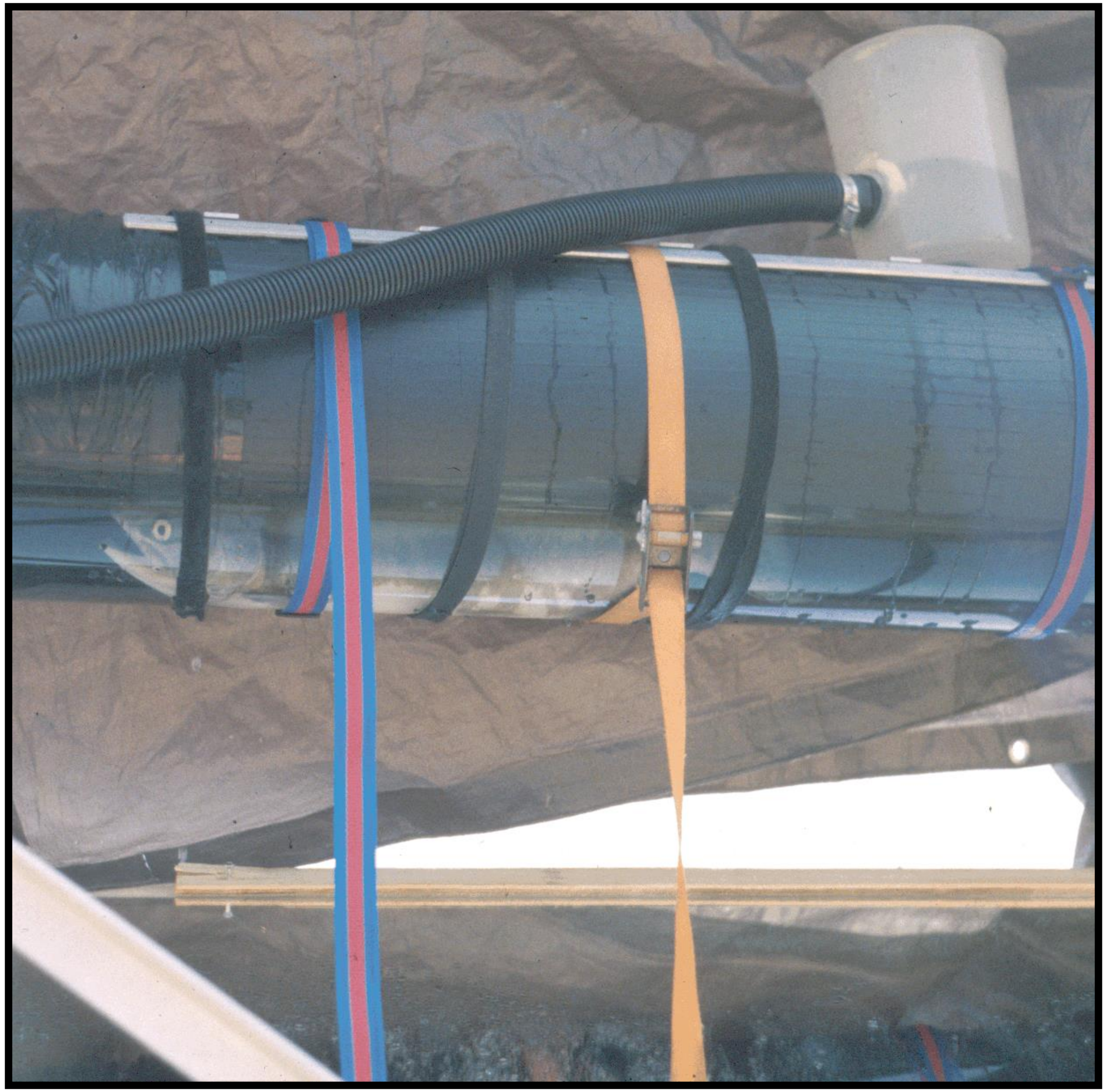
Adult Chinook (literature review by Richter and Kolmes 2005)

- 24 °C (distribution limits)
- 21 °C (migration cessation)
- 25 °C (UILT – 50% death in 24-96hr holding studies)

Adult Sockeye

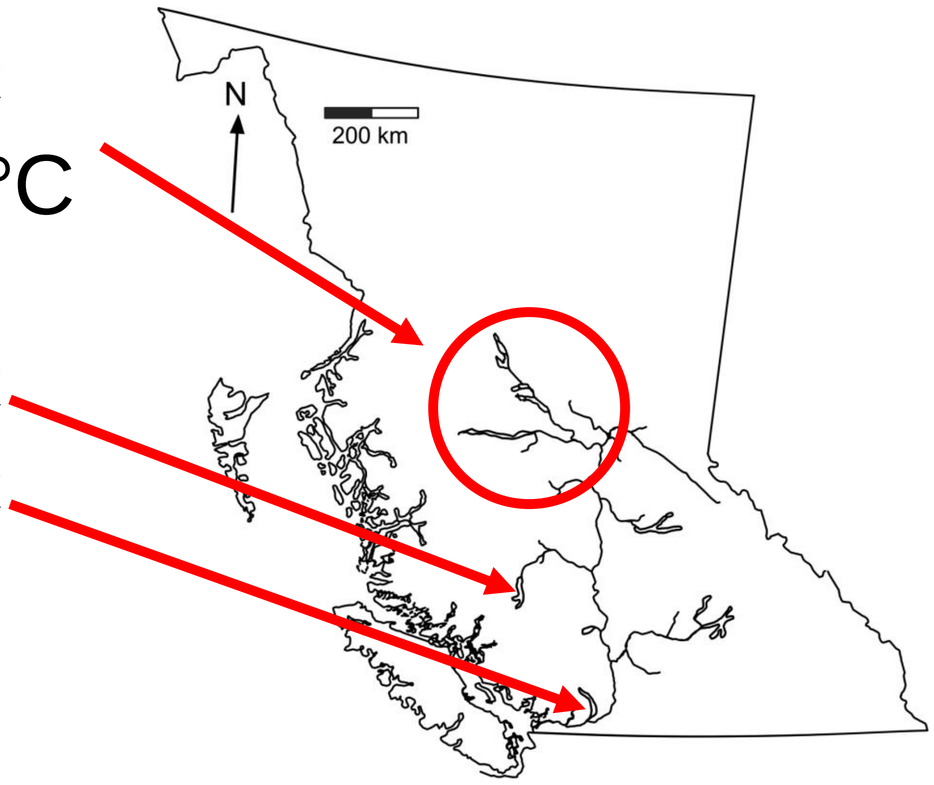
- 19 °C (20-30% mortality; telemetry tracking Stellako stock – Martins et al. 2011)
- 20 °C (40% mortality; telemetry tracking Stellako stock – Martins et al. 2011)
- 21 °C (100% mortality 72 hours following exhaustive exercise – summer runs – Robinson et al. 2015)

Swim tunnels used to examine metabolic performance



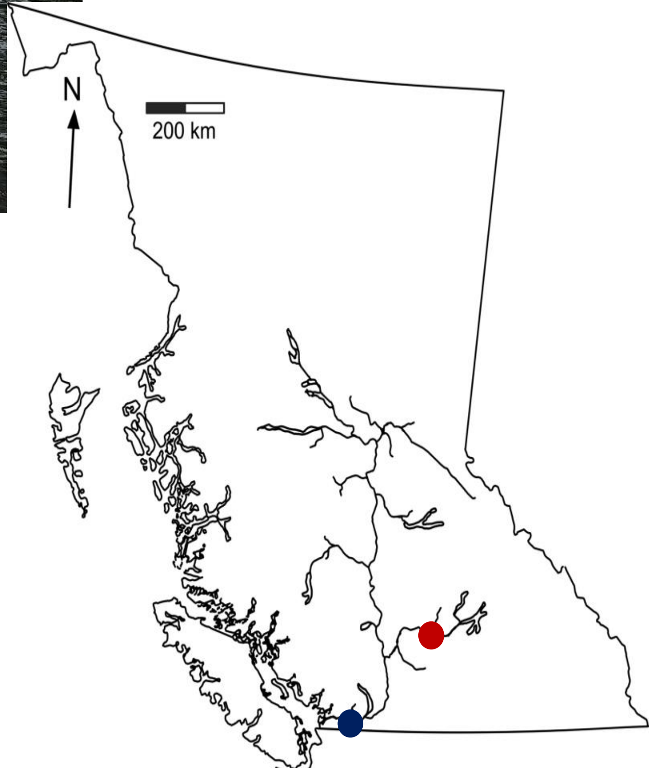
Thermal criteria from past swim tunnel work (Eliason et al. 2011)

	T_{opt}	T_{crit}
Nechako sockeye	17°C	24°C
Early Stuart sockeye	17.5°C	25.5°C
Chilko sockeye	17°C	28°C
Weaver sockeye	15°C	20°C



- T_{crit} estimates extrapolated from aerobic scope data
- T_{crit} are absolute upper limits and its likely that fish will perish at lower temperatures than these because aerobic scope, though available, would be low

Collecting Shuswap Chinook (~ 7 hr transport)



DFO Cultus Lake Lab – UBC Research Facility

All fish transported and held at 12 C until start of trials

Making the static respirometers (ea. 107 litres)

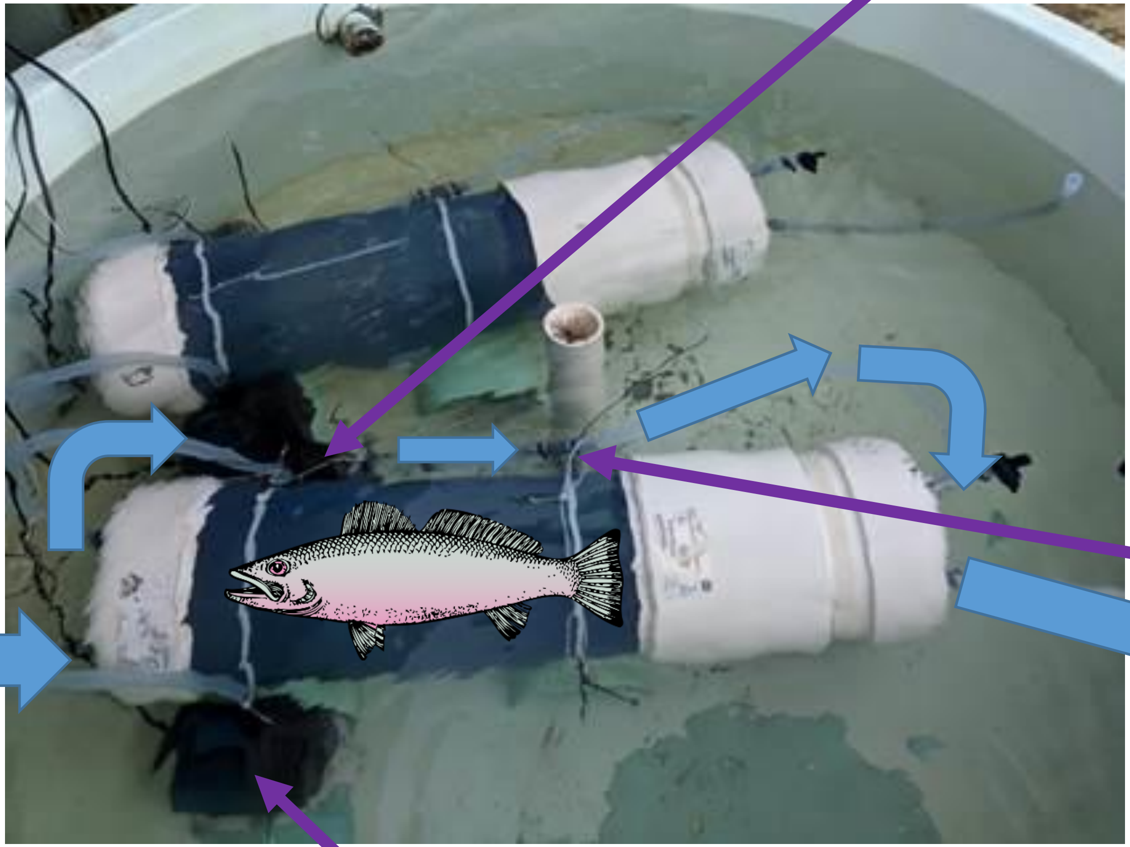
Intermittent-flow static respirometry

Intermittent-flow static respirometry

During Flush cycle:

Recirculation pump ON

Fresh water is pumped into the chamber



Fresh water

Oxygen probe

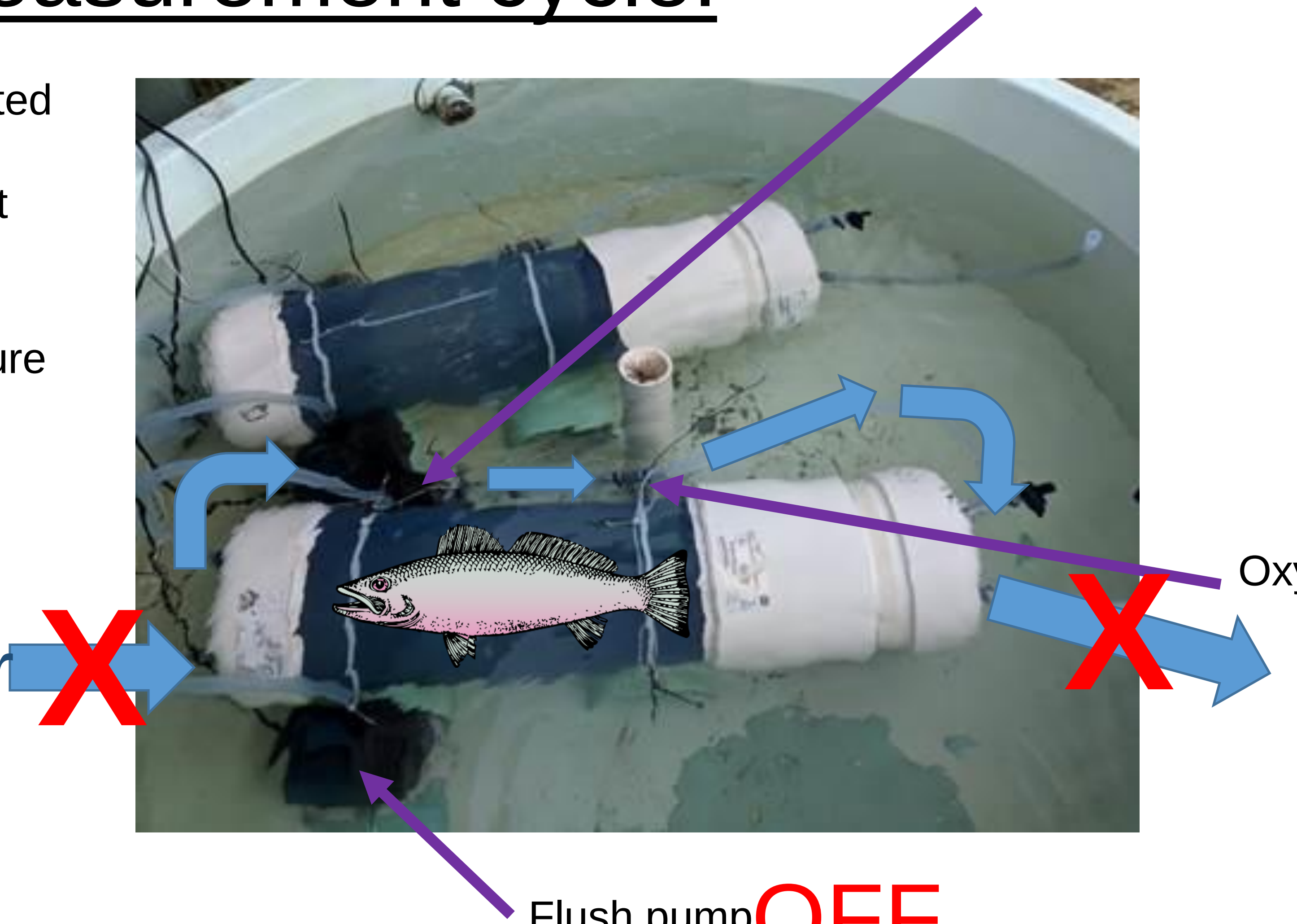
Flush pump ON

Intermittent-flow static respirometry

<u>During Measurement cycle:</u>

Water is still recirculated through the chamber past the O_2 probe, but flush is off.

We are able to measure how much O_2 the fish consumes from the water over time.

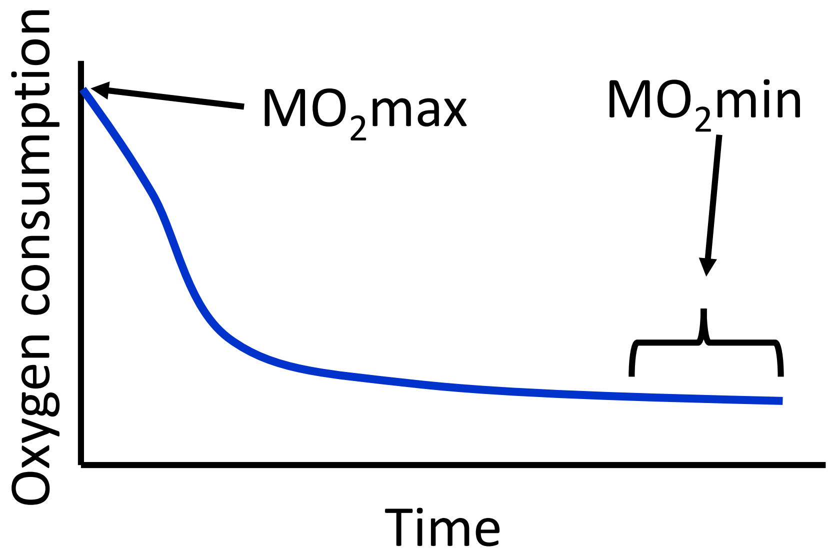


Intermittent-flow static respirometry

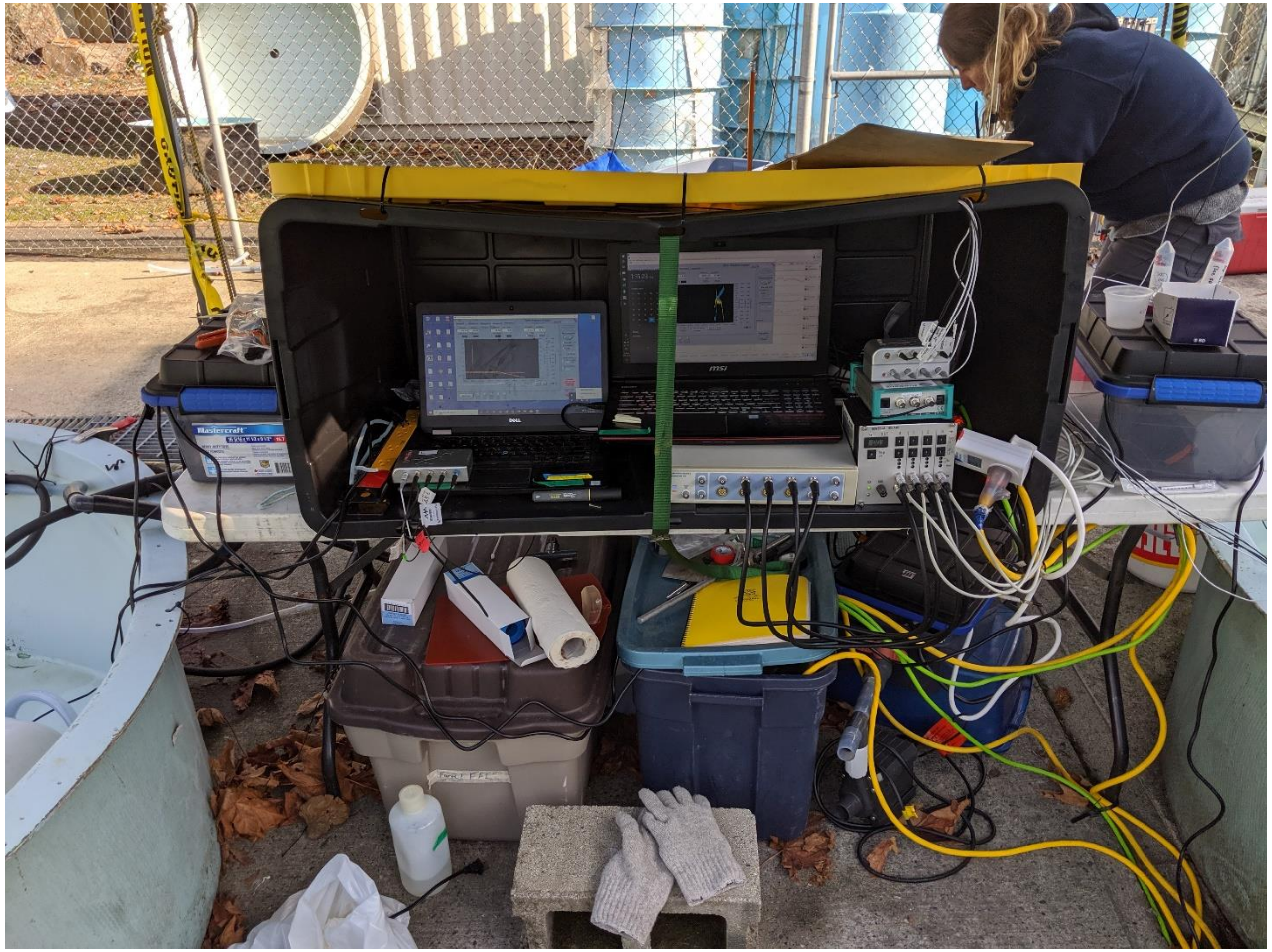
Protocol

- fish acclimated at 2 C per hour to an experimental temperature
- 3 minute chase and 1 minute air exposure
- put into respirometer and measure MO_2 max
-18 hours in respirometer and measure MO_2 min
- take fish out of respirometer, repeat chase and air exposure
- back into respirometer for re-measure of MO_2 max
- sacrifice fish, sample blood and organs to examine individual health

Aerobic scope = $MO_2max - MO_2min$



Intermittent-flow static respirometry



Results summary to date

- Summer-run adult Chinook were able to generally tolerate up to 21^{o}C throughout aerobic scope trials
  - At 24^{o}C, over half of individuals died and scope reduced by 40% from that expressed at optimum (cooler) temperatures

- 24^{o}C coincides with other studies' thermal limits for adult Chinook so this may be an important upper thermal constraint in the Nechako River

- Demonstrated that Chinook populations can differ in thermal tolerance as we have found with adult sockeye
  - Summer-run adult Chinook were able to survive relatively well at 21^{o}C but fall-run adult Chinook had much poorer survival at 21^{o}C, and no fall-run fish were able to survive aerobic scope trials at 24^{o}C

Next steps

-continue to work up adult Chinook thermal tolerance data

-plan juvenile Chinook thermal tolerance study for spring 2020

-plan adult upper Fraser sockeye thermal tolerance study (2020/2021)

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III) Future Research Directions

White sturgeon: the basics

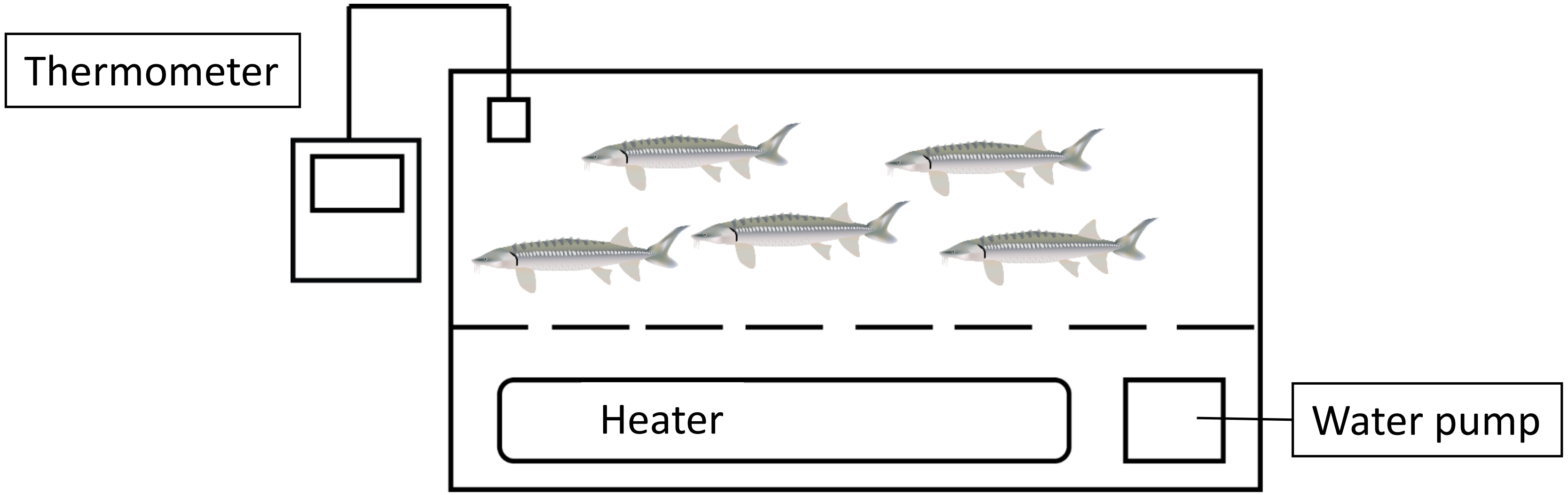
- Confined to a few river basins, including: the Sacramento – San Joaquin, the Columbia, and the Fraser

- Many populations are undergoing recruitment failure, the basis for which is unknown

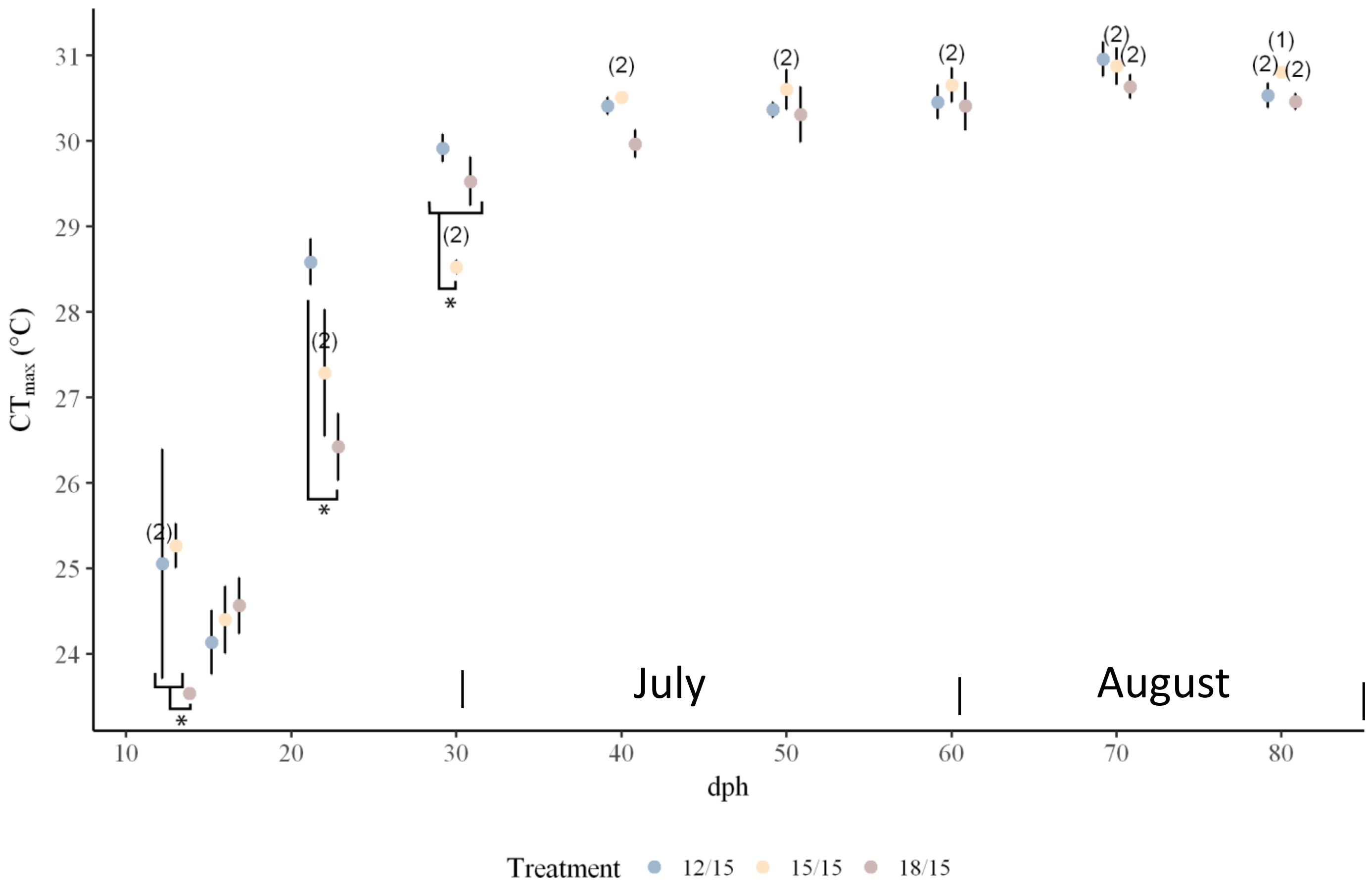
Hildebrand et al. (2016). Status of White Sturgeon

What is CTmax?

- Often used as an indicator of thermal tolerance
- Rapid and repeatable
- Obtained CTmax value is not indicative of long term tolerance at that temperature.



From Kat Cheung's work, UBC



In juvenile white sturgeon from the Nechako River, Vanderhoof Hatchery, thermal tolerance increases with development.

Current study

Objectives

① To determine if the current 20°C threshold is acceptable for juvenile white sturgeon development.

- ➢ Prediction: Sturgeon will not survive above 20°C

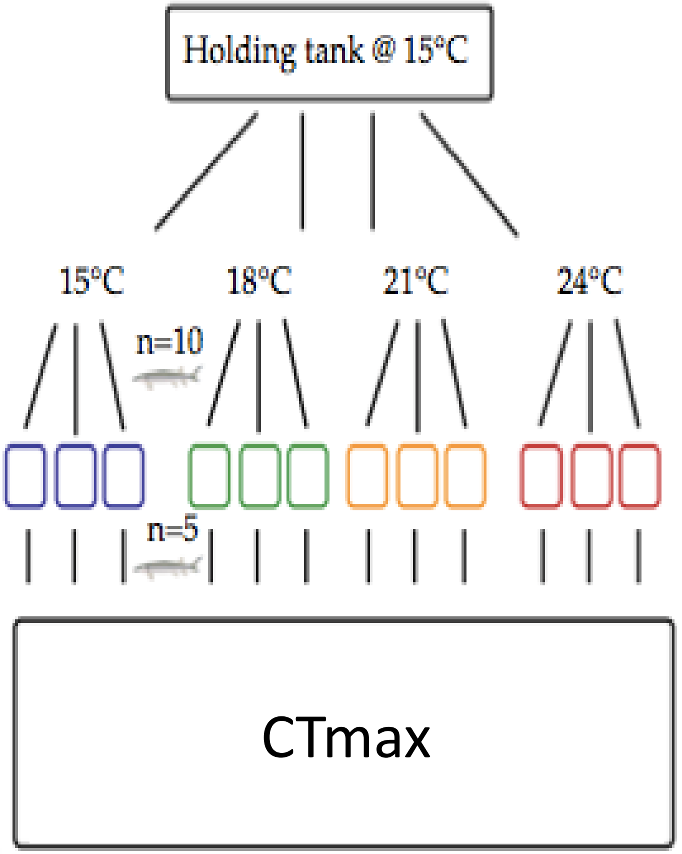
② To determine if temperature acclimation alters thermal tolerance.

- ➢ Prediction: Thermal tolerance will increase with increased acclimation temperature

Methods

Acclimation

- Fish held in holding tank at 15°C until acclimation.
- Fish were acclimated to one of four temperatures for two-weeks (15°C, 18°C, 21°C, or 24°C), where temperature was increased 3°C/day to reach target.
- One group of fish was acclimated in July (37-51 days post hatch (DPH)) and another group was acclimated in August (66-80 DPH)



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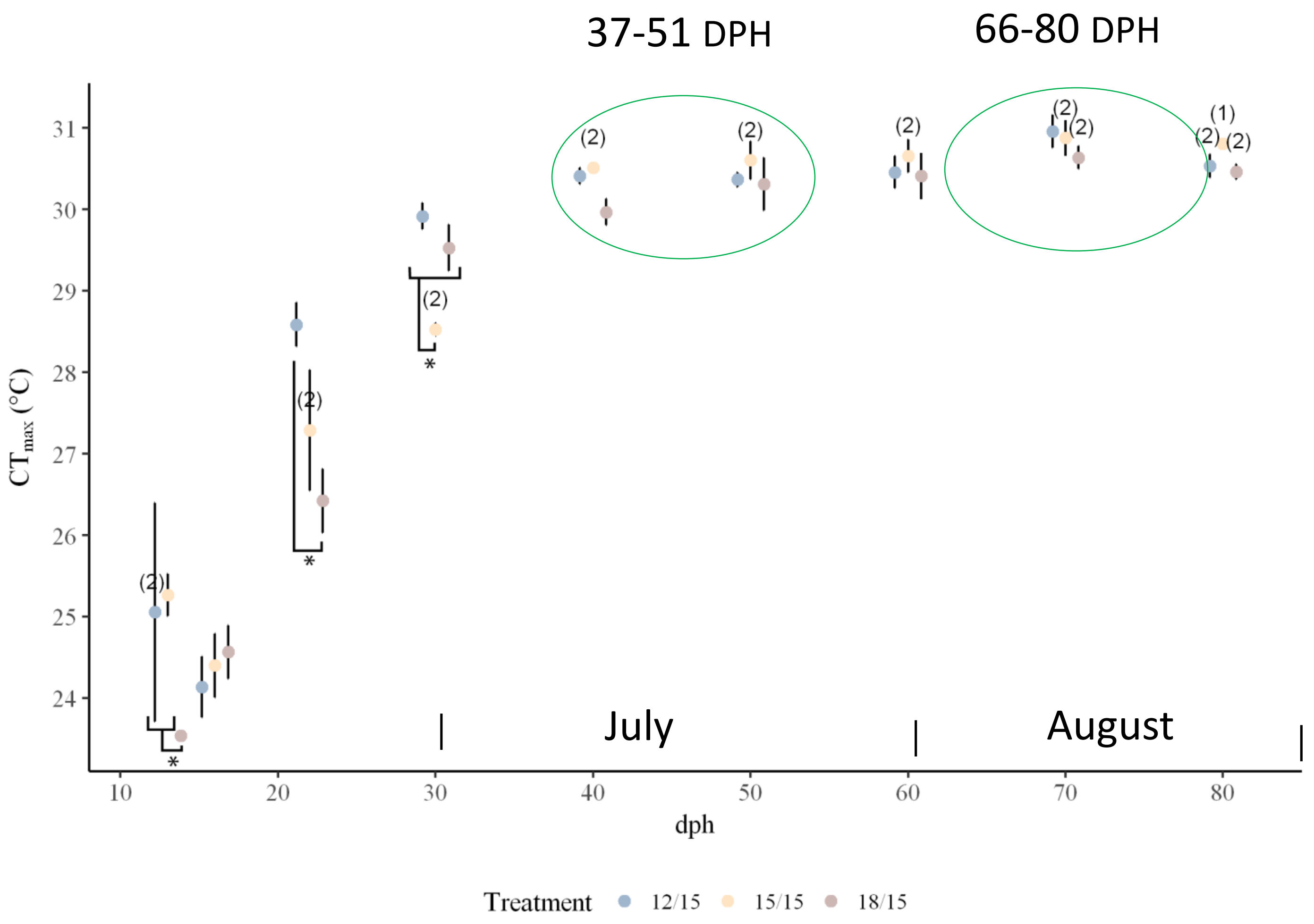
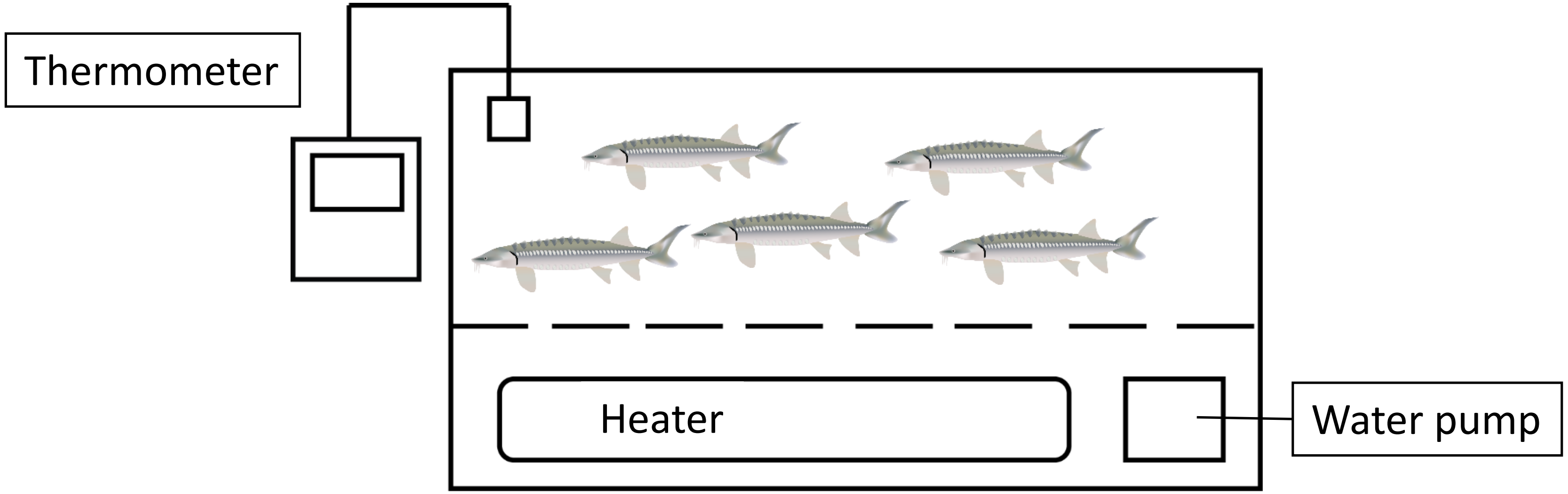


White Sturgeon from the Nechako River, Vanderhoof Hatchery were investigated at these developmental stages when Ctmax had plateaued.

Methods

Thermal tolerance testing

- Measured using critical thermal maximum as a proxy
- At the end of acclimation period, 5 fish were taken from each aquarium and a CTmax test was performed
- Temperature was increased at a rate of 0.3°C per minute until loss of equilibrium occurred



Current study

Objectives

① To determine if the current 20°C threshold is acceptable for juvenile white sturgeon development.

- ➢ Prediction: Sturgeon will not survive above 20°C **NO**

② To determine if temperature acclimation alters thermal tolerance.

- ➢ Prediction: Thermal tolerance will increase with increased acclimation temperature **YES**

Conclusions

- In Nechako River white sturgeon from Vanderhoof hatchery, survival is high up to 24°C following 2 weeks of exposure to elevated temperature.
- The higher the temperature to which fish were acclimated, the higher the CTmax value, indicating plasticity in thermal tolerance.
- This relationship did not appear to plateau indicating that white sturgeon may be able to acclimate to even higher temperatures than 24°C at these developmental stages.
- Hatchery fish are reared at a higher temperature than wild fish and thus are considerably larger for a given dph. This needs to be considered in assessments of thermal tolerance given how CTmax changes early in development.

Future directions

- Rear fertilized embryos from fertilization, to hatch and yolk sac absorption at 15, 18, 21 and 24 °C and monitor growth and survival.
- In June, July and August, conduct 2–4 week acclimations to 15, 18, 21, 24, 27 °C, and monitor survival, growth, mortality and conduct CTmax and aerobic scope measurements at the end of each acclimation.
- Together, these parameters will inform on thermal tolerance for white sturgeon at different developmental stages that are most likely to correspond with elevated river water temperatures.

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