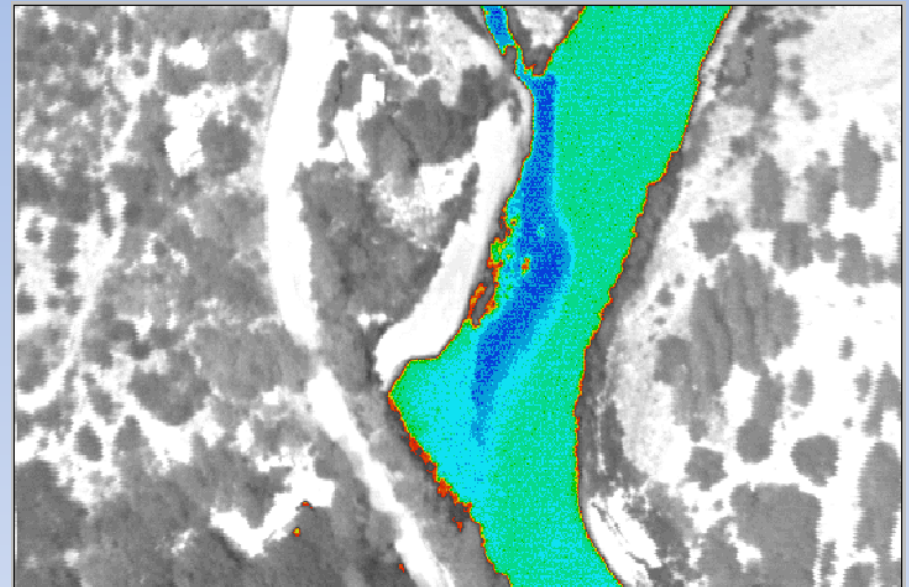
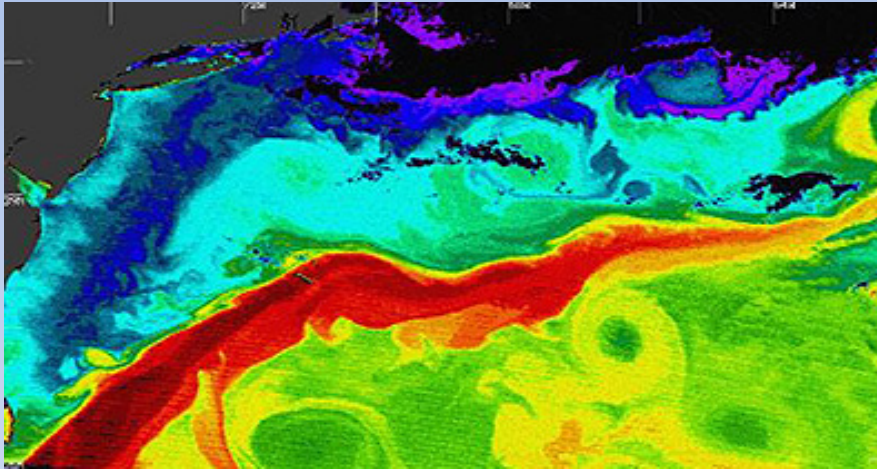


Cold water refuges: critical temporary habitats for migrating salmon and steelhead



Matthew Keefer & Christopher Caudill

**Department of Fish and Wildlife Sciences
University of Idaho**



University of Idaho
College of Natural Resources

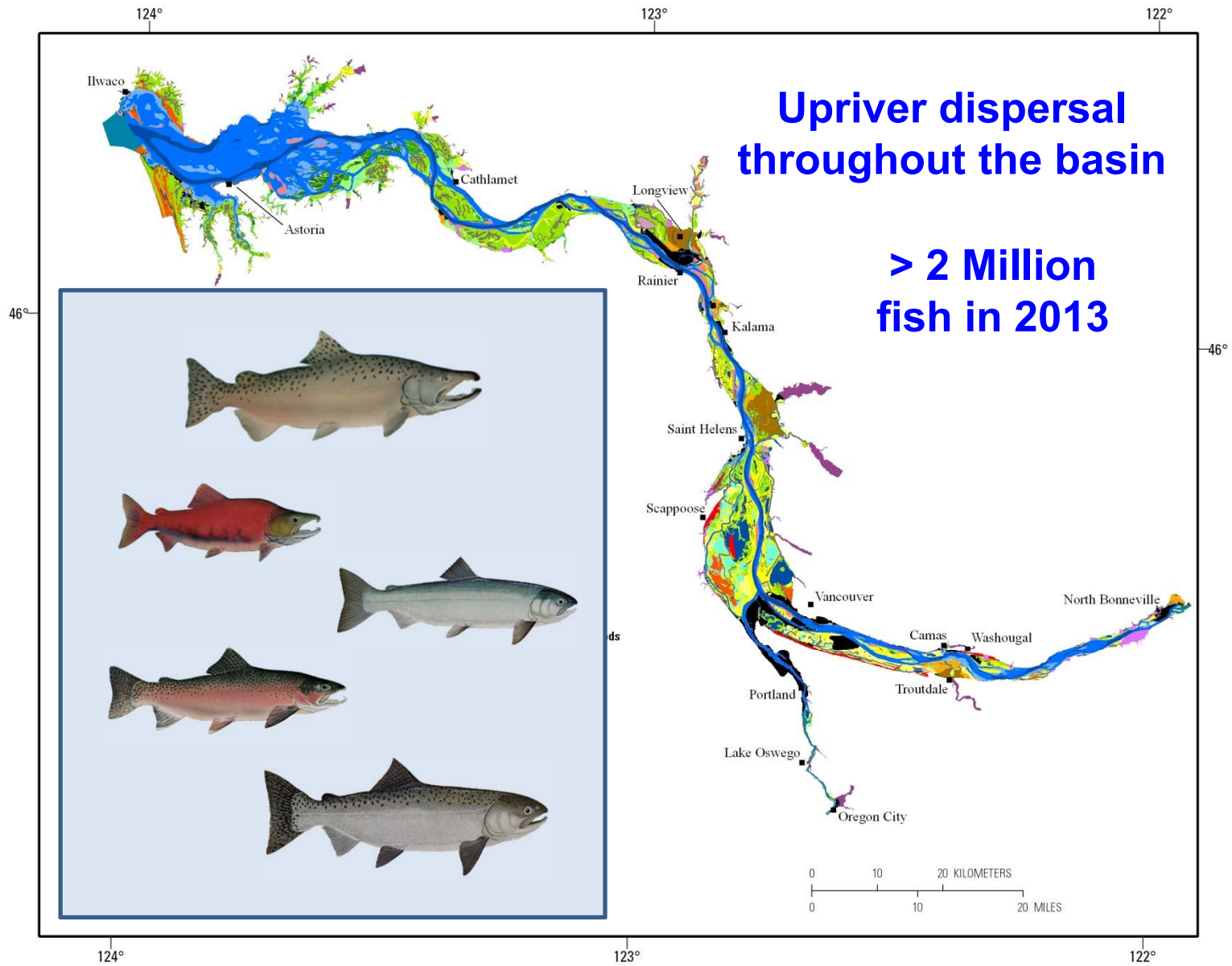
Preview

► Temperature effects on adult salmon & steelhead

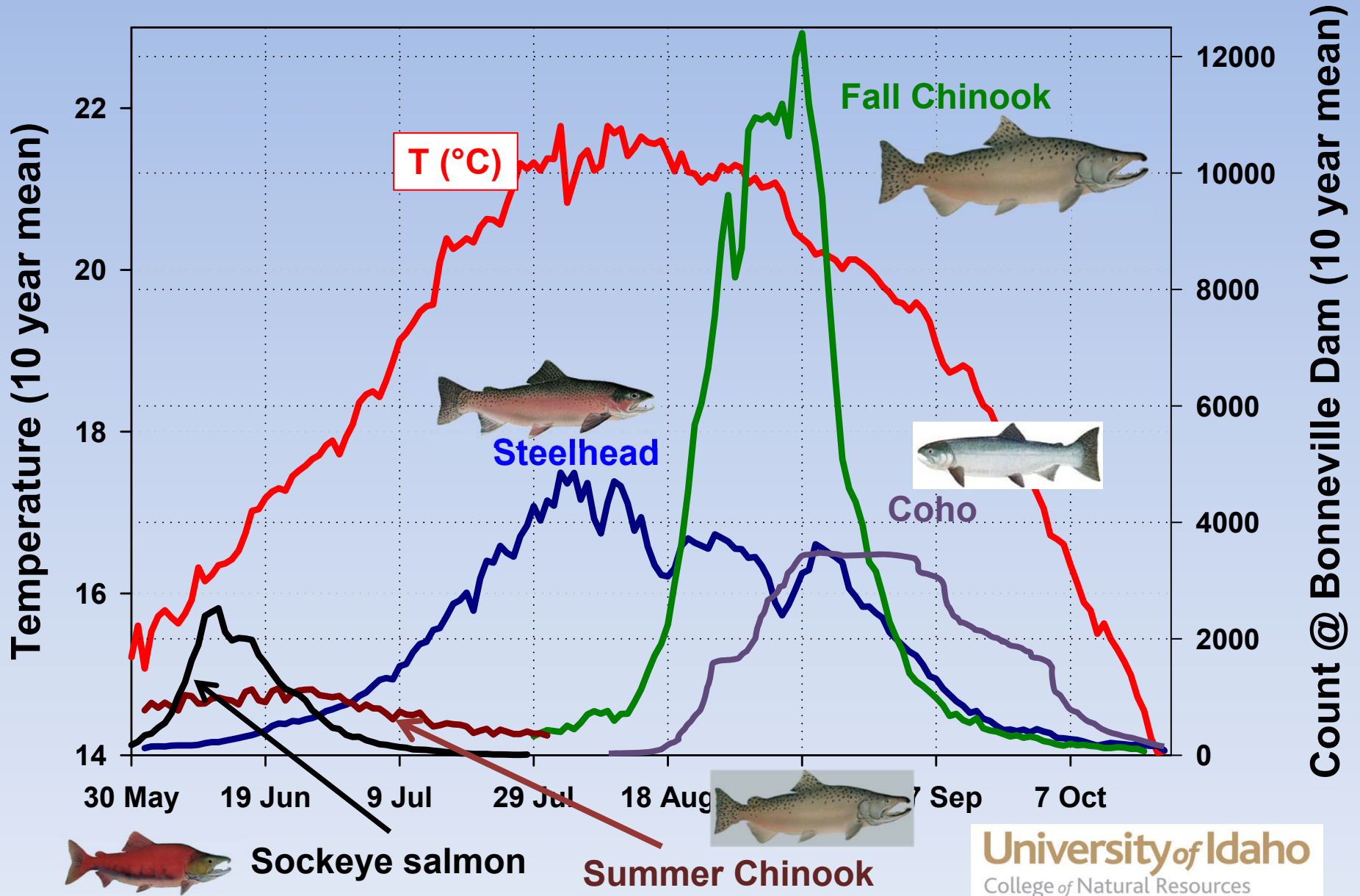
- **Migration corridors: seasonally stressful conditions for many species / populations**
- **Behavioral thermoregulation**
- ***Critical thermal habitats and opportunities for management / restoration***



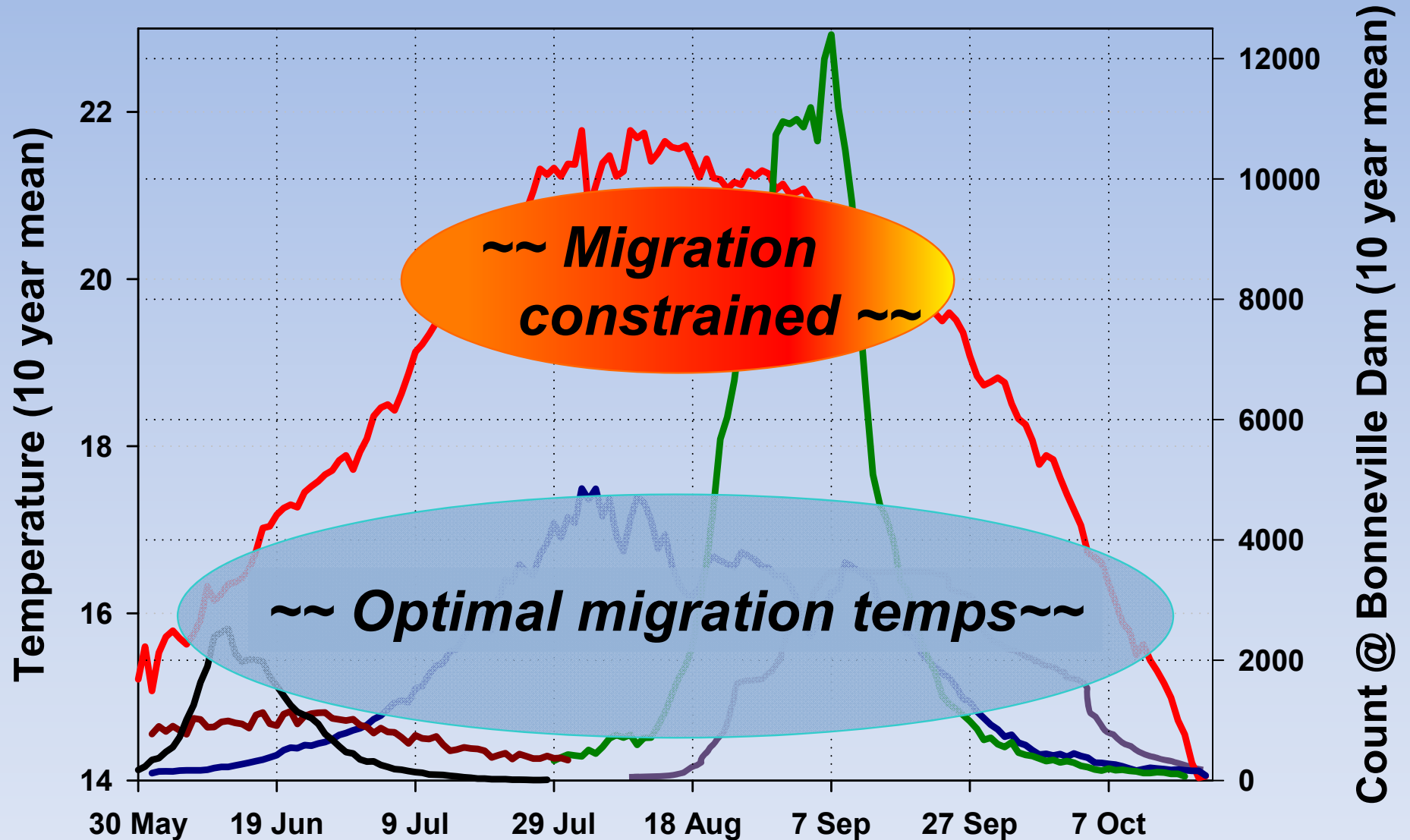
Estuary and Lower Columbia River = adult migration corridor



Adult run timing in relation to temperature



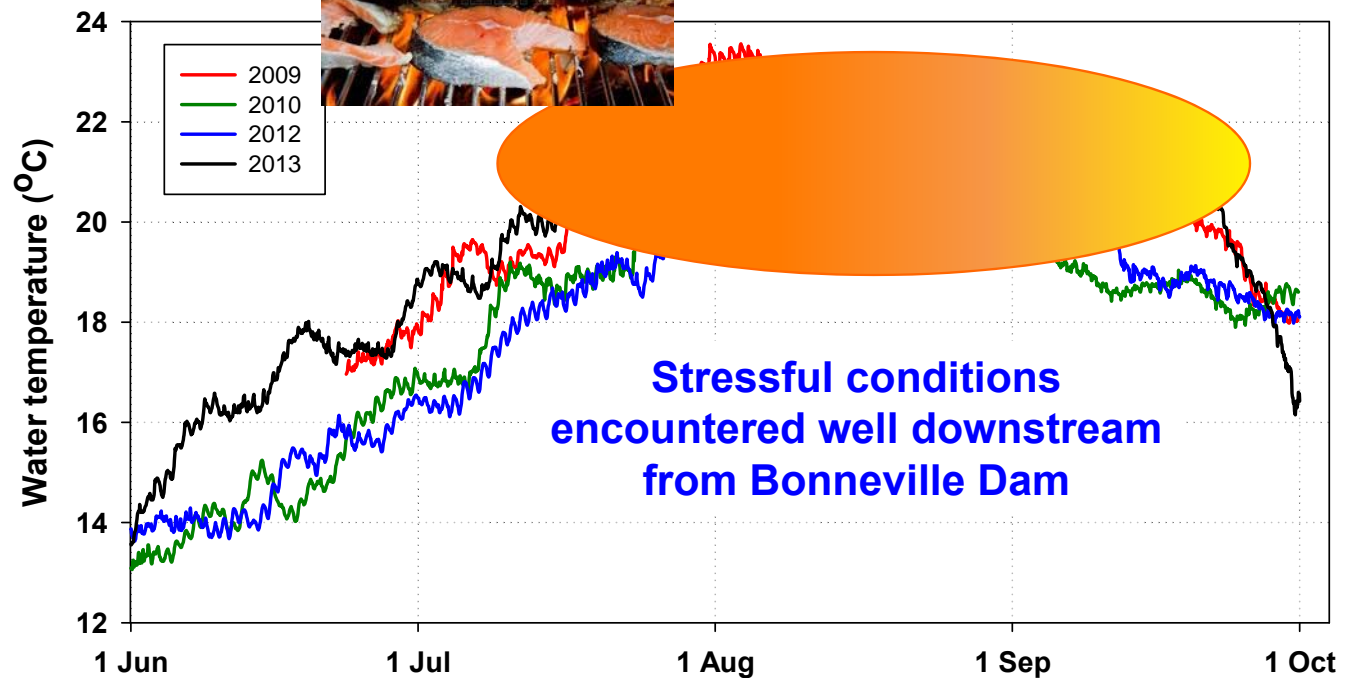
Migration ecology: warm migration corridor



Lower river water temperature

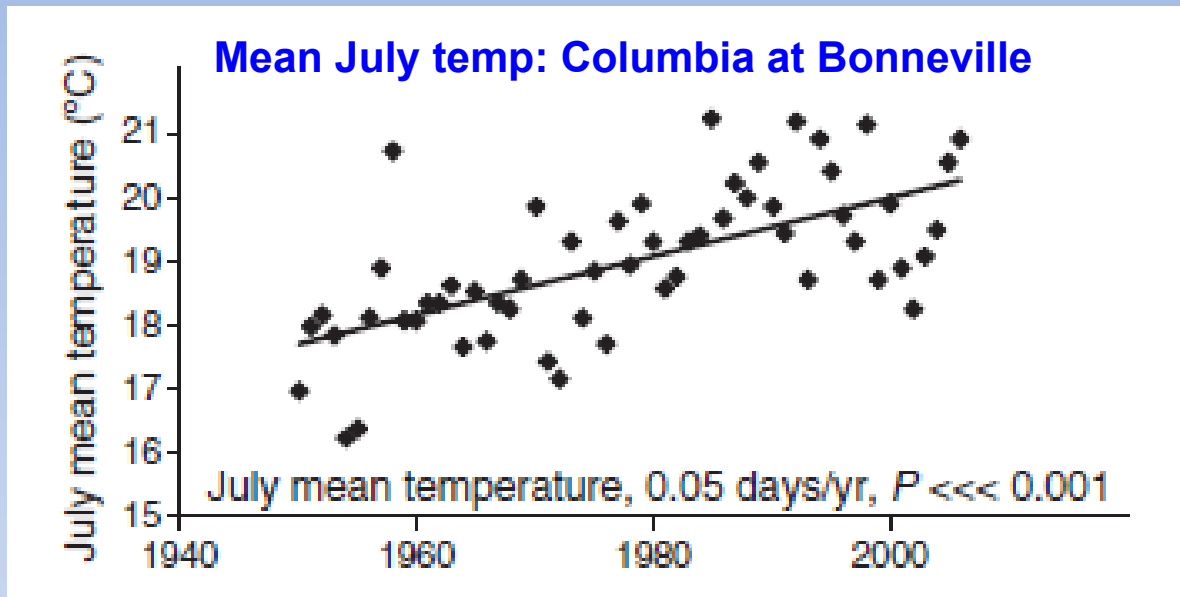


LOBO data
collected near
Quincy, OR
rkm = 85



Why it matters. . . .

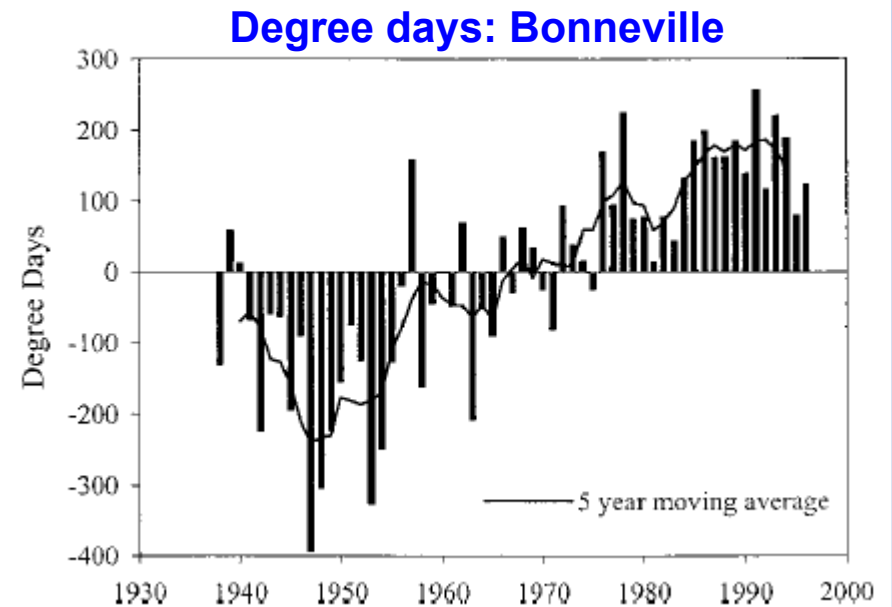
- Earlier warming
- Later cooling
- Higher T_{mean} & T_{max}



Crozier et al. (2008, Evol App)

- Increasingly stressful conditions for many populations

Robards & Quinn (2002, TAFS)



Why it matters. . . . Disease, fungal infections, energetic costs, *en route* migration mortality



Kline & Willard 2001; Naughton et al. (2005, CJFAS); Keefer et al. (2008, EFF)

Why it matters. . . . Prespawn mortality



**Chinook salmon prespawn mortality,
Middle Fork Willamette River**

Keefe et al. (2010, EFF); Keefe & Caudill (2010)

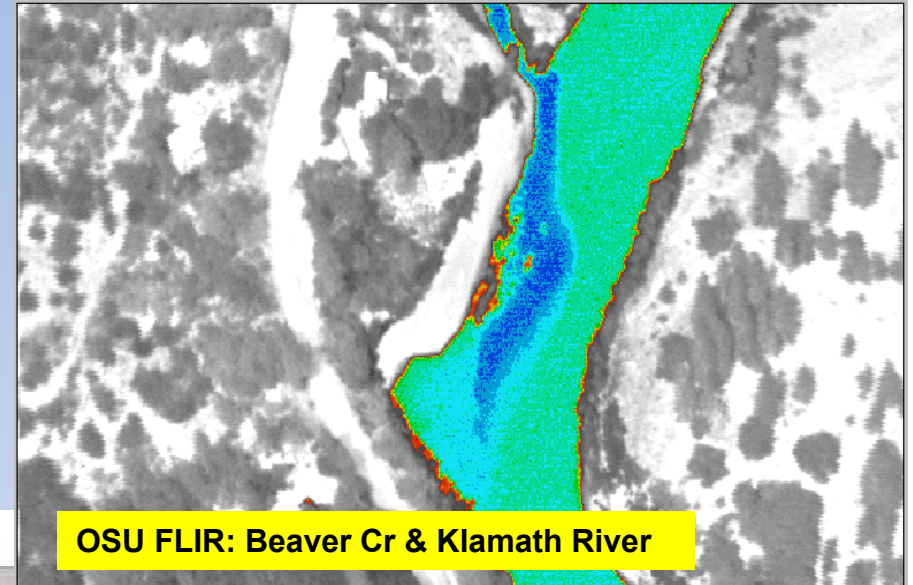


**Chinook salmon prespawn mortality,
South Fork Salmon River**

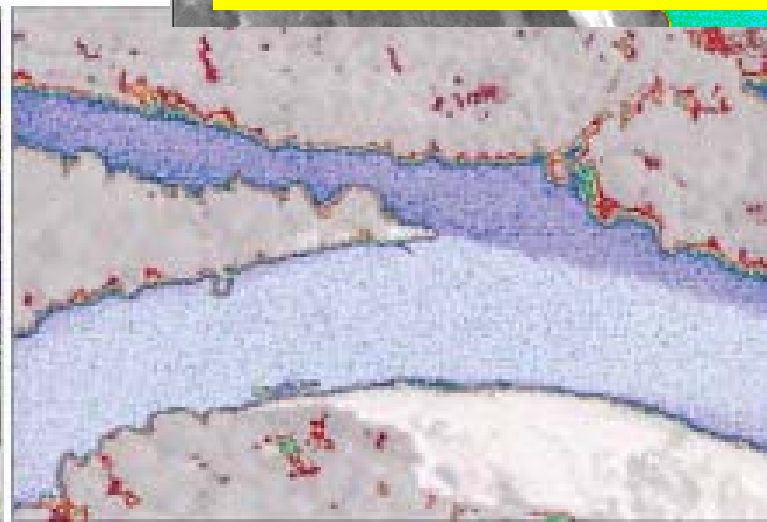
Hinch et al. (2012, JFB); Keefe et al. (2008, EFF)

One coping mechanism: behavioral thermoregulation

- Seek and use cool water refuge areas: adults, juveniles, resident fish



A. McKenzie River



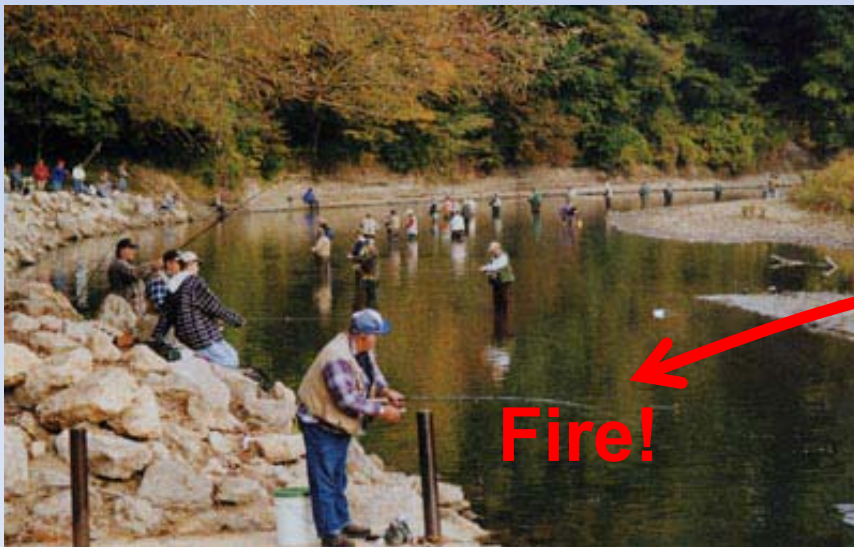
Torgersen et al. (2001, RSE)

Idaho

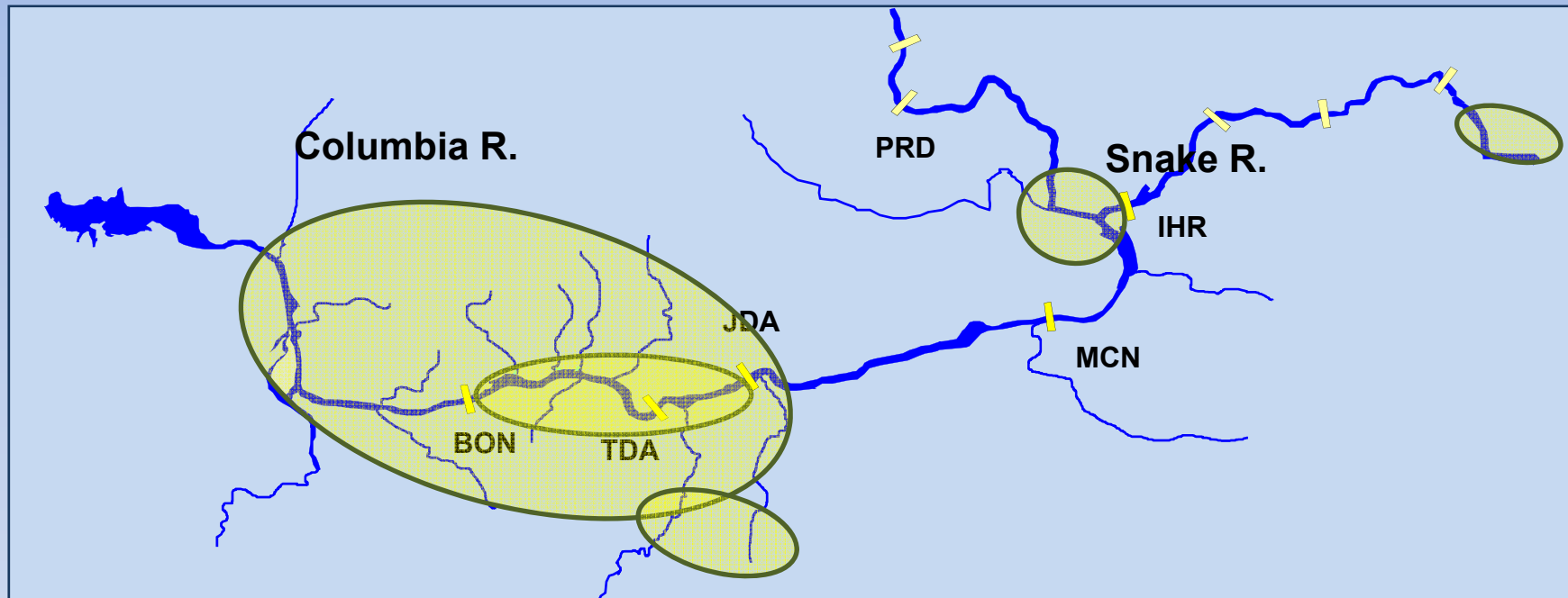
College of Natural Resources

Behavioral thermoregulation

- Adult migrants seek and use cool water refuge areas along migration routes
- Balance benefits (metabolism, energetics, etc.) against potential risks (migration delay, harvest, predation, etc.)

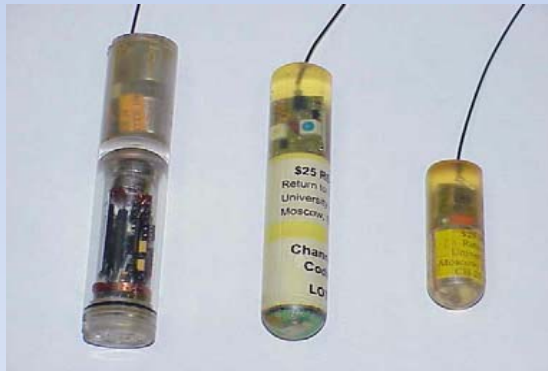


Behavioral thermoregulation: BON - JDD

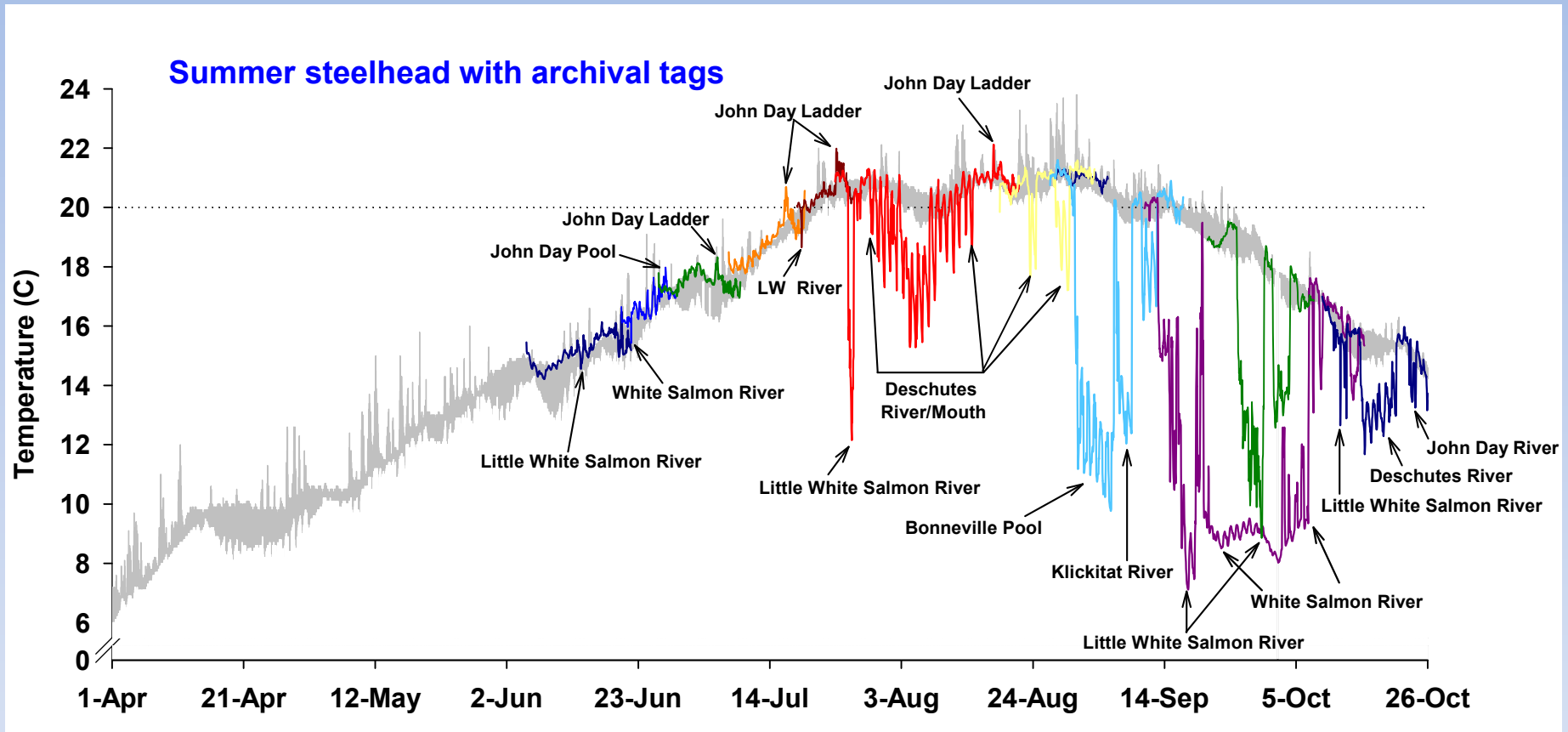


- Behavioral response potentially occurs at a variety of locations along the migration corridors

Adult salmon and steelhead radiotelemetry



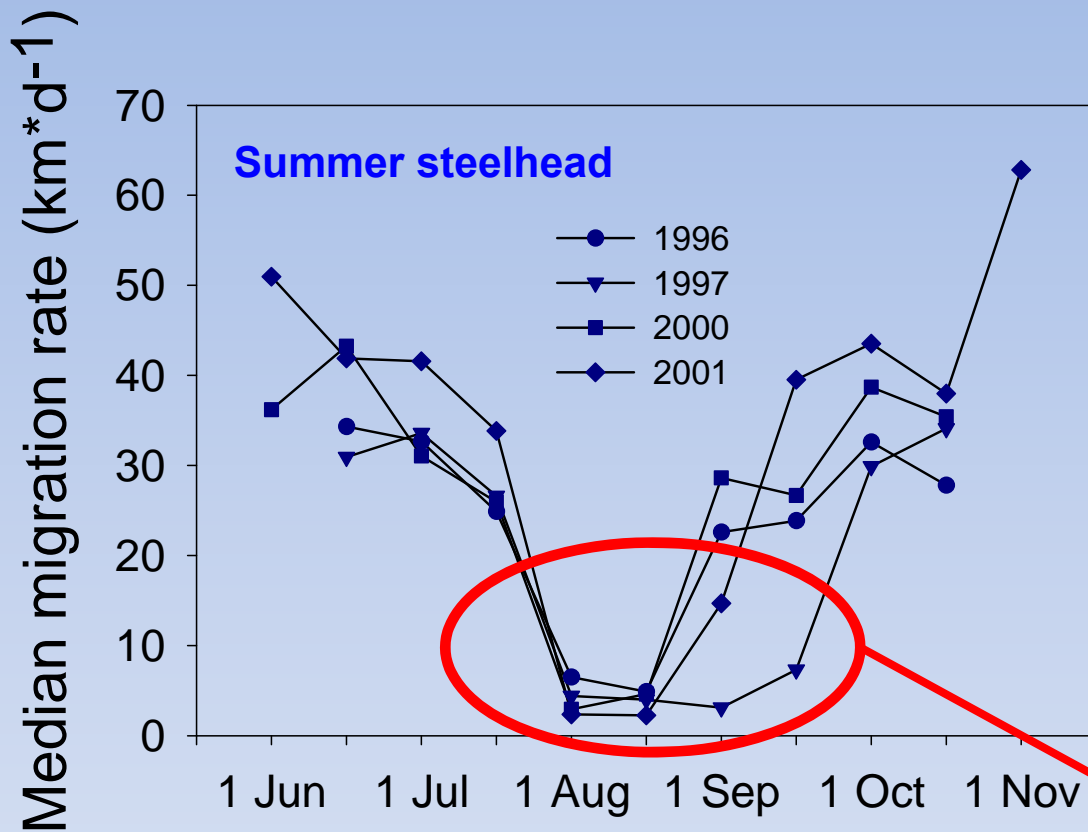
Behavioral thermoregulation



Caudill et al. *in prep*

- Steelhead migration relatively flexible and refugia use often lasts weeks

Behavioral thermoregulation



Keefe et al. (2004, TAFS)

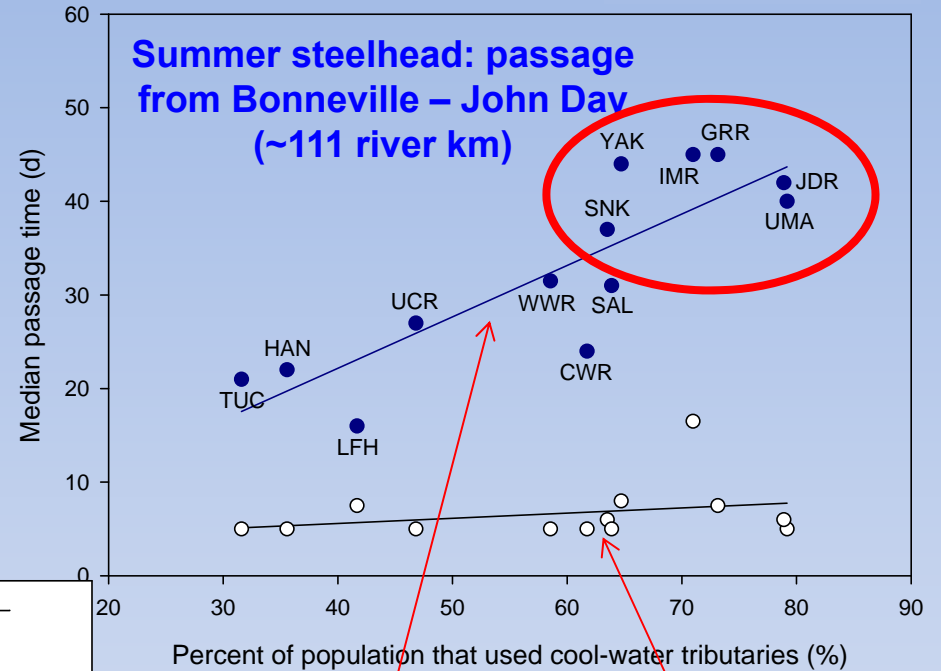
- Upstream migration rates from radiotelemetry studies show reduced swim speeds, extended holding behaviors

Cool-water refugia residence

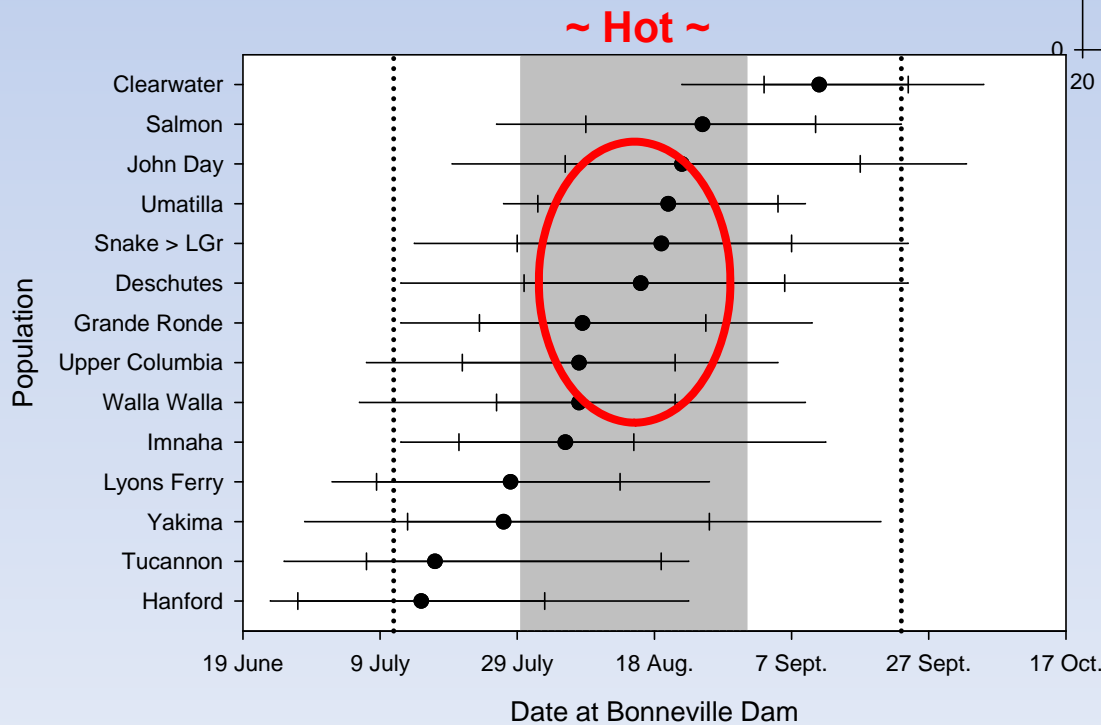
Behavioral thermoregulation



- Timing-based, among-population variability in behavior expression

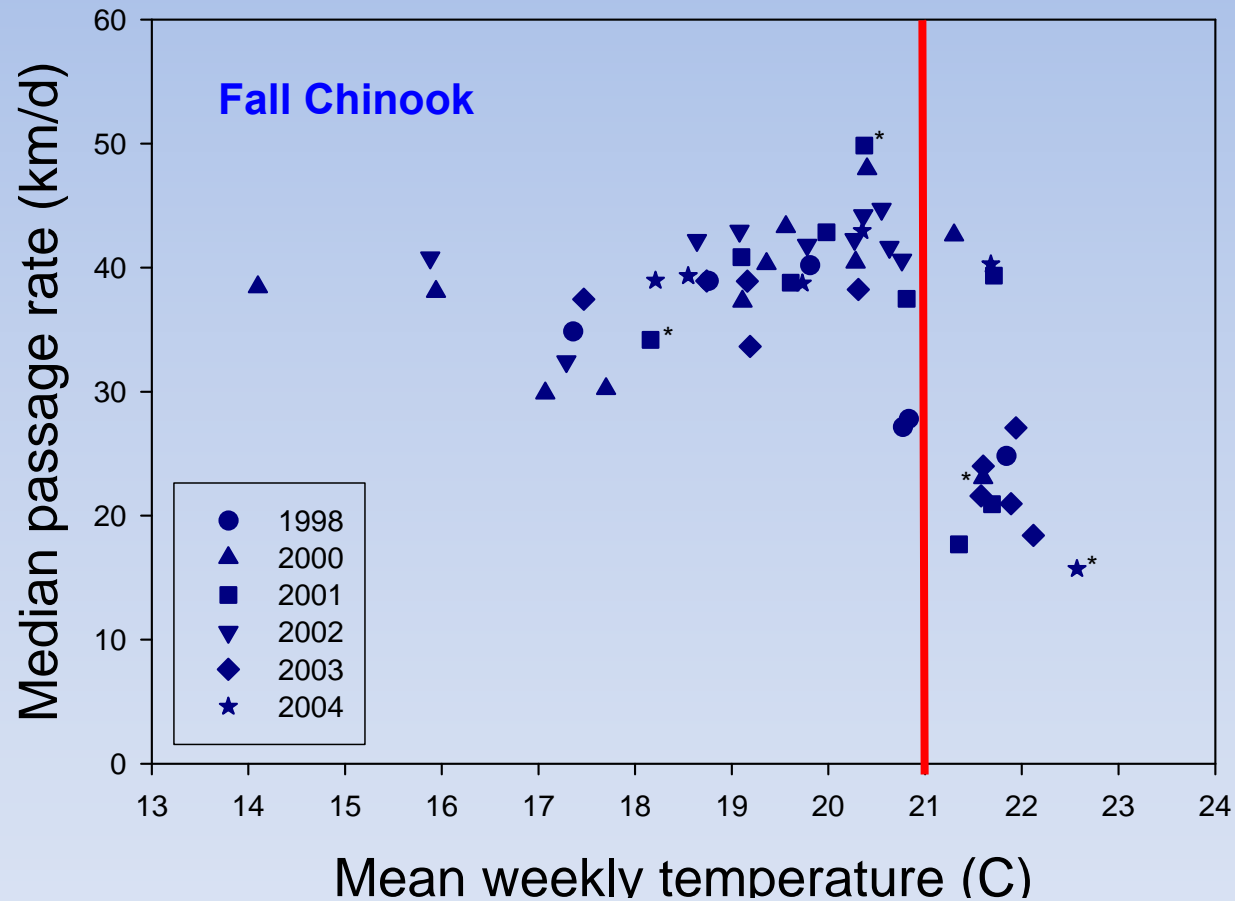


Did not use refugia
Used thermal refugia



Keefe et al. (2009, CJFAS)

Behavioral thermoregulation



Gonia et al. (2006, TAFS)

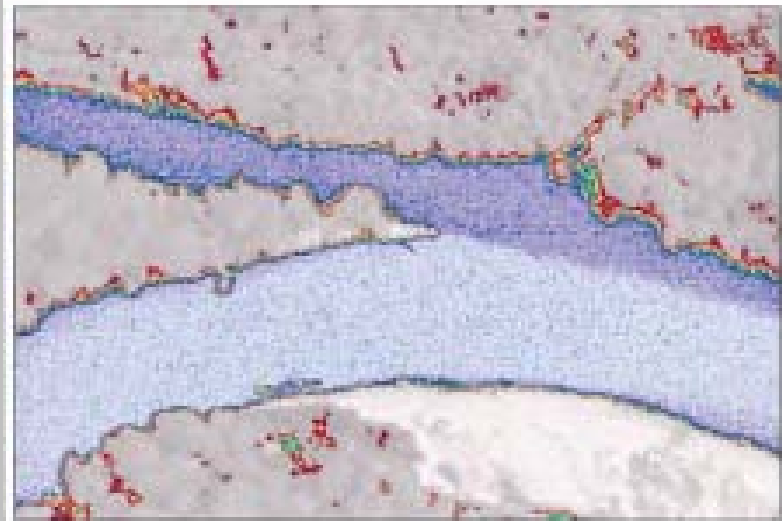
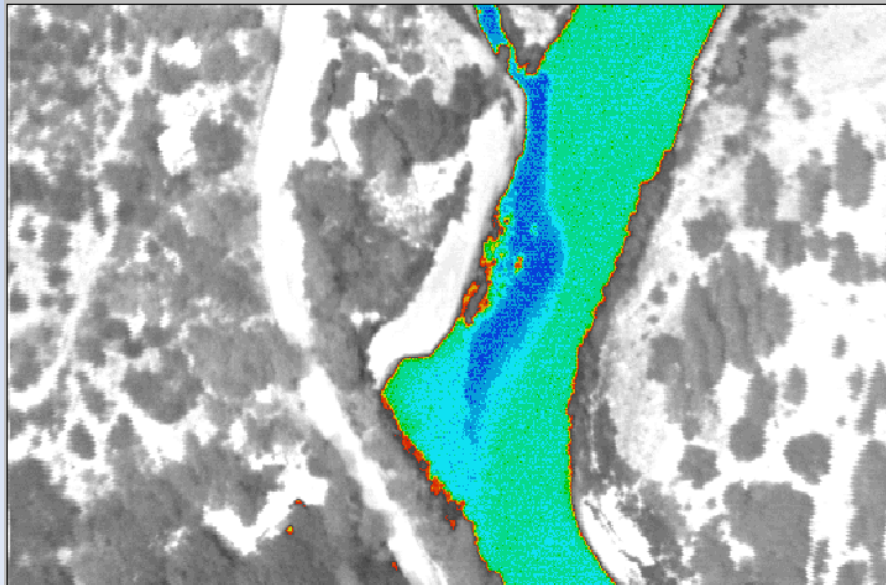
Critical habitats

- ▶ **Expectation: Preferred thermal habitats will be reduced as regional climate continues to warm**

Where / When will this become limiting?

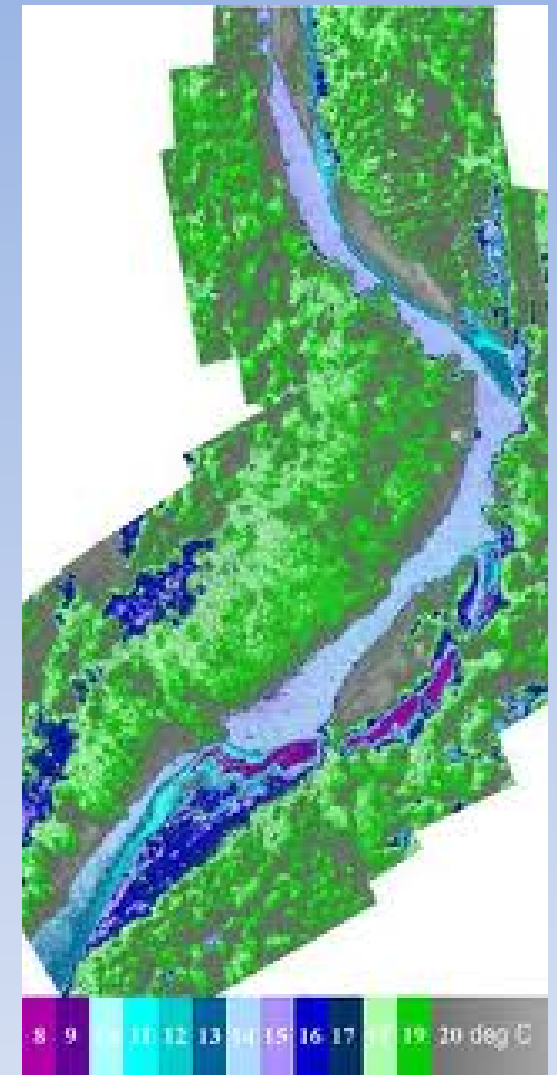
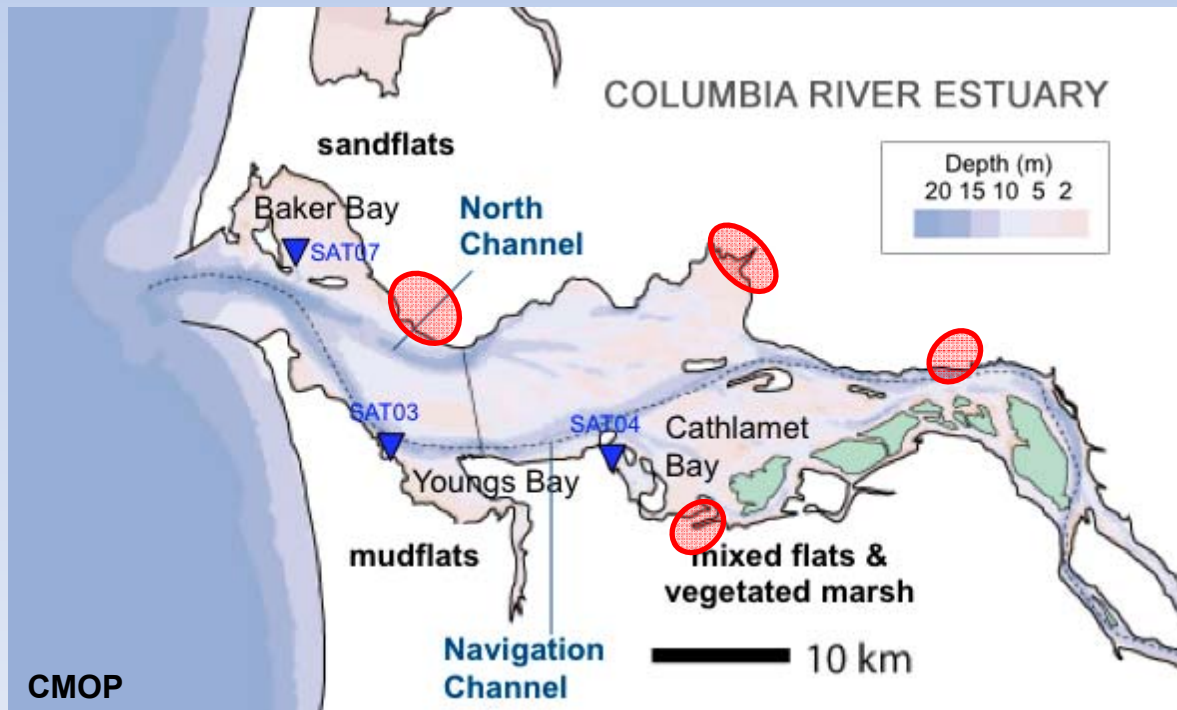
How can we maintain and / or restore patchy, but critically important habitats?

- **High-volume, high-quality sites: manage fisheries, ensure source**



Critical habitats

- Patchy, seasonally-beneficial sites: more challenging to identify
- Off-route, low-volume sites: less direct, tangible value to migrants
 - but high potential cumulative and 'local' value
 - habitat restoration opportunity

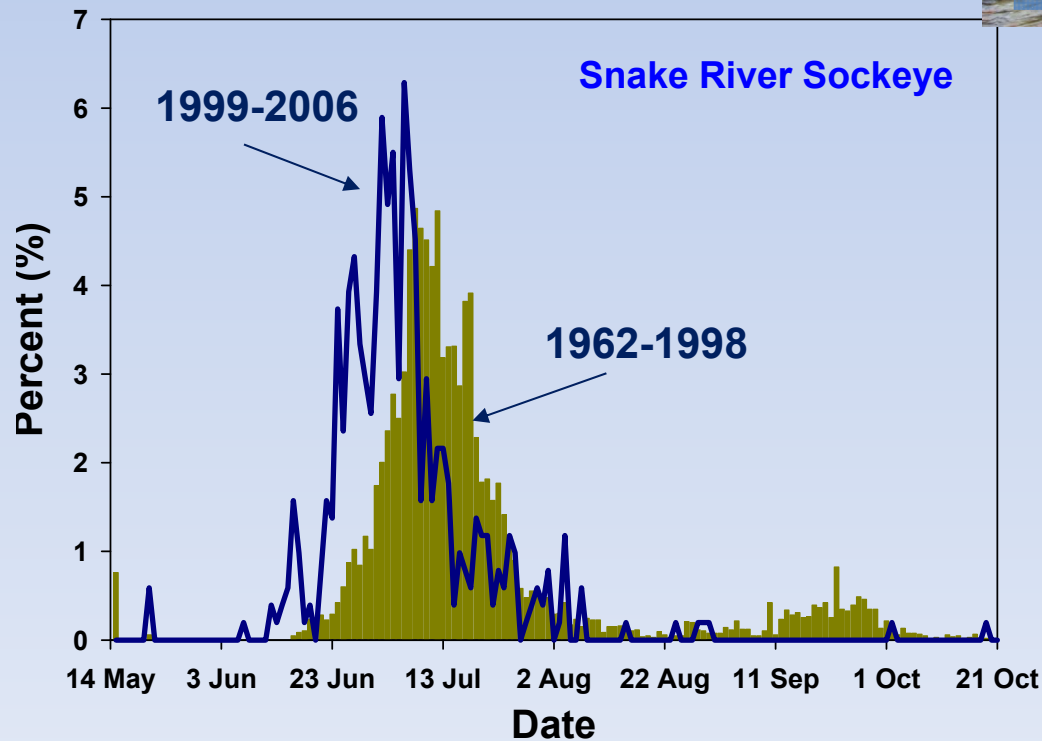


WA Dept. Ecology

Critical uncertainties

- ▶ Can adaptation keep pace with environmental change?

Margin for adaptation differs for Spring vs. Summer vs. Fall-run populations



Kefer et al. (2008, EFF)

‘Window of opportunity’ differs among life history types

Acknowledgements

T Bjornn

C Boggs

B Burke

T Clabough

D Clugston

B Daigle

T Dick

K Frick

D Griffith

M Jepson

E Johnson

K Johnson

D Joosten

M Langeslay

S Lee

R Mann

M Morasch

M Moser

G Naughton

D Queampts

C Peery

R Ringe

L Stuehrenberg

S Tackley

K Tolotti

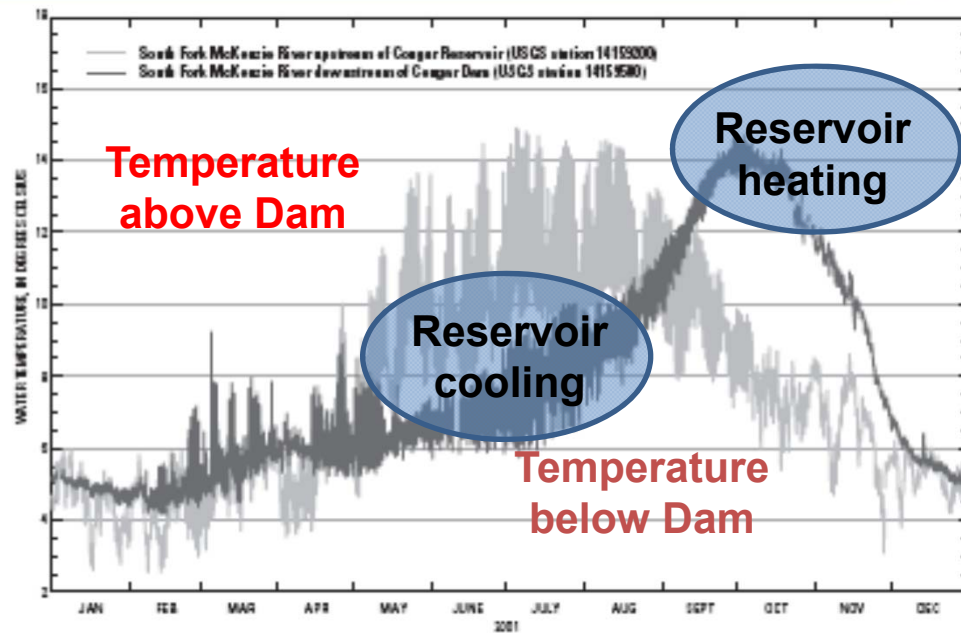


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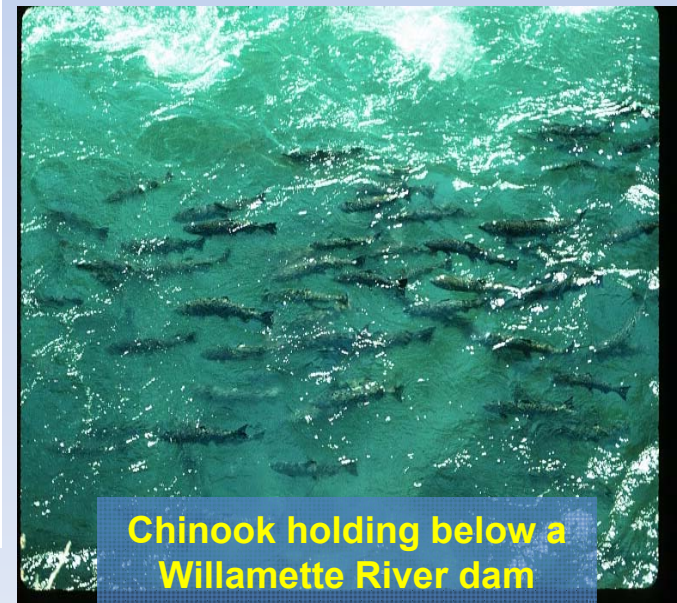


Critical uncertainties

- ▶ Can adaptation keep pace with the combination of environmental change + river regulation?



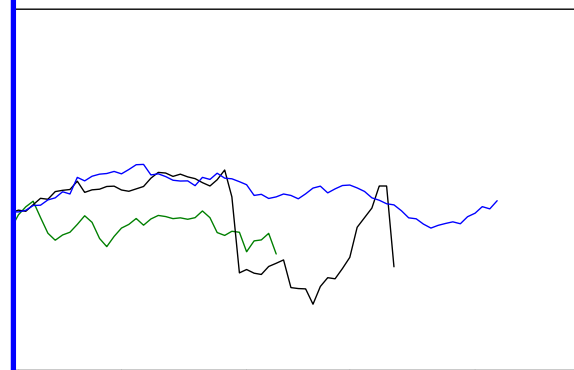
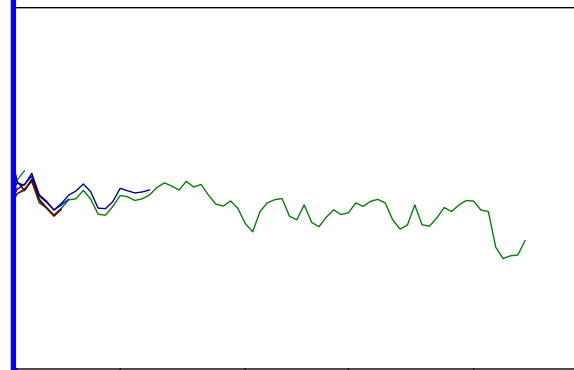
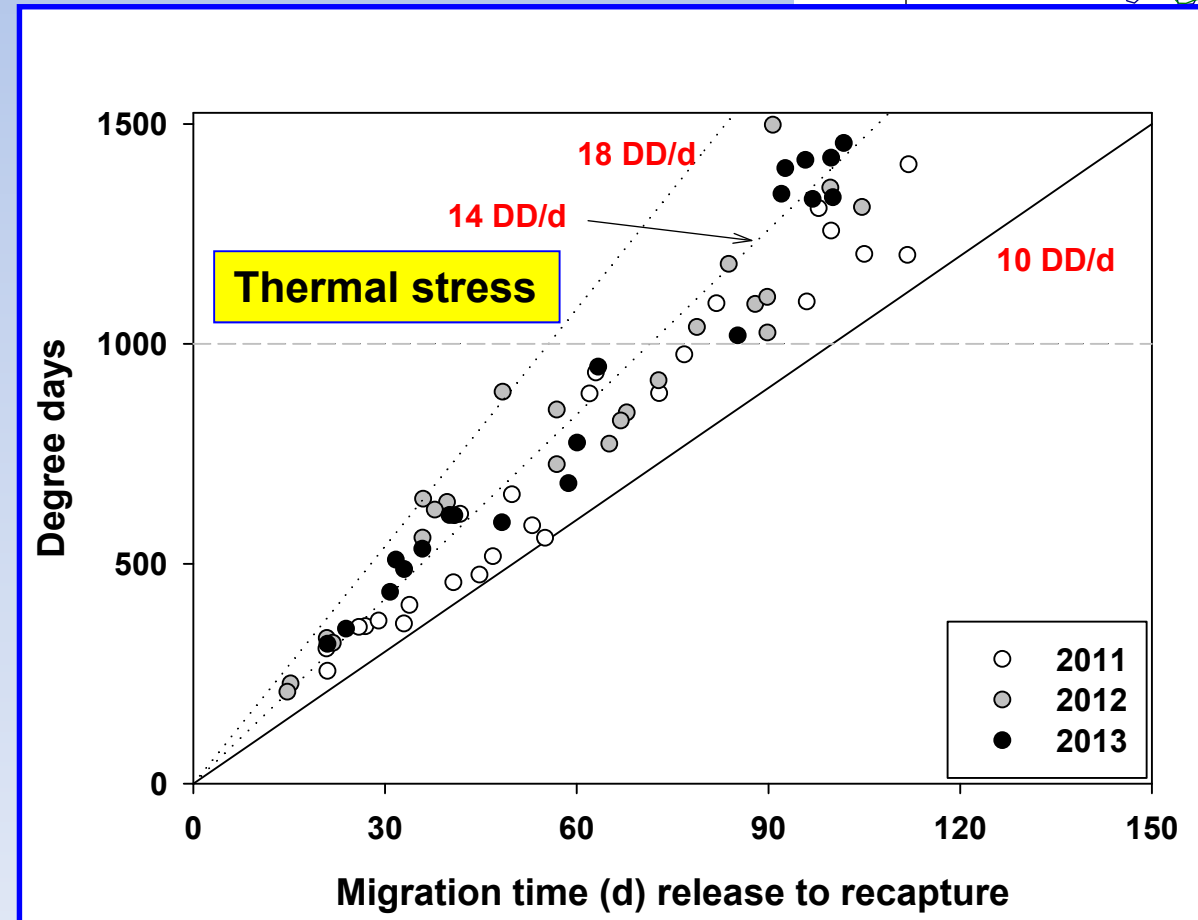
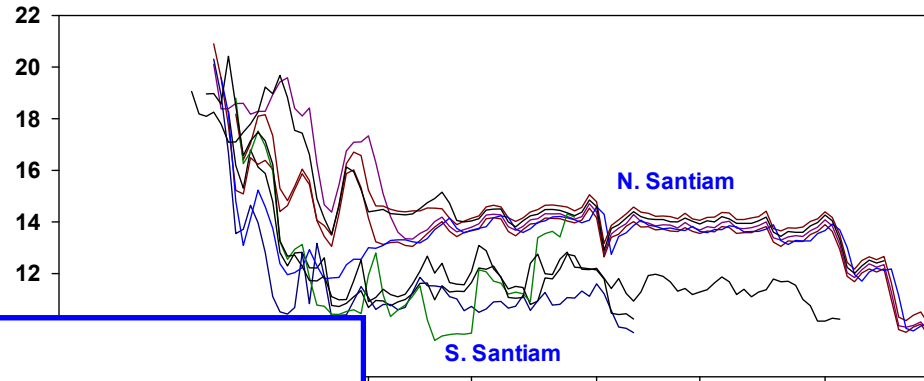
Rounds (2007, USGS)



Willamette River Chinook

- Limited evidence for thermal refugia use

Thermal histories: 2013



Jul 15 Jul 1 Aug 15 Aug 1 Sept 15 Sept