Northwest **Power** and
Conservation Council

August 2, 2016

MEMORANDUM

TO: **Council members**

FROM: **Lynn Palensky**

SUBJECT: **Presentation on cold water refuges in the mainstem Columbia: where they are, importance, and how adult salmon and steelhead use them**

BACKGROUND:

Presenter: Lynn Palensky, John Palmer, Environmental Protection Agency (EPA) and Matthew Keefer, Research Scientist at the University of Idaho

Summary: Climate change models predict a general warming trend with shifts in timing and perhaps quantity and type of precipitation. Increased temperatures and reduced snow packs and summer stream flows suggest that fish kills, such as observed in 2015, are likely to increase in frequency, extent, and severity. In the summer of 2015 the water temperatures rose to about five degrees above normal about a month earlier than normal and remained for an extended period. Cold water inputs from various tributaries to the mainstem (e.g. Wind and Deschutes Rivers) attract salmon and steelhead during their migration up the Columbia. Adult fish are often observed holding at river mouths and deltas with colder water temperatures during upriver migration. Some salmon and steelhead use several of these cold water sites as they migrate up river in an effort to avoid the warmer mainstem water. It is important that we understand the function, use and benefits of cold water refuges during peak migration times so as to maximize the benefits and protect those areas during already stressful conditions.

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We are gaining understanding, but we need to continue to put the pieces together. Some work has been done to inventory cold water refuges in the Willamette and in the mid-Columbia reach between Bonneville and McNary Dams. Some additional research has been done to understand where fish find and use cold water refuges in the upper Columbia. John and Matt will summarize what they know of cold water refuges along the mainstem and which fish use them, during what timeframes, and for how long.

Relevance: One of the Council's emerging high priorities addresses "preserving program effectiveness by … taking into account the effects of climate change." (See p. 116 of the Council's 2014 Fish and Wildlife Program.) The ISAB and ISRP's 2016 Critical Uncertainties Report extensively highlights the importance of thermal refuges. Some examples include the value of 1) understanding the locations of thermal refuges in the mainstem as temperatures increase with climate change, 2) securing thermal refuges and sufficient high quality water under predicted landscape-scale changes in hydrology, and 3) considering areas likely to provide thermal refuges for aquatic species when selecting areas for habitat restoration.

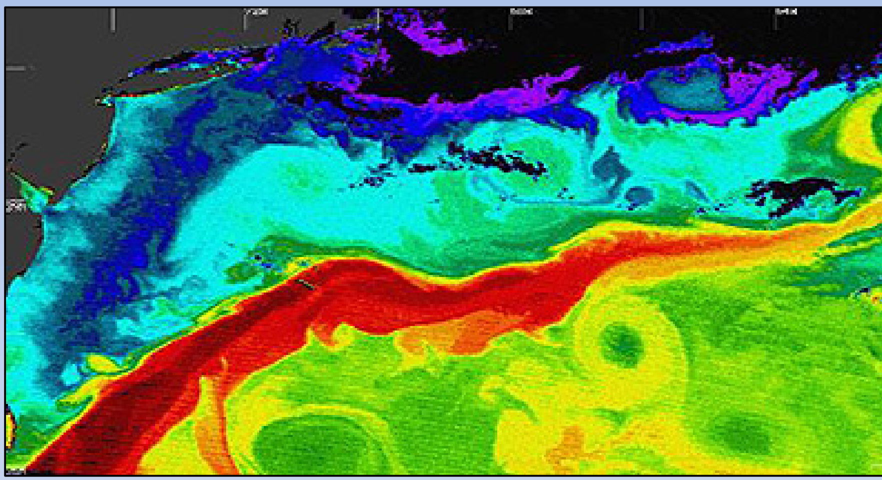
Workplan: This presentation addresses one of the Council's emerging priorities to implement adaptive management and take into account the effects of climate change. This work is tracked in the division's work plan under adaptive management.

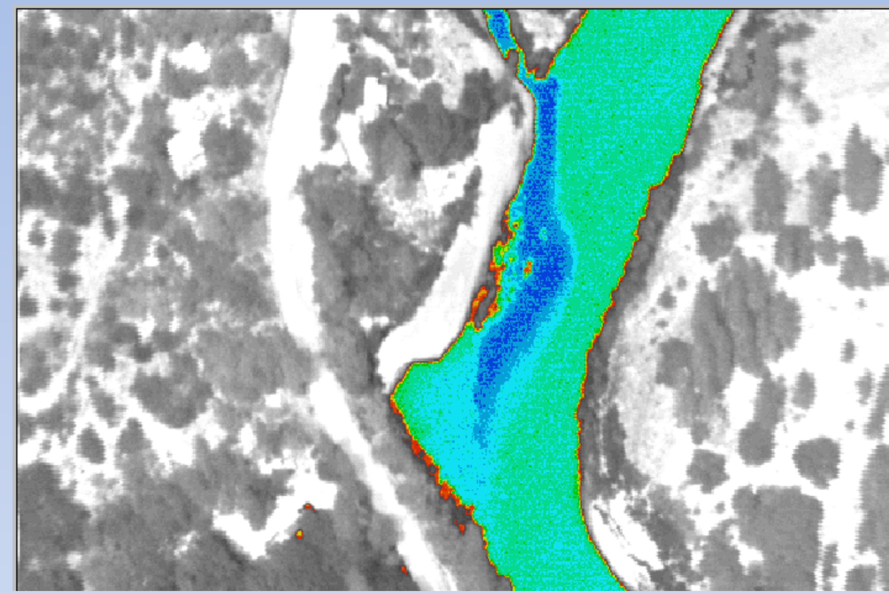
Background: Much of this information was presented at EPA's Columbia River Cold Water Refugia Project on June 1, 2016. This topic has been the focus of several Council presentations over the past year. The presentation at this meeting will help provide us with greater understanding of how and when fish use these areas.

More Info:

- Nov 2015 Presentation from Dan Isaak and Mike Young on Identifying, Protecting & Enhancing Climate Refugia for Salmonids: https://nwcouncil.app.box.com/files/0/f/5026695269/1/f_43890963189
- Dec 2015 Council Blog on Cold Water Habitats: https://www.nwcouncil.org/news/blog/cold-water-refugia/
- January 2016 Council briefing on the Distribution and use of Cold Water Refuges in the Willamette: https://www.nwcouncil.org/media/7149855/c02.pdf
- Graph of historic water temperatures in the mainstem Columbia (CRITFC): http://www.critfc.org/fish-and-watersheds/climate/#tempgraph

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





Matthew Keefer

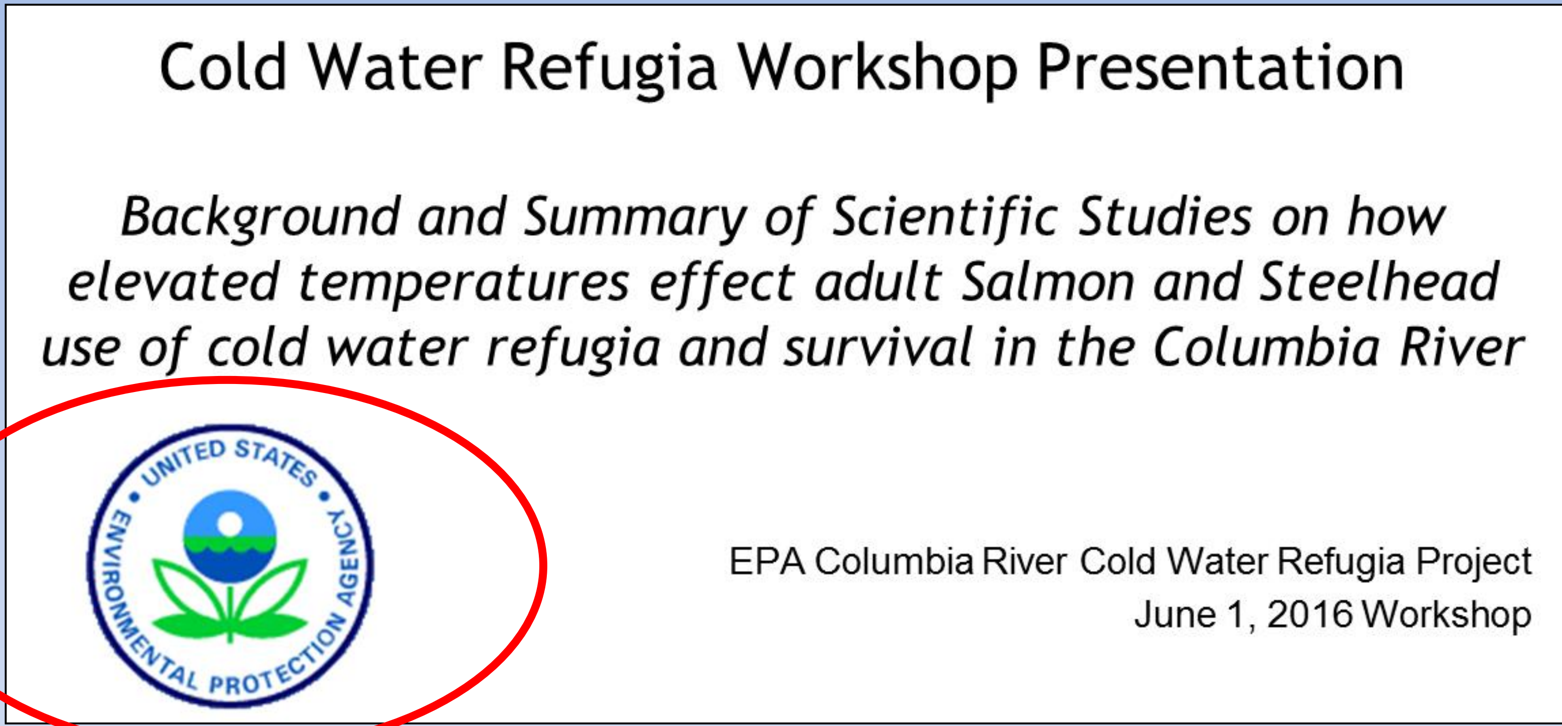
Department of Fish and Wildlife Sciences
University of Idaho

US Army Corps of Engineers®

NOAA

University of Idaho College of Natural Resources

Background. . . .



- ► 1 June 2015 workshop, led by John Palmer & team at EPA
- ► EPA, Oregon DEQ developing cold water refuge plans
- ► Response to NOAA's 2015 Biological Opinion
- **► Research: U. Idaho, NOAA Fisheries, Corps of Engineers**

Preview

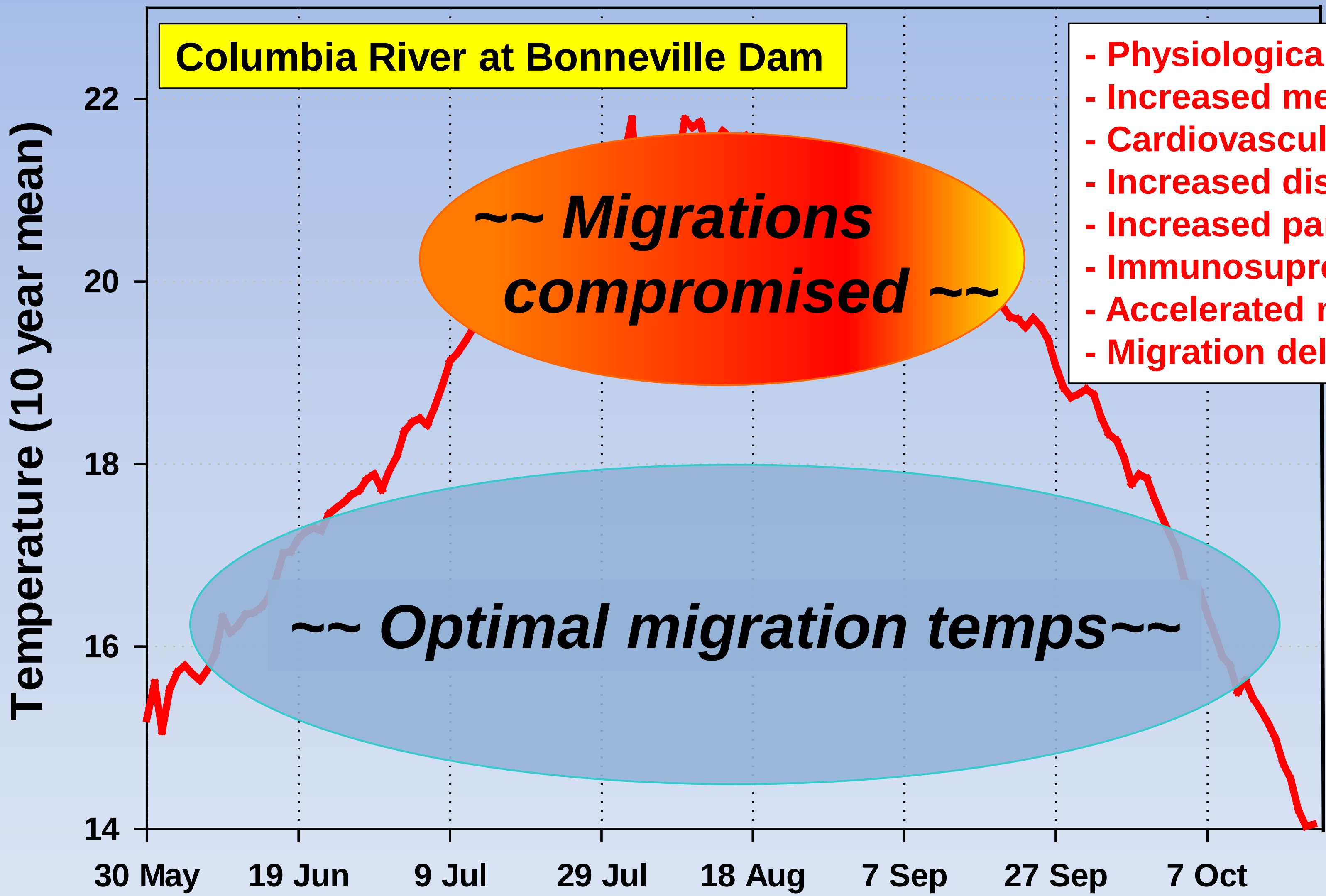
► **Warm main stem water temperatures and how migrating adult salmon & Steelhead respond**

- Migration corridors have seasonally stressful conditions for many species / populations

- Coping strategy: Find cool-water refuges along migration route

- Refuge use has many presumed benefits, but also some risks

The starting point: very warm migration corridors



- Physiological stress
- Increased metabolism
- Cardiovascular demands
- Increased disease risk
- Increased parasite load
- Immunosupression
- Accelerated maturation
- Migration delays

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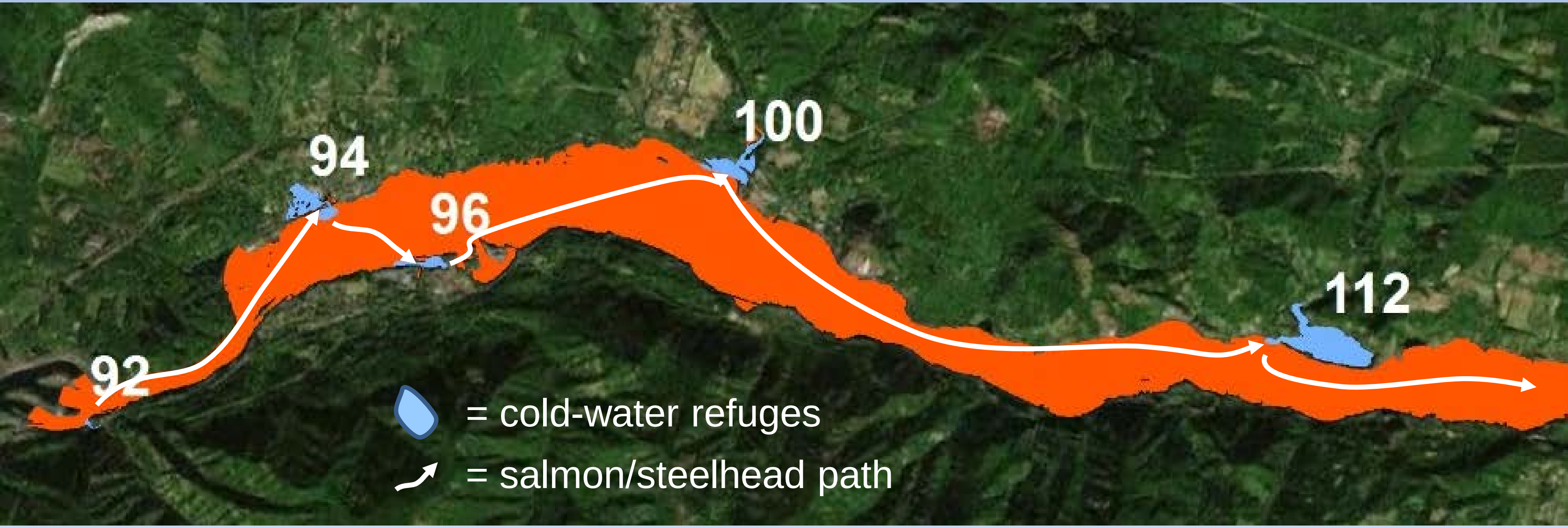
Adaptive response? Behavioral thermoregulation

Cool- and cold-water refuges along Columbia and Snake River migration corridors



How and when do adult salmon and steelhead use refuge sites? What are the consequences of use / non-use?

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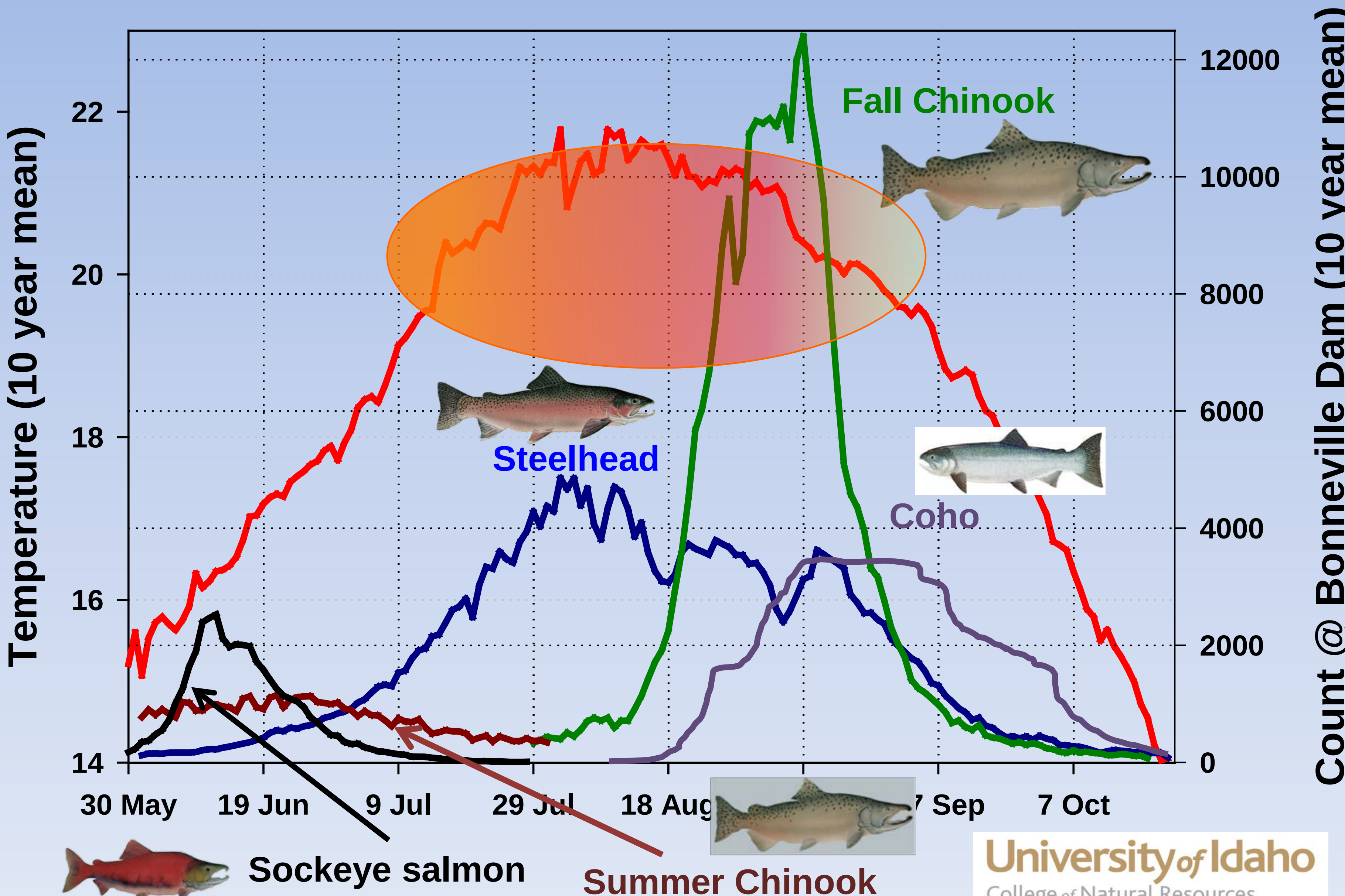
Adult run timing in relation to temperature



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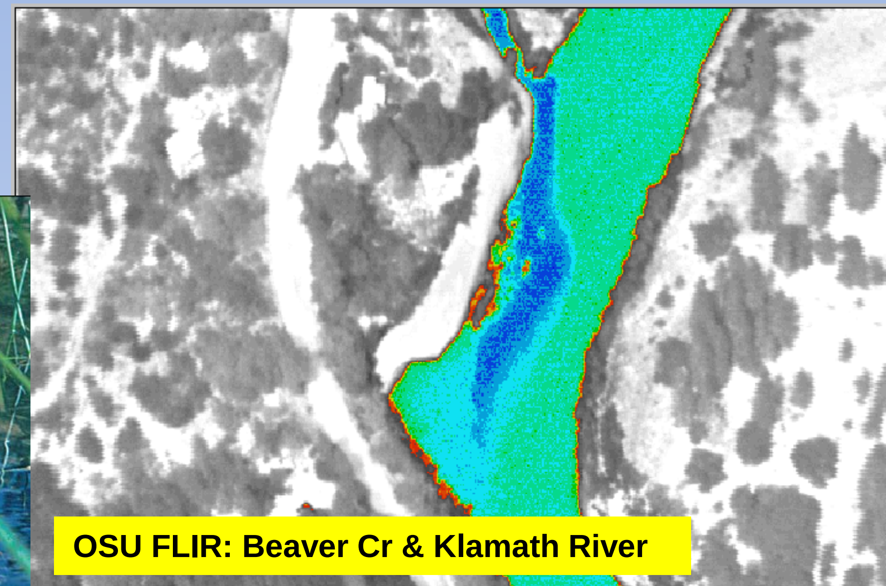
Identifying cool water refuge (CWR) sites

• Most are at tributary confluences along COL / SNR migration corridors



EPA 910-C-12-001

United States Environmental Protection Agency — Region 10, 1200 Sixth Ave., Seattle, WA 98101 — Alaska, Idaho, Oregon, Washington

Water Division — Office of Water and Watersheds — February 2012

EPA

Primer for Identifying Cold-Water Refuges to Protect and Restore Thermal Diversity in Riverine Landscapes

Torgersen et al. (2012)

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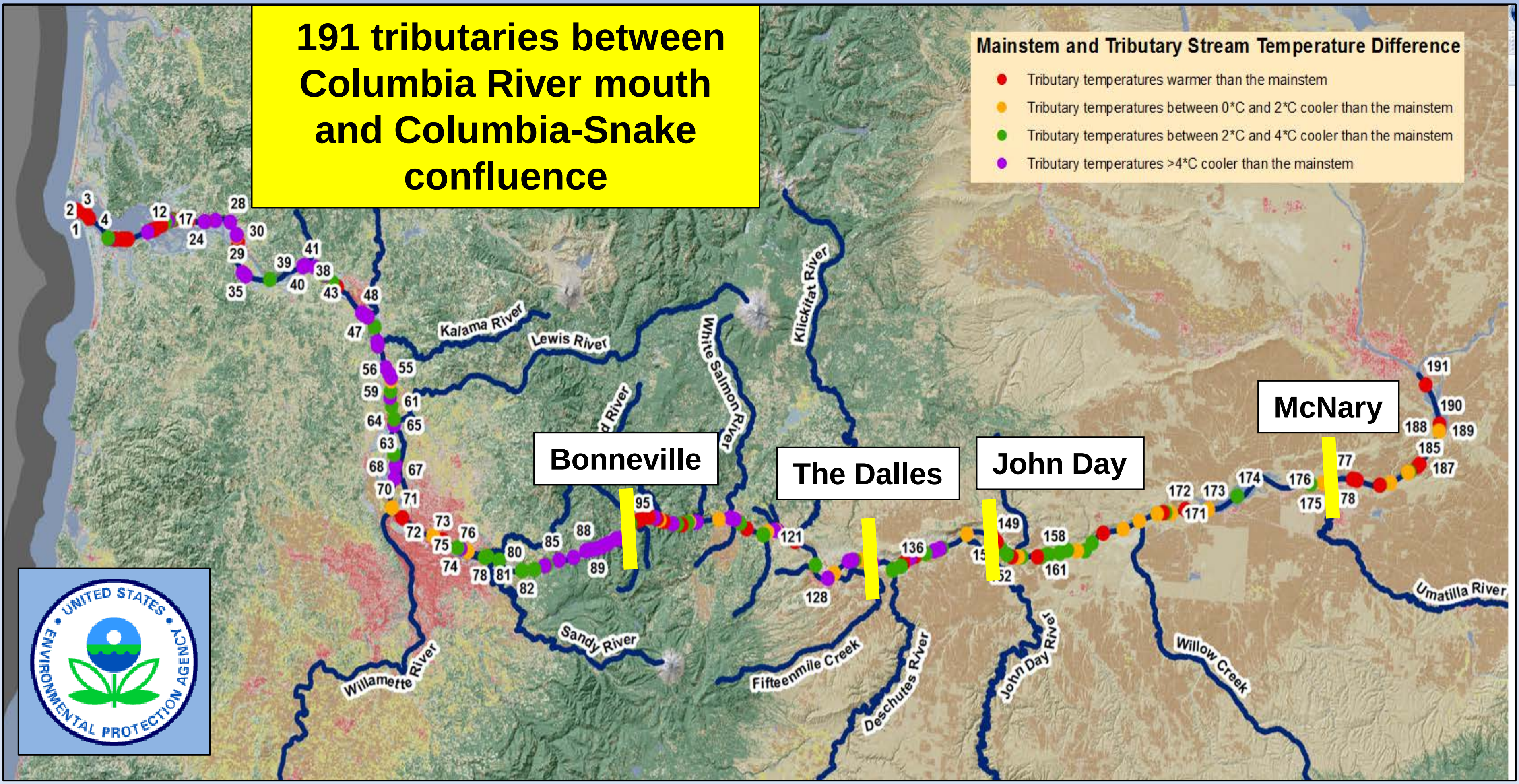
Lower & Mid Columbia: Cold water refuge tributaries identified in EPA catalog



Temperature data source: NorWest, USFS

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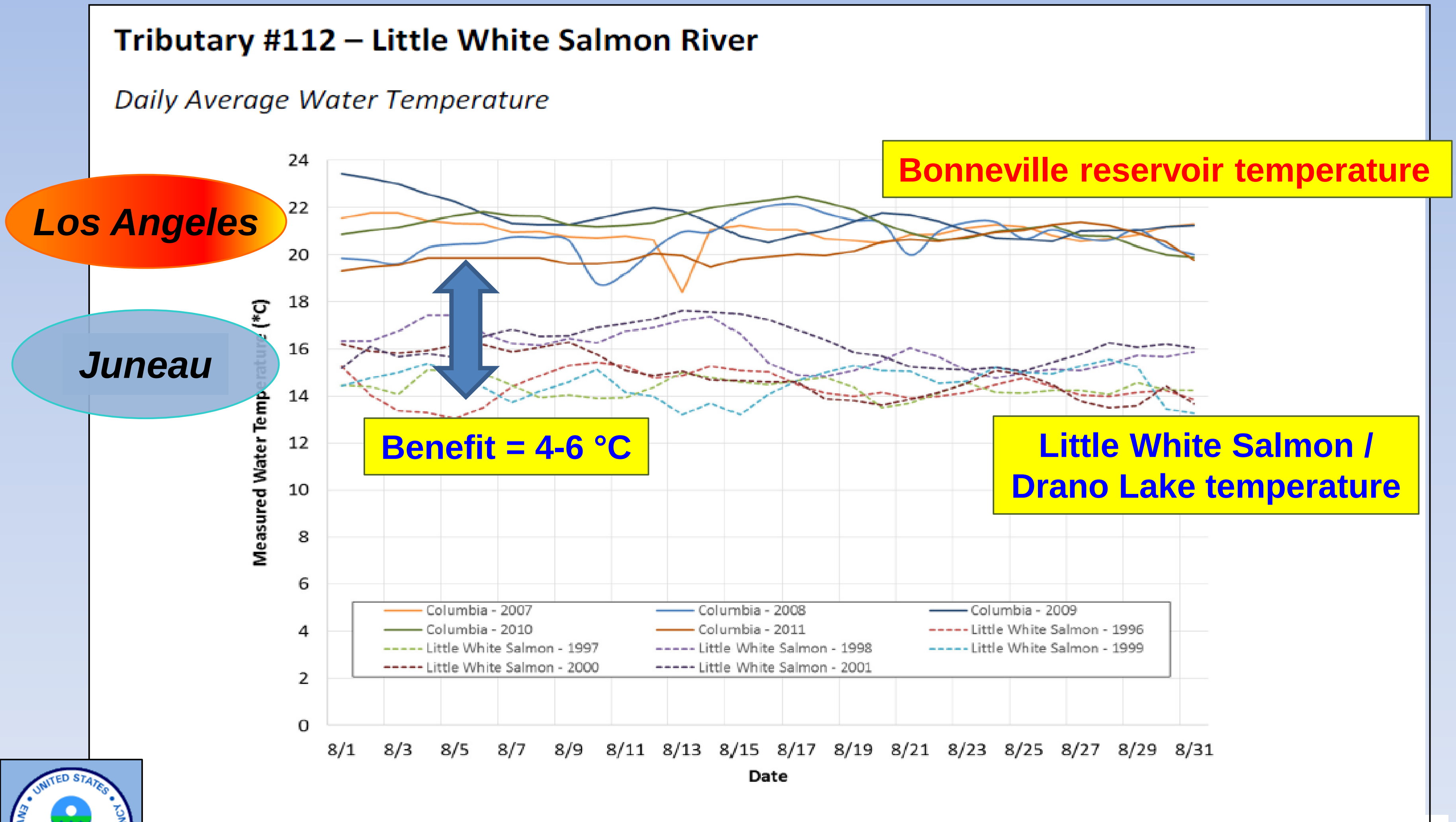
A classic thermal refuge site in Bonneville pool



Data source: NorWest, USFS

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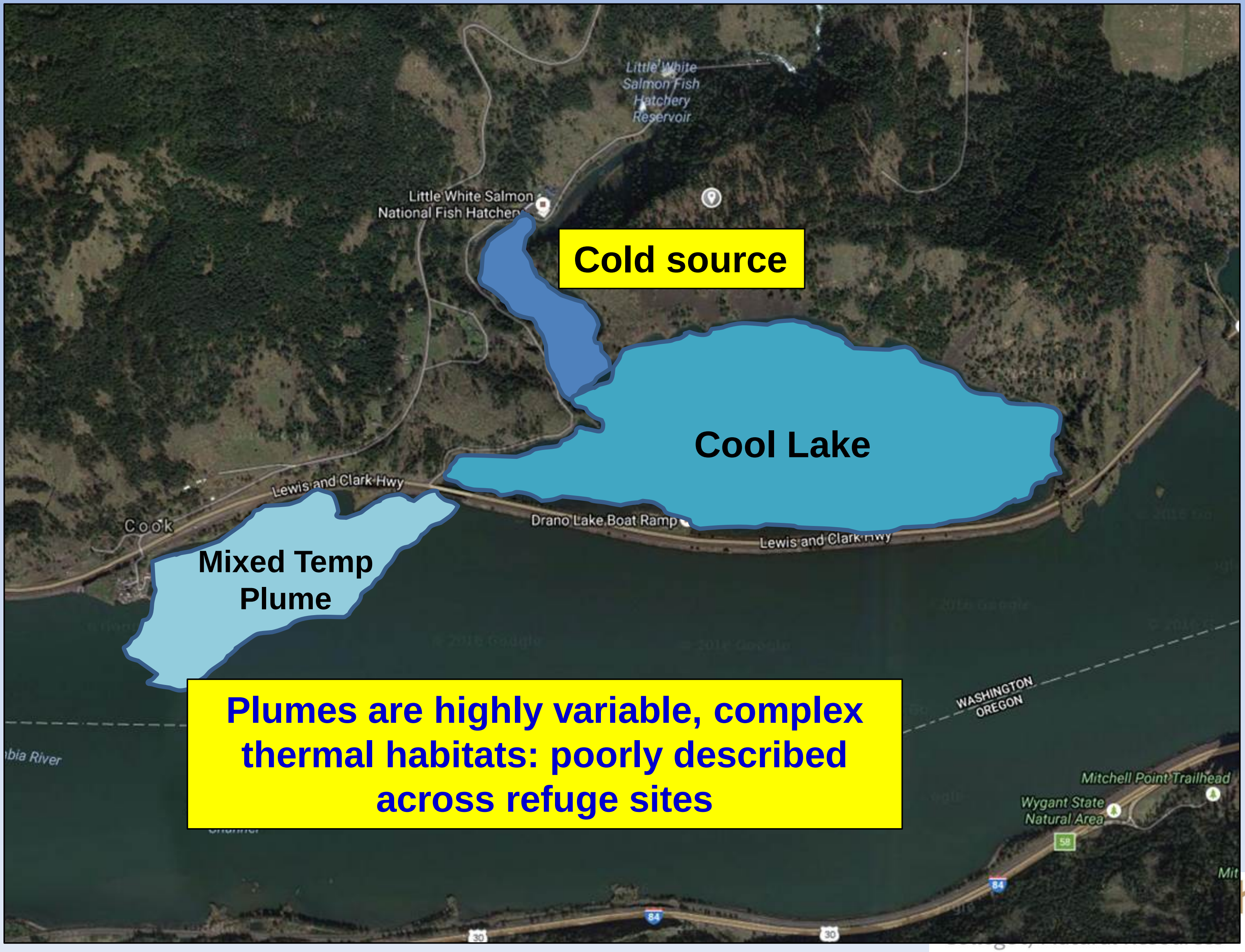
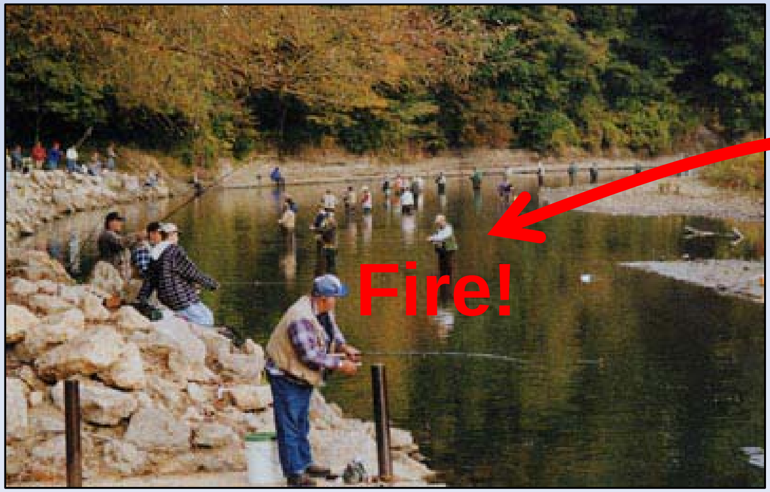
Little White Salmon / Drano Lake refuge (rkm 261)

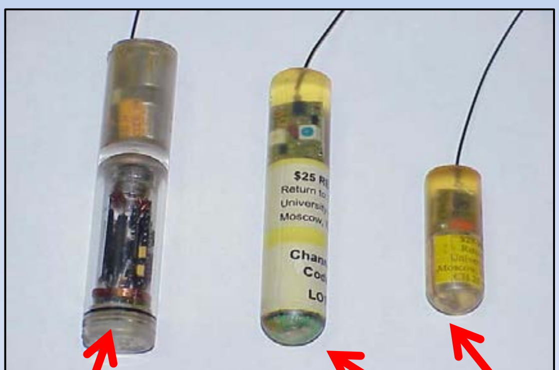


Drano Lake – A thermal refuge, but with a cost



Research: Adult salmon and steelhead telemetry

US Army Corps of Engineers ®



Temperature-recording
Radio transmitter (~100s)

Radio transmitters (~25,000)
At Bonneville from 1996-2015

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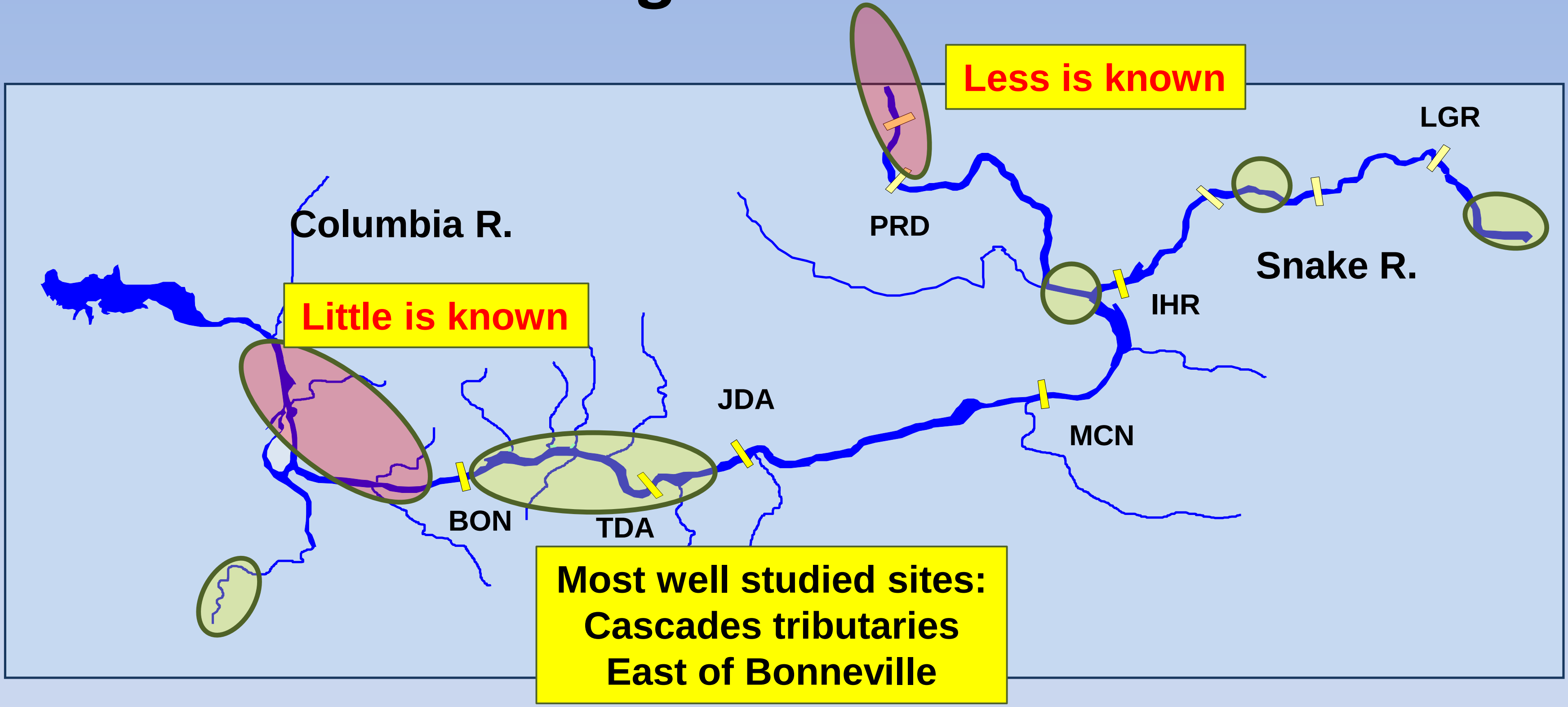
Behavioral thermoregulation studies



- **Behavioral response by salmon and steelhead identified at a variety of locations**

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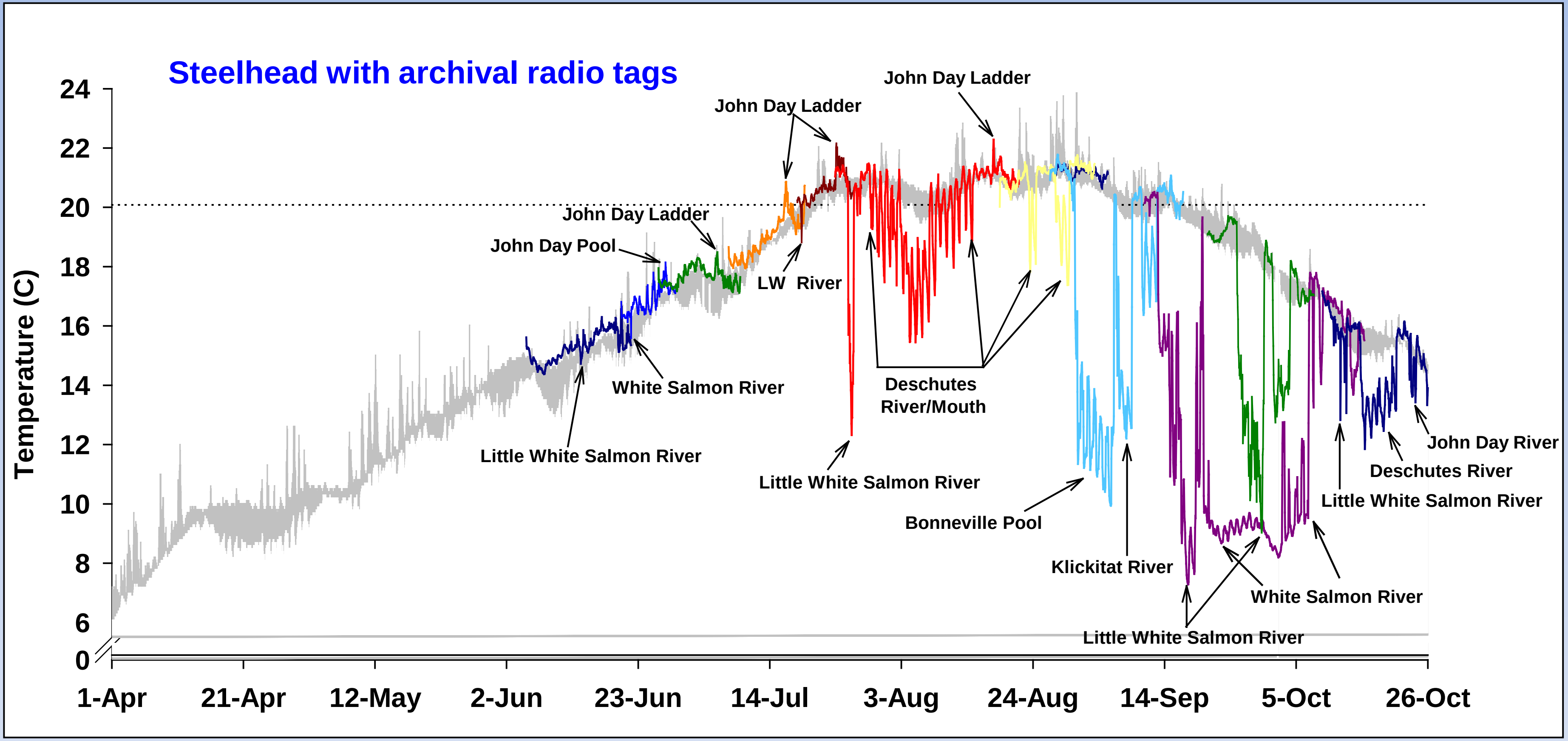
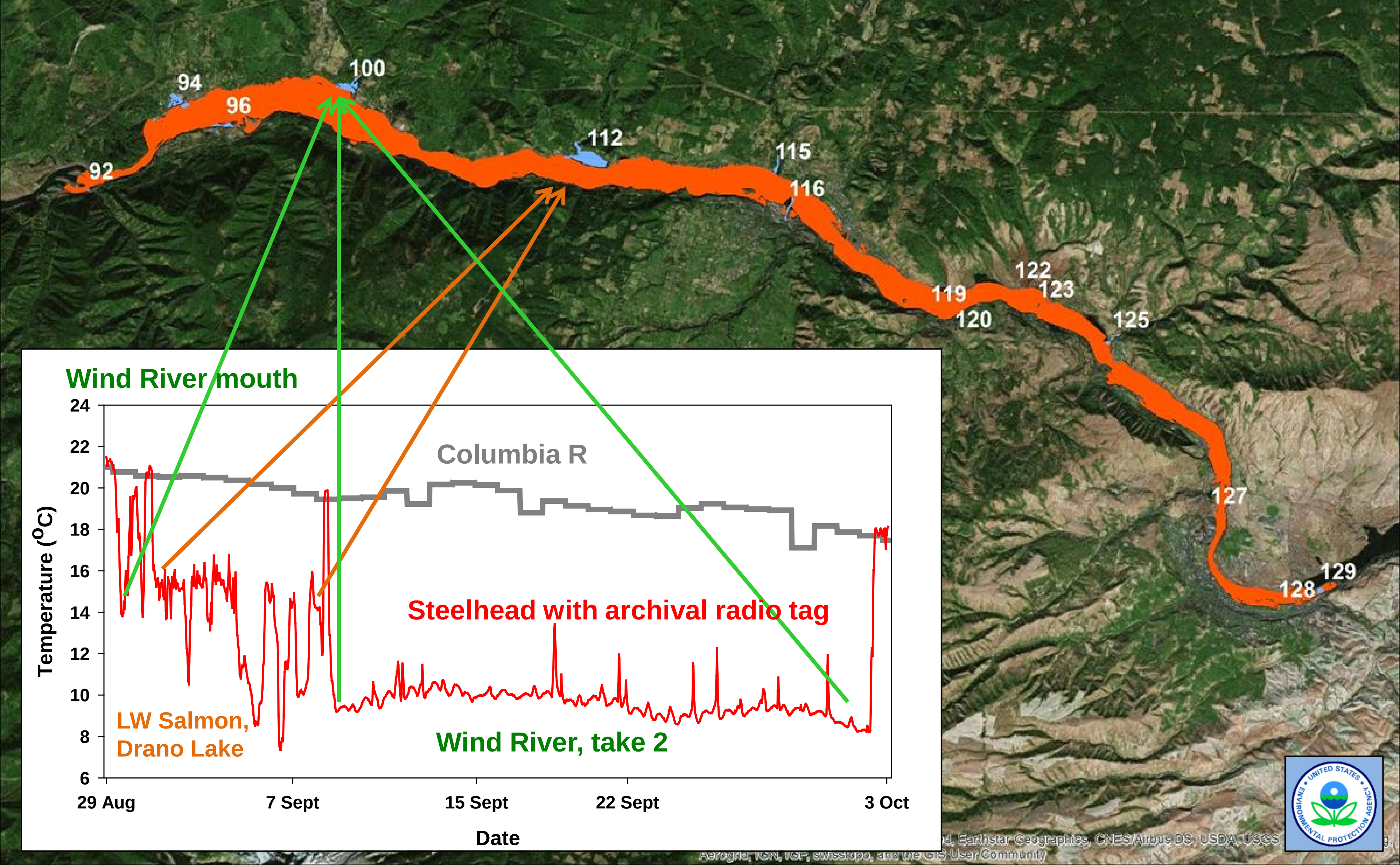
BON-MCN Refuge use: Steelhead



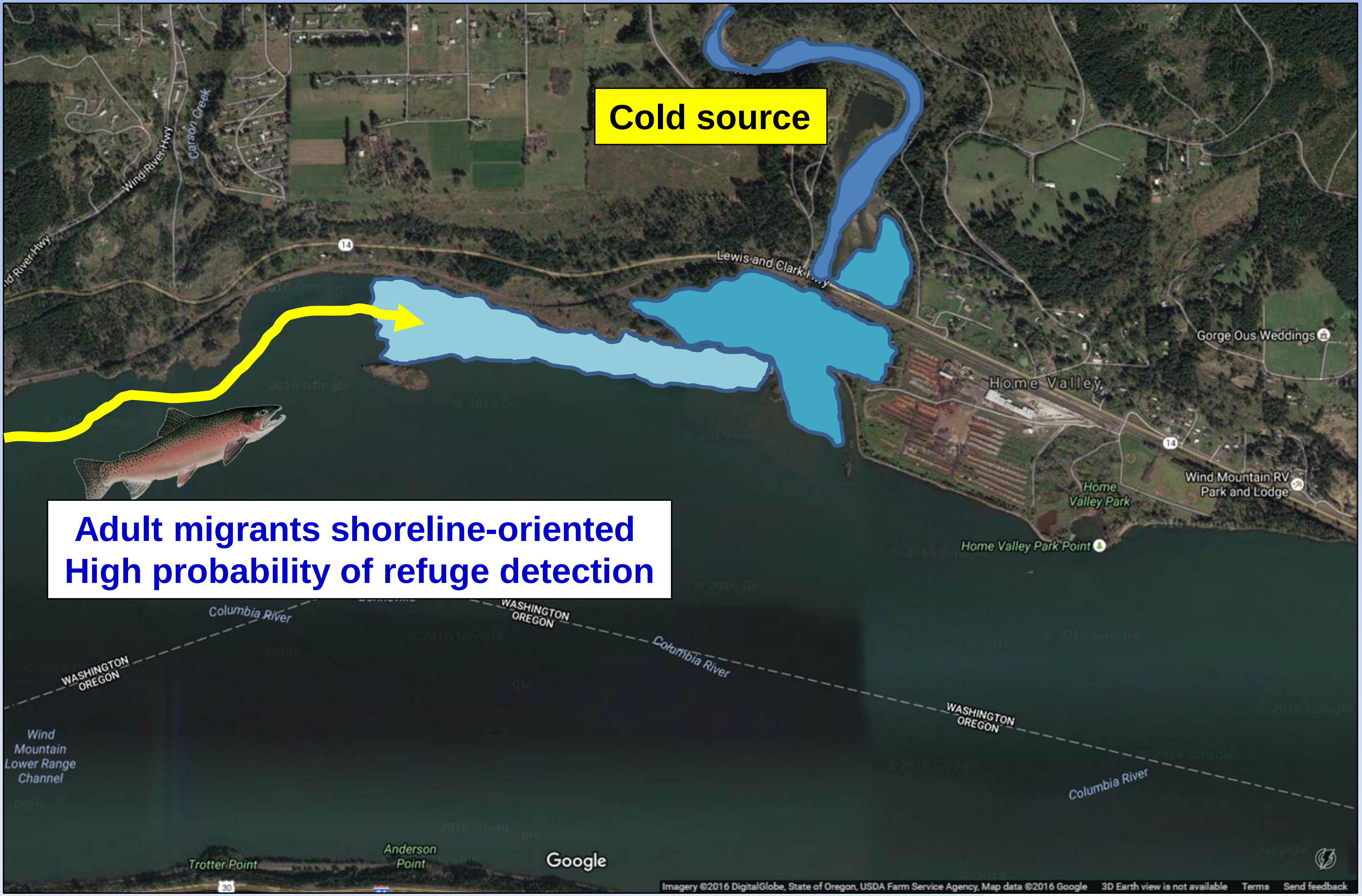
- **Steelhead have relatively flexible migration (spring spawners) and refuge use often lasts weeks**

Refuge use: Steelhead

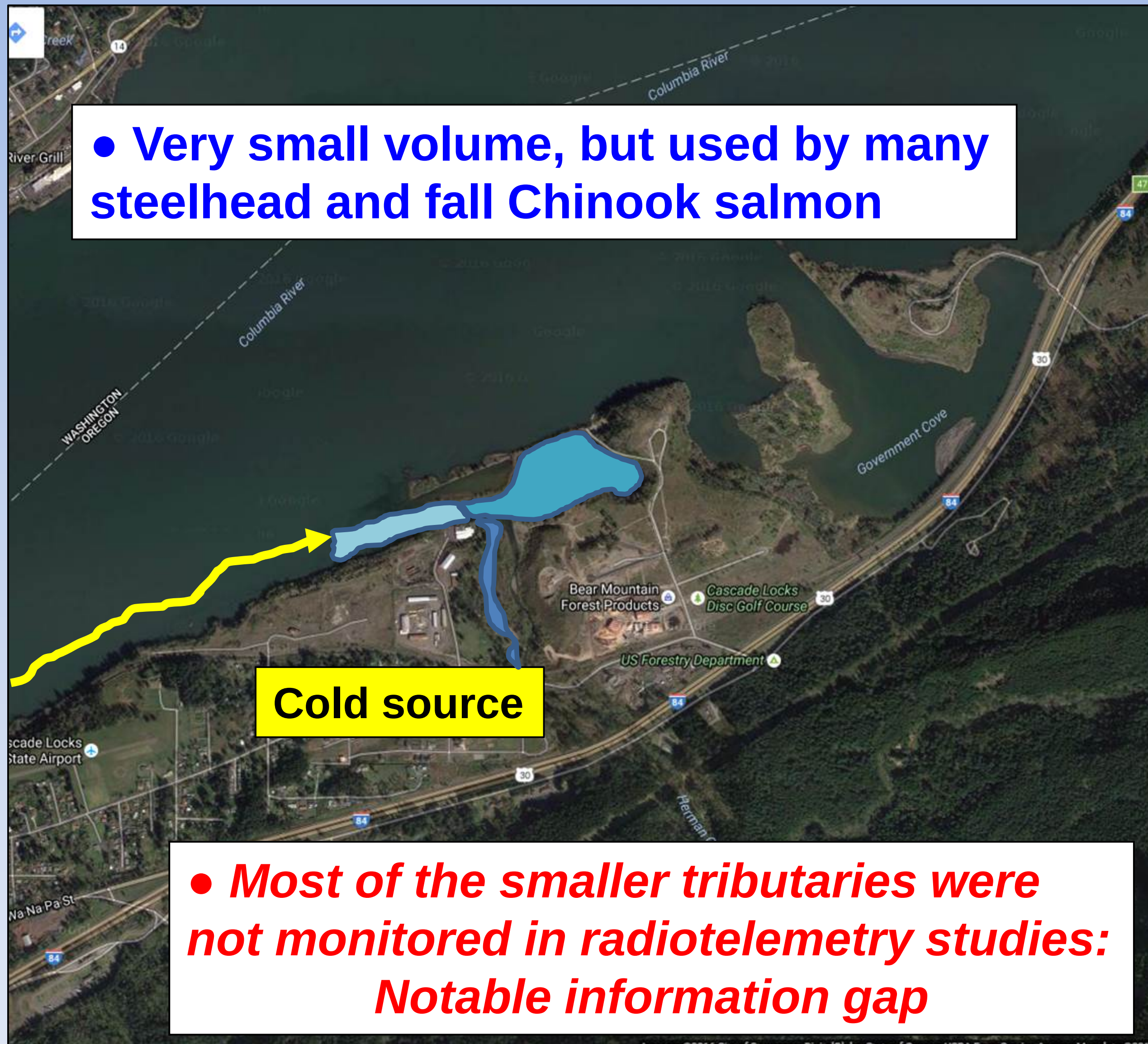
Columbia River between Bonneville Dam and The Dalles Dam



Wind River: large refuge (rkm 249)



Herman Creek: small refuge (rkm ~243)



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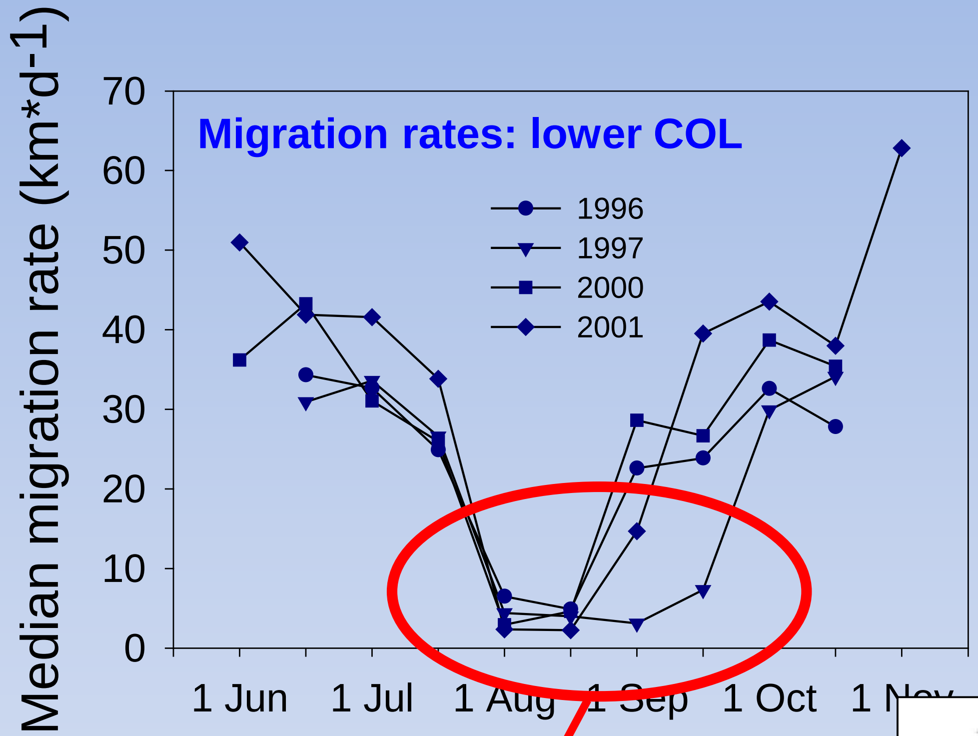
Steelhead: migration rates + refuge times

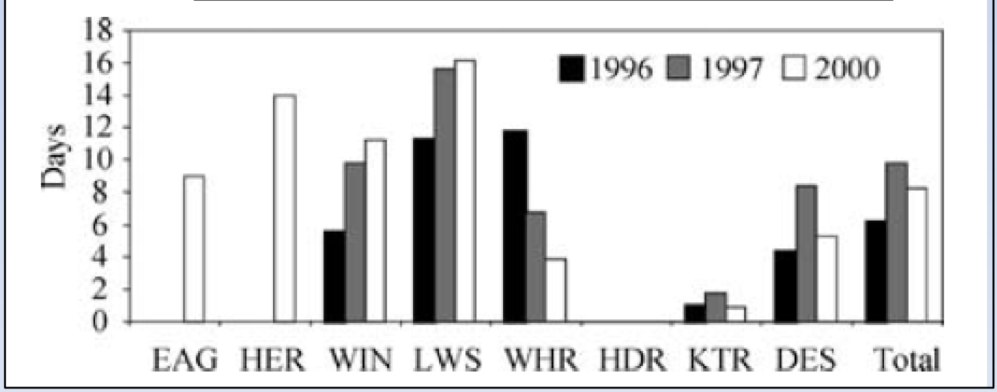


Keefer et al. (2004, TAFS)

Cool-water refuge residence by
Large majority of steelhead

● Upstream migration rates from large radiotelemetry studies show greatly reduced steelhead swim speeds & extended refuge use

Refuge use times (median days)



High et al. (2006, TAFS)

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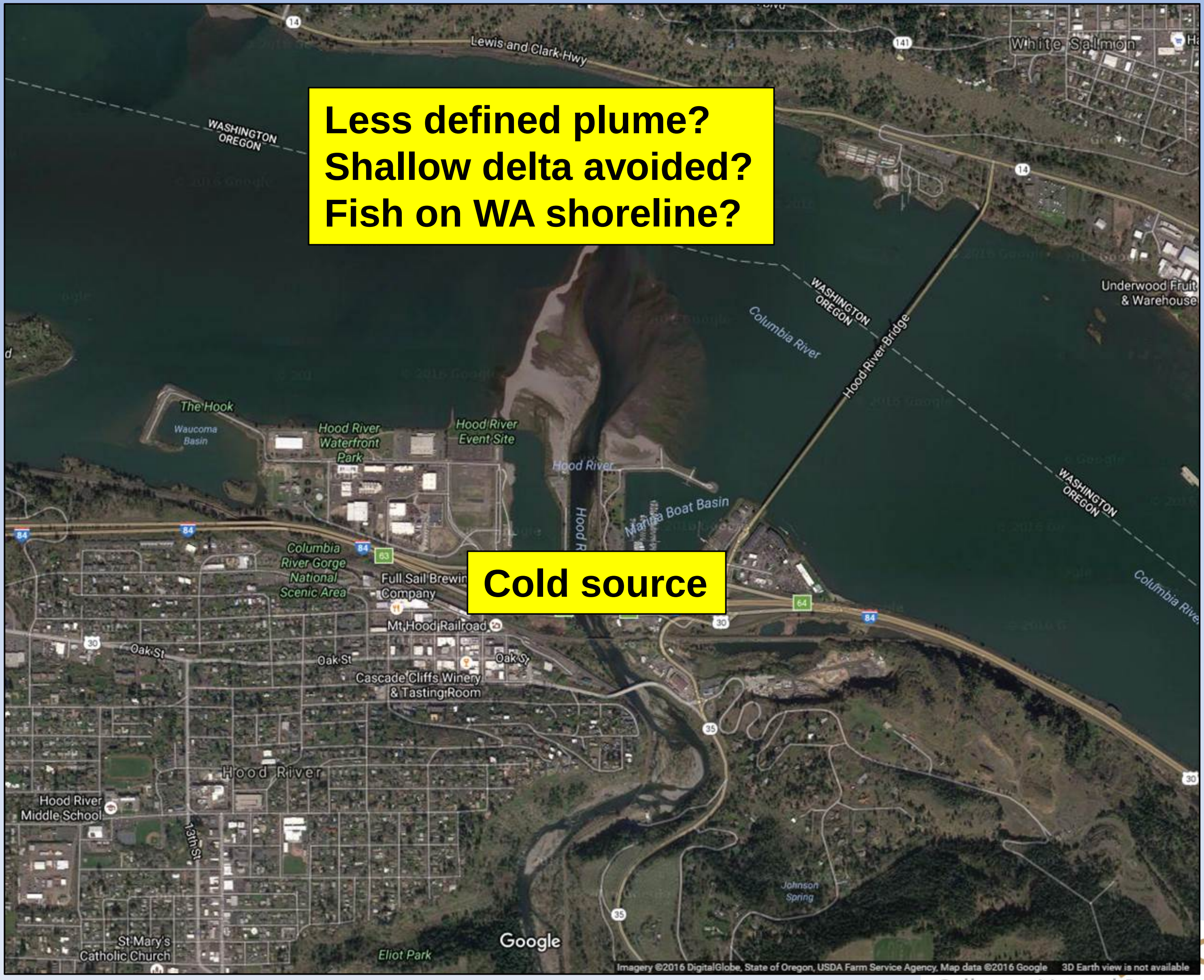
Hood River: limited-use refuge (rkm 273)



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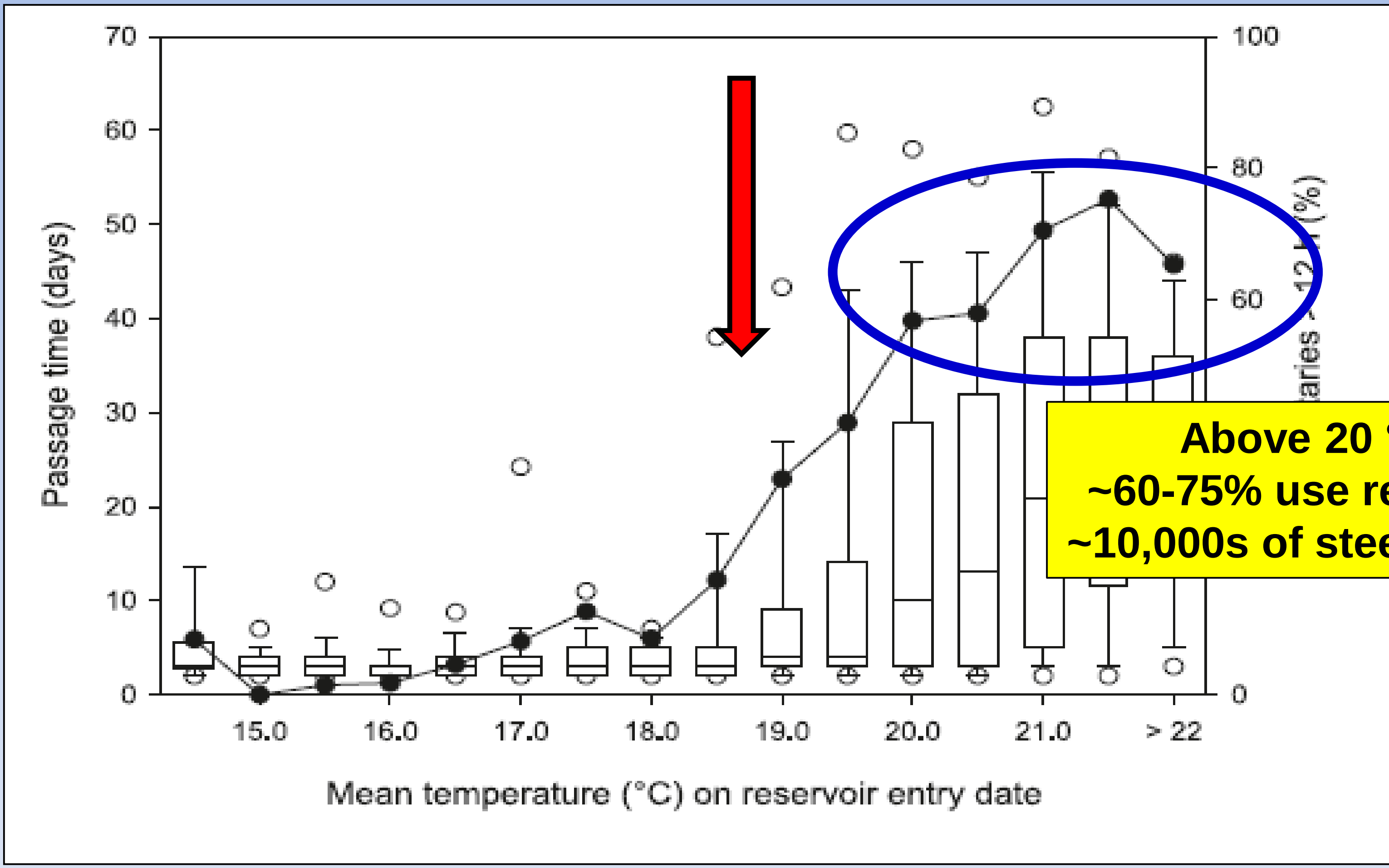
Steelhead: Threshold temperatures

Likelihood of using a refuge in Bonneville reservoir > 12 h



Above 20 °
~60-75% use refuge
~10,000s of steelhead

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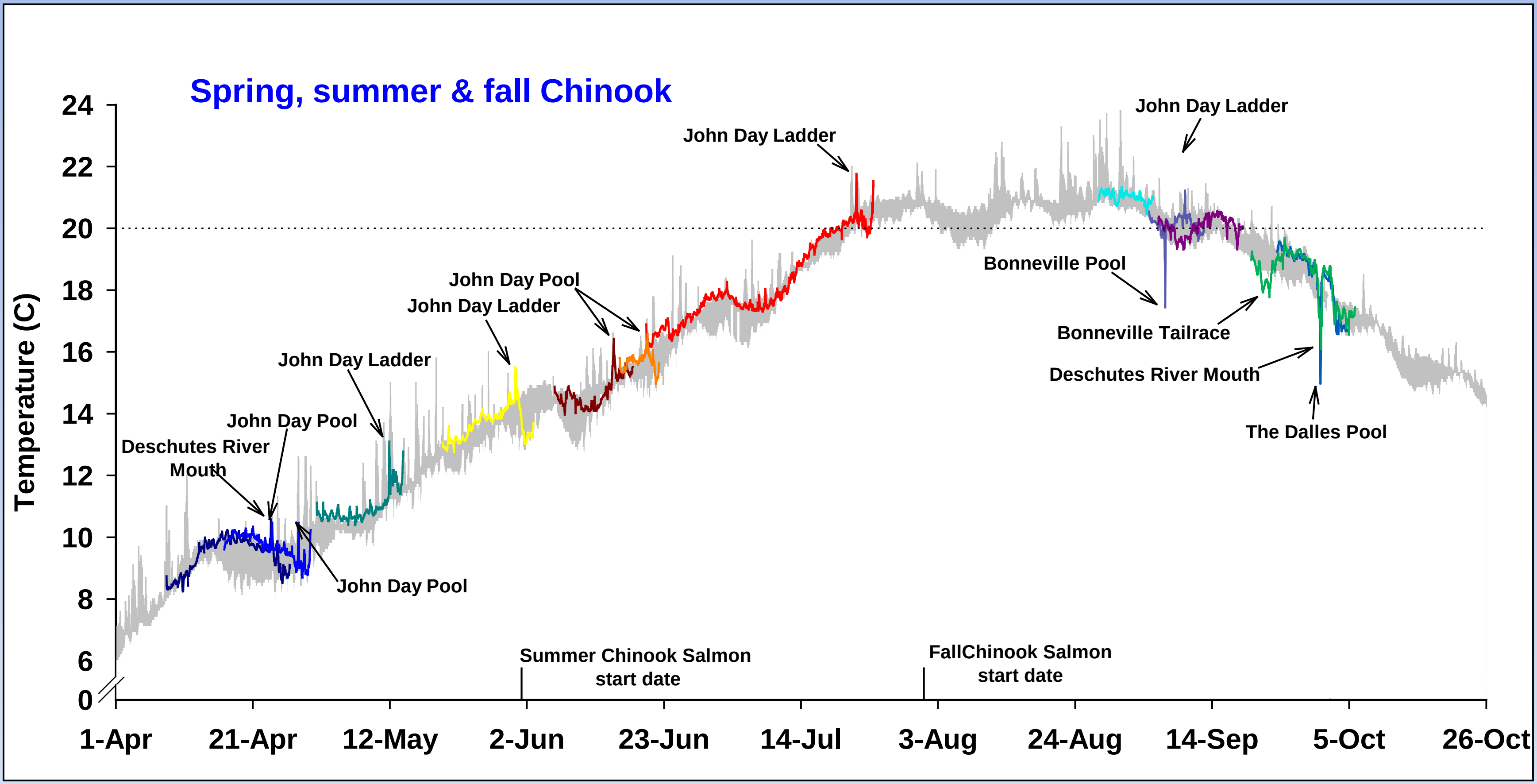
Refuge use: Chinook salmon



- **Chinook salmon have less flexibility, use refuges briefly (*median* = 3 d for fall Chinook)**

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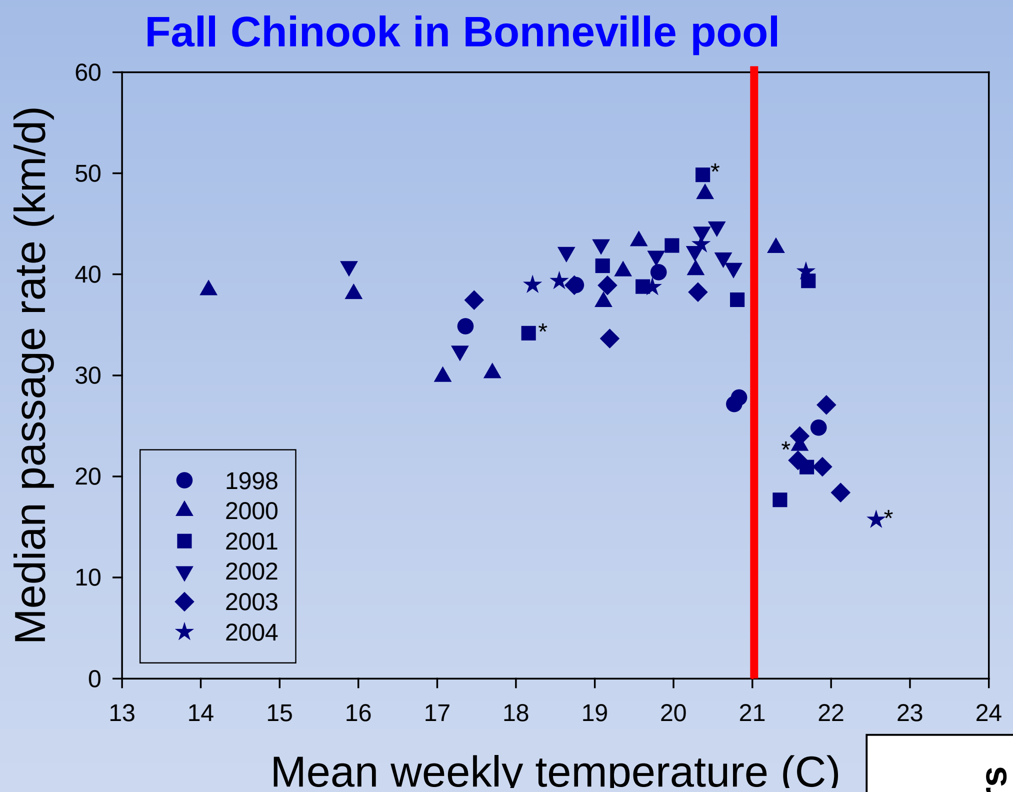
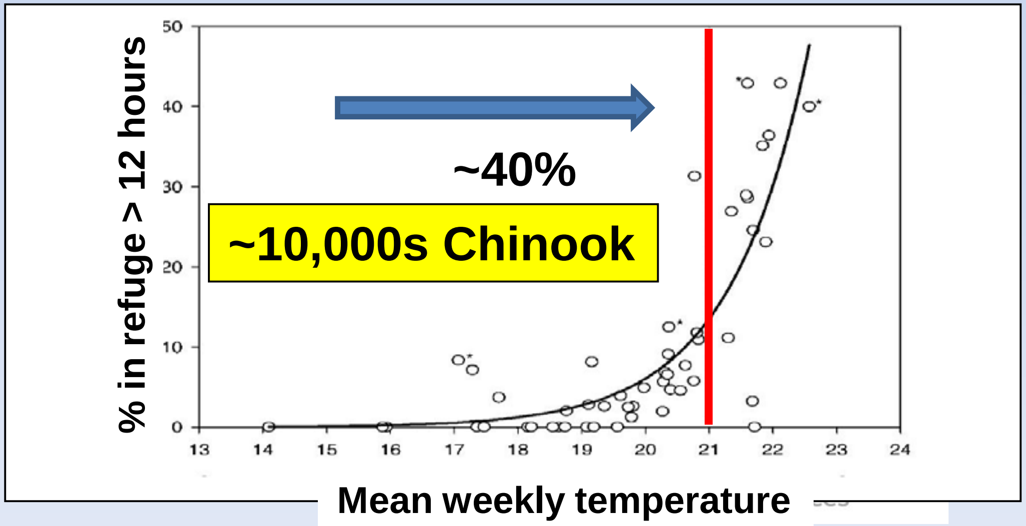
Chinook salmon: migration rates

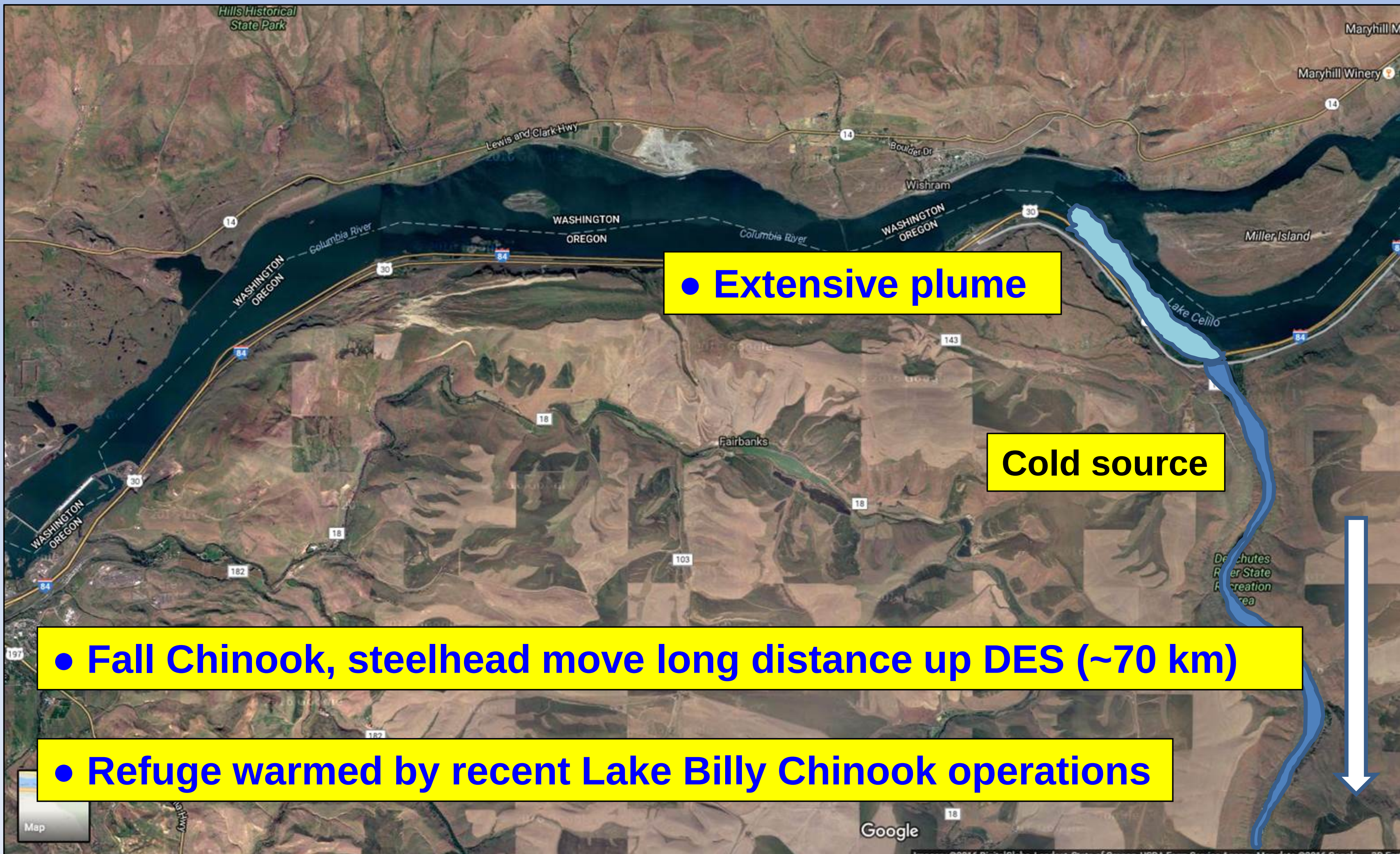


- **Fall Chinook salmon migration rates drop by ~50% at warmest main stem temperatures**



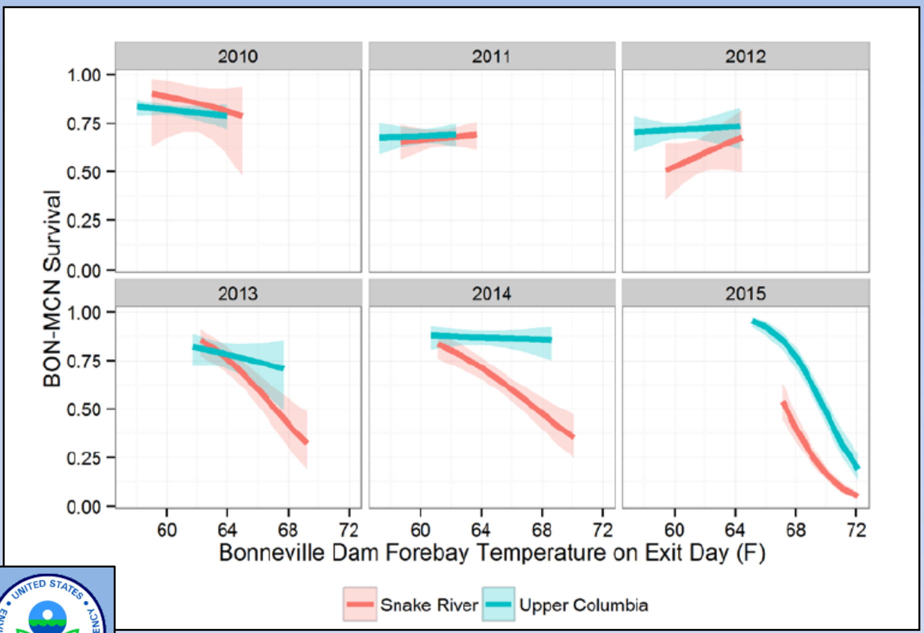
Goniea et al. (2006, TAFS)

Deschutes River: very large refuge (rkm 328)



Refuge use: Sockeye salmon

● Clear temperature – mortality signal for sockeye salmon, but. . .



● Very few (~1%) of 760 radio-tagged sockeye used refuge sites in Bonneville reservoir in 2013-2014 study

● Limited refuge use in Snake River in 2000 study despite temperatures >20°C

● Anecdotal reports of sockeye in refuge sites have mostly been of moribund fish

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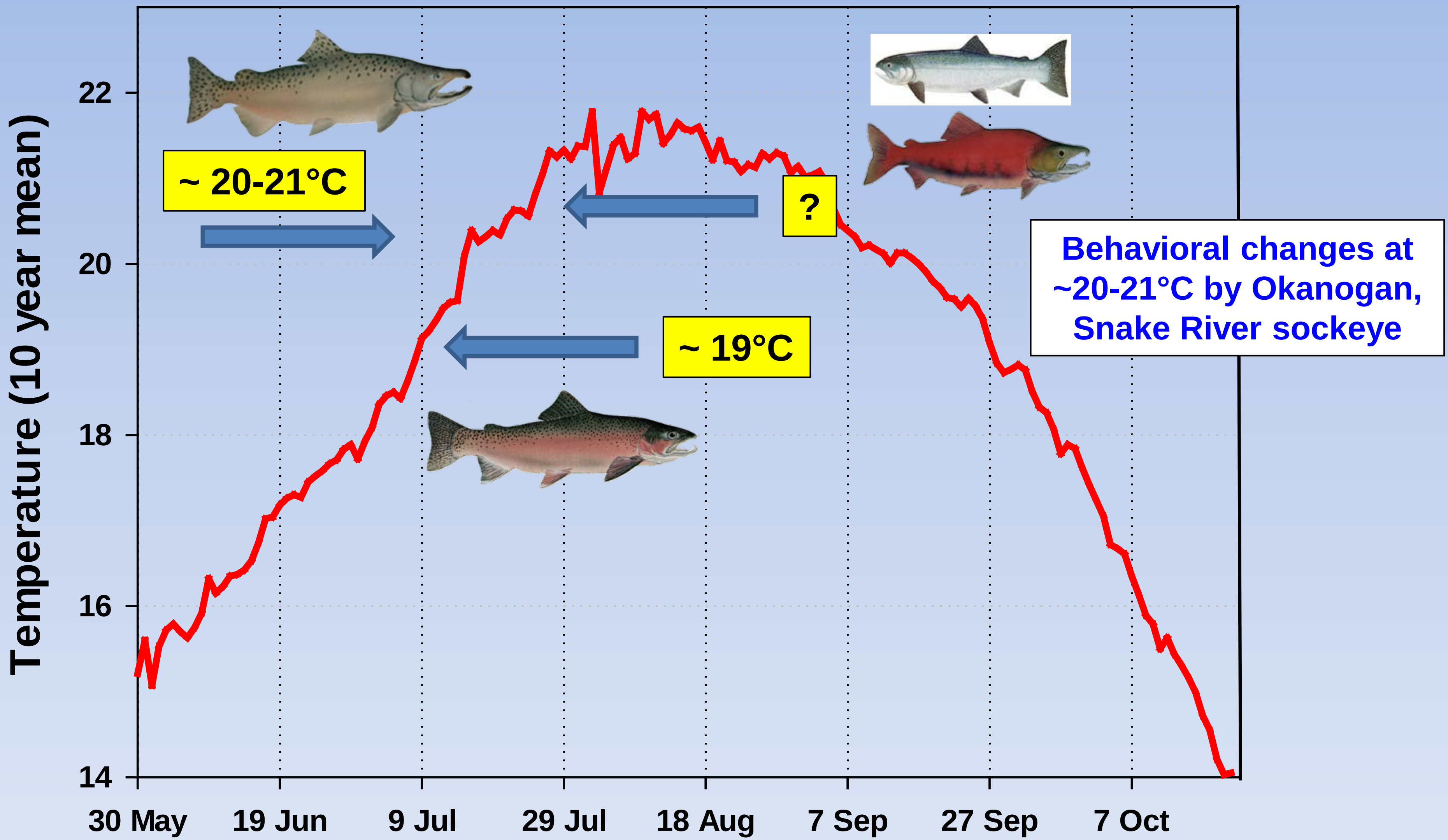
Threshold temperatures prompting refuge use



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Some important uncertainties

- Will warming continue?
- Will there be enough thermal refuge habitat?
- What are the relationships between refuge use / non-use and adult mortality and fitness?
- Can populations adapt to changing climate?

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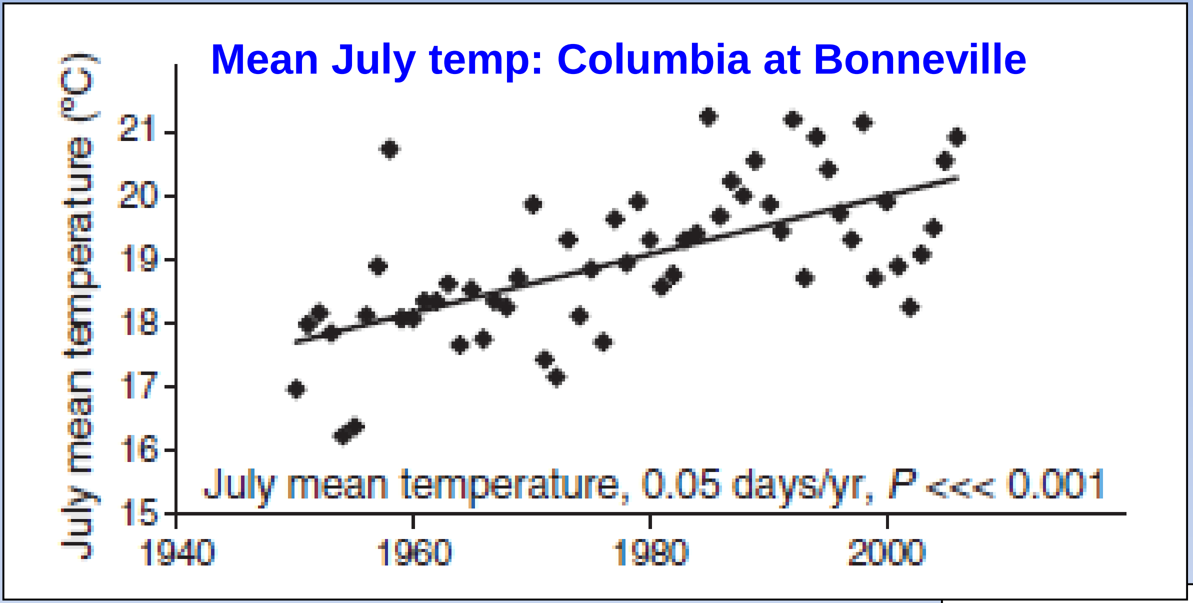
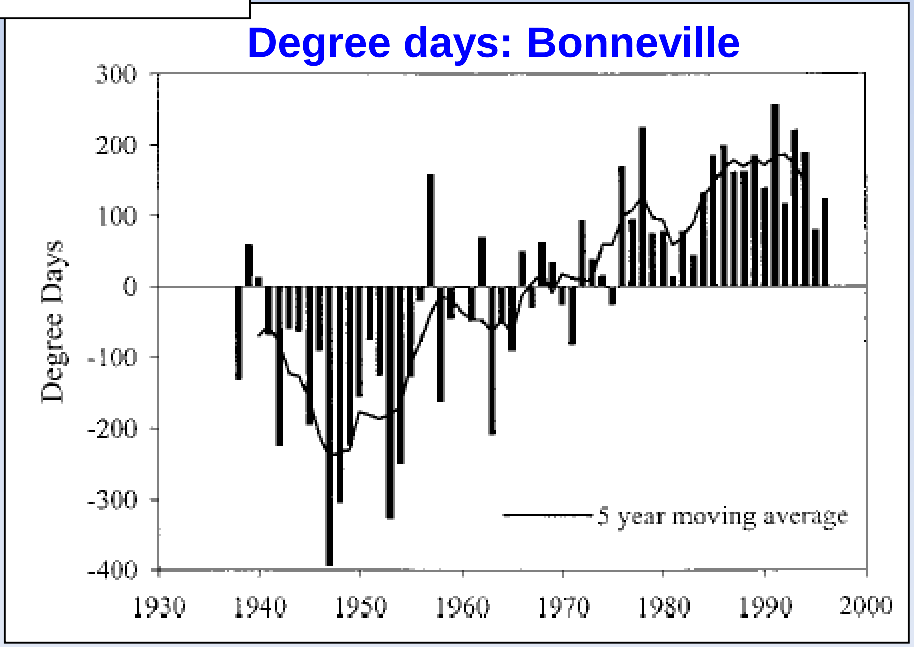
Will warming continue? (Probably)



Crozier et al. (2008, Evol App)

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

- Increasingly stressful conditions for many populations



Robards & Quinn (2002, TAFS)

Will warming Continue?

► **Long stretches of the main stem Columbia and Snake Rivers have no (or very limited) thermal refuge sites**

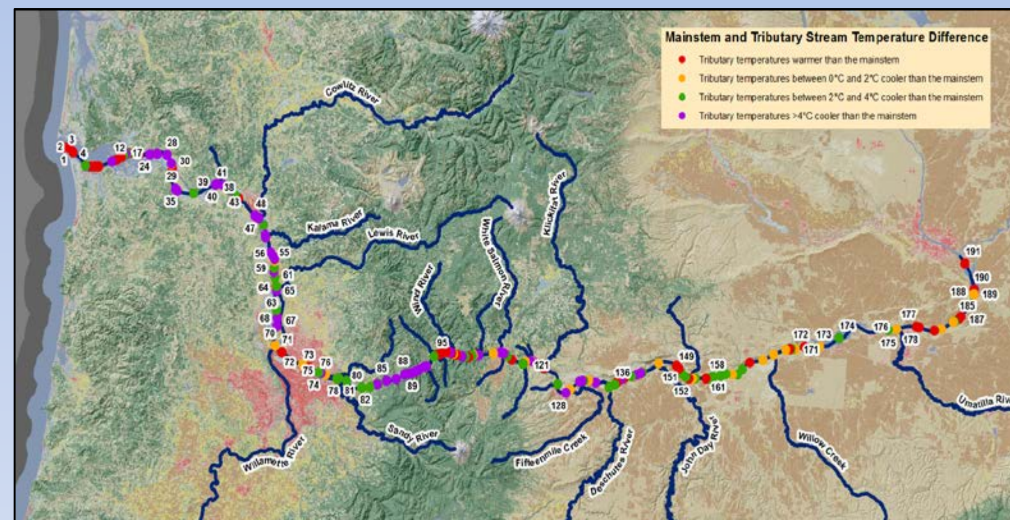
● These reaches may present significant migration barriers for adult fish – some barriers are episodic, some likely to become chronic

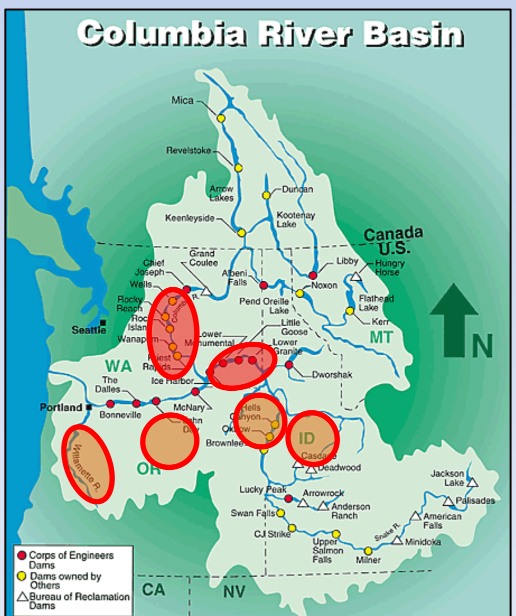
Will there be enough refuge habitat?

► Expectation: Preferred thermal habitats will be reduced as regional climate continues to warm

► A better inventory of existing refuge sites is needed

► Region needs to prioritize identification, protection, and restoration of high-quality thermal habitats





United States Environmental Protection Agency

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Costs / Benefits of refuge use?

Mostly untested assumptions: use of thermal refuge sites provide survival and/or fitness benefits. . . . .

. . . 80,000 steelhead can't all be wrong, right?

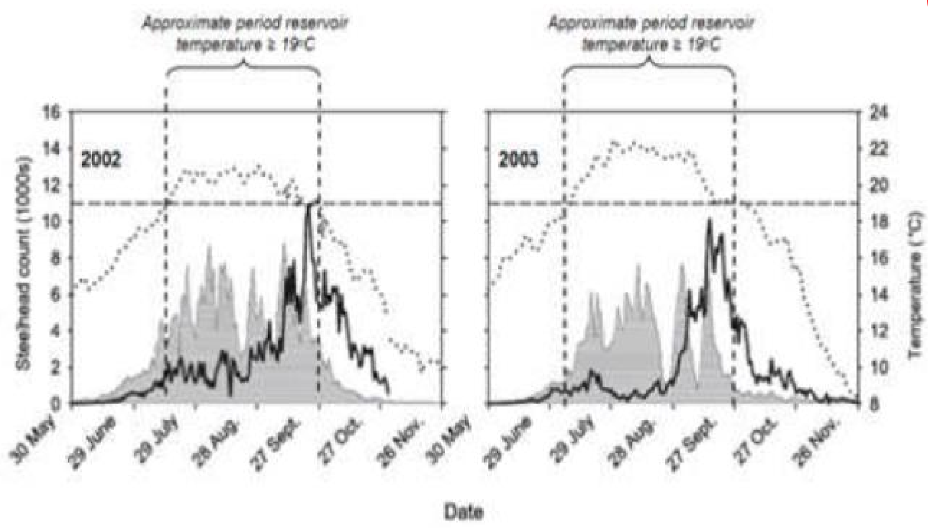


Figure 4. Number of steelhead counted at Bonneville Dam (shaded area) and at John Day (solid black line) for 2002-2003. The vertical dashed lines bound the time periods when an increased use of thermal refuges is observed. The horizontal dashed line at 66.2°F (19 °C) line is a threshold temperature where use of thermal refuges rapidly increases. The dotted lines are the average daily Columbia River water temperature at the Bonneville Dam. *Sources*: Graph modified from Keefer et al 2009, (2002 and 2003 years excerpted); Columbia River temperatures from DART (water quality monitoring site in Bonneville Dam forebay; *www.cbr.washington.edu/dart/river.html*).

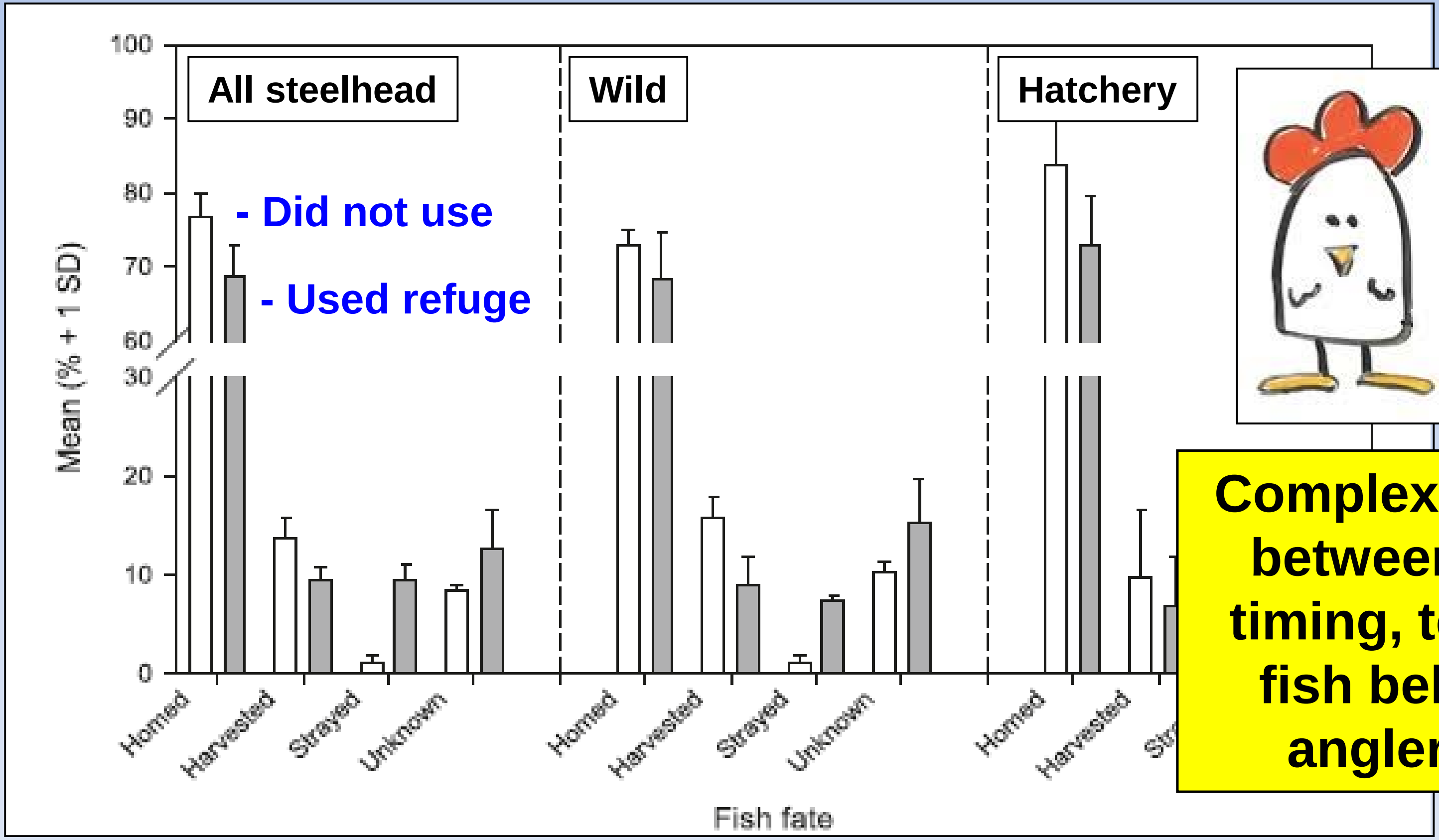
Source - Cramer Fish Sciences, 2011

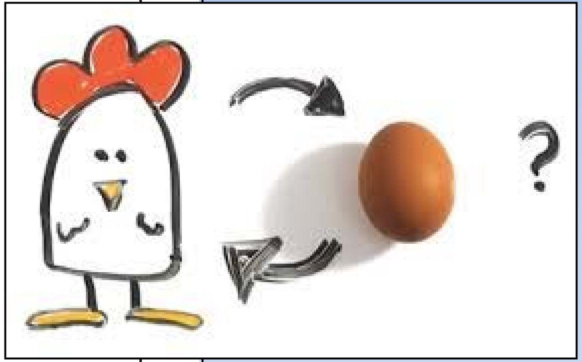
- Approximately 80,000 Steelhead in CWR tributaries in August
- Based on following rough estimate:

- BON July 15 – Aug 31 = Approx. 5,000 Steelhead/day = 225,000
- 225,000 x .76 (10 year avg. % expected to pass JDA) = 171,000
- JDA July 15 – Aug 31 = Approx. 2,000 Steelhead/day = 90,000
- 171,000 – 90,000 = 81,000 of Steelhead using CWR between BON- JDA

Costs / Benefits of refuge use?

Radio-tagged refuge users were less likely to survive to natal tributaries than non-users
- 5% (wild) to -11% (hatchery)





Complex interactions between migration timing, temperature, fish behavior, and angler behavior

Keefer et al. (2009, CJFAS)

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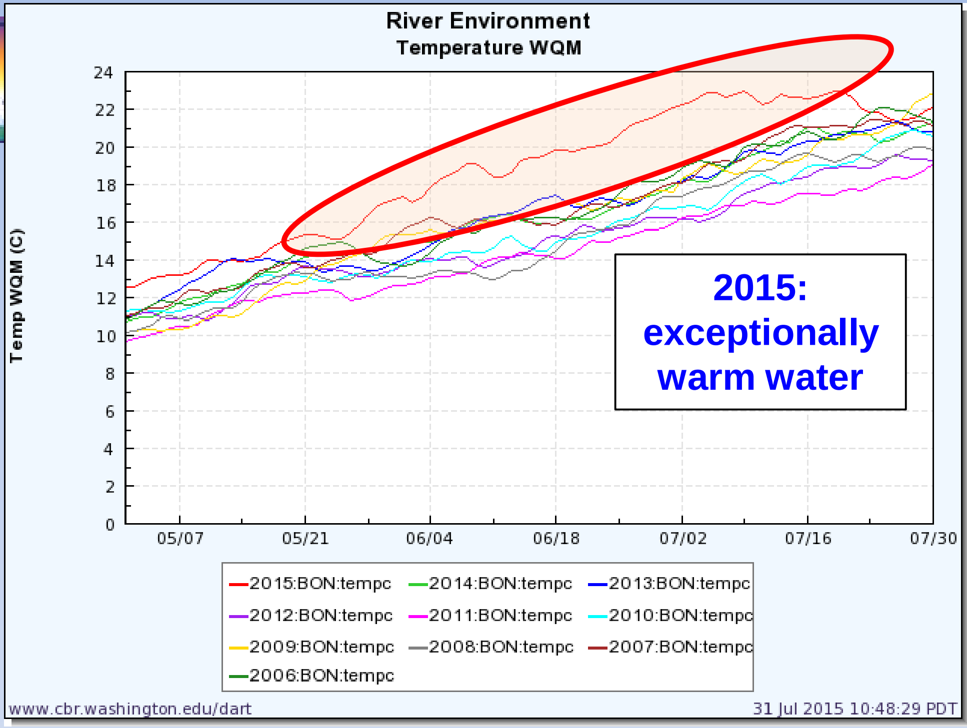
Can refuge use reduce *en route* mortality?

The Columbia Basin Fish & Wildlife News Bulletin

AP

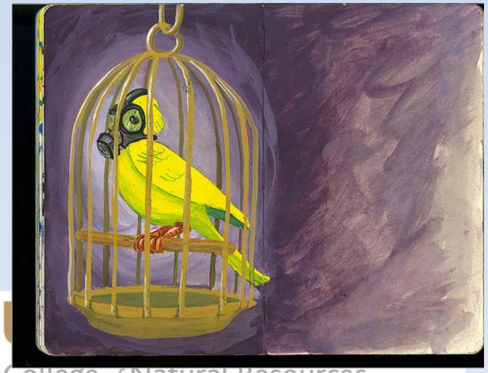


POST-MORTEM 2015 SNAKE RIVER SOCKEYE RUN; 90% OF FISH DEAD BEFORE REACHING ICE HARBOR DAM

WARM WATER HITTING RETURNING SOCKEYE HARD: NOAA SAYS MAYBE 80 PERCENT MORTALITY FOR UPPER COLUMBIA

250,000-400,000 Sockeye mortalities

=



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Does refuge use reduce prespawn mortality?

Chinook salmon prespawn mortality, Middle Fork Willamette River

Exposure to warm water during migration linked to premature mortality on spawning grounds

Chinook salmon prespawn mortality, South Fork Salmon River

Keefer et al. (2010, EFF); Keefer & Caudill (2010)
Hinch et al. (2012, JFB); Bowerman et al. (*in press*)

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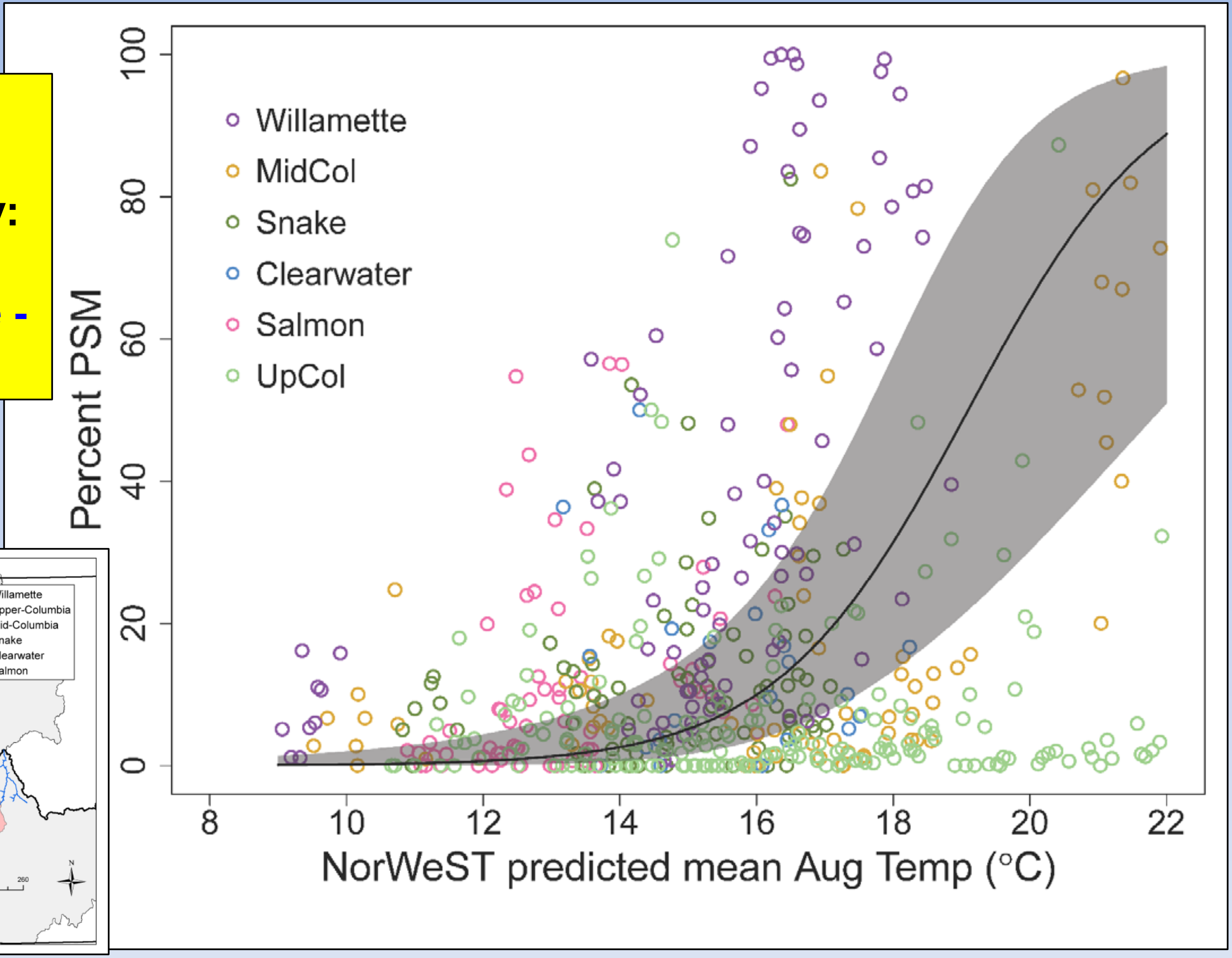
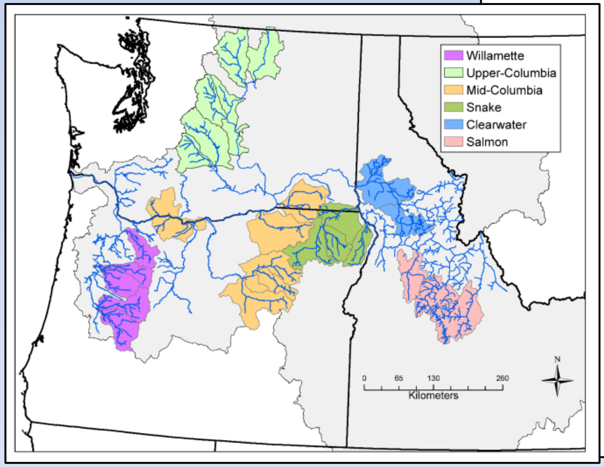
Does refuge use reduce prespawn mortality?

618 site years of Chinook salmon prespawn mortality:

Strong temperature - mortality signal





Bowerman et al. (*in preparation*)

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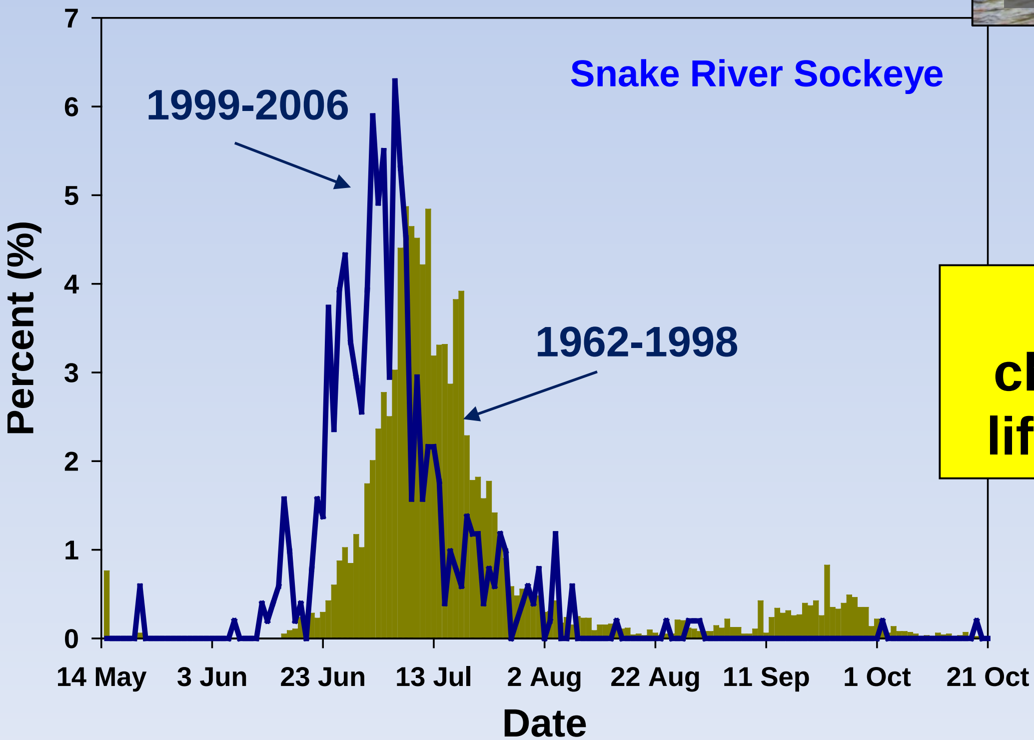
Adaptation?

► Can adaptation keep pace with environmental change?

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



Keefer et al. (2008, EFF)

'Window of opportunity' for change differs among species, life history types, & populations

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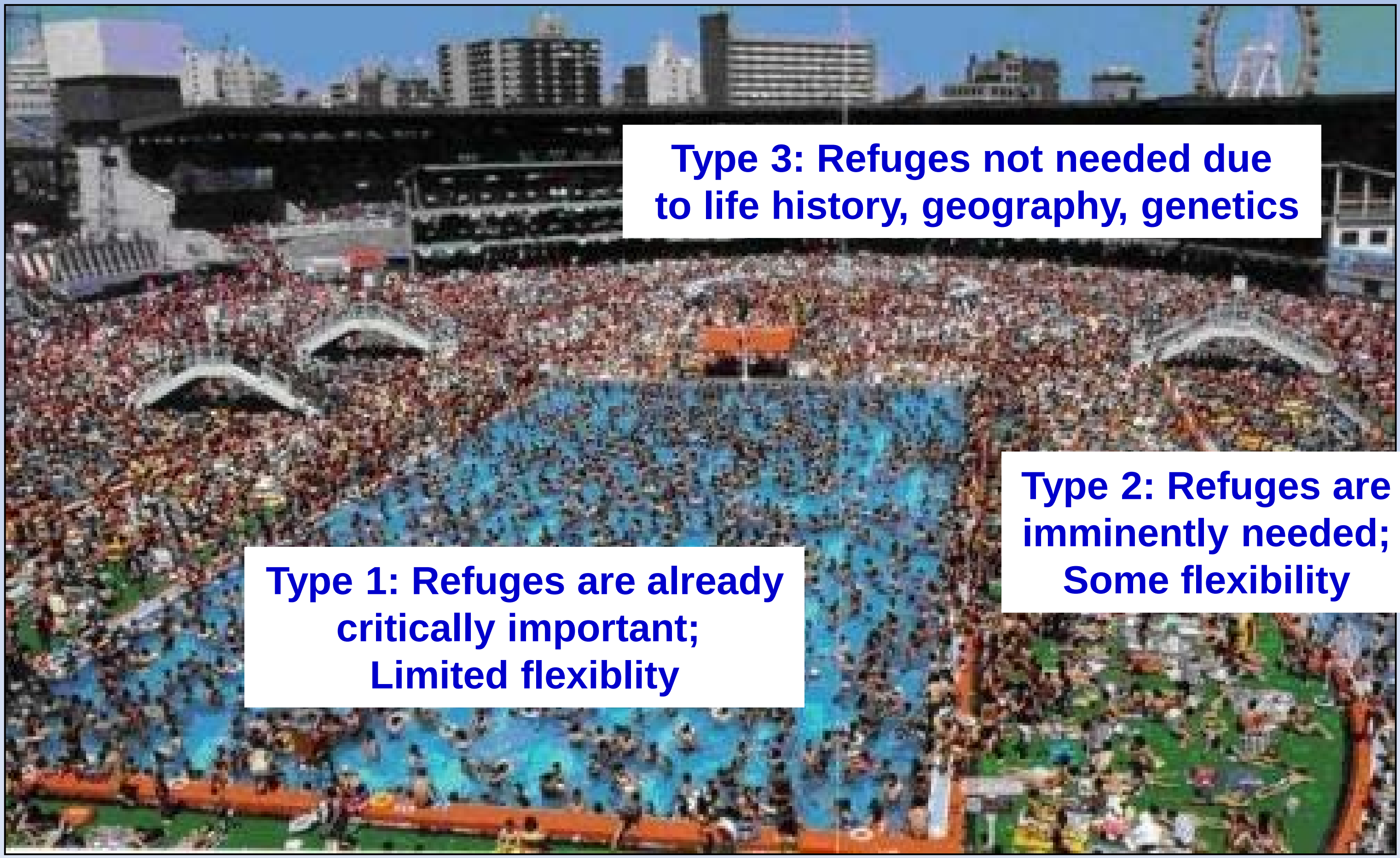
Adaptation?

► **Need for thermal refuges differs among populations**



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Thanks!

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

Some key references

Bowerman, T., M. L. Keefer, and C. C. Caudill. in press. Pacific salmon prespawn mortality: patterns, methods, and study design considerations. Fisheries.

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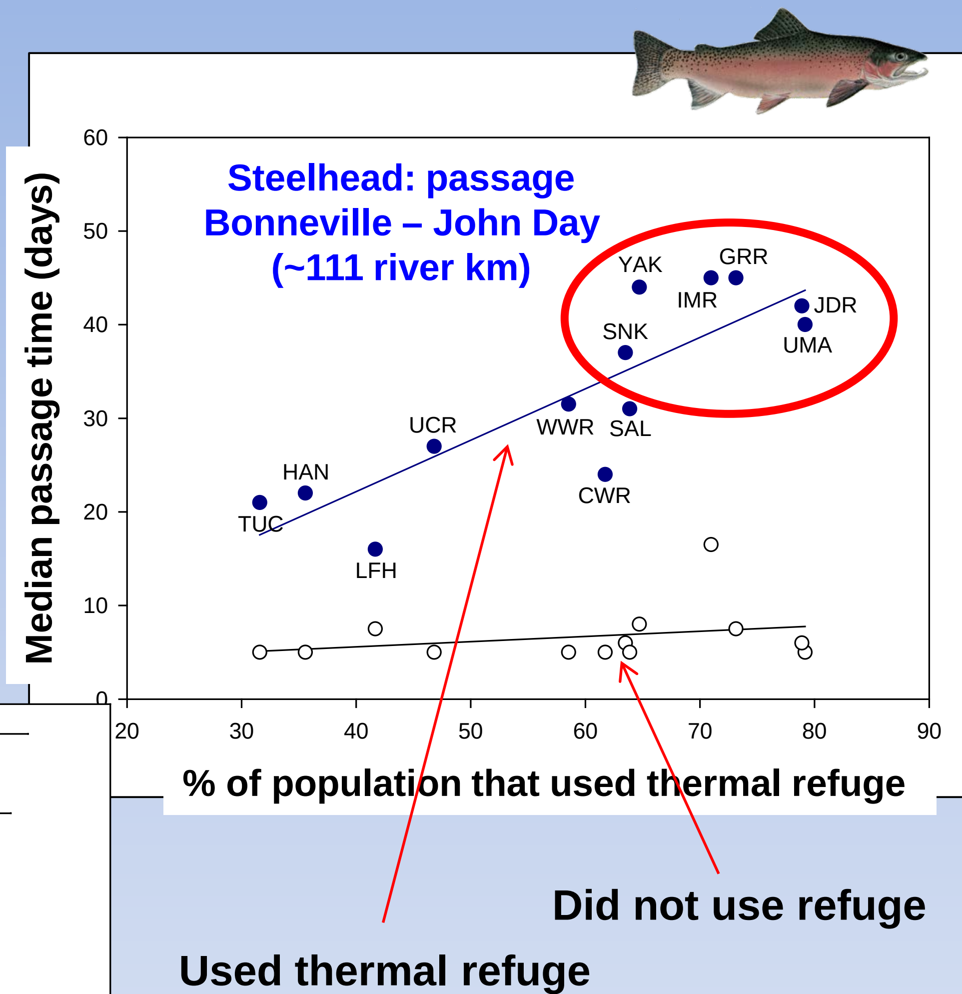
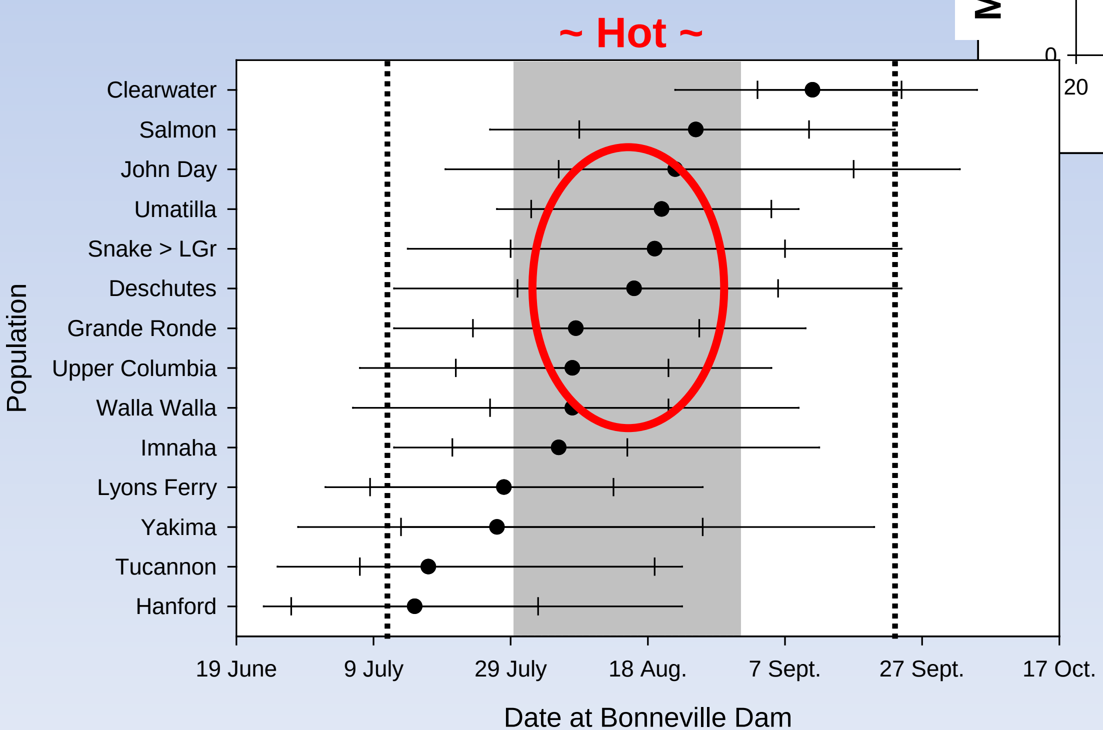
EPA Columbia River Cold Water Refugia (CWR) Plan

- Due November 2018 (NOAA Oregon Water Quality Standards 2015 BiOp RPA)
- Columbia River from mouth to Snake River confluence
- CWR Plan Elements
  1. Characterize current spatial and temporal CWR
  2. Characterize current salmon and steelhead use of CWR
  3. Assess whether current CWR is sufficient to meet Oregon's narrative criteria
  4. Identify potential locations to restore CWR
  5. Identify additional CWR needed to meet criteria
  6. Identify and prioritize actions to protect, restore, or enhance CWR
- Public draft early 2018
- Oregon DEQ developing CWR plan for lower Willamette River

Steelhead: population differences

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





Keefer et al. (2009, CJFAS)

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