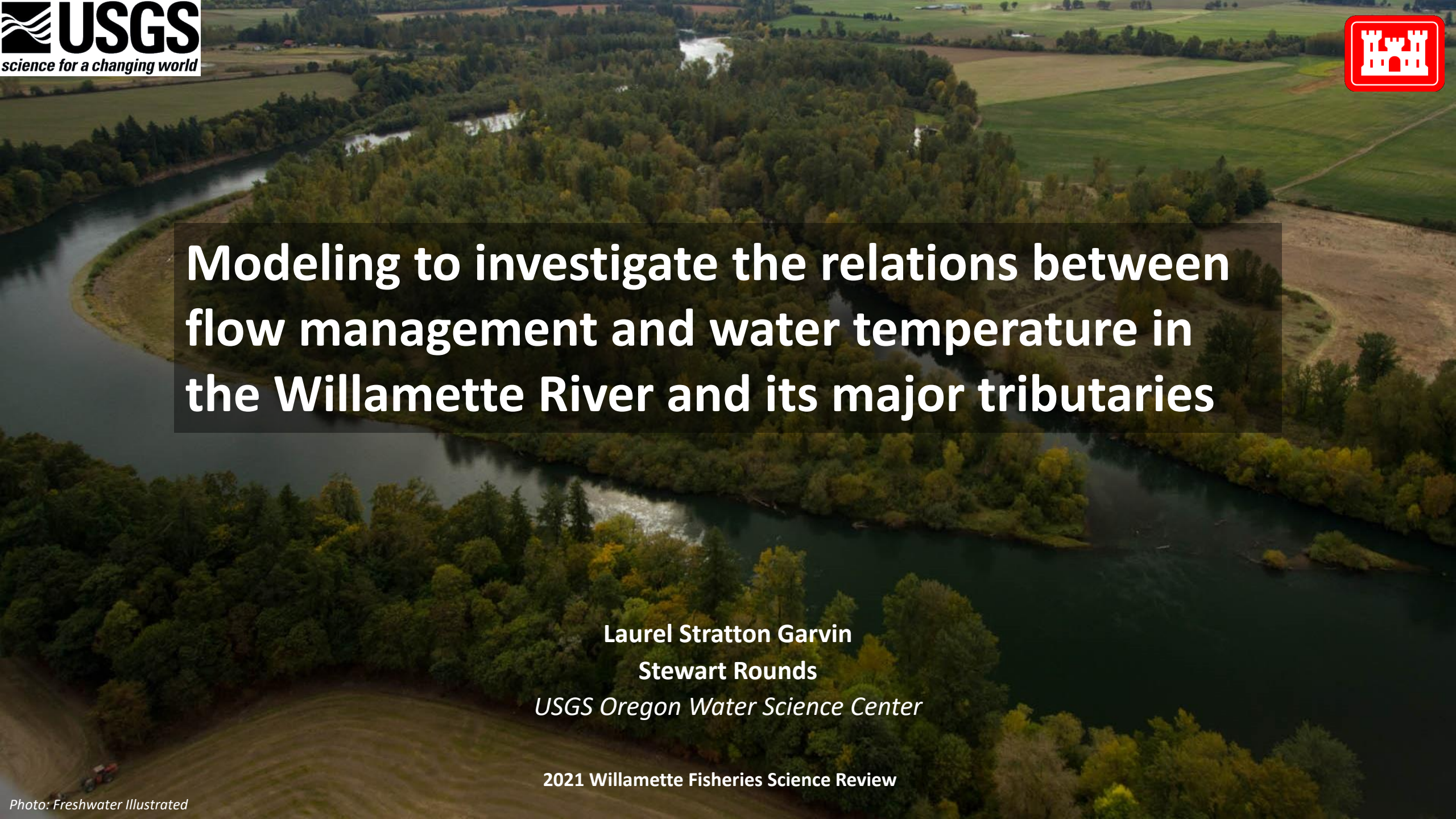


Modeling to investigate the relations between flow management and water temperature in the Willamette River and its major tributaries

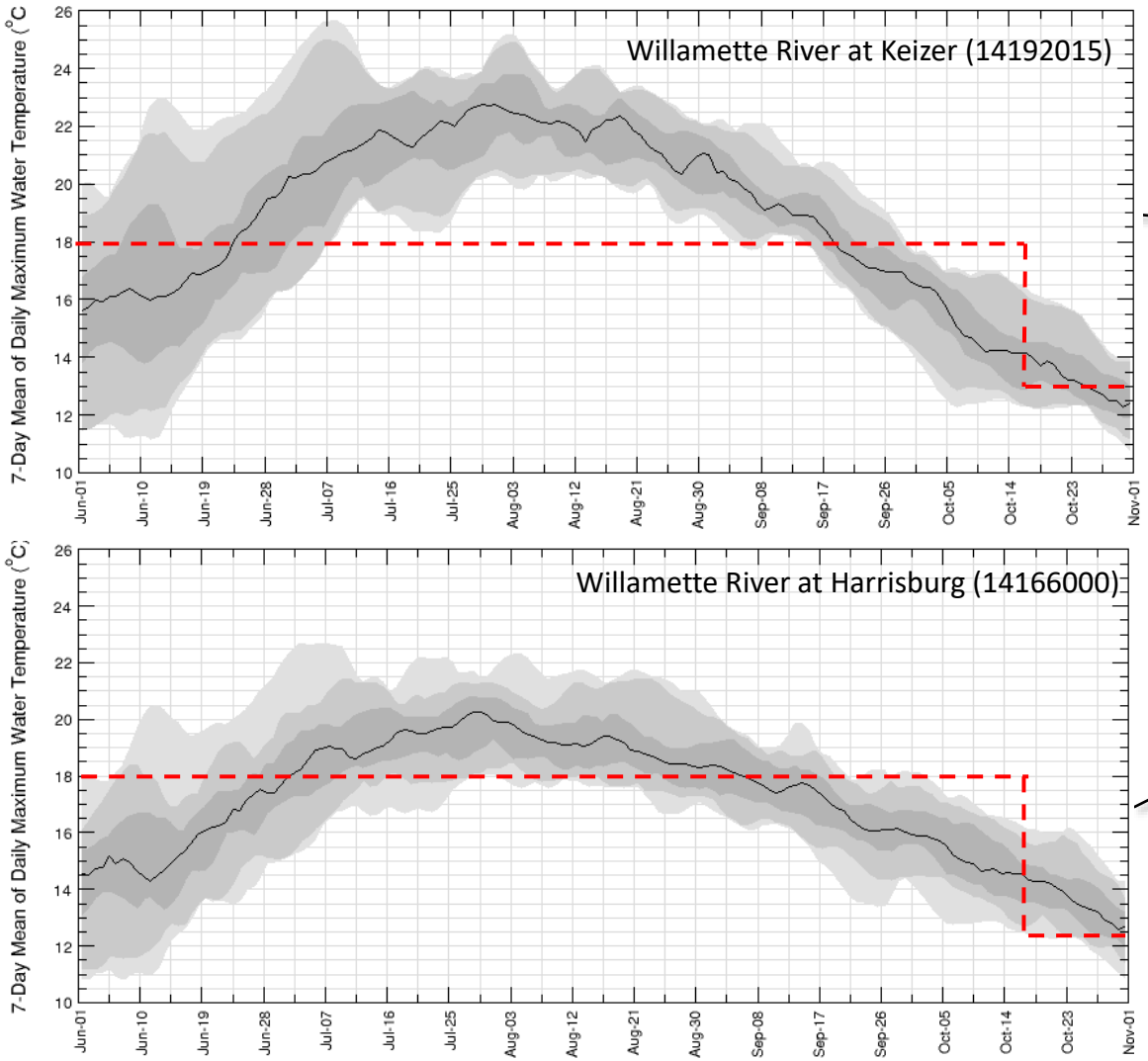
Laurel Stratton Garvin
Stewart Rounds
USGS Oregon Water Science Center

2021 Willamette Fisheries Science Review

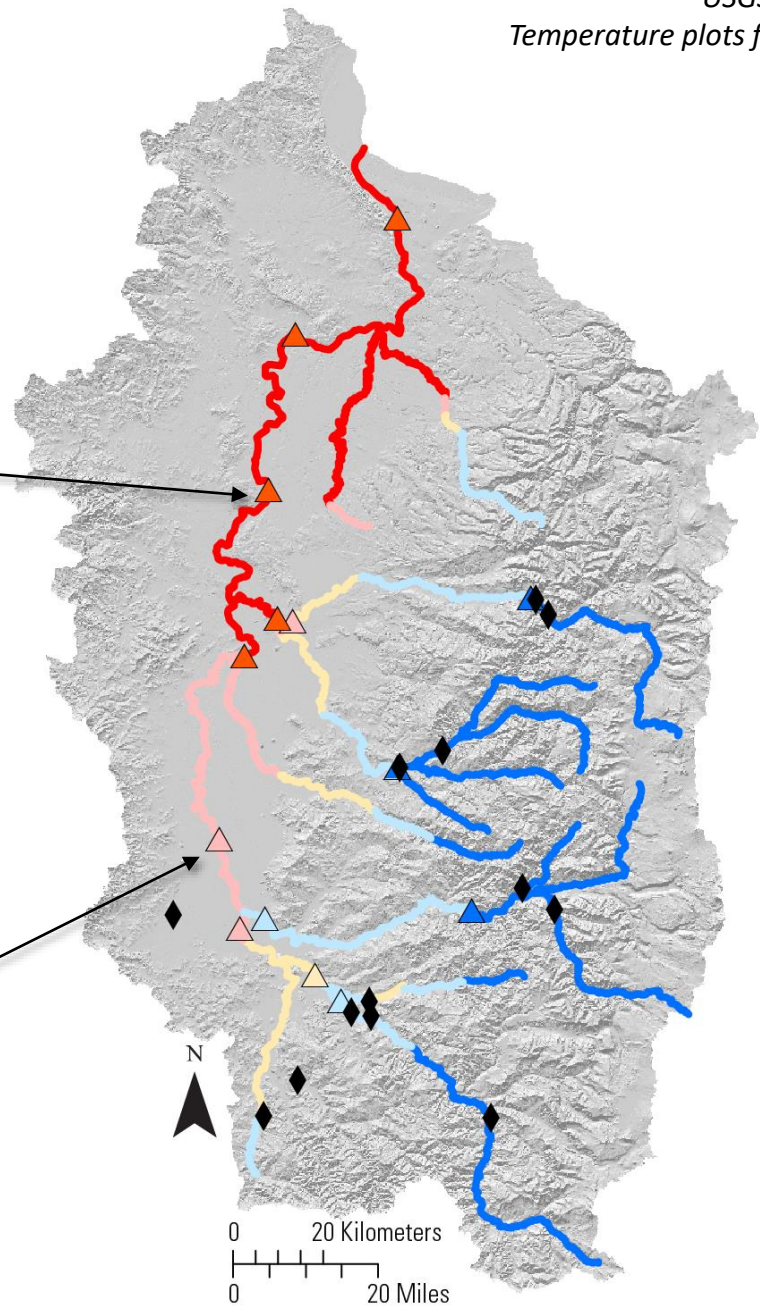
Photo: Freshwater Illustrated

WILLAMETTE RIVER THERMAL CONDITIONS: *Seasonally challenging for cold-water fishes*

USGS map by Gabe Gordon
Temperature plots from USGS Data Grapher



min-max
10-90 pctl
25-75 pctl
median
Regulatory threshold



Temperature percentiles 2000 - 2019

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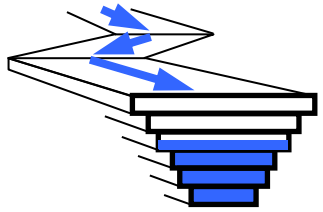
INVESTIGATING THE 'THERMAL LANDSCAPE' OF THE WILLAMETTE RIVER SYSTEM

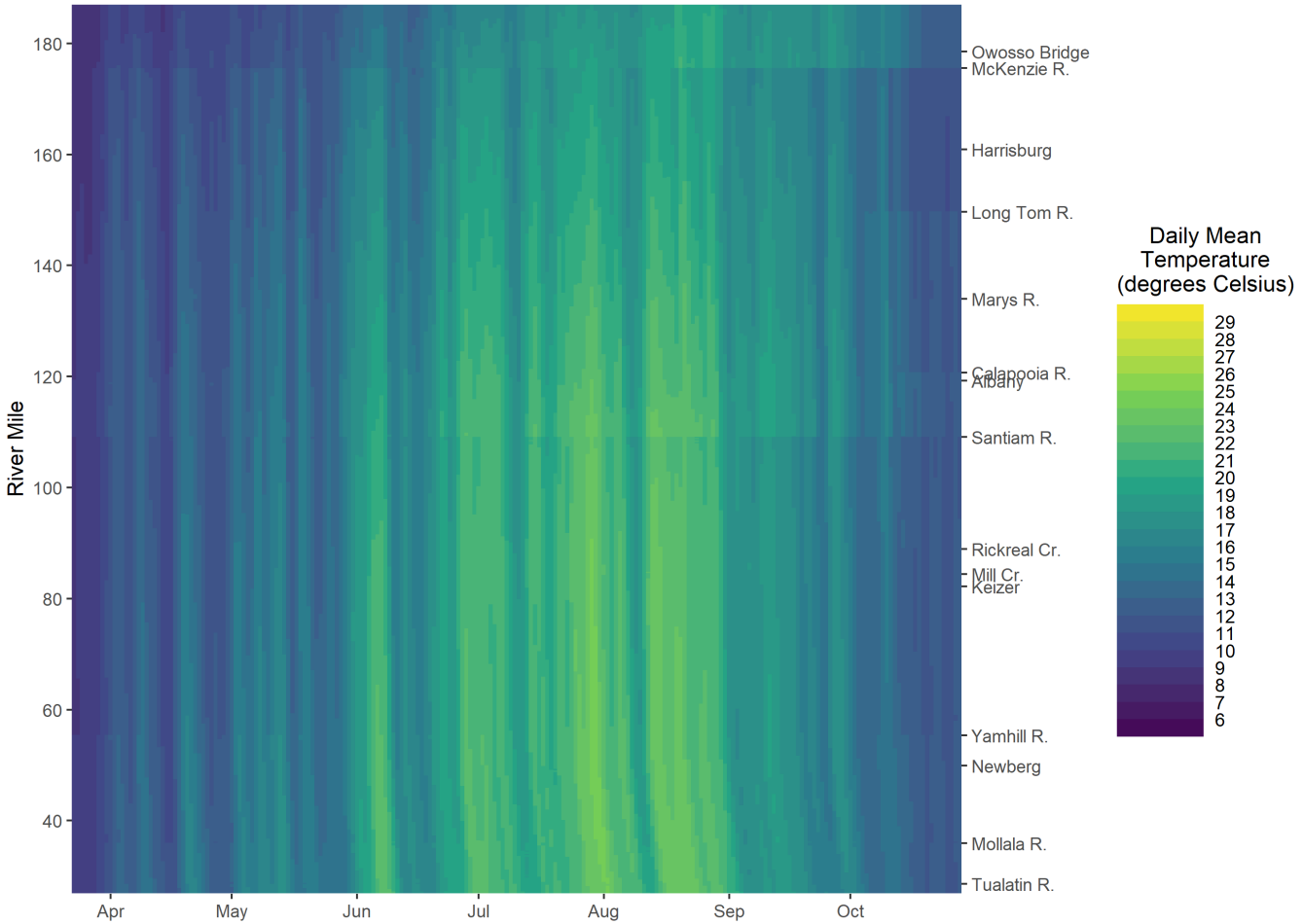
The variation of water temperature in time and space

- Water temperature modeled using CE-QUAL-W2, a 2D hydrodynamic and water quality model with full heat budget
- CE-QUAL-W2 models set up for three "Base Condition" model years representing range of recent hydrologic and climate conditions in the Willamette Valley:



CE-QUAL-W2

- **2011 (cool and wet)**
- **2015 (hot and dry)**
- **2016 (moderately hot and dry)**



2016 'base condition' CE-QUAL-W2 results

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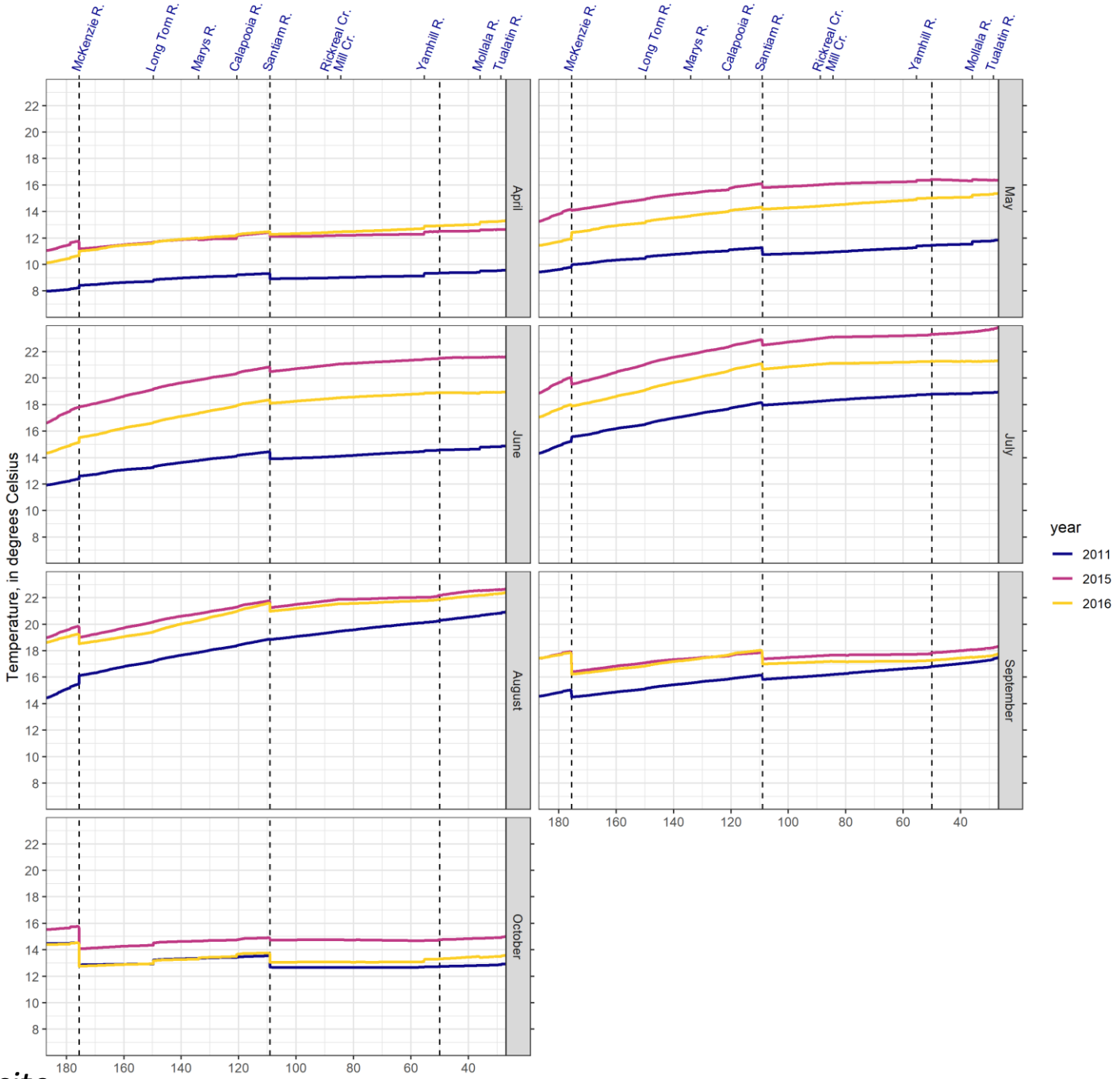
Preliminary data; subject to revision. Do not cite.

‘THERMAL REACHES’ OF THE WILLAMETTE RIVER

- Downstream warming rate varies by season
  - Willamette River is relatively isothermal in spring and autumn
  - Peak heating in July and August; average temperature in September is lower
- Large tributaries create thermal discontinuities in stream profile
  - McKenzie and Santiam Rivers
  - Smaller, un-regulated tributaries have minor influence (typically warming)



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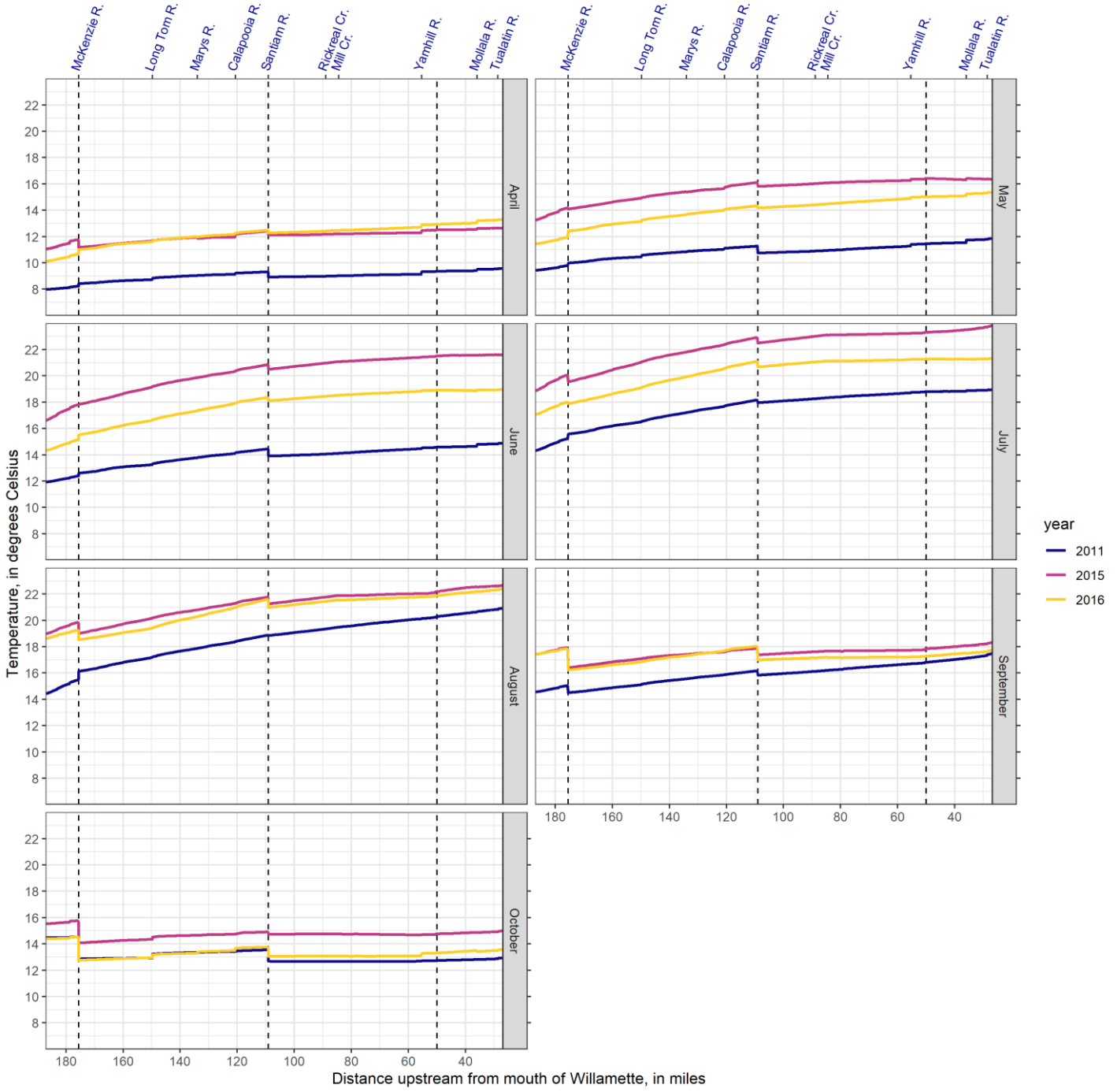
‘THERMAL REACHES’ OF THE WILLAMETTE RIVER

- Longitudinal rate of change varies by reach
  - Warming rate highest upstream; decreases downstream
  - Temperature varies by year, but reach-specific rate of change relatively consistent

→ Four characteristic ‘thermal reaches’ in the Willamette River above Willamette Falls:



Preliminary data; subject to revision. Do not

‘THERMAL REACHES’ OF THE WILLAMETTE RIVER

- Longitudinal rate of change varies by reach
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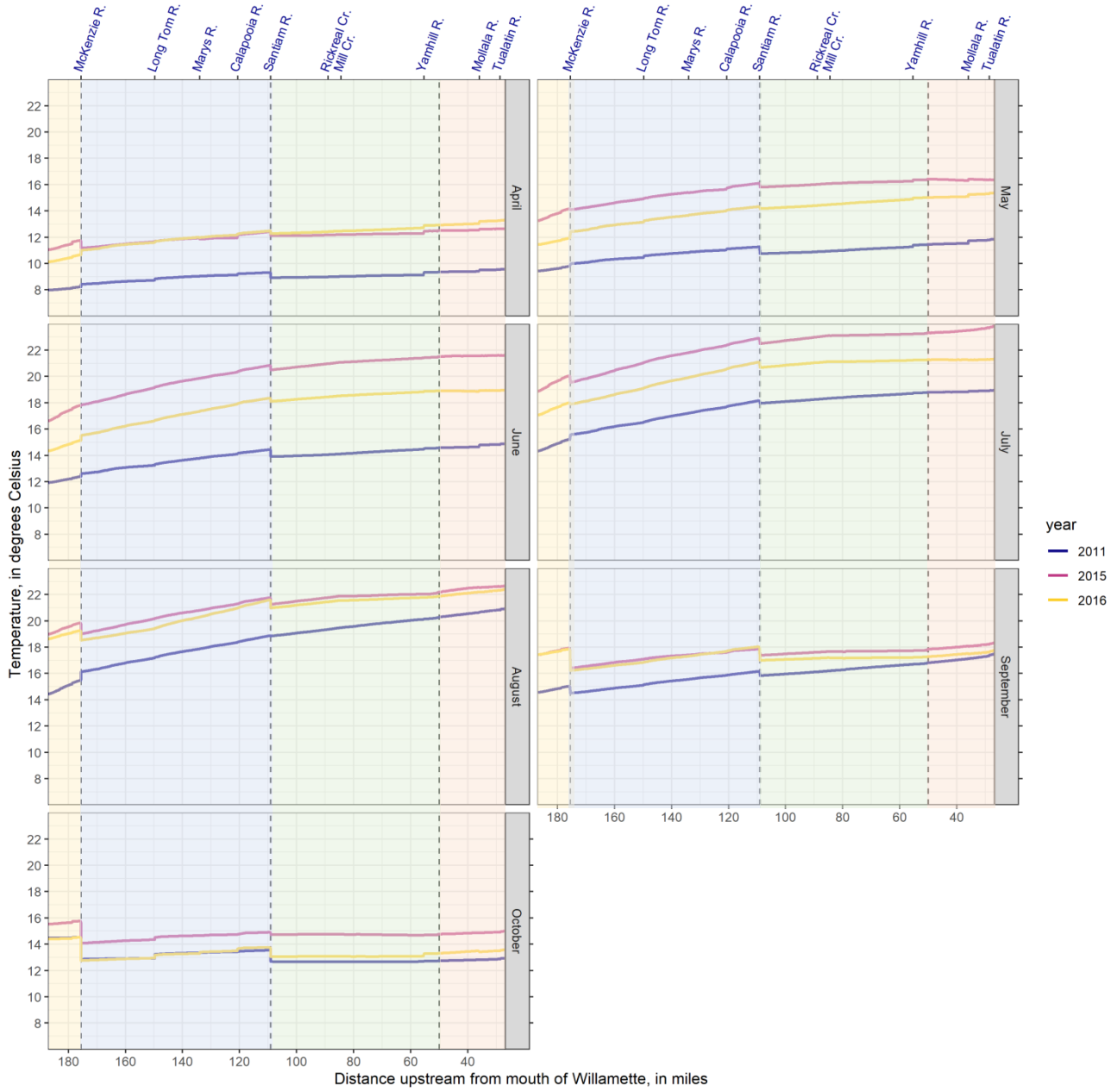
→ Four characteristic ‘thermal reaches’ in the Willamette River above Willamette Falls:

- Springfield-McKenzie Reach
- McKenzie-Santiam Reach
- Santiam-Newberg Reach
- Newberg Pool



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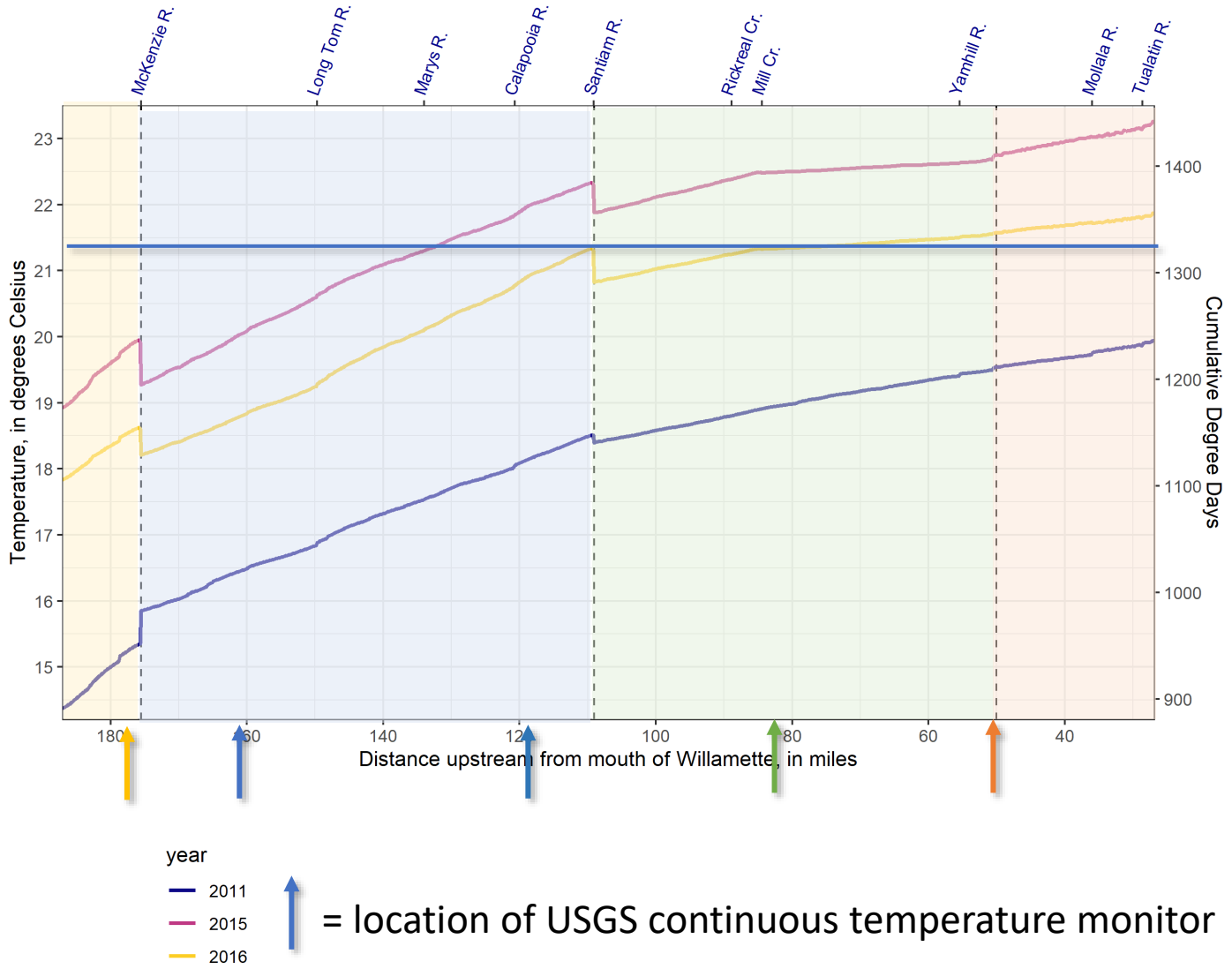
Preliminary data; subject to revision. Do not cite.

‘THERMAL REACHES’ OF THE WILLAMETTE RIVER

- In summer, Willamette River warms downstream, but not uniformly
  - Lower portions of each thermal reach experience more cumulative summer heating than upper sections of downstream reaches:
  - Willamette immediately upstream of Santiam River experiences similar cumulative summer heating as Willamette near Salem, ~ 40 miles downstream
- Thermal reaches provide context to interpret data from continuous temperature monitors

Cumulative degree day heating, July - August



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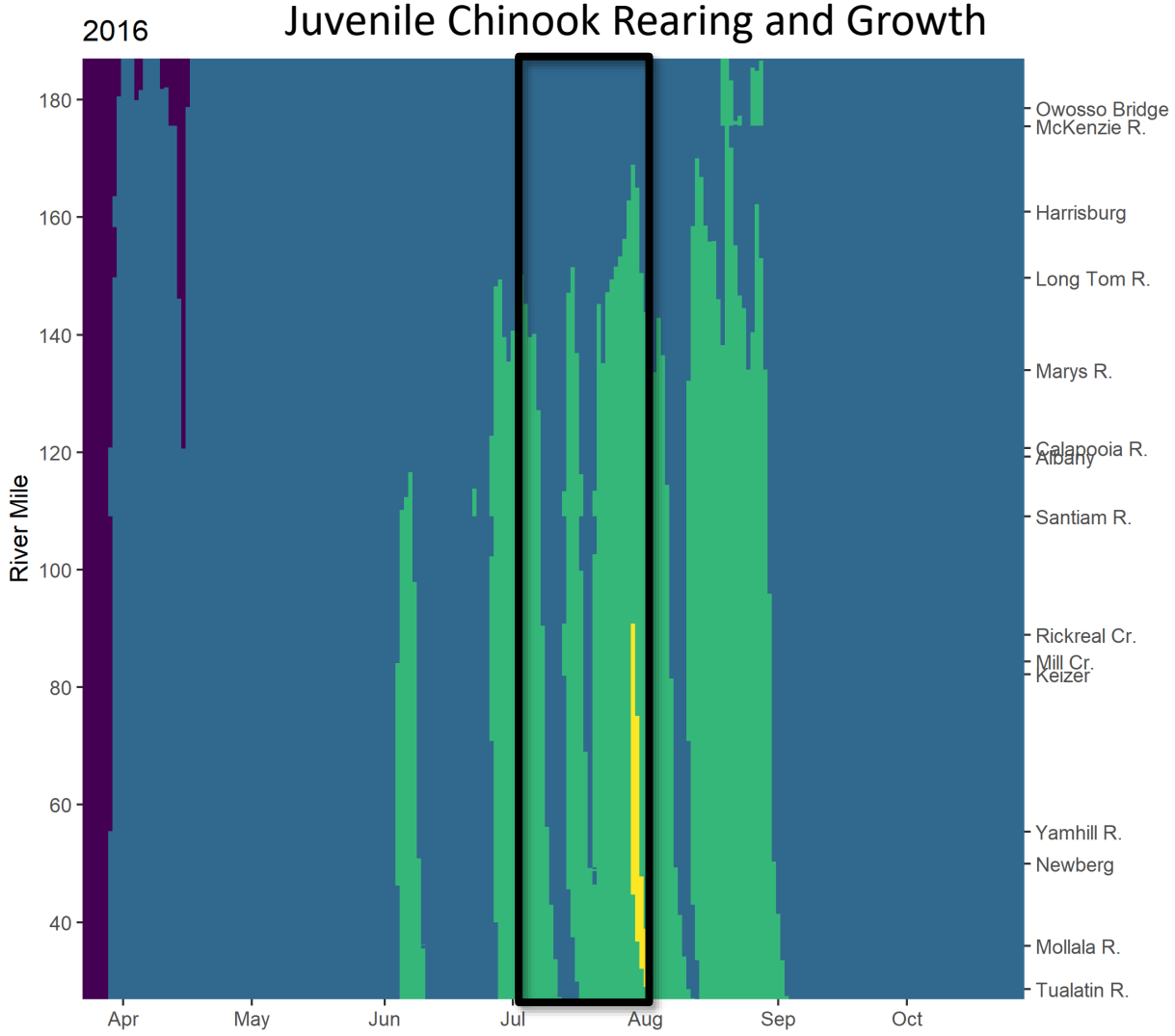
Preliminary data; subject to revision. Do not cite.

THERMAL RISK CATEGORIES, JUVENILE CHINOOK

Juvenile Chinook rearing and growth		Thermal Risk Category name
Temperature range (°C)	Effects on fish	
≥ 24 °C	Mortality	Lethal
≥20- 24 °C	Sub-optimal due to increased stress, decreased growth and potential for disease	Adverse
≥10 - 20 °C	Optimal	Optimal
<10 °C	Safe, but decreased growth	Suboptimal

Kock and others, 2020



In July 2016, modeled conditions for juvenile Chinook suggest:

- 2% of Willamette River length lethal
- 56% adverse
- 42% optimal

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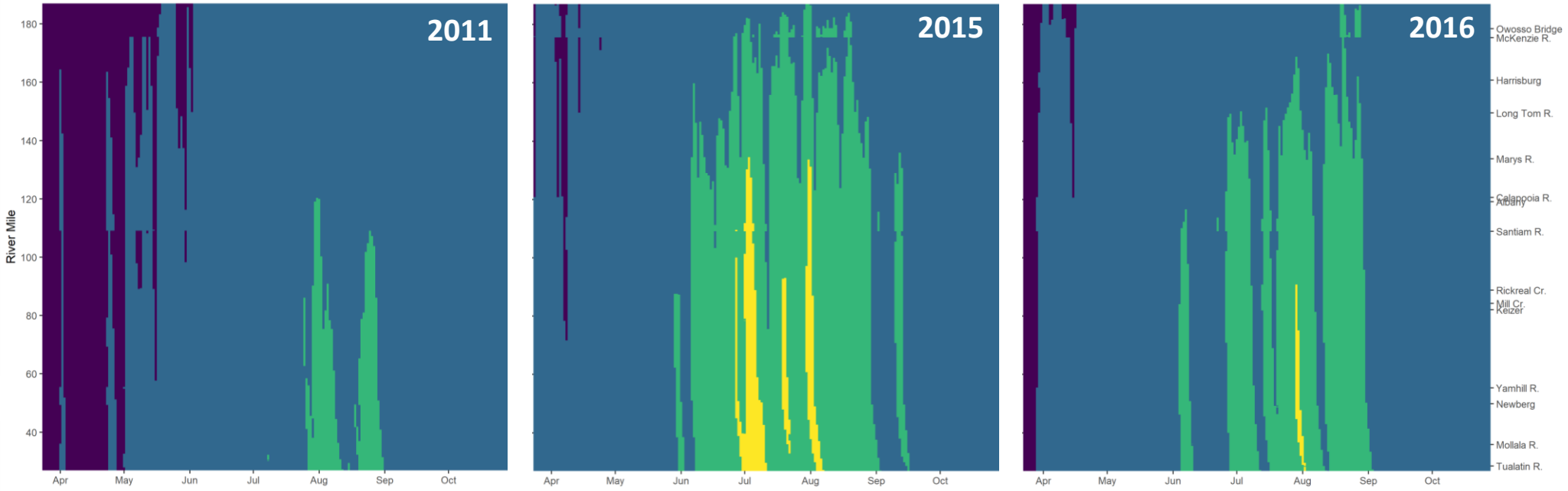
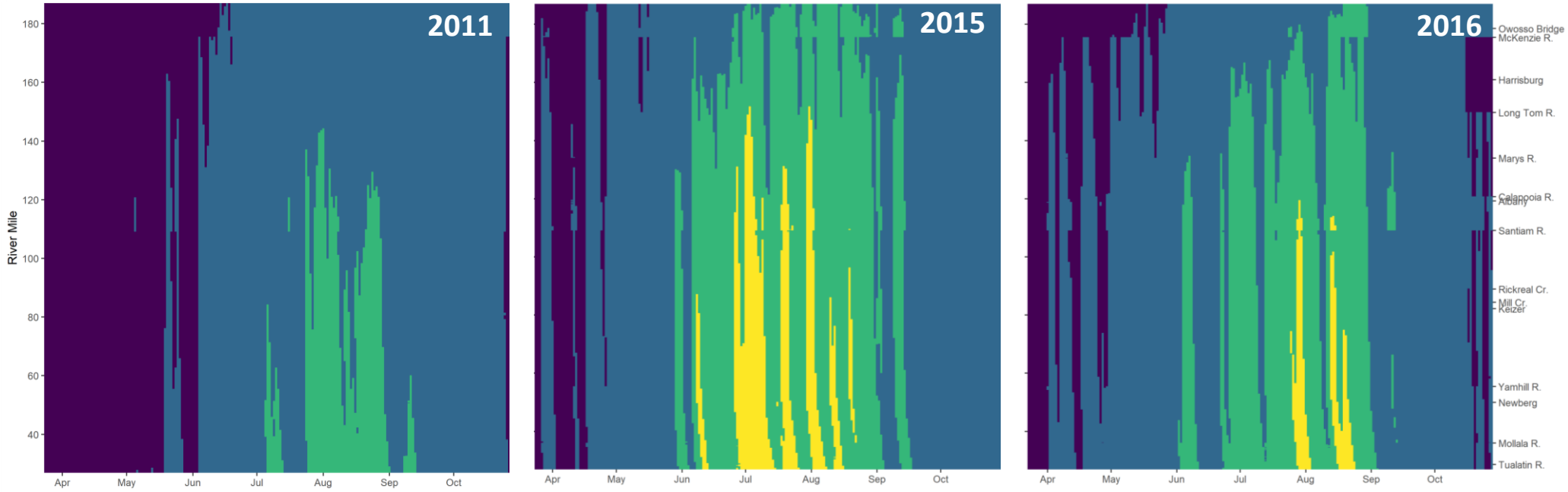
Preliminary data; subject to revision. Do not cite.

Juvenile Chinook rearing and growth



Adult Chinook migration



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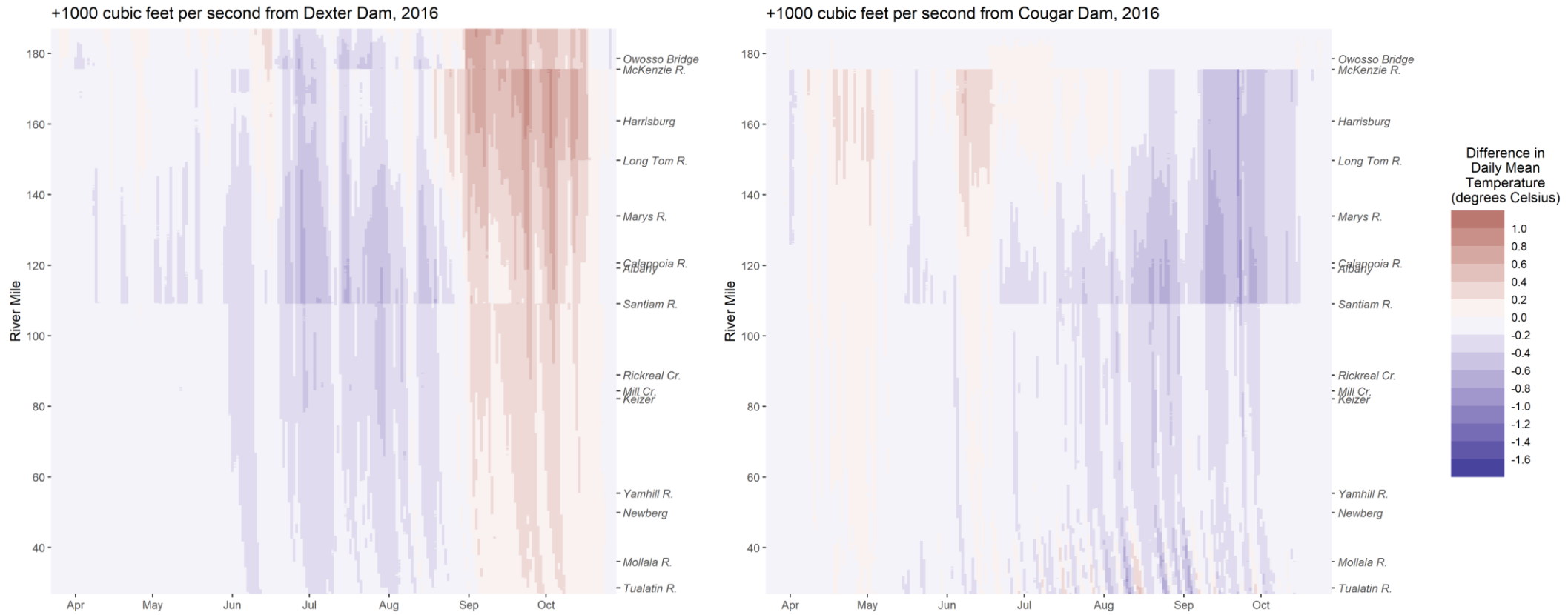
Preliminary data; subject to revision. Do not cite.

INVESTIGATING THE THERMAL INFLUENCE OF FLOW AUGMENTATION IN THE WILLAMETTE RIVER

Flow Augmentations Source (+ 1000 cfs to 'base case')	Daily Mean		Daily Maximum	
	Maximum cooling (°C)	Maximum warming (°C)	Maximum cooling (°C)	Maximum warming (°C)
Middle Fork Willamette River	-0.69	0.88	-1.06	0.89
South Fork McKenzie River	-1.00	0.46	-1.40	0.78
South Santiam River	-1.08	0.30	-1.62	0.49
North Santiam River	-1.24	0.26	-1.70	0.46



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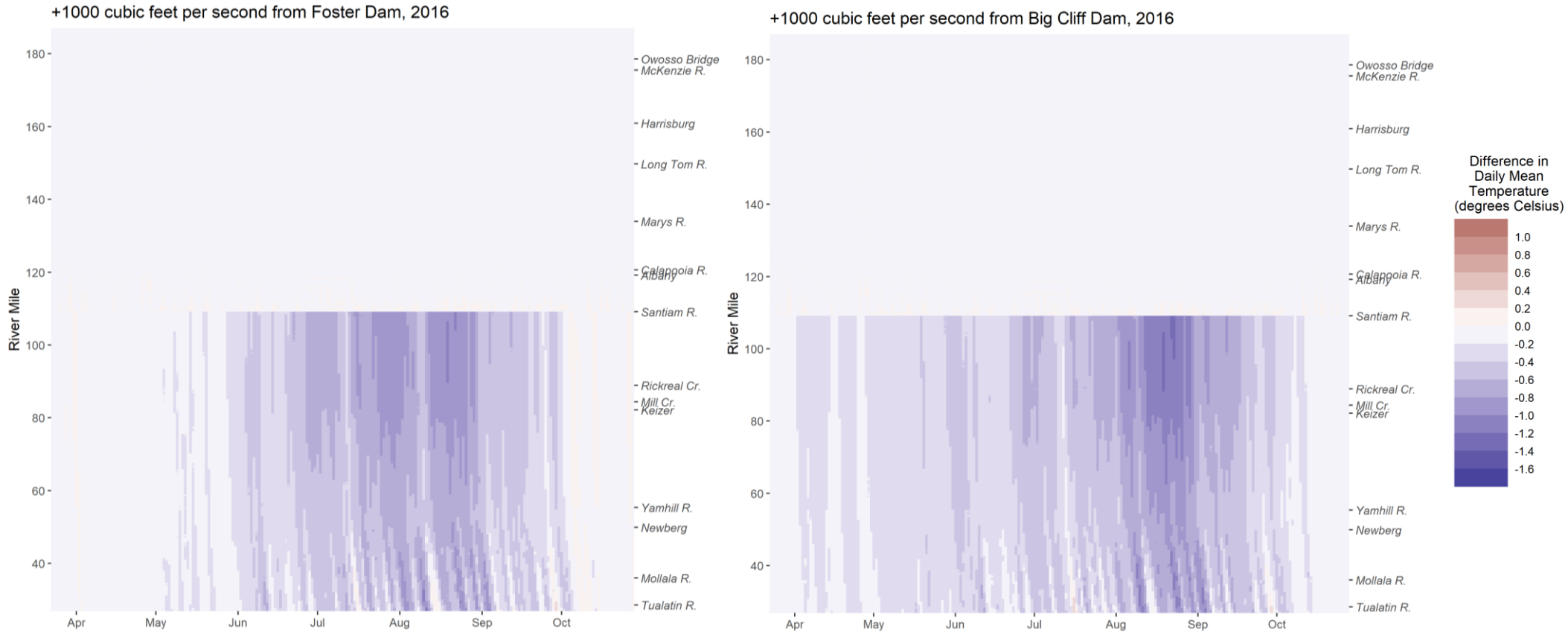

Preliminary data; subject to revision. Do not cite.

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INVESTIGATING THE THERMAL INFLUENCE OF FLOW AUGMENTATION IN THE WILLAMETTE RIVER

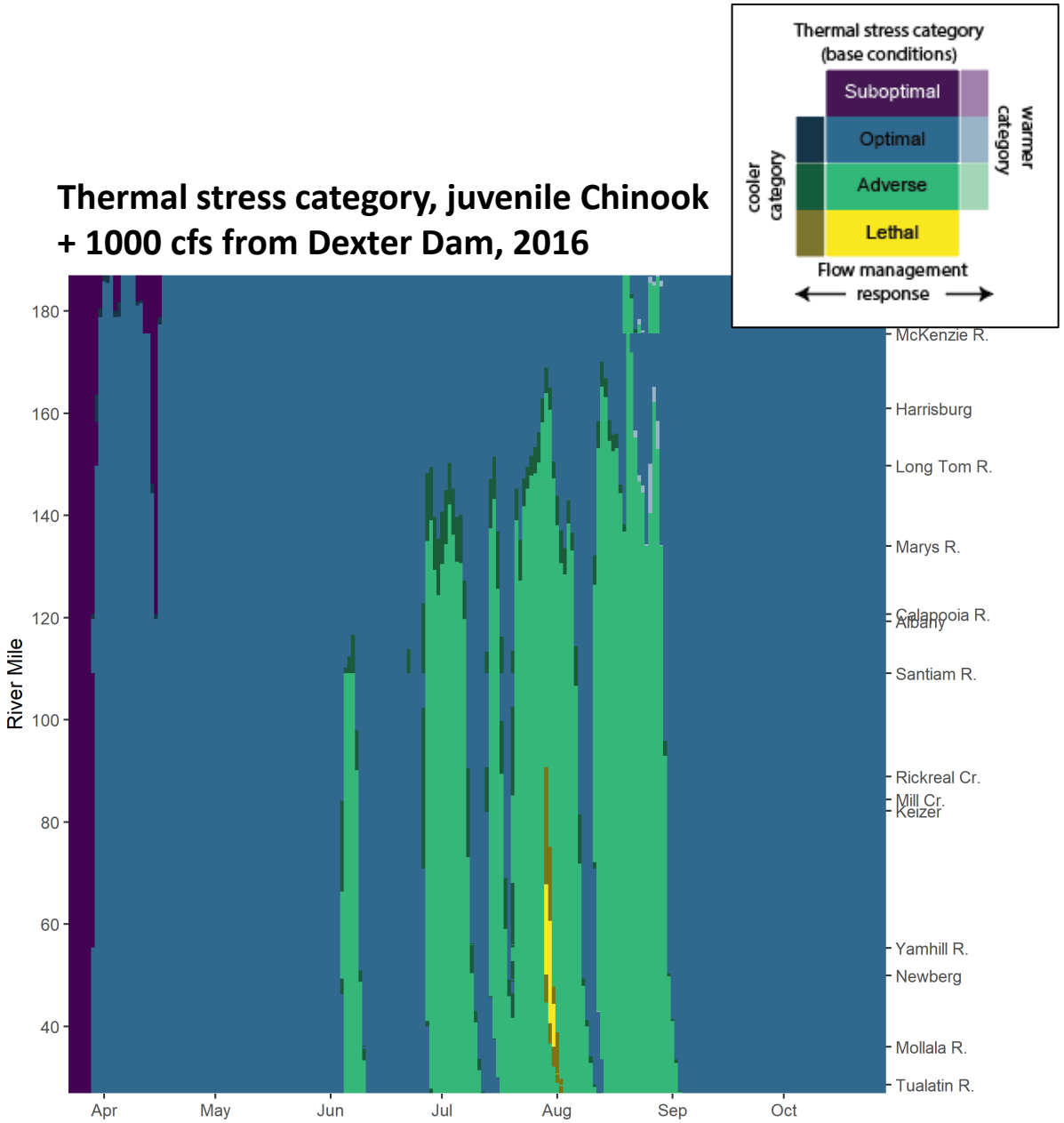
Potential influence on juvenile Chinook salmon

- Flow augmentation reduces duration and extent of thermally stressful conditions
  - Little effect in spring or autumn
  - Greatest effect in summer

Modeled percent change in river length in each thermal stress category for juvenile Chinook with additional 1000 cfs from Dexter Dam, 2016

	Apr	May	Jun	Jul	Aug	Sep	Oct
+1000 cfs from Dexter Dam							
Lethal	0	0	0	-0.96	-0.4	0	0
Adverse	0	0	-2.92	-5.19	-1.5	-0.05	0
Optimal	-0.66	0	2.92	6.15	1.92	0.05	0
Suboptimal	0.66	0	0	0	0	0	0

Thermal stress category, juvenile Chinook + 1000 cfs from Dexter Dam, 2016



USGS science for a changing world *Preliminary data; subject to revision. Do not cite.*

SUMMARY AND CONCLUSIONS

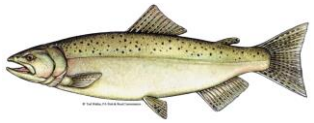
- Willamette River divisible into four distinct ‘thermal reaches’ with relatively linear downstream spring and summer warming rates
    - Large tributaries create thermal discontinuities up to several degrees Celsius
- Effect of flow augmentation on stream temperature varies seasonally and by tributary source
- Except in cool, wet years (2011), modeling suggests that adversely warm conditions for spring Chinook are extensive from June or July through August
- Modeling suggests that targeted flow management can reduce extent and duration of thermally stressful conditions for Chinook over short periods and distances, but:
- Flow augmentation appears limited in ability to fundamentally change thermal landscape of the Willamette River


USGS photo

Preliminary data; subject to revision. Do not cite.

ADDITIONAL QUESTIONS

- How do specific flow-management actions at USACE dams influence tributary and mainstem temperatures? How do the effects of those actions vary seasonally?
    - Temperature management; flow augmentation
- What are the implications of spatial and temporal thermal variability in the Willamette River for various life stages of spring Chinook and for winter steelhead?
- What are the thermal conditions in tributaries below USACE dams, how do they vary longitudinally and between rivers and how does this influence
    - Adult migration and disease
    - Spawning and incubation
    - Rearing



for spring Chinook and winter steelhead?

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Species diagrams: U.S. Fish and Wildlife Service

USGS photo

Acknowledgements

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Jim Peterson, Jessica Pease, Tyrell Deweber, Stan Gregory, and others from the SWIFT process
James White, Rose Wallick, Gabe Gordon, Krista Jones (USGS Oregon Water Science Center)

Upcoming publications:

- Stratton Garvin, L.E., Rounds, S.A., and Buccola, N.L., 2021, **Estimating stream temperature in the Willamette River Basin, Northwestern Oregon: A Regression-based Approach**. U.S. Geological Survey Scientific Investigations Report *(imminent)*

- Stratton Garvin, L.E., 2021, **Stream temperature predictions for the Willamette River Basin, northwestern Oregon estimated from regression equations (1954 – 2018)**: U.S. Geological Survey, https://doi.org/10.5066/P9PALKQZ *(imminent)*

- Stratton Garvin, L.E., and Rounds, S.A., 2021**. The thermal mosaic of the Willamette River: patterns and controls on stream temperature and implications for flow management and cold-water salmonids.** U.S. Geological Survey Scientific Investigations Report *(this summer)*

- Rounds, S.A. and Stratton Garvin, L.E., 2021, **Tracking heat in the Willamette River system, Oregon**. U.S. Geological Survey Scientific Investigations Report *(this summer)*

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