Trask River Watershed Study

Did Distributions of Summer Stream Temperatures Shift Following Forest Harvest in the Trask River Watershed

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Pacific Northwest Research Station

US Forest Service

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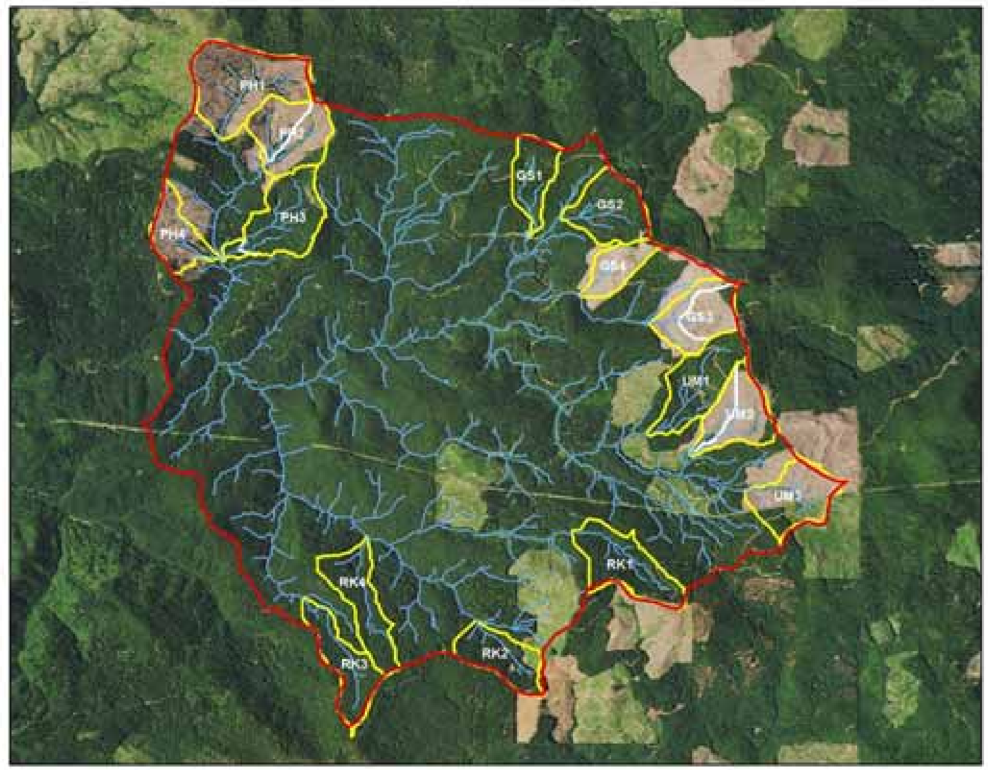
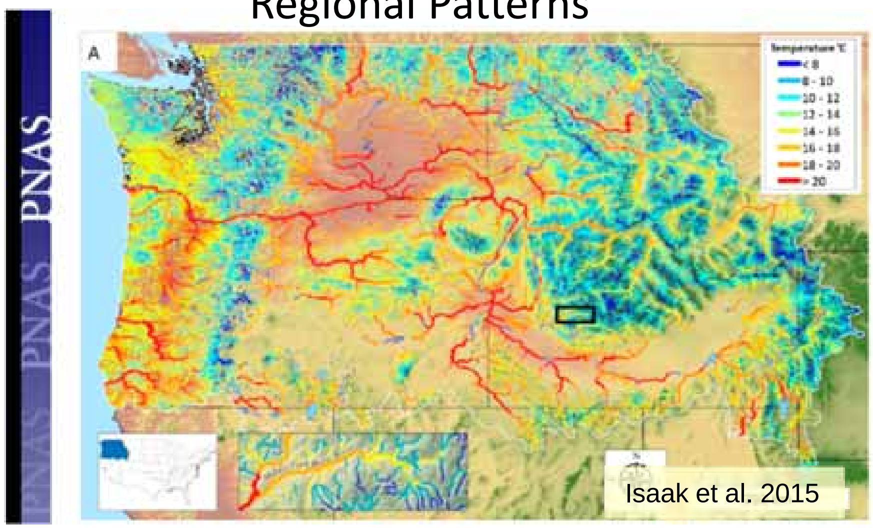
Weyerhaeuser Company



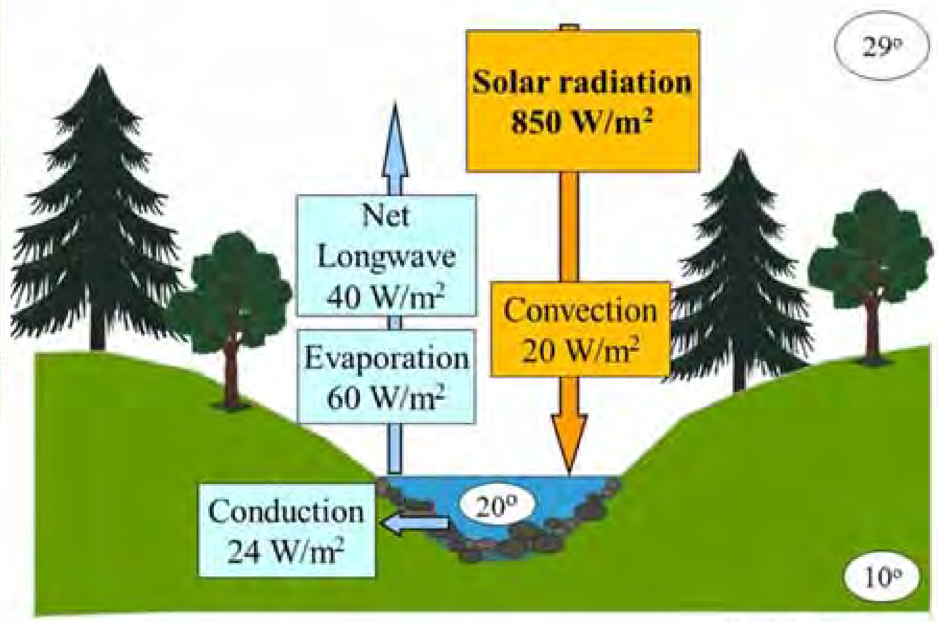
Thermal Riverscapes: Multiple Scales

Regional Patterns



Stream temperatures influenced by broad hydrologic, physiographic, and climatic conditions

Local Processes



Johnson 2004

Heat budgets in streams influenced by multiple proximal factors; greatest flux from solar radiation

Forested headwater streams can provide critical cold water habitat for aquatic biota

Small streams are very responsive

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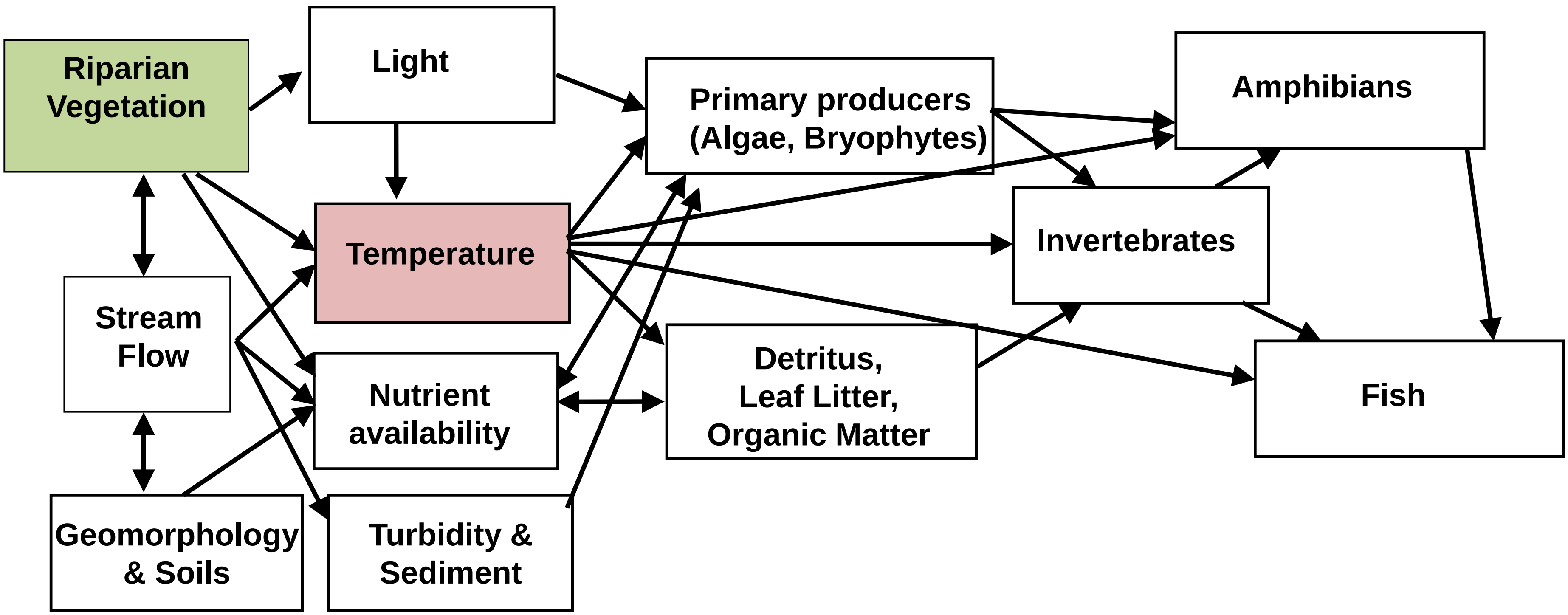
Forest-Stream Linkages

Trask Study was designed to evaluate effects of forest management on stream ecosystems









Metrics

-Clean Water Act directs EPA to set water quality guidelines that States implement, especially where there are threatened or endangered cold water fish species

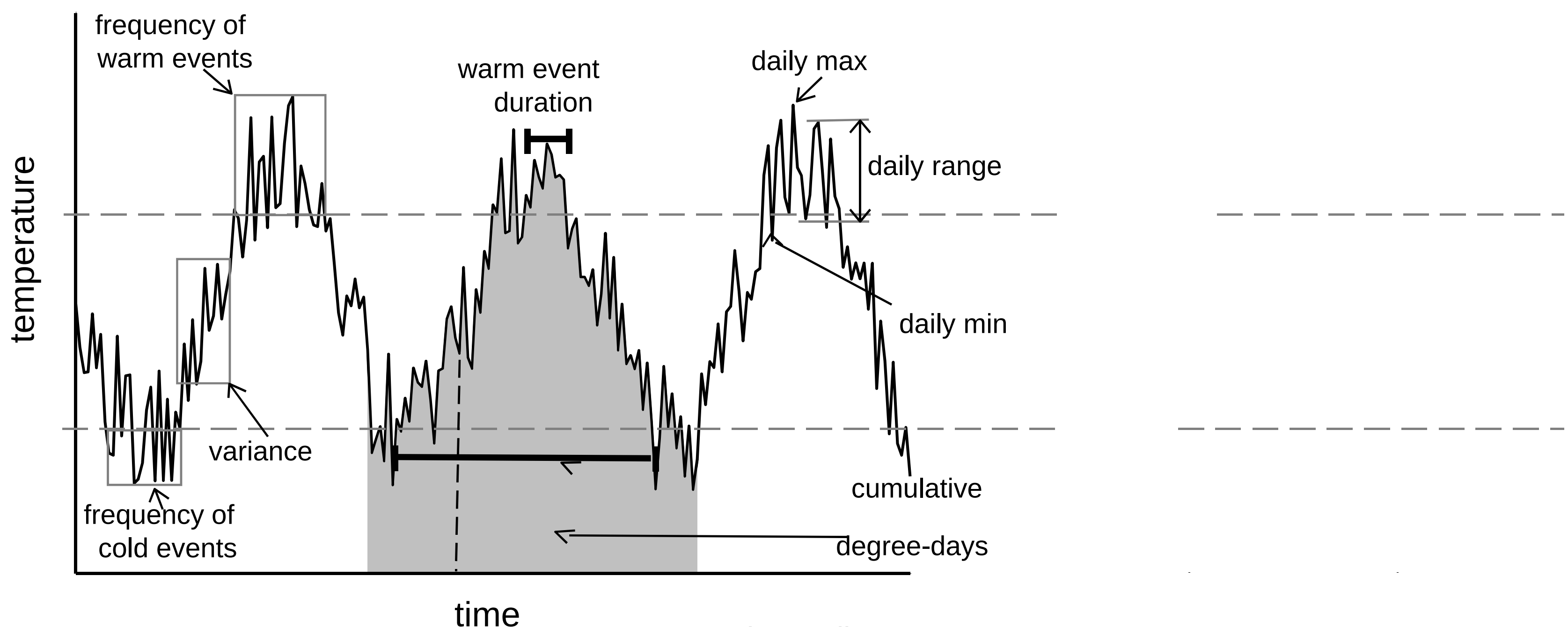
-Threshold temperatures are used to quantify effects of land use change – straightforward to calculate, but loss of information relevant to biota

Metrics

- Streaming data, sensor technology, and updates in computing allow us to go beyond simple thresholds and binary classifications

- Many metrics are possible in evaluating full thermal regime

natural thermal regime



Arismendi et al. 2013

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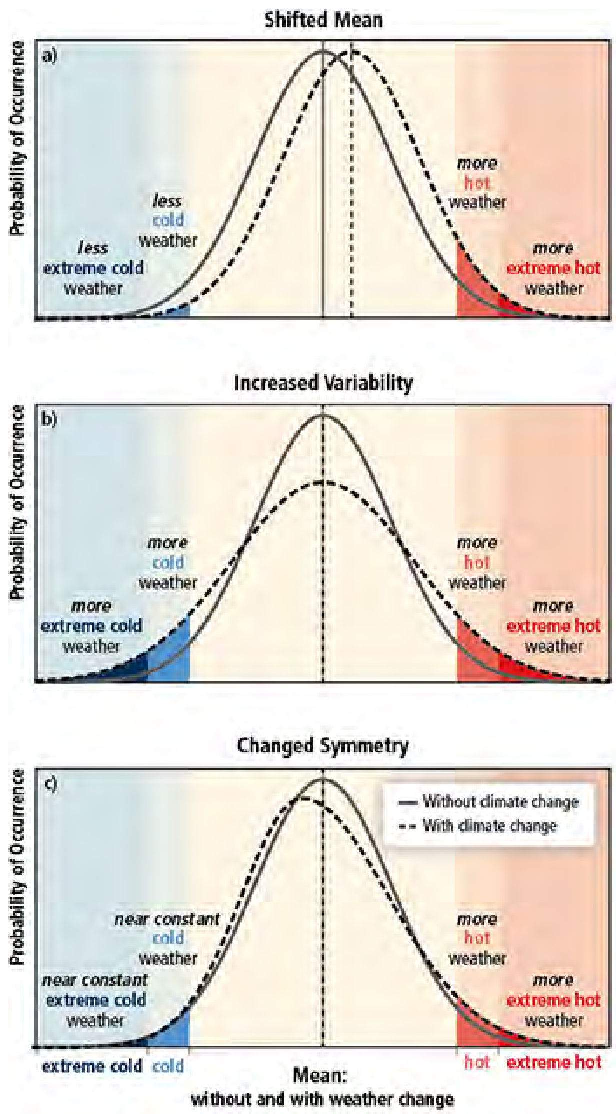
Distributions



(a) simple shift of the entire distribution

(b) increase in extremes with no shift in the mean

(c) altered shape of the distribution such as skew or kurtosis.

http://www.e3s-future-earth.eu/index.php/Project/Project

Arismendi et al. 2014

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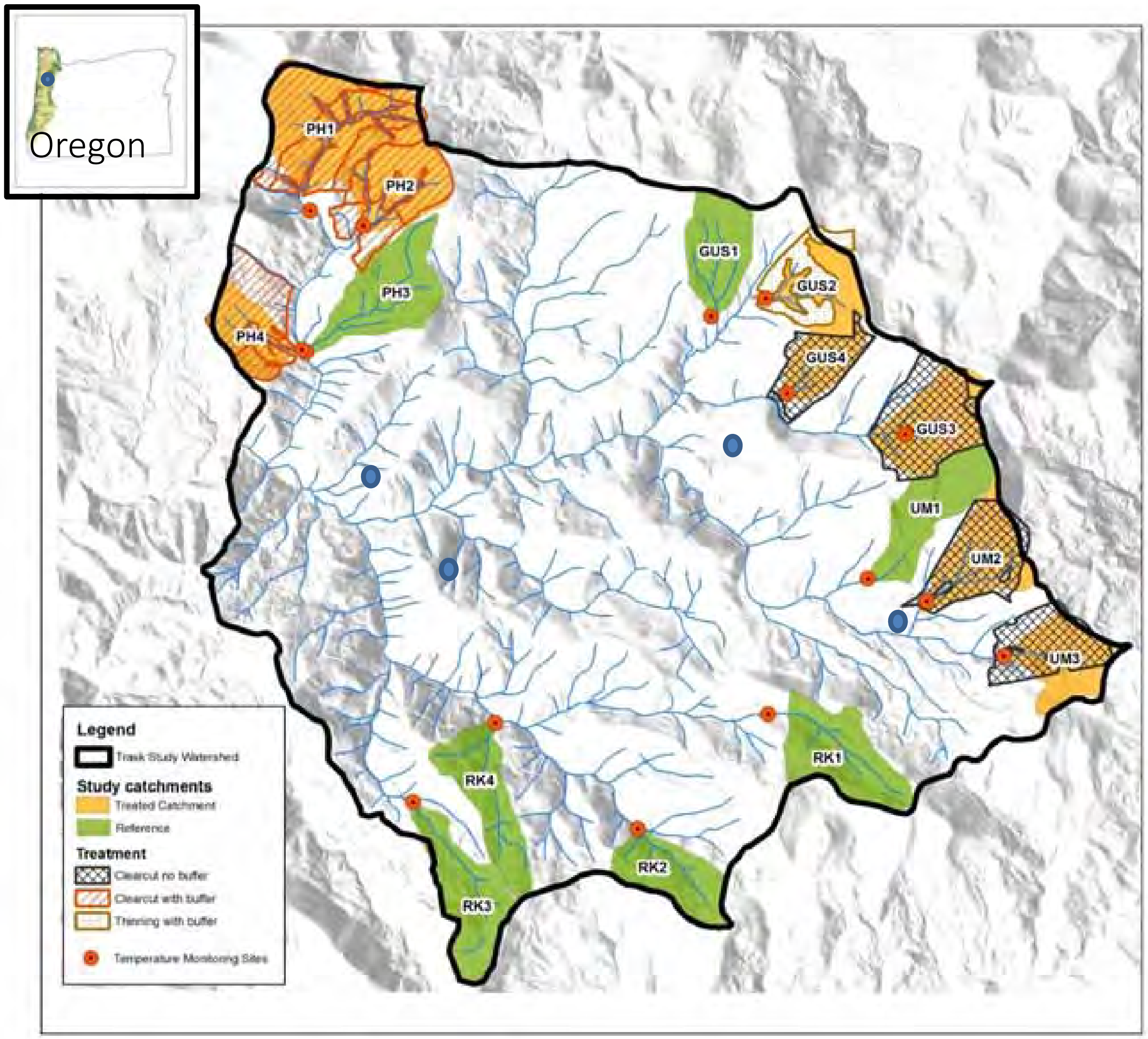
Trask Study



- **Headwater, whole catchment forest harvest**
- **Differences in riparian practices by landowner**
- **BACI design – reference and treated**
- **Headwater non-fish bearing streams**
- **On site and downstream study of responses**
- **6yrs pre-harvest & 4yrs post-harvest**

Trask River Watershed Study

Funding/Research Team

Collaborative effort-involved scientists and managers from multiple organizations: state, federal, private

Base funding: ODF, Weyerhaeuser
Infrastructure funding – OWEB
Matching funds for fish, amphibians, bird study– USGS
Other support – Counties, OSU, USFS, BLM, NCASI

Dr. Sherri Johnson, *PNW Research, USFS*
Dr. Bob Bilby, *Weyerhaeuser Company*
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Dr. Alba Argerich, *OSU College of Forestry*
Dr. Mark Meleason, *Oregon Dept. of Forestry*

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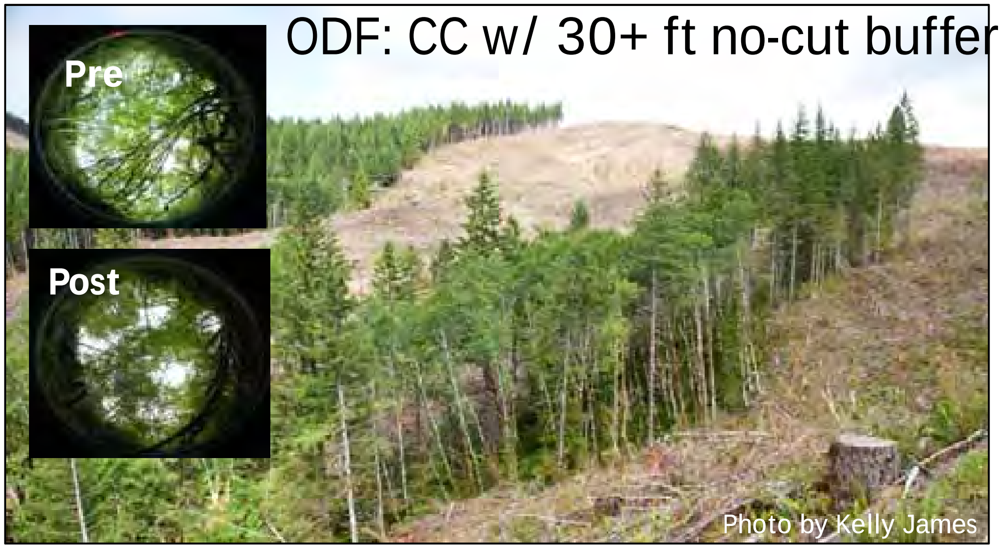
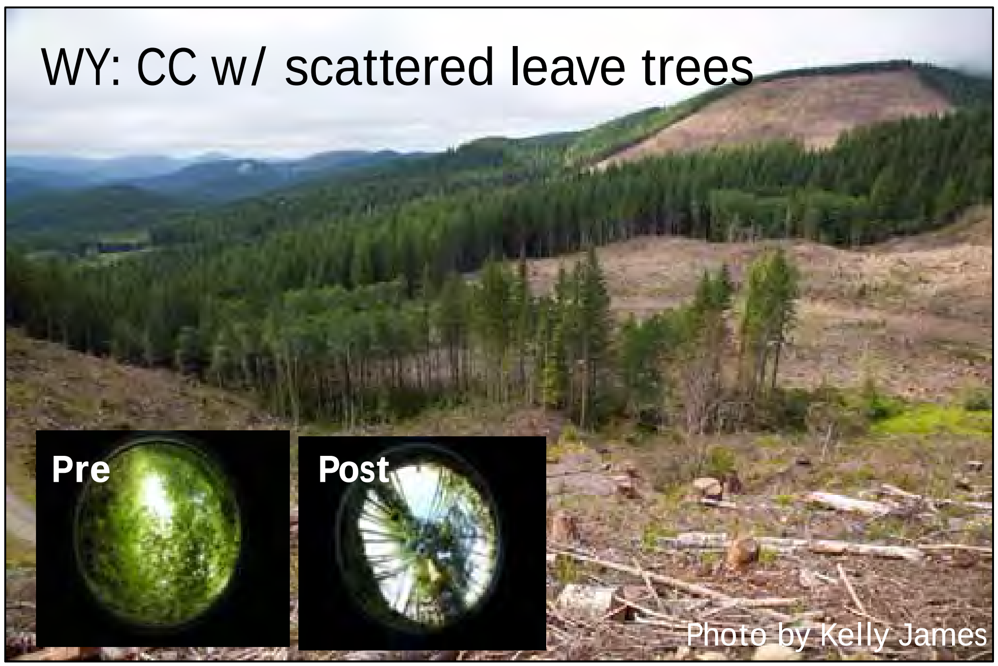
Harvest Treatments and Riparian Buffers





Not shown: BLM thinning with 50-ft buffer

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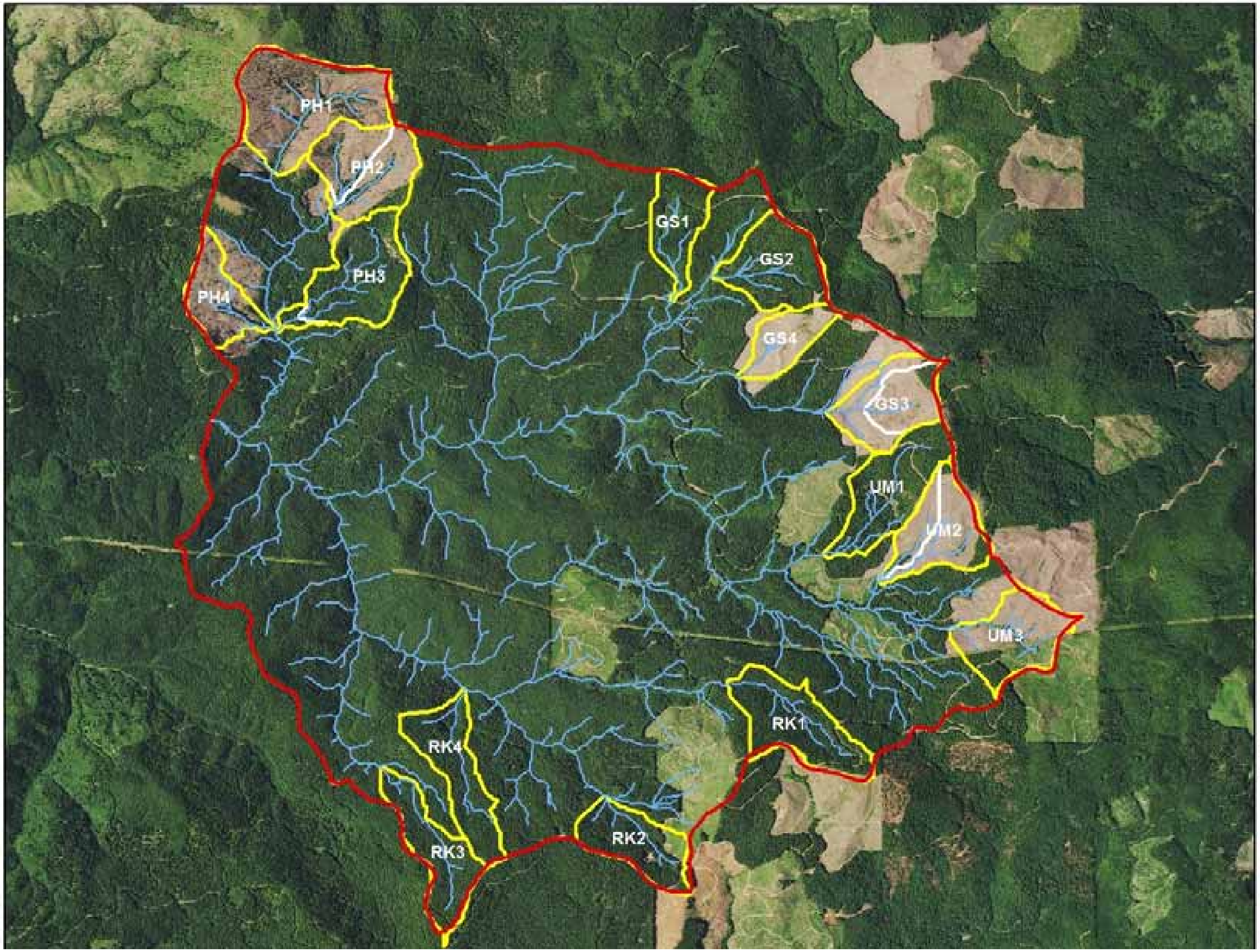
Post harvest



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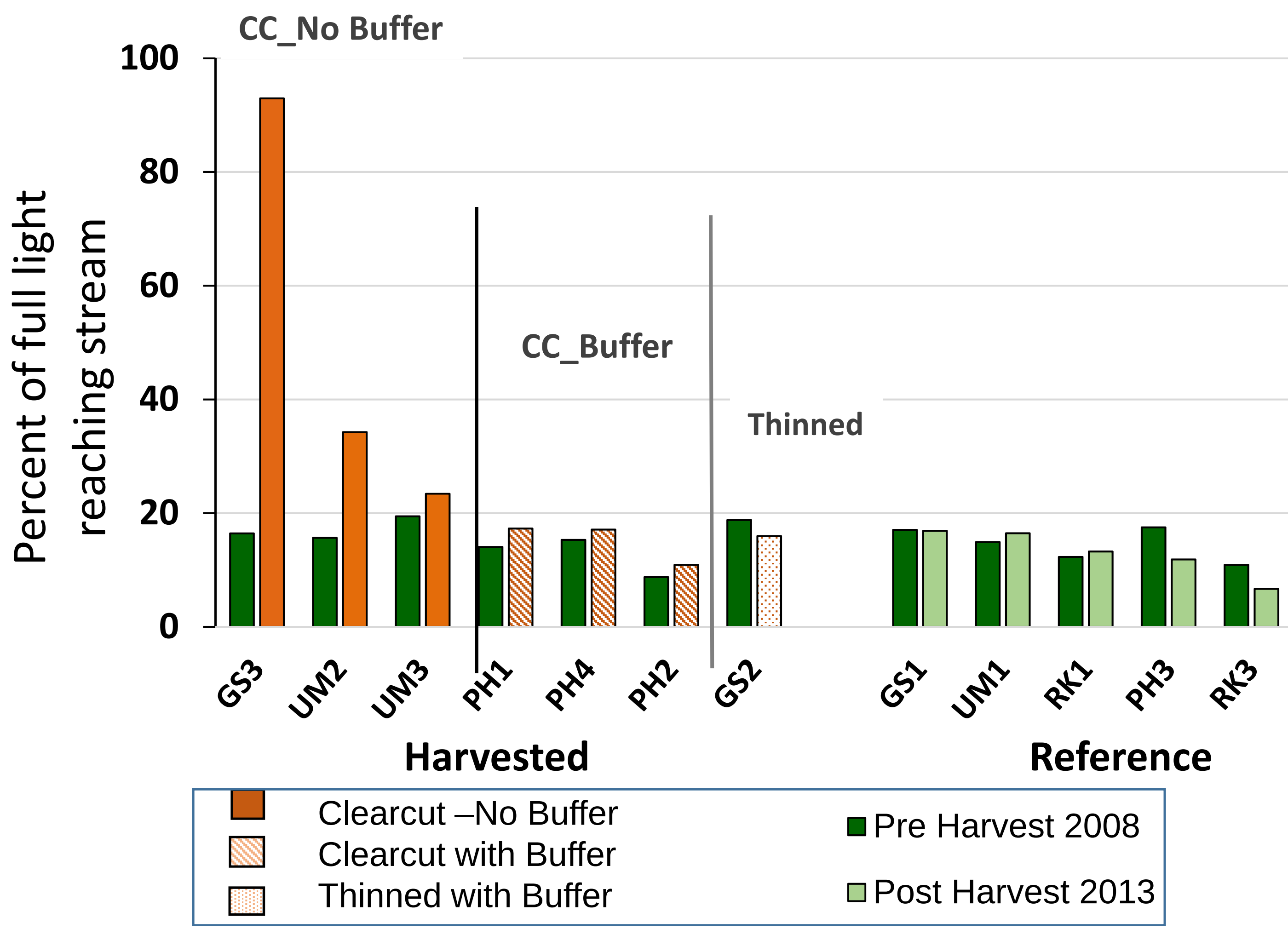
Changes in Light



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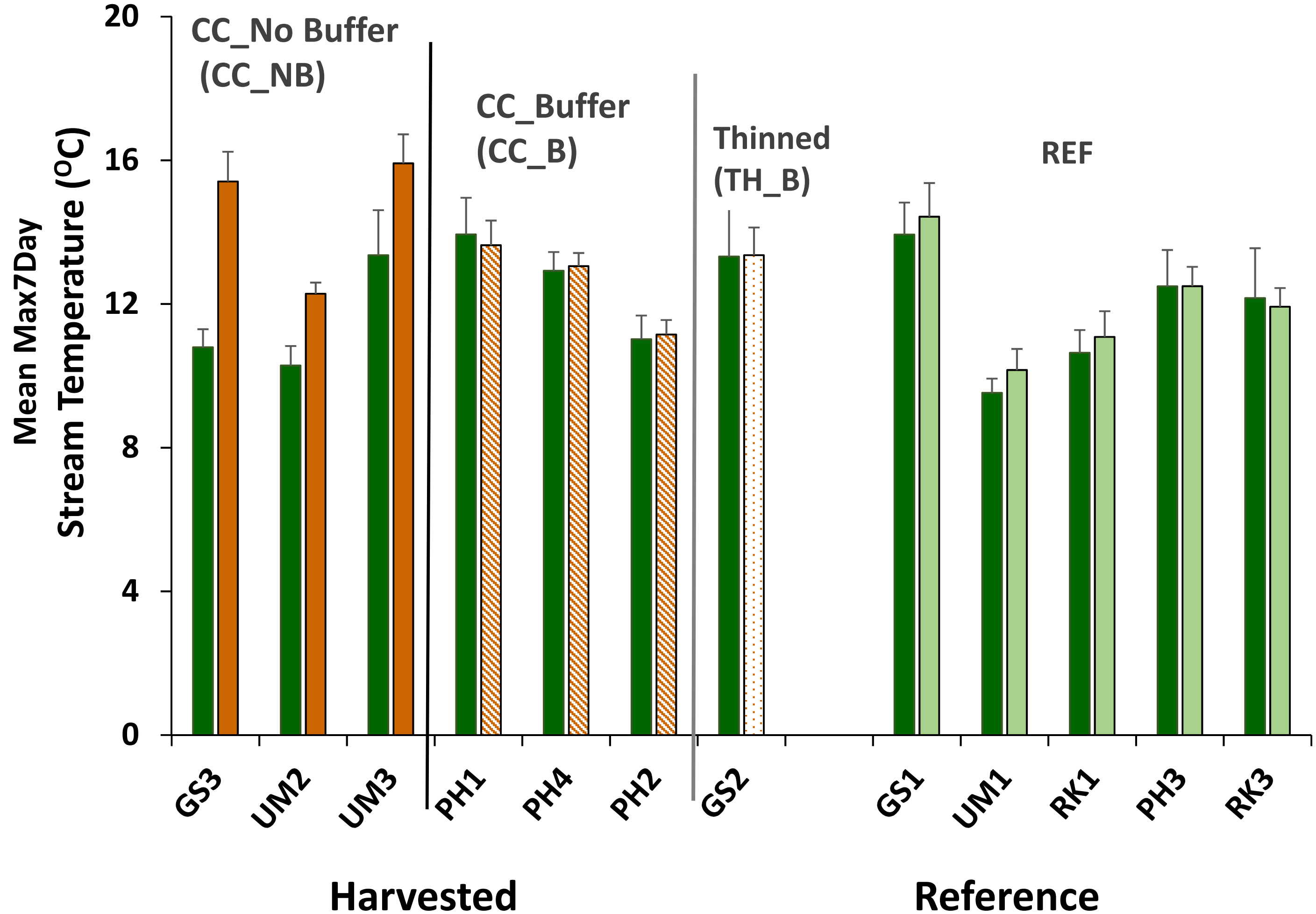
Maximum stream temperatures



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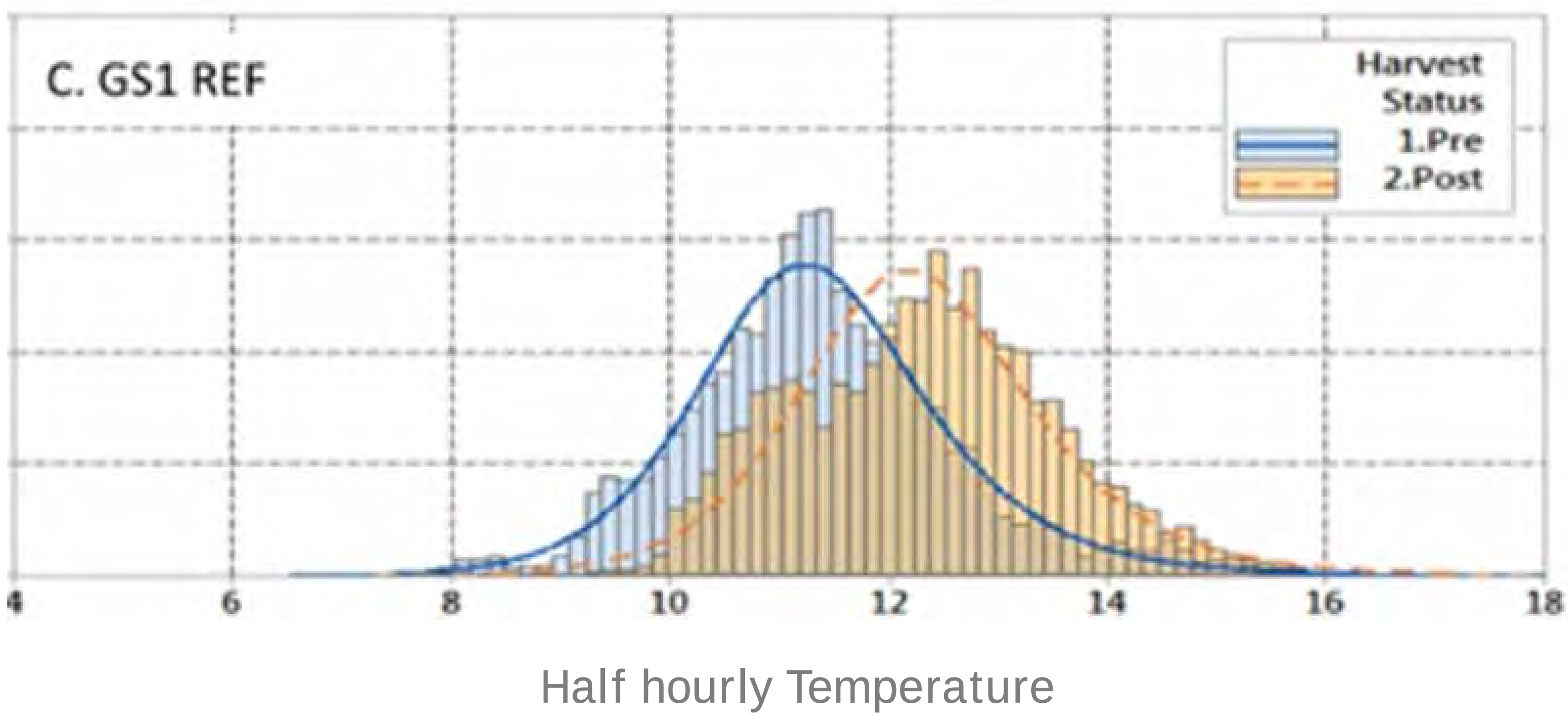
Temperature distributions

Example of Reference Watershed during pre- and post-harvest period



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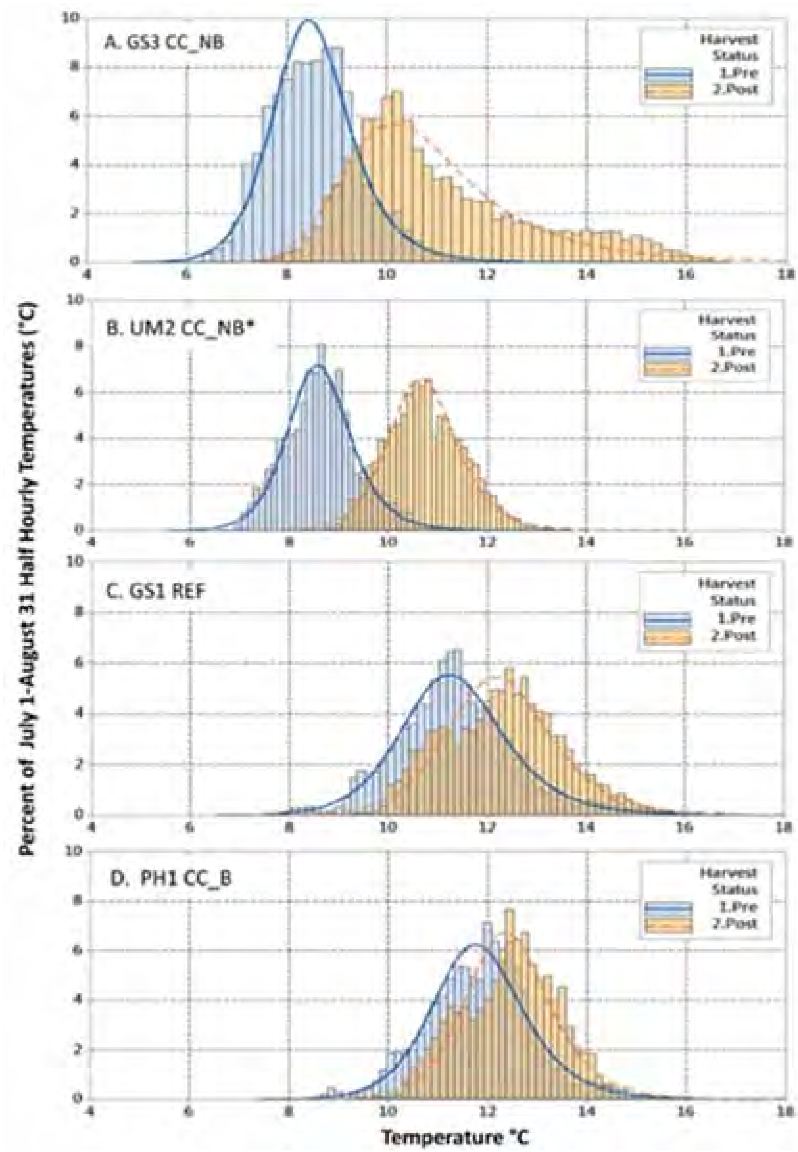
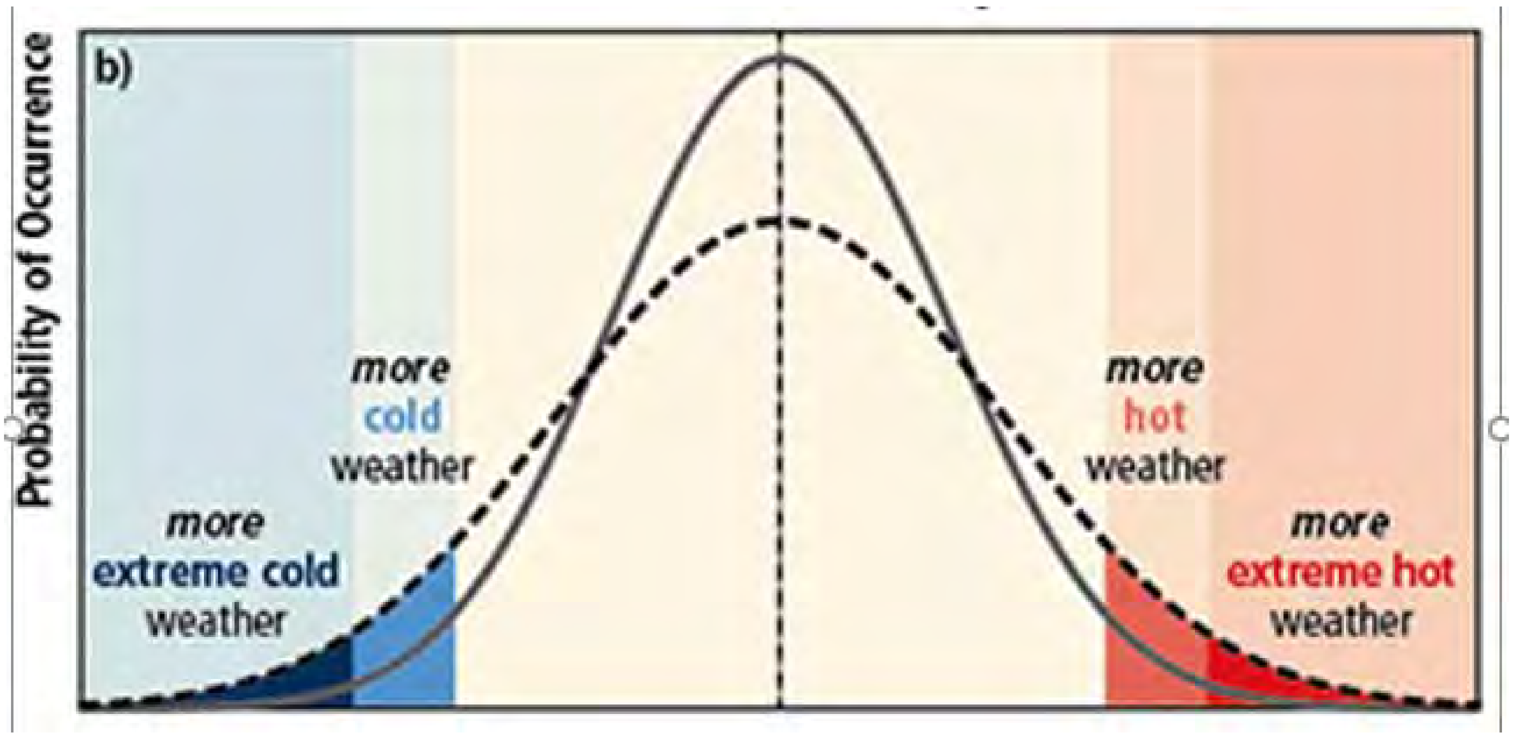
Temperature distributions



A comprehensive metric would go beyond a single value for each summer and examine full distribution of temperatures that biota are exposed to.

Temperature Percentiles



5%

50%

95%

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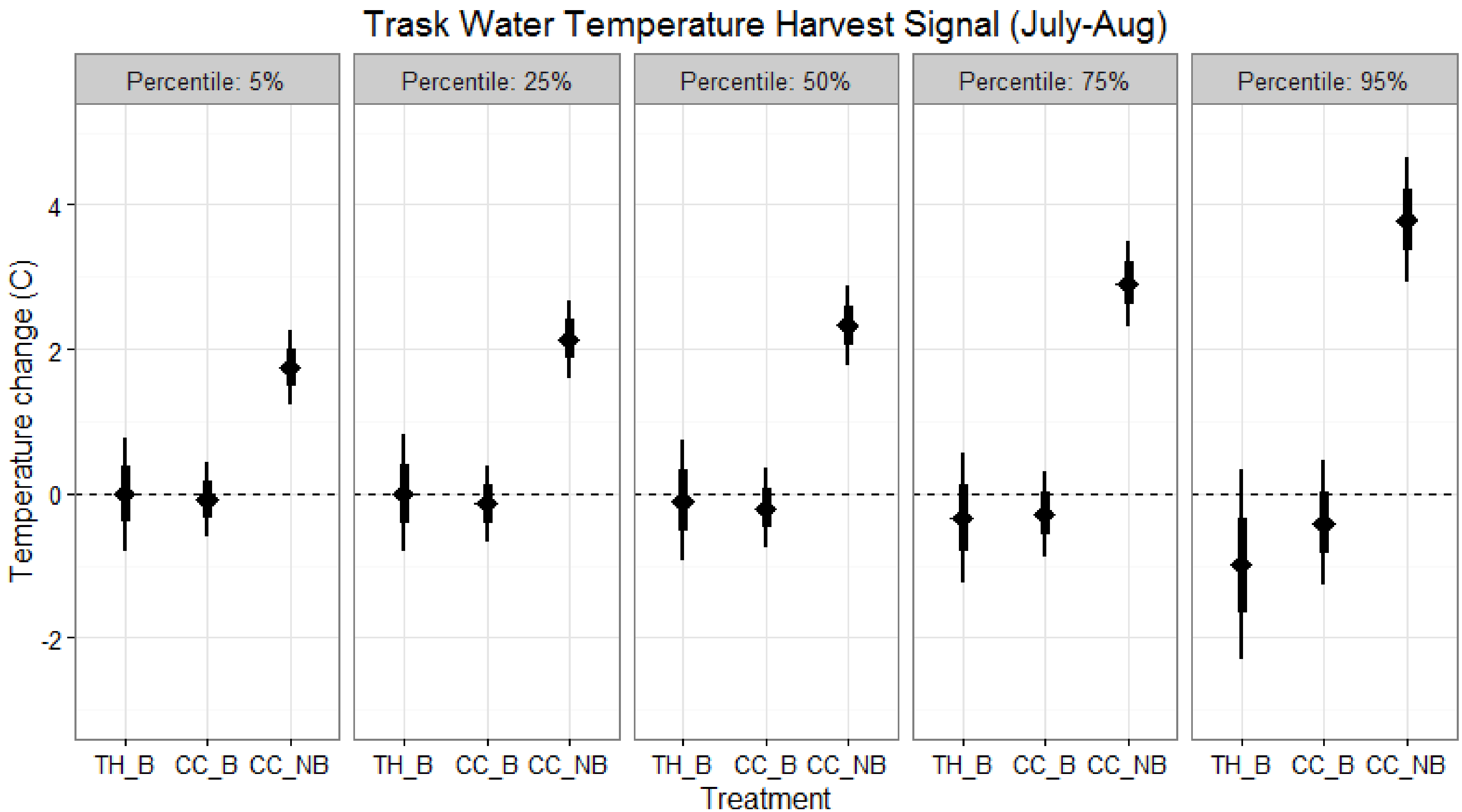
BACI : Estimated Treatment Effects



Fixed effects: Year, Trt, Year*Trt; Random effects: Site
Removed 2012 data
Included all Reference sites

Thick bar = +/- 1 SE; Thin bar = +/- 2 SE
Treatment effect estimator:

$$(\mu_{i,Trt,After} - \mu_{i,Trt,Before}) - (\mu_{i,Ctrl,After} - \mu_{i,Ctrl,Befor}$$

Temperature Distributions

Post-harvest temperatures:

Clear cut_No Buffer
- increase in all percentiles
- greater variation than the other treatments

Clear cut_Buffer and **Thinned_Buffer**
- no evidence of increased or decreased temperature for any percentiles.

Reiter et al.
In review Ecohydrology

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Temperatures and Amphibians

Ascaphus deposits its eggs in mid-summer. Eggs die in water >18.5 (Brown, 1975)

North American Journal of Fisheries Management 25:346–360, 2005

DOI: 10.1577/M03-231.1

Using Field Data to Estimate the Realized Thermal Niche of Aquatic Vertebrates

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Oregon Department of Environmental Quality, Watershed Assessment Section, 2020 Southwest 4th Avenue, Suite 400, Portland, Oregon 97201, USA

Low thermal tolerances of stream amphibians in the Pacific Northwest: Implications for riparian and forest management

R. Bruce Bury

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Distributions and Duration

Duration Above Thermal Indices

	Tailed Frog RTN		Coastal Giant Salamander RTN		Salmonid RTN	
	% > 15.0 °C		% > 16.0 °C		% > 18.0 °C	
Treatment	Pre	Post	Pre	Post	Pre	Post
REF	0.2	0.3	0.0	0.0	0.0	0.0
CC_B	0.1	0.0	0.0	0.0	0.0	0.0
CC_NB	0.3	9.3	0.0	2.6	0.0	0.0
TH_B	0.9	0.0	0.3	0.0	0.0	0.0

“Realized thermal niche (RTN) reflects not just the temperature of an organism’s environment, but also other factors such as competitive interactions with other species”.

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Implications for amphibians

Changes in HW thermal regimes for July-Aug following harvest:

Clear cut_No buffer:

- Duration above 15°C, average increase of 9%.
- Duration above 16°C, average increase of 2.3%.

Clear cut_Buffer

- No apparent temperature change

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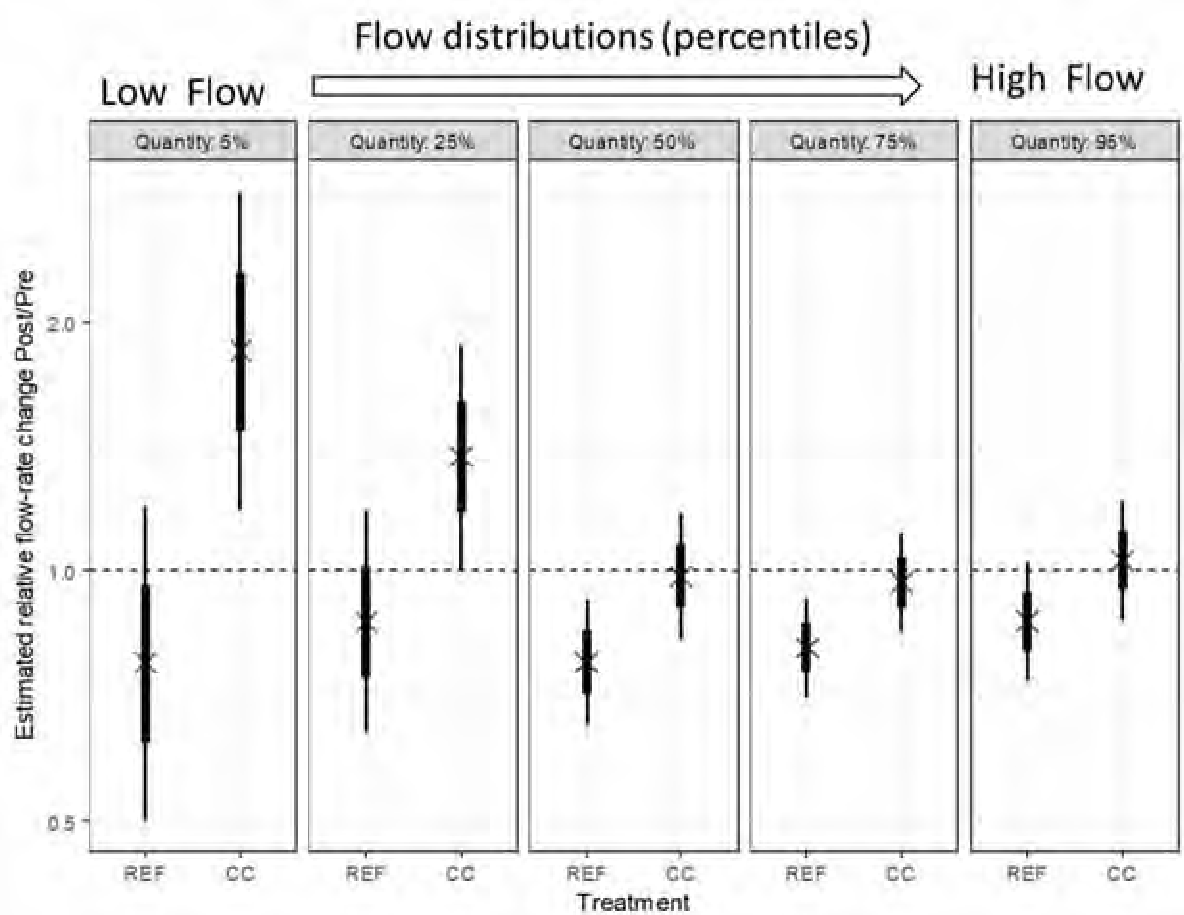
Summary

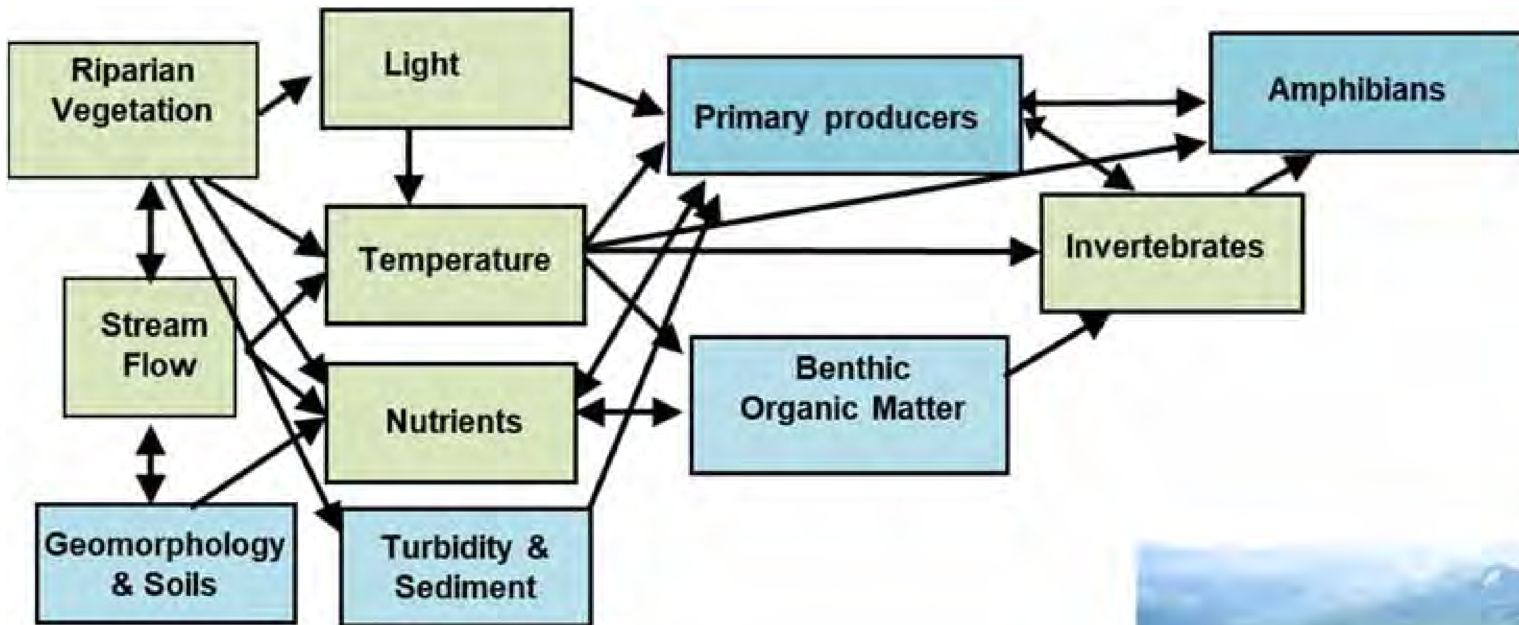


- Percentiles useful for examining multiple parameters.
- Variable responses with treatment
- Importance of reference sites as well as treated sites to capture climatic variability over time.

A comprehensive metric would go beyond a single value for each summer and examine full distribution of temperatures that biota are exposed to.

Summary
Headwater Responses

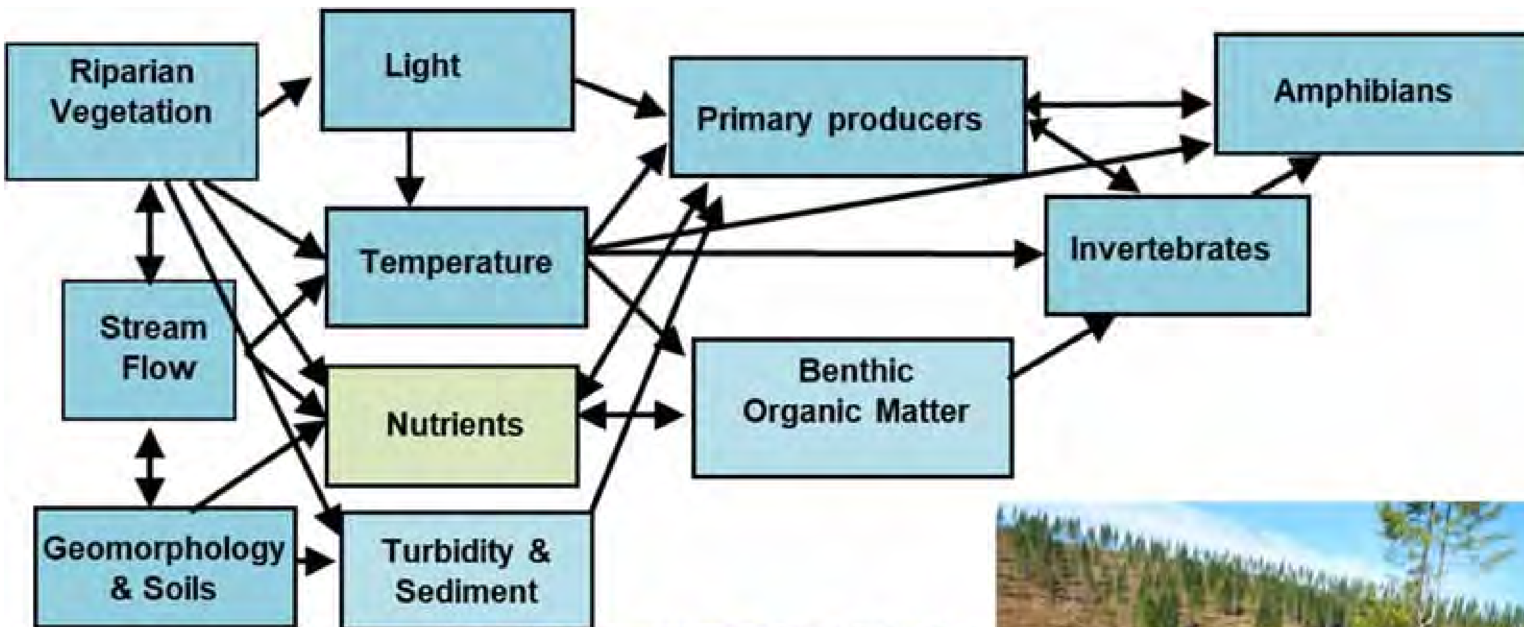
Clearcut –No Buffer



Green boxes=Change after harvest
Blue boxes= No Change

Summary
Headwater Responses

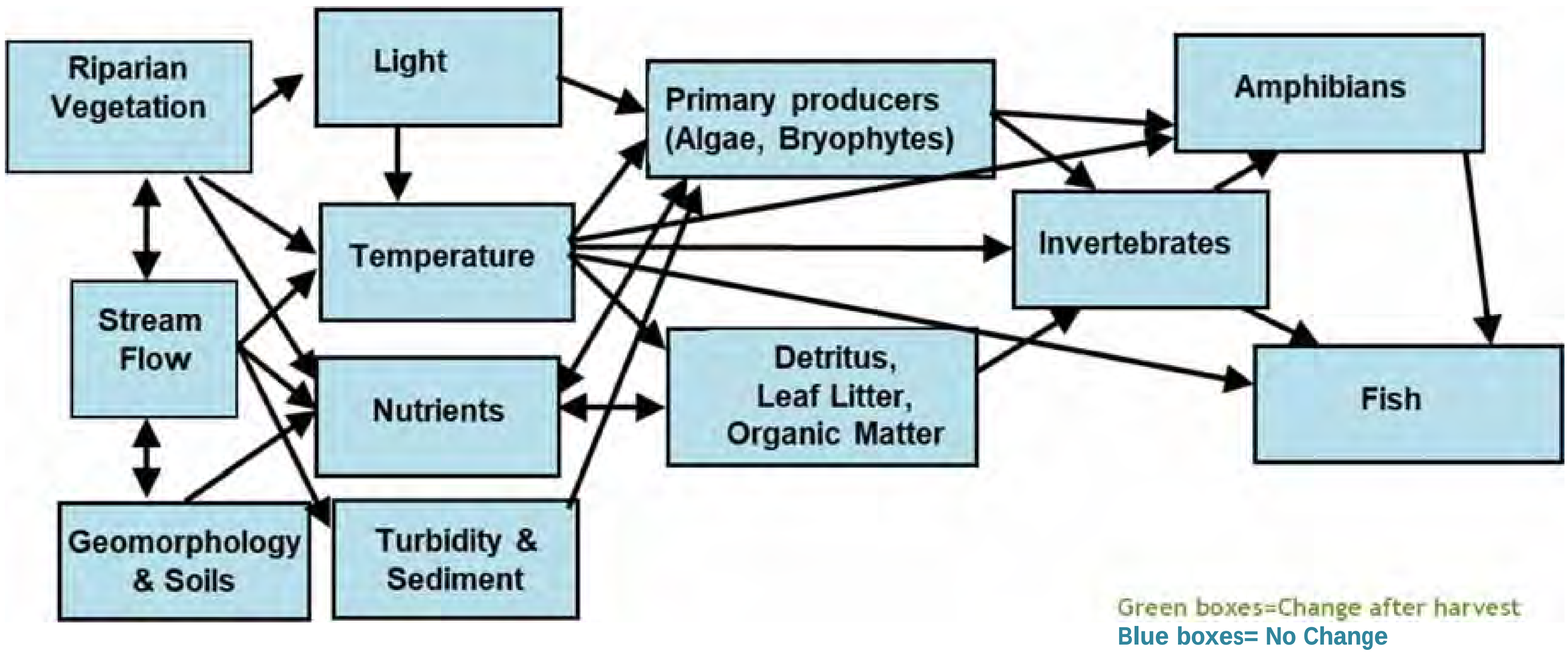
Clearcut with Buffer



Green boxes=Change after harvest
Blue boxes= No Change

Downstream Responses

Downstream Sites



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Questions

Weyerhaeuser

OREGON DEPARTMENT OF FORESTRY

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

OSU Oregon State UNIVERSITY

USGS science for a changing world

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF LAND MANAGEMENT

Why do we care?

- Stream temperature can be viewed a basic ecosystem metric for potential land use impacts
- Forested headwater streams can provide critical cold water habitat for aquatic biota
- Small streams are very responsive to changes in streamside vegetation; they are valuable sites for buffering impacts of changing climate by management of riparian areas

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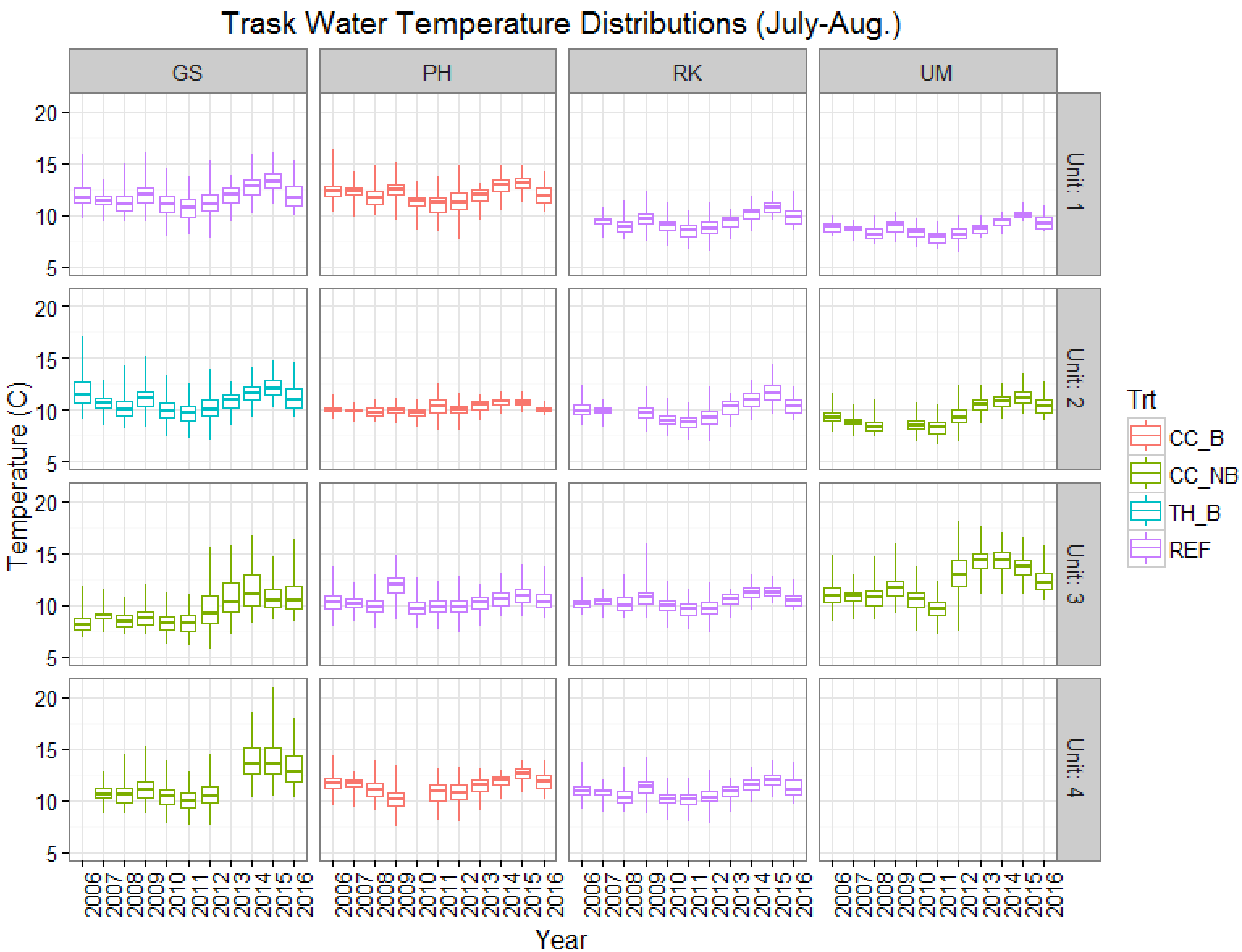
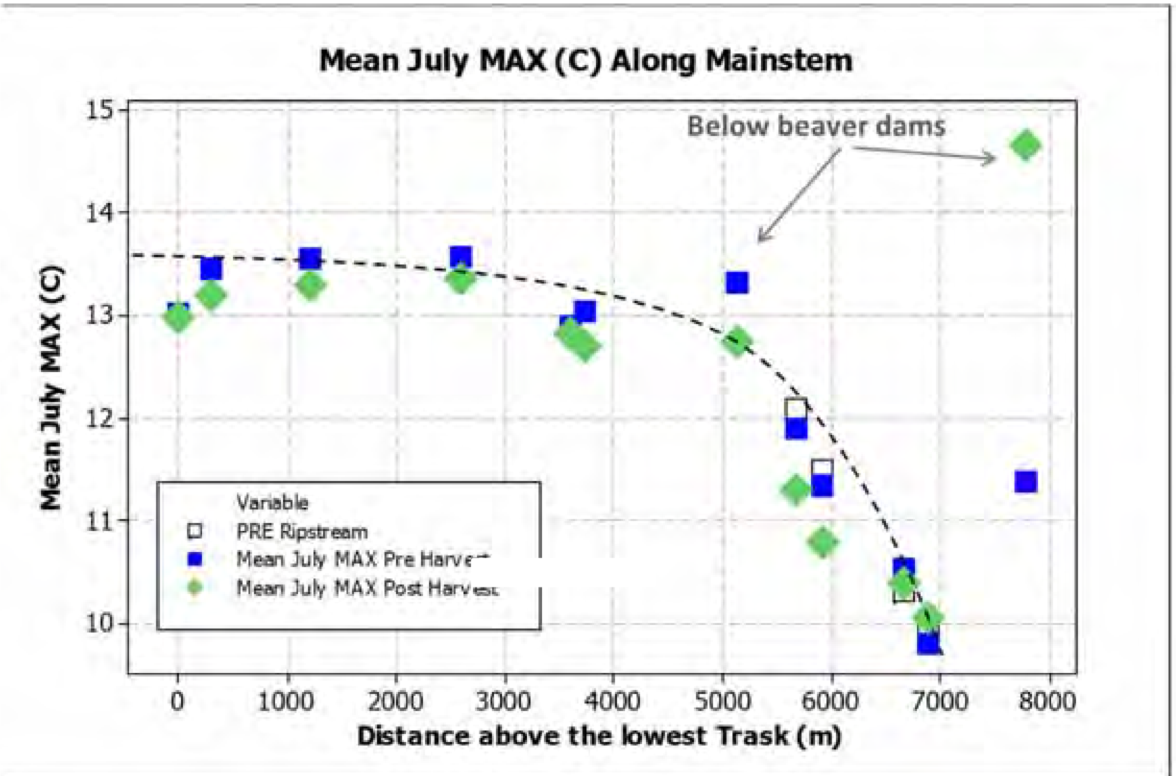
Stream temperature distributions



Trask River Watershed Study | Stream Temperature



- Water temperature increases were localized – no downstream response

- Even large temperature increases (harvest and/or beaver activity) had no detectable effect downstream

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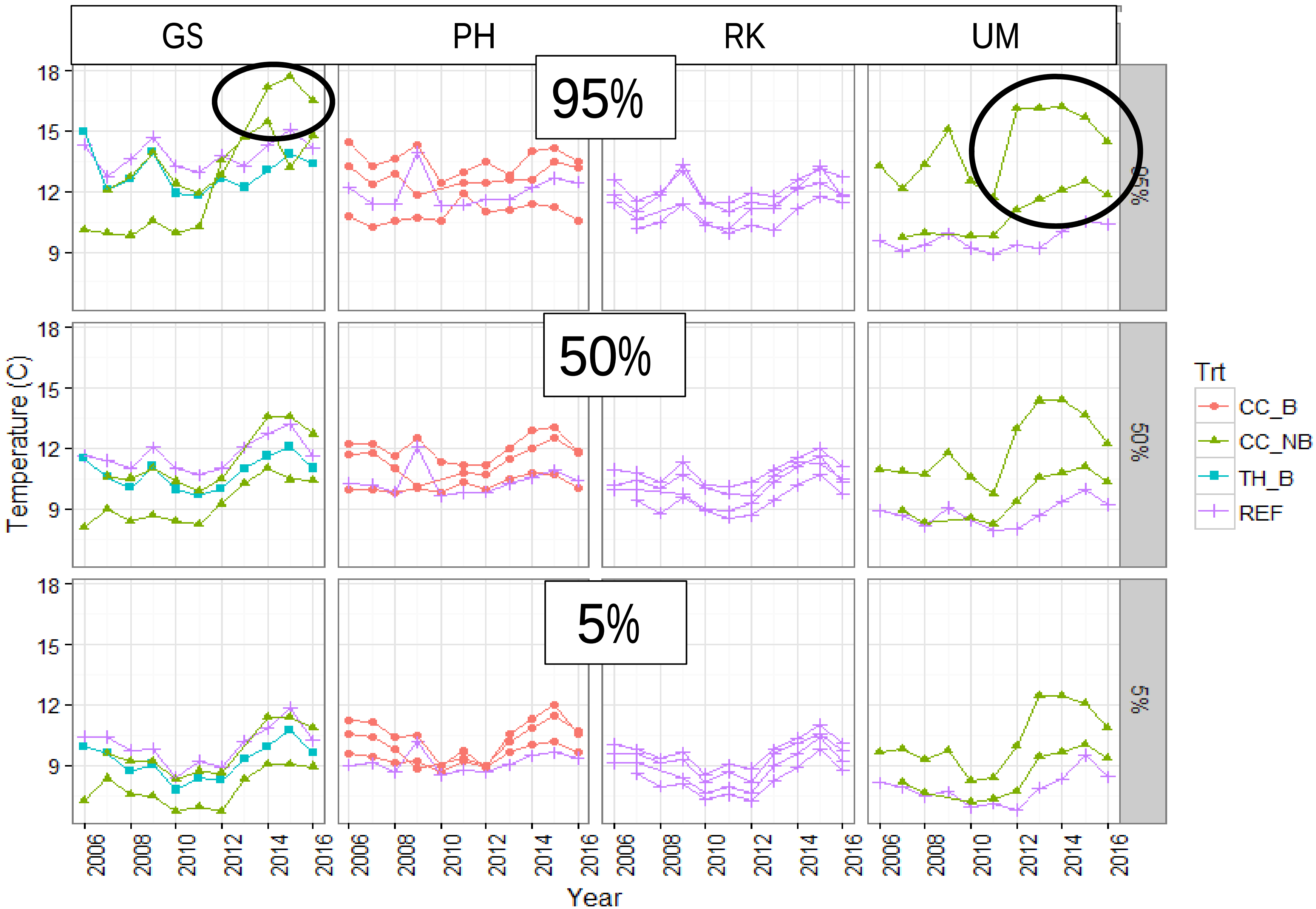
Temperature Percentiles by Treatment across Years



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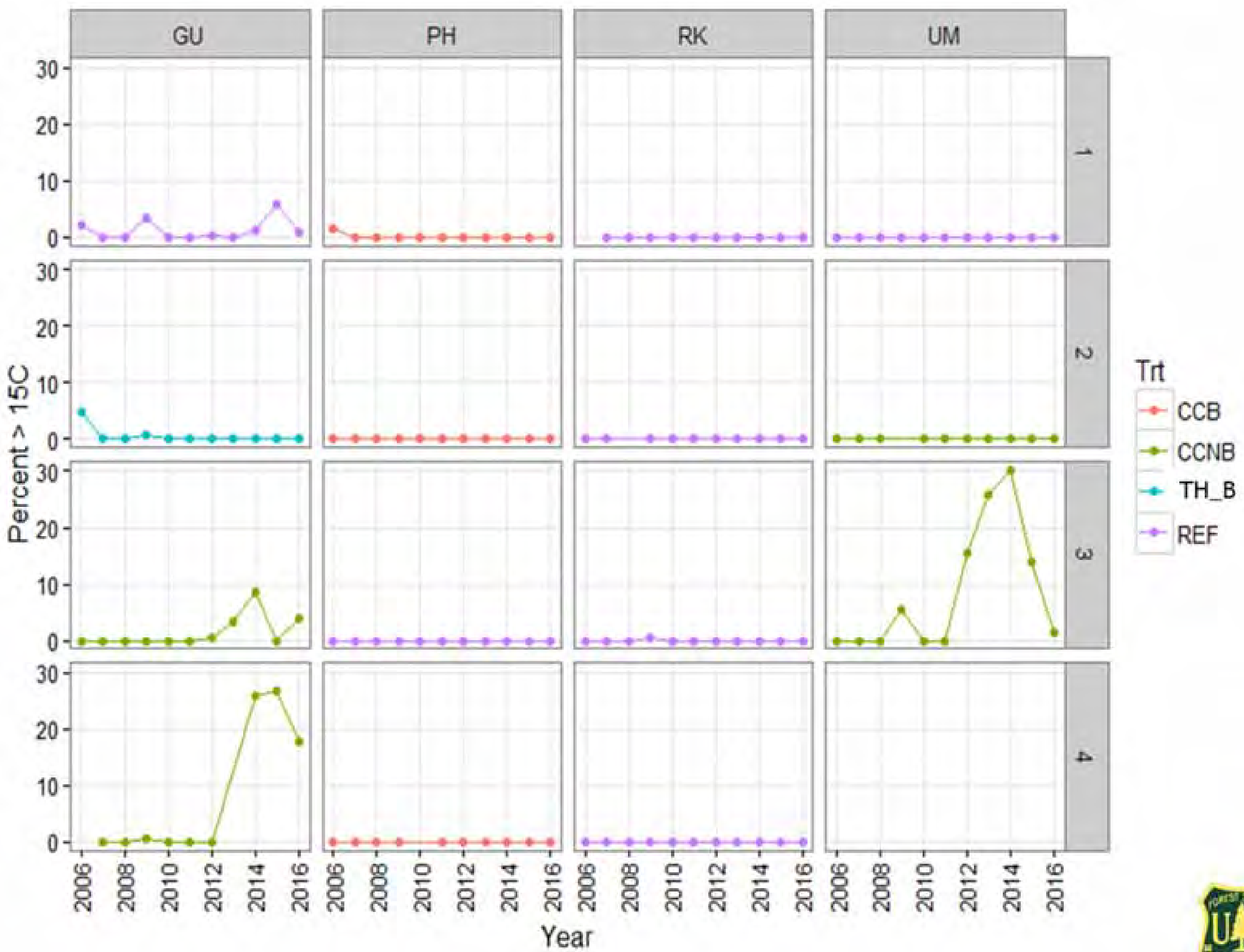
Duration of time above 15°C across years



Response of stream-associated amphibians to timber harvest with alternative riparian buffer configurations

Marc P. Hayes, Aimee P. McIntyre,
Reed Ojala-Barbour, Jay E. Jones,
Timothy Quinn, and Andrew J. Kroll

Ecosystem Responses to Riparian Forest Management along Small Streams

Pacific Northwest Chapter – Society for Freshwater Science
Newport, Oregon – 6-8 November 2019

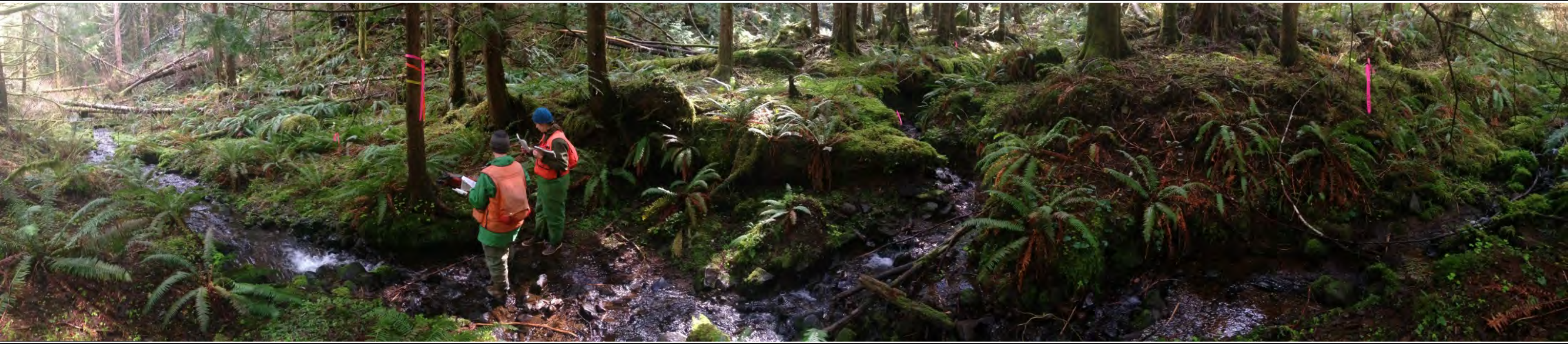
Headwater Streams

Source of all stream networks

Small first-, second- and third-order

Typically fishless or smaller fish densities

Comprise nearly 80% of stream networks in Pacific Northwest

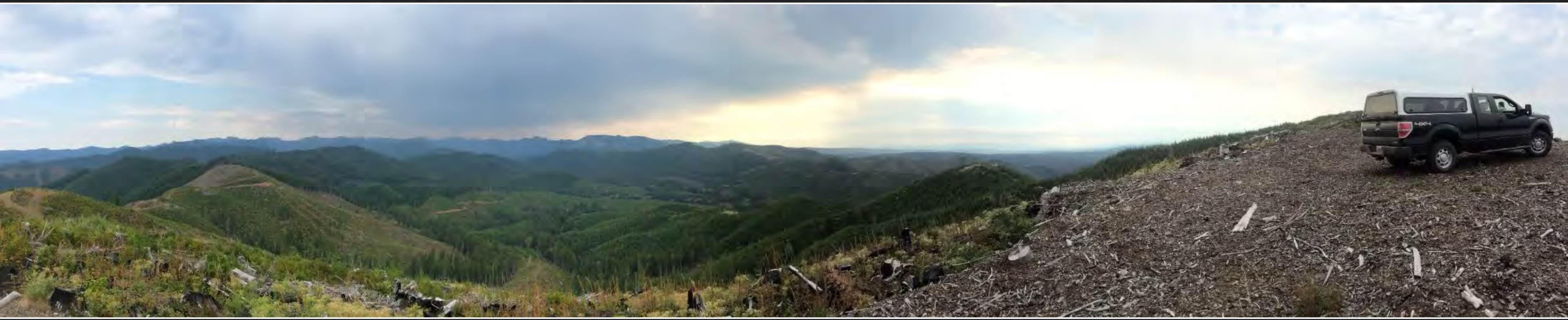


Headwater Management

Commonly located on managed timberlands

Exposed regularly to anthropogenic disturbances

Little is known about long-term effects



Study Objective

Evaluate effectiveness of clearcut harvest with alternative riparian buffers on non-fish-bearing perennial streams:

Stand structure & tree mortality, shade & water temperature, sediment, wood & organic inputs, channel structure, amphibians, exports (water temperature, suspended sediment, organic/nutrients, macroinvertebrates, discharge)

BACI Study Design

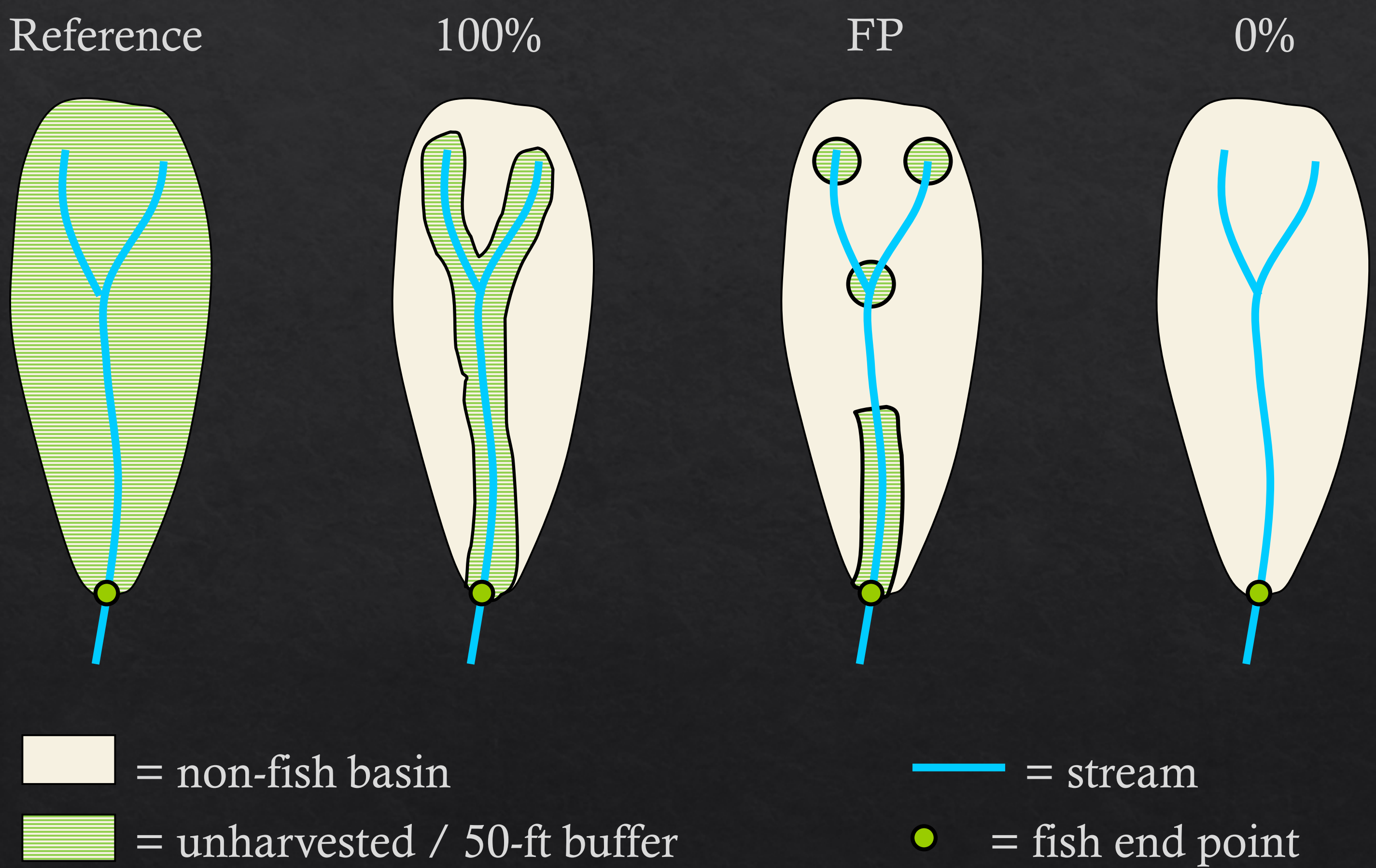
Pre- and post-treatment data collection

Spatial blocking of sites

Random assignment of sites to treatments (when possible)

Analyses at large spatial scale (non-fish-bearing basin)

Experimental Treatments



Study Sites

Perennial, non-fish streams

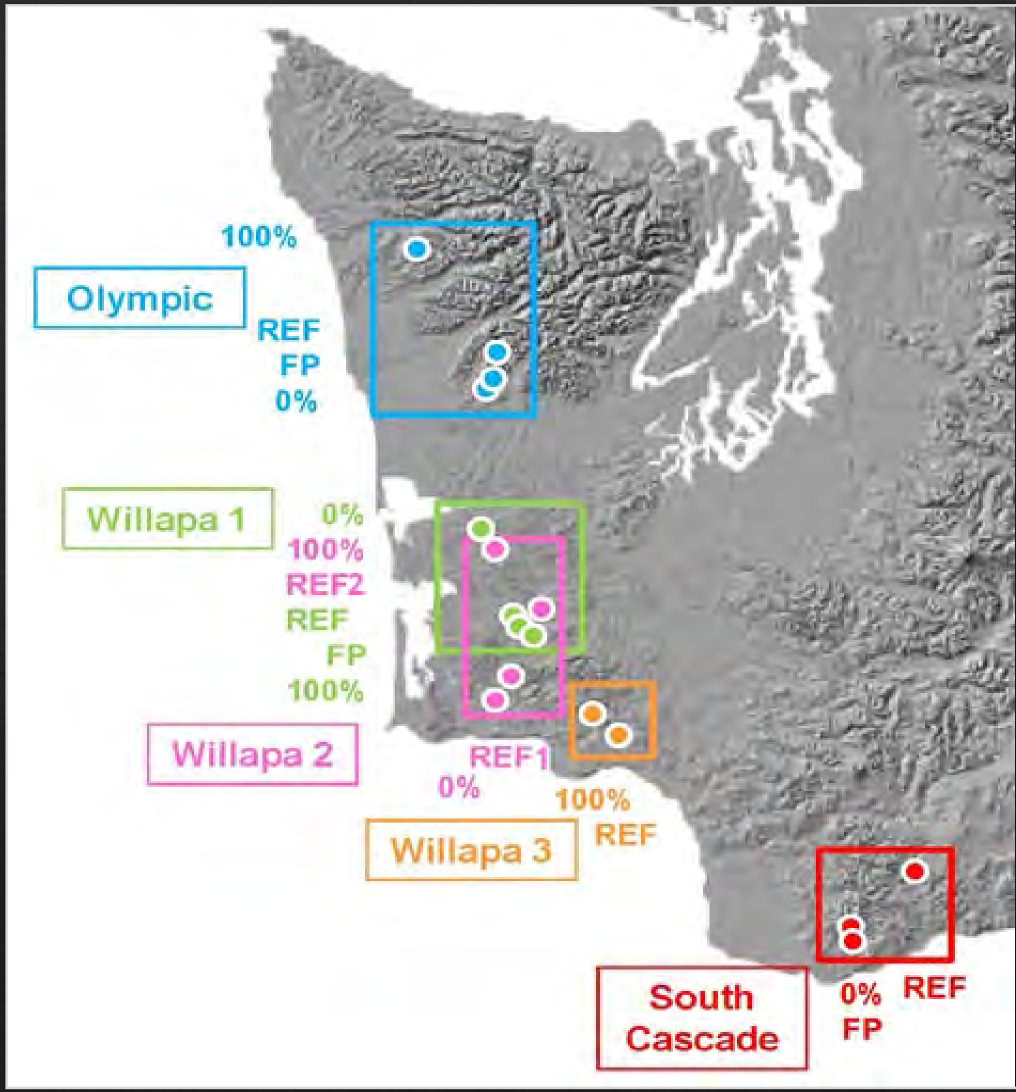
Hard rock lithology

Managed 2nd-growth forests

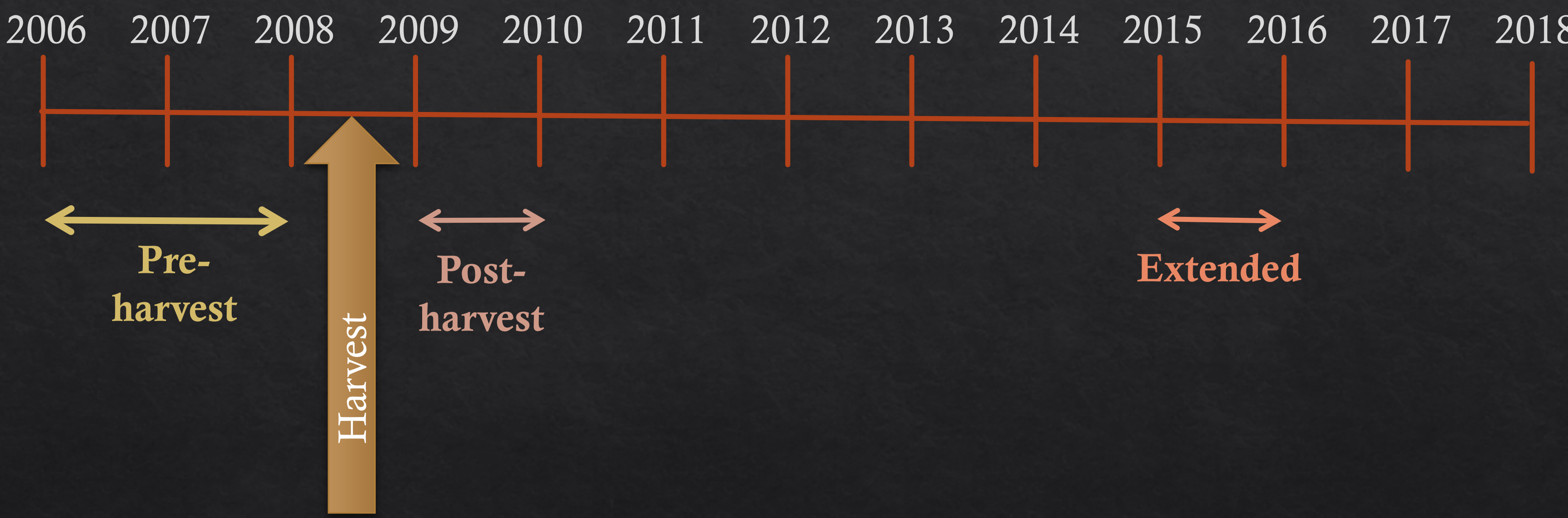
Private/state/federal

30-80 year old stands

30-133 acre basins



Timeline – Study Periods



Stream-associated Amphibians

Coastal Tailed Frog
(*Ascaphus truei*)

Torrent salamanders
(3 *Rhyacotriton* species)

Giant salamanders
(2 *Dicamptodon* species)

Methods: Amphibian Surveys

Diurnal surveys, July-September

Light-touch

Fish end point upstream to headwall

Turn moveable objects ≥ 64 mm

Within bankfull channel

Adjust for detection (Royle 2004)

Rubble-rouse in wood reaches

Install upper and lower nets

Remove substrates ≥ 32 mm

Assumes detection is 1

Royle, J. A. 2004. N-mixture models for estimating population size from spatially replicated counts. Biometrics 60:108-115.

Methods: Calculating Density

Estimate detection (buffer type, stream order, temperature)

Adjust counts by probability of detection*

Aggregate adjusted counts to basin-scale

Account for densities in wood obstructed reaches

Calculate treatment contrasts and 95% credible intervals as “evidence”

*Frequent zero counts for tailed frog in extended precluded detection adjustment

Results

21,194 amphibian observations

98% were focal taxa

1,994

0-4.5 larvae

0-2.5 post-metamorphs

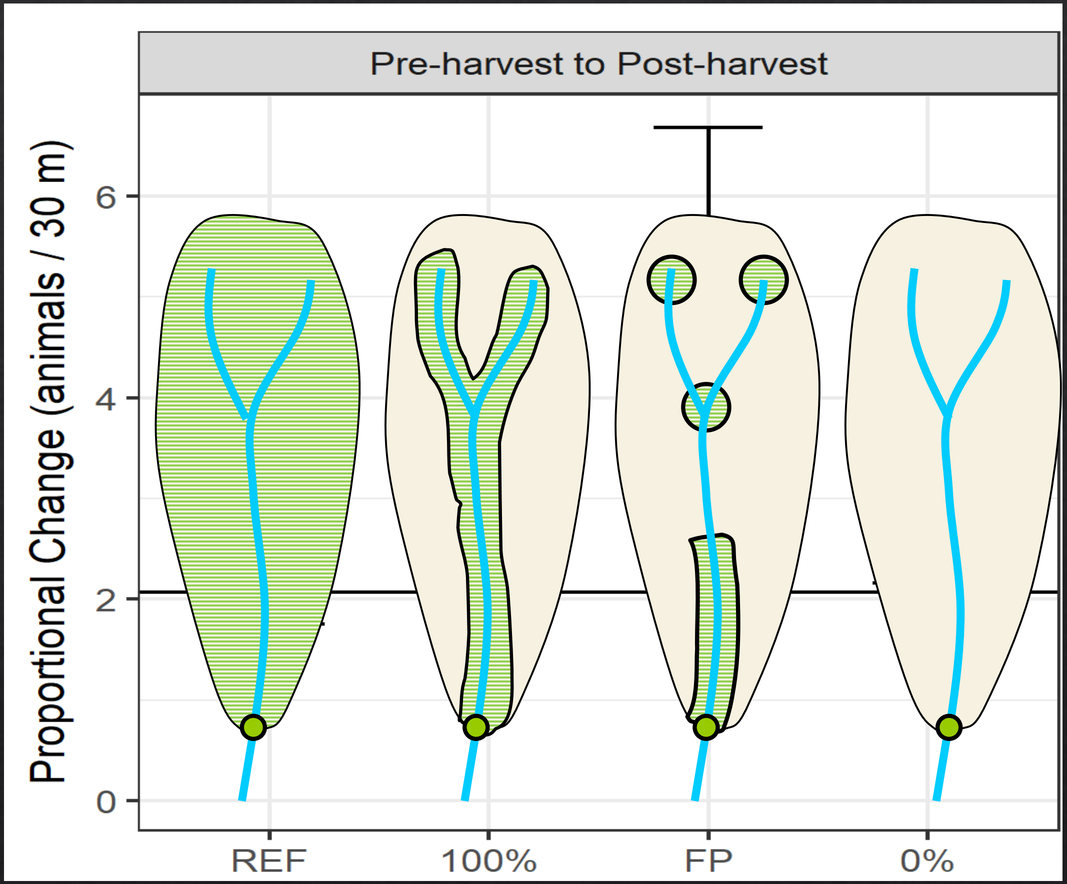
12,989

0-110

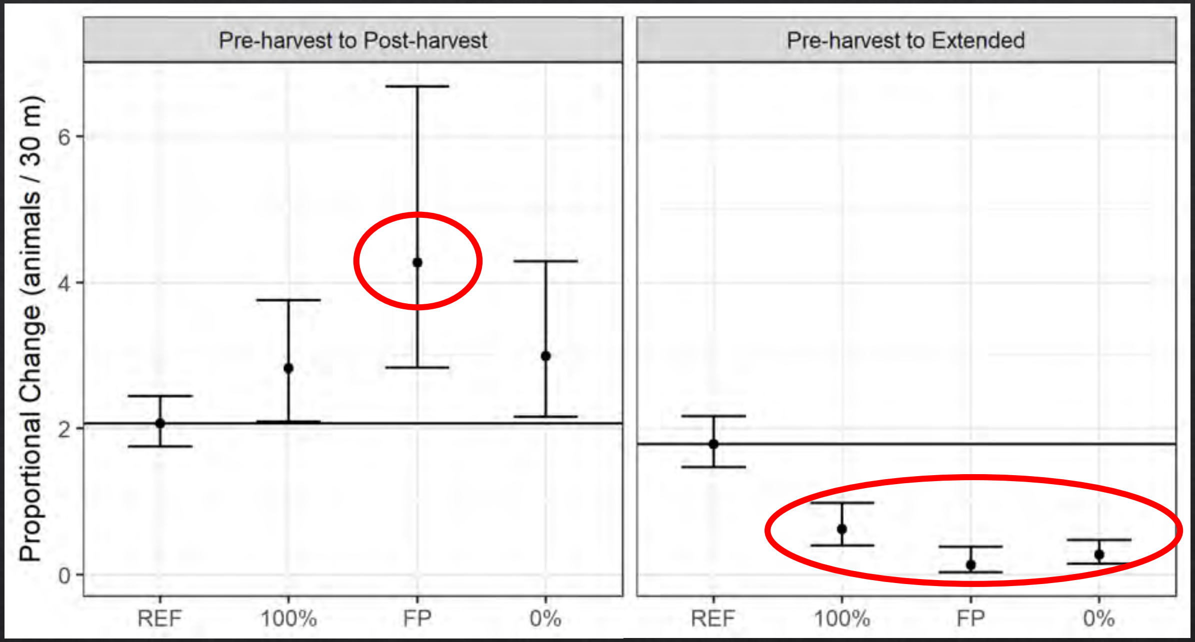
5,727

0.3-59

Results: General lay-out of figures



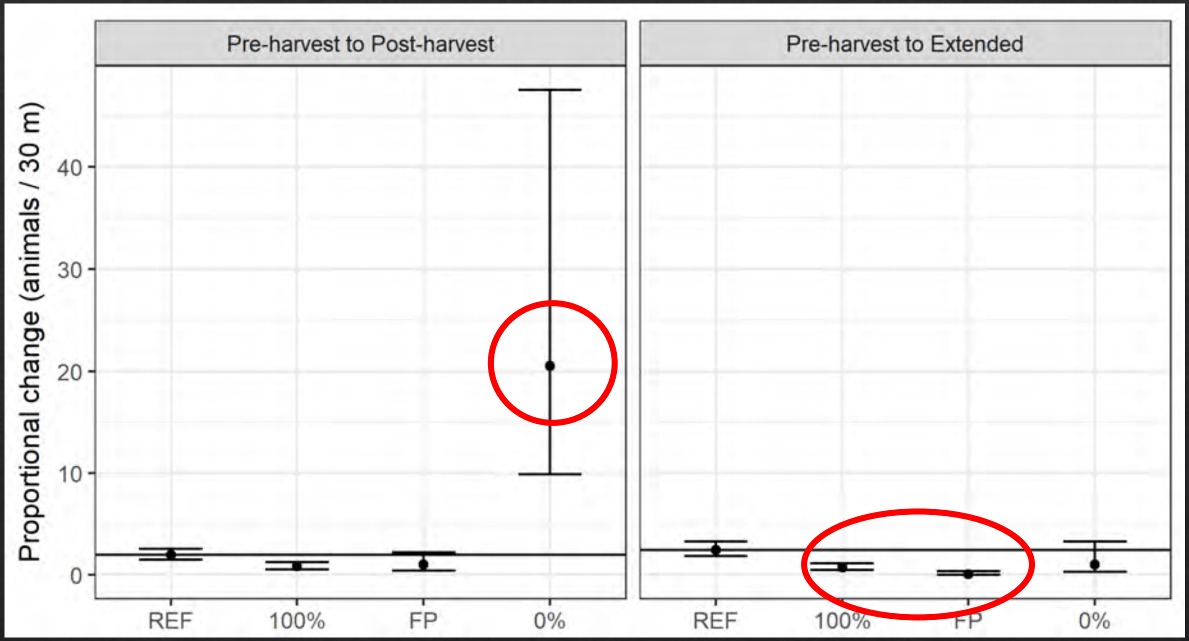
Results: Coastal Tailed Frog larvae



POST: +106% change in mean density in FP treatment compared to reference

EXTENDED: Changes in mean density in 100%, FP and 0% treatments compared to reference: 0.35 (0.21-0.57), 0.07 (0.02-0.21) and 0.16 (0.08-0.27)

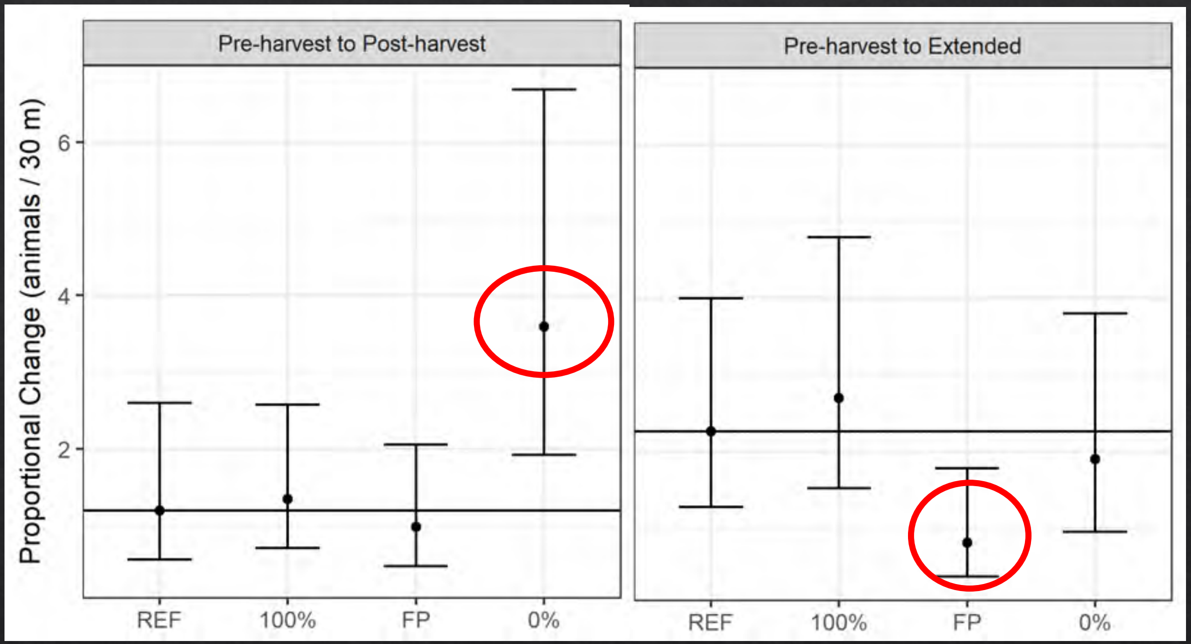
Results: Coastal Tailed Frog post-metamorphs



POST: +961% change in mean density in 0% treatment compared to reference (high uncertainty about effect magnitude)

EXTENDED: Changes in mean density in the 100%, FP and 0% treatments compared to reference: 0.29 (0.18-0.48), 0.03 (0.01-0.14) and 0.40 (0.12-1.38)

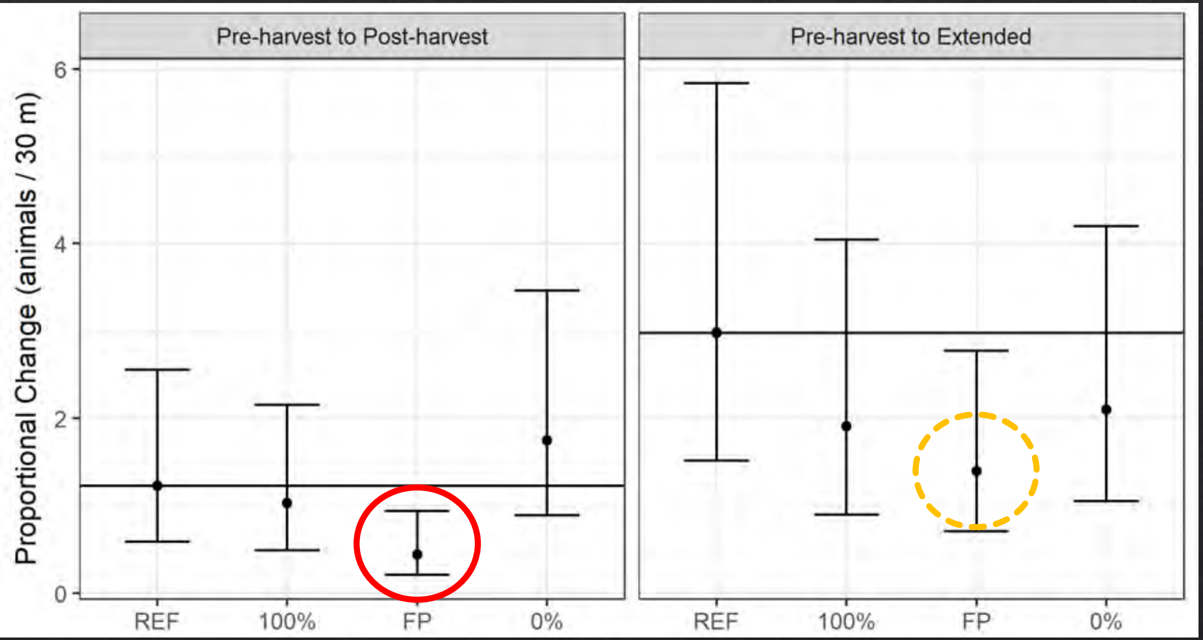
Results: Torrent Salamanders



POST: +198% change in mean density in 0% treatment compared to reference

EXTENDED: Changes in mean density in 100%, FP and 0% treatments compared to reference: 1.2 (0.59-2.43), 0.36 (0.14-0.90) and 0.84 (0.37-1.92)

Results: Giant Salamanders



POST: -64% change in mean density in FP treatment compared to reference

EXTENDED: Changes in mean density in 100%, FP and 0% treatments compared to reference: 0.64 (0.28-1.98), 0.47 (0.21-1.06) and 0.70 (0.32-1.55)

Conclusions

Evidence for:

Delayed, large decline in larval tailed frog density in all buffer treatments in EXTENDED

Decline in post-metamorphic tailed frog density in 100% and FP in EXTENDED

Decline of torrent salamander density in FP in EXTENDED

Decline of giant salamanders in FP in POST; weak evidence for effect in EXTENDED

Extended monitoring critical to observe these results




Acknowledgements

Landowners: Fruit Growers Supply Company, Gifford Pinchot National Forest, Green Crow, Hancock Timber Resource Group, Longview Timber, Olympic National Forest, Rayonier, The Nature Conservancy, Washington Department of Natural Resources, Weyerhaeuser

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Acknowledgements

Field Staff: Jack Armstrong, April Barecca, Adam Brown, Sidney Budd, Matthew Choowong, Allison Cook, Sarah Coven, Tierra Curry, Jennifer Dhundale, Keith Douville, Cristina Dressel, Robert Dyer, Charles Foxx, Nate Gilman, Megan Grugett, Nora Halbert, Daniel Harrington, Mychal Hendrickson, Tiffany Hicks, Katlyn Jacobs, Scott Jones, Eric Lund, Robert Lundergan, Hillary Lyons, Maria Machado, Doré Mangan, Jeffrey Marsten, Cale Myers, Rachel Norman, David Reavill, Courtney Reutzel, Casey Richart, Cole Roberts, Tucker Seitz, Rachel Stendahl, Alicia Terepocki, Curtis Thompson, Maureen Thompson, Jason Walker, Molly Ware, Charissa Waters, Teal Waterstrat, Nick Wenzel, Jacqueline Winter, Anna Yost, Kevin Young, Kyla Zaret



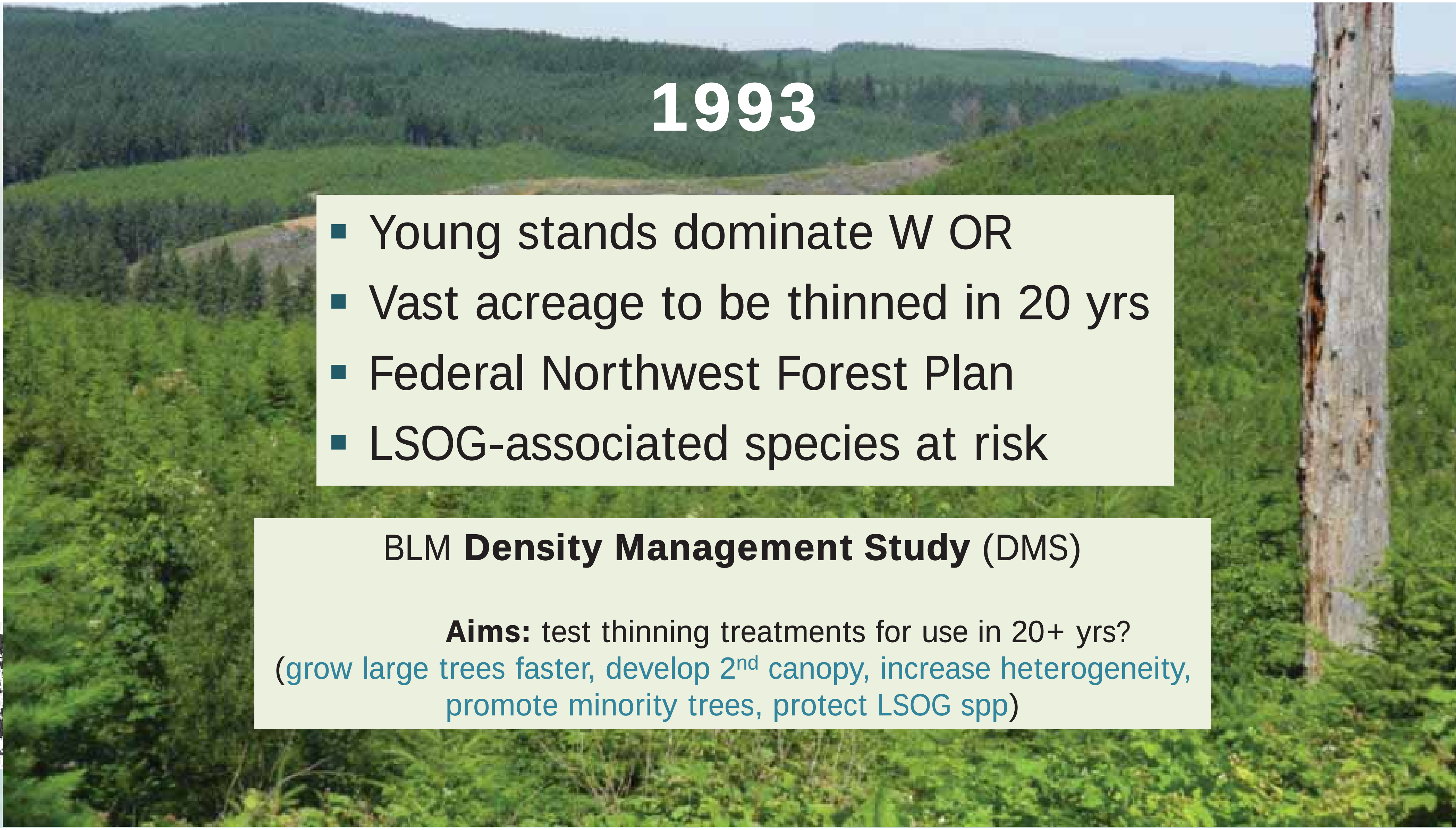

Questions?

Density Management and Riparian Buffer Study of Western Oregon: Lessons Learned after 25 Years, 1994-2019

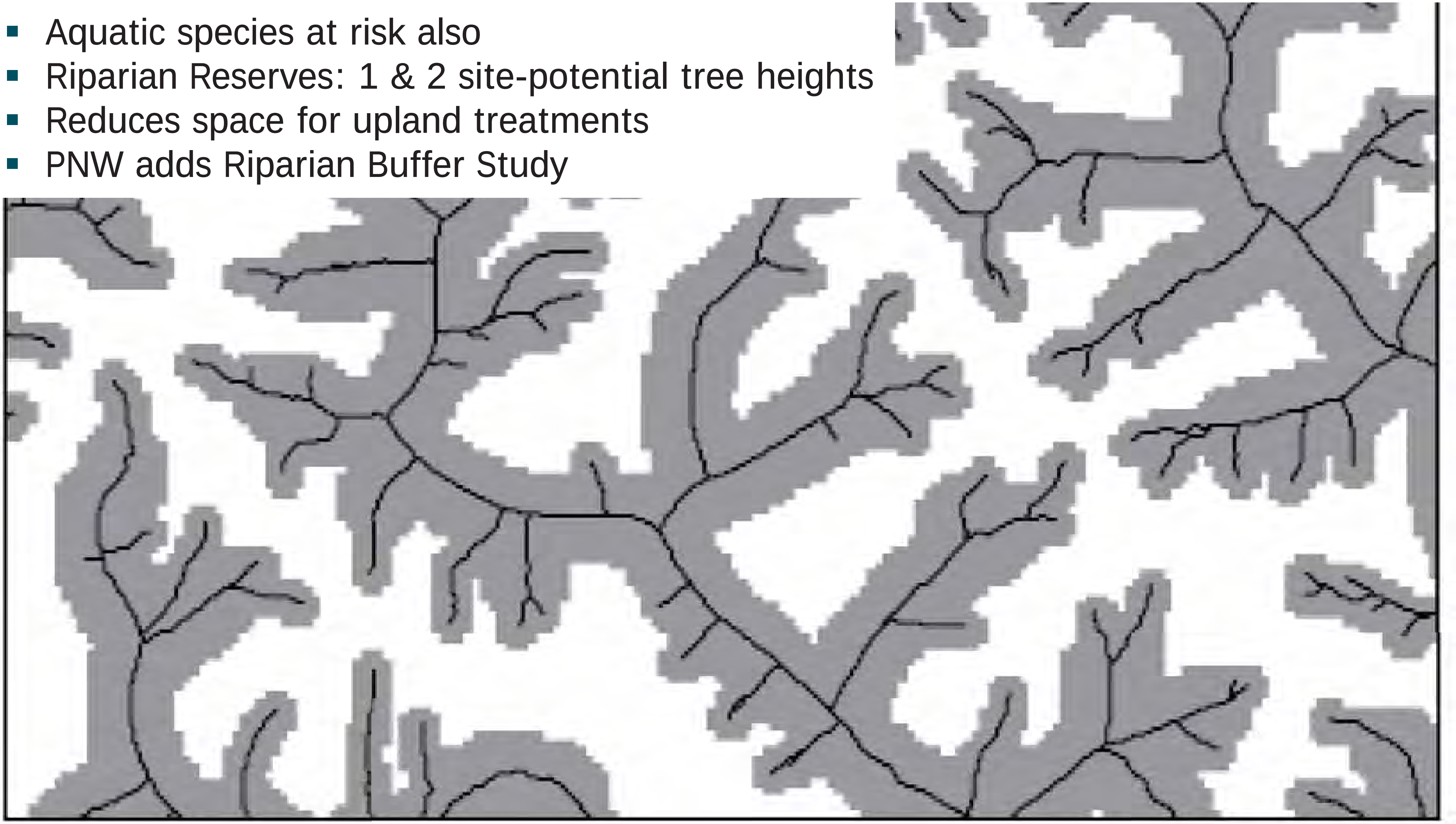
Deanna H. (Dede) Olson

Research Ecologist

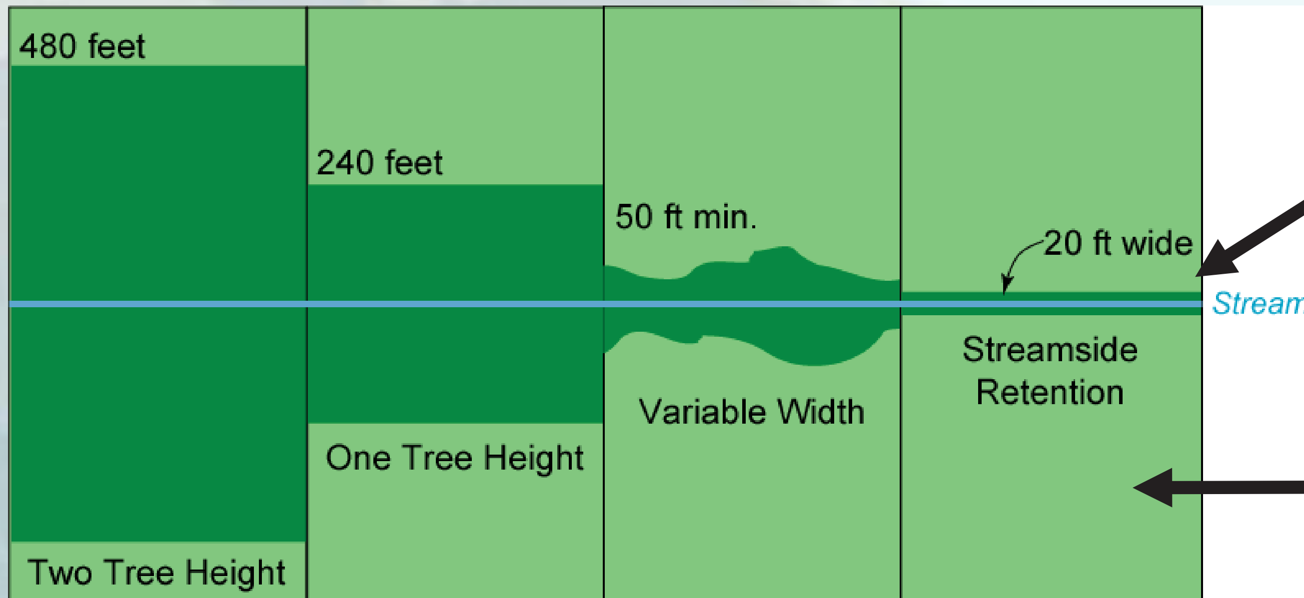
US Forest Service, Pacific Northwest Research Station, Corvallis, OR


1993
Young stands dominate W OR
Vast acreage to be thinned in 20 yrs
Federal Northwest Forest Plan
LSOG-associated species at risk
BLM Density Management Study (DMS)
Aims: test thinning treatments for use in 20+ yrs?
(grow large trees faster, develop 2nd canopy, increase heterogeneity, promote minority trees, protect LSOG spp)

- Aquatic species at risk also
- Riparian Reserves: 1 & 2 site-potential tree heights
- Reduces space for upland treatments
- PNW adds Riparian Buffer Study

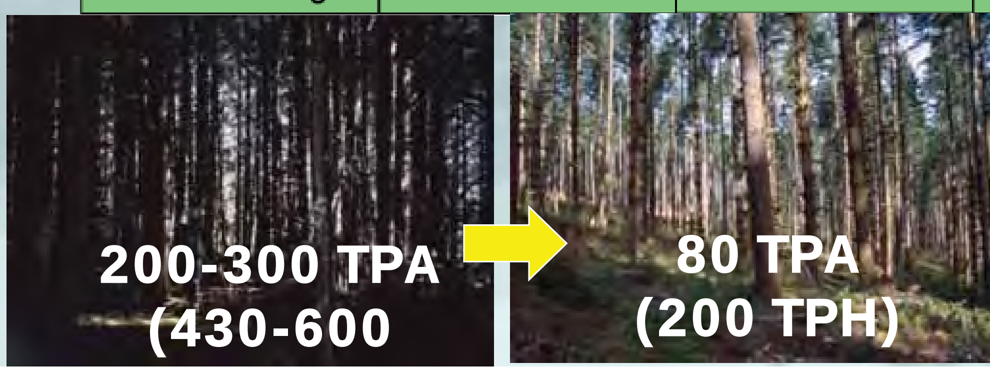


Density Management and Riparian Buffer Study of Western Oregon (1994 to present): BACI Design

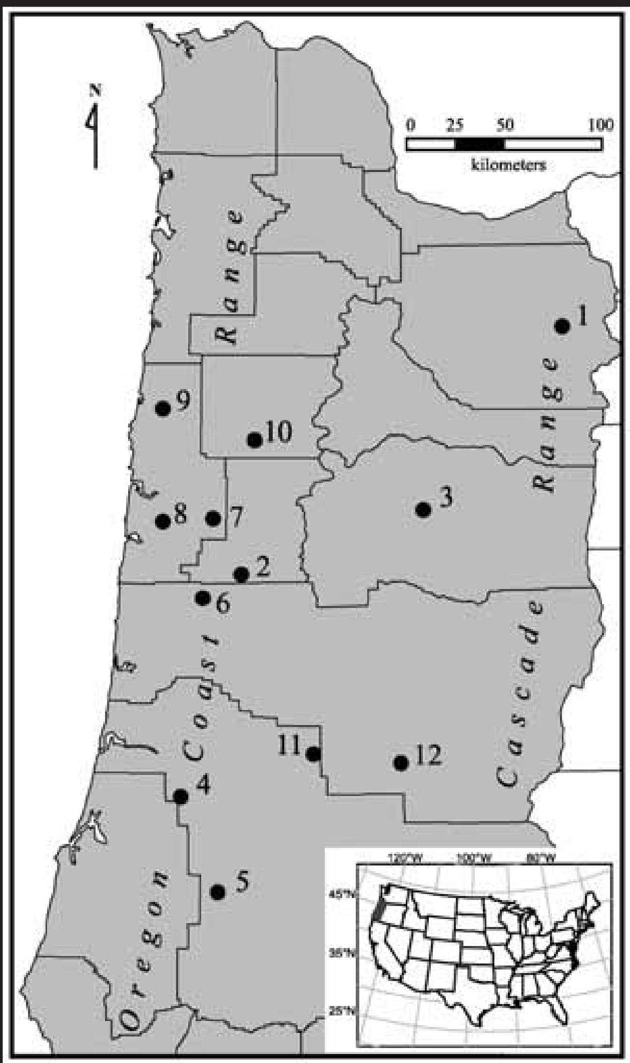


Stream reaches with 4 buffers examined
&
Unmanaged control stream reaches

Upland thinning

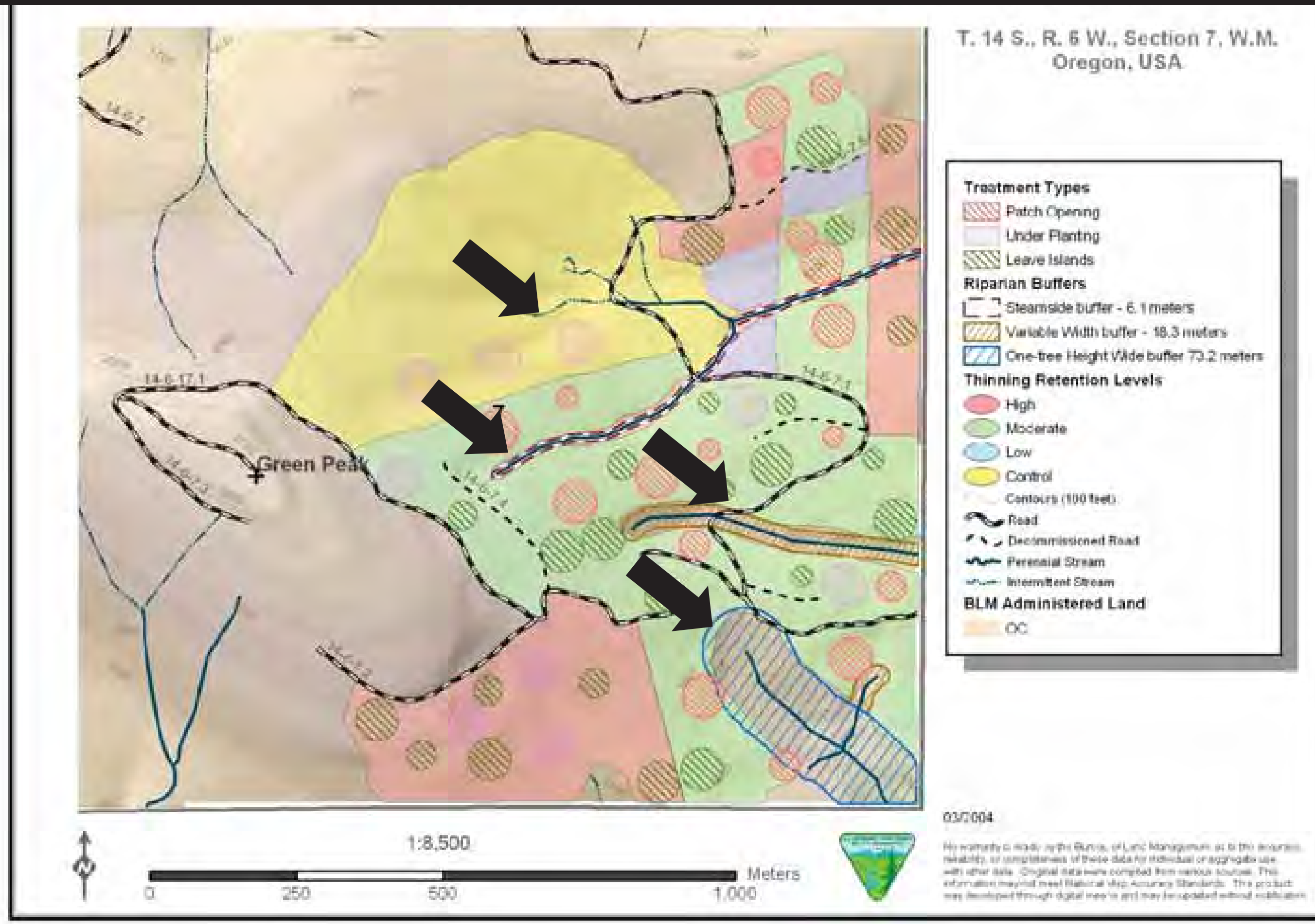


Western Oregon Study



Layout Example

Control and treatment stream reaches

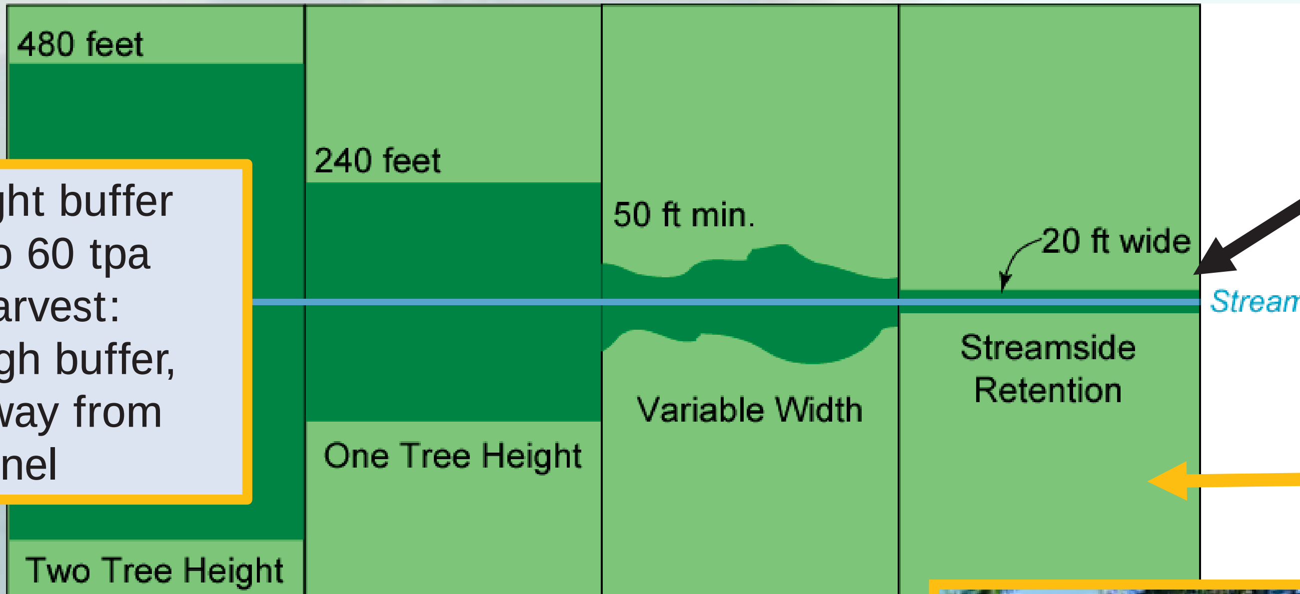


Example study site

Example study site

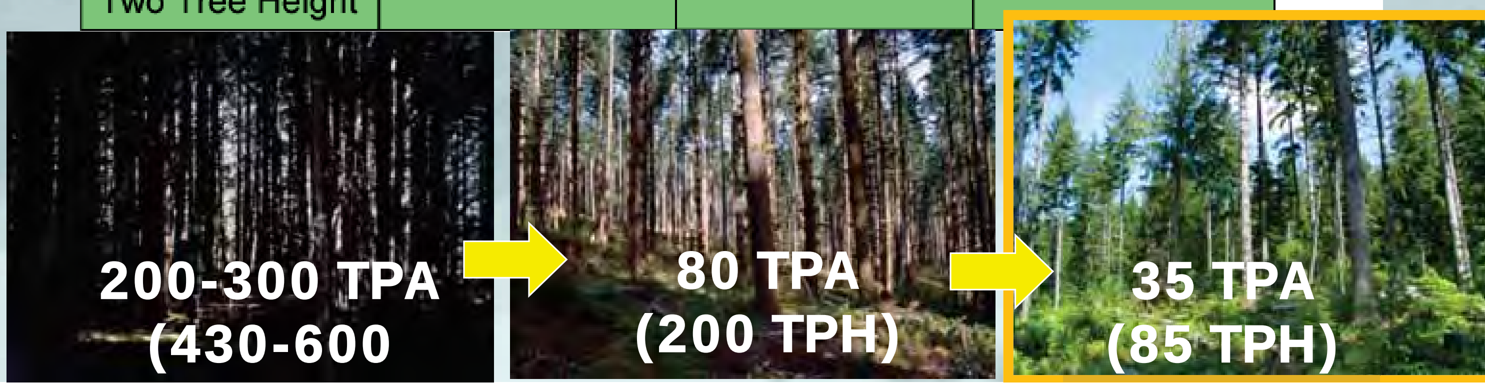
2nd Thinning: 10 years after 1st Thinning

2-tree-height buffer thinned to 60 tpa at 2nd harvest: Thin-through buffer, yarding away from channel



Stream reaches with **3** buffers examined & unmanaged control stream reaches

2nd thinning



Riparian Buffer Study

Aquatic Habitats and Vertebrate Diversity Study Component

Objectives

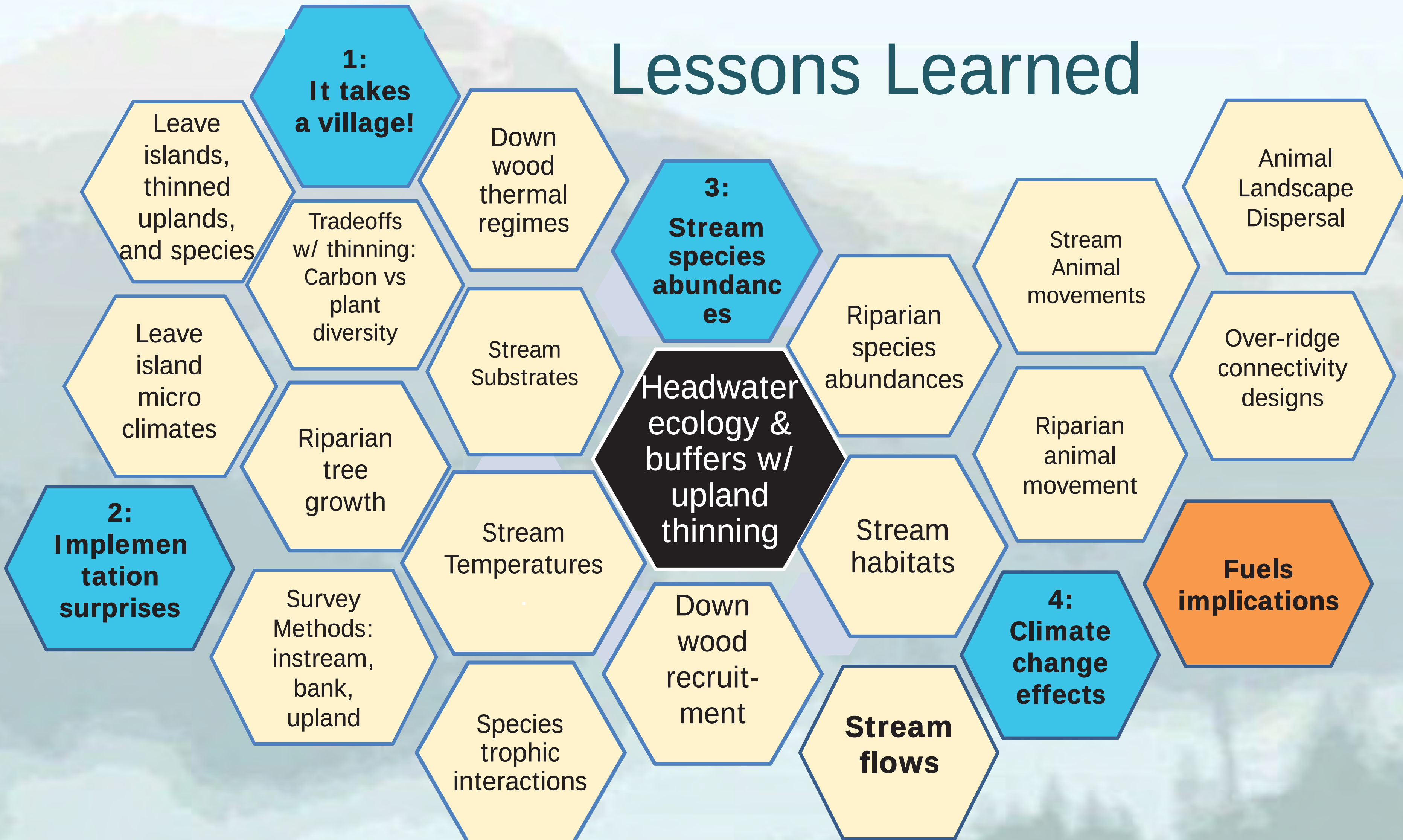
1) Characterize headwater species and habitats
2) Assess effects of buffers with upland thinning on aquatic spp & habitats
3) Advance inventory & monitoring approaches for headwaters
4) Integrate with other study components and studies
   - → Vegetation Response
   - → Microclimates and microhabitats of riparian & upland areas
   - → Developing landscape ecology perspectives

Timeline

	Pre-harvest	Phase I Thinning Effects 1-2 yrs Post-harvest	Phase I Thinning Effects 5 yrs Post-harvest	Phase I Thinning Effects 10 yrs Post-harvest	Phase II Thinning Effects 1 yr Post-harvest	Phase II Thinning Effects 5 yrs Post-harvest	Phase II Thinning Effects 10 yrs Post-harvest
Instream & Bank	X	X	X	X	X	*	2020-2022
Upland		X	X	X			
Other	X		X	X	X		

X = 44 Products out * = Papers in prep.

Lessons Learned



Lesson 1:
Partnerships Matter!
Thank you, partners!

PIs	Agency partners	Post-docs	Students	Others
John Tappeiner	Charley Thompson	George Weaver	Dave Rundio	Loretta Ellenburg
Klaus Puettmann	Floyd Freeman	Julia Burton	Chris Sheridan	Dan Mikowski
Sam Chan	Hugh Snook	Jason Leach	Stephanie Wessell	Cindy Rugger
Paul Anderson	Craig Kintop	Adrian Ares	Jessica Rykken	Rich Nauman
	John Cissel		Jina Sagar	Rebecca Thompson
INFLUENCERS	Louisa Evers		Matt Kluber	Bruce Hansen
Jim Sedell	Peter O'Toole		Kenny Ruzicka	Kelly Burnett
Dave Hohler	Frank Price			Kelly Christiansen
Larry Larsen	Rick Schultz			Kathryn Ronnenberg
Kim Titus	Sharmila Premdas			
Charlie Peterson	Craig Snider			

Lesson 2: Implementation Surprises

Year	No. Study Sites	Comments
1994	13	9 BLM, 3 Forest Service sites
1998	11	1 BLM site stalled: Umpqua cutthroat trout ESA concern 1 BLM site design issues
2004	8	Trees cut for down wood at 3 FS sites

Lesson 2: Implementation Surprises

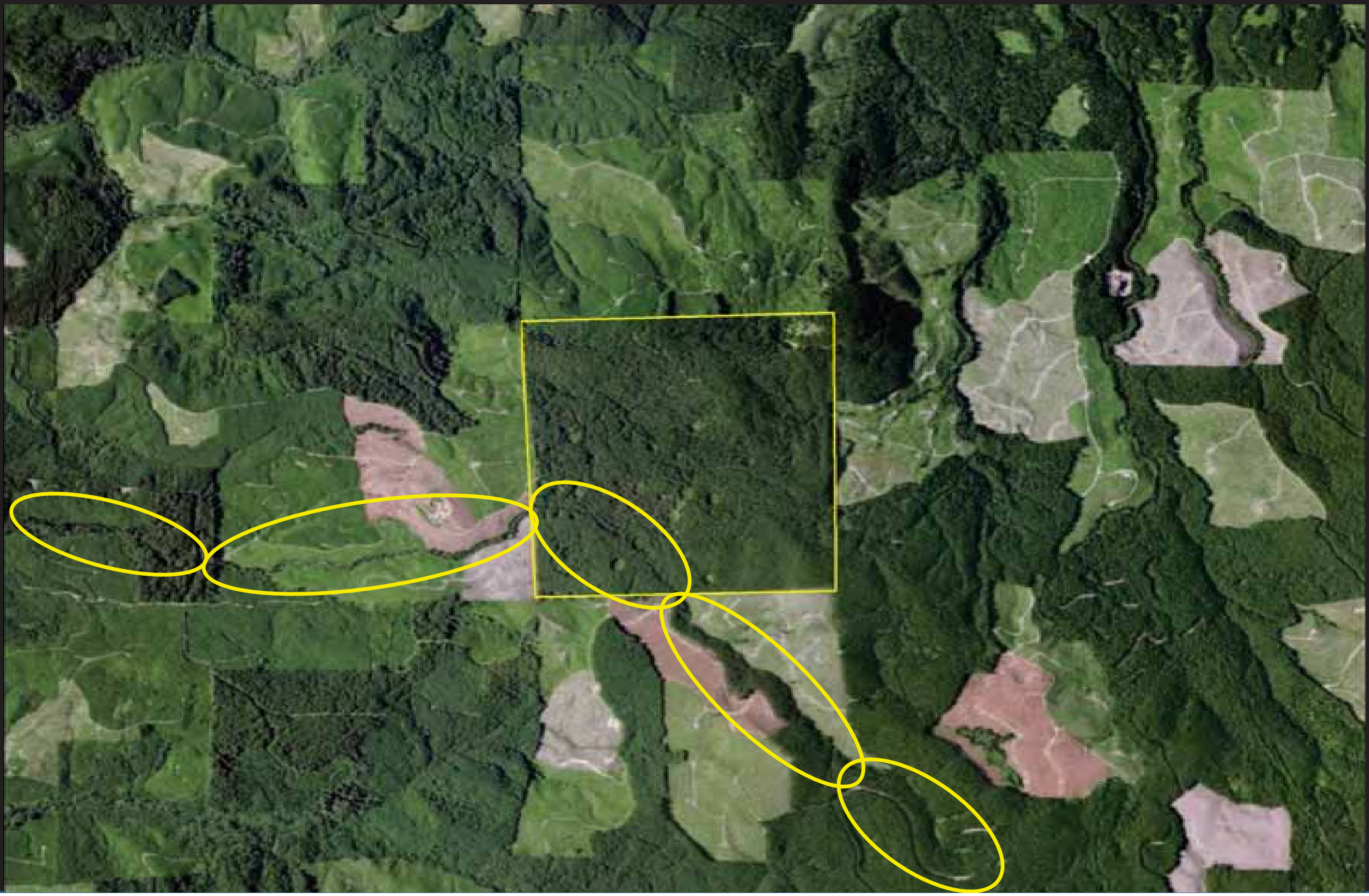
But we learned how to overcome conflicts to achieve multiple resource aims:

Issue	Resolution	But…
Land-use allocation	Treatments were actually consistent with goals of Matrix, Late-successional Reserves and some other LUAs needing restoration	1 Matrix site dropped due to 30-yr monitoring period
Site-specific conditions	Sites avoided if: owl activity, marbled murrelet zone, key watersheds, listed fish, extensive root rot, likely wind damage, soil erosion and landslide potential, or heterogeneous stand conditions	1 site with small patch of upland blowdown; 2019 snowpocalypse
Stream geometry, high or low density	Riparian Buffer Study Component initiated to test narrower buffers; odd stream geometry affected layout of thinning treatments and sometimes riparian treatments	Could not have complete random design of treatment or buffer design
Rare Species and Special Habitats	Leave islands and Riparian reserves used around isolated wetlands, wolf trees with “hotspots” of rare lichens, bryophytes, and mollusks	Concern for owl or murrelet dispersal habitat led to set-asides of some areas
Old-growth controls	We could not find OG sites to match our treatment sites, so we relied on a BACI design	Separate study characterized OG sites: Coos Bay area

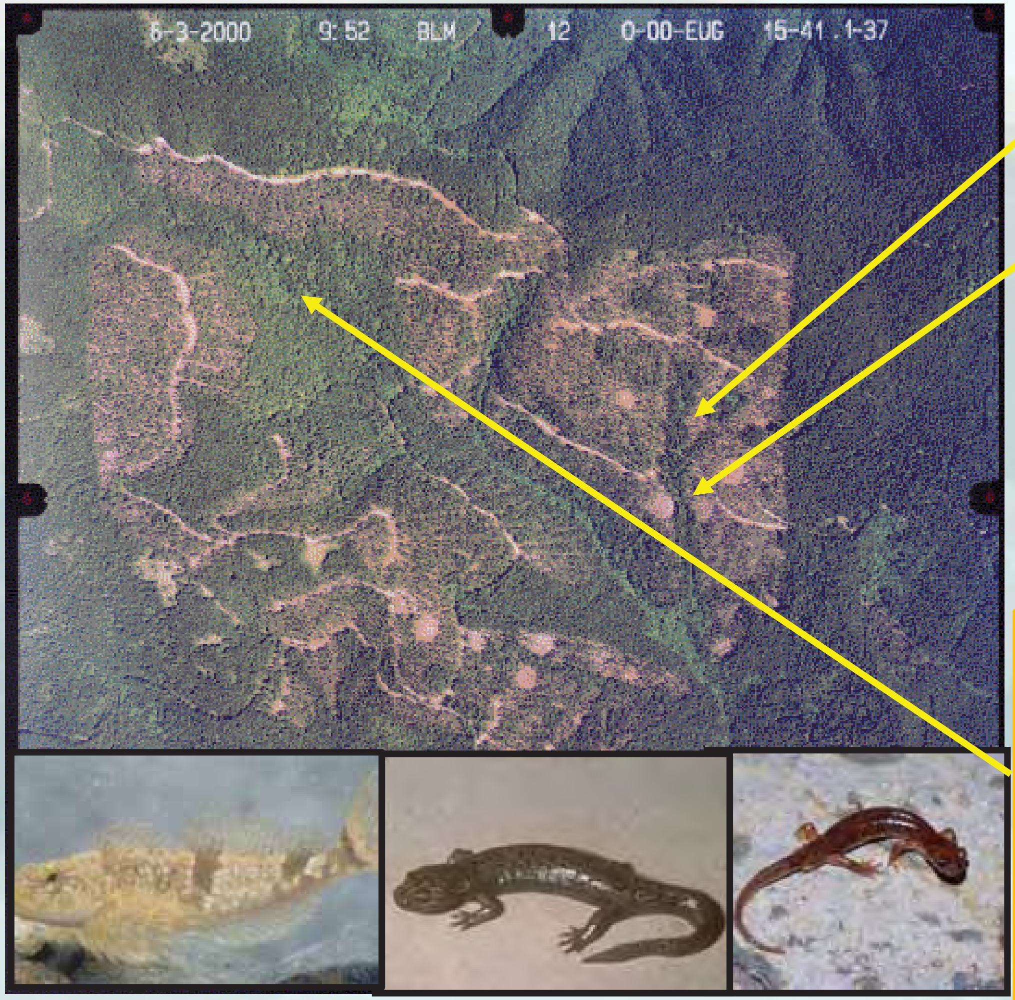
Olson et al. 2002, PNW-GTR-563

Lesson 3:

Is there a signature of Riparian Buffer strategies on headwater species?



Yes, with a Time Progression of Results



At 10 yrs after 1^{st} thinning, **lower** counts of Dunn's salamanders in 6-m buffers (Olson et al. 2014)

At 1 yr after 2^{nd} thinning, **lower** counts of Dunn's and Torrent salamanders in 6-m buffers

and, **higher** counts of Dunn's and Torrent salamanders in 15-m and 70-m buffers (Olson & Burton 2014)

At 5 yr after 2^{nd} thinning, **higher** counts of Giant and Torrent salamanders in 70-m (1-tree) buffers.

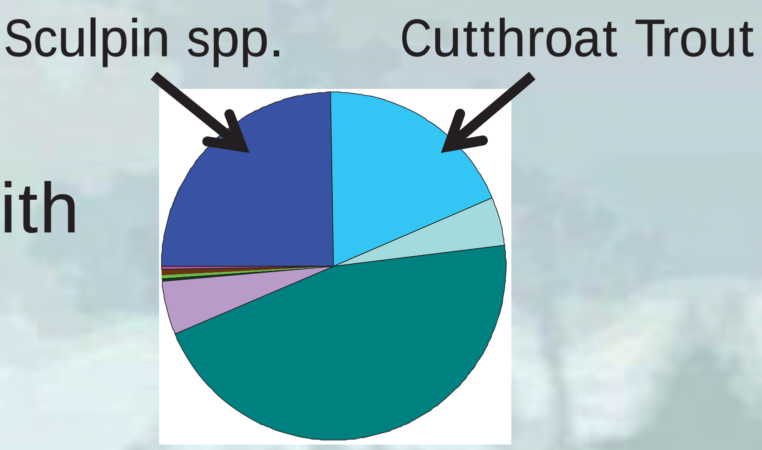
But 1-Tree = Control for Torrents

(Olson & Ares in prep.)

The Fish Tale

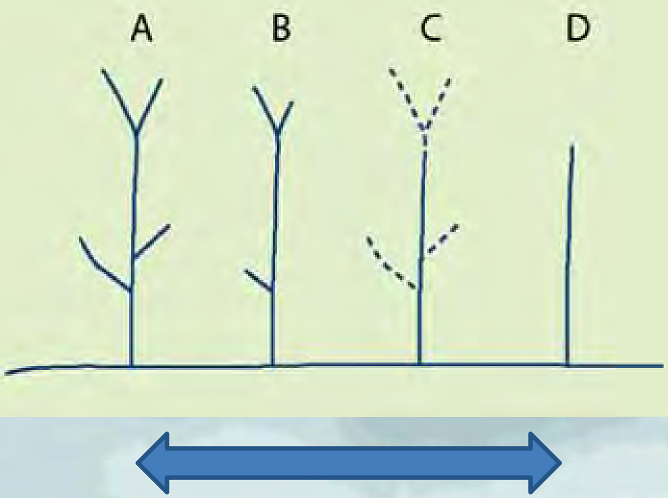
- 2 fish taxa in some perennial reaches
- Variable occupancy among reaches & sites
- Challenge for species-specific analyses
- No species-specific effects seen previously

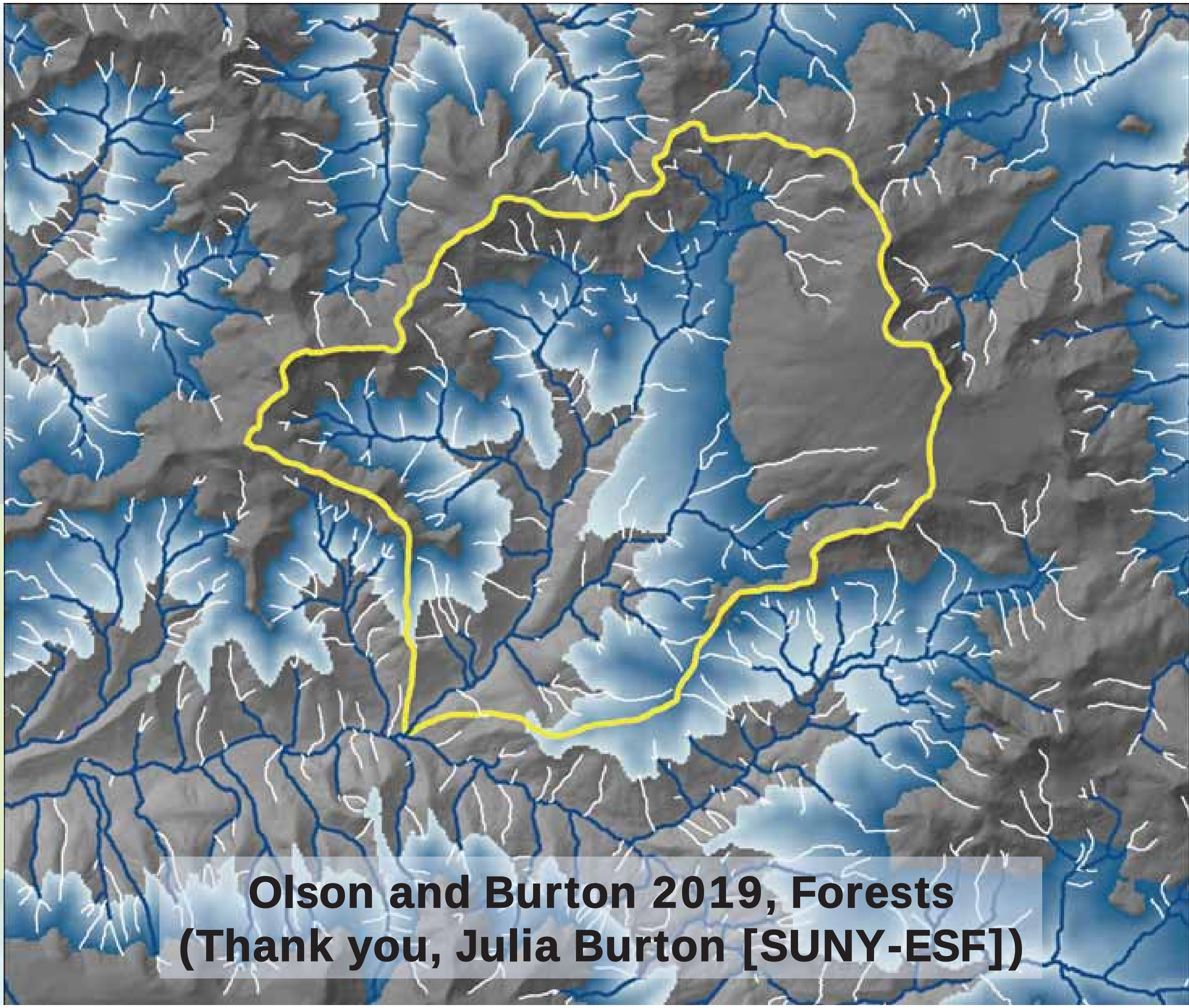
At 5 yrs after 2nd thinning:
Higher **sculpin** counts associated with
1-Tree = Var = SR > C



Lesson 4

Streamflow concerns with forest harvest and climate change?





Olson and Burton 2019, Forests
(Thank you, Julia Burton [SUNY-ESF])

Method

65 stream reaches @ 13 study sites
16-year time span (1996-2011)
27 streamflow metrics
22 climate variables

Ordination: Best predictor of change in streamflow = % Dry channel length

Multivariate Modeling:
% Dry length as a function of climate, buffers, basin area

↓

Future climate models

↓

Landscape projection

Results

% Dry length positively related to 2 Climate Metrics
% Dry length negatively related to Basin Area

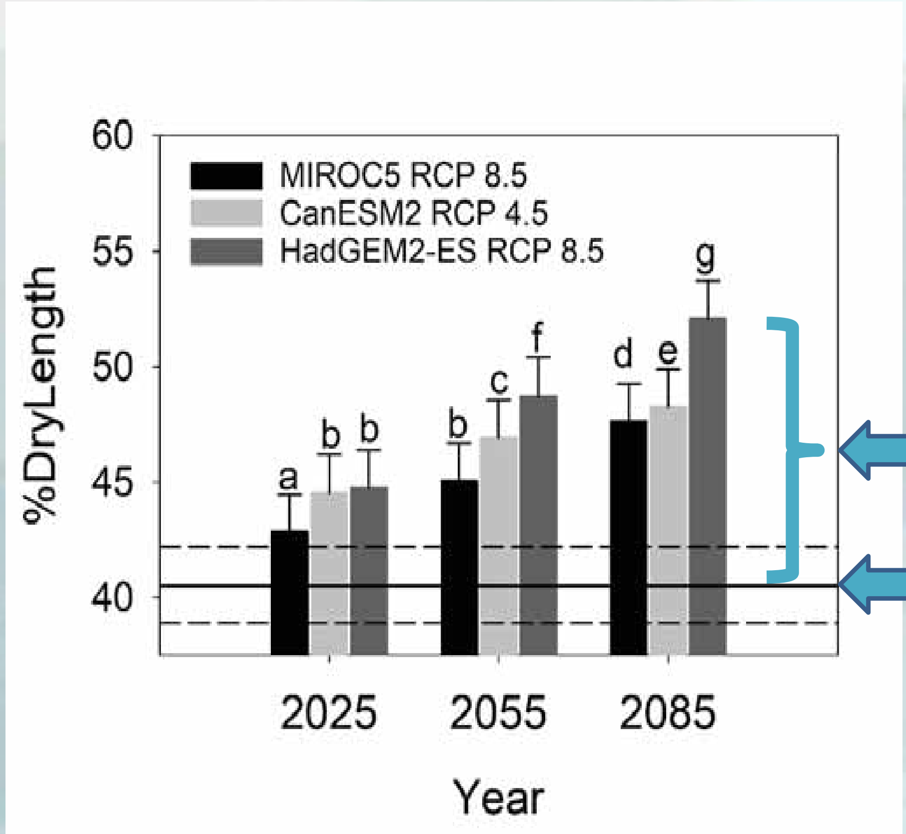
- Summer Heat: Moisture Index ($p < 0.001$)
- Mean Minimum Summer Temperature ($p=0.009$)
- Basin area ($p = 0.002$)

Buffer treatment (ns)

Yes, we have shrinking 'heads' from past climate variation in small basins

Climate Change Projections

3 scenarios analyzed
3 time steps: 2025, 2055, 2085



% Dry Length increases:

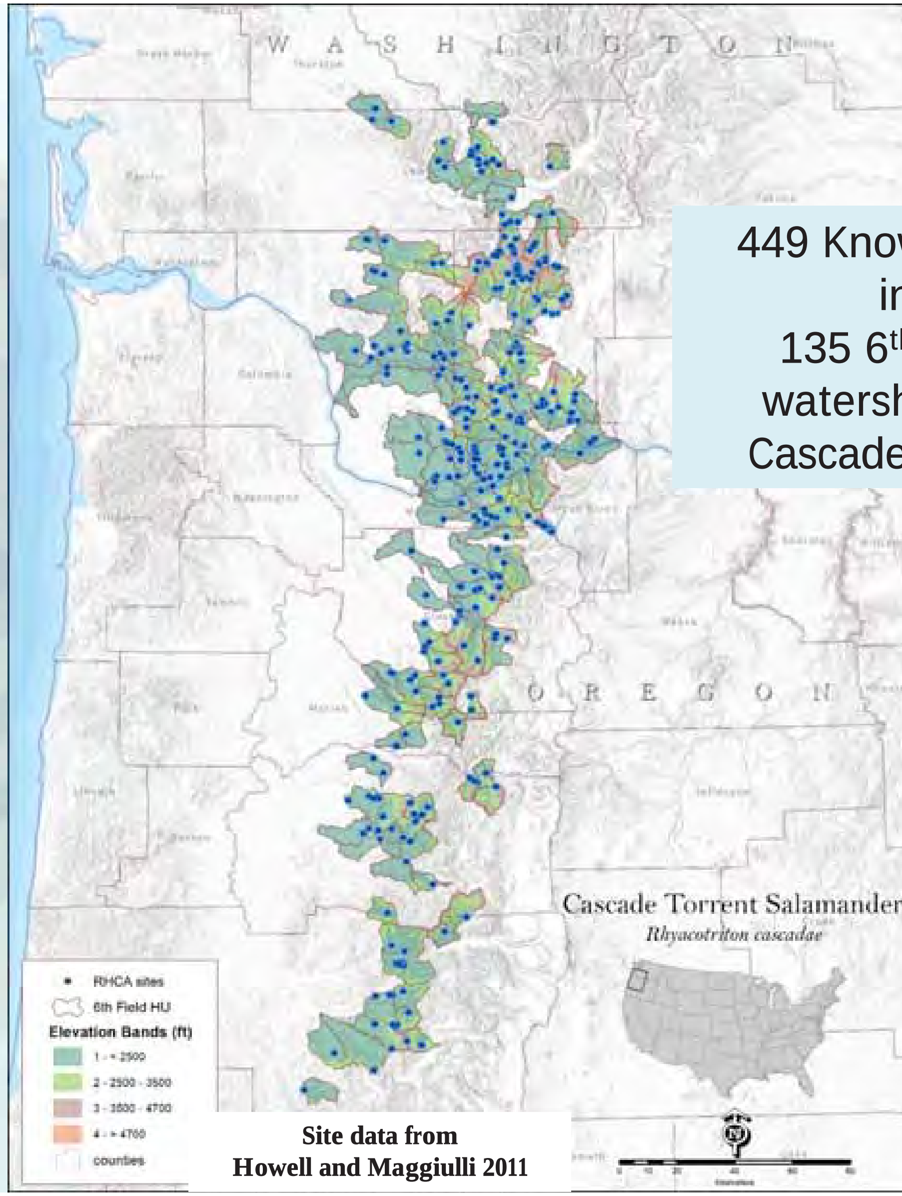
By 2085, a 7.1 to 11.5% increase in % Dry length from recent conditions

*** Increasing 'shrinking heads' with time projected**

Landscape Projection

How much habitat would be lost over the range of the Cascade Torrent Salamander (*Rhyacotriton cascadae*)?

- Associated with intermittent streams
- Proposed for US-ESA listing as Threatened & Endangered



Site data from Howell and Maggiulli 2011

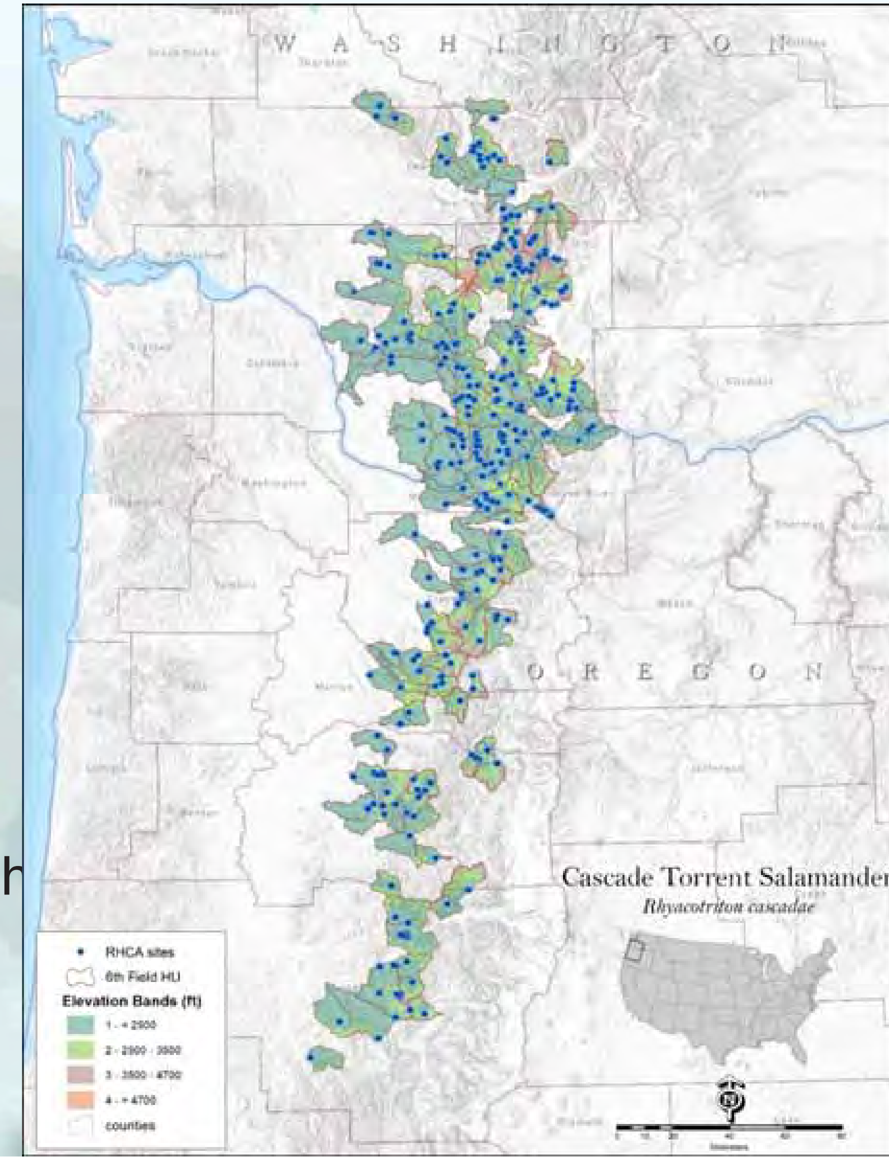
449 Known sites in 135 6th-field watersheds in Cascade Range

Cascade Torrent Salamanders known to occur to 1433 m (4700 ft) elevation

1) Modeled streams using NetMap

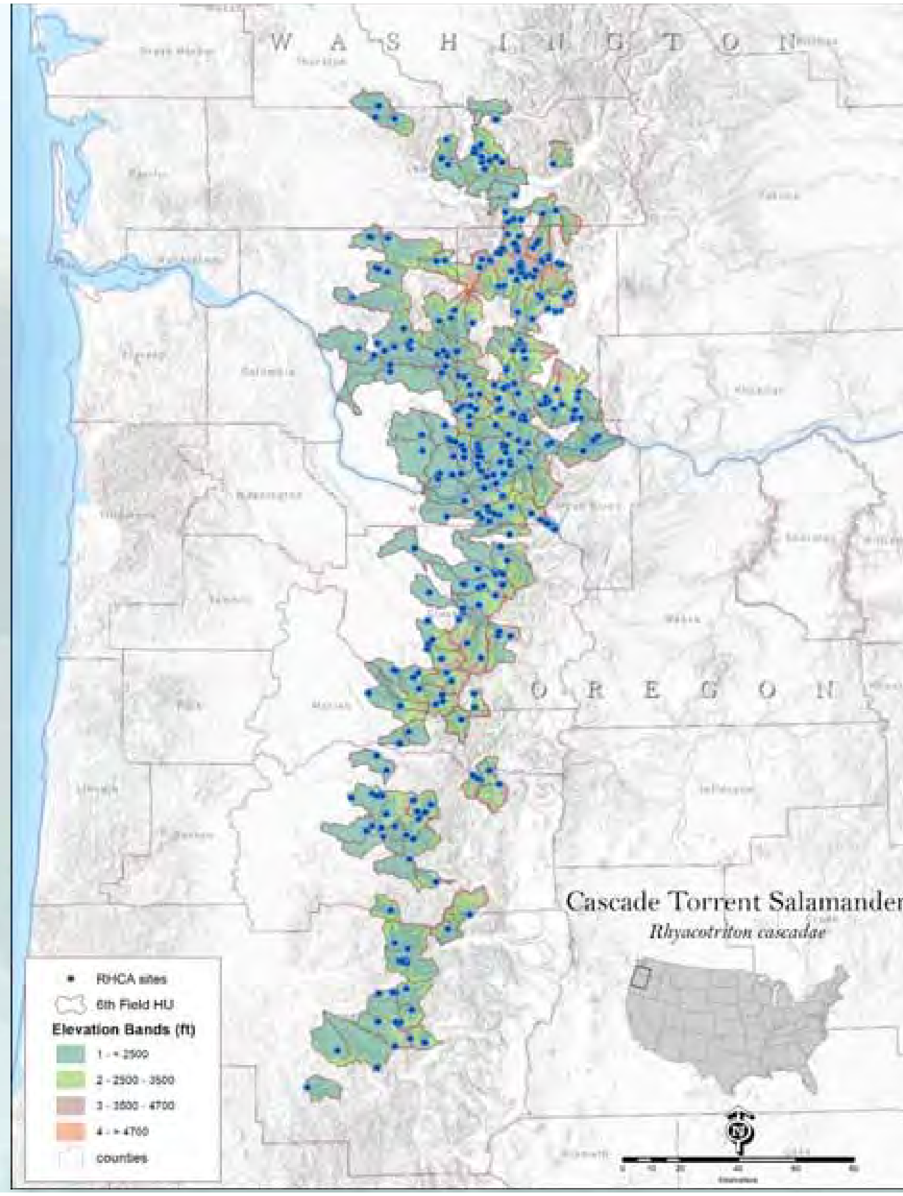
2) Assessed stream lengths
   a) In 6th field watershed in species range
      i) In first-order streams
      ii) In small drainages $\leq$12.6 ha (2.5 ac)
   b) At elevations $\leq$ 1433 m (4700 ft)

3) Calculate **7.1 to 11.5 %** stream length loss with future climate projections
      a) **Sum of wetted channel length lost**

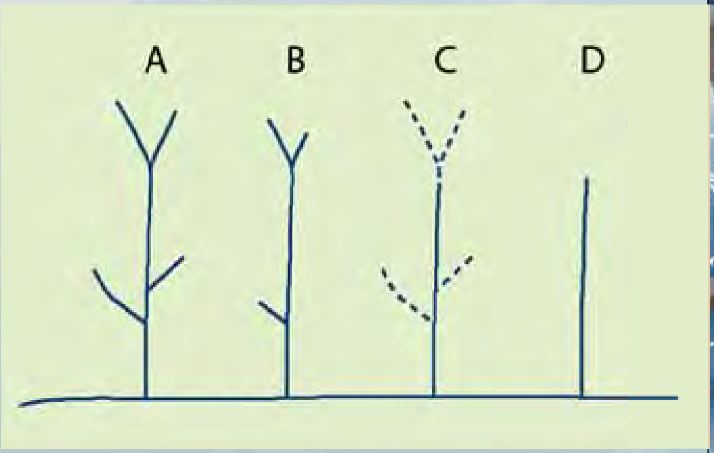


With 2055 and 2085 climate scenarios:

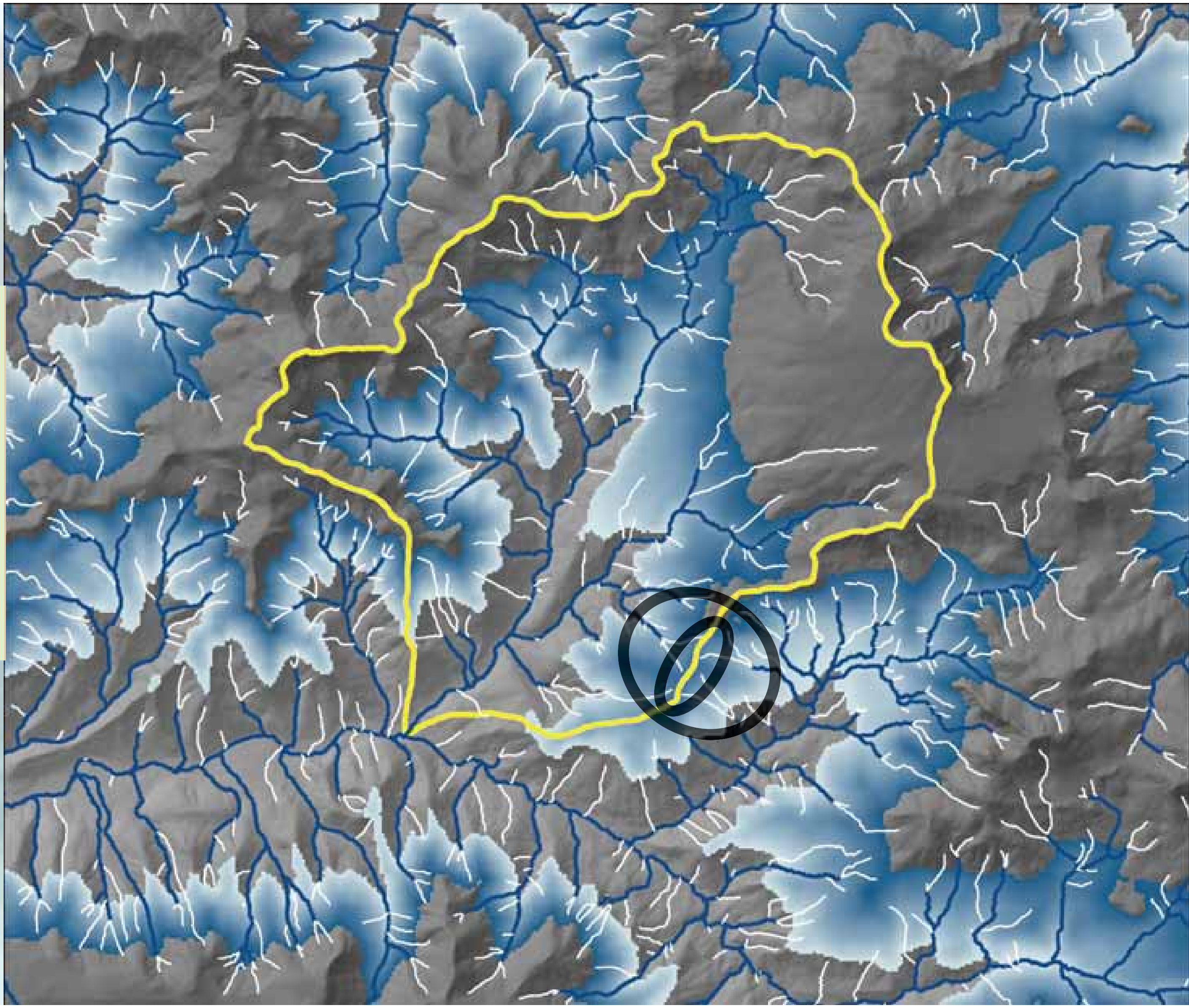
- 1st order stream loss = 1270 to 2058 km (789-1279 miles)
- Stream loss in basins <12.6 ha = 940 to 1525 km (584-948 miles)



Streamflow concerns?



Yes!
Consider perennial streams for future habitat protections, and for over-ridge connectivity designs.



Final Thoughts

- We are still learning.
- Long-term studies are useful, the story can change.
- Risks to some amphibians and fish are being documented.
- Next-generation field experiments & demonstrations are needed.

Role of buffers with:

- climate change
- fuels-management activities
- hillshading & cold-water refuges
- aquatic-land habitat connectivity
- larger perennial reaches with fish
- larger spatial scale applications

Thanks Everyone!!

Food Web Responses to Riparian Thinning in Redwood Headwater Streams

David Roon[1], Jason Dunham[2], Ryan Bellmore[3], Dede Olson[3], and Bret Harvey[4]

1. Oregon State University, Department of Fisheries and Wildlife 2. USGS, Forest and Rangeland Ecosystem Science Center 3. Forest Service, Pacific Northwest Research Station 4. Forest Service, Redwood Sciences Lab

OSU Oregon State University

USGS science for a changing world

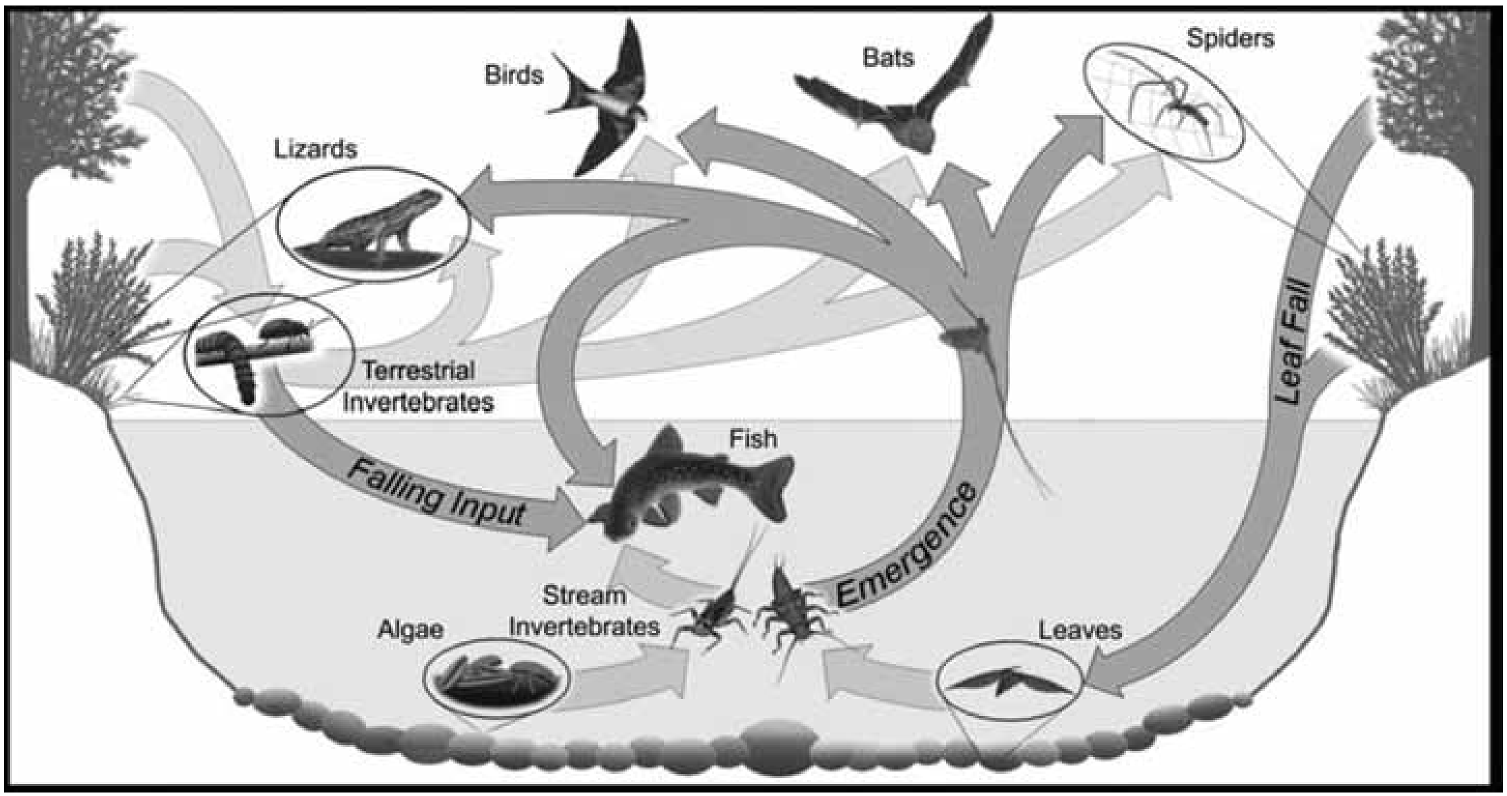
Forest Service U.S. Department of Agriculture

Green Diamond Resource Company

National Park Service

Save The Redwoods League

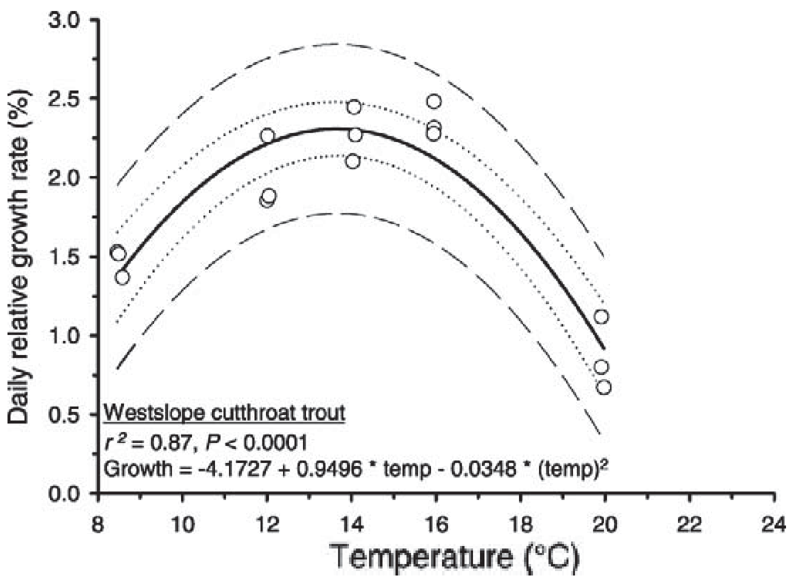
Streams and riparian forests are highly connected



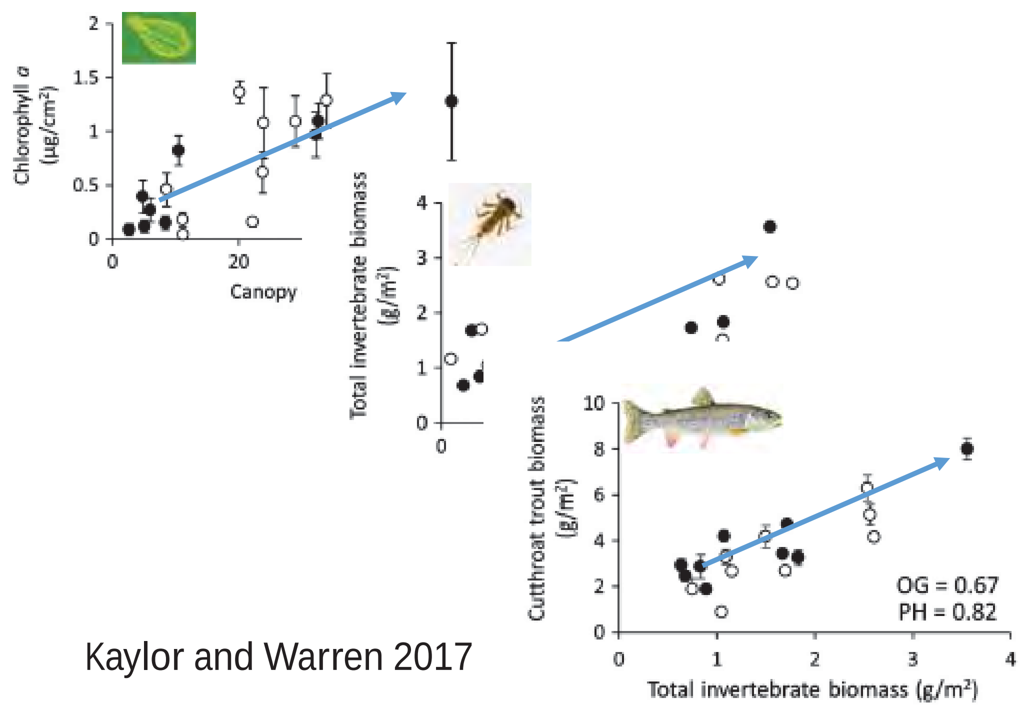
Baxter et al. 2005

Large-scale changes in riparian canopies can result in ecological trade-offs for streams

- Increases in stream temperature (-)
- Increases in aquatic productivity (+)



Bear et al. 2007

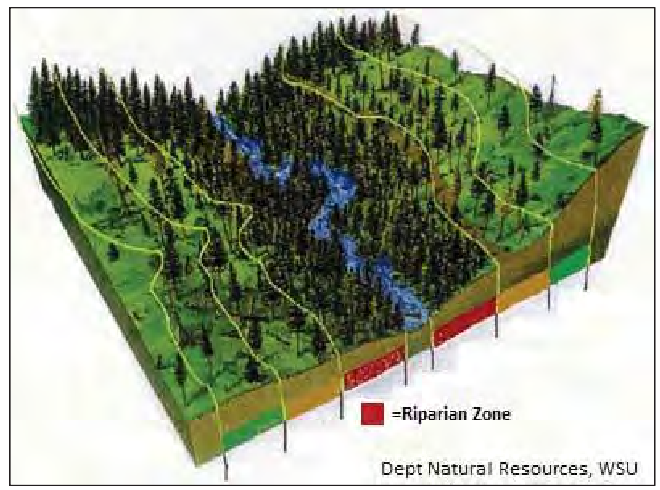


Kaylor and Warren 2017

Riparian forest buffers implemented as management strategy to mitigate previous impacts

then

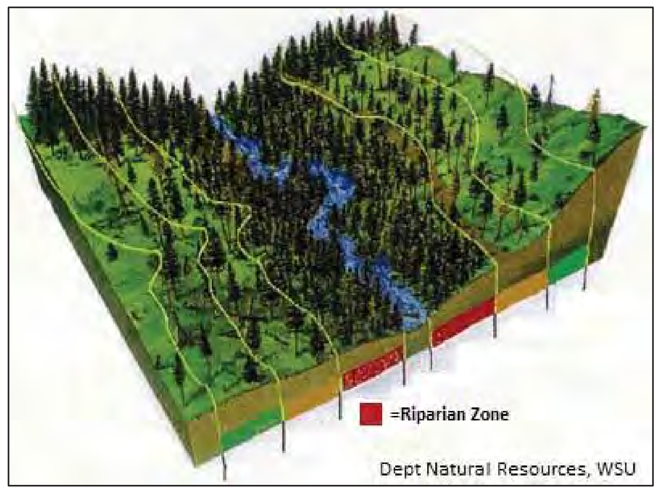
now



However, less is known about effects of contemporary forest management practices

then

now



Thinning a solution for second-growth riparian forests?

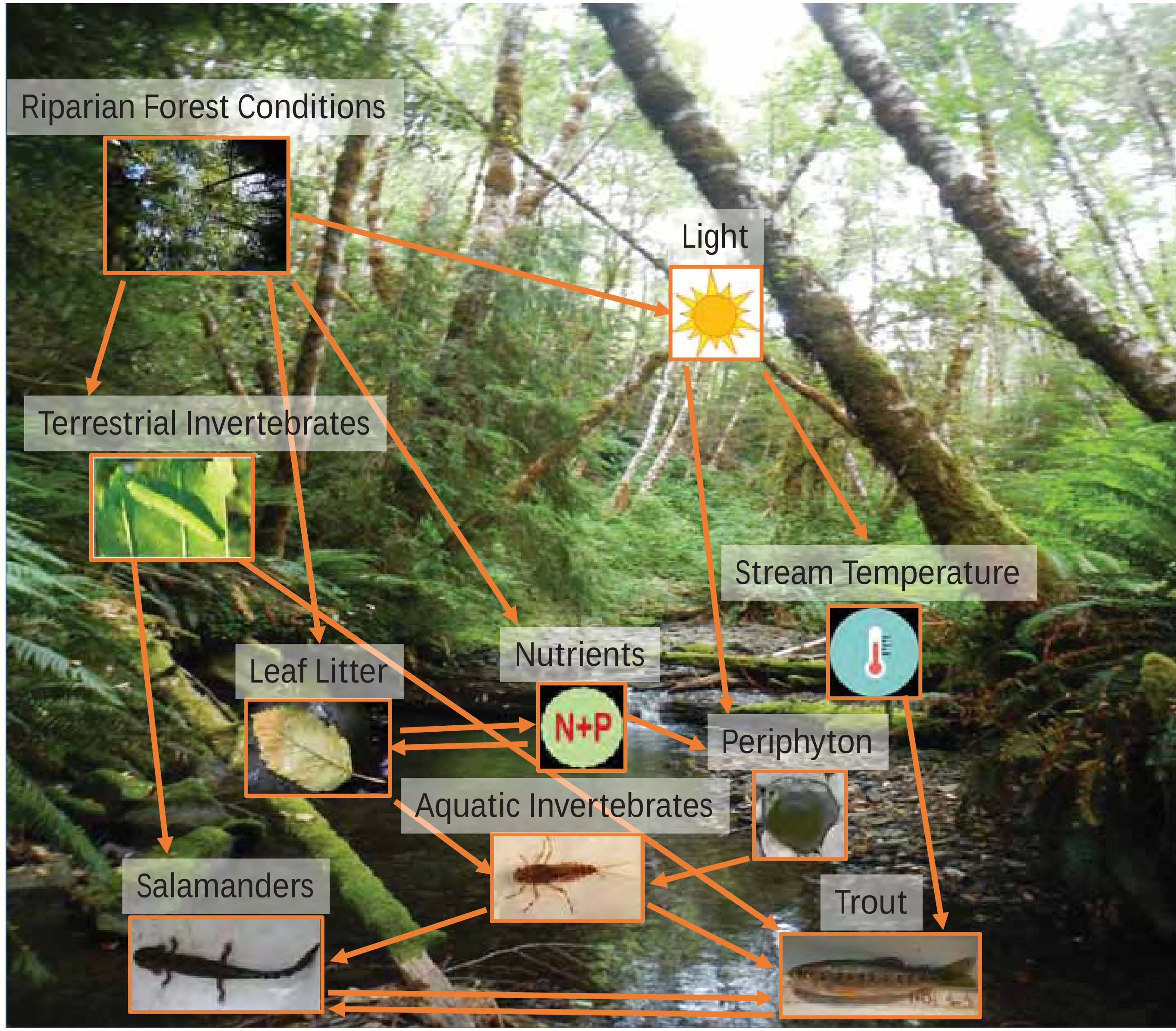
- Accelerate recovery of old-growth forests
- Shift successional trajectory to provide future source of large woody debris
- Strike balance between stream temperature and aquatic productivity
- However, immediate effects unknown…

Research Objectives

1) Riparian shade, light, and stream temperature

2) Stream-Riparian food webs

3) Growth and Bioenergetics of Trout



Research Objectives

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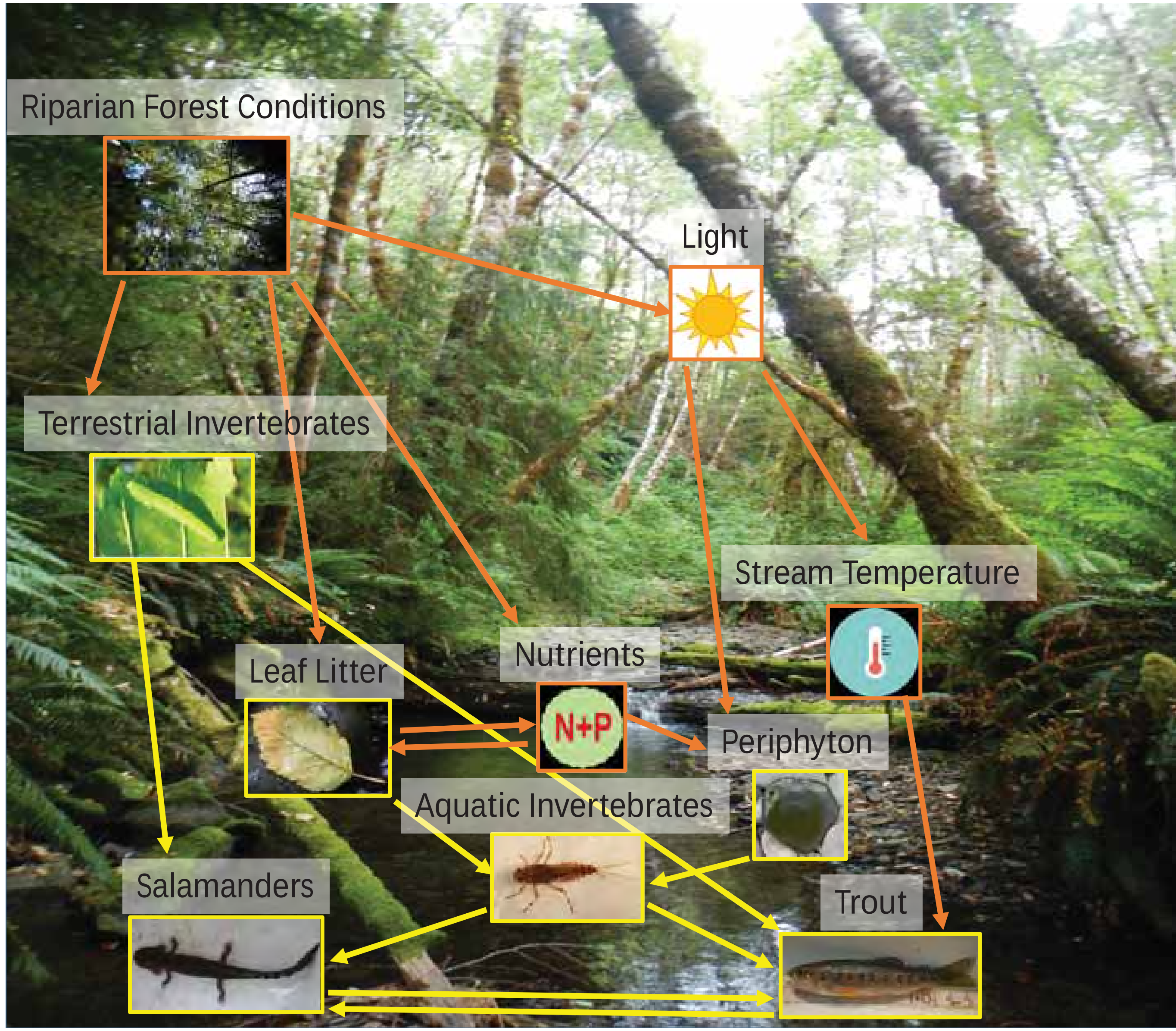
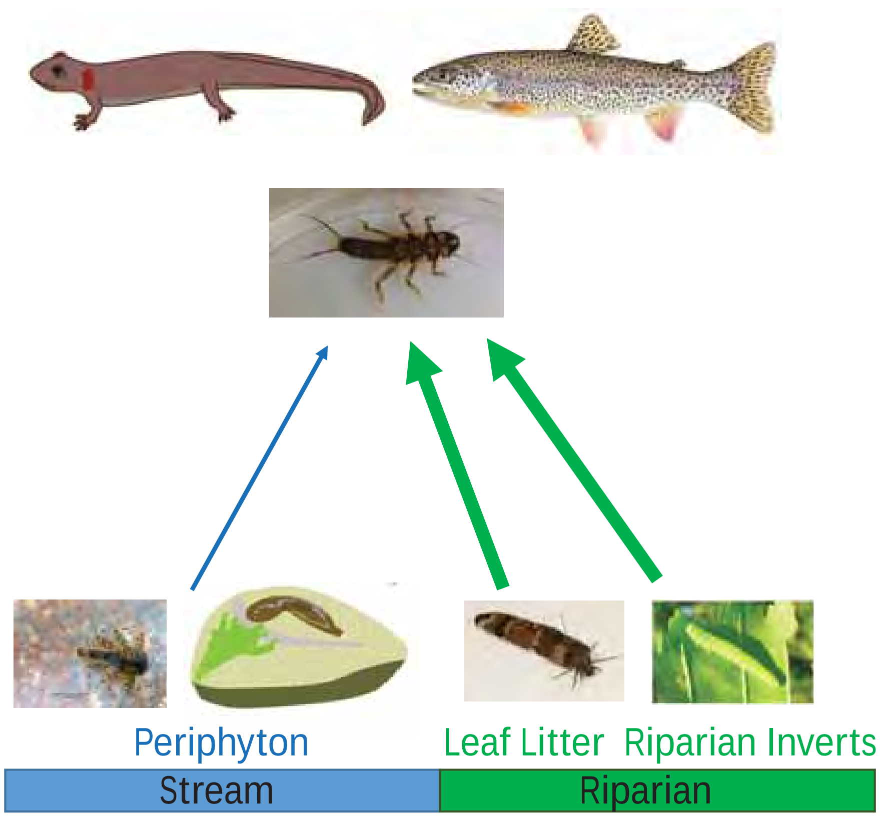


Stream food web conceptual model



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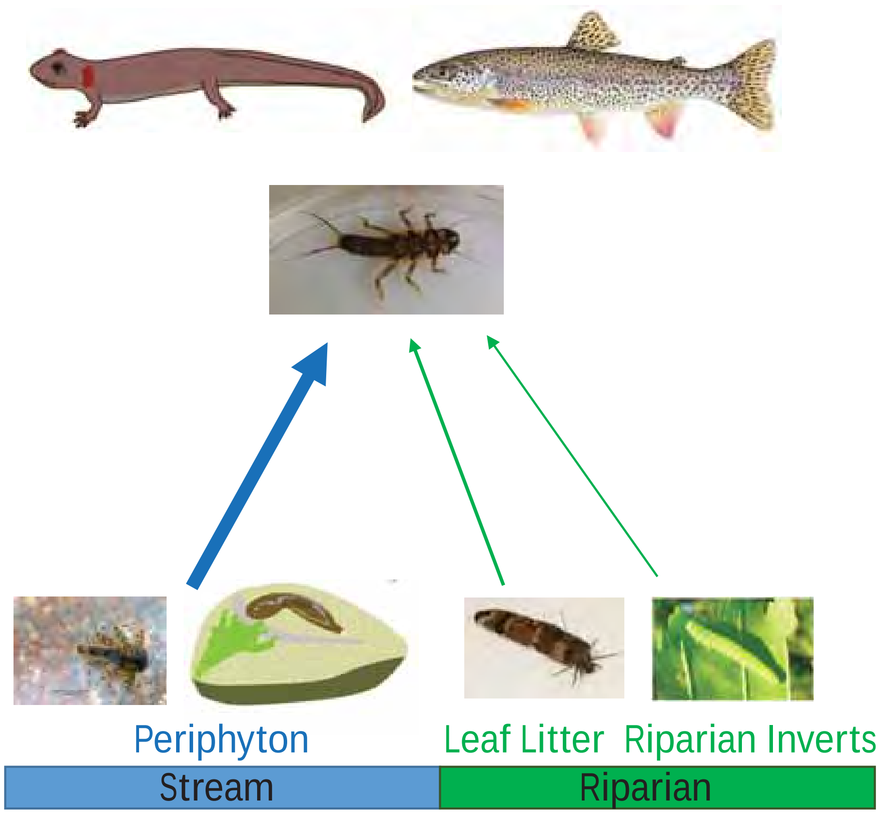
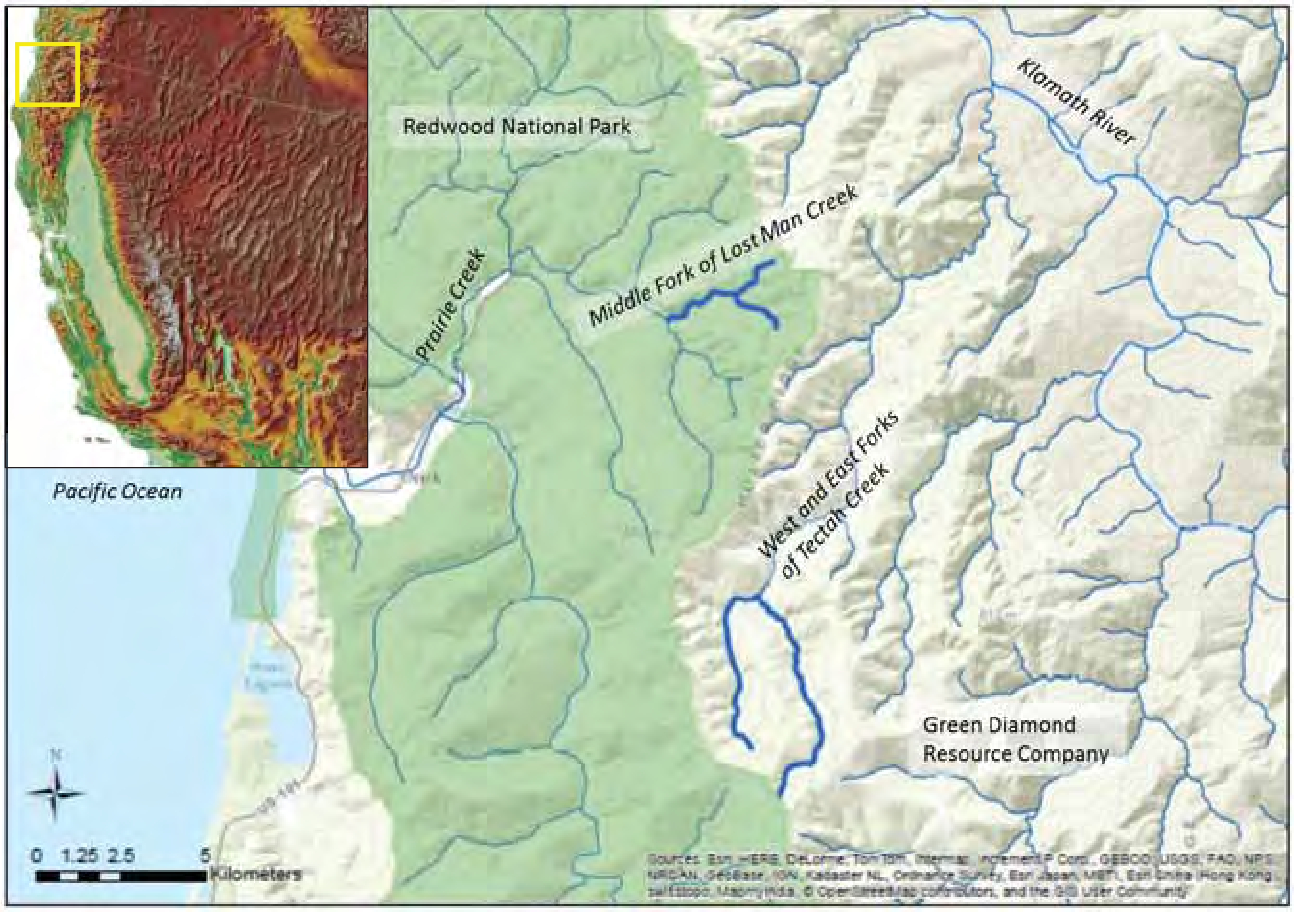
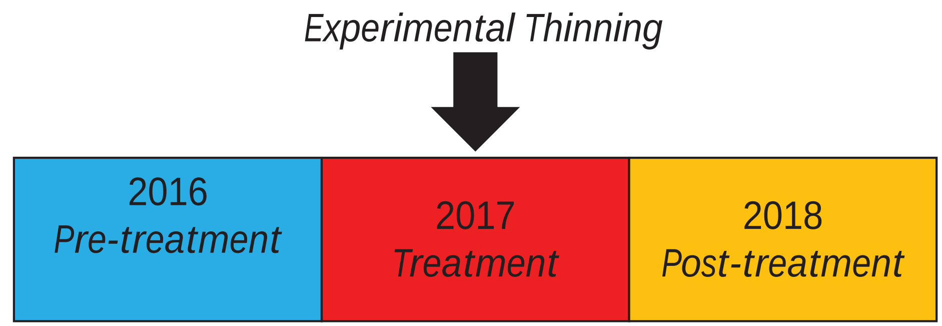


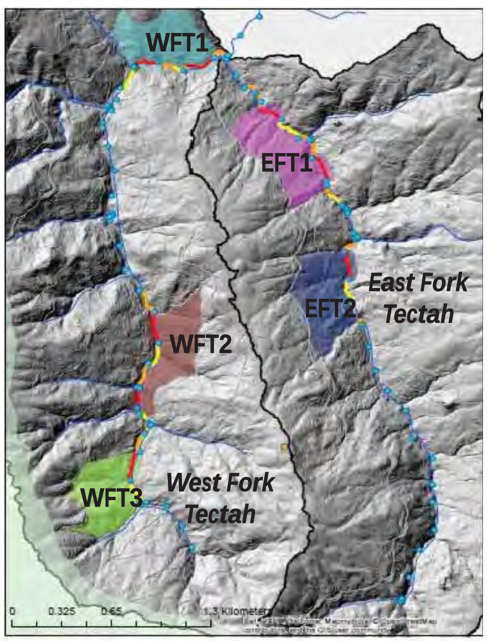
Study Watersheds

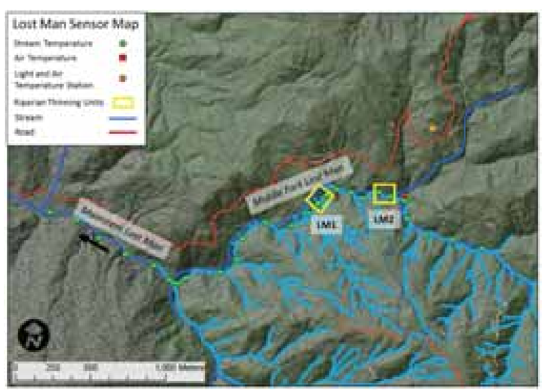


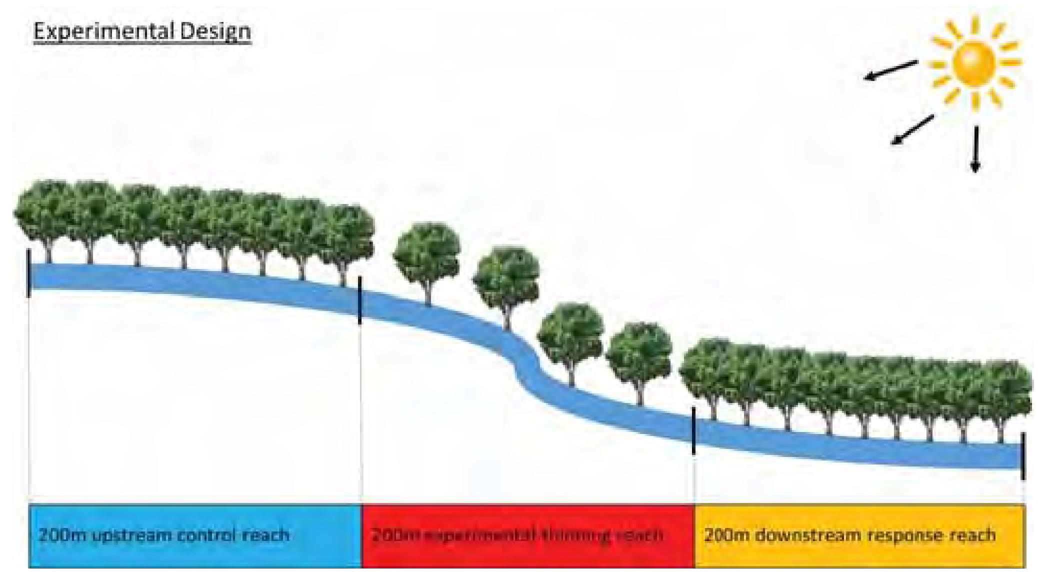
Experimental Design

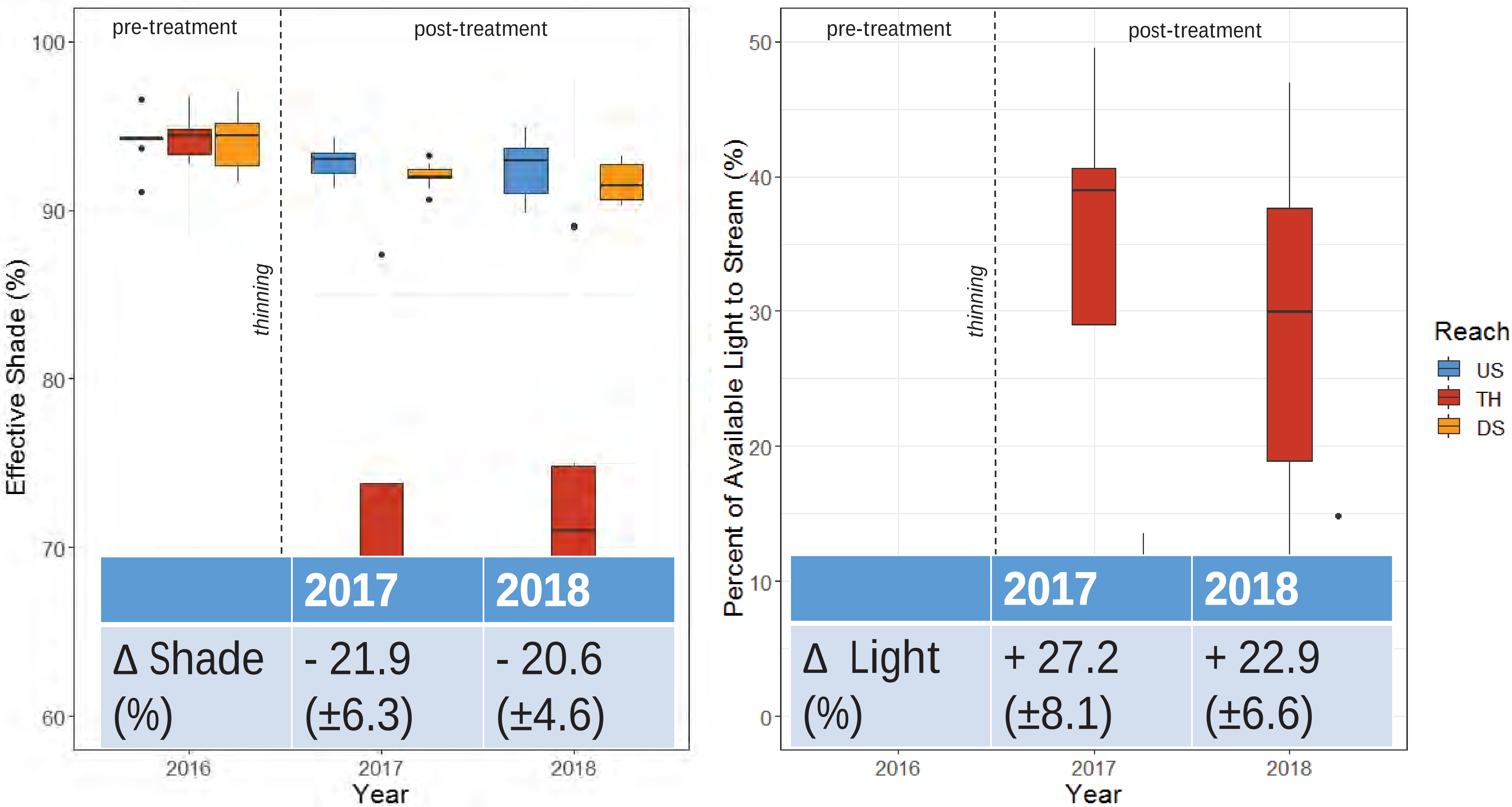
- Before After Control Impact
- Seasonal sampling
  - Spring, Summer, Fall







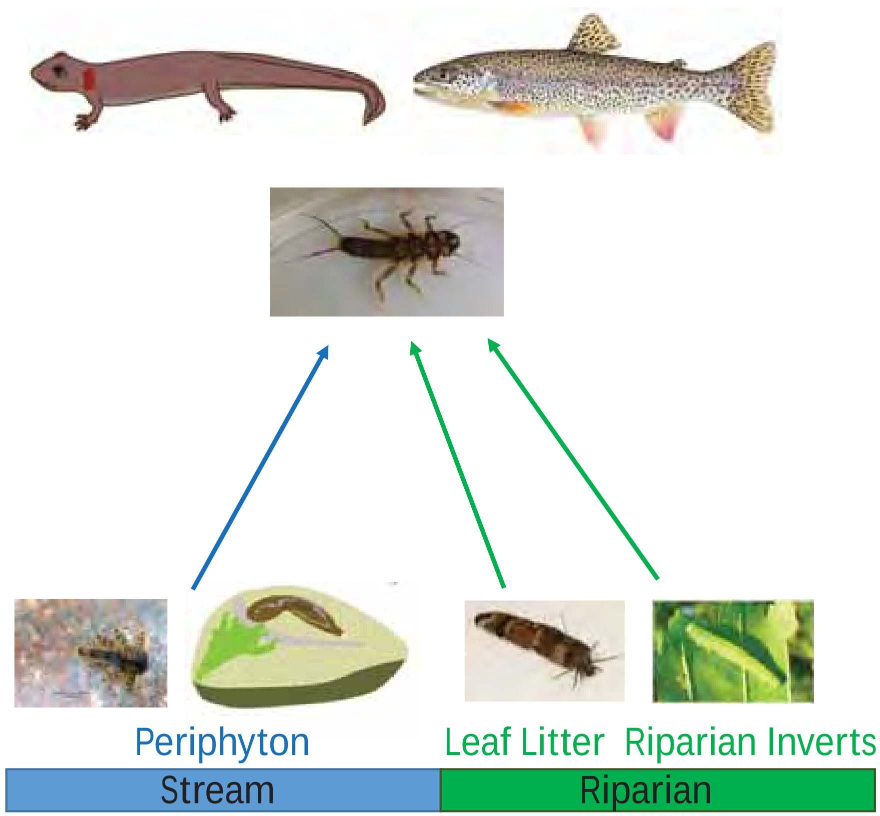




	2017	2018
Δ Shade (%)	- 21.9 (±6.3)	- 20.6 (±4.6)

	2017	2018
Δ Light (%)	+ 27.2 (±8.1)	+ 22.9 (±6.6)

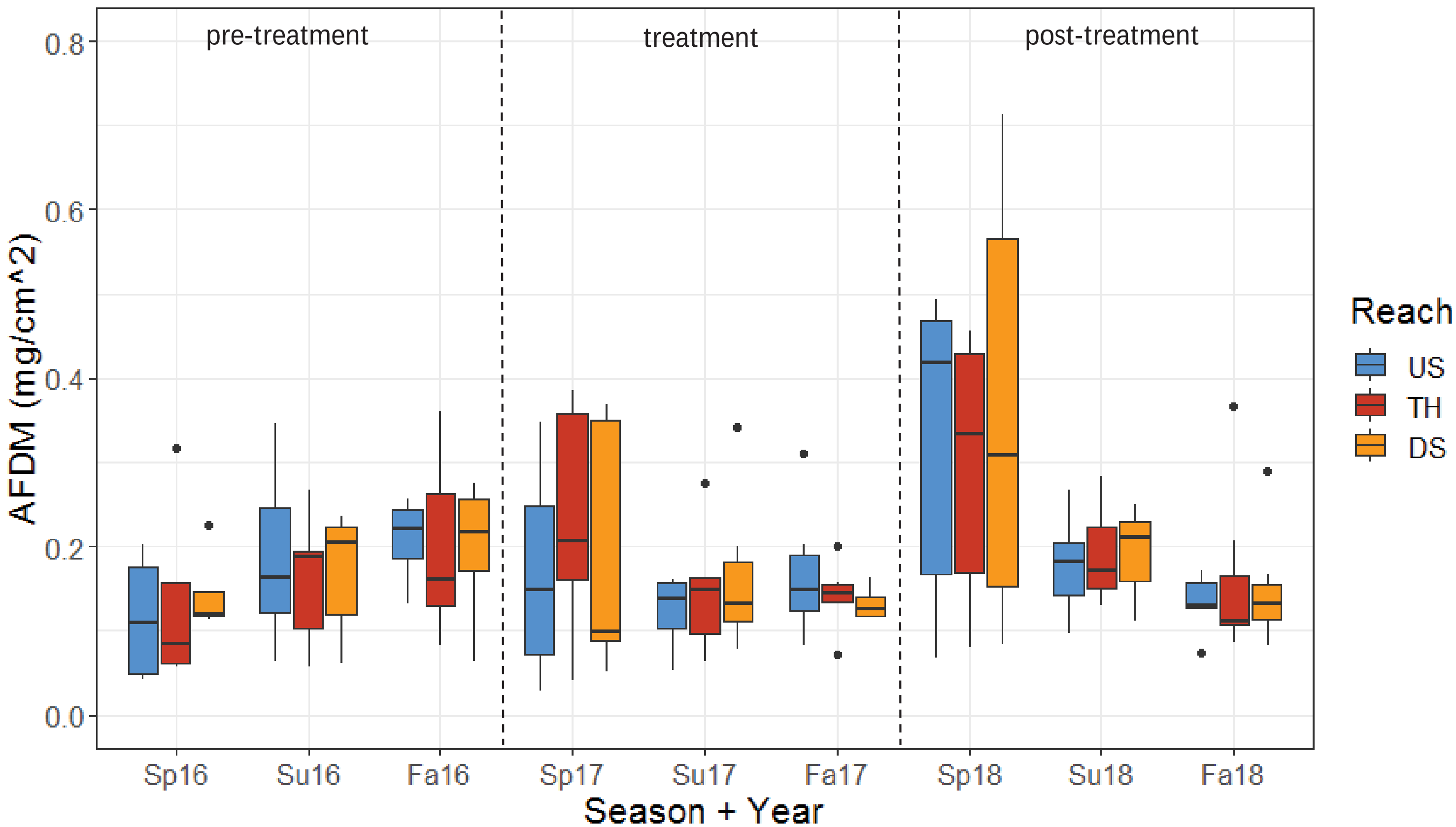
What does this mean for stream food webs?



Stream Periphyton

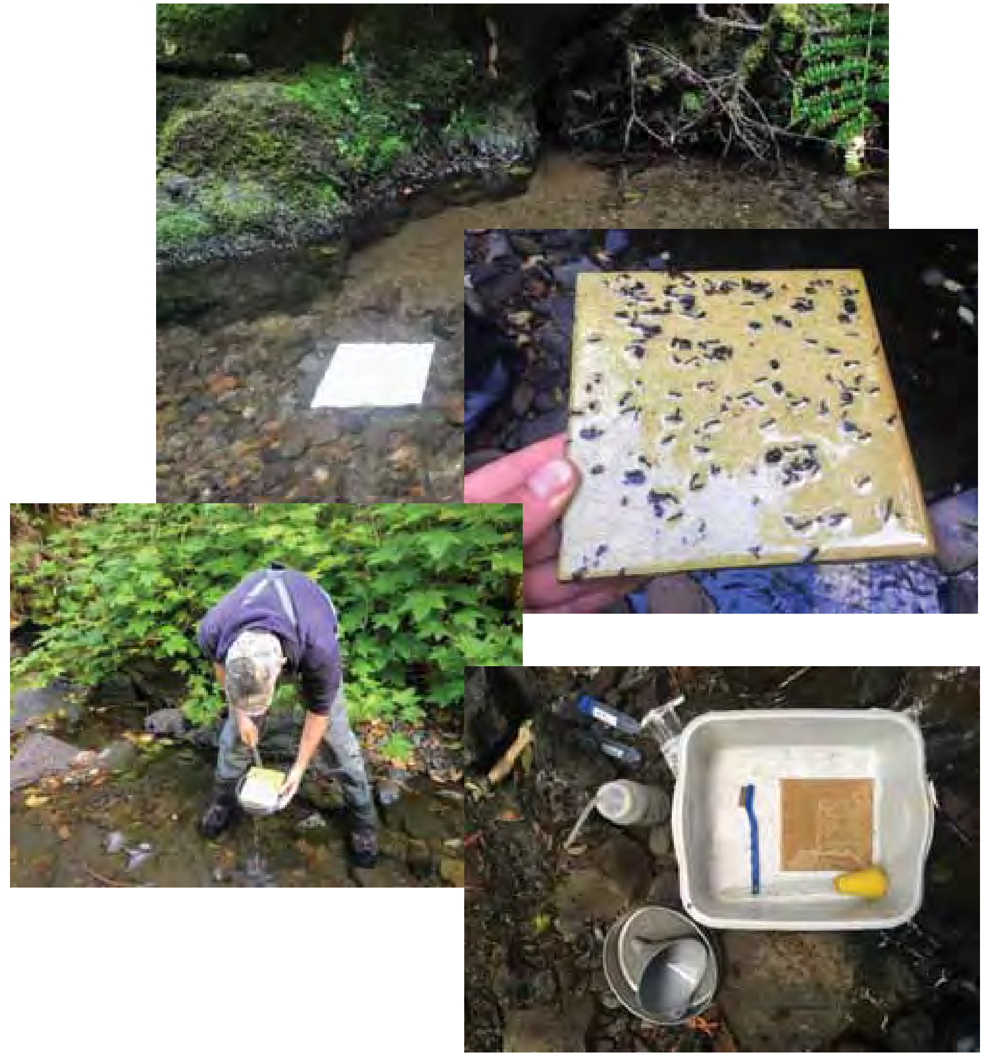
- Hypothesis: thinning will increase abundance of periphyton
- Methods:
  - Sampled periphyton Spring, Summer, Fall
  - Abundance (AFDM) from natural substrates (n=450)

Thinning did not increase stream periphyton abundance on natural substrates

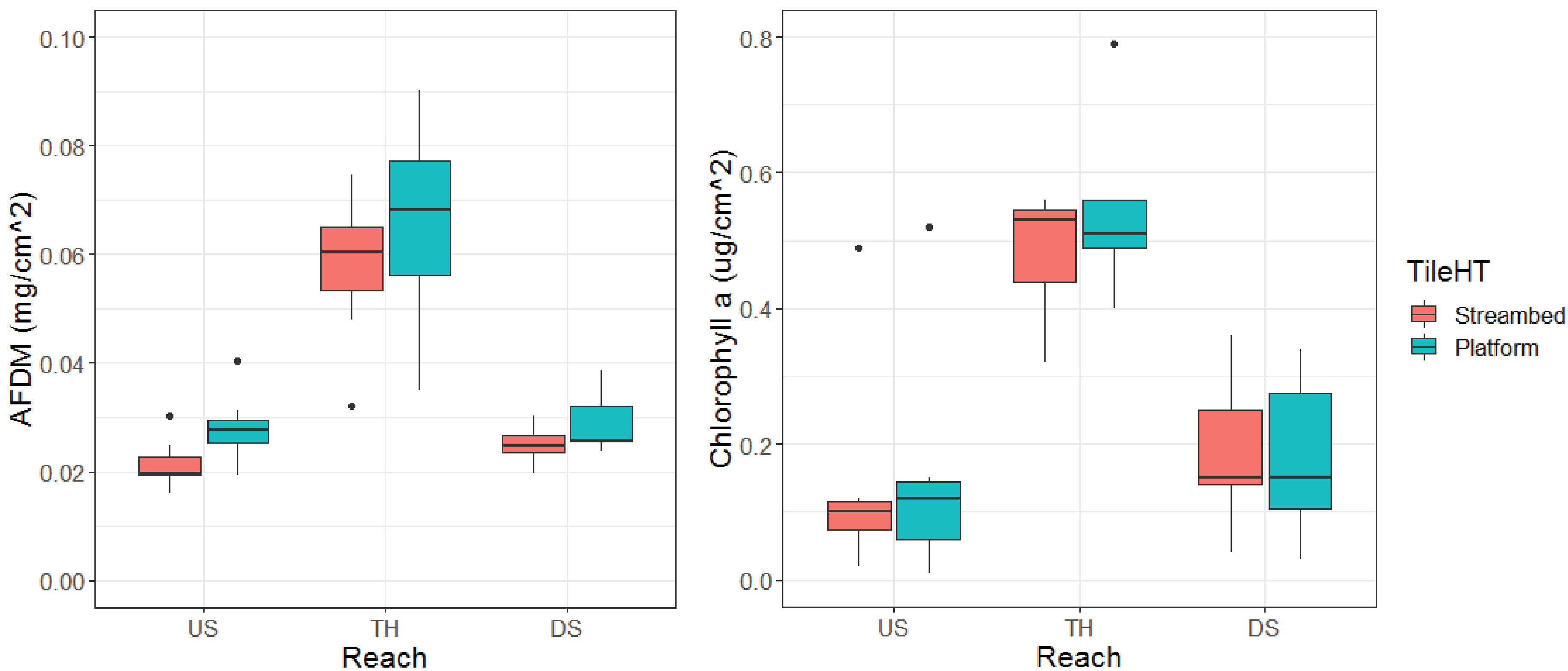


2018 Tile Experiment

- Hypothesis:
- thinning will increase periphyton on tiles
- Consumers will decrease periphyton abundance
- Methods:
- Streambed and Elevated Tiles deployed for 5 weeks late summer (n=210)
  - Abundance (AFDM)
  - Abundance/Quality (Chlorophyll a)
  - Macroinvertebrate Biomass and Composition



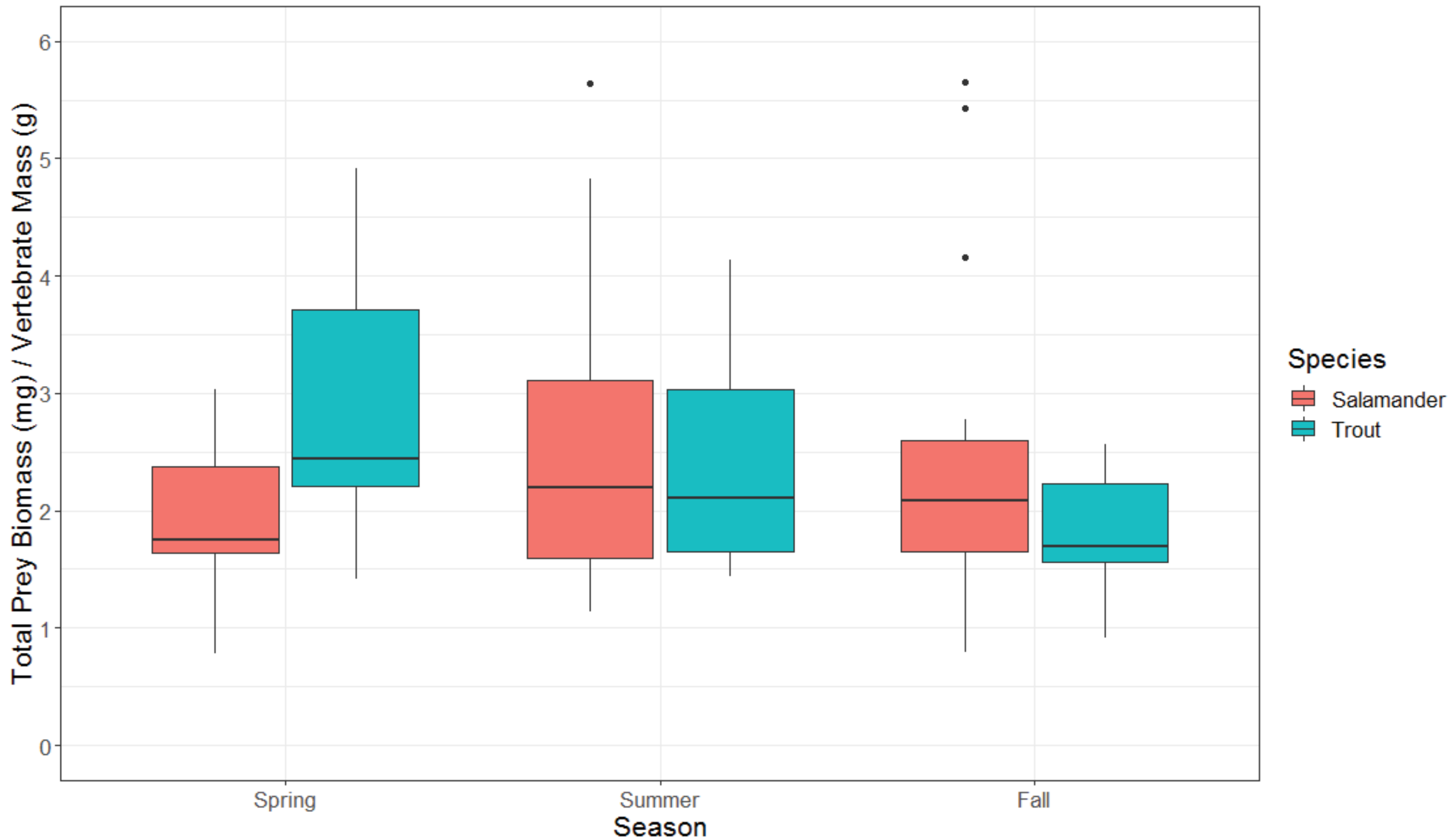
Thinning increased periphyton colonization on experimental tiles



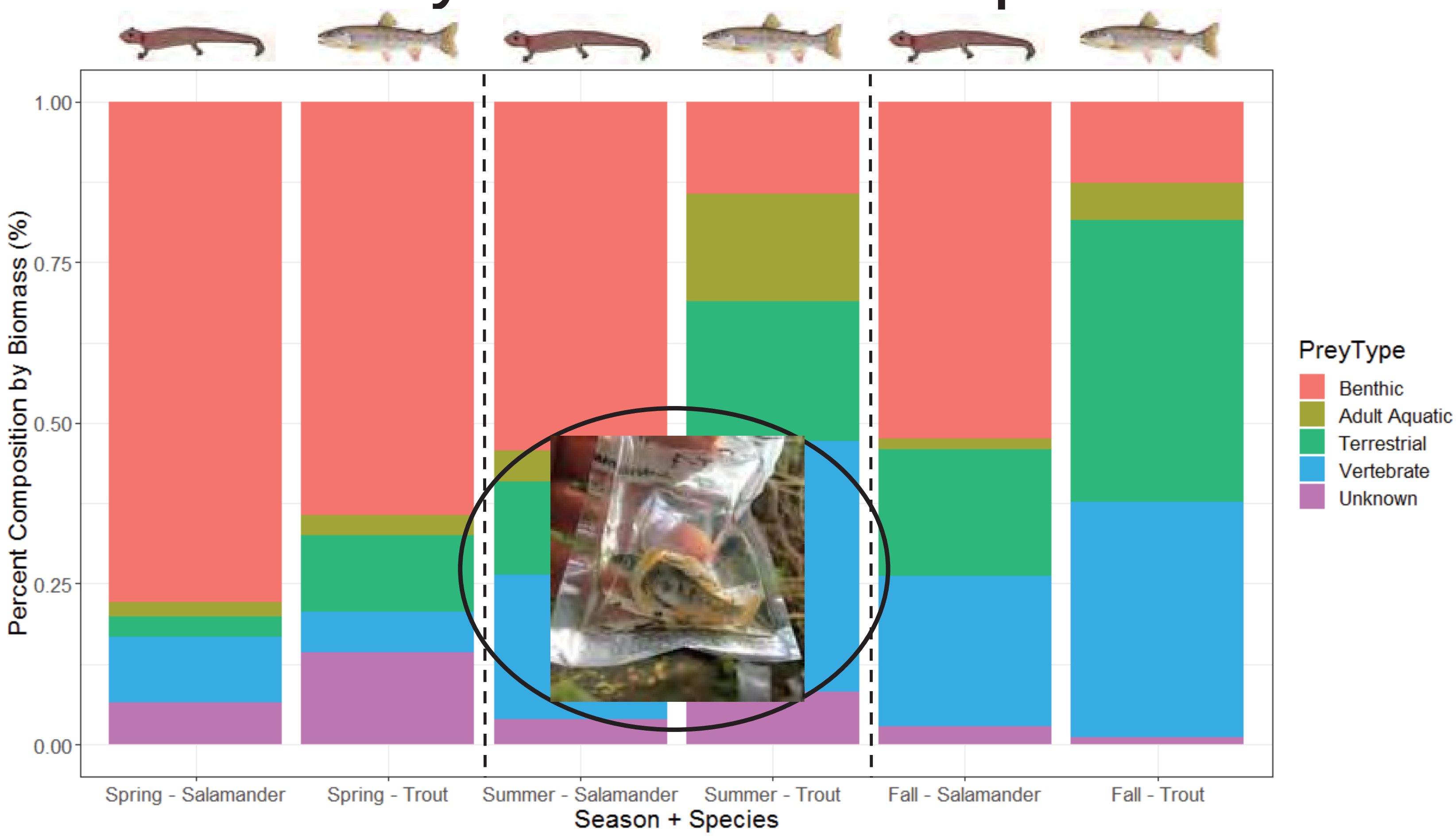
Diet Analysis

- Hypothesis: increase in periphyton will shift macroinvertebrate communities present in diets of top predators
- Methods:
  - Non-lethal gastric lavage samples from salamanders and trout (n=15/species/reach, n=1125 in 2016)

Seasonal patterns in prey consumption

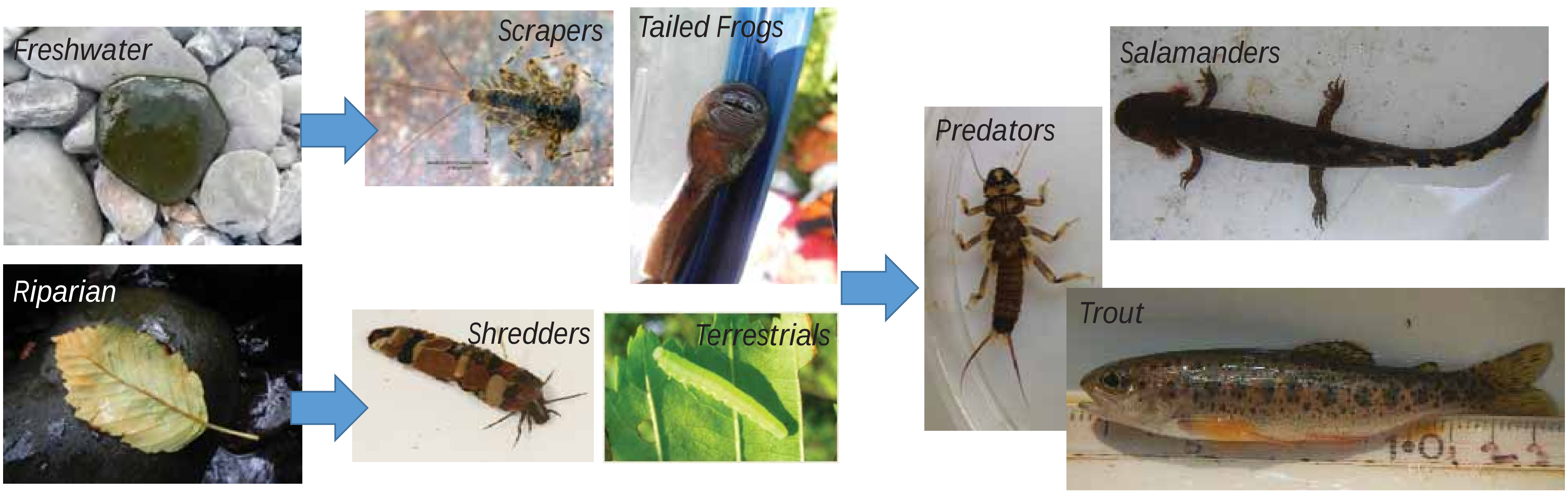


Pre-treatment prey composition patterns shifted seasonally and between species

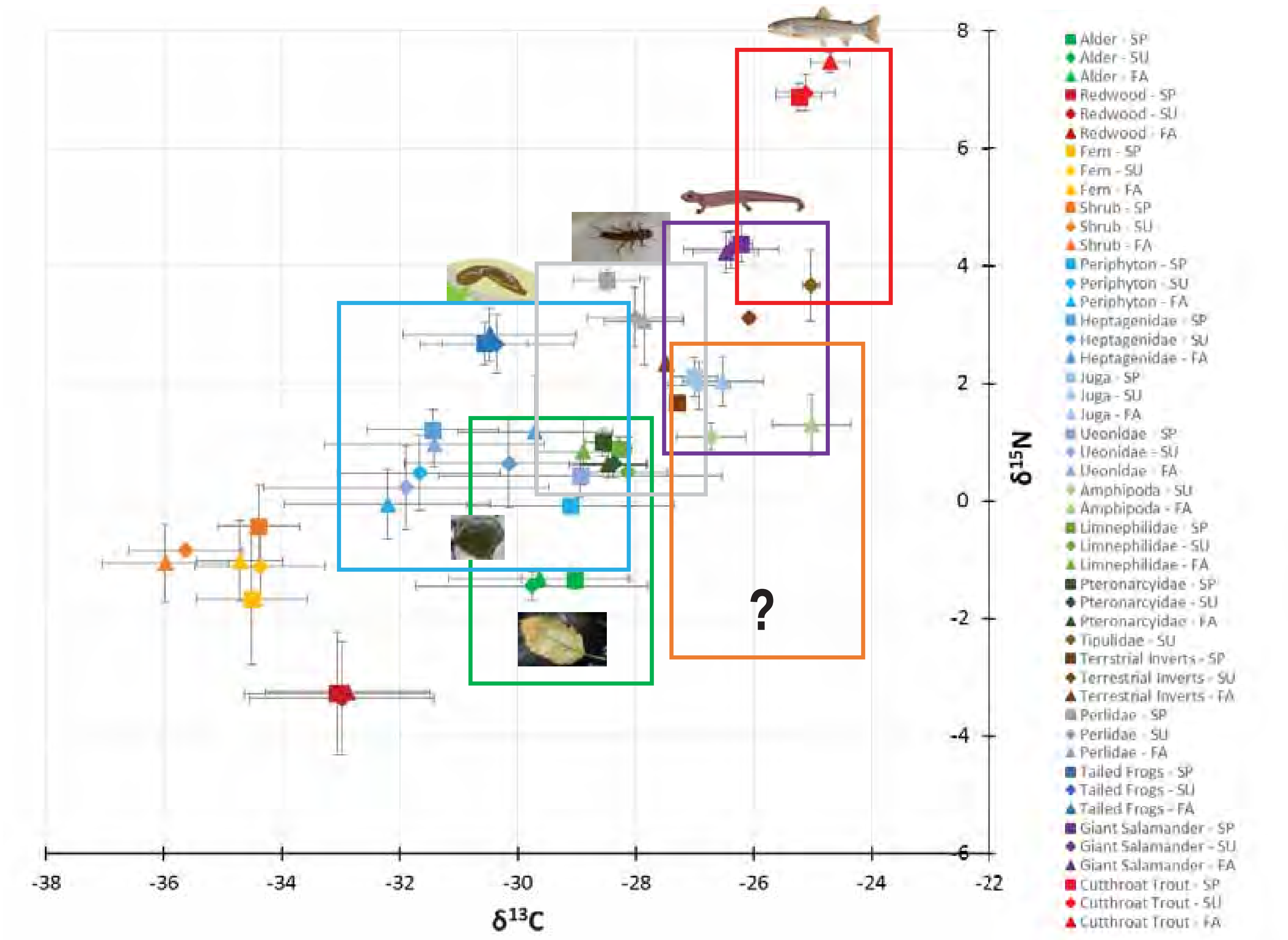


Stable Isotopes

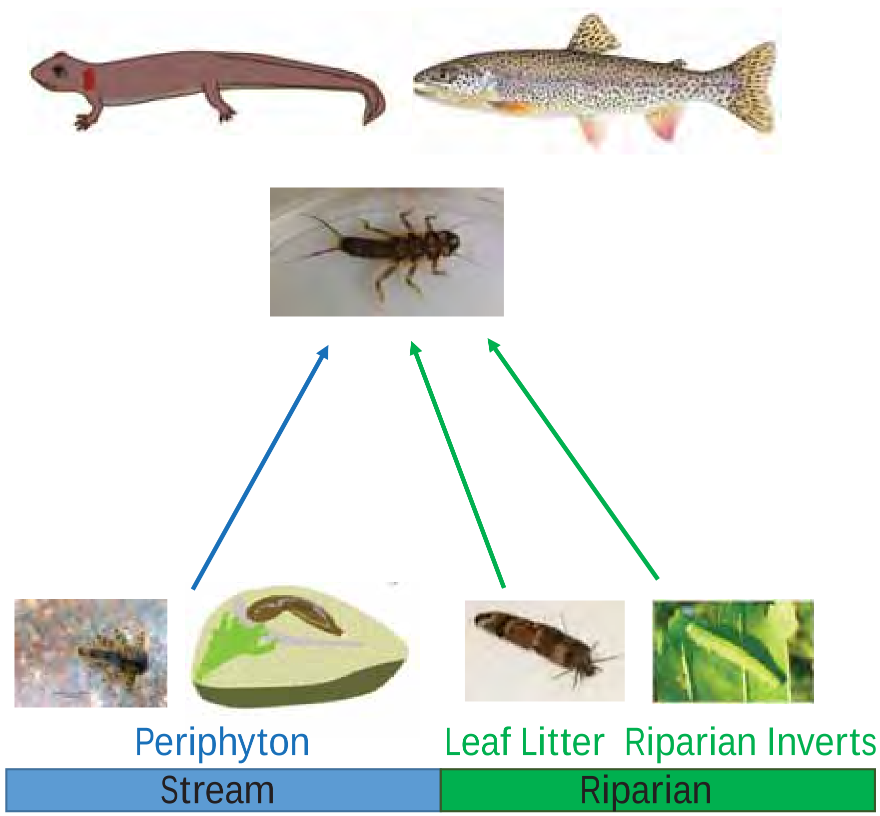
- Hypothesis: thinning will shift structure of stream-riparian food webs
- Methods: Carbon (food source) and Nitrogen (trophic level)
  - Basal Resources: riparian leaf litter, periphyton
  - Primary Consumers: Tailed frogs, invertebrate shredders and scrapers, terrestrial inverts
  - Top Predators: Invertebrate predators, trout, and salamanders



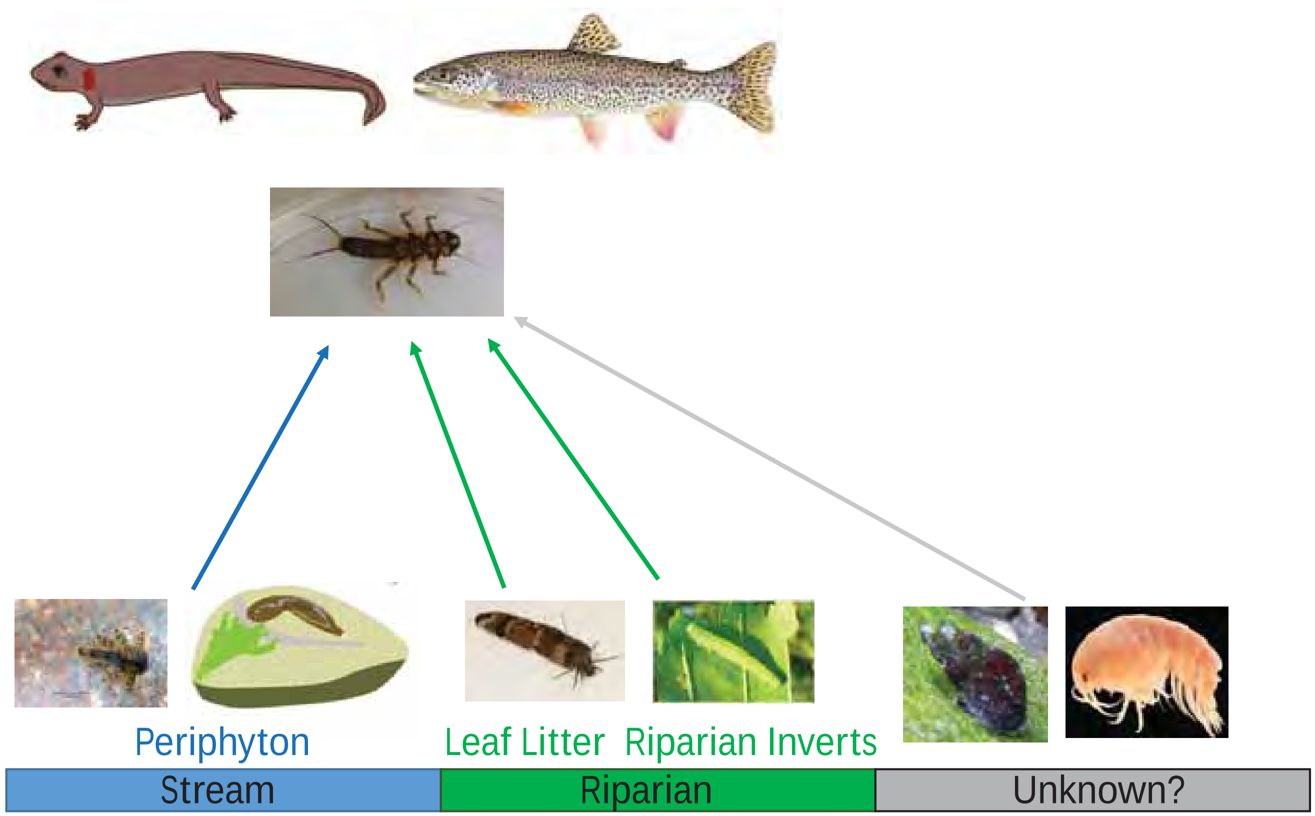
Pre-Treatment Stable Isotopes



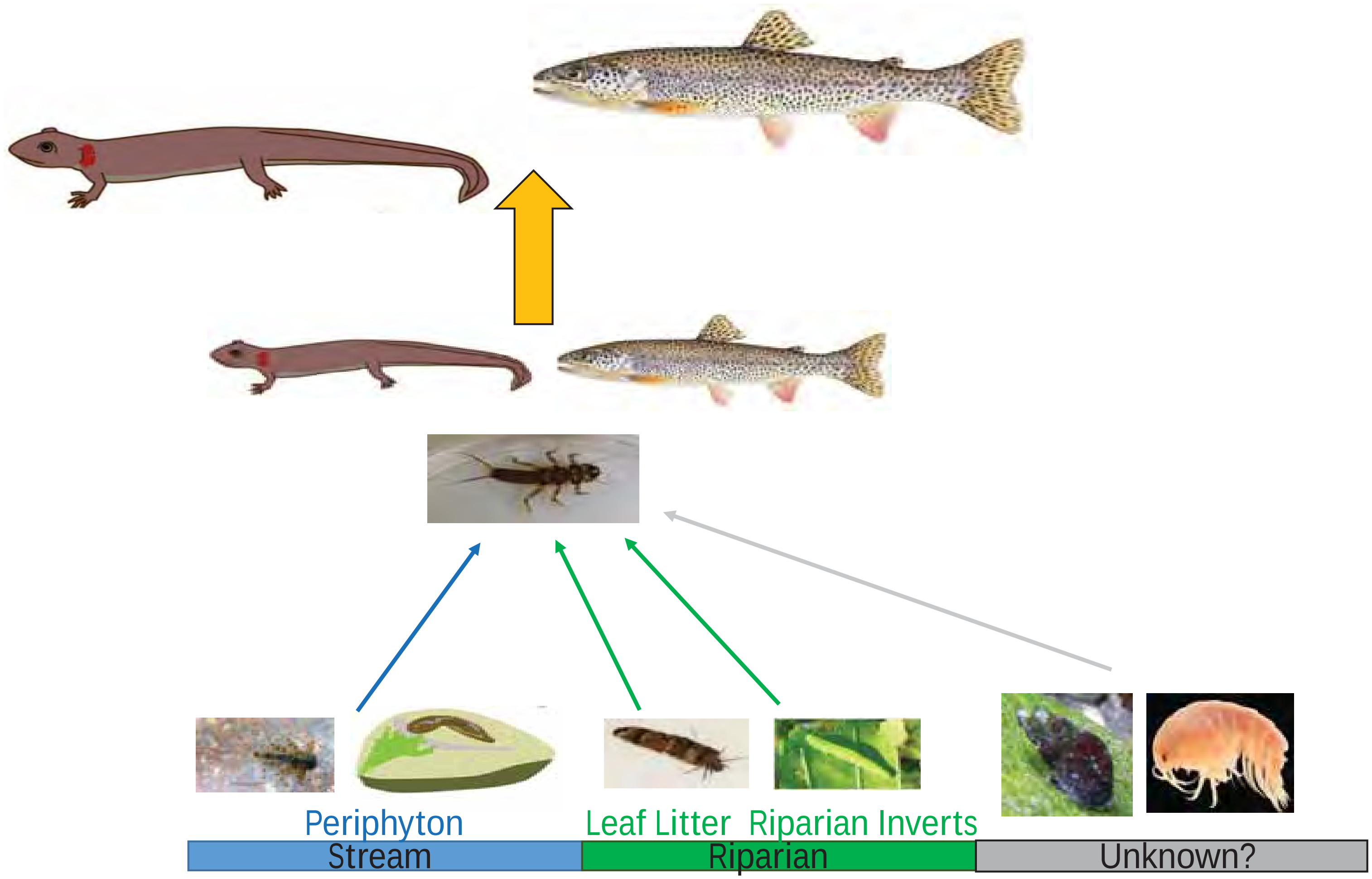
Original conceptual model of a stream food web



Revised conceptual model of a stream food web



Revised conceptual model of a stream food web



Acknowledgements

- Collaborative Effort: OSU, USGS FRESC, USFS PNW Research Station, USFS Redwood Sciences Lab, Green Diamond Resource Company, Redwood National Park
- Funding Sources: OSU Department of Fisheries and Wildlife, USFS, USGS FRESC, Green Diamond, Save the Redwoods League
- Field technicians: Ashley Sanders, Morgan Turner, Thomas Starkey-Owens, Mary Carlquist, Kyle Smith, Jerika Wallace, Green Diamond Aquatics Team, HSU student volunteers
- Lab technicians: Ashley Sanders, Cedar Mackaness, Laura Nepstad, Alex Scharfstein

Questions?

MODIFYING CANOPY SHADING IN THE RIPARIAN ZONE DURING TIMBER HARVEST: RESULTS FROM SALMONID (*Oncorhynchus* spp.) AND COASTAL GIANT SALAMANDER (*Dicamptodon tenebrosus*) MONITORING IN NORTHWESTERN CALIFORNIA

MATT R. KLUBER, MATTHEW R. HOUSE

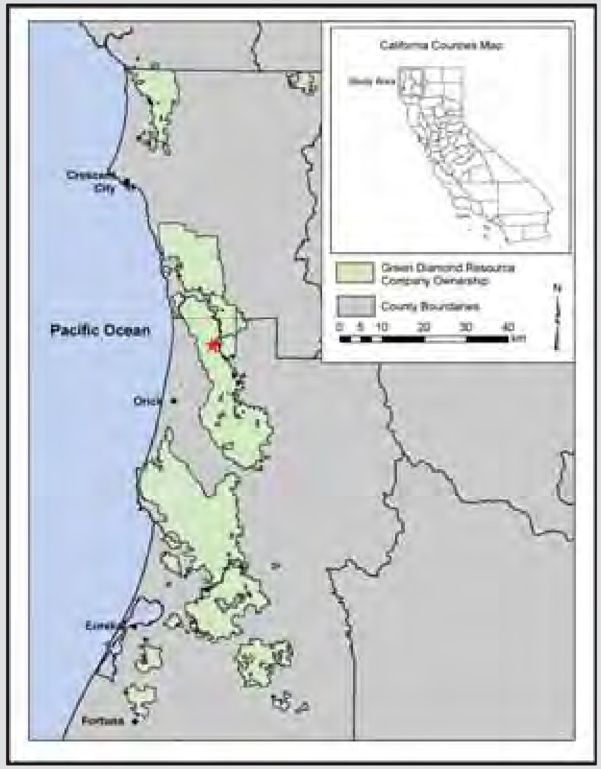
GREEN DIAMOND RESOURCE COMPANY

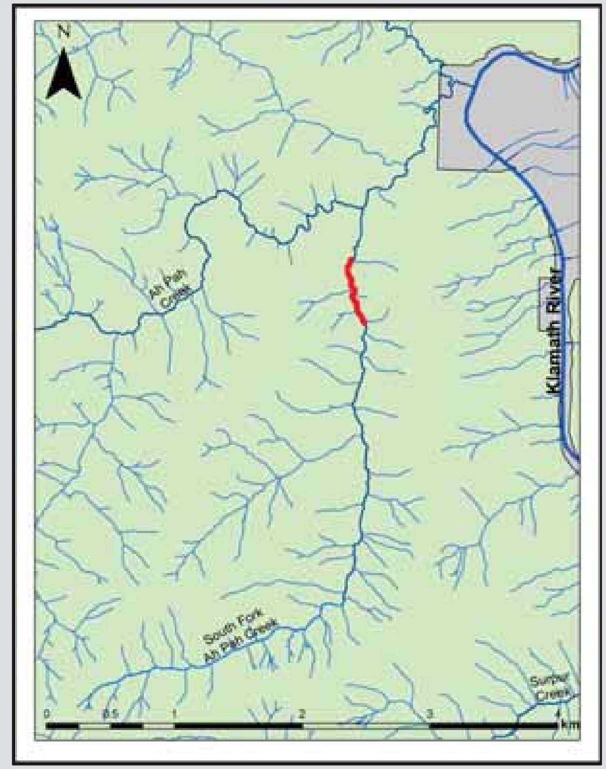
TRENT MCDONALD

WEST INC.

STUDY AREA

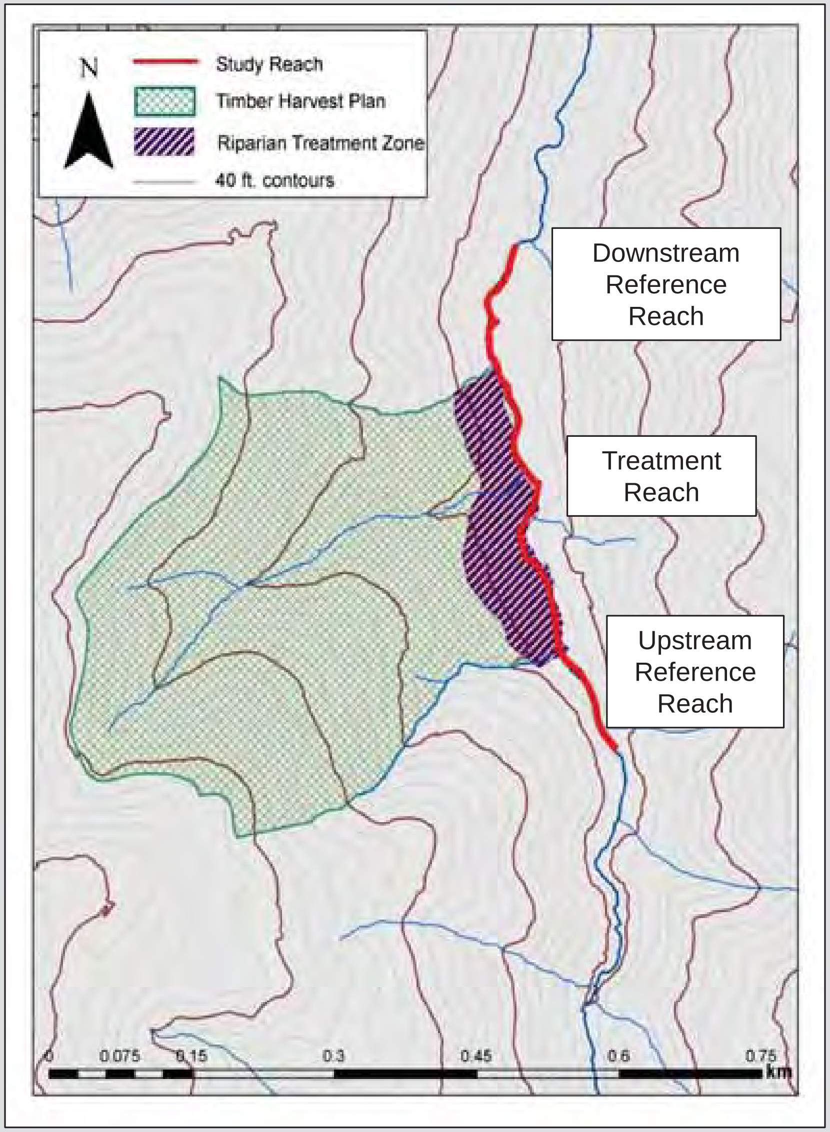
- Private timberlands in NW CA
- Forest stands dominated by:
    - Coast Redwood (*Sequoia sempervirens*)
    - Douglas-fir (*Pseudotsuga menziesii*)
    - Red Alder (*Alnus rubra*) dominated riparian areas
- SF Ah Pah Creek
    - Experimental watershed
    - Tributary to Ah Pah Creek, which is a tributary to the lower Klamath River





STUDY AREA

- 600 m study reach
  - 100 m downstream reference reach
  - 300 m treatment reach
  - 200 m upstream reference reach



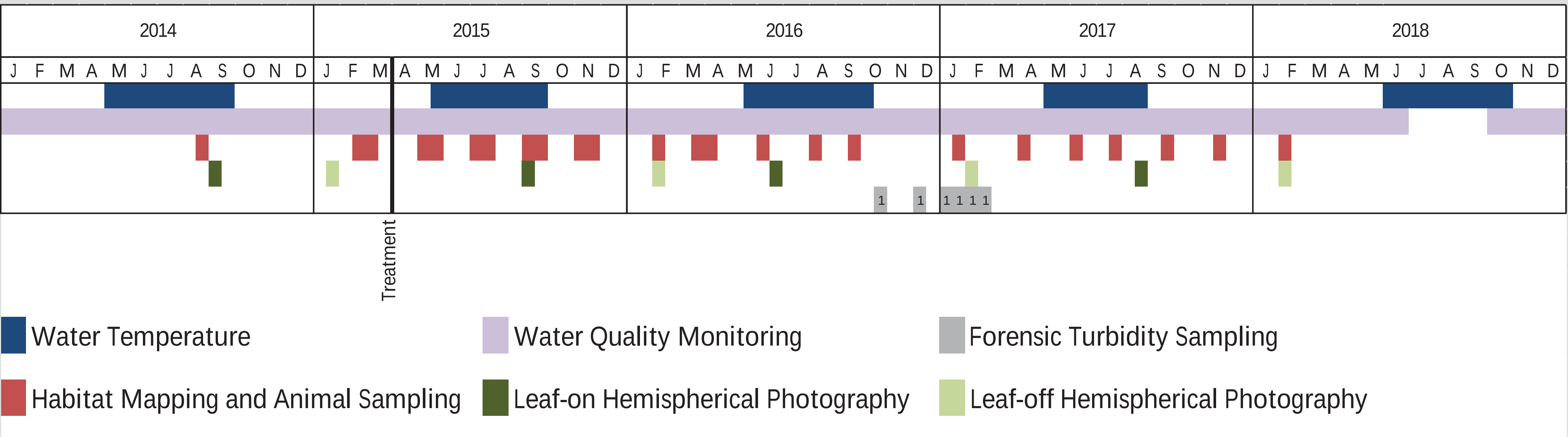
Primary Objectives of Pilot Project

- Receive an approved THP that included a riparian zone thinning experiment
- Test the feasibility of extracting trees from the riparian zone
- Monitor potential effects of a riparian thinning experiment
  - Hydrological
  - Biological – Salmonid and amphibian growth and movement

QUESTIONS FOR TODAY:

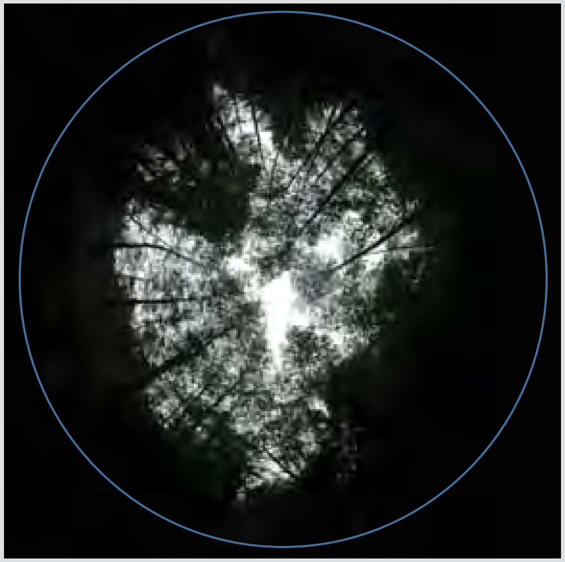
- Primary: What happens when we reduce canopy in the riparian?
- Statistical: How do we assign growth to a specific reach?
  - In an open system where individuals have free range
  - When we obtain locations of individuals only during capture events

PROJECT TIME LINE



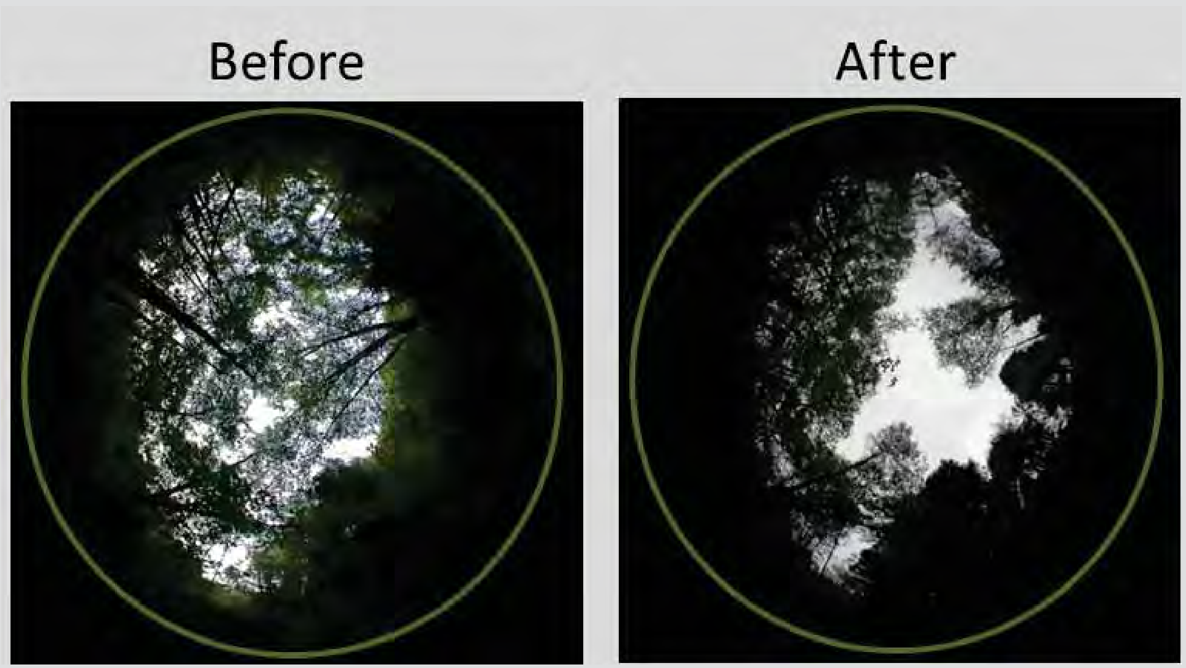
Methods: Canopy Closure

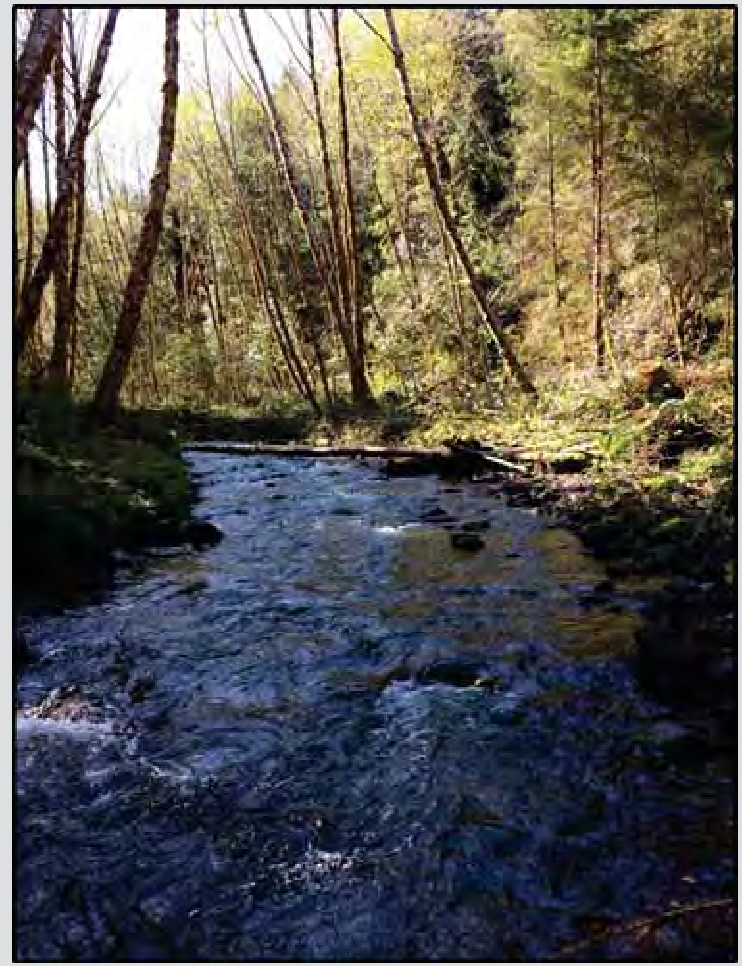
- Hemispherical photo monitoring
  - 18 locations (4 in the DSR, 10 in the TRT and 4 in the USR)
  - Locations established in center of bankfull channel
  - 4’ long, ½” rebar pounded into the substrate.
- Targeted for low-light conditions for photos
  - During four leaf-on and leaf-off periods from 2014 to 2018
- HemiView 2.1 software (Delta-T Devices) used for analysis.



RESULTS: CANOPY CLOSURE

- Max canopy reduction over stream ~ -6.6%
  - ~60% canopy closure achieved in middle of 150’ riparian buffer



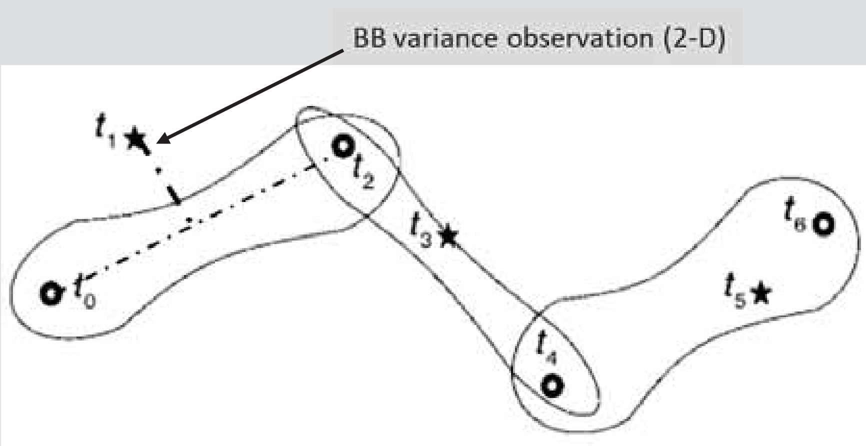


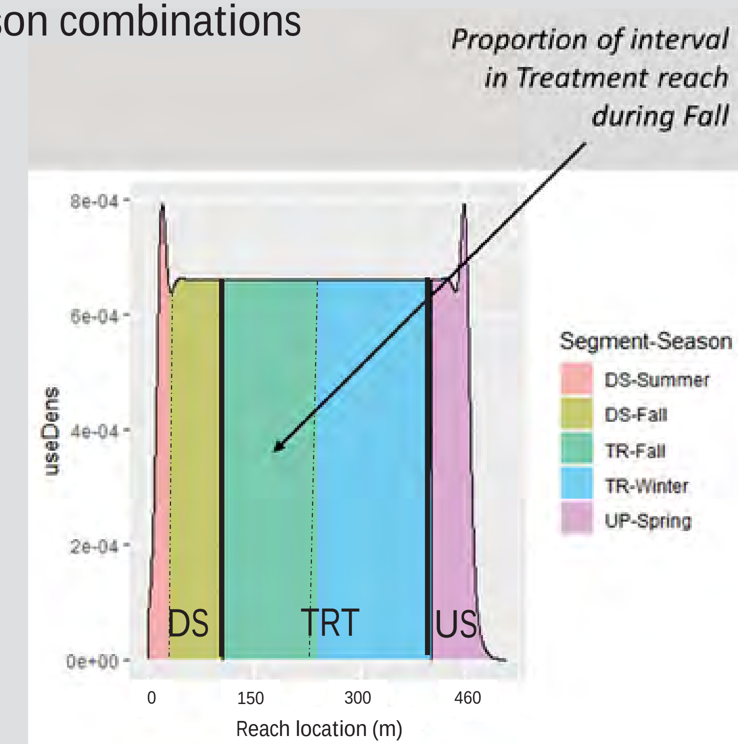
Methods: Animal Sampling

- Target Species
  - Steelhead trout (*Oncorhynchus mykiss*)
  - *Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*)
  - *Larval Coastal Giant Salamanders (*Dicamptodon tenebrosus*)
- Animal Sampling
  - Fish and amphibian sampling bi-monthly (FEB 2015-FEB 2018)
  - Electrofishing & rubble rousing
- Marking
  - Trout >70mm fork length = PIT tags
  - Coastal Giant Salamanders
    - <45 mm SVL = Visible Implant Elastomer (VIE)
    - >45 mm SVL = PIT tags

Methods: Movement Estimation

- 1-dimensional Brownian Bridge Movement Model (Horne et al. 2007)
  - Allowed for approximation of amount of time an individual spent in a particular reach during a season
  - Assigns proportion of growth to Reach and Season combinations
  - Two parameters
    - 1) Measured variance in daily movements
    - 2) Measured variance in location estimates
      - Estimated from "triplets" of captures





METHODS: GROWTH RATE ESTIMATION

- Total growth of individuals calculated between capture intervals
- Total growth was allocated to season and reach using weighted values derived from the Brownian Bridge distributions
- Average growth rate for all combinations of season and reach was calculated by averaging over an individual's and capture intervals
- Variation was calculated using a bootstrap method

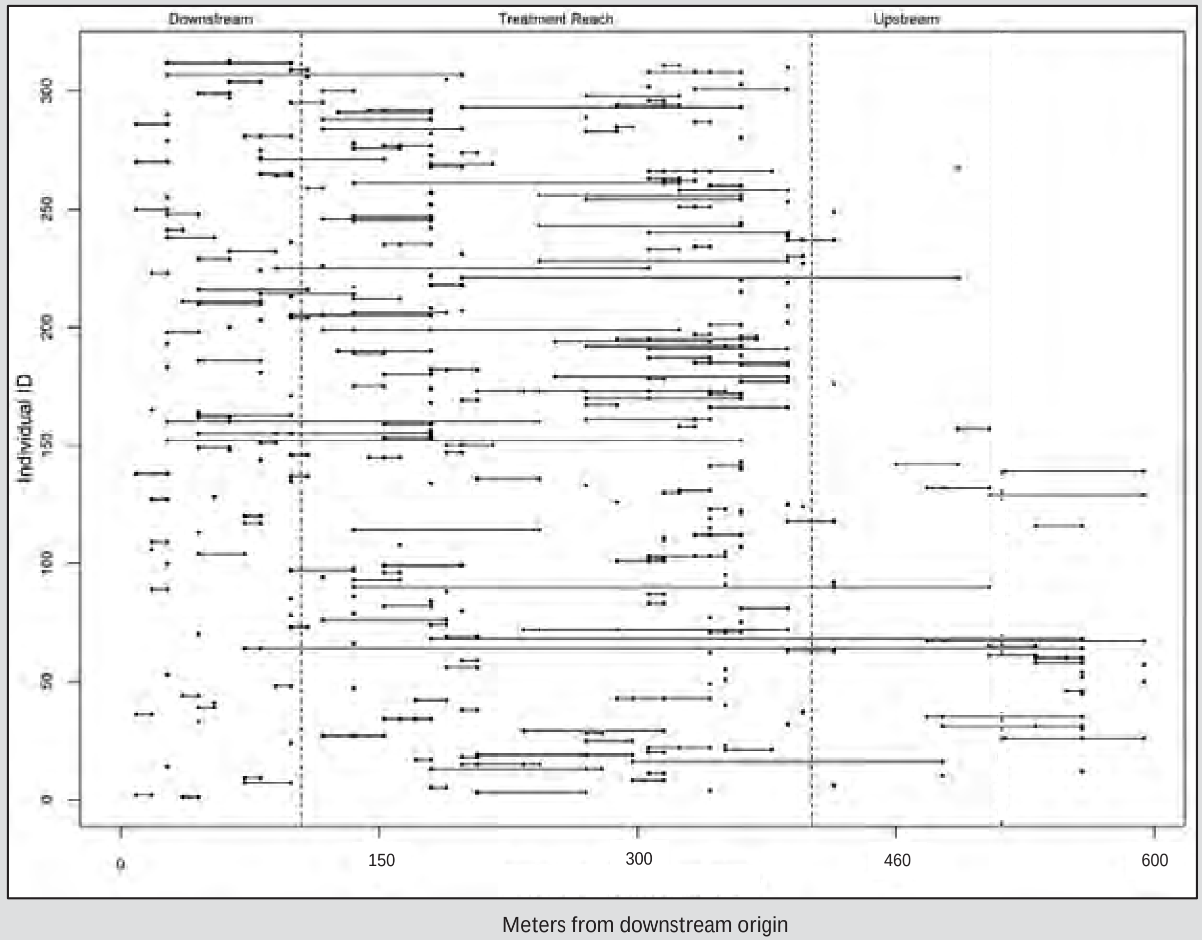
Results: Captured and Marked

Total Marked Animals

	Species				
Reach	CU	CGS	SH	TR	Totals
DSR	76	558	25	57	716
TRT	220	1382	52	221	1875
USR	49	441	27	41	558
Totals	345	2381	104	319	3149

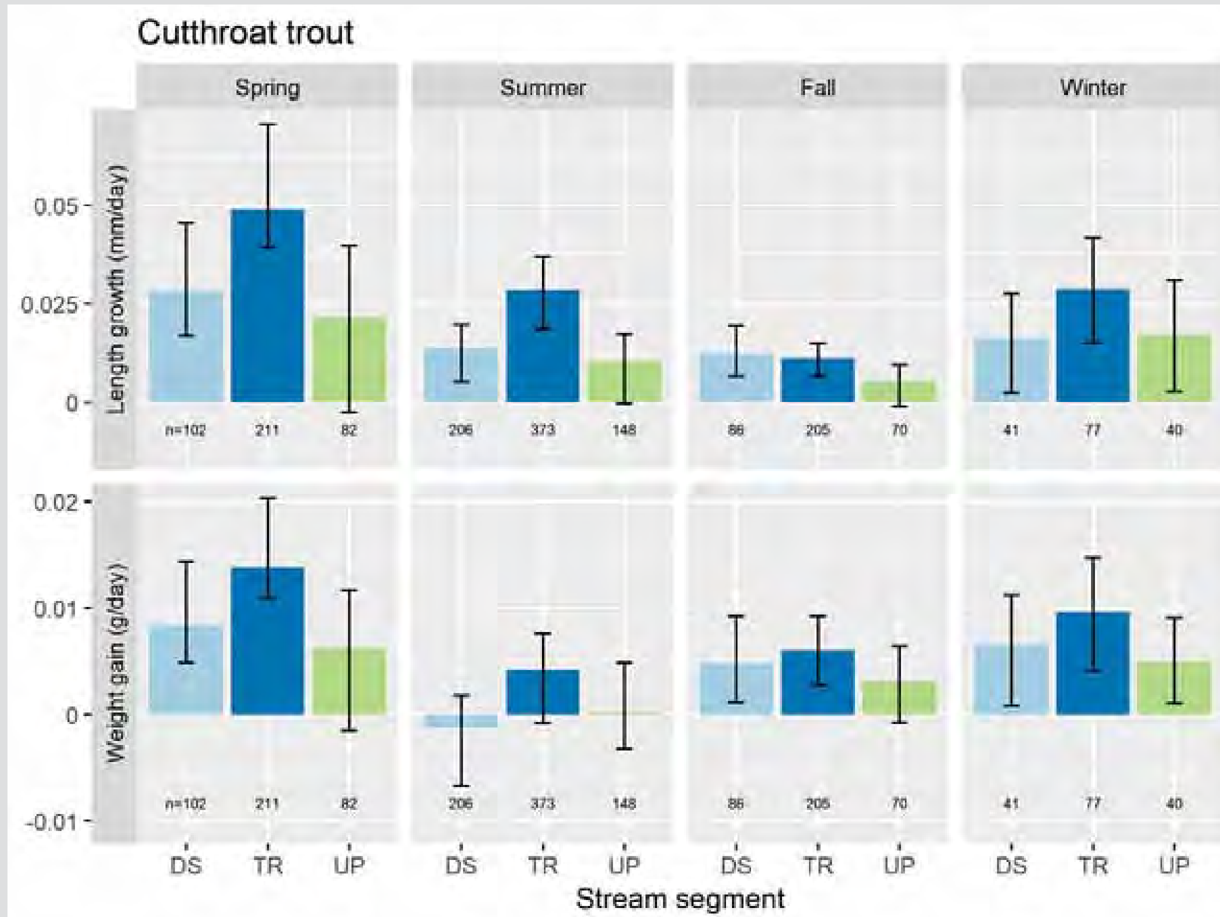
RESULTS: MOVEMENT

- Relatively little movement over the course captures
- Individuals remained primarily within their reach of initial capture



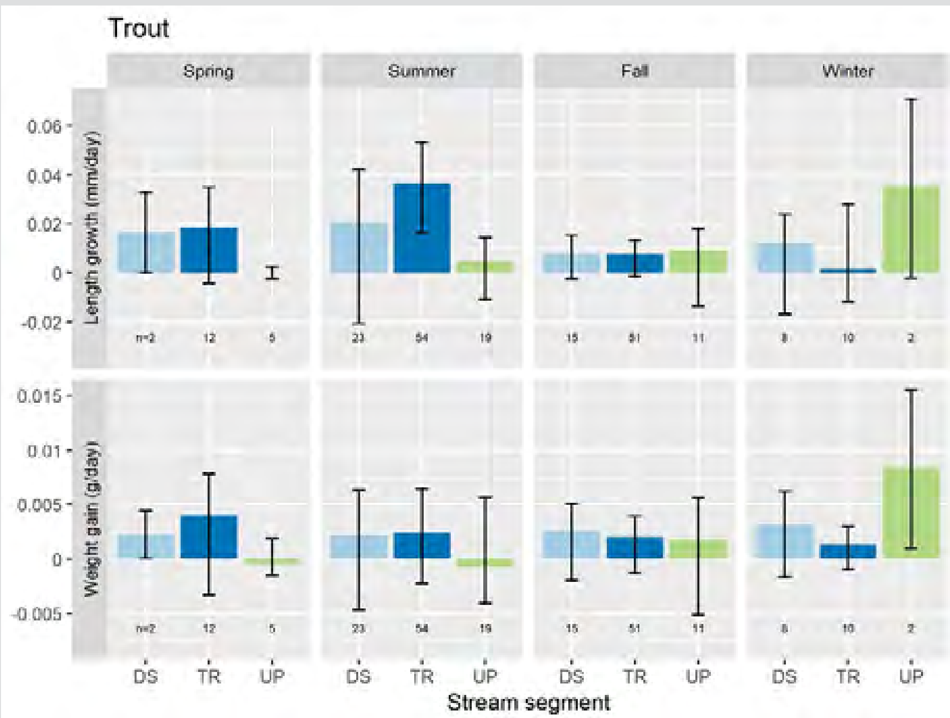
RESULTS: CUTTHROAT TROUT GROWTH

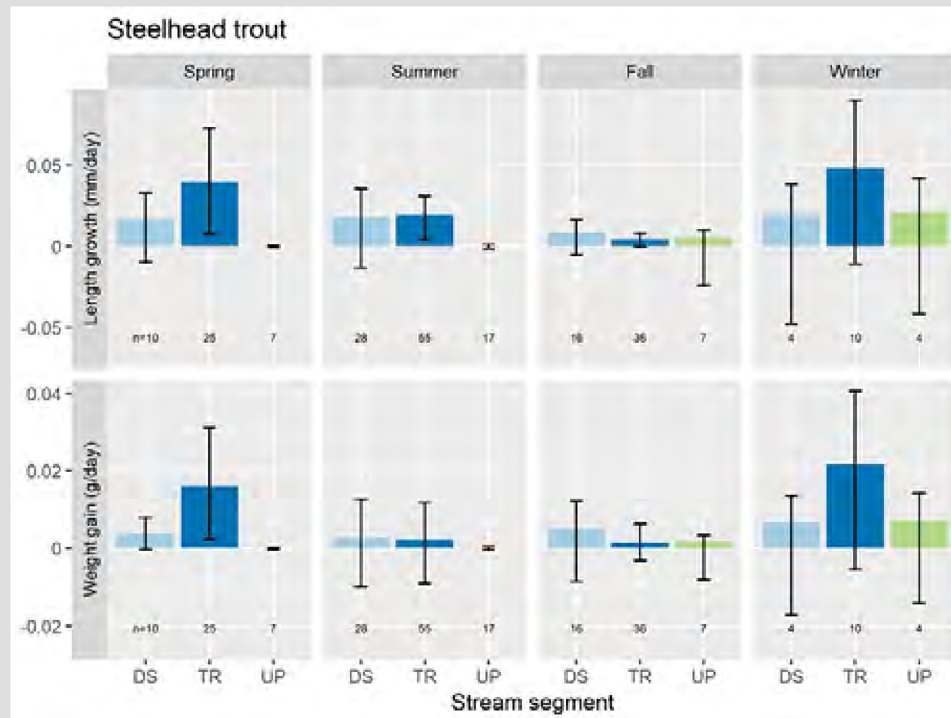
- CV's: 50% to 100%
- Equivalent or higher growth rate in treatment
- Highest growth rate seasonally in Spring



RESULTS: TROUT SPP. AND STEELHEAD GROWTH

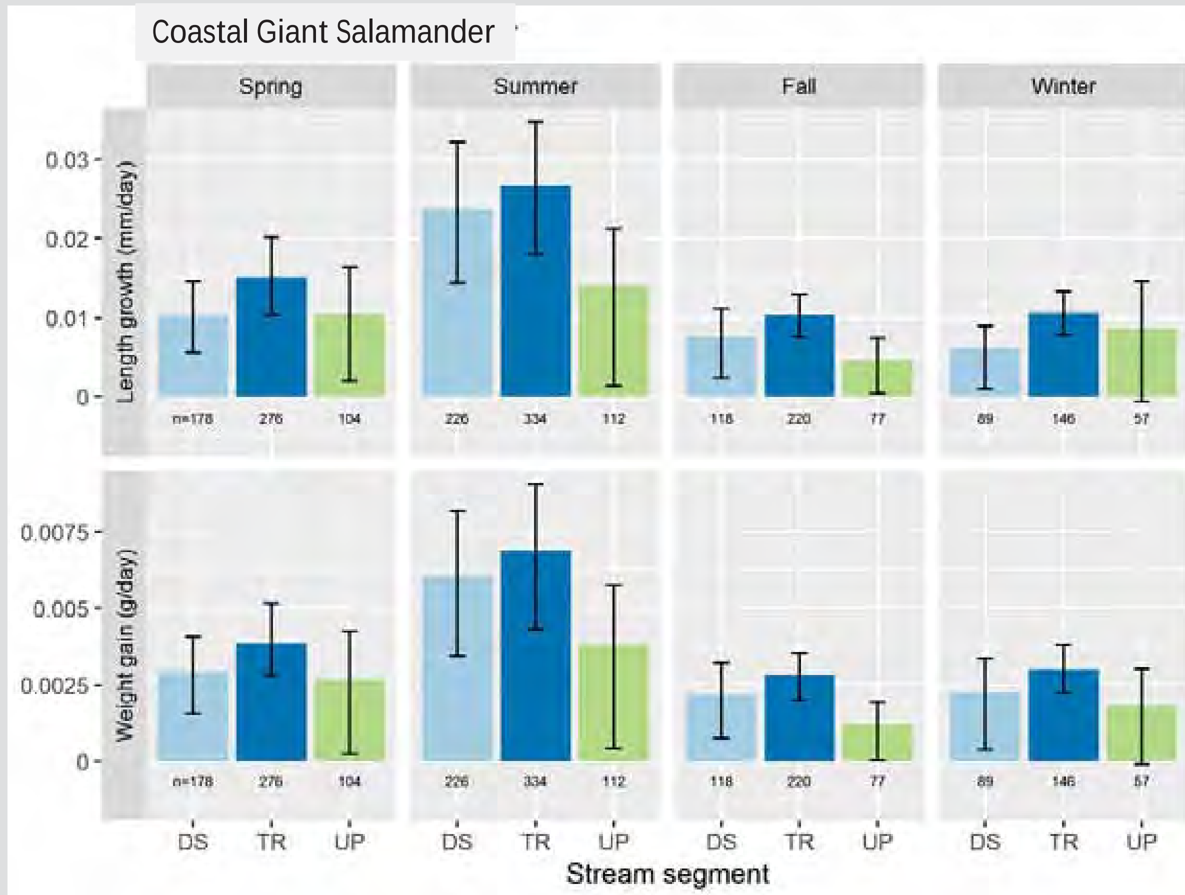
- CV's: 100% to 250% (low sample sizes)
- Mostly equivalent or higher growth in treatment reach





RESULTS: COASTAL GIANT SALAMANDER GROWTH

- CV's: 25% to 100%
- Equivalent or higher growth rate in treatment reach



IN SUMMARY…

- Generally higher growth rates observed in treatment reach when compared to reference reaches
- Cutthroat
  - Higher growth in treatment during spring, summer and winter
  - Highest seasonal growth during spring
- Coastal Giant Salamanders
  - Higher growth rates observed in treatment across all seasons
  - Highest seasonal growth during summer
- Upstream reference reach generally had lower overall growth compared to downstream reference and treatment reaches

Discussion: Two Explanations

- Maybe: Treatment reach was great habitat to begin with
  - Removing trees lowered growth rates in treatment but not below that of reference reaches
  - Canopy removal over stream was slight (~3%)
    - More removal could cause larger deleterious effects
- More likely: Individuals in treatment benefitted (at least not negatively affected) in short term by riparian tree removal
  - One possibility: Flow increased following tree removal and increased light lead to increased macroinvertebrate populations benefitting fish and amphibians


THANK YOU!
matt.kluber@greendiamond.com

- **References**

- Horne, J. S., E. O. Garton, S. M. Krone, and J. S. Lewis. 2007. Analyzing animal movements using Brownian bridges. Ecology 88:2354–2363.

Results: Captured and Marked

Total Marked

Reach	CU	DITE	SH	TR	Totals
	Species				
DSC	76	558	25	57	716
TRT	220	1382	52	221	1875
USC	49	441	27	41	558
Totals	345	2381	104	319	3149

Total Recaptures

Reach	CU	DITE	SH	TR	Totals
	Species				
DSC	154	150	19	10	333
TRT	339	259	53	52	703
USC	55	57	1	9	122
Totals	548	466	73	71	1158

Includes multiple recaptures of same animal

Results: Captured and Marked

Total Marked

Reach	CU	DITE	SH	TR	Totals
	Species				
DSC	76	558	25	57	716
TRT	220	1382	52	221	1875
USC	49	441	27	41	558
Totals	345	2381	104	319	3149

# of Individuals Recaptured

Reach	CU	DITE	SH	TR	Totals
	Species				
DSC	71	121	11	10	213
TRT	179	233	33	45	490
USC	32	49	1	9	91
Totals	282	403	45	64	794

Total Recaptures

Reach	CU	DITE	SH	TR	Totals
	Species				
DSC	154	150	19	10	333
TRT	339	259	53	52	703
USC	55	57	1	9	122
Totals	548	466	73	71	1158

Includes multiple recaptures of same animal

METHODS: OVERVIEW

- Fall 2014, Riparian Canopy Modification Experiment (RCME) was established
- Prior to tree felling, a variety of monitoring activities were initiated:
  - Hydrologic
    - Water temperature
    - Turbidity
    - Suspended sediment concentration
  - Habitat typing
  - **Canopy closure**
  - **Salmonid growth**
  - **Amphibian growth**

METHODS: OVERVIEW

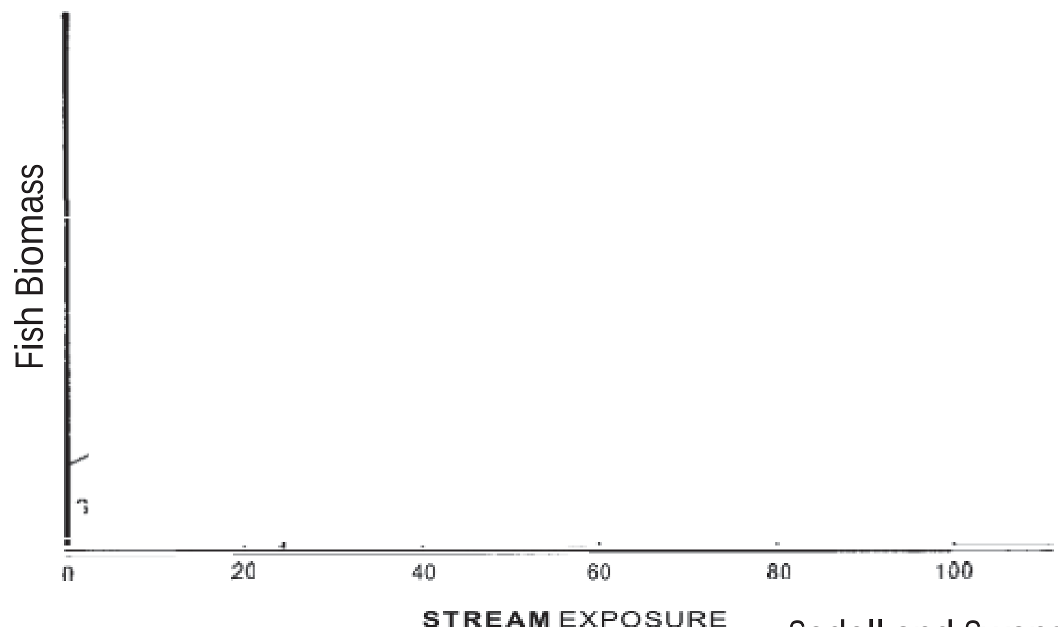
- Tree felling occurred March 2015
  - 220 hardwoods (mostly Red Alder)
    - Felled and yarded from riparian zone along left bank
      - Trees removed in association with a THP approved by CA Dept. of Forestry and Fire Protection
  - Goal was to reduce riparian canopy by 50%

Stream vertebrate and temperature responses to riparian canopy gaps in forested headwater streams

Allison Swartz, Dana Warren
Forest Ecosystems and Society and Fisheries and Wildlife, Oregon State University

Conceptual Framework

Light influences stream predators via ”Bottom-up” drivers in the food web



Sedell and Swanson (1984)

Conceptual Framework

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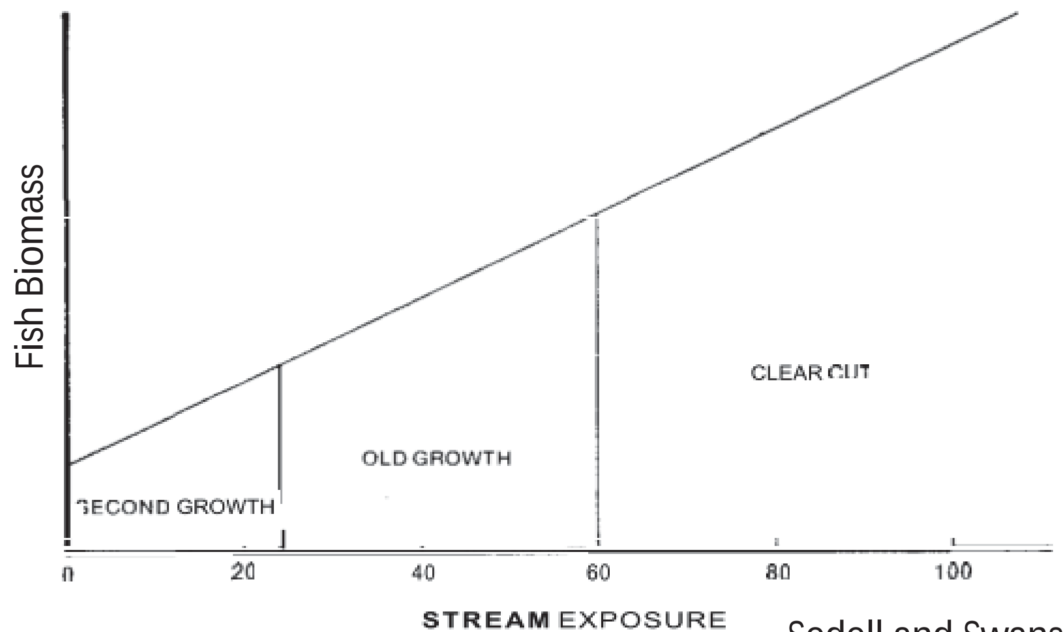

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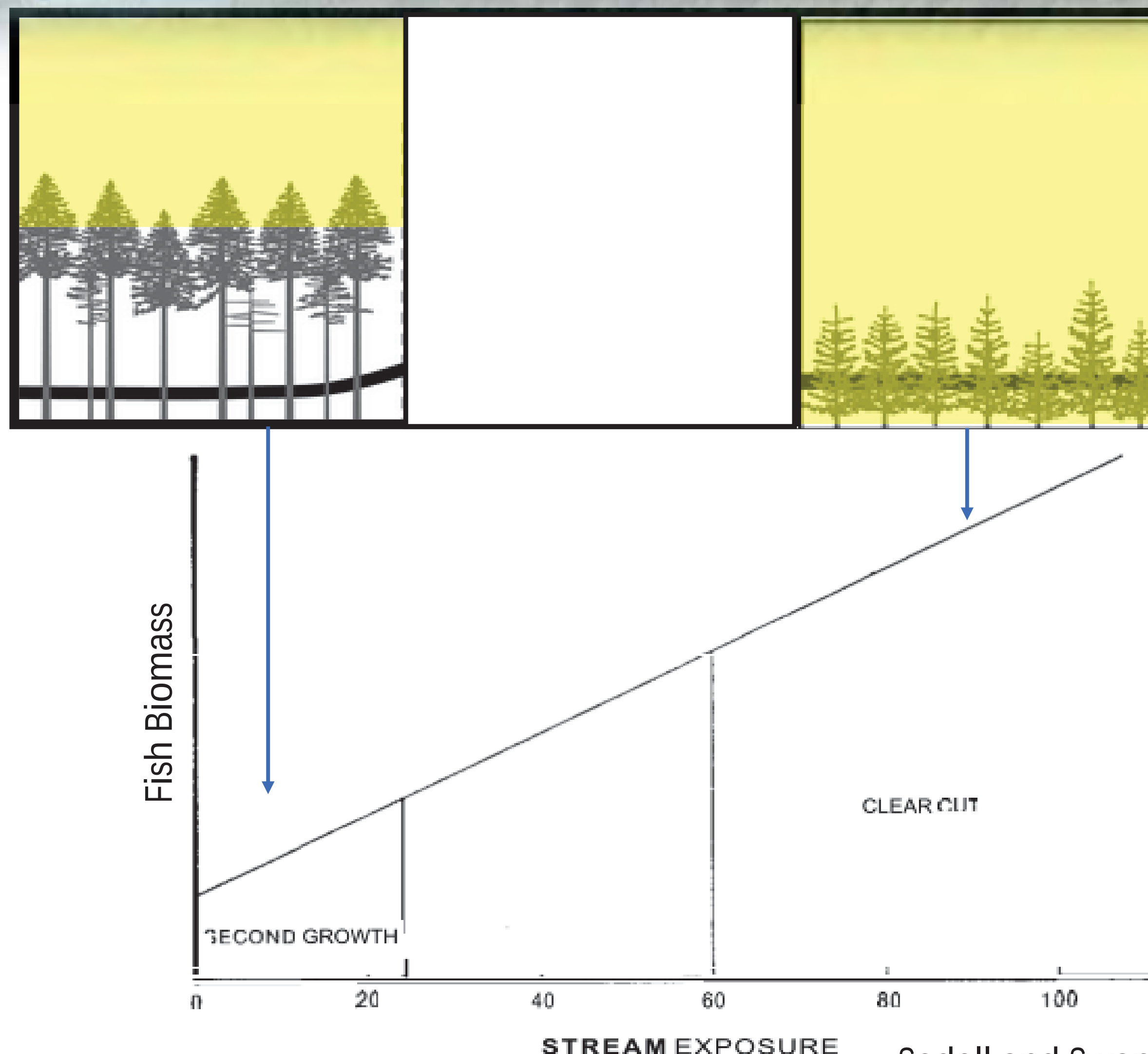

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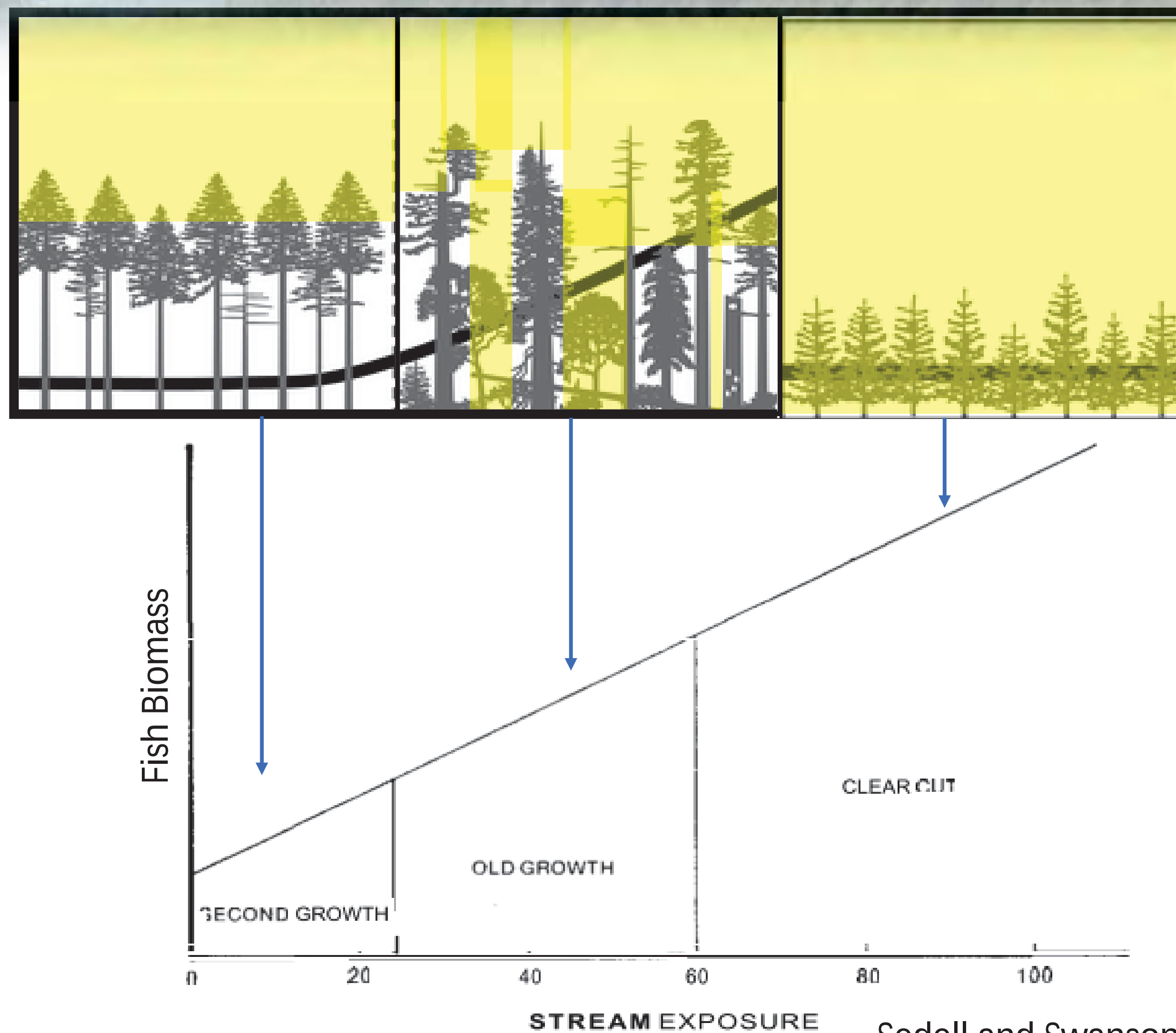

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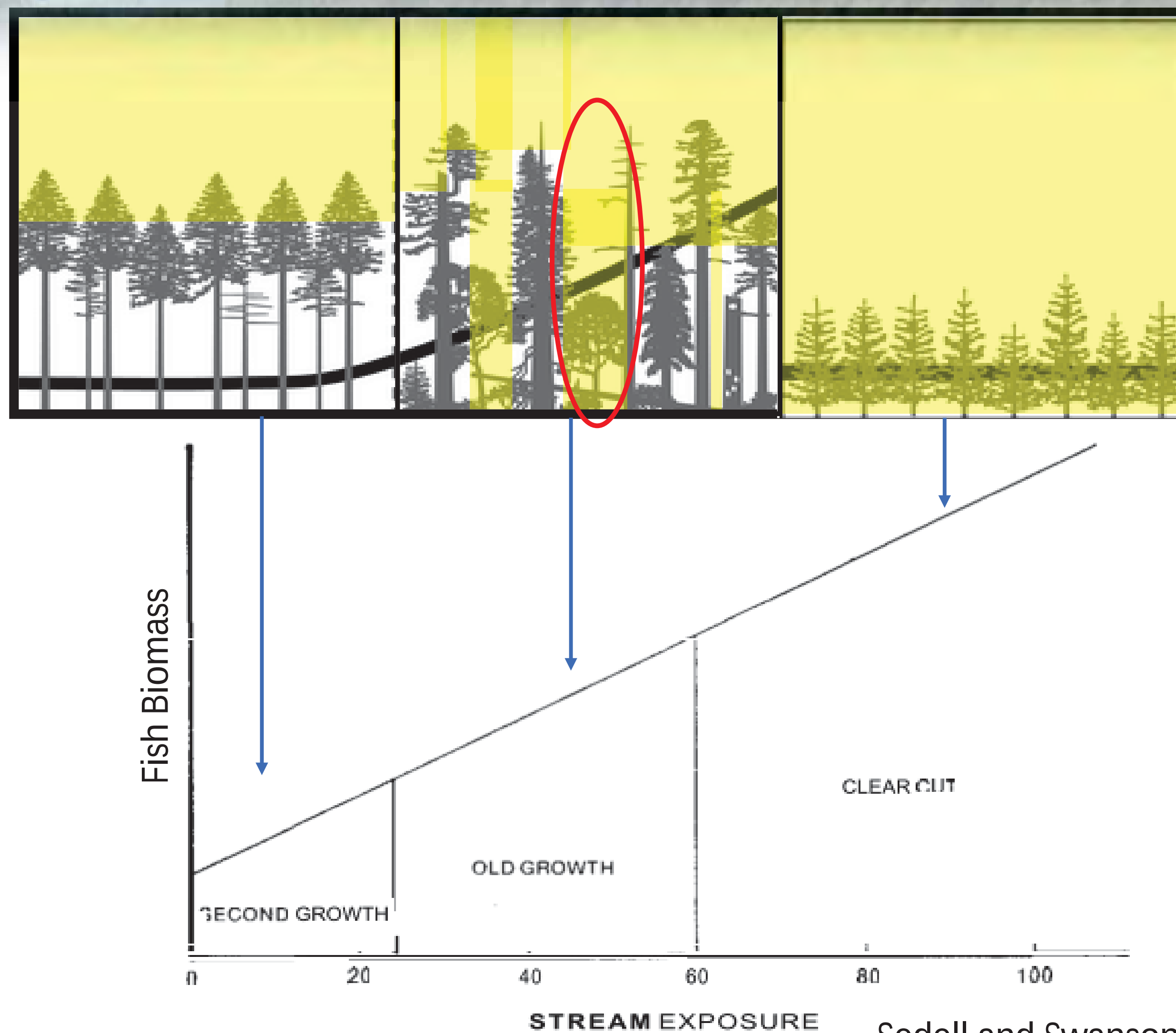
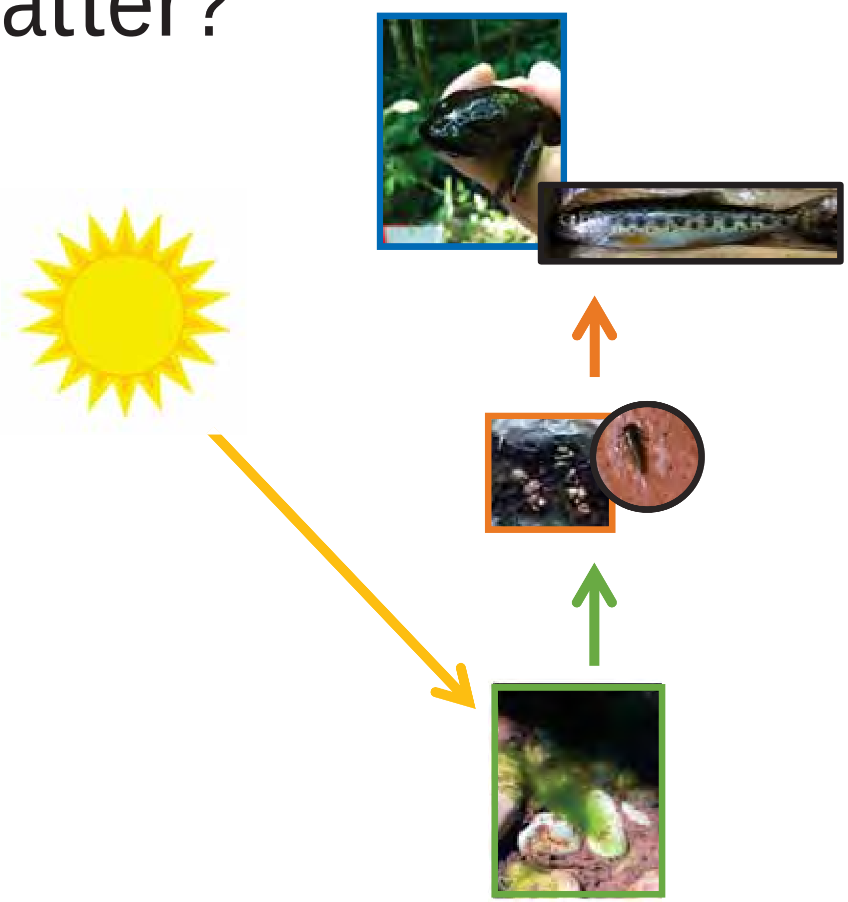


Sedell and Swanson (1984)

Why do GAPS matter?

- Primary production is often ***light-limited*** in forested headwater systems
- Food availability for consumers is often ***limited*** in these systems



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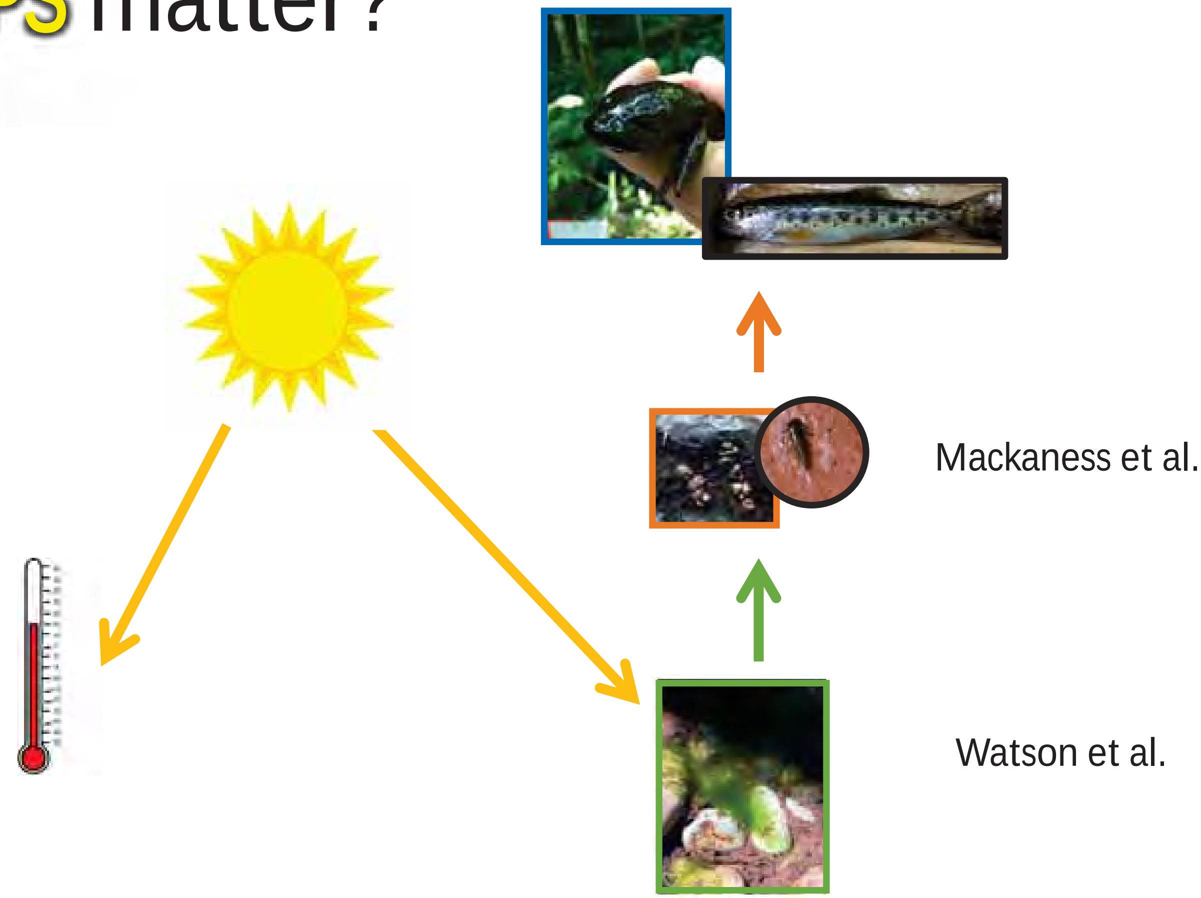
- Temperature affects biota and all ecosystem processes



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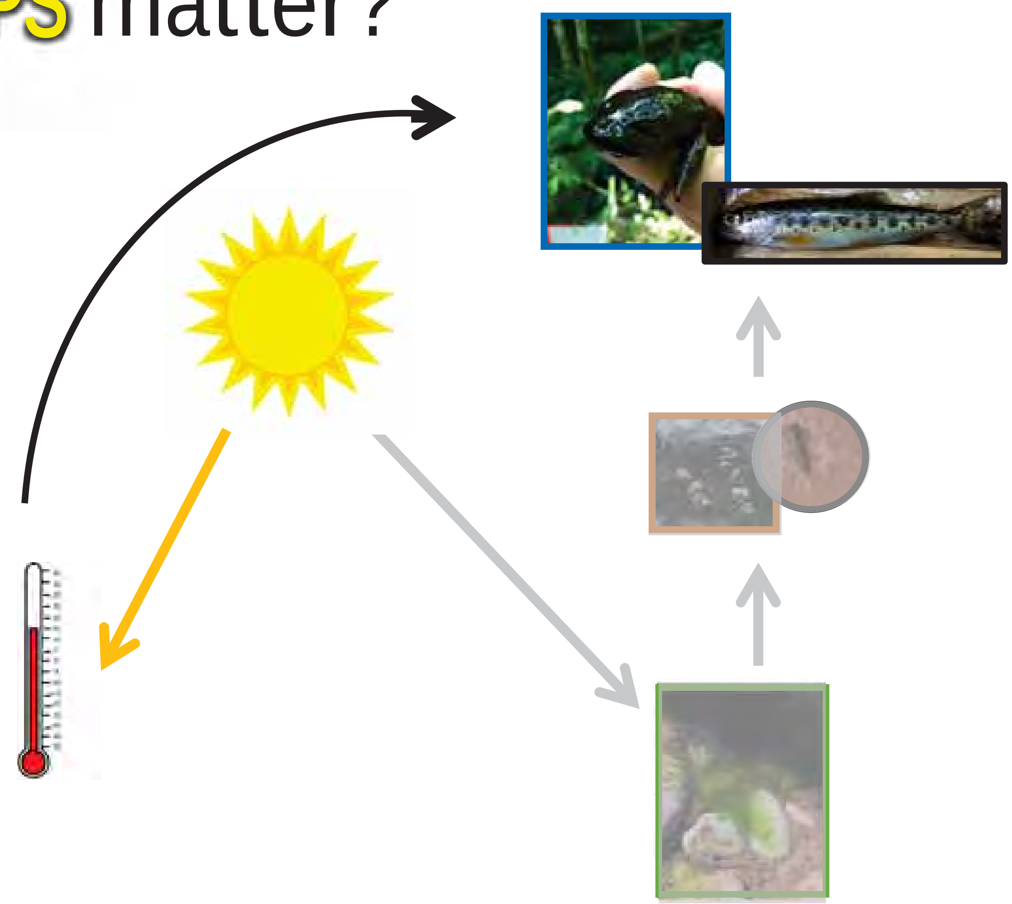
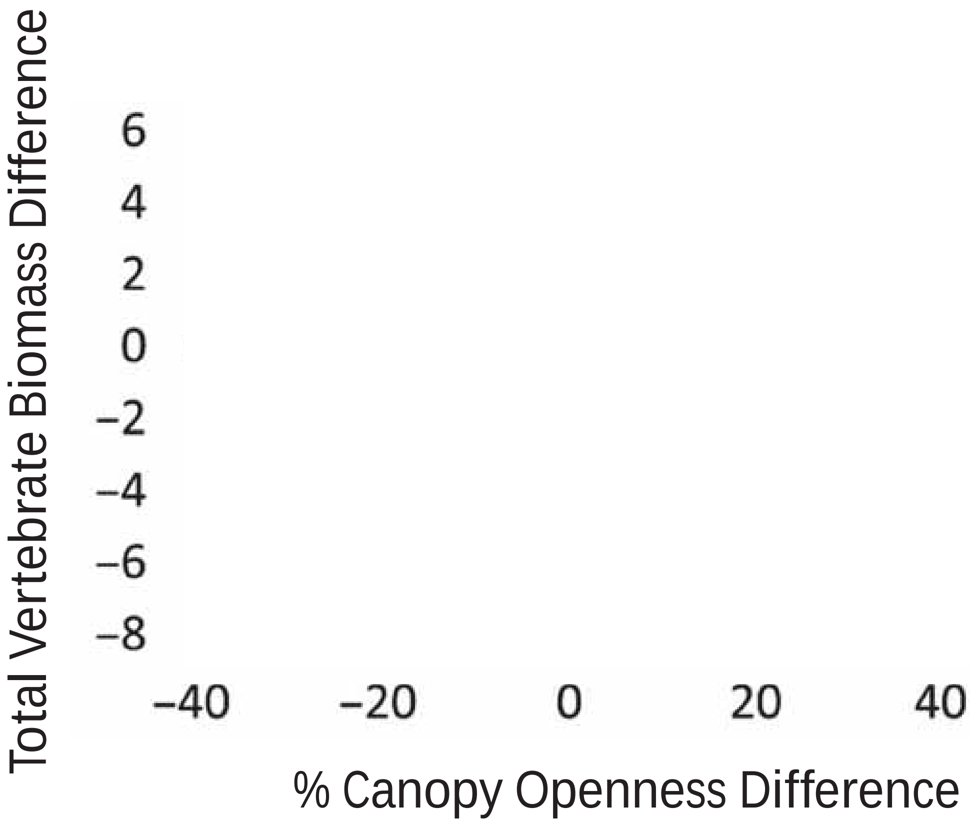
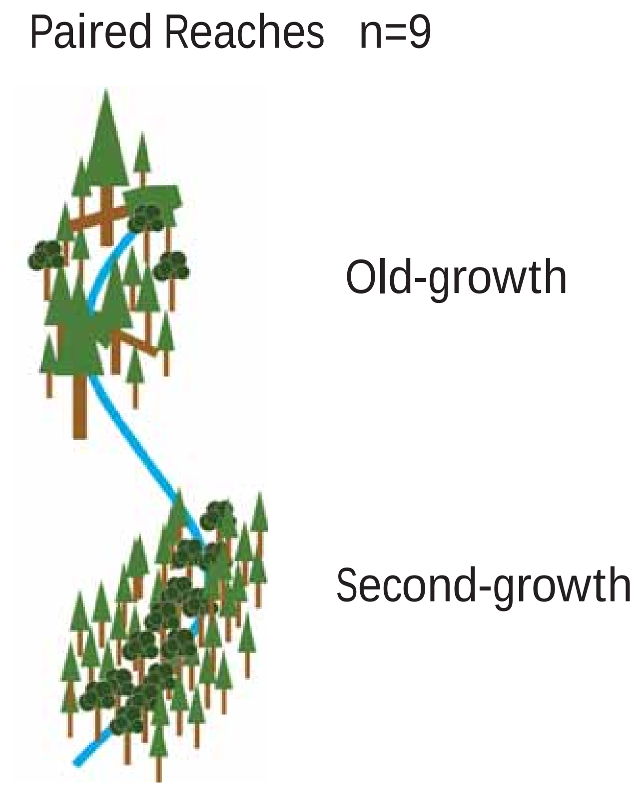


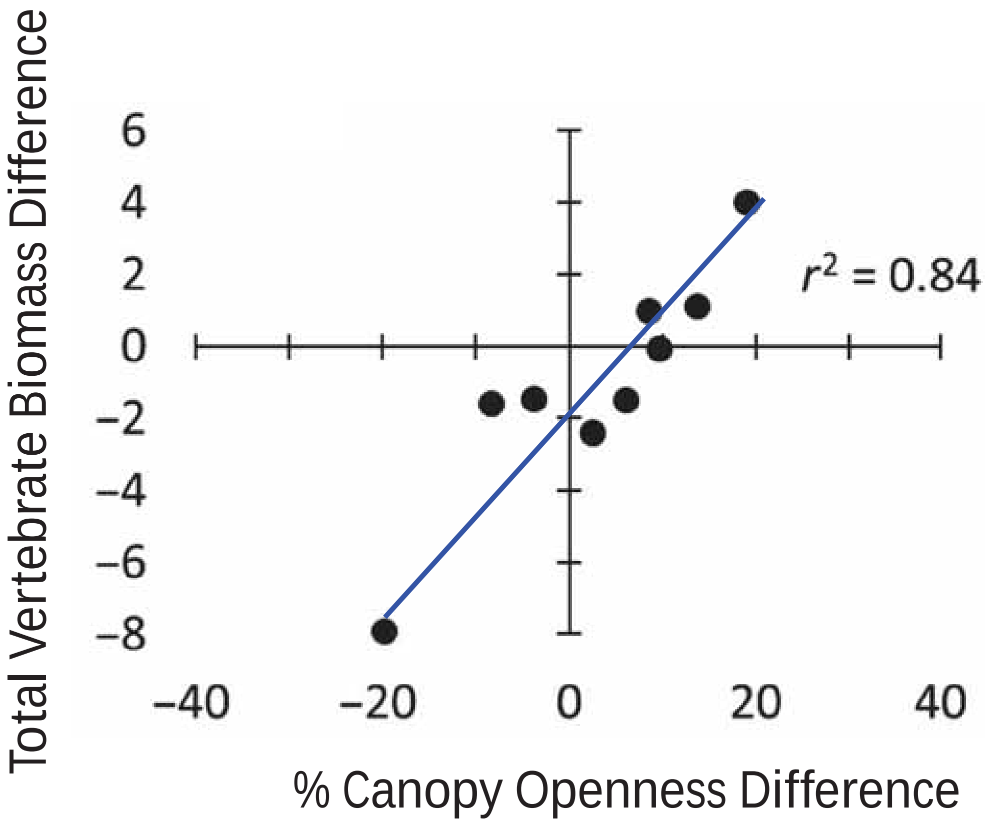
Correlation Study



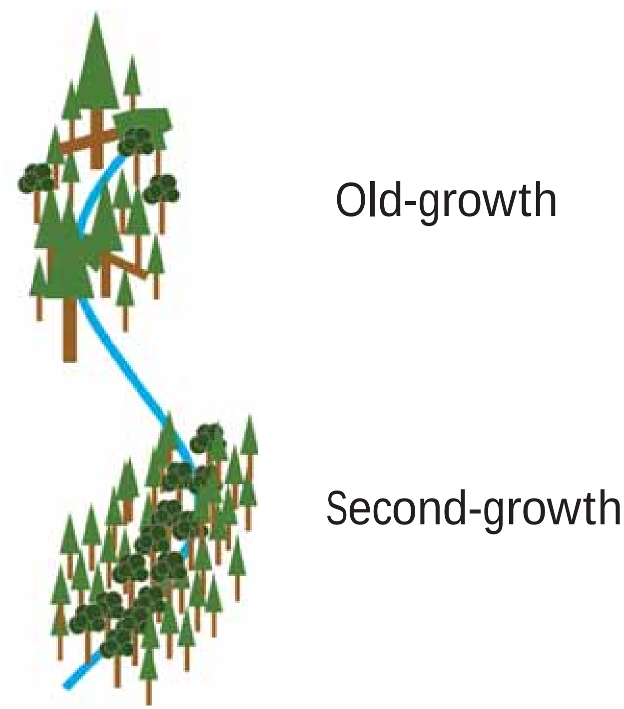


Kaylor et al. 2017

Correlation Study

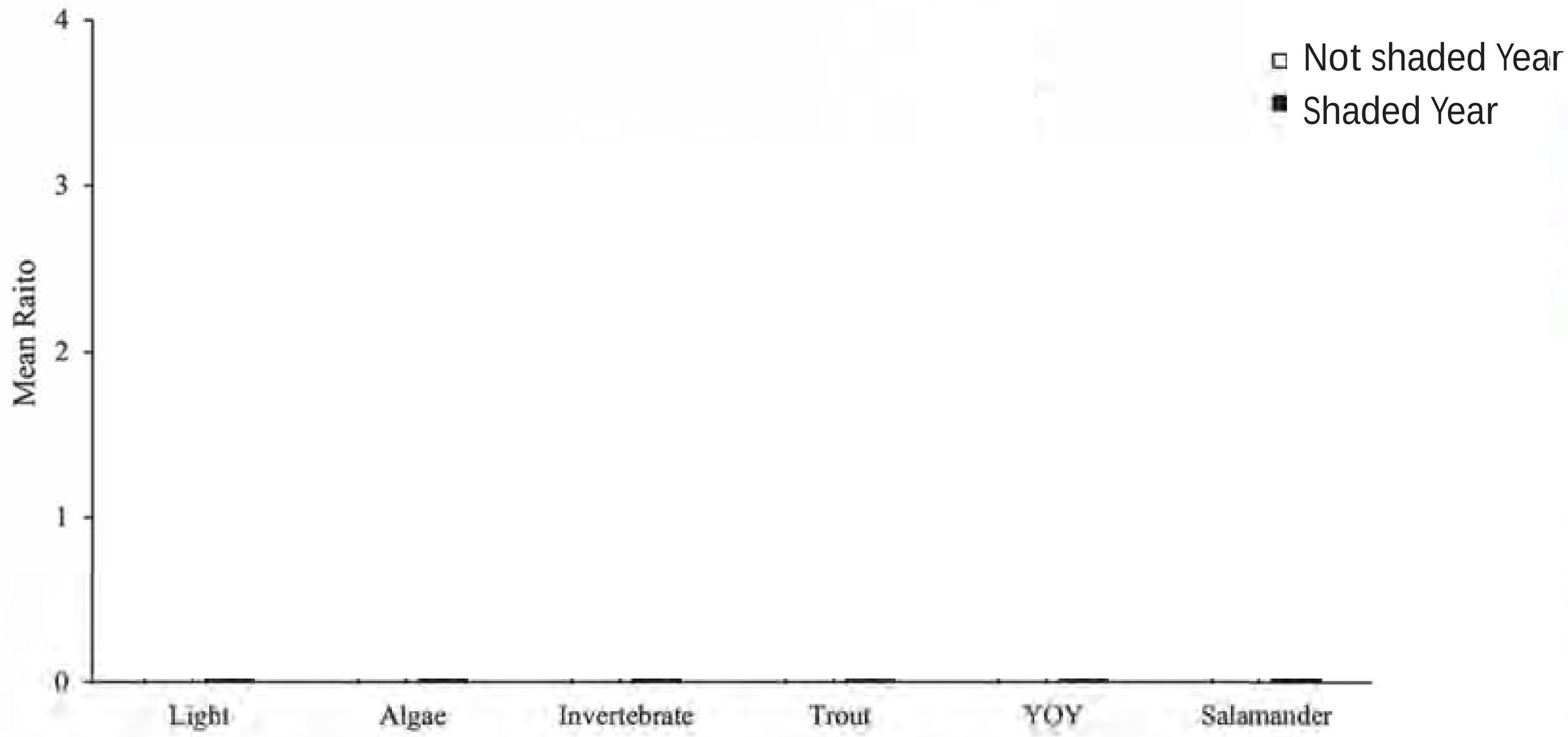


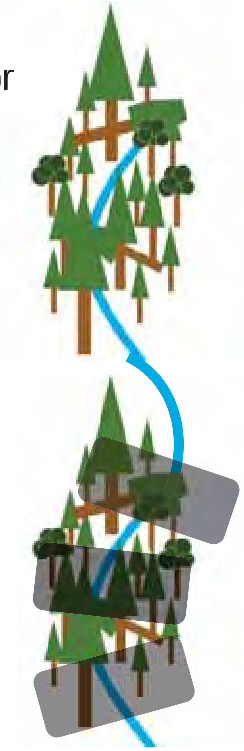
Paired Reaches n=9



Kaylor et al. 2017

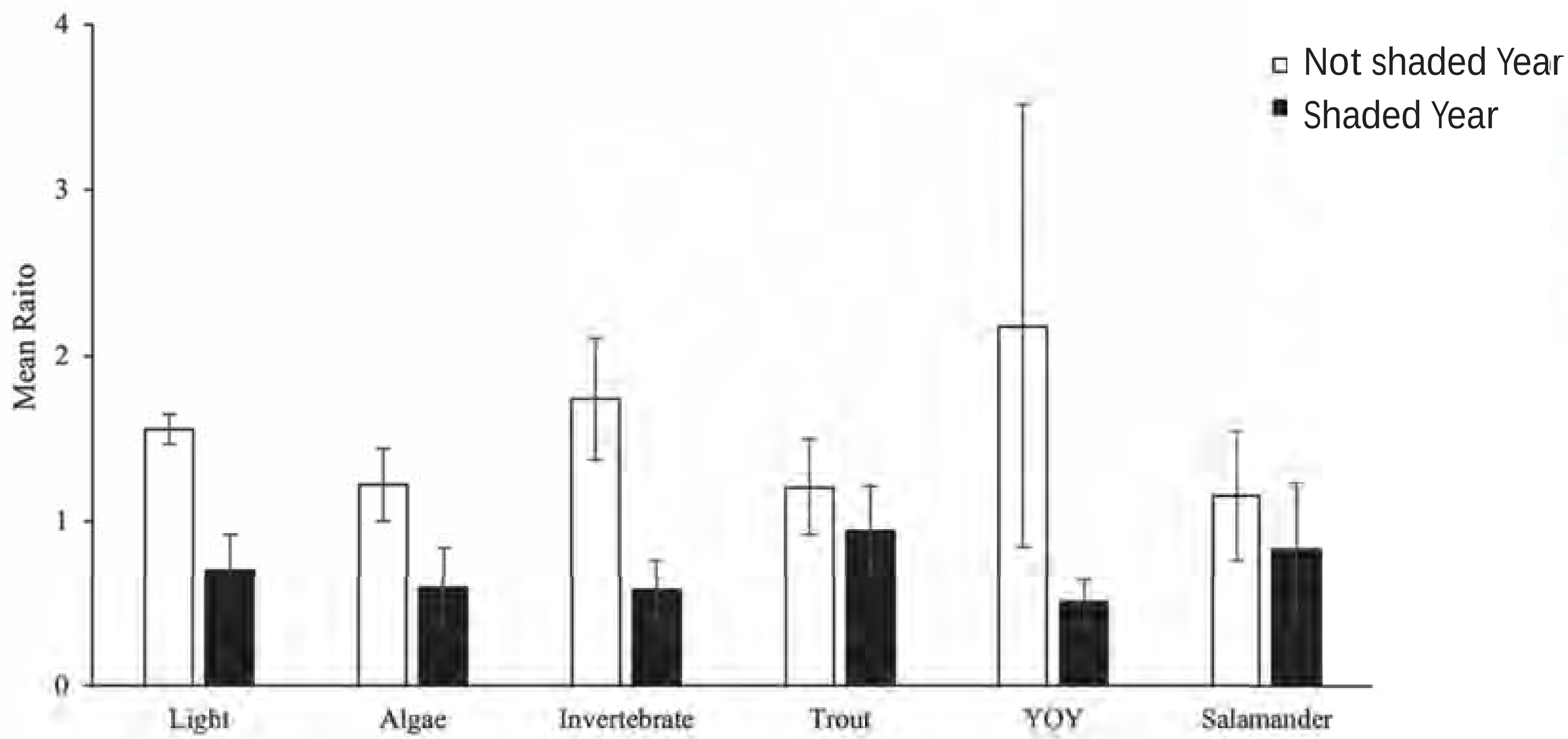
Experiment - Shading

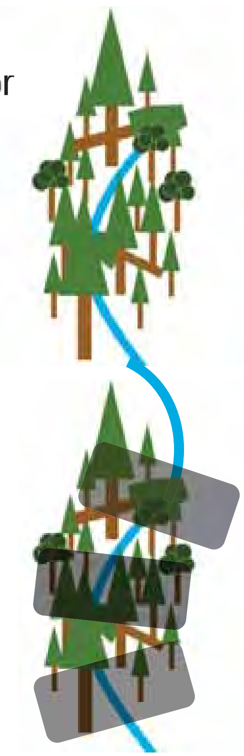




Heaston et al. 2018

Experiment - Shading



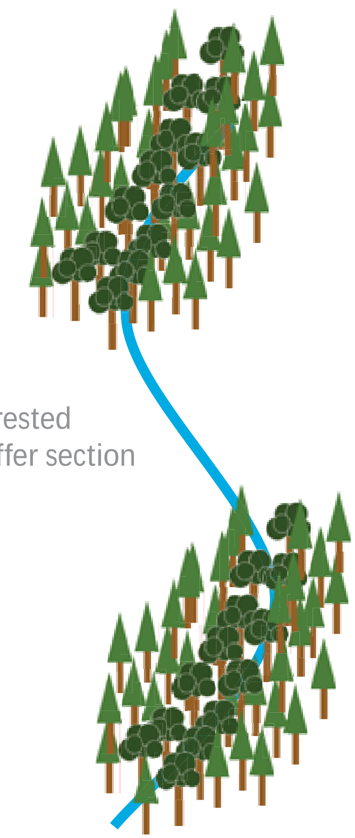


Heaston et al. 2018

Experiment - Gaps

Study design

Before- After-
Control- Impact



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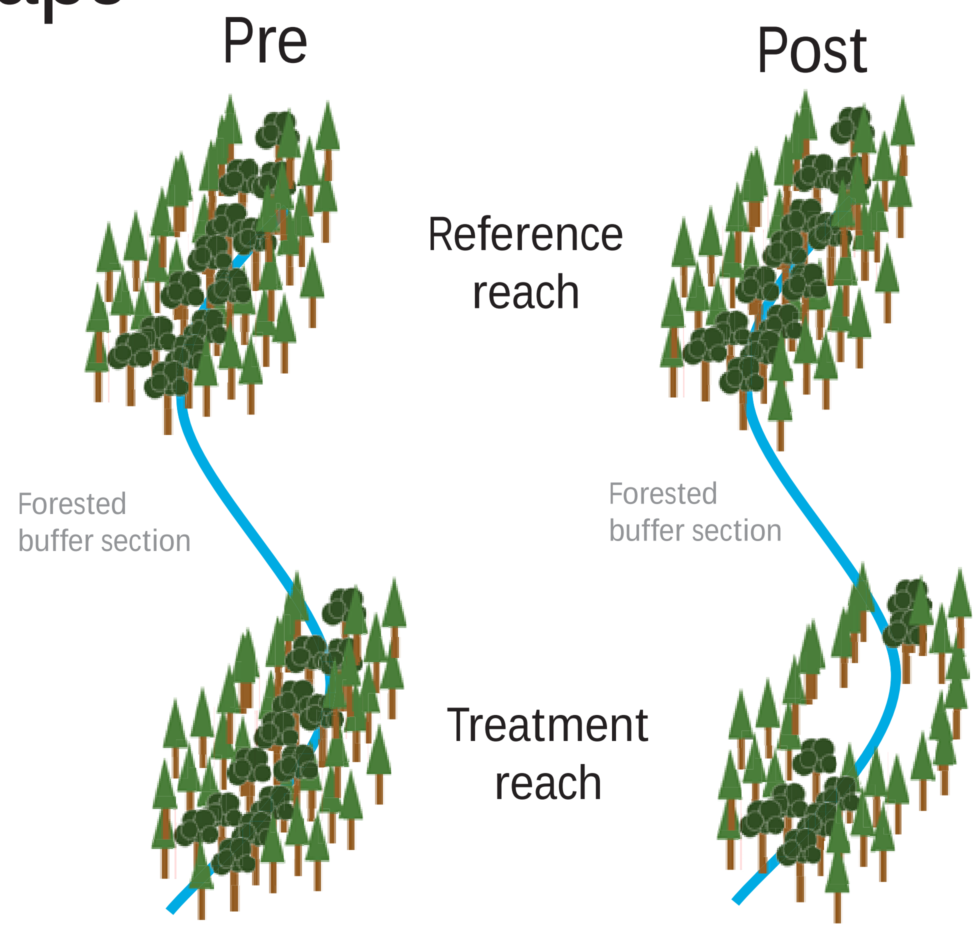


6 second and third order fish bearing streams

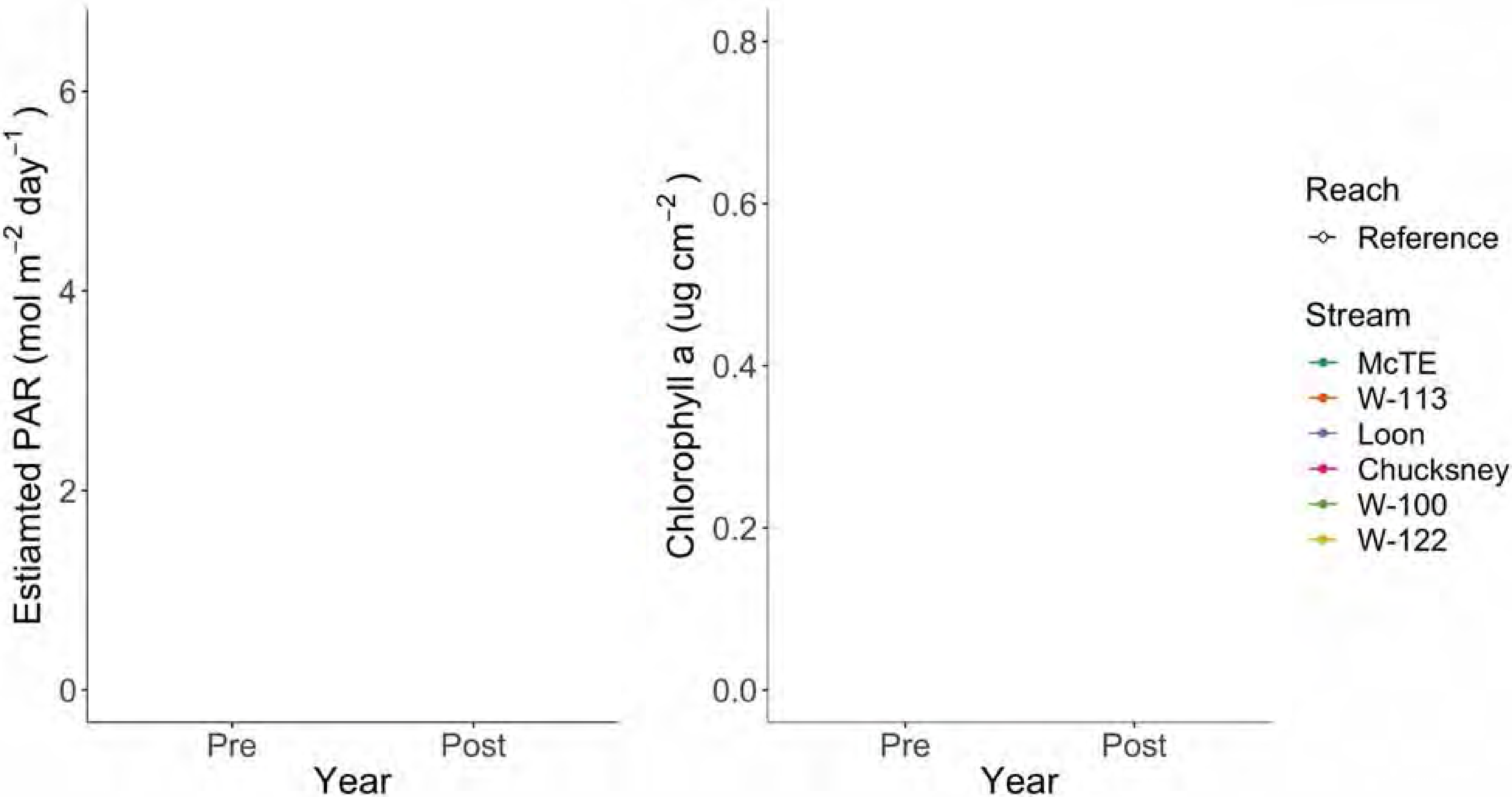
Loon Creek

Before

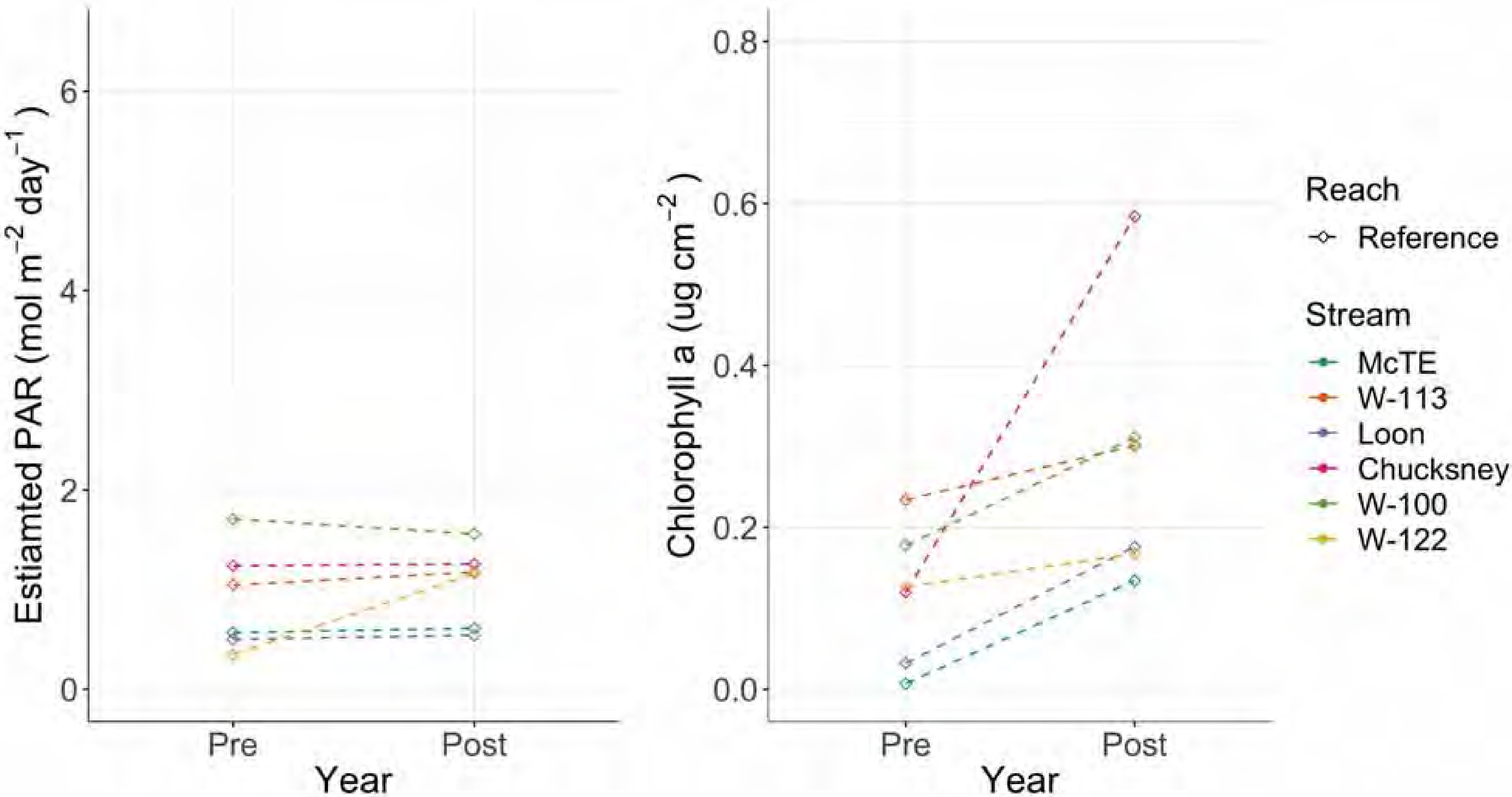
After

McTE

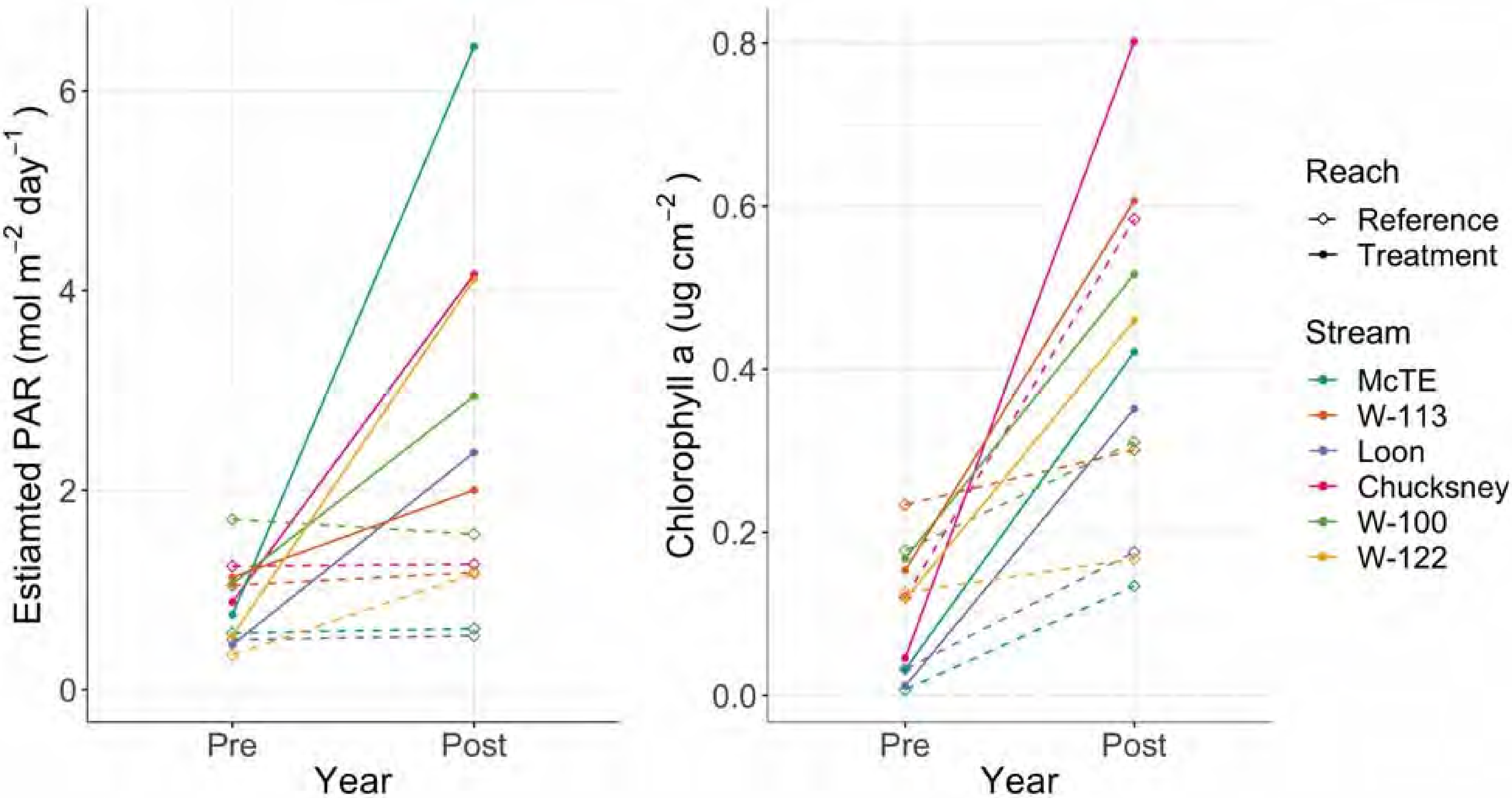
Reach Scale Responses



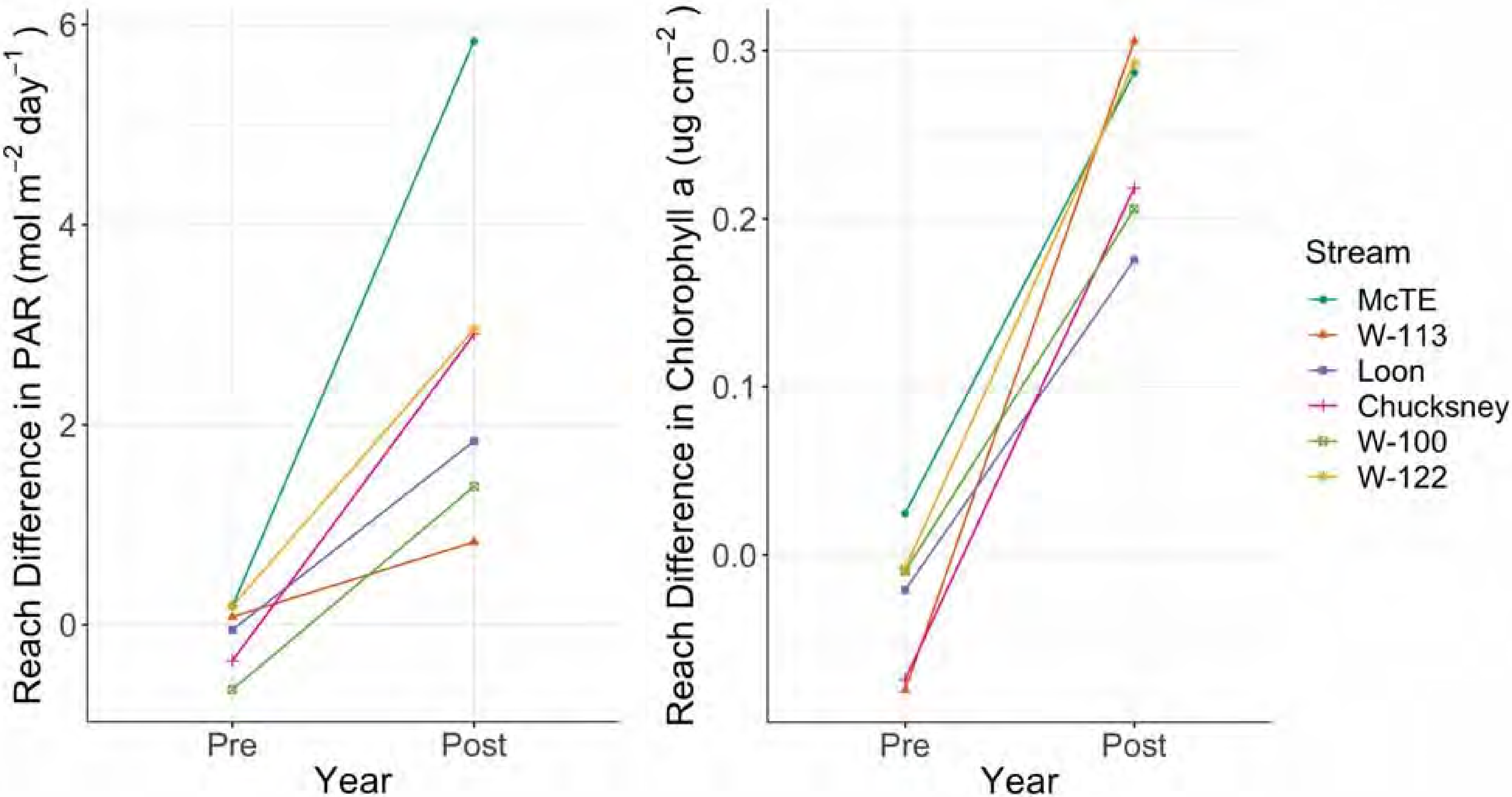
Reach Scale Responses



Reach Scale Responses

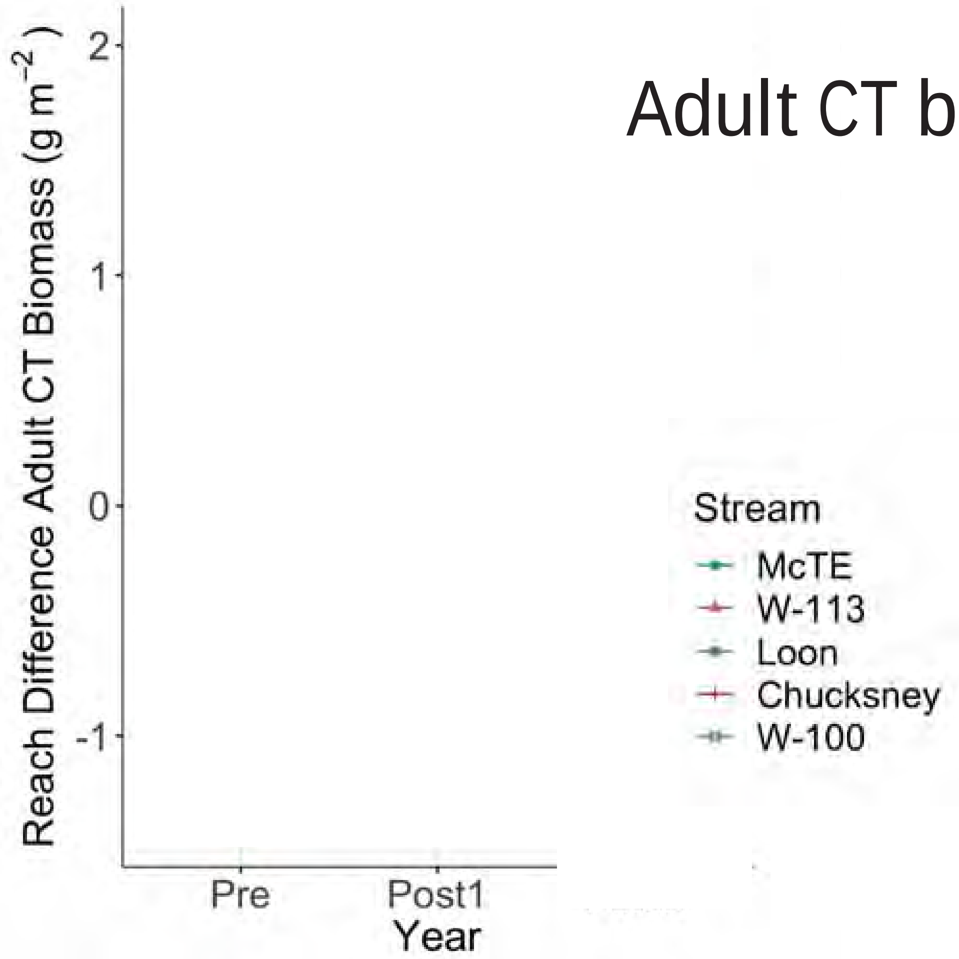


Reach Differences

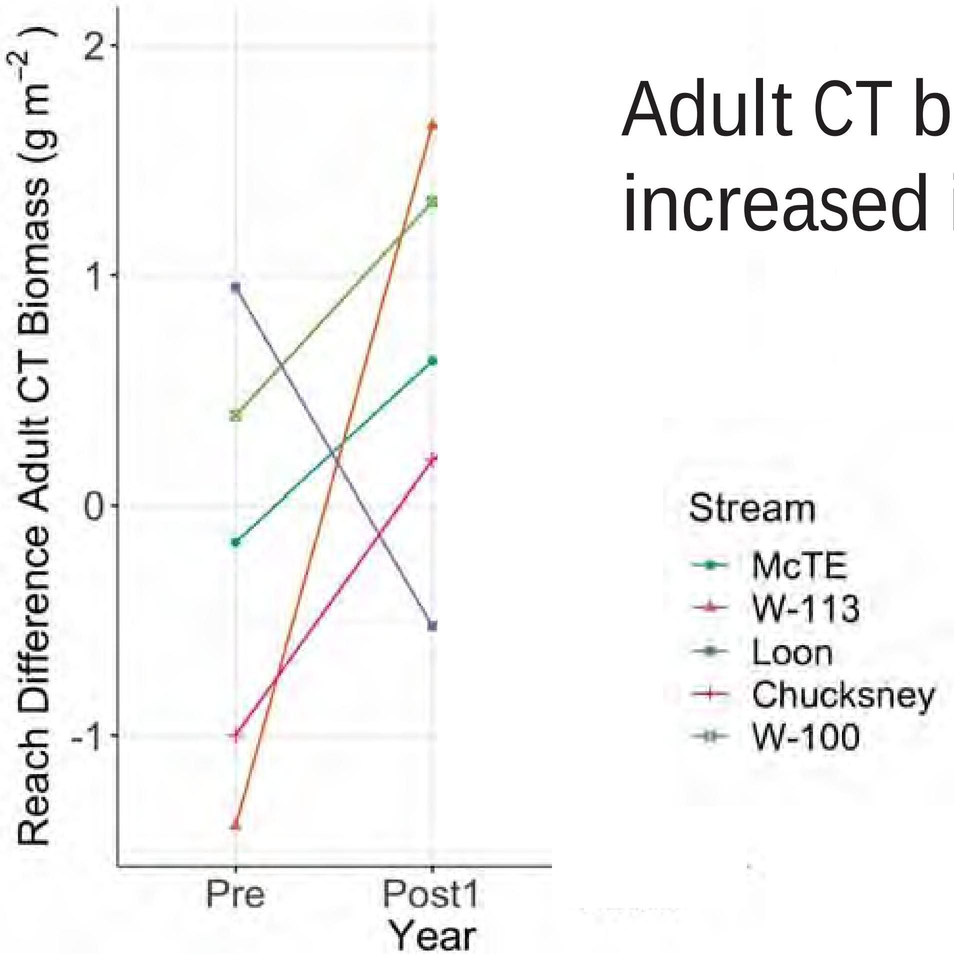


Reach Differences in Vertebrates

Adult CT biomass

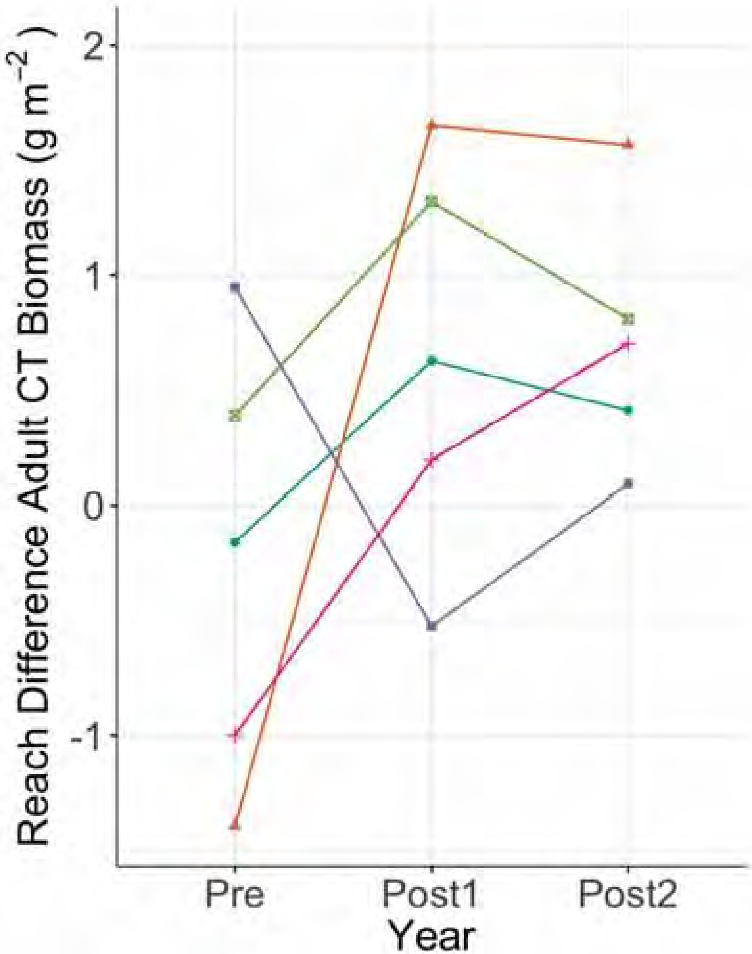


Reach Differences in Vertebrates



Adult CT biomass
increased in 4 of 5 streams

Reach Differences in Vertebrates



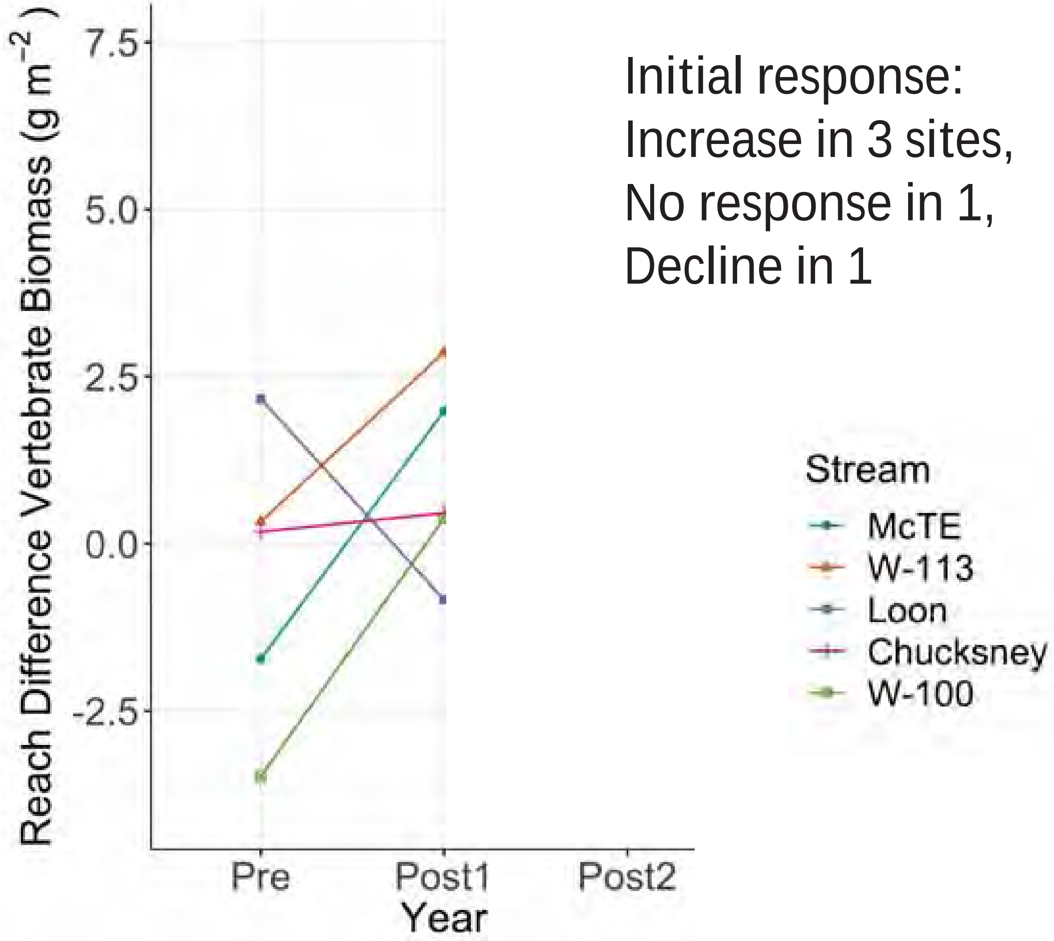
Two years later,
4 of 5 are still higher

Bottom up drivers?

Other factors?

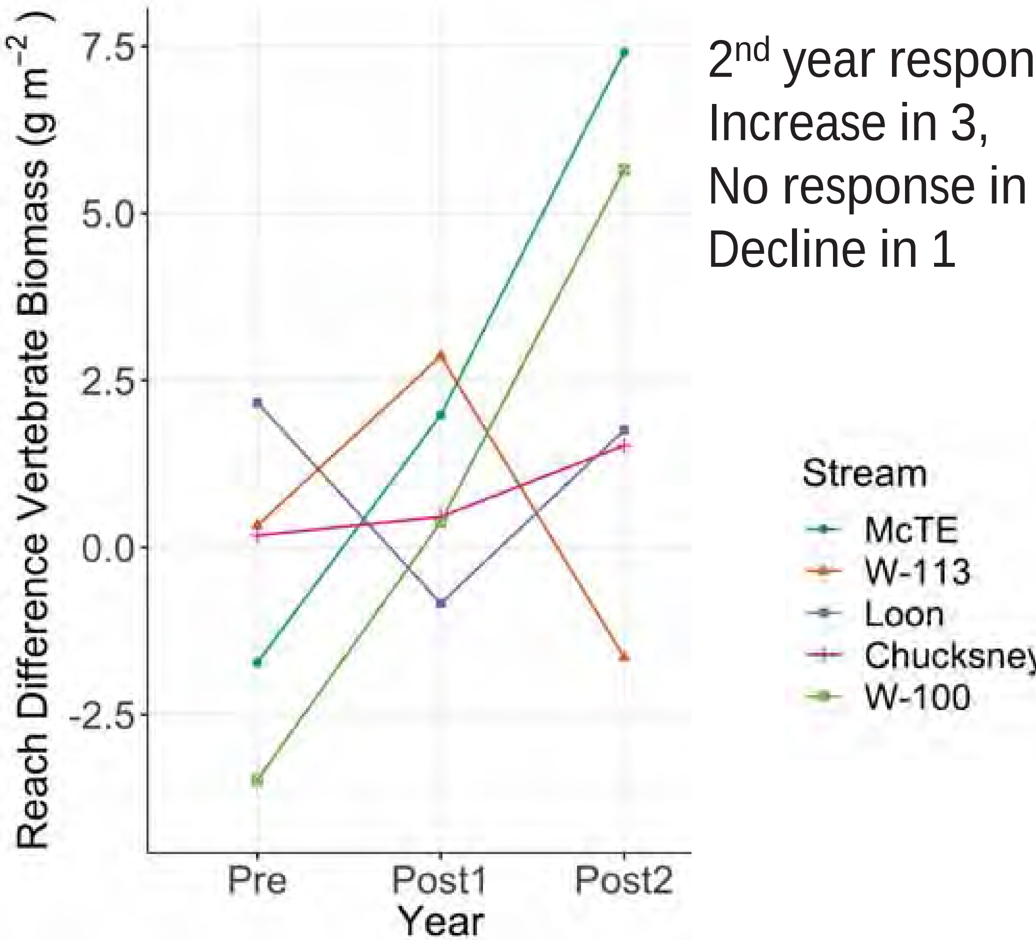
Other species?

Reach Differences in Vertebrates



Initial response:
Increase in 3 sites,
No response in 1,
Decline in 1

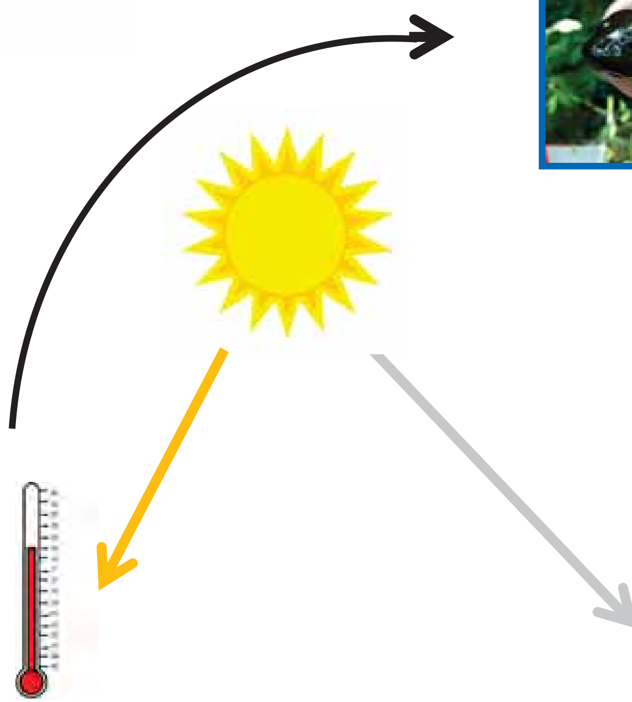
Reach Differences in Vertebrates

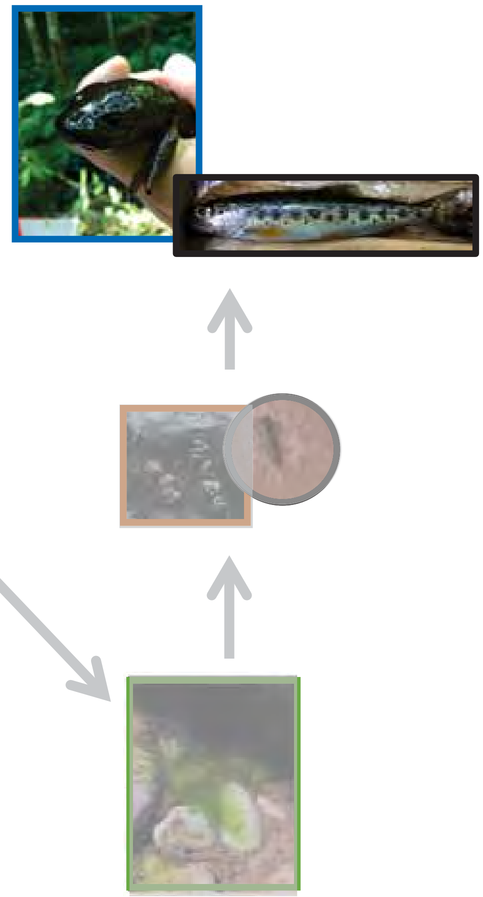


2nd year response:
Increase in 3,
No response in 1,
Decline in 1

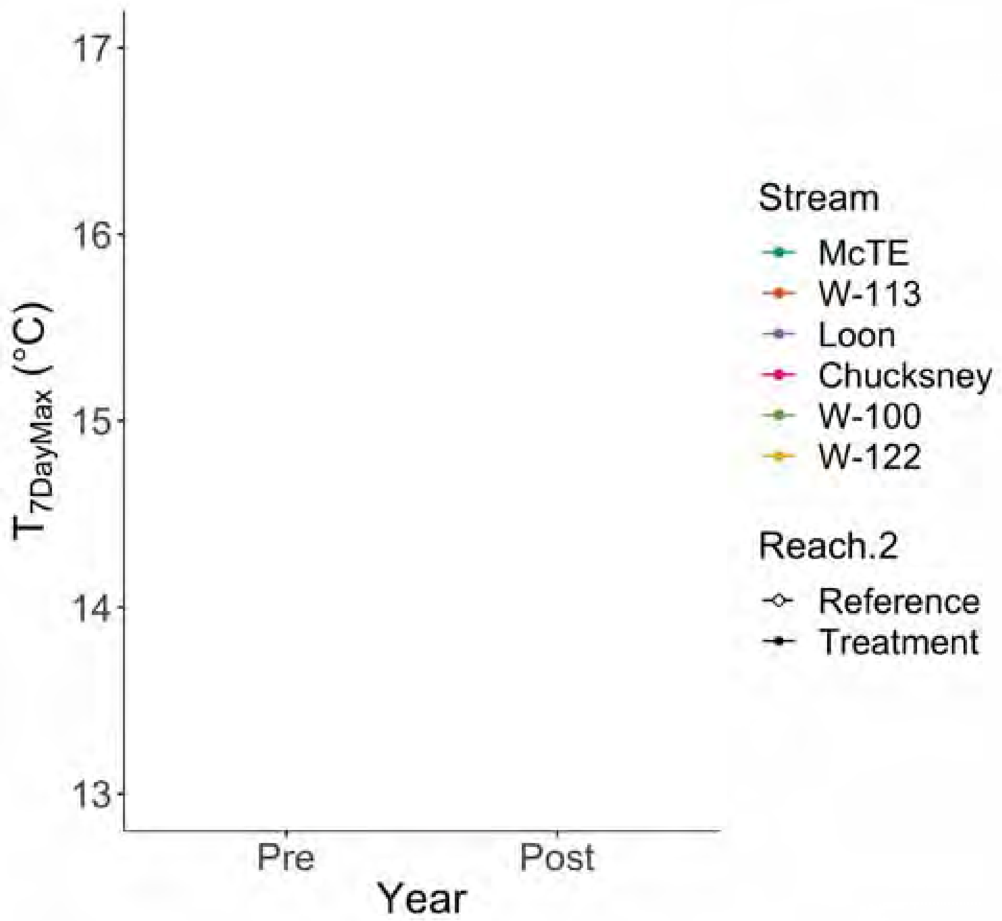
Why do GAPS matter?

- Primary production is often ***light-limited*** in forested headwater systems
- Food availability for consumers is often ***limited*** in these systems
- Light drives stream temperature
- **Temperature** affects biota and all ecosystem processes

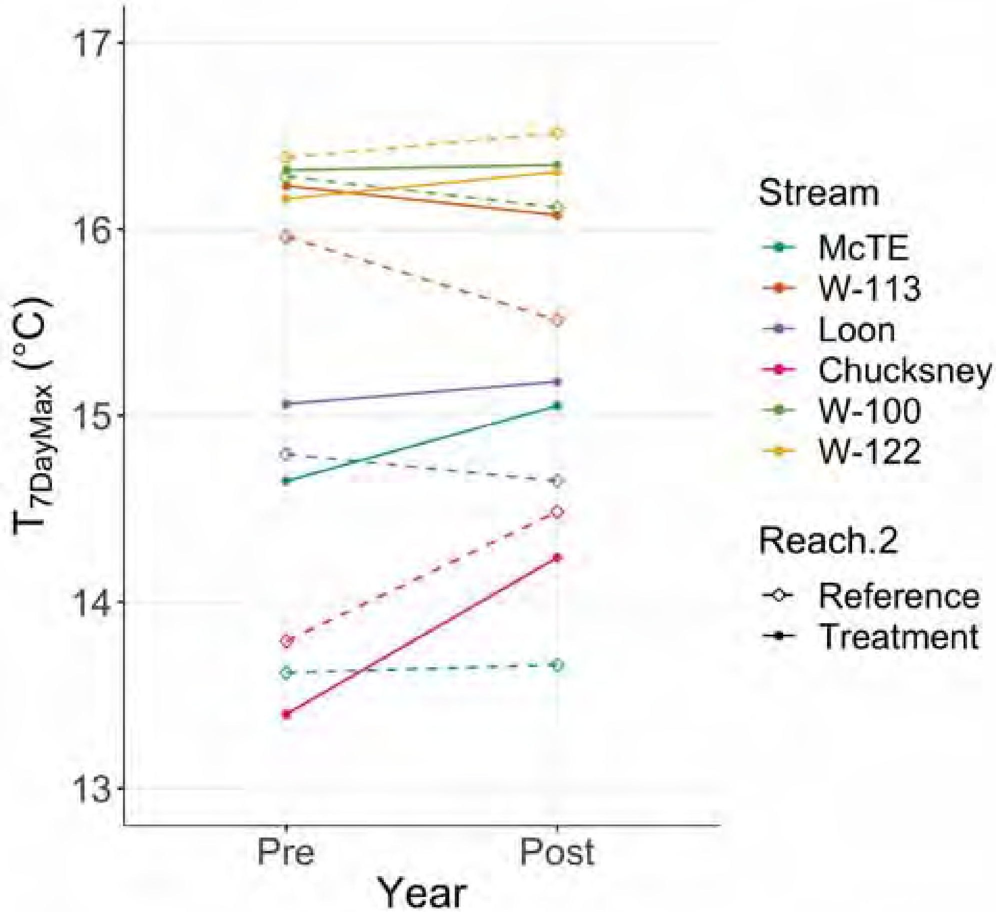




Temperature– *Max 7 Day Moving Average Max ($T_{7DayMax}$)*



Temperature– *Max 7 Day Moving Average Max ($T_{7DayMax}$)*

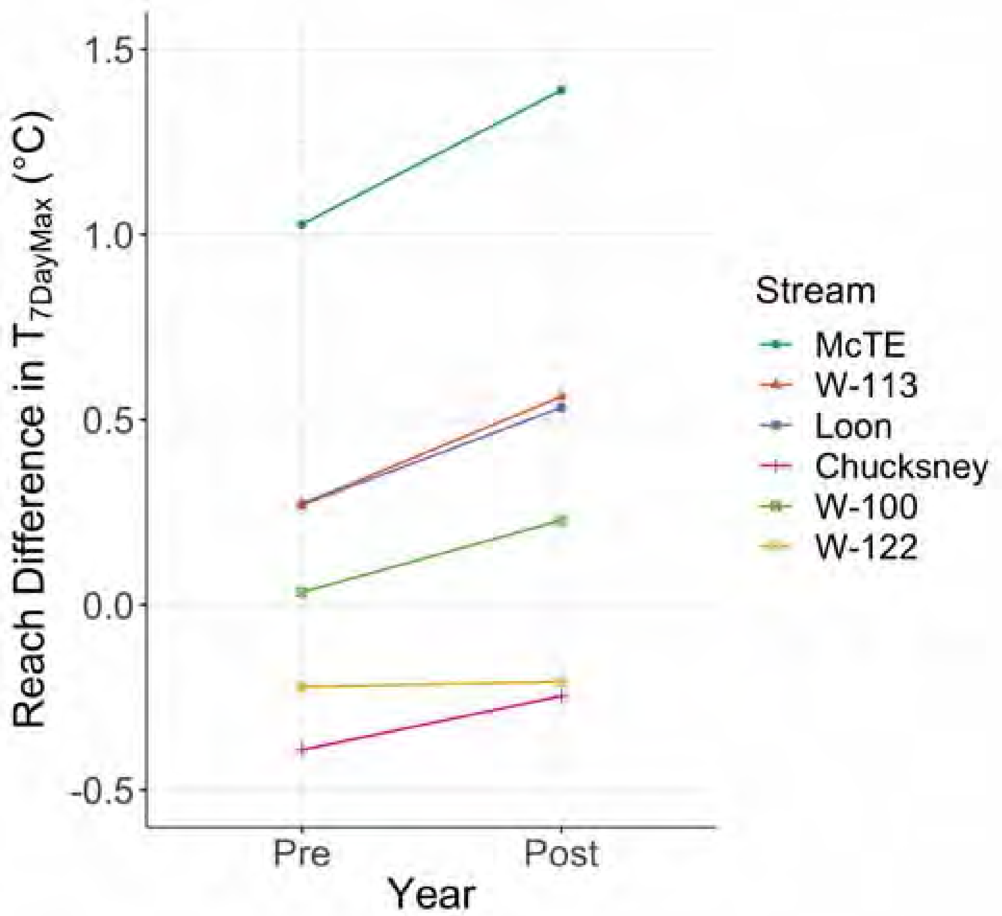


Mean response
= +**0.21 (**± **0.1) ºC**

Max response (McTE)
= +**0.36 (**± **0.1)ºC**

Min response (W-122)
= +**0.01 (**± **0.1)ºC**

Temperature– *Max 7 Day Moving Average Max* ($T_{7DayMax}$)

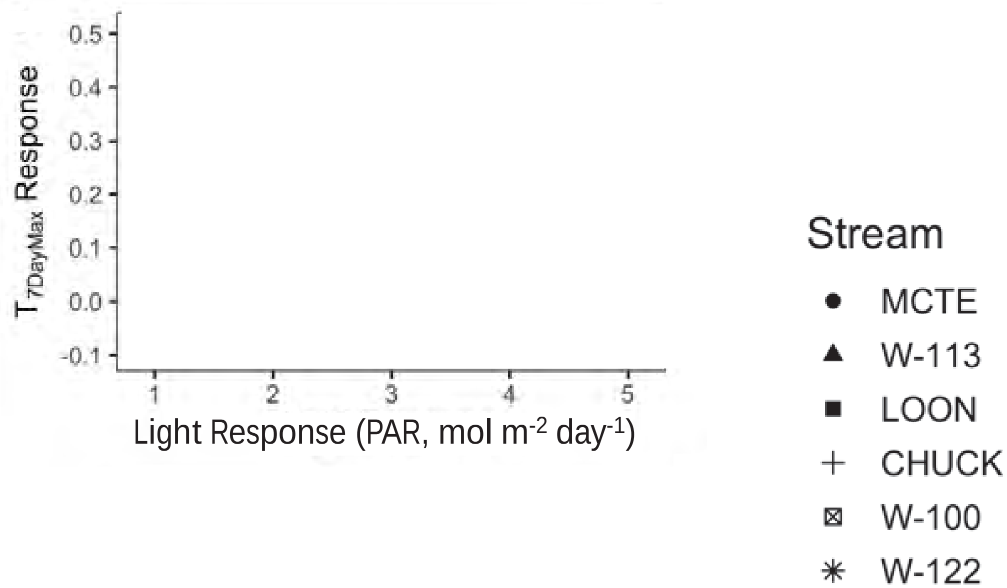


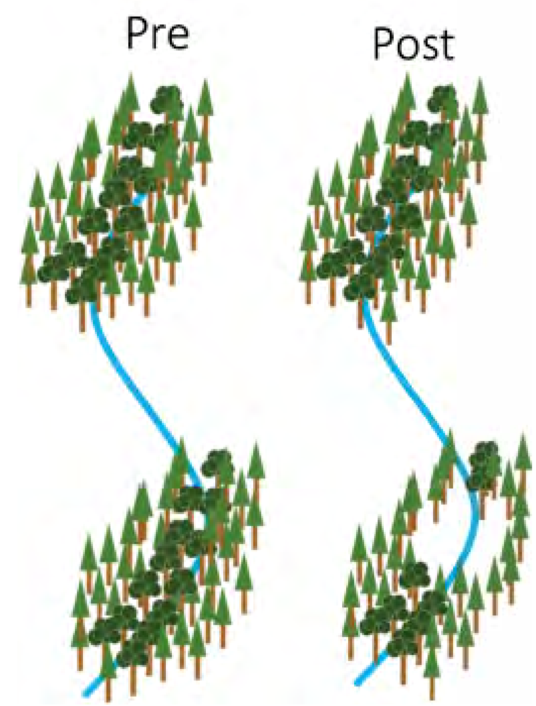
Mean response (n=6)
= +**0.21 (± 0.1) ºC**

Max response (McTE)
= +**0.36 (± 0.1)ºC**

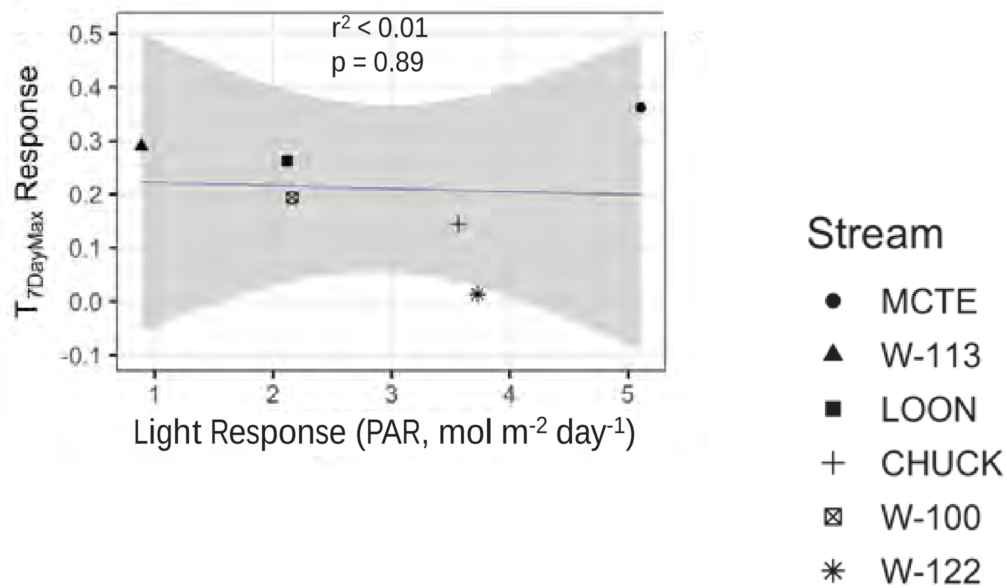
Min response (W-122)
= +**0.01 (± 0.1)ºC**

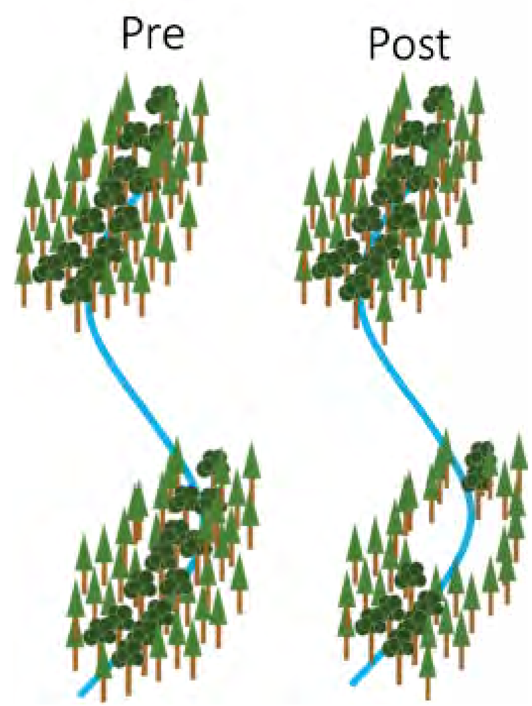
Temperature– *explanatory variables*



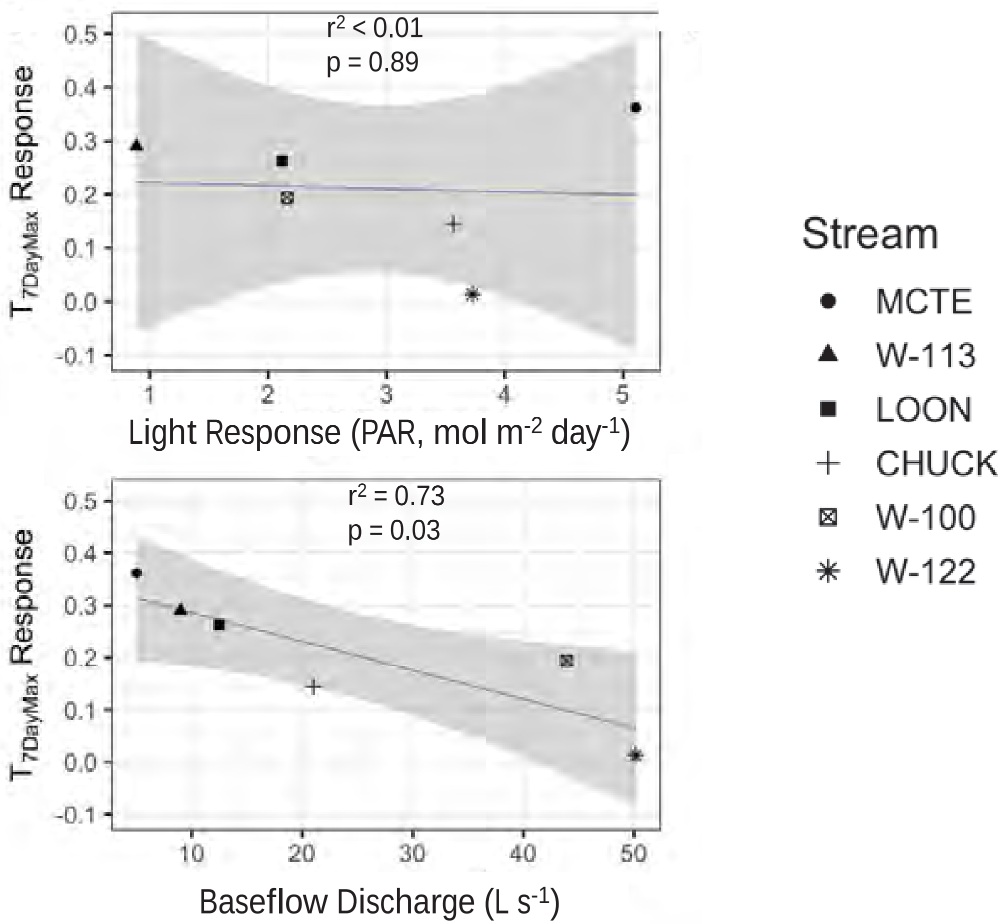


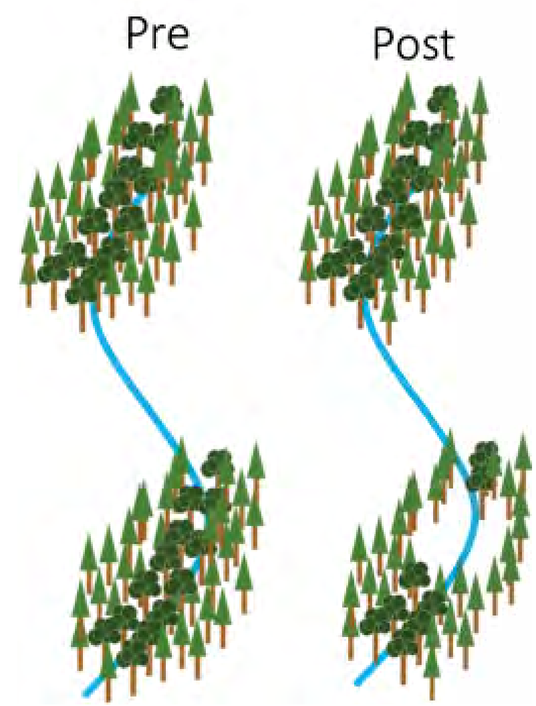
Temperature– *explanatory variables*



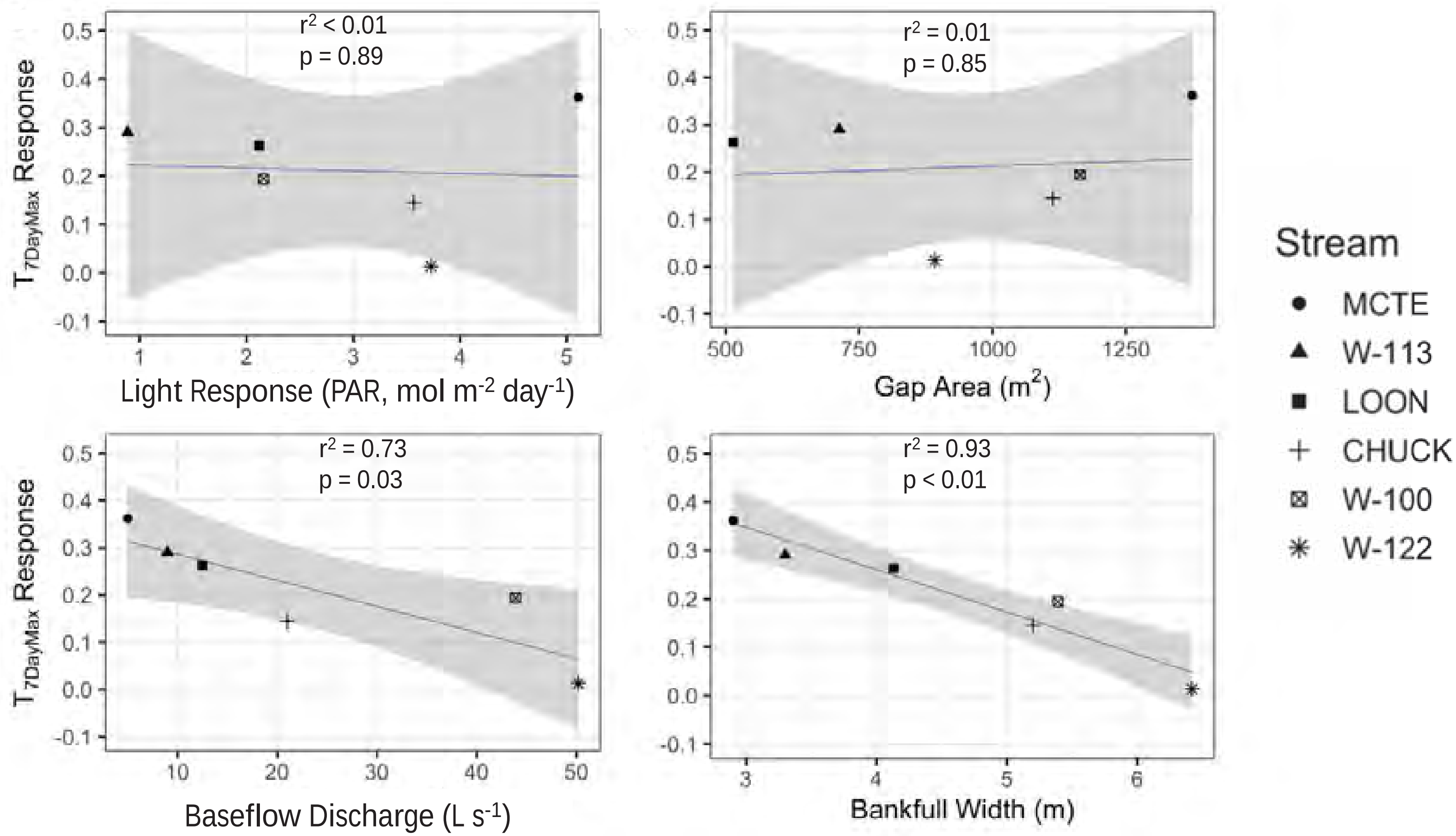


Temperature– *explanatory variables*

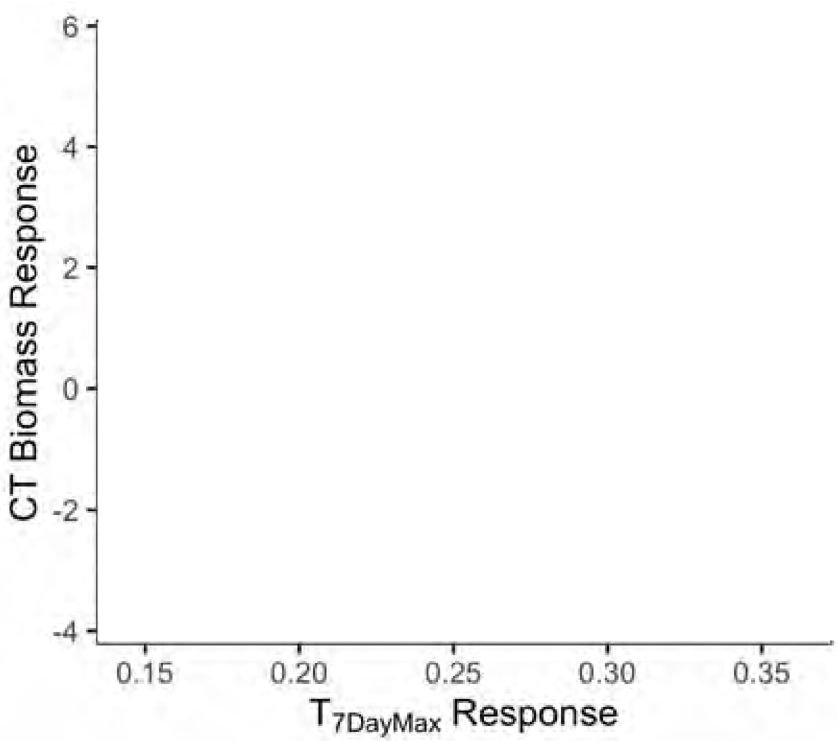




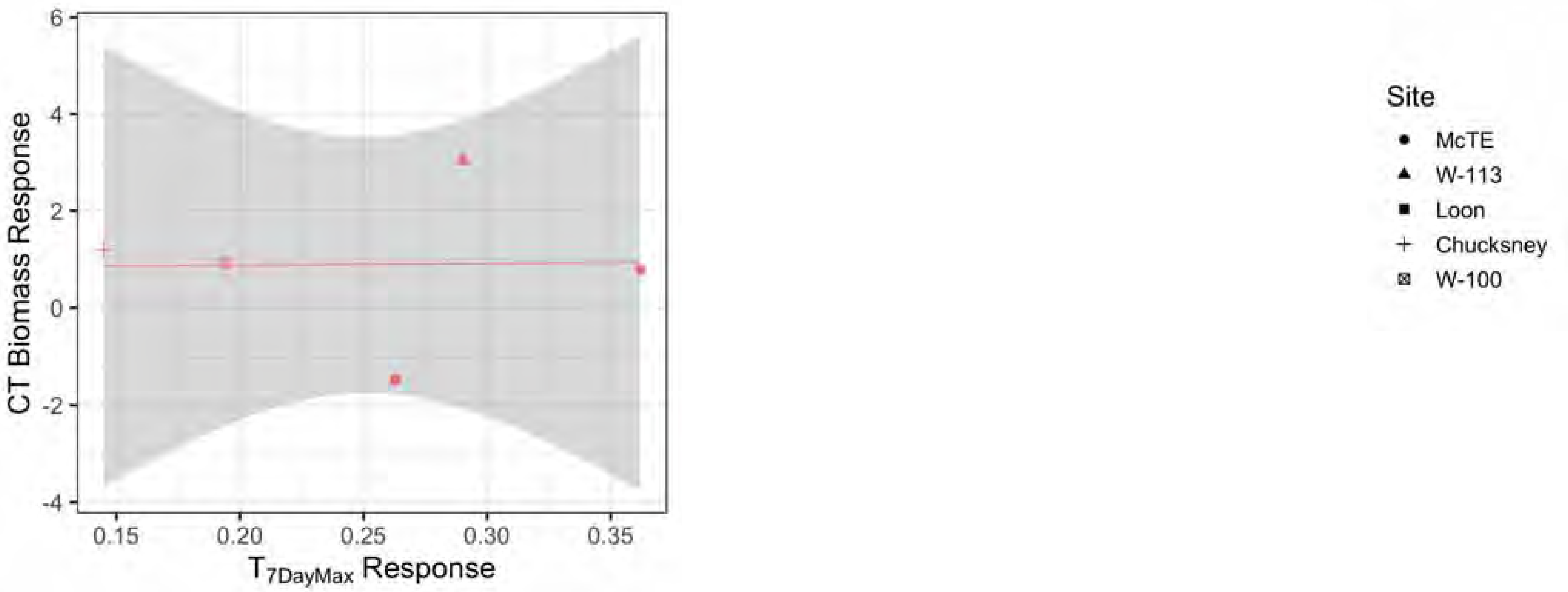
Temperature– *explanatory variables*



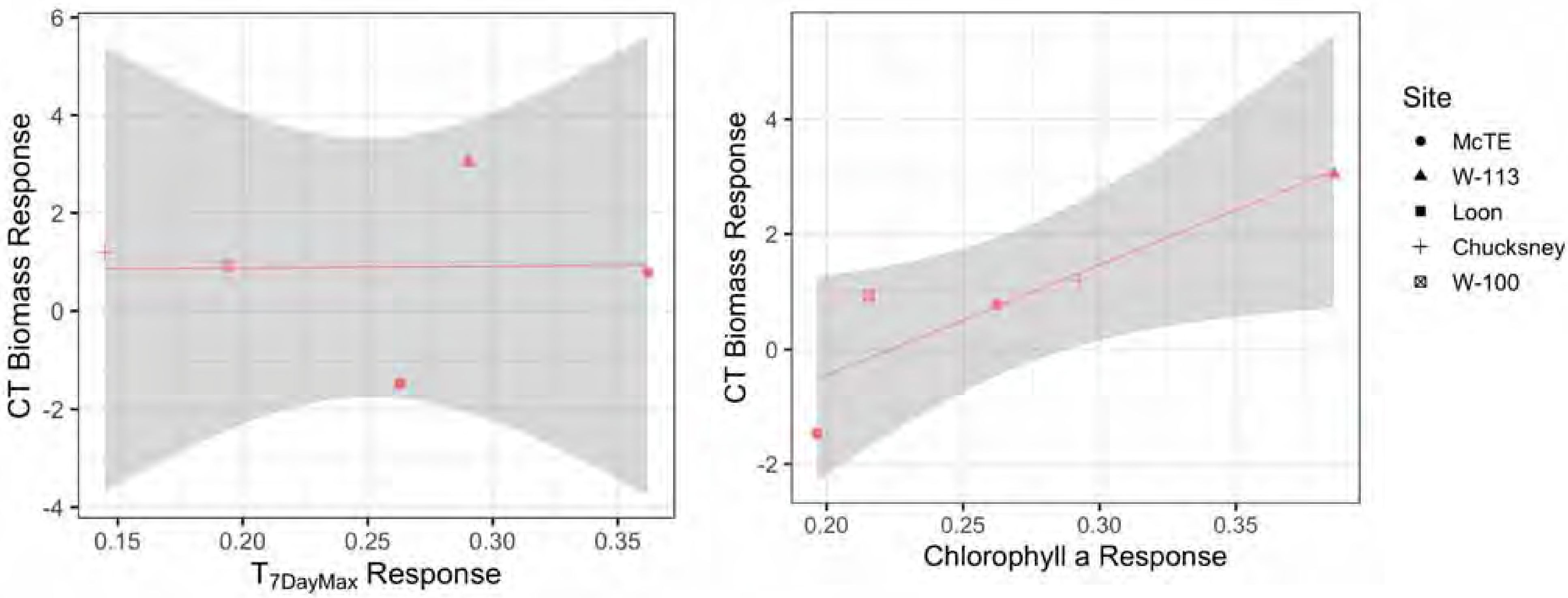
CT Biomass Responses – *explanatory variables*



CT Biomass Responses – *explanatory variables*



CT Biomass Responses – *explanatory variables*



Take home messages

- Light and chlorophyll a increased below gaps
- In 4 of 5 sites, gaps led to increases in fish and vertebrate responses

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Take home messages

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- The gap treatment did result in an increase in temperature
  - Overall increases were very small
  - The variability of the temperature responses was not well explained by the variability in light, but by stream size (thermal mass)
- Magnitudes of fish responses were not correlated with magnitudes of temperature responses, but were with chlorophyll a responses

Thank you

QUESTIONS?

Funding:

- Fish and Wildlife Habitat in Managed Forests Grant Program
- HJ Andrews LTER
- Bureau of Land Management
- USFS Willamette National Forest (McKenzie District)

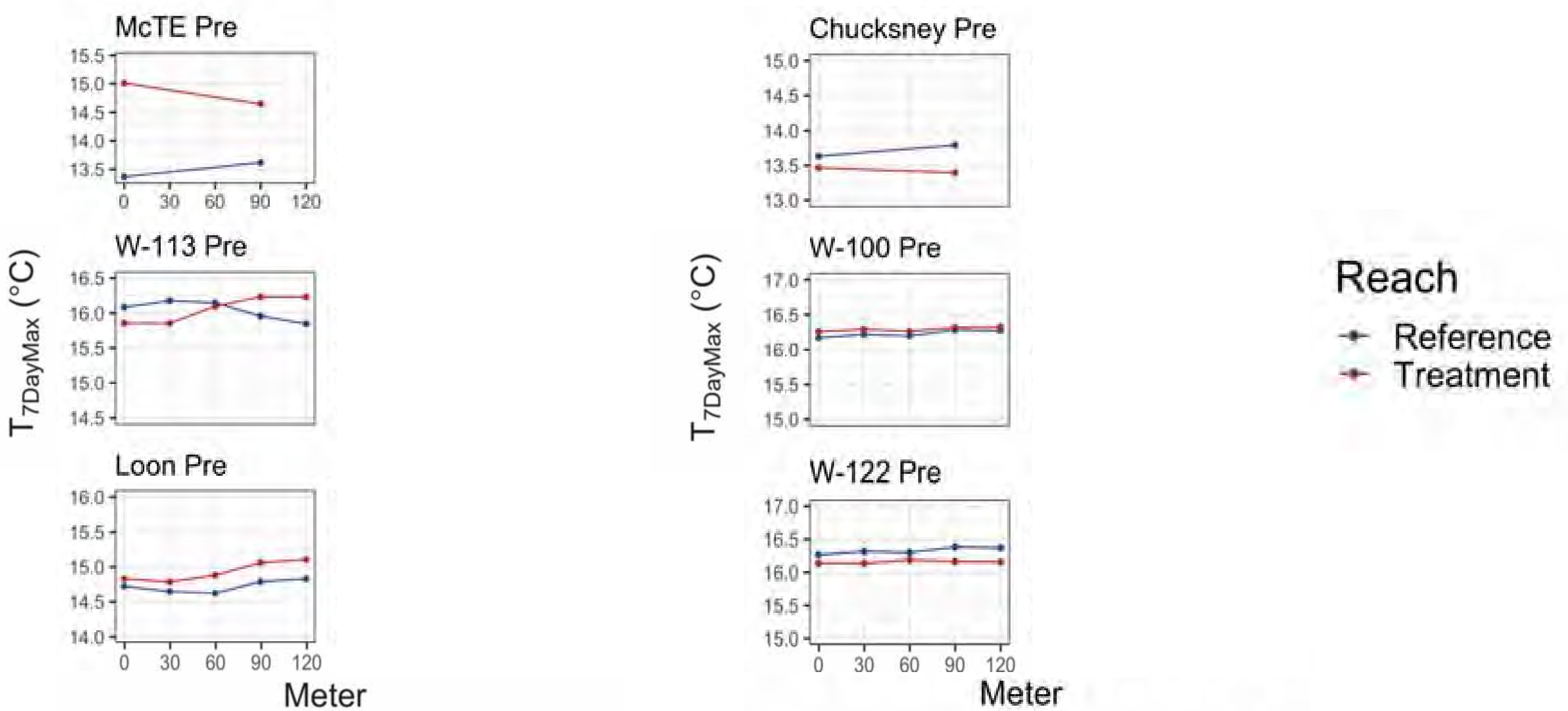
Other contributions:

- Maryanne Reiter
- Steve Perakis
- Cheryl Friesen
- Mark Shultz
- Kathy Motter
- Dave Roon
- Matt Kaylor
- Ashley Coble
- Ray Rivera
- Sherri Johnson
- HJA Staff

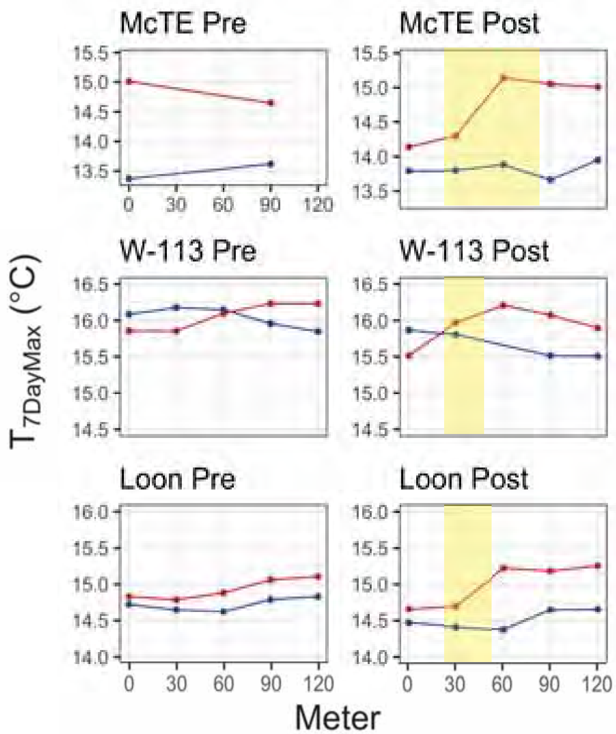
Fieldwork and data collection:

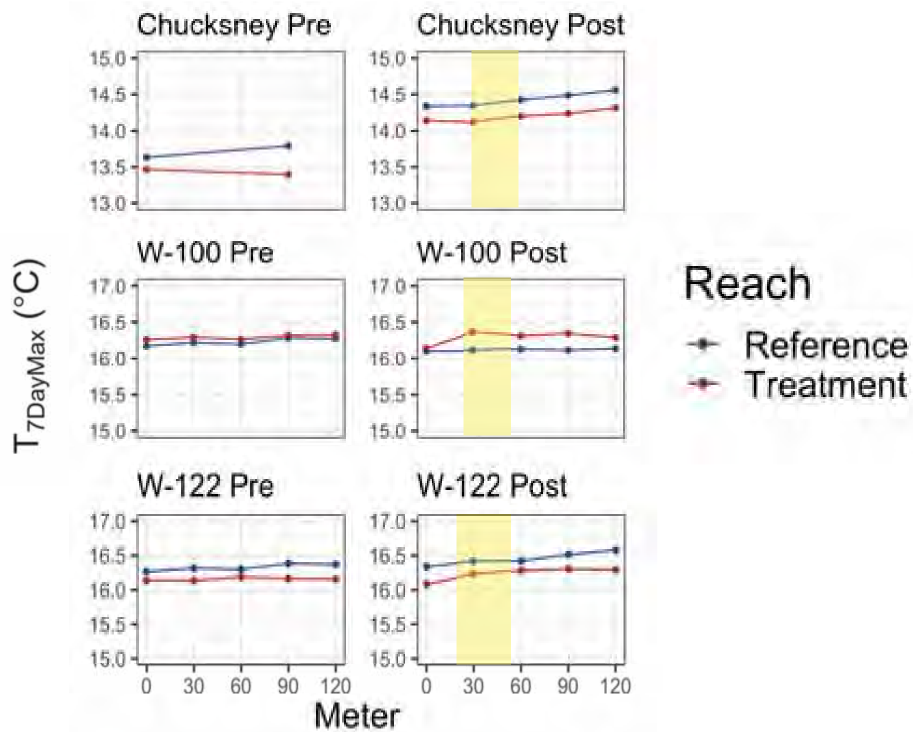
- Cedar Mackaness, Alvaro Cortes, Brian VerWey, Brook Mackaness, Nate Day, Corey Culp
- Greg Downing
- Jay Sexton

Temperature– *downstream effects*



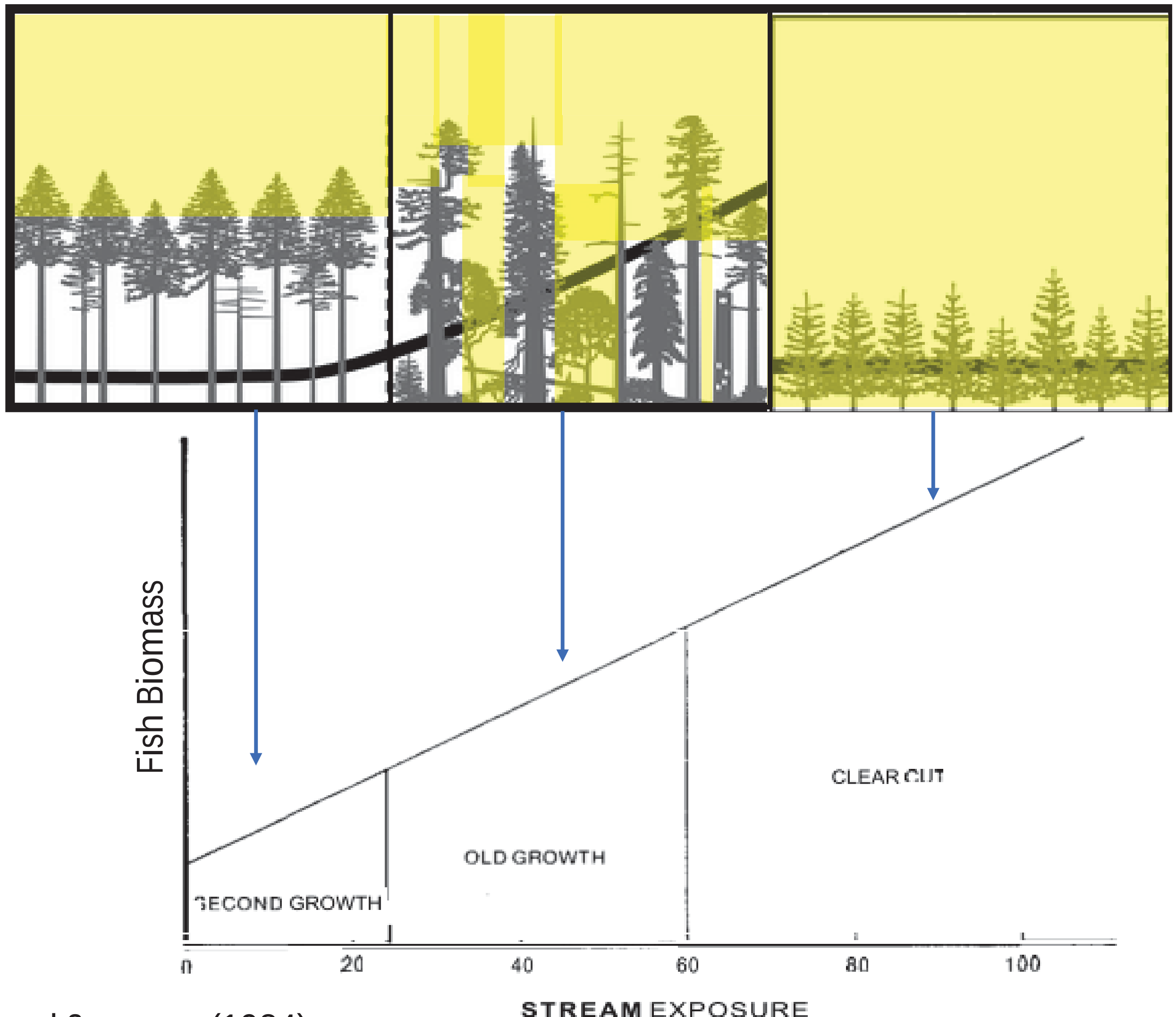
Temperature– *downstream effects*





Conclusions

The gap study provides empirical data for this conceptual framework

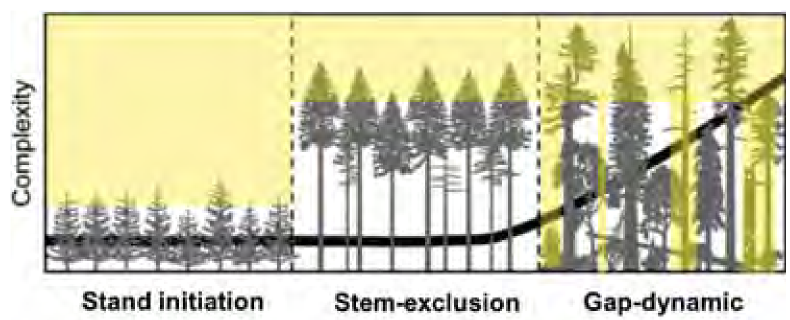


Sedell and Swanson (1984)

Overall Conclusions

Stand development that creates canopy gaps that lead to increases in light will lead to increases in chlorophyll *a*

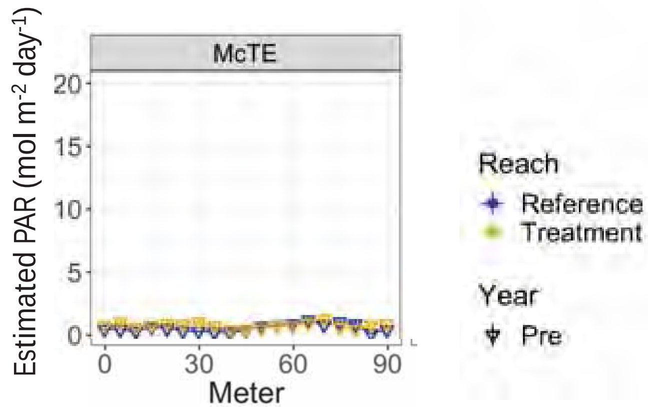
- Naturally occurring stand development:
  - Individual gaps resulted in greater increases in smaller streams



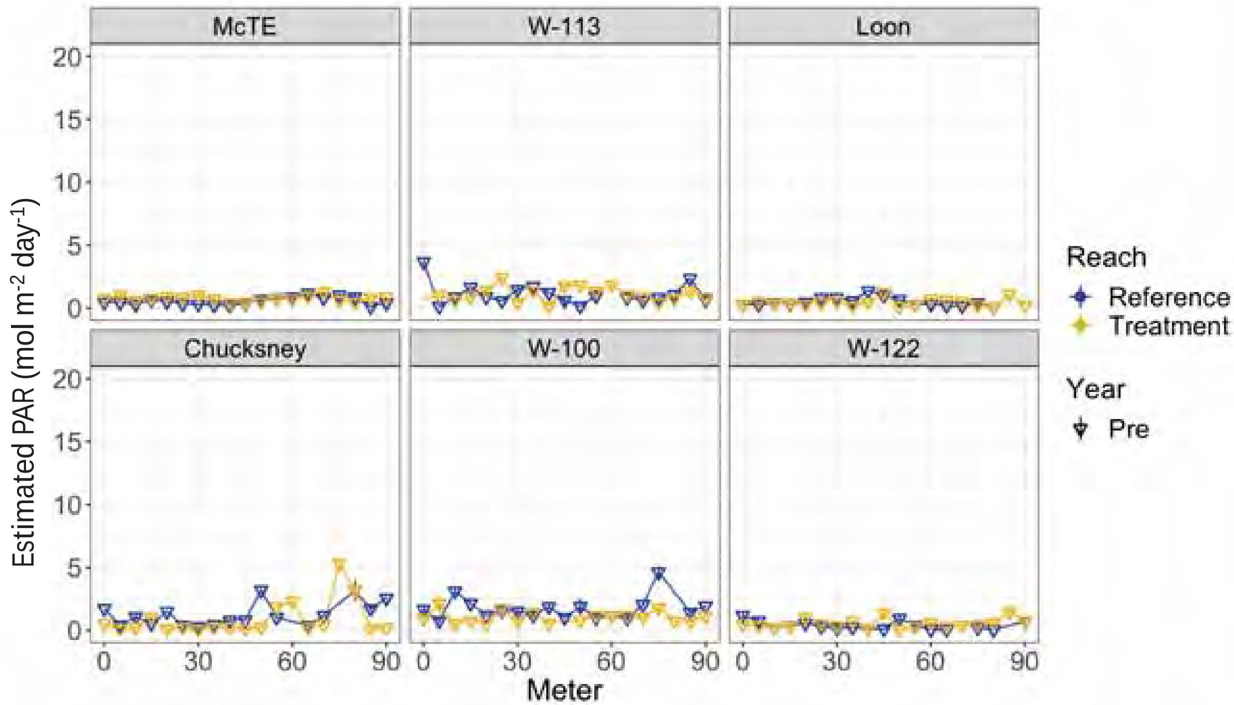
Overall Conclusions

- Naturally occurring stand development:
  - Individual gaps resulted in greater increases in smaller streams
- Management/Restoration:
  - larger streams were buffered against the increase in energy and had smaller responses, but background temperatures are already higher
- Landscape context matters

Light


McTE
Estimated PAR (mol m-2 day-1)
20
15
10
5
0
0
30
60
90
Meter
Reach
Reference
Treatment
Year
Pre

Light


McTE
W-113
Loon
Chucksney
W-100
W-122
Estimated PAR (mol m-2 day-1)
20
15
10
5
0
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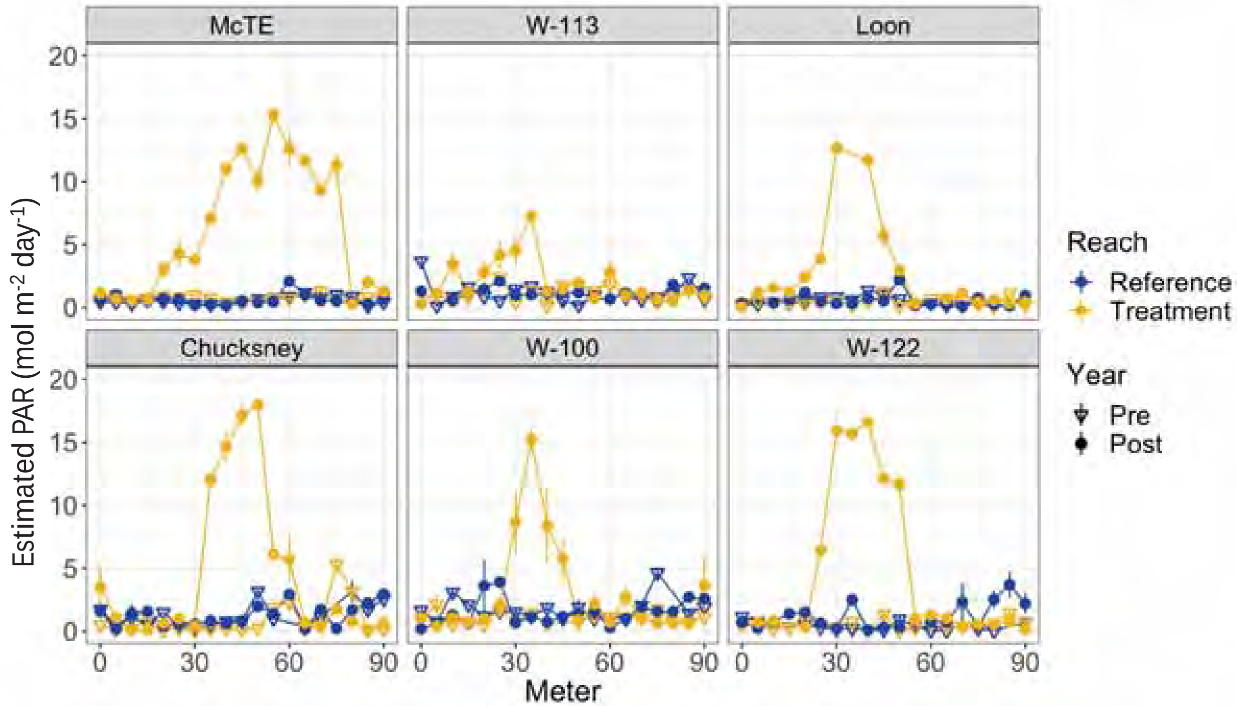
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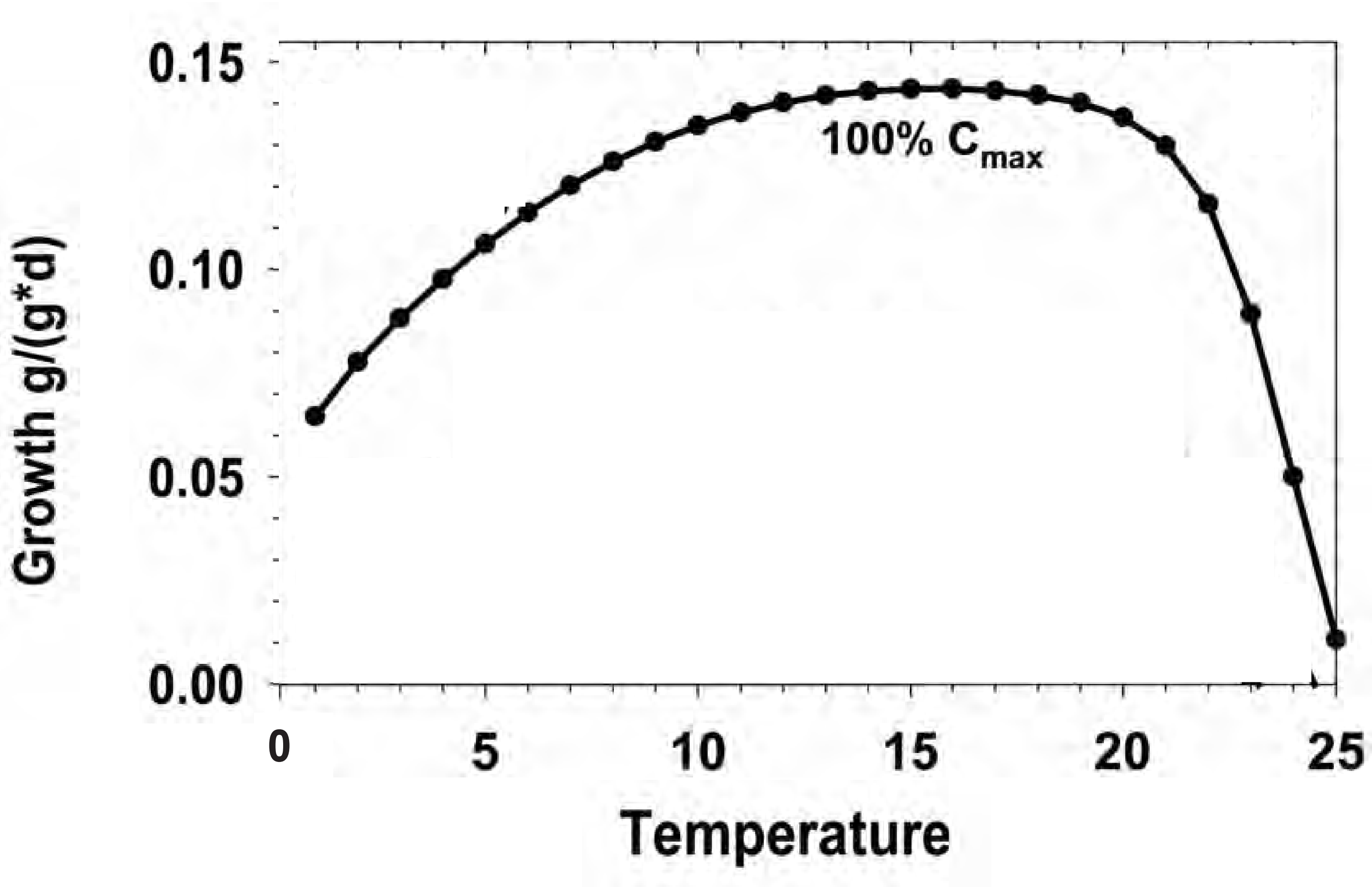
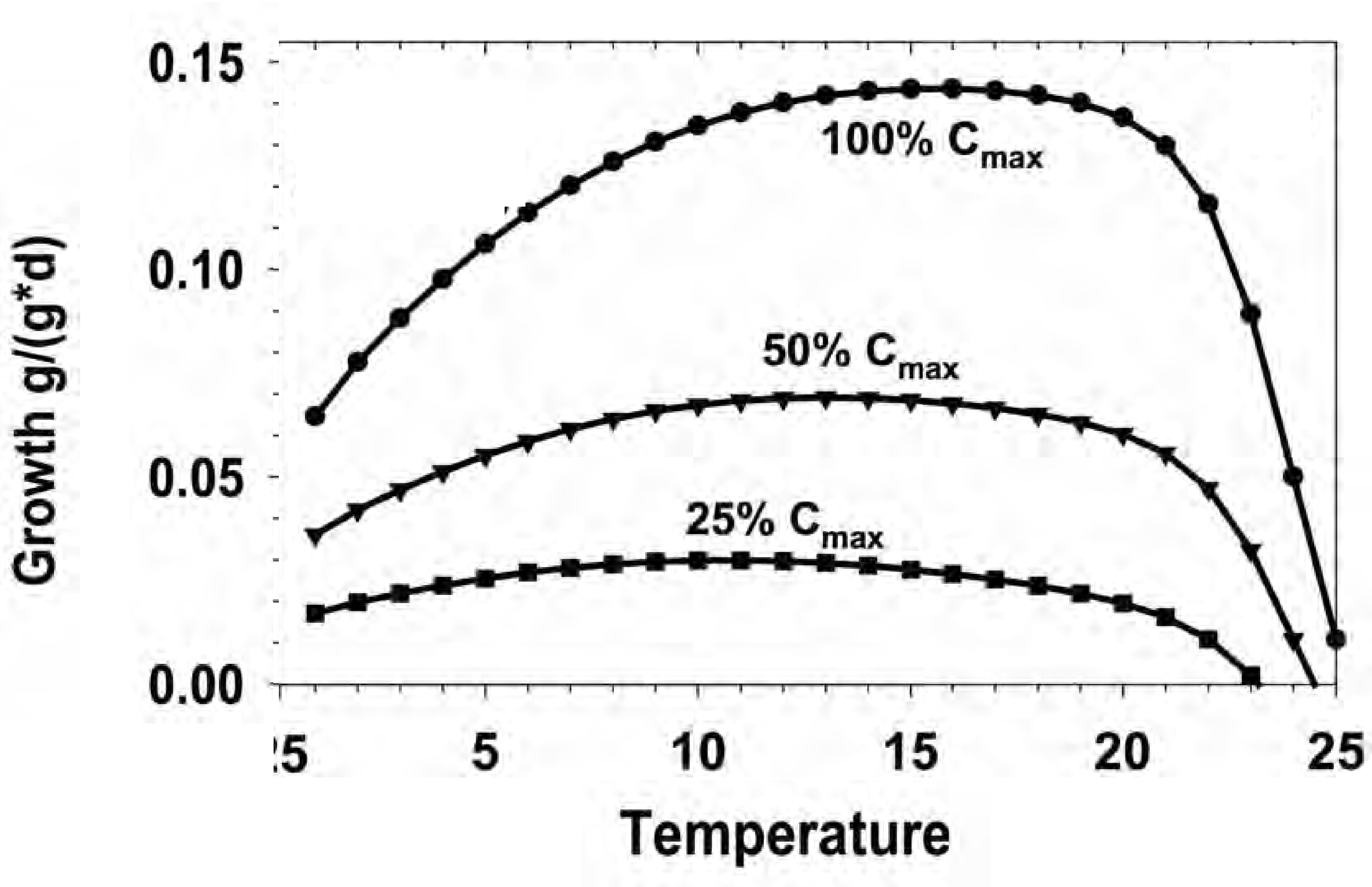


(Beauchamp, 2009)



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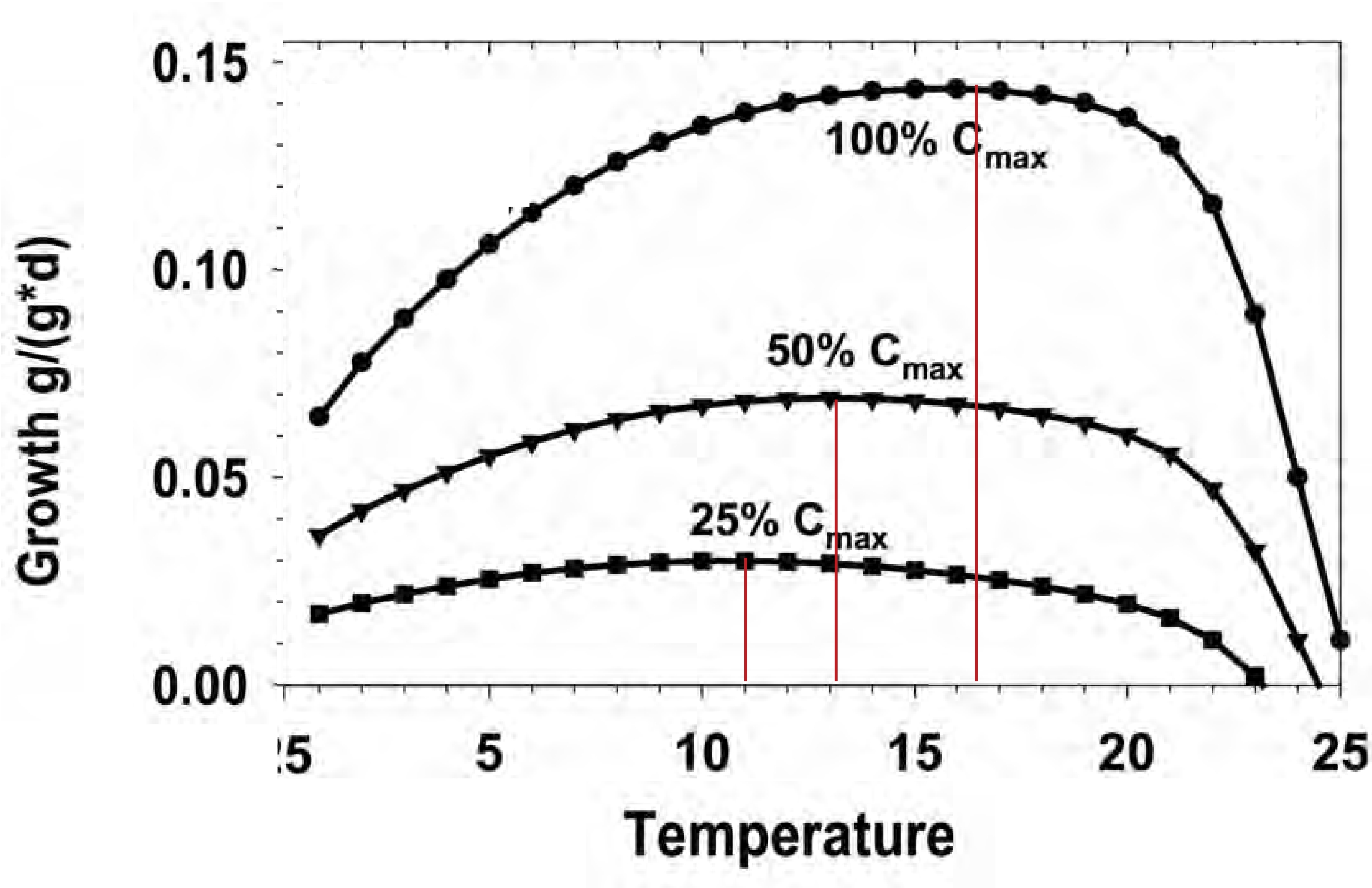
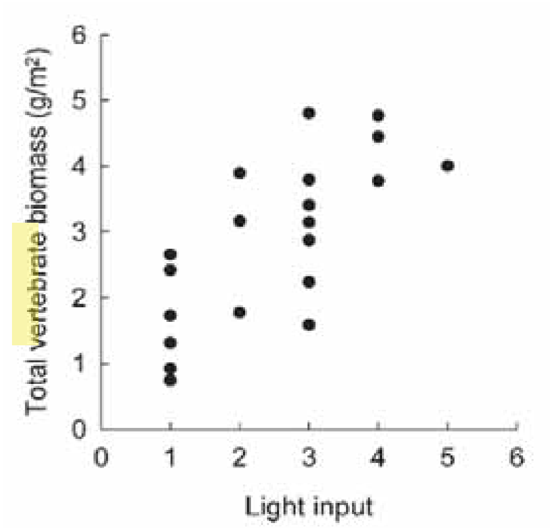


(Beauchamp, 2009)

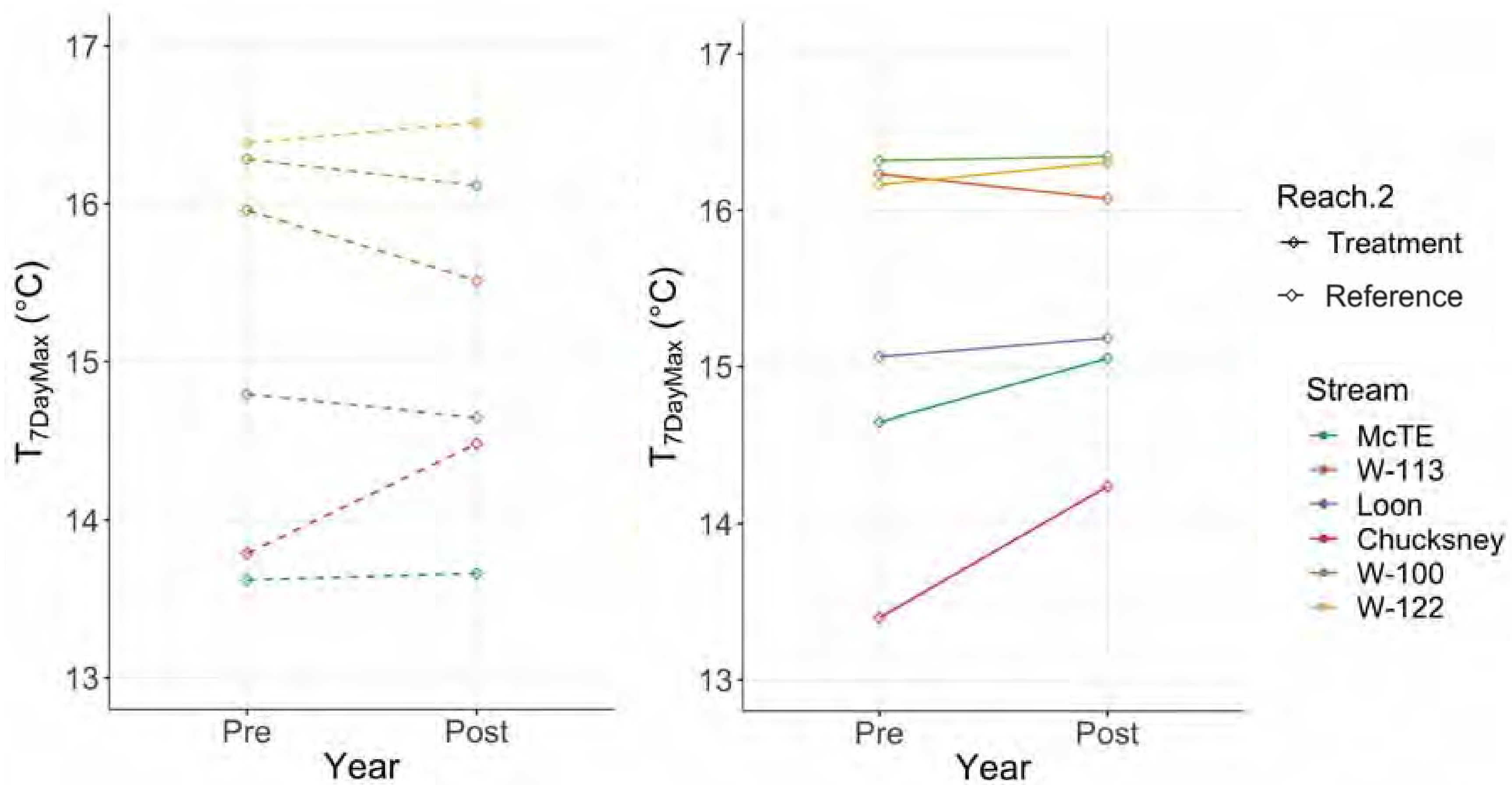
Correlations

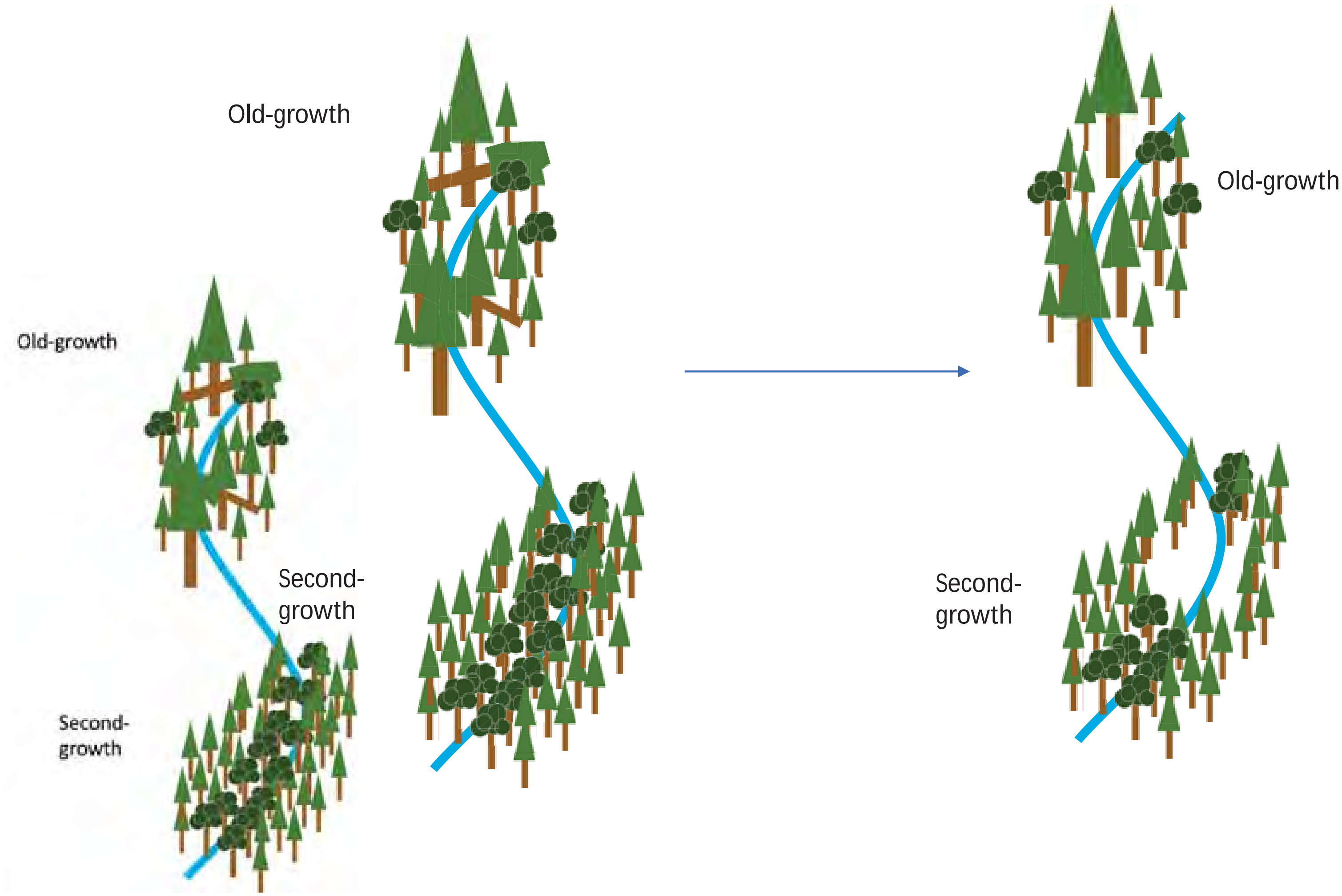
Includes:
Cutthroat trout
Sculpin
salamanders



Kiffney and
Roni 2007

Temperature– *Max 7 Day Moving Average Max* ($T_{7DayMax}$)




Old-growth
Second-growth
Old-growth
Second-growth
Old-growth
Second-growth

Valuing Water

Learning from the past to add resilience to our future

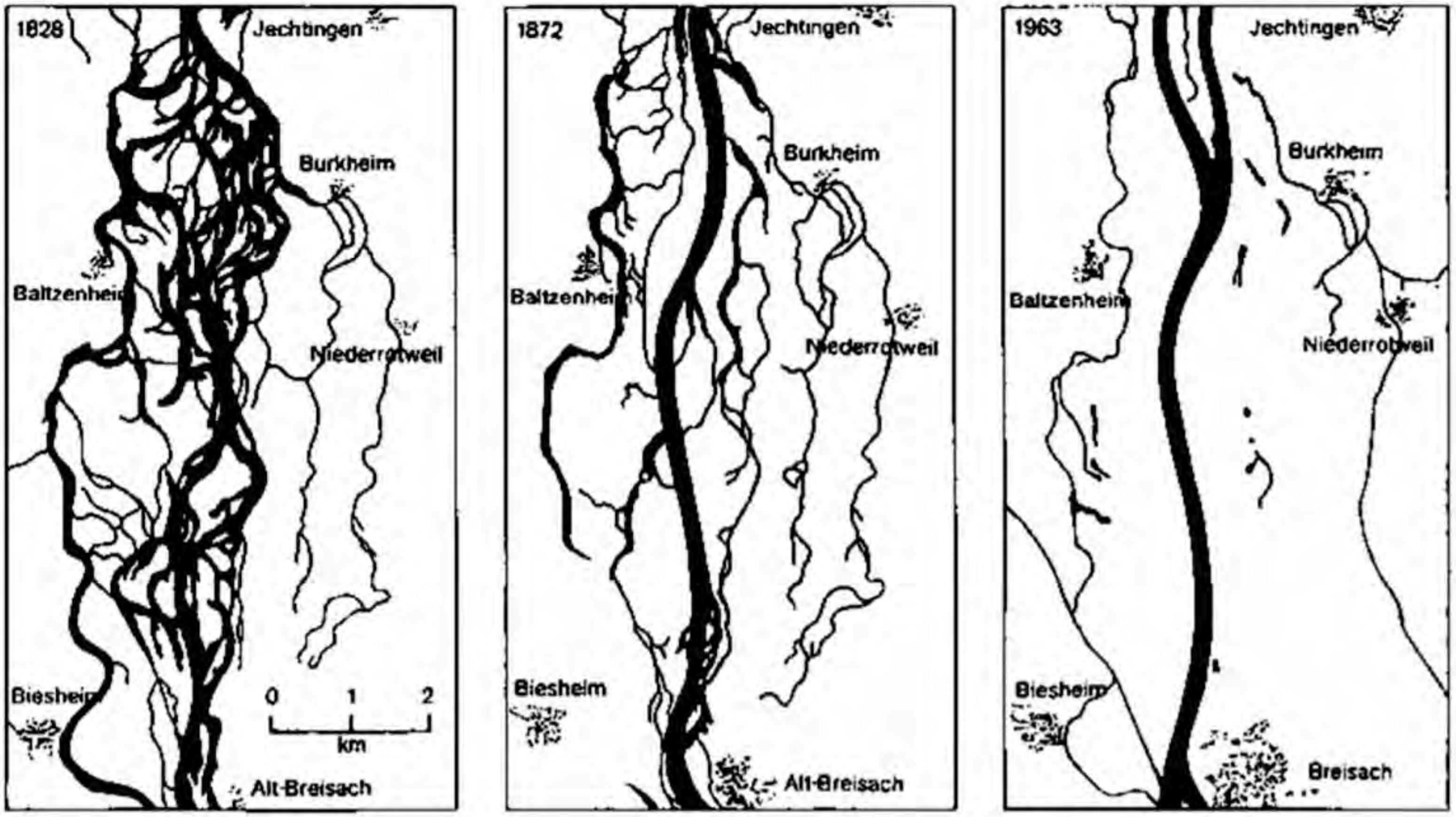
What we know about our past

And can we agree?

- 17th to the early 20th centuries European settlement (development & trapping)
- Pre-settlement condition (shallow & anabranching)
- Seminal geomorphic studies were based on channel and floodplain morphologies that were products of prior anthropogenic disturbance
  - Leopold and Maddock 1953
  - Wolman 1955
  - Wolman and Leopold 1957

Cluer et al., 2013

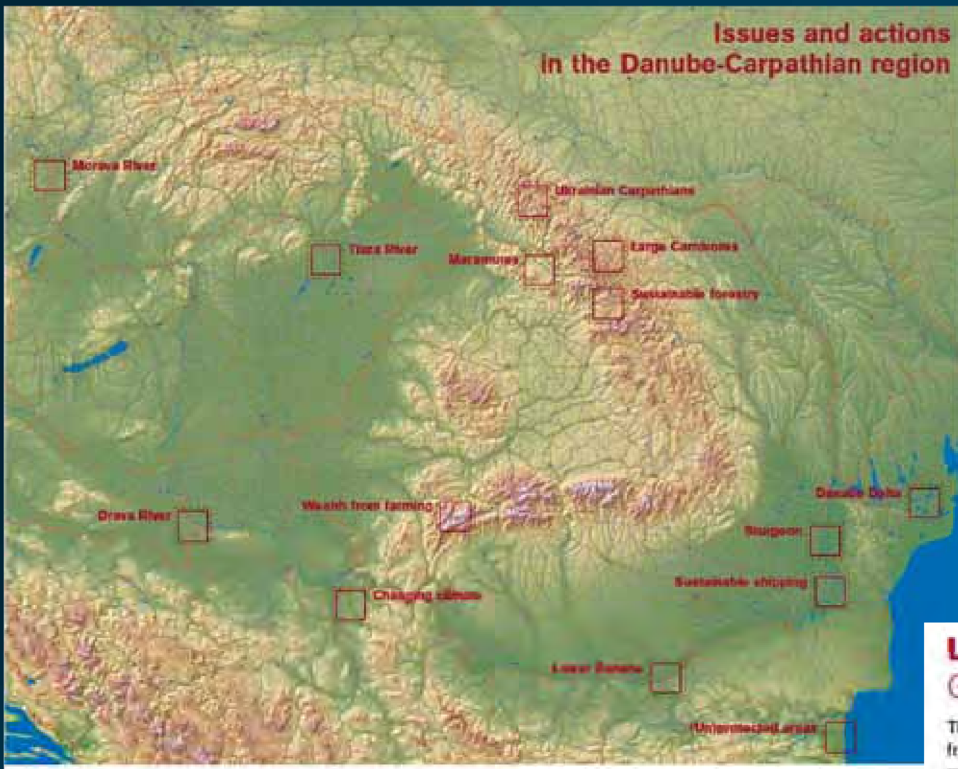
Example from Europe - Upper River Rhine at Breisach Germany



Anastomosed
1828 – Prior to
river training

Anabranched
1872 – after re-alignment
by Johann Gottfried Tulla

Meandering
1963 – fully canalised
single-thread



Global jewels *worth preserving*

The **Danube River** basin is the most international river basin in the world, draining 19 countries on its 2800 km journey from the Black Forest in Germany to the Black Sea. From the largely untamed middle and lower stretches of the river to the spectacular Danube Delta at its mouth, the Danube is home to some of the richest wetland areas in Europe and the world.

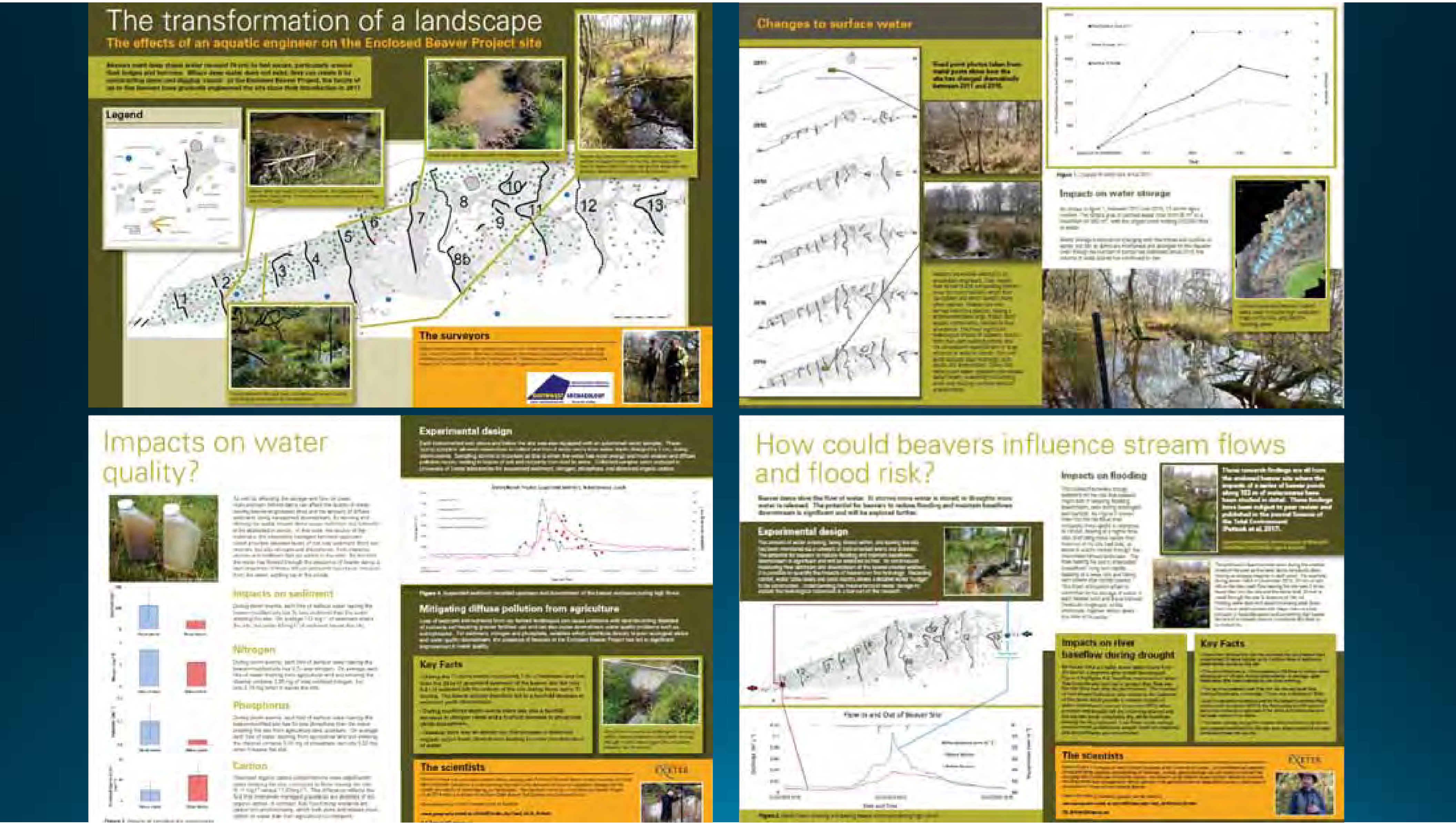
"Let the River Breath"

Lower Danube

Green Corridor

The last 1,000 km of the Danube contain the river basin's greatest treasures, from the spectacular Danube Delta to the Danube islands that are home to pygmy cormorants and other wildlife. The Lower Danube Green Corridor agreement signed by the governments of Romania, Bulgaria, Moldova and Ukraine and facilitated by WWF represents the most ambitious wetland protection and restoration project in Europe. Nearly 1 million ha are now under some form of protection, and a good start has been made toward achieving the 224,000 ha of wetlands that are to be restored under the agreement.

Lower Danube | photo © WWF-DCP


The transformation of a landscape
The effects of an aquatic engineer on the Enclosed Beaver Project site
Legend
The surveyors
Changes to surface water
Impacts on water storage
Impacts on water quality?
Impacts on sediment
Nitrogen
Phosphorus
Carbon
Experimental design
Mitigating diffuse pollution from agriculture
Key Facts
The scientists
EXETER
How could beavers influence stream flows and flood risk?
Experimental design
Impacts on flooding
Impacts on river baseflow during drought
Key Facts
The scientists
EXETER

Prior to European colonization beaver populations were estimated to number 60–400 million in North America (Naiman, Johnston, & Kelley, 1988). Beaver were intensively trapped for their pelts through the 1800s and eradicated from developed areas where they were often considered a nuisance. Beaver populations became isolated, and their numbers were dramatically reduced in urban and rural areas, with only about 10% of historical populations remaining (Wilson & Reeder, 2005).

Bailey et al., 2019

Example 1: Upper Mississippi and Missouri River Basins (Hey and Phillip 1995).

Researchers estimate that beaver ponds covered 51,100,000 acres in 1600 compared to 511,000 acres in 1990. They estimated wetlands at 44,700,000 acres in 1780 versus 18,900,000 acres in 1980. This reduction in ponds (surface water stored) and wetlands (groundwater stored) has resulted in a huge loss of flood control, and system stability during droughts and years with high precipitation.

Example 2: Elk Island National Park in east-central Alberta, Canada (Hood and Bayley 2008).

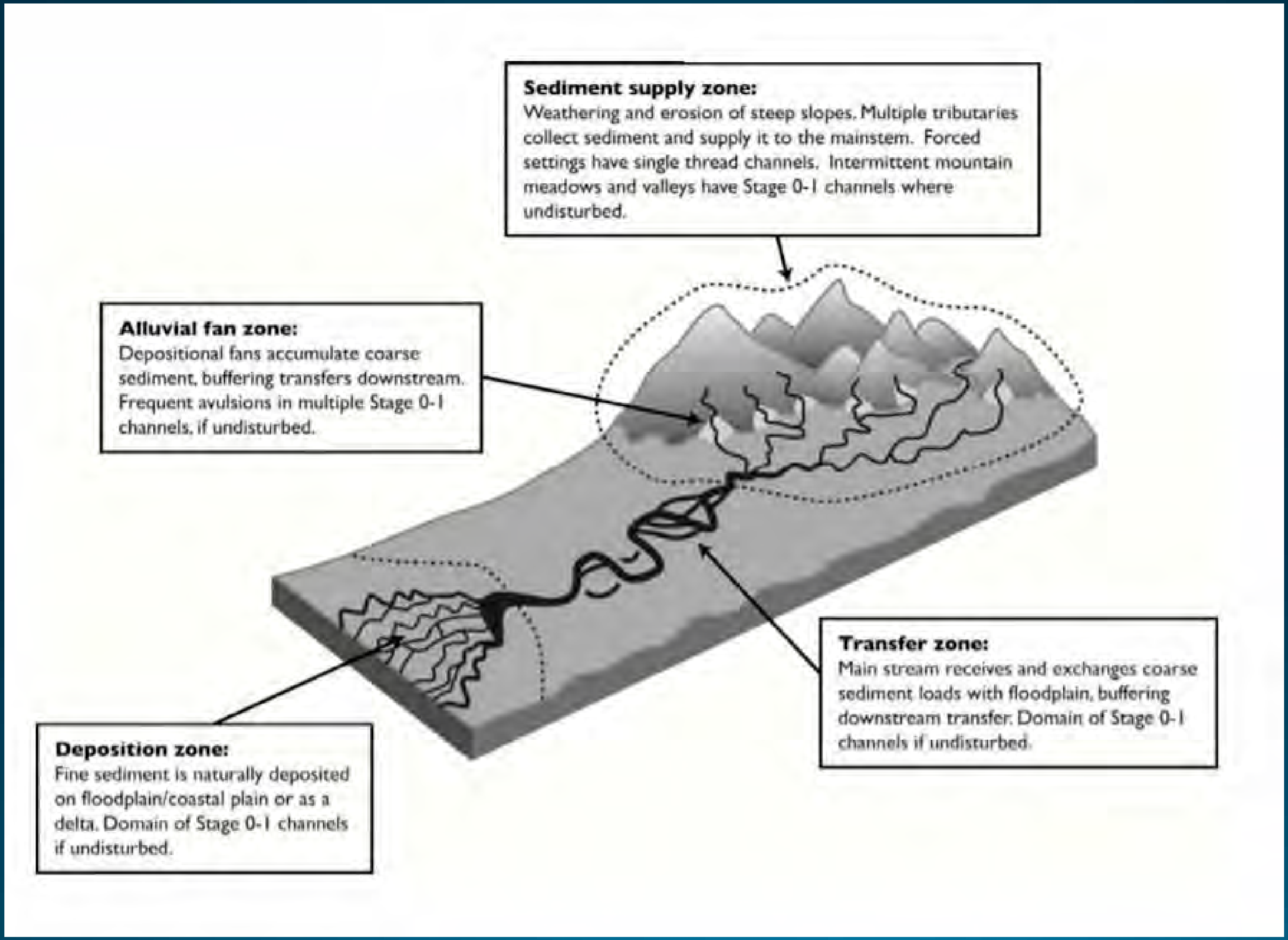
Documenting changes in the amount of open water during dry and wet years between 1948 and 2002 due to the presence, or absence, of beavers. The beaver dam building and maintenance made the area much less sensitive to drought and helped decrease downstream flood peaks by increasing the river's rapid access to its floodplain during high flows.

Example 3: Crane Creek, Oregon (Schaffer 1941).

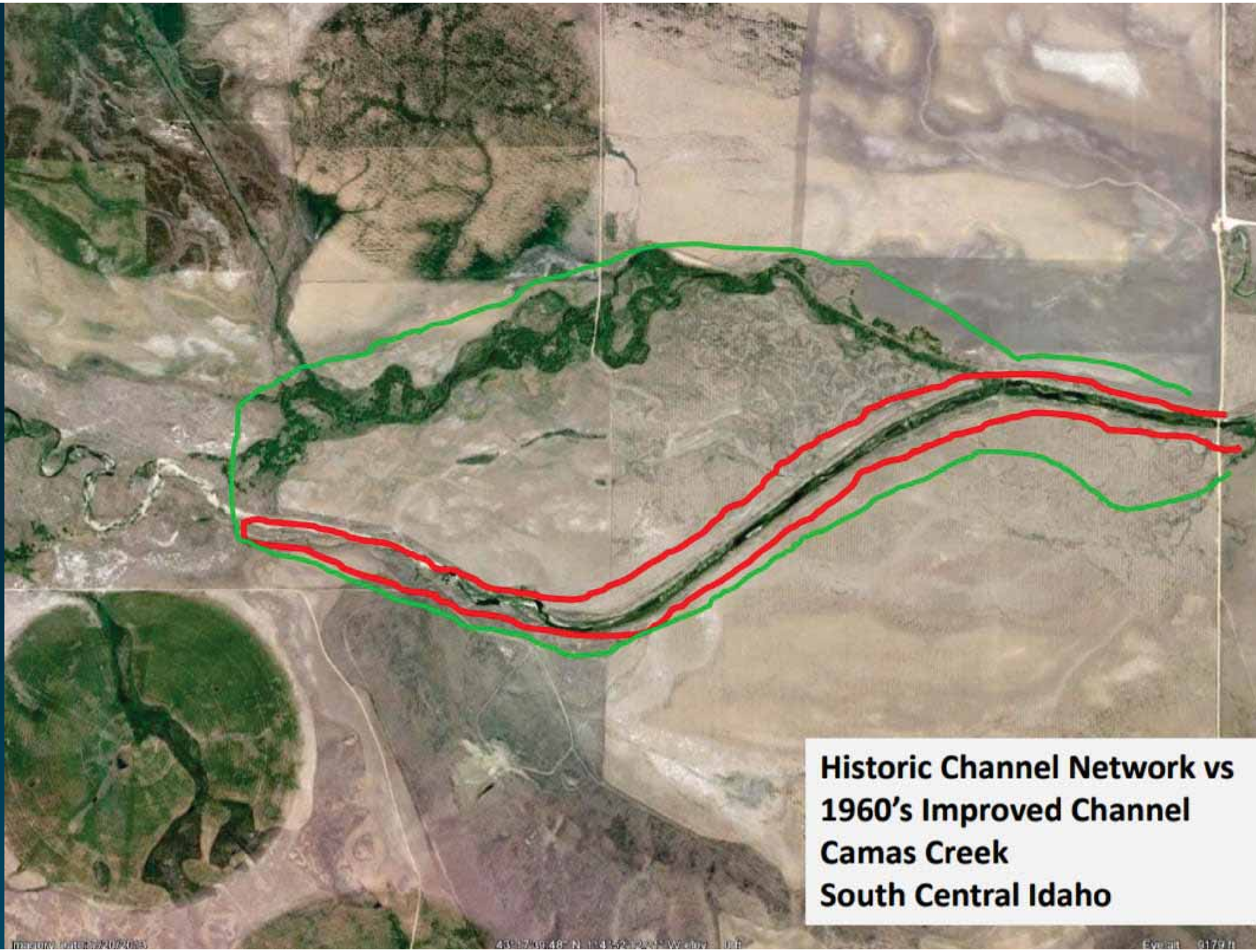
Prior to 1924 beavers were present in Crane Creek and the meadows had stirrup-high native grasses. The grasses were sub-irrigated by beaver ponds. In 1924 the beavers were trapped out. In 1925 the channel began to incise and by 1935 the channel had deepened 25 feet. In 1936 beavers were reintroduced, and by 1938 the water table had risen and the hay meadow production had improved. 1939 was a drought year, yet water was abundant on the ranch with beaver ponds, while absent downstream on the ranch without beaver ponds.

Fouty, 2008

For 100's of years we have actively converted depositional stream reaches into transport stream reaches.



Cluer et al., 2013


Historic Channel Network vs
1960's Improved Channel
Camas Creek
South Central Idaho

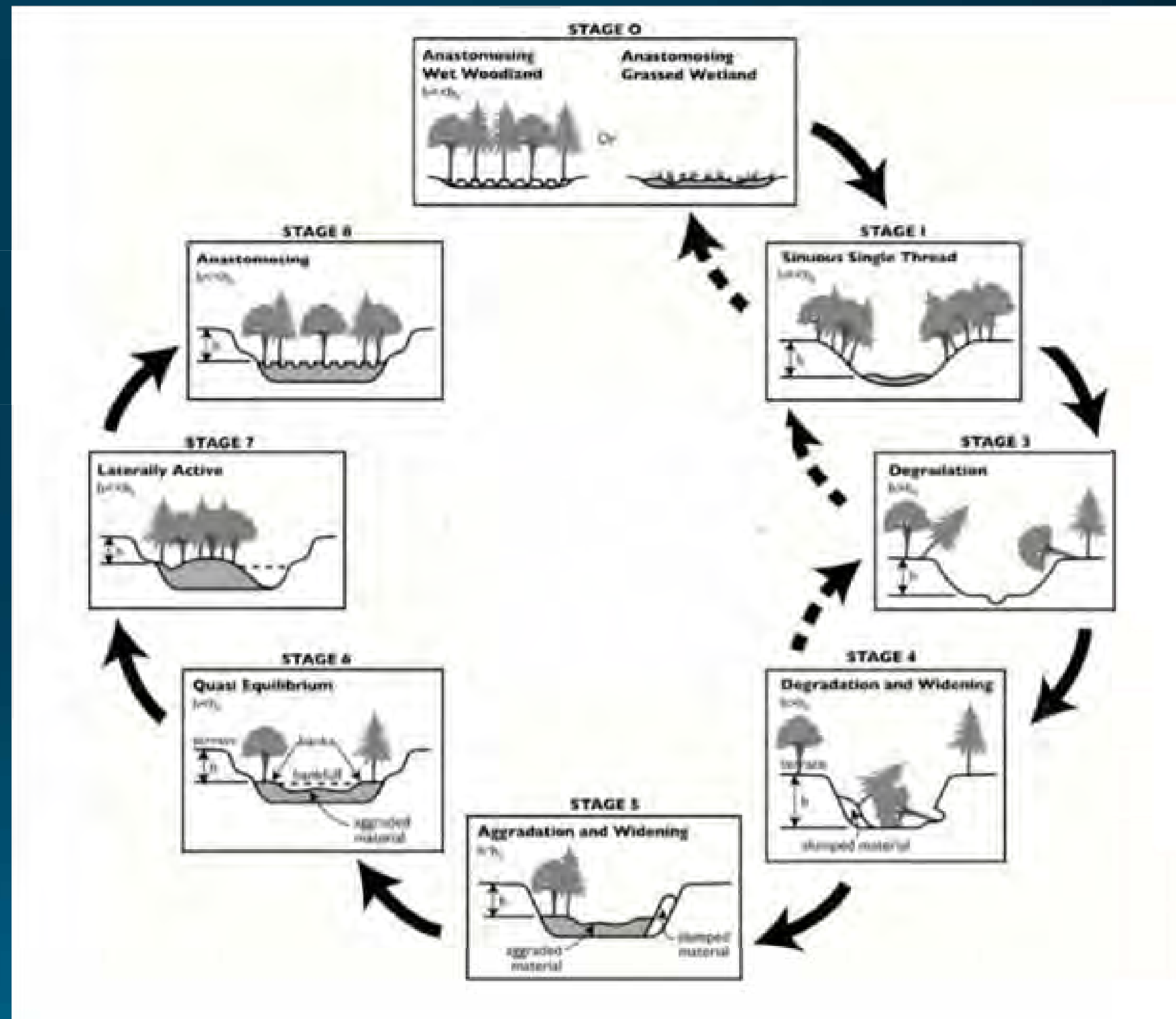
Cluer, 2018


It is now generally accepted that river engineering and management that works with rather than against natural processes is more likely to attain and sustain the multi-functional goals (e.g. land drainage, flood risk management, fisheries conservation, biodiversity, and recreation) demanded by local stakeholders and society more widely.

Wohl et al., 2005; Thorne et al., 2010

Cluer et al., 2013

The Evolution of Restoration in Low Gradient Depositional Streams



Cluer et al., 2013

Room to React

- Maximal flood attenuation
- Maximal GW recharge
- Maximal sediment pulse attenuation
- Resilient to entire range of watershed processes and pulses

Cluer et al., 2013

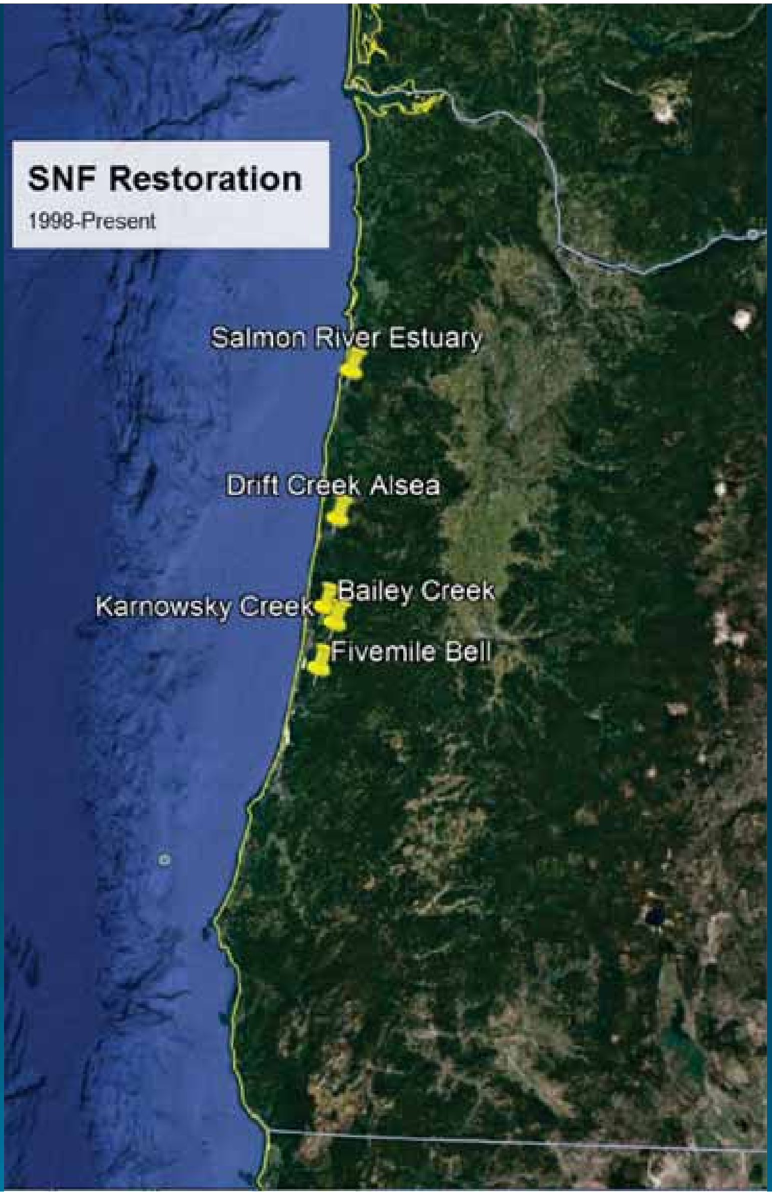
Recharge & Connection

- No deep drainage channel
- Stream flow and groundwater connection
- High interaction between flow, sediment, and vegetation
- Small channels easily moderated by vegetation

Cluer et al., 2013

Siuslaw National Forest Aquatic Restoration

- 1999 Bailey Creek- Enchanted Valley
- 2003 Karnowsky Creek
- 2006 Drift Creek-Alsea
- 2007-2017 Salmon River Estuary
- 2012-present Fivemile & Bell Creeks

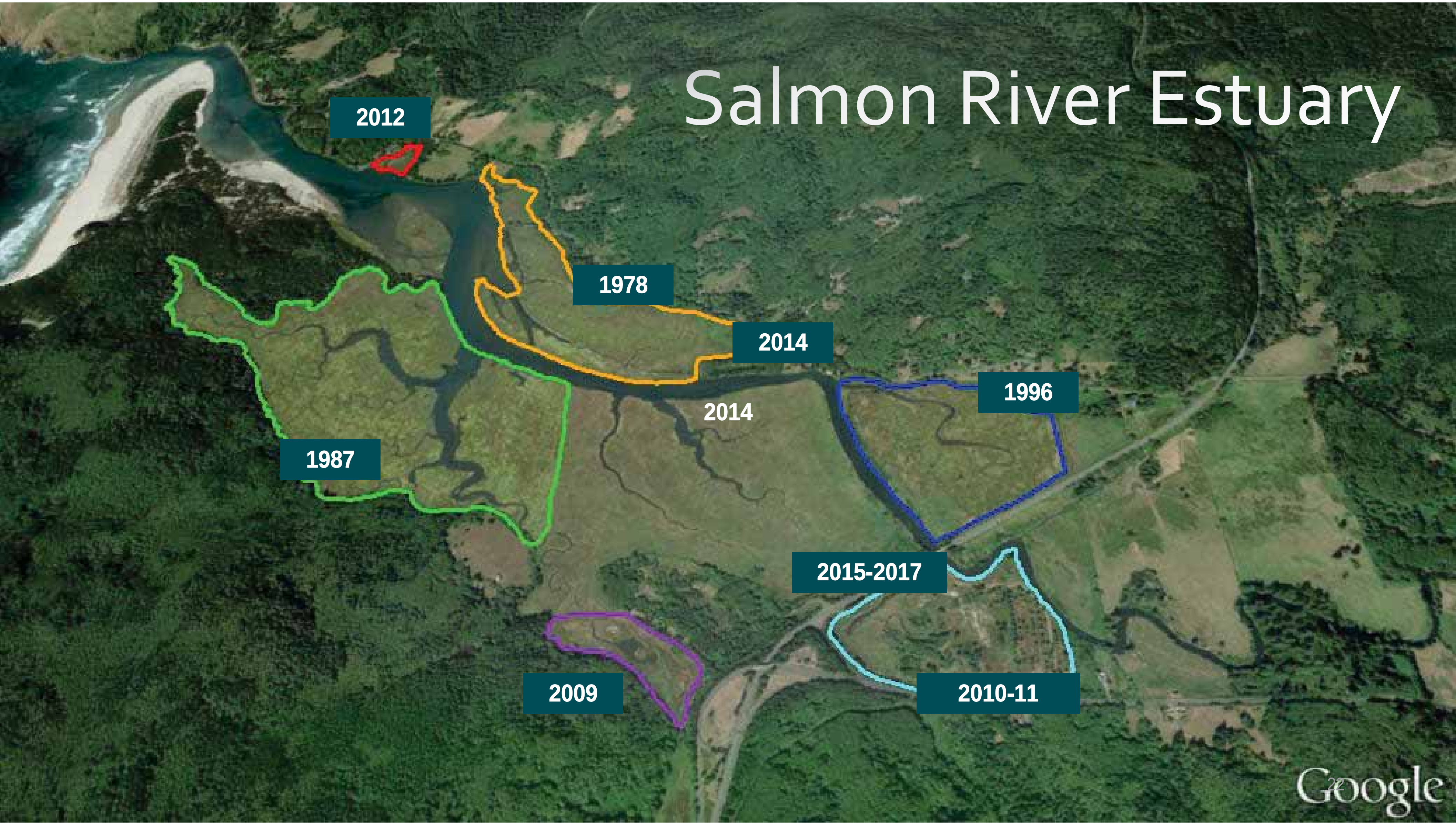



Bailey Creek-Enchanted Valley
2004 Photo


5034
Karnowsky Creek
2005 Photo

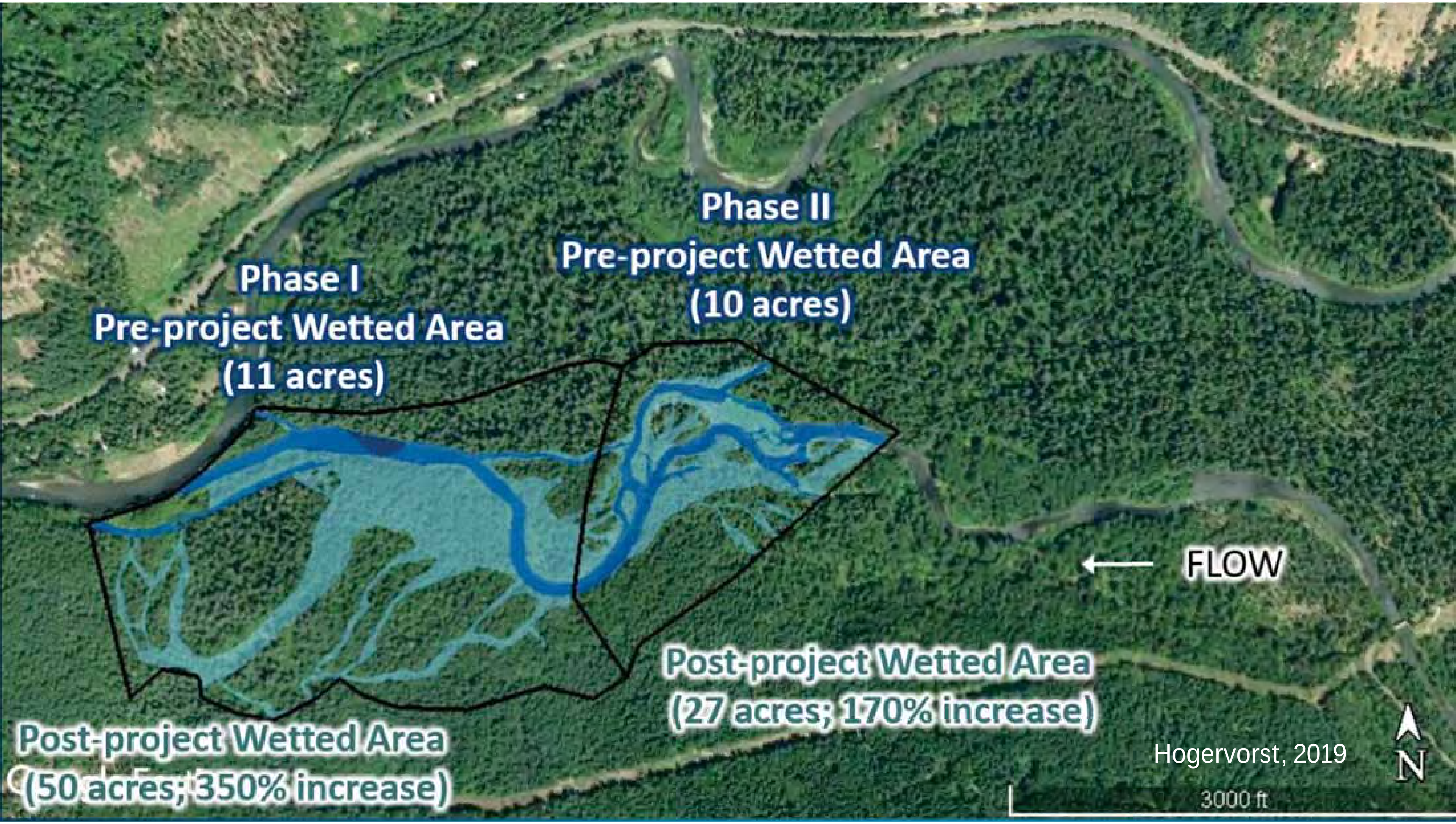

Drift Creek—Alsea River
2007 Photo

Fivemile & Bell Creeks


Salmon River Estuary
2012
1978
2014
2014
1996
1987
2015-2017
2009
2010-11
Google

Restored Hydrology

Working with Natural Processes


Phase II
Pre-project Wetted Area
(10 acres)
Phase I
Pre-project Wetted Area
(11 acres)
FLOW
Post-project Wetted Area
(27 acres; 170% increase)
Post-project Wetted Area
(50 acres; 350% increase)
Hogervorst, 2019
N
3000 ft

Willamette River Historic Channels, North of Corvallis, Oregon


Future Resilience


Hogervorst, 2019

Photo Credit—Duncan Berry

Room to React

- Maximal flood attenuation
- Maximal GW recharge
- Maximal sediment pulse attenuation
- Resilient to entire range of watershed processes and pulses

Cluer et al., 2013

Recharge & Connection

- No deep drainage channel
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- High interaction between flow, sediment, and vegetation
- Small channels easily moderated by vegetation

Cluer et al., 2013


Photo Credit—Louis-Marie Preau


RIPARIAN AREA
RESTORATION
UTAH DIVISION OF WILDLIFE RESOURCES
SPECIAL RESTRICTION AREA
CLOSED TO BEAVER HARVEST

THE SEARCH FOR FRESHWATER MUSSELS IN THE LOWER BOISE RIVER

Dorene MacCoy, City of Boise Public Works
Matt Laramie, US Geological Survey Forest and Rangeland Ecosystem Science Center

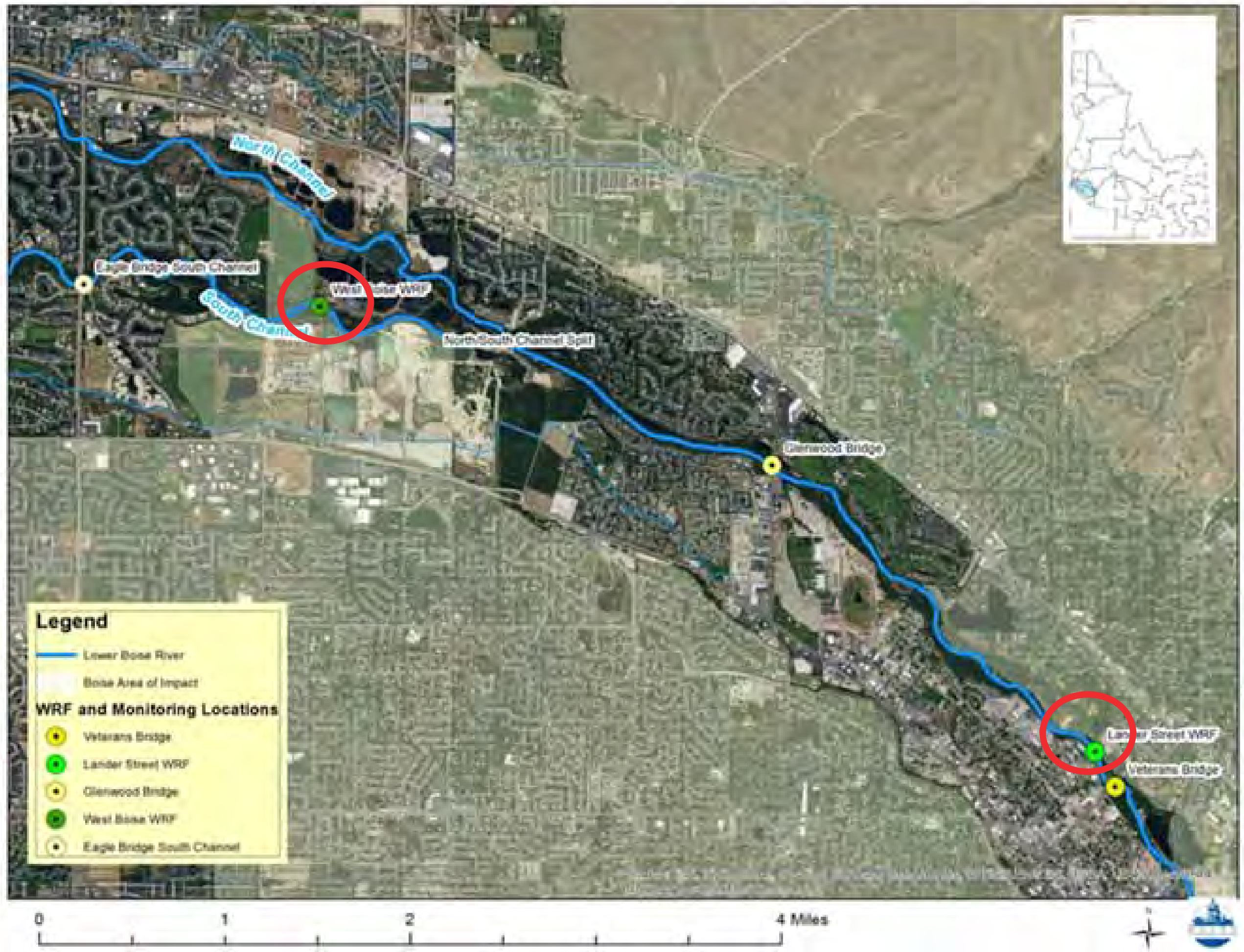
AGENDA

- Why is the City of Boise interested in freshwater mussels?
- Freshwater mussel life cycle
- Freshwater mussel habitat
- Occurrence of freshwater mussels in near by rivers
- City of Boise Reconnaissance efforts
  - Boise River Whitewater Park Phase 2 survey during construction
  - Geographical Information System (GIS) database habitat search
  - Physical survey and environmental DNA (eDNA) training and sampling
- eDNA analysis
- Next steps

WHY IS THE CITY OF BOISE INTERESTED IN FRESHWATER MUSSELS?

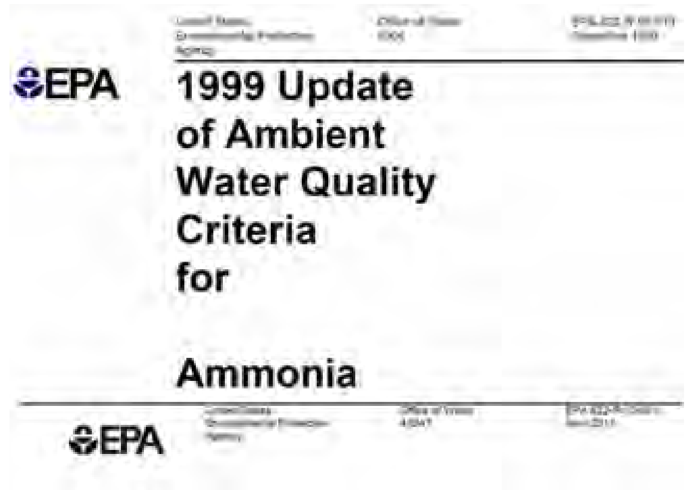
Lander Street Water Renewal Facility

West Boise Water Renewal Facility



WHY IS THE CITY OF BOISE INTERESTED IN FRESHWATER MUSSELS?

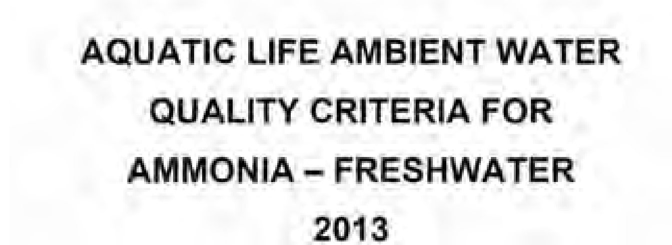
- Clean Water Act, Section 304(a) - protect aquatic species in receiving waters
- Ammonia – constituent of concern
- 1999 EPA guidance
  - Salmonids most sensitive
- 2013 EPA guidance
  - In waters with temperatures greater than 15ºC, freshwater mussels (family Unionidae) most sensitive


EPA

1999 Update of Ambient Water Quality Criteria for

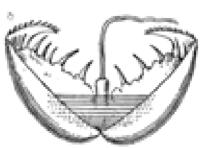
Ammonia

EPA


AQUATIC LIFE AMBIENT WATER QUALITY CRITERIA FOR AMMONIA – FRESHWATER 2013

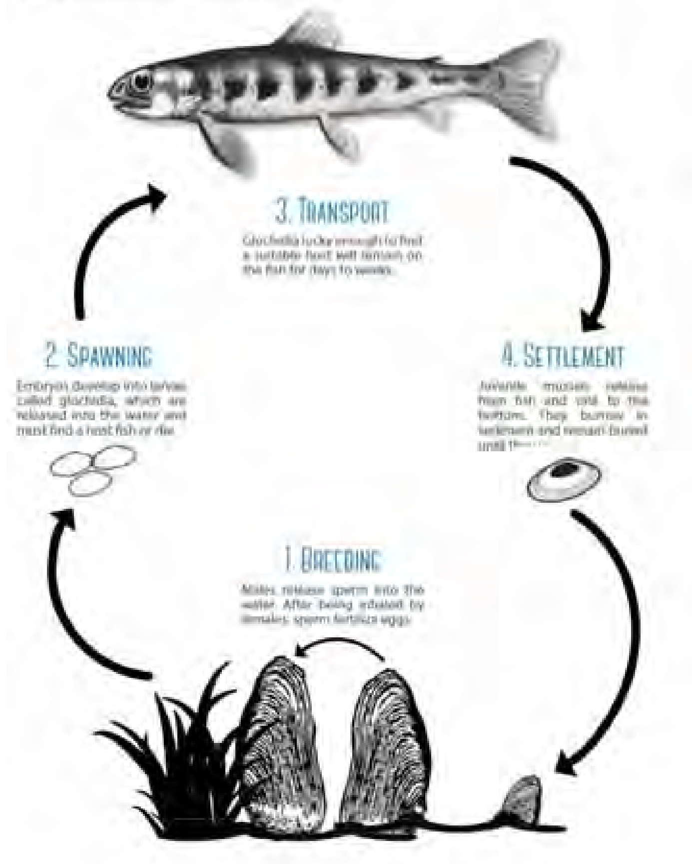
FRESHWATER MUSSEL LIFECYCLE

Blevins and others, 2017
www.xerces.org



1 week – 1 month

FIGURE A2.2: Freshwater Mussel Life Cycle



Video:
Lampsilis Mussel
and bass lure

FRESHWATER MUSSEL HABITAT

- Inundated rivers, streams, lakes, ponds (natural flow)
- Well oxygenated
- Burrowing substrate
- Stable habitat
  - Protected from scouring flow/shifting substrate/large flow fluctuations
- Fish bearing waters
  - Host fish present – usually native

Western Pearshell, Margaritifera falcata
Photo taken by Bryan DuFosse, City of Boise

NORTHWEST SPECIES FOUND IN IDAHO

Floaters
(California and Oregon species)

Anodonta

- Can live 10-20 years
- Least concern*
- Low elevation depositional
- Host fish – trout, sculpin, minnows, others

Western Ridged

Gonidea angulata

- Can live 30+ years
- Vulnerable*
- Diverse habitat
- Host fish – dace, sculpin, minnows, others

Western Pearlshell

Margartifera falcata

- Can live 100+ years
- Near threatened*
- Diverse habitat
- Host fish – trout, suckers, sculpin, others

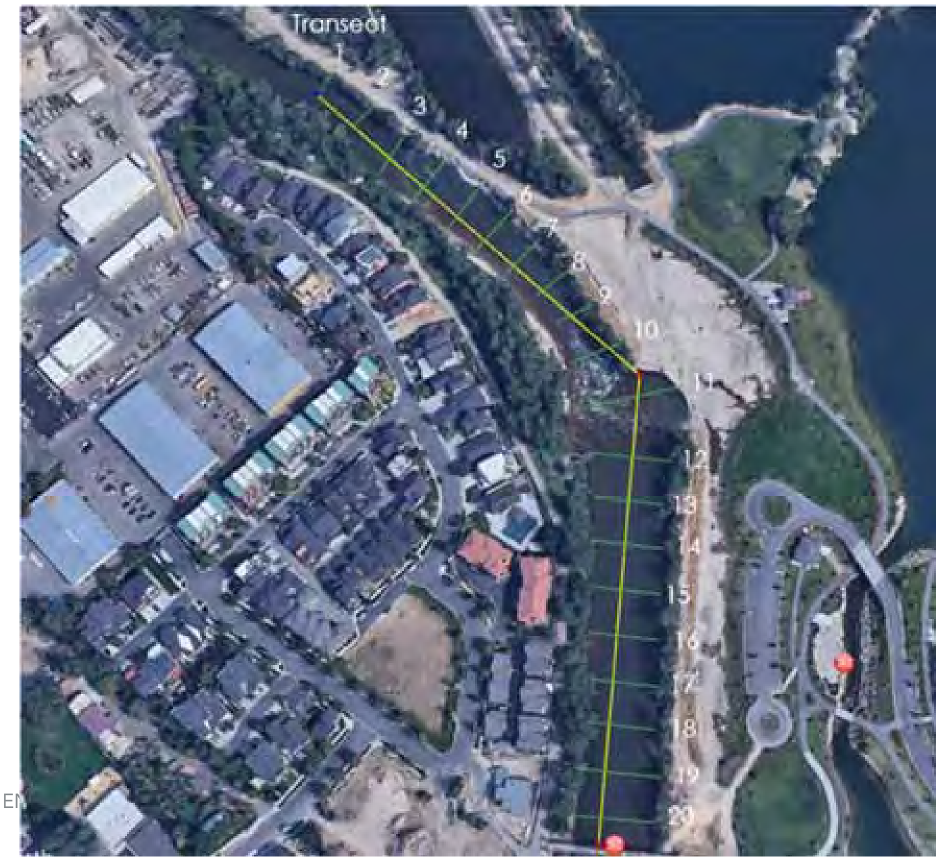
*IUCN, International Union for Conservation of Nature's Red list of threatened species,

MUSSEL OCCURRENCE

- USGS Boise River macroinvertebrate surveys 1995 – 2017 no finding
- USGS Statewide boassessment data *Gonidea angulata*, Western Ridged
  - Snake River
  - Malad River
  - Portneuf River

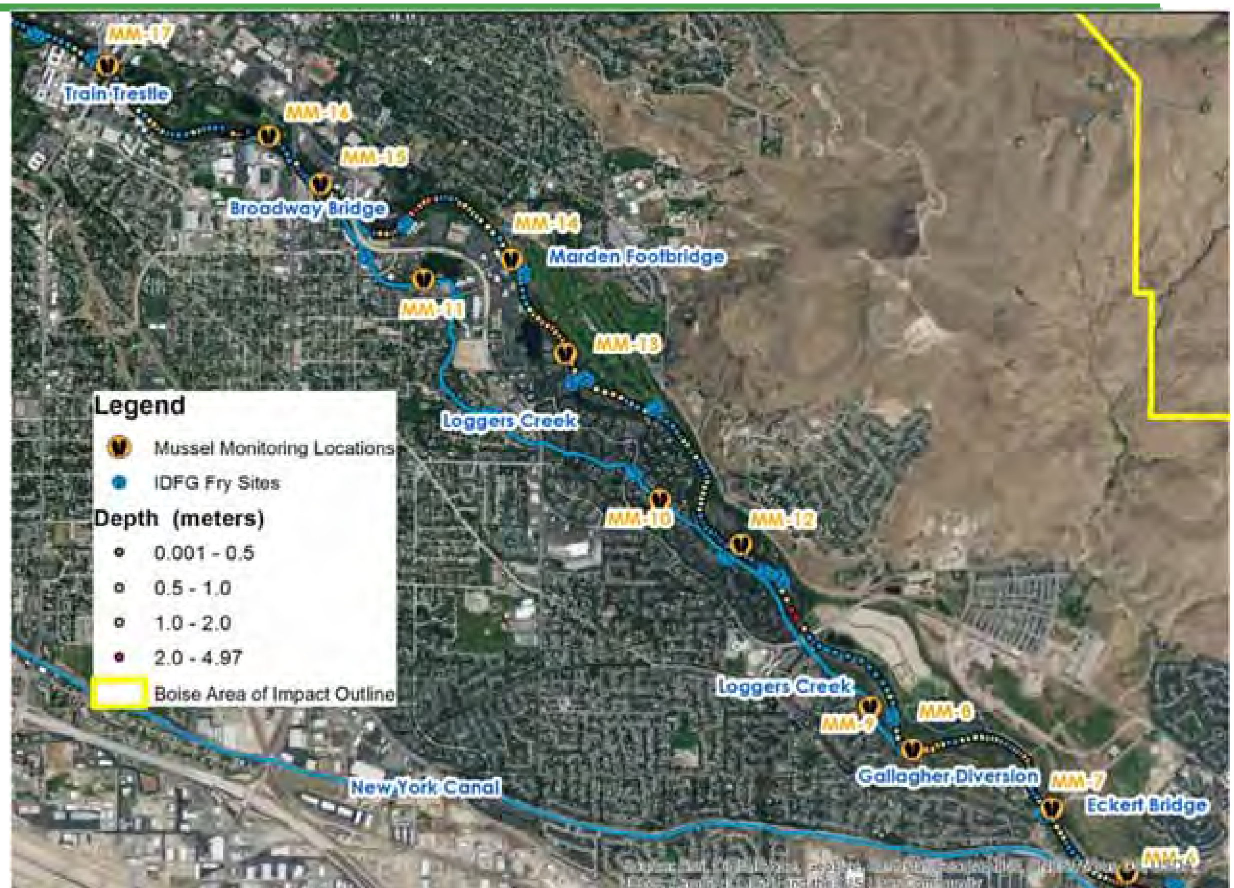
CITY OF BOISE RECONNAISSANCE EFFORTS

Boise River Whitewater Park Phase 2 construction – watered and dewatered survey - only mollusk observed from all transects was the pulmonated limpet, *Ferrissia sp*.



SEARCH FOR POTENTIAL HABITAT

- Boise River Enhancement Network (BREN)* reach information
- Preferred habitat (Blevins and others, 2017)
  - Protected from extreme flow fluctuation and scour
  - Cobble and/or burrowing sand
  - Continuous flow/adequate depth
- Near Idaho Department of Fish and Game fry monitoring sites



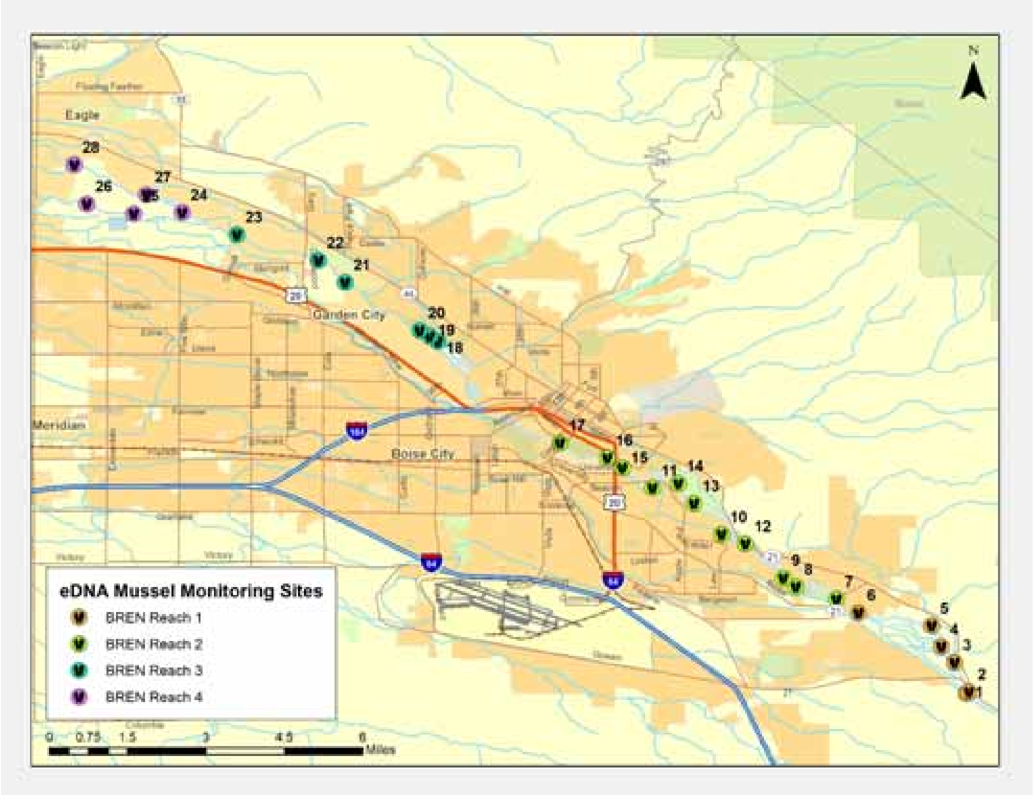
*BREN website: https://www.boiseriverenhancement.org/

PHYSICAL SURVEY AND ENVIRONMENTAL DNA (EDNA) SAMPLING

- Staff training
  - Suitable habitat
  - Species identification
  - eDNA sampling
- Smithroot® eDNA sampler
- Positive control samples
- Site reconnaissance
- Low Flow fall survey

EDNA ANALYSIS

- Pacific Northwest Environmental DNA Laboratory (Boise, Idaho)
- Fine scale sampling throughout Boise River study area in Fall 2019
- Refine the spatial distribution of habitat in mainstem, side-channel, and tributary habitats



EDNA ANALYSIS

- More sensitive to species presence than visual surveys (*i.e.* higher probability of detection)
- Species-specific qPCR molecular assays targeting:
  - *Margaritifera falcata*, Pearlshell
  - *Anodonta californiensis*, California floater
  - *Gonidea angulate*, Western ridged
- 'Positive control' samples collected in Bruneau River, South Fork Salmon River
- Negative controls at all stages of sampling and analysis to minimize and isolate potential for contamination

NEXT STEPS

- Complete survey
- Analyze physical survey data
- Analyze eDNA samples and summarize data
- Interpret findings
- Report findings to City management
- Determine additional sampling needs

THANK YOU

- Dave Hopper, US Fish and Wildlife Service, training and support
- Emile Blevins, training and background information
- David Pilliod and Matt Laramie, USGS eDNA expertise
- City of Boise Sampling and Monitoring Team, sampling
  - Bryan DuFosse
  - Paul Faulkner
  - Christine Hummer
  - Colin Custer
- Kate Harris, City of Boise Water Quality Environmental Program Manager, support

Questions:
Dorene MacCoy, City of Boise, Water Quality Sampling Coordinator
dmaccoy@cityofboise.org
Matt Laramie, Forest and Rangeland Science Center
mlaramie@usgs.gov

Rhithron Associates, Inc

Chironomidae of the Pacific Northwest: taxonomic needs and new records

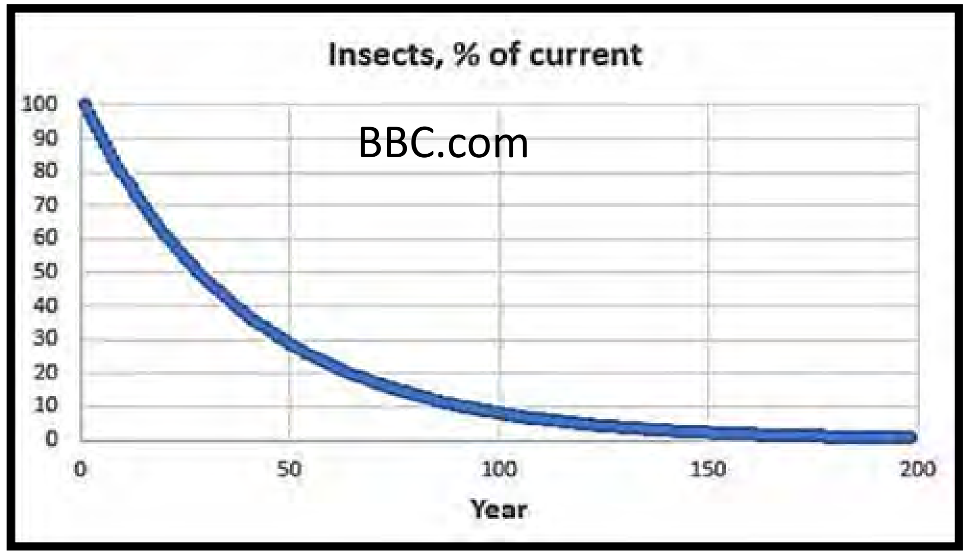
Barbara Hayford[1,2], Rebecca Spring[1], and Andrew Fasbender[1]

[1]Rhithron Associates, Inc., 33 Fort Missoula Rd, Missoula, MT 59804, USA

[2]Division of Biological Sciences, University of Montana, 32 Campus Dr, Missoula, MT 59812, USA

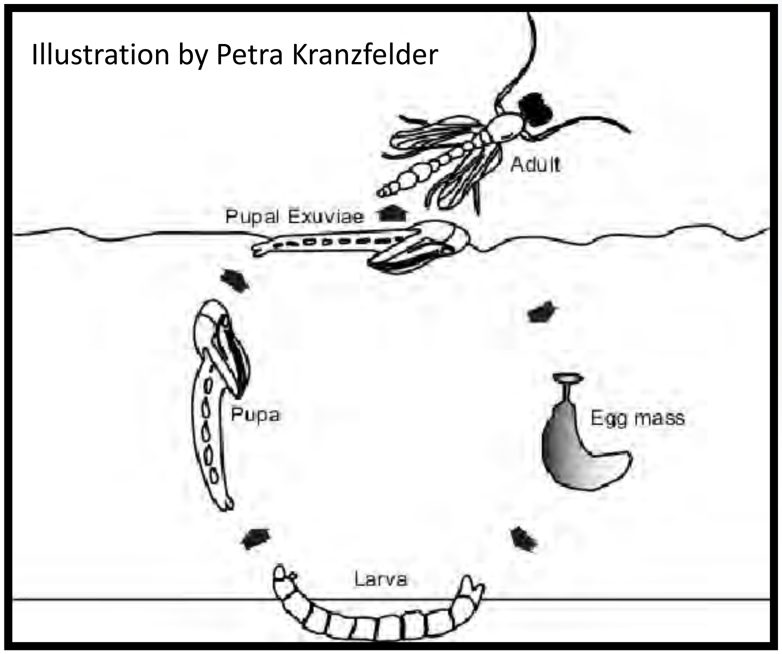
bhayford@gmail.com

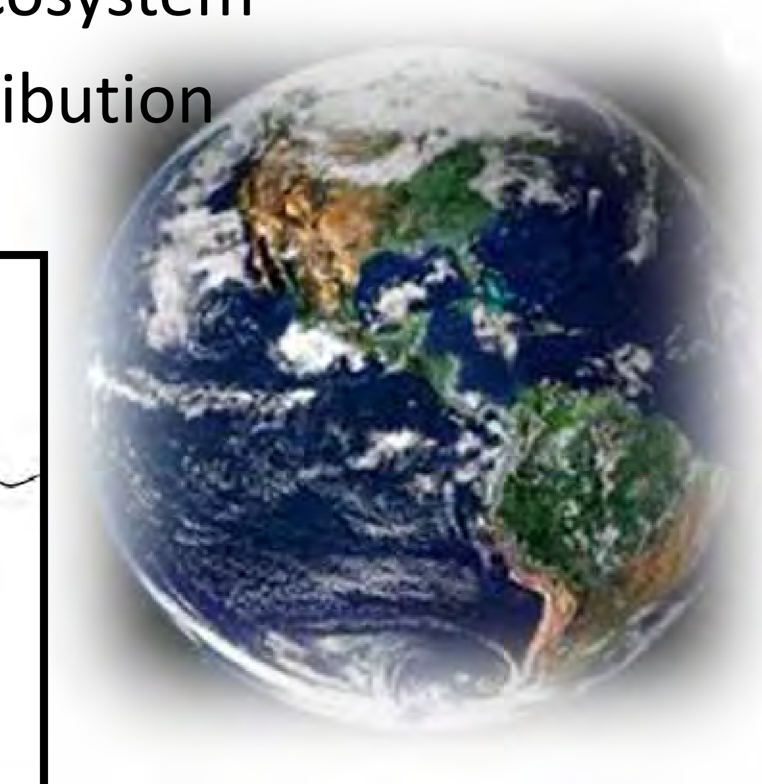
- Documentation of freshwater diversity lags behind terrestrial diversity.
- As does conservation.
- Indicating severe threats to declining biodiversity of freshwater ecosystems.
  - Strayer, D. L., 2006; Strayer, D. L. & D. Dudgeon, 2010.



Rhithron Associates, Inc

- Holometabolous, two stages aquatic
- Every aquatic ecosystem
- Worldwide distribution





Chironomidae

Rhithron Associates, Inc

Chironomidae

- Only insect to colonize the ocean
- Been in space (*Polypedilum vanderplanki)*
- Only holometabolous, free-living insect in Antarctica

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Chironomidae and taxonomic resolution

- Much early ecological, assessment, and monitoring research did not include identification to genus or species
- Currently, many studies still do not include higher level taxonomic resolution (e.g. Culp et al. 2019)

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- Sampling that targets taxa vastly increases known biodiversity for a region (MAIS, Gelhaus et al., 2003-2012; Borkent et al., 2018)
- Comprehensive biodiversity data needs, particularly for Chironomidae
- Informs diversity studies, fish feeding and food web research, ecosystem function, and evolution.

Chironomidae and taxonomic resolution

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- Chironomidae are very important in aquatic systems, often over 50% of a sample in raw numbers and taxon diversity
- Currently difficult or impossible to assign most immature specimens to species, especially in the west

Benthic macroinvertebrate assessment

Publishing databases

- Calls for publication of biodiversity data (e.g. Costello et al., 2018, 2013; JE Ball-Damerow et al., 2019).
- But still have not resulted in publication of data (JL Couture et al., 2019)

Publishing databases

- Catalogs need to be updated (Nearctic Catalog of Chironomidae is now 30 years out of date).
- Georeferenced data most important
- Provides range information
- Dates for time series and temporal analysis of changing systems

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- **<u>Objective</u>**: To determine the status of chiro taxonomy in PNW
- **Goals**

1. Create a database for midges of Washington State
2. Use the database to determine the status of chironomid taxonomy for the state
3. Document new records
4. Relate taxonomy to basic, bioassessment & monitoring, and systems ecology

- RAI taxonomy protocols and database
- Non-unique/redundant taxa culled
- Permission from clients or open source data
- Web of Science and other searches
- Keywords: Chironomidae, macroinvertebrates, Washington/state, streams, rivers, lakes, by specific watersheds
- Results of literature search compared to database to search for new taxonomic records.

Methods

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Results

Few articles found that related to macroinvertebrates in general or specifically to bioassessment for Washington State.

- Exception, Larson et al. (2019)

Ecological Indicators 102 (2019) 175–185

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Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

ELSEVIER

Original Articles

The first statewide stream macroinvertebrate bioassessment in Washington State with a relative risk and attributable risk analysis for multiple stressors

Chad A. Larson[a,*], Glenn Merritt[a], Jack Janisch[a], Jill Lemmon[a], Meghan Rosewood-Thurman[a], Brian Engeness[a], Stacy Polkowske[a], George Onwumere[b]

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ARTICLE INFO

Keywords:
Biomonitoring
Stream survey

ABSTRACT

We report results from the first statewide assessment of biological health in perennial streams in Washington State. Using a probabilistic sampling survey design, we were able to make unbiased estimates of biological condition of macroinvertebrate communities throughout the state based on 346 sites sampled from 2009 to

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- 2250 georeferenced sites
- Collected from nearly every part of the state
- Samples collected from 2001-2019
- Over all four seasons
- Number of unique taxa=161 from
- 6 subfamiles

Database overview

- Conservative estimates of 70 taxa represent new records.
- Very few taxa recorded from Washington State (Dillon and Oliver, 1990)
- Four additional published papers with chironomid taxa listed

New records

- However, the large list of taxa represented may also be due to updated and exhaustive collection methods (net size aperture, habitat sampling)
- Useful for collecting rare genera, terrestrial etc.
- 40 new genus records
- 29 new species records

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Subfamily	Tribe	Taxon
Chironominae	Chironomini	Cladopelma
Chironominae	Chironomini	Endochironomus
Chironominae	Chironomini	Microtendipes Rydalensis Gr.
Chironominae	Chironomini	Nilothauma
Chironominae	Chironomini	Parachironomus
Chironominae	Chironomini	Paratendipes
Chironominae	Chironomini	Robackia
Chironominae	Chironomini	Robackia demeijerei
Chironominae	Chironomini	Saetheria
Chironominae	Chironomini	Stenochironomus
Chironominae	Chironomini	Tribelos
Chironominae	Chironomini	Tribelos jucundus
Chironominae	Chironomini	Xenochironomus
Chironominae	Pseudochironomini	Pseudochironomus
Chironominae	Tanytarsini	Cladotanytarsus
Chironominae	Tanytarsini	Constempellina
Chironominae	Tanytarsini	Constempellina sp. C
Chironominae	Tanytarsini	Cryptotendipes
Chironominae	Tanytarsini	Demicryptochironomus
Chironominae	Tanytarsini	Rheotanytarsus
Chironominae	Tanytarsini	Stempellina
Chironominae	Tanytarsini	Stempellinella
Chironominae	Tanytarsini	Sublettea coffmani
Diamesinae		Pagastiella
Diamesinae		Potthastia Gaedii Gr.
Diamesinae		Potthastia Longimanus Gr.
Diamesinae		Protanypus
Orthocladiinae		Acricotopus
Orthocladiinae		Allocladius
Orthocladiinae		Apedilum
Orthocladiinae		Bryophaenocladius
Orthocladiinae		Cardiocladius
Orthocladiinae		Cardiocladius albiplumus
Orthocladiinae		Cricotopus (Isocladius)
Orthocladiinae		Cricotopus bicinctus
Orthocladiinae		Cricotopus trifascia
Orthocladiinae		Doithrix
Orthocladiinae		Doncricotopus bicaudatus
Orthocladiinae		Eretmoptera
Orthocladiinae		Eukiefferiella Brevicalcar Gr.
Orthocladiinae		Eukiefferiella Coerulescens Gr.
Orthocladiinae		Eukiefferiella Pseudomontana Gr.
Orthocladiinae		Eukiefferiella tirolensis
Orthocladiinae		Euryhapsis
Orthocladiinae		Georthocladius
Orthocladiinae		Gymnometriocnemus
Orthocladiinae		Heterotanytarsus
Orthocladiinae		Hydrosmittia
Orthocladiinae		Lopescladius
Orthocladiinae		Mesocricotopus
Orthocladiinae		Mesosmittia
Orthocladiinae		Metriocnemus
Orthocladiinae		nr. Heleniella
Orthocladiinae		Orthocladiinae Genus 5 (Coffman and Ferrington)/Orthocladiinae sp. (RAI
Orthocladiinae		Orthocladiinae sp. (RAI Taxon # 0001)
Orthocladiinae		Orthocladiinae sp. (RAI Taxon # 0004)/nr Heleniella
Orthocladiinae		Orthocladiinae sp. (RAI Taxon #0018)
Orthocladiinae		Orthocladius (Symposiocladius) lignicola
Orthocladiinae		Ortholcadiinae (RAI taxon #0016)/Compterosmittia sp. A
Orthocladiinae		Parachaetocladius
Orthocladiinae		Paracricotopus
Orthocladiinae		Parakiefferiella
Orthocladiinae		Platysmittia
Orthocladiinae		Platysmittia fimbriata
Orthocladiinae		Psilometriocnemus
Orthocladiinae		Smittia
Orthocladiinae		Stictocladius
Orthocladiinae		Stilocladius
Orthocladiinae		Symbiocladius
Orthocladiinae		Symposiocladius
Orthocladiinae		Tvetenia Discoloripes Gr.
Orthocladiinae		Tvetenia tshernovskii
Orthocladiinae		Tvetenia vitracies
Orthocladiinae		Xylotopus par
Prodiamesinae		Monodiamesa
Prodiamesinae		Odontomesa
Prodiamesinae		Prodiamesa
Tanypodinae		Apsectrotanypus johnsoni
Tanypodinae		Bilyjomyia algens
Tanypodinae		Clinotanypus
Tanypodinae		Guttipelopia
Tanypodinae		Hayesomyia senata
Tanypodinae		Helopelopia
Tanypodinae		Labrundinia
Tanypodinae		Larsia
Tanypodinae		Macropelopia
Tanypodinae		Meropelopia
Tanypodinae		Monopelopia
Tanypodinae		Natarsia
Tanypodinae		Nilotanypus
Tanypodinae		Radotanypus
Tanypodinae		Reomyia
Tanypodinae		Rheopelopia
Tanypodinae		Rheosmittia
Tanypodinae		Tanypus
Tanypodinae		Telopelopia
Tanypodinae		Trissopelopia

Subfamily	Tribe	Genus
Chironominae	Chironomini	Nilothauma
Chironominae	Chironomini	Paratendipes
Chironominae	Chironomini	Stenochironomus
Chironominae	Chironomini	Xenochironomus
Chironominae	Pseudochironomini	Pseudochironomus
Diamesinae		Pagastiella
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Orthocladiinae		Apedilum
Orthocladiinae		Bryophaenocladius
Orthocladiinae		Doithrix
Orthocladiinae		Eretmoptera
Orthocladiinae		Euryhapsis
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Orthocladiinae		
Prodiamesinae		
Prodiamesinae		
Prodiamesinae		
Tanypodinae		
Tanypodinae		
Tanypodinae		
Tanypodinae		
Tanypodinae		
Tanypodinae		

Subfamily	Tribe	Species
Chironominae	Chironomini	Microtendipes Rydalensis Gr.
Chironominae	Chironomini	Robackia demeijerei
Chironominae	Chironomini	Tribelos jucundus
Chironominae	Tanytarsini	Constempellina sp. C
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Orthocladiinae		Orthocladiinae sp. (RAI Taxon #0018)
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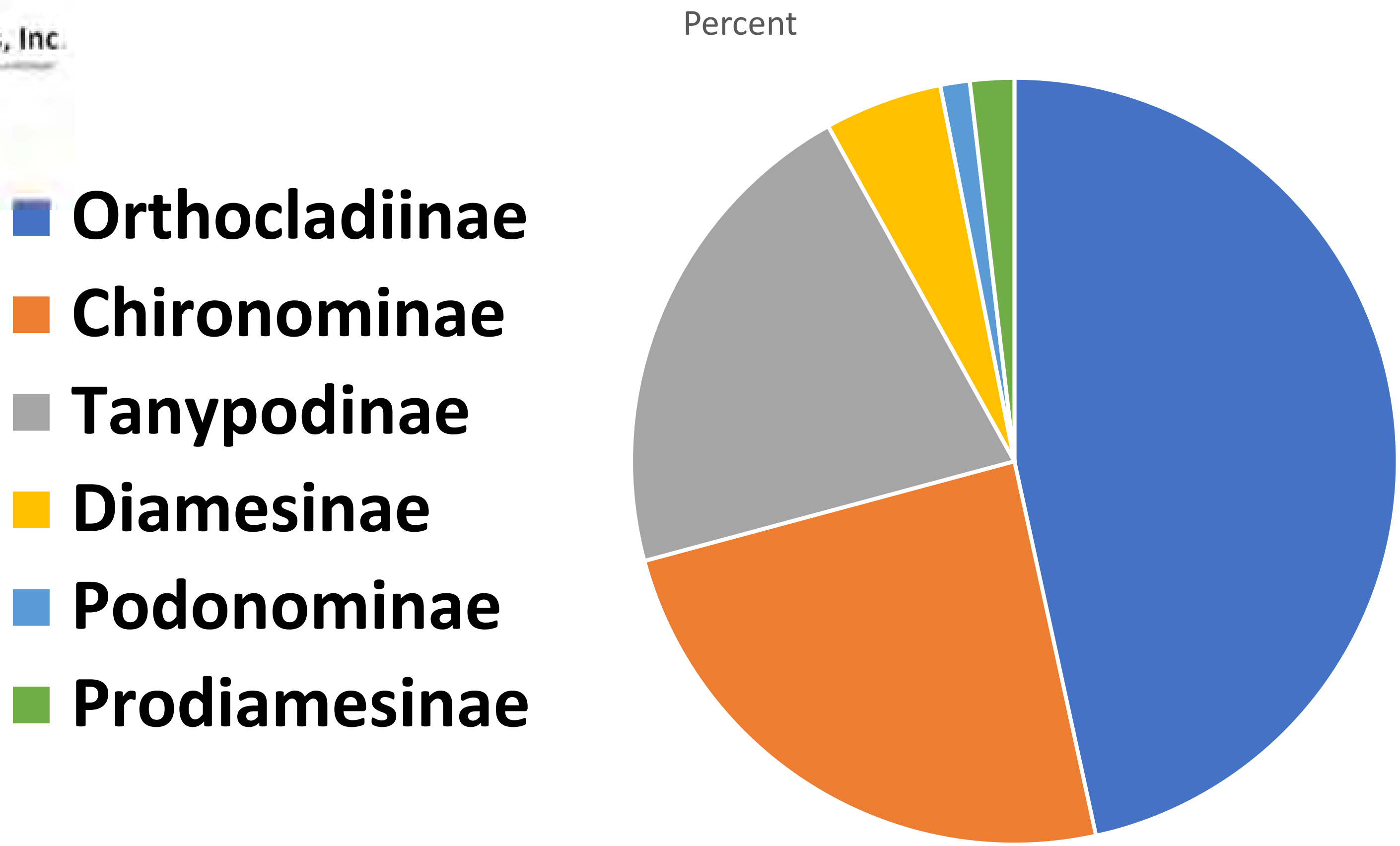
Orthocladiinae		Tvetenia tshernovskii
Orthocladiinae		Tvetenia vitracies
Orthocladiinae		Xylotopus par
Tanypodinae		Bilyjomyia algens
Tanypodinae		Hayesomyia senata



Subfamily overview

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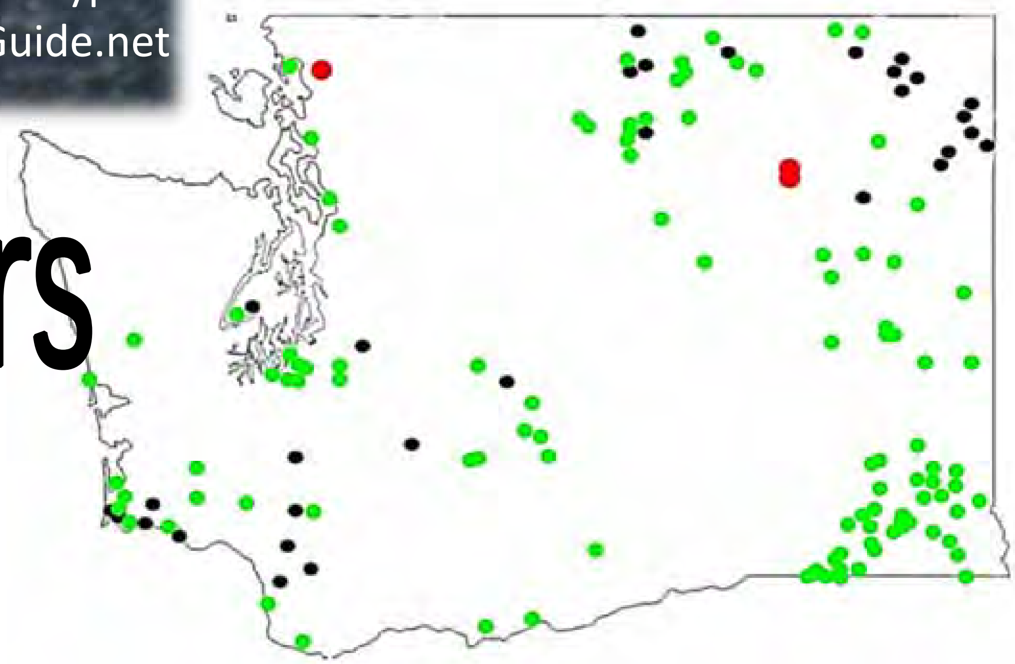
Green = *Radotanypus*
Black = *Bilyjomyia*
Red = *Apsectrotanyps*



Predators

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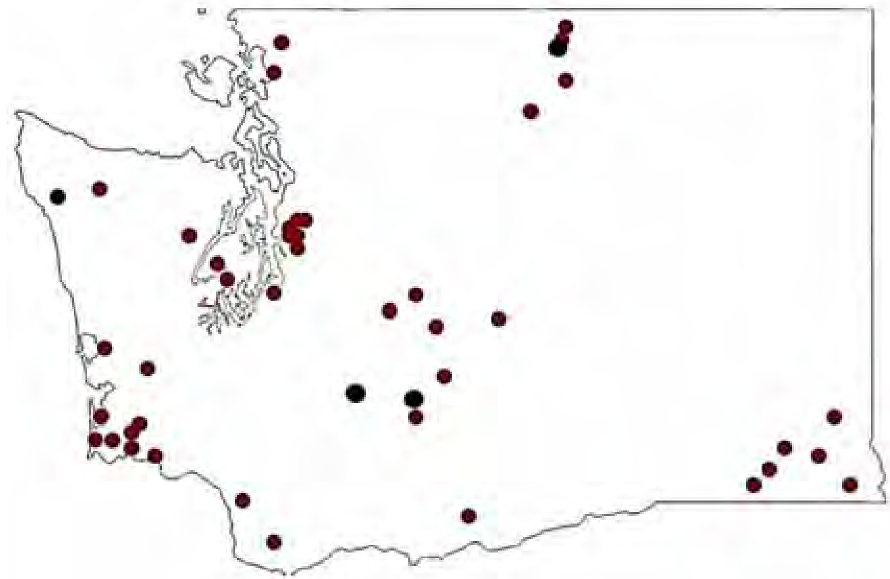
Boreochlus
chirokey.skullisland.info



Black= *Parochlus*
Red= *Boreochlus*

AUSTRAL

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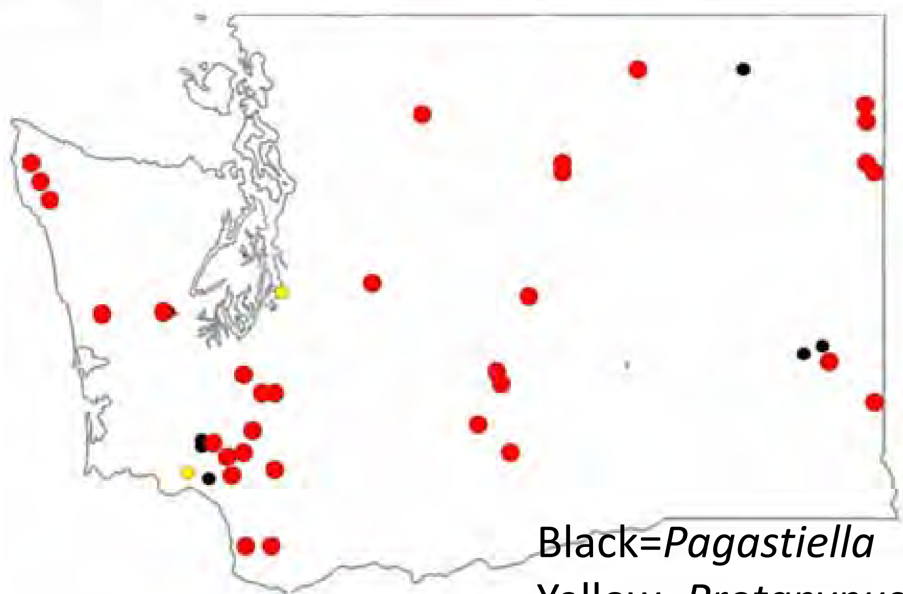
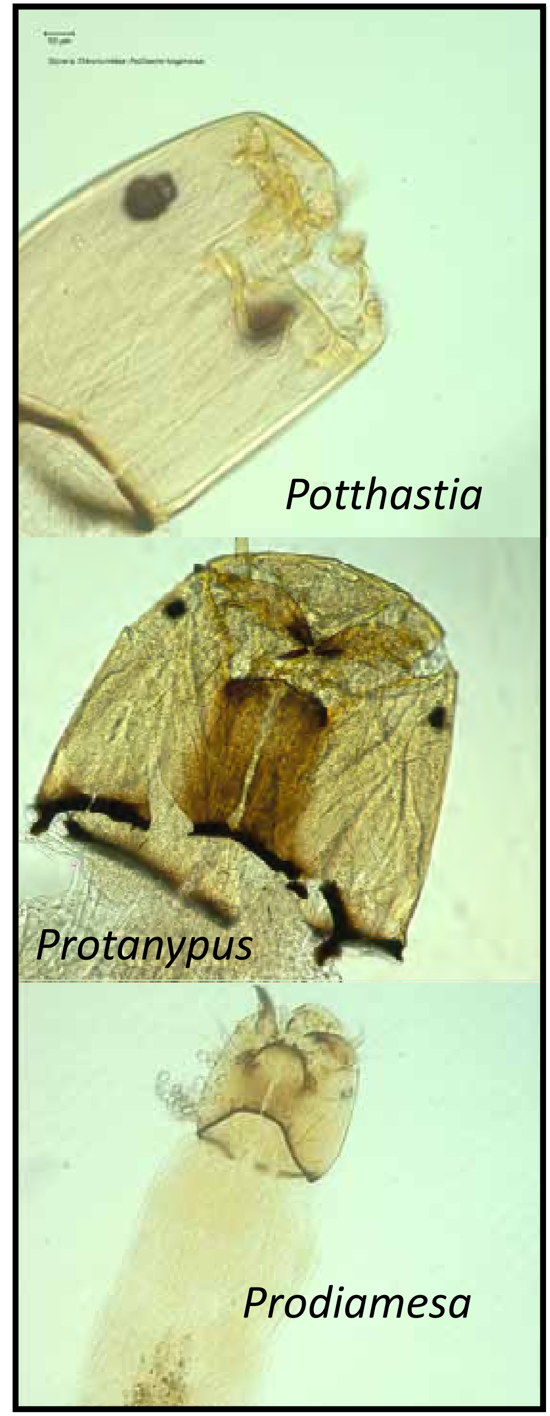


Black=*Pagastiella*
Yellow=*Protanypus*
Red=*Potthastia*

Chill



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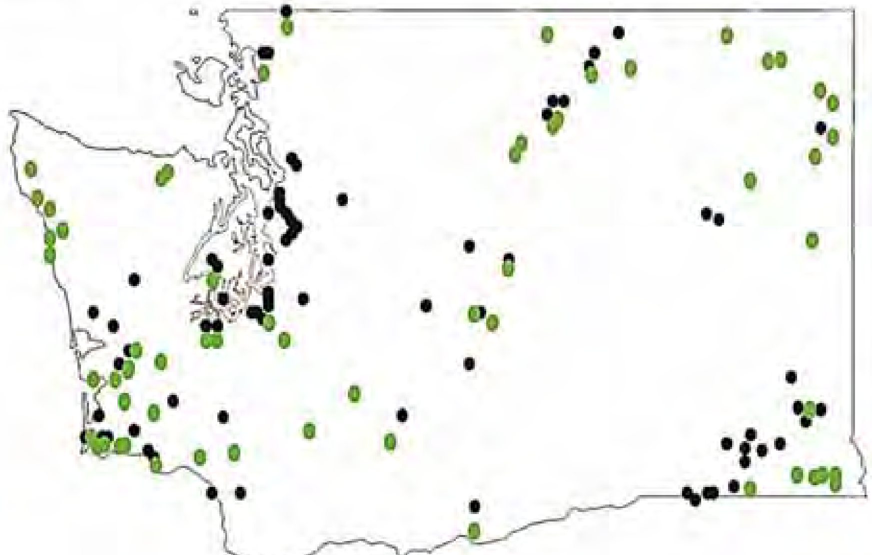
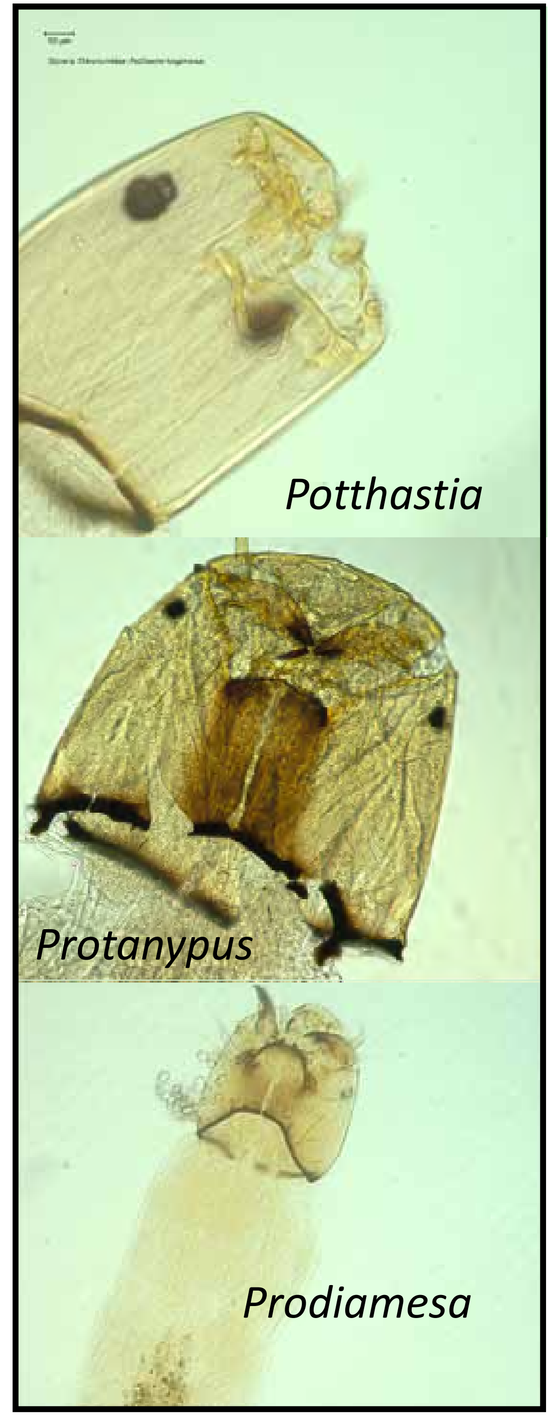


Black=*Prodiamesa*
Green=*Monodiamesa*

Chill



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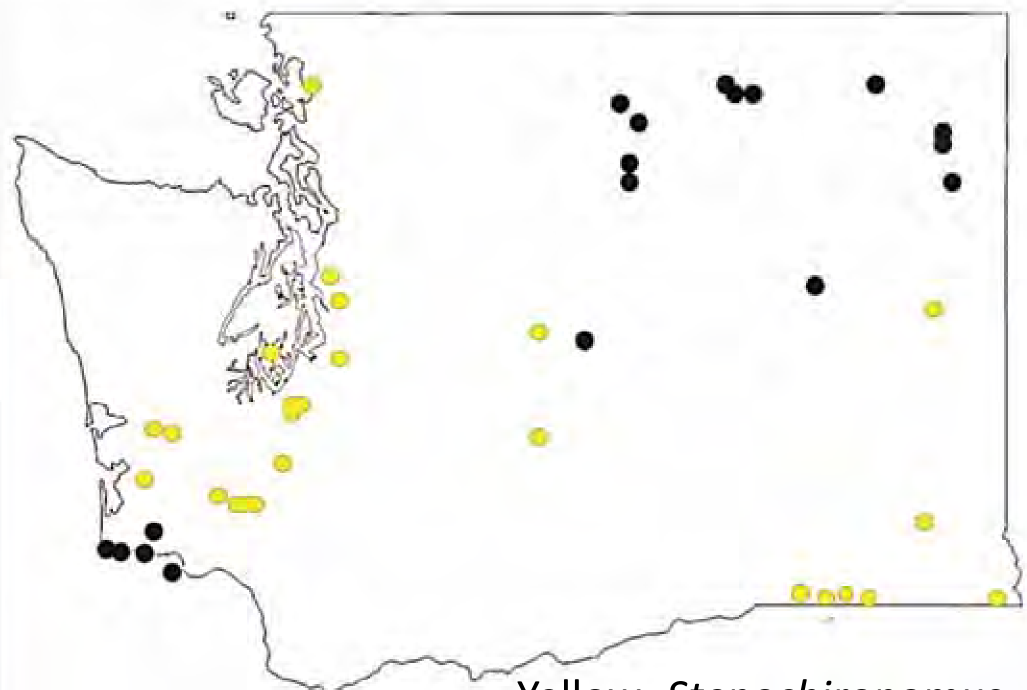

Yellow=*Stenochironomus*
Black=*Constempellina sp.C*

Habitat
New and Provisional

Orthocladiinae

- Most diverse subfamily in morphology of larvae and pupae
- Some genera differ only in a single life stage

L-R, top-bottom: *Heterotanytarsus* sp., *Metriocnemus fuscipes*, *Orthocladius lignicola*, *Psectrocladius psilopterus* gr.

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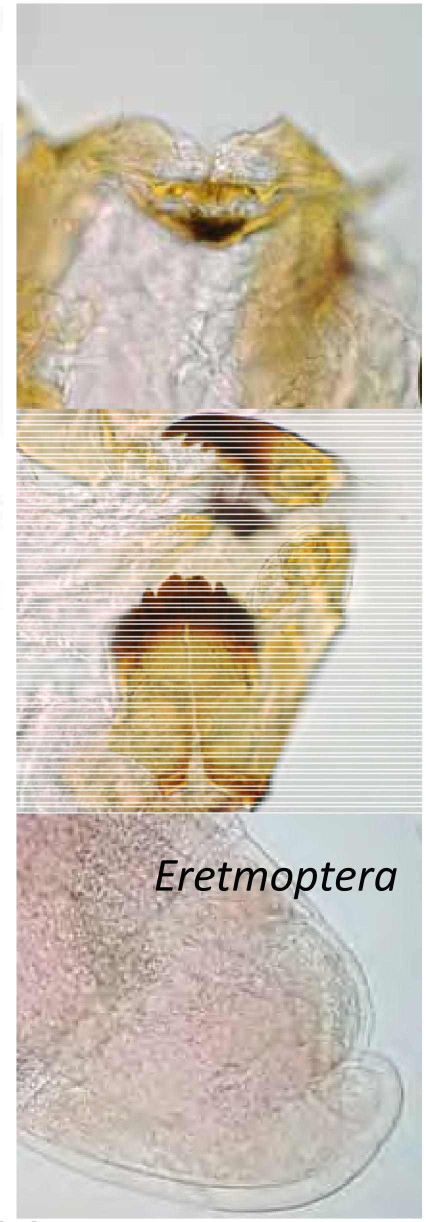

Eretmoptera Schaeffer Map

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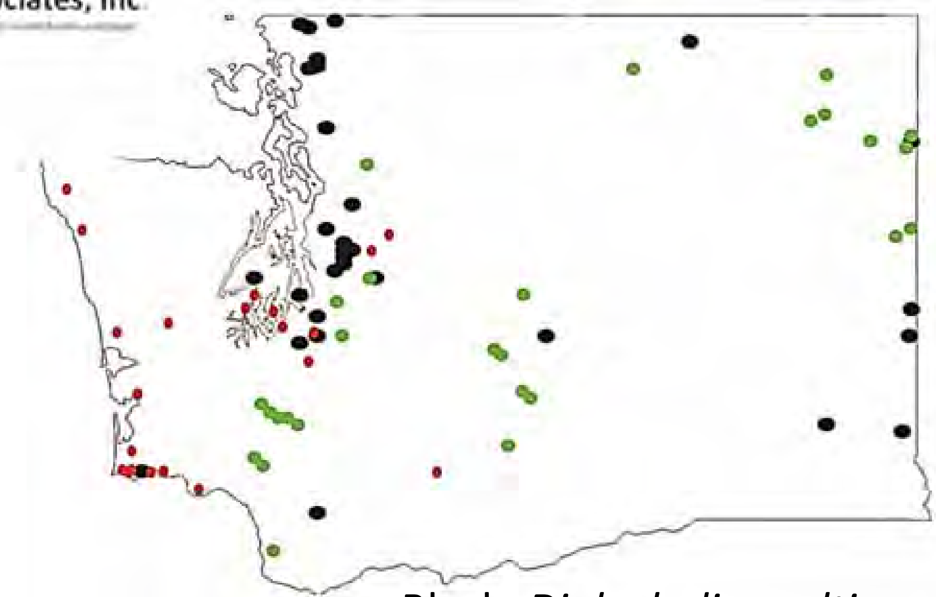


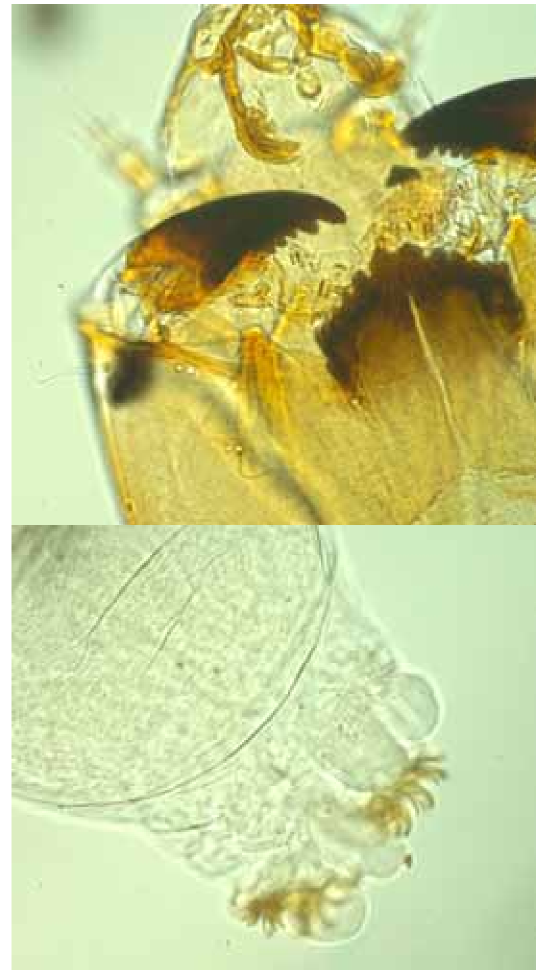
Black=*Diplocladius cultiger*
Red=*Heterotanytarsus*
Green=*Lopescladius*

Rheophile
Psammonphilic

Biomonitoring in western NA regularly turns up an unusual larva

Orthocladiinae (RAI #0018)

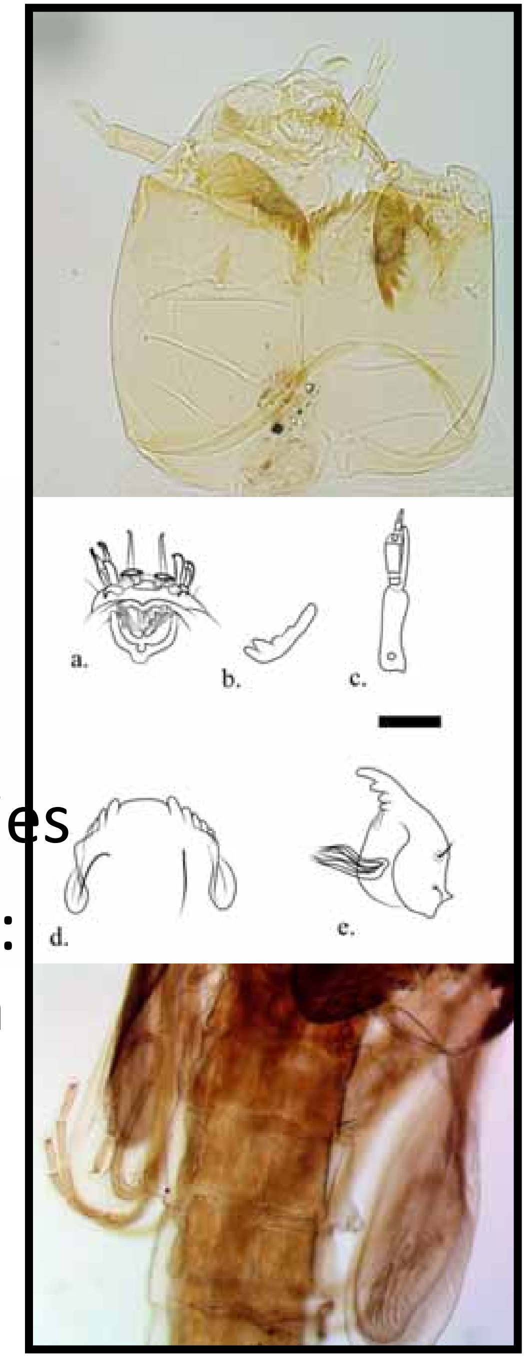
Orthocladiinae (RAI #0004)



Orthocladiinae (RAI #0016)

Oropuella Fasbender

- Collect, Associate, Describe
- One named male species, two unassociated female morphospecies
- Accepted, in revision, *Chironomus*: Journal of Chironomidae Research



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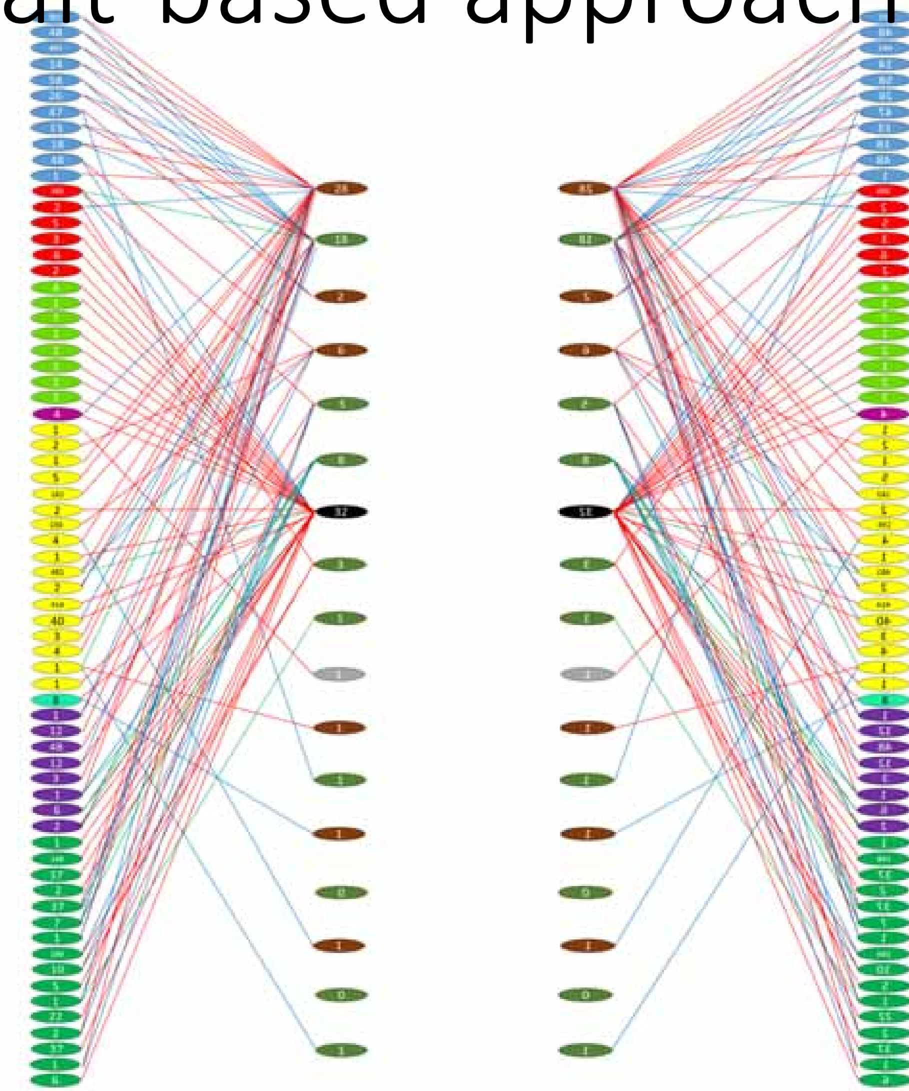
Eukiefferiella

- The genus has eight species groups recorded from North America
- **But only six named species**.
- The species groups are based on associations between larvae and adults for the European fauna and to a lesser extent eastern NA (Bode 1983).
- These groups do not always hold up in the Western US.
- Associations, description of new species, and keys are required to solve this.

Headcapsules
E. tirolensis, E. claripennis

Two species of
Eukiefferiella

Importance of data: trait-based approaches



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Conclusions

- Many of the new records are common taxa such as types of *Cricotopus* and *Eukiefferiella*
- Represents a gap in publishing databases rather than gaps in sampling and identification
- Some new records result from new taxonomic discoveries and provisional taxa
- More work needs to be done to resolve taxonomic questions.
- Autaxonomy and autecology are both necessary to inform and drive research in basic and applied aquatic ecology.

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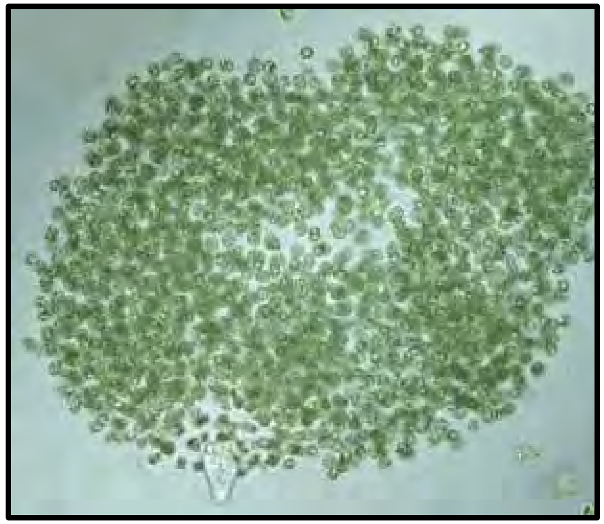
Acknowledgments

Thanks to our clients:
City of Bellevue
City of Bellingham
City of Bainbridge Island
City of Bothell
City of Federal Way
City of Issaquah
City of Kirkland
City of Redmond
King County
Pierce County
Seattle Public Utilites
Snohomish County Public Utilities Division
Vashon Nature Center, LLC
Washington State Department of Ecology

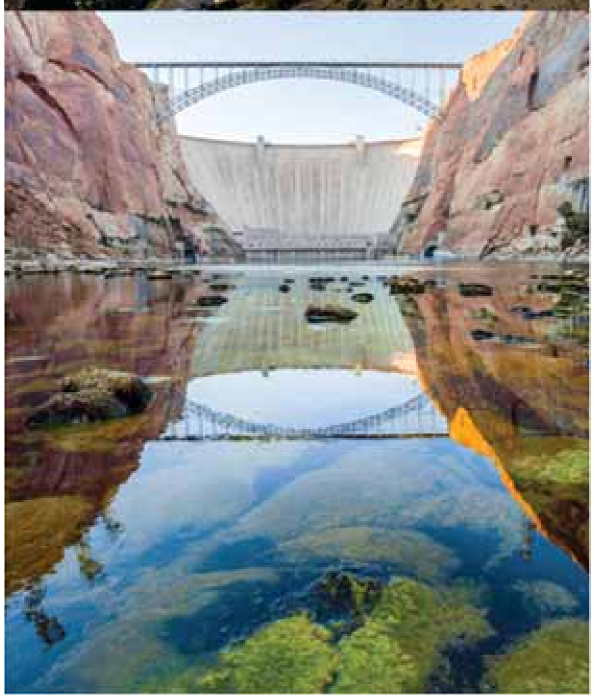
DOWNSTREAM DYNAMICS OF RESERVOIR-BORN CYANOBACTERIAL BLOOMS IN THE KLAMATH RIVER, CA



Laurel Genzoli[1], Jacob Kann[2], Susan Fricke[3],
Matt Hanington[4], Crystal Robinson[5]

[1]University of Montana, [2]Aquatic Ecosystem Sciences, LLC., [3]Karuk Tribe Department of Natural Resources, [4]Yurok Tribe Environmental Program, [5]Quartz Valley Indian Reservation Environmental Department

2019 PNW SFS, Newport Oregon



Dams can change productivity and species assemblages downstream

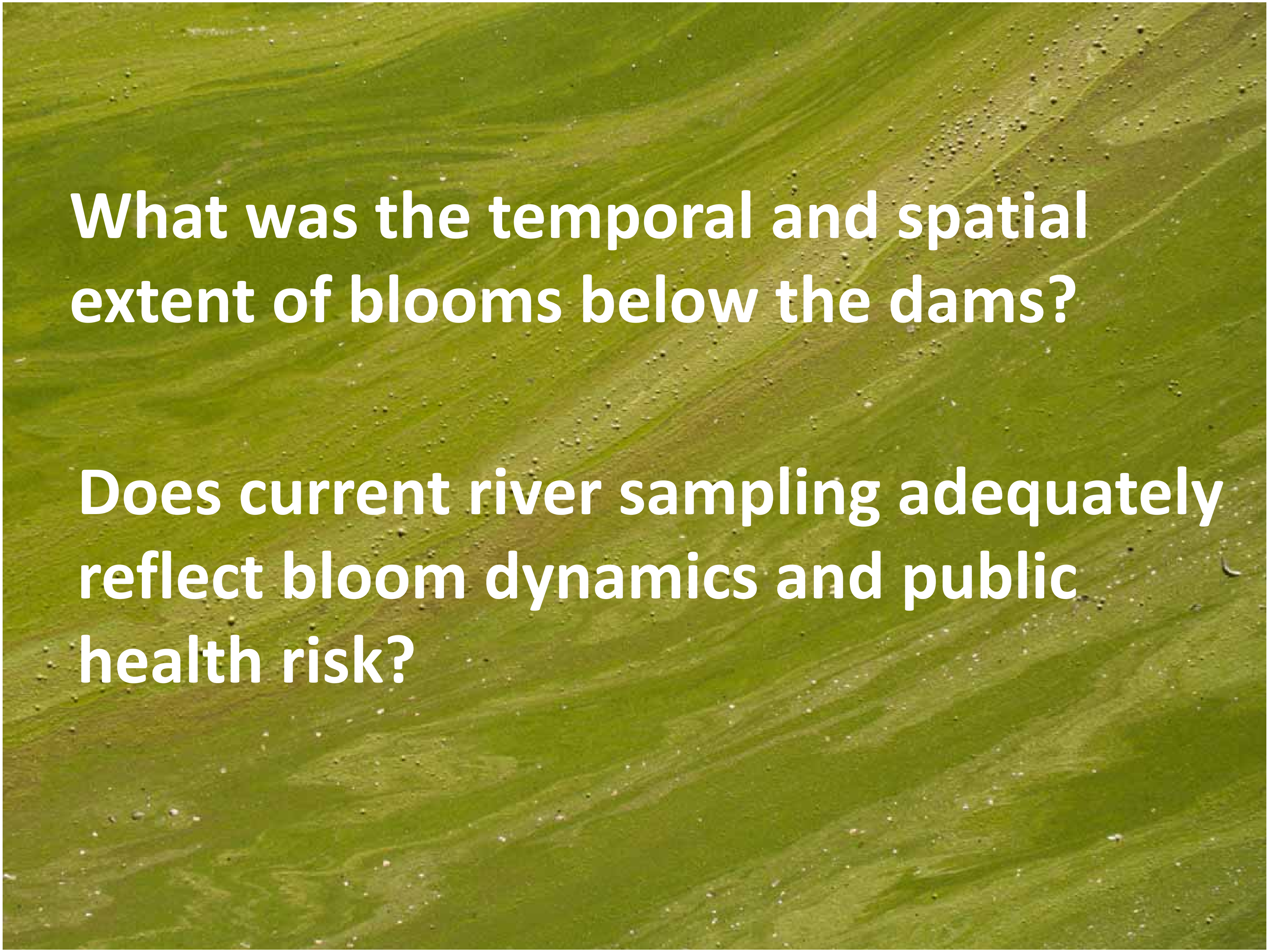
Predictions about how downstream rivers are affected depends on how a dam is designed and operated:

1. Hypolimnetic release
2. Epilimnetic release

Klamath River planktonic cyanobacterial blooms

Transported from epilimnion of reservoirs with:

- High N and P concentrations
- High water temps
- Increased water residence time

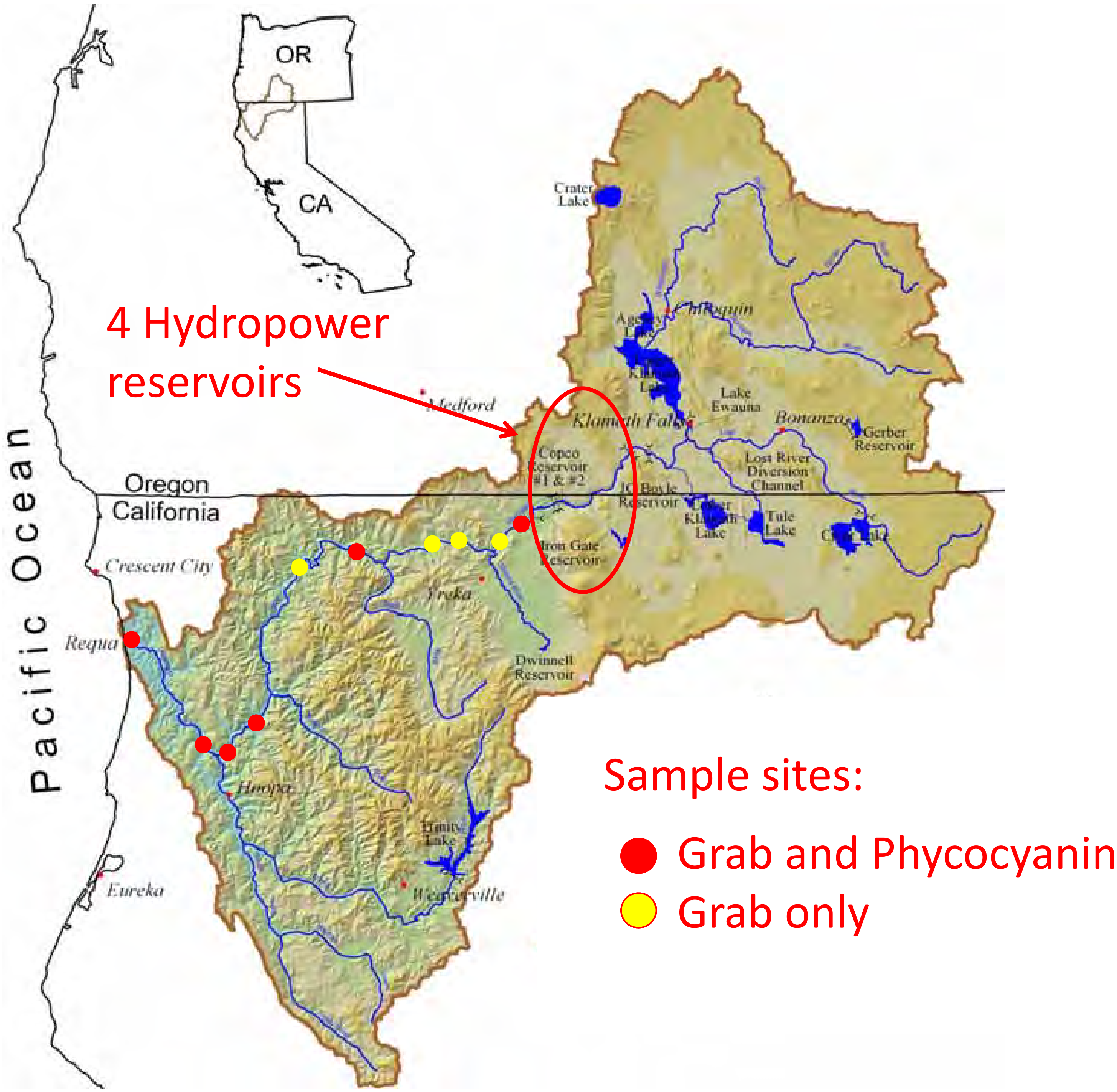


What was the temporal and spatial extent of blooms below the dams?

Does current river sampling adequately reflect bloom dynamics and public health risk?

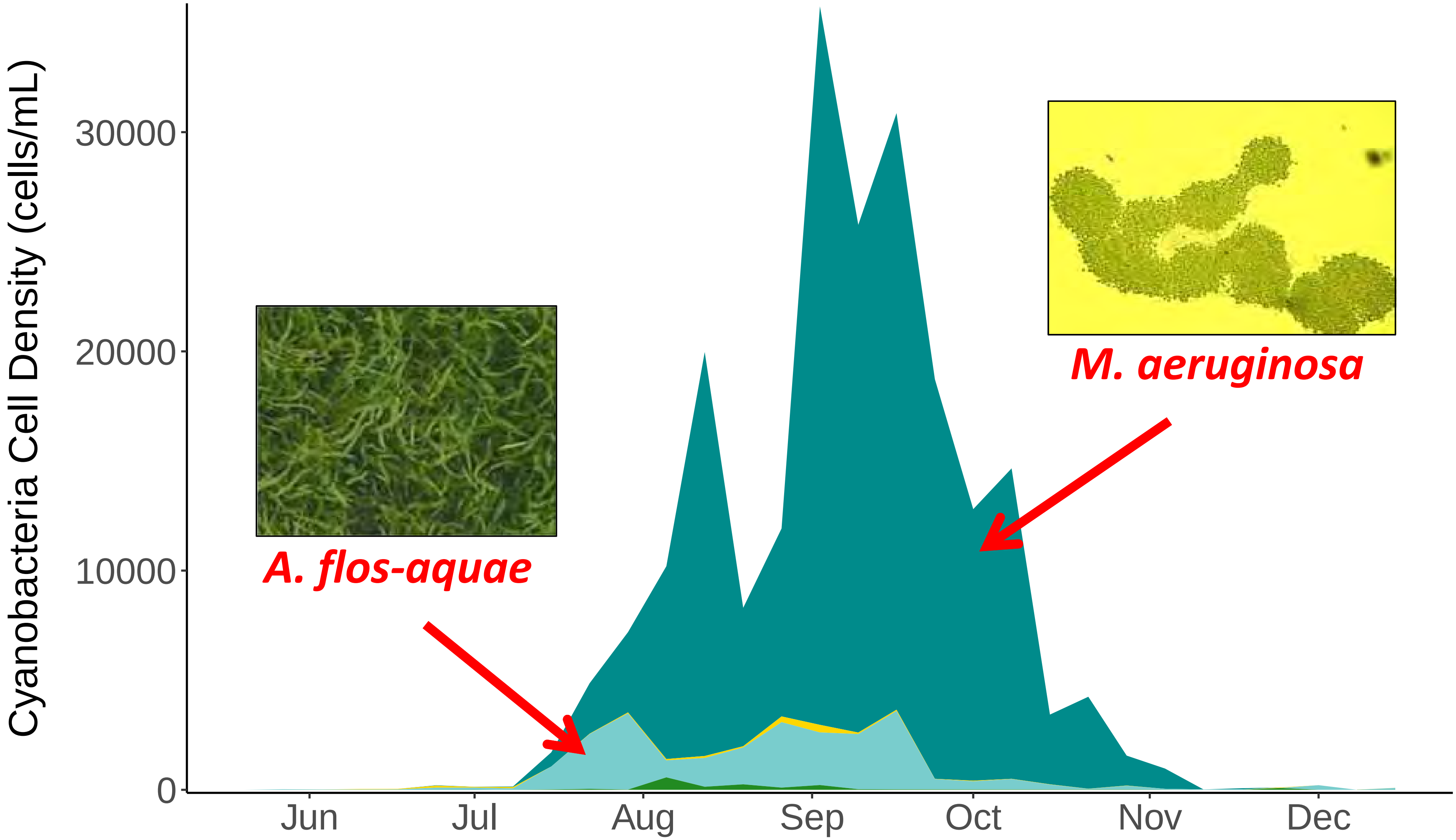
Tribal natural resource depts. collect water quality and public health samples (2009-2017)

- 12 sites spanned >300 river km
- Grab samples collected every 1-4 wks
  - Species ID and cell density
  - Microcystin toxin concentration
- Phycocyanin sensors collect data every 30-m (6 sites)

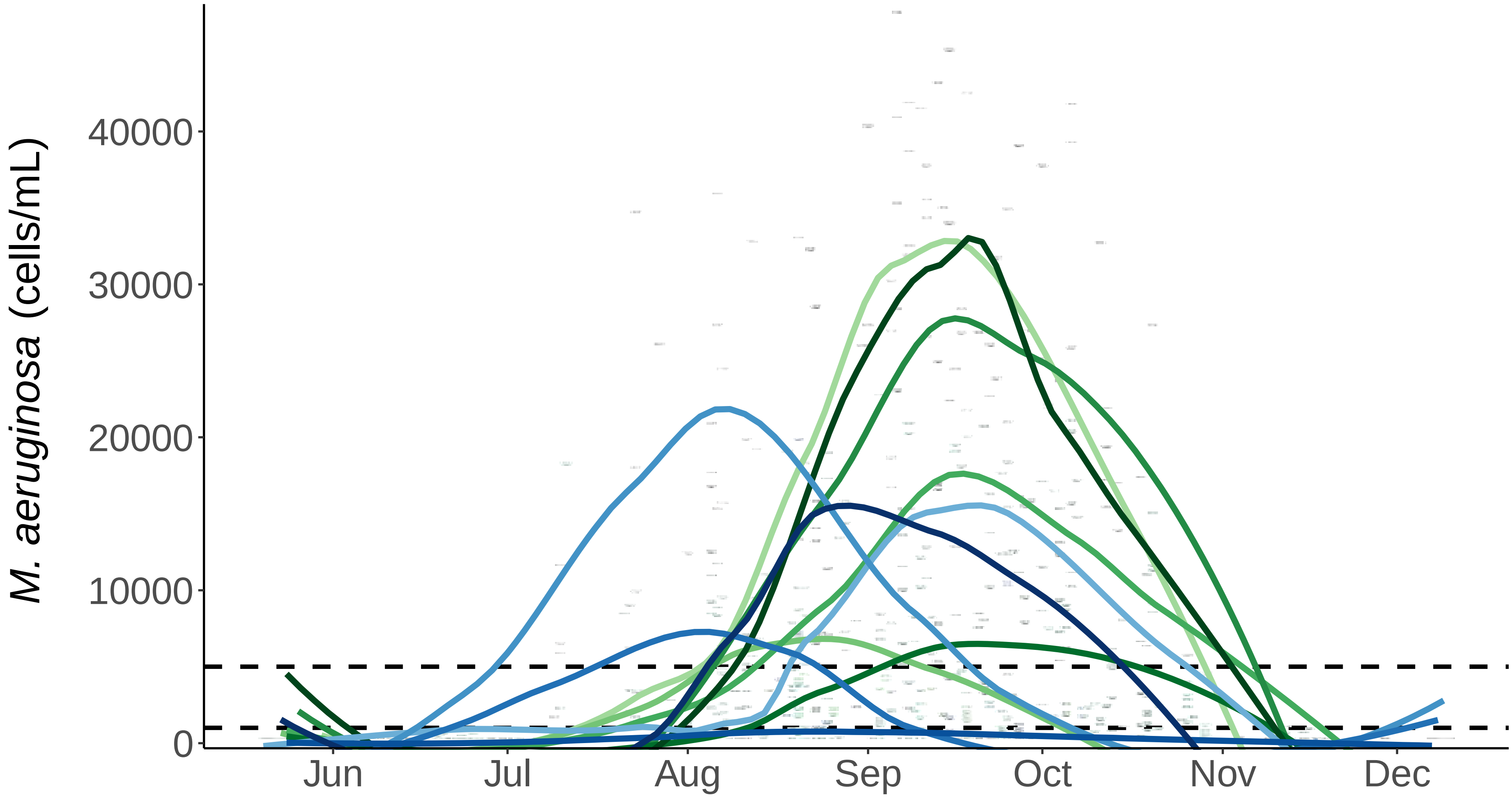

4 Hydropower reservoirs
Sample sites:
Grab and Phycocyanin
Grab only
OR
CA
Oregon
California
Pacific Ocean
Crescent City
Requa
Eureka
Hoopa
Yreka
Dwinnell Reservoir
Iron Gate Reservoir
Copco Reservoir #1 & #2
JC Boyle Reservoir
Crater Lake
Lake Ewauna
Bonanza
Gerber Reservoir
Lost River Diversion Channel
Tule Lake


What was the temporal and spatial extent of blooms below the dams?
Does current river sampling adequately reflect bloom dynamics and public health risk?

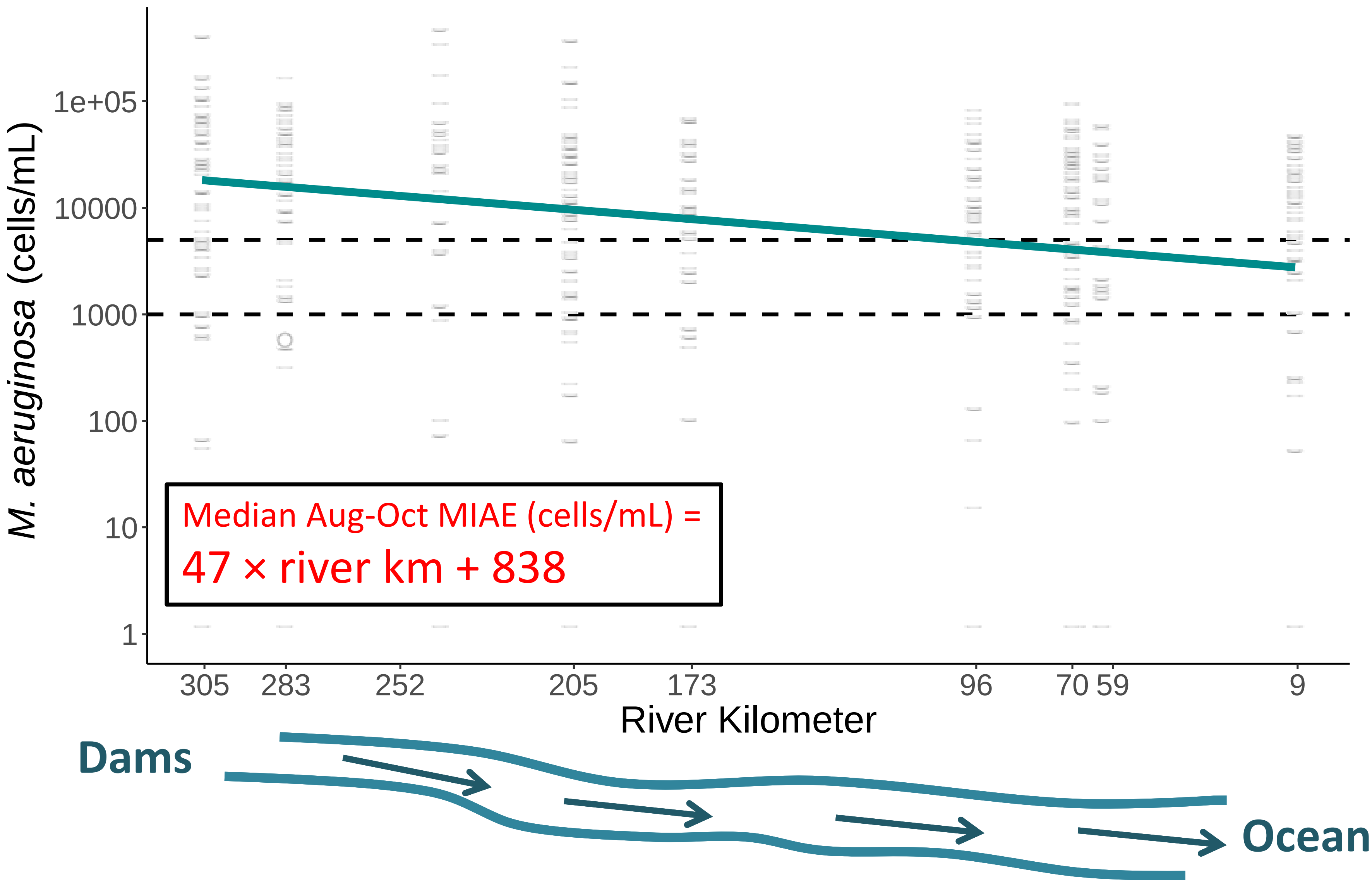
Microcystis aeruginosa dominated blooms

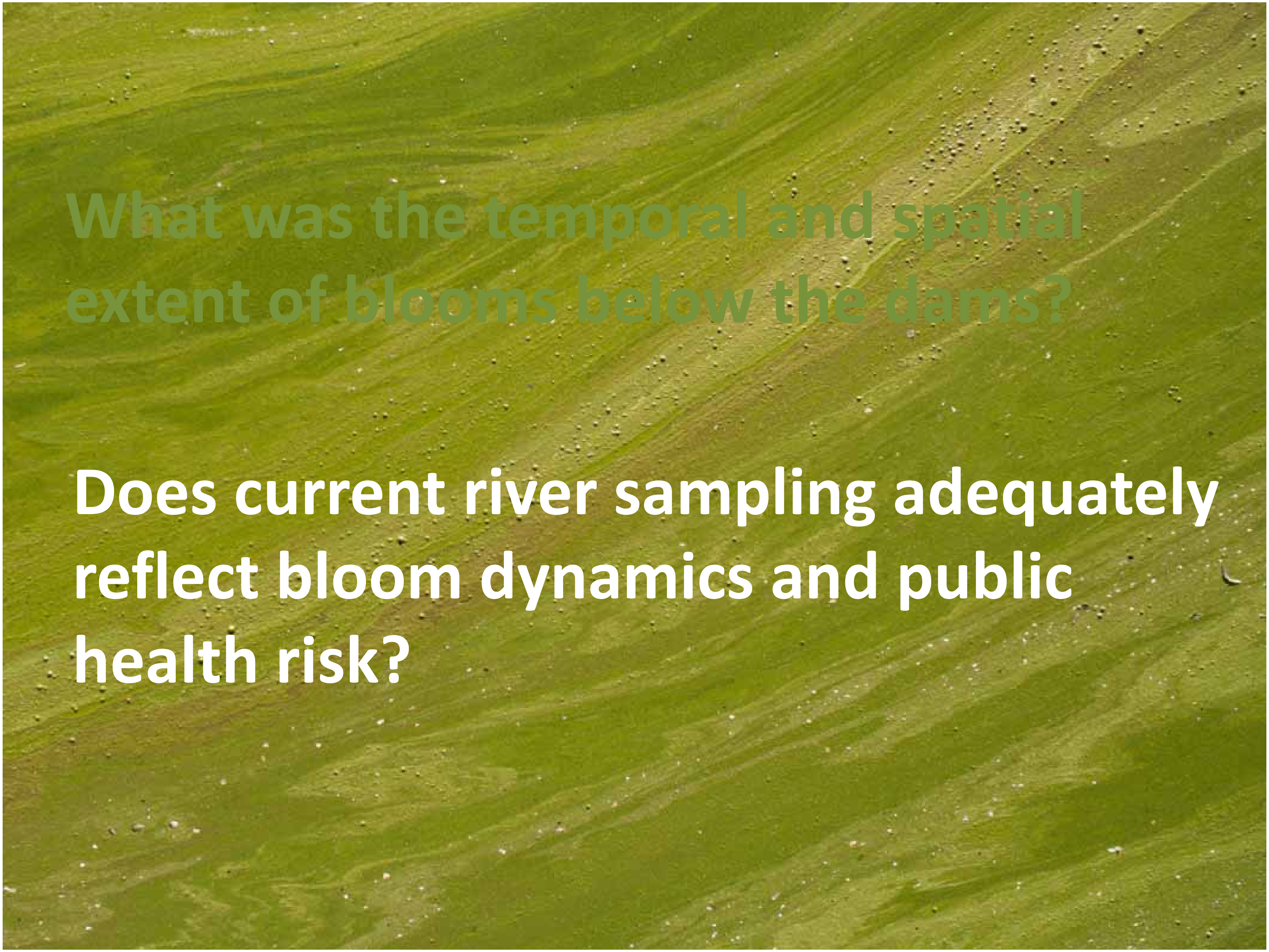


M. aeruginosa blooms occurred in late summer during every year of the study (2005-2017)



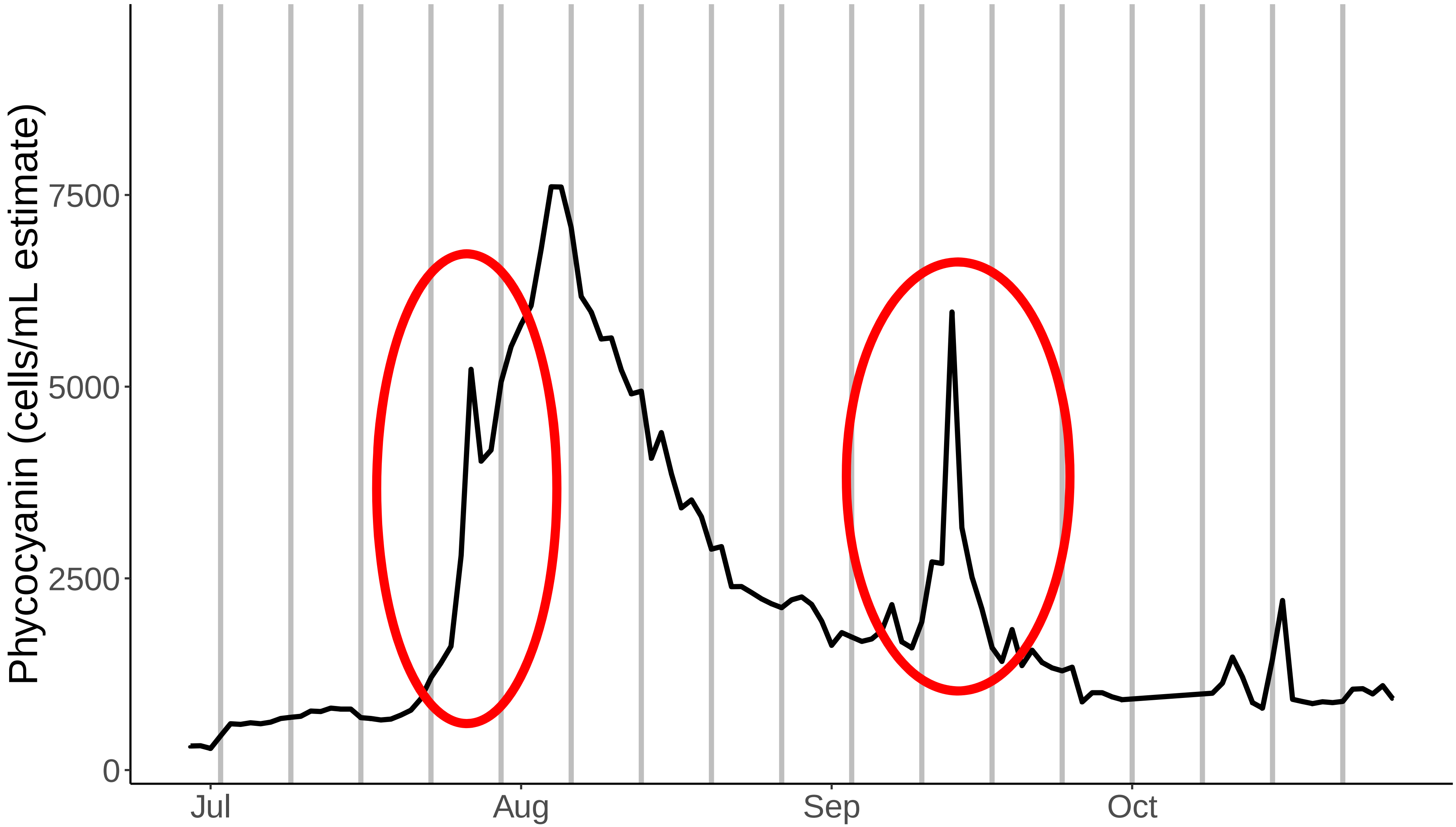
Reservoir blooms present in river > 300 kilometers below source



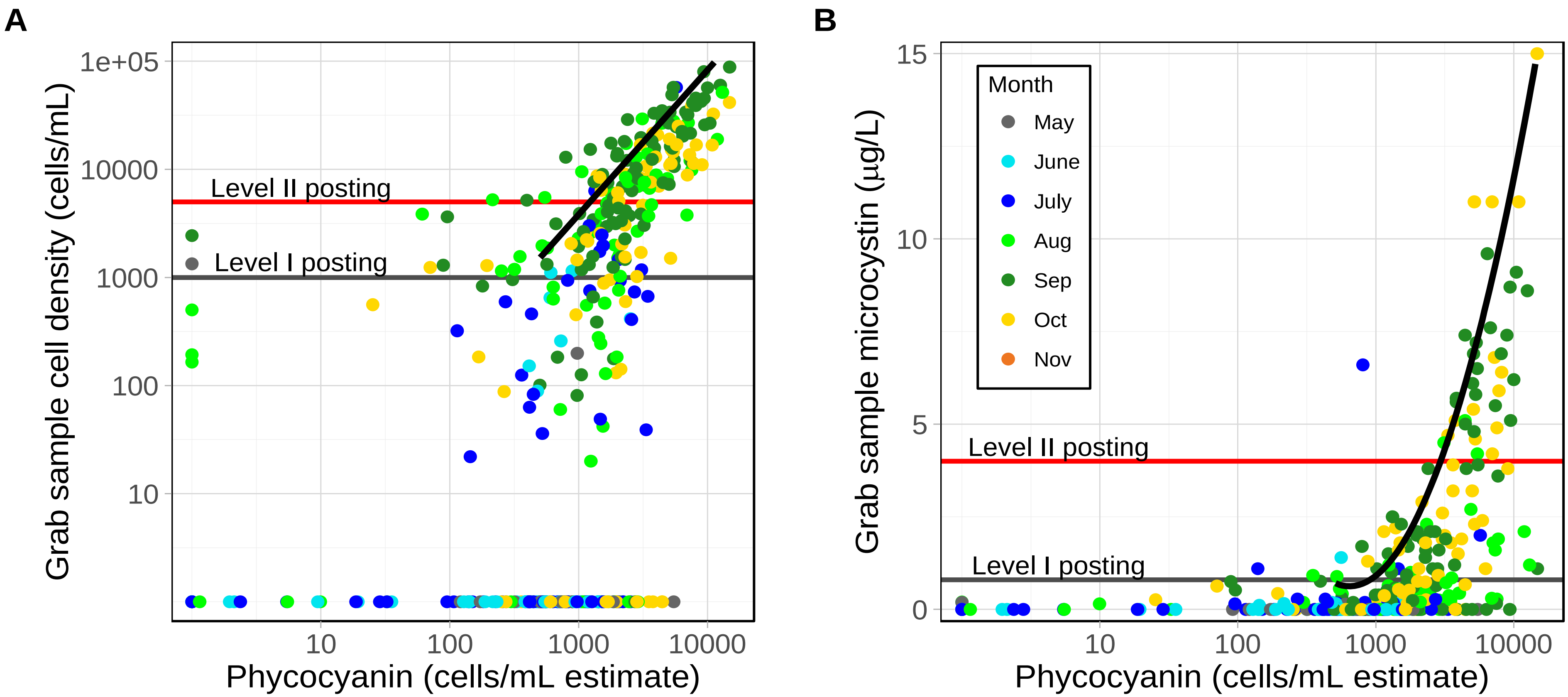

What was the temporal and spatial extent of blooms below the dams?
Does current river sampling adequately reflect bloom dynamics and public health risk?

We analyzed 30-minute phycocyanin data & deployed automated samplers

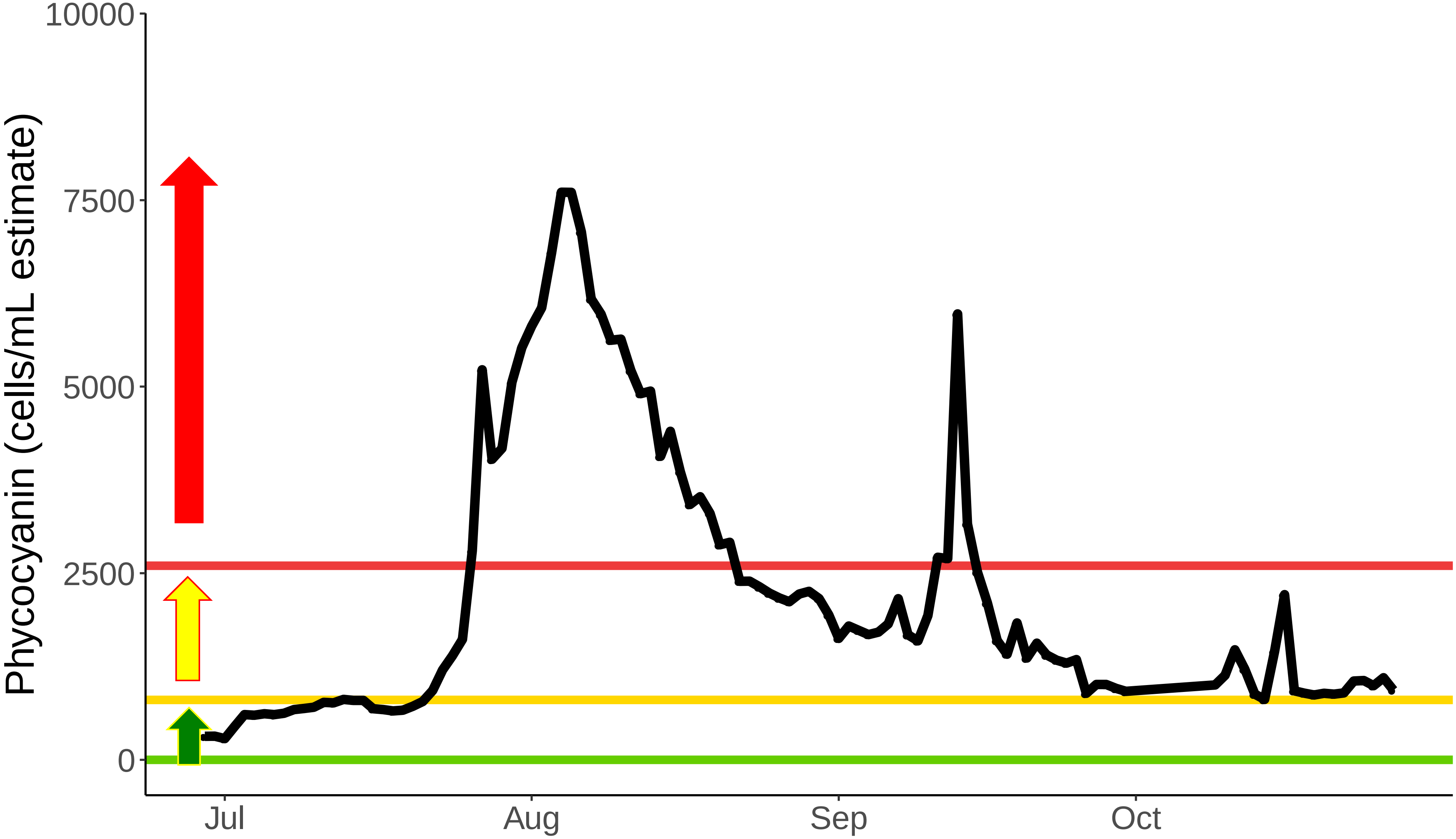
Mean daily phycocyanin varied varied between weekly grab samples



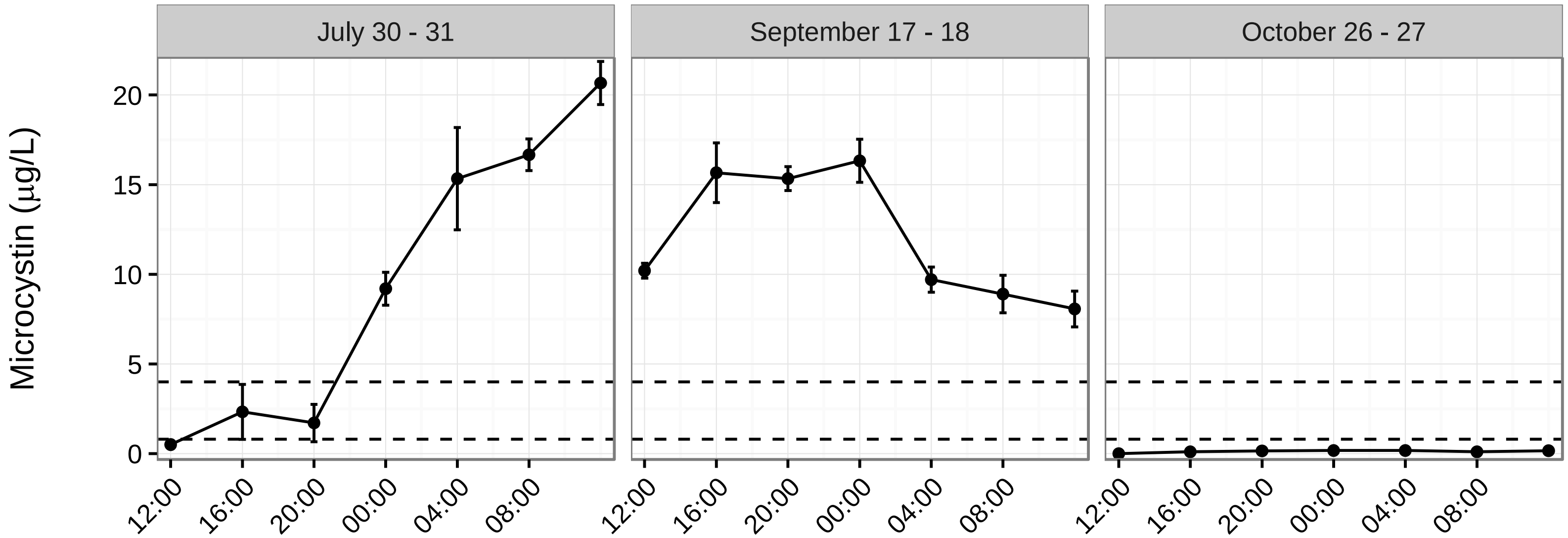
Phycocyanin data was related to grab sample cell densities and toxin concentrations



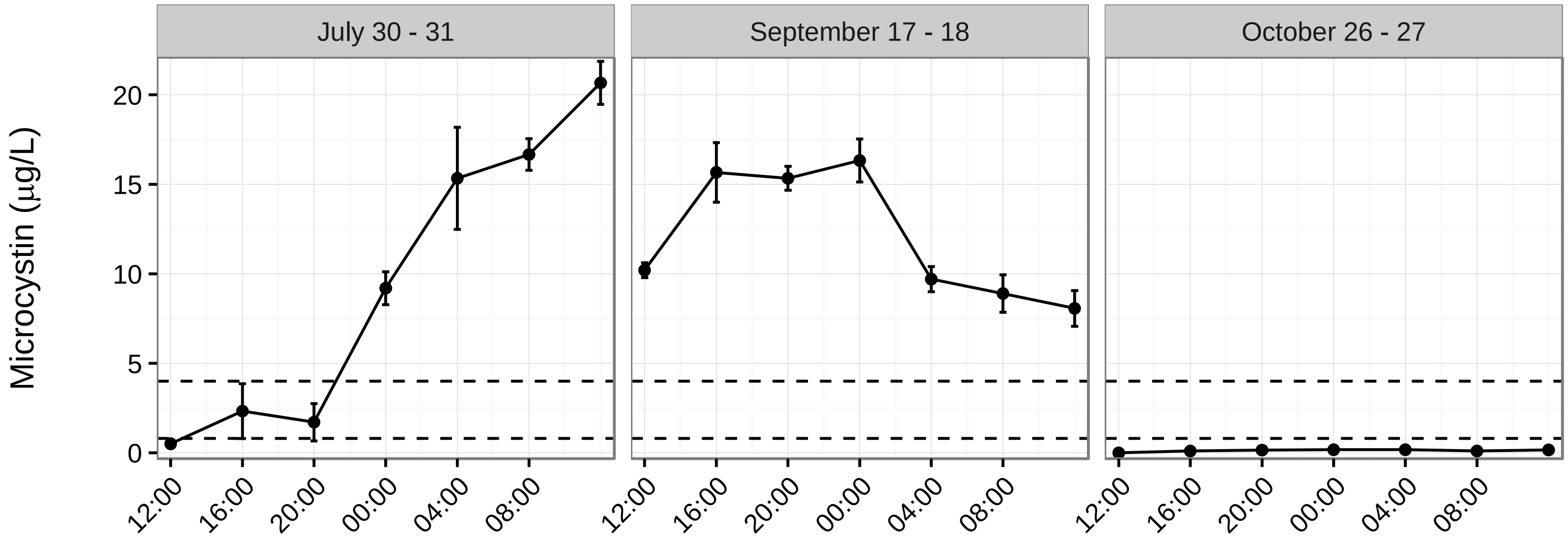
Use real-time phycocyanin data for early warning of changing river conditions



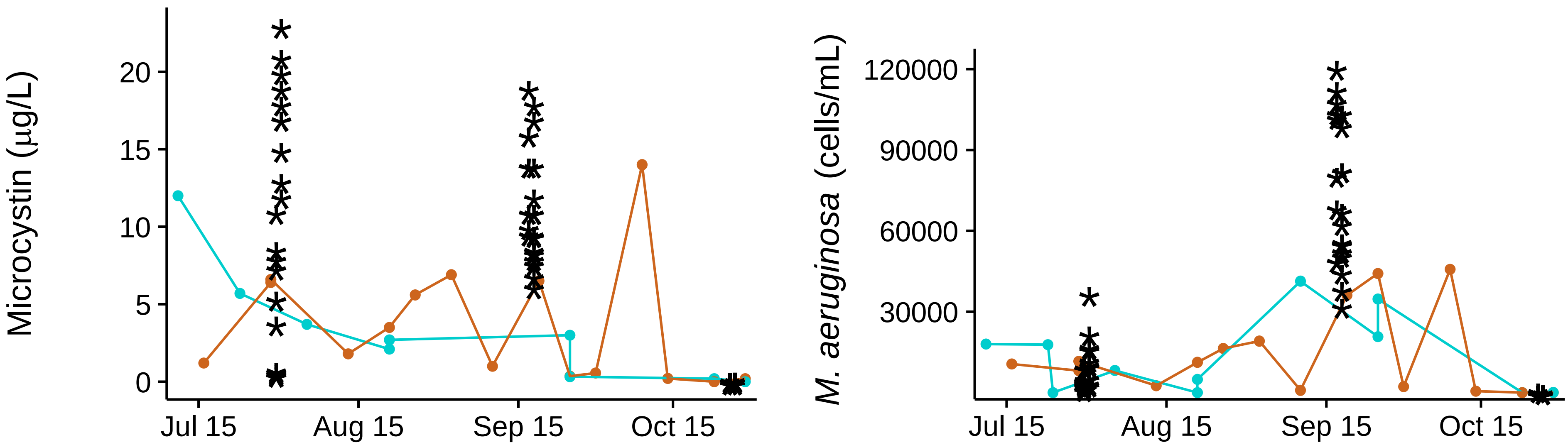
M. aeruginosa cell density and microcystin toxin concentration can be highly variable within 1-day



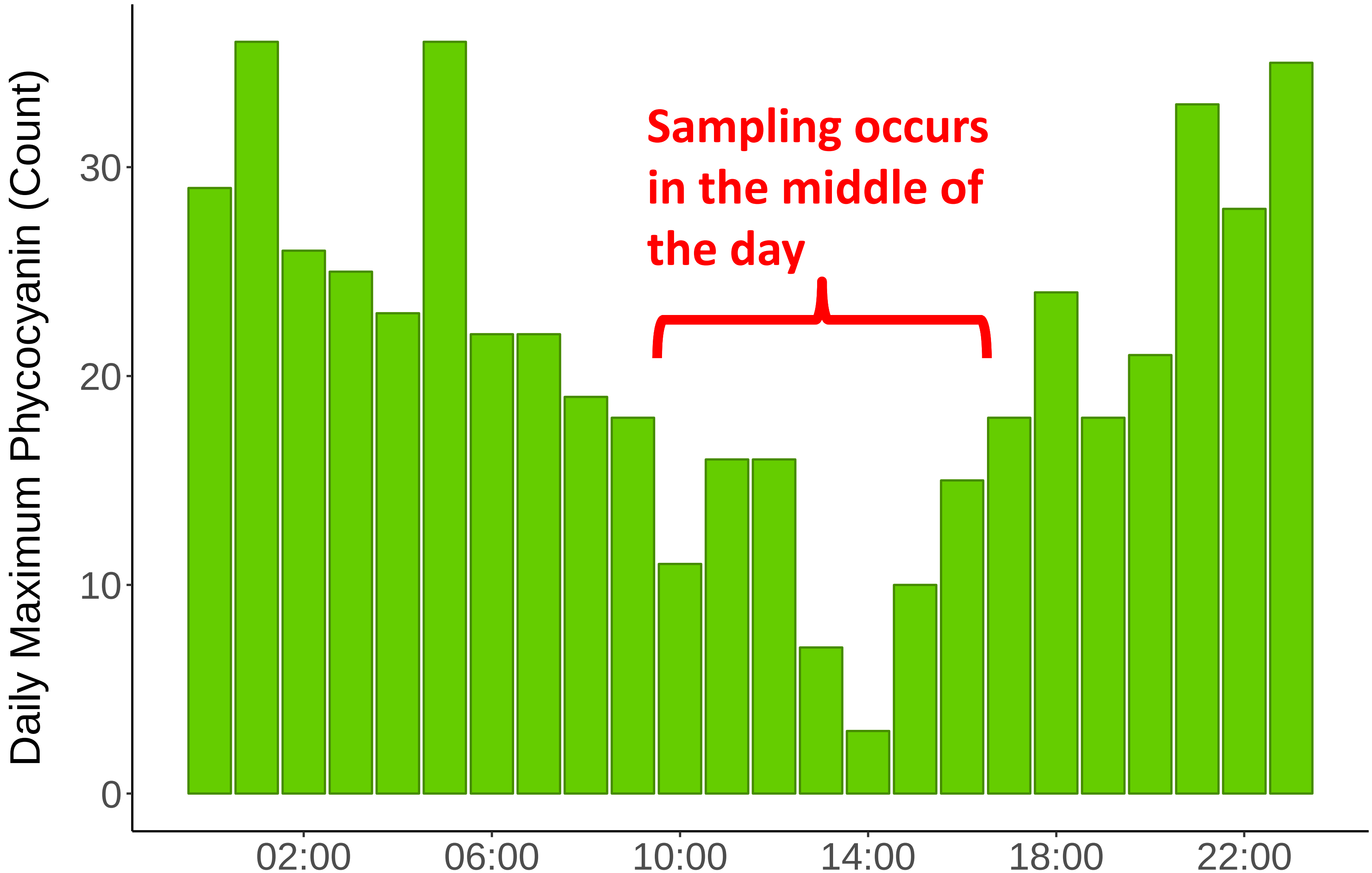
M. aeruginosa cell density and microcystin toxin concentration can be highly variable within 1-day

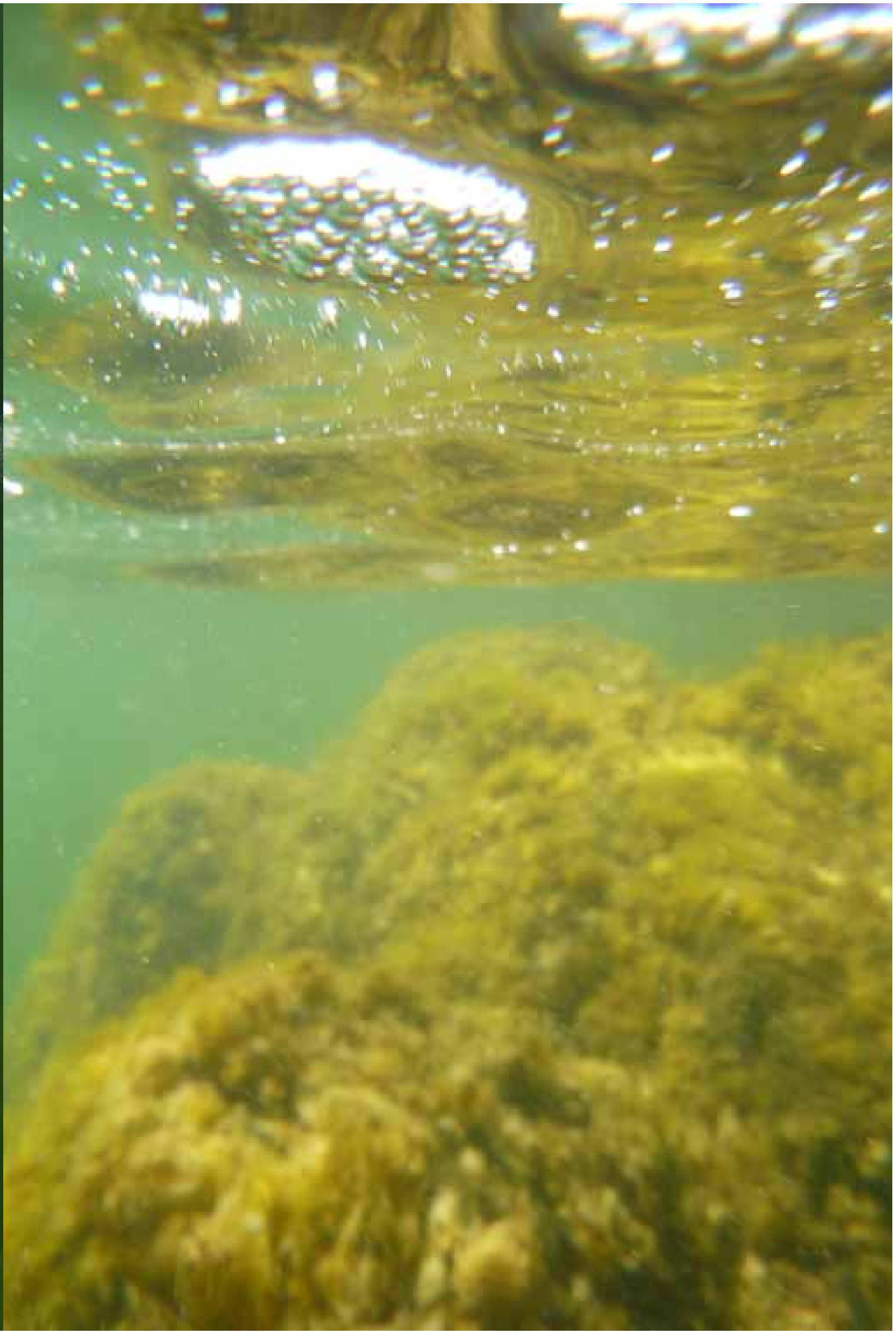


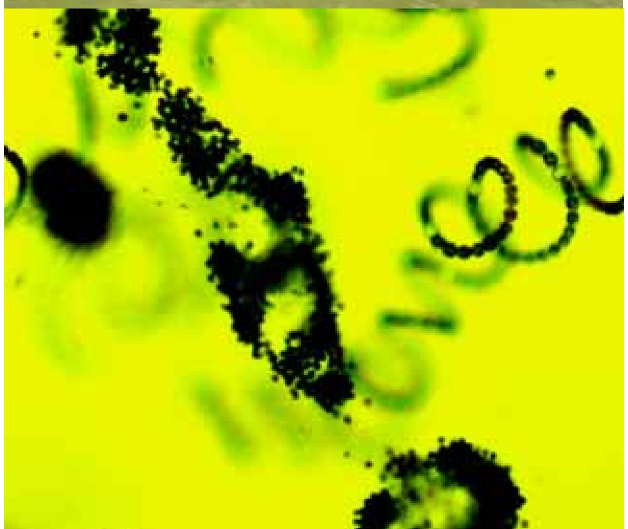
High daily variability was often not reflected in weekly samples



Standard grab samples are collected during potentially low cyanobacteria conditions




Conclusions

- Planktonic blooms can affect high-gradient rivers below lakes or reservoirs; *M. aeruginosa* was above public health thresholds each summer > 300 km below the source

- Weekly sampling does not adequately capture public health risk due to within-day variation and rapid changes between weekly sampling periods; real-time data can help fill this gap


Questions

Oregon DEQ Water Quality Program

Testing a new method for early detection of harmful algal blooms in Oregon lakes and reservoirs

November 7, 2019
Pacific Northwest Society for Freshwater Science Meeting
Newport, OR

Dan Sobota, Steve Hanson, Brian Fulfrost, Smita Mehta, and Sam Doak | Oregon Department of Environmental Quality
Victoria Avalos and Lara Janson | Environmental Sciences and Management Department, Portland State University

What are Harmful Algal Blooms?

- Excessive growth of aquatic plants (algae)
- Occur in marine and freshwater systems
- Cyanobacteria (blue-green algae) of most concern currently for rivers, lakes, and reservoirs in Oregon

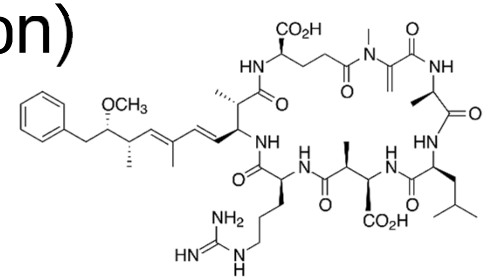
DEQ State of Oregon Department of Environmental Quality

Why do Harmful Algal Blooms matter in Oregon?

- Can be toxic to humans, pets, livestock, and fish
- Cause undesirable and degraded environmental conditions
- Impacts drinking water, recreational opportunities, agricultural production, fisheries, local economies, and aquatic habitats

Notable Cyanotoxins

- Hepatotoxins (disrupt liver function)
  - Microcystin
  - Cylindrospermopsin
  - Nodularin



- Neurotoxins (disrupt nervous system)
  - Anatoxin-a
  - Saxitoxin
- Dermatoxins (skin reactions)
  - Lyngbyatoxin-a
- BMAA (β-Methylamino-L-alinine)
  - May be linked to neurodegenerative disorders
- Other compounds with lesser known/unknown effects

Advisory Levels in Oregon

Recreational Use Guidance Values:

Table 2. Health advisory RUVs for cyanotoxins in Oregon recreational waters (µg/L)

*RUVs**	*Microcystin*	*Anatoxin-a*	*Saxitoxin*	*Cylindrospermopsin*
	8	15	8	15

EPA and Oregon have established Health Advisory Levels for drinking water:

Cyanotoxin	For Vulnerable People (ppb)	For Age 6 and Above (ppb)
Total Microcystins	0.3	1.6
Cylindrospermopsin	0.7	3

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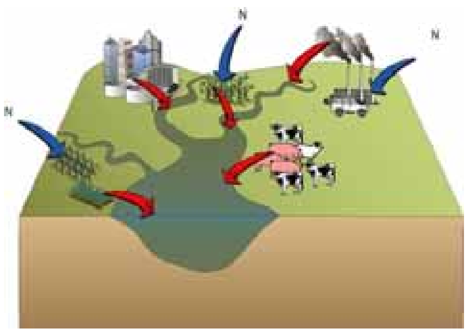
What causes Harmful Algal Blooms?



- High nutrient inputs
- Warm temperatures

- Slow-moving, stagnant, or stratified water

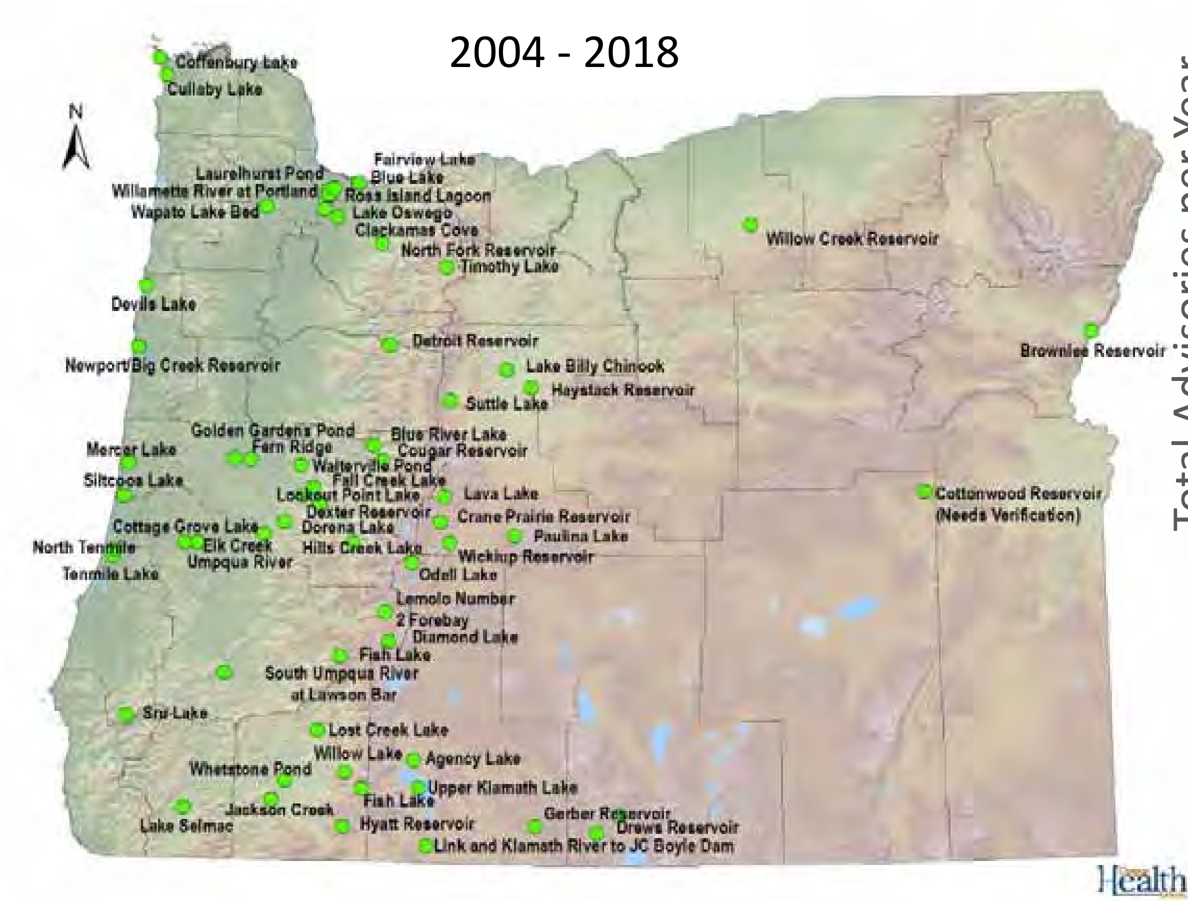
- Alteration of aquatic food webs
- **Can depend on the waterbody**

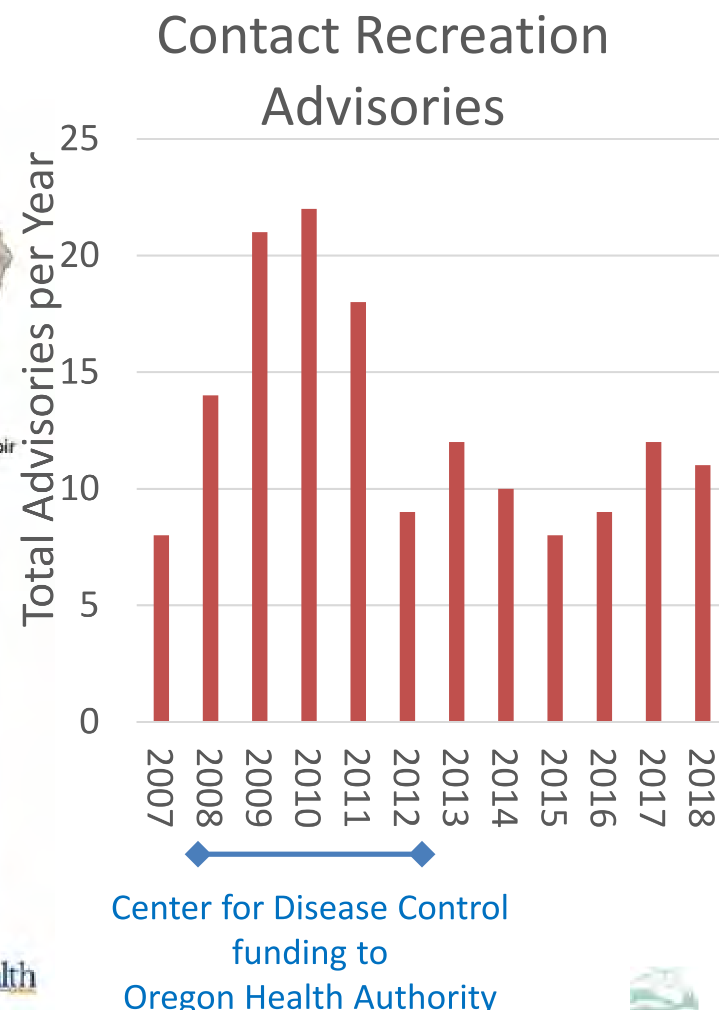
How do we currently detect Harmful Algal Blooms in Oregon?

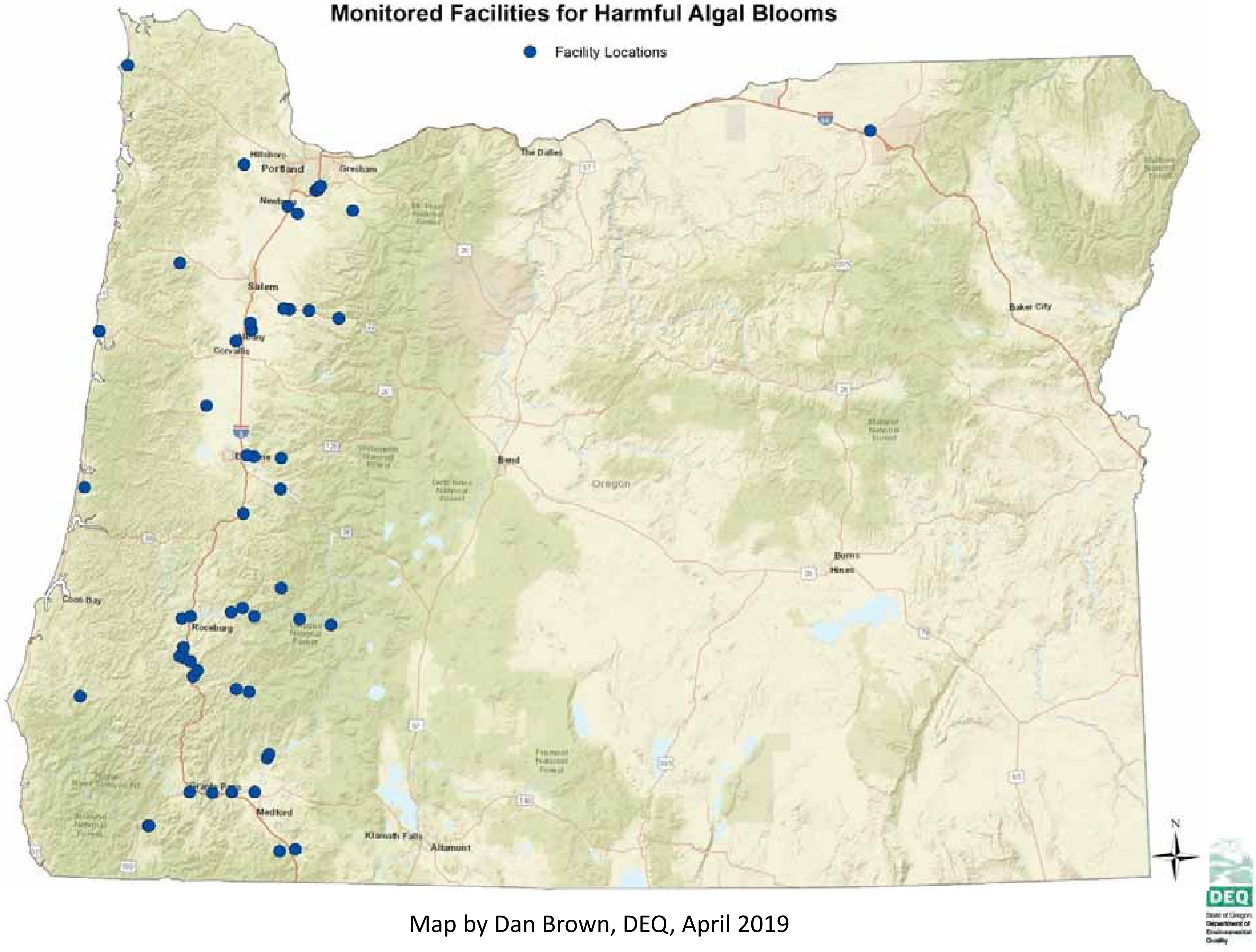
- Local reporting by lake managers or citizens:
  - Oregon Health Authority (OHA) – issue advisories
  - Oregon DEQ – tests samples and does follow-up monitoring
  - Other government entity – e.g., US Forest Service

- **New for 2019**: during routine monitoring of drinking water by municipalities

Where have Harmful Algal Blooms been documented in Oregon?







Map by Dan Brown, DEQ, April 2019

What can we do to improve statewide coordination on Harmful Algal Blooms?

- **Increase monitoring capacity to proactively detect blooms across the state**
- **Improve monitoring for the potential causes of blooms to identify waterbodies at risk**
- **Improve and increase public outreach**

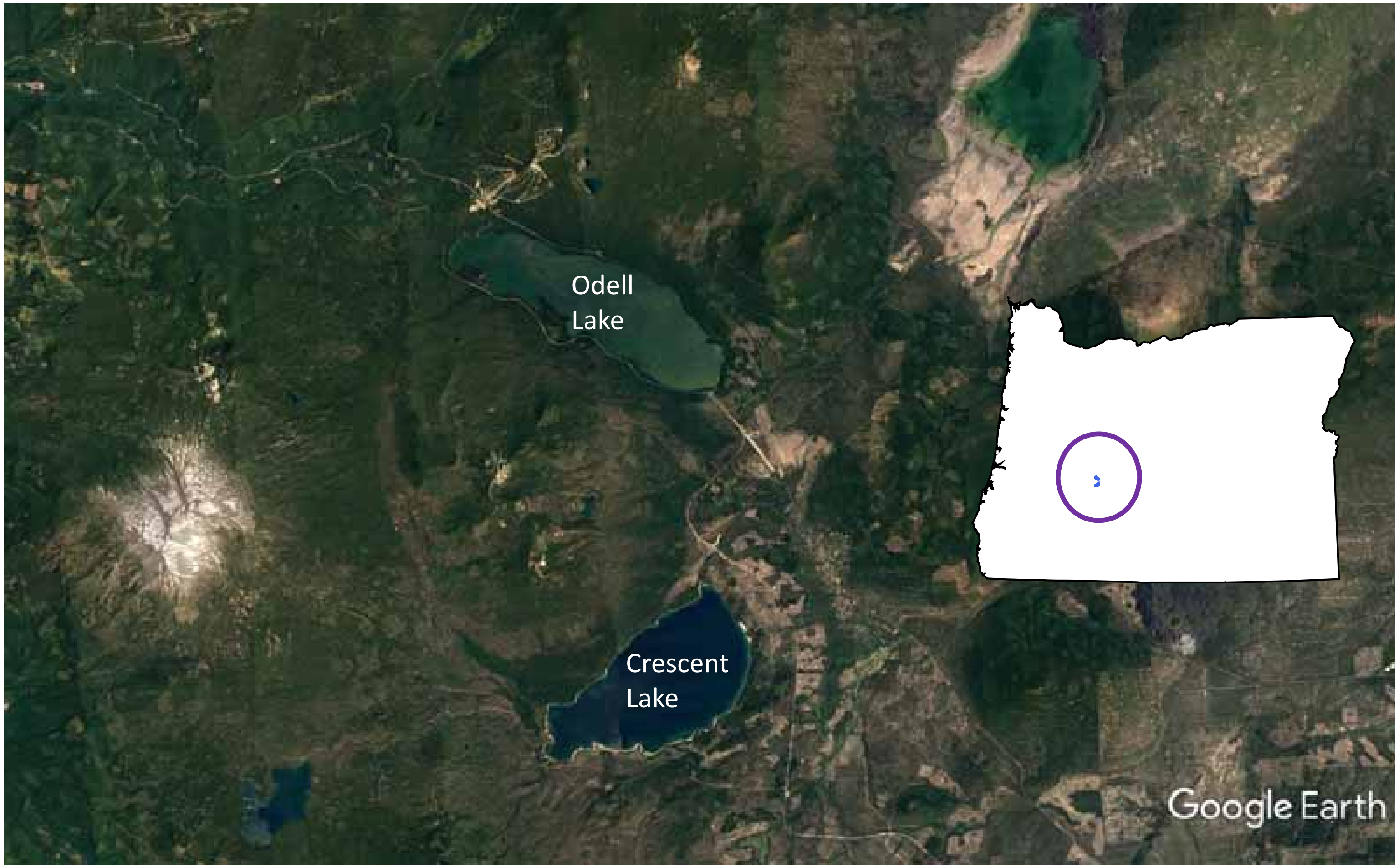
Pilot Project – Odell and Crescent Lakes

Project objectives

- Implement methods for detecting harmful algal blooms early
- Compare *in situ* monitoring data to satellite imagery
- Work with partners (US Forest Service and PSU) to monitor and investigate factors contributing to and characteristics of blooms

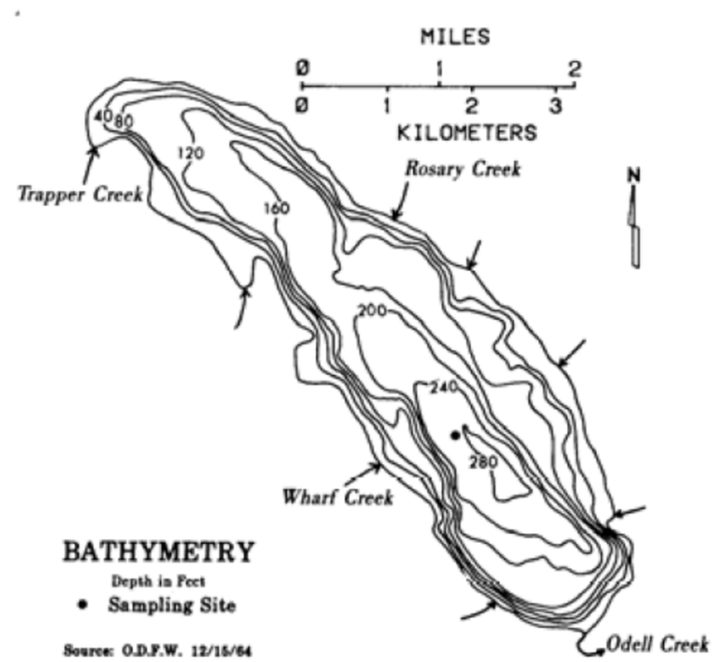
Why Odell and Crescent Lakes?

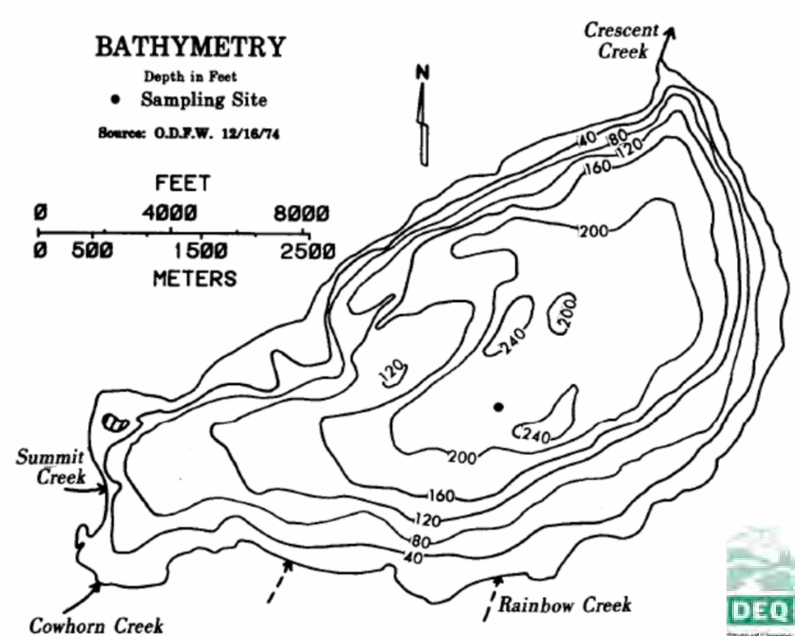
- Located near each other in central Oregon



Characteristics

- Both formed 10-12k ybp following glacial recession
- Odell is mesotrophic
    - History of recreational advisories
- Crescent is oligotrophic





Oregon Lakes Atlas 1985


ODELL LAKE
You will take the role of a fish.
If you make good decisions, you
can survive encounters with
various animals and learn about
your relationships to them.
Press SPACE BAR to continue

In situ monitoring

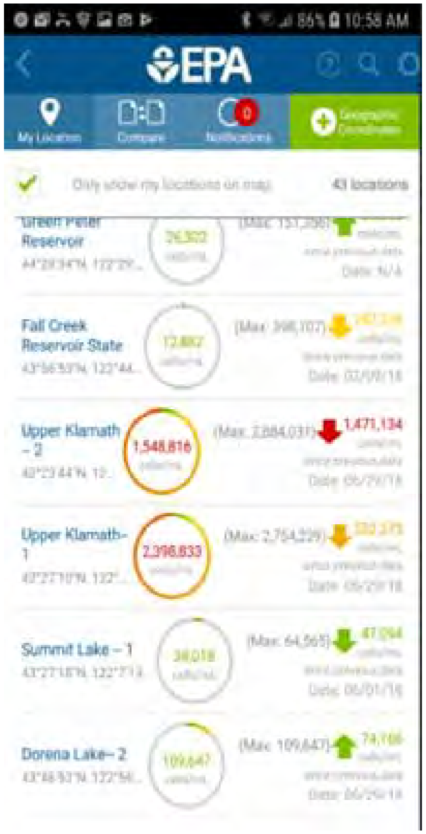
- Placed *in situ* monitoring devices to record (15 minute intervals):
  - Chlorophyll *a*
  - Phycocyanin (relative fluorescence)
  - Dissolved oxygen saturation
  - pH
  - Temperature

- Collected phytoplankton community, cyanotoxin, and nutrient data weekly to biweekly

- 26 June – 18 September 2019

Satellite imagery

- Cyanobacteria counts from EPA CyAN app (Google Play Store)
- Sentinel 3 satellite imagery converted to cell counts
- 300 x 300 m pixels
- Summarized at the lake level at 2 to 7 day intervals



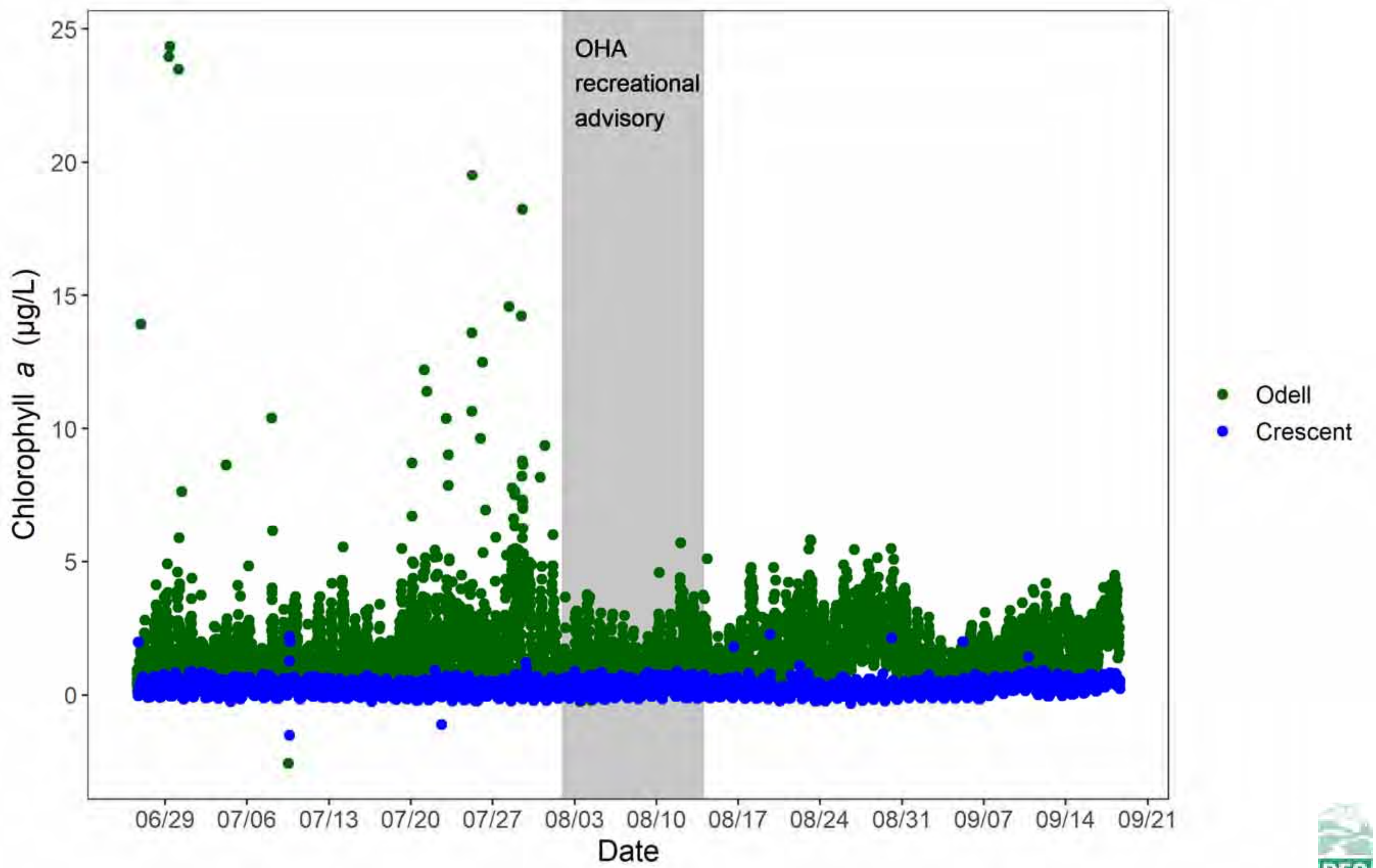
Odell Lake, summer 2019

- OHA issued a recreational use advisory for Odell Lake on August 2nd due to microcystin (14 μg/L)

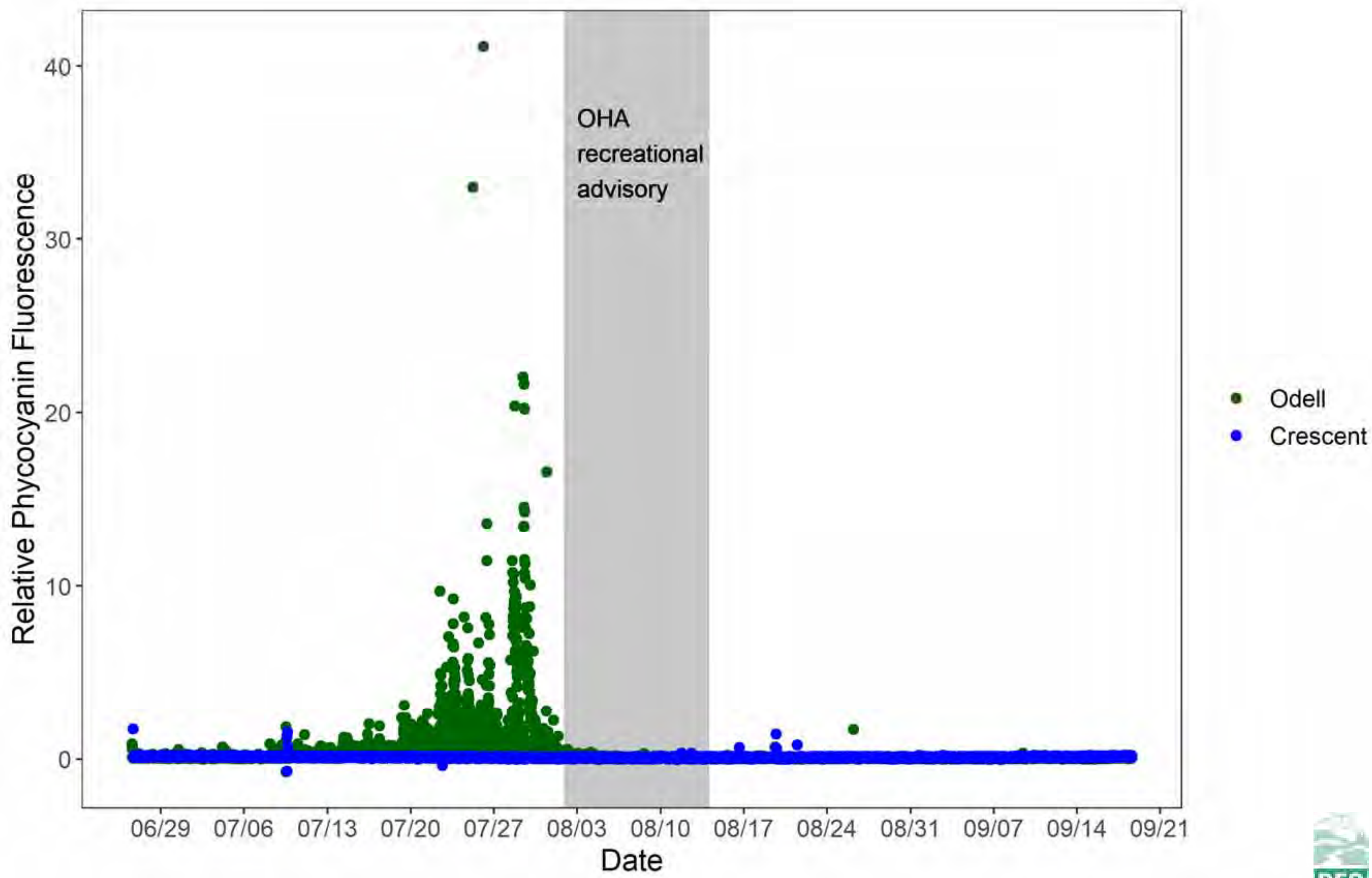
- Advisory lifted on August 14th

- No advisories on Crescent Lake

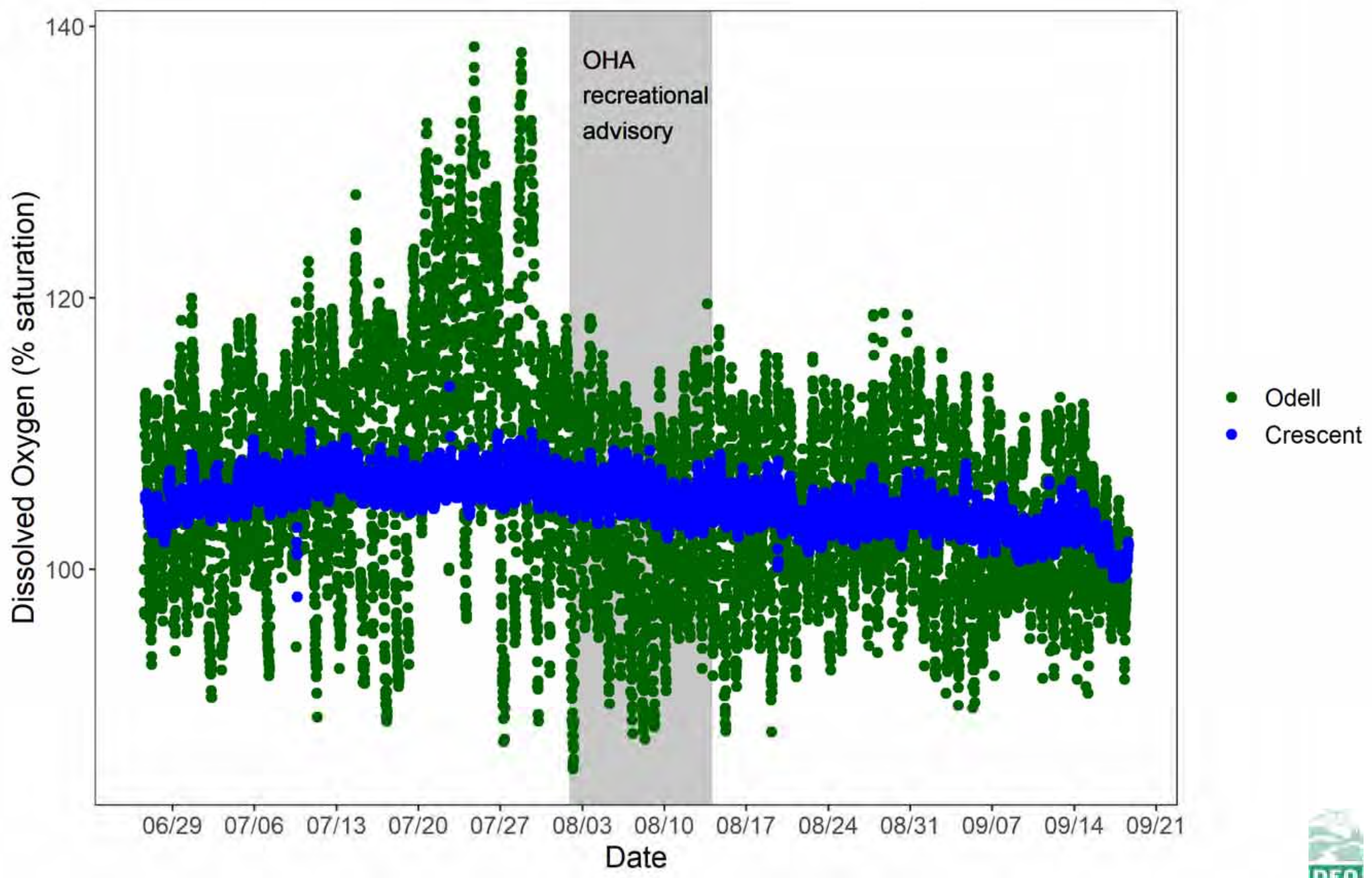
In situ monitoring – Chlorophyll *a*



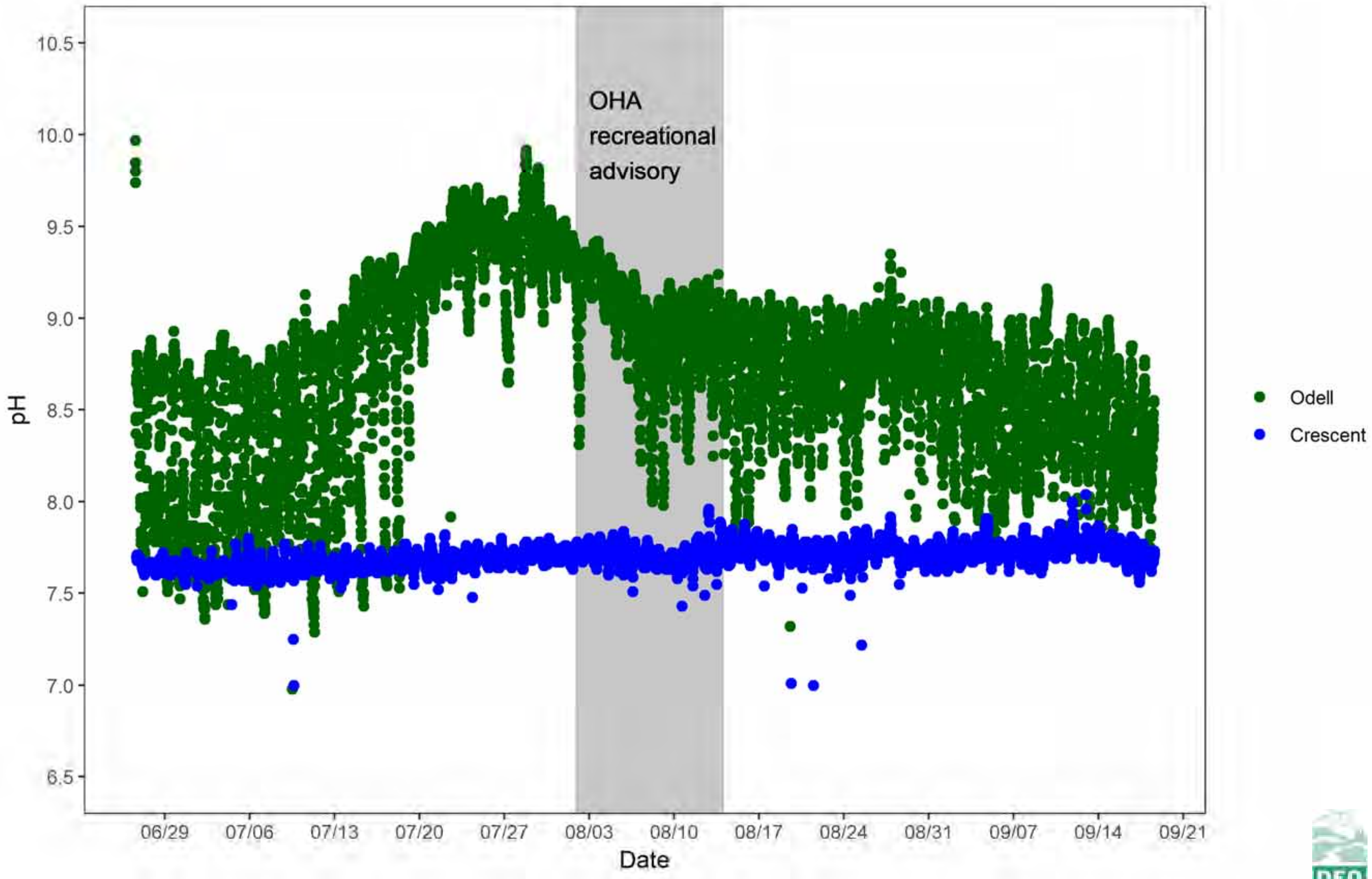
In situ monitoring - Phycocyanin



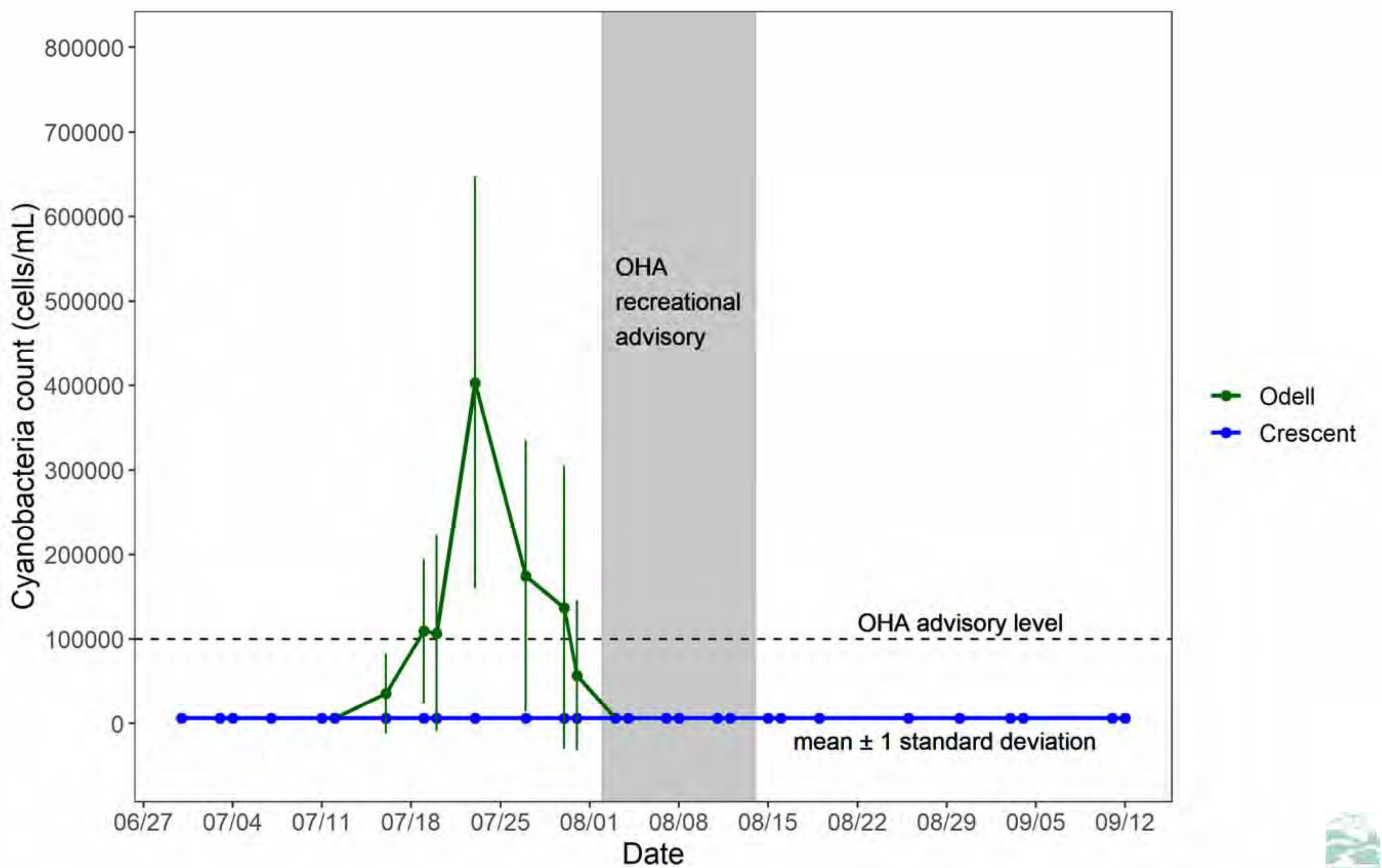
In situ monitoring – Dissolved oxygen



In situ monitoring – pH



Satellite data – CyAN app



Detection of blooms

- Quickest Detection of early-warning signals:

Ecological Monographs, 88(2), 2018, pp. 188–203

Early warning signals precede cyanobacterial blooms in multiple whole-lake experiments

Grace M. Wilkinson,[1,6] Stephen R. Carpenter,[2] Jonathan J. Cole,[3] Michael L. Pace,[4] Ryan D. Batt,[5] Cal D. Buelo,[4] and Jason T. Kurtzweil[2]

Oikos 123: 290–297, 2014
doi: 10.1111/j.1600-0706.2013.00539.x

Subject Editor: Dries Bonte. Accepted 24 July 2013

A new approach for rapid detection of nearby thresholds in ecosystem time series

Stephen R. Carpenter, William A. Brock, Jonathan J. Cole and Michael L. Pace

S. R. Carpenter (srcarpen@wisc.edu), Center for Limnology, Univ. of Wisconsin, Madison, WI 53706, USA. – W. A. Brock, Dept of Economics, Univ. of Wisconsin, Madison, WI 53706, USA and: Dept of Economics, Univ. of Missouri, Columbia, MO 65211, USA. – J. J. Cole, Cary Inst. of Ecosystem Studies, Millbrook, NY 12545, USA. – M. L. Pace, Dept of Environmental Sciences, Univ. of Virginia, Charlottesville, VA 22904, USA.

- Compares rolling window of statistics for algal and water quality measurements to detect blooms

- Compares a "baseline" to a "bloom" lake
  - *p*(Bloom state) / *p*(Non-bloom state)
  - Non-bloom state = Crescent Lake
  - Should increase over time
  - Compared 7, 14, and 21 day windows

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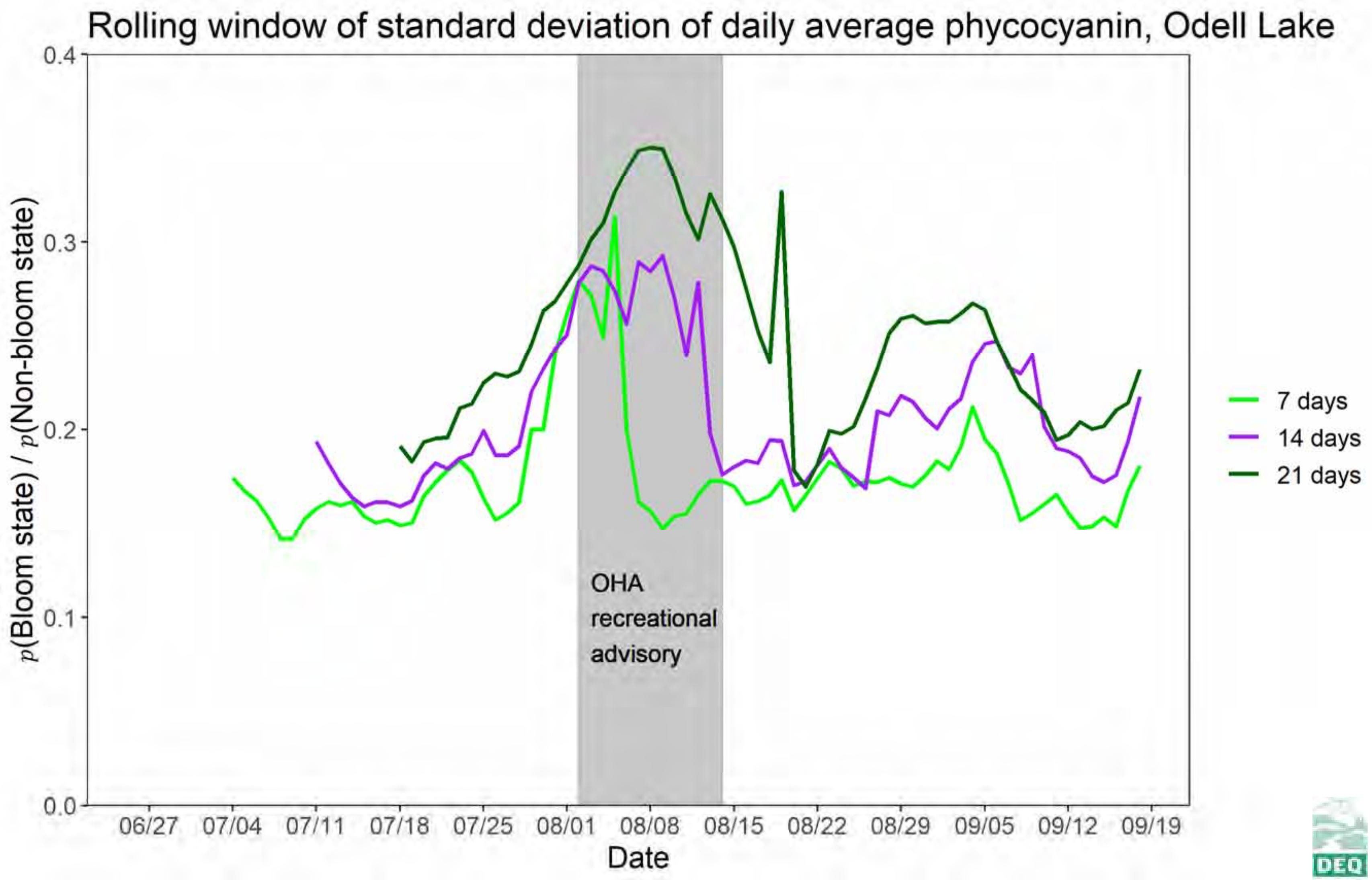
Early warning detection - Phycocyanin



Preliminary interpretations

- *In situ* data for phycocyanin, DO saturation, chlorophyll *a,* and pH all indicate bloom formation
- Satellite imagery corresponds to *in situ* data
- Rolling standard deviations of *in situ* data indicate bloom formation

State of Oregon Department of Environmental Quality

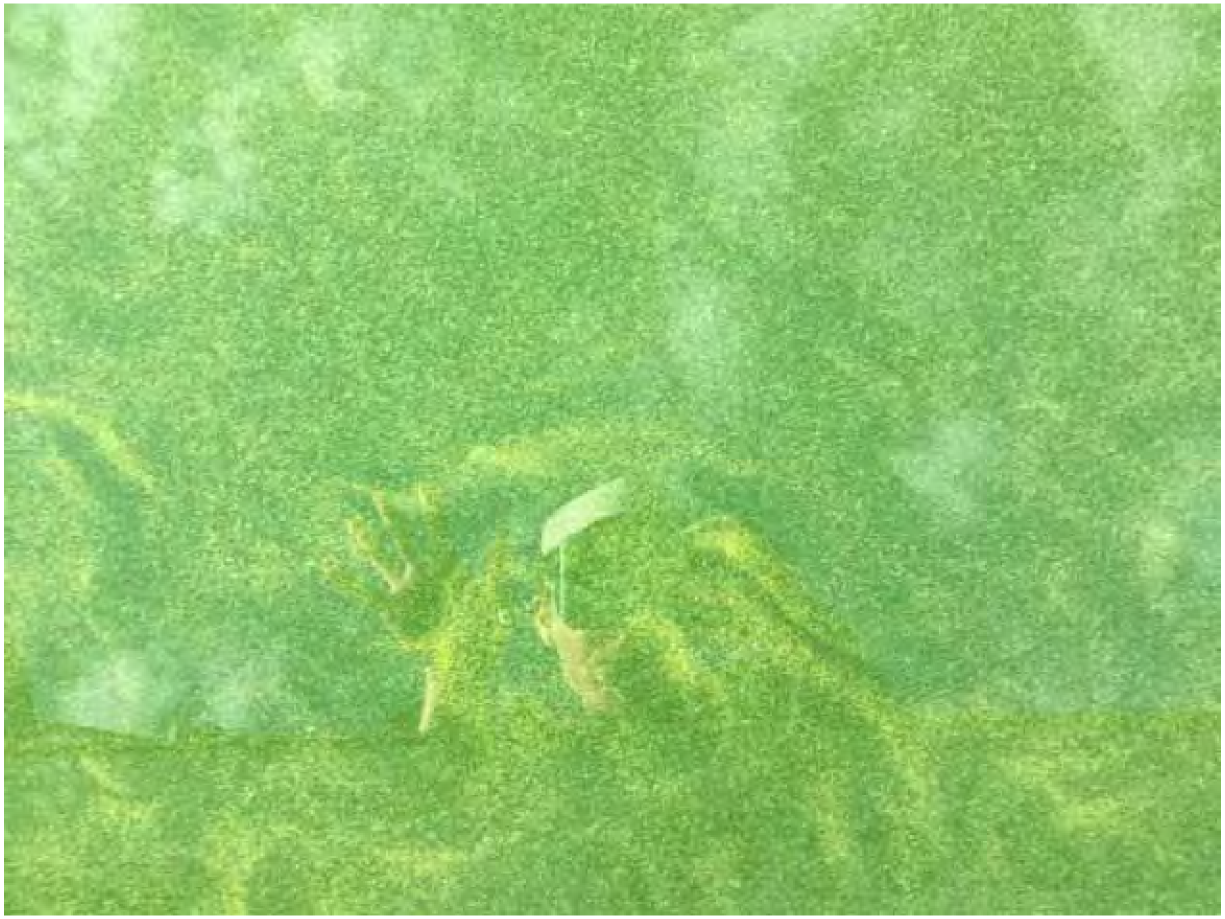
Next steps

- Longer time series of *in situ* and satellite data
- Continue development of early warning methods
- Examine factors causing blooms
  - Temperature
  - Nutrients
- Examine algal communities and toxin production over time (Victoria Avalos and Lara Jansen, PSU)

Questions?

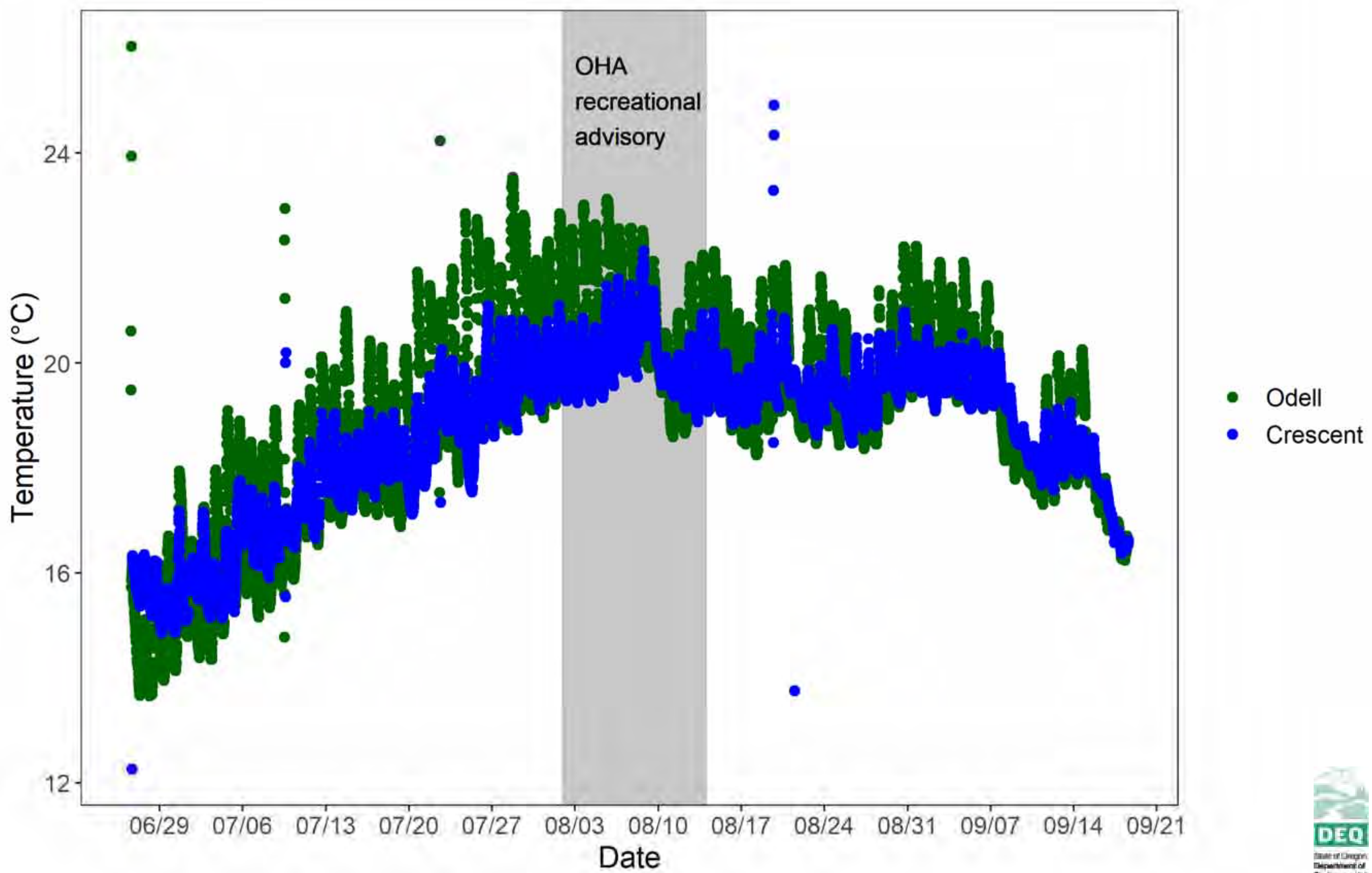
Thanks to:

- **Gene Foster (DEQ)**
- **Yangdon Pan (PSU)**
- **Cassie Smith (USGS)**
- **Joe Eilers (MaxDepth Aquatics)**
- **Erin Costello (DEQ)**
- **Kyle Wright (USFS)**
- **Jason Gritzner (USFS)**
- **Rebecca Hillwig (OHA)**

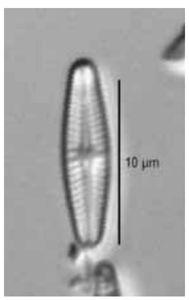


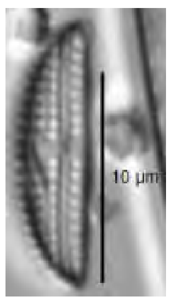
Dan Sobota
Oregon DEQ
Soboda.daniel@deq.state.or.us
503-229-5138

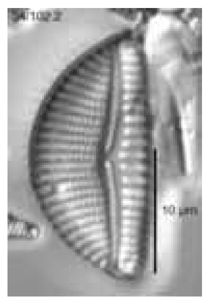
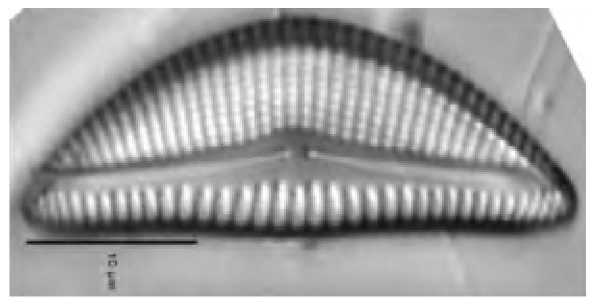
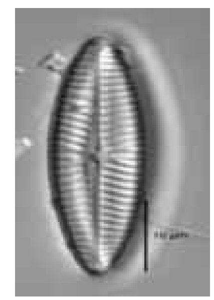
In situ monitoring – temperature



Diatom Community Composition Supports the Dissolved Oxygen (Delta DO) Threshold for Impairment Classification in Plains Steams , Montana, USA





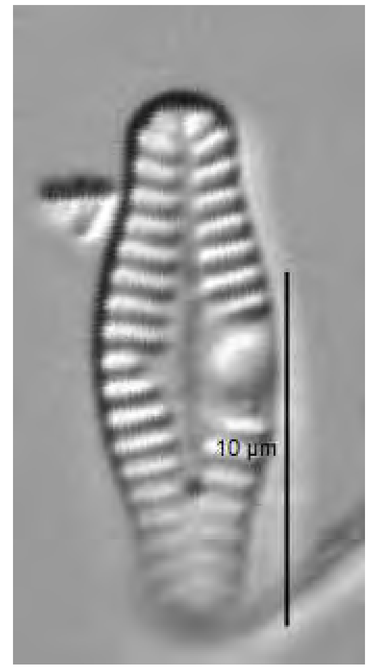
Sean Sullivan- Rhithron Associates, Inc.

Mike Suplee and Rosie Sada de Suplee- Montana DEQ

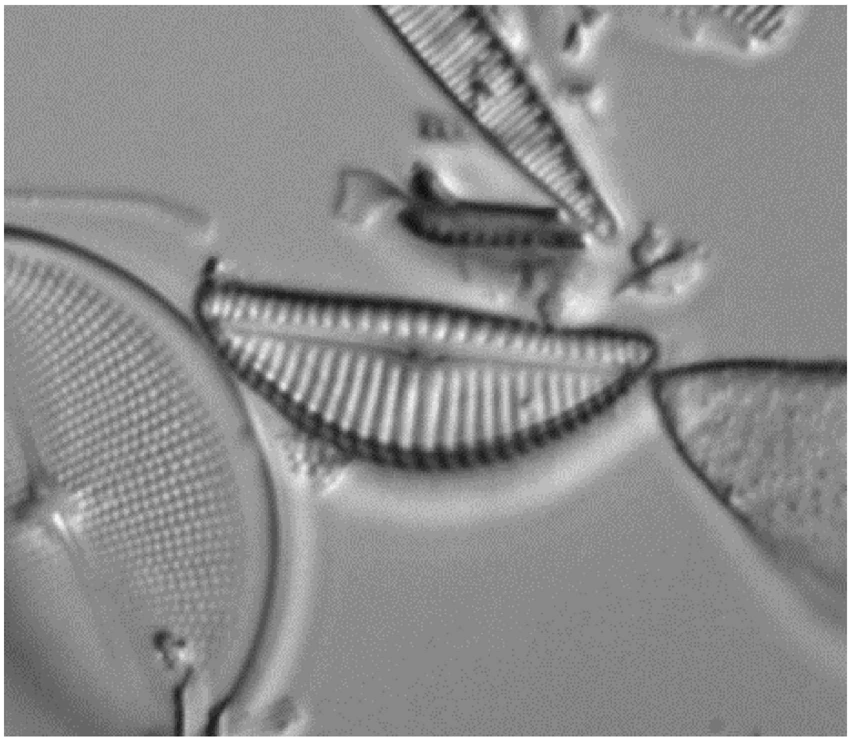
Box Elder Creek, MT-
American Prairie Preserve

Montana's Assessment Methodology: Plains Streams

- Level I Core Indicators
  - [Nutrient] (TN and TP)
  - Diatom Community (Teply 2010)
  - Delta DO
- Level II Core Indicators
  - [Nutrient] (TN and TP)
  - Diatom Community (Teply 2010)
  - Delta DO
  - BOD
  - Visual Field Assessments



Delta DO



- MTDEQ criterion
  - 5.3mg/L Delta DO (Max-Min)
  - Developed from 177 observations using a reference condition approach.
  - Other sources:
    - 4.5mg/L Delta DO- MPCA
    - 4.1 mg/L Delta DO-Fish (MPCA)

Table B-3. Nutrients – Plains Level I Decision Matrix

Scenario	Nutrient Binomial Test	Nutrient T-test	DO delta	Plains Region Diatom Increaser Taxa-Probability of Impairment	Resulting Decision	Further Sampling?	If you have collected the data for, or have the data for, a level II assessment:	Notes
8	FAIL	FAIL	≤ 5.3 mg/L	>51%	Waterbody is nutrient impaired. Both assessments of nutrient concentrations indicate elevated concentrations, and the diatom increaser taxa metric shows a nutrient impact. DO delta measurements may have missed high values (i.e., false negative).	No		
9	PASS	PASS	> 5.3 mg/L	≤51%	Unclear — Algae & plants might be taking up nutrients and leading to lower instream nutrient concentrations concurrent with high algae and plant biomass; however, diatom metric contradicts DO delta results. Normally in this scenario TP and/or TN would be expected to exceed criteria. Do a level II assessment to complete decision.	Yes. Do level II assessment. For this scenario this means a required 2nd summer of data collection. Collect BOD data. SEE NOTES TO RIGHT.	Go to "Plains 2" tab	If you suspect problem may be manifested via very high phytoplankton concentrations, collect phytoplankton Chla as well.
10	PASS	PASS	> 5.3 mg/L	>51%	Unclear — Algae may be taking up nutrients and leading to low instream nutrient concentrations with concurrent high algae and plant biomass; diatom metric supports this idea as do the DO delta results. Normally in this scenario TP and/or TN would be expected to exceed their criteria. Do a level II assessment to complete decision.	Yes. Do level II assessment. For this scenario this means a required 2nd summer of data collection. Collect BOD data. SEE NOTES TO RIGHT.	Go to "Plains 2" tab	If you suspect problem may be manifested via very high phytoplankton concentrations, collect phytoplankton Chla as well.

Objectives

- Evaluate nutrient or DO specific candidate metrics for responsiveness to Delta DO gradient.
- Establish a community change point threshold along the observed Delta DO gradient.
  - Evaluate the calculated threshold.
  - Develop new metric for use in Montana's Plains Streams.

The Data

- 71 unique stream reaches, collected between 2013 and 2017
- All located within the Northwestern Glaciated Plains and Northern Great Plains Level III ecoregions.
- 'Reference' status kept blind in these analyses

Methods

- 297 total periphyton samples.
  - Methods (Bahls 1993) 800 count Diatoms and RA/RB SBA*
  - Harmonized between labs (RAI and ANSP), over time (synonyms), reduced (<5% and <5 occurrences, genus only, and provisional taxa)
- 204 sampling events co-occur with measured Delta DO (15 min- 1 hr increment data) (Monthly Mean of Daily Delta DO)
  - Max:25mg/L, Min:0mg/L, Mean: 5.7, Median:4.12 mg/L

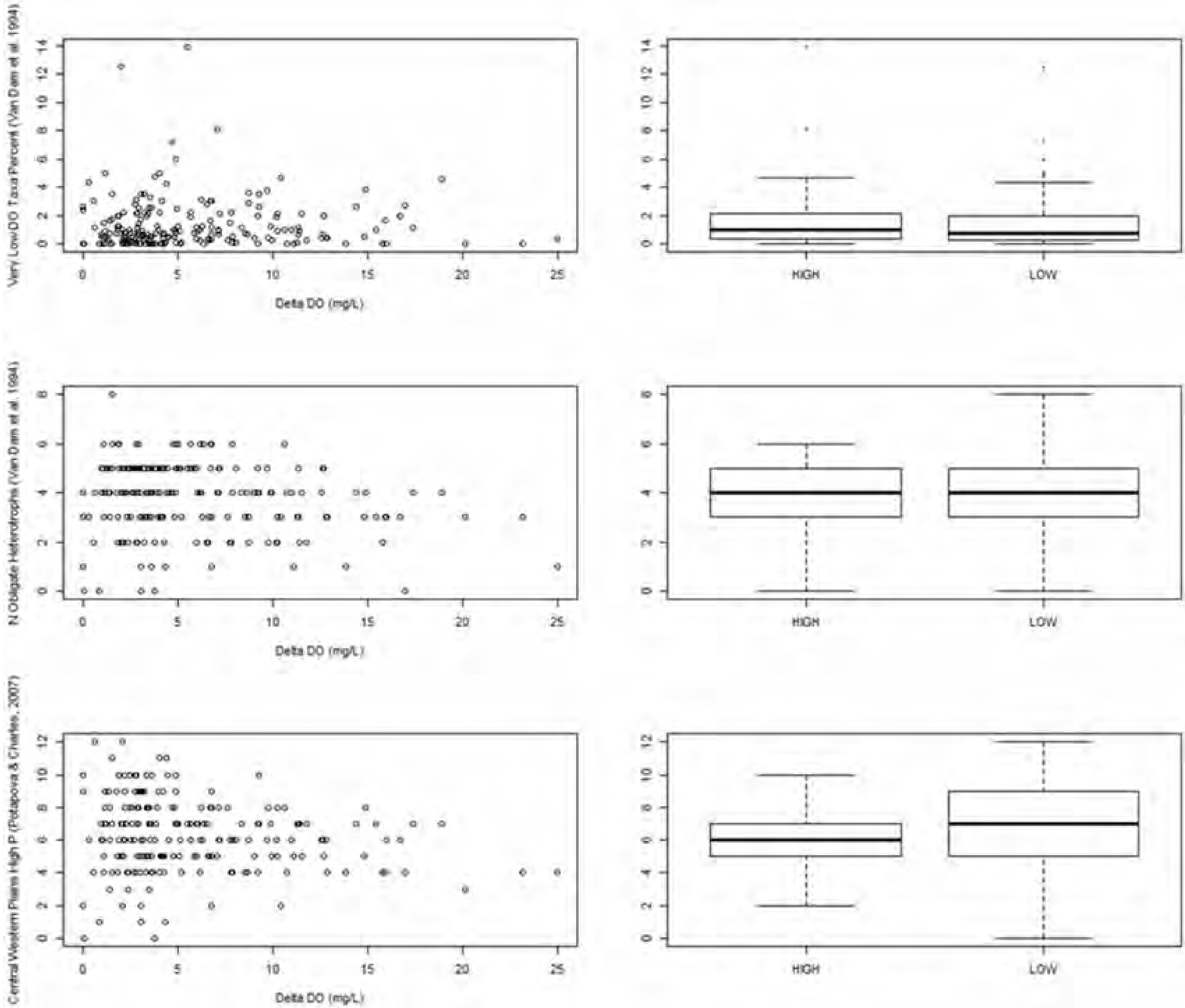
Objective 1:Evaluate select candidate metrics for relationship to Delta DO gradient.

- Calculate each metric for all 204 paired samples.
- Explore the relationships:
  - Calculate Pearson's Product Correlation
  - Evaluate metrics between high and low Delta DO (TH=5.3mg/L Delta DO) (t-test)

Candidate Metrics

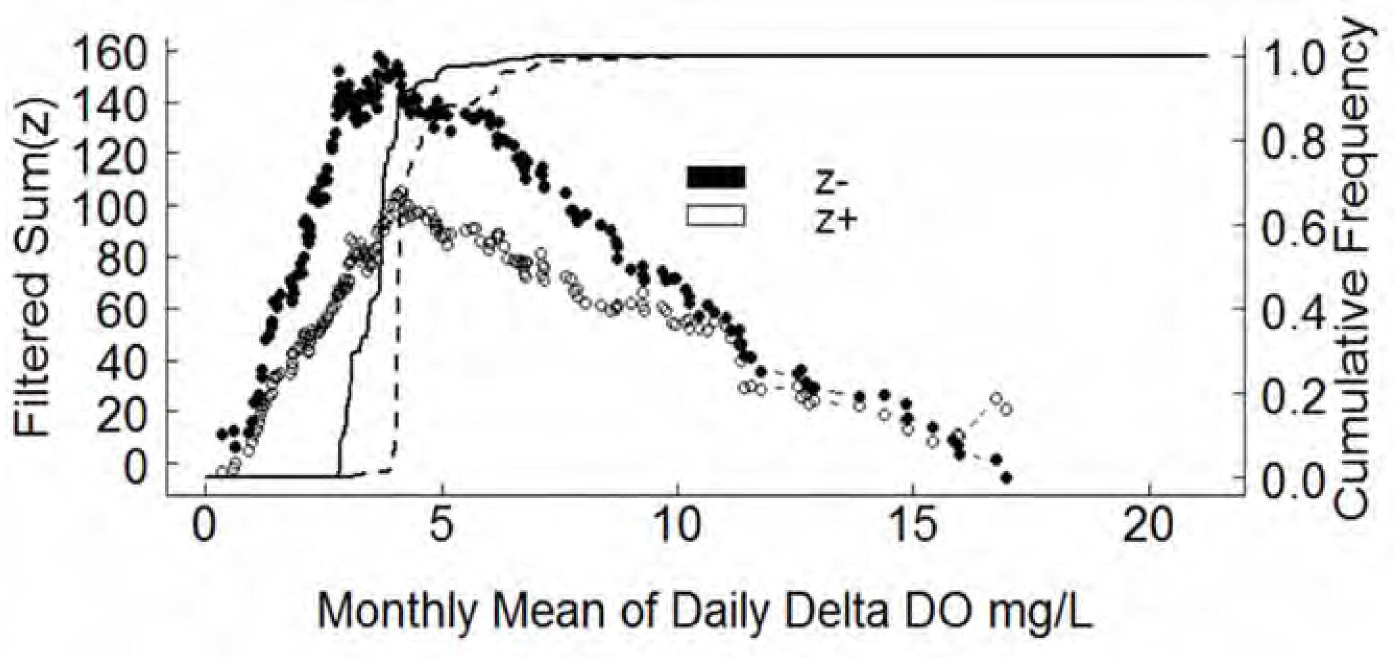
Table 1: List of the 20 candidate community metrics analyzed in this study, their sources, predicted response to increased delta dissolved oxygen, and Pearson Product correlation rho (*p<0.10, **p<0.05, ***p<0.01). CWP is equal to the Central Western Plains dataset only.

Metric Name	Source	Predicted Response	*rho*
High Nitrogen Taxa Percent (CWP)	Potapova and Charles, 2007	+	-0.039
High Nitrogen Taxa Richness	Potapova and Charles, 2007	+	0.380***
High Nitrogen Taxa Richness (CWP)	Potapova and Charles, 2007	+	-0.009
High Phosphorus Taxa Percent	Potapova and Charles, 2007	+	-0.138**
High Phosphorus Taxa Percent (CWP)	Potapova and Charles, 2007	+	-0.065
High Phosphorus Taxa Richness (CWP)	Potapova and Charles, 2007	+	0.572***
High Phosphorus Taxa Richness	Potapova and Charles, 2007	+	0.128*
Low DO Taxa Percent	Van Dam et al. 1994	+	0.111
Low Nitrogen Taxa Percent	Potapova and Charles, 2007	-	0.097
Low Nitrogen Taxa Percent (CWP)	Potapova and Charles, 2007	-	0.084
Low Nitrogen Taxa Richness	Potapova and Charles, 2007	-	0.289***
Low Nitrogen Taxa Richness (CWP)	Potapova and Charles, 2007	-	0.454***
Low Phosphorus Taxa Percent	Potapova and Charles, 2007	-	0.364***
Low Phosphorus Taxa Percent (CWP)	Potapova and Charles, 2007	-	0.064
Low Phosphorus Taxa Richness	Potapova and Charles, 2007	-	0.199***
Low Phosphorus Taxa Richness (CWP)	Potapova and Charles, 2007	-	0.694***
Obligate Nitrogen Heterotroph Taxa Percent	Van Dam et al. 1994	-	0.184***
Obligate Nitrogen Heterotroph Taxa Richness	Van Dam et al. 1994	-	0.688***
Polysaprobous Taxa Percent	Van Dam et al. 1994	+	0.179**
Very Low DO taxa Percent	Potapova and Charles, 2007	+	0.690***


Very Low DO Taxa Percent (Van Dam et al. 1994)
Delta DO (mg/L)
HIGH
LOW
N Obligate Heterotrophs (Van Dam et al. 1994)
Delta DO (mg/L)
HIGH
LOW
Central Western Plains High P (Potapova & Charles, 2007)
Delta DO (mg/L)
HIGH
LOW

Using TITAN to identify a threshold of diatom community change

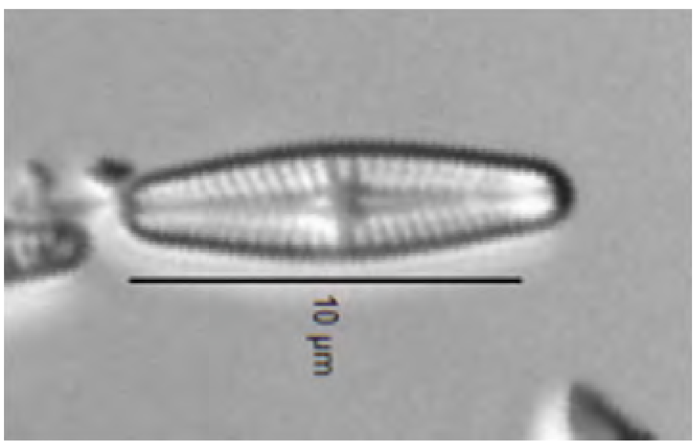
- Whole dataset evaluation of 'threshold'.
- TITAN model: 500 permutations, 500 Bootstraps, 95% reliability cutoff.
- Change points at 4.72 for Increaser and 3.71 Decreaser

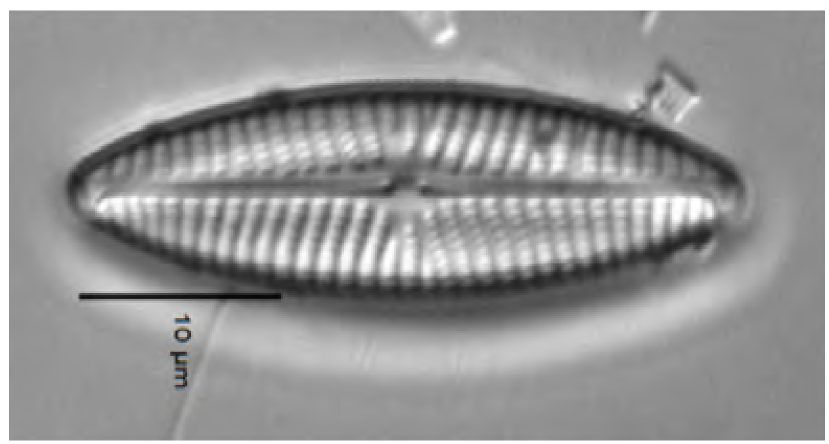


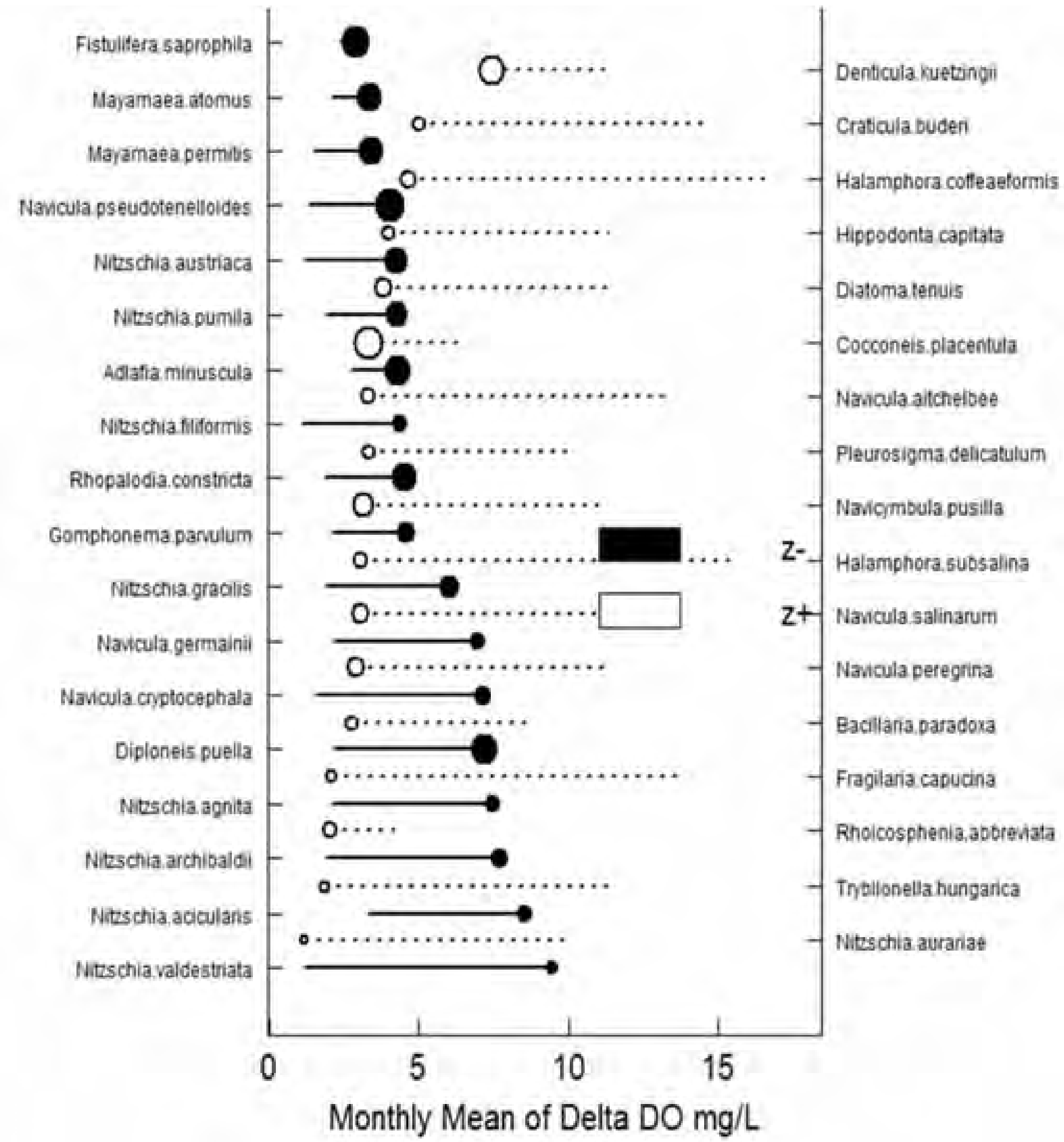
TITAN (Baker and King 2010)

Creating a New Metric

- Split data randomly into development (n=106) and validation datasets (n=98)
- Run TITAN model with same criteria as whole dataset.
- Identify Increaser and Decreaser Taxa



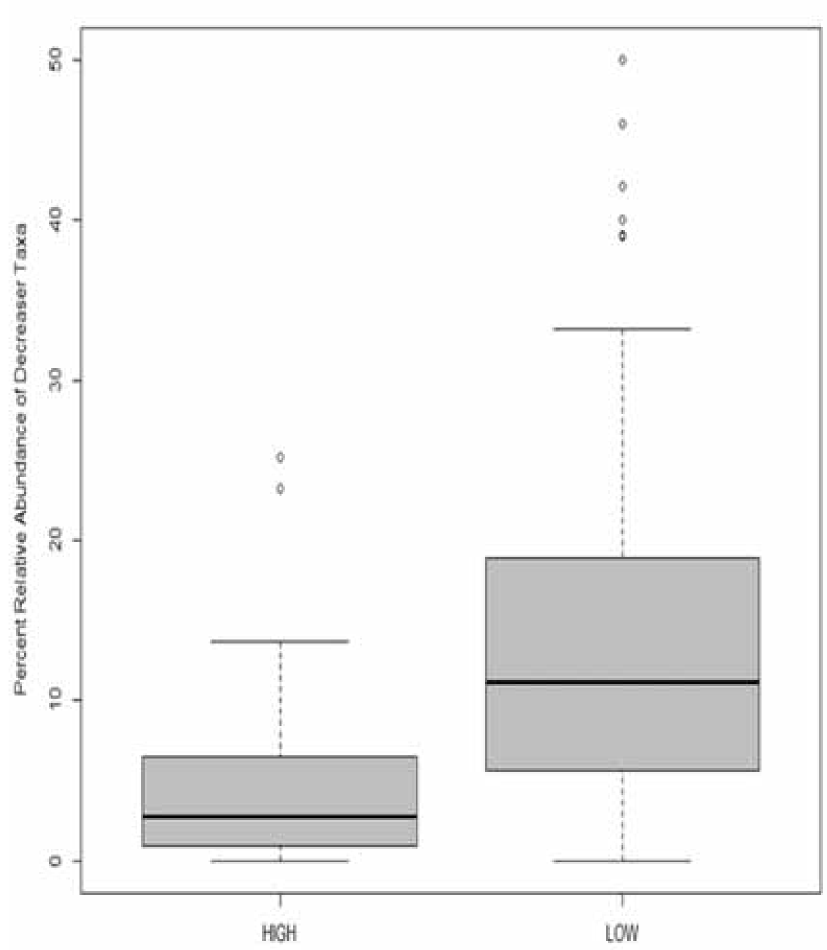


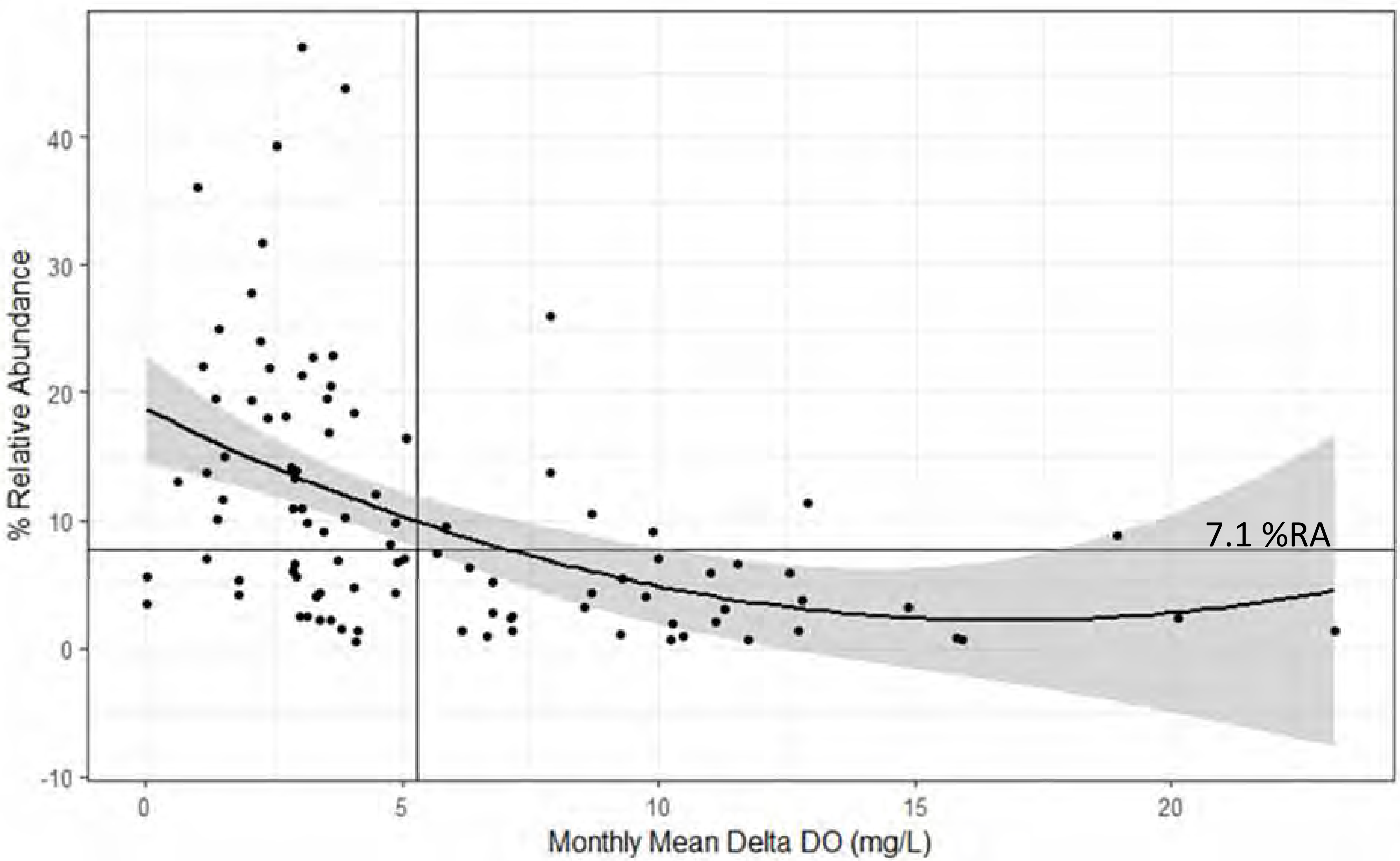


- Change points
  - 3.17 mg/L Delta DO (D)
  - 4.72 mg/L Delta DO (I)
  - 19 :P&R Decreaser
  - 17: P&R Increaser

New Metric Responsiveness

- Lower change points than whole dataset.
- Modeled polynomial regression of % RA of Decreaser taxa against Delta DO gradient.
- Increaser taxa ‘unresponsive’.
- T-test: p<0.01





% Relative Abundance
40
30
20
10
0
-10
0
5
10
15
20
Monthly Mean Delta DO (mg/L)
7.1 %RA

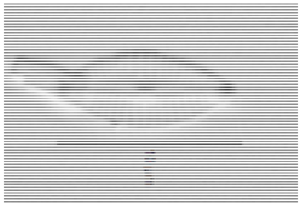
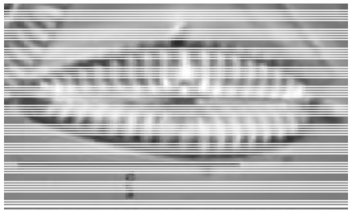
Discussion

- Seminal metrics respond well to the Delta DO gradient, but do not discriminate well against *a priori* thresholds.
- Many of the taxa (25%) in Van Dam et al. 1994 at "Very low DO" are confirmed using the %RA Decreaser Taxa metric.
  - Improved based on local taxa pool?

Discussion Continued

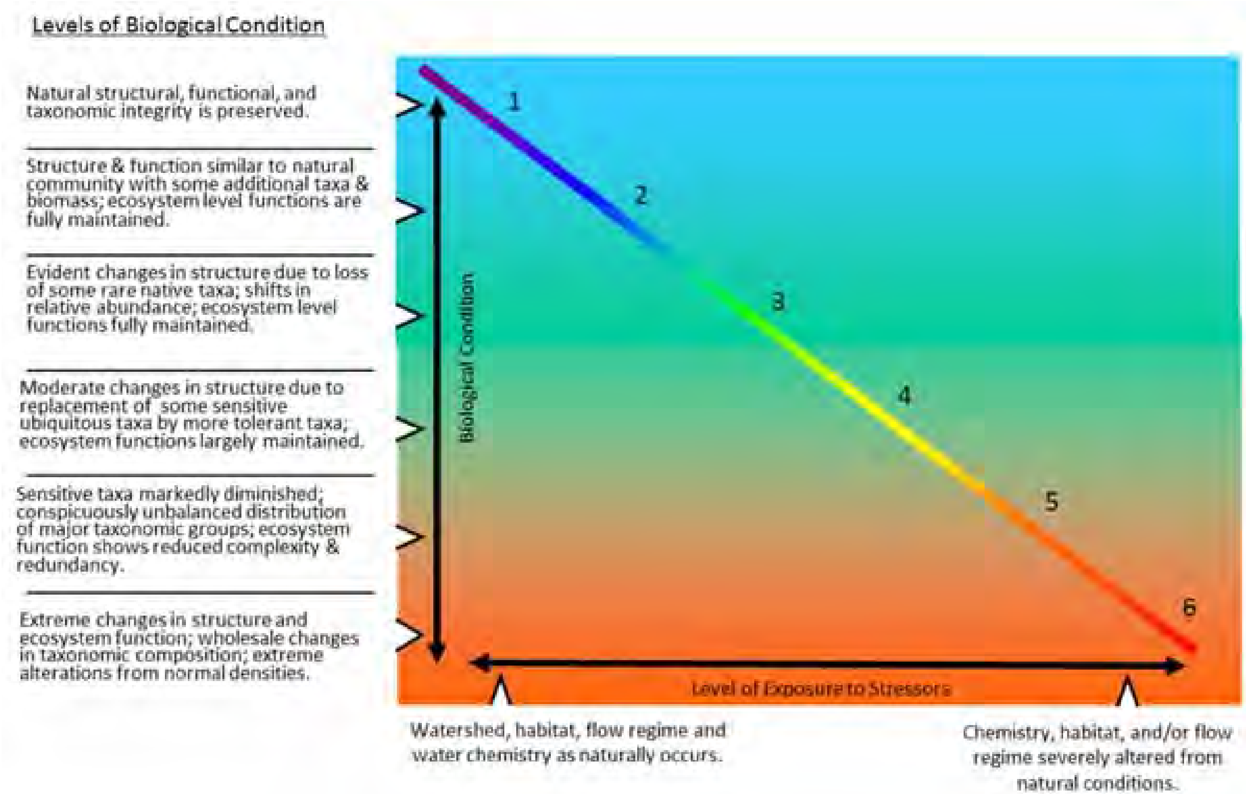
- Using the TITAN model the 5.3 mg/L threshold is 'protective' of sensitive Diatom species.
- The novel metric of % RA Decreaser Taxa could be useful in the impairment decision matrix.
- %RA Decreasers discriminates at the 5.3mg/L Delta DO threshold
- No taxa co-occur with Teply (2010) Nutrient Increasers list, so the metric could be isolating the DO signature.
  - Not based on previous impairment classifications

Deep Thoughts

- Adds to the weight of evidence in impairment listings.
- Adding an additional diatom community threshold to an impairment decision matrix could further complicate 303(d) processes and TMDLs
- Difficult for stakeholder digest.

The BCG: biological response to increasing stress

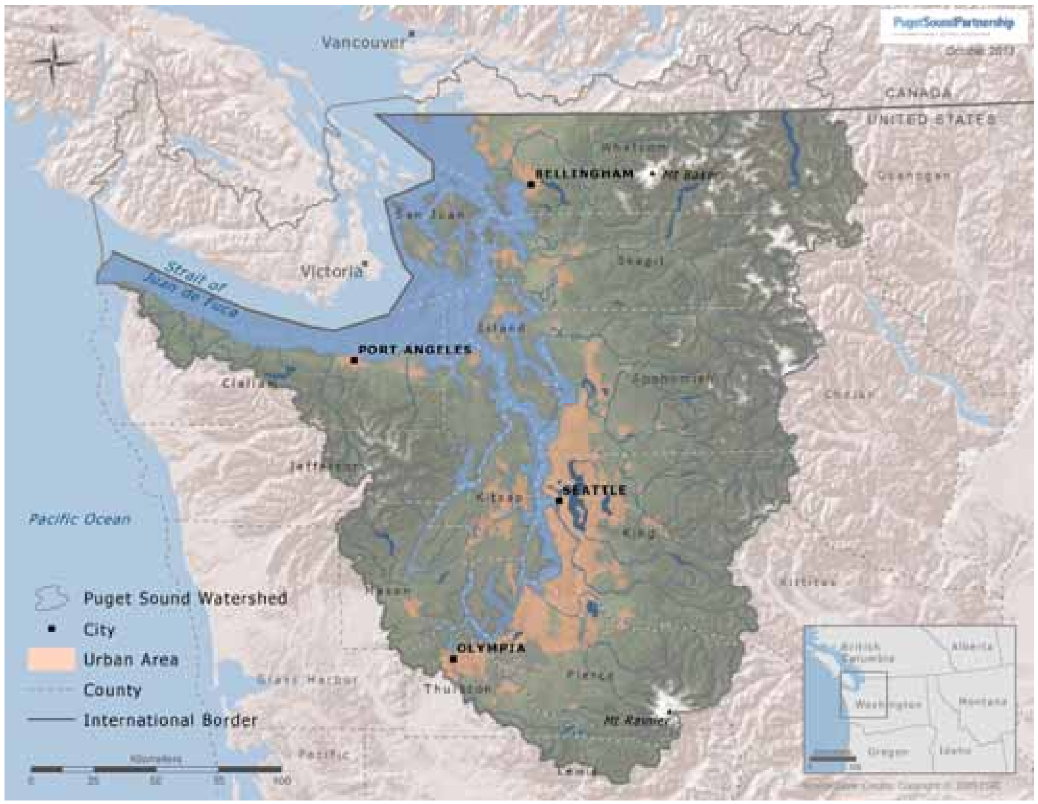


A Biological Condition Gradient (BCG) Model for Benthic Macroinvertebrate Assemblages in Puget Lowland & Willamette Valley Streams

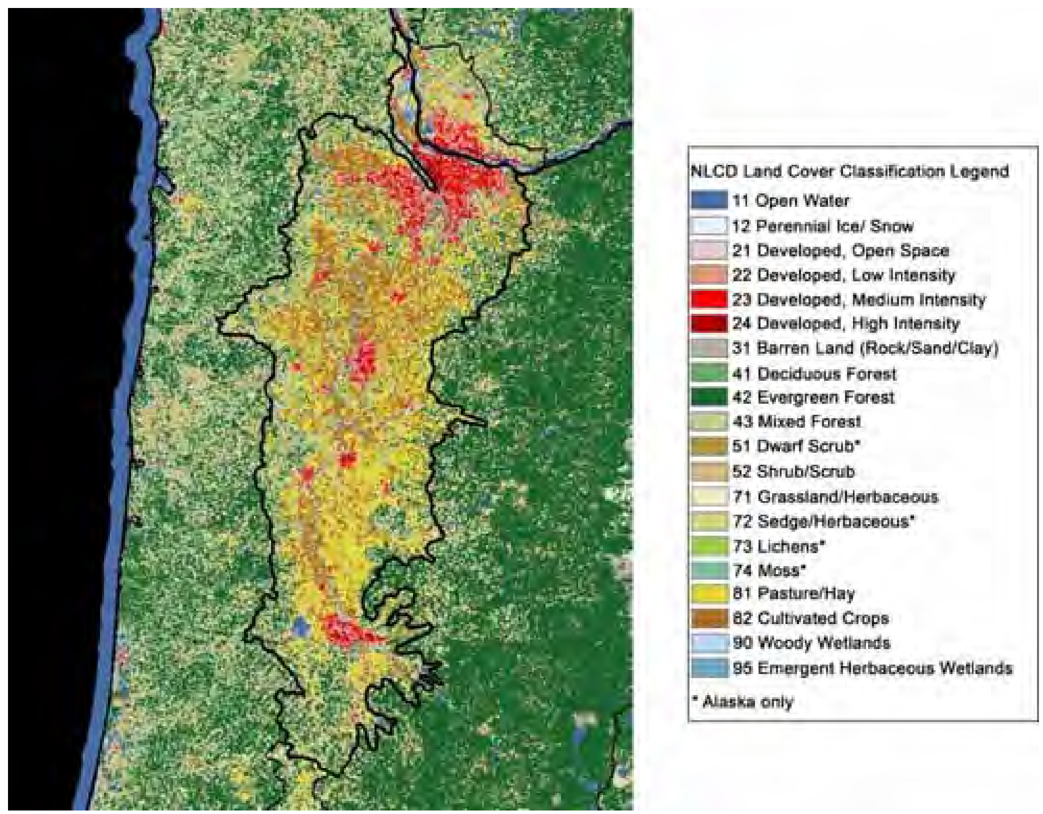
Presented by:
Robert Plotnikoff, Snohomish County Public Works
Chad Larson, Washington Department of Ecology

Pacific Northwest Chapter – Society for Freshwater Science
Wednesday, November 7th, 2018
Ketchum, ID

Puget Lowlands



Land cover in the **Willamette Valley** and neighboring ecoregions, based on the National Land Cover Database (2011 Edition, amended 2014; USGS 2014).



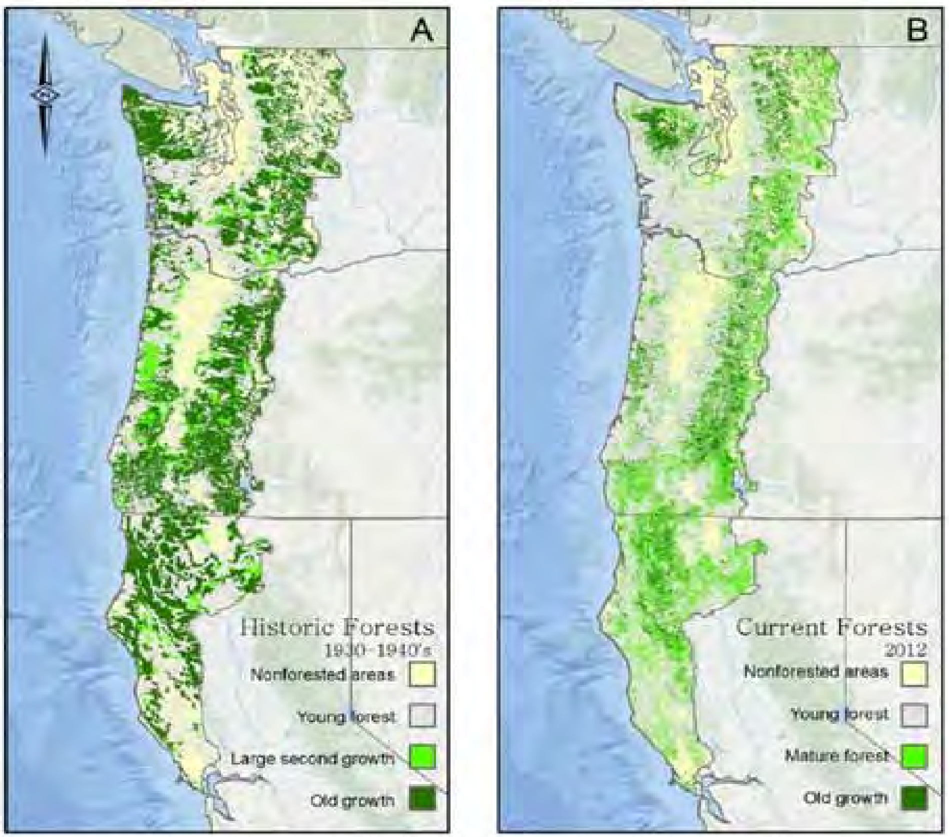
Update on a Biological Condition Gradient (BCG) Model for Benthic Macroinvertebrate Assemblages in the Maritime PNW

Bob Wisseman, Aquatic Biology Associates, Inc.
Sean Sullivan, Rhithron Associates, Inc.
Pacific Northwest Chapter, Society for Freshwater Science meeting Newport, OR Nov. 6-8, 2019

Model coverage expanded to include the maritime PNW Ecoregions

Or the “wet side” from the Pacific Coast to the Cascade Crest

Only western OR and WA benthic invertebrate data being used for model development

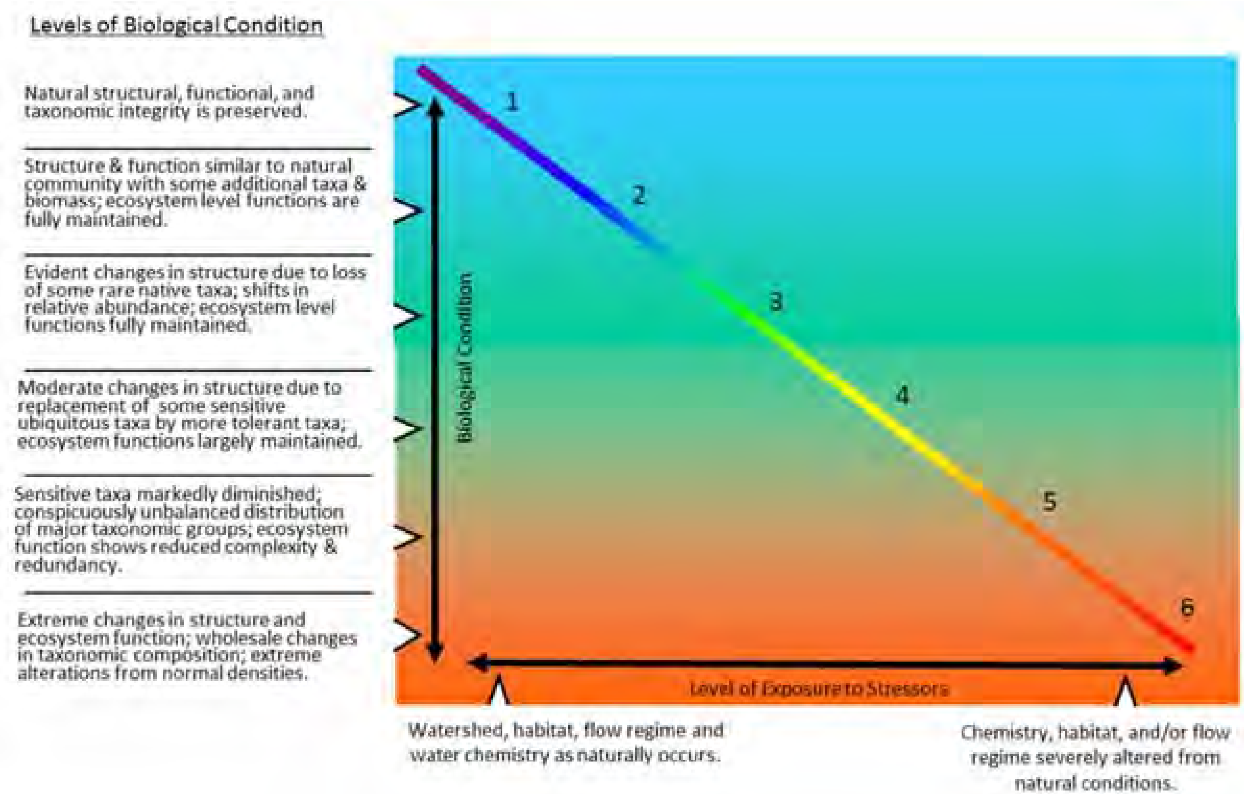


From Penaluma et al. 2017 (original source: Davis et al. 2015)

Acknowledgements

- Susan Jackson, EPA, Washington, D.C.
- Jen Stamp, Erik Leppo, Tetra Tech
- Rick Hafele, Apolysis, LLC
- Robert Plotnikoff, Snohomish County Public Works
- Expert panel members
- Data providers

The BCG: biological response to increasing stress

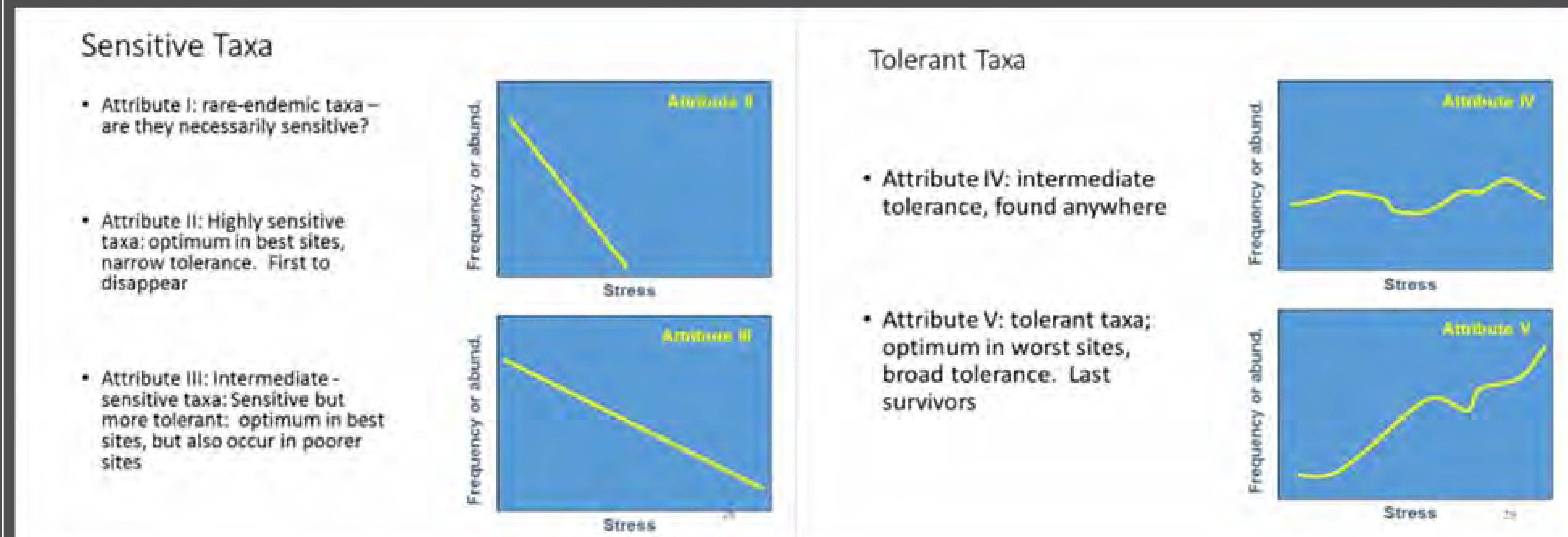


The BCG Process

Iterative – These steps are revisited throughout the process

1. Identify participants and expert panel
2. Compile data
3. Assign BCG attributes to taxa
   - Perform analyses to help inform assignments
4. Assign BCG levels to samples
5. Develop & refine BCG rules
6. Assess BCG model performance
   - Calibration
   - Confirmation
7. Automated BCG model (with narrative decision rules) that assigns BCG levels to samples

Taxon Attribute determined by response to stressor gradients



Human Derived Stressor Gradients

Urban Land (%)
Agricultural Land (%)
Road density
Development level

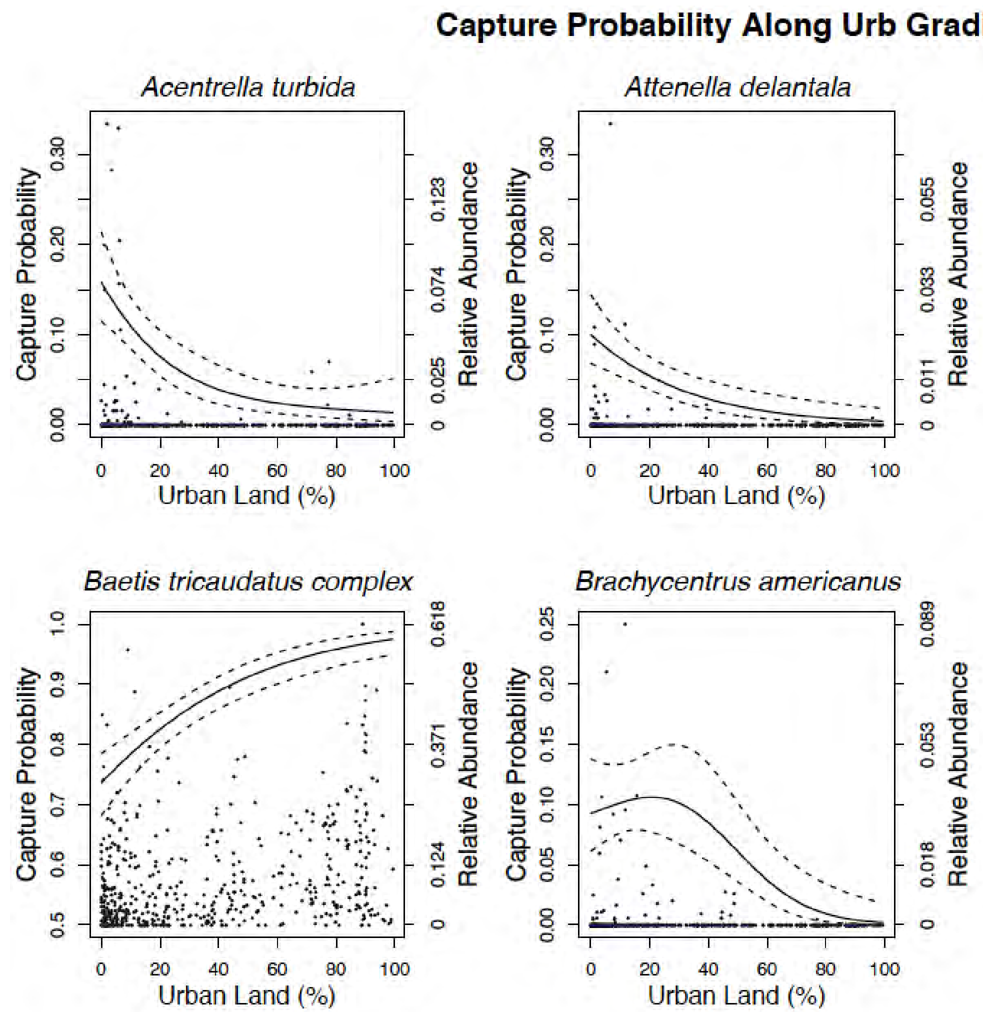


Table 1. BCG Levels and Rules for Puget Sound Lowland and Willamette Valley Freshwater Wadeable Streams (4/26/2018)
Low gradient (Low) = depositional (<1% NHDv2 flowline slope); high gradient (High) = transitional/erosional (≥ 1% NHD v2 flowline slope).

BCG level 1: Natural or native condition			
Placeholder			
BCG level 2: Minimal changes in structure of the biotic community and minimal changes in ecosystem function - virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.			
Narrative Descriptions	Metric	Numeric Rules	
		Low	High
Diverse assemblage with moderate to high numbers of total taxa	Number of total taxa	≥ 30 (25-35)	
A fair number of highly sensitive species are present	Number of Attribute Ii+II taxa	> 5 (3-8)	
A third or more of total taxa belong to one of the three sensitive groups, with slightly higher proportions expected in higher gradient streams	% Attribute Ii+II+III % taxa	≥ 35% (30-40)	≥ 40% (35-45)
Sensitive taxa comprise a almost a quarter of the organisms	% Attribute Ii+II+III % individuals	≥ 20% (15-25)	
Tolerant and non-native taxa make up a very small fraction of the organisms (or are absent)	% Attribute V+VI taxa	≤ 5% (3-7)	
	% Attribute V+VI individuals	≤ 5% (3-7)	
Sensitive EPT species are present in high numbers	Number of Attribute Ii+II+III EPT taxa	≥ 15 (10-20)	
Tolerant non-insect taxa comprise a small percentage of the individuals (or are absent). Juga and Rissooidea are excluded from consideration for reasons described below[1]	% Attribute IV+V+VI non-insect, individuals, excluding Juga and Rissooidea[1]	≤ 15% (10-20)	

Draft Products from the Puget Lowland/Willamette Valley BCG process

BCG model

Description of aquatic habitats in the Puget Lowlands and Willamette Valley

Defining BCG level 1 and an index for flagging watersheds that may have exemplary biodiversity

BCG model differentiates between low and high gradient streams

Low gradient valley-basin streams (soft-bottomed)

Higher gradient foothill and montane streams (hard-bottomed)

BCG level 1: Natural or native condition			
Placeholder			
BCG level 2: Minimal changes in structure of the biotic community and minimal changes in ecosystem function - virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability			
Narrative Descriptions	**Metric**	**Numeric Rules**	
		Low	**High**
Diverse assemblage with moderate to high numbers of total taxa	Number of total taxa	≥ 30 (25-35)	
A fair number of highly sensitive species are present	Number of Attribute Ii+II taxa	≥ 5 (3-8)	

Appendix E draft nearly ready for review
Detailed description of the Willamette Valley and Puget Lowlands – past, present and future

Rick Hafele and Robert Plotnikoff

Key Environmental Changes from 1850's to present	Watershed Effects	Biological Results	Possible Restoration Actions
Rapid and near complete removal of beaver	Significant shift in hydrology and stream habitat due to: – Less water storage. – More rapid runoff. – Lower summer streamflows. – Warmer water temperatures. – Increased erosion & higher amount of fine sediment deposition. – Loss of lentic habitat for aquatic and terrestrial species.	– Significant loss of biological diversity. – Loss of lentic and depositional aquatic invertebrate species. – Increase in sediment tolerant and temperature tolerant invertebrate species. – Increase in erosional habitat & rheophilic invertebrate species. – Loss of fish habitat, especially for juvenile salmon and trout. – Loss of habitat for waterfowl and other terrestrial plants and animals that depend on wetlands and diverse aquatic habitats.	– Reintroduce beaver. – Protect and restore wetlands.

Defining Biological Condition Gradient Level 1…….Exemplary Biodiversity

Fundamental Characteristics	Description
Stream channel	Channel connected to hyporheos and flood plain including wetlands, beaver ponds, etc.; diverse habitats present (e.g. braided channels, side channels, debris jams, mixture of steps and pools consistent with stream gradient); wood debris typically present and may be abundant; quality habitat and refugia persists during periods of both low and high stream-flows.
Riparian & watershed	Riparian zone supports intact community of overstory, understory and groundcover plants (including a mixture of mature conifer and hardwood trees with a diverse age structure in forested watersheds); upper watershed vegetation intact, supporting delivery of water of high chemical and thermal quality to lower reaches.
Hydrologic regime	Hydrologic regime natural, without alteration from dams and/or irrigation withdrawals or return flow; cool-cold water common from springs, groundwater accretion, and/or natural runoff; perennial surface or subsurface flow. Re-charge in the watershed sustains flow, especially during years of extreme drought. Perennial surface water in some portion of watersheds maintain endemic taxa that serve as recolonization sources sustaining high biodiversity at select locations. These locations promote resiliency in stream reaches that are periodically de-watered.
Disturbance regime and resilience	Natural seasonal range of high and low stream-flows present, which enhances and maintains channel and habitat complexity. Natural sediment transport based on local geology, soils and stream gradient . High resilience (ability to recover from disturbance) to natural and anthropogenic watershed stressors (Flotemersch et al. 2016). Watershed integrity maintains disturbance levels within ranges tolerable by endemic taxa and promotes connectivity for purpose of recolonization.
Ecosystem function	Watershed supports full range of ecological processes and functions essential to maintaining high biodiversity provided by a minimally disturbed ecosystem. Food web, nutrient and energy flow linkages between aquatic and terrestrial environments fully supported .
Biodiversity	Benthic macroinvertebrate community typically with high taxa richness, including many micro-habitat specialist taxa and taxa sensitive to human disturbance. Habitat complexity results in diversity of both rheophilic and lotic-depositional taxa. Non-native, invasive taxa not present.

Biological Condition Gradient (BCG) Level 1 Biodiversity Index

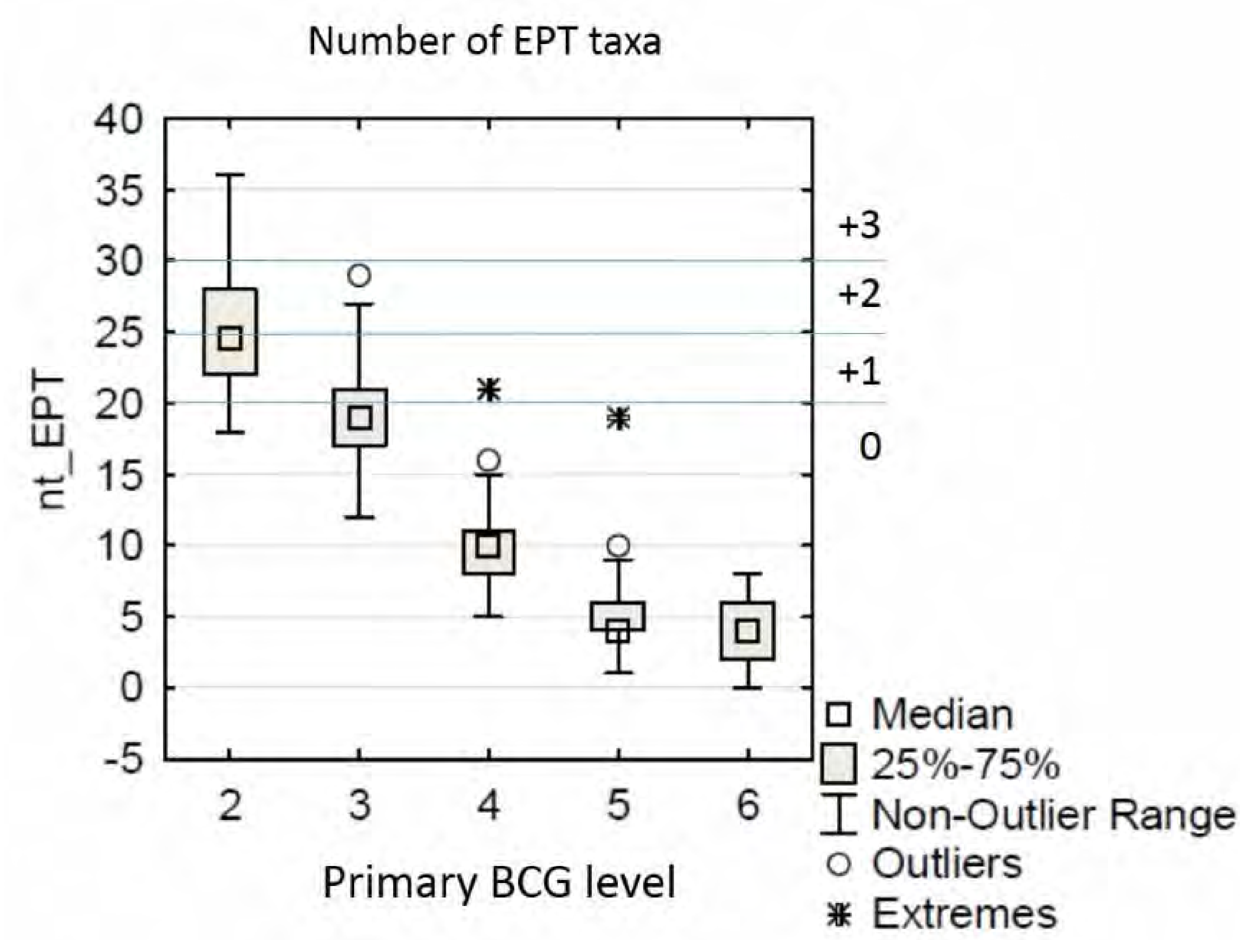
Draft for review by the Pacific NW BCG Expert Panel nearly ready

Using benthic macroinvertebrate biomonitoring data to flag stream sites in the maritime Pacific Northwest that may possess exemplary biodiversity.

Robert W. Wisseman, Aquatic Biology Associates, Inc. Corvallis, OR

Table 2. BCG Level 1 Biodiversity Index (draft, version 1) - community composition metrics and scoring thresholds.
*The list of noteworthy taxa and rationale for their inclusion can be found in Attachment A

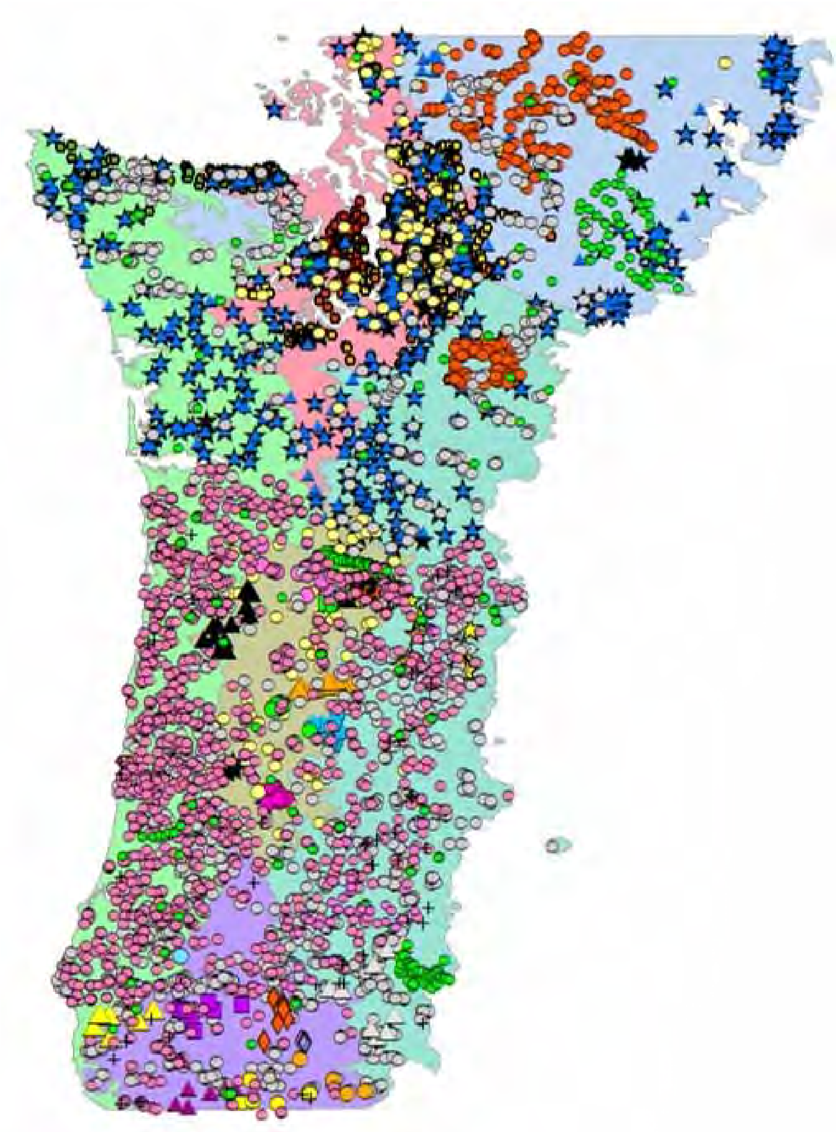
Metric	Scoring criteria (points)			
	0	1	2	3
Total taxa richness	<40	40-49	50-59	≥ 60
EPT taxa richness	<20	20-24	25-29	≥ 30
BCG attribute 1i, 1m & 2 taxa	<2	2-5	6-8	≥ 9
Shannon-Weaver diversity ($\log_e x$)	<2.75	2.75-2.99	3.0-3.24	≥ 3.25
Long-lived taxa richness	<6	6-8	9-11	≥ 12
Ephemerellidae taxa richness	0-2	3	4	≥ 5
Heptageniidae taxa richness	0-2	3	4	≥ 5
Nemouridae taxa richness	0-2	3	4	≥ 5
Perlidae taxa richness	0	1	2	≥ 3
Rhyacophila taxa richness	0-2	3-4	5	≥ 6
Predator taxa richness	<10	10-12	13-15	≥ 16
Noteworthy taxa richness	Add an additional score point for each noteworthy taxa present			



Number of EPT taxa
nt_EPT
Primary BCG level
40
35
30
25
20
15
10
5
0
-5
2
3
4
5
6
+3
+2
+1
0
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Table 3. BCG Level 1 Biodiversity Index (draft, version 1) – overall scores and ratings, as well as recommendations.

Rating	Score	Description
High	≥ 30	Exemplary biodiversity and high habitat complexity and resilience probable. Acquire additional information and data on the site and watershed that is readily available. Alert stakeholders, including government and non-government organization conservation agencies.
Medium	21-29	Moderate habitat complexity/resilience and biodiversity indicated. Further evaluation of the site and watershed is recommended.
Low	<20	Unexceptional biodiversity indicated. Mostly widespread and common taxa present.



Progress on BCG model for the Maritime Pacific Northwest

Data acquisition complete

Data harmonization complete

Capture probability plots will soon be run on a variety of human stressor gradients and natural gradients

BCG attributes will be assigned this November and December

Model development to come in 2020 but funding has become erratic.

Data sources for maritime PNW Biological Condition Gradient model development

WA Department of Ecology and the Puget Sound Stream Benthos database
OR Department of Environmental Quality database
US EPA EMAP, NARS and STAR programs
USGS Biodata
University of Utah Buglab, primarily BLM and Forest Service
National Park Service: North Cascades, Mount Rainier, Crater Lake and Oregon Caves
About 24 municipalities
About 15 county and water district programs
About 11 watershed councils
Misc. NGO's and private data sets

Many thanks to data providers for their cooperation and patience.
Special thanks to Jen Stamp for coordinating this effort!

Benthic invertebrate data sources from 1995 to 2018 from the maritime Pacific Northwest

- 2600 unique taxon names

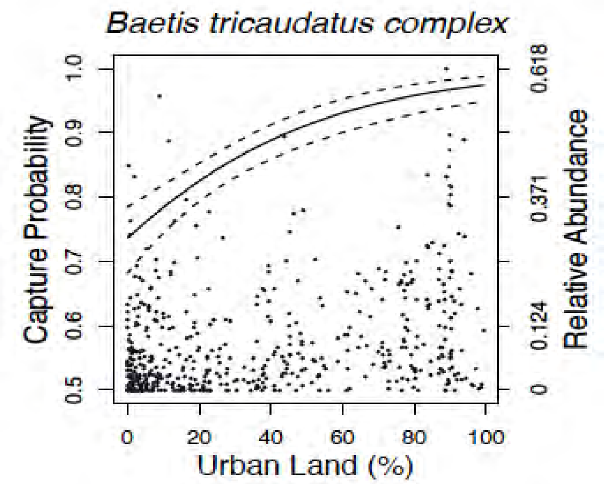
- 1160 unique names after reconciliation:

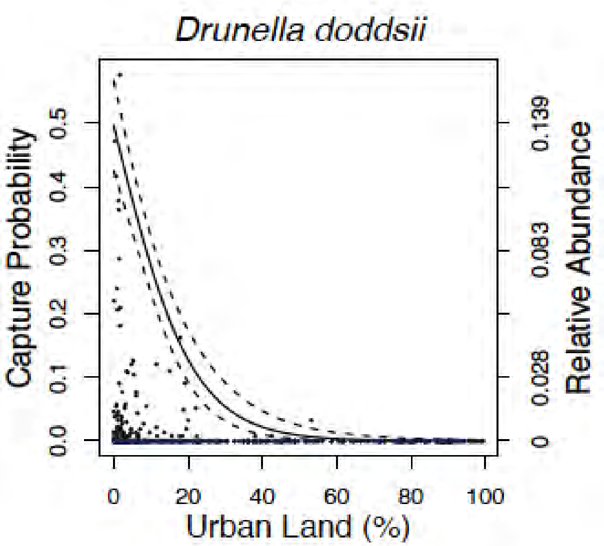
  Nomenclature updates, synonyms, rejecting non-benthic taxa and erroneous names, etc.

  Preservation of lowest, consistent taxonomic level whenever possible.

  Use for capture probability plots along gradients of human disturbance and other variables such as temperature, elevation, etc.

- 770 final OTU's (Operational Taxonomic Units) will be used for model development.





CAPTURE PROBABILITY GRADIENTS

- Index of Watershed Integrity
- Index of Catchment Integrity
- % urban
- % agricultural
- NorWest mean August stream temperature
- Elevation
- Stream size

Revising the index of watershed integrity national maps

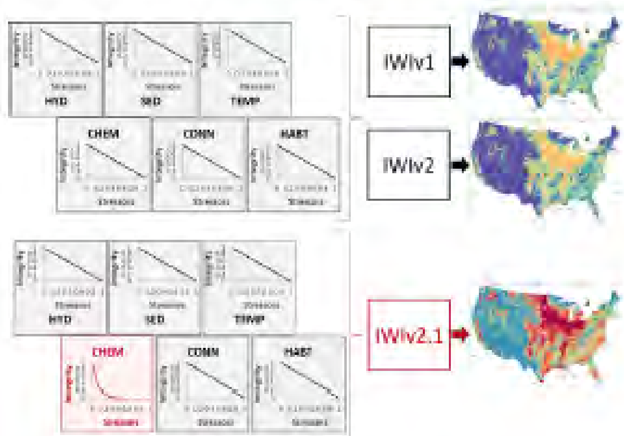
Zachary C. Johnson [a,*], Scott G. Leibowitz [b], Ryan A. Hill [a]

[a] Oak Ridge Institute for Science and Education (ORISE) Post-Doctoral Fellow c/o U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division, 200 SW 35th St., Corvallis, OR 97333, USA
[b] U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, 200 SW 35th St., Corvallis, OR 97333, USA

HIGHLIGHTS

- Indices of catchment and watershed integrity aid in management decisions.
- This study makes these previously developed indices directly comparable.
- Data-driven revision of the national maps of watershed and catchment integrity
- Models revealed non-linear relationships between stressors and water quality metric.
- Methods outlined can be implemented iteratively with new or improved data.

GRAPHICAL ABSTRACT



Local

A. Local Catchments for Reaches 20, 21, and 22

<u>Local catchment</u>

Definition: the landscape area draining to a single stream segment, excluding upstream contributions.

In this example, there are three local catchments (associated with unique flowline segments) –

- # 20 (green)
- # 21 (gray)
- # 22 (brown)

Each local catchment has a unique identifier (COMID or FEATUREID).

Total watershed

B. Total Upstream Watershed for Reach 20

<u>Watershed-level</u>

Definition: the local catchment plus the accumulated area of all upstream catchments

In this example there is one total watershed, comprised of the three local catchments (#20 + #21 + #22).

Standard Taxonomic Effort (STE)

For processing benthic macroinvertebrate biomonitoring samples from freshwater habitats

https://www.pnamp.org/project/northwest-standard-taxonomic-effort

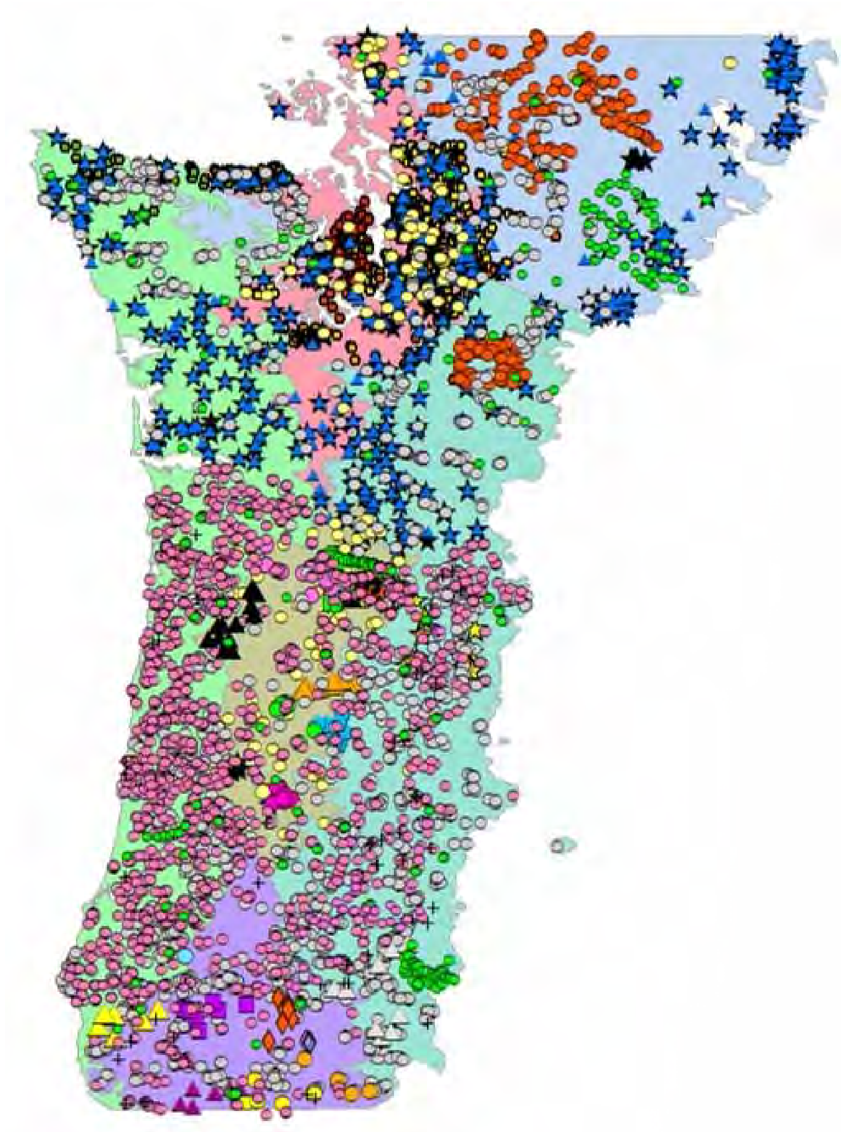
pacific northwest aquatic monitoring partnership
supporting aquatic habitat and salmonid monitoring programs

DRAFT Northwest Standard Taxonomic Effort Taxa Lists 2015-11-03
Date Posted: November 3, 2015

Taxonomists

Bob Wisseman, Aquatic Biology Associates, Inc.
Sean Sullivan, Rhithron Associates, Inc.
John Pfeiffer, EcoAnalysts, Inc.

are leading the development of the NW STE taxa lists.
The project is coordinated by PNAMP staff biologist Amy Puls.



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Capture probability plots will soon be run on a variety of human stressor gradients and natural gradients

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Model development to come in 2020 but funding has become erratic.

The 2015 STE level 2 draft posted is a very rough draft that is seriously out of date already

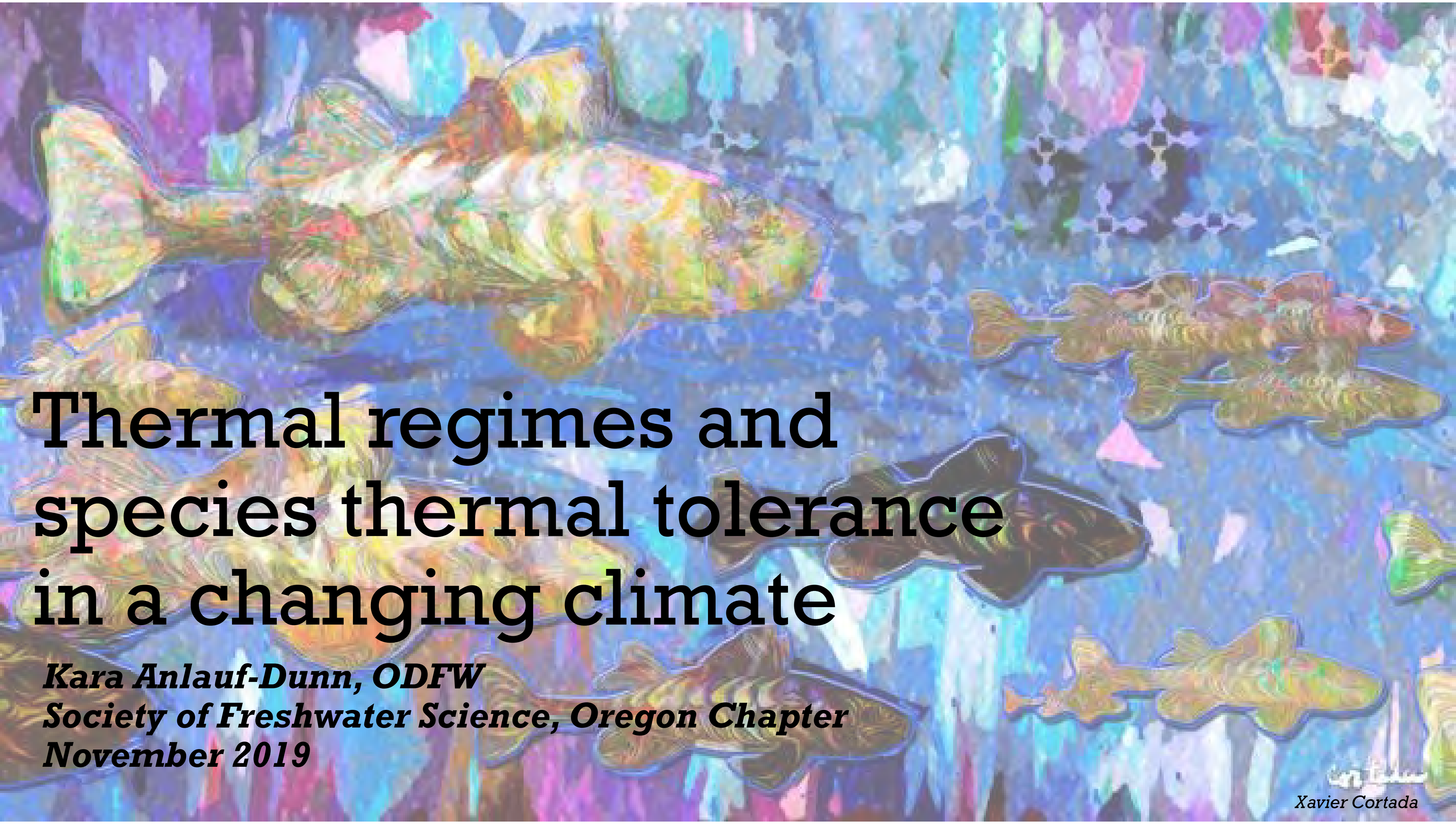
We have reached the limits of a volunteer effort to date and some source of funding is needed to motivate completion and periodic updates.

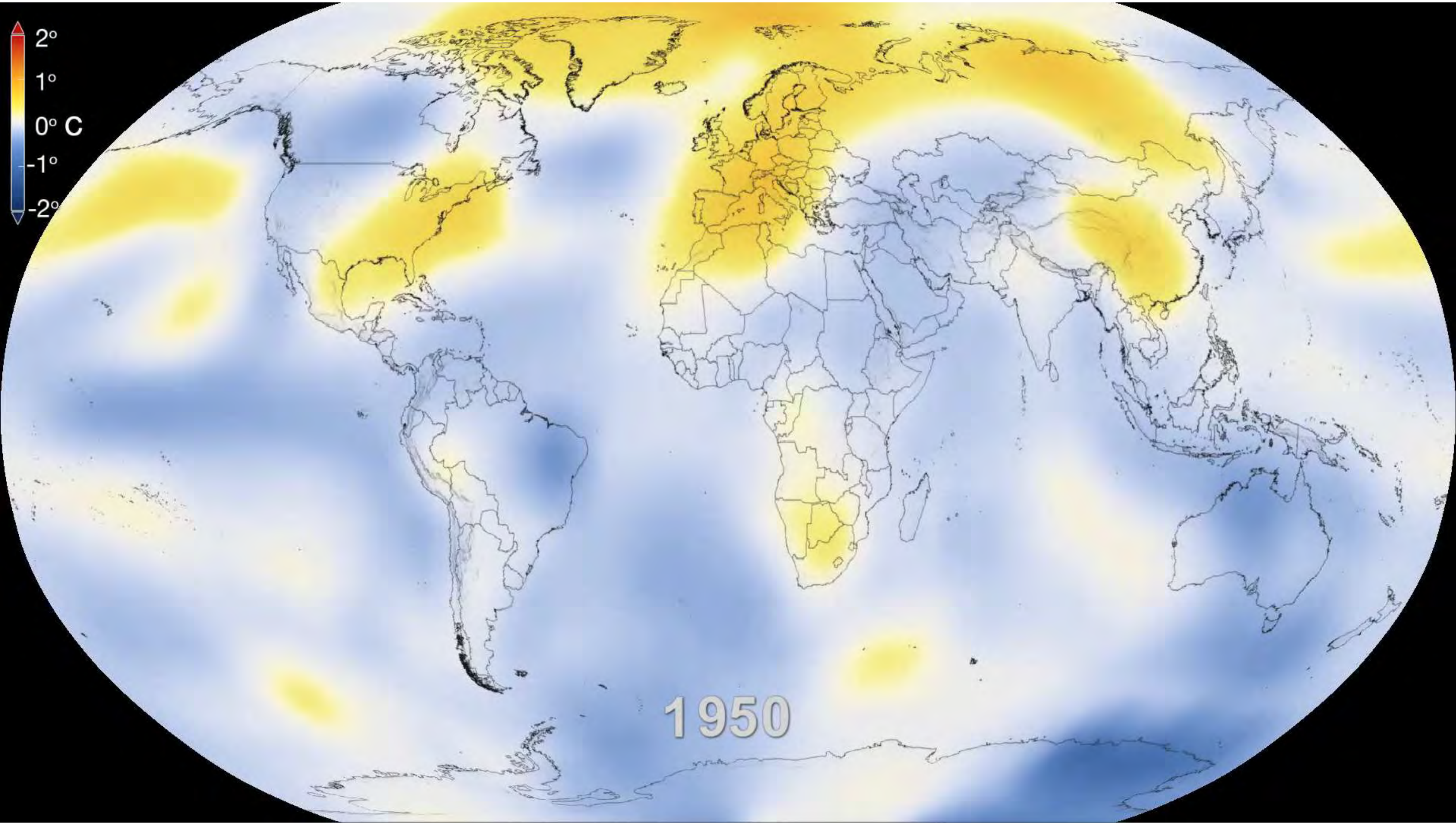
Thermal regimes and species thermal tolerance in a changing climate

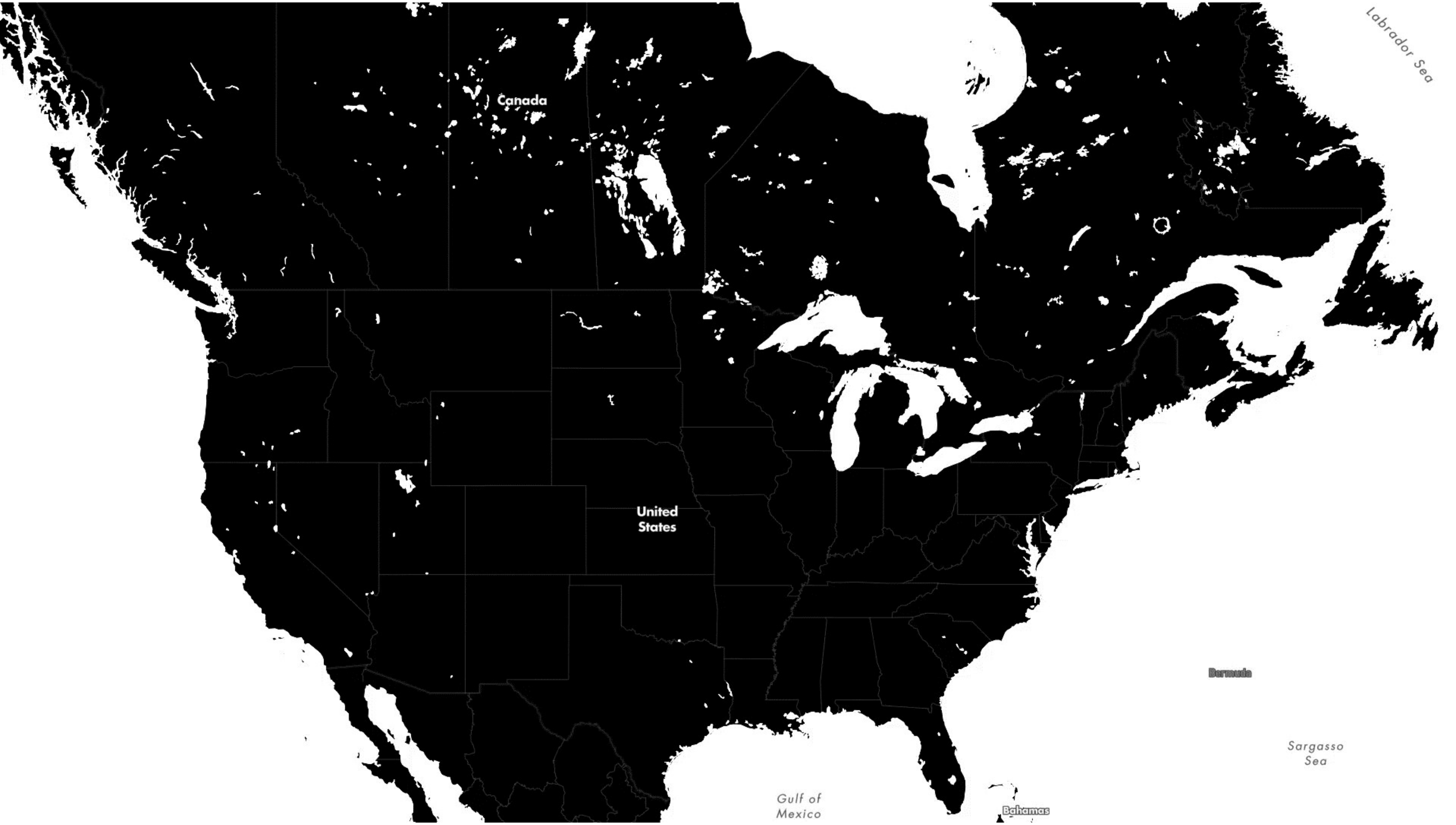
Kara Anlauf-Dunn, ODFW

Society of Freshwater Science, Oregon Chapter

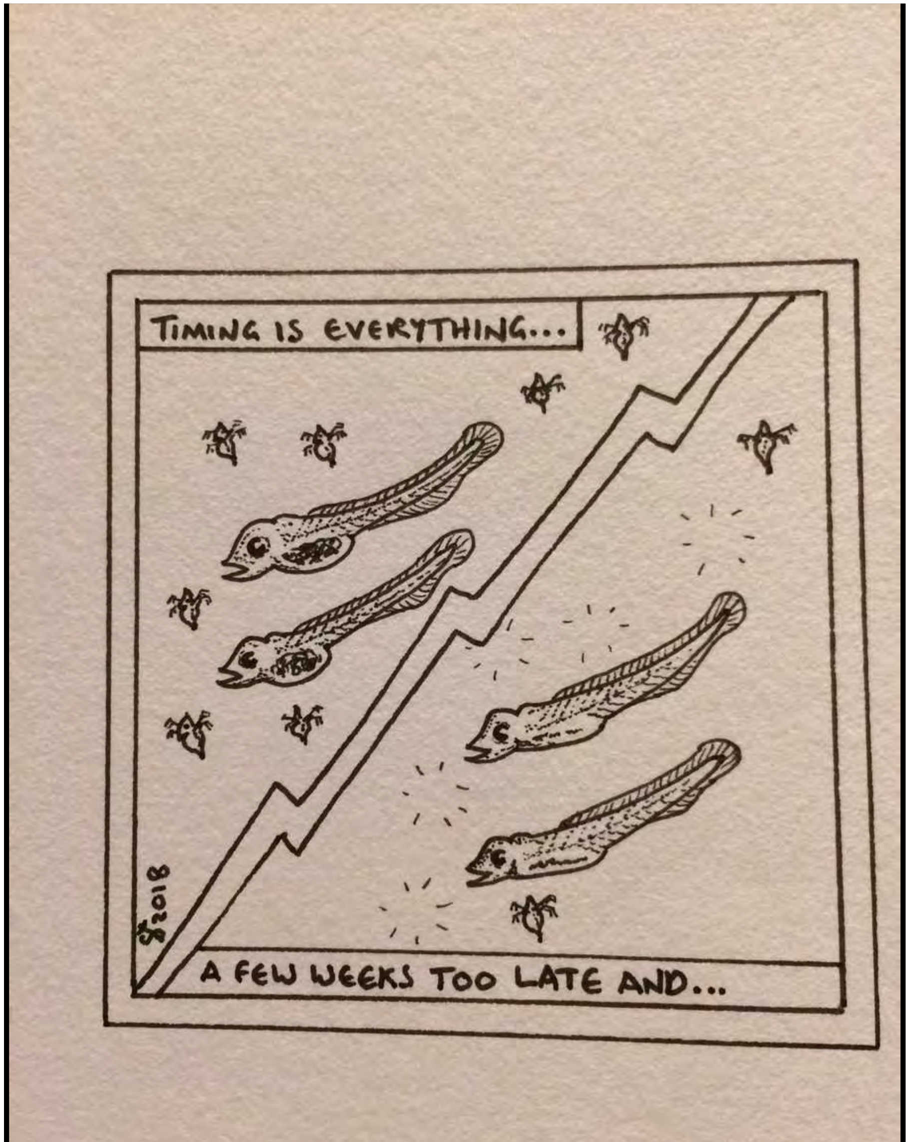
November 2019




2°
1°
0° C
-1°
-2°
1950

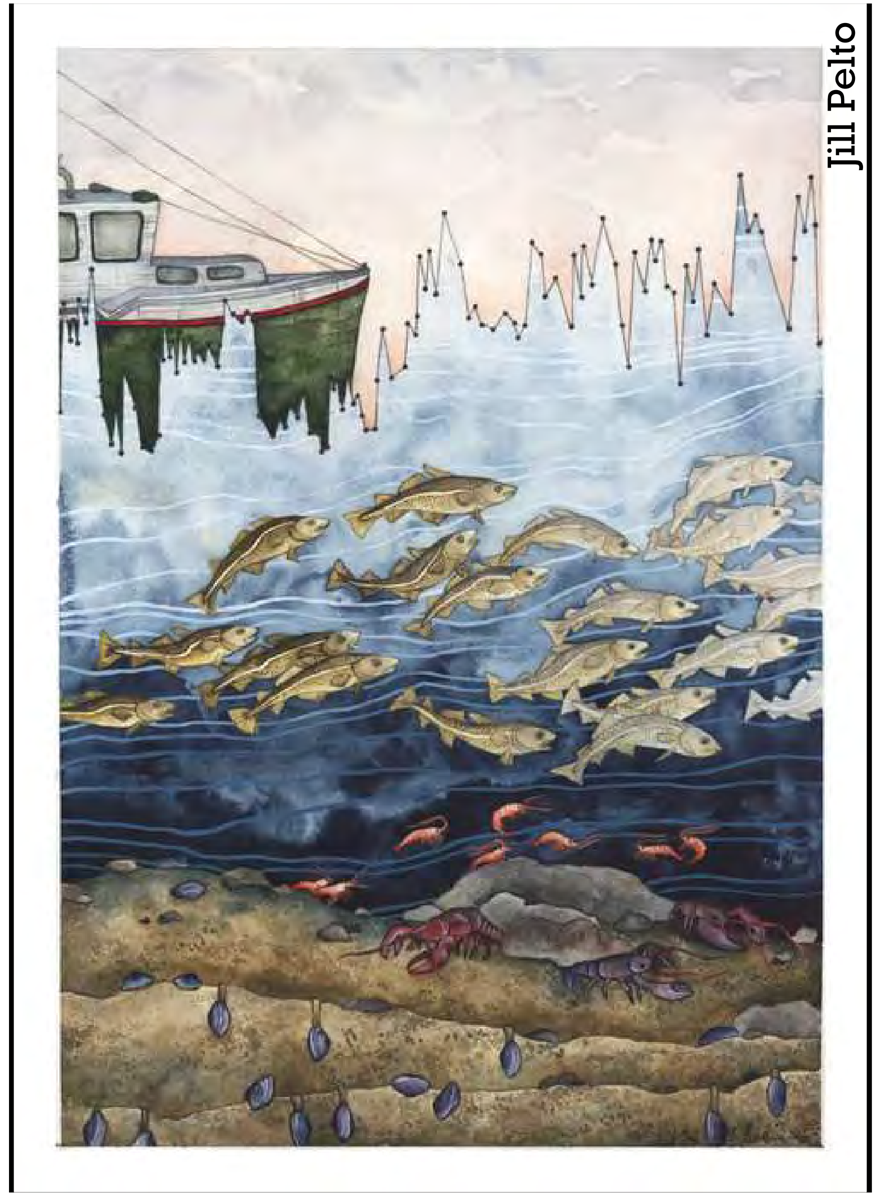

Labrador Sea
Canada
United States
Bermuda
Sargasso Sea
Gulf of Mexico
Bahamas

Phenology



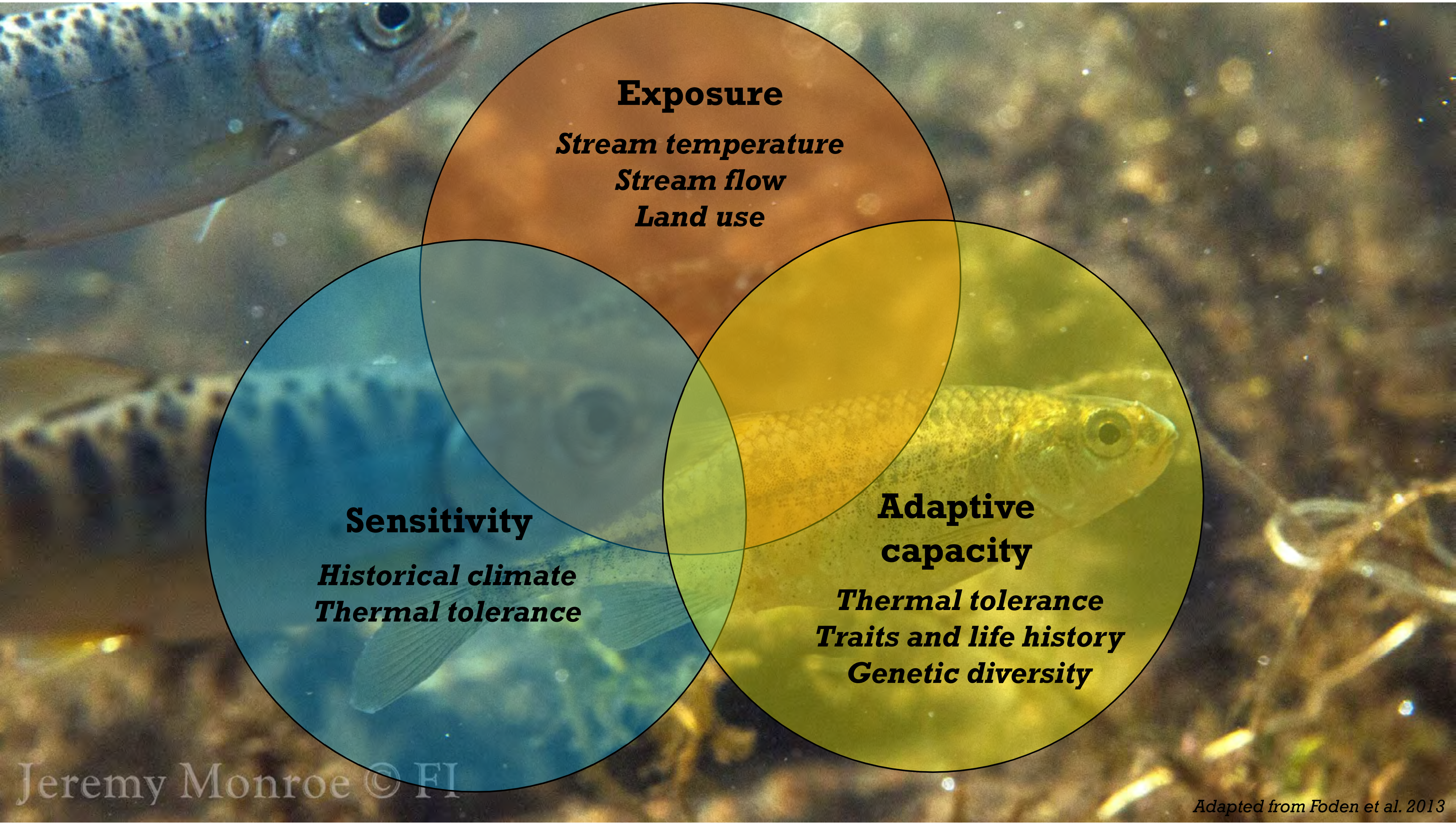
https://twitter.com/SteveThackeray

Distribution

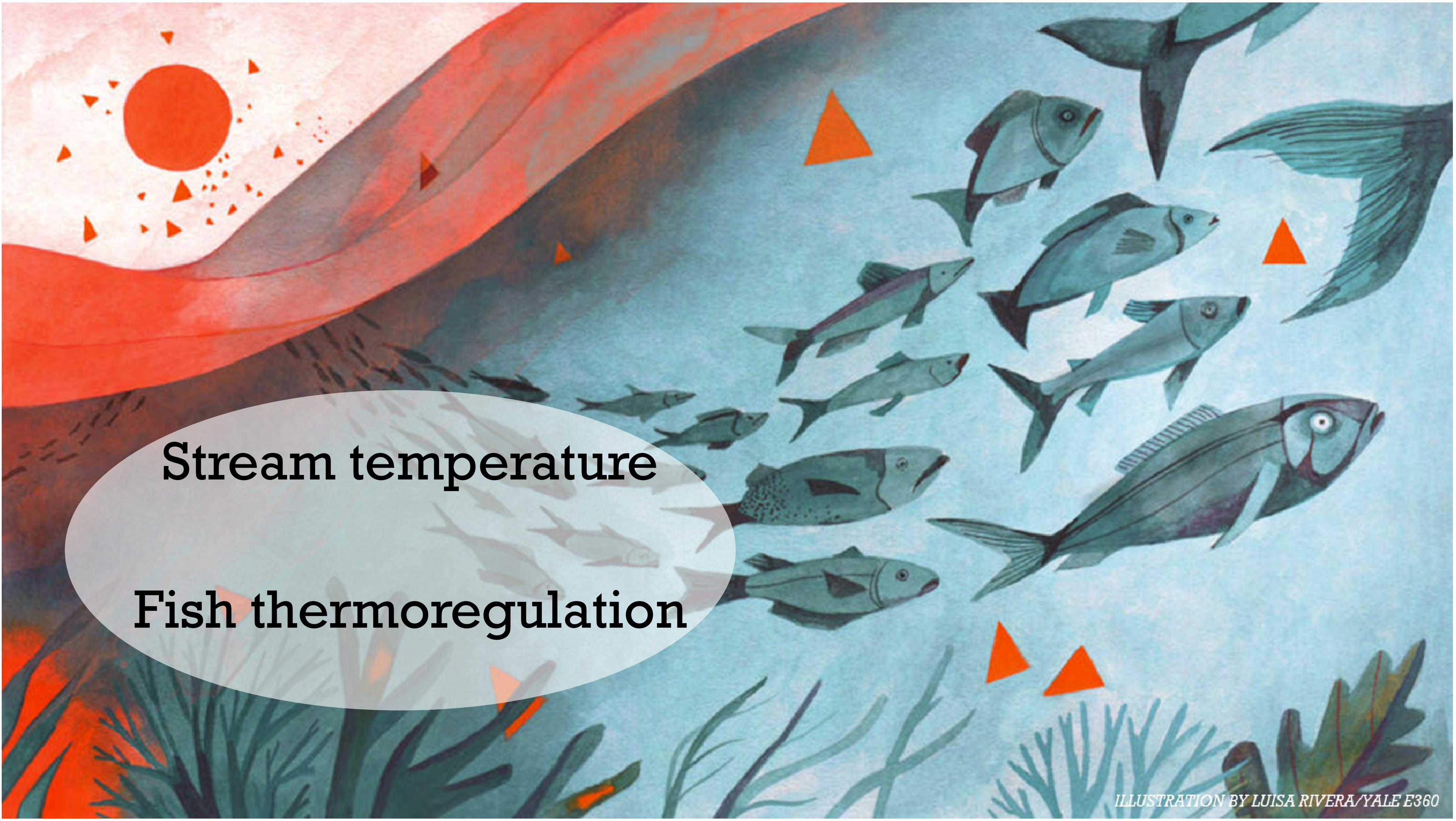


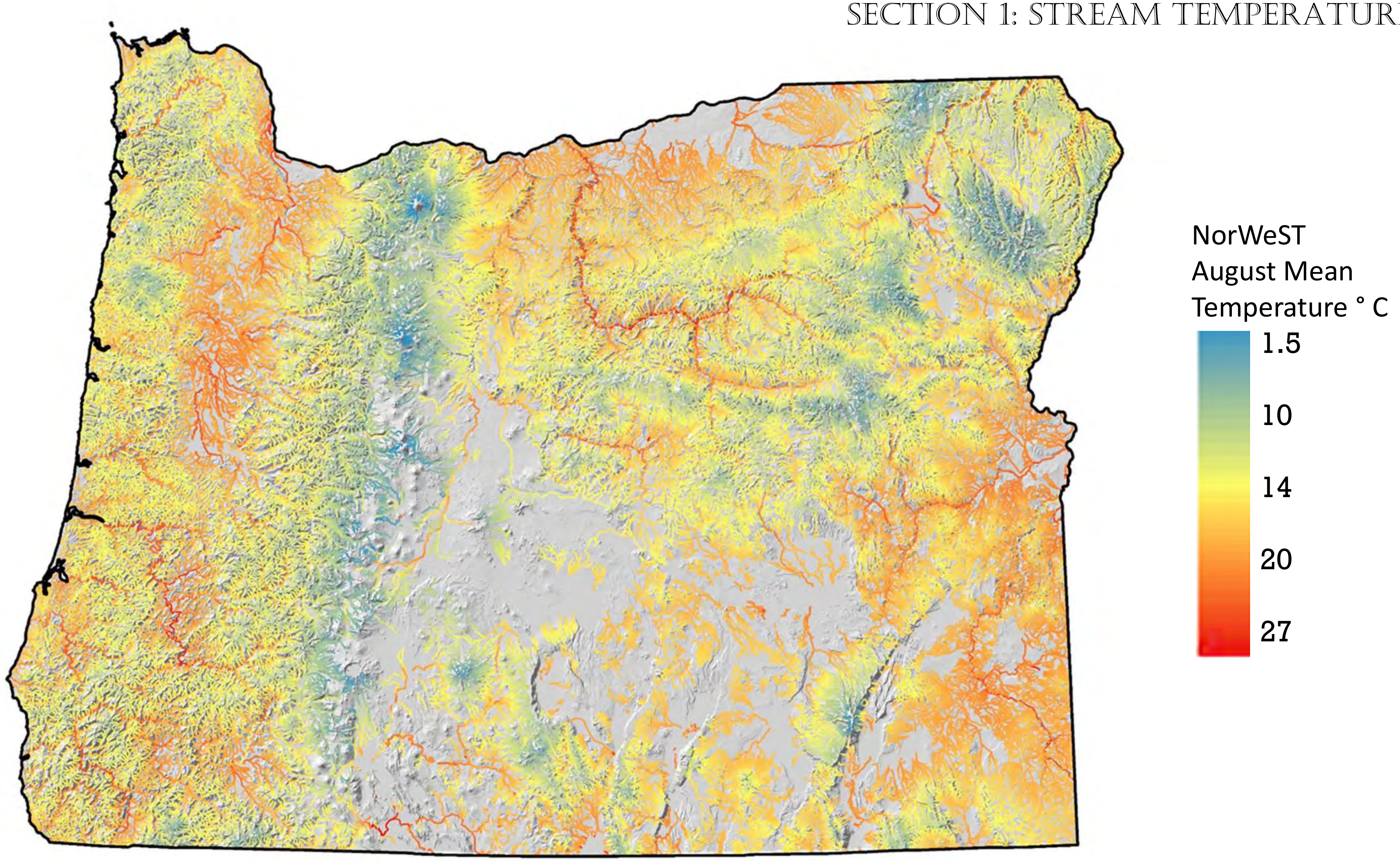
Lynne Yoon
Fort Lee, New Jersey
2016, Middle School, Art


Jeremy Monroe © FI

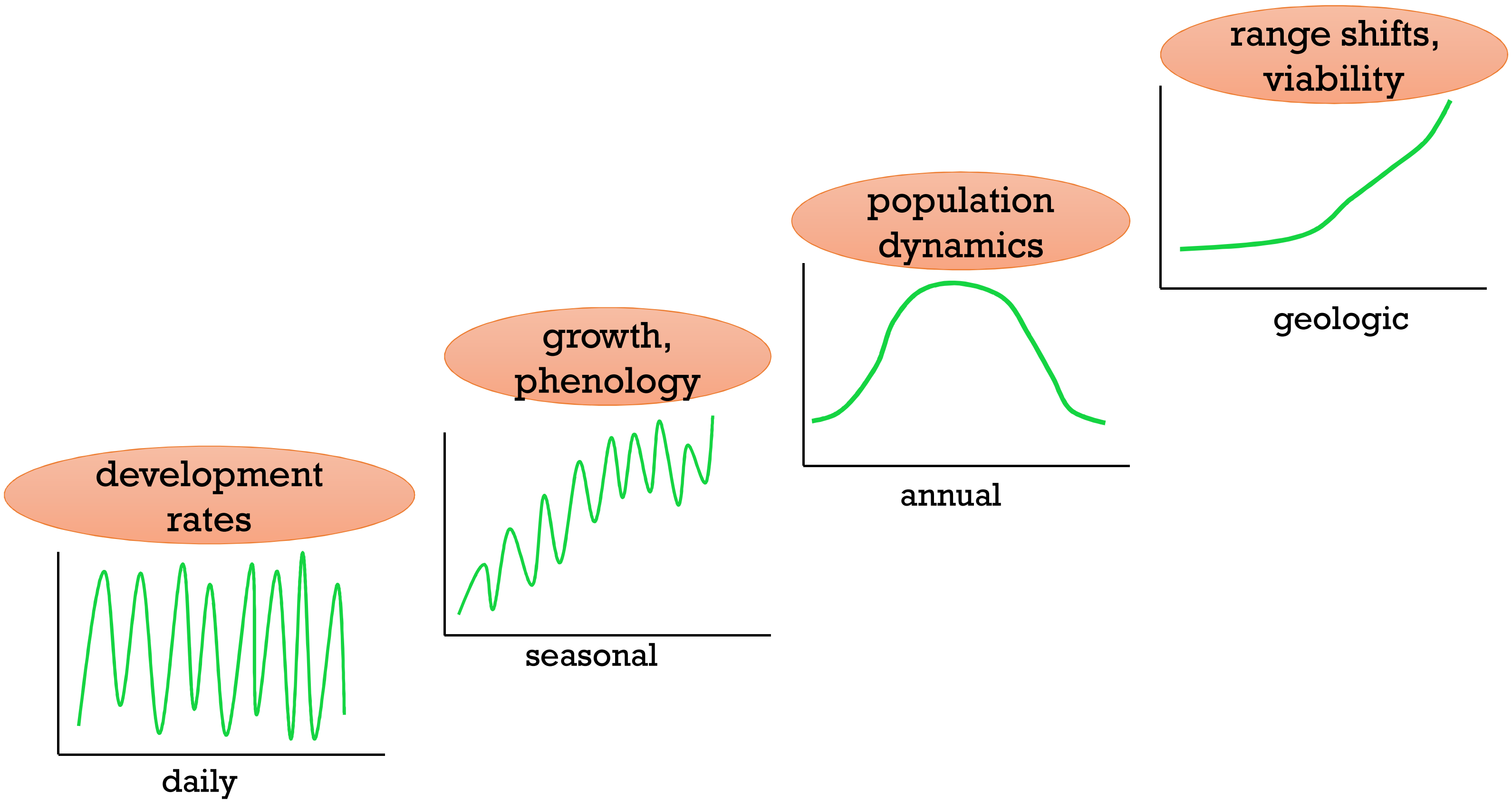


Exposure
Stream temperature
Stream flow
Land use
Sensitivity
Historical climate
Thermal tolerance
Adaptive capacity
Thermal tolerance
Traits and life history
Genetic diversity
Jeremy Monroe © FI
Adapted from Foden et al. 2013


Stream temperature
Fish thermoregulation
ILLUSTRATION BY LUISA RIVERA/YALE E360


NorWeST
August Mean
Temperature ° C
1.5
10
14
20
27

Temporal patterns at multiple scales

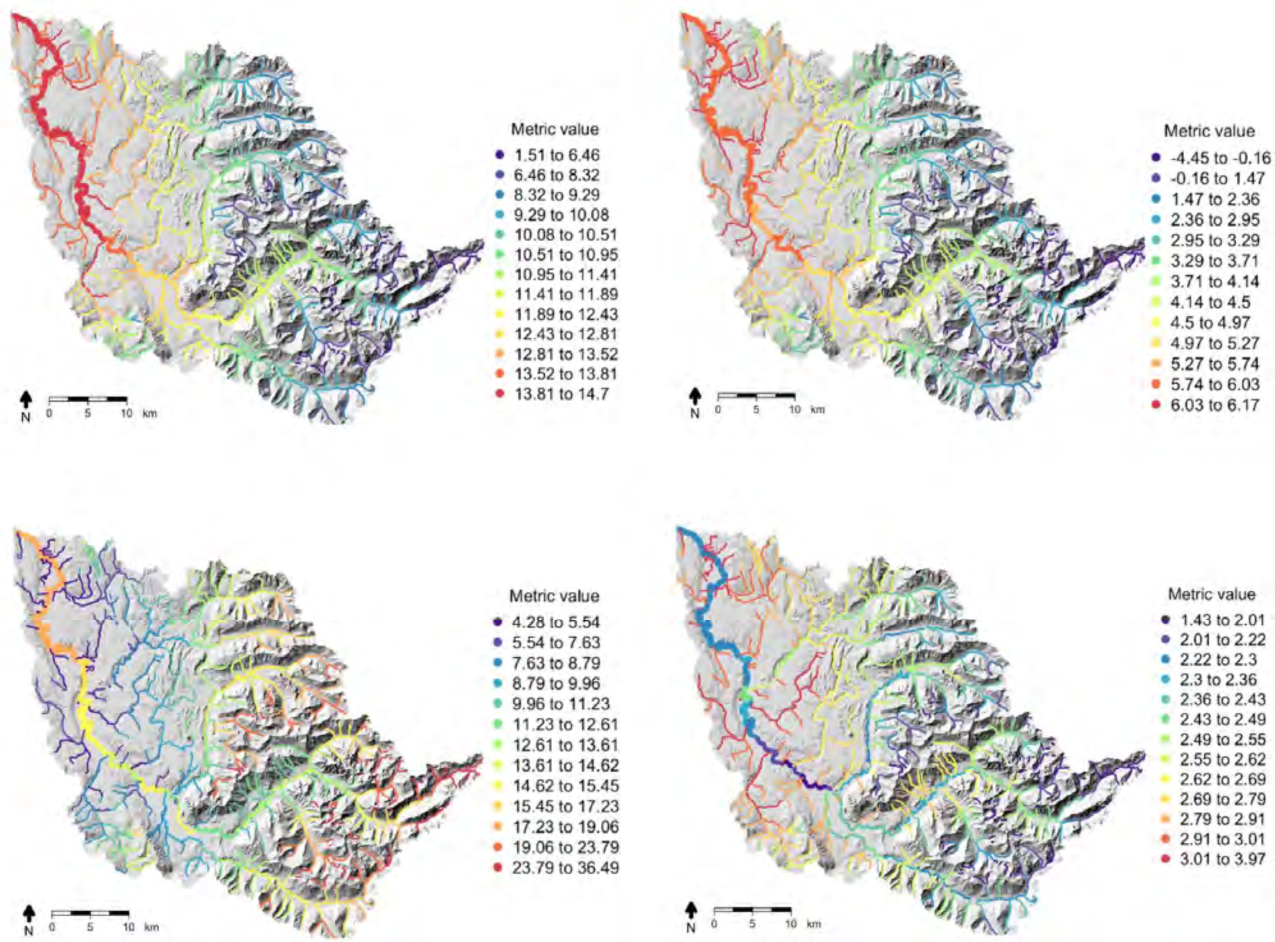


Beyond the mean

summer | winter

mean

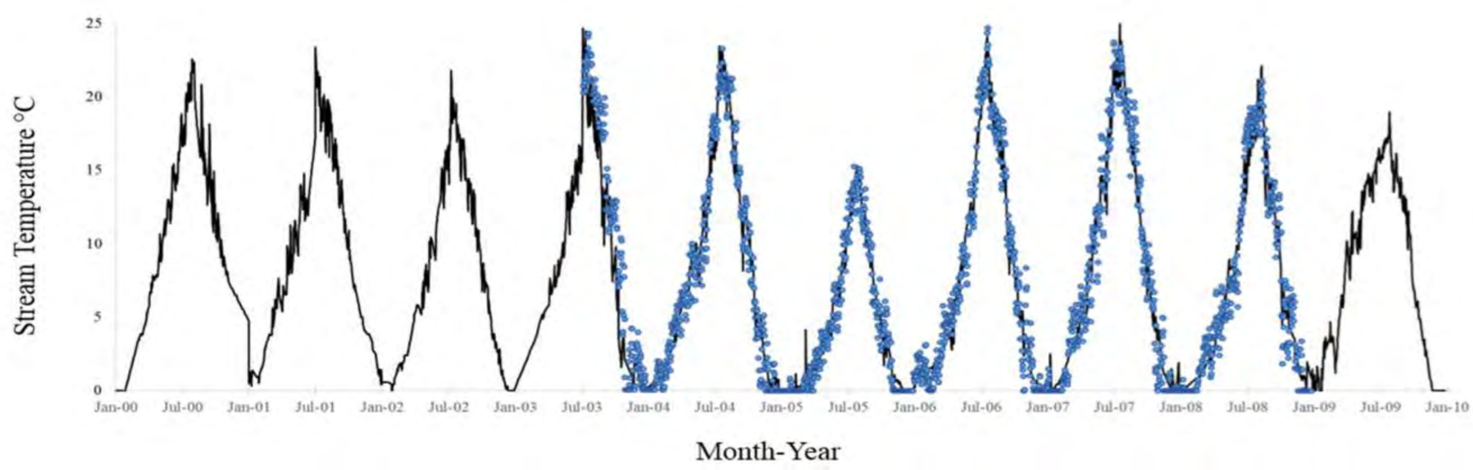
variability



Steel et al. 2017

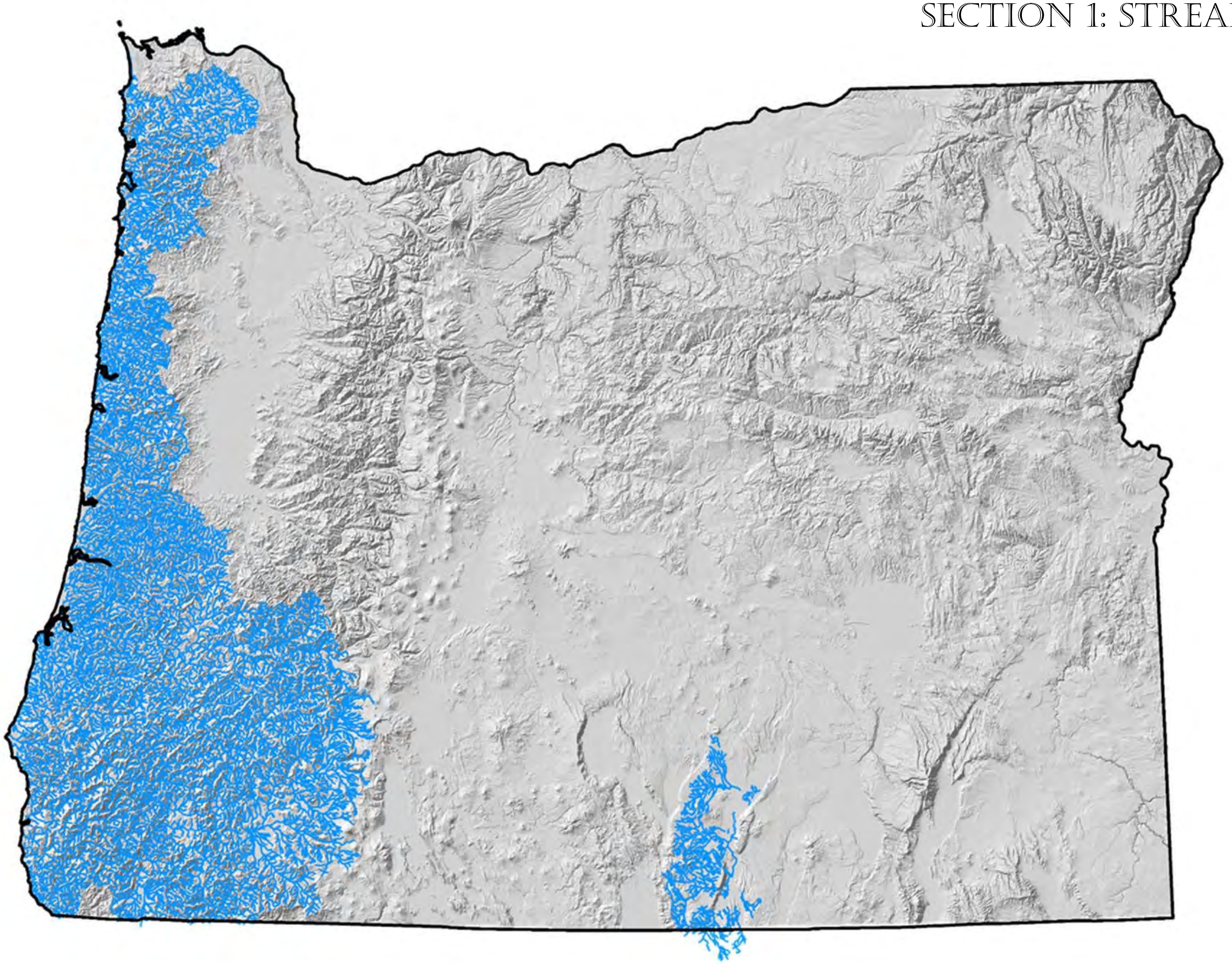
Modeling in space AND time

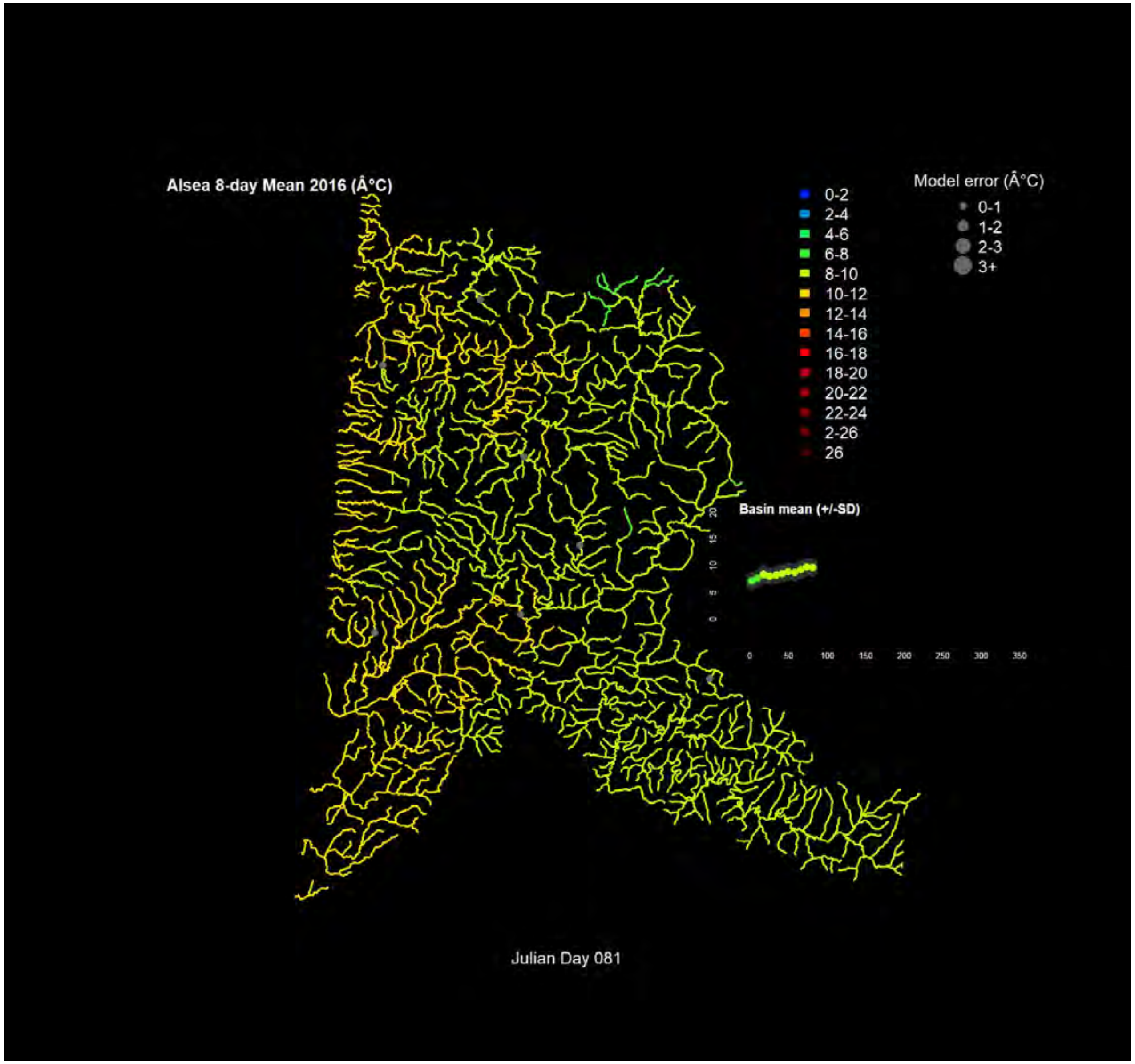
remotely sensed land surface temperature & thermistors



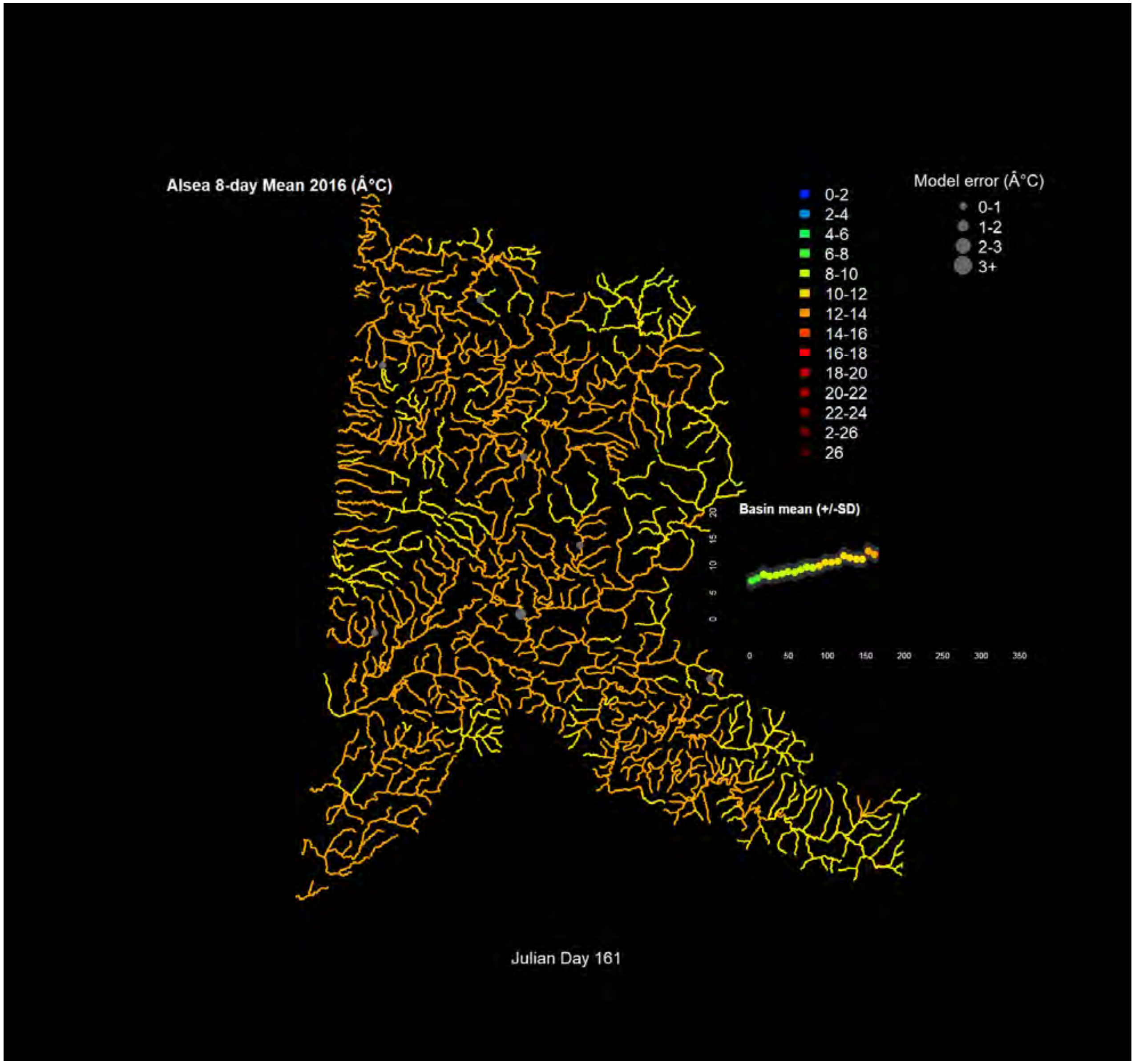
McNyset et al. 2015

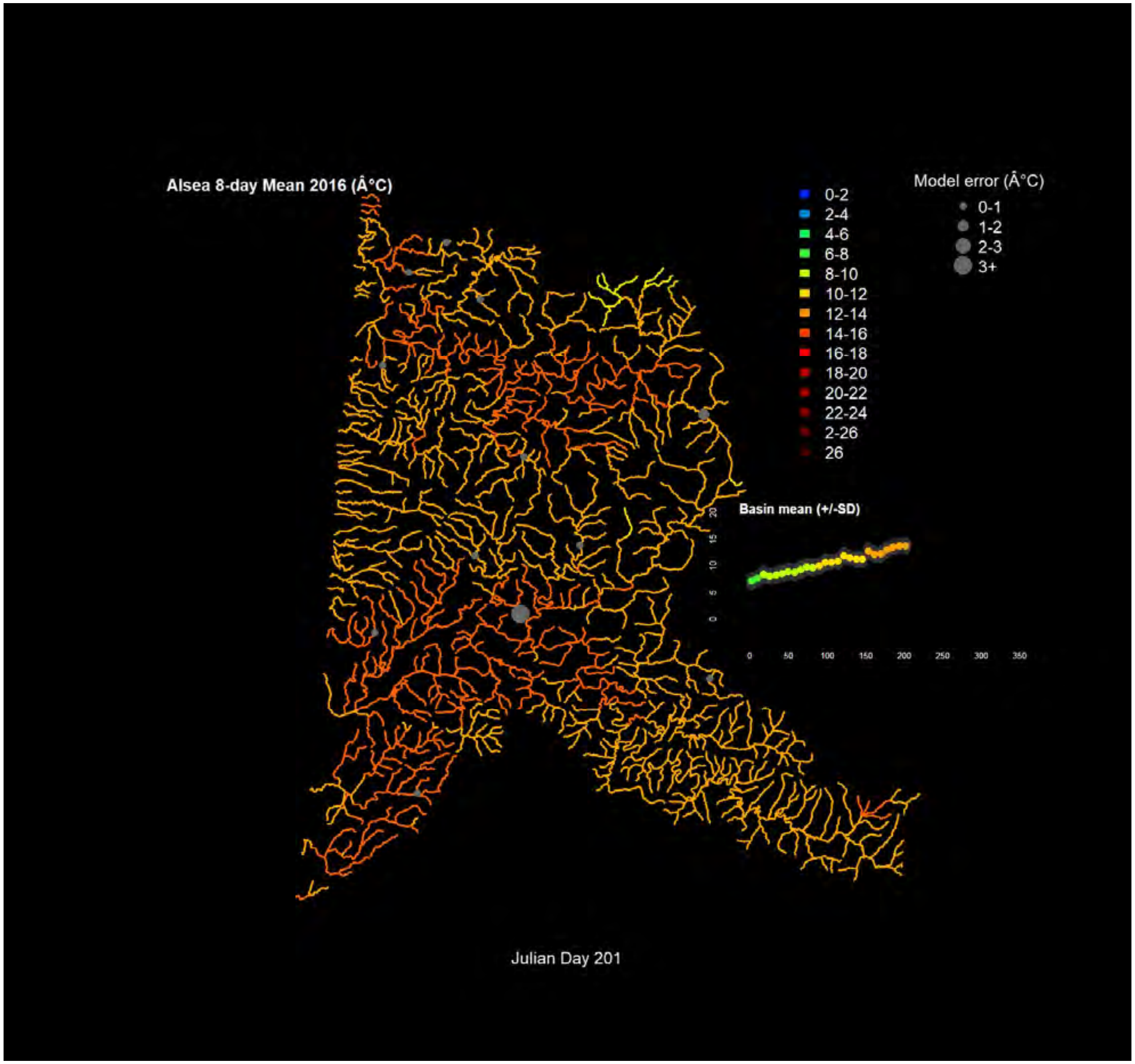
SECTION 1: STREAM TEMPERATURE





Alsea 8-day Mean 2016 (Â°C)
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
20-22
22-24
2-26
26
Model error (Â°C)
0-1
1-2
2-3
3+
Basin mean (+/-SD)
0
50
100
150
200
250
300
350
Julian Day 081


Alsea 8-day Mean 2016 (Â°C)
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
20-22
22-24
2-26
26
Model error (Â°C)
0-1
1-2
2-3
3+
Basin mean (+/-SD)
0
5
10
15
20
0
50
100
150
200
250
300
350
Julian Day 161



Alsea 8-day Mean 2016 (Â°C)
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
20-22
22-24
2-26
26
Model error (Â°C)
0-1
1-2
2-3
3+
Basin mean (+/-SD)
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15
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0
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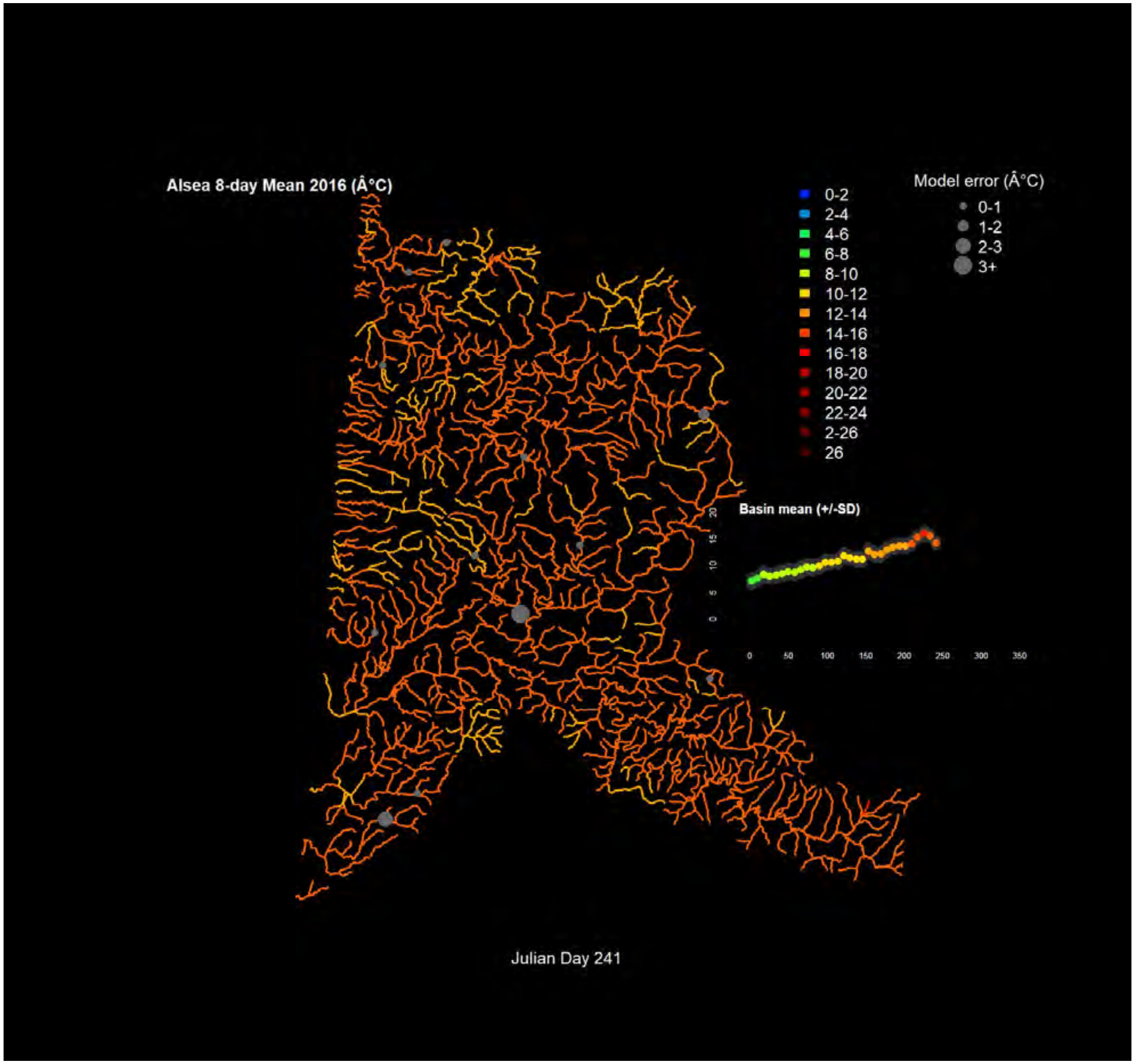
100
150
200
250
300
350
Julian Day 201


Alsea 8-day Mean 2016 (Â°C)
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
20-22
22-24
2-26
26
Model error (Â°C)
0-1
1-2
2-3
3+
Basin mean (+/-SD)
0
5
10
15
20
0
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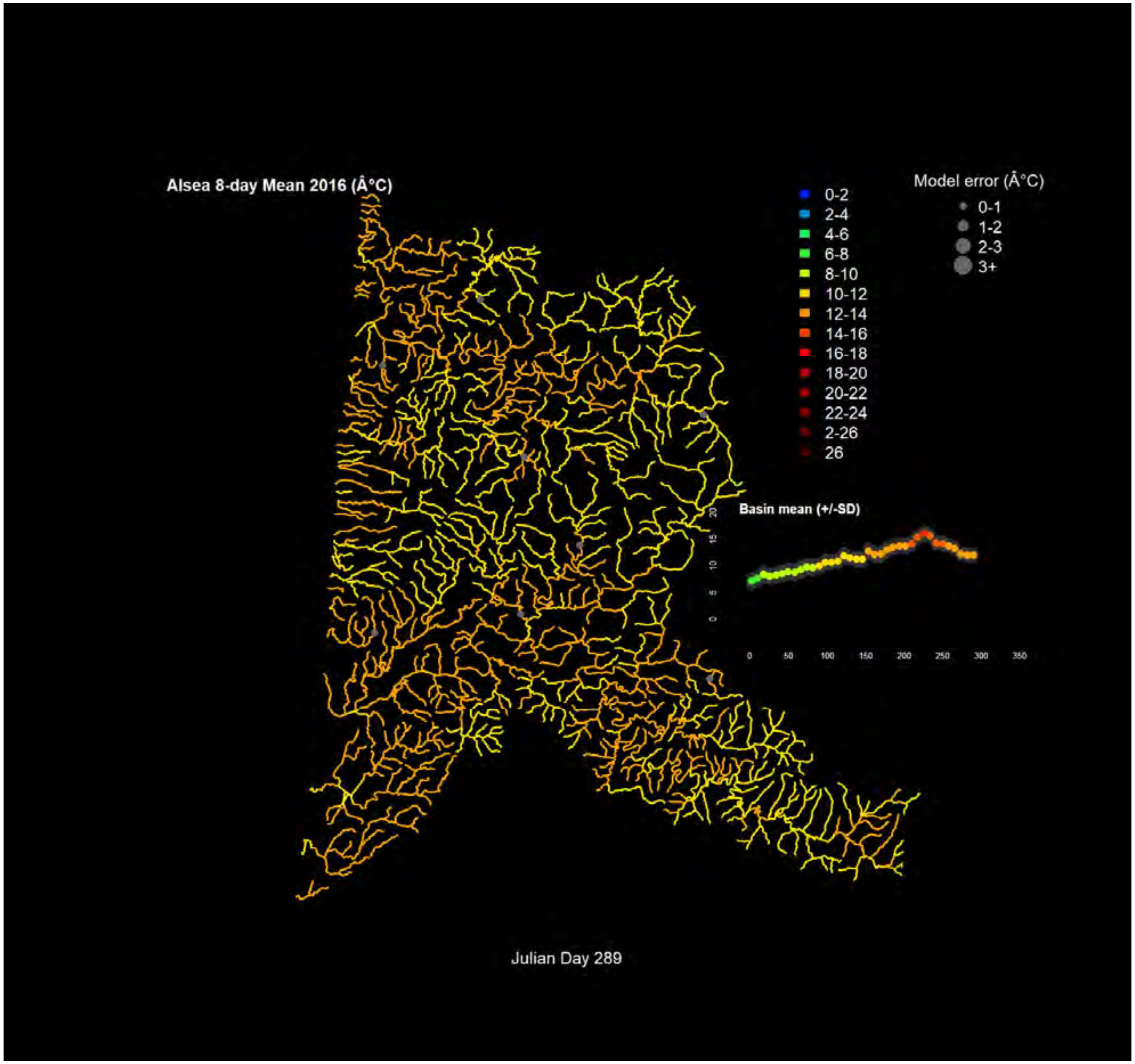
100
150
200
250
300
350
Julian Day 241



Alsea 8-day Mean 2016 (Â°C)
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
20-22
22-24
2-26
26
Model error (Â°C)
0-1
1-2
2-3
3+
Basin mean (+/-SD)
20
15
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5
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200
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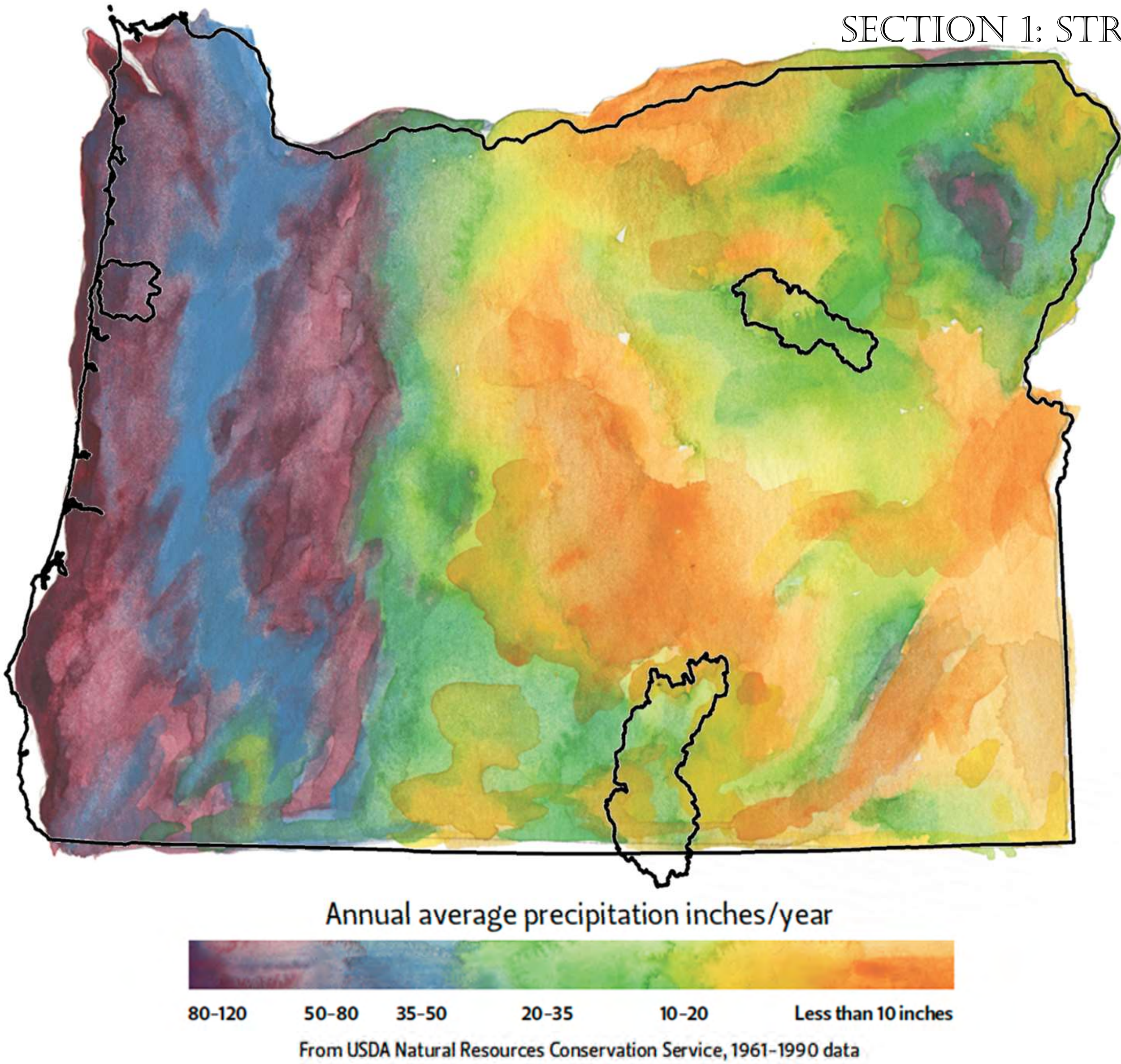
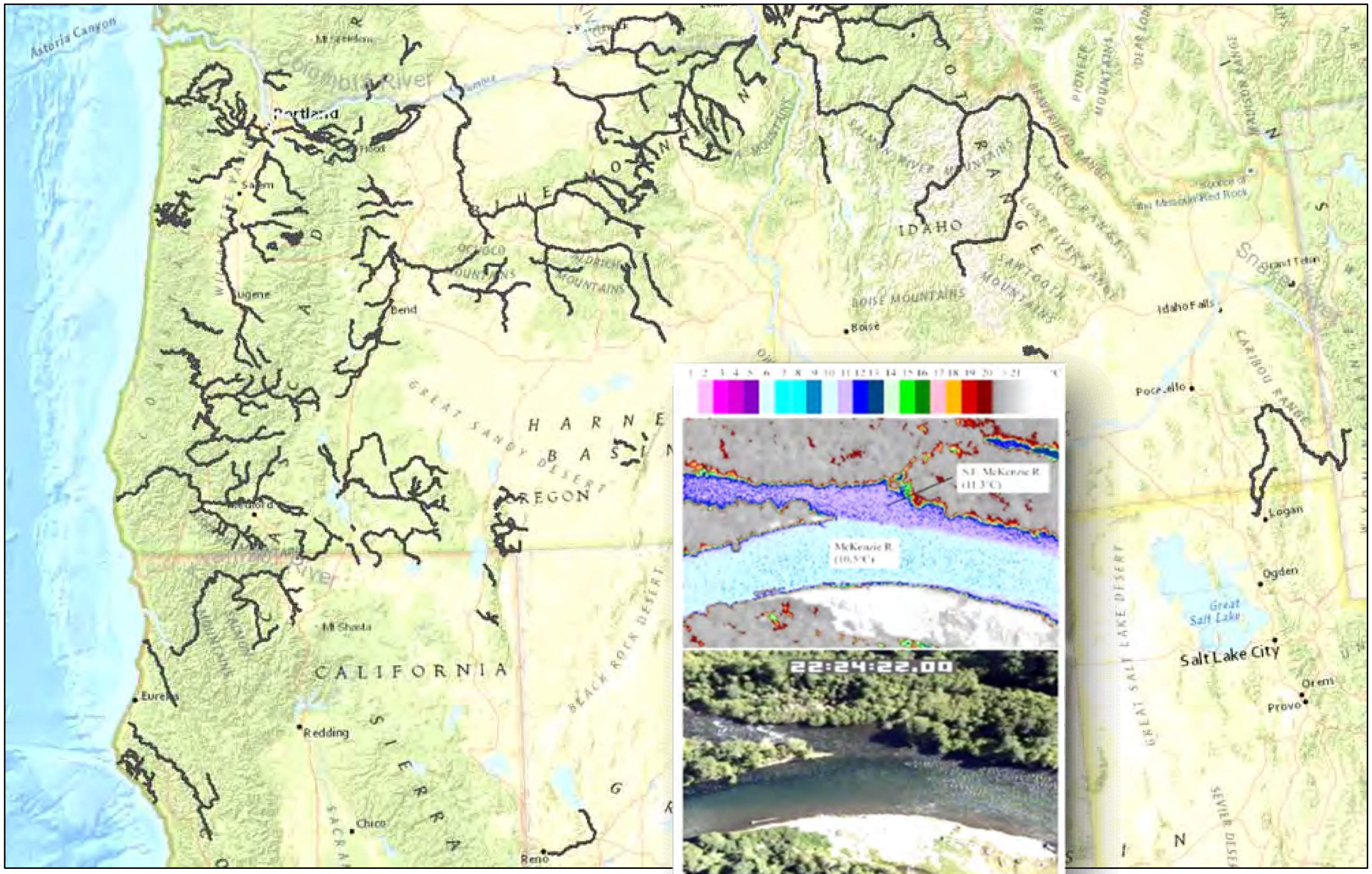
Julian Day 289

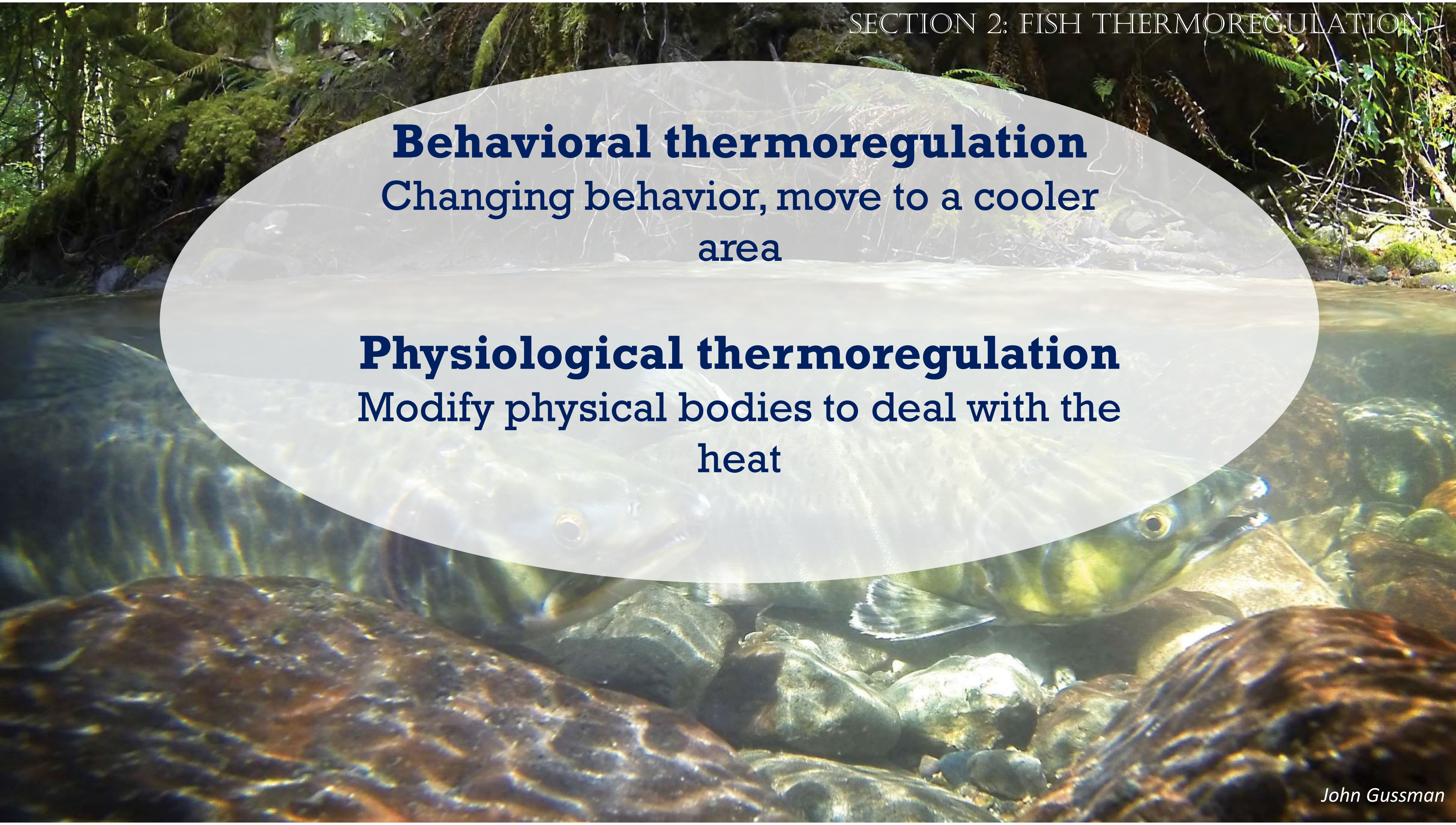

Annual average precipitation inches/year
80-120
50-80
35-50
20-35
10-20
Less than 10 inches
From USDA Natural Resources Conservation Service, 1961-1990 data

Airborne thermal infrared (TIR) surveys

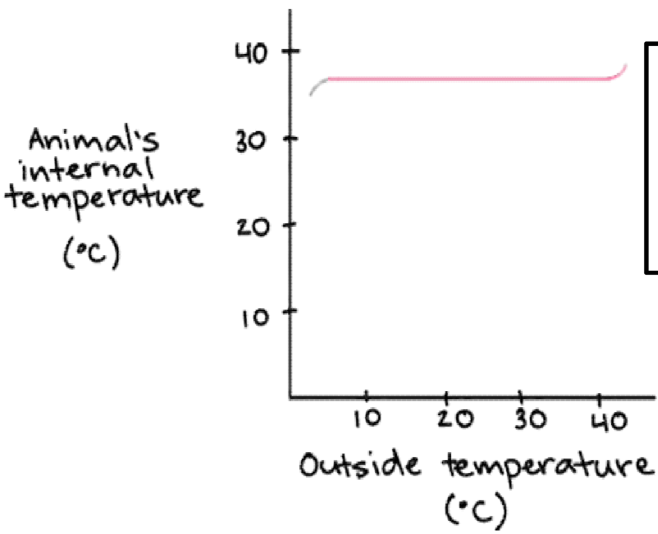


SECTION 1: STREAM TEMPERATURE

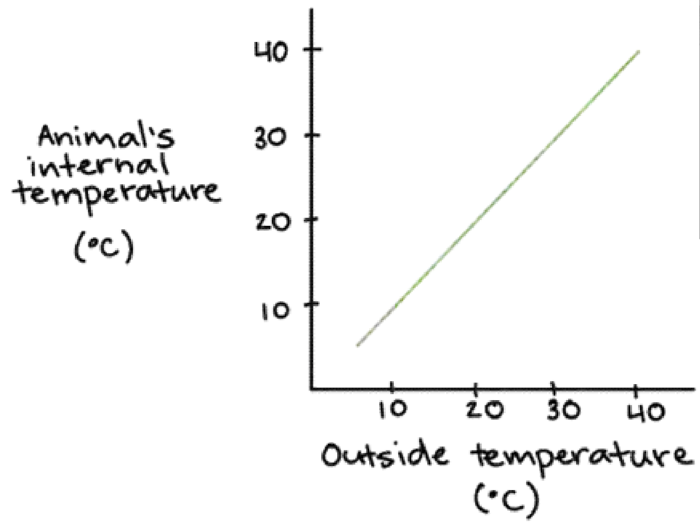
Figure: Aimee Fullerton


SECTION 2: FISH THERMOREGULATION
Behavioral thermoregulation
Changing behavior, move to a cooler area
Physiological thermoregulation
Modify physical bodies to deal with the heat
John Gussman

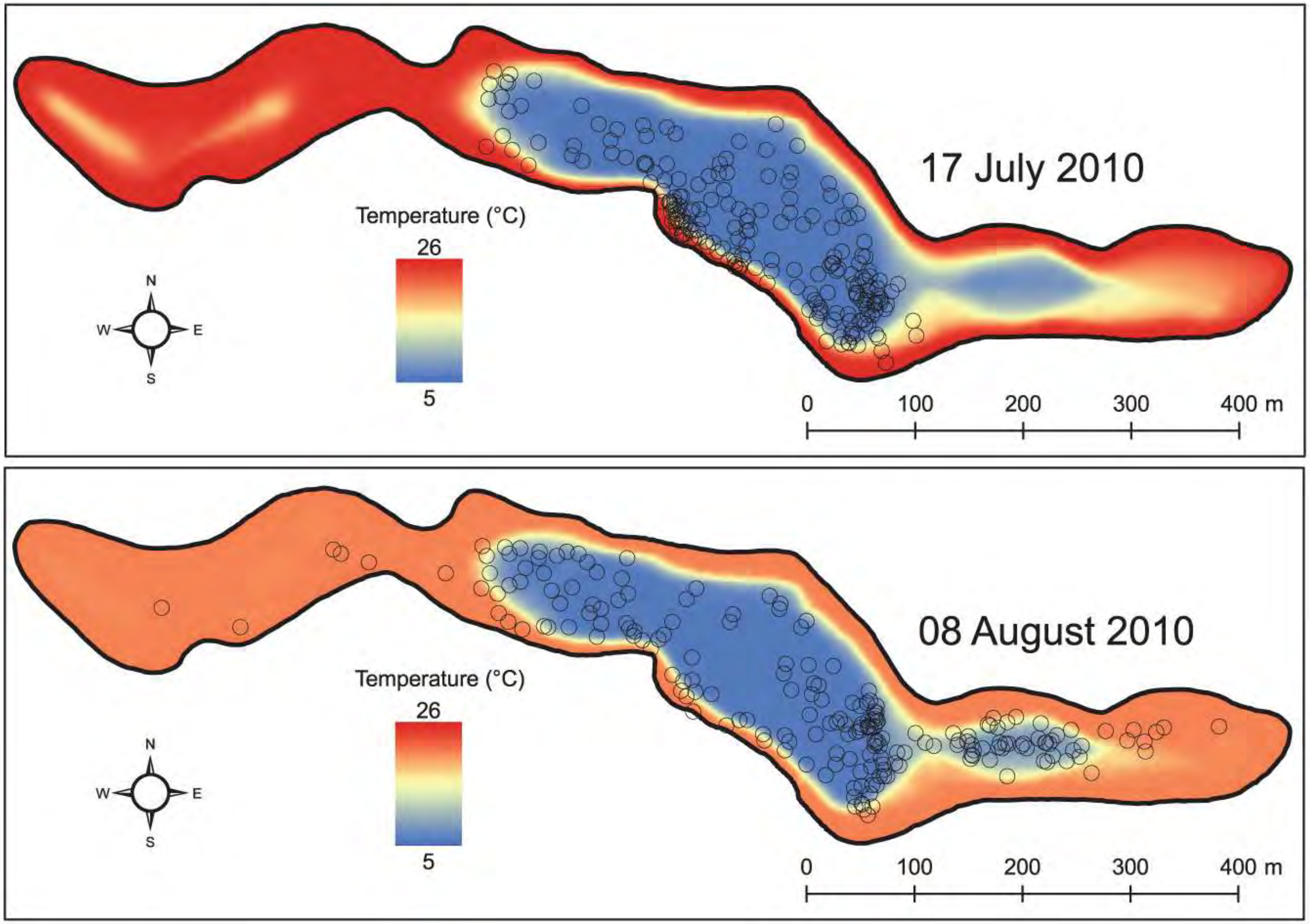
Endotherm vs. Ectotherm



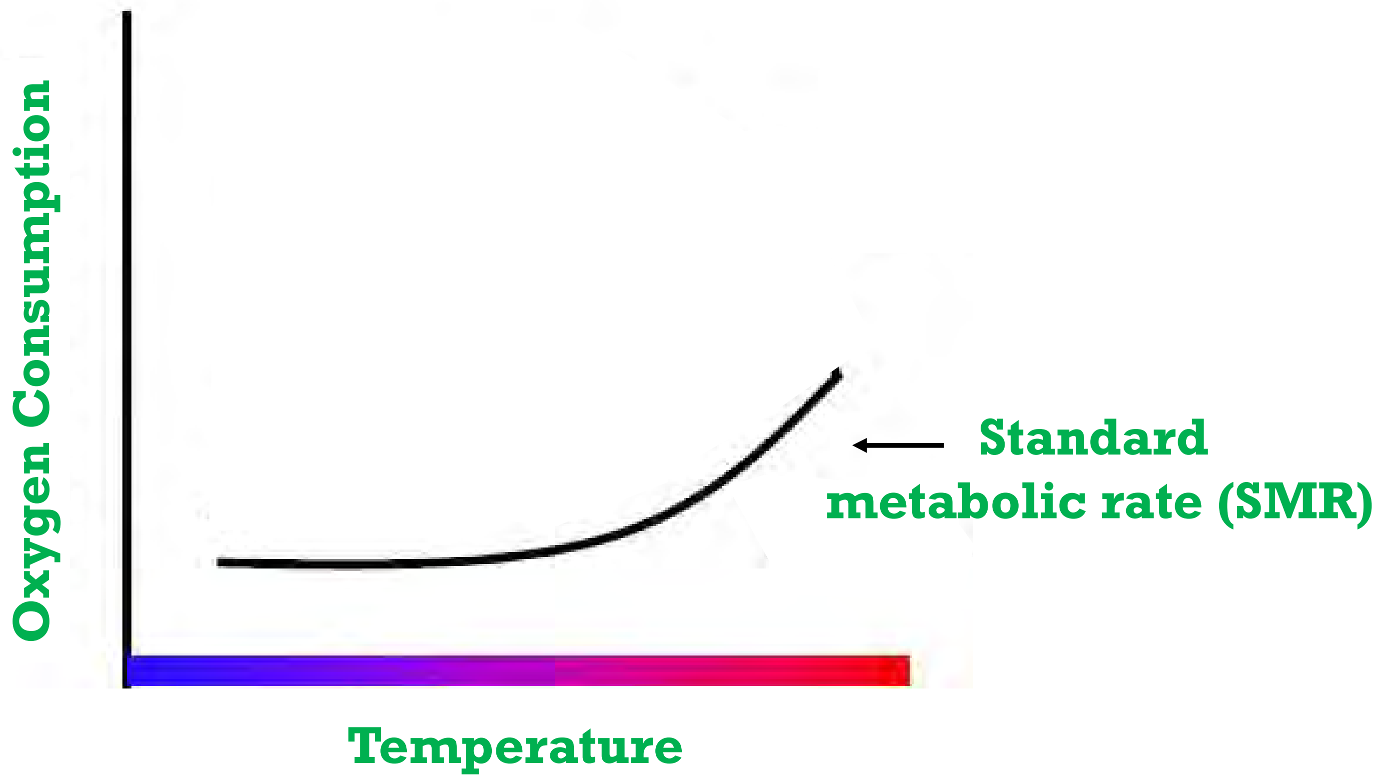
ENDOTHERMS
like the mouse
generate metabolic
heat to maintain
internal temperature



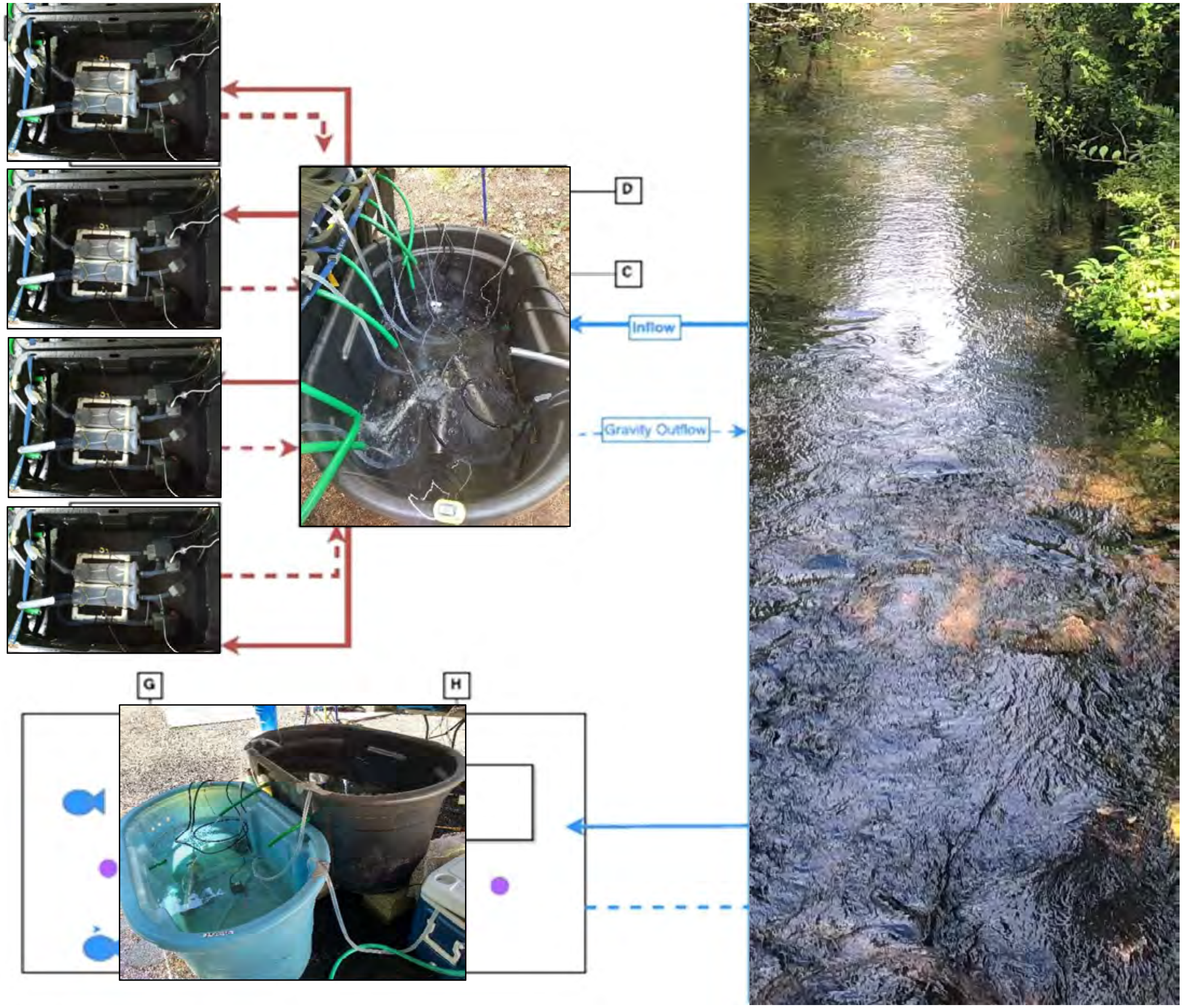
ECTOTHERMS
like the fish have a
body temperature
that changes with
the temperature
of the environment



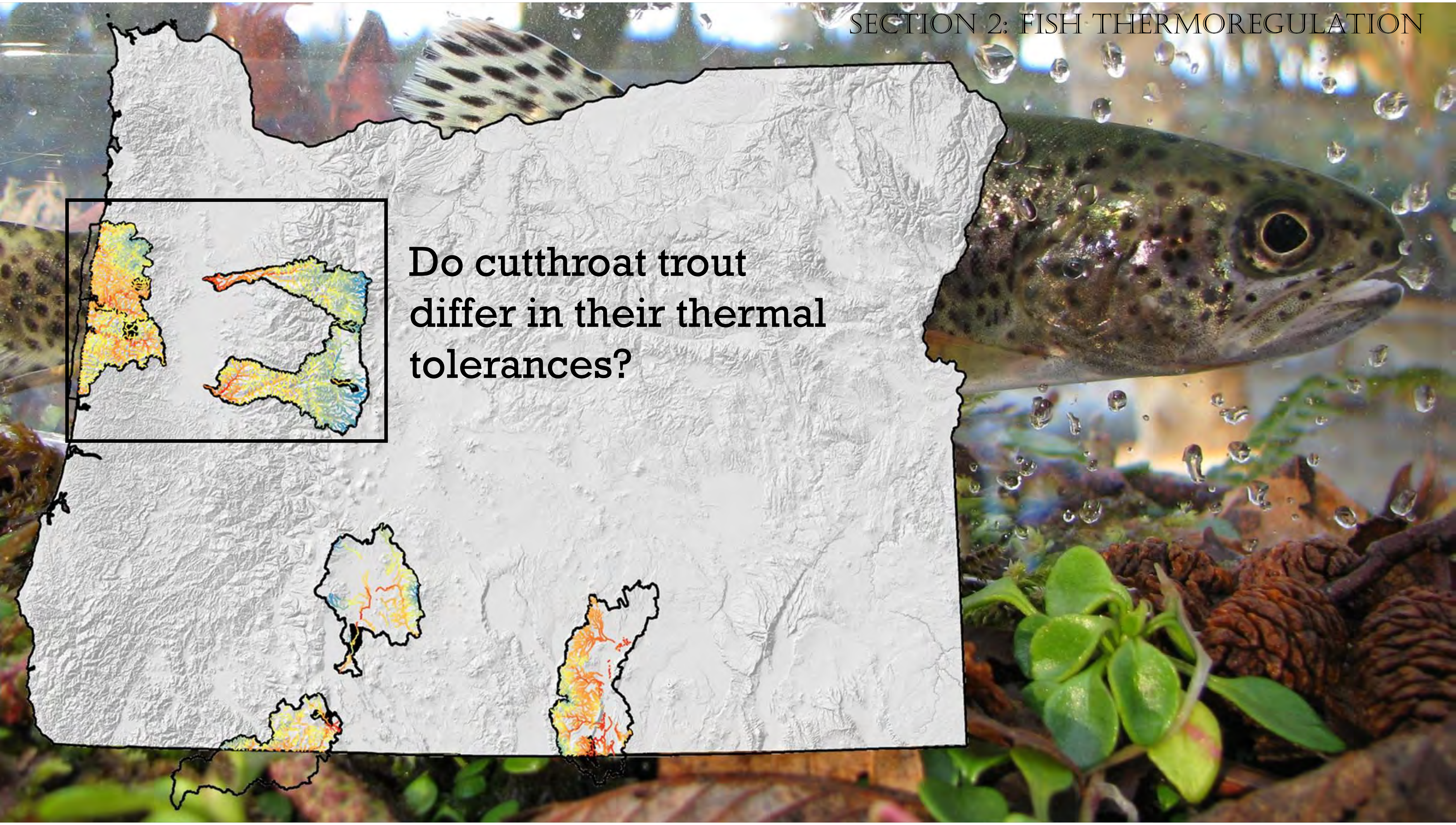
Goyer et al. 2014

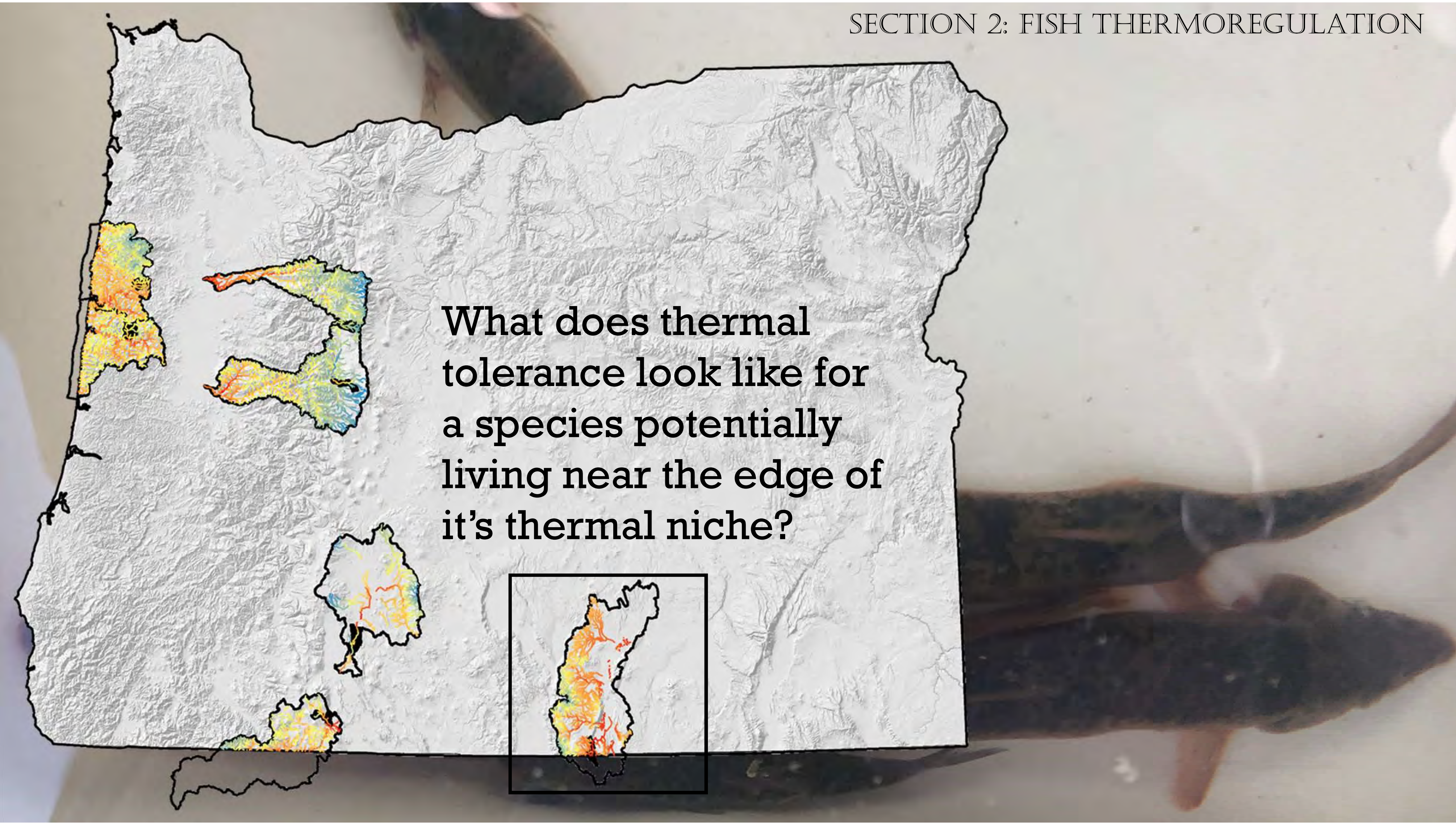

Oxygen Consumption
Standard
metabolic rate (SMR)
Temperature

Crooked Creek - Klamath

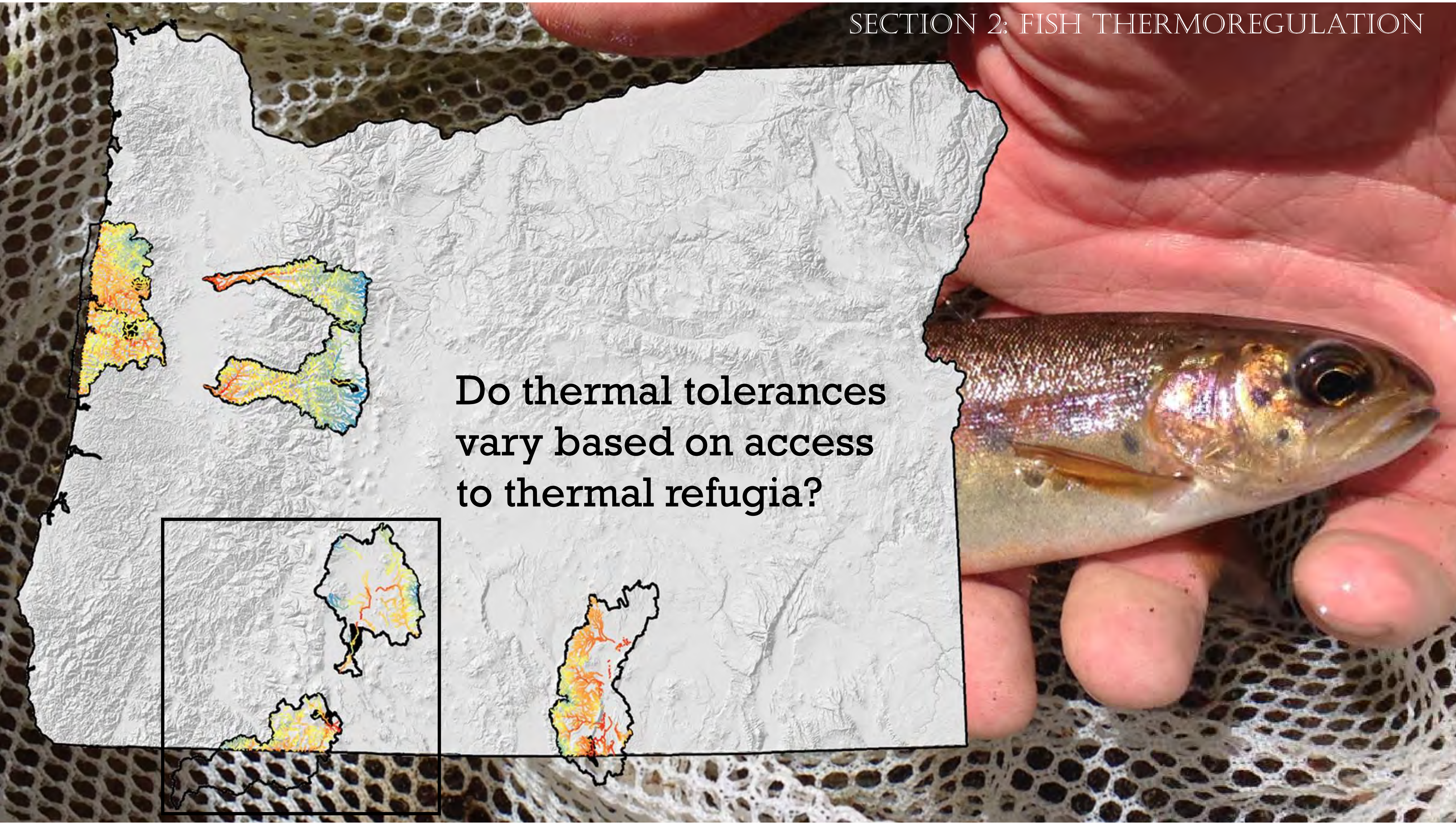

D
C
Inflow
Gravity Outflow
G
H

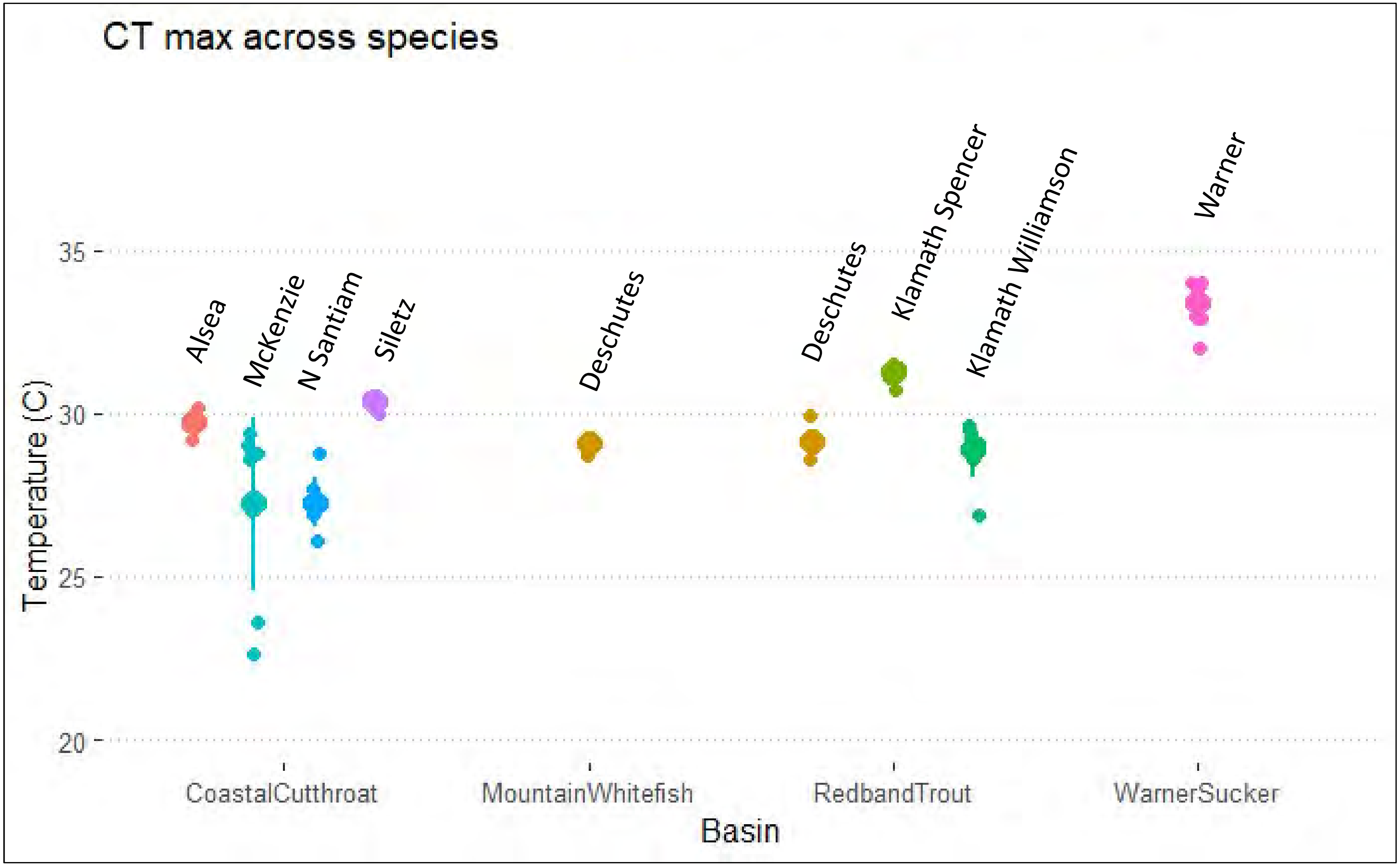

I love warm water, it's the best !!
What !? Cold water is better !! Are you really salmon?
Chihiro Kinoshita


Do cutthroat trout
differ in their thermal
tolerances?



What does thermal tolerance look like for a species potentially living near the edge of it’s thermal niche?


SECTION 2: FISH THERMOREGULATION
Do thermal tolerances vary based on access to thermal refugia?


CT max across species
Alsea
McKenzie
N Santiam
Siletz
Deschutes
Deschutes
Klamath Spencer
Klamath Williamson
Warner
35
30
25
20
Temperature (C)
CoastalCutthroat
MountainWhitefish
RedbandTrout
WarnerSucker
Basin

The salmon come home at the end of their lives.
They spawn, and each little egg that survives
will start the cycle over again
with the coming of the rain,
and silver smolt will discover the sea
and turn to salmon swimming free,
and tiny fish will one day hatch
(with their dinners still attached)
from the eggs of a salmon, born to travel,
that hide in the nest of rocky gravel
far beyond the shady pool,
filled with water, clear and cool,
that flows in the stream in the forest.

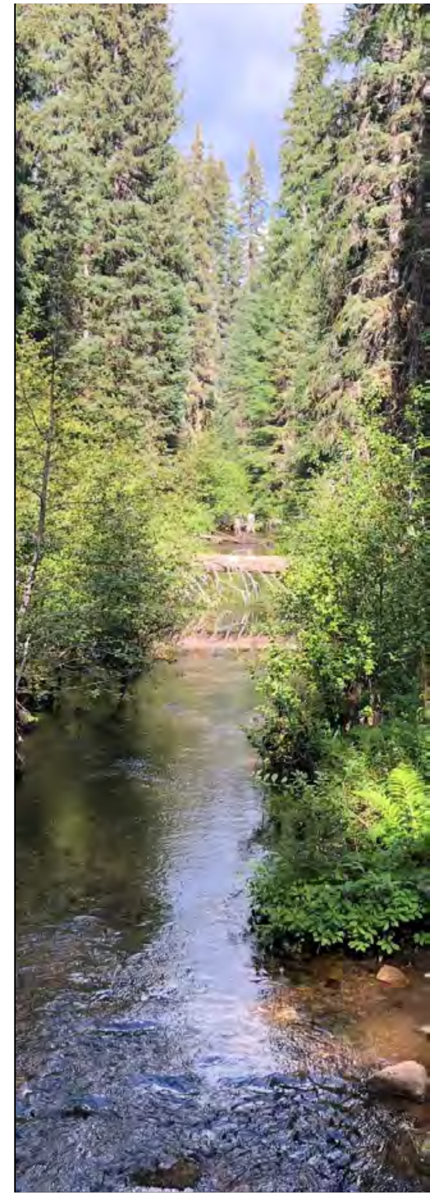
Salmon Stream
Carol Reed-Jones

Acknowledgments

Eliason Lab
University of California, Santa Barbara

Aimee Fullerton
NOAA Fisheries

REDD
Oregon Department of Fish and Wildlife



CHALLENGES AND OPPORTUNITIES FOR LINKING RIVERSCAPE THERMAL REGIMES TO FISH POPULATIONS

Joe Ebersole , Marcia Snyder, and Nathan Schumaker

US Environmental Protection Agency, Pacific Ecological Systems Division, Corvallis, OR USA

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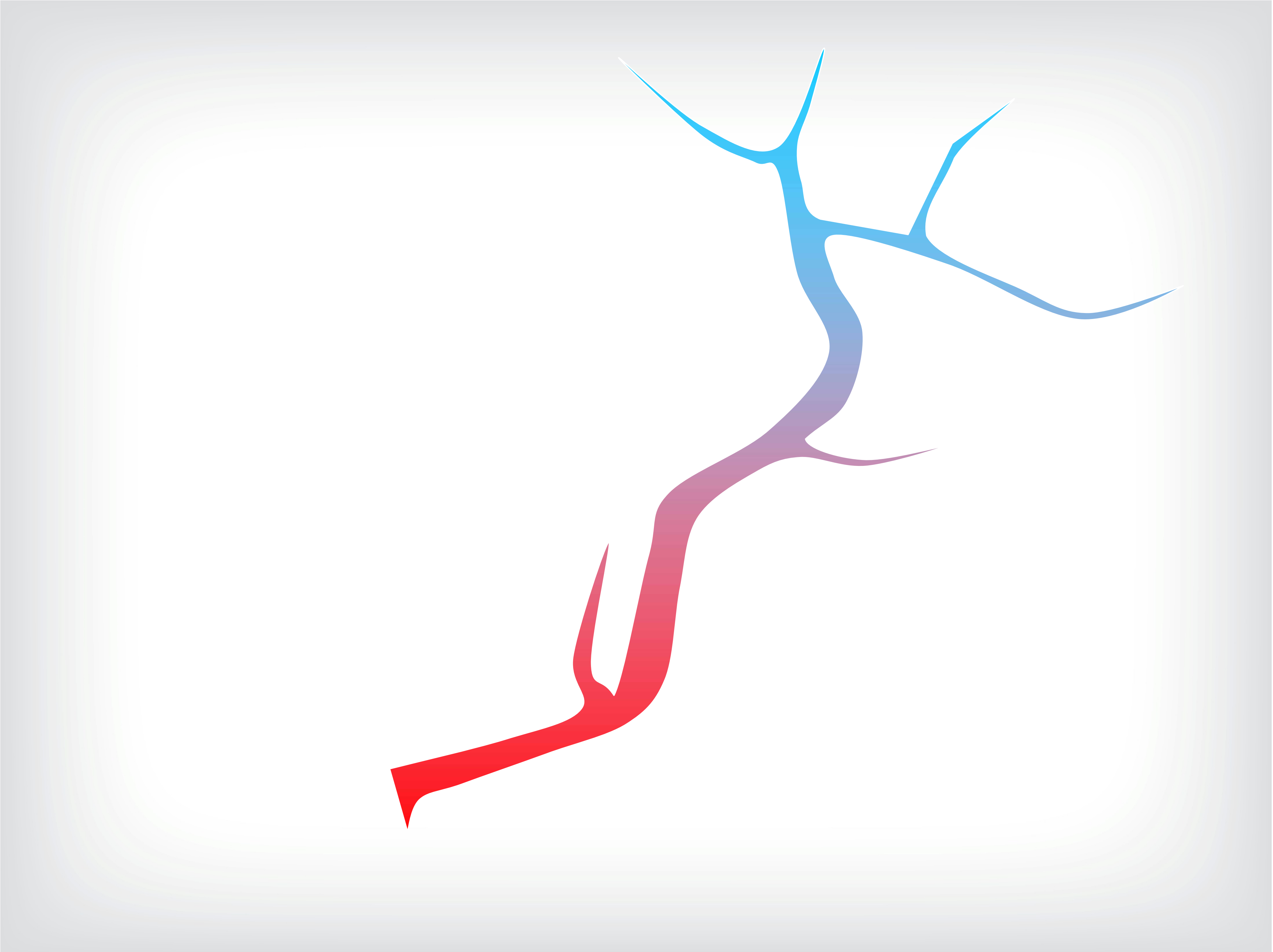
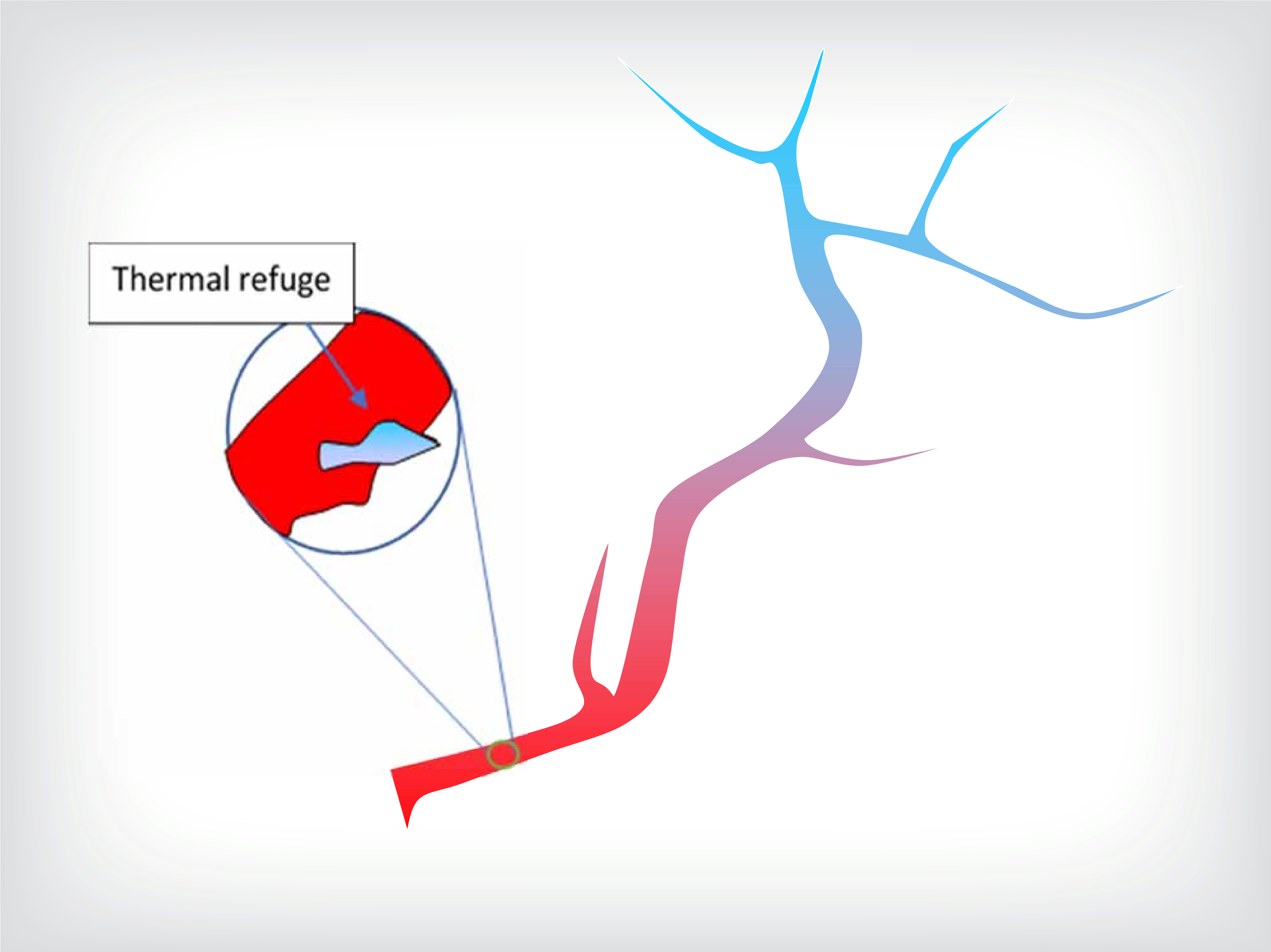
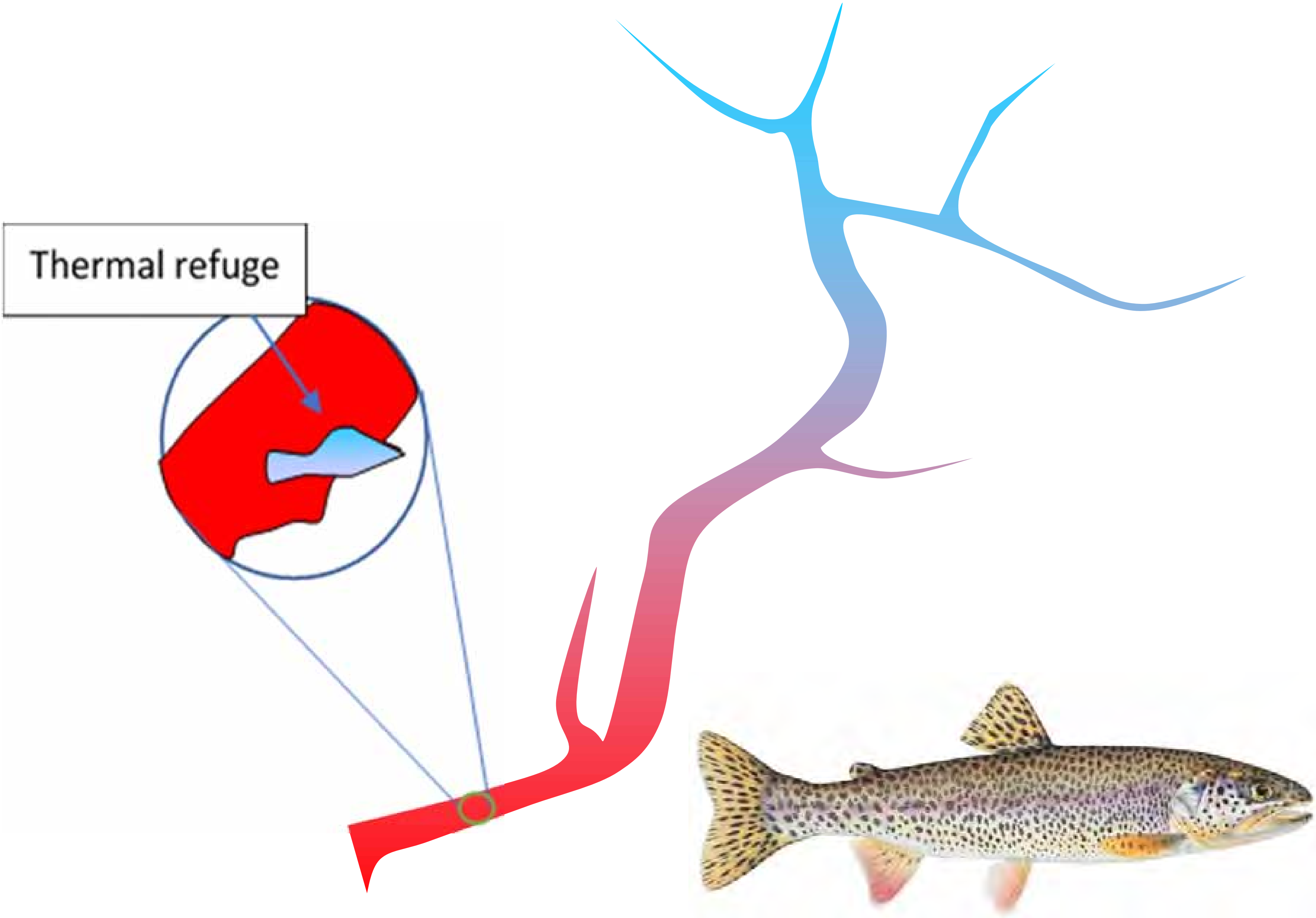
Jason Dunham
Matt Keefer
John Palmer
Peter Leinenbach
Rochelle Labiosa
Jenny Wu
Matthew Waller
Joan Baker
Denis White




Thermal refuge


Thermal refuge

Tools for Assessing Fish Population Responses

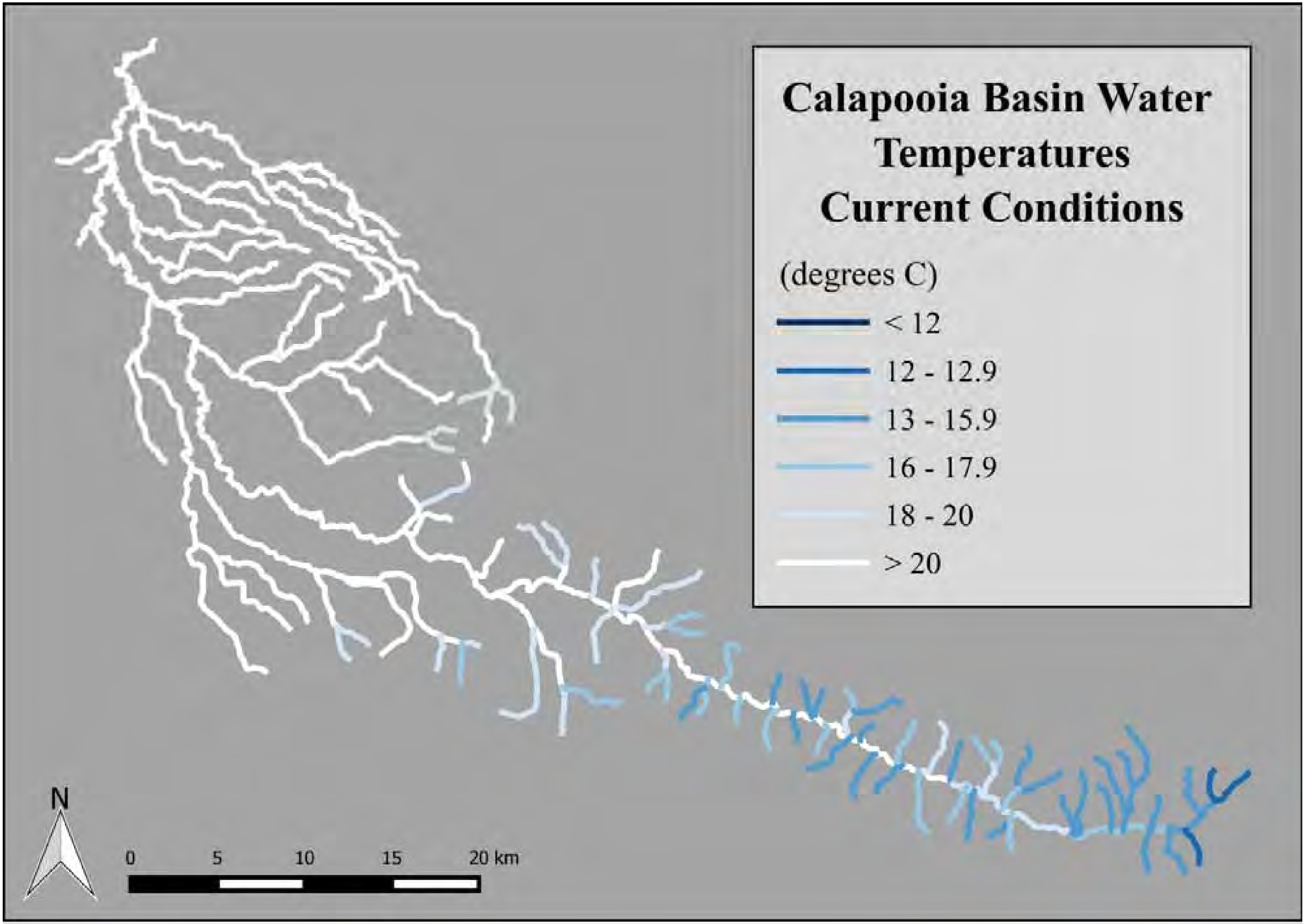
I. Fish assemblage simulation model (SMURF)
II. Individual based model (HexSim)

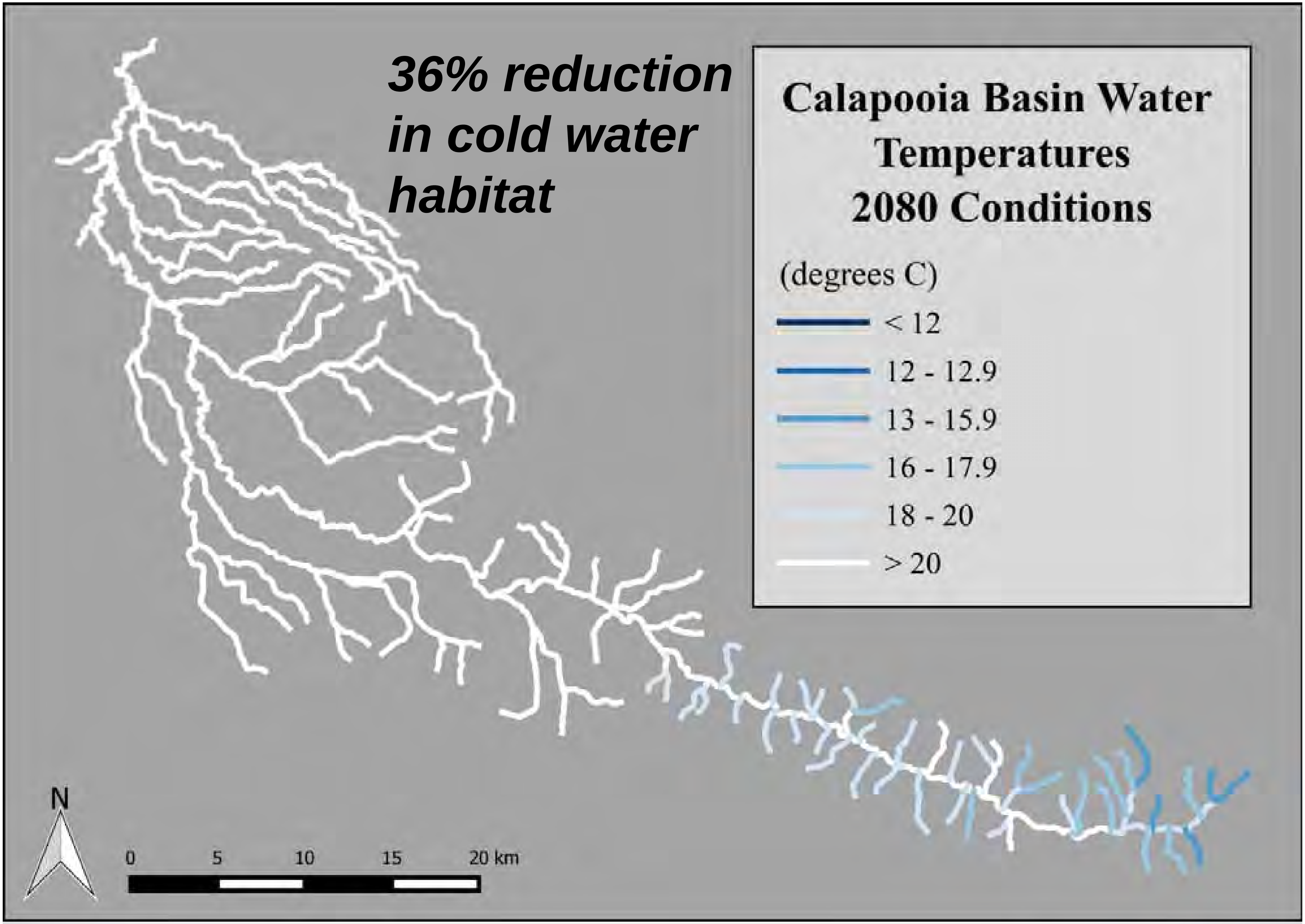
Illustrations © Joe Tomelleri

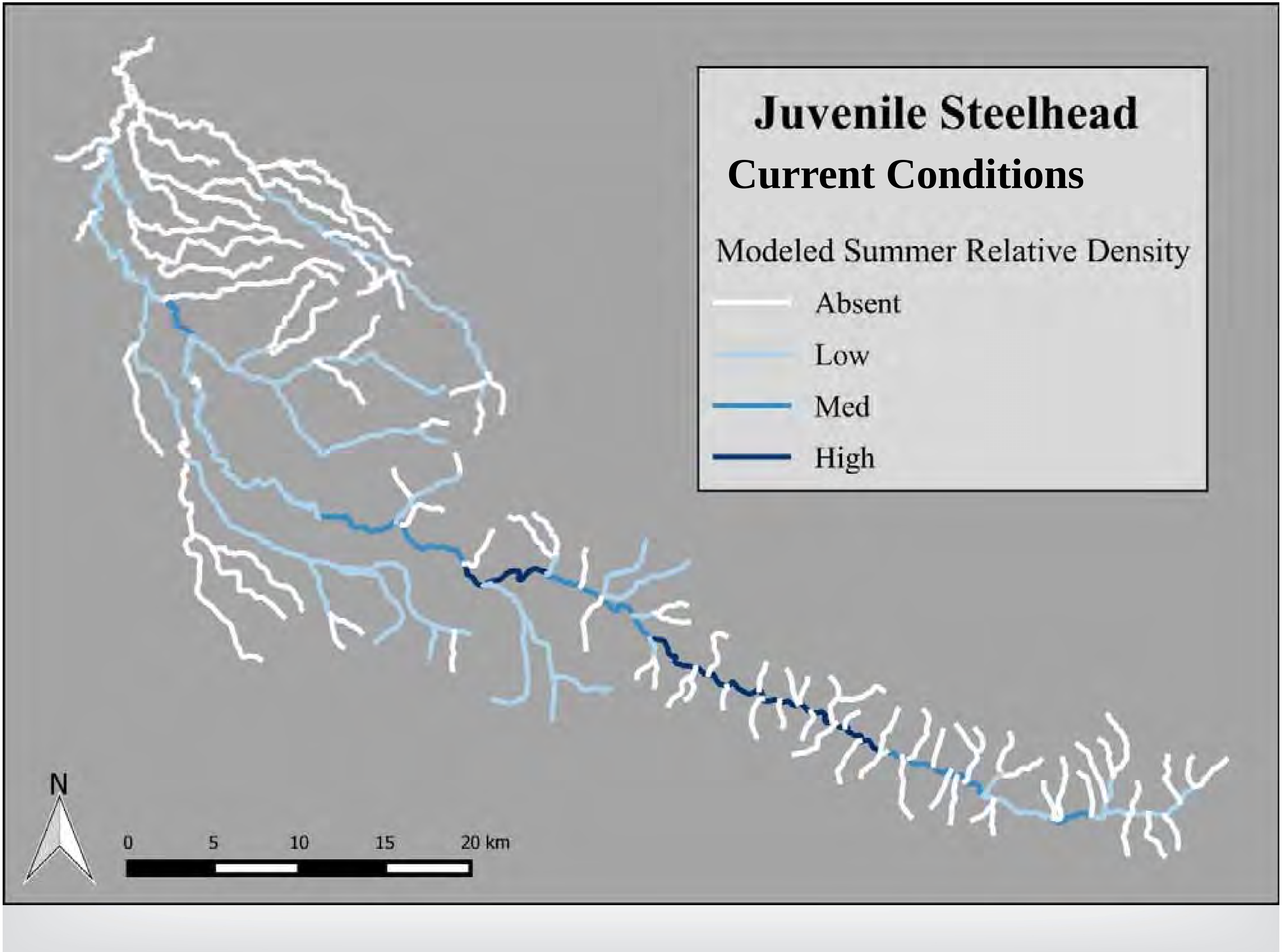
Fish Assemblage Simulation Model

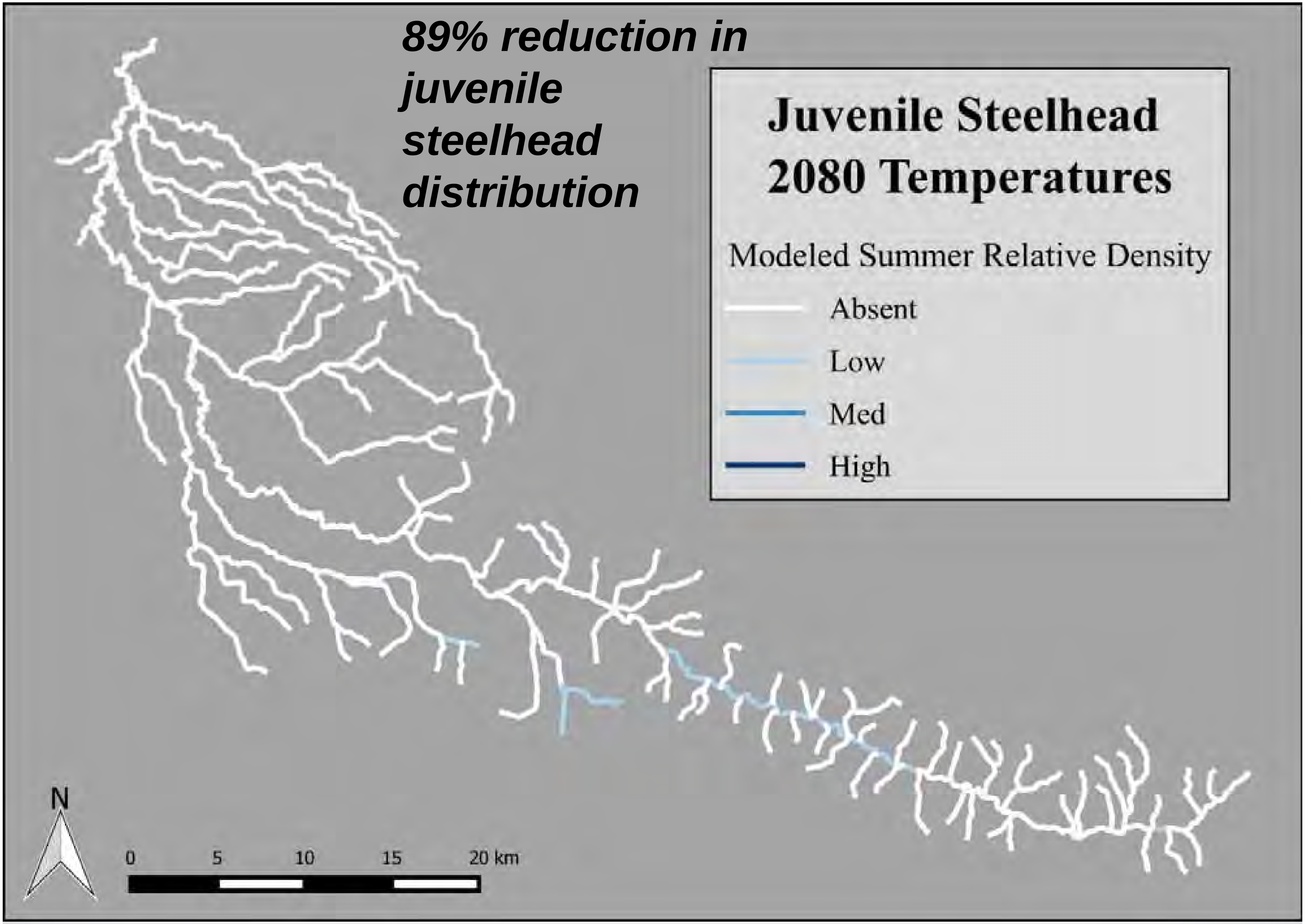
Simulating Metacommunities of Riverine Fishes

- ***Age-structured***
- ***Species interactions***
- ***Movement***
- ***Habitat suitability***


Calapooia Basin Water Temperatures Current Conditions
(degrees C)
< 12
12 - 12.9
13 - 15.9
16 - 17.9
18 - 20
> 20
N
0
5
10
15
20 km


36% reduction in cold water habitat
Calapooia Basin Water Temperatures 2080 Conditions
(degrees C)
< 12
12 - 12.9
13 - 15.9
16 - 17.9
18 - 20
> 20
N
0
5
10
15
20 km


Juvenile Steelhead
Current Conditions
Modeled Summer Relative Density
Absent
Low
Med
High
N
0
5
10
15
20 km


89% reduction in juvenile steelhead distribution
Juvenile Steelhead
2080 Temperatures
Modeled Summer Relative Density
Absent
Low
Med
High
N
0
5
10
15
20 km

Fish Assemblage Simulation Model
Simulating Metacommunities of Riverine Fishes

Utility

- Survival in response to habitat conditions
- Emergent properties of movement and competition
- Assess connectivity, spatial arrangement

Limitations

- Individual effects
- Life history variation
- Fine scale heterogeneity

Sustaining Cold Water Fish Populations

Shrinking cold water habitat

↓

Increased non-attainment of standards

↓

NOAA biological opinion – jeopardy

↓

EPA and ODEQ charged with assessing refugia

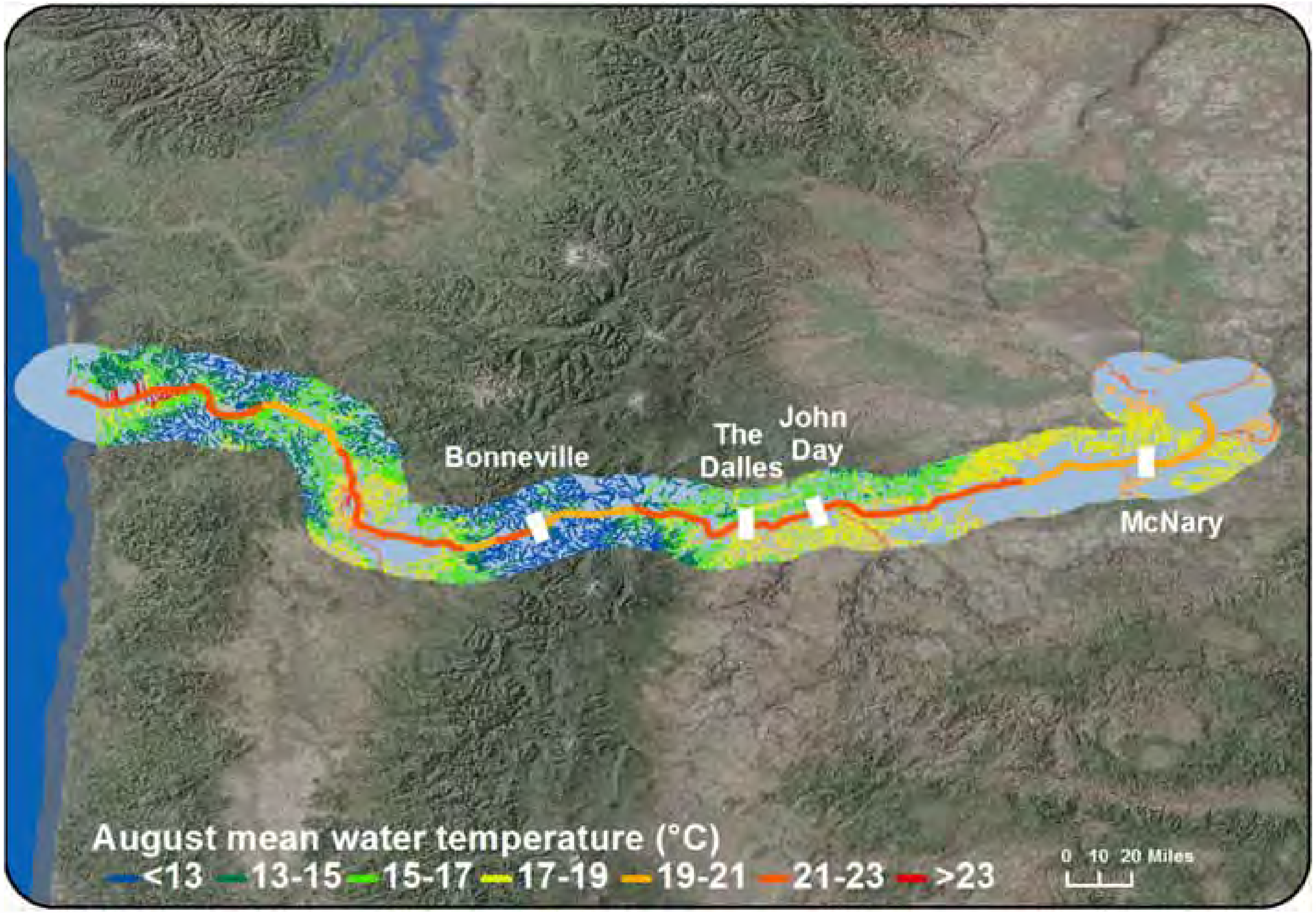
The New York Times

Finding Refuge for Salmon, Cold Water Preferred

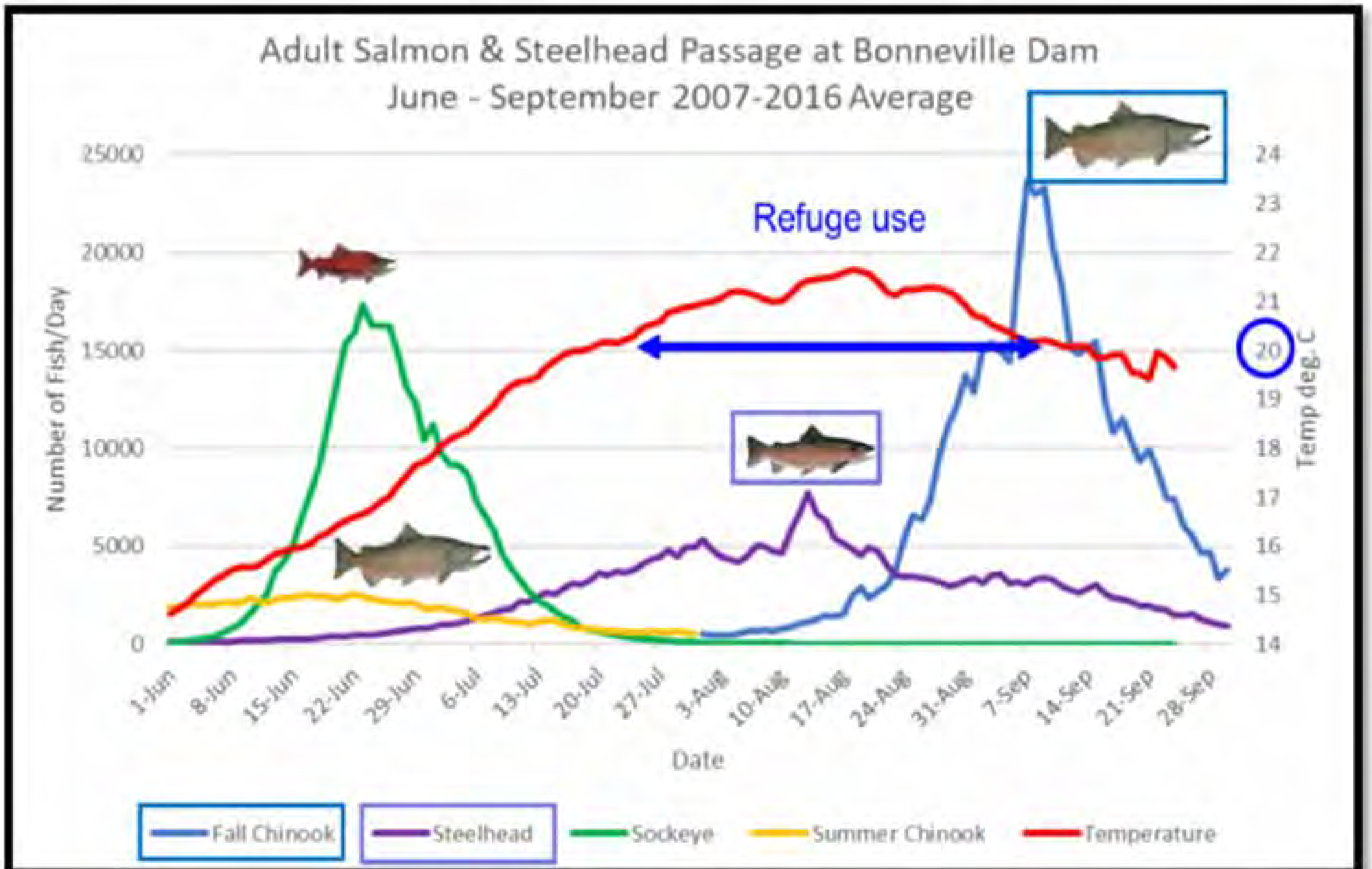
By KIRK JOHNSON DEC. 11, 2015

A salmon testing center in Washington State. Threats to salmon abound, but location matters greatly, with the fish doing better in some waterways than in others. Ruth Fremson/The New York Times

Columbia River migration corridor

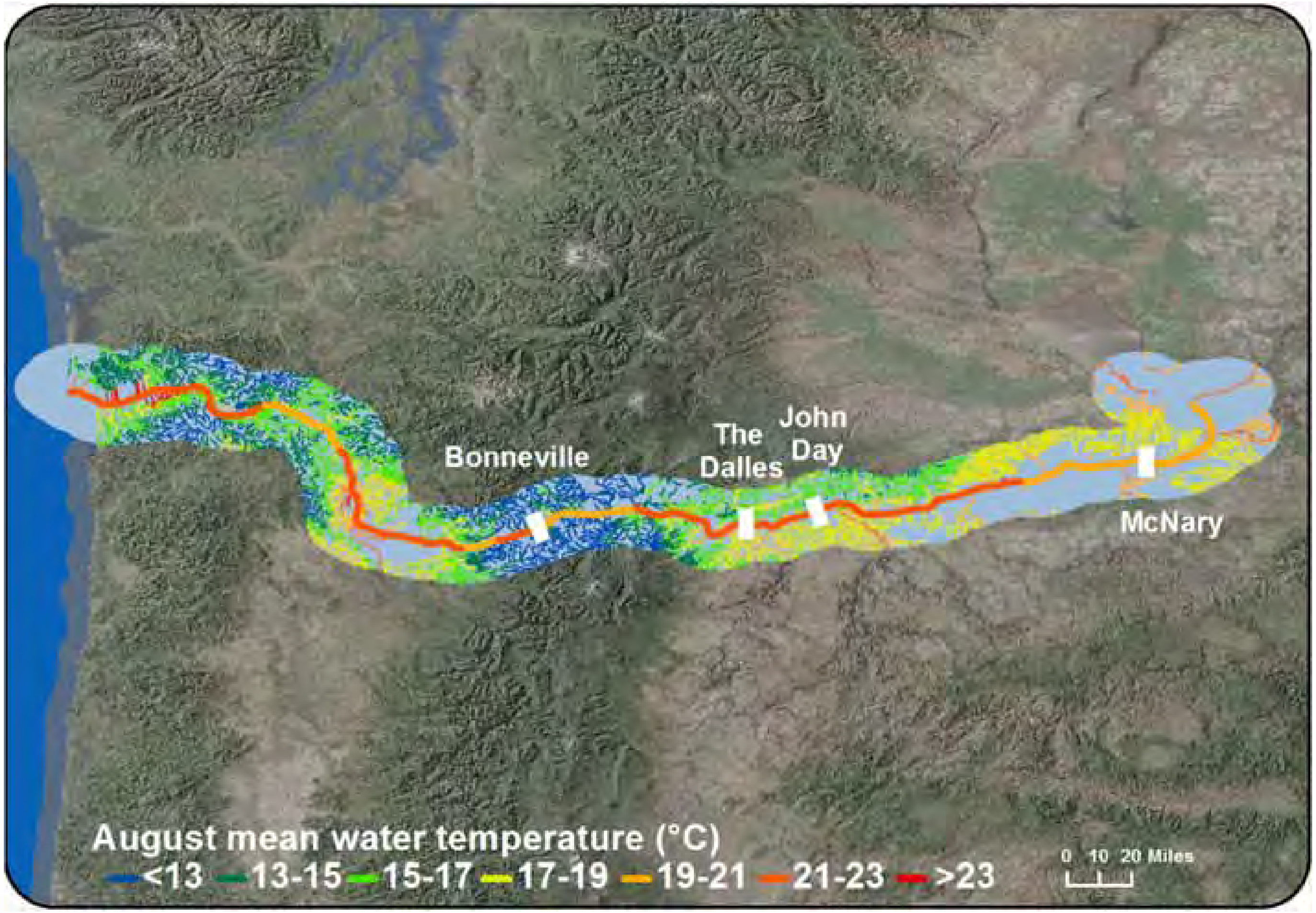


Run timing and Columbia River temperature



University of Idaho

Columbia River migration corridor



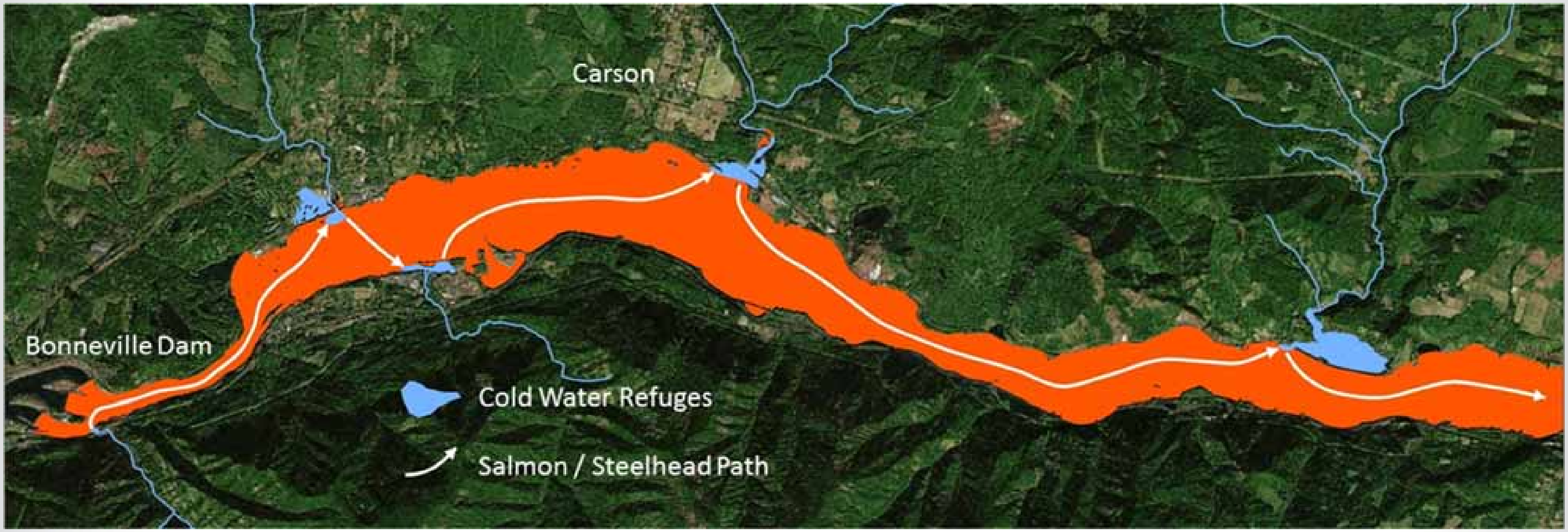
Cold water refuge

…"those portions of a water body where, or times during the diel cycle when, the water temperature is at least 2 °C colder than the daily maximum temperature of the adjacent well mixed flow of the water body"

- Oregon DEQ

Assess role of refugia

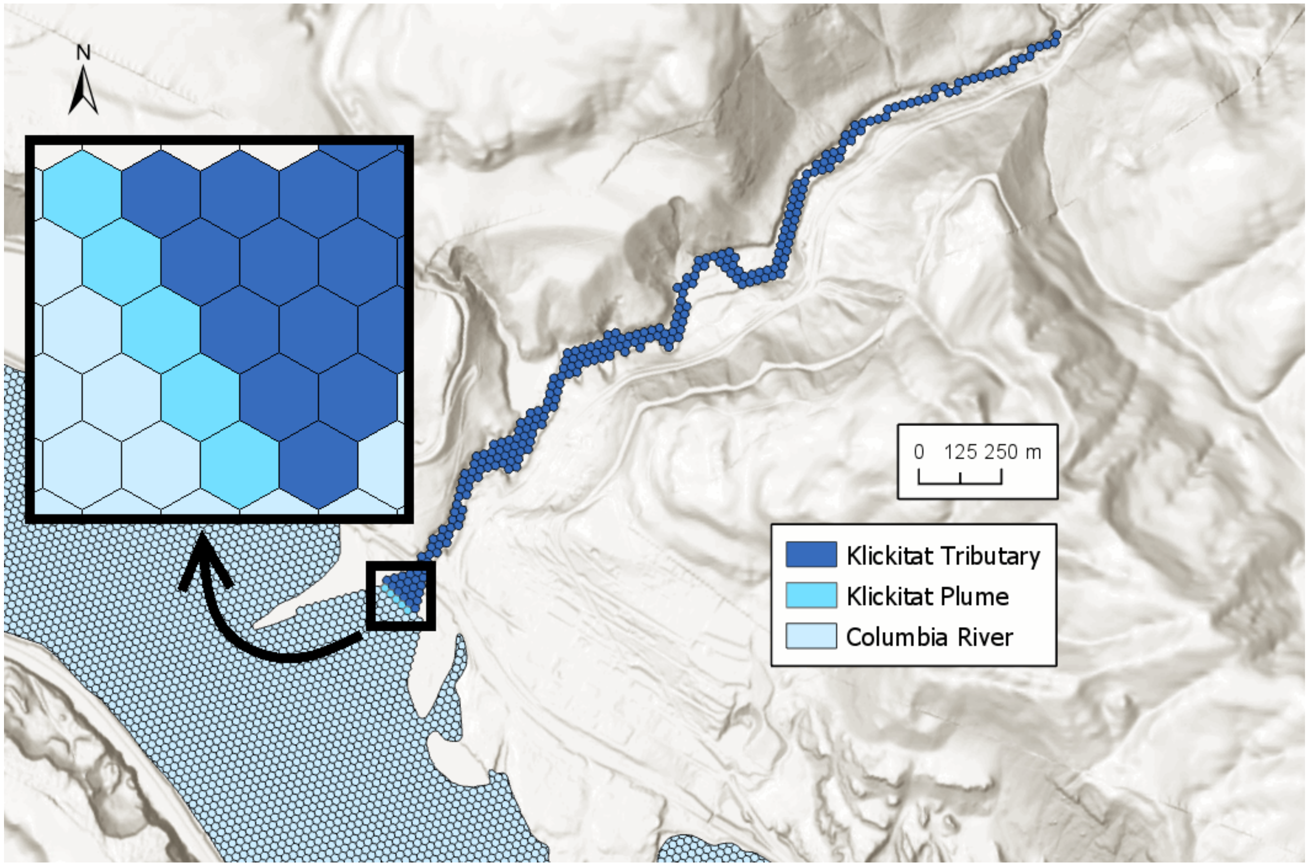
HexSim simulations



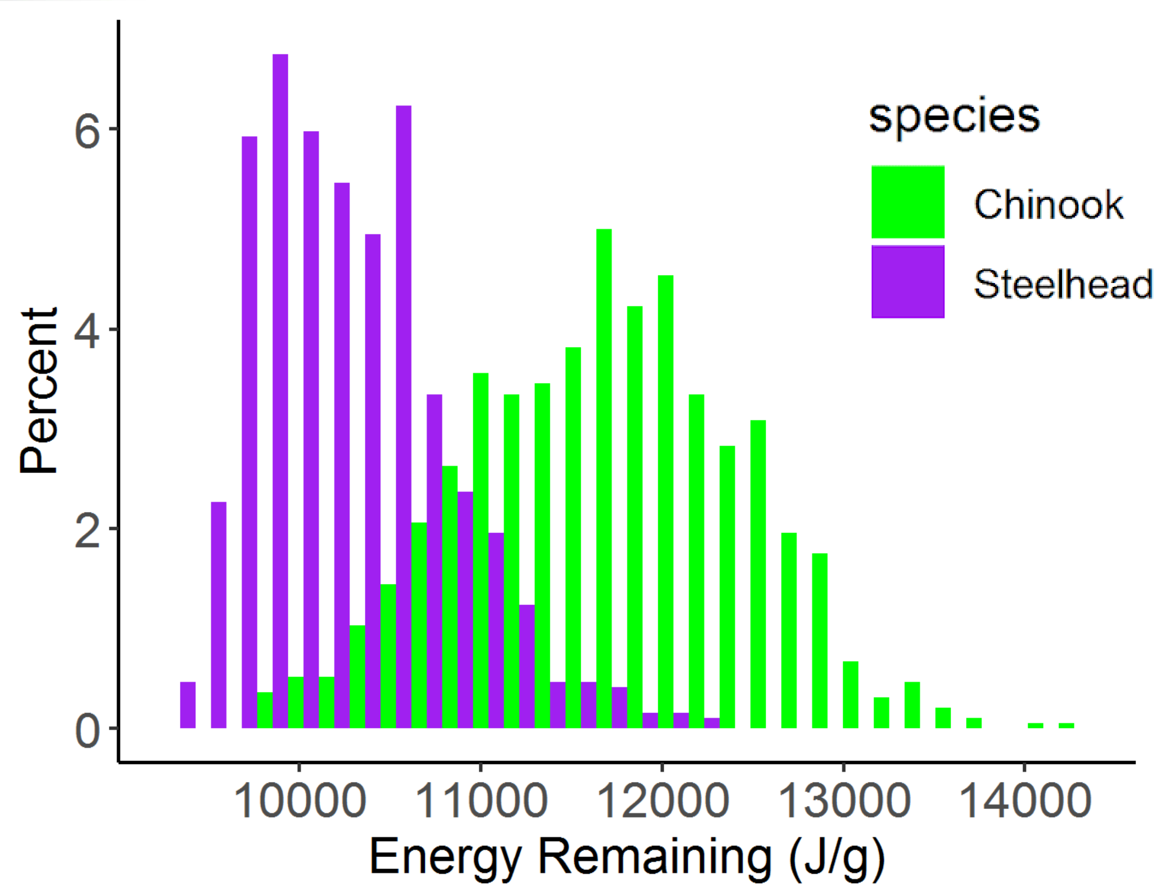
- Track individual exposure through space and time
    - Measure cumulative thermal exposure throughout migration
    - Quantify risk from multiple interacting threats (harvest, predation, disease)
    - Assess net effect of exposure and risk to survival and egg viability
- Allows comparison of travel paths, spacing, size, quality of cold-water refuges

What are benefits of cold water refuges at population and landscape scales?

Model thermalscape



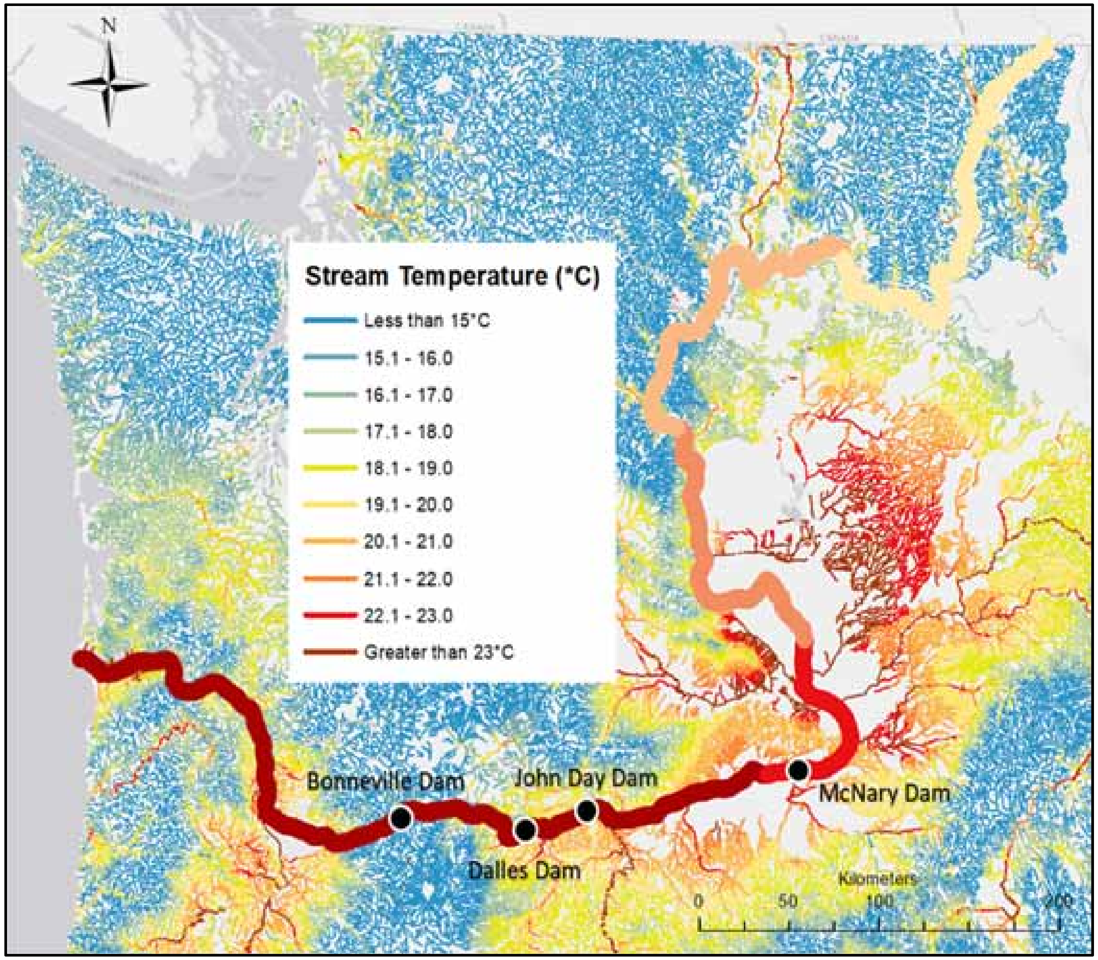
Simulation outcomes



Cold water refuge sufficiency can be evaluated using model outcomes:

- survival rates
- energy status
- cause of mortality
- cumulative degree days
- passage timing

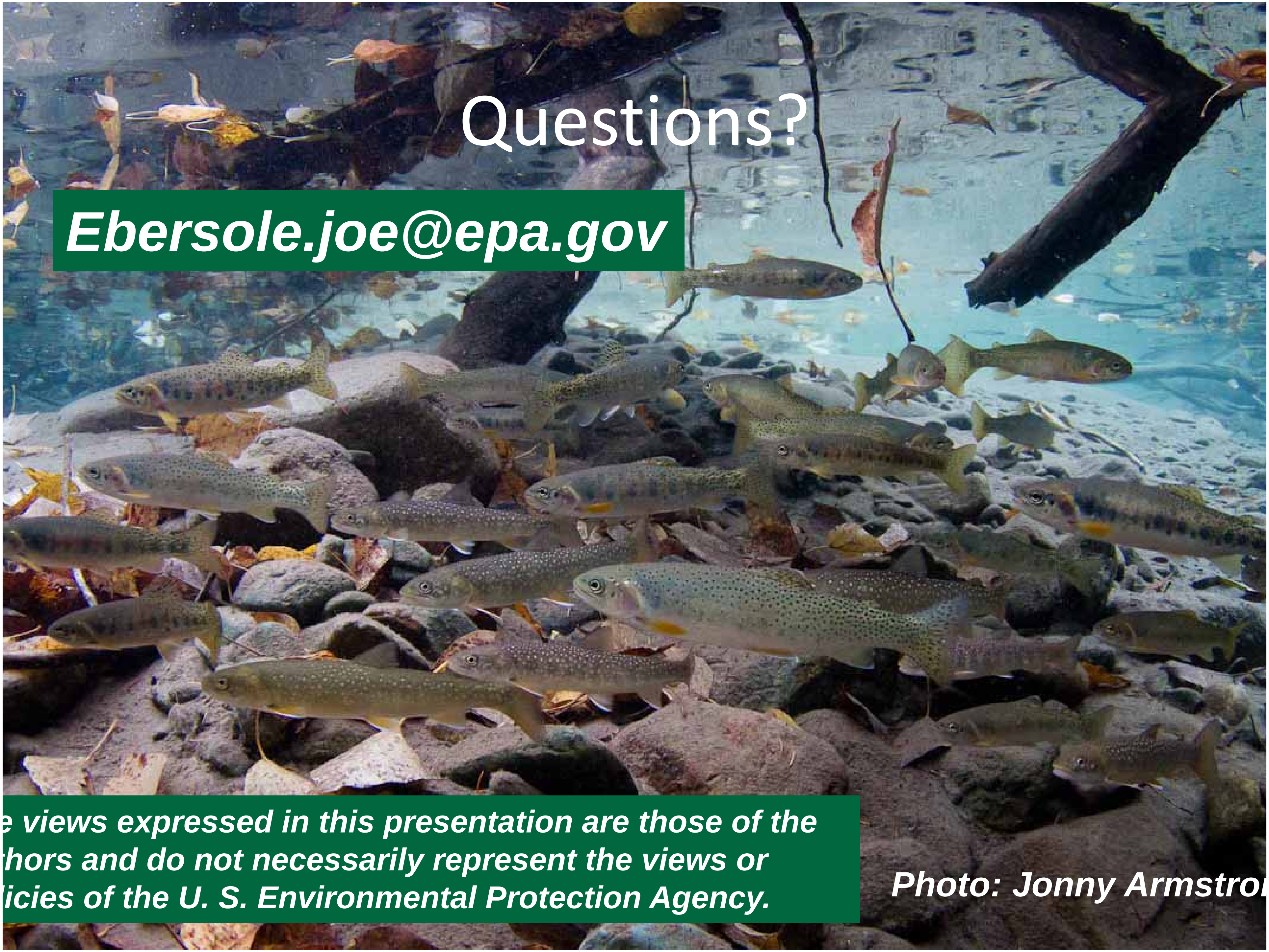
Future scenarios



Predicted temperature August mean 2080

Temperature characterization

Model	Temporal Resolution	Spatial Resolution	Extent	Source	Value
SMURF	seasonal	NHD reach	227 NHD reaches	SSN	Mean Fall/winter, spring, summer
HexSim	hourly	25 m	~10 million hexagons	In situ / modeled	hourly from Jul 1 – Oct 31



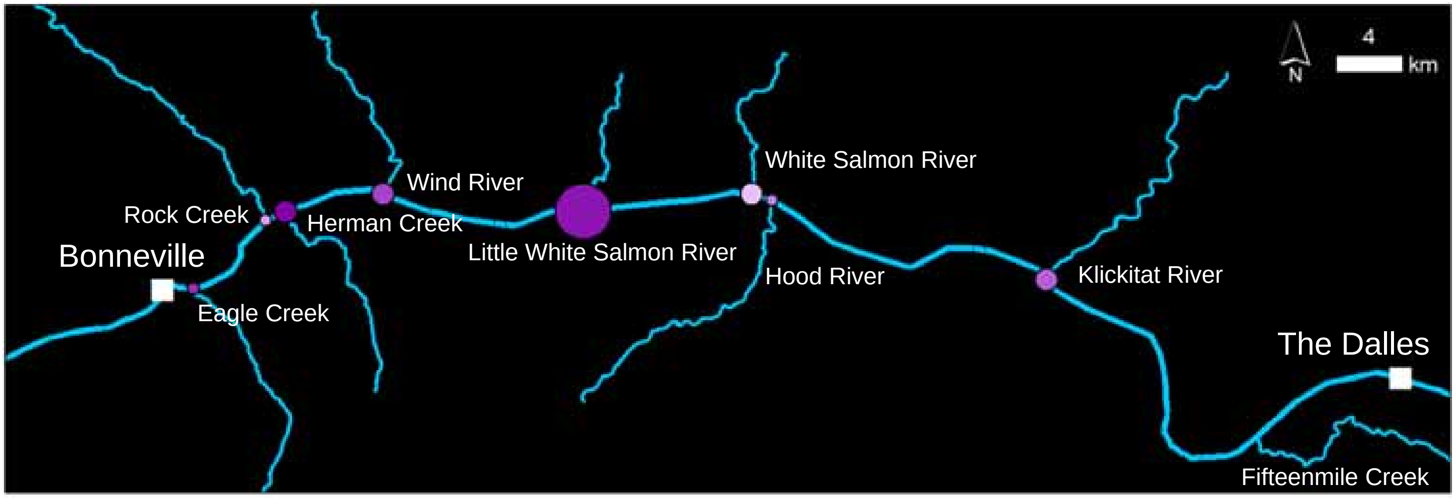
Questions?

Ebersole.joe@epa.gov

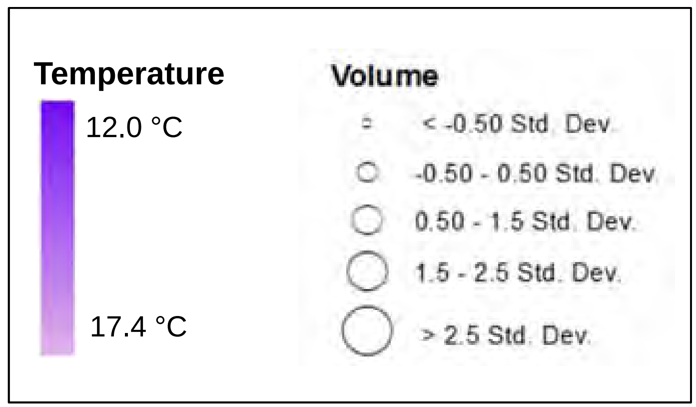
***e views expressed in this presentation are those of the
thors and do not necessarily represent the views or
licies of the U. S. Environmental Protection Agency.***

Photo: Jonny Armstro

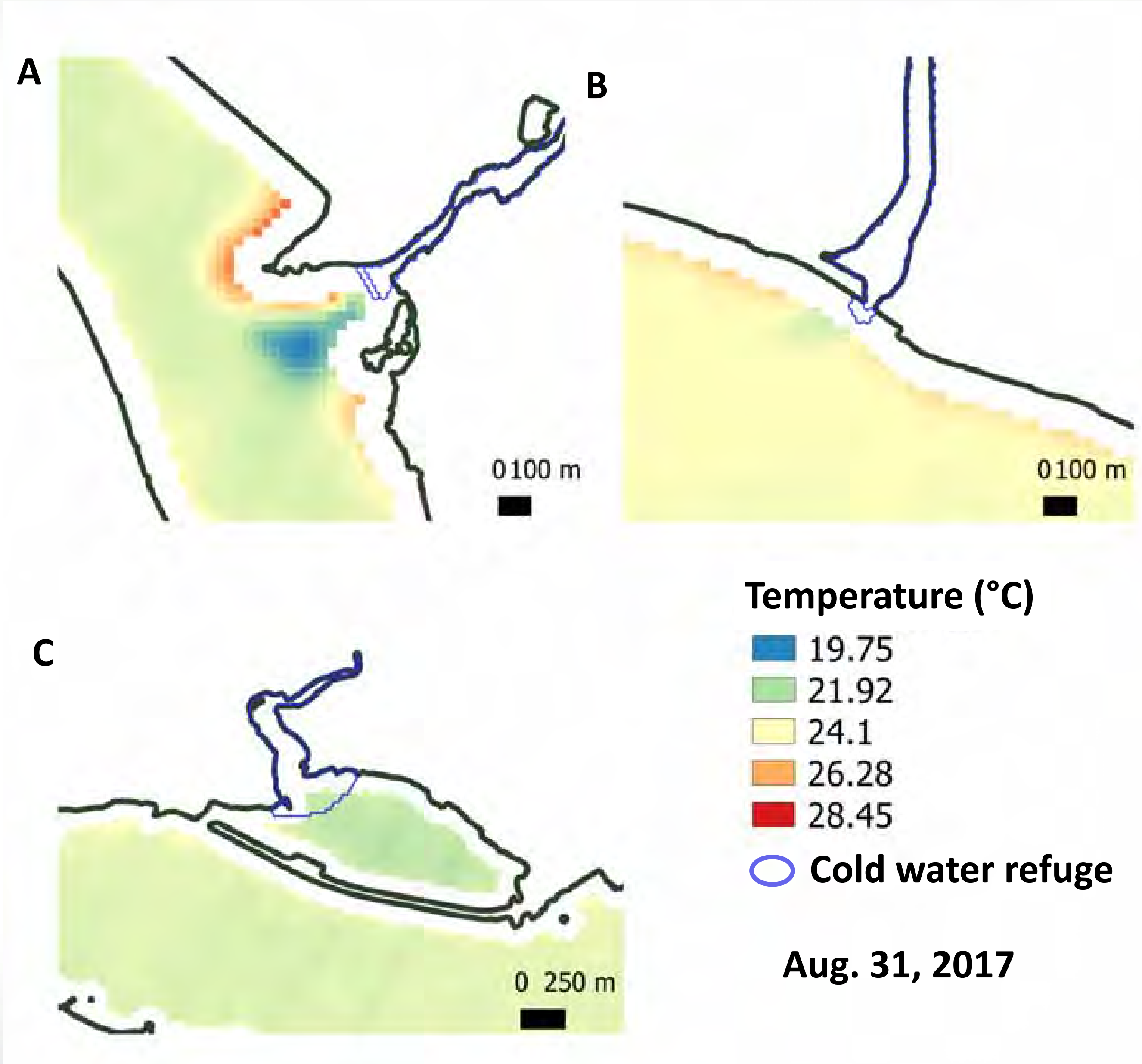
Riverscape: temperature



Hourly water temperatures in our model change independently in the Columbia river, plumes, and tributaries.



Landsat 8 ARD Surface Temperature



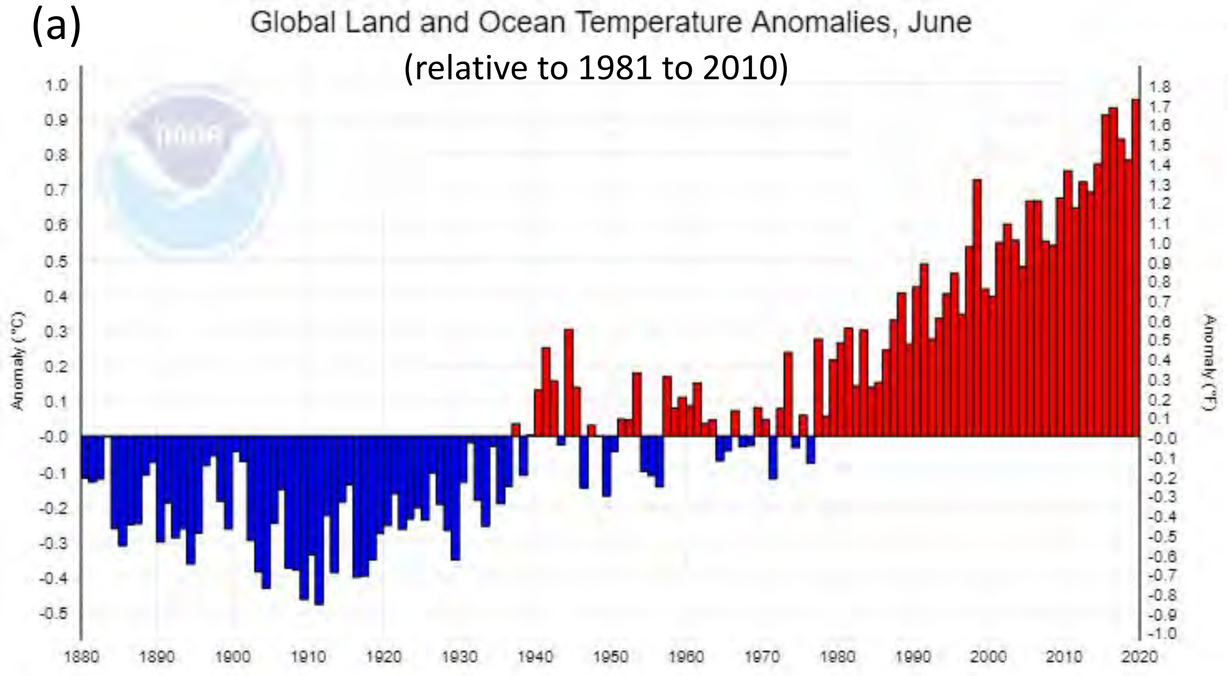
Evaluating the Impacts of Climate Change on the Future Distribution of Stream Macroinvertebrates, Fish and Amphibians in Washington using Species Distribution Models

Jennifer Elliott, Chad Larson, Glenn Merritt, Stacy Polkowske
Department of Ecology, Washington State
November 7, 2019

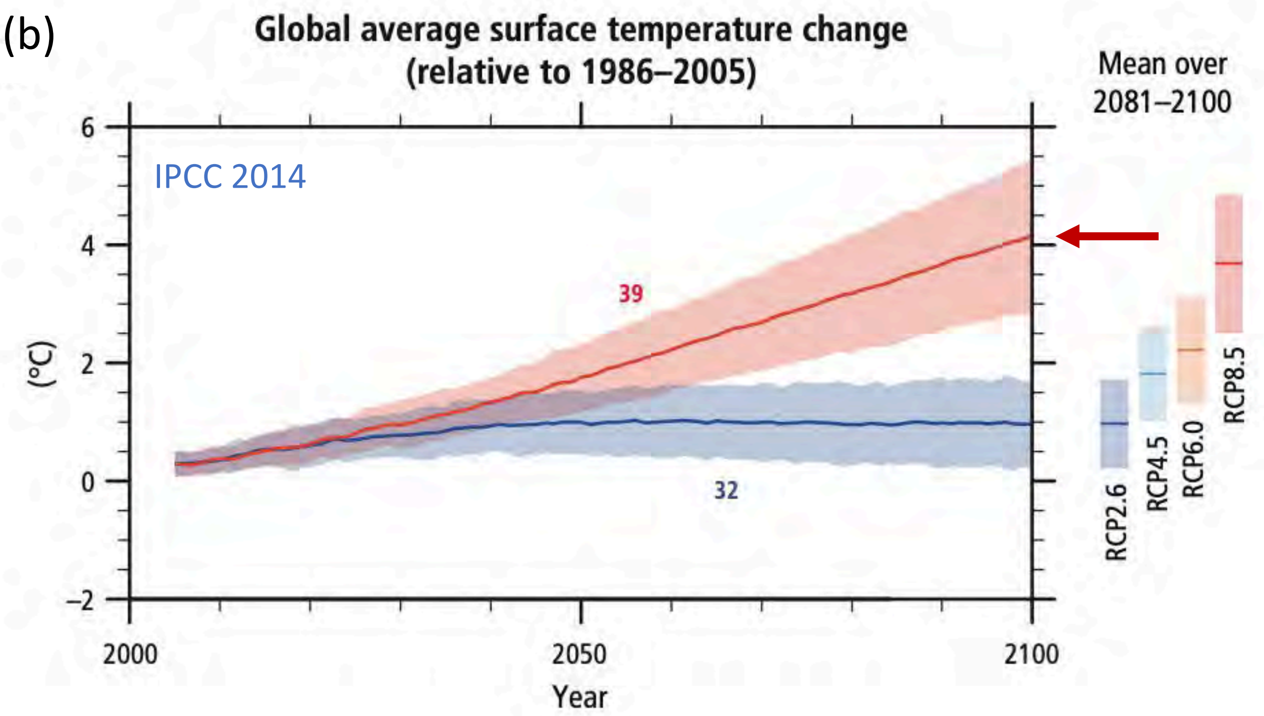
DEPARTMENT OF
ECOLOGY
State of Washington

Global climate change

(a)



(b)

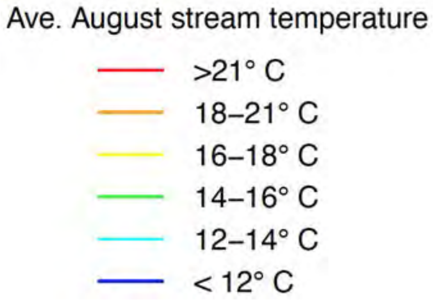


(c)

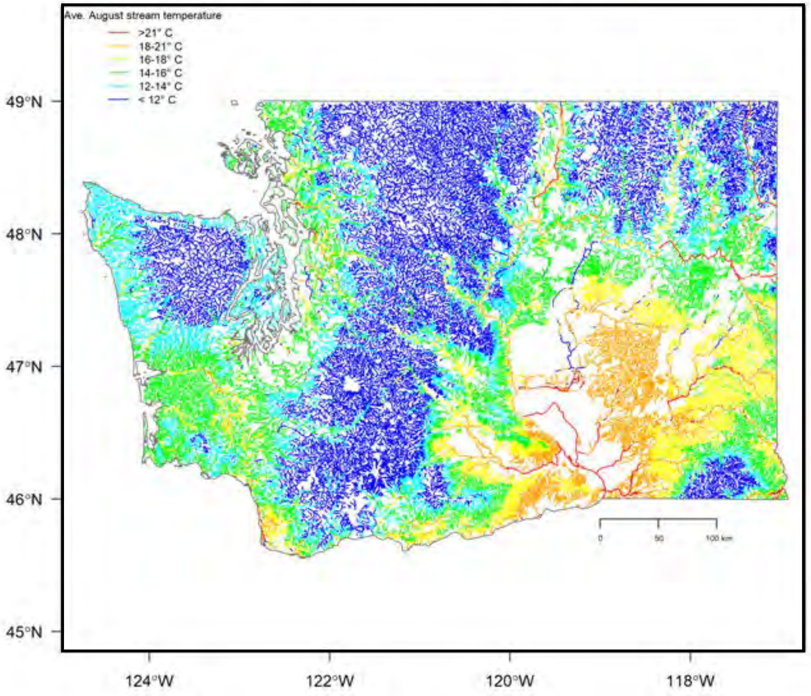
IPCC AR5 global warming increase (°C) projections

	2046 - 2065	2081-2100
Scenario	Mean (Range)	Mean (Range)
RCP 2.6	1.0 (0.4 – 1.6)	1.0 (0.3 – 1.7)
RCP 4.5	1.4 (0.9 - 2.0)	1.8 (1.1 – 2.6)
RCP 6.0	1.3 (0.8 - 1.8)	2.2 (1.4 - 3.1)
RCP 8.5	2.0 (1.4 – 2.6)	3.7 (2.6 to 4.8)

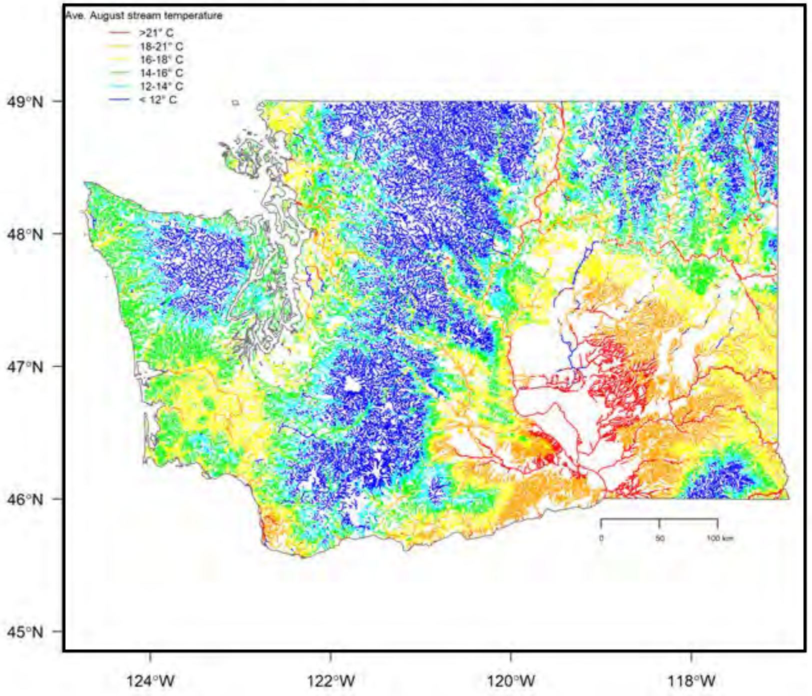
NorWeST regional stream temperature model
Average August temperature



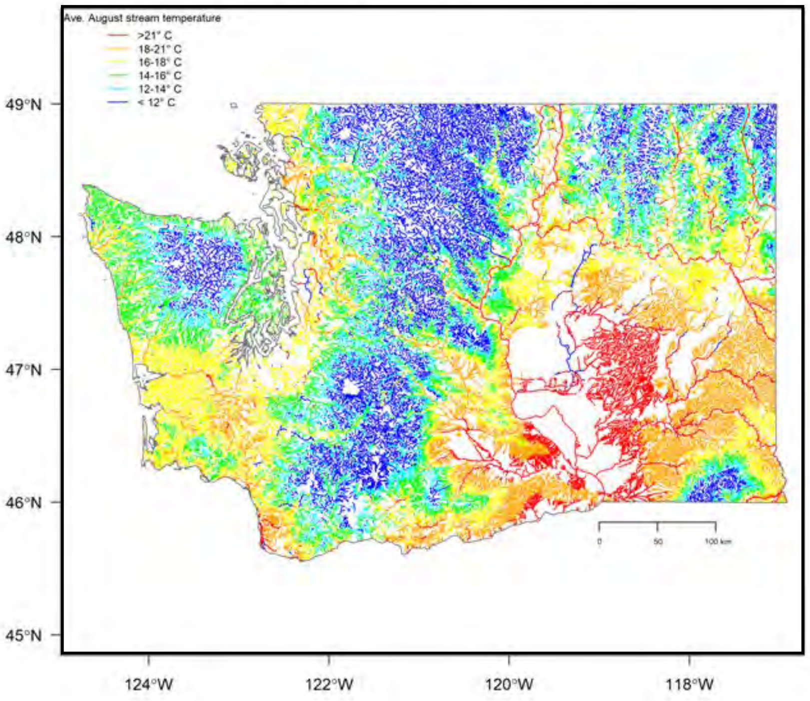
WA historic temperature 1993-2011



WA A1B warming trajectory 2040



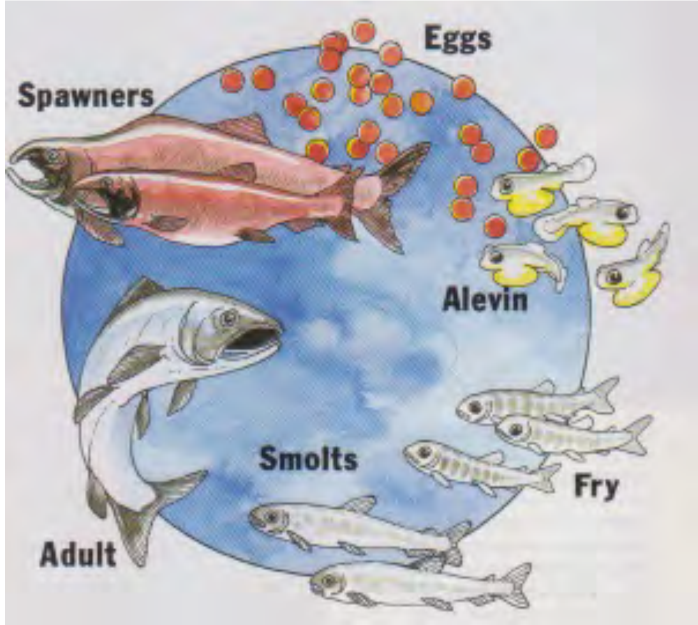
WA A1B warming trajectory 2070



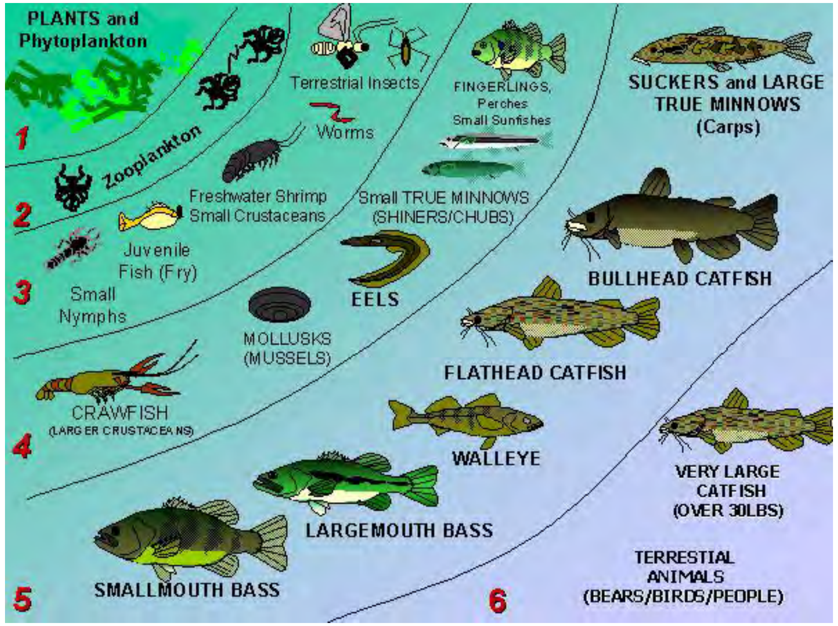
For more information: **http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html**

Small temperature increase matters!

- Temperature affects the metabolic rate of living organisms
- Temperature affect growth, survival, reproduction in the longer term



Alterations of the foodweb!



https://creation.com/pacific-salmon; http://www.combat-fishing.com/streamecology.html

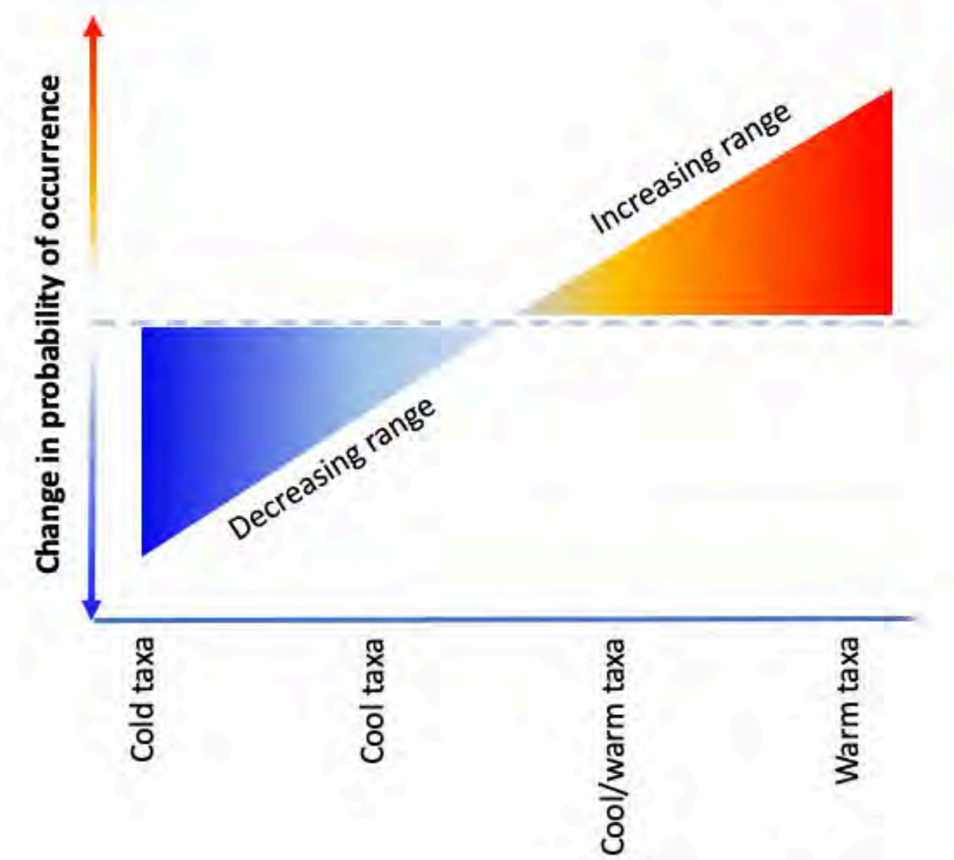
Research questions

- Can the temperature tolerance of freshwater taxa be used to predict their distribution under RCP 8.5 for 2070?
- How will the distribution of freshwater taxa change under RCP 8.5 for 2070 relative to historical trends?

Hypothesis

- The range of cold-water adapted taxa will contract and the range of warm-water adapted taxa will expand

Conceptual Model



Taxa temperature tolerance

- Fish and amphibian temperature tolerance
  - Temperature classification based on the National Rivers and Stream Assessment (NRSA) attribute table
  - Classifies taxa as cold, cool or warm water taxa
- Macroinvertebrate temperature tolerance
  - Developed a categorical temperature classification using weighted averaging
  - Classifies taxa as cold, cool, cool-warm or warm taxa

Study sites and datasets

- 559 sites for fish & amphibians
  - WA DOE
  - NRSA
  - EMAP-WEST
- 401 sites for macroinverts
  - WA DOE
  - Identified to genus, species level

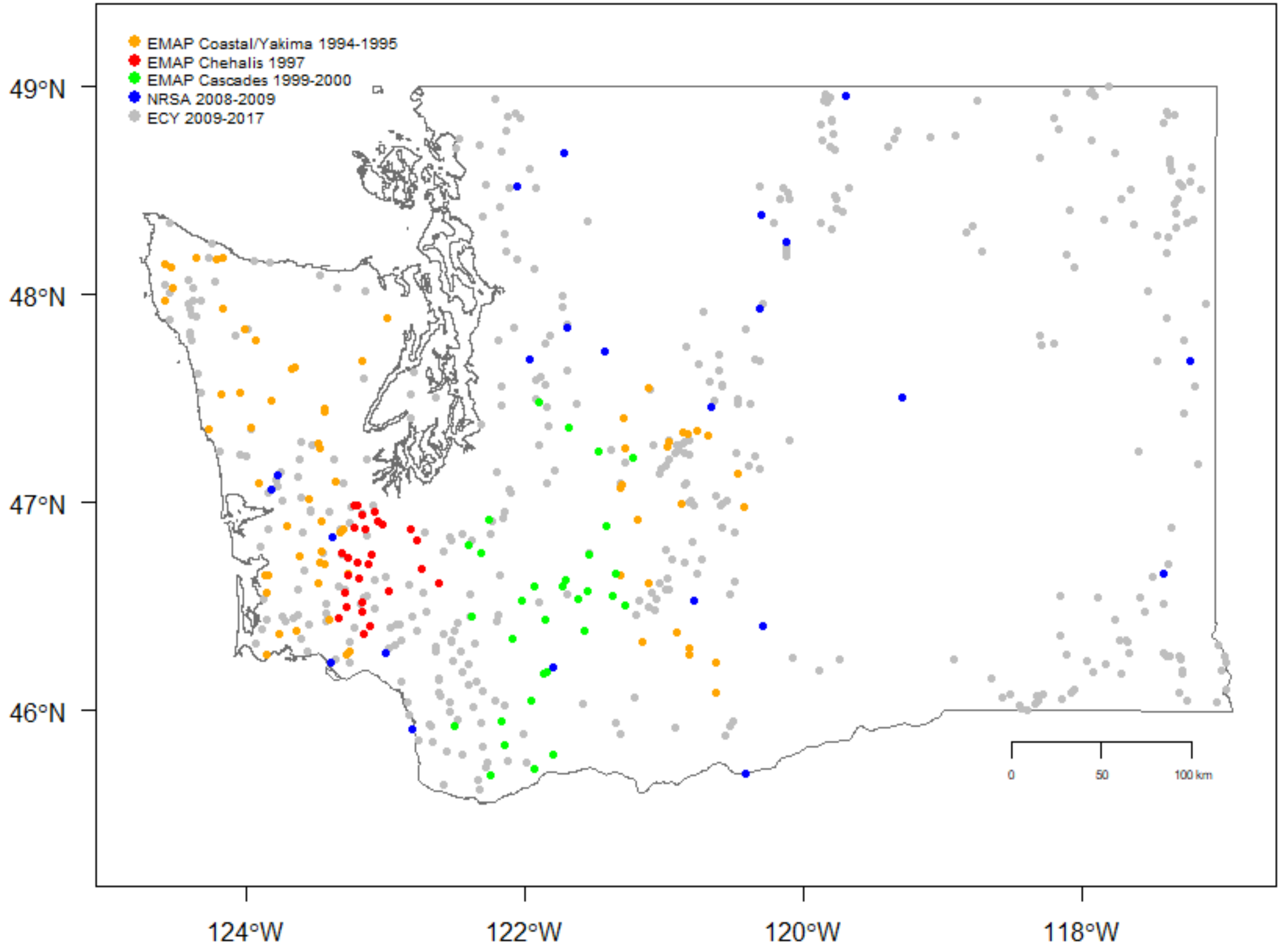


Photo credits : Insect pictures from Chad Larson; https://www.pressdemocrat.com/news/7185992-181/at-eel-river-dam-thousands; https://alchetron.com/Richardsonius-balteatus; Rhinichthys osculus by Dan Suzio; https://www.inaturalist.org/taxa/111224-Ptychocheilus-oregonensis; http://www.roughfish.com/species/1150; https://pubs.usgs.gov/sir/2006/5111/figure9.html; http://www.roughfish.com/paiute-sculpin; http://www.roughfish.com/mountain-whitefish; http://www.roughfish.com/prickly-sculpin; https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=890; https://calphotos.berkeley.edu/cgi/img_query? enlarge=0000+0000+0999+0027; https://news.orvis.com/fly-fishing/fish-facts-chinook-salmon-oncorhynchus-tshawytscha; https://www.goodfreephotos.com/animals/fish/rainbow-trout-oncorhynchus-mykiss.jpg.php; https://www.marylandbiodiversity.com/viewSpecies.php?species=220; https://www.pbase.com/crocodile/image/45326150; https://news.orvis.com/fly-fishing/fish-facts-brook-trout-salvelinus-fontinalis; https://www.fishbase.se/summary/Cottus-confusus; https://microfishing.com/2017/10/19/northwest-microfishing/; https://www.flickr.com/photos/coreyraimond/16095278020; https://www.alamy.com/stock-photo-alaska-silvercoho-salmon-oncorhynchus-kisutch-spawning-colors-male-27190435.html; https://microfishing.com/2017/10/19/northwest-microfishing/; https://www.alamy.com/stock-photo-metamorphosed-rocky-mountain-tailed-frog-ascaphus-montanus-yahk-river-18027620.html ;

Methods

- Species Distribution Models (SDMs) – one model per taxa
- Model input:
  - Use presence-absence data for fish, amphibians, macroinvertebrates (1993-2018)
  - Climatic and environmental variables (1993-2018)
  - Predicted Climatic and environmental variables (2070)
- Model output:
  - Probability of occurrence in past (1993-2018)
  - Probability of occurrence in the future (2070)
  - Calculate '*change in probability of occurrence*' = prob. future – prob. past
    - Range expansion or contraction or little to no change

SDM - variables

Climatic variables

1. Average August stream water temperature (NorWeST)

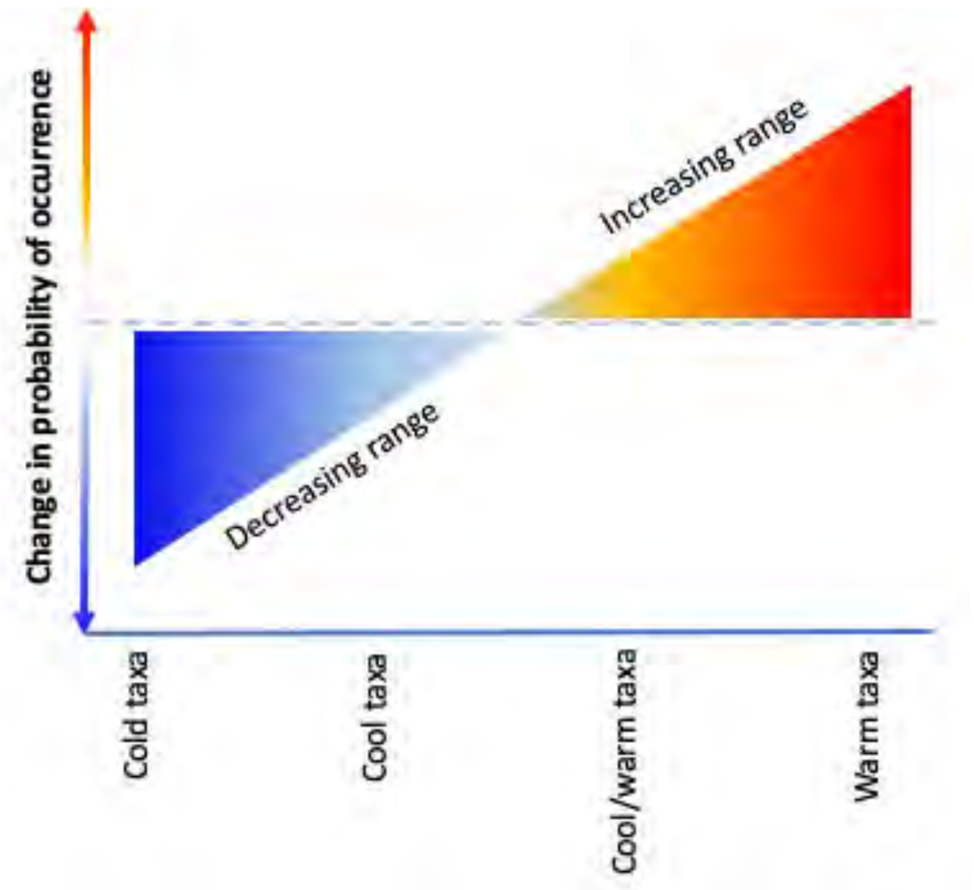
2. Air temperature seasonality
3. Max air temp warmest month
4. Precipitation driest month
5. Precipitation seasonality

 # 2-5 BioClim variables (https://www.worldclim.org/bioclim)

Environmental variables

6. Elevation
7. Slope

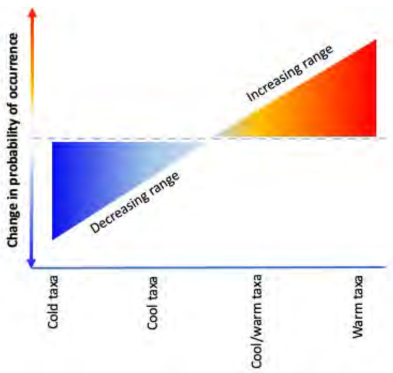
RCP 8.5 2070



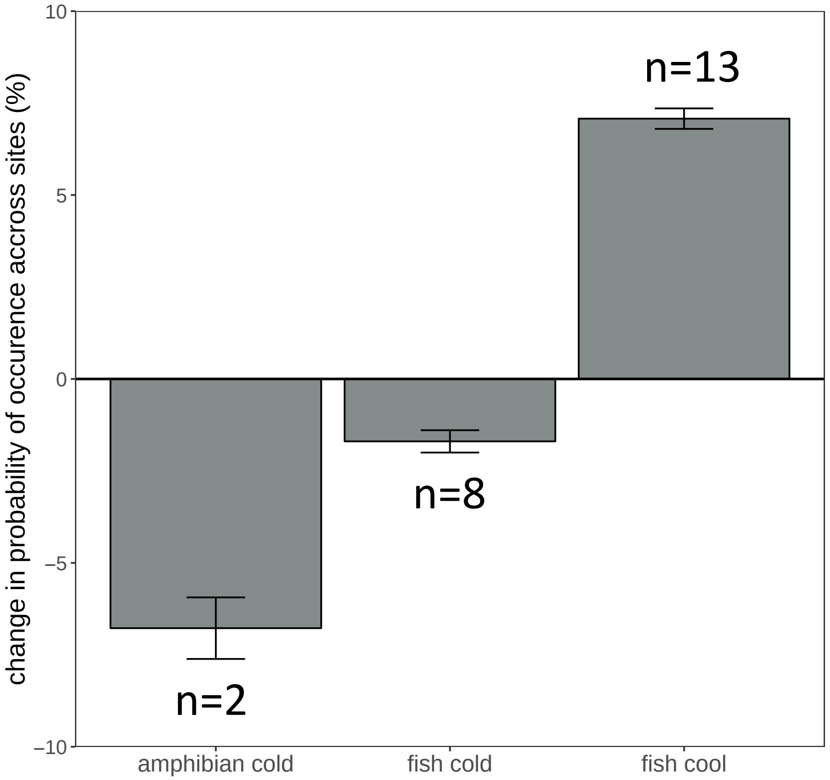
1. Can the temperature tolerance of freshwater taxa be used to predict their distribution under RCP 8.5 for 2070?

RCP 8.5 2070

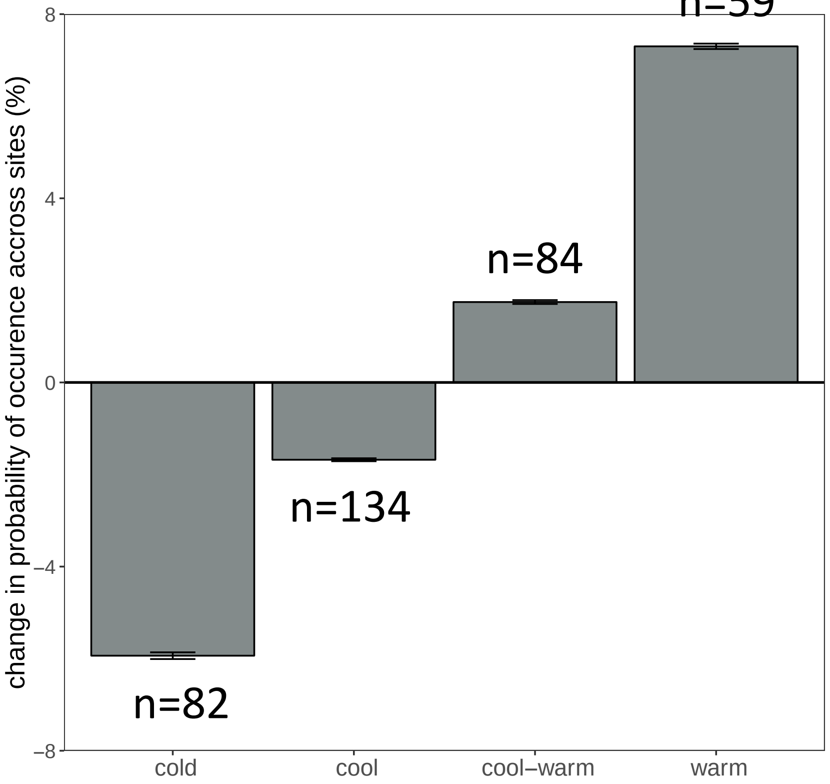
Results support our conceptual model



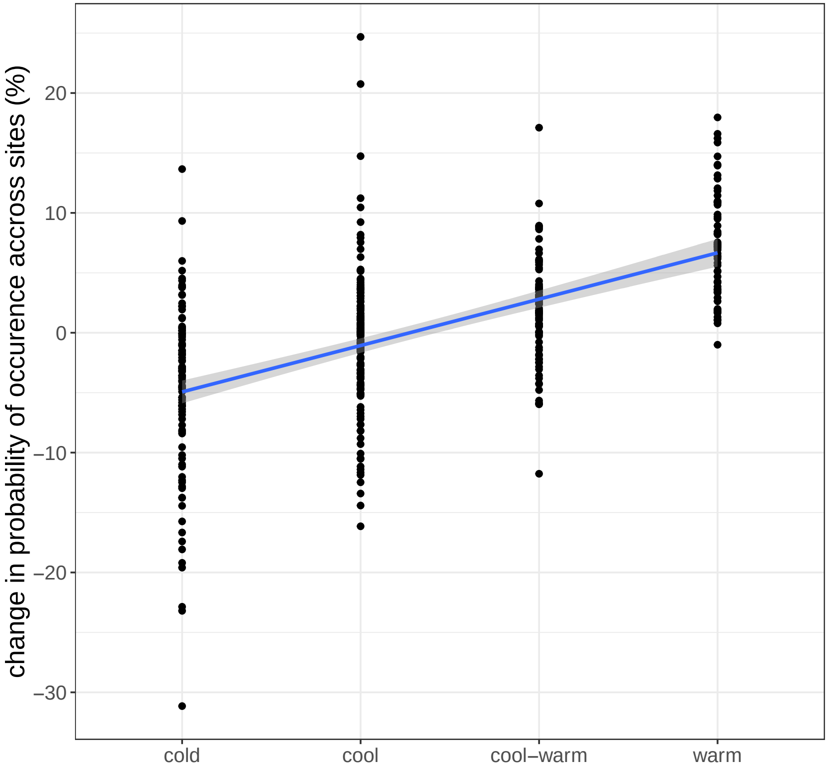
(a) Fish and amphibians (n=23)



(b) Macroinvertebrates (n=359)



(c) Fish, amphibians, macroinvertebrates (n=382)

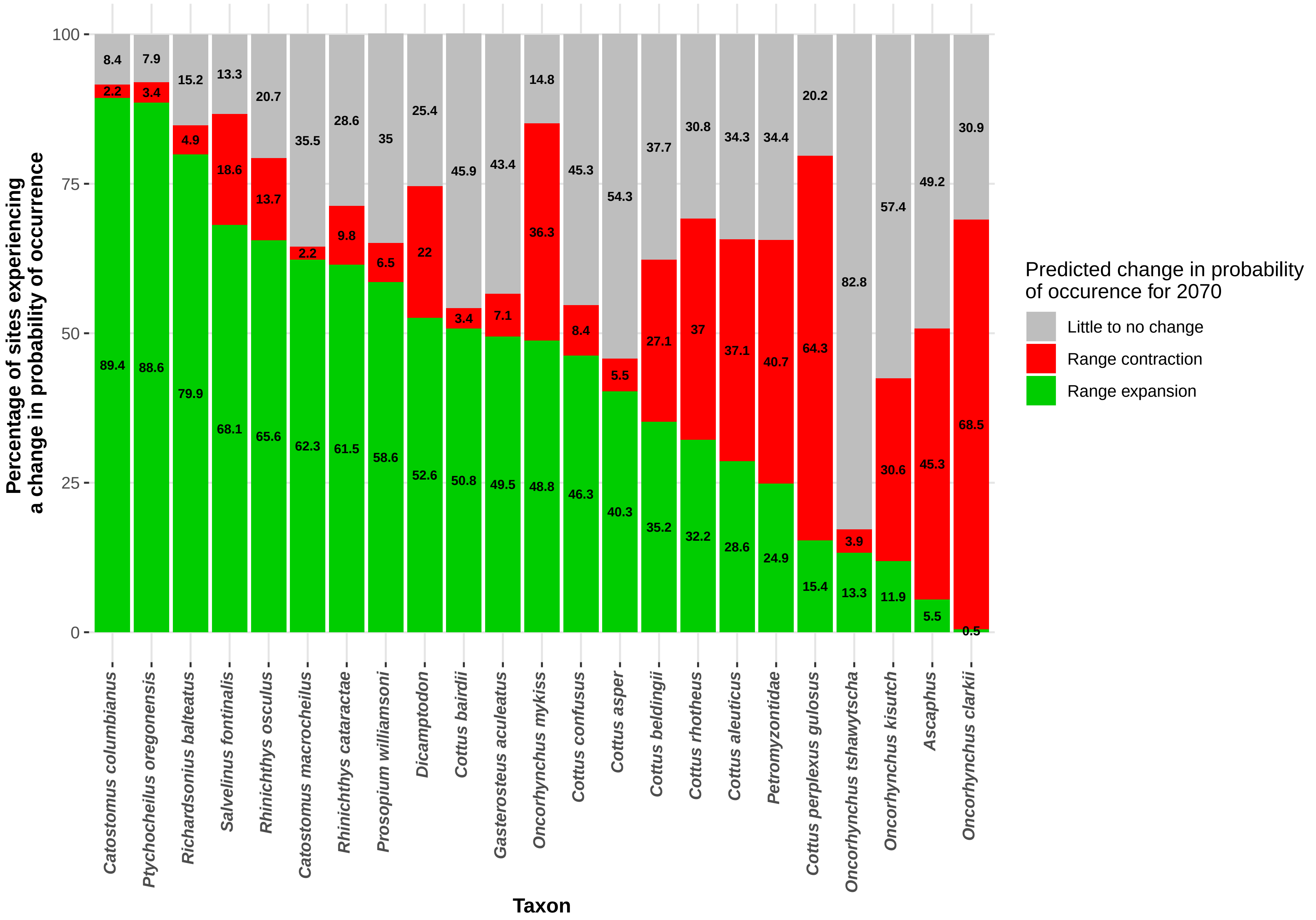


2. How will the distribution of freshwater taxa change under RCP 8.5 for 2070 relative to historical trends?

1. Varies by taxa – winners, losers and 'inbetween'
2. All taxa experience some 'range shifts'

RCP 8.5 2070

	#	Taxon	Common name	Category	NRSA Temp Tolerance	NET % change relative to historical trends
	1	*Catostomus columbianus*	bridgelip sucker	Winner	Cool	24.7
	2	*Ptychocheilus oregonensis*	northern pike minnow	Winner	Cool	20.8
	3	*Richardsonius balteatus*	redside shinner	Winner	Cool	14.8
	4	*Catostomus macrocheilus*	large-scale sucker	Winner	Cool	11.3
	5	*Prosopium williamsoni*	mountain whitefish	Winner	**Cold**	9.4
	6	*Rhinichthys osculus*	specked dace	Winner	Cool	7.5
	7	*Cottus bairdii*	mottled sculpin	Winner	Cool	7.0
	8	*Rhinichthys cataractae*	long-nose dace	Winner	Cool	6.3
	9	*Gasterosteus aculeatus*	three-spinned stickleback	Winner	Cool	5.2
	10	*Cottus asper*	prickly sculpin	Inbetween	Cool	4.6
	11	*Cottus confusus*	short-head sculpin	Inbetween	**Cold**	4.5
	12	*Oncorhynchus mykiss*	rainbow trout	Inbetween	**Cold**	3.8
	13	*Salvelinus fontinalis*	brook trout	Inbetween	**Cold**	3.8
*	14	*Oncorhynchus tshawytscha*	chinook salmon	Inbetween	**Cold**	2.5
	15	*Dicamptodon*	giant salamanders	Inbetween	**Cold**	-0.1
	16	*Cottus beldingii*	piaute sculpin	Inbetween	Cool	-3.1
	17	*Petromyzontidae*	lampreys	Inbetween	Cool	-3.3
*	18	*Oncorhynchus kisutch*	coho salmon	Inbetween	**Cold**	-3.9
	19	*Cottus rhotheus*	torrent sculpin	Inbetween	**Cold**	-4.9
	20	*Cottus aleuticus*	coastrange sculpin	Loser	Cool	-6.4
	21	*Cottus perplexus gulosus*	reticulate-riffle sculpin	Loser	Cool	-13.5
	22	*Ascaphus*	tailed frog	Loser	**Cold**	-14.4
	23	*Oncorhynchus clarkii*	cutthroat trout	Loser	**Cold**	-22.9



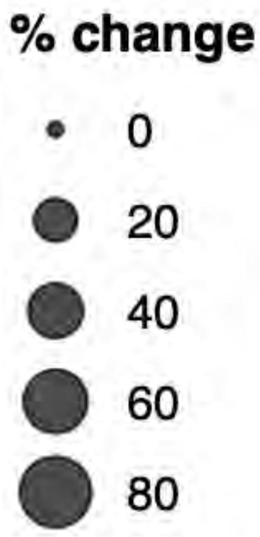
Percentage of sites experiencing a change in probability of occurrence
100
75
50
25
0
Taxon
Catostomus columbianus
Ptychocheilus oregonensis
Richardsonius balteatus
Salvelinus fontinalis
Rhinichthys osculus
Catostomus macrocheilus
Rhinichthys cataractae
Prosopium williamsoni
Dicamptodon
Cottus bairdii
Gasterosteus aculeatus
Oncorhynchus mykiss
Cottus confusus
Cottus asper
Cottus beldingii
Cottus rhotheus
Cottus aleuticus
Petromyzontidae
Cottus perplexus gulosus
Oncorhynchus tshawytscha
Oncorhynchus kisutch
Ascaphus
Oncorhynchus clarkii
8.4 2.2 89.4
7.9 3.4 88.6
15.2 4.9 79.9
13.3 18.6 68.1
20.7 13.7 65.6
35.5 2.2 62.3
28.6 9.8 61.5
35 6.5 58.6
25.4 22 52.6
45.9 3.4 50.8
43.4 7.1 49.5
14.8 36.3 48.8
45.3 8.4 46.3
54.3 5.5 40.3
37.7 27.1 35.2
30.8 37 32.2
34.3 37.1 28.6
34.4 40.7 24.9
20.2 64.3 15.4
82.8 3.9 13.3
57.4 30.6 11.9
49.2 45.3 5.5
30.9 68.5 0.5
Predicted change in probability of occurence for 2070
Little to no change
Range contraction
Range expansion

Legend on the distribution plots

(a) **Predicted change in probability of occurrence for 2070**

- Little to no change — < 5% increase or decrease
- Range contraction — > 5% decrease
- Range expansion — > 5% increase

(b)



Each circle represents one site

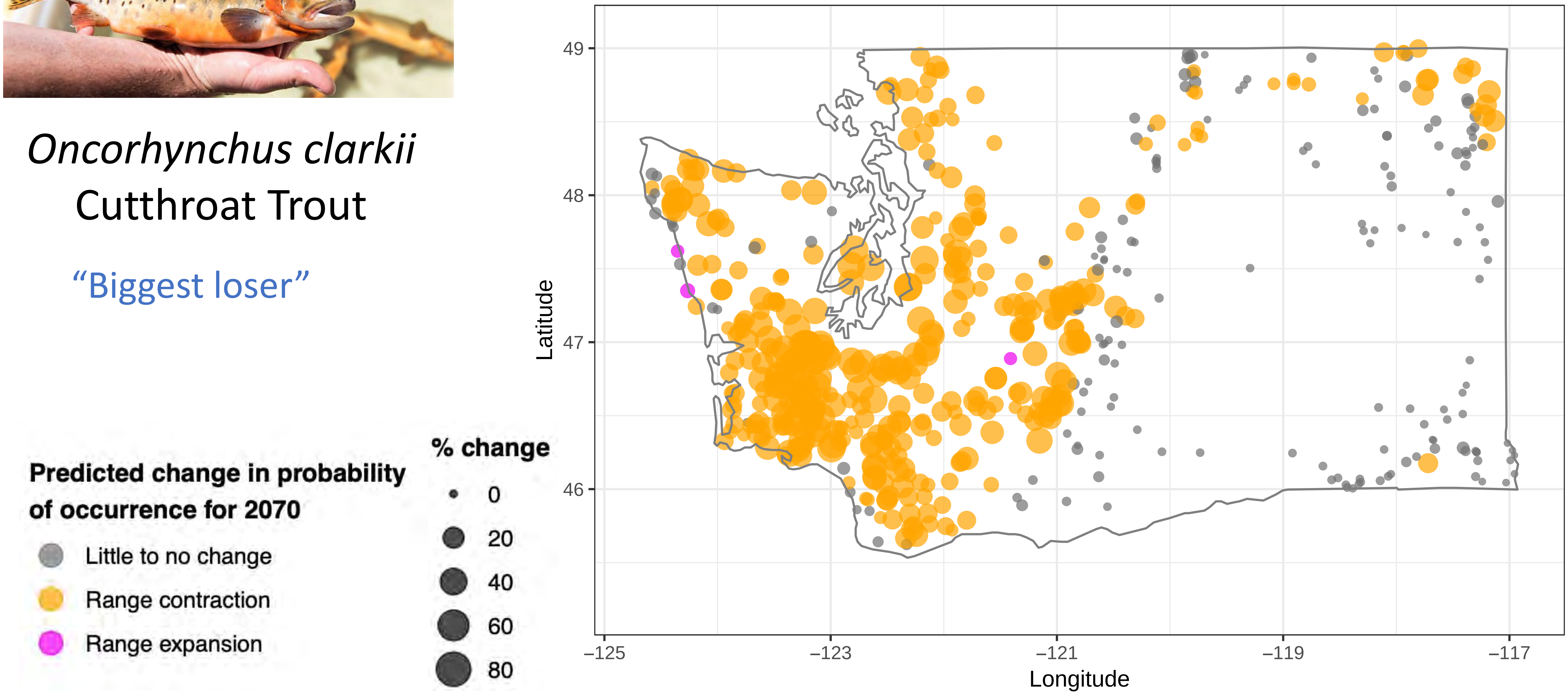
Size of circle indicates extent of change

RCP 8.5 2070

Oncorhynchus clarkii

Cutthroat Trout

"Biggest loser"



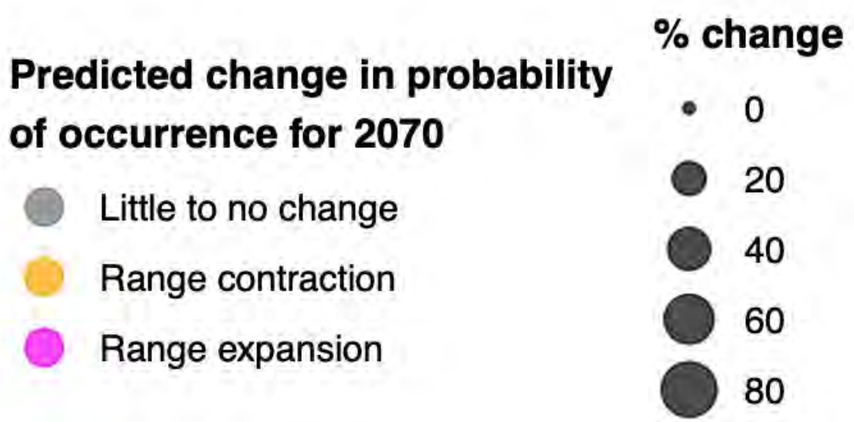
RCP 8.5 2070

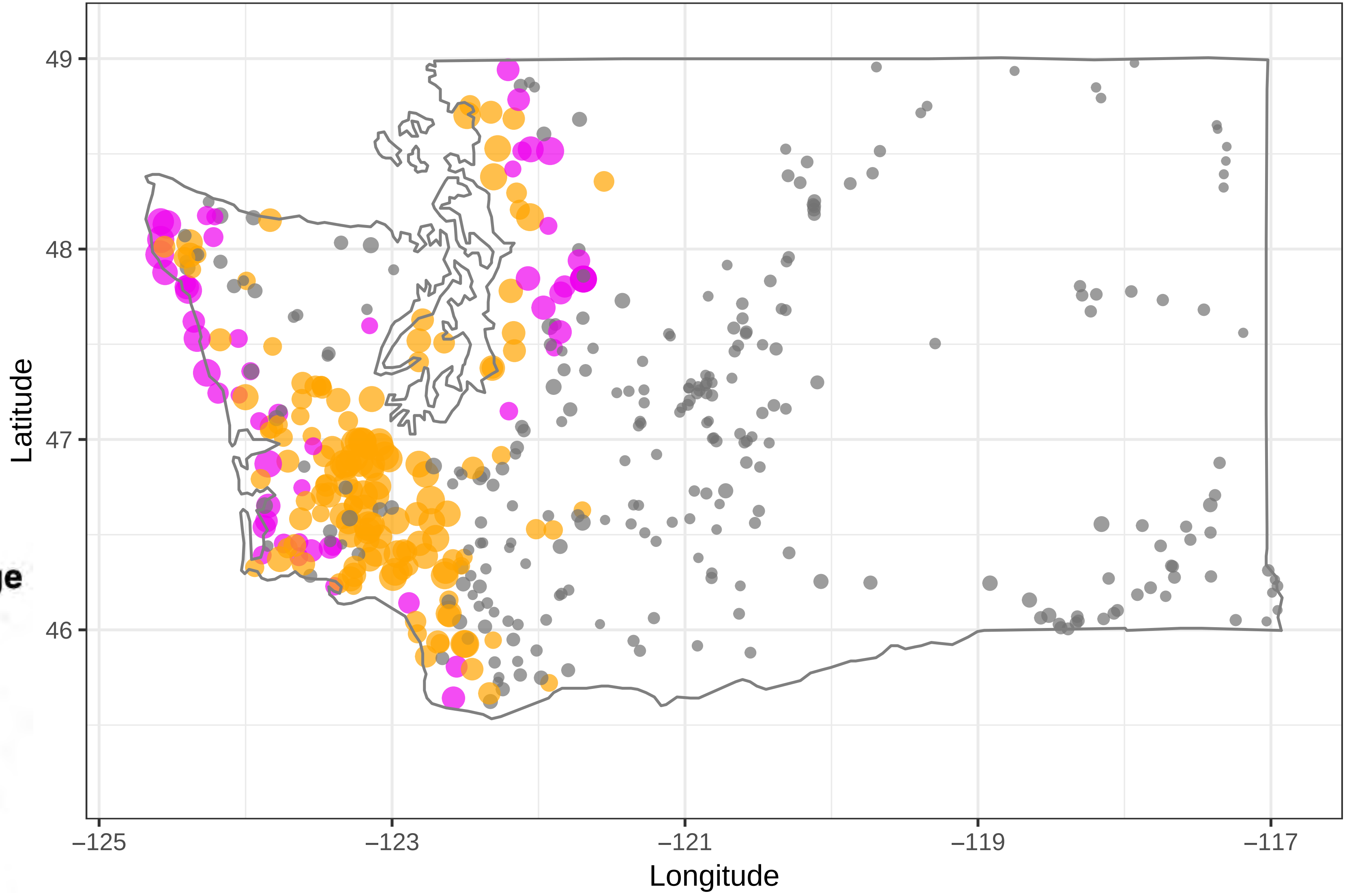
Oncorhynchus kisutch

Coho salmon

“Inbetween”

Juveniles only





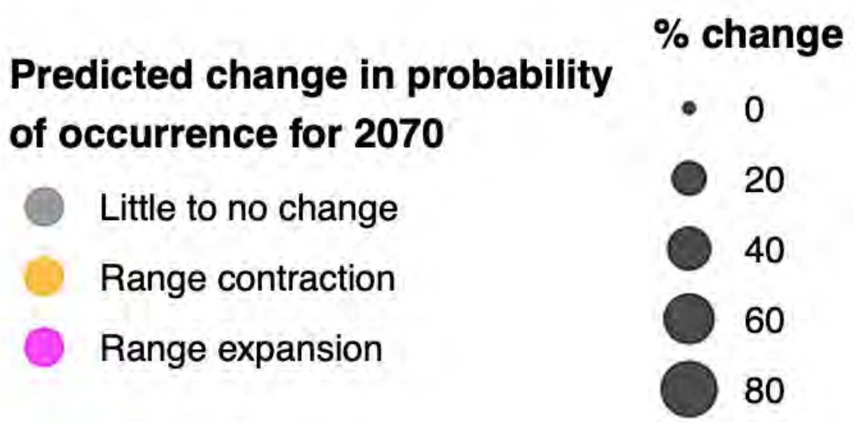
RCP 8.5 2070

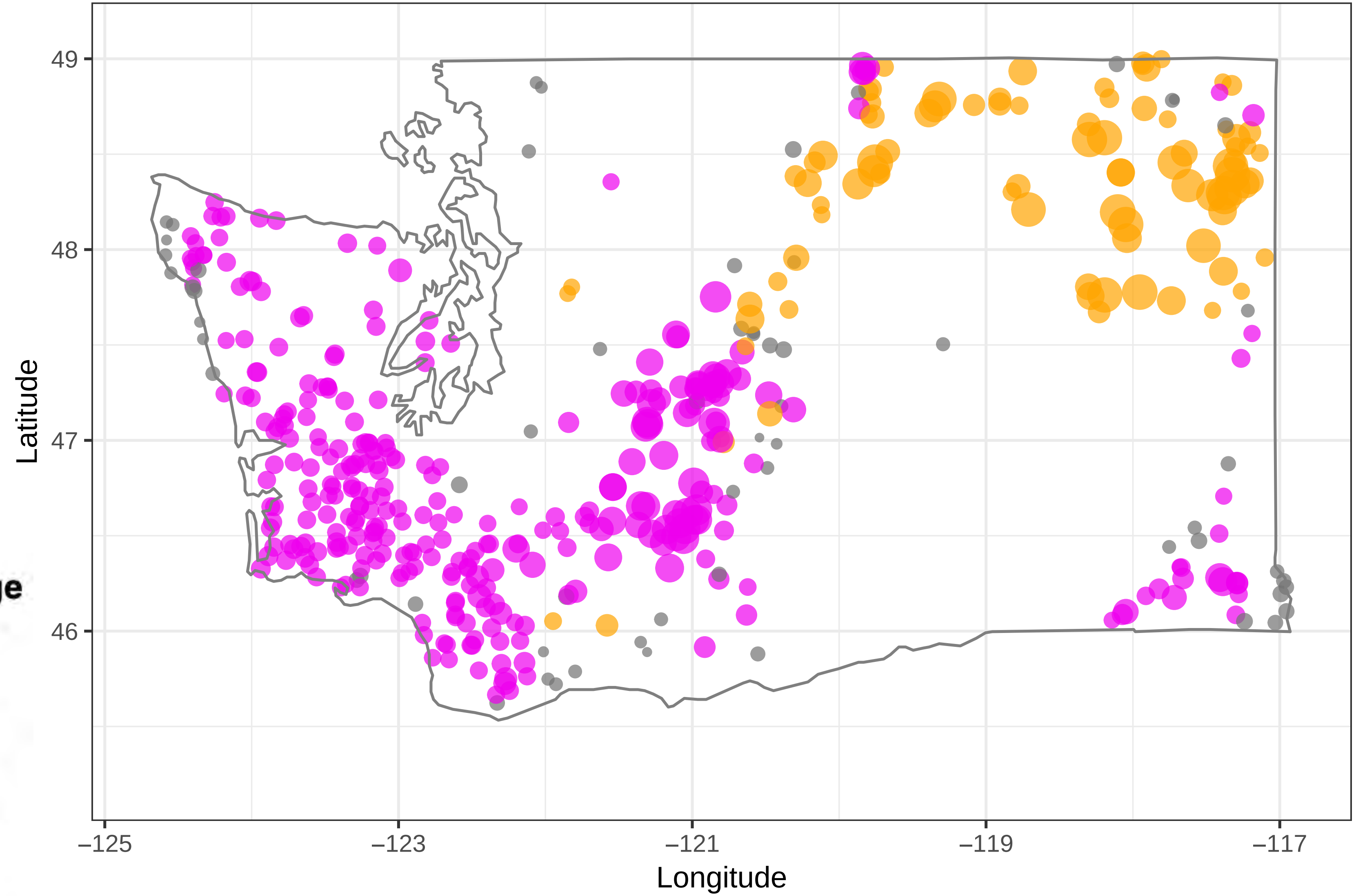
Salvelinus fontinalis

Brook Trout

"Winner"

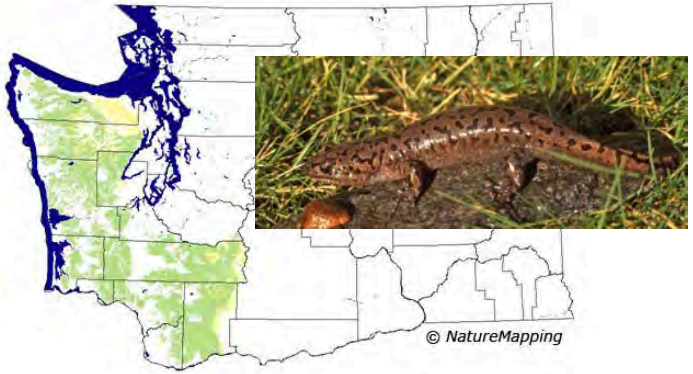
Non-native





Cope's Giant Salamander *(Dicamptodon copei)*

Species Code: DICO

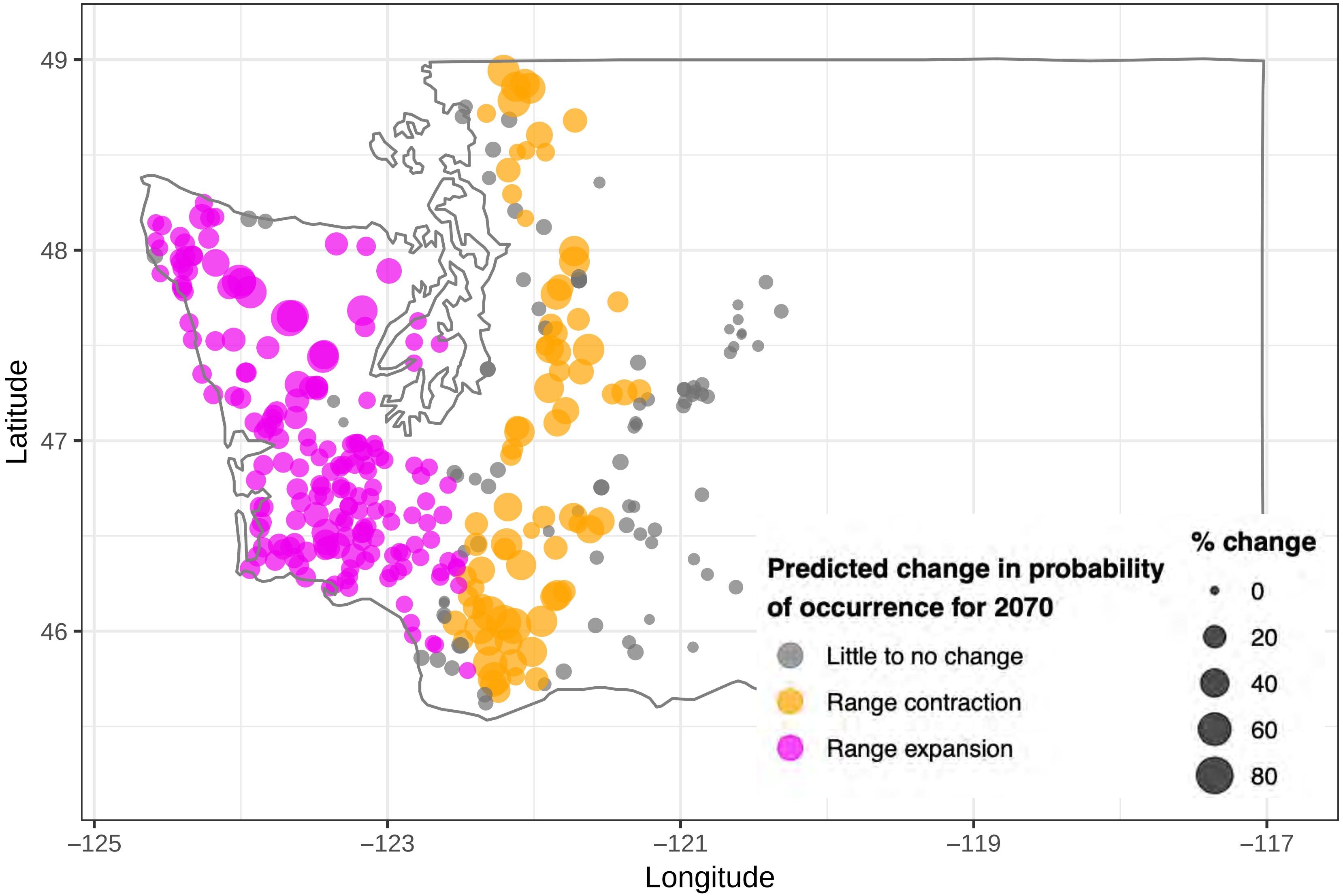


RCP 8.5 2070

Dicamptodon

Salamanders

"Inbetween"



Pacific Giant Salamander *(Dicamptodon tenebrosus)*

Species Code: DITE

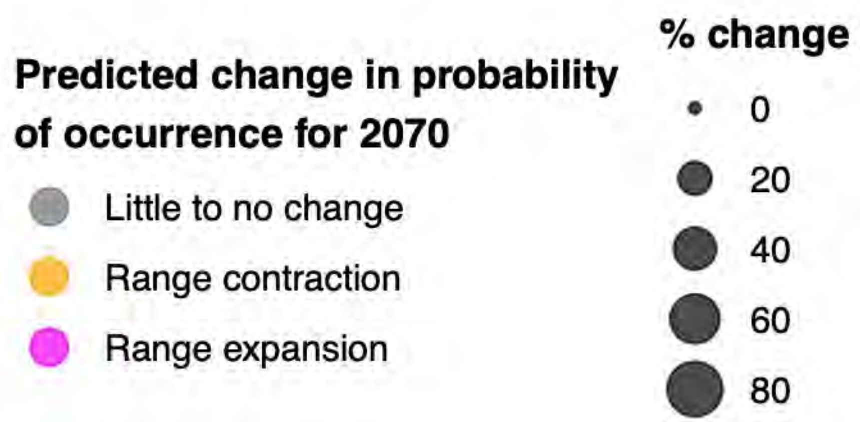
Maps and Photos: Burke Museum

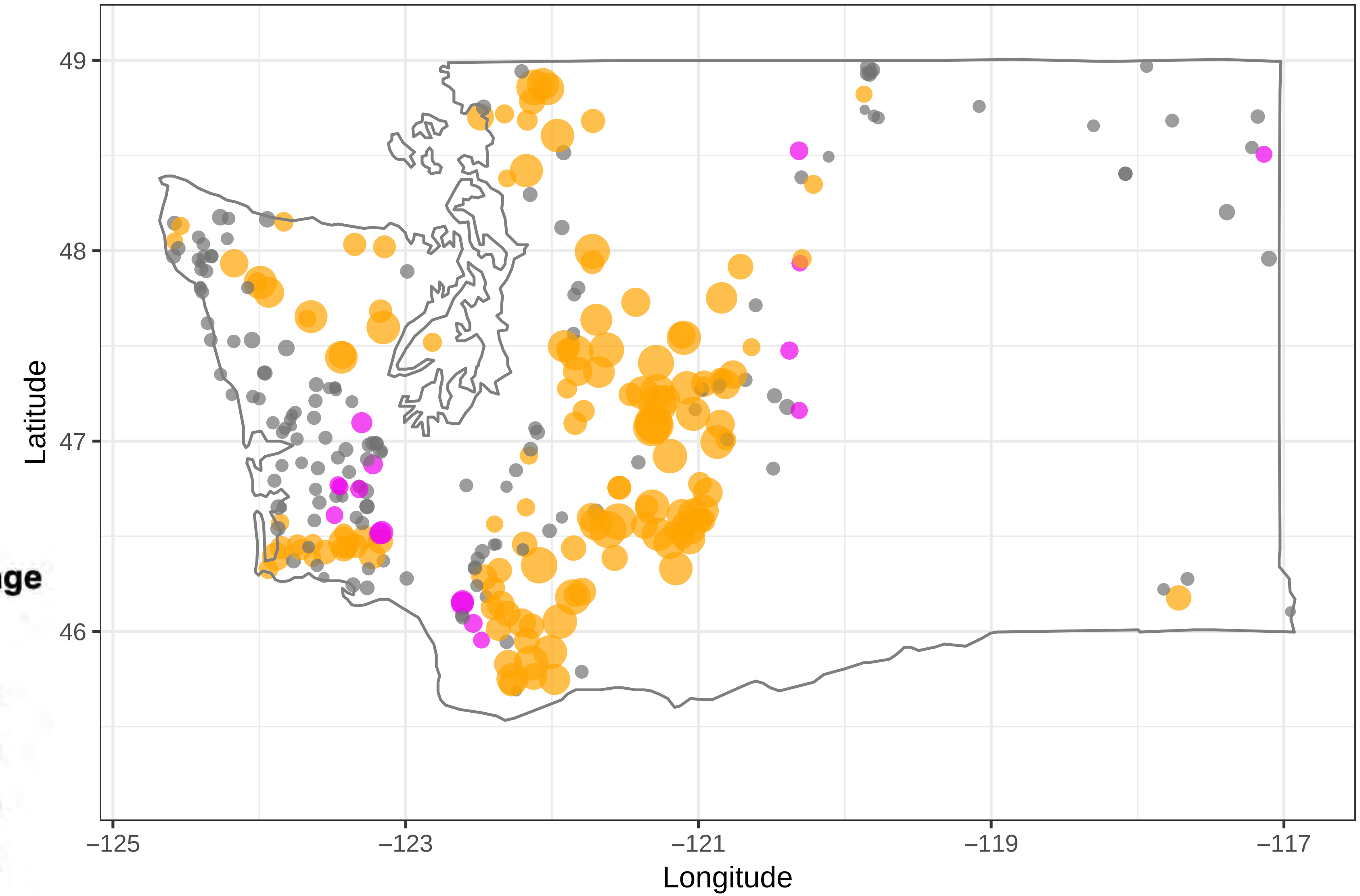
RCP 8.5 2070

Ascaphus

Tailed frog

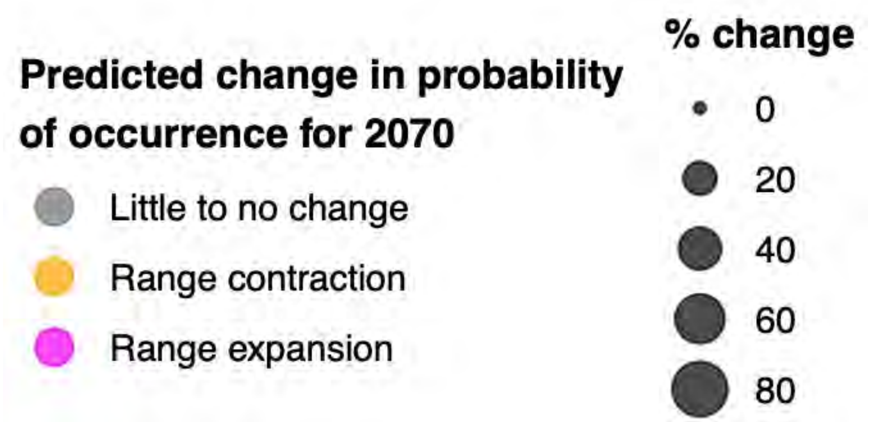
"Loser"

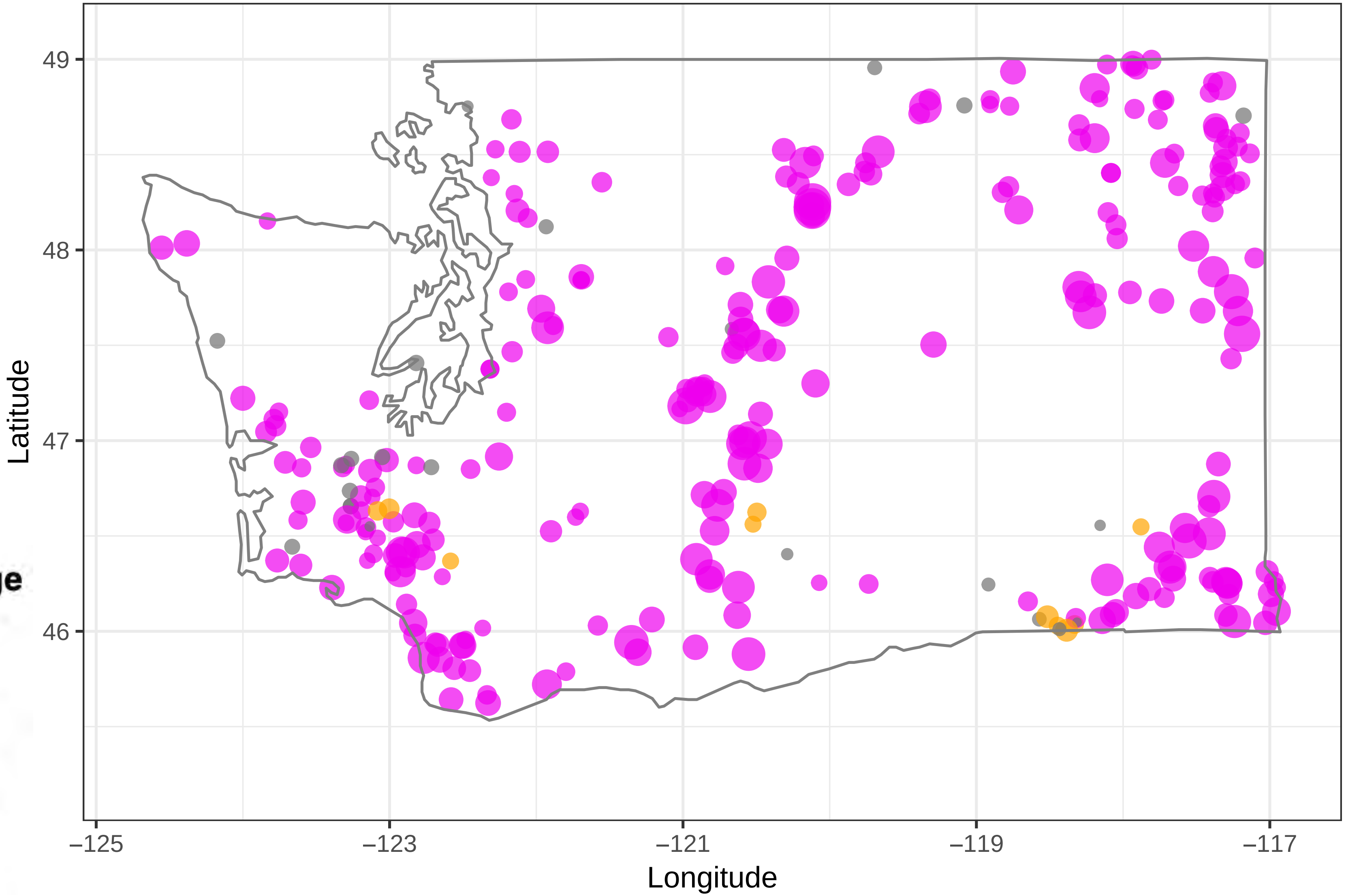




Ptychocheilus oregonensis
Northern Pike Minnow

"Winner"





Conclusions – scenario RCP 8.5 2070

- Range contraction
  - Cold amphibians, cold fish, cold and cool macroinvertebrates
- Range expansion
  - Cool fish , cool-warm and warm macroinvertebrates
- Significant alterations to stream communities – *winners, losers, 'inbetween'*
- Non-native taxa *Brook Trout* & *Northern Pike Minnow* predicted increase
  - Potential to displace cutthroat trout
  - Increased predation on other salmon species
- *Tailed frog* an *indicator species* predicted to decrease
  - Indication of significant environment change - 'canary in the coal mine'
- Potential alterations to inter species interactions, e.g. competition, predation
- Future work: expand on patterns observed in macroinvertebrates – significant change in EPT distribution - implications fish/amphibian diet

References

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- 7. Guisan A, Thuiller W. *Predicting species distribution: offering more than simple habitat models.* Ecol Lett. 2005;8: 993–1009. doi:10.1111/j.1461-0248.2005.00792.x
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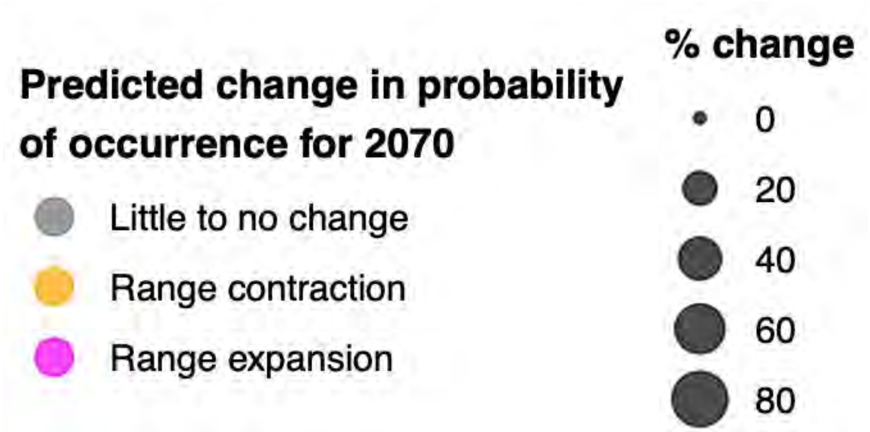
Questions

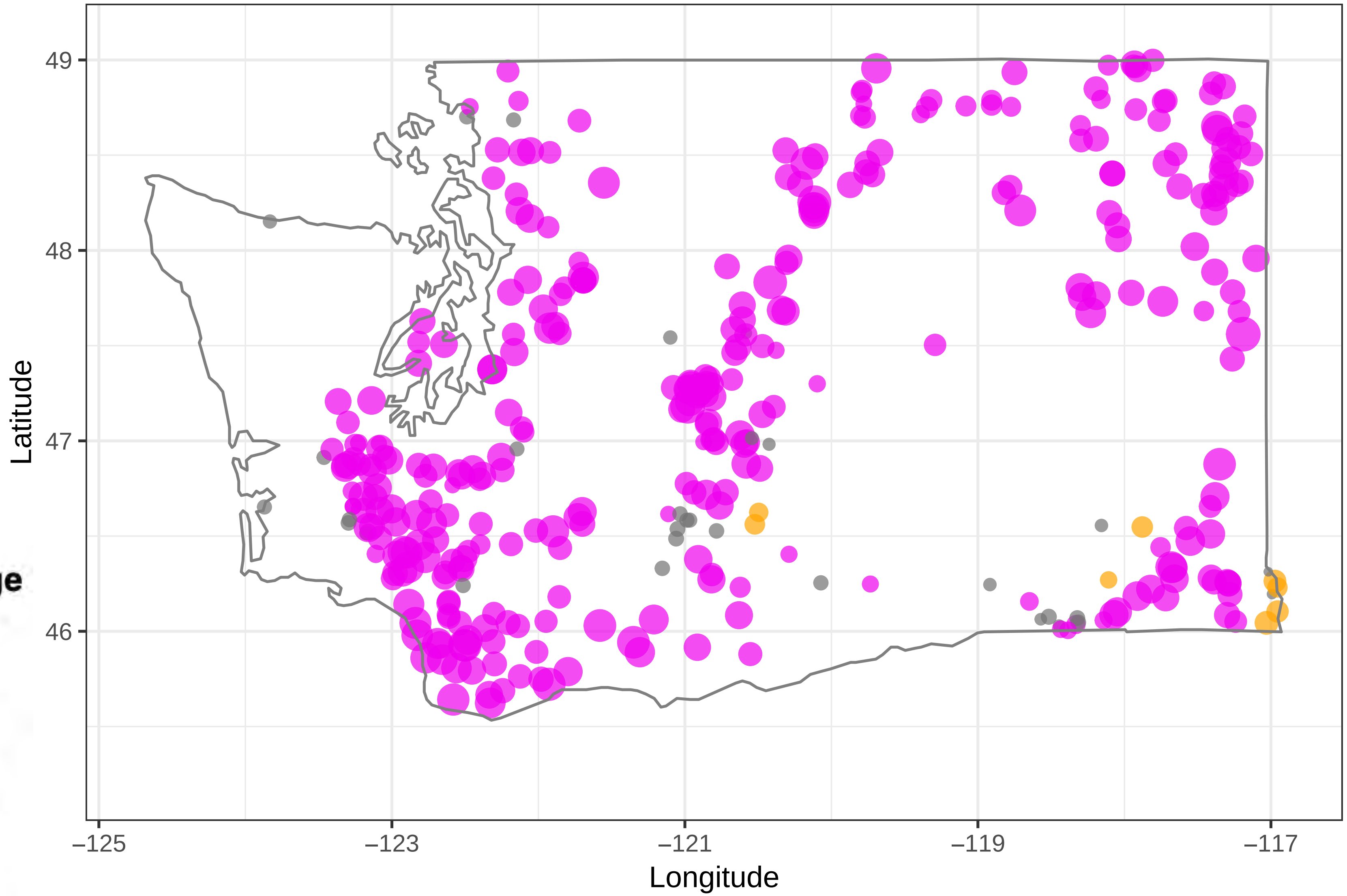
RCP 8.5 2070

Catostomus columbianus

Bridgelip Sucker

“Biggest winner”





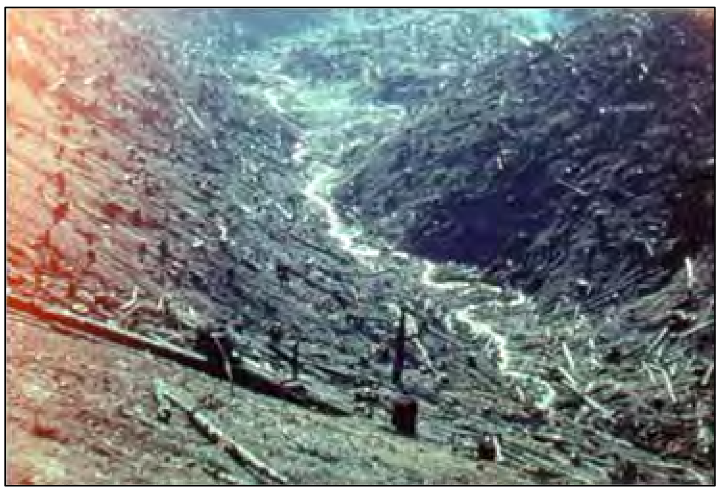
Thermal responses to riparian thinning in redwood headwater streams at multiple spatial scales

David Roon[1], Jason Dunham[2], and Christian Torgersen[2]

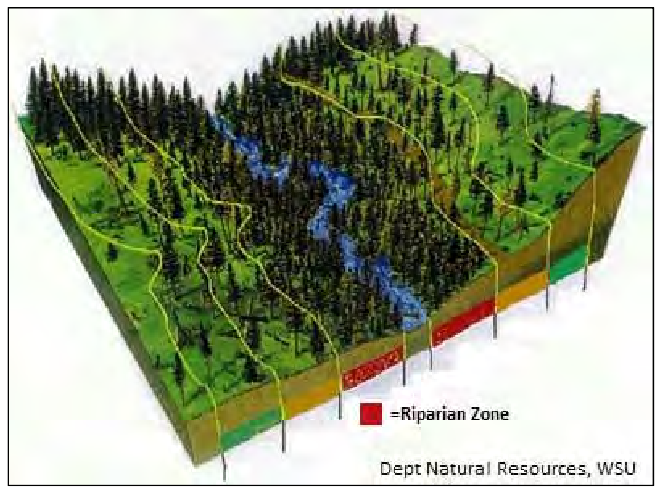
1. Oregon State University, Department of Fisheries and Wildlife
2. USGS, Forest and Rangeland Ecosystem Science Center

Riparian forests are changing…

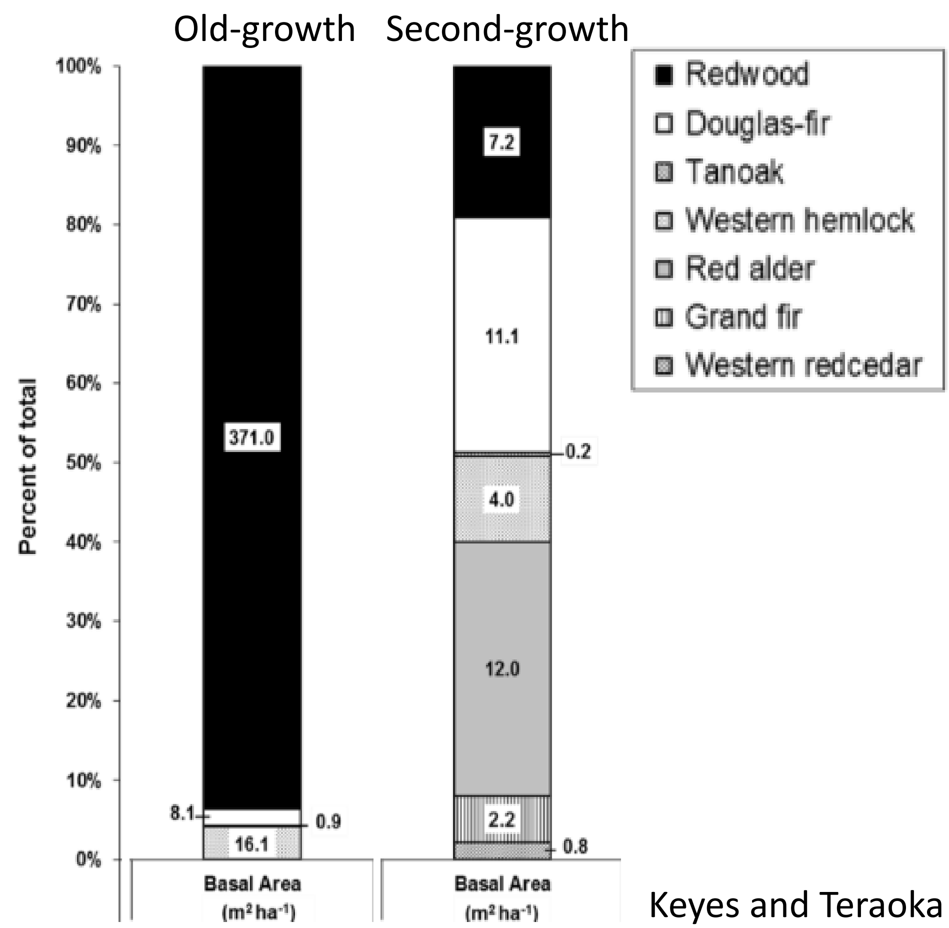
then



now



In redwoods, second-growth differs from old-growth



Keyes and Teraoka 2014

Thinning a solution for second-growth riparian forests?

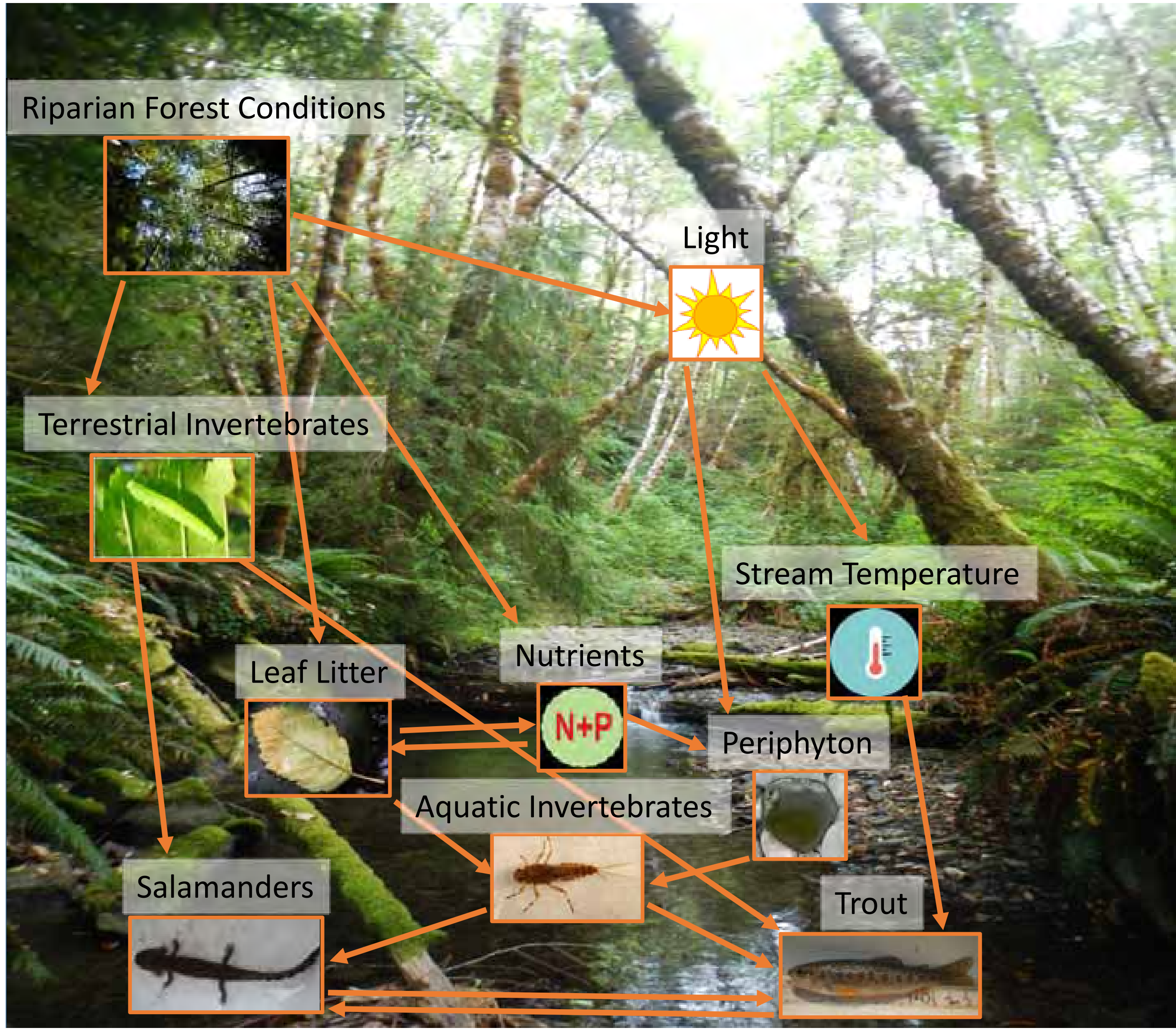
- Accelerate recovery of old-growth redwoods
- Shift successional trajectory to provide future source of large woody debris
- Strike balance between stream temperature and aquatic productivity
- However, immediate effects unknown…

→

→

Research Objectives

1) Riparian shade, light, and stream temperature
2) Stream-Riparian food webs
3) Growth and Bioenergetics of Trout



Research Objectives

1) Riparian shade, light, and stream temperature

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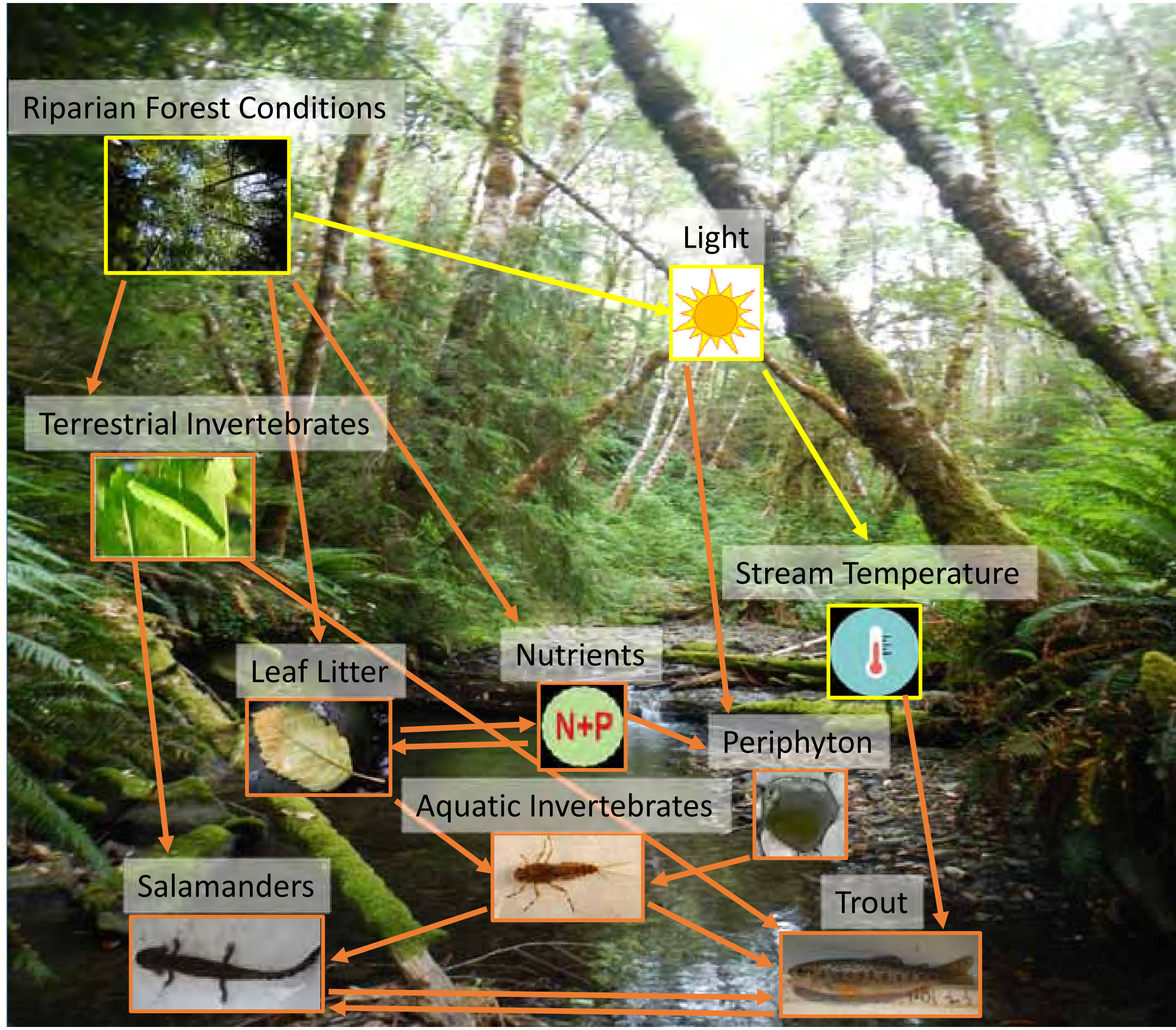
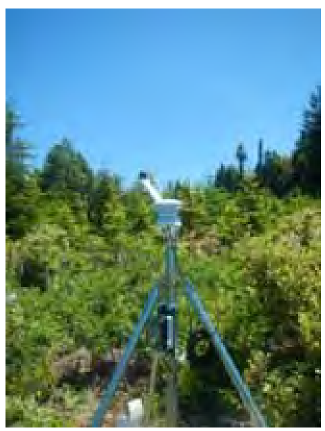
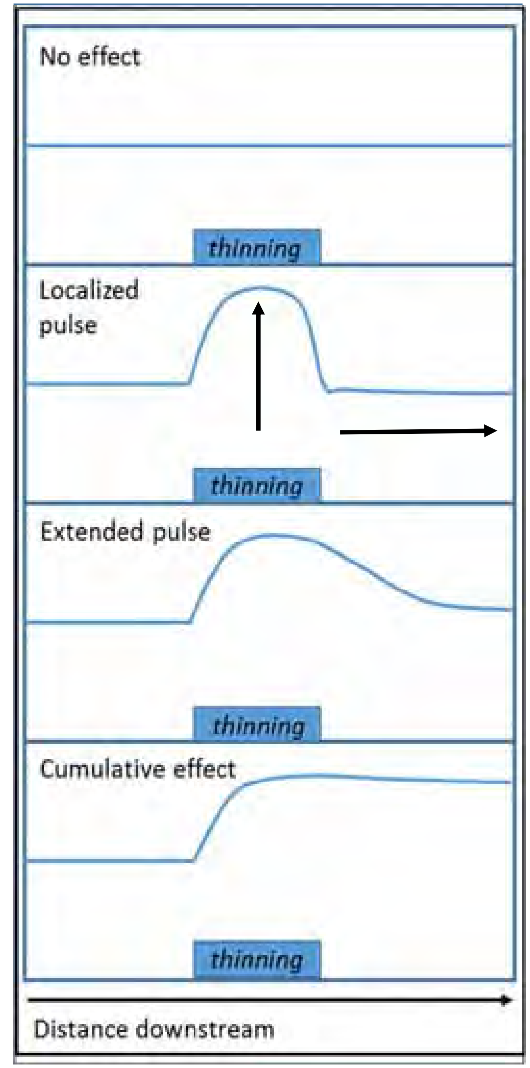


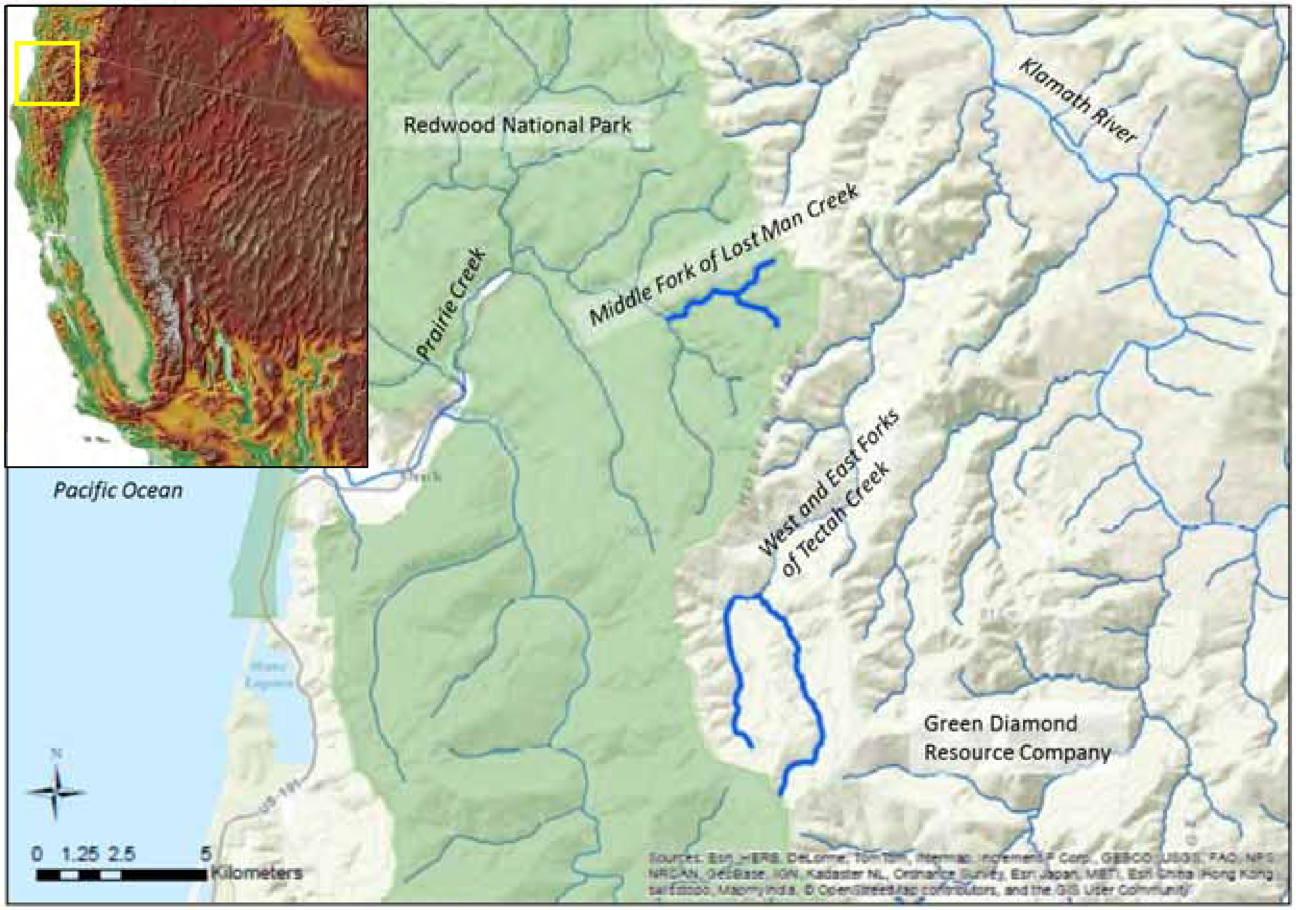
Hypotheses

- Riparian thinning will:
  - reduce riparian shade
  - increase light
  - resulting in minor increase (<1 °C) in stream temperature
  - Magnitude and extent of local and downstream responses



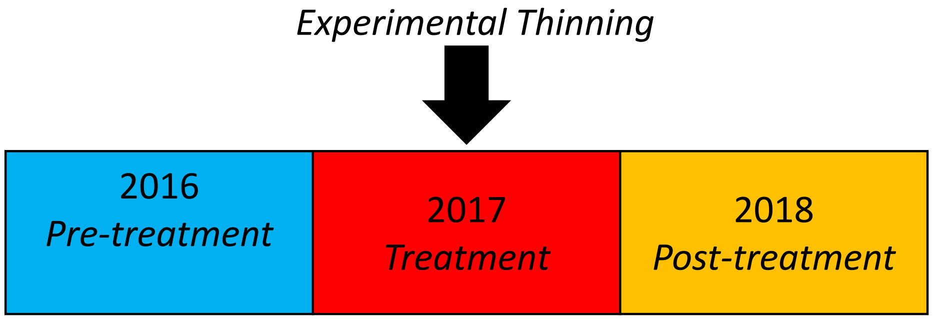


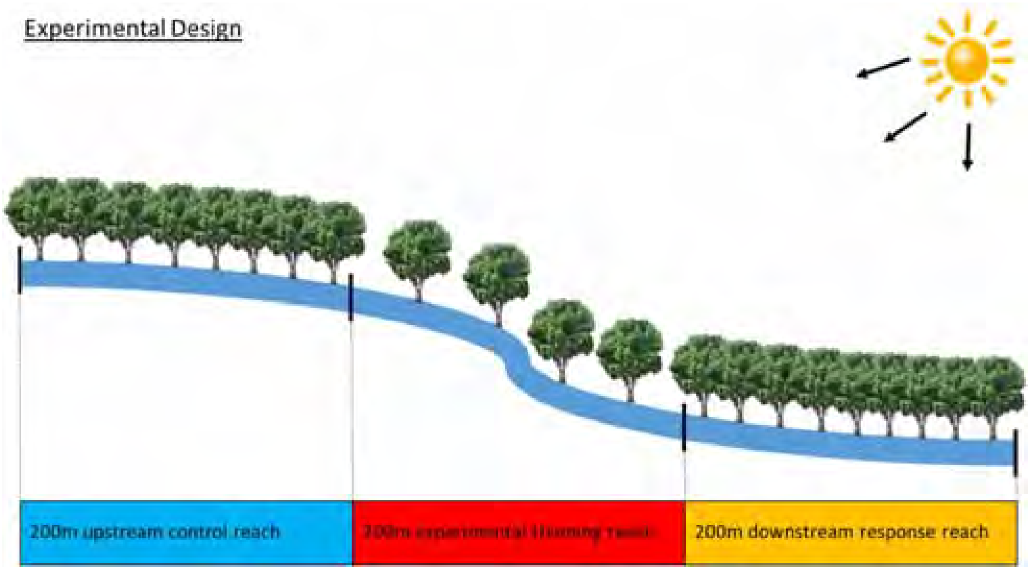
Study Watersheds



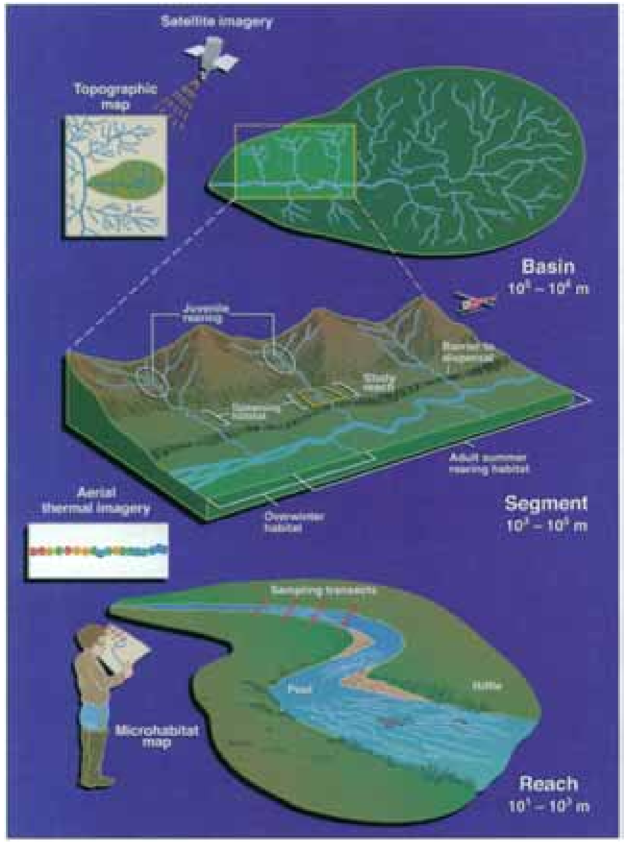
Experimental Design

- Before After Control Impact



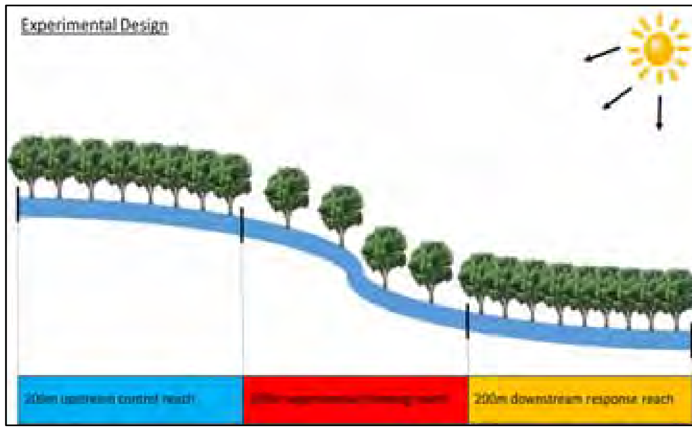


Experimental Design

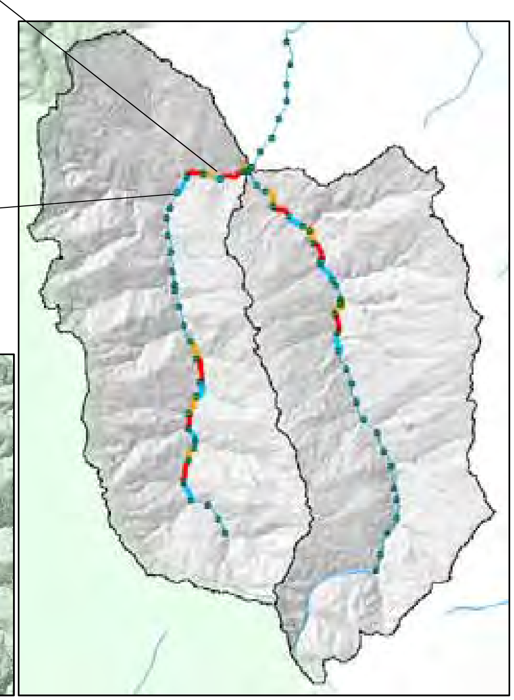


Fausch et al. 2002

Reach-scale



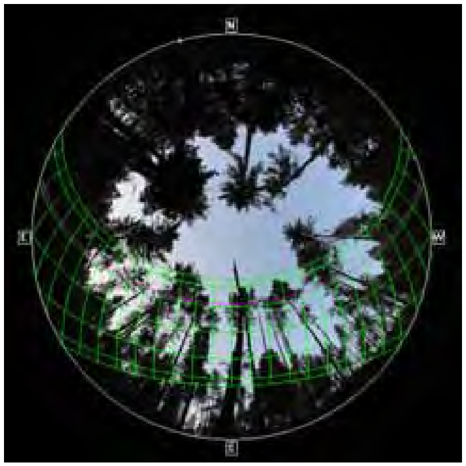
Watershed-scale

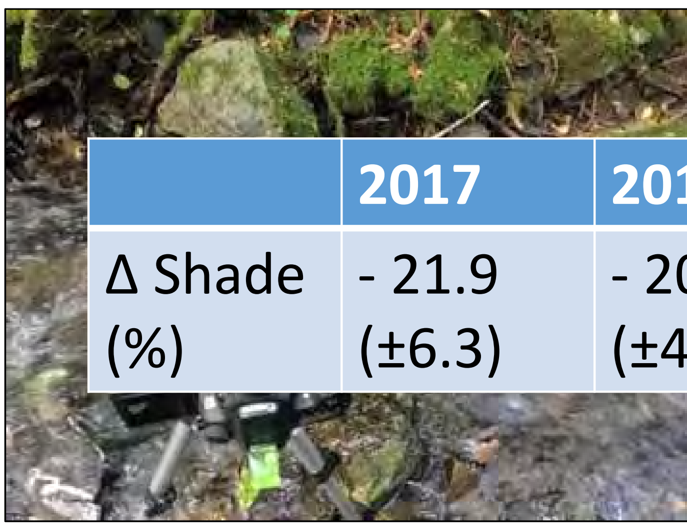


Thinning Treatments - Lost Man

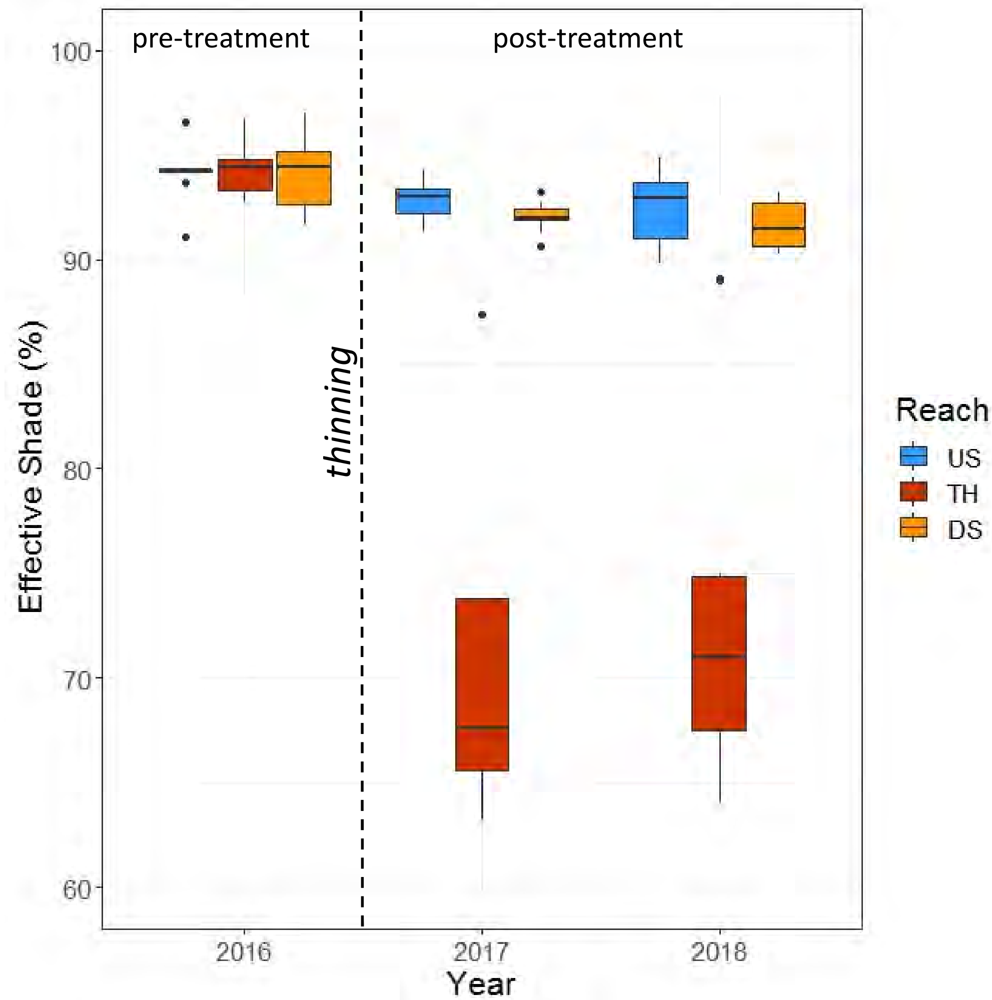
Thinning Treatments - Tectah

Thinning reduced riparian shade…

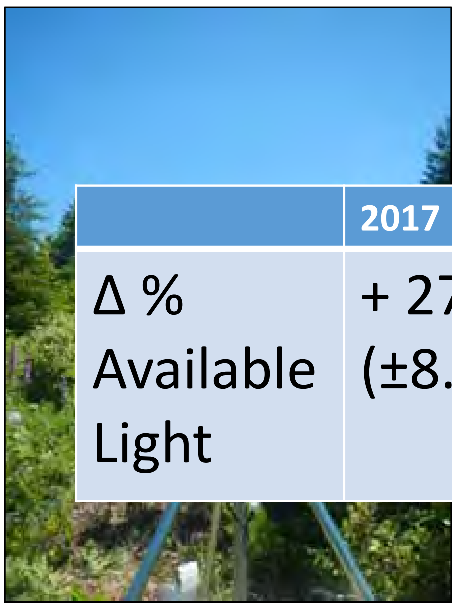


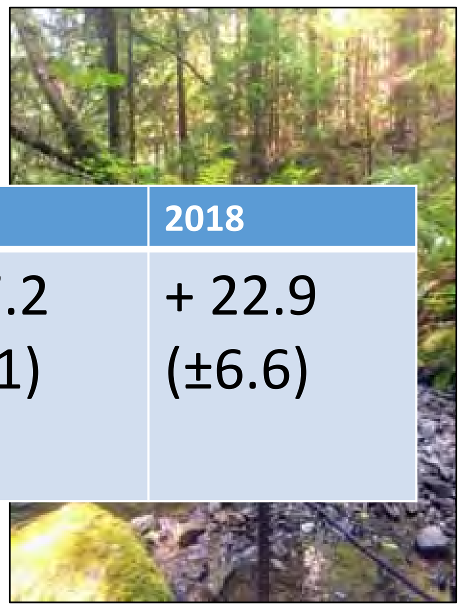


	2017	2018
Δ Shade (%)	- 21.9 (±6.3)	- 20.6 (±4.6)

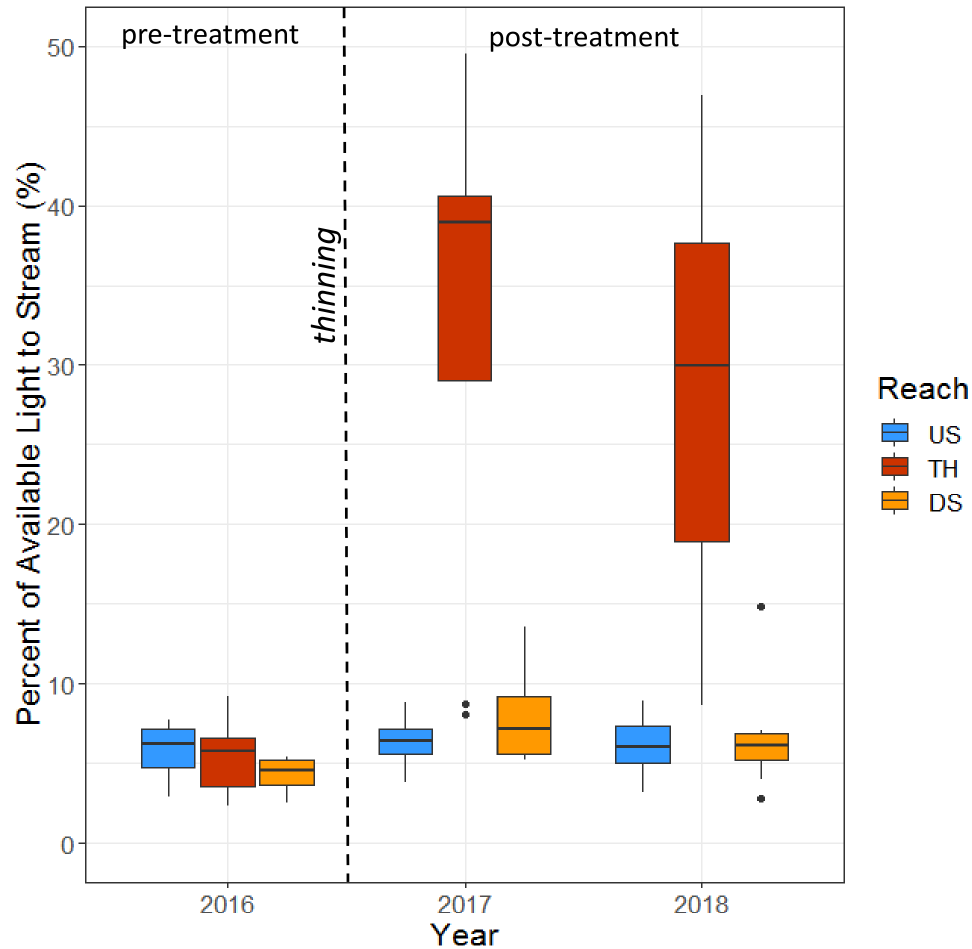


Thinning increased light to stream…

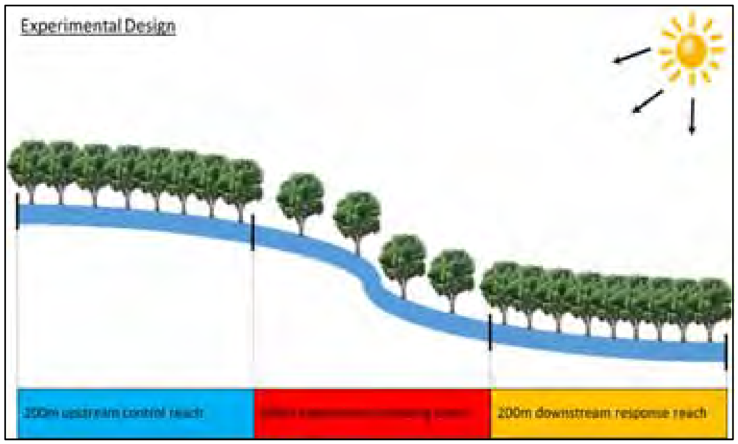


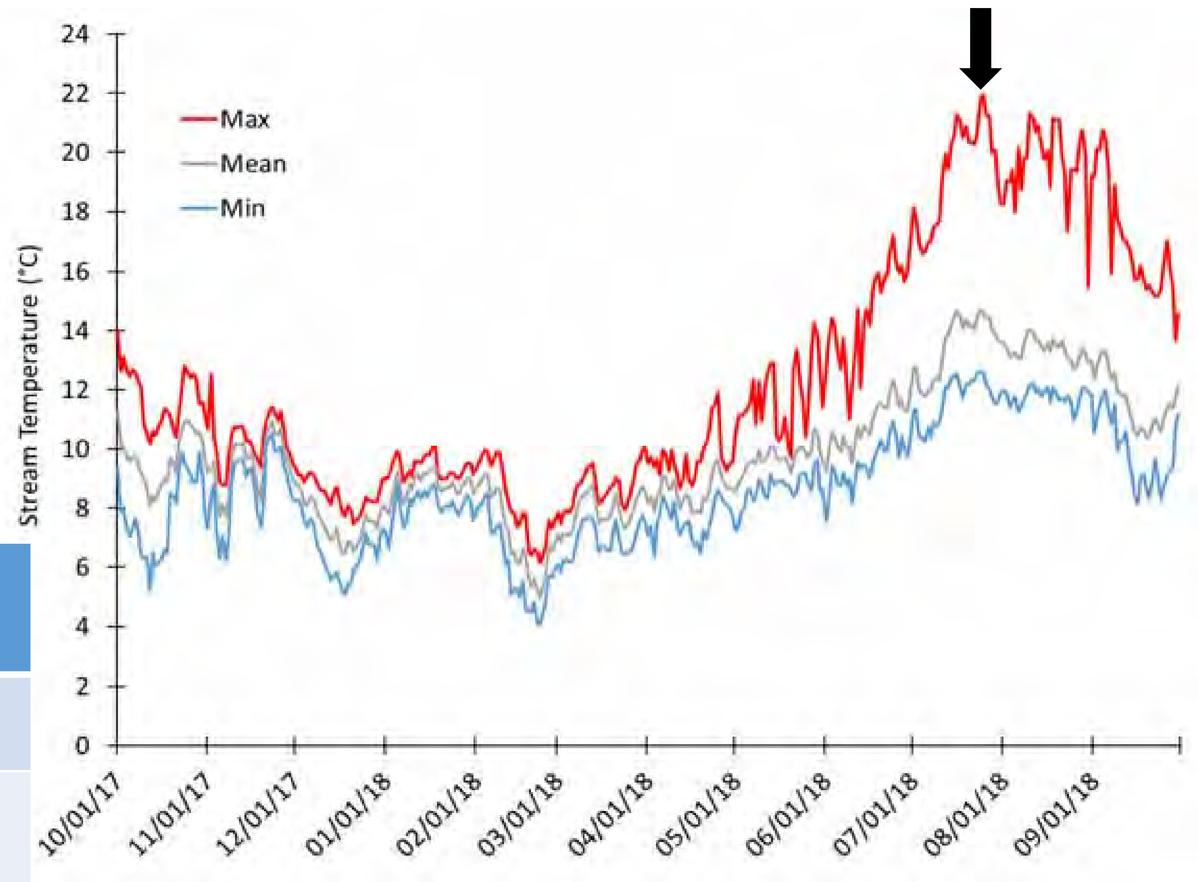


	2017	2018
Δ % Available Light	+ 27.2 (±8.1)	+ 22.9 (±6.6)

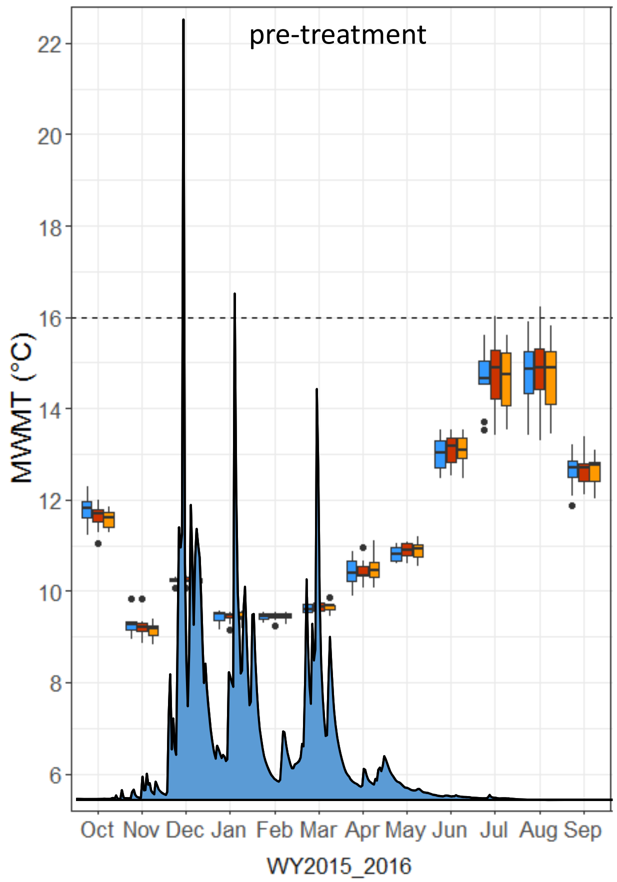


Stream temperature: reach-scale patterns

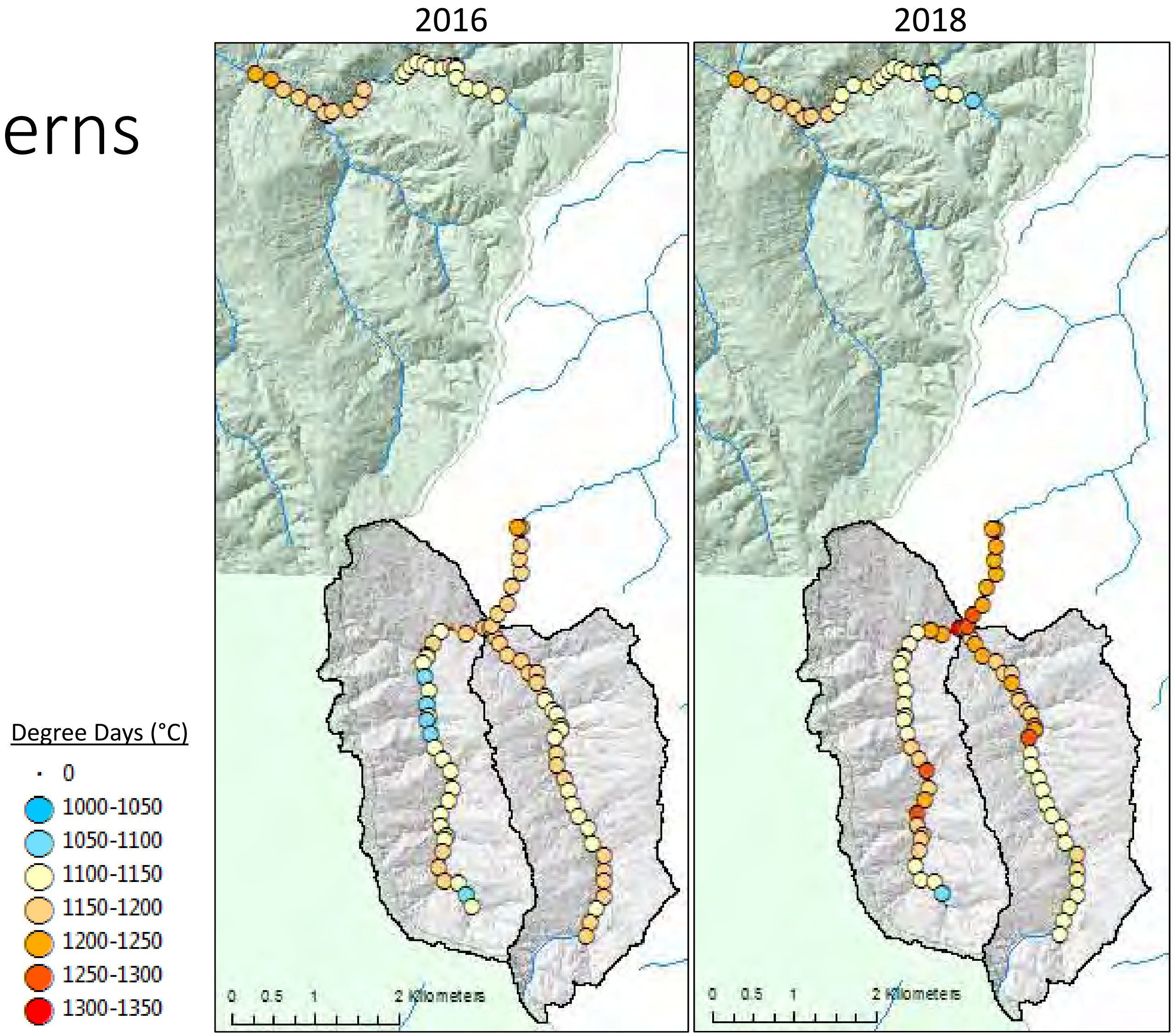




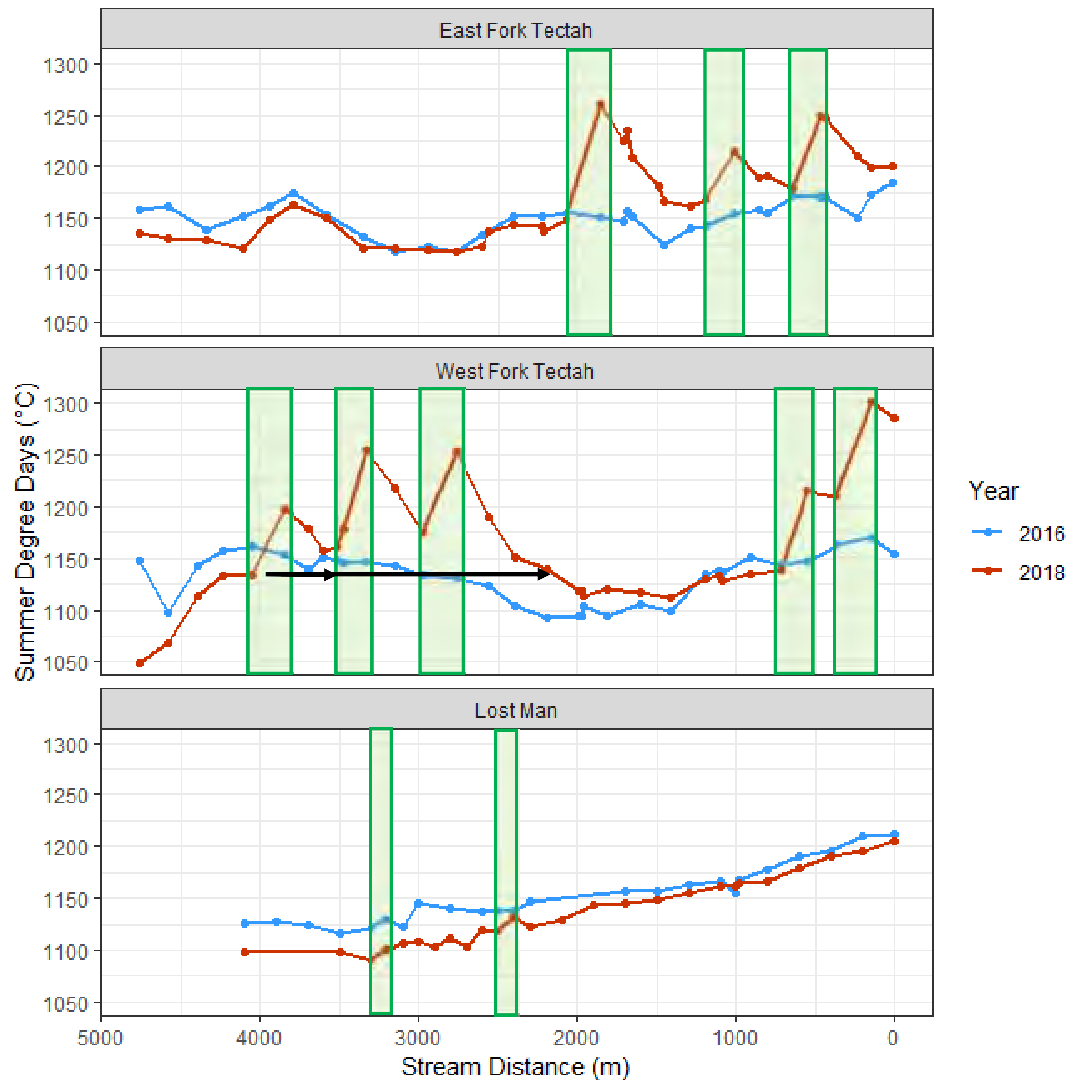
At a reach scale, thinning increases stream temperature May - September



Watershed scale patterns

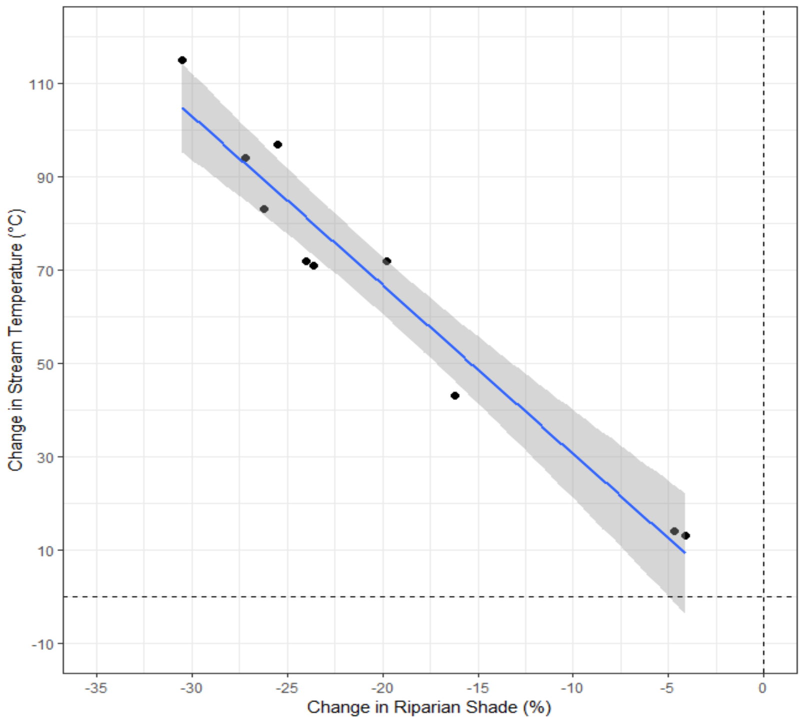


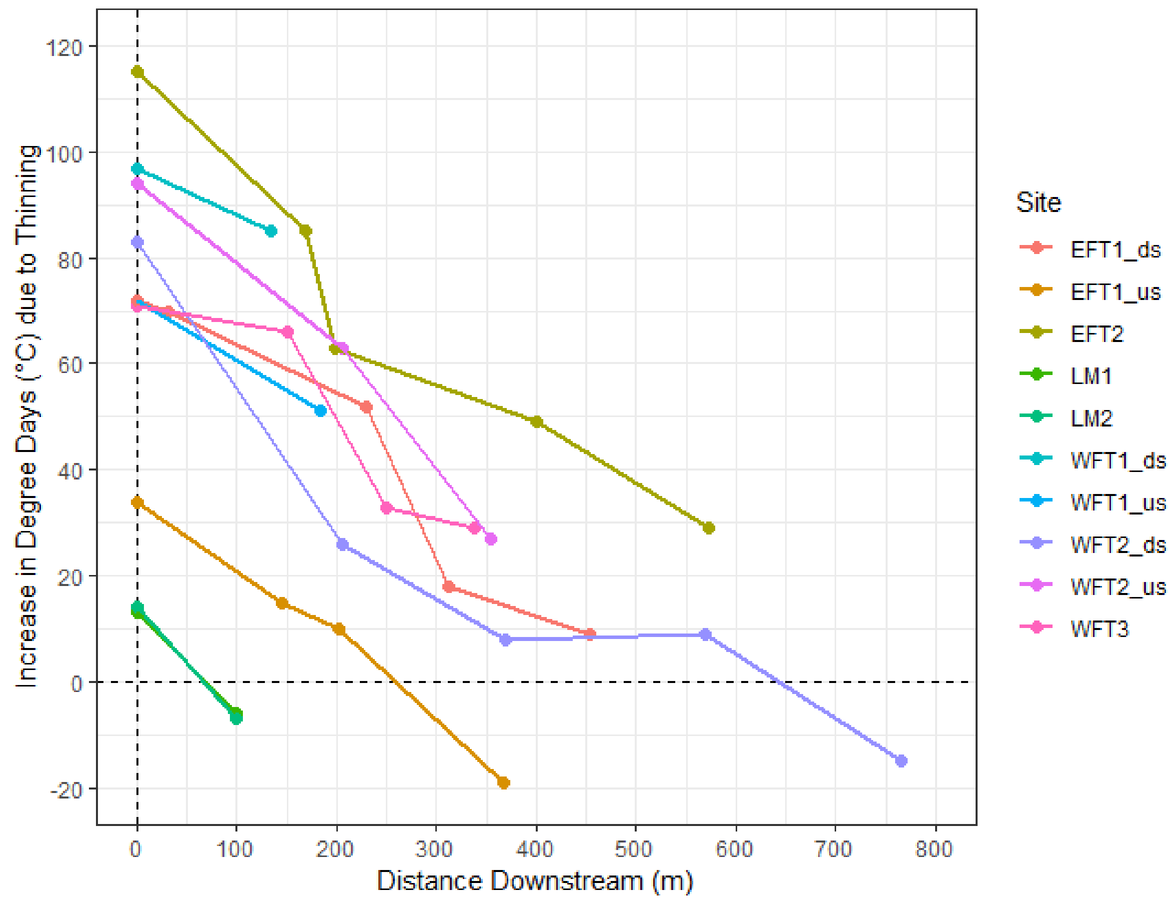
How do these increases in temperature travel through the watershed?



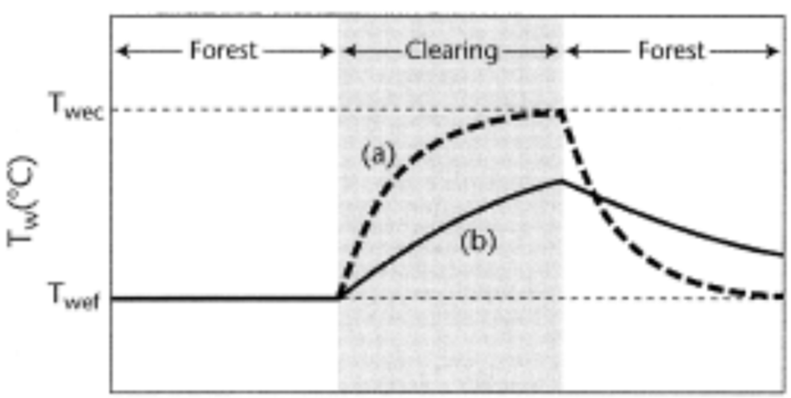
How far downstream do increases in temperature travel?

- Riparian Shade

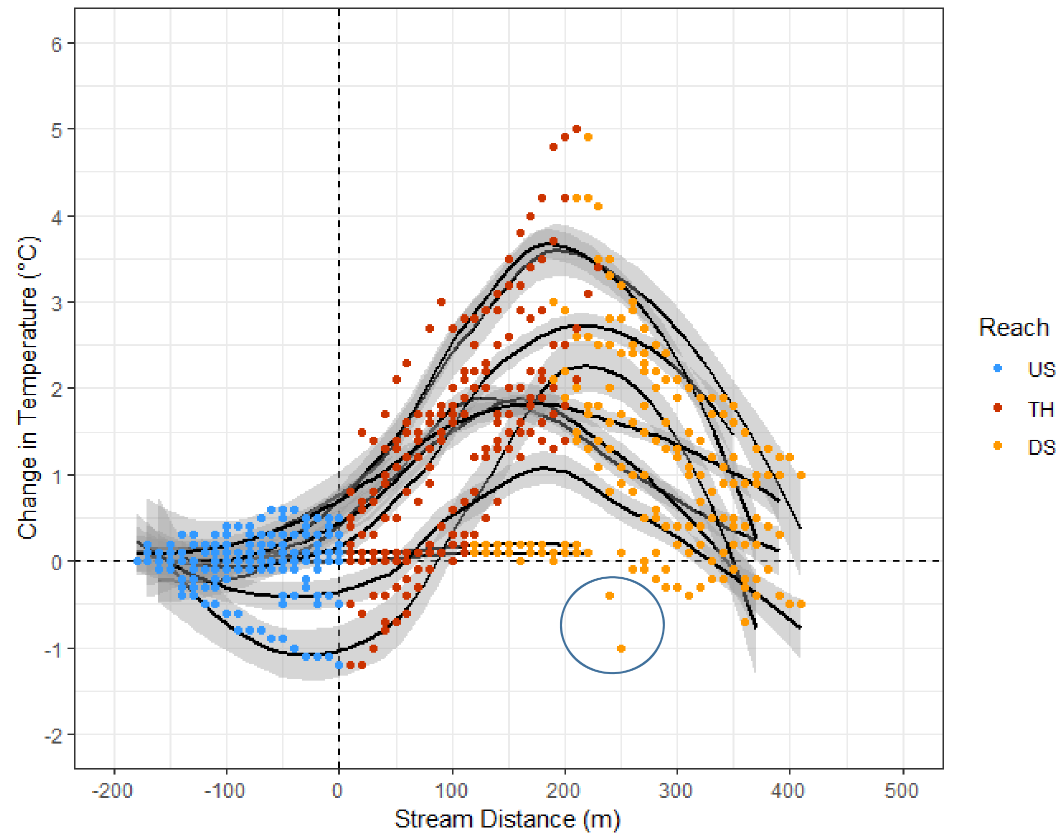




Fine-scale patterns



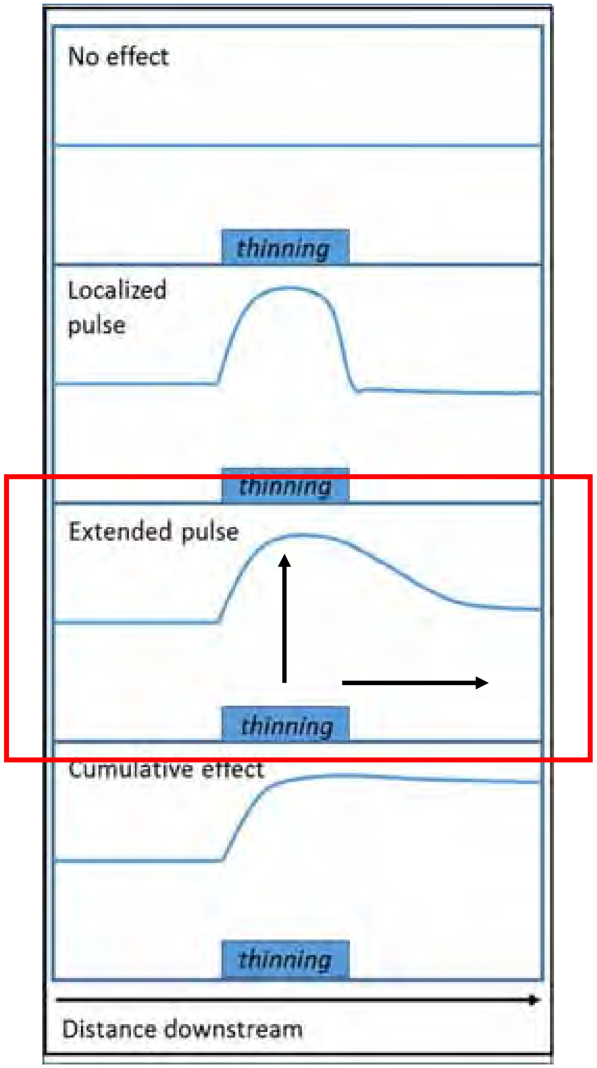
Moore et al. 2005



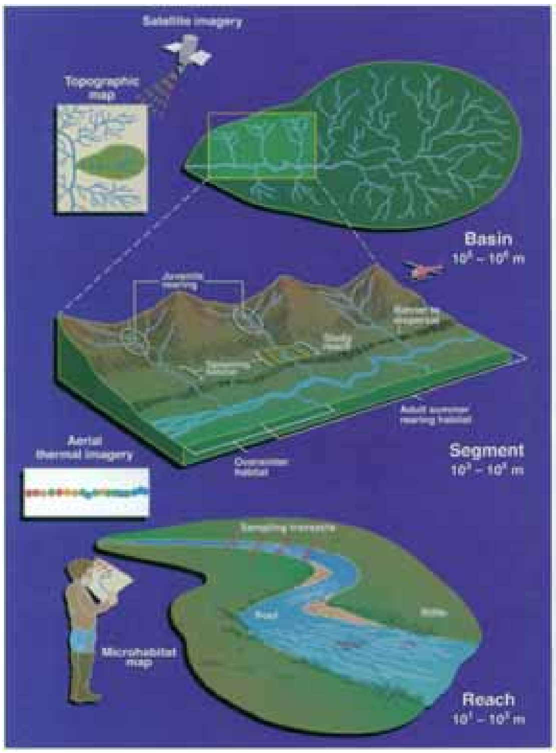
In conclusion, riparian thinning:

- Riparian Shade: decreased ~21 (±6)%
- Light: increased ~25 (±7)%
- Stream Temperature:
  - Reach scale: local increases ~2.5 °C
  - Watershed scale: increases traveled 100-700m

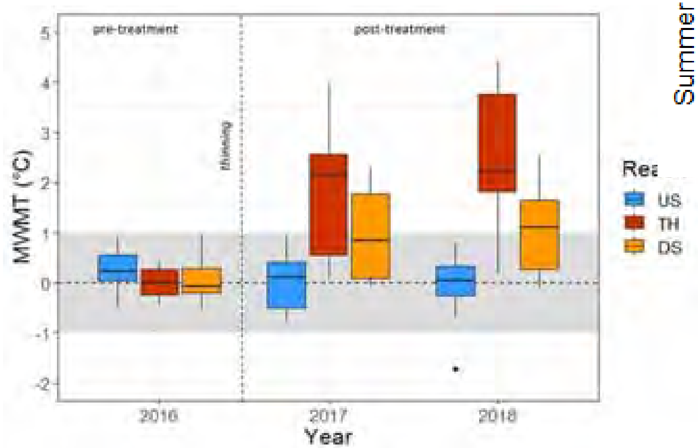
- Increased locally and continued downstream but eventually dissipated

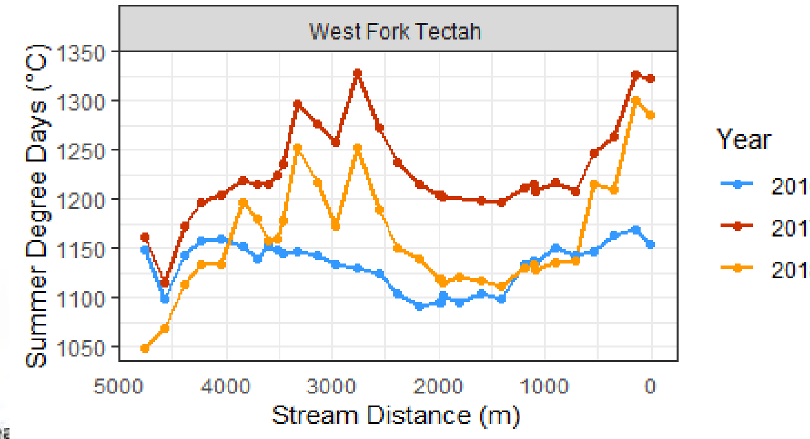


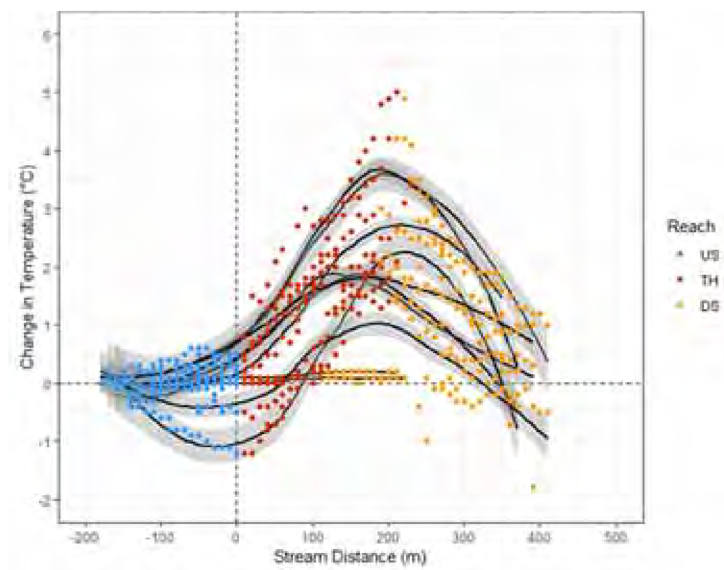
Understanding thermal responses at multiple spatial scales



Fausch et al. 2002







Acknowledgements

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- Funding Sources: OSU Department of Fisheries and Wildlife, USFS, USGS FRESC, Green Diamond, Save the Redwoods League
- Field technicians: Ashley Sanders, Morgan Turner, Thomas Starkey-Owens, Mary Carlquist, Kyle Smith, Jerika Wallace, Green Diamond Aquatics Program, HSU student volunteers

Questions?

Spatial-Temporal Patterns


East Fork Tectah_Pre-Treatment
East Fork Tectah_Post-Treatment
West Fork Tectah_Pre-Treatment
West Fork Tectah_Post-Treatment
Lost Man_Pre-Treatment
Lost Man_Post-Treatment
Upstream Position
Month
October November December January February March April May June July August September
degreedays
400
300
200


East Fork Tectah_Pre-Treatment
East Fork Tectah_Post-Treatment
West Fork Tectah_Pre-Treatment
West Fork Tectah_Post-Treatment
Lost Man_Pre-Treatment
Lost Man_Post-Treatment
Upstream Position
Month
October
November
December
January
February
March
April
May
June
July
August
September
MWMT
18
15
12
9

Linking Temperature and Discharge to Expressed Behavior of Fishes; Implications for Climate Change

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**Oregon State University
*** University of California at Merced
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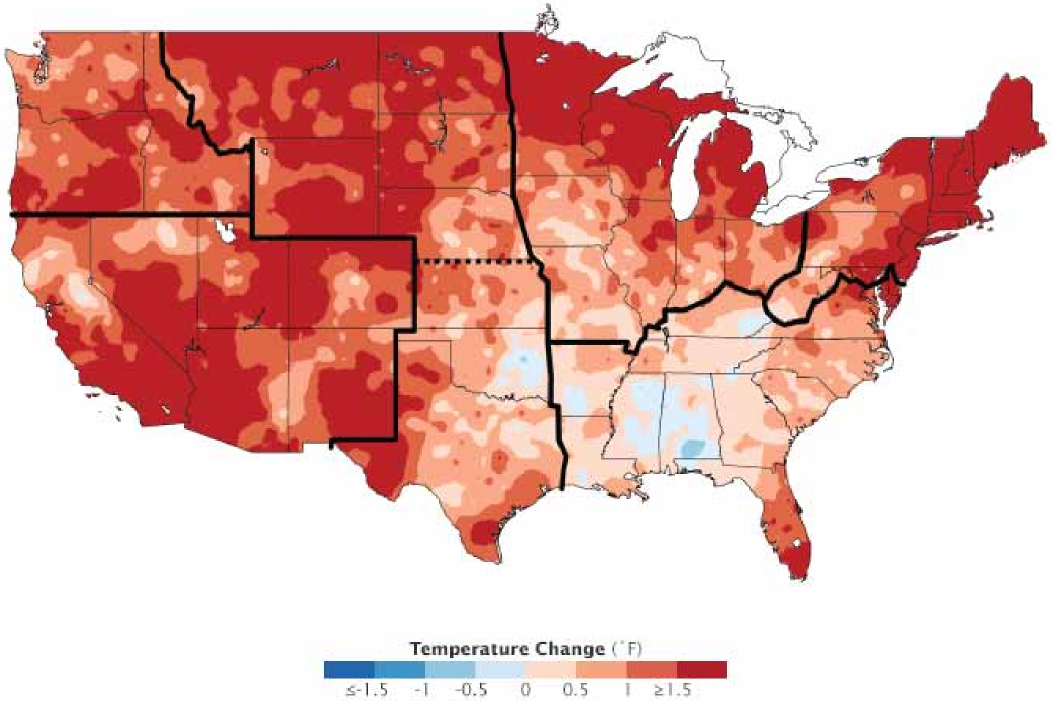
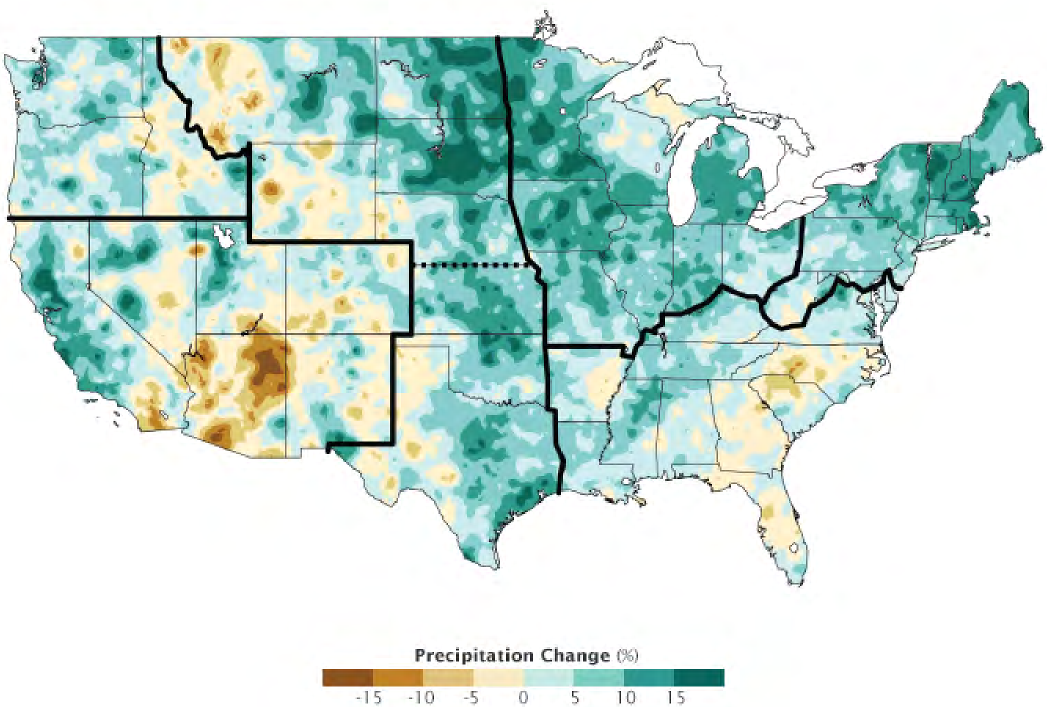
How will climate influence resilience of Pacific salmon?

Pacific salmon are broadly distributed in freshwaters connected to the North Pacific and Arctic Oceans. Their life cycle requires migration between freshwater and marine environments.

Changes in Temperature and Precipitation are wide-spread in the U.S.





Changes: 1901-1960 to 1991-2012

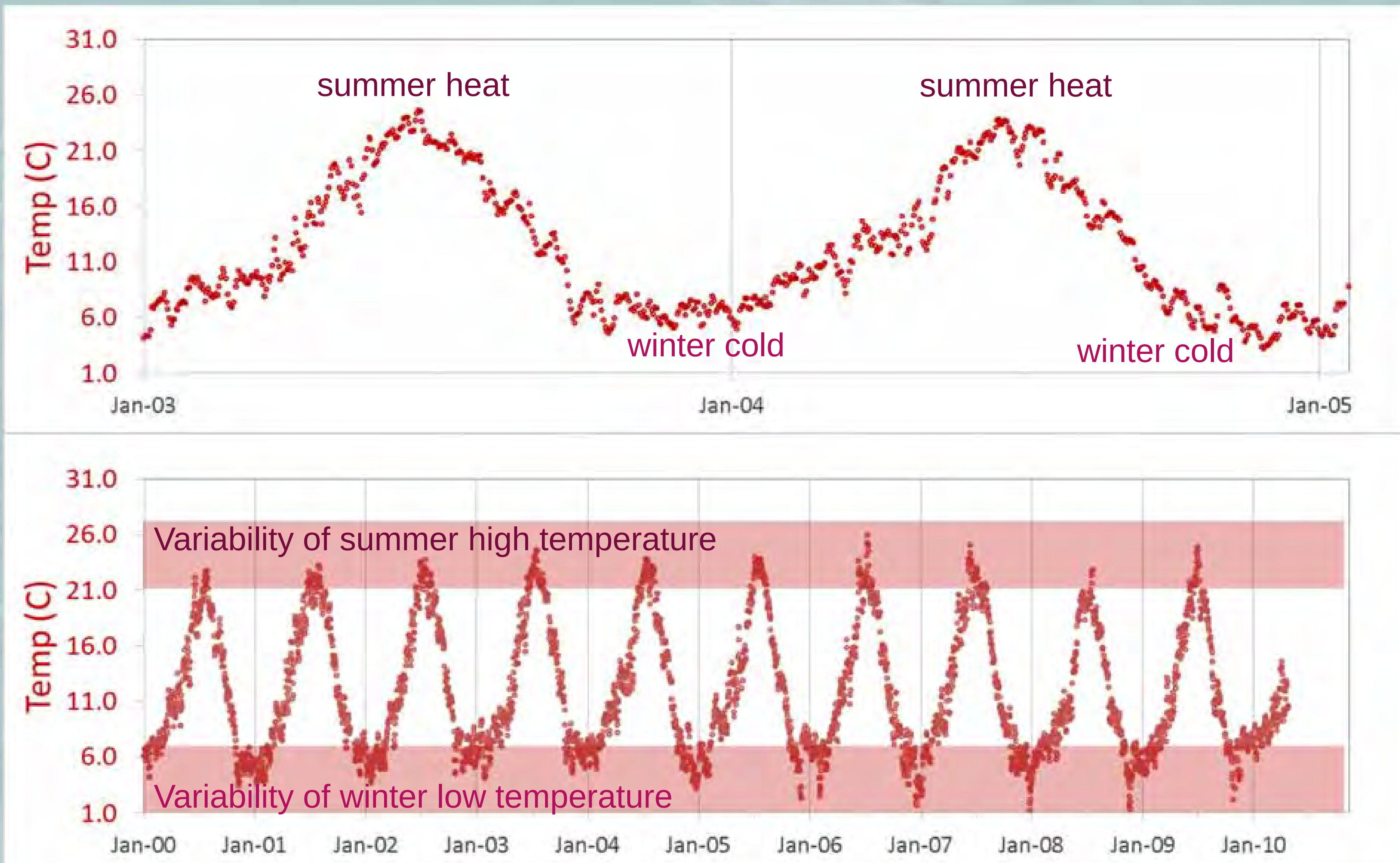
US Climate Change Research Report 2014

Phenology is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate as well as habitat.

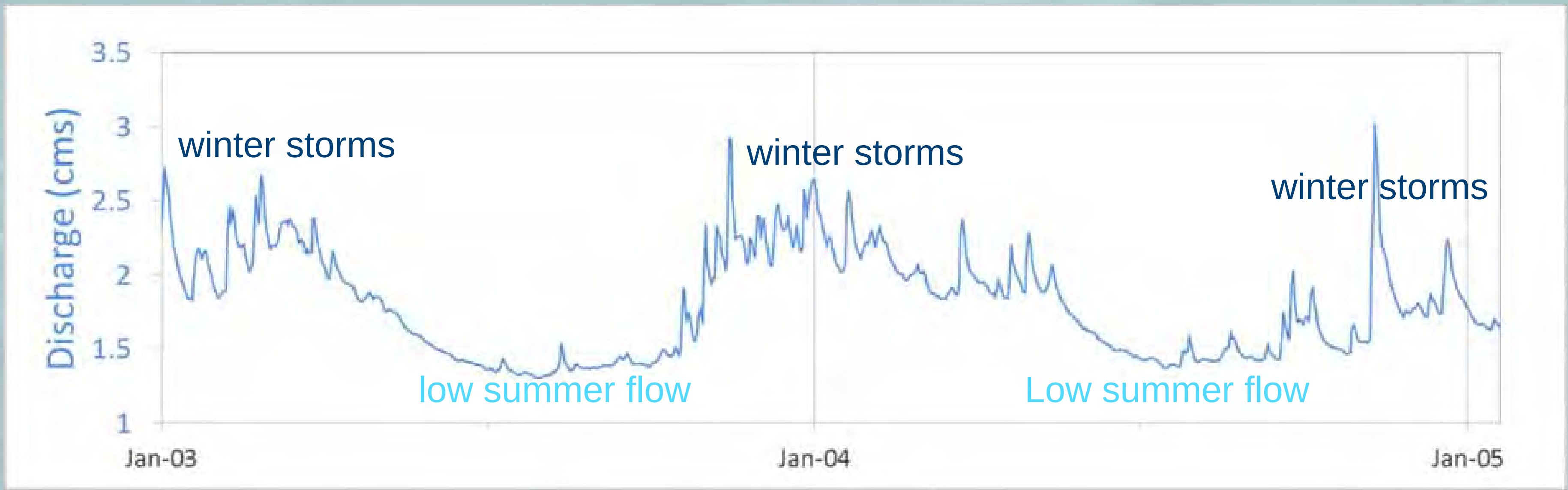
- Precipitation
- Temperature
- Flow
- Salinity
- Sediment
- Food sources

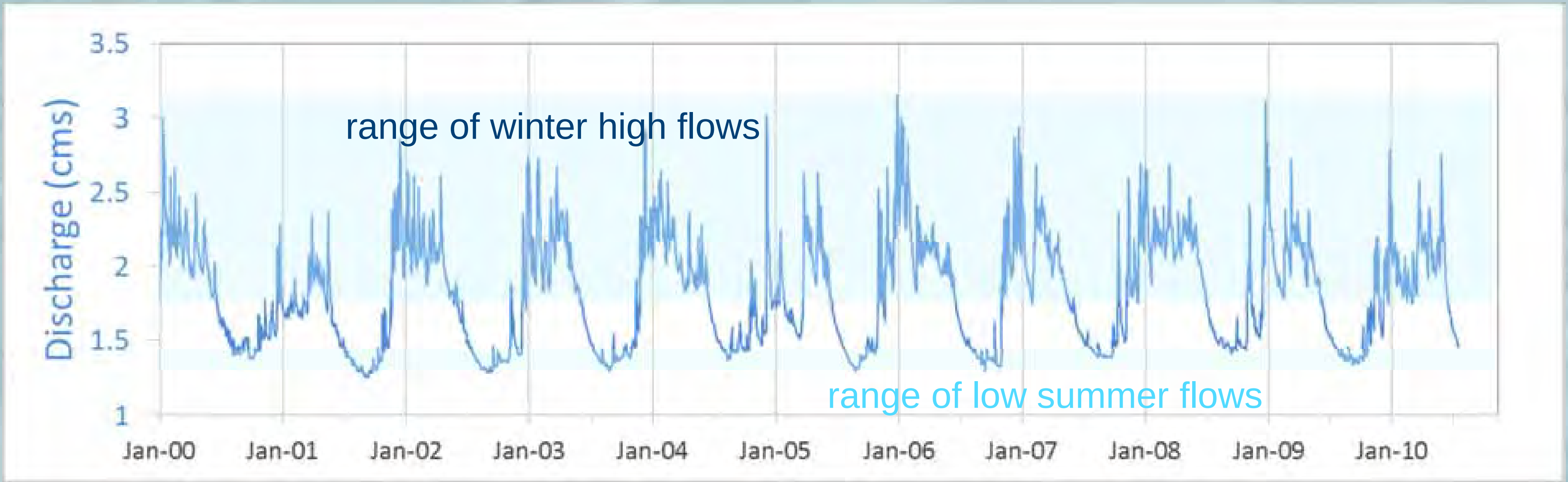
Source: FCS Phenology Field Guide

Native aquatic species are adapted to seasonal and inter-annual patterns in water temperature

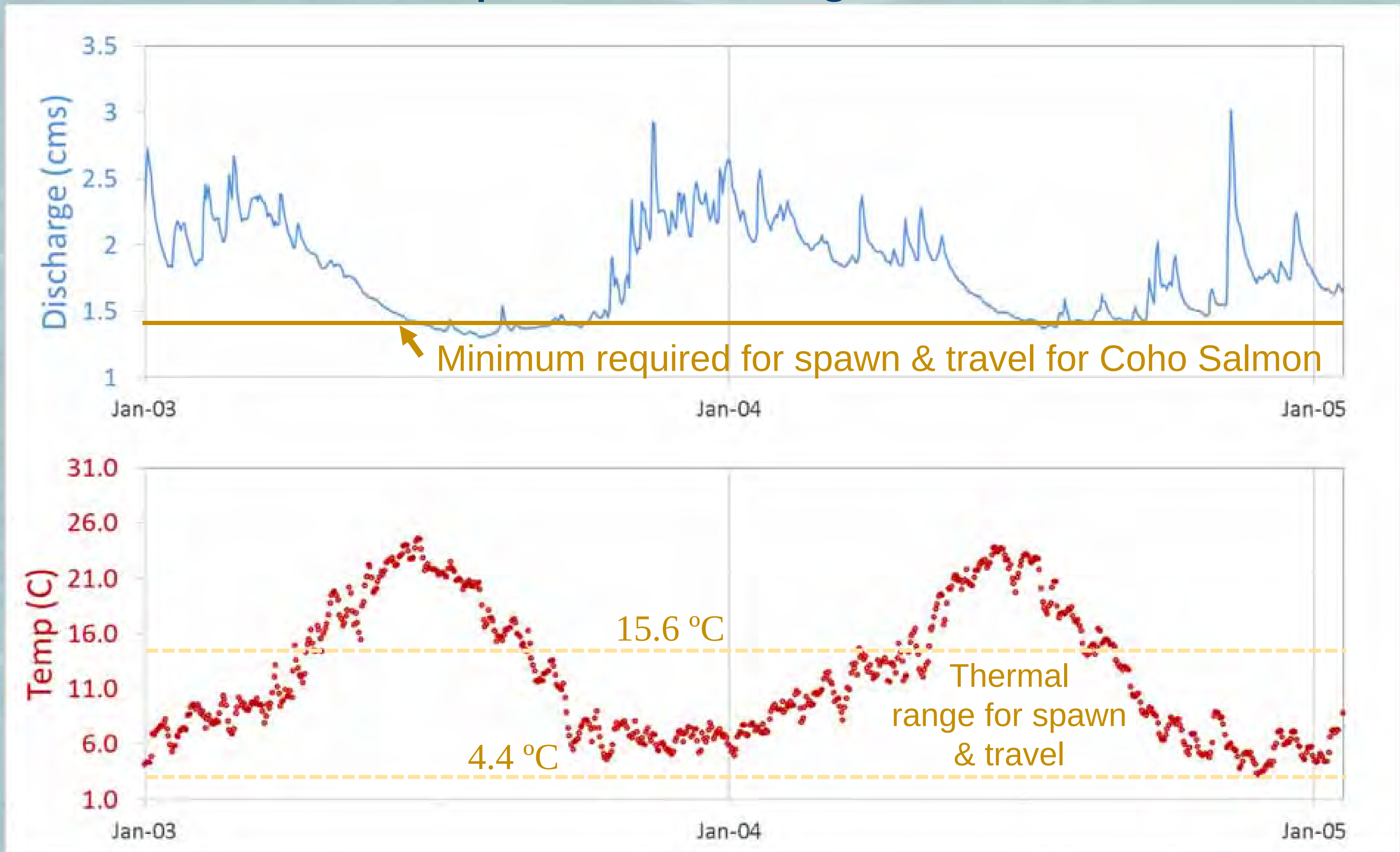


Seasonal and inter-annual patterns in streamflow (discharge) frame important environmental conditions



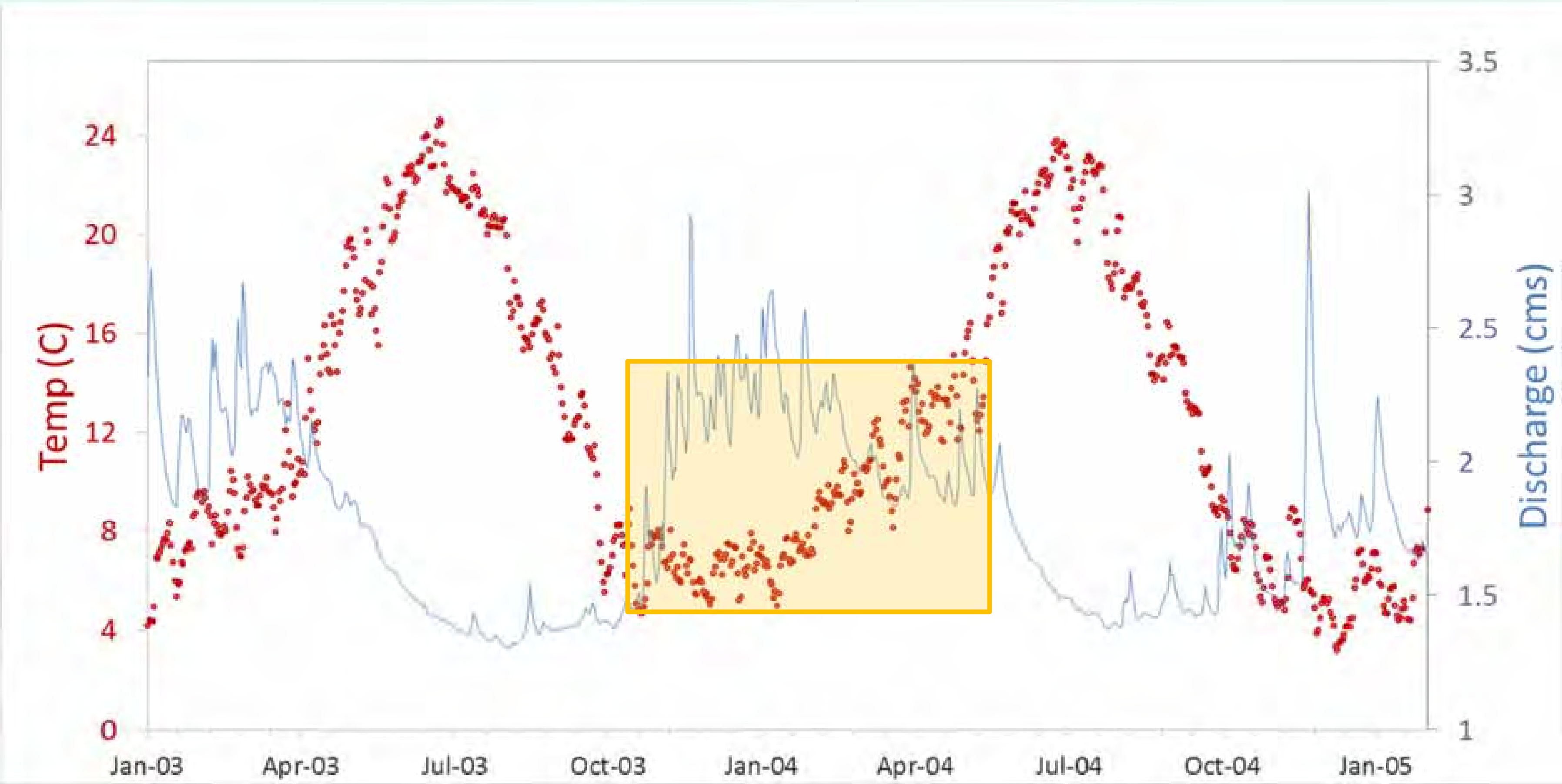


Temperature and discharge create conditions for specific life stage events



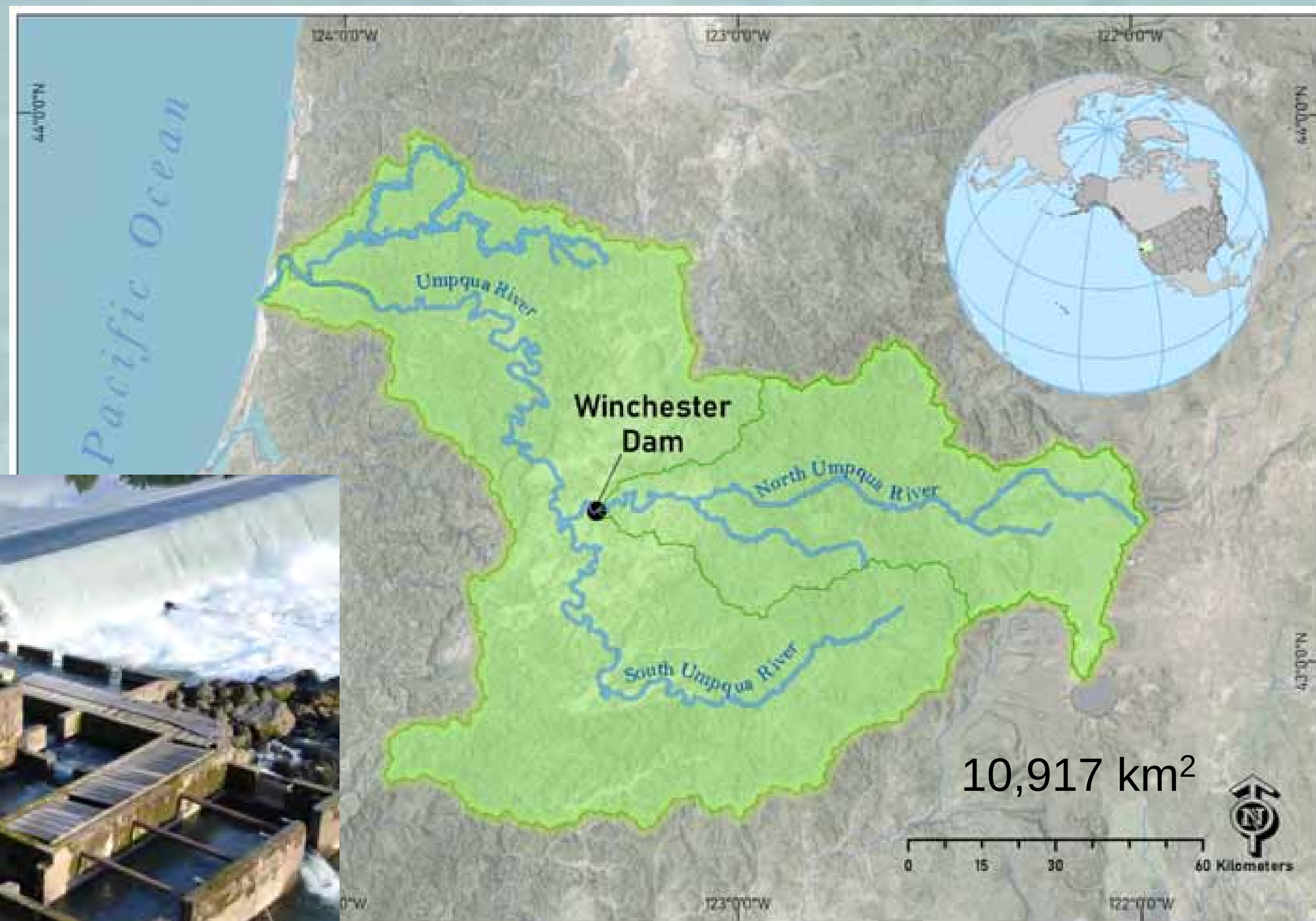
Physical thresholds for metabolism can be placed within the seasonal framework of temperature and discharge.

Temperature and discharge as combined selection forces



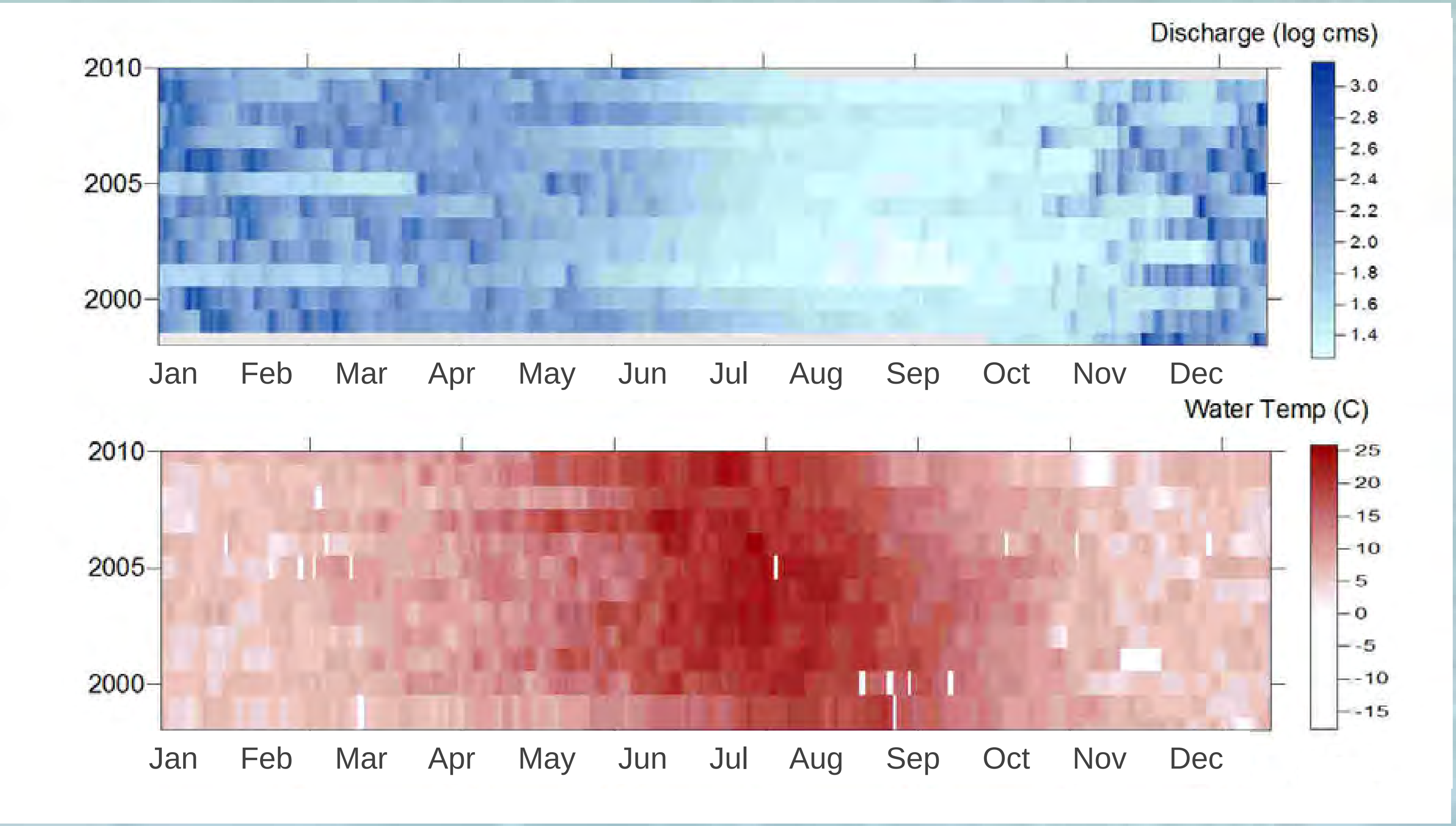
Adaptation to hydrologic conditions is demonstrated by behavioral variation present within a population.

Long-term census datasets provide critical information about adaptation to environmental conditions



Fish counts at Winchester Dam on the North Umpqua River, Oregon, USA, provide important information about the community of fishes at this location.

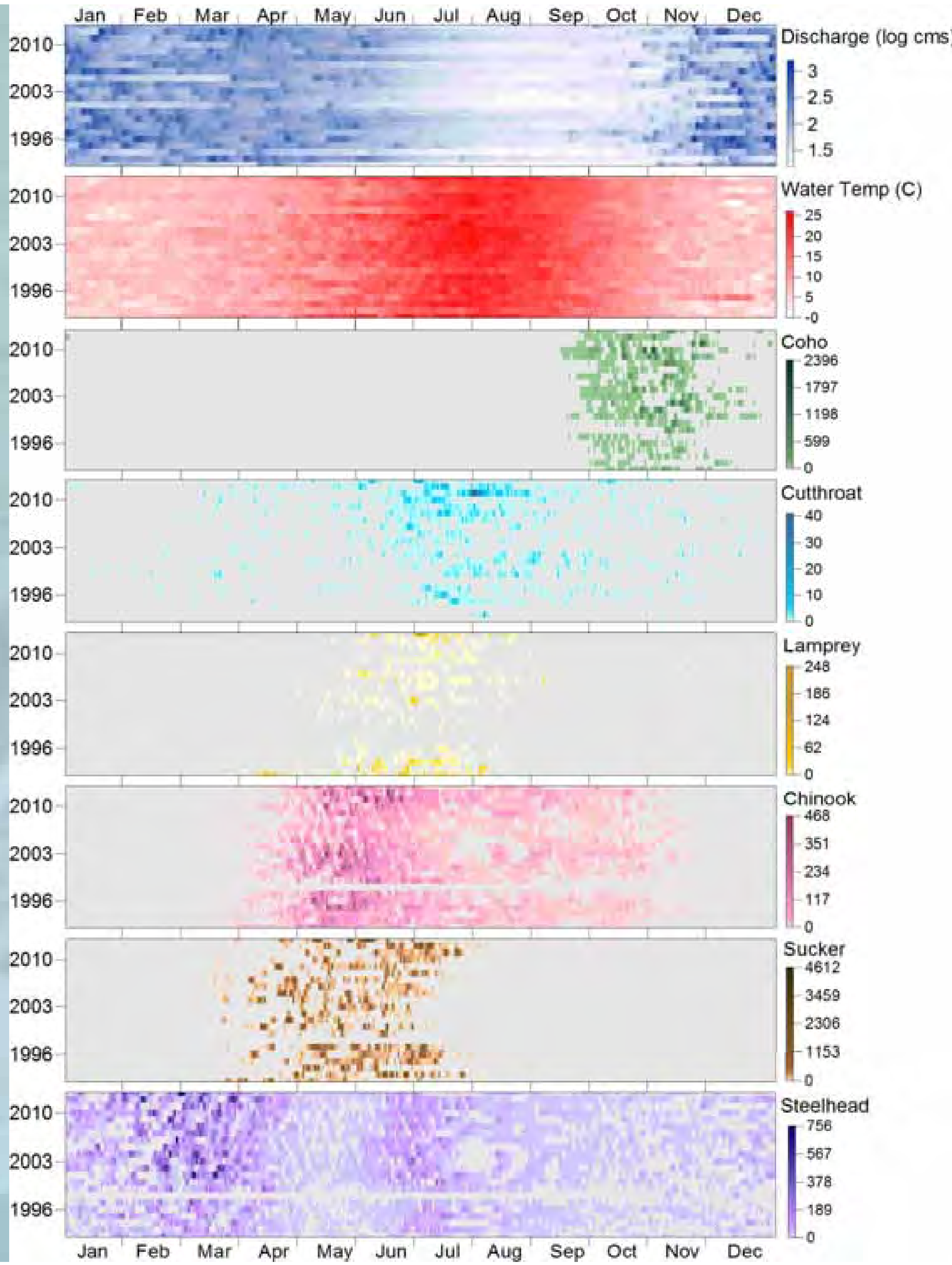
Seasonal and inter-annual patterns in streamflow and temperature can be visualized using a raster-based graphic.



Upriver Fish Migrations

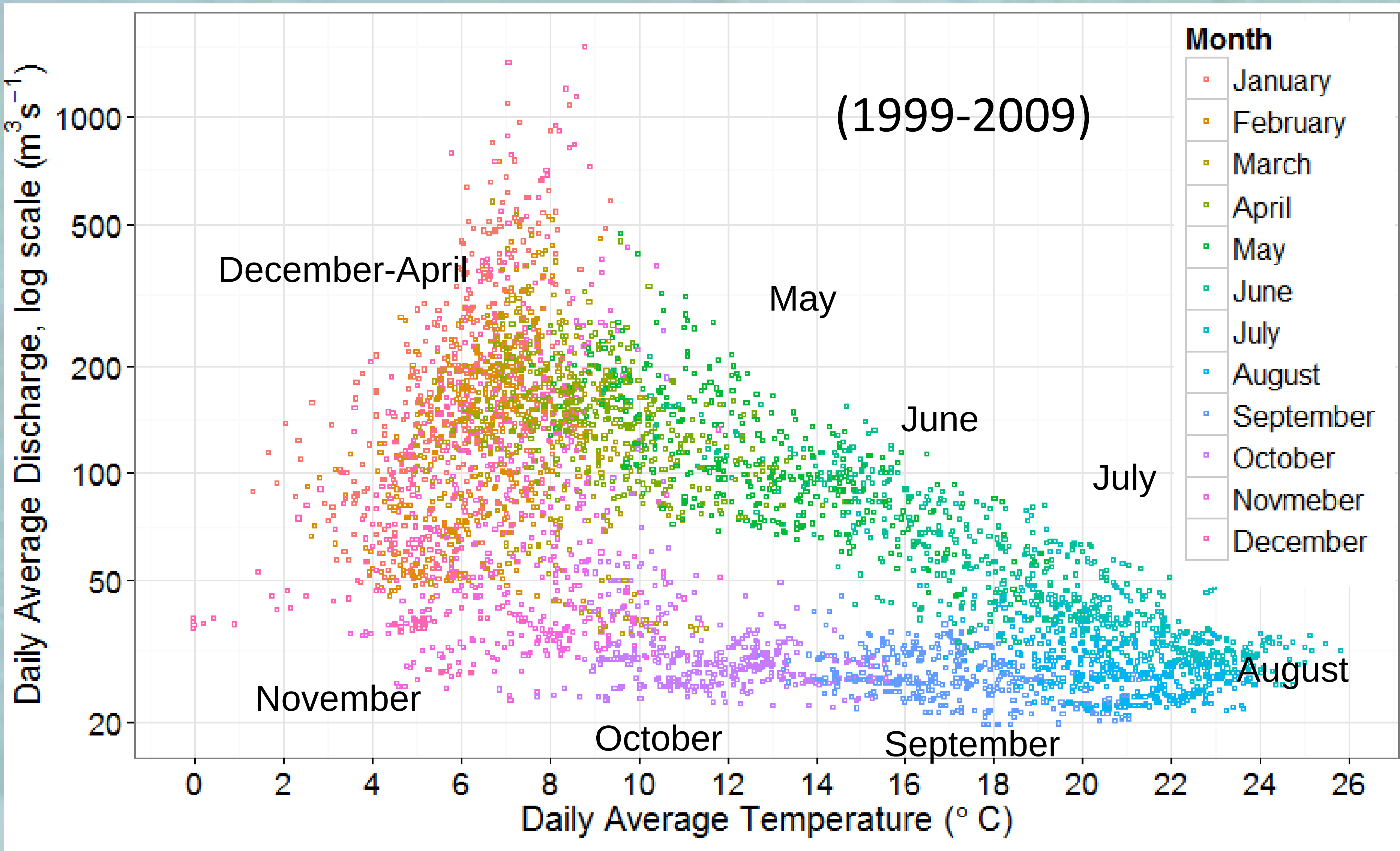
Winchester Dam 1992-2013

Diversity among and within fishes on the North Umpqua River indicates times of vulnerability to flow conditions at Winchester Dam.



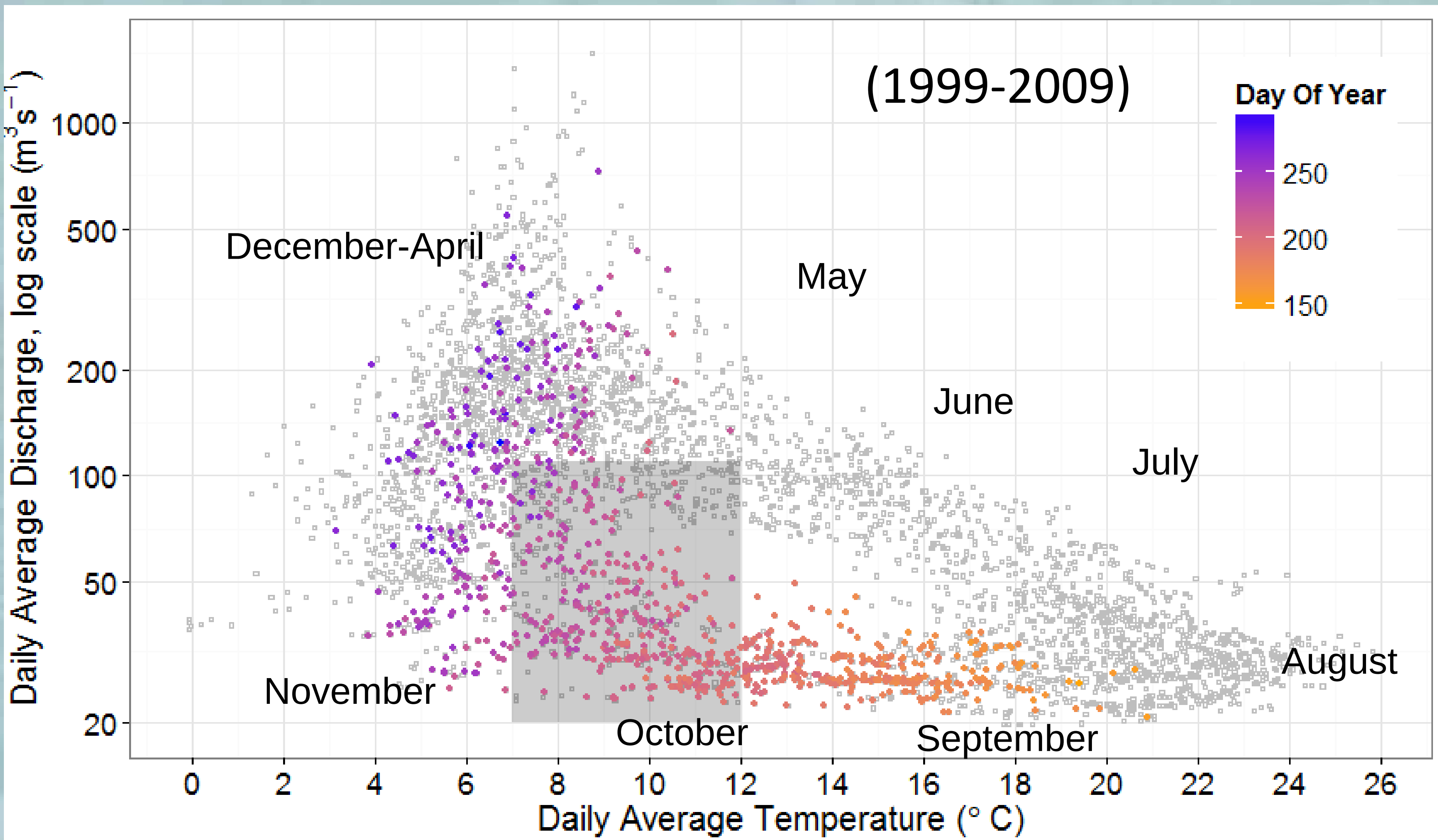
(Sensu Flitcroft et al. 2016)

Daily Discharge and Temperature Create a Cyclical and Predictable pattern of Annual Temperature



Lovellford 2013

Mainstem Migration: discharge and temperature frame ideal season for migration

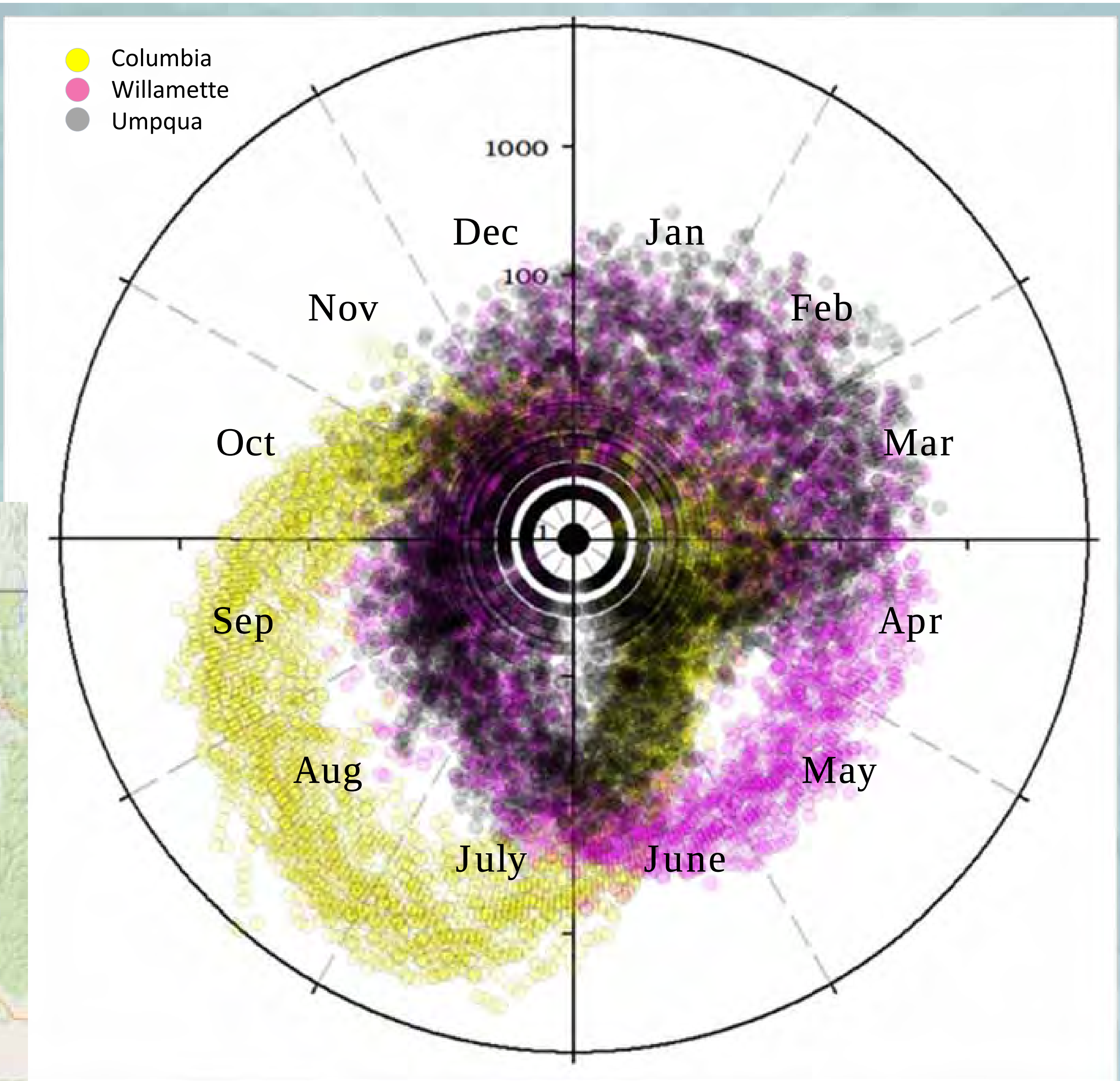


Long-term census datasets at hydroelectric facilities can reveal expressed behavior of fishes

>10 years of continuous data

Comparisons of run timing by different migratory fishes across this broad geographic range indicated patterns of synchrony, and variability.

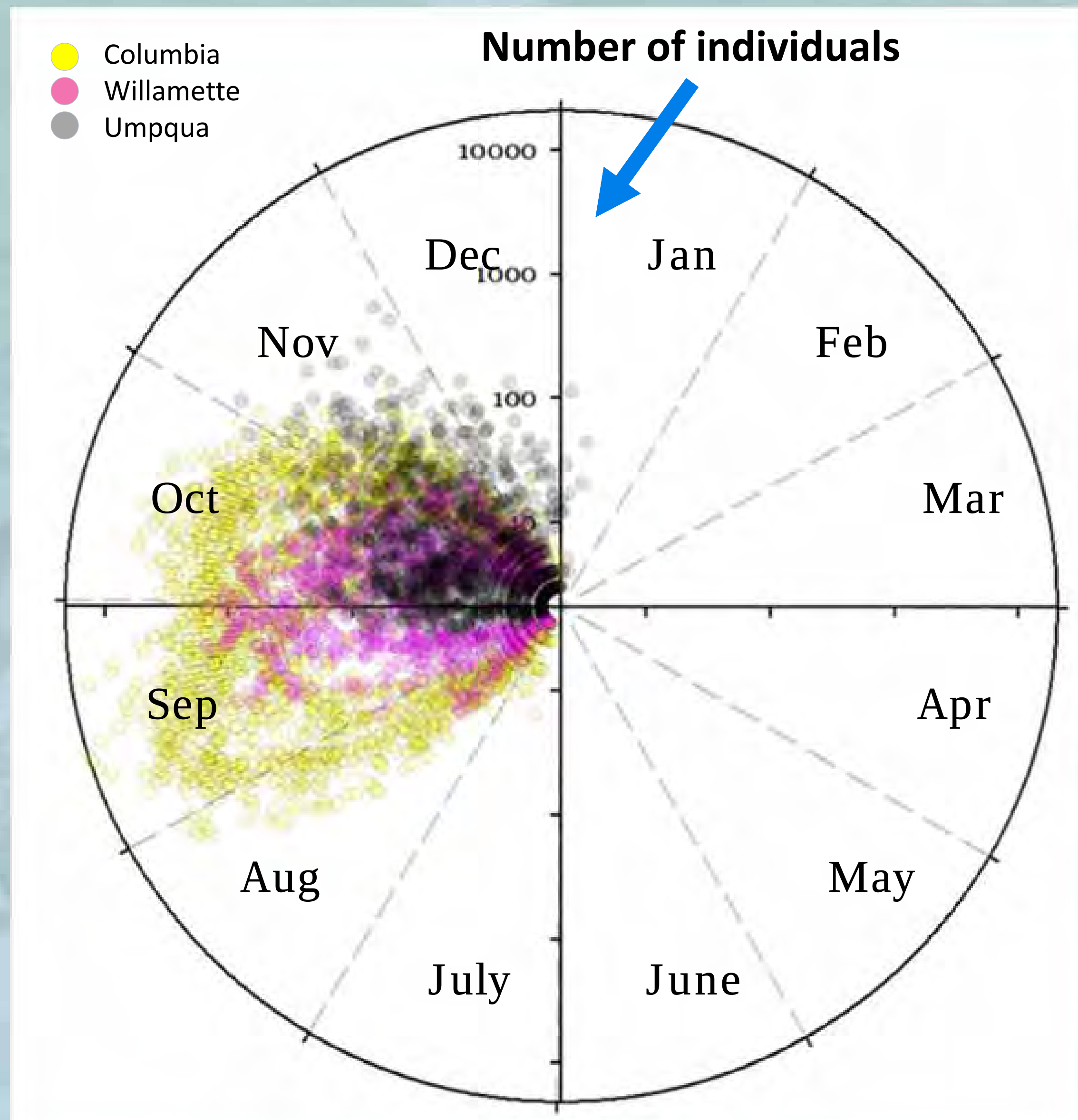
Steelhead Trout

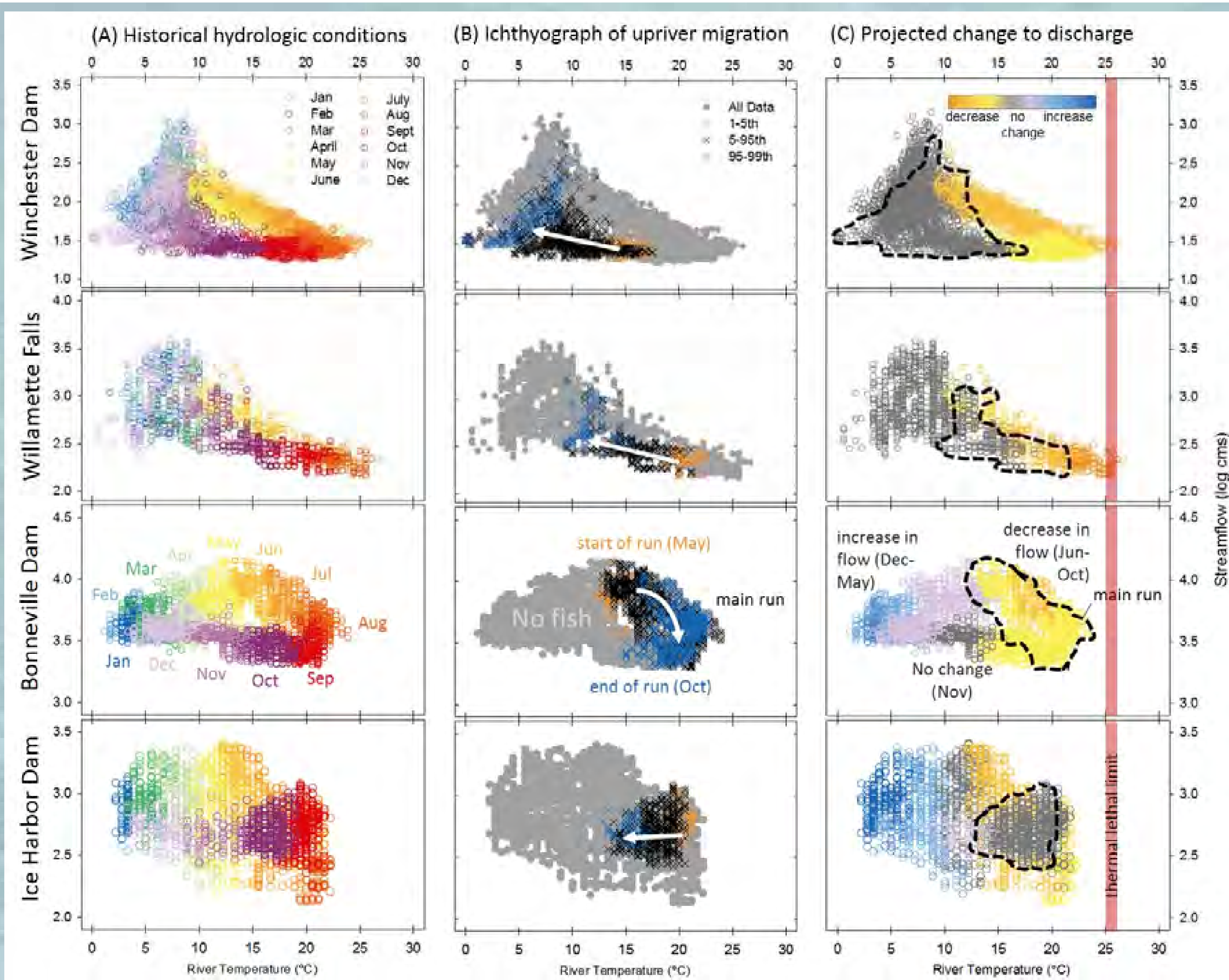


Steelhead counts at Willamette falls include both hatchery and wild fish.

Coho Salmon


Vancouver
Seattle
WASHINGTON
Portland
Columbia
Willamette
OREGON
Umpqua


Columbia
Willamette
Umpqua
Number of individuals
10000
1000
100
10
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec



Flitcroft et al. 2018

In Summary

- Adaptation to predictable patterns of temperature and discharge are influenced by local condition (i.e. location within a stream network) and broad scales of process (i.e. latitude).
- Future climate change may cause complex effects for aquatic species that will vary by location.
- Hydro management may have an opportunity to play a role in better understanding local species adaptation to environmental conditions, and possibly mediate for climate change effects through flow and temperature regulation.

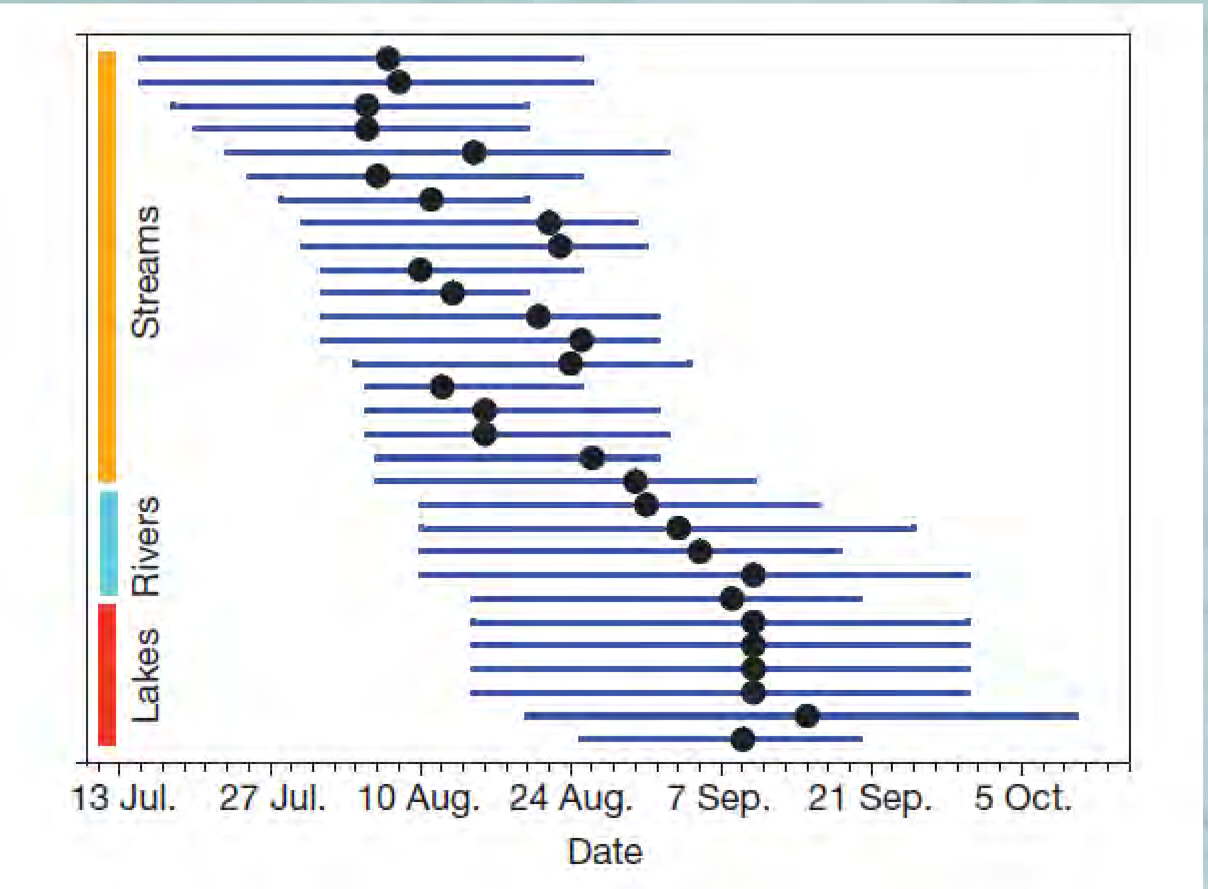
Acknowledgements

- Oregon State University, Engineering Department
- ODFW – Roseburg District office
- Army Corp of Engineers

- Laura Jackson
- Fabian Carr
- Holly Huchko
- Tom Ditterich
- Scott Jordan


Thank you!

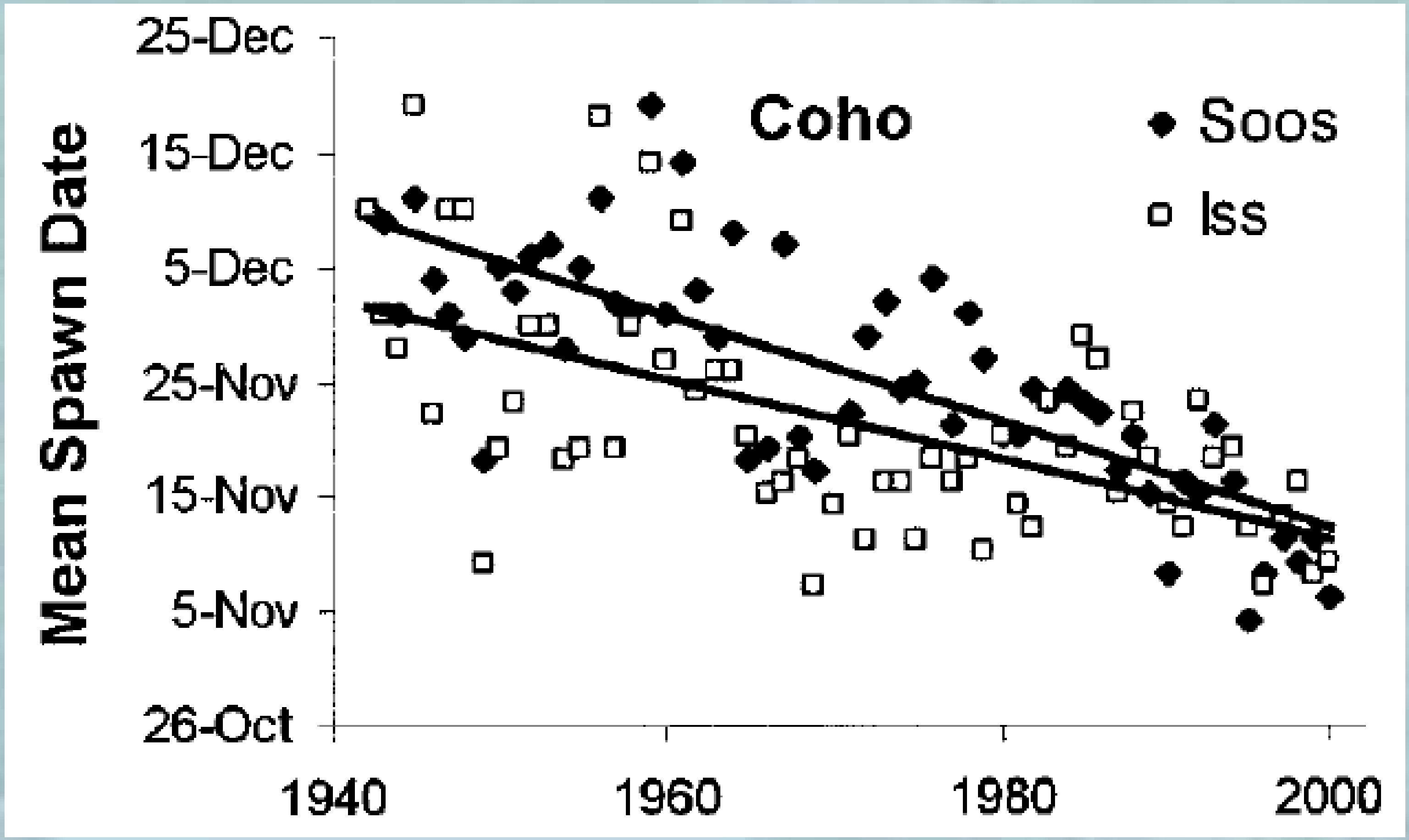
Expressed variability of behavior can be captured in a species-specific "Portfolio"



Spawning timing and occupancy of different types of habitats by sockeye salmon in the Wood River system, Alaska, USA, indicate differentiation by type and broad thermal variability.

Schindler et al. 2010

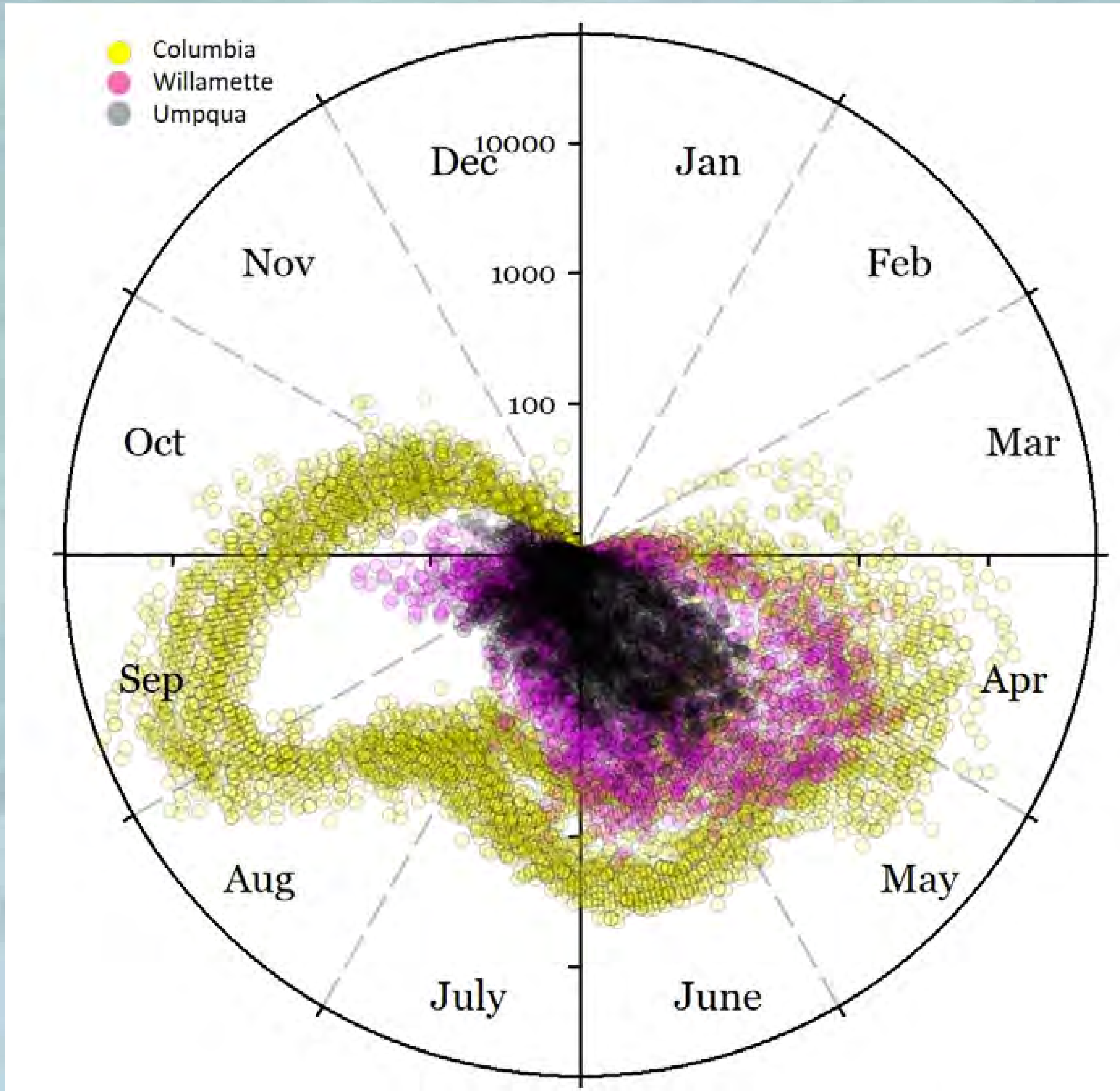
For salmon, spawn return timing is strongly heritable



For returning Coho Salmon, hatchery practices that spawned early returning fish exerted selection pressure resulting in a run of fishes with less variability in return time, and an earlier run.

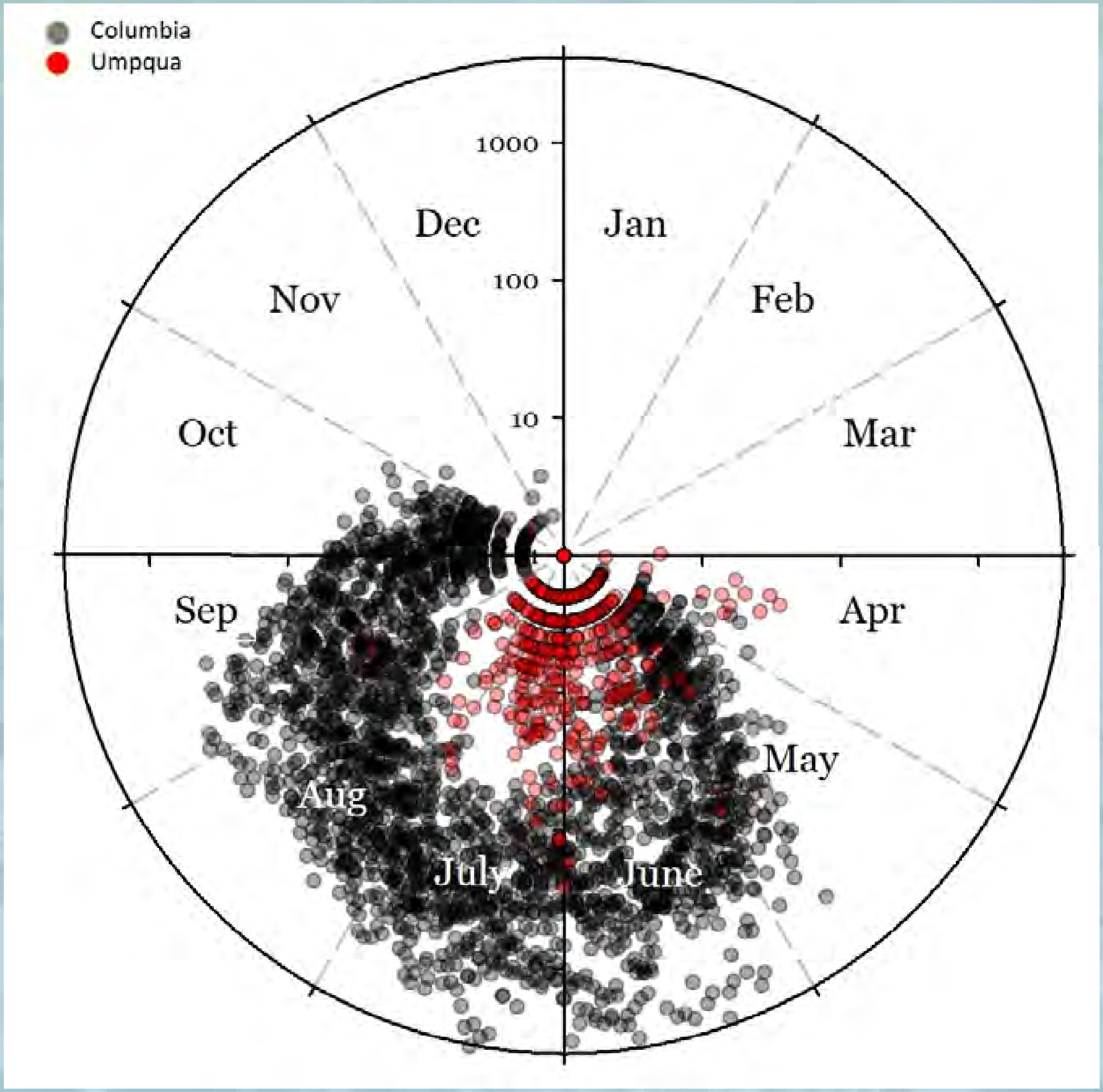
Quinn 2002

Chinook Salmon

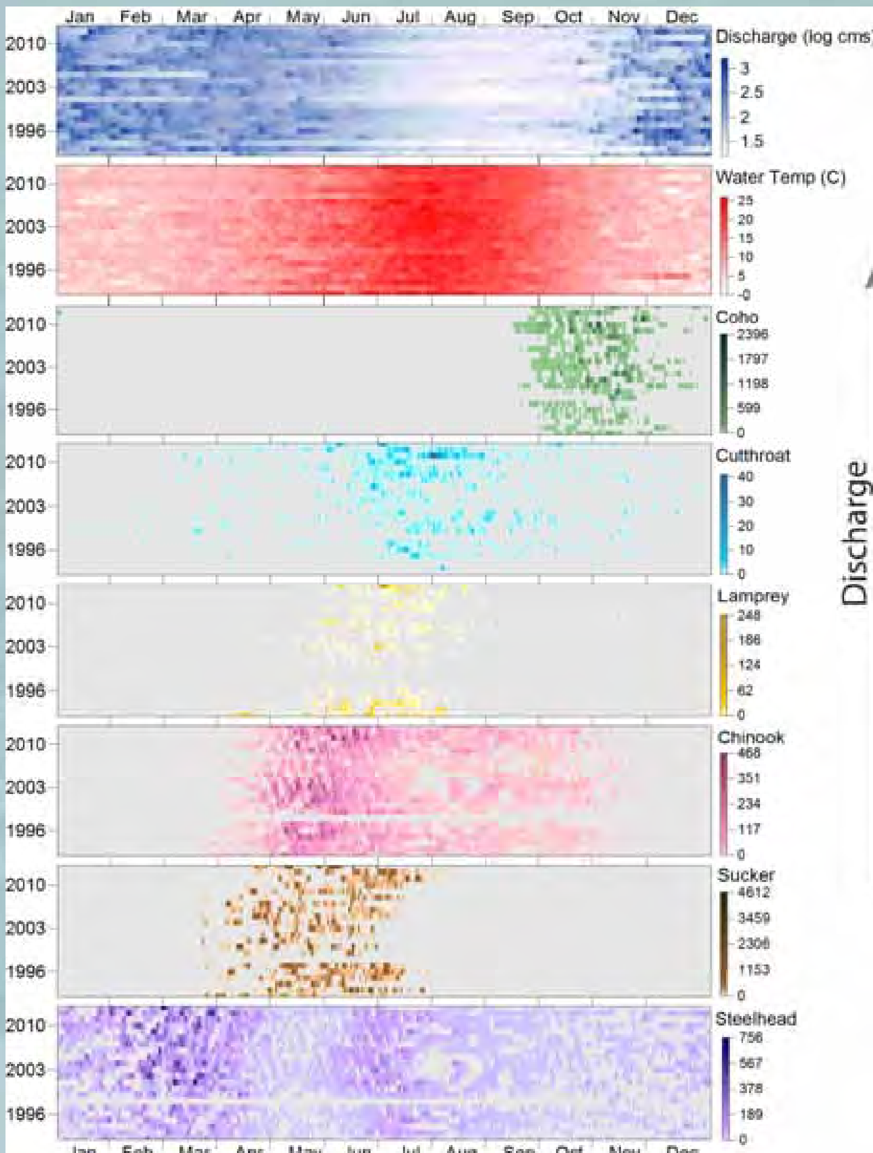


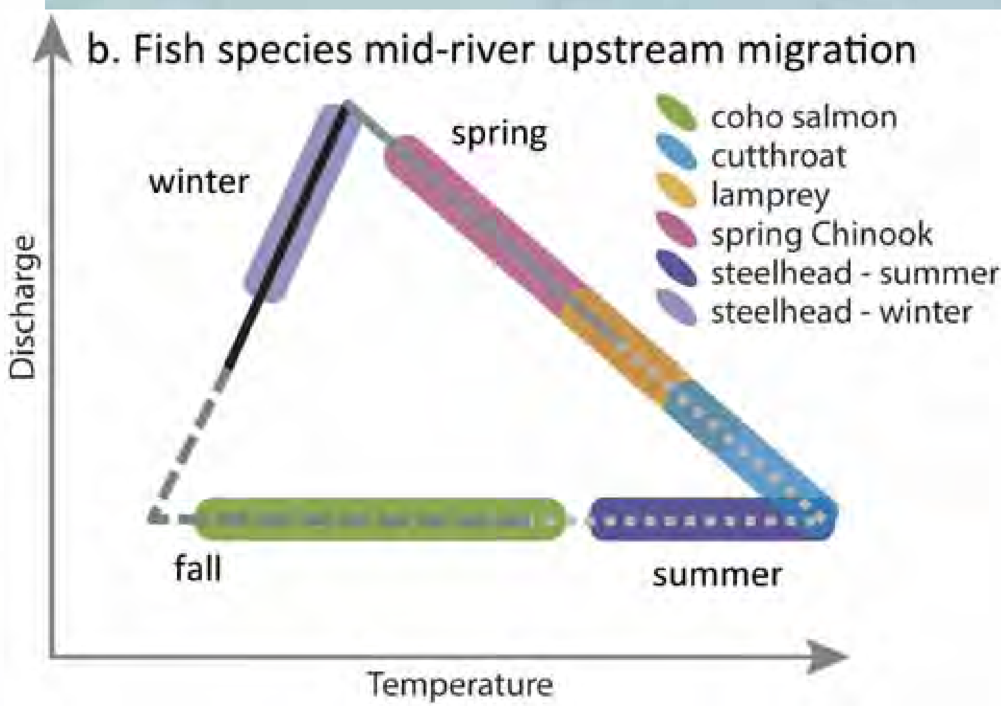
February through July – Spring Chinook or Stream Type
July through December – Fall Chinook or Ocean Type Healey (1991)

Pacific Lamprey



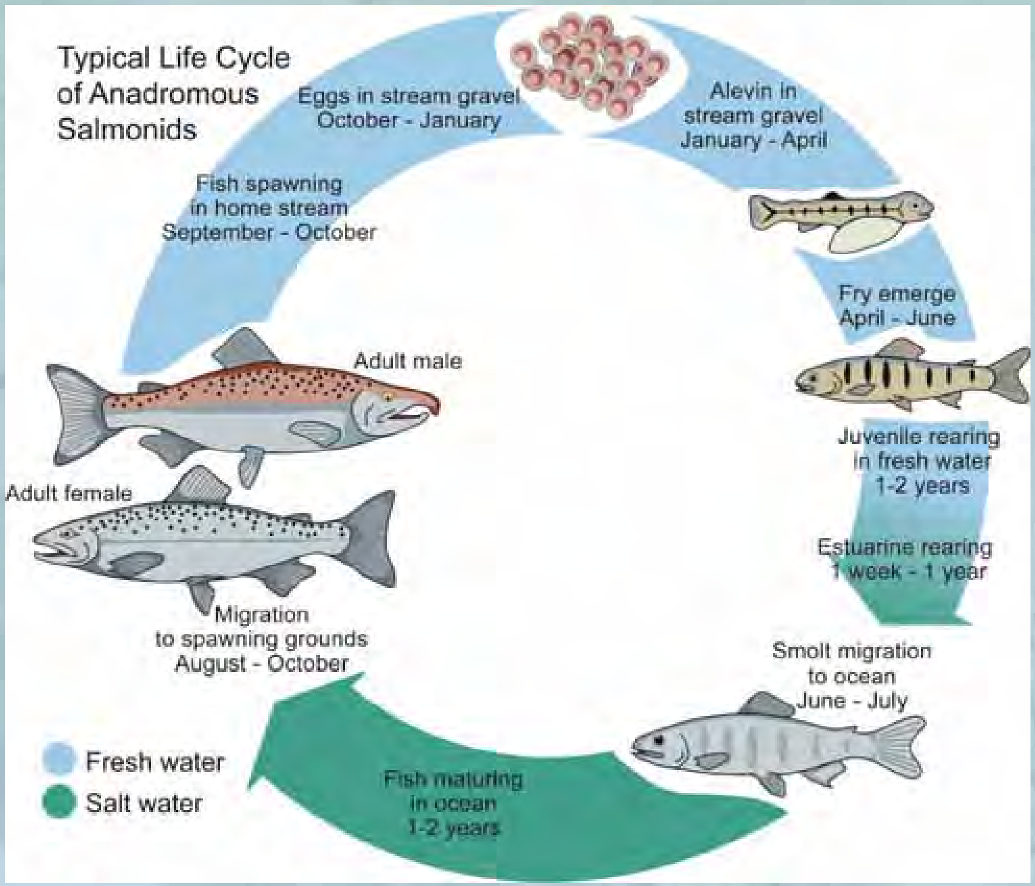
Ichthyographs summarize patterns of temperature and discharge related to life histories of native fishes



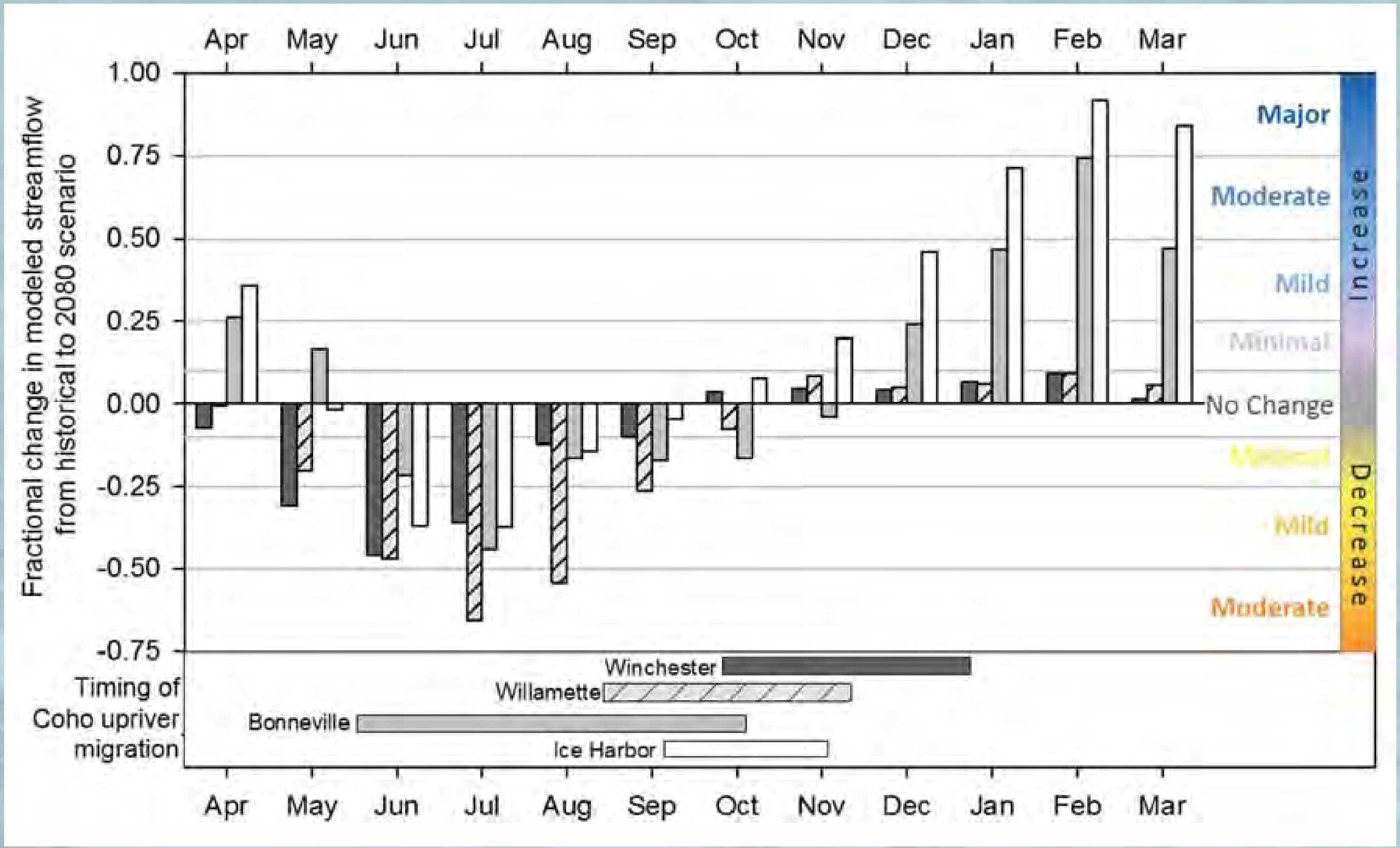


Flitcroft et al. 2016

Single-species ichthyographs across a diversity of hydrologies and modeled future climate



Timing of fish use, and predicted changes in discharge and temperature, vary by location for Coho Salmon



Flitcroft et al. 2018

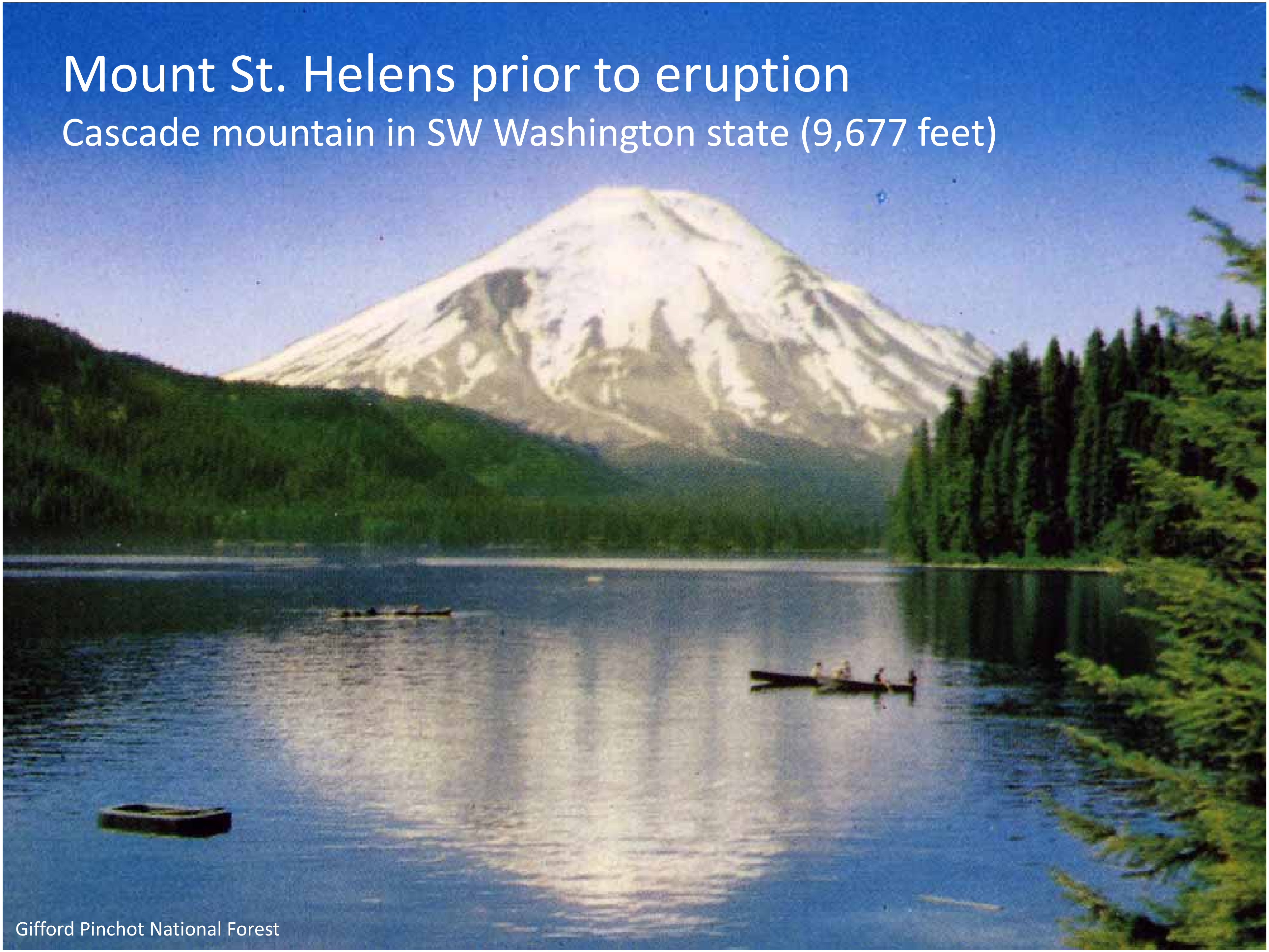
Vulnerability of Coho Salmon to predicted changes in hydrology varies by location and may be influenced by river management.

Stream community assembly 36 years after the catastrophic eruption of Mount St. Helens

Shannon Claeson (FS-PNW Research),
Carri LeRoy (Evergreen State College),
Rosalina Stancheva (CA State Univ. San Marcos)

Mount St. Helens prior to eruption

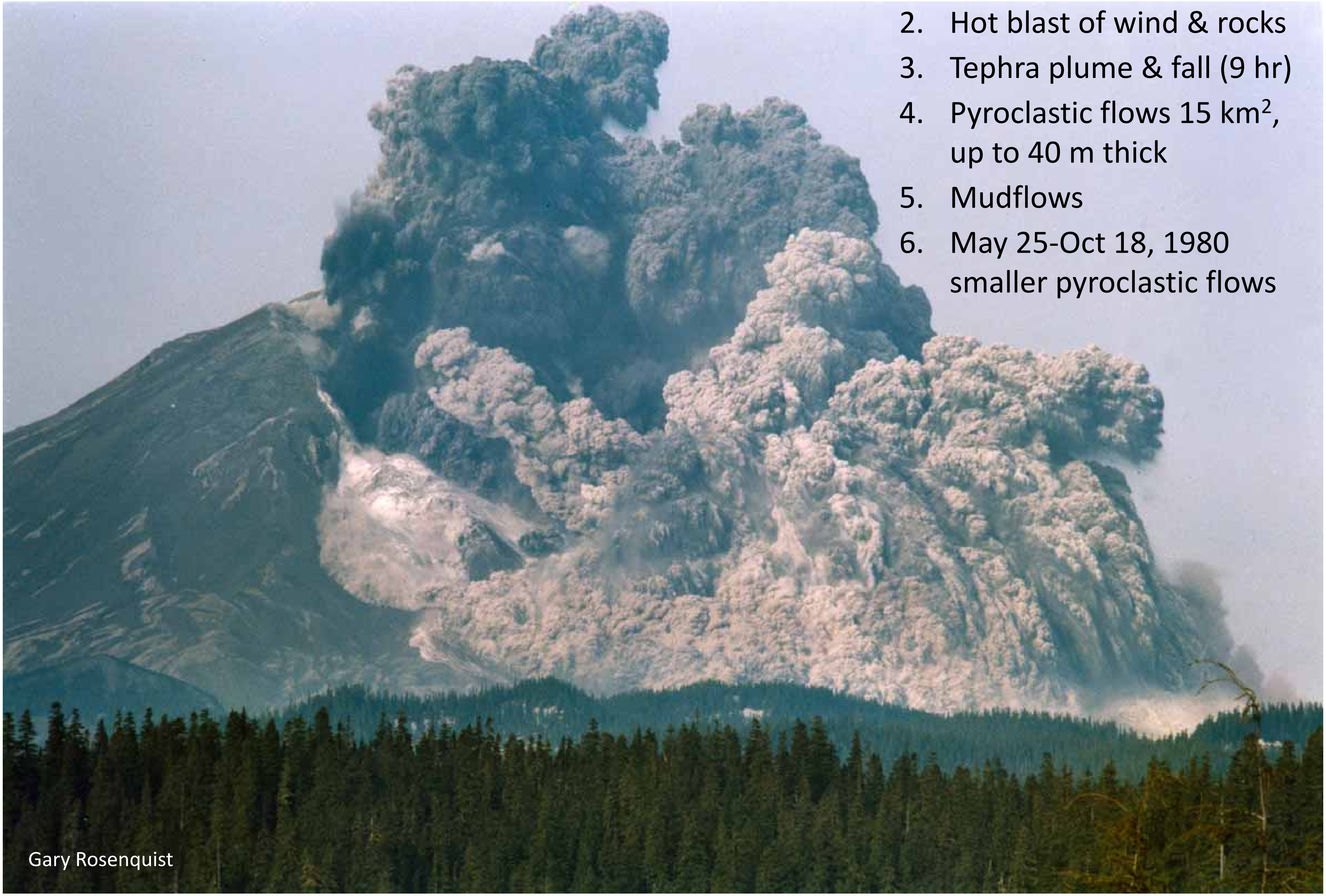
Cascade mountain in SW Washington state (9,677 feet)



Gifford Pinchot National Forest

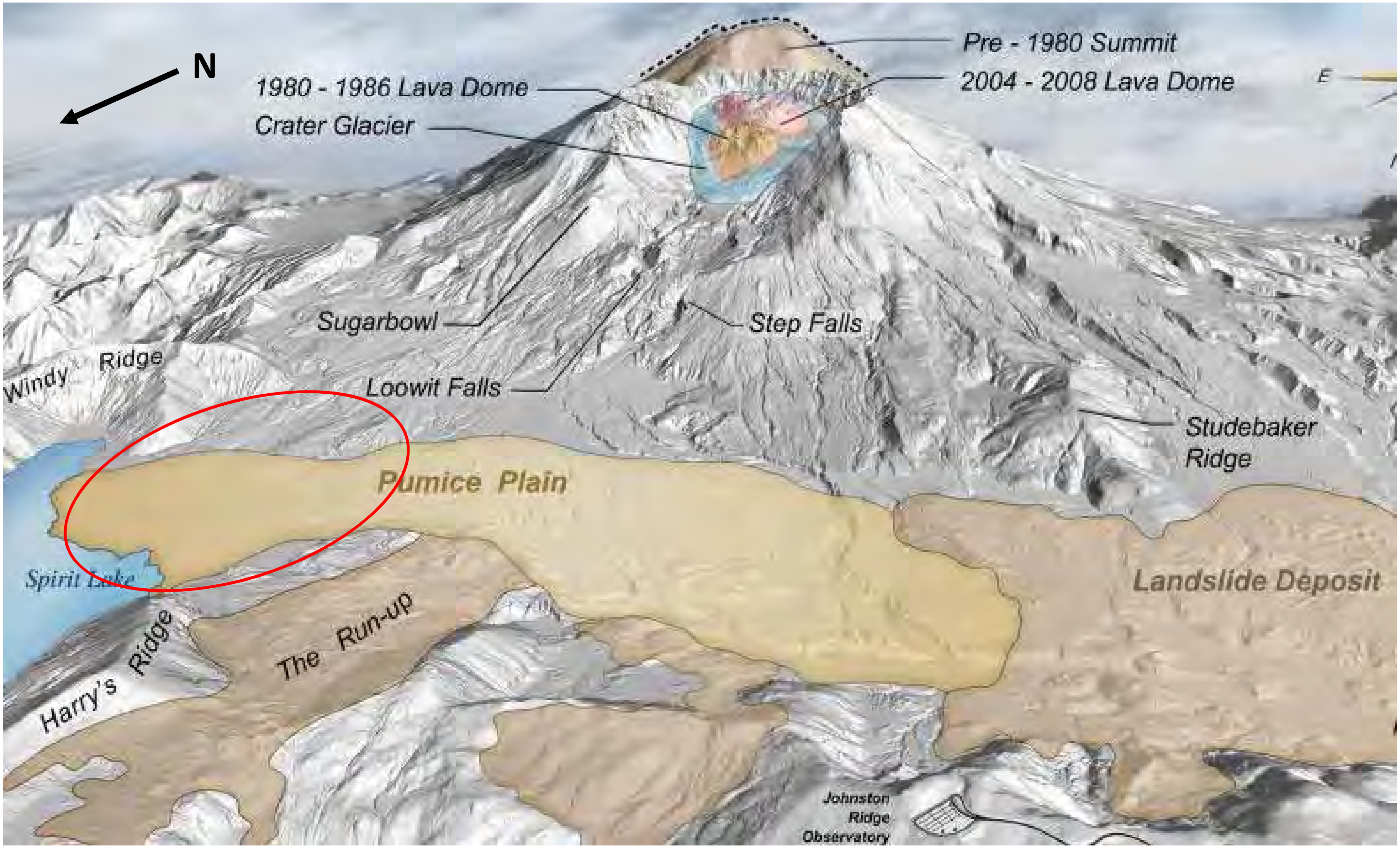
Eruption on May 18, 1980 at 8:32 am

1. Debris avalanche 60 km^2, 10-195 m thick
2. Hot blast of wind & rocks
3. Tephra plume & fall (9 hr)
4. Pyroclastic flows 15 km^2, up to 40 m thick
5. Mudflows
6. May 25-Oct 18, 1980 smaller pyroclastic flows



Pumice Plain – most disturbed area

(debris avalanche, hot blast, tephra fall, pyroclastic flows, mudflows)



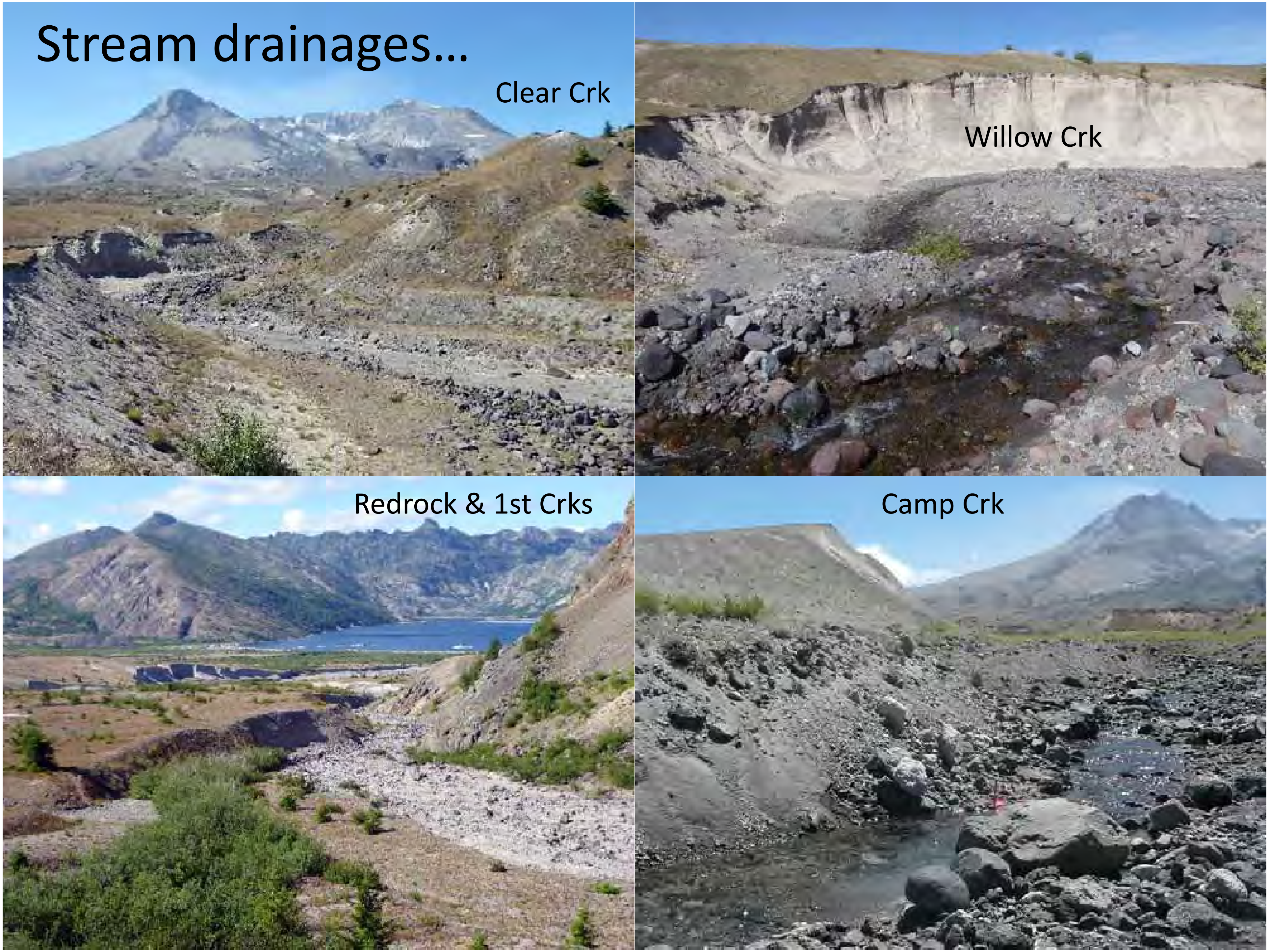
Pumice Plain just after eruption (1980)

Spirit Lake the day after eruption (1980)

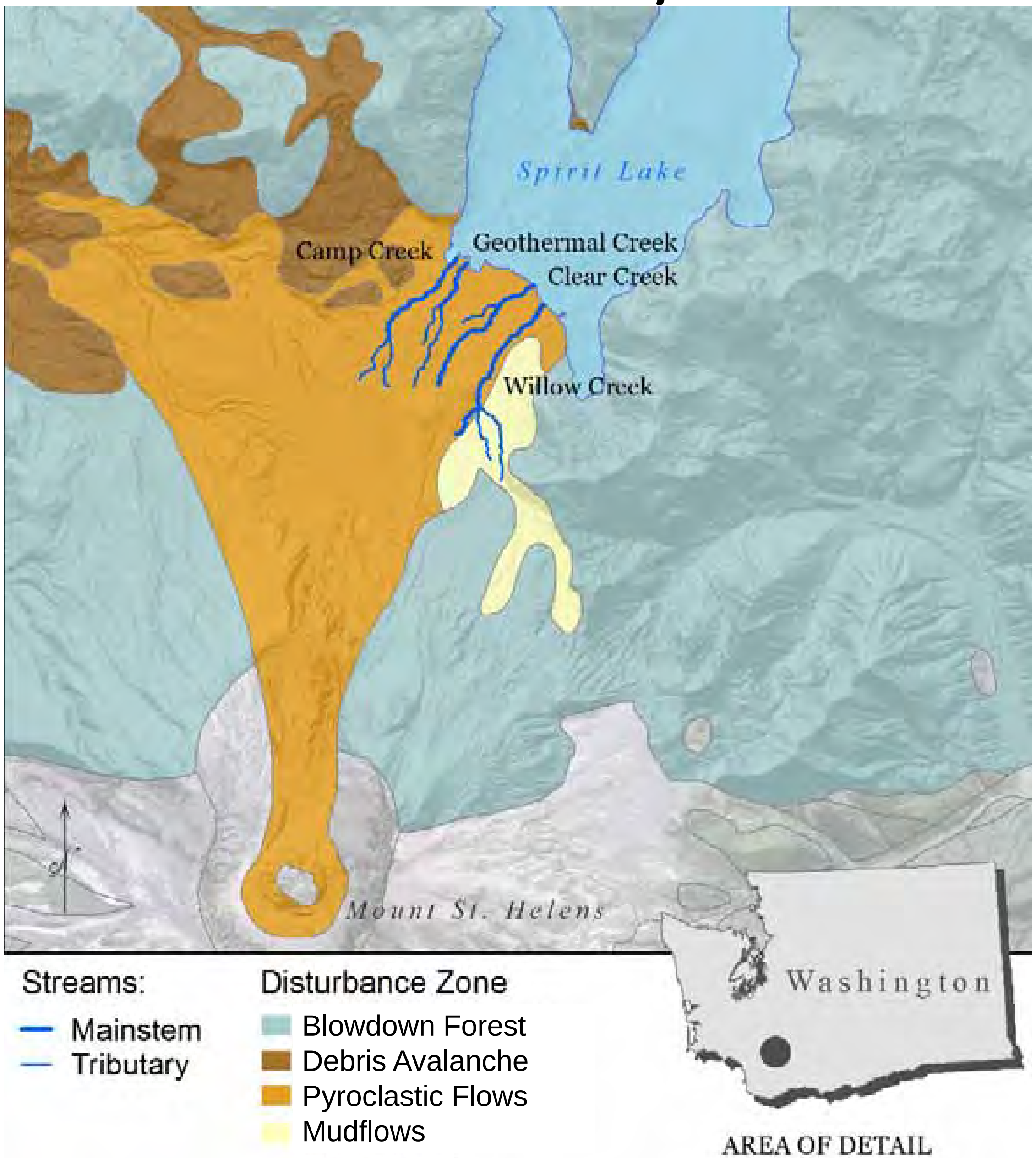
- Lake level raised 64 m
- Covered with downed logs
- Surface area nearly doubled to 10 km^2
- 85°C, anoxic, methanotrophic for 2 yrs


Mount St. Helens today (8,365 feet)
Shannon Claeson - May 9, 2019

Pumice Plain and Spirit Lake today…


Stream drainages…
Clear Crk
Willow Crk
Redrock & 1st Crks
Camp Crk

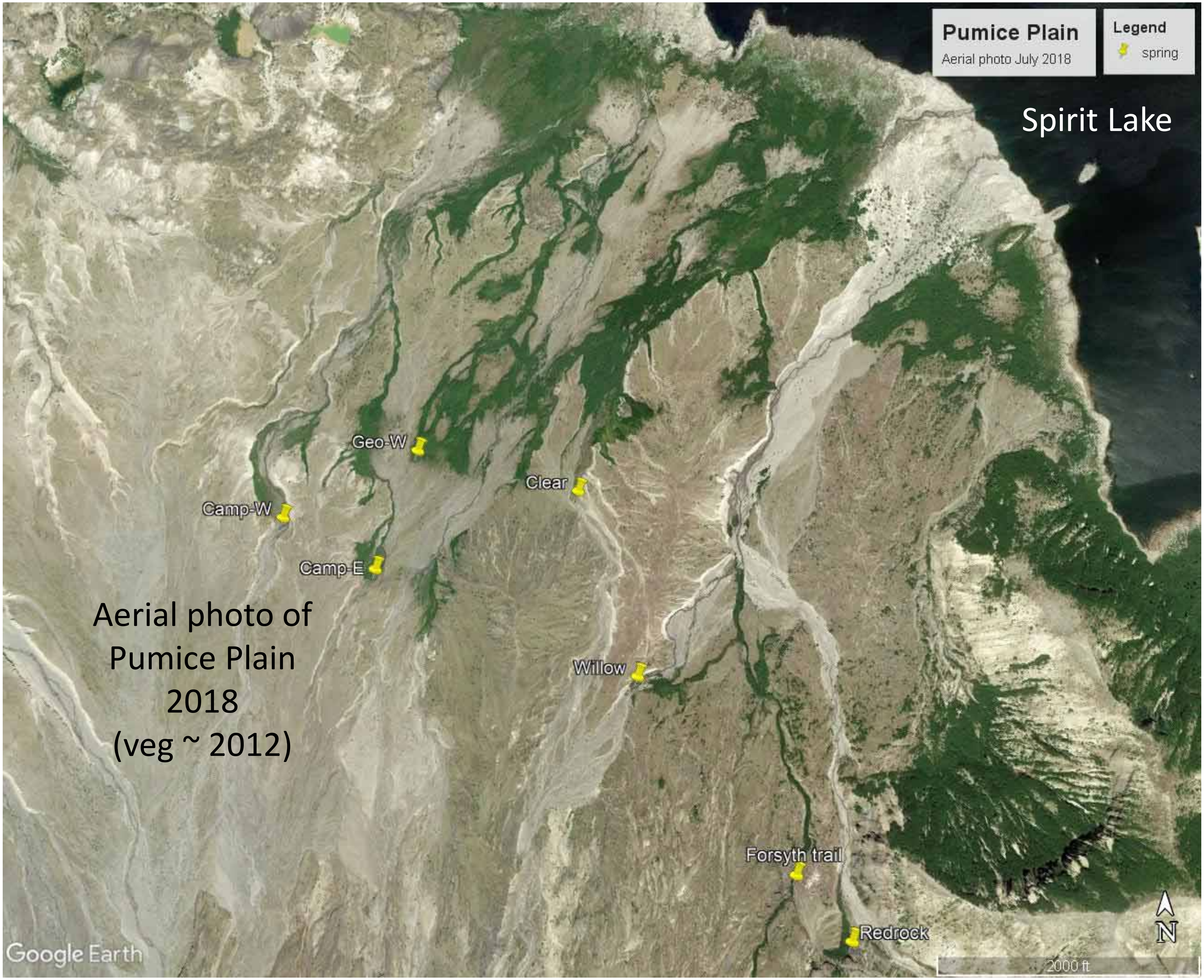
Pumice Plain study streams

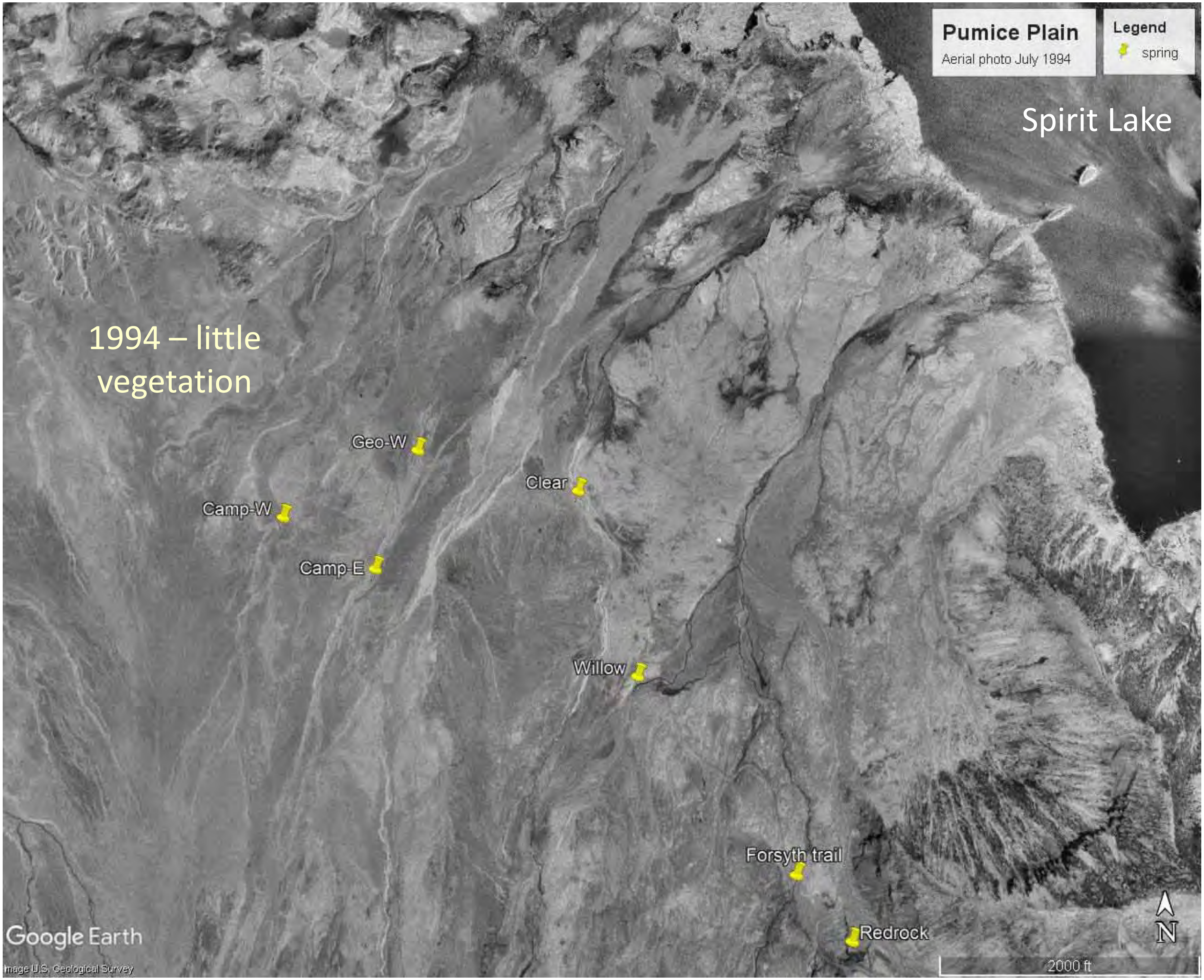


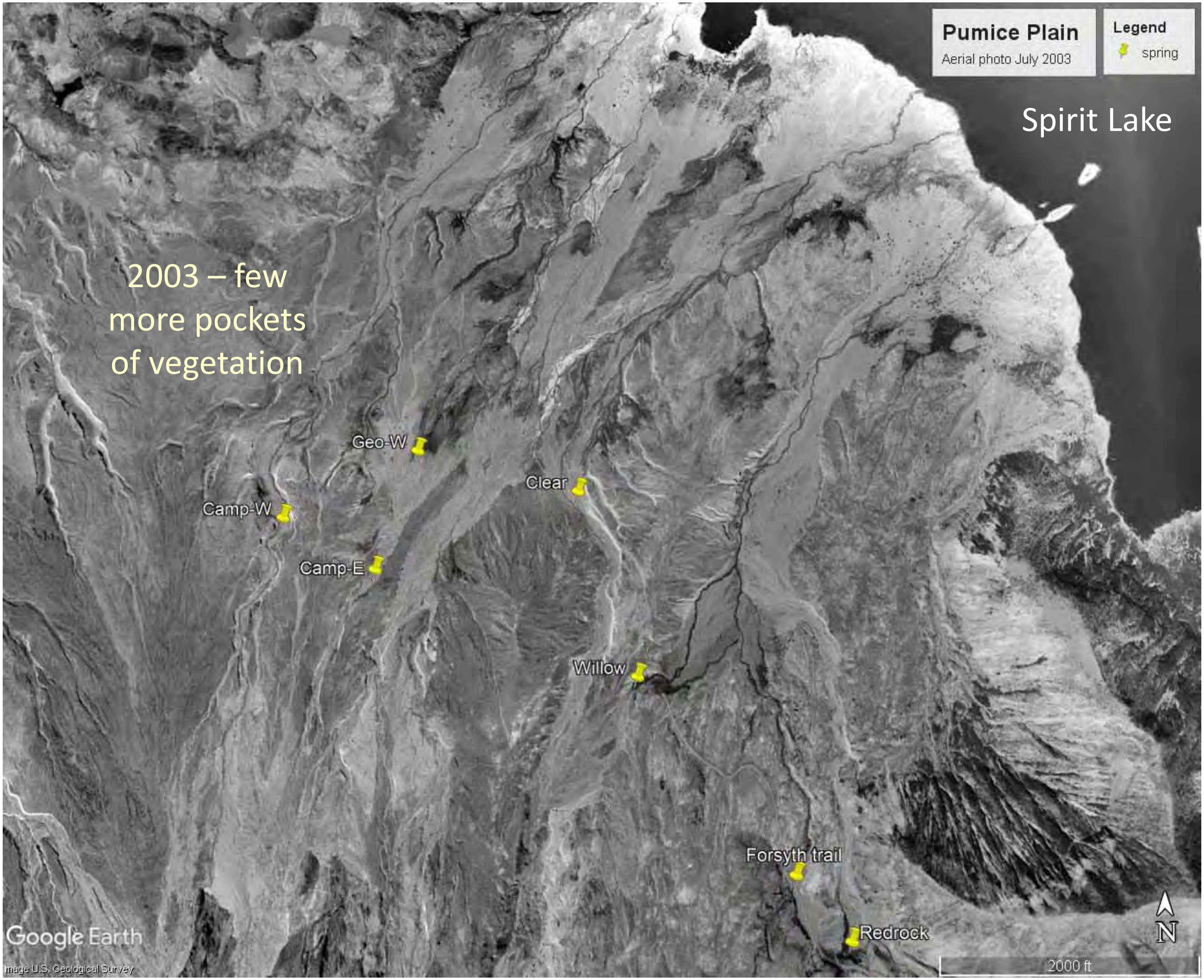
4 drainages &
<u>major tributaries:</u>

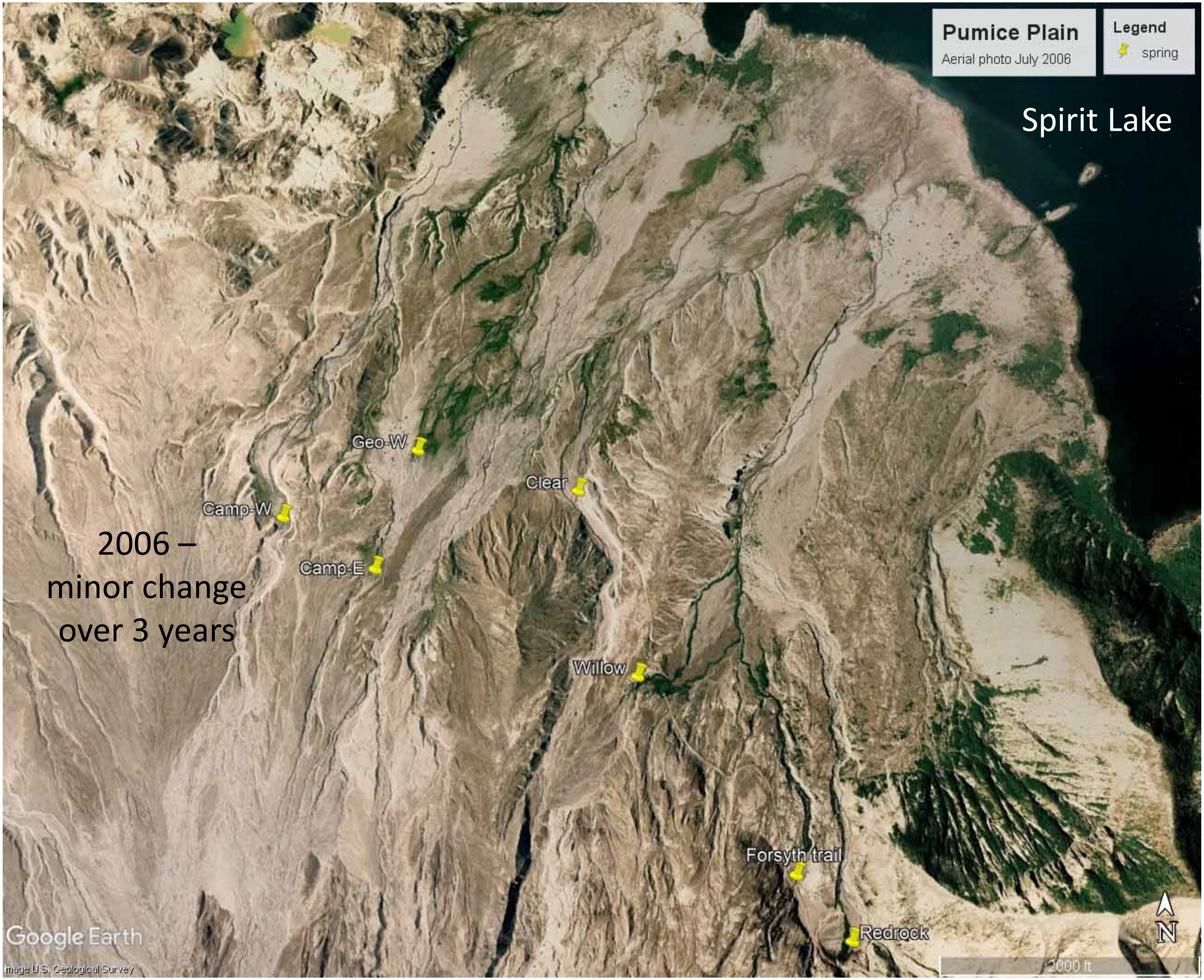
- Camp Creek
- Geothermal Creek
  - Geo-West
  - Geo-East
- Clear Creek
- Willow Creek
  - Willow
  - Forsyth
  - Redrock

Headwater streams sourced from mountain-side springs, created after eruption.

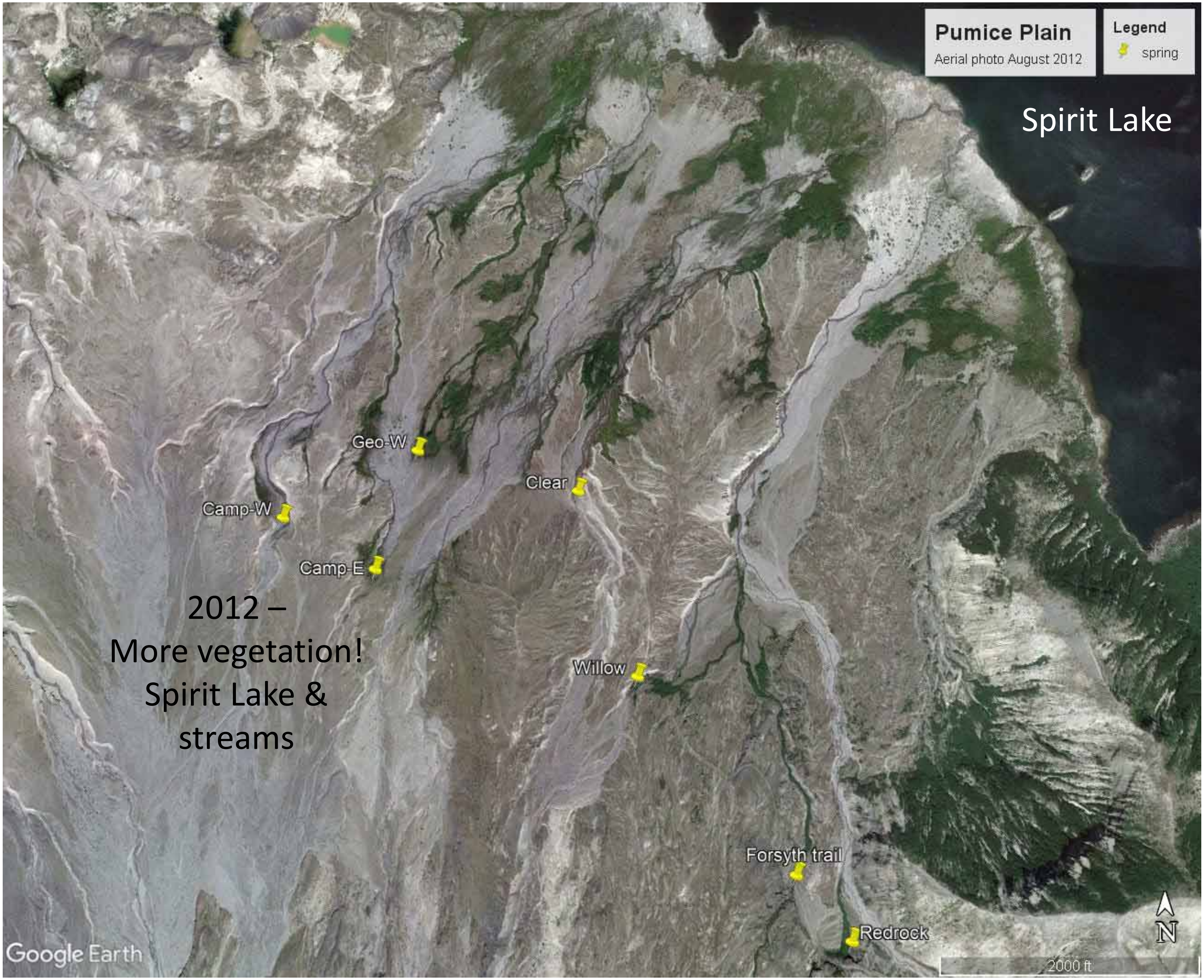

Pumice Plain
Aerial photo July 2018
Legend
spring
Spirit Lake
Geo-W
Clear
Camp-W
Camp-E
Willow
Forsyth trail
Redrock
Aerial photo of
Pumice Plain
2018
(veg ~ 2012)
N
2000 ft
Google Earth


Pumice Plain
Aerial photo July 1994
Legend
spring
Spirit Lake
1994 – little vegetation
Geo-W
Clear
Camp-W
Camp-E
Willow
Forsyth trail
Redrock
N
2000 ft
Google Earth
Image U.S. Geological Survey

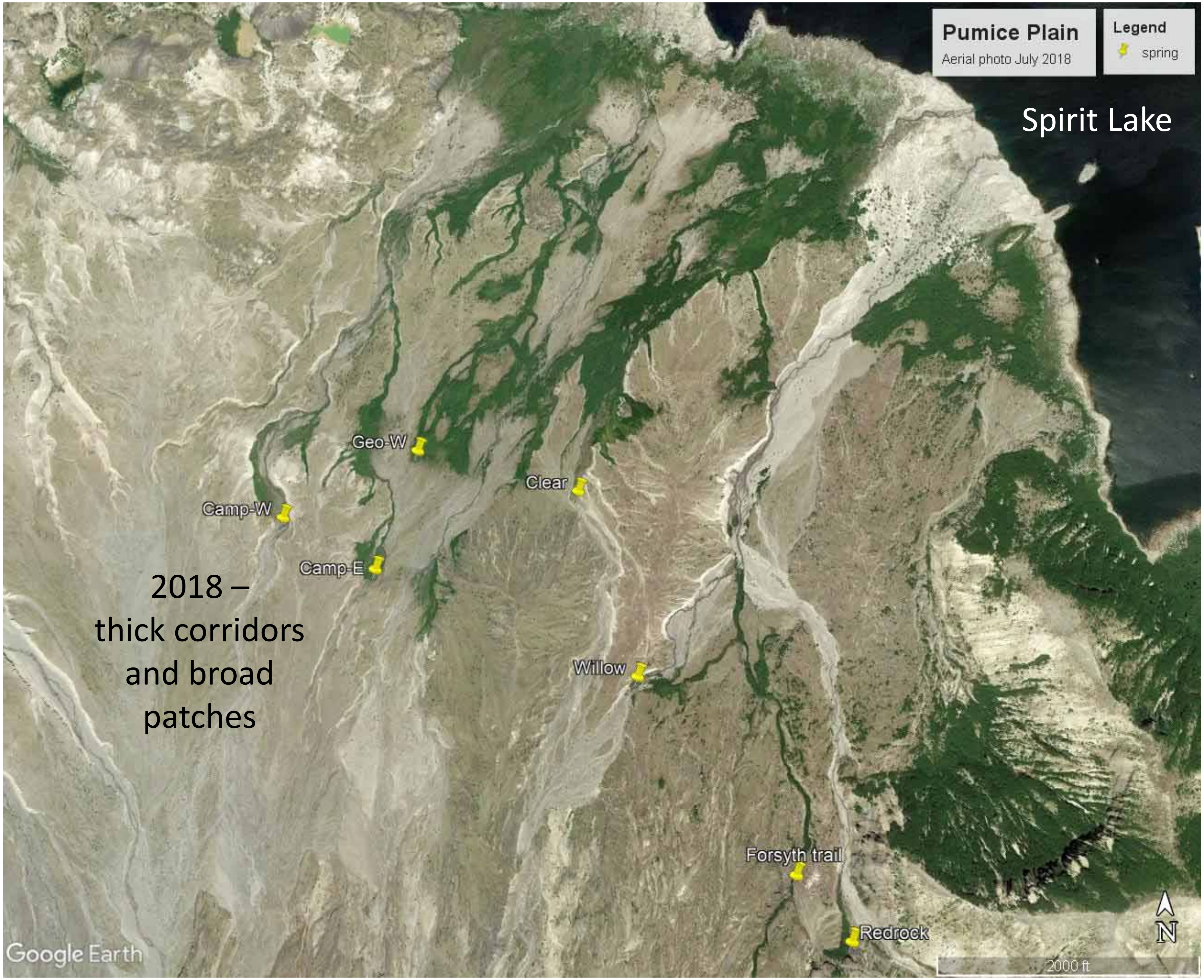

Pumice Plain
Aerial photo July 2003
Legend
spring
Spirit Lake
2003 – few more pockets of vegetation
Geo-W
Clear
Camp-W
Camp-E
Willow
Forsyth trail
Redrock
Google Earth
Image U.S. Geological Survey
N
2000 ft



Pumice Plain
Aerial photo July 2006
Legend
spring
Spirit Lake
Geo-W
Clear
Camp-W
Camp-E
Willow
Forsyth trail
Redrock
2006 –
minor change
over 3 years
Google Earth
Image U.S. Geological Survey
N
2000 ft



Pumice Plain
Aerial photo August 2012
Legend
spring
Spirit Lake
Geo-W
Clear
Camp-W
Camp-E
2012 –
More vegetation!
Spirit Lake &
streams
Willow
Forsyth trail
Redrock
Google Earth
N
2000 ft


Pumice Plain
Aerial photo July 2018
Legend
spring
Spirit Lake
Geo-W
Clear
Camp-W
Camp-E
Willow
Forsyth trail
Redrock
N
2000 ft
Google Earth
2018 –
thick corridors
and broad
patches

In 2016, stream habitat varied and only **36 years old.**

Are the **riparian, algal**, & **macroinvertebrate** communities different in these young streams?

Biotic communities:

H1: no difference

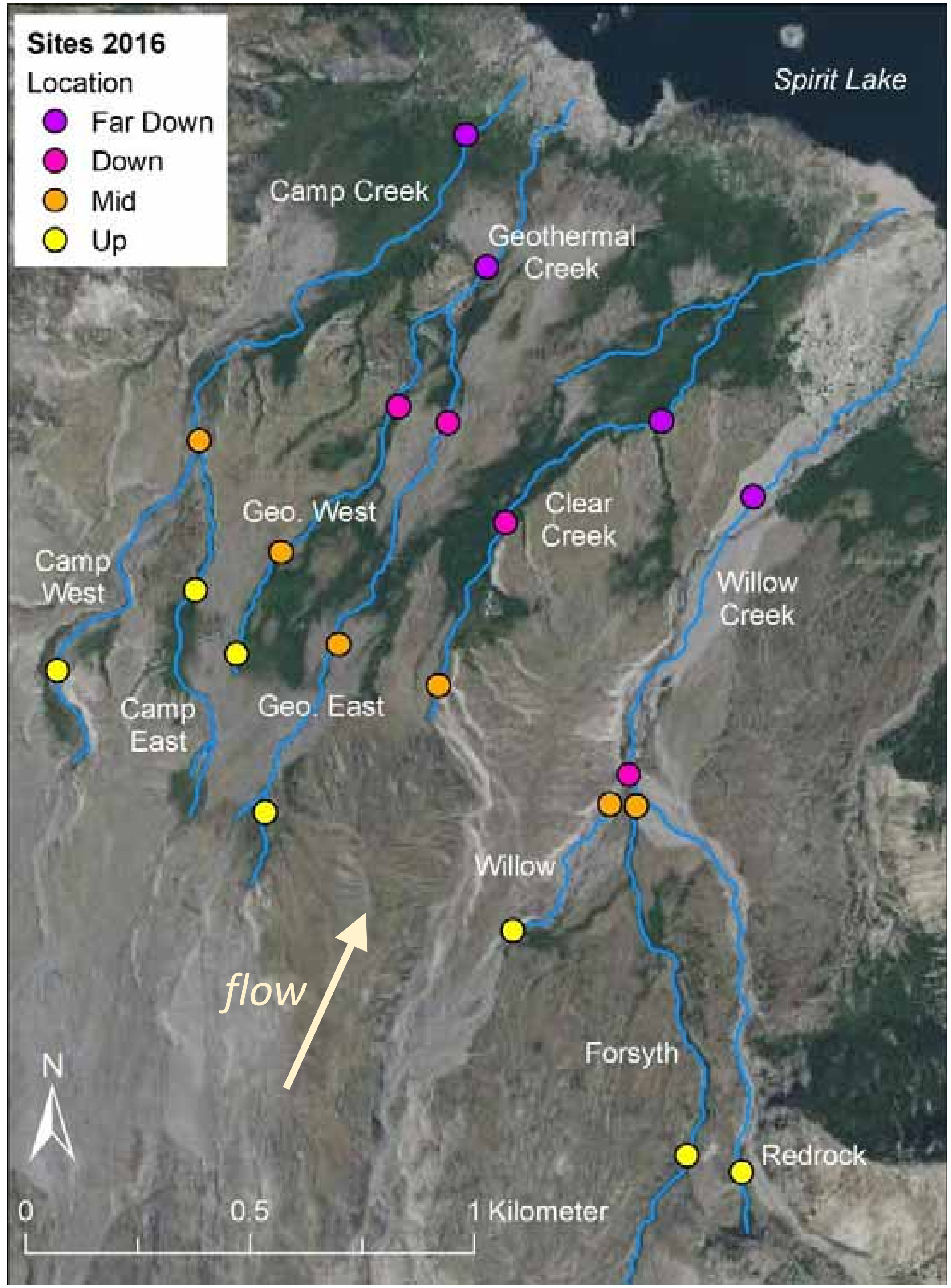
but if there is difference:

H2: spatially driven

H3: habitat driven

Stream reach surveys

- July 2016
- ~6 streams or tributaries
- 4 locations along streams
- 21 sites total



Reach survey measurements

- Wetted & bankfull widths, depth, slope
- Discharge, temperature (hourly), substrate size (D_{50}), embeddedness
- DO, pH, conductivity, alkalinity, CDOM, DOC, nutrients
- Riparian vegetation composition, canopy cover
  - 8 1-m^2 plots / site
- Periphyton composition, biomass (chl-*a*)
  - 5 substrates / site
- Benthic macroinvertebrate composition, biomass (dry mass)
  - 8 1-ft^2 subsamples / site

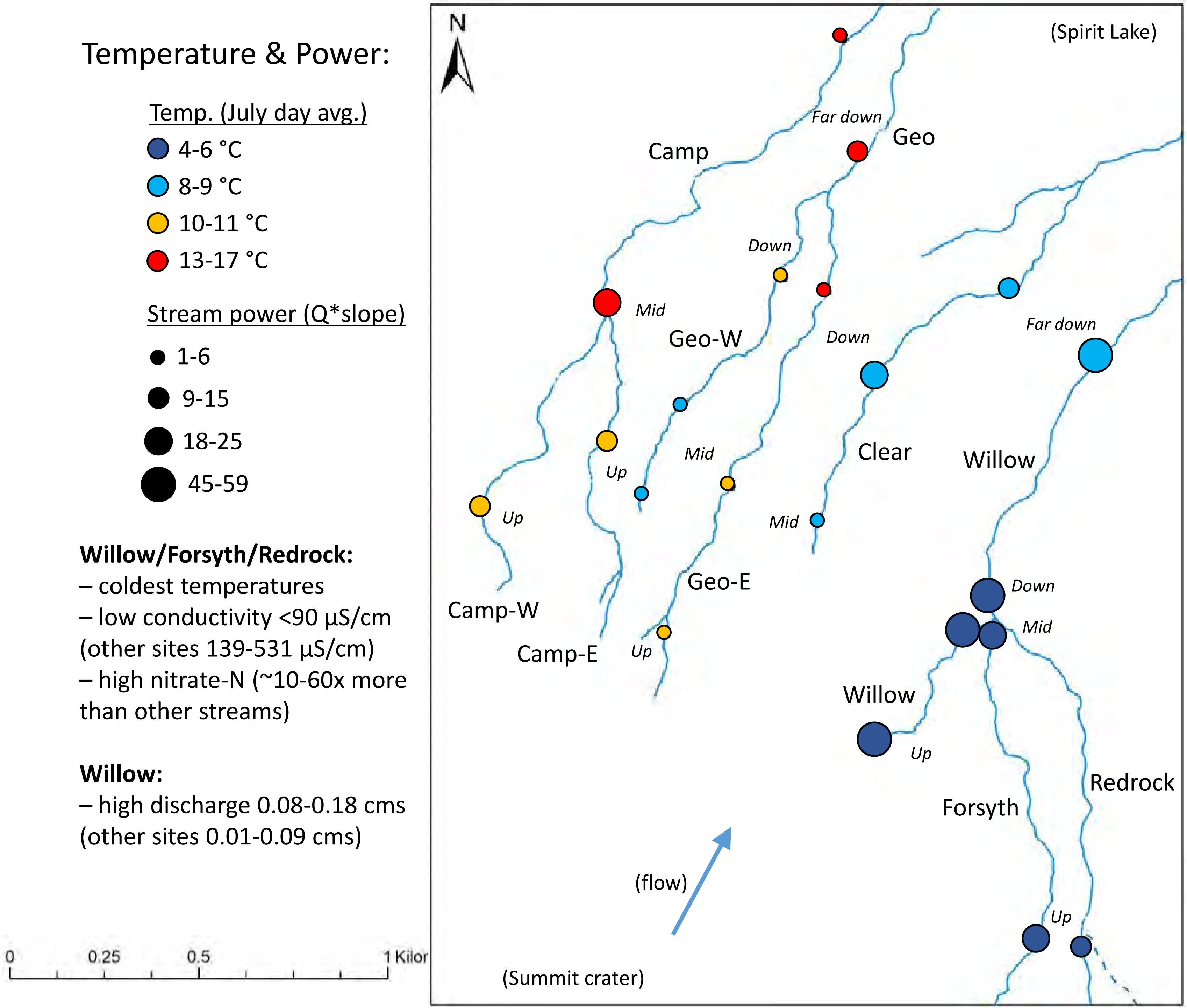
Temperature & Power:

Temp. (July day avg.)
- 4-6 °C
- 8-9 °C
- 10-11 °C
- 13-17 °C

Stream power (Q*slope)
- 1-6
- 9-15
- 18-25
- 45-59

Willow/Forsyth/Redrock:
– coldest temperatures
– low conductivity <90 µS/cm (other sites 139-531 µS/cm)
– high nitrate-N (~10-60x more than other streams)

Willow:
– high discharge 0.08-0.18 cms (other sites 0.01-0.09 cms)



Principle Components Analysis (21 sites)

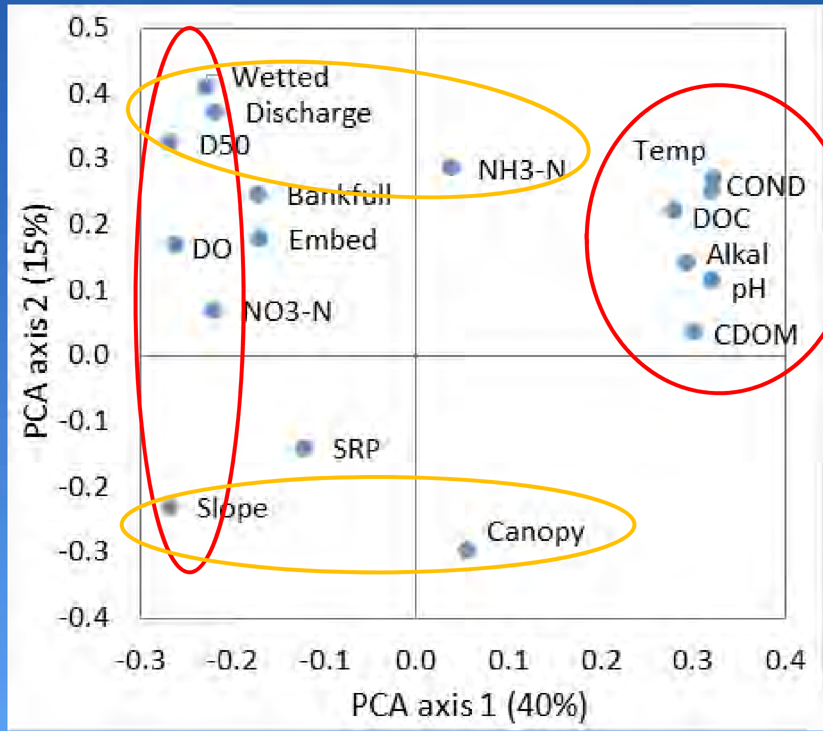
Major factor loadings:

PCA axis 1

- + temperature, conductivity, alkalinity, pH, DOC, CDOM
- - discharge, wetted and bankfull widths, slope, substrate D_{50}, DO, nitrate-N

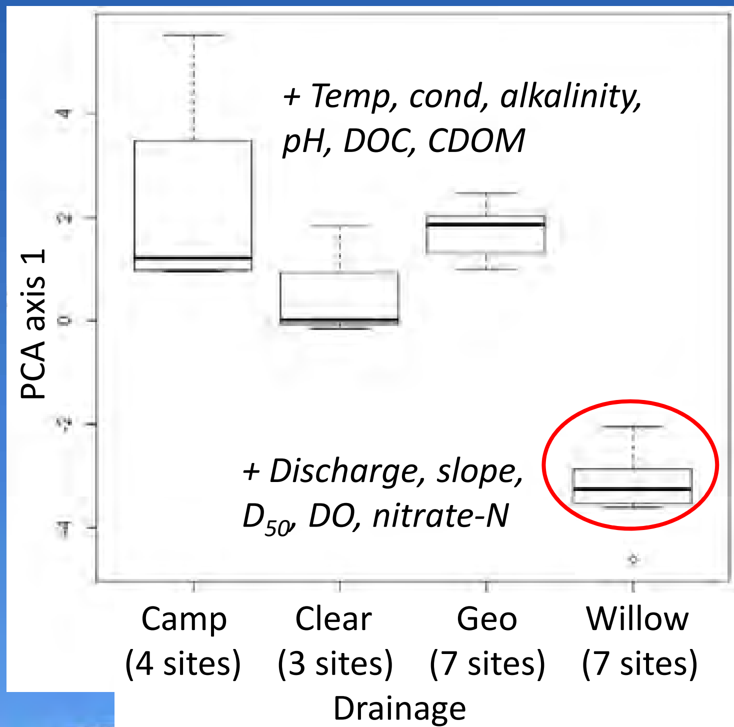
PCA axis 2

- + discharge, wetted width, substrate D_{50}, ammonium-N
- - canopy cover, slope

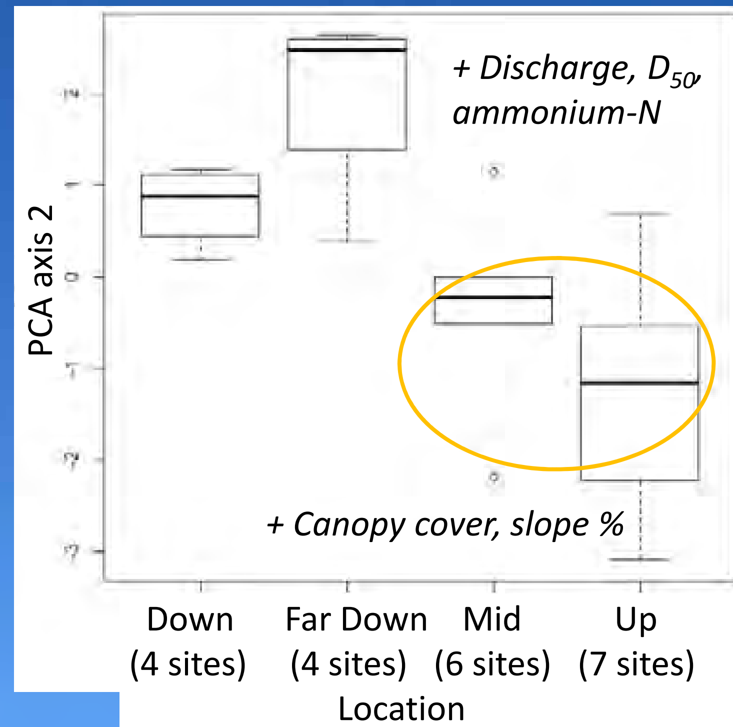


PCA loadings across streams & site locations:

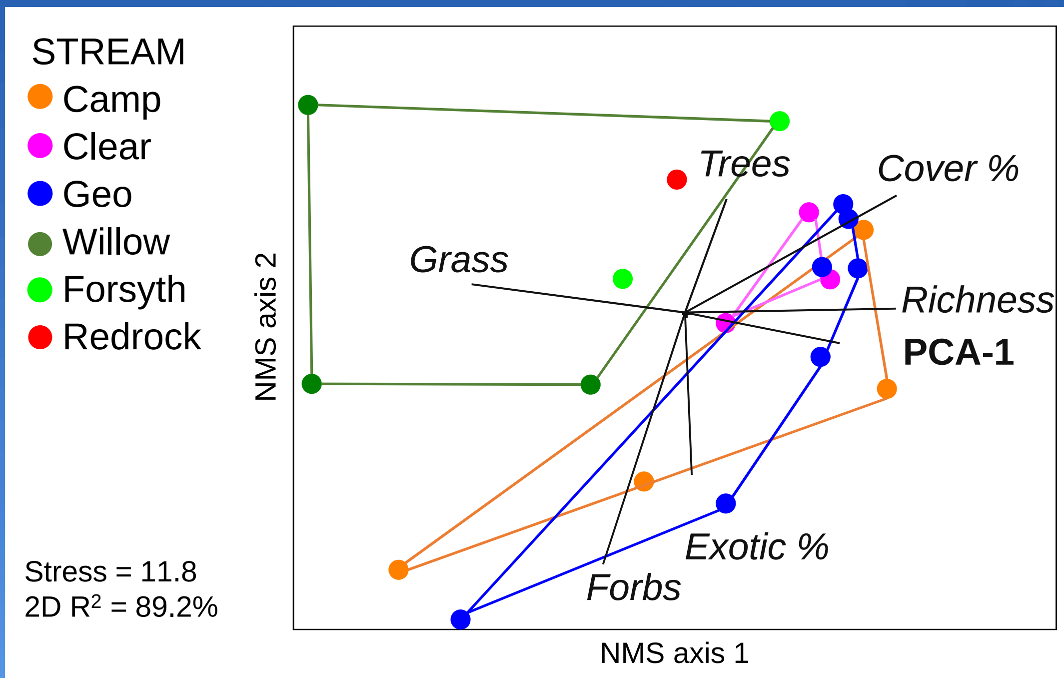
Axis 1 ~ Drainage



Axis 2 ~ Location



Riparian vegetation communities



39 plant species:

~Sitka willow & green alder

Willow:

Low richness, low cover %

- correlated with PCA axis 1

(> discharge, widths, slope, D50, DO, nitrate)

Forsyth, Redrock:

Med richness, high cover %

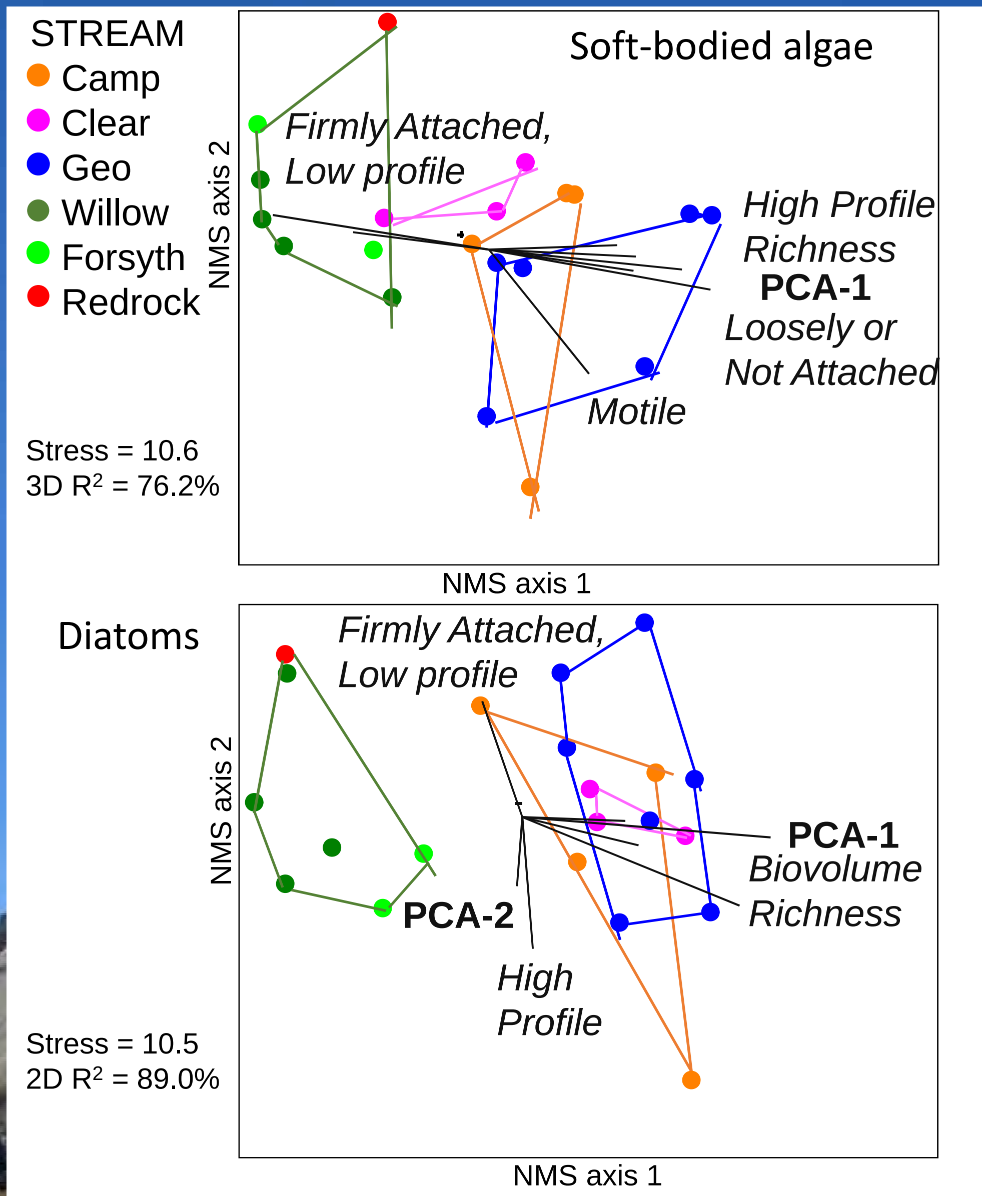
Camp, Clear, Geo:

Variable richness and cover %,

+ correlated with PCA axis 1

(> temp., cond., alkalinity, pH, DOC)

Periphytic soft-algae & diatom communities



55 soft-bodied taxa

~cyanobacteria

96 diatom taxa

~*Planothidium amphibium*

Willow, Forsyth, Redrock:

Low richness, no N-fixers,

~Low profile, firmly attached taxa

- correlated with PCA axis 1

(> discharge, widths, slope, D50, DO, nitrate)

Camp, Clear, Geo:

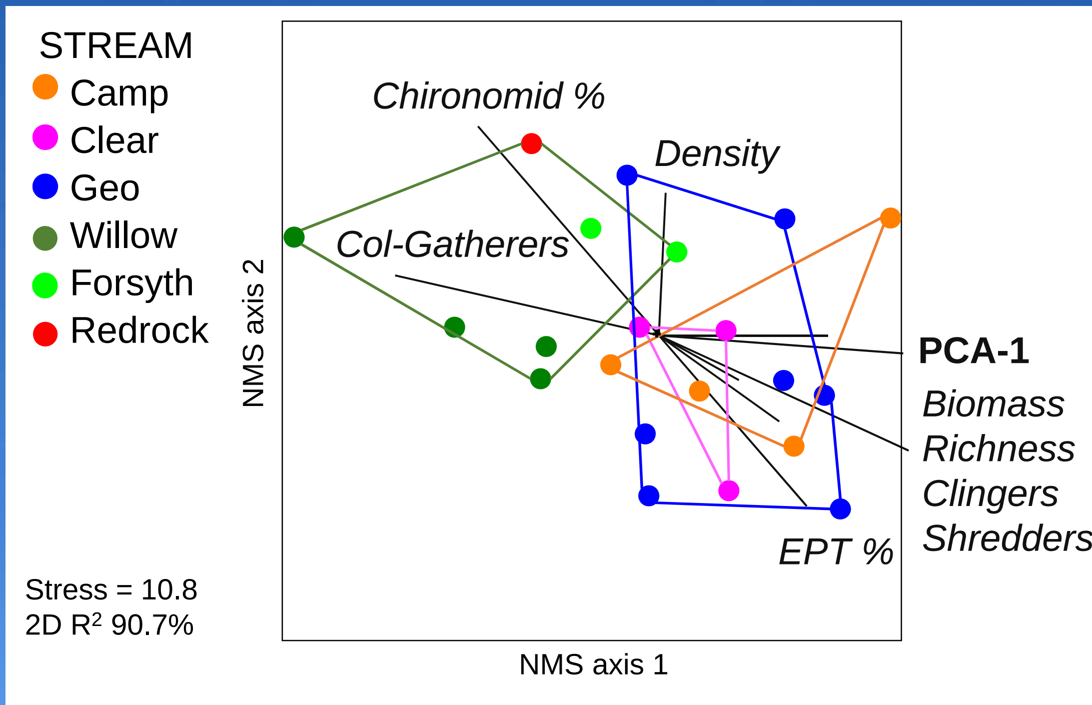
High richness, yes N-fixers,

Diverse ecological guilds,

+ correlated with PCA axis 1

(> temp., cond., alkalinity, pH, DOC)

Benthic macroinvertebrate communities



74 insect taxa:

~chironomids, baetids, simuliids, capniids, nemourids

6 non-insect & 2 snail taxa

Willow:

Low density, low richness

- correlated with PCA axis 1

(> discharge, widths, slope, D50, DO, N)

Forsyth, Redrock:

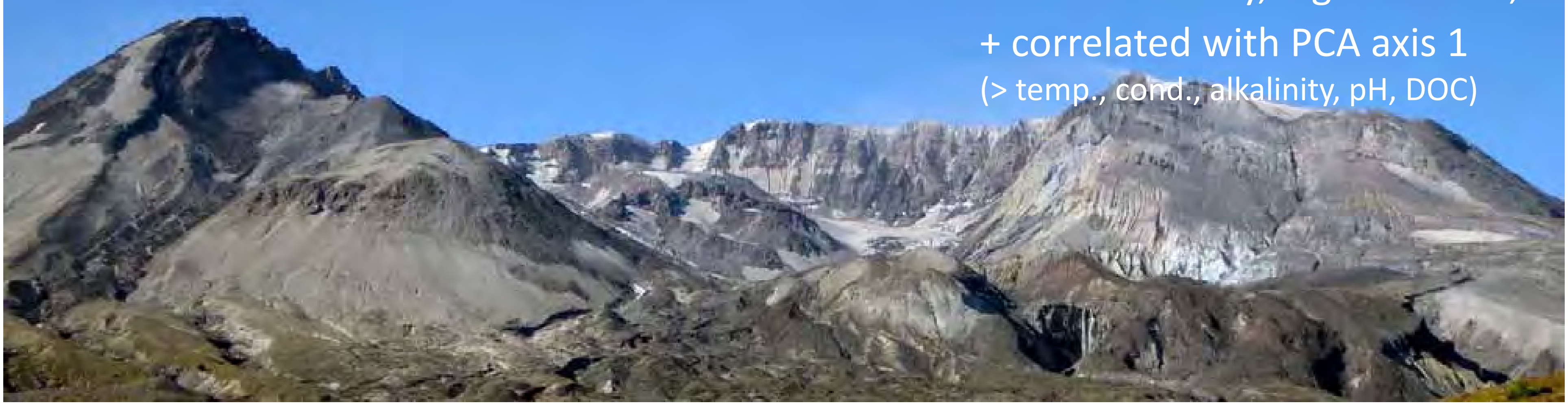
High density, low richness

Camp, Clear, Geo:

Variable density, high richness,

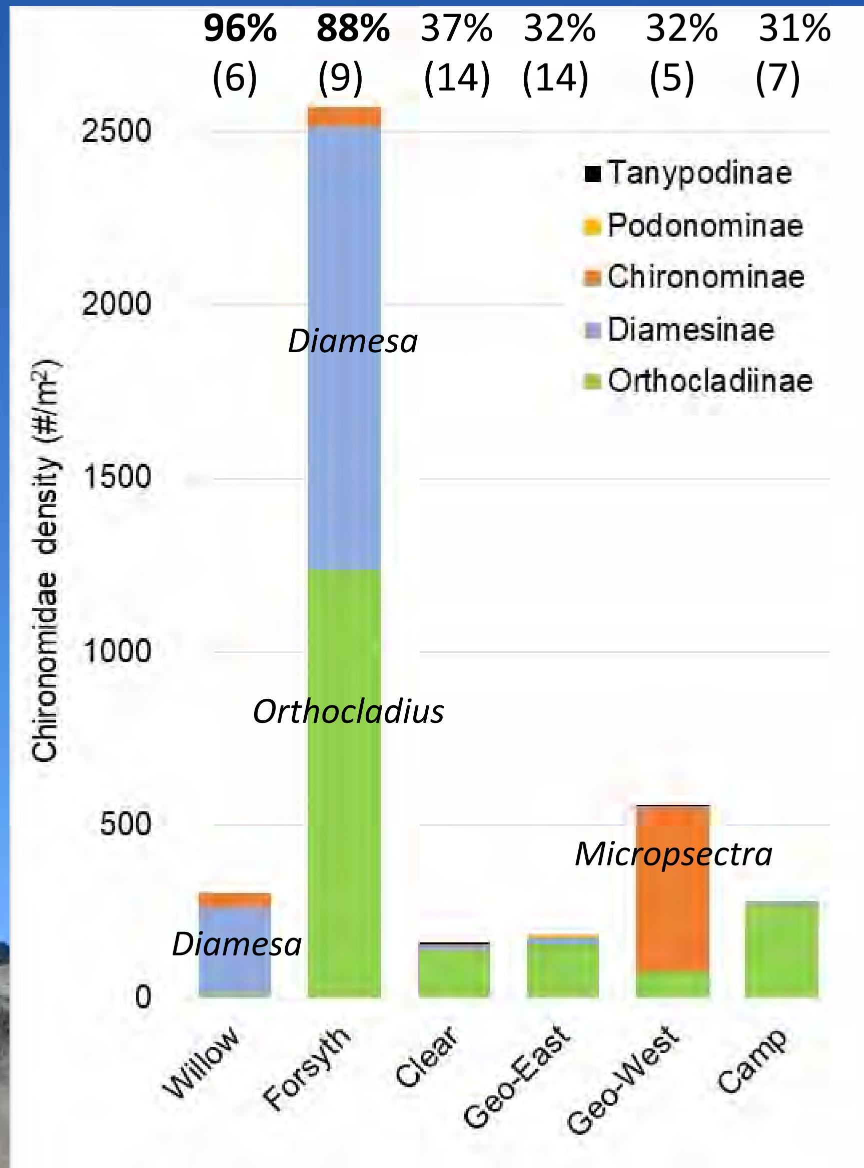
+ correlated with PCA axis 1

(> temp., cond., alkalinity, pH, DOC)



Chironomidae density & taxa at Mid sites

(ID to subfamily at all other sites)



% of total invertebrates (# of Chironomid taxa in parentheses)

<u>22 taxa total:</u>

1 Tanypodinae
2 Podonominae
1 Chironominae
4 Diamesinae
14 Orthocladiinae

(6 taxa = uncommon)

Communities & Habitat Differences by Stream

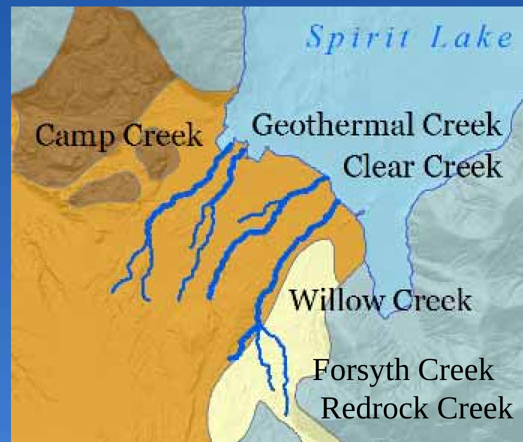
Willow

+ discharge, widths, slope, substrate D_{50}, DO, nitrate

Riparian veg – grass or none

Periphyton – low-profile & firmly attached

Insects – low EPT richness, low FFG diversity (primarily chironomids)



Camp, Geo, Clear

+ temperature, conductivity, alkalinity, pH, DOC

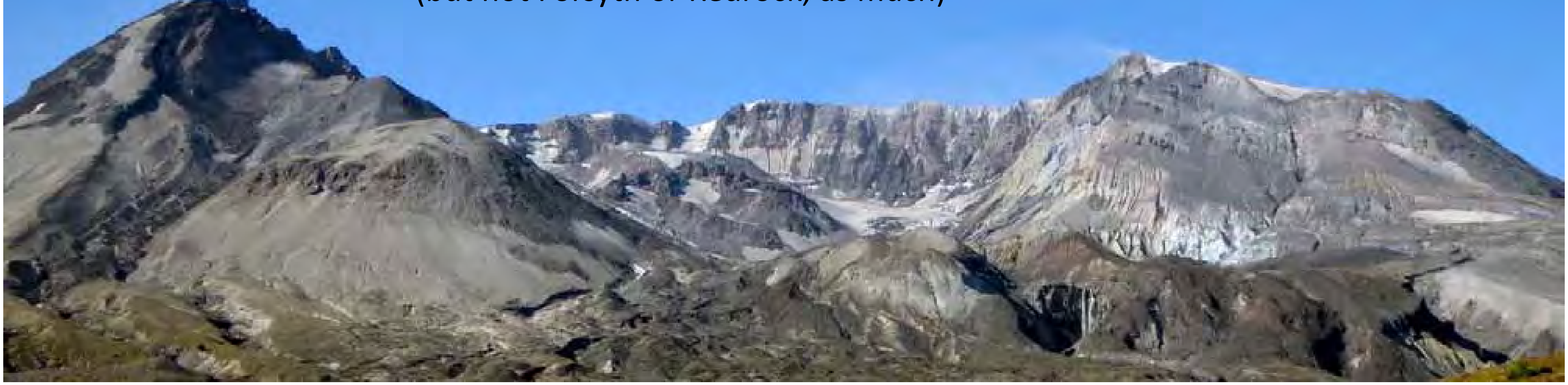
Riparian veg – diverse forbs & trees

Periphyton – diverse diatoms & soft-bodied algae

Insects – high EPT richness, high FFG diversity, high biomass

Communities indicate low resource availability and high disturbance!

(but not Forsyth or Redrock, as much)



Why is Willow Creek so different?

1. Different spring water sources
   - Willow/Forsyth/Redrock: groundwater from Forsyth glacier?
   - Clear/Geo/Camp: deeper groundwater?
2. Willow vs. Forsyth/Redrock
   - Greater sediment source & transport (discharge, upslope area)
   - Different eruption disturbance zone???

In-stream algal succession

Rushforth et al. (1986) predicted:

1) early dominance by *Achnanthes* spp. (diatom),
2) growth of filamentous chlorophyte,
3) increases in adnate diatoms,
4) dominance by chlorophyte-diatom or cyanophyte-diatom communities.

J. Phycol. 22, 129–137 (1986)

ALGAL COMMUNITIES OF SPRINGS AND STREAMS IN THE MT. ST. HELENS REGION, WASHINGTON, U.S.A. FOLLOWING THE MAY 1980 ERUPTION[1]

Samuel R. Rushforth[2], *Lorin E. Squires*

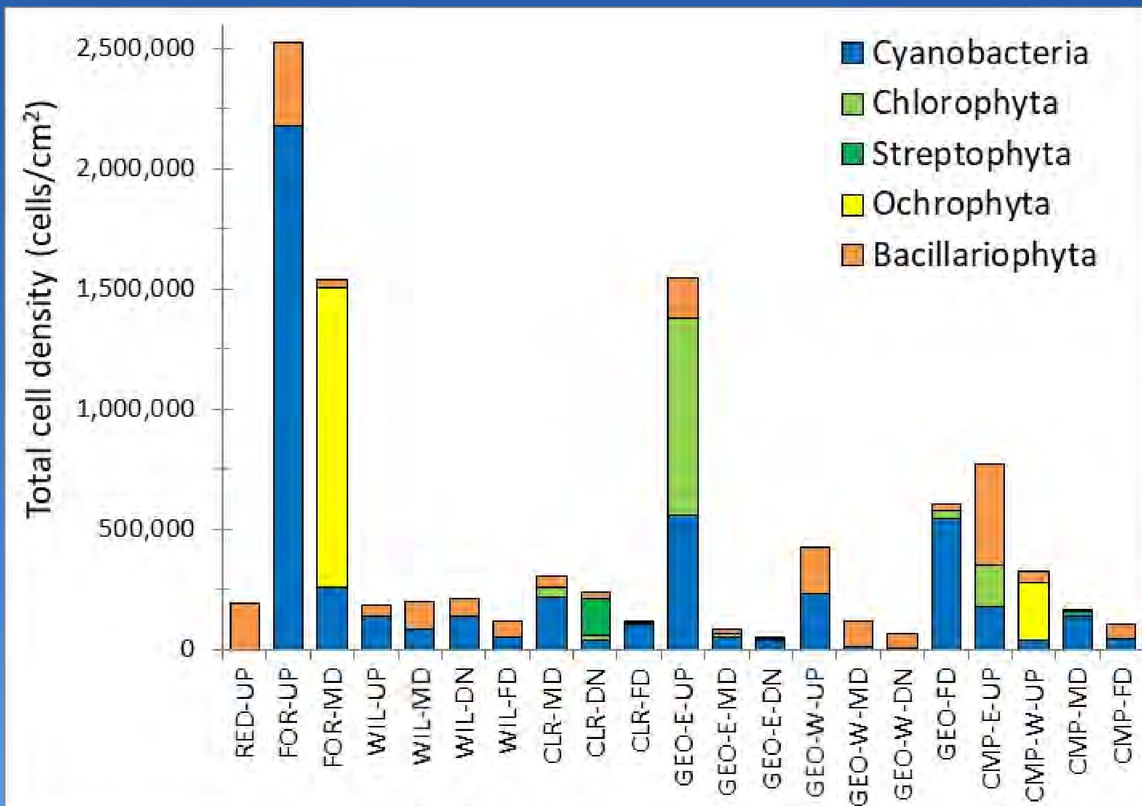
Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602

and

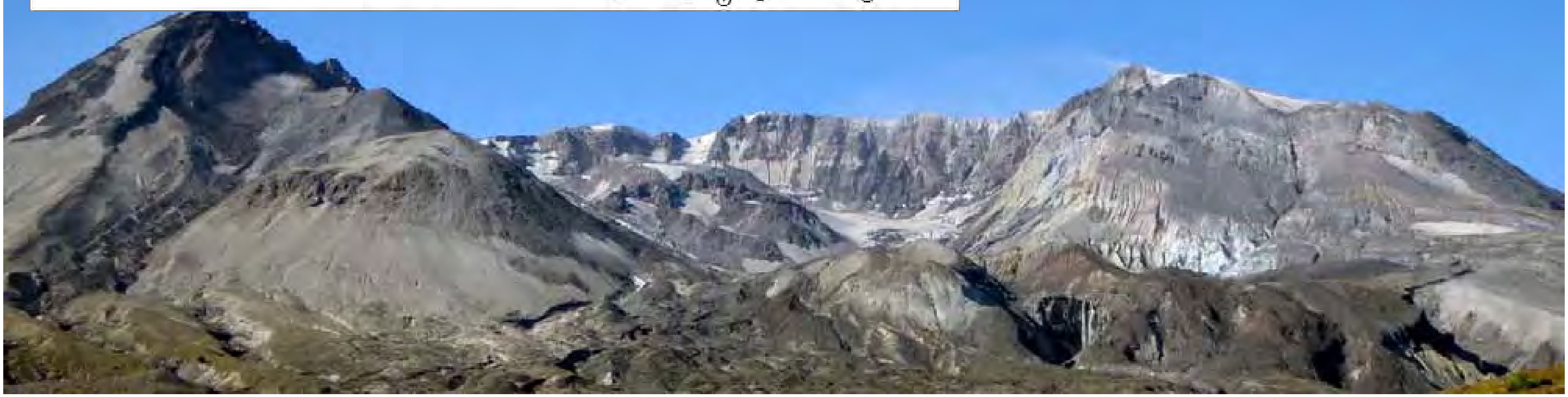
Colbert E. Cushing

Earth Sciences Department, Battelle, Pacific Northwest Laboratories, Richland, Washington 99352

In-stream algal succession - 2016



- Diatoms common at most sites (Bacillariophyta).
- Filamentous chlorophytes are only dominant at two upper sites.
- Cyanobacteria-diatom communities are common at ~half sites.



MSH comparison with AK glacial retreat streams

Differences: History, latitude, and geologic material.

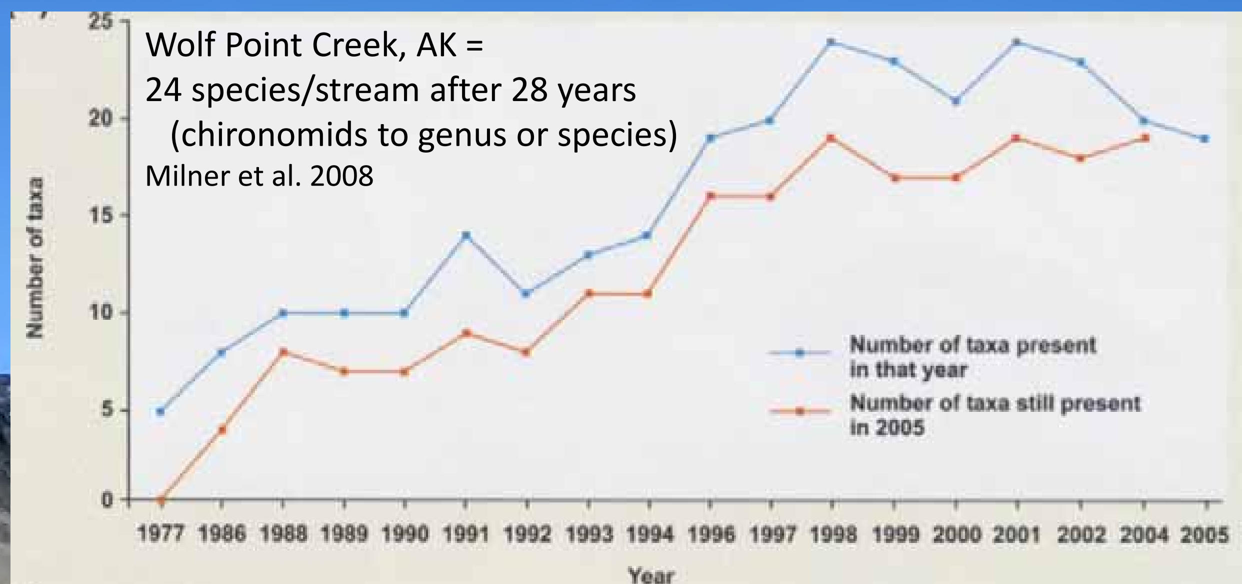
Similarities: Create stream habitat for primary succession,

- Early plant colonization by of willow & alder.
- Early insect colonization by Chironomidae, Baetidae, Capniidae, & Simuliidae.
- Cold temperatures and substrate instability limit benthic invertebrate diversity.
- Community assembly initially deterministic, with tolerance a major mechanism.

Milner et al. 2000
Robertson & Milner 2006
Milner et al. 2011
Etc.

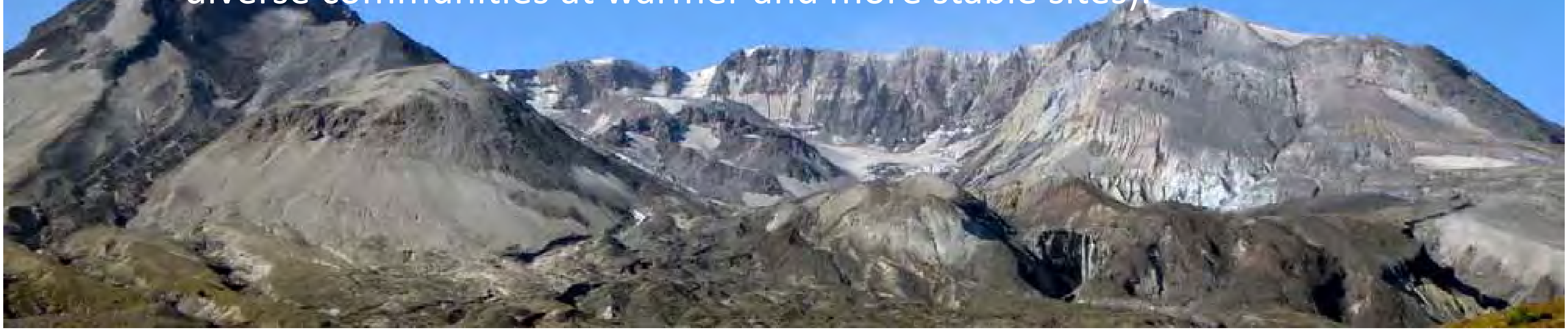
MSH Pumice Plain =
38-58 species/stream after 36 years
(chironomids to subfamily)

Wolf Point Creek, AK =
24 species/stream after 28 years
(chironomids to genus or species)
Milner et al. 2008



Conclusions – MSH Pumice Plain streams

- These watersheds provide a unique opportunity to explore community development and early stream succession.
- Overall, rapid development of aquatic communities in 36 years despite no connected sources for colonization.
- Riparian, algal, & invertebrate communities differed considerably between some streams, primarily due to geomorphology, water quality and temperature differences.
- Taxa tolerance is an important community assembly mechanism as all streams share the same most abundant group of taxa.
- Deterministic pathways dominate when conditions are harsh, but that stochastic processes occur as conditions become less harsh (i.e., more diverse communities at warmer and more stable sites).



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- Rosalina Stancheva, California State University-San Marcos

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- Emily Wolfe and Andy Berger (TESC)

Mount St. Helens National Volcanic Monument

US Forest Service PNW Research Station

The Evergreen State College

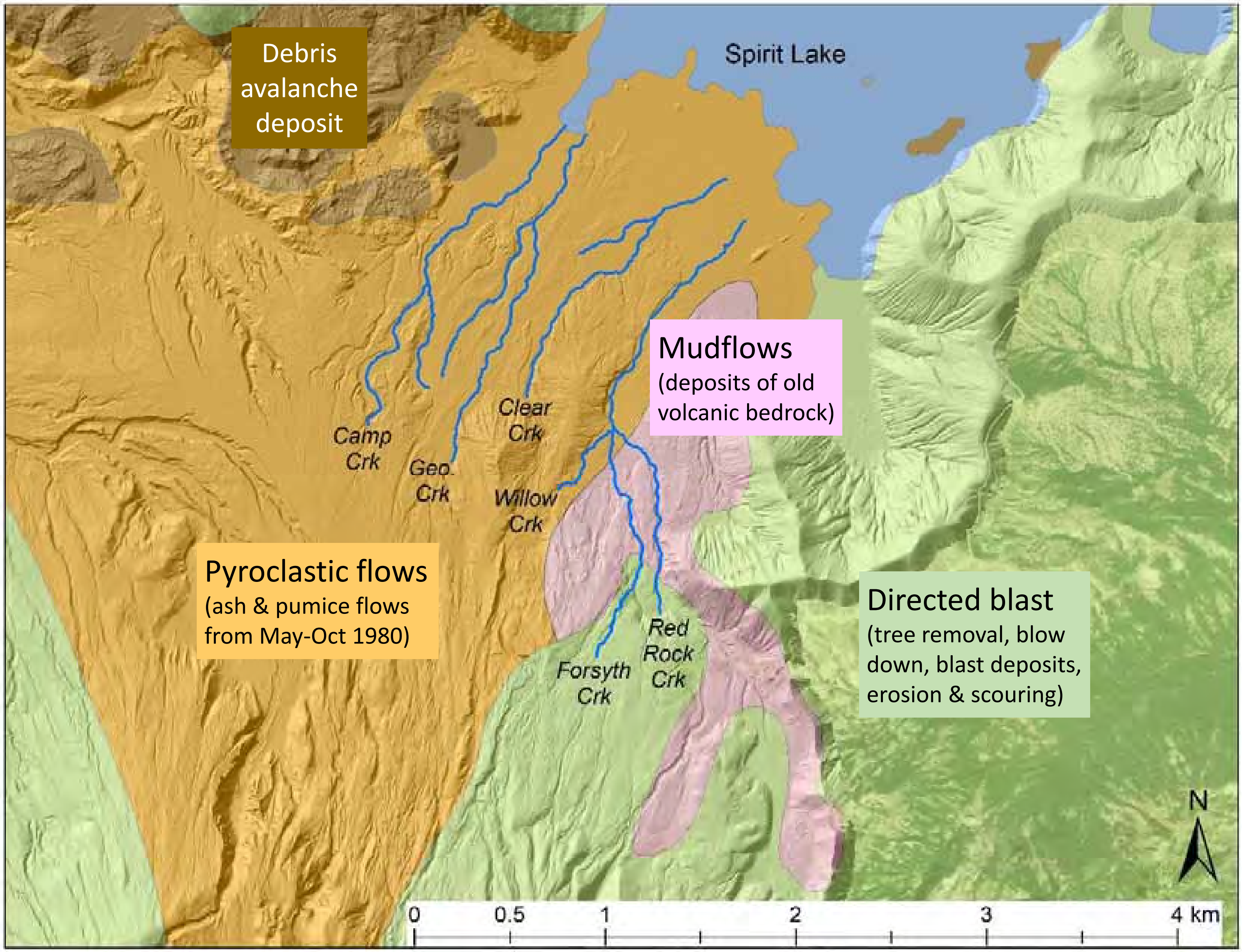
- Research grant 2017

National Science Foundation Grant DEB

- #1836387

Questions? Contact Shannon at Shannon.Claeson@usda.gov

Post-eruption disturbance zones



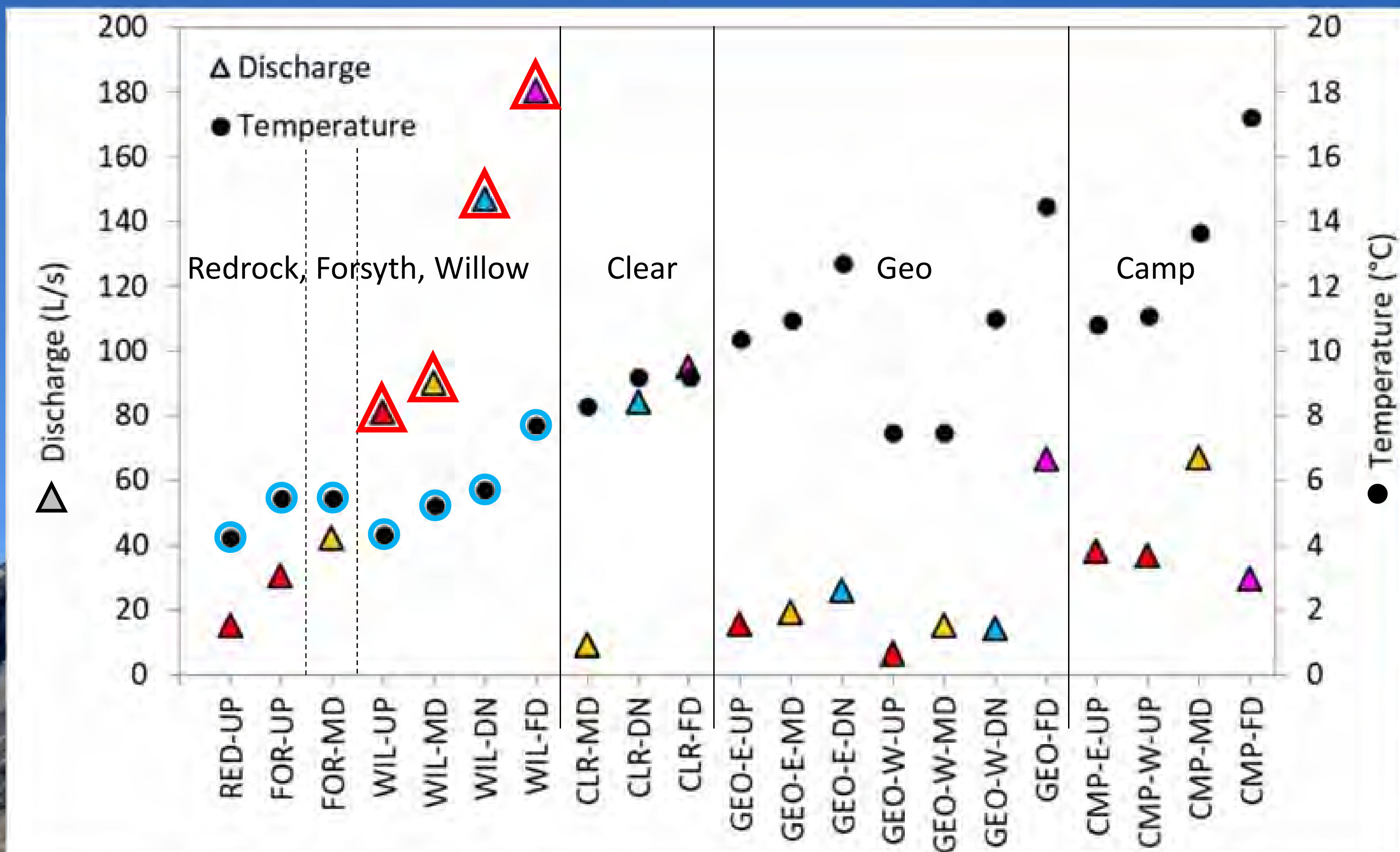
Geologic deposits and features from the 1980 eruptions (Swanson & Major 2005, adapted from Lipman & Mullineaux 1981)

Discharge & Water temperature (21 sites)

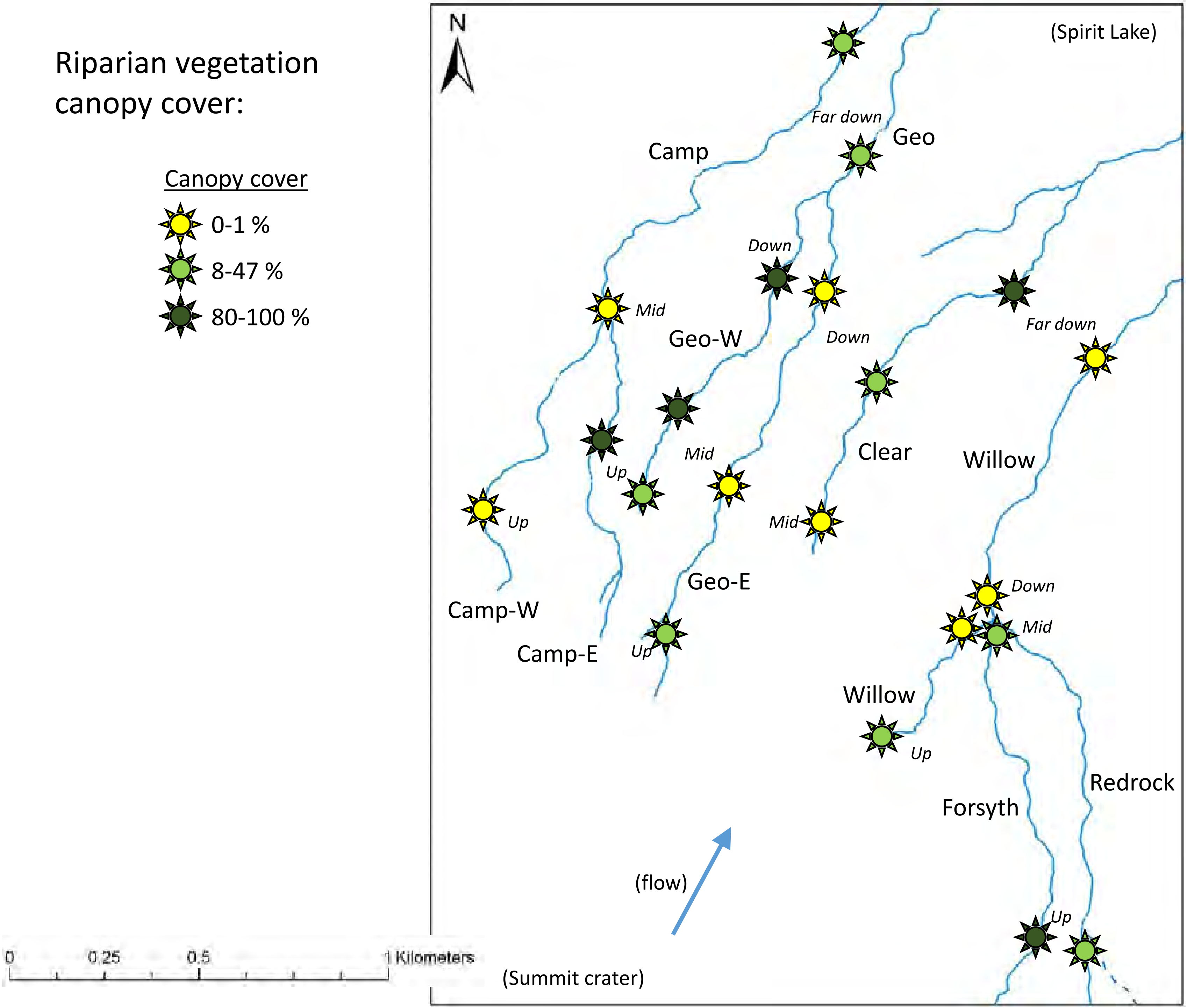
Willow/Forsyth/Redrock – coldest temperatures (even far downstream)

- low conductivity <90 µS/cm (other streams 139-531 µS/cm)
- high nitrate-N (~10-60x more than other streams)

Willow – greatest discharge by site location (Up, Mid, Down, Far Down)



Water temperature is the hourly mean over the 10-day sampling period (July 18-27, 2016).
Discharge was taken at the time of BMI sampling.



Riparian vegetation canopy cover:
Canopy cover
0-1 %
8-47 %
80-100 %
N
(Spirit Lake)
Far down
Geo
Camp
Down
Mid
Geo-W
Down
Far down
Clear
Willow
Mid
Up
Up
Mid
Geo-E
Down
Mid
Camp-W
Camp-E
Up
Willow
Up
Redrock
Forsyth
(flow)
Up
0
0.25
0.5
1 Kilometers
(Summit crater)

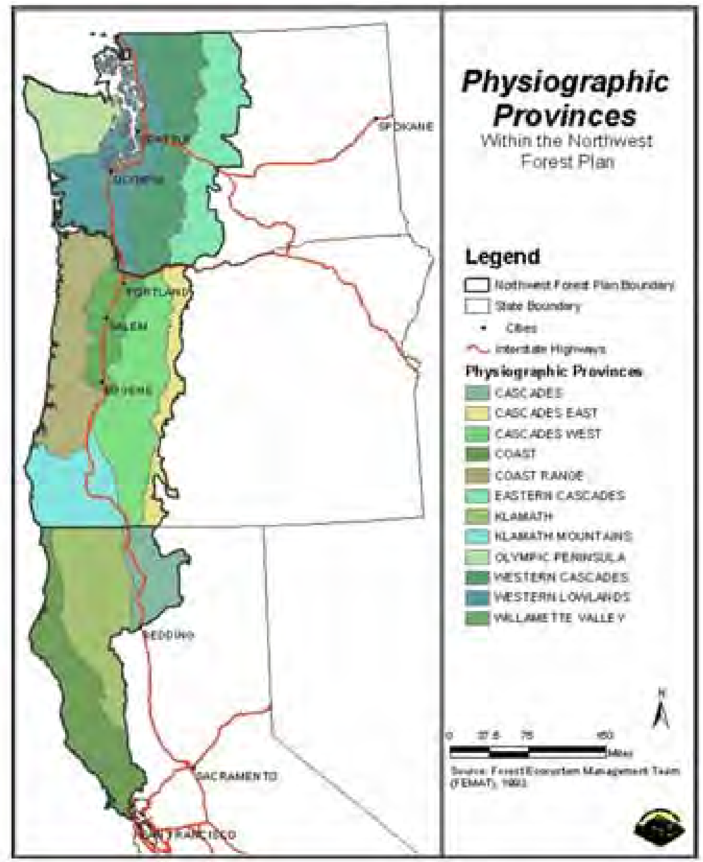
Thermal Sensitivity of Mountain Streams in the Western US

Junjie Chen - PSU
Heejun Chang - PSU
Andres Holz - PSU
Sean Gordon - PSU
Jason Dunham - USGS
Christine Hirsch - FS
David Hockman-Wert - FS

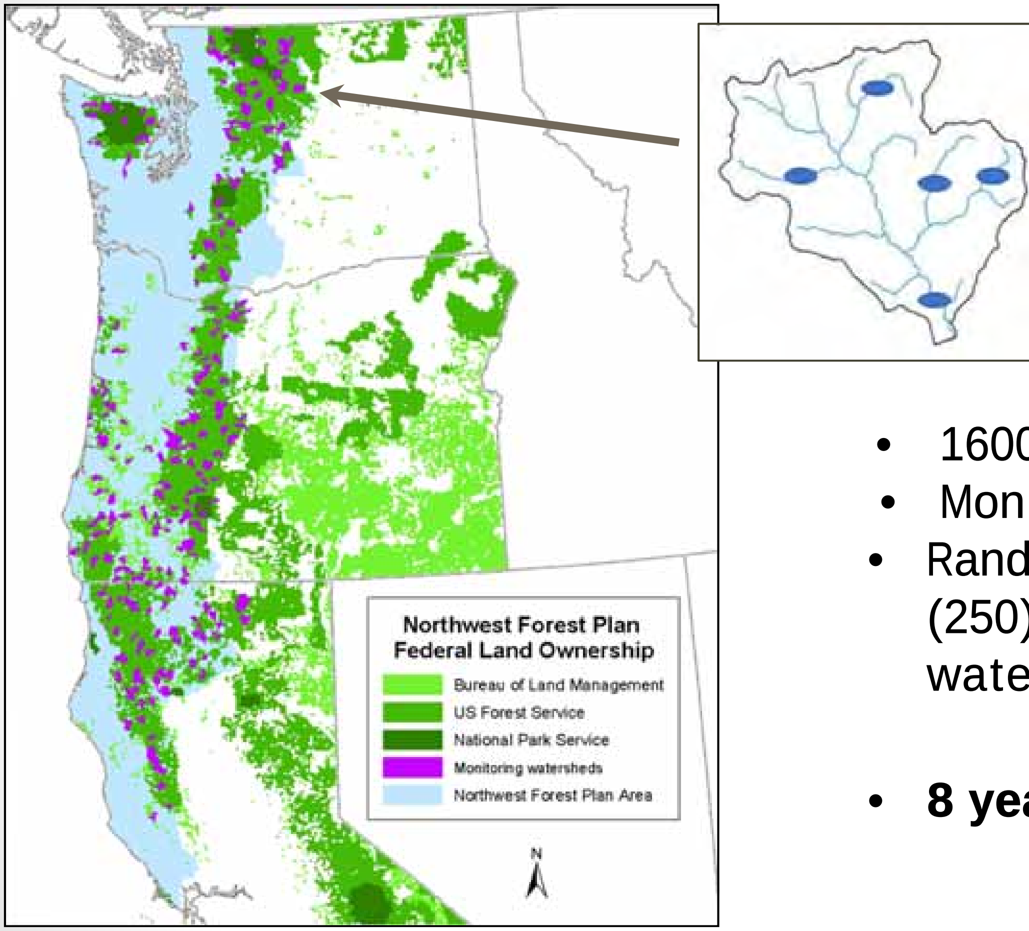
Court-ordered mandate for monitoring

The NWFP was implemented in 1994 for all Federal lands within the range of the NSO with protections for owls, murrelets, and salmon.

Passive restoration



Aquatic and Riparian Effectiveness Monitoring Plan (AREMP)



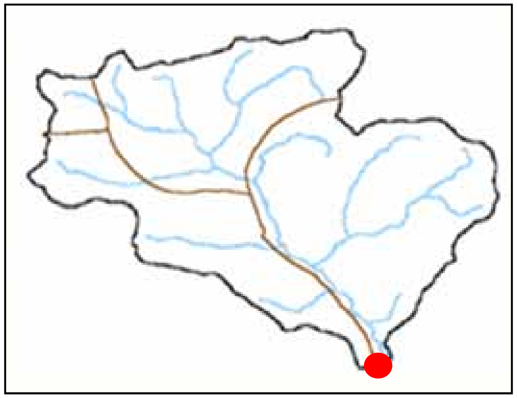
Northwest Forest Plan
Interagency Regional Monitoring Program

- 1600 watersheds
- Monitoring started in 2001
- Randomly select both watersheds (250) and sample sites (4-10 per watershed).

- **8 year revisit cycle**

Stream Temperature Monitoring

- Stream temperature: stated standards for cold water fish
- In-channel data logger installed near the downstream outlet of the each watershed.
- Data mostly available for the month of August
- Data validation, outliers removal from malfunctioned device



Research Questions

1. How does thermal sensitivity vary across different climate and watersheds?

1. How does thermal sensitivity relate to land type, hydrologic landscapes, riparian vegetation cover, and stream flow?

1. Where are key areas of high thermal sensitivity, and how does it relate to watershed conditions?

Air Temperature vs. Stream temperature

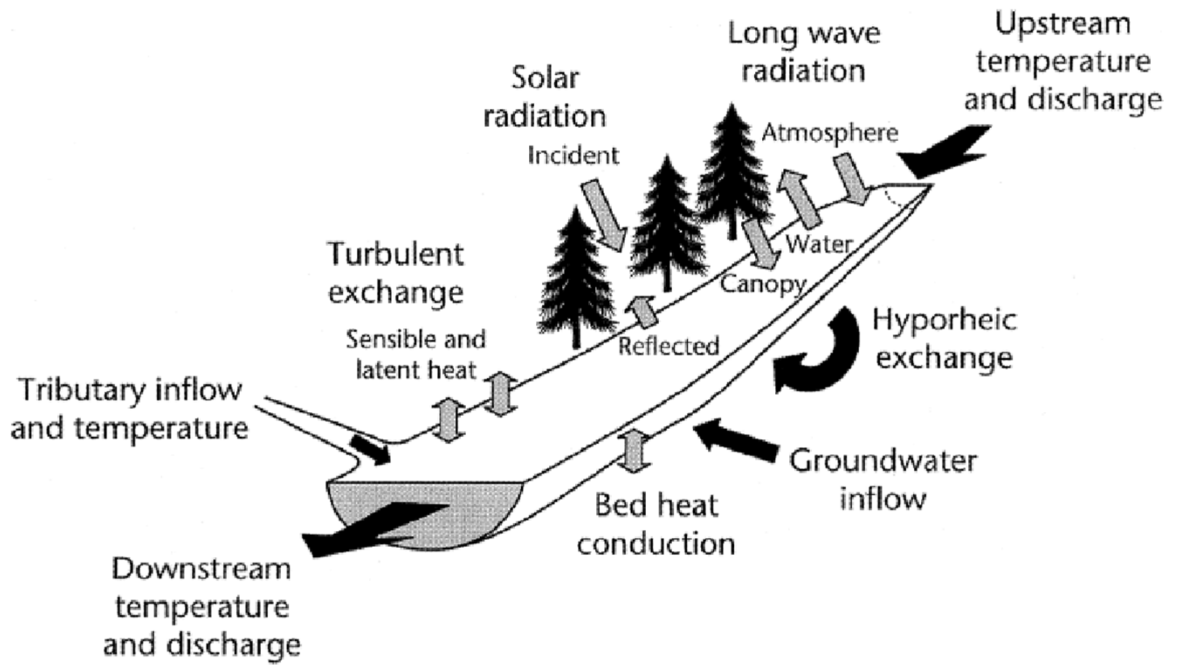
LocationID	DeployID	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ORABT001	ORABT001IN01											0.323			0.348	1.093		0.406	0.433907	
ORALS001	ORALS001IN01								0.171				0.356				0.188	0.089		
ORALS003	ORALS003IN01										0.338									
ORASH001	ORASH001IN01			-0.151	-0.061													0.294	0.31878	
ORBAD001	ORBAD001IN01						0.423	0.332												
ORBAD003	ORBAD003IN01														0.382					
ORBAD003	ORBAD003IN02																0.303	0.218		
ORBAK001	ORBAK001IN01						0.681							0.458						
ORBAR001	ORBAR001IN01											0.472	0.391							
ORBAR003	ORBAR003IN01													0.368	0.252	0.409		0.301	0.223301	
ORBDR001	ORBDR001IN01					0.283061														
ORBDR003	ORBDR003IN01														0.262	0.326				
ORBER001	ORBER001IN01				0.139	0.527268							0.147115	0.632813	0.444781	0.753148			0.286258	0.91442
ORBES001	ORBES001IN01						0.401							0.218	0.080	0.163	0.253	0.089	0.148708	
ORBLD001	ORBLD001IN01						0.388													
ORBLD003	ORBLD003IN01															0.344	0.253	0.360	0.183967	0.45841
ORBLW001	ORBLW001IN01									0.243			0.261					0.328	0.181505	0.443584
ORBLZ001	ORBLZ001IN01													0.469				0.217		
ORBRC001	ORBRC001IN01					0.227984	0.484408								0.221					
ORBRW001	ORBRW001IN01				0.548	0.496123							0.368			-0.172		0.417		
ORBUL001	ORBUL001IN01																	0.182	0.124818	0.227768
ORBUL002	ORBUL002IN01													0.348	0.364	0.452				
ORBWN001	ORBWN001IN01													0.101	0.163	0.274	0.185	0.172		

Snap-shot of Oregon sites with correlation values from 2001-2018

Green: Cool Climate
Yellow: Average Climate
Red: Warm Climate

Climate year categorization: Monthly Maximum of 7 Day Average of Daily Maximum Air Temperature, split into 3rd for 18 years

Factors associated with Thermal Sensitivity



From Moore et al. 2005

Measures of Thermal Sensitivity

- We assumed the sensitivity to be linear since the temperature range is small and looking just at August will not show inter-annual variation
- Sensitivity metrics
  - Linear regression slope
  - Pearson Correlation Coefficient
  - Spearman's Rank Correlation Coefficient
- PCA conducted, selected **Spearman's Correlation** due to least amount of assumptions and n=31

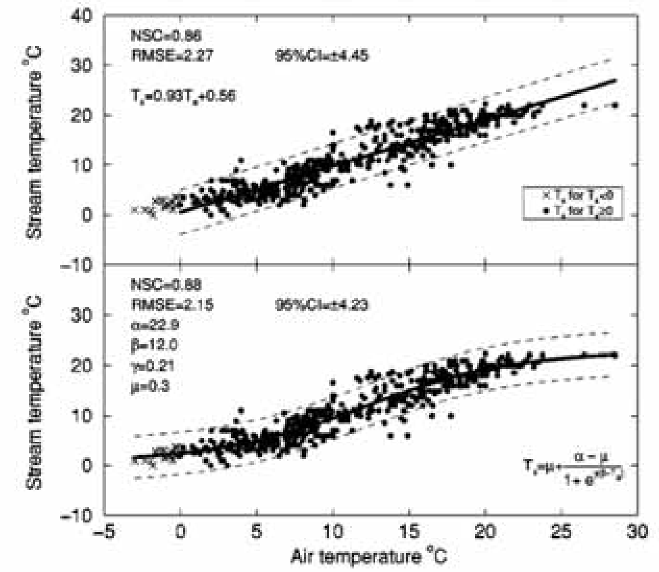


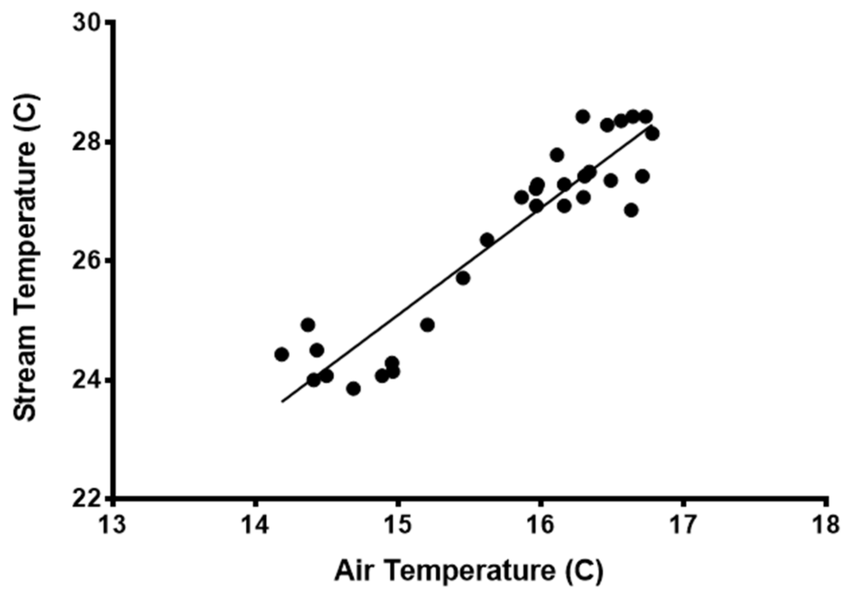
Fig. 1. Linear and nonlinear correlation plots of weekly mean air temperature and instantaneous stream temperatures for Lober River, Germany

$$T_s = \mu + \frac{\alpha - \mu}{1 + e^{\gamma(\beta - T_a)}} \quad (1)$$

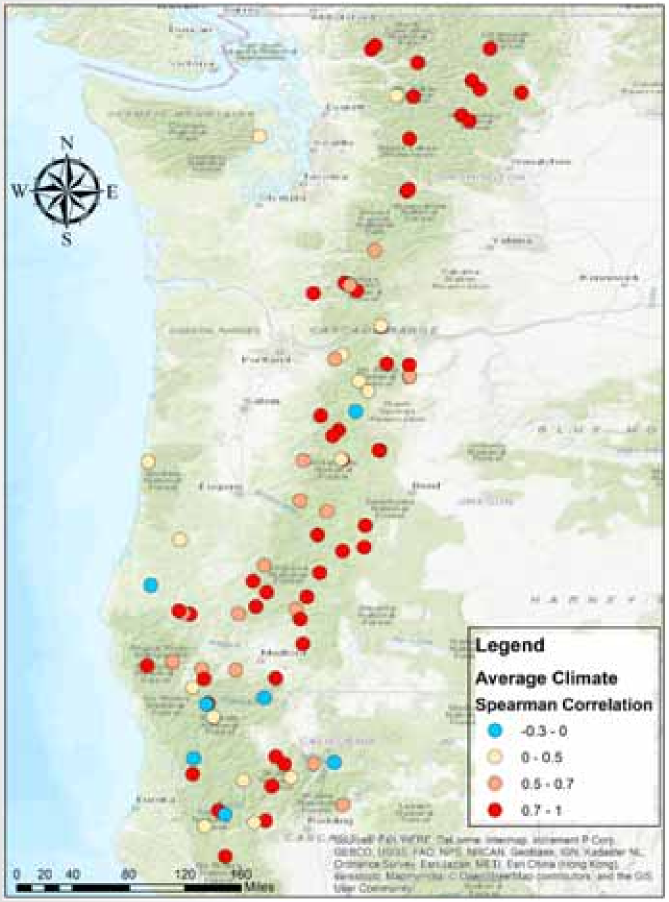
$$\alpha = \overline{T}_{s\,\max} + K_E S_{\max} \quad (2)$$

Data Processing

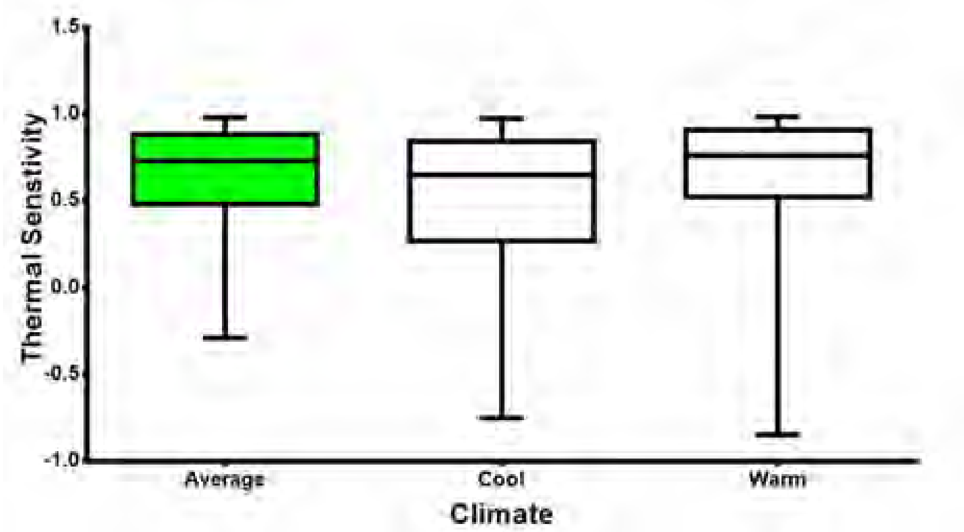
- Air Temperature
  - Daymet, 1km grid, hourly data, 7DADM of air temperature
- Stream Temperature
  - Hourly data, 7DADM of daily maximum stream temperature
- Analyzed for the month of August between 2001-2018
- Hysteretic behavior



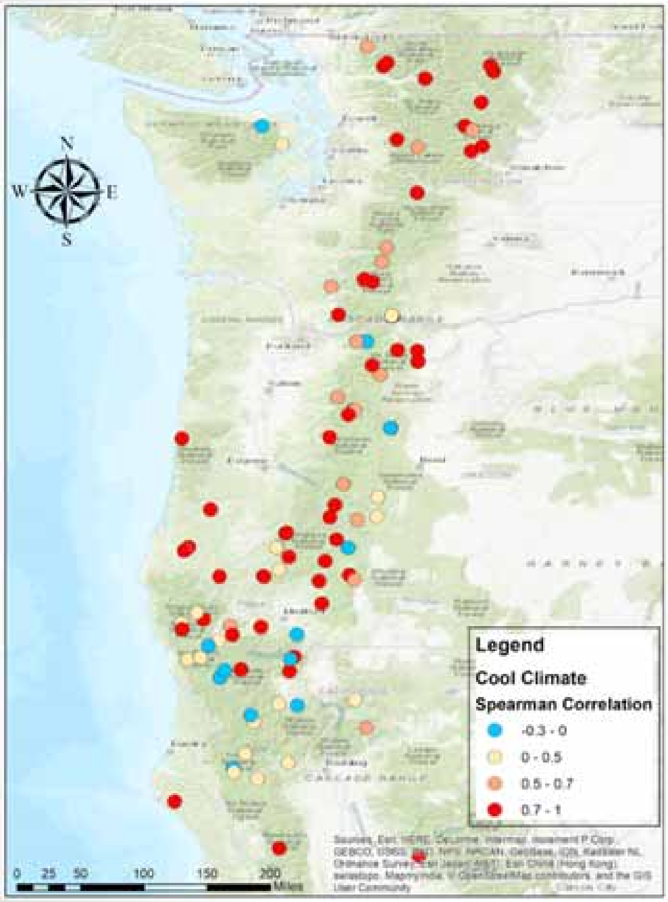
Map of Spearman Correlation during normal climate year (n=116)

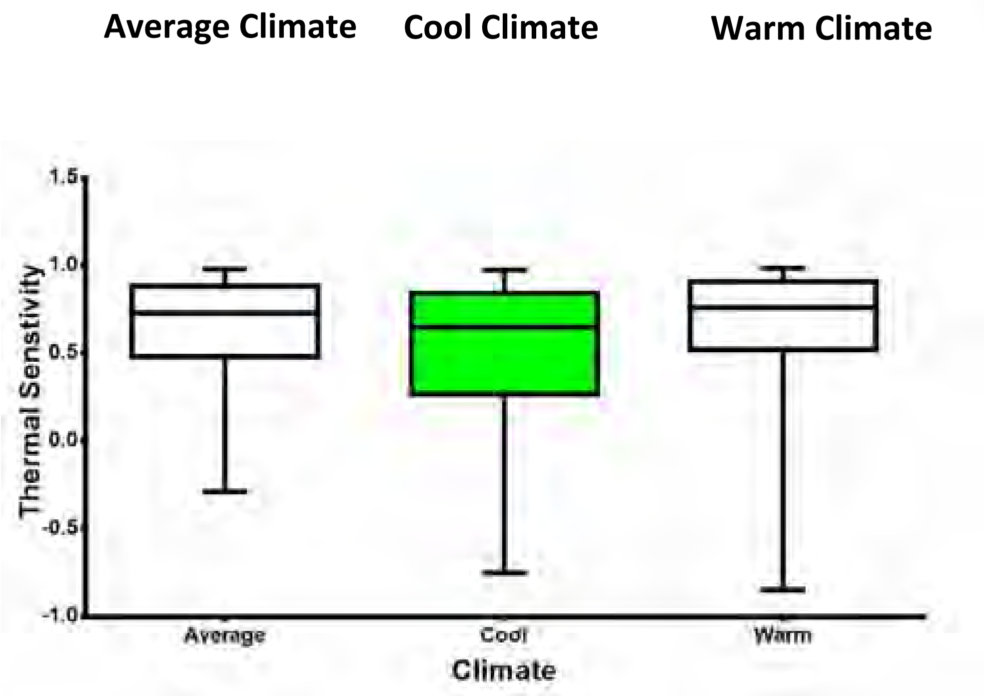


Average Climate **Cool Climate** **Warm Climate**

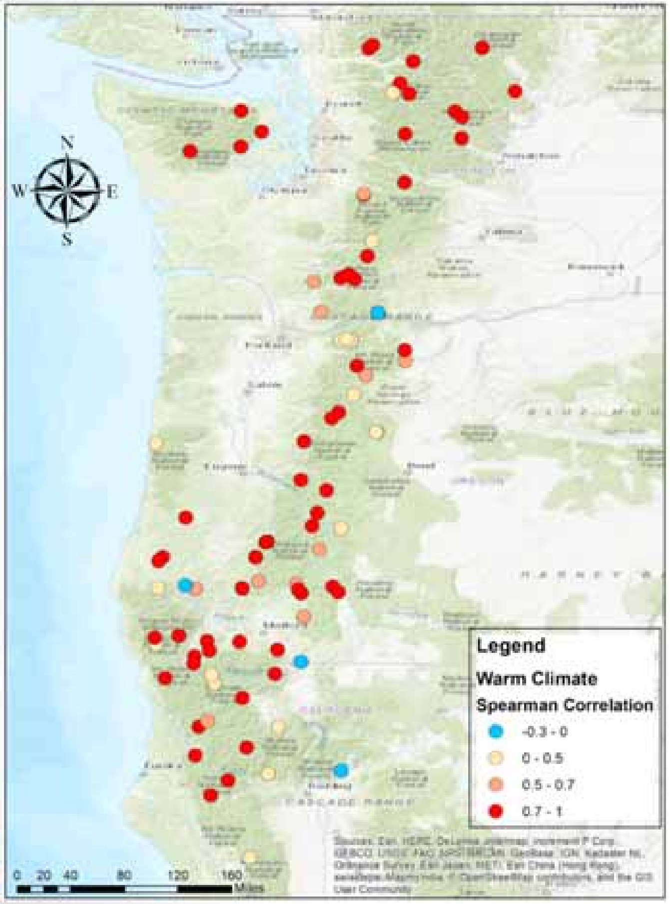


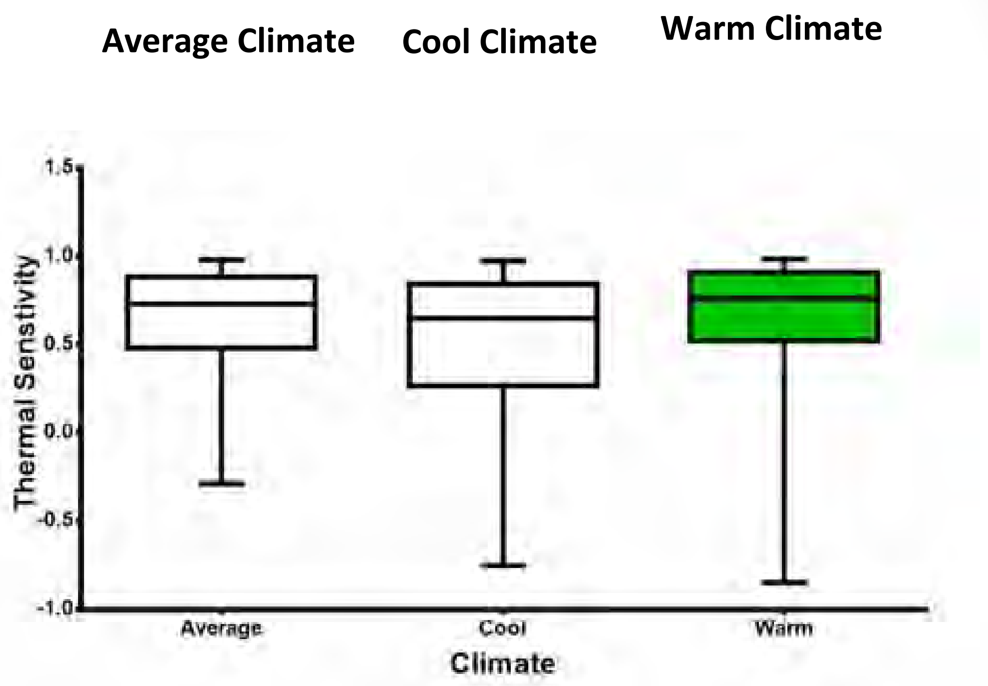
Map of Spearman Correlation during cool climate year (n=161)





Map of Spearman Correlation during warm climate year (n=137)





Conclusions and future works

- Stream temperature appears to be slightly more sensitive in warmer climate than cooler climate
  - Thermal sensitivity values showed greater variation during cool and warm climate years
  - Observed a few negative Spearman's R values, most common during cooler years in Northern California
- Next steps
  - Relate thermal sensitivity to covariates such as stream discharge, land cover/vegetation, landform, and hydrologic landscapes
  - Investigate further into negative thermal sensitivity values
  - Assign riparian risk score of exceeding thermal threshold for each watershed

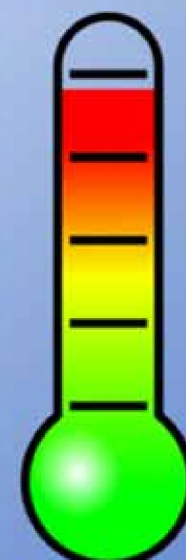
Water temperature tools: What do we have? What do we need?

Dr. Anne Timm, USDA Forest Service, Northern Research Station

Society of Freshwater Science, PNW Meeting, November 7, 2019

Overview of talk:

- Thermal habitat connectivity and stream temperature
- How tools are applied to quantify spatial and temporal variability
- Challenges for quantifying urban stream thermal regime
- Ideas for further research needs



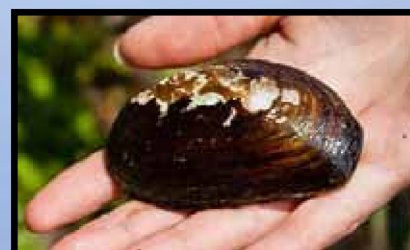
Temperature tolerance: (varies by species)

- Trout, stress at 21-22°C (Herb et al. 2010); critical thermal maximum (CMT), 28-30°C (Wehrly et al. 2010)

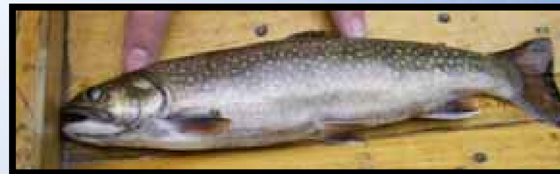
- Freshwater mussels, CMT from 39.5°C to 42.7°C (Galbraith et al. 2012)

Brook floater (39.5°C)

Creeper (40.0°C)

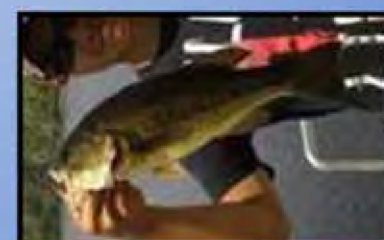


Eastern eliptio (42.7°C)



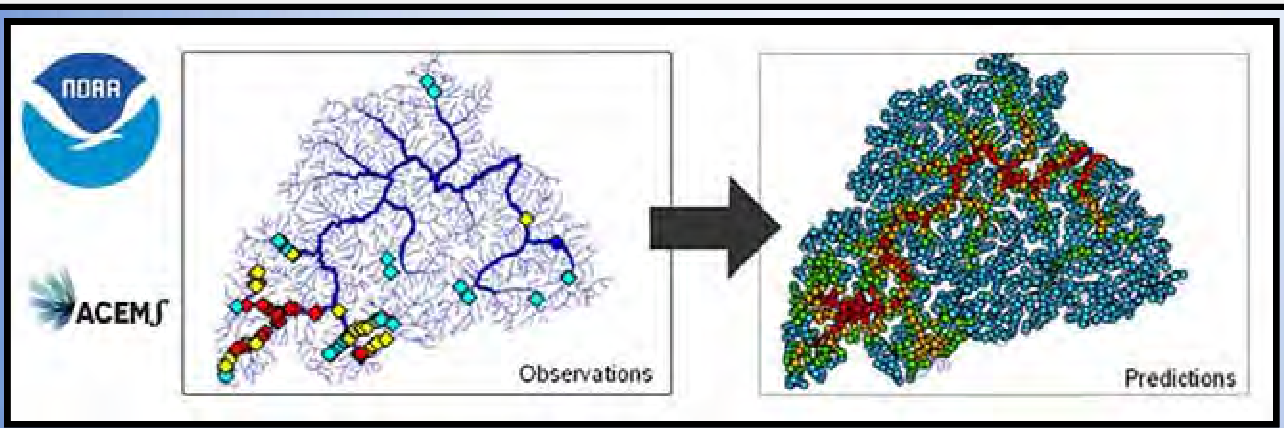
Coldwater (≤ 24.3°C)

Coolwater (26.5-29.9°C)



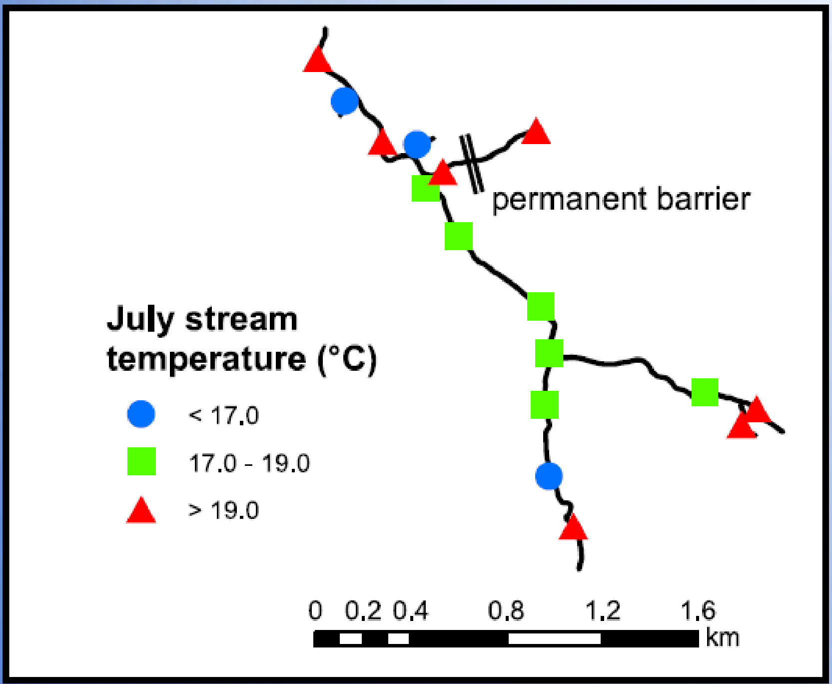
Warmwater (≥30°C)

Why do we need tools to quantify stream temperature?

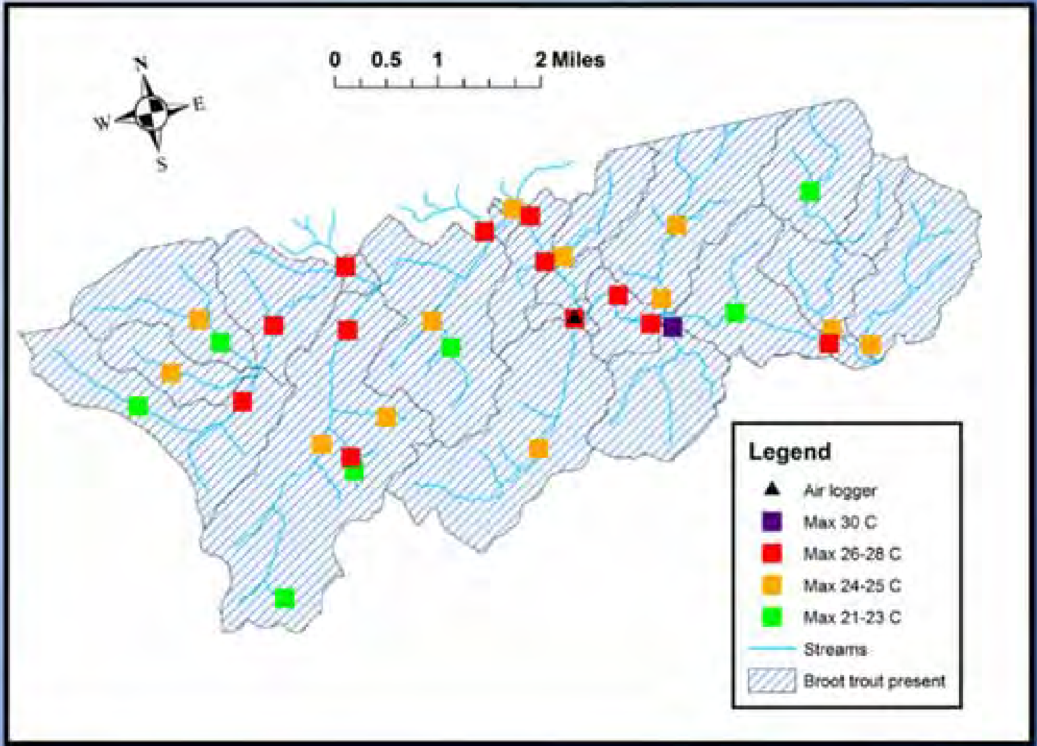


- Clean Water Act TMDLs for temperature, Endangered Species Act
- Effectiveness monitoring for management and restoration
- Long-term conservation planning to maintain thermal heterogeneity
- Identify coldwater patches, or refugia for periods of thermal stress (Torgersen et al. 1999; Ebersole 2001, 2003)

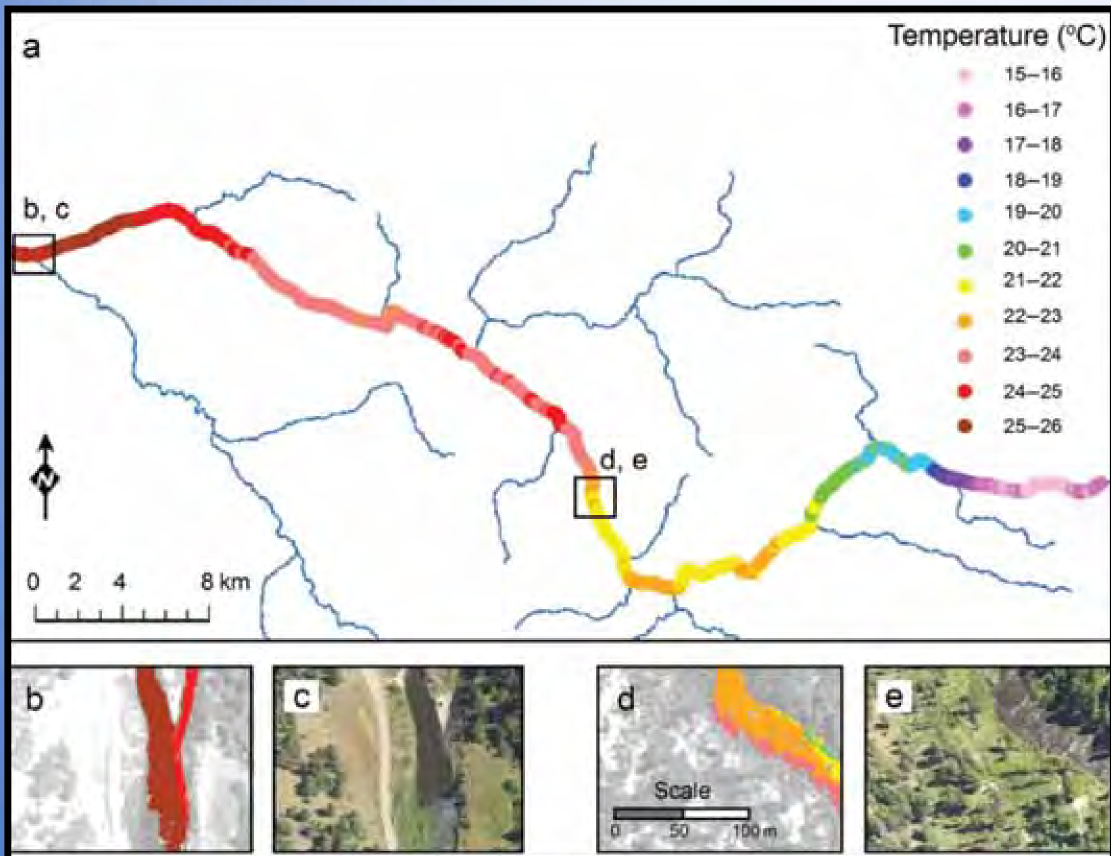
Thermal connectivity and spatial scale:



Kanno et al. 2014 *River Research & Applications*, Vol 30, Pages 745-755



Stream temperature (spatial):

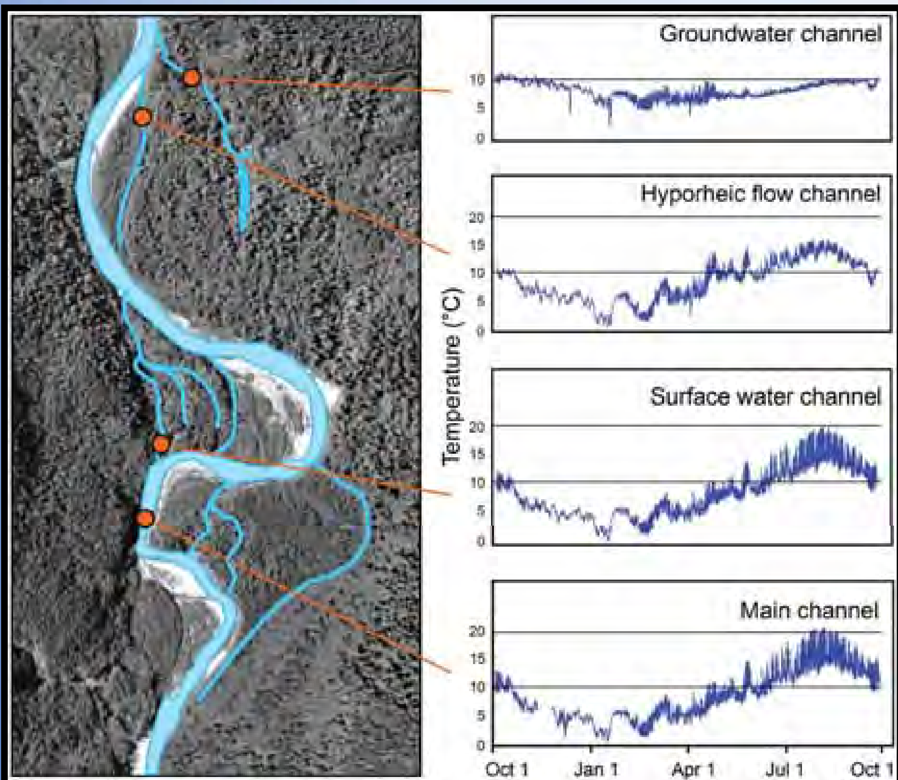


- **Climate and local weather**
- **Land cover, riparian**

- **Tributaries (b)**
- **Groundwater seeps (d)**
- **Vegetation (c, e)**

Steel et al. 2017 *BioScience*, Volume 67, Pages 506–522

Stream temperature (temporal):



- **Weather and seasonal climate**
- **Snow driven systems, drought, summer month heat stress**

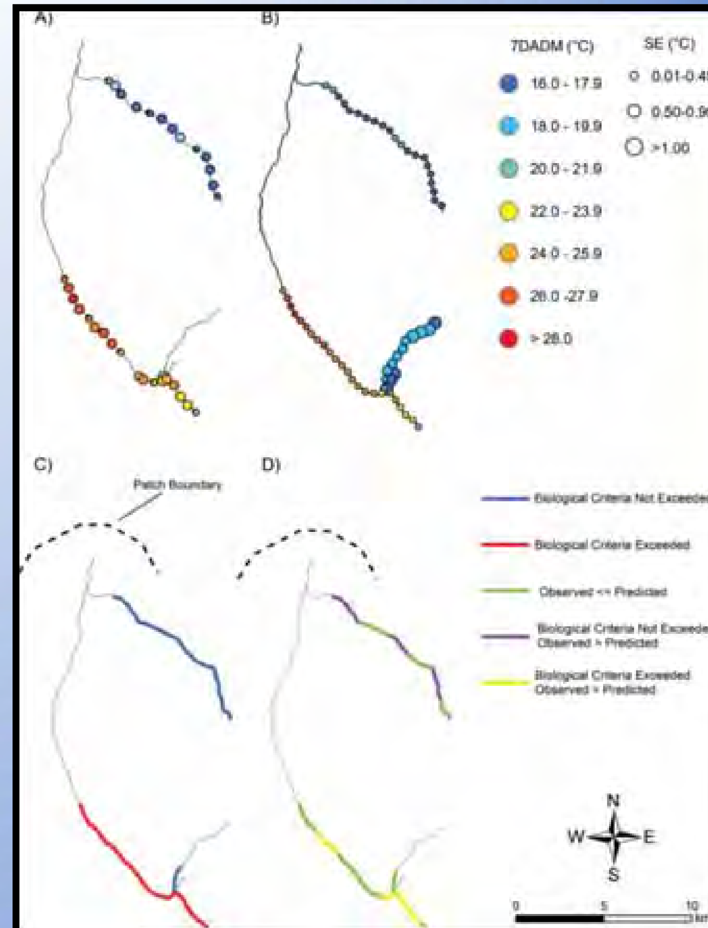
Annual data:

- **Seasonal patterns**
- **Diel patterns**
- **Lateral relationships**

Steel et al. 2017 *BioScience*, Volume 67, Pages 506–522

Spatial Stream Network Model (SSNM):

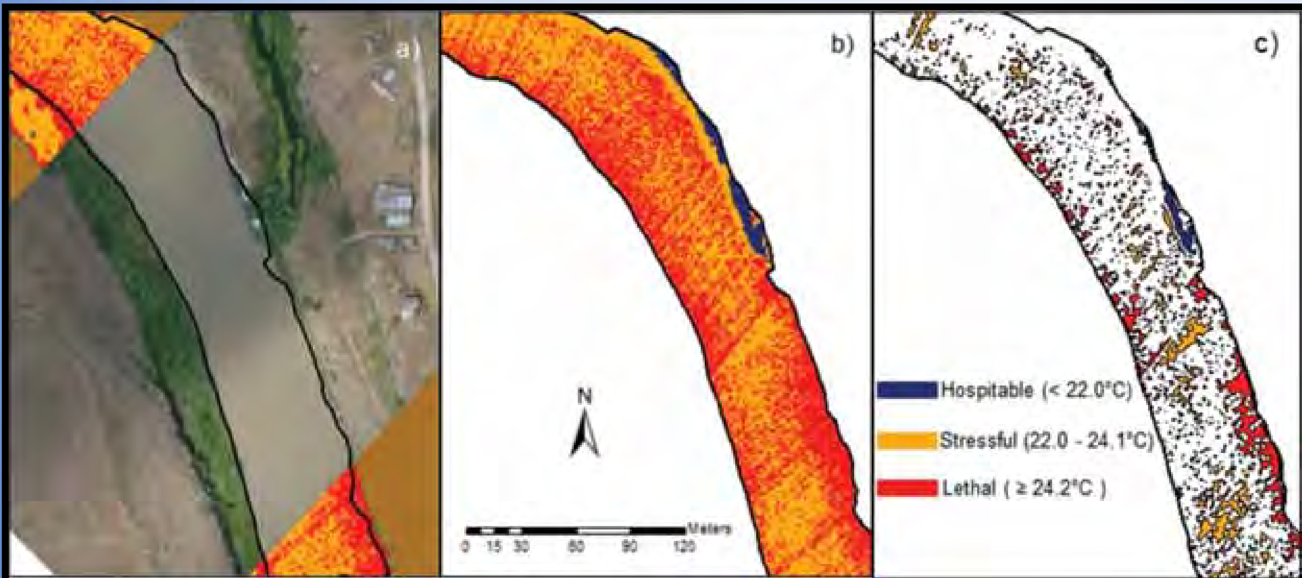
- **7 day moving average, daily max (7DADM)**
- **Observed (a); predicted (b) every 0.5 km**
- **Reaches categorized for exceedance criteria**



STARS ArcGIS tool, calculates spatial information for spatial statistical models at stream network scale (Peterson and Ver Hoef 2014)

Falke et al. 2016. A Simple prioritization tool to diagnose impairment of stream temperature. North American Journal of Fisheries Management 36: 147-160.

Airborne thermal infrared imagery (TIR) remote sensing:

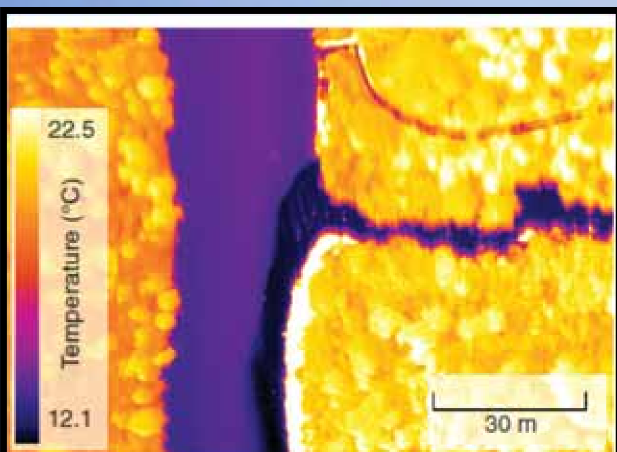


Hillard and Keeley (2012) *Transactions of the AFS*, Vol. 141, Pages 1649-1663, (Bonneville Cutthroat Trout)

Torgersen et al. 2012

- **Spatial mapping**
- **Raster, high resolution (0.9 m^2)**

TIR to identify CW Refugia:

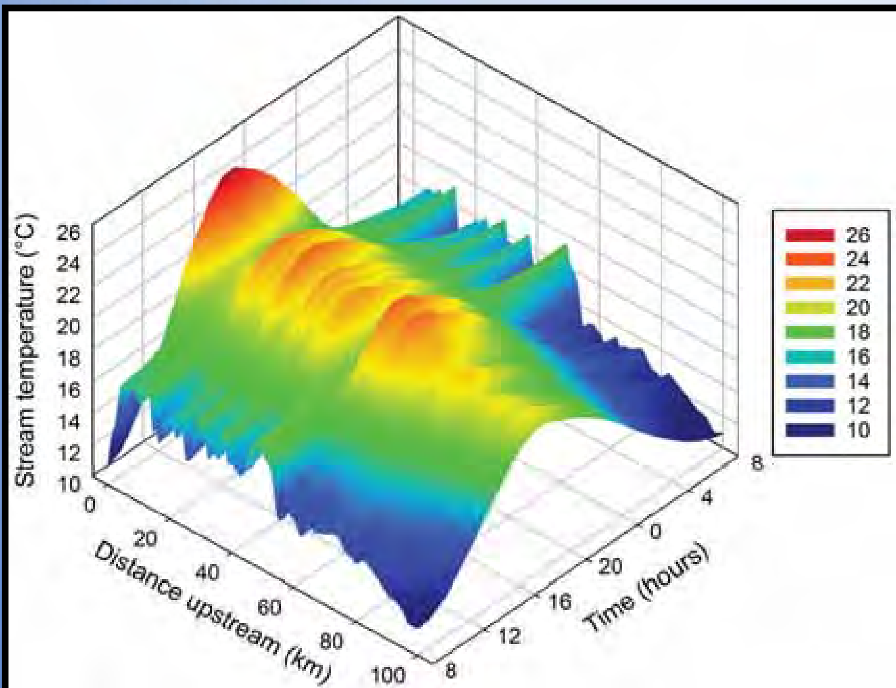


Dugdale et al. 2016

≥ 3 °C colder, coldwater patches or refugia (Ebersole et al. 2001, 2003; Torgersen et al. 1999, 2012)

Side channels, groundwater seeps

Combining stationary loggers and TIR:



Daily maximum and minimum had greatest spatial variability

Steel et al. 2017 *BioScience*, Volume 67, Pages 506–522 (modified from Vatland et al. 2015)

Urban stream Syndrome (Walsh et al. 2005)

Human-made structures and thermal regimes

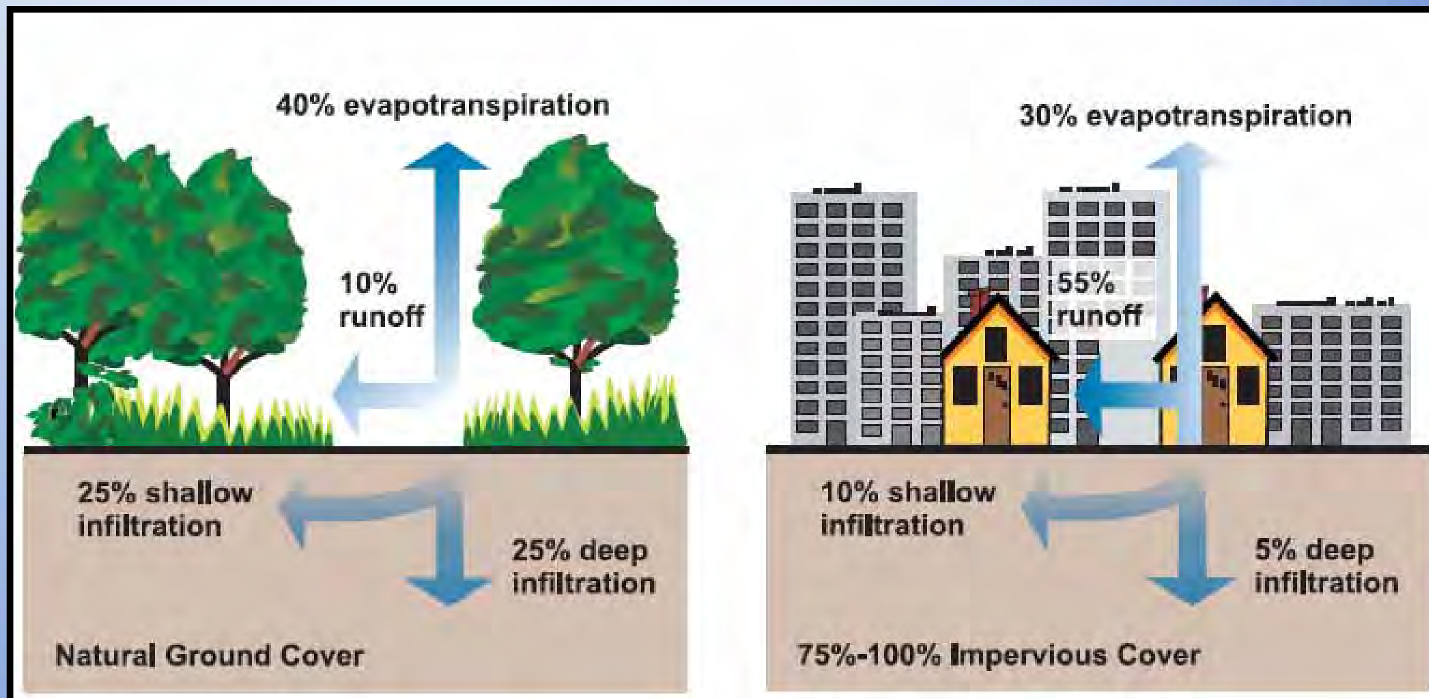
Hydrology and thermal drivers? Aquatic species?

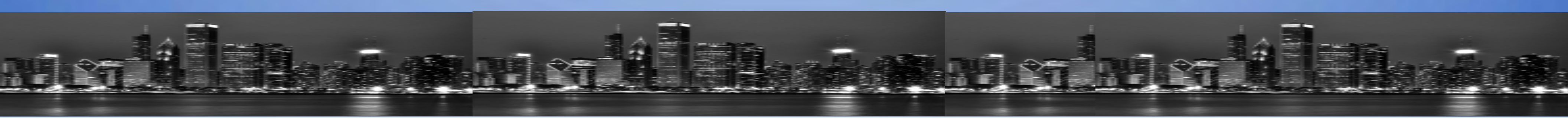
Increase in 1% impervious in watershed = 0.25 °C increase (Pluhowski 1970)

Stormwater and infiltration:

- Impervious cover
  - Parking
  - Building
  - Road

↳ Modification of surface runoff





Thermal regime and effective impervious (Walsh et al. 2005)

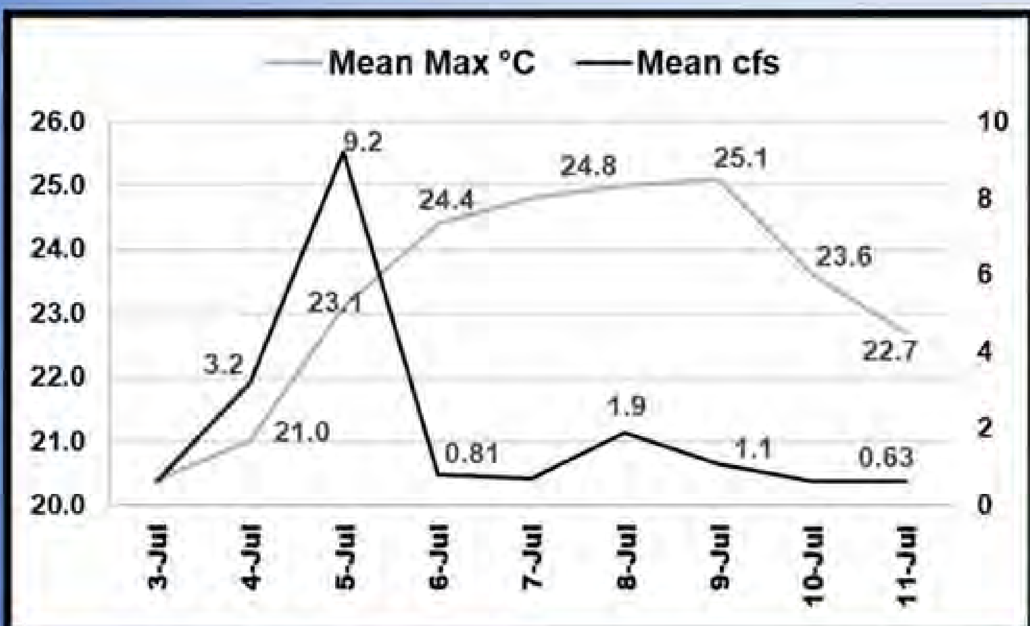
Seattle, WA (Phuong Le photo)

8-10% EI (Wang et al. 2001)
2% EI (Wenger et al. 2008)

Esteban Camacho Steffensen, Springfield, OR Upstream Art Project

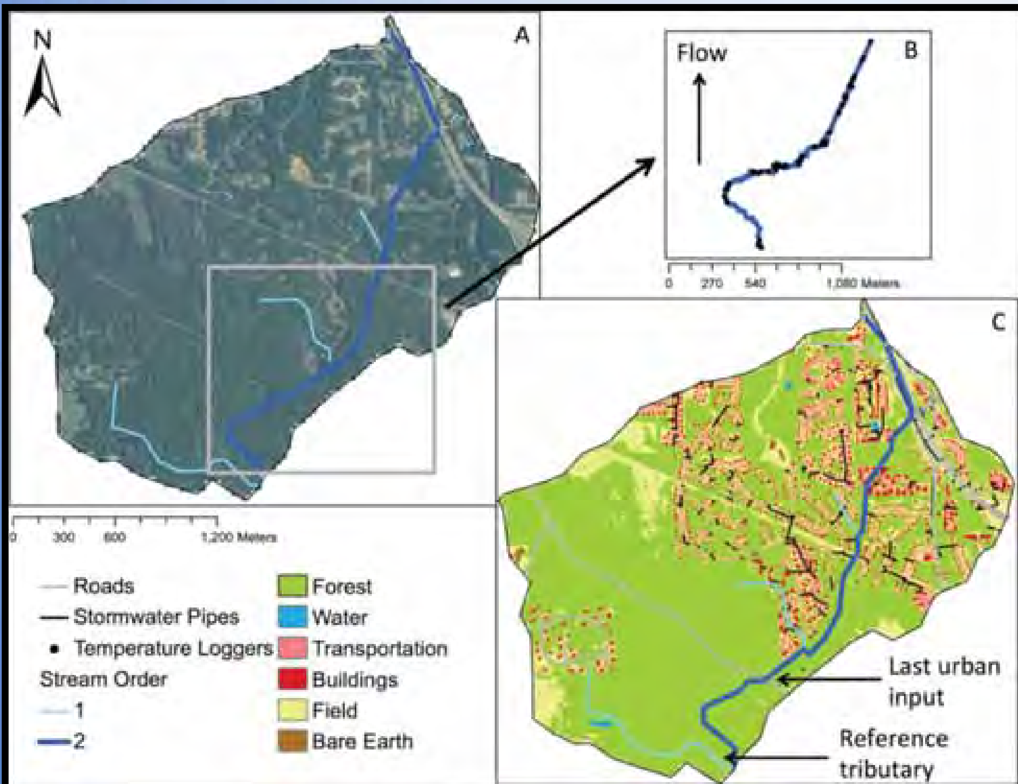
Potential Mechanisms (Temperature):

- Thermal fluxes, greater frequency and extended elevated temperature
- Avg. summer thermal surges 3.5 °C in 30 minutes, 3 hour dissipation; >7°C max temperature increase, 7 hour duration (Nelson and Palmer 2007)



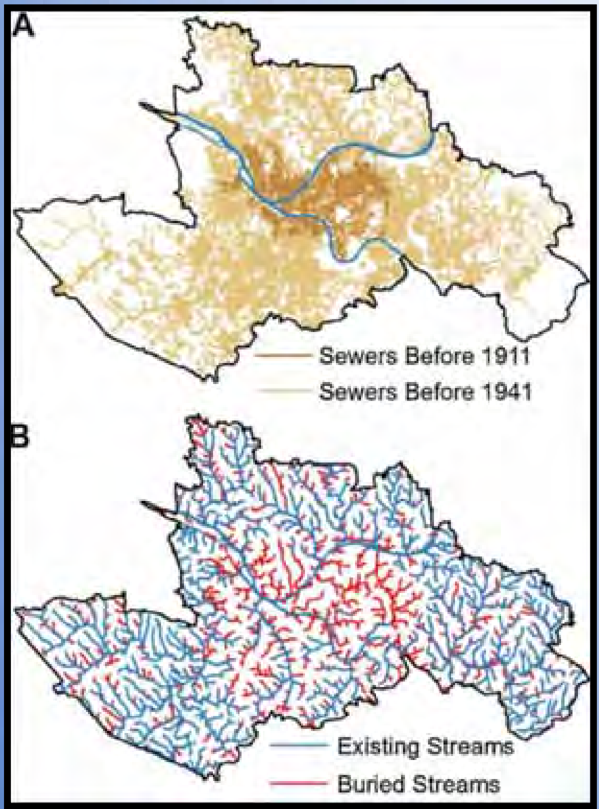
USGS Gage, Scotts Level Branch, July 2016 (8.37 km^2 gage; loggershed 33% impervious)

Somers et al. (2016)- heat pulse distance



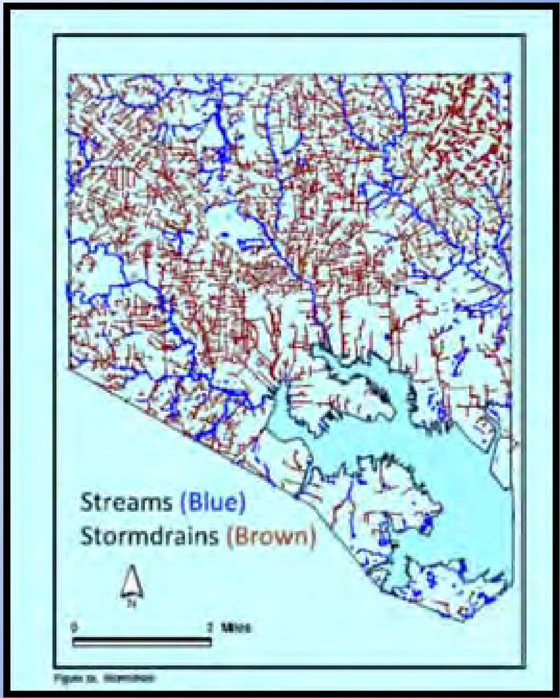
- 11% impervious
- >1 °C heat pulses, 42 of 54 storms (78%)
- 11 storms, 1 km downstream
- Mapped SW outlets, streams in municipal boundary (38 of 40 km within 1 km)

Conversion of headwater streams to pipes and thermal regime:

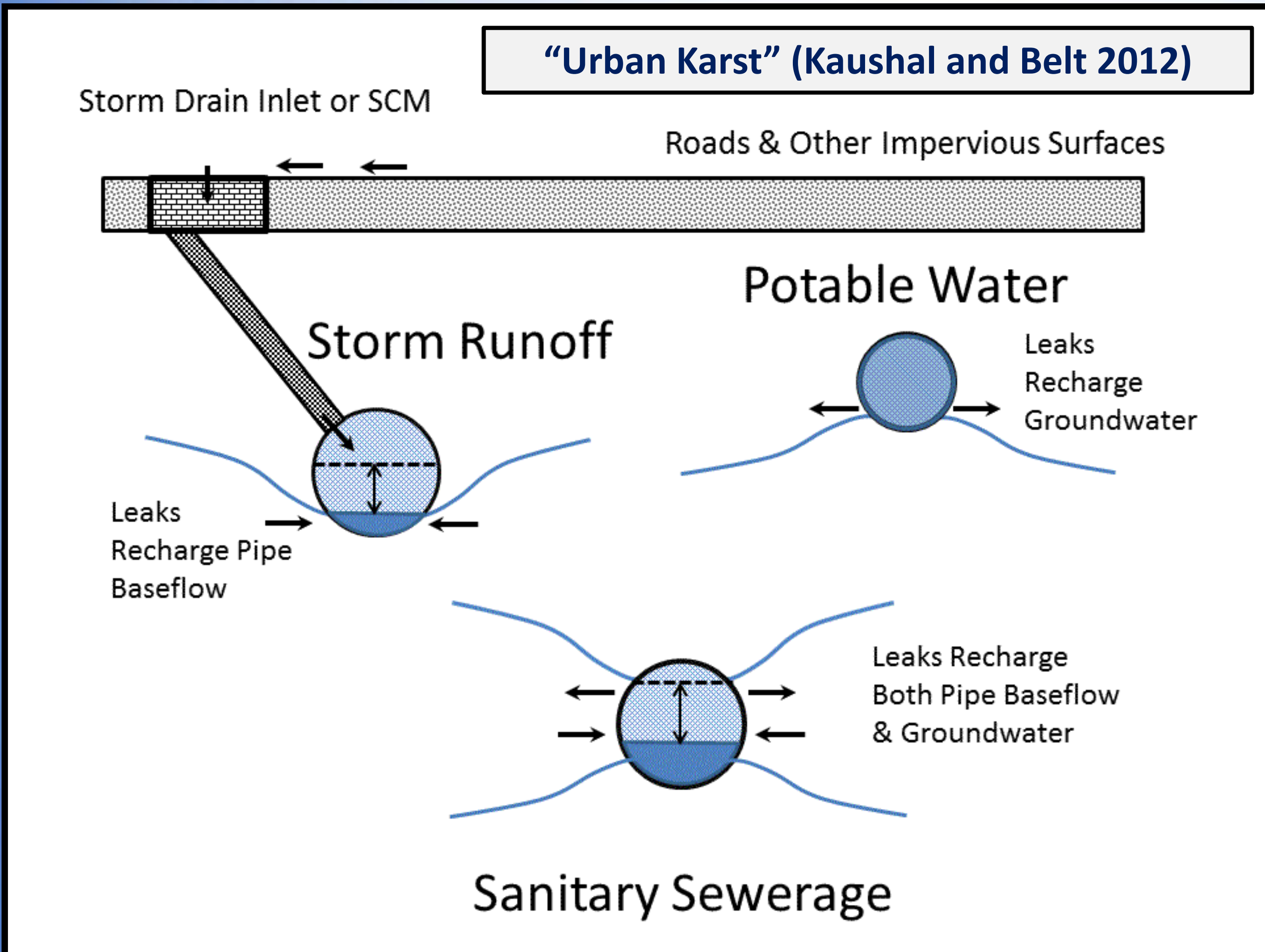


Pittsburgh, PA – 41% burial (Hopkins and Bain 2018)

Baltimore City (Ken Belt)



Baltimore, MD – 66% burial (Elmore and Kaushal 2008; Kaushal and Belt 2012)



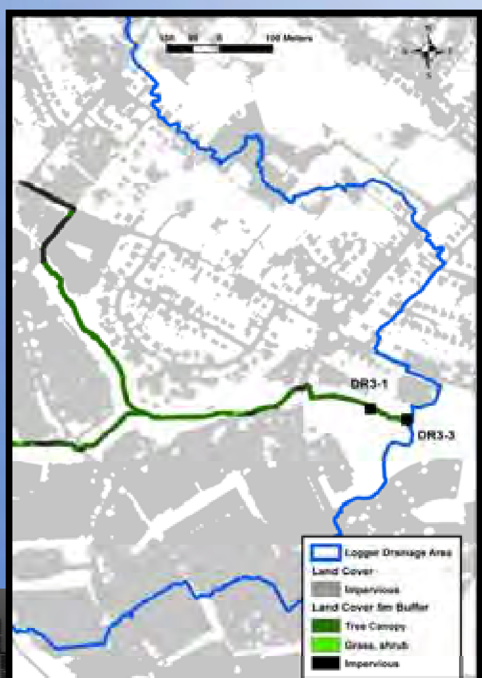
Buried stream baseflow, interactions with GW

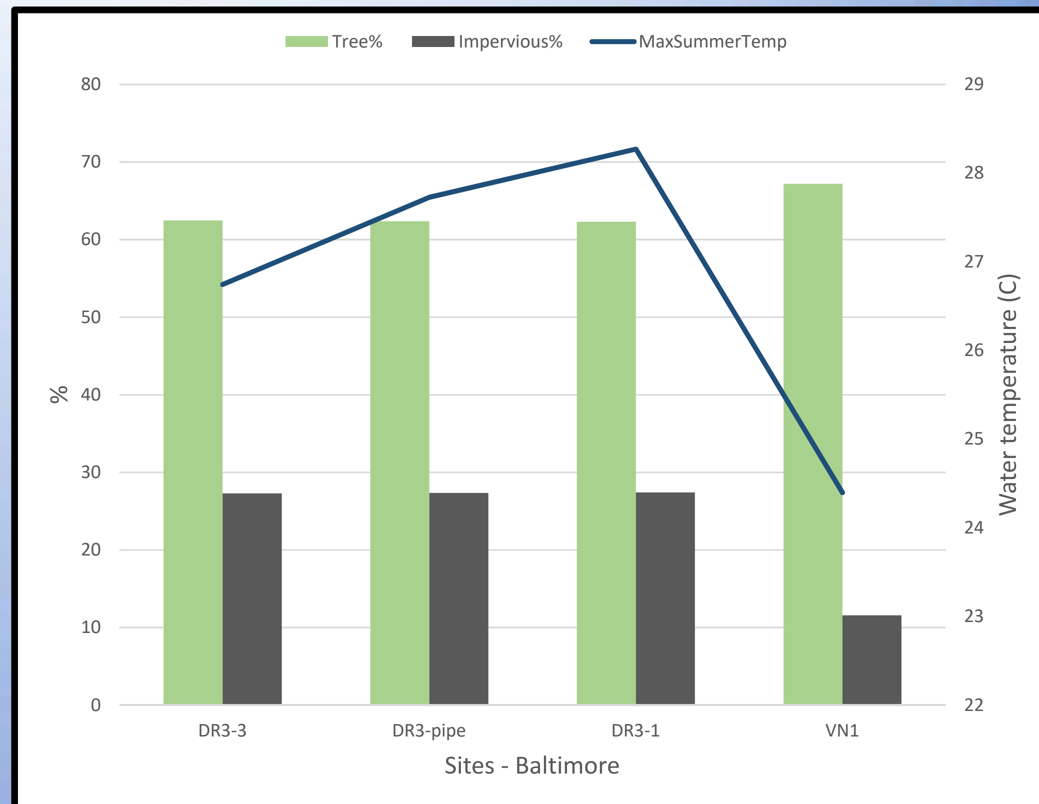
-20-30% leaks Potable (Garcia-Fresca 2007)

-65% avg flow volume from leaky sewer pipes, Gwynns Falls, Baltimore

Urban drivers – results: pipes

- **Summer max warmer or cooler depending on pipes, GW**
- **Daily variation 2 °C (4 °C others)**

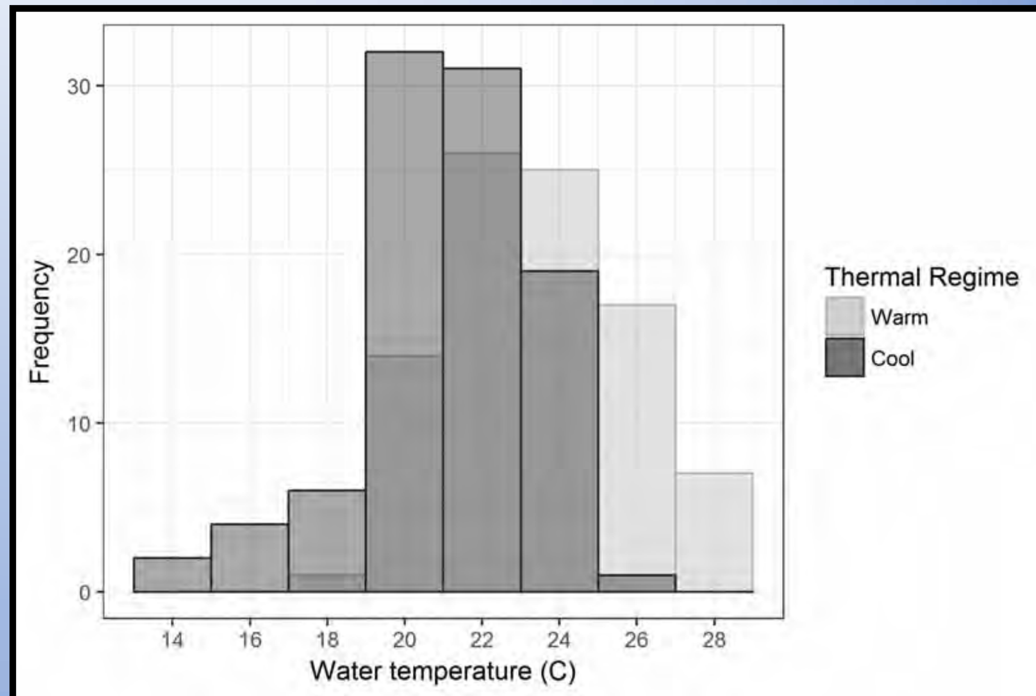


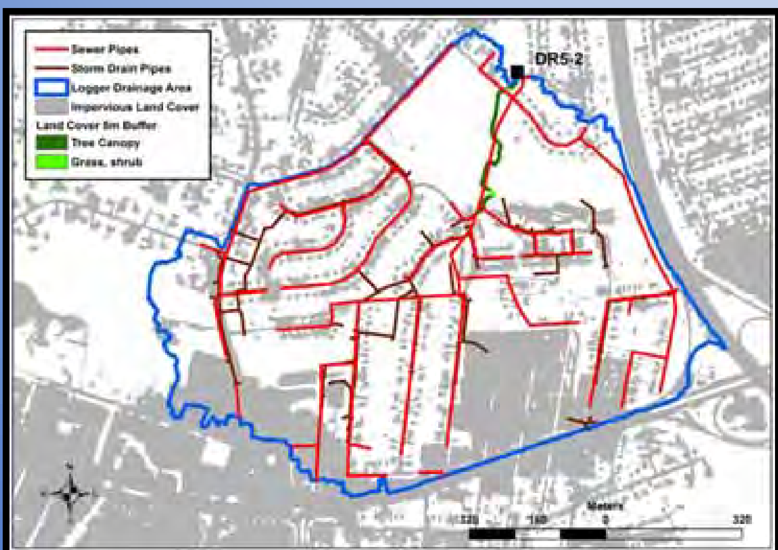


Sites	Storm drain pipe (m)	Stream length (m)	Pipe/stream
DR5	5269	1569	3.36

‘Warm’ minimum:

-daily, minimum less variation, not as cold at night





Data to quantify urban thermal regime?

- How does stream temperature change depending on percent headwater burial, pipe to stream ratio in urban catchments?

- Stream temperature: Annual variation; US and DS of SW outfalls
- Peak flow (magnitude, frequency), thermal surge
- Groundwater flow
- Infrastructure: Effective impervious, pipe network density, % HW burial

Acknowledgements:

Dede Olson, US Forest Service PNW Research Station

Valerie Ouellet, Danny Croghan, David Hannah - University of Birmingham, Edgbaston, Birmingham, UK

Melinda Daniels - Stroud Water Research Center, Avondale, PA

QUESTIONS??

O. Ponce, C. Plybon, M. Bailey, T. Ratliff, T. Vinson, Newport Aquarium

Anne Timm
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Linking variables across different scales in river macrosystems research: a graph-based theoretical approach

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Rhithron Associates Inc & Division of Biological Sciences, University of Montana

Sally Clark

Department of Mathematics, University of Alabama

Marcella Jurotich

Department of Geology, Carleton College

Jon Gelhaus

Department of Biodiversity, Earth and Environmental Science, The Academy of Natural Sciences of Drexel University

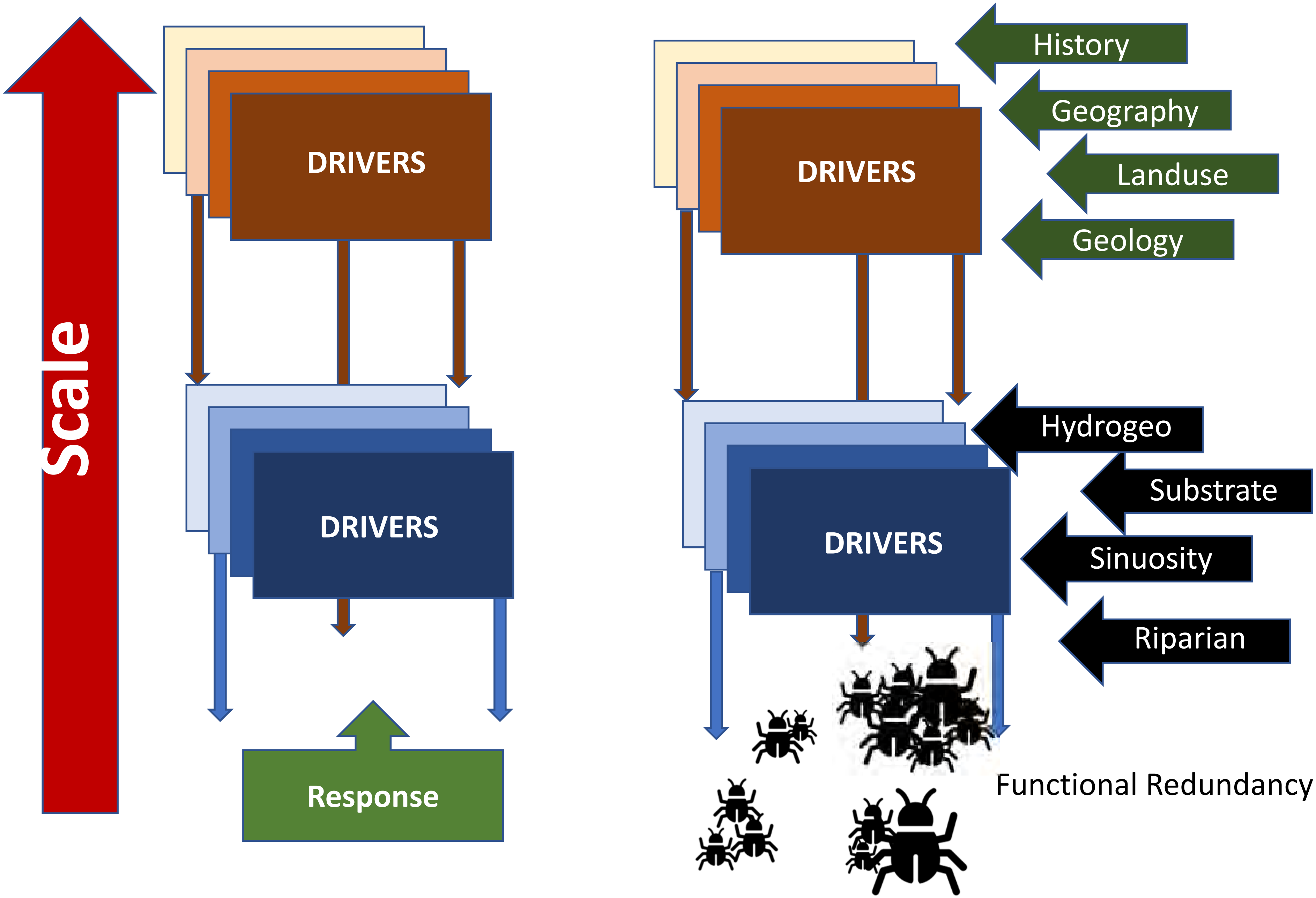
Macrosystems

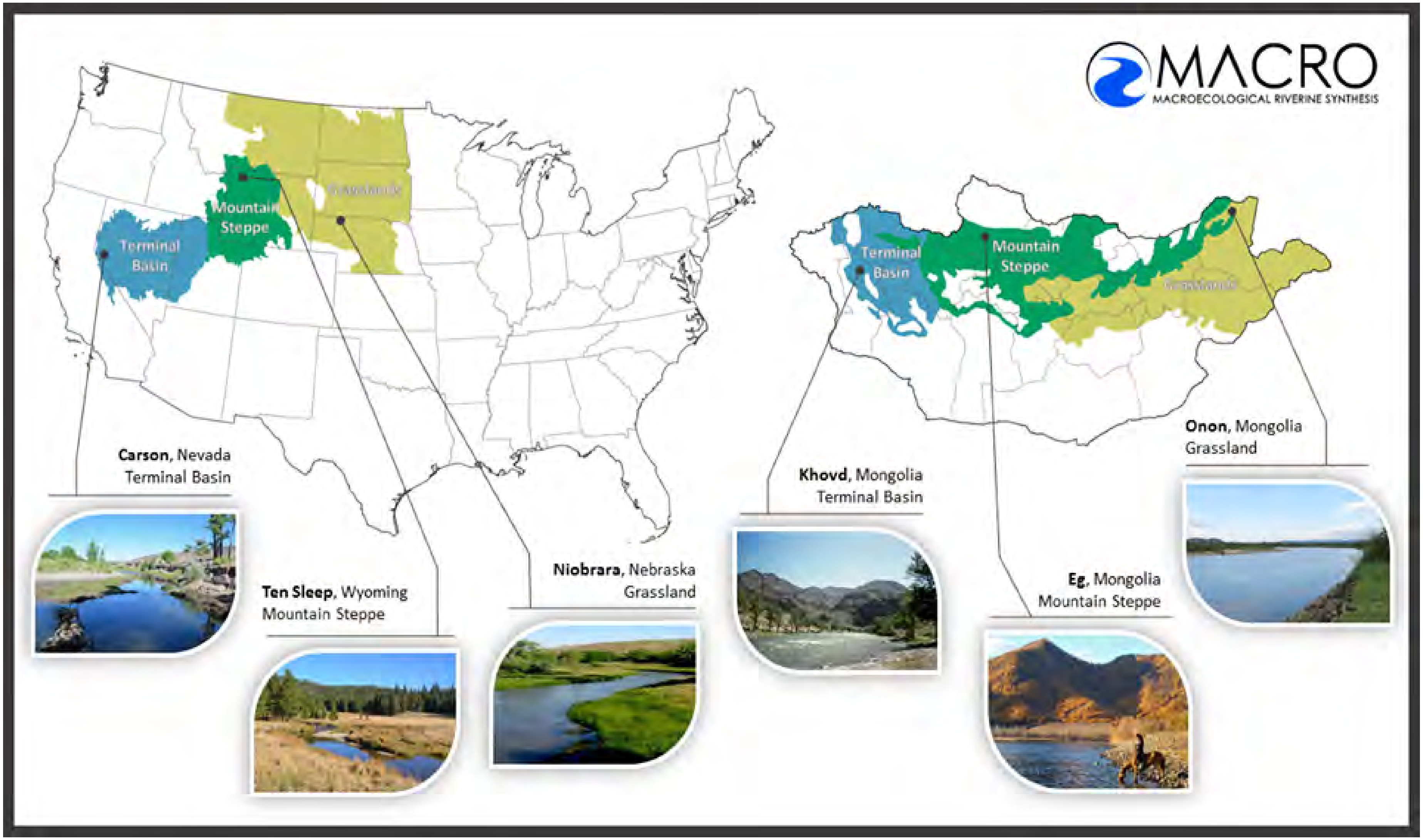
- Macroecosystems research is used to ask questions about **<u>stream ecosystem function across large spatial scales</u>**
- Study over broad spatial scales = $>10^2$ km^2

- And/or temporal scales =over decades to millennia (Thorp 2014)
- Inherently hierarchical
- Useful for natural resource management:
  - Complex features of watersheds
  - Downstream impacts of upstream land uses.
  - Large to small scales

Macrosystems

Modelled after Soranno et al. 2014





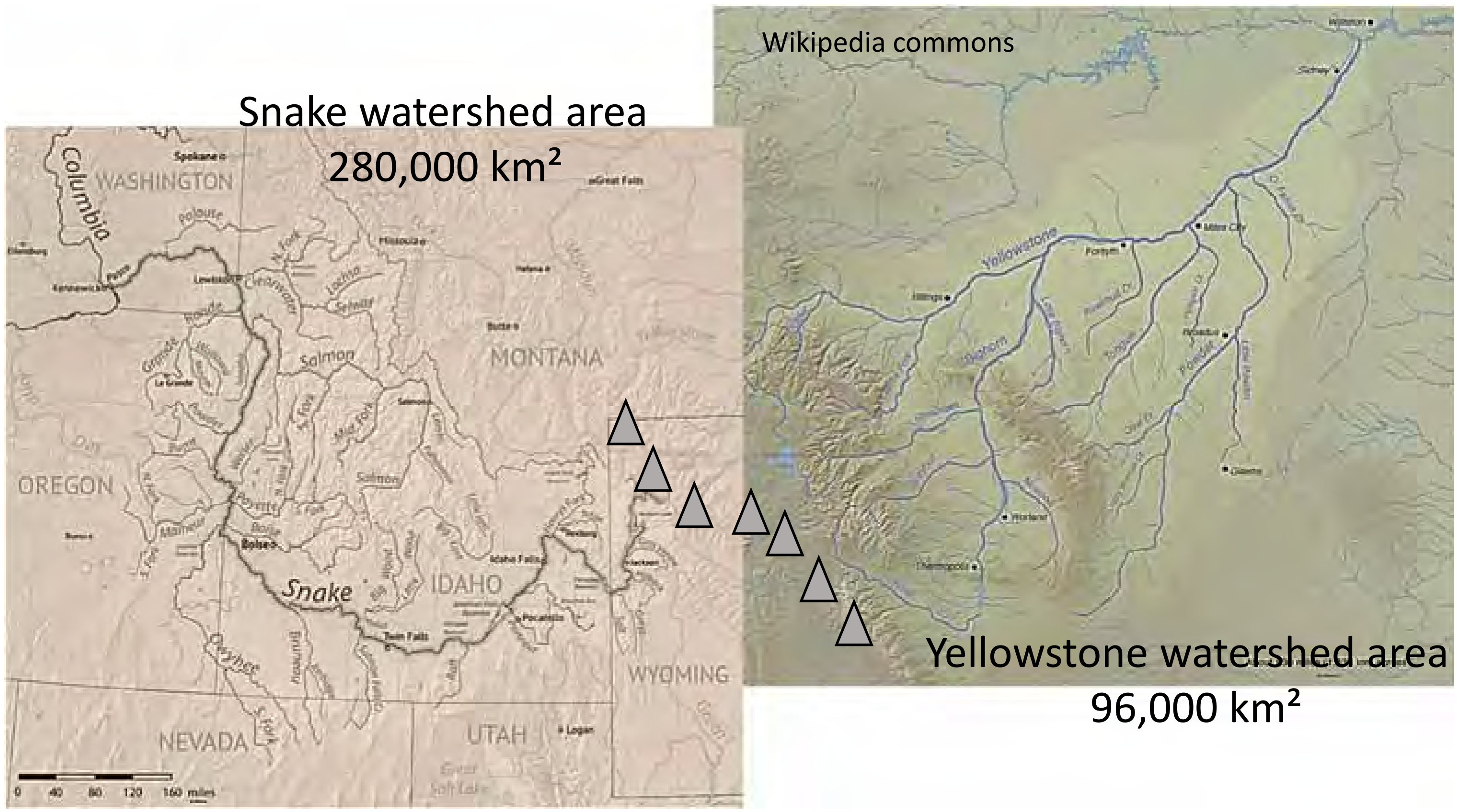
MACRORIVERS

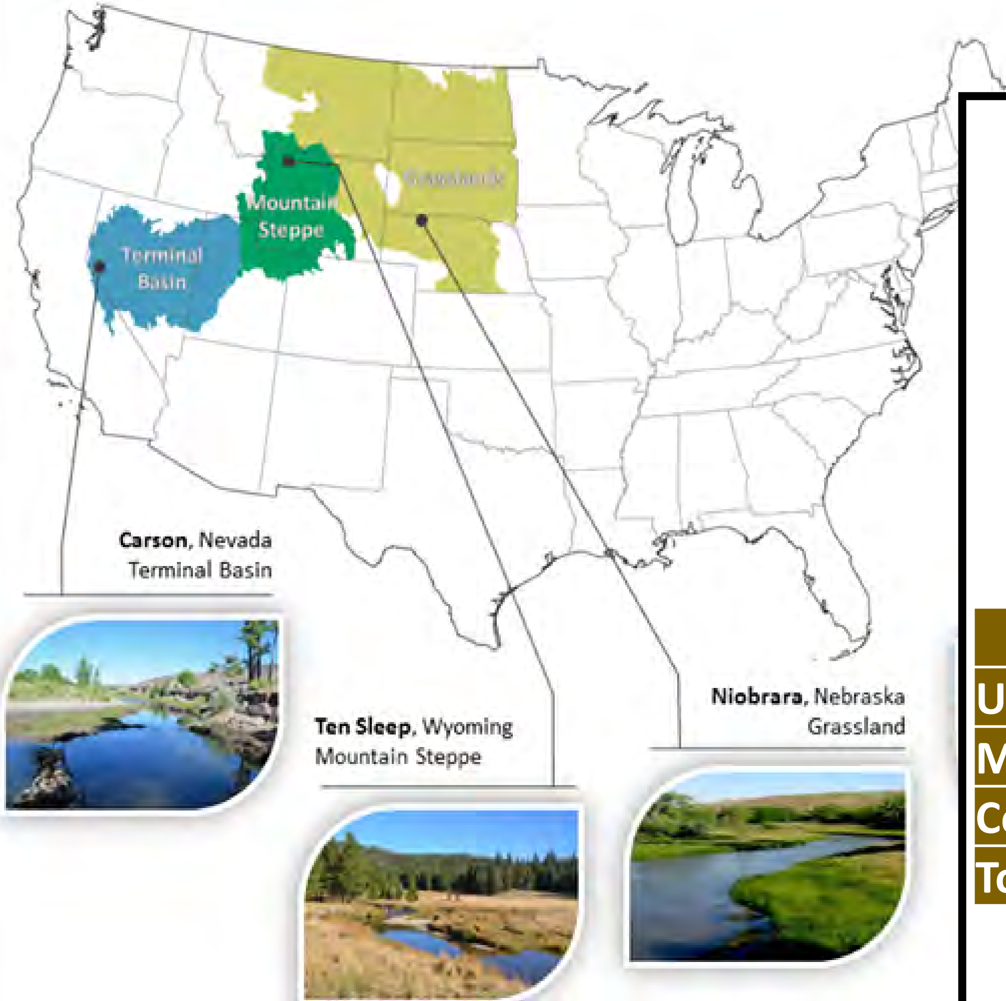
Objectives

- To explore the use a graph-based theoretical approach in linking environmental variables at different scales to functional trait diversity

- **METHODS**: Data were retrieved from the National Rivers and Streams Assessment (NRSA)
- Data were compiled from 2000-2004 and the 2008, 2009 sampling seasons
- Once compiled data were reviewed, 10% of sites/site data were compared to original dataset for QC.

- Data from the Yellowstone and Snake River watersheds were selected for this study.
- Data on geology were retrieved from USGS geology maps for the watersheds.





Site selection

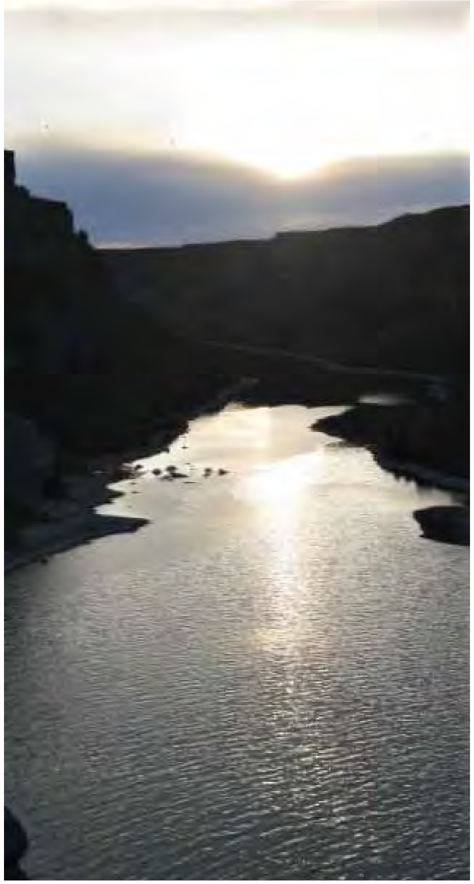
Related to other studies in the MACRO rivers project

Mountain Steppe (MS)	**Yellowstone**
	Snake

Removed sites that:	
Urban	**NRSA**
Most impacted	**NRSA**
Center Pivot	**Google Pro**
Towns	**Google Pro**

Functional Traits

- Genus level identification
- Assigned trait scores using fuzzy coding
  - (Chevenet 1994, Maasri and Gelhaus 2012)
- Final list of 28 functional traits
- Functional redundancy calculated as simple relative richness




Regressions

Model building

- 25 continuous variables
- Transformed by natural log if necessary
- 4 categorical variables
- Used robust multiple regression to select variables to create final regression models.

Model building

- Final regressions used forward selection with switching to remove highly correlated variables.
- Model constrained to 7 variables to avoid over inflating R^2 while retaining predictive power.

Model R^2 = 0.70,
Adjusted R^2 = 0.59

Percent sand or smaller substrate (-)

Geology*

Latitude (-)

Elevation (-)

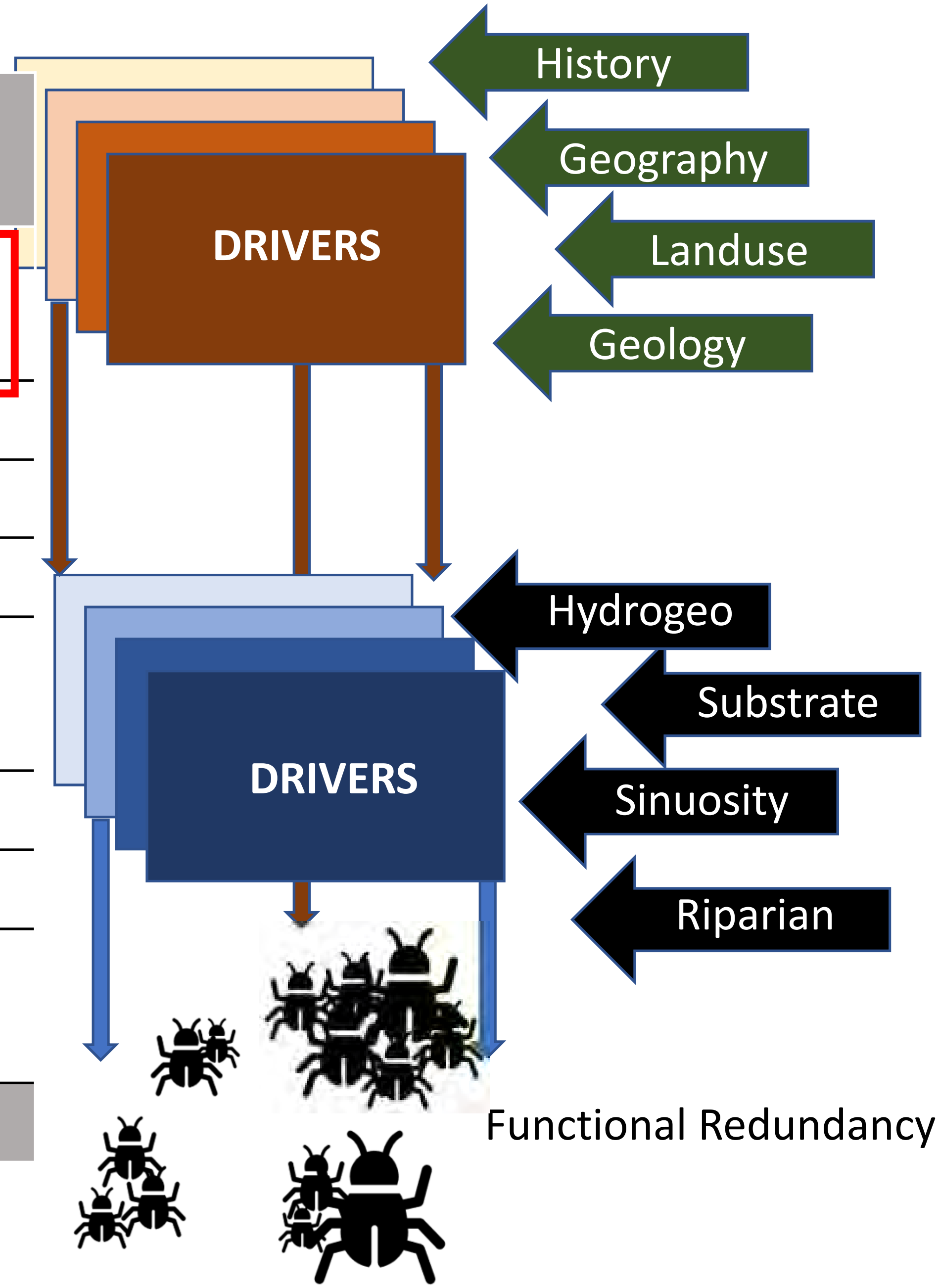
Percent bare ground (-)

Percent Pool (+)

Watershed Area (-)

Percent wetted width (+)

*Permian Metam



Model R^2 = 0.70,
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Percent Pool (+)

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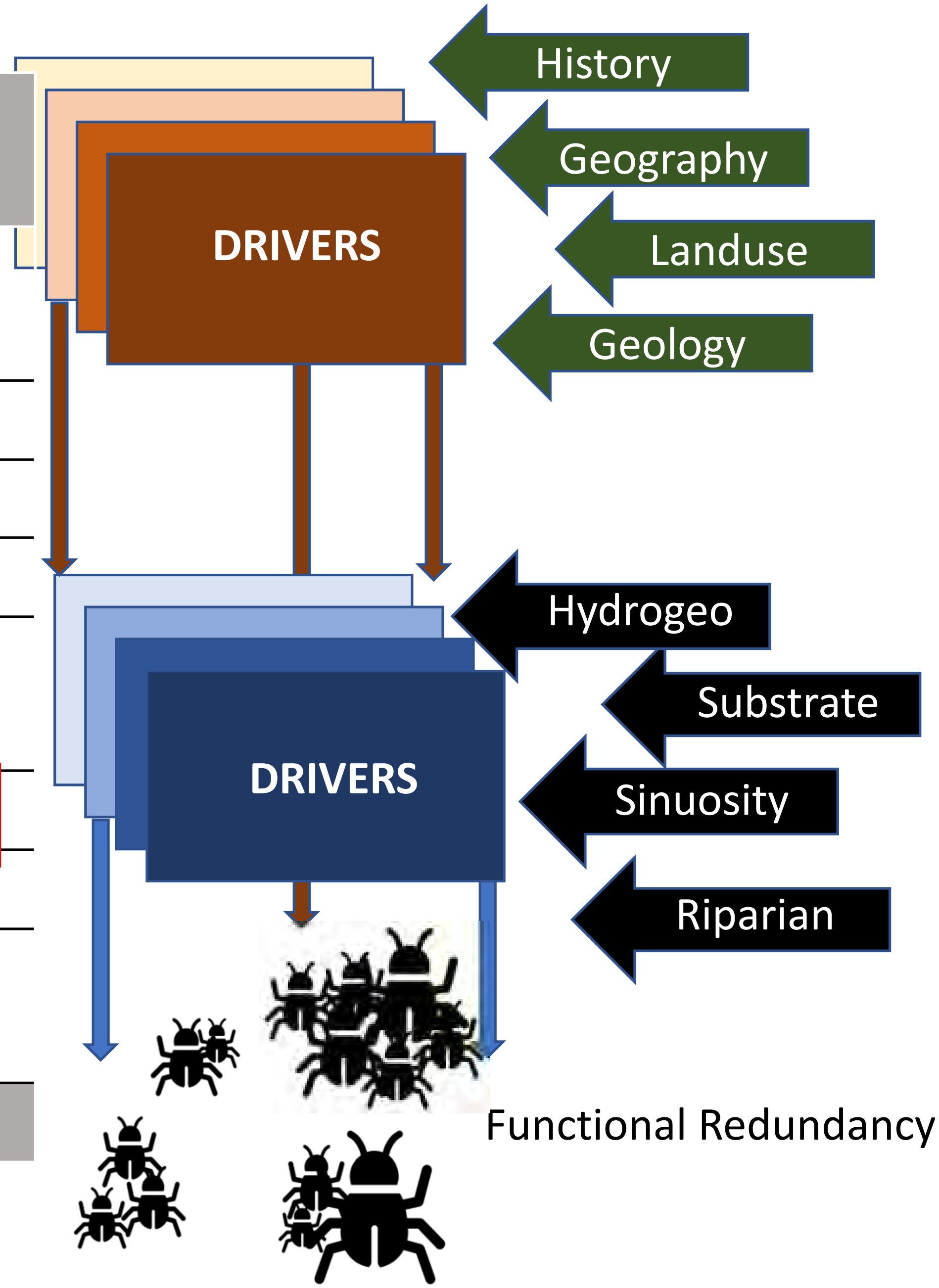
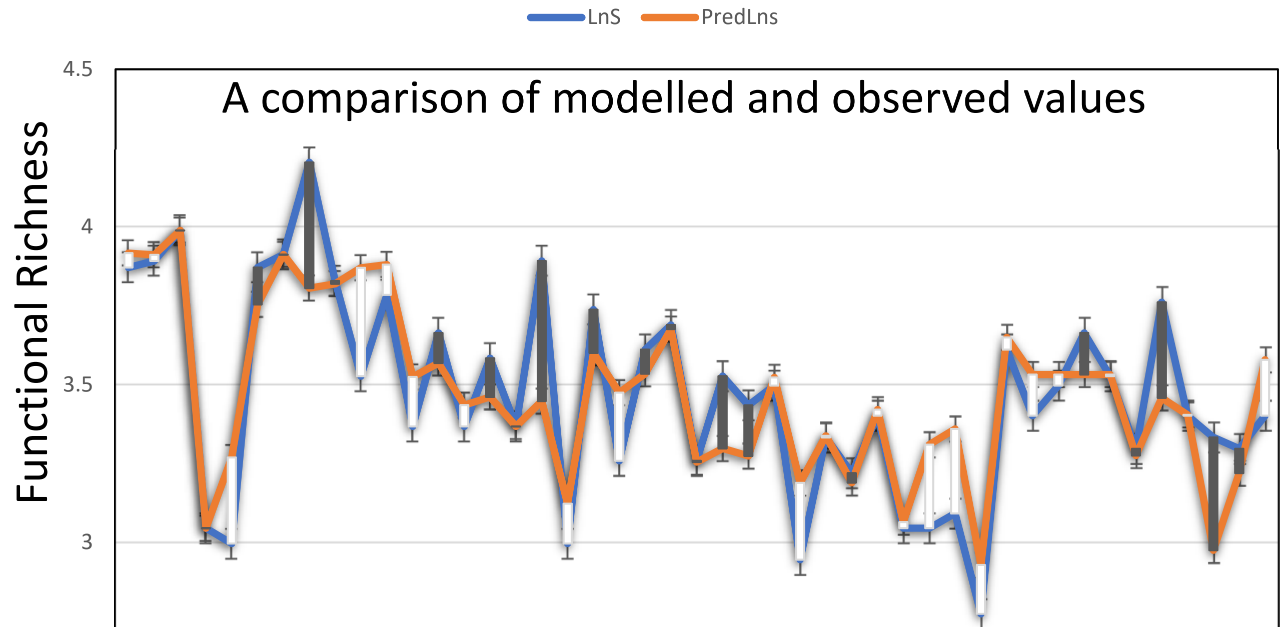
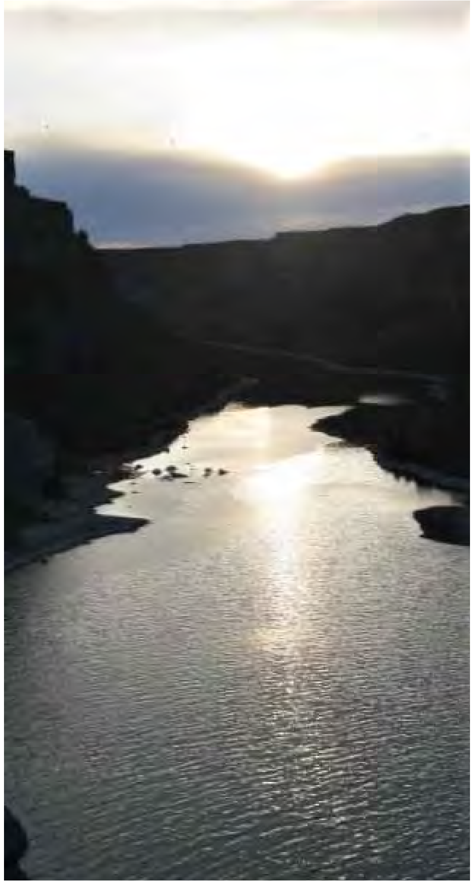
Percent wetted width (+)

*Permian Metam

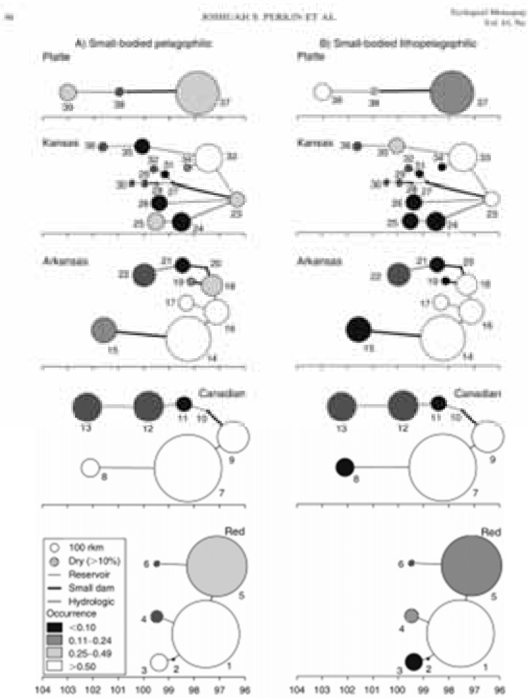


MACRO
MACROECOLOGICAL RIVERINE SYNTHESIS

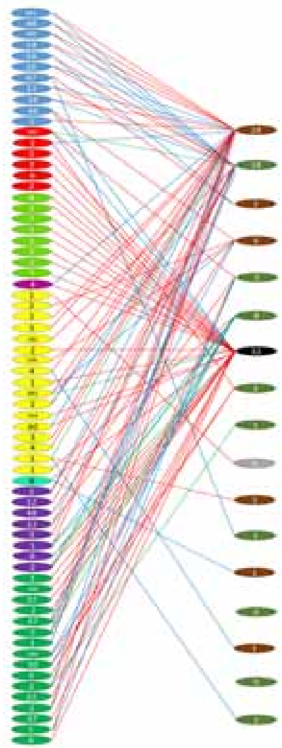




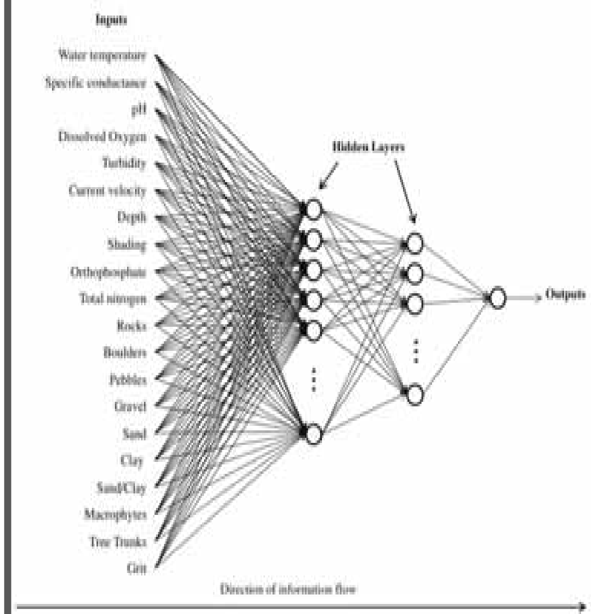

Signal Flow Graph Models



Patch-based graphs
Perkin et al., (2015)



Descriptive
Digraph, Jurotich et al. (2017)

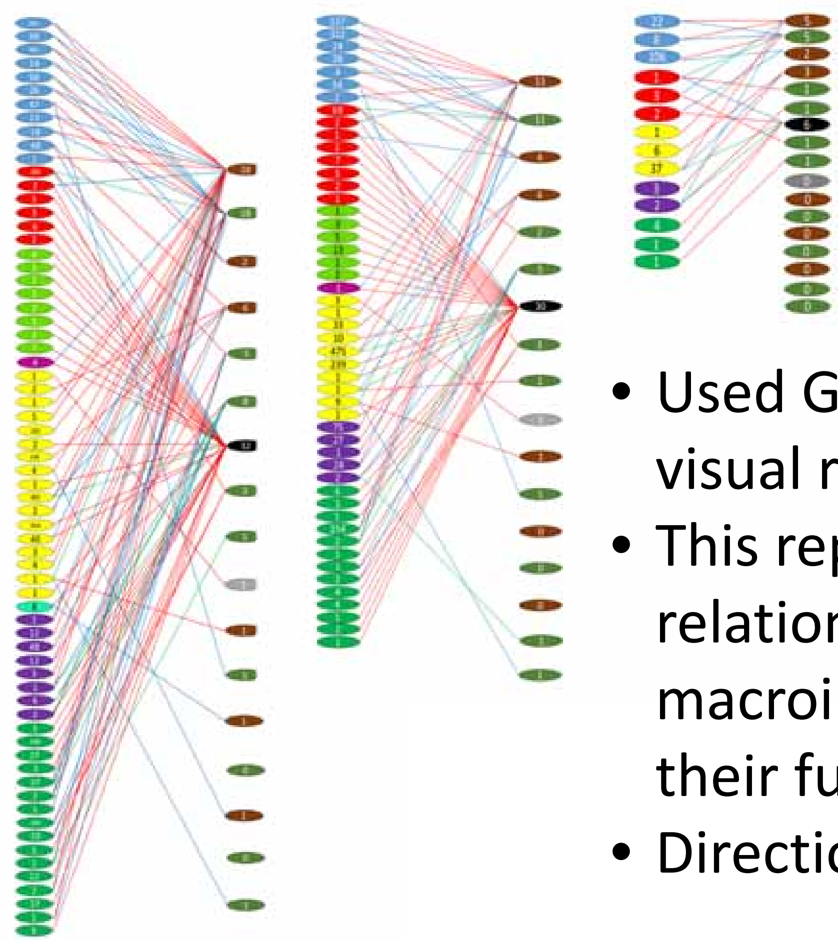


Predictive
Artificial Neural Networks
Rocha et al. (2017)

Previous research

Previous Research

Jurotich et al. 2017



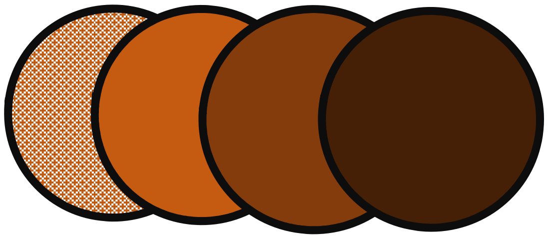
Left vertices=taxa
Right vertices=functions
Edge colors=1°, 2°, 3° fx

- Used Graph Theory to create a visual representation
- This represented the relationship between macroinvertebrate taxa and their functions
- Directional graph

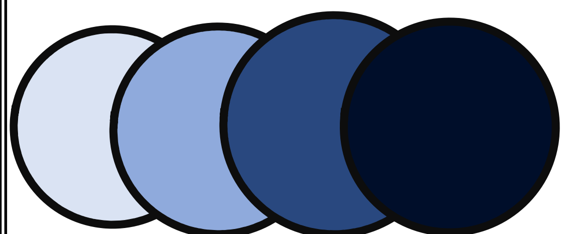
MACRO

MACROECOLOGICAL RIVERINE SYNTHESIS

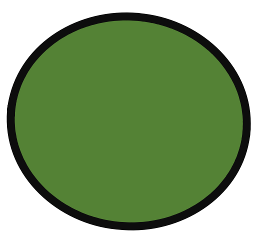
NSF

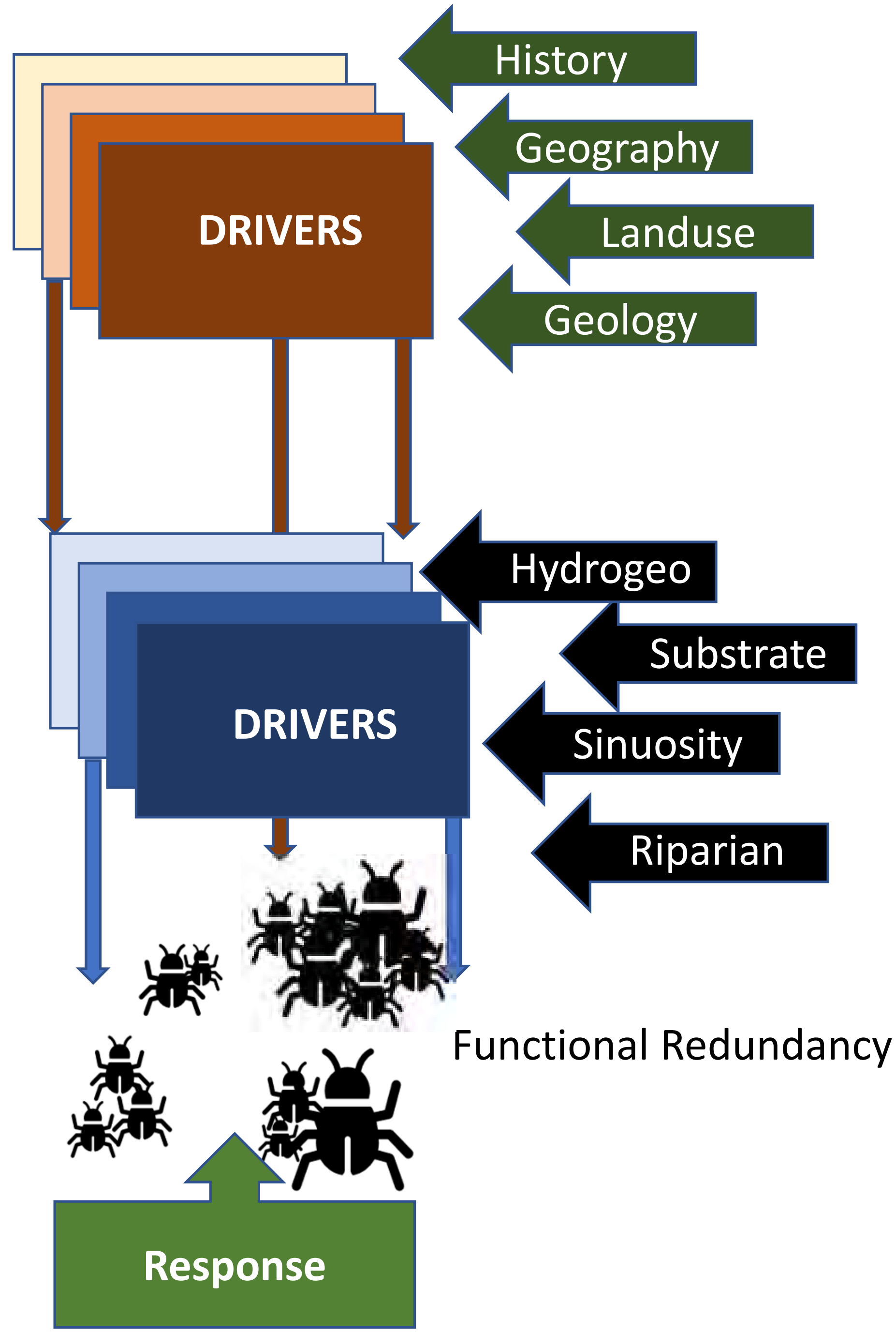


Flow graphs link nodes by a relationship such as regression

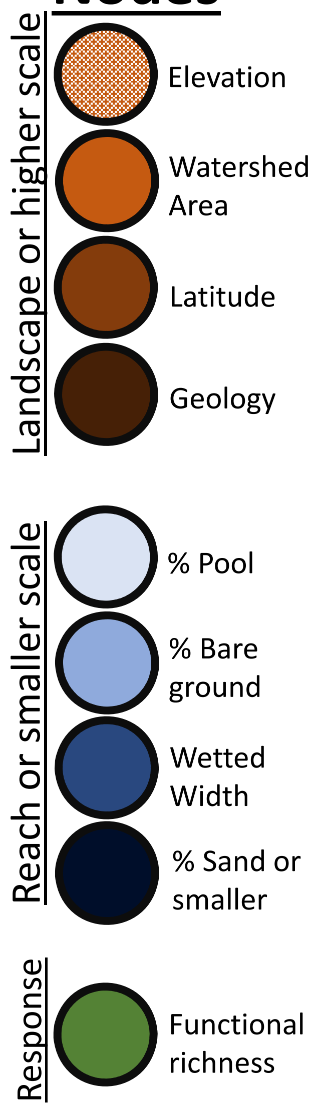


Signal flow graph

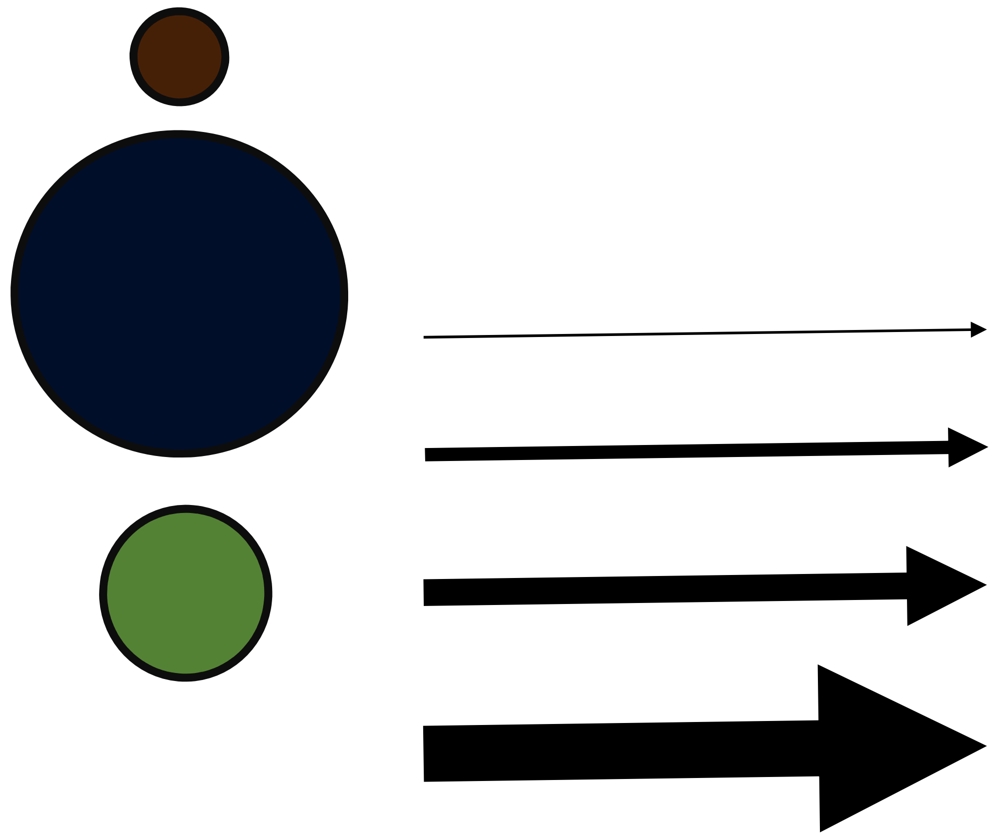




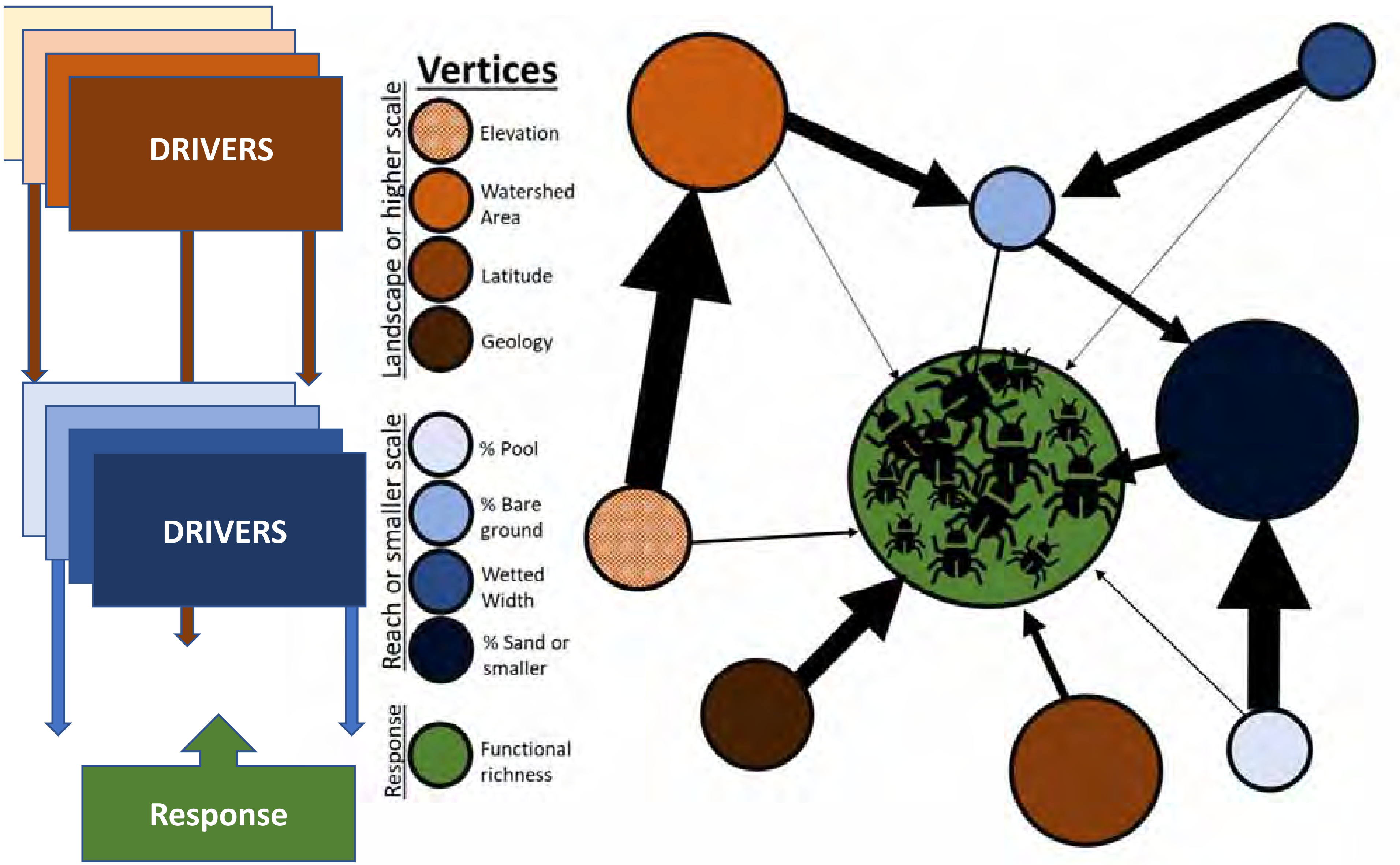
Vertices/ Nodes



Nodes weighted by standardized regression coefficients
Arbitrarily assigned the highest a value
Smaller values a proportion of that



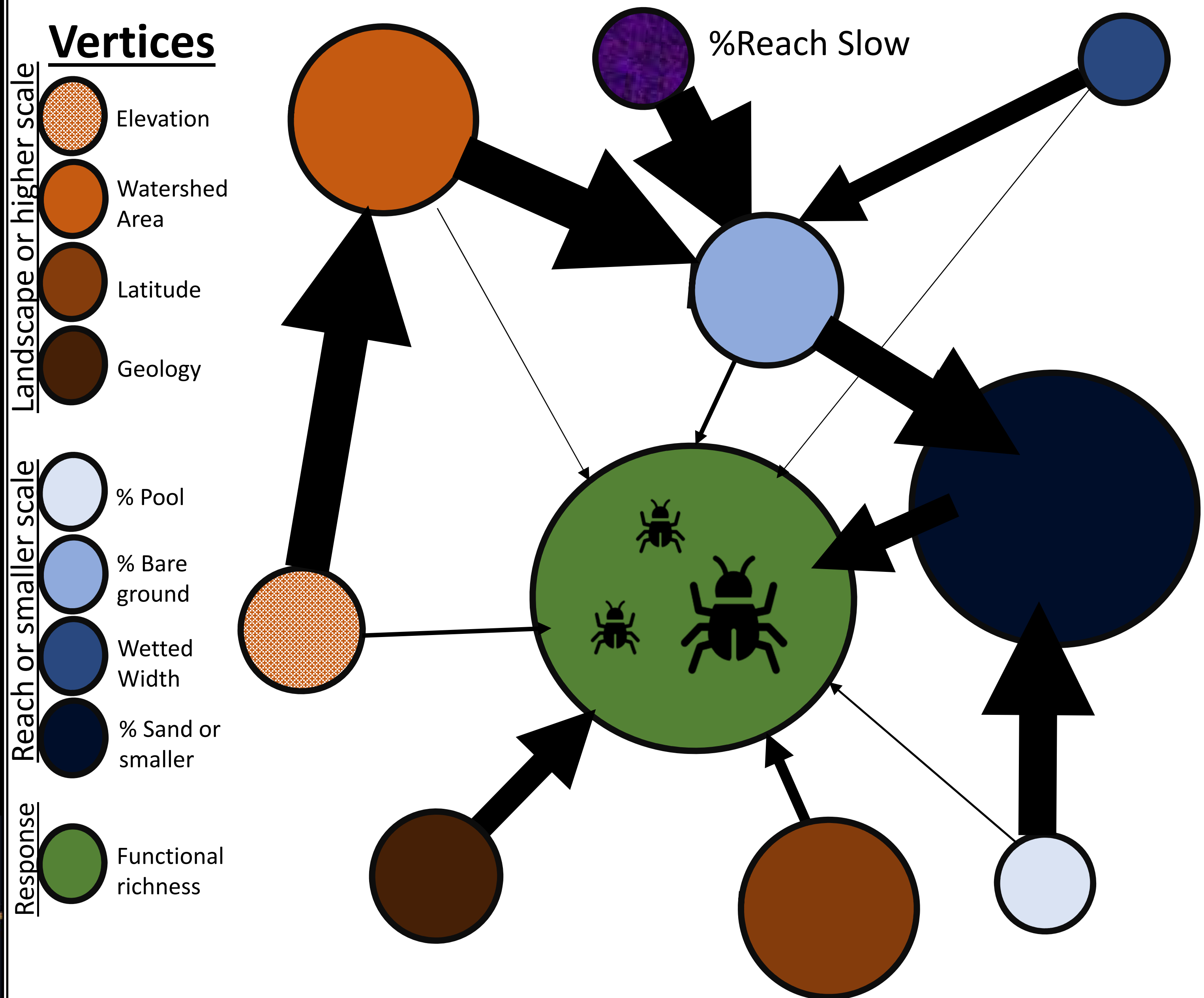
Edges or relationships weighted by R^2 values
Arbitrarily assigned the highest a value
Smaller values a proportion of that


DRIVERS
DRIVERS
Response
Vertices
Landscape or higher scale
Elevation
Watershed Area
Latitude
Geology
Reach or smaller scale
% Pool
% Bare ground
Wetted Width
% Sand or smaller
Response
Functional richness

MACRO

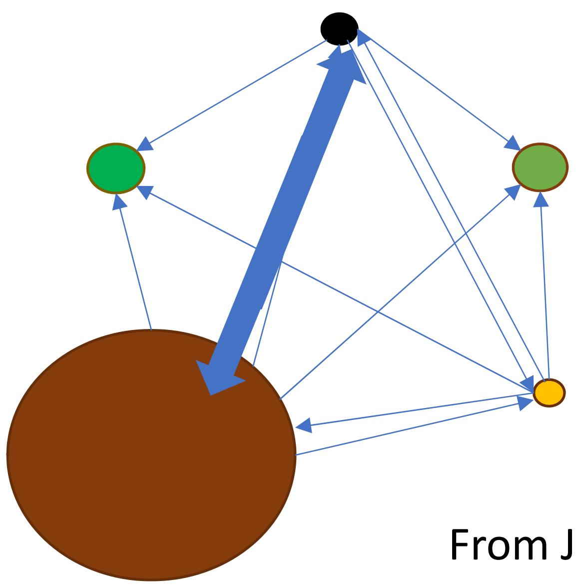
MACROECOLOGICAL RIVERINE SYNTHESIS

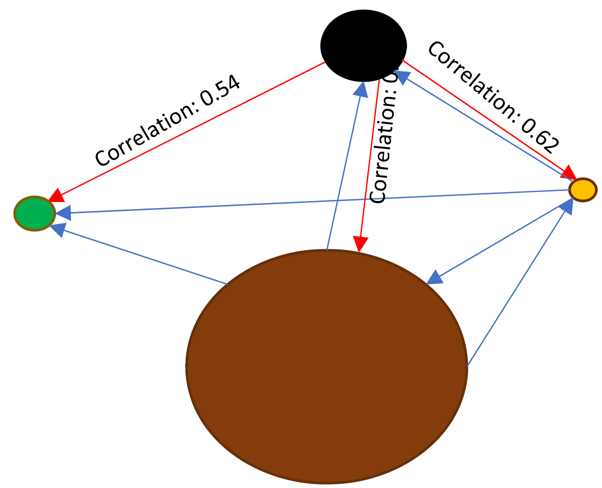
NSF



Next:

- Explore feedback interactions
  - How do functional traits drive ecosystem function
    - Dispersal
- Apply to MACROrivers data





From Jurtotich, 2018

More and better data

MACRO

MACROECOLOGICAL RIVERINE SYNTHESIS

NSF


Uses and Importance
• Visually compelling for stakeholders and public
• May be coded for swift modeling of relationships
• Predictive

Thanks to . . .

- NRSA
- Kaitlyn Dougherty, Department of Mathematics, University of South Dakota
- NSF macrosystem ecology grant 1442595
- PI J.H. Thorp
- Co-P.I.s in Europe (**Alain Maasri**), Mongolia (Bazartseren Boldgiv), and the USA (Sudeep Chandra, Walter Dodds, Jon Gelhaus, Barbara Hayford, Olaf Jensen, Scott Kenner, Mark Pyron, and Daniel Reuman).
- Postdoctoral fellows, graduate students, and undergraduate students.
- Rhithron Associates, Inc

Developing a spatial modeling approach to estimate O/E scores within streams and lakes in the conterminous US (CONUS)

Presentation by Jessie Doyle

Authors: Jessie Doyle[1], Ryan Hill[2], Scott Leibowitz[2], and Paul Ringold[2]

[1]Oak Ridge Institute Science and Education Research Fellow c/o USEPA, [2]Pacific Ecological Systems Division

https://www.epa.gov/environmental-economics

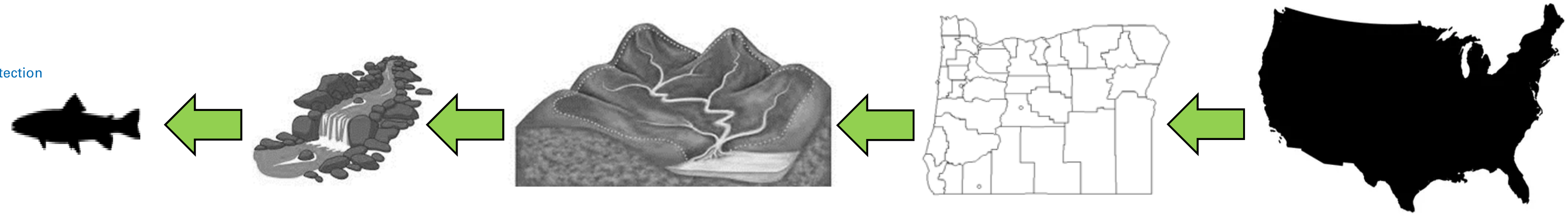
https://www.epa.gov/environmental-economics

https://www.thestreet.com/

Shutterstock.com

How much are people willing to pay for incremental changes in the ecological condition of nearby waters?

EPA
United States
Environmental Protection
Agency

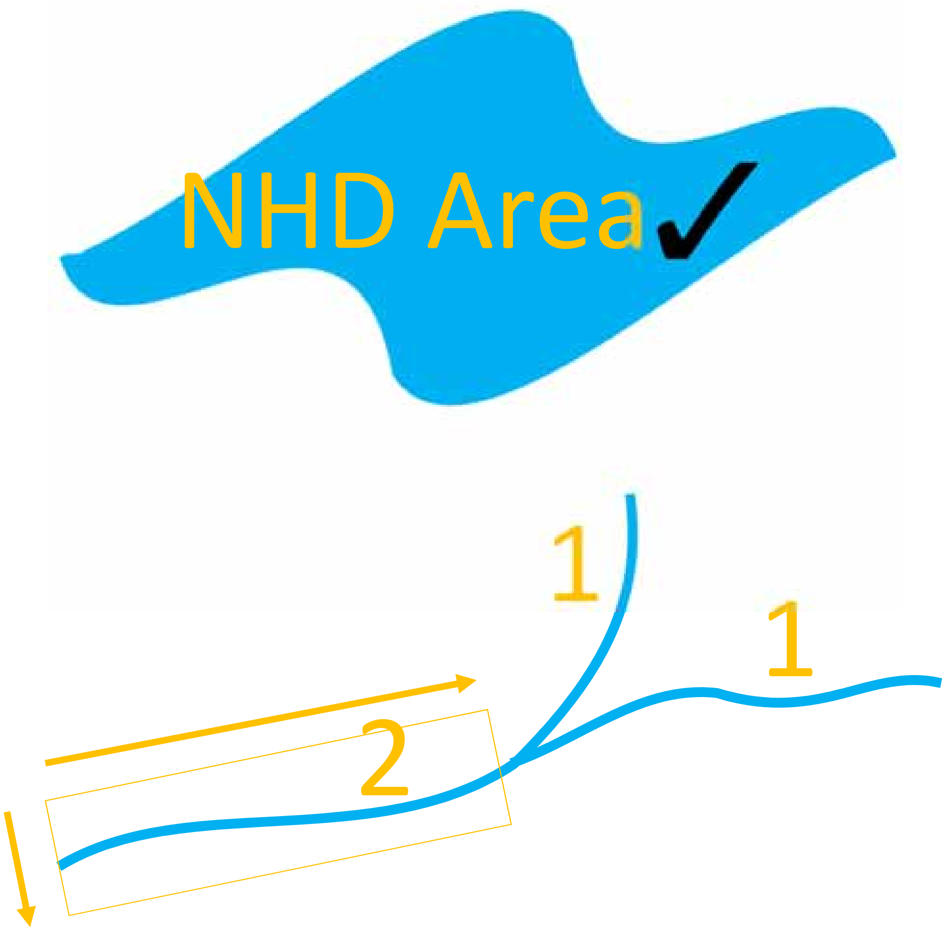


Objective: Produce information on taxa loss for lakes and streams in the conterminous US at a fine resolution for NCEE analysis of the willingness-to-pay

Taxa Loss (O/E)

Fish, Inverts, Plankton

Lakes and Streams



Stream Order?
Bankfull Width?
Wetted Width?

Fine Resolution

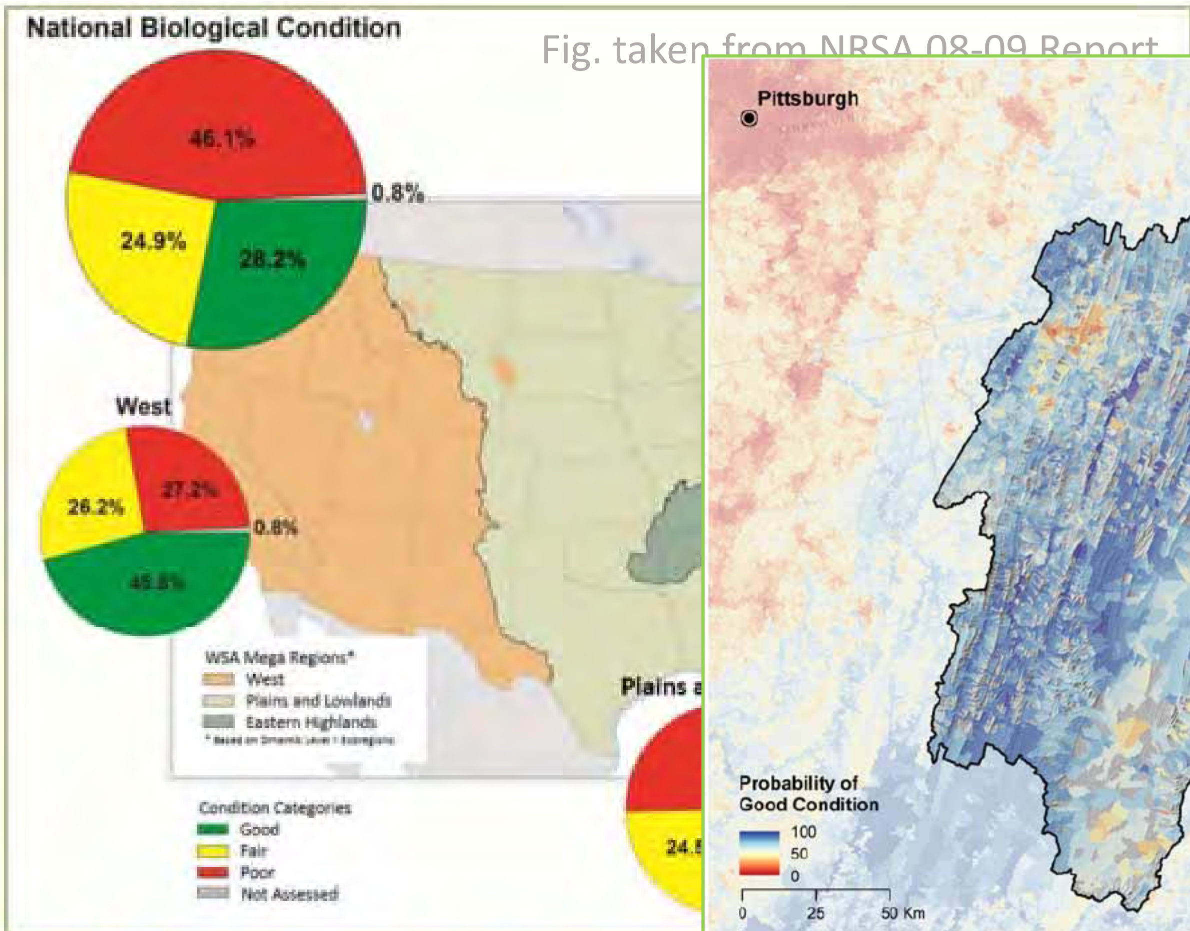
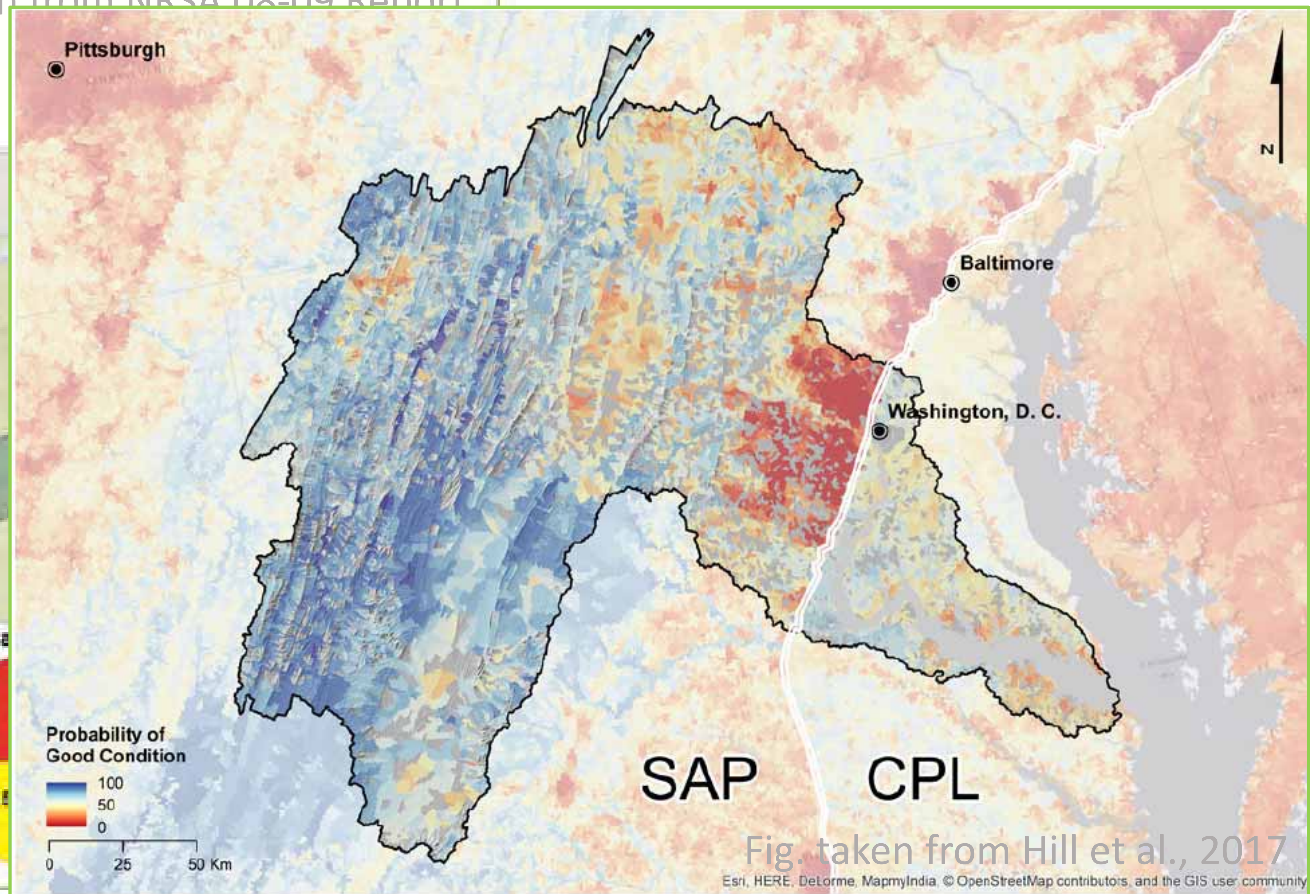
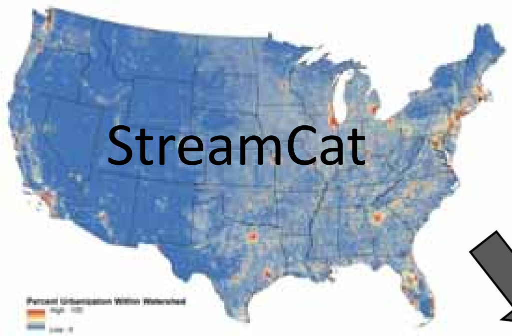


Figure 1. Biological condition of the nation's rivers and streams, based on the Macroinvertebrate Multi-metric Index (EPA/NRSA).



Previous Work – MMI



Random Forest Models

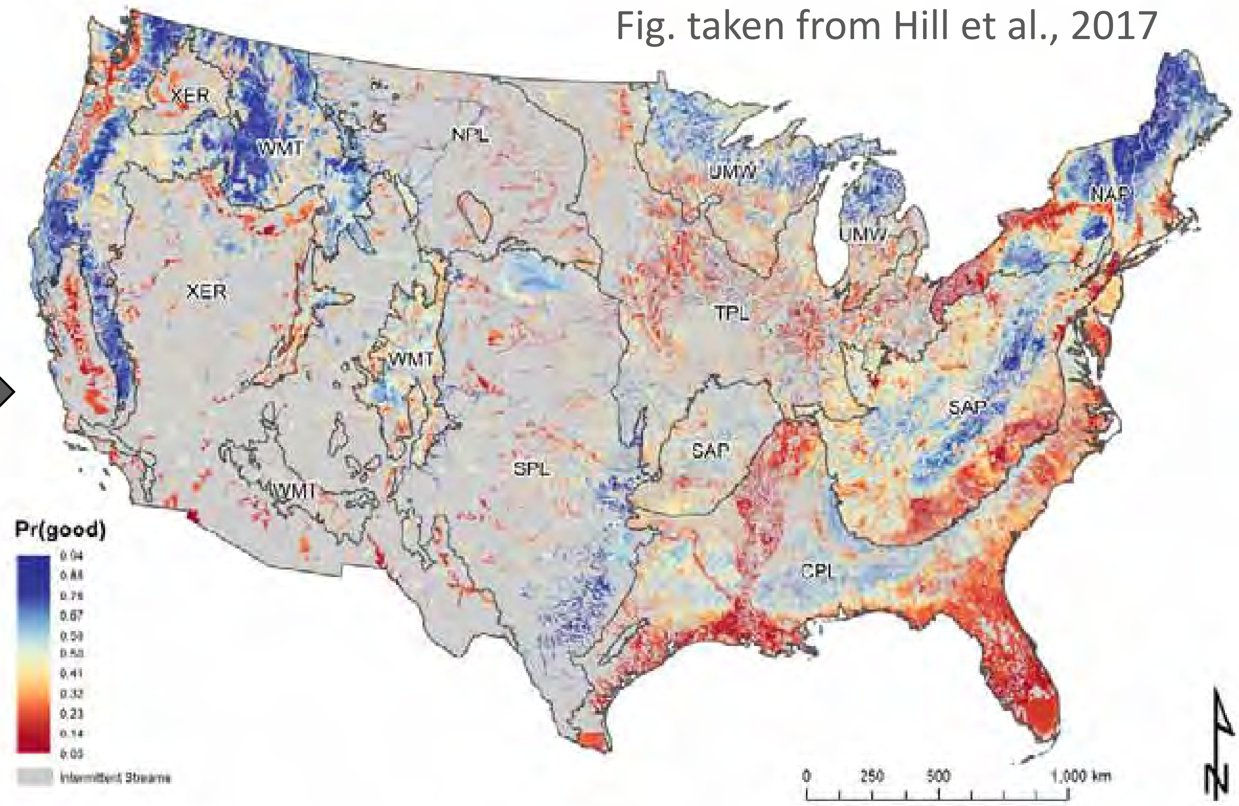
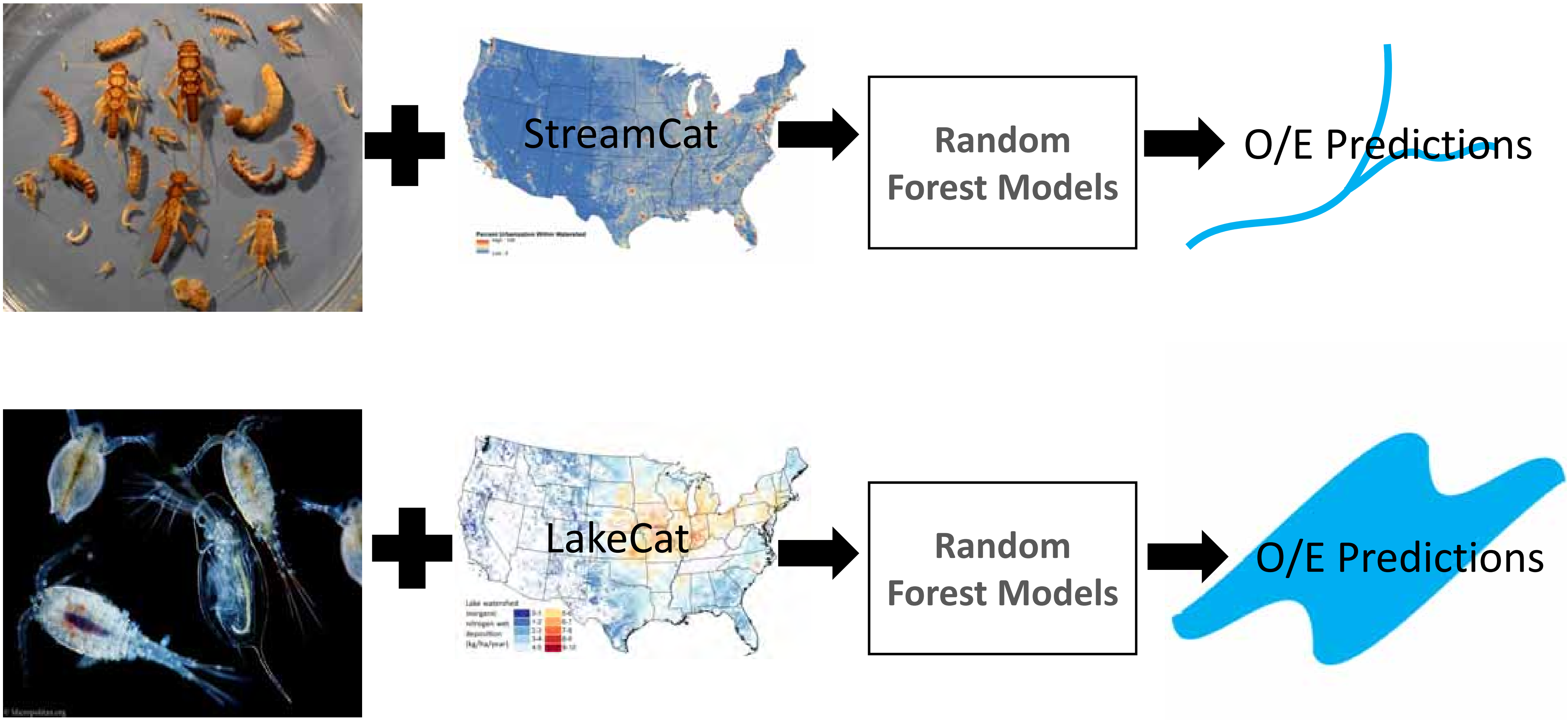
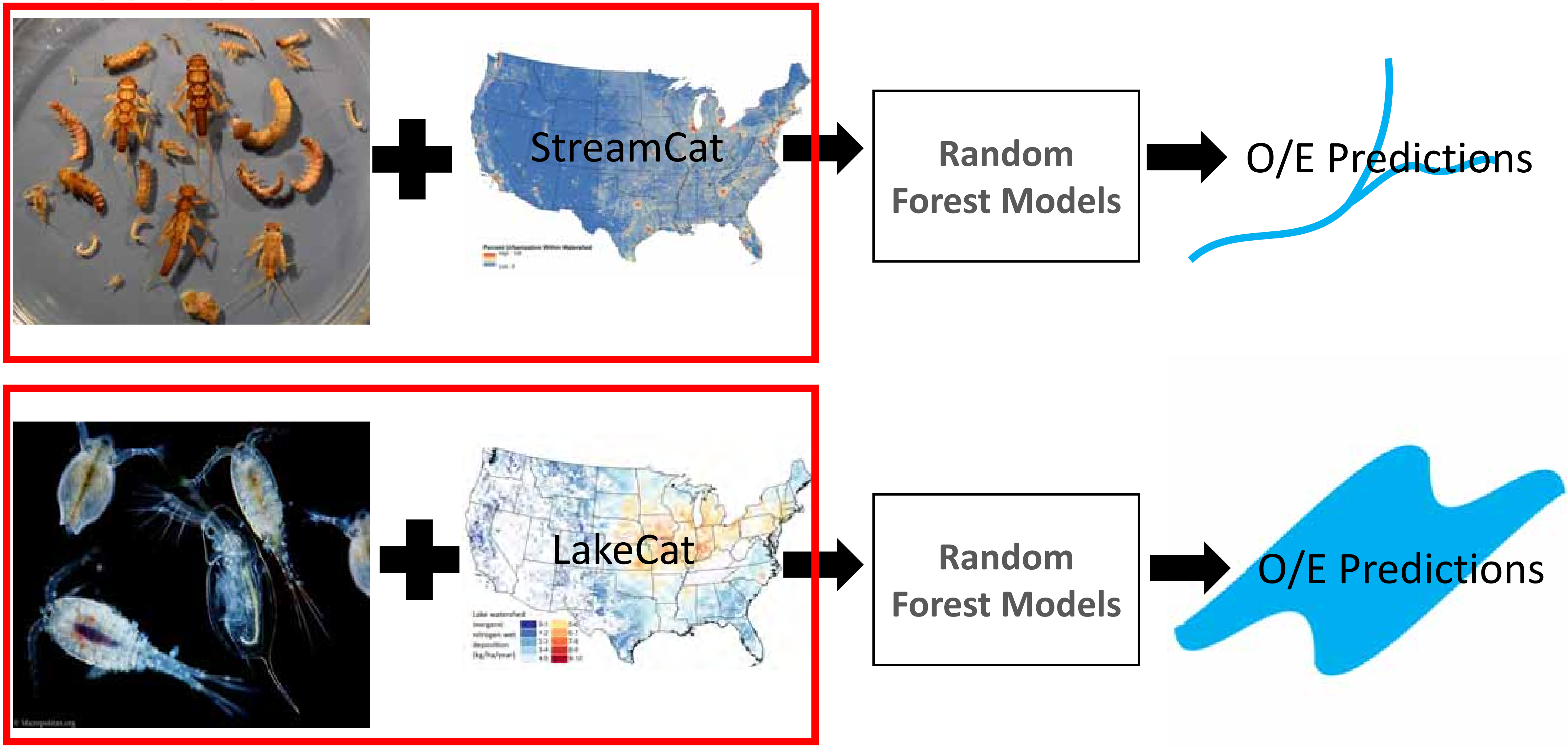


Fig. taken from Hill et al., 2017

Methods

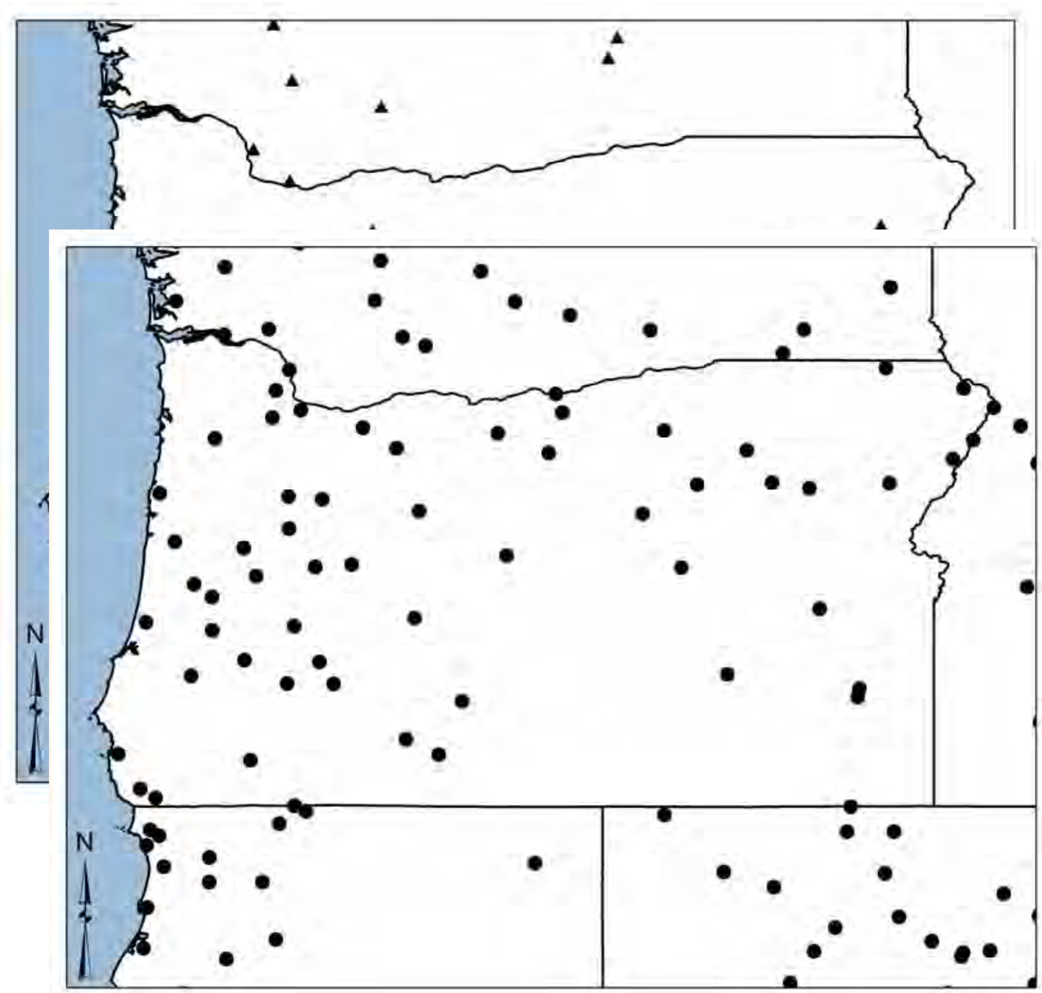

StreamCat
Random
Forest Models
O/E Predictions
LakeCat
Random
Forest Models
O/E Predictions

Methods



StreamCat
Random Forest Models
O/E Predictions
LakeCat
Random Forest Models
O/E Predictions

Previous Work – NARS

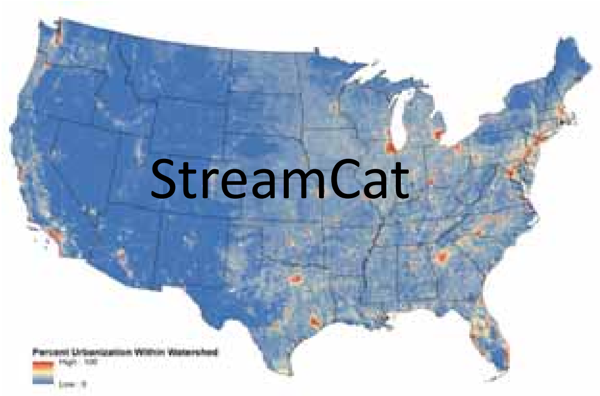


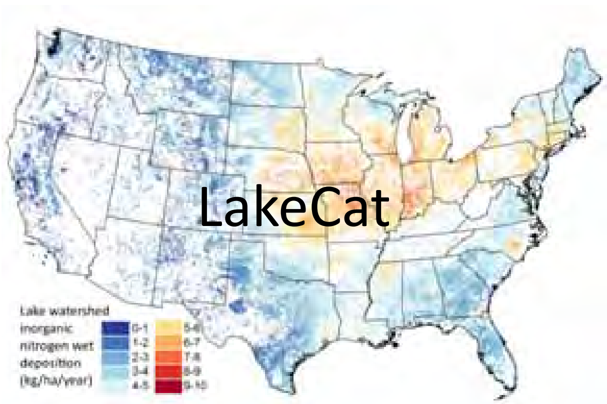
The National Aquatic Resource Surveys (NARS) are statistical surveys designed to assess the status of and changes in quality of the nation's coastal waters, lakes and reservoirs, rivers and streams, and wetlands.

National Lakes Assessment (NLA) - 2007 & 2012

National Rivers and Streams Assessment (NRSA) – 2001-2004 [WSA], 2008-2009, & 2013-2014

Previous Work – StreamCat/LakeCat





Full watershed summaries

Natural features (e.g., soils, geology, climate)

Anthropogenic features (e.g., urbanization, agriculture, forest loss)

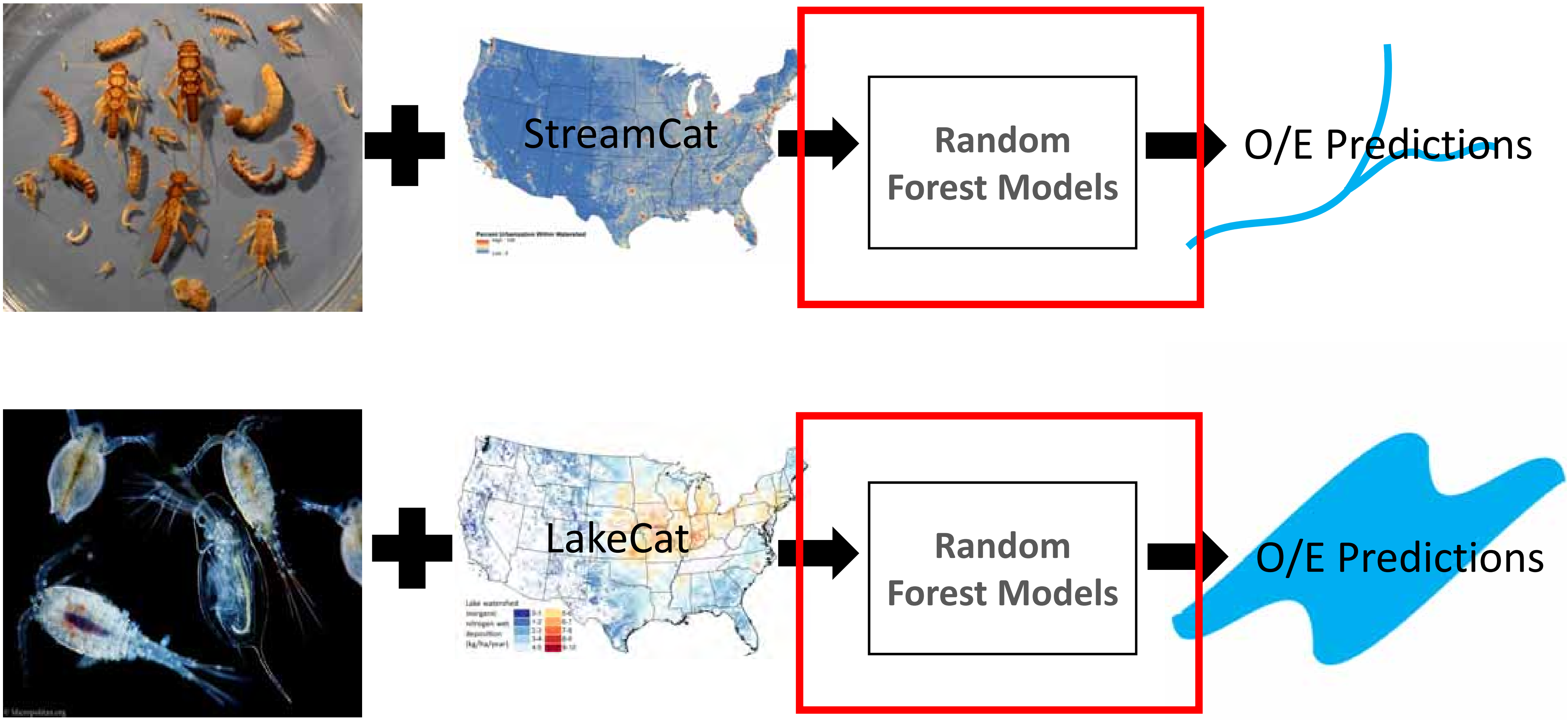
For –

2.6 million **stream** segments

378K **lakes** across the US

https://www.epa.gov/national-aquatic-resource-surveys/streamcat
https://www.epa.gov/national-aquatic-resource-surveys/lakecat

Methods



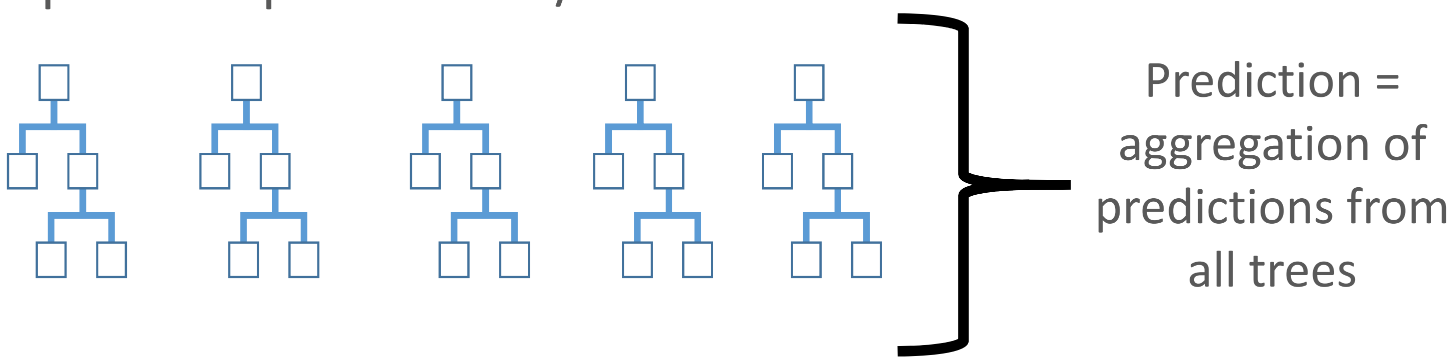
StreamCat
Random
Forest Models
O/E Predictions
LakeCat
Random
Forest Models
O/E Predictions

Methods – Modeling

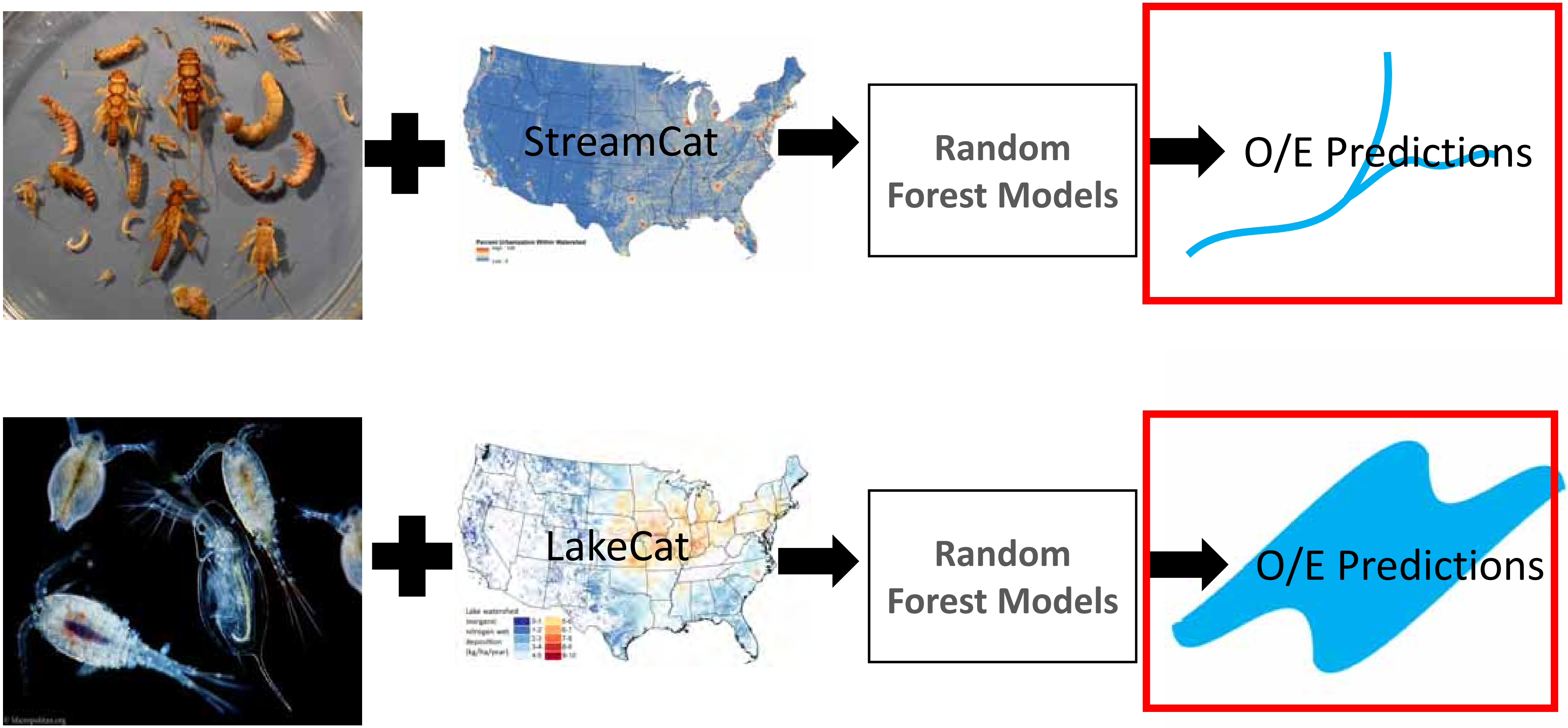
Empirical modeling to predict probable condition

Random forests

- Tree based modeling approach
- Builds many trees from randomized subsets of the data and predictors instead of just 1 tree
- Requires very little tuning and captures non-linear relationships and interactions
- Can produce predicted O/E scores

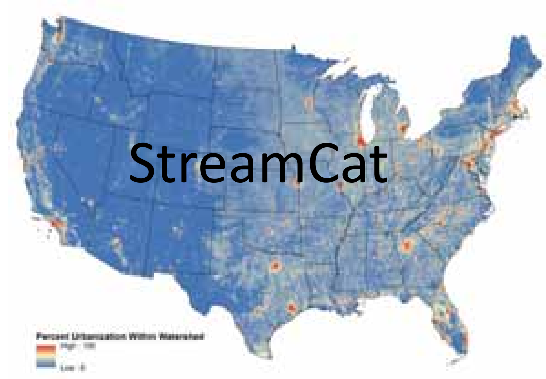


Methods


StreamCat
Random Forest Models
O/E Predictions
LakeCat
Random Forest Models
O/E Predictions

Methods – Wetted Width Model

+

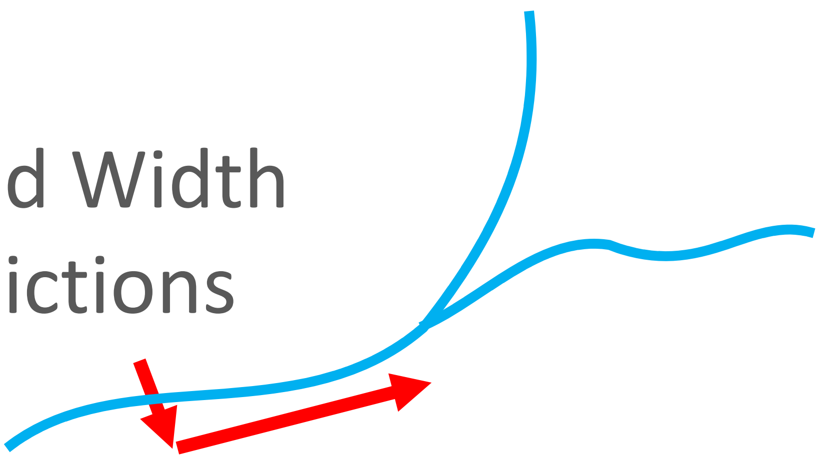


→ **Random Forest Model**

↓

Wetted Width Predictions

Wetted Width Predictions



NHD Length

Wetted Width X NHD Length = Stream Area

Other Applications for us and others

- Conservation/restoration planning
- Identification of potential reference sites
- Improve understanding of patterns of current ecological condition (richness) across conterminous US
- Testing management/restoration scenarios
- ...

Acknowledgements

- Project collaborators from the NARS team at the Pacific Ecological Systems Division, Office of Water, & National Center of Environmental Economics

Questions?

Contact:
doyle.jessie@epa.gov

Management of Chinook salmon (*Oncorhynchus tshawytscha*) stocks in Washington State using the Fishery Regulation Assessment Model (FRAM)

Oliver Miler, Northwest Indian Fisheries Commission (NWIFC)

20 member tribes: Lummi, Nooksack, Swinomish, Upper Skagit, Sauk-Suiattle, Stillaguamish, Tulalip, Muckleshoot, Puyallup, Nisqually, Squaxin Island, Skokomish, Suquamish, Port Gamble S'Klallam, Jamestown S'Klallam, Lower Elwha Klallam, Makah, Quileute, Quinault, Hoh

Overview

- FRAM: deterministic Chinook fisheries model (similar model for Coho)
- Programmed in Visual Basic with a User Interface
- Used in North of Falcon fisheries negotiations between WDFW and tribes (fisheries from Cape Falcon, OR to US-Canada Border)
- Focus on Puget Sound and Strait of Juan de Fuca
- Goal: Calculation of exploitation rates for specific stocks
  - Number of fish caught in fisheries (mortality) / (Number of fish caught in fisheries (mortality) + Number of fish escaping fisheries to spawn in the river (escapement))
- Fisheries are managed to limits of exploitation rates and escapement of wild stocks
- Hatchery fish usually have their adipose fin clipped (except those used for conservation/restoration purposes)

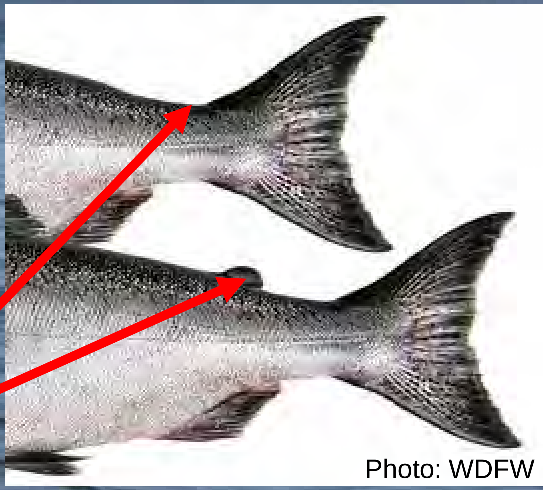


Photo: WDFW

Chinook Life Cycle

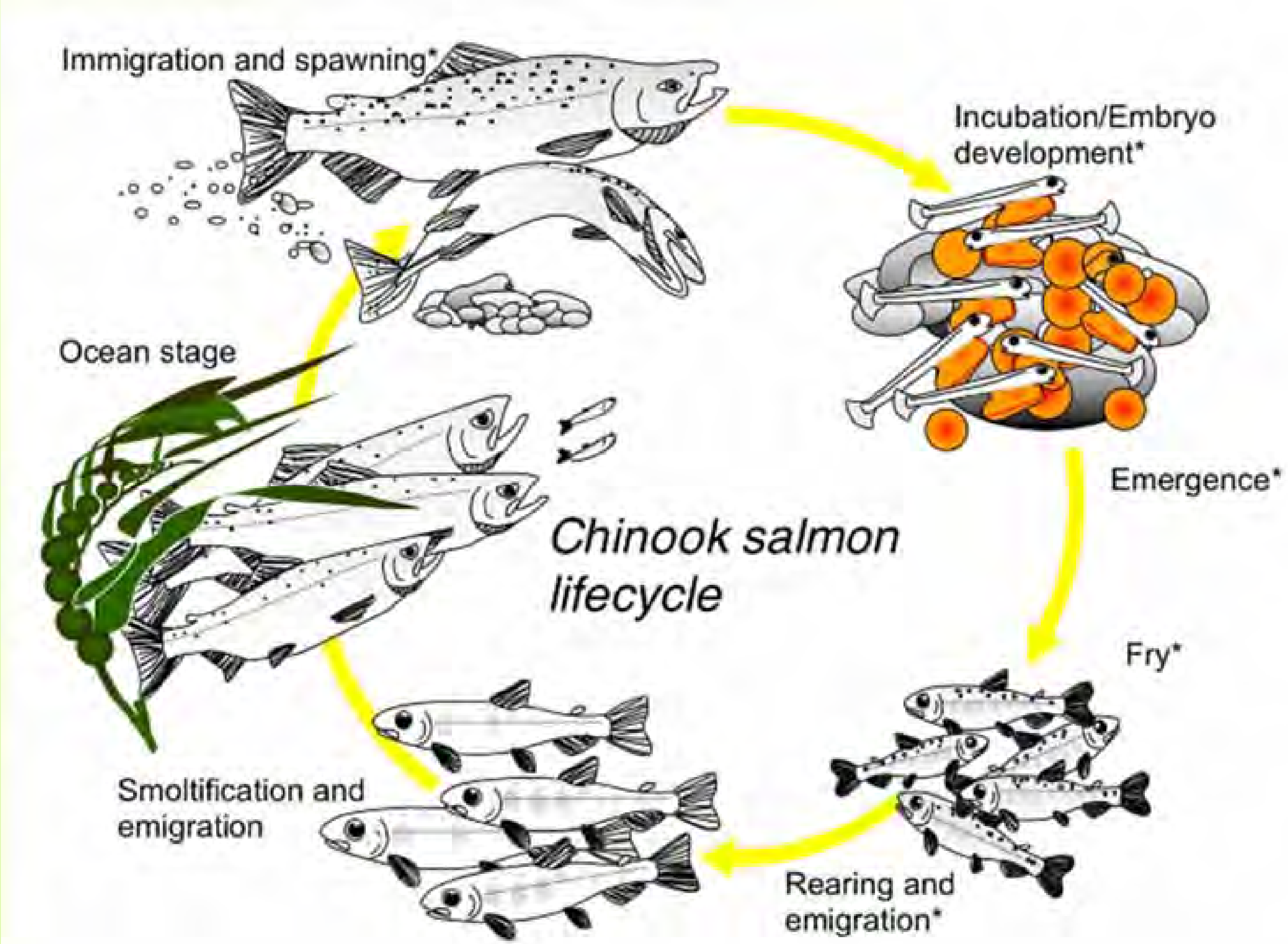
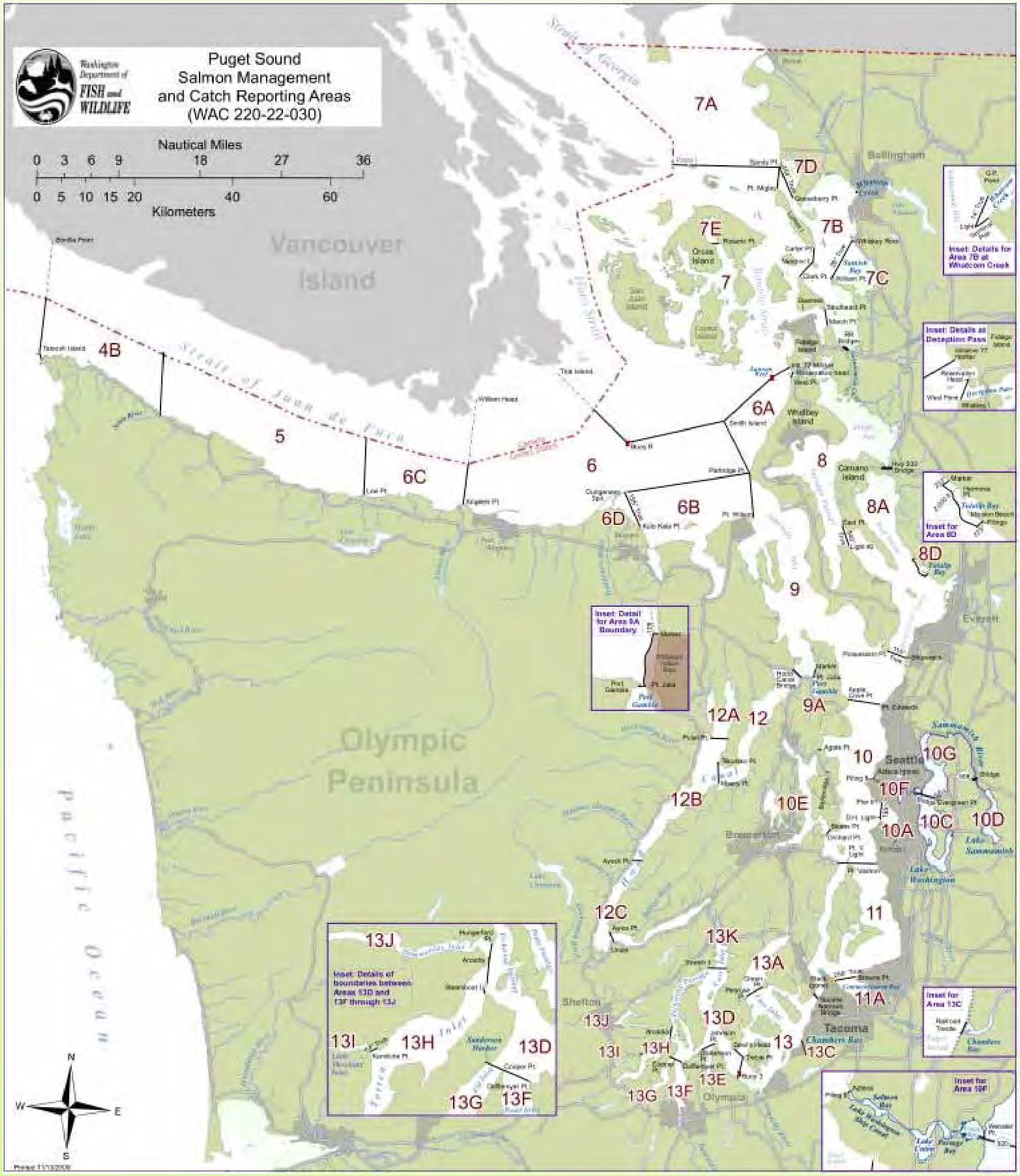


Photo: KRAMER Fish Science 2018 & Merz et al. 2013

- Chinook return to spawn at ages 2 ('jacks') to 5 (and older)
- Maturation during the spawning migration → mature individuals in terminal freshwater & estuarine areas



Washington State Commercial Fishery Management Areas

- Fishery year: May - April
- FRAM model time steps 1 (October-April), 2 (May-June), 3 (July-September), 4 (October-April)
- Pre-terminal fisheries = marine fisheries
- Terminal fisheries = fisheries in freshwater and estuaries/bays
- FRAM model: fish affected by natural mortalities, fishery mortalities and maturation rates

Inputs

- Cohort abundances based on forecasts (in number of fish) of stocks from Georgia Strait to California (Central Valley)
- Size-limits
- Mortality inputs (in number of fish) for fisheries from Southeast Alaska (Yakutat Bay) to California (U.S.A. -Mexico Border)
- Sport fisheries inputs (mark-selective, non-selective, incidental mortalities)
- Drop-off/drop-out mortalities (when a fish drops of a hook or out of a net) & release mortalities
  - sublegal fish, i.e. fish below the size limit
  - Chinook caught in fisheries closed for Chinook, but open for trout, Coho, Chum, Sockeye or Pink salmon
  - Wild (unclipped) Chinook caught in mark-selective fisheries
- Net and troll fisheries inputs differentiated by tribal and non-tribal fisheries

Calculation of Starting Cohorts

- Chinook forecasts provided in early spring for Terminal Run Sizes (Escapement + Mortality in Terminal Areas)
- Backwards FRAM → Starting Cohorts are calculated as Number of Fish in the Ocean, i.e. Terminal Run Size + Natural Mortality + Fishery Mortalities from the previous fishing year
- Fishery Impacts and Maturation Rates are applied on the starting cohorts

Population Statistics and Size limits

Population Statistics

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Population Statistics

StockName	Age	T1-Coh	T1-postNM	T1-postPT	T1-Mat	T1-Esc	T2-Coh	T2-postNM	T2-postPT	T2-Mat	T2-Esc	T3-Coh	T3-postNM	T3-postPT	T3-Ma
U-NkSm FF	2	3845	2854	2844	0	0	2844	2612	2603	0	0	2603	2291	2256	[illegible]
U-NkSm FF	3	2231	1812	1805	0	0	1805	1700	1643	0	0	1643	1503	1407	742
U-NkSm FF	4	635	558	550	0	0	550	530	500	0	0	500	473	425	421
U-NkSm FF	5	30	28	28	0	0	28	28	27						
M-NkSm FF	2	74873	55578	55371	0	0	55371	50852	50681						
M-NkSm FF	3	43444	35285	34941	0	0	34941	32924	31778						
M-NkSm FF	4	10511	9228	8893	0	0	8893	8568	8074						
M-NkSm FF	5	412	388	388	0	0	388	381	374						
U-NFNK Sp	2	920	683	675	0	0	675	620	617						
U-NFNK Sp	3	530	431	422	0	0	422	397	370						
U-NFNK Sp	4	204	179	168	0	0	168	162	152						
U-NFNK Sp	5	31	29	28	0	0	28	28	26						
M-NFNK Sp	2	13493	10016	9899	0	0	9899	9091	9043						
M-NFNK Sp	3	7781	6320	6119	0	0	6119	5766	5368						
M-NFNK Sp	4	3928	3449	3091	0	0	3091	2978	2806						
M-NFNK Sp	5	180	169	163	0	0	163	161	153						
U-SFNK Sp	2	22461	16673	16479	0	0	16479	15134	15053						
U-SFNK Sp	3	12952	10520	10296	0	0	10296	9702	9032						
U-SFNK Sp	4	1215	1066	997	0	0	997	961	905						
U-SFNK Sp	5	12	11	11	0	0	11	10	10						
M-SFNK Sp	2	0	0	0	0	0	0	0	0						
M-SFNK Sp	3	0	0	0	0	0	0	0	0						
M-SFNK Sp	4	0	0	0	0	0	0	0	0						
M-SFNK Sp	5	0	0	0	0	0	0	0	0						
U-Skag FF	2	8365	6210	6203	0	0	6203	5697	5683						
U-Skag FF	3	22477	18256	18236	0	0	18236	17183	16855						
U-Skag FF	4	17199	15099	14528	0	0	14528	13998	13284						
U-Skag FF	5	2752	2588	2538	0	0	2538	2494	2375						
M-Skag FF	2	924	686	685	0	0	685	629	628						
M-Skag FF	3	528	429	428	0	0	428	404	391						

EXIT

Database: example FRAM database with final run 2719.mdb

RecordSet: Chin0919_Alt3

Size Limit Edit

ClipBoard Copy

Fishery Size Limits

Name	#	Oct-Apr-1	May-June	July-Sept	Oct-Apr-2
SEAK Troll	1	670	670	670	670
SEAK Net	2	****	100	100	****
SEAK Sport	3	****	670	670	****
N/C BC Net	4	****	100	100	****
WCVI Net	5	100	100	100	100
GeoStr Net	6	100	100	100	100
BC JDF Net	7	100	****	100	100
BCOutSport	8	450	450	450	450
N/C BC Trl	9	****	670	670	****
WCVI Troll	10	550	550	550	550
WCVI Sport	11	450	450	450	450
GeoS Troll	12	620	620	620	620
N GS Sport	13	620	620	620	620
S GS Sport	14	620	620	620	620
BC JDF Spt	15	450	450	450	450
NT 3:4 Trl	16	****	670	670	****
Tr 3:4 Trl	17	520	570	570	520
Ar 3:4 Spt	18	****	570	570	****
NoWACstNet	19	****	****	****	****
NT 2 Troll	20	****	670	670	****
Tr 2 Troll	21	****	570	570	****
Ar 2 Sport	22	****	570	570	****
NT GHb Net	23	****	****	100	****
Tr GHb Net	24	****	****	100	****

OK - Done | Cancel

Database: example FRAM database with final run 2719.mdb

RecordSet: Chin0919_Alt3

Flow chart for Chinook FRAM

Fishery mortality & escapement values are scaled to a base-period (mean values, i.e. number of fish in each fishery, age and time step in the timeperiod between 2007-2012)

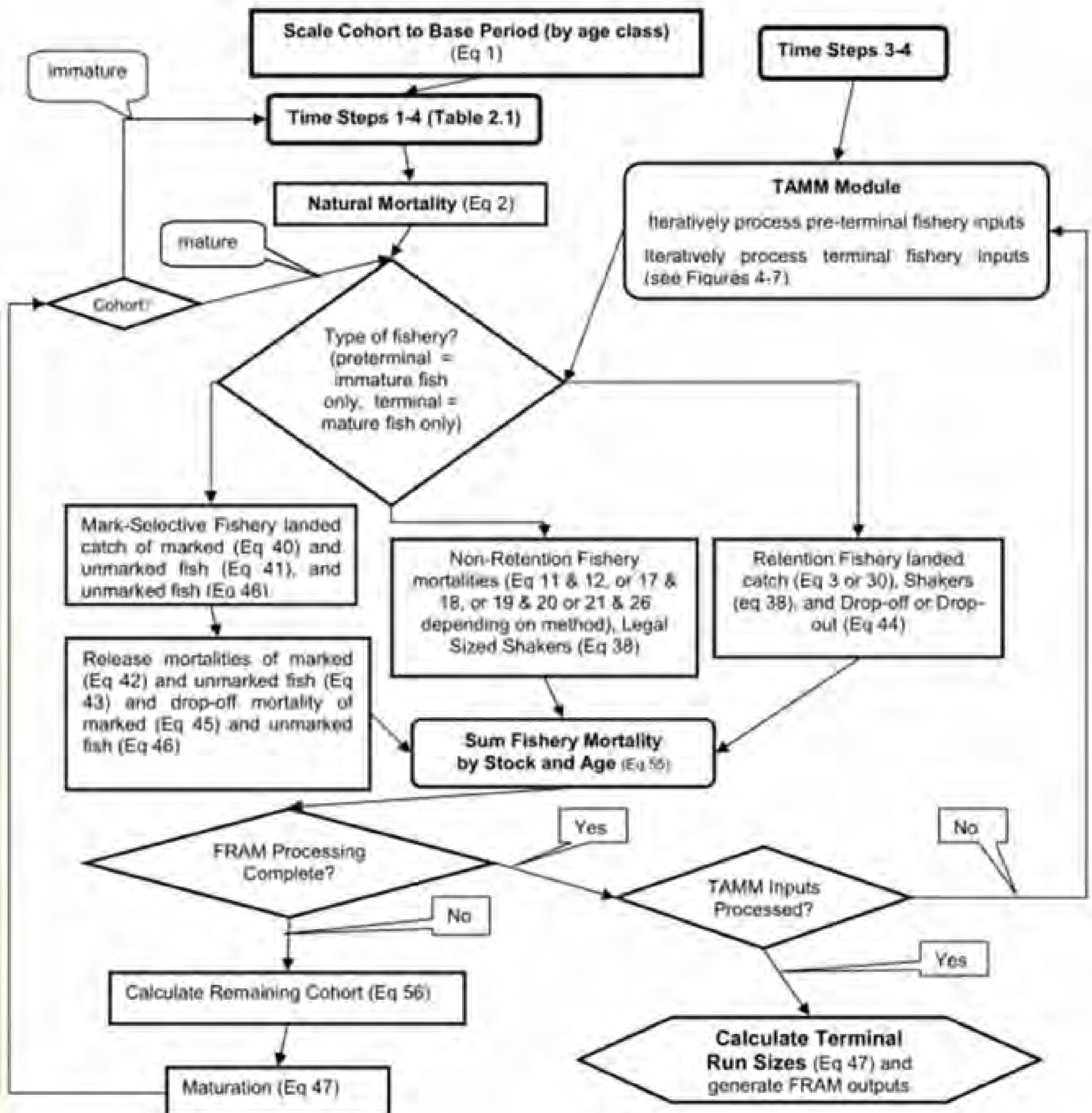

Figure: FRAM Technical Documentation, PFMC 2008

Landed Catch Report

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CHINOOK Landed Catch

Mortality Type: Landed Catch

FisheryName	Age	Oct-Apr1	May-June	July-Sept	Oct-Apr2	Total
SEAK Troll	Sum	20572	14309	62312	20572	117765
	2	0	0	7	0	7
	3	310	515	5318	409	6552
	4	9694	10029	37850	12242	69815
	5	10568	3765	19137	7921	41391
SEAK Net	Sum	0	4924	12076	0	17000
	2	0	83	404	0	488
	3	0	914	699	0	1613
	4	0	2802	8905	0	11707
	5	0	1125	2068	0	3192
SEAK Sport	Sum	0	17241	8889	0	26130

FVS_SelectiveFisheryScreen

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Selective Fishery Impacts

Choose Mark Selective Fishery: Ar 7 Sport - October-April — NT Area 7 Sport-October-April

StockName	Age	UnM Hand	UnM Cat	UnM NonR	UnM Drop	UnM SbLg	Mrk Hand
Nooksack/Samish Fall	2	0	0	0	0	5	
Nooksack/Samish Fall	3	10	0	1	1	1	
Nooksack/Samish Fall	4	4	0	0	0	0	
NF Nooksack Spr	2	0	0	0	0	2	
NF Nooksack Spr	3	3	0	0	0	0	
NF Nooksack Spr	4	3	0	0	0	0	
SF Nooksack Spr	2	0	0	0	0	43	
SF Nooksack Spr	3	64	1	6	3	11	
SF Nooksack Spr	4	20	0	2	1	0	
Skagit Summer/Fall Fing	4	161	2	16	8	0	5
Skagit Summer/Fall Fing	5	17	0	2	1	0	0
Skagit Summer/Fall Year	4	15	0	1	1	0	0
Skagit Spring Year	3	7	0	1	0	1	8
Skagit Spring Year	4	53	1	5	3	0	44
Skagit Spring Year	5	13	0	1	1	0	3
Snohomish Fall Fing	2	0	0	0	0	2	0
Snohomish Fall Fing	3	4	0	0	0	0	4
Snohomish Fall Fing	4	102	1	10	5	0	131
Snohomish Fall Fing	5	11	0	1	1	0	12
Snohomish Fall Year	3	0	0	0	0	5	0
Snohomish Fall Year	4	24	0	2	1	0	79
Snohomish Fall Year	5	22	0	2	1	0	65
Stillaguamish Fall Fing	2	0	0	0	0	1	0
Stillaguamish Fall Fing	3	2	0	0	0	0	2

WDFW MSF Report | EXIT

FVS_FishStkCompScreen

ClipBoard Copy

Fishery Stock Composition (Percent)

Choose Fishery: NT Area 7 Sport — NT Area 7 Sport

StockName	Oct-Apr	May-June	July-Sept	Oct-Apr-2	Time 2-4	Total
UnMarked Nooksack/Samish Fall	0.16	****	0.41	0.19	0.30	0.26
Marked Nooksack/Samish Fall	7.11	****	13.03	8.13	10.65	9.51
UnMarked NF Nooksack Spr	0.06	****	0.02	0.07	0.05	0.05
Marked NF Nooksack Spr	2.50	****	0.45	2.40	1.40	1.75
UnMarked SF Nooksack Spr	1.36	****	0.56	1.76	1.14	1.21
UnMarked Skagit Summer/Fall Fing	0.56	****	5.48	0.41	3.02	2.23
Marked Skagit Summer/Fall Fing	0.09	****	0.33	0.05	0.20	0.16
UnMarked Skagit Summer/Fall Year	0.05	****	0.29	0.01	0.16	0.12
UnMarked Skagit Spring Year	0.26	****	0.26	0.49	0.37	0.34
Marked Skagit Spring Year	1.03	****	0.49	2.96	1.69	1.48
UnMarked Snohomish Fall Fing	0.41	****	0.64	0.34	0.50	0.47
Marked Snohomish Fall Fing	2.70	****	1.00	1.89	1.43	1.84
UnMarked Snohomish Fall Year	0.24	****	0.09	0.09	0.09	0.14

NonRetention Edit

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Non-Retention Inputs

Name	Values	Flg-1	Oct-Apr-1	Flg-2	May-June	Flg-3	July-Sept	Flg-4	Oct-Apr-2
SE Alaska Troll	Value-1	0	0	0	0	3	46000.6667	0	0
	Value-2	*	0	*	0	*	30464.3333	*	0
	Value-3	*	0	*	0	*	0	*	0
	Value-4	*	0	*	0	*	0	*	0
SE Alaska Net	Value-1	*	****	0	0	3	1557	*	****
	Value-2	*	****	*	0	*	4134.3333	*	****
	Value-3	*	****	*	0	*	0	*	****
	Value-4	*	****	*	0	*	0	*	****
SE Alaska Sport	Value-1	*	****	0	0	0	0	*	****
	Value-2	*	****	*	0	*	0	*	****
	Value-3	*	****	*	0	*	0	*	****
	Value-4	*	****	*	0	*	0	*	****
BC No/Cent Net	Value-1	*	****	0	0	4	2911.6667	*	****
	Value-2	*	****	*	0	*	0	*	****
	Value-3	*	****	*	0	*	0	*	****
	Value-4	*	****	*	0	*	0	*	****
BC WCVI Net	Value-1	0	0	0	0	4	127.6667	0	0
	Value-2	*	0	*	0	*	0	*	0
	Value-3	*	0	*	0	*	0	*	0
	Value-4	*	0	*	0	*	0	*	0
BC Georgia Strait Net	Value-1	0	0	0	0	4	122.6667	0	0
	Value-2	*	0	*	0	*	0	*	0
	Value-3	*	0	*	0	*	0	*	0
	Value-4	*	0	*	0	*	0	*	0
BC JDF Net	Value-1	0	0	*	****	4	423.3333	0	0
	Value-2	*	0	*	****	*	0	*	0

Flag Values	Field1 Values	Field2 Values	Field3 Values	Field4 Values
1 = Computed CNR	--- not used ---	--- not used ---	SubLegal Selectivity	Legal Selectivity
2 = Ratio of CNR Days	CNR Days	Open Days	SubLegal Selectivity	Legal Selectivity
3 = Legal/SubLegal Enc	Legal Encounters	SubLegal Encounters	--- not used ---	--- not used ---
4 = Total Encounters	Total Encounters	--- not used ---	--- not used ---	--- not used ---

Database: sample FRAM database with final run 2719.mdb

RecordSet: Chin0819_Alt3

OK – Done | Zero All Fields | Import NonRetention | Export to Spreadsheet | Cancel

AEQ and TAMM

- AEQ Total Mortality (adult equivalents): Total mortalities of fish that would have matured and escaped to spawn in the absence of fishing
- Adjusts for natural mortality that would have occurred subsequent to time step and age of fishery mortality
- TAMM (Terminal Area Management Module)
  - excel file,
  - receives inputs from FRAM
  - calculates specific terminal fishery mortalities
  - splits out fishery mortalities in more detail by stock

Exploitation Rates & Management Objectives

Stock	Management Criteria			Model Prediction			
	Abundance Tier	ER Ceiling	ER Type	Escapement	Total ER	SUS ER	PT-SUS ER
Spring/Early:							
Nooksack - Total		10.5%	SUS		33.2%	**10.5%**	5.8%
North/Middle Fork	< LAT			167			
South Fork	< LAT			75			
Skagit - Total	> LAT	37.5%	Total	1,616	**32.1%**	21.2%	4.6%
Upper Sauk	> LAT			957			
Upper Cascade	> LAT			182			
Suiattle	> LAT			478			
White	> UMT	22.0%	SUS	1,834	24.3%	**16.7%**	5.1%
Dungeness	> UMT	10.0%	SUS	945	5.5%	**1.2%**	1.1%
Summer/Fall:							
Skagit - Total	> LAT	48.0%	Total	12,504	**36.7%**	16.4%	3.8%
Upper Skagit	> LAT			9,274			
Sauk	> LAT			587			
Lower Skagit	> LAT			2,363			
Stillaguamish - Total	900-1200	24.0%	Total	943			
Unmarked ER		8.0%	UM SUS		**18.0%**	**8.0%**	5.2%
Marked ER		12.0%	M SUS		20.4%	**10.9%**	8.2%
Snohomish - Total		21.0%	Total	3,208	**15.8%**	**6.5%**	5.0%
Skykomish	< LAT	15.0%	SUS	2,414			
Snoqualmie				794			
Lake WA (Cedar R.)	> UMT	13.0%	PT-SUS	1,217	33.2%	22.0%	**12.9%**
Green	> UB	13.0%	PT-SUS	5,842 9,500	53.8%	42.6%	**12.9%**
Puyallup	> UMT	13.0%	PT-SUS	2,695 4,613	51.1%	39.9%	**12.9%**
Nisqually	> LAT	47%	Total	11,467	**48.7%**	41.9%	15.3%
Western Strait-Hoko	> UMT	10%	SUS	2,315	20.7%	**2.4%**	2.4%
Elwha	> UMT	10%	SUS	6,662	5.8%	**1.4%**	1.4%
Mid-Hood Canal	< LAT	12%	PT-SUS	286	21.8%	12.1%	**11.8%**
Skokomish	> UMT	50%	Total	2,667 22,568	**48.2%**	38.6%	12.4%

Conclusions

- FRAM allows calculation of exploitation rates in AEQ units → determine (plus escapement) if management goals are met
- Degradation of spawning and juvenile rearing stream habitats, disadvantageous changes in ocean foraging conditions (‘Warm Blob’) → recent years: low Chinook escapement, severe fisheries restrictions
- Necessary to precisely monitor, control and enforce the negotiated fishery terms
- Constant need to (1) update model inputs (e.g. forecasts, escapements, fishery mortalities), (2) error check and improve model calculations, (3) ensure model transparency, processing efficiency, ease of access of model results for policy and technical staff of tribes and WDFW
- Caveat: FRAM describes catches & not spatial abundances → adjustments by fishing effort (see Shelton et al. 2019, CJFAS)

Thank you very much for your attention !

NORTHWEST TREATY TRIBES
Protecting Natural Resources for Everyone

Northwest Indian Fisheries Commission

Washington Department of FISH and WILDLIFE

Characterizing Mercury Bioaccumulation and Toxicity in Larval Dragonflies

Ongoing Research

Cailin Mackenzie

MS Student | Dept. of Fisheries & Wildlife

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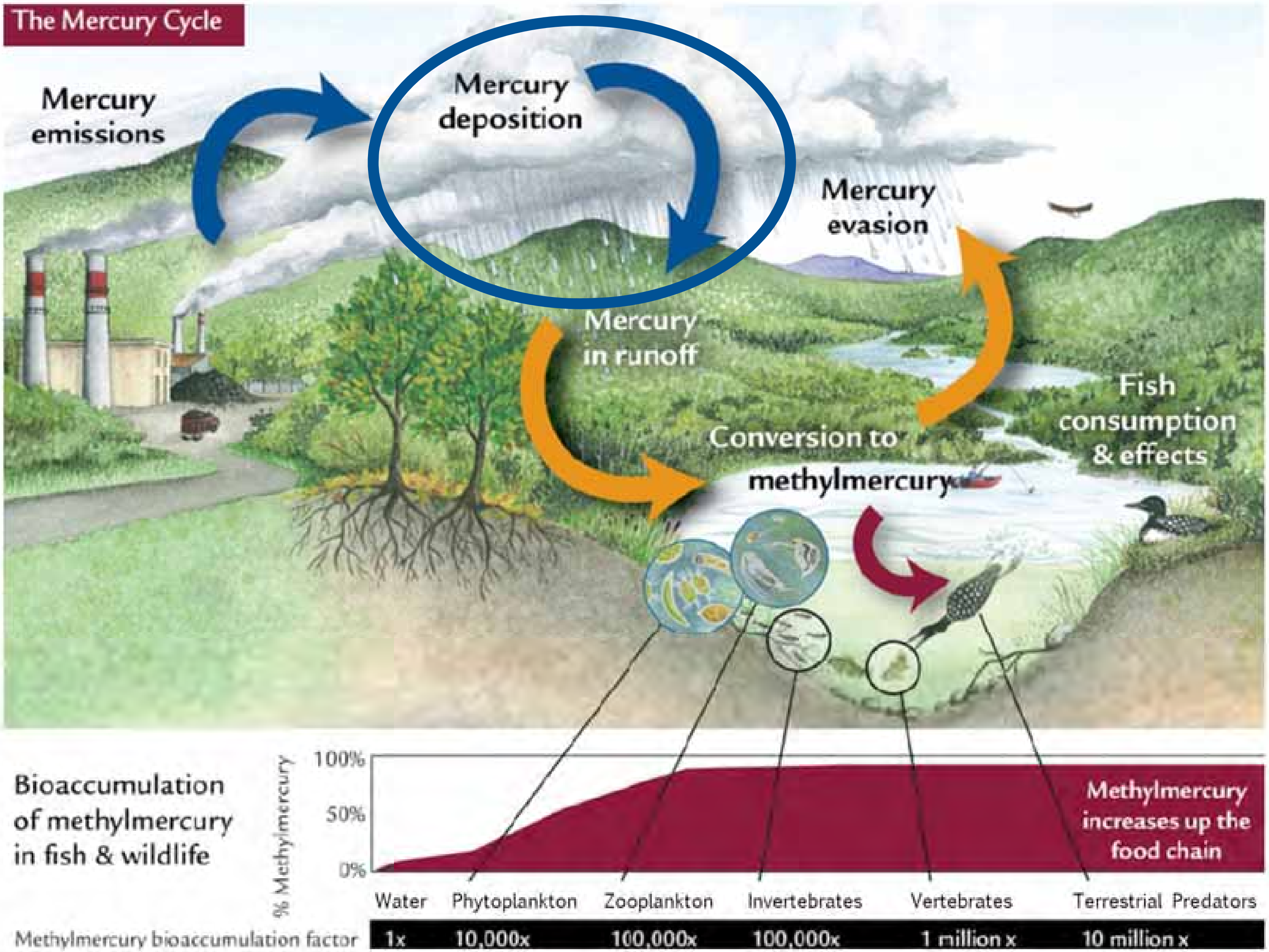


Figure: Evers et al. 2011

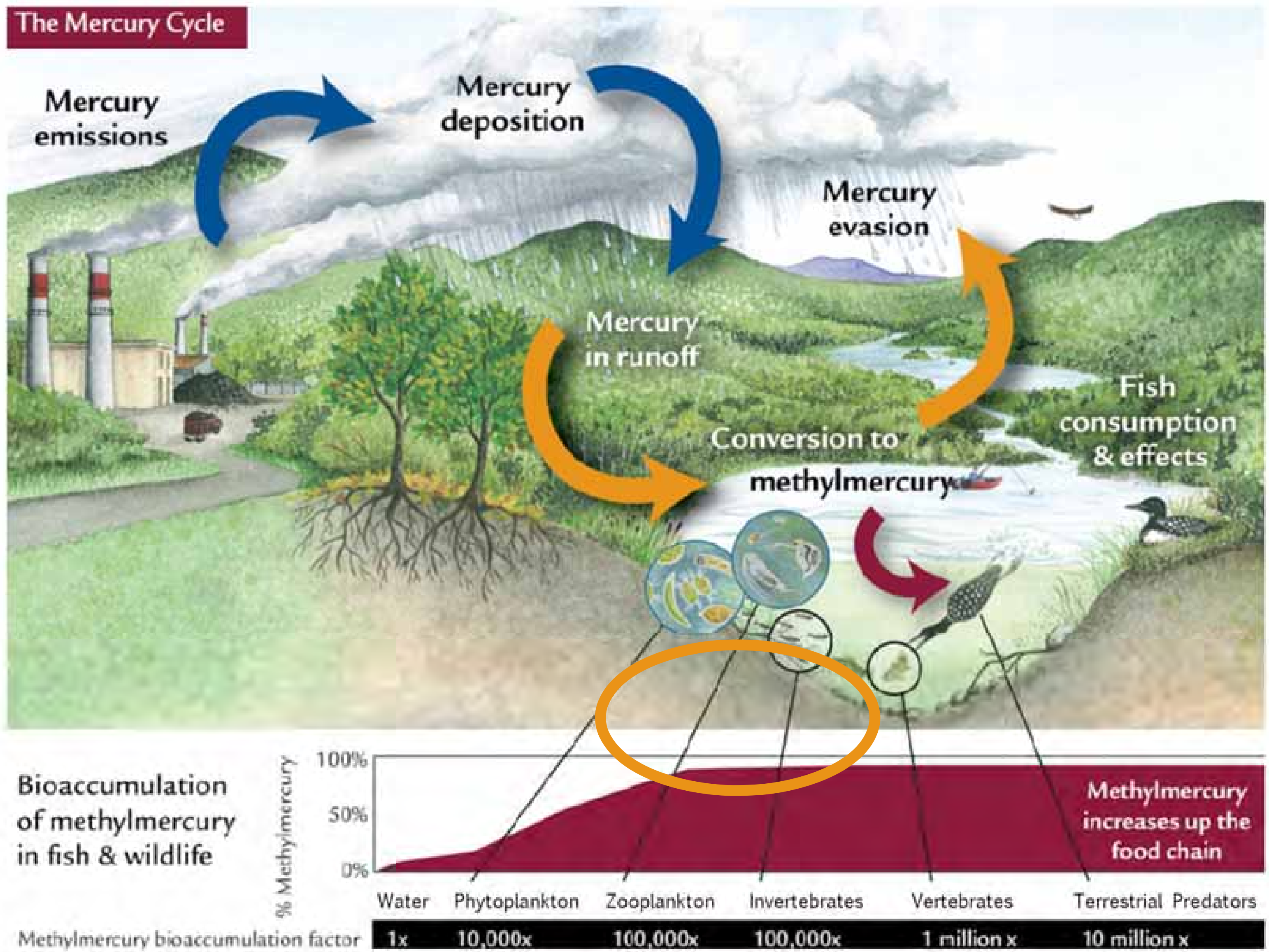


Figure: Evers et al. 2011

Generalized Pond Food Web

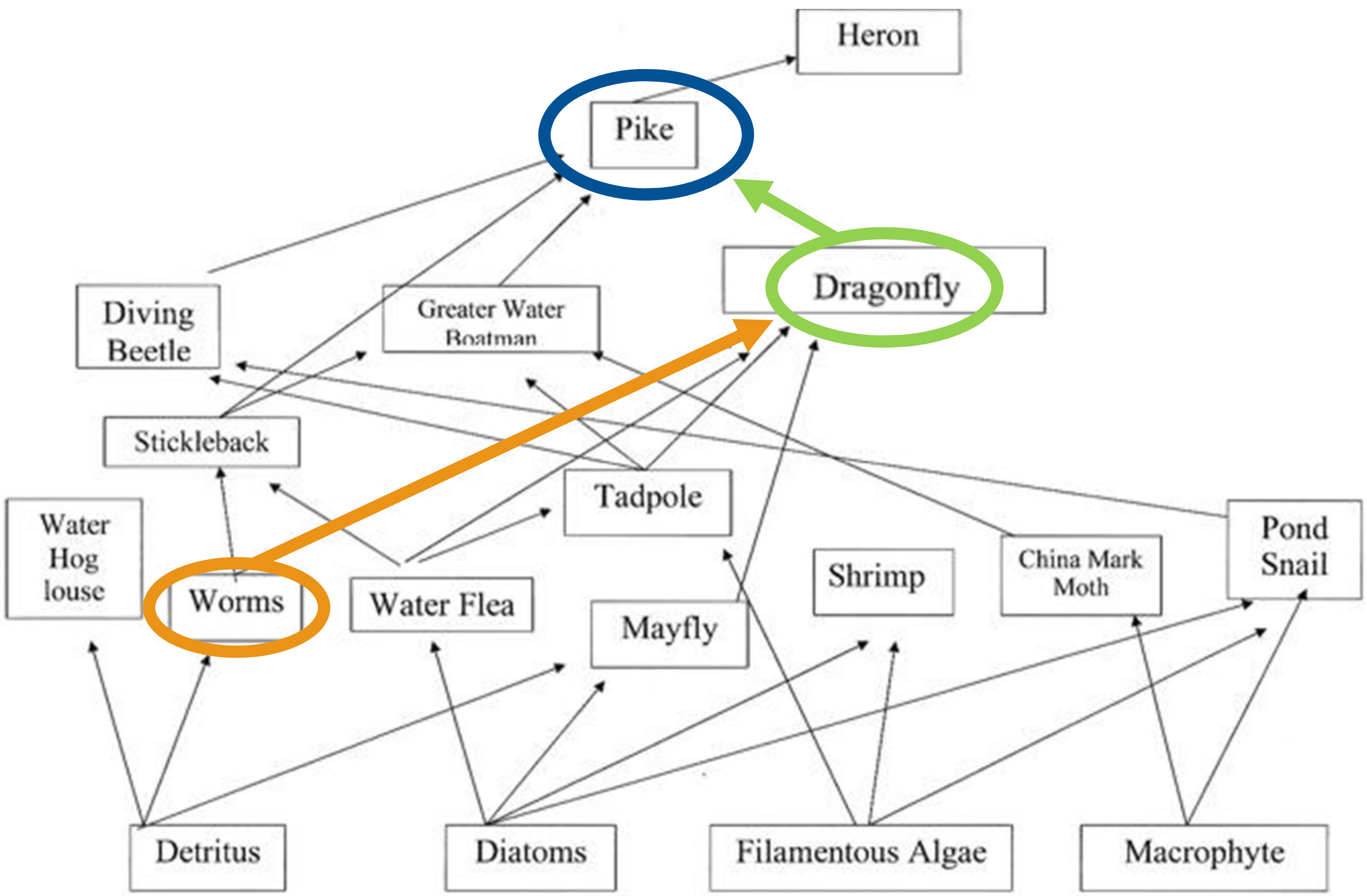
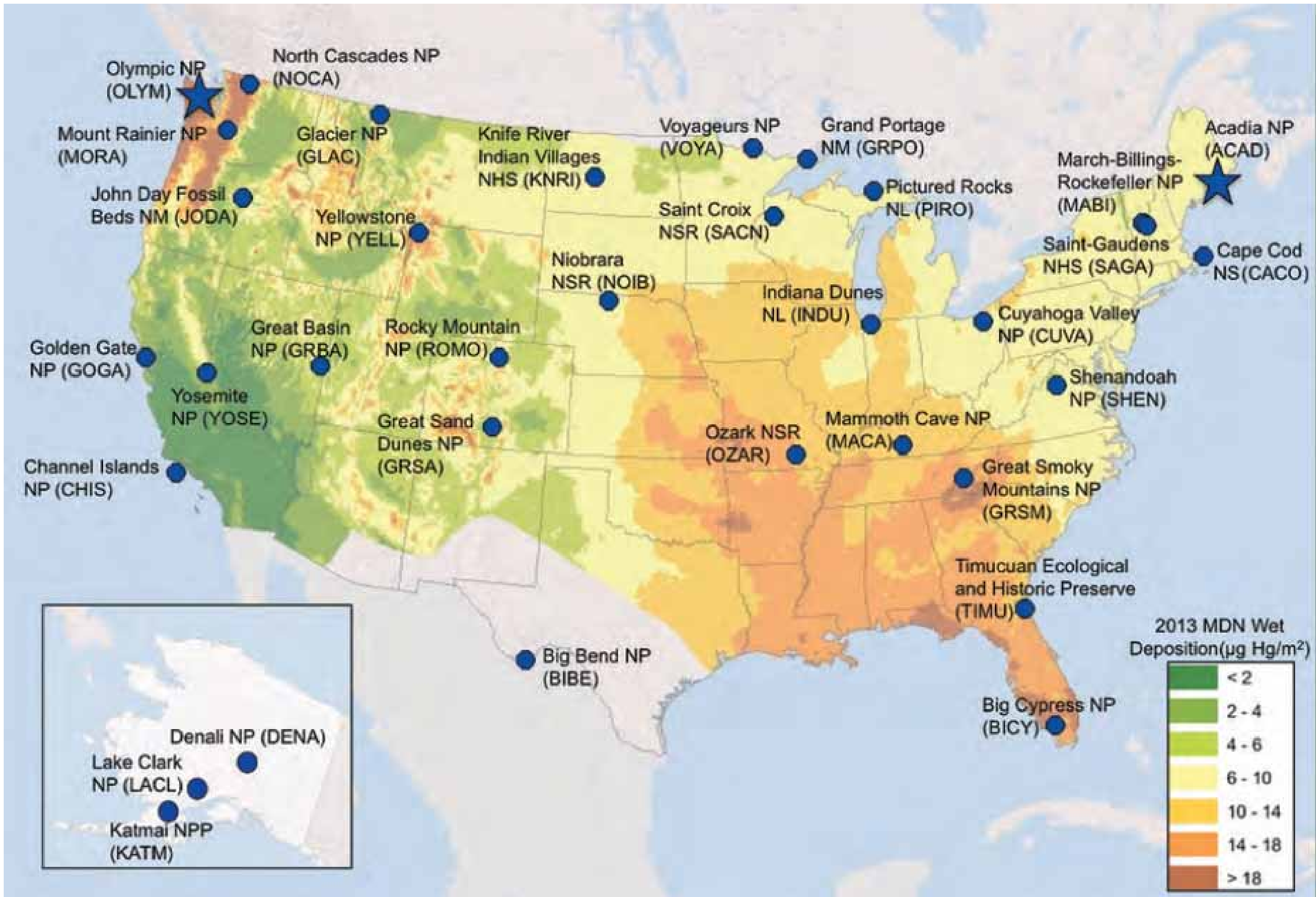


Figure: Field Studies Council: Biology Fieldwork

Dragonfly Mercury Project

Photos: Flanagan & Nelson 2013; Flanagan Prize & Nelson 2017; Nelson et al. 2015; Eagles-Smith et al. 2016; Dan Bell

Dragonfly Mercury Project

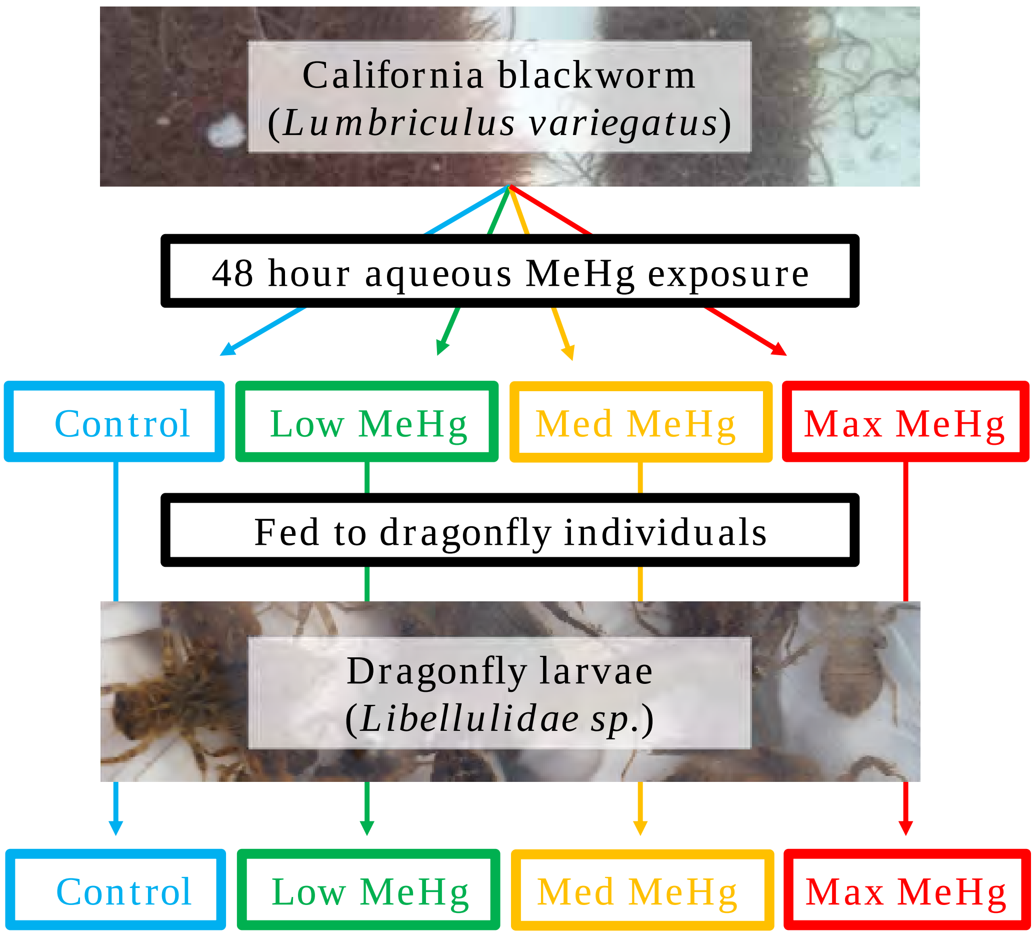


Eagles-Smith et al. 2016

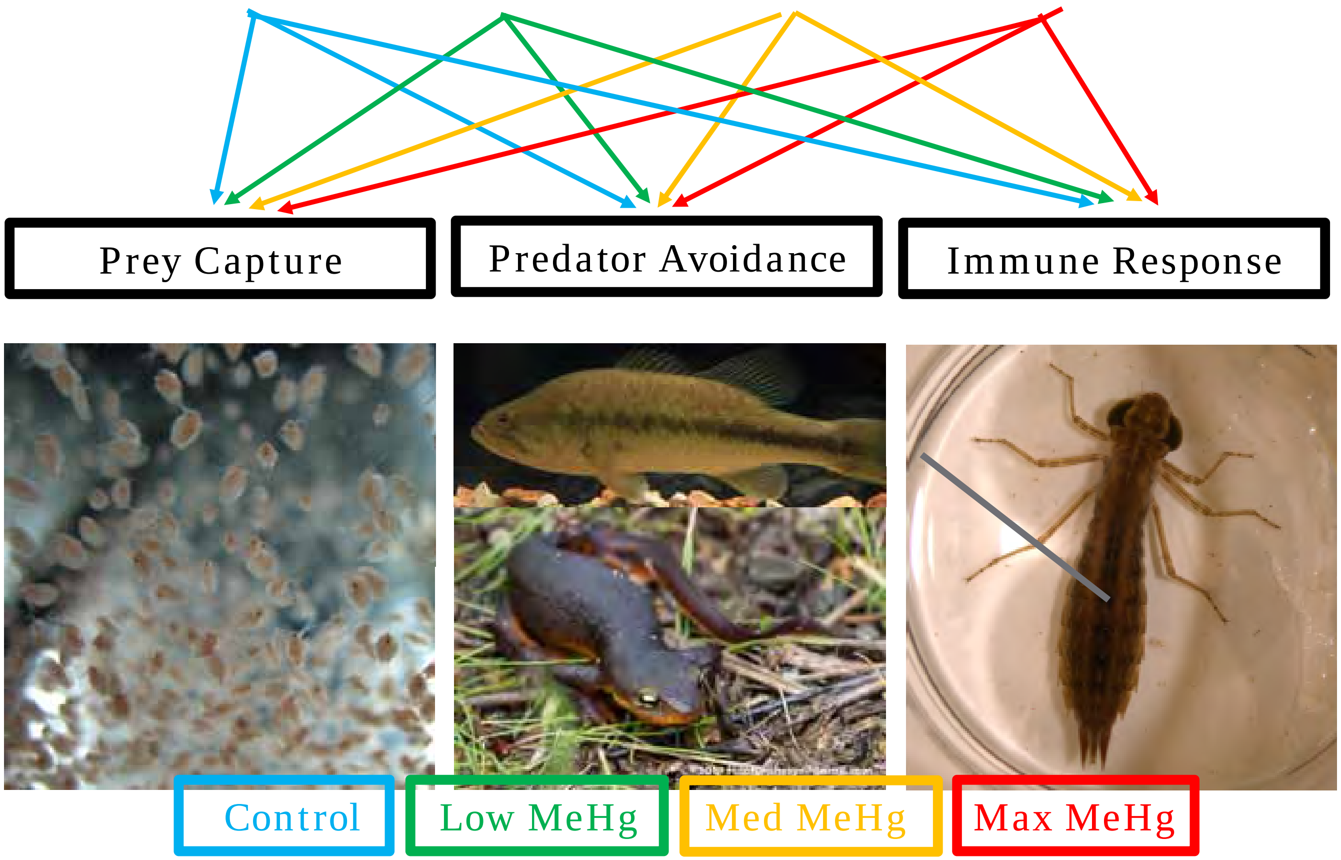
Data Gaps

- Mercury transfer from prey to dragonflies
- Mercury toxicity to dragonflies
- Mercury transfer from dragonflies to predators

Design


California blackworm
(*Lumbriculus variegatus*)
48 hour aqueous MeHg exposure
Control
Low MeHg
Med MeHg
Max MeHg
Fed to dragonfly individuals
Dragonfly larvae
(*Libellulidae sp.*)
Control
Low MeHg
Med MeHg
Max MeHg

Design


Prey Capture
Predator Avoidance
Immune Response
Control
Low MeHg
Med MeHg
Max MeHg

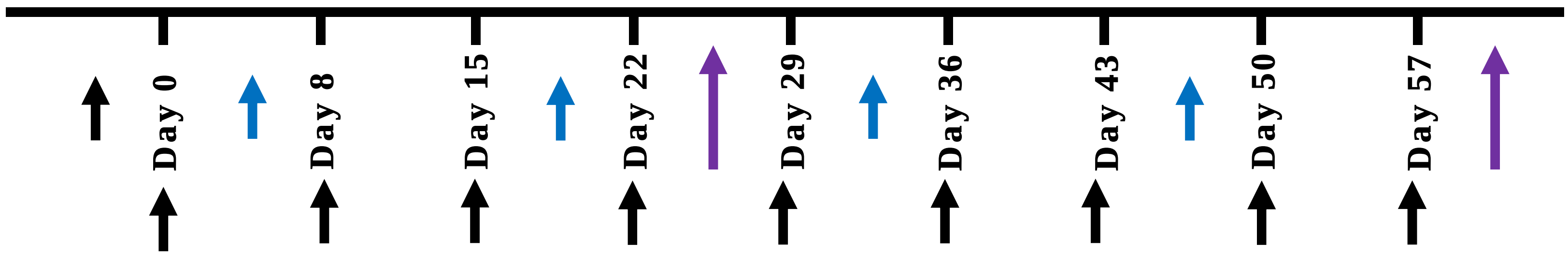
Methods

Photos: Christopher Cousins

Methods

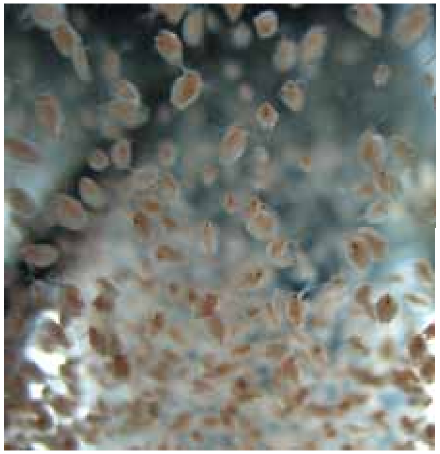
Methods

Timeline

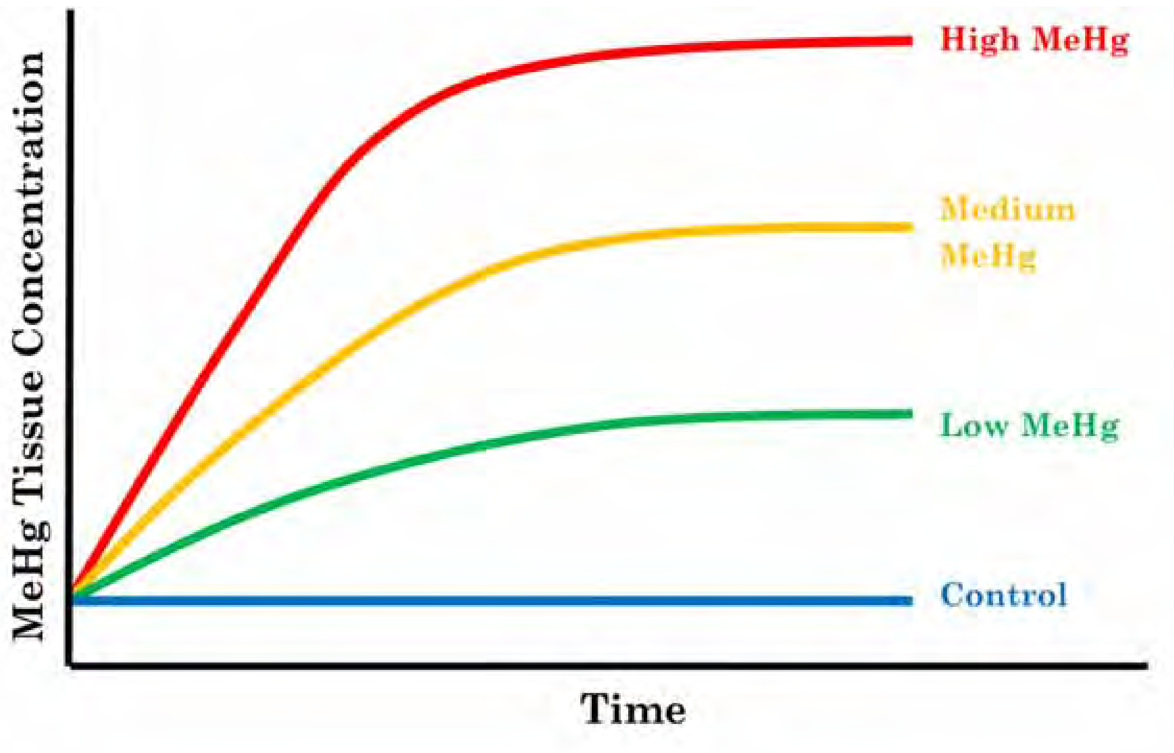


- Larvae acclimating to lab conditions and depurating mercury
- All larvae imaged and weighed, diet treatments start, n=28 sampled
- 7 larvae from each treatment starved then sampled
- Feeding rate measured
- Toxicity assays performed

Toxicity Assays

Prey Capture	Predator Avoidance	Immune Response
		
Jinguji et al. 2018 • Time to capture first prey item • Total number of strikes • Total prey consumed	Duong & McCauley 2016 • General activity rate • Refuge use	Moore, Lis & Martin 2018 • Melanin deposited

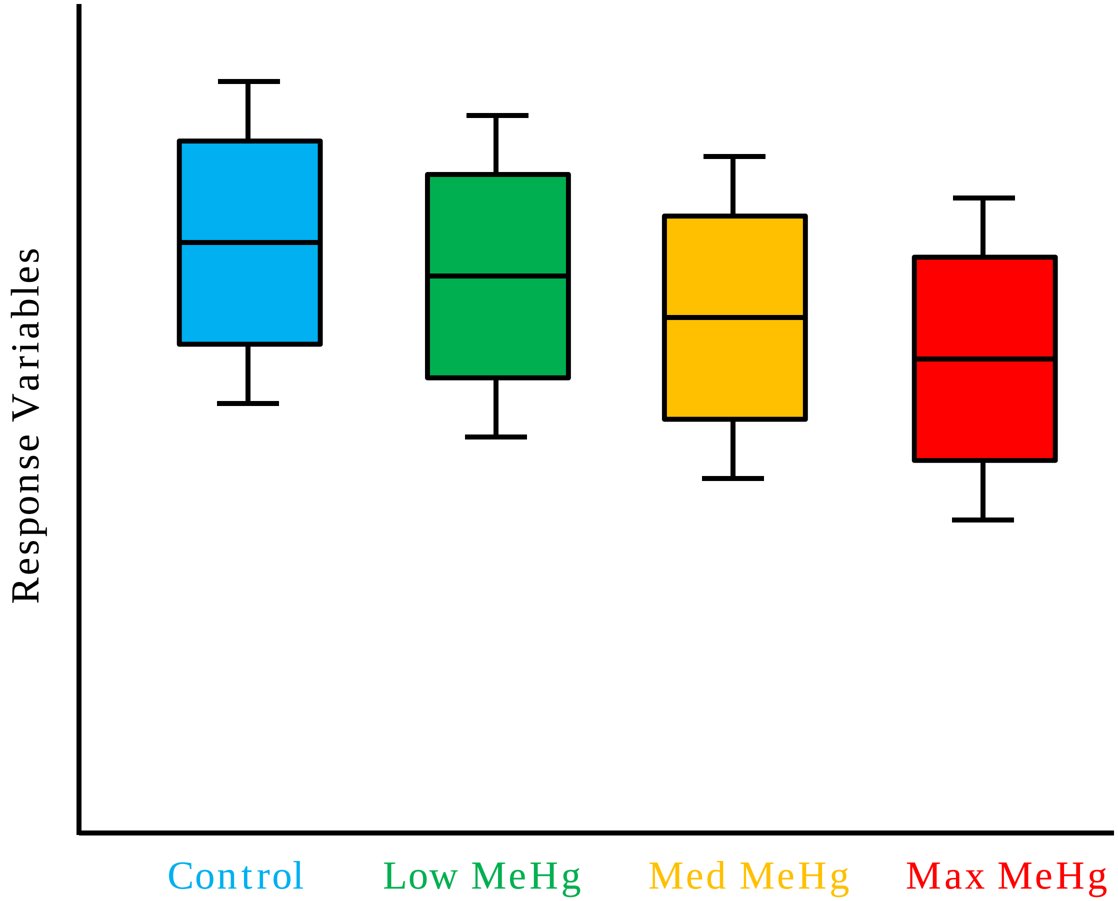
Bioaccumulation Hypotheses



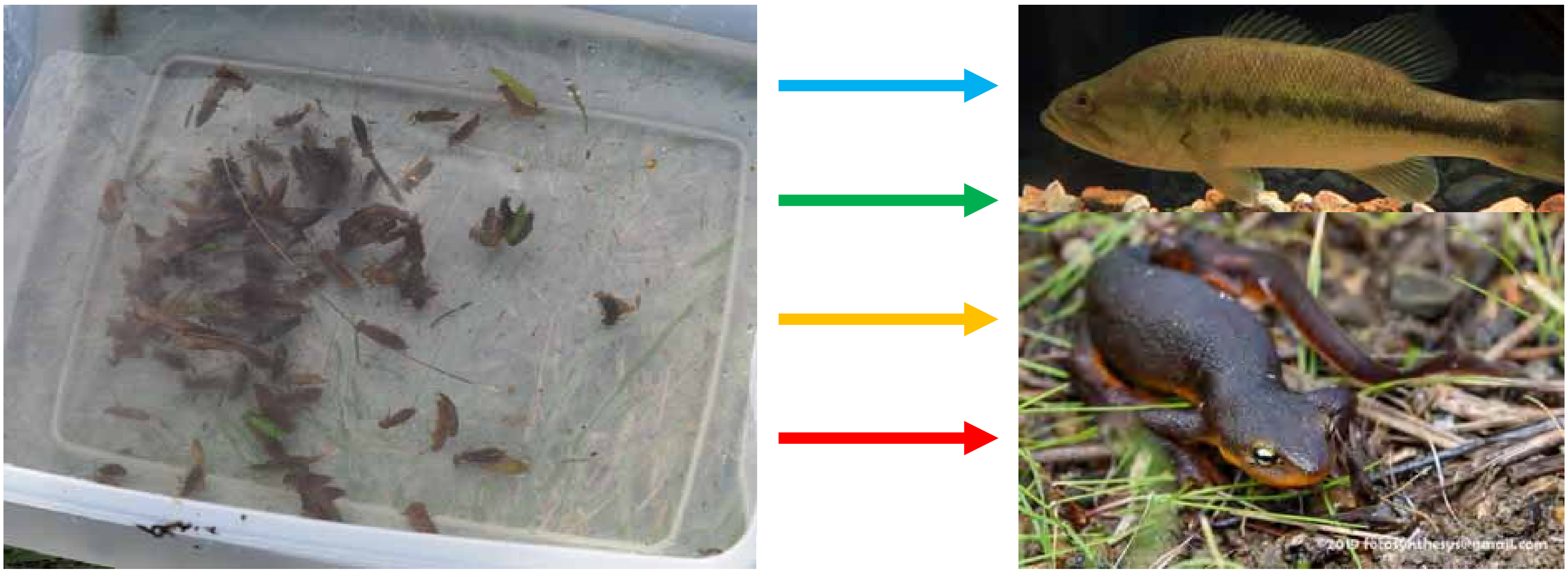
Toxicity Hypotheses

Response Variables:

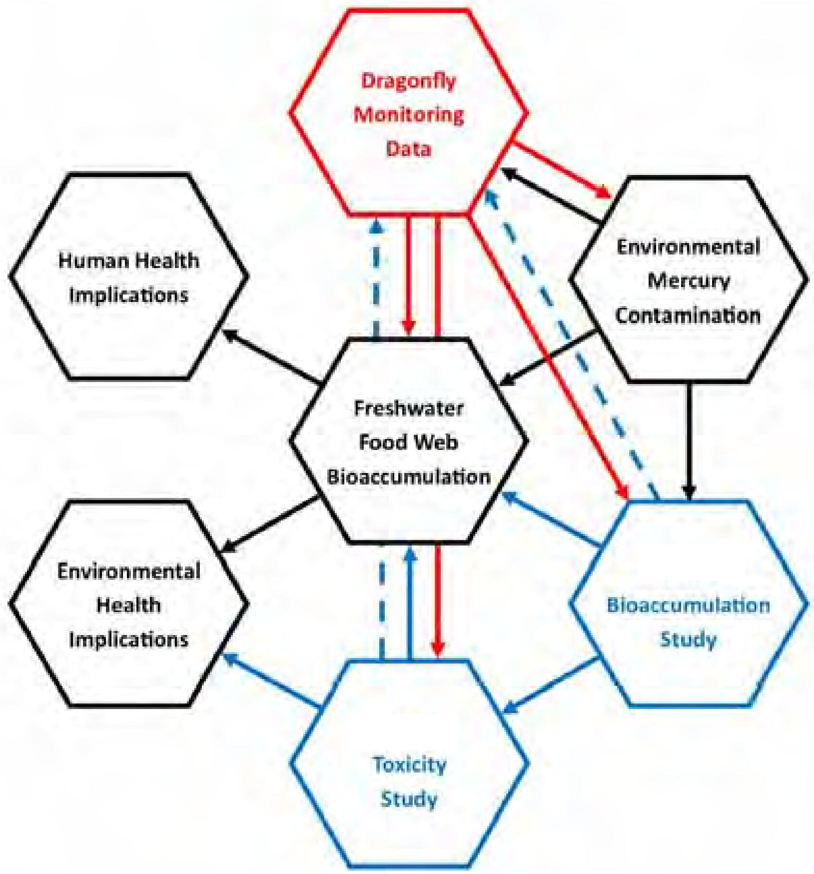
- Prey capture efficiency
- Prey capture success
- Predator avoidance
- Immune response
- Growth
- Body condition



Future Work



Broader Impacts



Thank you!

Advisors: Tiffany Garcia & Collin Eagles-Smith

Committee Members: David Lytle & Katherine McLaughlin

Funder: National Parks Service

Thank you:
Oregon State University Department of Fisheries and Wildlife,
Garcia Lab, Contaminant Ecology Research Team

Questions? Ideas?

Photo: JHoppenbrouwers