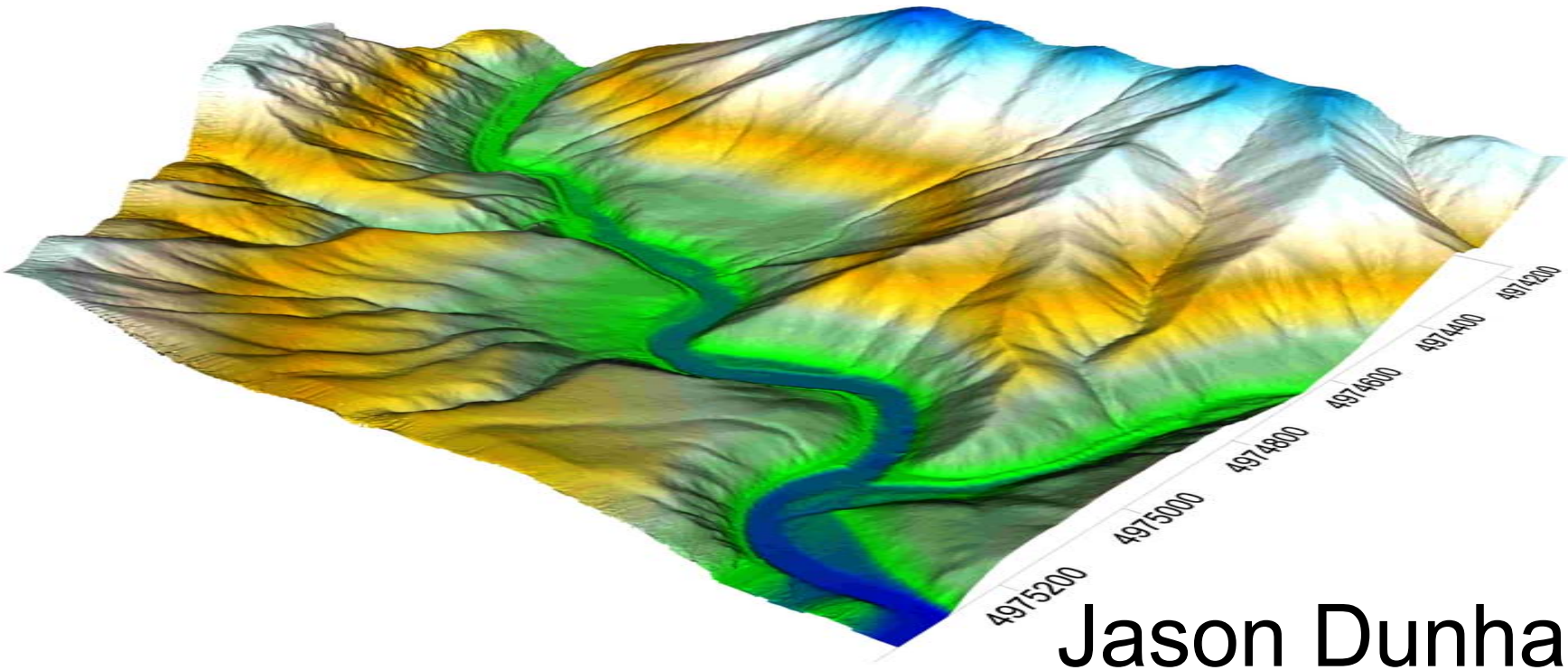
Climate Change and Native Species Responses in Riverine Ecosystems of the Pacific Northwest



Jason Dunham

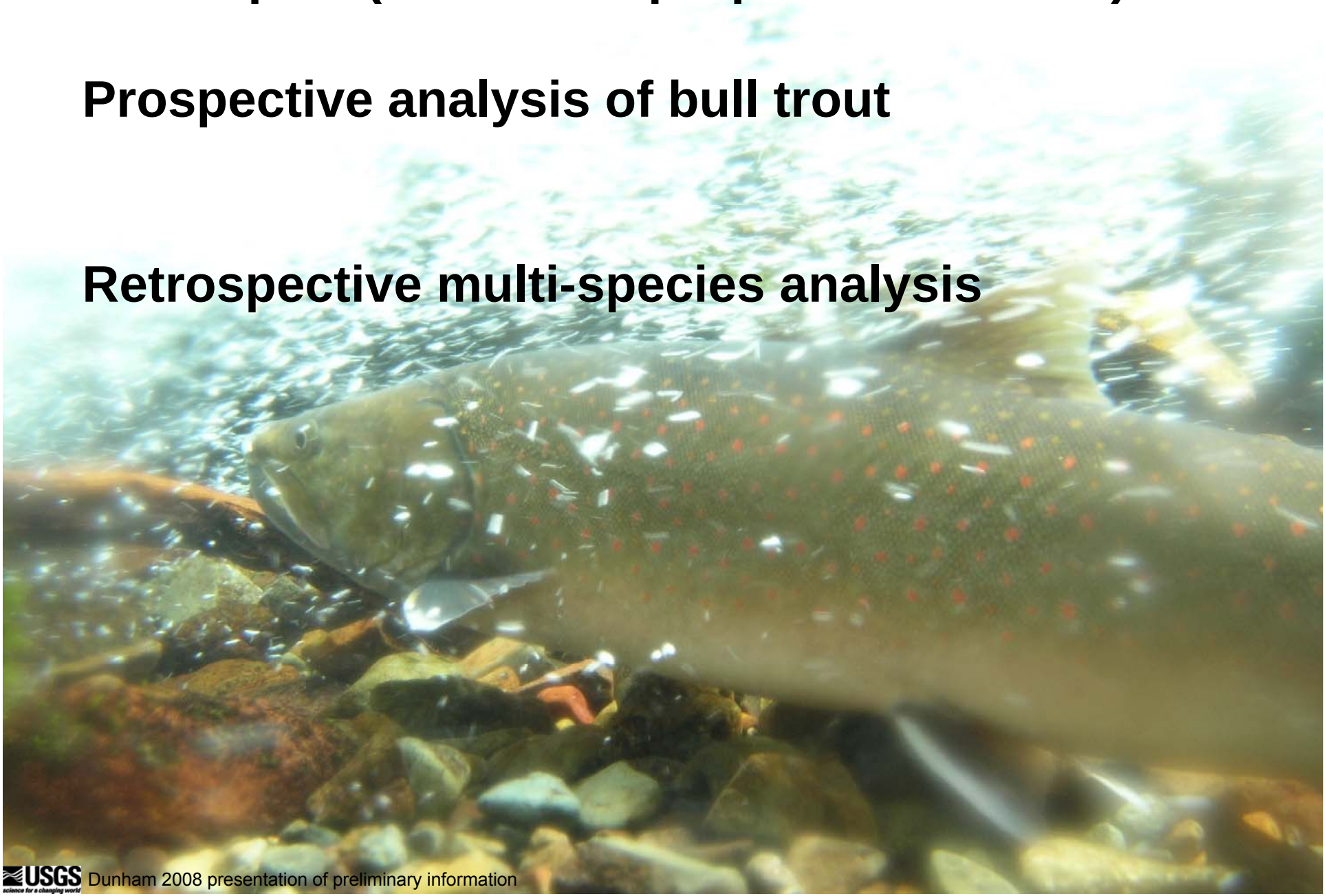
USGS Forest and Rangeland Ecosystem Science Center

U.S. Department of Interior
U.S. Geological Survey

Two topics (active and proposed research):

Prospective analysis of bull trout

Retrospective multi-species analysis



Coauthors/collaborators

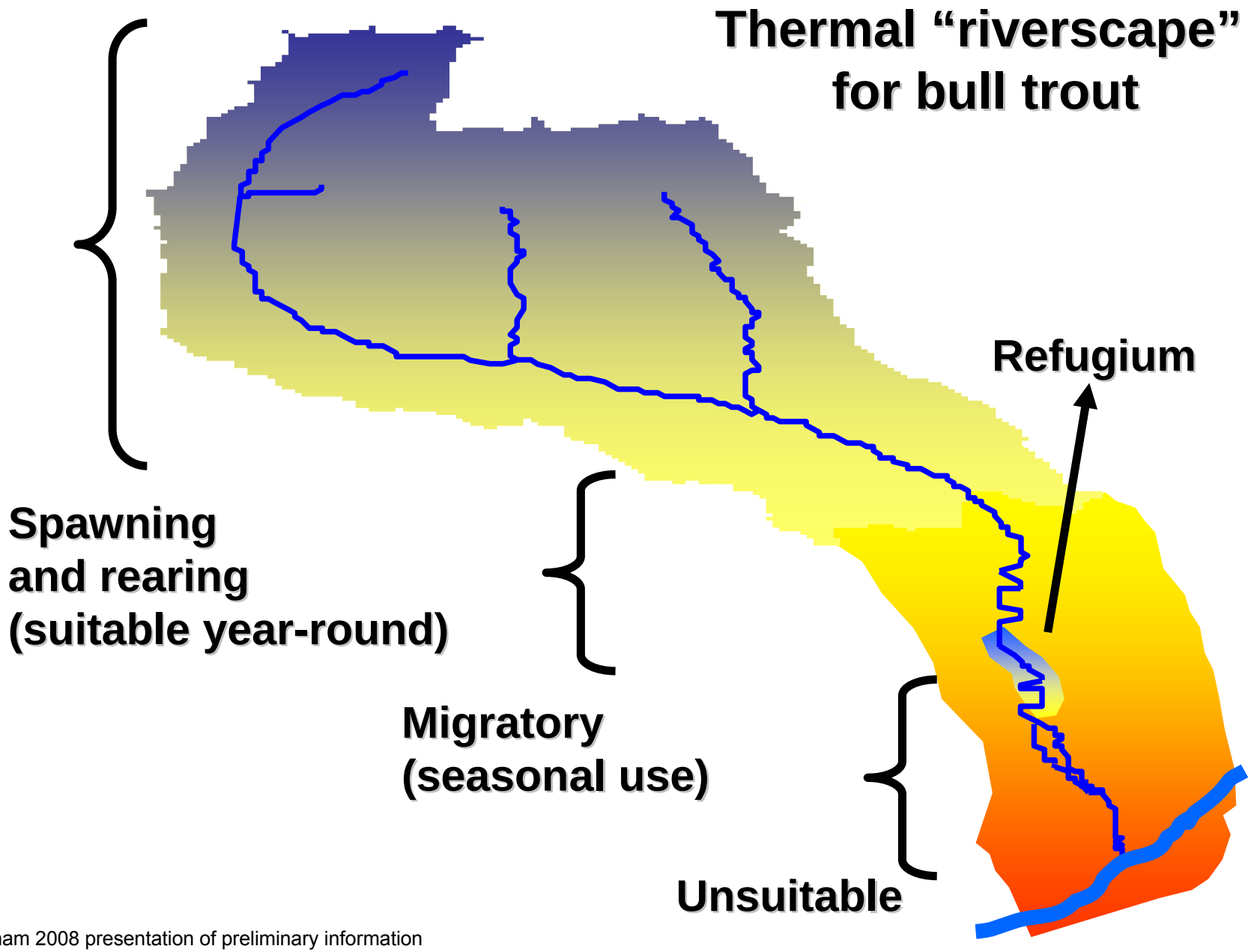
Prospective analysis of bull trout

John Buffington, Christopher Cuhaciyan, **Dan Isaak**, Gordon Grant, Charlie Luce, USFS; Christina Tague, USCB; Jim O'Connor, USGS

Retrospective multi-species analysis

Bryan Black, OSU; Sarah Shafer, USGS

Bull trout habitat requirements



Climate change and bull trout

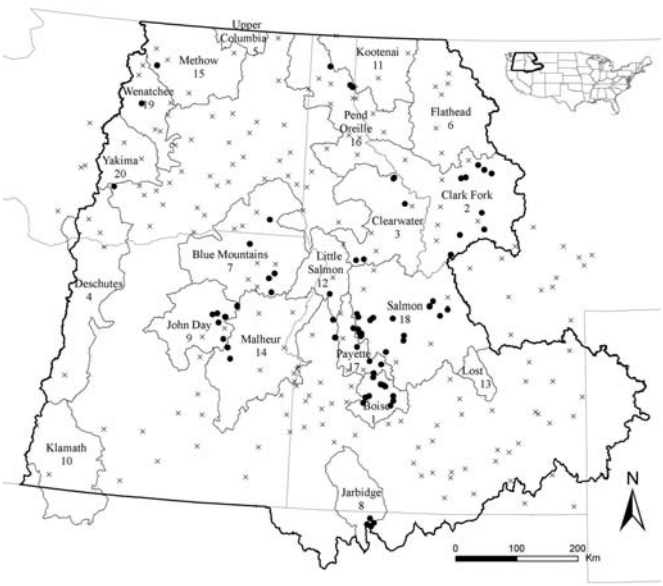
Bull trout sensitive to loss of cold water

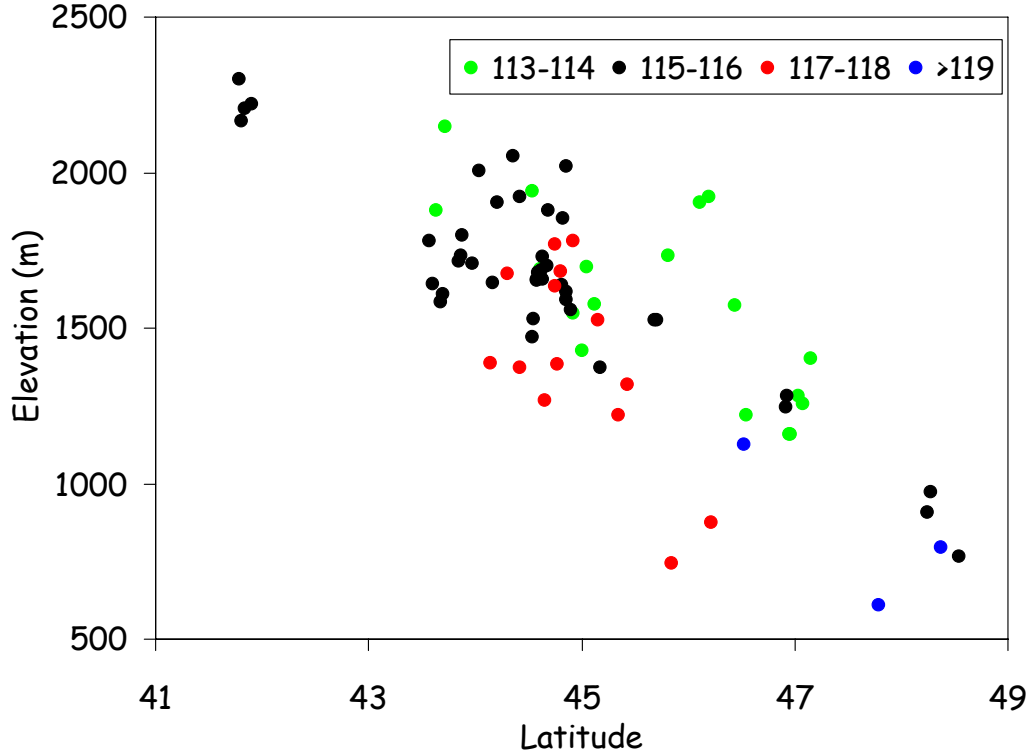
Water temperature data are limited

Elevation and air temperature data are not

- Can these variables predict effects of climate change?

Elevation, air temperatures, bull trout





Juvenile Bull Trout Lower Elevation Limit (R^2 = 0.74)
Y = 18693 - 191(lat) + 73.6(long)

1° lat = -191 m; 1° long = 73.6 m

Mean Annual Air Temperature (R^2 = 0.89)
Y = 67 – 0.86(lat) + 0.12(long) - 0.0062(ele)

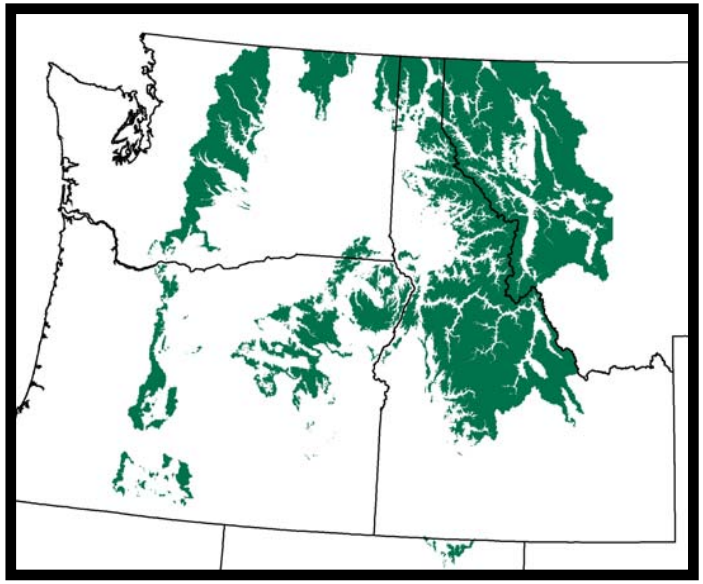
1° lat = -138 m; 1° long = 88 m

(Rieman et al. 2007; images courtesy Dan Isaak, USFS)

Projections based on bull trout – elevation elevation – air

(Rieman et al. 2007; images courtesy Dan Isaak, USFS)

Currently Suitable



Projections based on bull trout – elevation elevation – air

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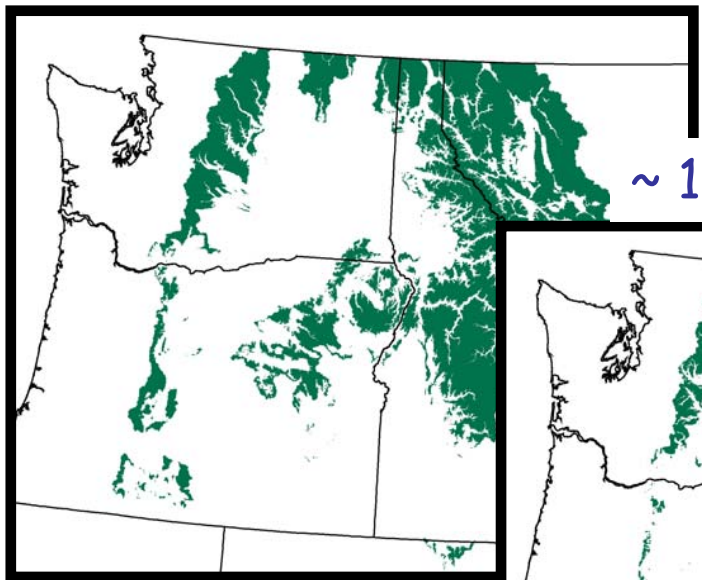
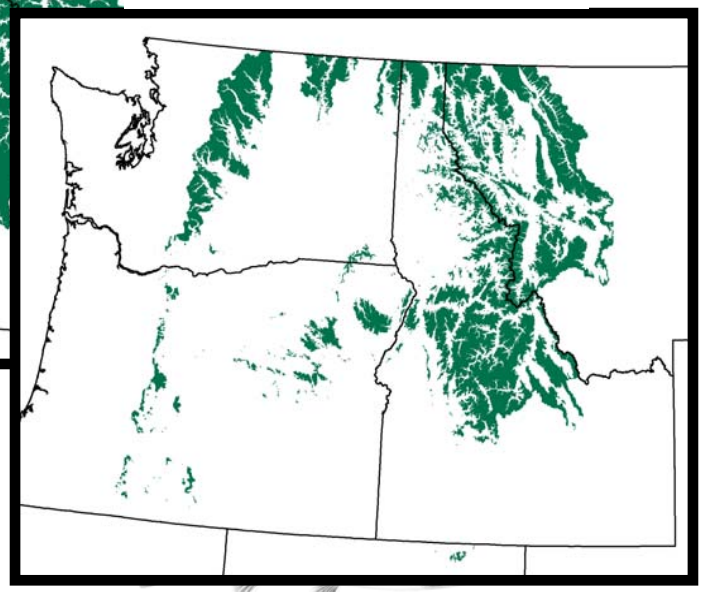


~ 1.6 °C Increase

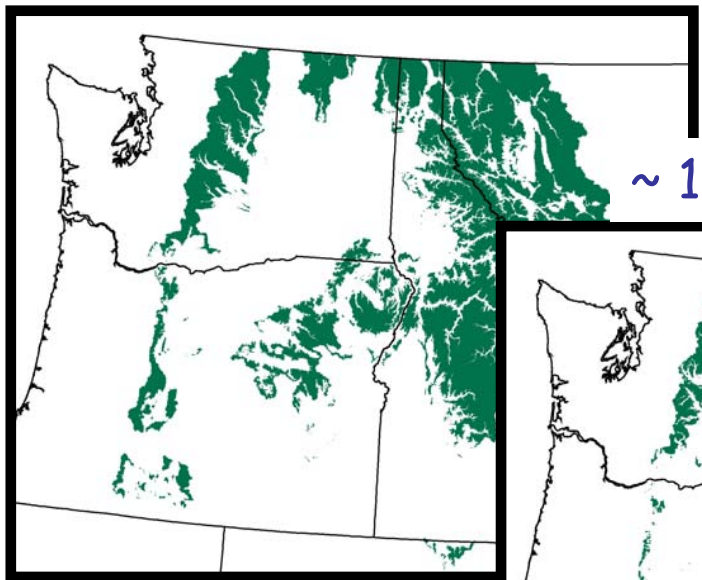


Habitat Reduction	Areal Extent	# Patches >5000 ha
Rangewide	-40%	-60%
Idaho	-37%	-70%

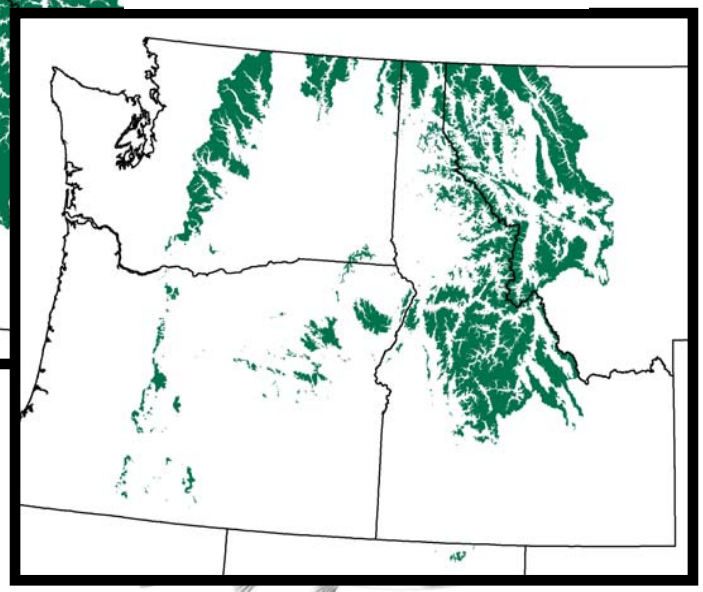
Projections based on bull trout – elevation elevation – air

(Rieman et al. 2007; images courtesy Dan Isaak, USFS)

Currently Suitable

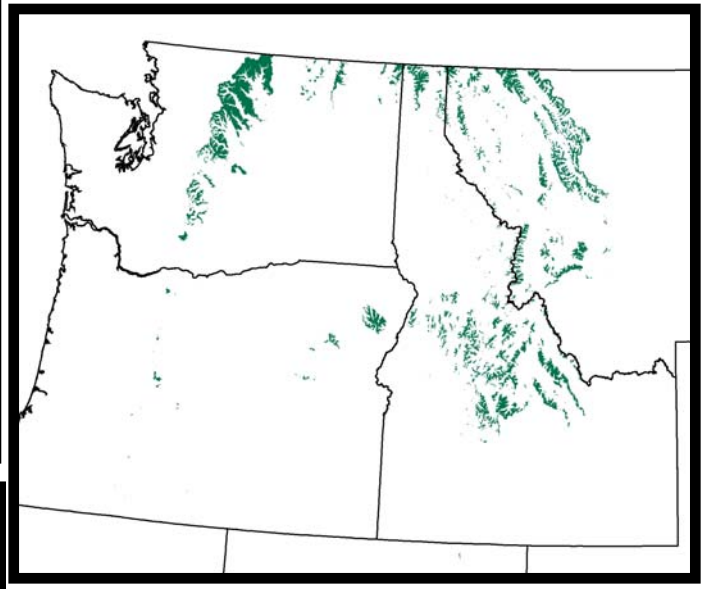


~ 1.6 °C Increase



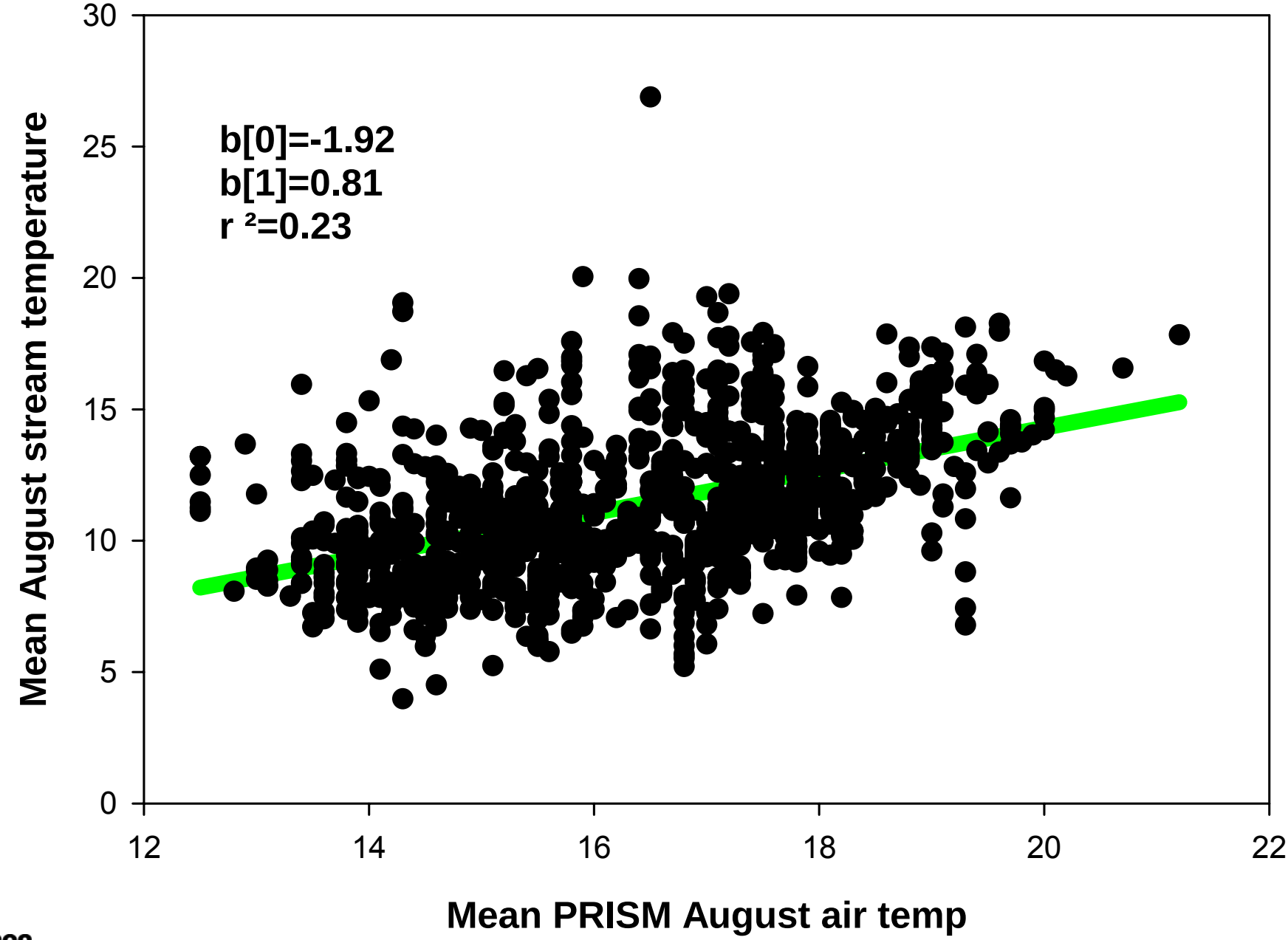
Habitat Reduction	Areal Extent	# Patches >5000 ha
Rangewide	-40%	-60%
Idaho	-37%	-70%

~ 5.0 °C Increase



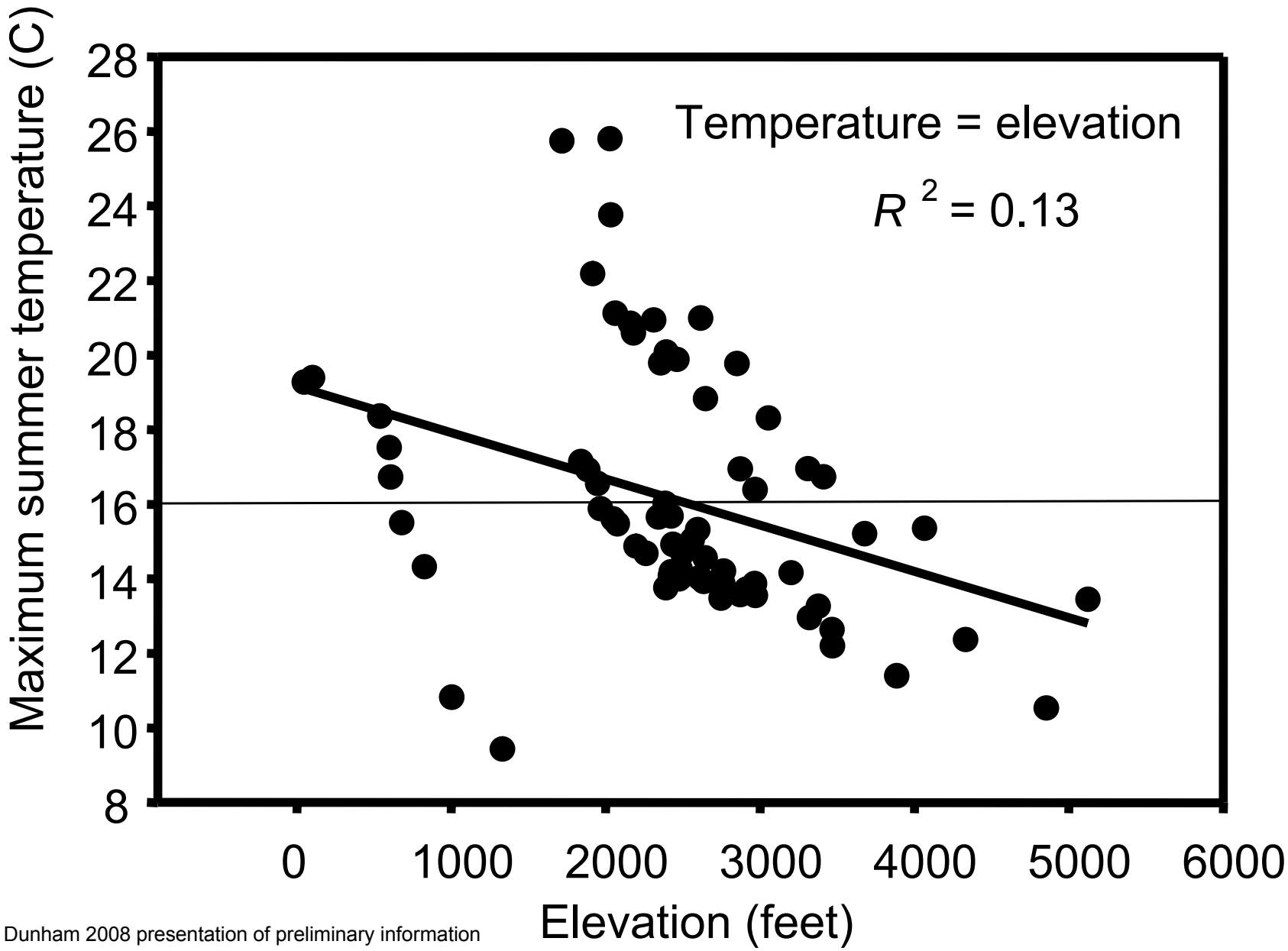
Habitat Reduction	Areal Extent	# Patches >5000 ha
Rangewide	-92%	-99%
Idaho	-94%	-100%

Air temperatures ≠ water temperatures in the PNW



USGS science for a changing world Dunham 2008 presentation of preliminary information

Water temperature vs **elevation** in Washington State

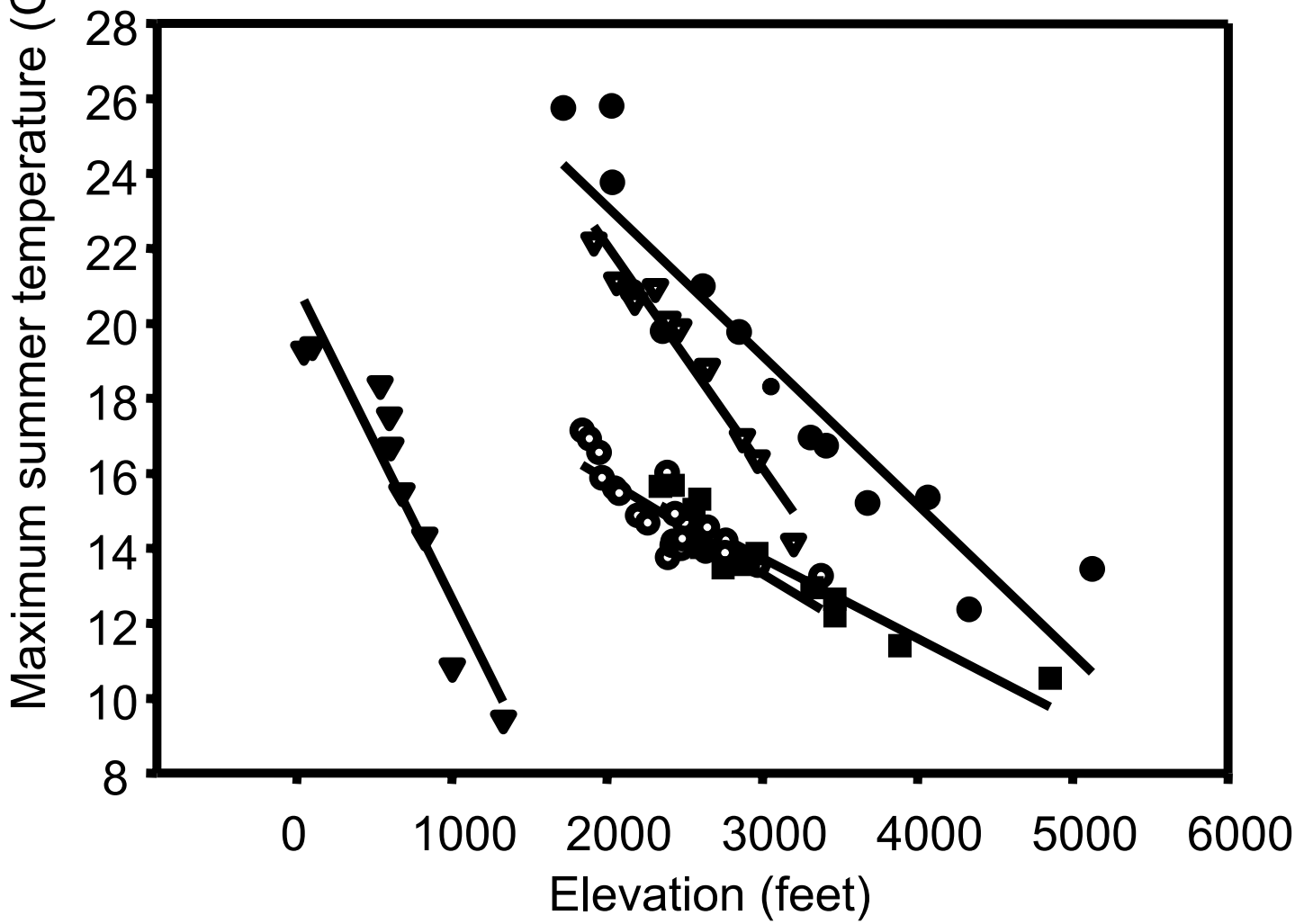


USGS science for a changing world Dunham 2008 presentation of preliminary information

Localized “stream effects” and elevation predictions

Temperature = stream + elevation + stream*elevation

$R^2 = 0.94$



Paradoxes: bull trout and climate

- **Contemporary** bull trout distributions tied to **elevation** and **air** temperature gradients at broad scales

Paradoxes: bull trout and climate

- Contemporary bull trout distributions tied to elevation and air temperature gradients at broad scales
- Bull trout also tied to **water** temperatures

Paradoxes: bull trout and climate

- Contemporary bull trout distributions tied to elevation and air temperature gradients at broad scales
- Bull trout also tied to water temperatures
- Water temperatures **weakly** related to elevation or air temperature
- *What's missing?*

Paradoxes: bull trout and climate

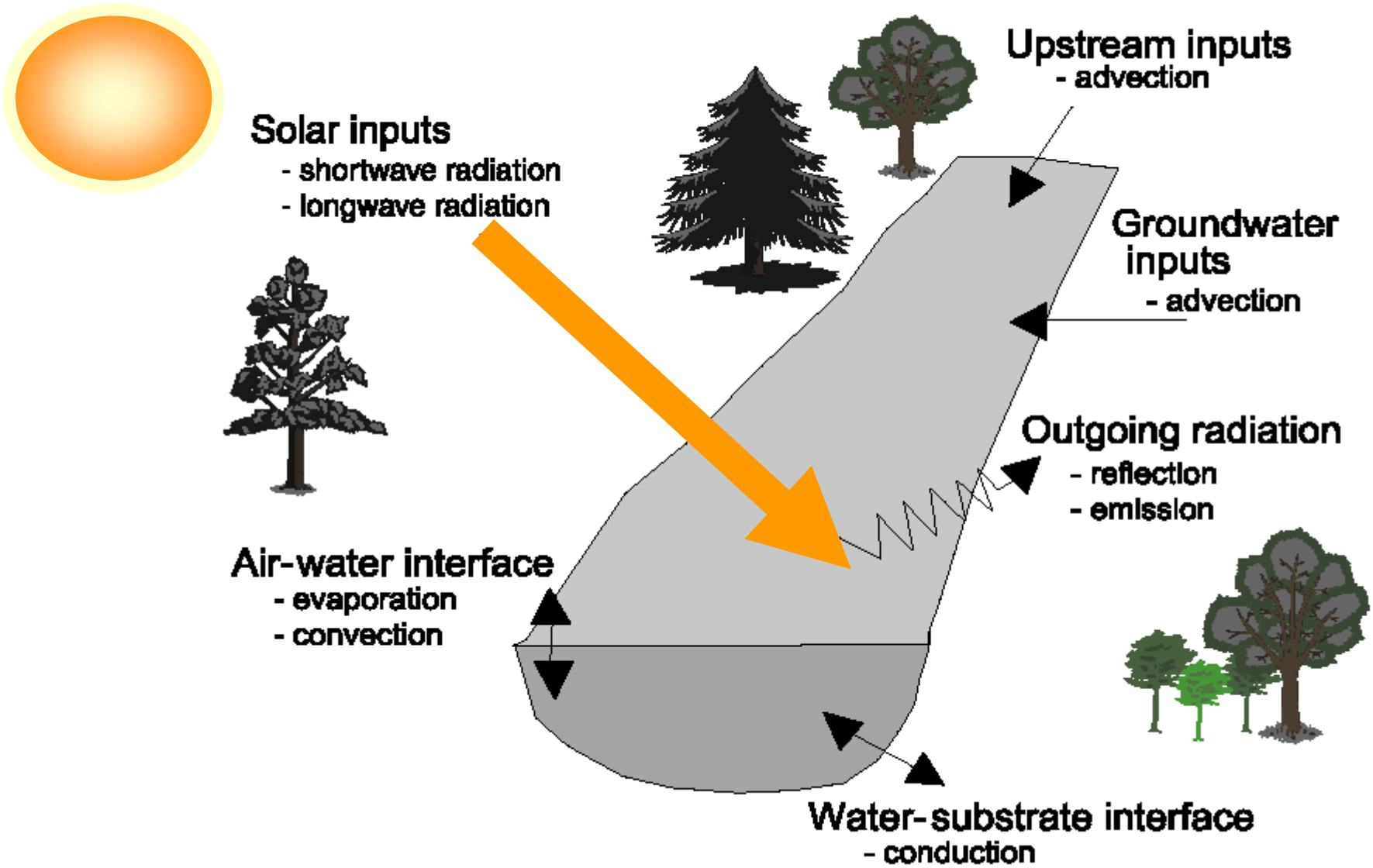
What's missing? –

The Future

Links to physical process

What processes actually influence water temperatures?

Fig. 1. Factors and mechanisms influencing stream temperature.



*Modified from Johnson and Jones CJFAS 2000

What will change?

- Elevations and long-lat won’t change

What will change?

- Elevations and long-lat won't change
- Air temps will increase
  - But air doesn't heat water efficiently

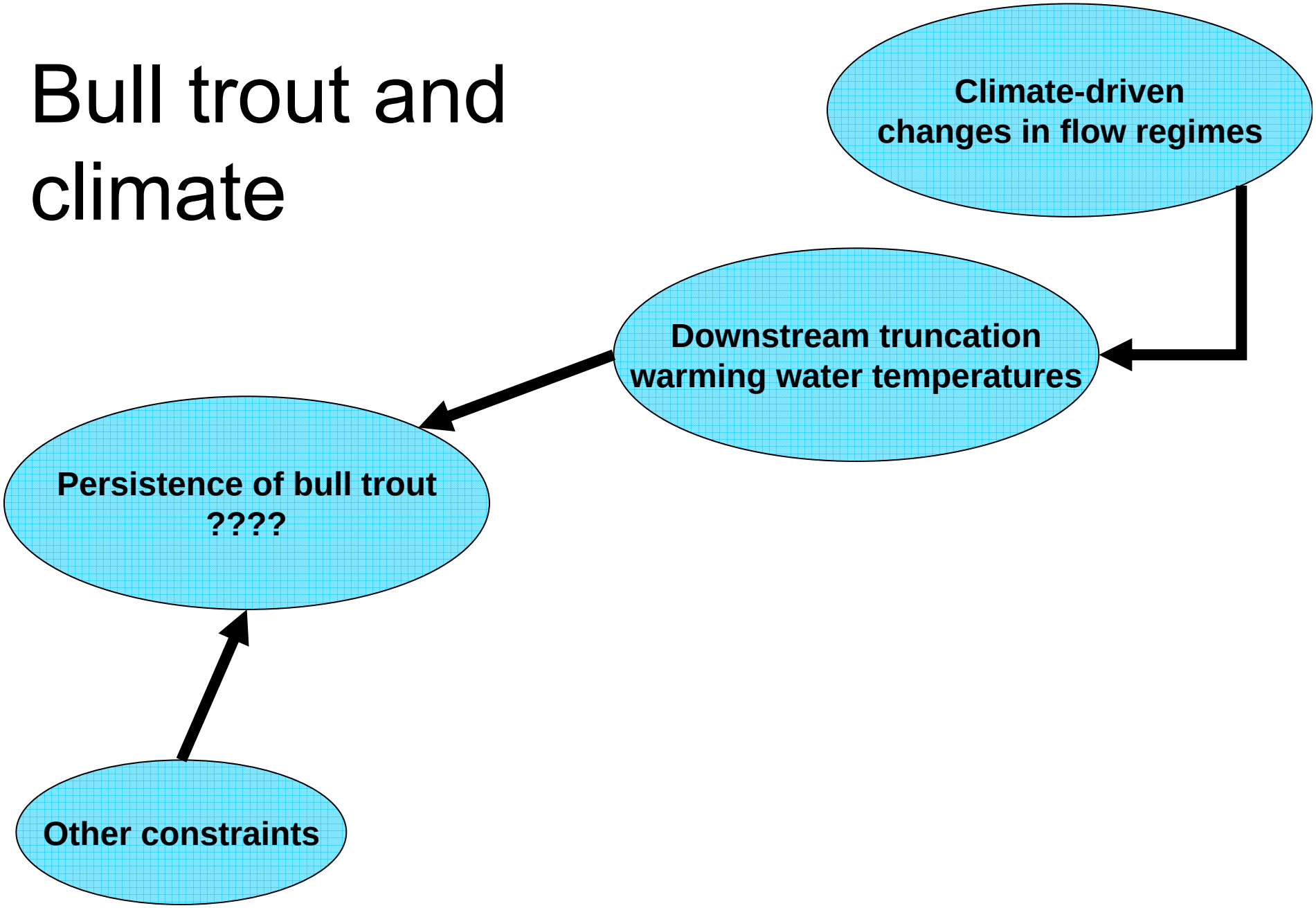
What will change?

- Elevations and long-lat won't change
- Air temps will increase
  - But air doesn't heat water
- The sun (and short wave radiation) will still be here
  - But riparian zones could change

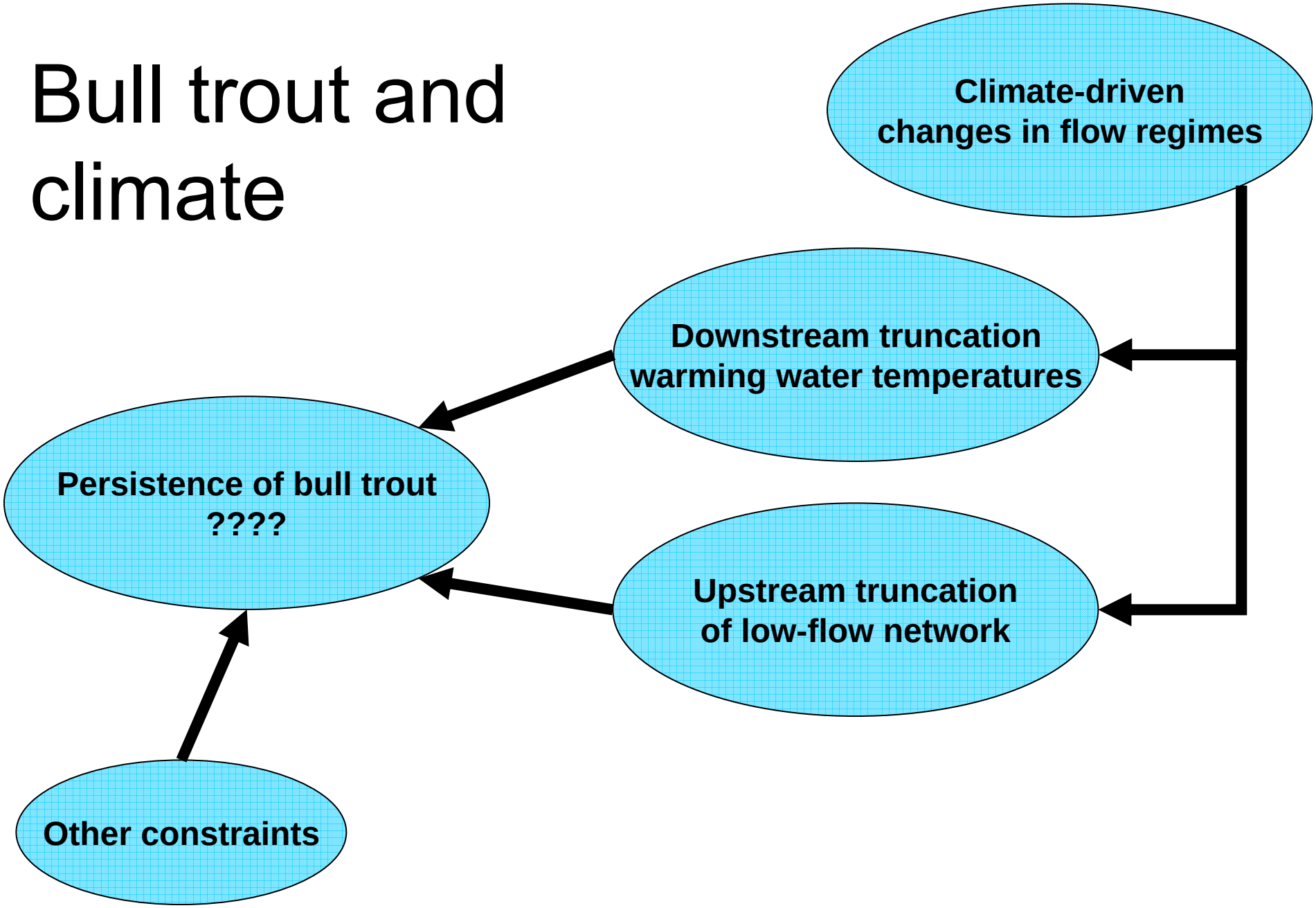
What will change?

- Elevations and long-lat won't change
- Air temps will increase
  - But air doesn't heat water
- The sun will still be here
  - But riparian zones could change
- **Stream hydrology** will change
  - indirect influences of timing, amount, type of precipitation and routing of water

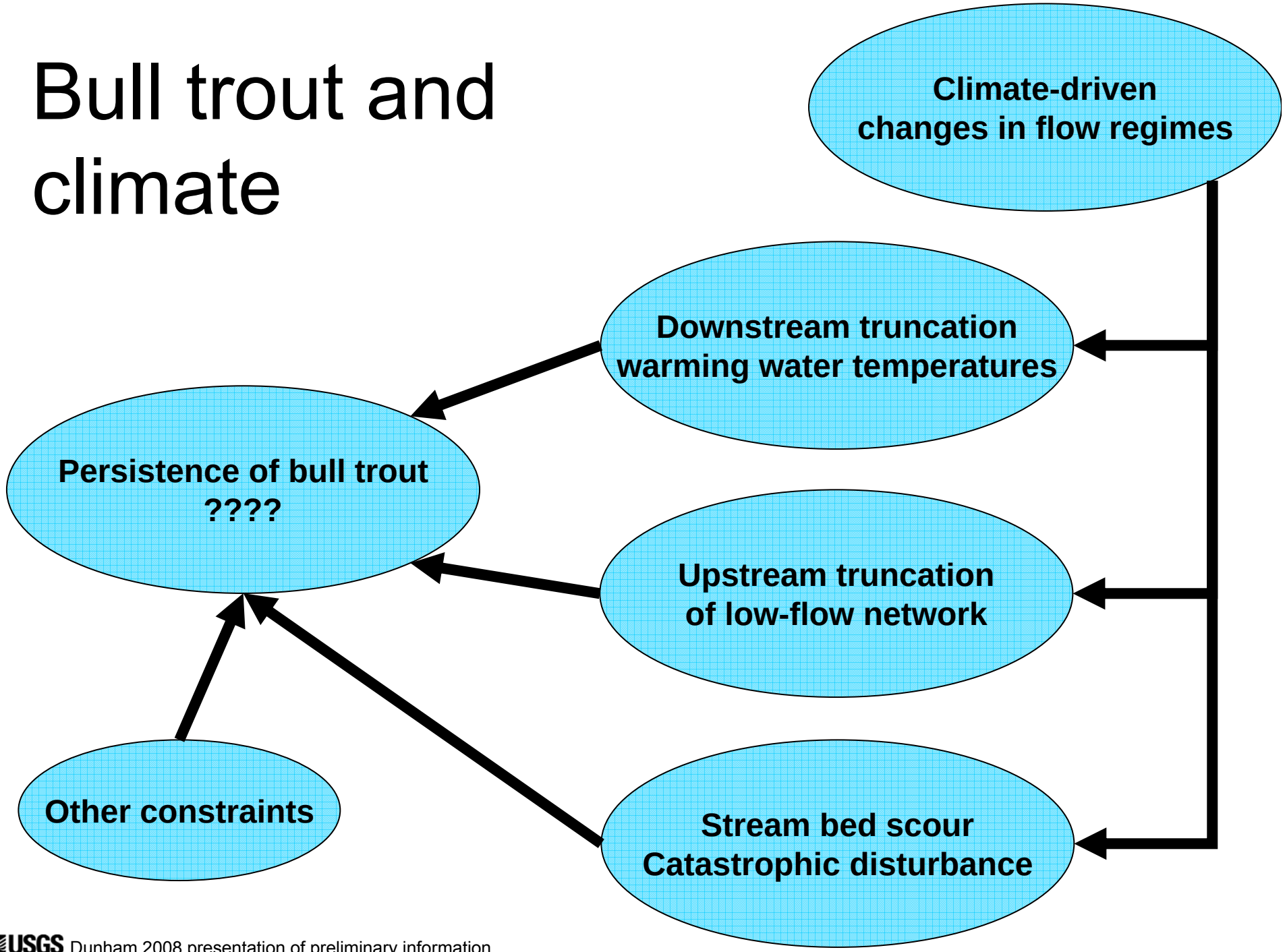
Bull trout and climate

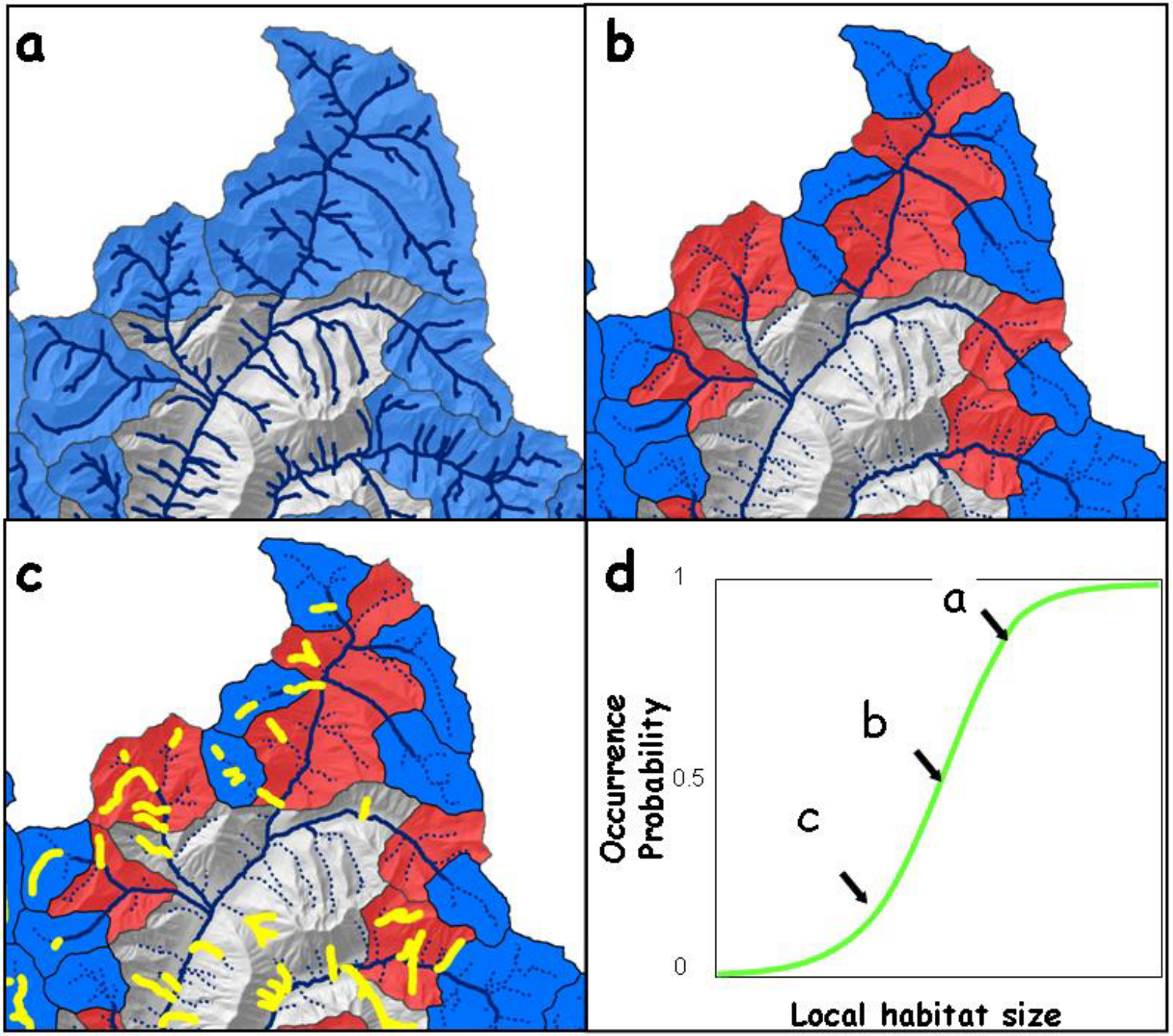


Bull trout and climate



Bull trout and climate




a
b
c
d
1
0.5
0
Occurrence Probability
Local habitat size
a
b
c

Bottom lines for bull trout

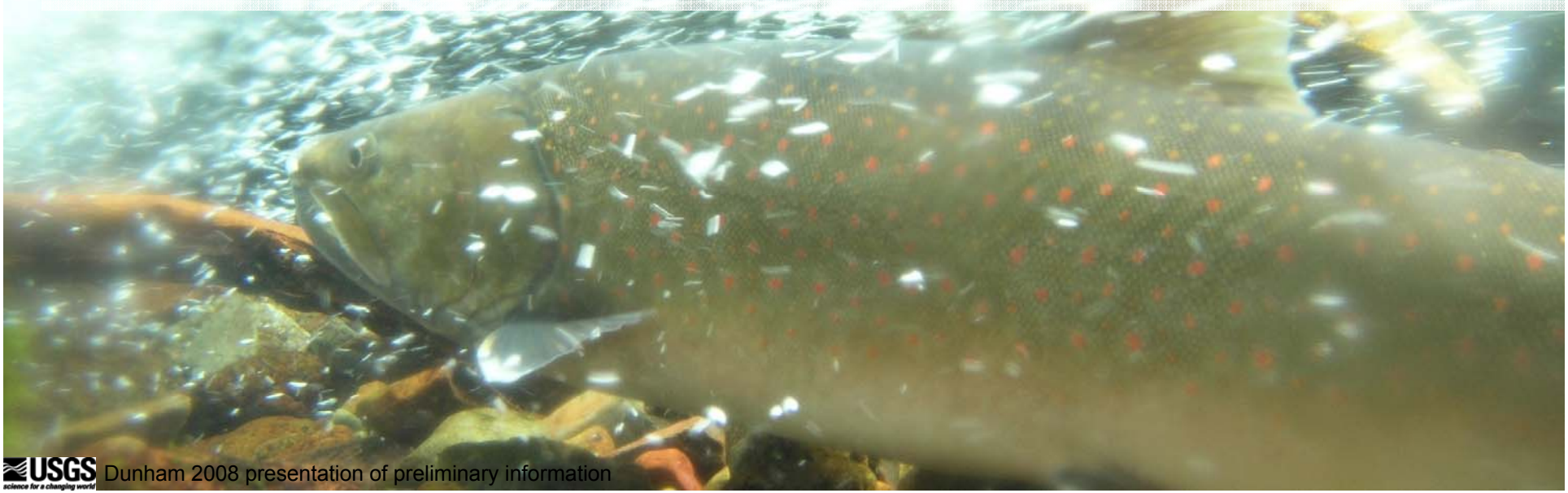
- **Temperature is critical**
  - But the future is highly uncertain
- **Other influences may be critical**
  - Stream bed scour, disturbance
- **Surprises likely from interacting factors**
  - Invasive species
  - Climate impacts on other factors (e.g., wildfire)
  - Other changing human influences

- For more details, see AFS special session website:

www.fs.fed.us/rm/boise

Larger lessons: how we do science

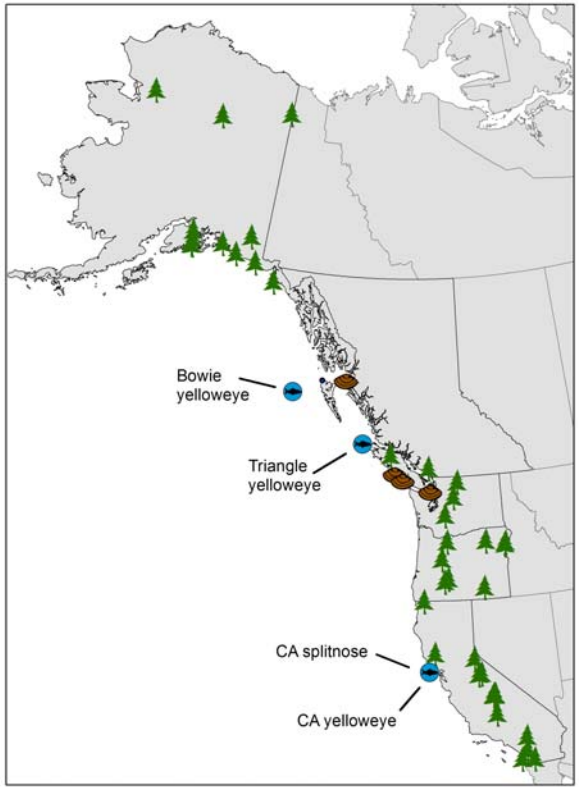
- Biologists are good at biology
- Physical scientists are good at what they do
- "Interdisciplinarity" complex problem ≠ simple solution
  - Collaboration
  - Integration
  - Scale
  - Relevance



Retrospective multi-species analysis

- Bryan Black, Oregon State University
- Sarah Shafer, USGS

How have species responded to climate change in marine, terrestrial, and riverine ecosystems?



Tools for reconstructing the past

Geochronology

-Sediment cores

-Debris fans

Dendrochronology

-Tree rings

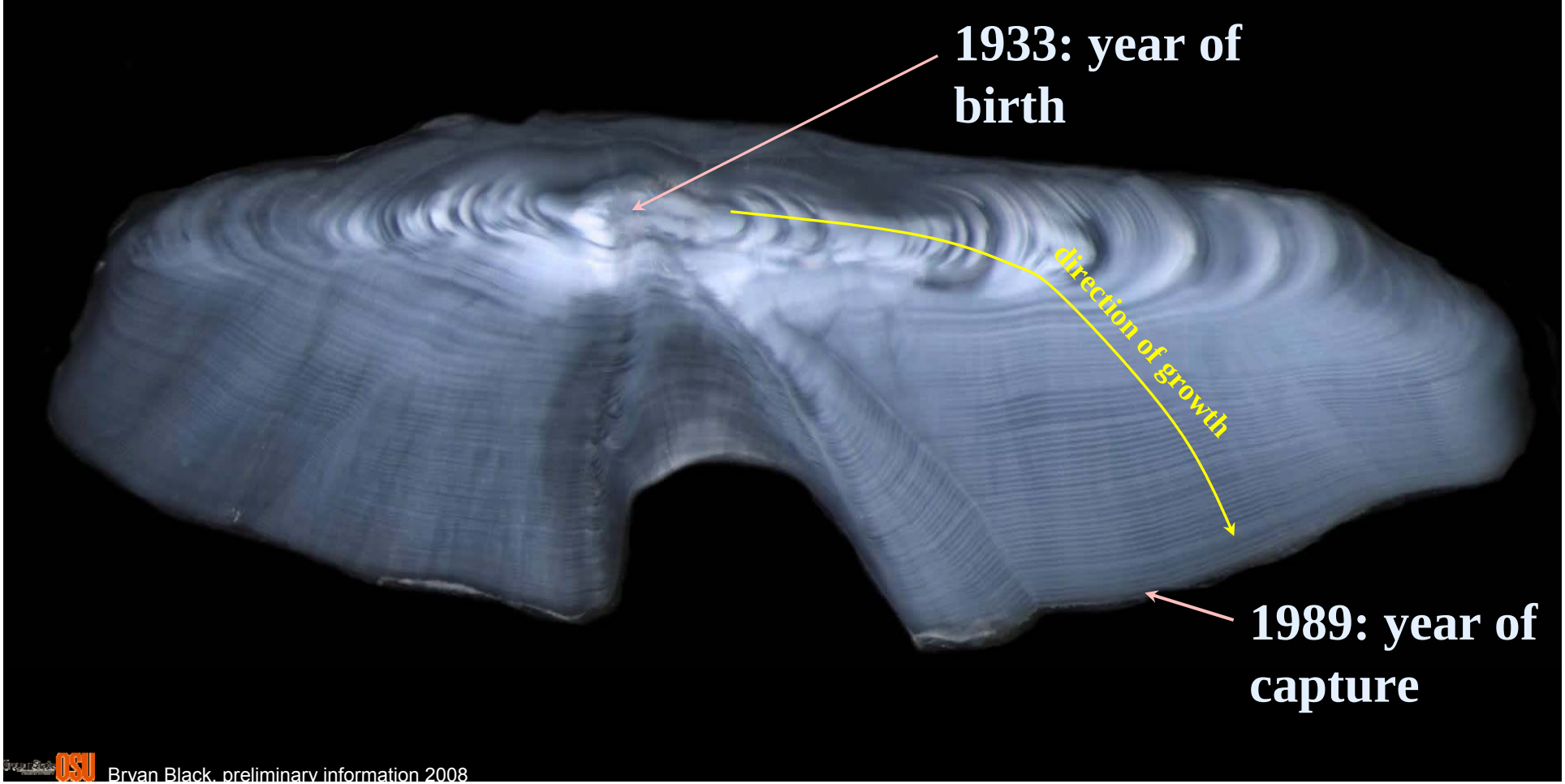
Dendrochronology applied to animals

Many animals live a long time
-e.g., bivalves, fish

Can we apply dendro methods to learn about how different species and ecosystems respond to climate change?

Rockfish otolith increments

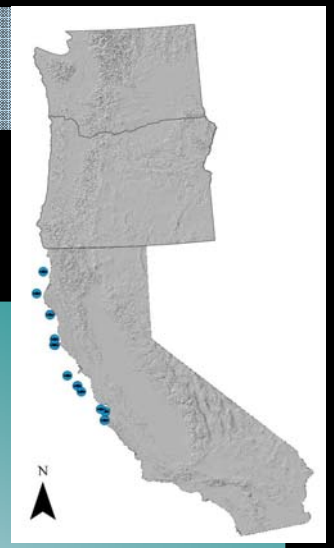
- opaque zone: fast growth, low protein
- translucent zone: slow growth, high protein

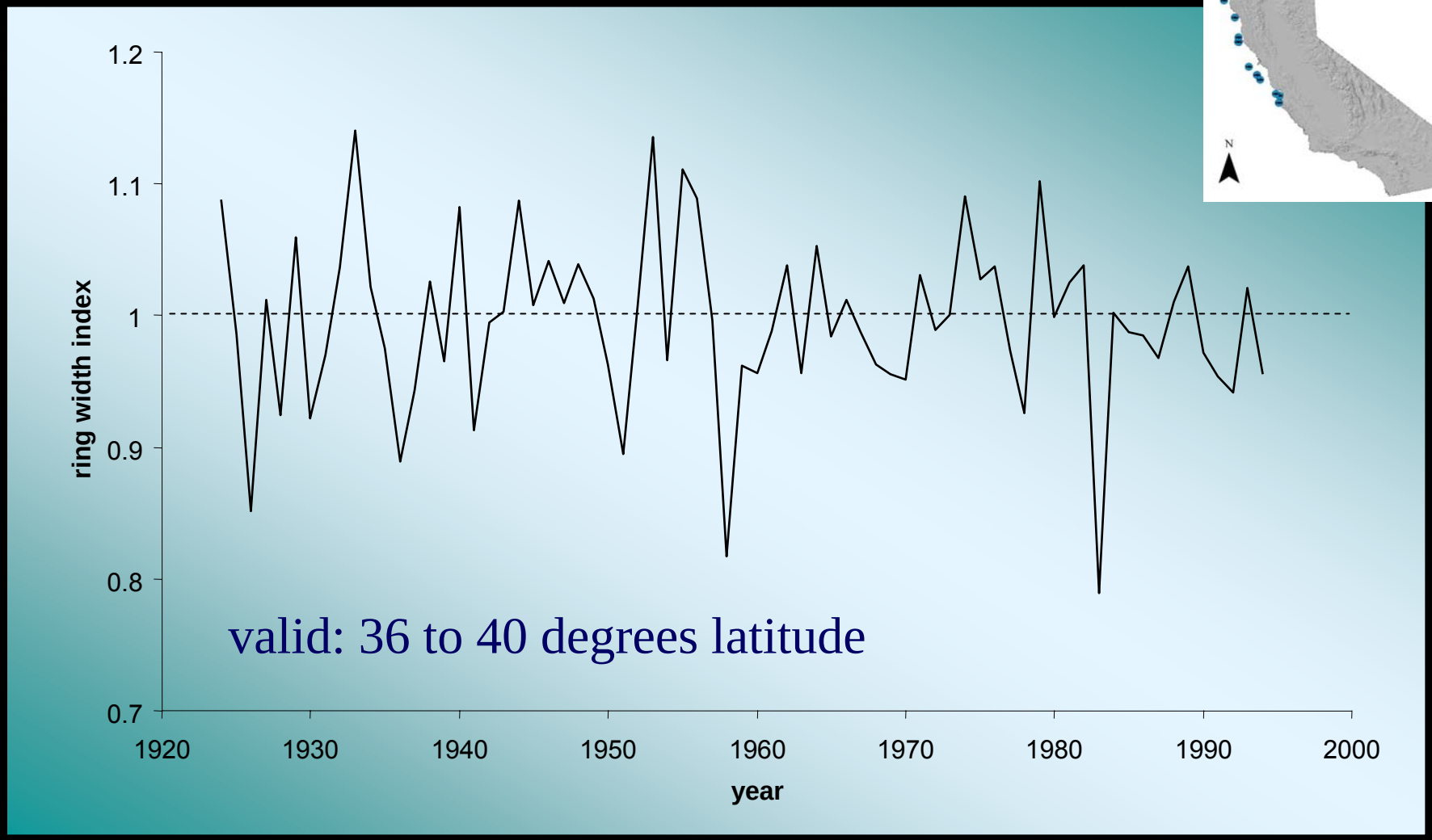


Bryan Black, preliminary information 2008

Splitnose chronology: 48 otoliths

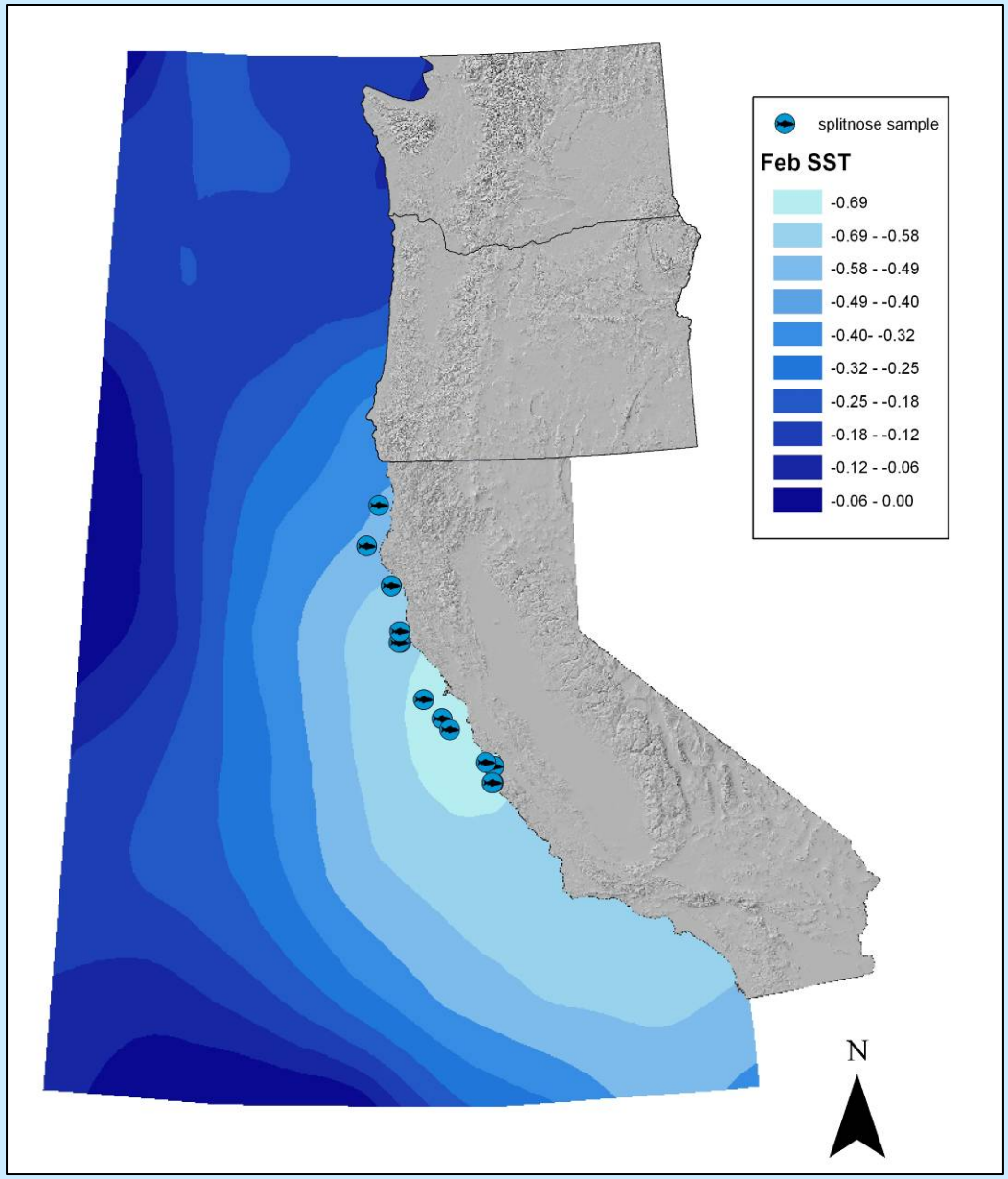
Negative exponential detrending





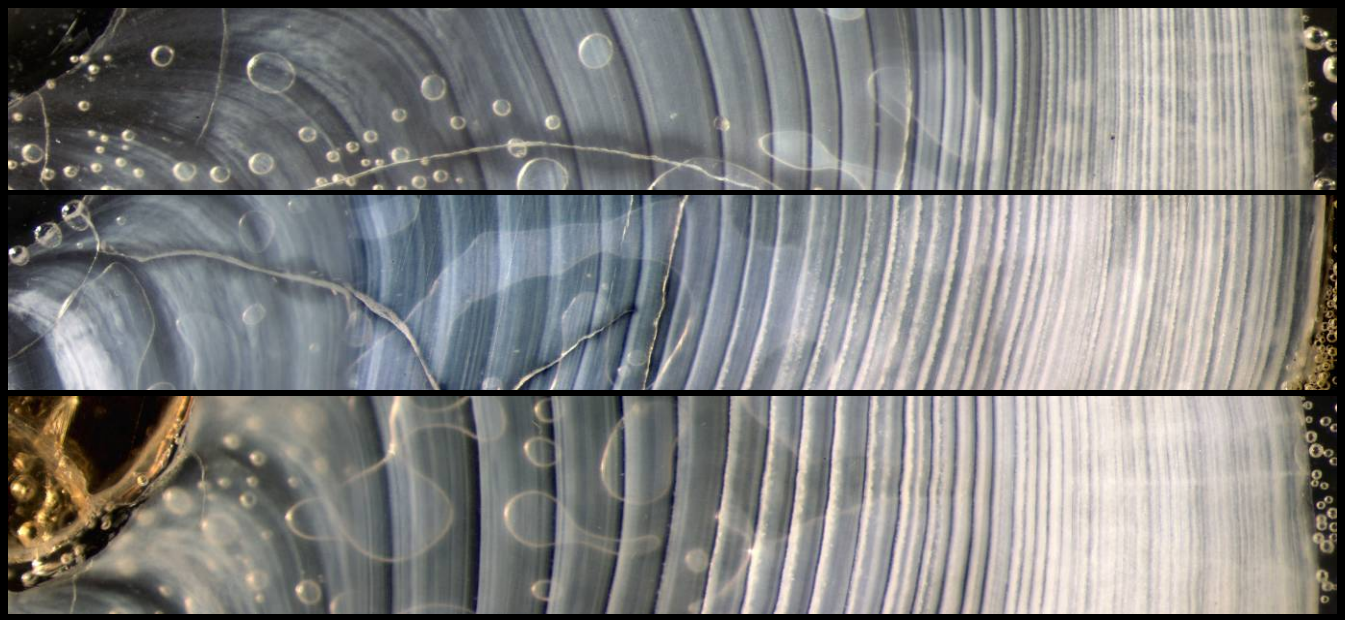
Bryan Black, preliminary information 2008

February SST



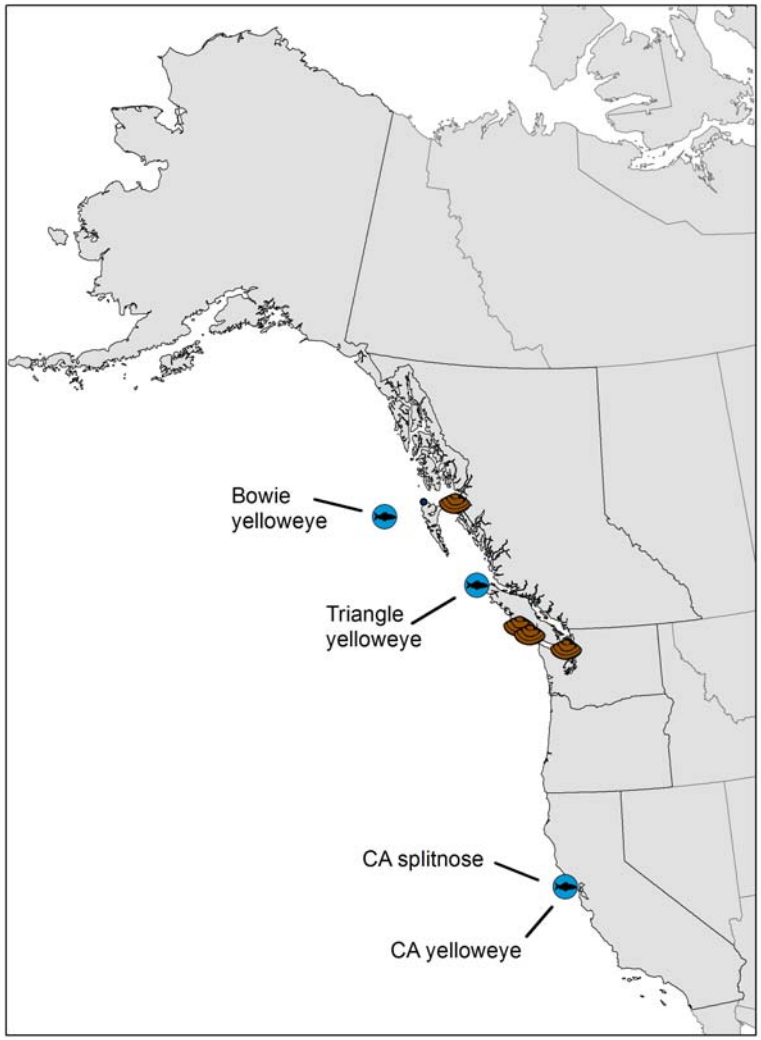
Bryan Black, preliminary information 2008

Pacific Geoduck

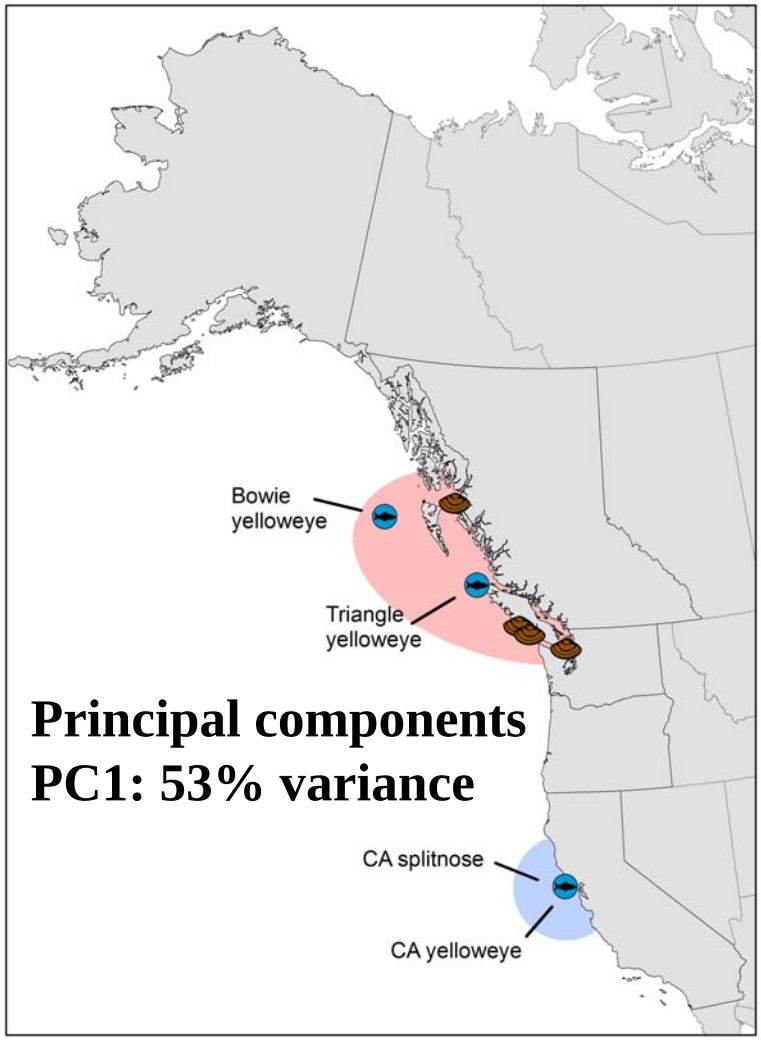


150 yrs old

Rockfish and geoduck chronologies

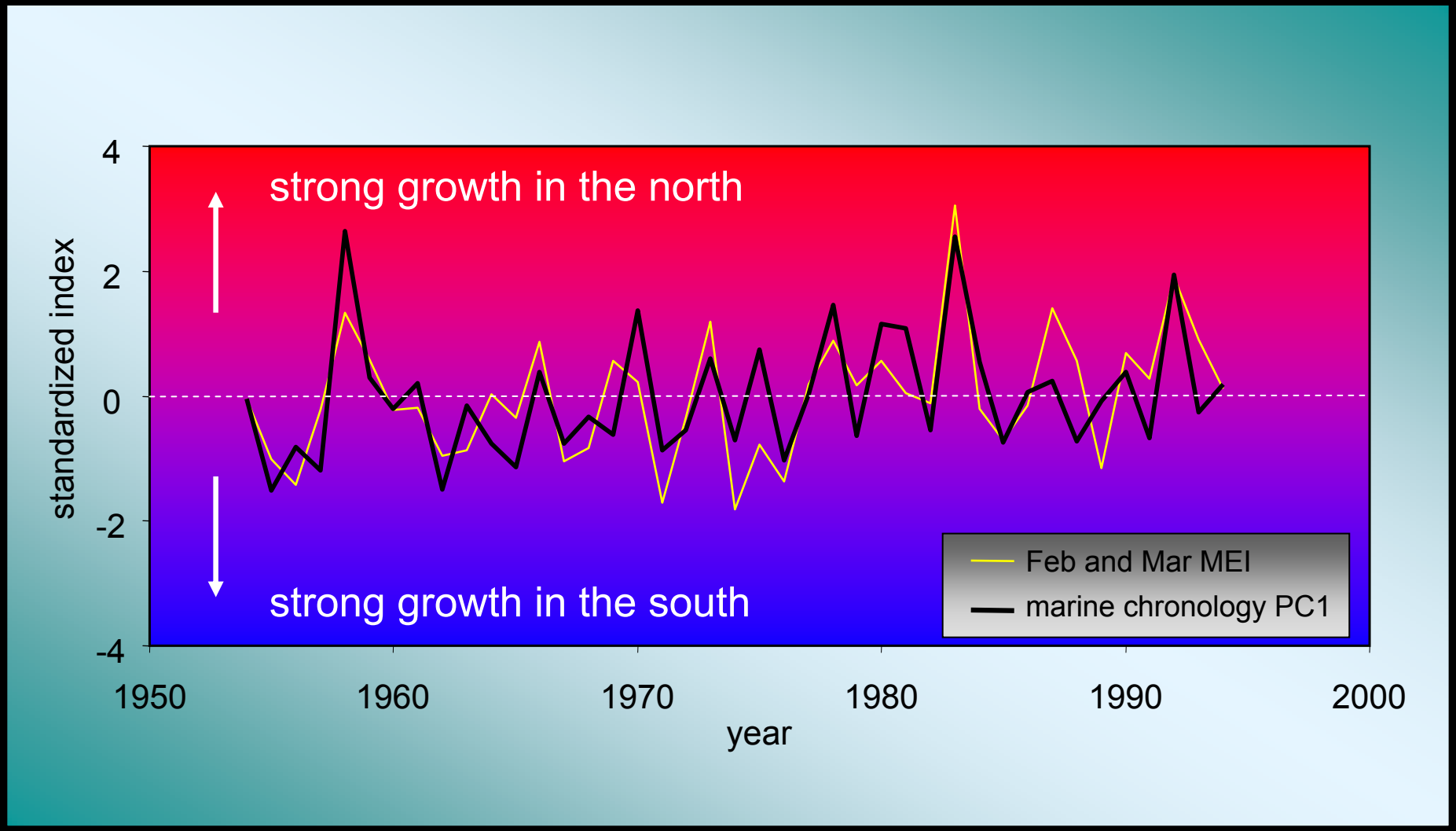


Rockfish and geoduck chronologies



Principal components
PC1: 53% variance

Leading principal component



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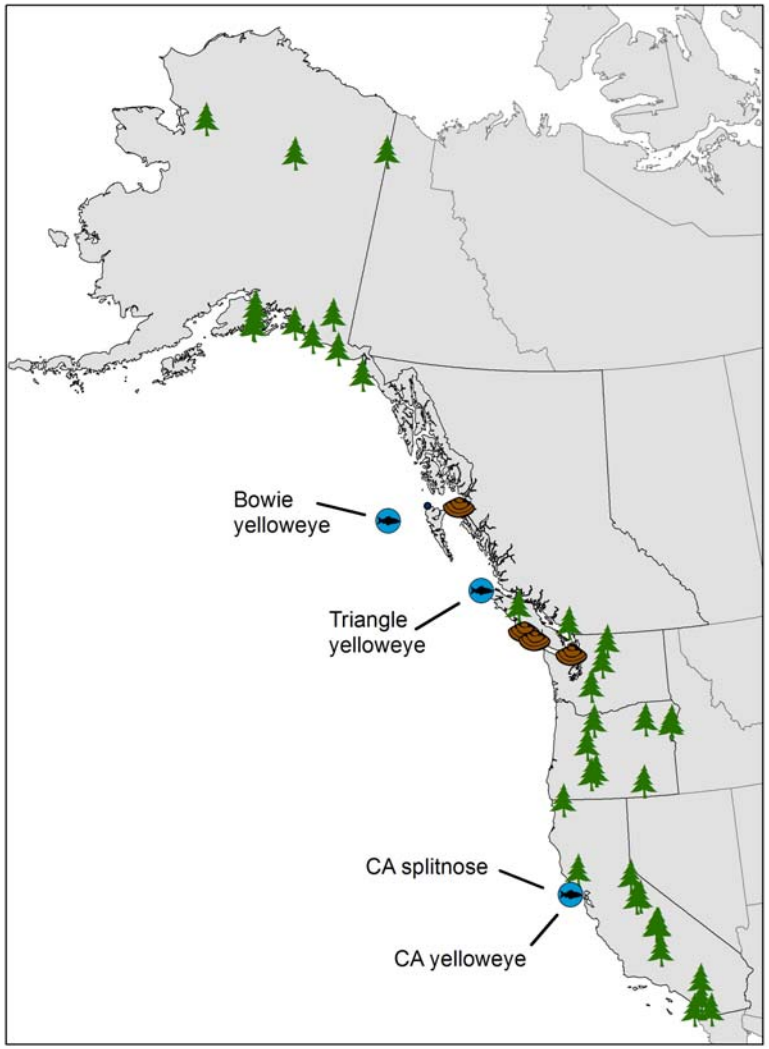
Geoduck and tree-rings



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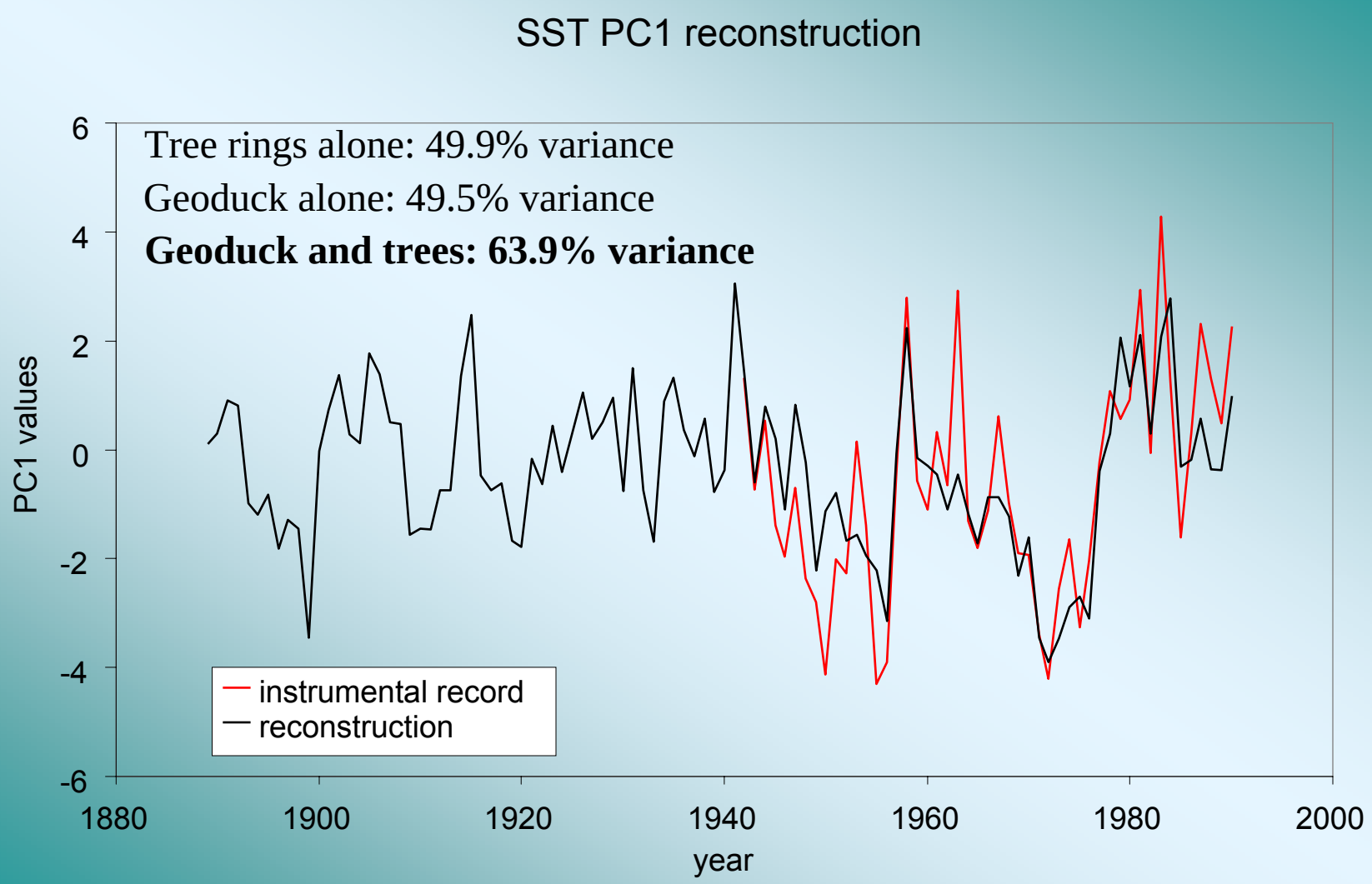
SST reconstruction – back to the 19th century



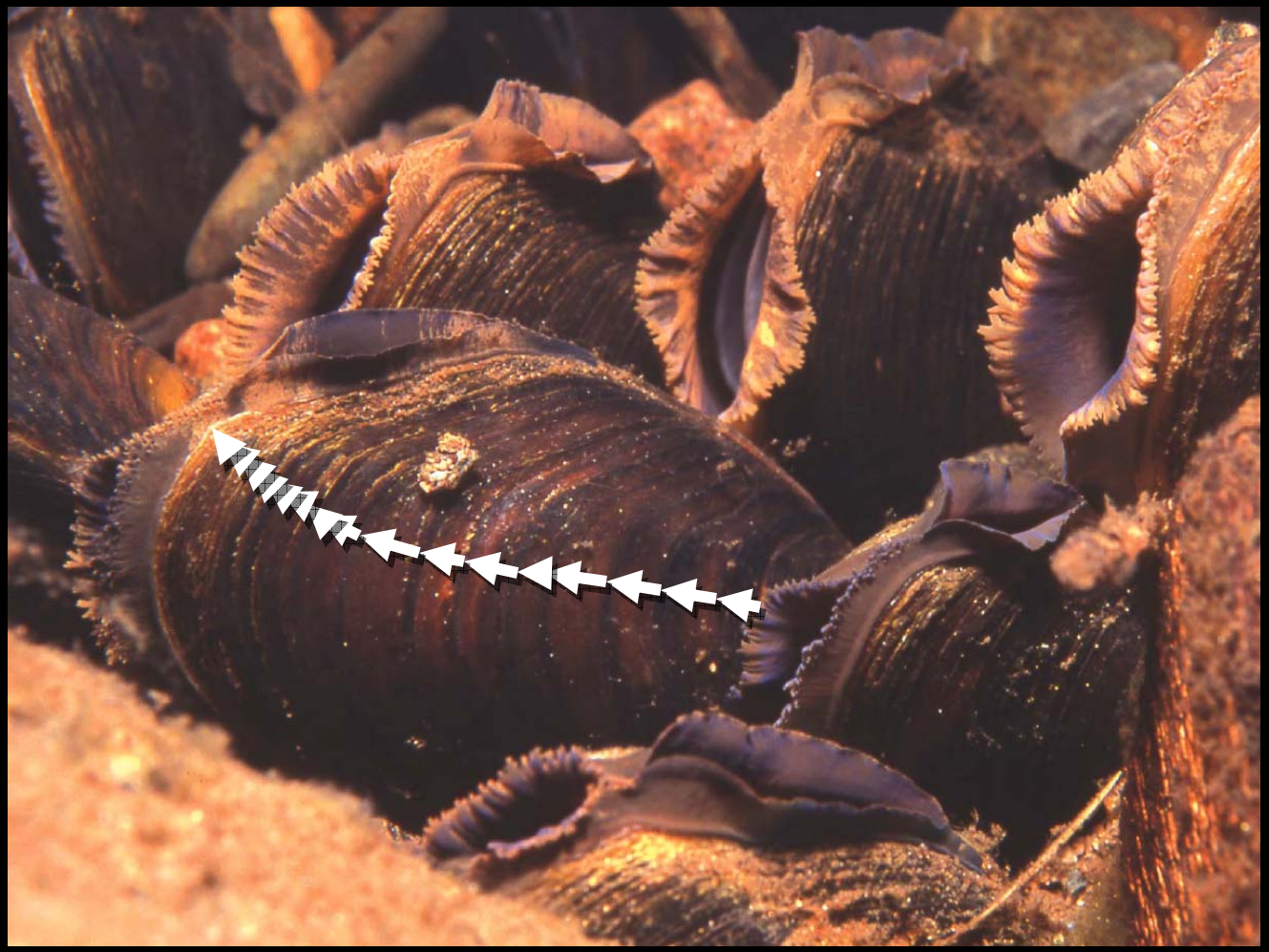
Bryan Black, preliminary information 2008

Western Pearshell Mussel *Margaritifera falcata*

Sessile and long-lived

- 50-100 years

Widely distributed



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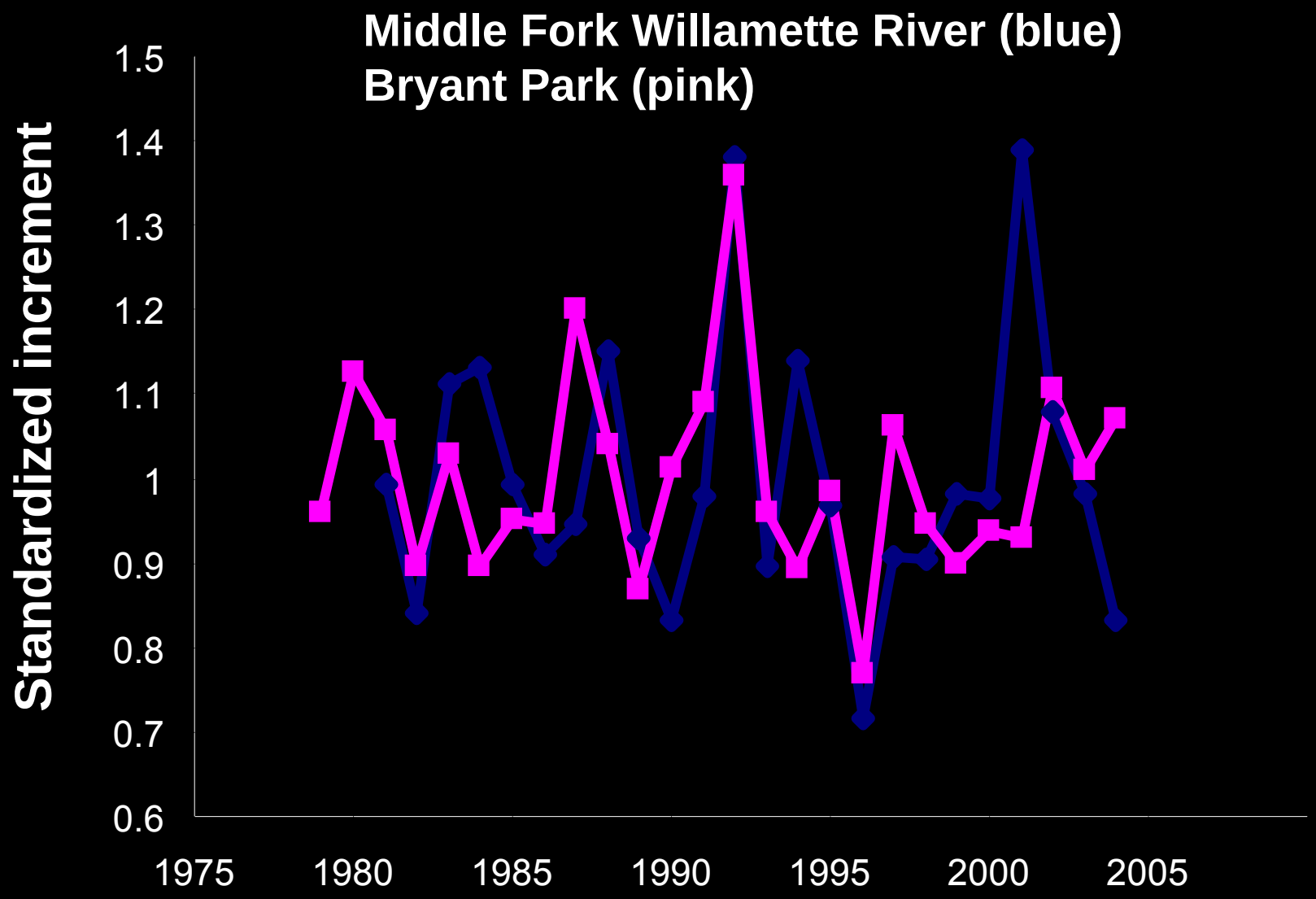
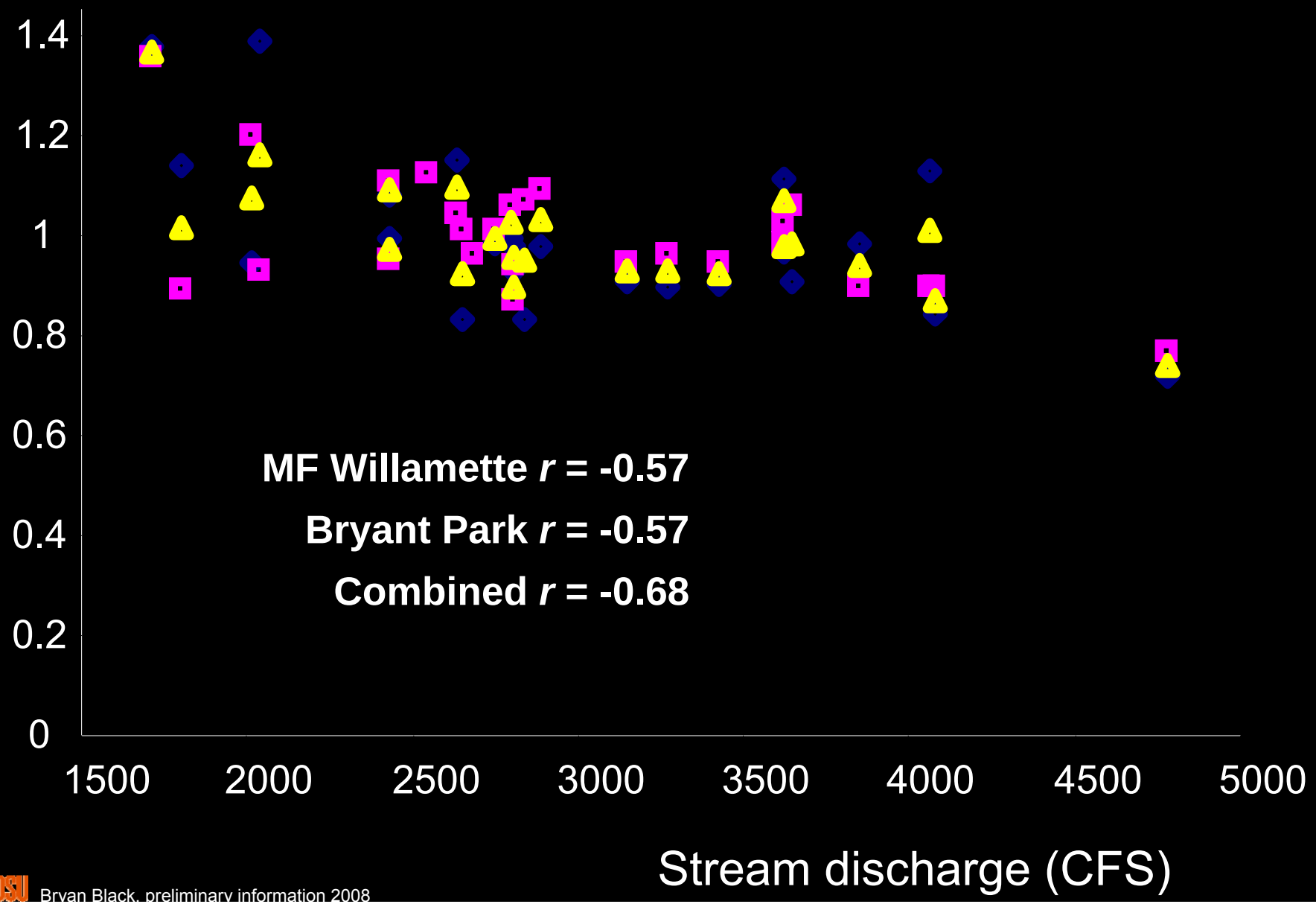
Master chronologies *Margaritifera falcata*



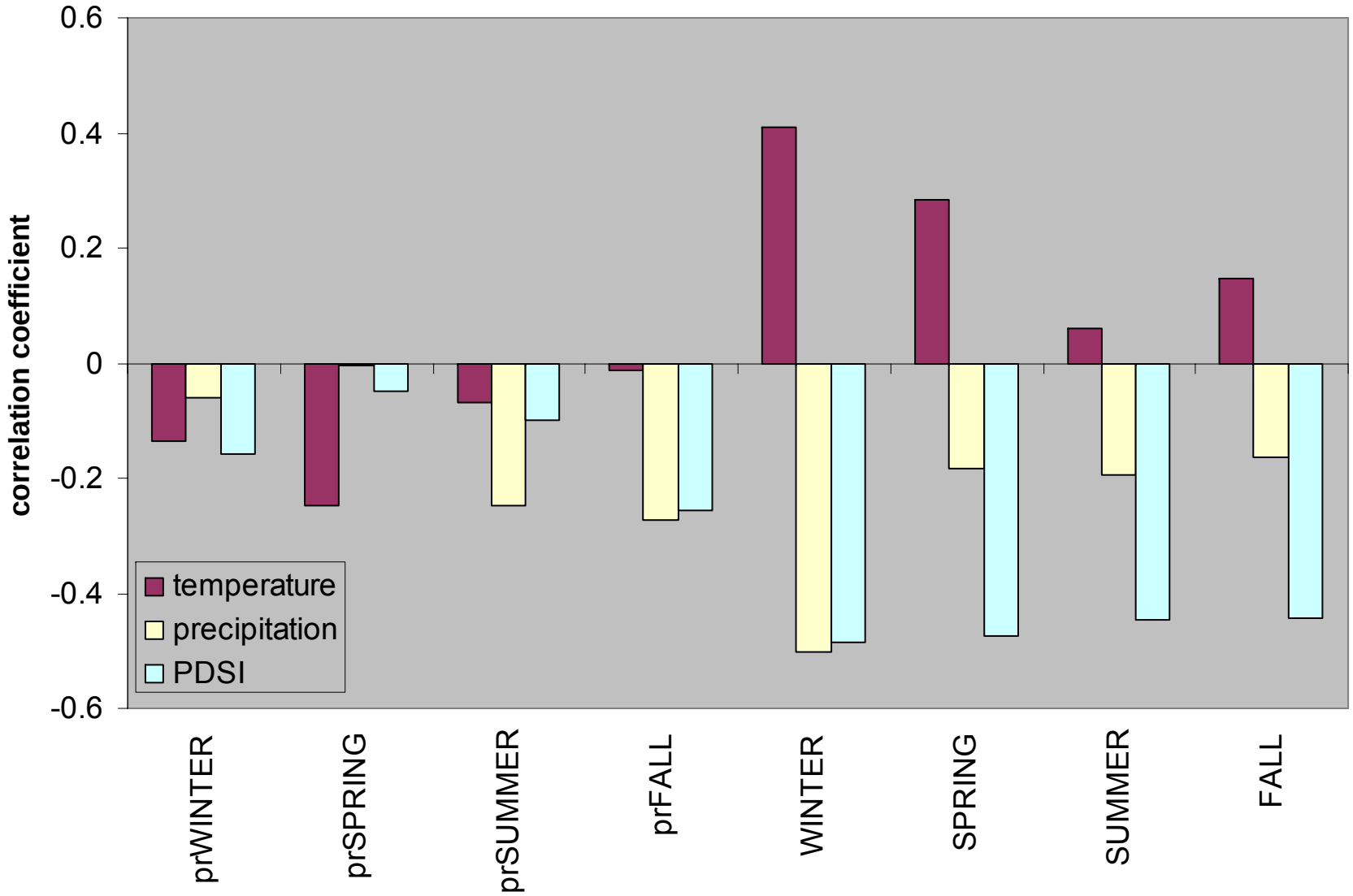
Bryan Black, preliminary information 2008

Ring increments and local discharge



Bryan Black, preliminary information 2008

Ring increments and seasonal climate



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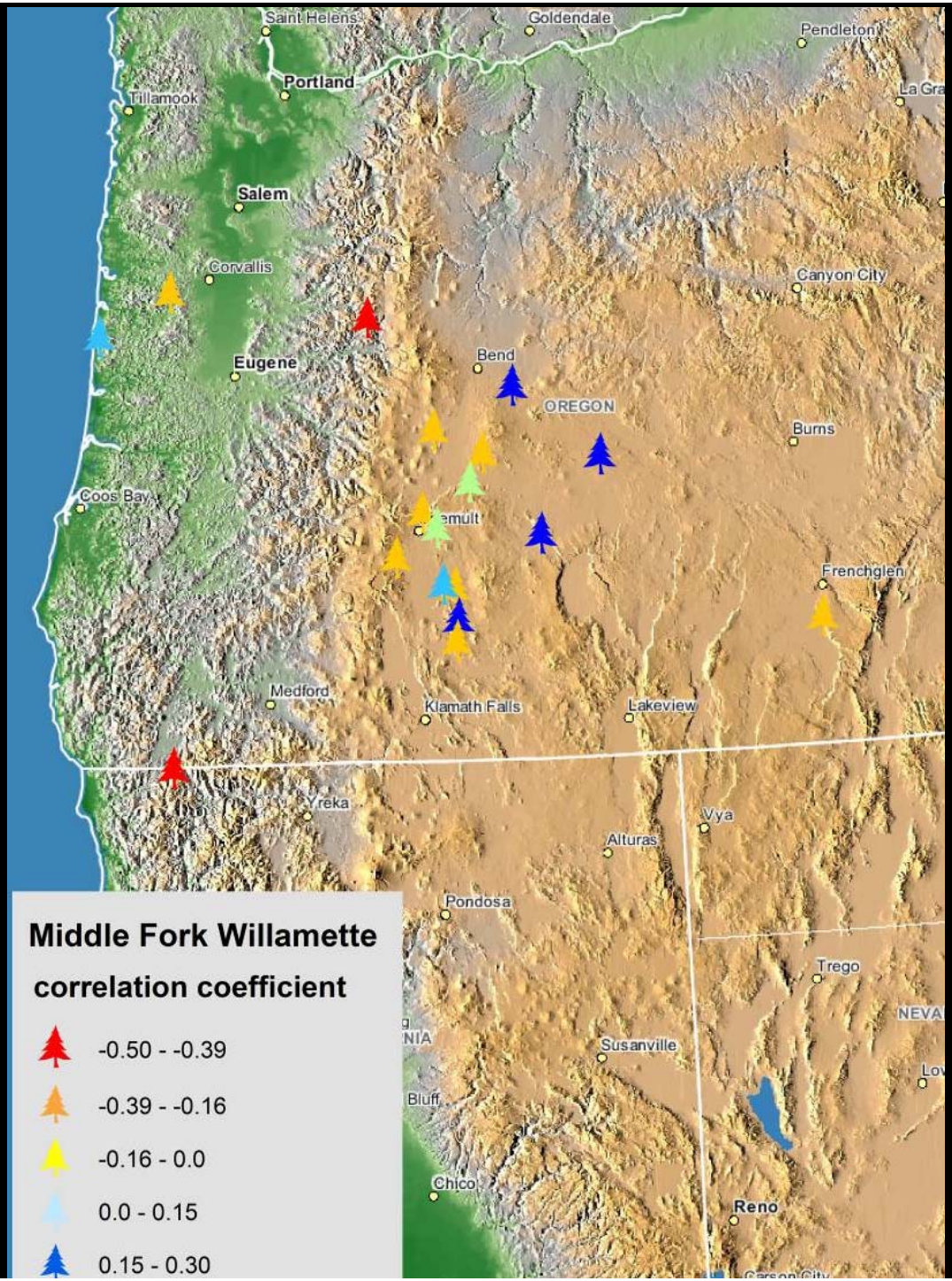
Mussels vs. trees



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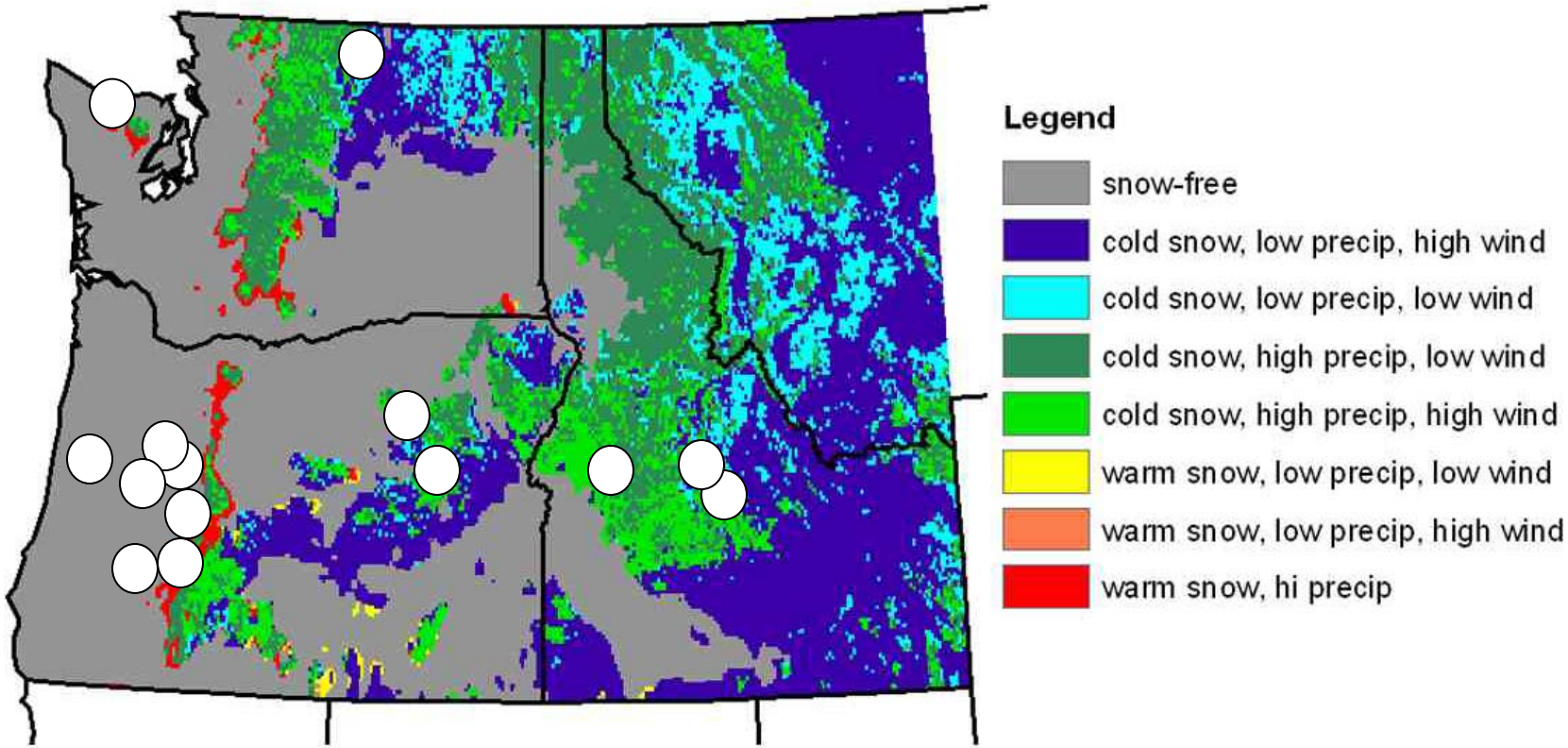
Ring increments in rivers across the PNW



Analyze patterns of spatial and temporal synchrony
Climate vs. local drivers of response to change in rivers

Brett Blundon, MS, OSU

Bryan Black, preliminary information 2008

Bio-chronologies and climate change

tree rings
forests

mussel rings
rivers

clam rings
nearshore

fish rings
continental shelf

Opening a new toolbox

- How do species in different ecosystems actually respond to climate change?

Opening a new toolbox

- How do species in different ecosystems actually respond to climate change?
- What influences appear to be the most important in driving responses?
  - Local, regional, seasonal?

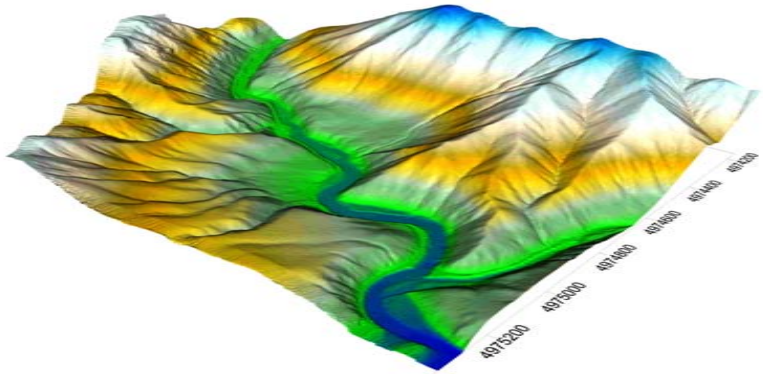
Opening a new toolbox

- How do species in different ecosystems actually respond to climate change?
- What influences appear to be the most important in driving responses?
- Can we use biological chronologies to reconstruct environmental histories?

Opening a new toolbox

- How do species in different ecosystems actually respond to climate change?
- What influences appear to be the most important in driving responses?
- Can we use biological chronologies to reconstruct environmental histories?
- Can we use bio-chronologies to look even deeper into history???
  - Middens, museum collections

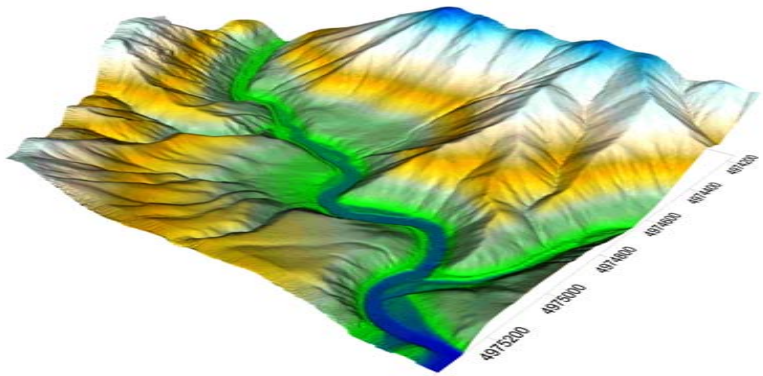
Climate Change and Native Species Responses in Riverine Ecosystems of the Pacific Northwest



Main themes

- Prospective and retrospective views
- Biology + physical process “interdisciplinarity”
- Cross-ecosystem responses
- Local and regional variability – space + time

Climate Change and Native Species Responses in Riverine Ecosystems of the Pacific Northwest



Main themes

- Prospective and retrospective views
- Biology + physical process "interdisciplinarity"
- Cross-ecosystem responses
- Local and regional variability – space + time

- Climate change has changed science
- Δ science α science support