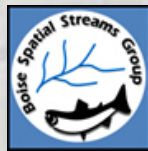
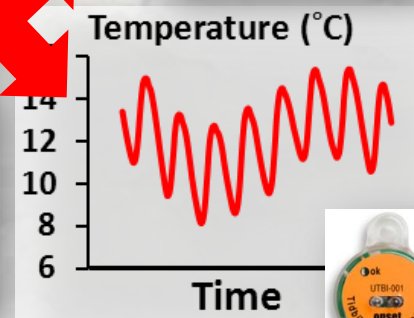
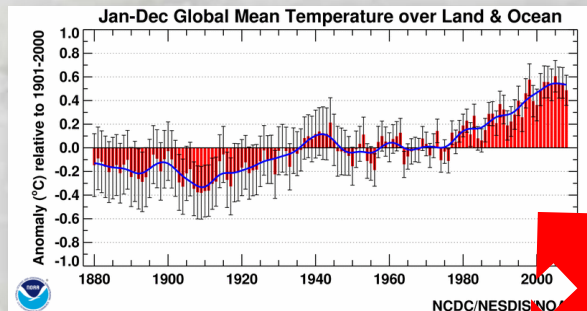


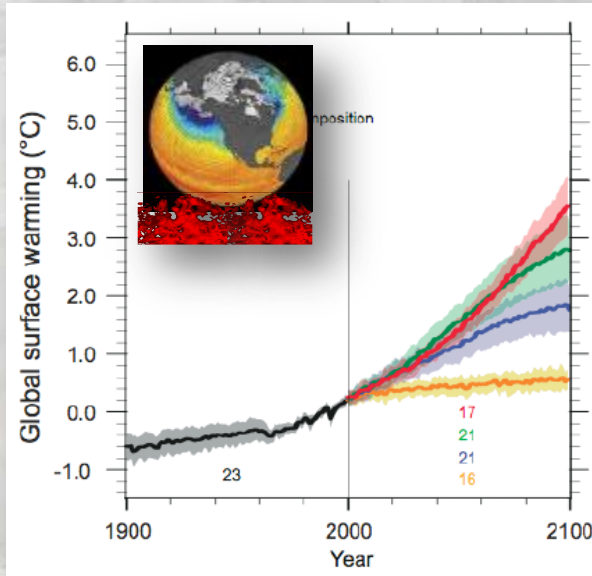
Slow Climate Velocities of Mountain Streams Impart Thermal Resistance to Headwater Refugia Across the West

Dan Isaak, Mike Young, Charlie Luce, Steve Hostetler, Seth Wenger, Erin Peterson, Jay Ver Hoef, Dona Horan, Matt Groce, Gwynne Chandler, Sherry Wollrab, Dave Nagel

US Forest Service
US Geological Survey
University of Georgia
Queensland University
of Technology
NOAA

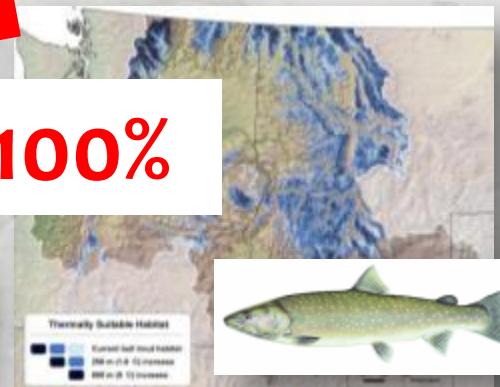


Common Perception: Cold-Water Fish World is Ending...



- Meisner 1988
- Keleher & Rahel 1996
- Eaton & Schaller 1996
- Reusch et al. 2012
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.

• Huge declines: 50%-100%



Common Perception: Cold-Water Fish World is Ending...

Meisner 1988

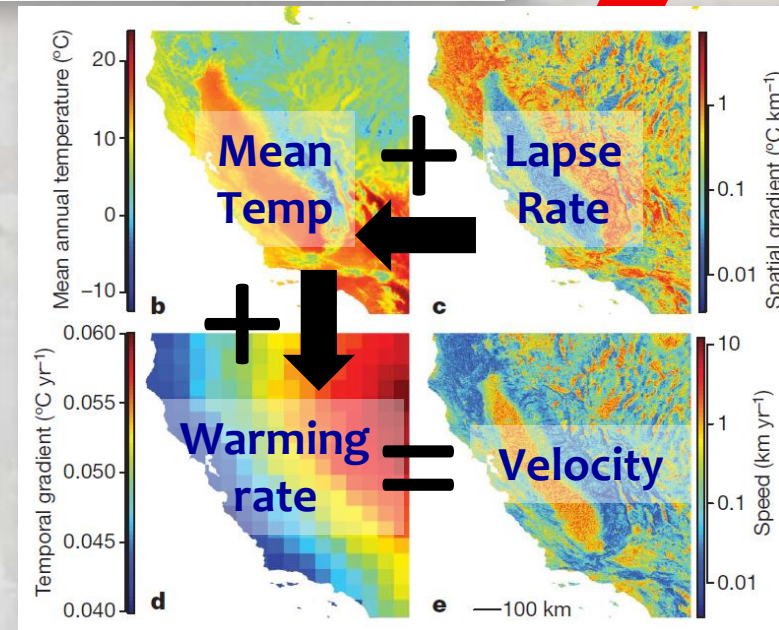
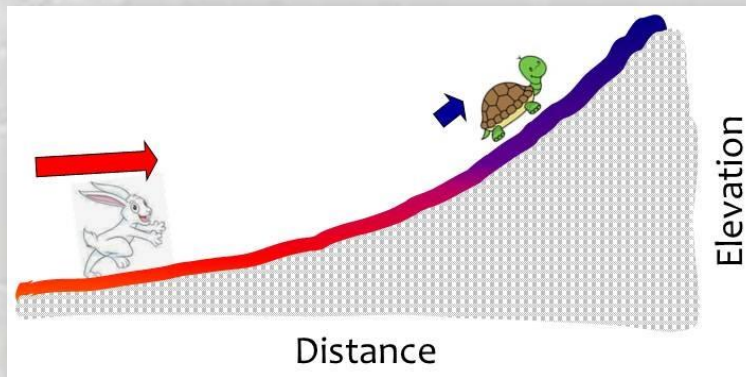
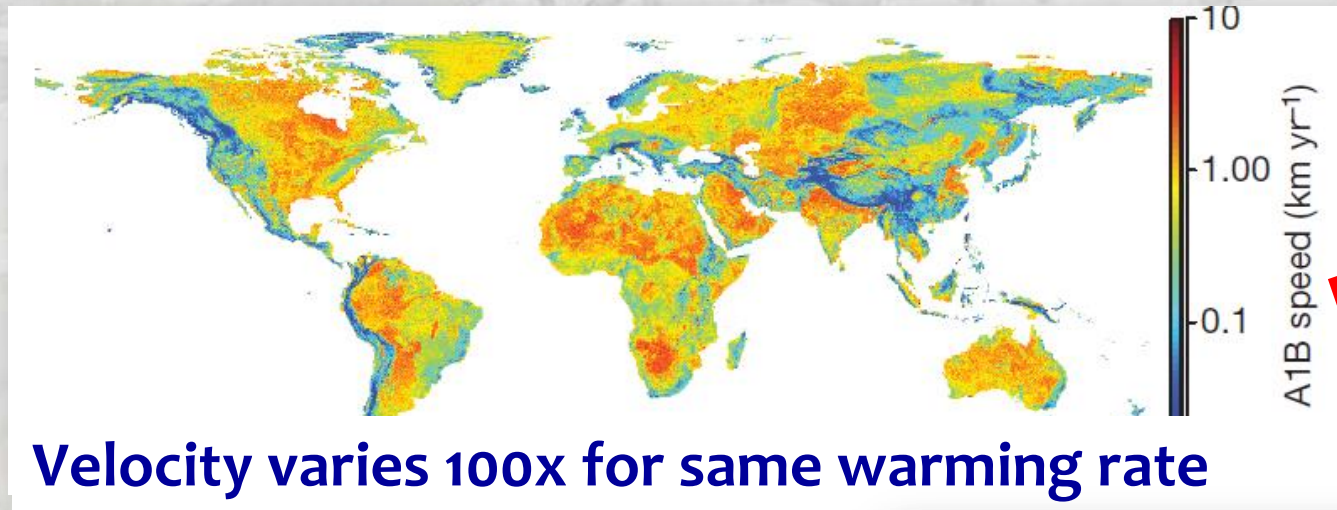


**We've been predicting
doom for almost 30 years**

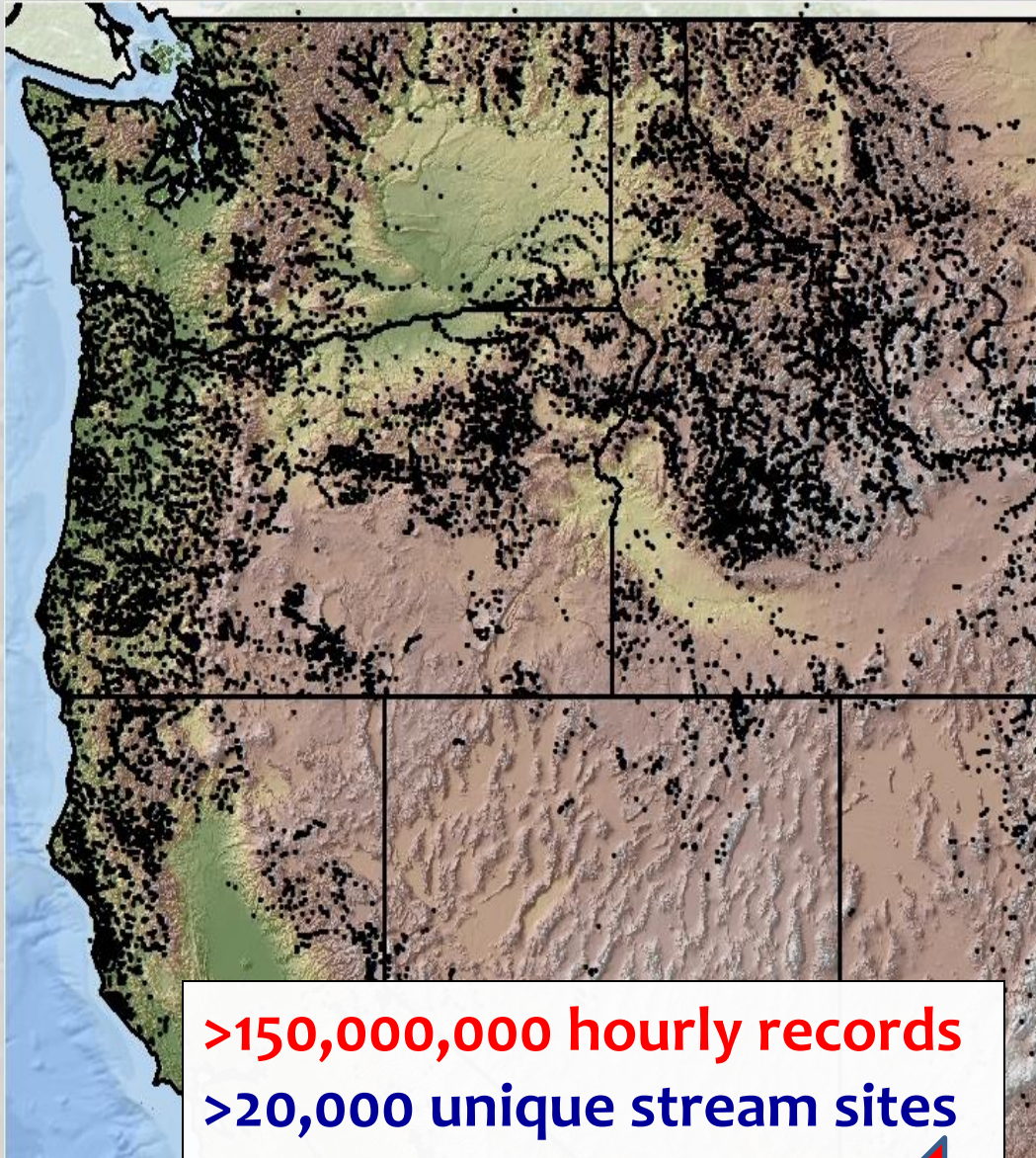


Climate “Velocity” is What’s Biologically Relevant

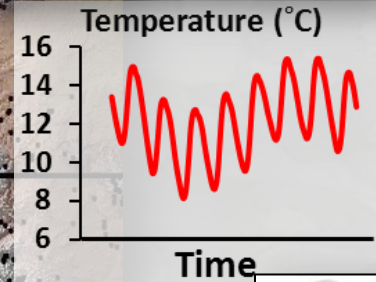
Rate at Which Isotherms & Thermal Niches Shift



Application to Streams Required Some Data



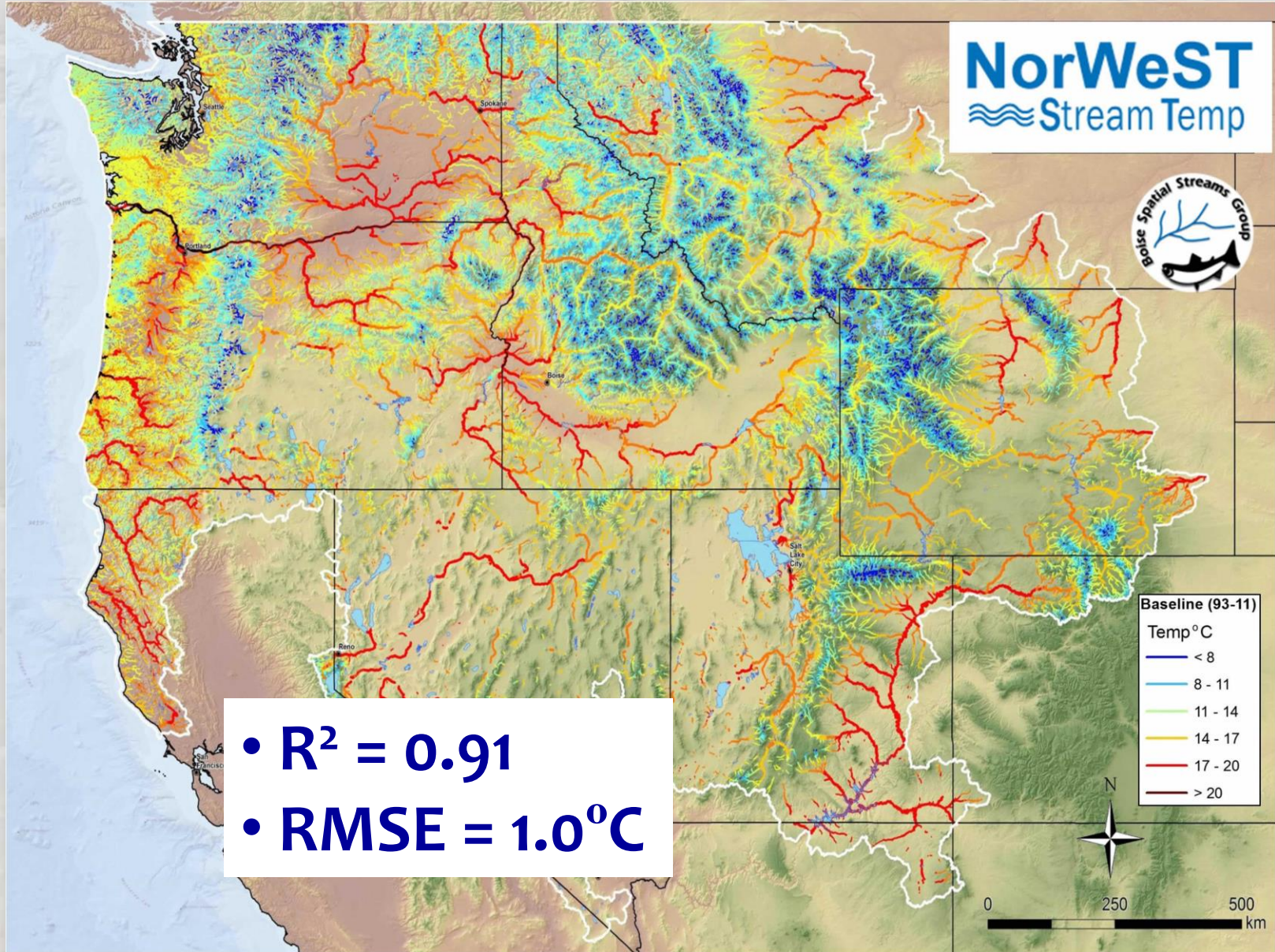
NorWeST
Stream Temp



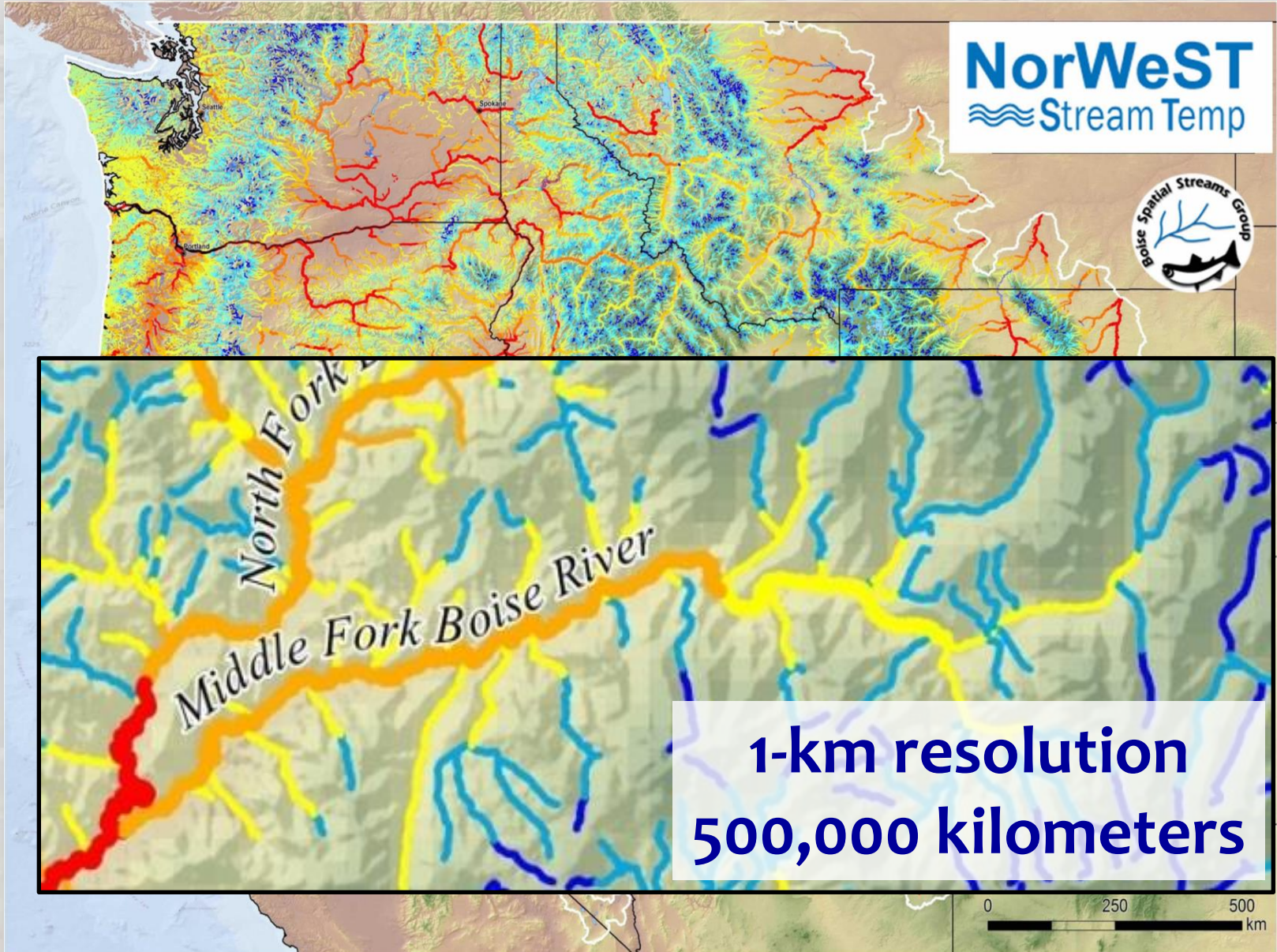
>150,000,000 hourly records
>20,000 unique stream sites
>100 resource agencies



& Some High-Resolution Scenarios



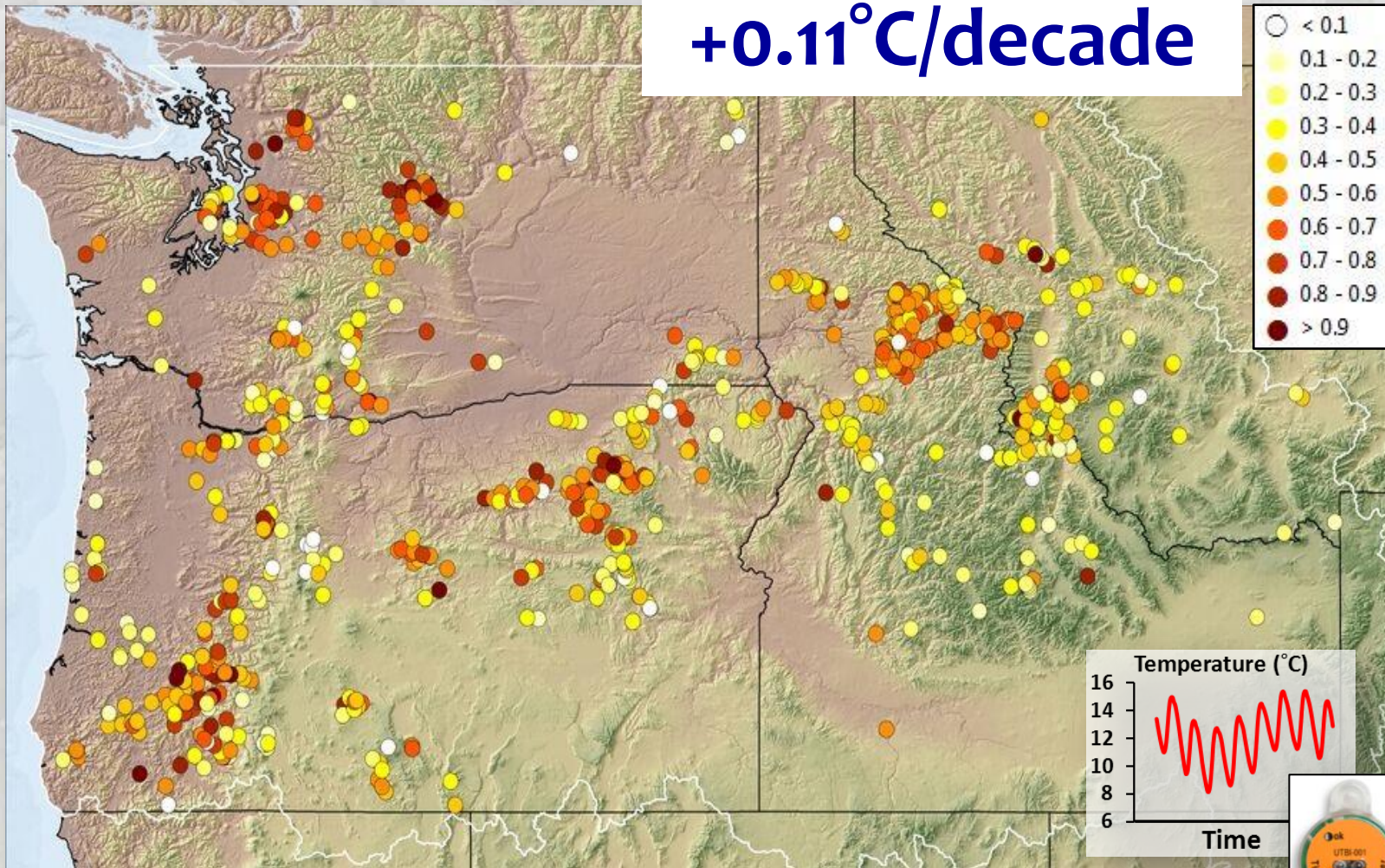
& Some High-Resolution Scenarios



Stream Warming Rates 1968-2011

923 sites in NorWeST database with >10 year records

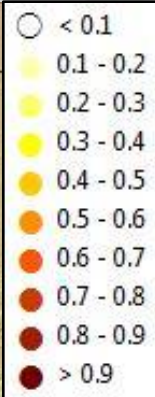
+0.11°C/decade



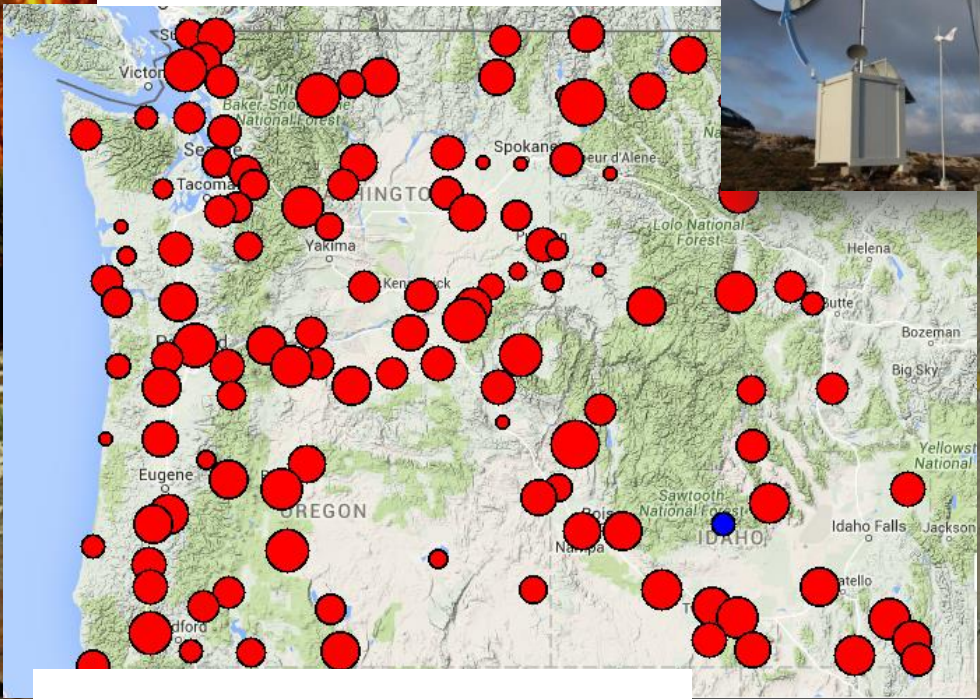
Stream Warming Rates 1968-2011

923 sites in NorWeST database with >10 year records

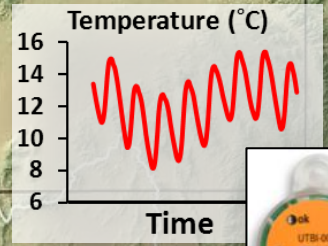
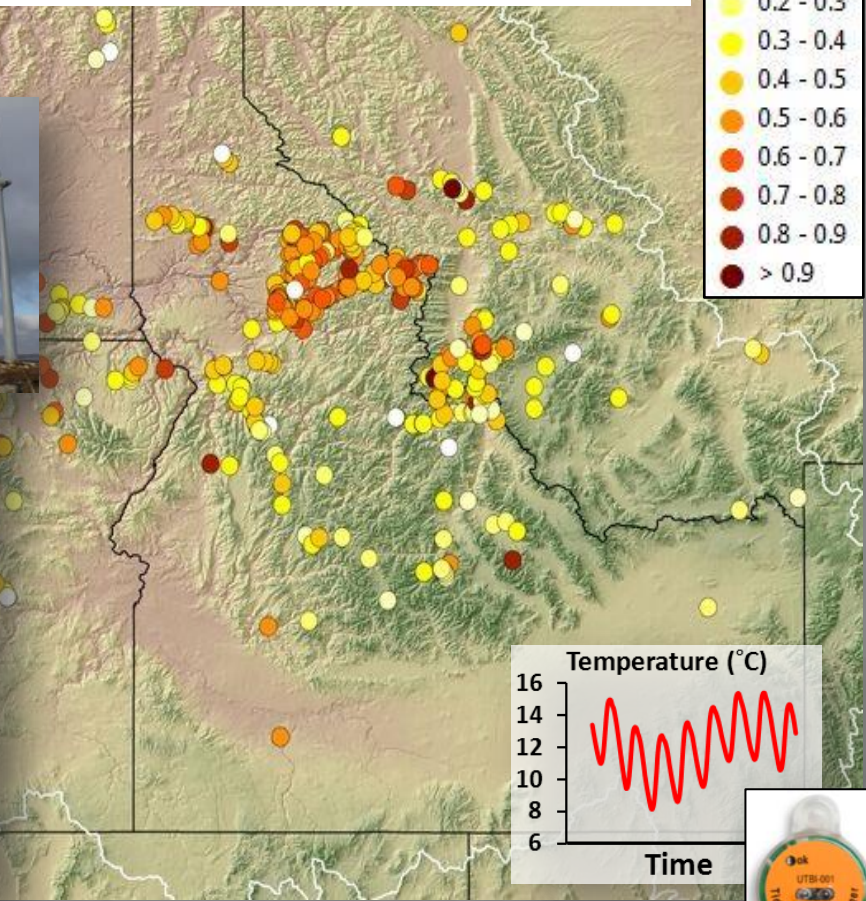
+0.11°C/decade



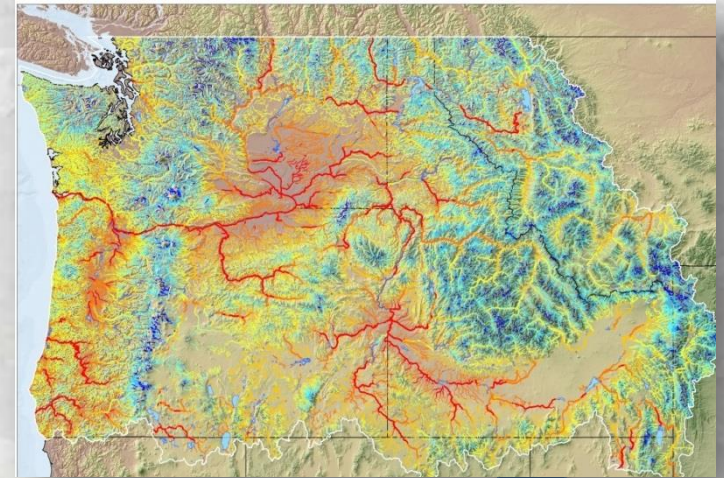
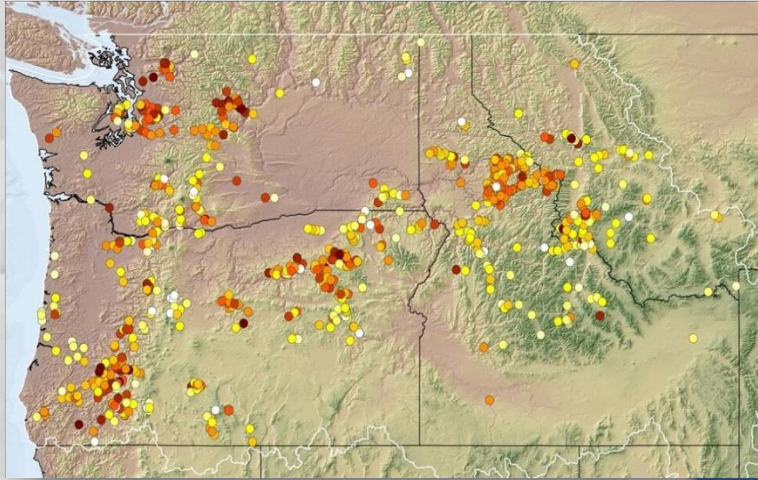
Weather Stations



0.21°C/decade

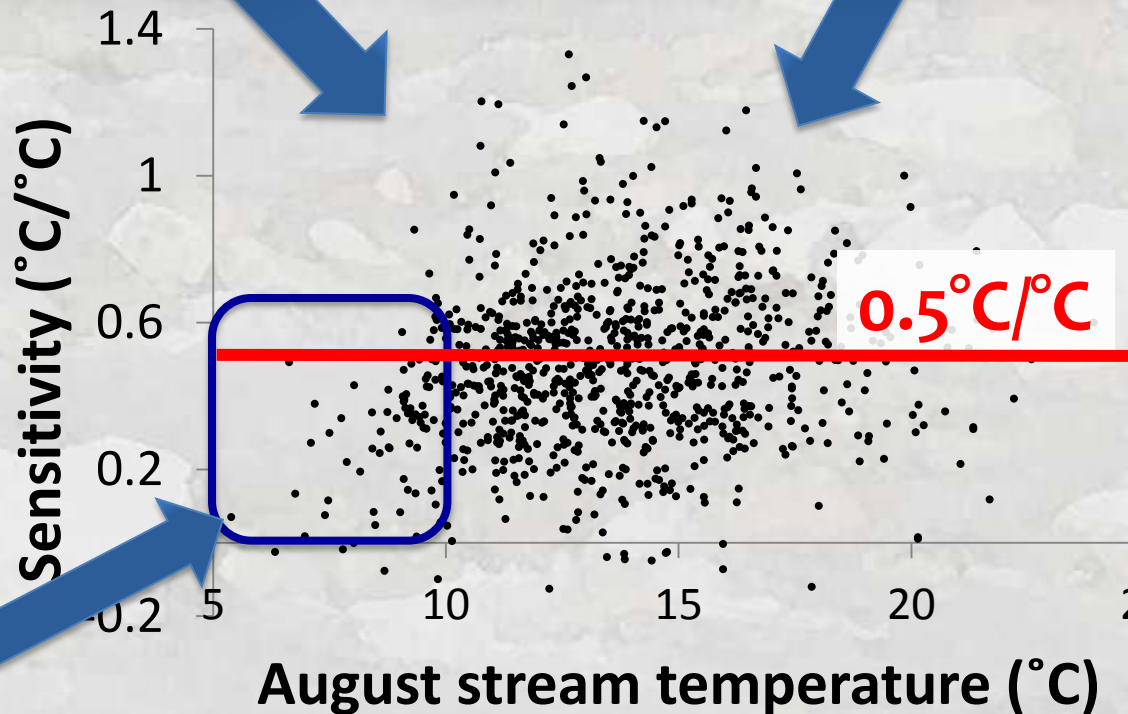


Coldest Streams Warming More Slowly



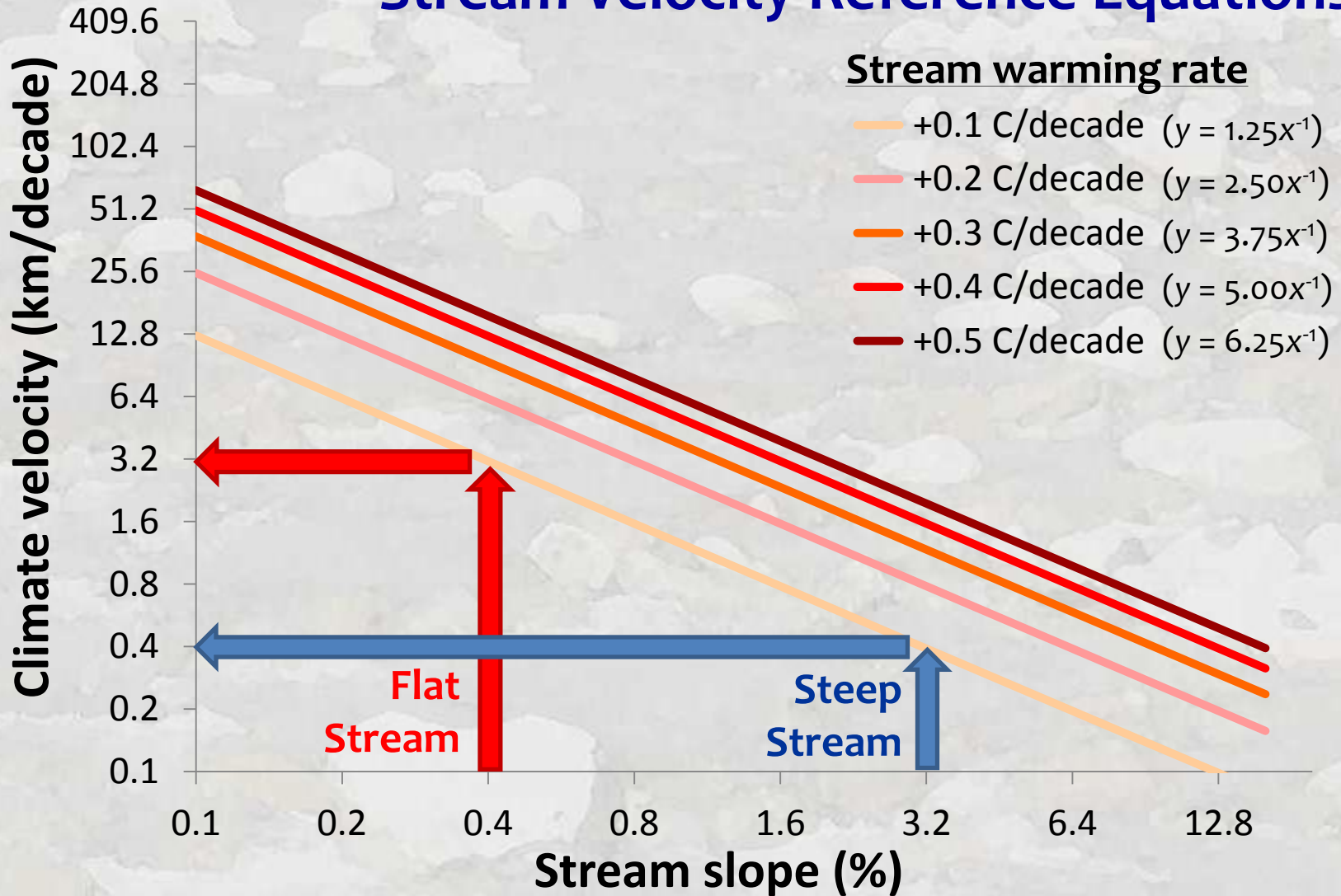
So...
 $\sim 0.07^{\circ}\text{C}/\text{decade}$

$0.32^{\circ}\text{C}/^{\circ}\text{C}$

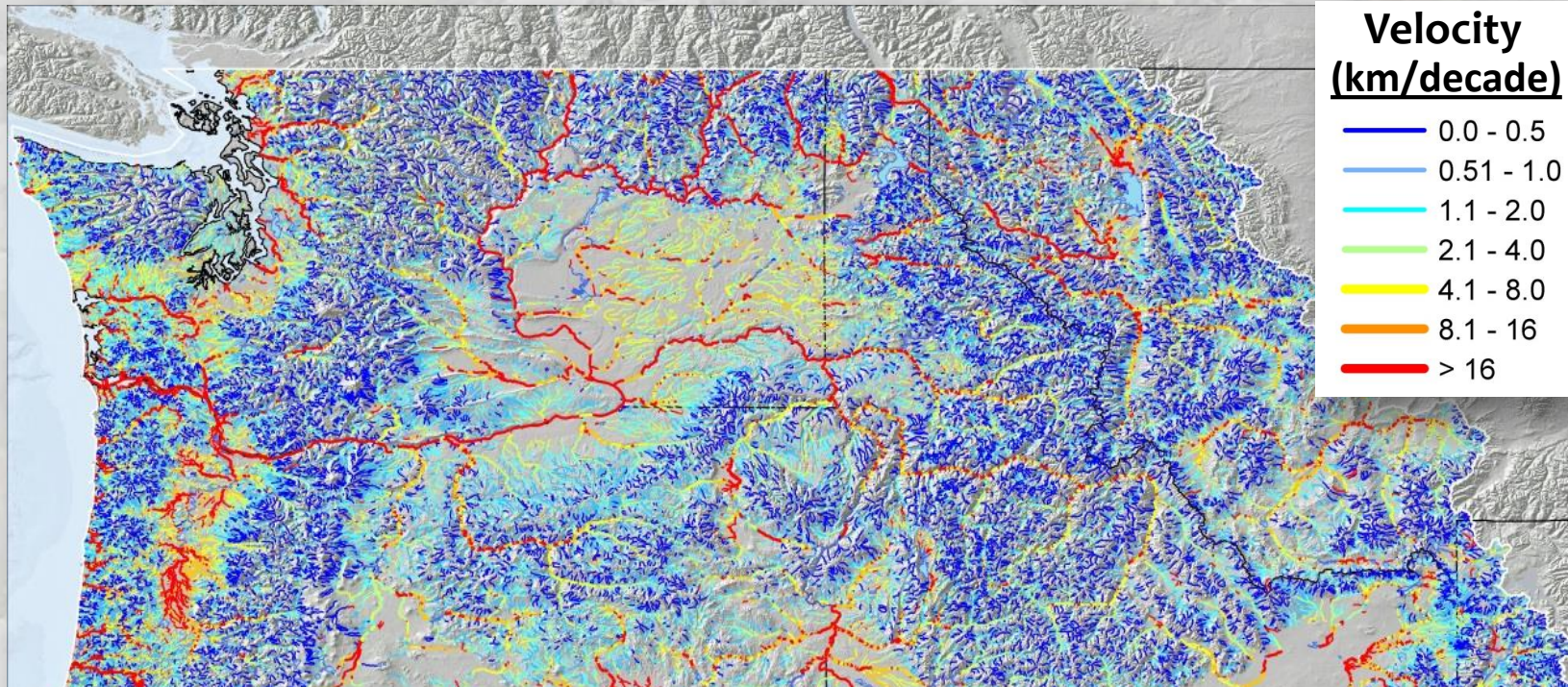


BUT... Velocity is What Matters!

Stream Velocity Reference Equations



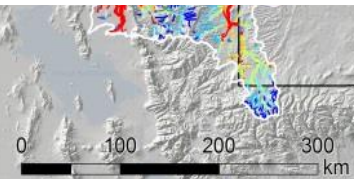
Climate Velocity Map for Regional Network



>10x Slower Than Velocities of Global Marine & Terrestrial Environments (Burrows et al. 2011)

1968-2011 Median Stream Velocity:

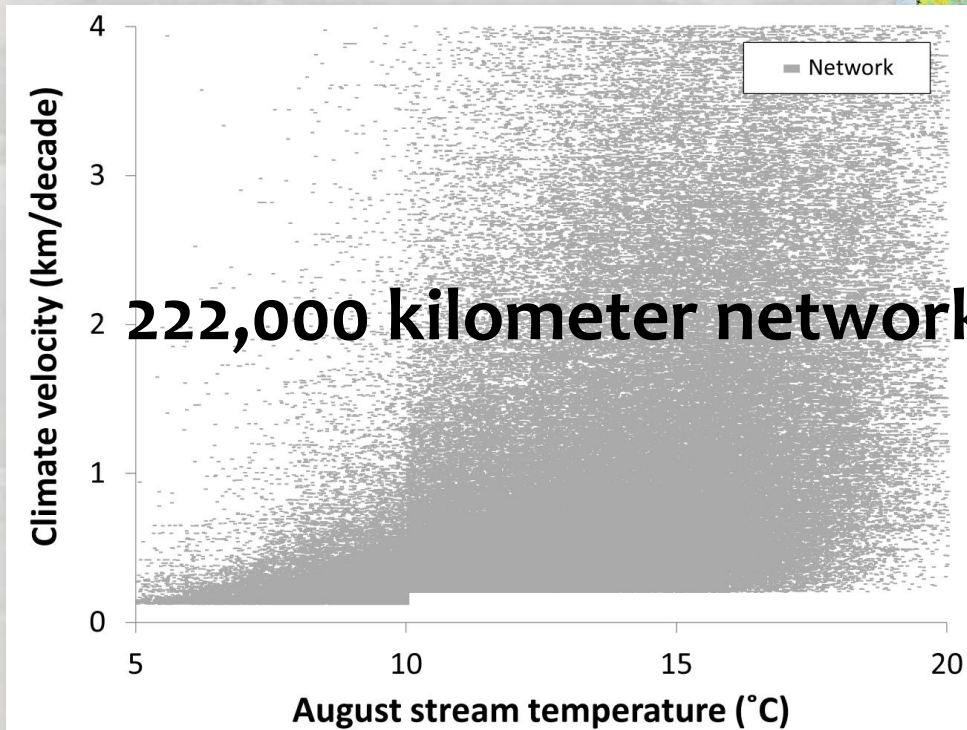
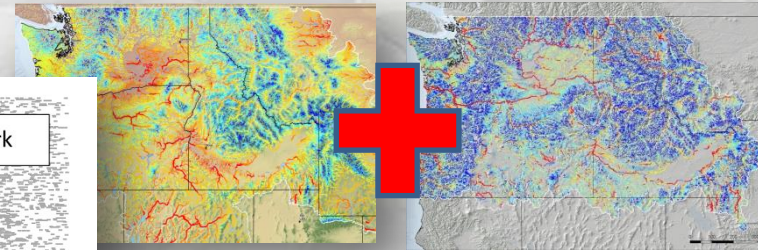
1.07 km/decade



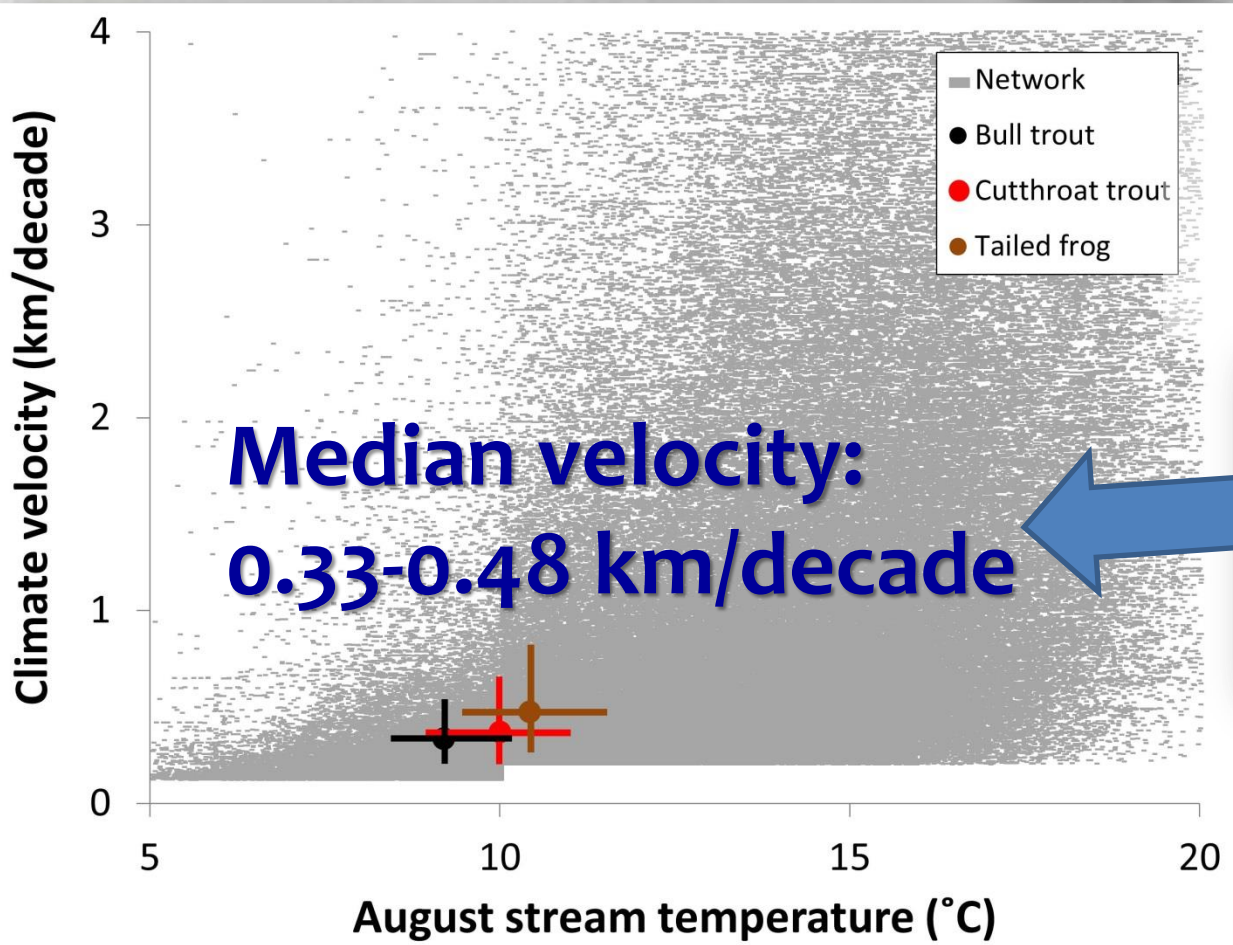
Where do Those “Doomed” Headwater Species Live?



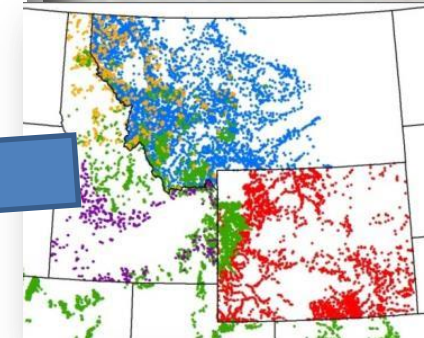
Climate scenario & velocity maps



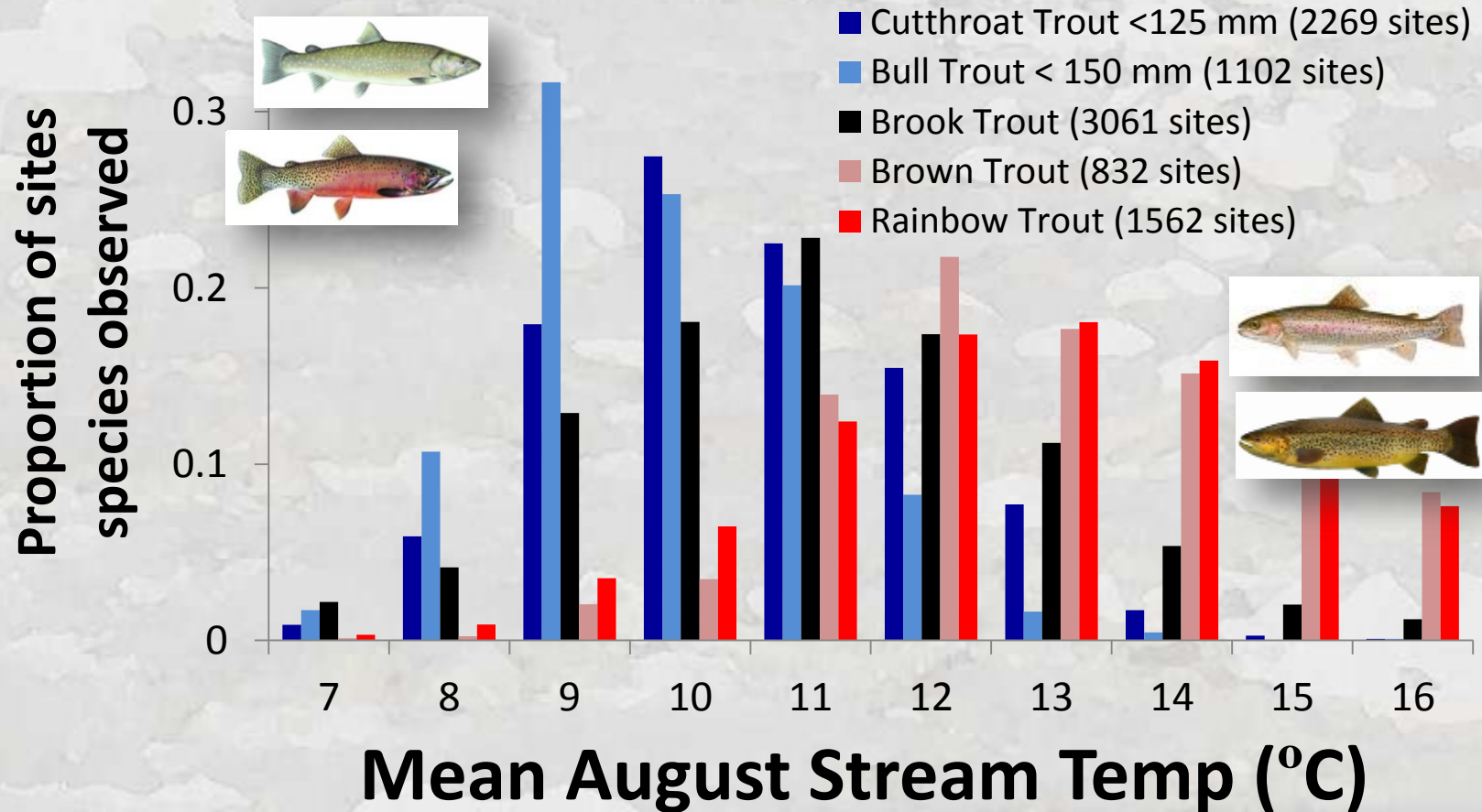
Where do Those “Doomed” Headwater Species Live?



BIG biological databases – 1000s of sites



Cold Climates Also Exclude Most Invasive Species from Mountain Headwaters




**BEWARE
THE
INVASION**

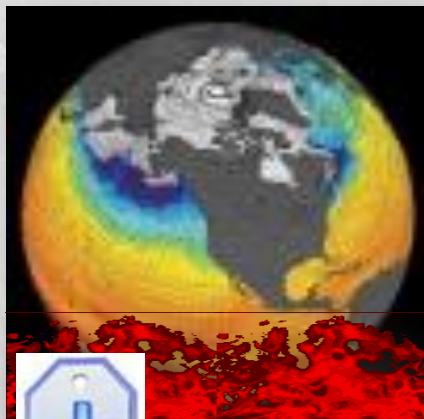


The Cold-Water Climate Shield

Delineating Refugia for Preserving Native Trout

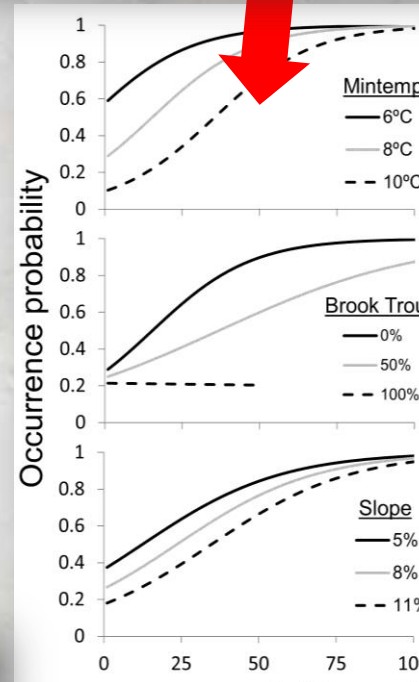
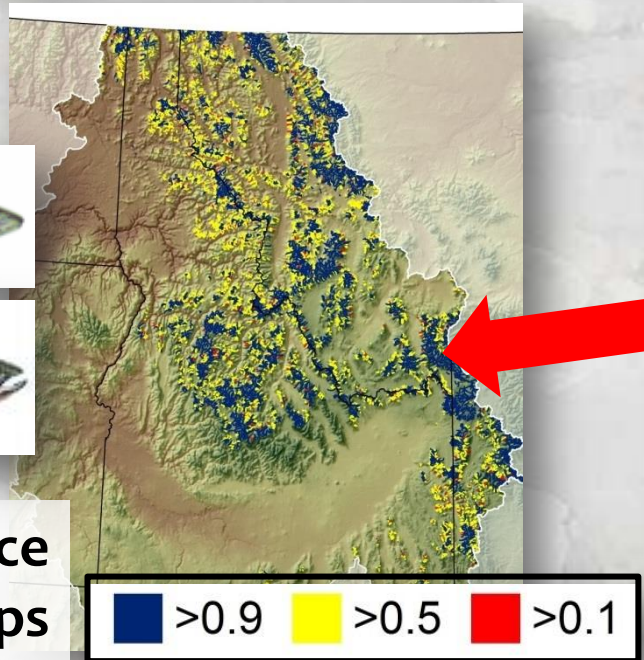
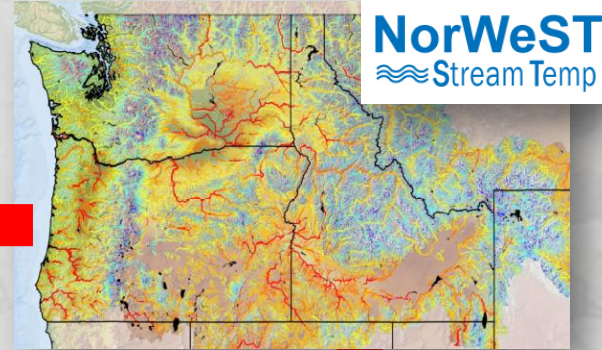
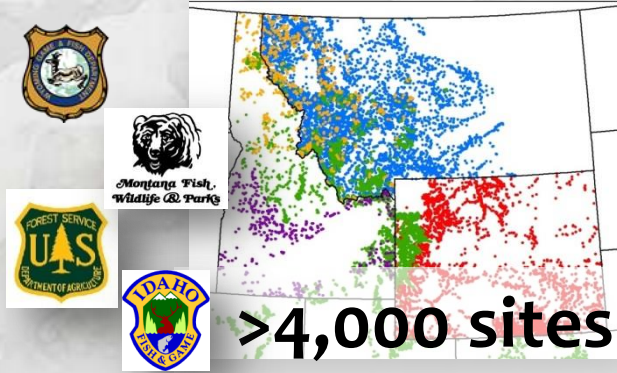
Dan Isaak, Mike Young, Dave Nagel, Dona Horan, Matt Groce

US Forest Service - RMRS



Precise Species Distribution Models to Highlight Climate Refugia

BIG FISH DATA



Temperature & other predictor variables

Isaak et al. 2015. The cold-water climate shield: Delineating refugia for preserving native trout through the 21st Century. *Global Change Biology* 21 doi:10.1111/gcb.12879

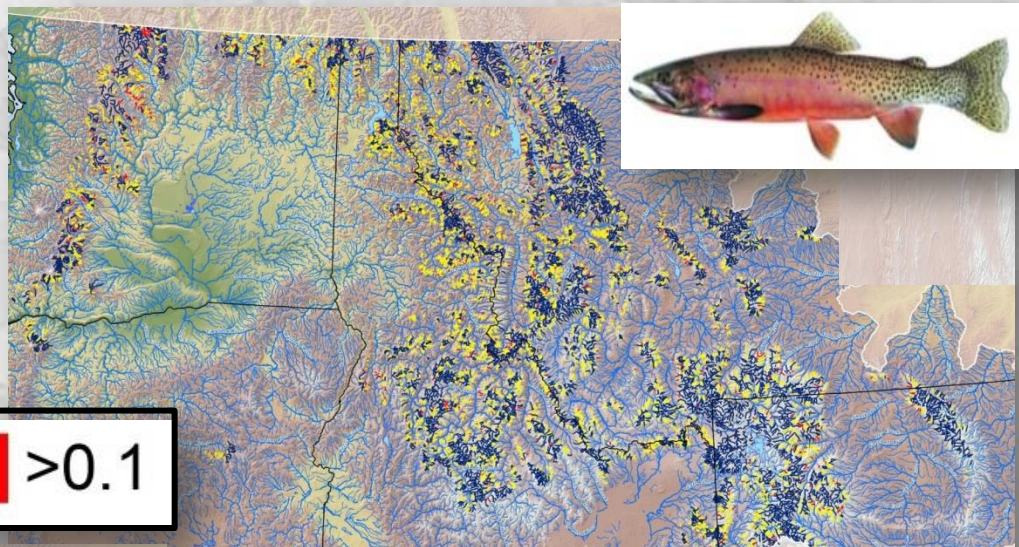
2040s Occurrence Probability Maps

Cutthroat Trout

7,914 >0.1 habitats

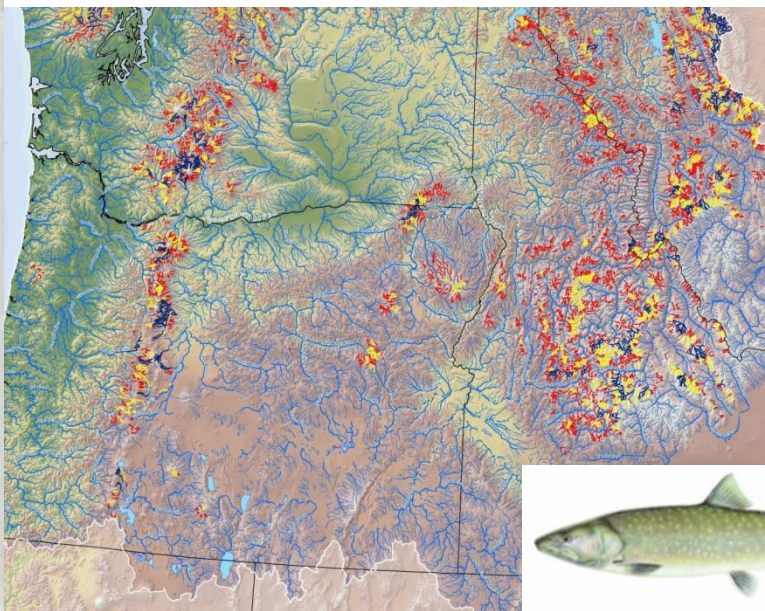
7,153 >0.5 habitats

2,179 >0.9 habitats



■ >0.9 ■ >0.5 ■ >0.1

Many Streams Will Continue to Support Populations!



Bull Trout

3,304 >0.1 habitats

641 >0.5 habitats

130 >0.9 habitats



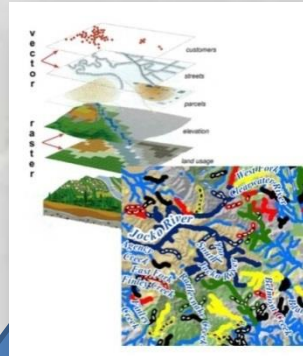
Website Provides Information in User-Friendly Digital Formats

<http://www.fs.fed.us/rm/boise/AWAE/projects/ClimateShield.html>

Presentations & Publications



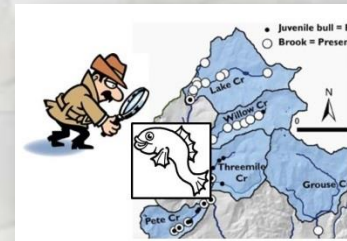
Digital Maps & ArcGIS Shapefiles



Fish Data Sources



Distribution Monitoring



File formats:

- ArcGIS files
- pdf files







15 Scenarios:

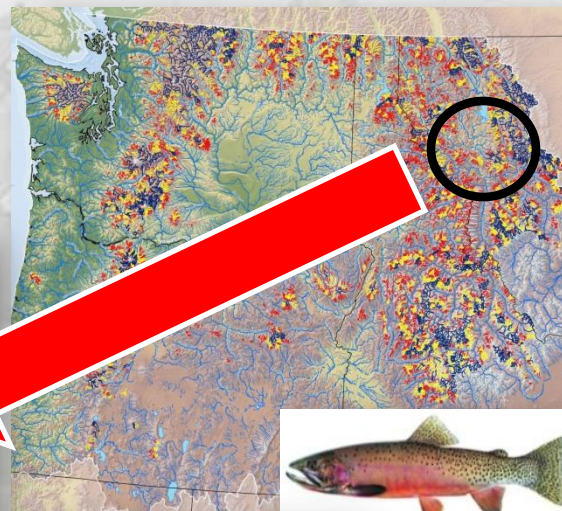
- 3 climate periods
- 5 Brook invasion levels



High-quality Spatial Information Empowers the Aquatic Army...







Occupancy Probability

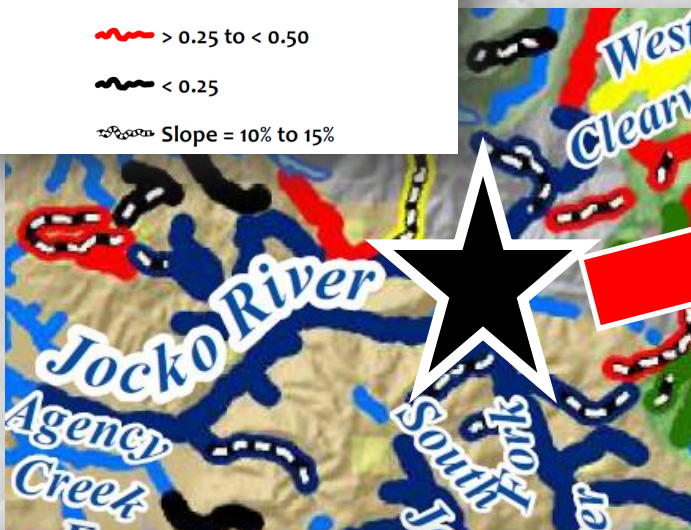
-  > 0.90
-  > 0.75 to < 0.90
-  > 0.50 to < 0.75
-  > 0.25 to < 0.50
-  < 0.25
-  Slope = 10% to 15%



High-quality Spatial Information Empowers the Aquatic Army...

Occupancy Probability

-  > 0.90
-  > 0.75 to < 0.90
-  > 0.50 to < 0.75
-  > 0.25 to < 0.50
-  < 0.25
-  Slope = 10% to 15%



Highest priority conservation investment!



If It's Steep, It Slows the Creep...

Many Headwater Refugia
in Western Landscapes

