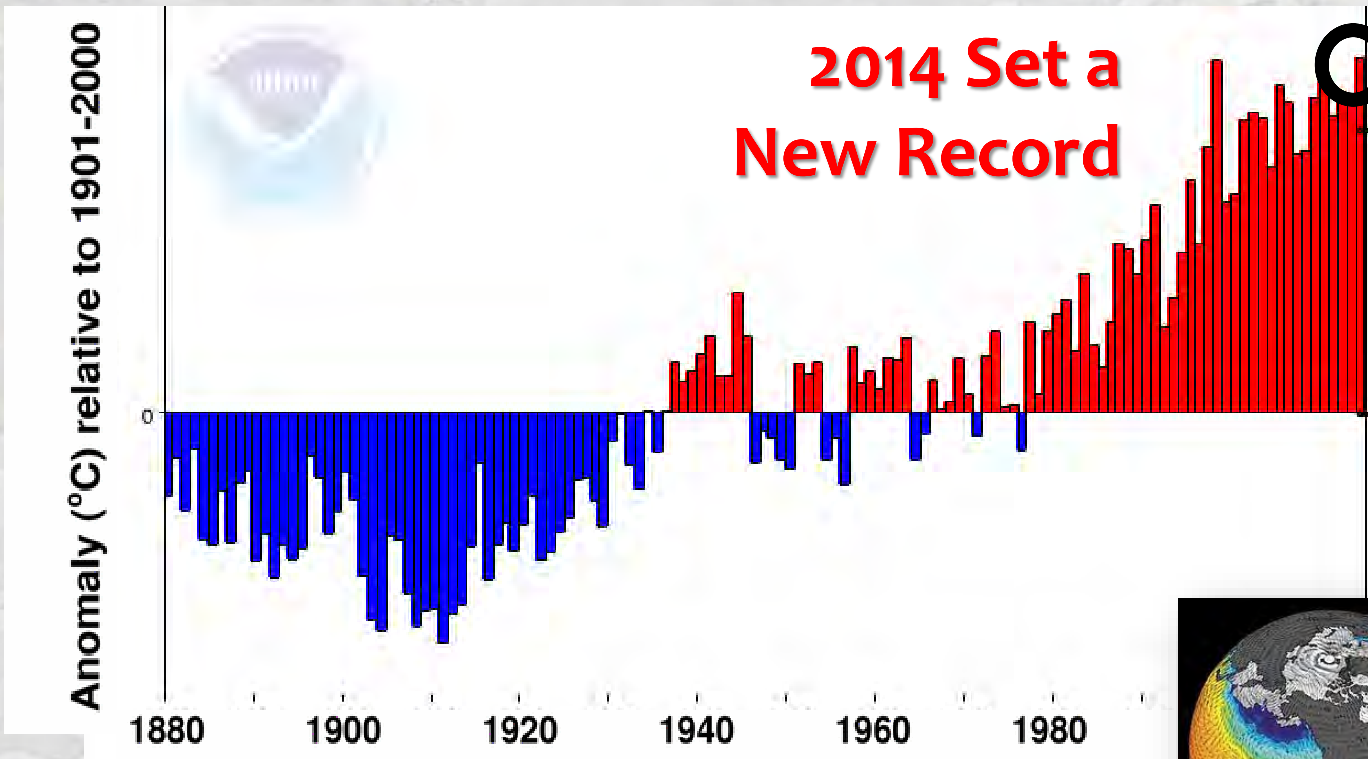
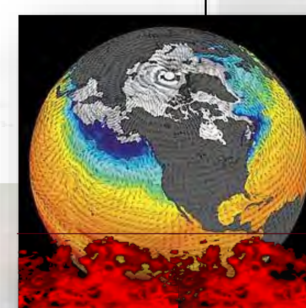
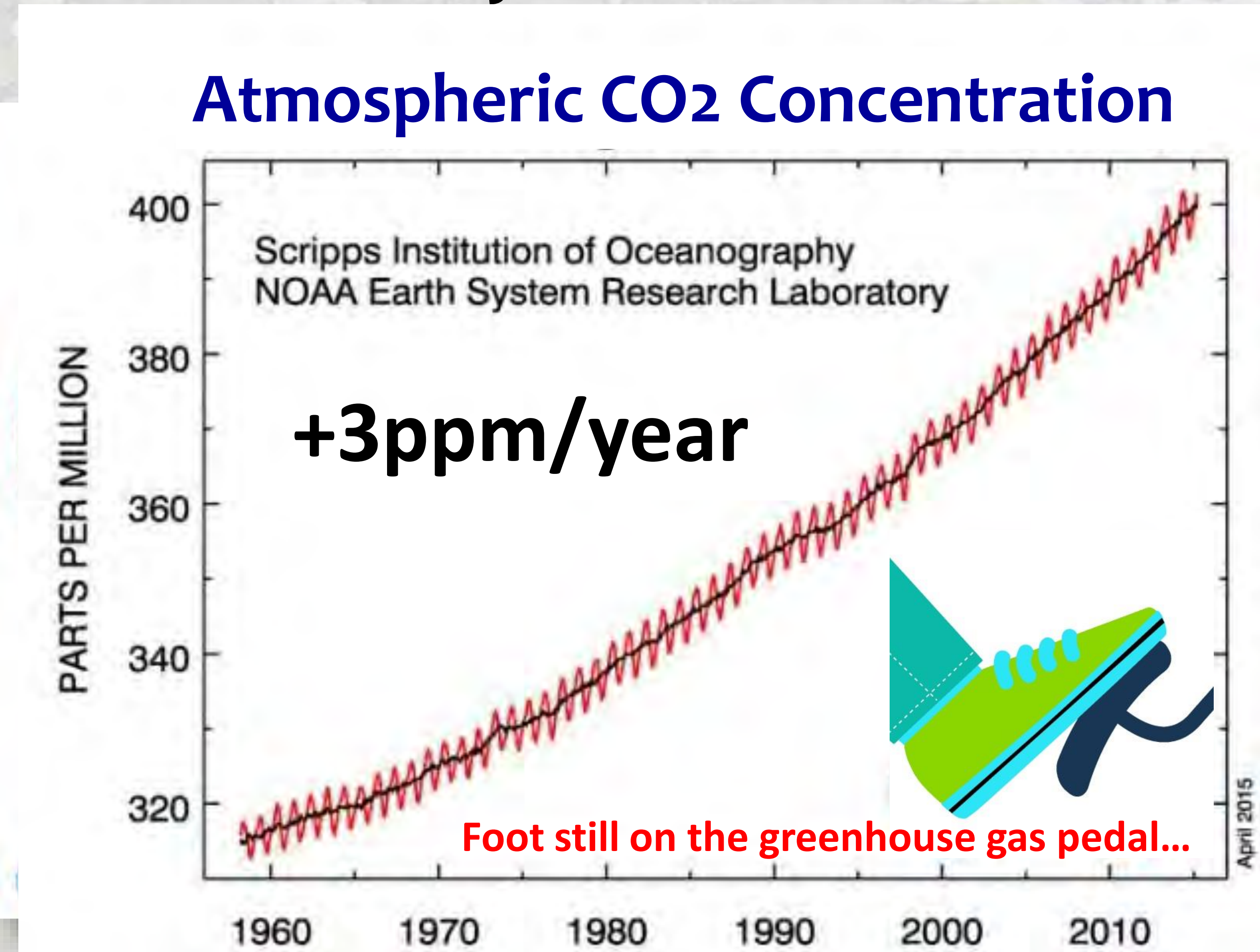
The New Reality…

1880-2014 Global Air Temperature Trend



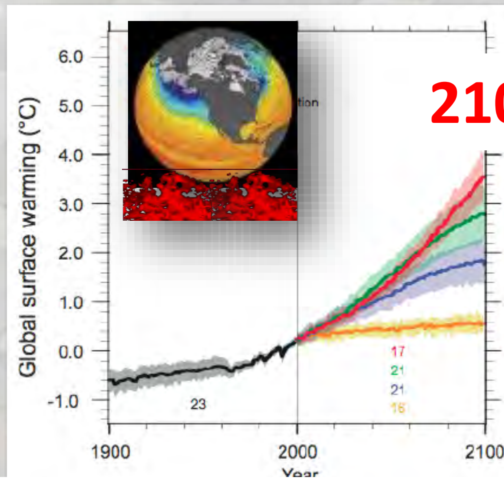


The New Reality…

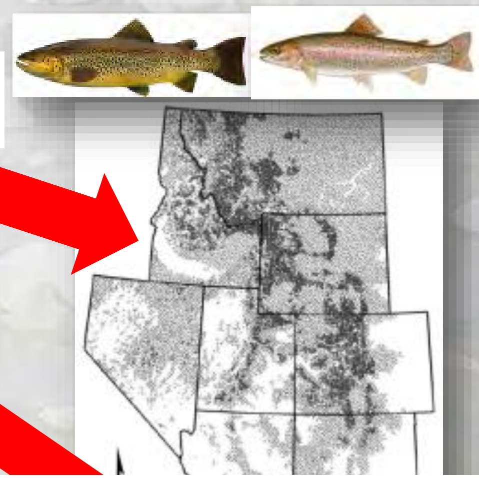


Plan on continued warming for decades…

Obviously, the Cold-Water Fish World Will End in Immolation…

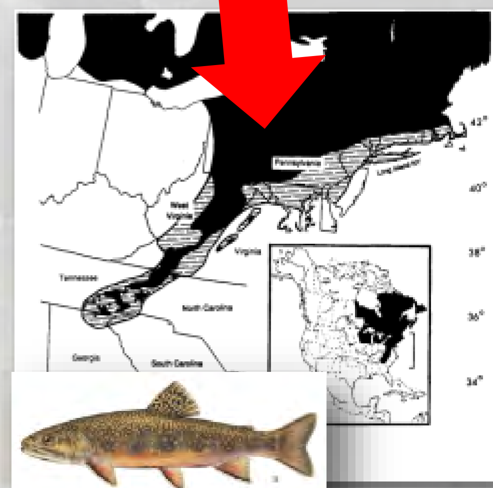


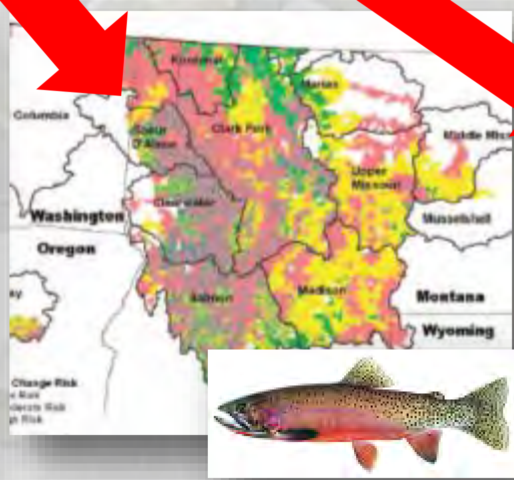
2100



- 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.

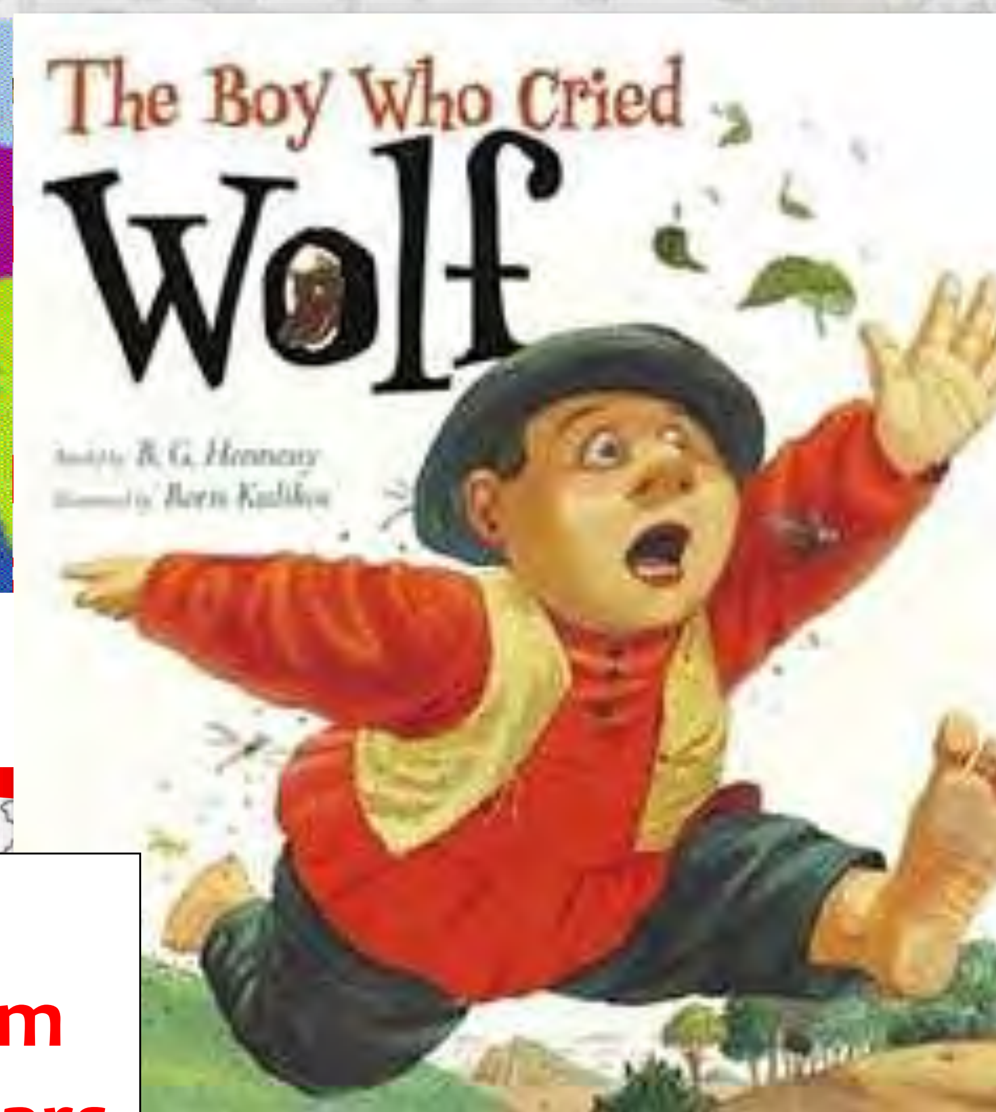
- **Huge declines: 50%-100%**





Obviously, the Cold-Water Fish World Will End in Immolation…

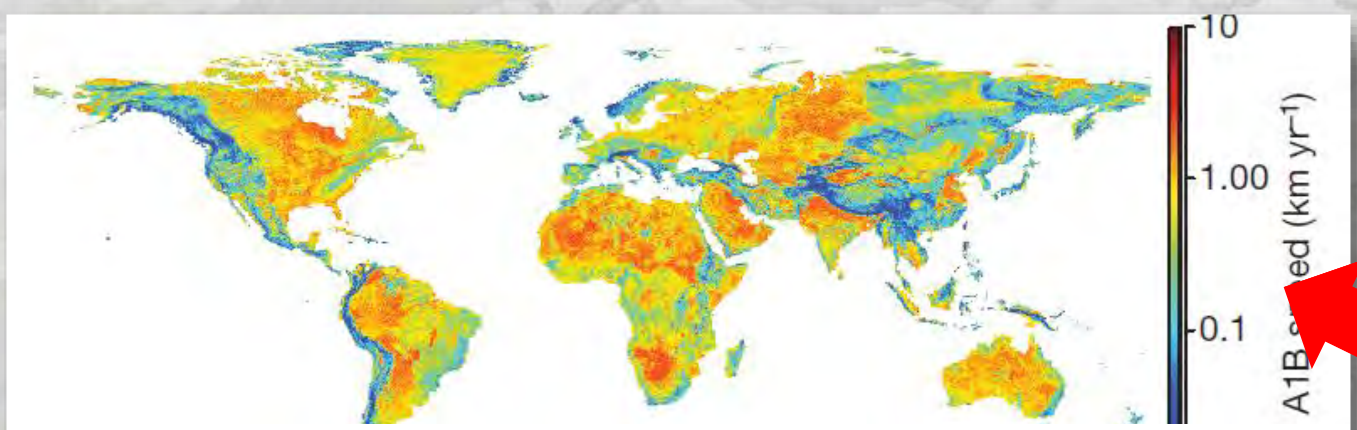
Double-Whammy in Mountain Headwaters!



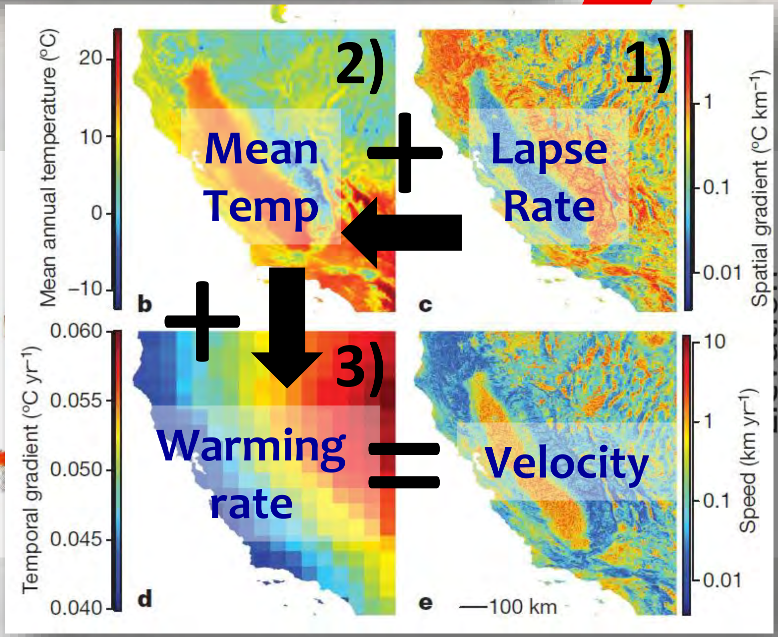
We've been predicting doom for almost 30 years

Climate “Velocity” is What’s Biologically Relevant

Rate at Which Isotherms & Thermal Niches Shift



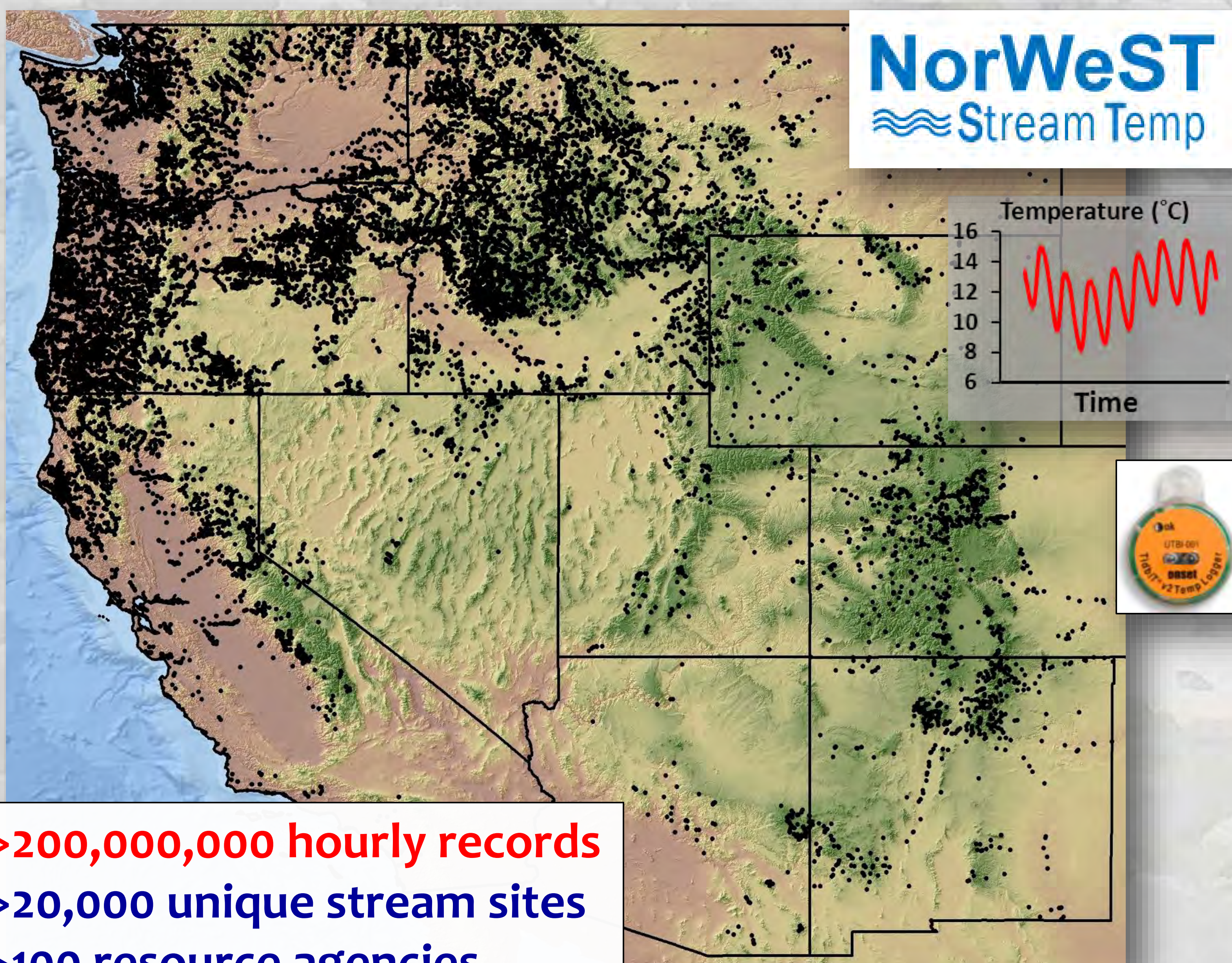
Velocity varies 100x for same warming rate



Loarie et al. 2009. The Velocity of Climate Change. *Nature* **462:**1052-1055.

Stream Application Required Some Data

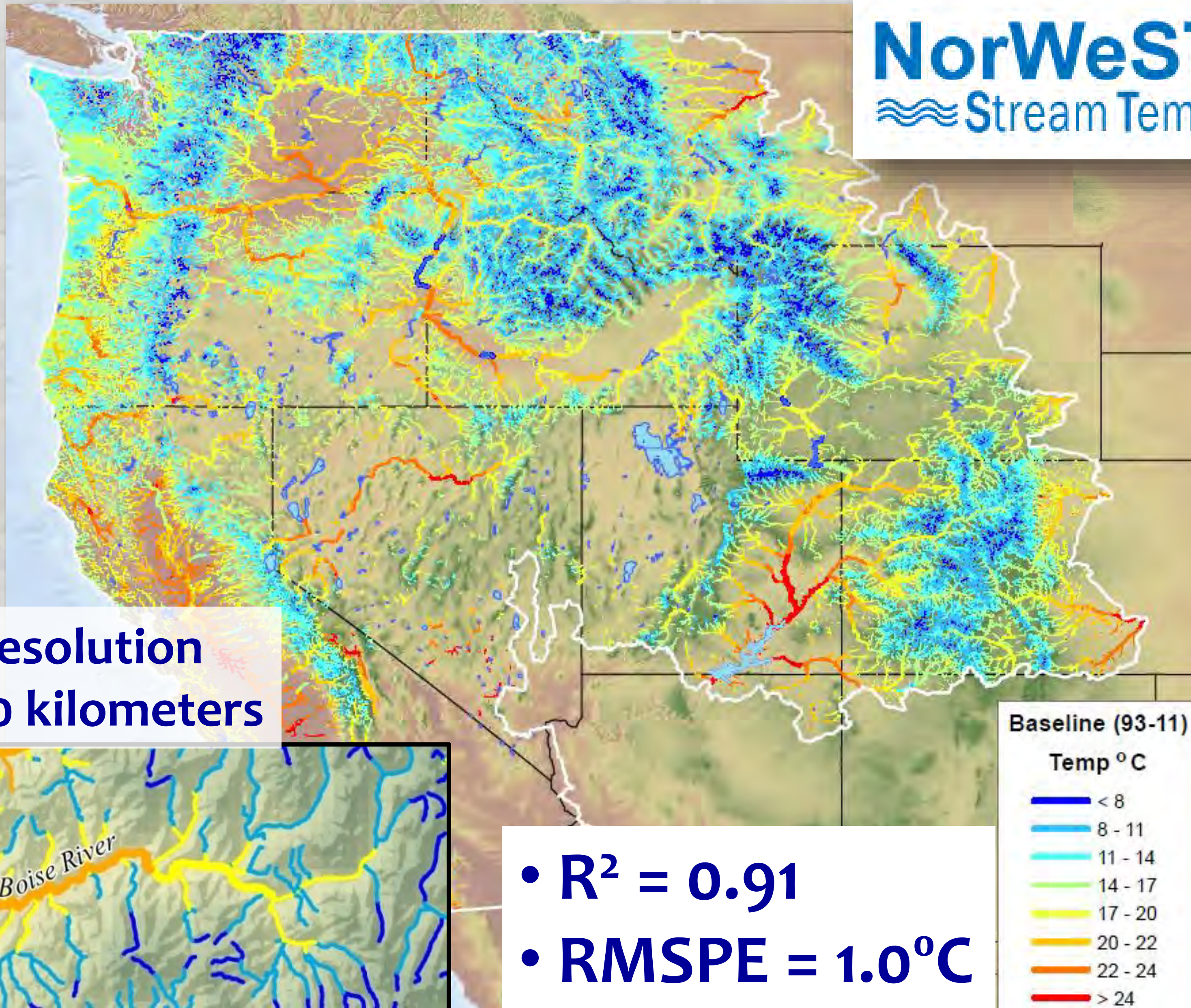
NorWeST
Stream Temp



>200,000,000 hourly records
>20,000 unique stream sites
>100 resource agencies

& Accurate Stream Temperature Scenarios

NorWeST Stream Temp

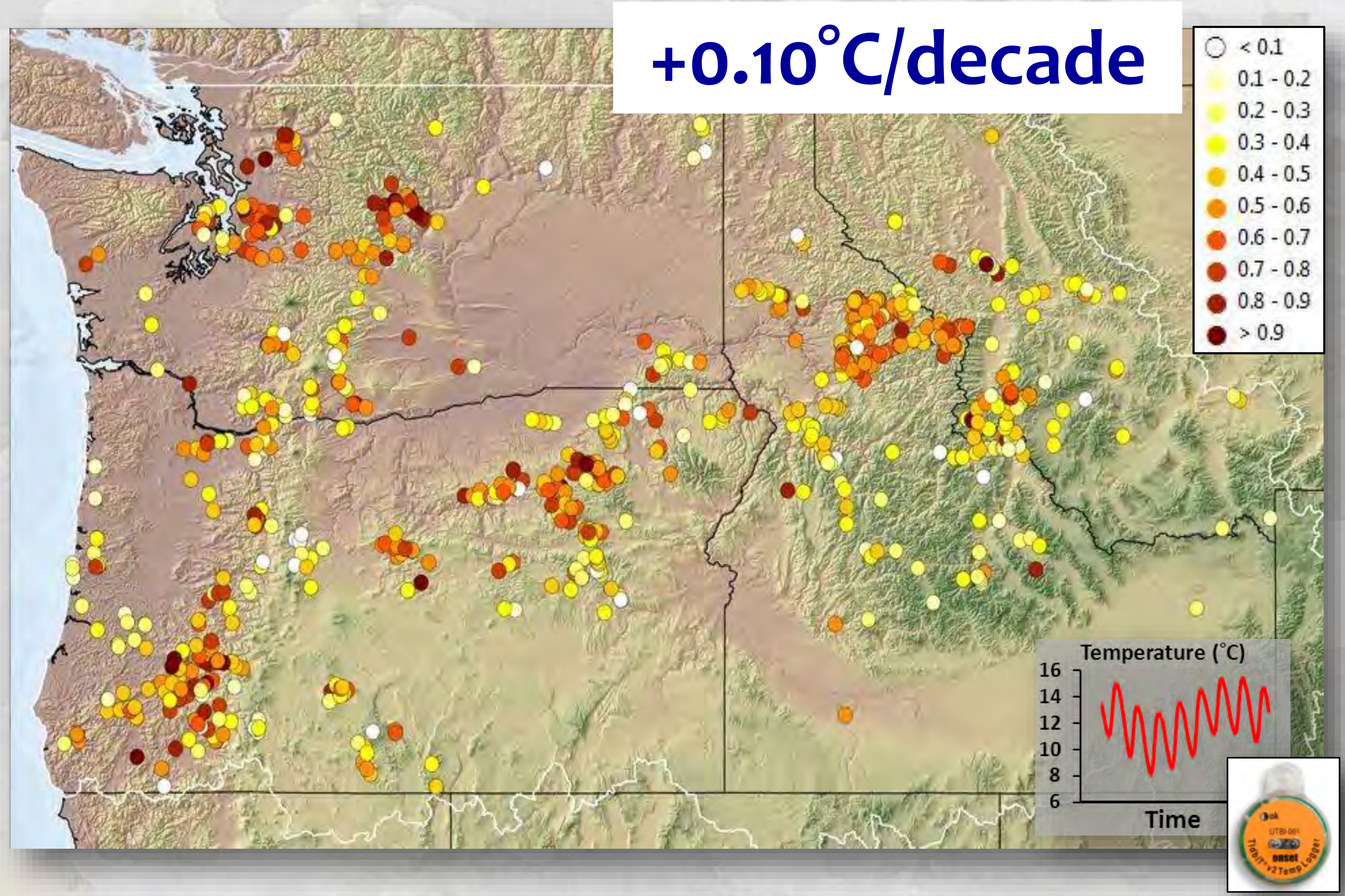


1-km resolution
1,000,000 kilometers

- $R^2 = 0.91$
- RMSPE = 1.0°C

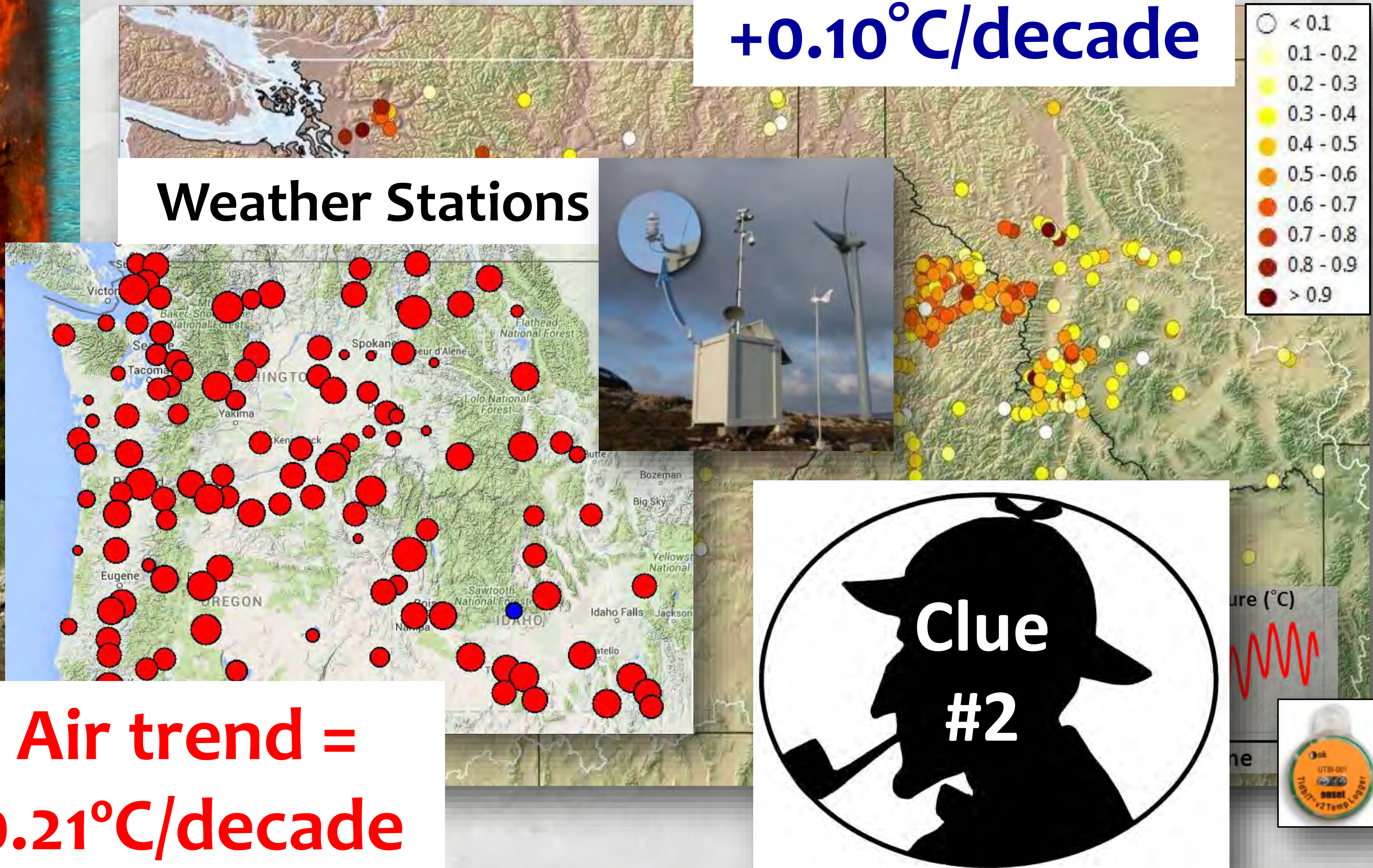
Stream Warming Rates 1968-2011

923 sites in NorWeST database with >10 year records



Stream Warming Rates 1968-2011

923 sites in NorWeST database with >10 year records

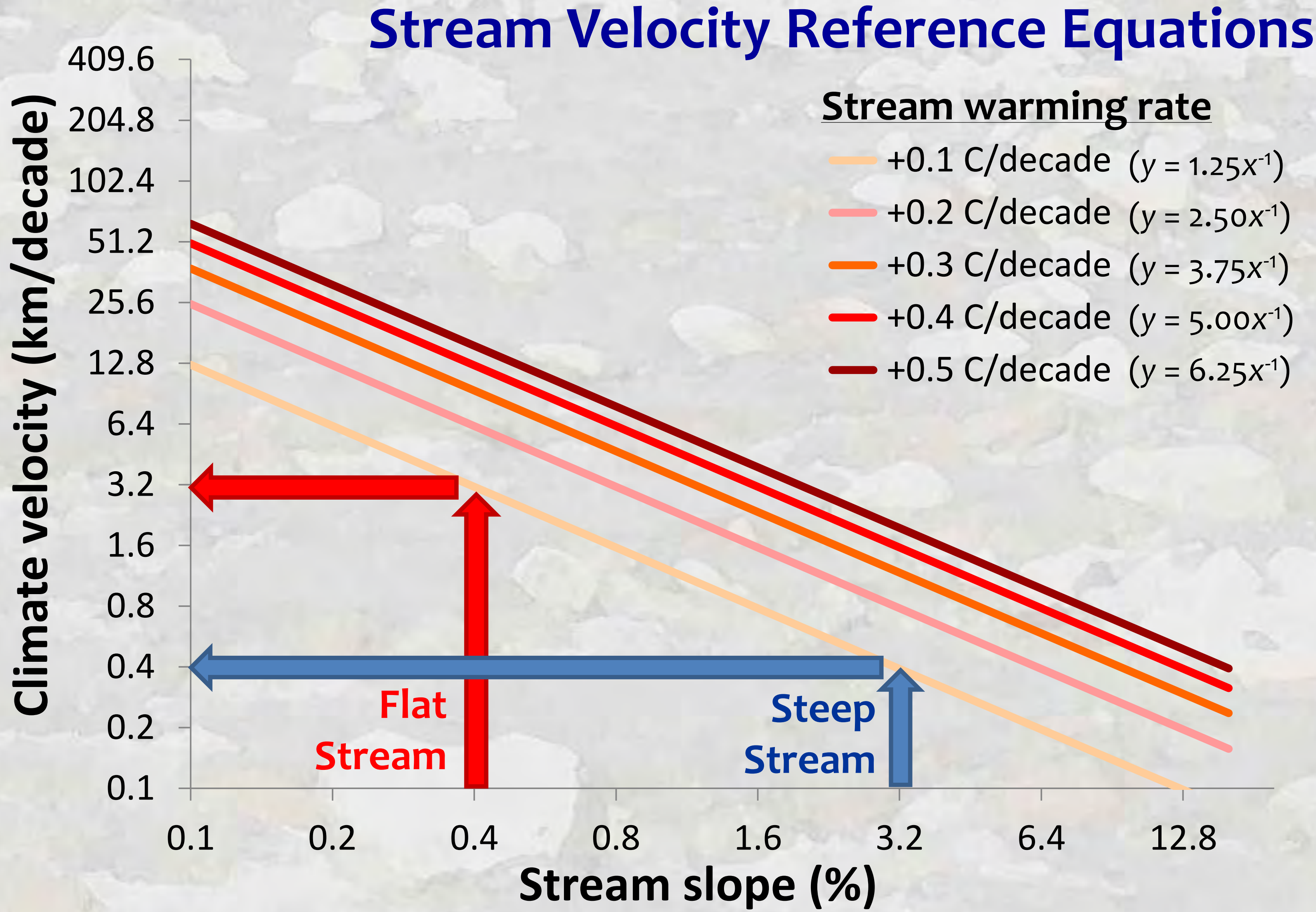


+0.10°C/decade

Weather Stations

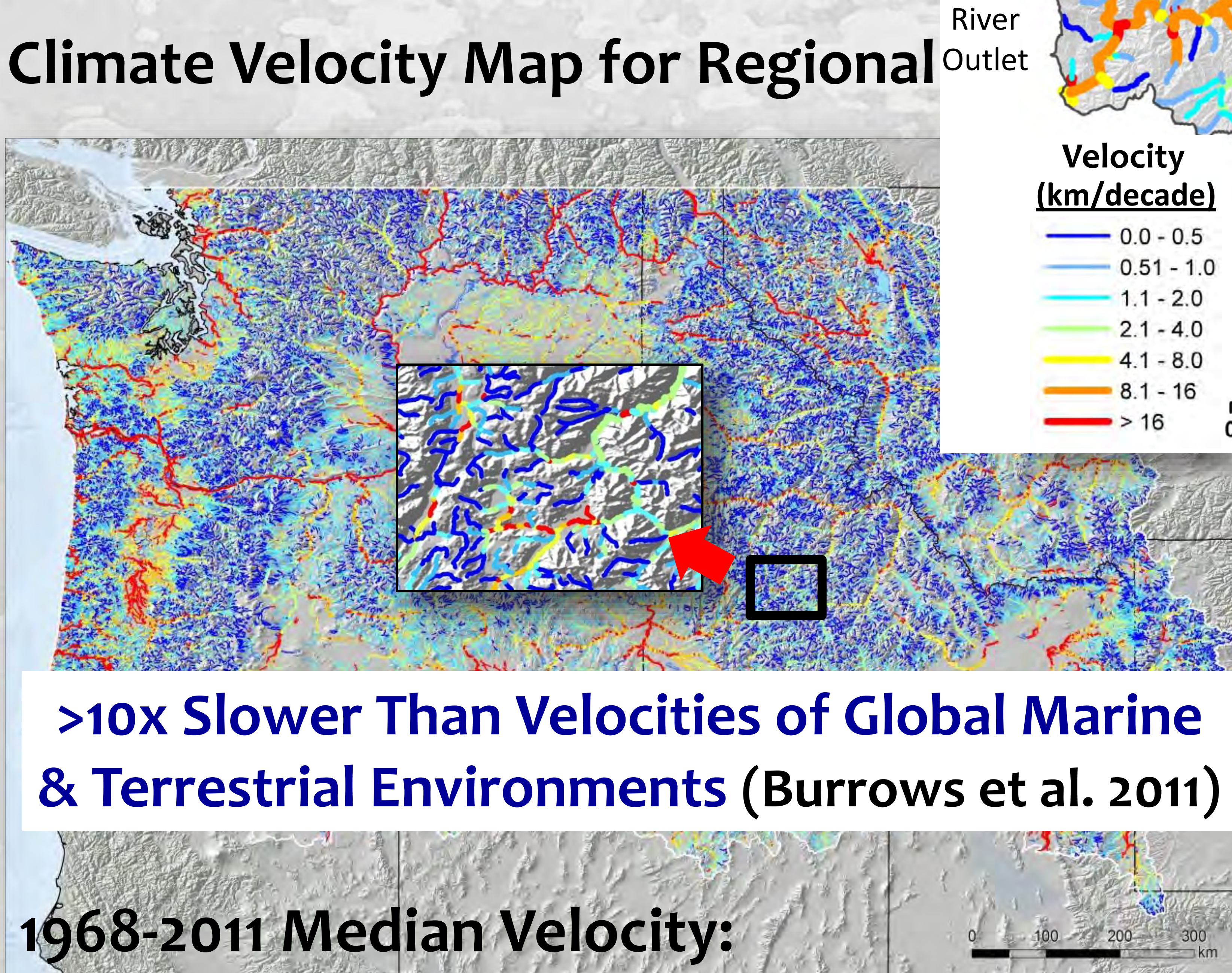
Air trend = 0.21°C/decade

Remember… Velocity is What Matters!



Isaak & Rieman. 2013. *Global Change Biology* **19**:742-751.

Climate Velocity Map for Regional

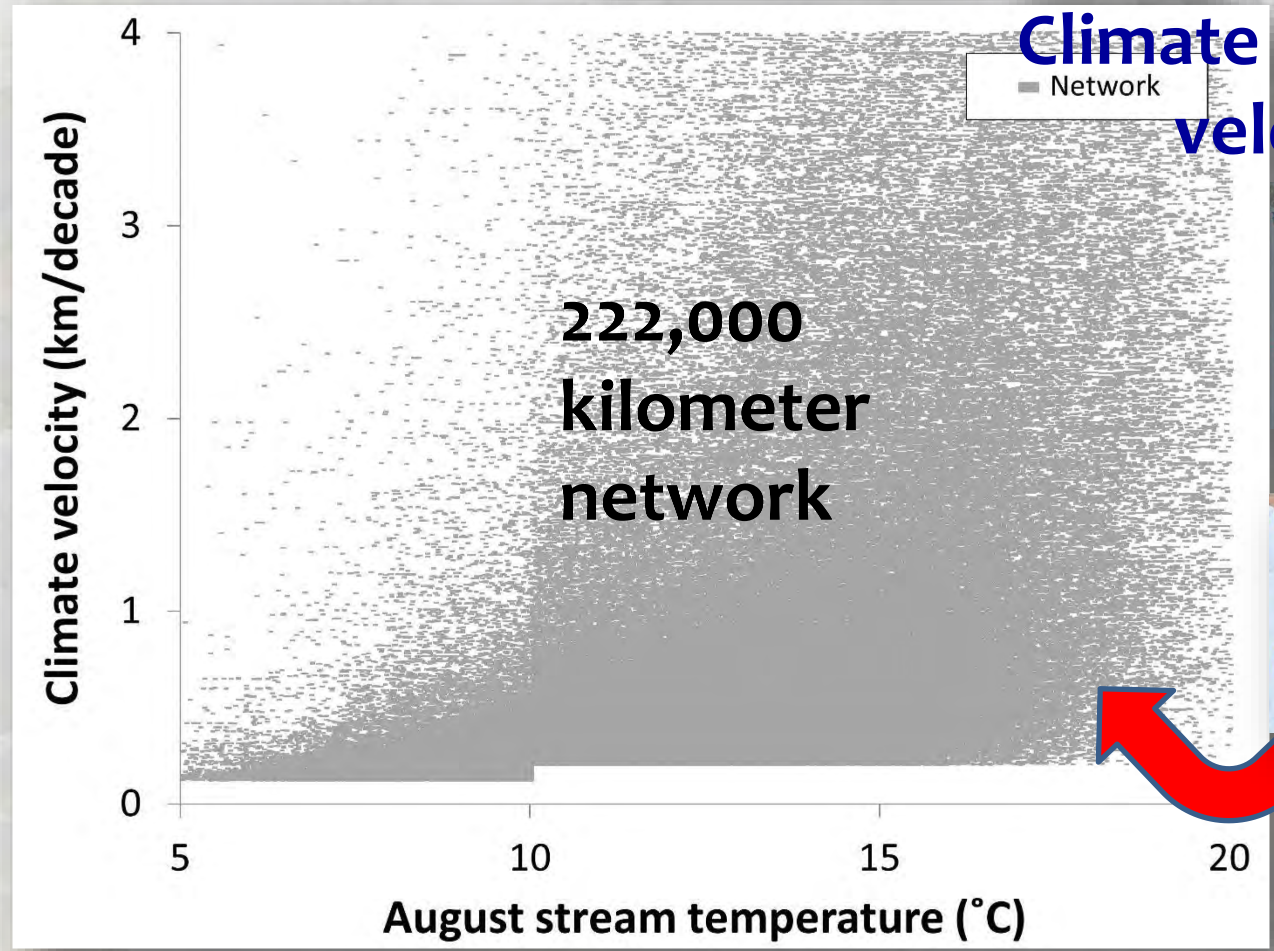


>10x Slower Than Velocities of Global Marine & Terrestrial Environments (Burrows et al. 2011)

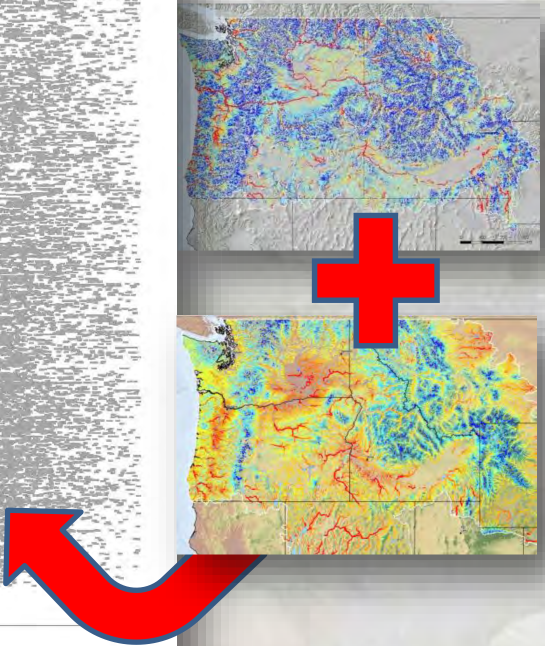
1968-2011 Median Velocity:

1.07 km/decade

Where do Those "Doomed" Headwater Species Live?

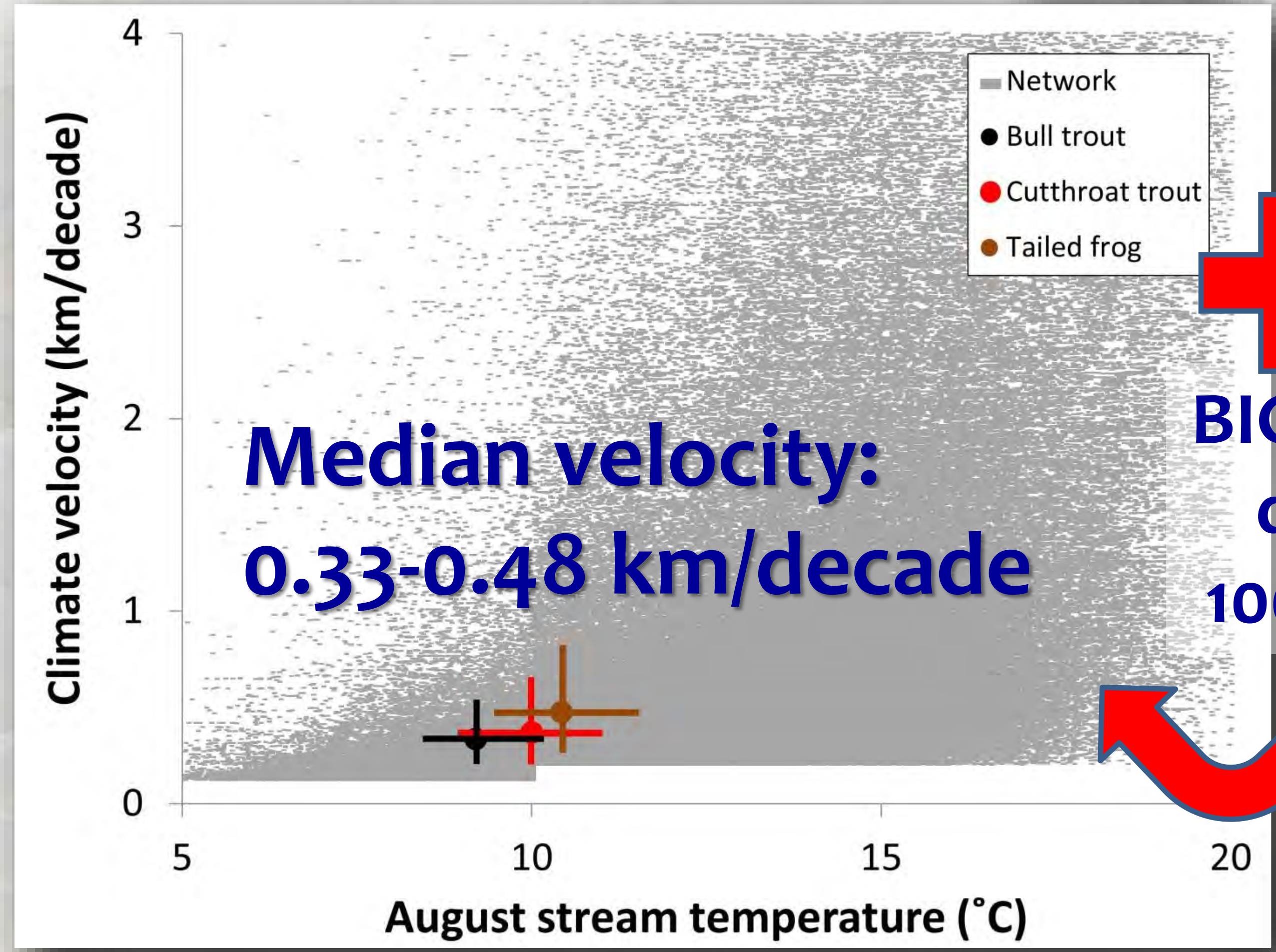


Climate scenario & velocity maps

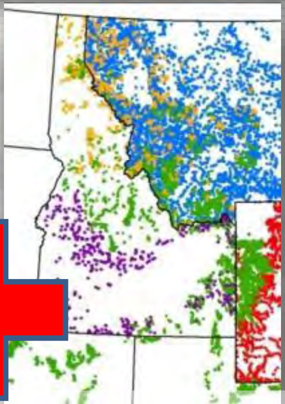


Isaak 2016. Slow climate velocities of mountain streams. *PNAS* **113**:4374-4380.

Where do Those "Doomed" Headwater Species Live?



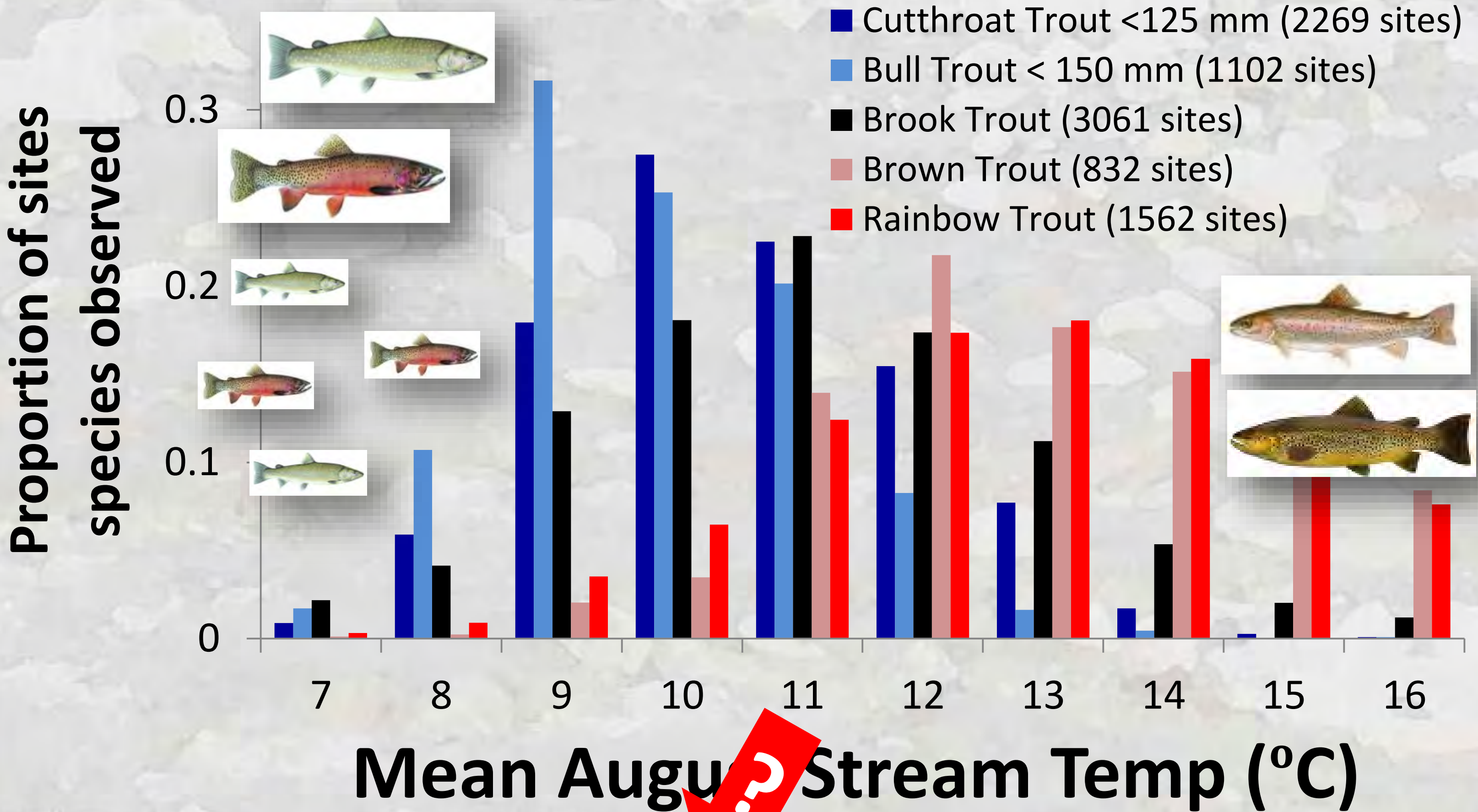
Median velocity: 0.33-0.48 km/decade



BIG biological databases – 1000s of sites

Isaak 2016. Slow climate velocities of mountain streams. *PNAS* **113**:4374-4380.

Cold Climates Also Exclude Most Invaders

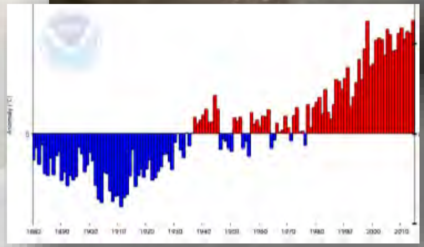


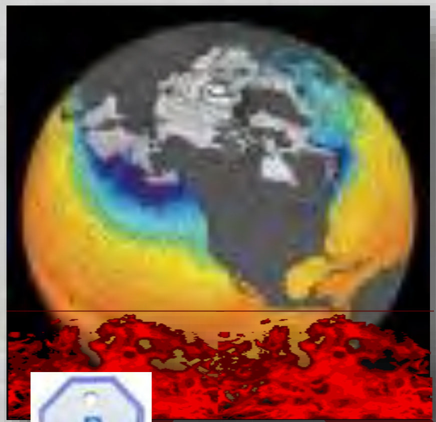
The Cold-Water Climate Shield

Delineating Refugia for Preserving Native Trout

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

US Forest Service - RMRS



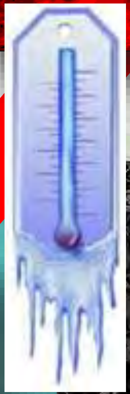


Climate Shield

Rocky Mountain Research Station

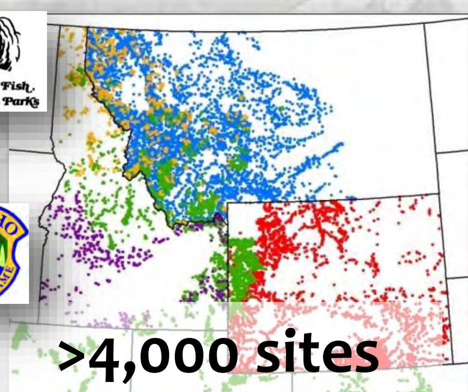
Boise Spatial Streams Group

NorWeST Stream Temp

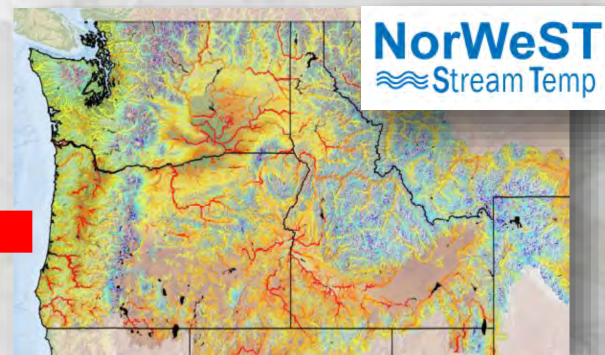


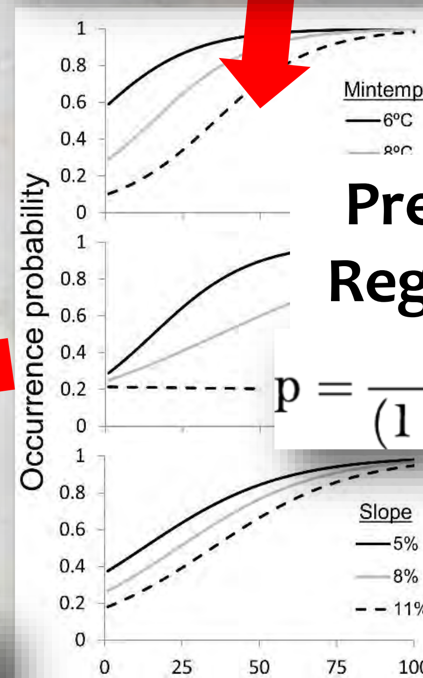
Precise Species Distribution Models to Highlight Climate Refugia

BIG FISH DATA



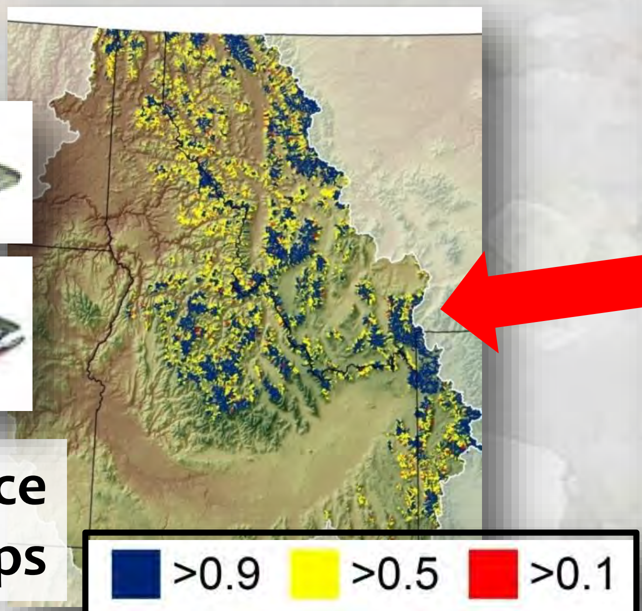
>4,000 sites
>500 streams





Predictive Logistic Regression Models

$$p = \frac{\exp(a + bx \ldots ny)}{(1 + \exp[a + bx \ldots ny])}$$



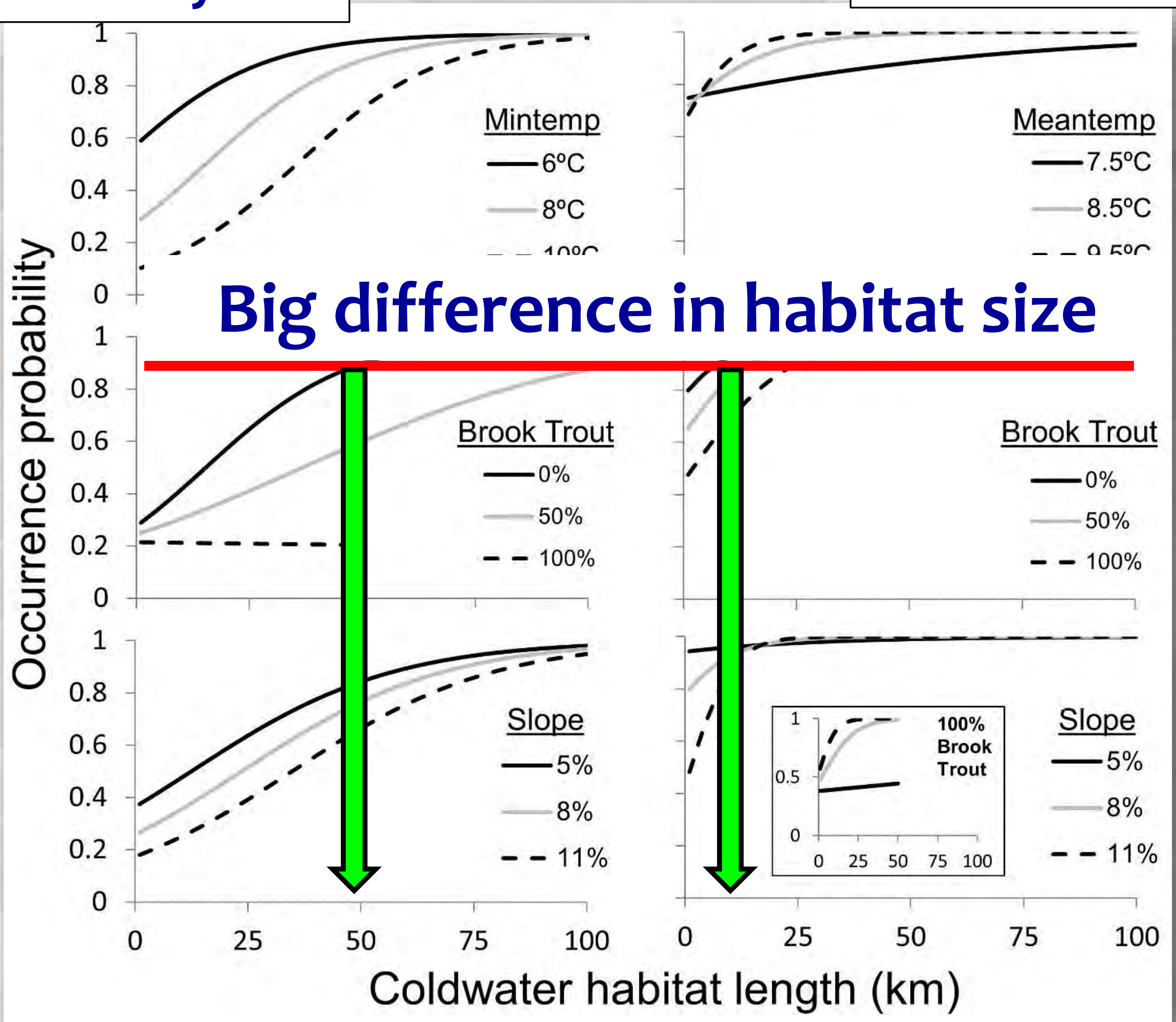
Occurrence probability maps

Isaak et al. 2015. The cold-water climate shield: Delineating refugia for preserving native trout through the 21st Century. *Global Change Biology* **21:** 2540-2553

78% classification accuracy

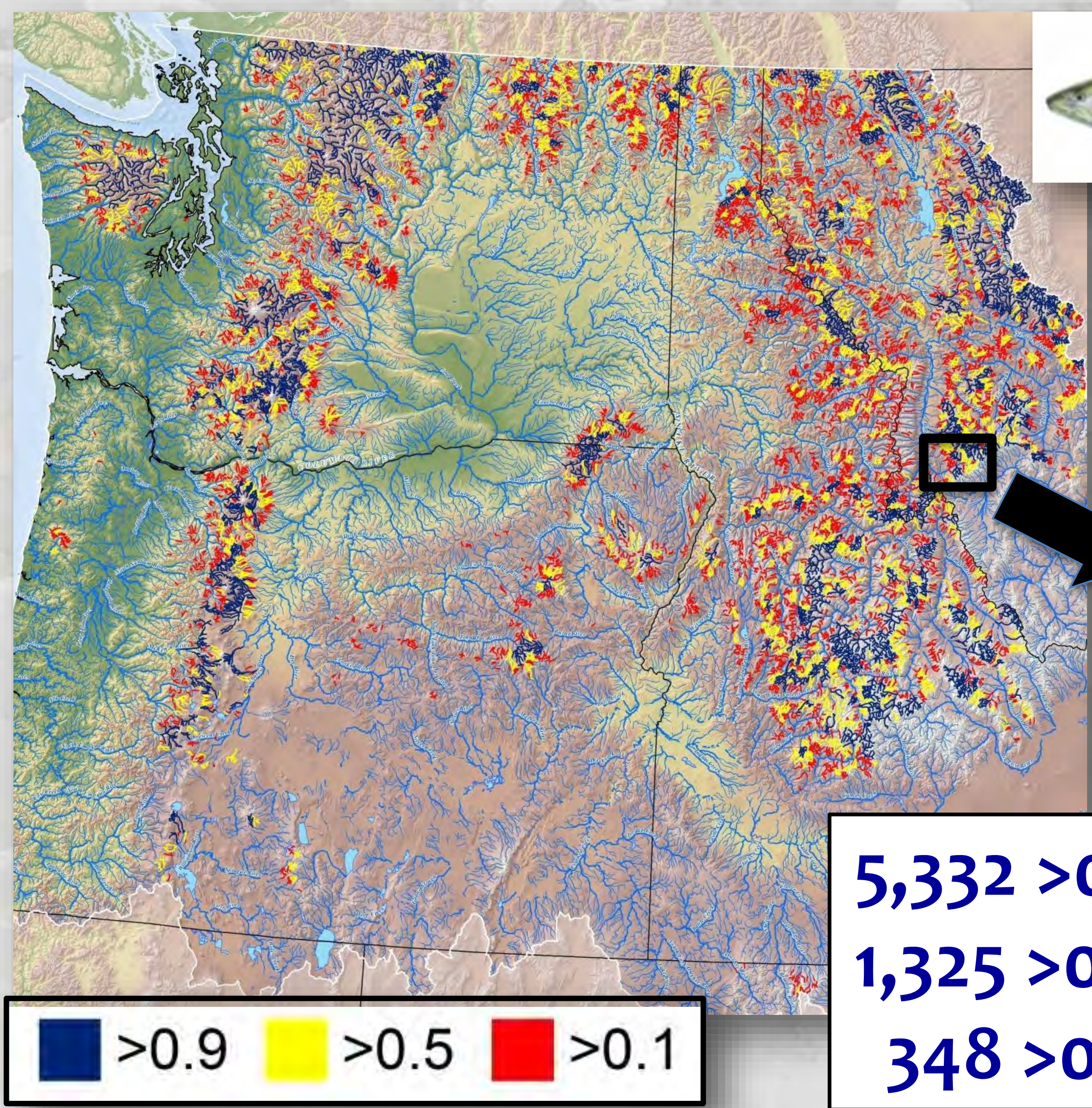
85% classification accuracy

Big difference in habitat size



Bull Trout Probability Map

1980s

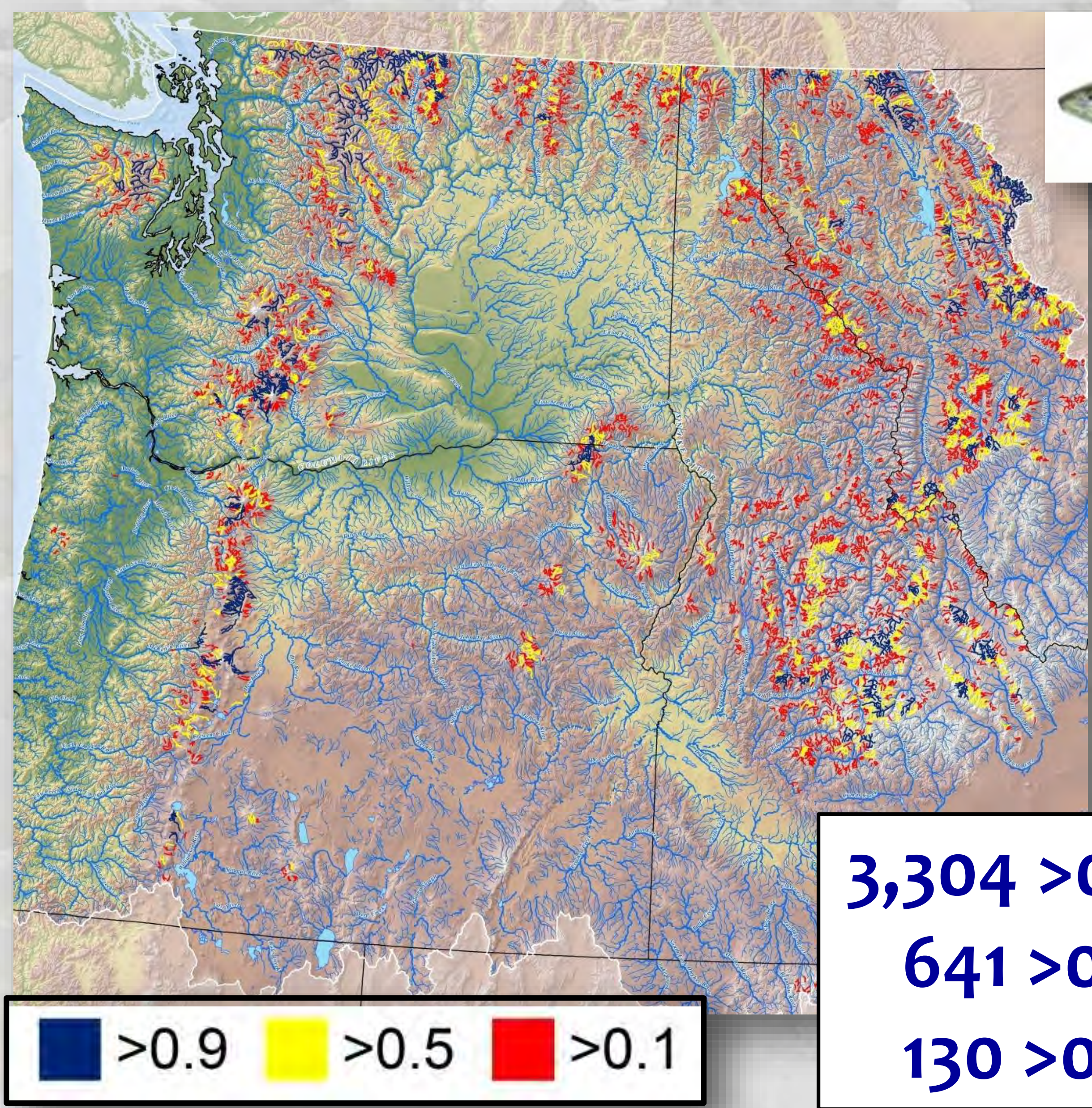


Stream population scale predictions

5,332 >0.1 habitats
1,325 >0.5 habitats
348 >0.9 habitats

Bull Trout Probability Map

2040s



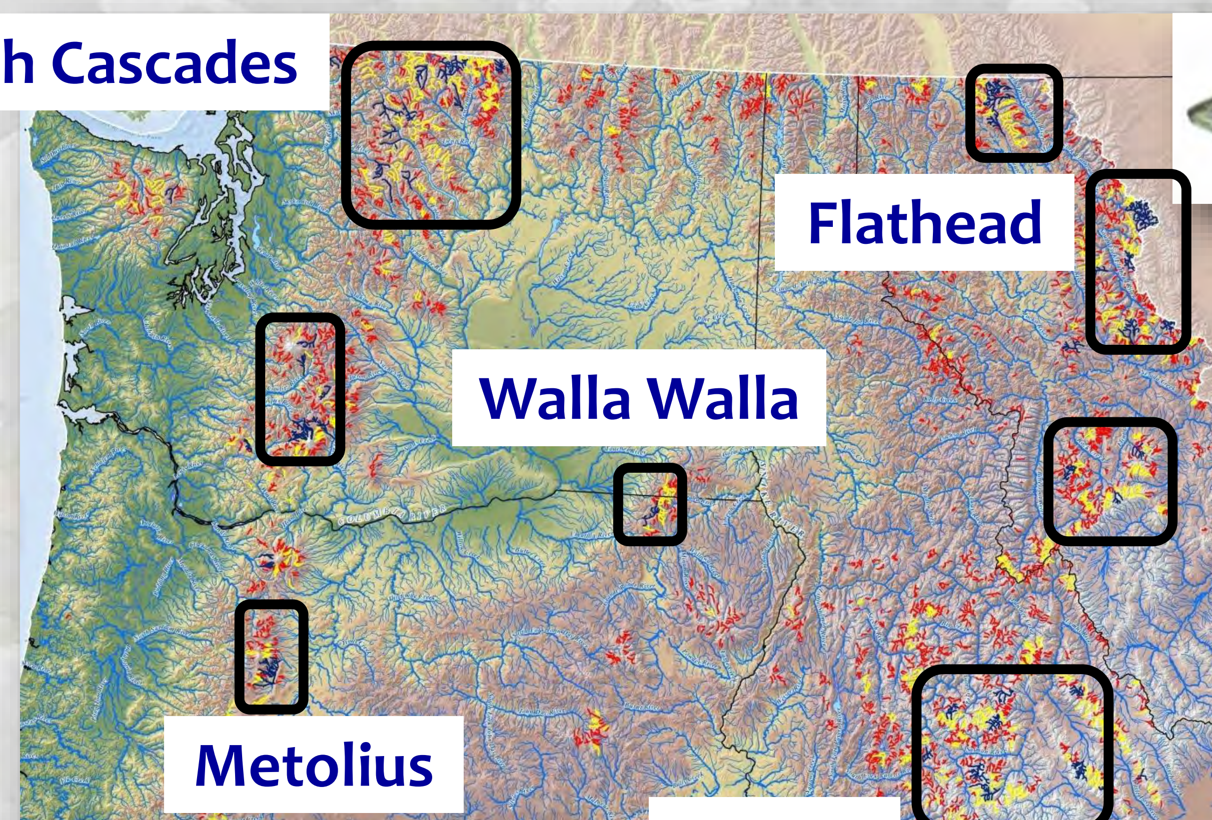
3,304 >0.1 habitats

641 >0.5 habitats

130 >0.9 habitats

Bull Trout Probability Map

2080s

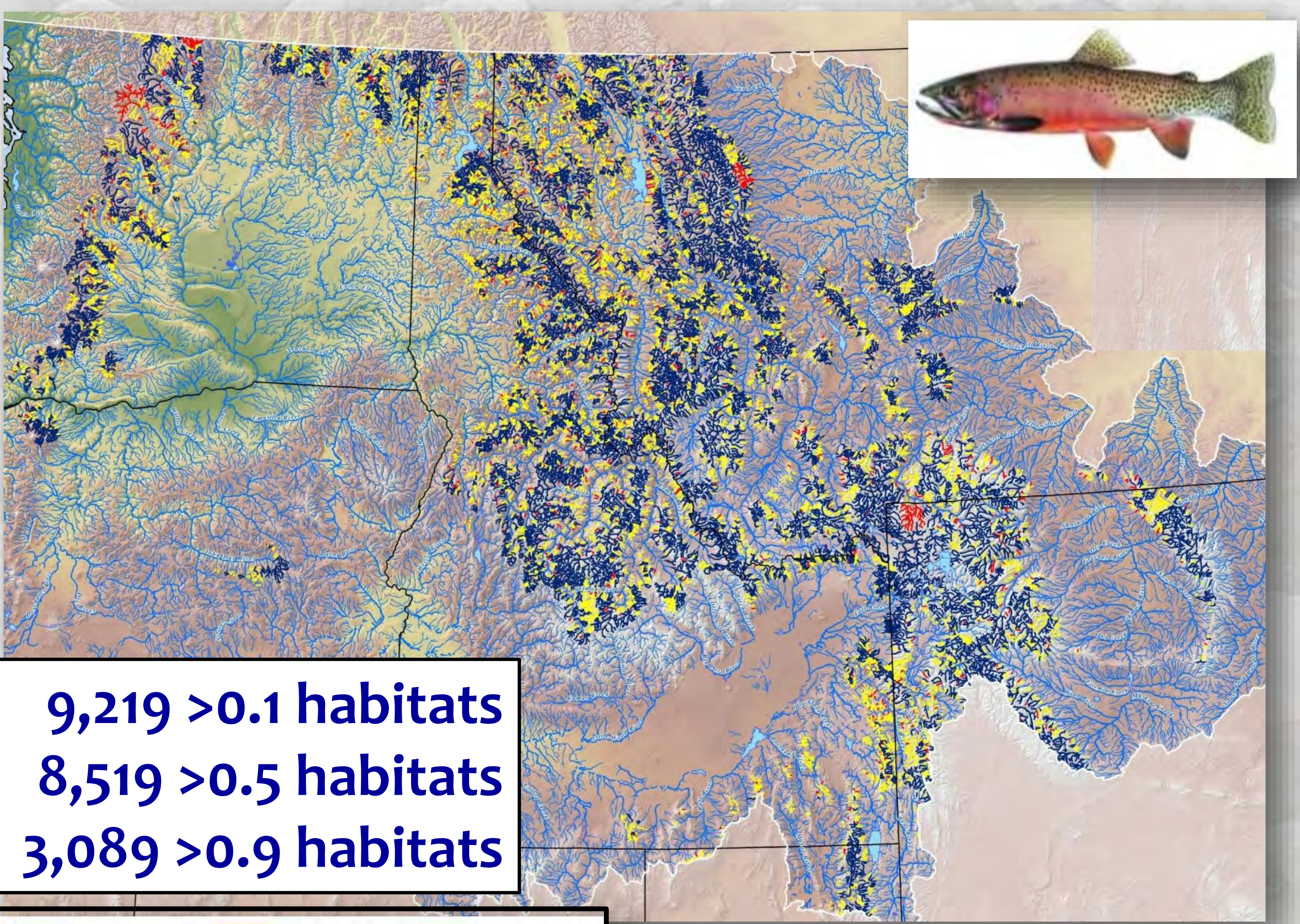


Extreme scenario!
+5°C

2,712 >0.1 habitats
460 >0.5 habitats
62 >0.9 habitats

Cutthroat Probability Map

1980s

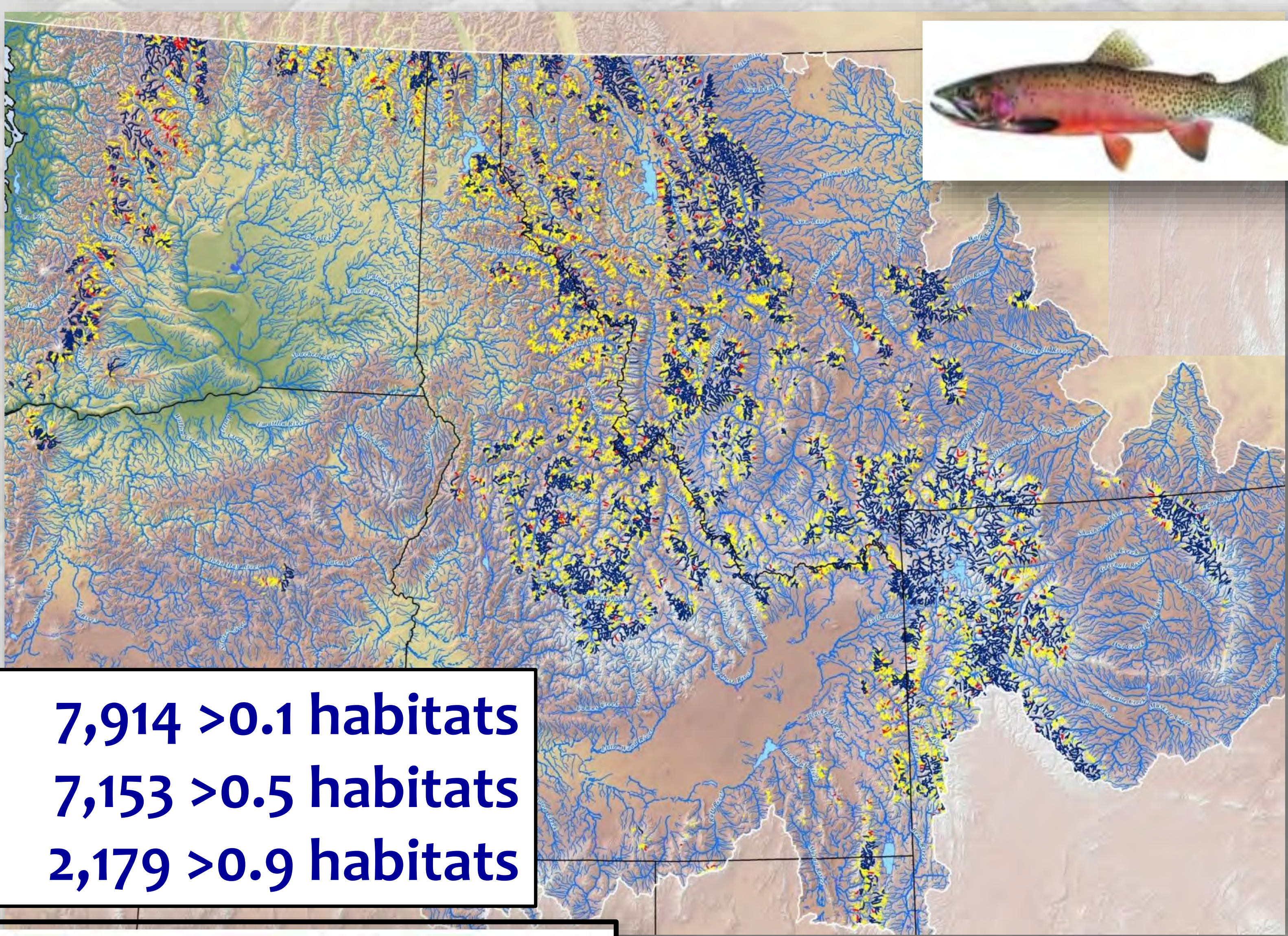


9,219 >0.1 habitats
8,519 >0.5 habitats
3,089 >0.9 habitats

>0.9 >0.5 >0.1

Cutthroat Probability Map

2040s



7,914 >0.1 habitats

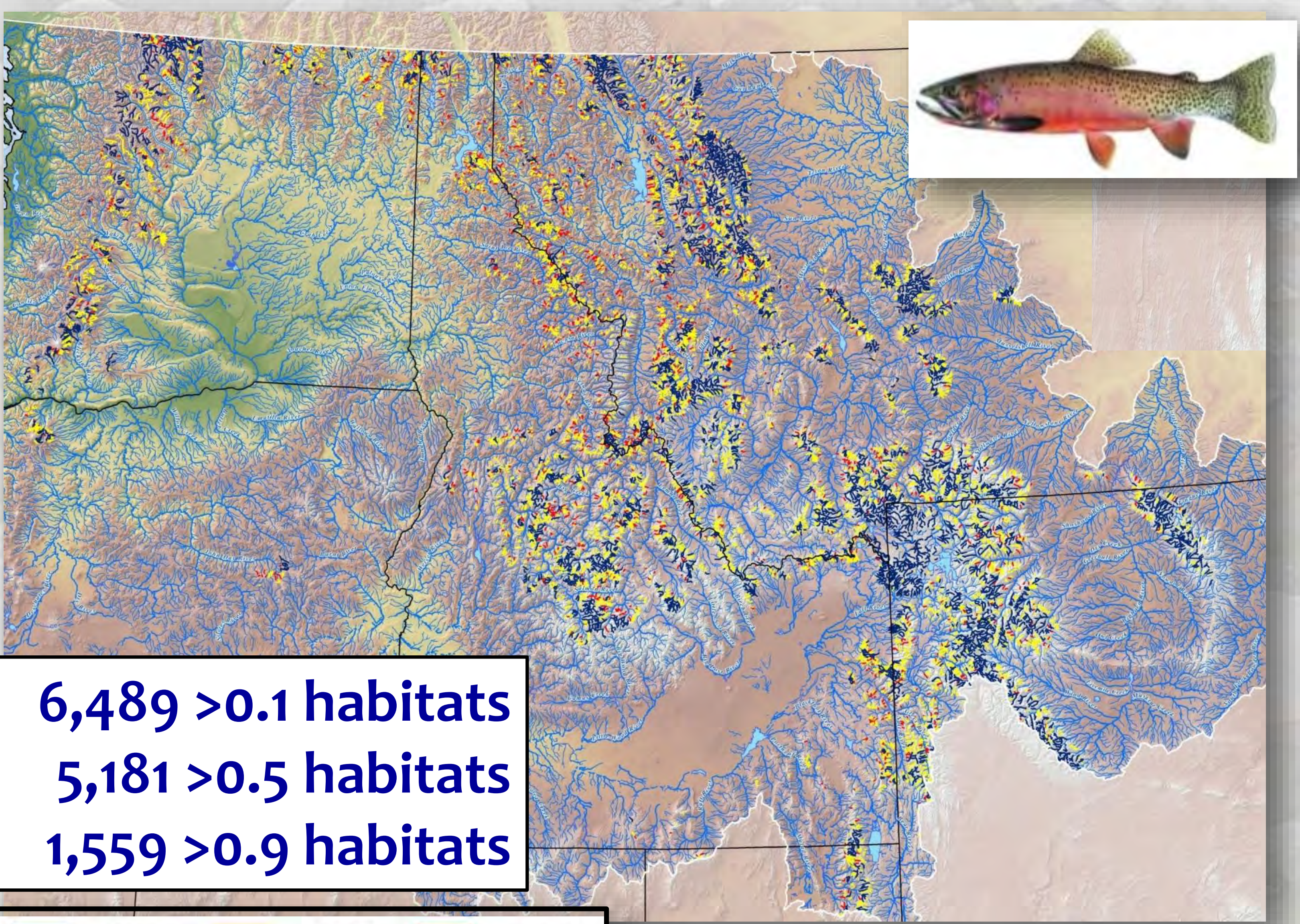
7,153 >0.5 habitats

2,179 >0.9 habitats

>0.9 >0.5 >0.1

Cutthroat Probability Map

2080s



6,489 >0.1 habitats
5,181 >0.5 habitats
1,559 >0.9 habitats

>0.9 >0.5 >0.1

About that Brook Trout Effect…

Number & Size of Refugia >0.9

	Period	Median size (km)	Refugia
Cutthroat Trout	1980s	11	3,089
		10	2,179
		9	1,559
Bull Trout		51	348
		54	130
	2080s	53	62

2x larger

…but *steeper* streams are also invasion resistant

Website Provides Information in User-Friendly Digital Formats

Climate Shield

Just Google "Climate shield trout"

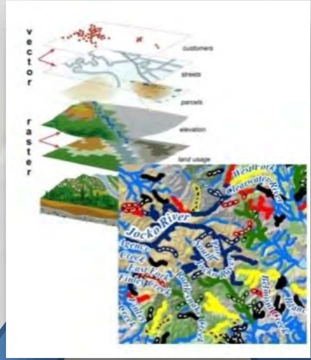
Presentations & Publications

Coldwater as a Climate Shield to Preserve Native Trout Through the 21st Century

Abstract

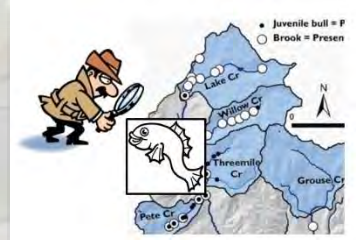
Introduction

Digital Maps & ArcGIS Shapefiles



Fish Data Sources

Distribution Monitoring



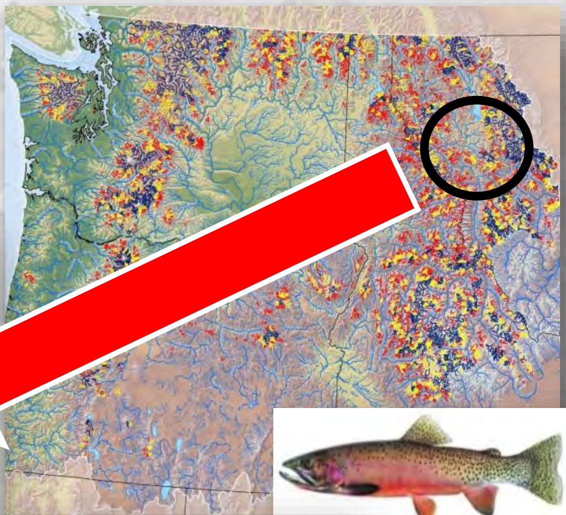
File formats:

- ArcGIS files
- pdf files

15 Scenarios:

- 3 climate periods
- 5 Brook invasion levels

High-quality Spatial Information Empowers the Aquatic Conservation Army…

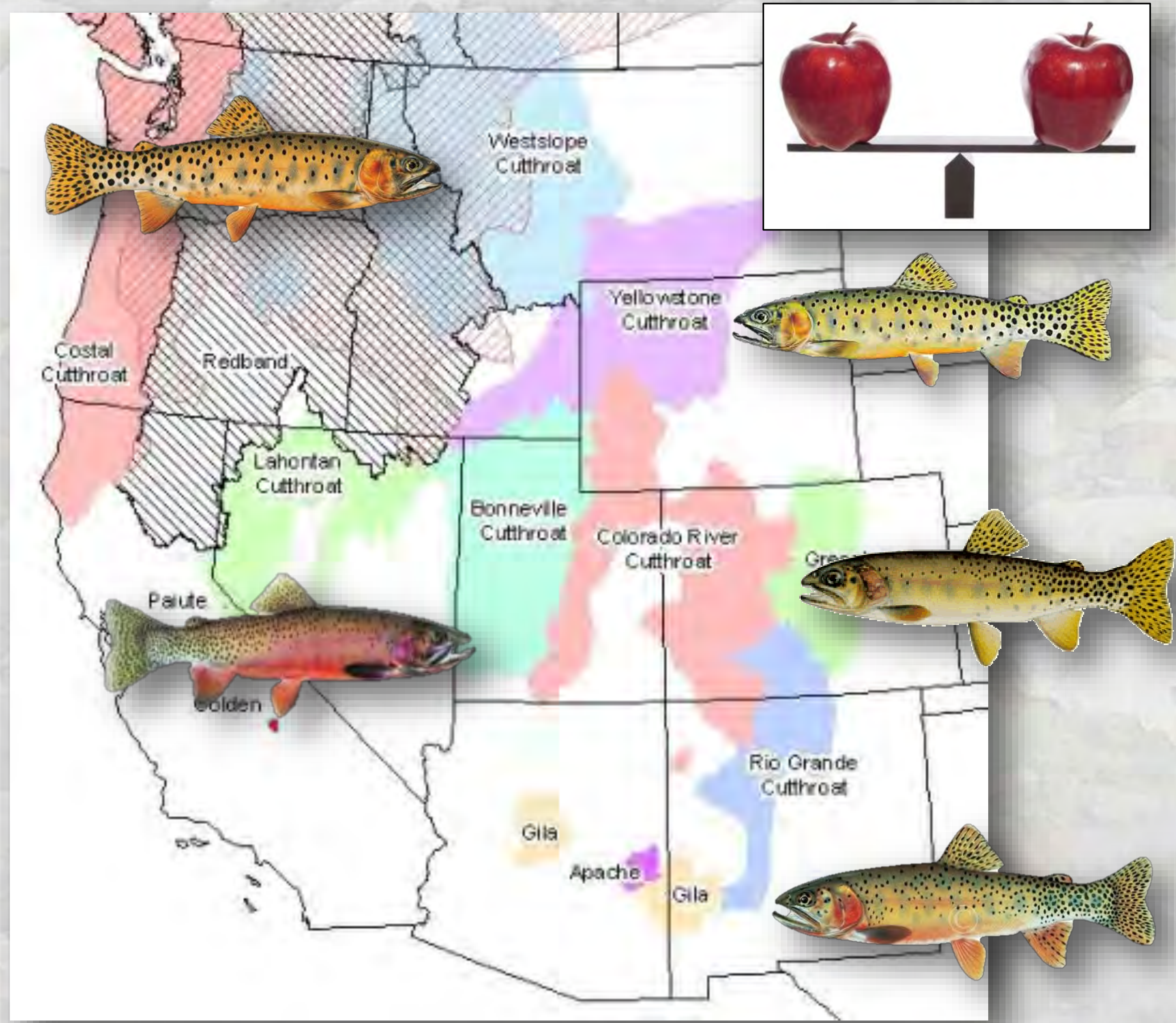


Highest priority conservation investment!

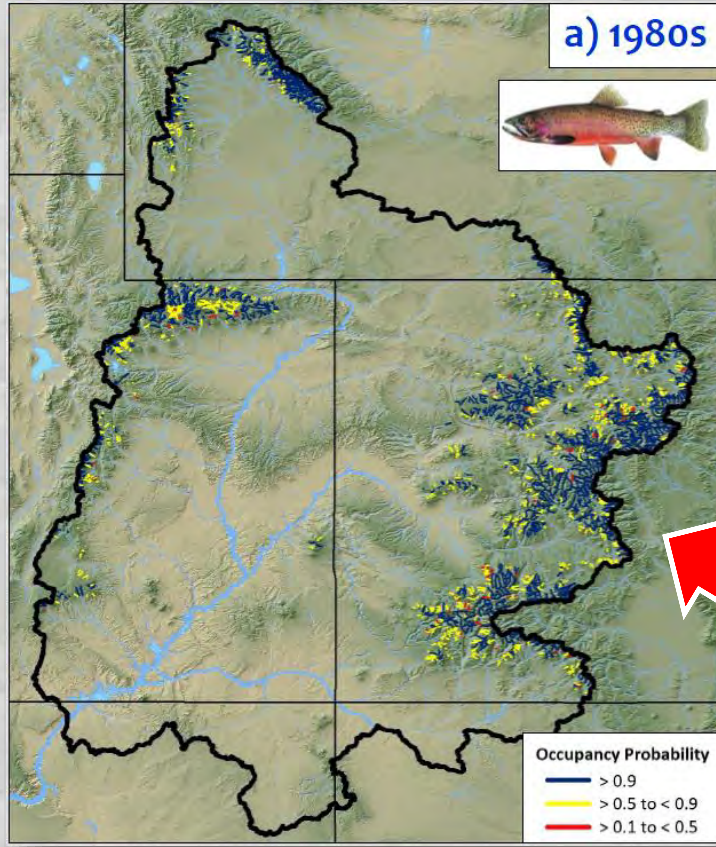
Uses for Climate Shield Information

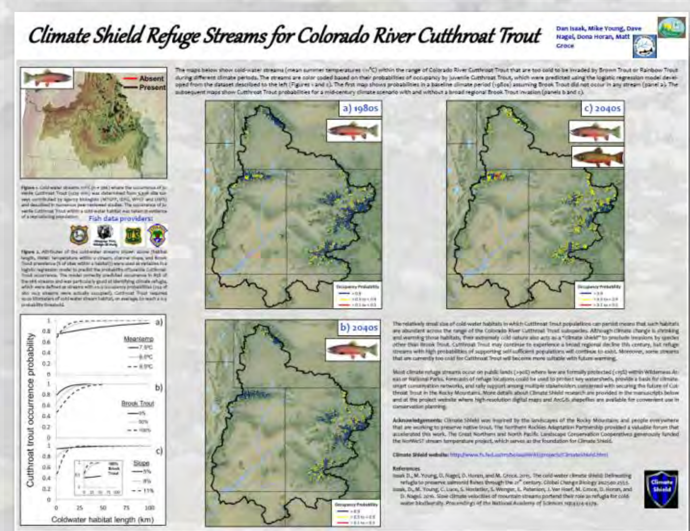
1. Designing and implementing climate-smart conservation networks
2. Identifying candidate streams for assisted migrations and founding new populations
3. Informing decisions about the locations (or need) for fish barriers, projects to eradicate non-native species, or habitat restoration
4. Quantifying amount of native trout habitat and potential changes this century
5. Designing efficient biological monitoring programs (e.g., eDNA)

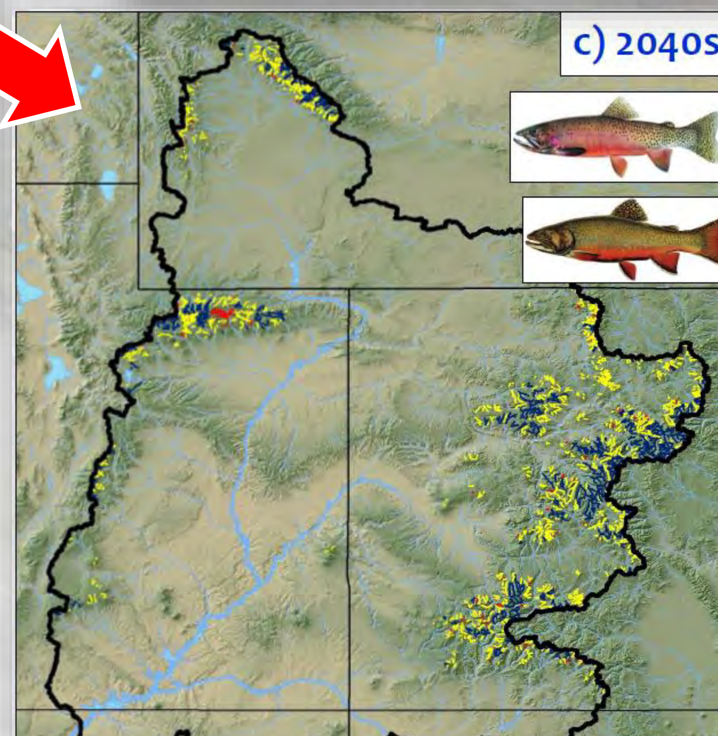
Consistent for all Rocky Mountain Streams



CRCT Cutthroat Probability Poster

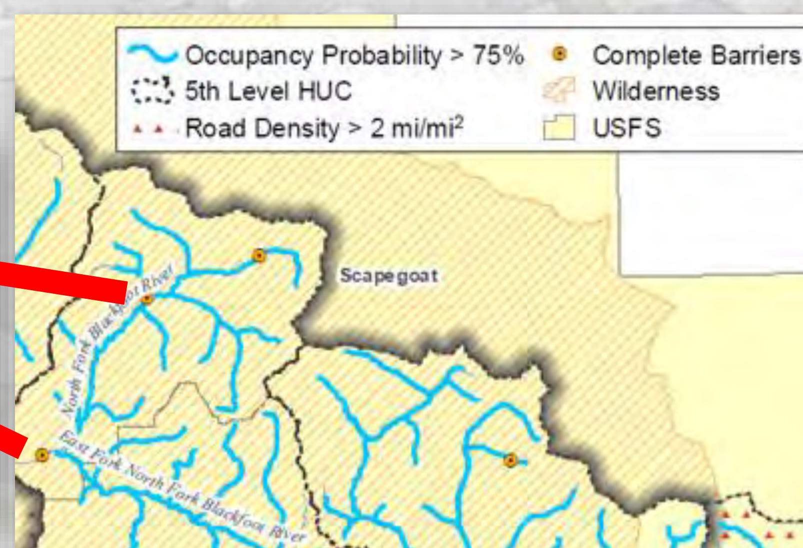




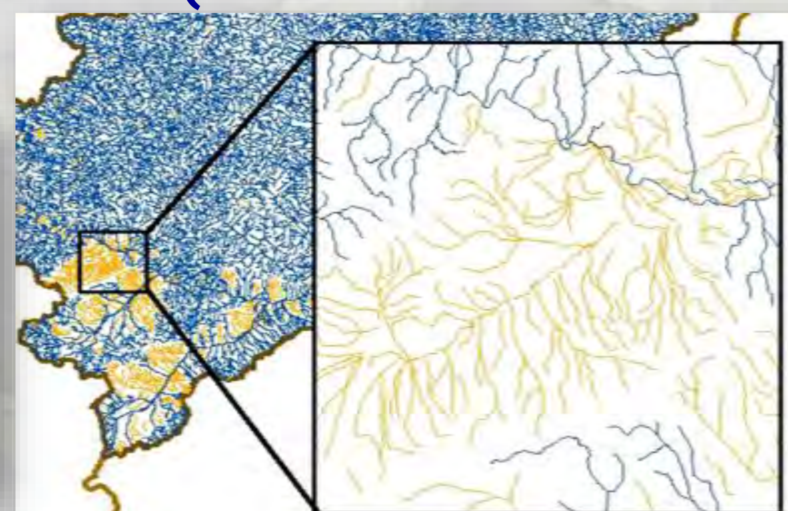


Cautions With Use of Climate Shield

Geologic barriers



NHD stream layer inaccuracies (intermittent reaches: Fcode = 46003)



USGS NHD Data Stewardship Program: http://nhd.usgs.gov/index.html

Fish Data Acknowledgements:

John Chatel & Scott Vuono - Sawtooth National Forest; Ralph Mitchell, Herb Roerick, & Mike Kellett - Boise National Forest; Bart Gamett - Salmon-Challis National Forest; James Brammer & Steven Kujala - Beaverhead-Deerlodge National Forest; Joan Louie - Lolo National Forest; Leslie Nyce - Montana Fish, Wildlife and Parks; Seth Wenger – University of Georgia; Kevin Meyer – Idaho Fish & Game

Map & Protect Climate Refugia for Many Aquatic Critters…







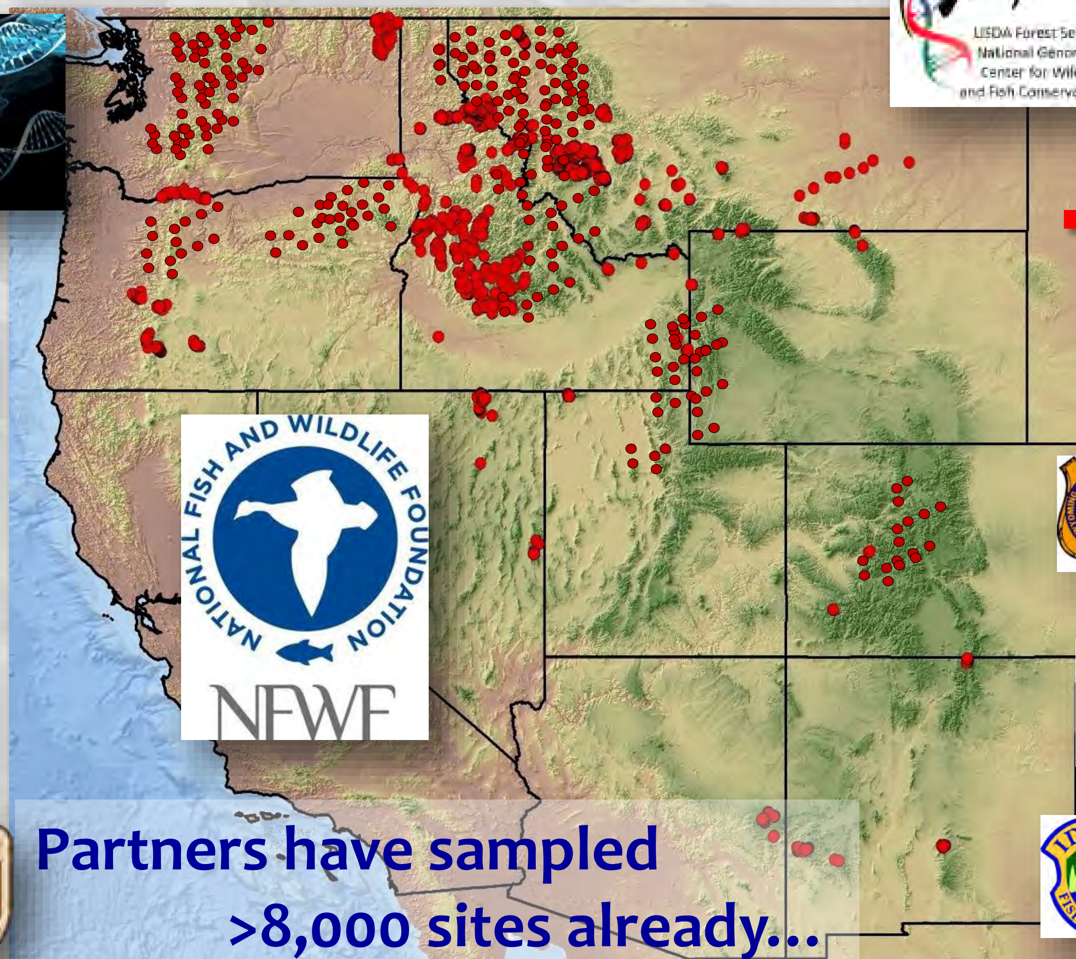





Aquatic eDNA Atlas Project: Sample & Map all Aquatic Species in the Western U.S.

National Genomics Center for Wildlife & Fish Conservation

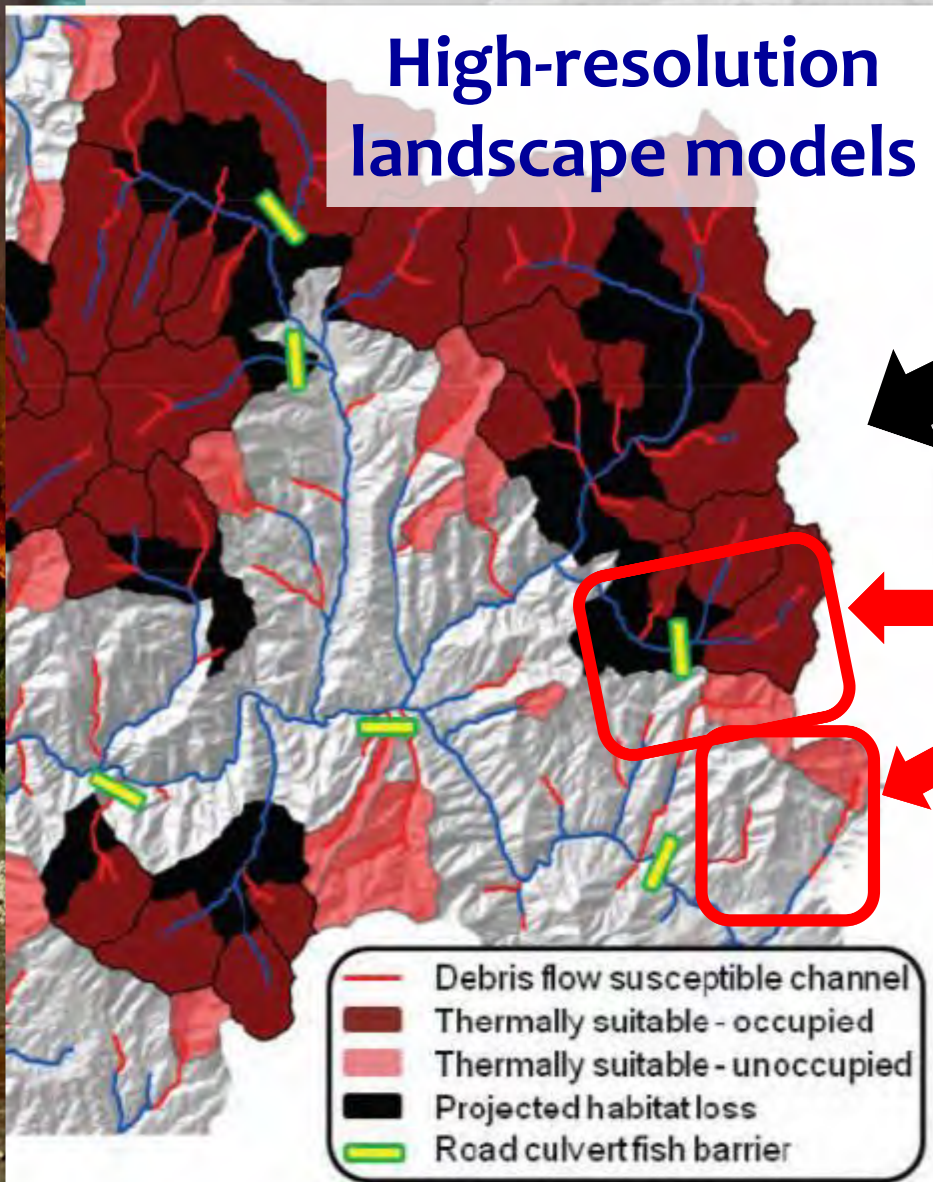
+



Partners have sampled

>8,000 sites already…

Goal: Precise Models & Databases for All Species



I'm going to invest here…

…instead of here