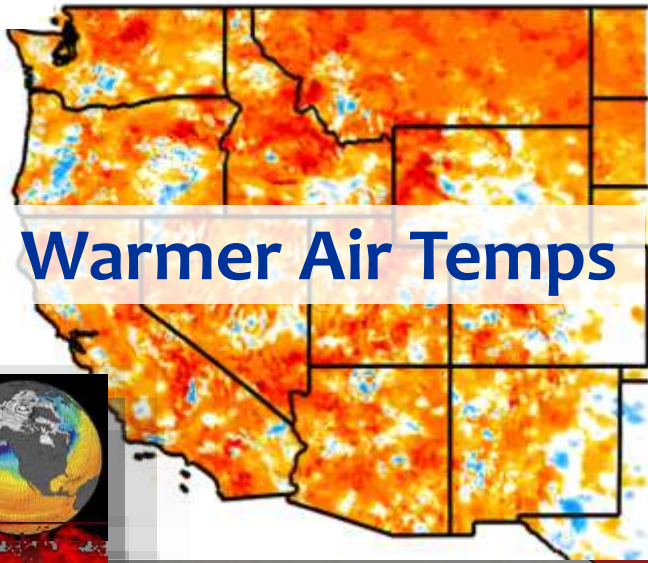
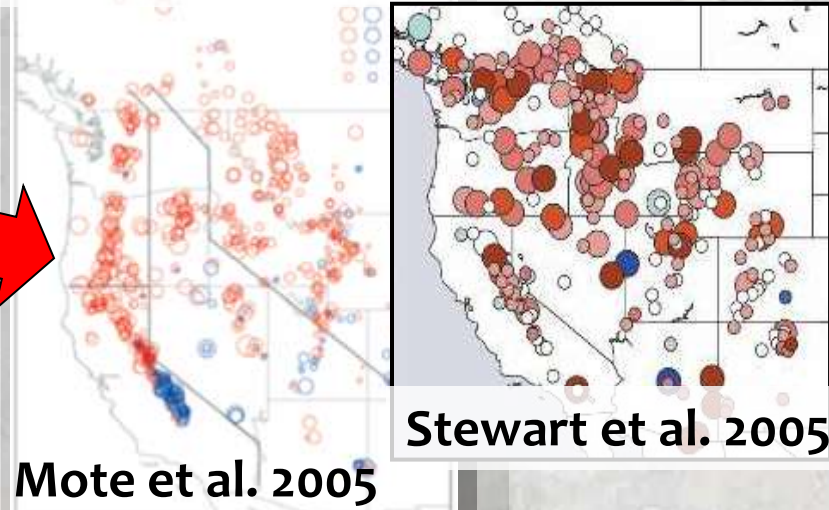


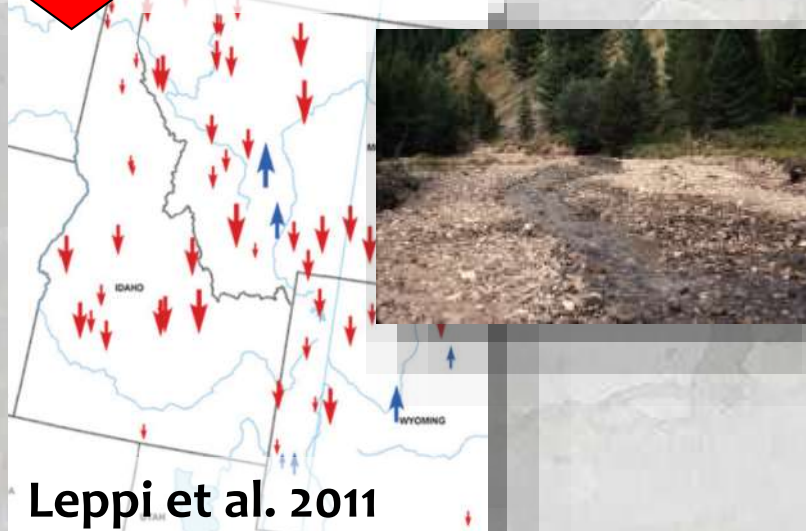
Environmental Trends Everywhere (1950-2009)



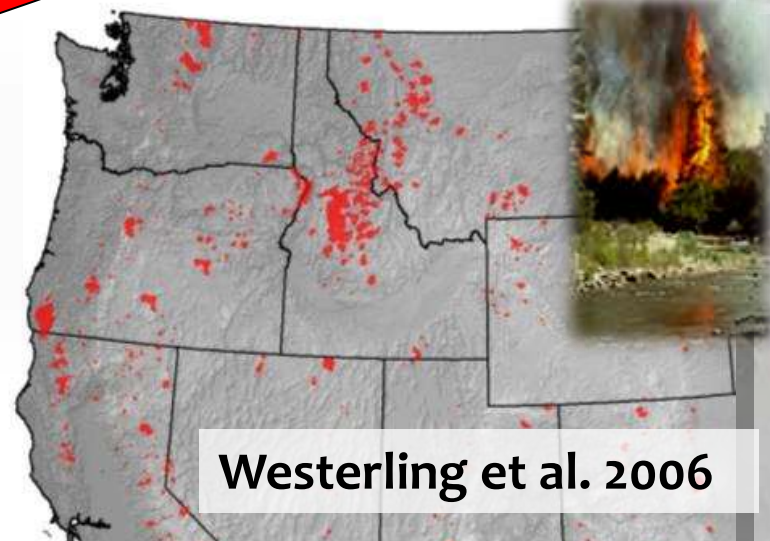
Less Snow & Earlier Runoff



Decreasing summer flows

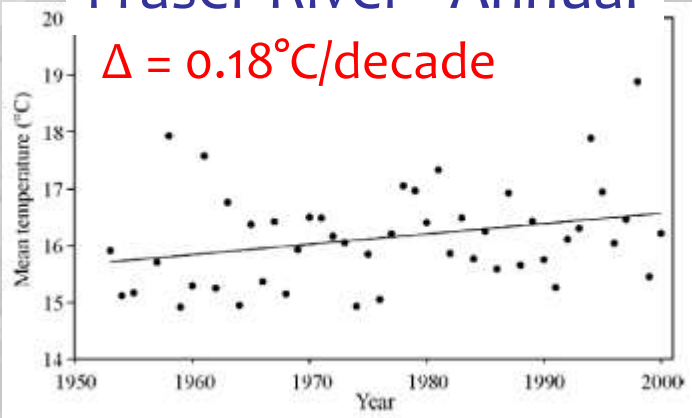


Wildfire Increases



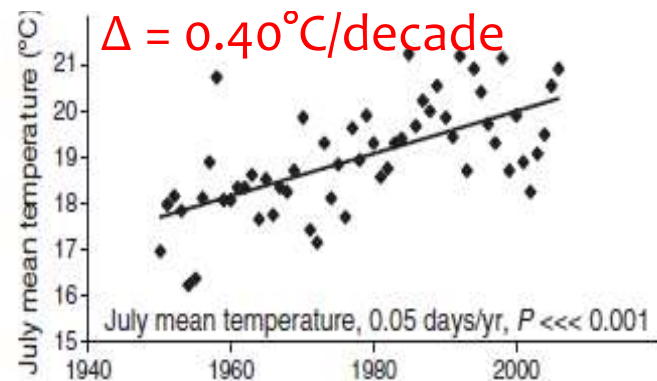
Historical River Temperature Trends

Fraser River - Annual



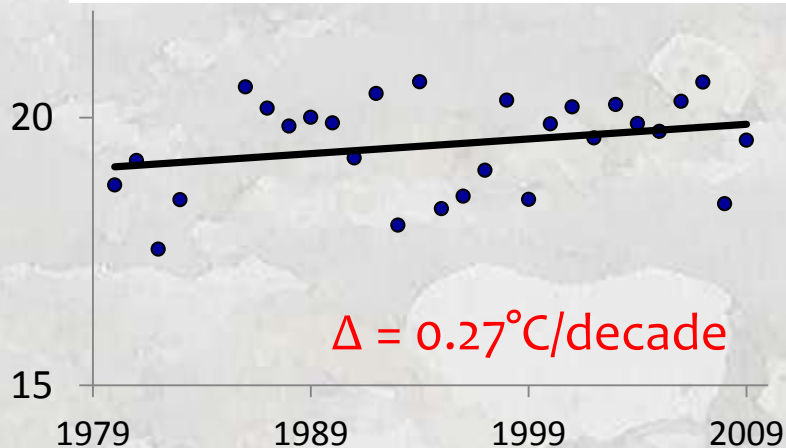
Morrison et al. 2001

Columbia River - Summer



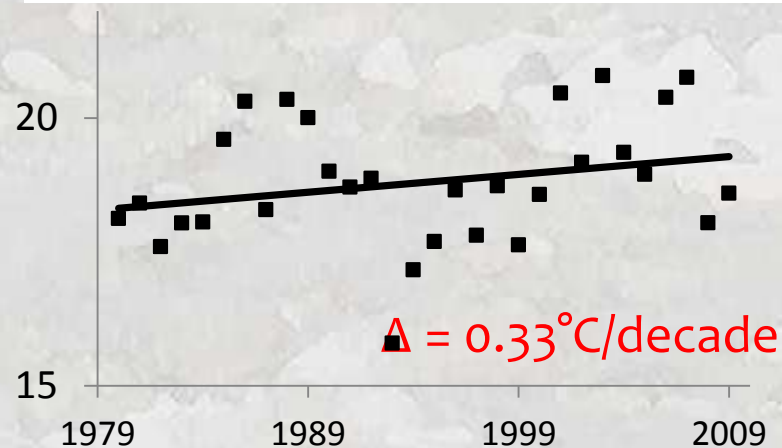
Crozier et al. 2008

Snake River, ID - Summer



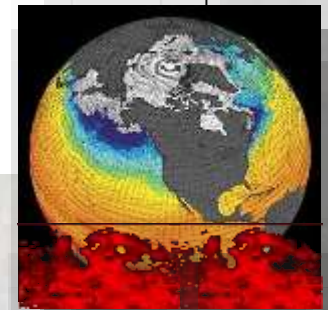
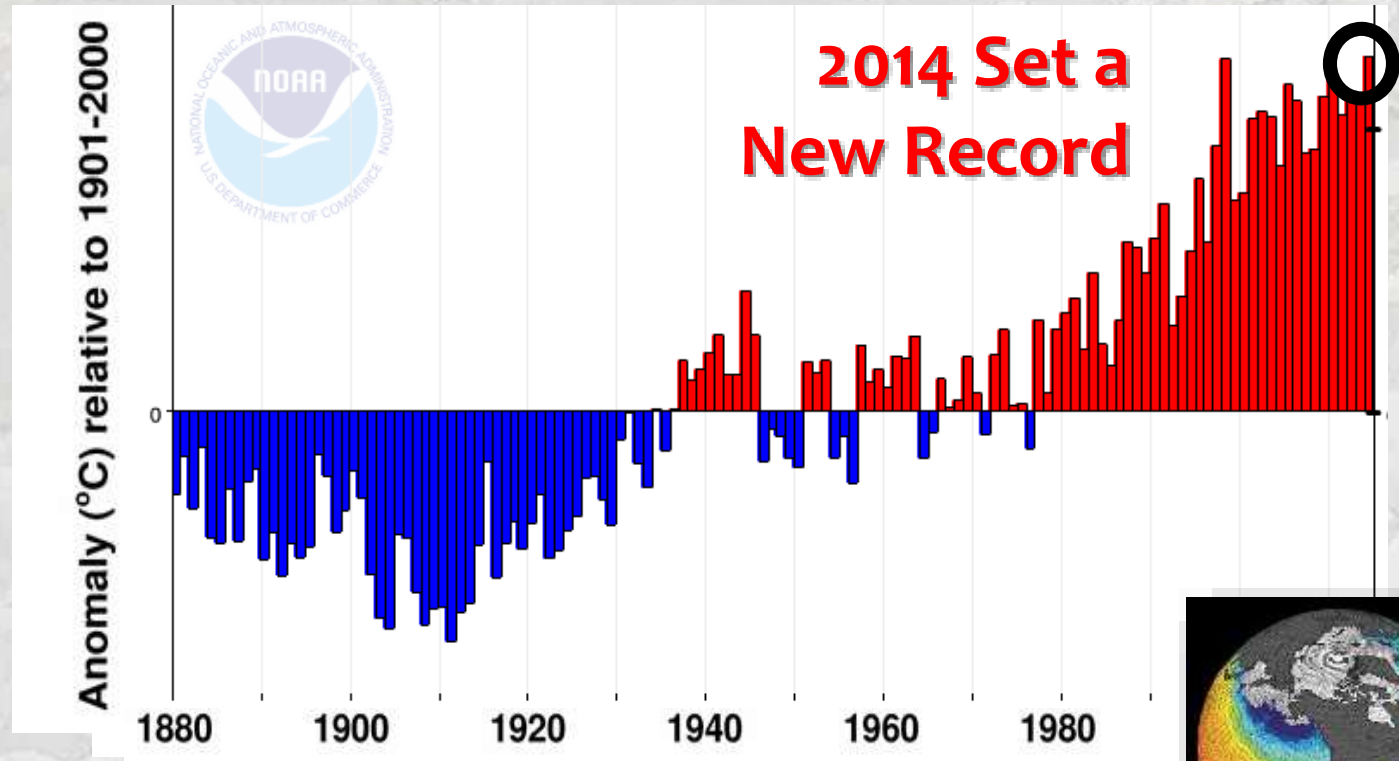
Isaak et al. 2012. *Climatic Change* 113:499-524.

Missouri River, MT - Summer



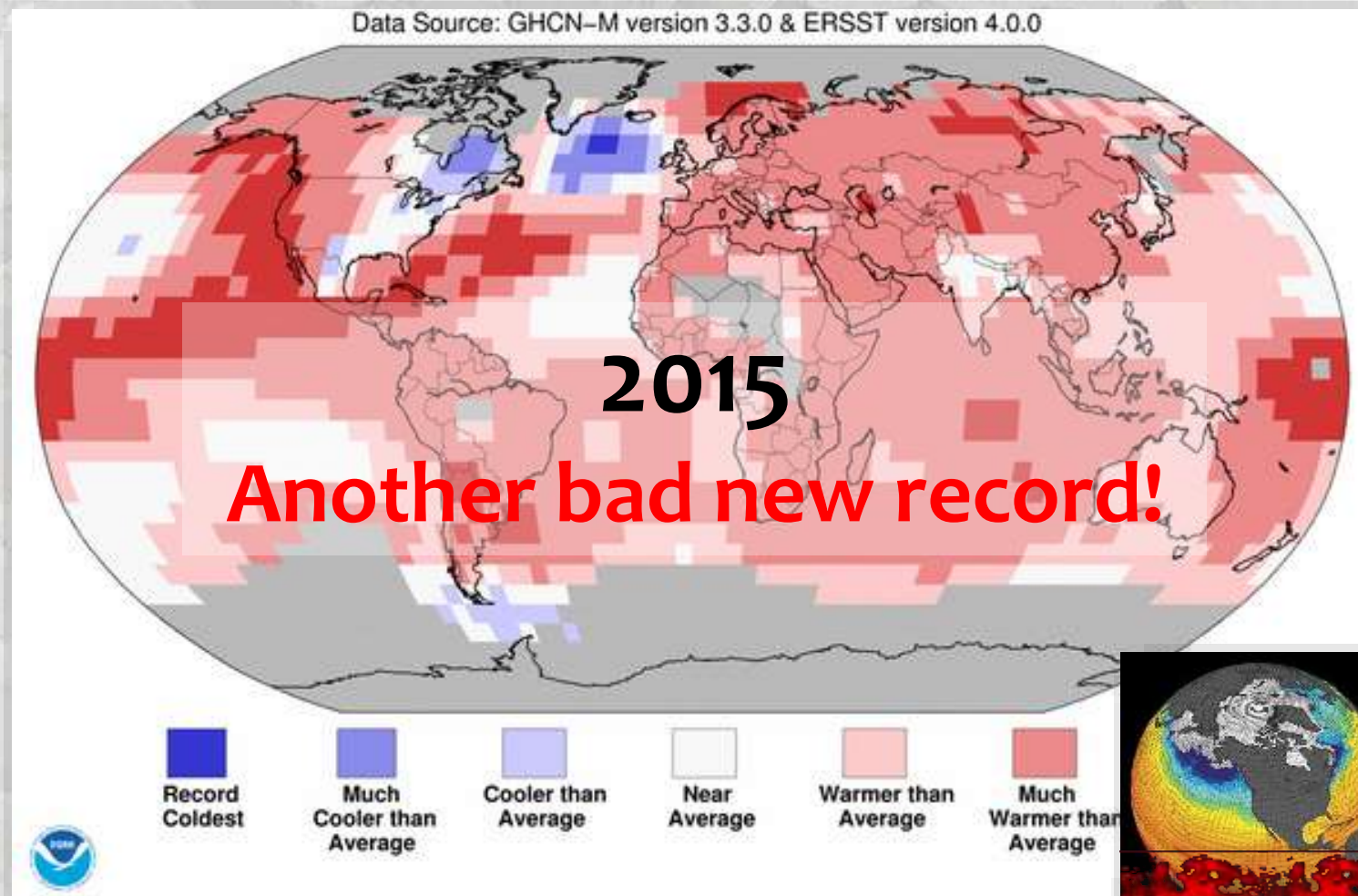
The New Reality...

1880-2014 Global Air Temperature Trend



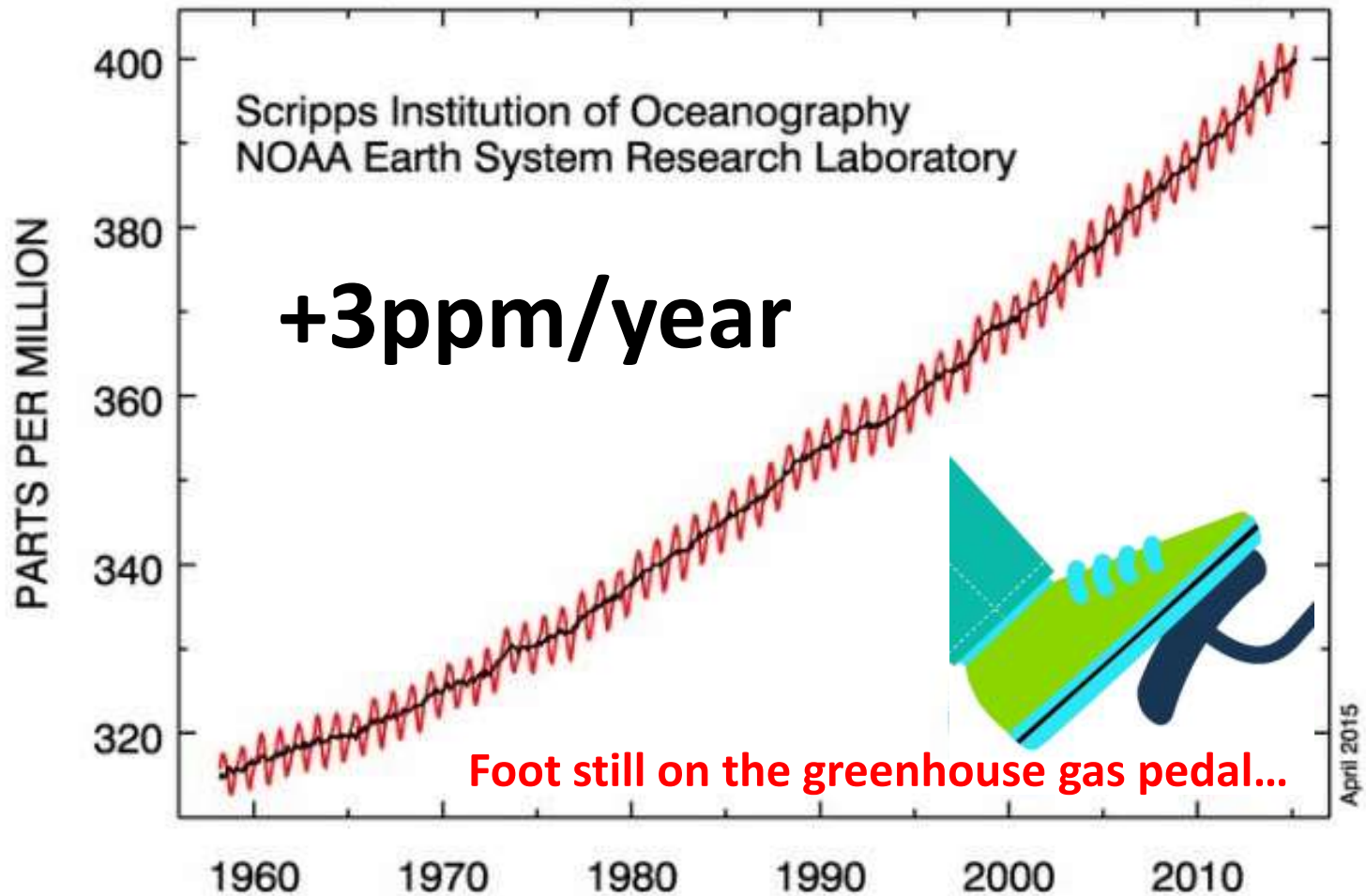
The New Reality...

1880-2014 Global Air Temperature Trend



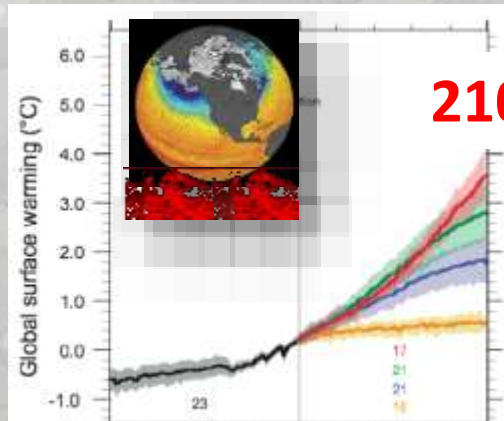
The New Reality...

Atmospheric CO₂ Concentration

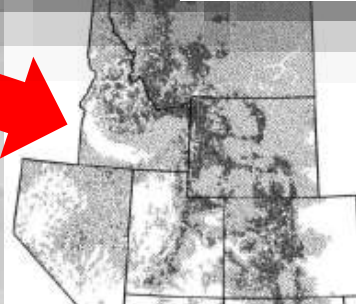


Plan on continued warming for decades...

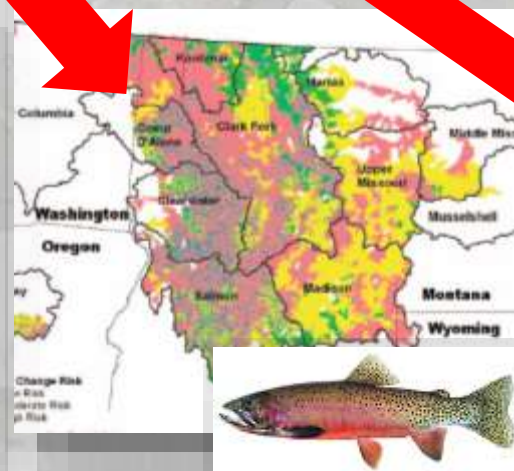
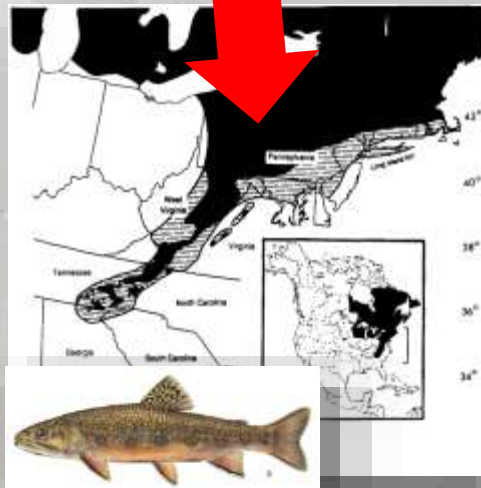
Obviously, the Cold-Water Fish World Will End in Immolation...



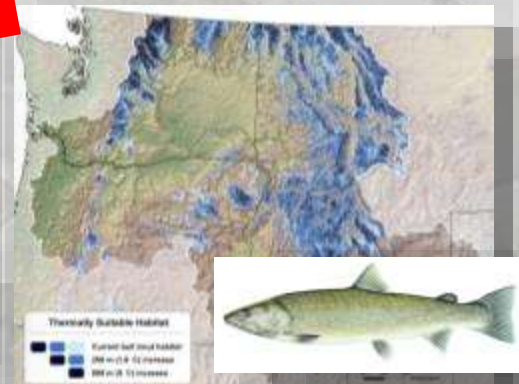
2100



• Huge declines: 50%-100%



- 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.



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

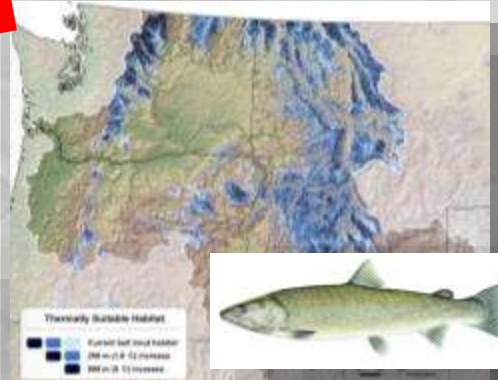


- Meisner 1988
- Keleher & Rahel 1996
- Eaton & Schaller 1996
- Reusch et al. 2012
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.

Double-Whammy in Mountain Headwaters!



Blue
Warmer Fish
at Risk



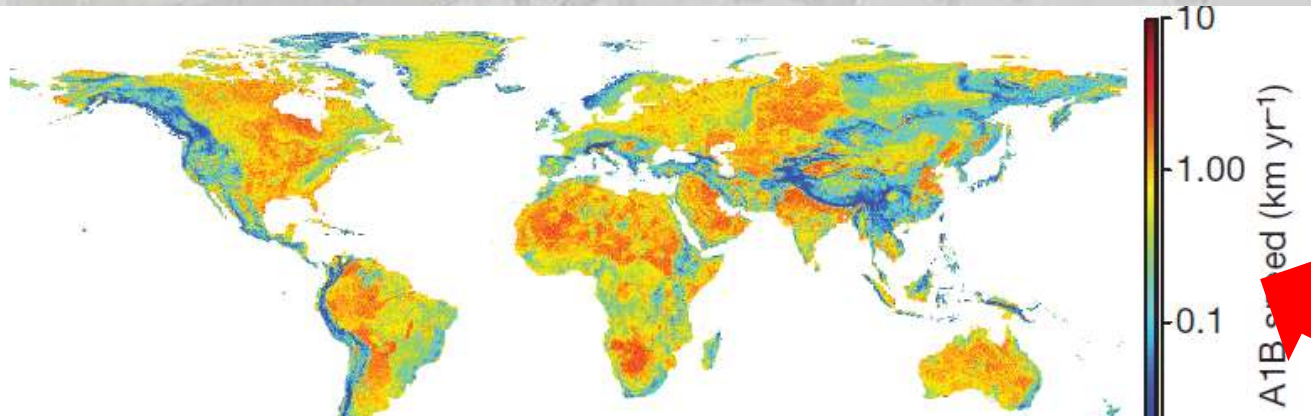
Obviously, the Cold-Water Fish World Will End in Immolation...



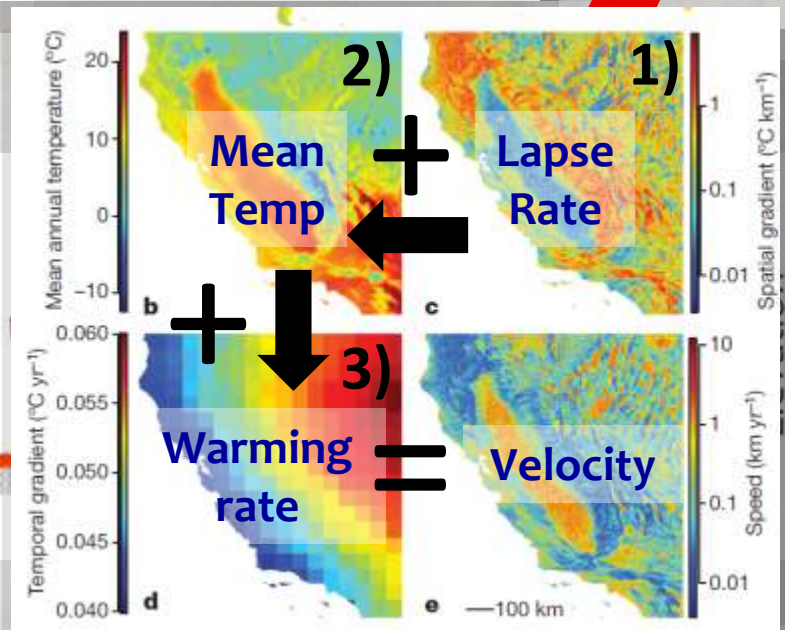
We've been predicting doom for almost 30 years



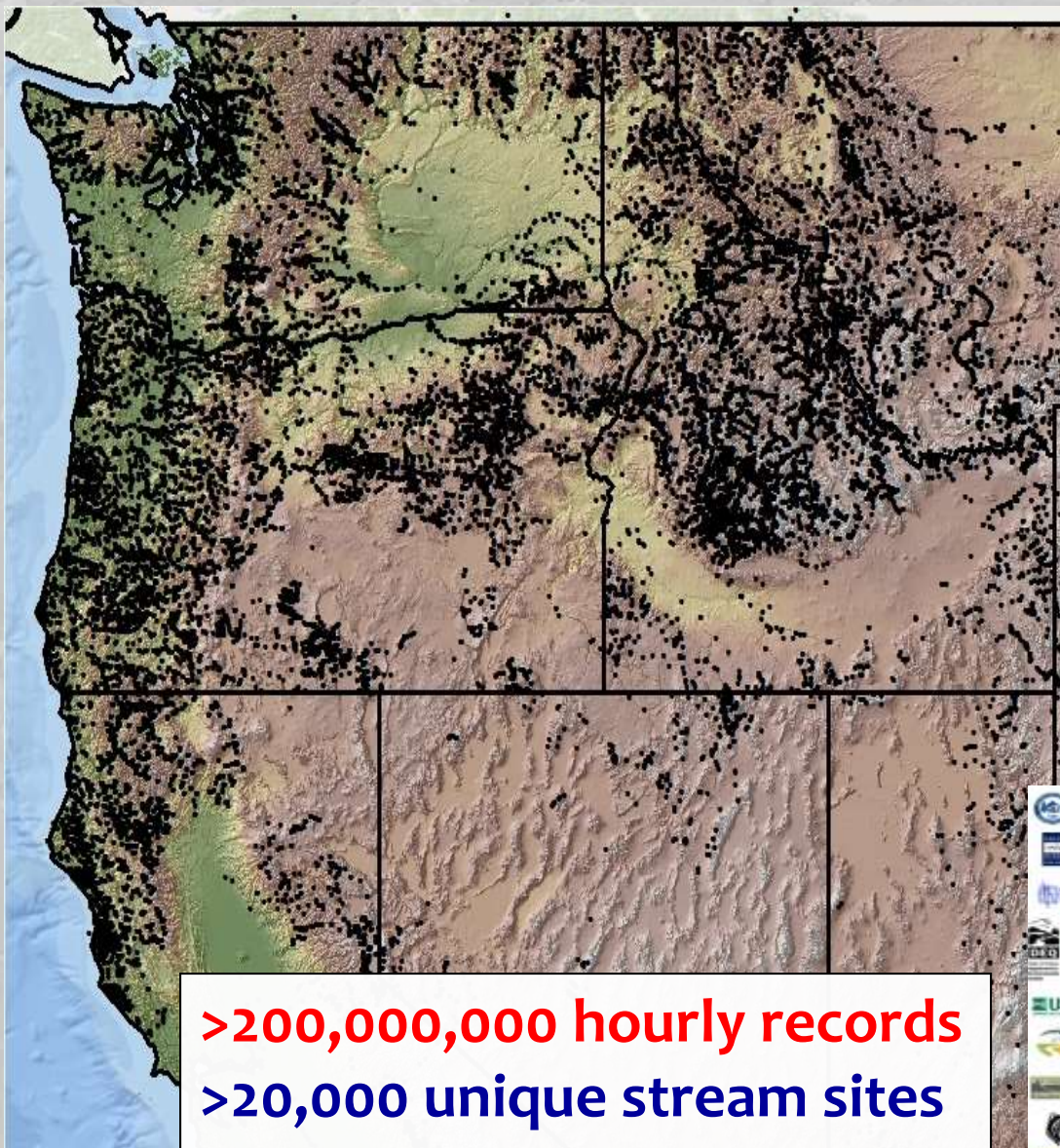
Climate “Velocity” is What’s Biologically Relevant Rate at Which Isotherms & Thermal Niches Shift



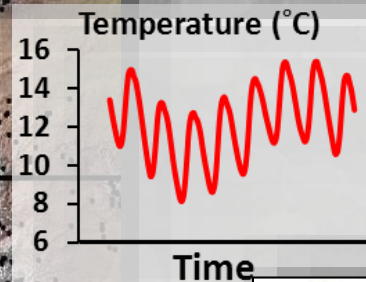
Velocity varies 100x for same warming rate



Stream Application Required Some Data



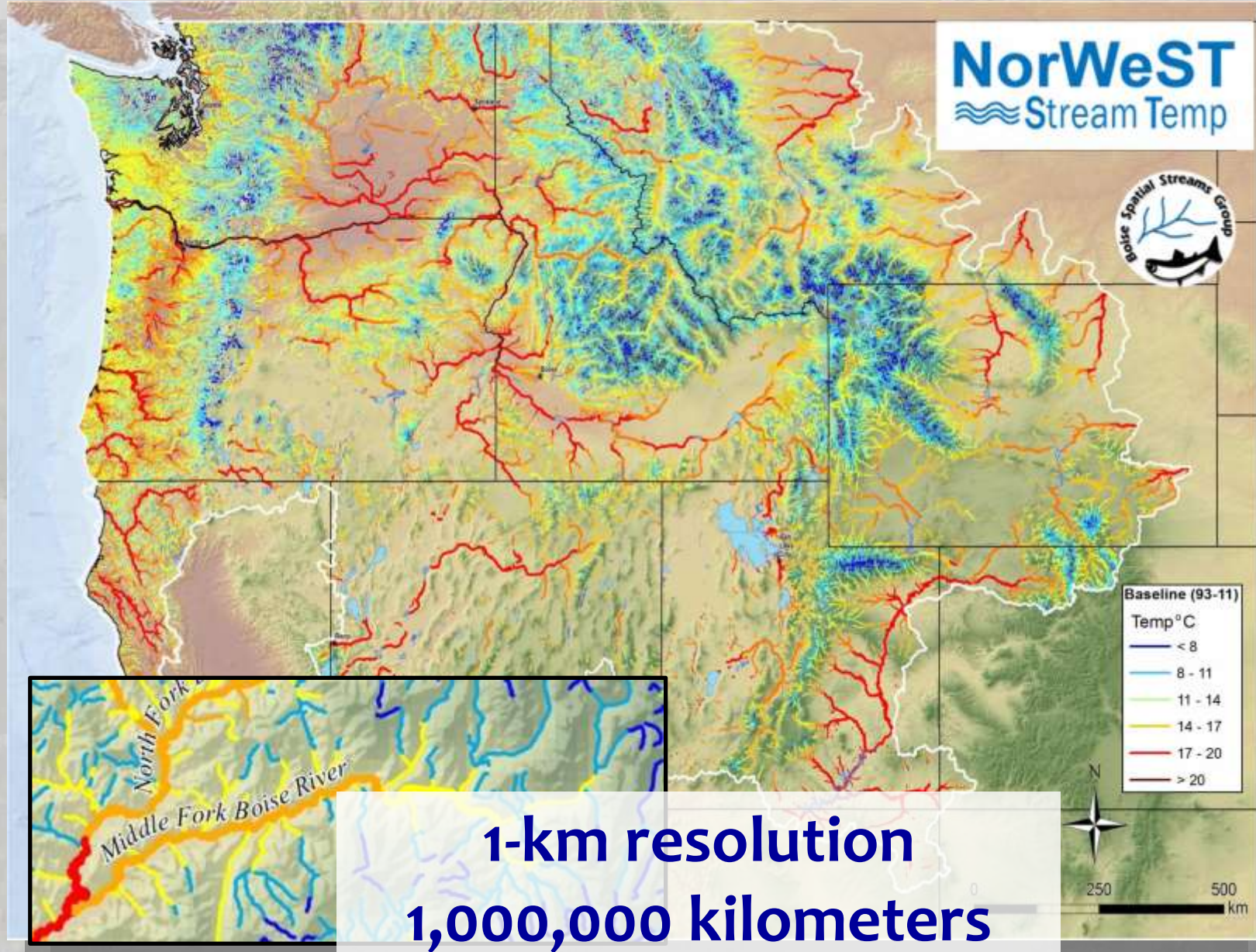
NorWeST
Stream Temp



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

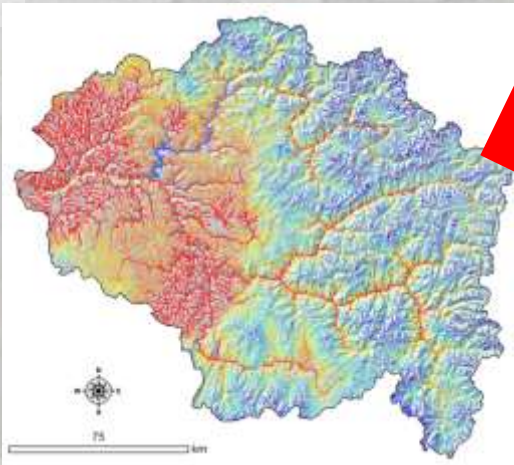


& Accurate Stream Temperature Scenarios

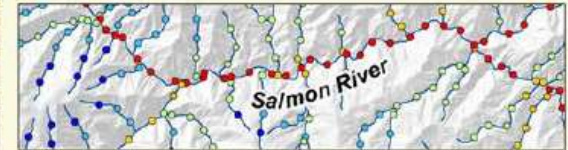


Website: Distributes Information in Useful Digital Formats (ArcGIS & .pdfs & Excel)

1) GIS shapefiles of stream temperature scenarios

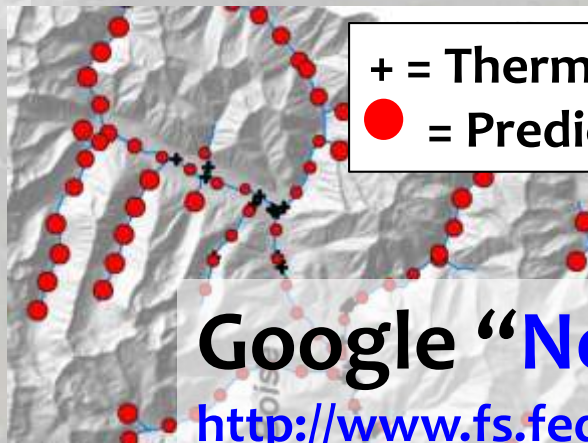


NorWeST
Stream Temp



Regional Database and Modeled Stream Temperatures

2) GIS shapefiles of stream temperature model prediction precision



+ = Thermograph
● = Prediction SE

3) Temperature data summaries

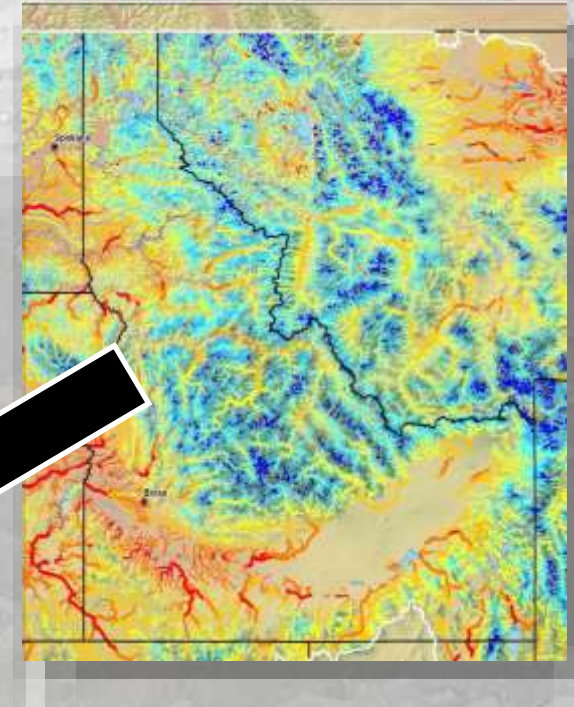
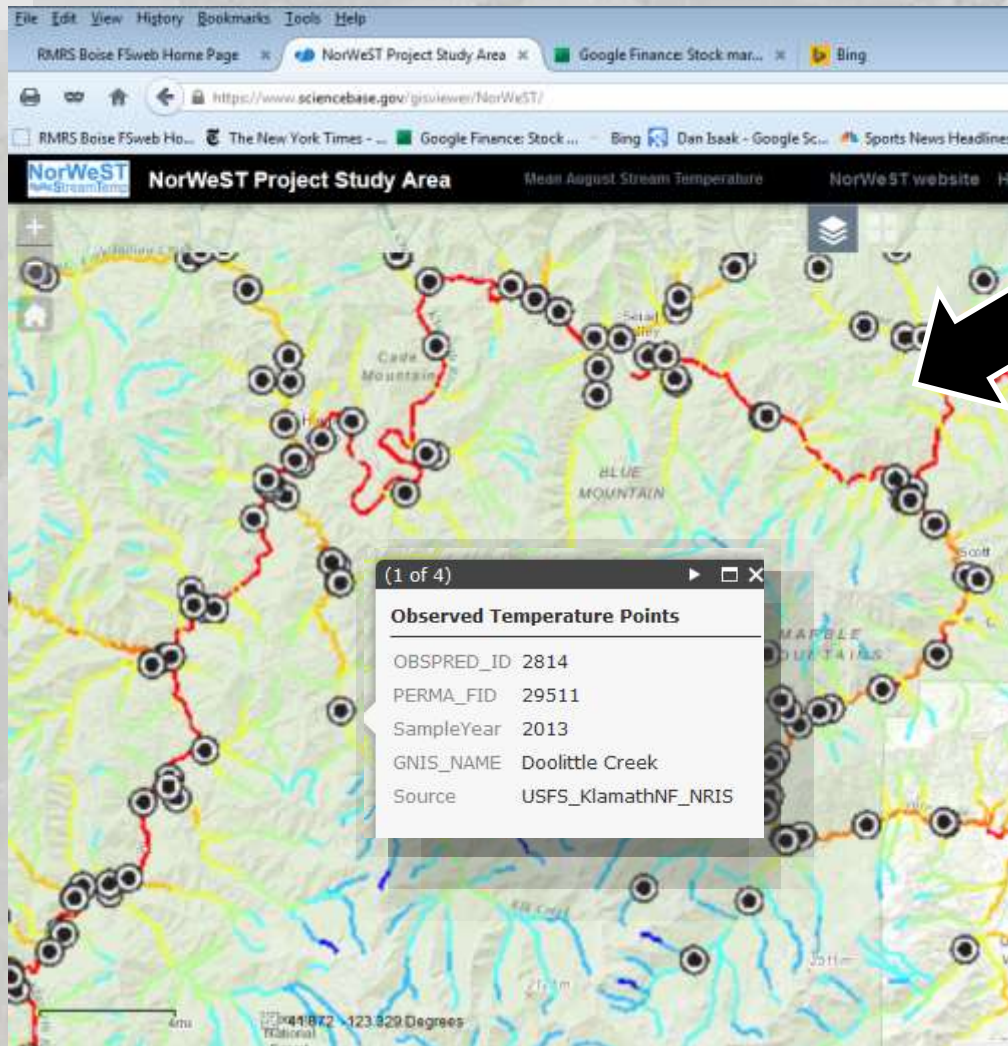


Google “**NorWeST**” or go here...

<http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.shtml>

Websurf from your Desktop

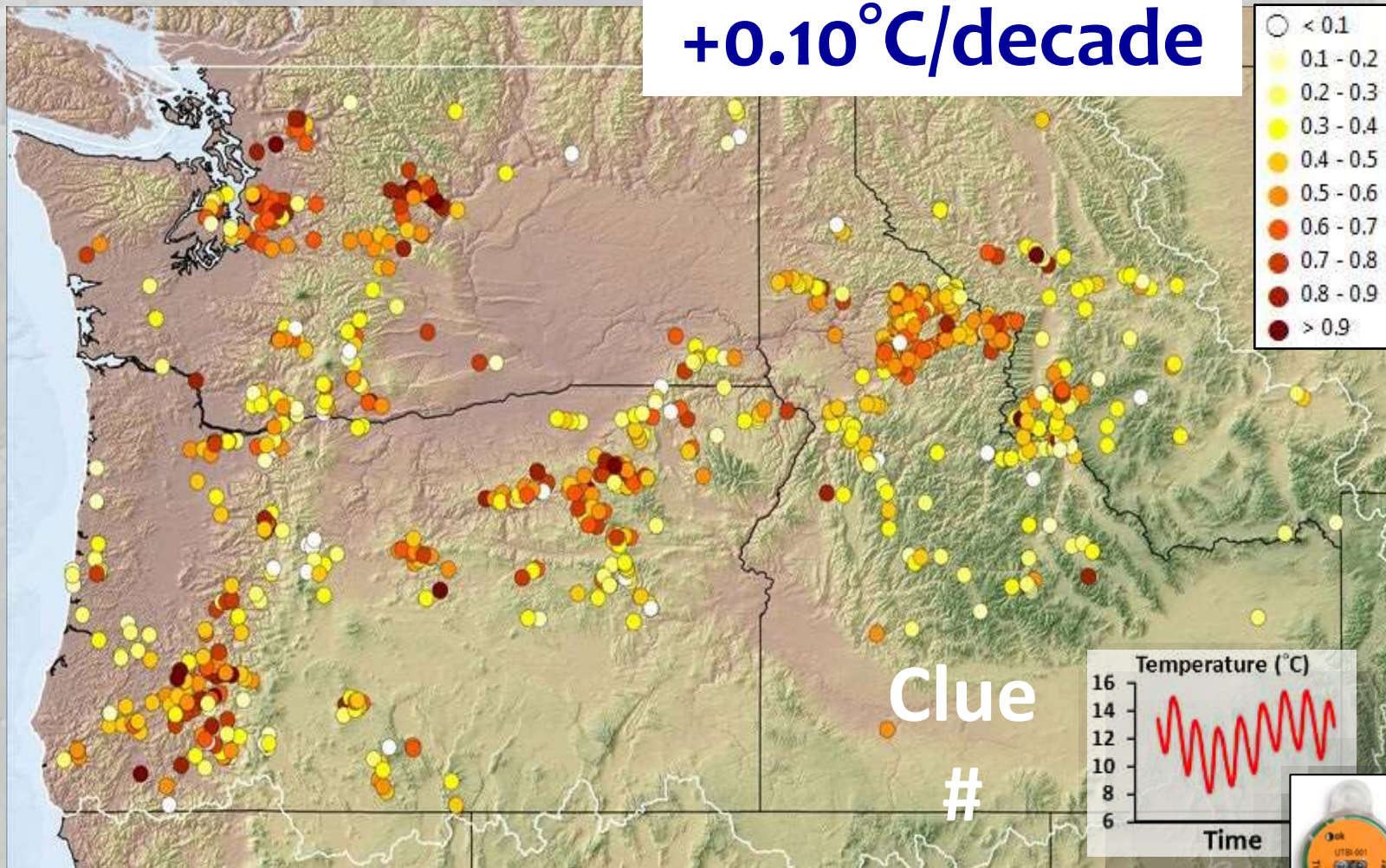
★ Dynamic Online Map Viewer



Stream Warming Rates 1968-2011

923 sites in NorWeST database with >10 year records

+0.10°C/decade



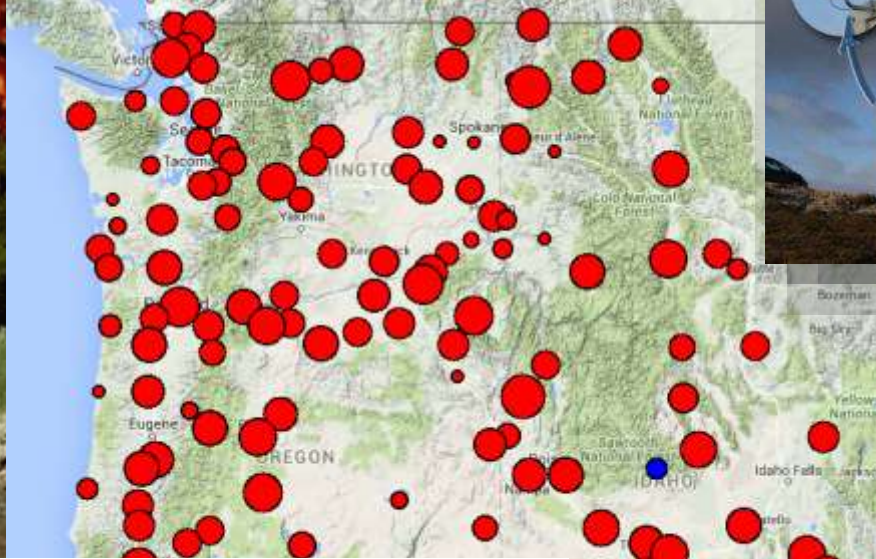
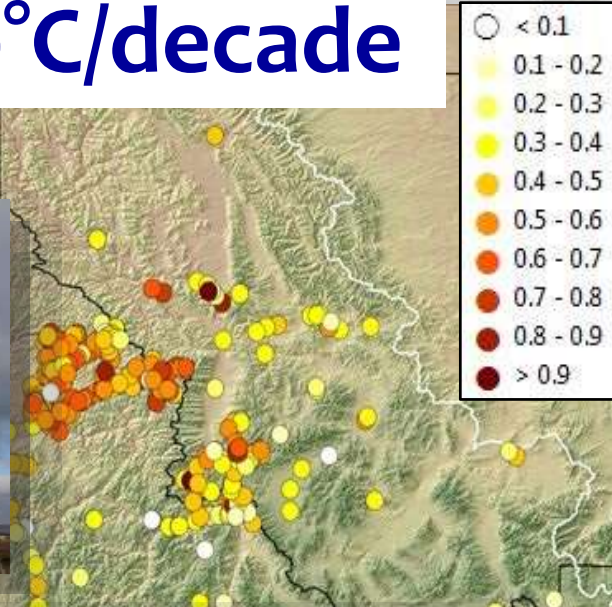
Stream Warming Rates 1968-2011

923 sites in NorWeST database with >10 year records

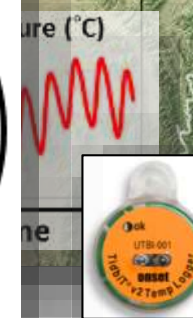
+0.10°C/decade



Weather Stations

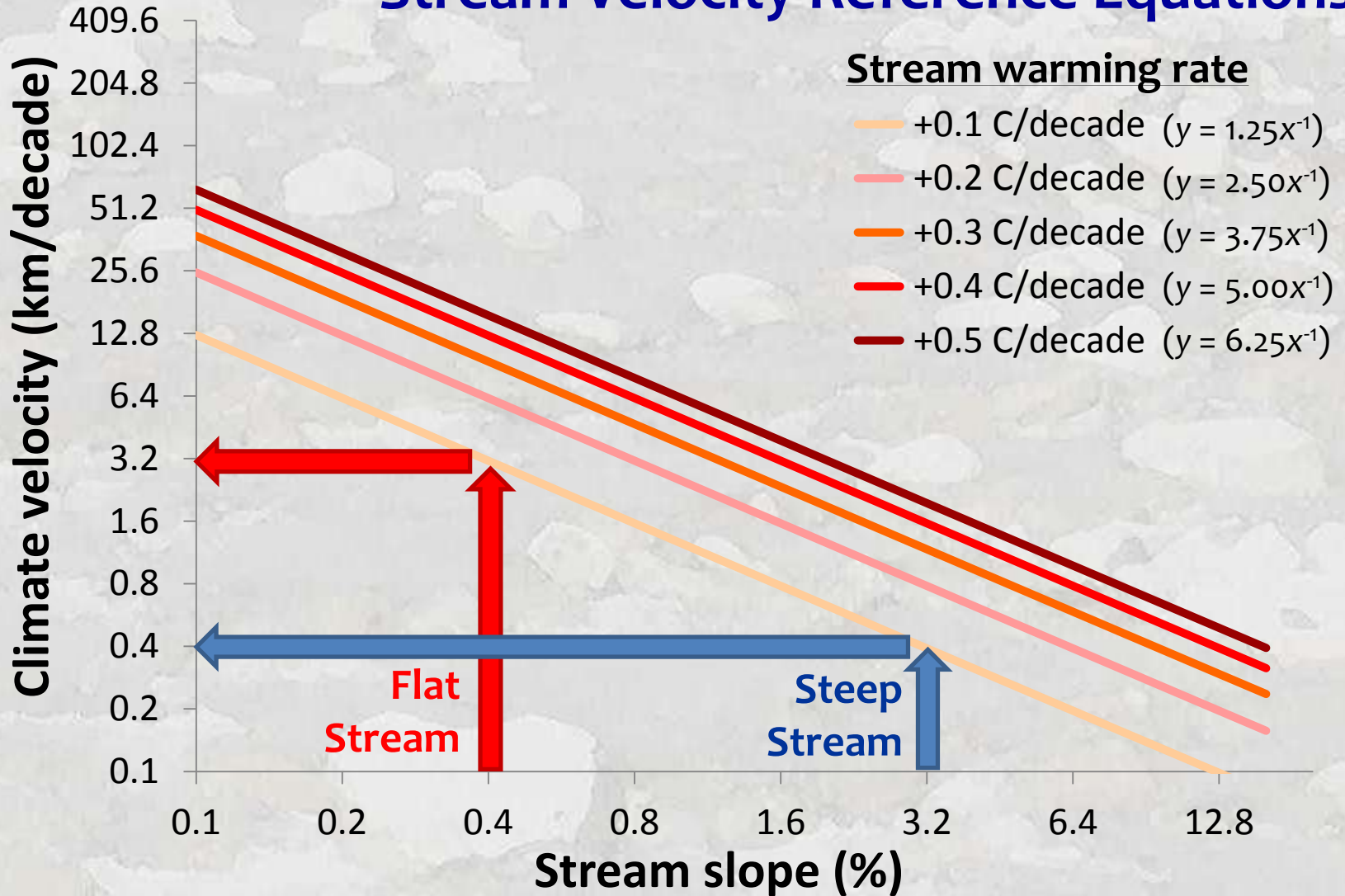


**Air trend =
0.21°C/decade**

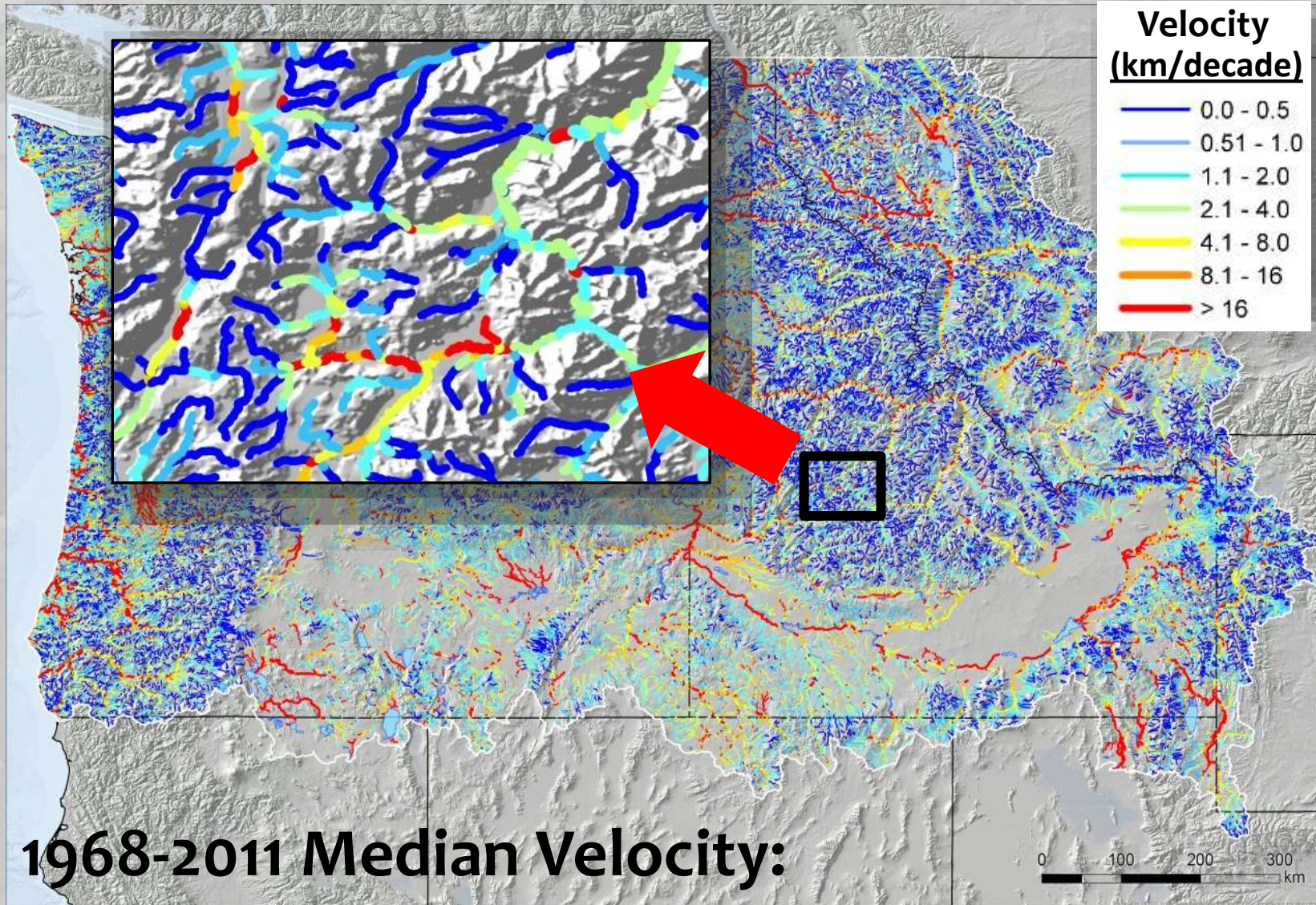


Remember... Velocity is What Matters!

Stream Velocity Reference Equations



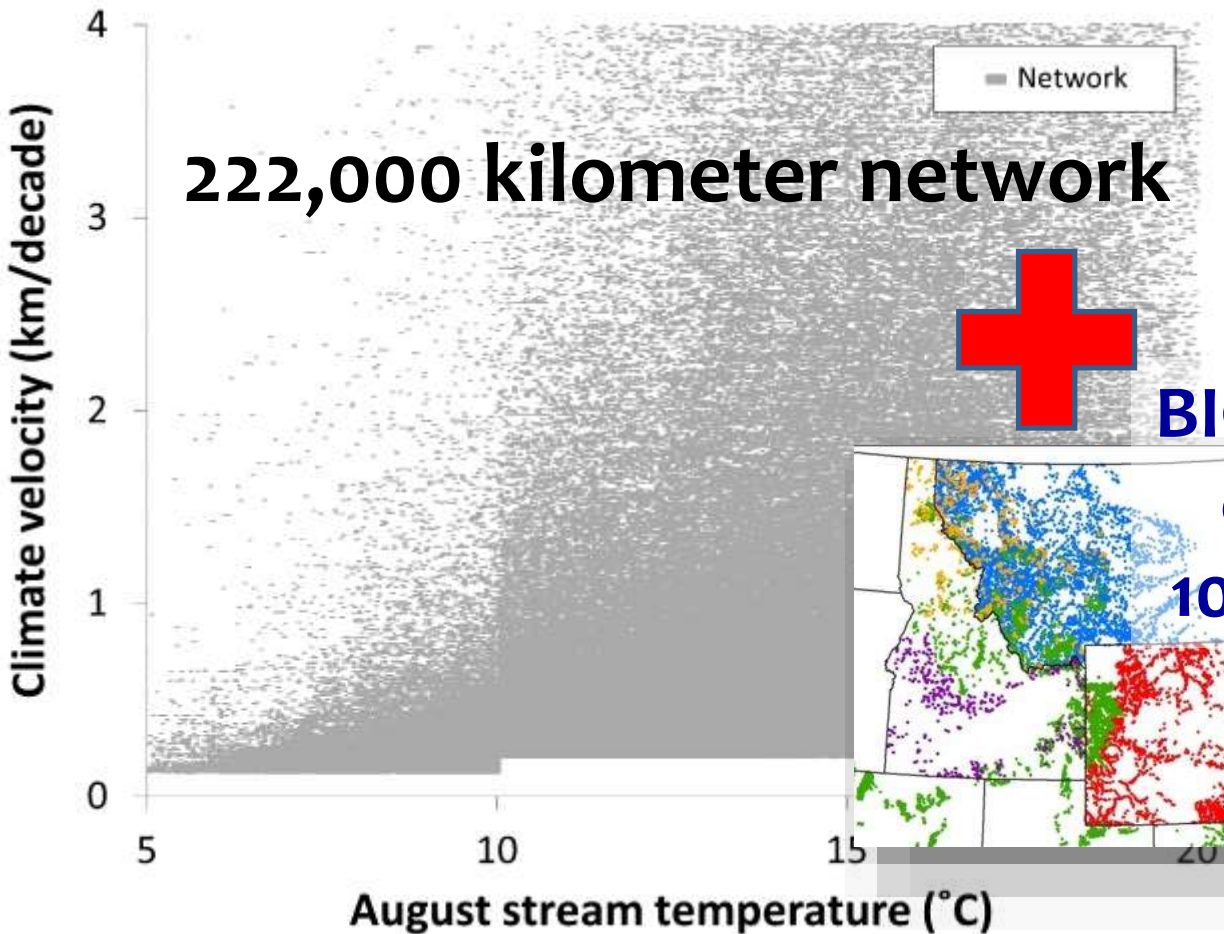
Climate Velocity Map for Regional Network



1968-2011 Median Velocity:
1.07 km/decade



Where do Those “Doomed” Headwater Species Live?

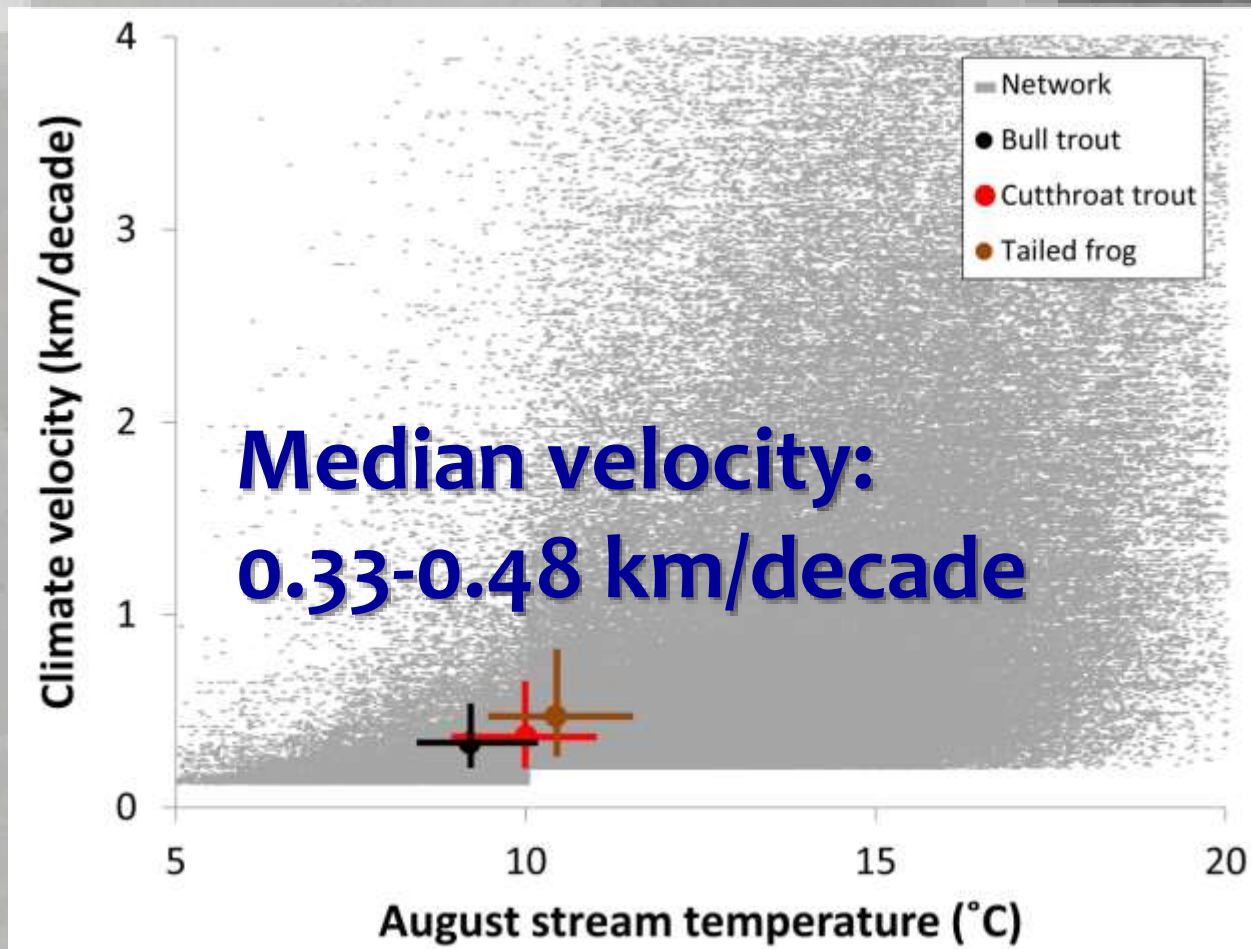


scenario & city maps

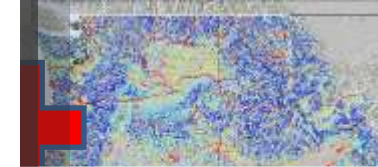
BIG biological databases – 1000s of sites



Where do Those “Doomed” Headwater Species Live?



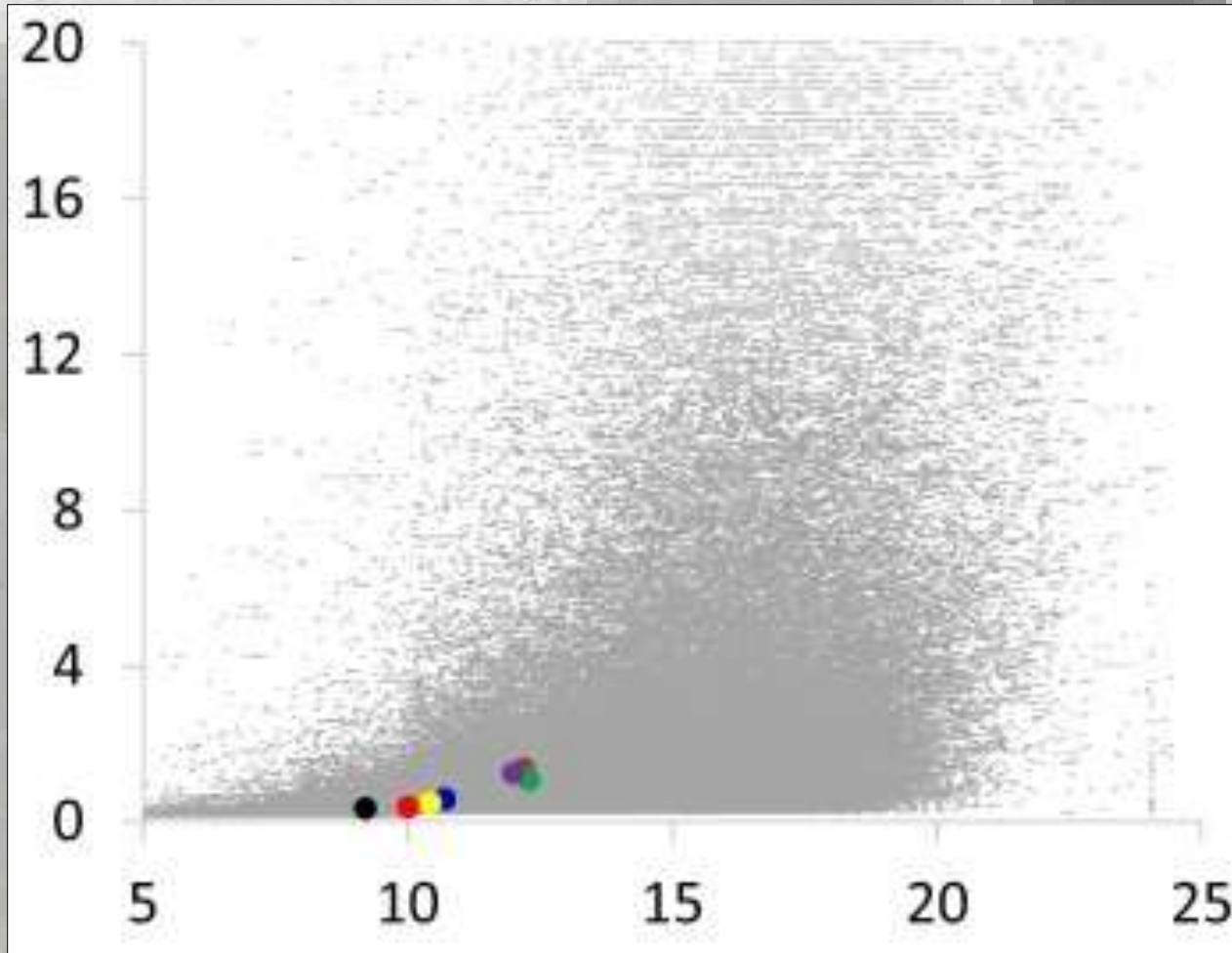
scenario & velocity maps



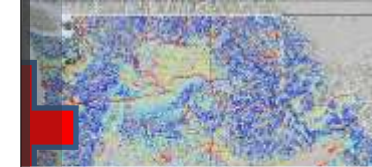
biological databases – 100s of sites



Where do Those “Doomed” Headwater Species Live?



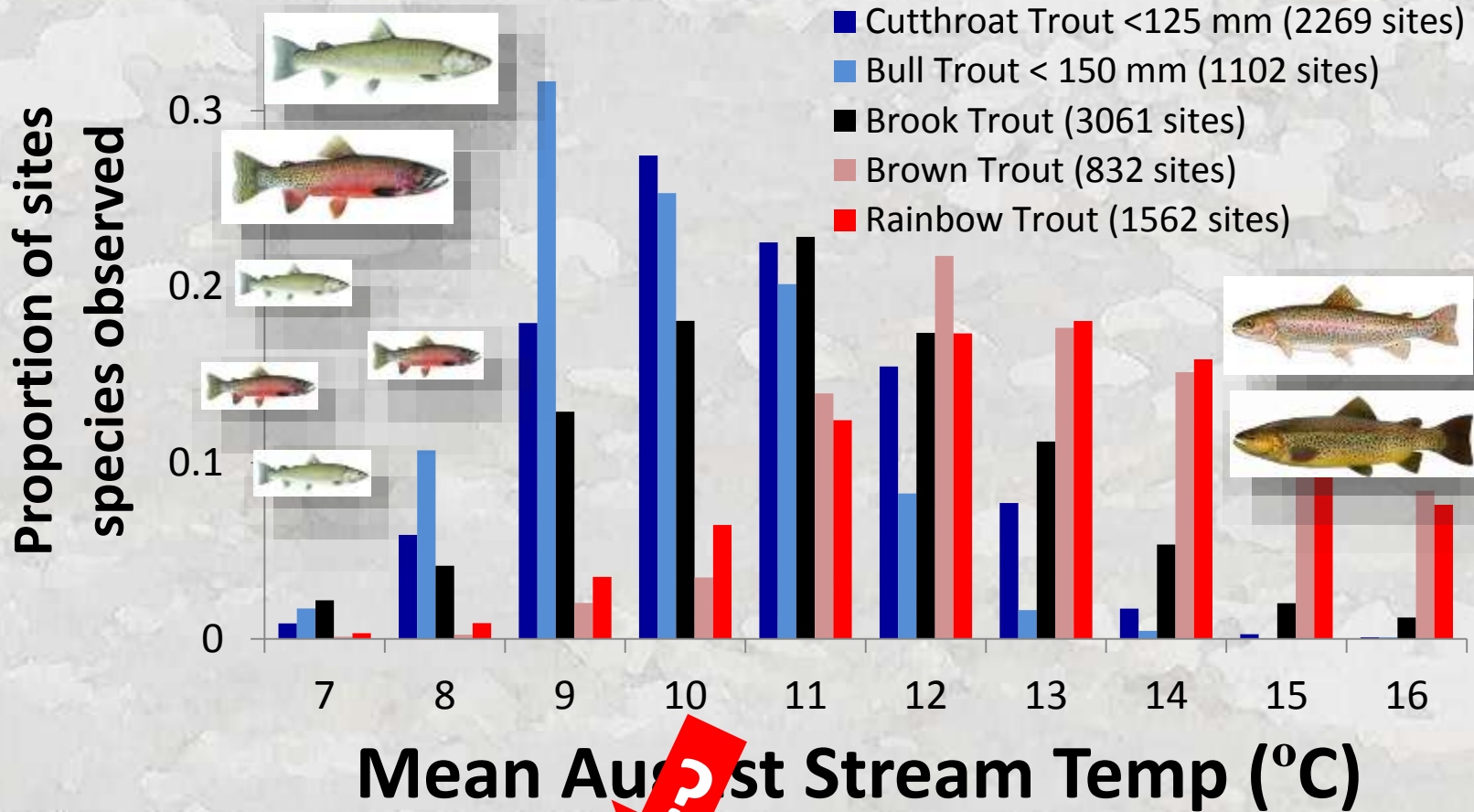
scenario &
city maps



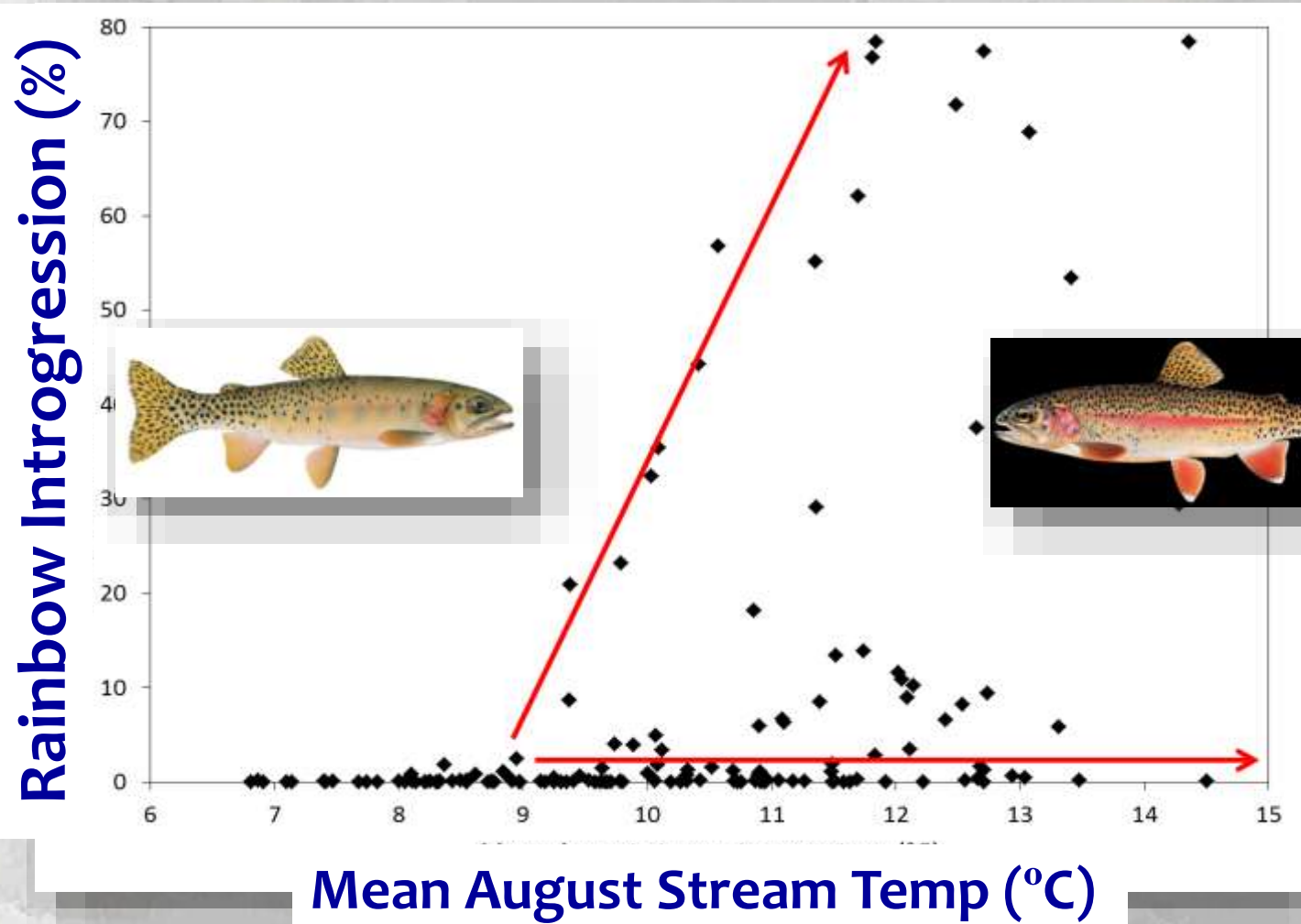
biological
databases –
00s of sites



Cold Climates Exclude Most Invaders



Cold Climates Reduce Cutthroat-Rainbow Trout Hybridization

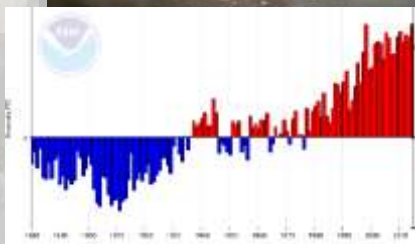
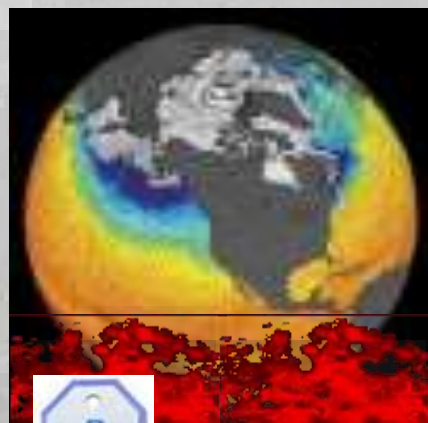


The Cold-Water Climate Shield

Delineating Refugia for Preserving Native Trout

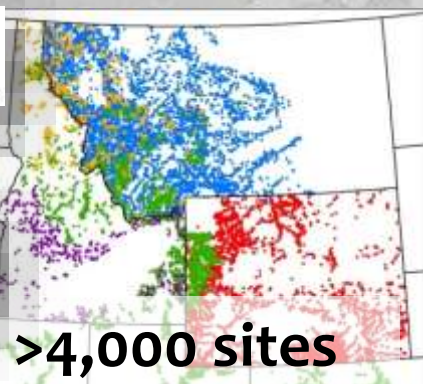
Dan Isaak, Mike Young, Dave Nagel, Dona Horan, Matt Groce

US Forest Service - RMRS



Precise Species Distribution Models to Highlight Climate Refugia

BIG FISH DATA



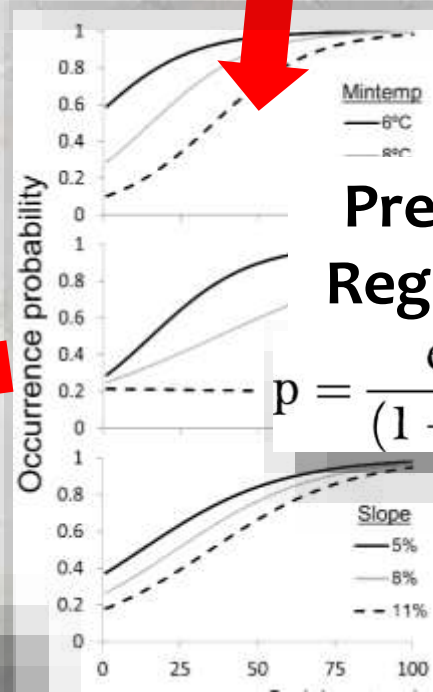
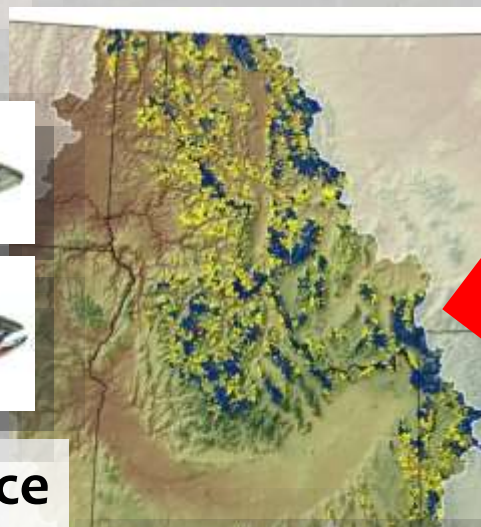
>4,000 sites
>500 streams



NorWeST
Stream Temp



Occurrence probability maps



Predictive Logistic Regression Models

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

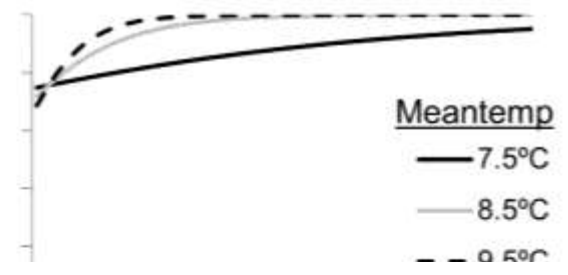
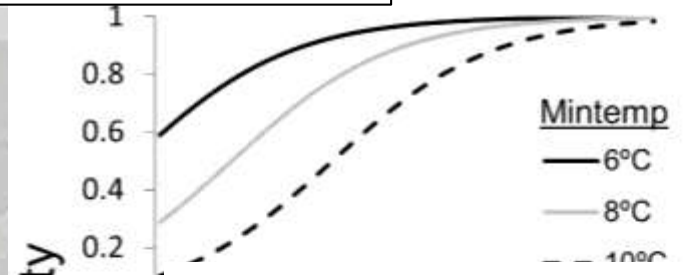
Isaak et al. 2015. The cold-water climate shield: Delineating refugia for preserving native trout through the 21st Century. *Global Change Biology* 21: 2540-2553



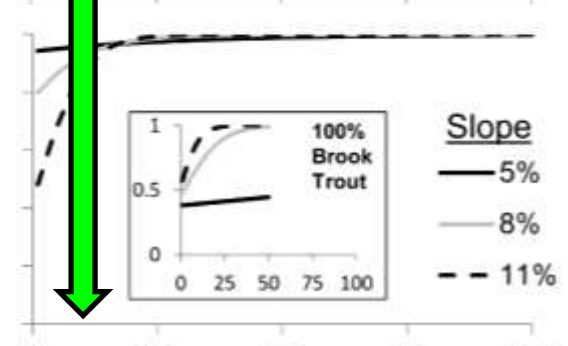
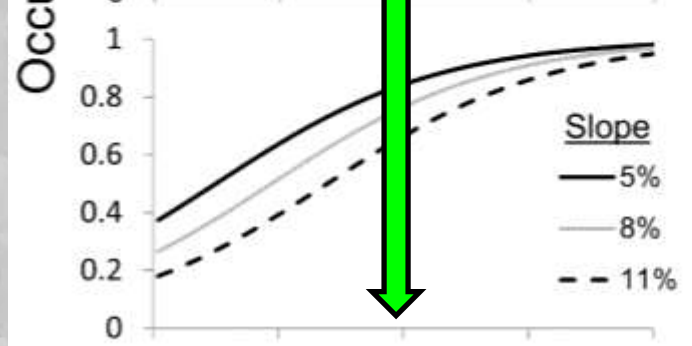
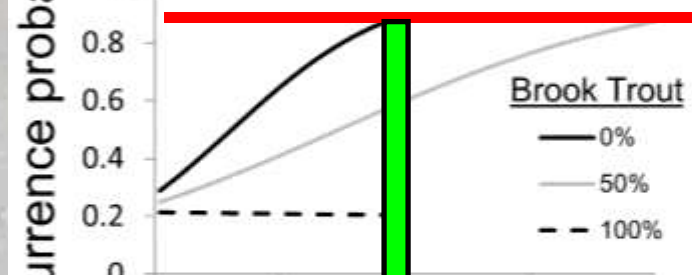
78% prediction accuracy



85% prediction accuracy



Big difference in habitat size



Coldwater habitat length (km)

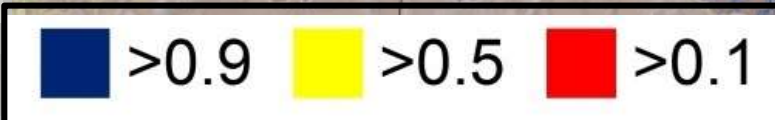
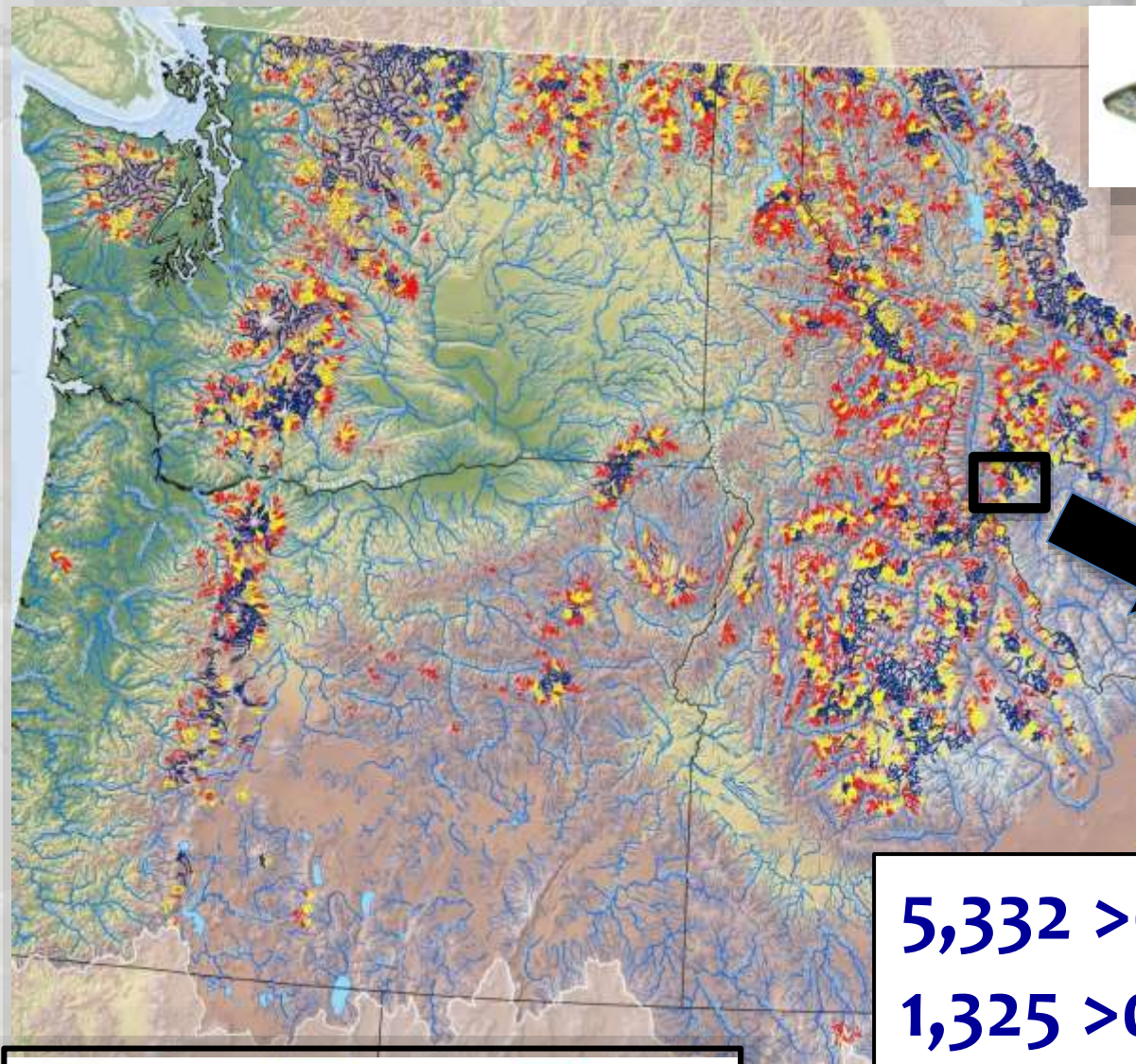


Bull Trout Probability Map

1980s



Stream
population scale
predictions

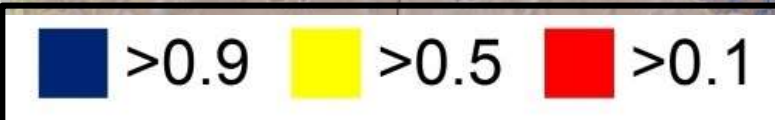
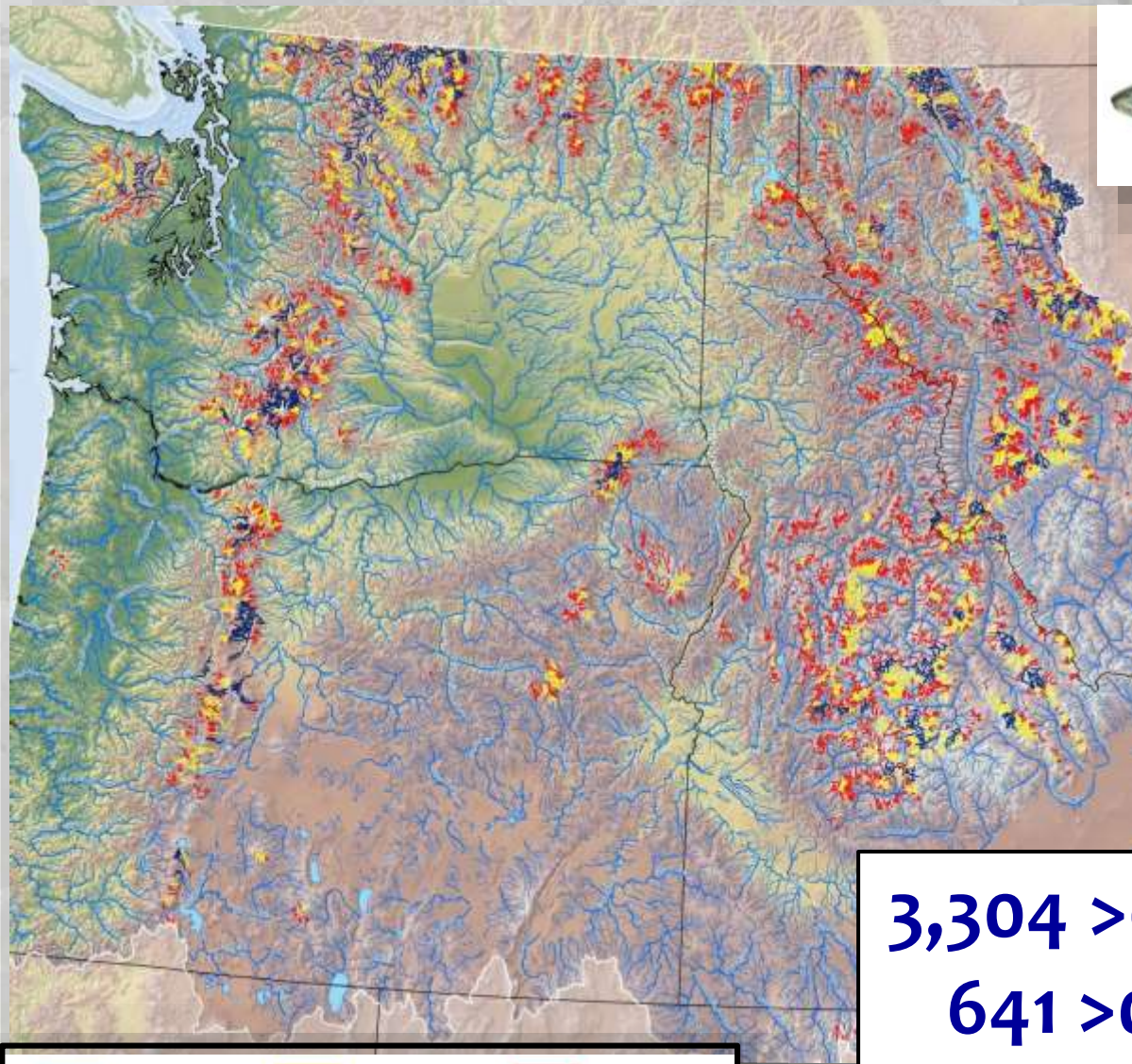


5,332 >0.1 habitats
1,325 >0.5 habitats
348 >0.9 habitats



Bull Trout Probability Map

2040s



3,304 >0.1 habitats
641 >0.5 habitats
130 >0.9 habitats



Bull Trout Probability Map

2080s

North Cascades



Flathead

Walla Walla

Extreme
scenario!
+5°C

Metolius

Central
Idaho

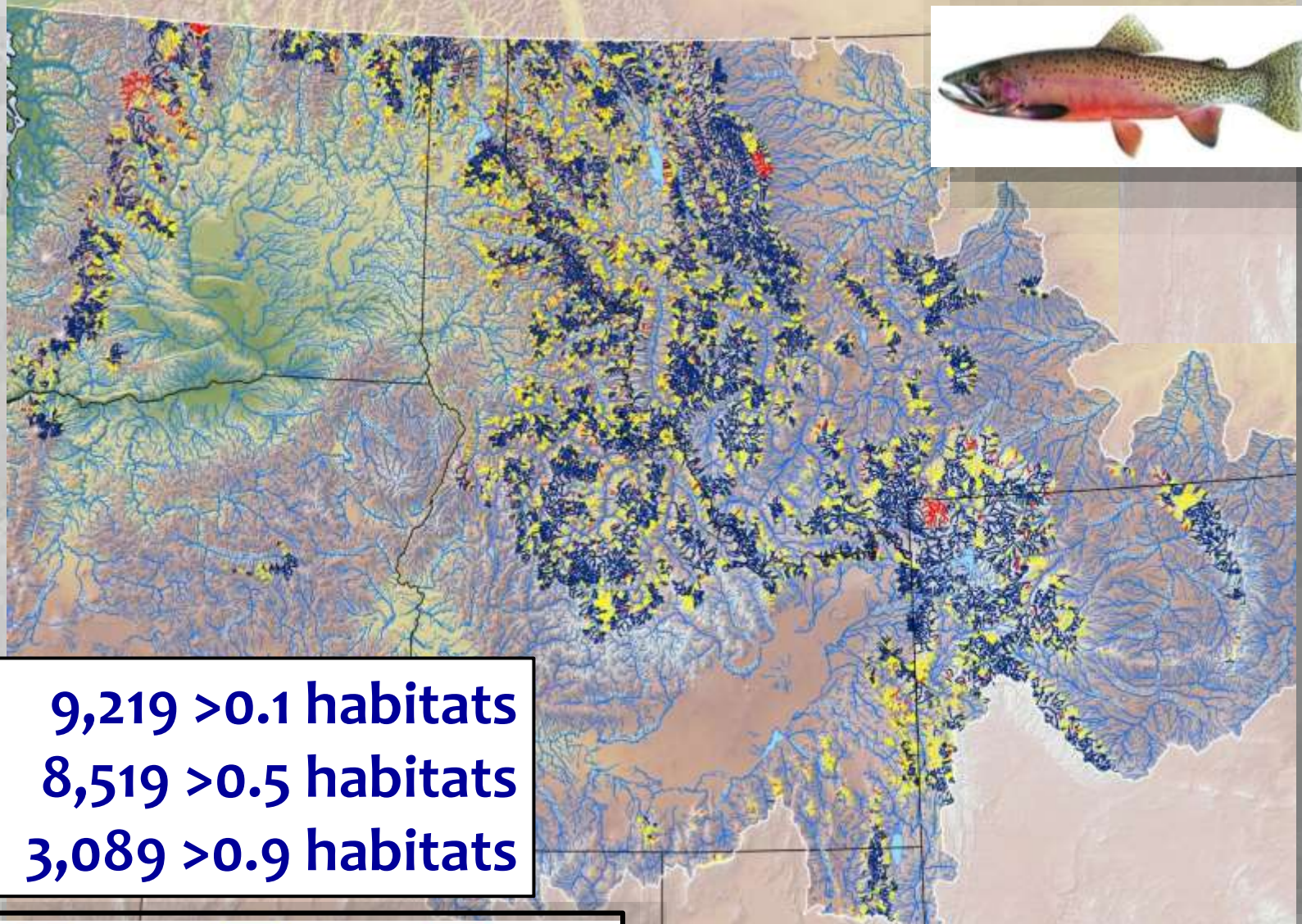
2,712 >0.1 habitats
460 >0.5 habitats
62 >0.9 habitats






>0.1

Cutthroat Probability Map

1980s

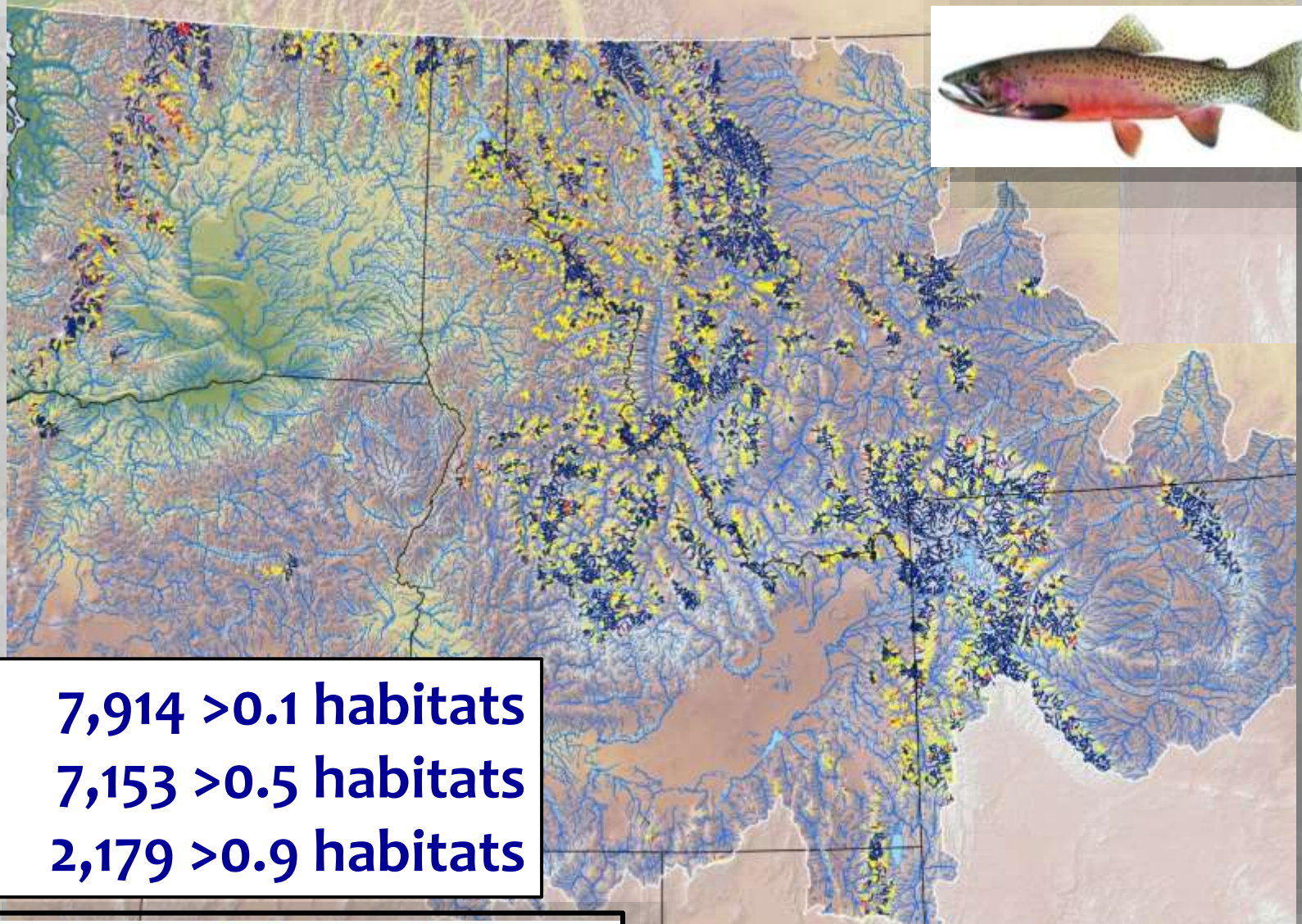


9,219 >0.1 habitats
8,519 >0.5 habitats
3,089 >0.9 habitats




 >0.9  >0.5  >0.1

Cutthroat Probability Map

2040s

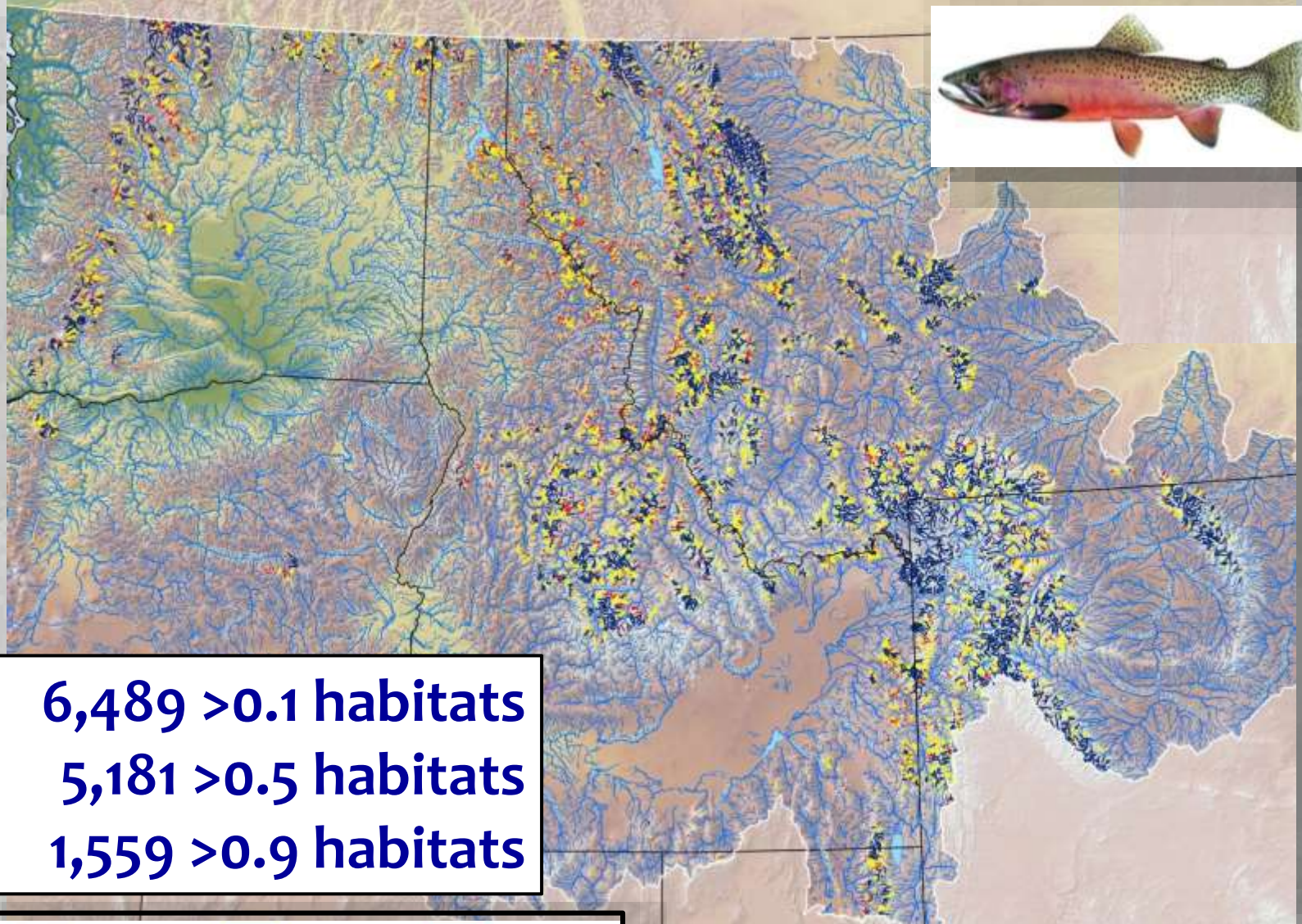


7,914 >0.1 habitats
7,153 >0.5 habitats
2,179 >0.9 habitats




 >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...



Size of Refugia for Probability >0.9

	Period	Median size (km)	
Cutthroat Trout	1980s	11	} 2x larger
	2040s	10	
	2080s	9	
Bull Trout	1980s	51	} larger
	2040s	54	
	2080s	53	



... but *steeper* streams are also invasion resistant



Website Provides Information in User-Friendly Digital Formats

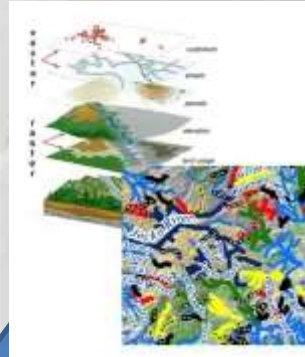


Just Google “Climate shield trout”

Presentations & Publications



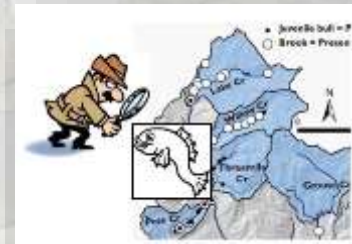
Digital Maps & ArcGIS Shapefiles



Fish Data Sources



Distribution Monitoring



File formats:







- ArcGIS files
- pdf files

15 Scenarios:

- 3 climate periods
- 5 Brook invasion levels

Precise Information Across Broad Scales Empowers Local Decision Makers...

Occupancy Probability

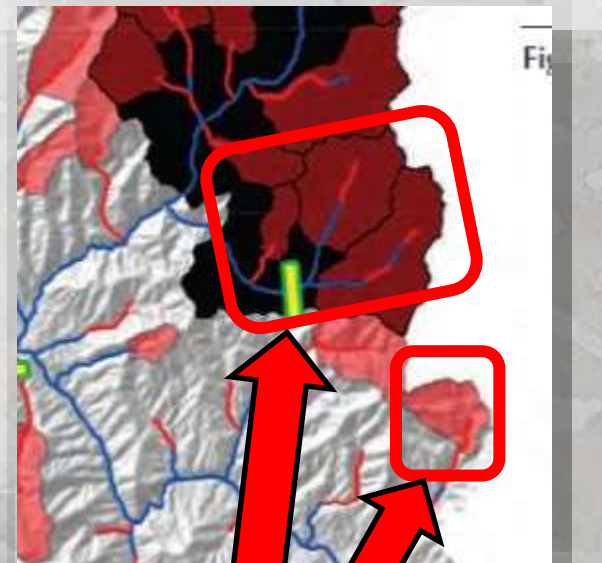
-  > 0.90
-  > 0.75 to < 0.90
-  > 0.50 to < 0.75
-  > 0.25 to < 0.50
-  < 0.25
-  Slope = 10% to 15%



Highest priority conservation investment!

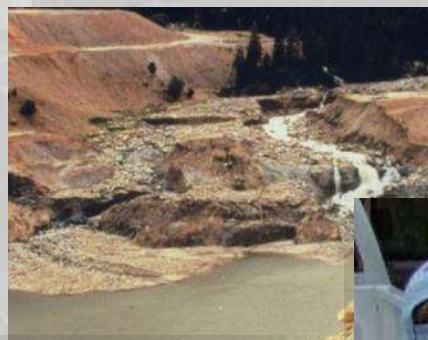
Many Conservation Investment Options Once we Know “Where”

- Maintaining/restoring flow...
- Maintaining/restoring riparian...
- Restoring channel form/function...
- Prescribed burns limit wildfire risks...
- Non-native species control...
- Improve/impede fish passage...



I'm going to invest here...

...not here



CLIMATE SHIELD is:

Cold-Water

+

PEOPLE

