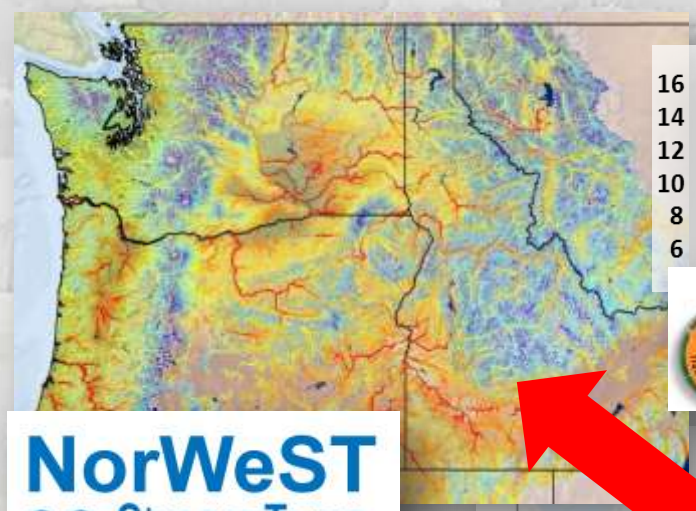
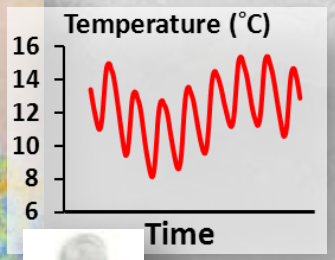
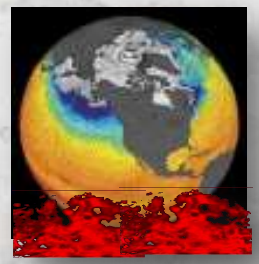
NorWeST, Climate Shield, & New Frontiers…

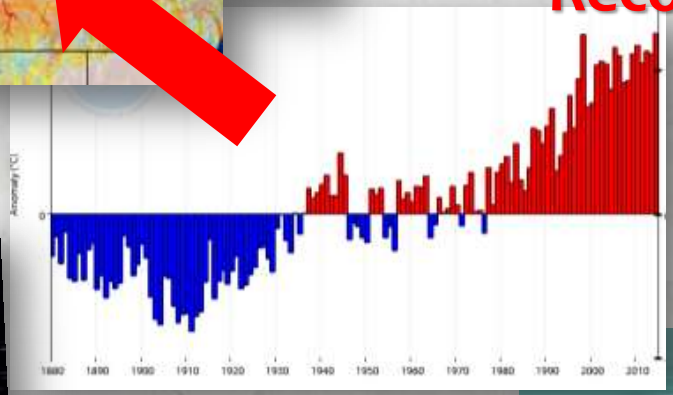




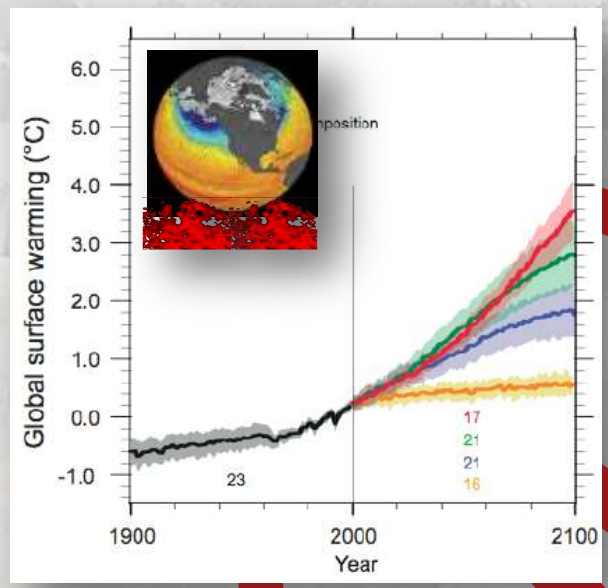


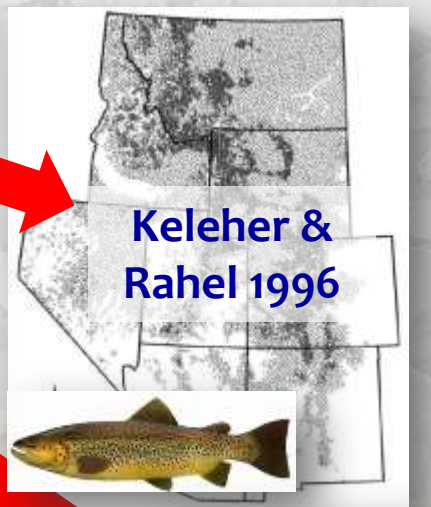
NorWeST
Stream Temp

2014 Set New Record



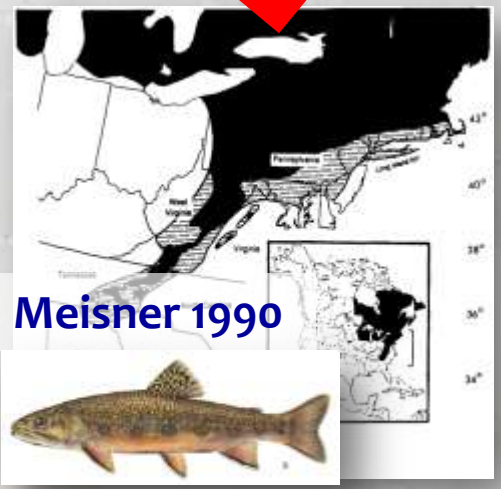
We've Been Predicting it Would Come…

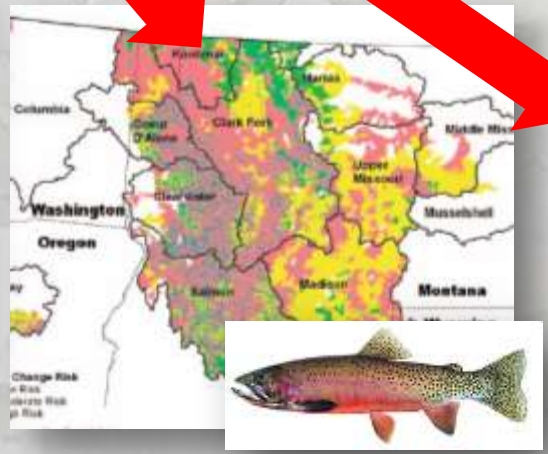


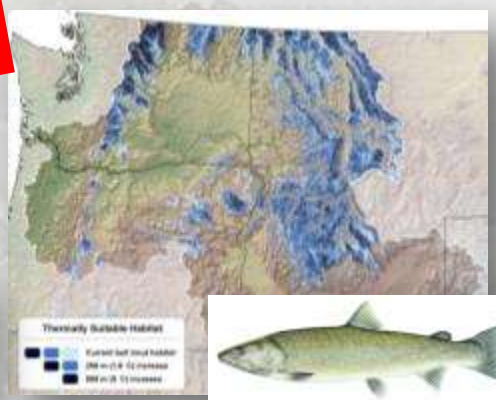


Et al…

- 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.

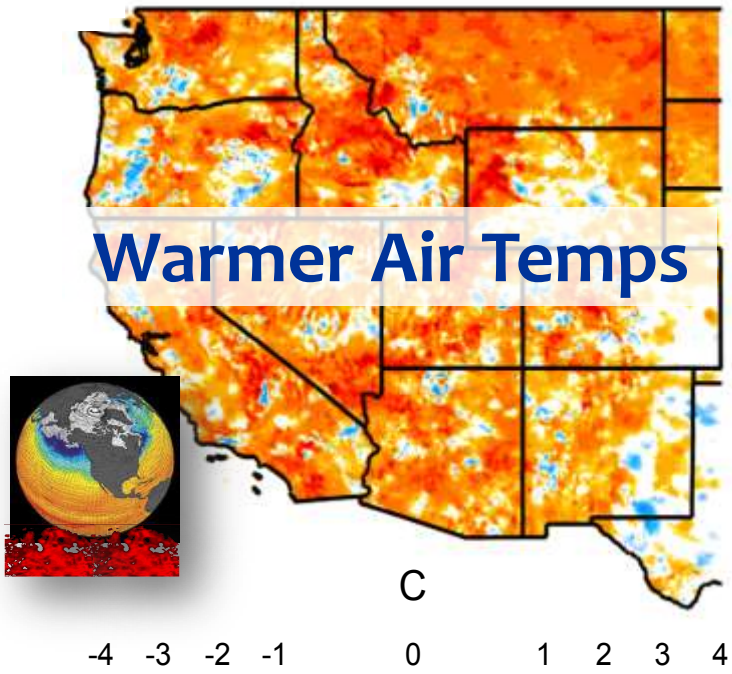






Environmental Trends Everywhere (1950-2009)

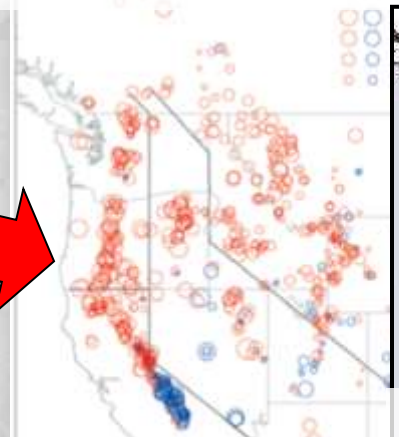
b)



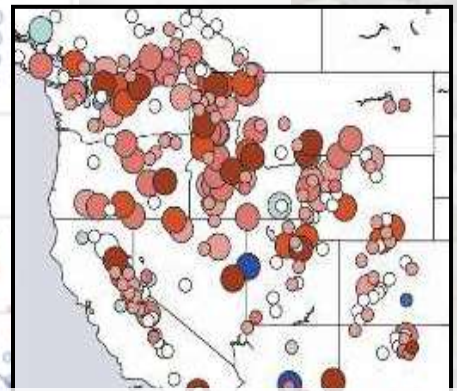
Warmer Air Temps

c)

Less Snow & Earlier Runoff

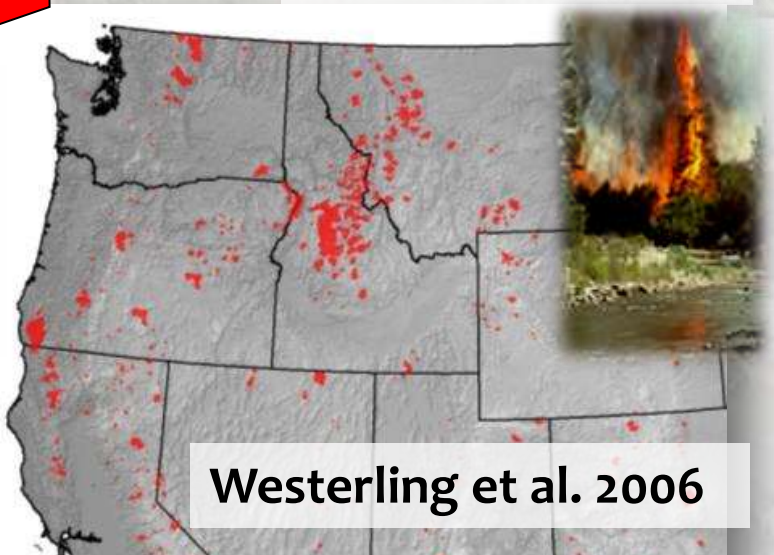


Mote et al. 2005



Stewart et al. 2005

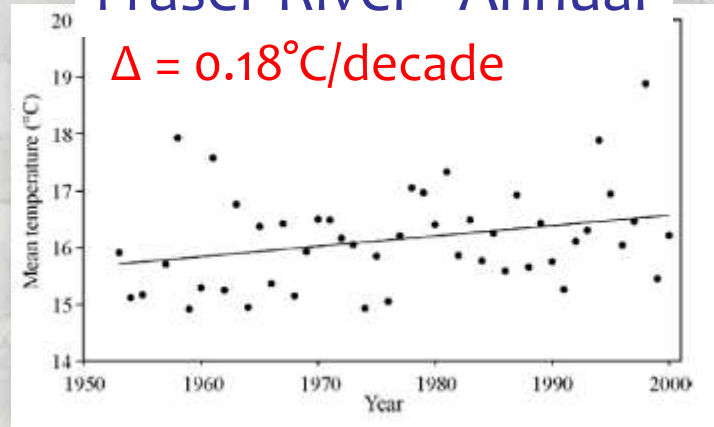
Wildfire Increases



Westerling et al. 2006

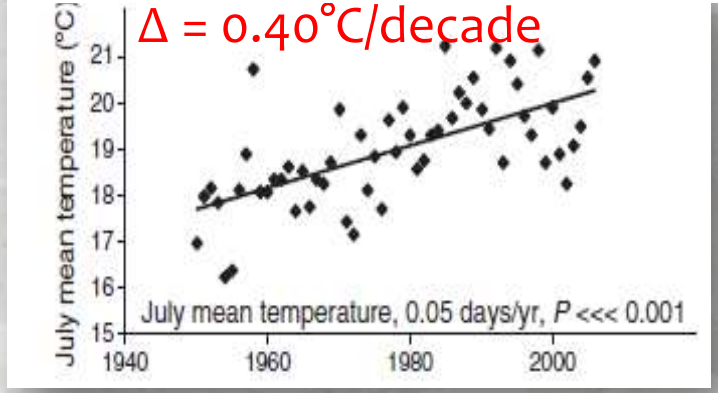
Temperature Trends In Northwest Rivers

Fraser River - Annual



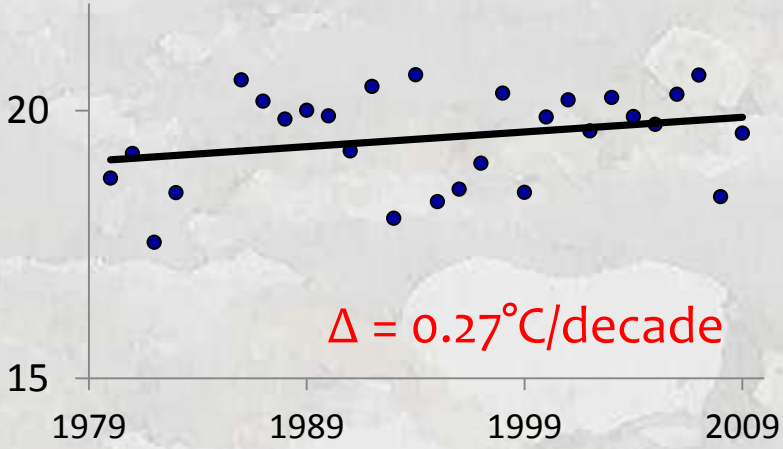
Morrison et al. 2001

Columbia River - Summer

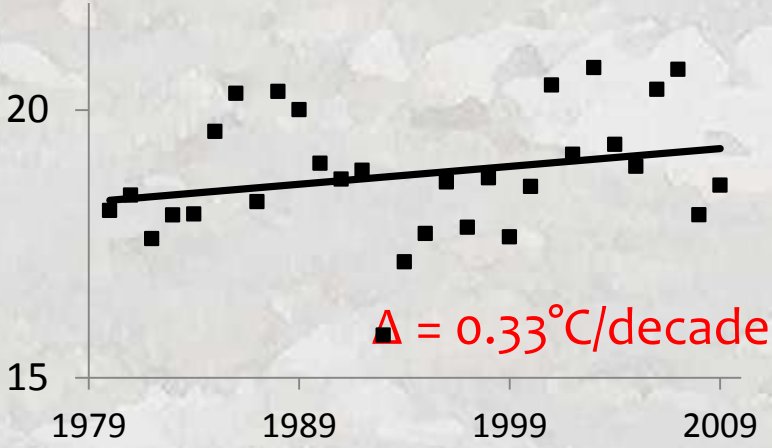


Crozier et al. 2008

Snake River, ID - Summer



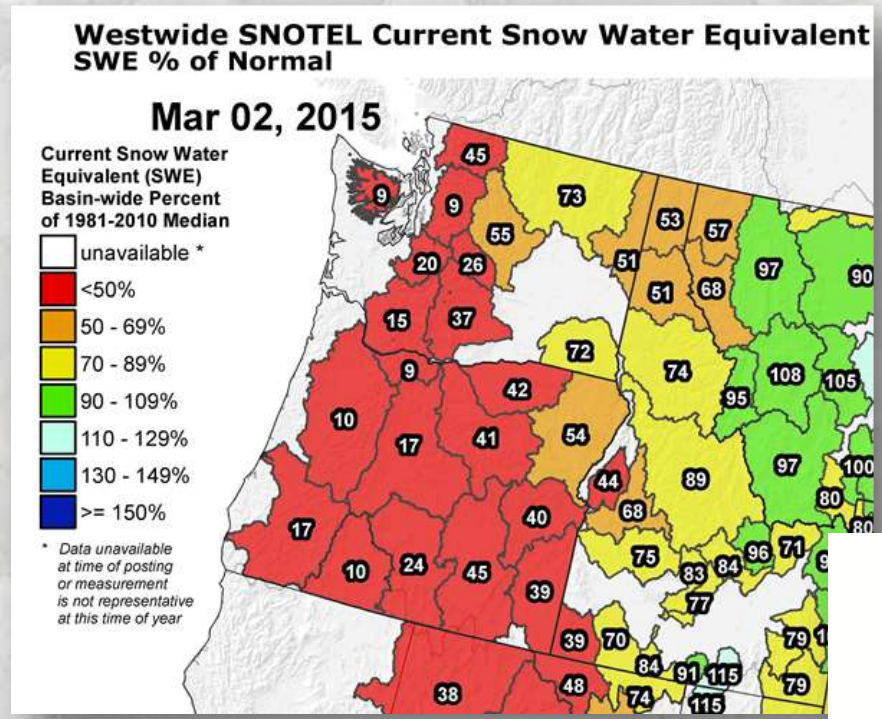
Missouri River, MT - Summer



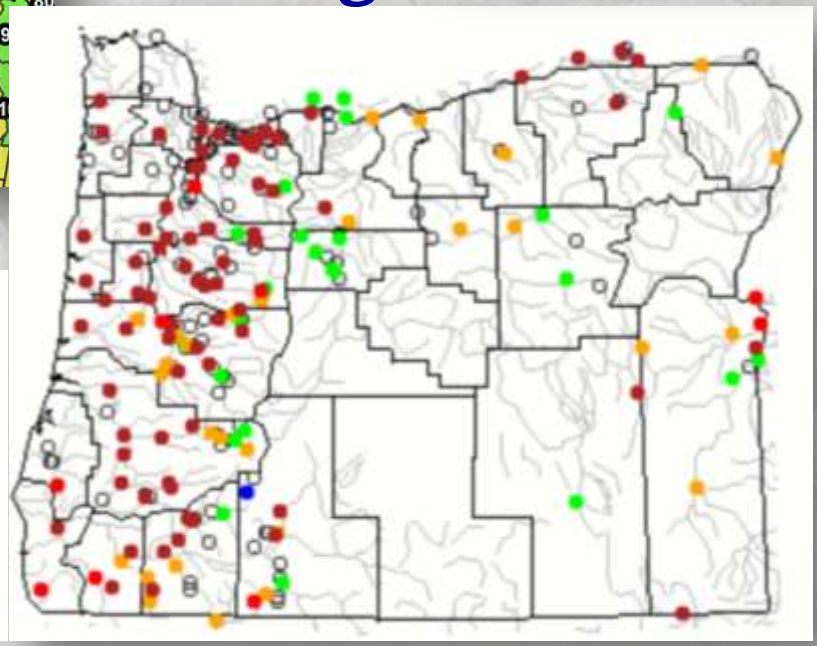
Isaak et al. 2012. *Climatic Change* **113**:499-524.

Extremes will Become More Extreme…

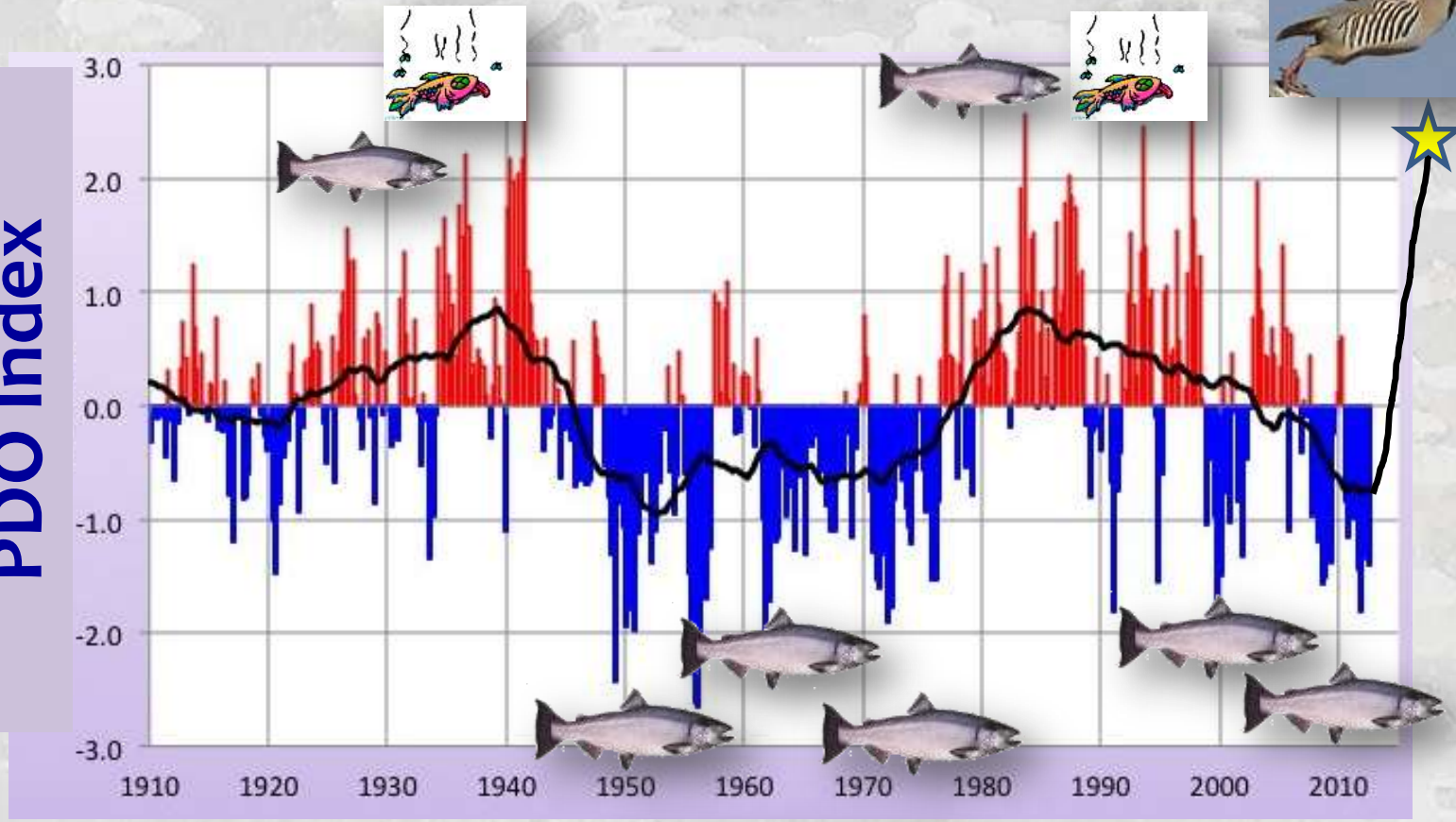
Current snowpack…



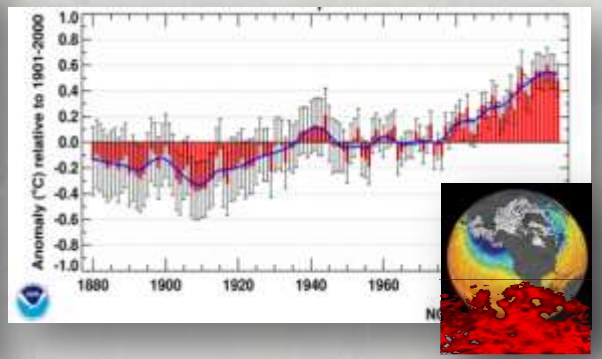
Current discharge…



PDO Bought us Time…

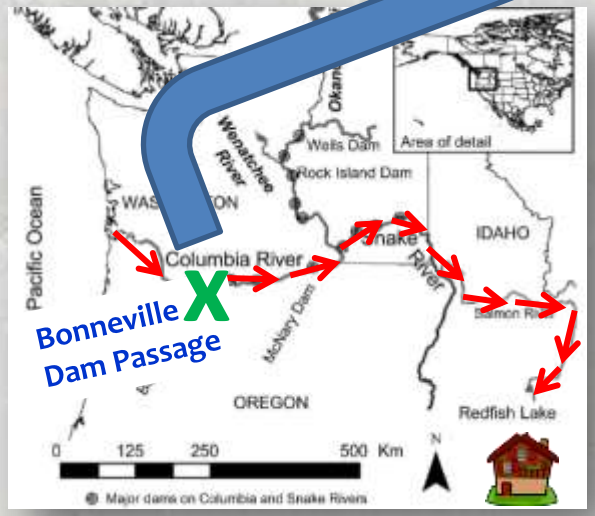


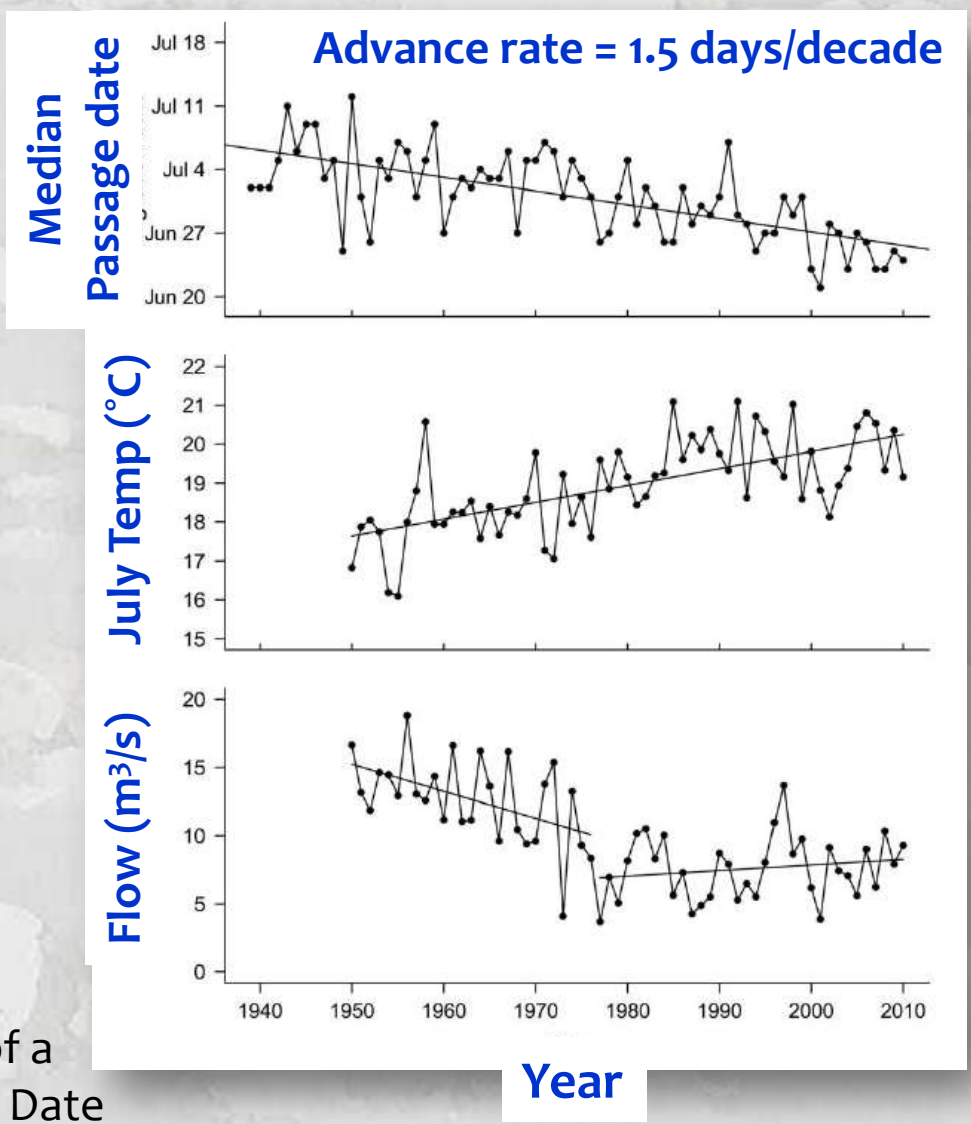
"Jack will be Back…"



Fish Follow Climate

Sockeye Migrations Happening Earlier…

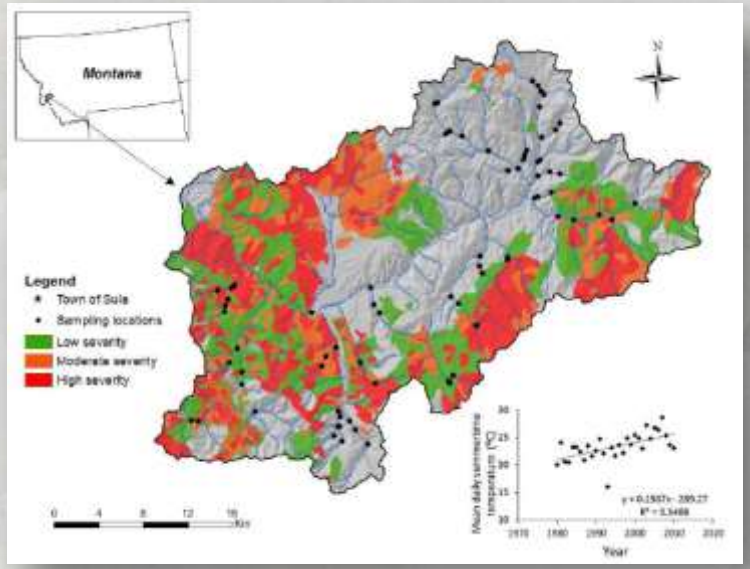




Crozier et al. 2011. A Case Study of a Shift toward Earlier Migration Date in Sockeye Salmon. *The American Naturalist* **178**:755-773.

Montana Bull Trout Range Contraction

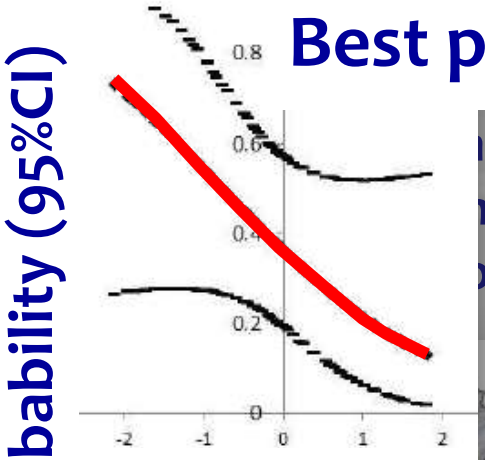
- Resurveyed Rich et al. 2003 sites 20 years later
- 77 sites, 500 m in length
- Modeled extirpations/colonizations accounting for detection efficiency

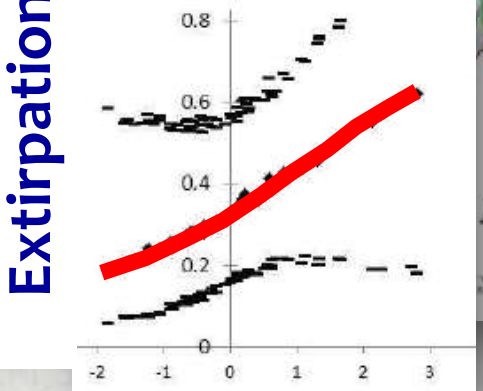


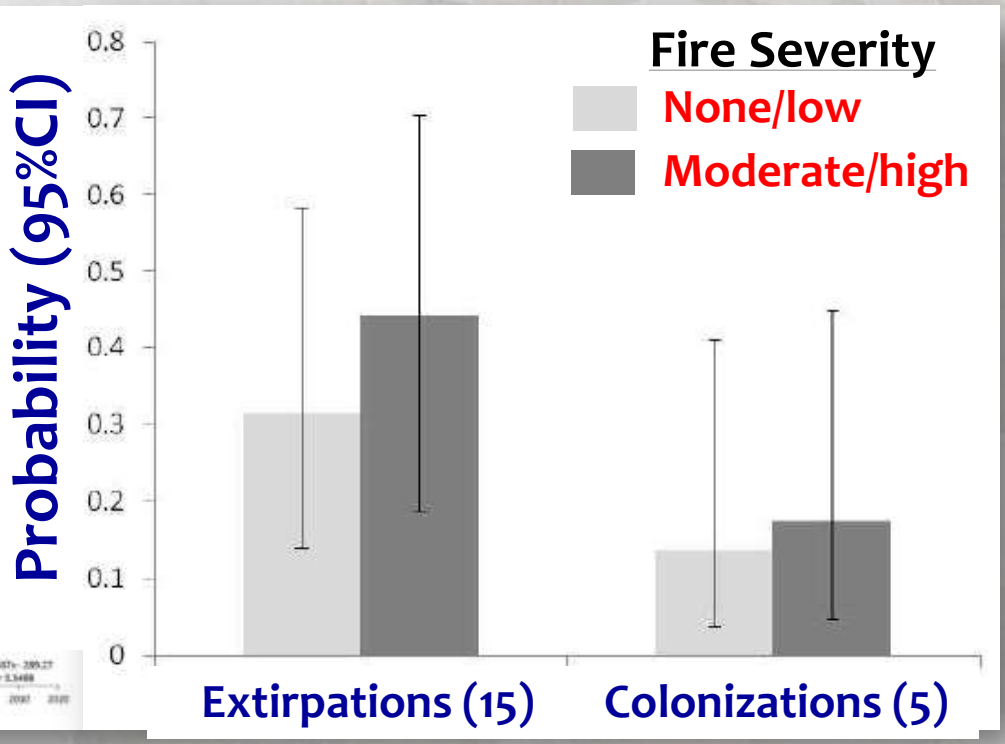
Eby et al. 2014. Evidence of climate-induced range contractions for bull trout in a Rocky Mountain watershed, U.S.A. *PLoS ONE* **9(6)**: e98812

Montana Bull Trout Range Contraction

Best predictors



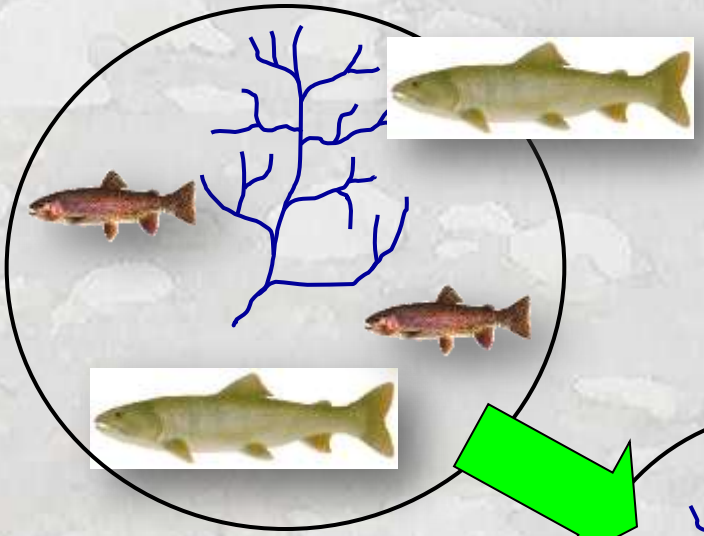


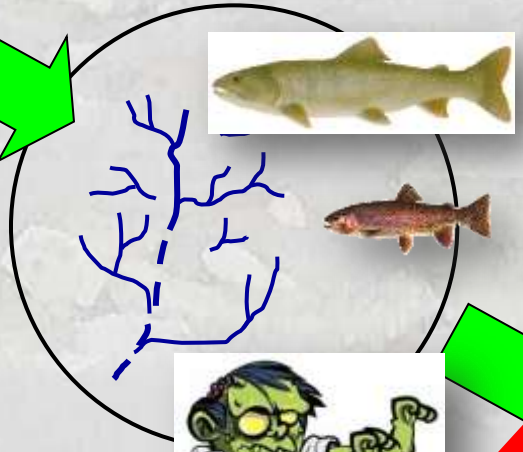


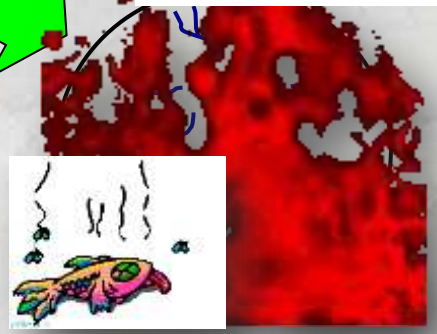
Eby et al. (2014). Fifty-year record of climate-induced range contractions for bull trout in a Rocky Mountain watershed, U.S.A. *PLoS ONE* **9(6)**: e98812

Resistance Will Be Futile Sometimes

Not Everything Can be Saved



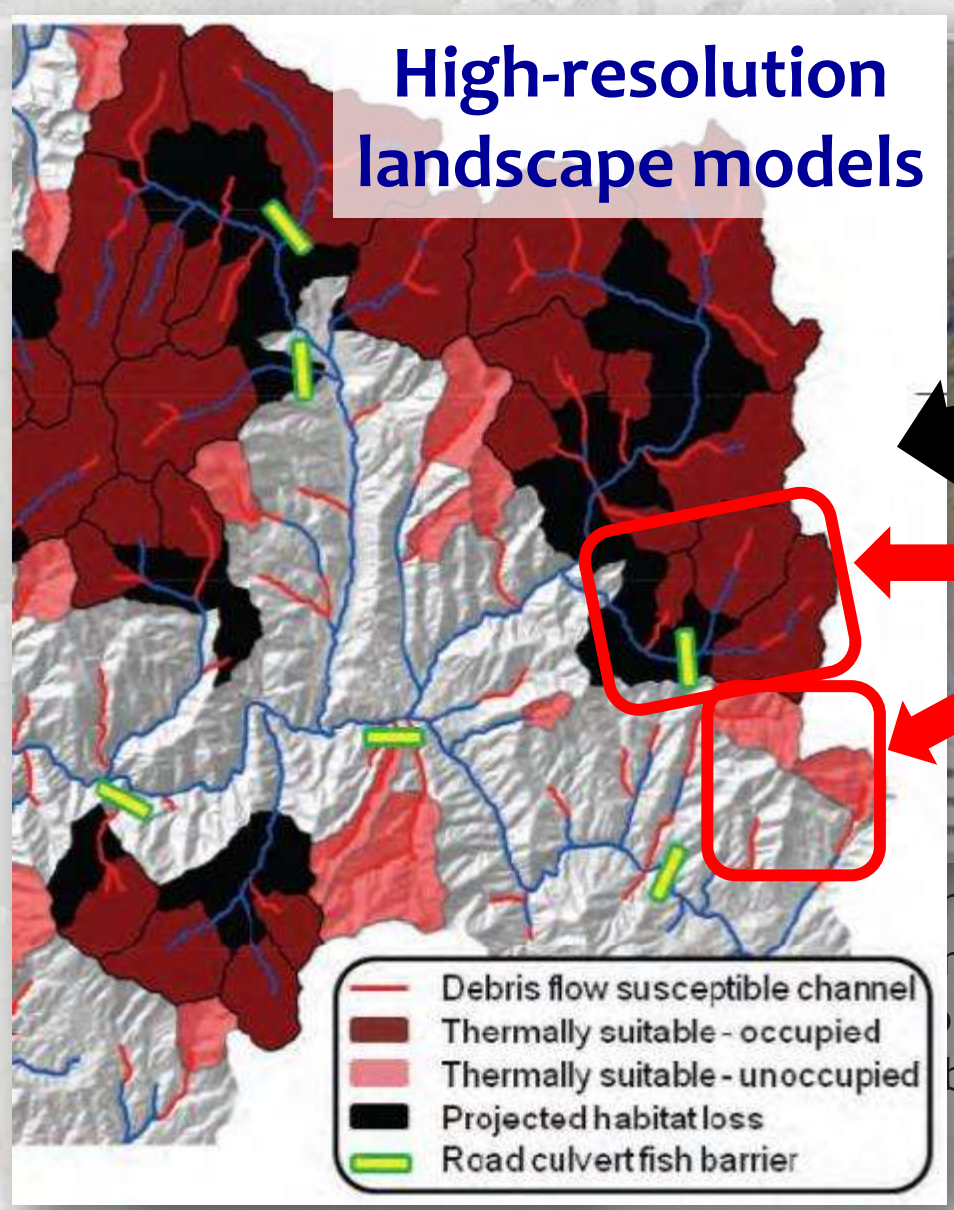




Sorry Charlie

Thresholds Beyond Which Populations Become "Walking Dead"

1st Generation Fish-Climate Models Were "Accurate" but Imprecise…



I'm going to invest here…

…instead of here

et al.

ng effe

pulati

bia Riv

565

The NorWeST Stream Temperature Database, Model, & Climate Scenarios

Dan Isaak, Seth Wenger[1], Erin Peterson[2], Jay Ver Hoef[3] Charlie Luce, Steve Hostetler[4], Jason Dunham[4], Jeff Kershner[4], Brett Roper, Dave Nagel, Dona Horan, Gwynne Chandler, Sharon Parkes, Sherry Wollrab, Colete Bresheares, Neal Bernklau

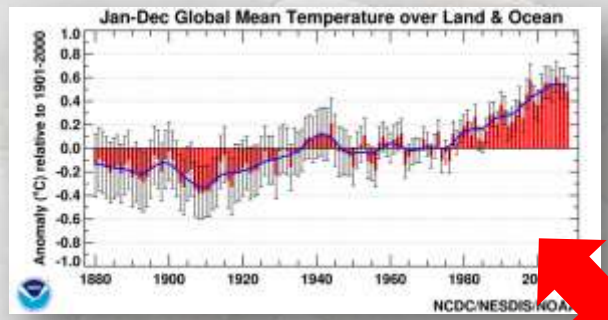
U.S. Forest Service

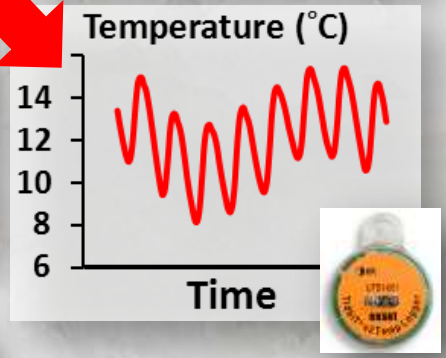
[1]Trout Unlimited

[2]CSIRO

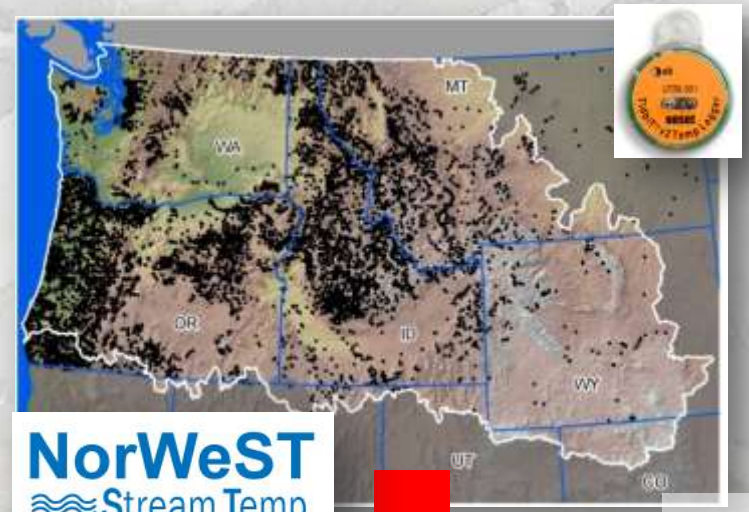
[3]NOAA

[4]USGS



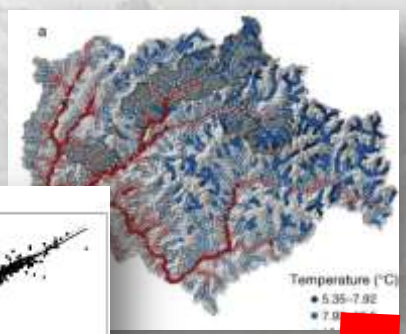


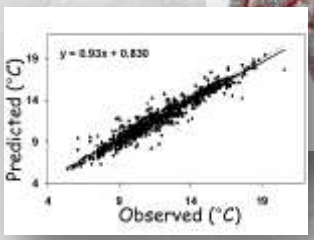
Regional Temperature Model



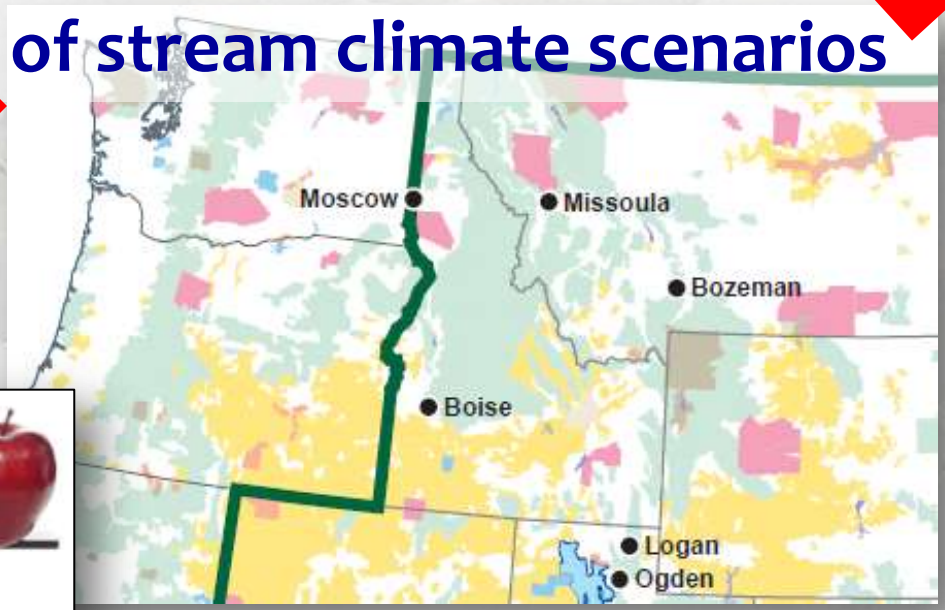
NorWeST Stream Temp

Accurate stream temp model

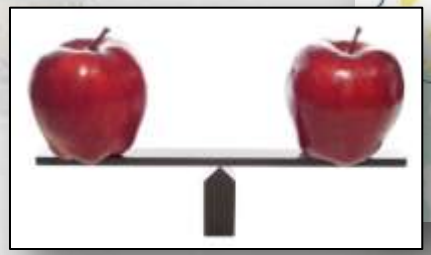




Cross-jurisdictional "maps" of stream climate scenarios

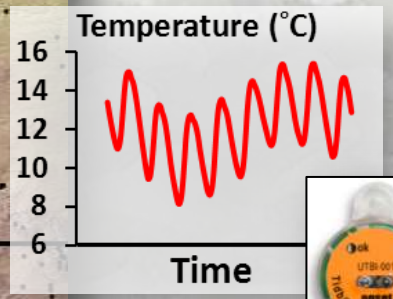


Consistent datum for strategic planning across 500,000 stream kilometers



Lots of Temperature Data Exist…

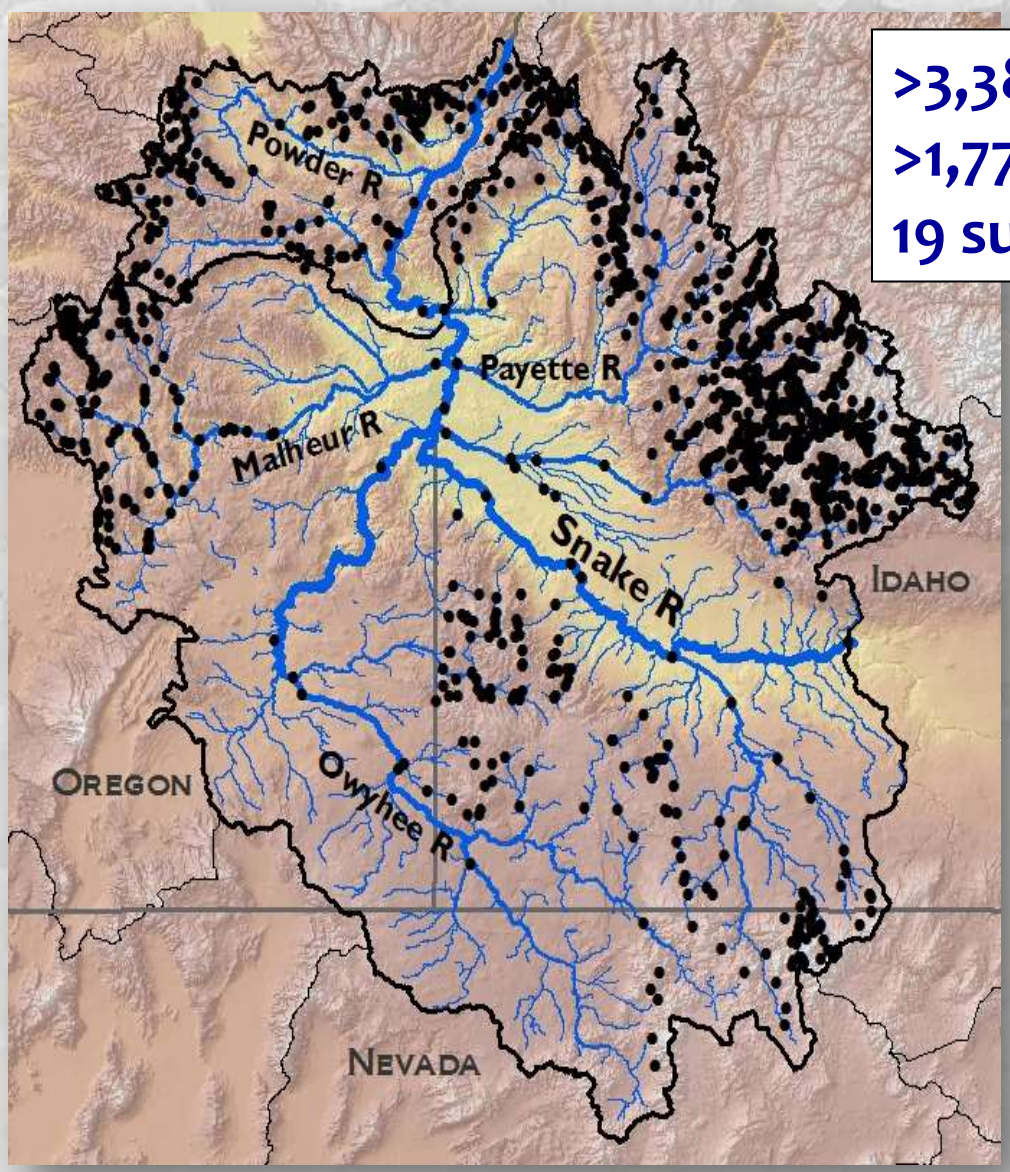
>50,000,000 hourly records
>15,000 unique stream sites
>80 resource agencies



$10,000,000

MidSnake River Basin Database

Data extracted from NorWeST



>3,384 August means
>1,773 stream sites
19 summers (1993-2011)

•Temperature site

MidSnake Temperature Model

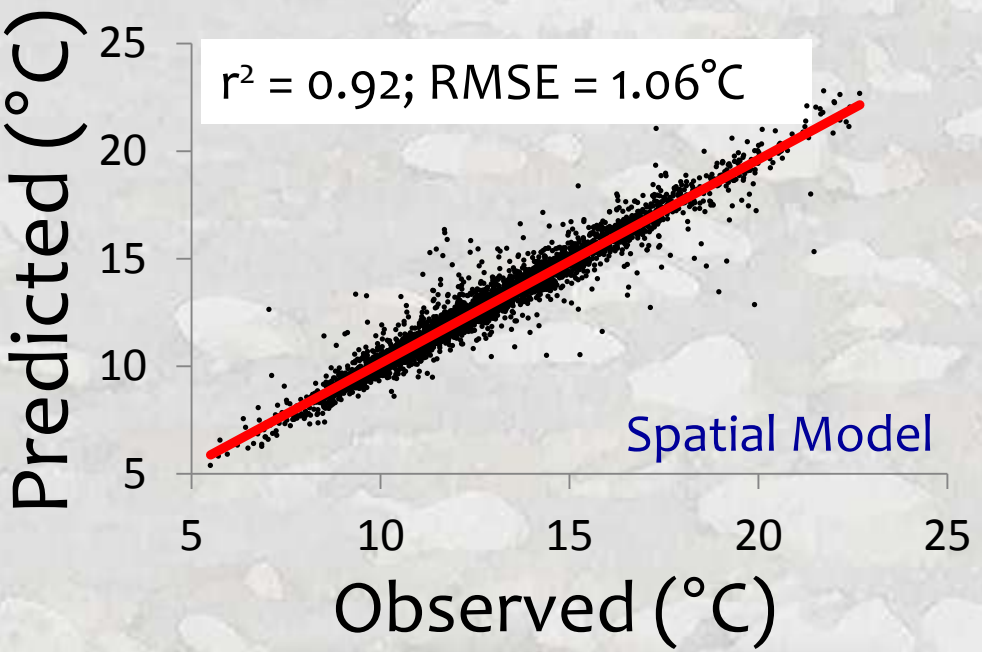
n = 3,384

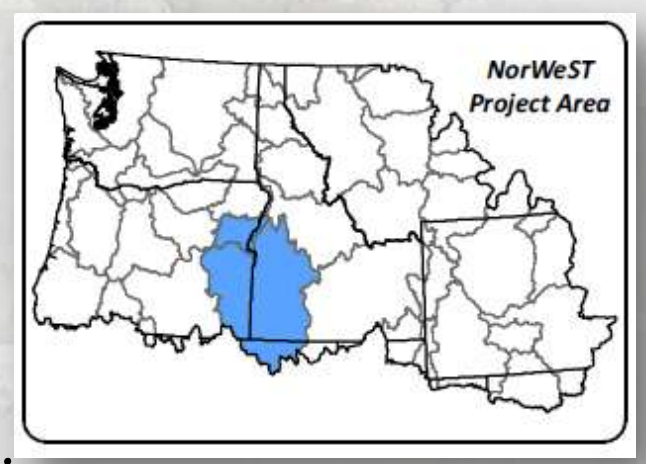
Covariate Predictors

1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Baseflow Index
8. Watershed size (km²)

9. Discharge (m³/s)
   USGS gage data
10. Air Temperature (˚C)
   RegCM3 NCEP reanalysis
   Hostetler et al. 2011

Mean August Temperature

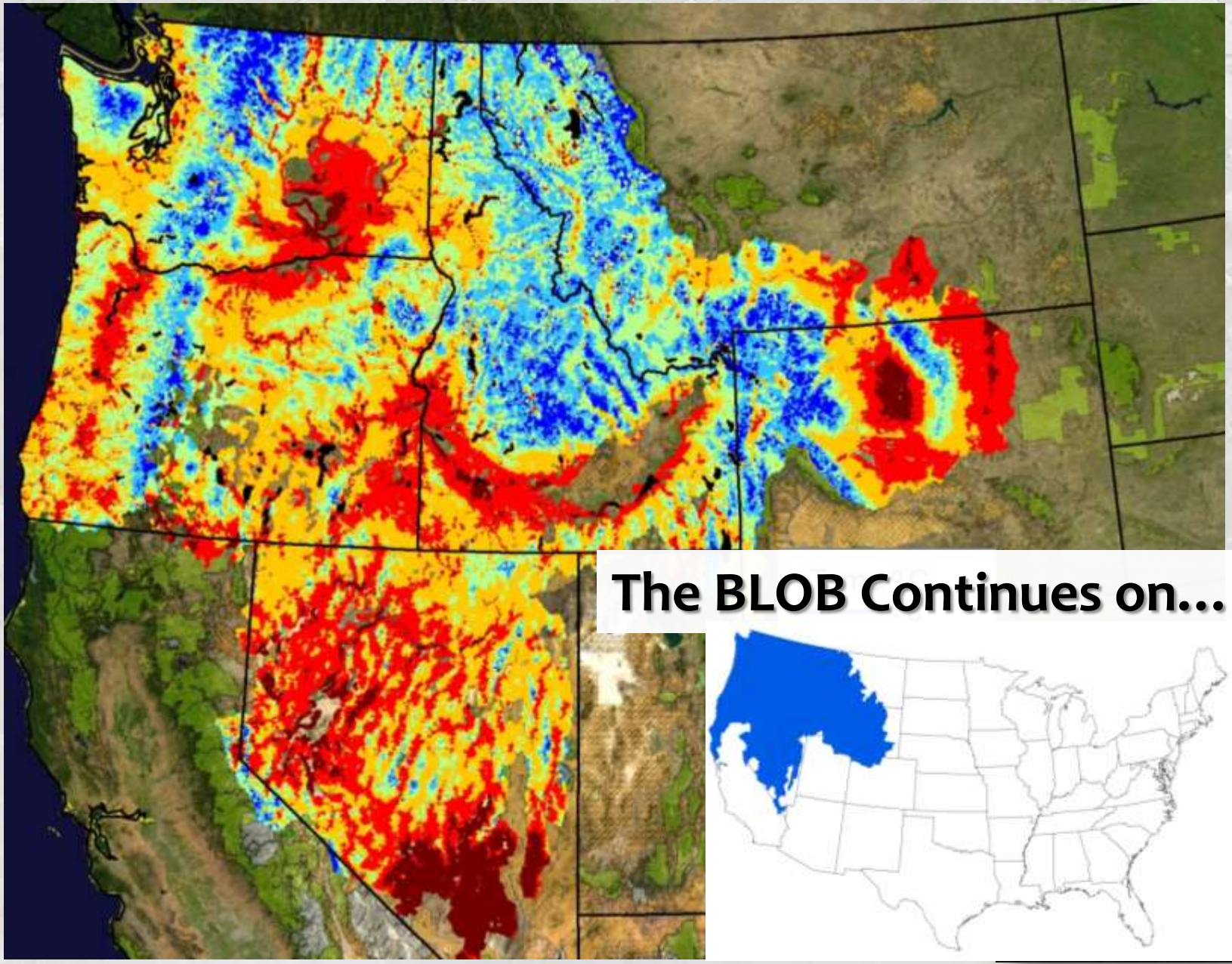




More details: **NorWeST website**

Isaak et al. 2010. *Ecol. Apps* **20**:1350-1370.

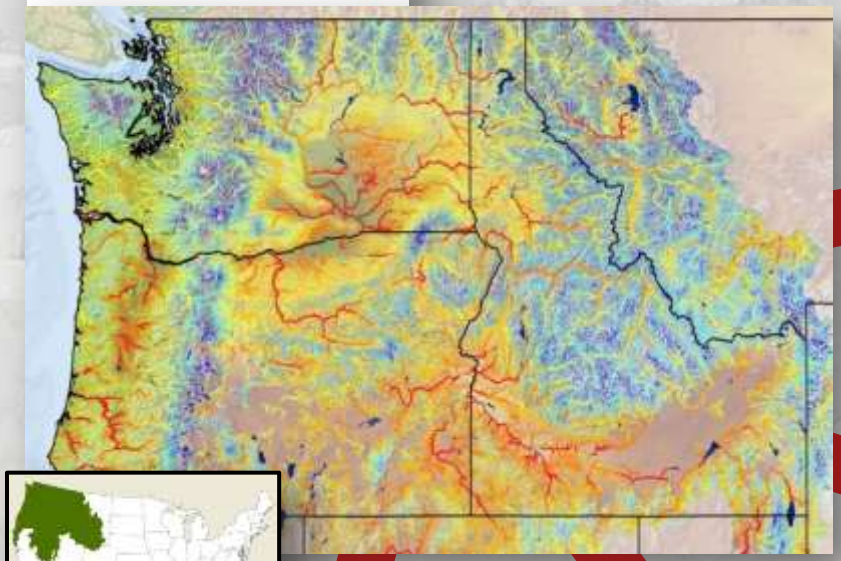
High-Resolution Stream Temp Scenarios



The BLOB Continues on…

NorWeST Stream Temp

Temperature Applications

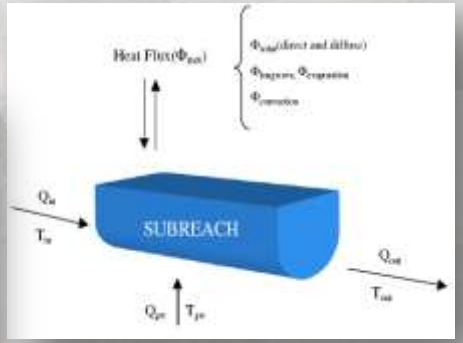


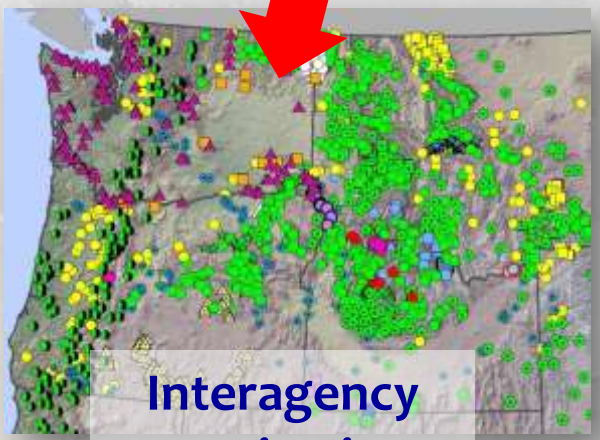
Regulatory temperature standards

Too Hot!

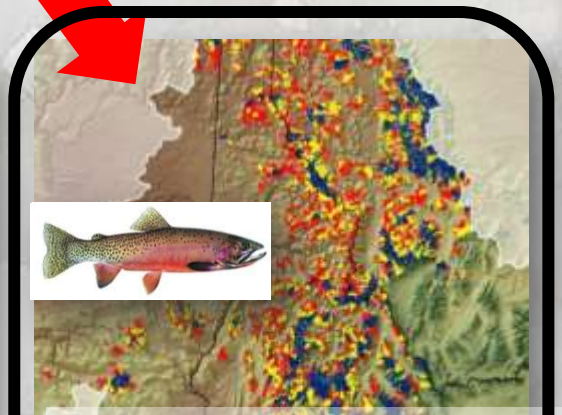
Too cold!

Data access accelerates temperature research





Interagency monitoring



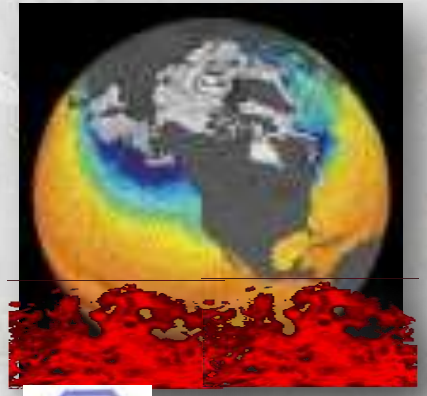
Species distribution models & climate assessments

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

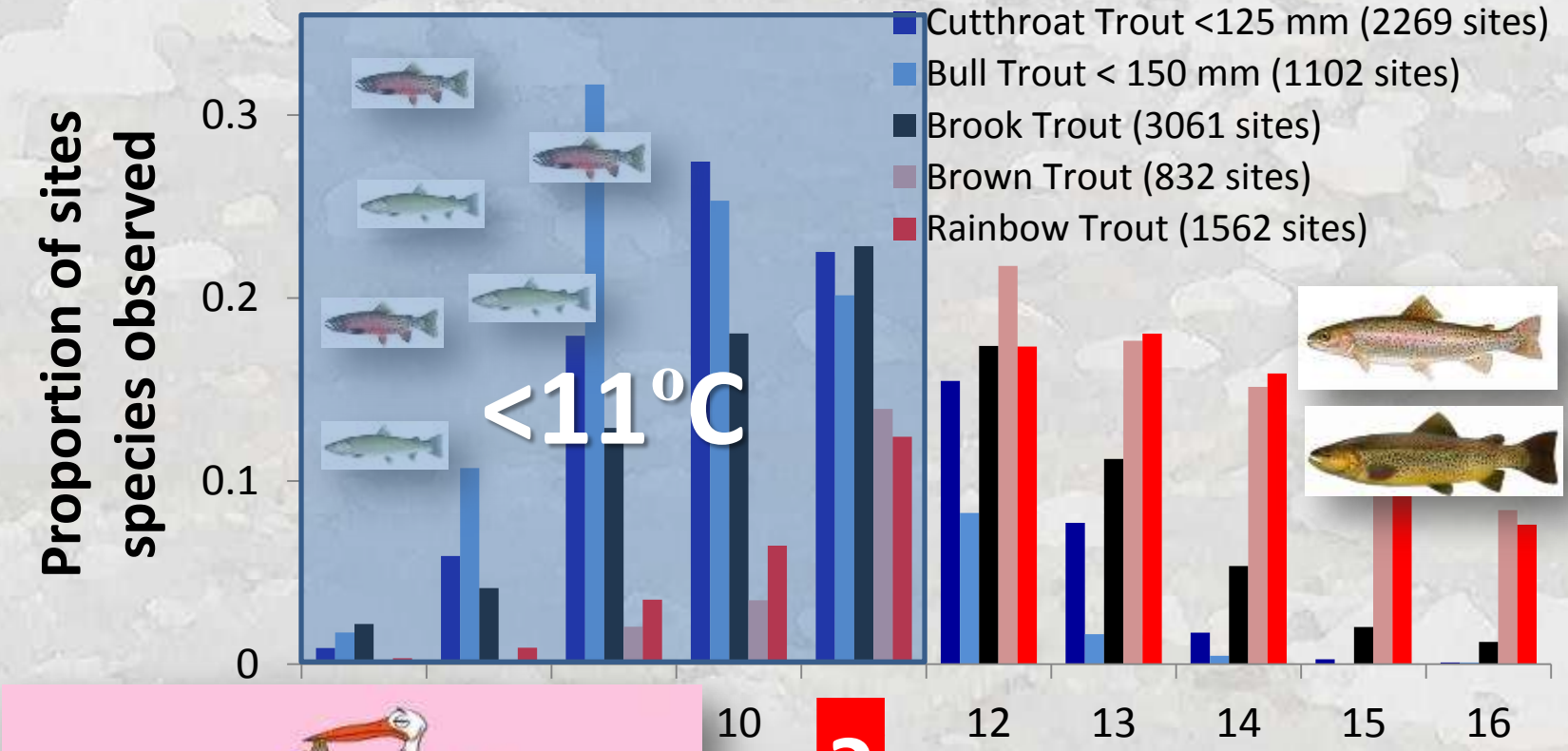


Boise Spatial Streams Group

Rocky Mountain Research Station

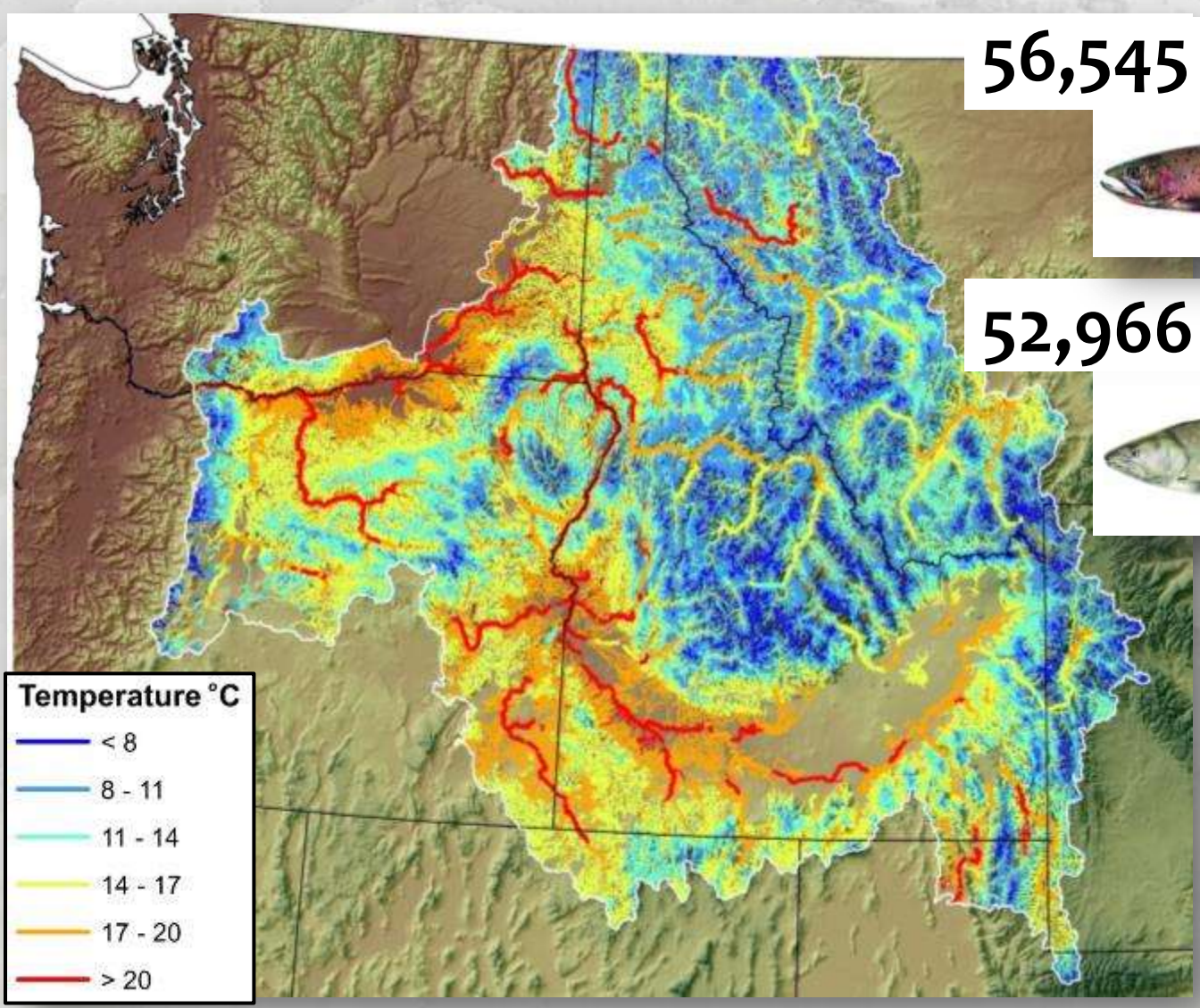
Northern Rock Adaptation Partnership

Cold Climates Exclude Most Invaders from Key Natal Habitats



<11°C Streams (1980s) & <15% slope

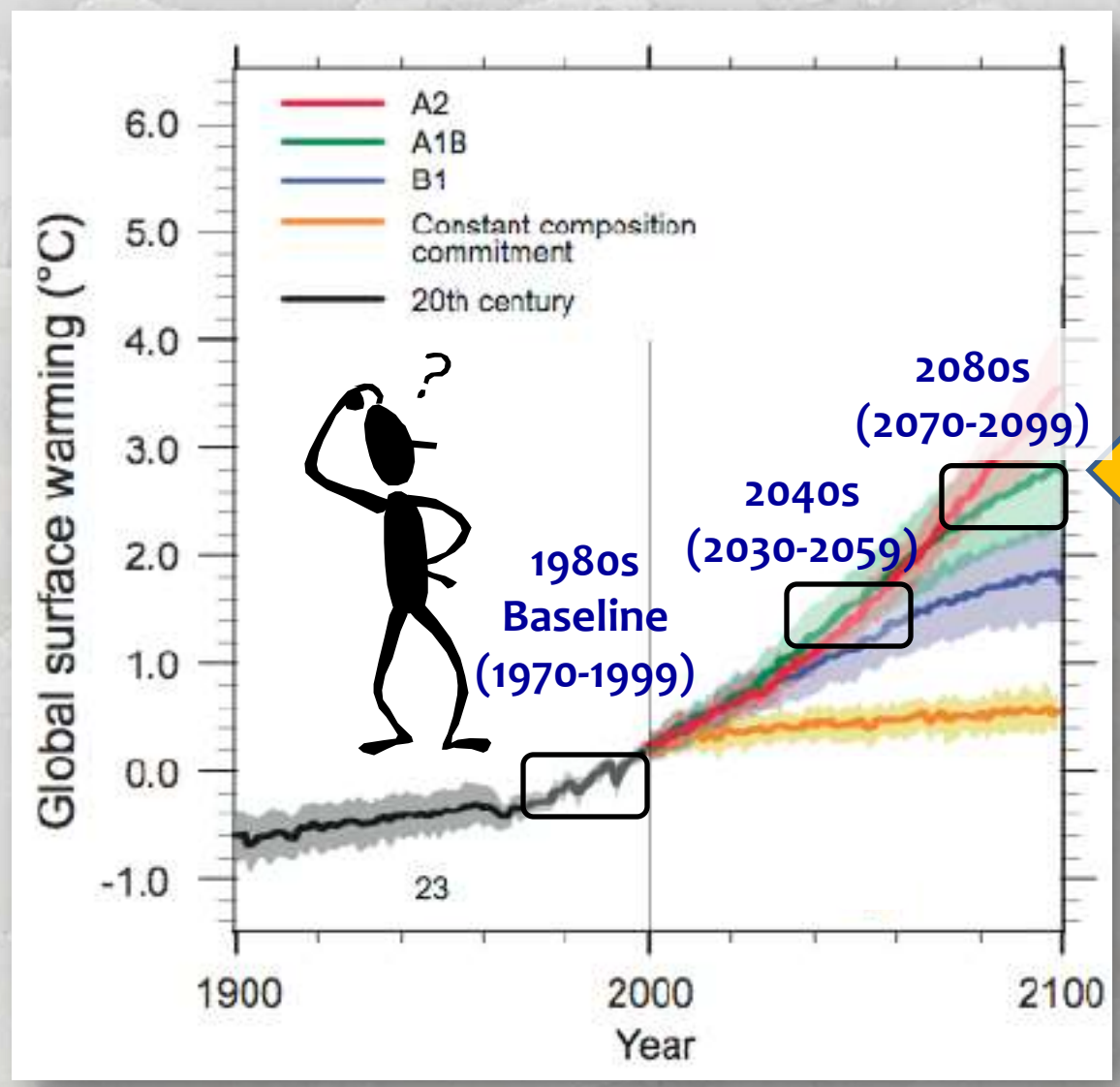
70,335 / 259,052 stream kilometers in analysis area



56,545 km

52,966 km

Future Changes in Stream Temperature?



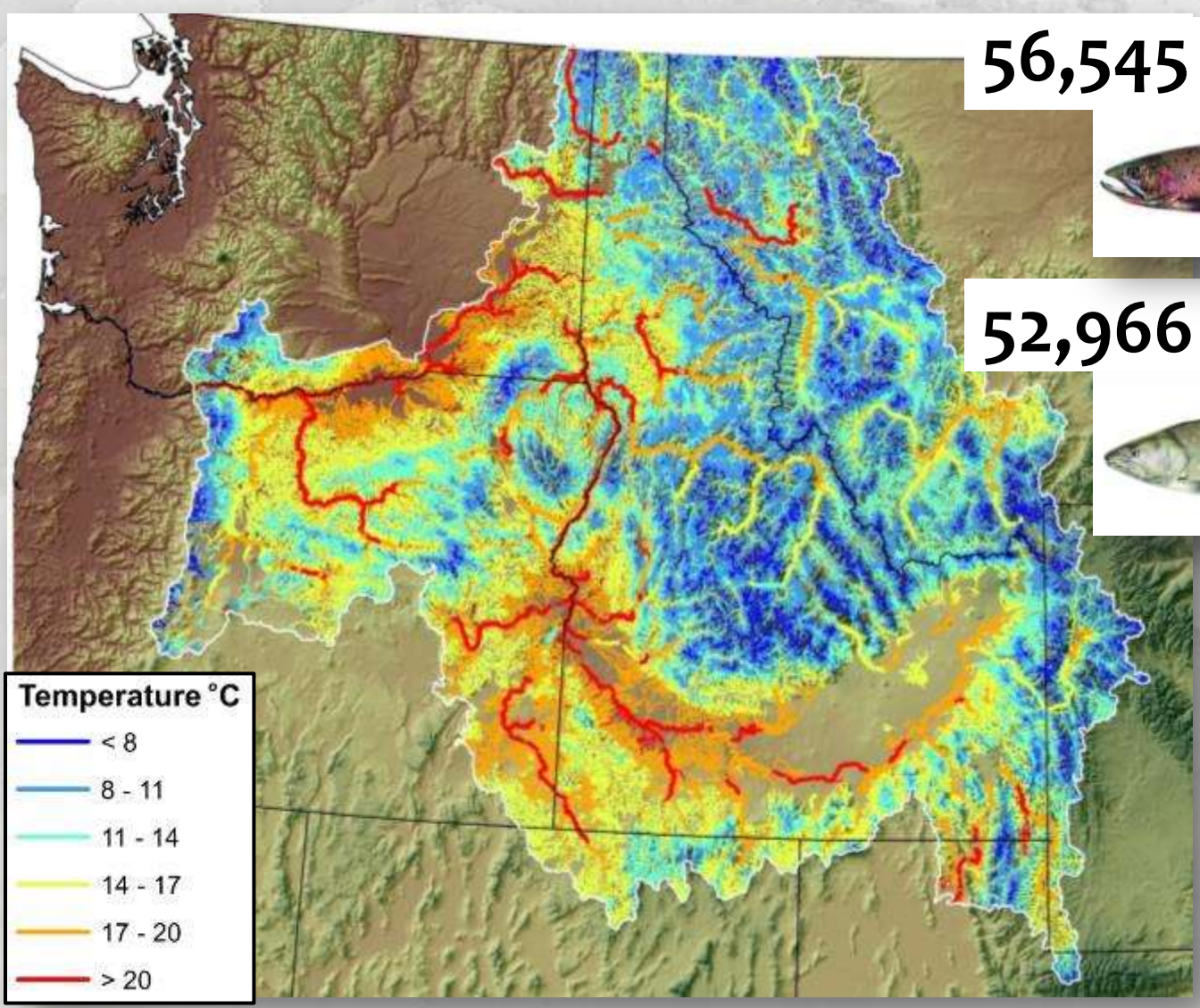
A1B

The Specifics are an "Unknowable Unknown"

Just plan on it gradually getting warmer…

<11°C Streams (1980s) & <15% slope

70,335 / 259,052 stream kilometers in analysis area

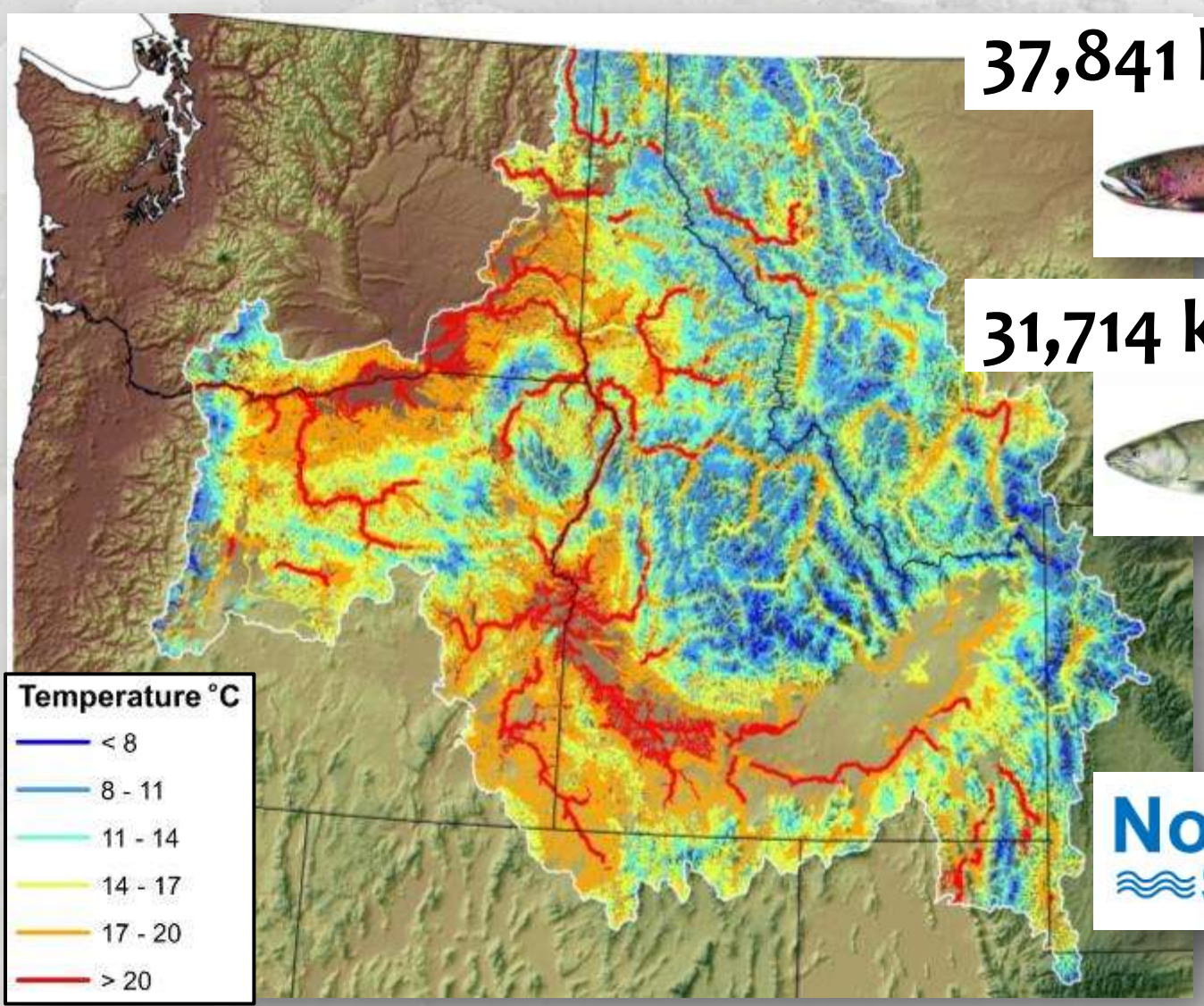


56,545 km

52,966 km

<11°C Streams (2040s) & <15% slope

43,556 / 248,330 stream kilometers in analysis area



37,841 km

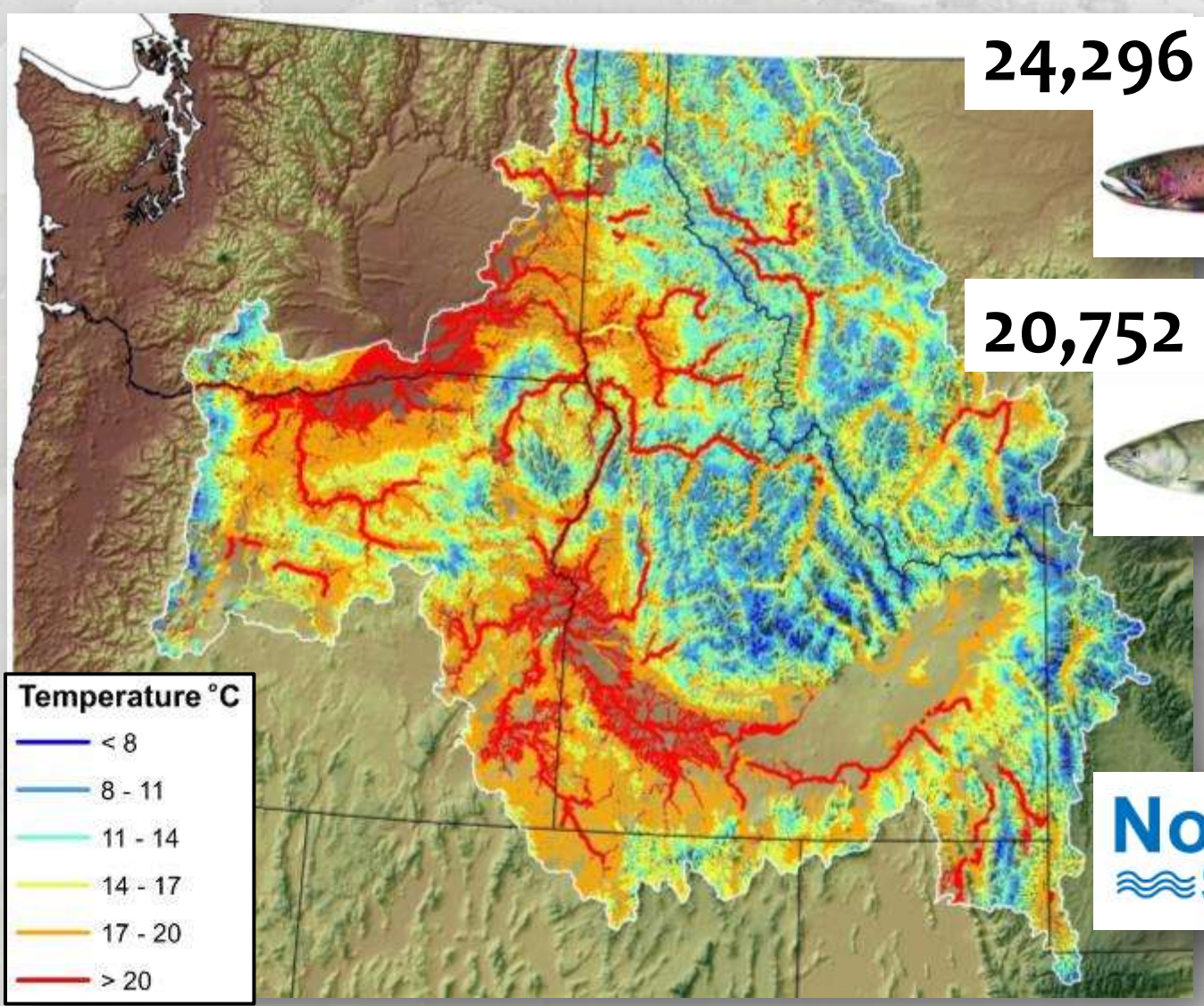
31,714 km

+1.3°C

NorWeST Stream Temp

<11°C Streams (2080s) & <15% slope

29,789 / 246,759 stream kilometers in analysis area

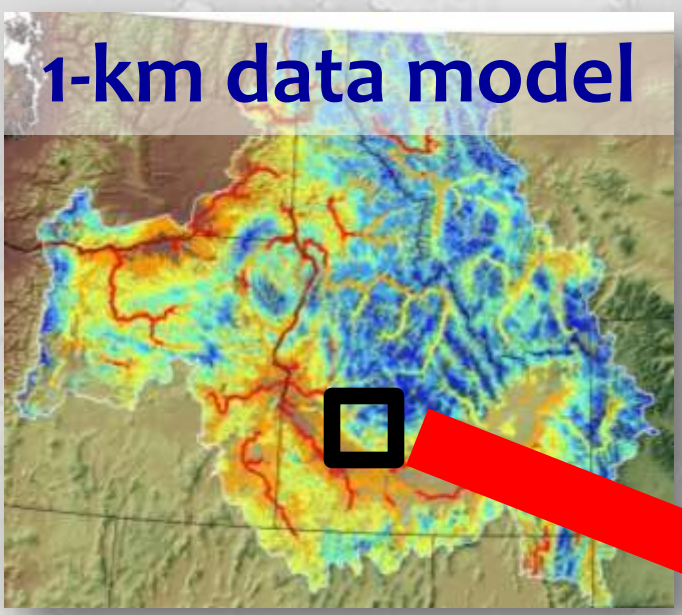


24,296 km

20,752 km

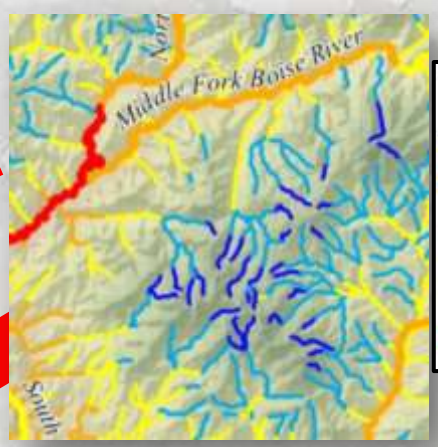
+2.1°C

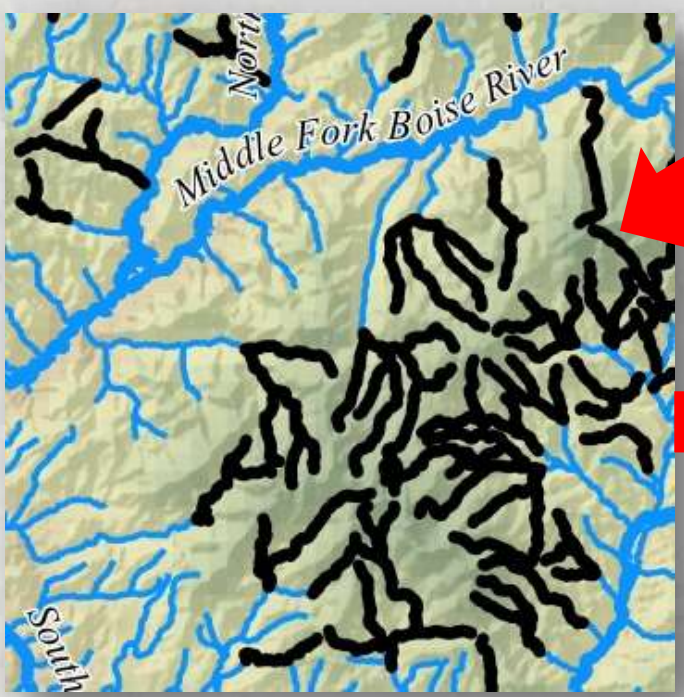
NorWeST Stream Temp



Additional Habitat Factors

- ArcGIS Python script aggregates discrete areas <11°C into "Cold-water habitats"





Predictor Variables…

- Habitat size (km <11°C)
- MeanTemp & MinTemp
- % Stream slope
- % Brook Trout

Fish Data for Species Occurrence Models

Present Absent

Fish sites = 3,655
Streams = 566

Fish sites = 4,506
Streams = 512

Fish data from agency monitoring programs…

Fish Data from Literature Sources…

Al-Chokhachy & Budy. 2008. Demographic Characteristics, Population Structure, and Vital Rates of a Fluvial Population of Bull Trout in Oregon. TAFS 137:1709–1722.

Allen et al. 2010. Distribution and Movement of Bull Trout in the Upper Jarbidge River Watershed, Nevada. U.S. Geological Survey, Open-File Report 2010-1033.

Benjamin et al. 2007. Invasion by nonnative brook trout in Panther Creek, Idaho: Roles of local habitat quality, biotic resistance, and connectivity to source habitats. TAFS 136: 875–888.

Dunham & Rieman. 1999. Metapopulation structure of bull trout: Influences of physical, biotic, and geometrical landscape characteristics. Ecol. Appl. 9: 642–655.

Dunham et al. 2007. Influences of Wildfire and Channel Reorganization on Spatial and Temporal Variation in Stream Temperature and the Distribution of Fish and Amphibians. Ecosystems 10:335-346.

Eby et al. 2014. Evidence of Climate-Induced Range Contractions in Bull Trout Salvelinus confluentus in a Rocky Mountain Watershed, USA. PloS one 9.6 (2014): e98812.

Isaak & Hubert. 2004. Nonlinear response of trout abundance to summer stream temperatures across a thermally diverse montane landscape. TAFS 133: 1254-1259.

Isaak et al. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecol. Appl. 20:1350–1371.

Isaak et al. 2009. A watershed-scale monitoring protocol for bull trout. GTR-RMRS-224. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 25 p.

Peterson et al. 2013. Patch size but not short-term isolation influences occurrence of westslope cutthroat trout above human-made barriers. Ecology of Freshwater Fish. DOI: 10.1111/eff.12108.

Rieman et al. 2007. Anticipated climate warming effects on bull trout habitats and populations across the interior Columbia River basin. TAFS 136:1552–1565.

Rieman et al. 2006. Have brook trout displaced bull trout along longitudinal gradients in central Idaho streams? CJFAS 63:63–78.

Shepard et al. 2005. Status and conservation of westslope cutthroat trout within the western United States. NAJFM 25:1426–1440.

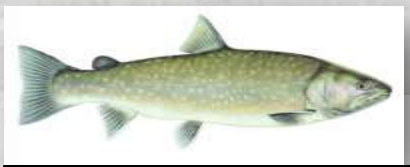
Wenger et al. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. PNAS 108:14175–14180.

Wenger et al. 2011. Role of climate and invasive species in structuring trout distributions in the Interior Columbia Basin, USA. CJFAS 68:988–1008.

Young et al. 2013. DNA barcoding at riverscape scales: assessing biodiversity among fishes of the genus Cottus (Teleostei) in northern Rocky Mountain streams. Molecular Ecology Resources 13:583–595.

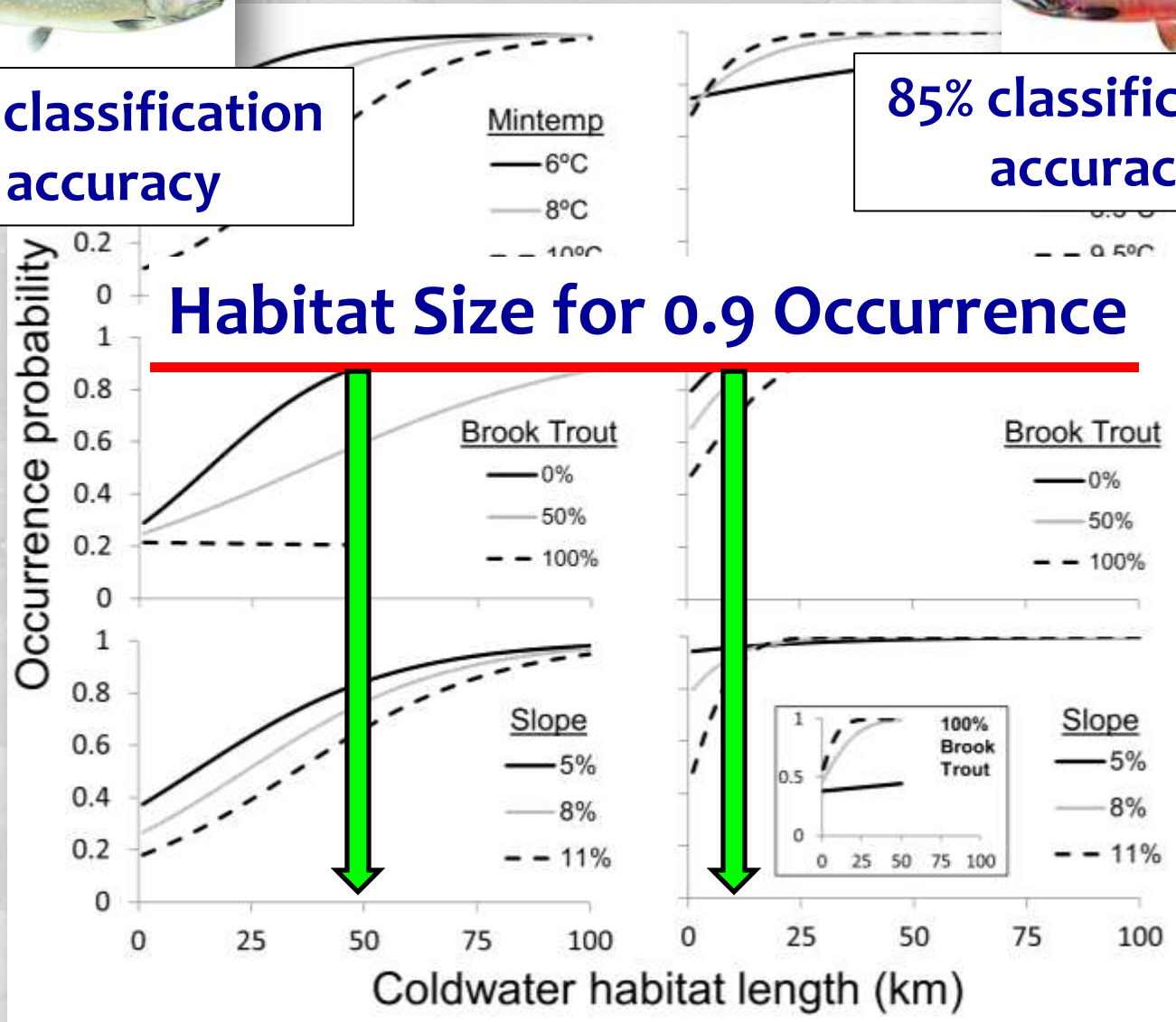
Species Response Curves from Logistic Regressions

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



78% classification accuracy

85% classification accuracy



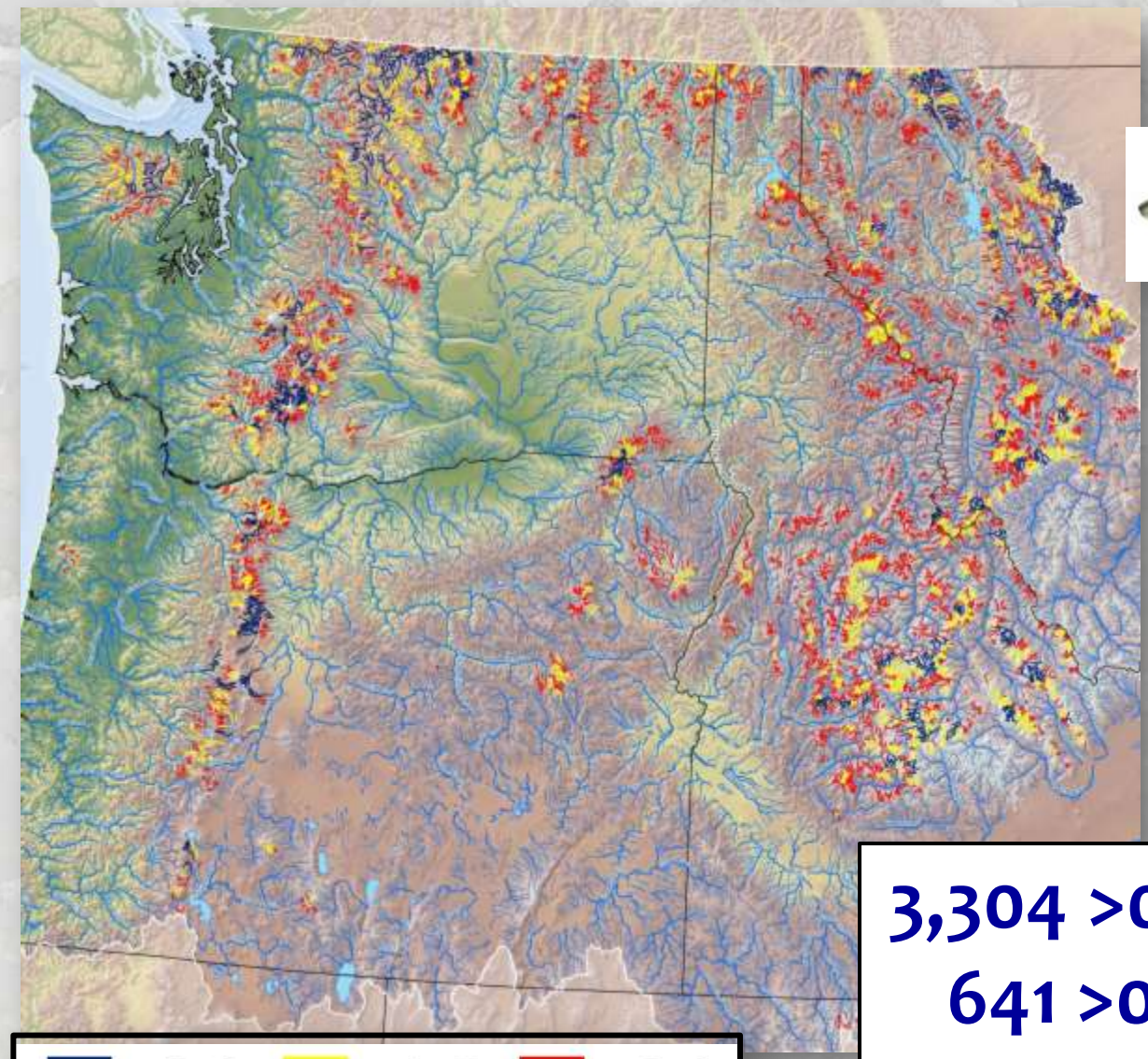
Species Occurrence Probability Map

1980s

>0.9 >0.5 >0.1

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

Species Occurrence Probability Map

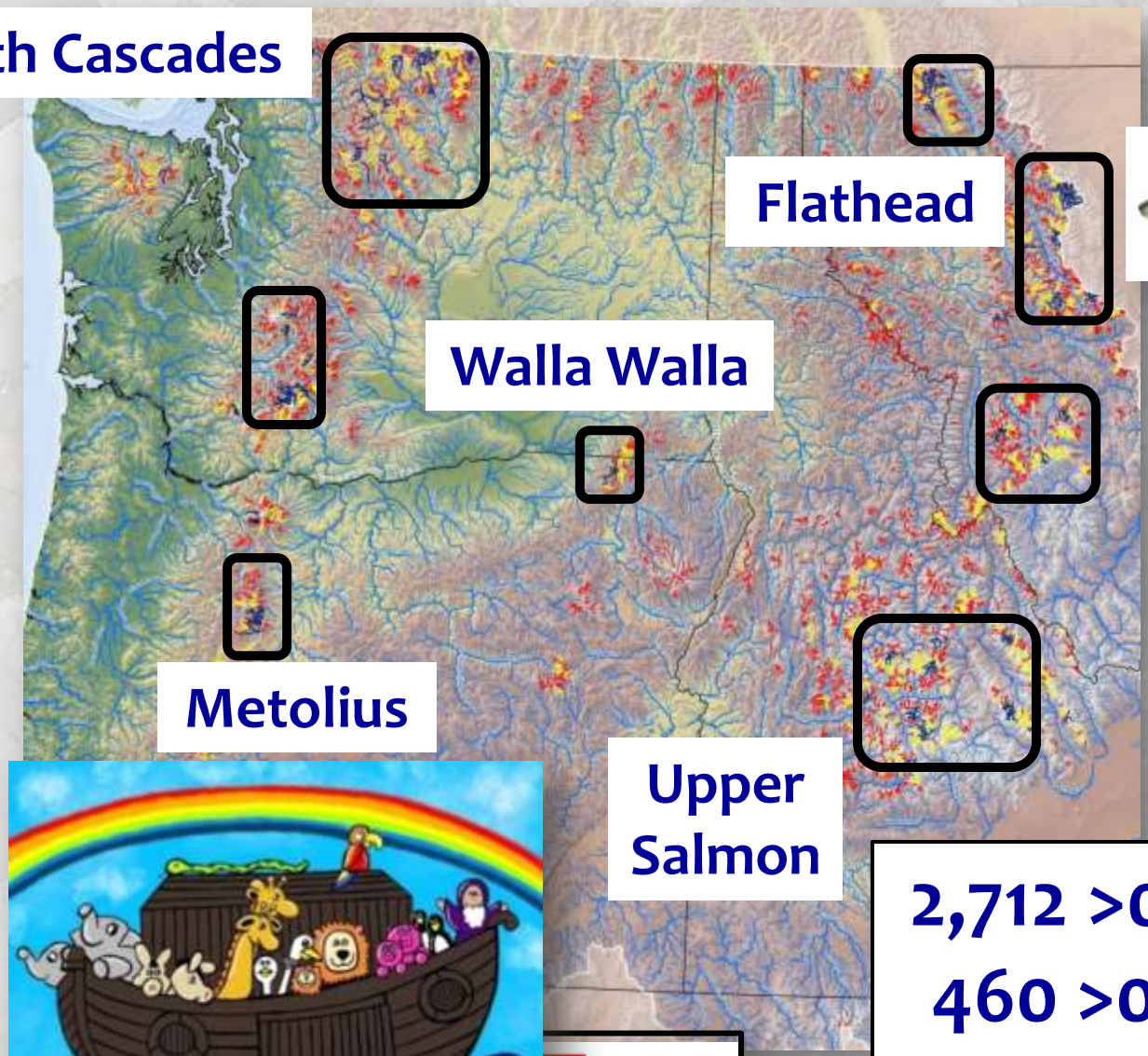


2040s

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

Species Occurrence Probability Map

2080s



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

About that Brook Trout Effect…

Number & Size of Refugia >0.9

	Period	Median size (km)	Refugia
Cutthroat Trout 	1980s	11	2,184
		10	1,425
		9	917
Bull Trout 		51	225
		54	68
	2080s	53	33

2x larger

How  =

About that Brook Trout Effect…

Number & Size of Refugia >0.9

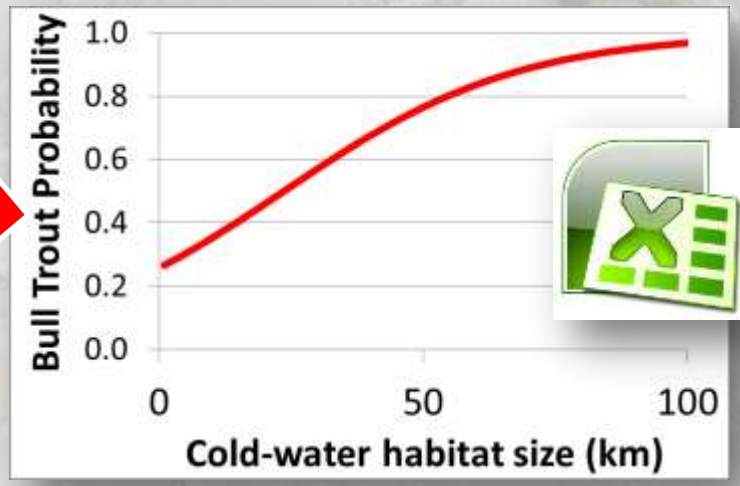
Period	Median size (km)	Refugia

Steeper & larger streams are invasion resistant

Brook Trout "What-If" Games…

Excel spreadsheet curve calculator

Predictor	b_x (SE)
Intercept	5.43
Size	0.0627
MinTemp	−0.632
Slope	−0.166
BKT	−0.00336
Size × BKT	−0.00064



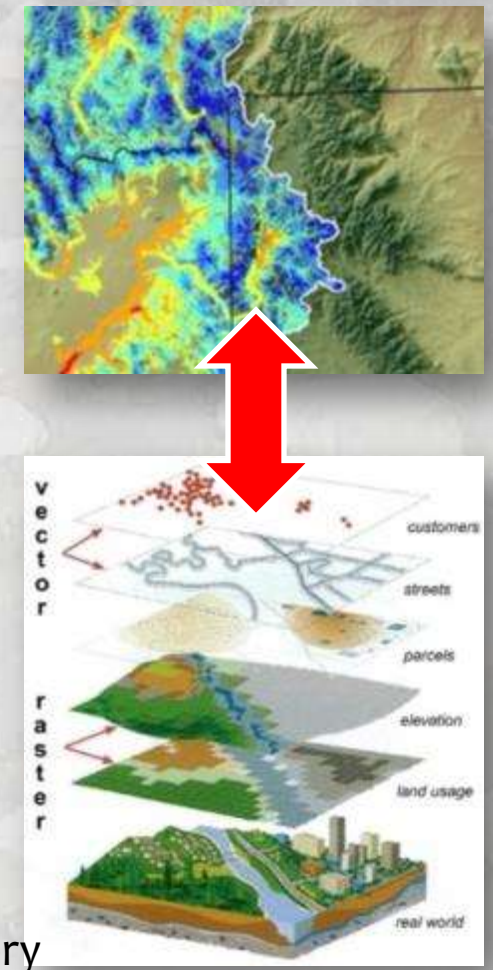
ArcGIS shapefile tables: scenarios for 0%/25%/50%/75%/100%

NorWeST	PATCH_ID	0%BRK	25%BRK	50%BRK	75%BRK	100%BRK
Clearwater	37	0.09	0.09	0.09	0.09	0.09
Clearwater	38	0.41	0.41	0.41	0.41	0.41
Clearwater	40	0.70	0.63	0.56	0.48	0.40
Clearwater	41	0.08	0.08	0.08	0.08	0.08
Clearwater	42	0.15	0.15	0.15	0.15	0.15
Clearwater	43	0.29	0.25	0.22	0.18	0.15
Clearwater	44	0.06	0.06	0.06	0.06	0.06

Land Administration GAP Analysis

<11°C streams in Bull Trout range

Land status	1980s	2080s
Private	5,580 (10.5)	1,099 (5.3)
Tribal	1,779 (3.4)	713 (3.4)
State/City	1,621 (3.1)	420 (2.0)
BLM	1,534 (2.9)	512 (2.5)
NPS	652 (1.2)	182 (0.9)
TNC	157 (0.3)	30 (0.1)
FS-wilderness	6,483 (12.2)	2,854 (13.8)
FS-nonwilderness	34,068 (64.3)	14,575 (70.2)
Other	1,093 (2.0)	367 (1.8)
Totals:	52,966	20,752



>90% on public lands

<15% protected in Wilderness or National Parks

Gergely and McKerrow 2013. PAD-US—National inventory of protected areas: U.S. Geological Survey. http://pubs.usgs.gov/fs/2013/3086/

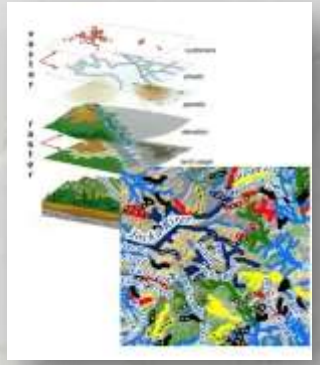
Open Access Information…

Climate Shield website:

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

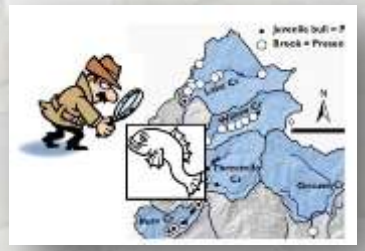
Presentations & Publications

Digital Maps & ArcGIS Shapefiles



Fish Data Sources

Distribution Monitoring

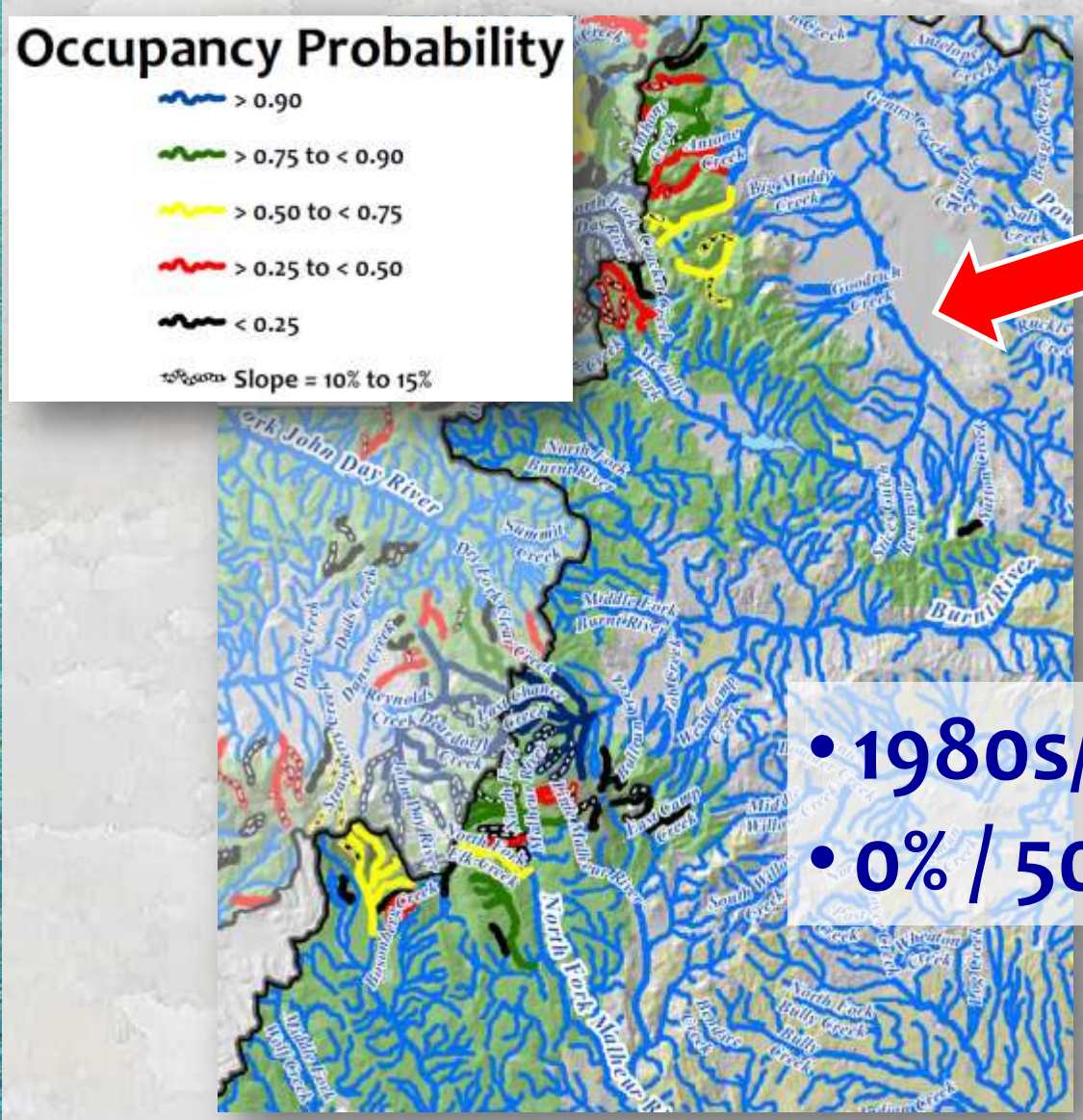


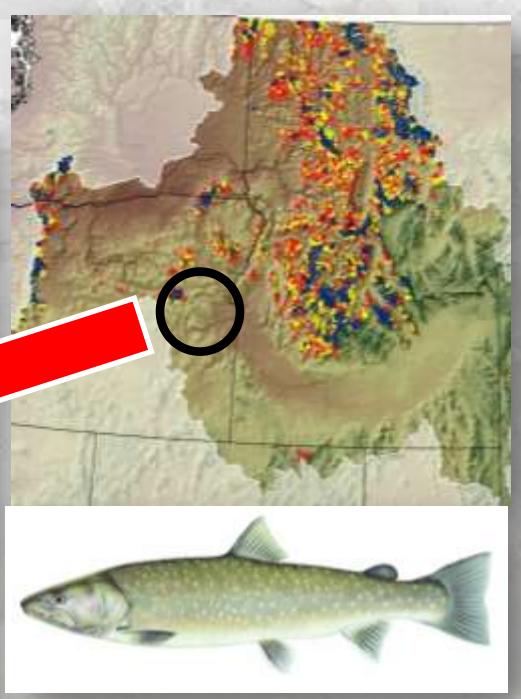
"User's Guide" (Peer-Reviewed Publication)

Isaak, D., M. Young, D. Nagel, D. Horan, and M. Groce. 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

Bull Trout Occurrence Probability Map

Malheur Specific Posters





- 1980s/2040s/2080s
- 0% / 50% BKT

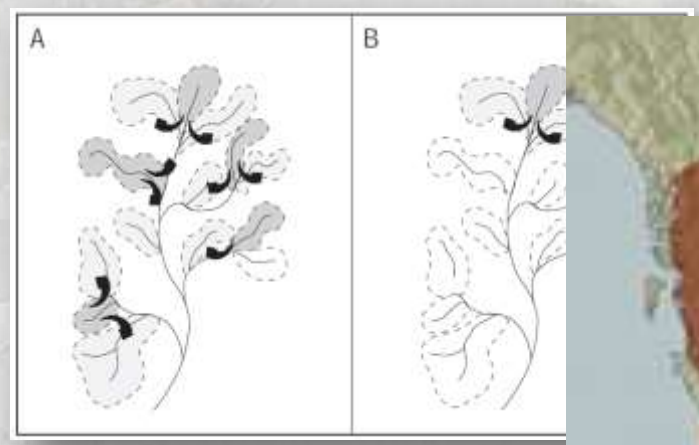
Bottom Lines for Malheur Bull Trout:

1) Make some habitats as BIG & healthy & connected as possible

2) Keep brook trout out

3) Reduce wildfire risks

4) Make tough choices & intelligent trade-offs



Aquatic eDNA frontier

USFS National Genomics Center for Wildlife & Fish Conservation

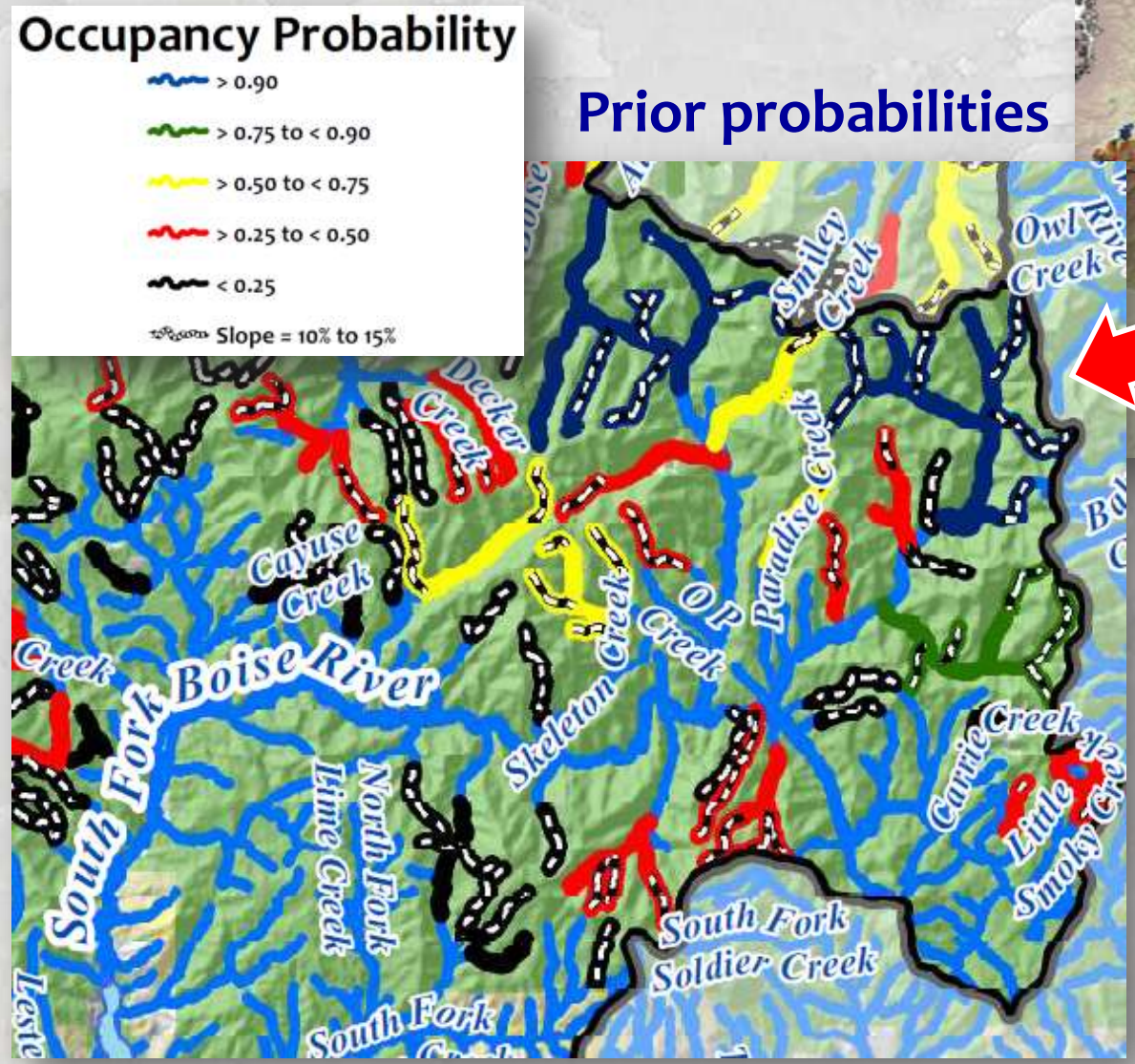
- Pioneered the technique for salmonids
- Species specific, highly reliable (1 trout / 100 m = 85% detection)
- Field-proven protocol
- Cost: $65 sample

Mike Schwartz
Kevin McKelvey
Mike Young

Google the website:
http://www.fs.fed.us/research/genomics-center/

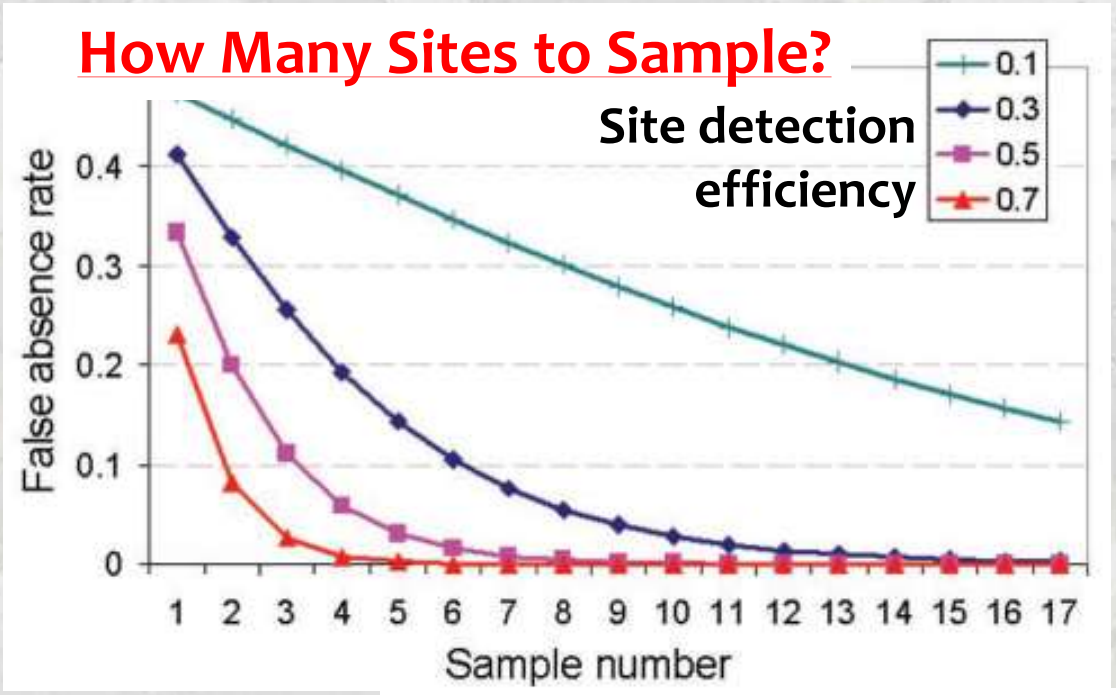
eDNA Applications…

Do bull trout live here?

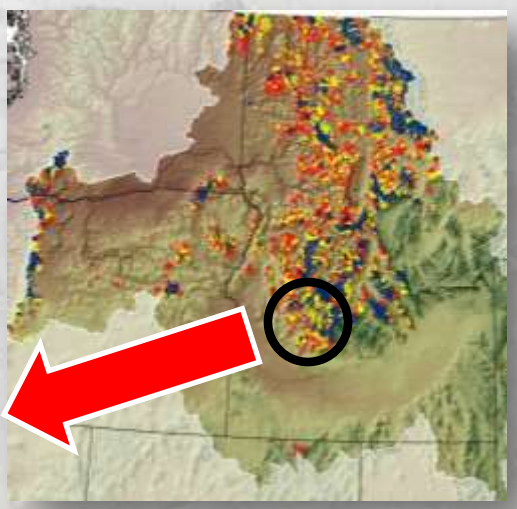


eDNA Applications…

Do bull trout live here?



Peterson & Dunham 2003



Detection >0.7

Detection = 0.52

Did we get all the bad guys?

Non-native Removals & Early Invasion Detections

Who all lives here?

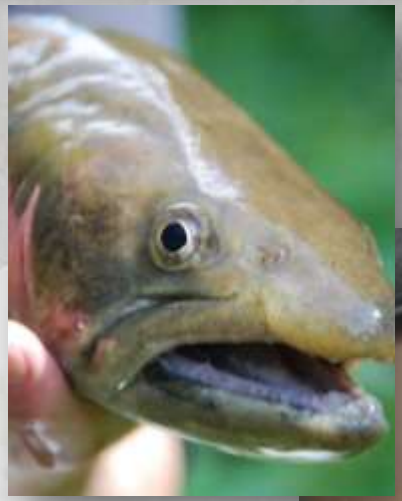
Building a biodiversity archive

Markers for…

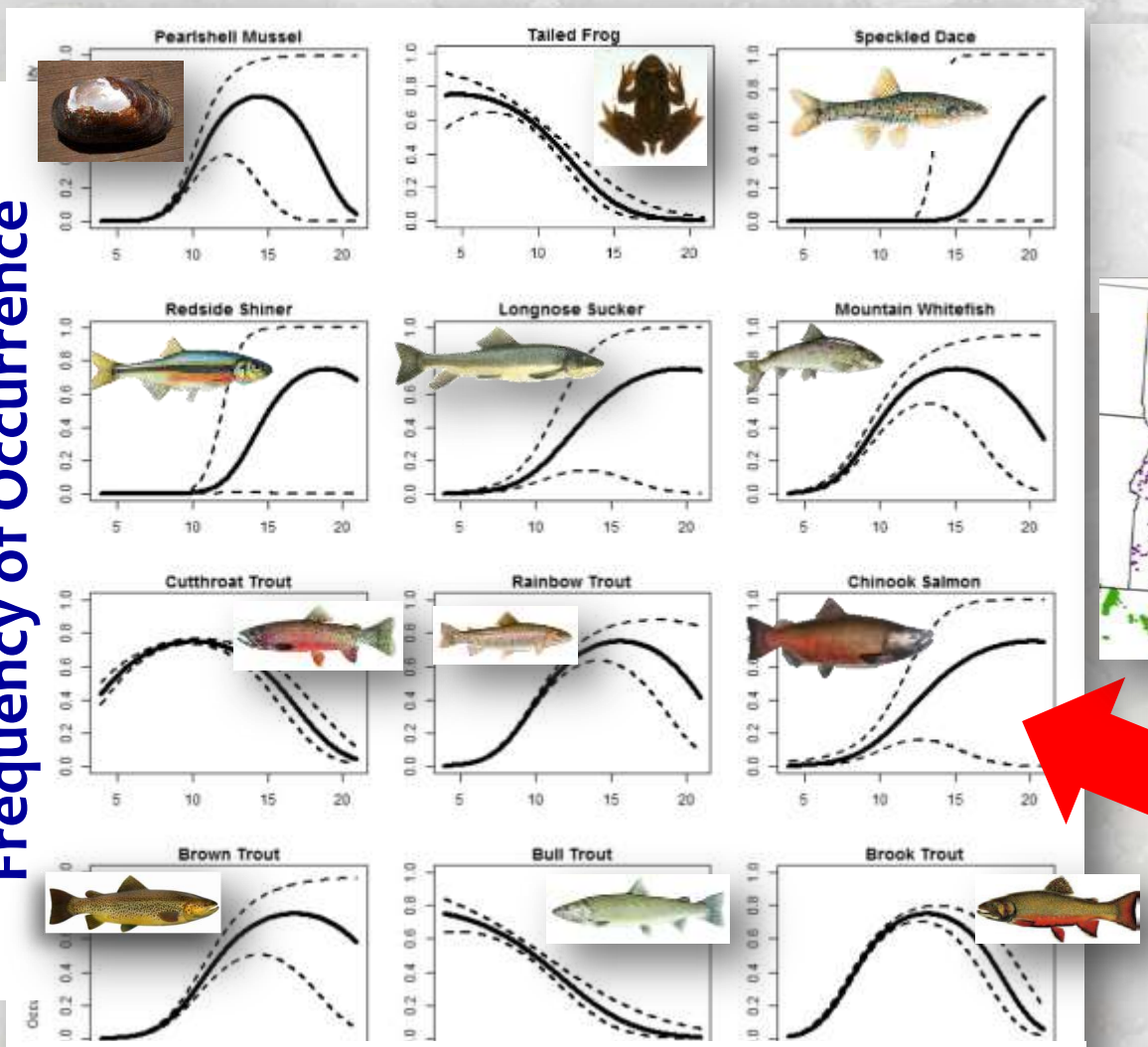
- All salmonids
- River otter
- Lamprey
- Etc…

New markers…

- Cost: $5,000/species



We Can Describe Their World Too…



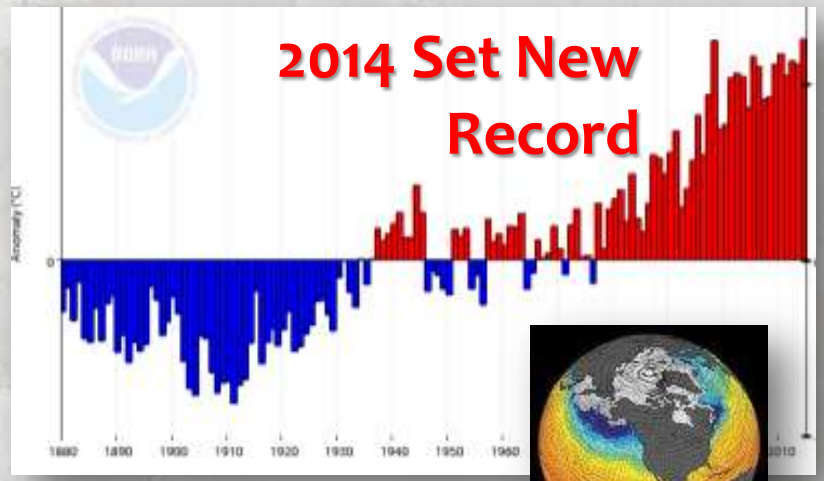
BIG DATA aquatic surveys

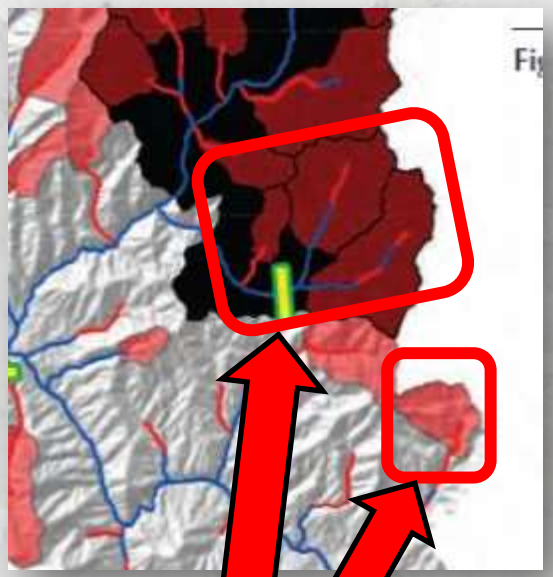
A revolution is happening

Wenger et al. *In Preparation.* Description of realized thermal niches using massive biological and temperature databases.

Good Information for Strategic Decision Making Will be Critical

The 21st-Century will Be a Transitional One





I'm going to invest here…

…not here