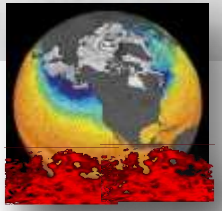
The Cold-Water Climate Shield

Delineating Refugia for Preserving Native Trout

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

US Forest Service - RMRS

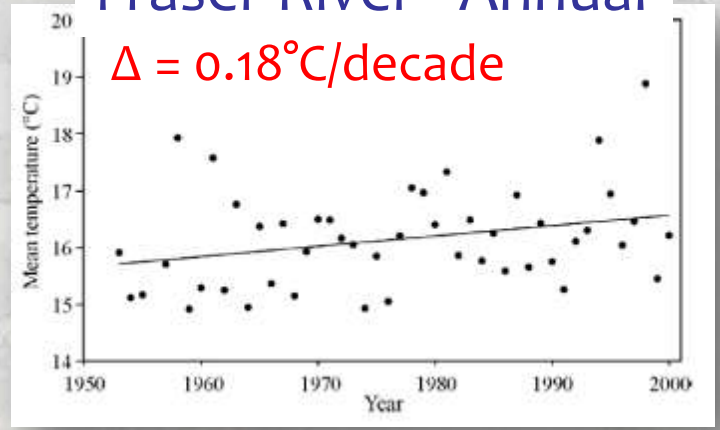


Rocky Mountain Research Station

Boise Spatial Streams Group

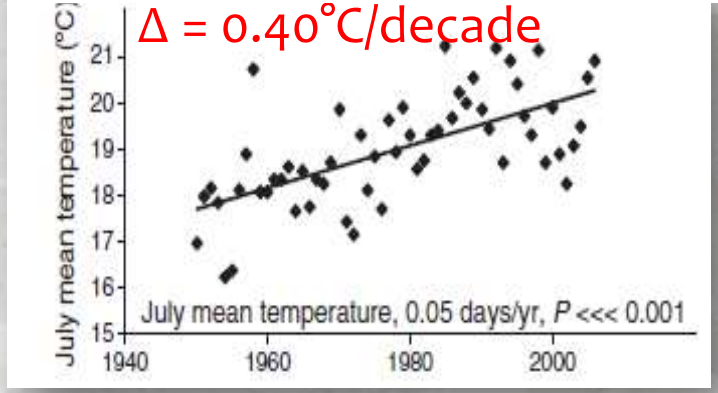
Temperature Trends In Northwest Rivers

Fraser River - Annual



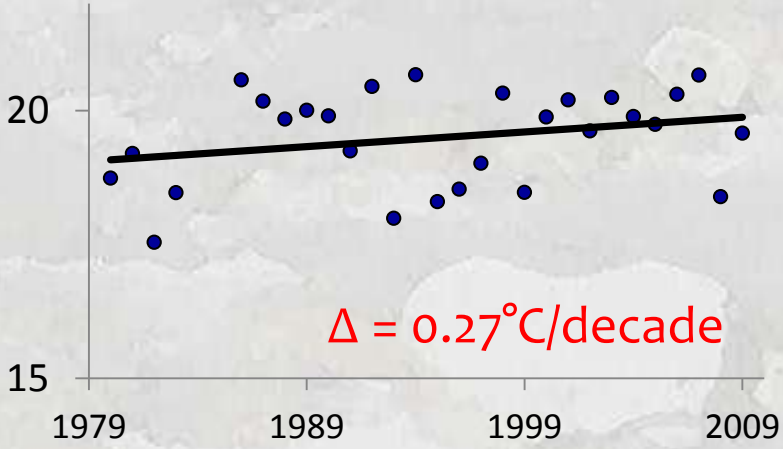
Morrison et al. 2001

Columbia River - Summer

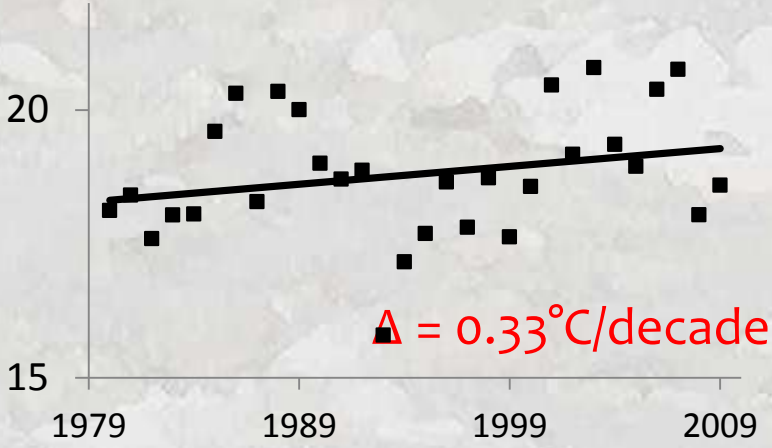


Crozier et al. 2008

Snake River, ID - Summer



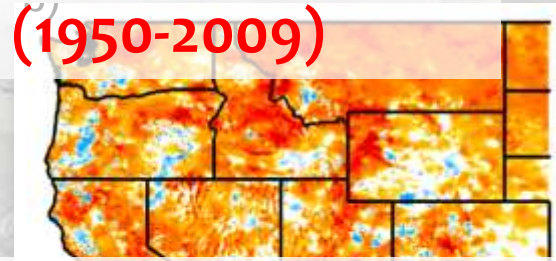
Missouri River, MT - Summer

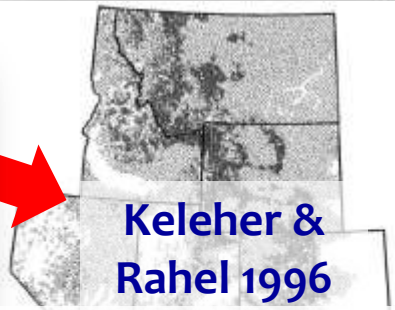


Isaak et al. 2012. *Climatic Change* **113**:499-524.

Future Climates Will Challenge Coldwater Fishes…

Air Temp trends (1950-2009)



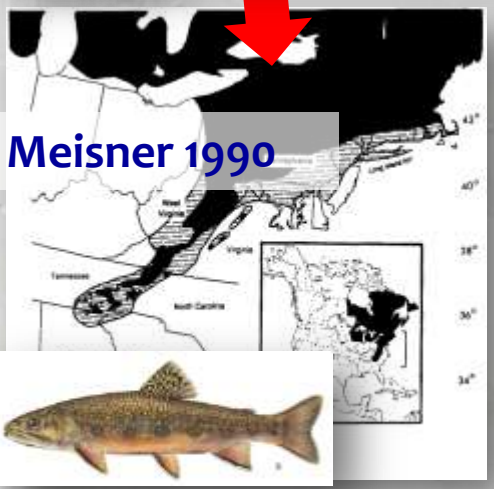


Keleher & Rahel 1996

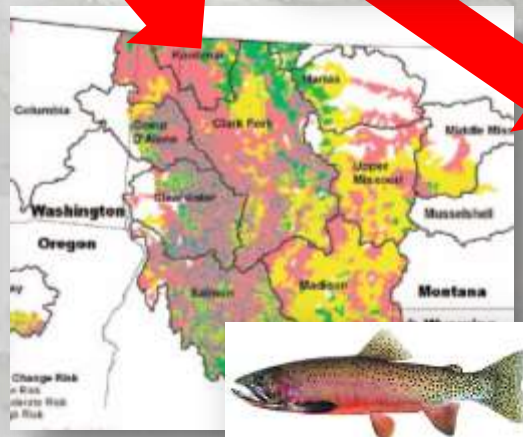
Many Others…

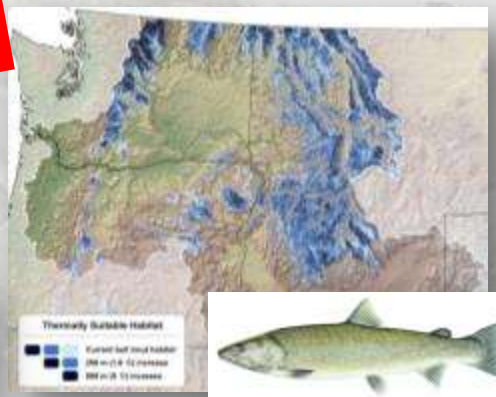
- Eaton & Schaller 1996
- Reusch et al. 2012
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.

20%-100% Declines



Meisner 1990

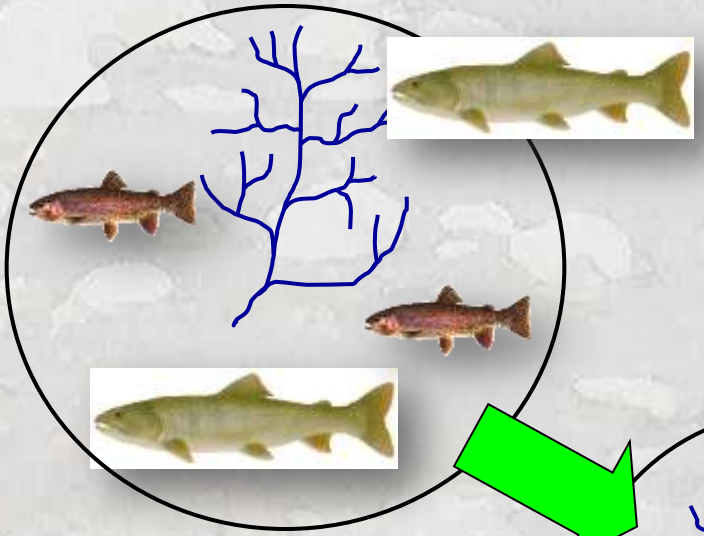


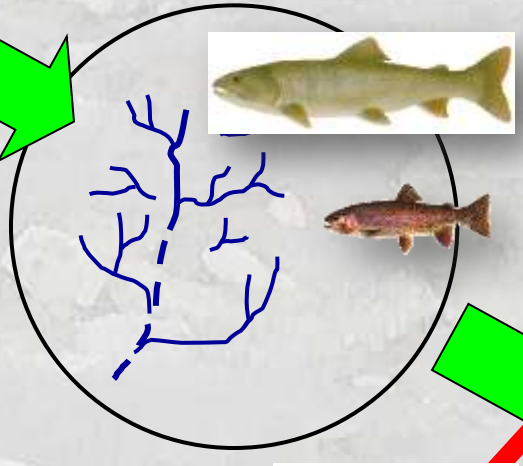


Invasive Species Compound Matters

Resistance Will Be Futile Sometimes

Not Everything Can be Saved



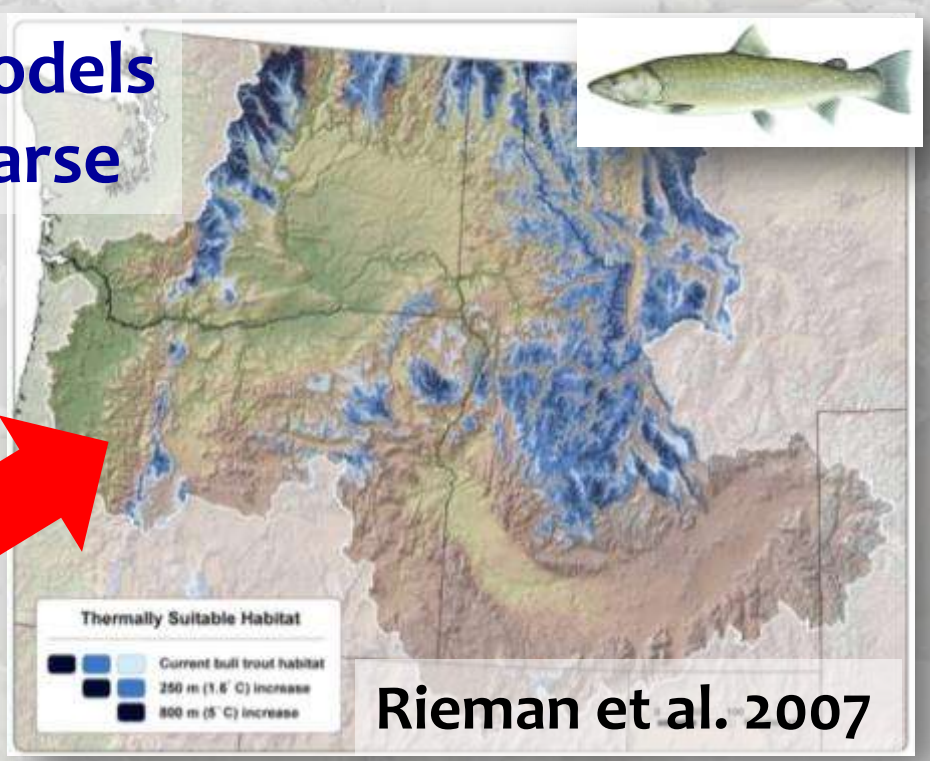


Thresholds Beyond Which Populations Become "Walking Dead"

Sorry Charlie

Precise Information for Tactical Decision Making…

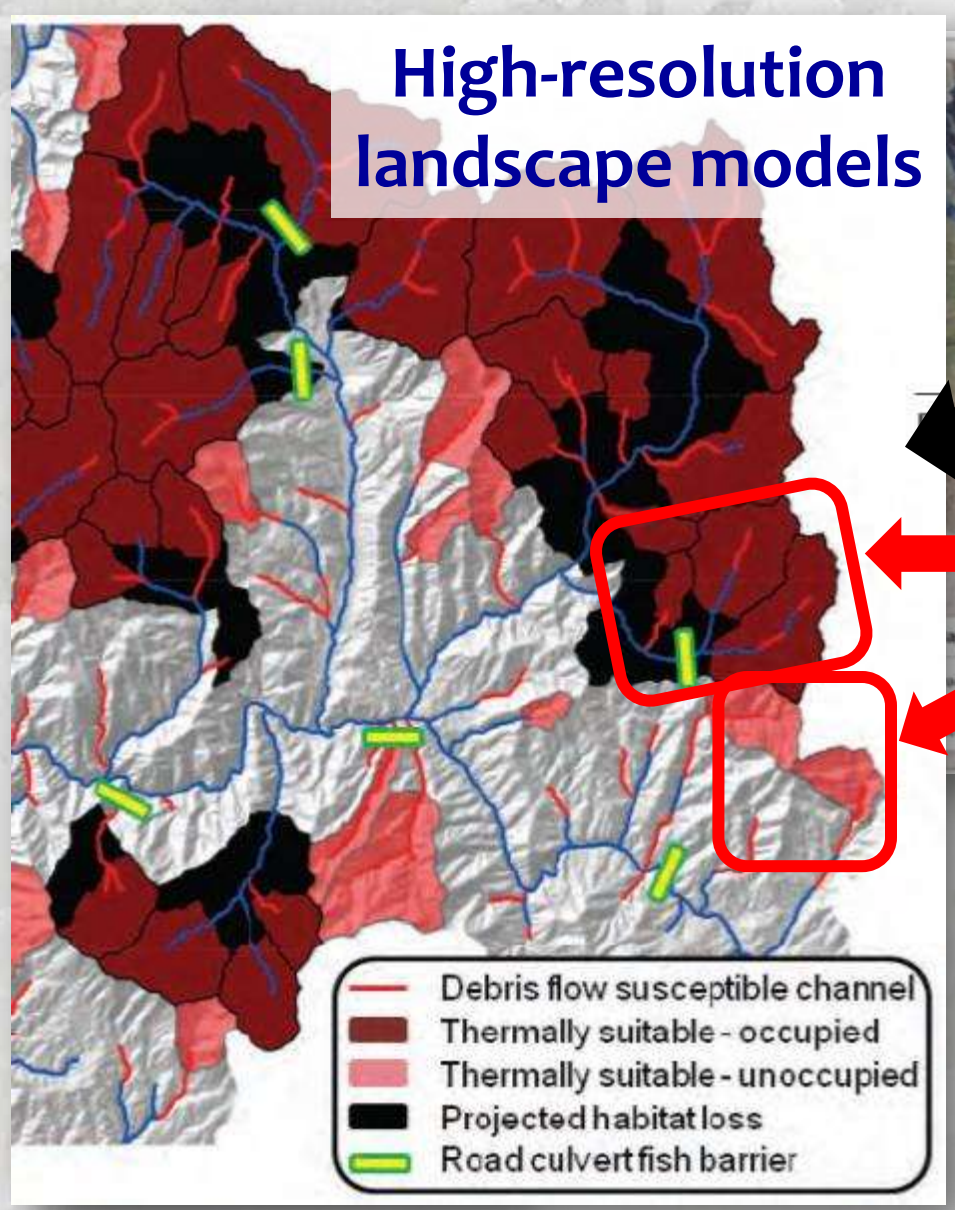
Previous models are too coarse



Rieman et al. 2007

Not Good Enough for Zombie Detection

Precise Information for Tactical Decision Making…

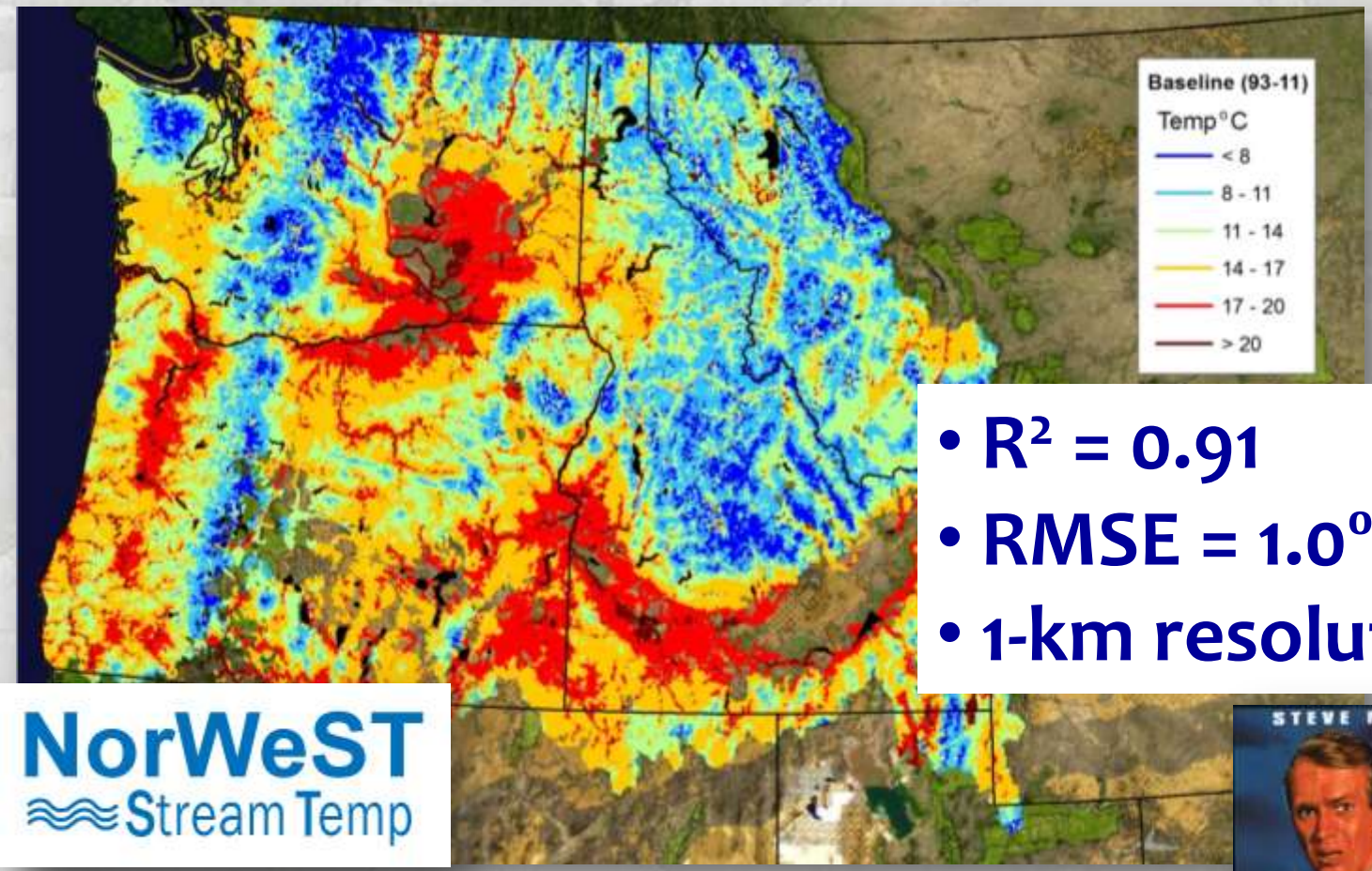


I'm going to invest here…

… instead of here

Strategic Information for Context

PNW Temperature Scenarios Done!



- R^2 = 0.91
- RMSE = 1.0°C
- 1-km resolution

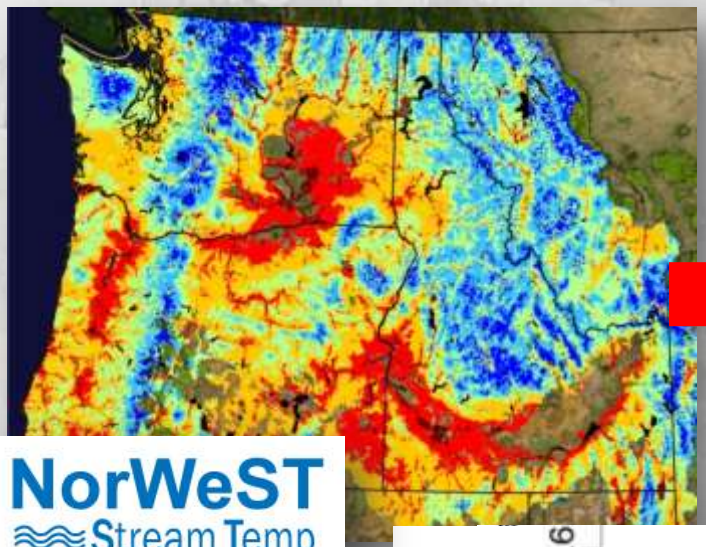
NorWeST Stream Temp

The BLOB ate Everything…

- 46,674 summers of data swallowed
- 467,000 stream kilometers of thermal ooze

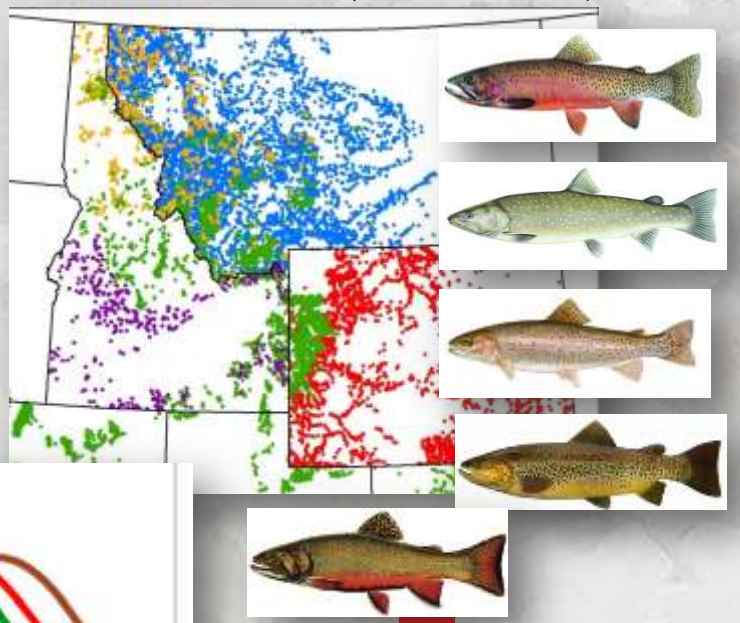
Temperature is a Master Variable for Species Distributions…

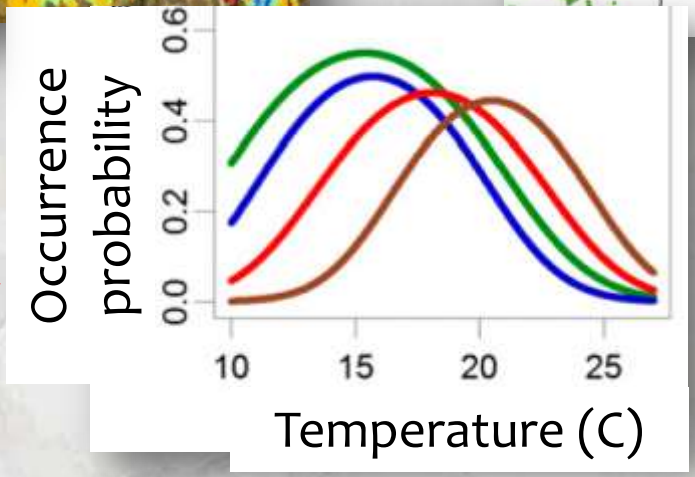
Stream temperature maps



NorWeST Stream Temp

Regional fish survey databases (n ~ 13,000)

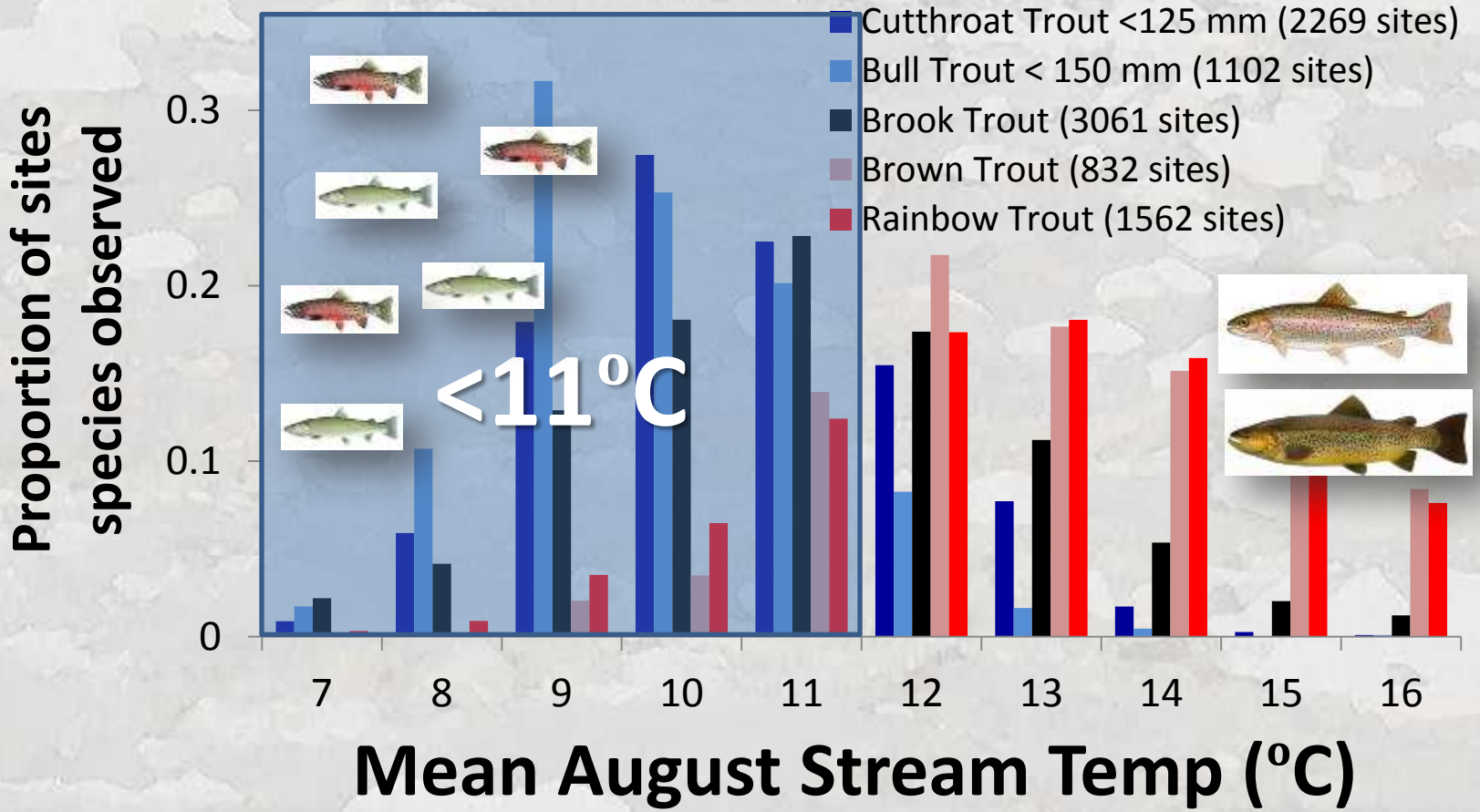




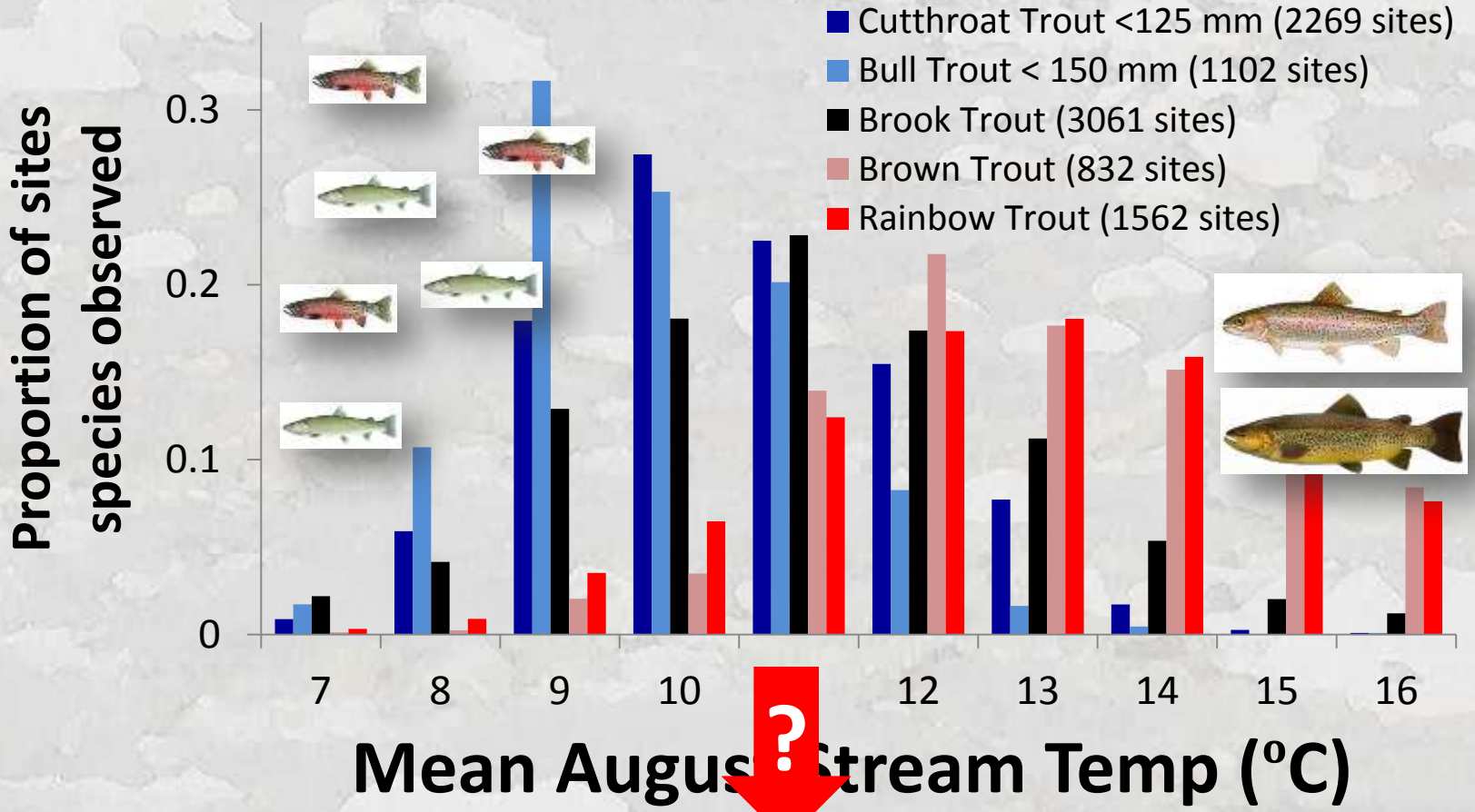
Wenger et al. 2011a. *PNAS* **108**:14175-14180

Wenger et al. 2011b. *CJFAS* **68**:988-1008; Wenger et al., *In Preparation*

Cold Climates Exclude Most Invaders from Key Natal Habitats

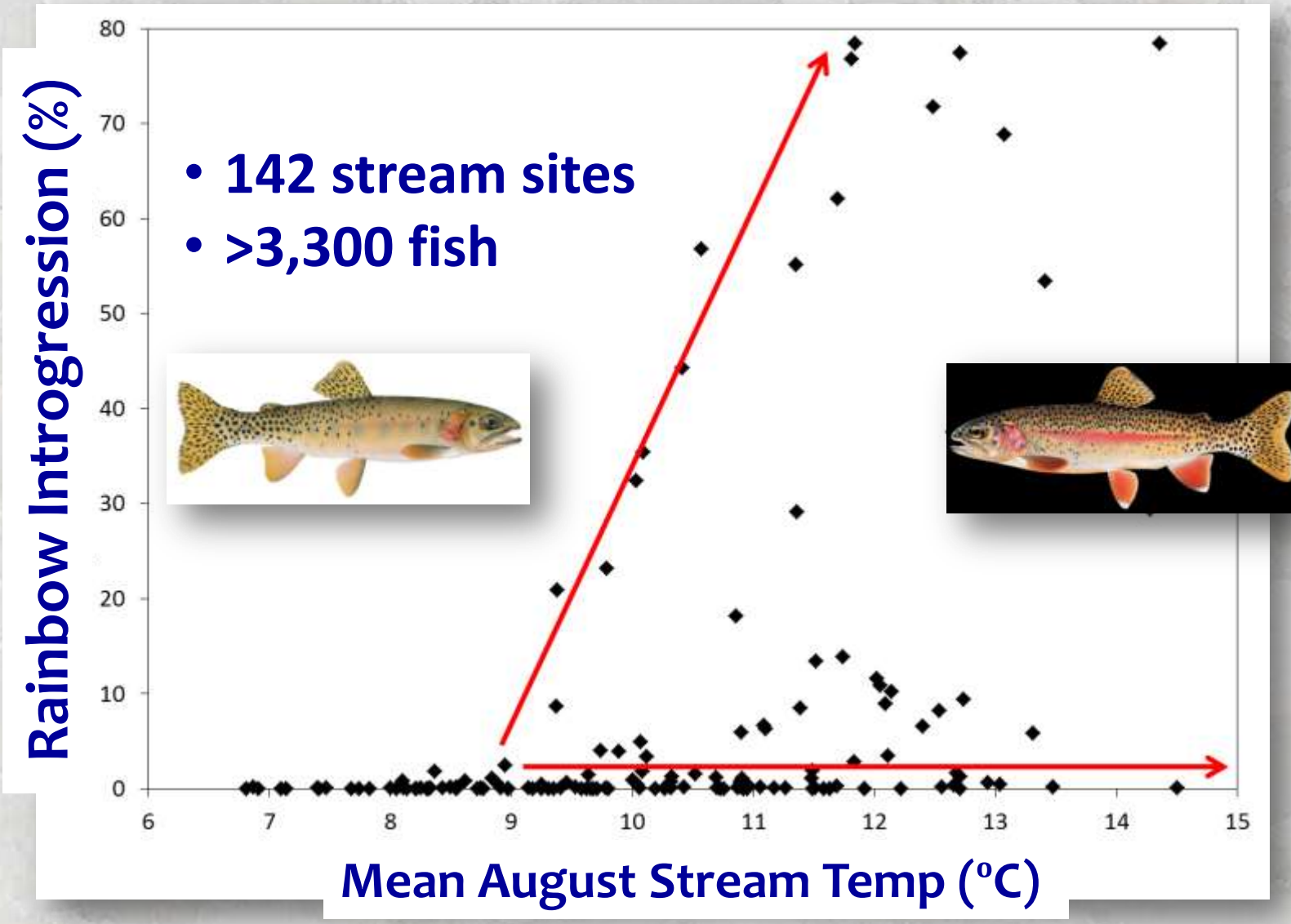


Cold Climates Exclude Most Invaders from Key Natal Habitats



BEWARE THE INVASION

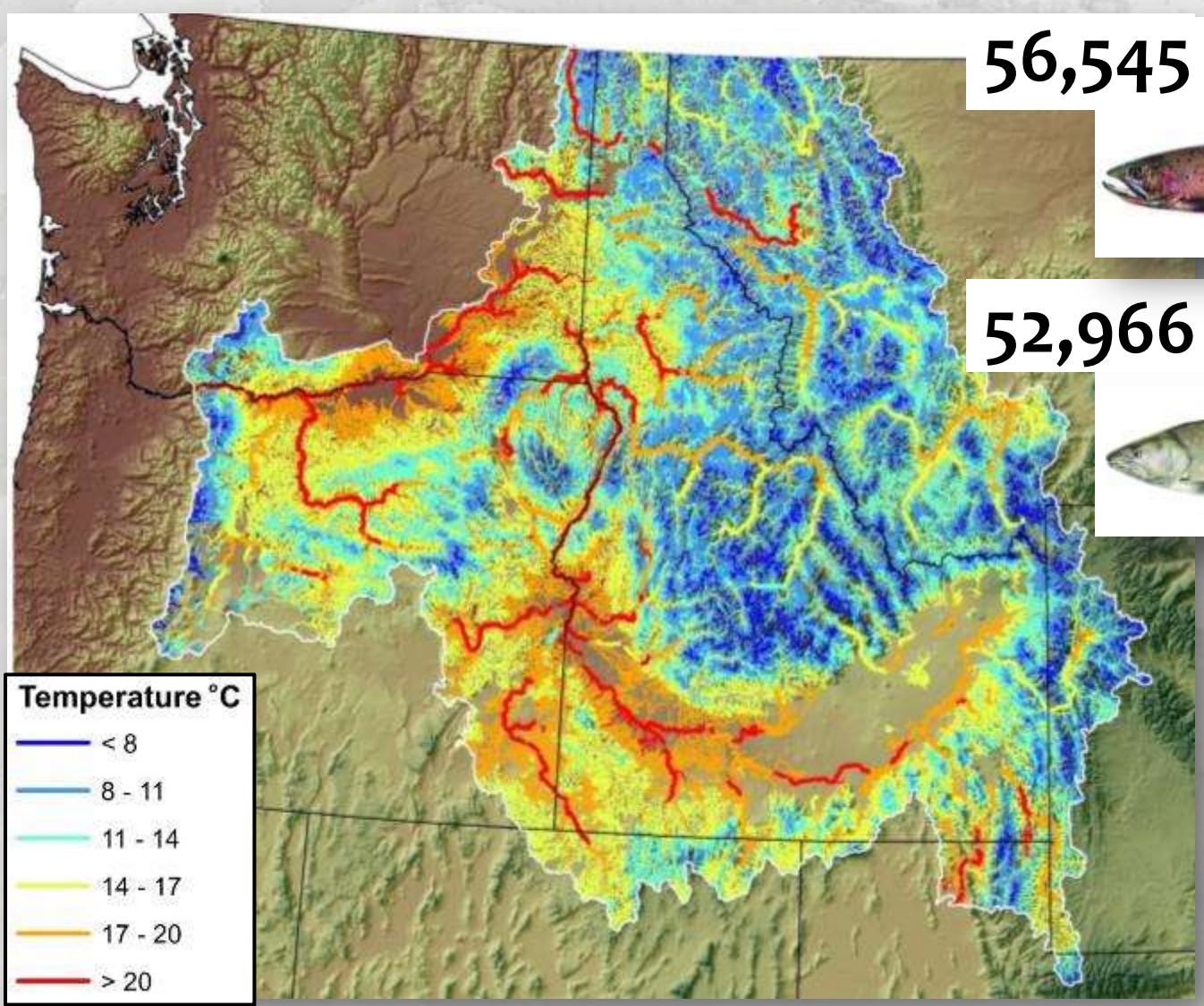
Cold Climates Exclude Most Hybrids



Young et al., In prep.

<11°C Streams (1980s) & <15% slope

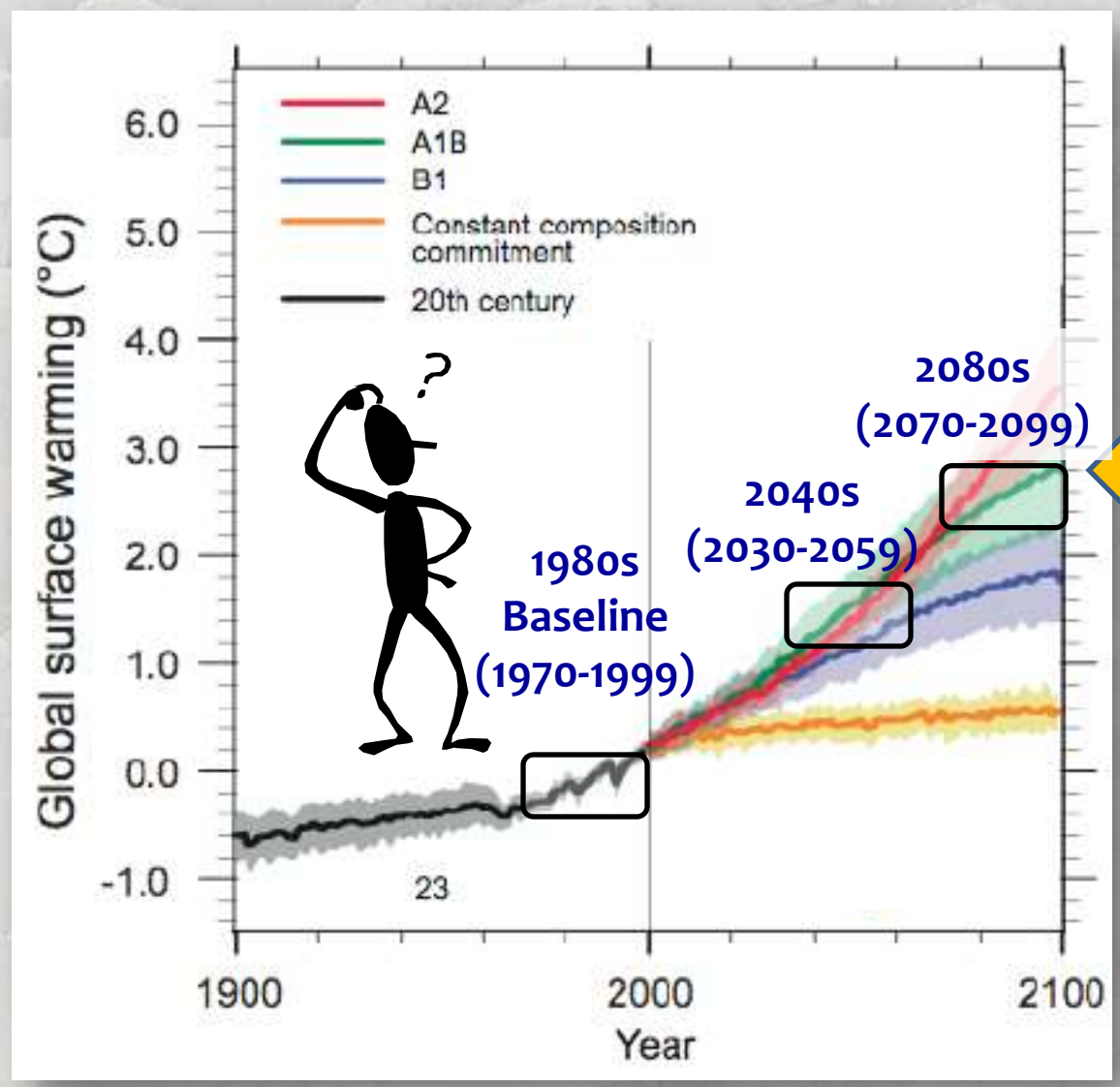
70,335 / 259,052 stream kilometers in analysis area



56,545 km

52,966 km

Future Changes in Stream Temperature?



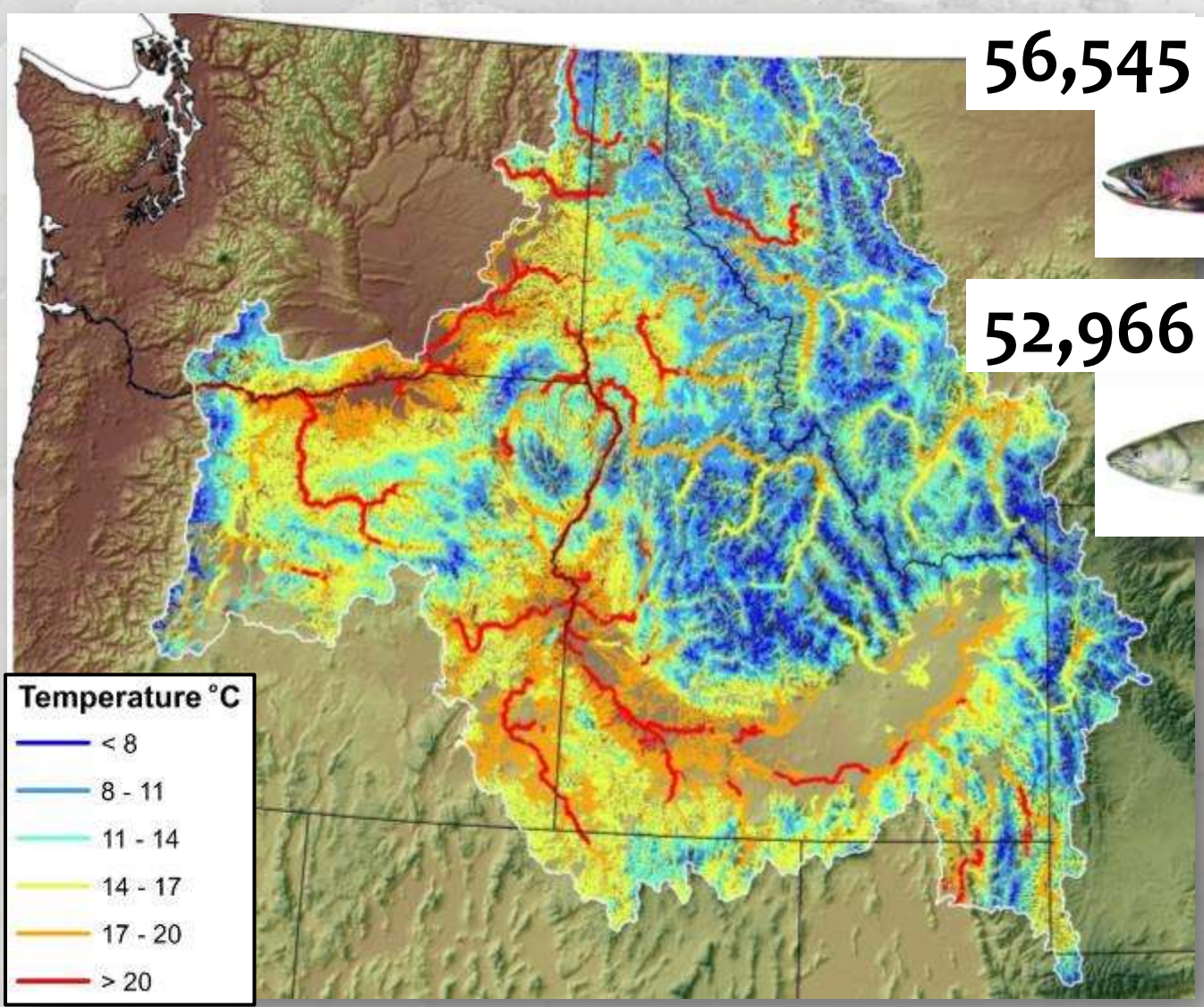
A1B

The Specifics are an "Unknowable Unknown"

Just plan on it gradually getting warmer…

<11°C Streams (1980s)

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

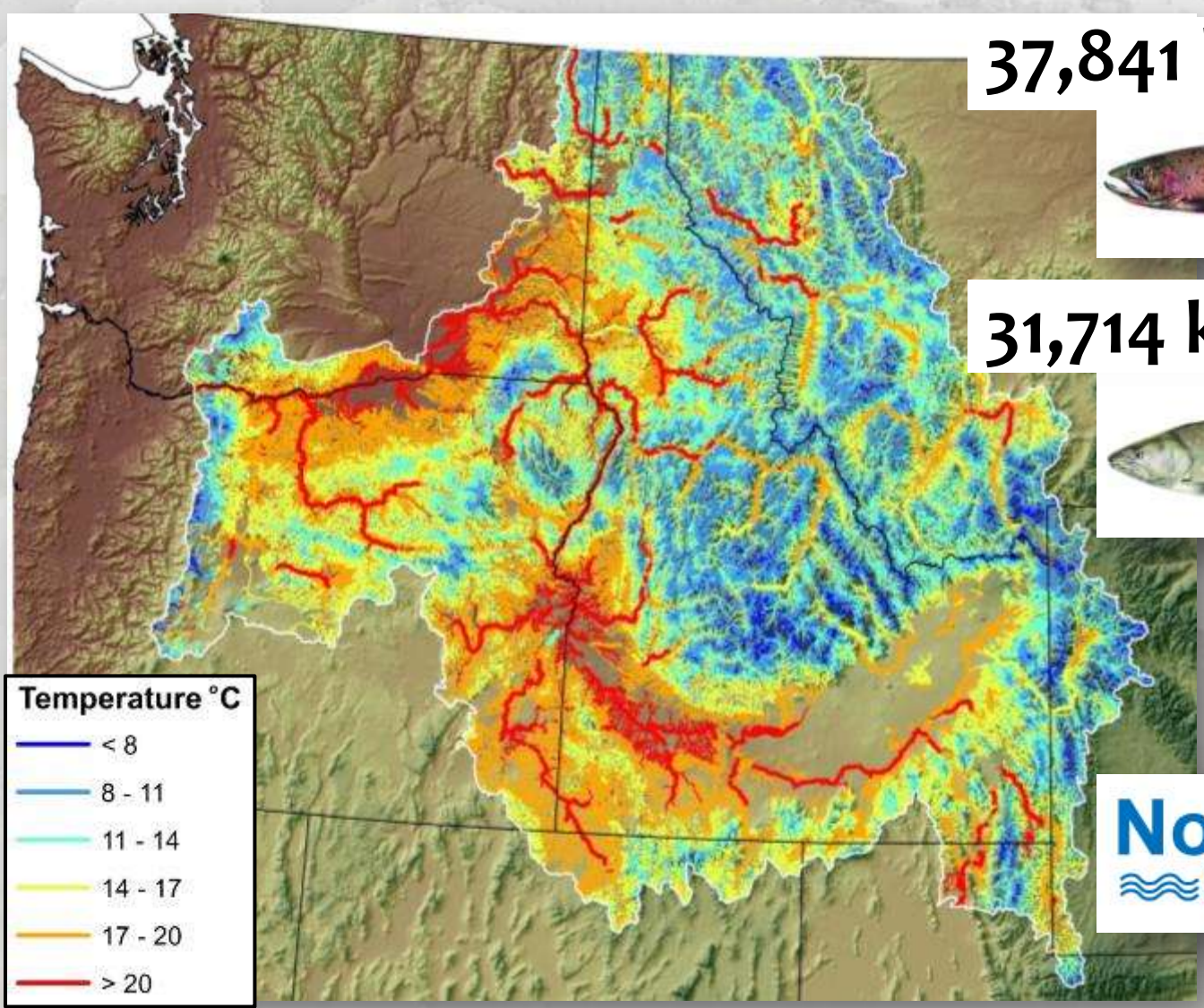


56,545 km

52,966 km

<11°C Streams (2040s)

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



37,841 km

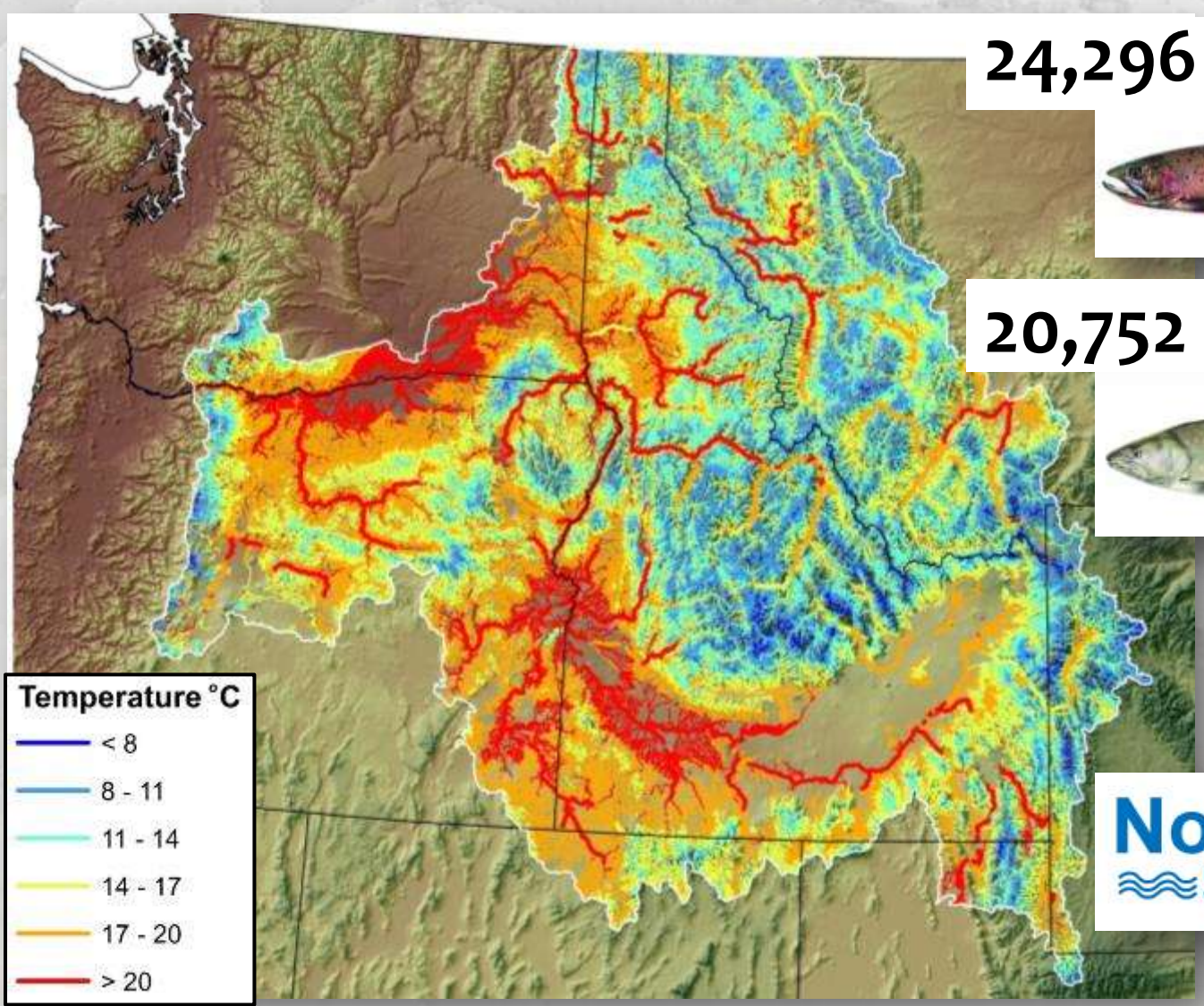
31,714 km

+1.3°C

NorWeST Stream Temp

<11°C Streams (2080s)

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

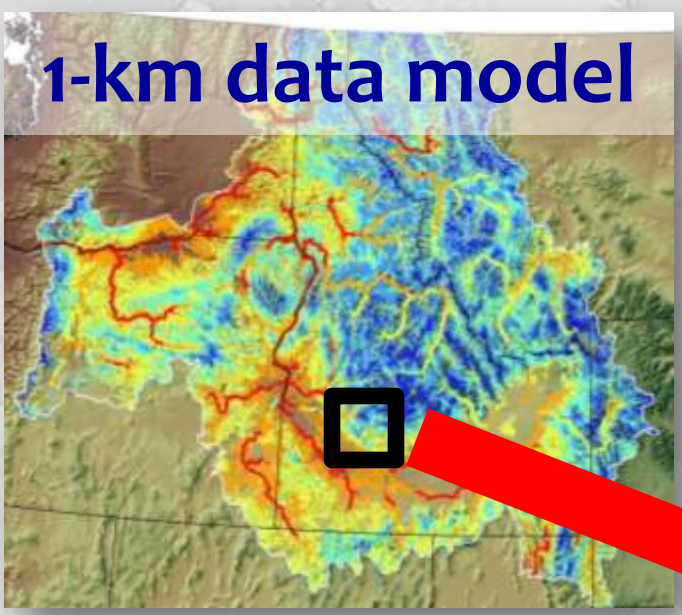


24,296 km

20,752 km

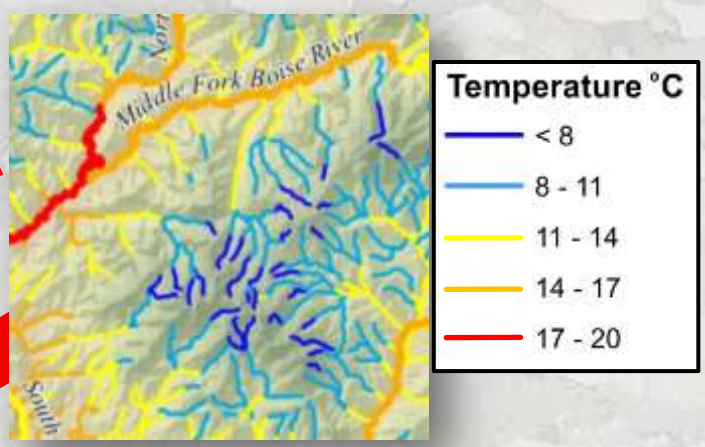
+2.1°C

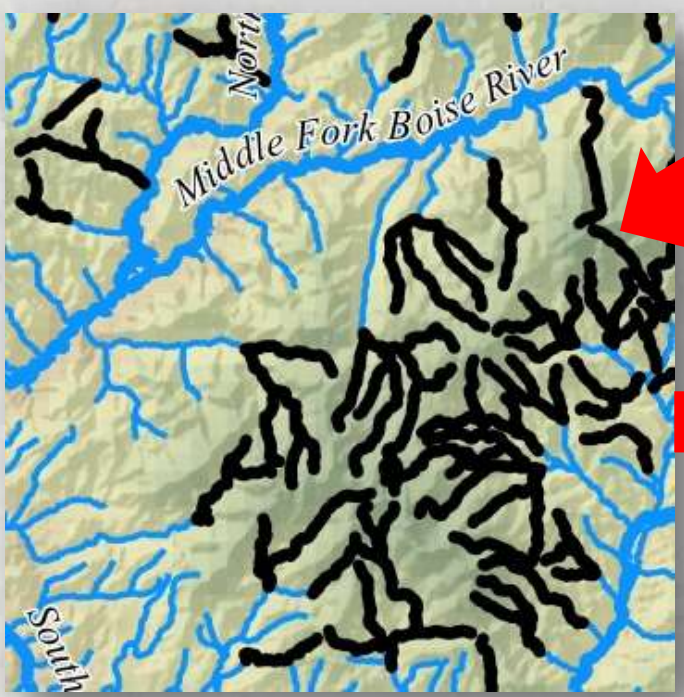
NorWeST Stream Temp



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

Cold-Water Habitats Used for Species Occurrence Models

Present Absent

Fish sites = 3,655
Patches = 566

Fish sites = 4,506
Patches = 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.

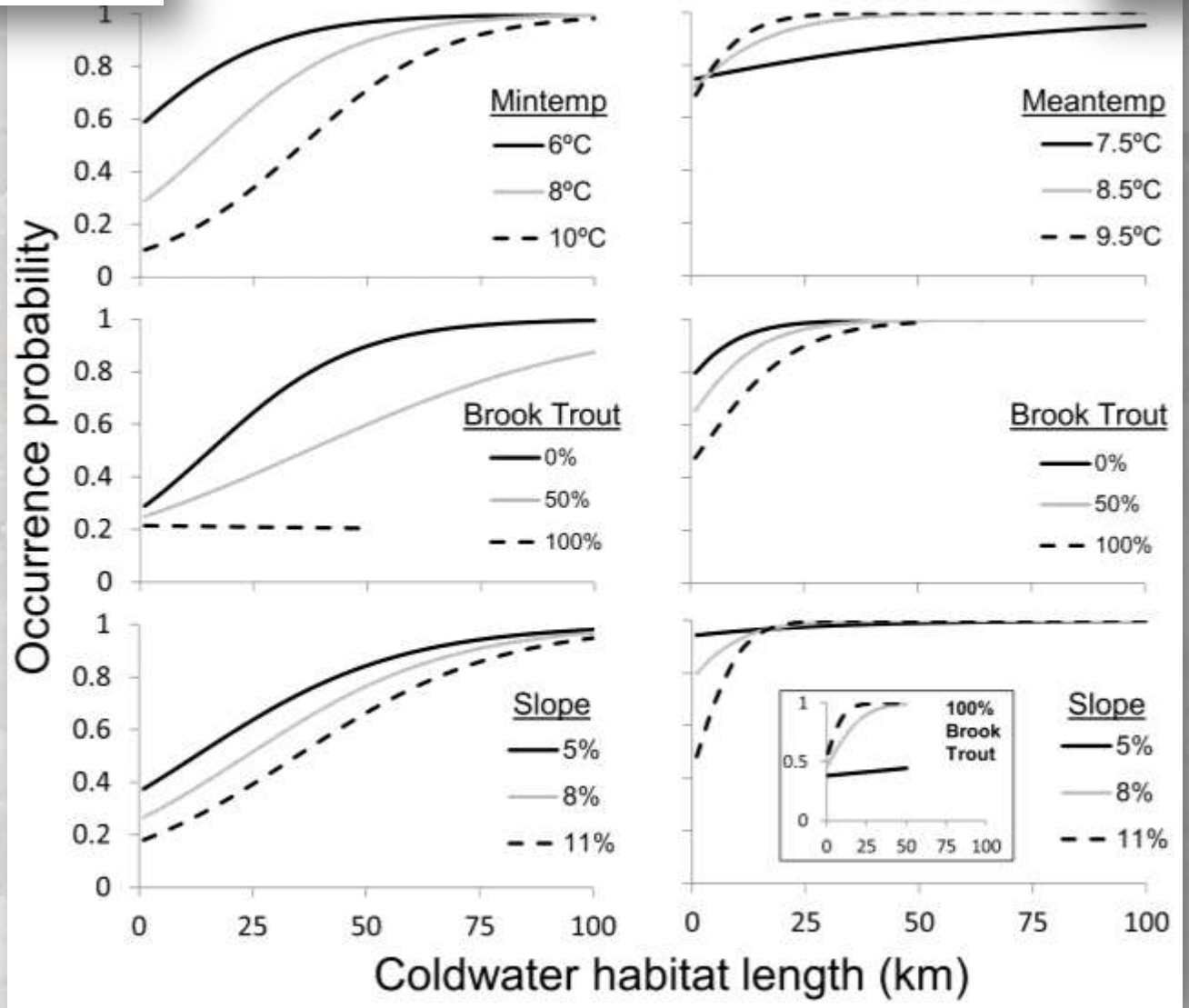
Young et al. 2013. DNA barcoding at riverscape scales: assessing biodiversity among fishes of the genus Cottus (Teleostei) in northern Rocky Mountain streams. Molecular Ecology Resources 13:583–595.

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



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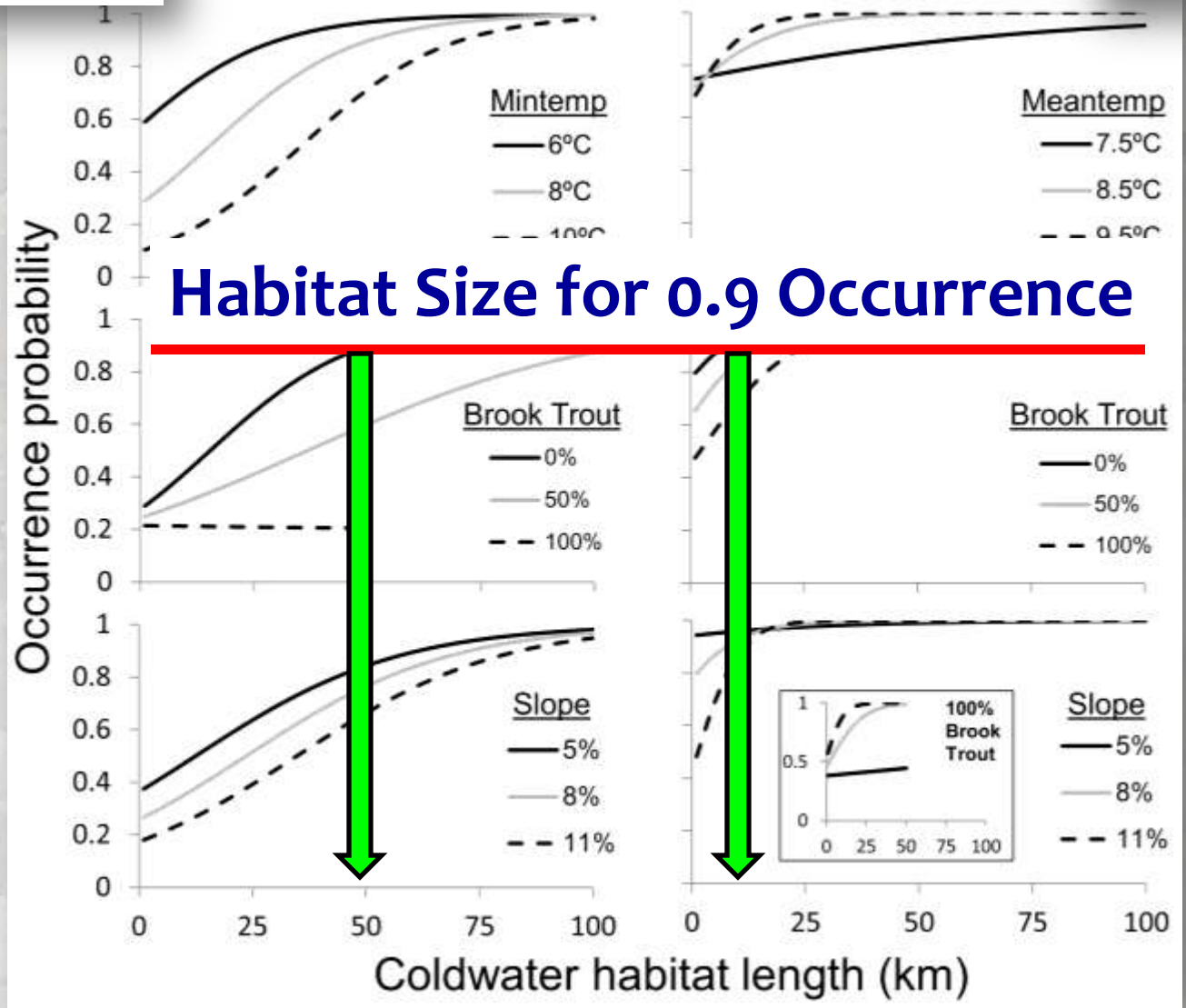
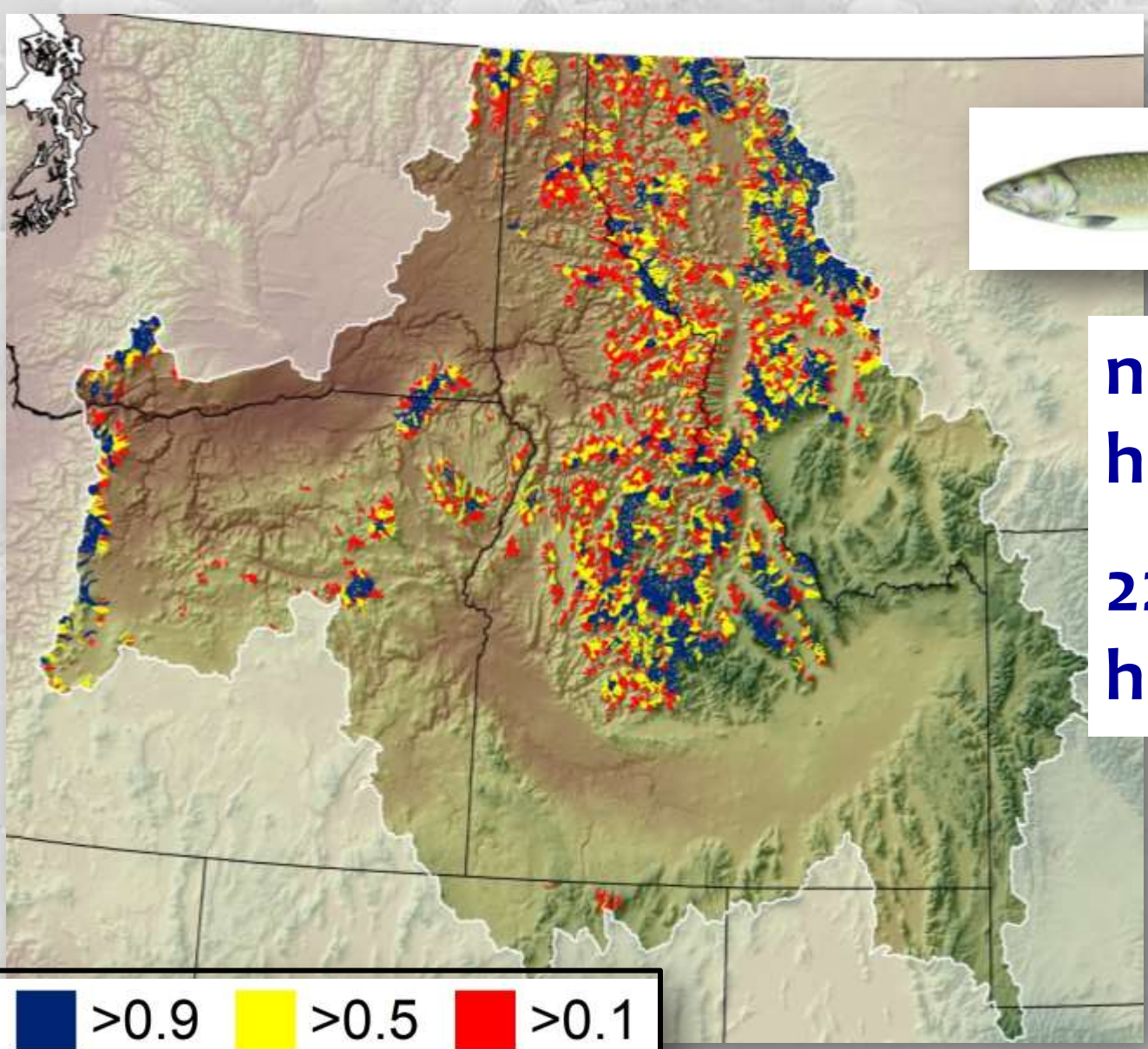


Species Occurrence Probability Map

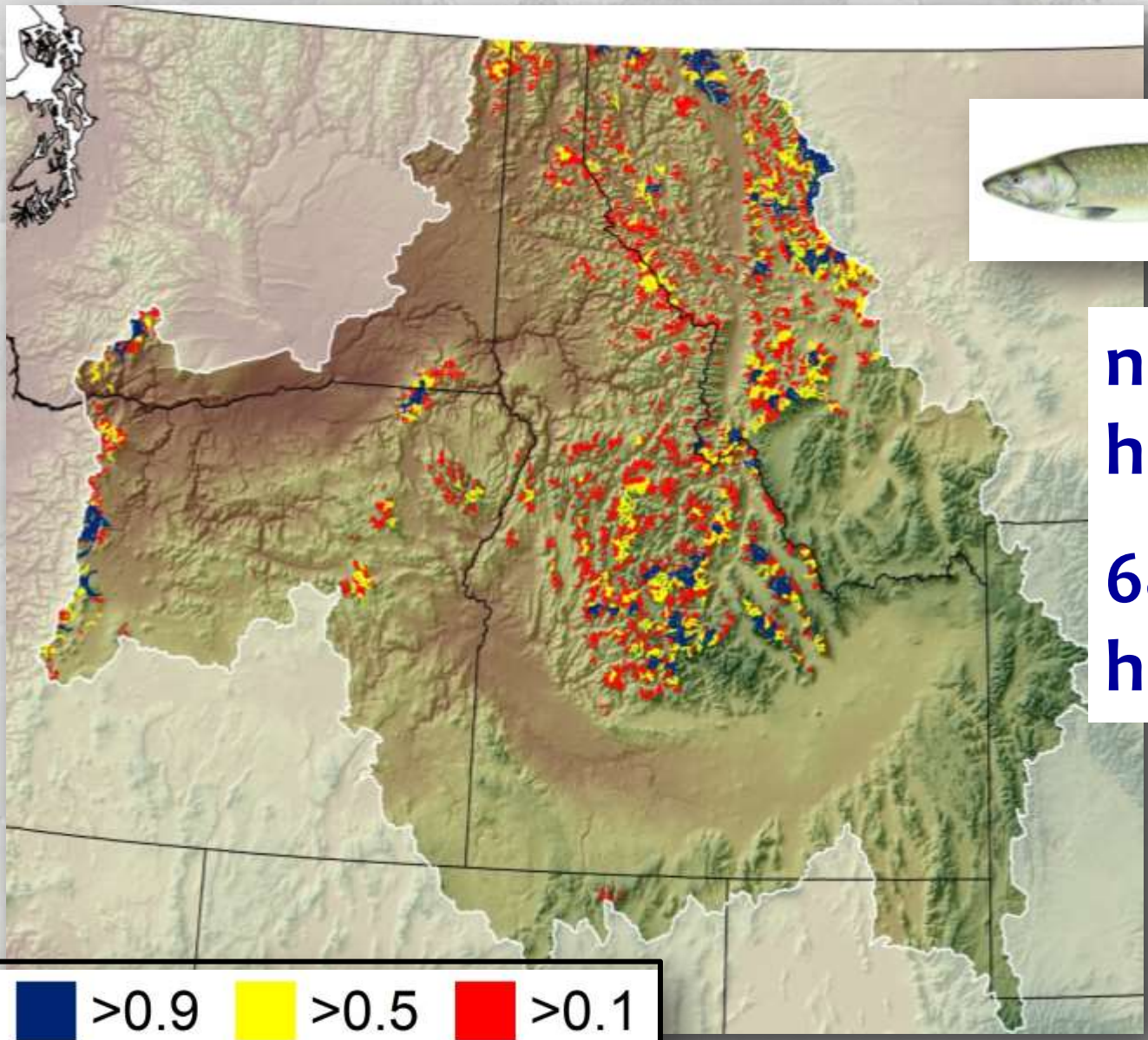


1980s

n = 3,750 habitats

225 >0.9 habitats

Species Occurrence Probability Map

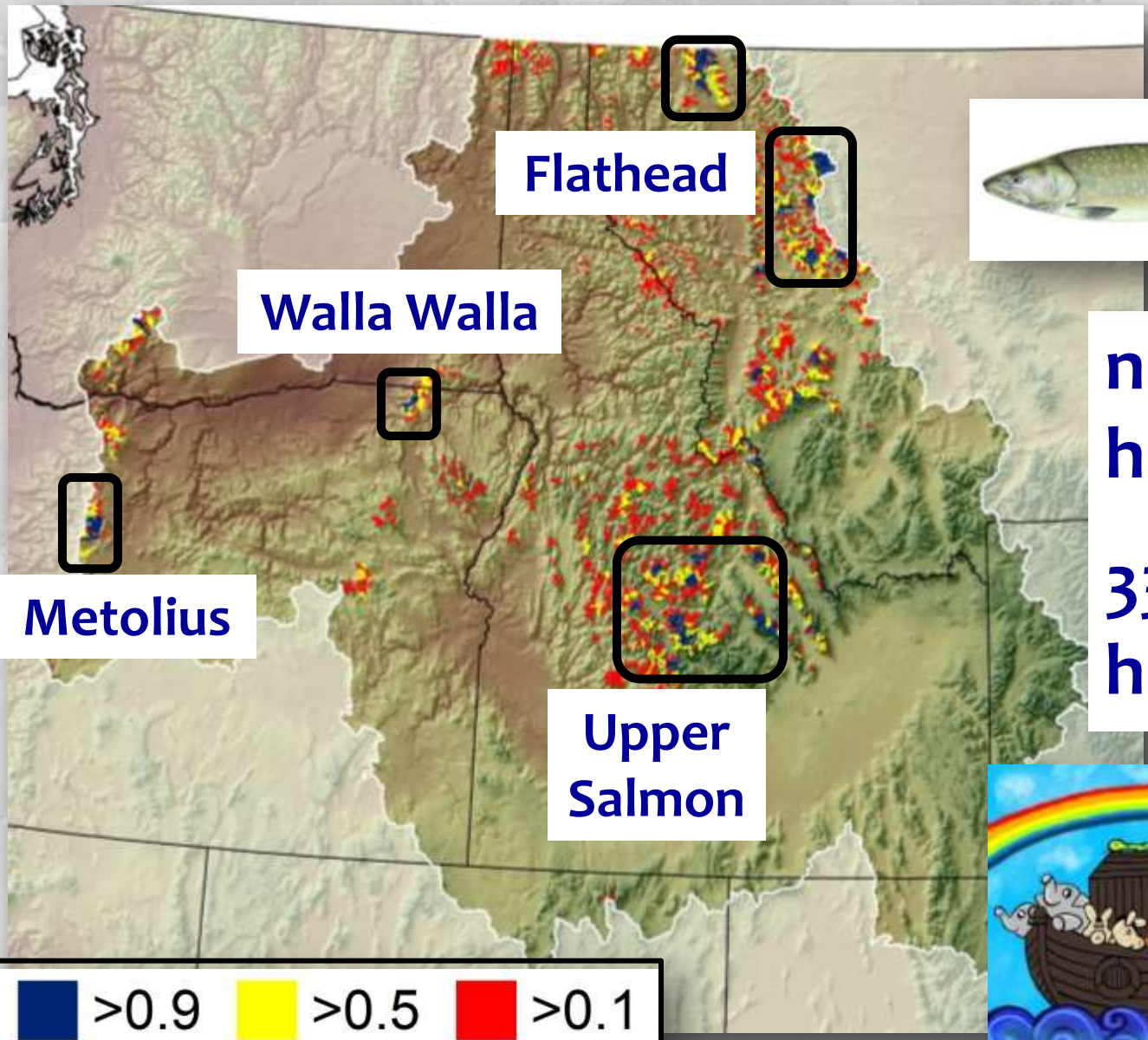


2040s

n = 2,837 habitats

68 >0.9 habitats

Species Occurrence Probability Map

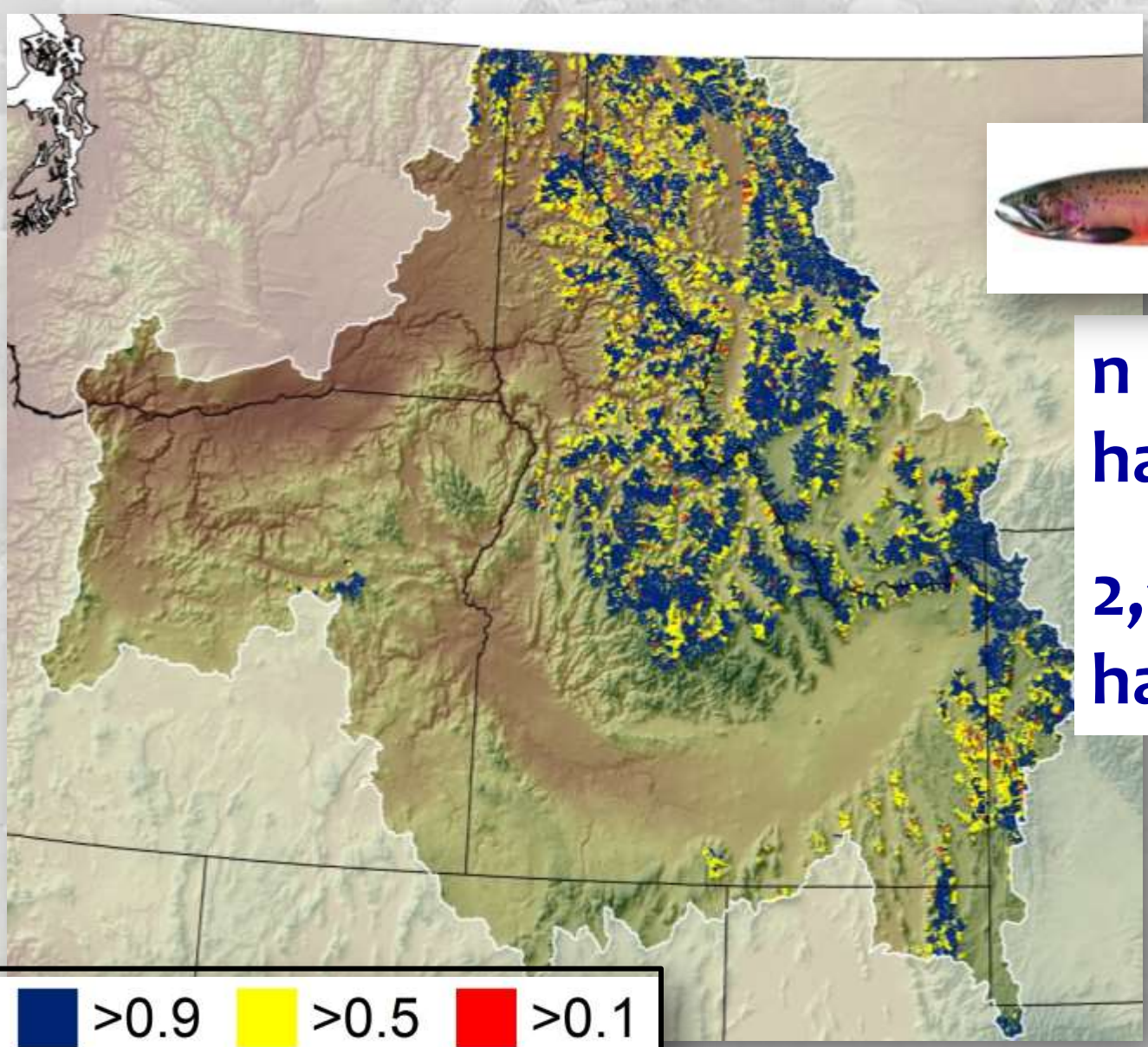


2080s

n = 1,973 habitats

33 >0.9 habitats

Species Occurrence Probability Map

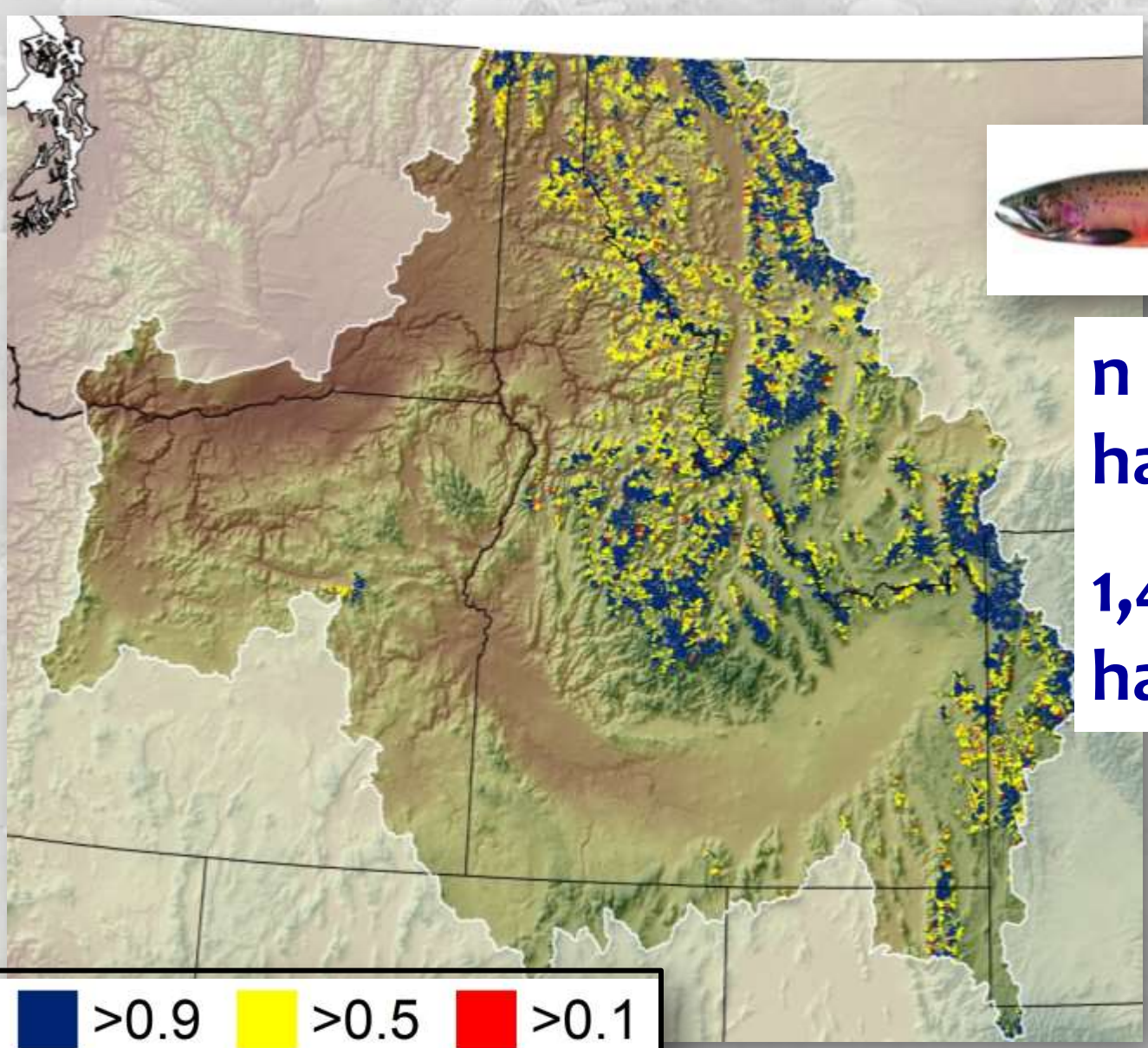


1980s

n = 6,784 habitats

2,184 >0.9 habitats

Species Occurrence Probability Map

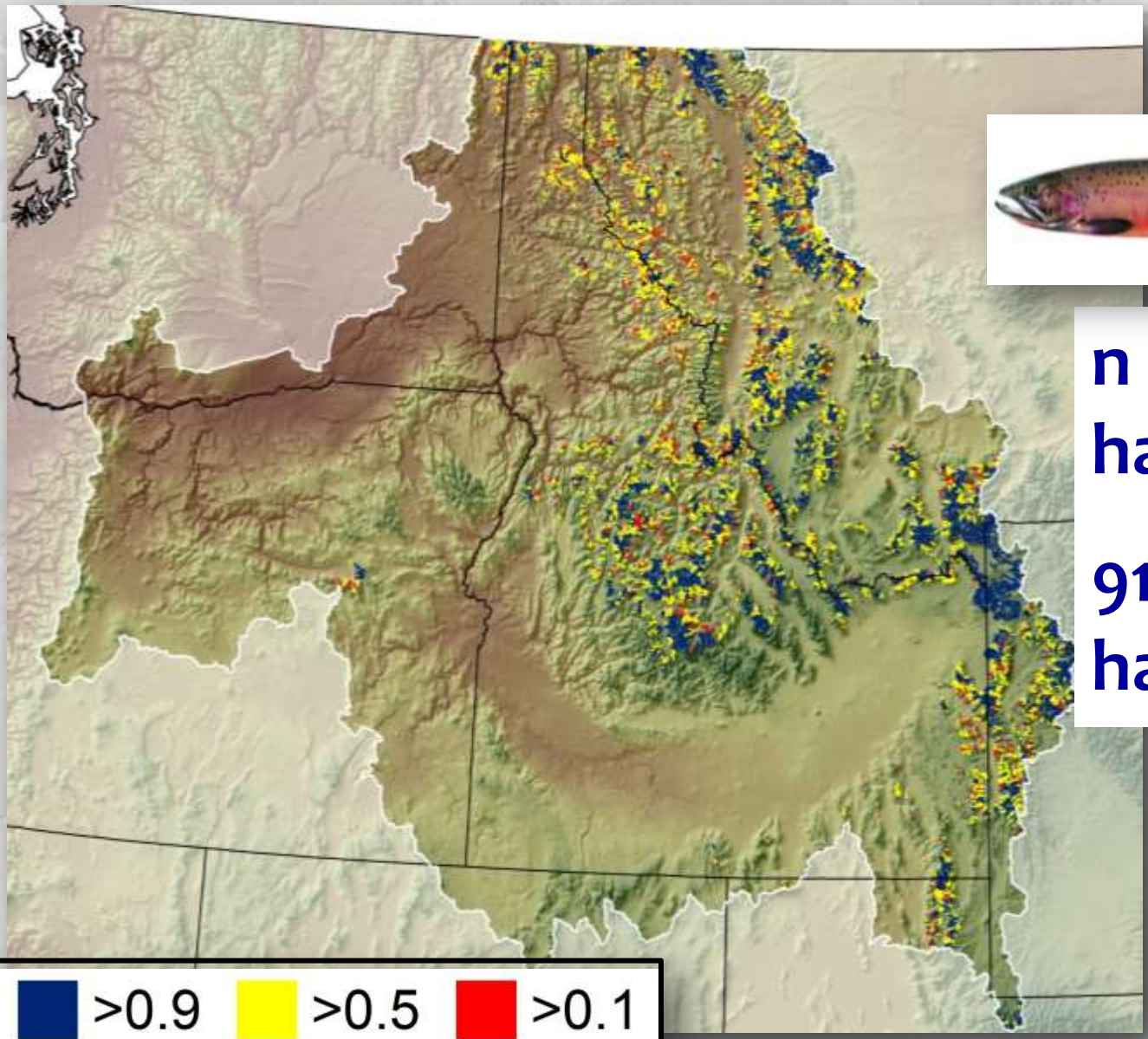


2040s

n = 5,718 habitats

1,425 >0.9 habitats

Species Occurrence Probability Map

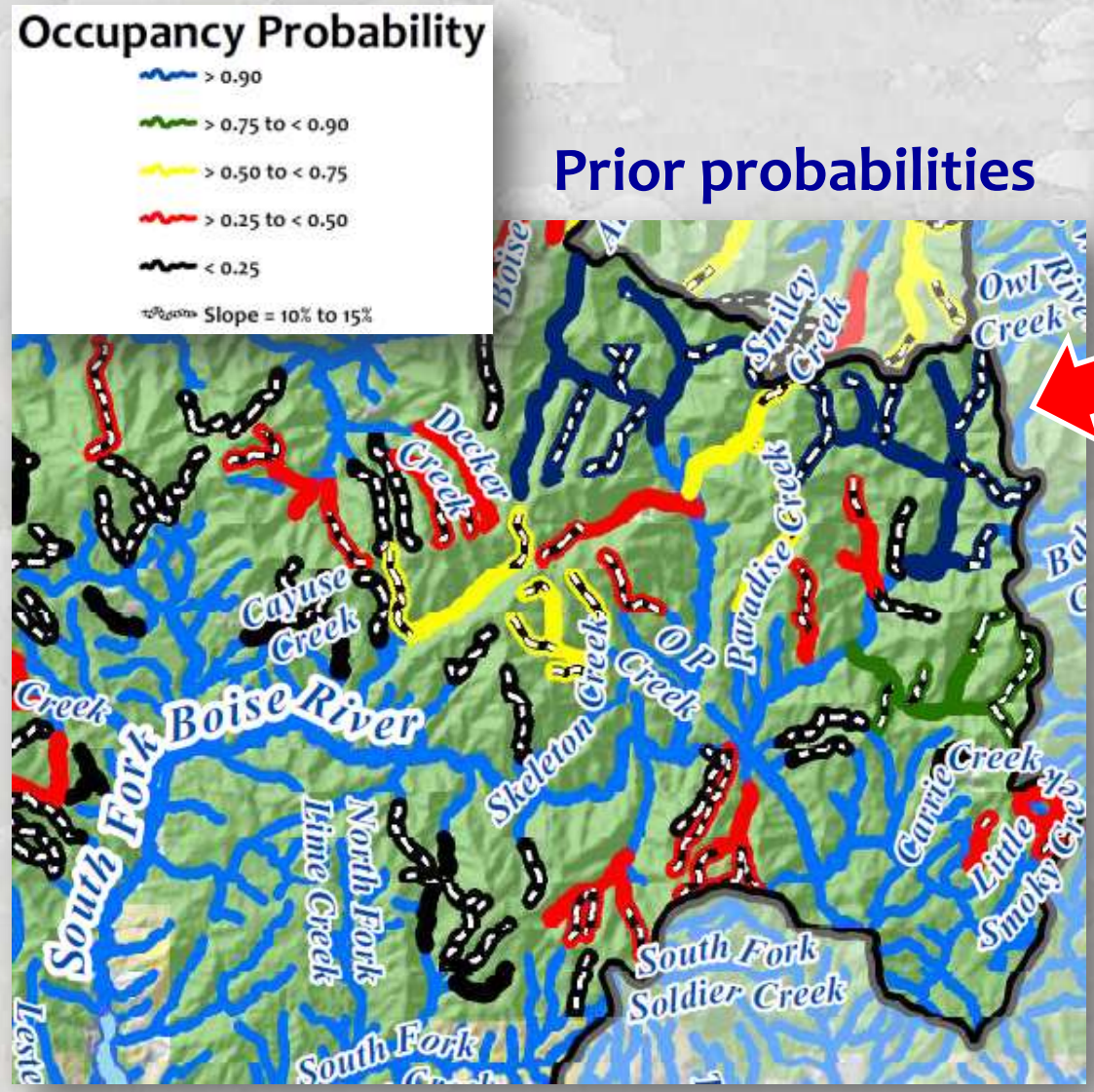


2080s

n = 4,502 habitats

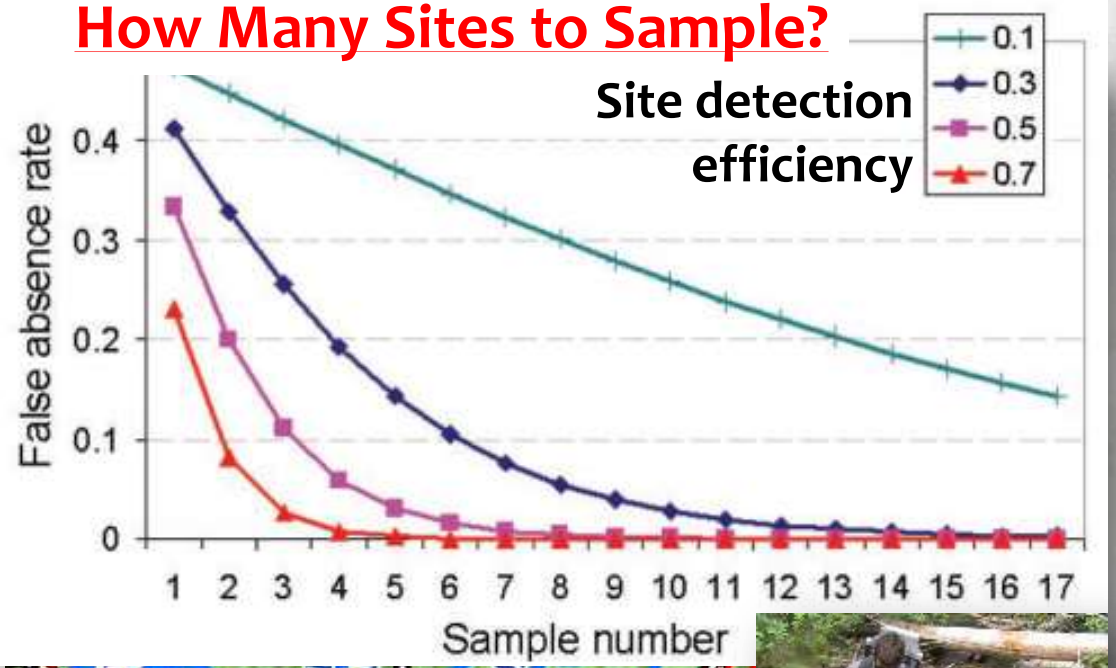
917 >0.9 habitats

Probability Maps + eDNA Enable Efficient Status & Trend Monitoring…



Probability Maps + eDNA Enable Efficient Status & Trend Monitoring…

How Many Sites to Sample?



Detection = 0.53

Detection ~ 0.85

USFS National Genomics Center Missoula

About that Brook Trout Effect…

Number & Size of Refugia >0.9

	Period	Median size (km)	Refugia
Cutthroat Trout	1980s	11	2,184
	2040s	10	1,425
	2080s	9	917
Bull Trout	1980s	51	225
	2040s	54	68
	2080s	53	33

How  =

Brook Trout Effect…

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

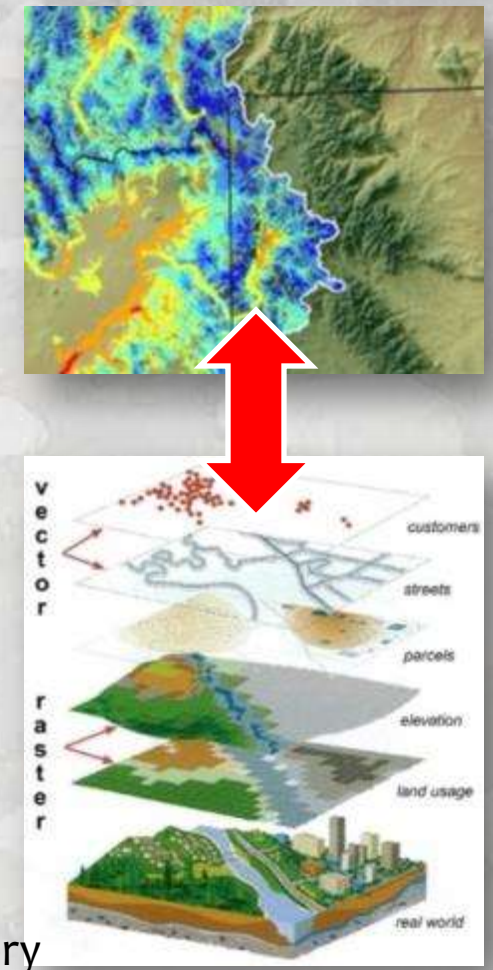
2x larger

…but steeper & larger streams are invasion resistant

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/

For More Information…

Peer-Reviewed Publication

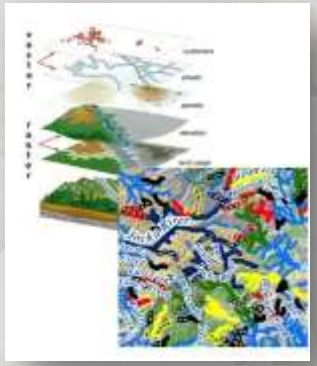
Isaak, D., M. Young, D. Nagel, D. Horan, and M. Groce. 2015. The cold-water climate shield: Delineating refugia for preserving native trout through the 21st Century. *Global Change Biology* **21** doi:10.1111/gcb.12879

Climate Shield website:

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

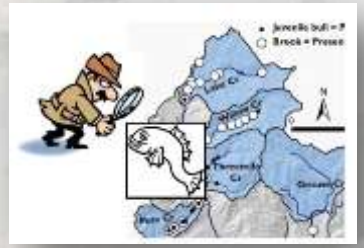
Presentations & Publications

Digital Maps & ArcGIS Shapefiles



Fish Data Sources

Distribution Monitoring



How to Use this Information?

1. Integrate with existing native trout conservation efforts (e.g., bull trout recovery plan, cutthroat trout working groups, WNTI)
2. Commit resources to places with best chance of success and where they make a difference
3. Look in detail at current/planned management activities in >0.9 habitats. How protected are they? are we building roads there or taking them out? Stocking nonnatives in headwater lakes or taking them out, etc
4. Lands GAP analysis could be used to highlight important habitats not in wilderness or national parks that might be better protected.
5. Refugia streams and other high probability cold-water habitats could be used as foundational elements in the design of climate smart conservation networks.
6. If investments made in low probability habitats, look at where they are relative to big habitats that could help support them. A "Largest plus nearest" strategy.
7. Assisted migration into high probability habitats that are not currently occupied.
8. Build/remove barriers in the smartest places.

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Northern Rockies Adaptation Partnership

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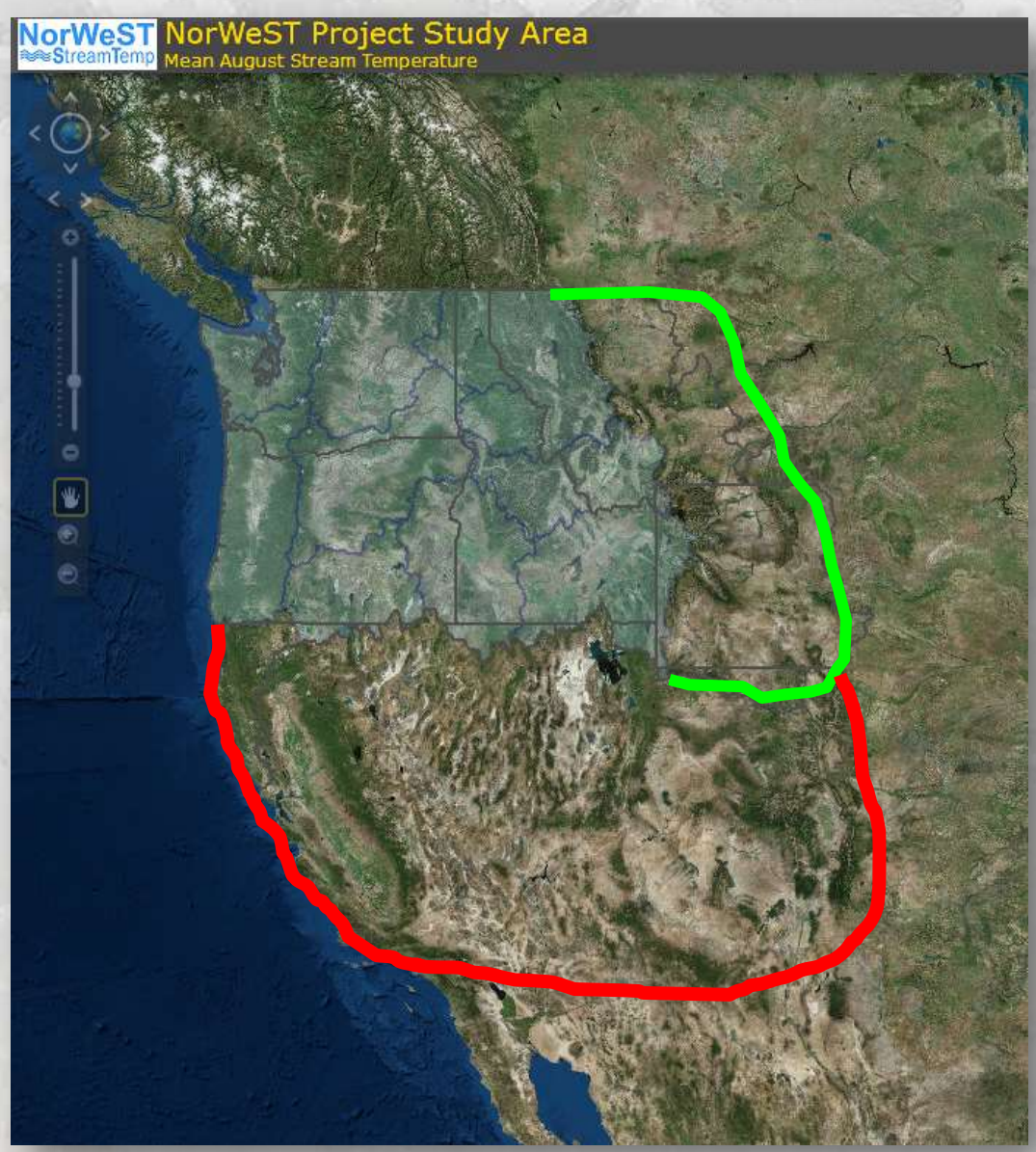
Climate Shield Expansion…



End 2015

Montana

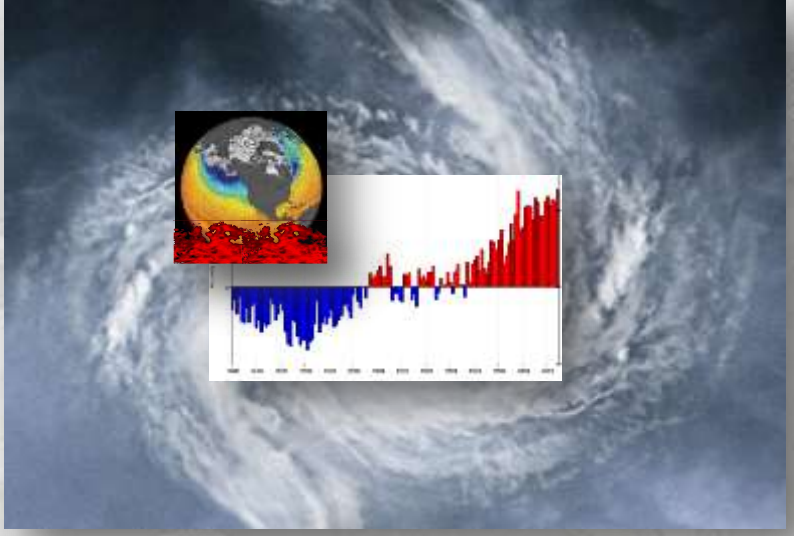
Wyoming

Future?

California

South Rockies

British Col.



CLIMATE SHIELD is:

Cold-Water

+

PEOPLE