Intermountain Adaptation Partnership:
Aquatic Organisms

Dan Isaak, Mike Young, Cynthia Tait, Dan Duffield, Dona Horan, Matt Groce

Kings Peak

Ogden, Utah, 4 May 2016

Outline

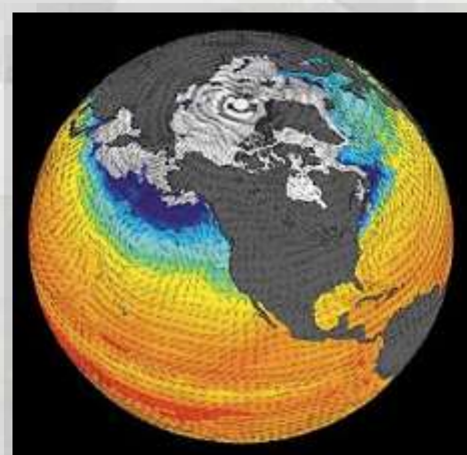
Climate to streams:
- Changes in flow
- Changes in temperature

Quantitative assessments:
- Bull trout (ESA listed)
- Cutthroat trout

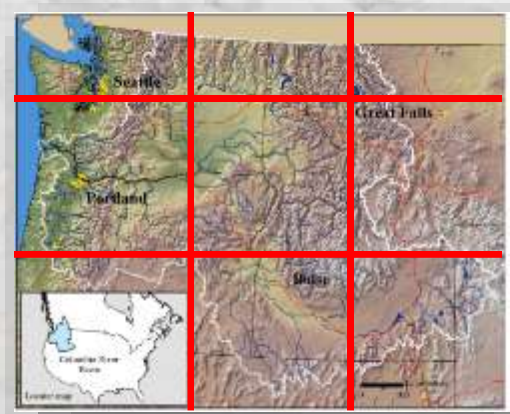
Final thoughts
- Strategies for other taxa
- Prioritization

Taking Climate into the Water…

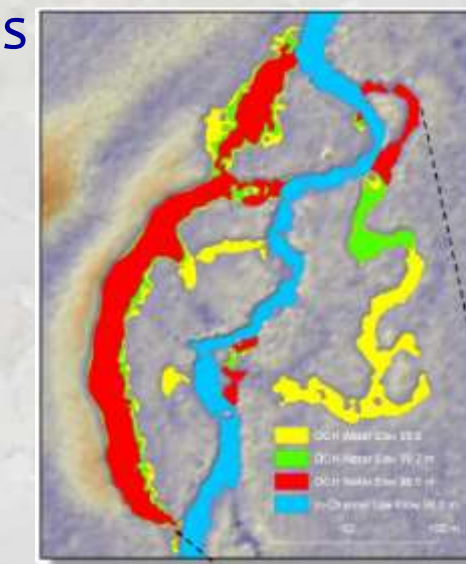
Climate model (air temp & precip)



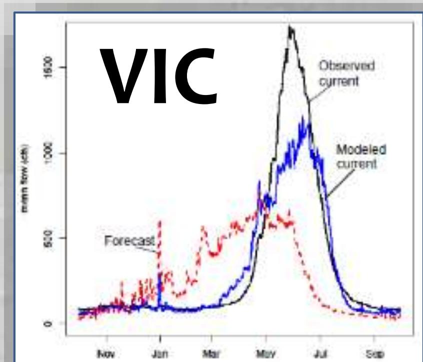
Regional patterns



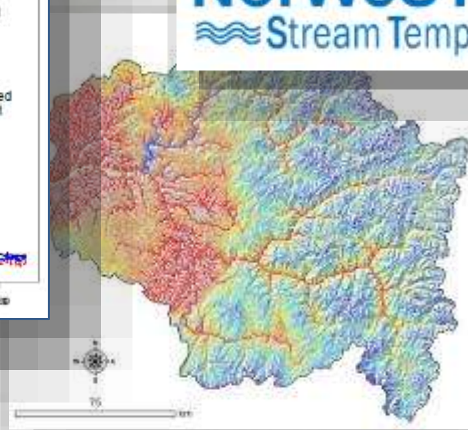
Stream reach patterns



Stream temperatures & flow

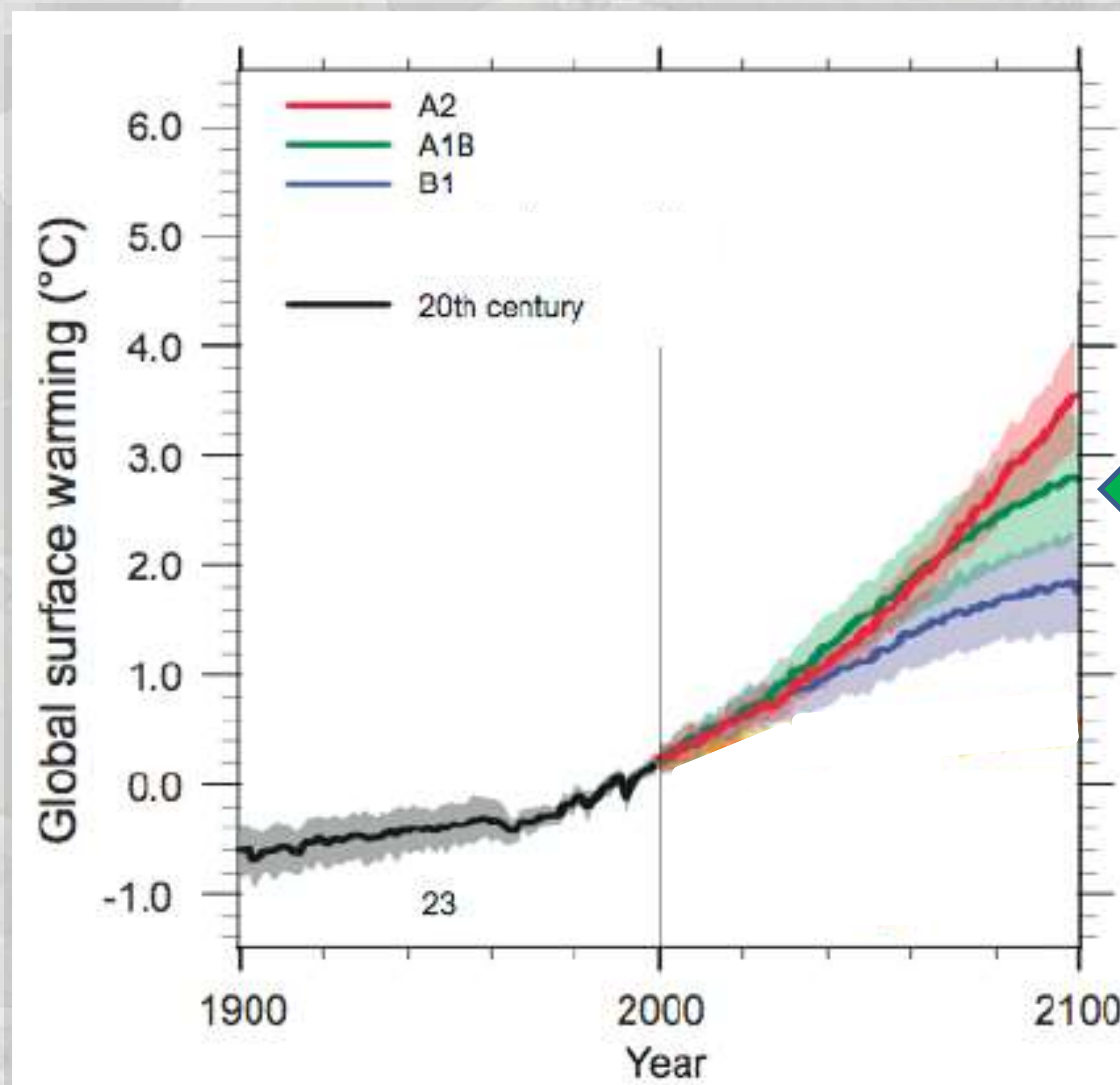


NorWeST Stream Temp



Future Climate Scenarios

A1B 10 GCM Ensemble from CIG



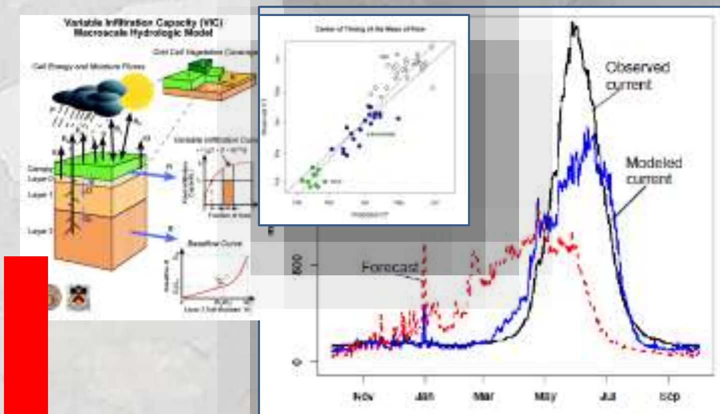
A1B

~RCP 6.0

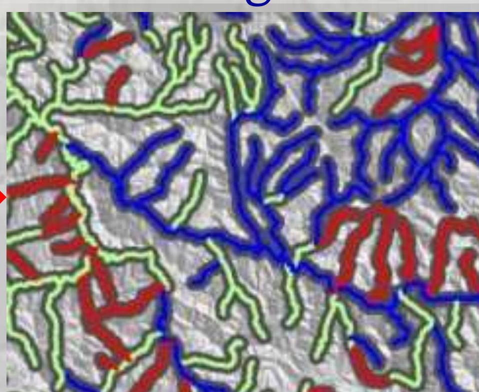
- Historical baseline (1970-1999)
- 2040s (2030-2059)
- 2080s (2070-2099)

Flow scenarios from Stream Flow Metrics website (ArcGIS & .pdfs & Excel)

[VIC streamflow scenarios]



[NHD+ stream segment resolution]



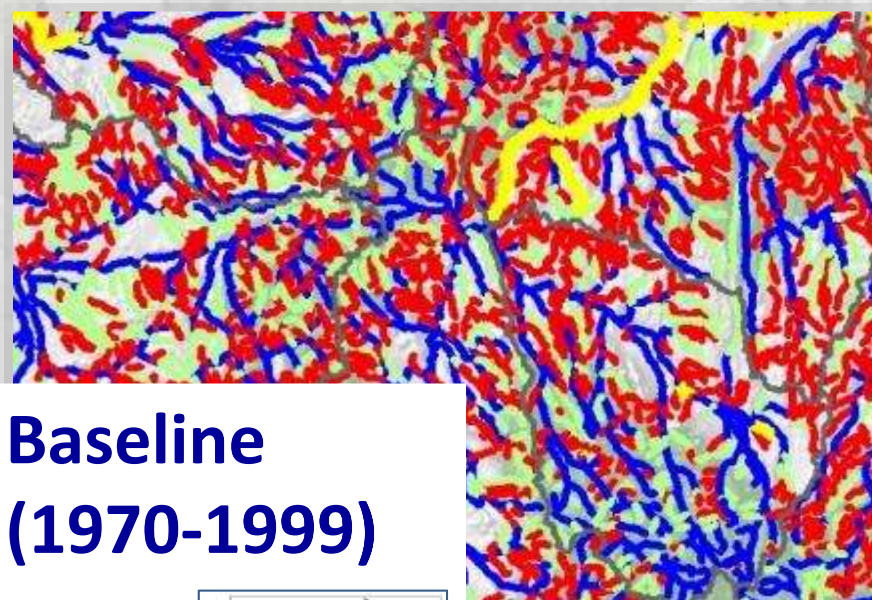
Google "Stream flow metrics"

Website: [fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml]

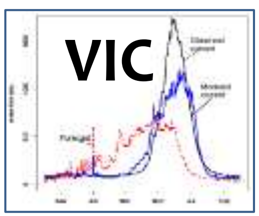
Liang et al. 1994. *J. Geophys Res* **99**:14415–14428.
Wenger et al. 2010. *Water Res Res* **46:**W09513.
Safeeq et al. 2014. *Hydrology and Earth System Sciences* **11:**3315-3357.

Stream Hydrography Base Layer

1:100,000 NHDPlus



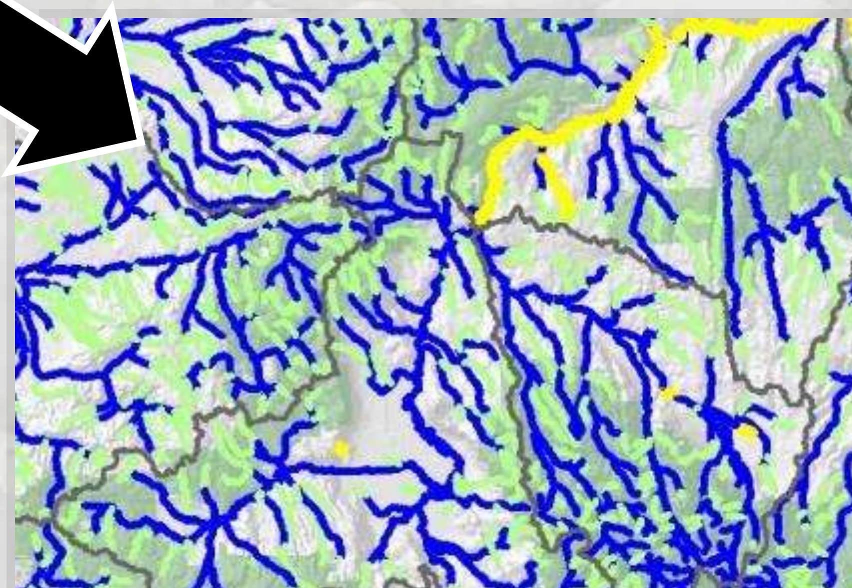
Baseline (1970-1999)



>0.006 m^3/s summer flow

<15% slope

Deleted intermittent channels

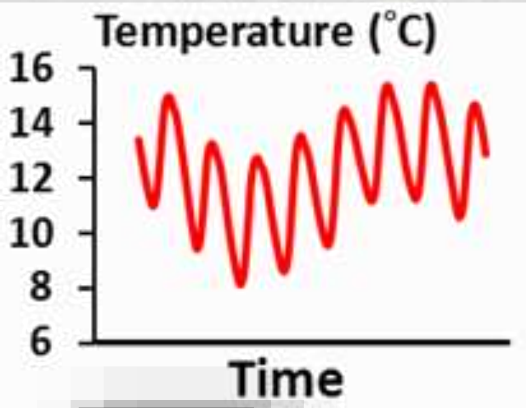


~65% network reduction

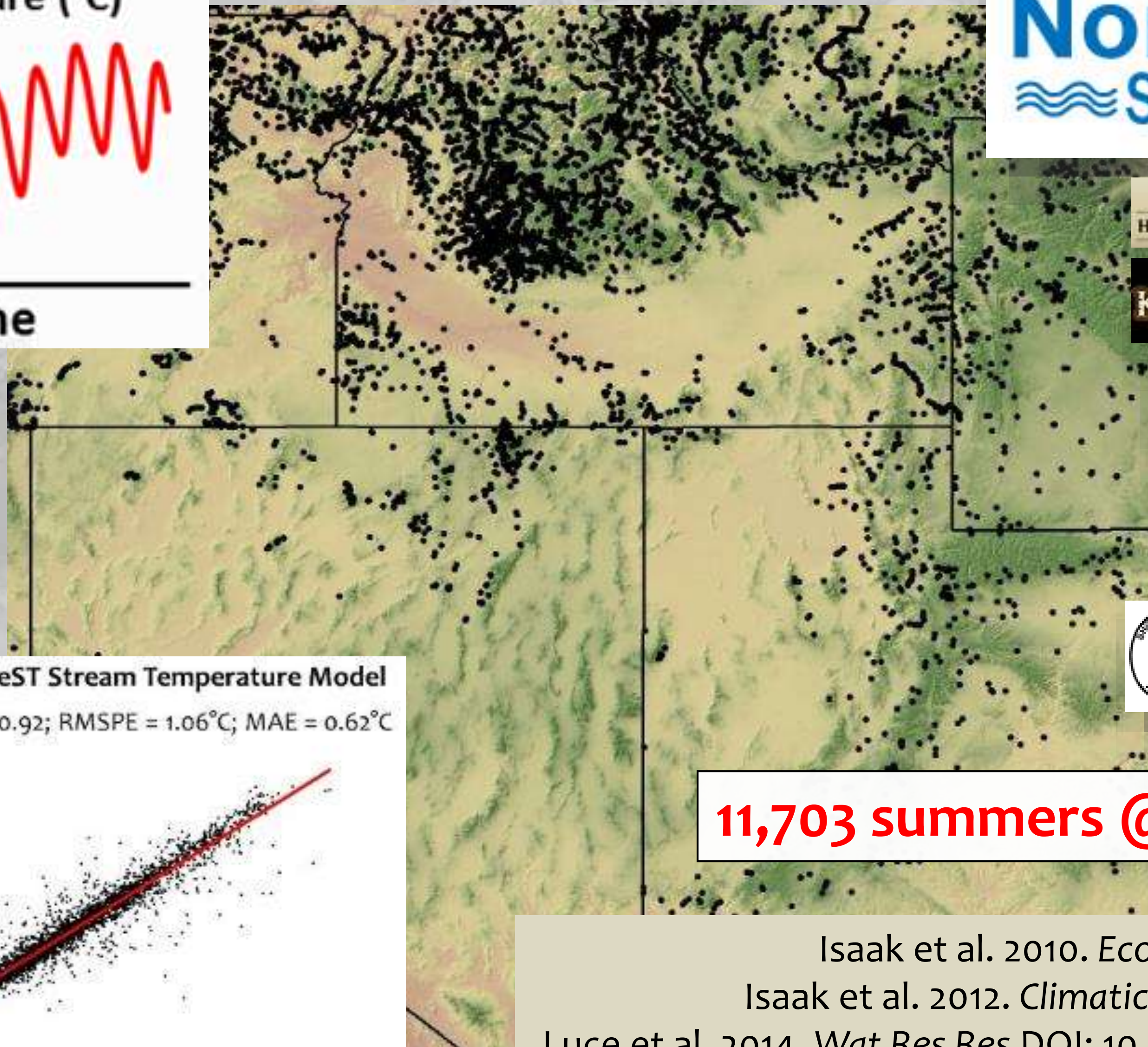
Stream Flow Statistics for A1B Warming Scenario

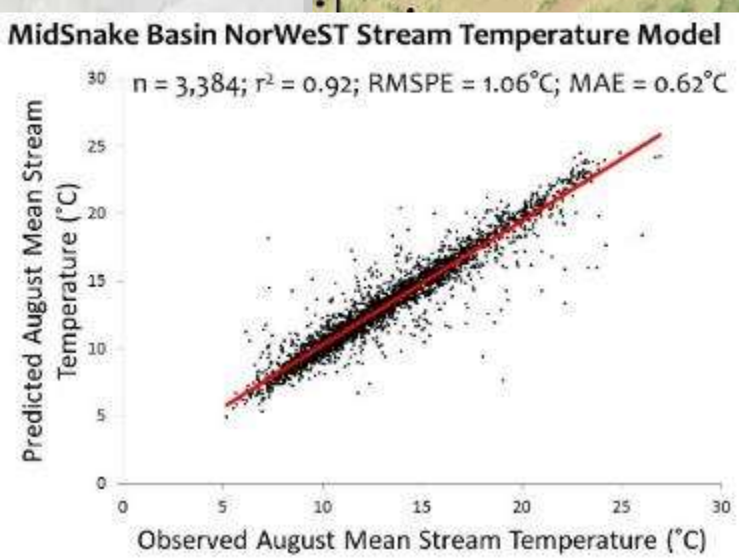
		Non-FS lands		FS lands	
Flow metric	**Climate period**	**Water year day**	**Days Advance**	**Water year day**	**Days Advance**
Median flow date	1980s	190	-	202	-
	2040s	181	-9 days	187	-15 days
	2080s	174	-16 days	175	-27 days
		Number of days	**Days increase**	**Number of days**	**Days increase**
Winter high flow days	1980s	5.5	-	3.0	-
	2040s	7.9	2.4	5.8	2.8
	2080s	10.0	4.5	9.1	6.1
		m^3/s	**% change**	**m^3/s**	**% change**
Mean summer flow	1980s	11.0	-	1.9	-
	2040s	8.0	-29.2	1.1	-42.1
	2080s	6.4	-43.4	0.8	-55.8
Mean annual flow	1980s	14.3	-	2.3	-
	2040s	14.9	4.2	2.4	4.3
	2080s	15.3	7.0	2.5	8.7

Stream Temperature Database & Scenarios



NorWeST Stream Temp





11,703 summers @ 5,461 sites

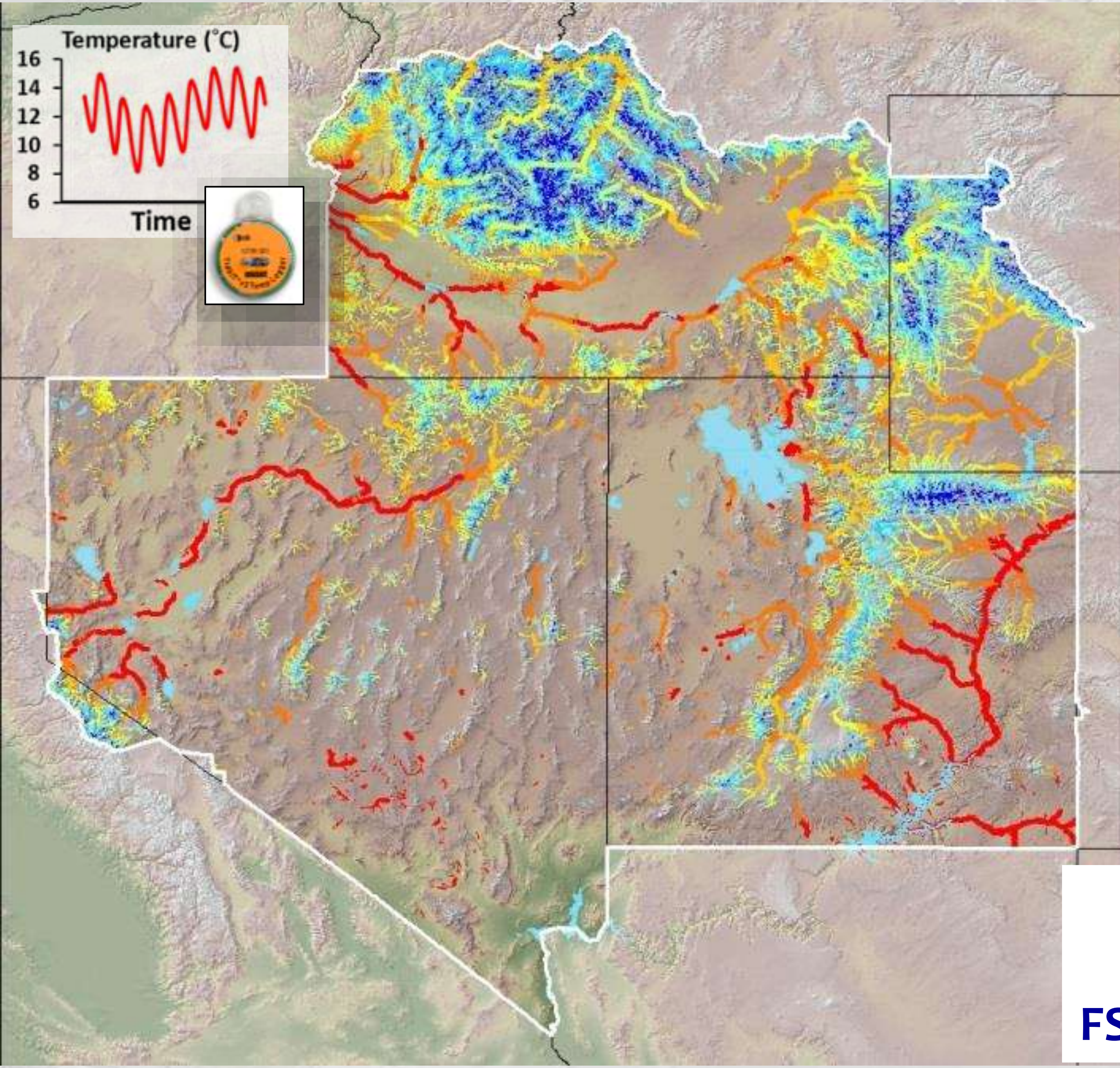
Isaak et al. 2010. *Ecol. Apps.* **20**:1350-1371
Isaak et al. 2012. *Climatic Change* **113**:499-524.
Luce et al. 2014. *Wat Res Res* DOI: 10.1002/2013WR014329
Ver Hoef et al. 2006. *Environ Ecol Stat* **13**:449-464.
Ver Hoef & Peterson. 2010. *Journal Am Stat Ass* **105**:6–18.

2000s

NorWeST Stream Temp

August Mean Temp (°C)

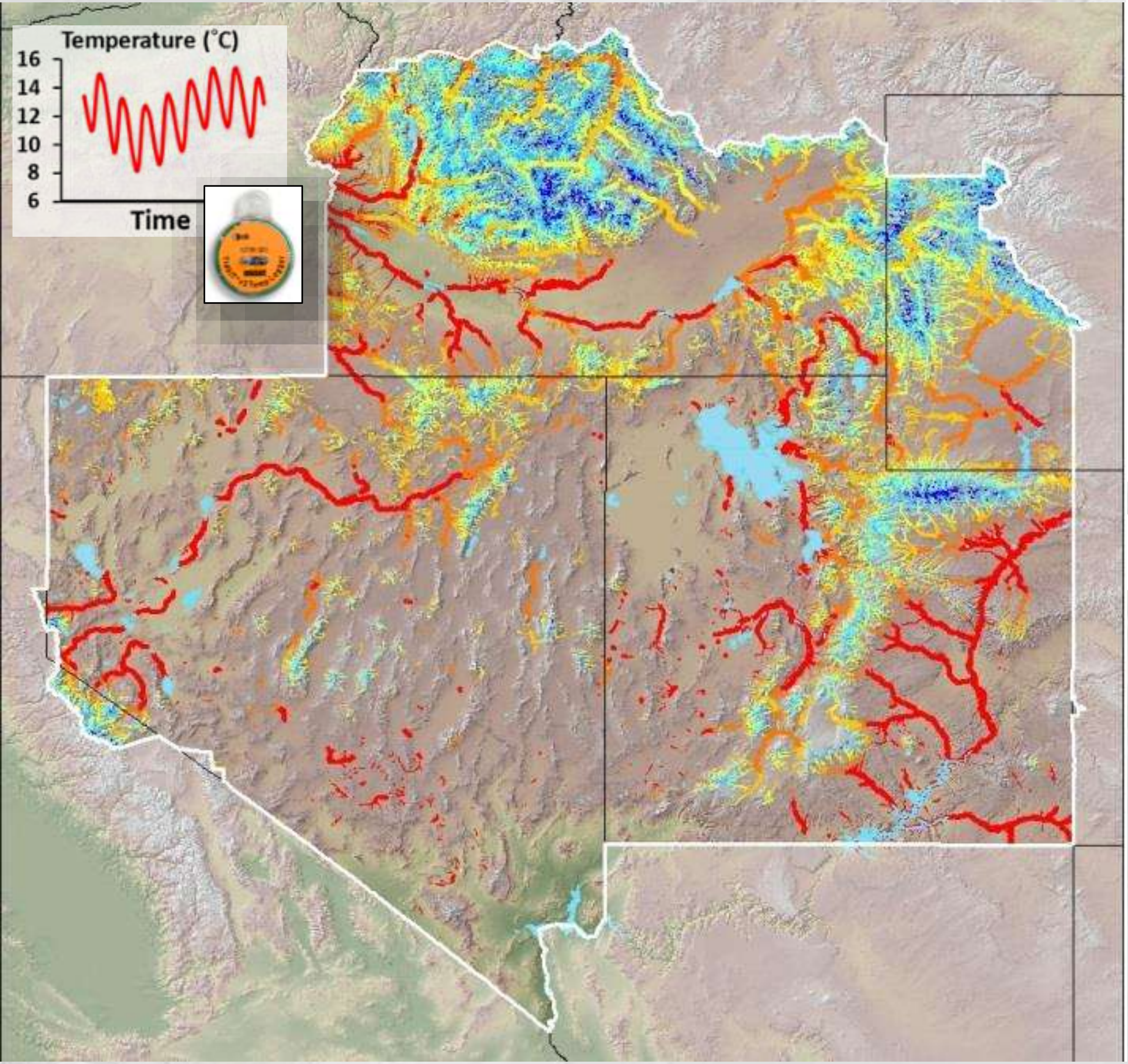
- < 8
- 8 - 11
- 11 - 14
- 14 - 17
- 17 - 20
- > 20



Overall = 14.1 ˚C

FS streams = 11.1 ˚C

2040s



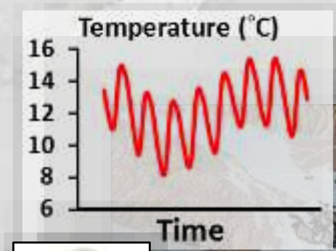
NorWeST
Stream Temp

August Mean Temp (°C)

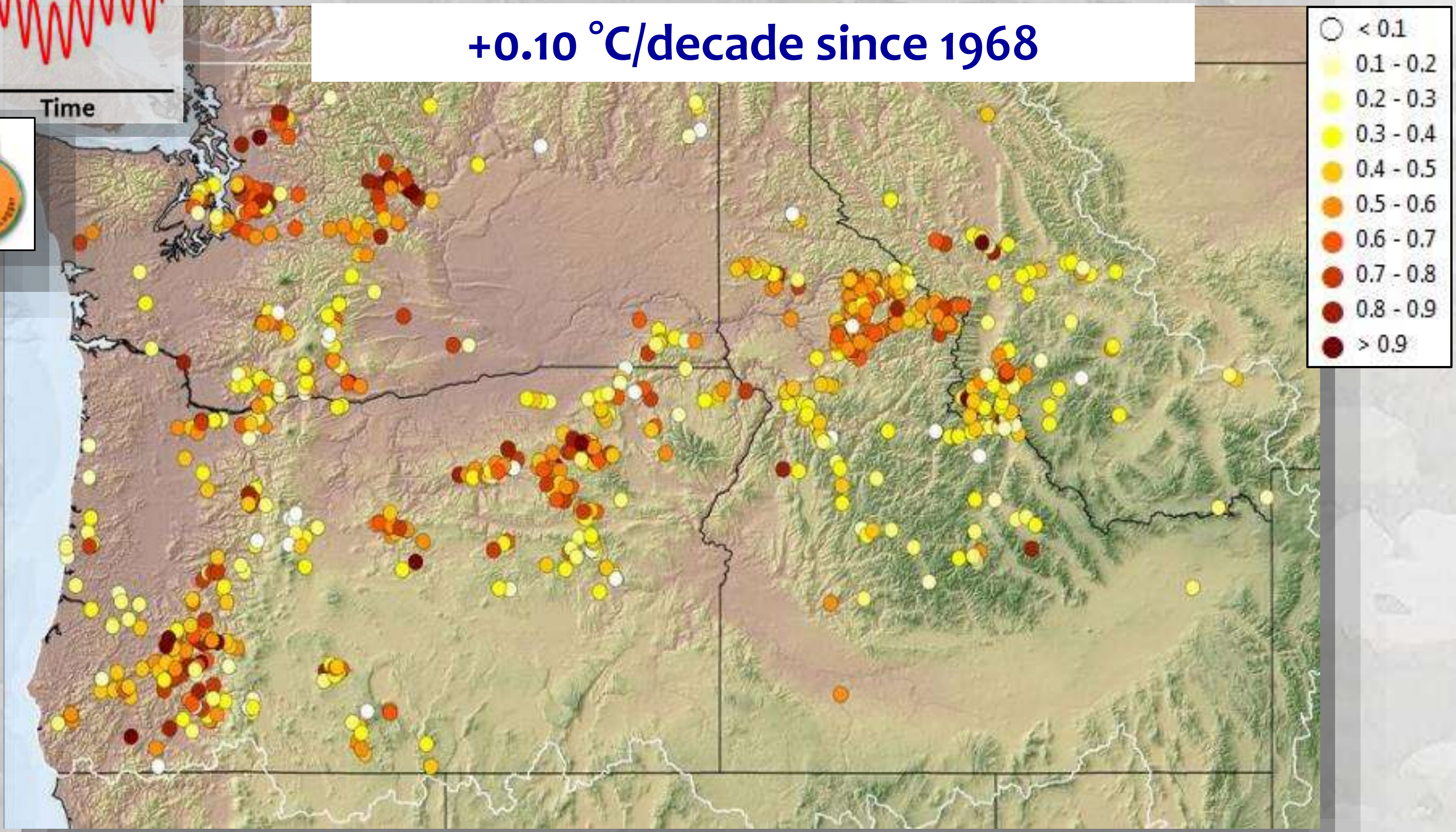
- < 8
- 8 - 11
- 11 - 14
- 14 - 17
- 17 - 20
- > 20

+ 1.0 °C

Slow Stream Warming Rates 1968-2011



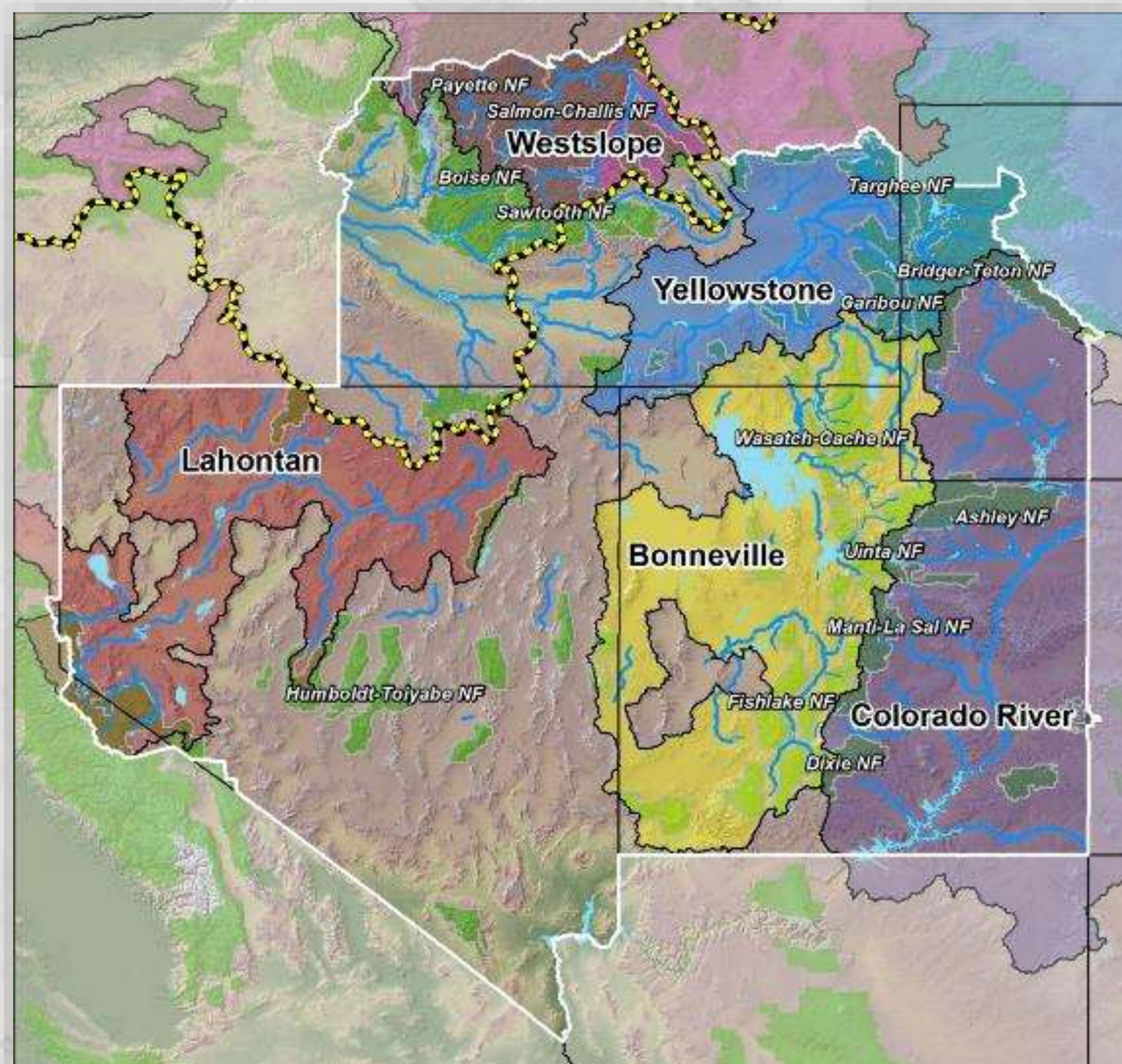
923 sites in NorWeST database with >10 year records



Isaak et al. 2016. Slow climate velocities of mountain streams portend their role as refugia for cold-water biodiversity. *Proc. Nat. Acad. Sciences* 113: 4374–4379.

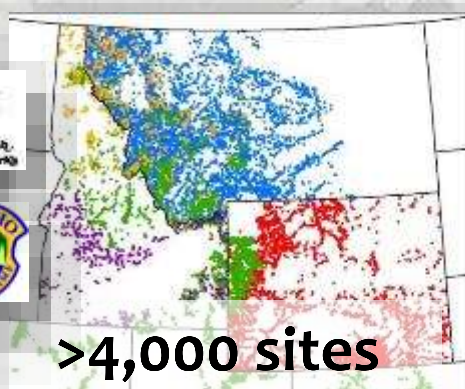
Quantitative assessments for:

- Bull trout
- Cutthroat trout



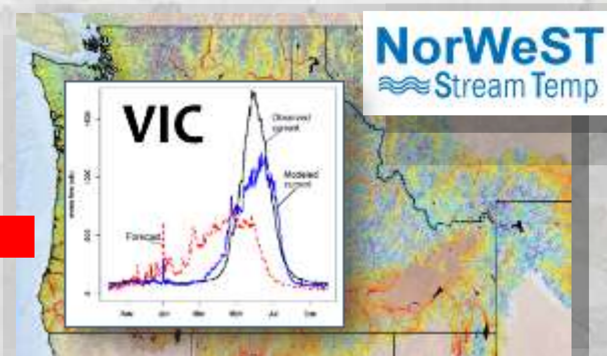
Species Distribution Models for Native Trout Climate Refugia

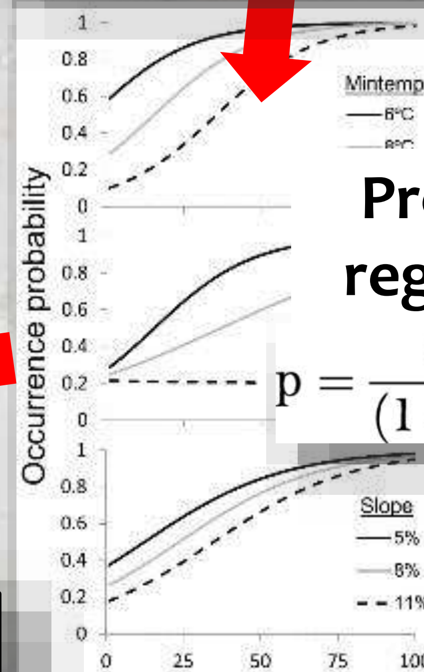
Agency biodata



>4,000 sites

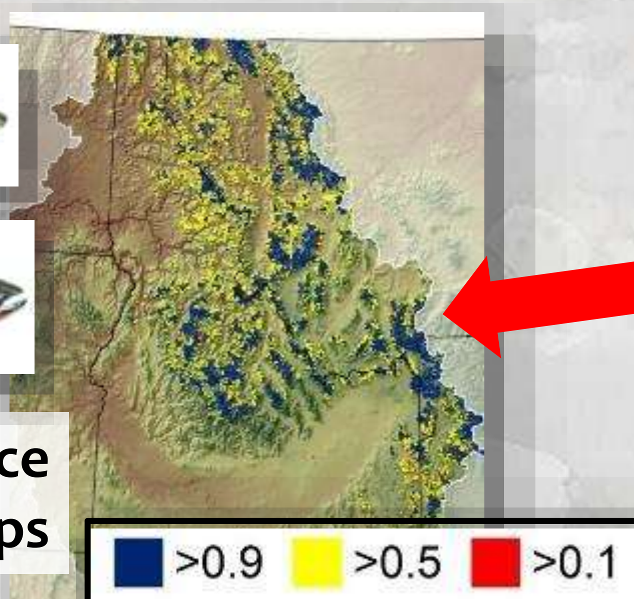
>500 streams





Predictive logistic regression models

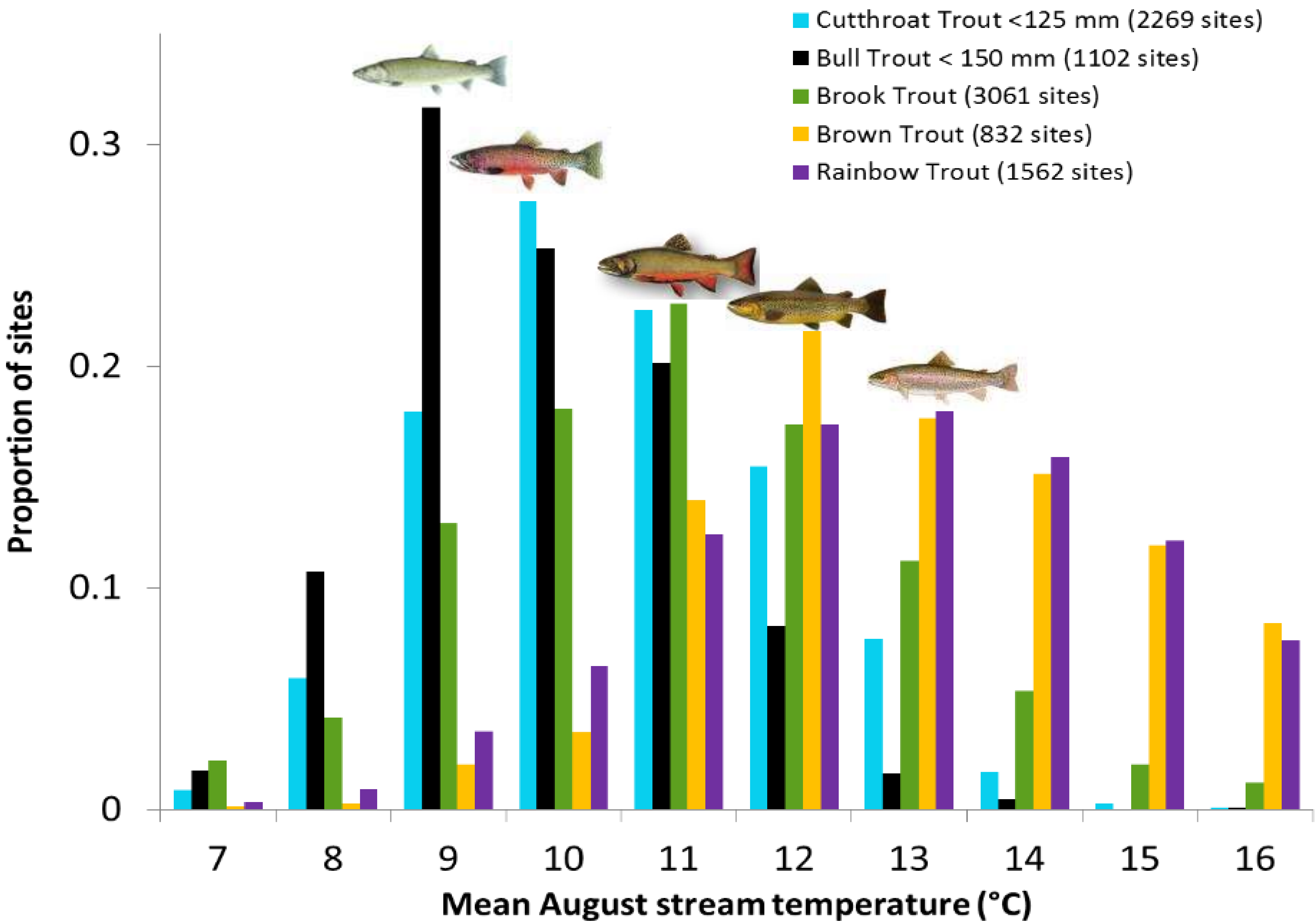
$$p = \frac{\exp(a + bx \ldots ny)}{(1 + \exp[a + bx \ldots ny])}$$



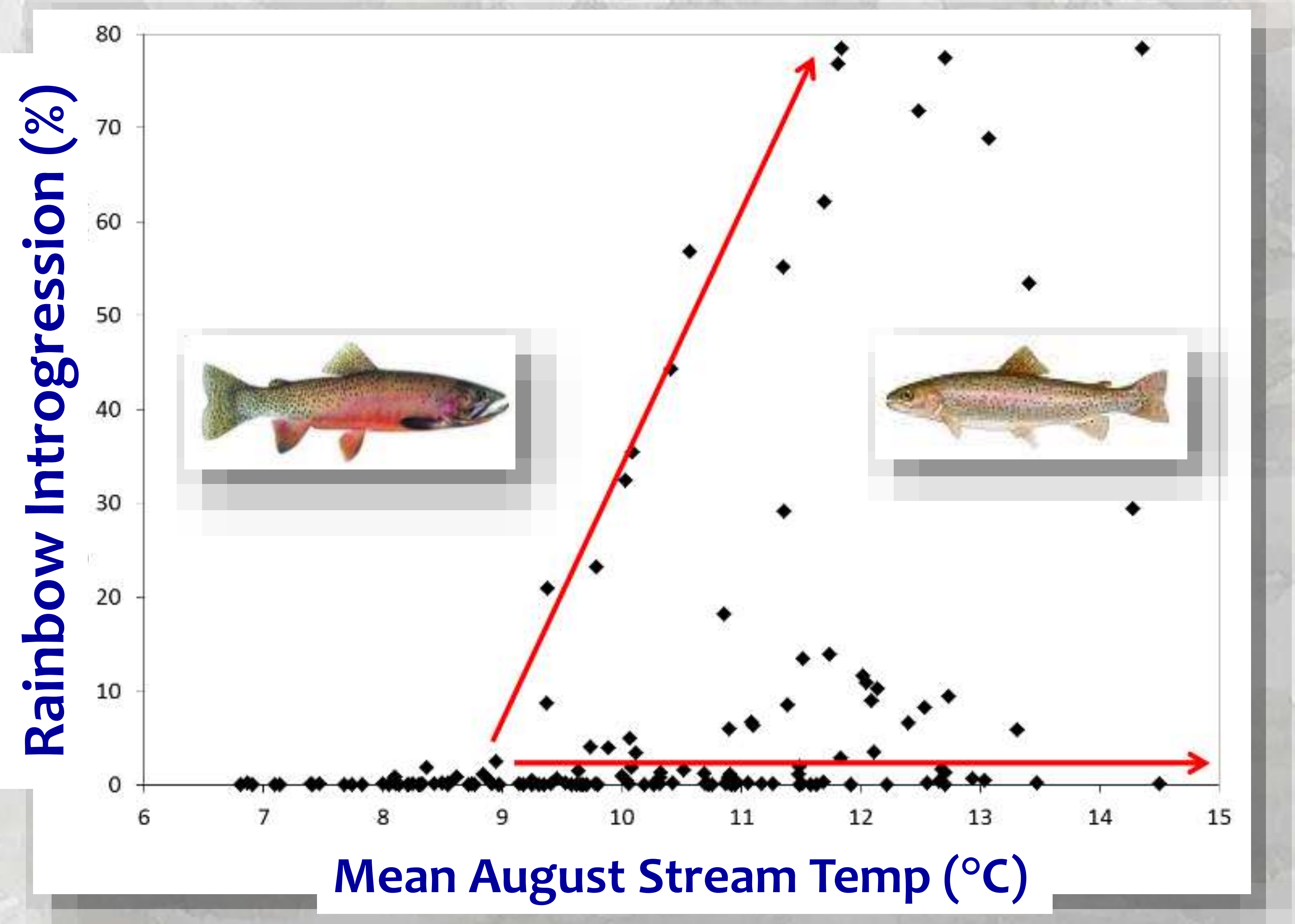
Occurrence probability maps

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

Cold Streams Exclude Most Invaders



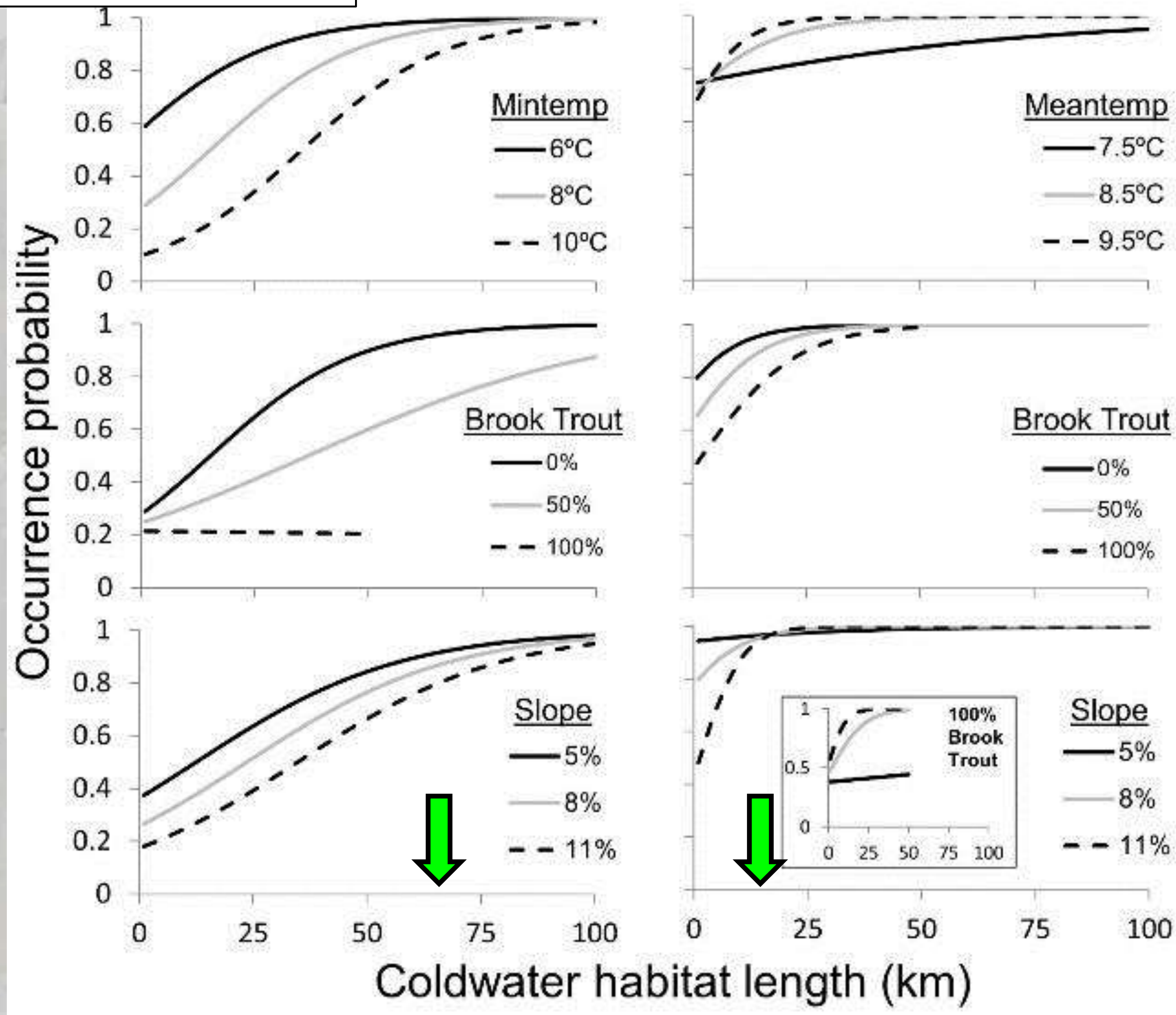
Cold Streams Exclude Rainbow Trout Hybrids



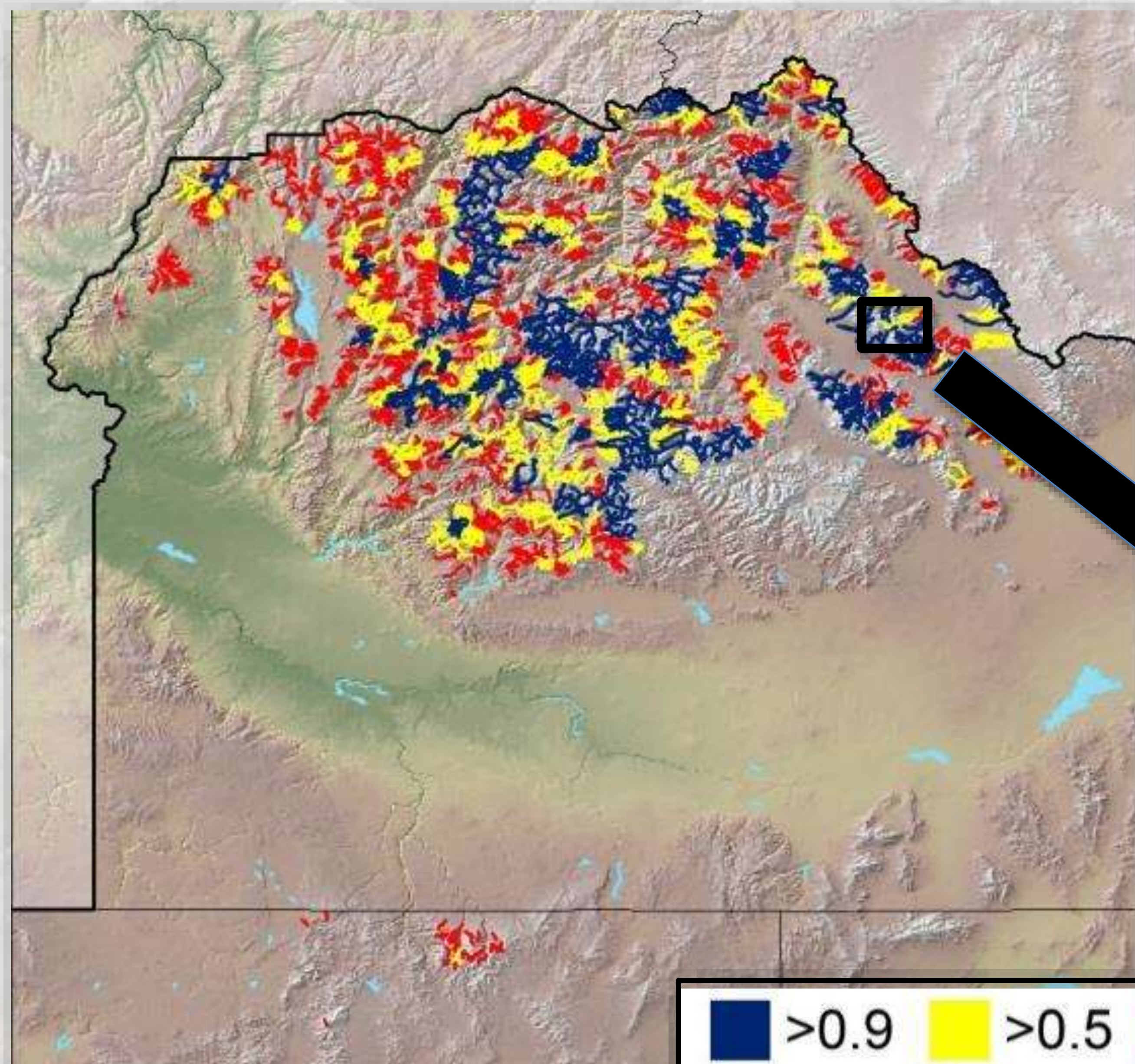
McKelvey et al. 2016; Young et al., In prep.

78% classification accuracy

85% classification accuracy



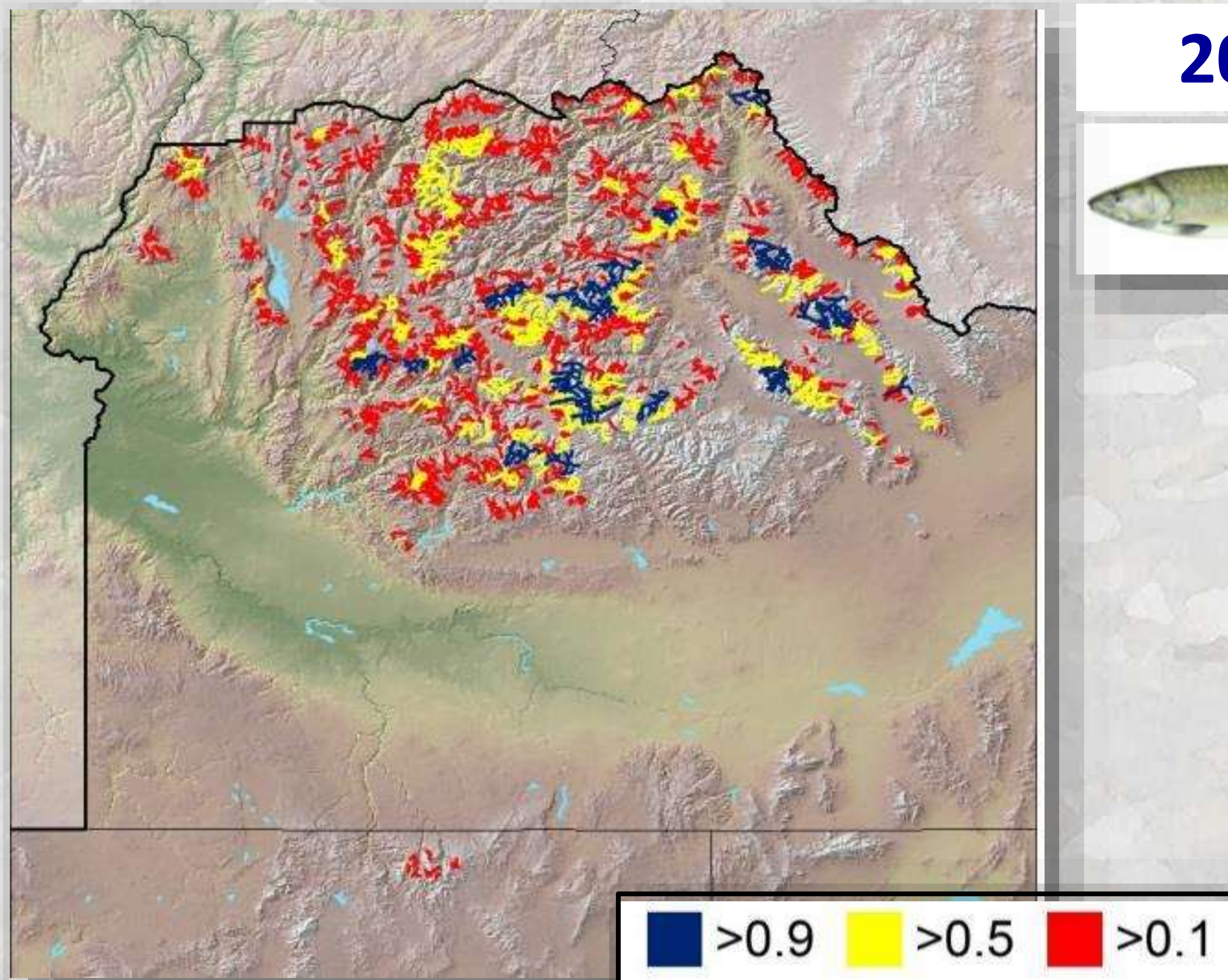
Bull Trout Probability of Occupancy



2000s

Stream population scale predictions

Bull Trout Probability of Occupancy



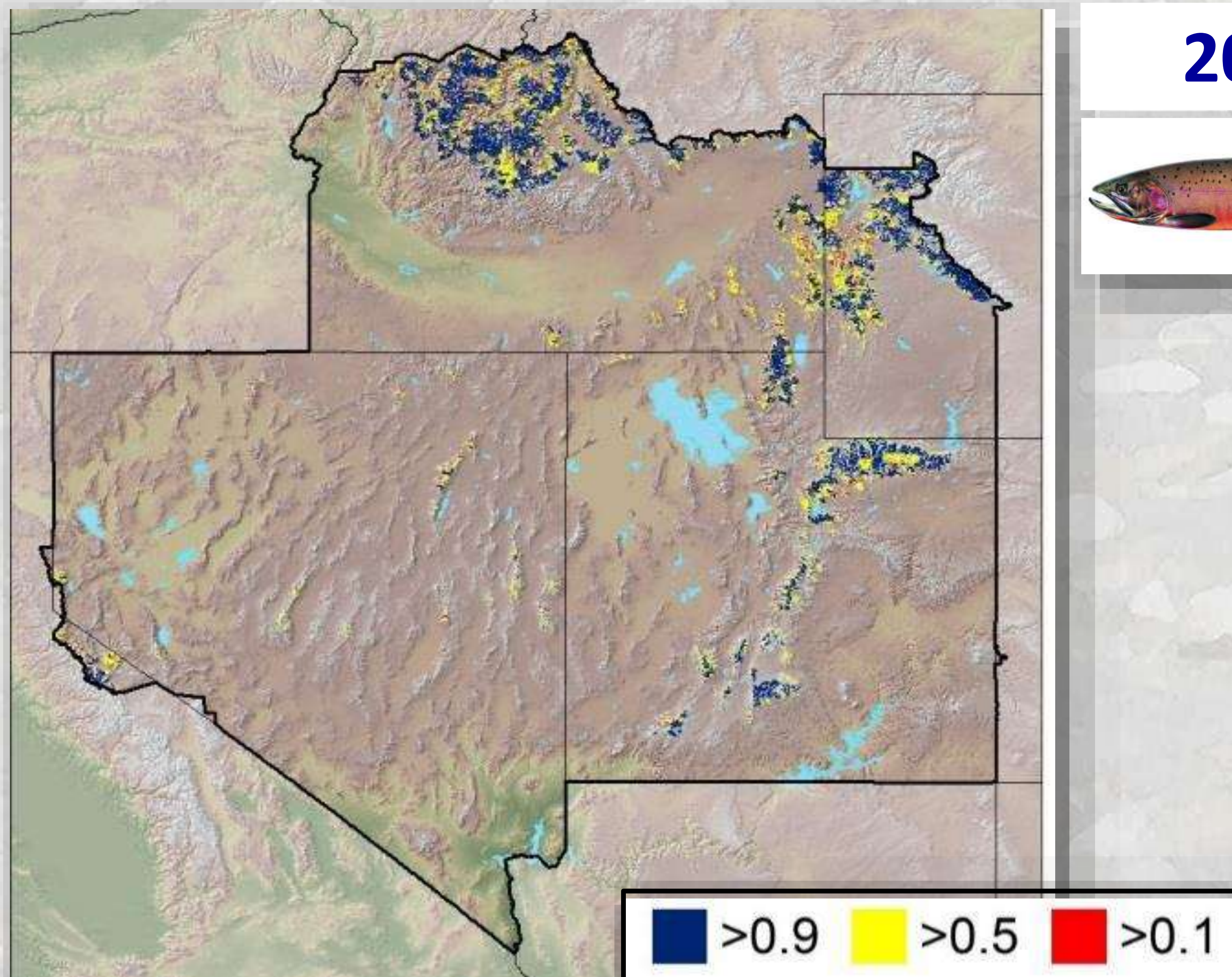
2040s

Number and Length of Bull Trout Habitats

		Probability of Occurrence					
Number of habitats		**< 0.25**	**0.25-0.50**	**0.50-0.75**	**0.75-0.90**	**> 0.90**	**Number**
	2000s	406	289	141	70	78	984
	2040s	538	216	90	31	23	898
	2080s	387	215	76	22	12	712
Length of habitats							**Stream KM**
	2000s	1,863	2,382	2,003	1,614	4,516	12,378
	2040s	2,623	1,983	1,407	747	1,233	7,993
	2080s	1,704	1,608	1,038	465	553	5,368

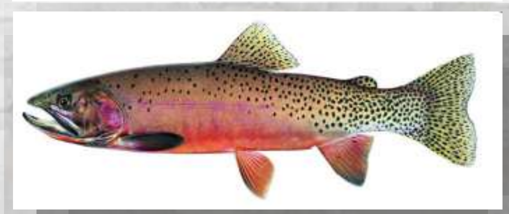
Cutthroat Trout Probability of Occupancy

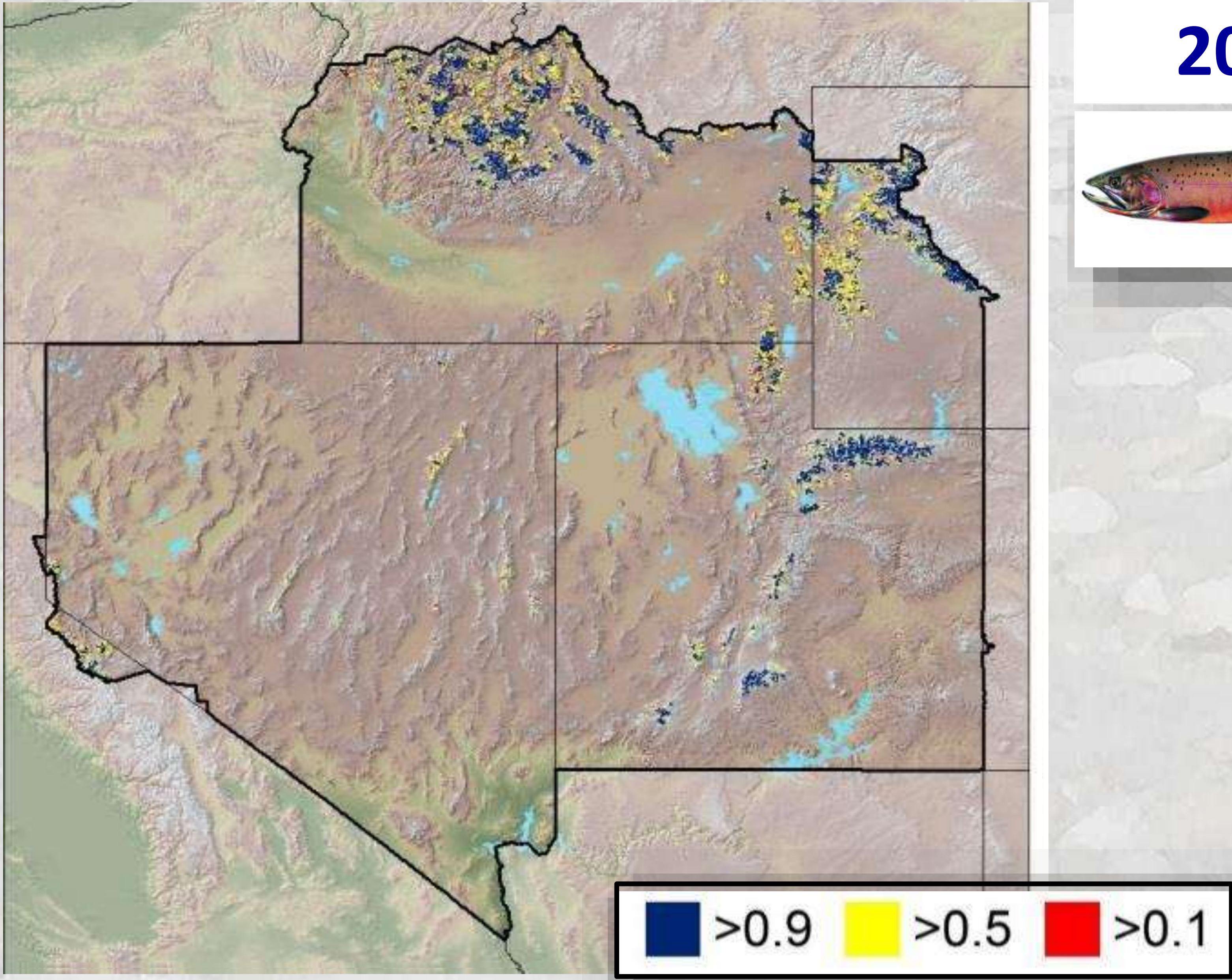
2000s



Cutthroat Trout Probability of Occupancy

2040s





Number and Length of Cutthroat Trout Habitats

		Probability of Occurrence					
Number of habitats		**< 0.25**	**0.25-0.50**	**0.50-0.75**	**0.75-0.90**	**> 0.90**	**Number**
	2000s	73	206	540	872	909	2,600
	2040s	49	170	544	791	680	2,234
	2080s	66	252	479	572	476	1,845
Length of habitats							**Stream KM**
	2000s	346	624	2,047	3,737	14,152	20,906
	2040s	110	464	1,530	2,990	9,448	14,542
	2080s	150	641	1,498	2,256	5,899	10,444

About that Brook Trout Effect…

Size of Refugia for Probability >0.9

	Period	Median size (km)
Cutthroat Trout	2000s	11
	2040s	10
	2080s	9
Bull Trout	2000s	51
	2040s	54
	2080s	53

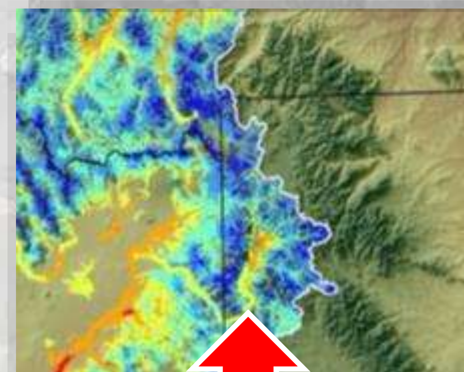
2x larger

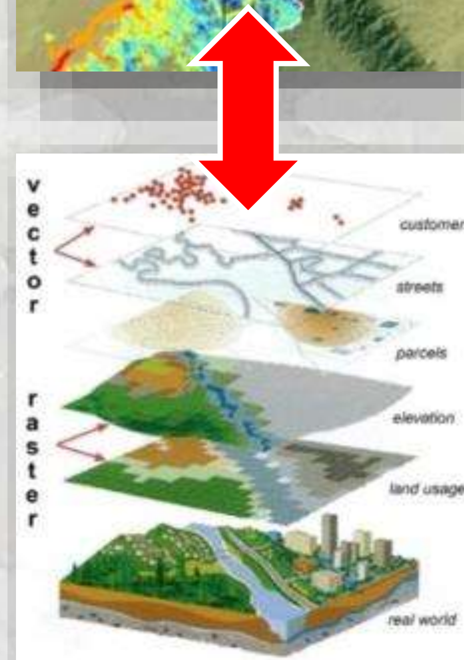
…but *steeper* streams are also invasion resistant

Land Administration GAP Analysis

<11 °C streams in bull trout range

Land status	2000s	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

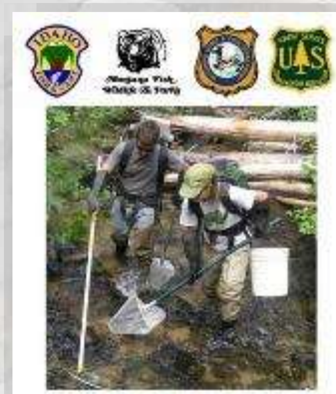
Website Provides Trout Scenarios in User-Friendly Digital Formats

Just Google “Climate Shield trout”

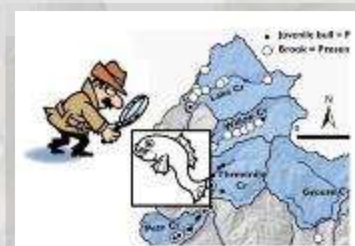
Presentations & Publications

Digital Maps & ArcGIS Shapefiles

Fish Data Sources



Distribution Monitoring



File formats:

- ArcGIS files
- pdf files

15 Scenarios:

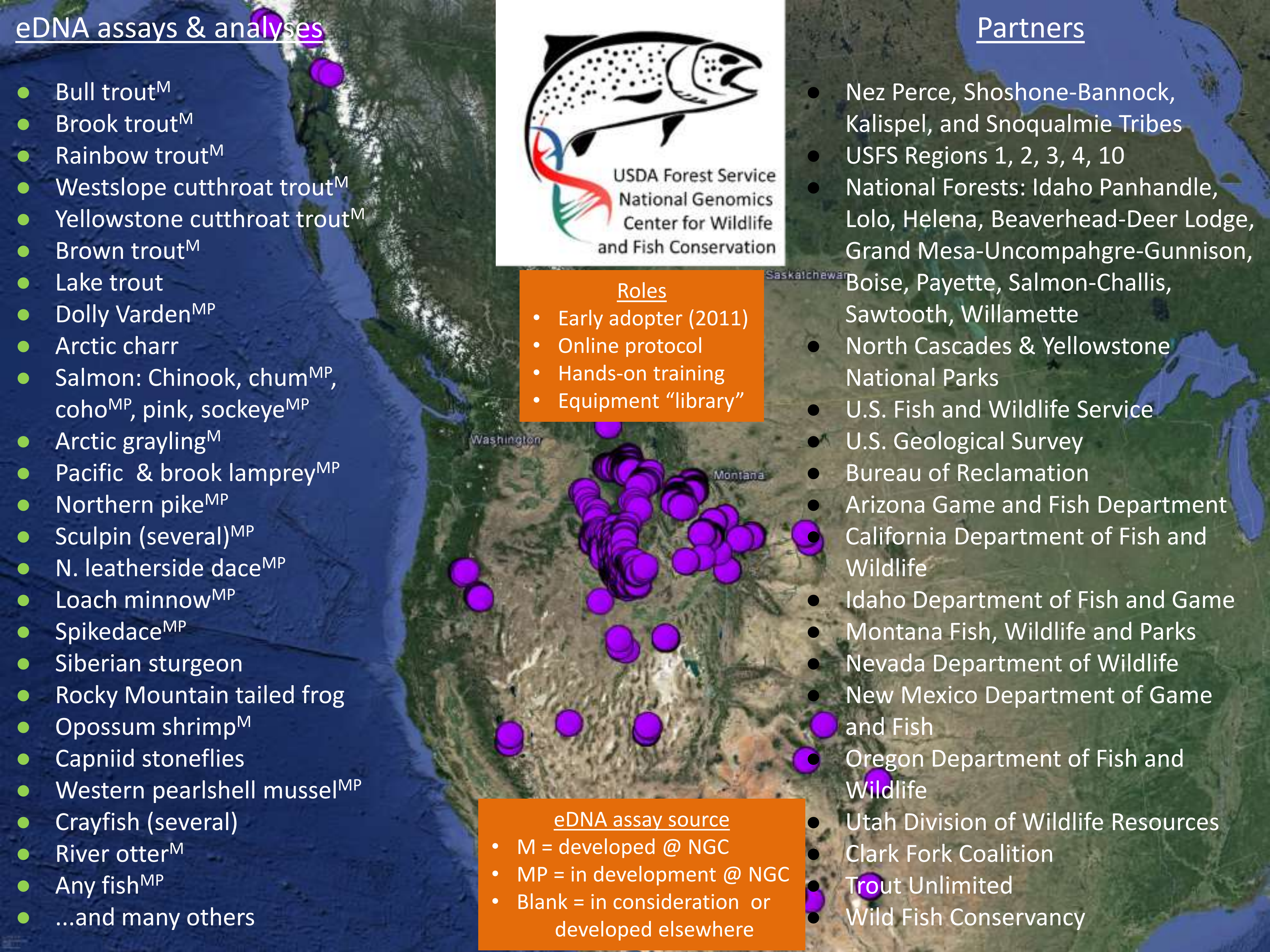
- 3 climate periods
- 5 Brook invasion levels

Narrative assessments for:

- Western pearlshell mussel
- Spring snails
- Rocky Mountain tailed frog
- Idaho giant salamander

Future Need: Better Biological Occurrence Databases

Aquatic eDNA sampling revolutionizing that



eDNA assays & analyses

- Bull trout[M]
- Brook trout[M]
- Rainbow trout[M]
- Westslope cutthroat trout[M]
- Yellowstone cutthroat trout[M]
- Brown trout[M]
- Lake trout
- Dolly Varden[MP]
- Arctic charr
- Salmon: Chinook, chum[MP], coho[MP], pink, sockeye[MP]
- Arctic grayling[M]
- Pacific & brook lamprey[MP]
- Northern pike[MP]
- Sculpin (several)[MP]
- N. leatherside dace[MP]
- Loach minnow[MP]
- Spikedace[MP]
- Siberian sturgeon
- Rocky Mountain tailed frog
- Opossum shrimp[M]
- Capniid stoneflies
- Western pearlshell mussel[MP]
- Crayfish (several)
- River otter[M]
- Any fish[MP]
- ...and many others

USDA Forest Service
National Genomics
Center for Wildlife
and Fish Conservation

Roles

- Early adopter (2011)
- Online protocol
- Hands-on training
- Equipment "library"

eDNA assay source

- M = developed @ NGC
- MP = in development @ NGC
- Blank = in consideration or developed elsewhere

Partners

- Nez Perce, Shoshone-Bannock, Kalispel, and Snoqualmie Tribes
- USFS Regions 1, 2, 3, 4, 10
- National Forests: Idaho Panhandle, Lolo, Helena, Beaverhead-Deer Lodge, Grand Mesa-Uncompahgre-Gunnison, Boise, Payette, Salmon-Challis, Sawtooth, Willamette
- North Cascades & Yellowstone National Parks
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- Bureau of Reclamation
- Arizona Game and Fish Department
- California Department of Fish and Wildlife
- Idaho Department of Fish and Game
- Montana Fish, Wildlife and Parks
- Nevada Department of Wildlife
- New Mexico Department of Game and Fish
- Oregon Department of Fish and Wildlife
- Utah Division of Wildlife Resources
- Clark Fork Coalition
- Trout Unlimited
- Wild Fish Conservancy

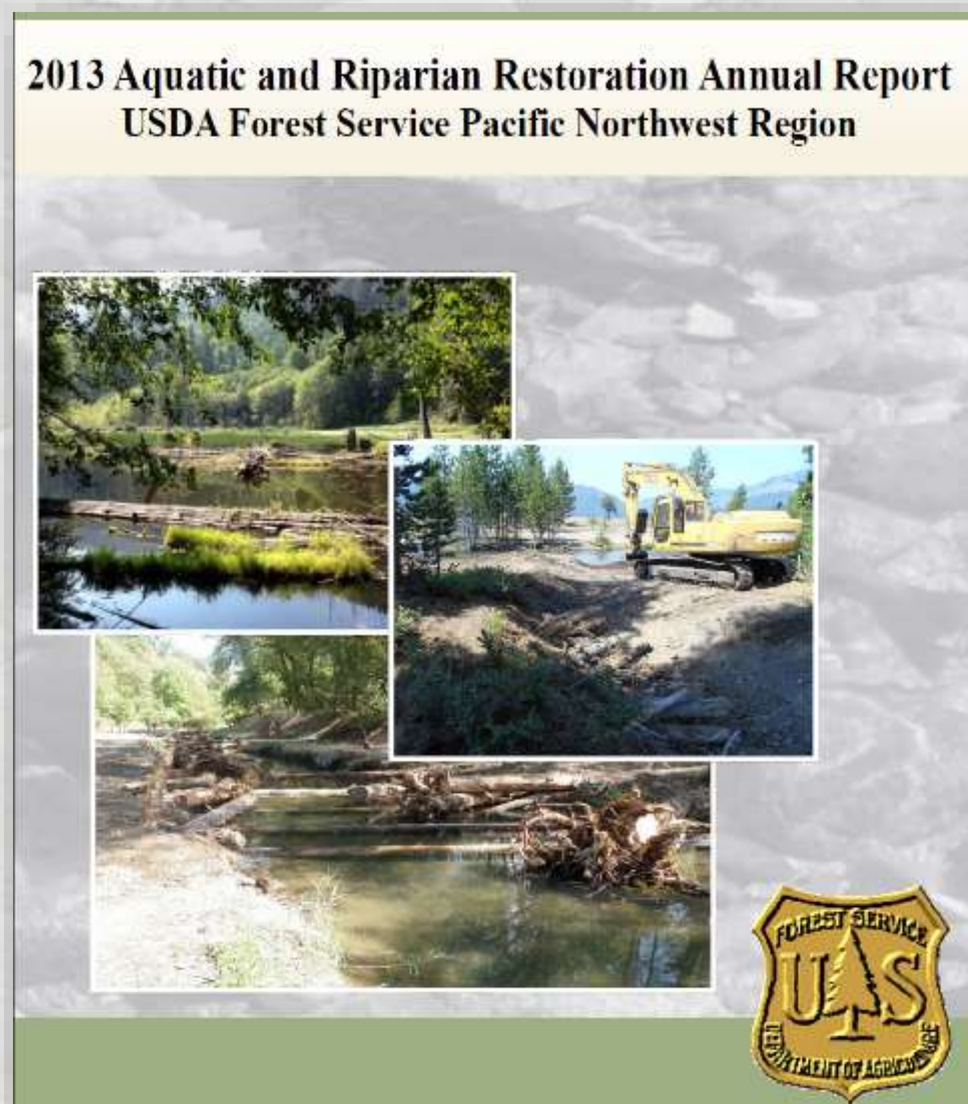
UNITED STATES DEPARTMENT OF AGRICULTURE - U.S. FOREST SERVICE

Rocky Mountain Research Station

Air, Water, & Aquatic Environments Program

The bull trout is an ESA-listed species with a historical range that encompasses many waters across the Northwest. Though once abundant, bull trout have declined in many locations and are at risk from a changing climate, nonnative species, and habitat degradation. Informed conservation planning relies on sound and precise information about the distribution of bull trout in thousands of streams, but gathering this information is a daunting and expensive task. To overcome this problem, we coupled 1) predictions from the range-wide, spatially precise **Climate Shield** model on the location of natal habitats of bull trout with 2) a sampling template for every 8-digit hydrologic unit in the historical range of bull trout, based on the probability of detecting bull trout presence using environmental DNA (eDNA) sampling (**McKelvey et al. 2016**). The template consists of a master set of geospatially referenced sampling locations at 1-km intervals within each cold-water habitat. We also identified sampling locations at this same interval based on the USFWS's designation of critical spawning and rearing habitat. Based on field tests of eDNA detection probabilities conducted by the **National Genomics Center for Wildlife and Fish Conservation**, this sampling approach will reliably determine the presence of populations of bull trout, as well as provide insights on non-spawning habitats used by adult and subadult fish. The result will be a rapid, robust, and repeatable range-wide assessment of natal habitats of this species, completed by 2018.

Climate Vulnerability Could Provide a Context for Prioritizing Stream Restoration Efforts…



- Modifying road culverts…
- Maintaining/restoring flow…
- Maintaining/restoring riparian…
- Restoring channel form/function…
- Non-native species control…
- Large woody debris…

Before → After

Forest Datasets Were Key to The Quality of This Assessment…

& Will Be Key to Improving Assessments in *Future* Decades…