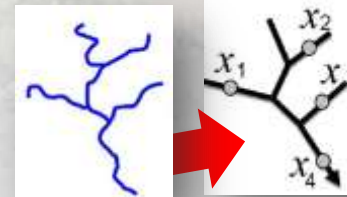
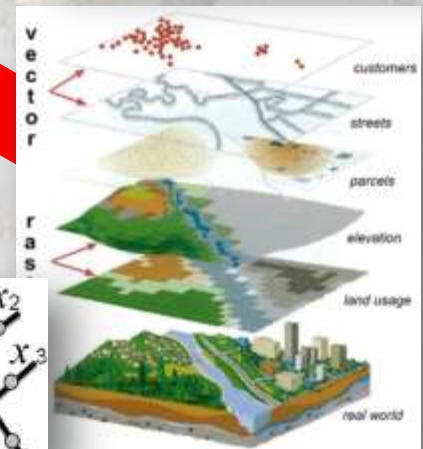
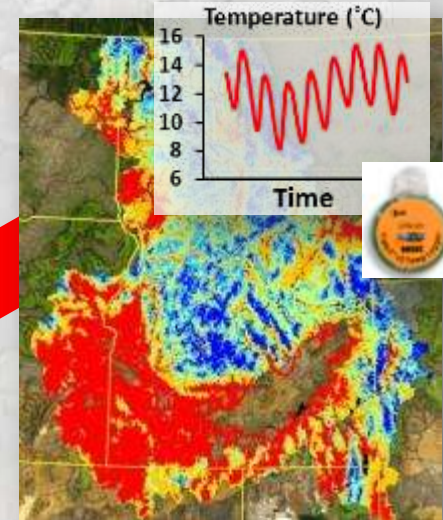


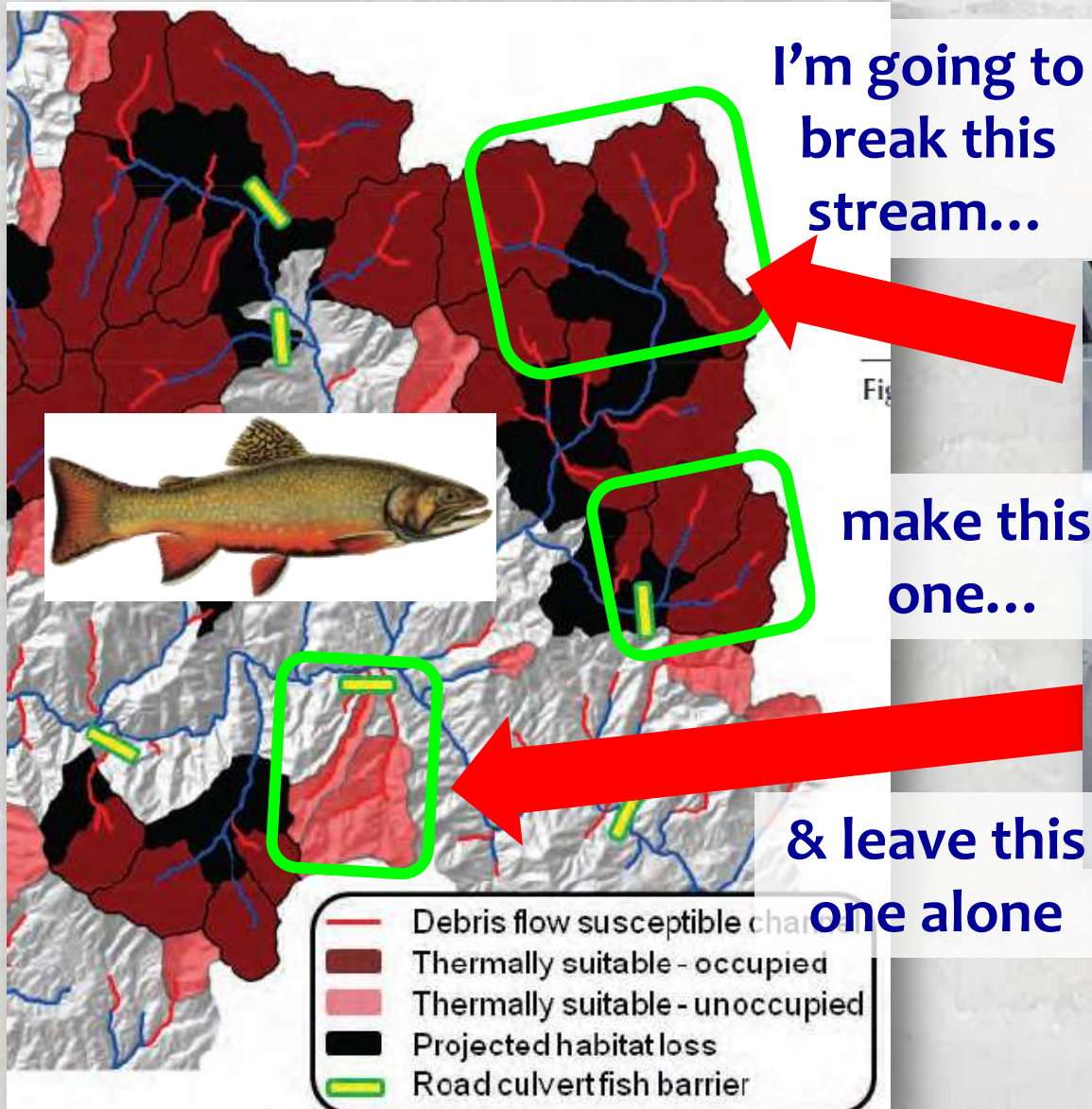
Informing “Make it or Break it” Decisions with High-Resolution Stream Geospatial Data & Climate Scenarios



Outline...

- I. Invasible habitats, environmental context, & old fuzzy habitat definitions
- II. Revolution #1: Quantity & quality of information mapped onto stream networks (GIS/spatial analysis/BIG DATA/sensor technology)
- III. Revolution #2: Information access & portability (websites/smartphones/dynamic digital maps)
- IV. Information overload & filtering the signal from the noise
- V. Think globally, act locally with “Make it or Break it” decisions

Precise Local Information is Crucial for Tactical Decision Making



The Right Choices Depend on Context

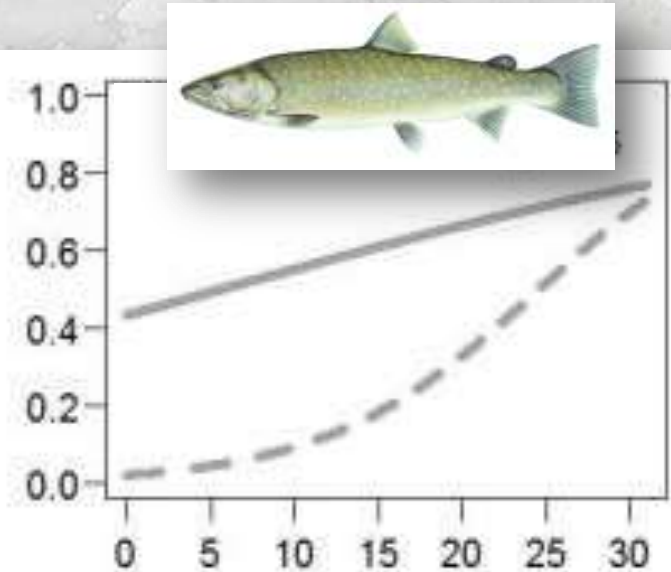
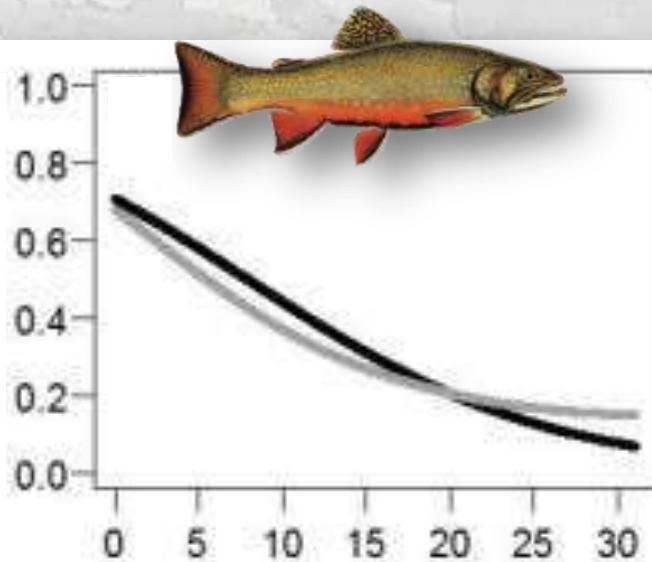
Habitat & Climate & Biology Determine Invasibility



The Right Choices Depend on Context

Habitat & Climate & Biology Determine Invasibility

Occurrence
Probability



Distance to Nearest Valley Bottom

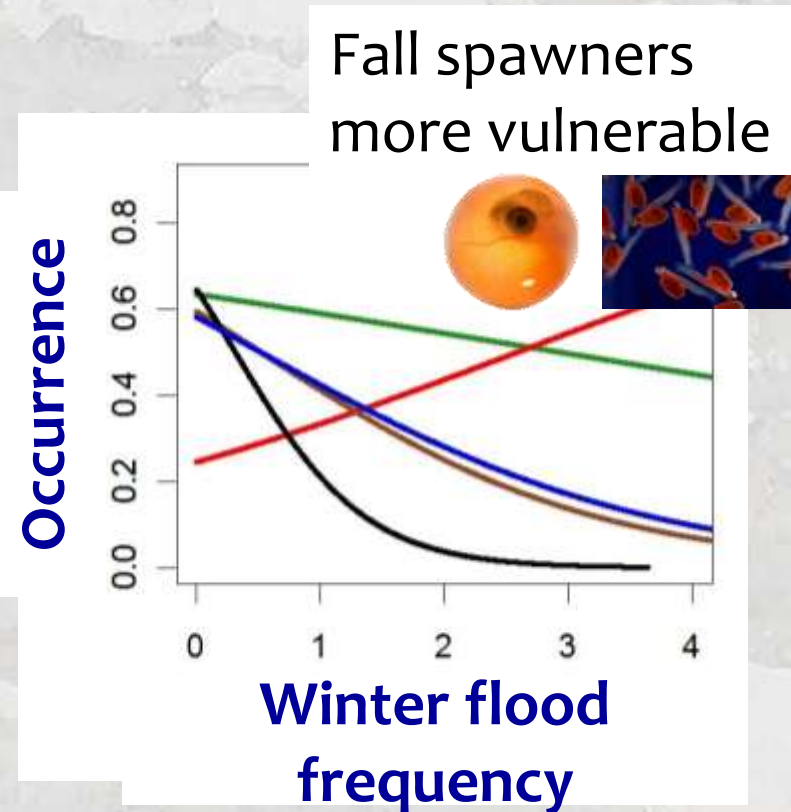
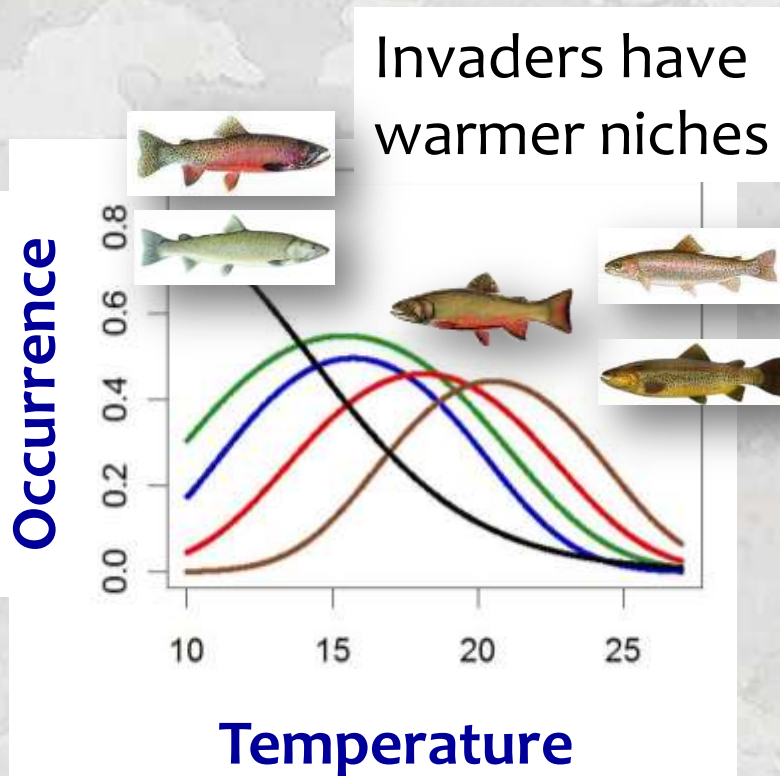
Wenger et al. 2011. *CJFAS* 68:988-1008.



Do we have “actionable intelligence”
that tells us where precisely
throughout networks?

The Right Choices Depend on Context

Habitat & Climate & Biology Determine Invasibility



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



Do we have “actionable intelligence” that tells us where precisely throughout networks?

Brett Roper's Contribution to Science

(When he's not busy directly controlling
invasive species)

North American Journal of Fisheries Management 15:49-53, 1995
© Copyright by the American Fisheries Society 1995

Observer Variability in Classifying Habitat Types in Stream Surveys

BRETT B. ROPER AND DENNIS L. SCARNECCHIA

Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho 83843, USA



Brett Roper's Contribution to Science

(When he's not busy directly controlling
invasive species)

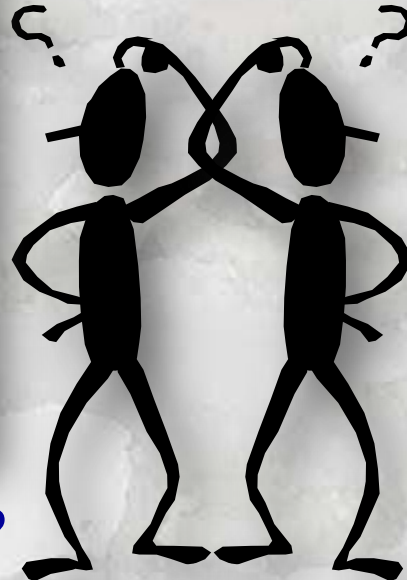
North American Journal of Fisheries Management 15:49-53, 1995
© Copyright by the American Fisheries Society 1995

Observer Variability in Classifying Habitat Types in Stream Surveys

BRETT B. ROPER AND DENNIS L. SCARNECCHIA

Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho 83843, USA

Describing habitat is subjective & imprecise

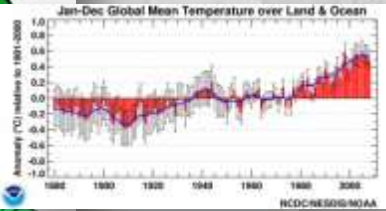
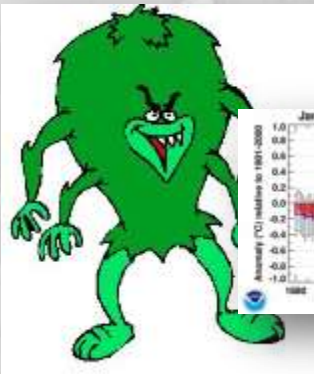


What is a Pool?

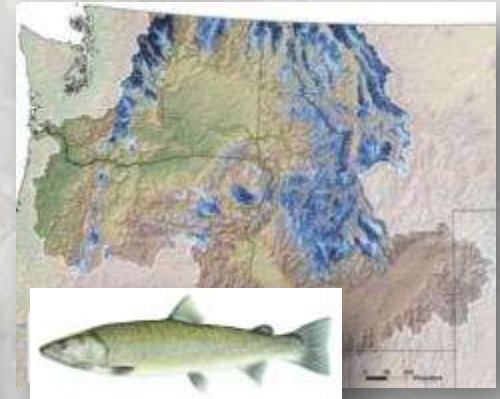
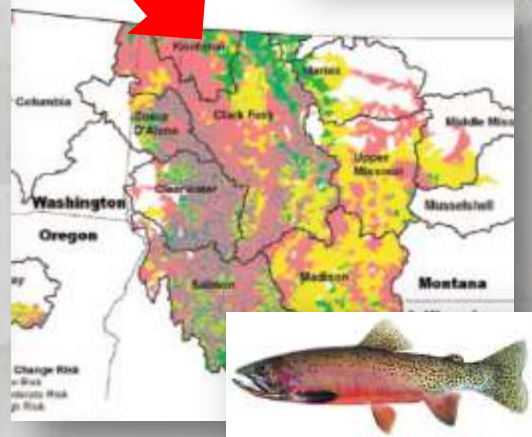
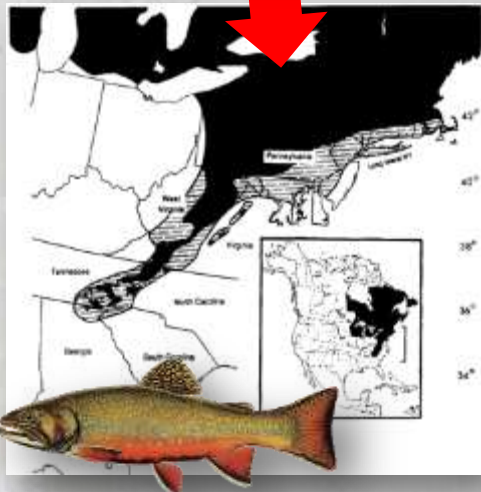
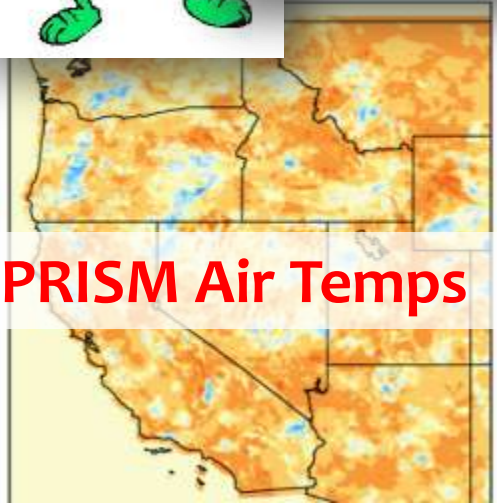
What is a Riffle?

We Don't Know... We're Not Fluvial Geomorphologists

Scary Climate Assessments Have Been Equally Imprecise



PRISM Air Temps



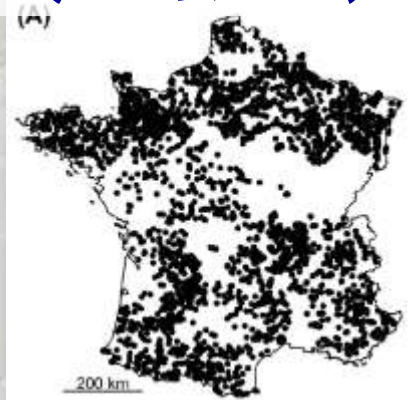
- Meisner 1988, 1990
- Eaton & Schaller 1996
- Keleher & Rahel 1996
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.

Fish Biologists Can Measure Fish & They're Starting to Move...

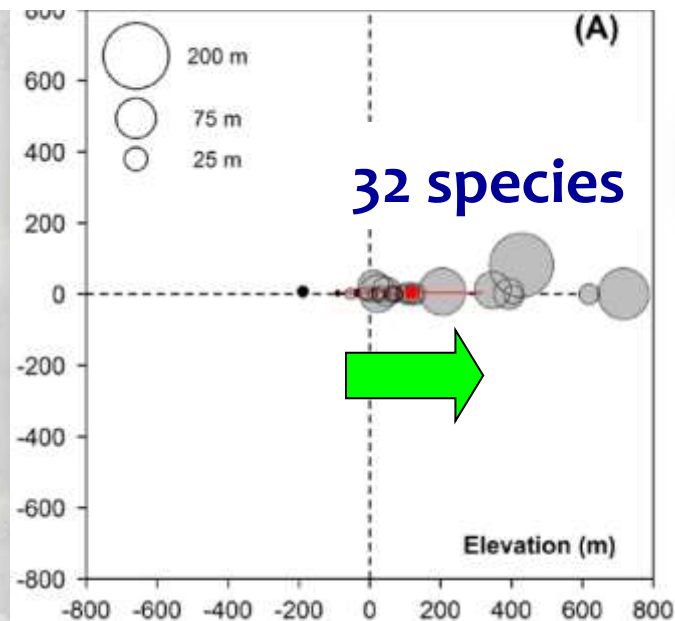


National French Study

Survey sites
(n = 3,500)



Difference in stream fish
distributions (1980's vs 2000's)



Change in Elevation (m)



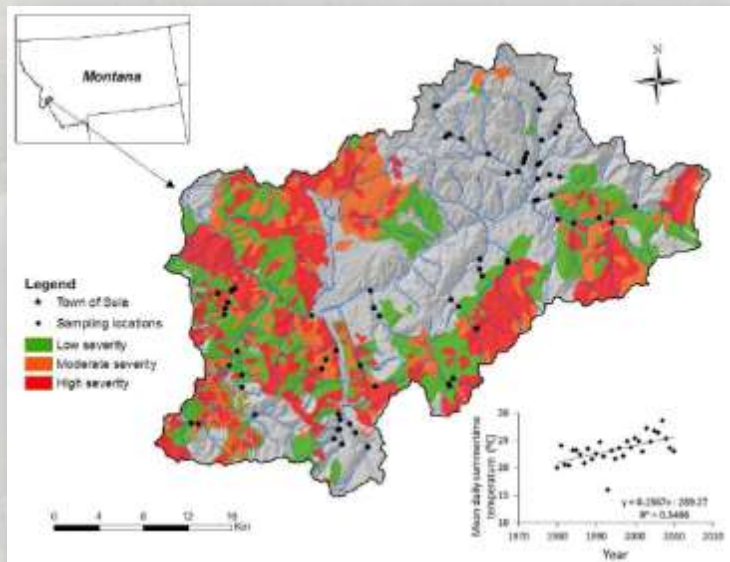
March of the fishes...



Comte & Grenouillet. 2013. Do stream fish track climate change? Assessing distribution shifts in recent decades. *Ecography* doi: 10.1111/j.1600-0587.2013.00282.x

Bull Trout Distribution Shifts in Montana

- Resurveyed 77 Rich et al. (2003) sites 20 years later
- Modeled extirpations/colonizations accounting for detection efficiency



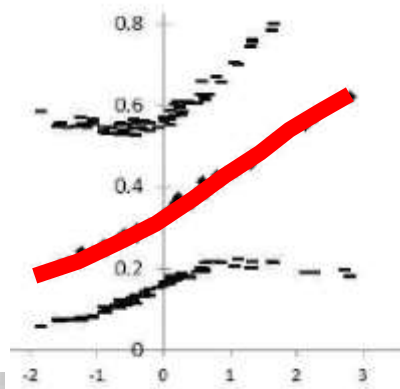
Eby et al. In Review. Evidence of climate-induced range contractions for bull trout in a Rocky Mountain watershed, U.S.A. *PLoS One*.

Bull Trout Distribution Shifts in Montana

Extirpation probability (95%CI)



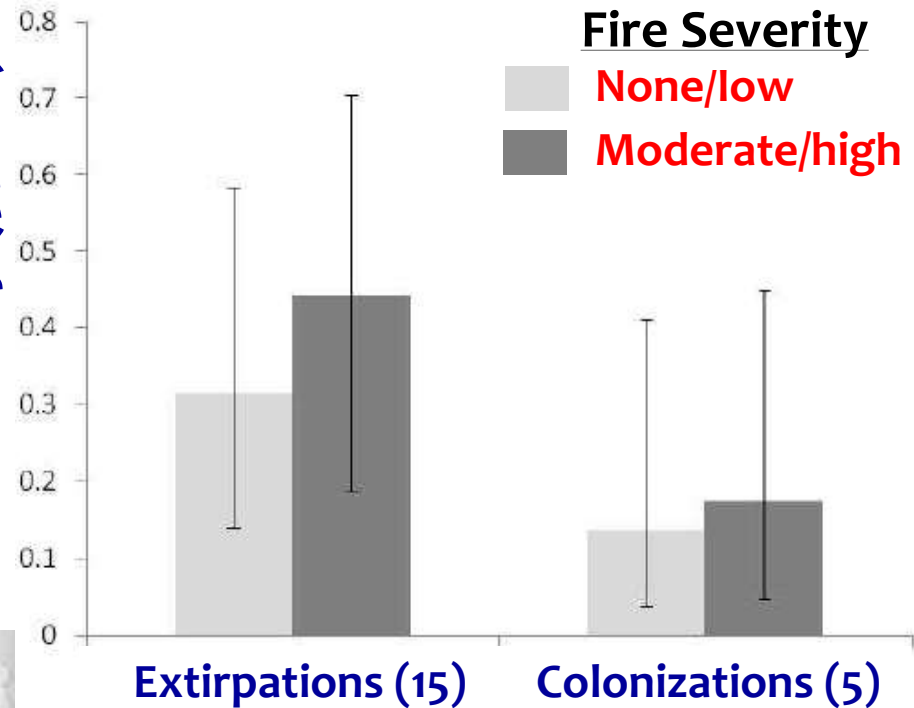
Standardized elevation



Standardized temperature

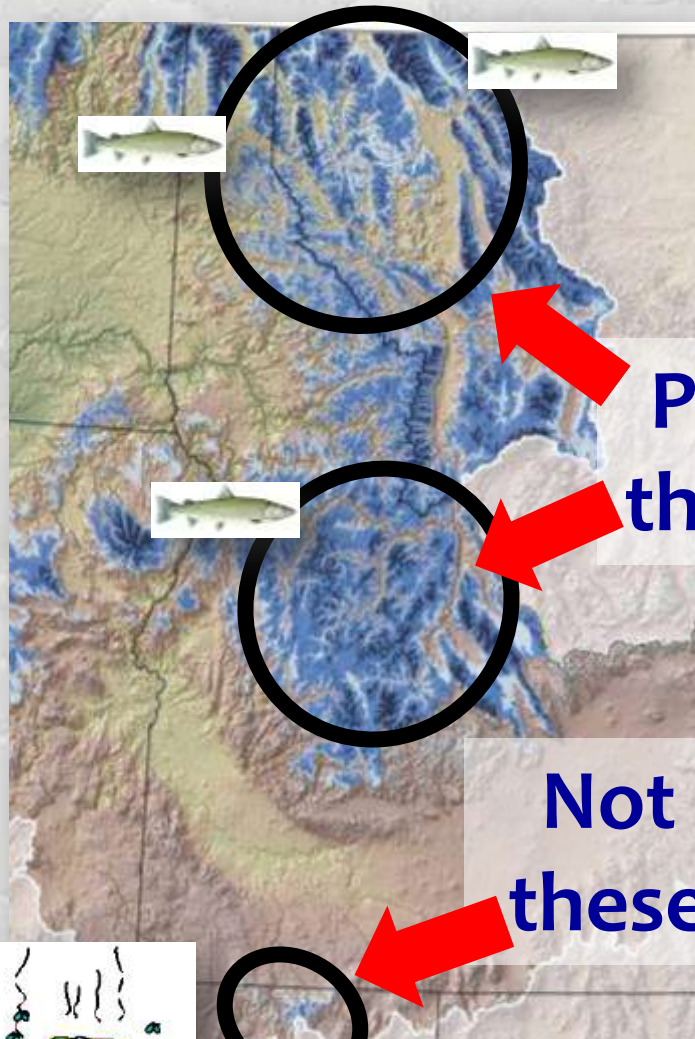


Probability (95%CI)



Local Decisions also Need a Strategic Context

**The 21st-Century will Be
a Transitional One**



**Pick
these**

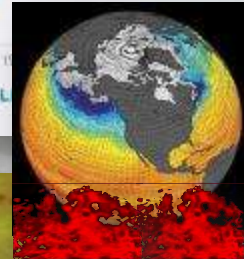
**Not
these**

Sorry Charlie

2012: HOTTEST YEAR ON RECORD
Average Annual Temperature in Contiguous U.S.



* Source: Climate Central, compiled from NOAA's National Climatic Data Center and Applied Climate Information System, based on observed temperatures through December 10, 2012 and an estimate of the Normal distribution of temperatures for the last 21 days of December based on data from the previous 117 years. (See Methodology)



Revolution #1: Quantity & Quality of Information is Exploding

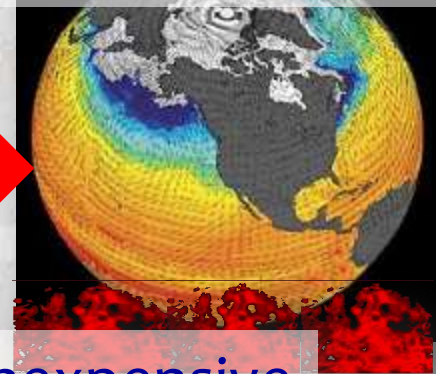
Remote Sensing



GIS / Computing Capacity



Climate, weather, GCM data online



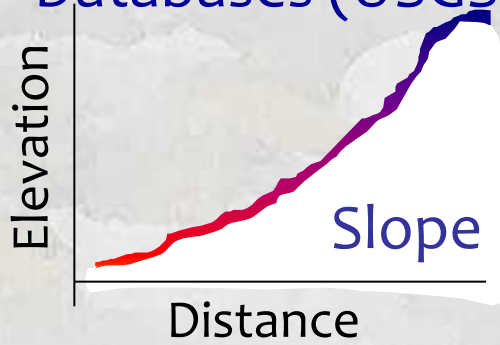
Visualization



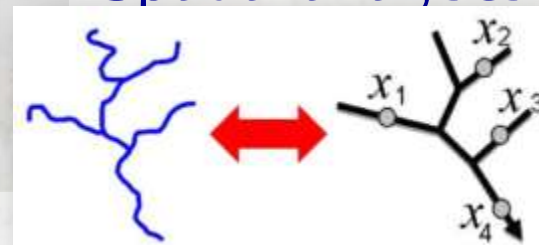
Inexpensive sensors



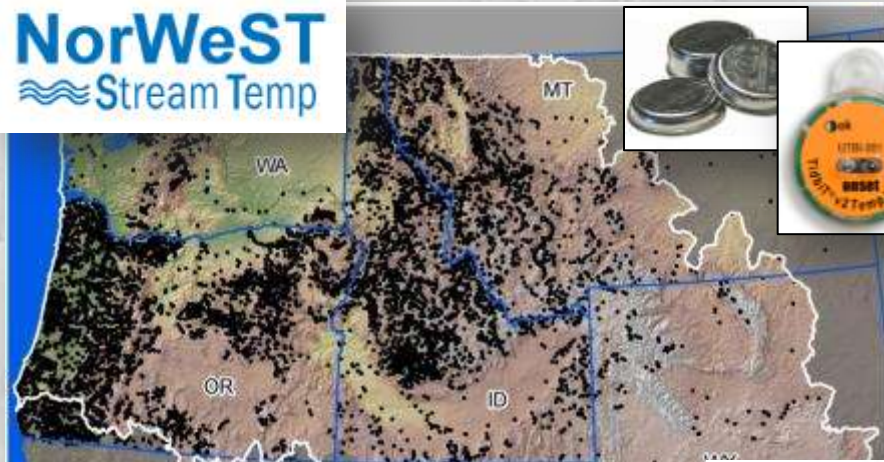
Nationally Consistent Hydrology Databases (USGS NHD+)



Spatial analyses

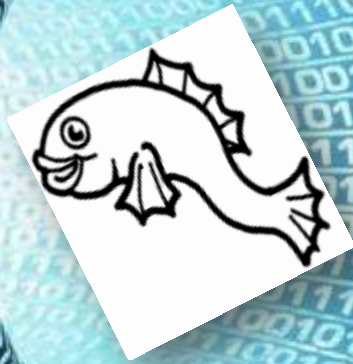


A vertical image showing a close-up of water with a greenish-blue tint, featuring ripples and reflections.



20,000 fish surveys

BIG DATA presents big challenges



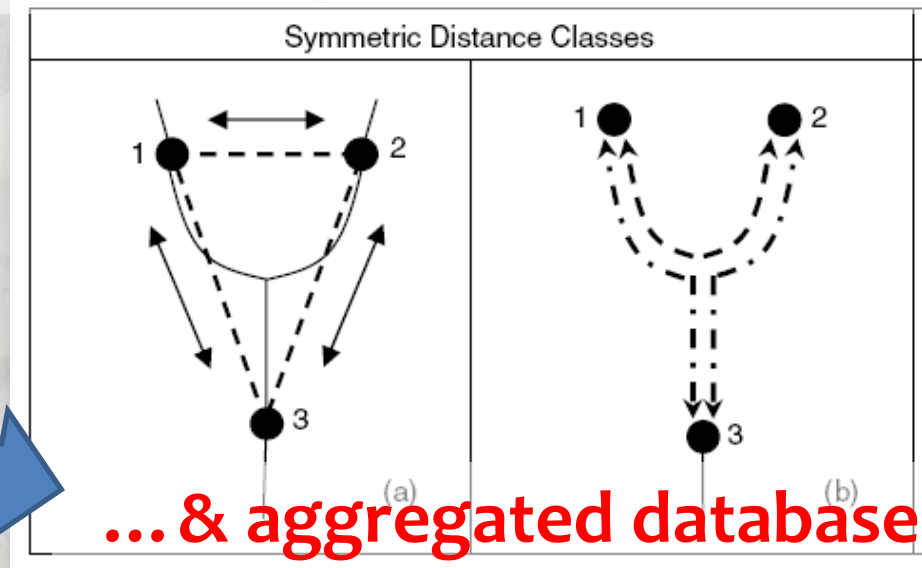
BIG DATA = BIG INFORMATION?

BIG DATA are often Autocorrelated

Spatial Statistical Network Models



Valid interpolation on networks



Advantages:

- flexible & valid autocovariance structures that accommodate network topology & non-independence among observations
- improved predictive ability & parameter estimates relative to non-spatial models

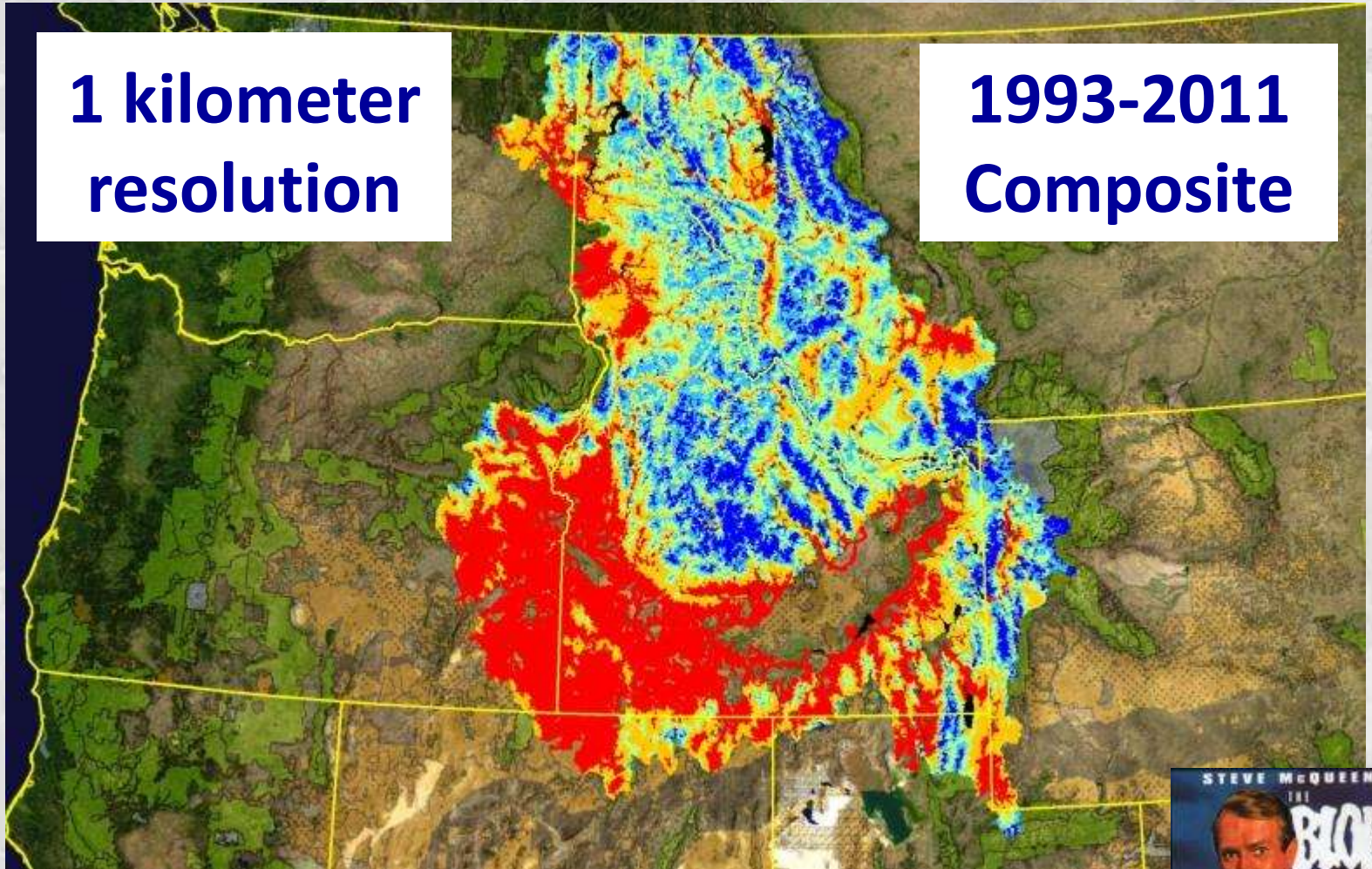
Accurate, Unbiased Information from Aggregated Stream Databases



High Resolution Stream Thermalscape

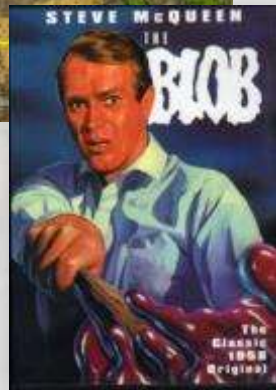
**1 kilometer
resolution**

**1993-2011
Composite**



The BLOB... it just keeps growing...

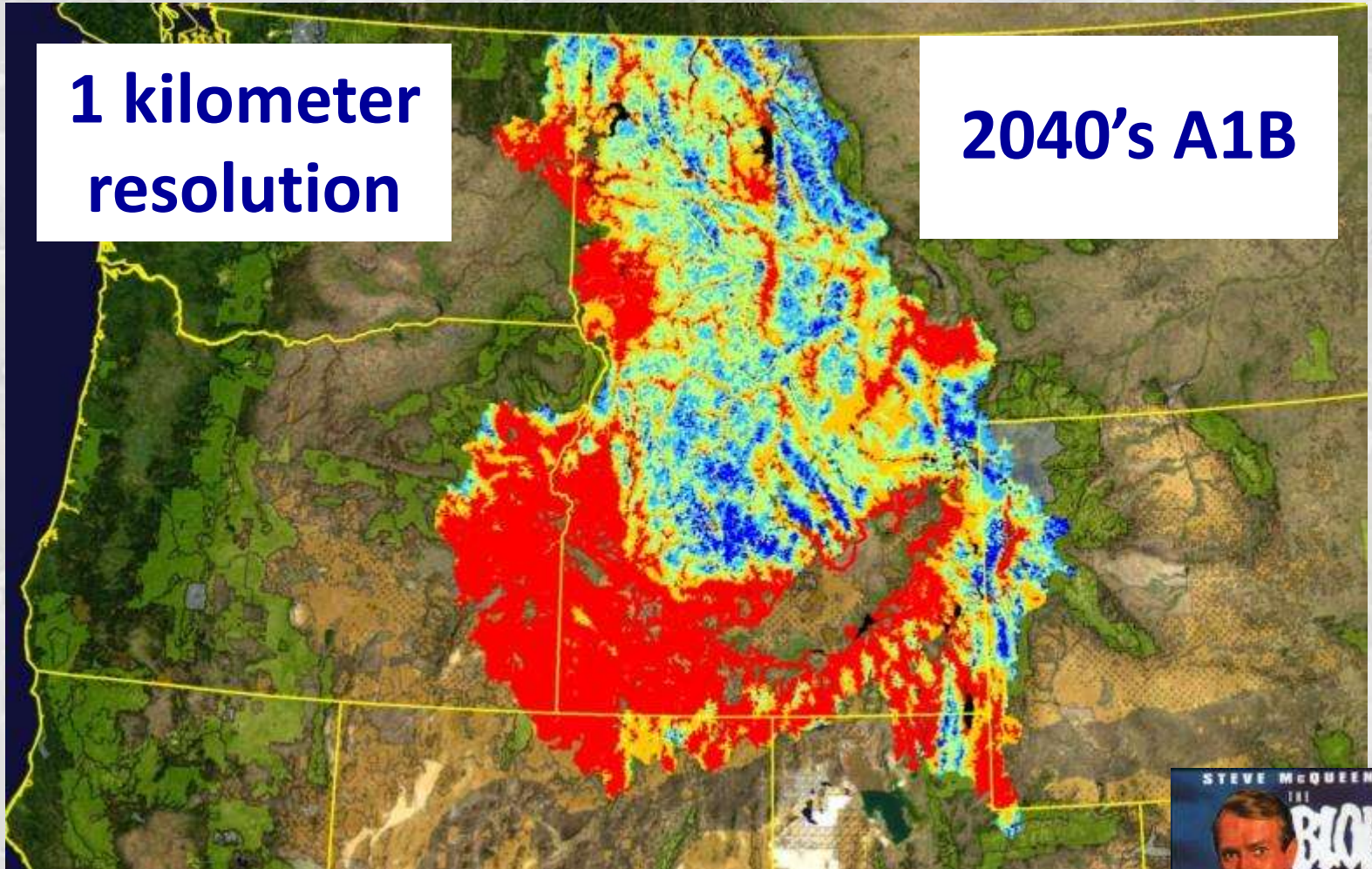
- 234,000 stream kilometers of thermal ooze
- 20,072 summers of data swallowed



High Resolution Stream Thermalscape

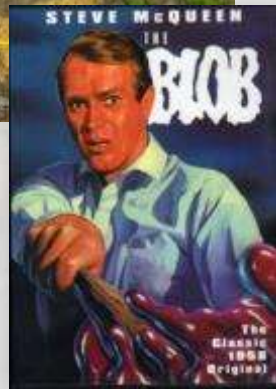
**1 kilometer
resolution**

2040's A1B



The BLOB... it just keeps growing...

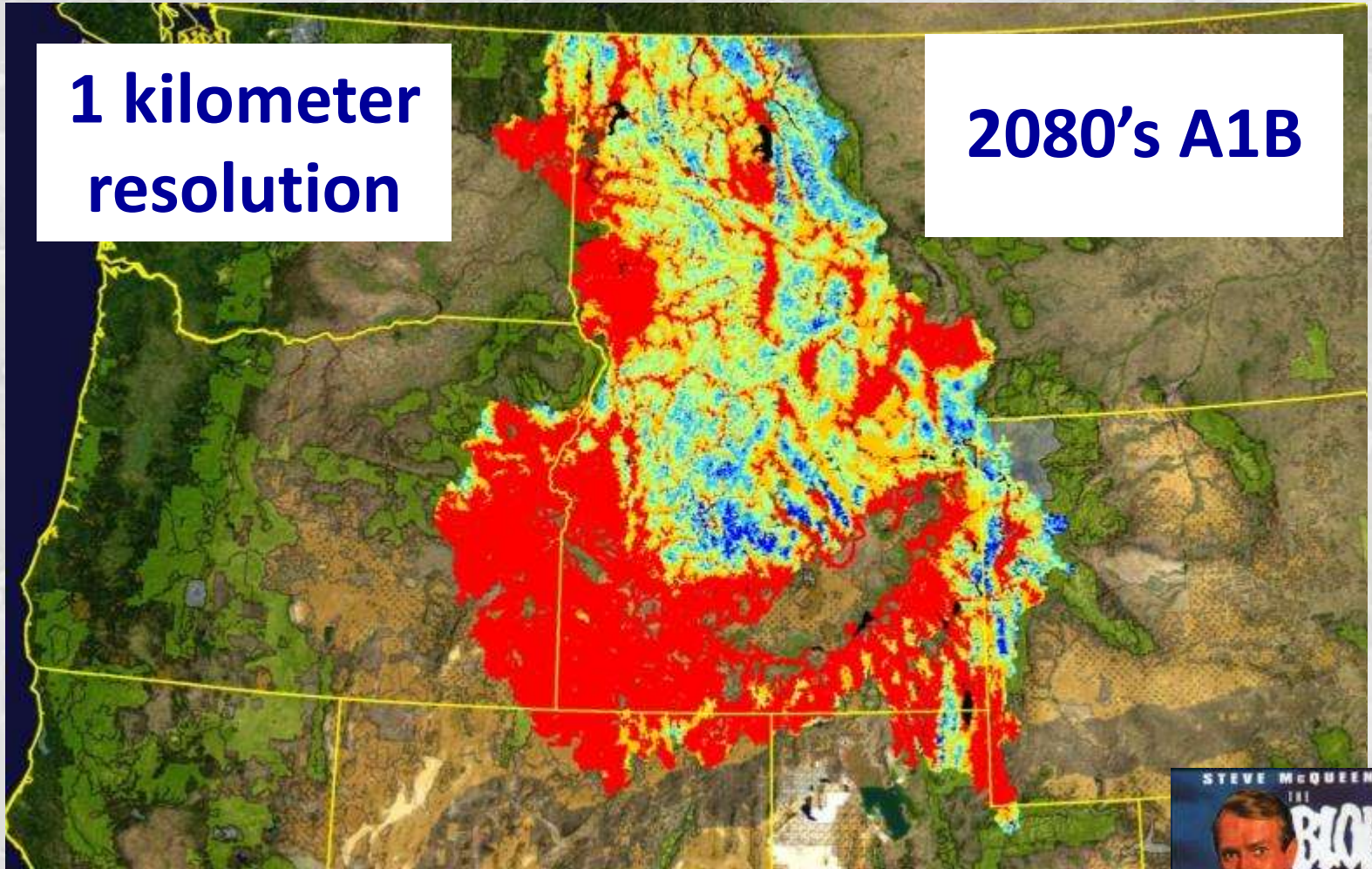
- 234,000 stream kilometers of thermal ooze
- 20,072 summers of data swallowed



High Resolution Stream Thermalscape

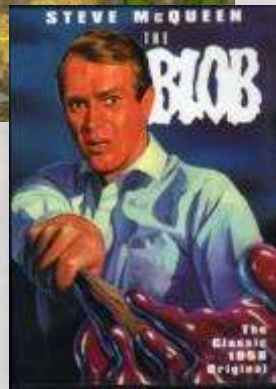
**1 kilometer
resolution**

2080's A1B



The BLOB... it just keeps growing...

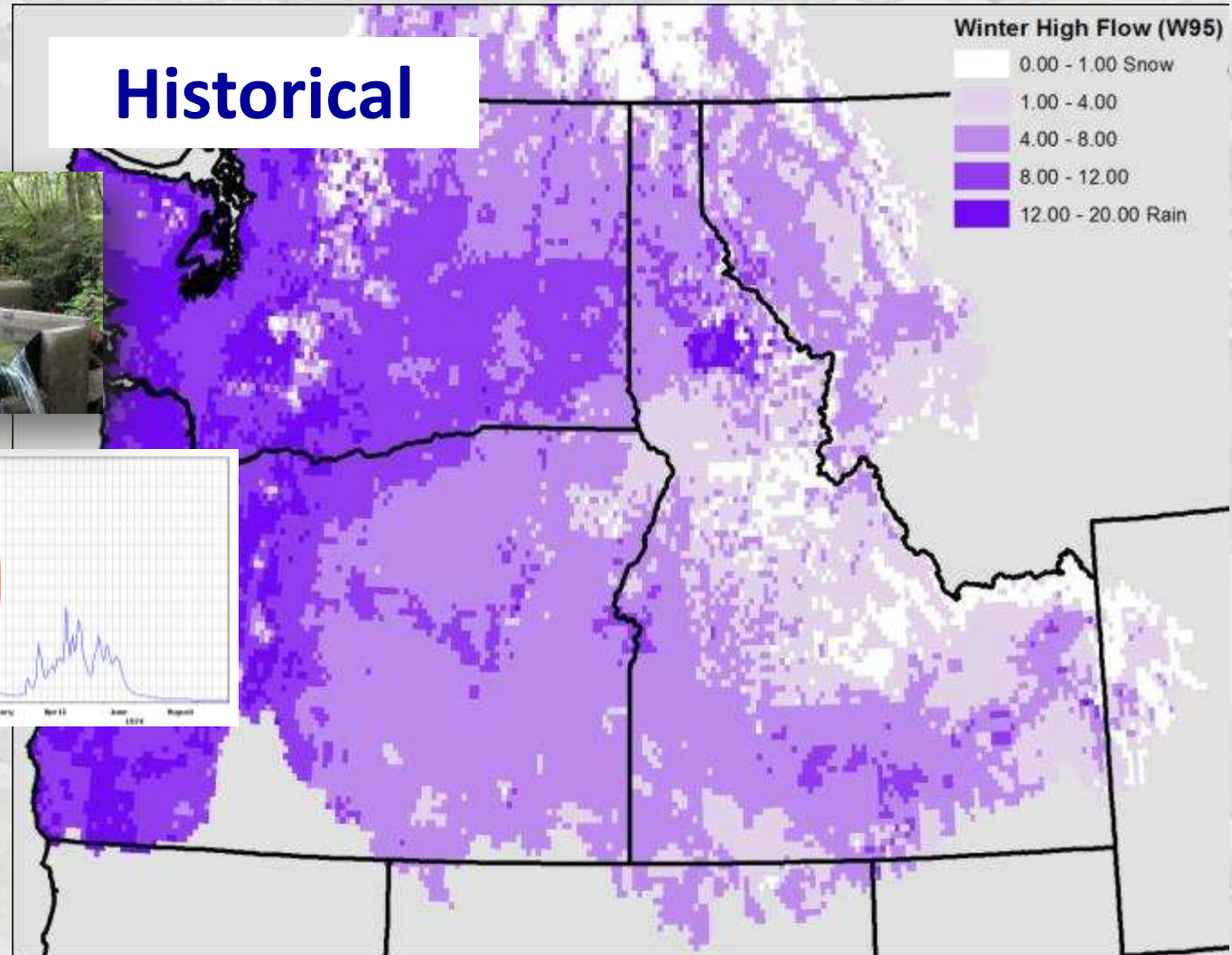
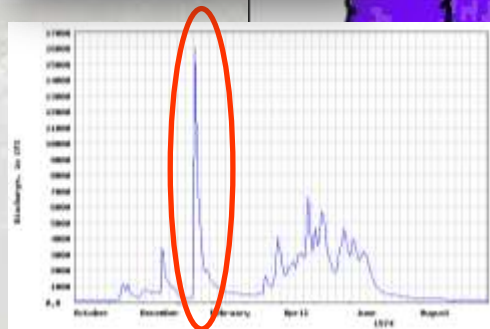
- 234,000 stream kilometers of thermal ooze
- 20,072 summers of data swallowed



VIC Streamflow Metrics & Scenarios

Winter flood frequency (95% event)

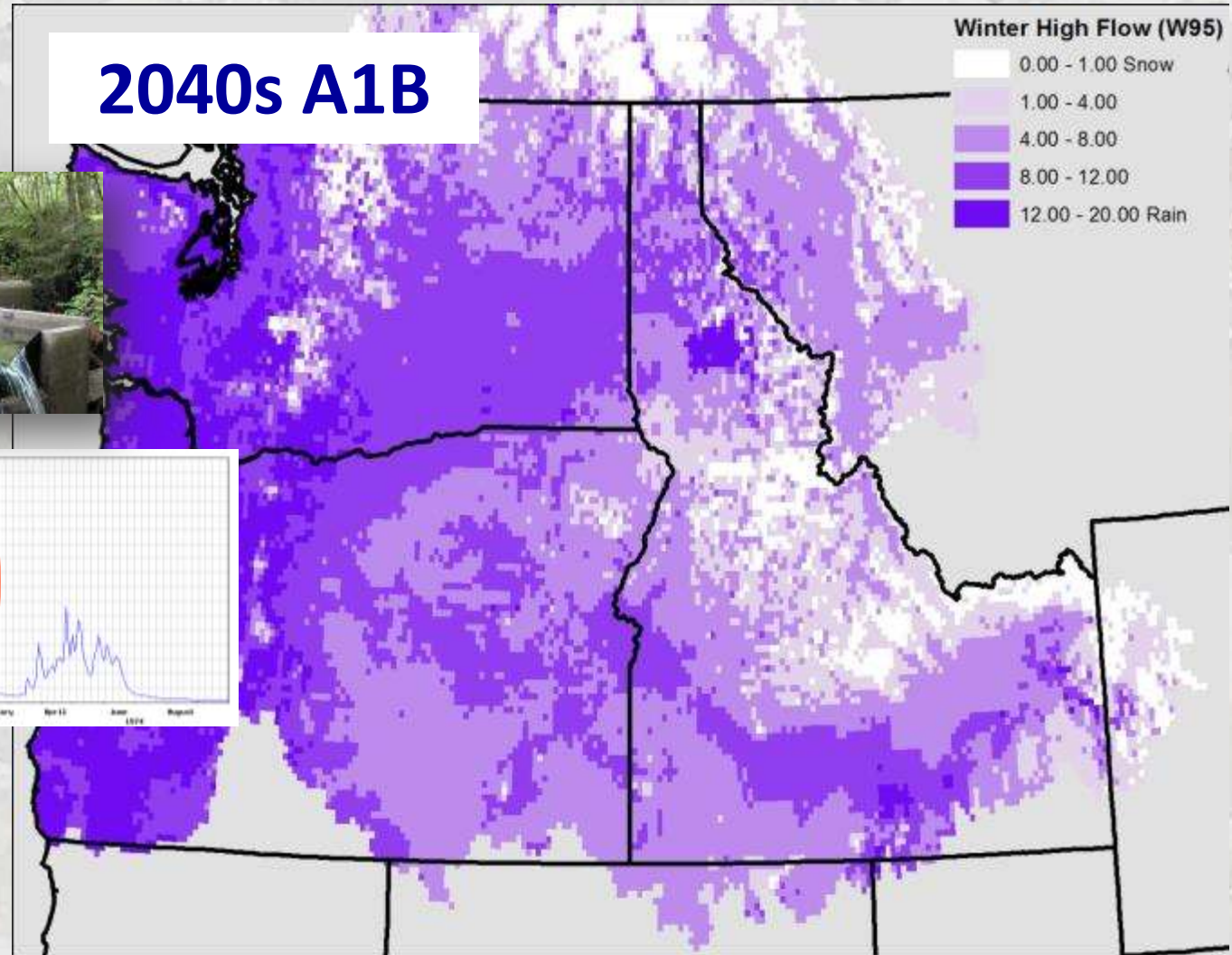
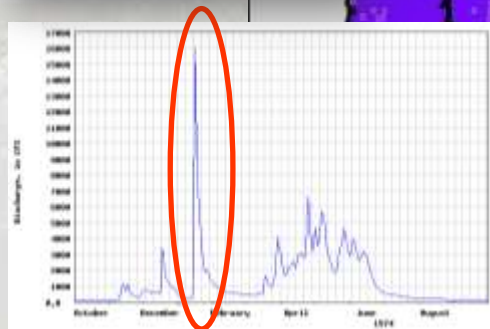
Historical



VIC Streamflow Metrics & Scenarios

Winter flood frequency (95% event)

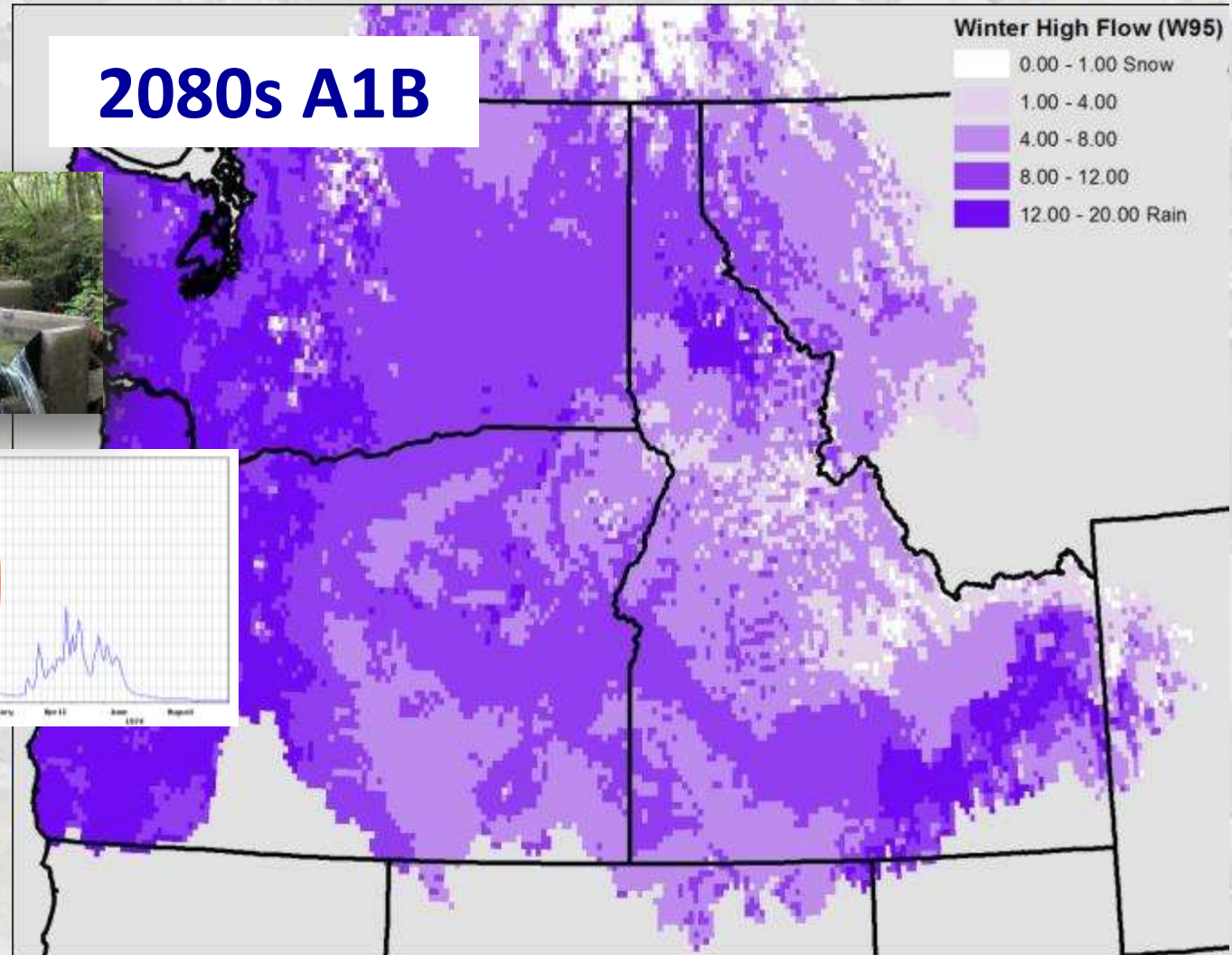
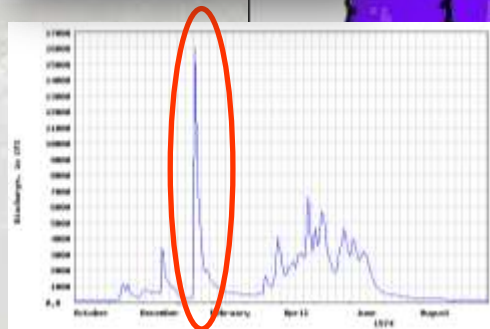
2040s A1B



VIC Streamflow Metrics & Scenarios

Winter flood frequency (95% event)

2080s A1B

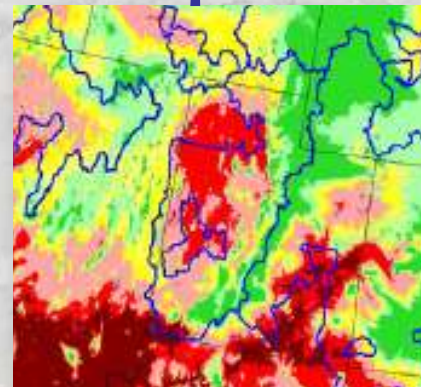


Lots of Stream Habitat Descriptors

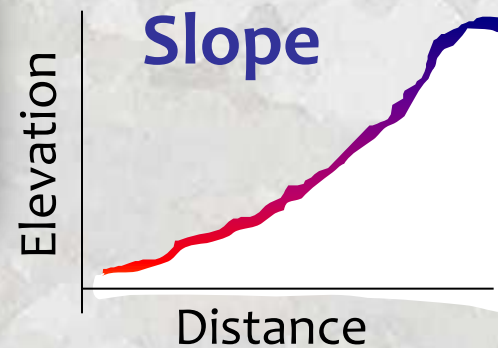
100's are Available (NHDPlus, NLCD, DEMs...)



Precipitation



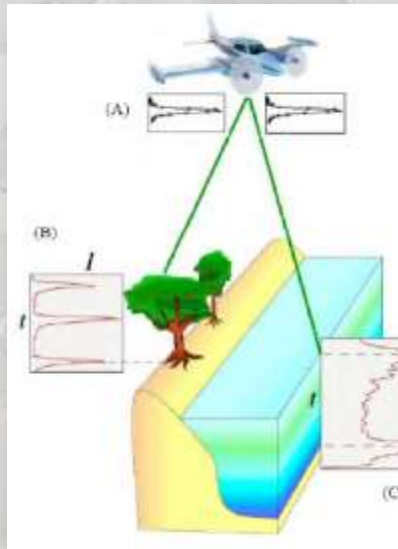
Drainage Area



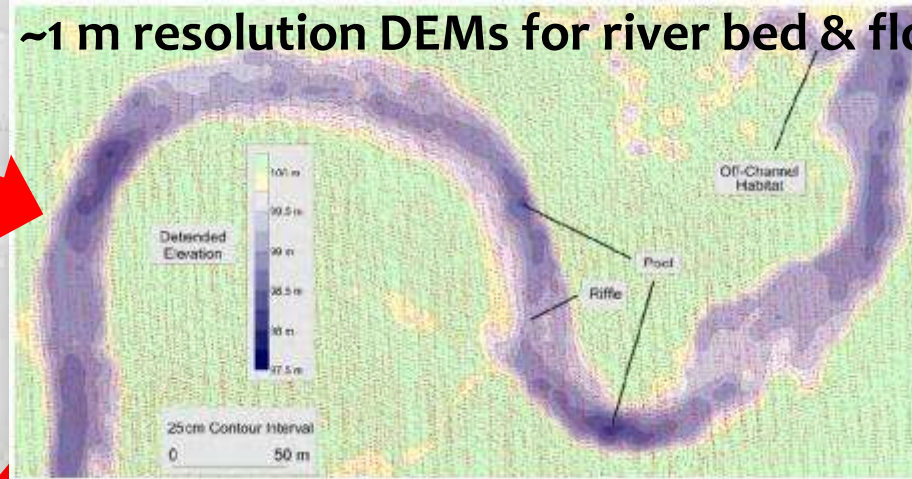
Wang et al. 2011. A Hierarchical Spatial Framework and Database for the National River Fish Habitat Condition Assessment. *Fisheries* 36:436-449.

Better Information for Mainstem Rivers

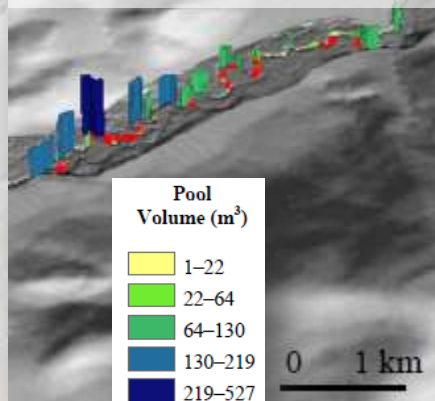
Green Lidar flown to census Lemhi River last October



~1 m resolution DEMs for river bed & floodplain

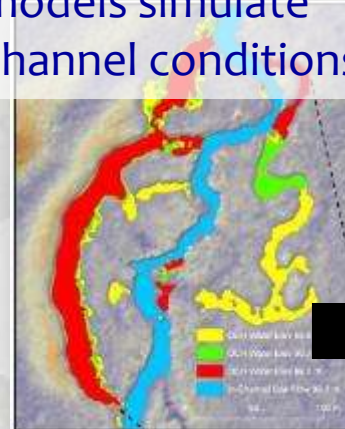


Precisely Quantify
Fish Microhabitats



McKean et al. 2008; McKean & Tonina 2013

Hydrodynamic
models simulate
channel conditions



Link to fish population
models

Smolts

Walters et al. 2013

— S-R capacity (13,185)
..... H capacity - 95% CI (11,481)
- - - H capacity - median (5,025)

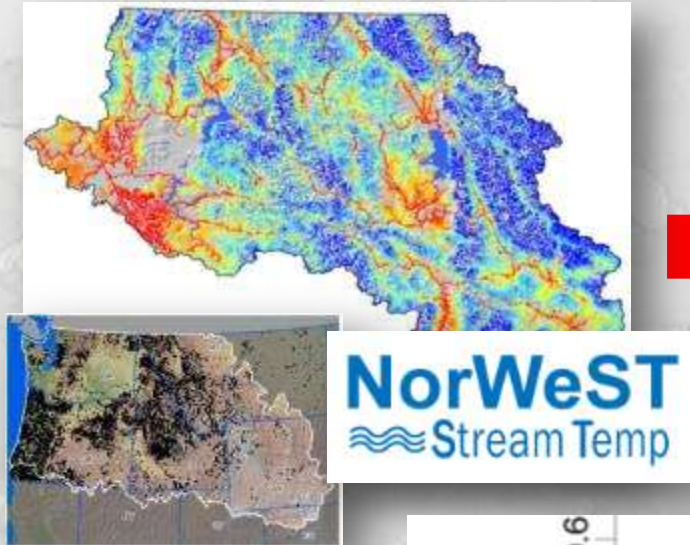
Redds

0 50 100 150 200 250 300 350

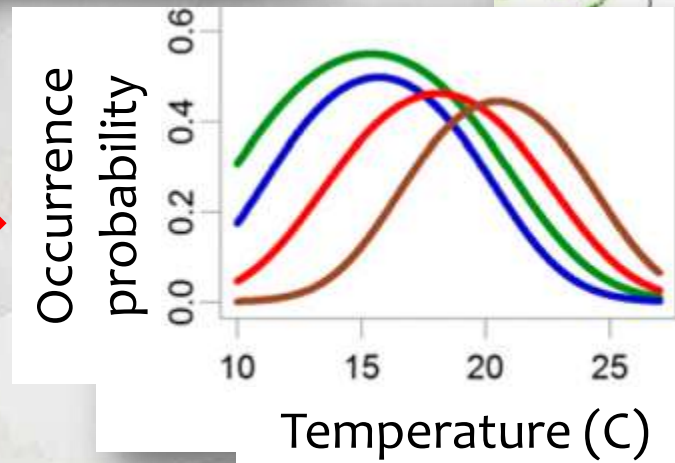
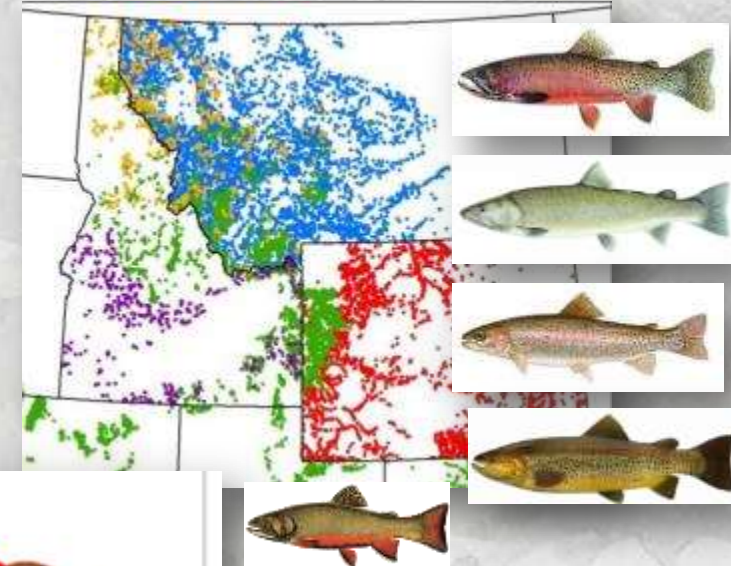
Synergies Emerge from Better Information

Regionally Consistent Thermal Criteria

Stream temperature maps



Regional fish survey databases (n ~ 20,000)



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

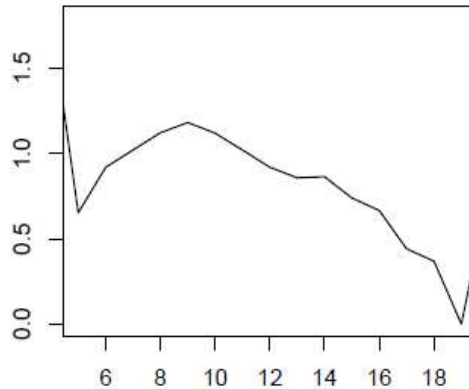
Wenger et al. 2011b. *CJFAS* **68**:988-1008; Wenger et al., *In Preparation*

Trout Thermal Niches

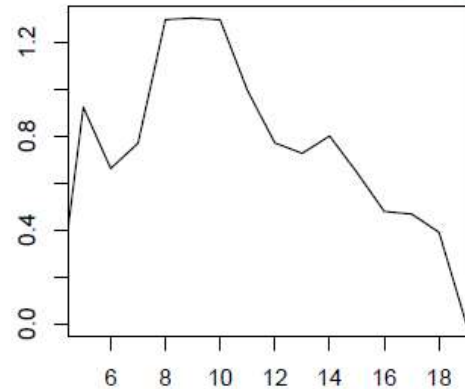
~20,000 fish
surveys

Frequency of Occurrence

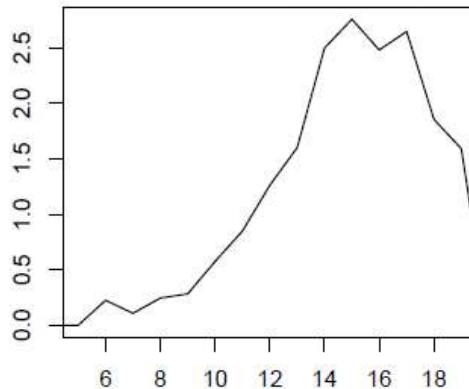
Cutthroat



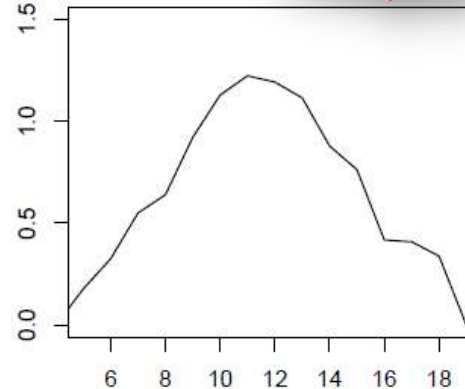
Bull



Rainbow



Brook

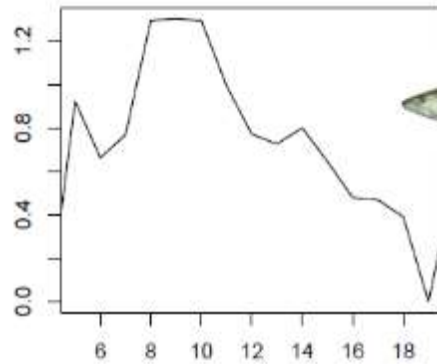


NorWeST Stream Temperature (S1)

Thermal Niche Nuances...

All Bull Trout

Frequency

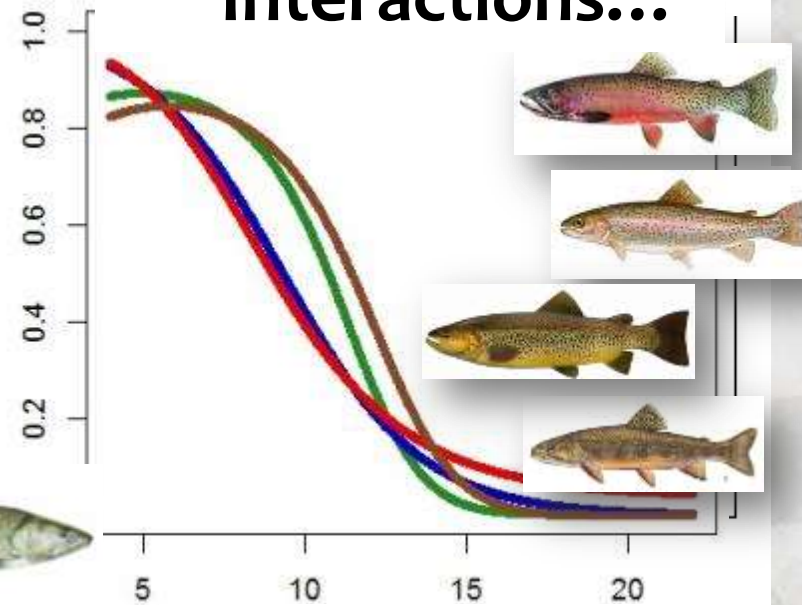


NorWeST
Temperature



Competitive
Interactions...

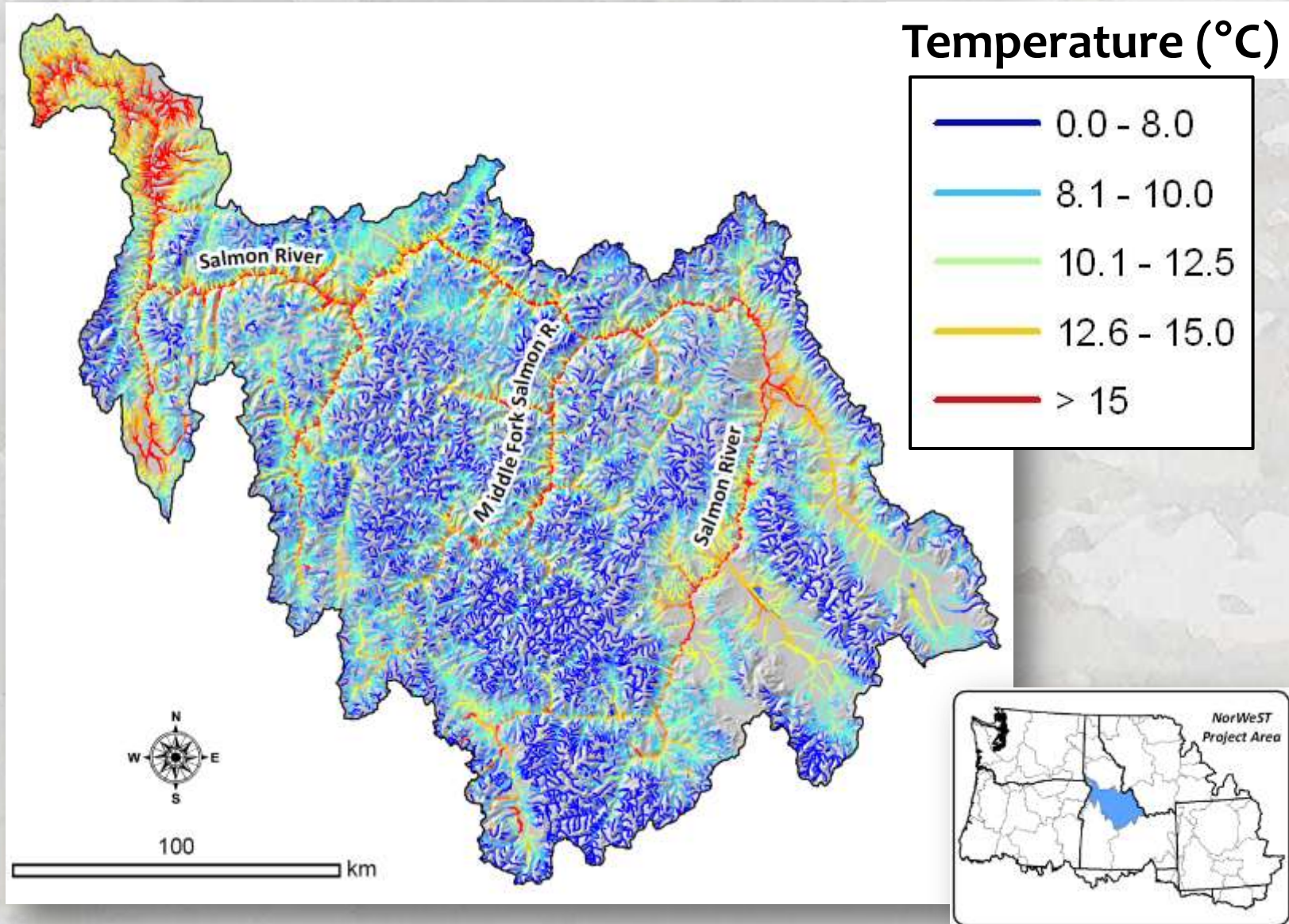
Frequency



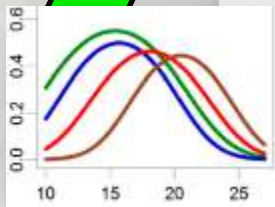
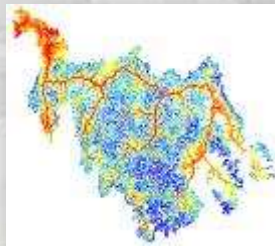
NorWeST
Temperature

Salmon River Temperature Scenario

Historic (1993-2011 Average August)



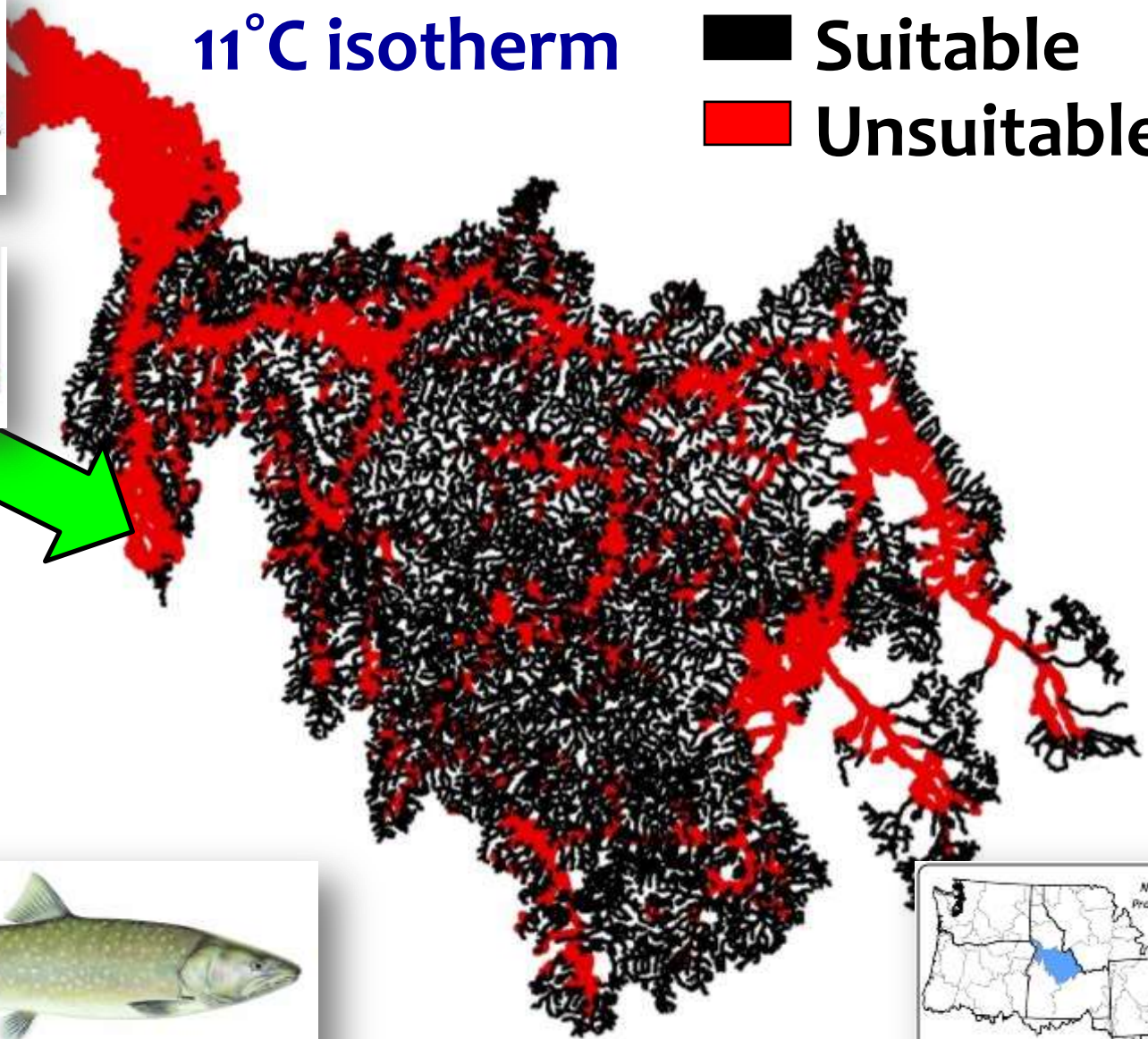
Bull Trout Natal Habitats = Historic



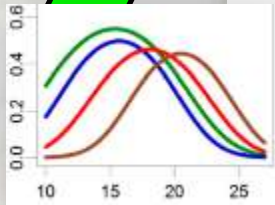
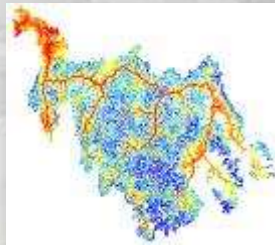
11°C isotherm

■ Suitable

■ Unsuitable

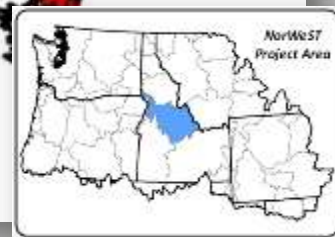
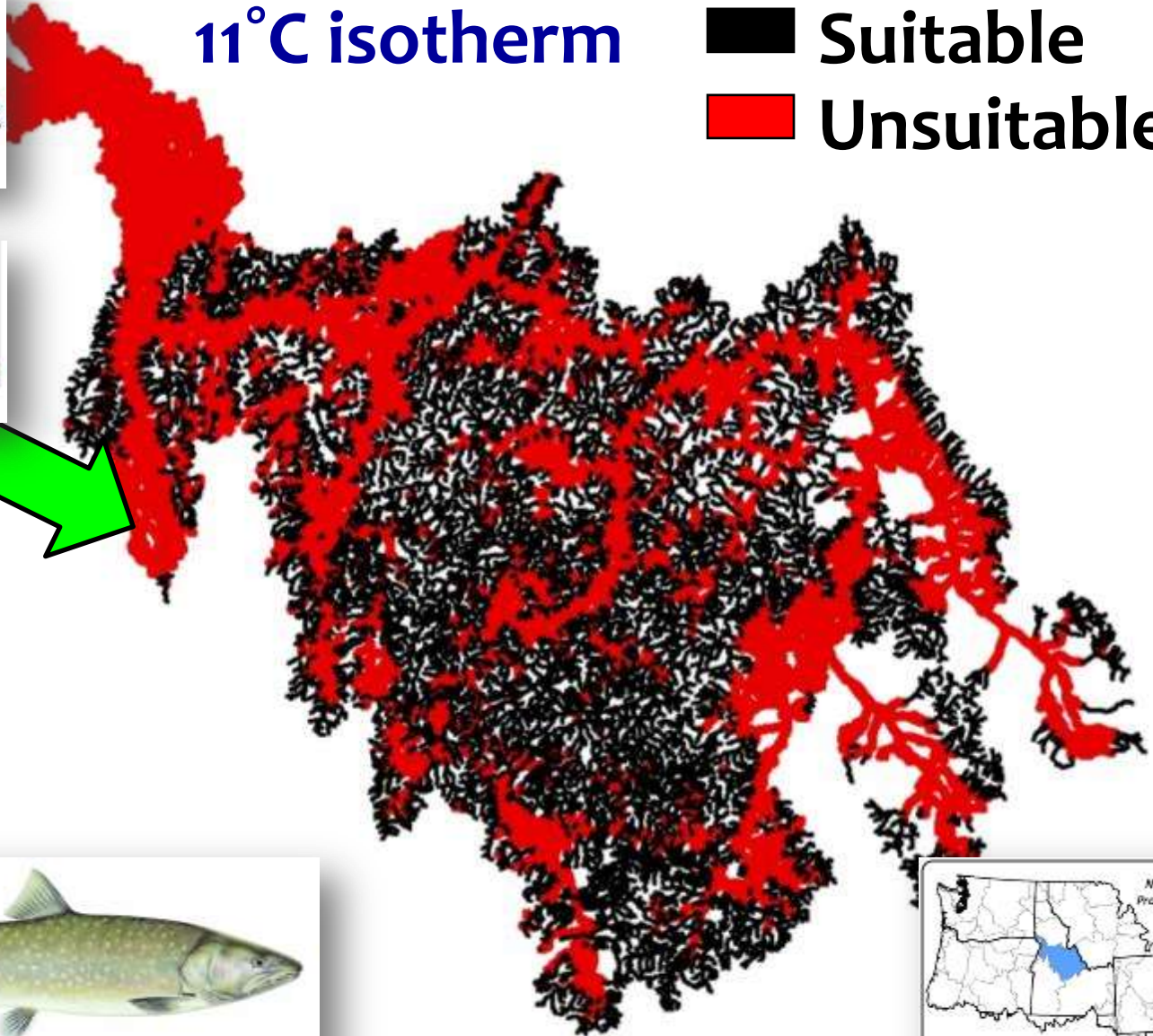


Bull Trout Natal Habitats = +1°C

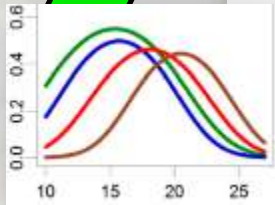
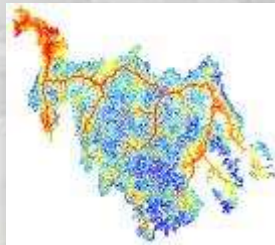


11°C isotherm

■ Suitable
■ Unsuitable

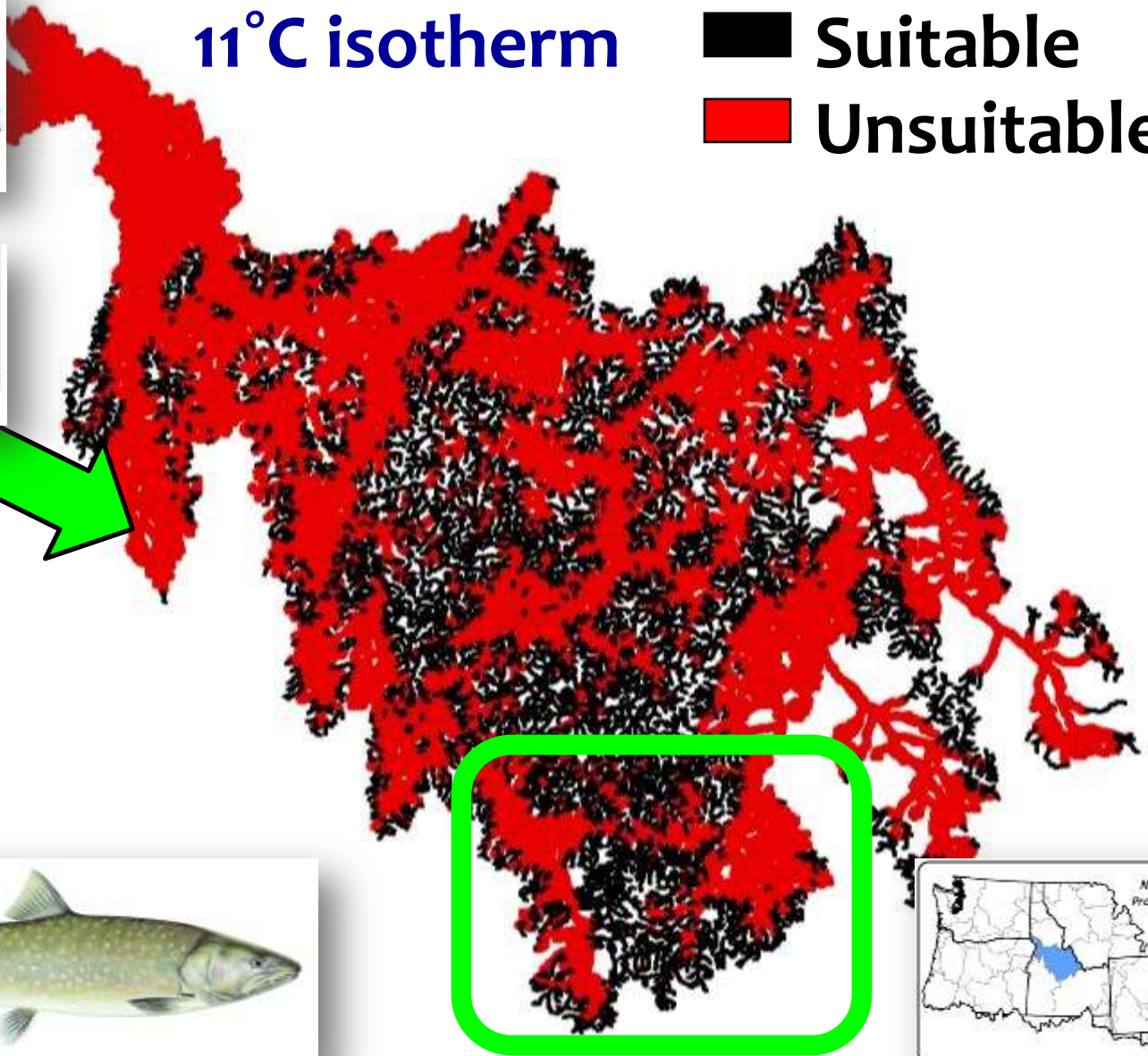


Bull Trout Natal Habitats = +2°C



11°C isotherm

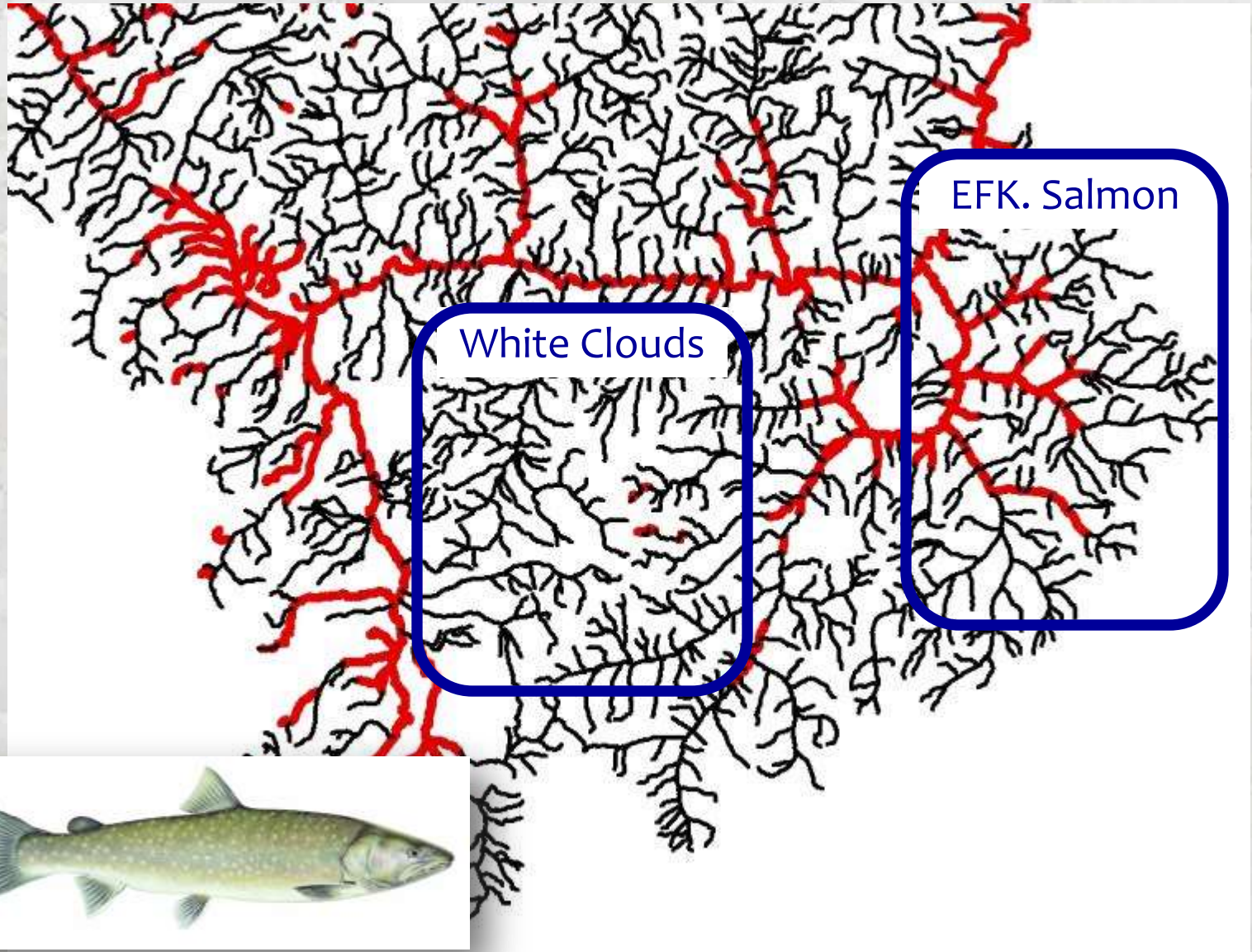
■ Suitable
■ Unsuitable



Spatial Variation in Habitat Loss

Historical scenario

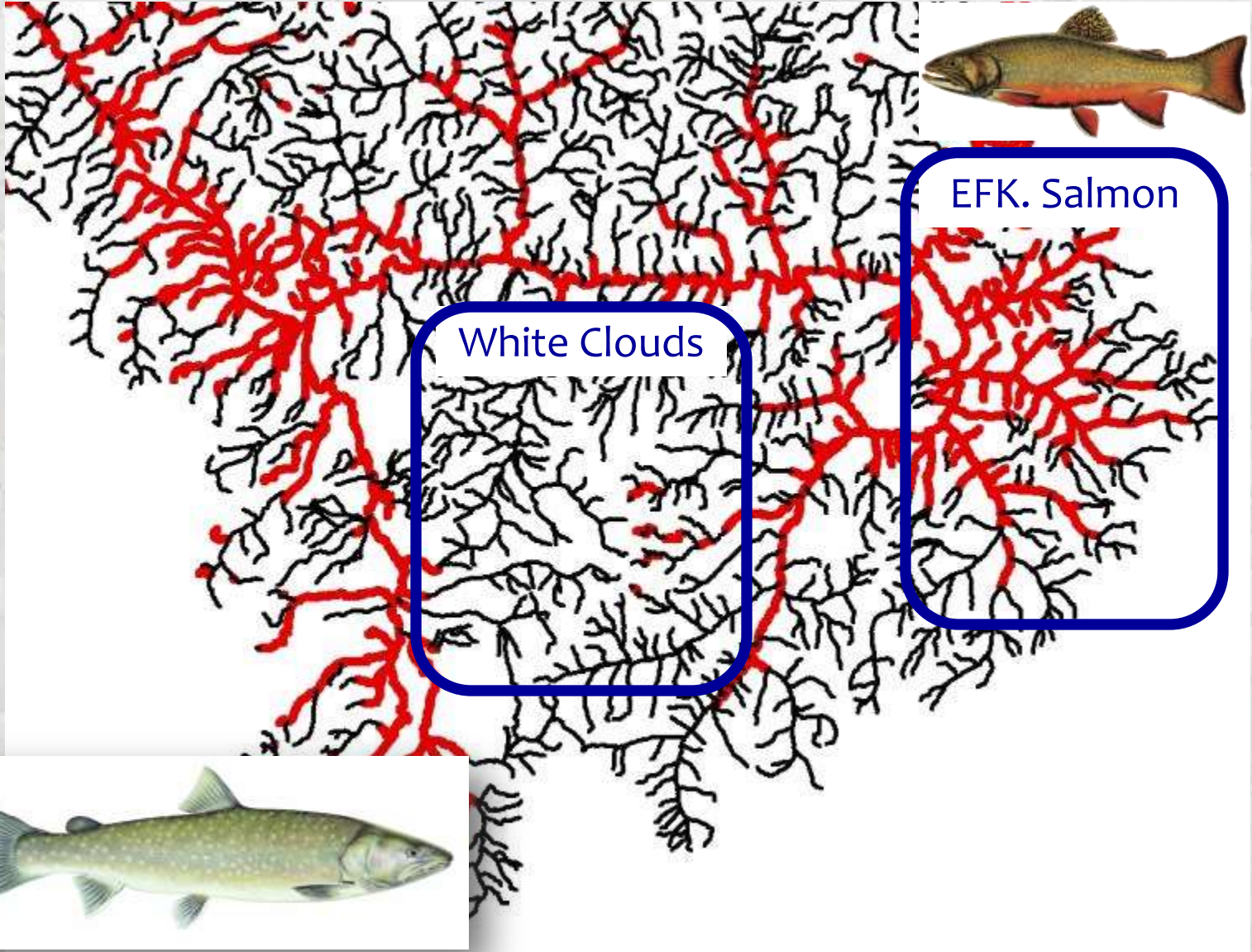
11°C isotherm



Spatial Variation in Habitat Loss

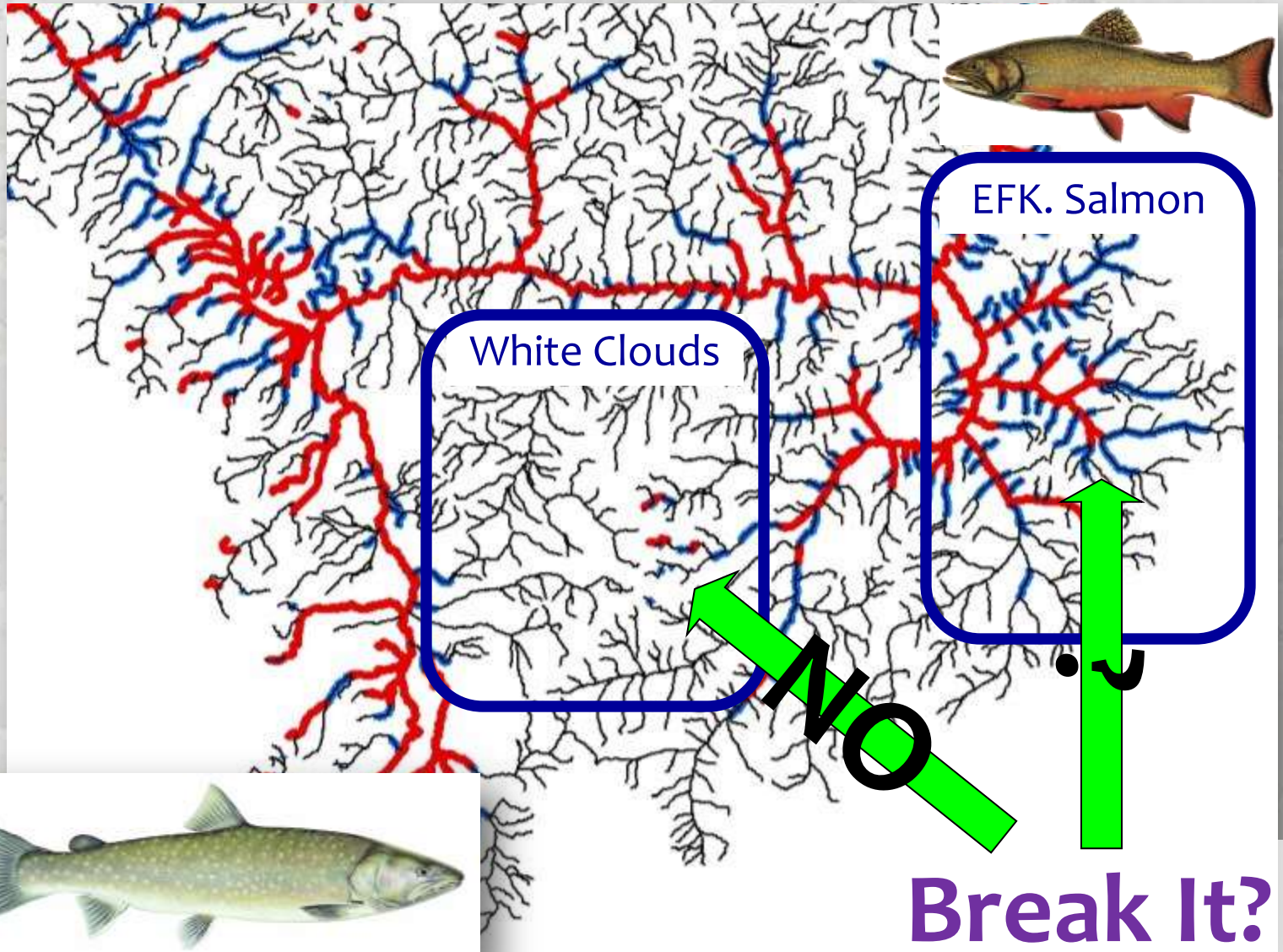
+1°C Scenario

11°C isotherm



Difference Map ~ Invasible Habitats

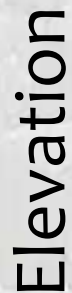
11°C isotherm



[illegible]

How much time is left on the clock?

Where could invasions occur?

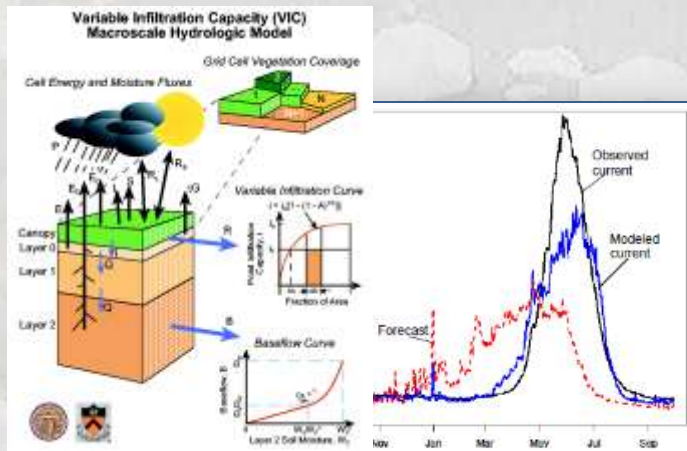


x km upstream shift by 2050

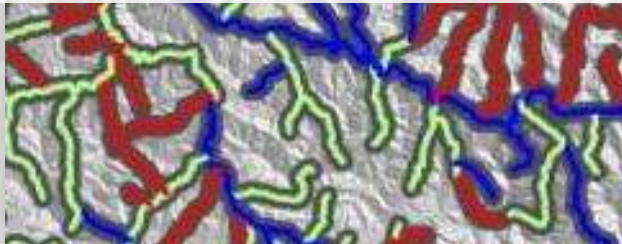


Revolution #2: Information Access

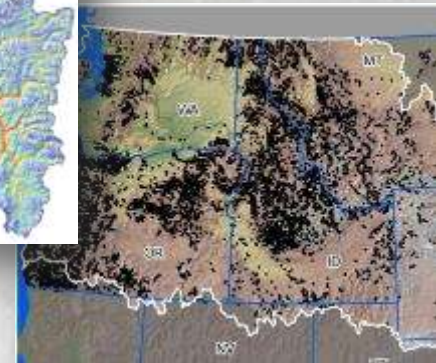
Websites Distribute Geospatial Stream Data 24/7...



Google “Stream flow Metrics”

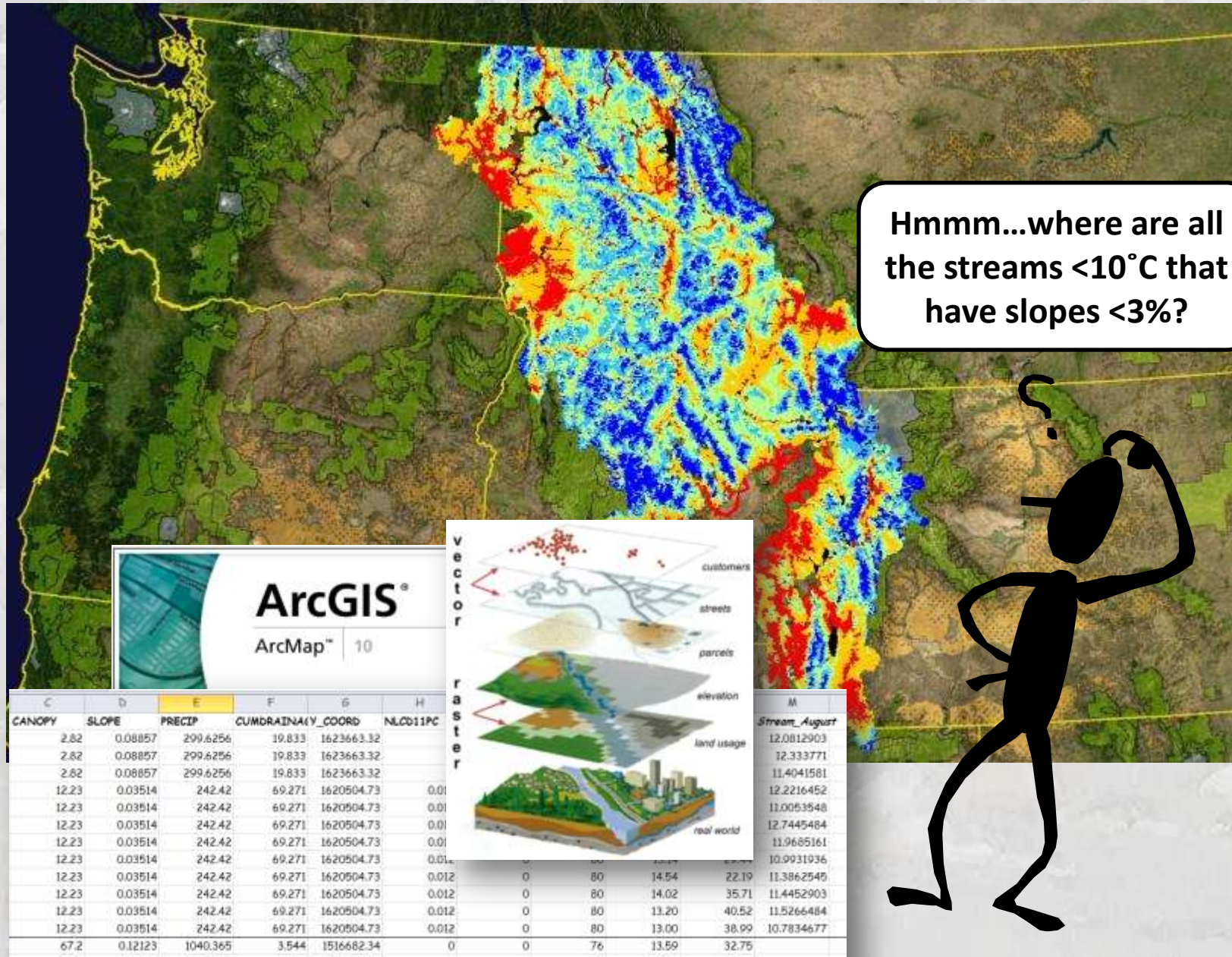


Google “NorWeST stream temp”



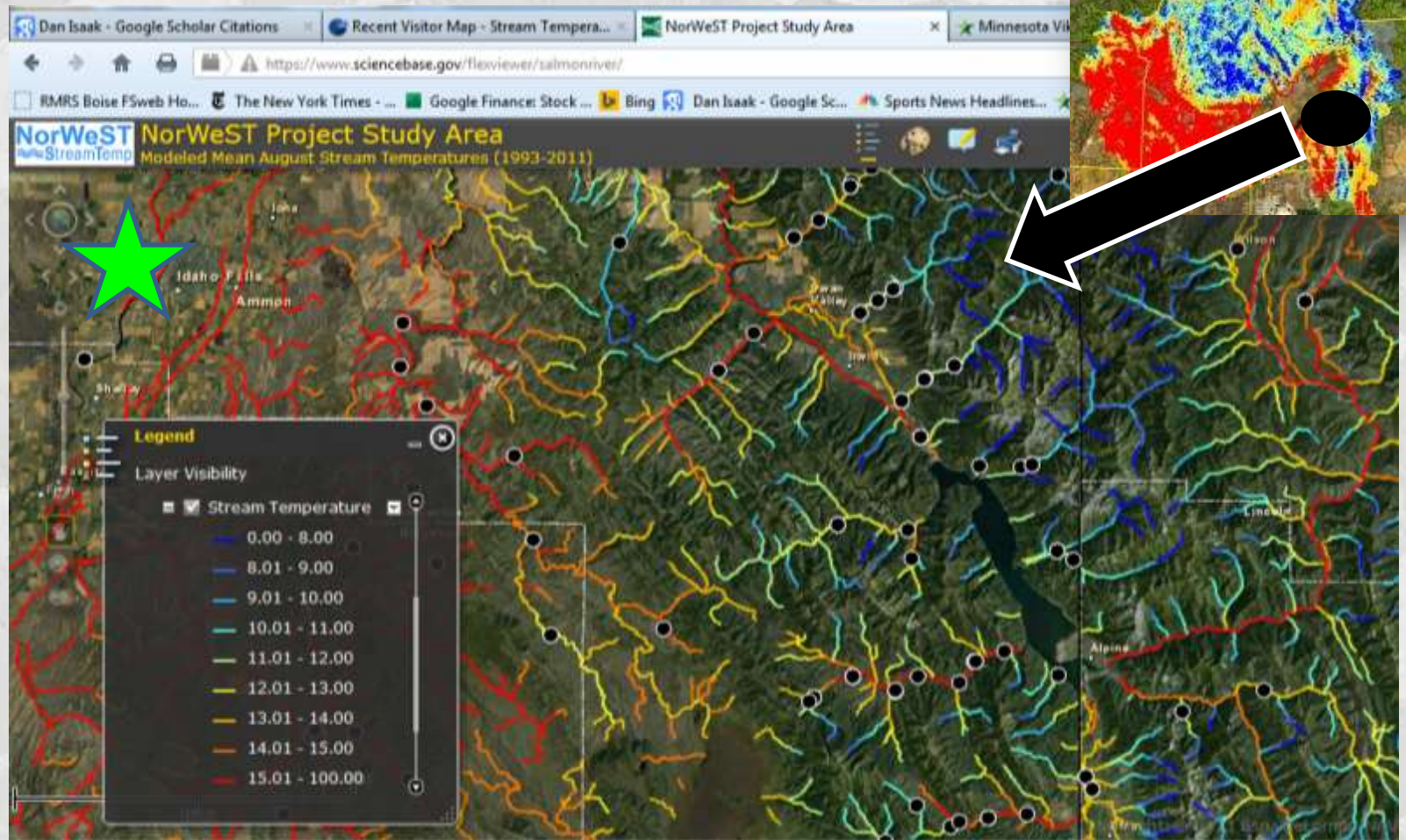
VIC Streamflow Scenarios

The BLOB is User-Friendly



Websurf the BLOB

Dynamic Online Map Viewer



See thermal patterns for all streams & data locations across all agencies from your desktop

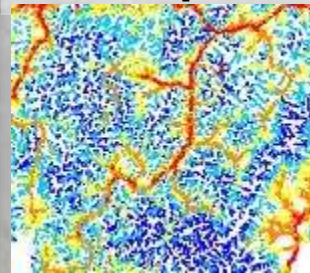
Take the BLOB with You – Go Wireless

Real-time Access to Accurate
Stream Data Anytime, Anywhere

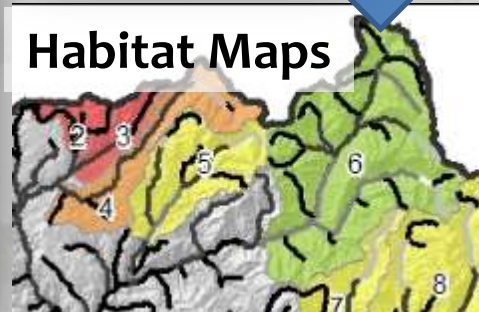


ArcGIS app

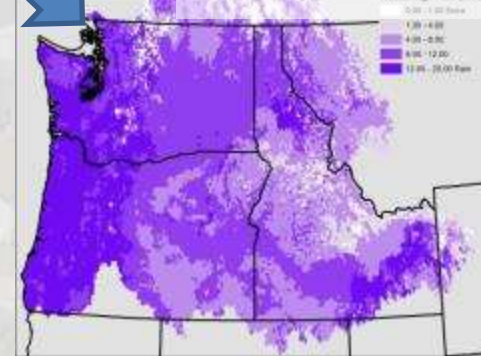
**Temperature
Maps**



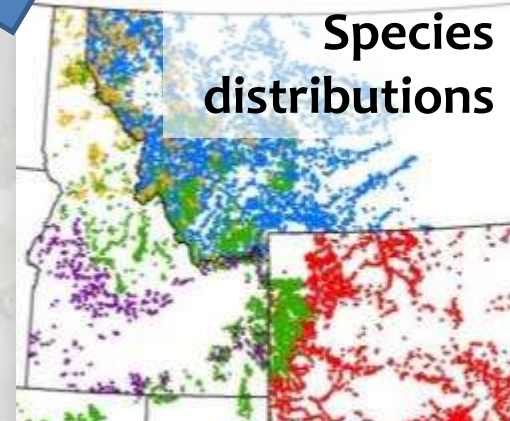
Habitat Maps



VIC flows



**Species
distributions**



Information Overload

How do We Filter it ?



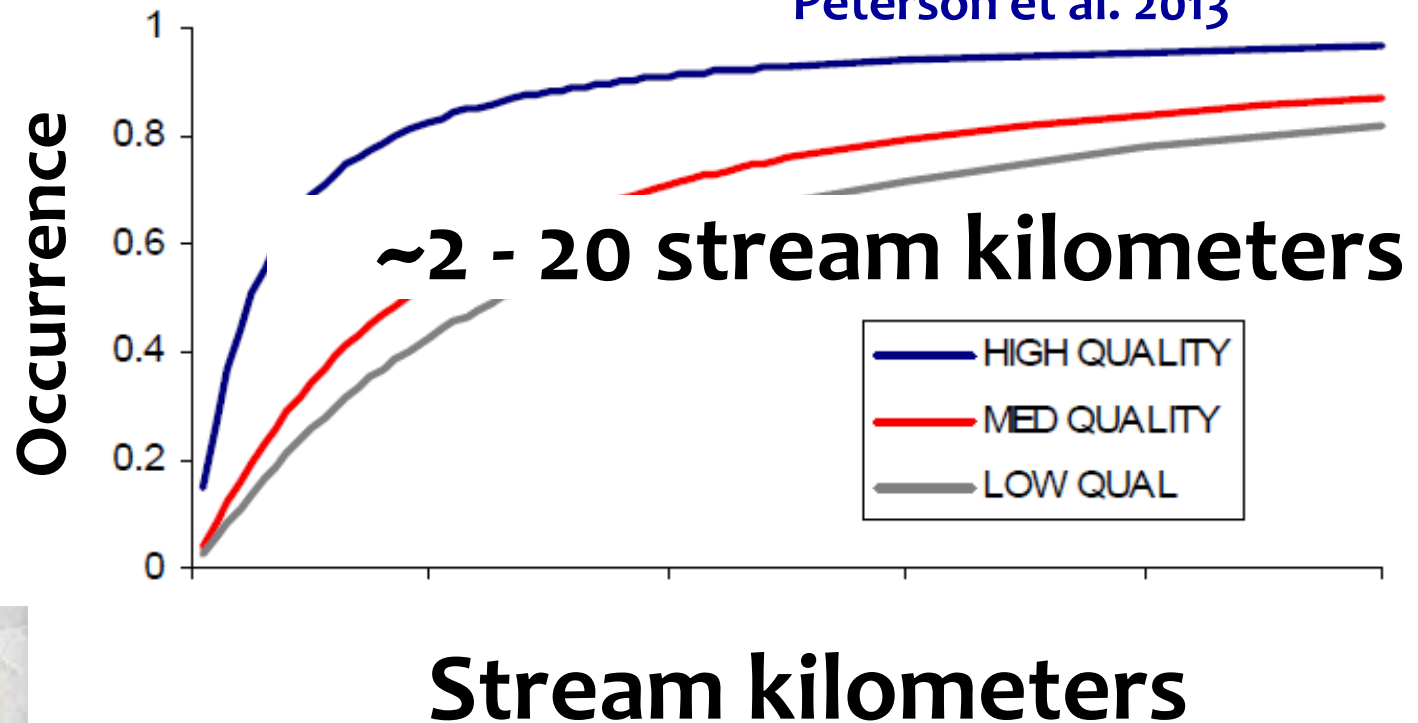
Filter #1: Amount of Habitat Needed to Support a Population



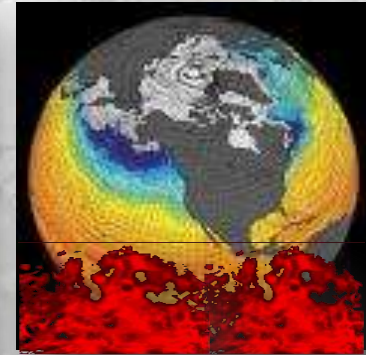
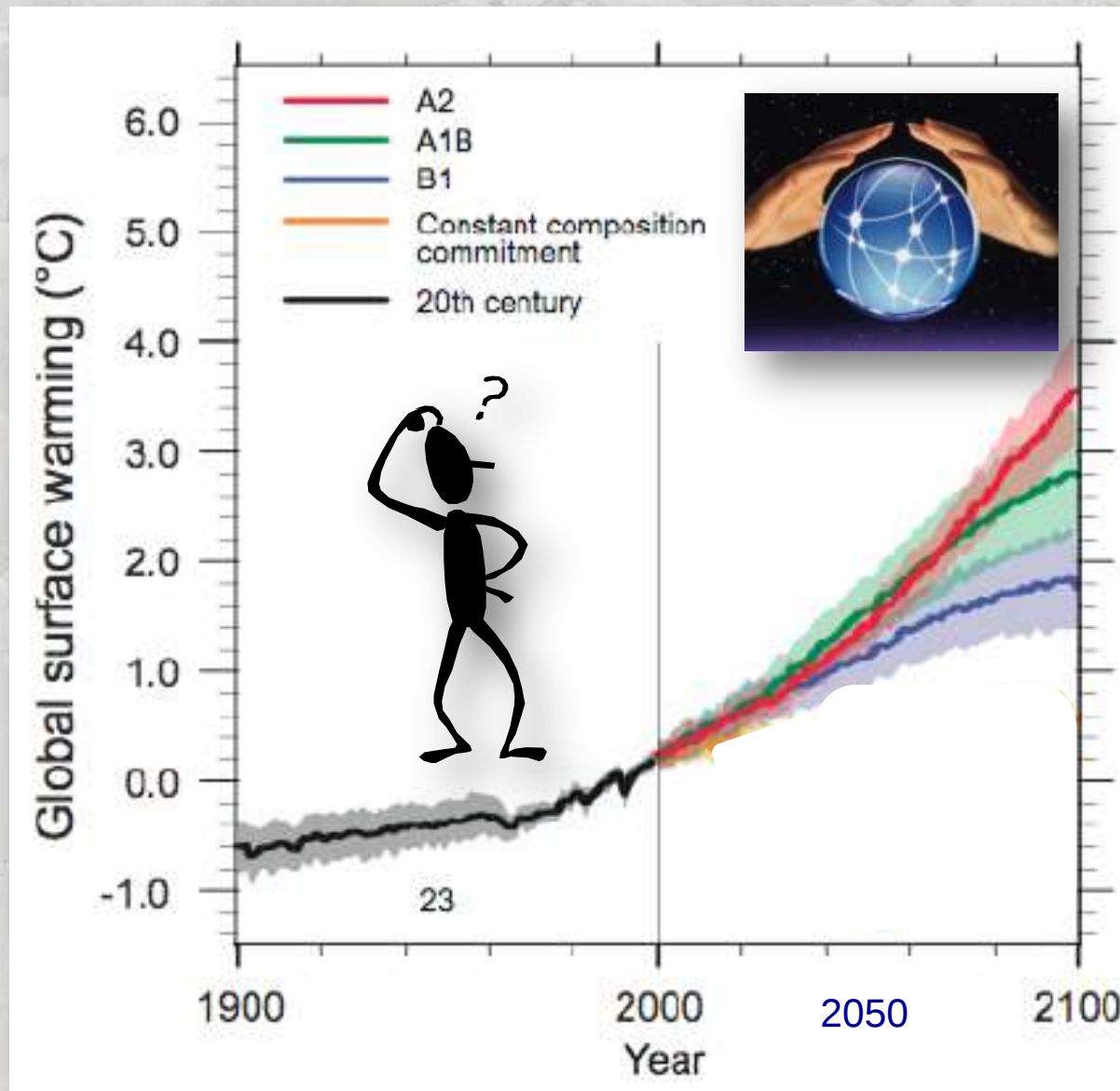
Rieman & McIntyre 1995
Dunham and Rieman 1999
Dunham et al. 2002



Harig et al. 2000
Hilderbrand & Kershner 2000
Roberts et al. 2013
Peterson et al. 2013

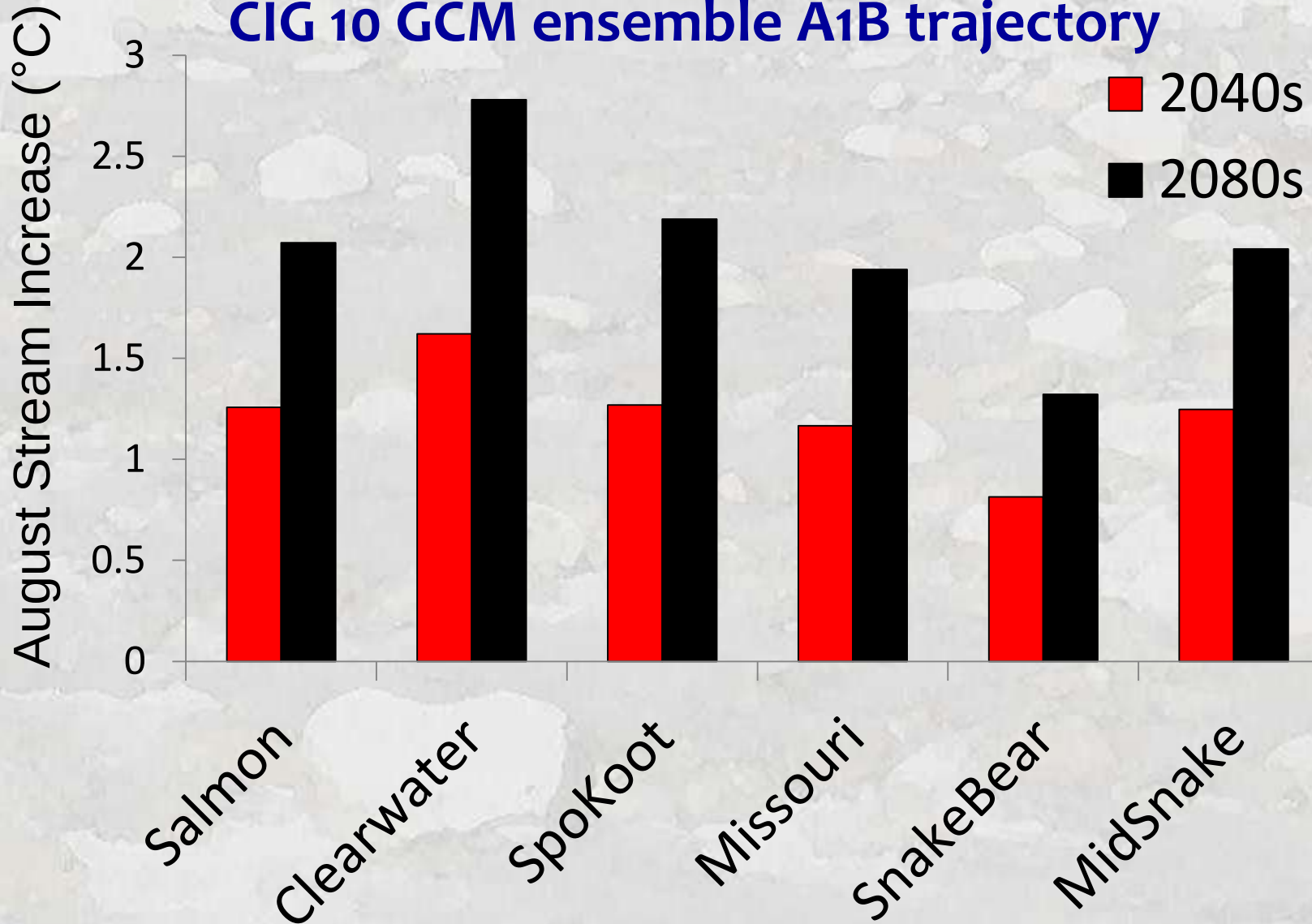


The Future will be Different...



NorWeST Predictions of Summer Stream Temperature Increases

CIG 10 GCM ensemble A1B trajectory



Climate Related Factors will Interact

Warmer temperatures
Reduced summer flows
Fire & debris flows
Winter flooding
Non-native invasions



**The Headwater
Trout Vise**

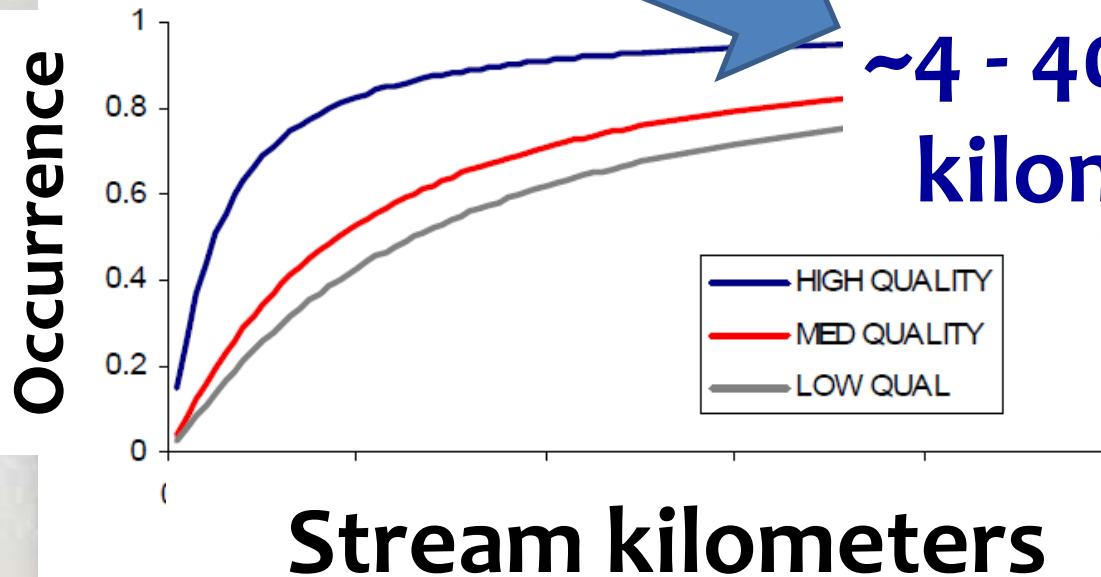
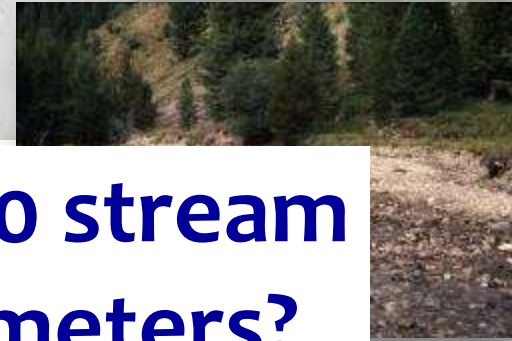


So We'll Need a Habitat Fudge Factor

Bigger Floods, Fires, & Droughts are Coming...



~~~2 - 20 stream  
kilometers~~

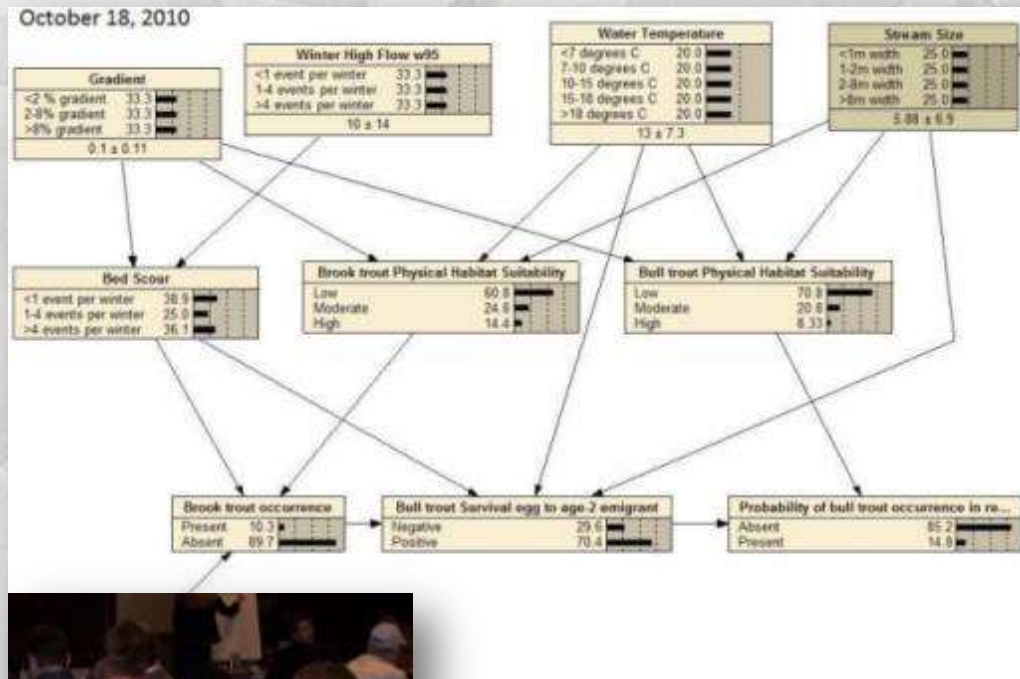


~4 - 40 stream  
kilometers?



# Filter #2: Decision Support Tools Integrate Information from Multiple Sources

## Structured Process & Transparent Logic



**Problem A: Spatial prioritization among populations**



**Problem B: Barrier installation or removal**

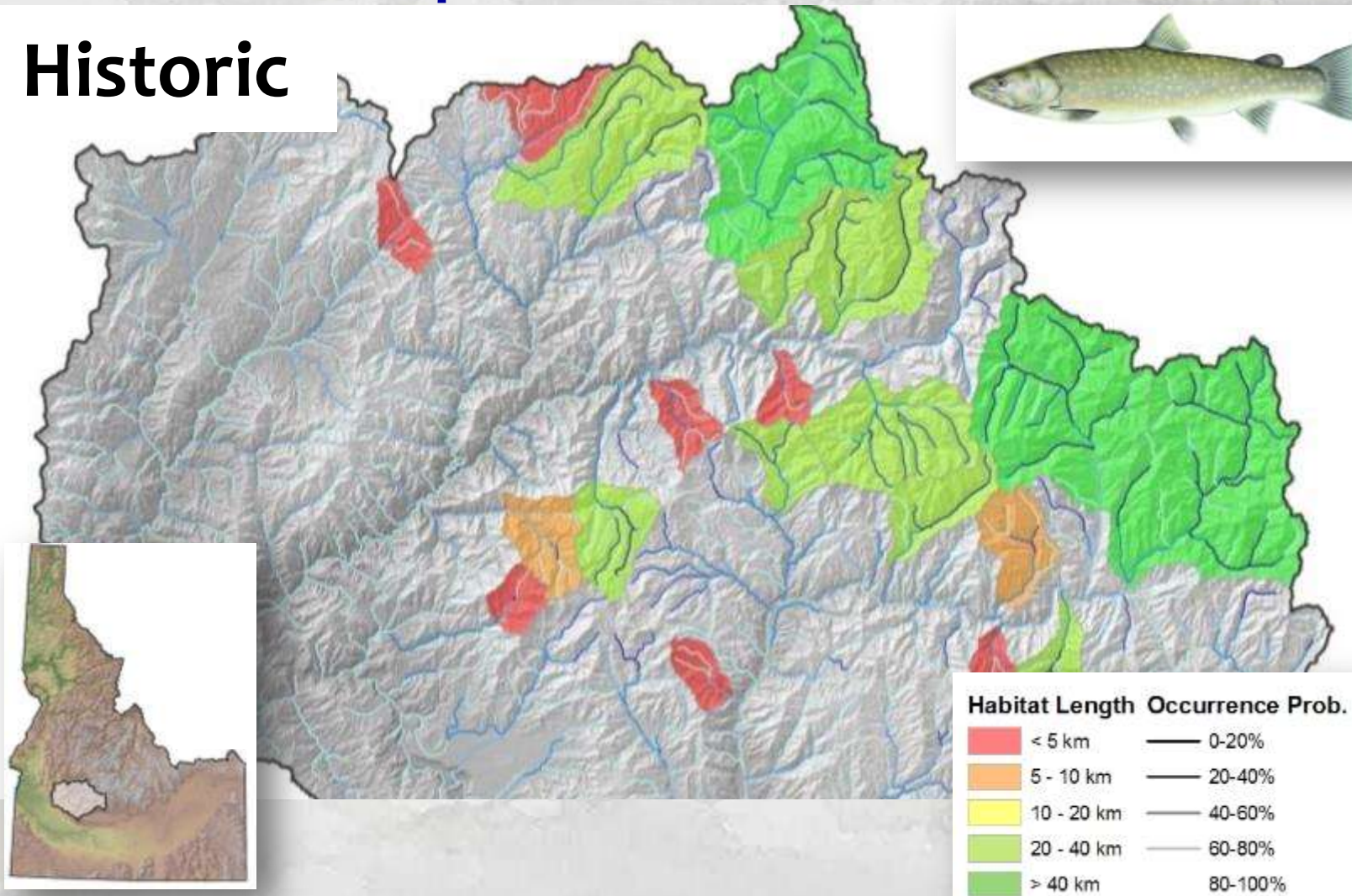


Peterson et al. 2013. Linking climate change and fish conservation efforts using spatially explicit decision support tools. *Fisheries* 38:112-127.

# Habitats Color Coded by Size & Population Persistence Potential

## Bull trout example in Boise River Basin

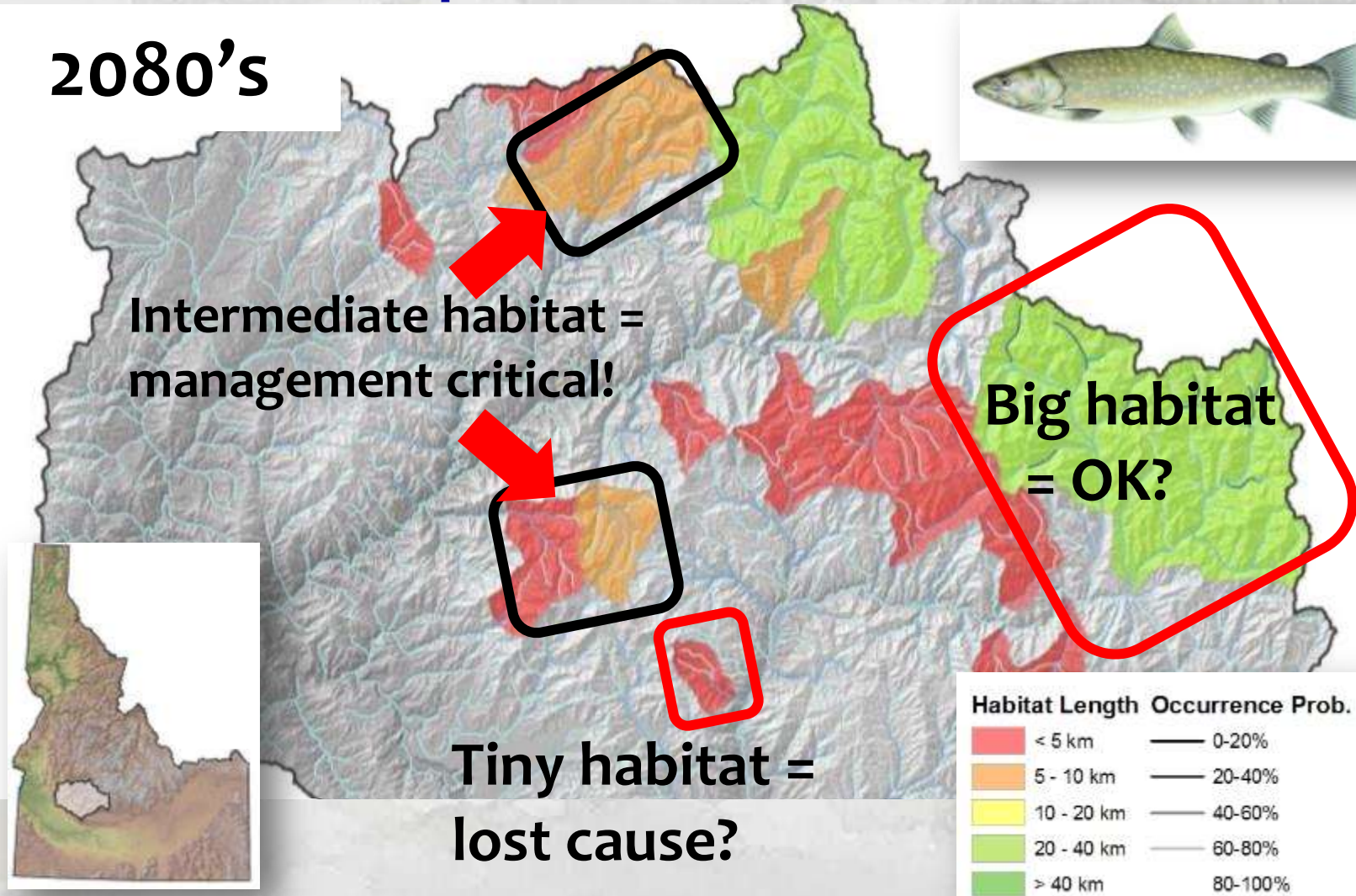
### Historic



# Habitats Color Coded by Size & Population Persistence Potential

## Bull trout example in Boise River Basin

2080's

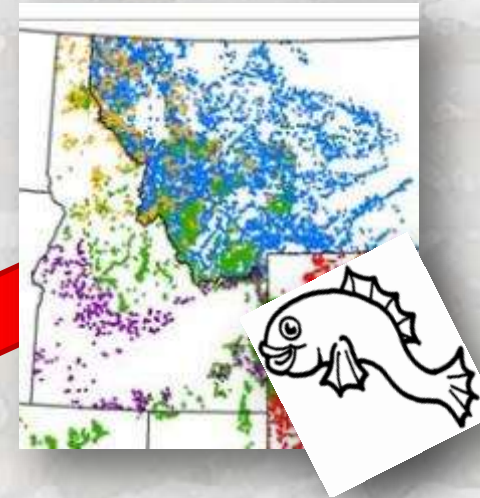


# Decision Tools Built From Regionally Consistent Geospatial Data to Enable Applications Anywhere

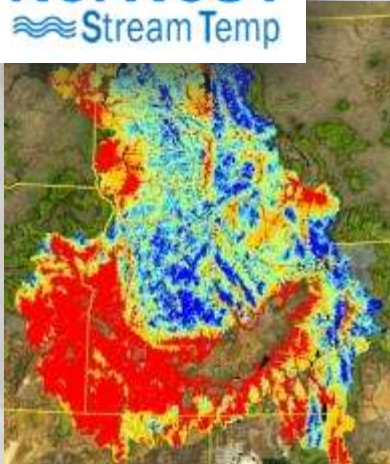
## Local Expertise



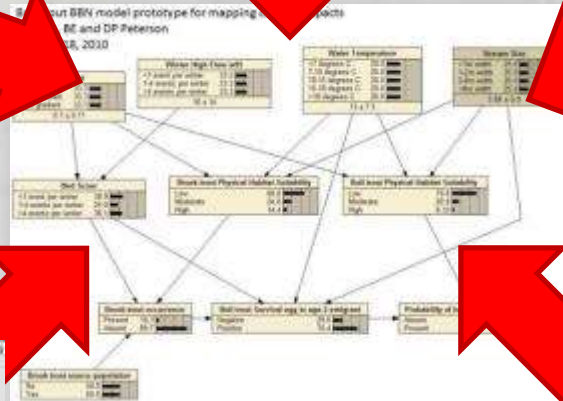
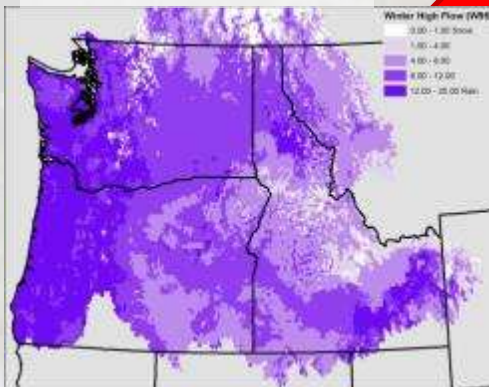
## BIG FISH Surveys



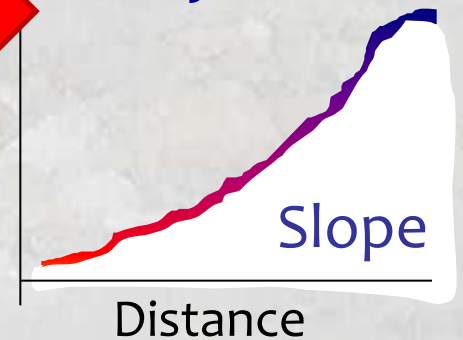
**NorWeST**  
Stream Temp



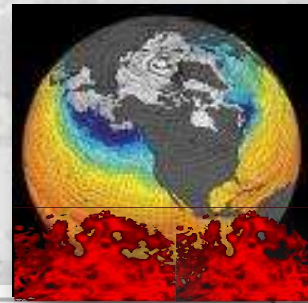
## VIC flows



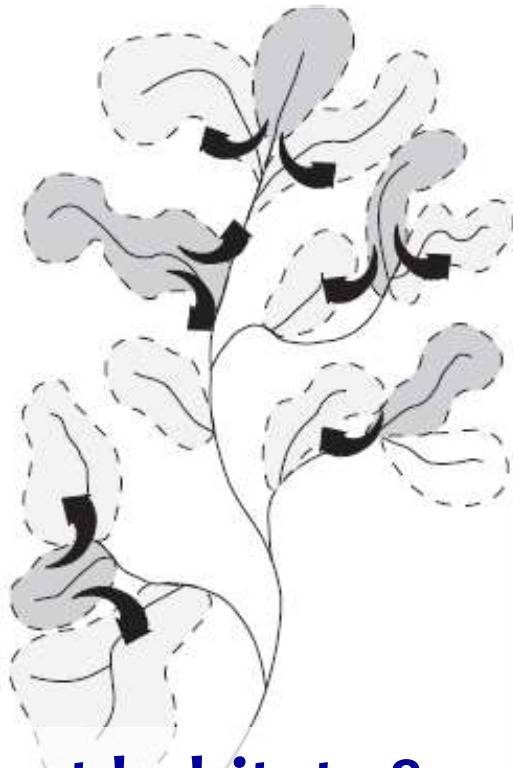
## NHDPlus Hydrology Layer Variables



# Think Globally, act Locally with “Make it or Break it” Decisions



**More of this...**

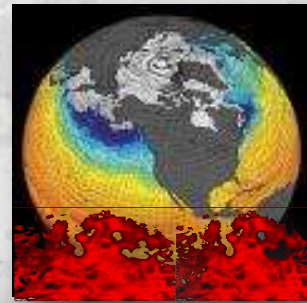


**Largest habitats &  
nearest neighbors...**

**Less of this...**



# Think Globally, act Locally with “Make it or Break it” Decisions



## Feature: FISHERIES MANAGEMENT

### Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities

Jack E. Williams, Richard N. Williams, Russell E. Thurow, Leah Elwell, David P. Philipp, Fred A. Harris, Jeffrey L. Kershner, Patrick J. Martinez, Dirk Miller, Gordon H. Reeves, Christopher A. Frissell, and James R. Sedell



