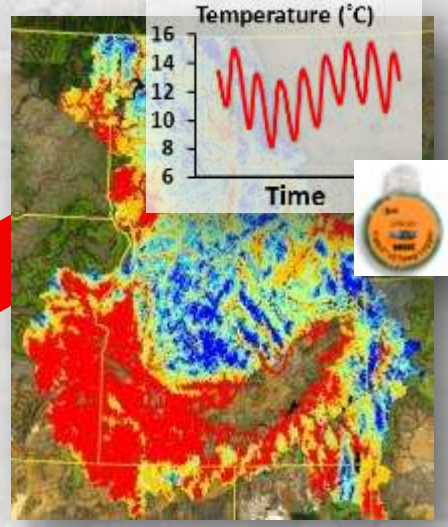
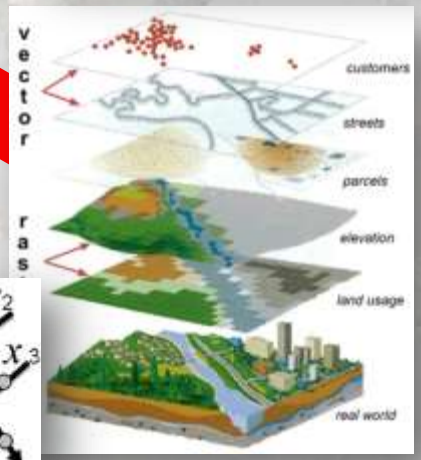
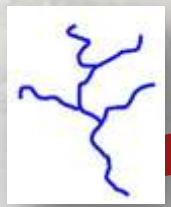
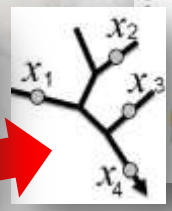
Informing "Make it or Break it" Decisions with High-Resolution Stream Geospatial Data & Climate Scenarios









Outline…

I. Invasible habitats, environmental context, & old fuzzy habitat definitions

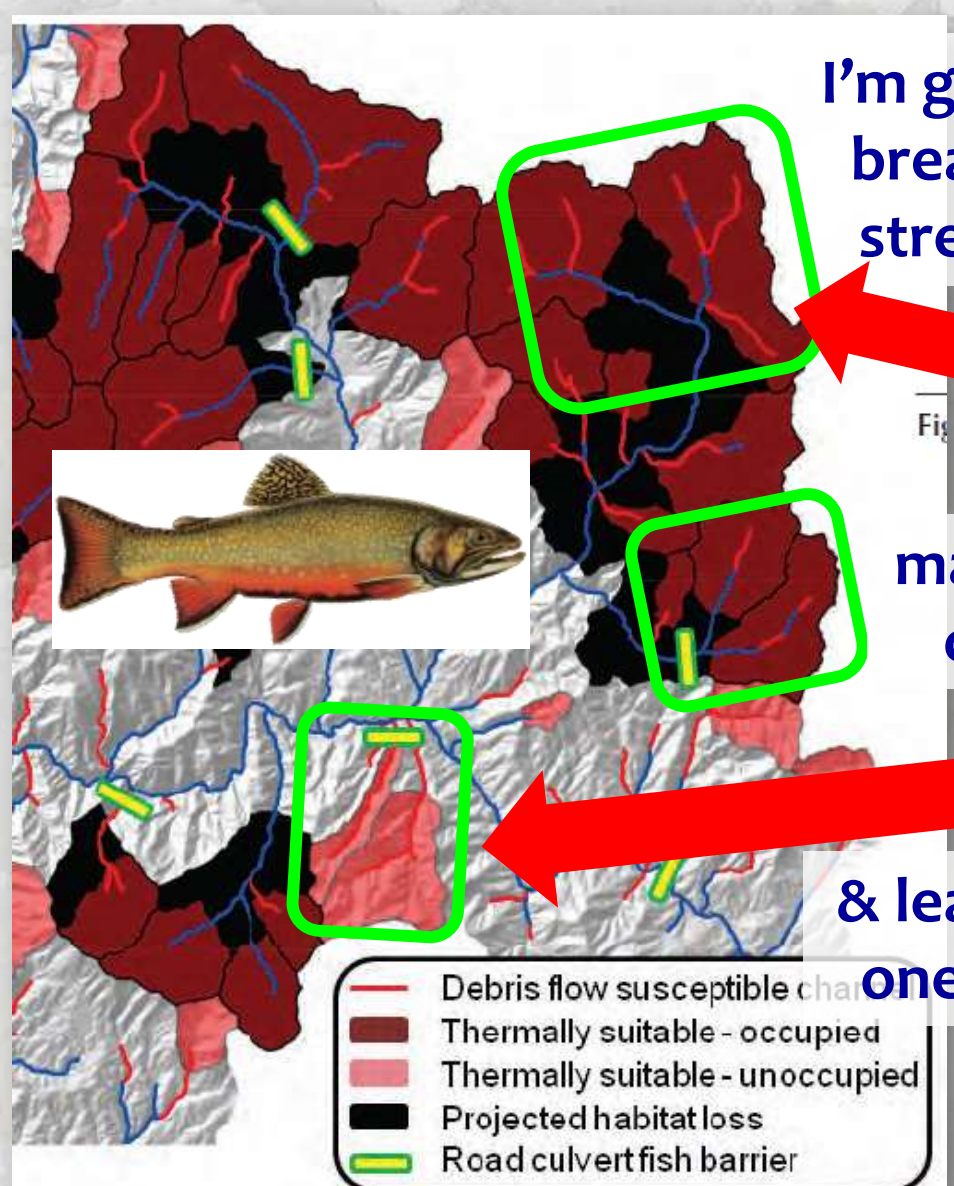
II. Revolution #1: Quantity & quality of information mapped onto stream networks (GIS/spatial analysis/BIG DATA/sensor technology)

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



I'm going to break this stream...

make this one...

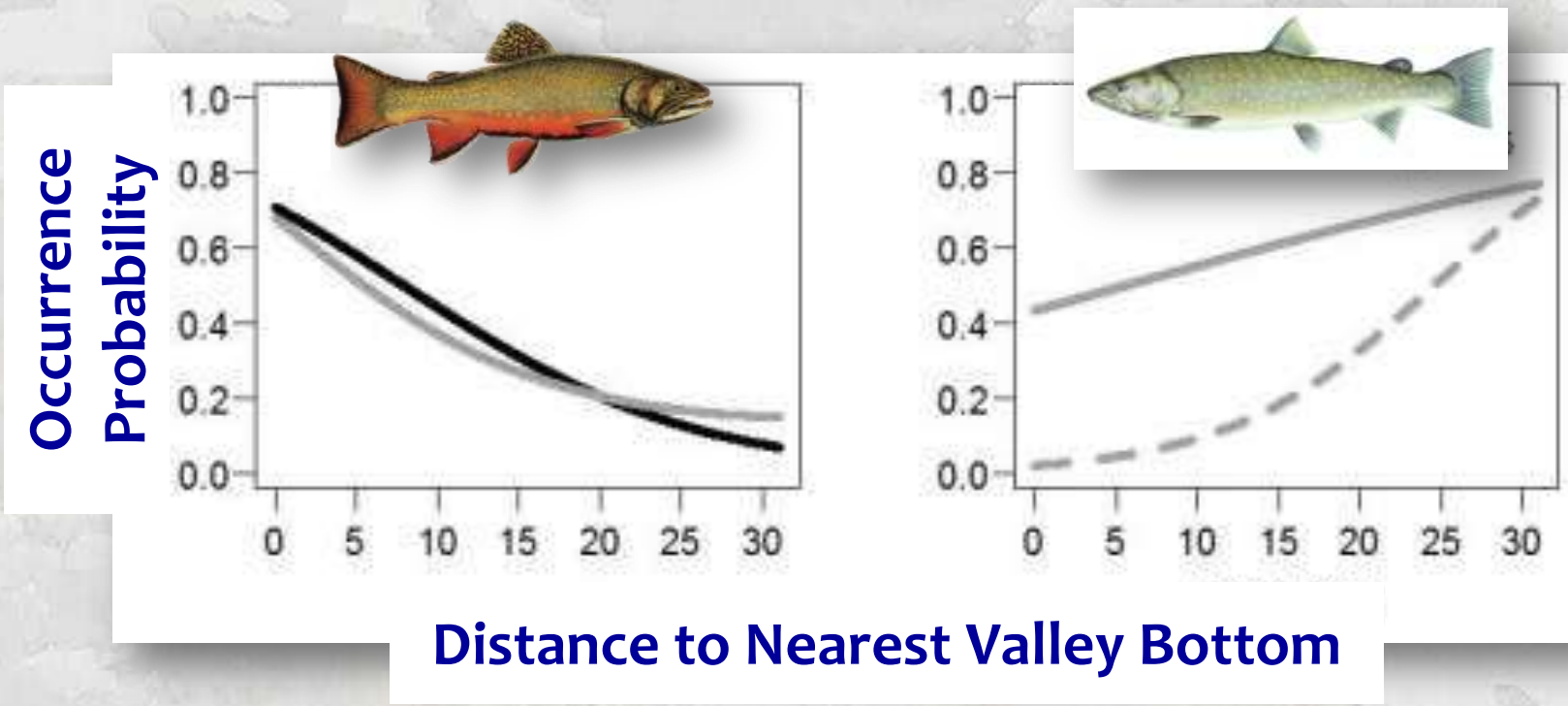
& leave this one alone

The Right Choices Depend on Context

Habitat & Climate & Biology Determine Invasibility

The Right Choices Depend on Context

Habitat & Climate & Biology Determine Invasibility



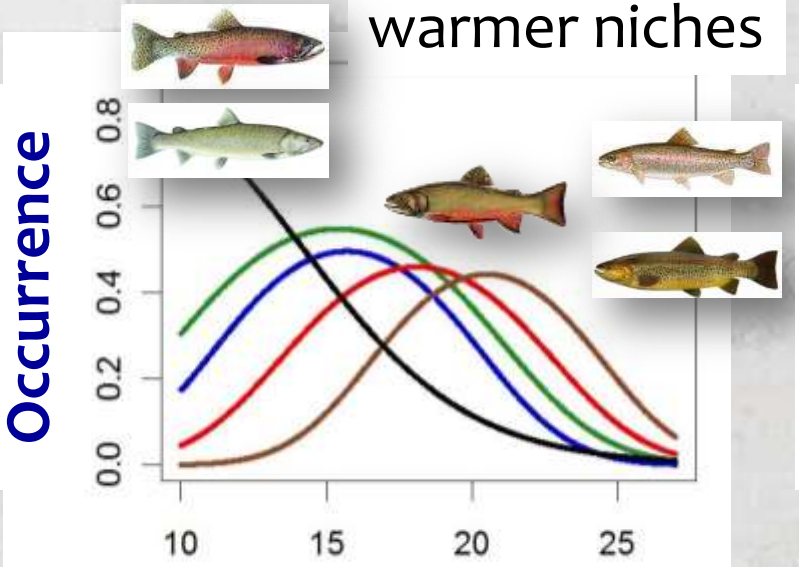
Wenger et al. 2011. *CJFAS* **68**:988-1008.

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

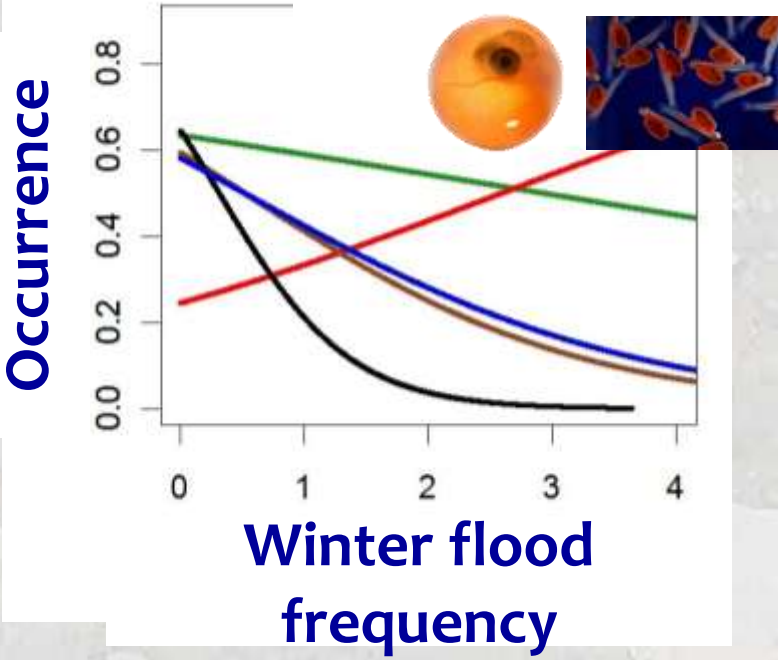
The Right Choices Depend on Context

Habitat & Climate & Biology Determine Invasibility

Invaders have warmer niches



Fall spawners more vulnerable



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
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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

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Observer Variability in Classifying Habitat Types in Stream Surveys

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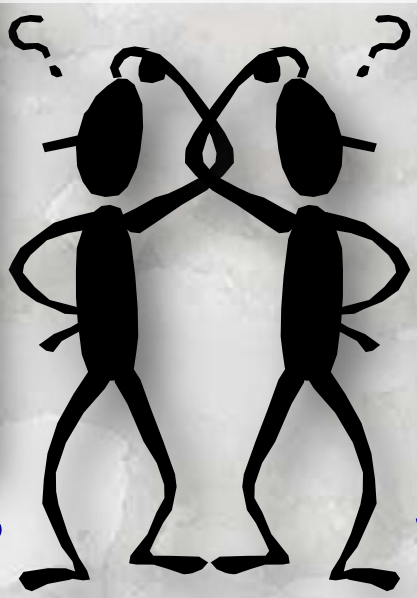
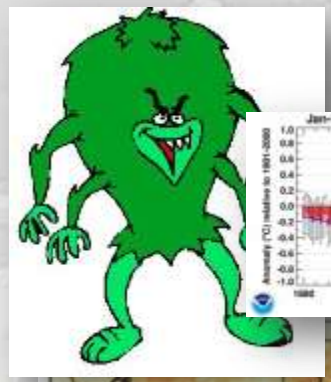
Describing habitat is subjective & imprecise

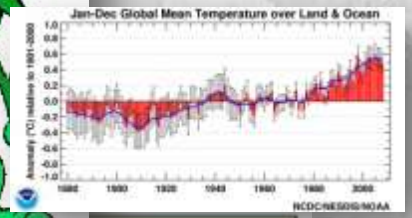


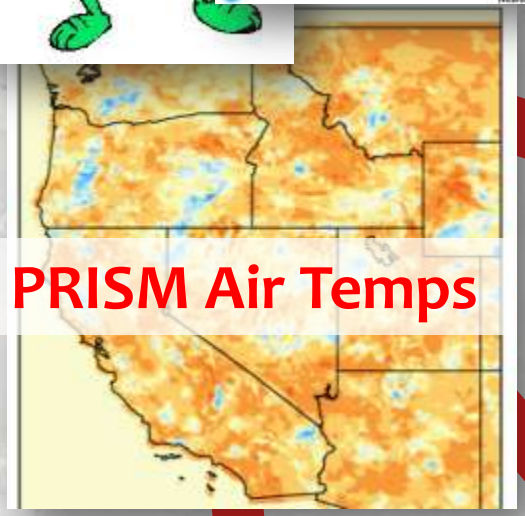
What is a Pool? What is a Riffle?

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

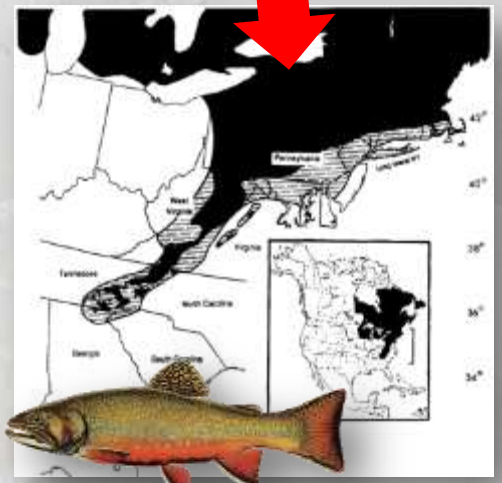
Scary Climate Assessments Have Been Equally Imprecise

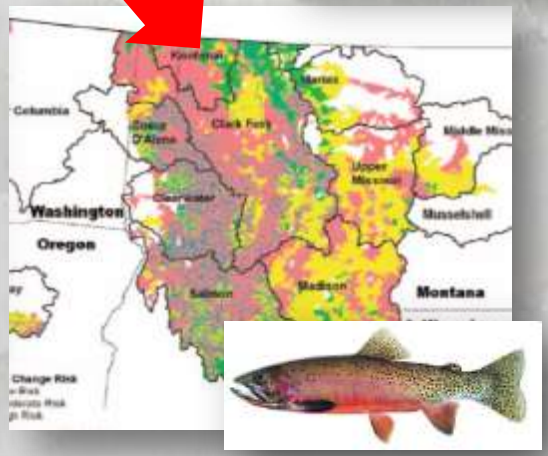


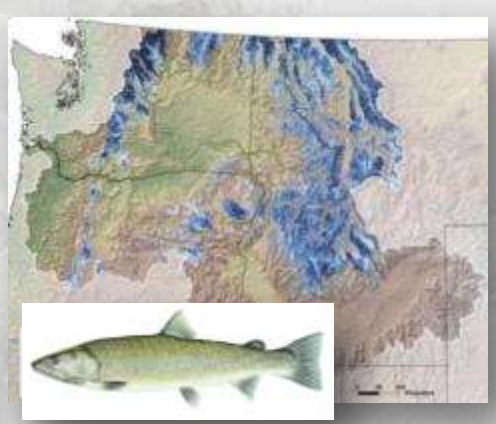




PRISM Air Temps





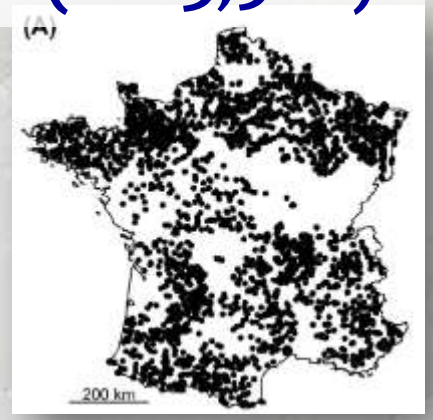


- Meisner 1988, 1990
- Eaton & Schaller 1996
- Keleher & Rahel 1996
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.

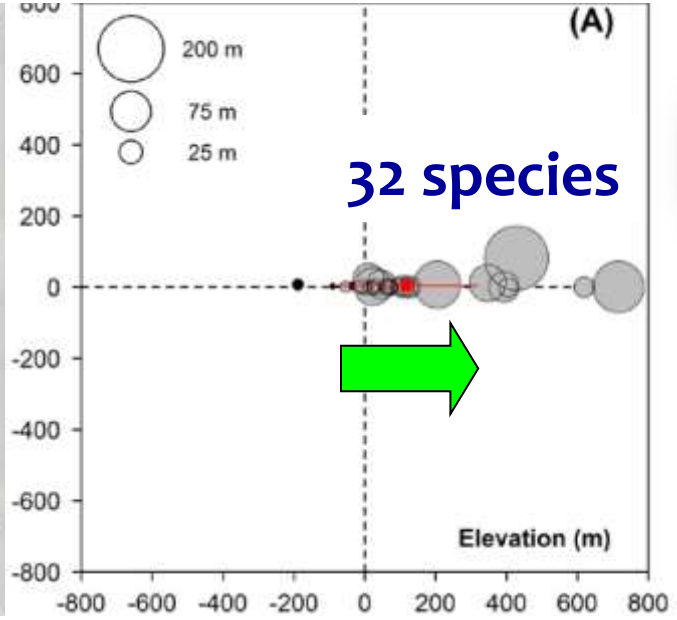
Fish Biologists Can Measure Fish & They're Starting to Move…

National French Study

Survey sites (n = 3,500)



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



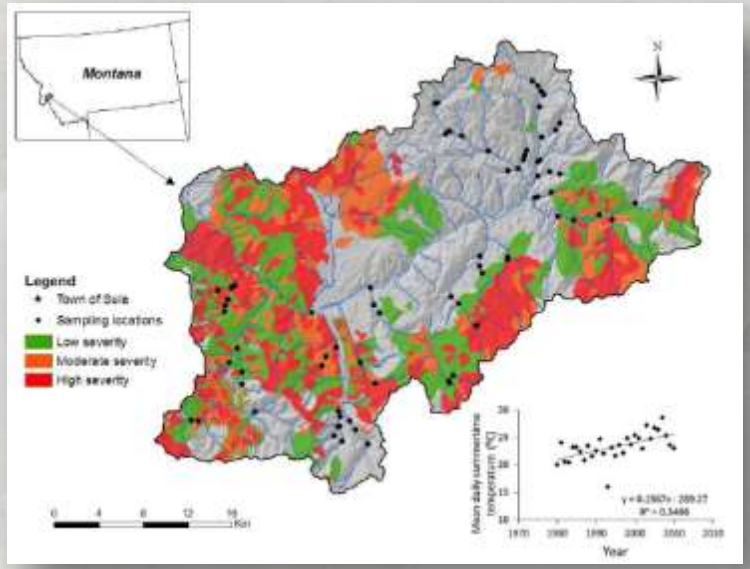
Change in Elevation (m)

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

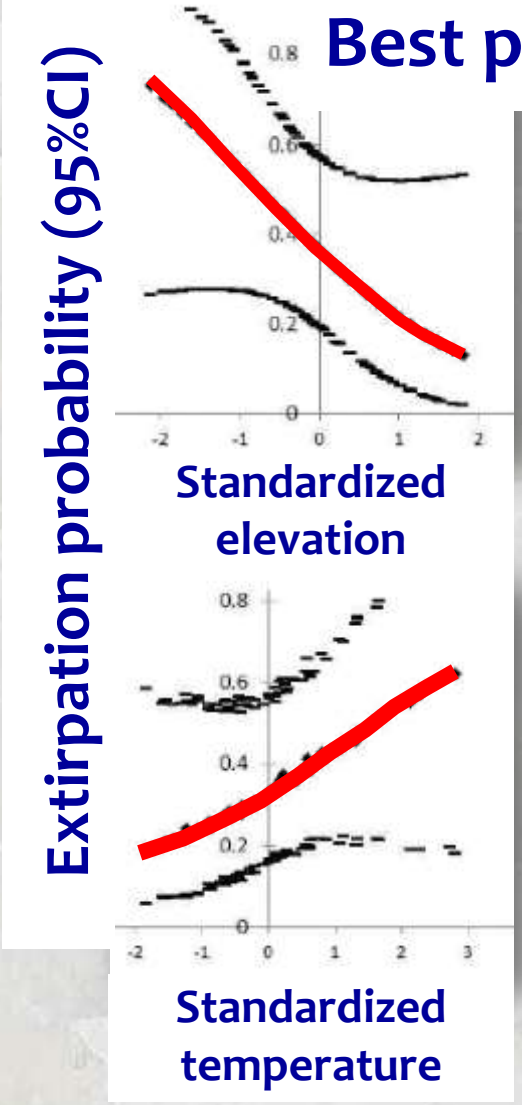
- Resurveyed 77 Rich et al. (2003) sites 20 years later
- Modeled extirpations/colonizations accounting for detection efficiency

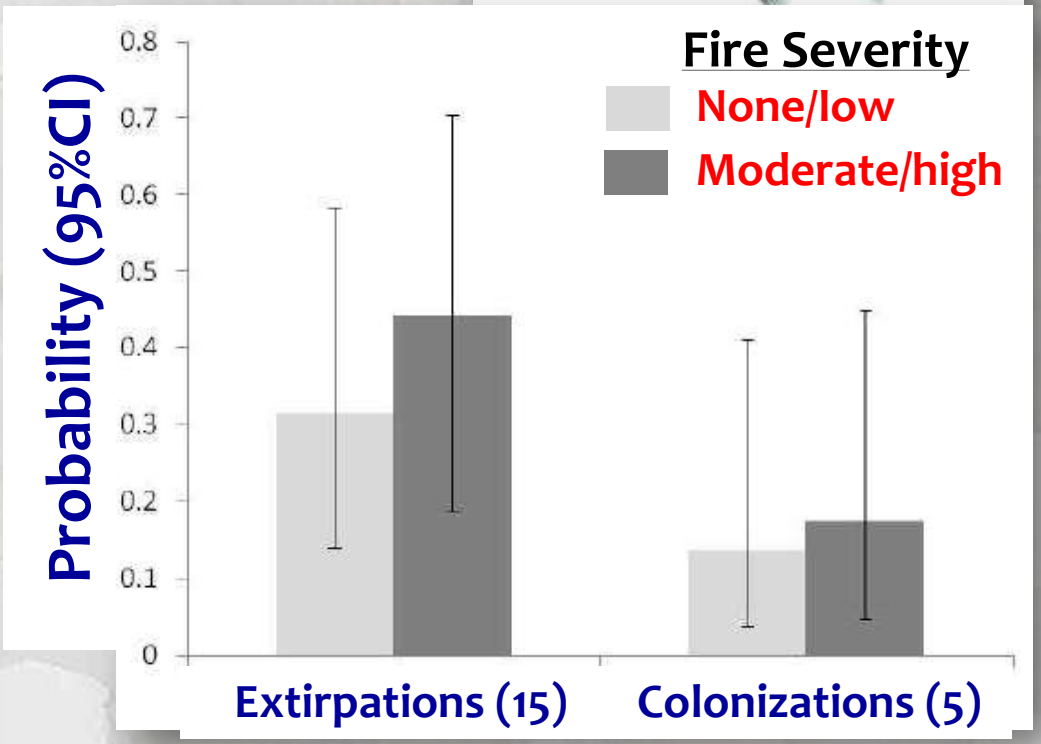


Eby et al. In Review. Evidence of climate-induced range contractions for bull trout in a Rocky Mountain watershed, U.S.A. *PLoS One.*

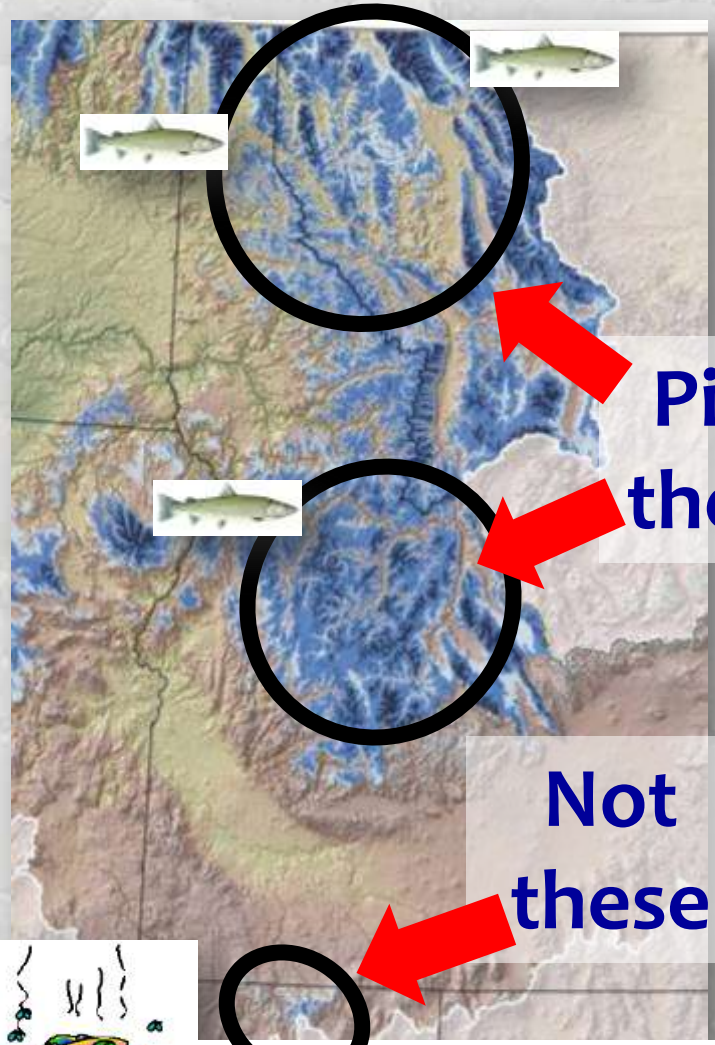
Bull Trout Distribution Shifts in Montana

Best predictors





Local Decisions also Need a Strategic Context

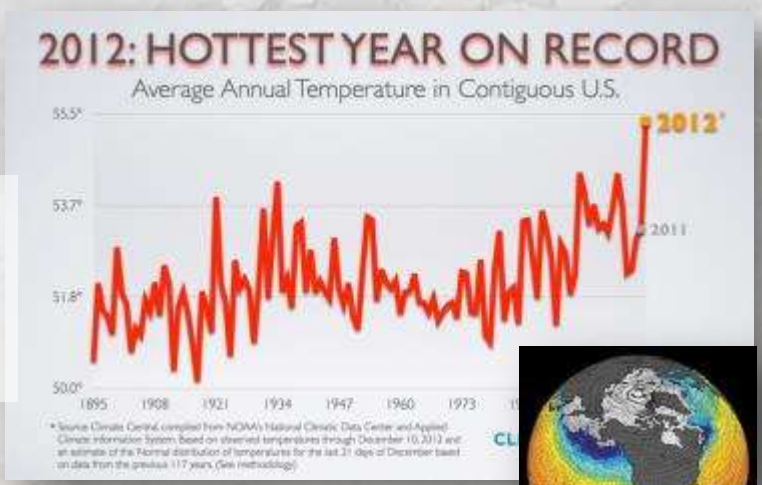


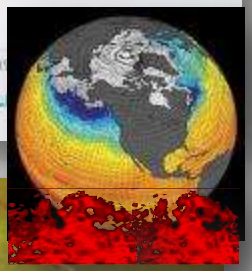
Pick these

Not these

Sorry Charlie

The 21st-Century will Be a Transitional One



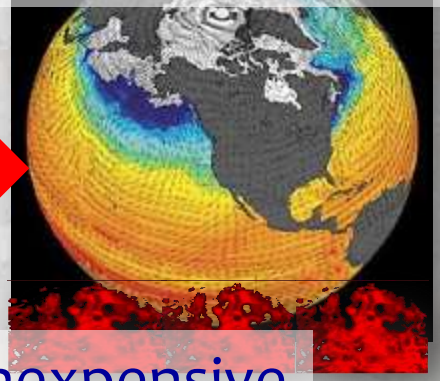


Revolution #1: Quantity & Quality of Information is Exploding

Remote Sensing

GIS / Computing Capacity

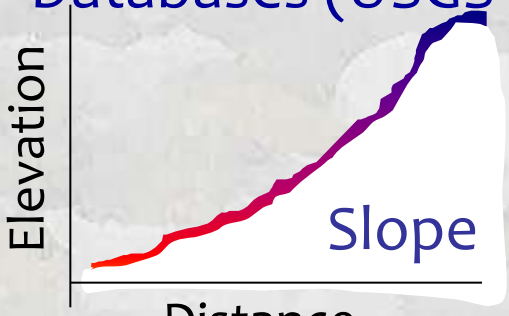
Climate, weather, GCM data online



Visualization

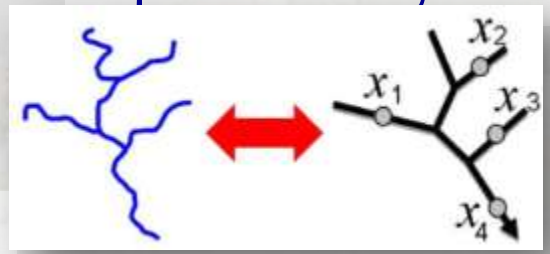
Inexpensive sensors

Nationally Consistent Hydrology Databases (USGS NHD+)



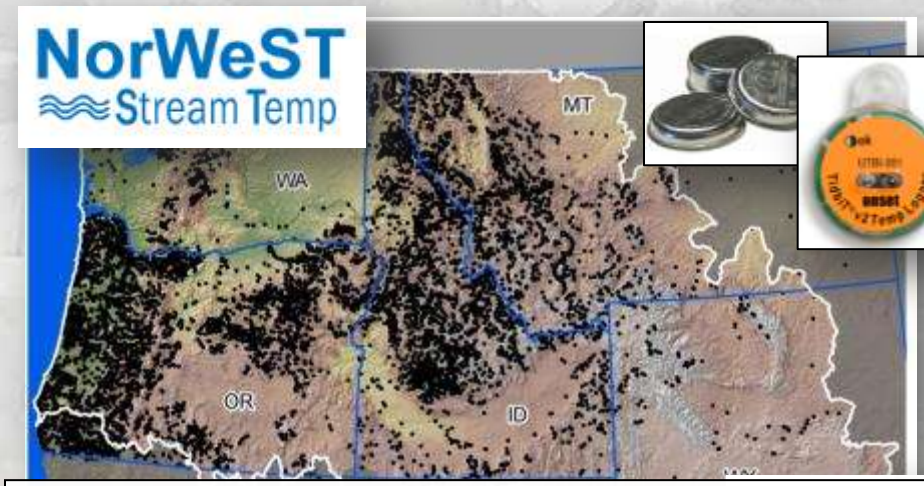
Drainage Area

Spatial analyses



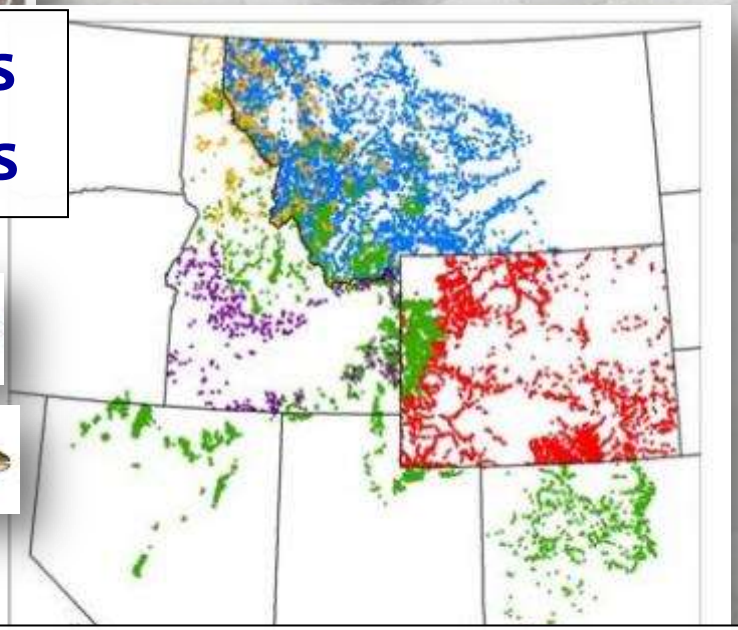
The Era of BIG DATA is Here

NorWeST Stream Temp



>45,000,000 hourly records

>15,000 unique stream sites



20,000 fish surveys

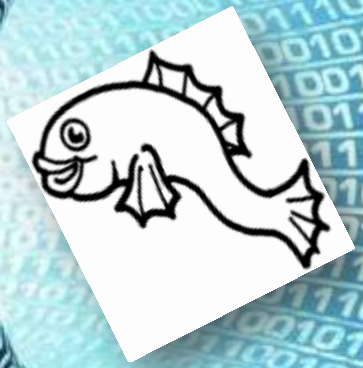
USGS science for a changing world

NOAA Fisheries

IDAHO POWER.

HENRY'S FORK

BIG DATA presents big challenges



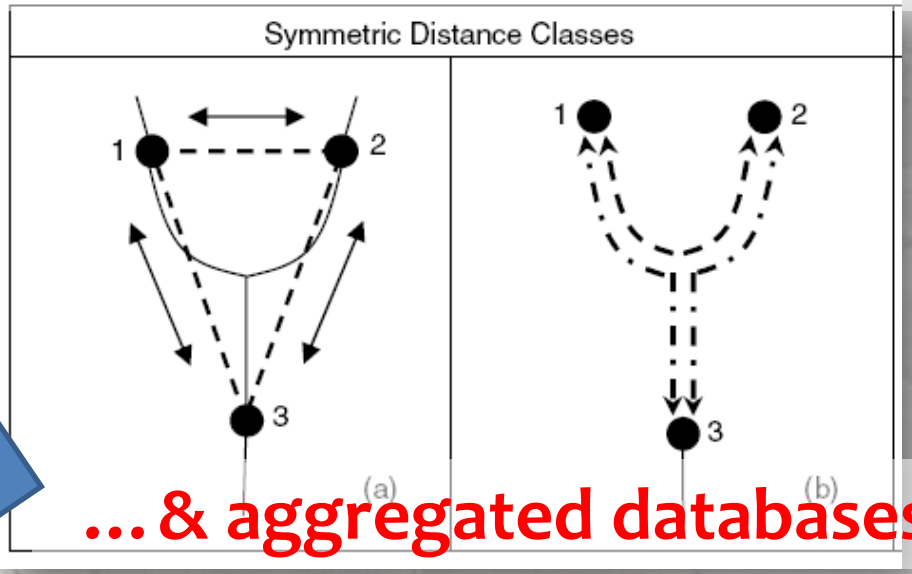
BIG DATA = BIG INFORMATION?

BIG DATA are often Autocorrelated

Spatial Statistical Network Models

Let's us connect the dots…

Valid interpolation on networks



…& aggregated databases

Advantages:

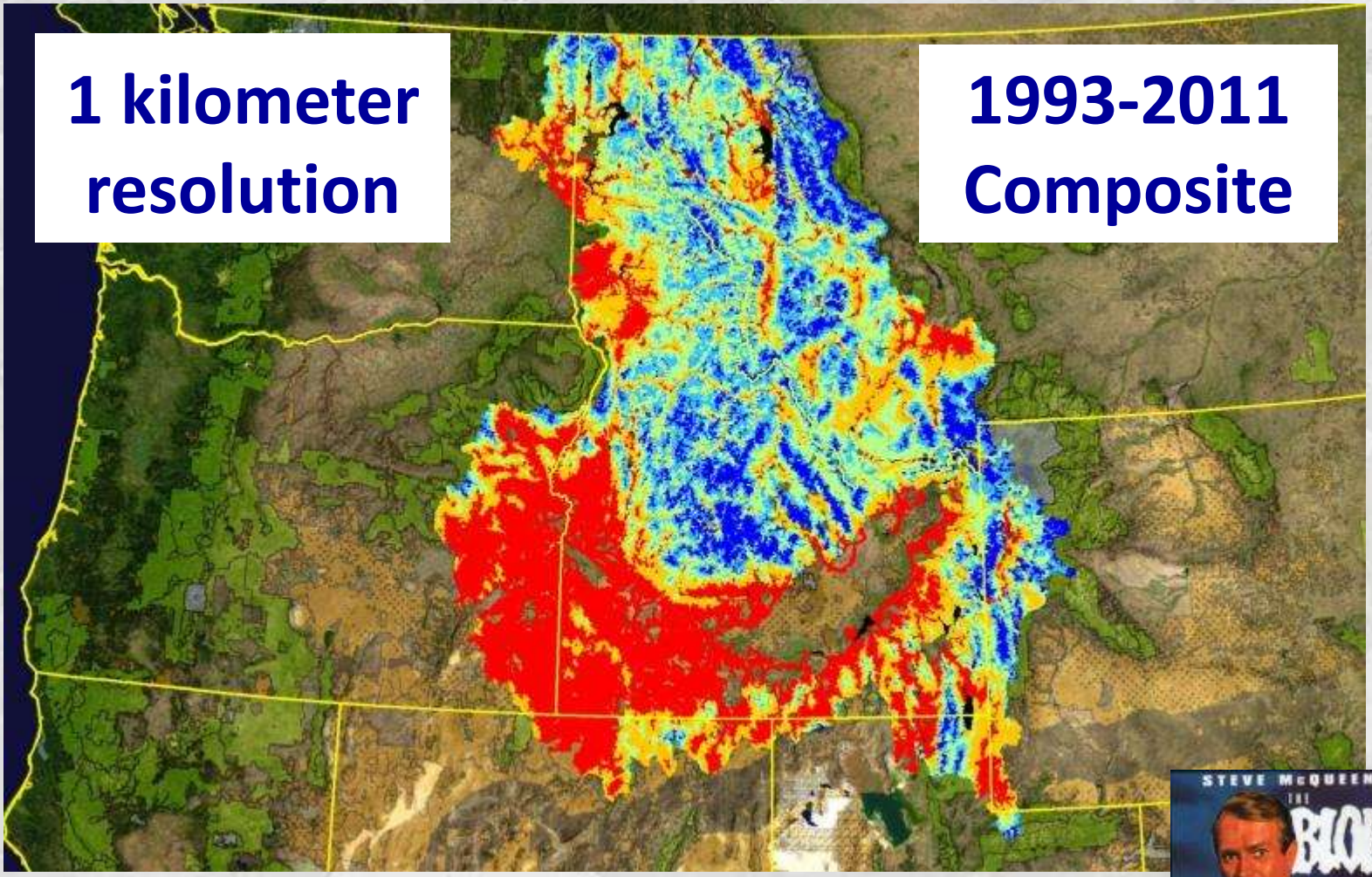
-flexible & valid autocovariance structures that accommodate network topology & non-independence among observations

-improved predictive ability & parameter estimates relative to non-spatial models

Ver Hoef et al. 2006; Ver Hoef & Peterson 2010; Peterson & Ver Hoef 2013

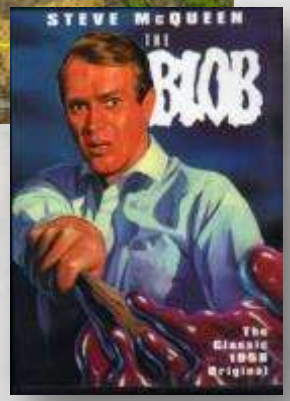
Accurate, Unbiased Information from Aggregated Stream Databases

High Resolution Stream Thermalscape

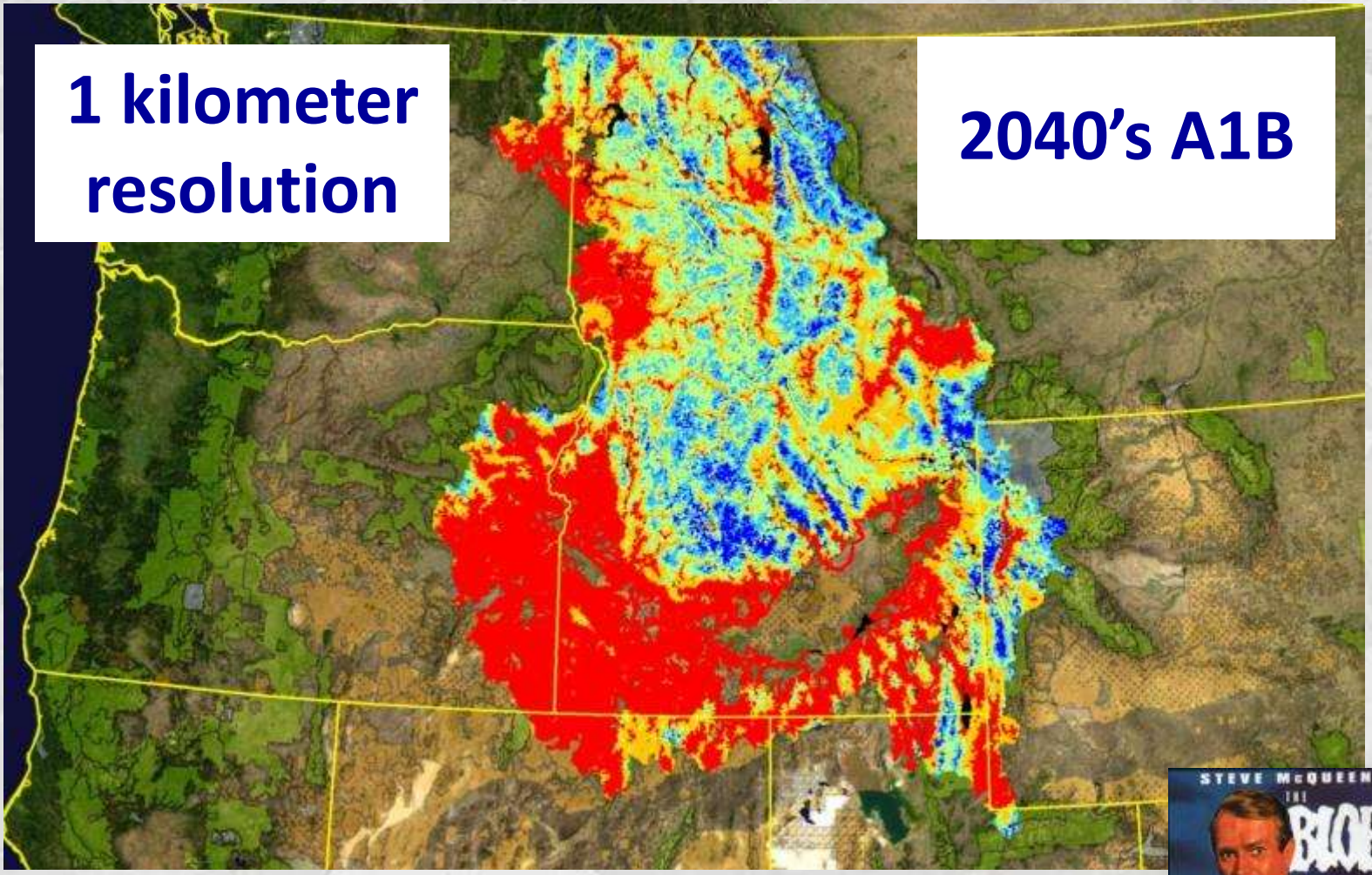


The BLOB…it just keeps growing…

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



High Resolution Stream Thermalscape



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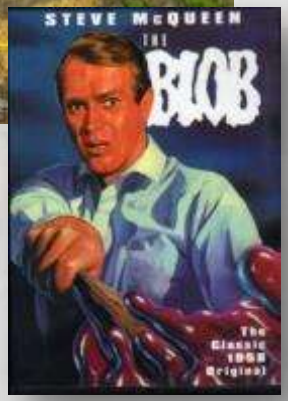

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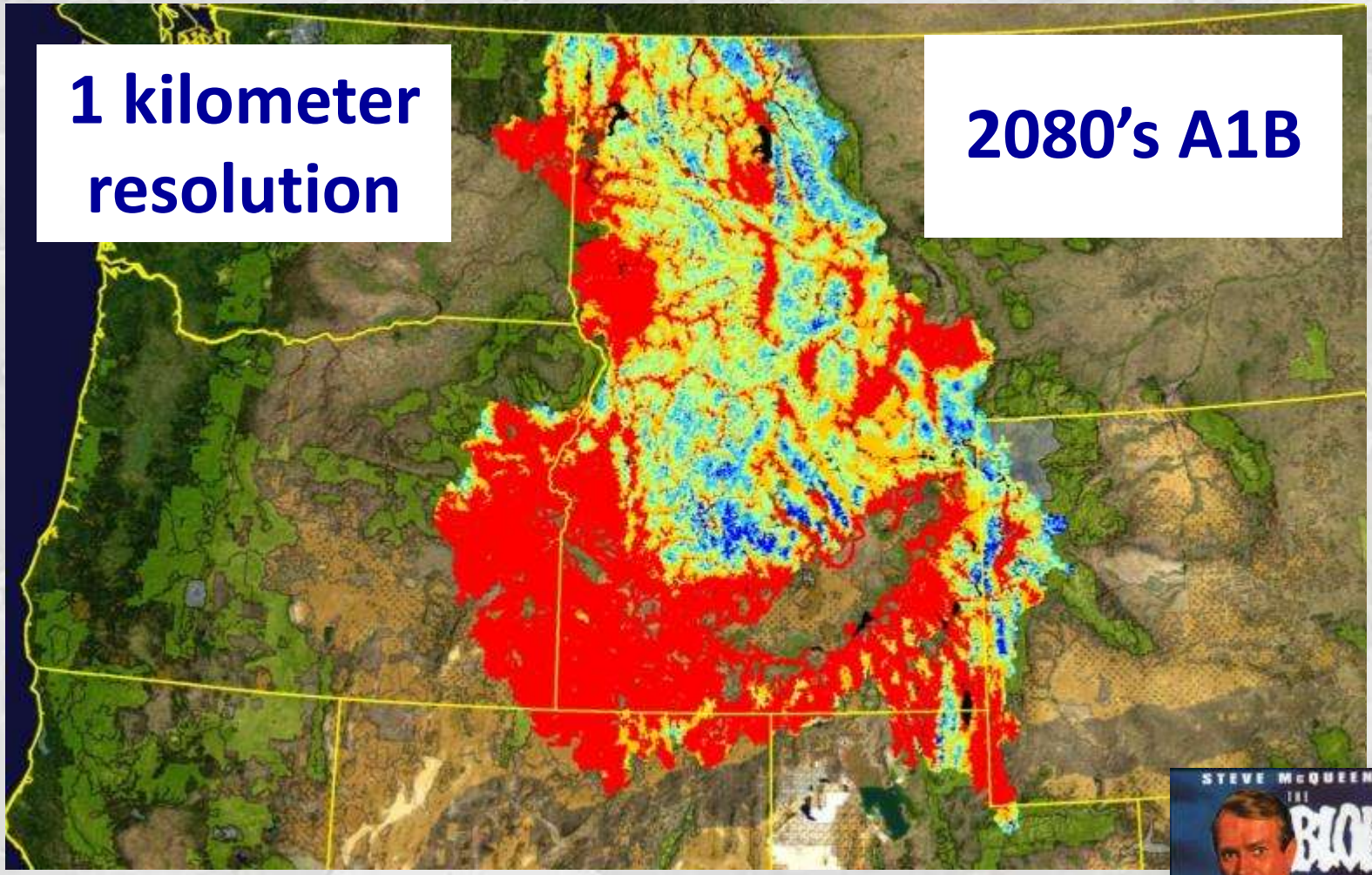

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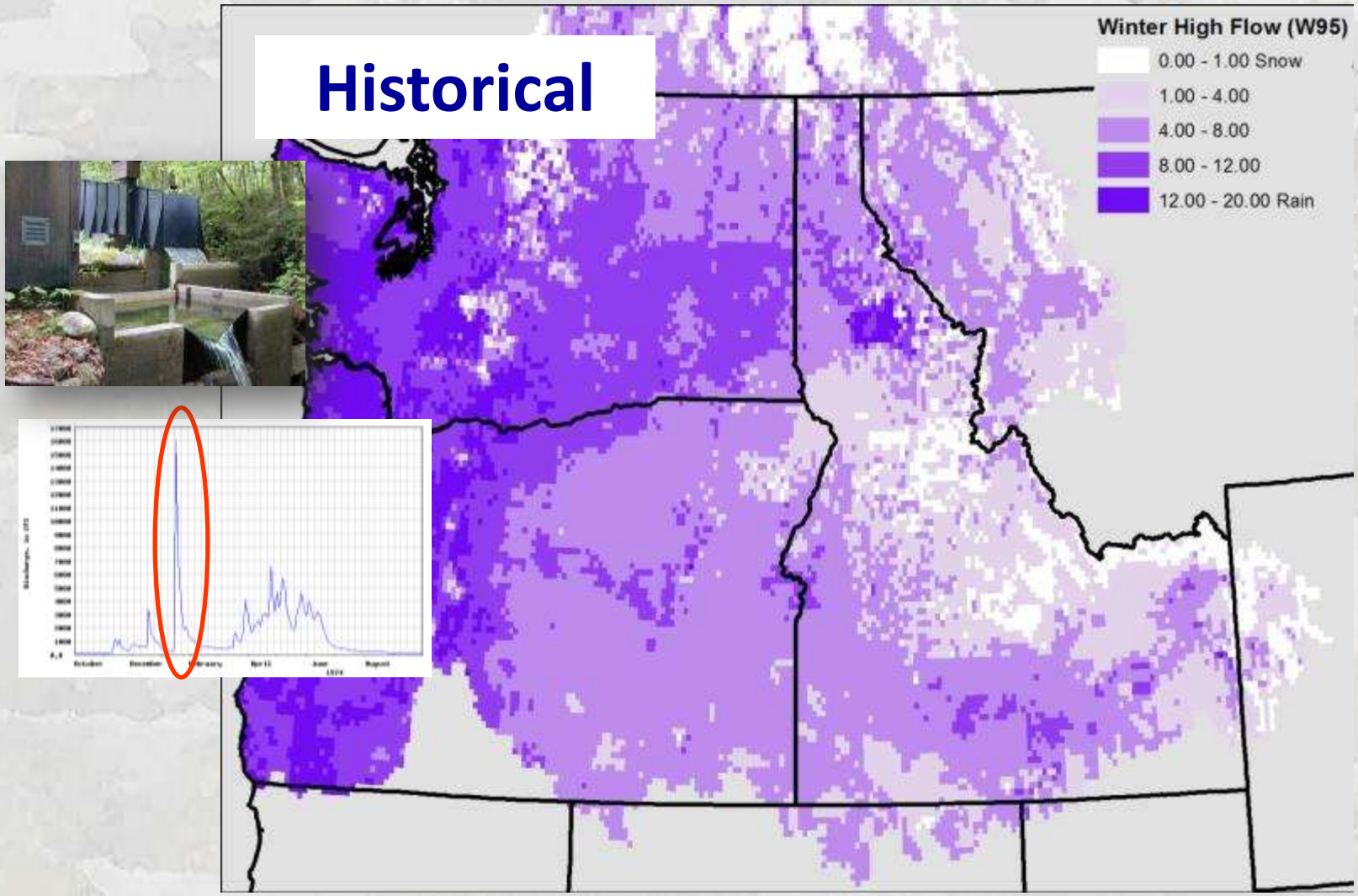
VIC Streamflow Metrics & Scenarios

Winter flood frequency (95% event)



Wenger et al. 2010. *WRR* **46**, W09513; Wenger et al. 2011. *PNAS* **108**:14175-14180

VIC Streamflow Metrics & Scenarios

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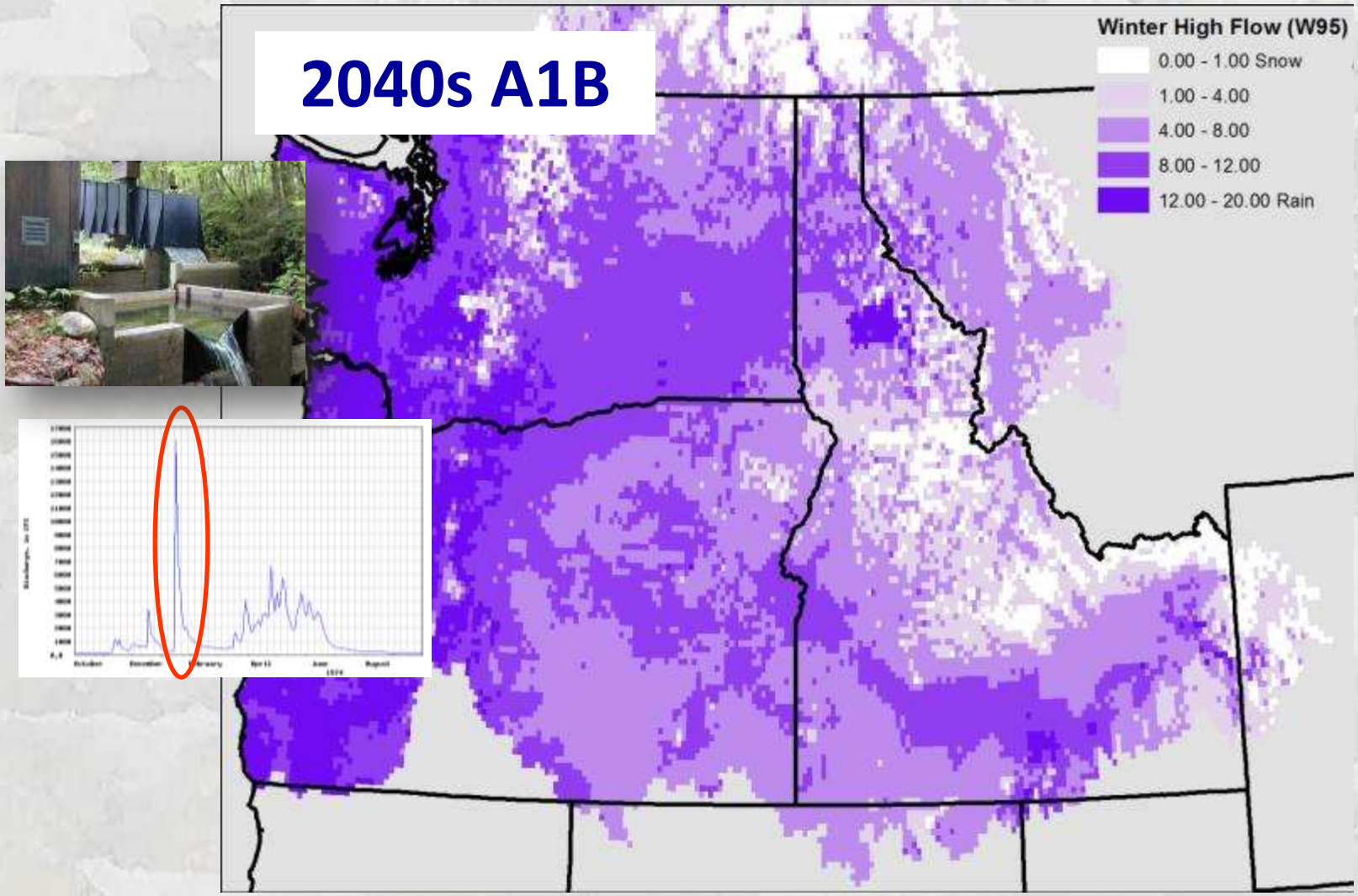

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VIC Streamflow Metrics & Scenarios

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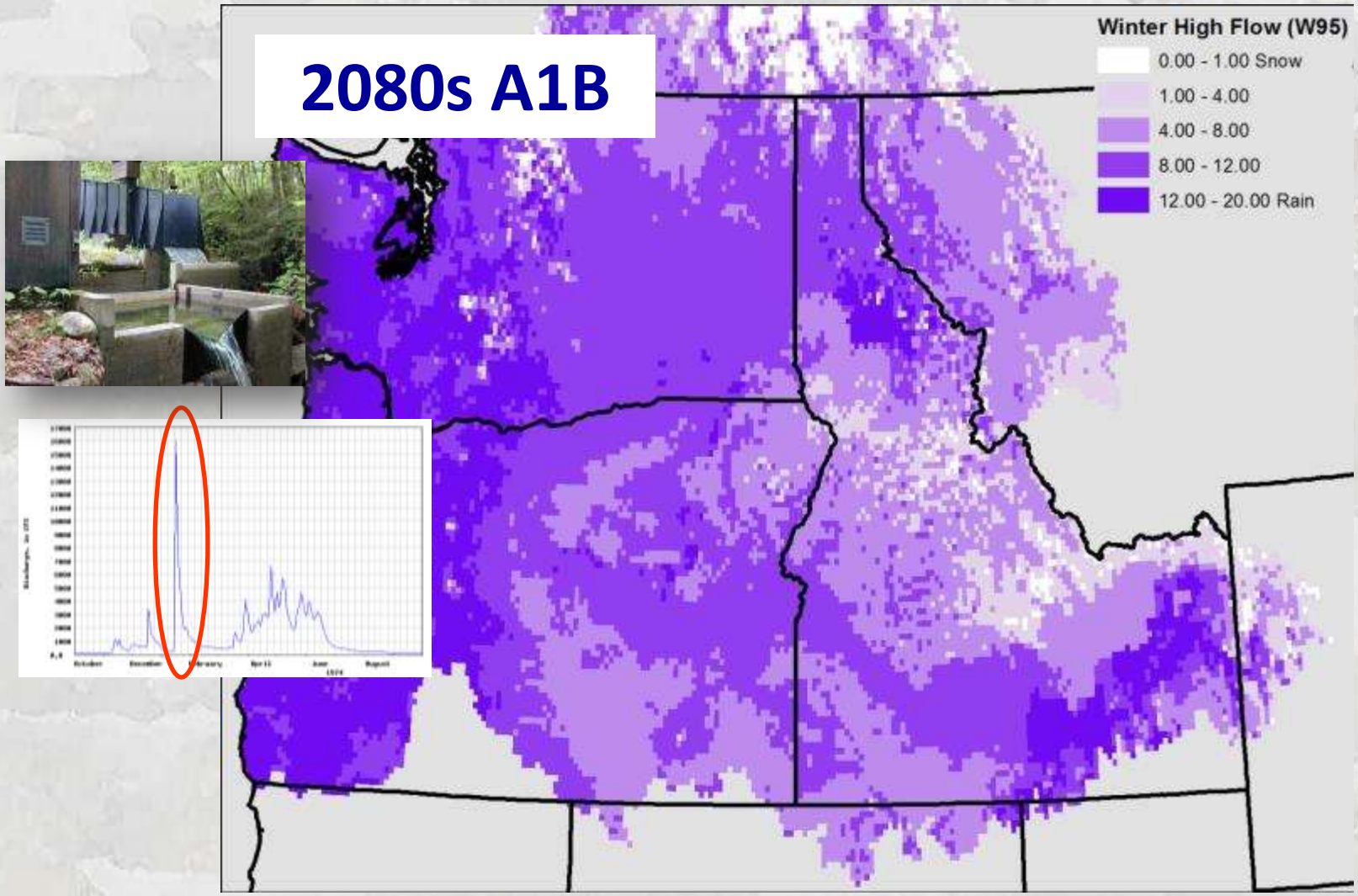


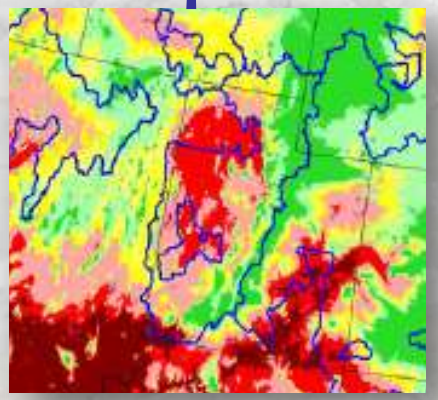
Wenger et al. 2010. *WRR* **46**, W09513; Wenger et al. 2011. *PNAS* **108**:14175-14180

Lots of Stream Habitat Descriptors

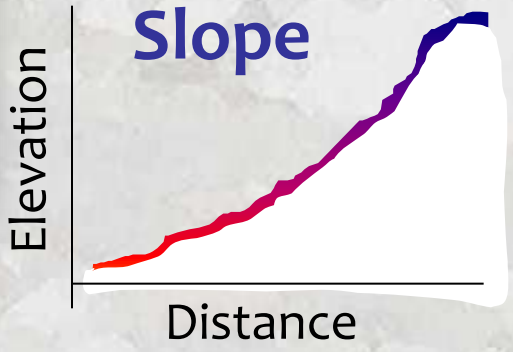
100's are Available (NHDPlus, NLCD, DEMs…)

% Landuse

Precipitation



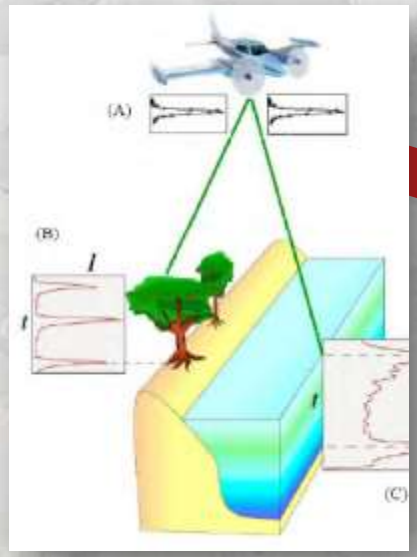
Drainage Area



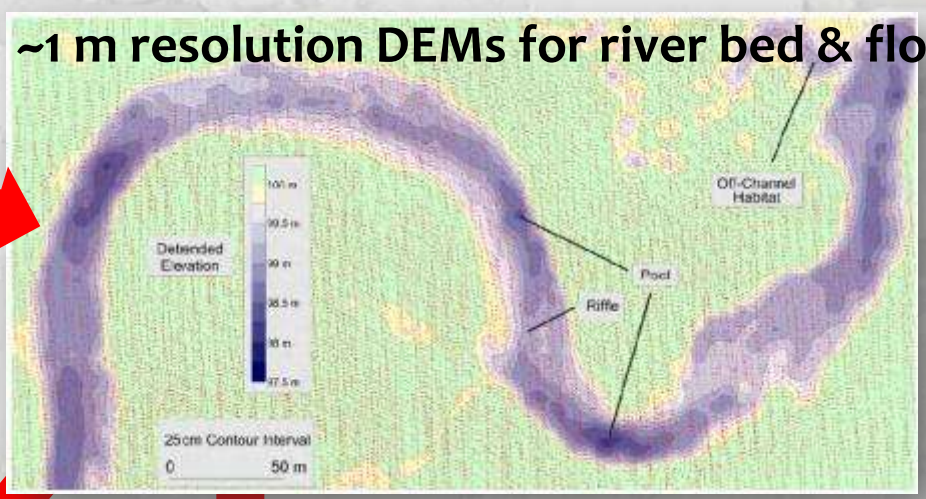
Wang et al. 2011. A Hierarchical Spatial Framework and Database for the National River Fish Habitat Condition Assessment. *Fisheries* **36**:436-449.

Better Information for Mainstem Rivers

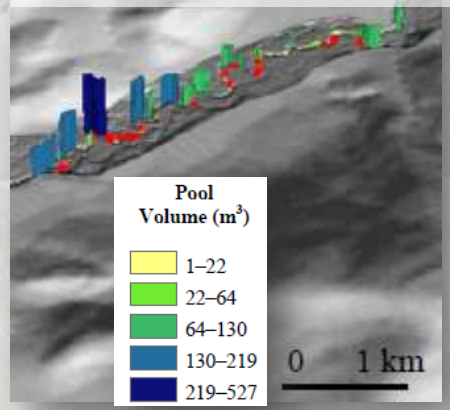
Green Lidar flown to census Lemhi River last October



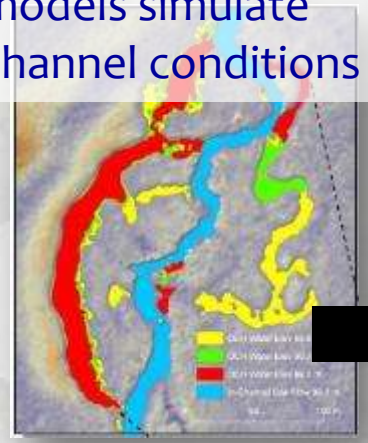
~1 m resolution DEMs for river bed & floodplain



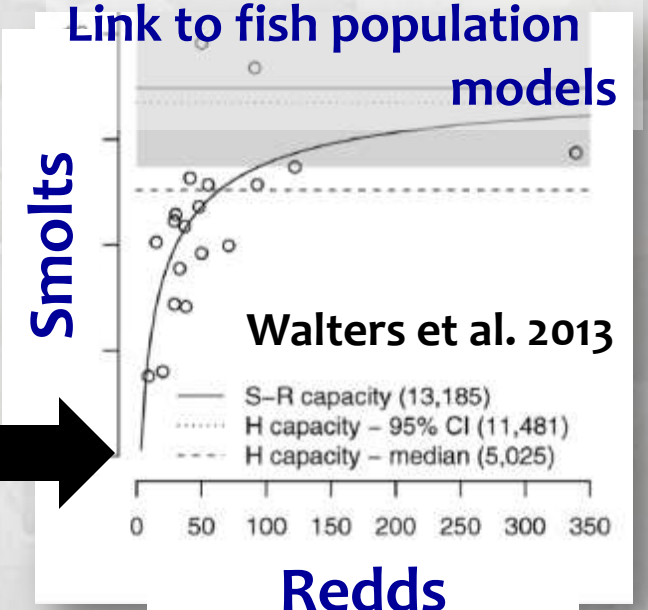
Precisely Quantify Fish Microhabitats



Hydrodynamic models simulate channel conditions



Link to fish population models

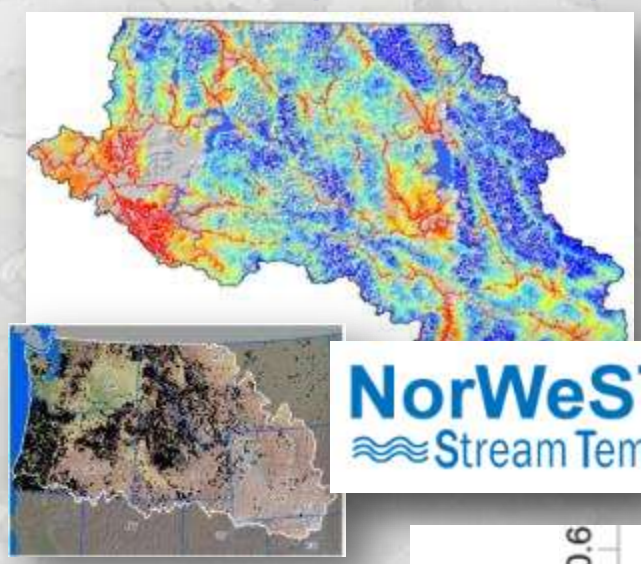


McKean et al. 2008; McKean & Tonina 2013

Synergies Emerge from Better Information

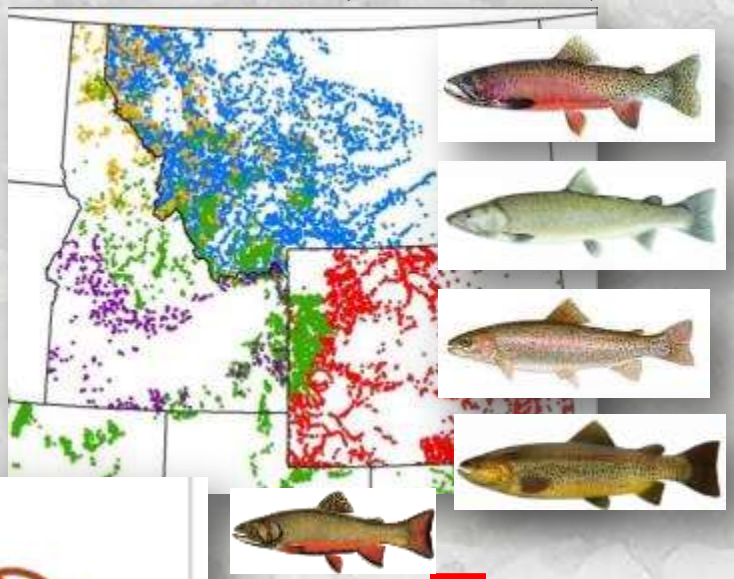
Regionally Consistent Thermal Criteria

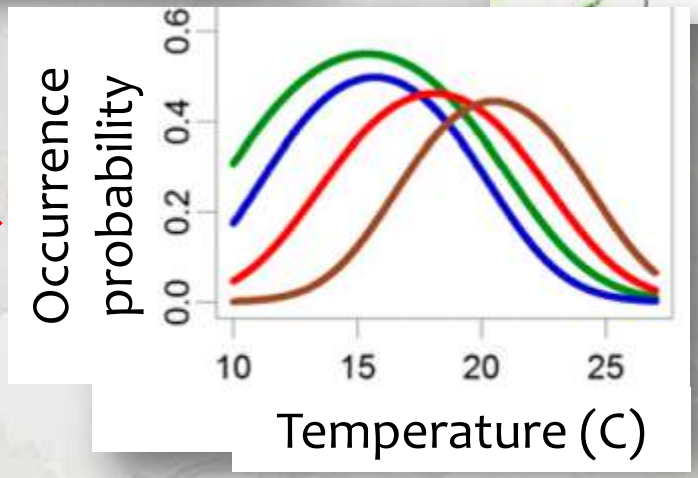
Stream temperature maps



NorWeST Stream Temp

Regional fish survey databases (n ~ 20,000)



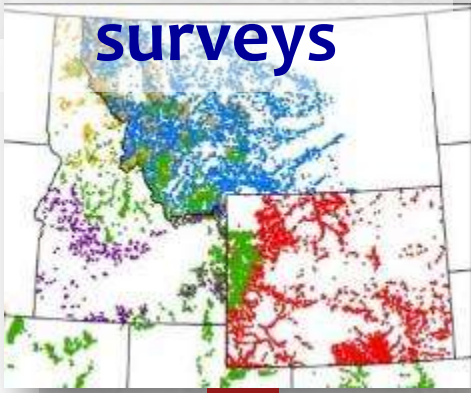


Wenger et al. 2011a. *PNAS* **108**:14175-14180

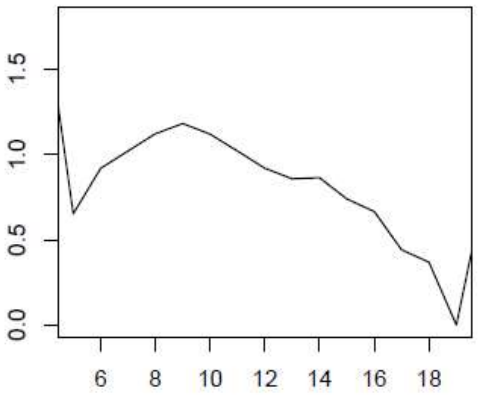
Wenger et al. 2011b. *CJFAS* **68**:988-1008; Wenger et al., *In Preparation*

Trout Thermal Niches

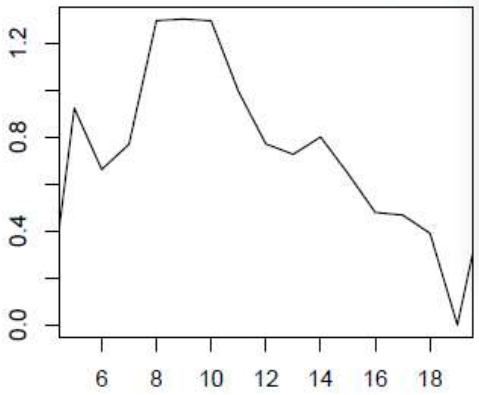
~20,000 fish surveys



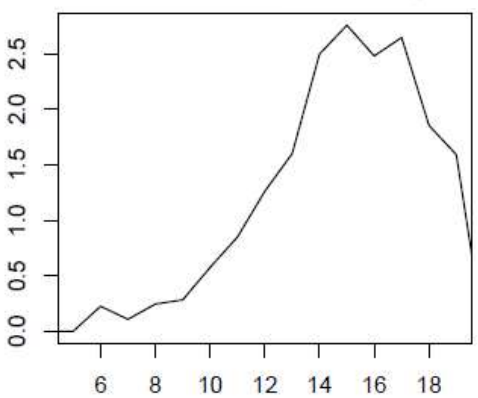
Cutthroat



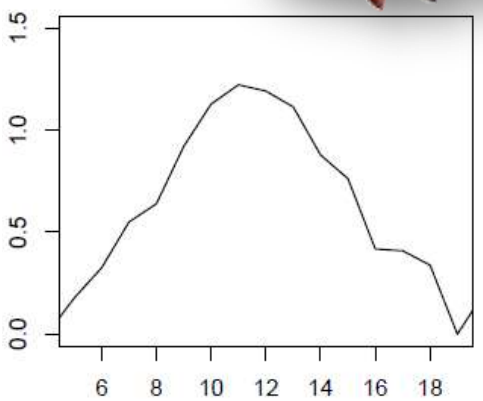
Bull



Rainbow



Brook

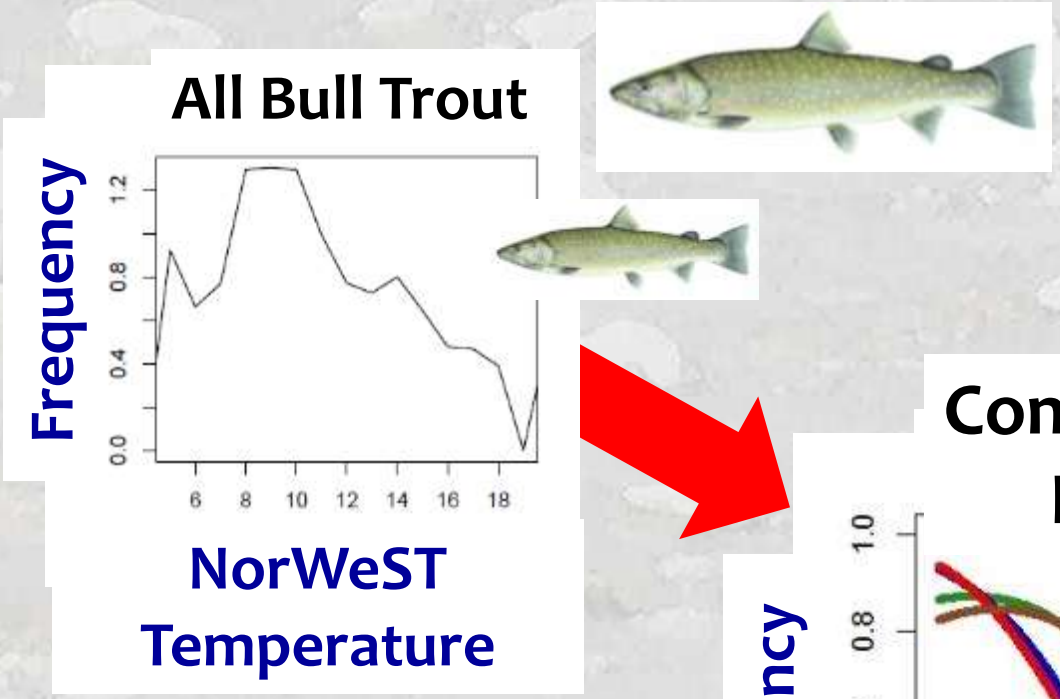


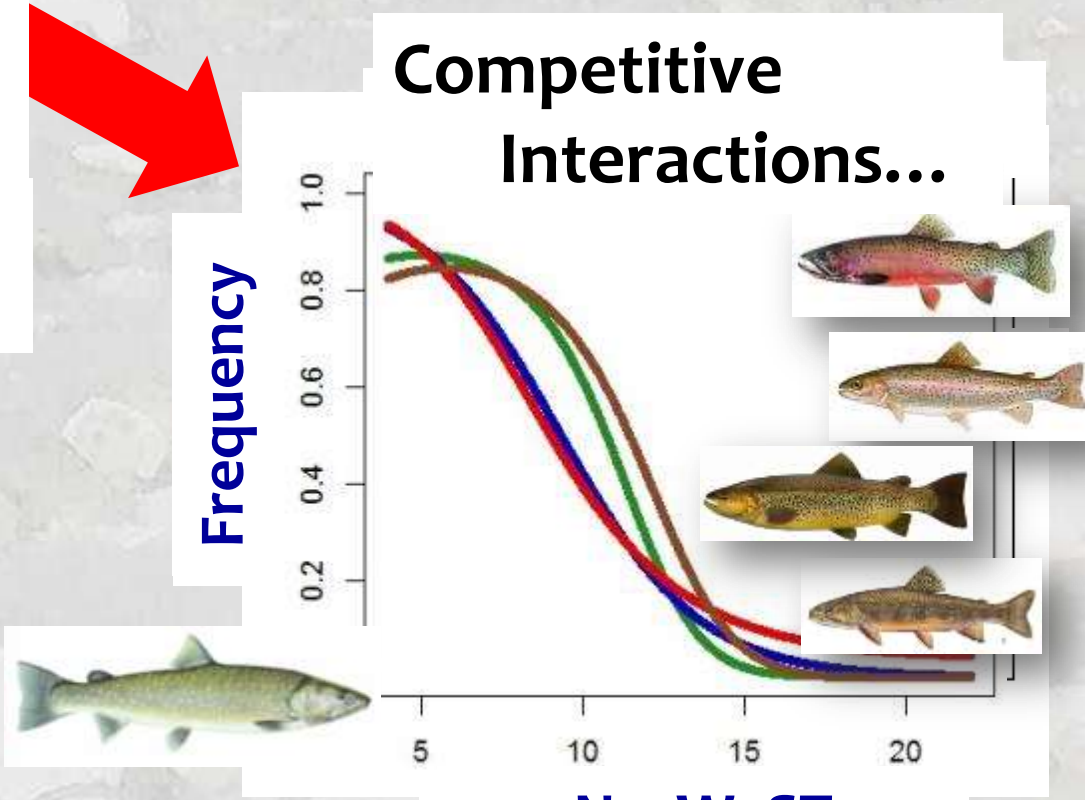
Frequency of Occurrence

NorWeST Stream Temperature (S1)

Wenger et al., *In Preparation*

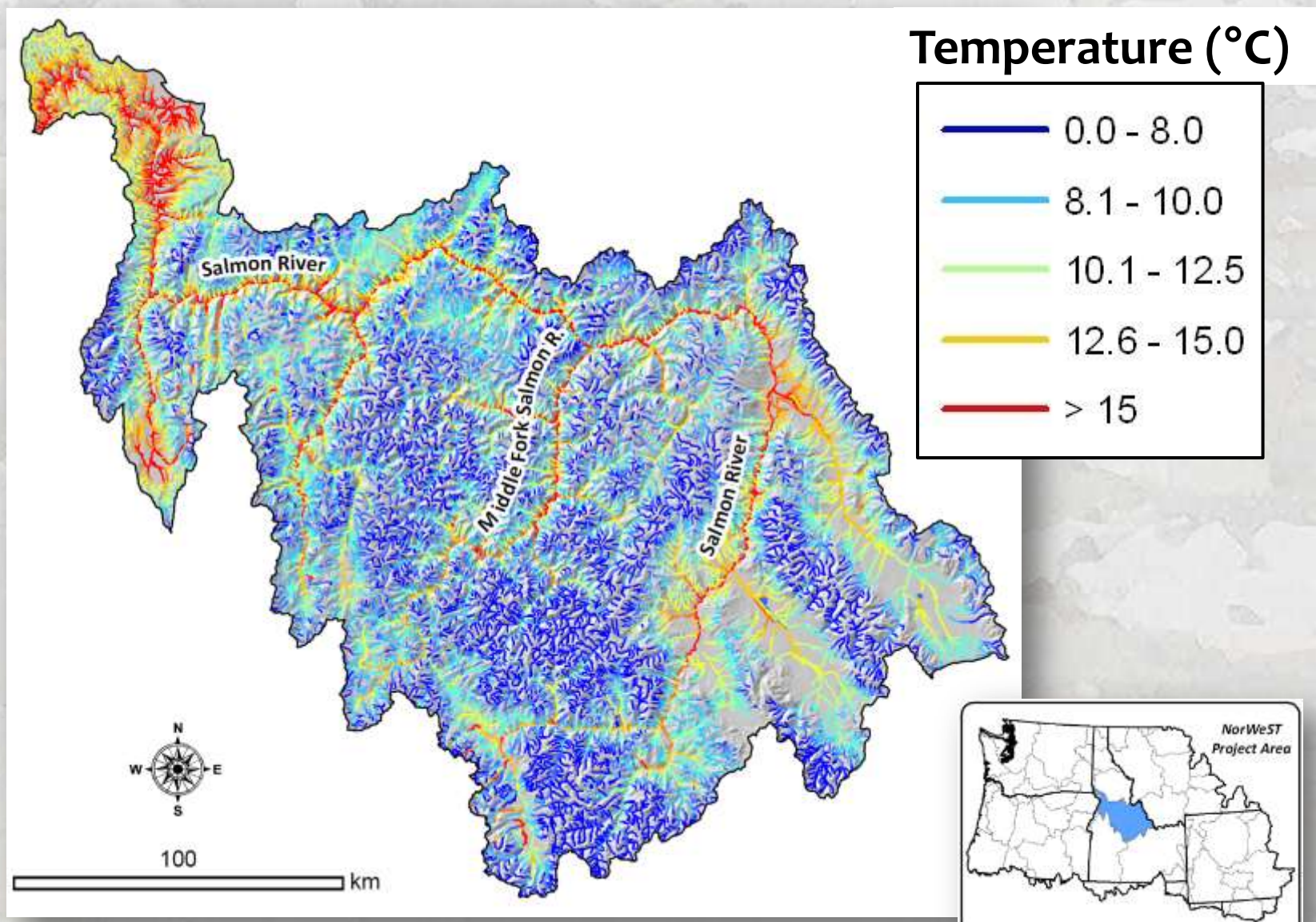
Thermal Niche Nuances…



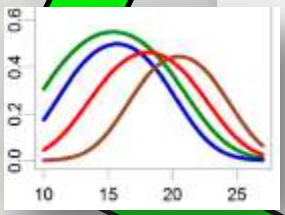


Salmon River Temperature Scenario

Historic (1993-2011 Average August)



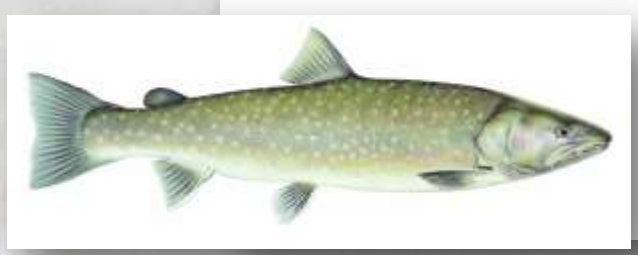
Bull Trout Natal Habitats = Historic



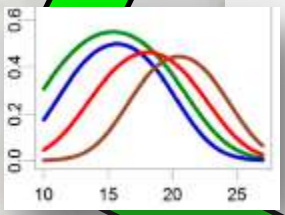
11°C isotherm

Suitable

Unsuitable



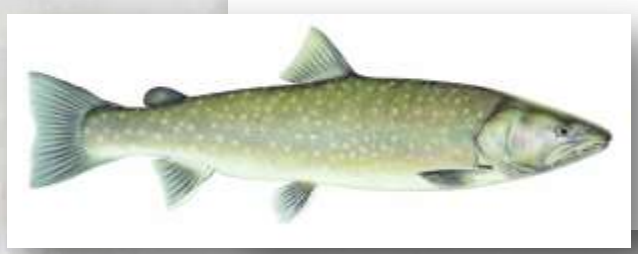
Bull Trout Natal Habitats = +1°C



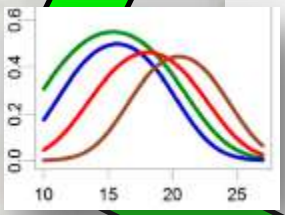
11°C isotherm

Suitable

Unsuitable



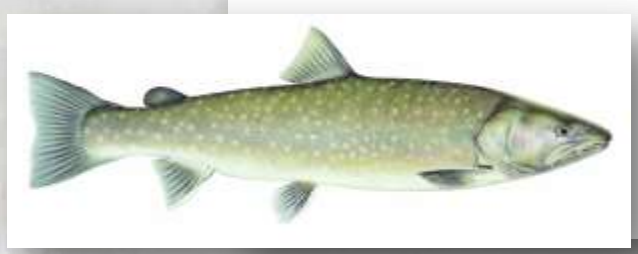
Bull Trout Natal Habitats = +2°C



11°C isotherm

Suitable

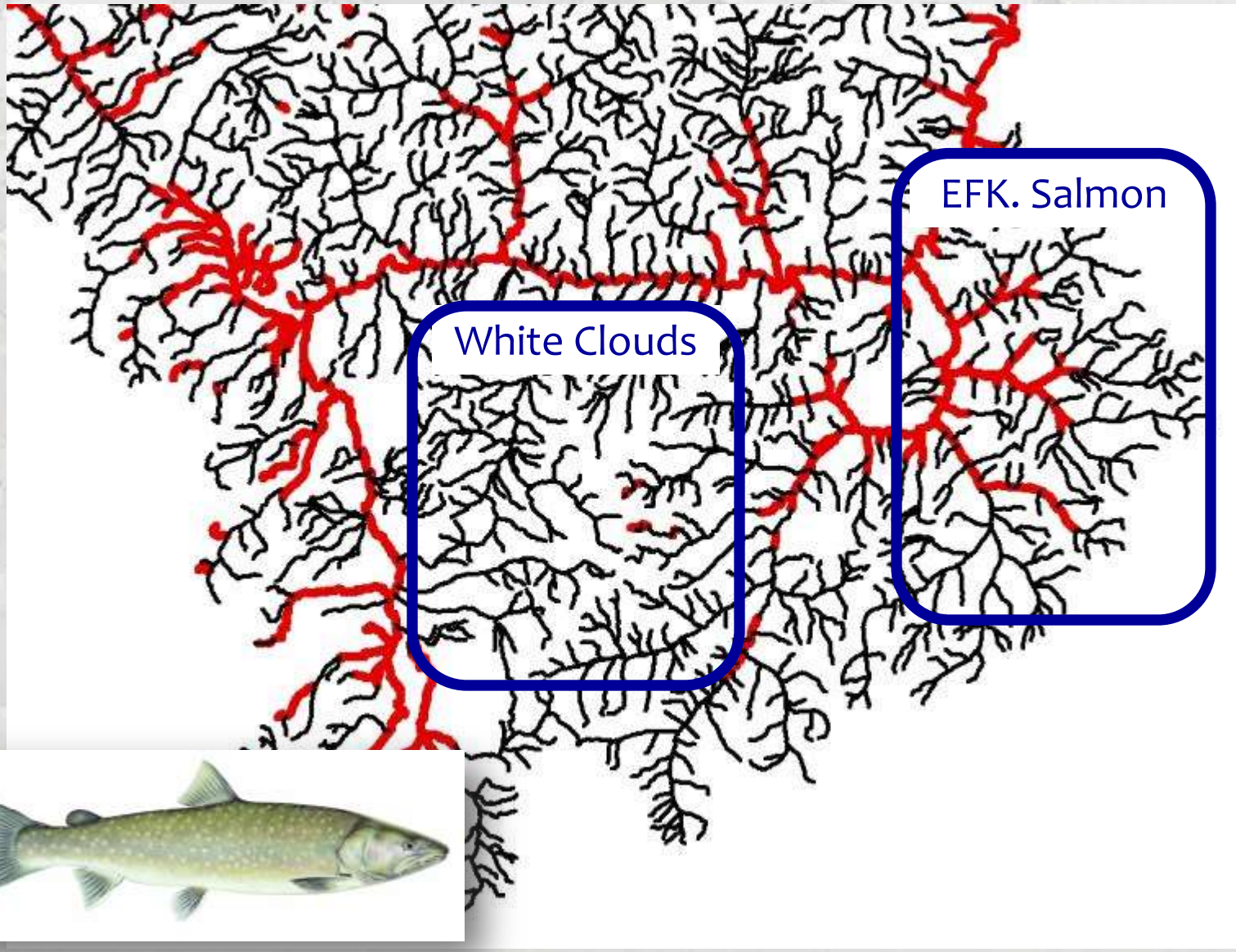
Unsuitable



Spatial Variation in Habitat Loss

Historical scenario

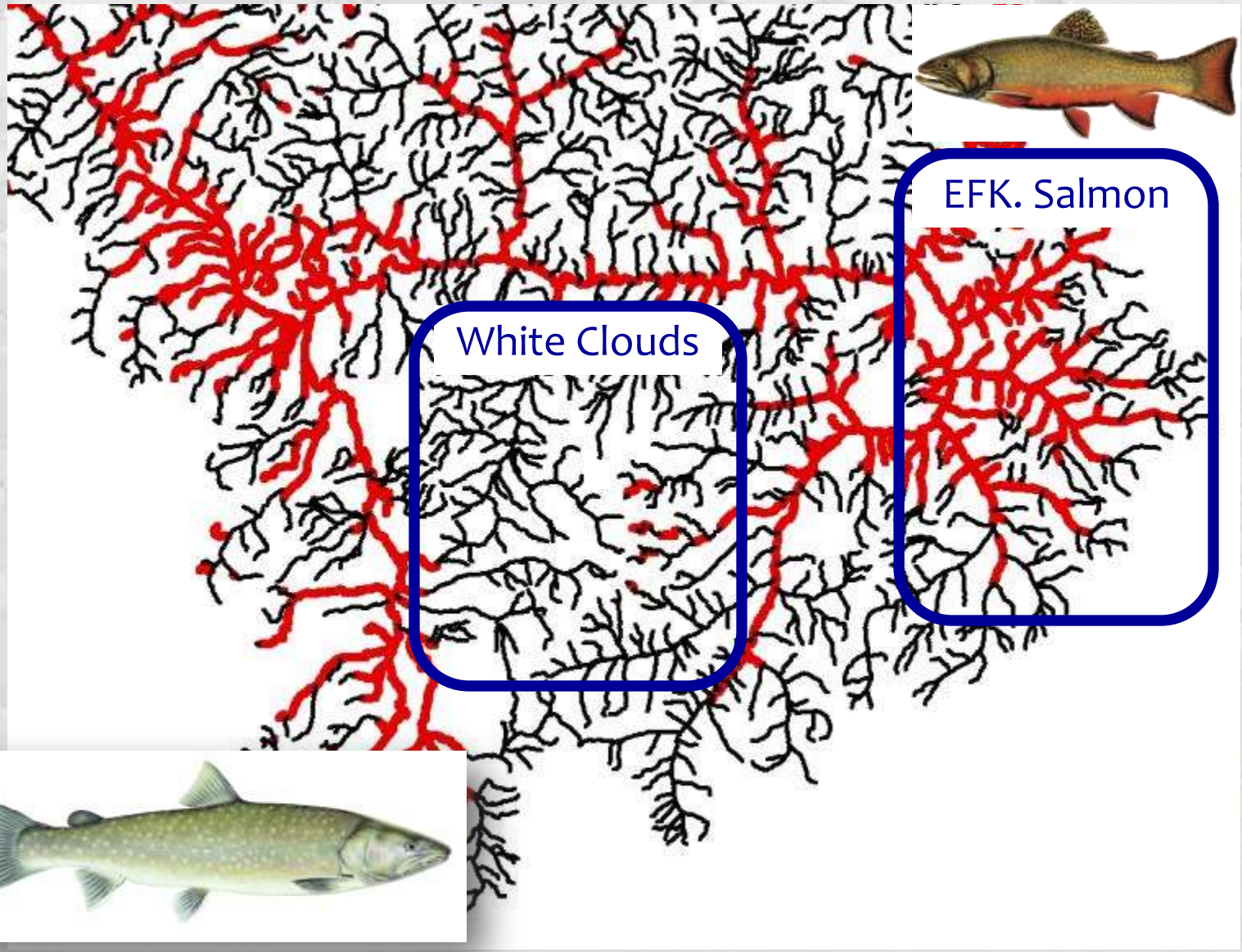
11°C isotherm



Spatial Variation in Habitat Loss

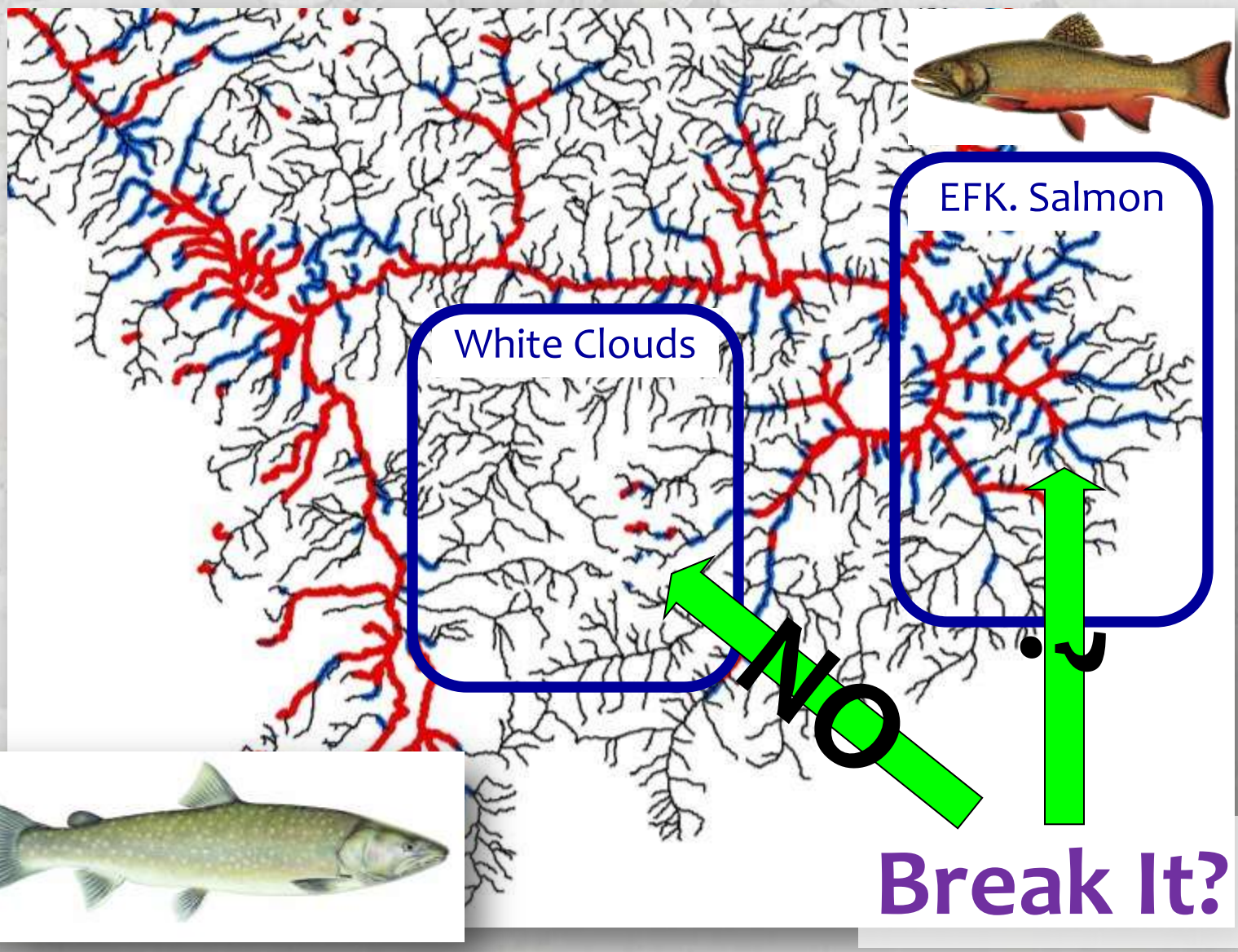
+1°C Scenario

11°C isotherm



Difference Map ~ Invasible Habitats

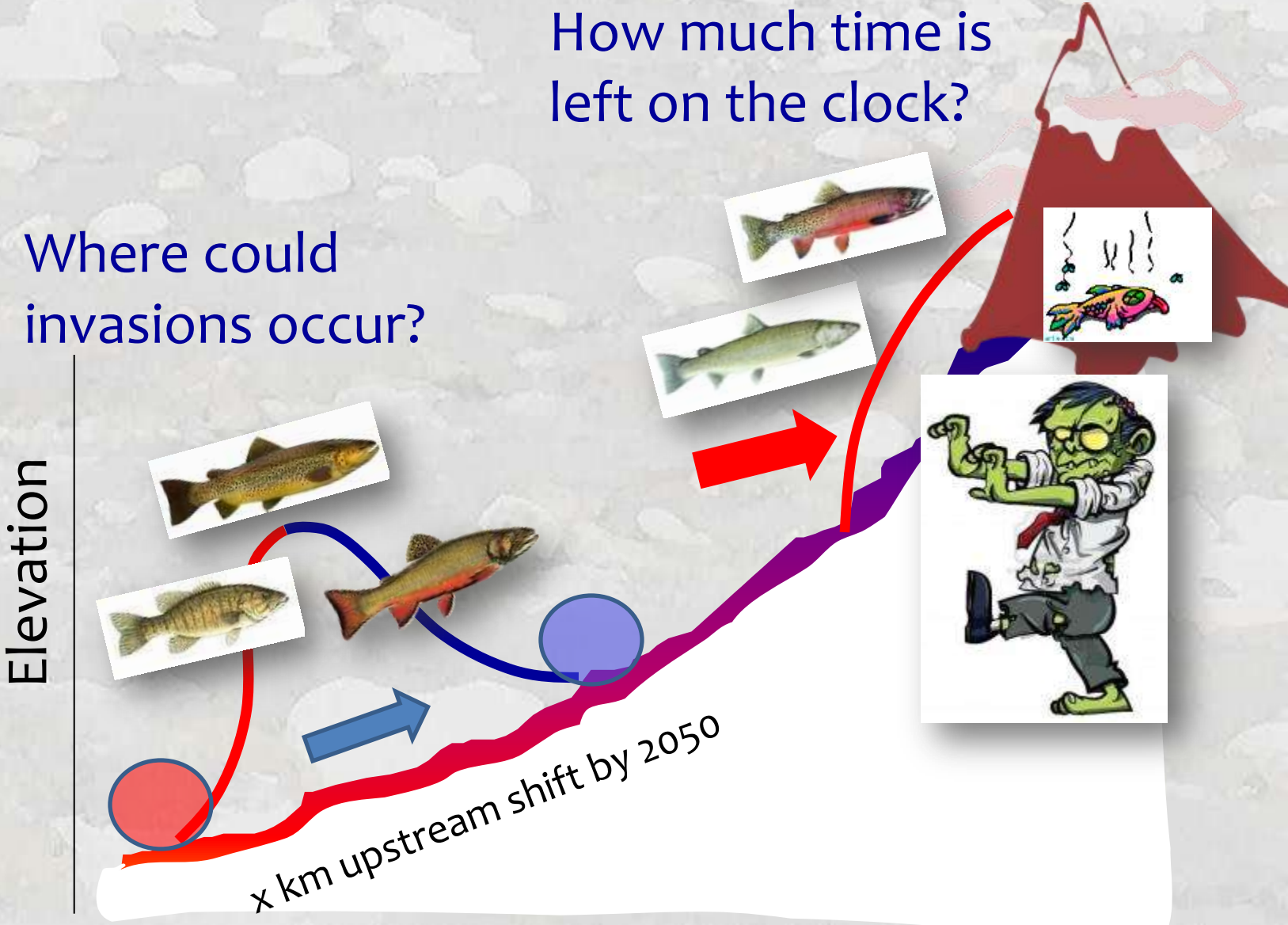
11°C isotherm



Precise Predictions of Invasible Habitats & "Zombie" Populations

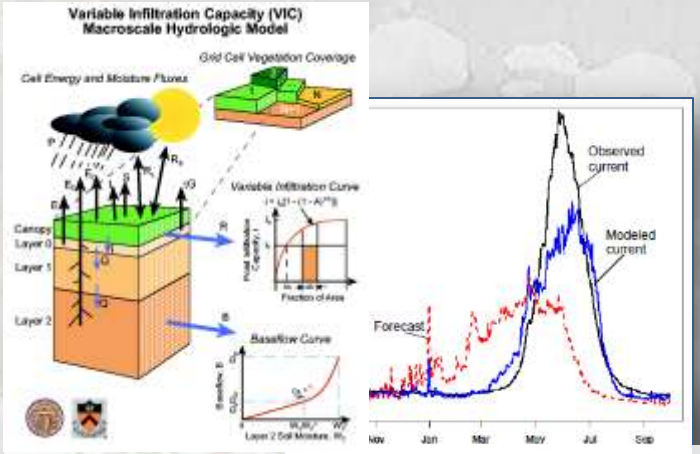
How much time is left on the clock?

Where could invasions occur?

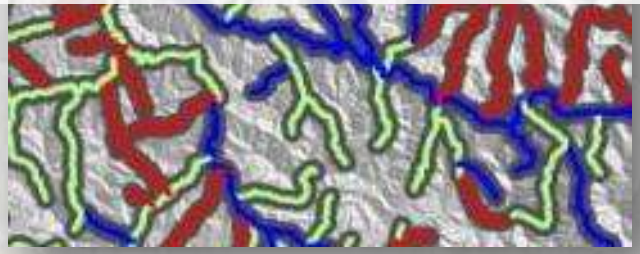


Revolution #2: Information Access

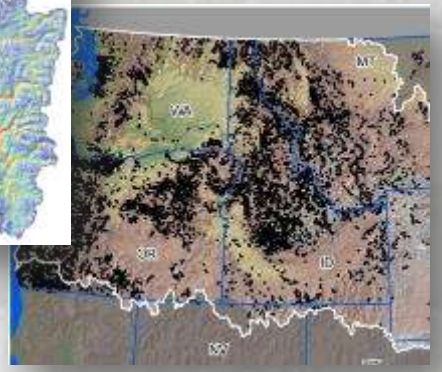
Websites Distribute Geospatial Stream Data 24/7…



Google "Stream flow Metrics"

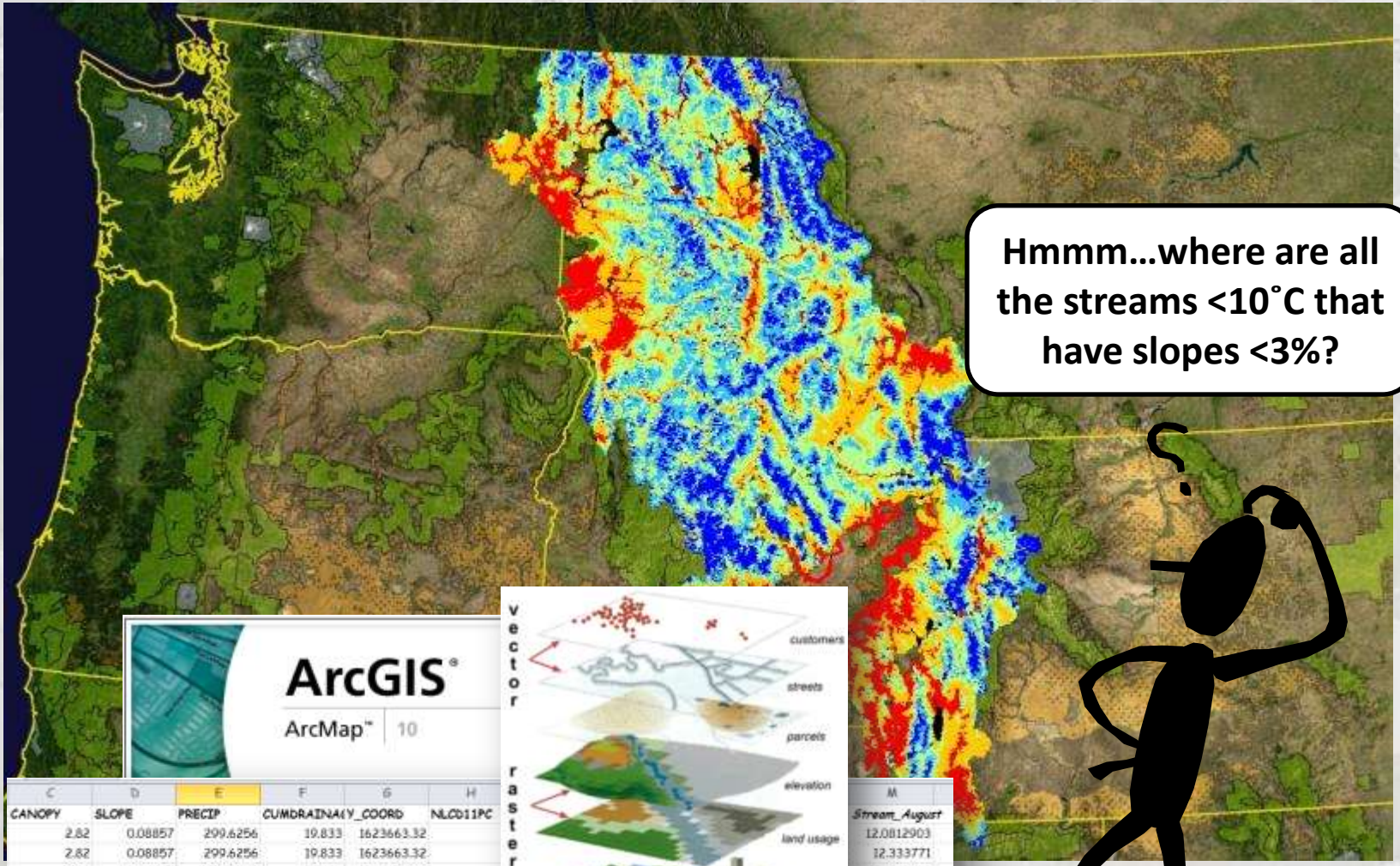


Google "NorWeST stream temp"



VIC Streamflow Scenarios

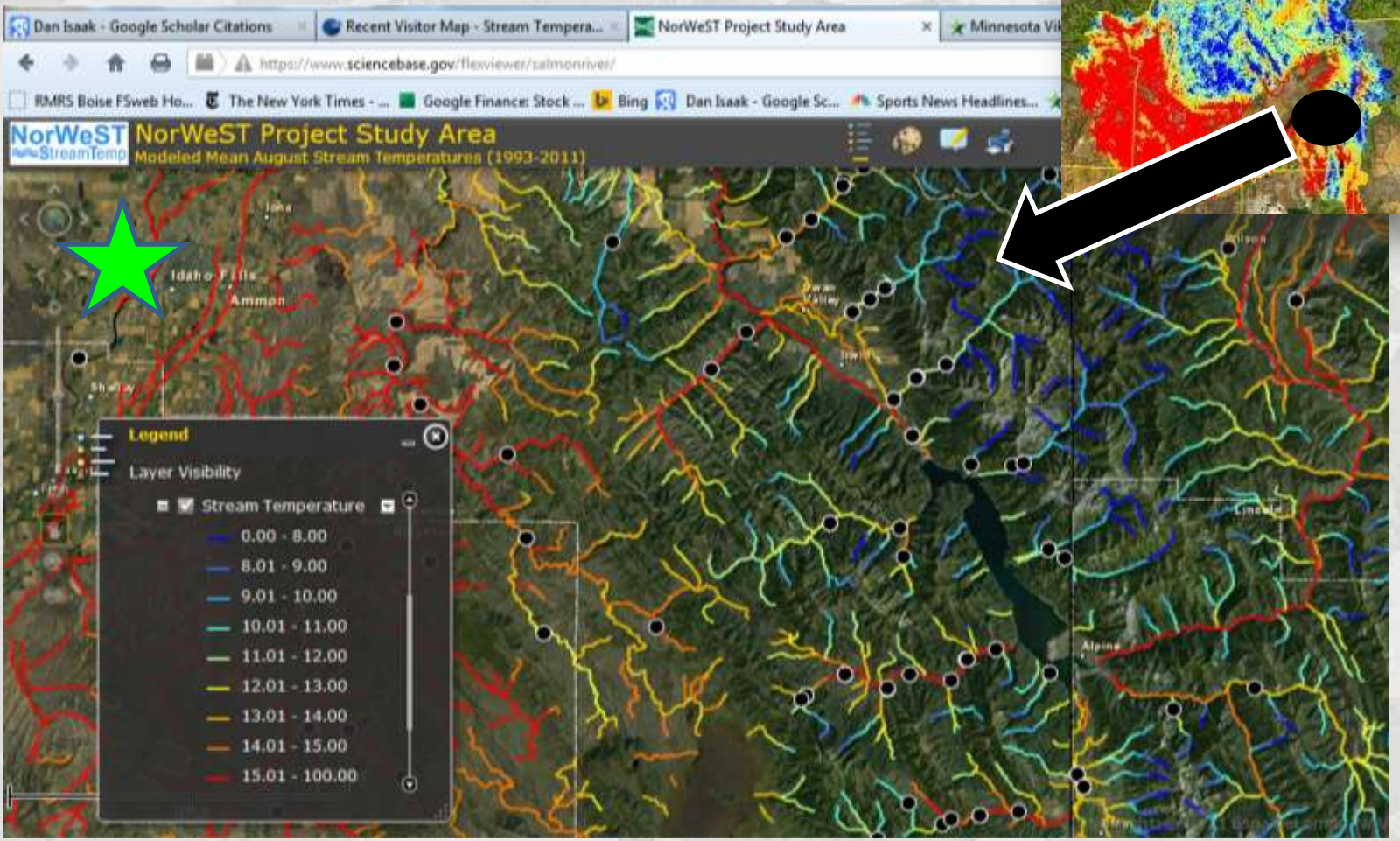
The BLOB is User-Friendly

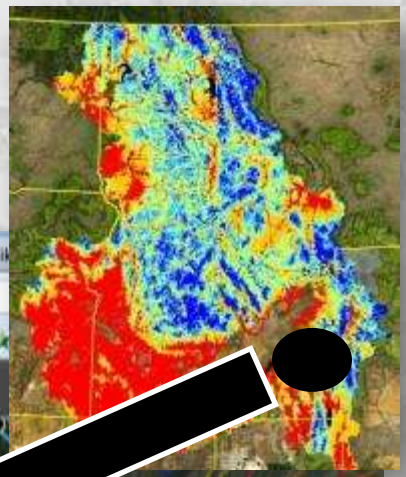


C	D	E	F	G	H					M
CANOPY	SLOPE	PRECIP	CUMDRAINA	Y_COORD	NLCD11PC					Stream_August
2.82	0.08857	299.6256	19.833	1623663.32						12.0812903
2.82	0.08857	299.6256	19.833	1623663.32						12.333771
2.82	0.08857	299.6256	19.833	1623663.32						11.4041581
12.23	0.03514	242.42	69.271	1620504.73	0.01					12.2216452
12.23	0.03514	242.42	69.271	1620504.73	0.01					11.0053548
12.23	0.03514	242.42	69.271	1620504.73	0.01					12.7445484
12.23	0.03514	242.42	69.271	1620504.73	0.01					11.9685161
12.23	0.03514	242.42	69.271	1620504.73	0.01					10.9931936
12.23	0.03514	242.42	69.271	1620504.73	0.012	0	80	14.54	22.19	11.3862545
12.23	0.03514	242.42	69.271	1620504.73	0.012	0	80	14.02	35.71	11.4452903
12.23	0.03514	242.42	69.271	1620504.73	0.012	0	80	13.20	40.52	11.5266484
12.23	0.03514	242.42	69.271	1620504.73	0.012	0	80	13.00	38.99	10.7834677
67.2	0.12123	1040.365	3.544	1516682.34	0	0	76	13.59	32.75	

Websurf the BLOB

Dynamic Online Map Viewer





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

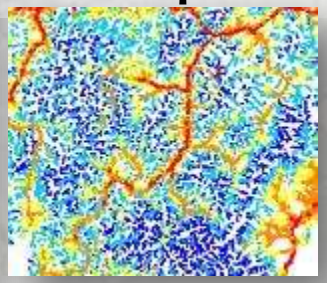
Take the BLOB with You – Go Wireless

Real-time Access to Accurate Stream Data Anytime, Anywhere

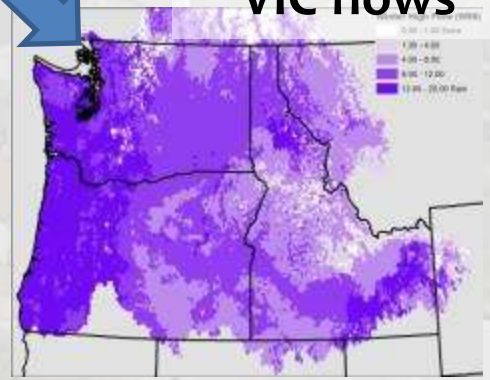
ArcGIS app

ESRI

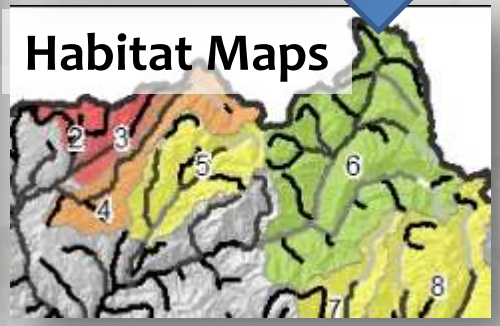
Temperature Maps



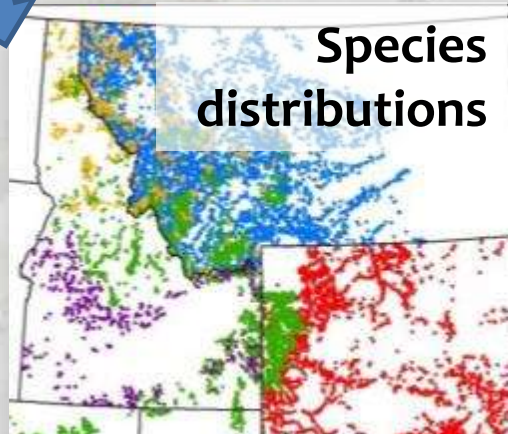
VIC flows



Habitat Maps



Species distributions



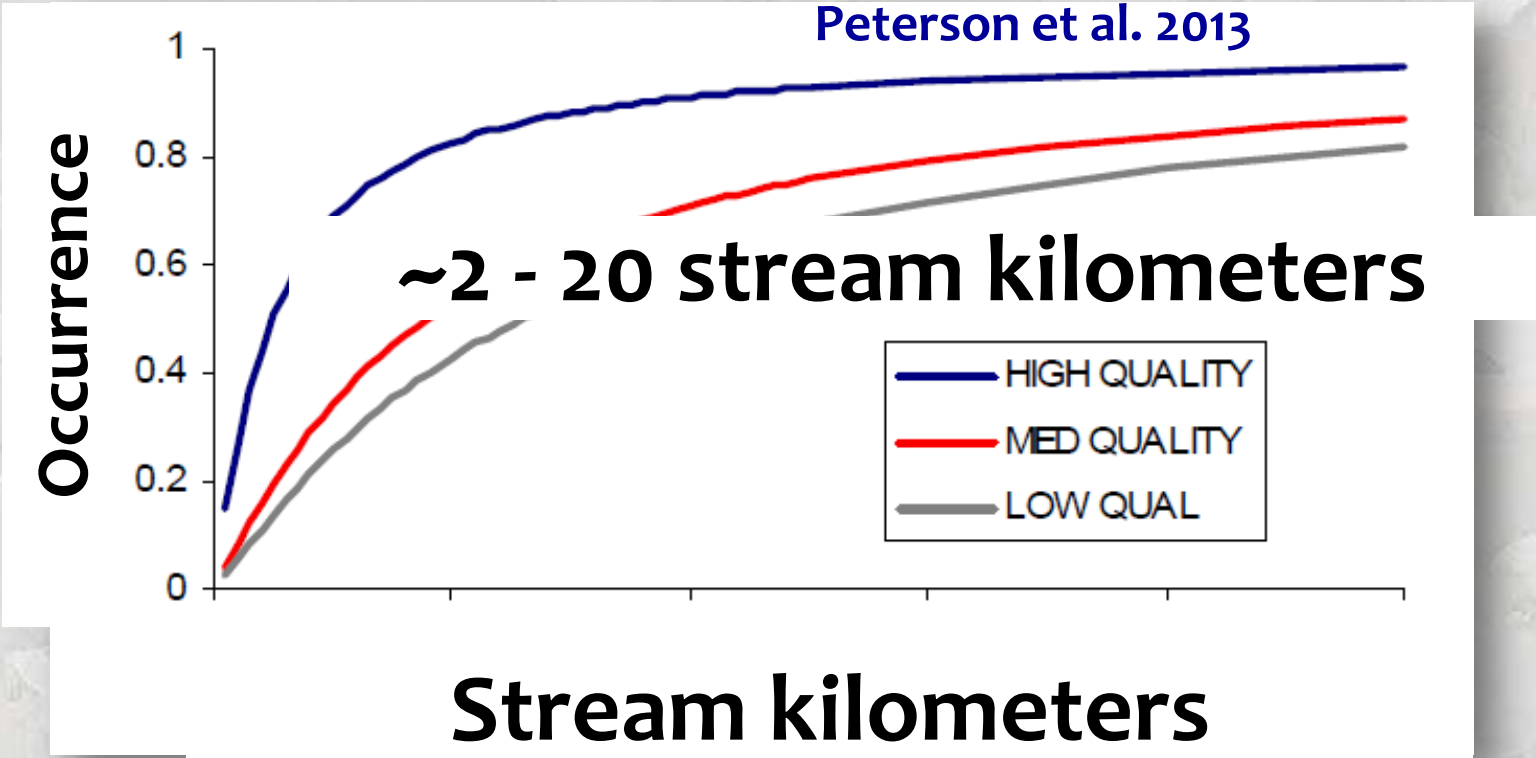
Information Overload

How do We Filter it ?

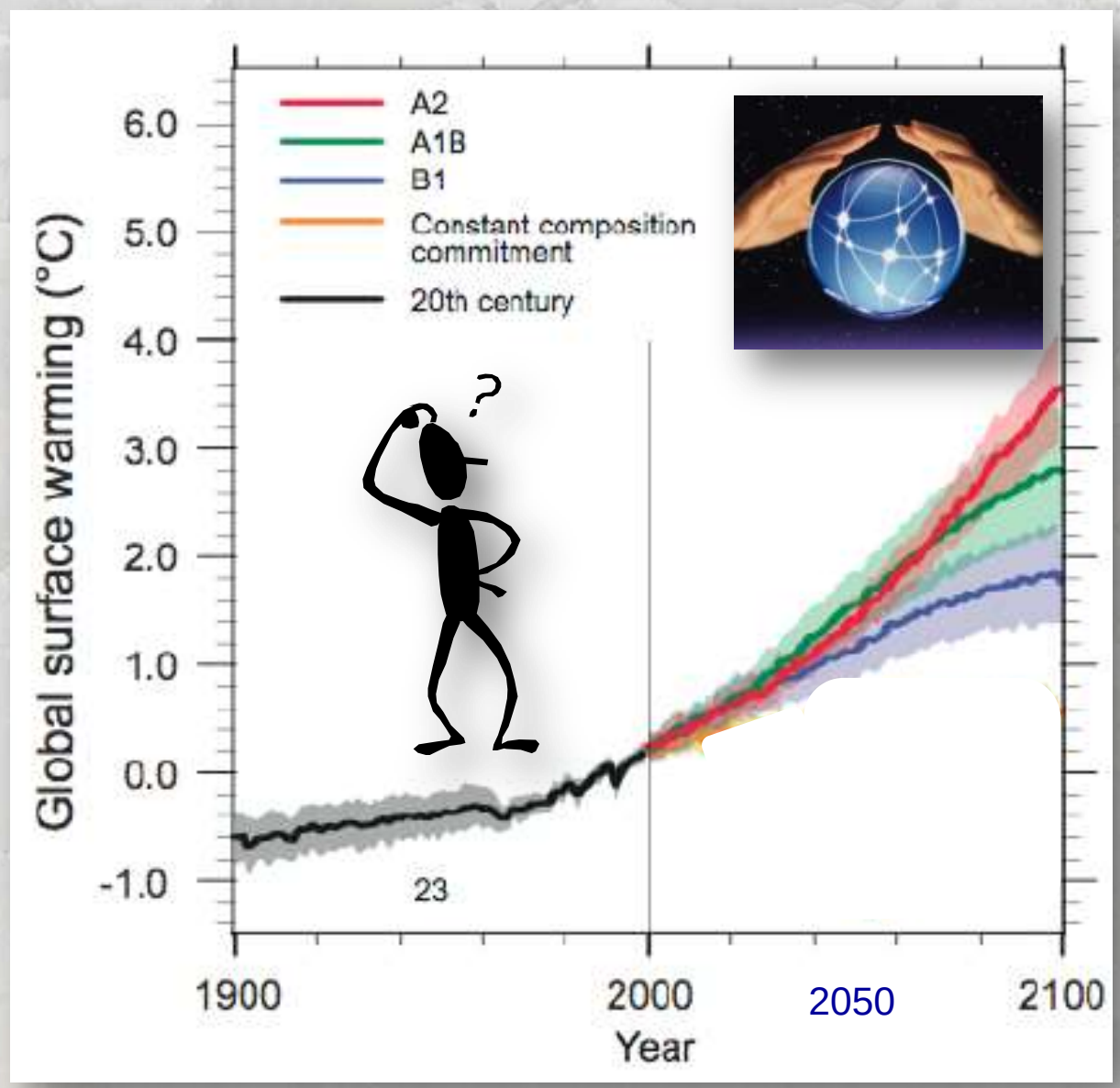
Filter #1: Amount of Habitat Needed to Support a Population

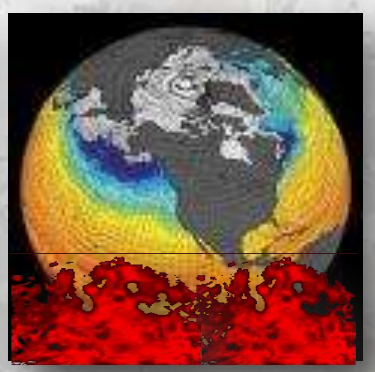
Rieman & McIntyre 1995
Dunham and Rieman 1999
Dunham et al. 2002

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

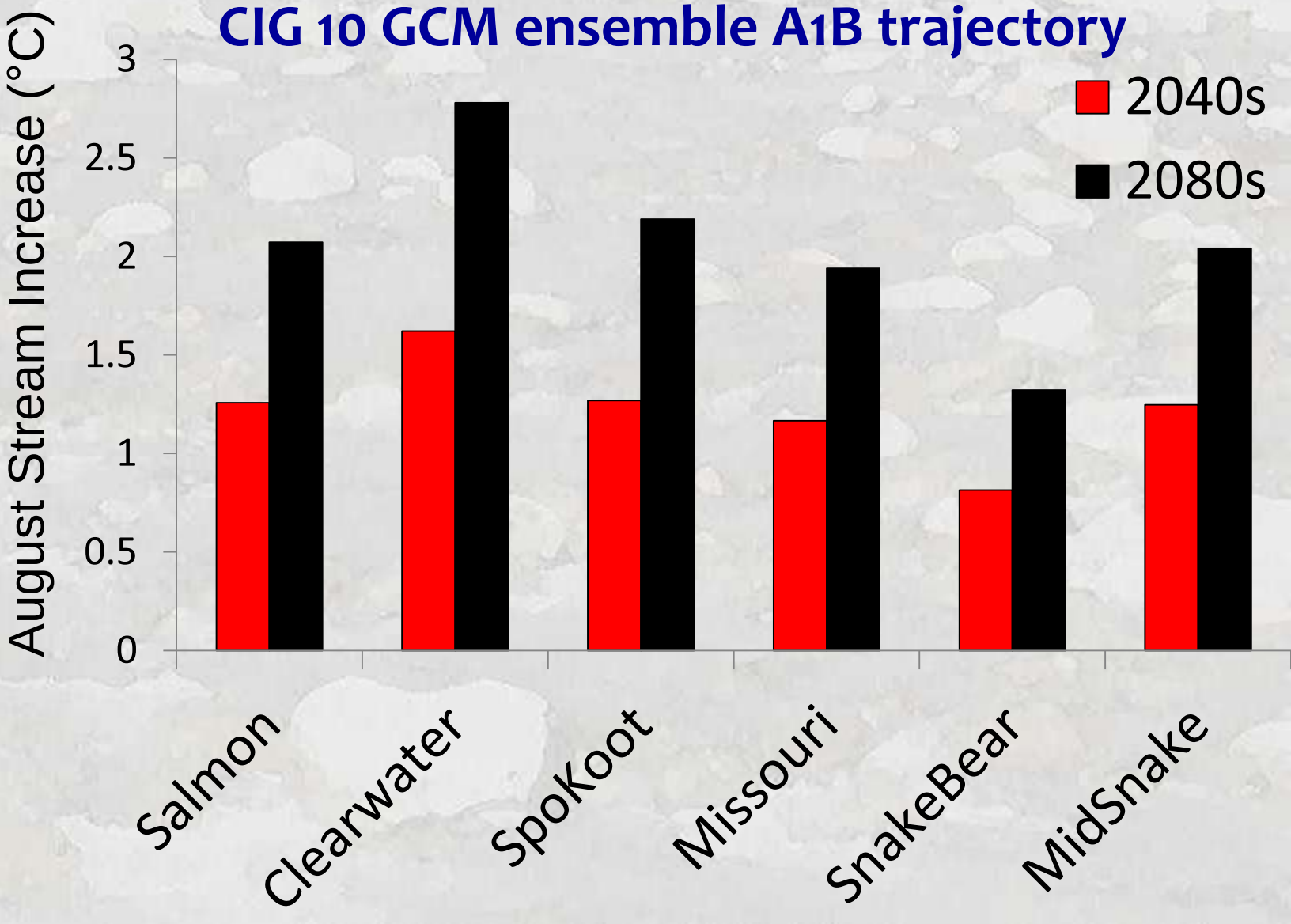


The Future will be Different…





NorWeST Predictions of Summer Stream Temperature Increases



Climate Related Factors will Interact

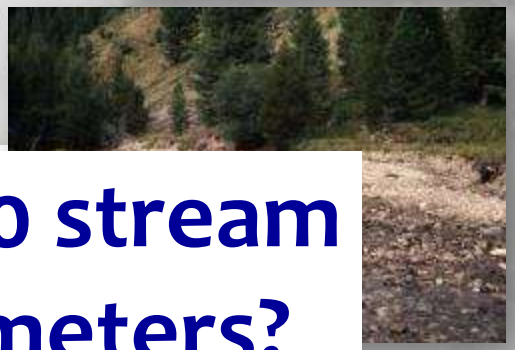
Warmer temperatures
Reduced summer flows
Fire & debris flows
Winter flooding
Non-native invasions

The Headwater Trout Vise

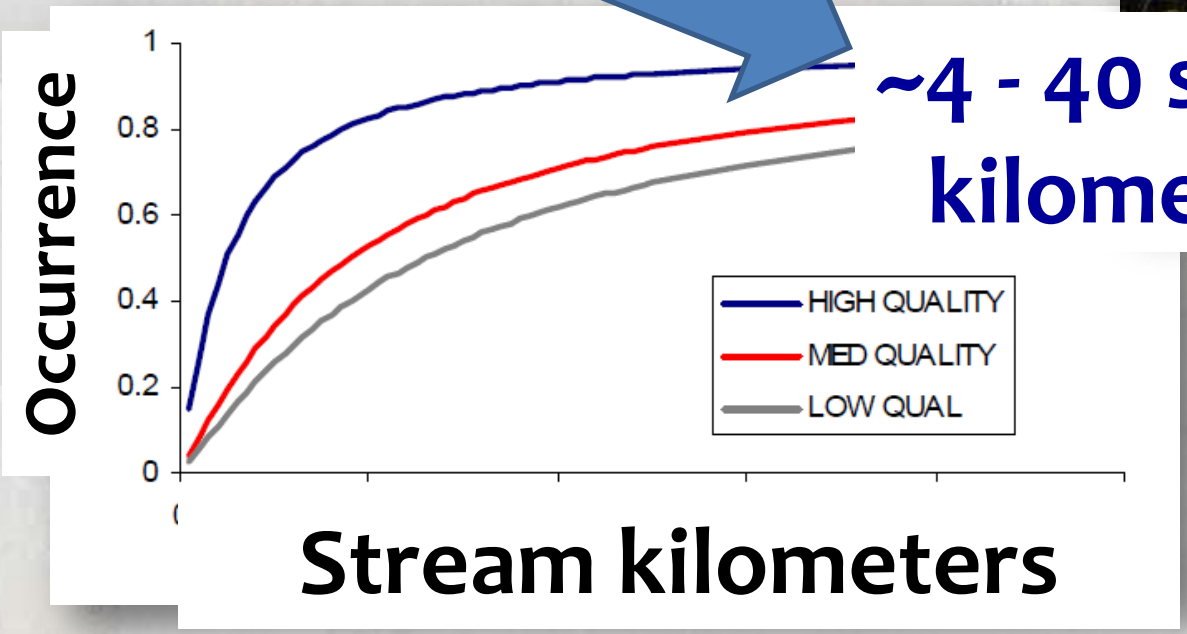
So We'll Need a Habitat Fudge Factor

Bigger Floods, Fires, & Droughts are Coming…

~~~~2 - 20 stream kilometers~~~~



~4 - 40 stream kilometers?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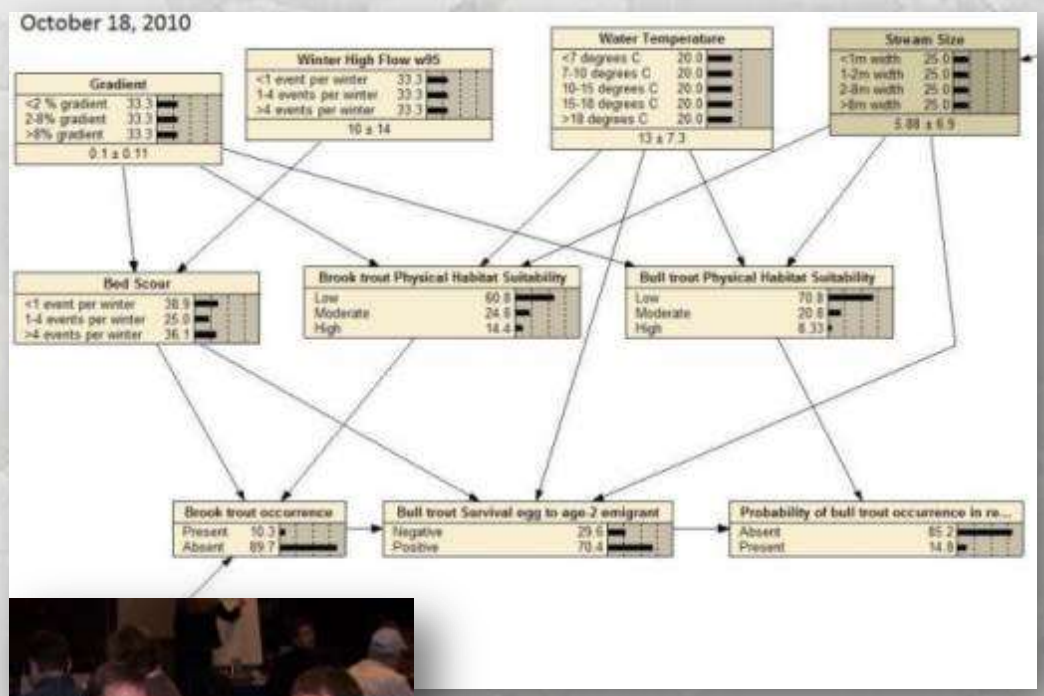
Filter #2: Decision Support Tools Integrate Information from Multiple Sources

Structured Process & Transparent Logic



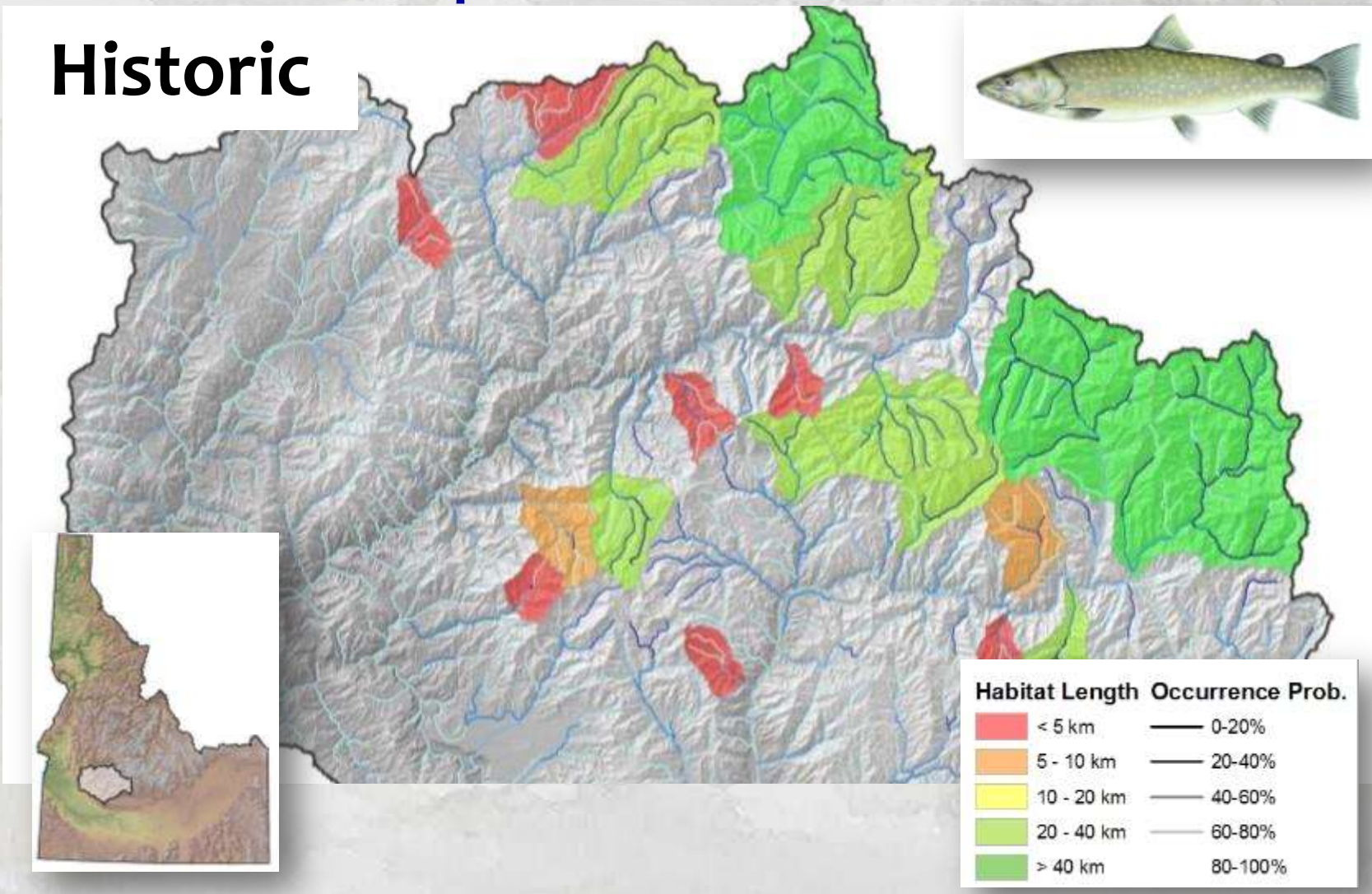
<u>Problem A:</u> Spatial prioritization among populations

<u>Problem B:</u> 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.

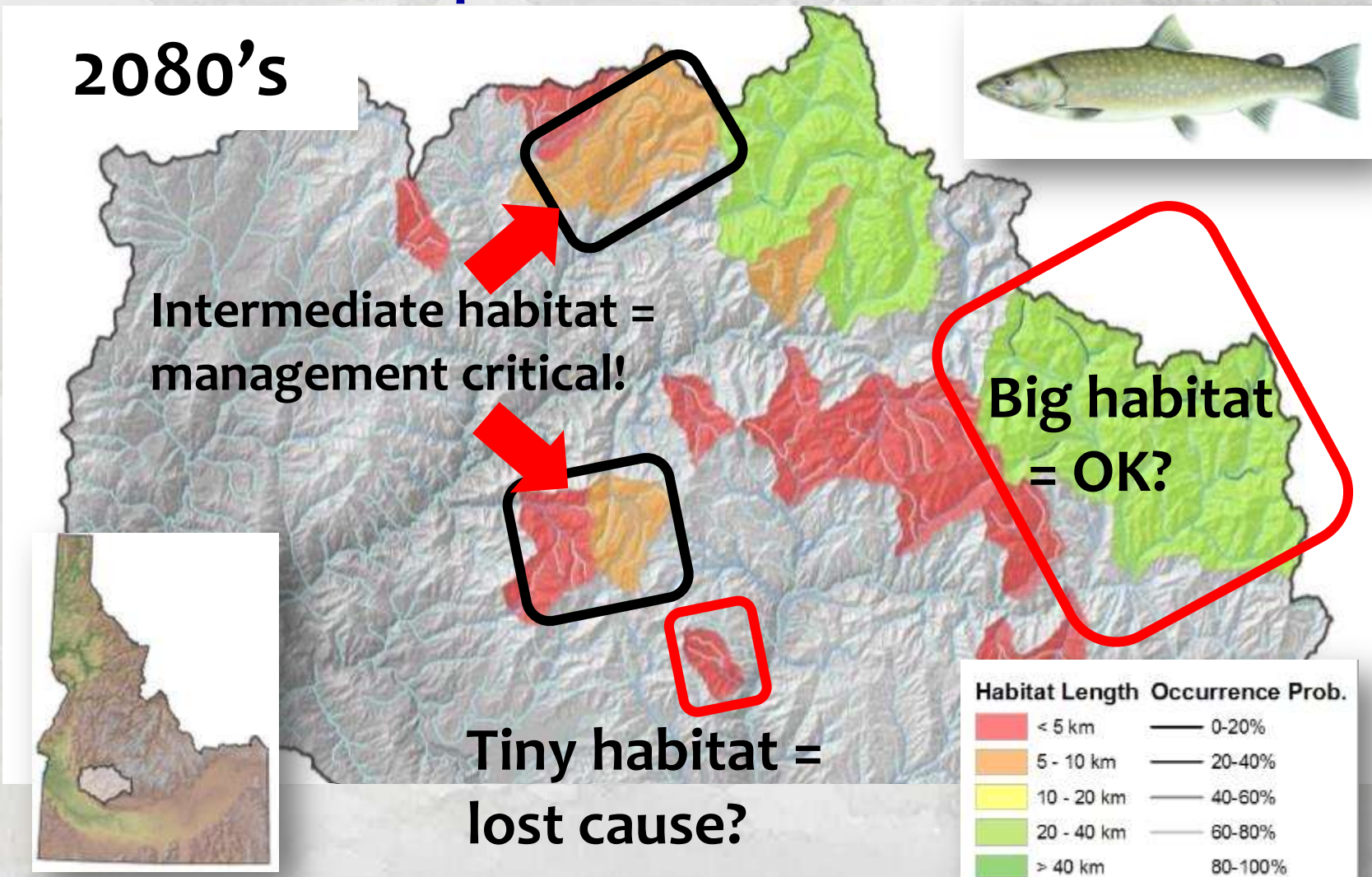
Habitats Color Coded by Size & Population Persistence Potential

Bull trout example in Boise River Basin



Habitats Color Coded by Size & Population Persistence Potential

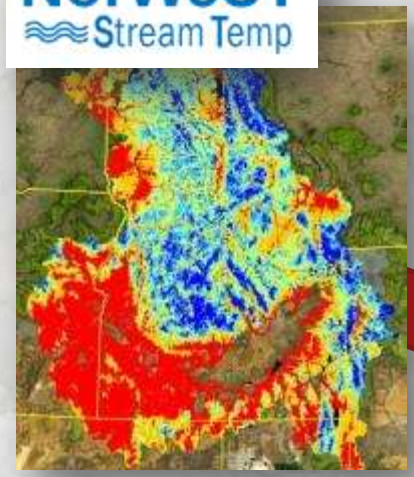
Bull trout example in Boise River Basin



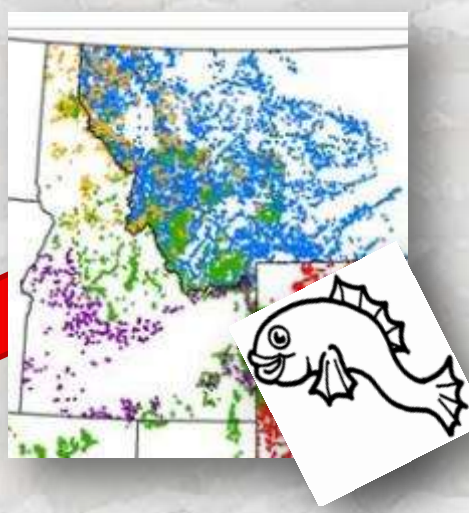
Decision Tools Built From Regionally Consistent Geospatial Data to Enable Applications Anywhere

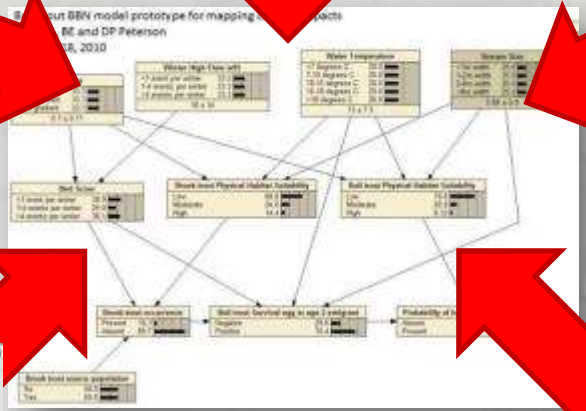
Local Expertise

NorWeST Stream Temp

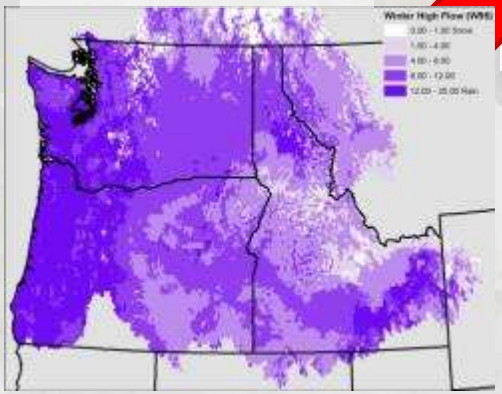


BIG FISH Surveys

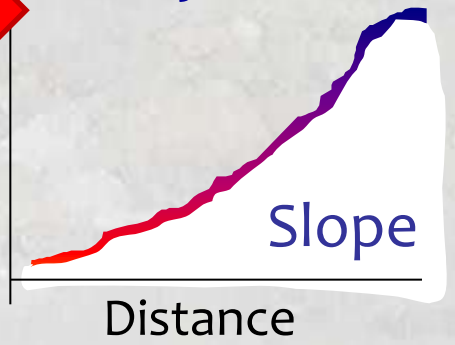




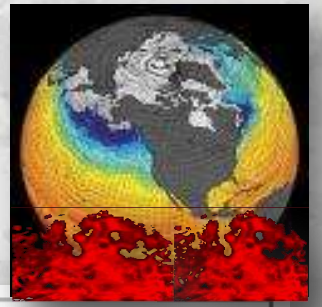
VIC flows



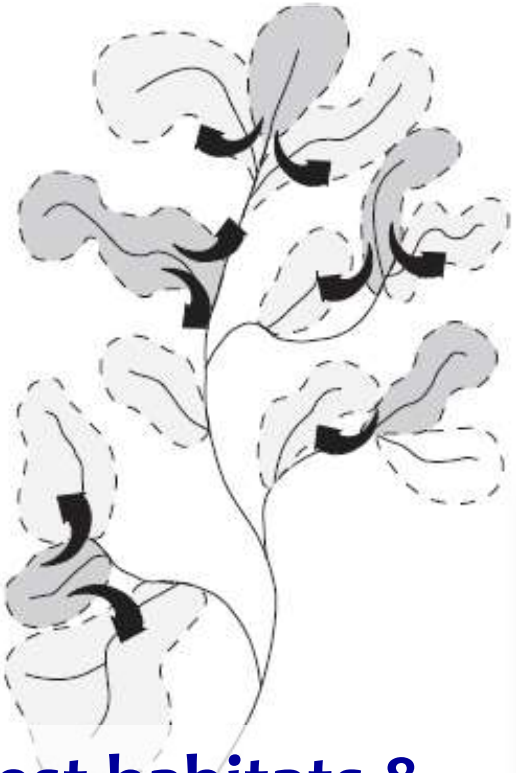
NHDPlus Hydrology Layer Variables



Think Globally, act Locally with "Make it or Break it" Decisions



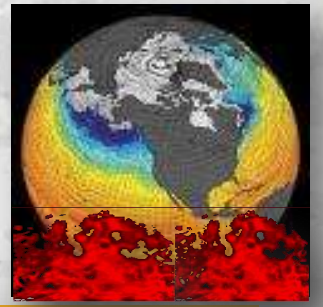
More of this…



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 F. 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

The End