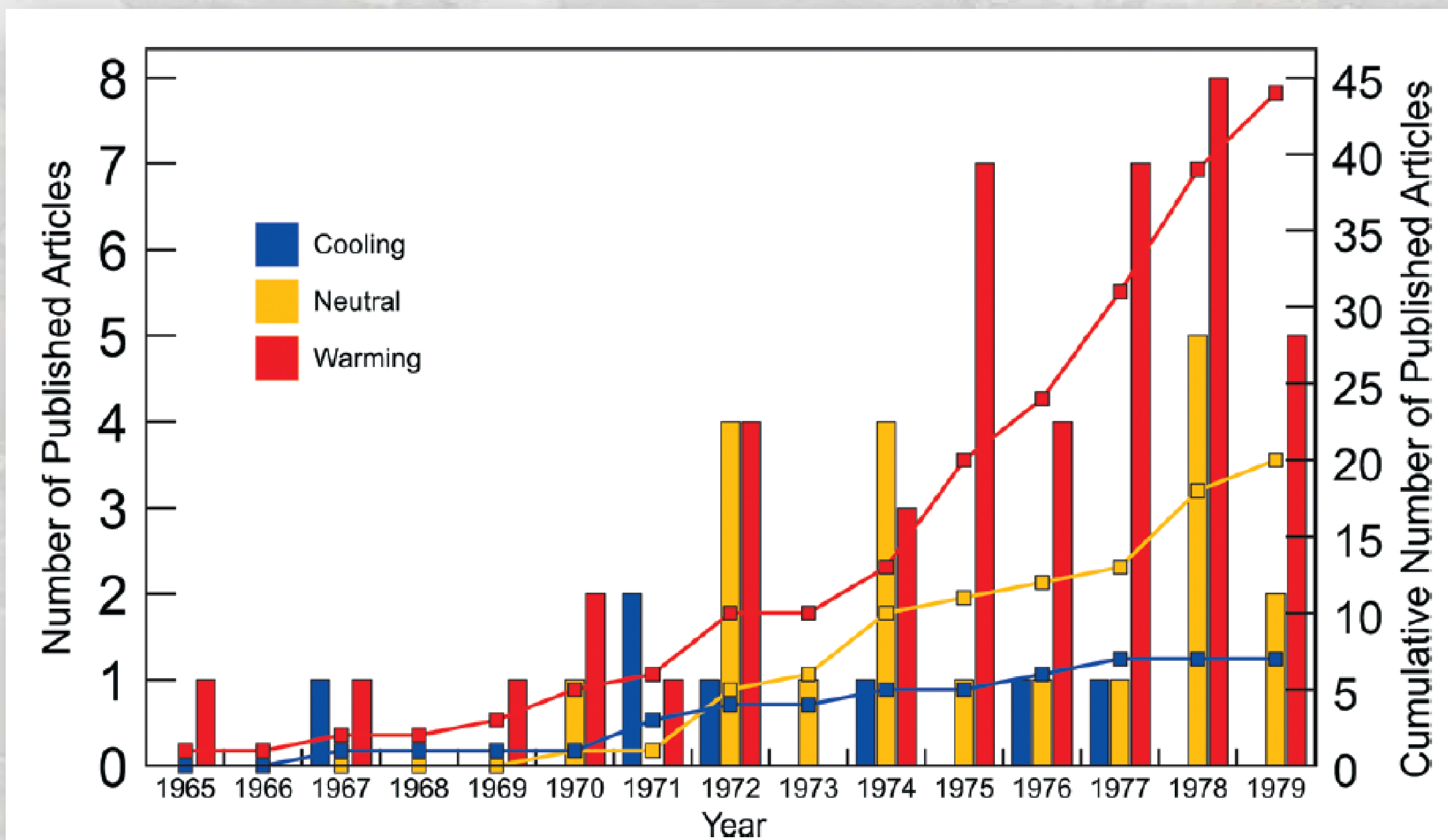
Where's the Beef?

Why 20 Years of Predicted Global Warming Effects on Fish Distributions Remain Unsubstantiated

Dan Isaak and Bruce Rieman (retired, sort of…)

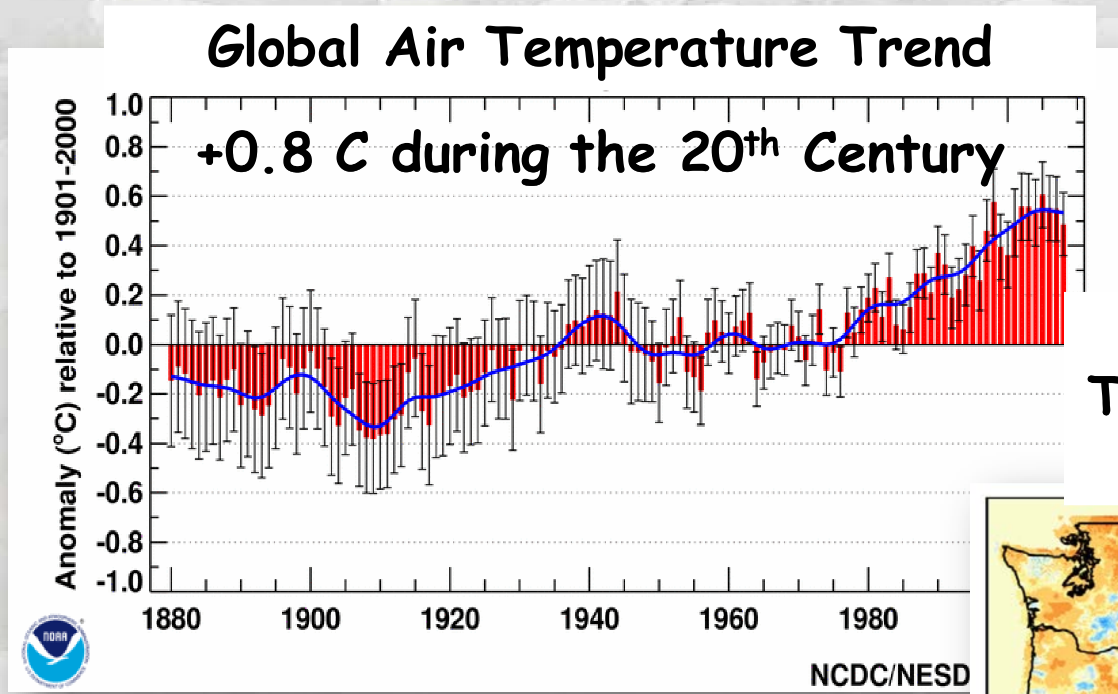
US Forest Service – Air, Water & Aquatics Program
Rocky Mountain Research Station
Boise, ID 83702

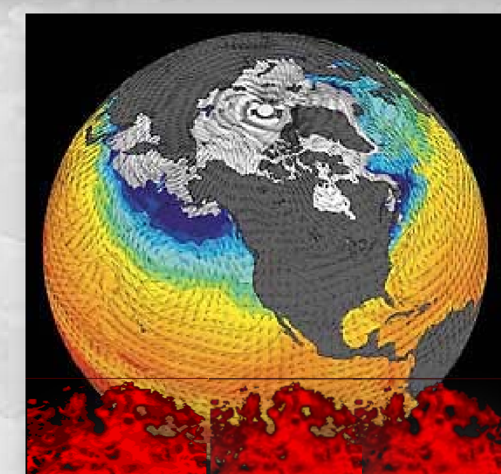
Scientific Consensus That Global Warming Would Occur for 30+ Years

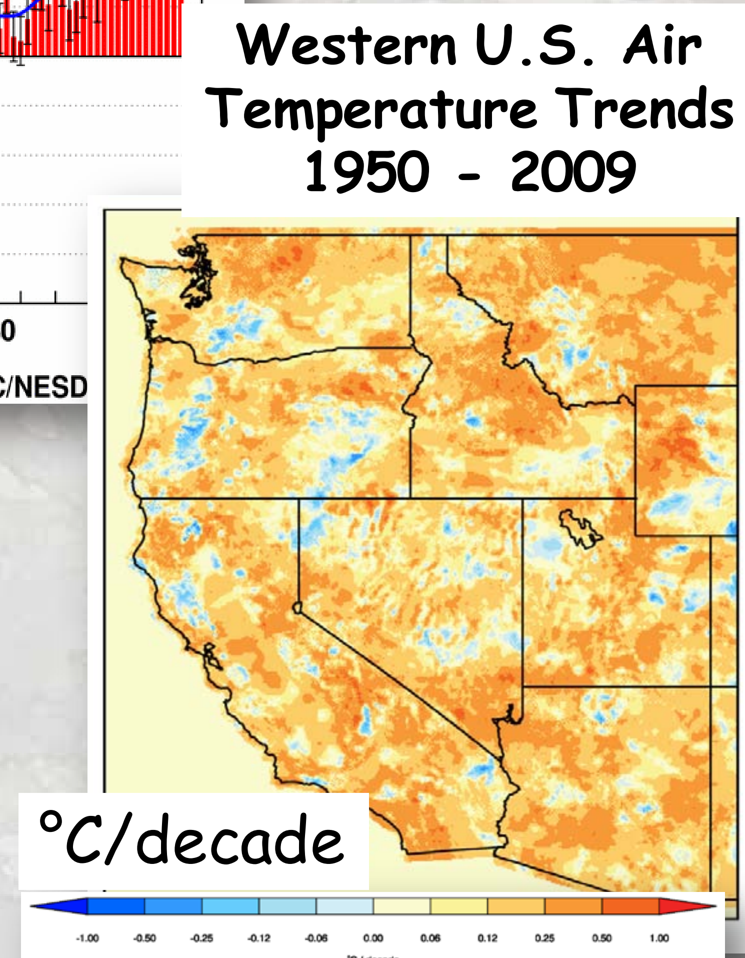


Peterson et al. 2008. *Bull. Amer. Metero. Soc.* 1325-1337.

Strong Empirical Support for Warming

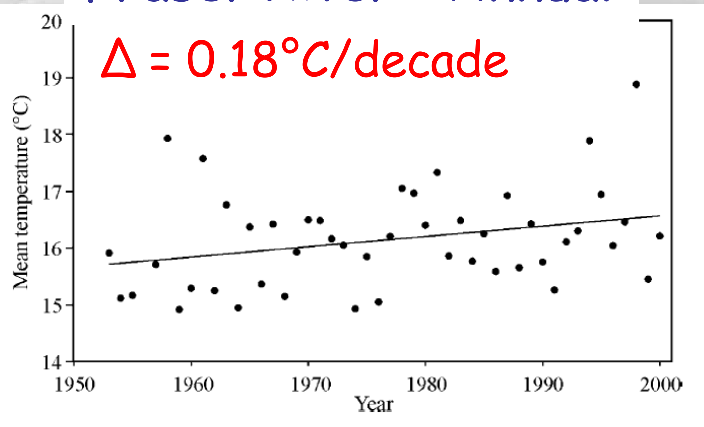






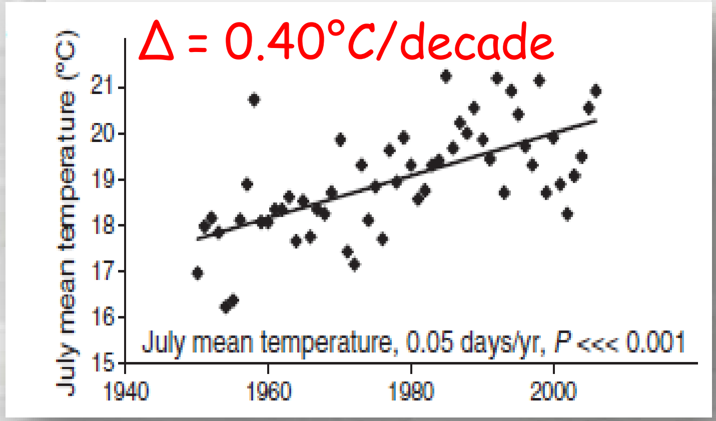
Regional Trends In Northwest Rivers

Fraser River - Annual



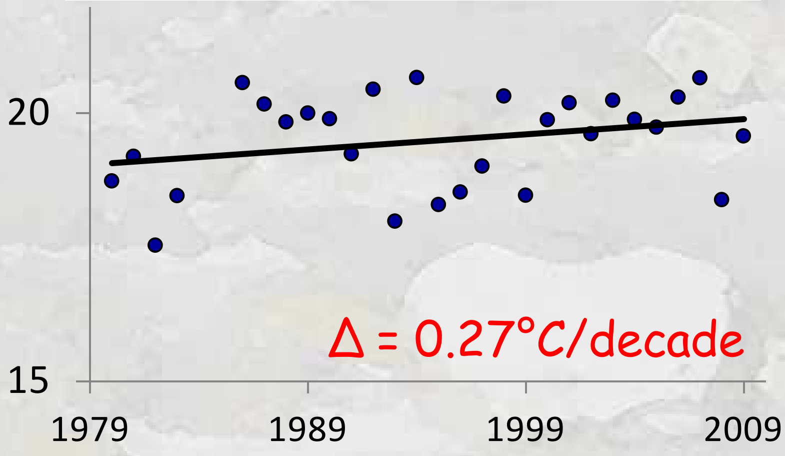
Morrison et al. 2002

Columbia River - Summer

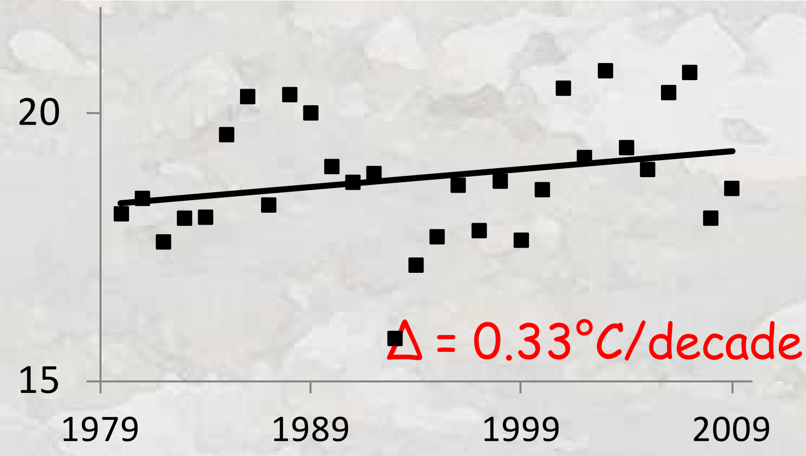


Crozier et al. 2008

Snake River, ID - Summer



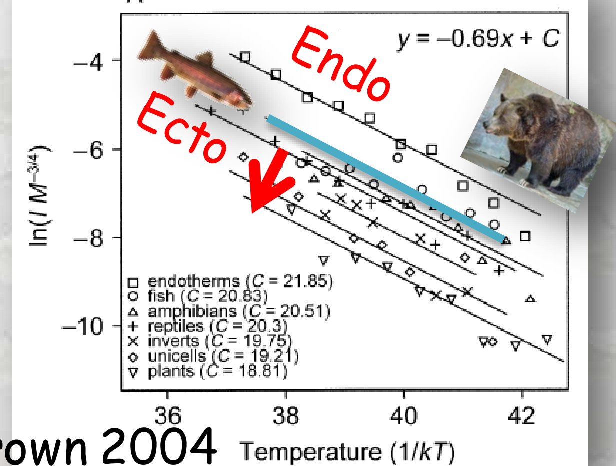
Missouri River, MT - Summer



Isaak et al. 2011. *Climatic Change*

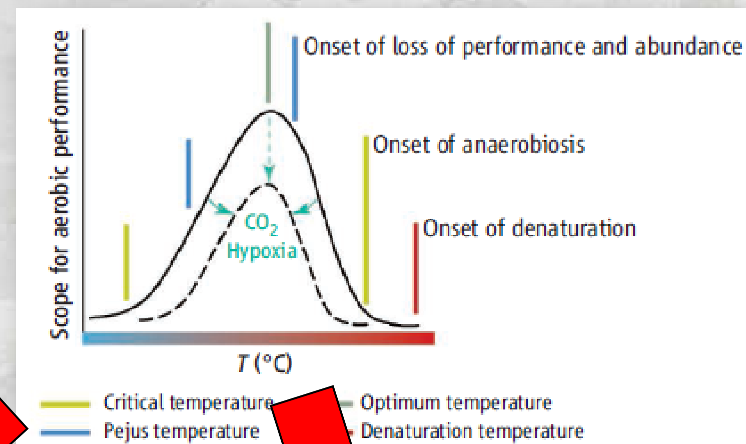
Temperature is Primary Control for Ectotherms Like Fish

Temperature & metabolic rates

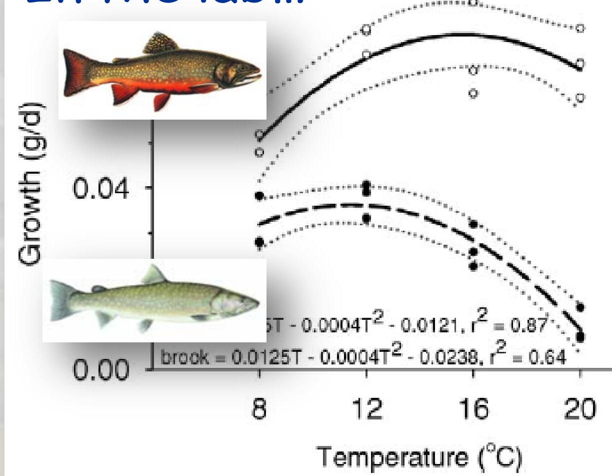


Brown 2004

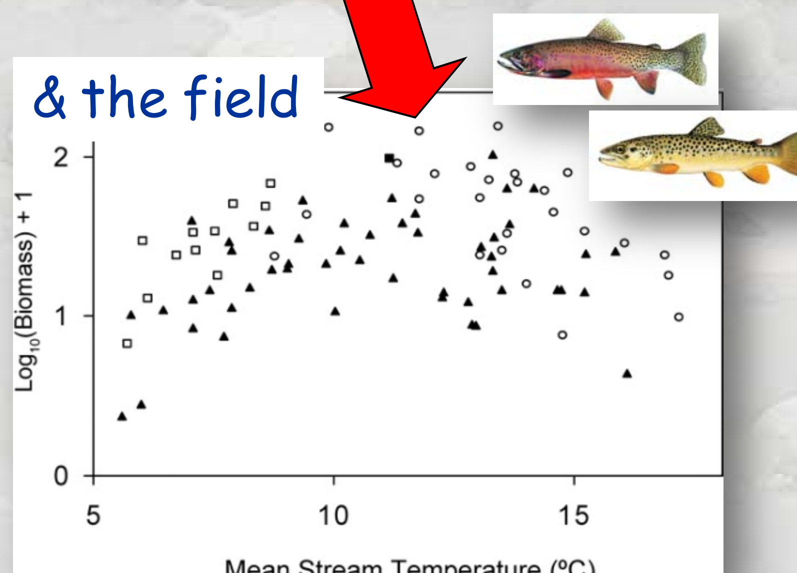
Thermal Niche



In the lab…



& the field

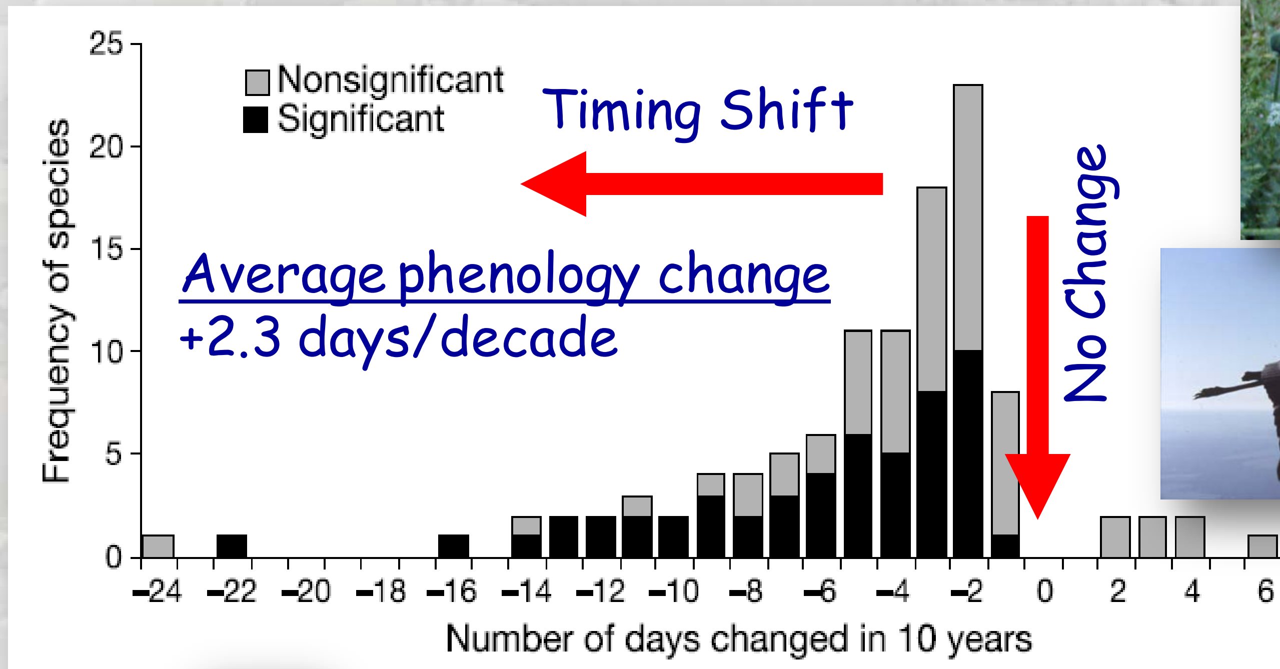


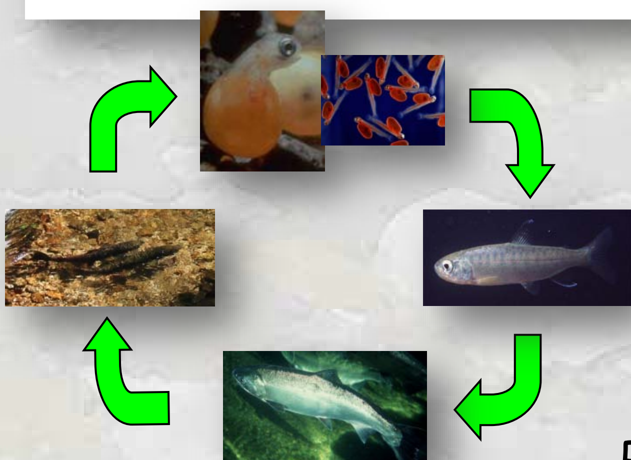
McMahon et al. 2007

Isaak & Hubert 2004

Are Species Distributions Shifting?

Temporal distribution shifts

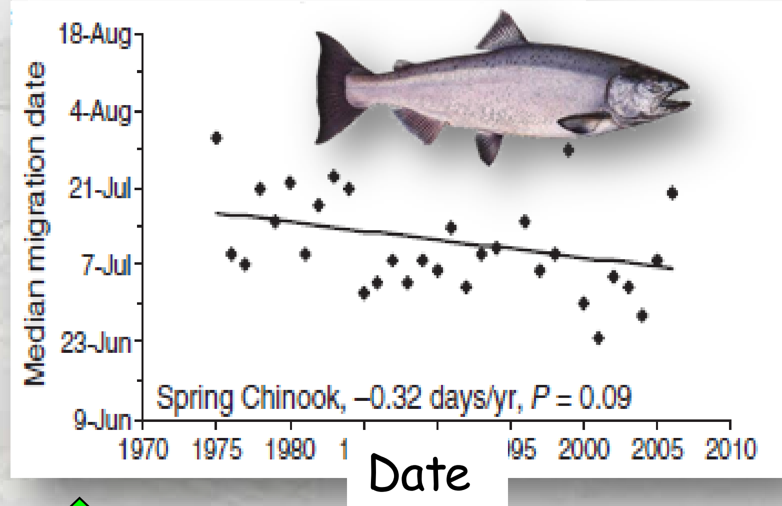




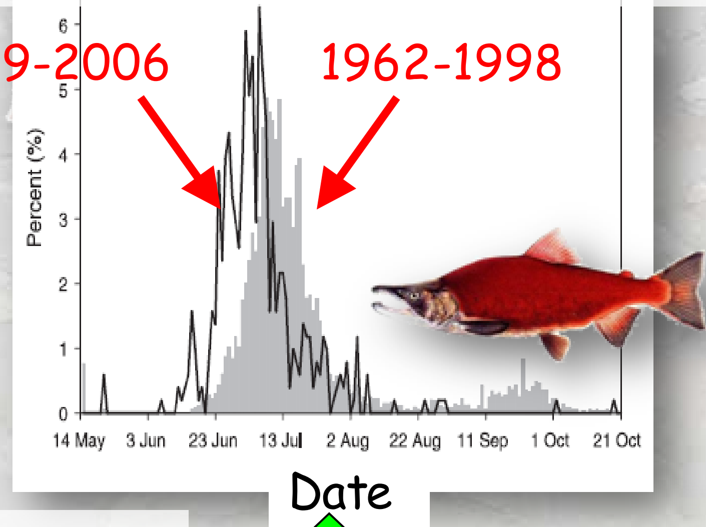
Parmesan and Yohe. 2003. *Nature* 421:37-42.

Shifts in Salmon Migration Timing

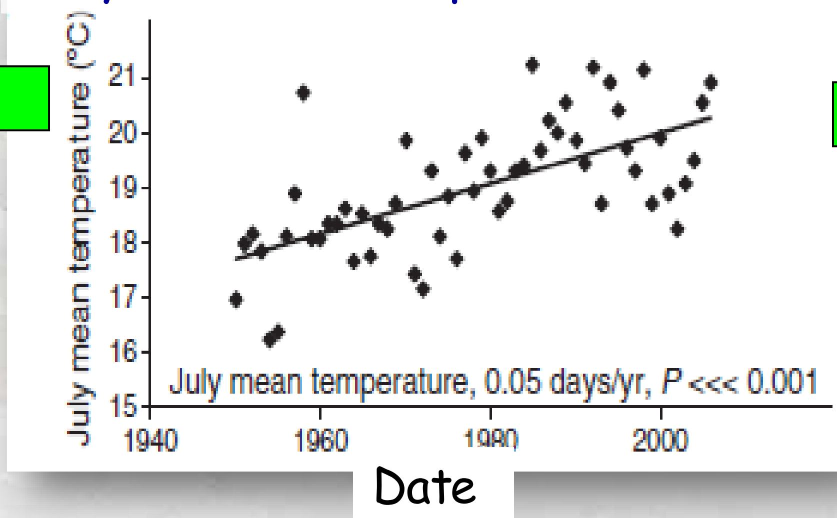
Median Spring Chinook Migration Dates at Bonneville



Distribution of Sockeye Migrations at Lower Granite



July Stream Temps at Bonneville

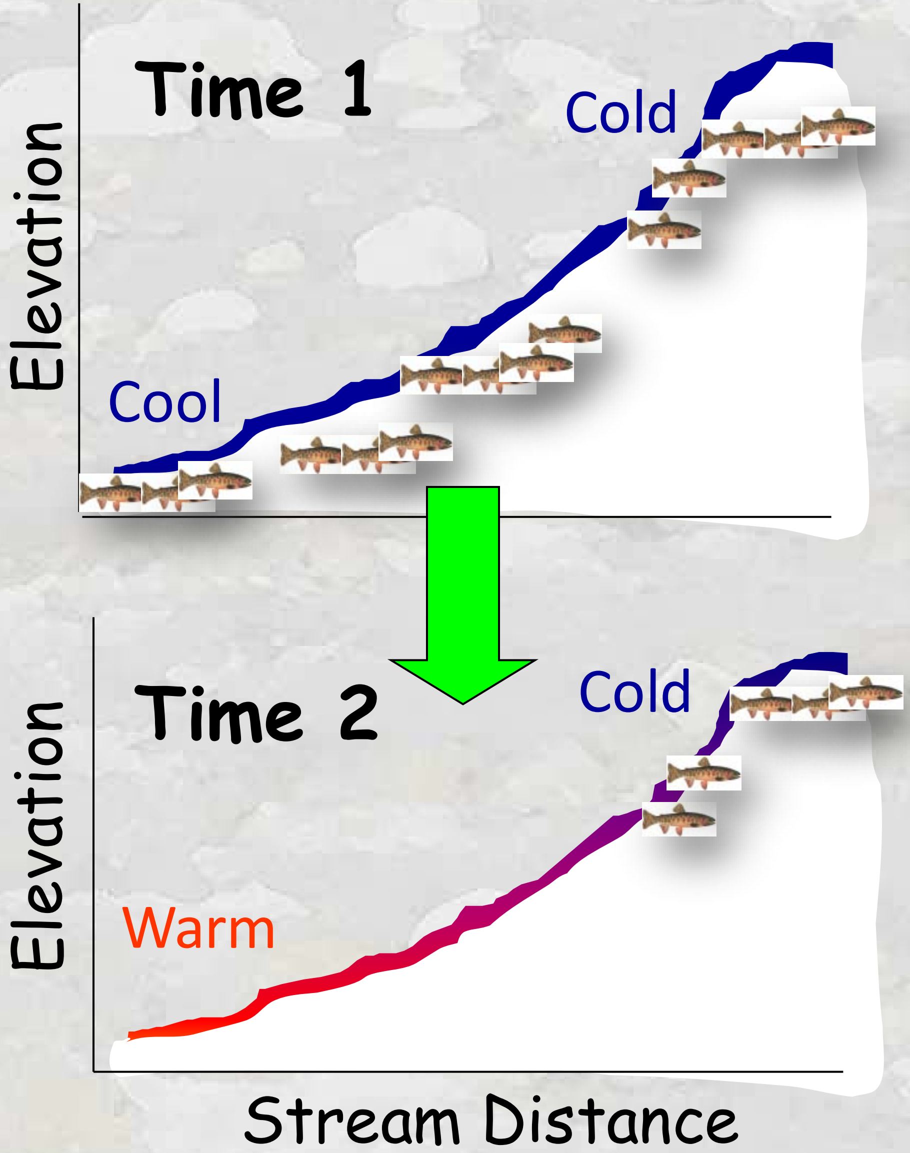


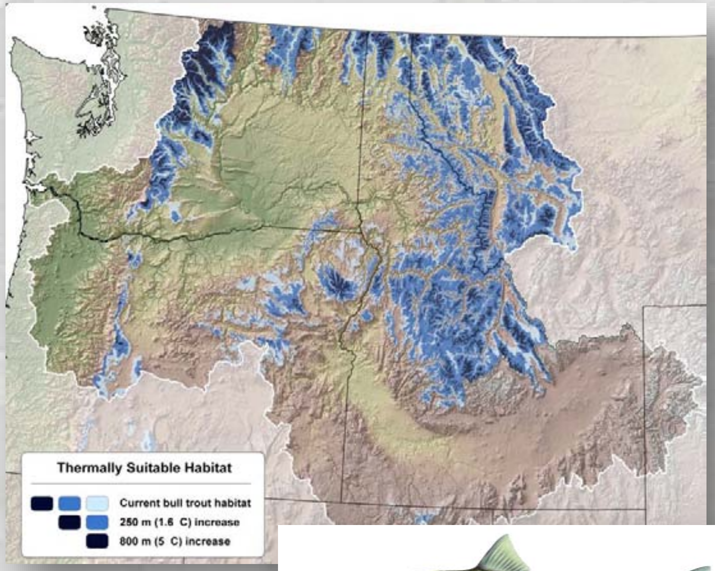
Studies…

- Juanes et al. 2003
- Crozier et al. 2008
- Keefer et al. 2009
- Wedekind & Kung 2010
- Crozier et al. 2011
- Etc.

Are Species Distributions Shifting?

Spatial distribution shifts





Average distribution shift across taxa =

6.1 km/decade poleward

OR

6.1 m/decade higher

Parmesan and Yohe. 2003. *Nature* 421:37-42.

We've Predicted It for 20+ Years…

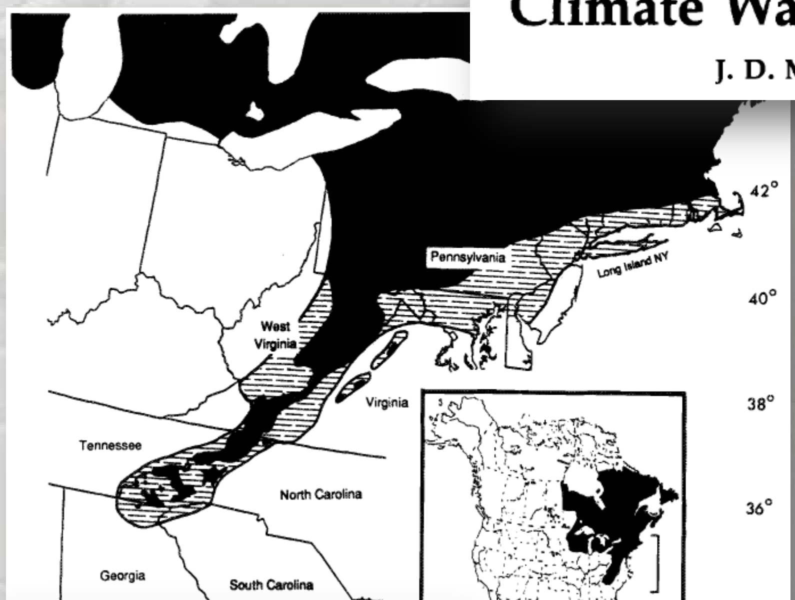
Early brook trout climate assessments

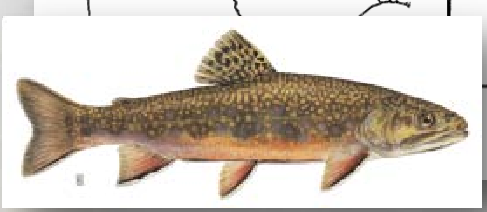
Effect of Climatic Warming on the Southern Margins of the Native Range of Brook Trout, *Salvelinus fontinalis*

J. Donald Meisner[1]

The Role of Groundwater in the Impact of Climate Warming on Stream Salmonines

J. D. Meisner, J. S. Rosenfeld, and H. A. Regier





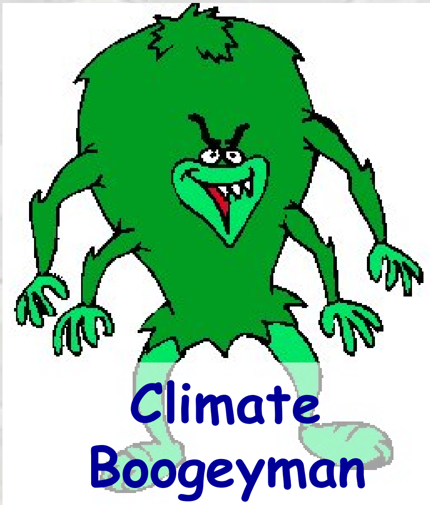
Similar climate studies

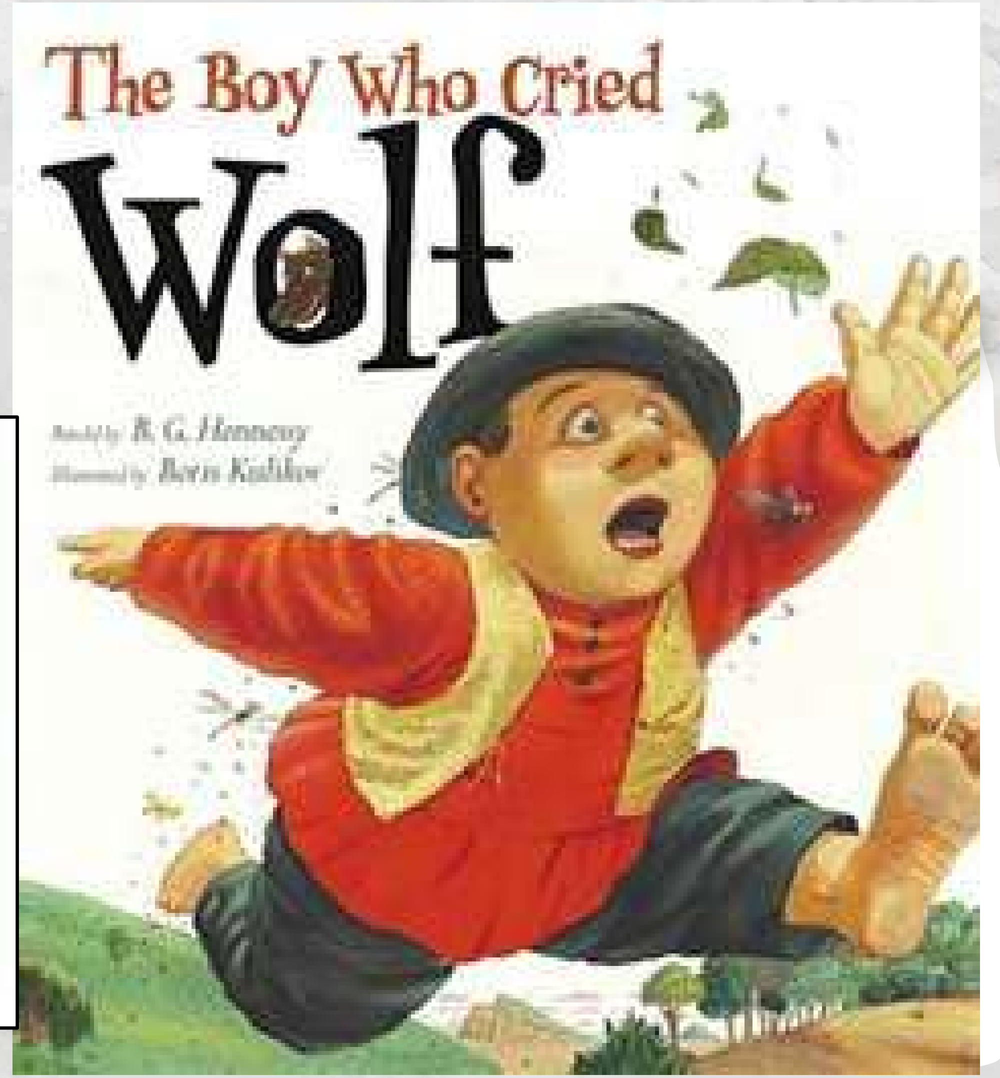
- Meisner 1988, 1990
- Eaton & Schaller 1996
- Keleher & Rahel 1996
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Isaak et al. 2010
- Wenger et al. 2011
- Etc.

Meisner et al. 1988. *Fisheries* 13(3):2-8; Meisner 1990. *CJFAS* 47:1065-1070

Biological Validation Doesn't Exist

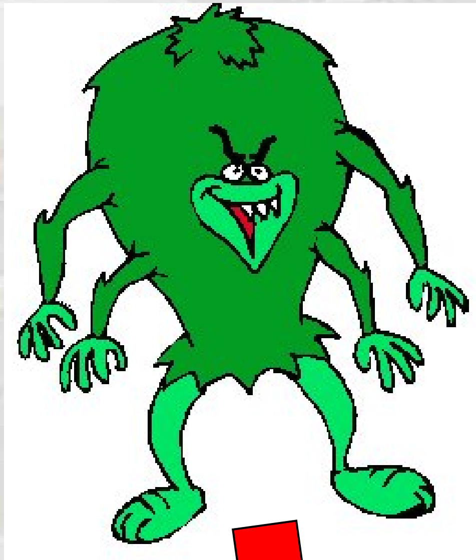
Fact or Fiction?





There's A Lot on the Line

Climate Boogeyman



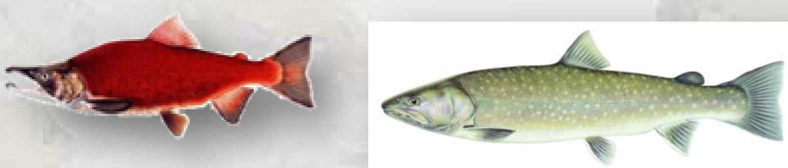
Recreational Fisheries

Low Flows Prompt Fishing Closure On Upper Beaverhead River And Reduced Limits On Clark Canyon Reservoir

Wednesday, September 29, 2004
Fishing

High Water Temperature In Grande Ronde Kills 239 Adult Spring Chinook
Columbia Basin Bulletin, August 14, 2009 (PST)

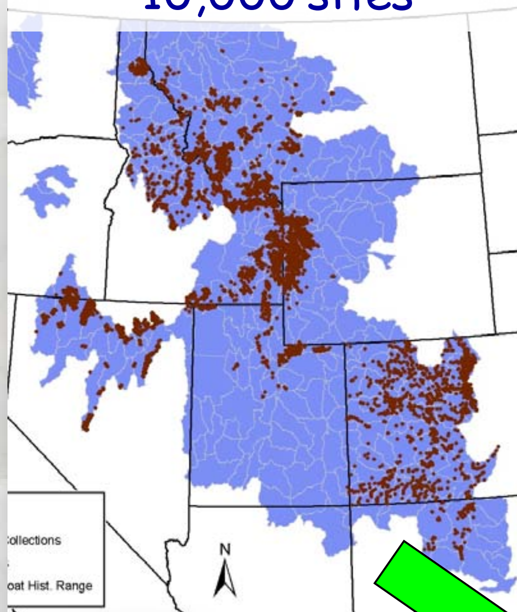
ESA Listed Species



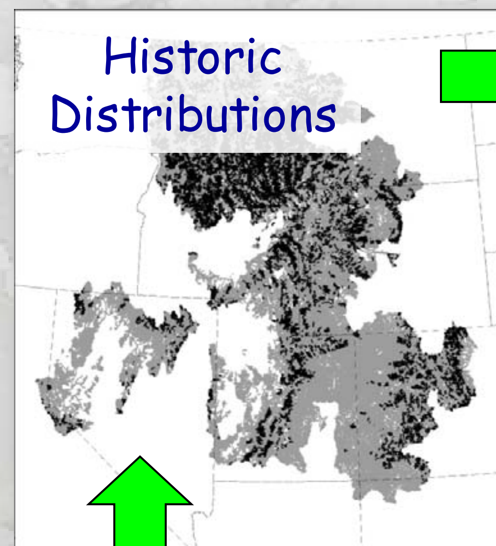
Land Use & Water Development

Western Trout Climate Assessment

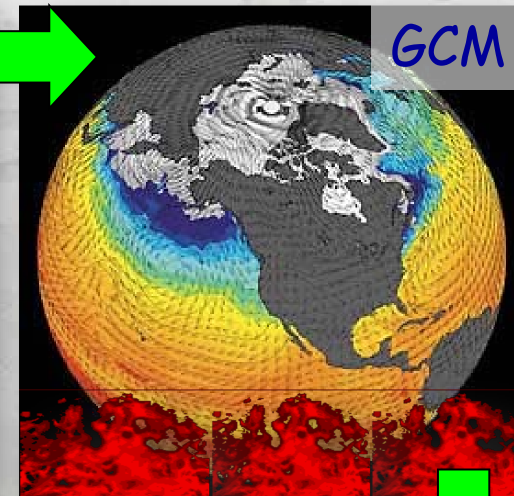
Fish survey database
~10,000 sites



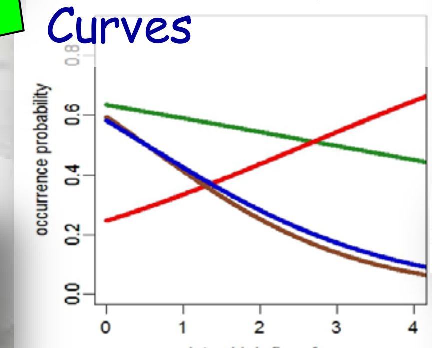
Historic
Distributions

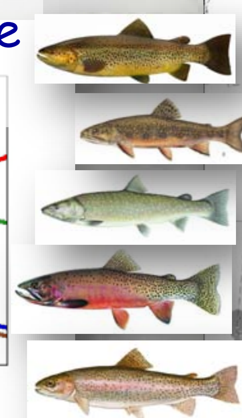


GCM

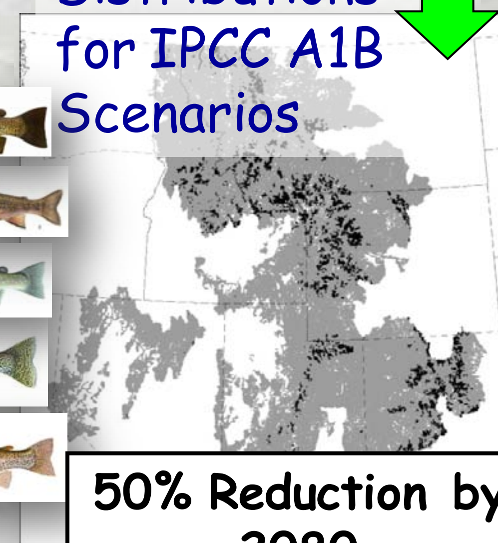


Species-Specific
Habitat Response
Curves





Distributions
for IPCC A1B
Scenarios

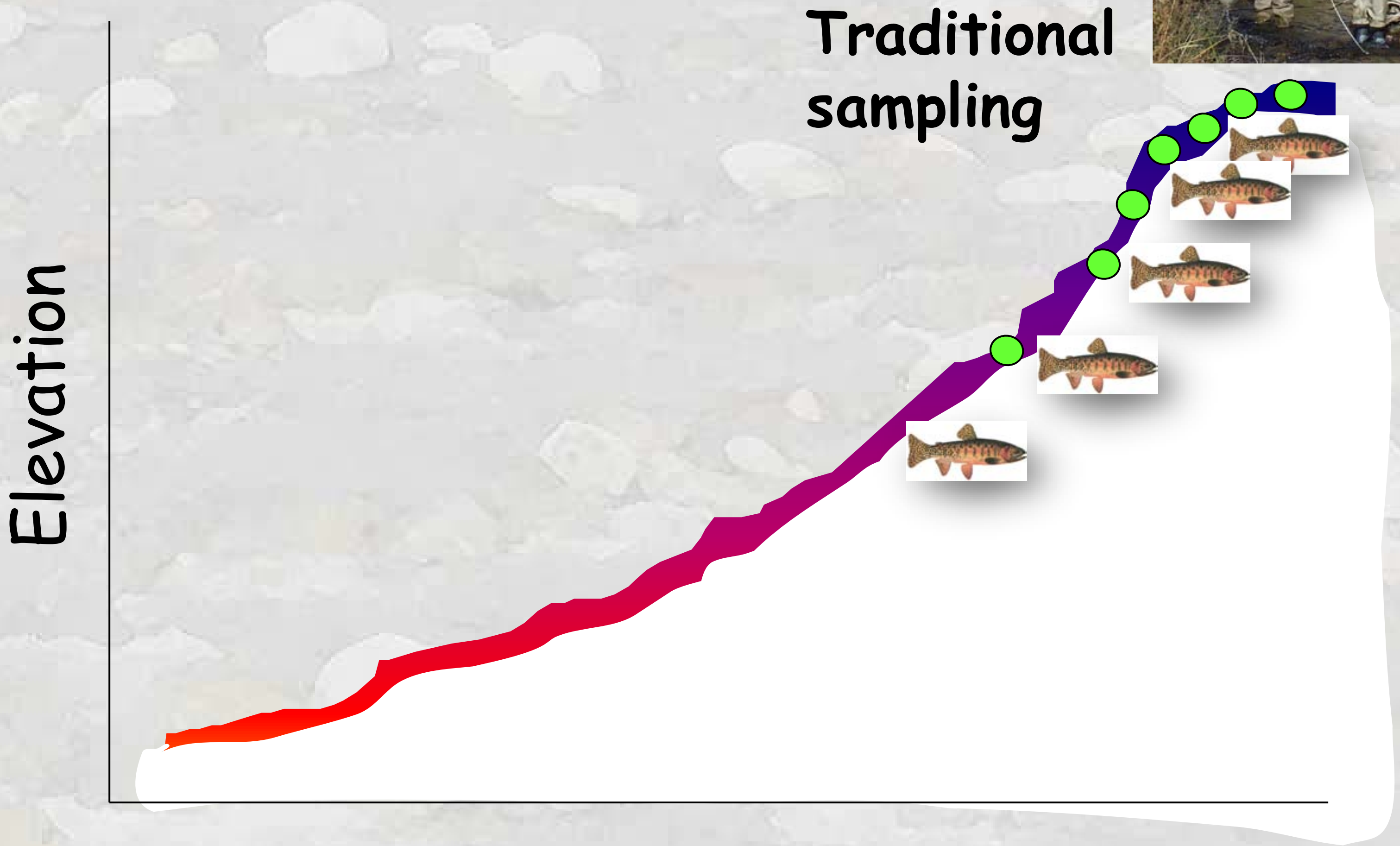


50% Reduction by 2080

Wenger et al. 2011. *Proc. Nat. Acad. Sciences*

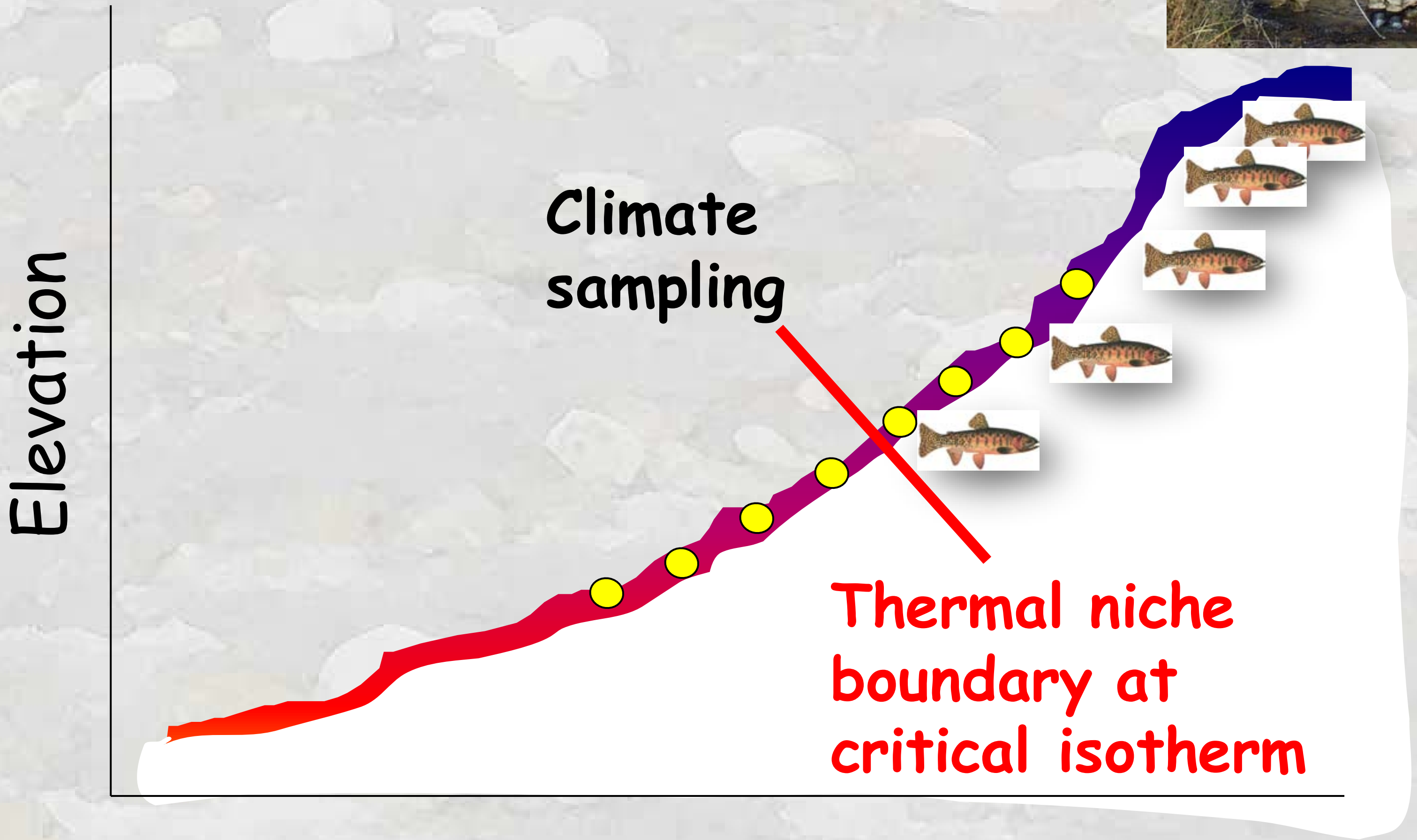
Why Doesn't Biological Validation Exist?

We're not sampling the right places



Why Doesn't Biological Validation Exist?

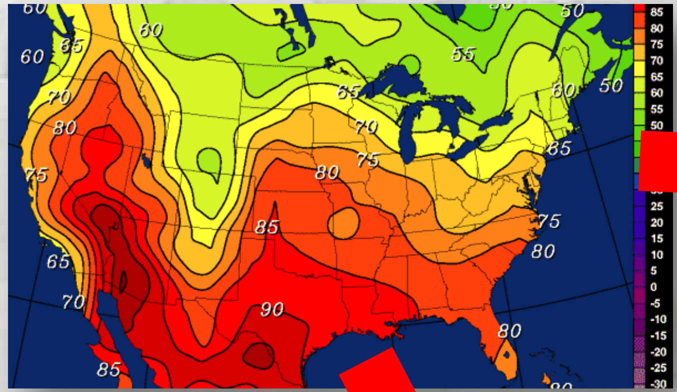
Need to sample across thermal boundaries



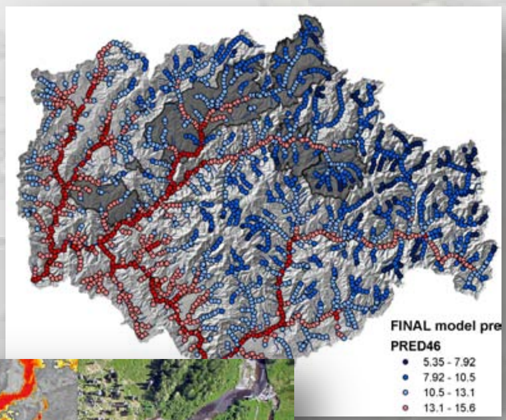
What is an Isotherm?

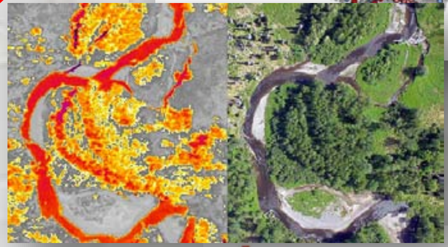
How Does it Apply to Streams?

Line connecting locations with equal temperatures

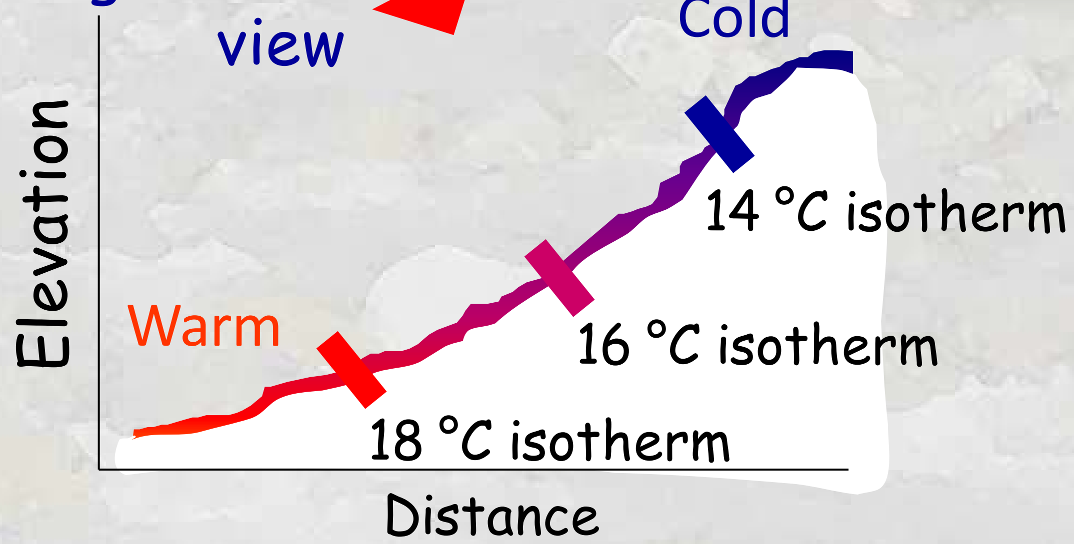


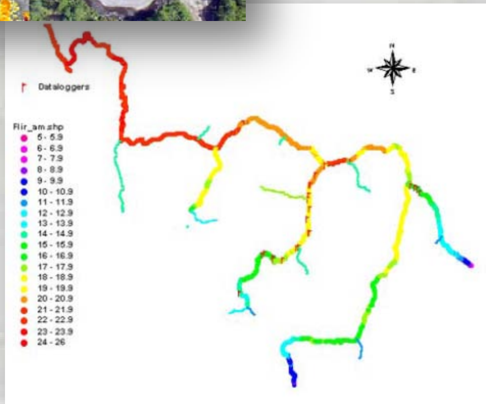
Plan view





Longitudinal view

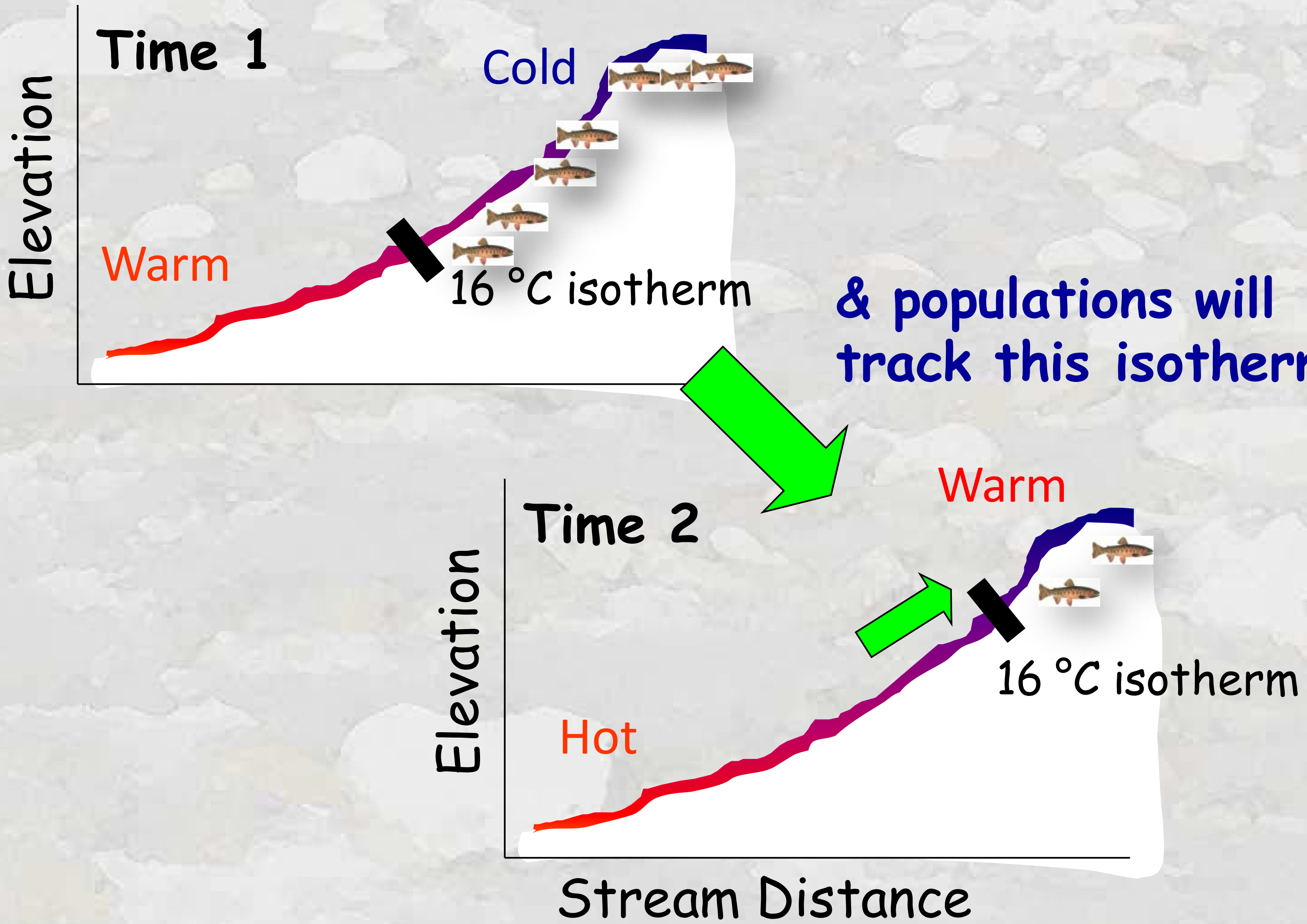




Salmon River FLIR profile

Key BioClimate Model Assumption:

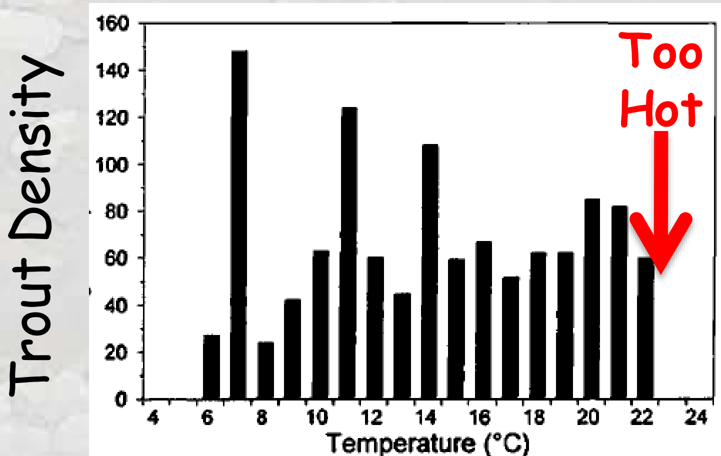
Critical isotherm delimits population boundary

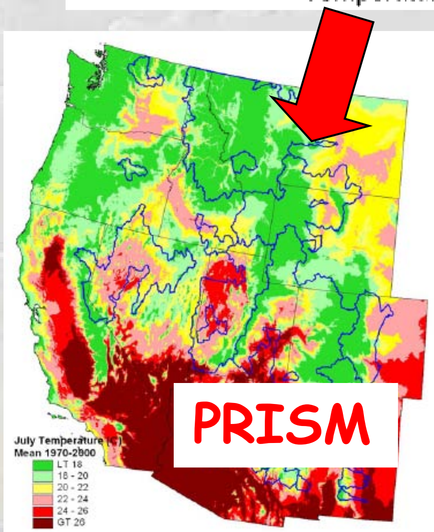


& populations will track this isotherm

Regional BioClimatic Model Predictions are Not Testable

Temperature isotherms mapped instead of fish distributions

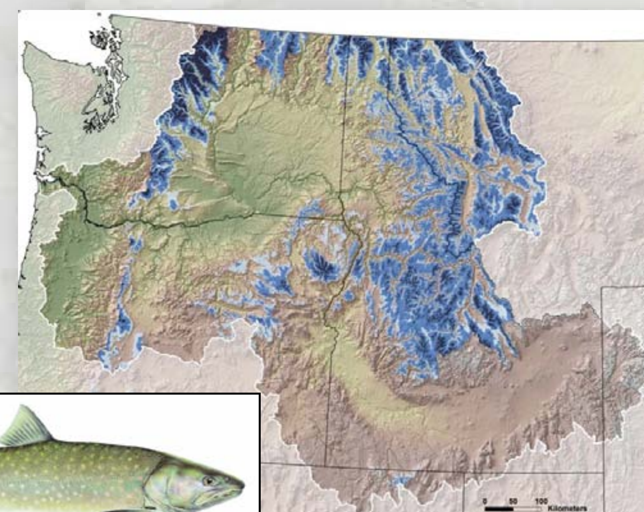




OR

<u>Statistically imprecise</u>

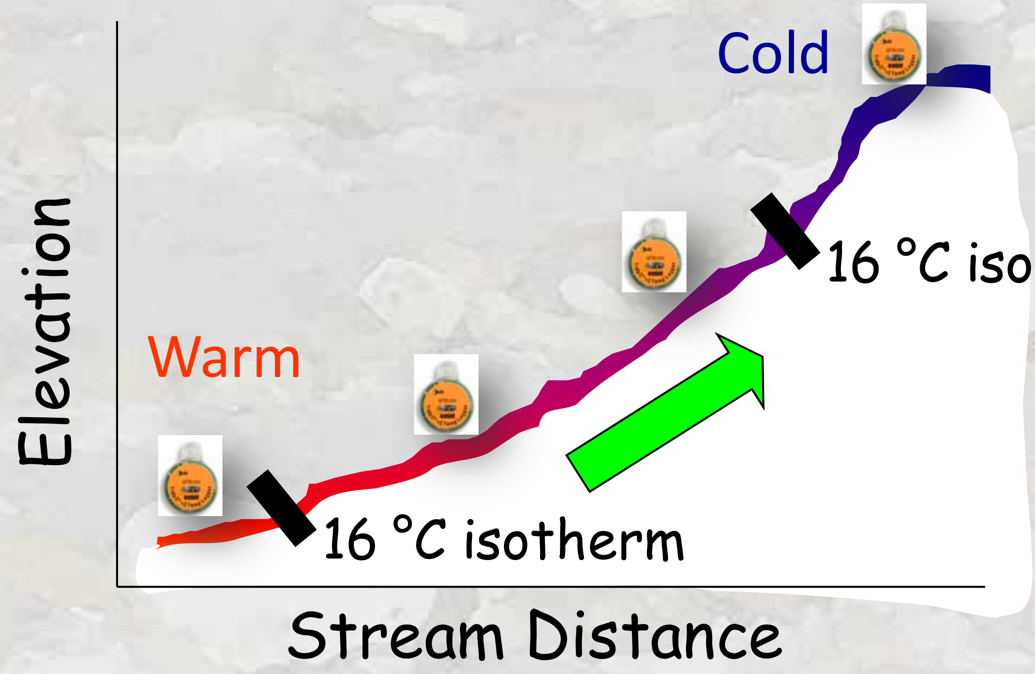
- Bull trout lower elevation limit x = 1,567m, 95% CI = 172m
- 52 years for detectable range shift (assuming +0.2 C/decade)



Rieman et al. 2007

Stream-Specific Predictions of Isotherm Shifts Needed for Precision

1) Stream temperature lapse rate (°C / 100 m)
2) Long-term stream warming rate (°C / decade)
3) Stream slope (degrees)
4) Stream sinuosity

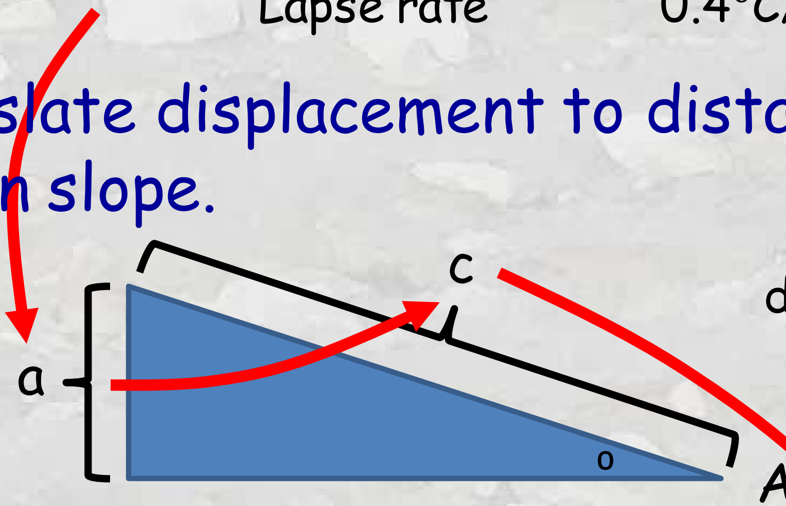


A Use for High School Trigonometry!

1. Calculate vertical displacement for a given stream lapse rate and long-term warming rate.

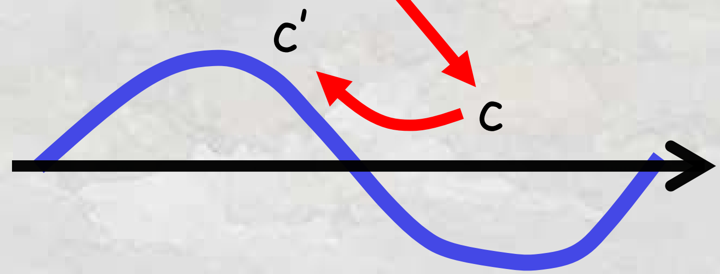
$$\text{Displacement (a)} = \frac{\text{Warming rate}}{\text{Lapse rate}} = \frac{0.2^{0}C/\text{decade}}{0.4^{0}C/100m} = +50m/\text{decade}$$

2. Translate displacement to distance along stream of a given slope.



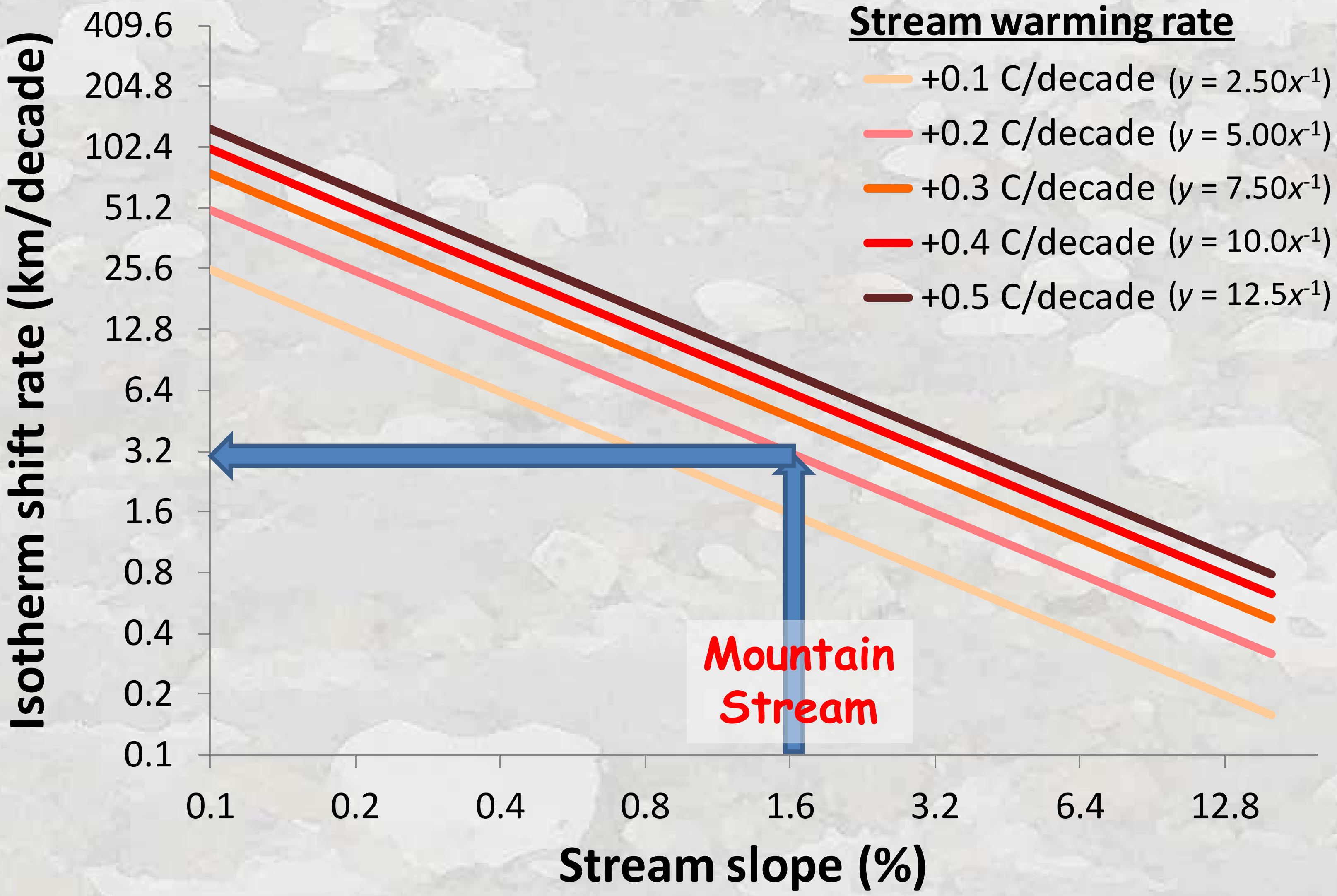
$$\text{Slope distance (c)} = \frac{a}{\sin A^{o}}$$

3. Multiply slope distance by stream sinuosity ratio in meandering streams.



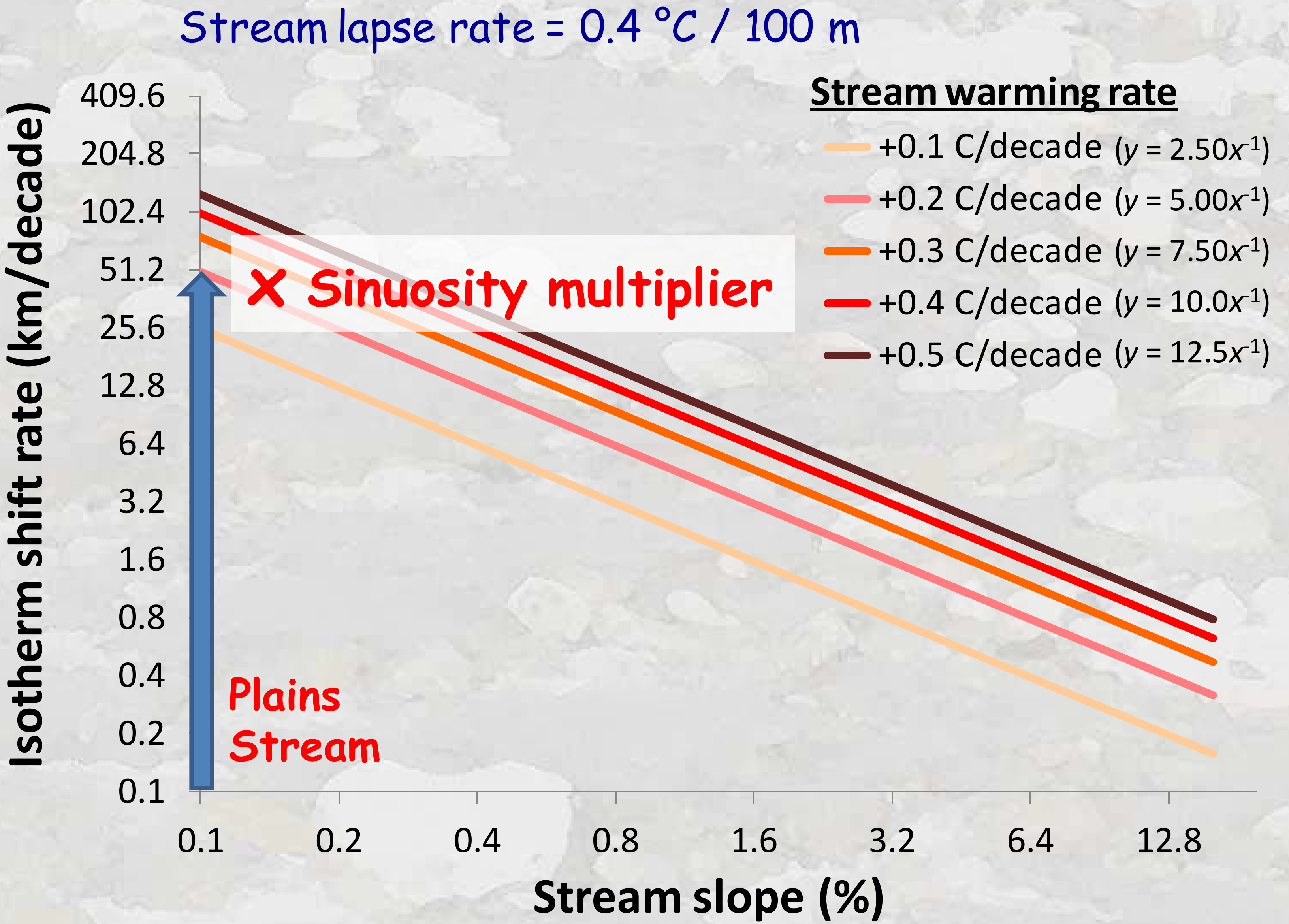
Isotherm Shift Rate Curves

Stream lapse rate = 0.4 °C / 100 m



Isaak & Rieman, In prep. for *Global Change Biology*

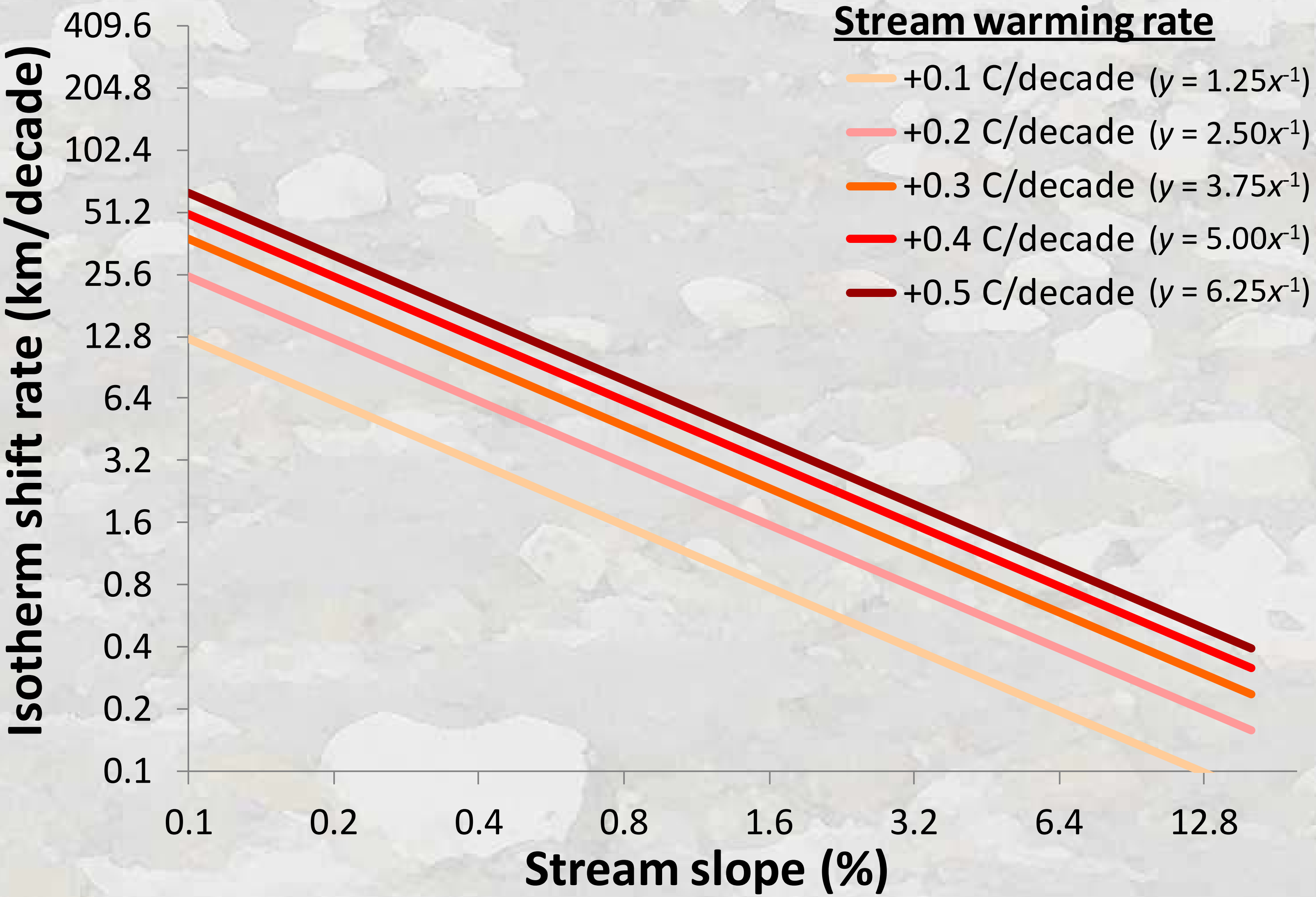
Isotherm Shift Rate Curves



Isaak & Rieman, In prep. for *Global Change Biology*

Isotherm Shift Rate Curves

Stream lapse rate = 0.8 °C / 100 m

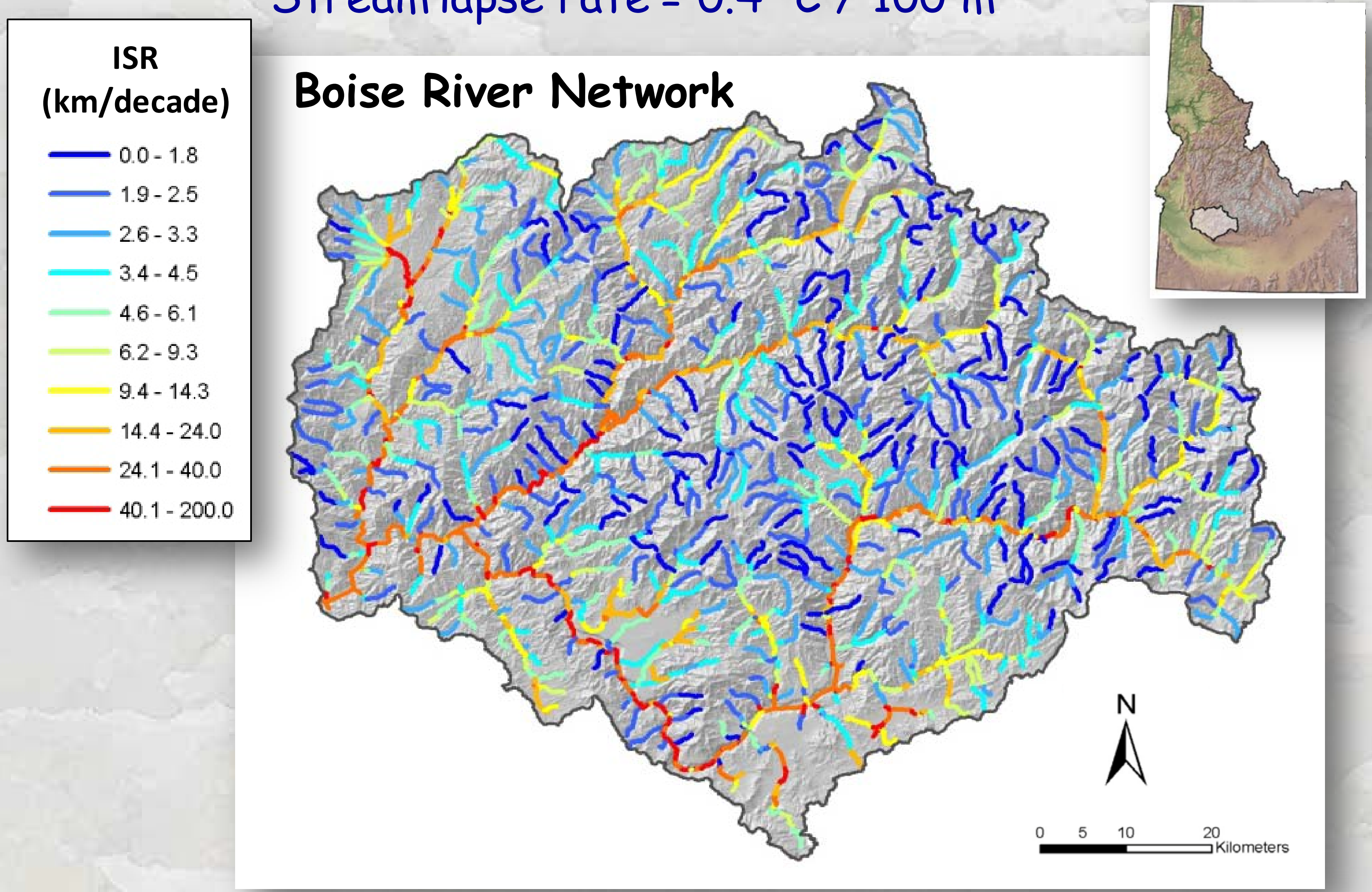


Isaak & Rieman, In prep. for *Global Change Biology*

Mapping Climate Change "Velocity"

Long-term stream warming rate = 0.2°C/decade

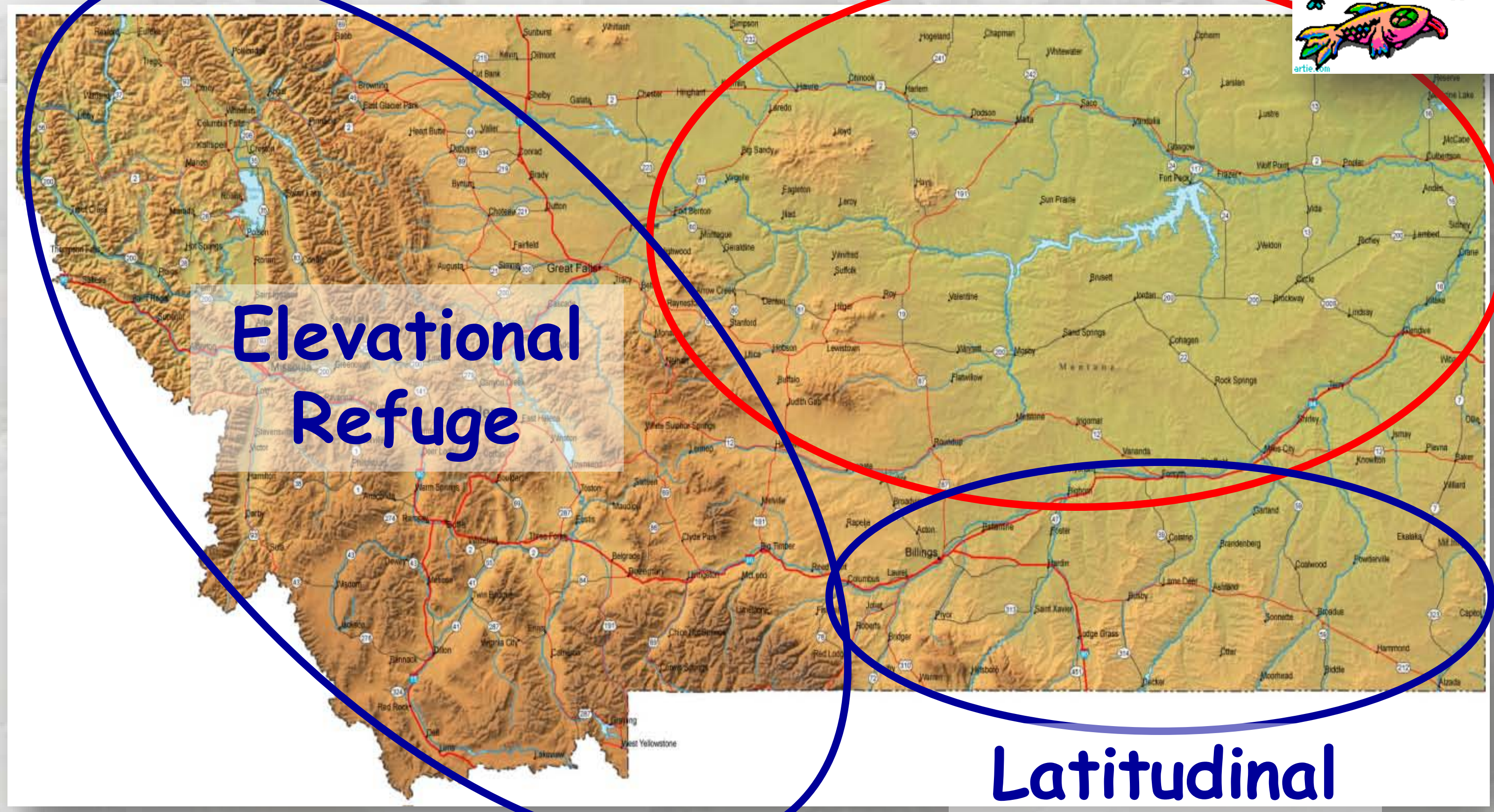
Stream lapse rate = 0.4 °C / 100 m



sensu Loarie et al. 2009. *Nature* 462:1052-1055.

Climate Vulnerability & Physiography

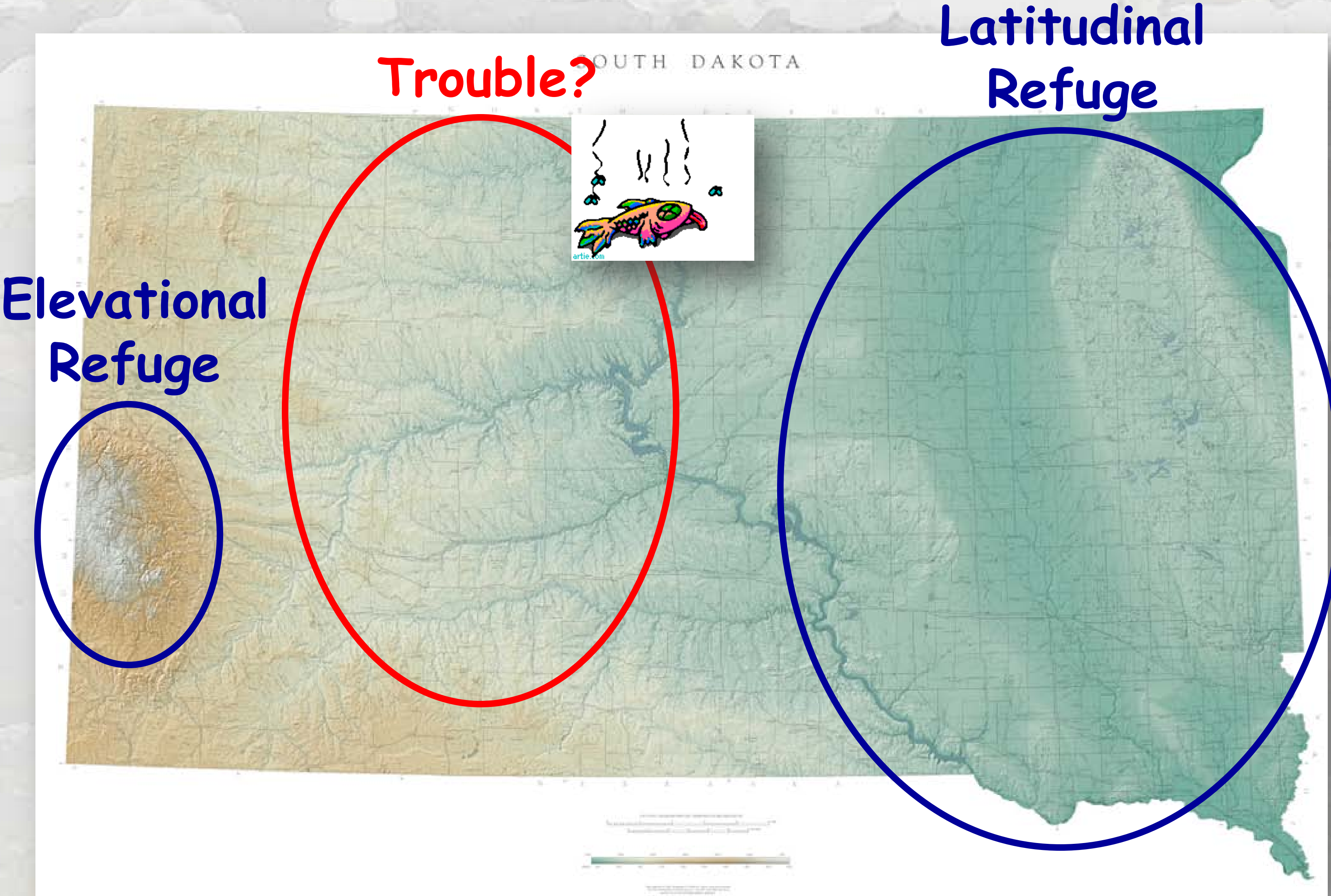
Trouble?



Elevational Refuge

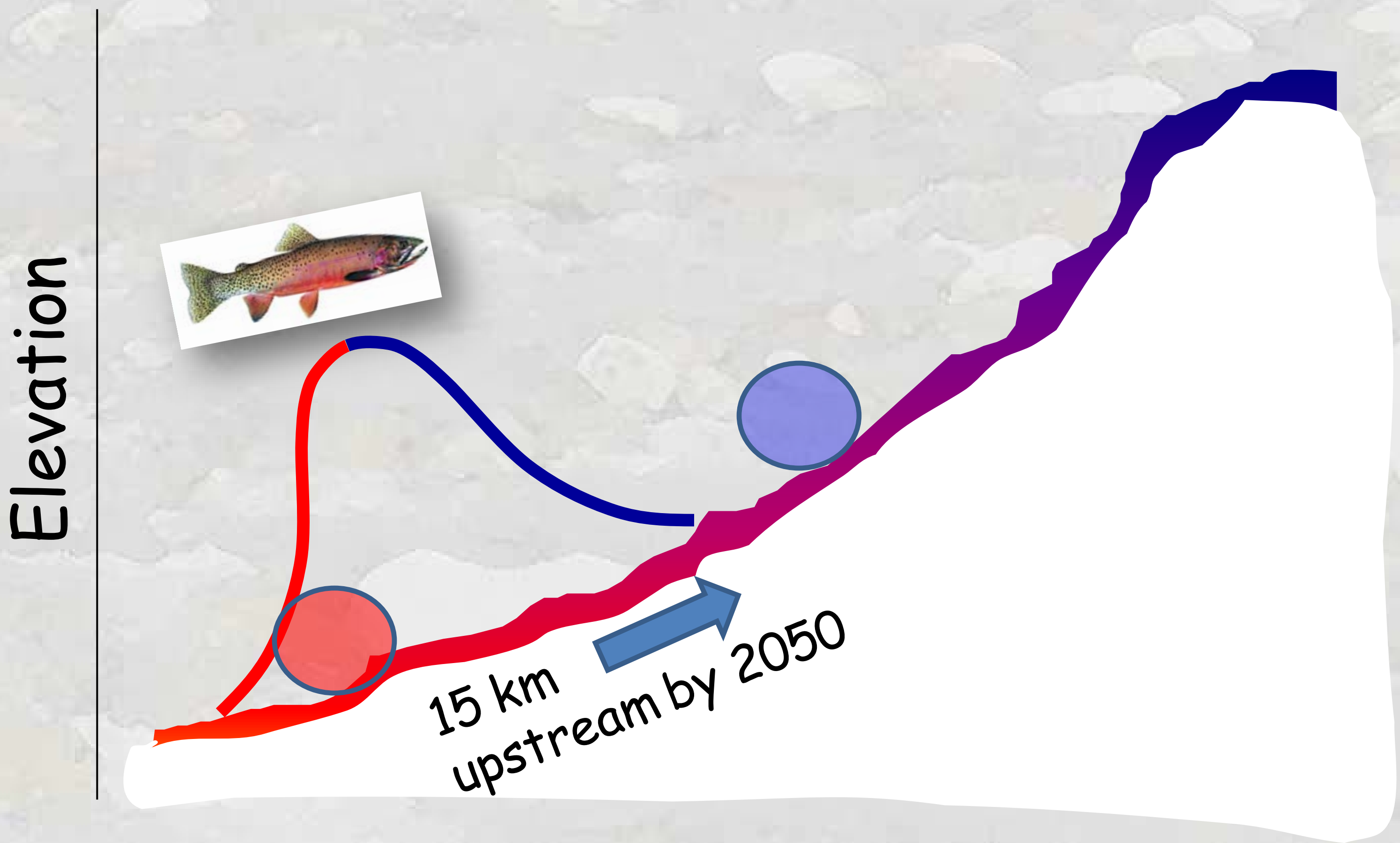
Latitudinal Refuge

Climate Vulnerability & Physiography



Precise Isotherm Shift Predictions

Is it a problem?

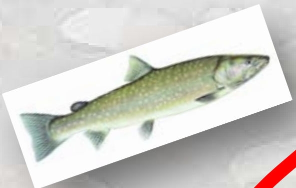


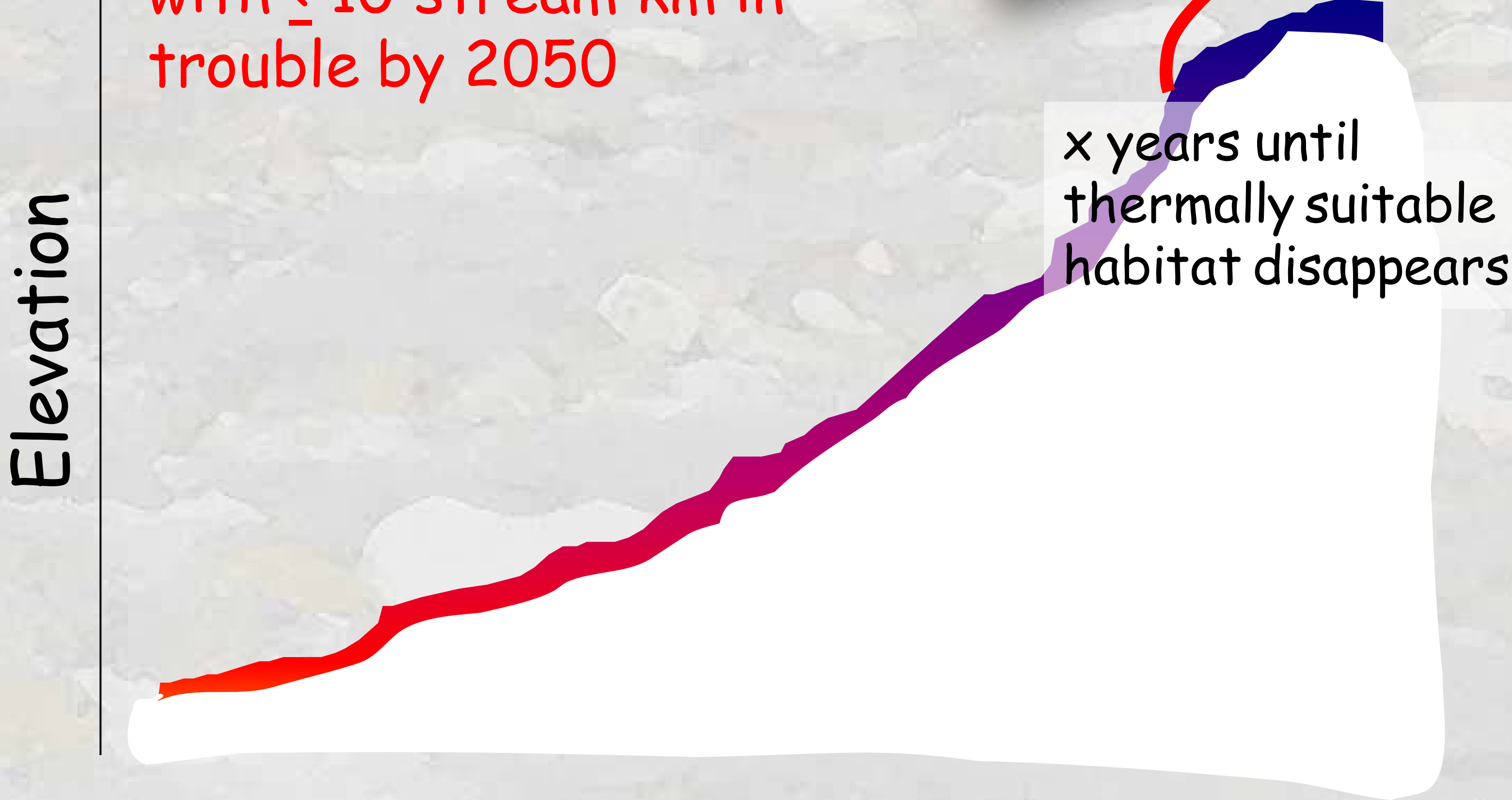
Precise Isotherm Shift Predictions

Is it a problem?

How much time left on the clock?

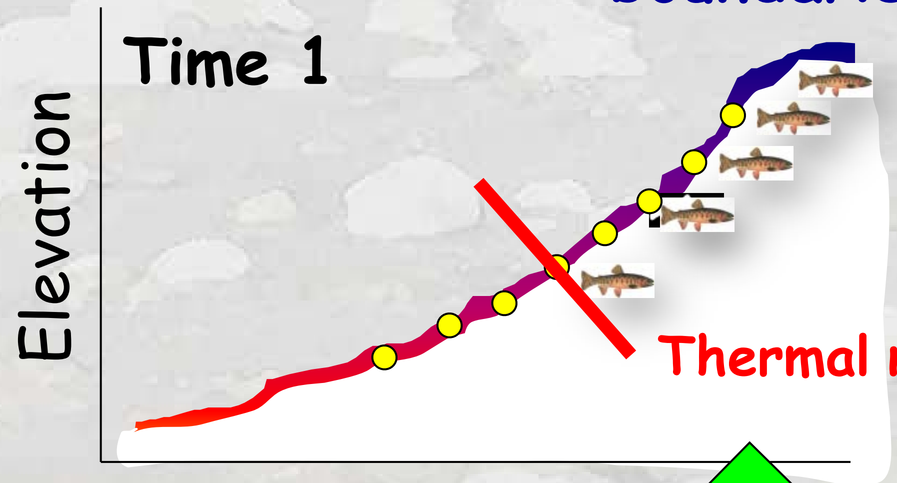
Headwater populations with ≤ 10 stream km in trouble by 2050





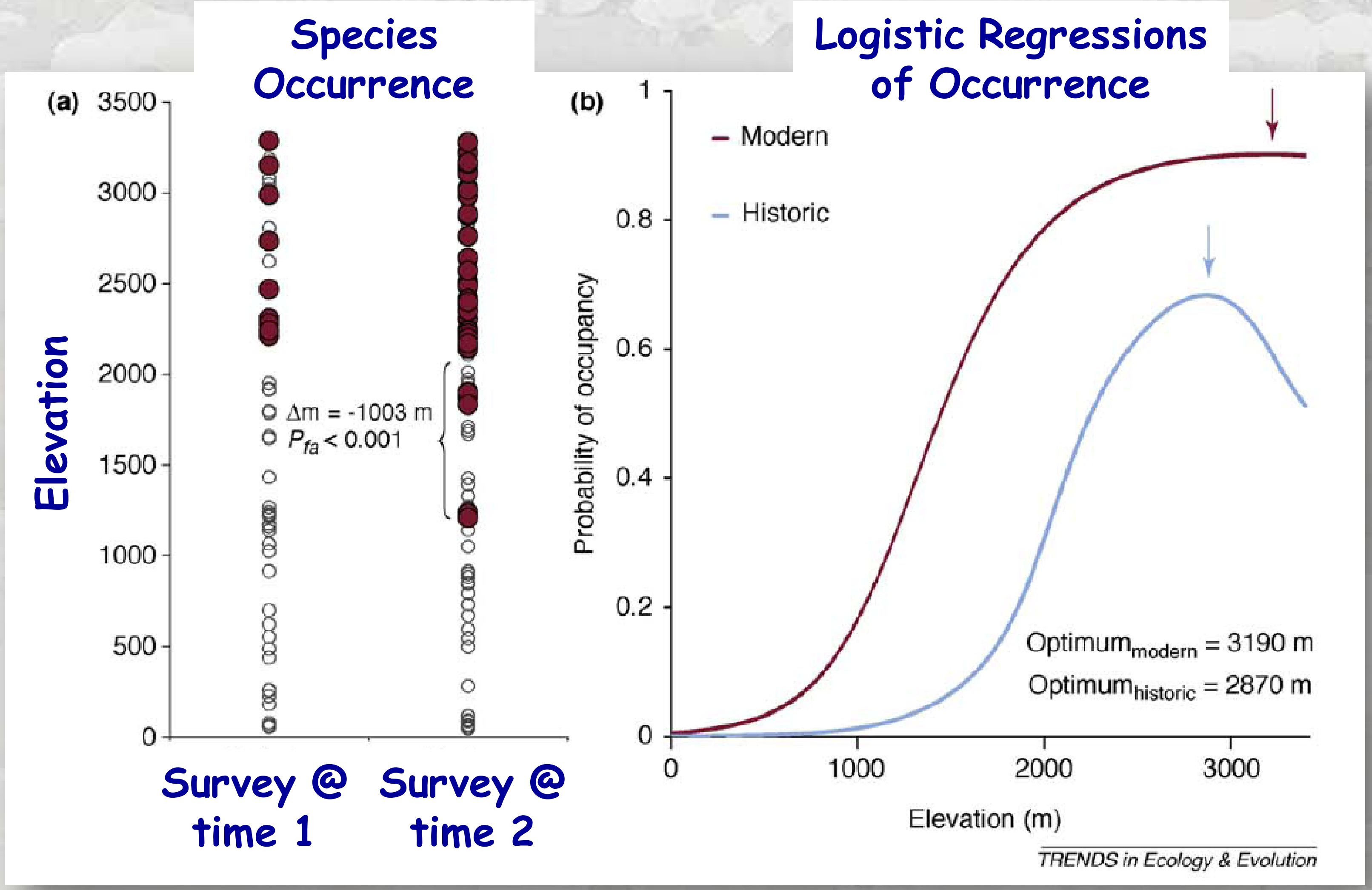
Biological Monitoring Implications

Longitudinal surveys to map population boundaries & establish baseline



Resurvey to track population boundary

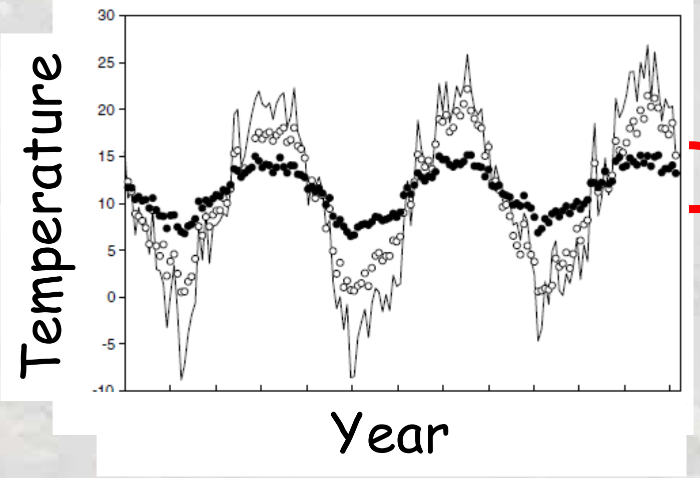
Measure Shift Between Surveys



Tingley & Bessinger. 2009. Detecting range shifts from historical species occurrences. *TREE* 24:625-633.

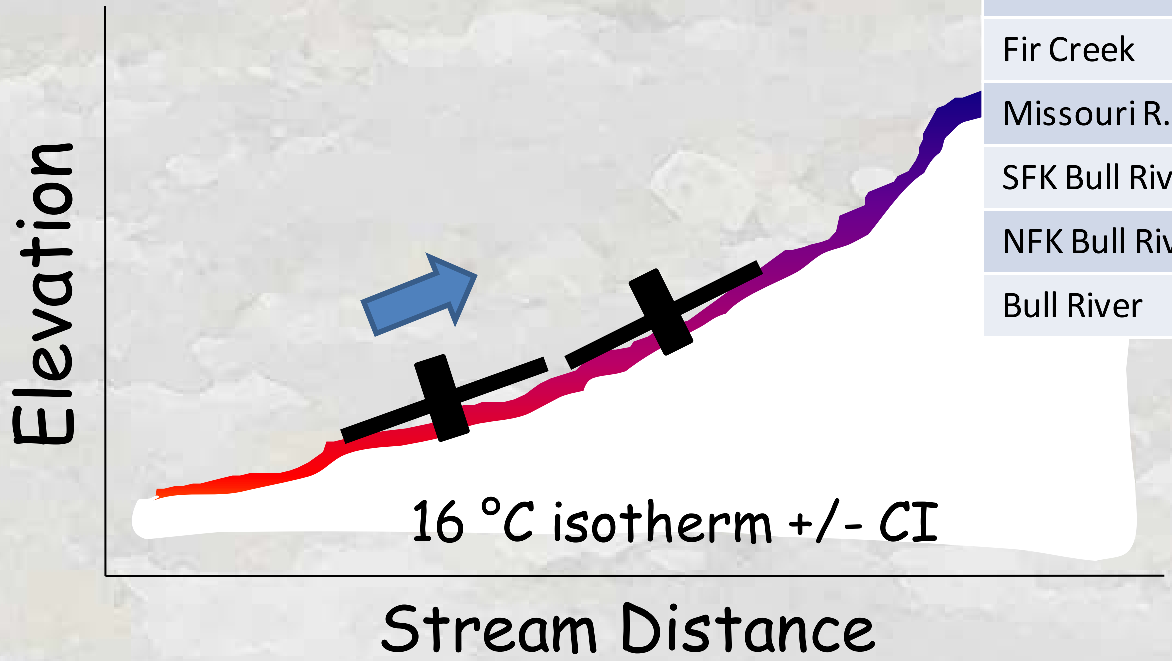
Power Analysis for Trend Detection

How long would monitoring have to occur?



Streams differ in thermal variation & this variation partially masks climate signal that populations receive

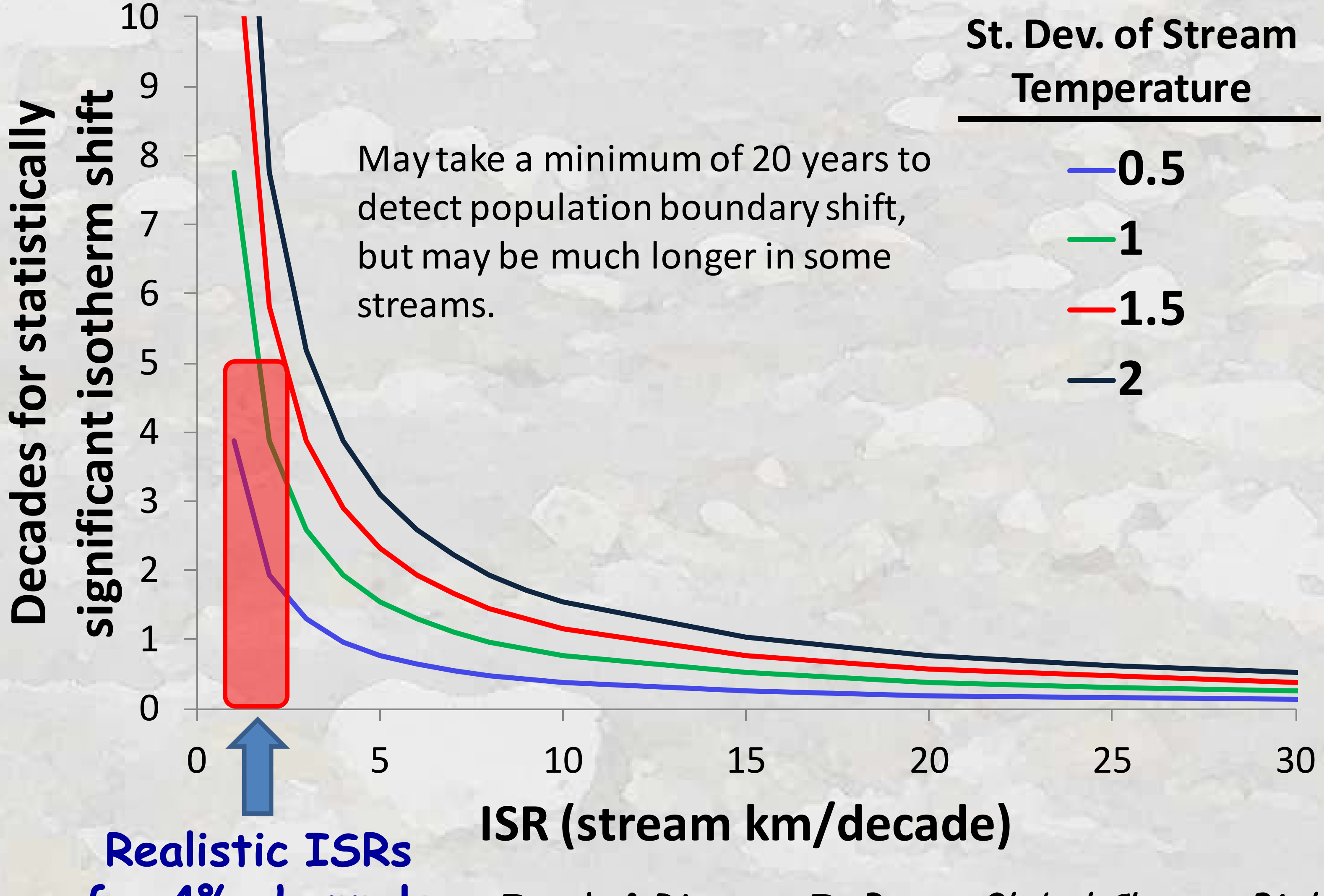
Stream	Summer SD	Annual SD
NFK Clearwater	1.41	0.70
Fir Creek	0.82	0.51
Missouri R.	1.17	0.64
SFK Bull River	0.86	0.55
NFK Bull River	0.36	0.44
Bull River	0.82	0.58



Isaak et al. 2011. *Climatic Change*

Power Curves for Isotherm Shifts

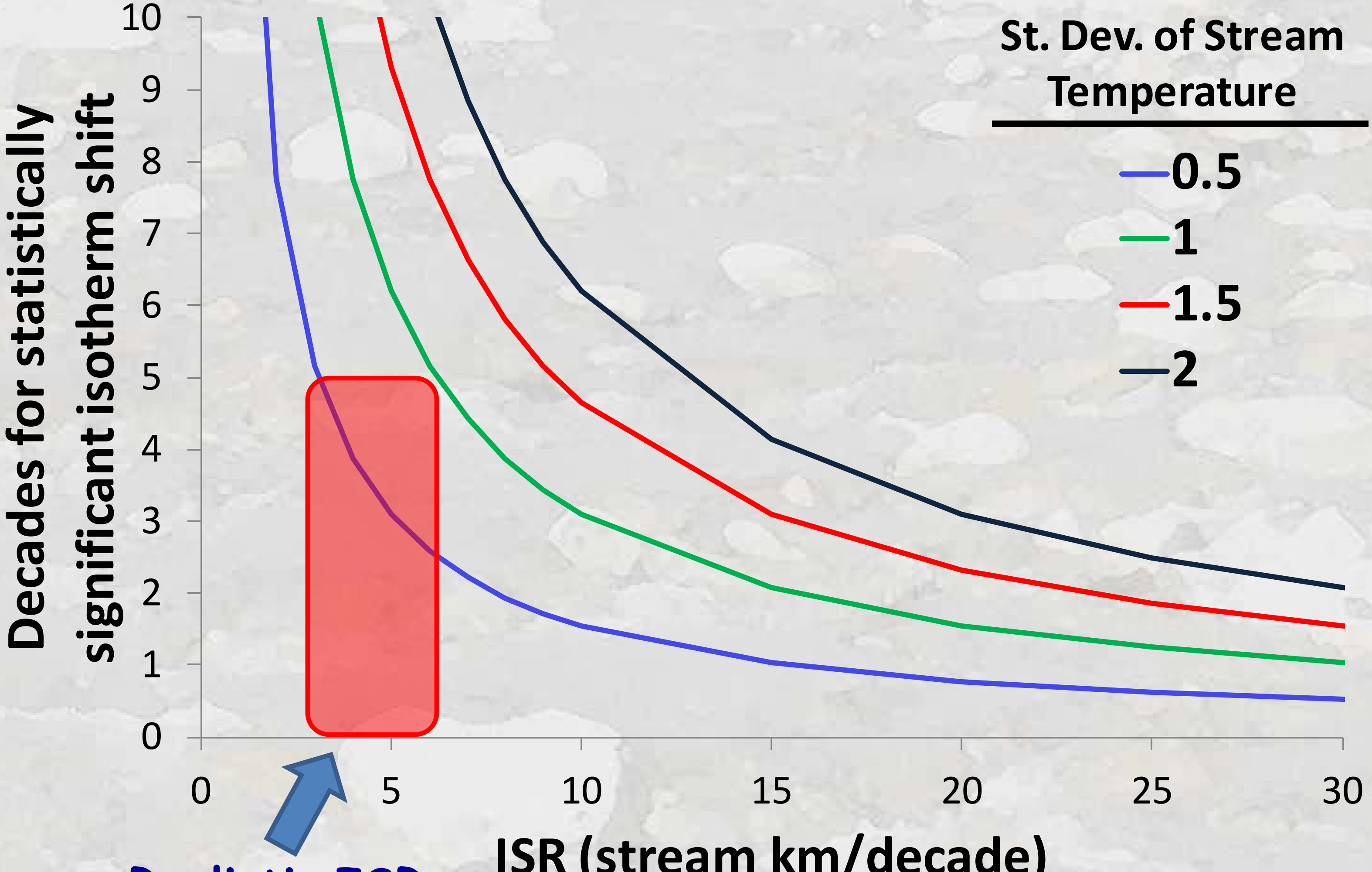
Stream lapse rate = 0.4 °C / 100 m
Stream slope = 4%



Isaak & Rieman, In Prep. *Global Change Biology*

Power Curves for Isotherm Shifts

Stream lapse rate = 0.4 °C / 100 m
Stream slope = 1%



Realistic ISRs for 1% channels

Isaak & Rieman, In Prep. *Global Change Biology*

Empirical Evidence in the Short-Term

Resample stream profiles from 20+ years ago

ALTITUDINAL DISTRIBUTION OF BROWN TROUT AND OTHER FISHES IN A HEADWATER TRIBUTARY OF THE SOUTH PLATTE RIVER, COLORADO

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(MS received August 9, 1968; accepted March 10, 1969)

Fish Assemblages and Habitat Gradients in a Rocky Mountain–Great Plains Stream: Biotic Zonation and Additive Patterns of Community Change

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WAYNE A. HUBERT

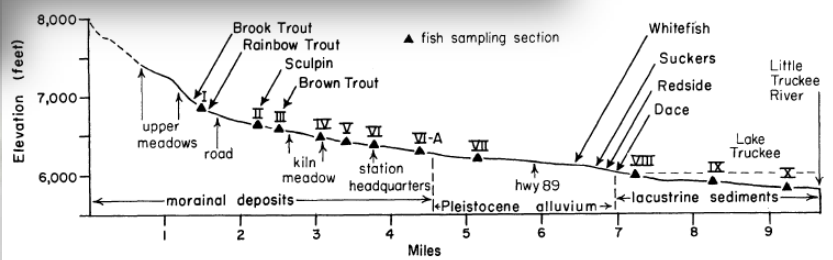
Transactions of the American Fisheries Society 120:319–332, 1991

Species	Site number and elevation (m)									
	1 2,234	2 2,030	3 2,015	4 1,591	5 1,559	6 1,524	7 1,510	8 1,490	9 1,470	10 1,423
Upstream species										
(1) Brook trout	100	79	72	6						
(2) Brown trout		21	24	+	+	+			2	
Species showing an additive pattern										
(1) White sucker			4	42	34	13	26	51	35	39
(2) Longnose dace				23	18	52	6		33	12
(3) Longnose sucker				2	19	12	13	1	1	2
(4) Creek chub				27	27	20	6	47	28	24
(5) Sand shiner						1	12	+		14
(6) Bigmouth shiner							6	+		4
(7) Fathead minnow							8			+
(8) Common shiner										4
(9) Brassy minnow										+

DISTRIBUTION AND ABUNDANCE OF FISHES IN SAGEHEN CREEK, CALIFORNIA

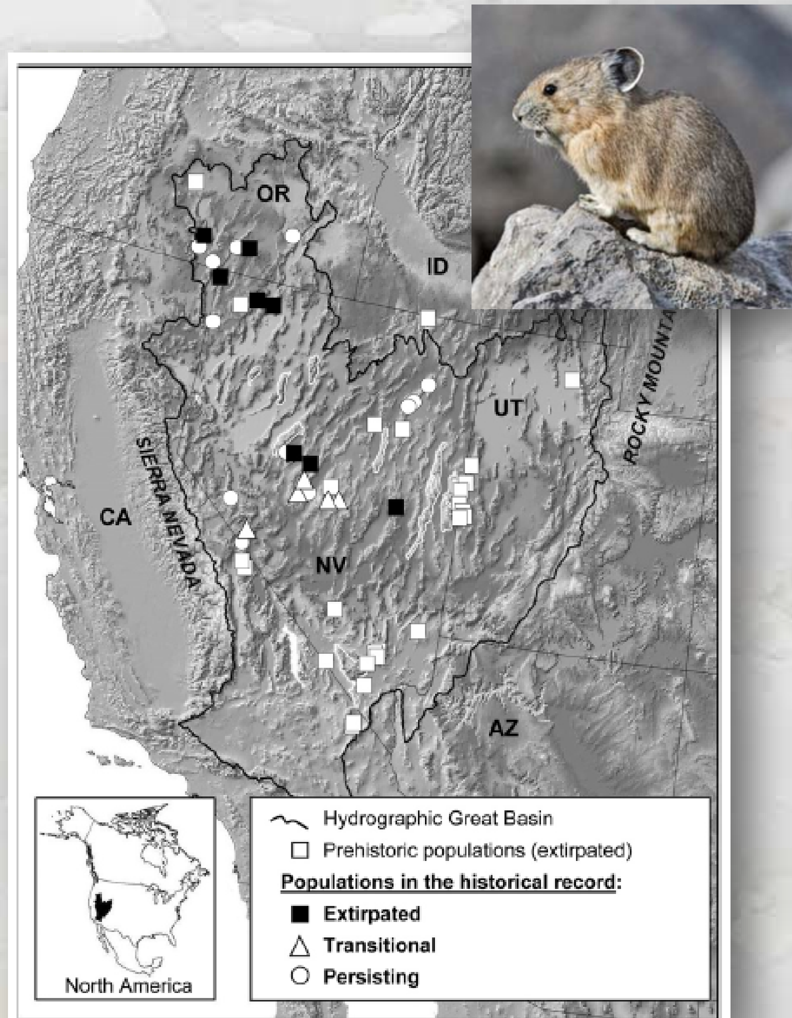
RICHARD GARD, School of Forestry and Conservation, University of California, Berkeley 94720[1]
GLENN A. FLITTNER, Bureau of Marine Sciences, California State University, San Diego 92100

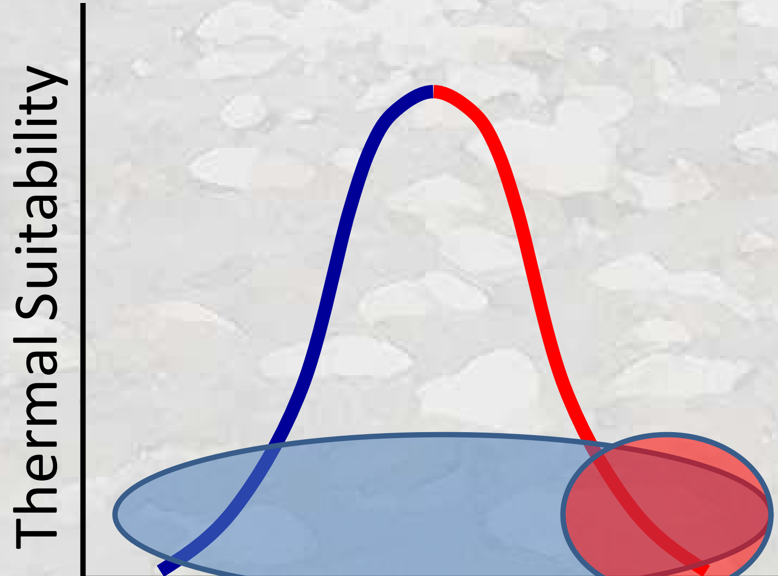
J. Wildl. Manage. 38(2):1974



Broad Distributional Resurveys

Assess site extirpation/colonization frequencies relative to temperature





t_1 t_2

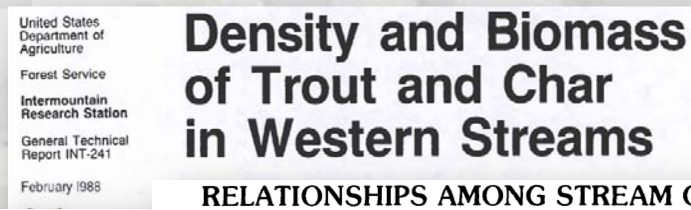
1 → 0

Site occupancy

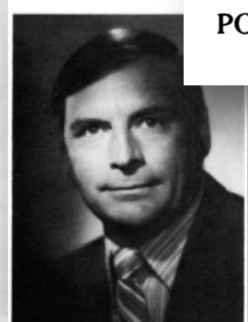
Beever et al. 2003; 2010

Broad Distributional Resurveys

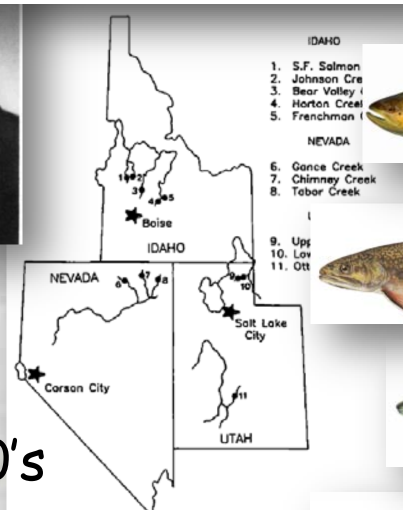
Assess site extirpation/colonization frequencies relative to temperature


United States Department of Agriculture
Forest Service
Intermountain Research Station
General Technical Report INT-241
February 1988

Density and Biomass of Trout and Char in Western Streams



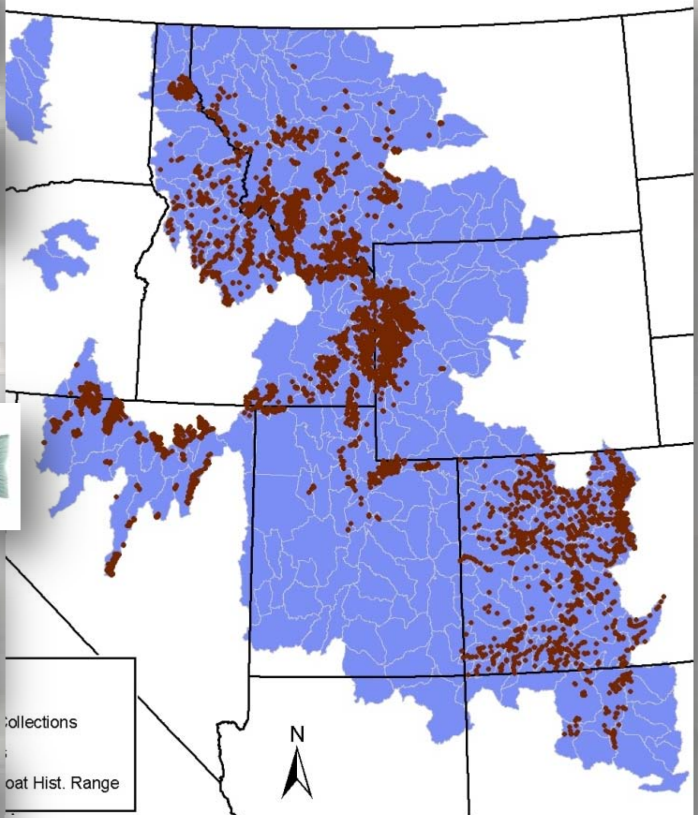
RELATIONSHIPS AMONG STREAM ORDER, FISH POPULATIONS, AND AQUATIC GEOMORPHOLOGY IN AN IDAHO RIVER DRAINAGE



Platts
70's/80's

Bjornn
1960's/70's

Fish survey database
~10,000 sites



Wenger et al. 2011. *PNAS*

Conclusions/Discussion

•Estimates of biological shift rates is *the* "X Prize" and critical information necessary to facilitate accurate climate risk assessments ***& empower managers to make tough decisions***.

•Monitoring efforts should focus on streams with fast ISRs and low thermal variance. Detection of biological shifts will require a minimum of 20 years (but could be much longer).

•Resurveys of historical sites are needed to provide empirical evidence of biological shifts in near future.

•Headwater populations that occupy < 10 km of stream & lack upstream elevational refuges may be extirpated by 2050.

•Interesting ecological questions:

a) Do shift rates differ between temperature mediated boundaries where populations are allopatric or sympatric (with nonnative competitors)?

b) Do shift rates differ at warm (extirpation) or cold (colonization) boundaries?


The End