Spatial structure of stream thermal sensitivity affects climate change forecasts for brook trout

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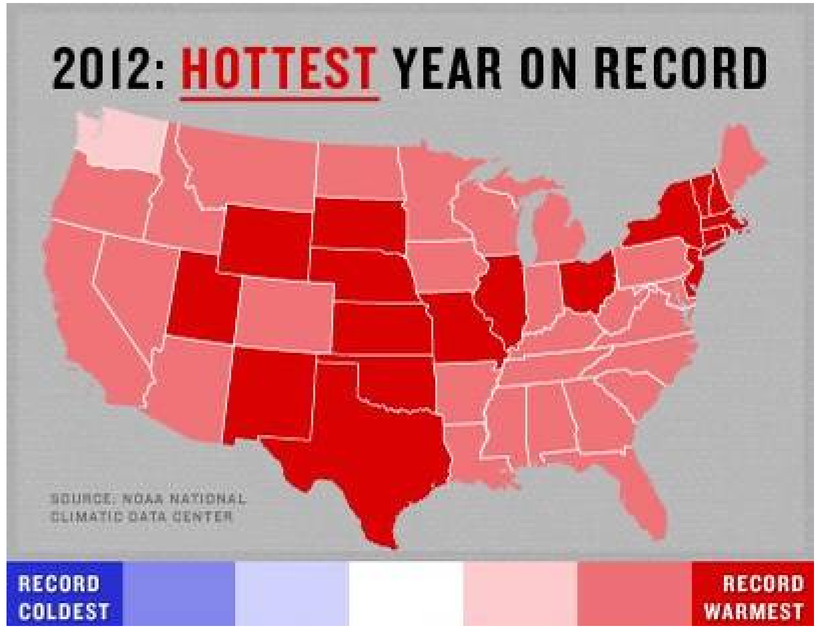
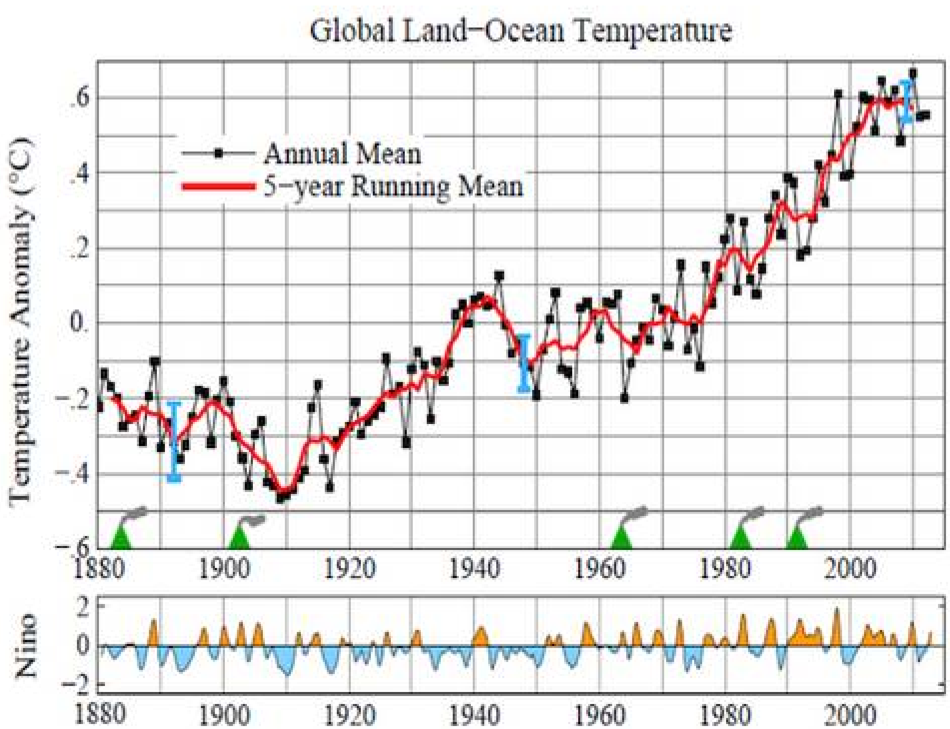
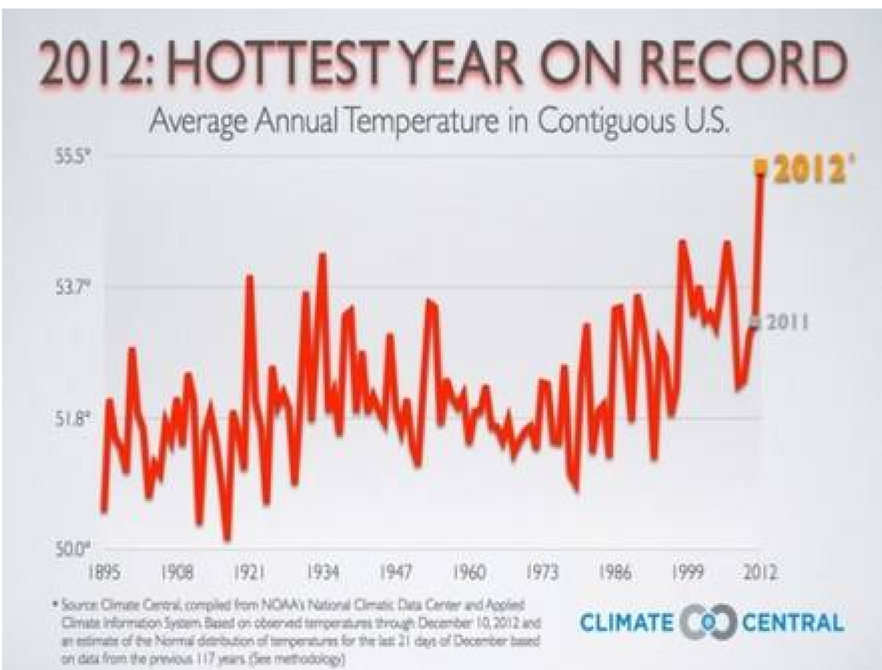
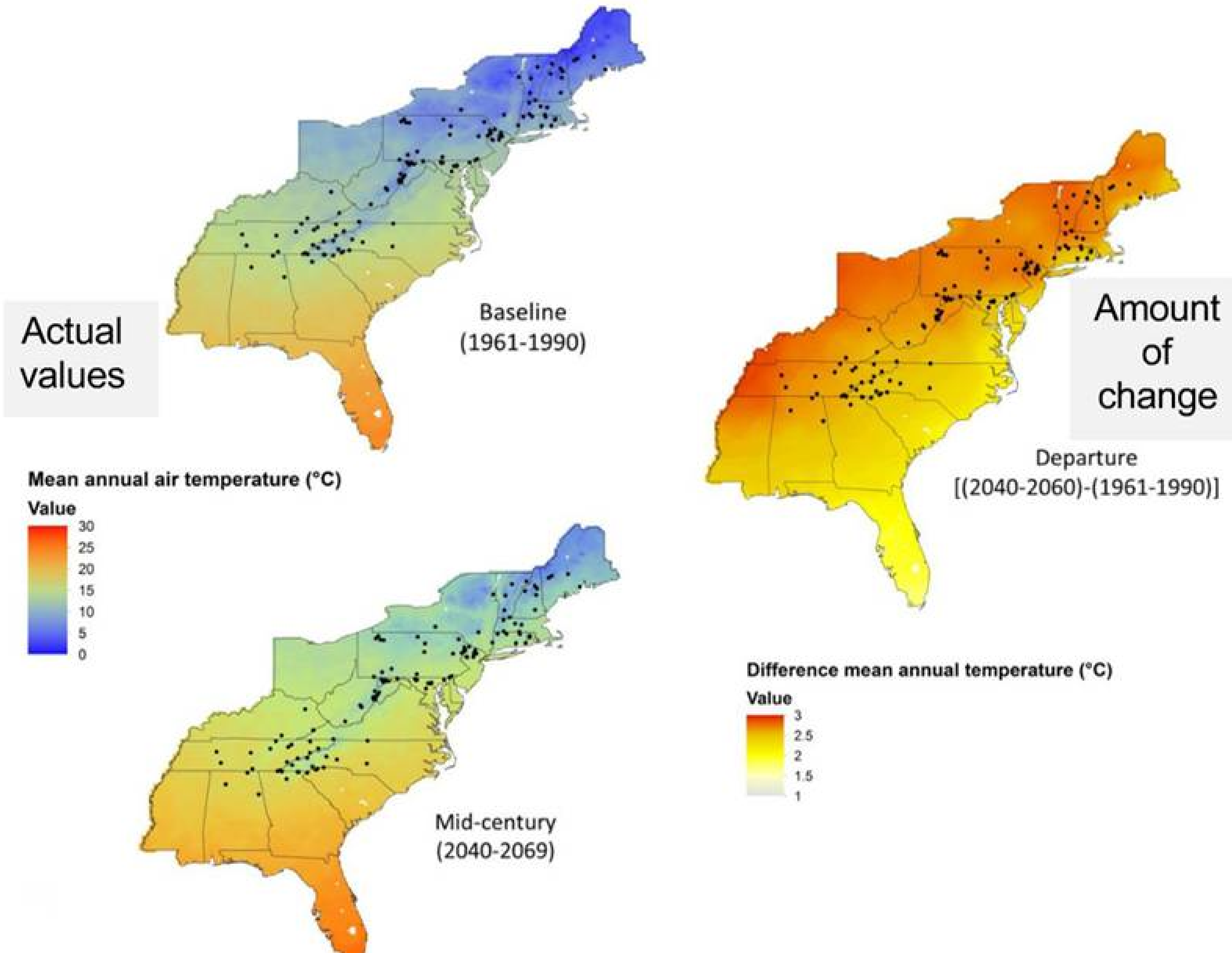
science for a changing world


2012: HOTTEST YEAR ON RECORD
SOURCE: NOAA NATIONAL CLIMATIC DATA CENTER
RECORD COLDEST
RECORD WARMEST


Global Land−Ocean Temperature
Annual Mean
5−year Running Mean
Temperature Anomaly (°C)
.6
.4
.2
0.
−.2
−.4
−.6
1880
1900
1920
1940
1960
1980
2000
Nino
2
0
−2
1880
1900
1920
1940
1960
1980
2000


2012: HOTTEST YEAR ON RECORD
Average Annual Temperature in Contiguous U.S.
55.5°
53.7°
51.8°
50.0°
2012*
2011
1895
1908
1921
1934
1947
1960
1973
1986
1999
2012
* 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)
CLIMATE CENTRAL

Expected change in mean annual air temperature

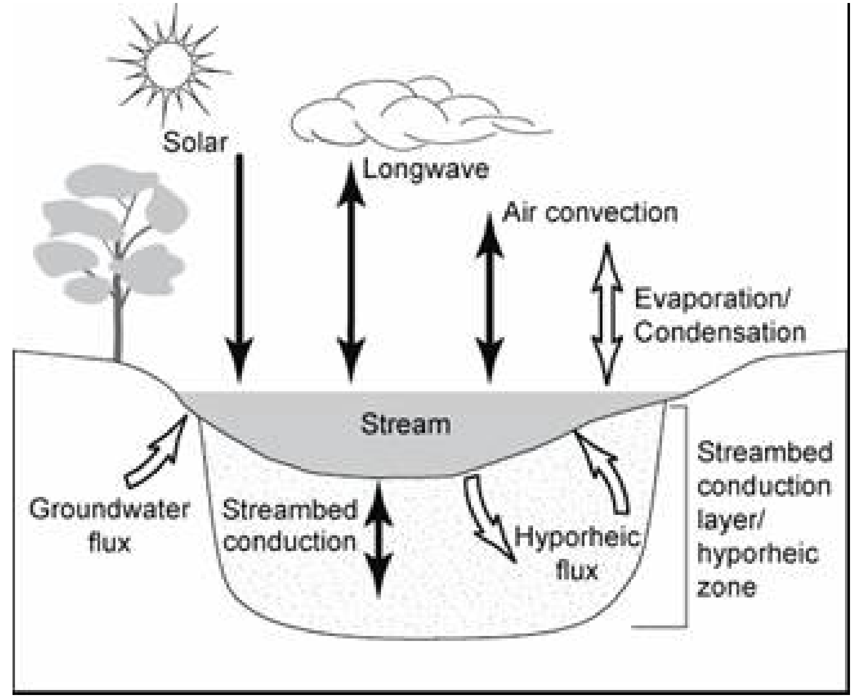


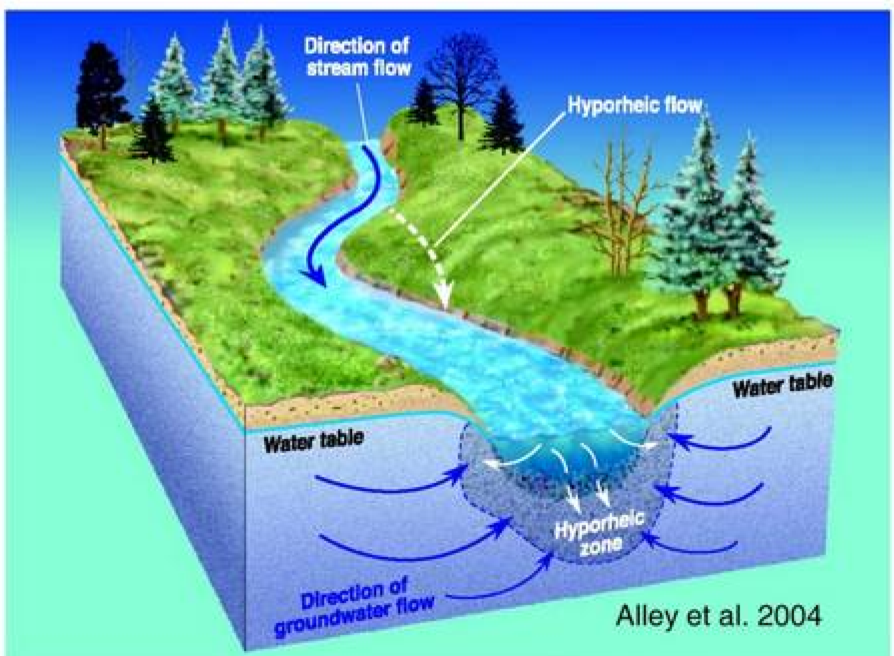
Unpublished data, J. Stamp, et al. TetraTech and USEPA

Key questions

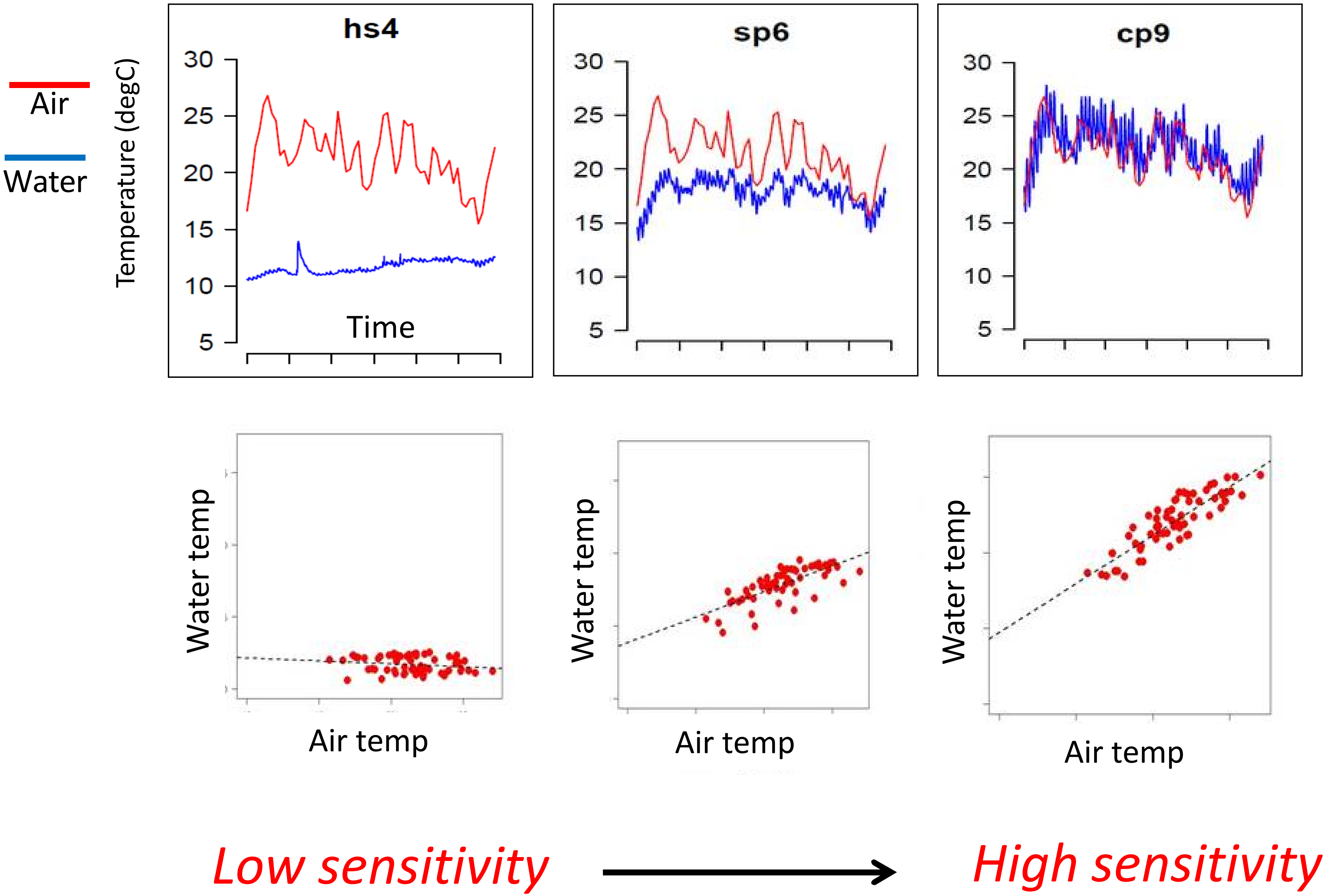
- As air temperatures increase, will streams respond uniformly across space, or will responses be organized at finer spatial scales?
- How do such considerations affect forecasts for brook trout thermal habitat?
- What does this mean for stream restoration and conservation planning?

Many factors regulate stream temperature

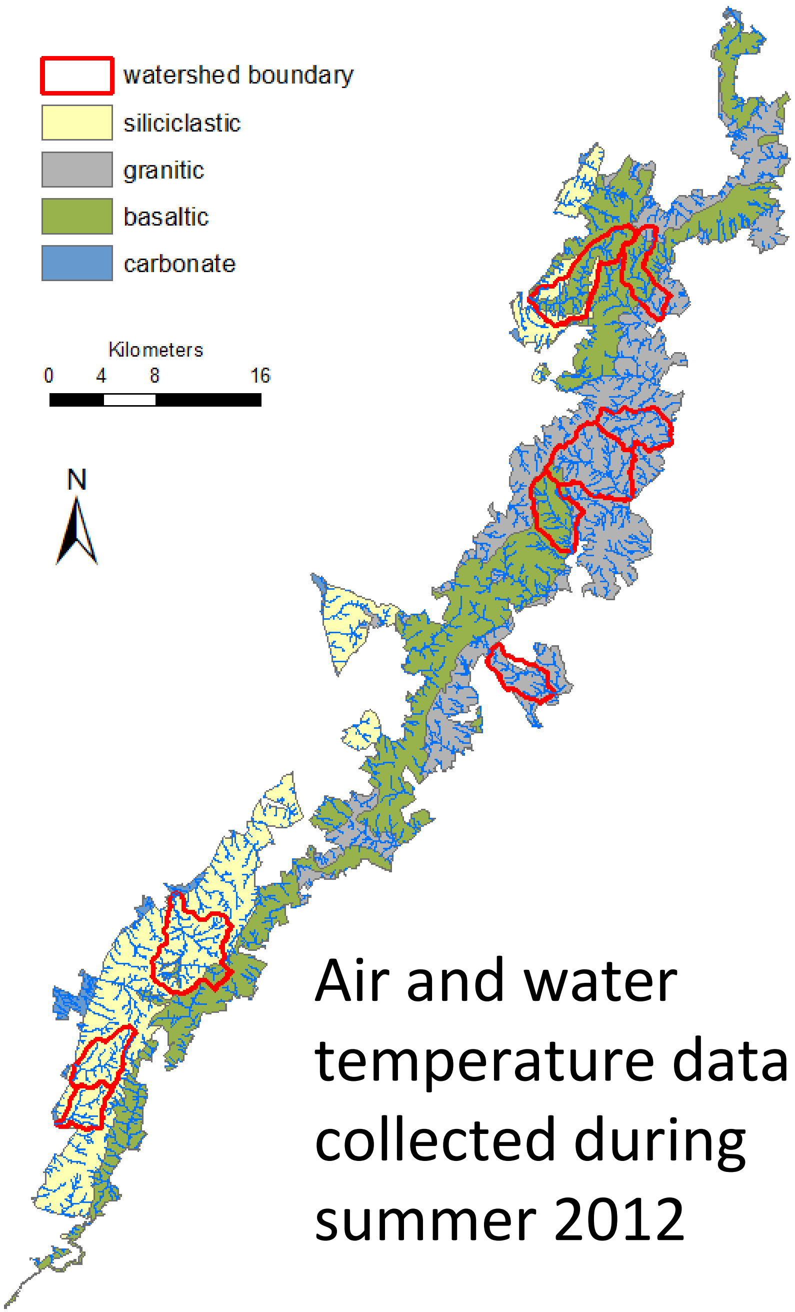




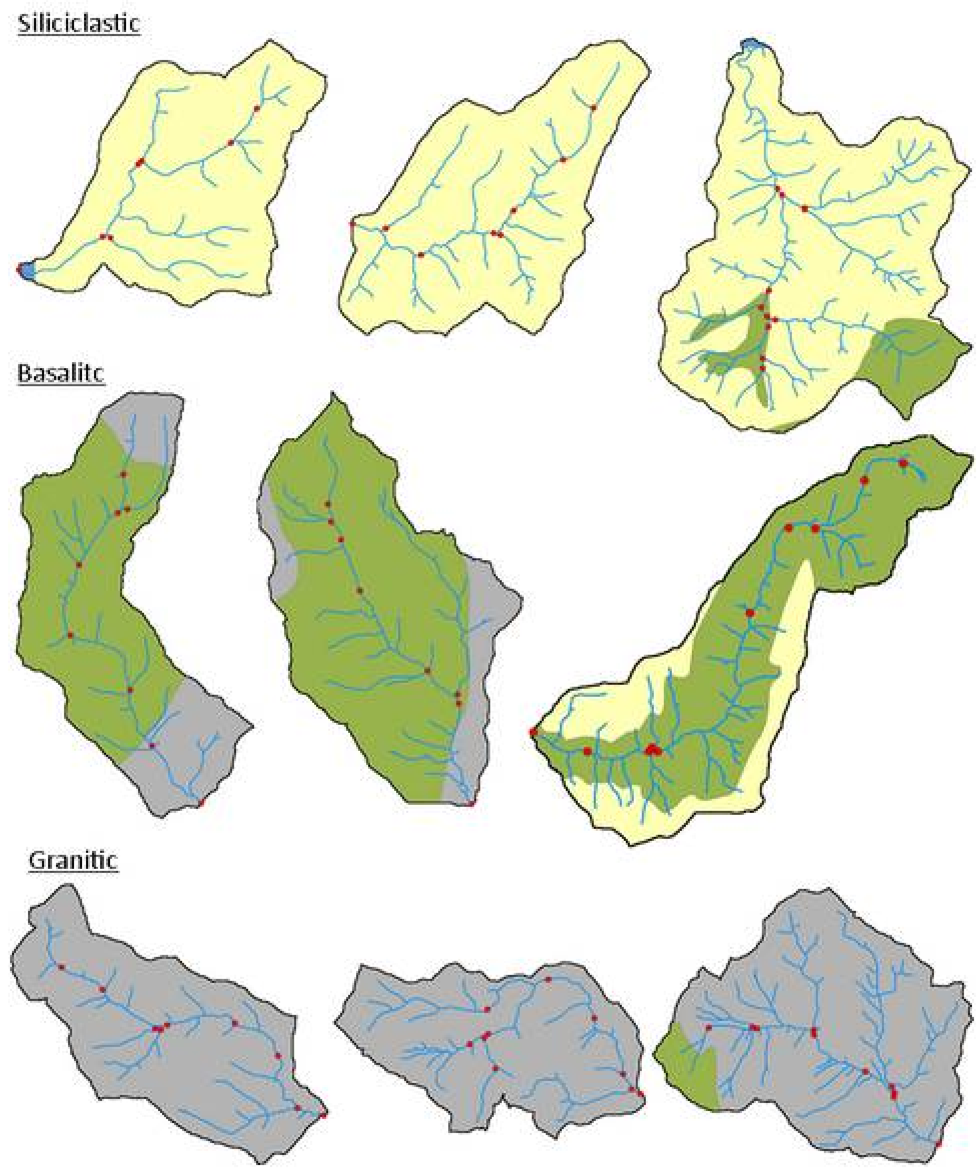
<u>Groundwater inputs</u> are organized at multiple spatial scales: basin, stream, reach


Air
Water
Temperature (degC)
hs4
sp6
cp9
30
25
20
15
10
5
Time
Water temp
Air temp
Low sensitivity
High sensitivity

Shenandoah NP case study



Air and water temperature data collected during summer 2012

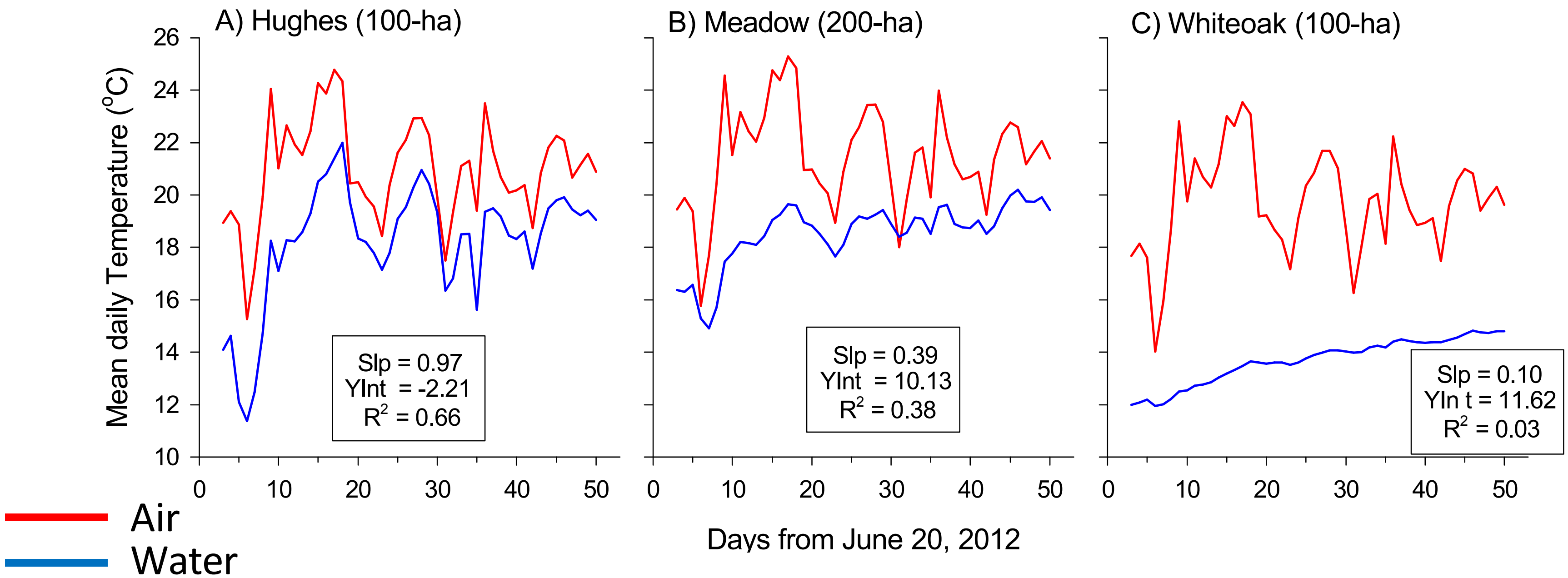


Spatial model comparisons

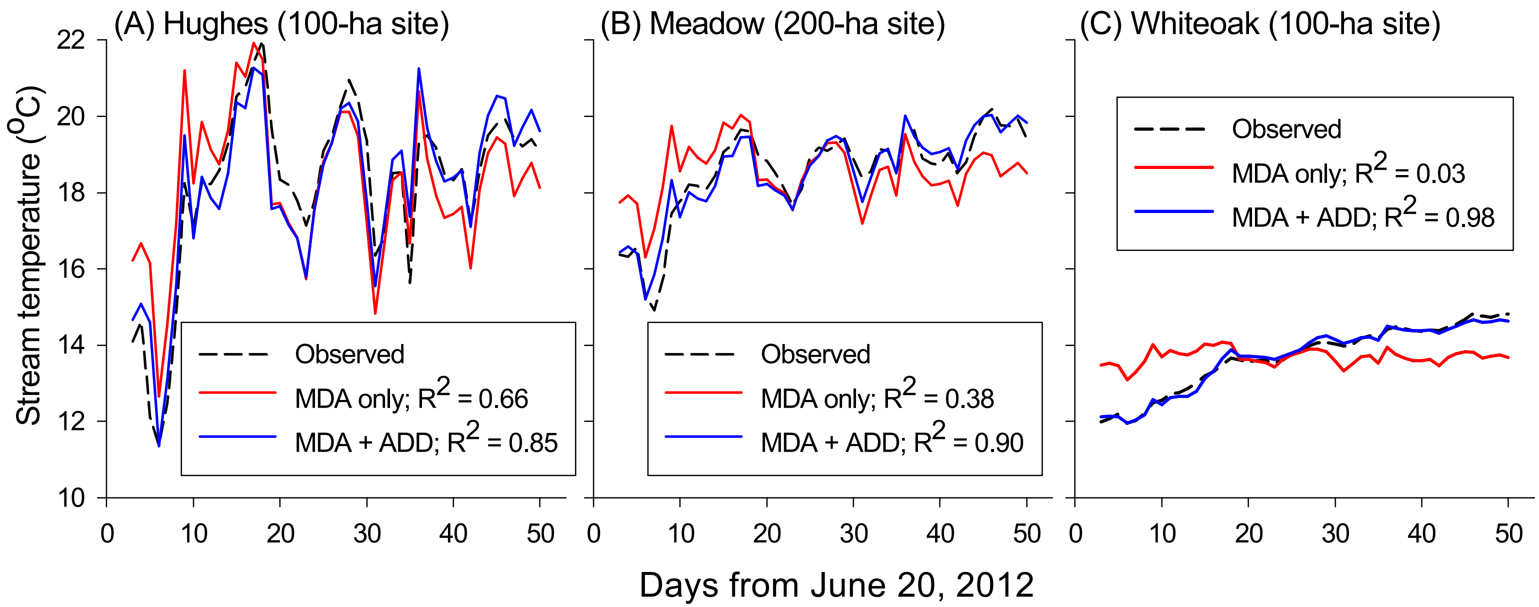
Scale	Thermal Sensitivity
Reach model	Measured at **fine spatial grain** (within-stream variation)
Watershed model	Measured at **HUC-12 spatial grain**
Boundary model	**Not measured**; assumed strong (1:1) and spatially uniform

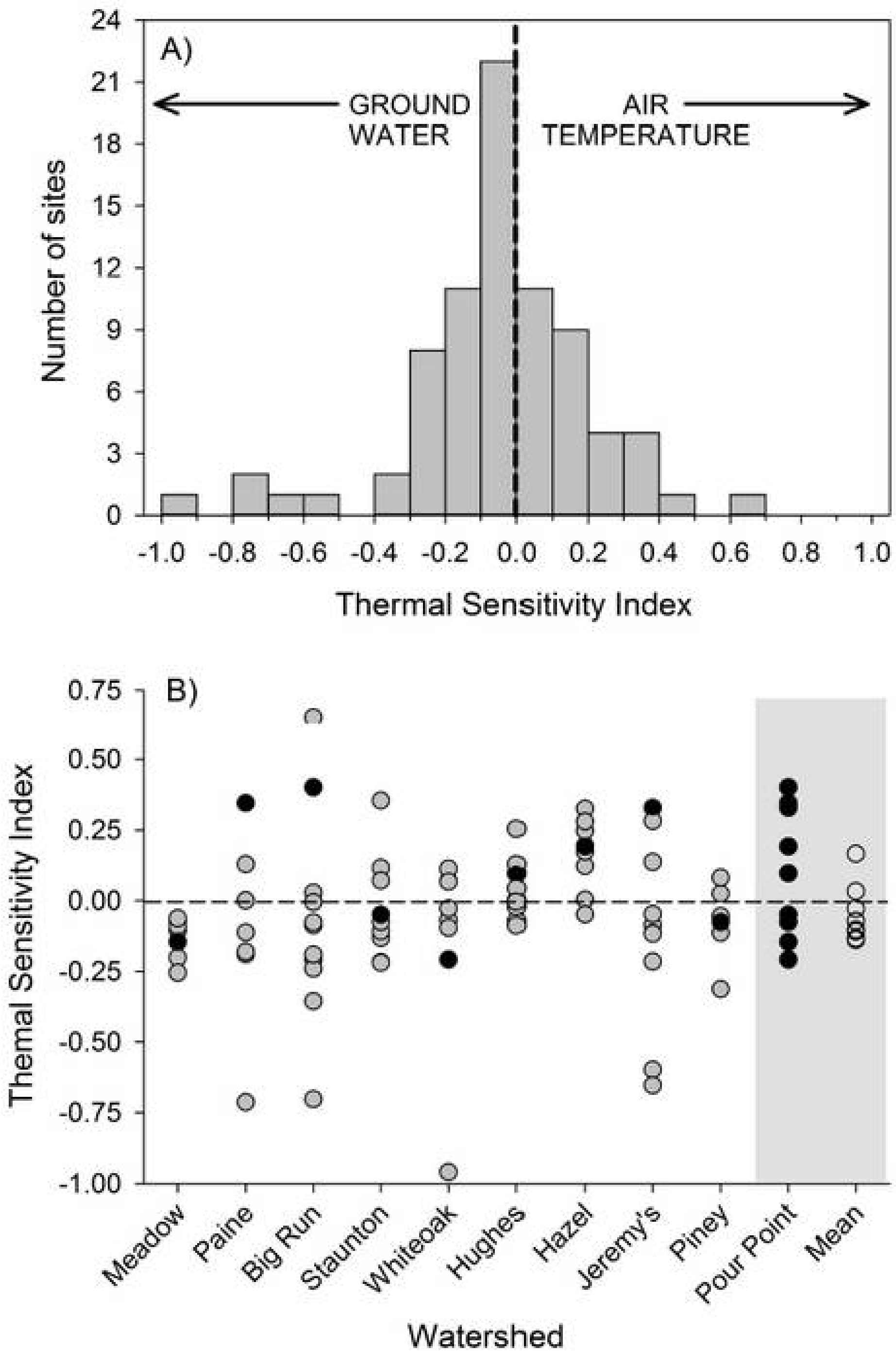
Forecast habitat suitability for brook trout from climate change scenarios at 3 spatial scales

Air temperature: weak predictor of water temperature



Air temperature + groundwater: strong predictor of water temperature





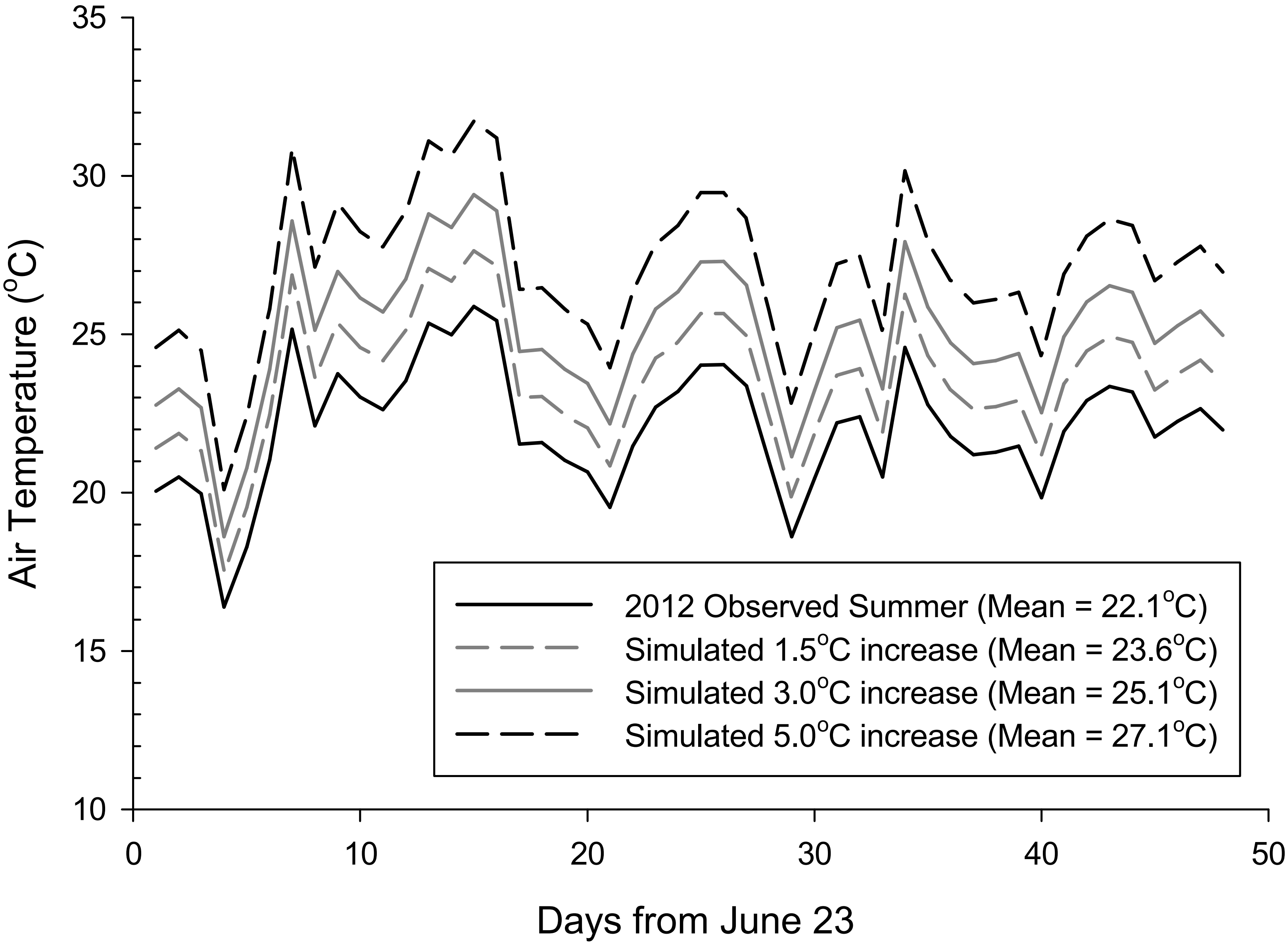
Index of groundwater vs. air temperature controls

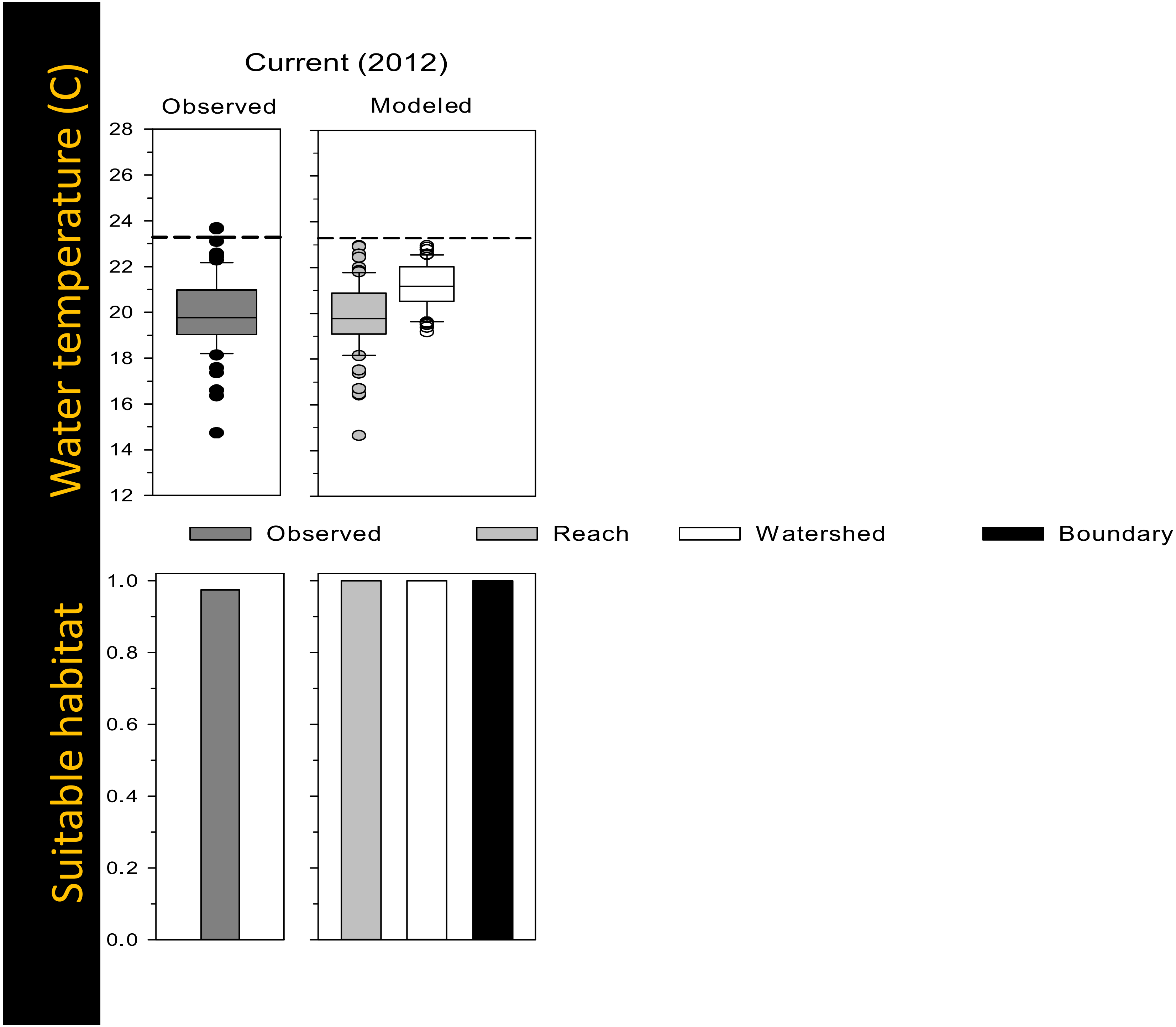
(ratio of standardized linear model coefficients)

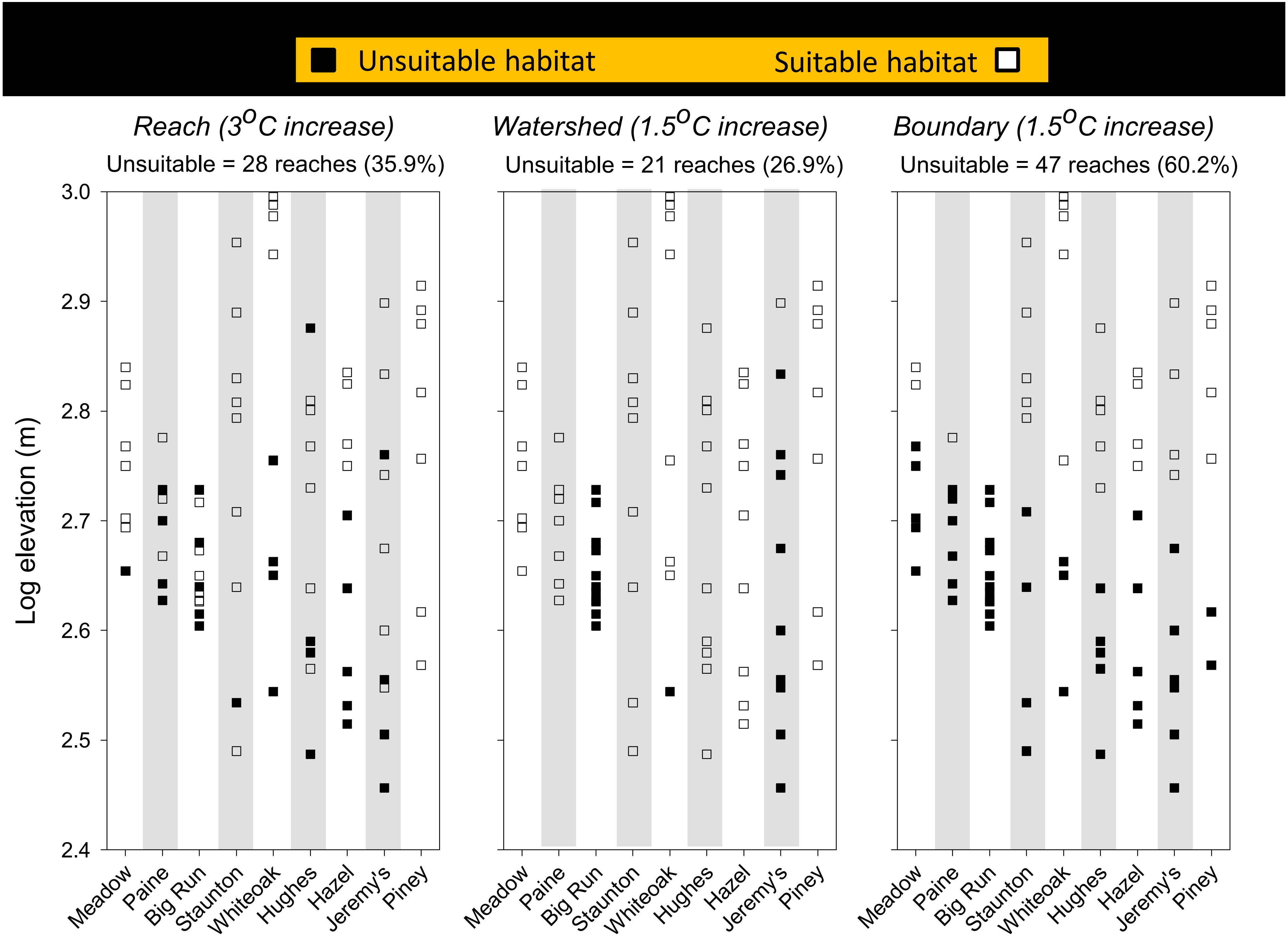
Spatial variation in thermal sensitivity

within and among watersheds

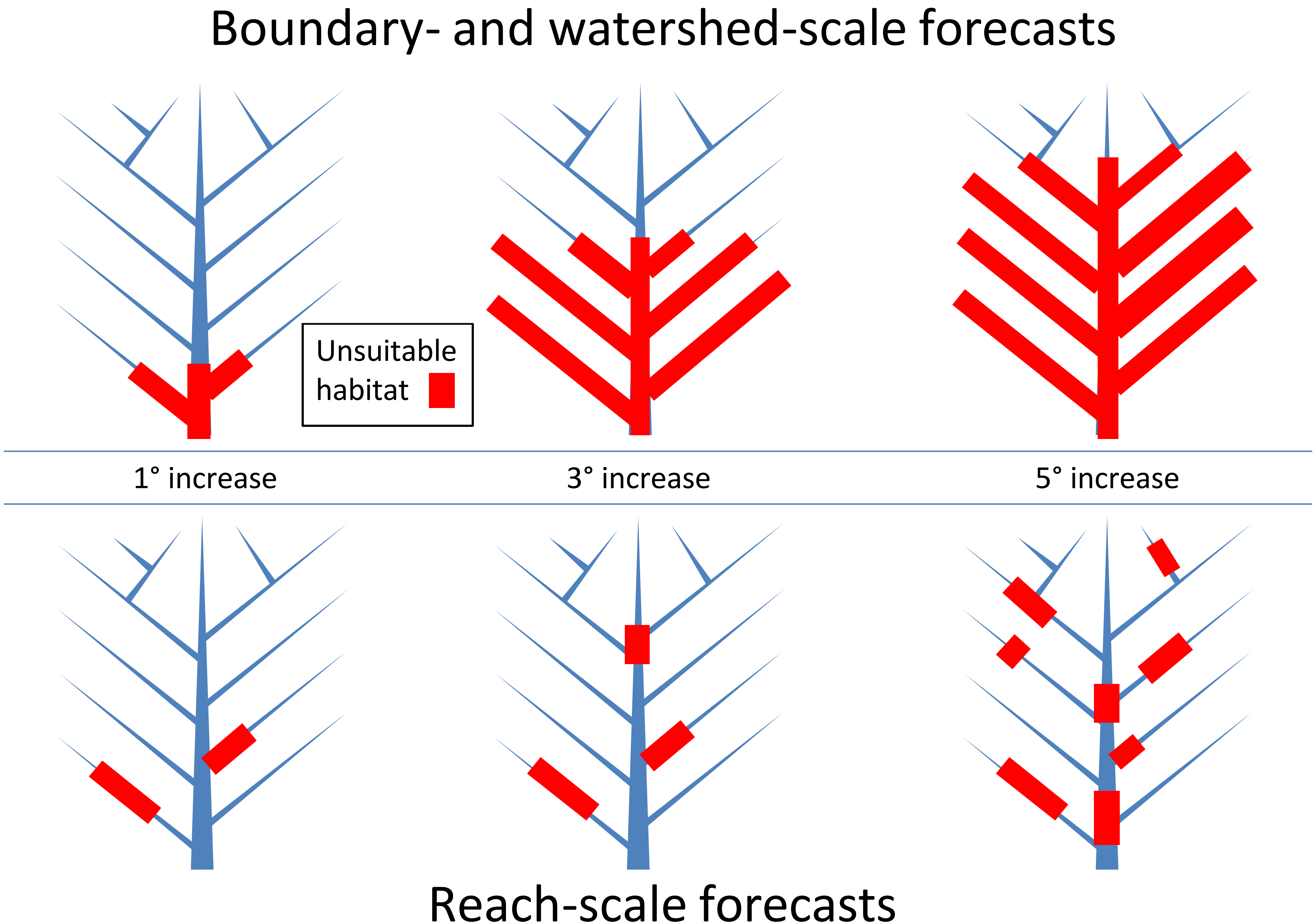
Stream temperature scenarios




Water temperature (C)
Suitable habitat
Current (2012)
Observed
Modeled
28
26
24
22
20
18
16
14
12
Observed
Reach
Watershed
Boundary
1.0
0.8
0.6
0.4
0.2
0.0



Unsuitable habitat
Suitable habitat
Reach (3°C increase)
Unsuitable = 28 reaches (35.9%)
Watershed (1.5°C increase)
Unsuitable = 21 reaches (26.9%)
Boundary (1.5°C increase)
Unsuitable = 47 reaches (60.2%)
Log elevation (m)
3.0
2.9
2.8
2.7
2.6
2.5
2.4
Meadow
Paine
Big Run
Staunton
Whiteoak
Hughes
Hazel
Jeremy's
Piney


Boundary- and watershed-scale forecasts
Unsuitable habitat
1° increase
3° increase
5° increase
Reach-scale forecasts

Summary

- Individual stream locations may not represent watershed (e.g., HUC-12) responses to climate change
- Elevation and watershed-based climate change forecasts for brook trout thermal habitat suitability may overestimate future habitat loss and underestimate future habitat fragmentation
- Conservation and restoration planning should consider habitat within reach networks

Next steps

- Evaluate landform predictors of reach-scale thermal sensitivity (i.e., hyporheic flow)
- Model temporal variation in brook trout population dynamics with landform predictors
- Evaluate relative importance of riparian reforestation for groundwater-influenced reach stability

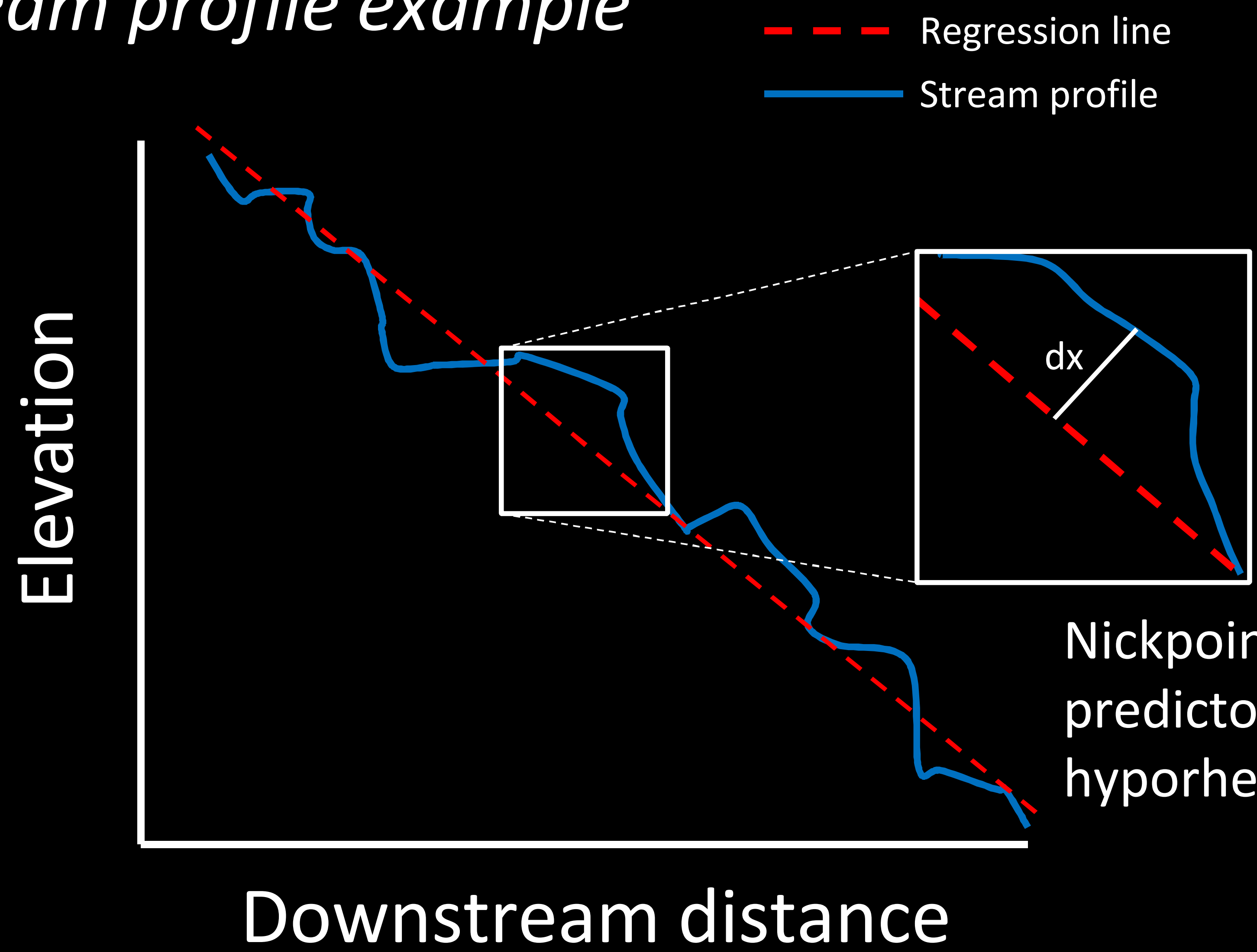
Stream channel mini-piezometers:

Vertical hydraulic gradient

Groundwater temperature

Bounded alluvial valley segments…
Nickpoints for hyporheic flow

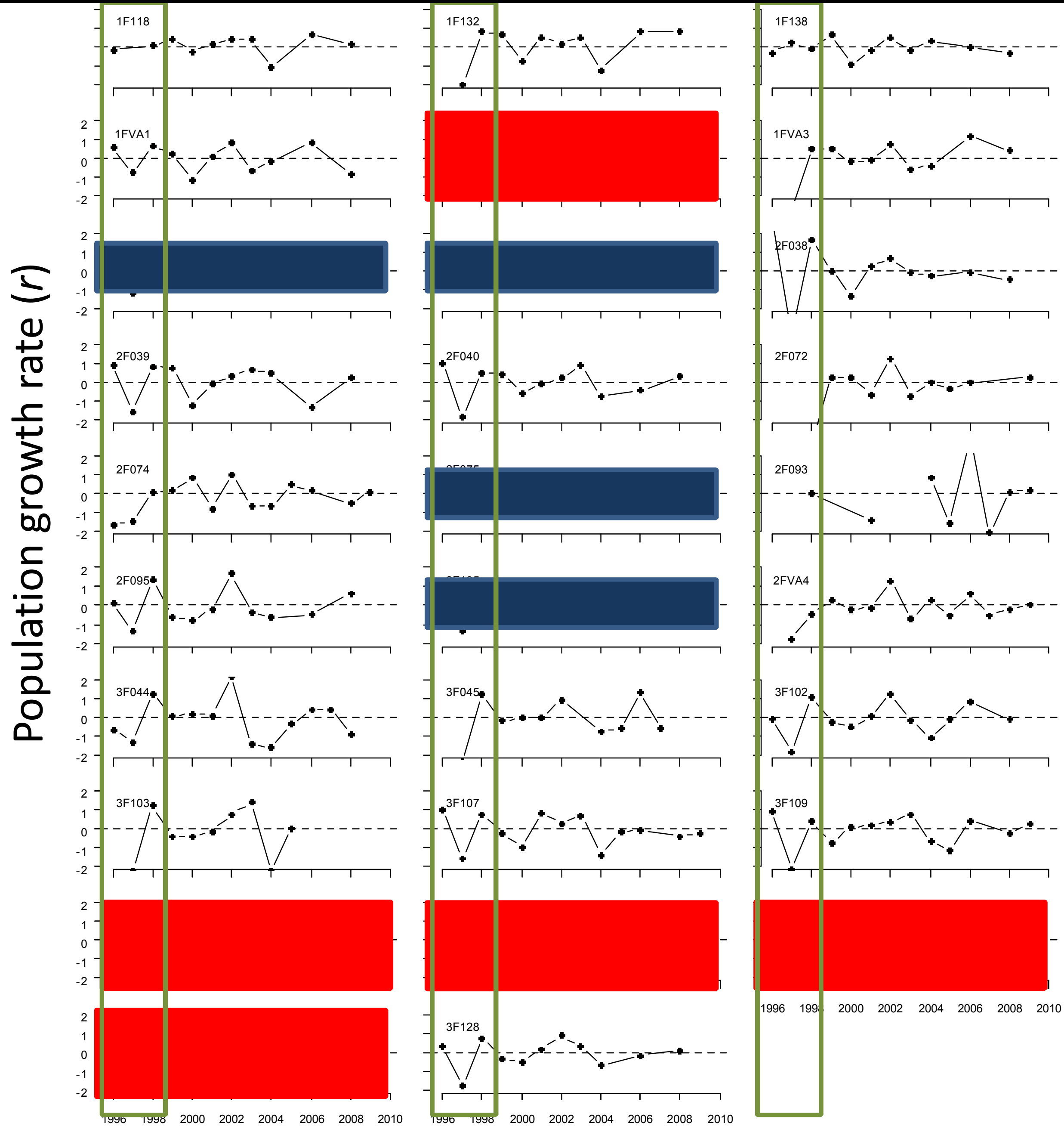
Stream profile example



Nickpoints as predictors of hyporheic flow?

From Cavalli et al. (2008)

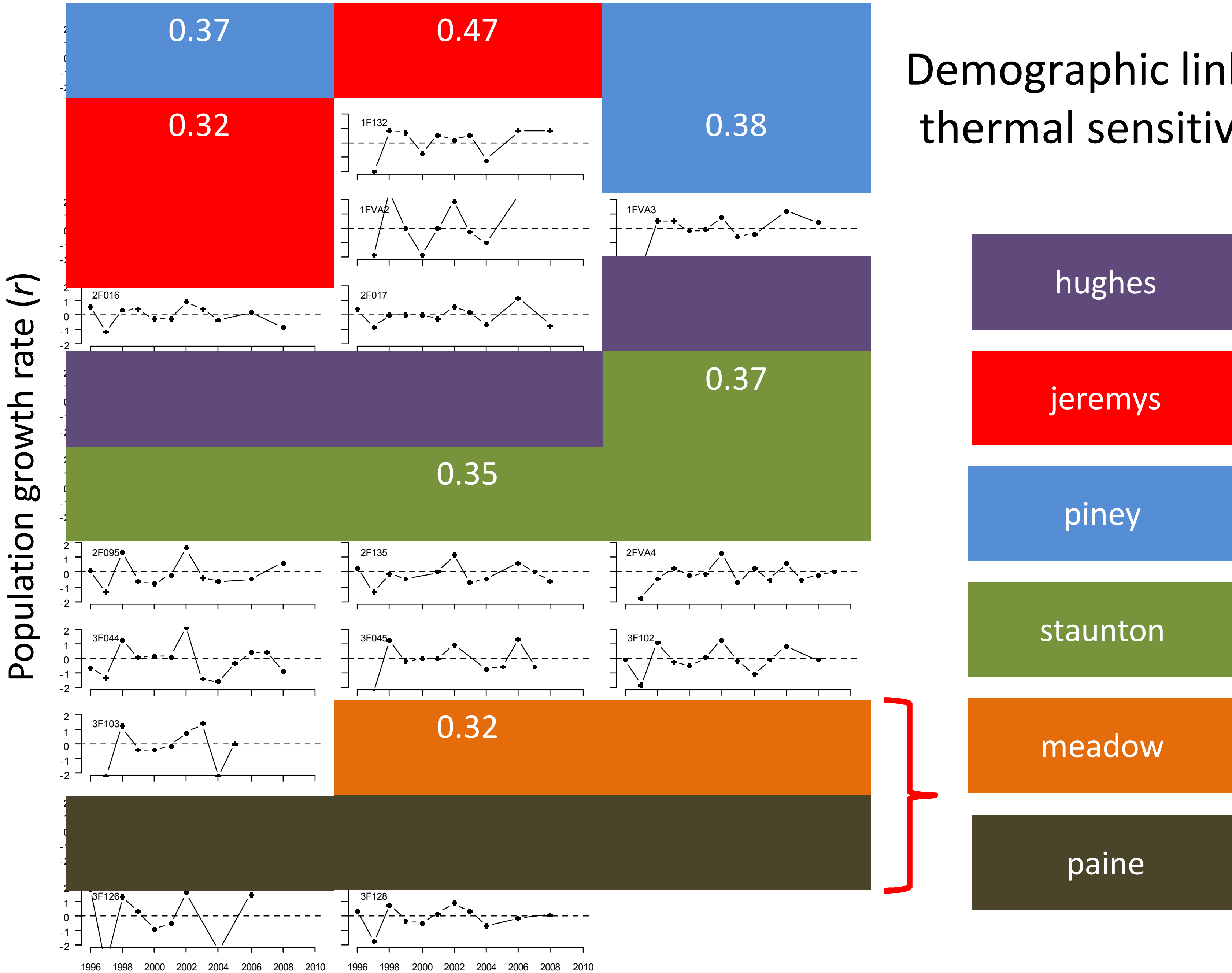
Shenandoah National Park long-term trout monitoring data



- Populations appear stable (*r* ≈ 0) overall
- Some sites are more variable over time than others
- Some years show consistent patterns in population growth

Jastram et al. (2013)

Demographic links to thermal sensitivity?



Experimental stream laboratory

Currently under construction at USGS Leetown Science Center

Thermal control
Biotic interactions
Groundwater control
Replicate units

Acknowledgements

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