Forecasting Changes in Stream Flow, Temperature and Salmonid Populations in the Eastern United States as a Result of Climate Change

USGS Conte Anadromous Fish Research Center
Ben Letcher, Ana Rosner, Kyle O'Neil, Dan Hocking, Chris Jennison and Yoichiro Kanno
March28, 2014

Meeting goals

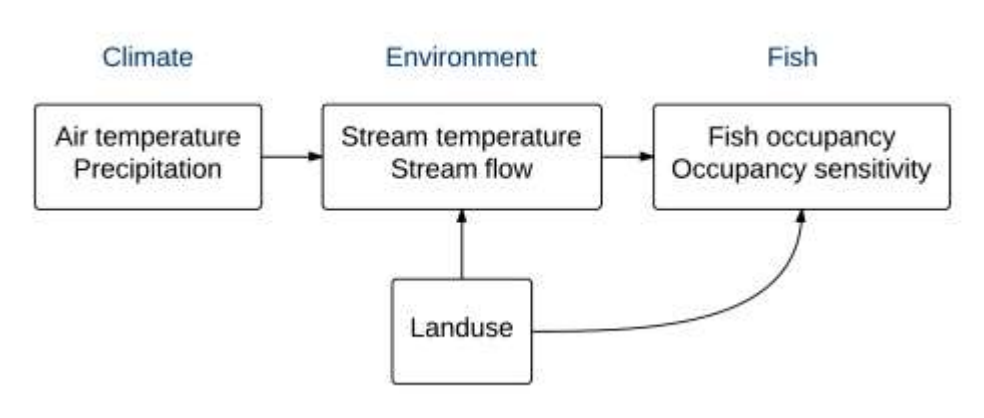
- Overview of project results
  - Current conditions, future conditions, sensitivity
  - Updatable
- Variables
  - Stream flow
  - Stream temperature
  - Brook trout
    - Species – specific
    - Data rich, widespread, cold-water habitat indicator
- Products
  - Maps, layers
  - Web application

Project goals

Environmental Drivers

Brook Trout Occupancy and Abundance

- Understand brook trout population response to environmental variation
  - Stream temperature
  - Stream flow
  - Driven by land use, air temperature, and precipitation changes



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Challenge: Incomplete data for fish, stream temperature, flow

- Space
  - Many missing/unsampled catchments
- Time
  - Years, seasons within a year

Solution: broad spatial models

- Estimate unsampled locations, times

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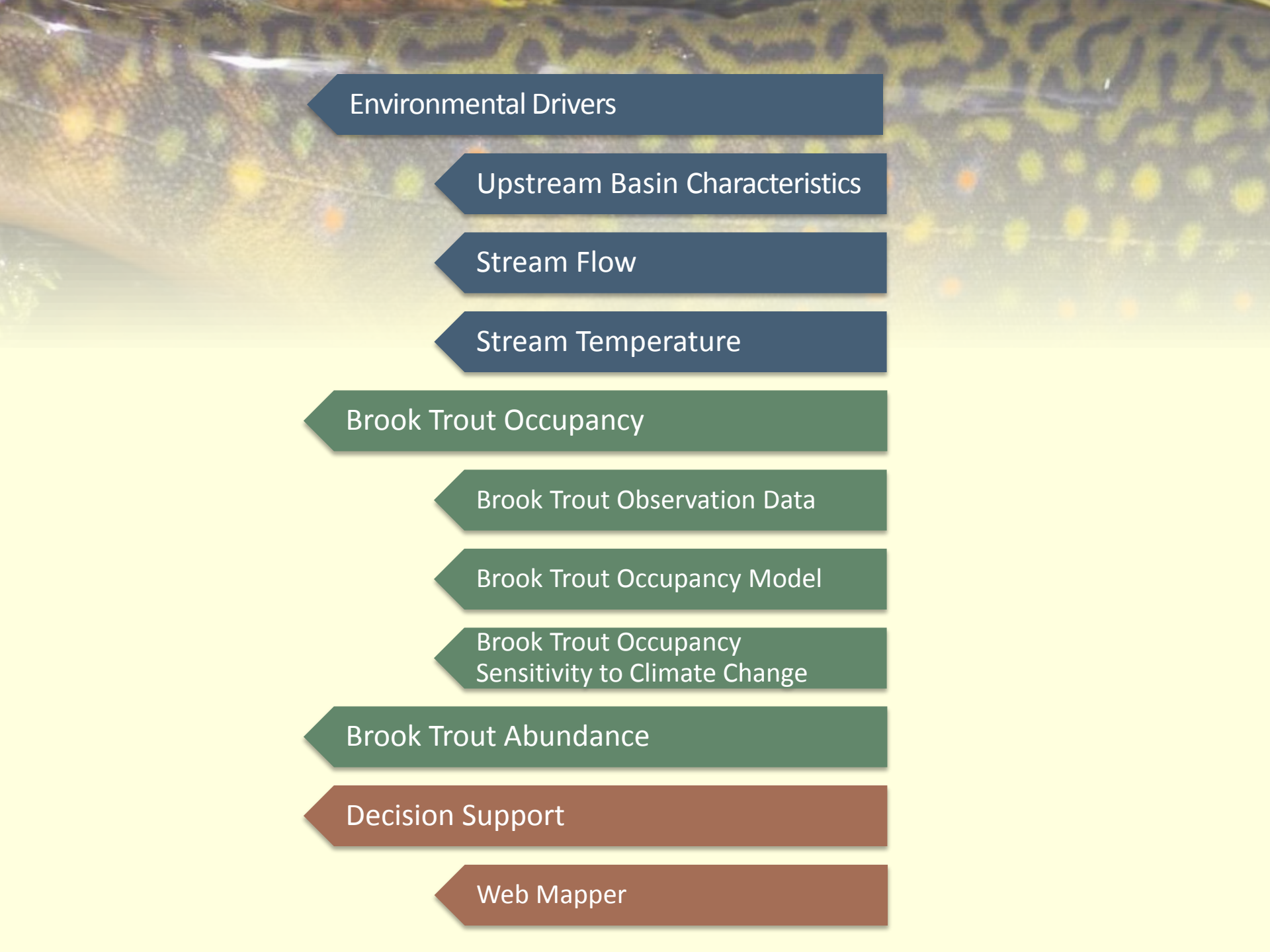
Decision Support

- Make results accessible and relevant to management decisions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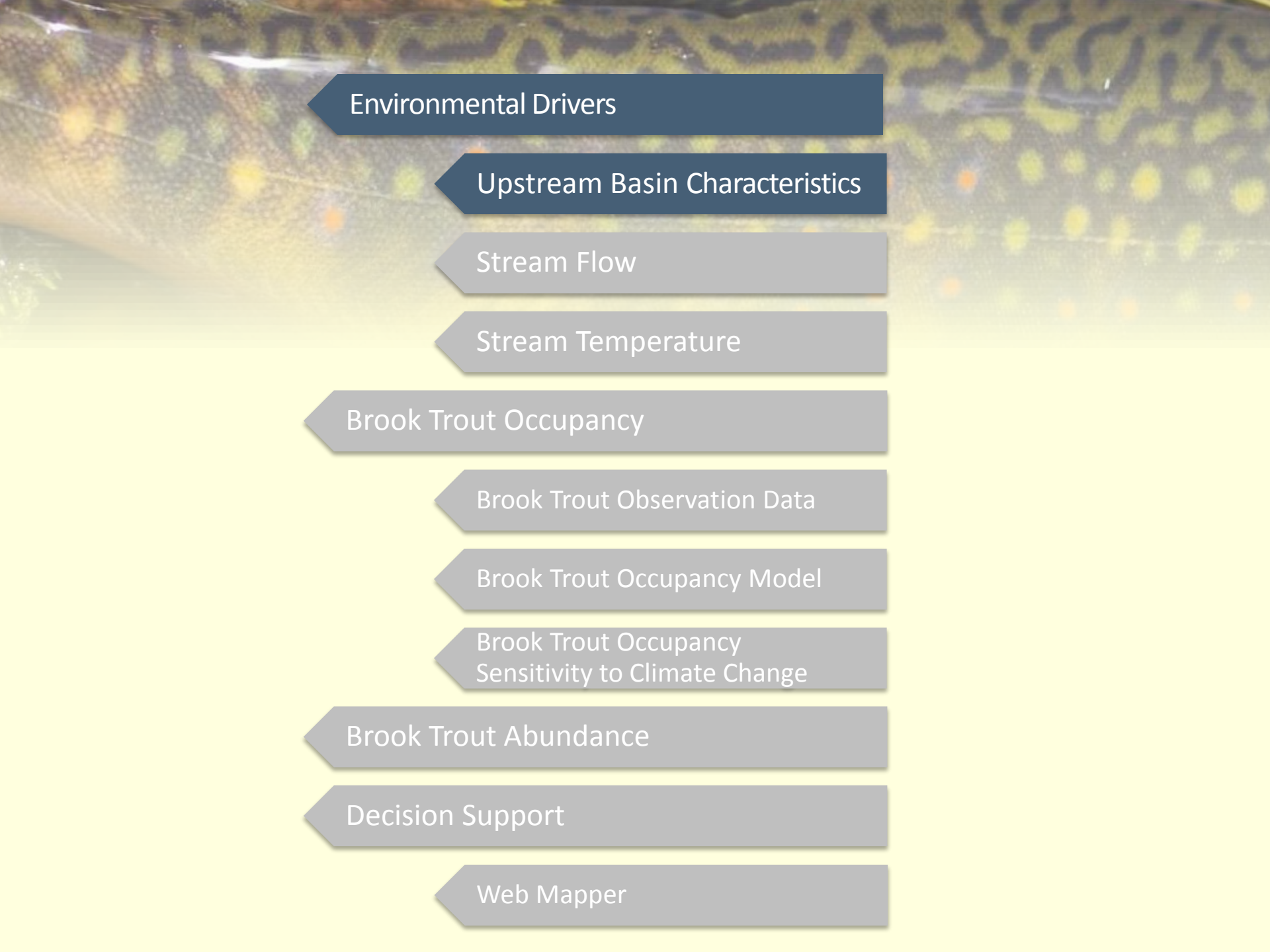
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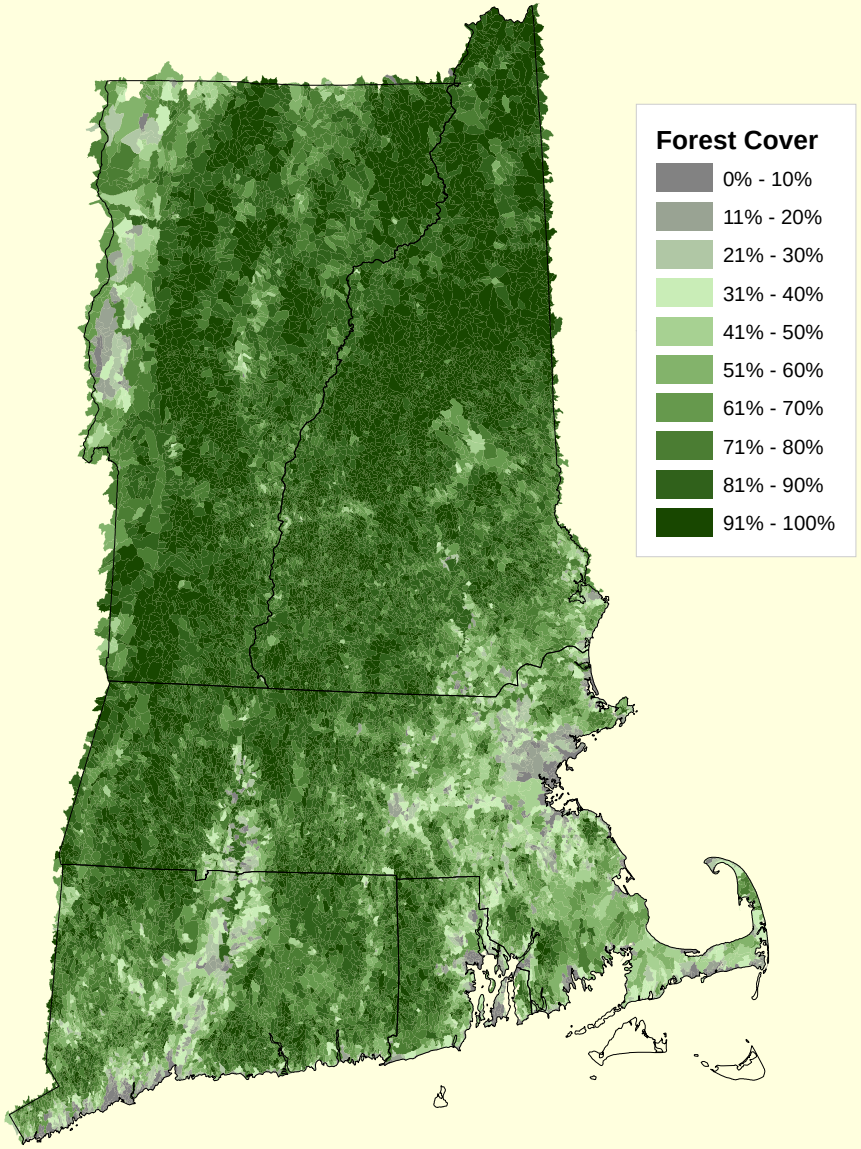

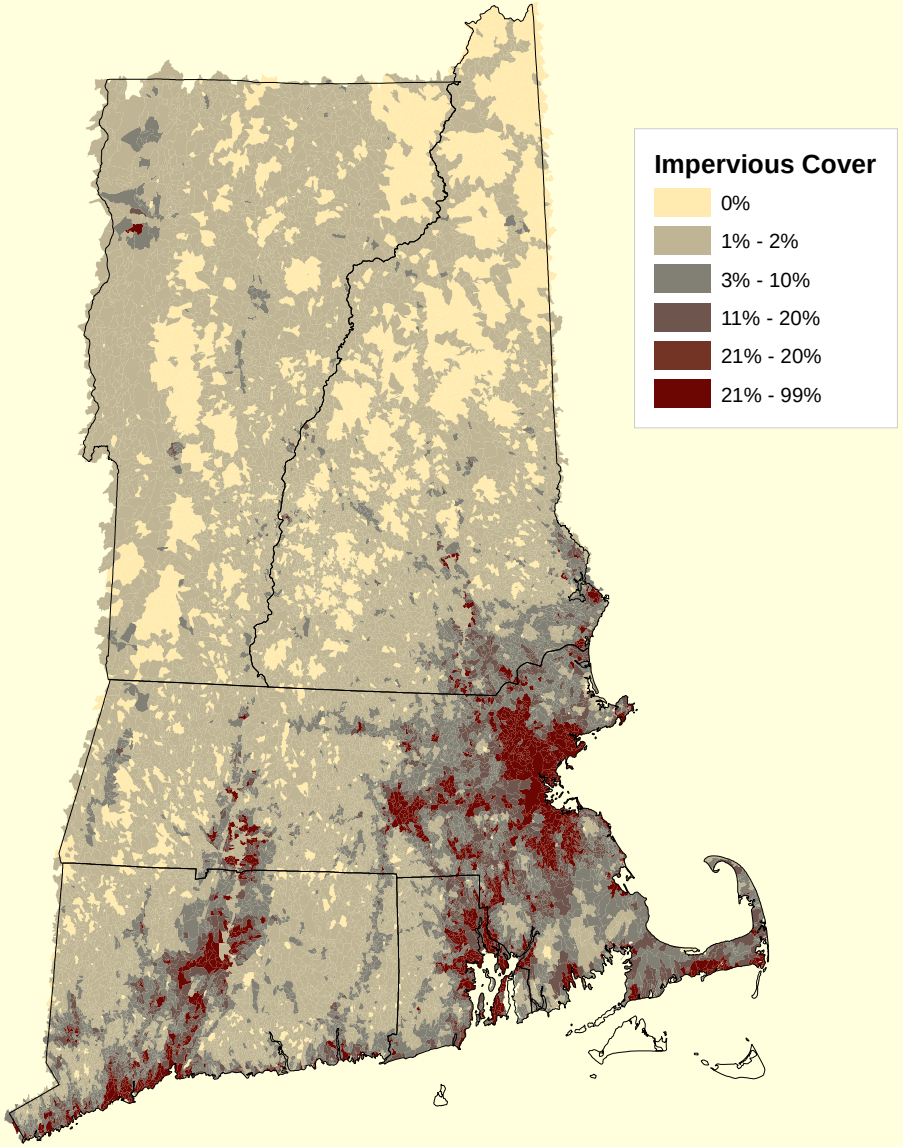

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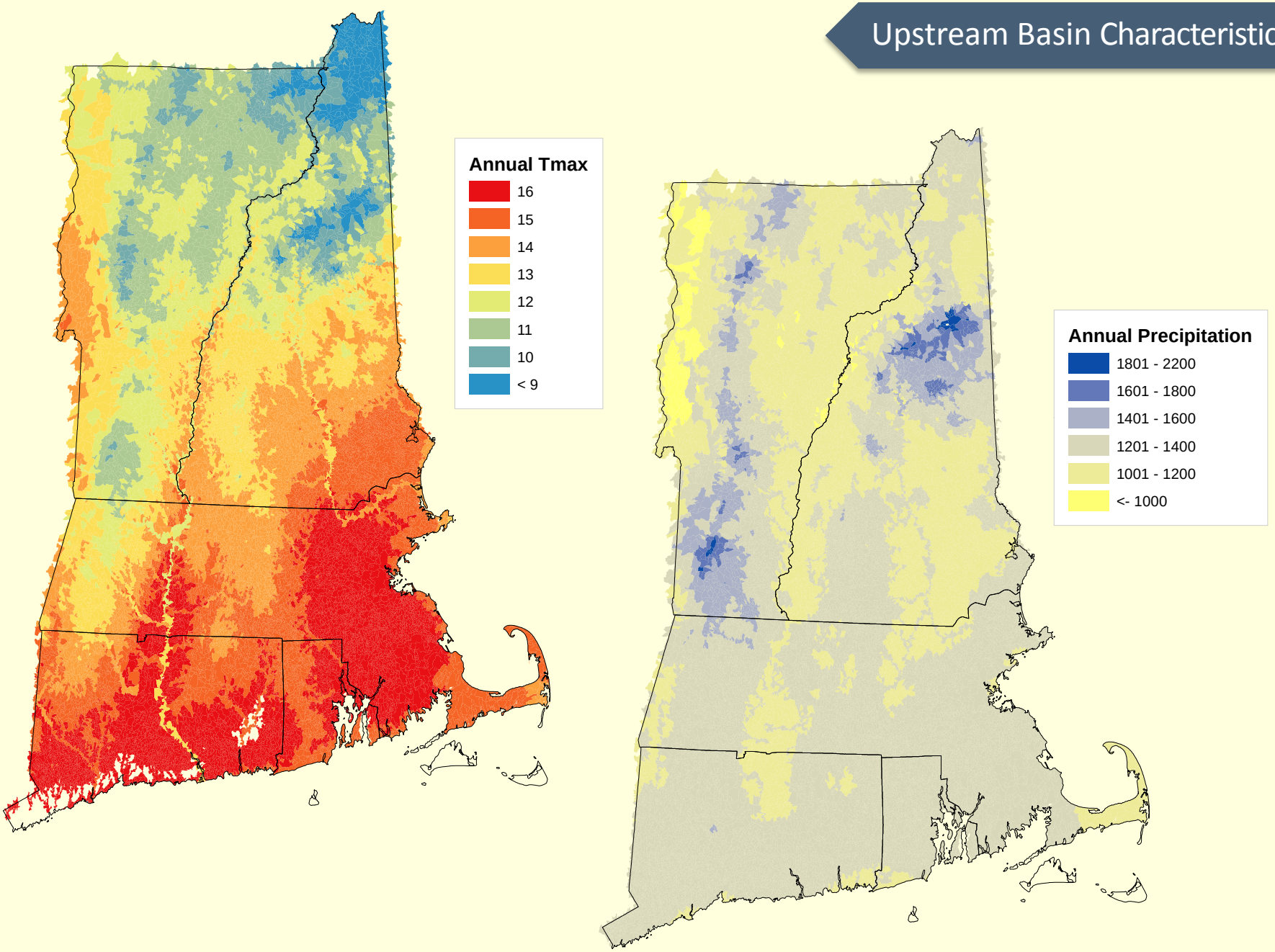

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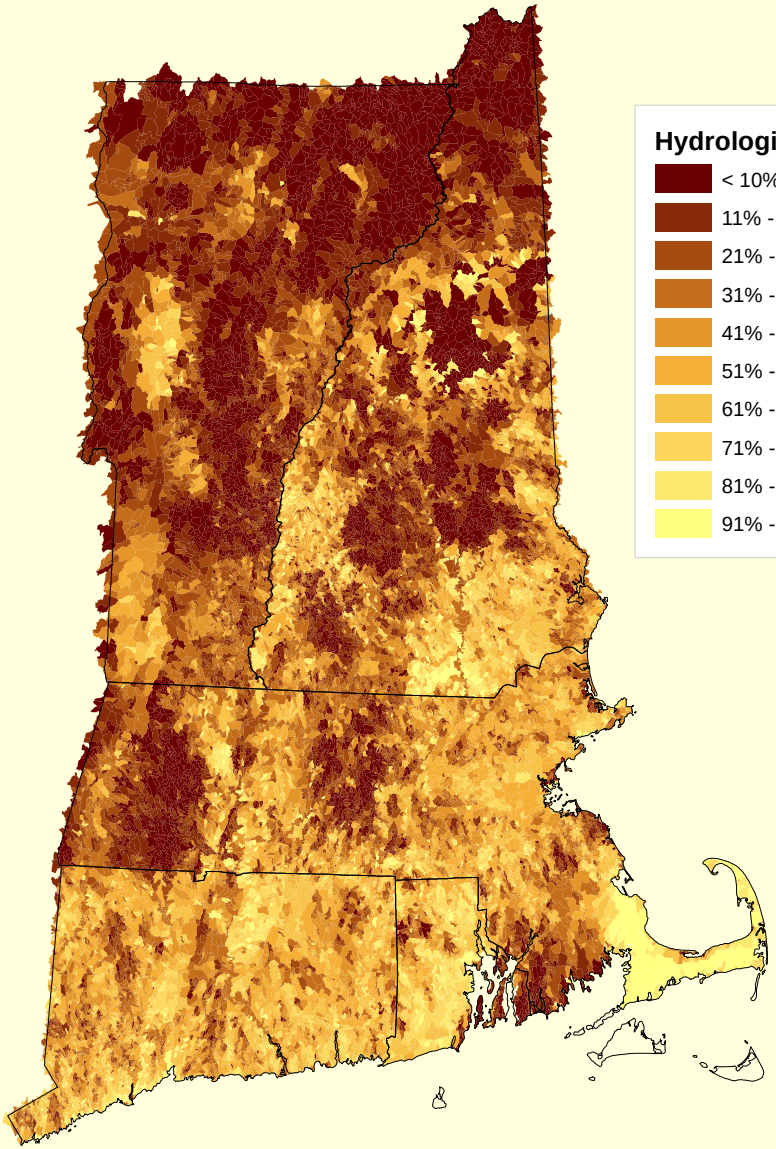

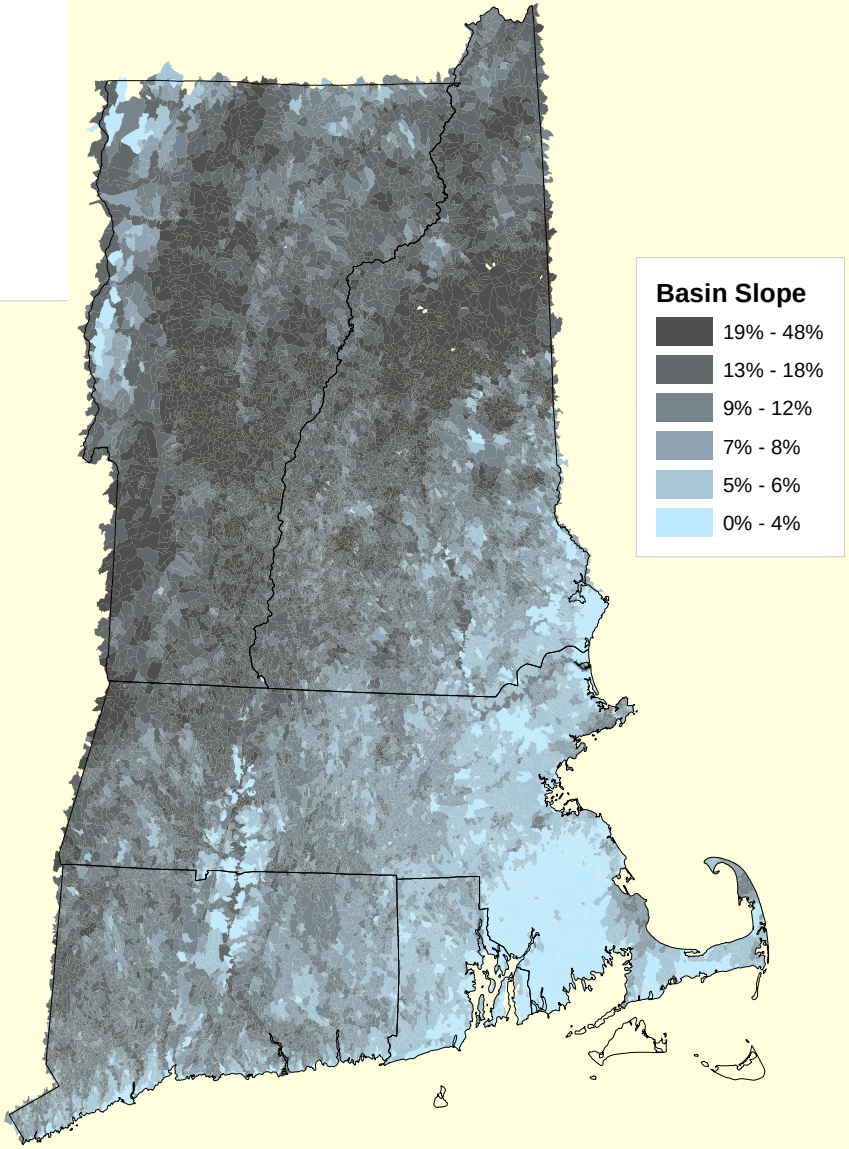

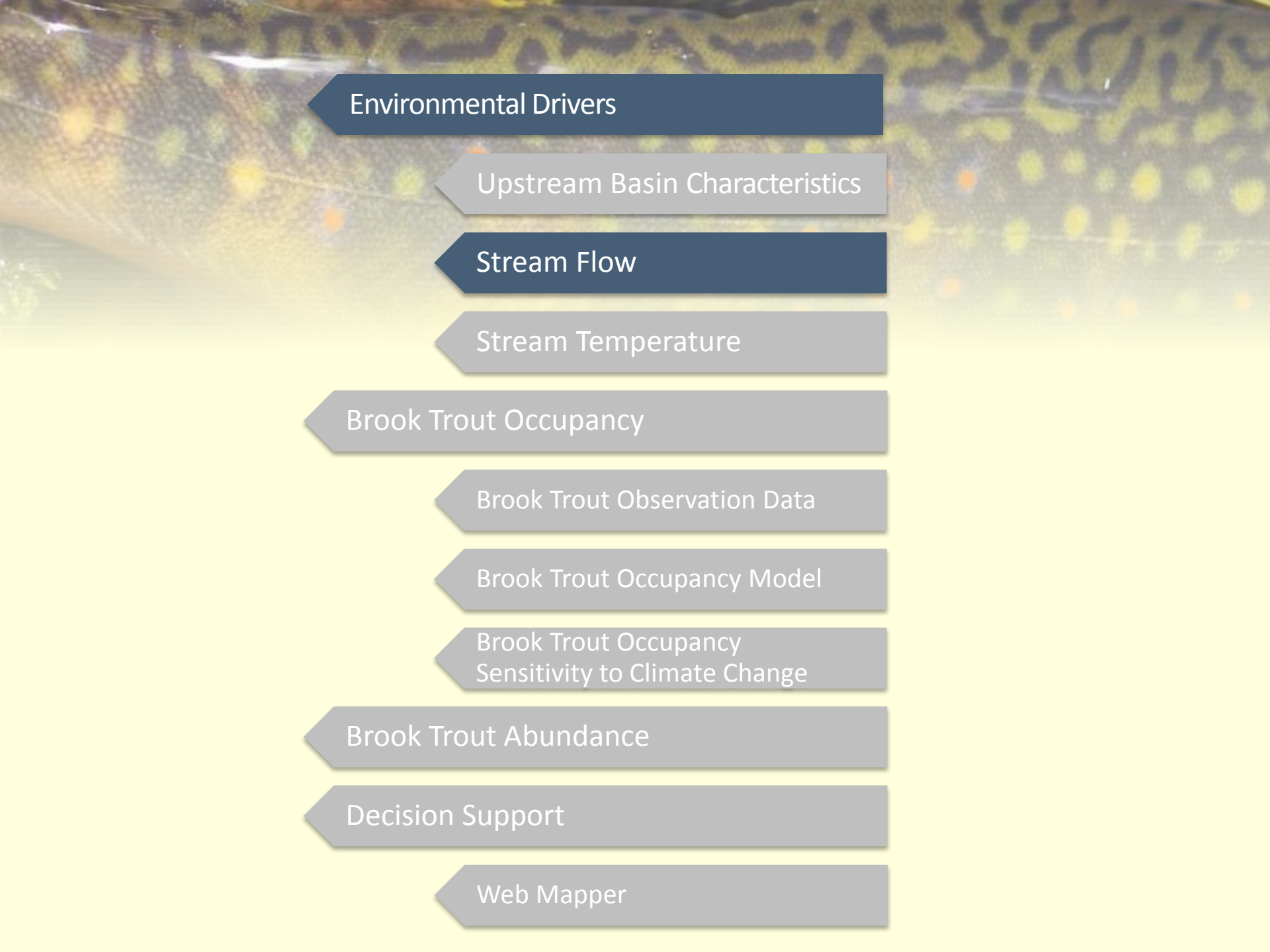
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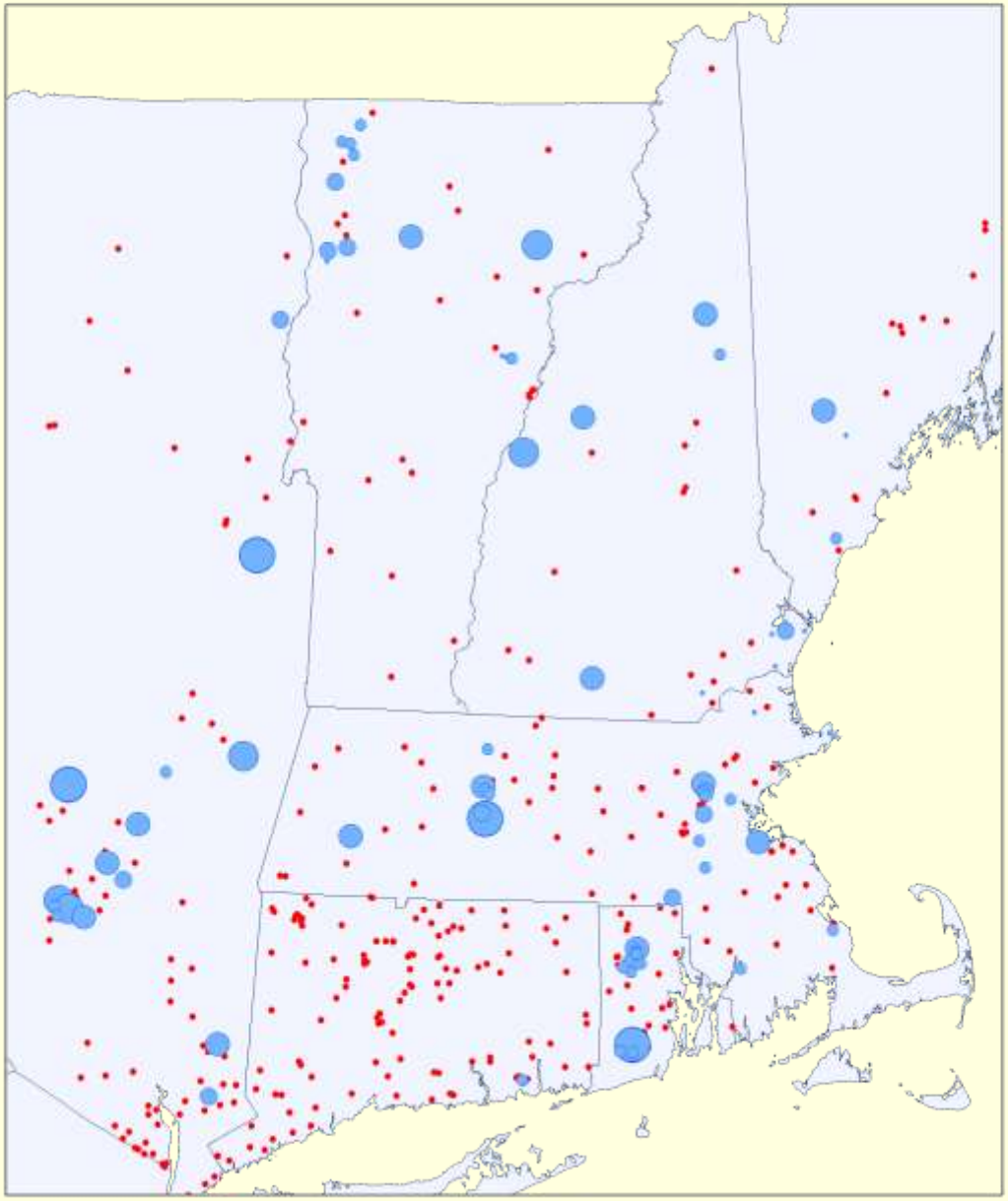
Stream Flow



Focus on smaller basins

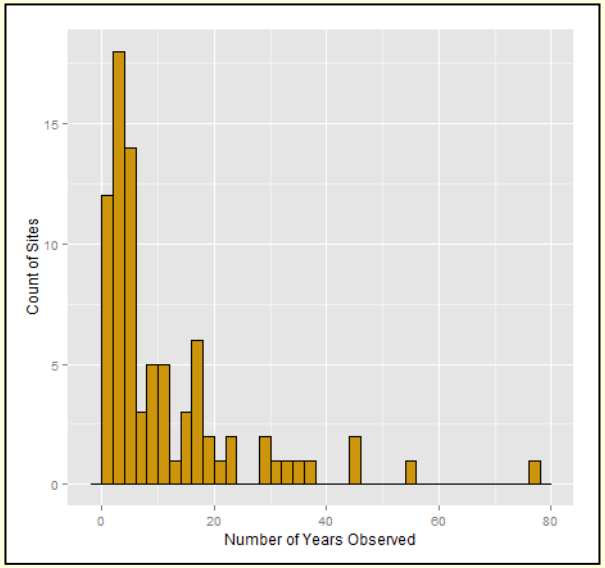
- Tailored for analysis of headwater ecosystems

Due to data scarcity for small basins, include

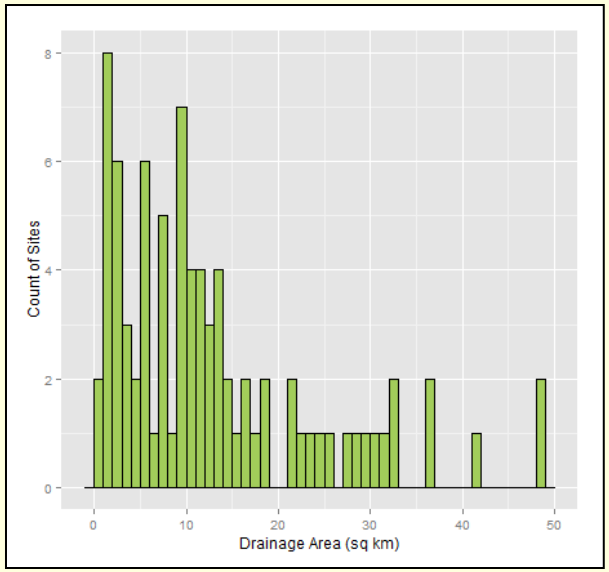
- Sites with short periods of record
- Sites with some small upstream dams or impoundments

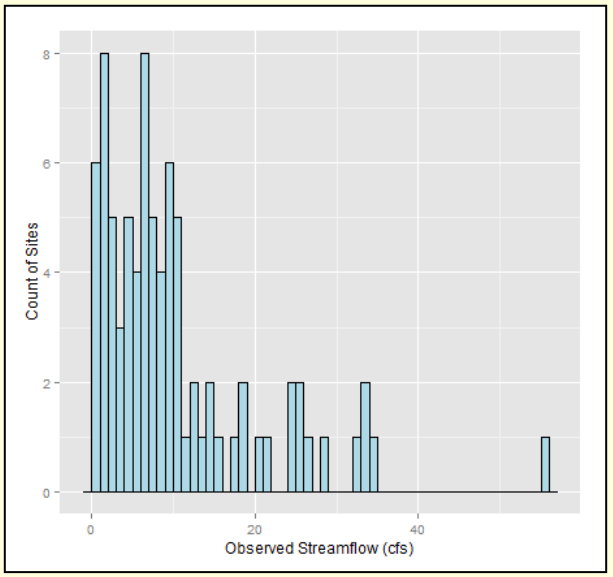
Streamflow gaged data used for statistical streamflow model

Number of Years Observed



Basin size and mean streamflow





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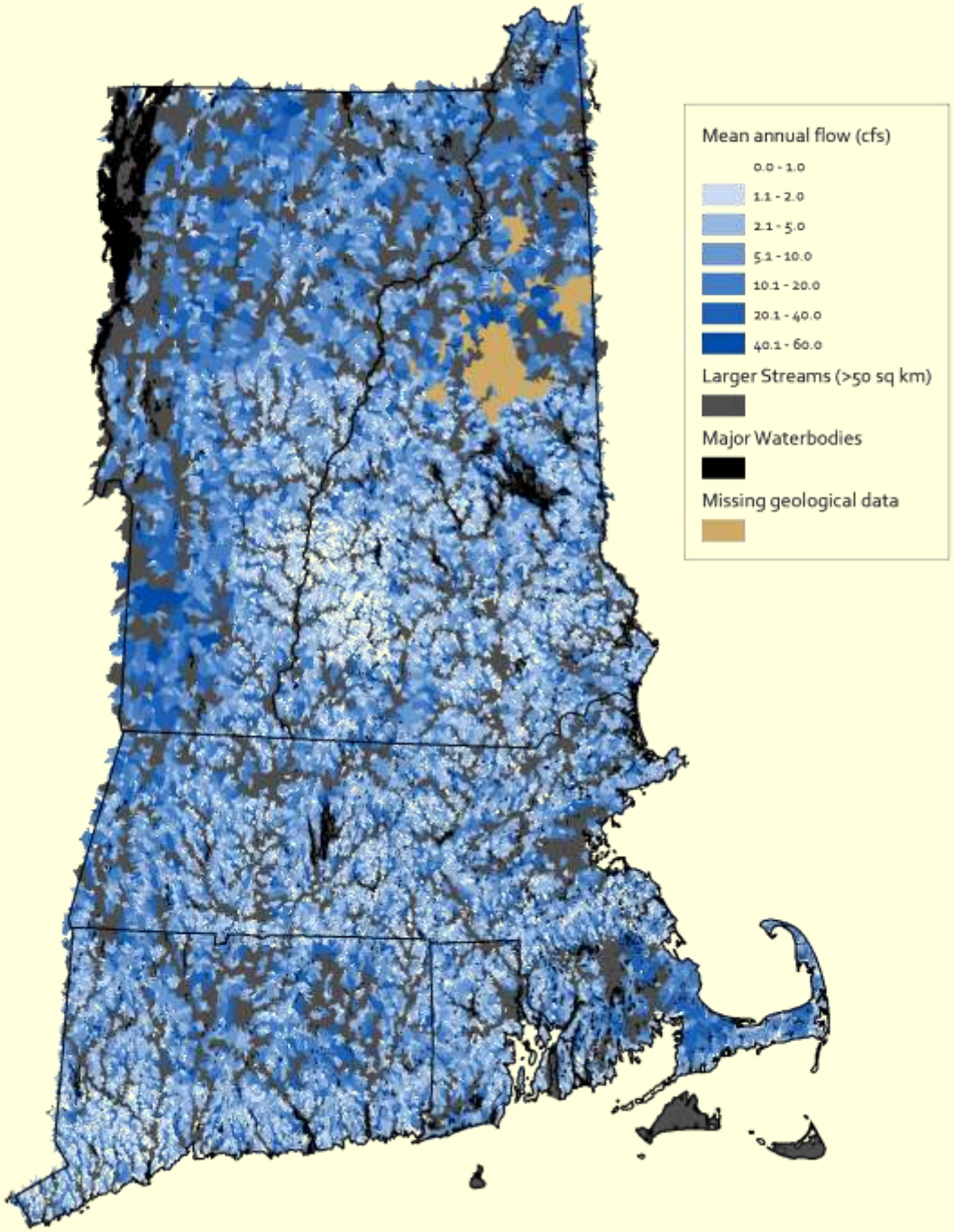


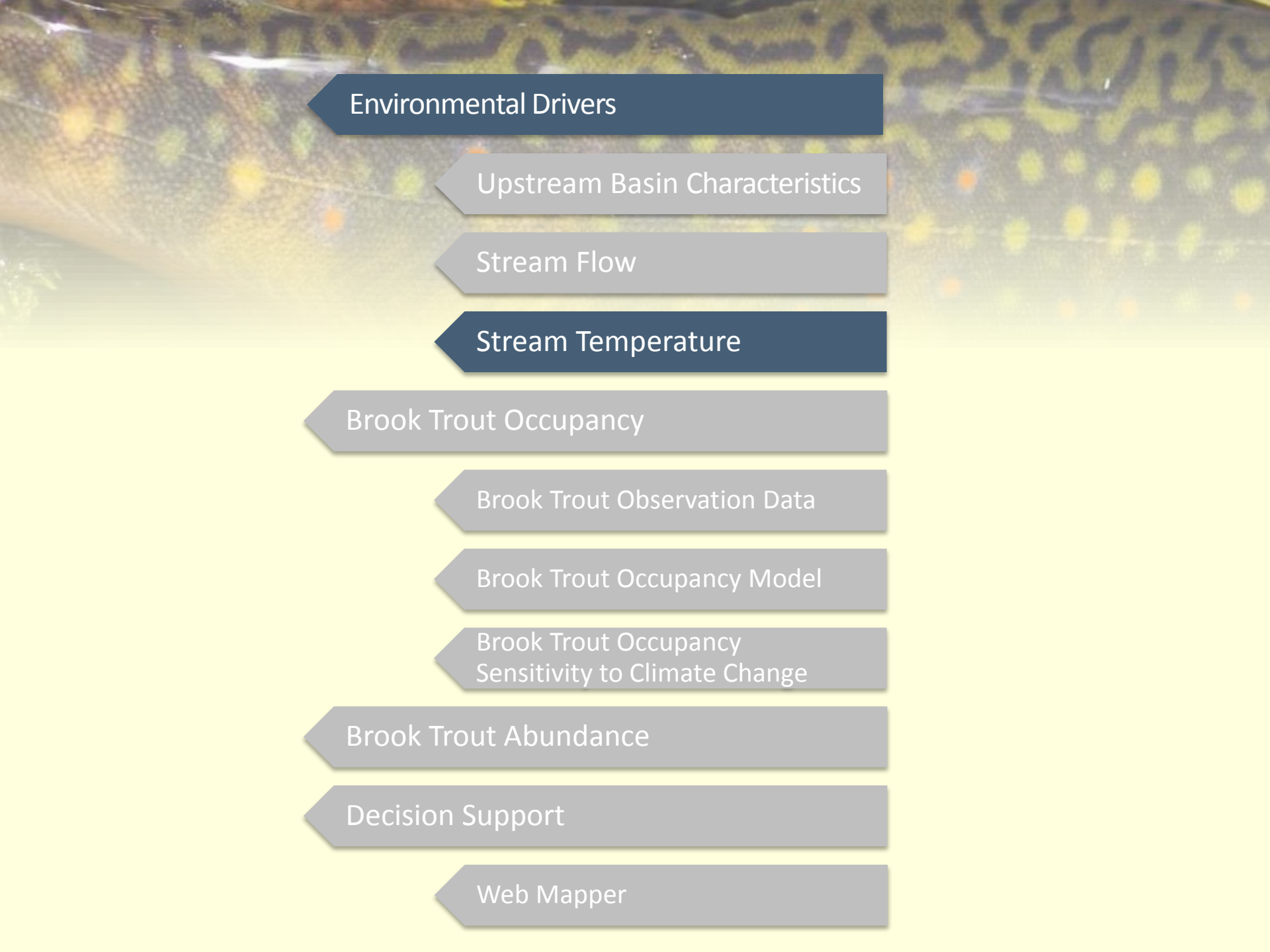
Weighted Least Squares model of long-term mean annual flow and other inter-annual statistics

Driven by basin characteristics:

Drainage area	+
Precipitation	+
Developed Area	-
Hydrologic Soils A & B	-

R-squared: ~ 95%
(for mean annual flow)

Additional model under development includes year-specific meteorological data, to better utilize sites with short records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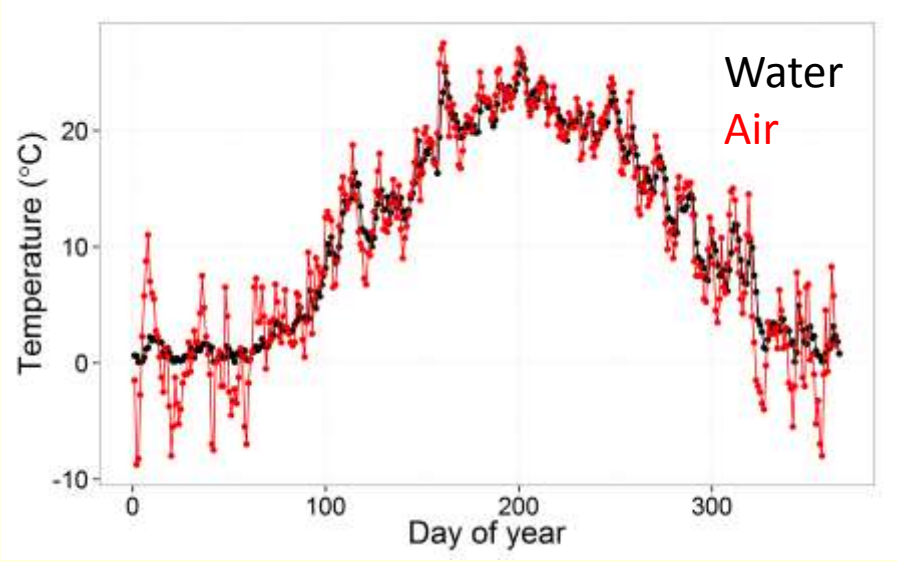
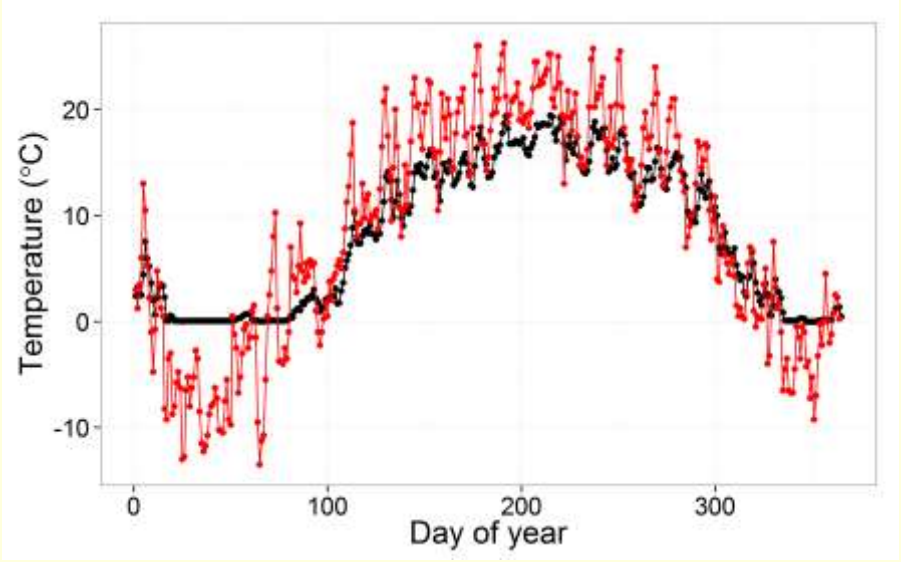
Stream Temperature

Stream 1

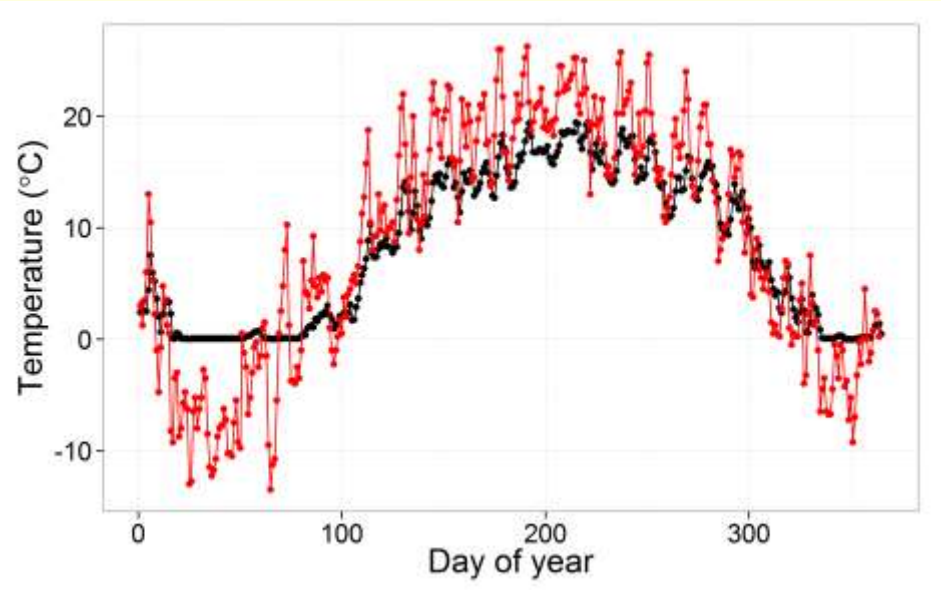


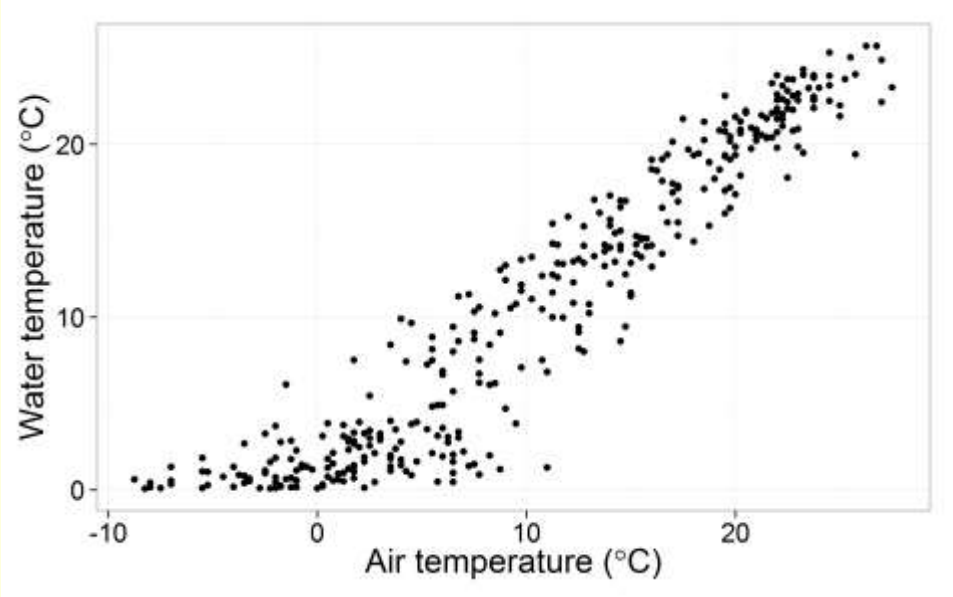
Stream 2



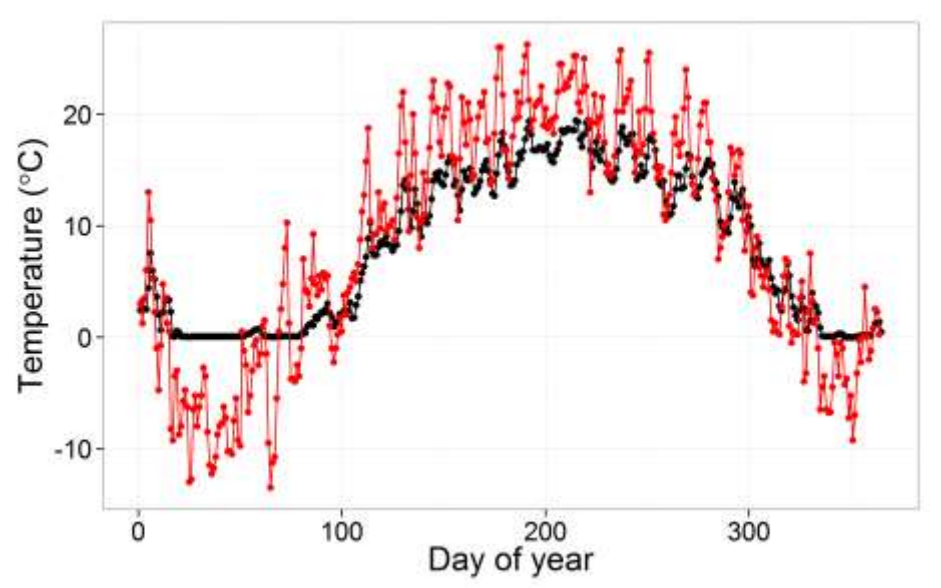
Can we model year-round stream temperature as a function of air temperature and catchment characteristics?

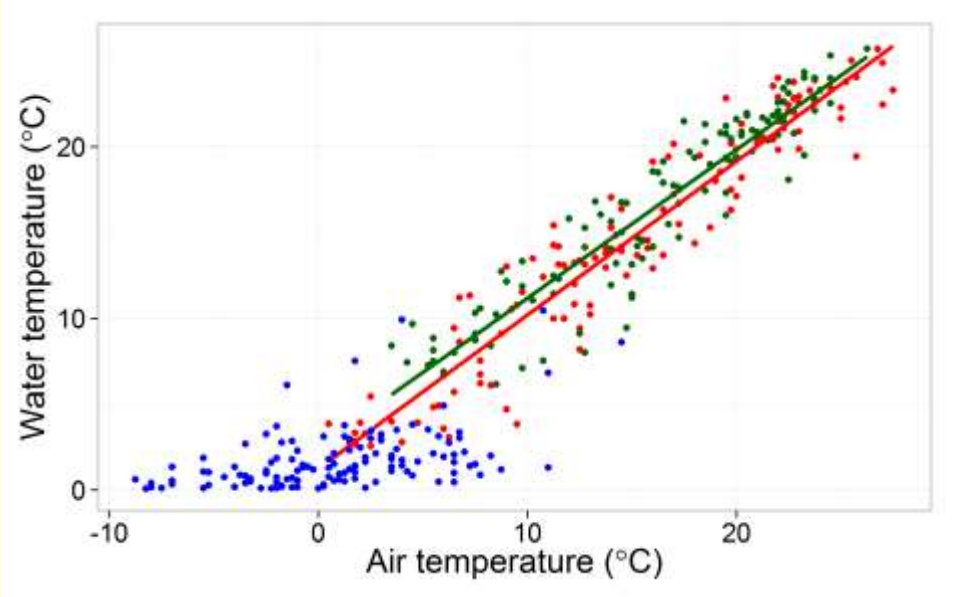
Stream Temperature





Stream Temperature

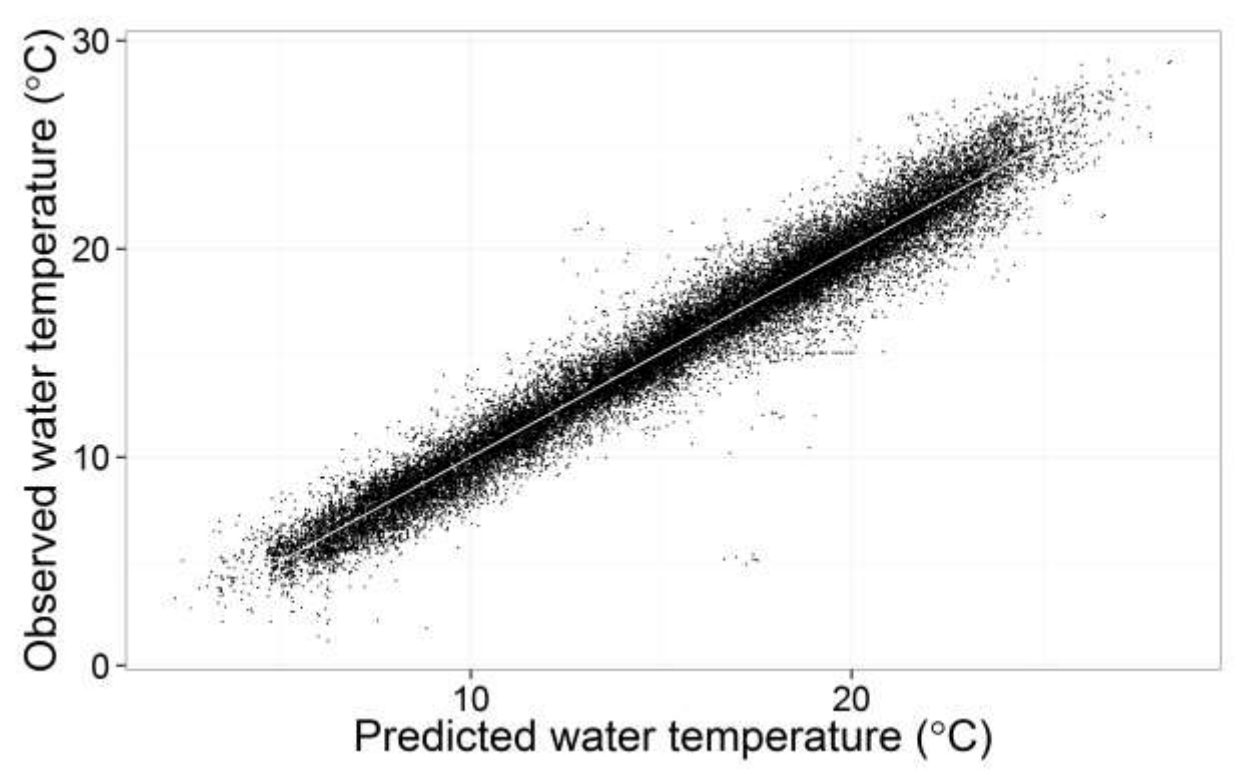




Synchronization approach

➔Advantages

- Good daily estimates for spring-fall (primary ecological concern)
- Can use partial-year data
- Useful metrics



R^2 = 0.96, RMSE =1.0 ^oC

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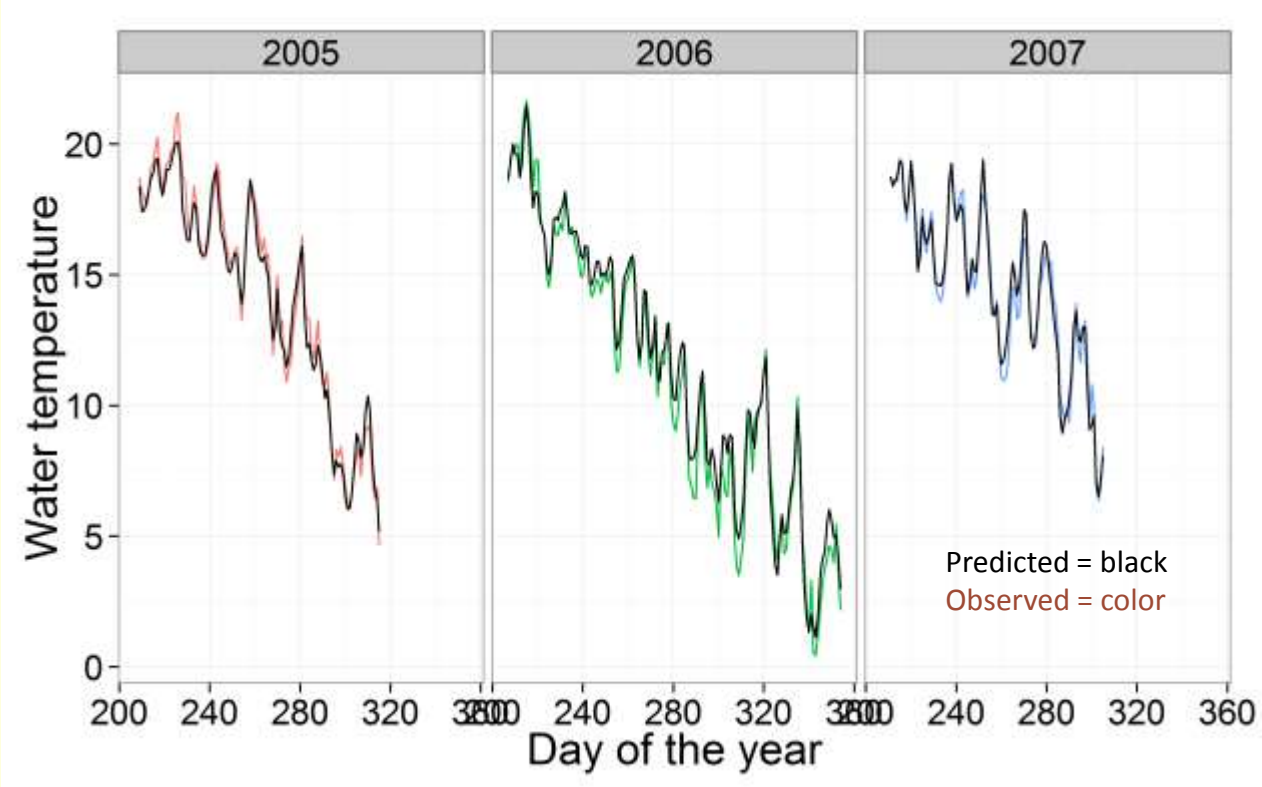
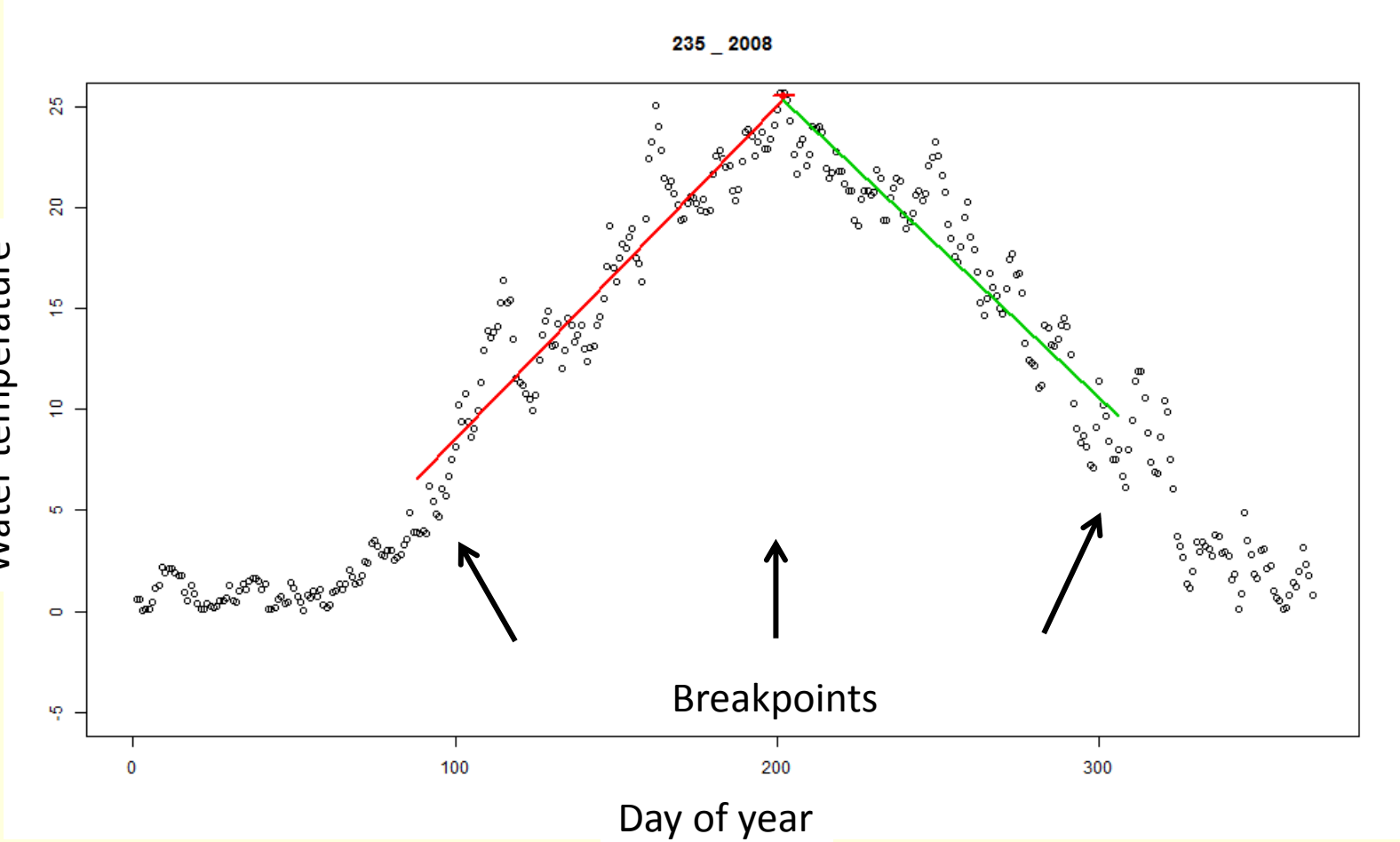
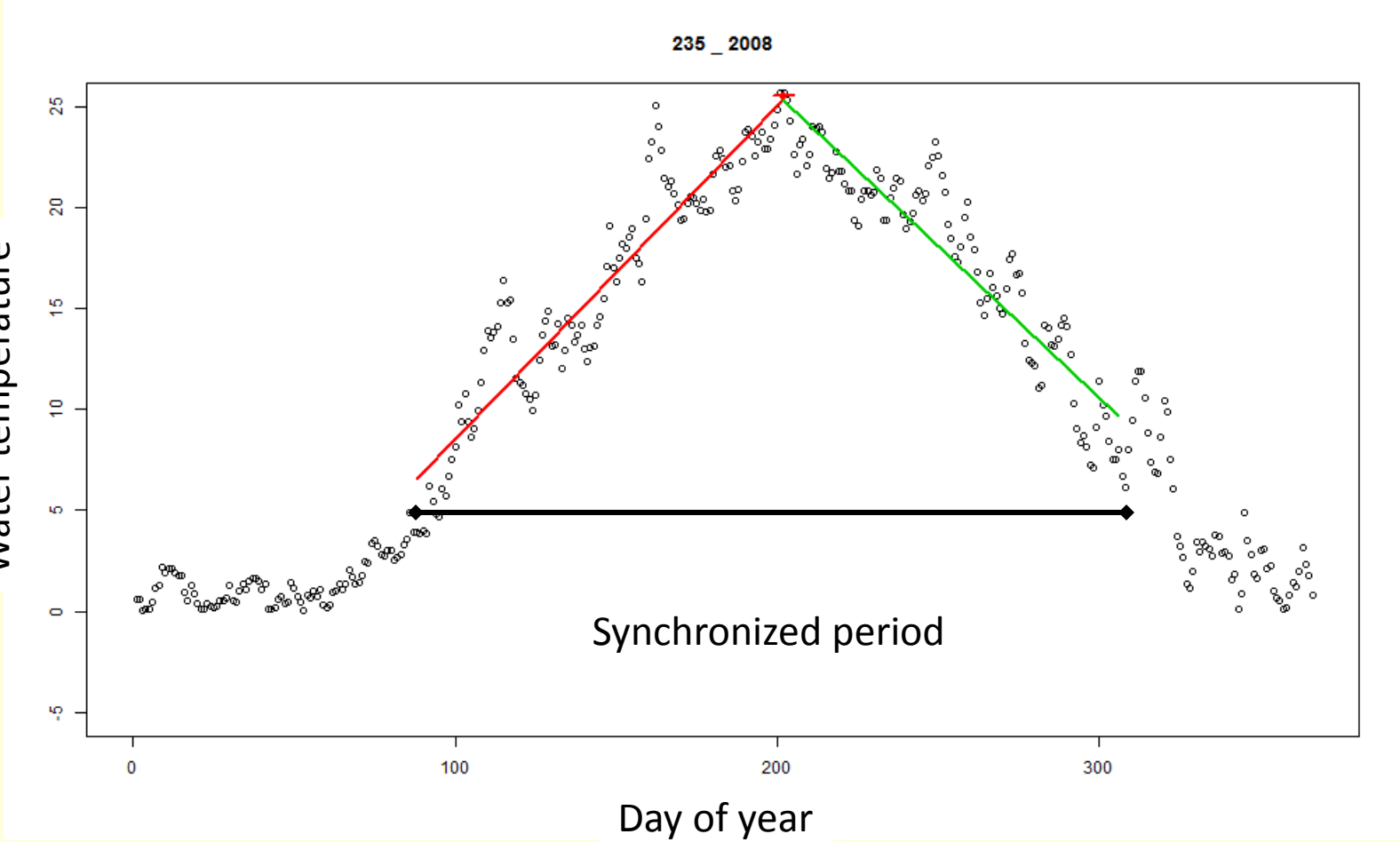


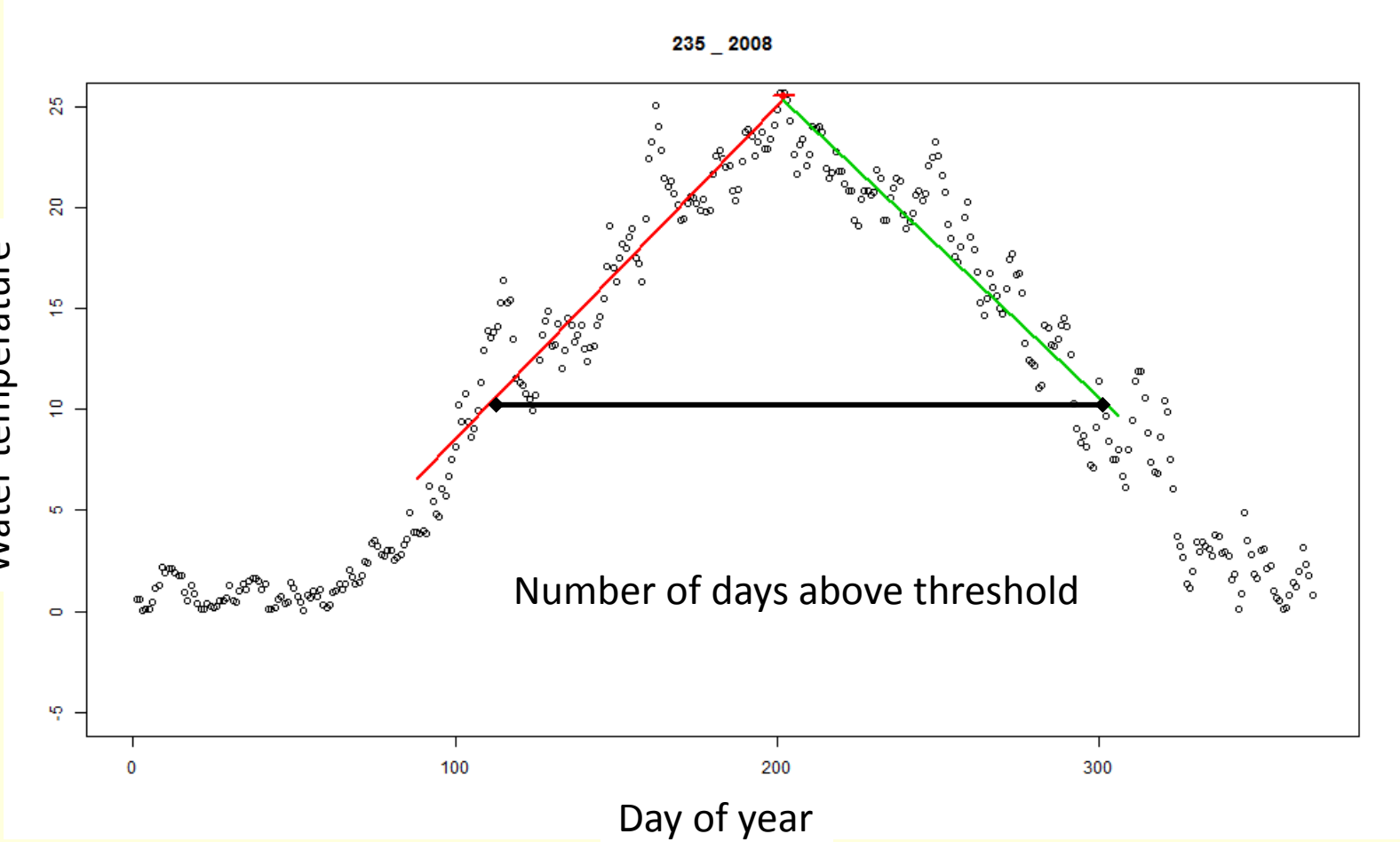
Metrics


235 _ 2008
Water temperature
25
20
15
10
5
0
-5
0
100
200
300
Day of year
Breakpoints

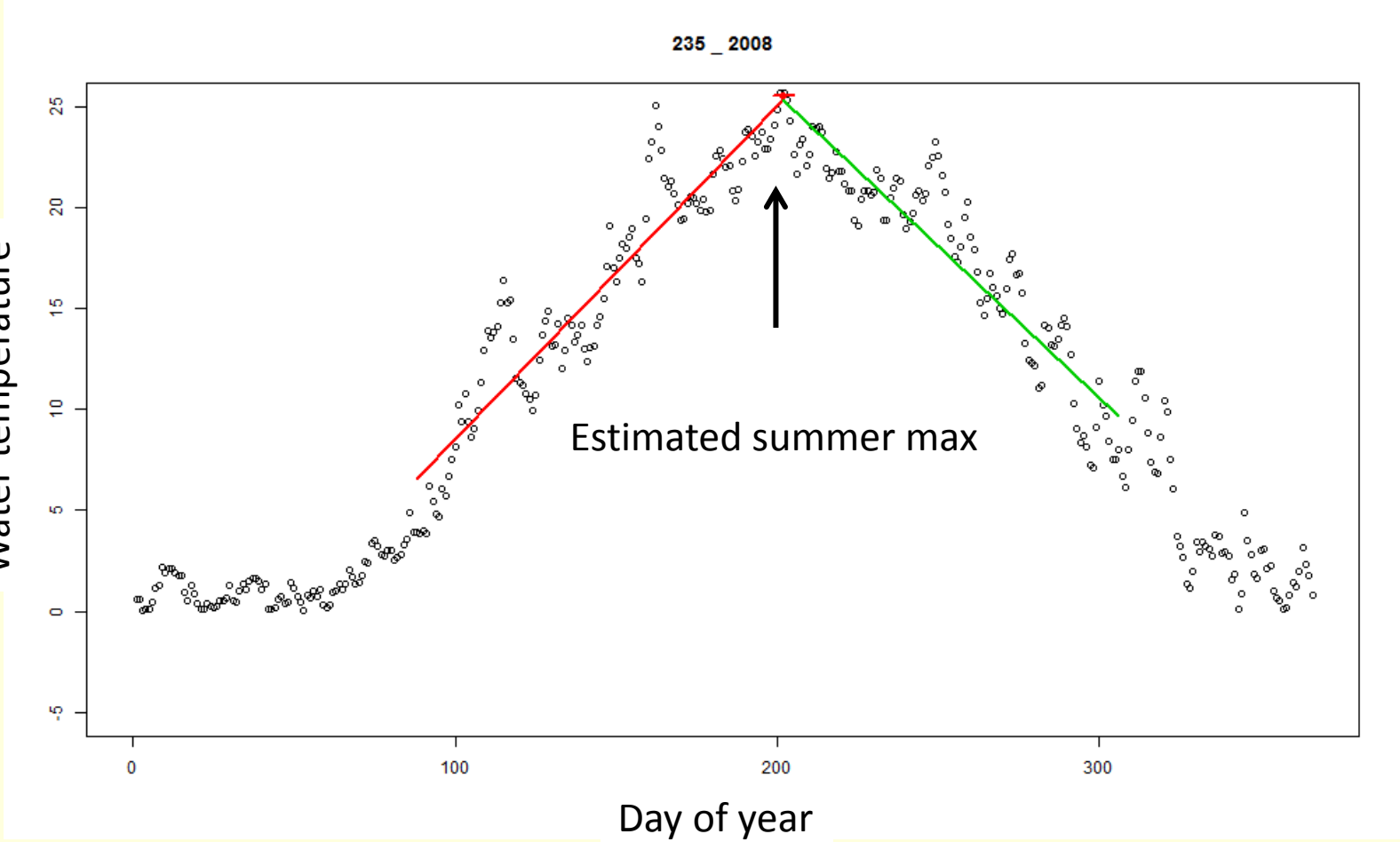
Metrics


235 _ 2008
Water temperature
25
20
15
10
5
0
-5
0
100
200
300
Day of year
Synchronized period

Metrics

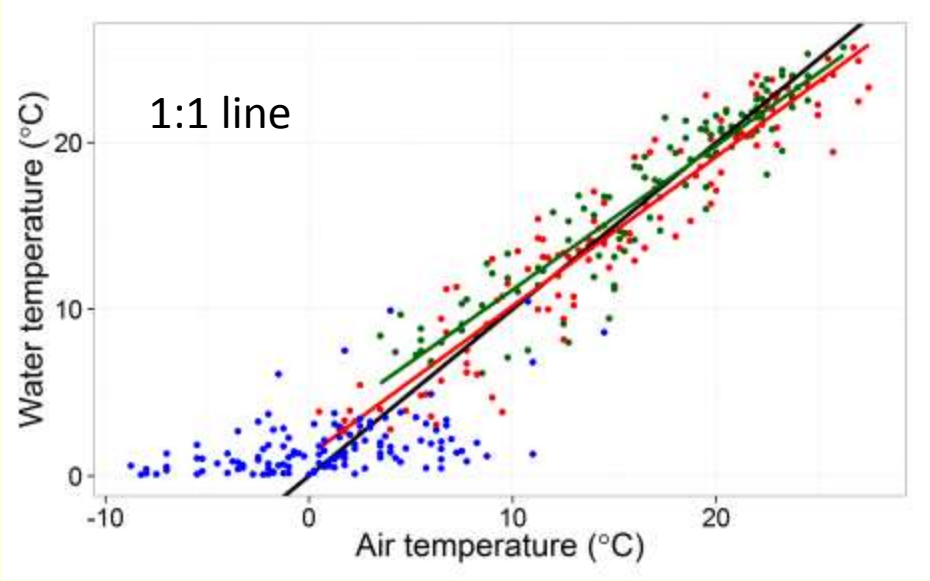

235 _ 2008
Water temperature
25
20
15
10
5
0
-5
0
100
200
300
Day of year
Number of days above threshold

Metrics

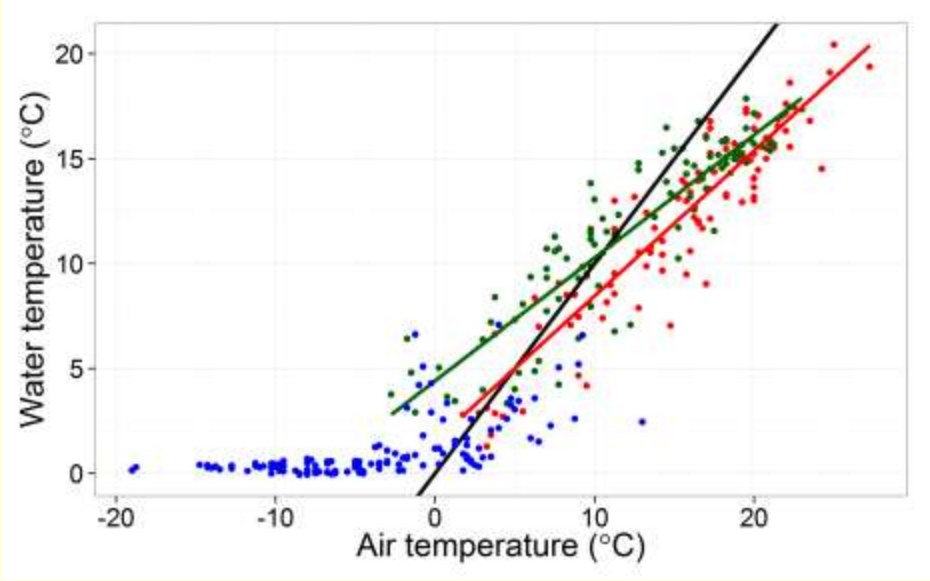

235 _ 2008
Water temperature
Day of year
Estimated summer max
-5
0
5
10
15
20
25
0
100
200
300

Metrics

Less resilient



More resilient

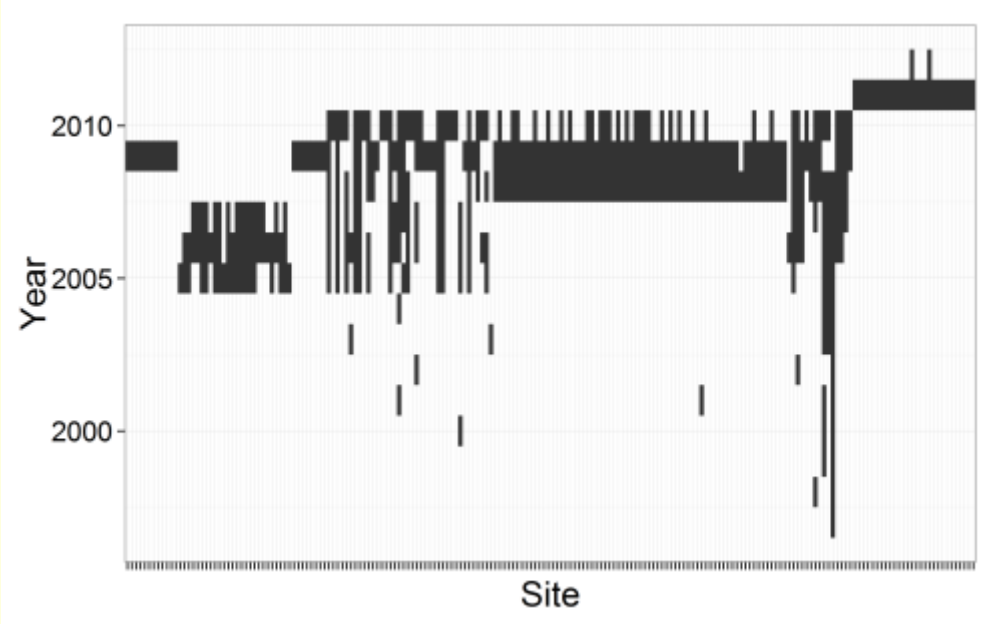


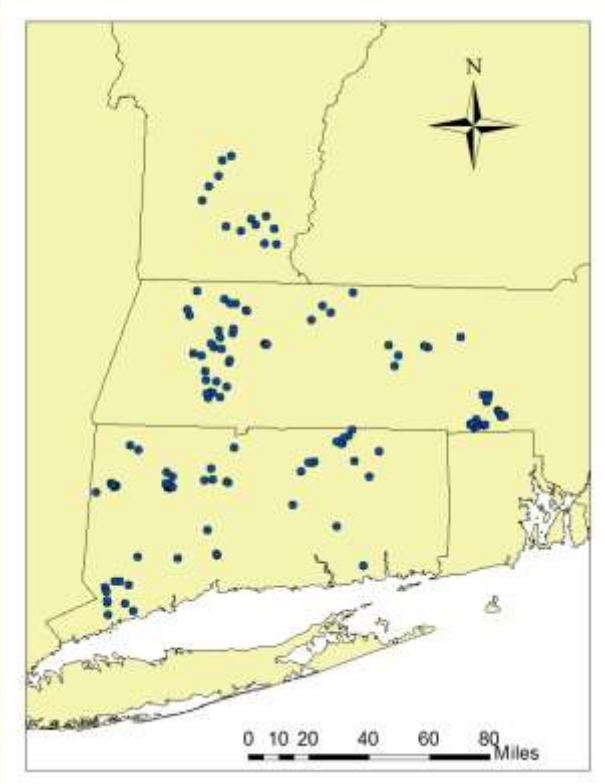
Slopes ~ resilience to air temperature change

Existing water temperature data

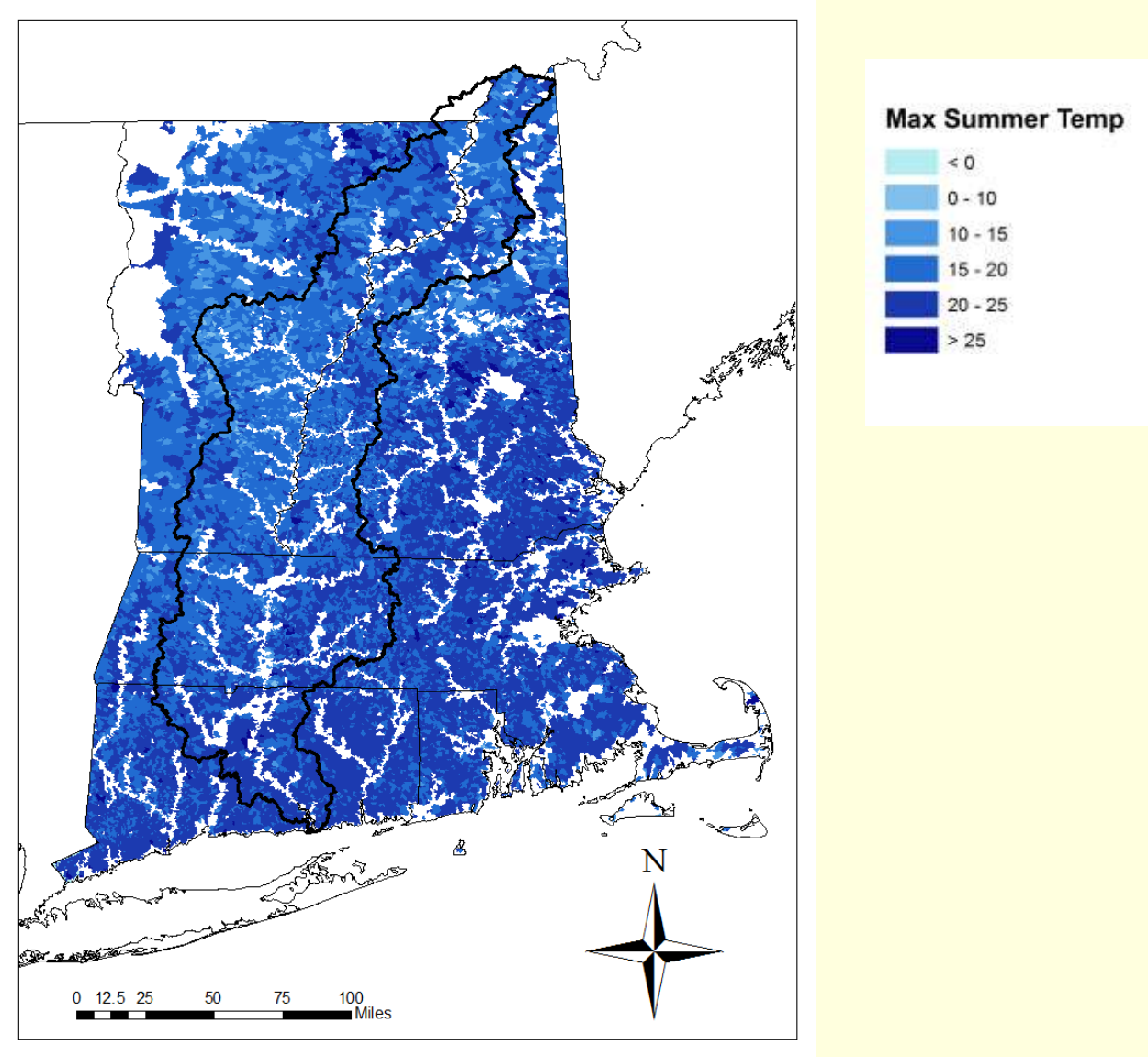
➔195 sites, scattered over 1997-2012

➔> 41,000 observations

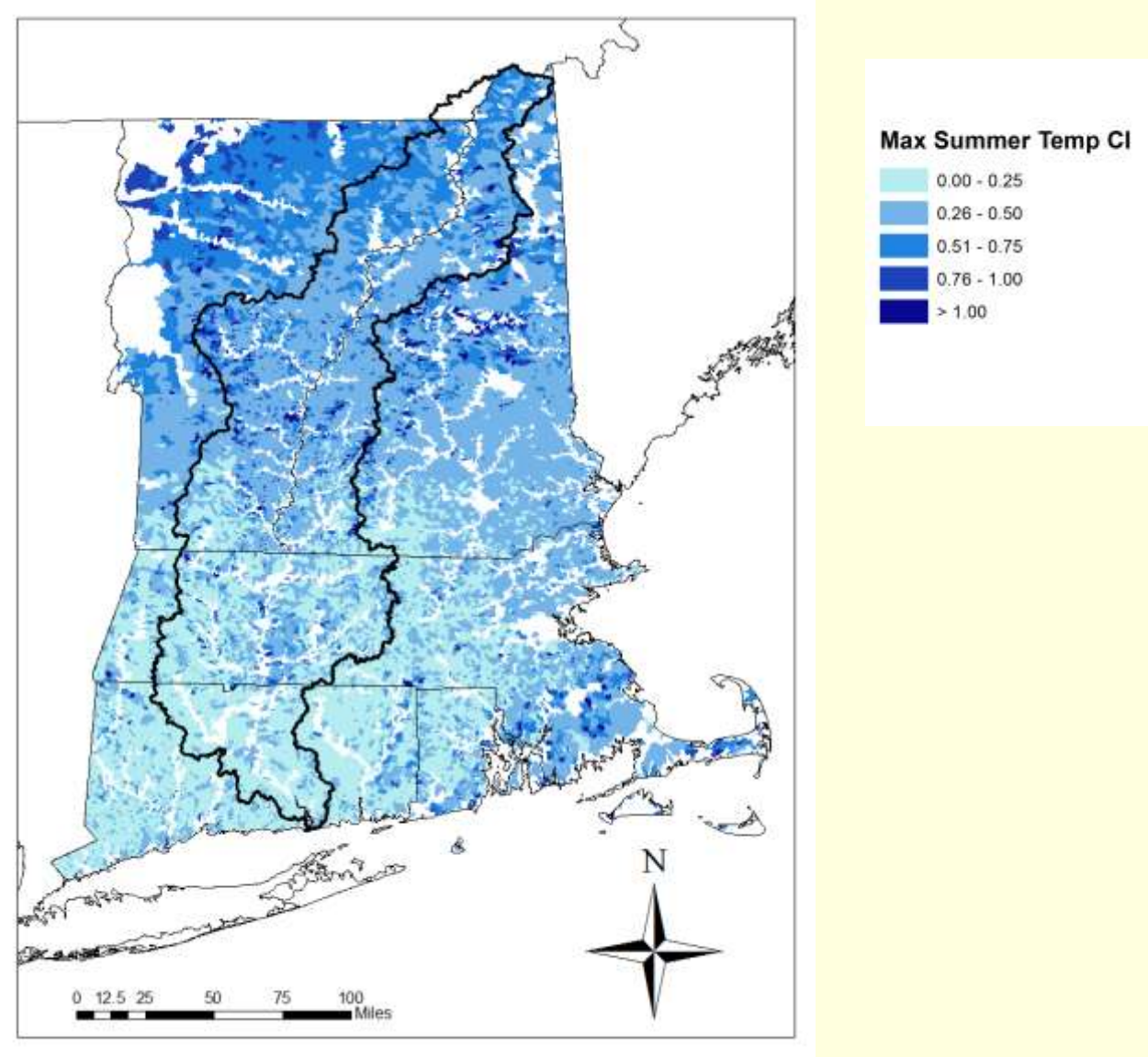




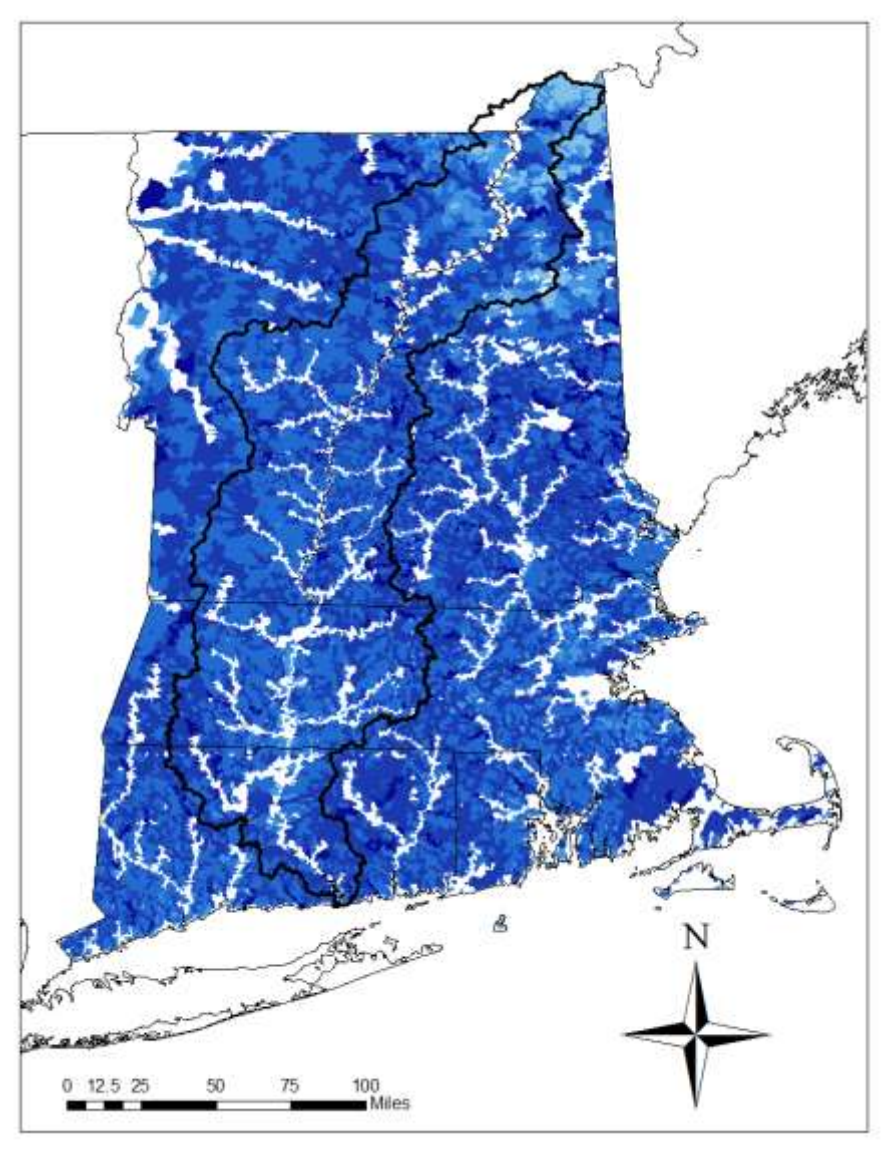
Summer Maximum Stream Temperature



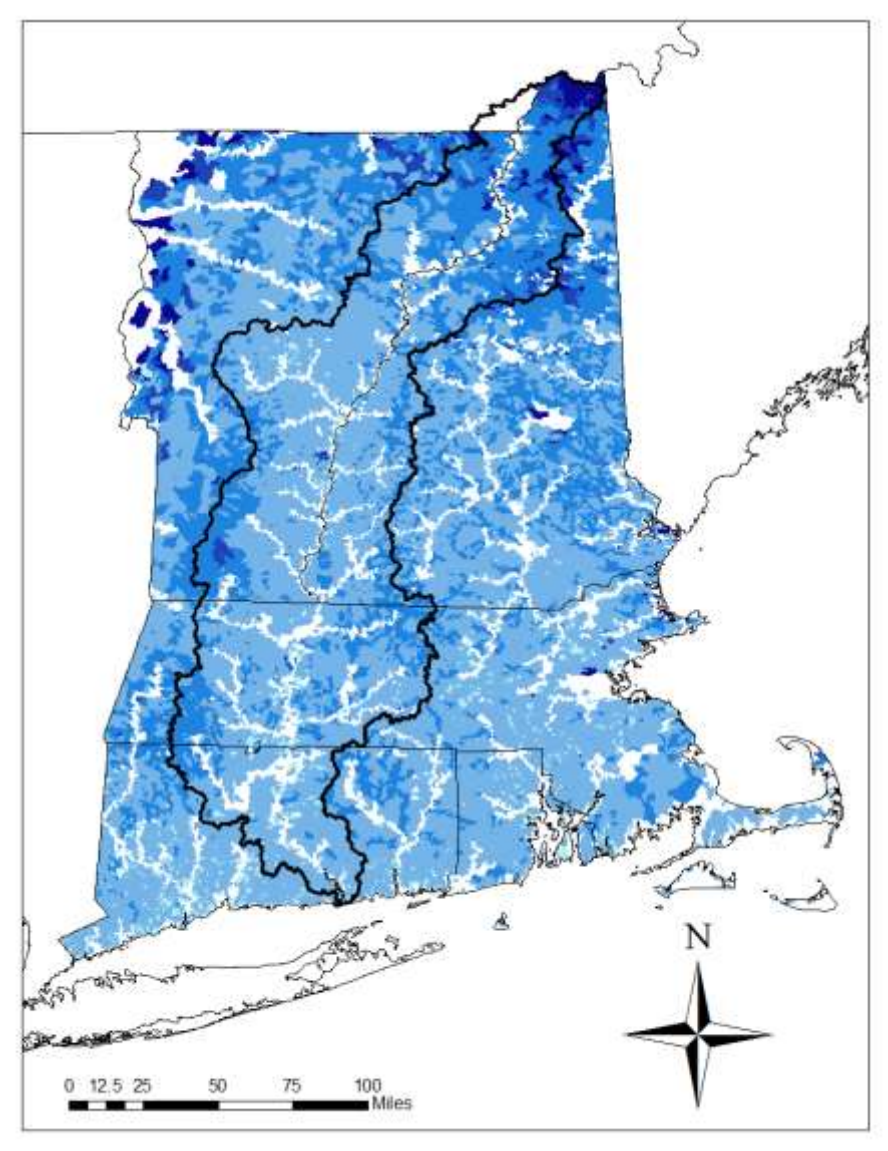
Summer Maximum Temperature Confidence Intervals

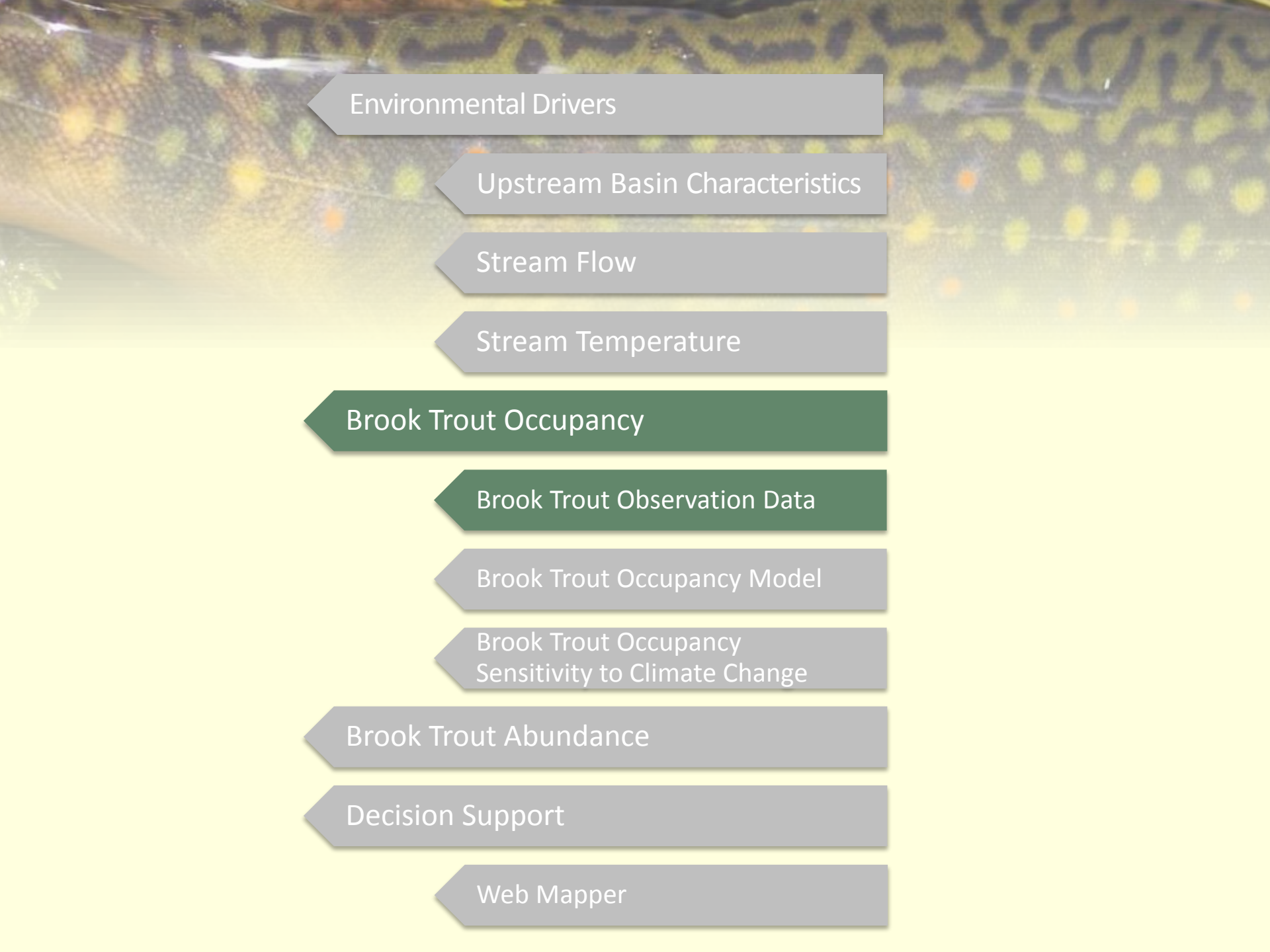


Stream Temperature Rising Slope



Rising Slope Confidence Intervals

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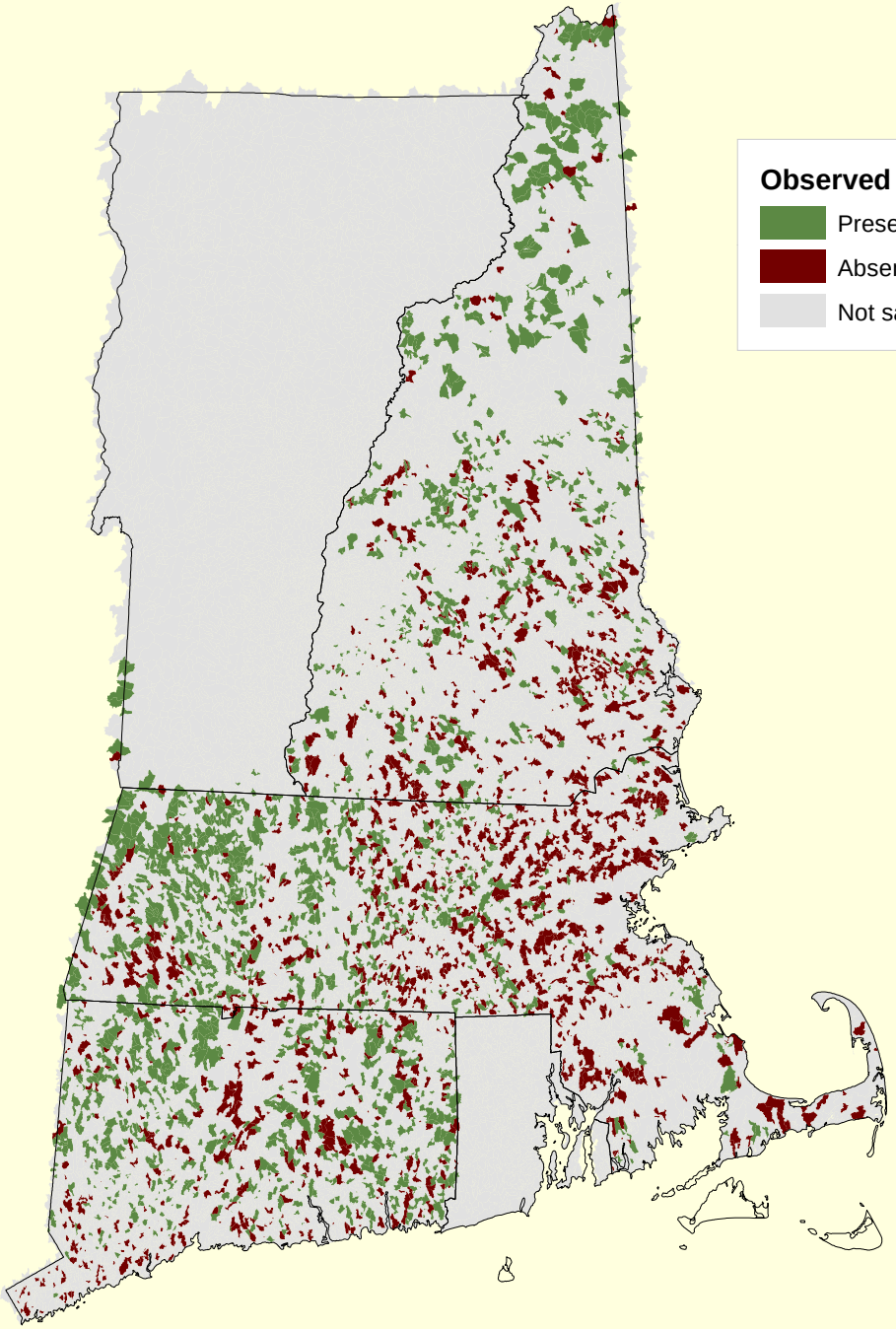

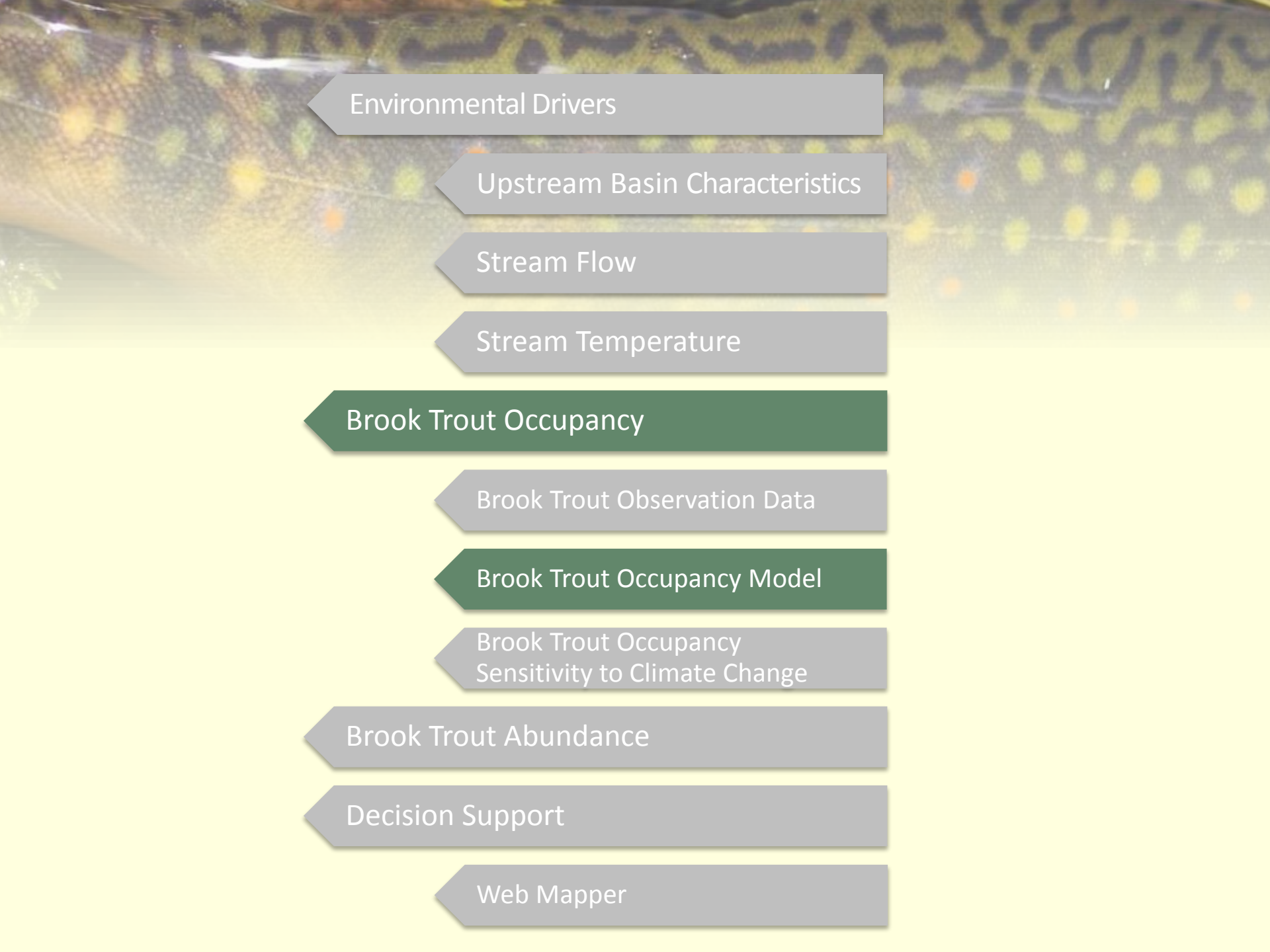
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- Mixed effect model
- Driven by stream and basin characteristics

- Two versions of model
  1. Driven by climate conditions
     - More clearly demonstrates climate impacts
     - Precipitation and Air Temperature
  2. Driven by stream conditions
     - Uses modeled stream flow and stream temperature values

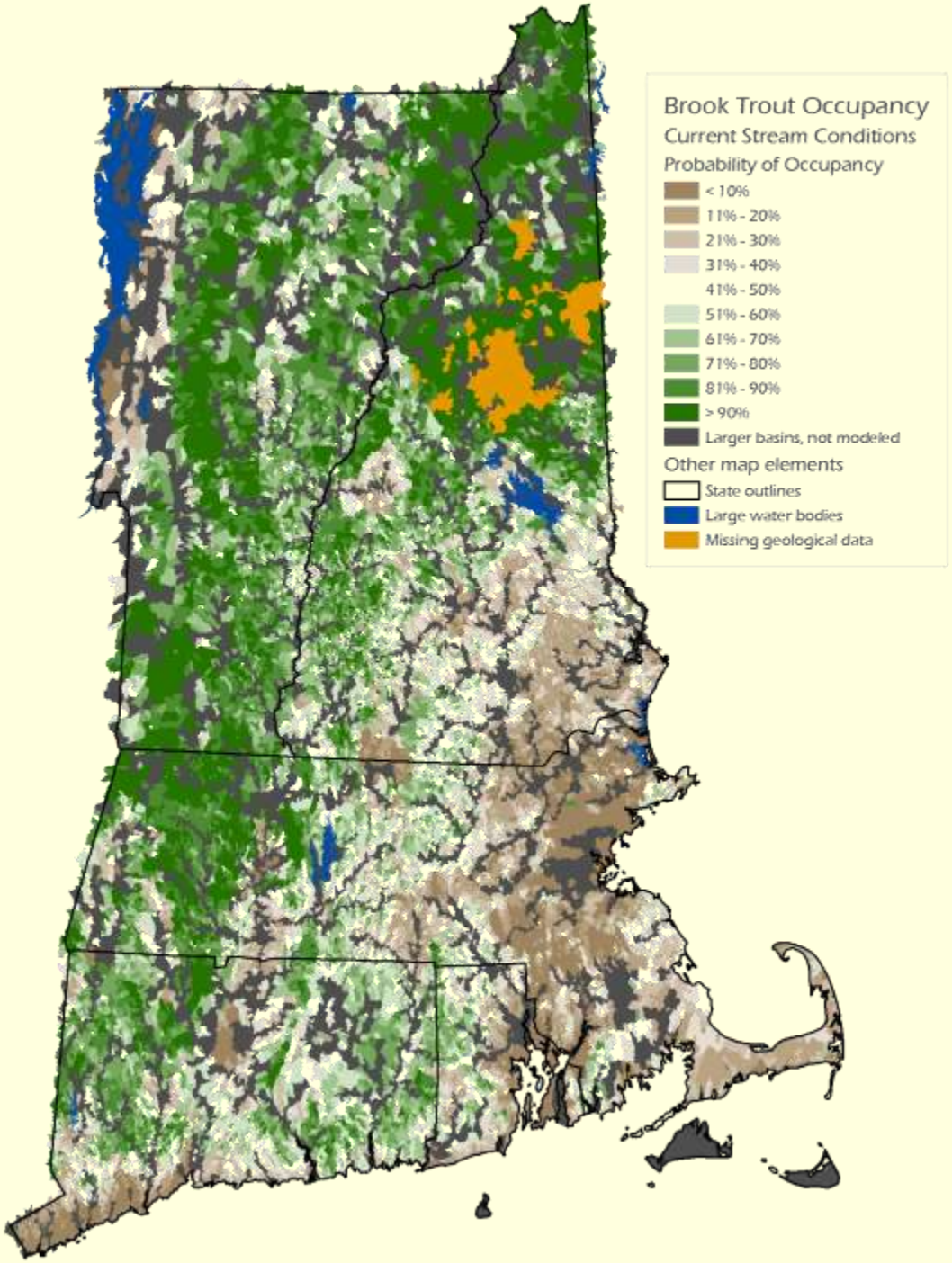
Climate-driven model

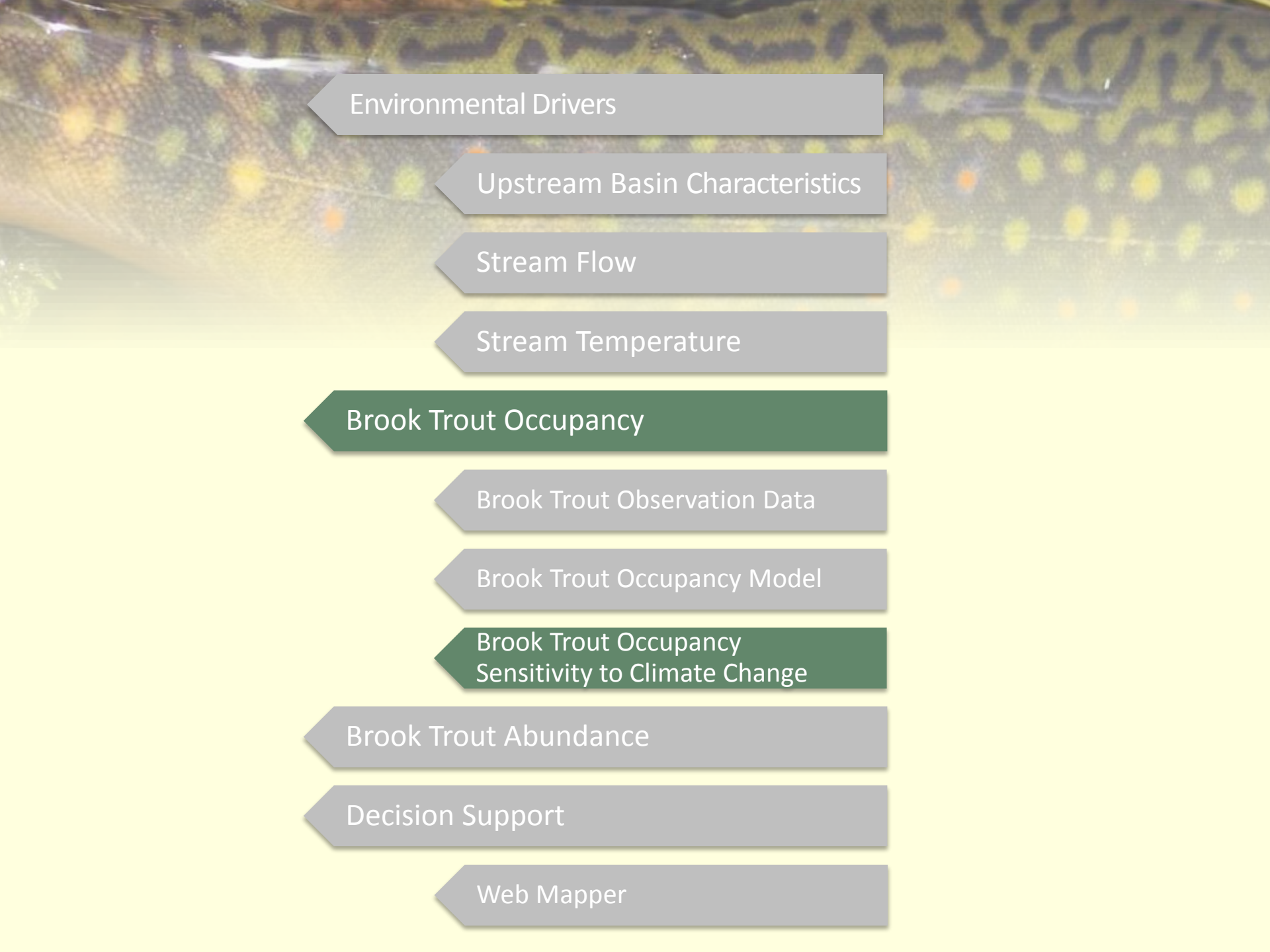
Drainage area	-
Precipitation	+
Air Temperature	-
Forest Cover	+

Stream conditions-driven model

Stream flow	+
Max Stream Temp	-
Stream Temp Rising Slope	-
Forest Cover	+

Brook Trout Occupancy Model

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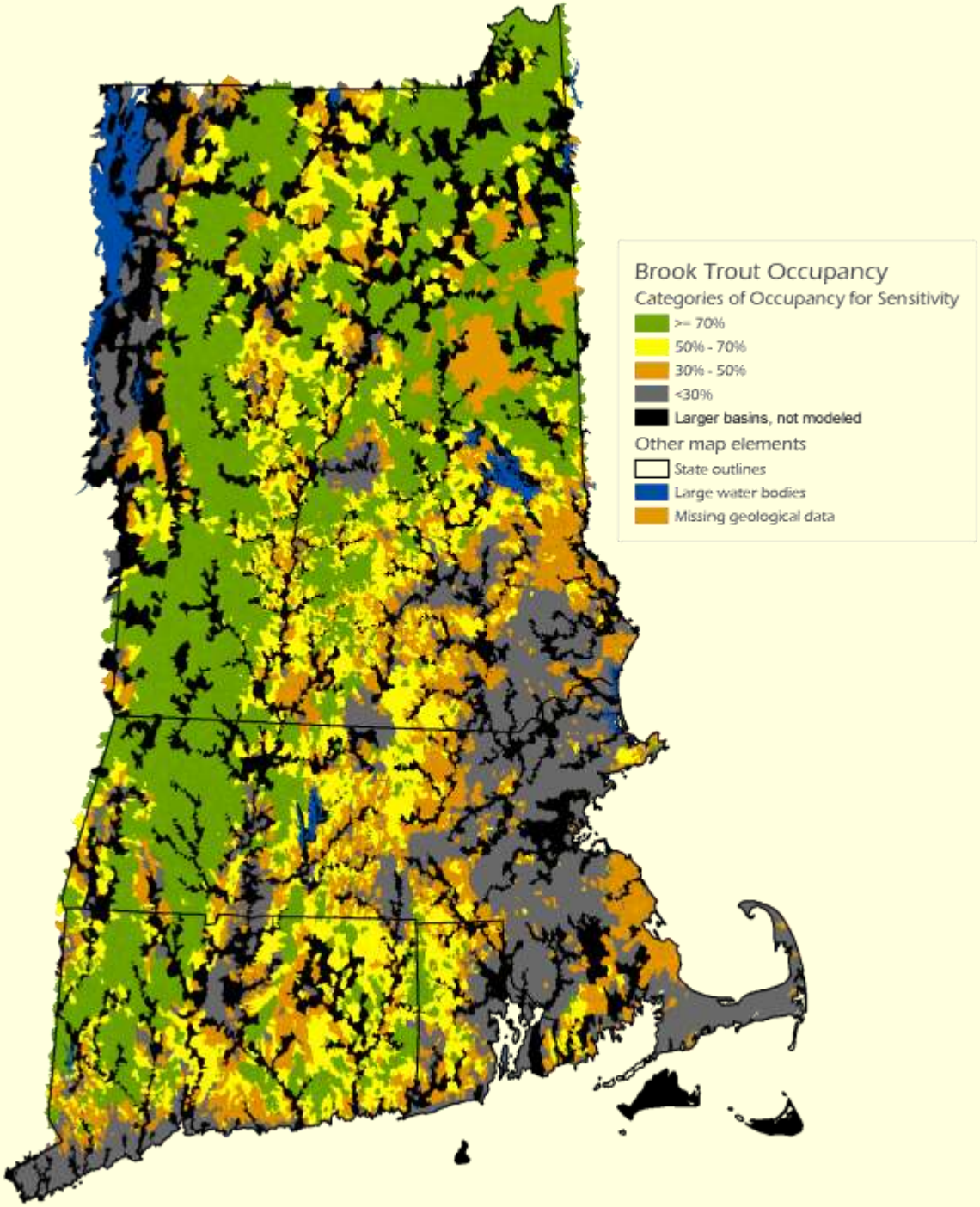
Brook Trout Occupancy Sensitivity to Climate Change



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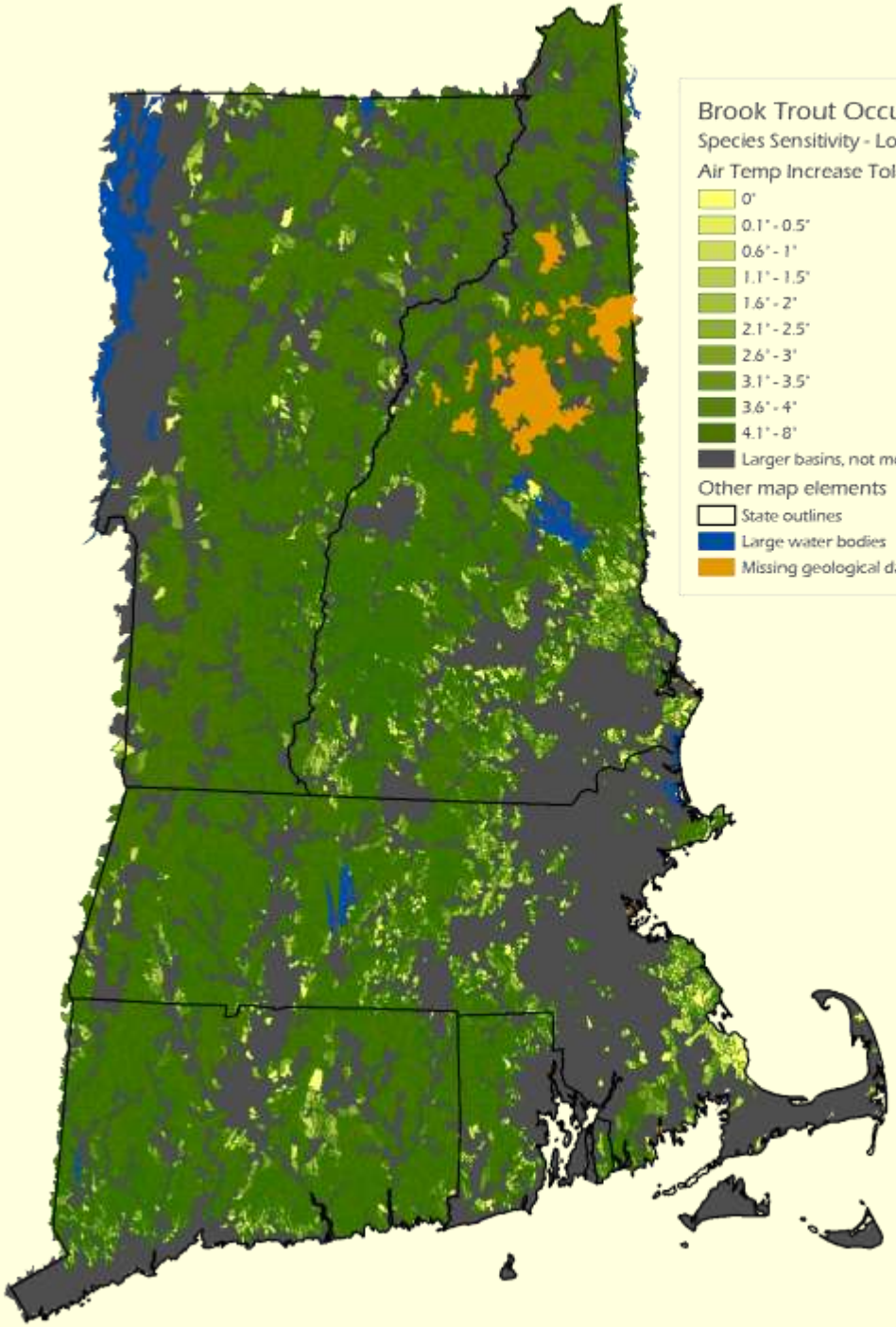

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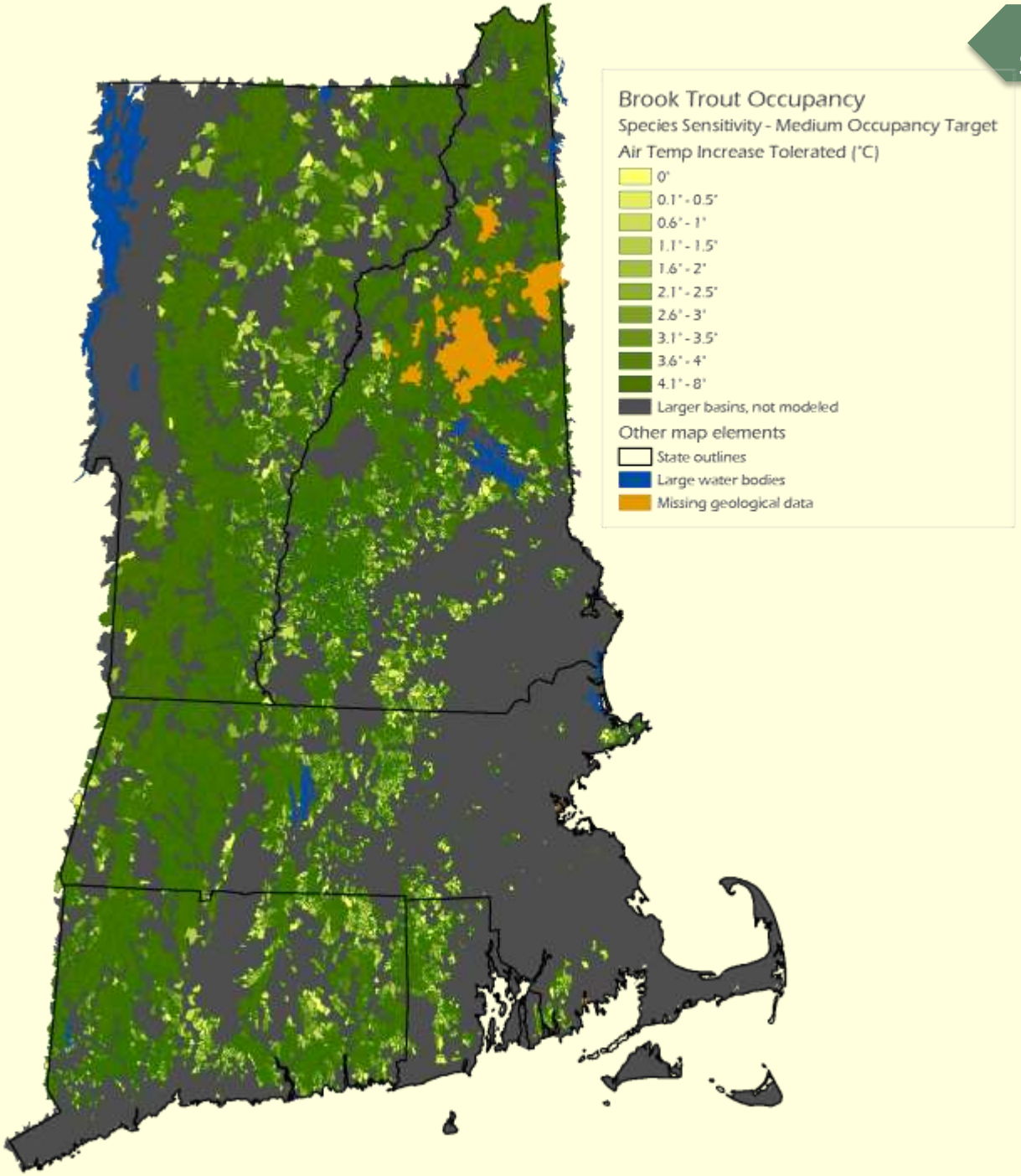

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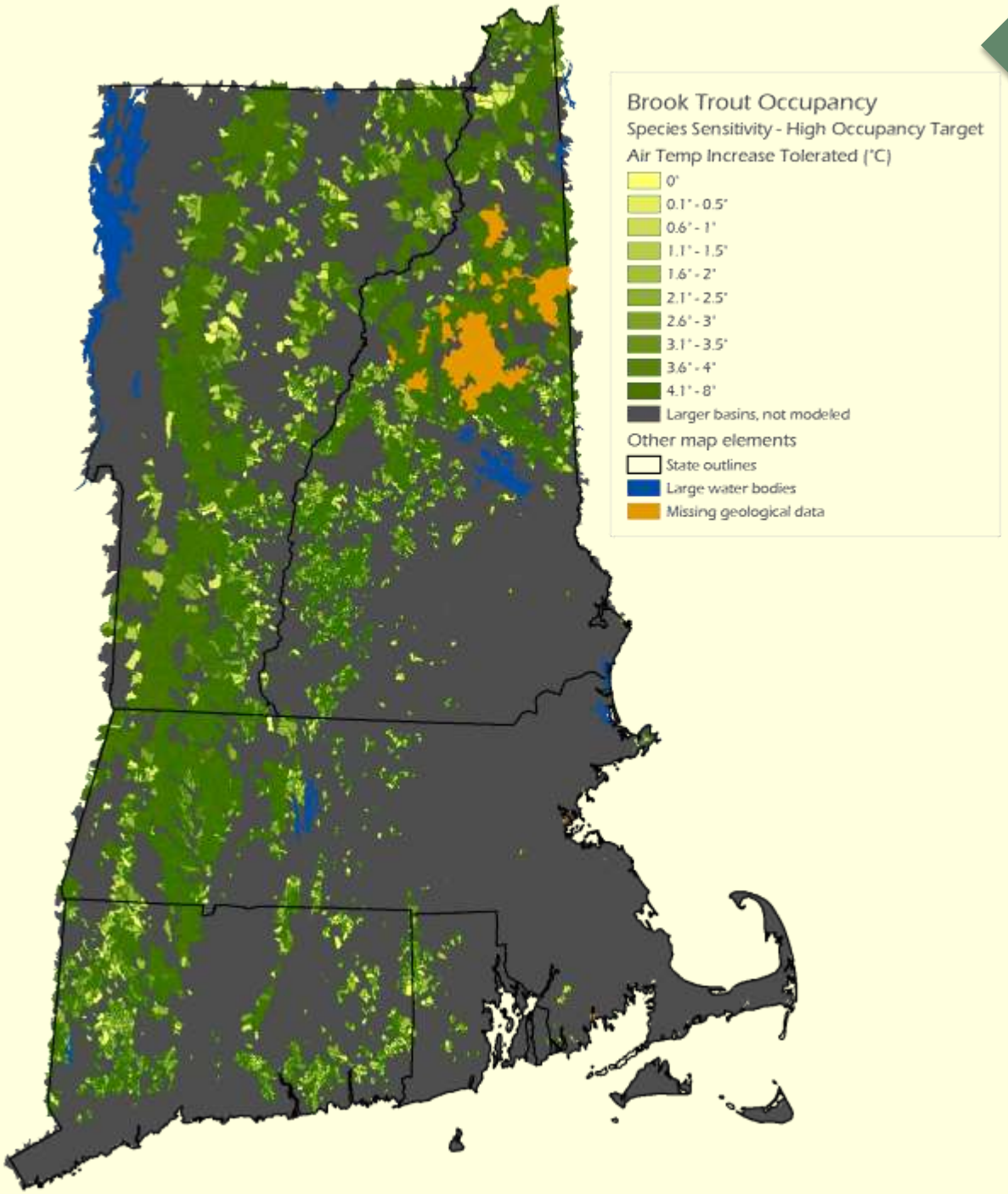
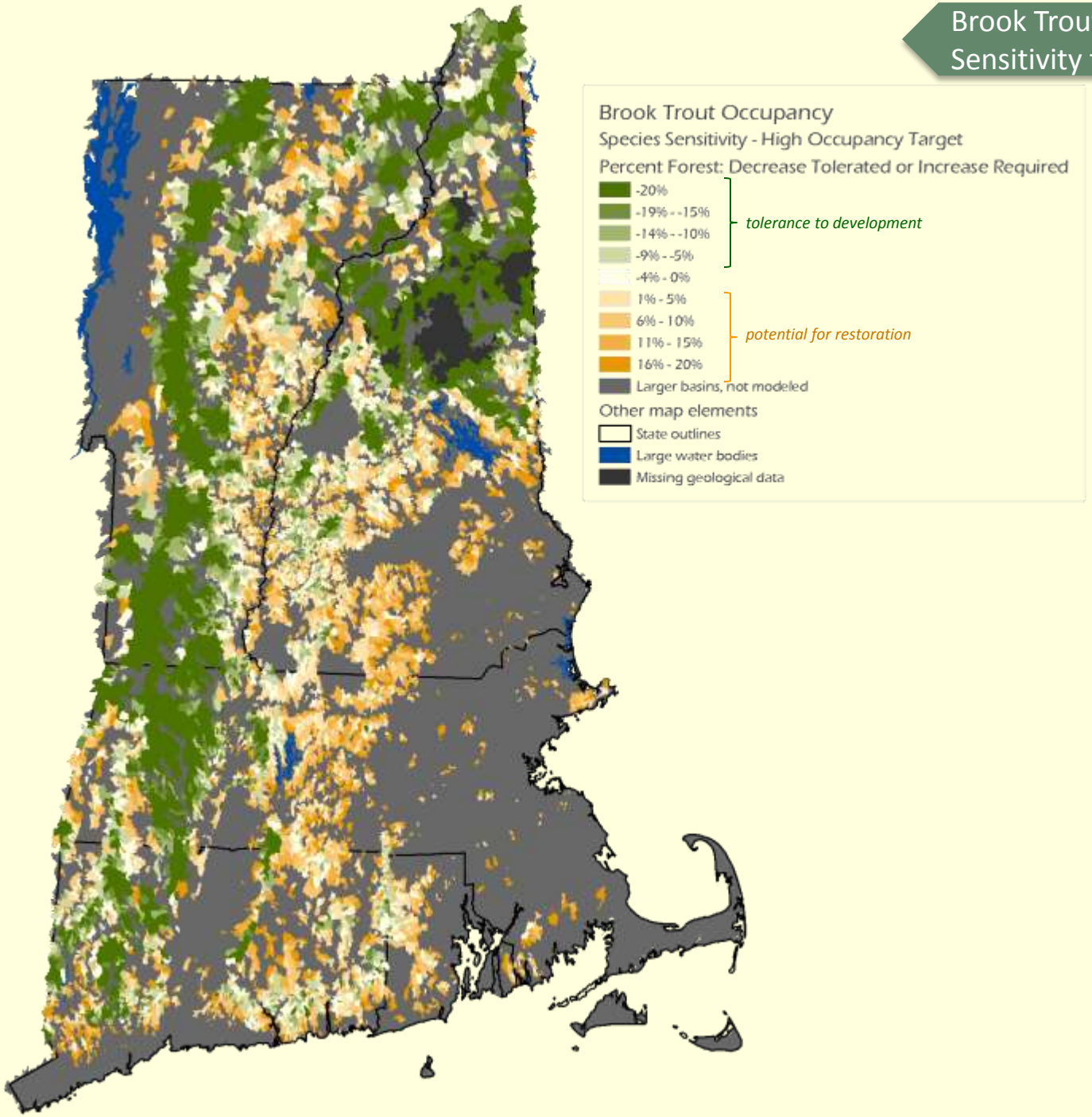
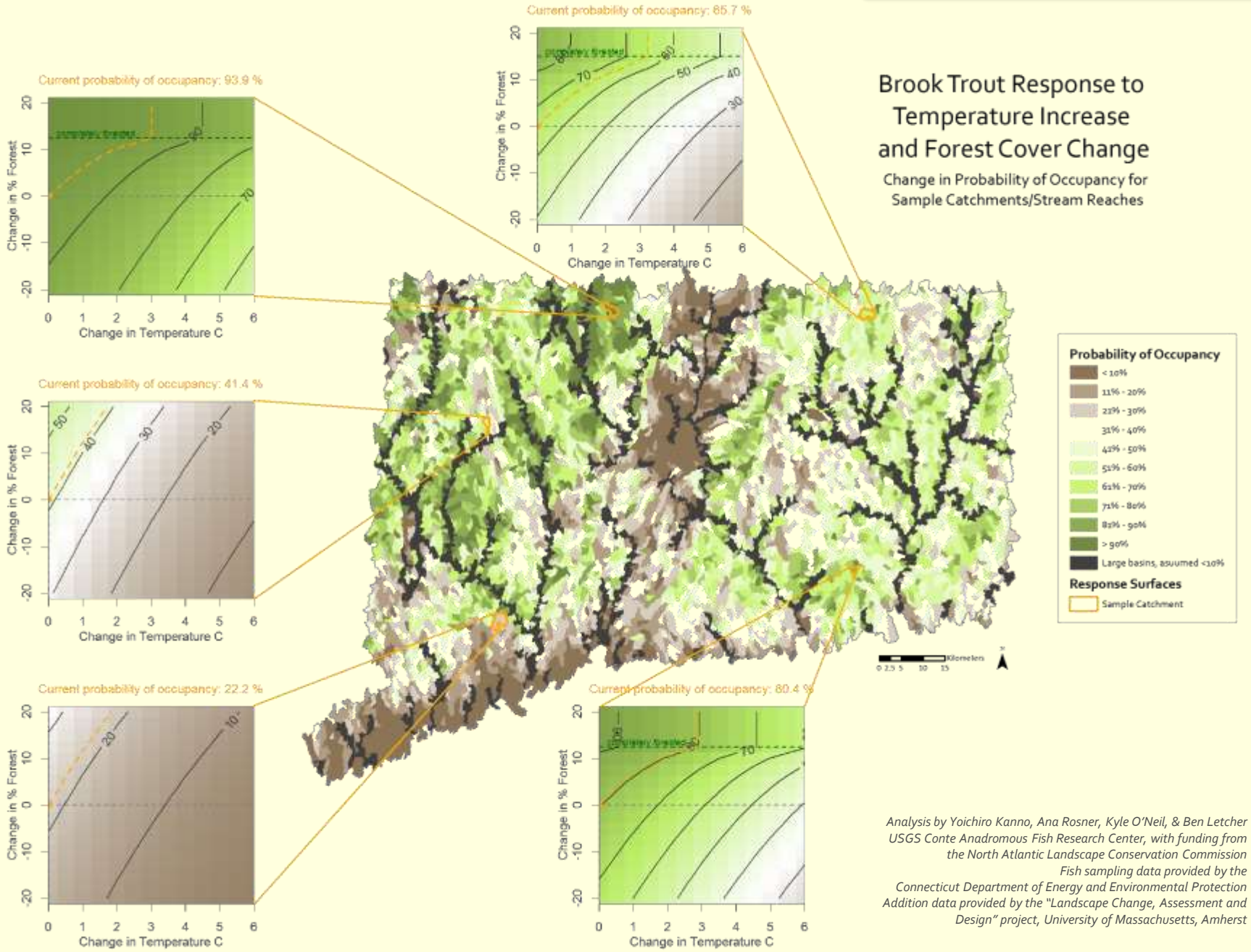


Brook Trout Occupancy Sensitivity to Forest Change



Brook Trout Resilience: Response Surfaces



Analysis by Yoichiro Kanno, Ana Rosner, Kyle O'Neil, & Ben Letcher
USGS Conte Anadromous Fish Research Center, with funding from the North Atlantic Landscape Conservation Commission
Fish sampling data provided by the Connecticut Department of Energy and Environmental Protection
Addition data provided by the "Landscape Change, Assessment and Design" project, University of Massachusetts, Amherst

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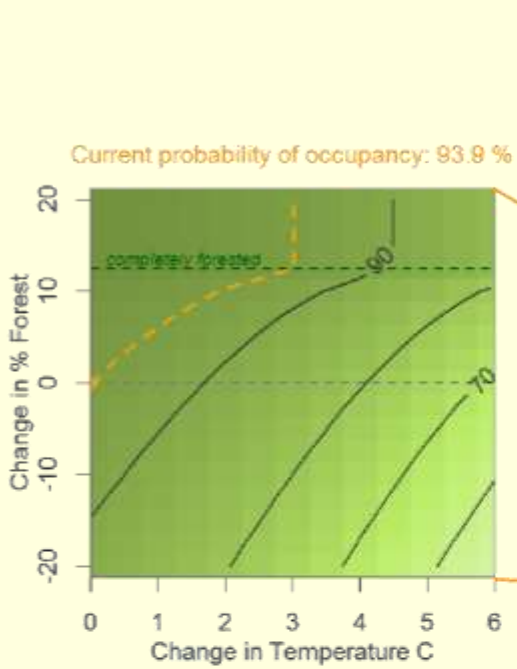
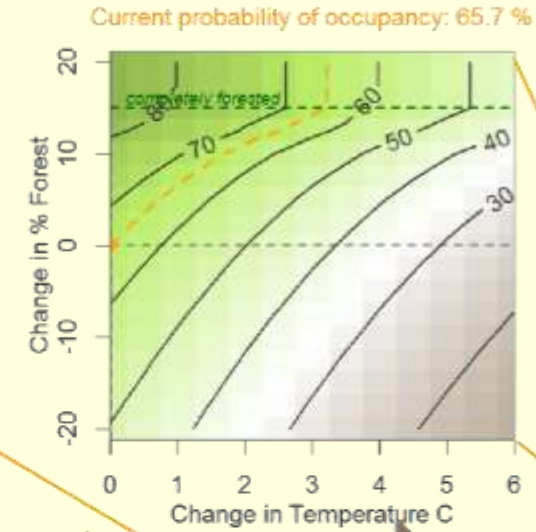
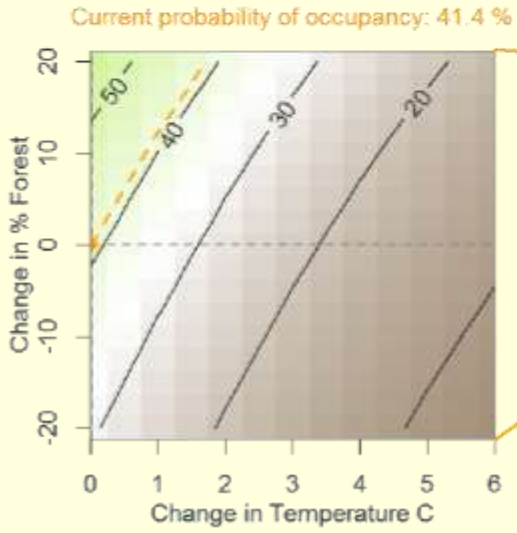
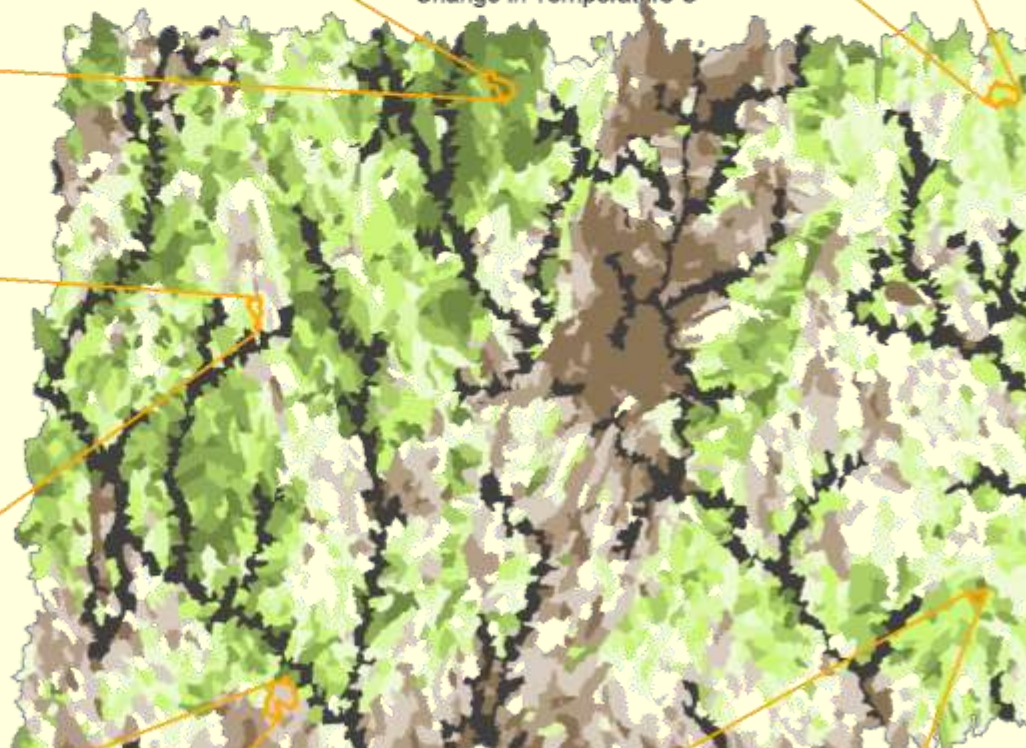
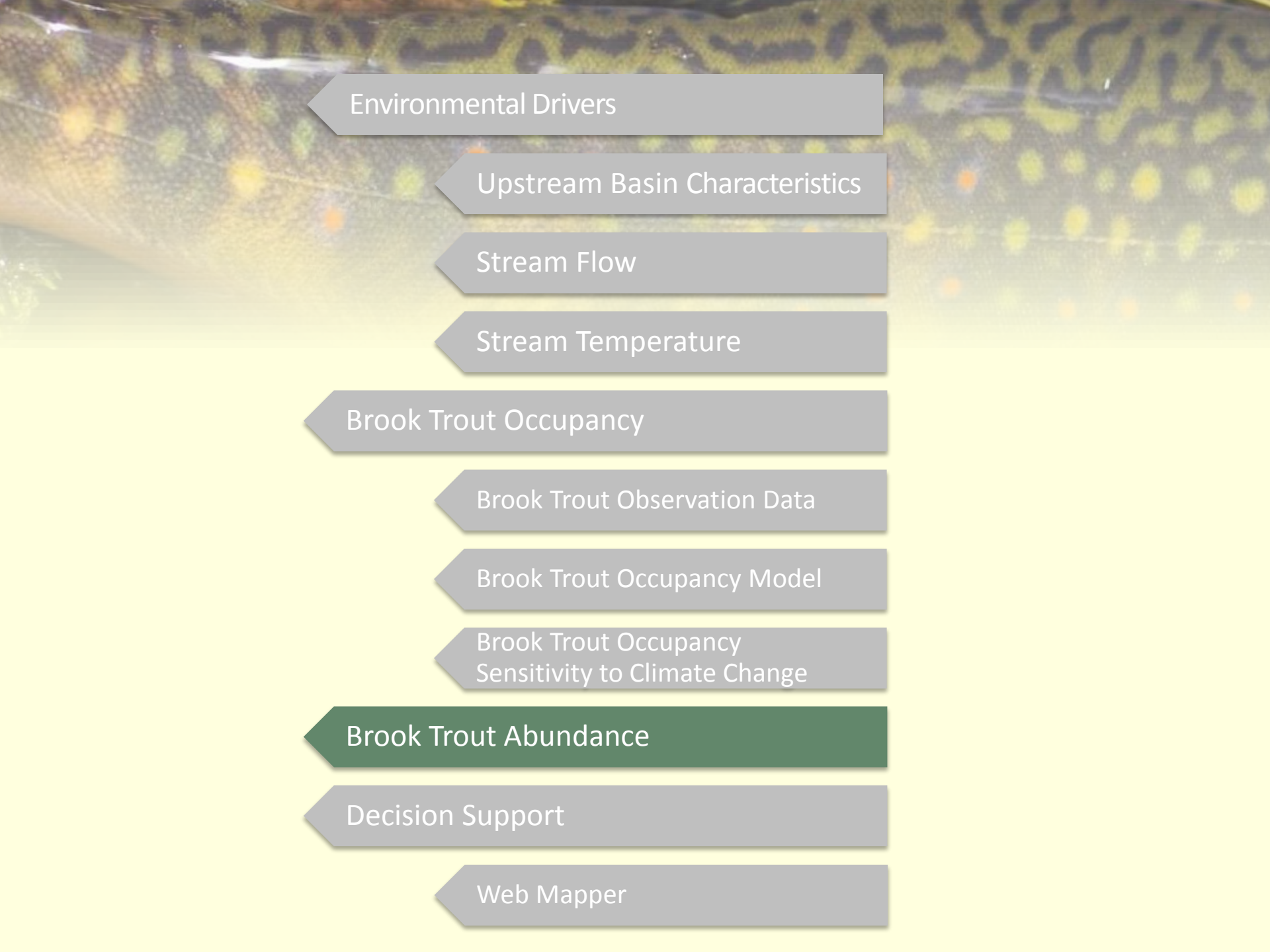
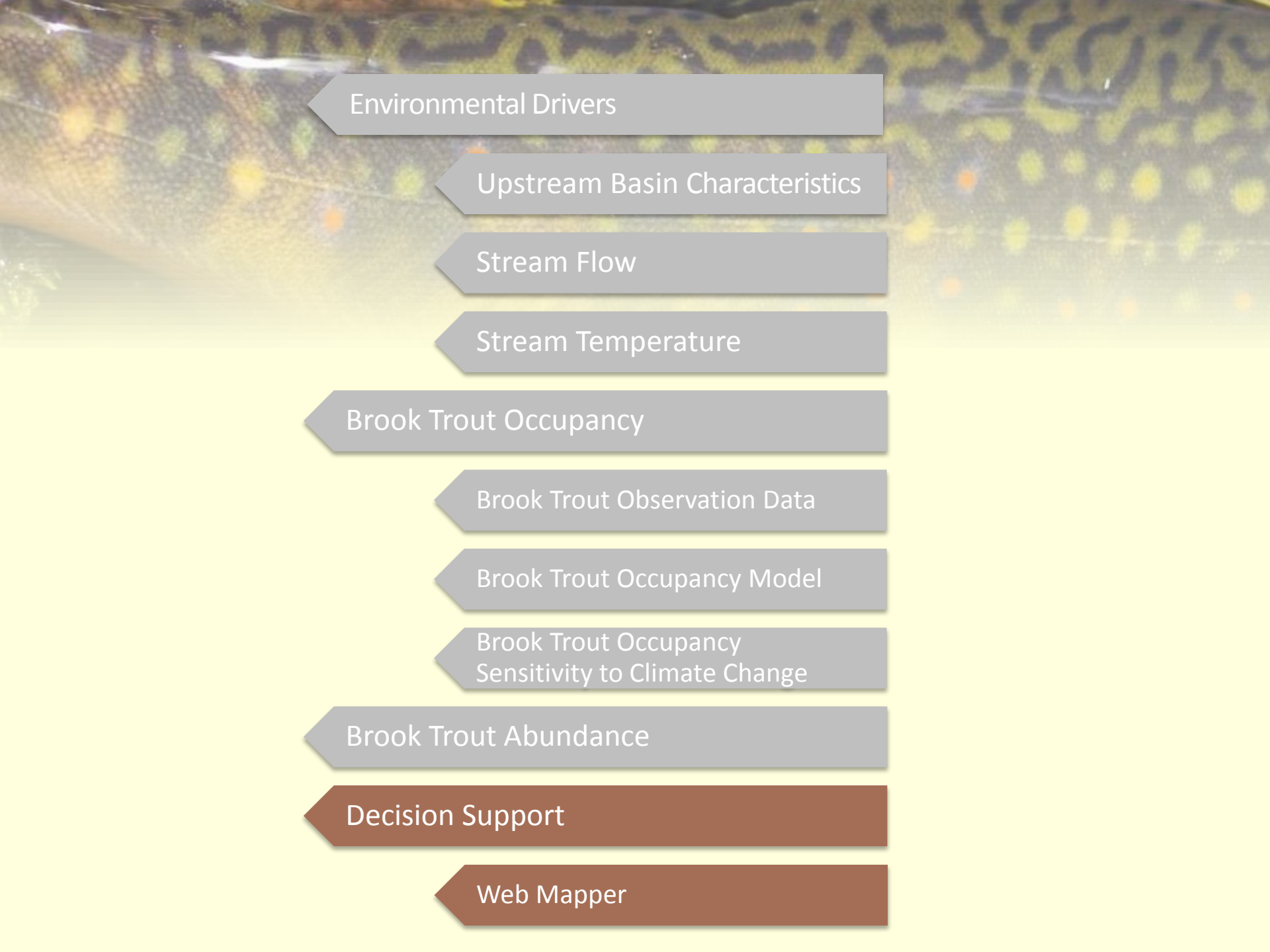









Environmental Drivers
Upstream Basin Characteristics
Stream Flow
Stream Temperature
Brook Trout Occupancy
Brook Trout Observation Data
Brook Trout Occupancy Model
Brook Trout Occupancy Sensitivity to Climate Change
Brook Trout Abundance
Decision Support
Web Mapper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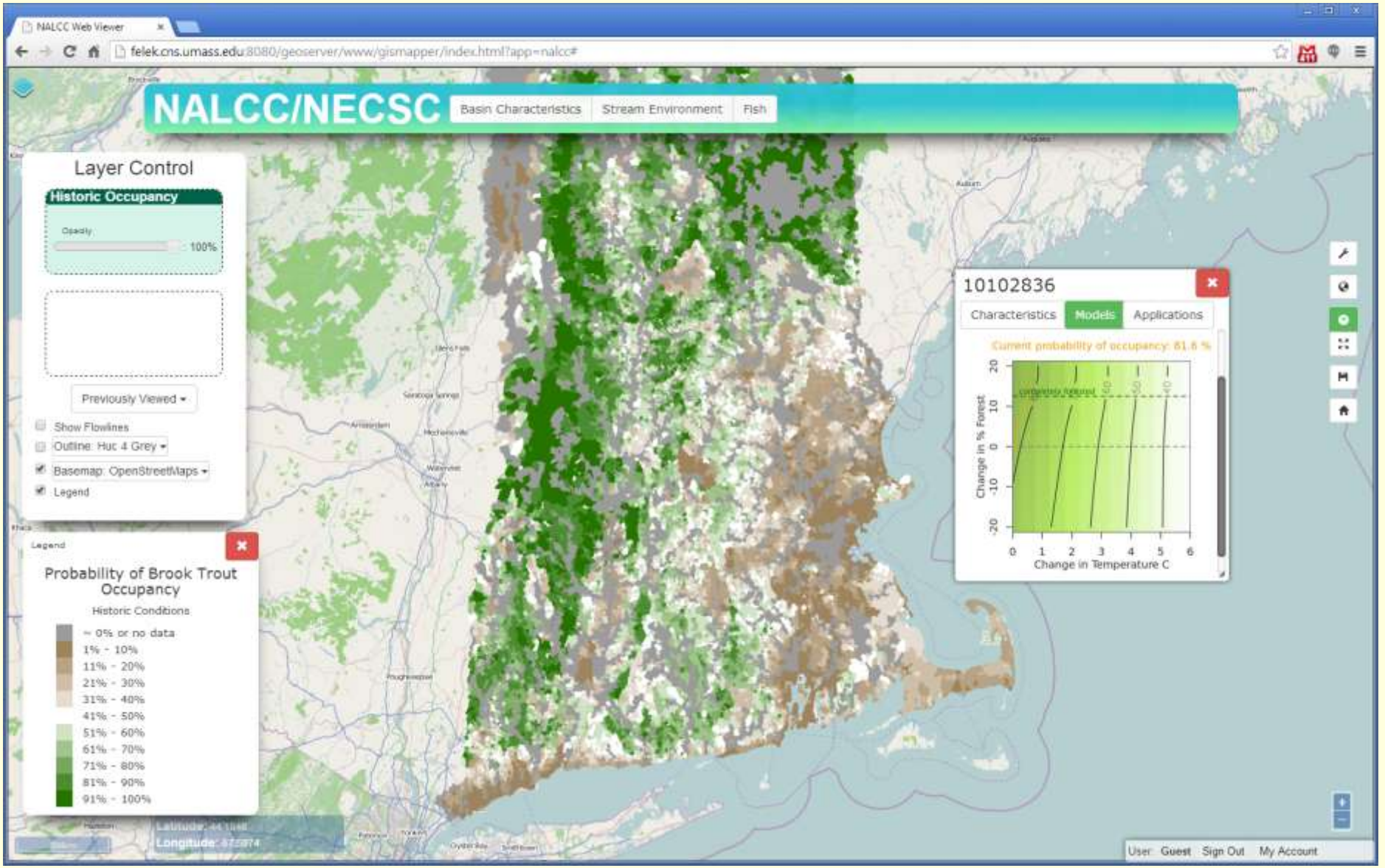
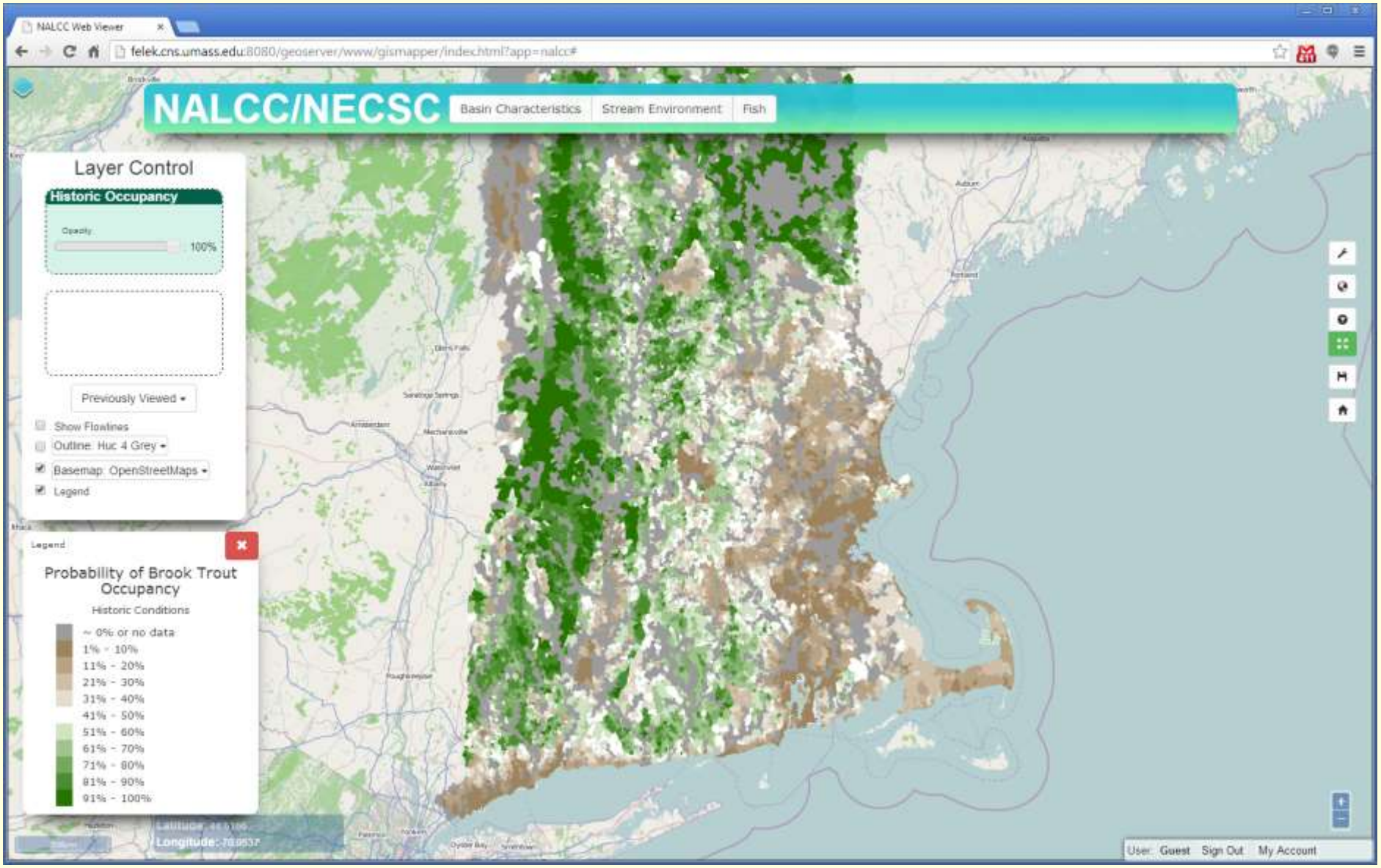

NALCC Web Viewer
felek.cns.umass.edu:8080/geoserver/www/gismapper/index.html?app=nalcc#
NALCC/NECSC
Basin Characteristics
Stream Environment
Fish
Layer Control
Historic Occupancy
Opacity
100%
Previously Viewed
Show Flowlines
Outline: Huc 4 Grey
Basemap: OpenStreetMaps
Legend
Legend
Probability of Brook Trout Occupancy
Historic Conditions
~ 0% or no data
1% - 10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
91% - 100%
10102836
Characteristics
Models
Applications
Current probability of occupancy: 81.6 %
Change in % Forest
Change in Temperature C
User: Guest
Sign Out
My Account

Web Mapper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61% - 70%
71% - 80%
81% - 90%
91% - 100%
Latitude: 44.5106
Longitude: -73.9537
User: Guest
Sign Out
My Account

Ben Letcher, Ana Rosner, Kyle O'Neil,
Dan Hocking, and Chris Jennison
USGS Conte Anadromous Fish Research Center

Yoichiro Kanno, Clemson University

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University of Massachusetts, Amherst