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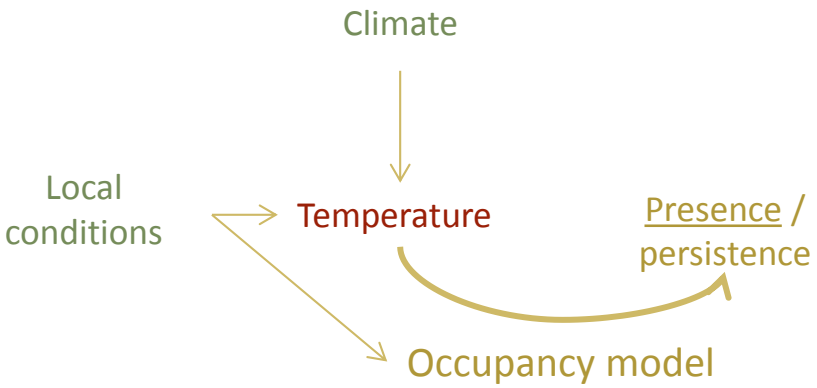
Stream temperature modeling and brook trout response

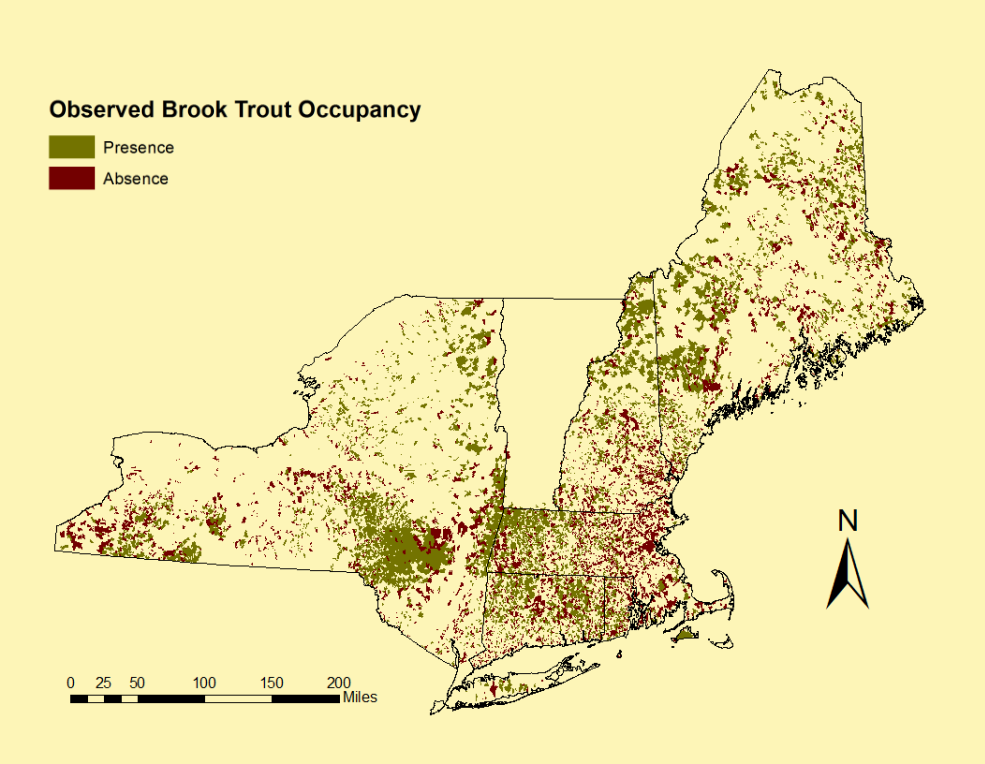
Project goal

- Link environmental variation to fish population response
  - Stream temperature
  - Stream flow
  - Local conditions (land use, etc.)
- Challenge: incomplete data in space and time
  - Space
    - Many missing catchments
  - Time
    - Seasons within a year
    - Years
- Solution: broad spatial models
  - Estimate unsampled locations, times
  - Fish, stream temperature, flow



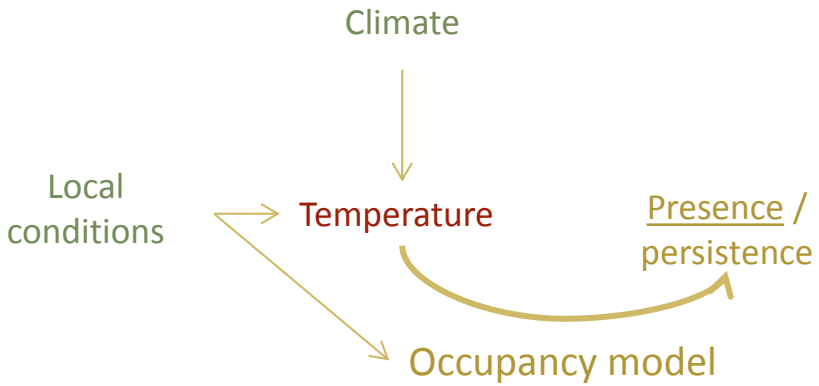
Temperature effects across space

- Fish data
  - Presence/absence
- Environmental covariates
  - Summer stream temperature max
  - Stream temperature sensitivity
  - Annual stream flow
  - Soil drainage class
  - Drainage area
  - Forest cover
  - Stream slope
- Occupancy model
  - Presence/absence ~ (env covariates)
  - Probability of occupancy

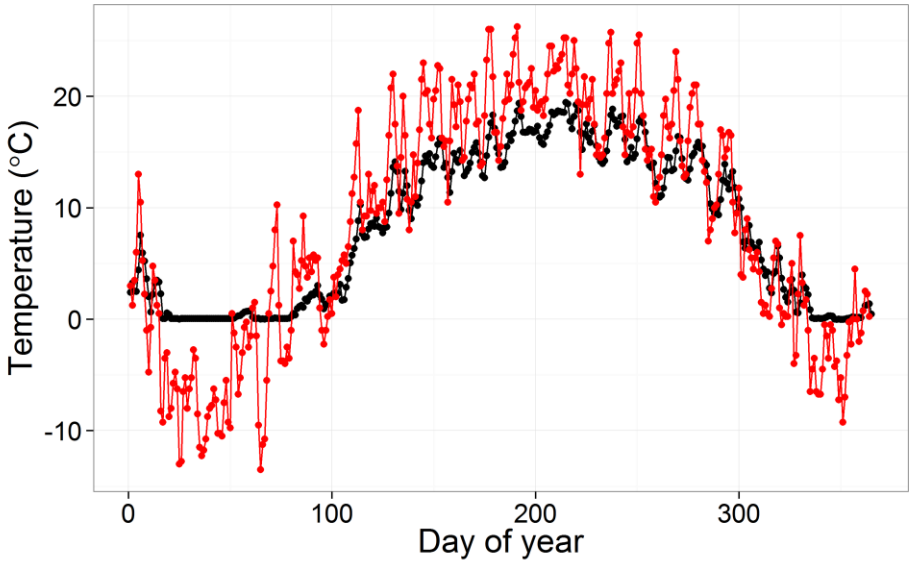


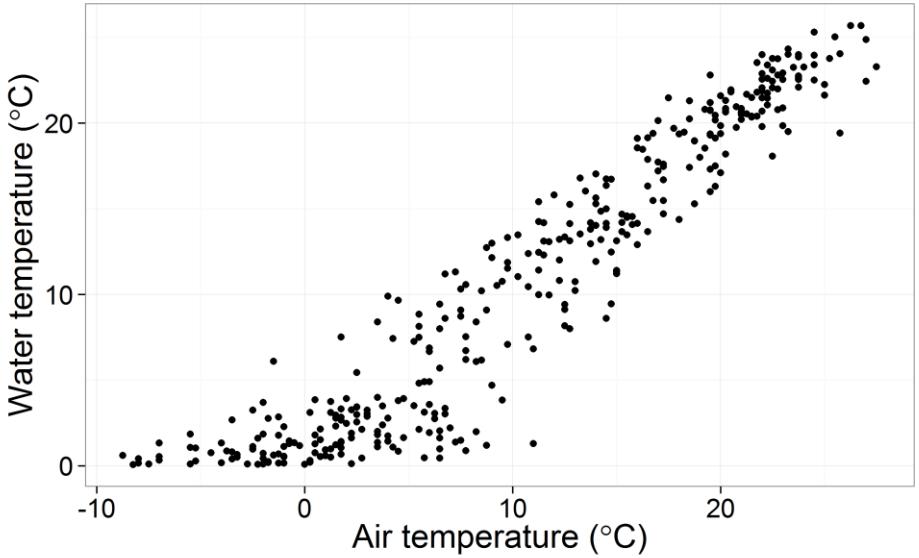
Daily stream temperature model

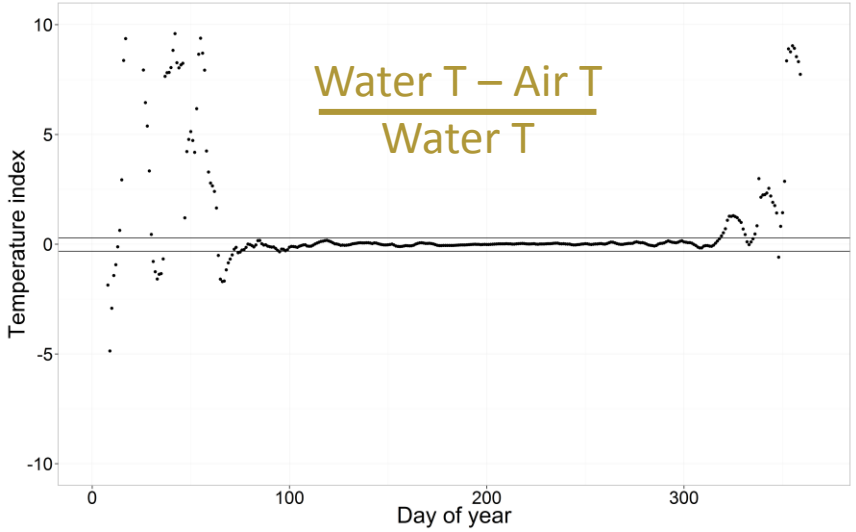
- Air temperature / water temperature synchronization and breakpoint model
  - Model daily water temperatures during times of year that water and air temperature are synchronized



When are stream and air temperature synchronized?







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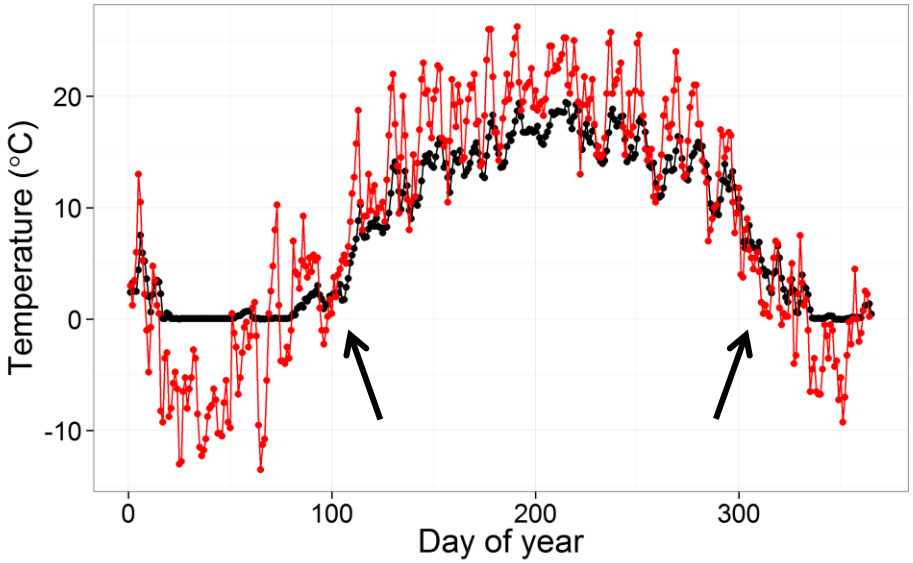

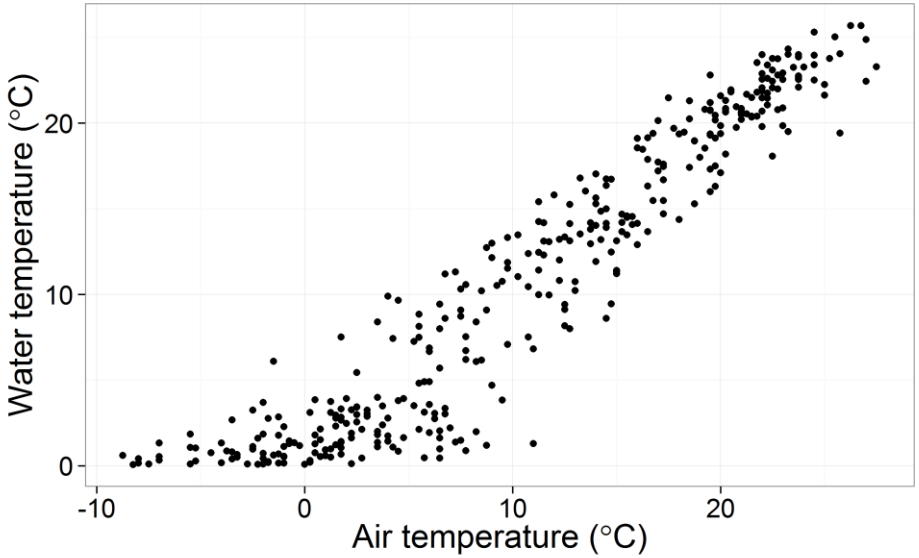

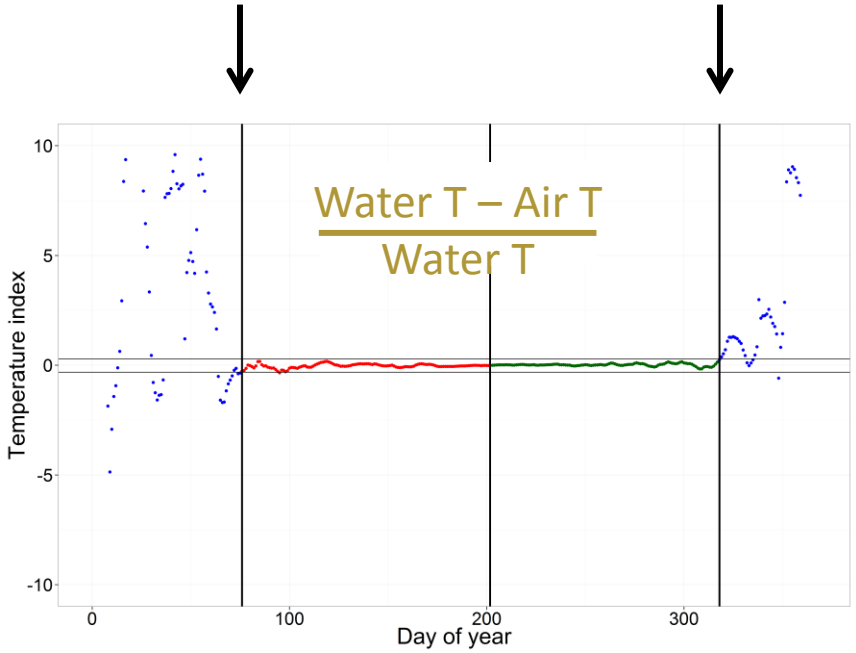

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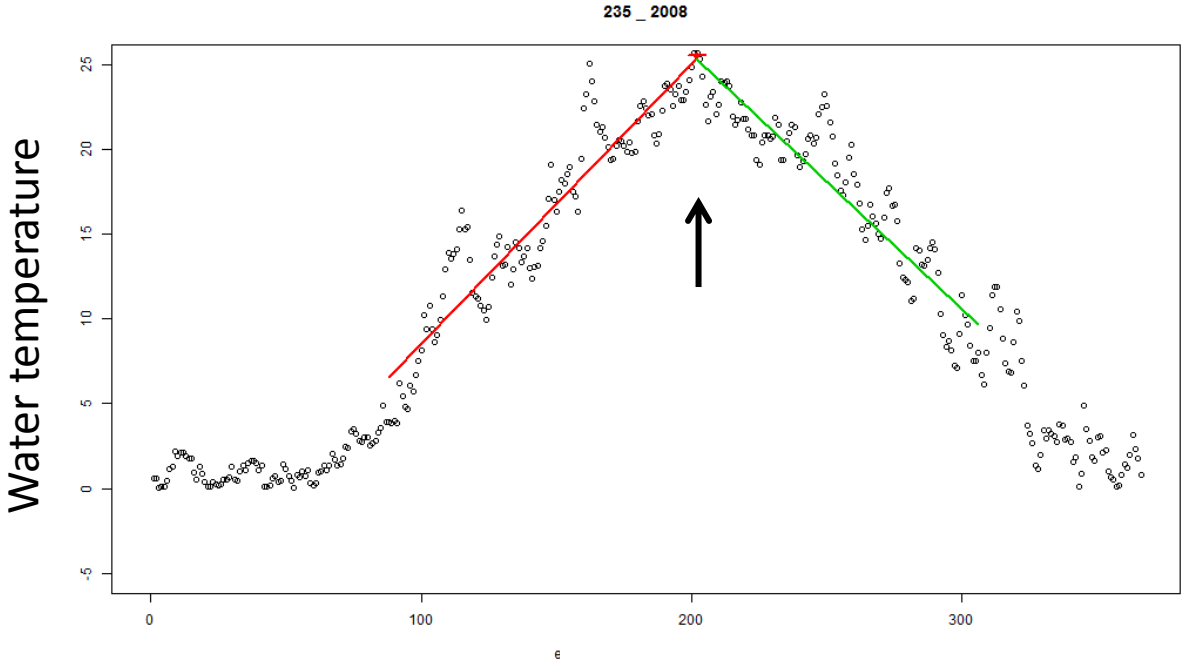

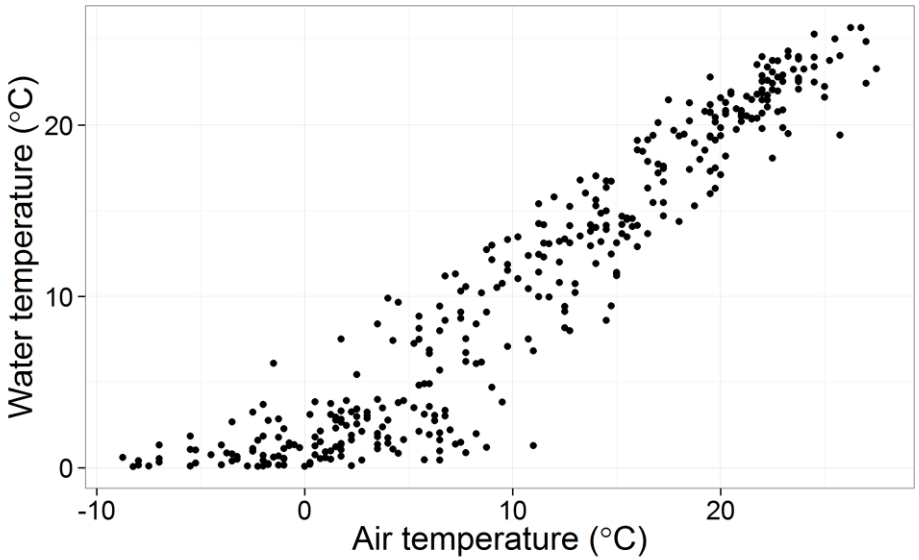

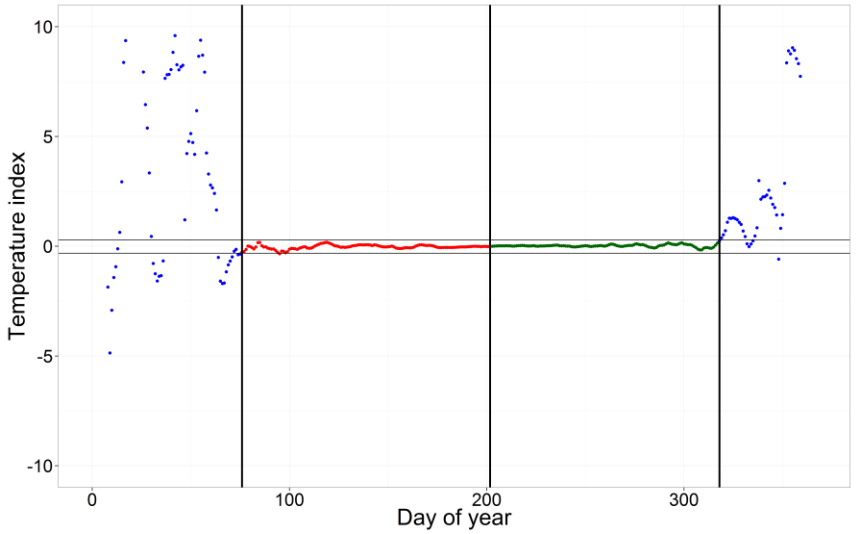

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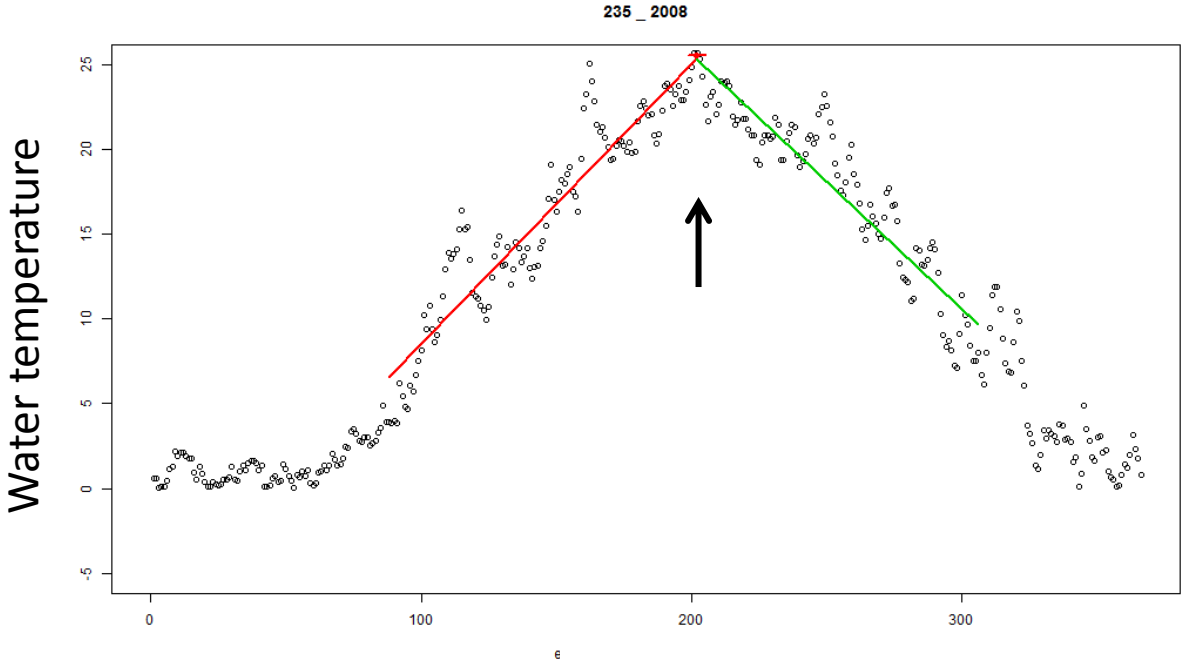
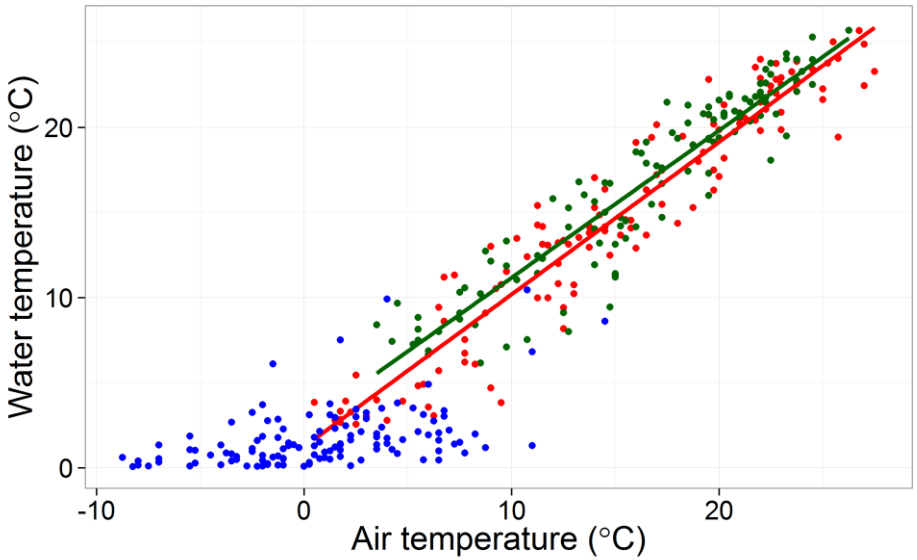
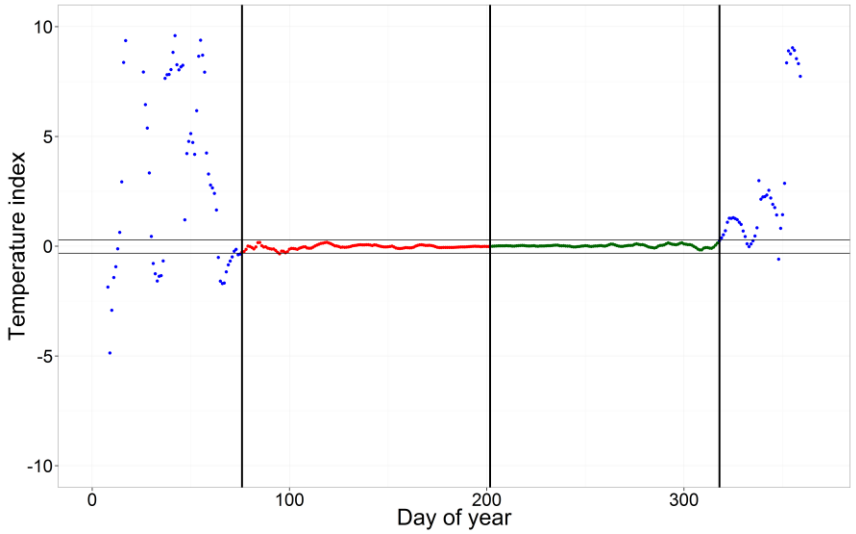




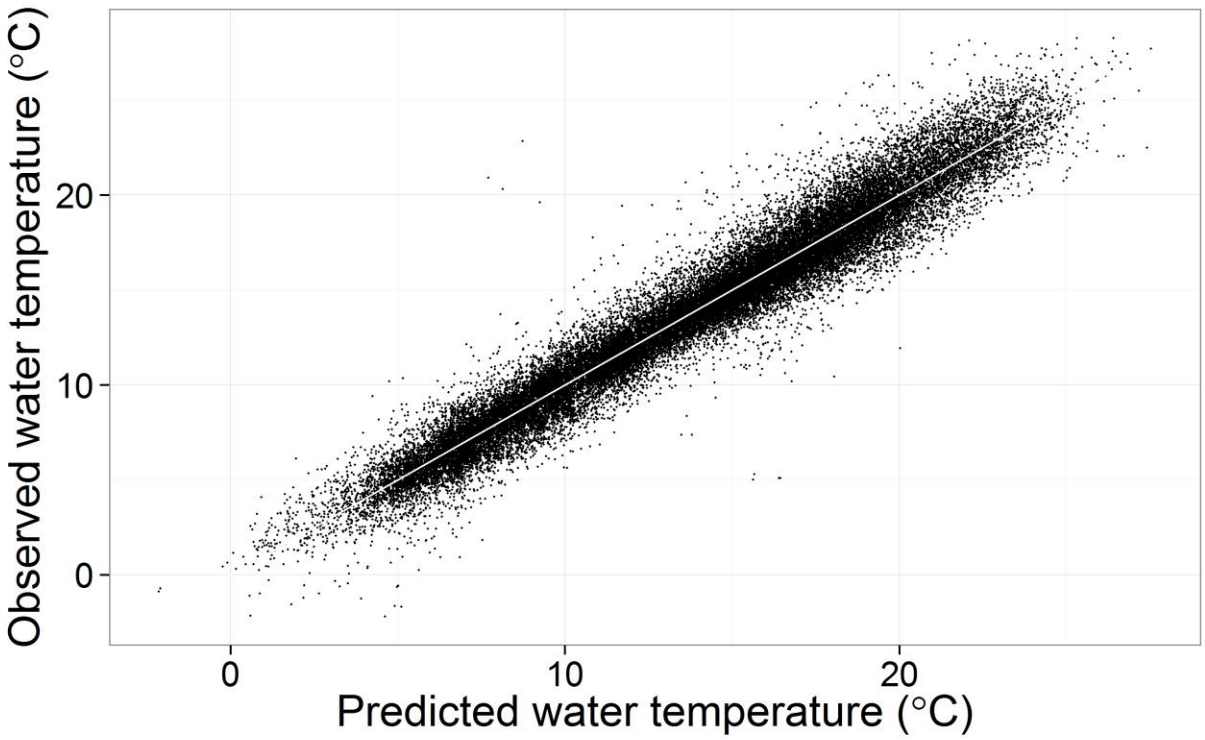


Stream temperature model

- Stream temperature / air temperature synchronization and breakpoint model

  - Simple linear models for the rising and falling segments
    - Dependent variable
      - Mean daily stream temperature
    - Independent variables
      - Mean daily air temperature
      - Lagged mean daily air temperature
      - Day length, snow-water equivalent, solar radiation, precipitation (running mean)
      - Landcover
      - Drainage area, % upstream impounded
      - Topography
      - Geology
      - Latitude, longitude

Observed vs. predicted stream temperature

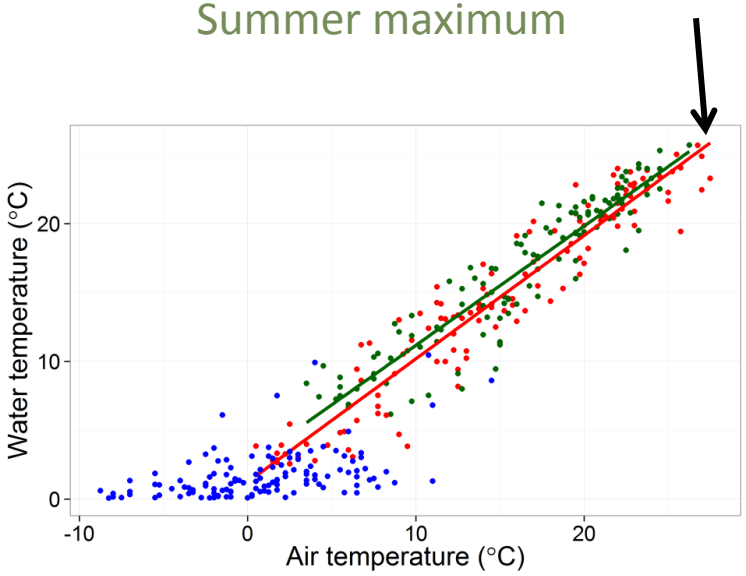


RMSE = 1.0 ^{o}C, model r^2 = 0.96

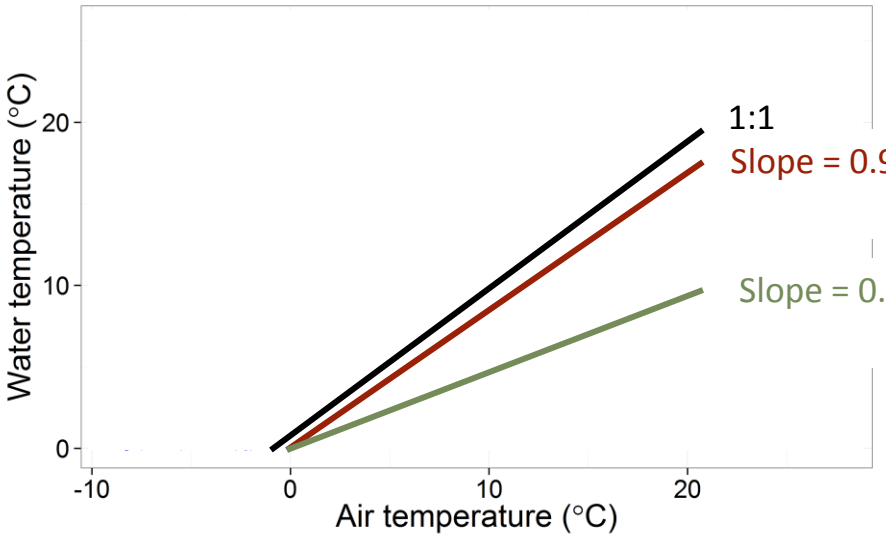
Validation RMSE = 1.1 ^{o}C

Predicted temperature parameters

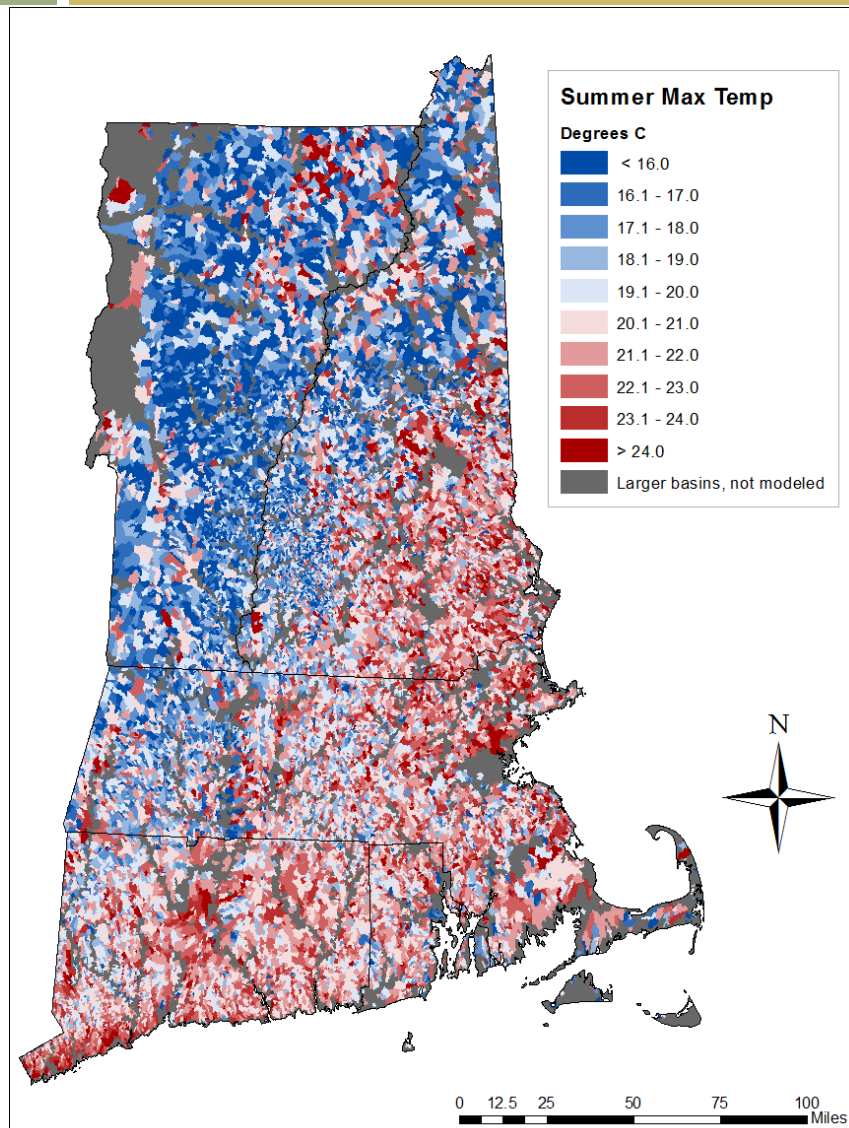
Summer maximum

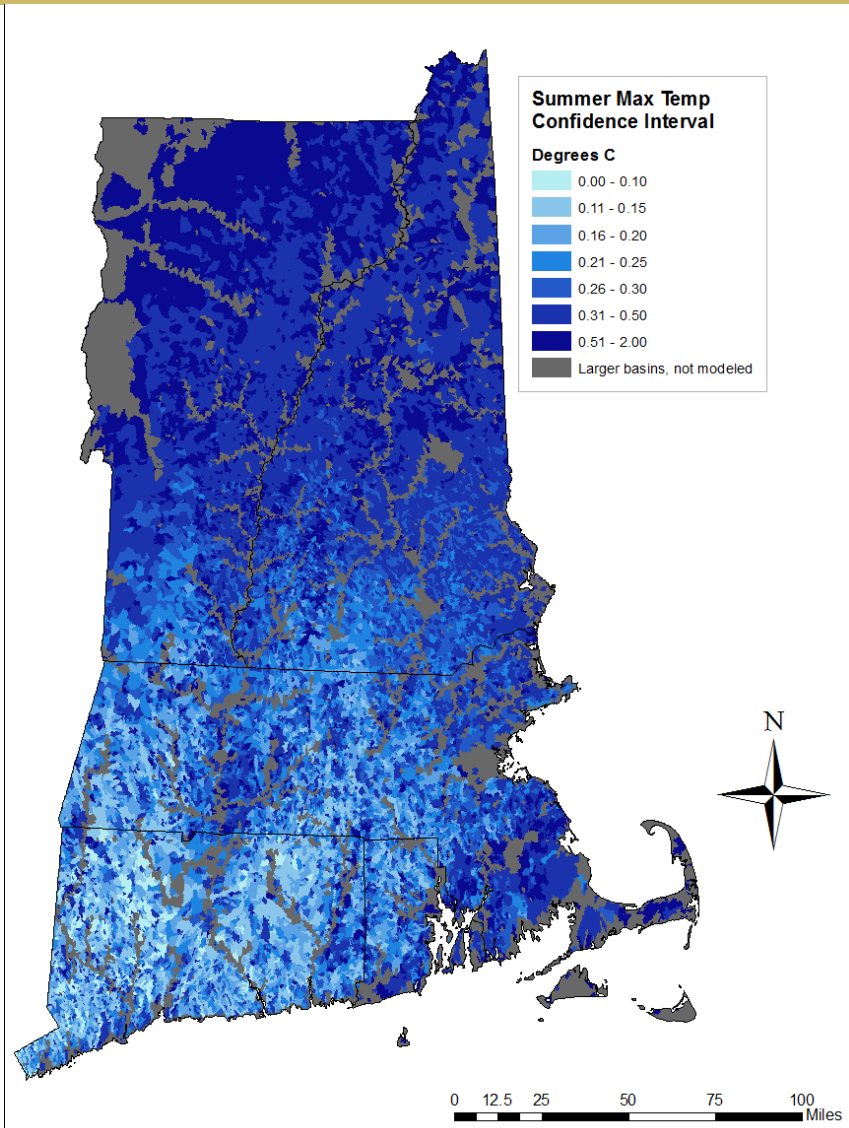


Stream water sensitivity

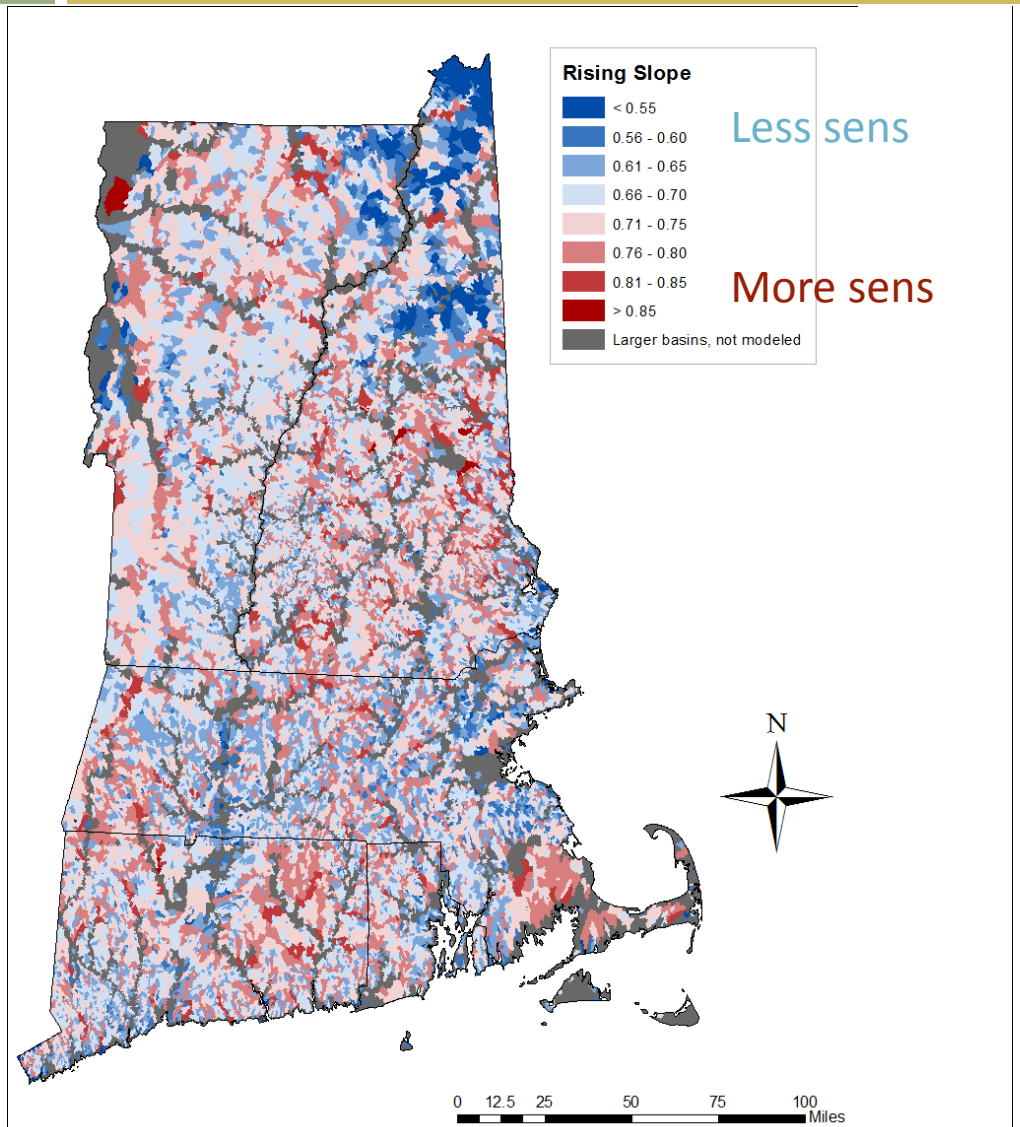


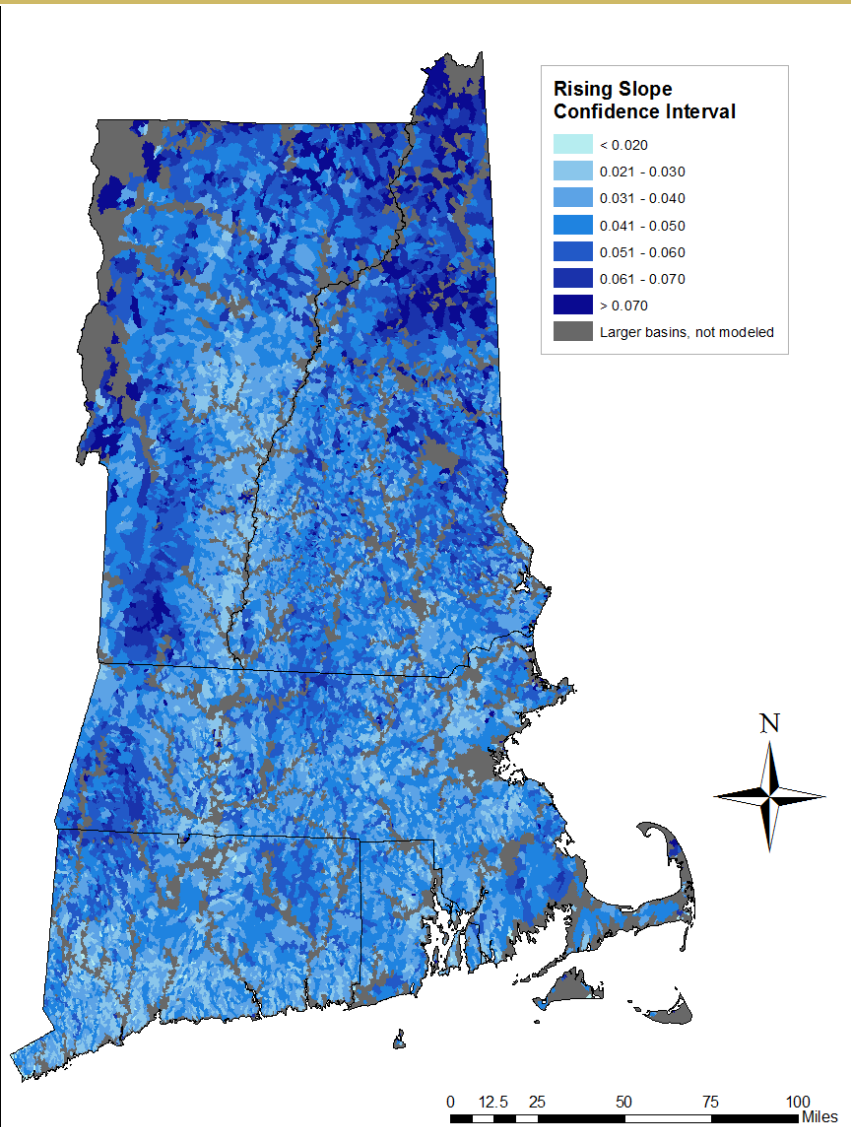
Summer maximum stream temperature





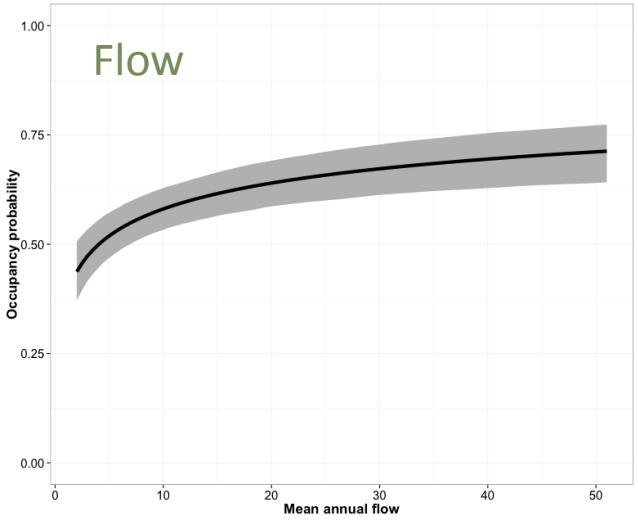
Stream temperature sensitivity

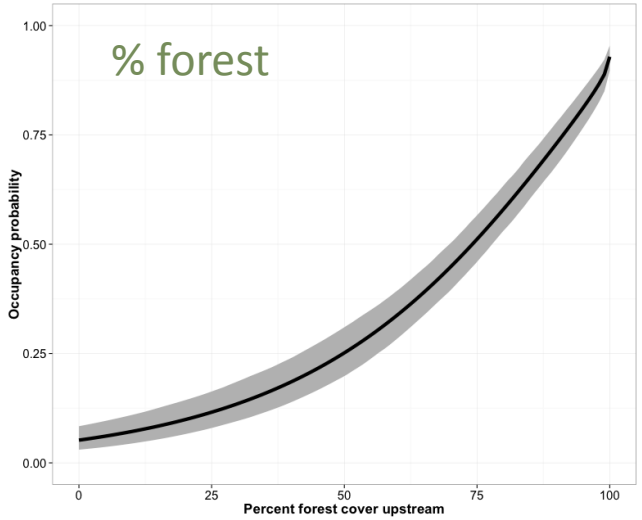


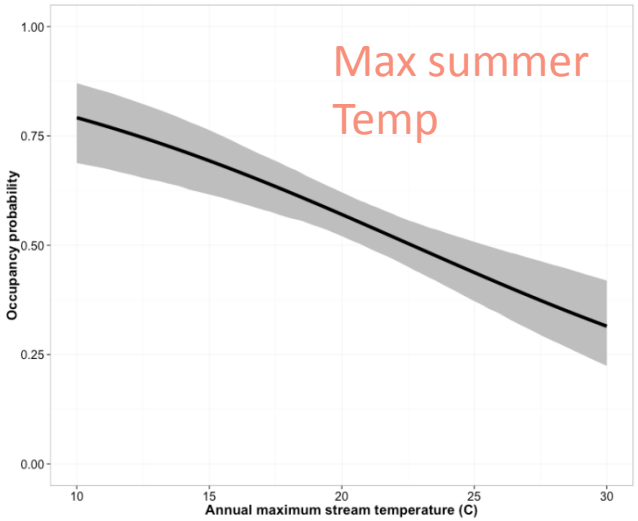


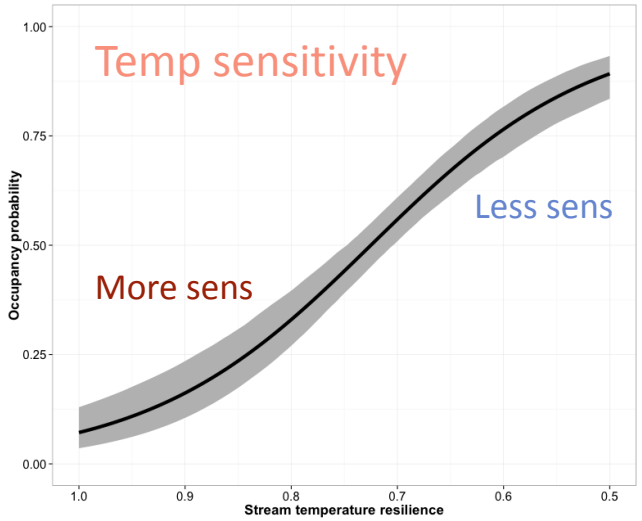
Model estimates

- Presence / absence
  - Occupancy models
    - Stream temperature sensitivity
    - Summer stream temperature max
    - Annual stream flow
    - Soil drainage class
    - Drainage area
    - Forest cover
    - Stream slope

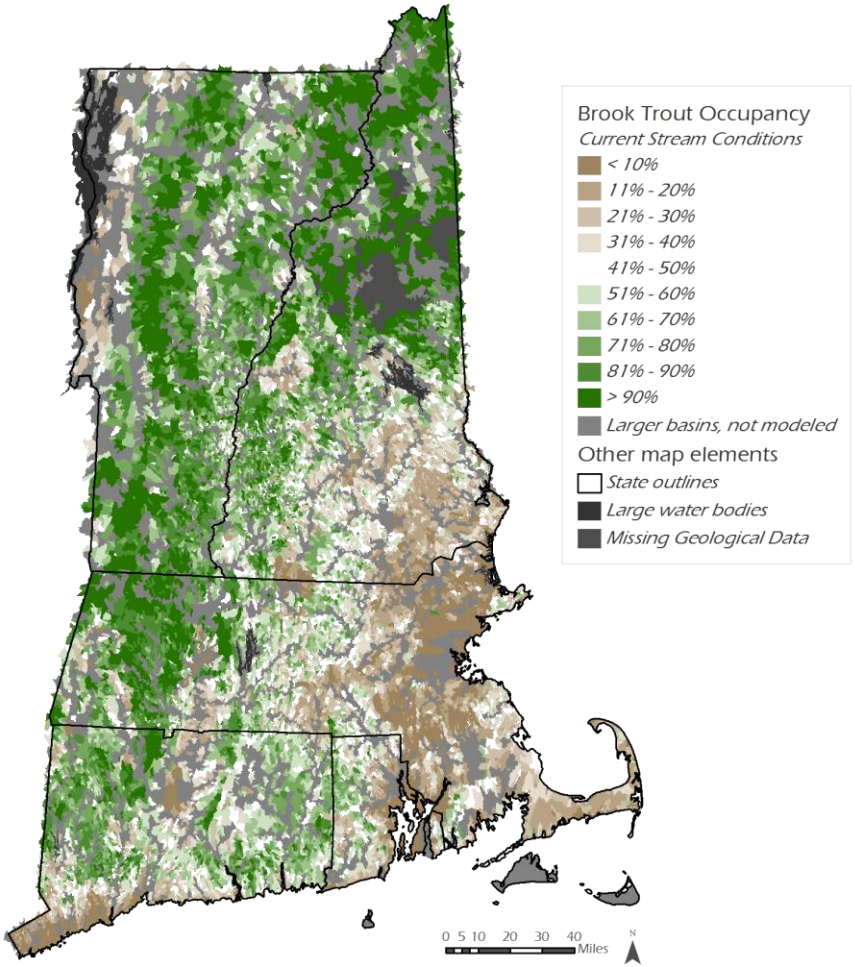




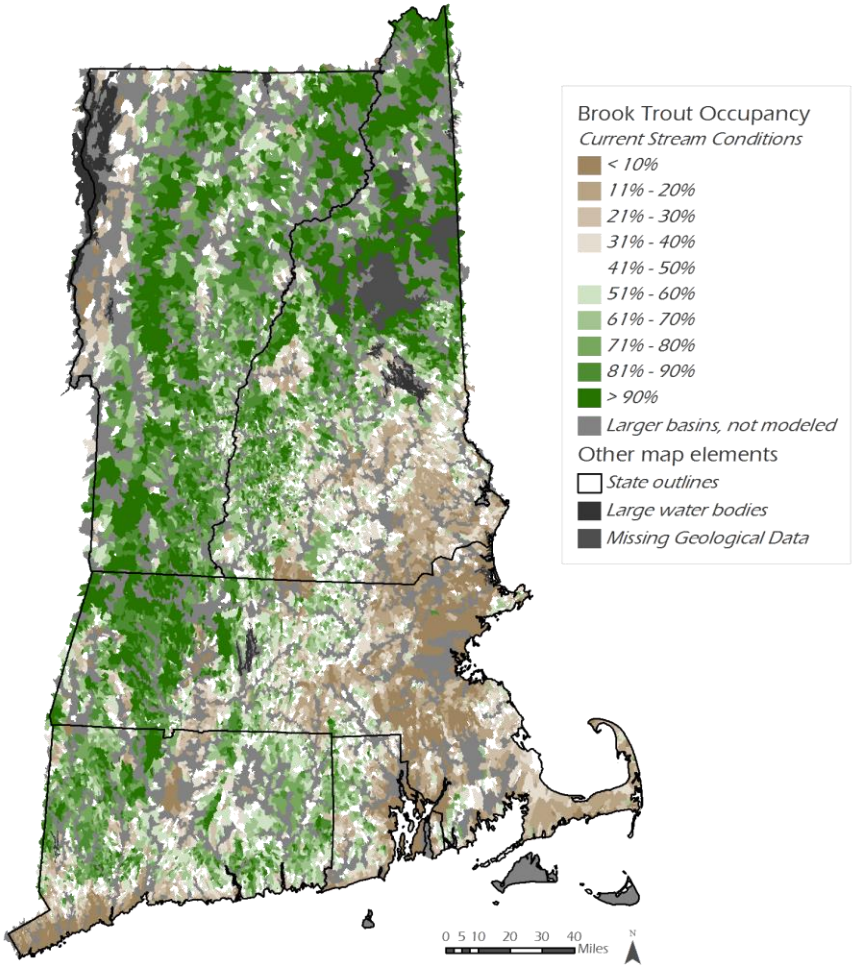


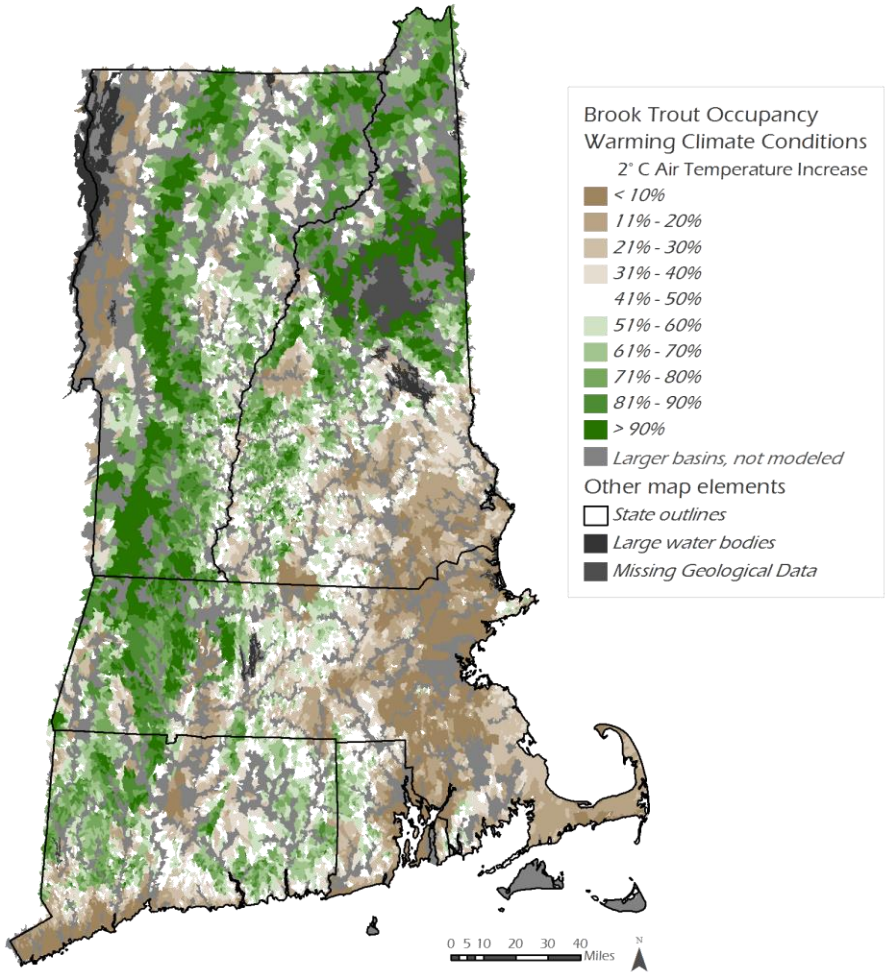


Predicted occupancy



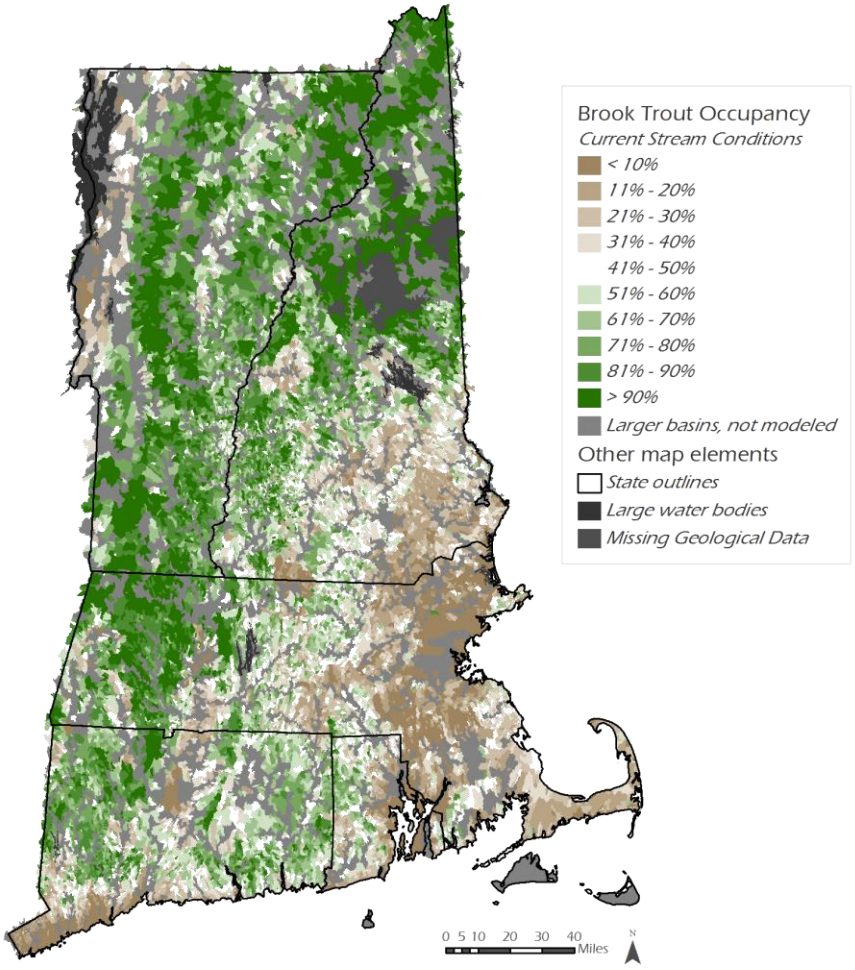
Predicted occupancy, 2^{o} C increase

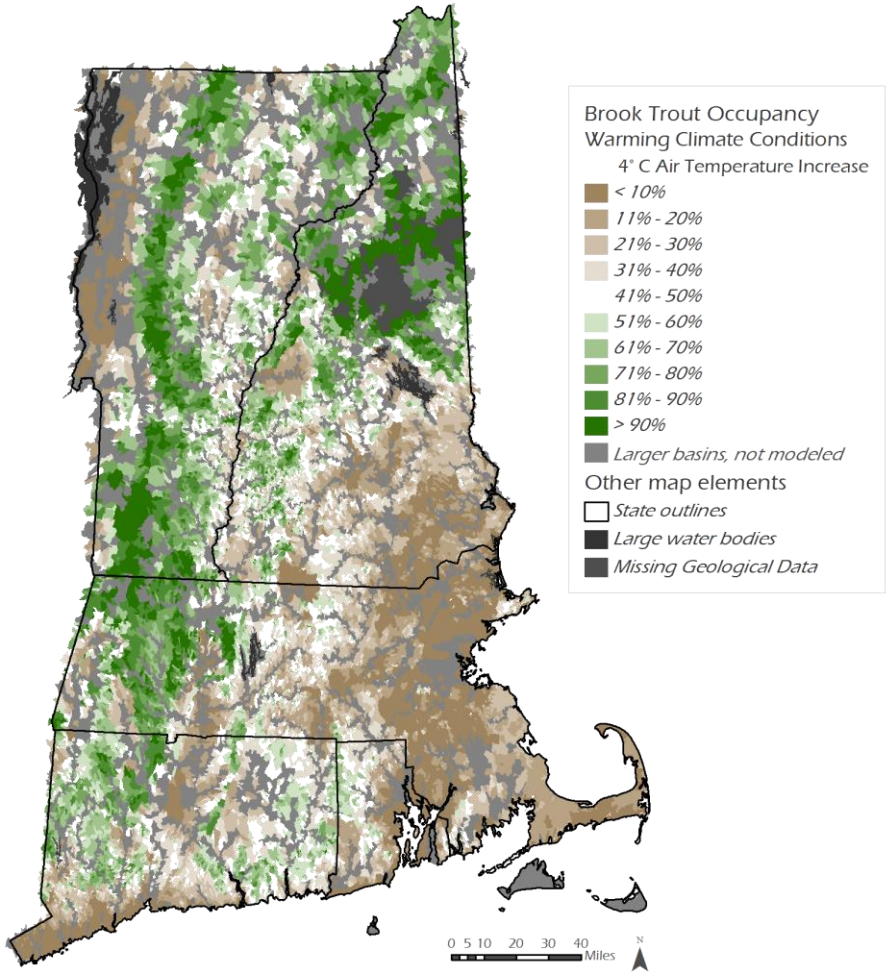




Fix temperature, how does occ vary?

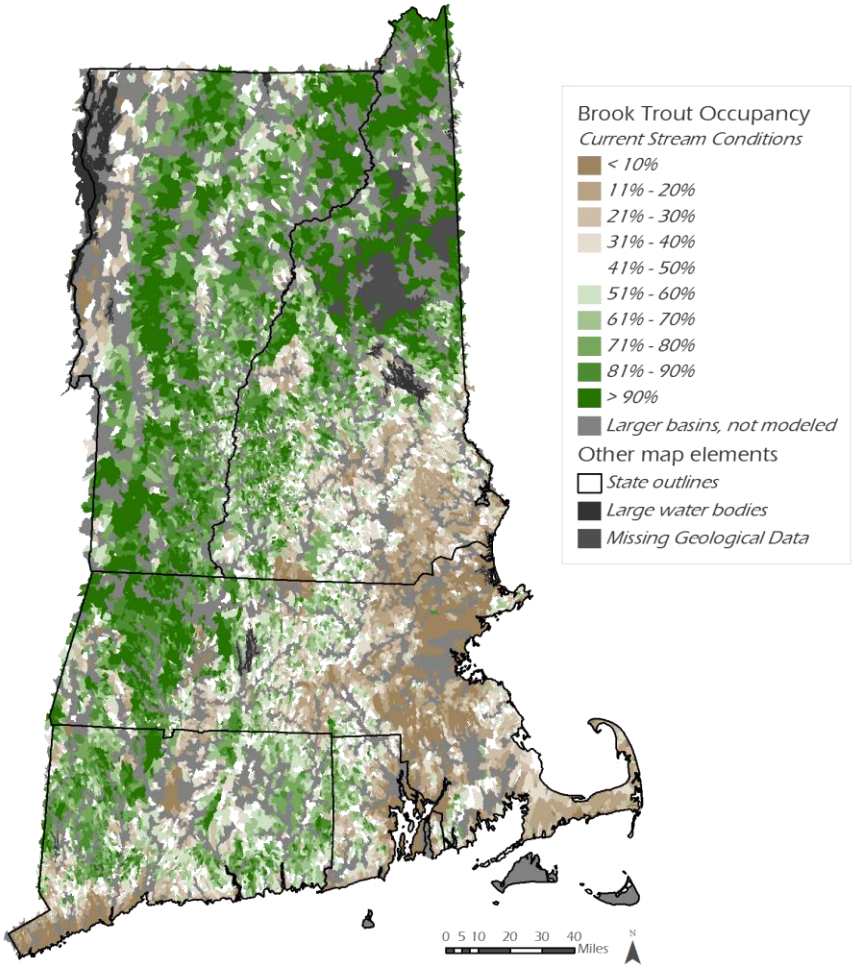
Predicted occupancy, 4º C increase

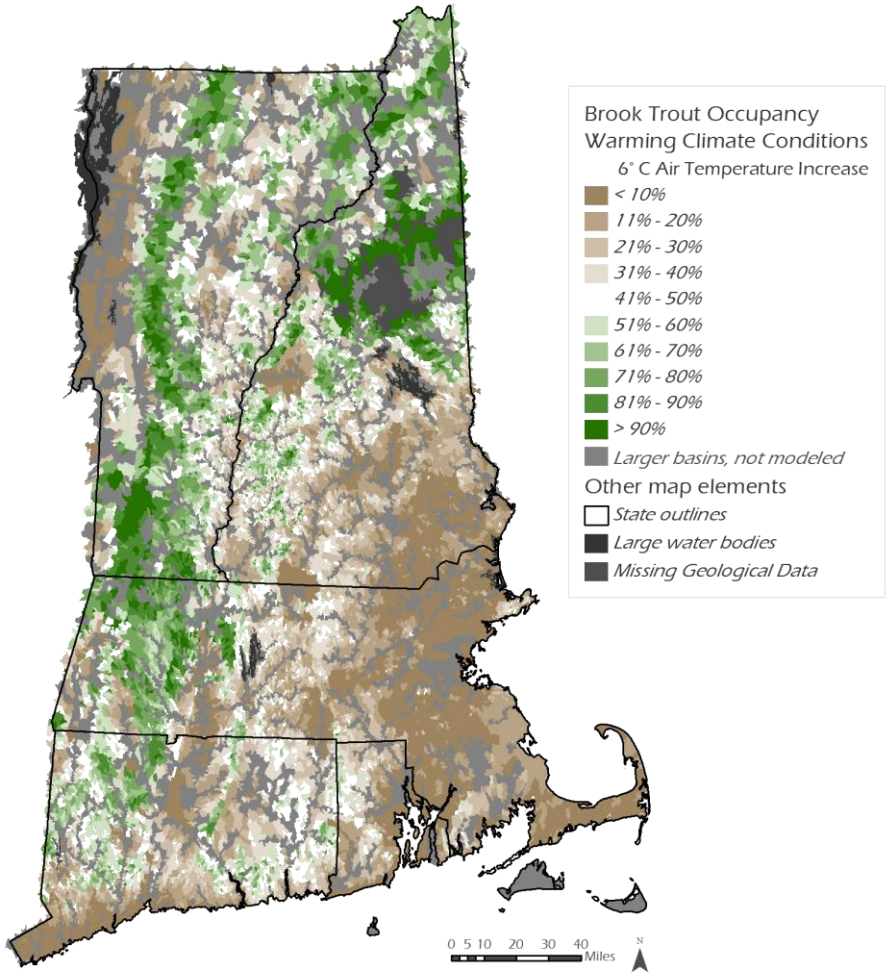




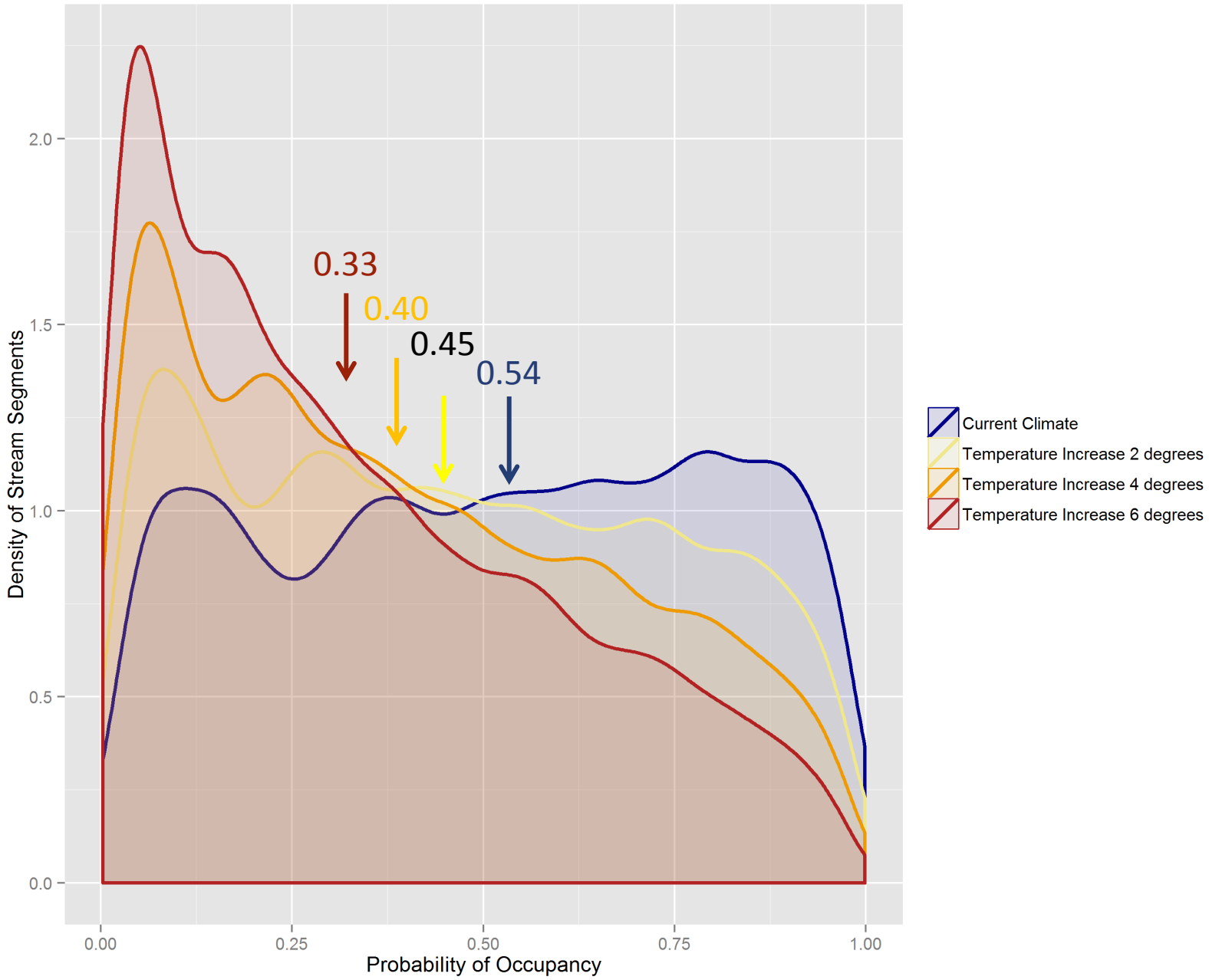
Fix temperature, how does occ vary?

Predicted occupancy, 6^{o} C increase

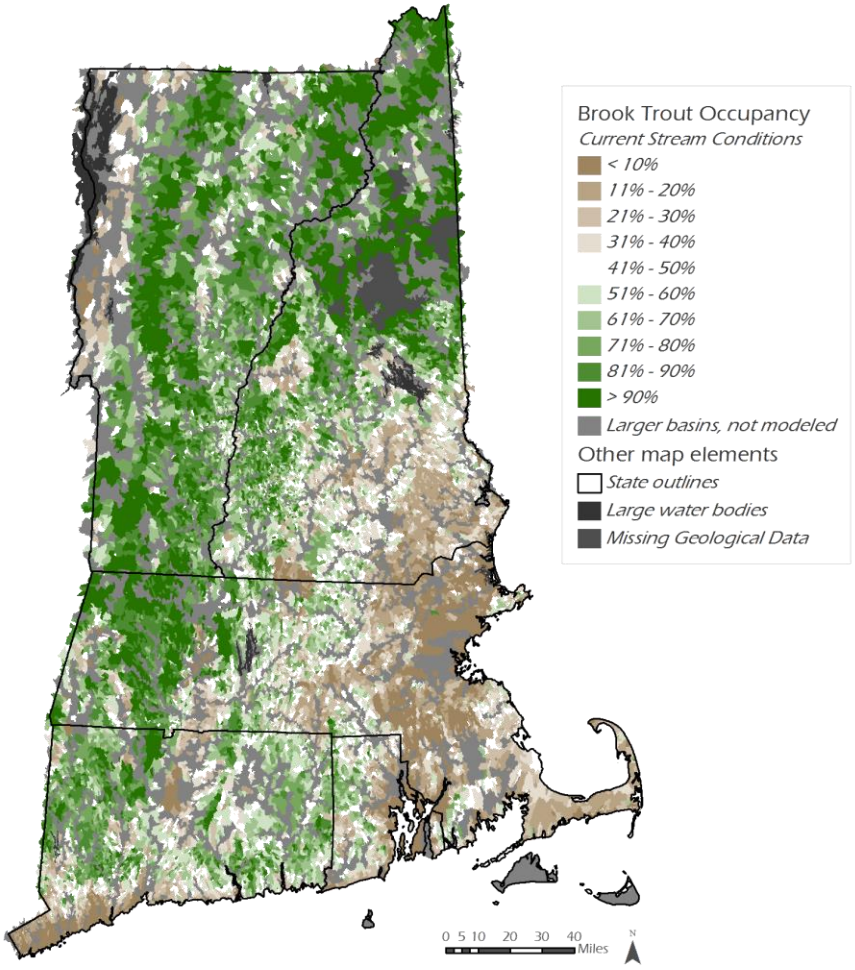


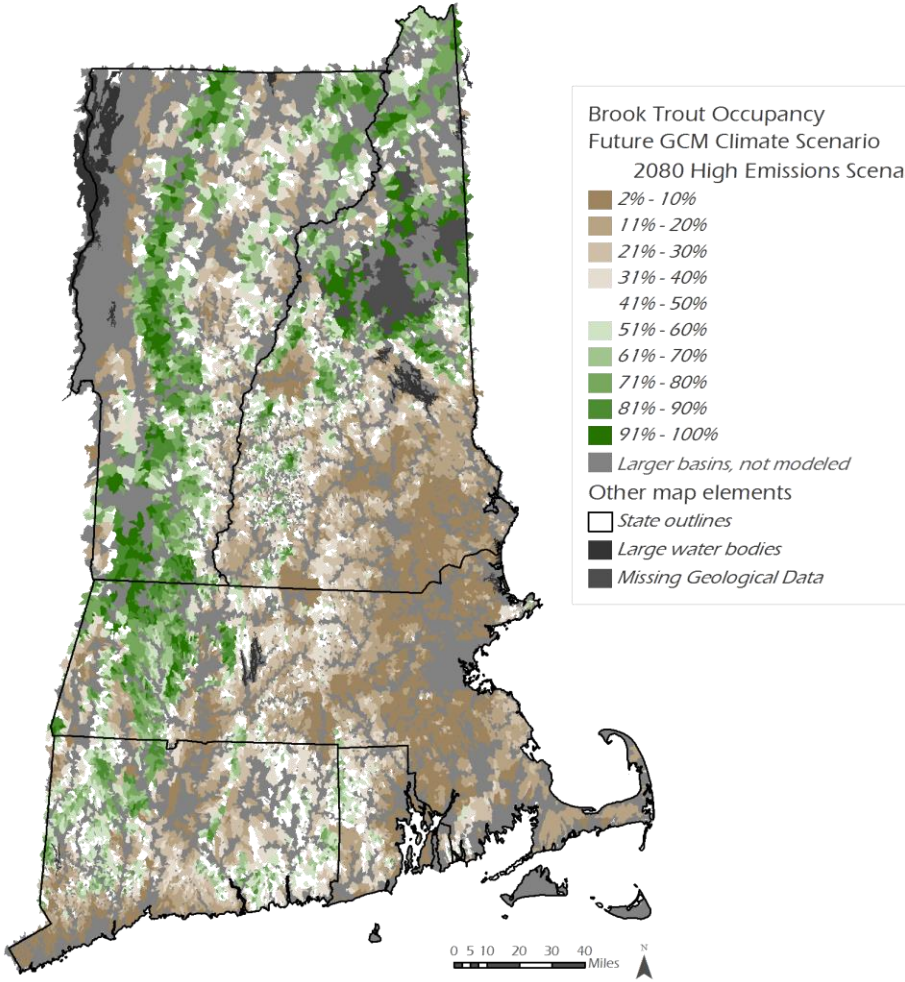


Fix temperature, how does occ vary?


0.33
0.40
0.45
0.54
Density of Stream Segments
Probability of Occupancy
0.0
0.5
1.0
1.5
2.0
0.00
0.25
0.50
0.75
1.00
Current Climate
Temperature Increase 2 degrees
Temperature Increase 4 degrees
Temperature Increase 6 degrees

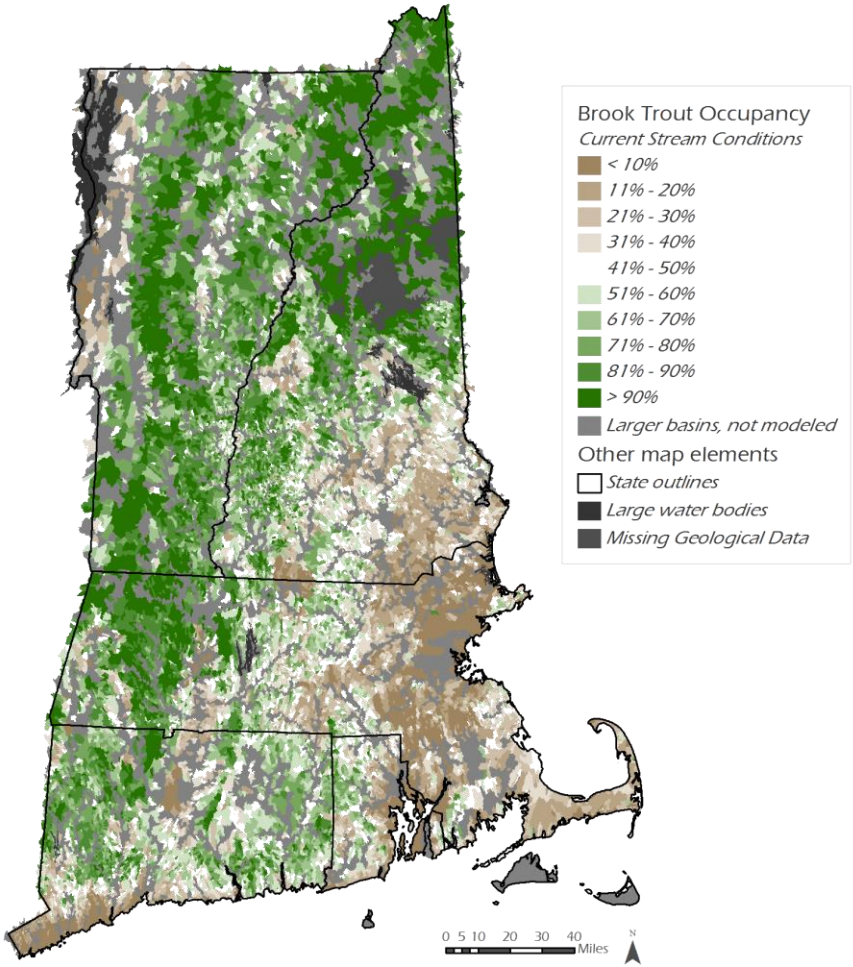
Predicted occupancy, GCM (2080 high emission scenario)

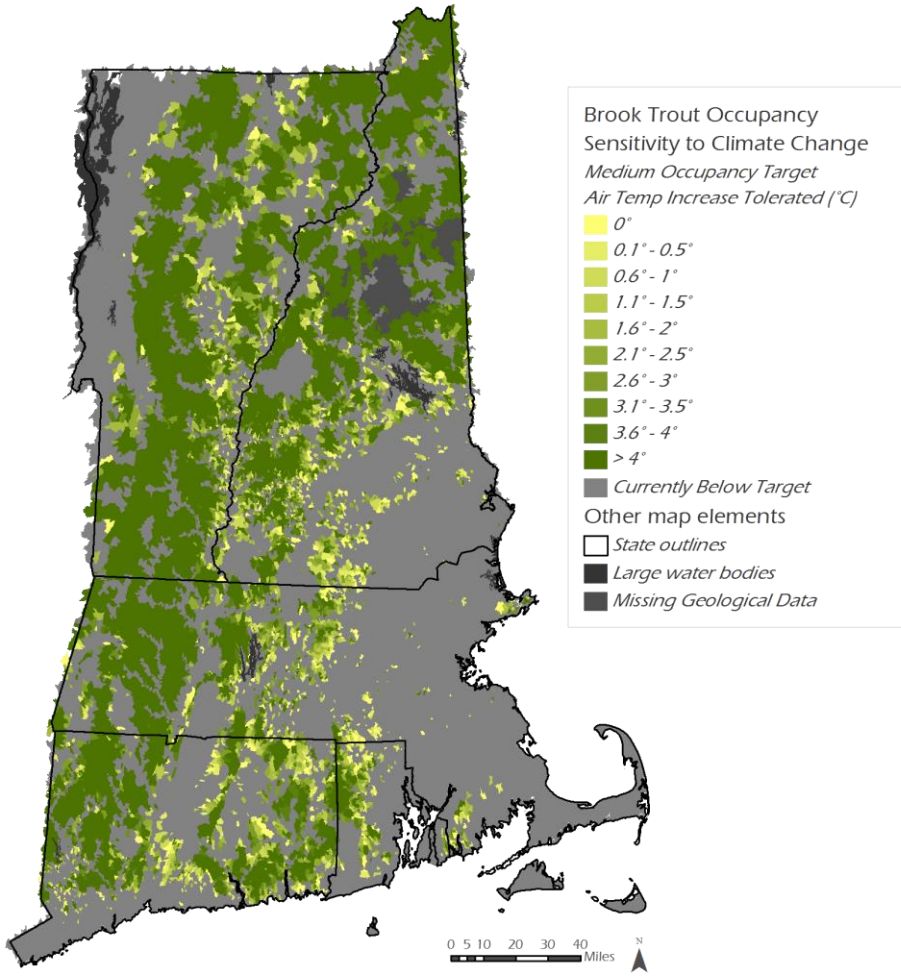




Fix climate, how does occ vary?

Predicted occupancy, Temperature tolerance





Fix occ, how does temperature tolerance vary?

Summary

- Daily synchronization / breakpoint temperature model seems effective
  - Many useful derived parameters, low RMSE
- Using temperature model to link climate to occupancy takes full advantage of temperature and fish data
  - 2 ^{o}C increase in air temperature ~ 0.07 decrease in p(occ)
- These simple statistical models are easy to update with new data
- Forecasting ability will improve with more data (space, time)
- Approach not limited to brook trout, or single species