Macroinvertebrate Tolerance Values

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Outline

- What are tolerance values?
- Generalizing the tolerance value estimation method
  - Weighted averaging
- Problems with weighted averaging
- Regression techniques
  - Maximum likelihood inference
- Some examples
- Use in biological assessment

What are tolerance values?

- The "original" tolerance values provided a relative measure of a taxon's sensitivity to organic pollution.

- Example Hilsenhoff tolerance values:
  - *Acroneuria* 0
  - *Ameletus* 0
  - *Aeshna* 5
  - *Callibaetis* 9

Hilsenhoff, WL. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist 20:31-37.

Can we estimate tolerance values for other stressors?

- How did Hilsenhoff develop his numbers?
  - Sampled streams with different levels of organic pollution
  - Assigned a value characterizing the level of organic pollution in each stream
  - Averaged the pollution values for streams in which each taxon was found.
  - ...plus best professional judgment.

The empirical process is a variant of weighted averaging.

Weighted averaging

- Estimate a taxon's *optimum* as the average of the environmental conditions at sites where it is observed.

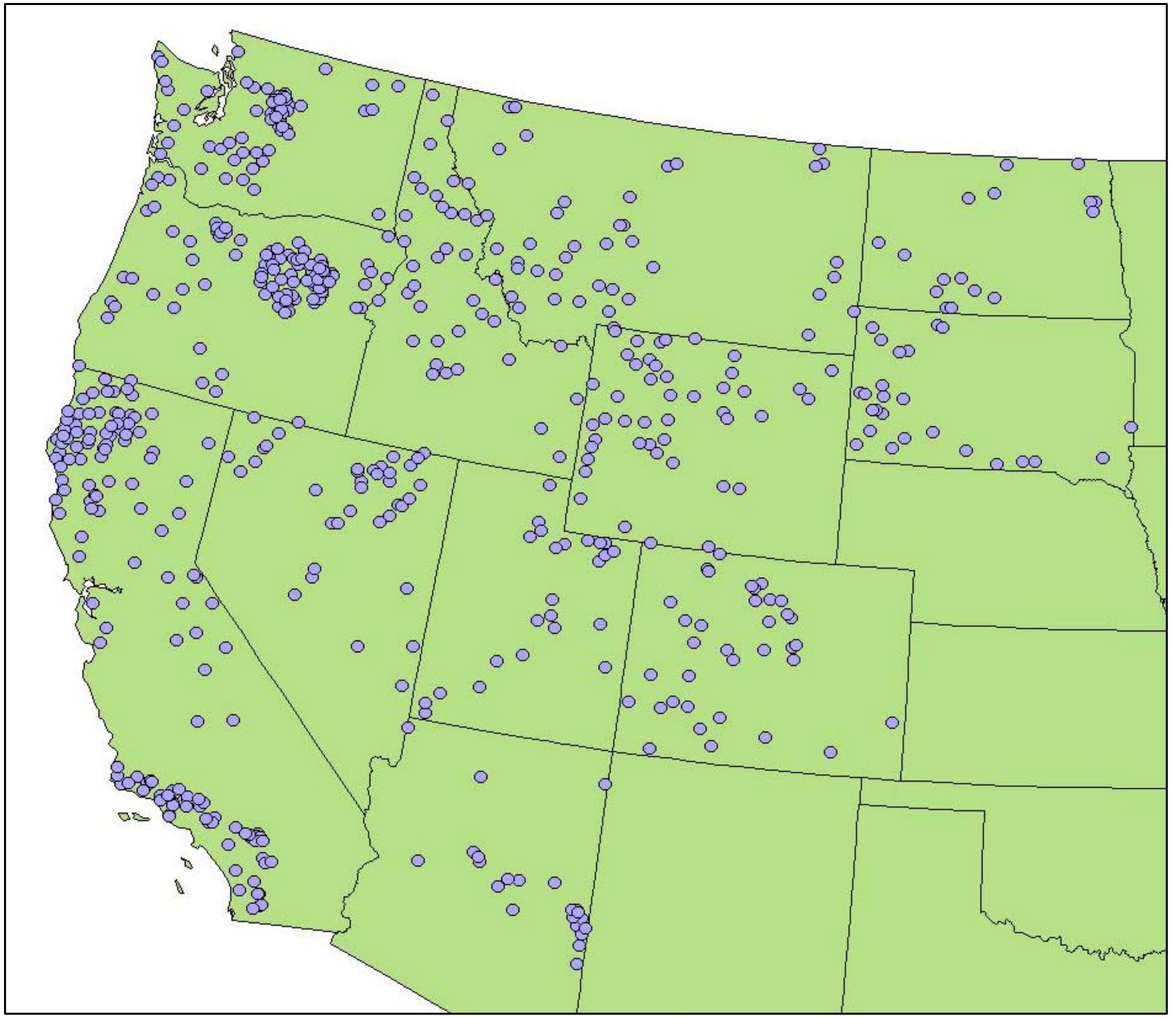
- Technique has long been used in ecology.
  - Curtis and McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology 32: 476-496.

Weighted averaging methods have been refined by paleolimnologists

- Use organism remains to infer past conditions in lakes, oceans, and estuaries.
  - Used to reconstruct past temperature, acidity, nutrient concentrations, and other environmental variables.

- Goal is explicitly defined as inferring environmental conditions from biological information.
  - Contrast with Hilsenhoff Biotic Index

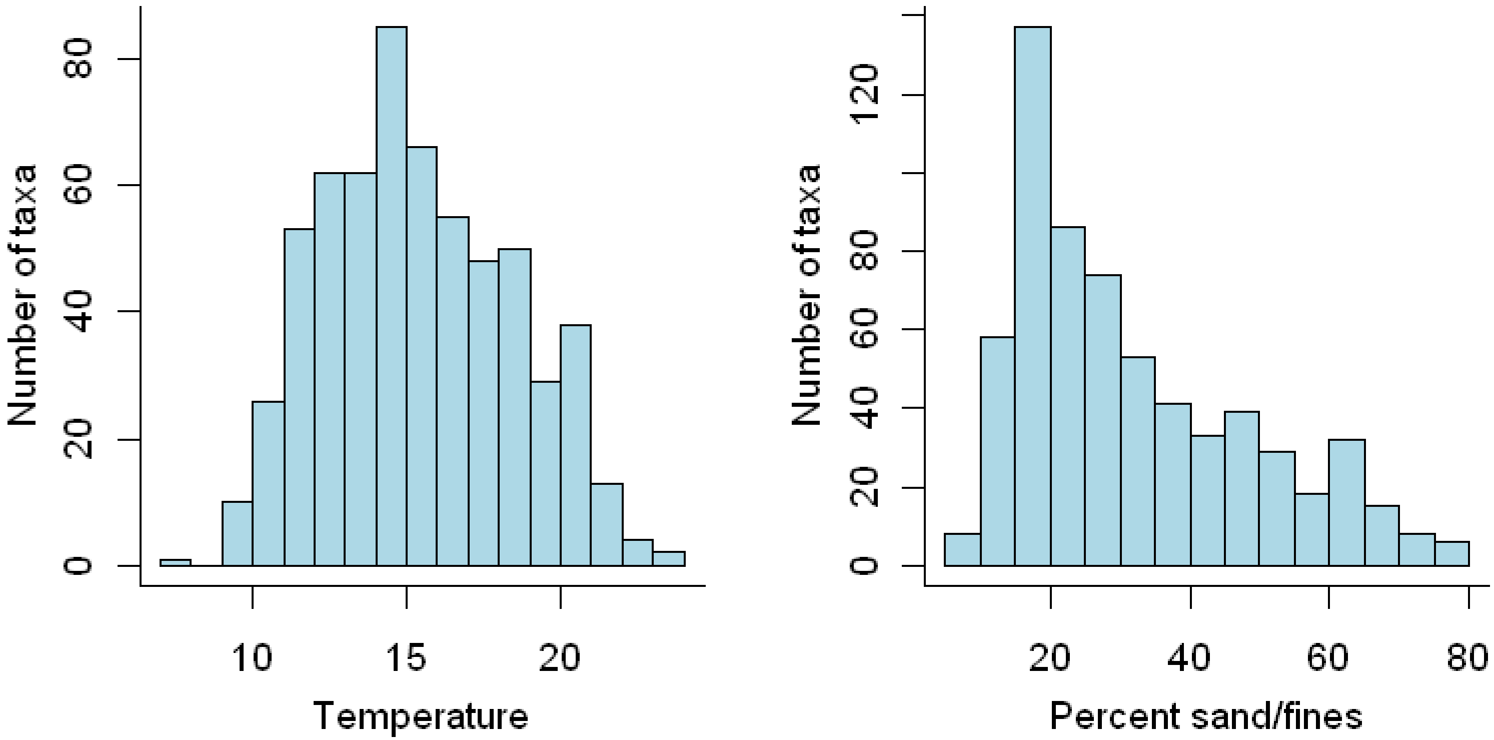
Western EMAP data



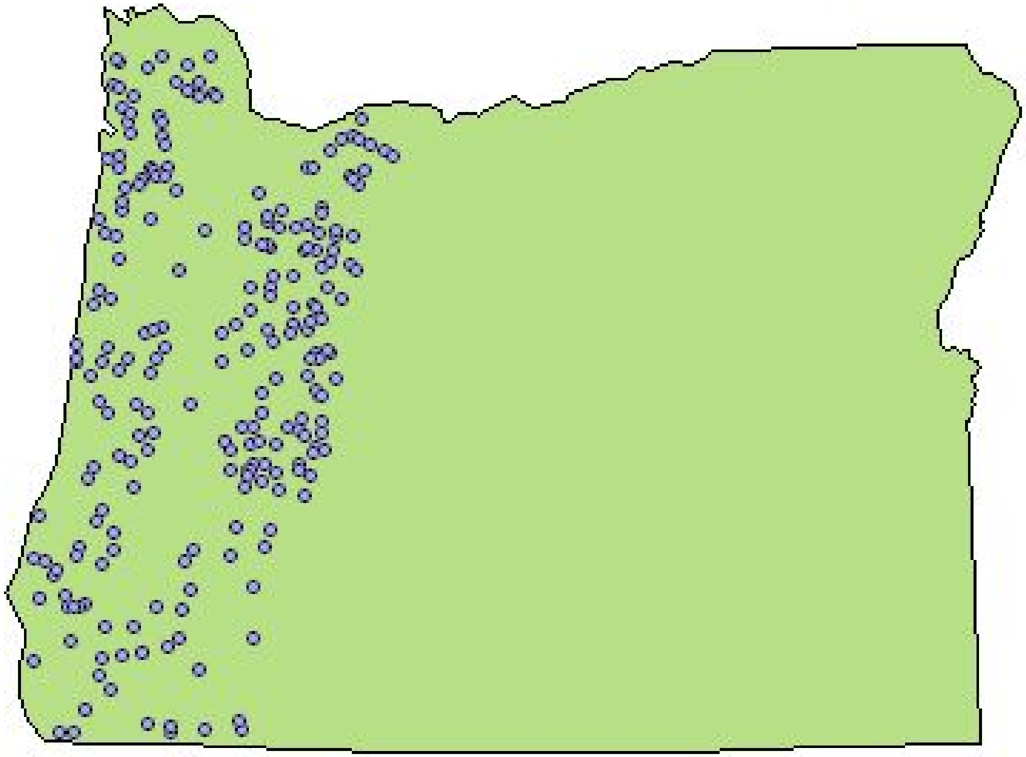
Data

- Macroinvertebrates
- Grab temperature
- Wolman pebble count, summarized as percent sand/fines.
- N = 838

Weighted average optima from EMAP-W

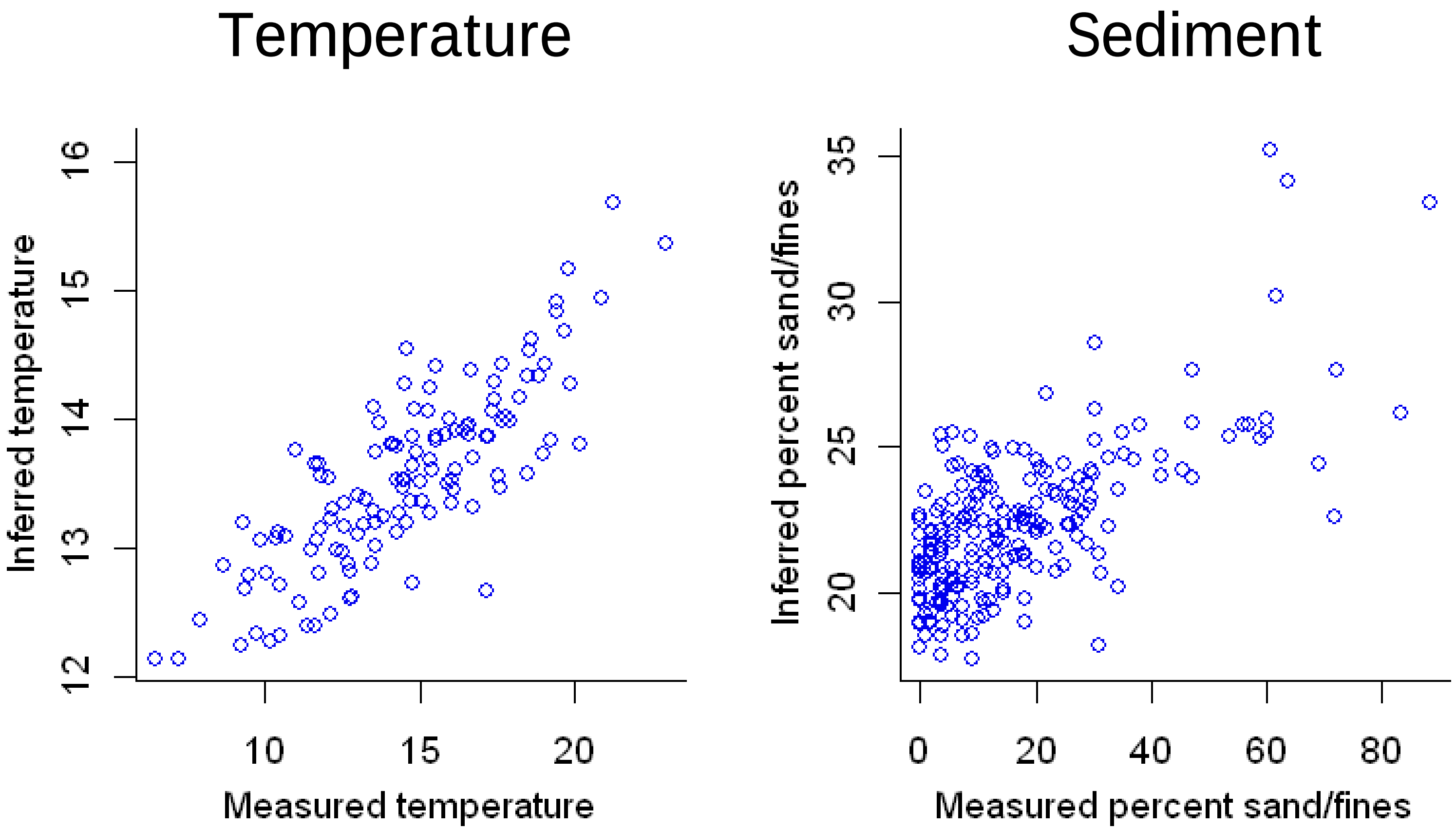


Validation data set: Western Oregon

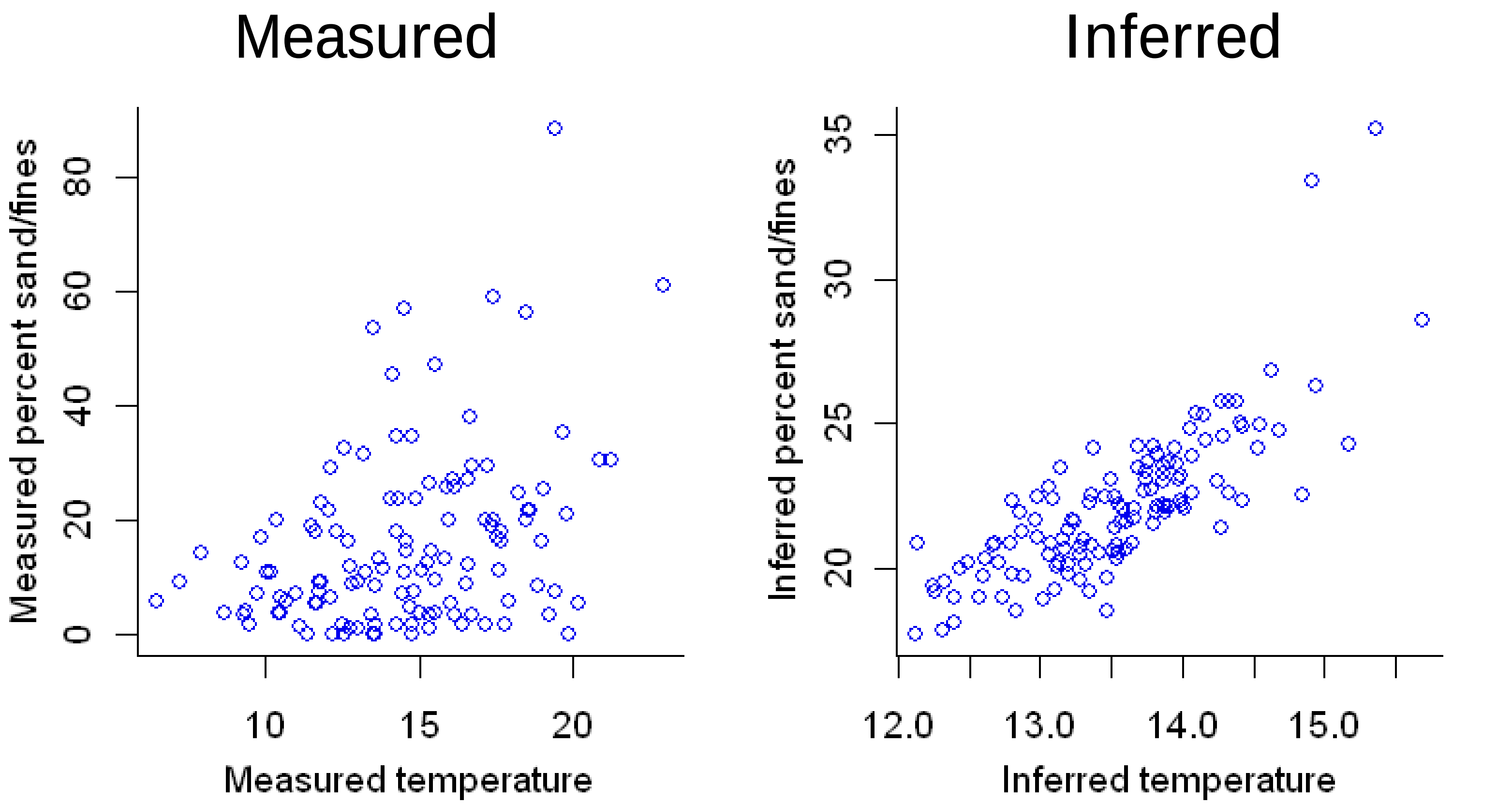


Data from Oregon Department of Environmental Quality

Weighted average predictions for OR

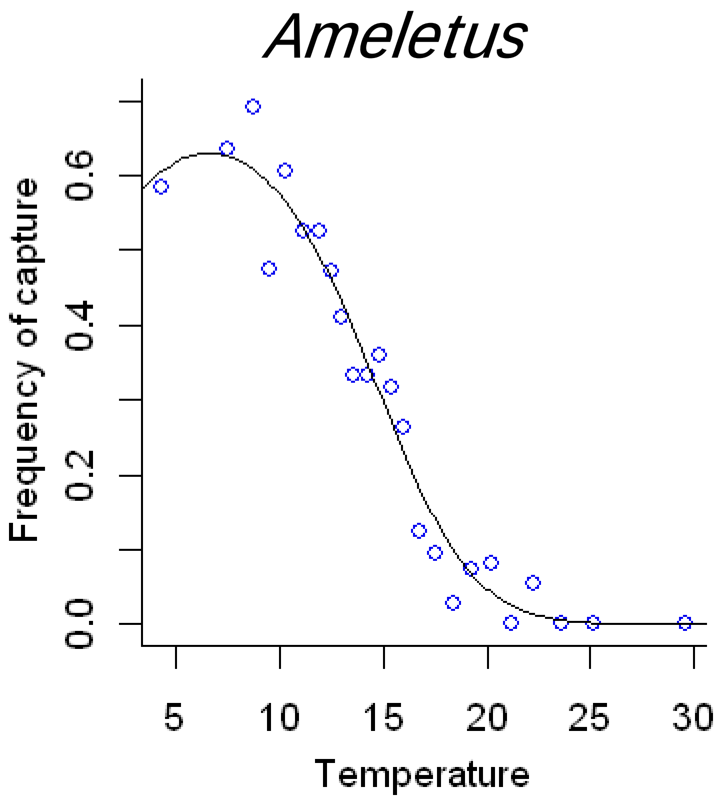


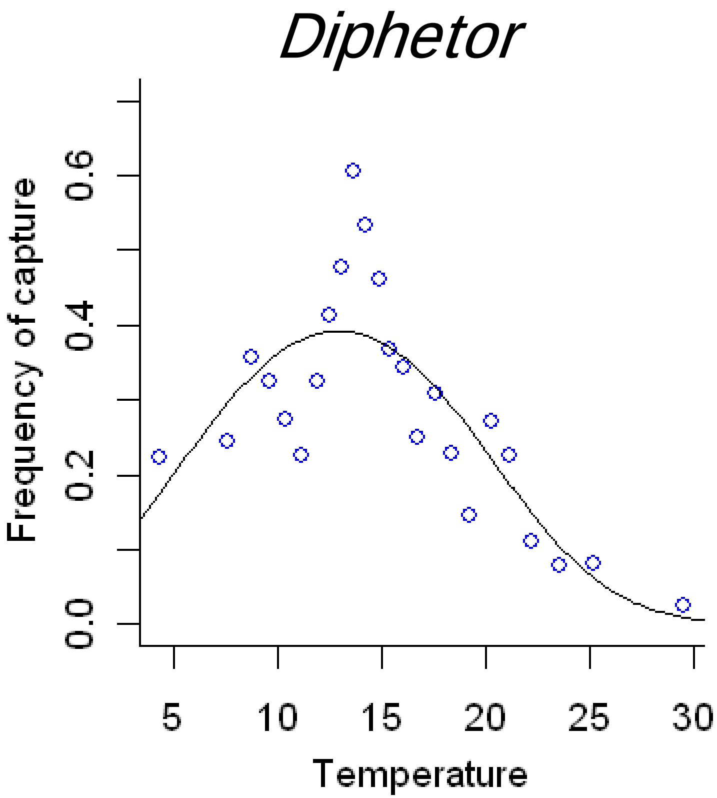
Sediment and temperature covary



Weighted averaging increases the strength of covariance between different variables because only a single variable can be modeled at a time!

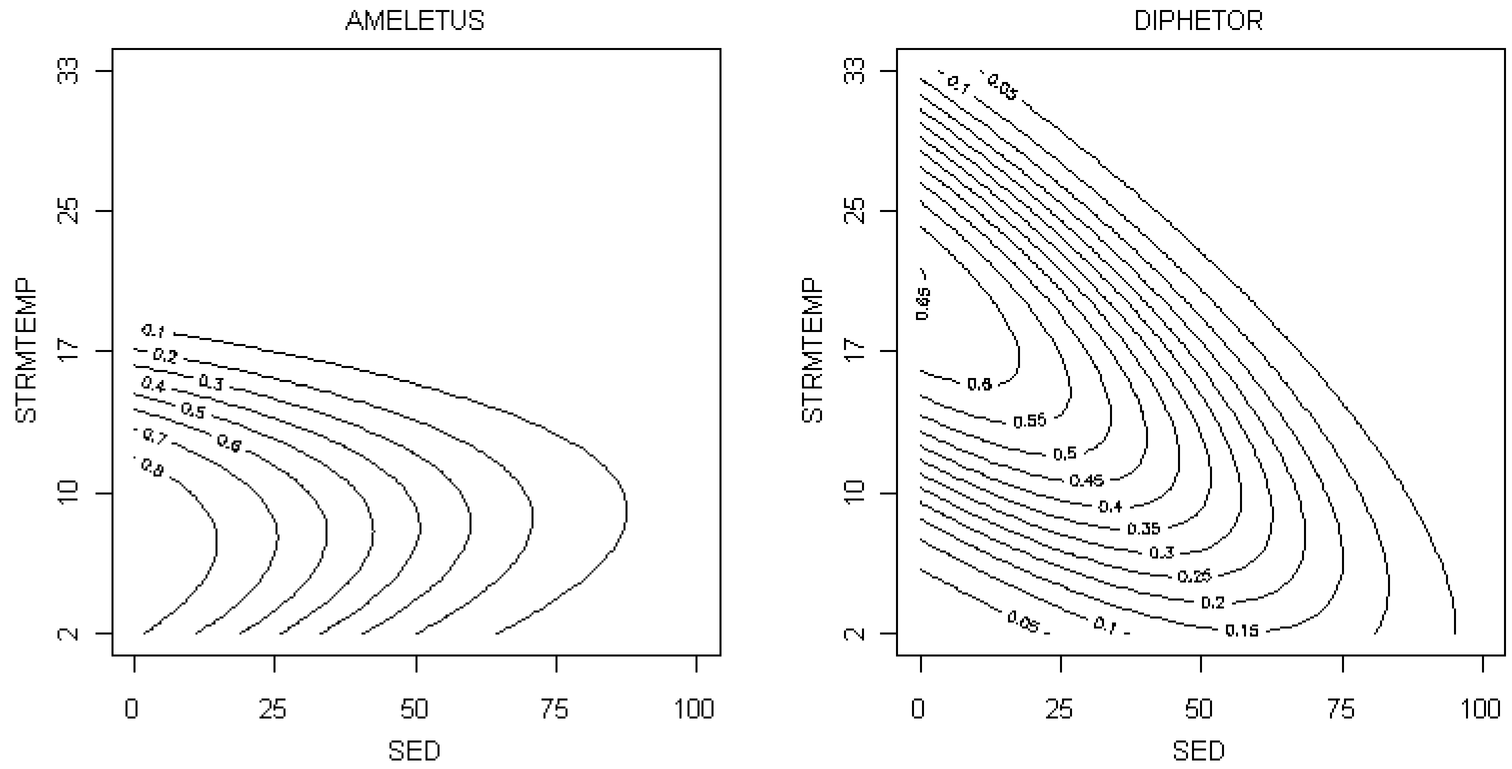
Logistic Regression





Each circle shows the frequency of occurrence in ~20 samples around the indicated temperature.

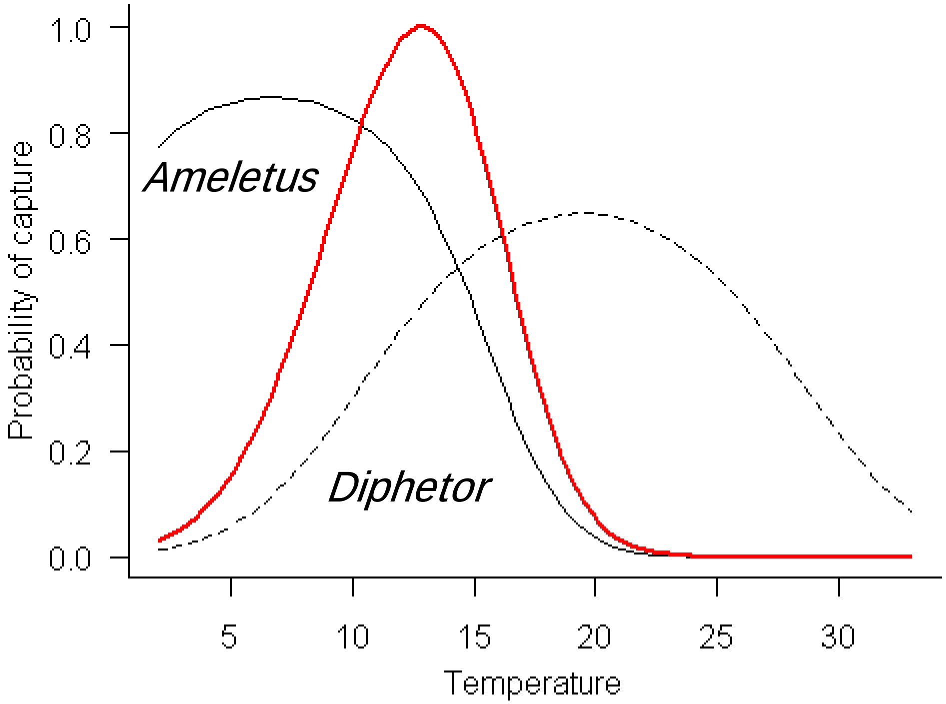
Multiple variables can be modeled simultaneously



Contours show the modeled mean probability of capture.

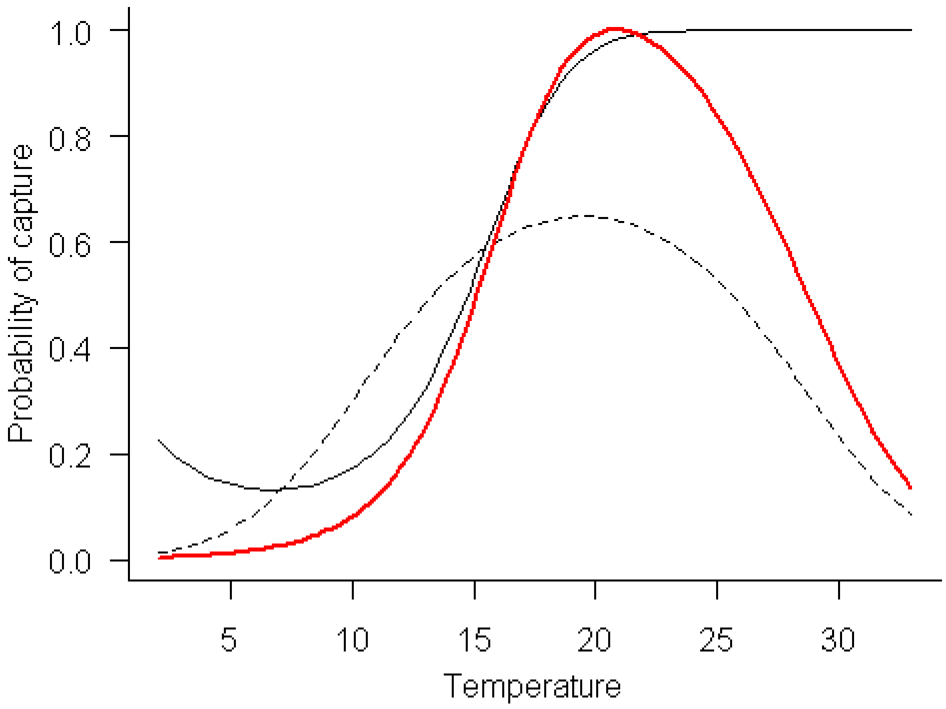
Maximum likelihood inference

Example 1: Both *Ameletus* and *Diphetor* present at the site.



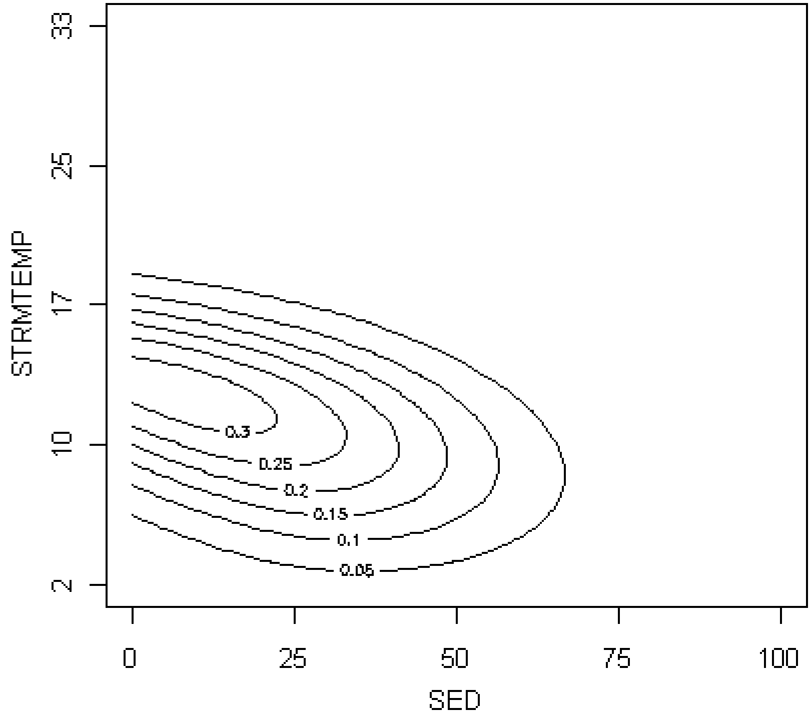
Maximum likelihood inference

Example 2: *Ameletus* absent and *Diphetor* present.

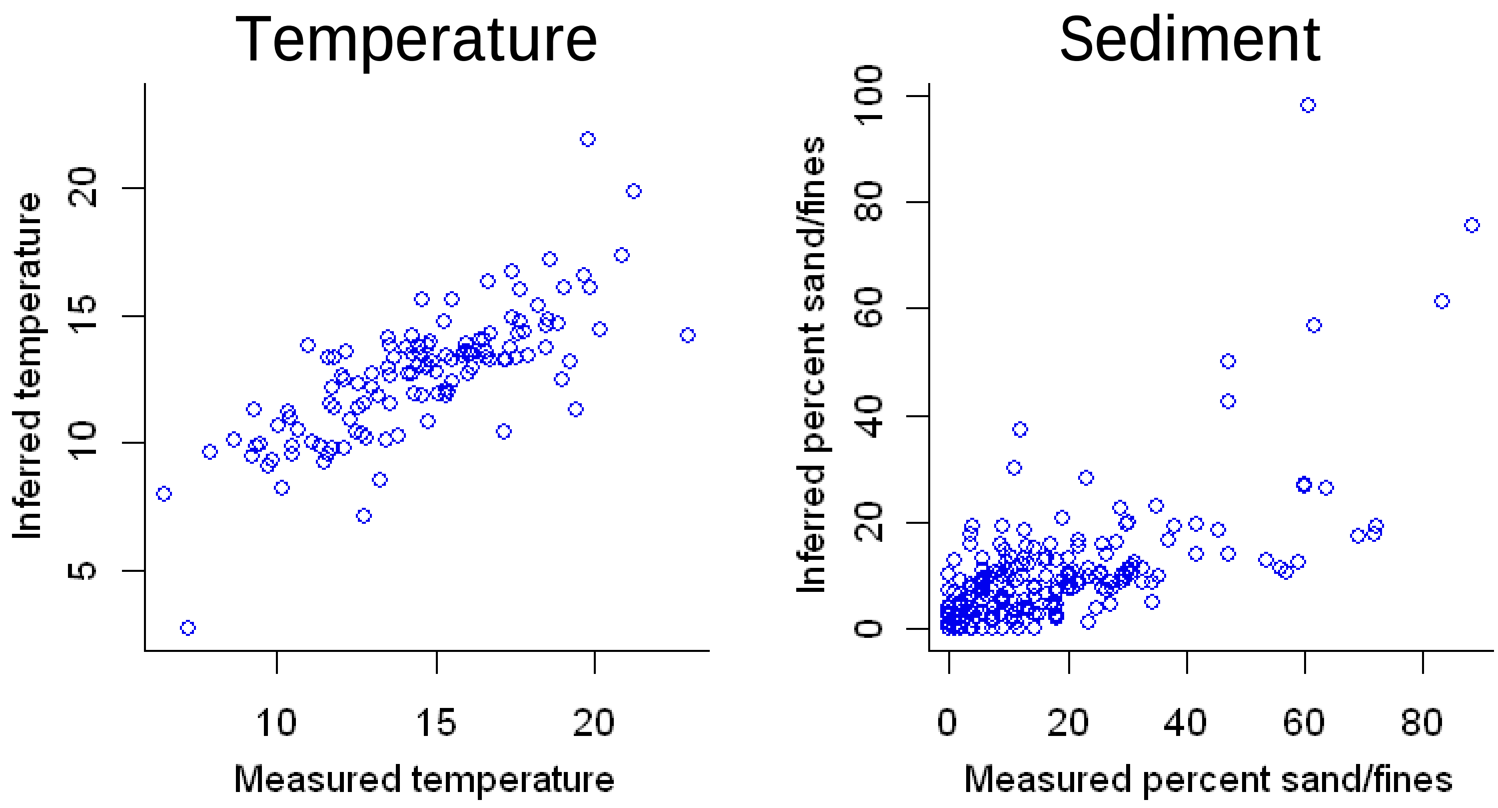


Maximum likelihood inference: Multiple gradients

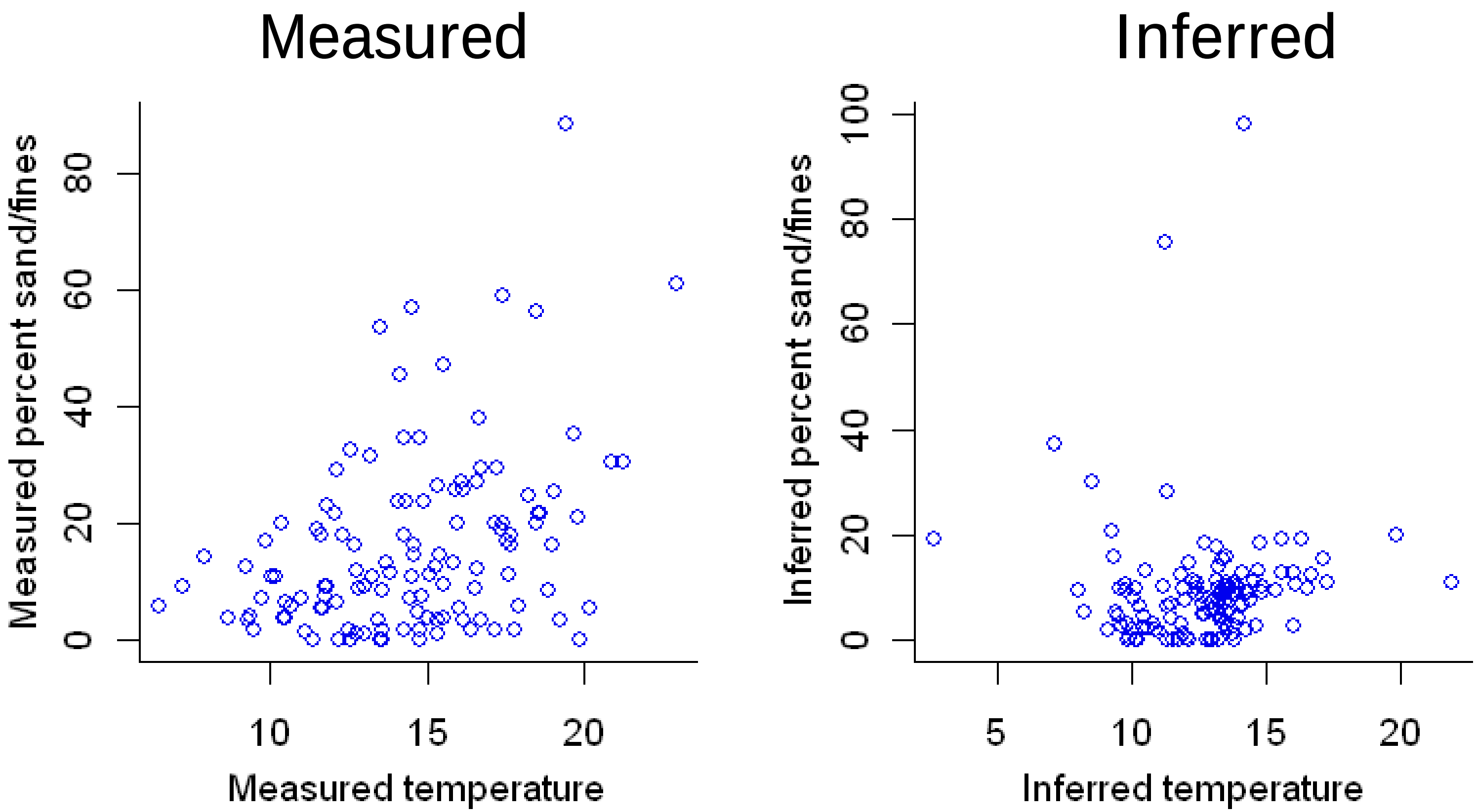
Likely conditions when both *Ameletus* and *Diphetor* are present.



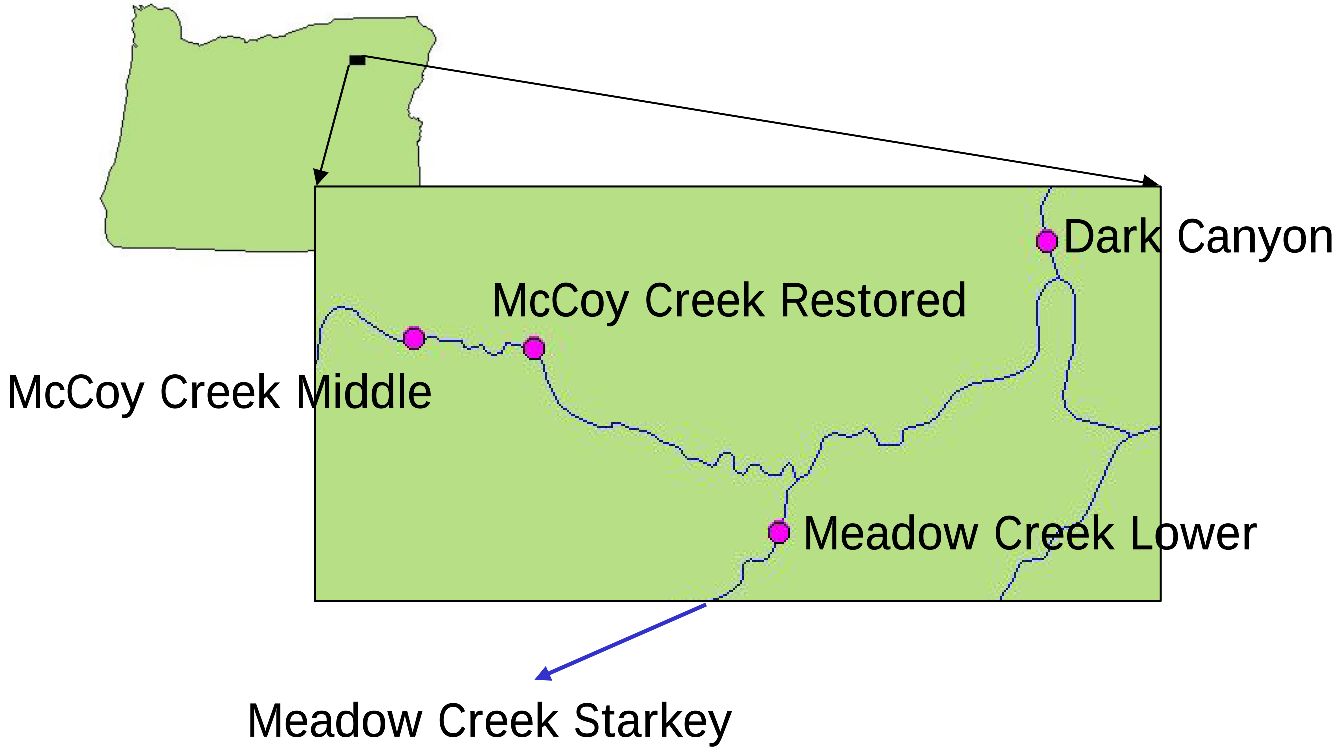
ML predictions of sediment and temperature are accurate



Spurious covariance is controlled

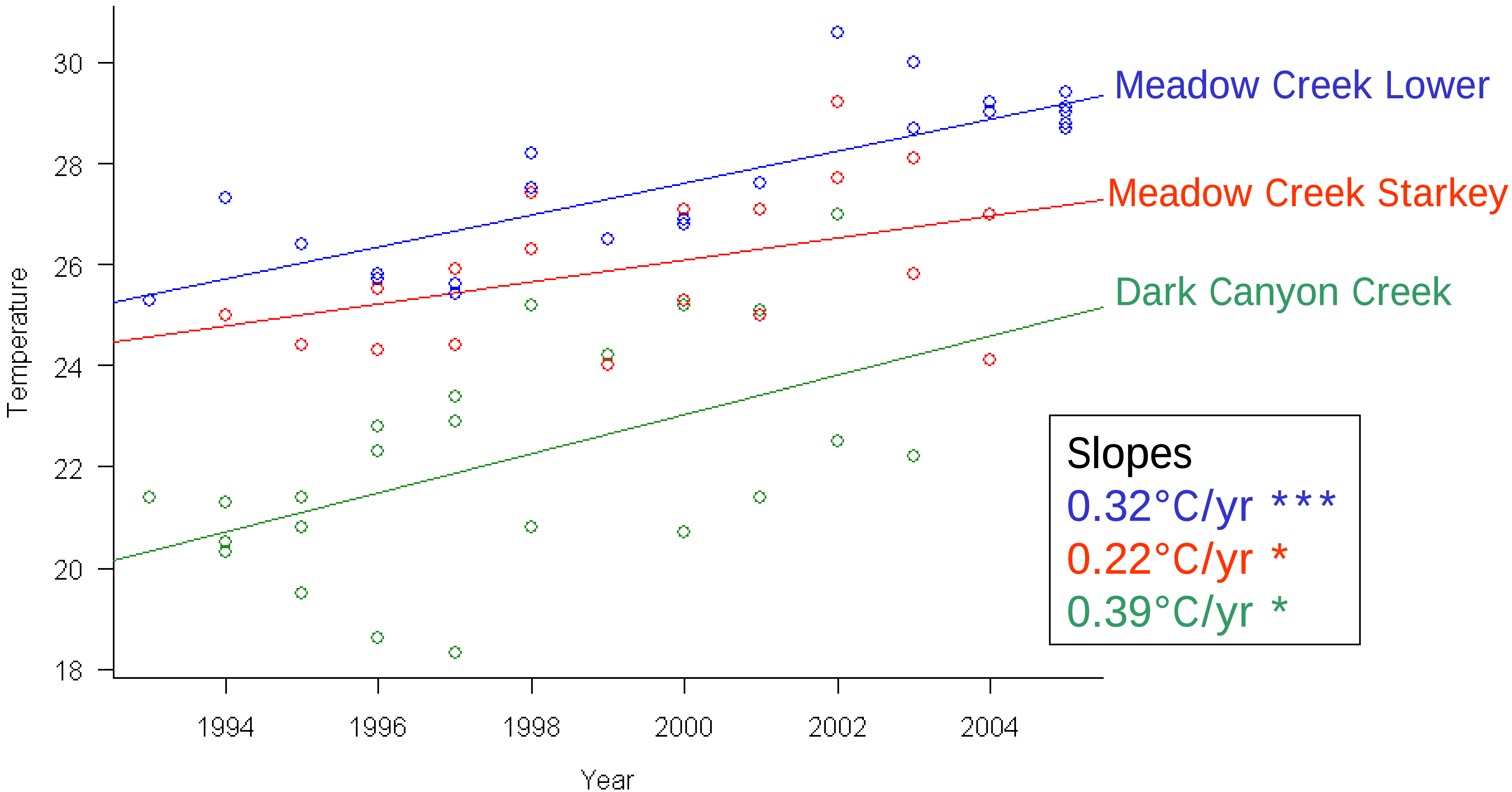


Within-site changes: McCoy Creek, OR: 1993-2005



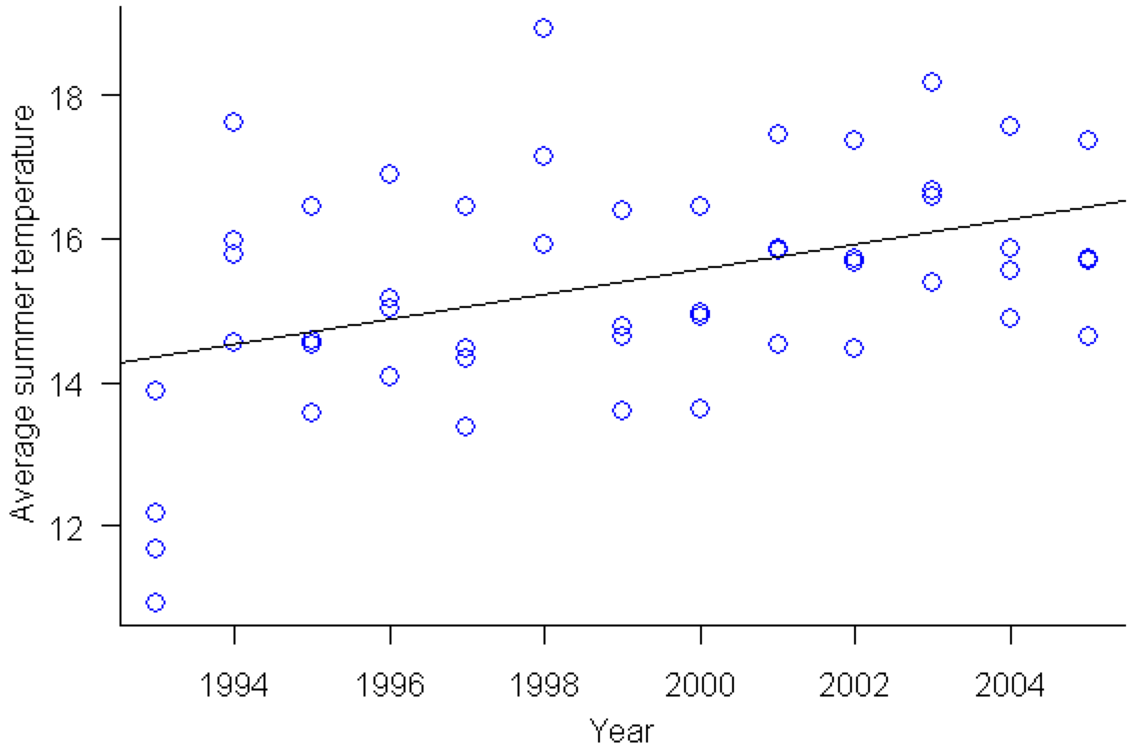
McCoy Creek rerouted to historical channel (McCoy Creek Restored) in 1997. Data from Oregon Department of Environmental Quality.

Measured temperature: Control sites



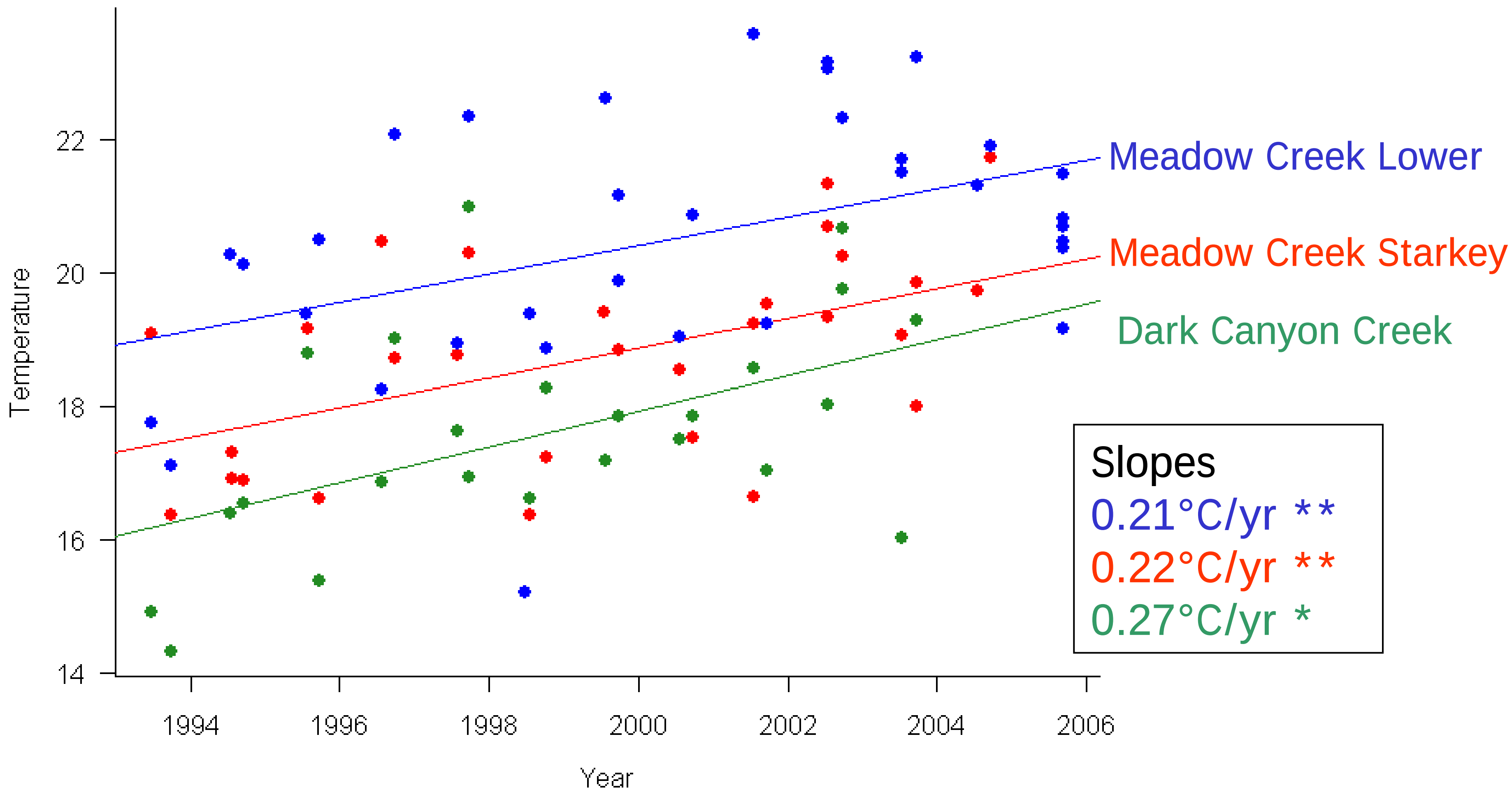
Stream temperature recorded hourly and summarized as 7-day average maximum.

Regional Trend in Air Temperature



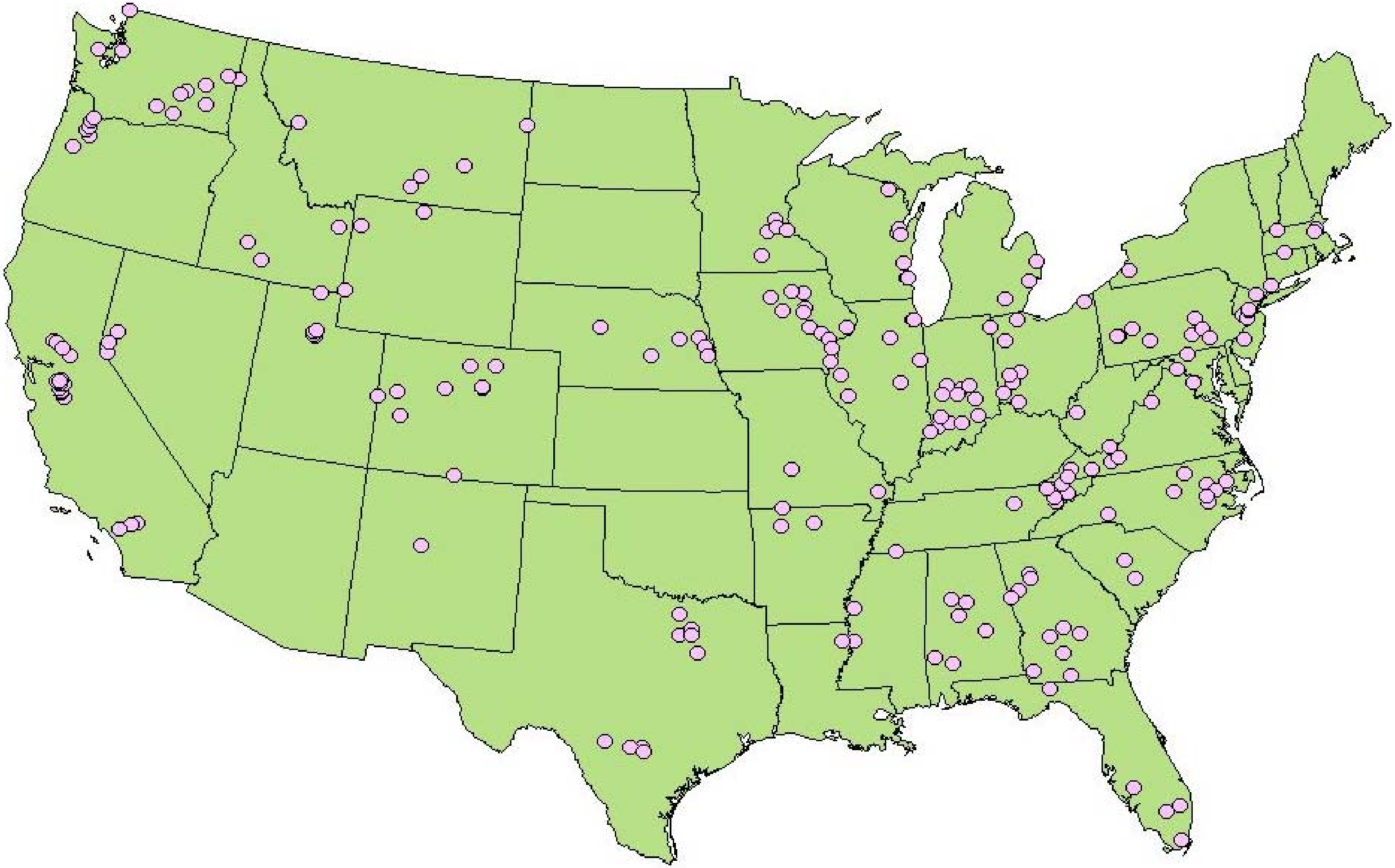
Daily air temperature data from three neighboring SNOTEL stations.
Summarized as average summer temperature.
Mean increase: 0.17° C/year

Biologically-inferred temperatures: Control streams



Biologically-inferred temperatures seem to reproduce temperature trends.

NAWQA Pesticide Sampling Locations

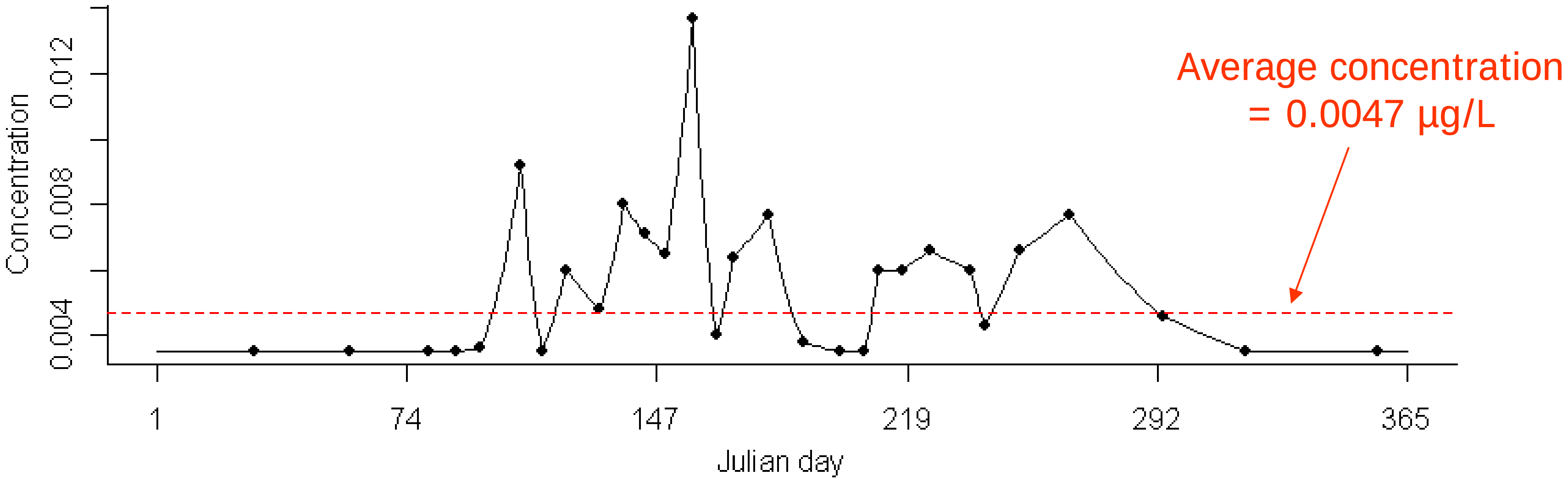


NAWQA: National Water Quality Assessment Program (USGS)

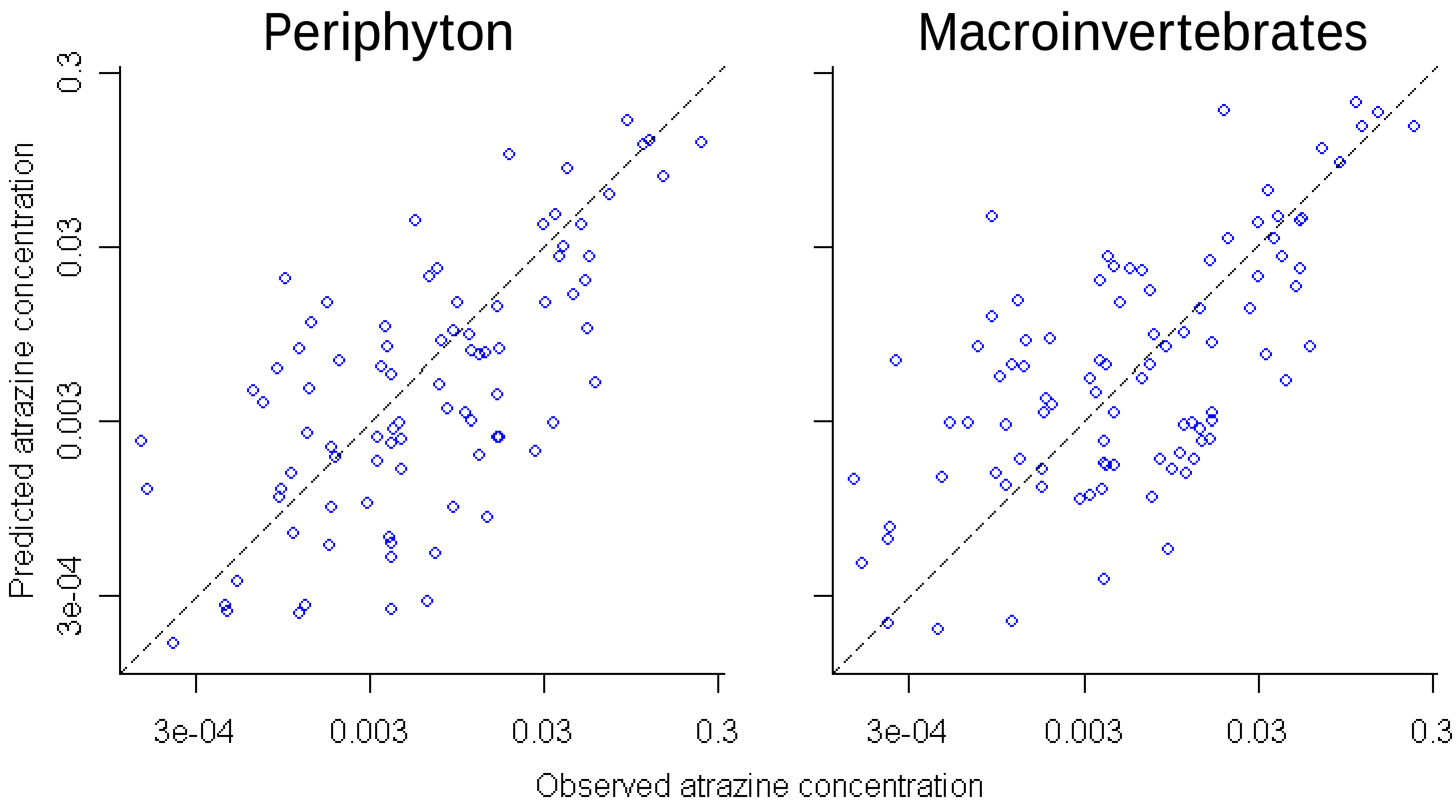
Time-weighted Annual Average Concentration

- Linear interpolation between successive, transformed measurements.
- Beginning and ending values assumed to be non-detects.
- Equal weight assigned to each day
- At least 6 measurements required for each year.
- Long-term average concentration at each station computed as the average of all valid yearly averages.

Atrazine concentration, Norwalk River at Winnipauk, CT, 2002



Predictive Accuracy



$R^2 = 0.45$

$R^2 = 0.42$

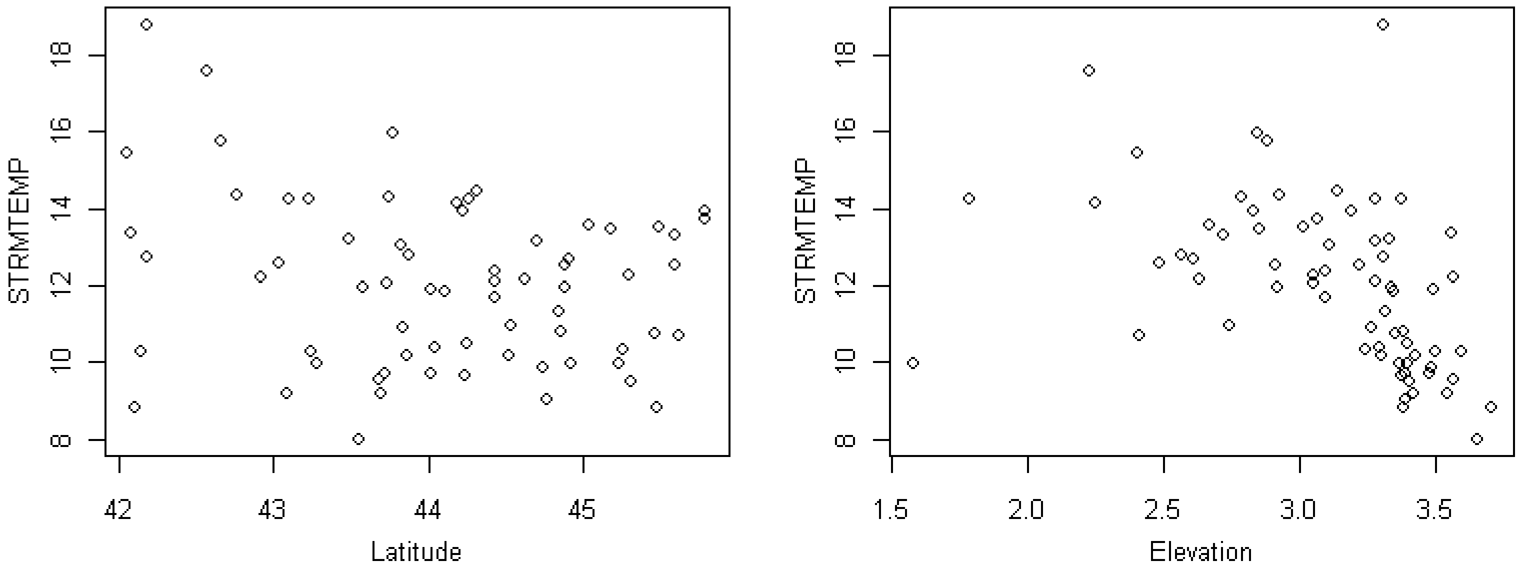
Combined model for periphyton and macroinvertebrates: $R^2 = 0.49$

Using biologically-based inferences in assessment

- Temperature and sediment (and many other environmental factors) vary because of both natural and anthropogenic influences.

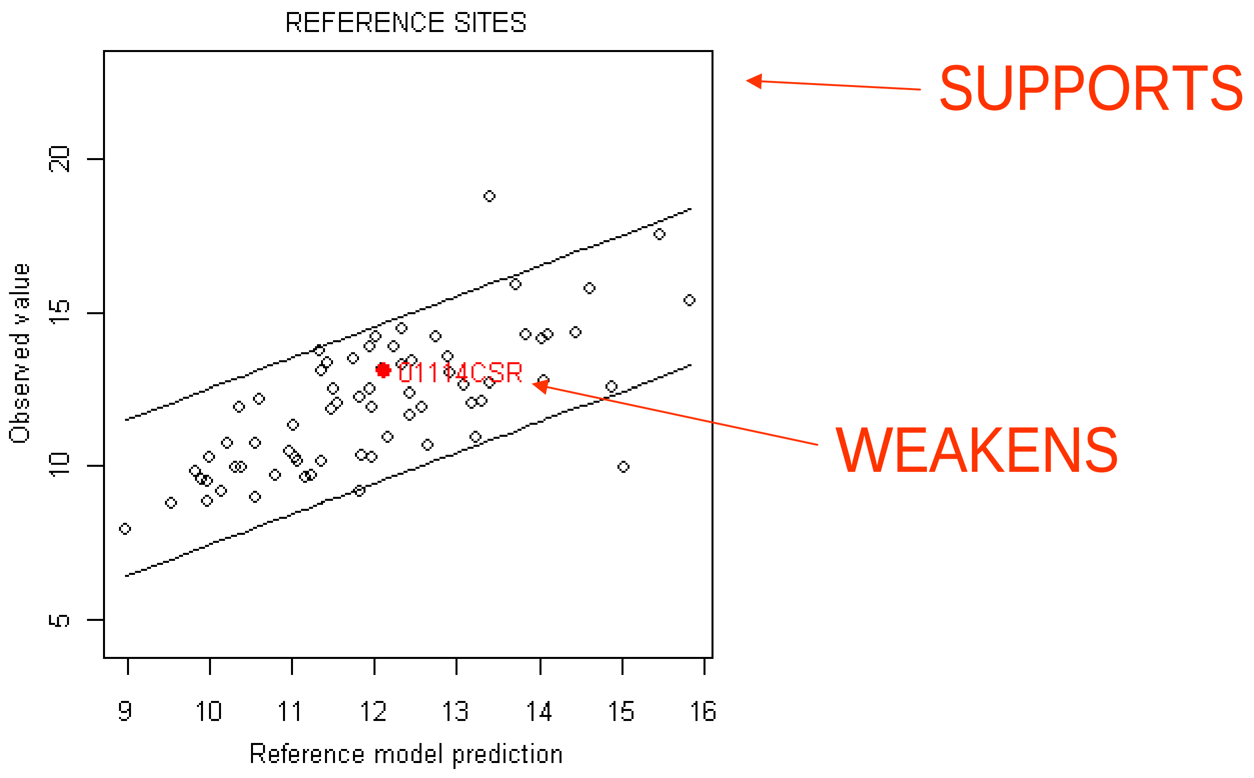
- Must establish reference expectations for the inferred conditions.

Oregon Stream Temperature



Inferred stream temperatures in Oregon reference sites are a function of elevation and latitude.

Reference model predictions vs. observations



Conclusions

- Weighted averaging accurately predicts single variables, but can artificially increase covariance between different variables.

- Maximum likelihood inferences control covariances by modeling several variables simultaneously.

- Inferences accurately reproduce environmental changes within sites and have been developed for several different environmental variables.

More information

- R scripts for predicting environmental conditions from biological observations are available from http://cran-r.project.org
  - Library name: bio.infer

- Background information on the underlying statistics can be found at http://www.epa.gov/caddis

Acknowledgements

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