Macroinvertebrate Tolerance Values

Lester Yuan

National Center for Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency

The views expressed in this presentation are those of the authors and do not represent those of the U.S. Environmental Protection Agency.
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

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

Temperature

Sediment

Inferred temperature vs. Measured temperature

Inferred percent sand/fines vs. Measured percent sand/fines
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.

Slopes:
- Meadow Creek Lower: 0.32°C/yr ***
- Meadow Creek Starkey: 0.22°C/yr *
- Dark Canyon Creek: 0.39°C/yr *
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 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

Average concentration = 0.0047 µg/L
Predictive Accuracy

Periphyton

Macroinvertebrates

$R^2 = 0.45$

$R^2 = 0.42$

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

REFERENCE SITES

SUPPORTS

WEAKENS
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
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