

# Factor-ceilings:

A possible alternative to a  
'fixed' reference condition

*The fundamental problem ...*

# Prologue

*The difficulty associated with establishing reference conditions is a major limitation to the development of bioassessments.*

*(EPA Science Advisory Board)*

# Outline

- ◆ Describe limits and the distributions to which they can be applied.
- ◆ Provide examples from ecology and impact assessments.
- ◆ Demonstrate a method for their estimation and application.

*A little background on limits ...*

# Law of the Minimum



- ◆ Justus von Liebig (1803-1873) in 1840
  - Organic chemist that “formalized” agricultural chemistry and demonstrated that even if all necessary nutrients are present – that which is minimum relative to need limits growth
- ◆ “Sprengel-Liebig Law of the Minimum”
  - Carl Sprengel published an article in 1828 on soil chemistry and mineral nutrition of plants – also the “law of the minimum”

# Law of Tolerance

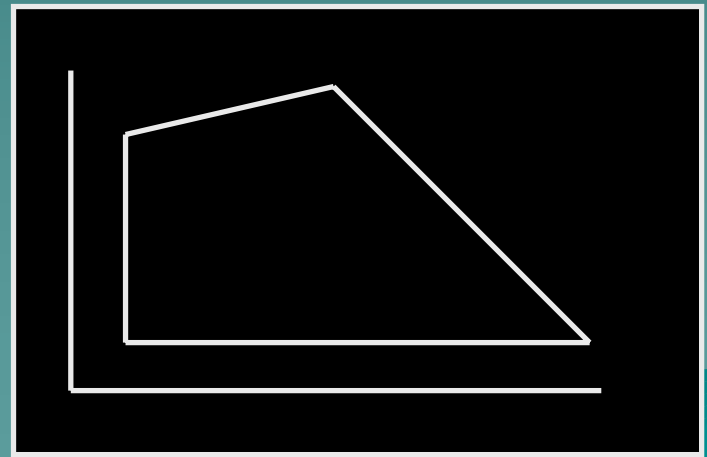
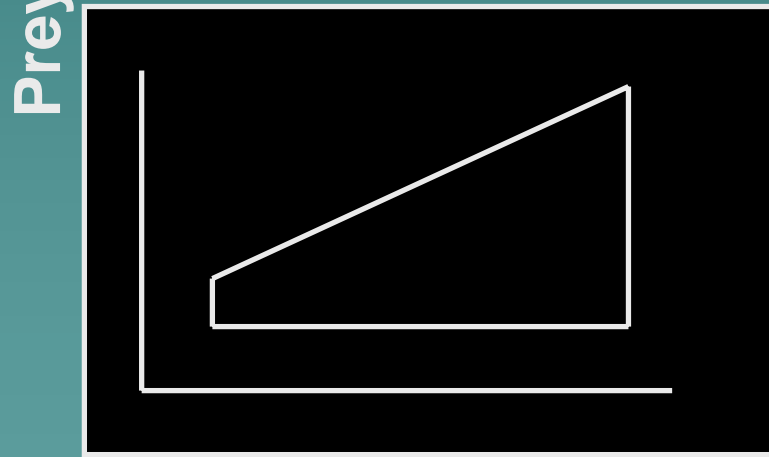
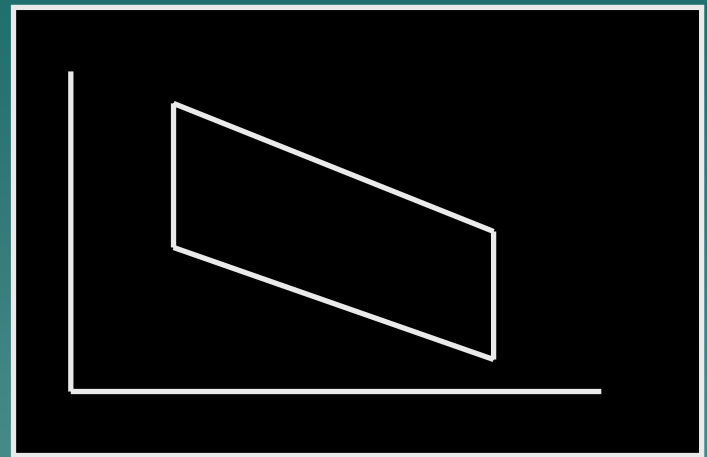
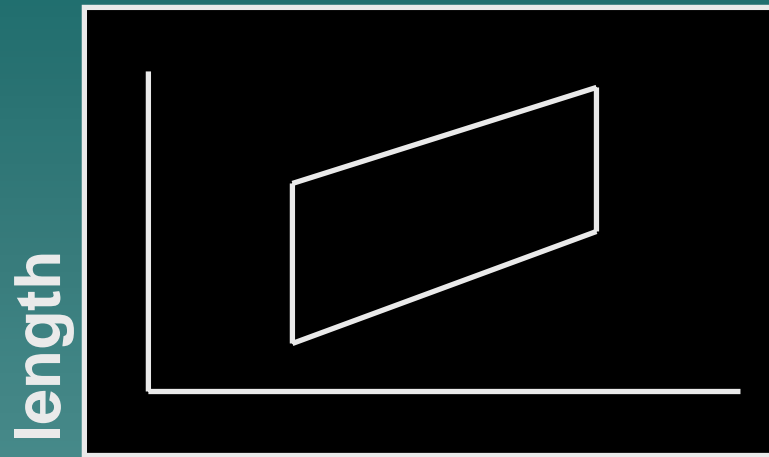
- ◆ F.E. Blackman, a plant physiologist, noted that too much as well as too little could also limit growth.
  - *“When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest factor.”* from Blackman (1905) *Ann. Bot.* 19, 281
- ◆ V.E. Shelford (1913) proposed a more general concept - *“The Law of Tolerance”*
  - Survivorship
  - Growth and reproduction
  - Geographical and ecological distribution

# Polygonal Distributions

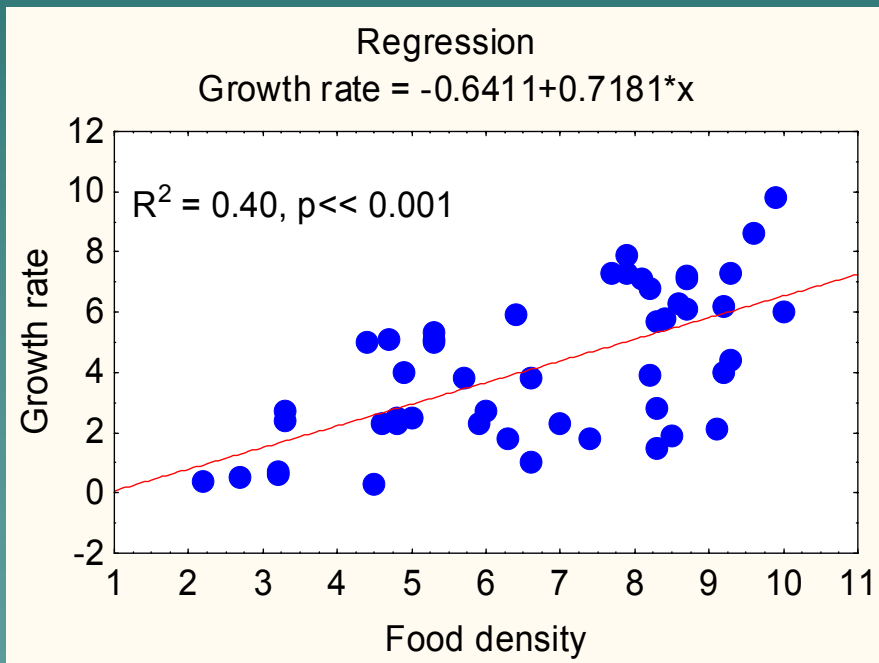
Observation and approach

Thomson et al. 1996

# Polygonal Relationships

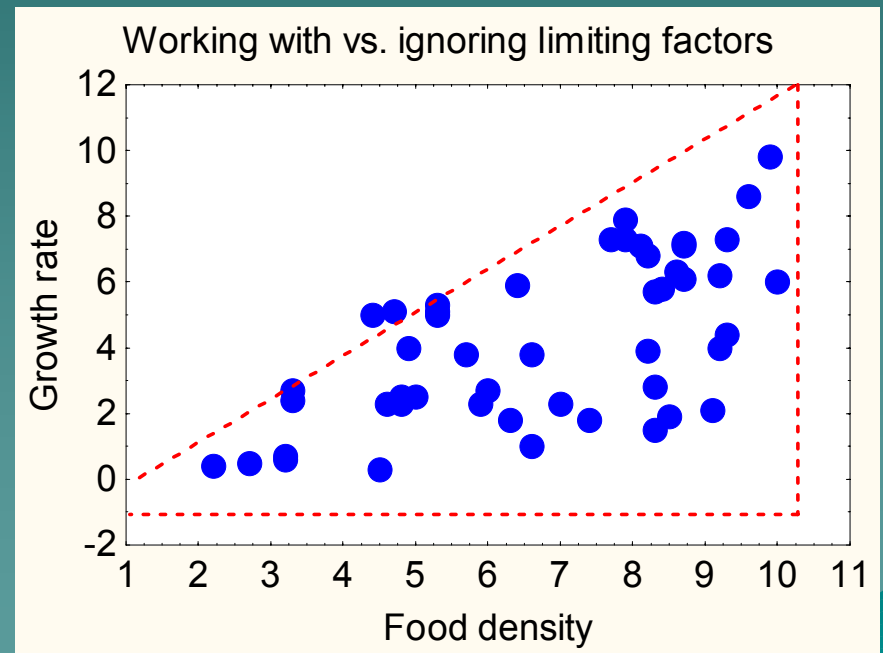
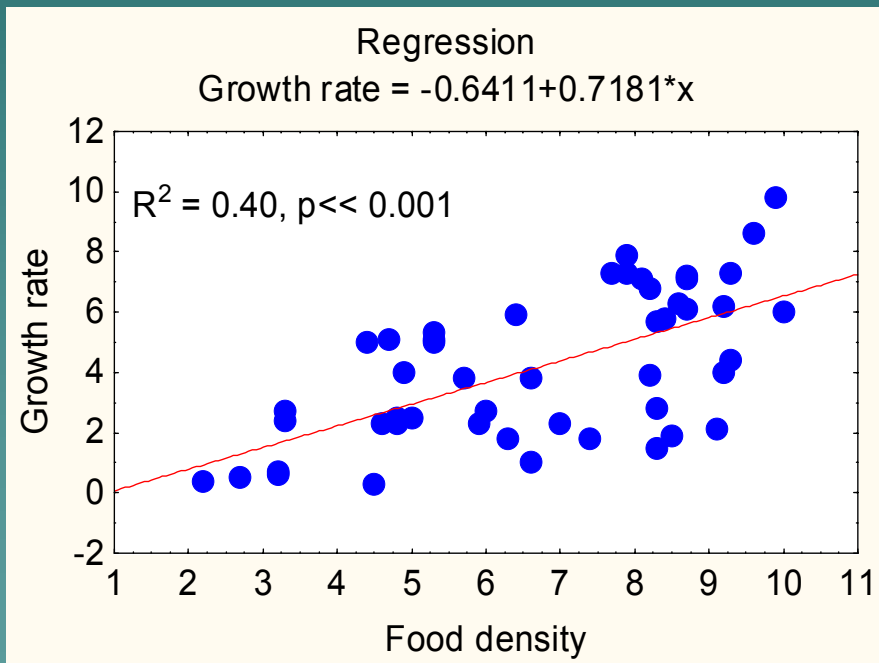


# Is Simple Linear Regression Ecologically Realistic?

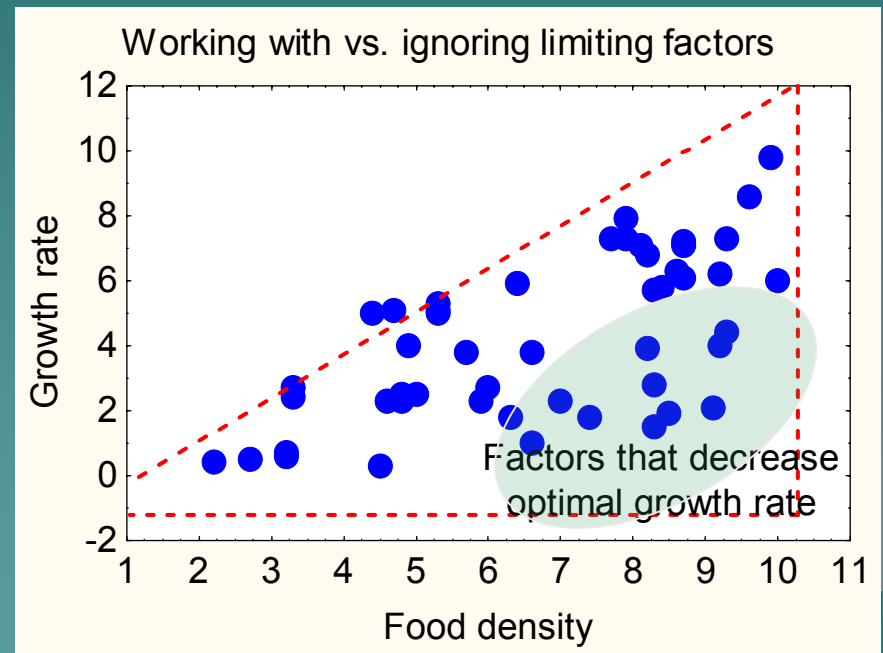
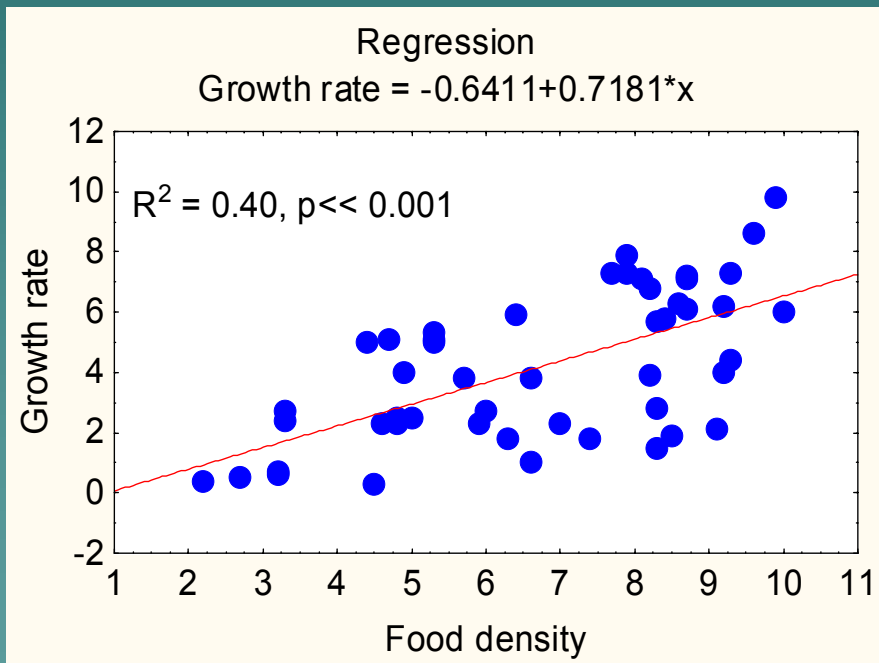




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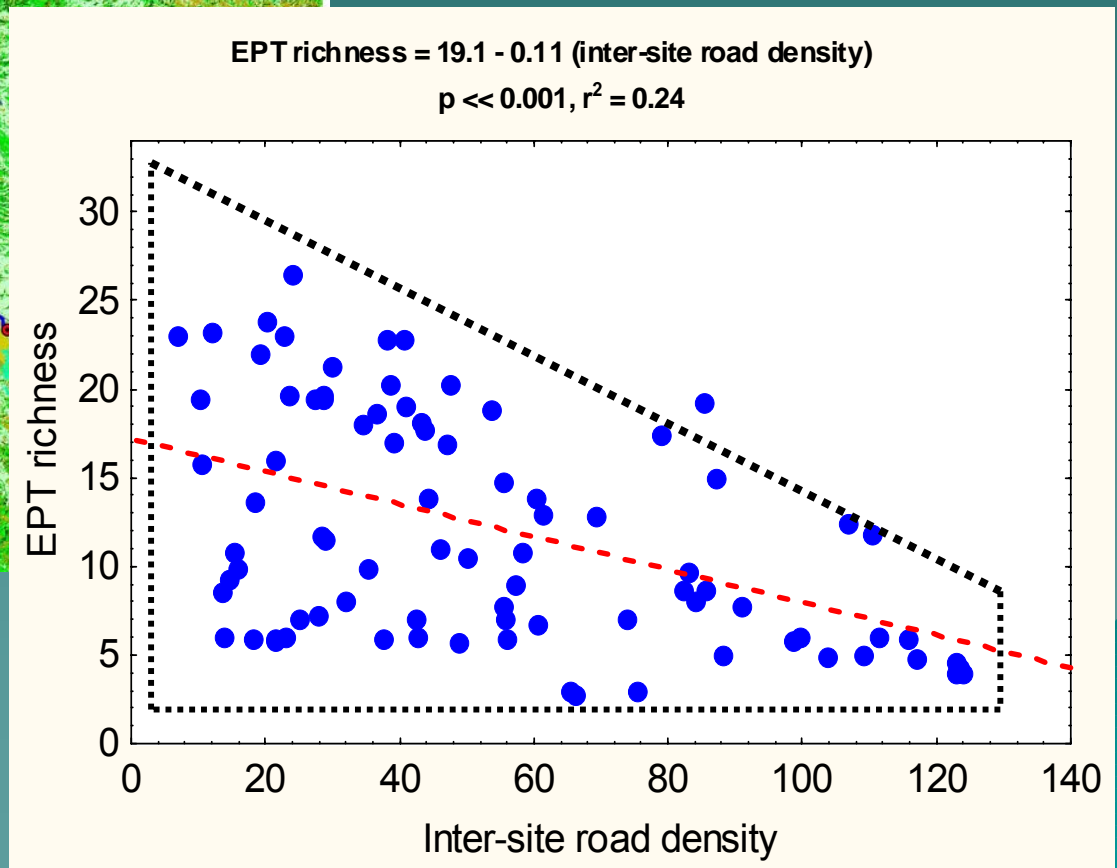
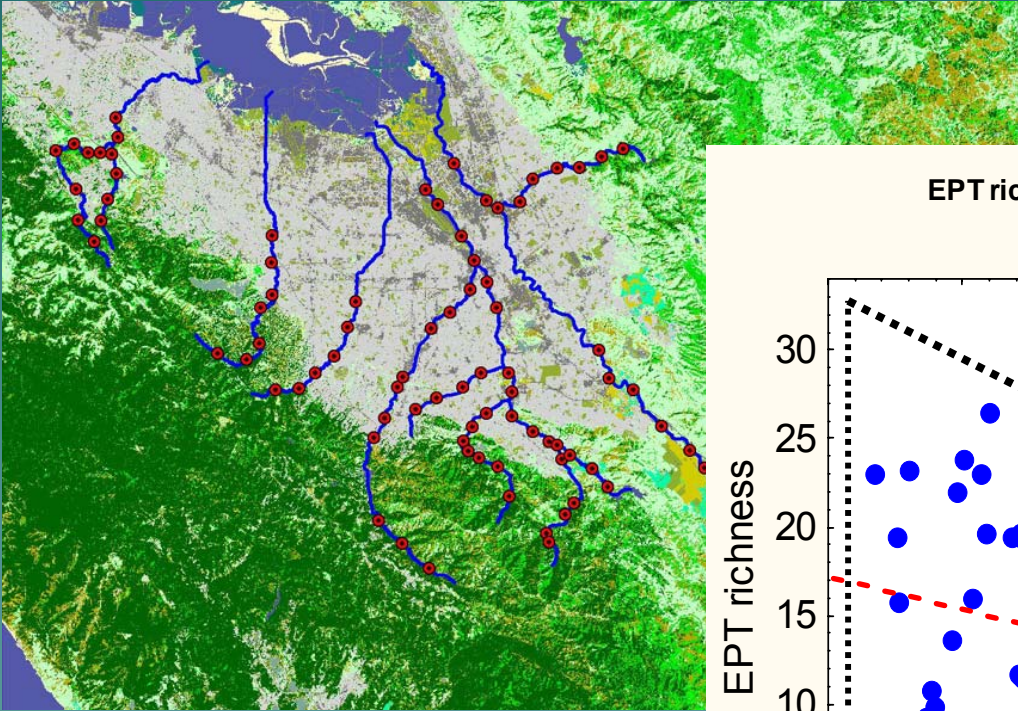


# Examples From Impact Assessments

*These relationships are often observed in impact assessments ...*

# Santa Clara Valley

Working within the constraints of an urban environment



# Large-scale Urban Study

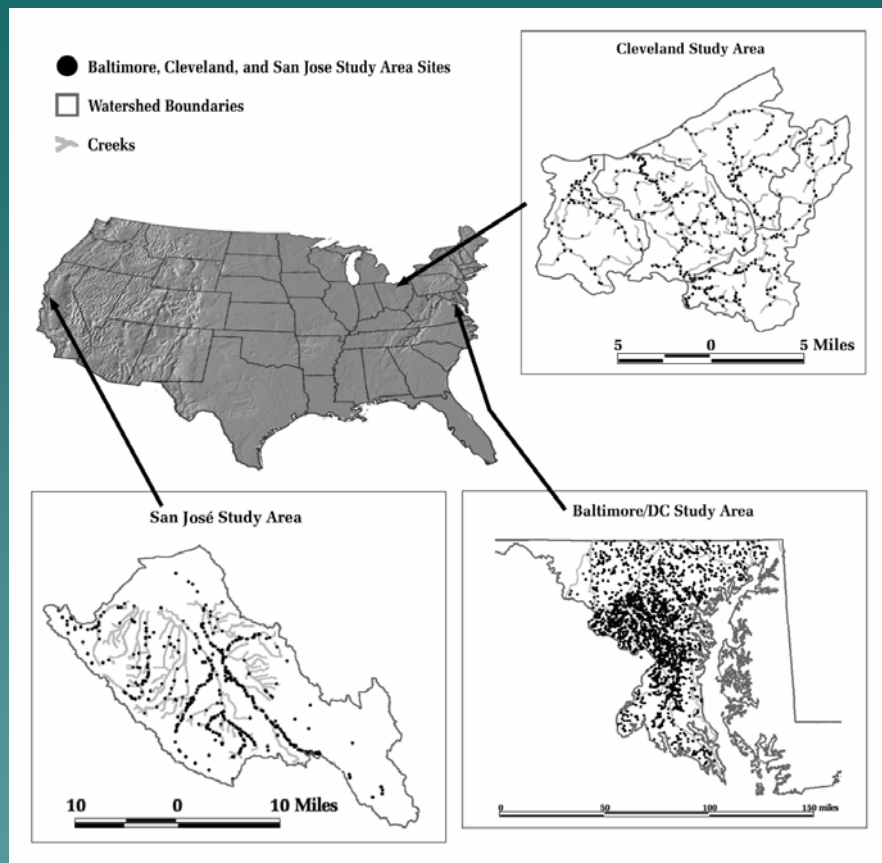


Figure 1. A map of the United States showing the location of the three study regions and sampling sites: Mid-Atlantic (Baltimore, Maryland), Midwest (Cleveland, Ohio), and Pacific Coast (San Jose, California).

## Linear regression

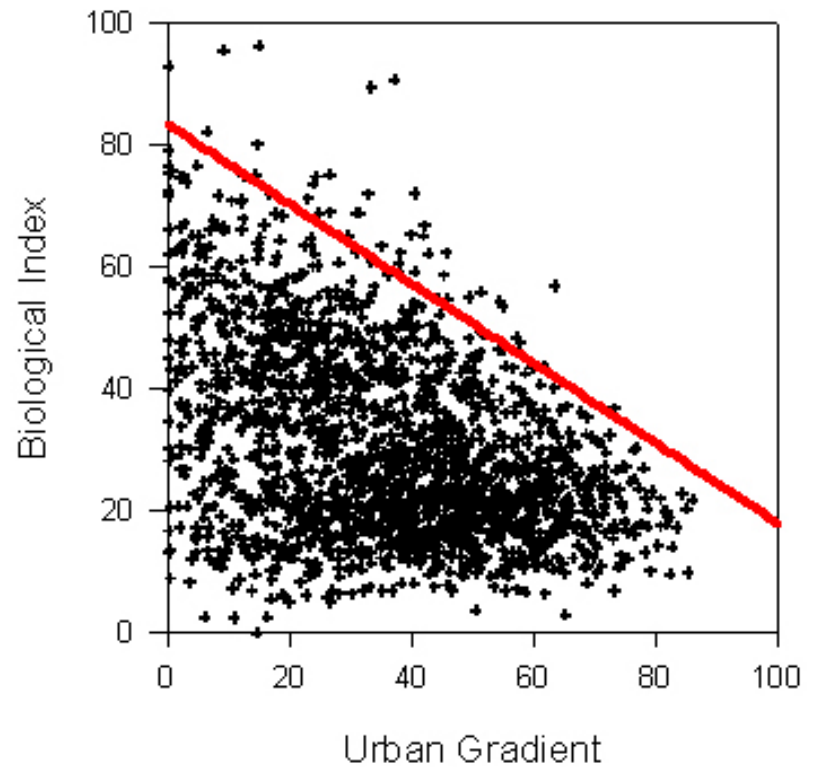
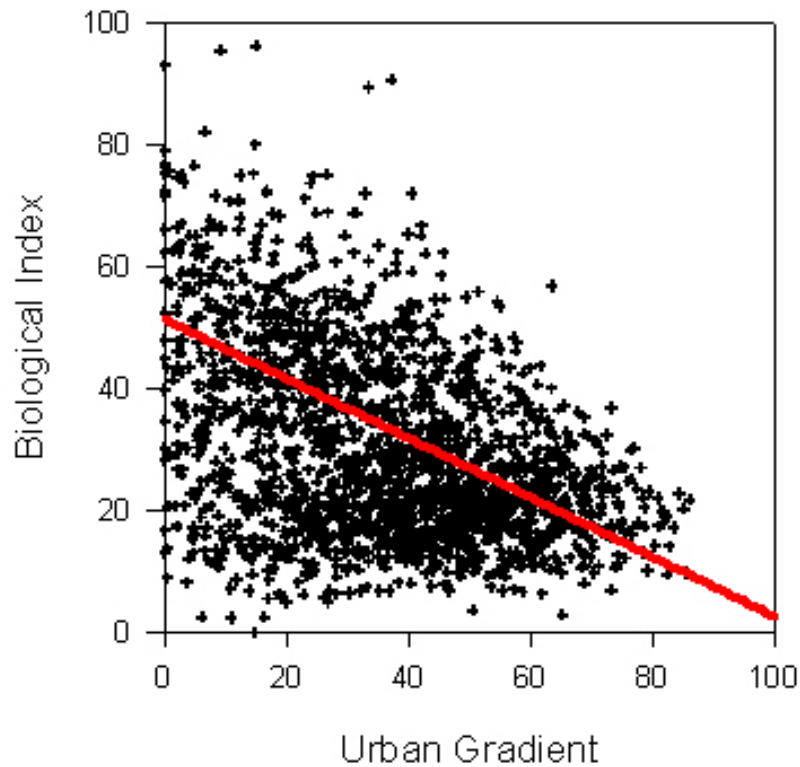
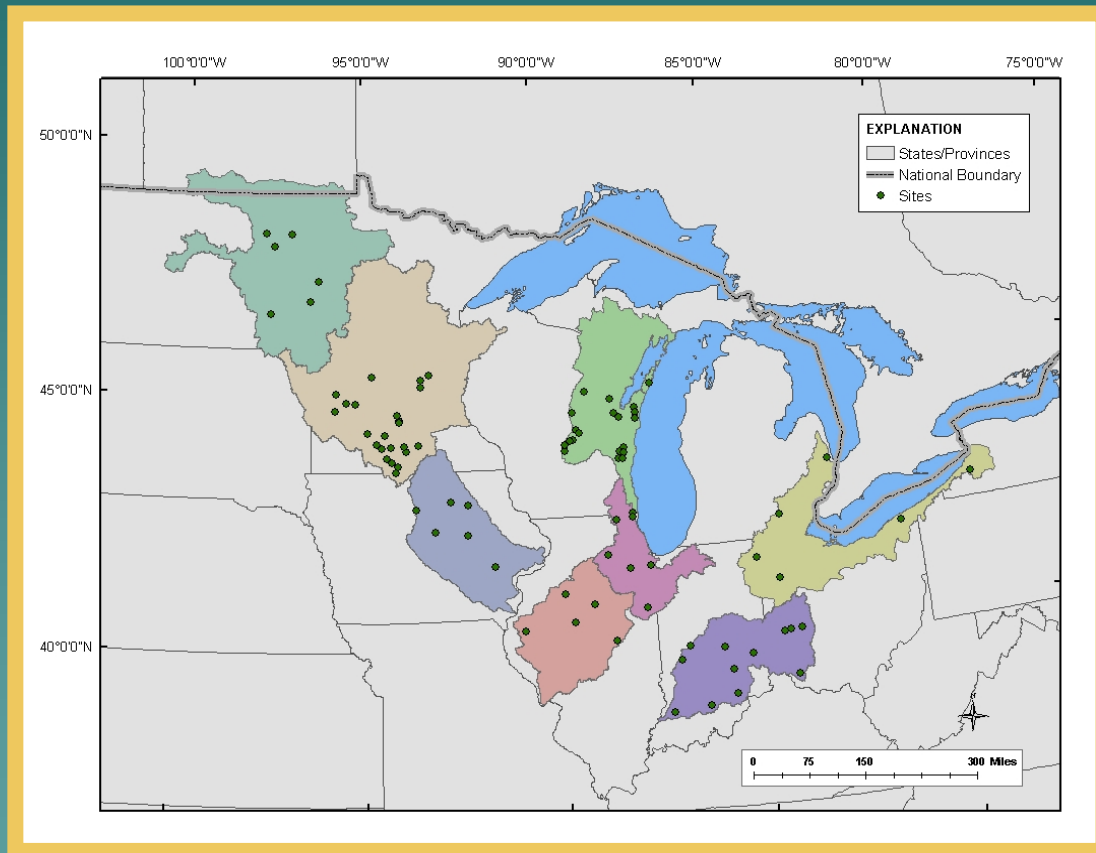
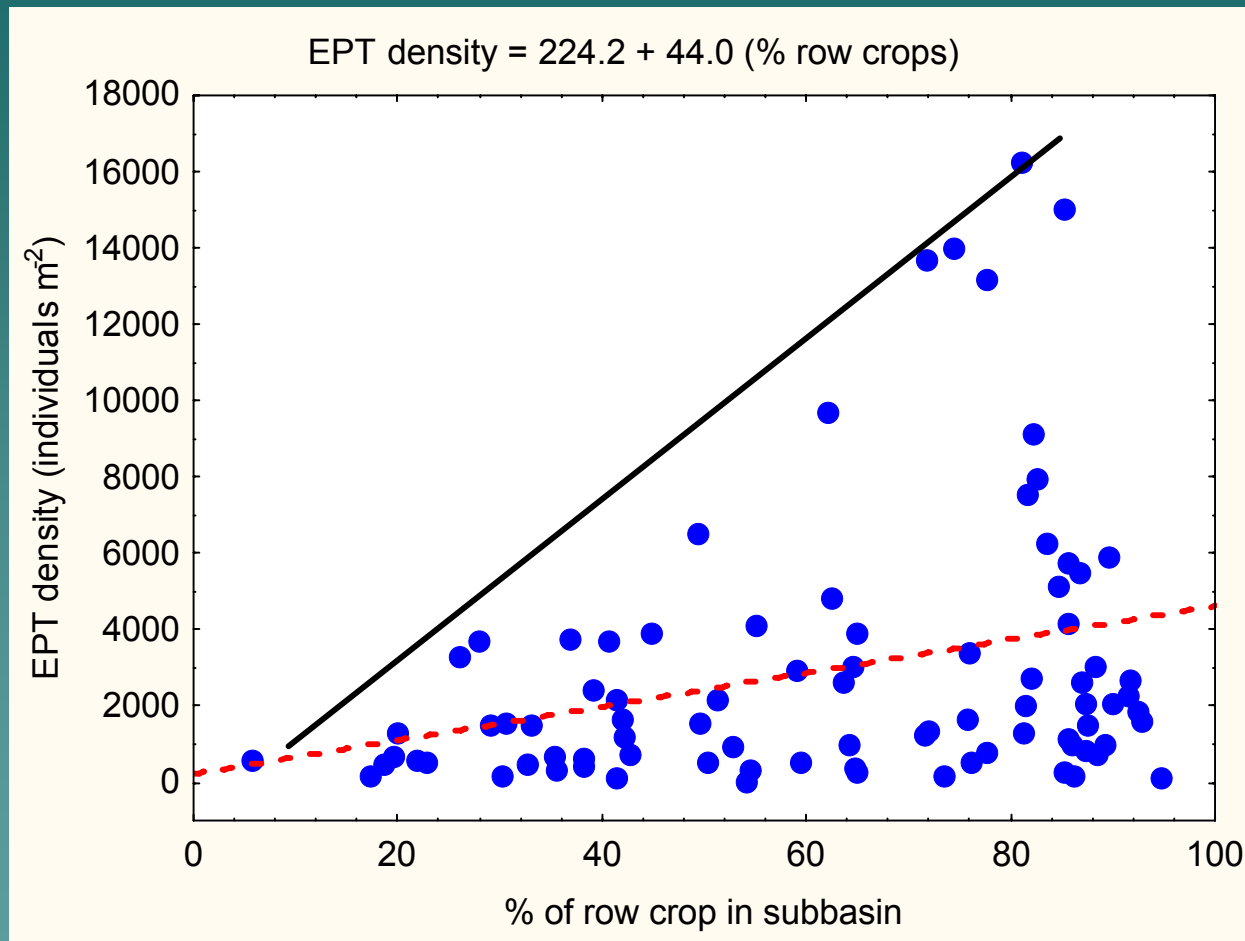


Figure 2. Example of scatterplots showing a biological index (Y-Axis) plotted against an urban gradient (X-Axis). The plot on the left shows an example of a linear regression line ( $r^2 = 0.19$ ), while the plot on the right shows an example of a 95% quantile regression line to better characterize the upper boundary of the wedge-shaped plot.

# Large-scale Agriculture (upper mid-west)



# Upper Mid-west Ag Study





# Small-scale “Single Stressor” Study

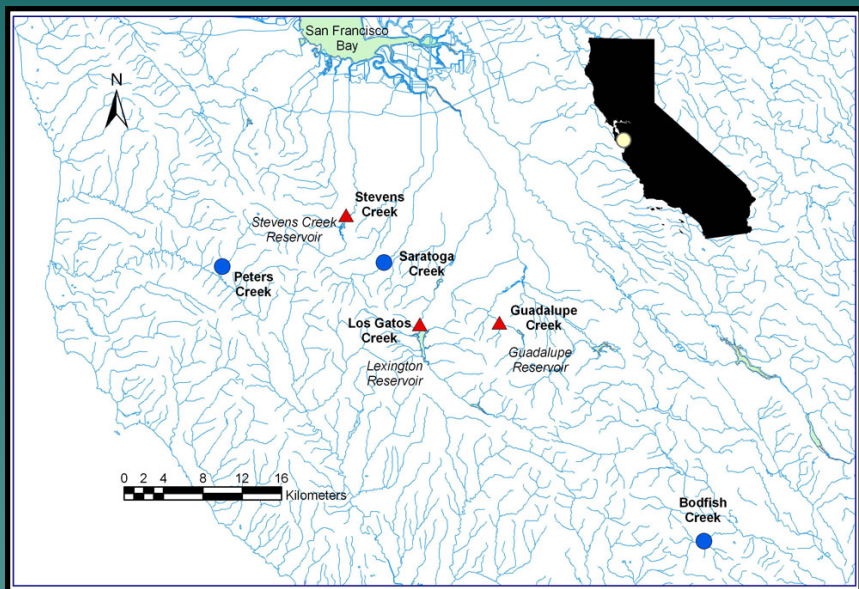
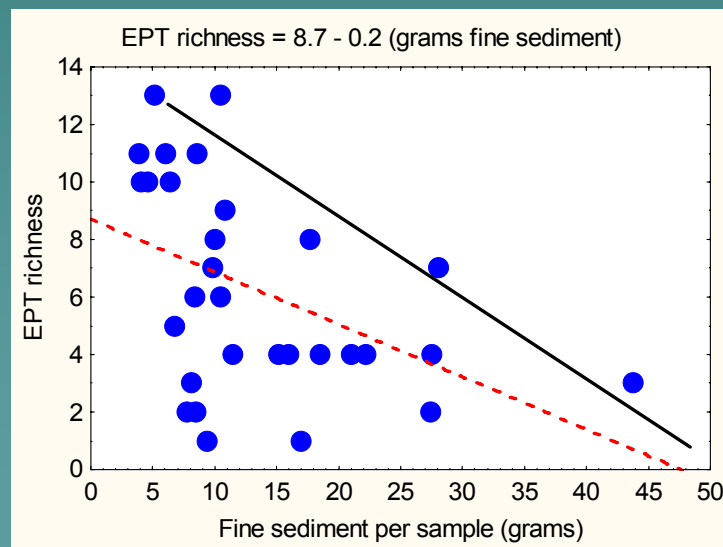
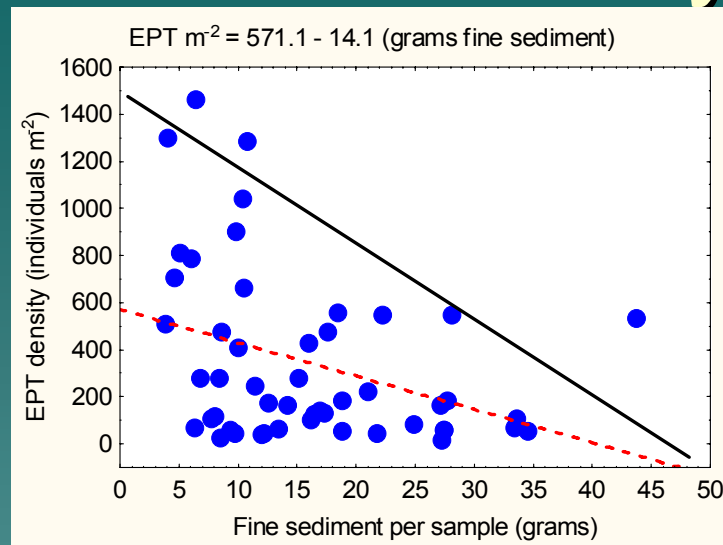
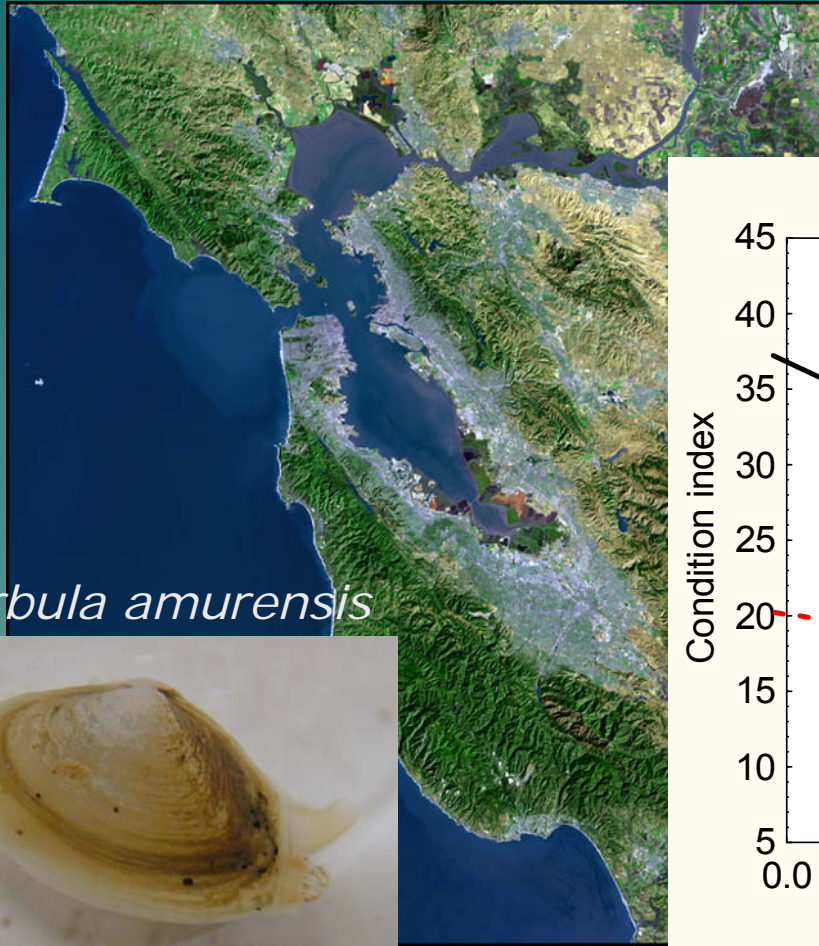


Figure 1. Santa Clara Valley Area showing site locations. ● are sites on non-regulated streams, ▲ are sites on regulated streams.

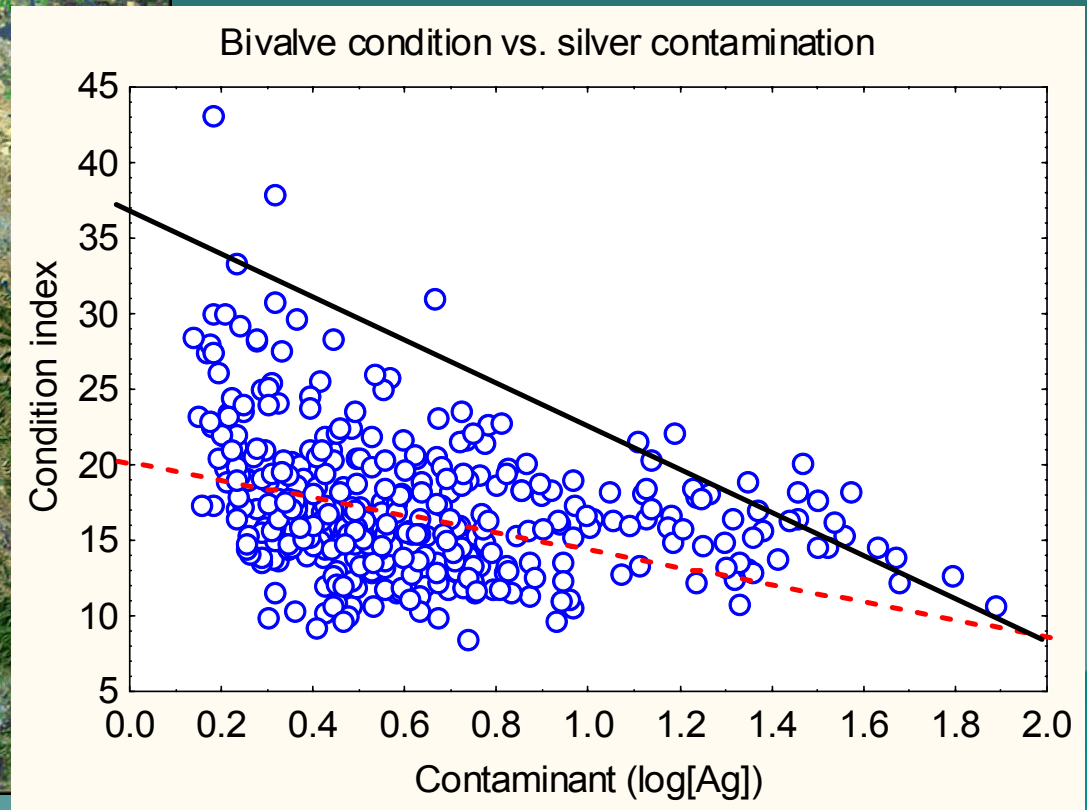
Janny Choy and friends



# SF Bay contaminants



*Corbula amurensis*



# Methods for Estimating The Ceilings

And  
Some Possible  
Applications

# Two Proposed Methods

## ◆ Partitioned regression

- Simple regression defines two groups based on the sign of the residual
- Iterate the above to produce more groups and identify a ceiling

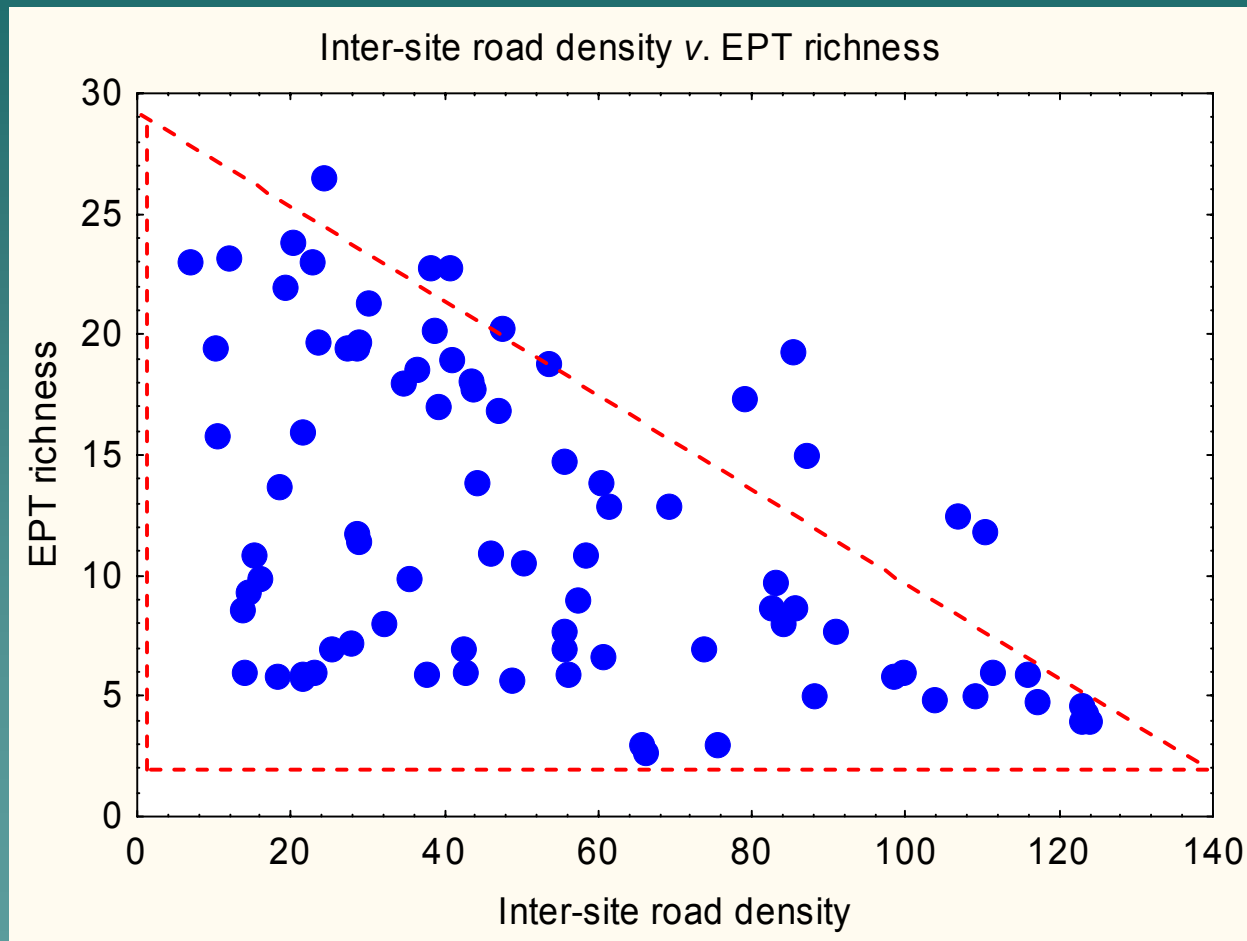
Thomson et al. 1996

## ◆ Quantile regression

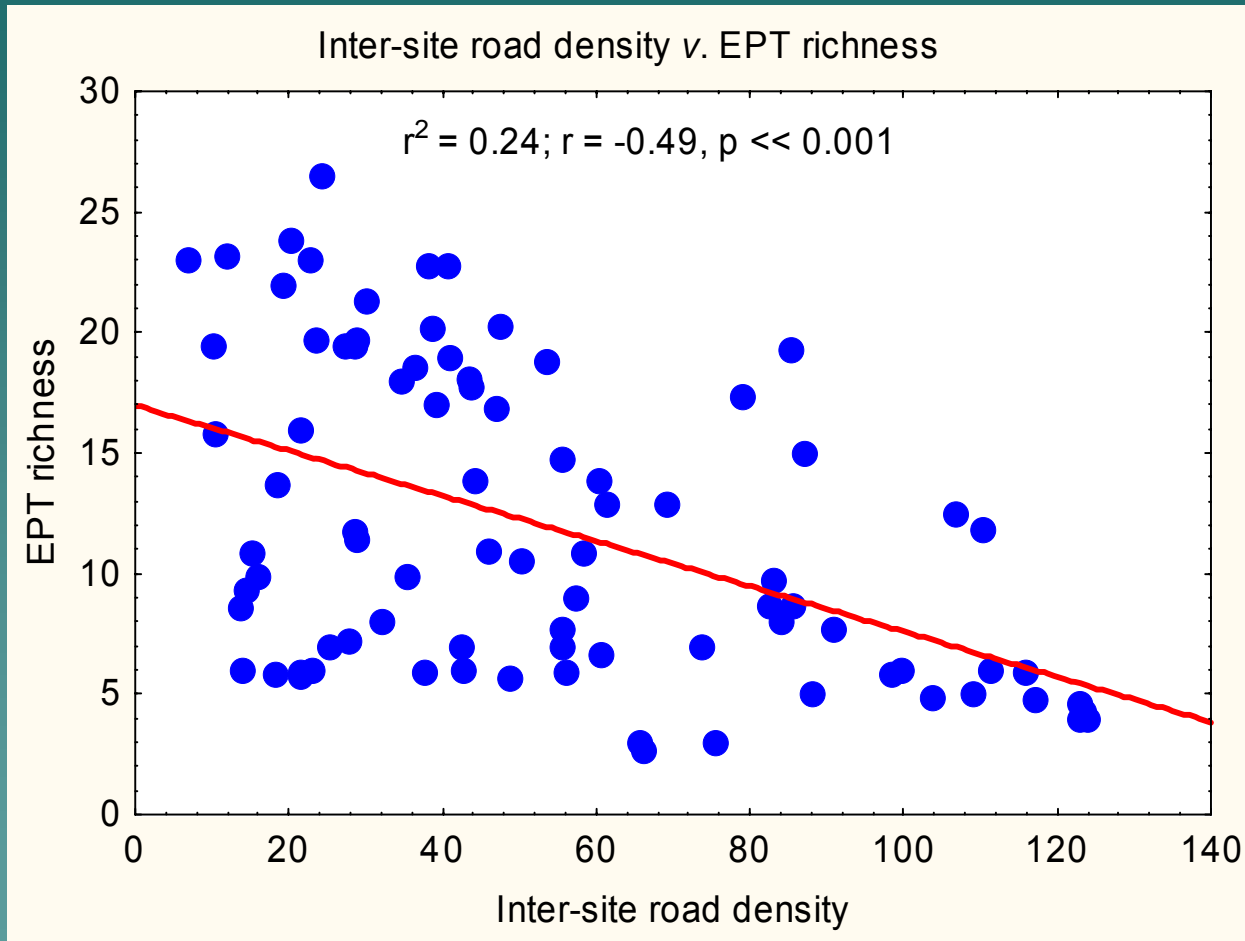
- Group on the independent variable (e.g., classing by  $\sim$  equal  $n$ , effect-level, etc.)
- Regress on a chosen percentile to establish a ceiling ...  
or
- Weighted regression

Koenker 2000 and earlier;  
Scharf et al. 1998; Cade 1999

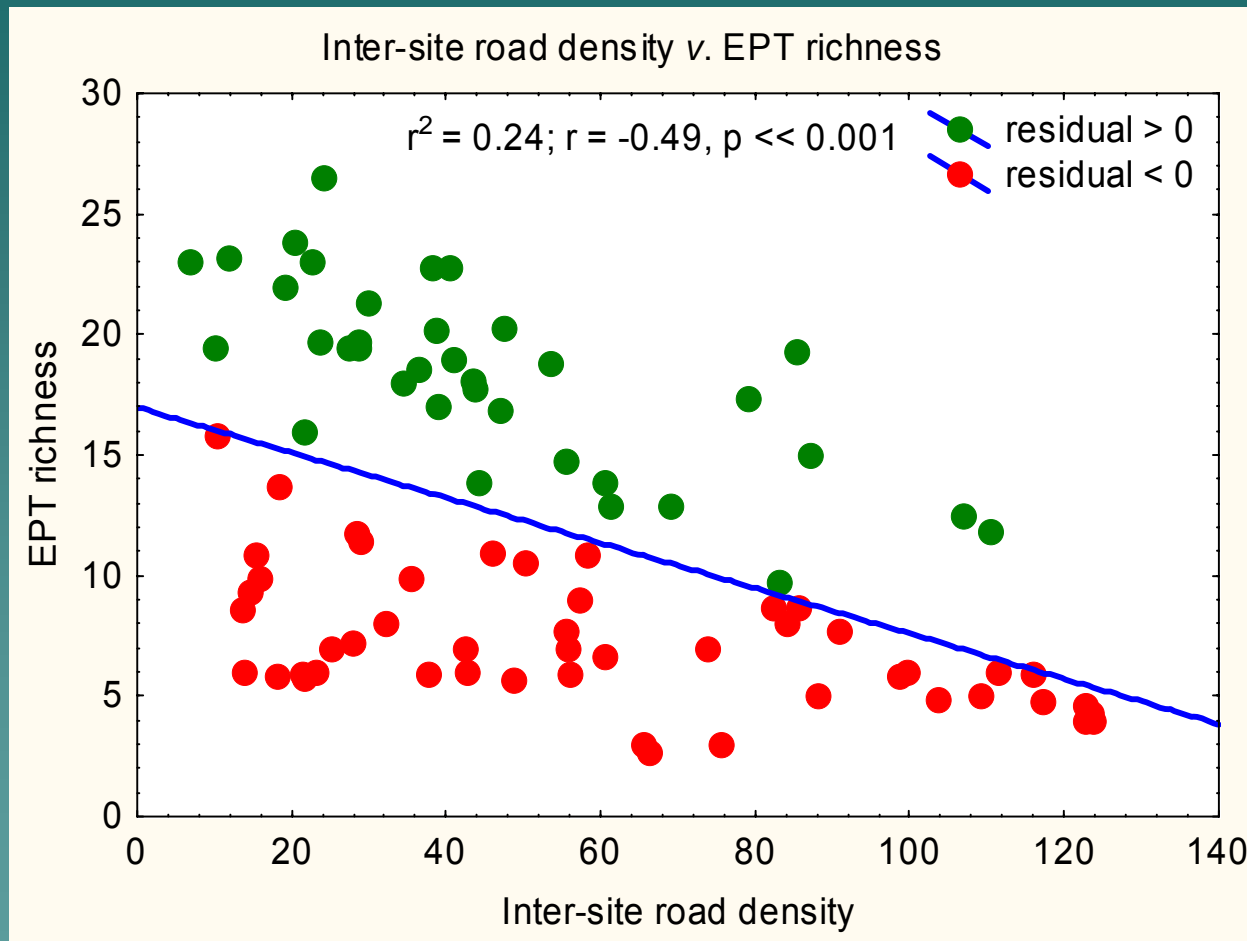
# Our Polygonal Distribution



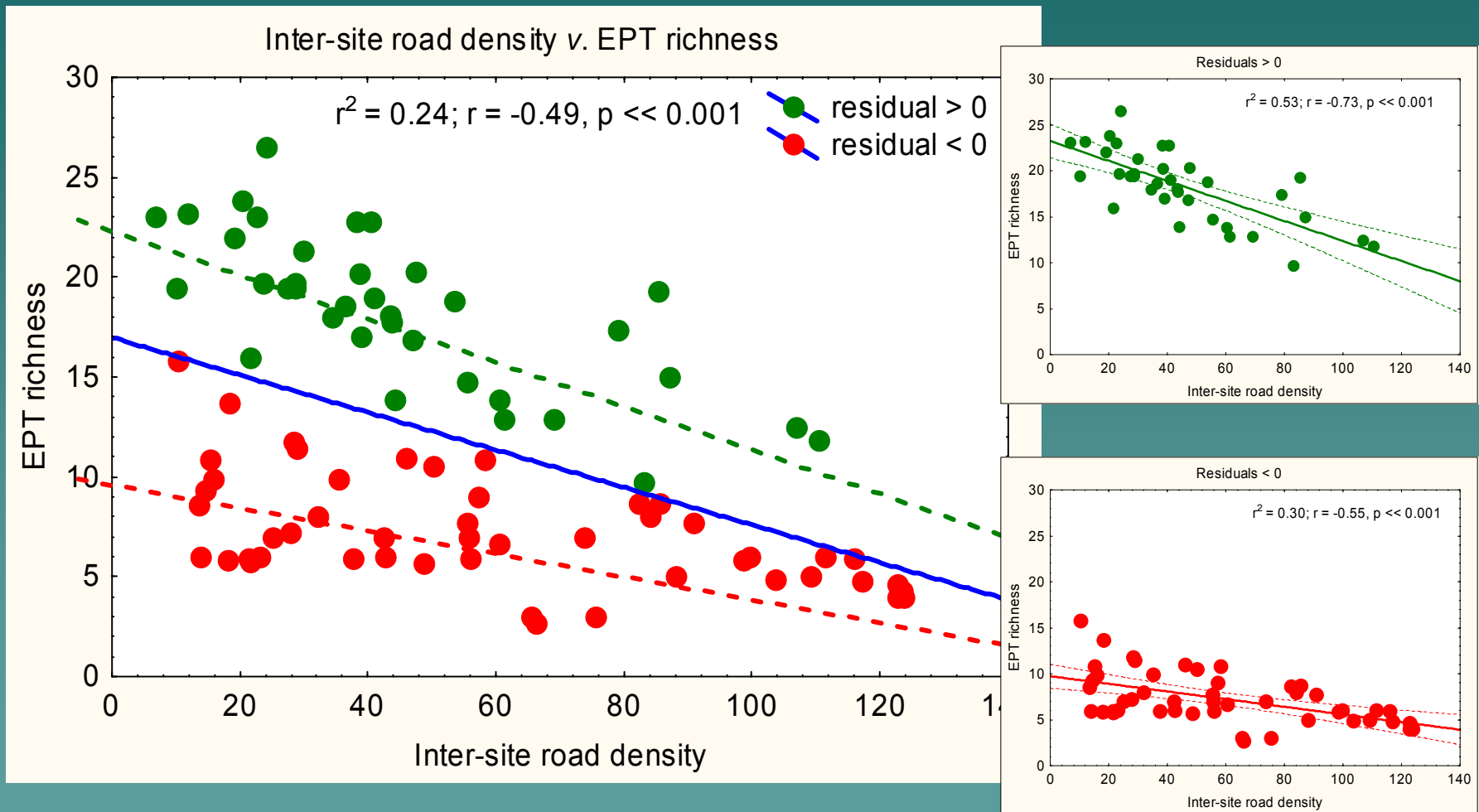
# Regress



# Partitioned by Residuals



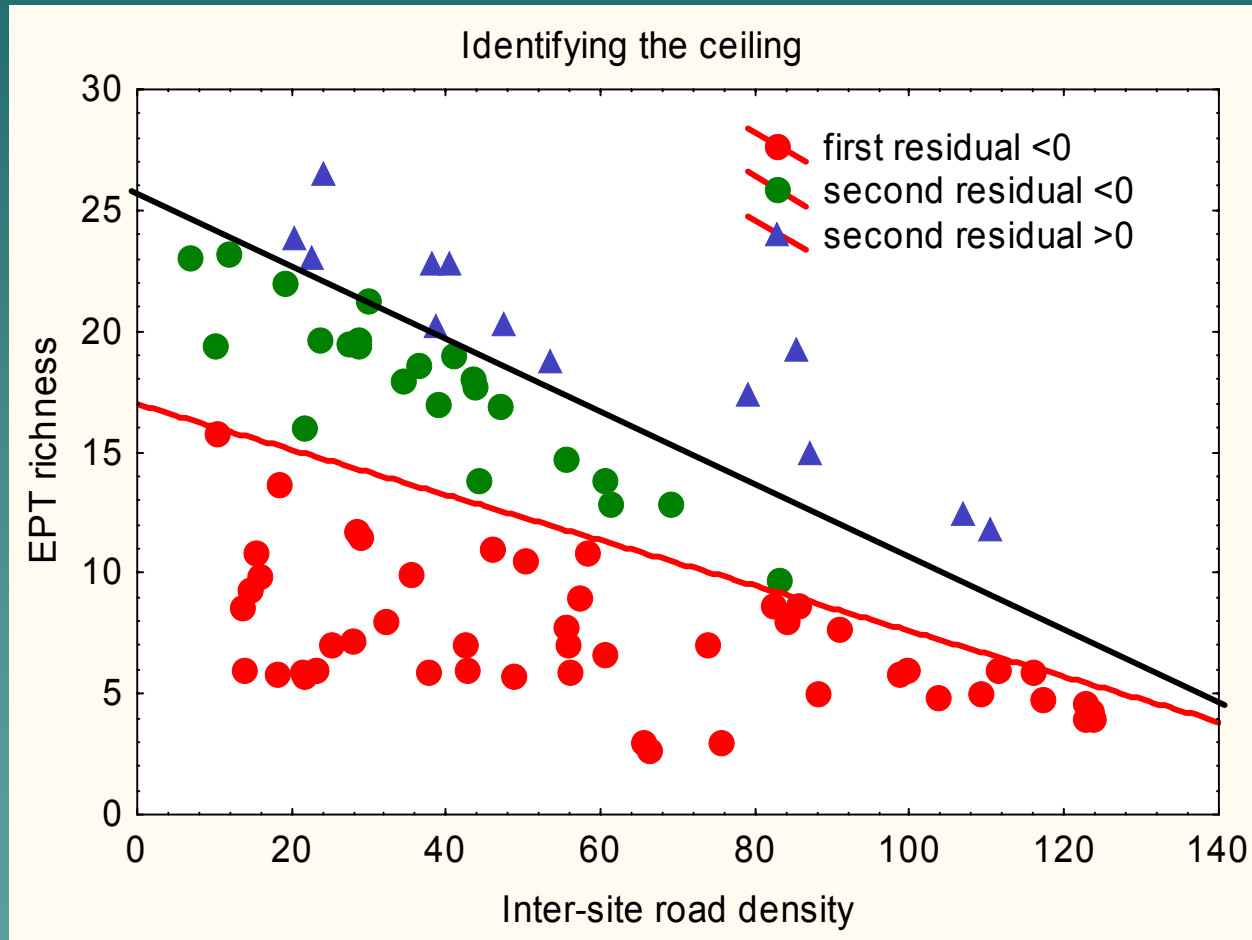
# Regress and Partition Again





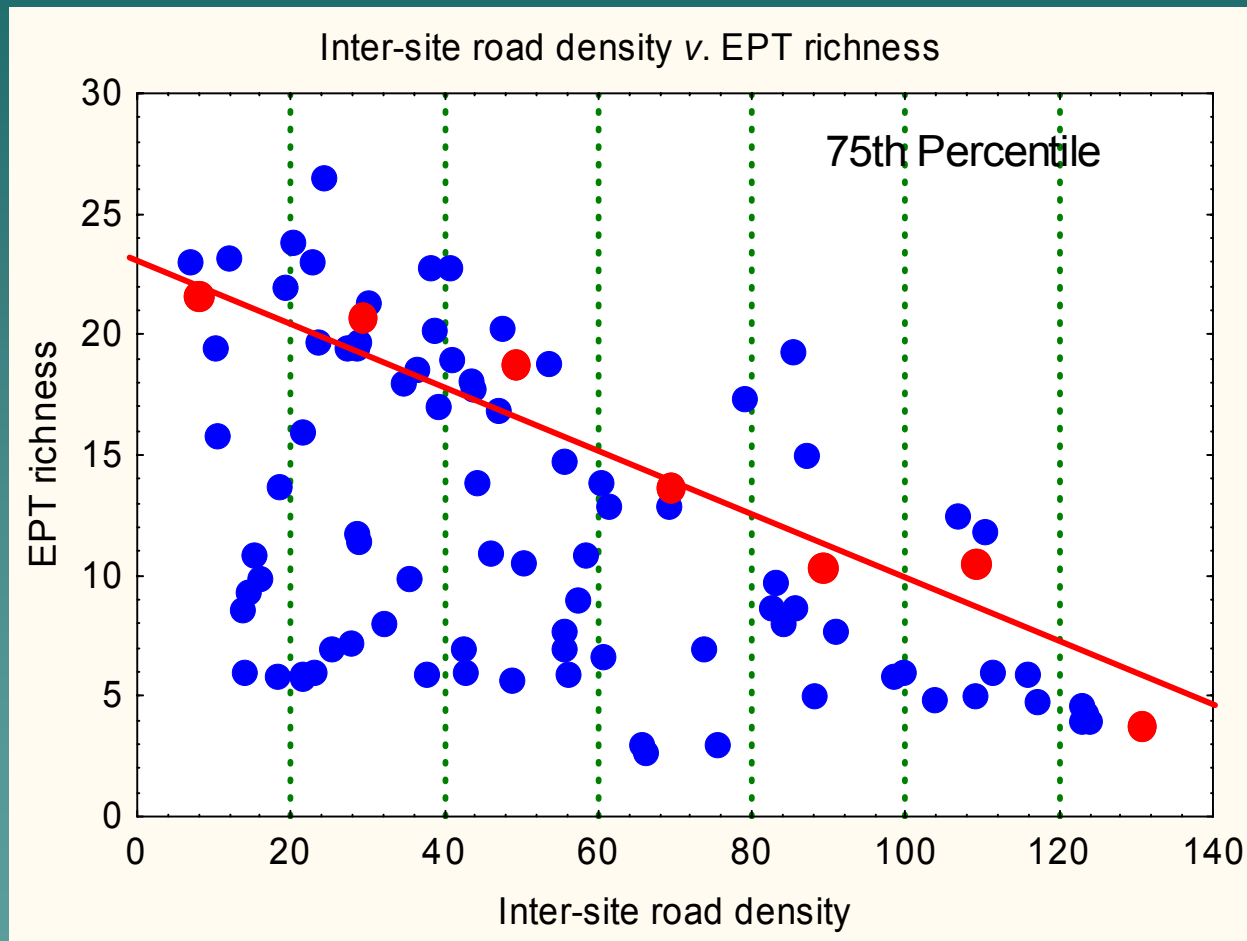
# Identifying the Ceiling

= maximum current biological potential per unit urbanization



# Quantile Regression

via Scharf – but see Koenker / Cade / others



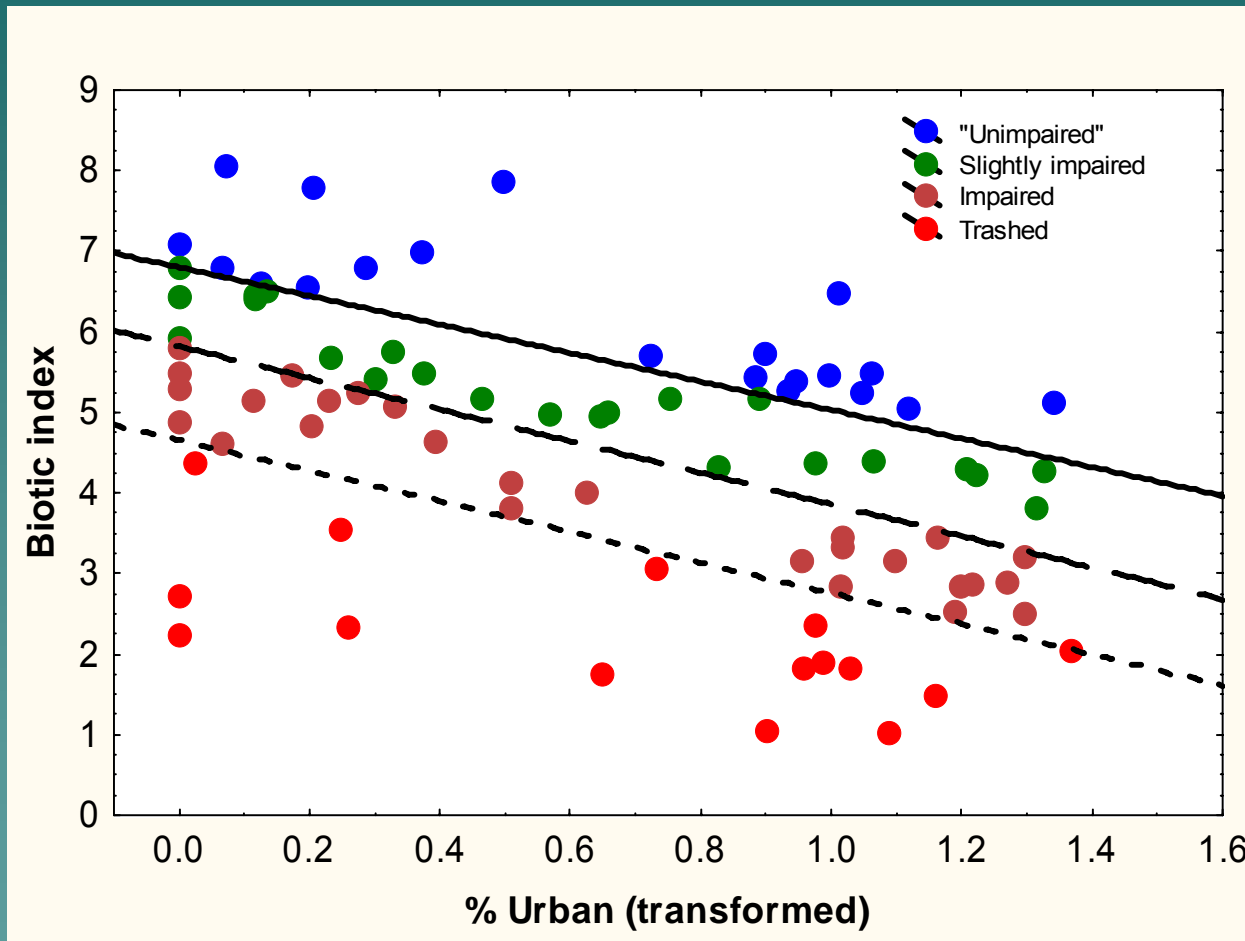
# Quantile Regression

Cade, B. S., and B. R. Noon. 2003. A gentle introduction to quantile regression for ecologists. *Front Ecol Environ* 1(8): 412-420.

<http://www.fort.usgs.gov/Products/Software/blossom/>

Cade, B.S., and J.D. Richards. 2005. User manual for Blossom statistical software. Fort Collins, CO: U.S. Geological Survey, Fort Collins Science Center. Open-File Report 2005-1353. 124 p.

# Extending the Technique



# In Summary

- ◆ There is an upper limit to stream quality in practically any anthropogenically influenced area.
  - This limit is set by existing and historic land cover and land use.
- ◆ Even if mitigation occurs via BMPs and restoration, it's likely that some anthropogenic influences will not be totally eliminated
  - e.g., urban impervious surface, agricultural land use
- ◆ Therefore, it's prudent to account for these influences, which are often in the form of gradients, in the process of establishing realistic (i.e., attainable) reference conditions
  - Which we defined as the maximum biological potential of a site.

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- ◆ Therefore, it's prudent to account for these influences, which are often in the form of gradients, in the process of establishing realistic (i.e., attainable) reference conditions
  - Defined as the maximum biological potential of a site as set by a factor-ceiling.

The world is composed of  
gradients not boxes –  
we've probably ignored them for  
too long.

*In questions of sciences, the  
authority of a thousand is not  
worth the humble reasoning of a  
single individual.*

Galileo