

**U***of***A** UNIVERSITY OF ARKANSAS  
DIVISION OF AGRICULTURE

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NUTRIENT CRITERIA DEVELOPMENT MINI-WORKSHOPS FOR  
USEPA REGION VI STATES

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## Nutrient Criteria Development Mini-Workshops for USEPA Region VI States

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The U.S. Environmental Protection Agency (USEPA) has been encouraging states to accelerate their efforts in developing numeric nutrient criteria to promulgate within respective water quality standards and regulations. Based on USEPA recommendations, many states are pursuing nutrient criteria development by assessing frequency distributions and stressor-response relationships in historical databases, various special studies and the literature. The mini-workshops described here were targeted toward state agency personnel and stakeholder groups with an interest in understanding statistical techniques that could be used to aide, guide and support numeric nutrient criteria. An initial workshop was conducted at the USEPA Regional Technical Assistance Group meeting in February 2010, but it was poorly attended because of the development of harsh weather and travel conditions. The limited state and USEPA personnel in attendance gave a positive response, and subsequent workshops were planned for each state agency with regulatory authority to develop water quality standards. The workshops were designed to be one working day, starting at 0900 and ending at 1600, and the topics covered included: workshop goals, objectives and tasks; measurement and ecological indicators of water quality impairment by nutrients; basic statistical methods; advanced statistical methods; and application of the statistical methods and interpretation of results. The number of participants varied from 5 at one workshop (participants specific to state agency developing numeric nutrient criteria) to over 20 (where various state agencies and stakeholder groups were represented). The series of topic presentations were followed by two group exercises that put the statistical tools discussed into action, where smaller working groups had to suggest numeric nutrient criteria for a watershed with ample data and then one with a very limited amount of data. The case studies were hypothetical in nature, but the stressor-response relationships shown mimicked those observed in aquatic systems and reported in the literature. The numeric values were defined only as nutrient, not specifically nitrogen or phosphorus; the intent here was to keep this a more open and unbiased exercise, especially for states that might have promulgated specific nutrient criteria. The results of the workshops were not specifically recorded, allowing the participants freedom to present, discuss and criticize without formal record. The proposed numeric nutrient criteria did vary between smaller working groups within a given workshop, but the range proposed was similar across workshops. The workshops were not intended to provide training so that the participants would walk away with the knowledge to actively pursue the techniques discussed. Rather, they were intended to provide a foundation for participants to understand what tools are available for the process of numeric nutrient criteria development and to be exposed to the potential pitfalls and benefits of various approaches. Overall, the feedback from all of these workshops was overwhelmingly positive by the states.

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### INTRODUCTION

The U.S. Environmental Protection Agency (USEPA) has been encouraging states to accelerate their efforts in developing numeric water quality criteria for nitrogen and phosphorus. Based on EPA recommendations, many states are pursuing nutrient criteria development by assessing frequency distributions and stressor-response relationships in their historical monitoring databases and from special studies. Although EPA has provided some guidance for states to develop nutrient criteria, many advanced statistical techniques that may be effectively used to aid in criteria development are poorly understood and therefore not widely used. Furthermore, many states have struggled with how to incorporate sound science into their nutrient criteria development. The purpose of designing this mini-workshop was to demonstrate some of the statistical methods available to states that could be used to assist in the development of nutrient criteria based on a weight of evidence approach. The mini-workshops described here were targeted toward state agency personnel and other related stakeholders that were interested in understanding quantitative techniques that could be used to aid in numeric nutrient criteria development.

### WORKSHOP LOCATIONS, DATES, & PARTICIPATION

An initial workshop was partially conducted at the EPA Region 6 RTAG meeting in February 2010, but was poorly attended and finished early due to a snowstorm that occurred in Dallas on the scheduled workshop date. In response, workshops were planned for each environmental state agency in EPA Region 6:

- Louisiana Department of Environmental Quality, May 2010 – 5 participants

- Texas Commission on Environmental Quality, August 2010 – 21 participants
- Oklahoma Water Resources Board/Oklahoma Environment Department, December 2010 – 16 participants
- New Mexico Environment Department, June 2011 – 12 participants
- Arkansas Department of Environmental Quality, TBD – number of participants unknown

### WORKSHOP CONTENT

Workshops were conducted within a single day at each location. A typical workshop agenda is shown in Table 1. Workshops always began with a presentation of the workshop goals and an outline of the content. This was followed with a presentation and discussion regarding what water quality measurements and indicators could be useful in numeric nutrient criteria development. Three powerpoint presentations followed that provided an overview of both basic and advanced statistical methods that can be used for nutrient criteria development, and recommendations on how to interpret data from these analyses. Throughout these presentations, time was allotted for questions and discussion. Following these topic presentations, the workshops concluded with two exercises (i.e., breakout sessions) where smaller working groups proposed nutrient criteria based on one example with ample data and a second example with limited biological data.

Following these technical presentations we asked workshop participants to divide into multiple groups to interpret two hypothetical datasets. The point of these exercises was to have participants interpret output from both basic and advanced statistical analyses of two data sets: one with a large amount of data and one with a relative small amount of data. The participants were asked to recommend nutrient criteria based on a weight of evidence approach

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**Table 1.** Typical workshop agenda, using the Louisiana DEQ workshop conducted on May 18, 2010.

<b>LDEQ MEETING – Nutrient Criteria Development Mini-Workshop</b>	
<b>AGENDA 18 May 2010</b>	
<b>PURPOSE:</b> Demonstrate the statistical methods available to States that may be used to assist in the development of nutrient criteria for streams and rivers, based on a weight of evidence approach.	
<b>0900</b>	INTRODUCTION & GOALS OF THIS MINI-WORKSHOP – Brian Haggard
<b>0910</b>	WHAT WATER QUALITY INDICATORS SHOULD WE CONSIDER? – Thad Scott <i>This presentation will ask the question – what water quality indicators should we focus on?</i>
<b>0930</b>	Group Discussion
<b>1000</b>	Refreshment Break and Discussion
<b>1030</b>	STATISTICAL TOOLS 101: Percentiles, Associations & LOESS – Brian Haggard
<b>1050</b>	STATISTICAL TOOLS 201: Thresholds, Change Points and Hierarchy – Thad Scott
<b>1115</b>	APPLICATION OF THESE TOOLS: Interpreting Your Data – Brian Haggard
<b>1130</b>	Lunch Break
<b>1300</b>	TASK 1: Develop Nutrient Criteria for a Hypothetical Watershed with Lots of Data
<b>1315</b>	Breakout Session ( <i>teams get together to evaluate materials from Research Watershed</i> )
<b>1400</b>	BREAKOUT SUMMARY – Brian Haggard & Thad Scott
<b>1415</b>	Refreshment Break and Discussion
<b>1430</b>	TASK 2: Develop Nutrient Criteria for a Hypothetical Watershed with Limited Data
<b>1445</b>	Breakout Session ( <i>teams get together to evaluate materials from Not Much Data Watershed</i> )
<b>1530</b>	BREAKOUT SUMMARY – Brian Haggard & Thad Scott
<b>1545</b>	FINAL DISCUSSION
<b>1600</b>	ADJOURN

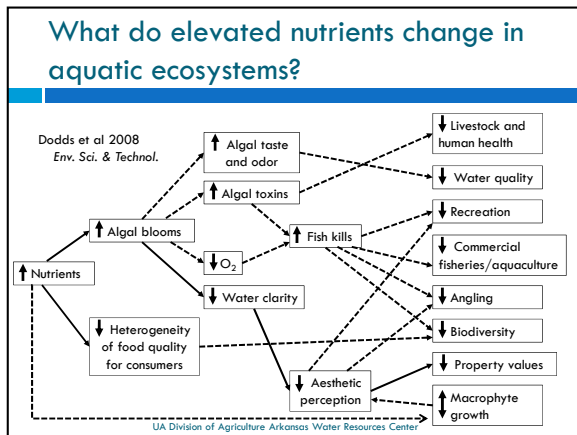
from the data provided. Workshops were ended with a discussion on the methods and limitations to developing numeric nutrient criteria.

### TECHNICAL PRESENTATIONS

Four technical presentations were prepared for each workshop on the following topics:

- Workshop goals, objectives and tasks (*Workshop Goals*, Appendix 1)
- Measurements and ecological indicators of water quality impairment by nutrients (*What Water Quality Indicators Should We Consider?*, Appendix 2)
- Basic statistical methods (*Statistical Tools 101*; Appendix 3)
- Advanced statistical methods (*Statistical Tools 201*; Appendix 4)
- Application of statistical methods and interpretation of results (*Application of these Tools: Interpreting your Data*, Appendix 5)

The fundamental aspect of any water quality monitoring and assessment program is identifying the designated uses of water-bodies and the water quality standards needed to protect that use. Nutrient criteria are no exception. Although some chemical species of plant nutrients must be managed because of their potential toxicity (i.e., nitrate in drinking water causing methemoglobinemia or blue-baby syndrome; or ammonia toxicity for organisms with gills), the more broad implication of nutrient enrichment is stimulating the growth of organisms (plants, algae, and other micro-organisms) that utilize nutrients from water to grow larger and reproduce. The ecological quality of many water bodies can be altered due to nutrient enrichment by accelerating the eutrophication process. Accelerated eutrophication can lead to some predictable water quality responses, but the effect of nutrient enrichment on aquatic biological communities and the translation of these effects to water quality impairments is still poorly understood (Figure 1, Appendix 2). Therefore, there is a

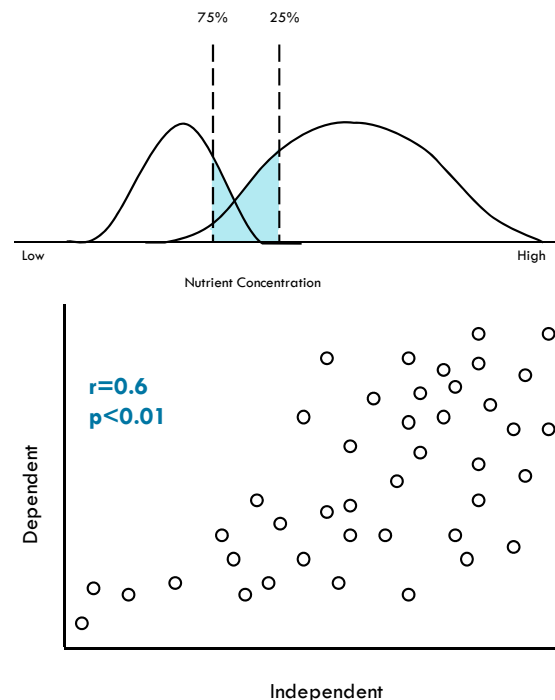


**Figure 1.** Relationship between nutrient enrichment and water quality, ecological, and economic outcomes (from Dodds et al. 2008).

great need for states to identify what they intend to protect in specific waterbodies by establishing numeric nutrient criteria and using the proper techniques to identify what nutrient concentrations cause a potentially adverse effect. These ecological outcomes may be drastically different for different waterbodies. For example, very low nutrient concentrations may be needed to protect the native biodiversity in rare or sensitive water bodies, but much higher nutrient concentrations may be acceptable in other waterbodies where the intended use is sport fish production. These are important details that regulators need to address so that they can identify the appropriate data and statistical methods to use in identifying numeric nutrient criteria.

Some basic statistical techniques have already been applied in developing recommendations for numeric nutrient criteria (Appendix 3). For example, the United States EPA used frequency distributions of nutrient concentrations from historical monitoring data collected by state and federal water quality regulatory agencies to recommend ecoregional nutrient criteria using the frequency distribution approach. The frequency distribution approach involves assessing nutrient concentrations for either selected

“reference” sites or for both reference and potentially impacted waterbodies over broad spatial and temporal scales. The 75th percentile of nutrient concentrations in reference waterbodies, and the 25th percentile of nutrient concentrations of all waterbodies covering a broad spatial scale were proposed as potential benchmarks for nutrient criteria (Figure 2, USEPA 2000). Although this method allows nutrient criteria to be more easily developed, it assumes that the 75th percentile of nutrient concentrations in reference waterbodies for a region is similar in magnitude to the 25th percentile of nutrient concentrations for all waterbodies (Haggard and Scott 2011). Furthermore, adopting a numeric nutrient standard based on the 25th percentile distribution from all waterbodies in a region automatically results in listing 75% of waterbodies in that region as being potentially impaired.



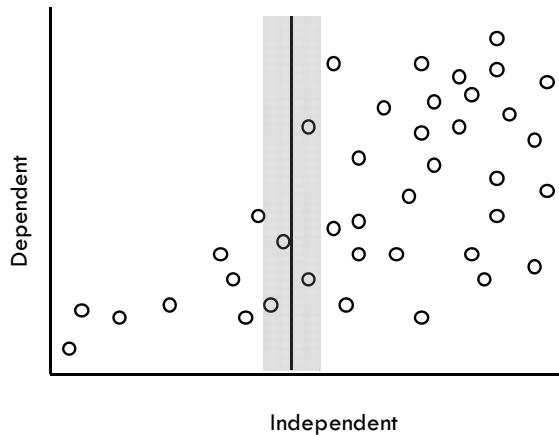
**Figure 2.** Top panel is a frequency distribution approach to setting nutrient criteria. Bottom panel shows a correlation example where nutrient concentrations are related to a response variable.

EPA has recognized the limitation(s) associated with the frequency distribution approach and urged states to develop nutrient criteria based on stressor-response relationships (USEPA 2010, 2011). Indeed, the stressor response model has many advantages for some waterbodies such as lakes where there is a very predictable pattern of cause and effect between nutrient enrichment and increased algal productivity. Under these circumstances, correlation analysis and regression analysis are very simple and useful techniques for quantifying the strength of the stressor-response relationship (Figure 2 bottom panel) and the magnitude of interaction between the stressor (nutrient) and response variable (algal biomass or productivity). Correlation analysis can be conducted via parametric (Pearson correlation) or nonparametric (Spearman Rank) approaches. Correlation analysis is useful because it is an effective way to convey simple relationships, it is easy to understand, it quantitatively measures association between two variables, and it is readily available in many data management and statistical software packages. Correlation analysis provides limited information because it may not detect complex relationships, a lack of statistical significance might not mean lack of association between variables, large sample sizes can lead to significant but not necessarily meaningful relationships, and it does not quantify predictive relationships. Regression analysis is similar to correlation analysis but actually models the variation in one variable in response to the variation in one or more predictor variables. Regression analysis is useful because it is a predictive analysis, the results are easy to interpret, relationships between variables are quantitatively modeled, the analysis can handle multiple predictors of a single response variable, and the model shows which variables are the strongest predictors. Regression analysis is limited because some complex models can be difficult to interpret or evaluate, the analysis can be sensitive to outliers, and results cannot

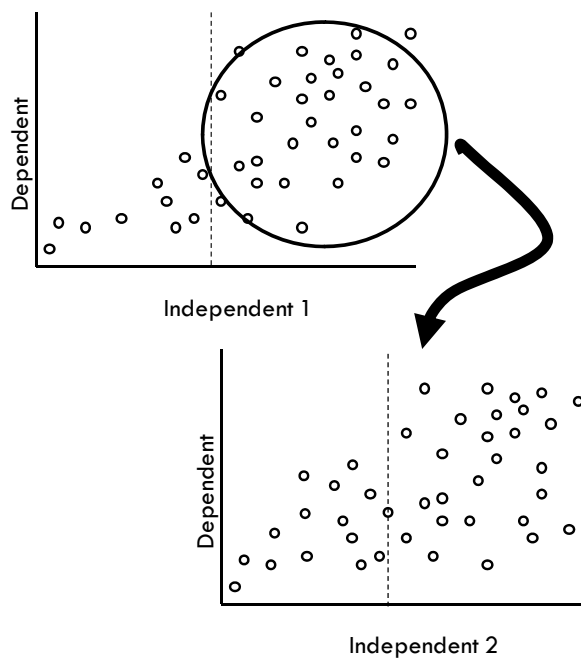
be effectively extrapolated beyond the boundaries of the data.

Although basic statistical techniques like correlation and regression analysis are useful for identifying and quantifying some stressor-response relationships, they are most effective for predicting linear relationships. However, the relationship between nutrient concentrations and ecological variation in waterbodies is often non-linear and sometime involves hierarchical relationships between predictor variables (Appendix 2 and 4). Threshold analyses such as changepoint analysis and categorical and regression tree analysis are useful for analyzing data with nonlinear and hierarchical relationships. Furthermore, these analyses may be particularly useful for identifying specific nutrient concentrations that induce a substantial change in an ecological attribute to cause a threshold-type response.

Changepoint analysis is a statistical technique that identifies a threshold at which a change in variation (deviance) occurs in a response variable. Changepoint analysis is useful for identifying specific nutrient concentrations where shifts may occur in water quality or ecological attributes. Changepoint analysis uses recursive partitioning to divide data into two subsets and establishes a threshold value when the threshold effectively results in a deviance reduction. Model strength can be derived from the relative error associated with a threshold and resampling techniques such as bootstrapping can be used to determine cumulative probability or error rates surrounding individual thresholds. Changepoint analysis is particularly useful in nutrient criteria development because it can identify a specific value (+/- error) of an independent variable (nutrient concentration) at which a water quality or ecological change occurs (Figure 3, Appendix 4). The relative simplicity of model output makes data interpretation relatively simple. The limitations to changepoint analysis are that the procedure is



**Figure 3.** Response of a dependent variable (ecological attribute) to an independent variable (nutrient concentration) threshold.



**Figure 4.** Example of CART analysis showing quantitative thresholds in predictor variables and hierarchical structure among predictors.

not available in most conventional statistical software packages and that executing the procedure requires substantial amounts of data. Furthermore, changepoint analysis is similar to correlation analysis in that it can only identify threshold relationships between a

single predictor variable and a single response variable.

Categorical and regression tree (CART) analysis is simply an extension of changepoint analysis that permits the user to provide multiple predictor variables for a single response variable. In that sense, CART analysis is analogous to multiple linear regression but instead uses a nonparametric approach to identifying thresholds in predictor variables. However, CART analysis also has another advantage over multiple linear regressions in that CART can identify hierarchical structure in multiple variable models. When multiple predictors are included in a CART model the best possible threshold among all predictors is selected as an initial changepoint for the data, which are then partitioned into two separate subgroups based on the threshold. CART then quantifies and selects the best possible threshold(s) to explain variation in each of the data subsets. This process is repeated until the entire data set is divided into increasingly homogeneous subgroups. Predictor variables can be repeated at any point in the tree structure and CART models can include a single predictor where multiple changepoints can be identified. Similar to changepoint analysis, CART is useful because it can identify specific values (+/- error) of independent variable at which change occurs in a dependent value. CART can also identify multiple change-points in one predictor or change-points in multiple predictors. However, the CART procedure is not available in most common statistical software packages and the analysis requires substantial amounts of data.

The statistical techniques discussed in this section may be applied to assist in the development of numeric nutrient water quality criteria. It should be noted that the most reasonable application of these methods is in a weight of evidence approach where information from several analyses that use substantial data can build a systematic case for enforcing a

single nutrient concentration that results in a water-quality impairment. Assessment and standard development programs should consider how other variables may confound the outcome of data analyses that cannot provide a definitive cause-effect relationship. It should also be noted that the methods described here are simply tools and will most definitely provide information no matter the quality of the input data. Therefore, these procedures can be easily misapplied and result in a garbage-in/garbage-out scenario. Great care and caution should be exercised in choosing both predictor and response variables that will be used in standard development. Furthermore, visual inspection and interpretation of data along with these techniques is essential for justifying the mechanistic relationships that are being identified in a correlative framework.

#### **BREAKOUT SESSIONS**

In order to give the workshop participants some experience with these methods, we developed two hypothetical case studies in which the participants were given scatterplots of stressor-response relationships and the statistical output from the procedures outlined above. The participants were asked to use a weight of evidence approach to recommend a specific nutrient criterion for each case study based on the data provided. This process was done twice, once with a data set that included relatively large amounts of data (Appendix 6) and again with a watershed that had much less data (Appendix 7). The data in the workshop was presented simply as nutrient concentration and was intentionally not specific to either nitrogen or phosphorus. We did this to hopefully provide the participants with a more open format and view to propose numeric nutrient criteria, since it was not tied to a specific nutrient. The workshop participants were separated into groups of three or more, and then separated such that each group worked through each exercise independently. At the

end of each exercise, we reformed as the larger group and discussed the results.

The large data set example was intended to give the participants a substantial degree of confidence in the measured stressor-response relationships based on well known ecological information. Although the threshold relationships in the examples were intentionally varied, the amount of variation was intentionally small. The intention was that this would give the participants confidence to recommend nutrient criteria for the examples in a fairly narrow range.

The smaller data set example was intended to instill a great amount of uncertainty in the measured stressor-response relationships. In most cases the direction and magnitude of ecological change was based on expected ecological patterns, but the data supporting specific thresholds was very weak. In some cases we also intentionally randomized data for expected relationships and switched the direction of change in some response variable. This exercise was simply intended to create uncertainty in the weight of evidence.

The results of the breakout session for the large data set were remarkably consistent among groups at each workshop and even among the workshops themselves. However, results from the breakout session with the limited datasets were much more variable. In all workshops the limited data set breakout sessions stimulated substantial discussion about how much emphasis to place on certain relationships and how much others might be dismissed. The hypothetical numeric nutrient criteria proposed by the smaller working groups varied at each workshop, but the range was rather consistent across each workshop. We noticed that smaller groups composed of higher administrative personnel did not consistently propose less or more stringent numeric nutrient criteria than smaller groups made of personnel still working



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in the field; this was purely observational and not quantified.

**SUMMARY**

The feedback from these workshops was overwhelmingly positive. The workshops were not intended to provide training so that the participants would walk away with the knowledge to actively pursue the techniques discussed. Rather, they were intended to provide a foundation for participants to understand what tools are available for the process of numeric nutrient criteria development and to be exposed to the potential pitfalls and benefits of various approaches. As of December 2011, we had conducted workshops at four (Louisiana, Texas, Oklahoma, and New Mexico) of the five states that comprise EPA Region 6. A workshop is being planned in 2012 for the only remaining state (Arkansas), where a tentative workshop is being scheduled for February. The number of participants varied from 5 at the initial LDEQ workshop to over 20 at the TCEQ workshop, and the participants included various state agencies (outside of the environmental agency responsible for water quality standards) such as state conservation commissions, soil and water boards, and wildlife management, as well as representative from stakeholder groups such as environmental personnel from state farm bureaus.

**LITERATURE CITED**

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**Appendix 1.** The first presentation focused on goals, objectives and tasks to set the stage for the day long workshop; the presentations given at the NMED workshop are used as an example in the appendix.

Slide 1

## Workshop Goals

**Brian Haggard**  
Associate Professor and Director,  
Arkansas Water Resources Center

Slide 2

## Workshop Outline

1. WQ Indicators
2. Group Exercise
  1. What Indicators?
3. Statistics 101
4. Statistics 201
5. Group Exercise
  - Less Studied Watershed
6. Group Exercise
  - More Studied Watershed
7. Comments and Summary

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2012 September 10-11, University of Arkansas, Fayetteville, AR 72701  
9100 Craddock Hall, Fayetteville, AR 72701

### Nutrient Criteria Development Mini-Workshop

New Mexico Environmental Department

#### AGENDA

1300 INTRODUCTION AND GOALS  
1305 WATER QUALITY INDICATORS SHOULD WE CONSIDER?  
1310 OPEN DISCUSSION  
1340 STATISTICAL TOOLS 101: PROBABILITY, CORRELATION & REGRESSION  
1345 STATISTICAL TOOLS 201: LEVELS, CPA & CAP  
1400 APPLICATION OF THESE STATISTICAL TOOLS  
1405 Break  
1410 TASK1: Develop Nutrient Criteria for a Hypothetical Watershed with Lots of Data  
1415 BREAKOUT SUMMARY  
1420 TASK2: Develop Nutrient Criteria for a Hypothetical Watershed with Limited Data  
1425 BREAKOUT SUMMARY  
1430 BREAKOUT SUMMARY  
1435 FINAL DISCUSSION AND ADDRESS

Appendix 1 continued.

Slide 3


## GROUP EXERCISE FORMAT

- When needed, we will break into assigned teams...
  - State representatives should be spread out...
  - Only one person per state in groups
  - Maybe one EPA Region 6 representative in groups
- The group will need to complete exercise...
- We (Thad & I) serve as technical advisors...
  - We can help with data explanations, statistics, etc.

Slide 4

## GROUP EXERCISE FORMAT

- Each group exercise will have a one page sheet...
  - This needs to be filled out,
  - And, turned in when workshop ends.
- We will keep things confidential, where specific names are not revealed...
  - If used in future workshops, etc.



Appendix 1 continued.

Slide 5

### 1<sup>st</sup> Exercise: Water Quality Indicators

□ We want to know what are we really trying to protect...

- Nutrient Criteria




Slide 6

### 2<sup>nd</sup> Exercise: Nutrient Criteria

□ The goal is to develop nutrient criteria, based upon the available information from a watershed with:

- Few Data Points or Sampling Sites
- But, Where You Have Lots of Different Data



Appendix 1 continued.

Slide 7

### 3<sup>rd</sup> Exercise: Nutrient Criteria

- The goal is to develop nutrient criteria, based upon the available information from a watershed with:
  - A Relatively Large Number of Sampling Sites
  - And, Where You Have Lots of Different Data



Slide 8

### The point is...

- We want to walk through these exercises, where:
  - You have limited number of data points to evaluate stats.
  - You have lots of data points to assist with stats.
- We want to understand:
  - Why there might be variability between teams,
  - And, what helps provide confidence in decisions.
- Finally, we hope that this workshop will lead to future workshops...
  - Groups get different data sources, and rely on literature...
  - We hope to eventually evaluate the Red River Basin...

The final slide called for questions and comments from the workshop participants.

**Appendix 2.** The second presentation focused on what water-quality indicators should we consider, asking the question what are we really trying to protect when defining impairment.

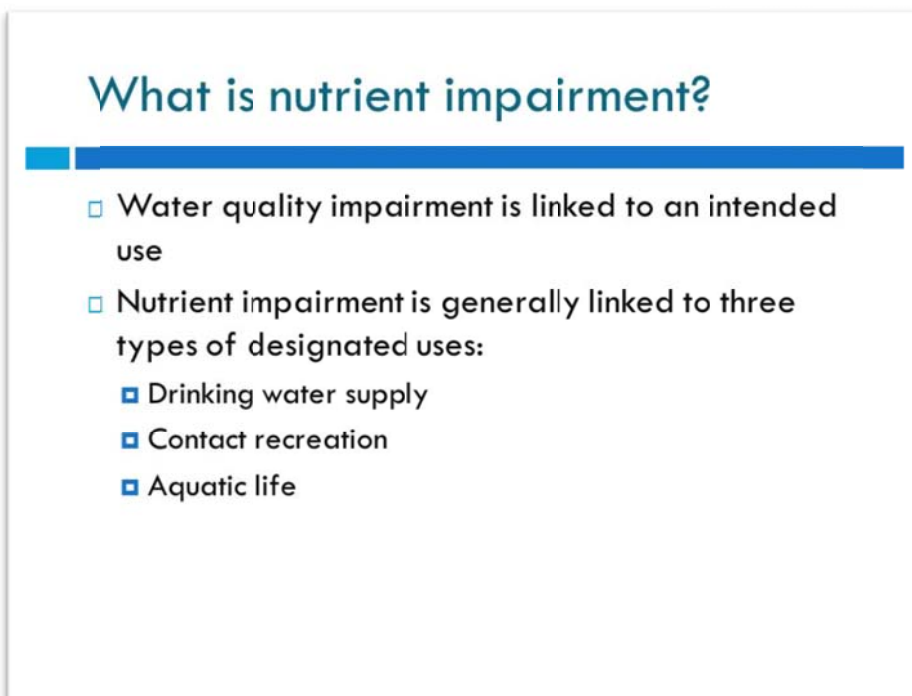
*Slide 1*



What Water Quality Indicators  
Should We Consider?

**Thad Scott**  
Assistant Professor, Environmental Water Science  
University of Arkansas

*Slide 2*



What is nutrient impairment?

- Water quality impairment is linked to an intended use
- Nutrient impairment is generally linked to three types of designated uses:
  - ▣ Drinking water supply
  - ▣ Contact recreation
  - ▣ Aquatic life

Appendix 2 continued.

Slide 3

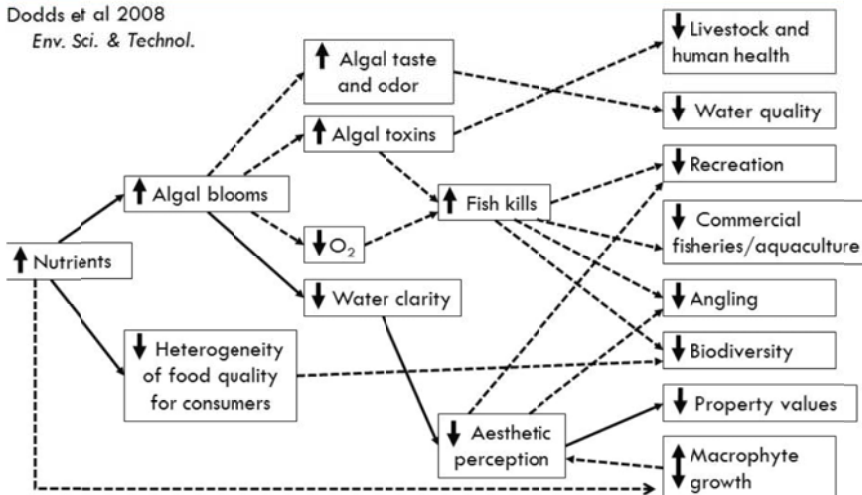
## What do elevated nutrients change in aquatic ecosystems?

- Nutrients, particularly nitrogen (N) and phosphorus (P), change growth and metabolism of osmotrophs
- Osmotrophs (microorganisms and plants) acquire nutrients directly from water in aquatic systems
- Elevated nutrients can increase osmotroph biomass and metabolism, resulting in higher trophic state
- Osmotrophs are the base of the aquatic food web, and nutrient enrichment changes their chemistry

Slide 4

## What do elevated nutrients change in aquatic ecosystems?

Dodds et al 2008  
*Env. Sci. & Technol.*



Appendix 2 continued.

Slide 5

## What should we measure & assess?

<ul style="list-style-type: none"><li>• Nutrient concentrations</li><li>• Algal biomass   sestonic and/or benthic</li><li>• Water clarity</li><li>• Diurnal DO</li></ul>	}	Most waterbodies (drinking water supply, contact recreation)
<ul style="list-style-type: none"><li>• Consumer food quality   Element ratios (C:N, C:P)   of periphyton,   leaf litter, seston?</li><li>• Biodiversity   Macroinvertebrates   Fish</li></ul>		Autotrophic response – obvious in <u>lakes, reservoirs, and large rivers</u> . Not obvious in shaded streams (light limitation)
	}	Sensitive or rare waterbodies (unique natural resource, state or national river, scenic waterway, etc)
		Heterotrophic response – overwhelmed by autotrophic response in lakes, reservoirs, and large rivers. Only signal of ecological change in <u>shaded streams</u>

Slide 6

## Questions or discussion?

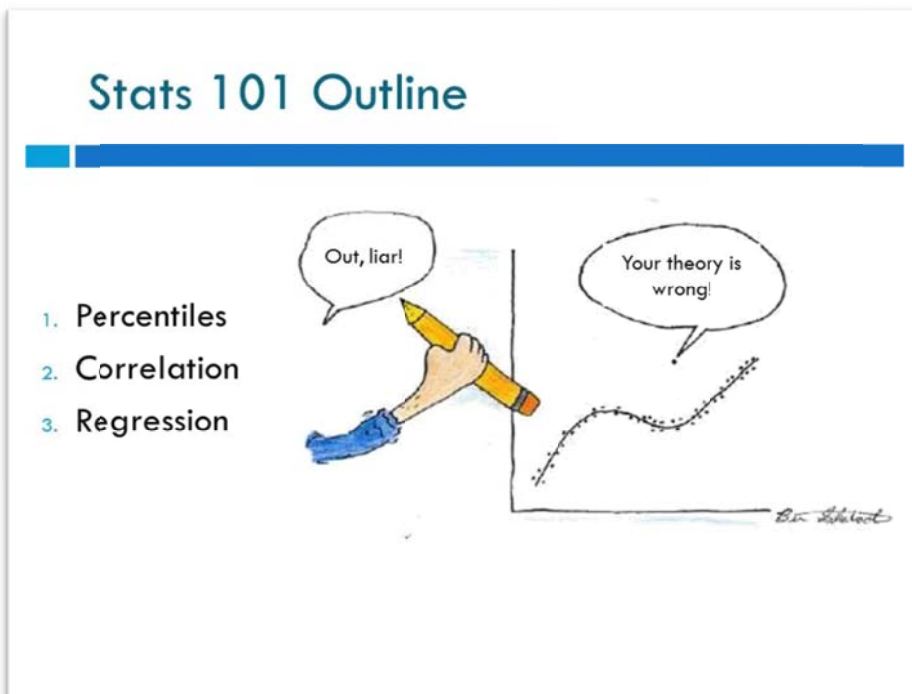


**Appendix 3.** The third presentation focused on simple statistical tools, i.e. *Statistical Tools 101*, that might be useful in the development of numeric nutrient criteria, including data distributions, correlation and regressions.

Slide 1

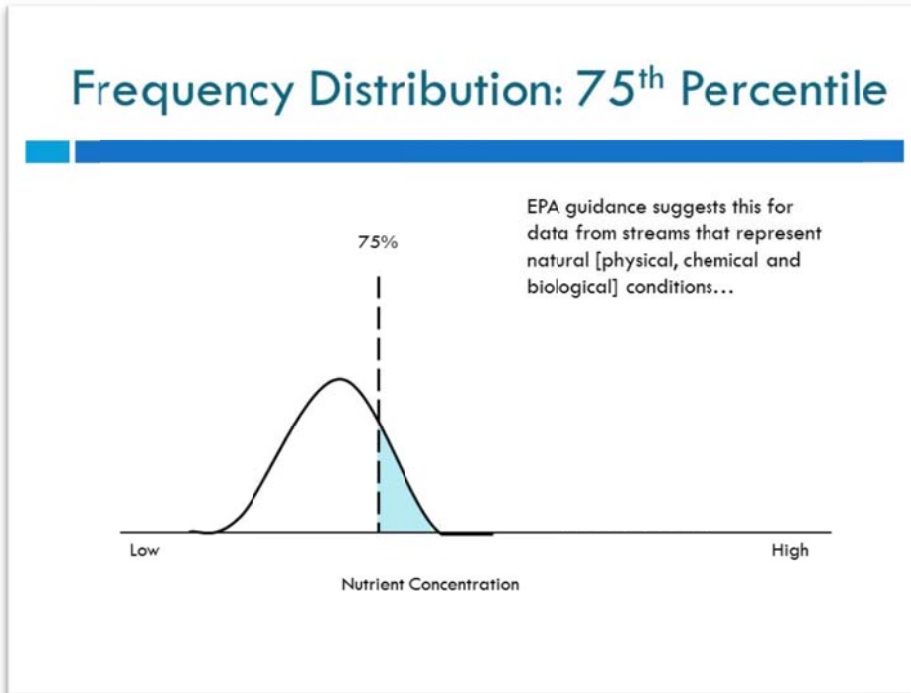


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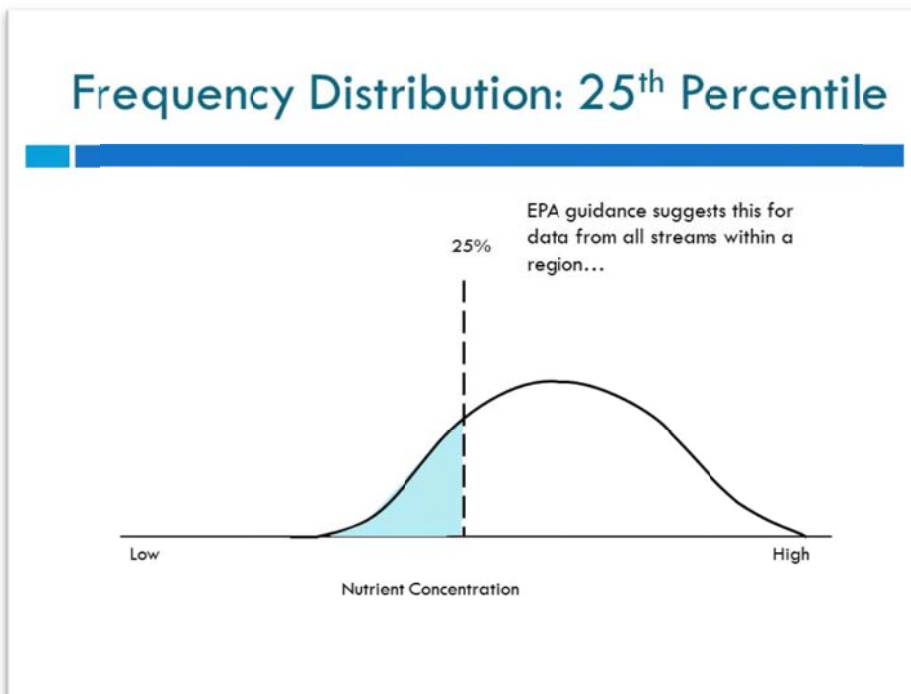


Appendix 3 continued.

Slide 3

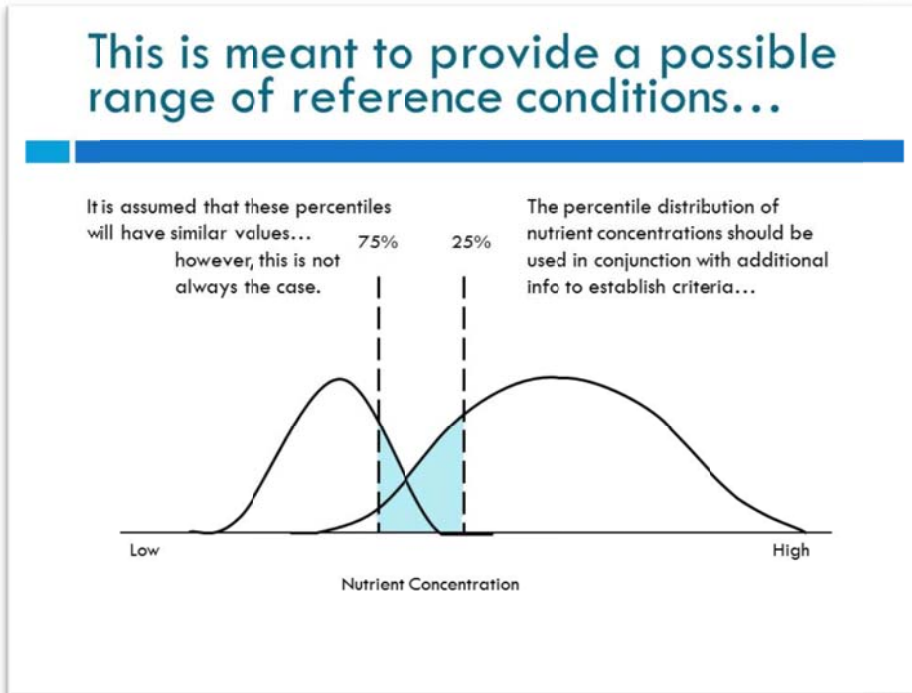


Slide 4

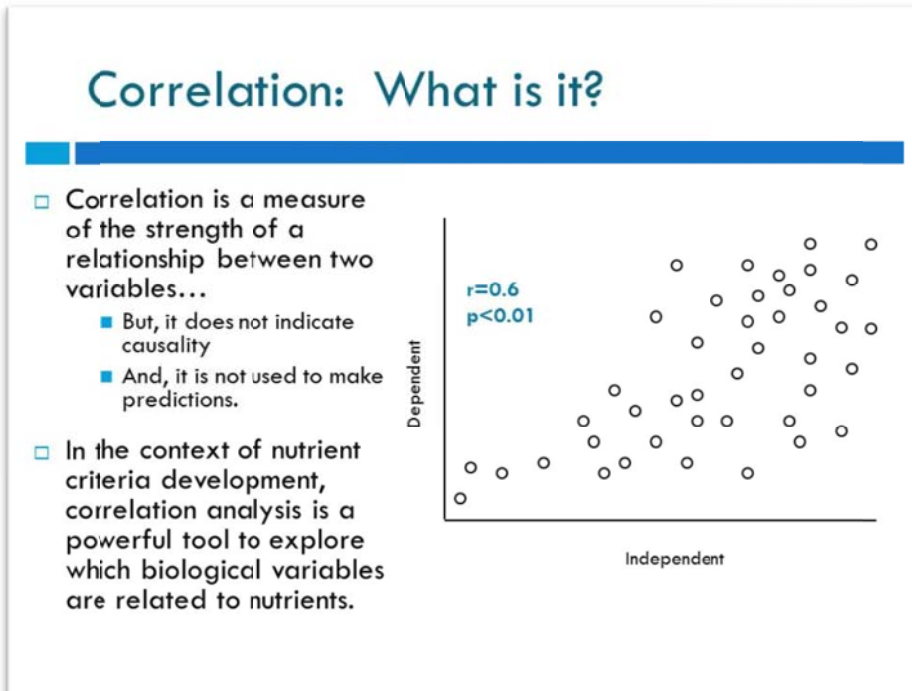


Appendix 3 continued.

Slide 5



Slide 6



Appendix 3 continued.

Slide 7

## Correlation: How does it work?

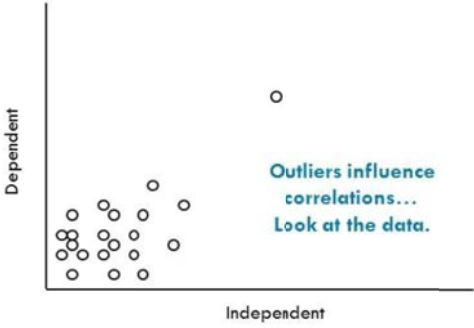
- **PEARSON** Correlation Coefficient
  - Parametric
  - Assumes data is normally distributed
- **SPEARMAN** Rank Correlation
  - Non-Parametric
  - No assumptions about relations between variables

\*The closer to one the stronger these relations

Slide 8

## Correlation: What stats do we want?

- Report the correlation coefficient, the number of data pairs or degrees of freedom, and the significant (p value) or type 1 error rate (alpha).
- Pros of Correlation:
  - Effective way to convey simple relationships
  - Easy to understand
  - Quantitatively measures association between two variables
- Cons of Correlation:
  - Hard to detect complex relationships
  - Lack of significance does not mean lack of association
  - Large sample sizes can lead to significant but not necessarily meaningful relationships
  - Not predictive



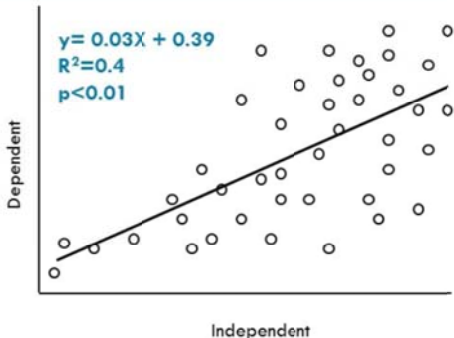
Outliers influence correlations...  
Look at the data.

Appendix 3 continued.

Slide 9

## Regression: What is it?

- A technique that treats one variable as a function of another, resulting in an equation that can be used to predict a response.
- Useful to consider more complex relations of different orders (e.g., polynomial).



Dependent

Independent

Example types:

- Simple linear
- Multiple linear
- Non-linear (logistic, exponential, and polynomial)

Slide 10

## Regression: How does it work?

- If a strong enough relationship between a response variable and an independent variable is identified, then regression can be used to establish a predictive relation.
- The most common regression approach is to minimize the sum of squared deviations.

Appendix 3 continued.

Slide 11

## Regression: What stats do we want?

- **Linear Regression:** Report the regression equation, significance of the model (p value), degrees of freedom,  $R^2$  (measures what proportion of the variability in the relationship is explained by the regression)
- **Logistic Regression:** Report the parameter estimates and associated significance, and the goodness-of-fit results

<ul style="list-style-type: none"><li>□ <b>Pros of Regression:</b><ul style="list-style-type: none"><li>■ Predictive analysis</li><li>■ Easy to interpret</li><li>■ Relationships can be modeled</li></ul></li></ul>	<ul style="list-style-type: none"><li>□ <b>Cons of Regression:</b><ul style="list-style-type: none"><li>■ Assumptions constrain analysis</li><li>■ Complex models difficult to evaluate</li><li>■ Sensitive to outliers and hard to extrapolate</li></ul></li></ul>
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Slide 12

## Things to remember...

- **PERCENTILES**
  - Tool that is valuable to criteria development, but it should be used in combination with additional information.
- **CORRELATION**
  - Tool that is extremely useful for data exploration, evaluating the relation between biological variables and nutrients.
  - But, it only gives us association not predictive.
- **REGRESSION**
  - Tool that defines relations between dependent (e.g., biological response) and independent variables (e.g., nutrients), but it has limitations to consider also.

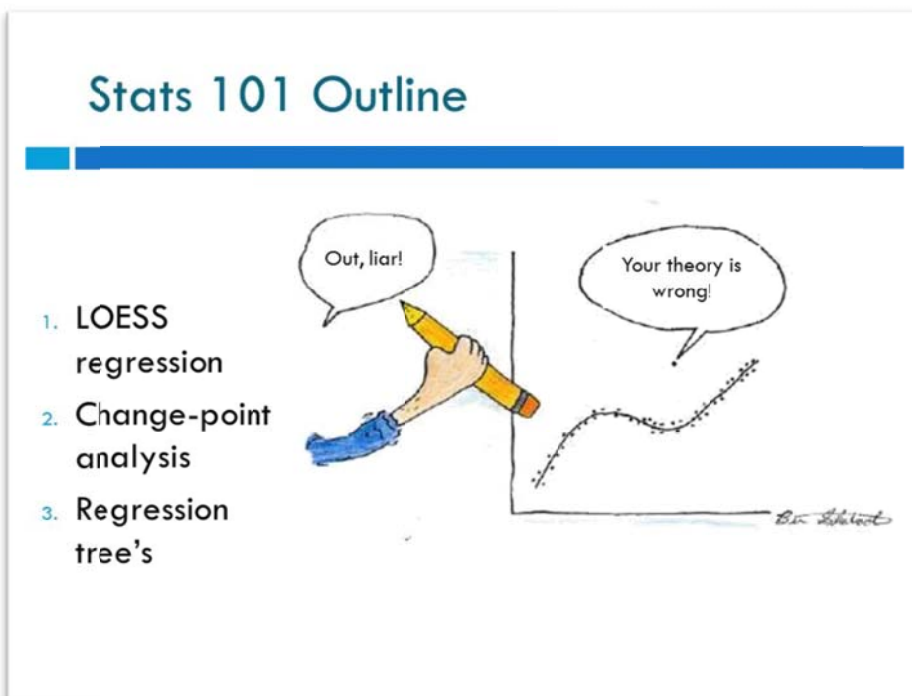
**Appendix 4.** The fourth presentation focused on more advance statistical methods that could be used in the development of numeric nutrient criteria, such as locally weighted regression, change-point analysis, and regression trees to identify hierarchical structure in environmental data.

Slide 1



Slide 1 is a presentation slide with a white background and horizontal lines. A blue horizontal bar at the top contains the title "Statistical Tools 201" in white text. Below the bar, the name "Thad Scott" is written in bold, followed by "Assistant Professor, Environmental Water Science" and "University of Arkansas" in a smaller font.

Slide 2



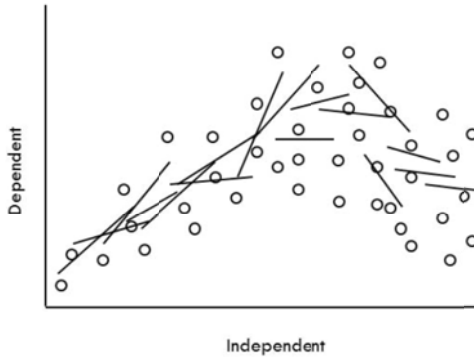
Slide 2 is a presentation slide with a white background and horizontal lines. A blue horizontal bar at the top contains the title "Stats 101 Outline" in white text. Below the bar, a list of three items is shown: "1. LOESS regression", "2. Change-point analysis", and "3. Regression tree's". To the right of the list is a cartoon illustration of a hand holding a yellow pencil, pointing at a graph. The graph shows a jagged line with a speech bubble above it saying "Out, liar!". Another speech bubble above the graph says "Your theory is wrong!". The signature "Ben Schmitt" is visible at the bottom right of the graph.

Appendix 4 continued.

Slide 3

### LOESS Regression: What is it?

- Locally weighted regression – LOESS
- Average of many regressions calculated for subsets of data
- Powerful tool non-linear relationships between physical or biological variables and nutrient concentrations.

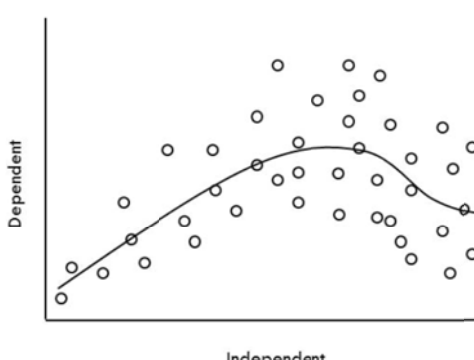


A scatter plot with 'Dependent' on the y-axis and 'Independent' on the x-axis. The data points are scattered, showing a non-linear trend. Several short, straight regression lines are drawn across different subsets of the data, illustrating the locally weighted nature of the LOESS method.

Slide 4

### LOESS Regression: How does it work?

- Must specify the degree of smoothing desired
- Provides model  $[y = f_{\text{ant}}(x)]$
- Residuals can be useful for identifying relationships w/other variables



A scatter plot with 'Dependent' on the y-axis and 'Independent' on the x-axis. The data points are scattered, showing a non-linear trend. A single, smooth curve is drawn through the data points, representing the LOESS regression model.



Appendix 4 continued.

Slide 5

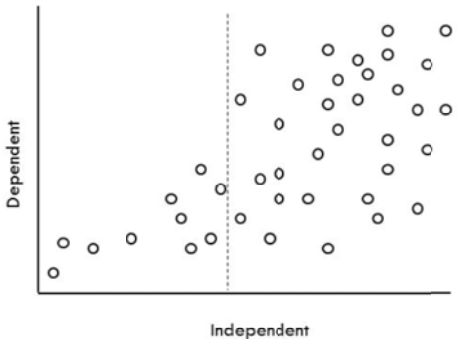
## LOESS: What stats do we want?

- Probability and strength of fit statistics are generally difficult to quantify in LOESS regression
- Pros of LOESS:
  - Effective way to display non-linear relationships
  - Easy to understand
  - Quantitative relationship between two variables
- Cons of LOESS:
  - Difficult to quantify error and statistical significance
  - Difficult to estimate strength of association (no  $R^2$ )

Slide 6

## Change-point analysis: What is it?

- A technique that identifies a threshold at which a change in variation (deviance) occurs in response
- Useful for identifying specific nutrient concentrations where shifts occur

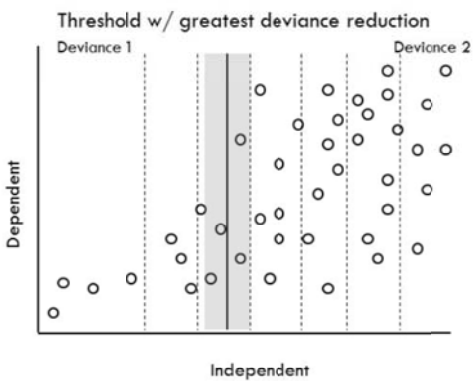


Appendix 4 continued.

Slide 7

### Change-point analysis: How does it work?

- Uses recursive partitioning to divide data into two subsets
- Quantifies deviance of resulting subsets
- Establishes threshold if deviance reduction occurs choosing threshold value with greatest deviance reduction
- Resampling used to determine error rates and statistical sig.



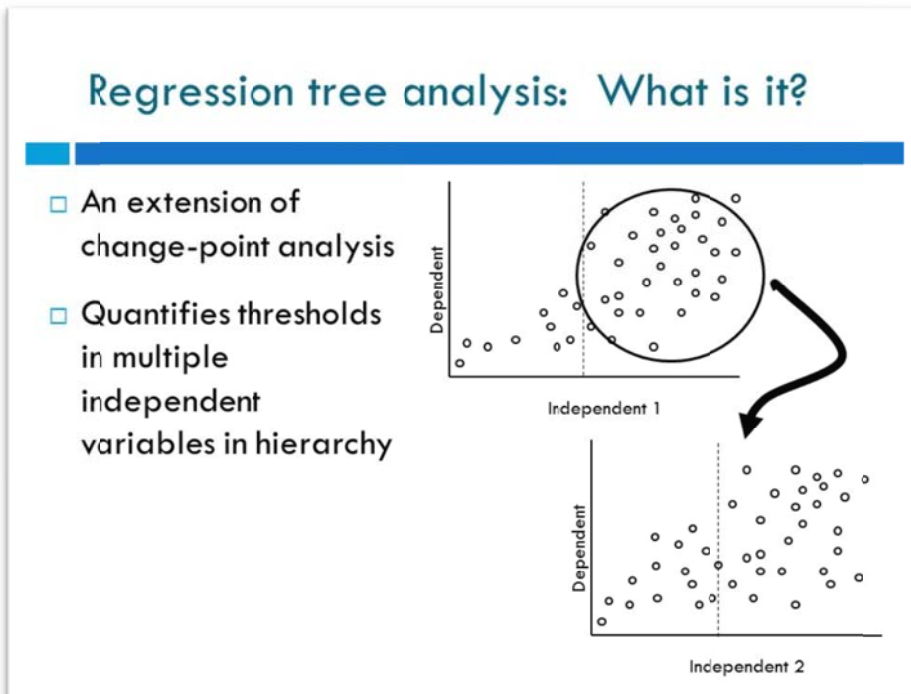
Slide 8

### Change-point: What stats do we want?

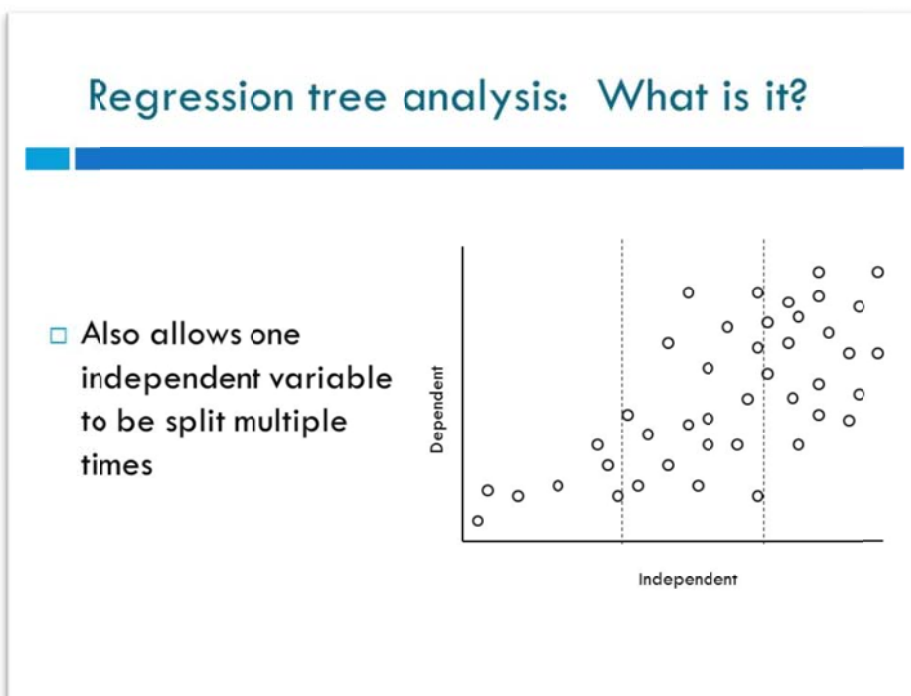
- Threshold value of independent variable; mean, median, and standard deviation of dependent variable data subsets on either side of threshold; cumulative probability curve or confidence intervals
- Pros of Change-point:
  - Identifies specific value (+/- error) of independent variable at which change occurs
  - Easy to interpret
- Cons of Change-point:
  - Not available in most conventional statistical software packages
  - Cannot identify multiple change-points or quantify relationships
  - Requires a lot of data

Appendix 4 continued.

Slide 9



Slide 10



Appendix 4 continued.

Slide 11

## Regression tree analysis: How does it work?

- Initially similar to changepoint
- Added step is that changepoint is performed on data subsets
- Independent variable with greatest deviance reduction chosen at each split
- Model over-fit must be evaluated and corrected

Development of Environmental Thresholds for Nitrogen and Phosphorus in Streams  
 Patricia A. Chambers,\* Daryl J. McGoldrick, Robert B. Brua, Chantal Vis, Joseph M. Colp, and Glenn A. Benoy

Legend:  
 Montane Cordillera: ● BC, ○ OC  
 Mixedwood Plains: + CN, × NB  
 Prairies & transition to boreal Plains: △ MB, × NB

Slide 12

## Regression tree: What stats do we want?

- Threshold value of independent variable; mean, median, and standard deviation of data subsets on either side of threshold; cumulative probability curve or confidence intervals; tree pruning statistics; partial  $R^2$  and model  $R^2$

<ul style="list-style-type: none"> <li>□ Pros of Change-point:                     <ul style="list-style-type: none"> <li>■ Identifies specific value (+/- error) of independent variable at which change occurs</li> <li>■ Can identify multiple change-points in one predictor, or change-points in multiple predictors</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>□ Cons of Change-point:                     <ul style="list-style-type: none"> <li>■ Not available in most conventional statistical software packages</li> <li>■ Requires a lot of data</li> </ul> </li> </ul>
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**Appendix 4 continued.**

*Slide 13*

### Things to remember...

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- 201 techniques are complex and require substantial attention to details
- When conducted appropriately, these techniques may be most useful for nutrient criteria development
- Using multiple techniques in a weight-of-evidence approach is best

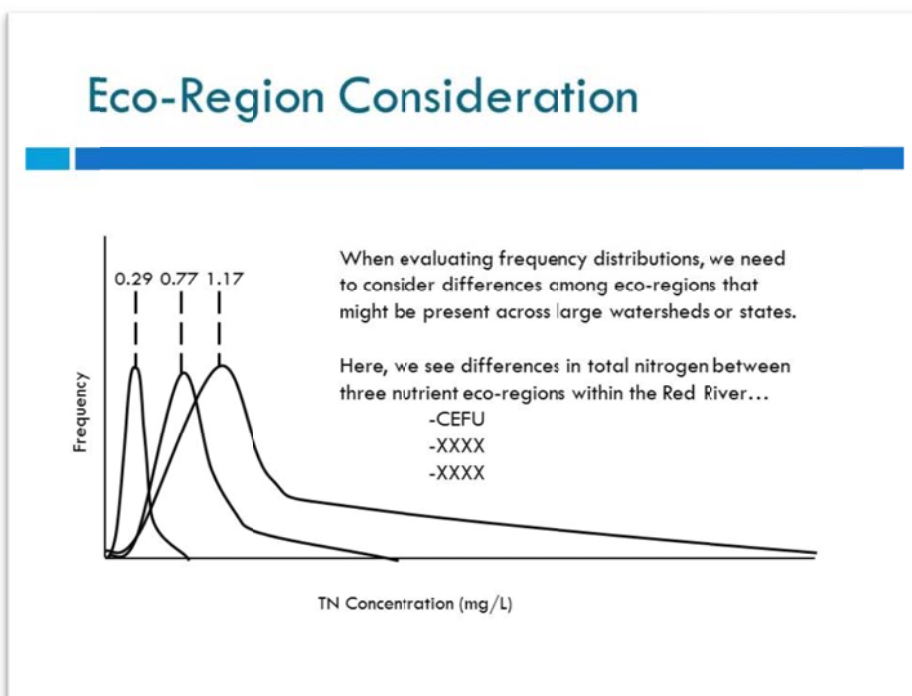
**Appendix 5.** The fifth presentation covered some general considerations in the application of these statistical tools when interpreting your data, with special consideration on eco-regional differences, land use effects, data transformations, and thresholds in response verse impairments.

Slide 1

**Application of these Tools:  
Interpreting your Data**

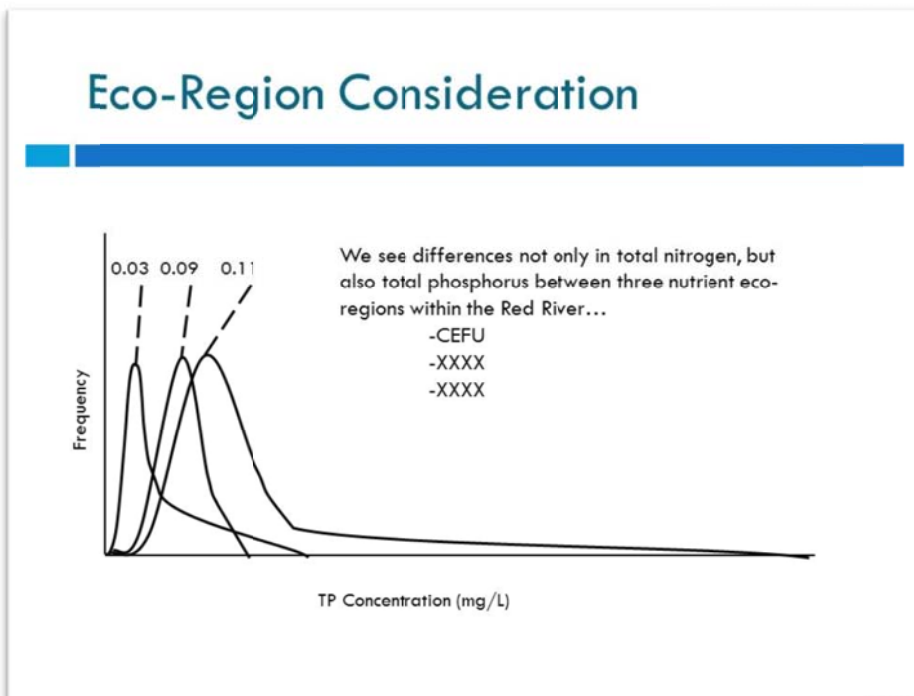
**Brian Haggard**  
Director and Associate Professor, Arkansas Water  
Resources Center  
University of Arkansas

Slide 2

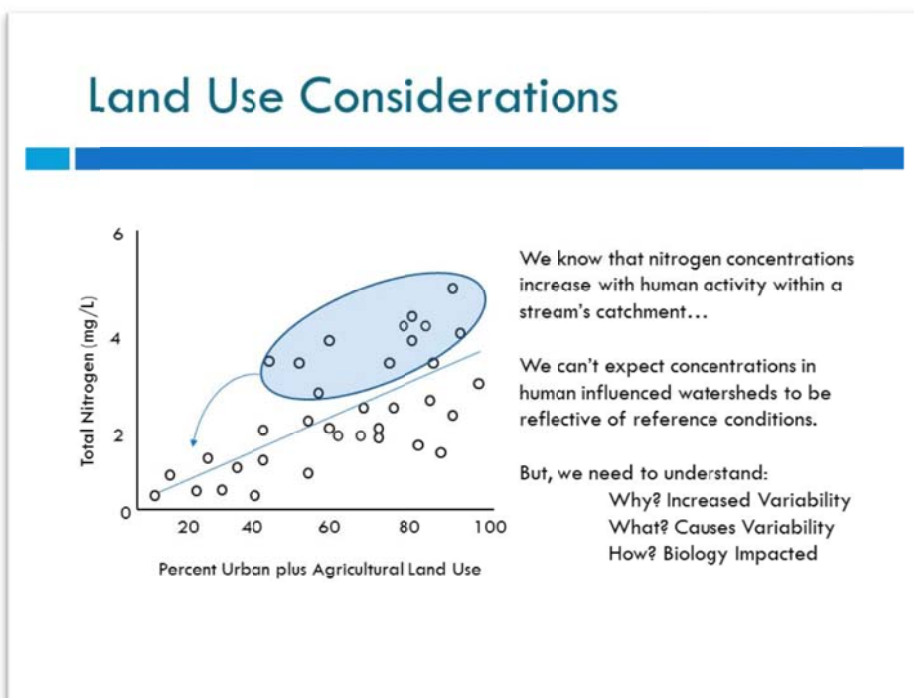


Appendix 5 continued.

Slide 3

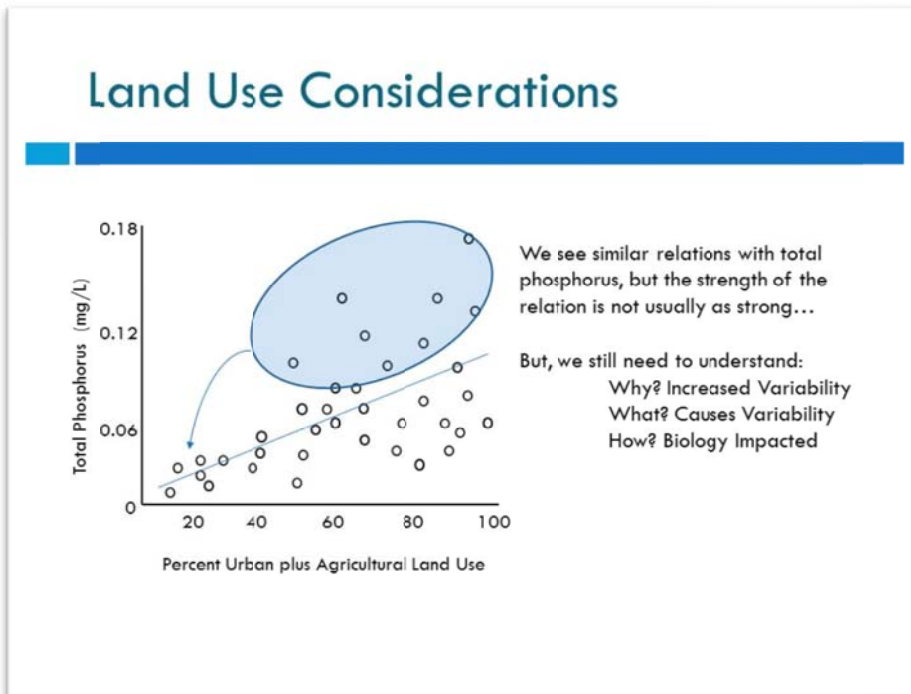


Slide 4

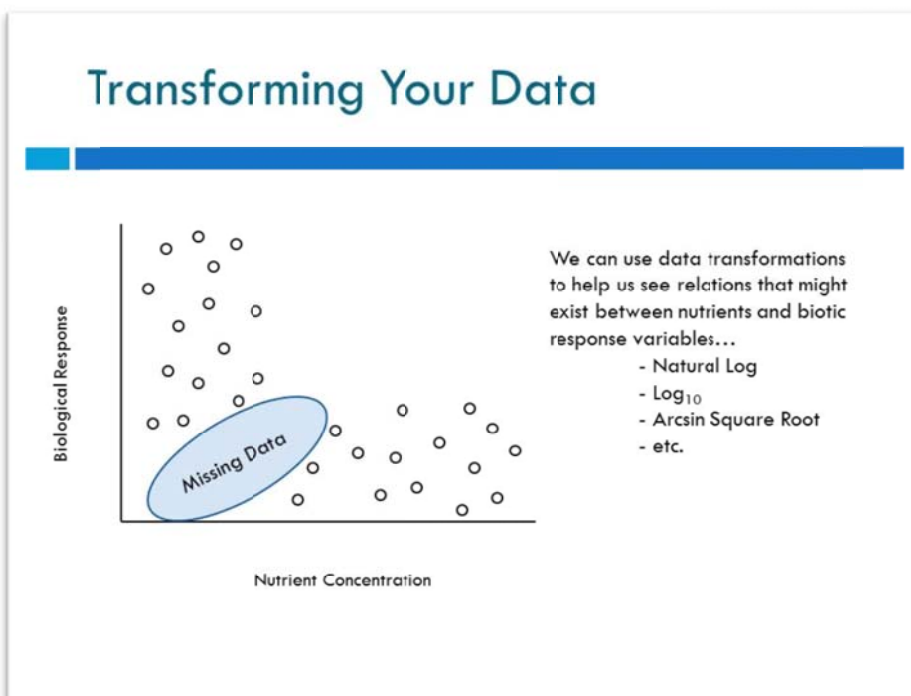


Appendix 5 continued.

Slide 5



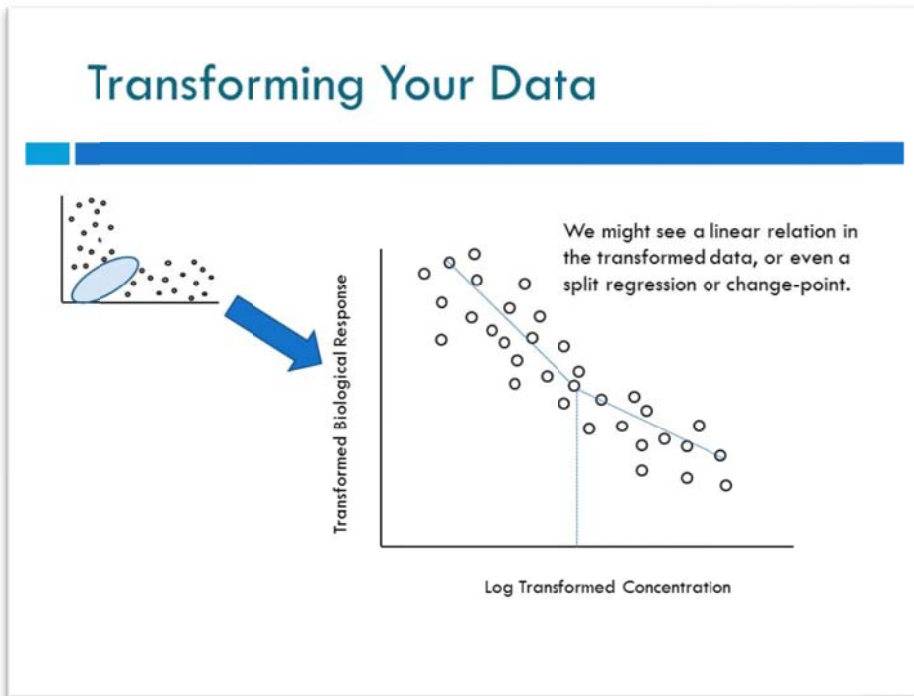
Slide 6



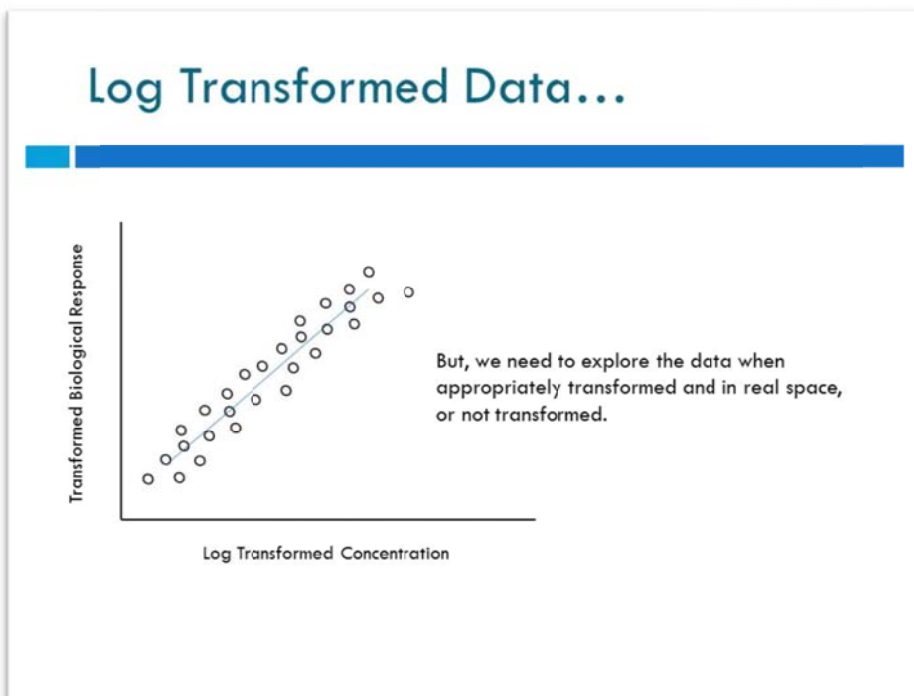


Appendix 5 continued.

Slide 7

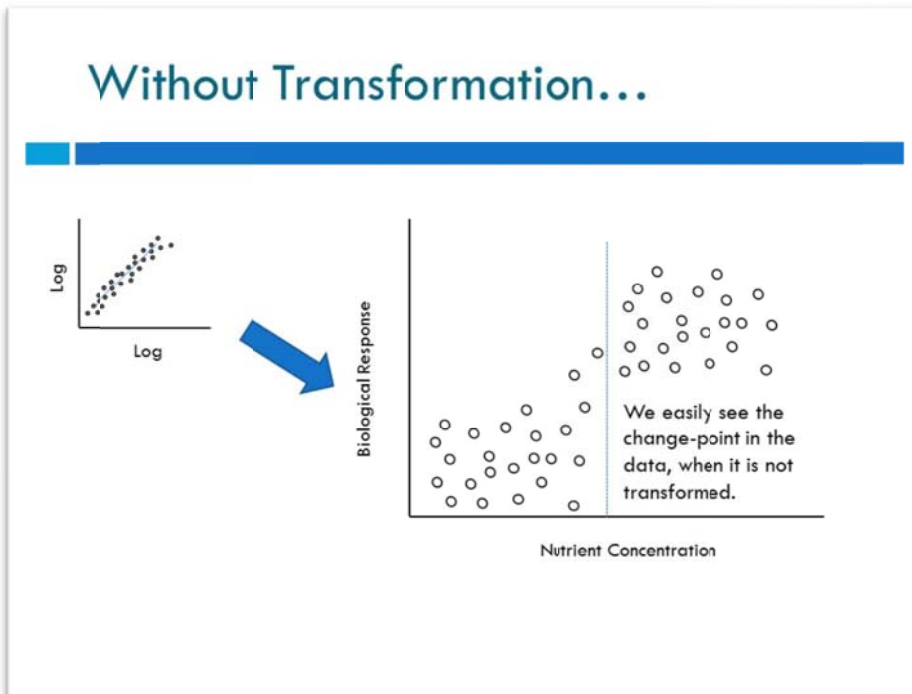


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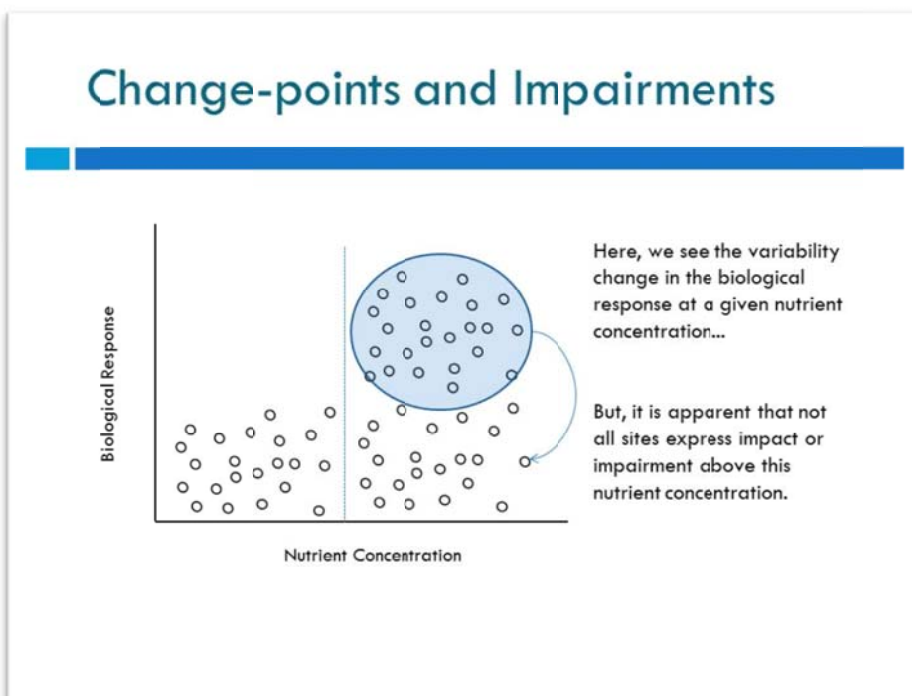


Appendix 5 continued.

Slide 9

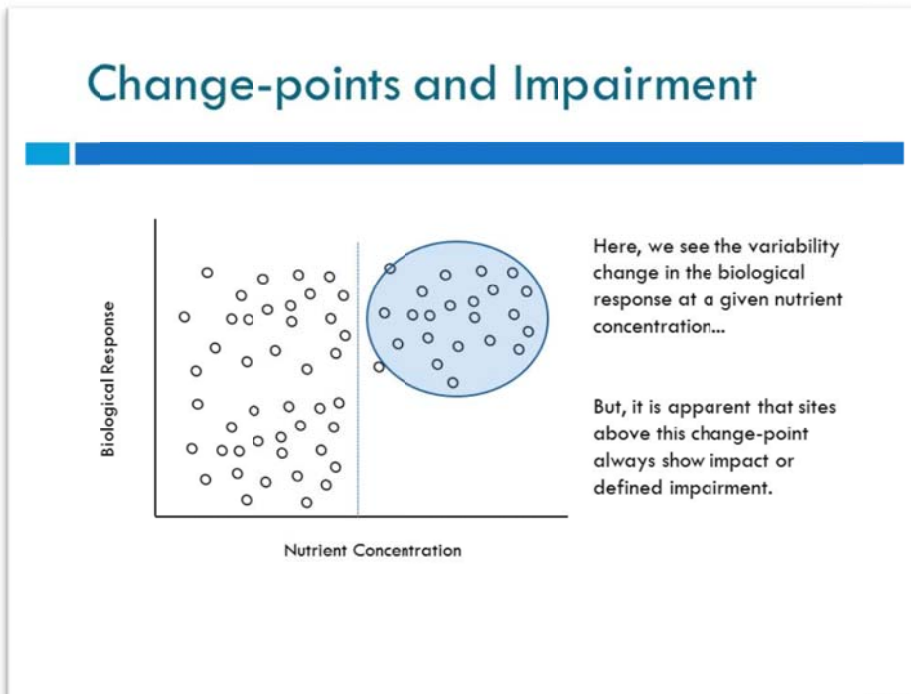


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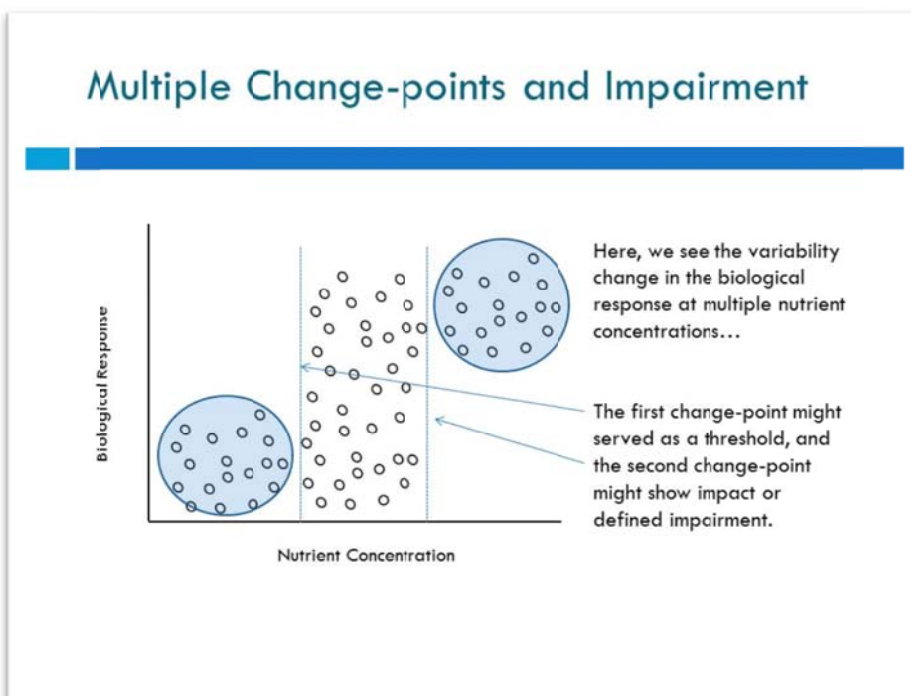


Appendix 5 continued.

Slide 11

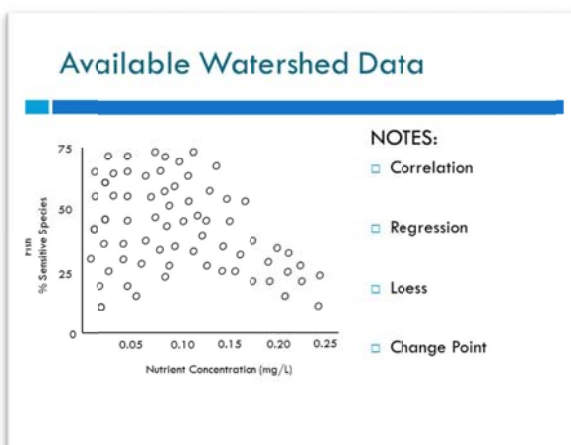
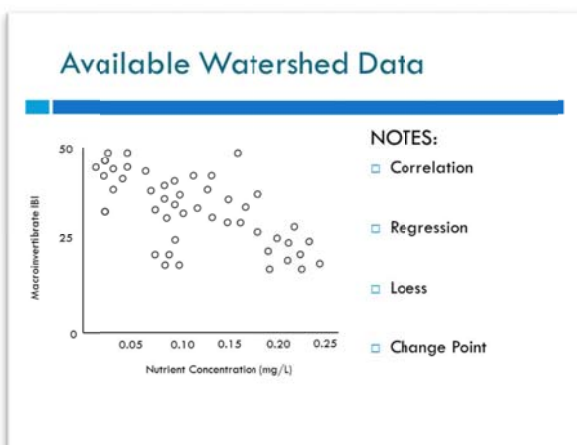
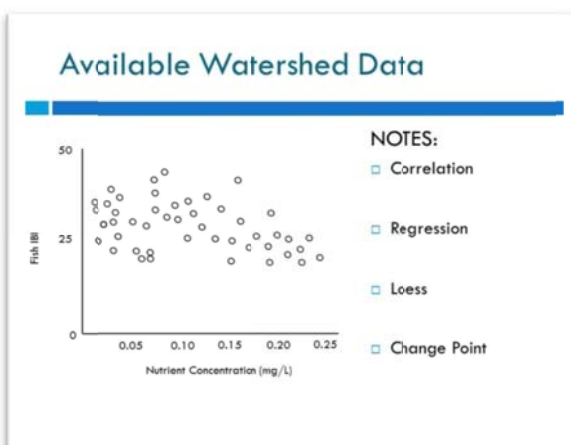
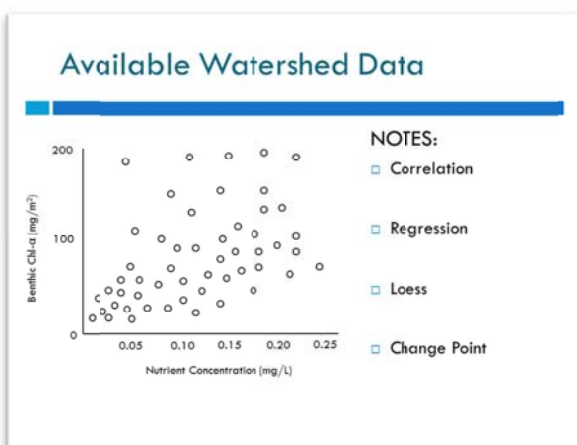
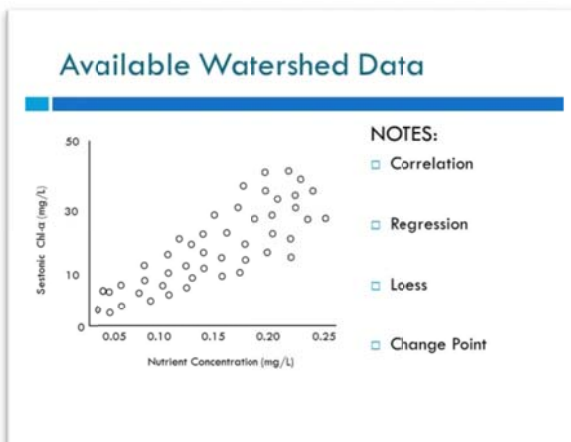
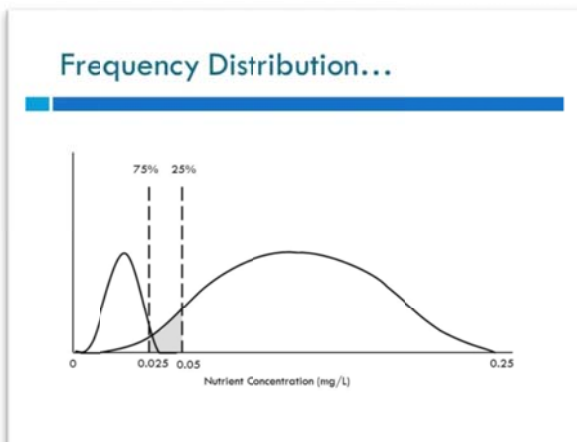


Slide 12



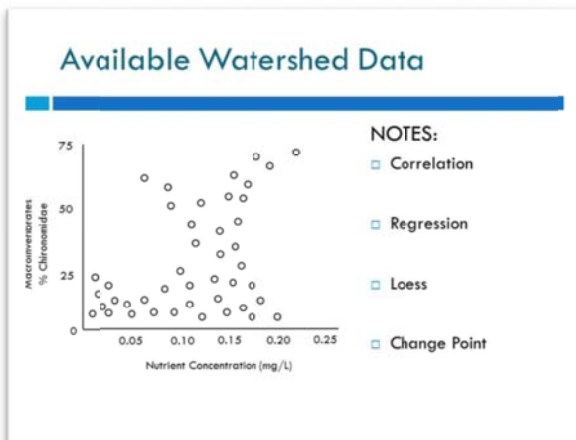
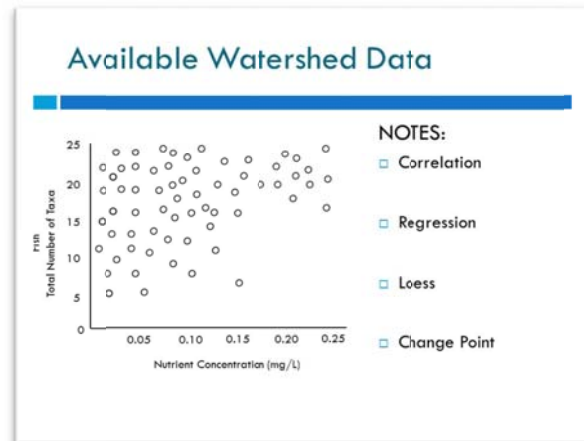
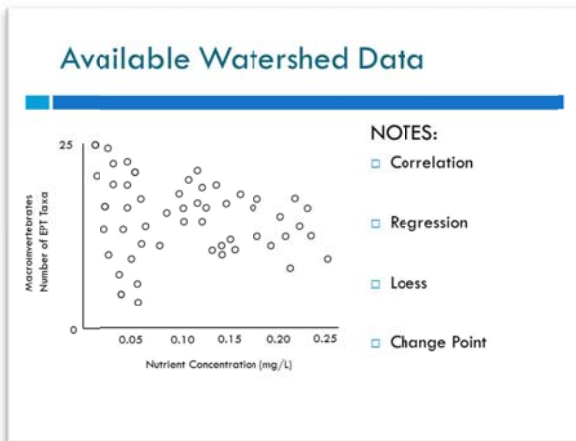
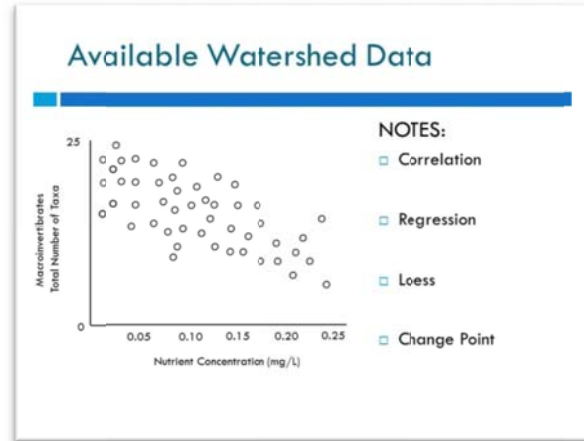
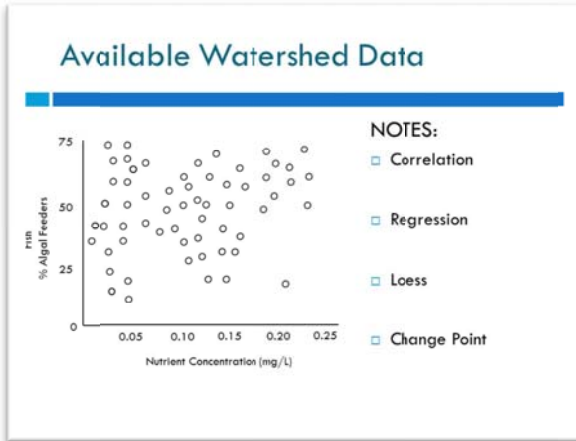
# ARKANSAS WATER RESOURCES CENTER – UNIVERSITY OF ARKANSAS TECHNICAL PUBLICATION NUMBER MSC 367 – YEAR 2012

**Appendix 6.** The first exercise usually used an example watershed where *ample* biological data was available over a nutrient concentration gradient; the smaller working groups used the frequency distributions and stressor-response relationships to propose numeric nutrient criteria.



ARKANSAS WATER RESOURCES CENTER – UNIVERSITY OF ARKANSAS  
TECHNICAL PUBLICATION NUMBER MSC 367 – YEAR 2012

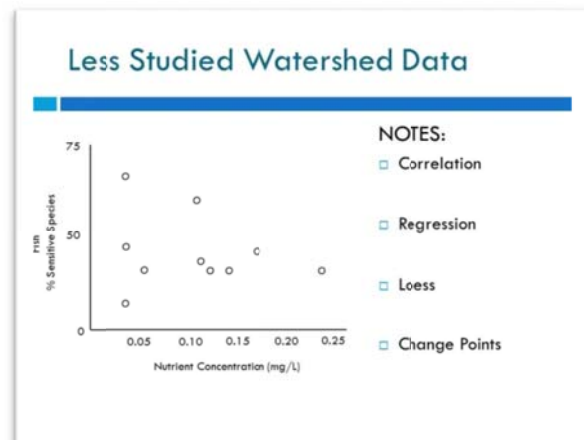
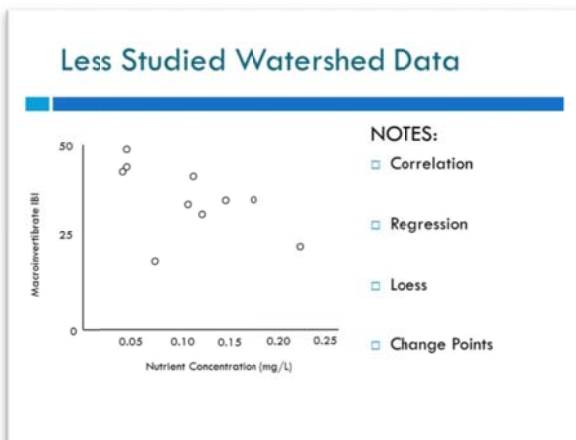
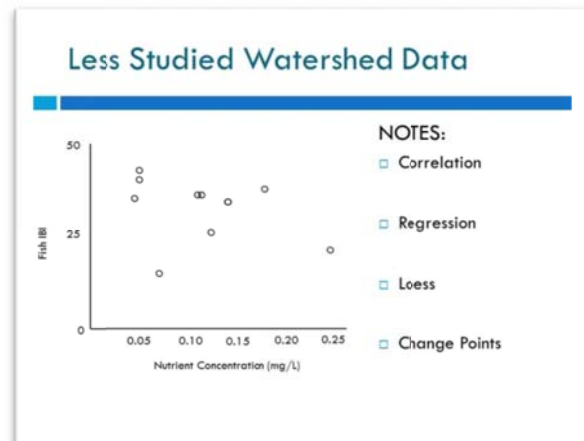
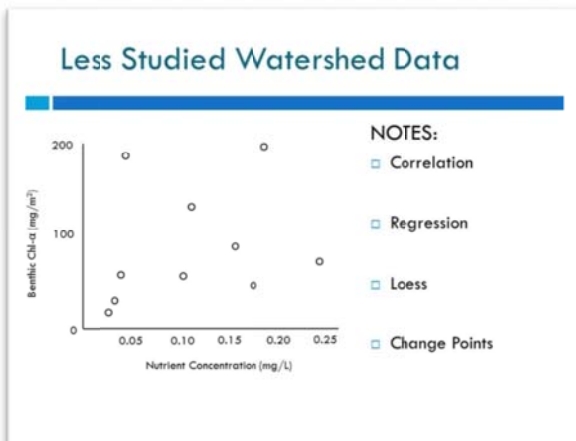
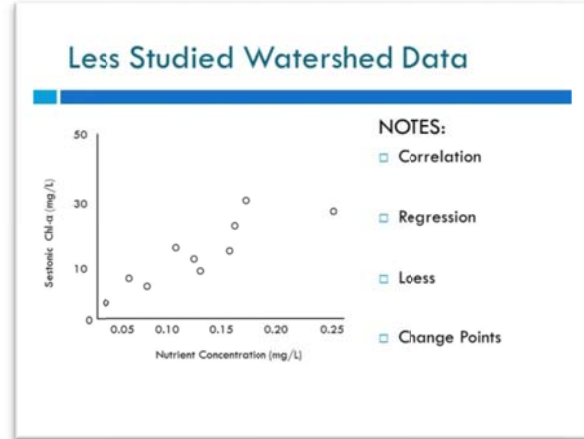
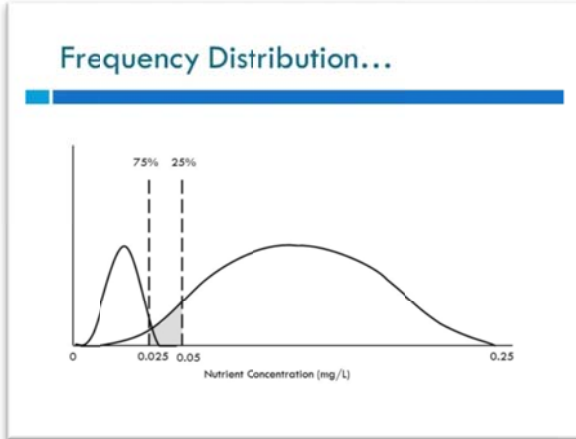
Appendix 6 continued.



# ARKANSAS WATER RESOURCES CENTER – UNIVERSITY OF ARKANSAS

## TECHNICAL PUBLICATION NUMBER MSC 367 – YEAR 2012

**Appendix 7.** The second exercise usually used an example watershed where *little* biological data was available over a nutrient concentration gradient; the smaller working groups used the frequency distributions and stressor-response relationships to propose numeric nutrient criteria.



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Appendix 7 continued.

