Flow Alteration – Biological Response Relationships to Assist with the Determination of Ecological Flows

RTI Internal Research and Development Project

RTI International is a trade name of Research Triangle Institute.

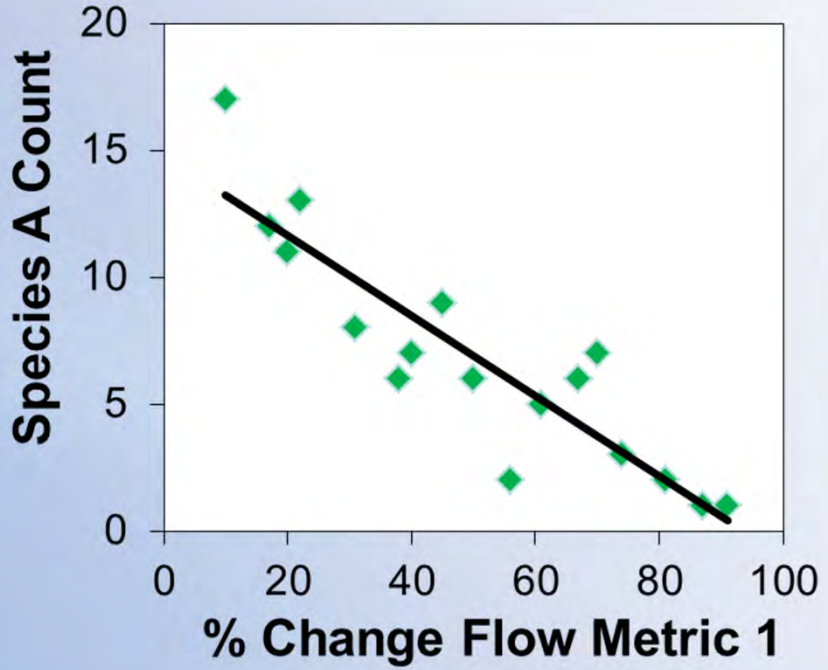
Outline of Presentation

- Objectives
- Methods:
  - Aquatic biota
  - Flow metrics
  - Statistical analyses

Project Objectives:

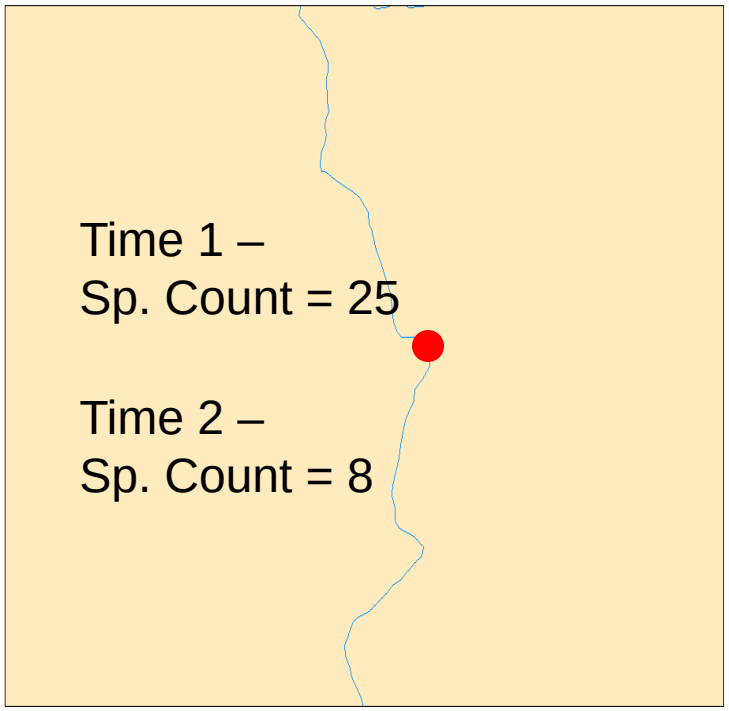
- To use a combined approach of:
  - unaltered and current flows determined with WaterFALL model
  - large, state-wide aquatic biota datasets (monitoring programs)

  to determine species-specific flow alteration – biological response relationships that are useful to water managers.

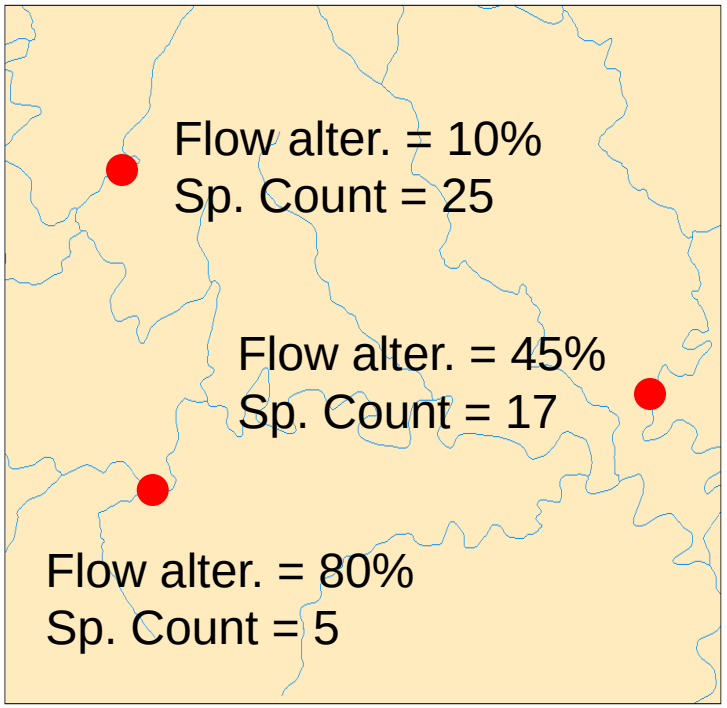


Project Objectives:

Time for Time Approach



Space for Time Approach

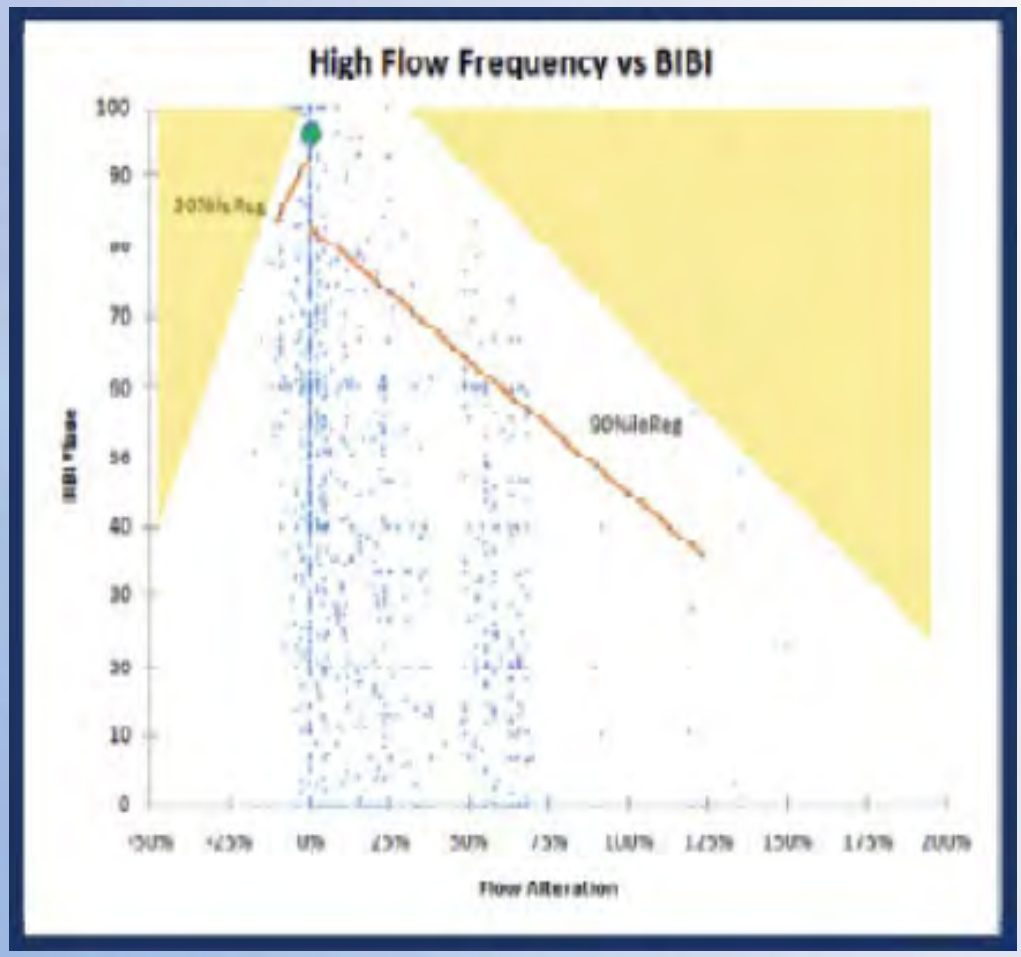


Project Objectives:

"*transferable quantitative relationships between flow alteration and ecological response*" cannot be easily developed, and "***large databases***, *if analyzed with an eye toward degree of* ***flow alteration***, *carefully selected* ***response metrics***, *stream typology, and* ***multiple environmental drivers***, *hold the potential to reveal important relationships*" – Poff and Zimmerman (2010)

Project Objectives:

- Studies that have adopted this approach:
  - Middle Potomac Environmental Flows
  - Virginia DEQ Environmental Flows
  - Carlisle et al. (2011) – USGS effort across U.S.



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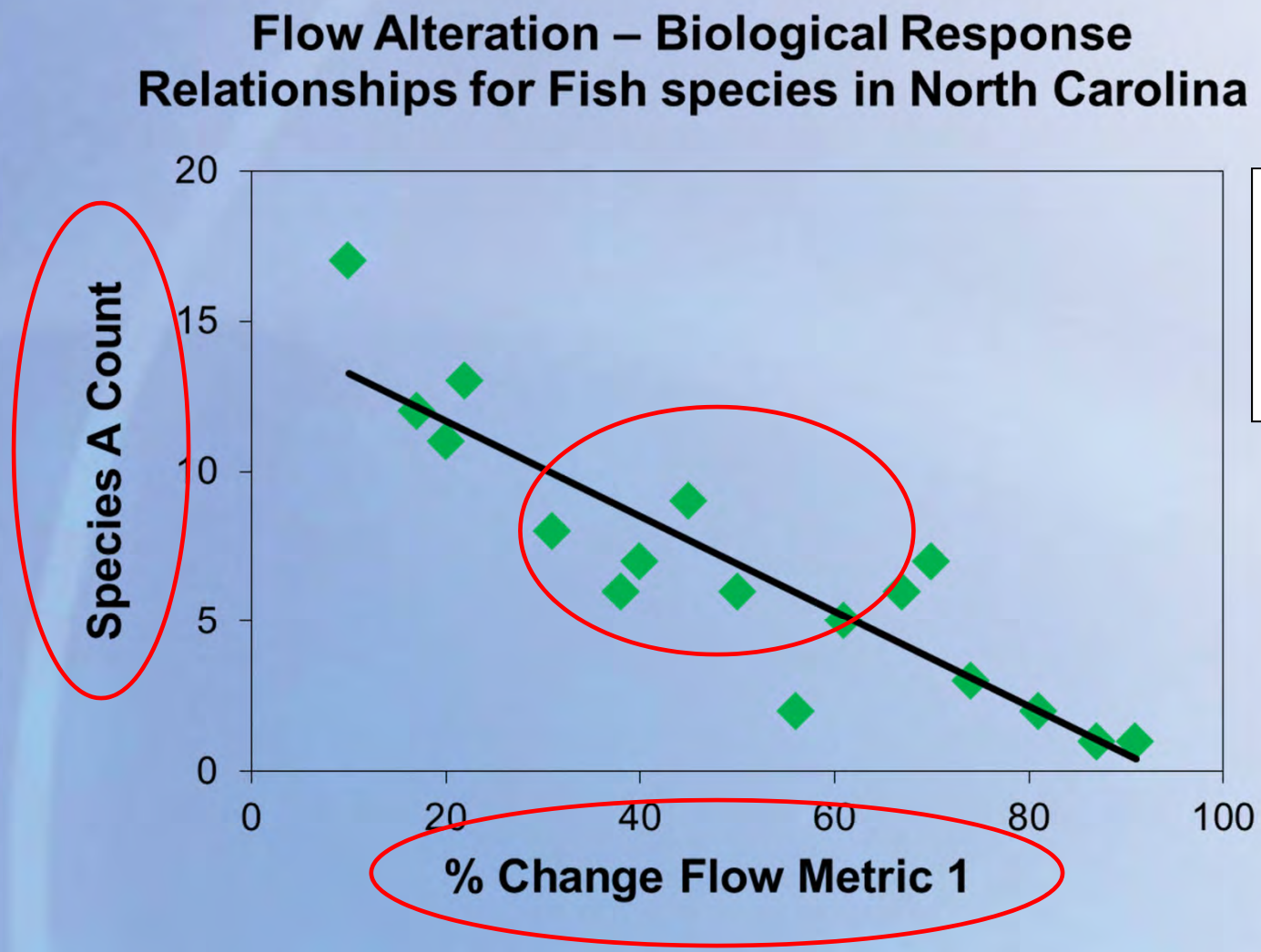
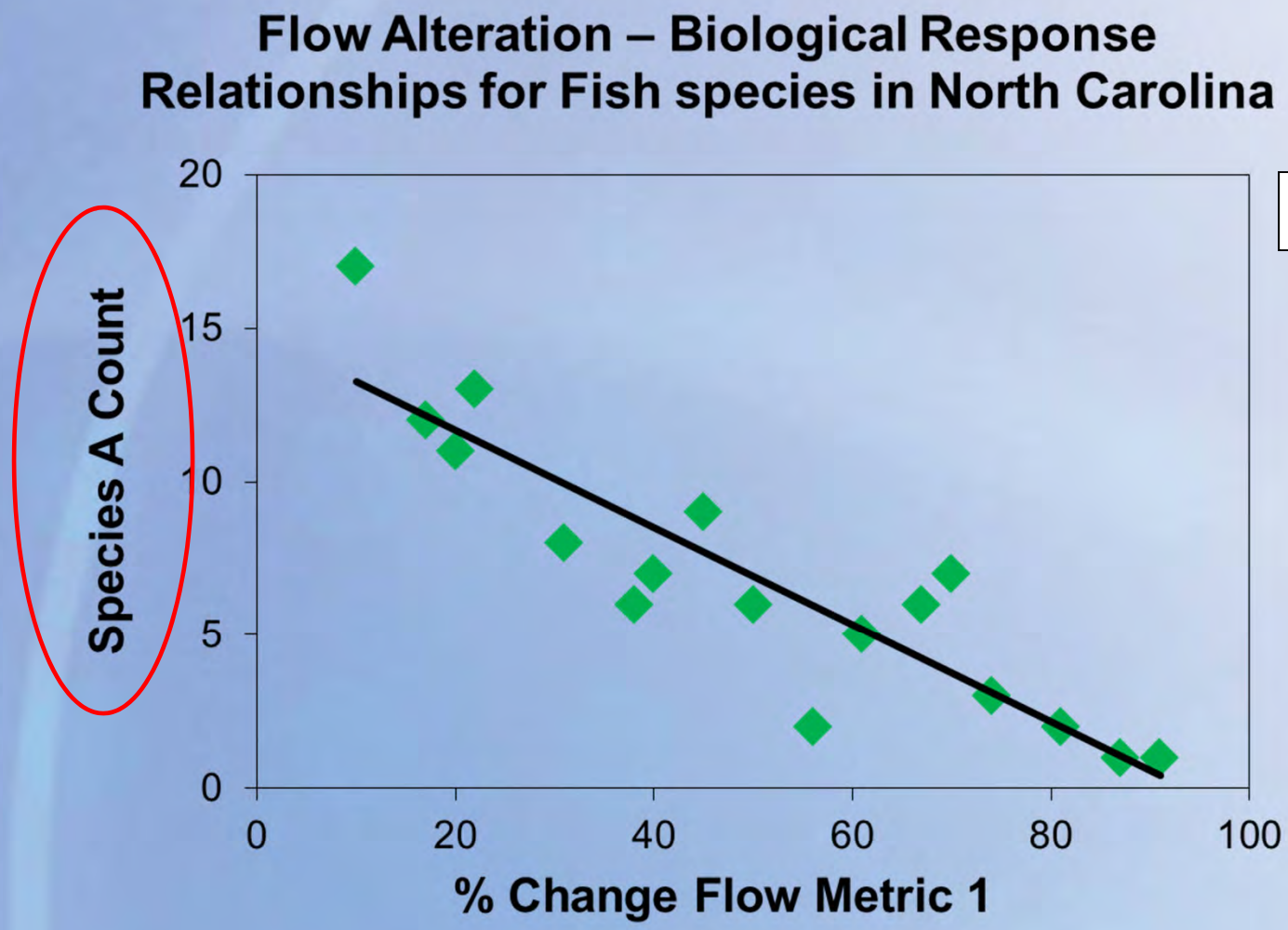
Methods:



- Species
- Flow metrics
- Statistical analyses

Methods:



- Species

Methods – Biological Response:

- Fish:
  - Top of the food chain integrators
  - Relatively fast recovery time to climatic events that may cause local extirpation
  - Valued by wide segments of society
- Datasets:
  - NC DWQ Fish Community
  - USGS National Water Quality Assessment Program (NAQWA)

Methods – Biological Response:

- Species:
  - Individual species
  - Assigned to guilds indicative of flow requirements

Methods – Biological Response:

- Guilds (Persinger et al., 2010):
  - based on study in North Fork Shenandoah River, VA

Guilds
Fast-generalist
Riffle
Pool-run
Pool-cover

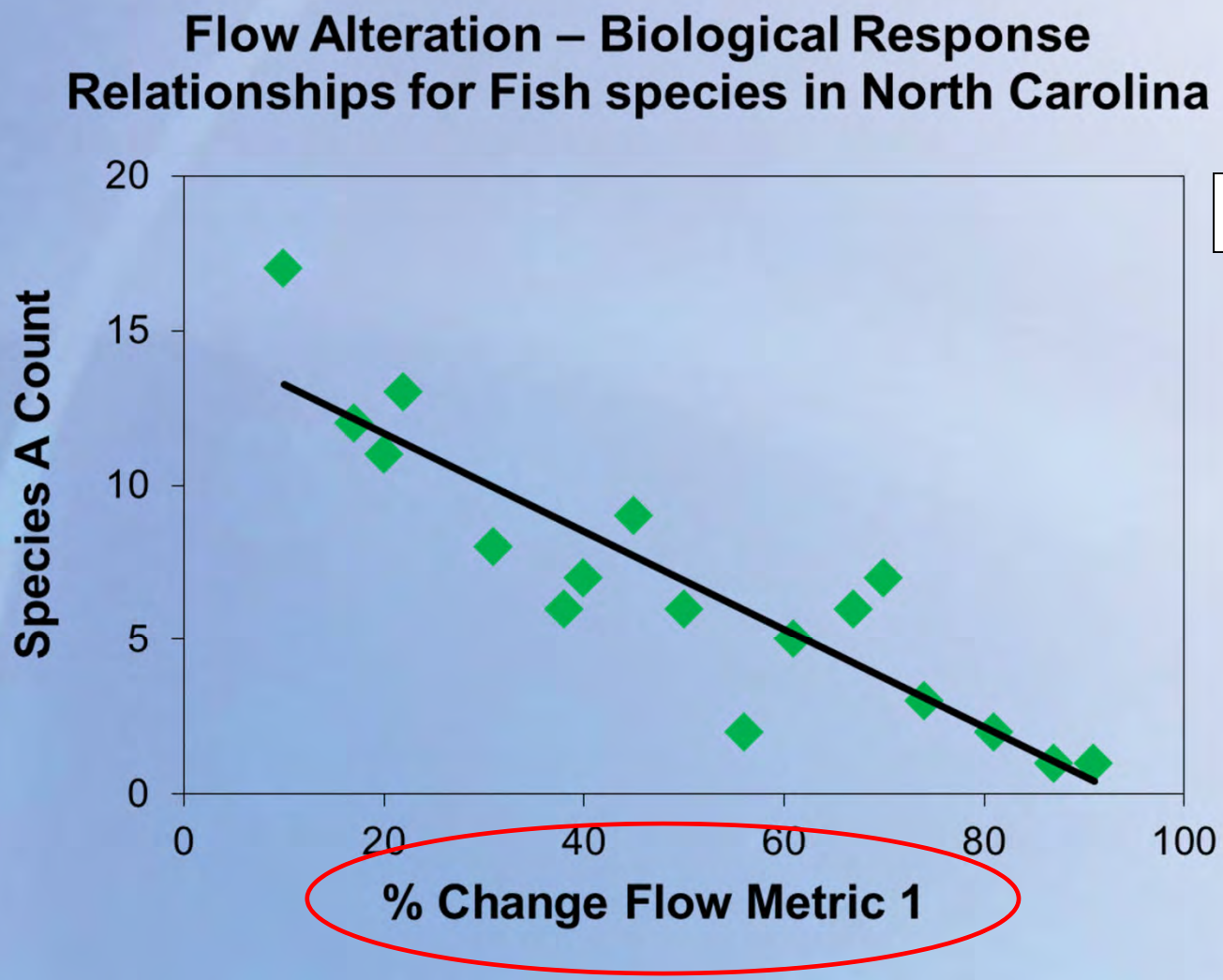
Methods – Biological Response:

- Species:
  - Individual species
  - Connected to guilds indicative of flow requirements
  - Species – Guild Approach:
    - identifies “canaries” within guilds
    - assign significant flow metrics to guild for management purposes
  - Up to 20 species

Methods – Biological Response:

- Species:
  - Up to 20 species:
    - Riffle guild
    - Well distributed (state or regionwide)
    - Large number of records (i.e., > 50)
    - Life history stages and requirements well known
    - Single guild through-out life
    - Exploratory statistical analyses to identify species (and associated flow metrics) with significant responses to altered flows

Methods:



- Flow metrics

Methods – Flow metrics:

- Selection criteria:
  - Biologically relevant
  - Amenable to management
  - Can be expressed as % change
  - Can be effectively modeled with WaterFALL

Methods – Flow metrics:

- Biologically relevant:
  - Review of flow-biology hypotheses for fish:
    - Increases and decreases in low, high and median/stable/base flows
    - Important events all months of the year
  - Represent the five components of flow
    - Magnitude, timing, duration, frequency, rate of change
- Amenable to Management:
  - Magnitude, timing, duration, frequency, rate of change
  - Focus on low flows and reductions in flow

Methods – Flow metrics:

- Selection criteria:
  - Biologically relevant
  - Amenable to management
  - Expressed as % changes
  - Can be effectively modeled
- Flow metrics
  - TNC Indicators of Hydrologic Alteration (IHA) = 67 metrics
  - Additional metrics

Methods – Flow metrics

Monthly Measures	**Annual Measures**
Extreme low flow (10th percentile)	**3-, 7-, 30-, and 90-day minimum**
Low flow (25th percentile)	**3-, 7-, 30-, and 90-day maximum**
Median/Base flow (50th percentile)	**Extreme low flow (10th percentile)**
High flow (75th percentile)	**Extreme low flow count**
	Extreme low flow duration (longest duration during year)

bold = IHA metrics

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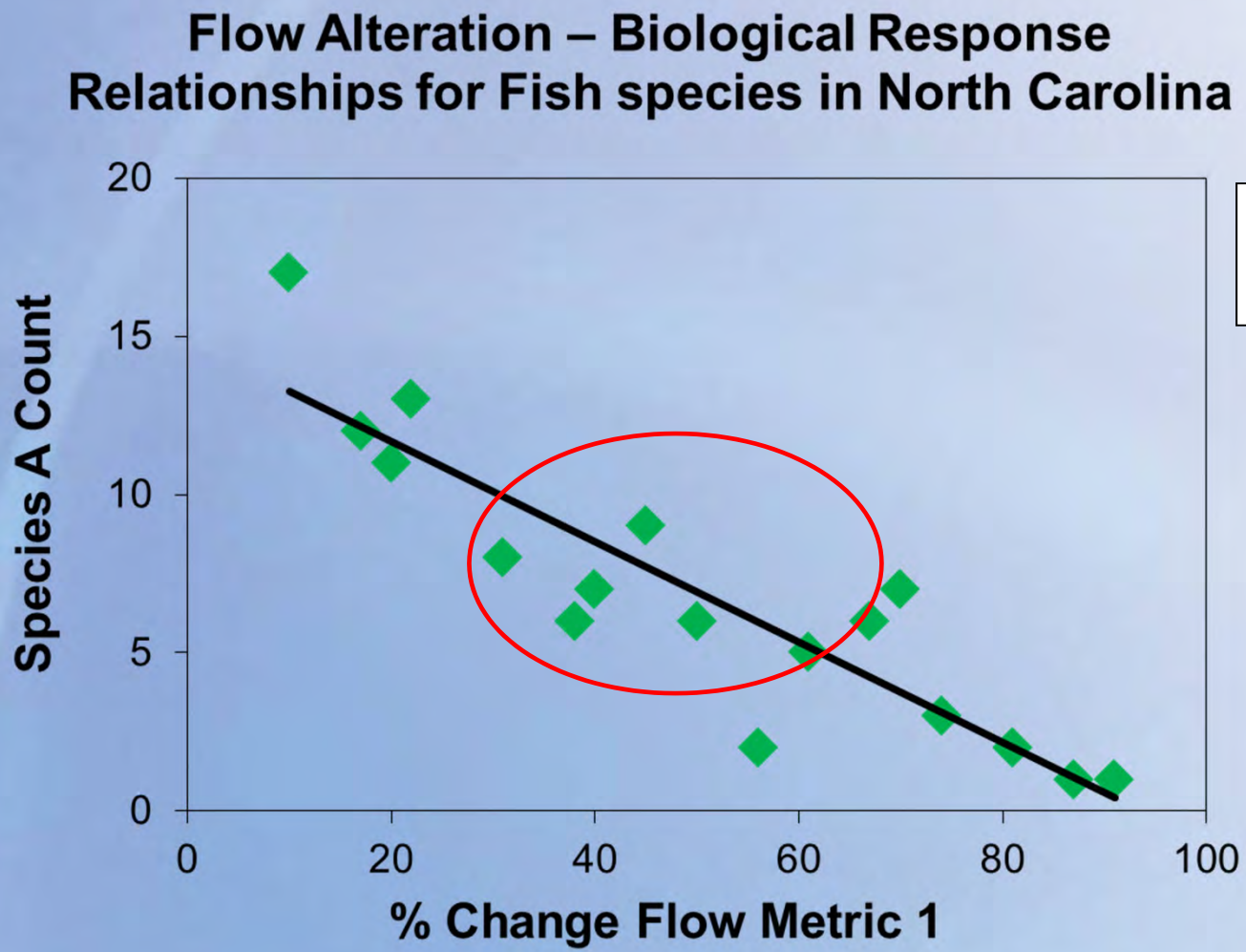
Methods – Flow metrics:

- Flow metric calculations:
  - WaterFALL hydrographs for unaltered/historic and current condition:
    - Unaltered/Historic = Potential Natural Vegetation (PNV) or 1970s land-cover
    - Current = 2006 NLCD + sources of instream flow alteration (dams, withdrawals, discharges)
  - 30+ years of climate data
  - Expressed as % change
  - Focus analyses on reductions in flow

Methods:



- Statistical analyses

Methods – Statistical analyses:

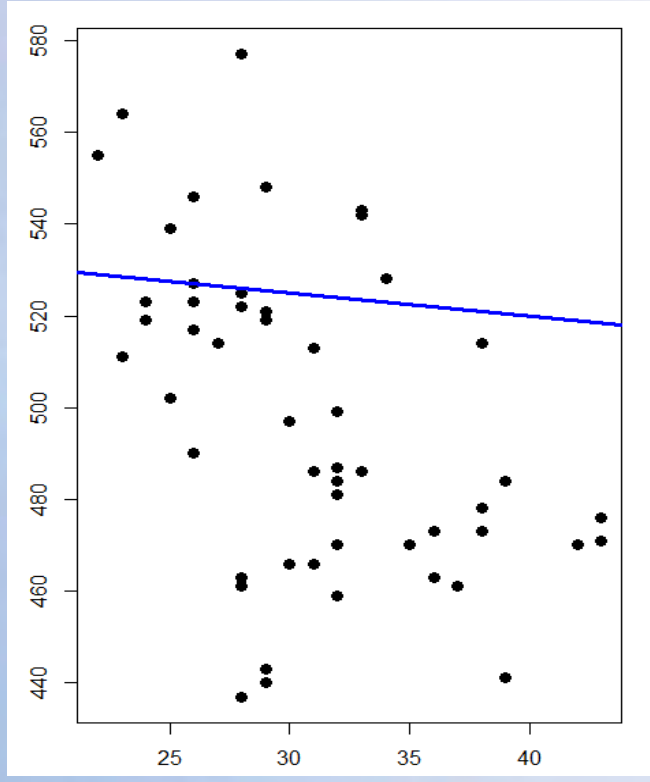
- Multiple and Single Predictor Analyses:

Methods – Statistical analyses:

Multiple Predictor Analysis

$$Y = a + b_1*X_1 + b_2*X_2 + ..+ b_p*X_p$$

Single Predictor Analysis



Methods – Statistical analyses:

- Multiple and Single Predictor Analyses:
  - Multiple Predictors:
    - Multiple regressions (or comparable non-parametric analyses)

$$Y = a + b_1*X_1 + b_2*X_2 + ..+ b_p*X_p$$

    - Benefits:
      - gain a better understanding of the degree to which species is influenced by altered flows versus other factors
      - reduces the amount of error (i.e., accounts for a larger proportion of the variance in the relationship)

Methods – Statistical analyses:

- Multiple and Single Predictor Analyses:
  - Multiple Predictors:
    - Negatives:
      - Application of relationship is restricted to locations where have data for the other factors (or need to assume default or average values for factors)
      - Complicates the flow alteration – biological response relationship
    - Co-variates included in analysis = measures of water quality, channel morphology, habitat, climatic events, sampling date, interspecific interactions

Methods – Statistical Analyses

Component	Attribute/Dataset
Water Quality	DO, pH, conductance (DWQ Habitat and USGS NAQWA datasets)
	303d listing
Channel Morphology	Sinuosity/Linear Length
	Slope
	Physiographic Region
Habitat	NC Habitat Score (DWQ Habitat dataset)
	Fragmentation x 2 (stream length between obstructions) – same stream length and summed stream length of network

Methods – Statistical Analyses

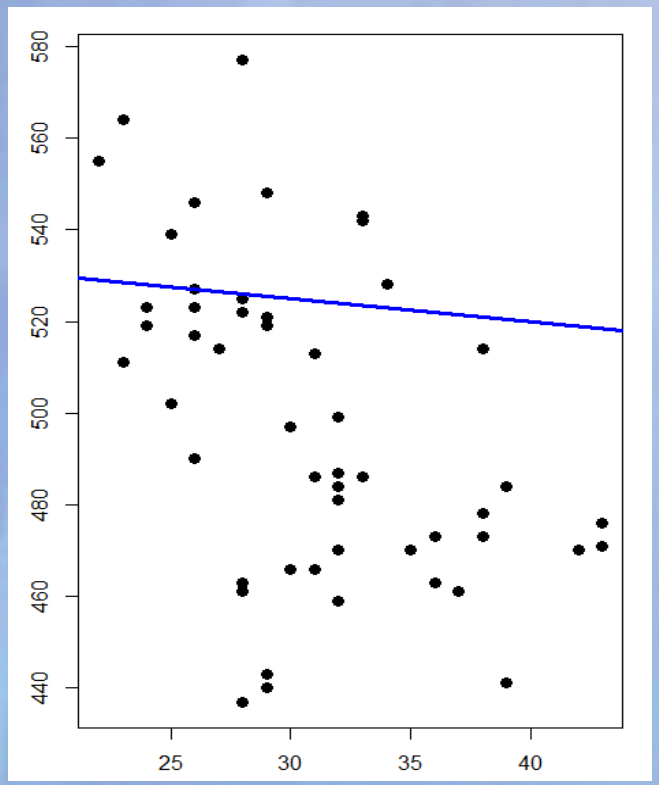
Component	Attribute/Dataset
Climatic Events	Preceding year total precipitation
	Average of preceding 3 years of total precipitation
Date	Sampling Month
Interspecific Interactions	Influence of exotic and injurious introduced/ exotic fish species

Methods – Statistical analyses:

- Multiple and Single Predictor Analyses:
  - Single Predictor:
    - linear or quantile regressions (or comparable non-parametric analyses)

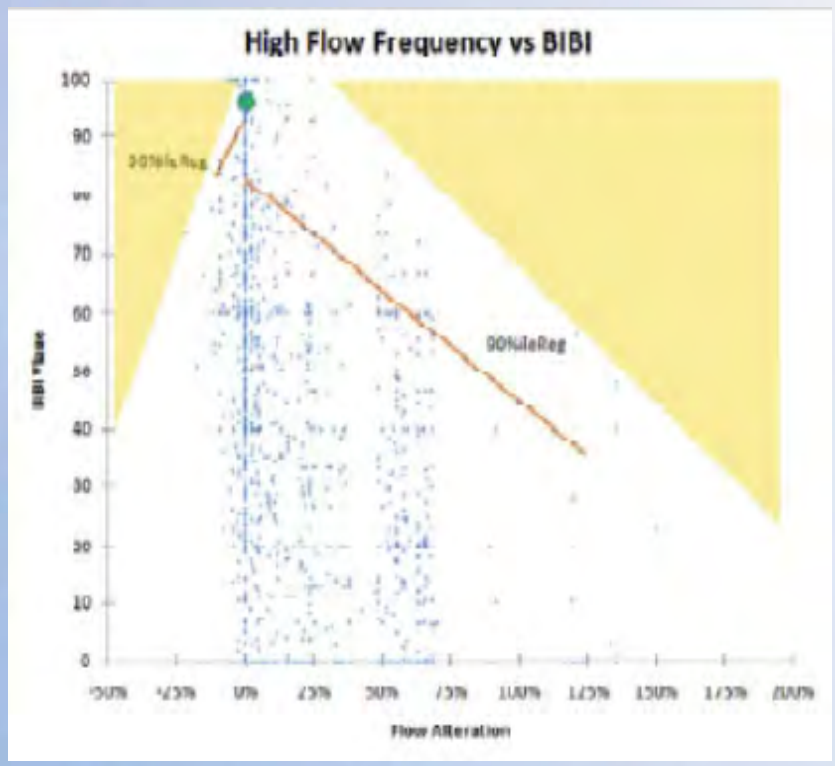
Methods – Statistical analyses:

Linear Regression



Predictor 1

Quantile Regression



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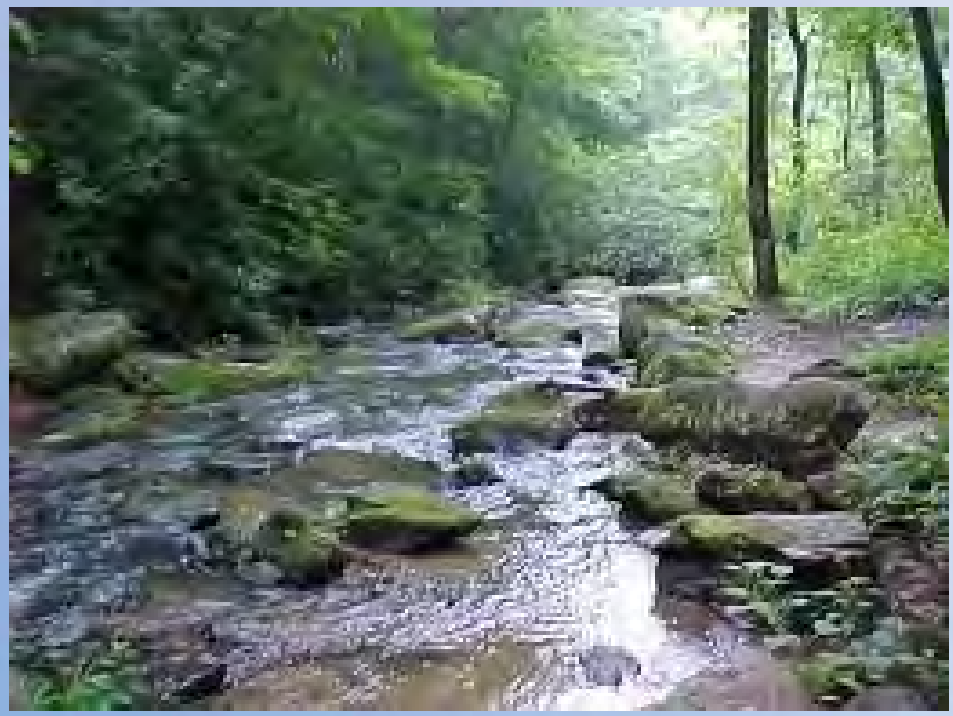
Methods – Statistical analyses:

- Multiple or Single Predictor Analyses:
  - Singe Predictor:
    - linear or quantile regressions (or comparable non-parametric analyses)
    - Benefits:
      - Only based on response to % change of flow metric, so application in water management is more straight forward
    - Negatives:
      - Potentially large amount of error which will reduce the strength of the relationships

Methods – Statistical analyses:

- Multiple or Single Predictor Analyses:
  - Combination of analyses provides:
    - water managers with an understanding of the relative importance of flow alterations and other influential variables for each species
    - Flow-biology relationships with which to model/predict the impacts of flow alteration on biological responses

Questions:



Fall Creek