A Comparison of Water Quality Measures in Costa Rica and in the US to Evaluate Environmental Health

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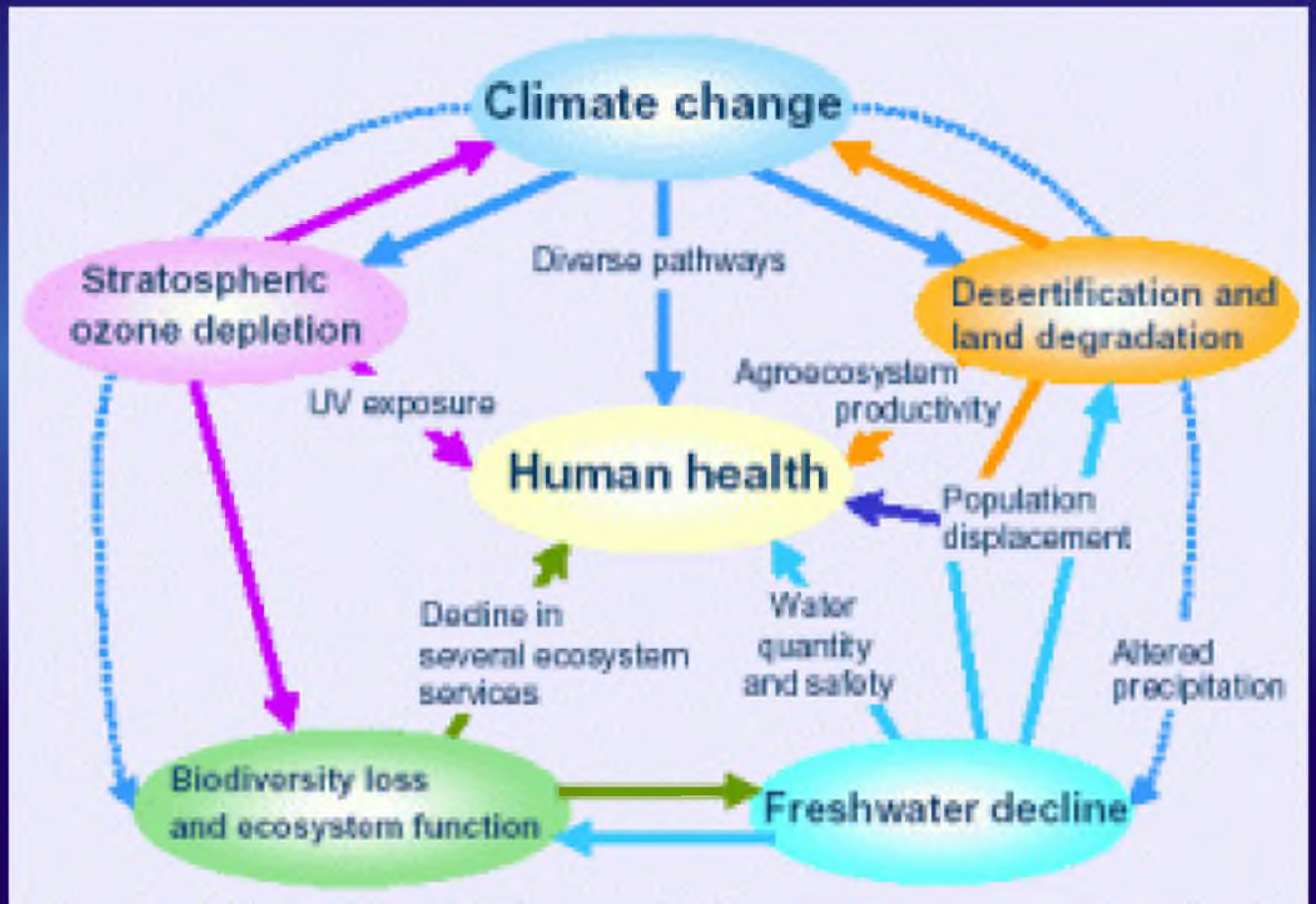
Human Impacts on the Environment Affect Human Health

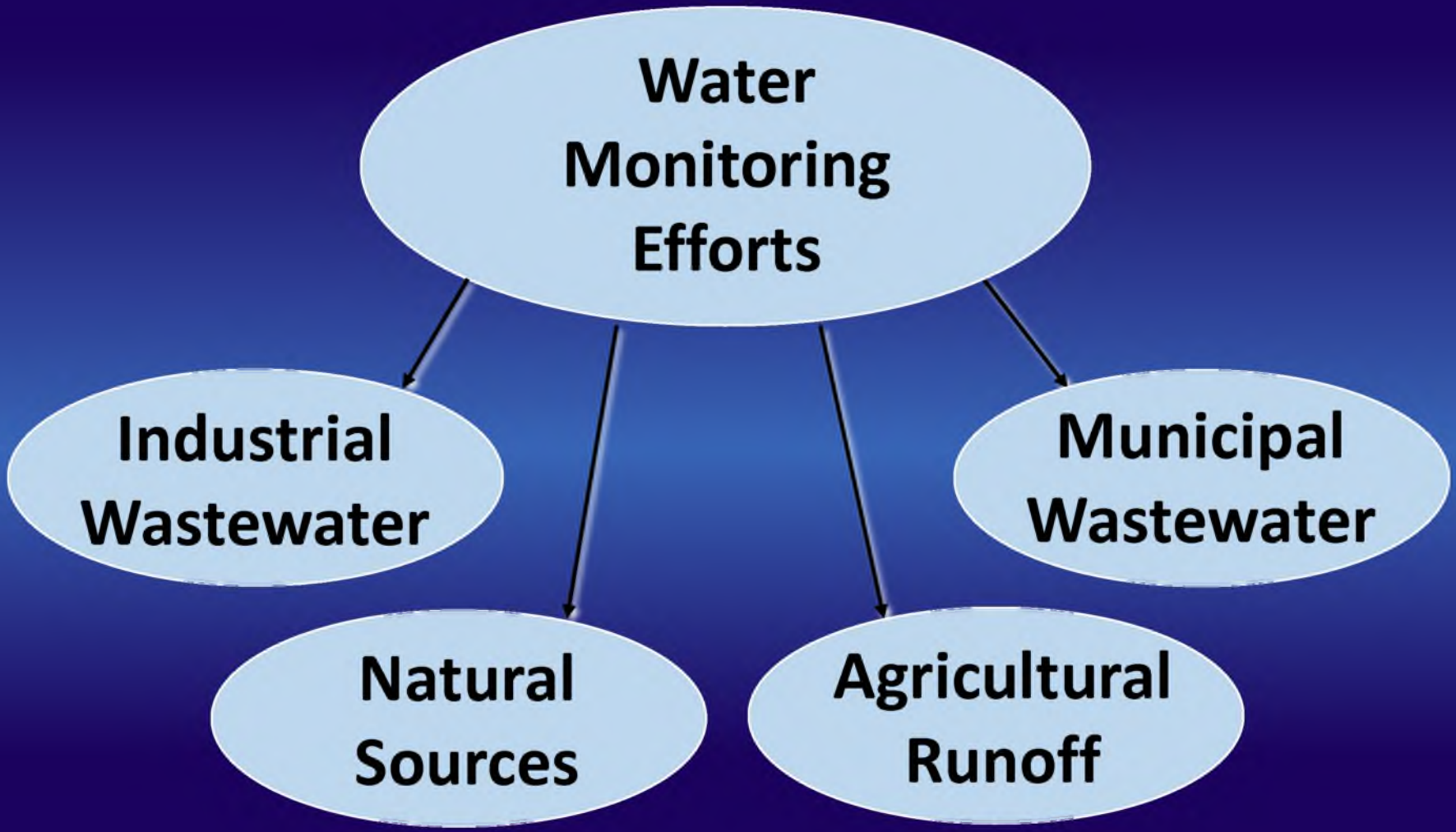
Population growth causes a decline in ecosystem services → negative consequences on human well-being.



Global Concern for Water Quality Increasing

- Human activities affect quality & quantity of water resources
  - land use changes
  - climate change affecting water cycles
  - declines in freshwater biodiversity
  - declines in water purification
  - increased needs in waste management
  - changes in soil & vegetation generation and renewal cycles
  - loss of pollinators for crops and natural vegetation
  - human need for outdoor recreation impacts
  - And much more …

Monitoring of Water Resources



Monitoring of Water Resources

Type of Monitoring	Indicator categories	Indicators
Biological	Fish	Sensitive taxa; Relative species richness; Size/age structure; Disease incidence; Alien species; Trophic structure; Life history traits; Reproductive traits
	Invertebrates	Relative species richness; Size/age structure; Life history traits; Sensitive taxa; Trophic structure; Community composition
	Algae	Taxa composition; Sensitive taxa; Algal biomass
	Macrophytes	Taxa composition; Abundance
	Microbial pollutants	*E. coli*, total coliform count
Physico-chemical	Metabolic	Oxygen: Dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD); Temperature; pH; Light penetration (Secchi depth); Conductivity/salinity;
	Trophic	Nutrients (N, P, NH4, NOX, soluble P); Chlorophyll A
	Toxicants	Heavy metals (Cd, Hg, Cr, Cu, etc.); Pesticides; Other organic pollutants (oil, phenol, polychlorinated biphenyls (PCBs), endocrine disruptors)
Hydromorphological	Aquatic habitats	Colonizable substrates; Substrate condition; Velocity and depth variability; Sediment deposition; Channel flow; Habitat diversity; Aquatic vegetation; Off-channel aquatic habitats
	Riparian habitats	Bank stability; Bank vegetative protection; Human influence

Research Objective

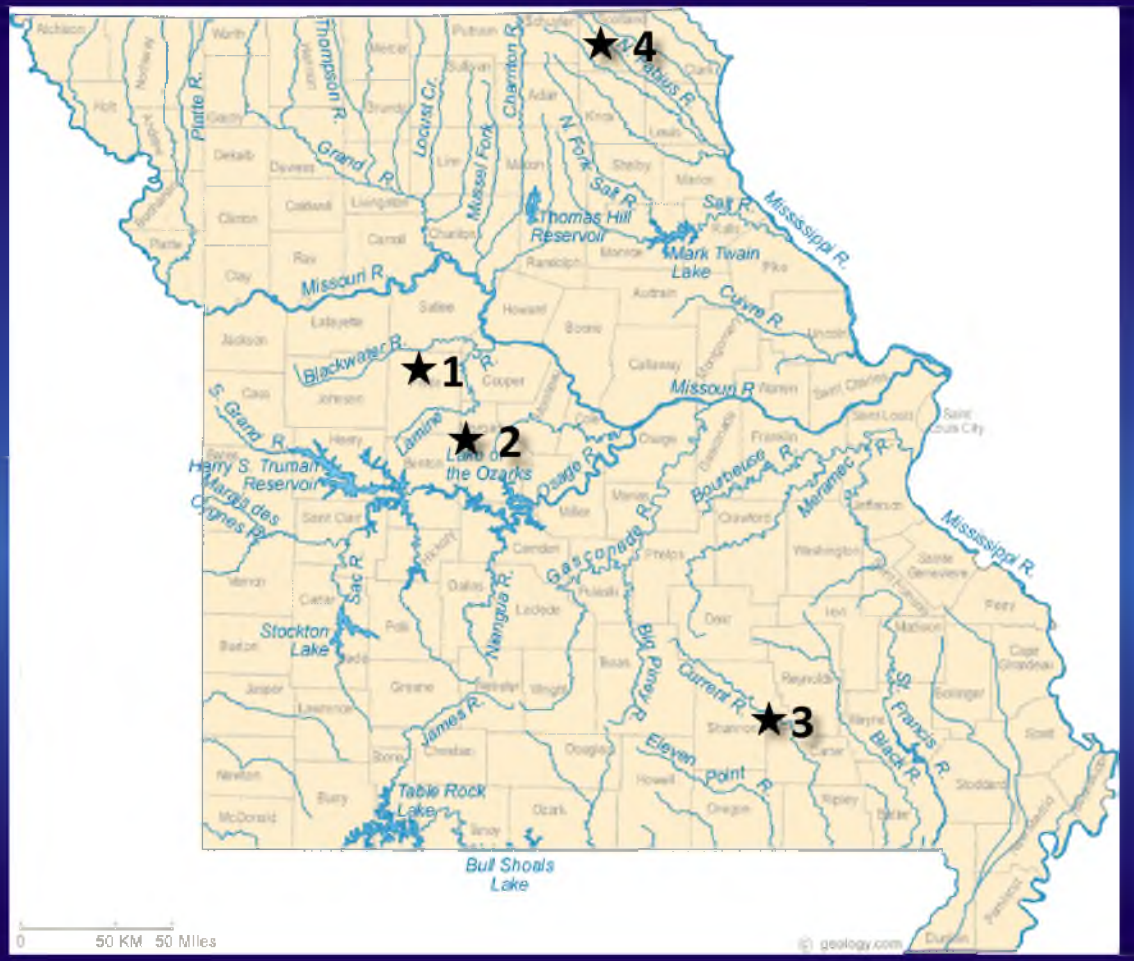
Compare the application of various water quality indexes from a number of different locations under a variety of water management conditions.

1. **Obtain onsite measurements for a set of water quality parameters for various locations.**
2. **For each location, calculate various water quality indexes and compare all to look for inconsistencies in conclusions about environmental health.**

Study Locations

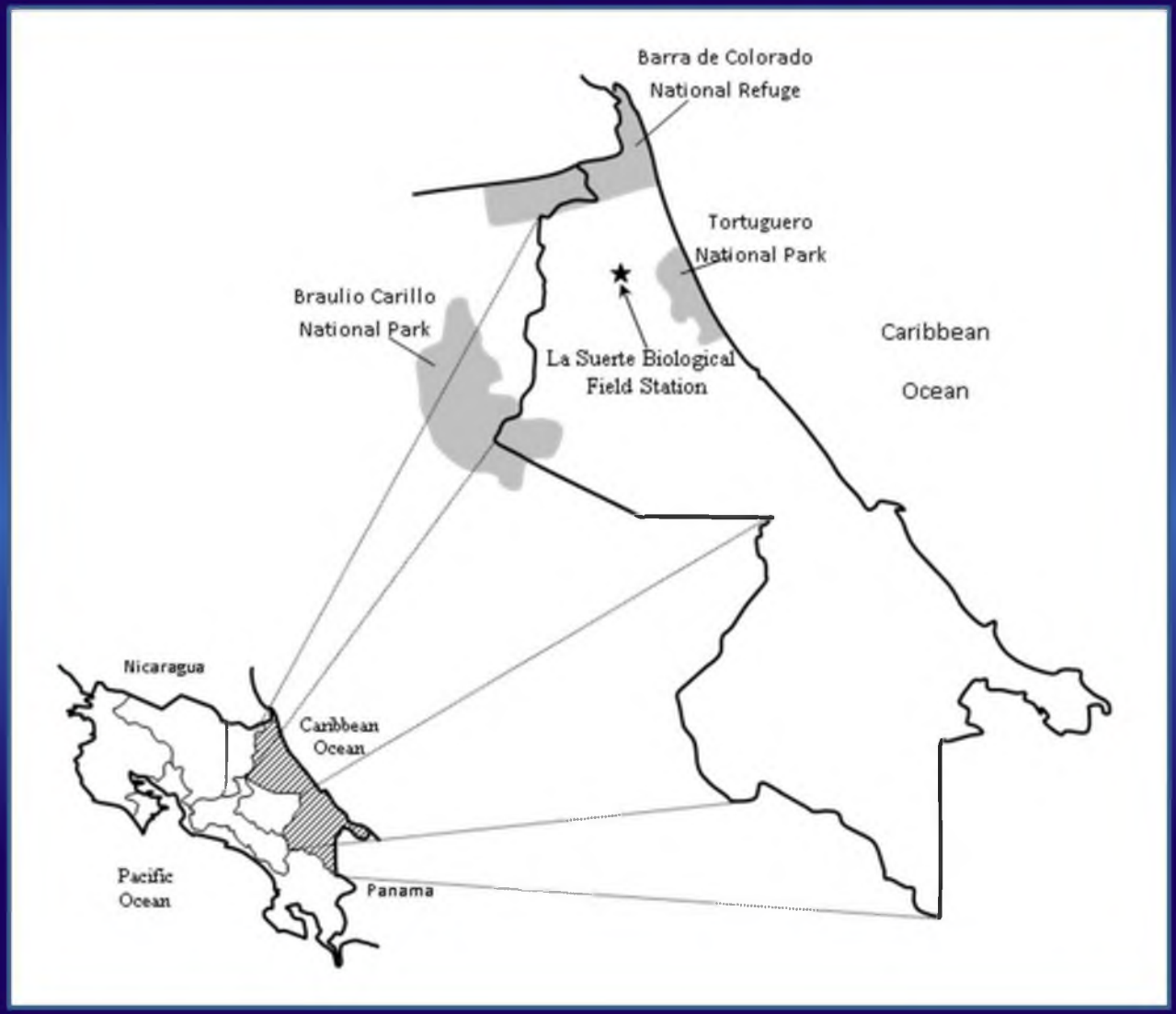
- Central and NE Missouri, USA (2004 – 2010)

- Region 1 – 5 yrs
- Region 2 – 3 yrs
- Region 3 – 3 yrs
- Region 4 – 3 yrs



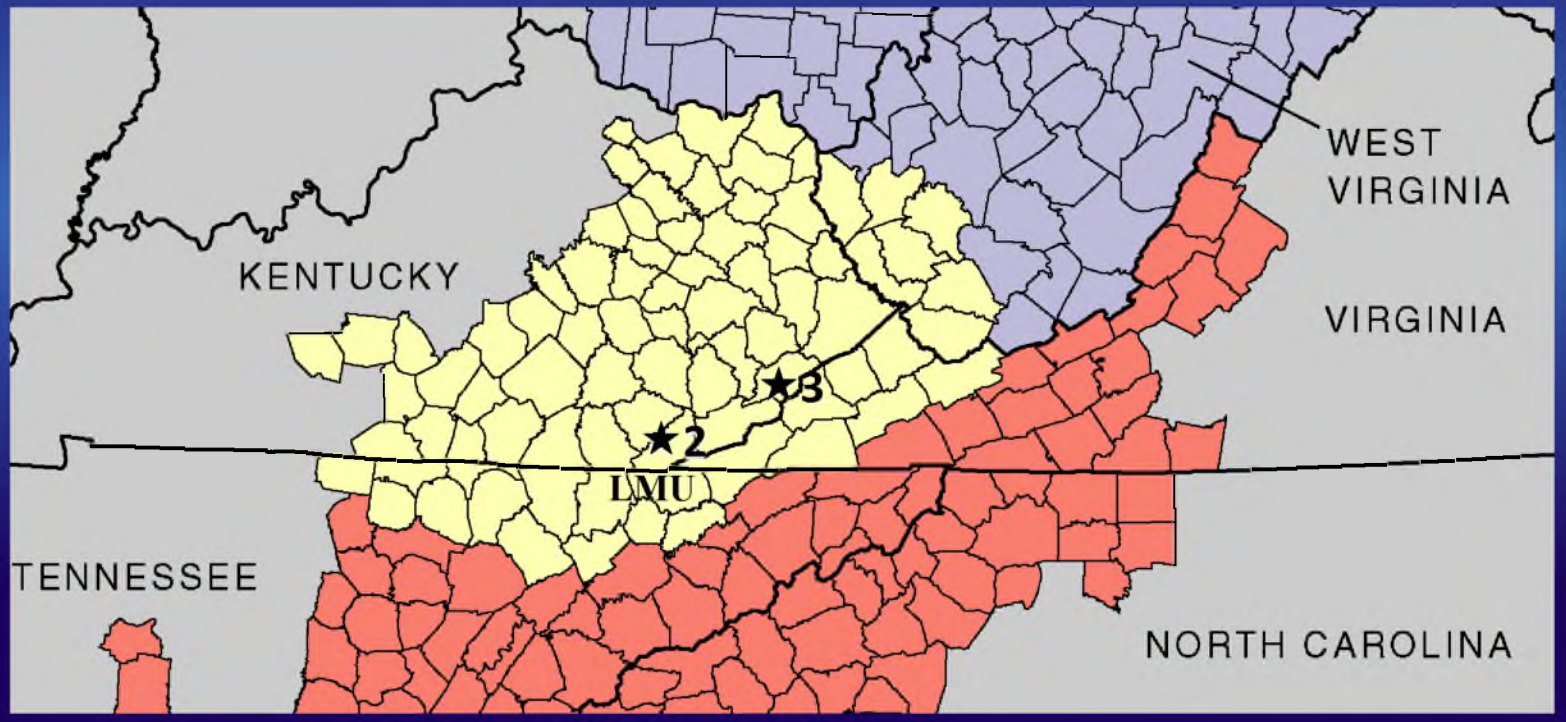
Study Locations

- La Suerte Biological Field Station, Costa Rica (2009 – 2014)



Study Locations

- **Southern Appalachia, USA (started 2017)**



Water Quality Measures

Based on Missouri Stream Team Parameters

- Biological Health Index
  - Macro-invertebrate surveys
    - Based on organismal sensitivity to pollution

  Not standard for Missouri Stream Team Program
  - Biological Oxygen Demand
  - Faecal coliform, *E. coli*

- Physio-chemical Parameters
  - Turbidity
  - Temperature
  - pH
  - Conductivity → indirect total dissolved solids
  - Nitrates
  - Phosphates
  - Dissolved Oxygen

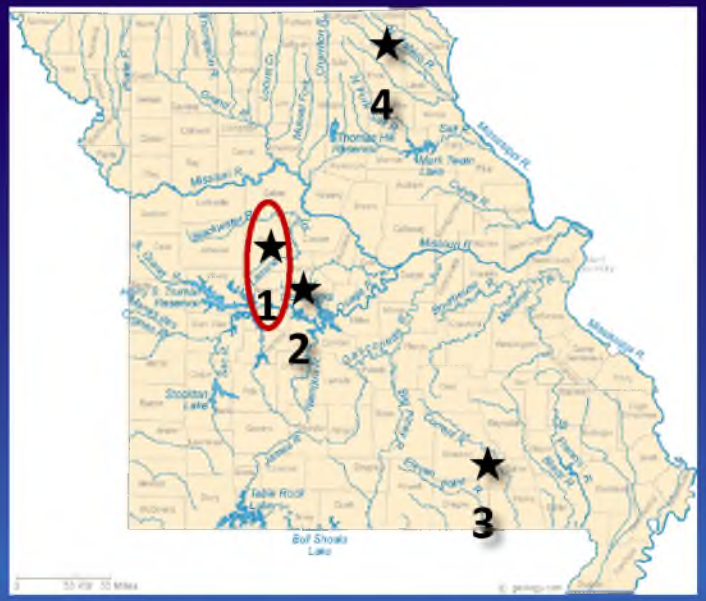
Initial Analyes

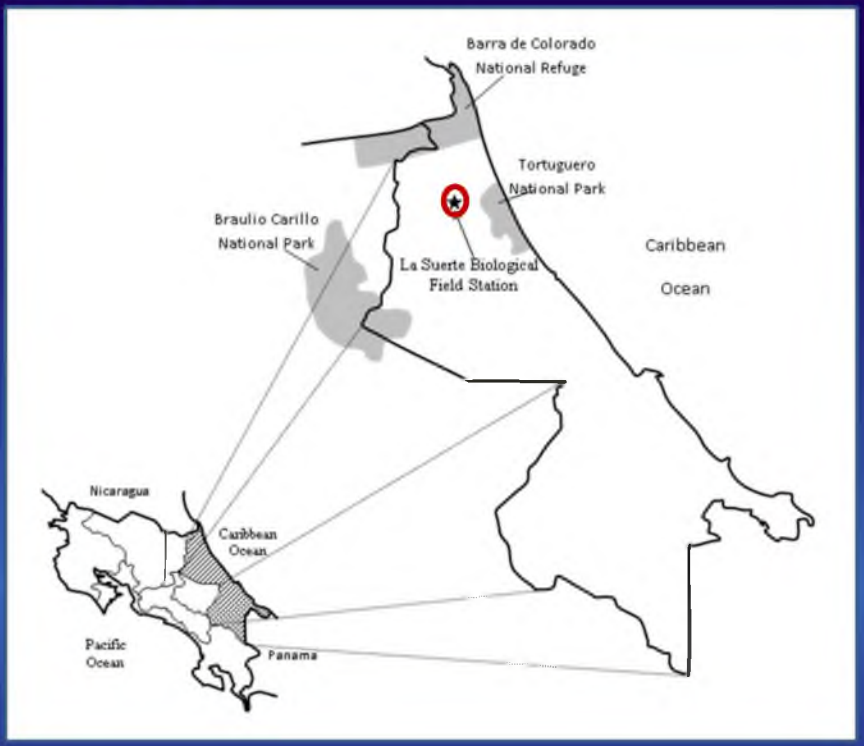
Monitored across multiple data collections across multiple years

- **Macro-invertebrate Biological Health Index**
- **Faecal coliform, *E. coli***
- **Biological Oxygen Demand**
- **Physio-chemical Parameters**
  - **Example: Nitrates**

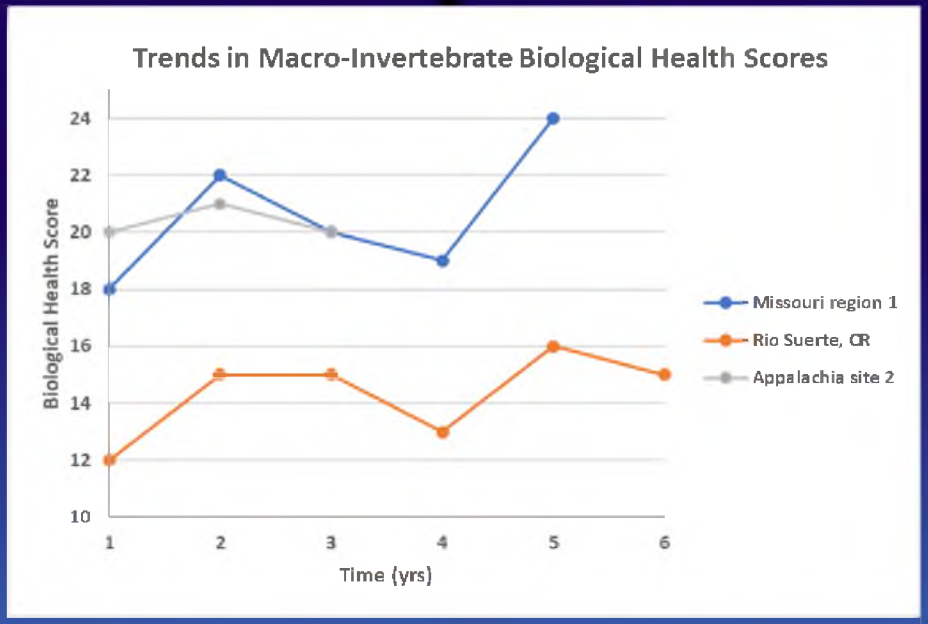
Excerpts from Original Analyses

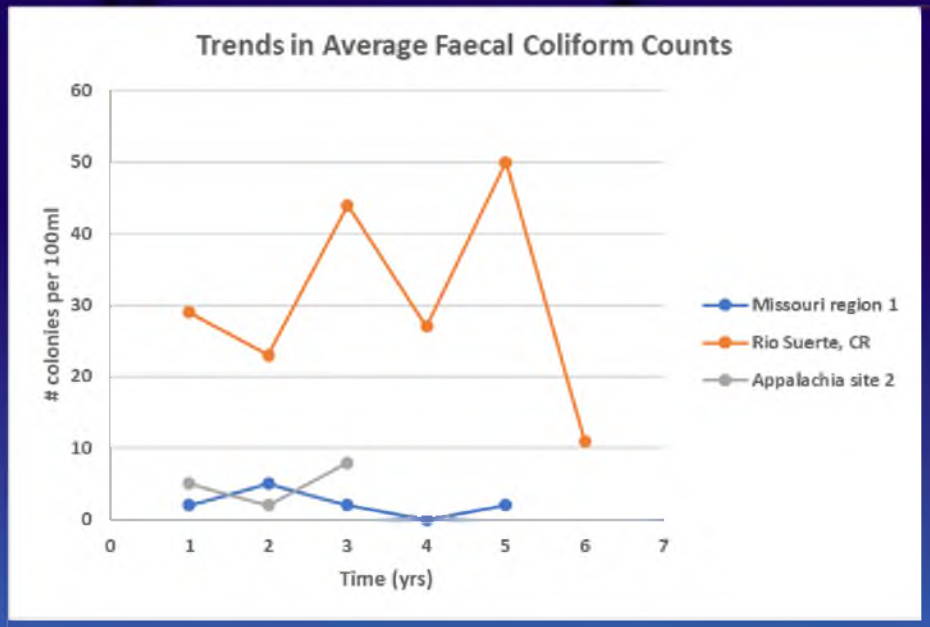
- Graphic representation from 3 sites

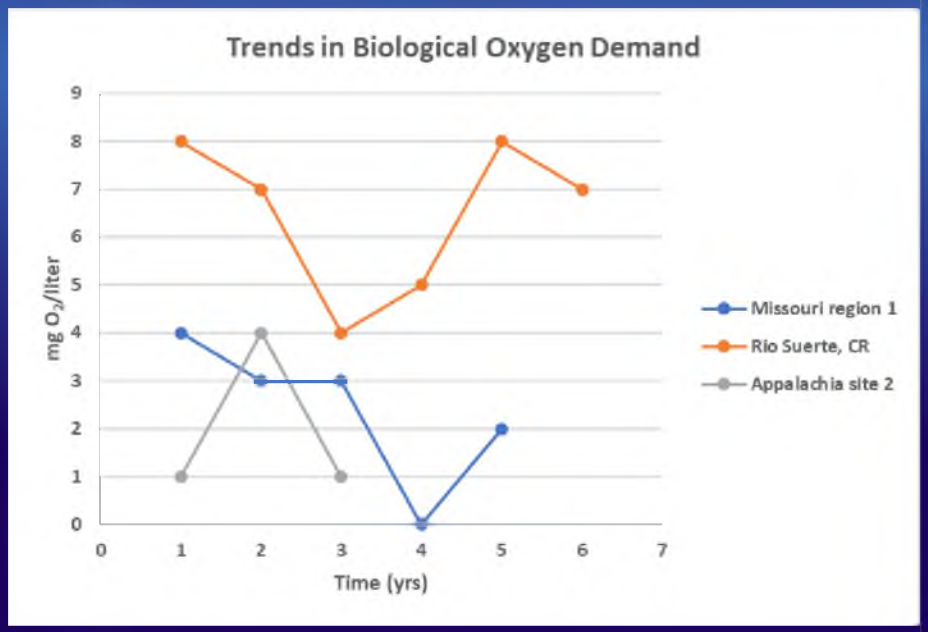


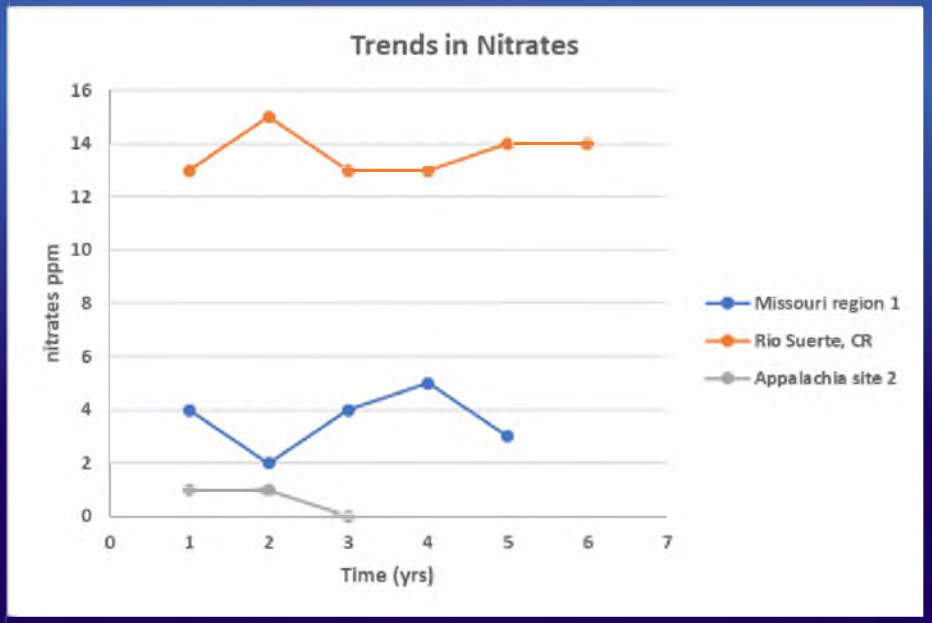


Excerpts from Original Analysis









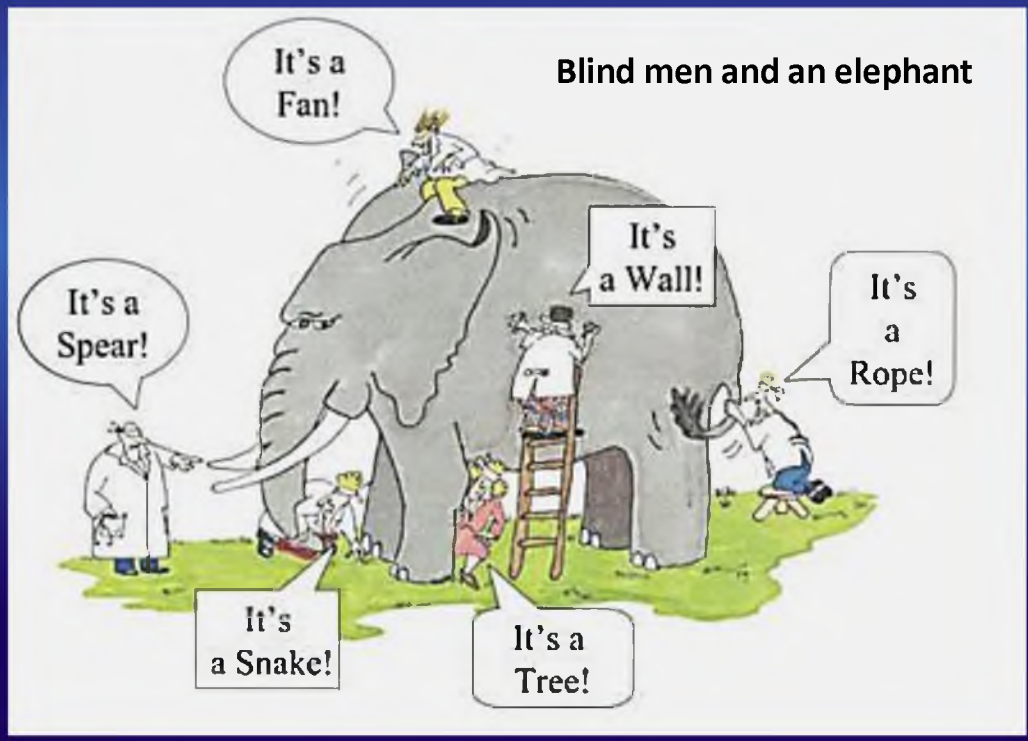
Questions Continue

1. Is it valid to use an evaluation tool designed for temperate, nearctic streams and rivers?

2. If each water quality parameter contributes to an overall assessment of water quality, can these measurements be combined to produce an index that can be used to compare water quality across time and space?

Challenges in Water Quality Assessment

- No universally accepted standard methodology for monitoring water quality.
- Democratic approach to management of water resources
  - Variation in responsible agency
  - Variation in resource management objectives
  - Variation in national, regional, and local standards



Possible Solution: Water Quality Indexes

1. Standardize/normalize parameters to a common scale and weight their contribution to water quality.

2. World Health Organization Water Quality Index
   a) applicable to varying standards and number of water quality parameters
   b) incorporates the frequency of sampling and the magnitude to which parameters exceed their respective standards

Problems with Water Quality Indices

- many applications are limited to specific locations and sampling events (*e.g.*, parameter ranks may vary).
- attempts to create a water quality index often assume each measured parameter affects water quality in a linear manner.
- water quality index calculations assume that increase in a parameter always decreases water quality (*e.g.*, dissolved oxygen).
- maximum standard of 0 is not easily incorporated (*e.g.*, faecal coliform).
- many have not been validated or tested for reliability

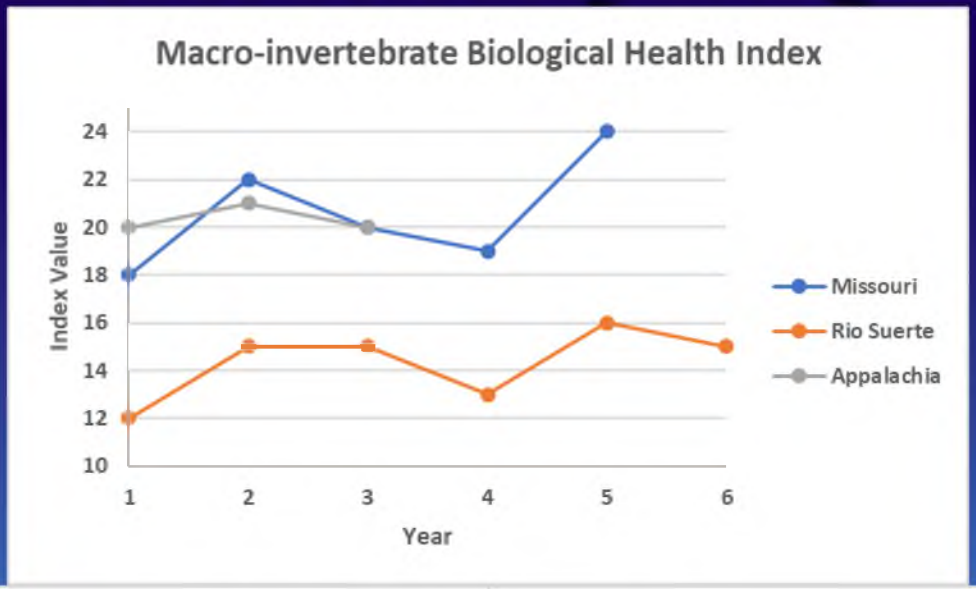
Water Quality Indices: Current Study

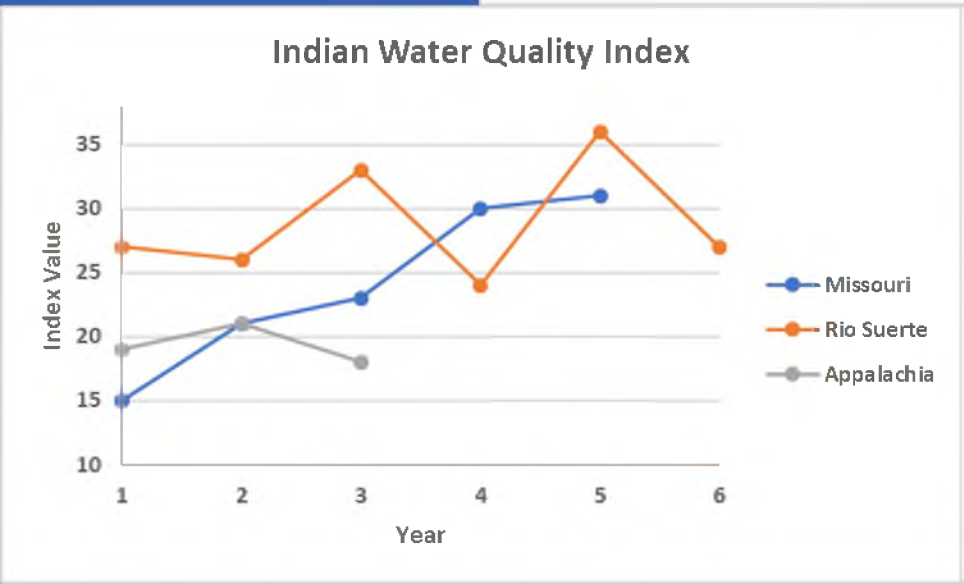
- Macro-invertebrate Biological Health Index (MBHI)
- Suneetha, *et al*, 2015 Indian Water Quality Index (IWQI)
  - Weighting factor W (subjective importance)
  - Normalizing factor q (relative contribution based on water quality standards)
- Etim, *et al* 2013, Nigeria Water Quality Index (NWQI)
  - Weighting factor W (proportional contribution by standard)
  - Normalizing factor q (relative contribution based on water quality standards)

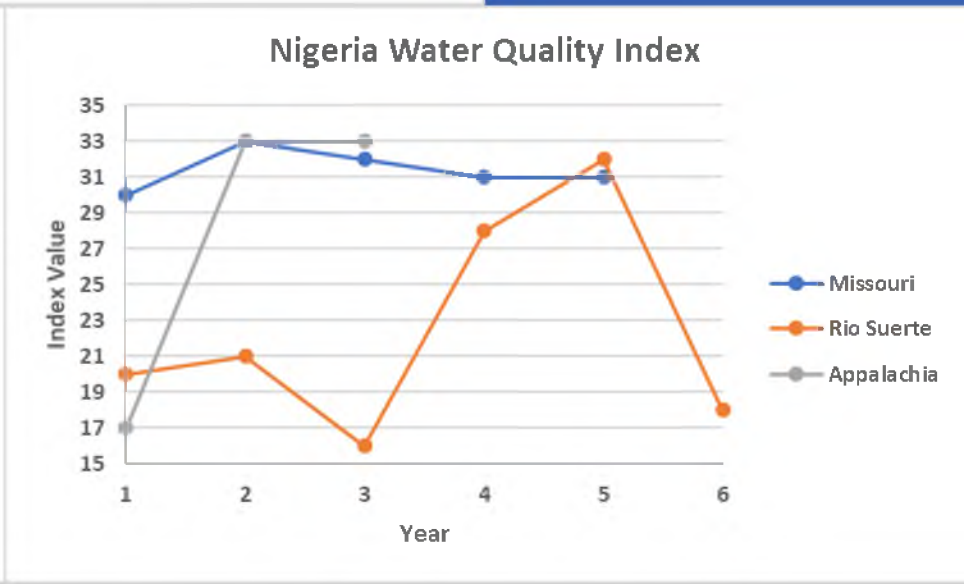
Water Quality Indices: Current Study

- Stream Keepers Water Quality Index (SKWQI)
  - Multidisciplinary identification of 9 parameters
  - Average weighting factors
  - Average contribution to water quality
- World Health Organization, Global Water Quality Index (GWQI)
  - Canadian Water Quality Index
  - incorporates the frequency of sampling and the magnitude of parameters deviation from standard
  - can be applied to international, national, regional, local standards
  - recommended exclusion of faecal coliform/*E. coli*
  - Utilized 9 parameters identified for SKWQI

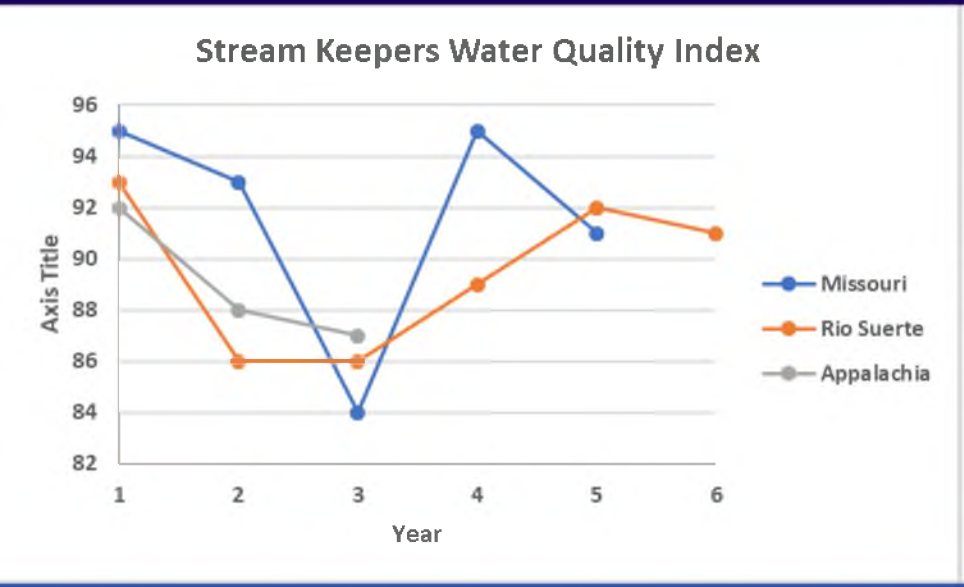
Representative Comparisons of Location by WQI

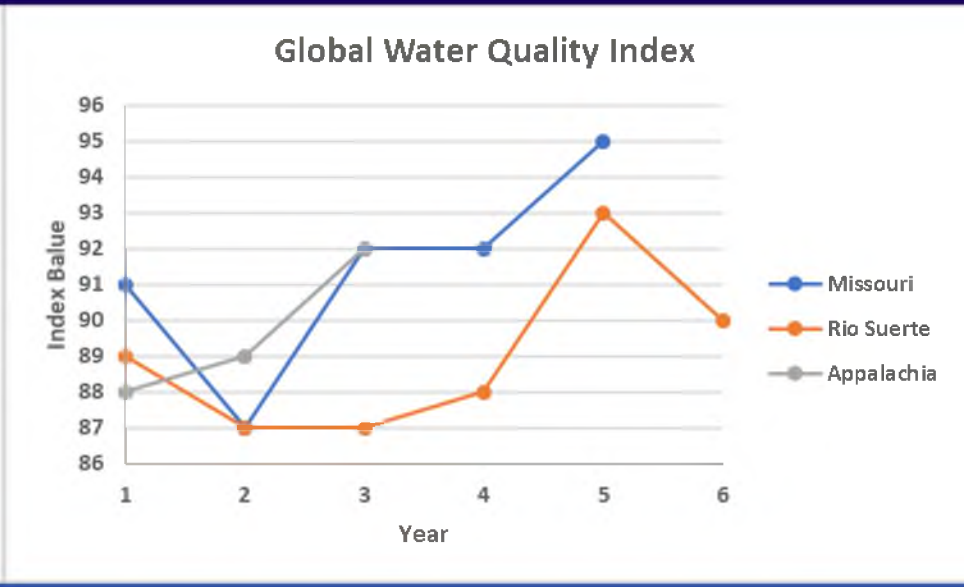






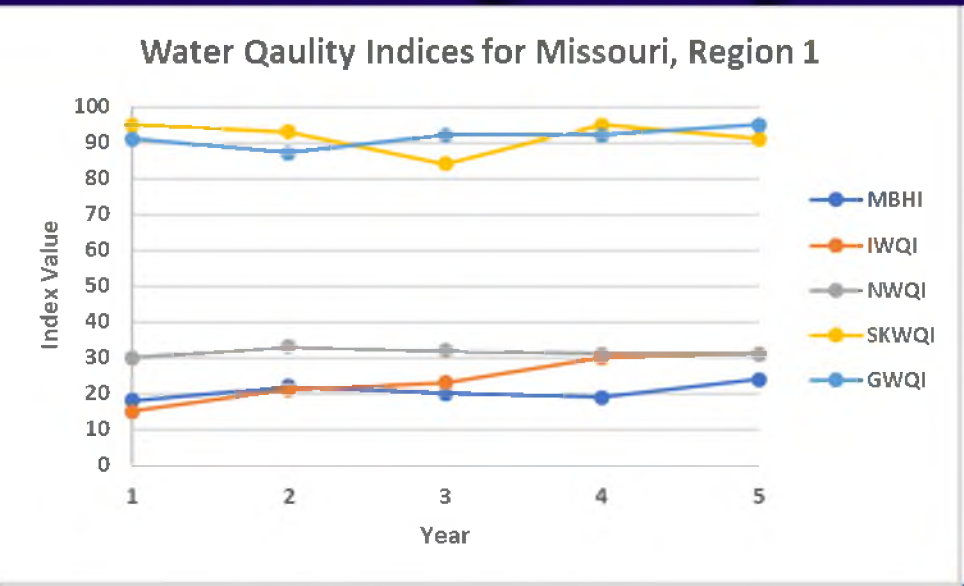
Representative Comparisons of Location by WQI

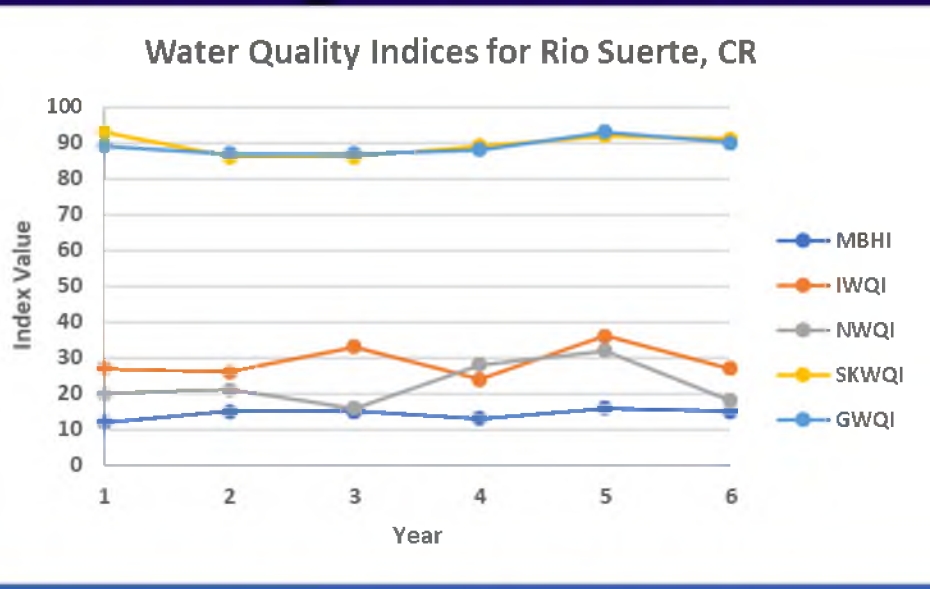


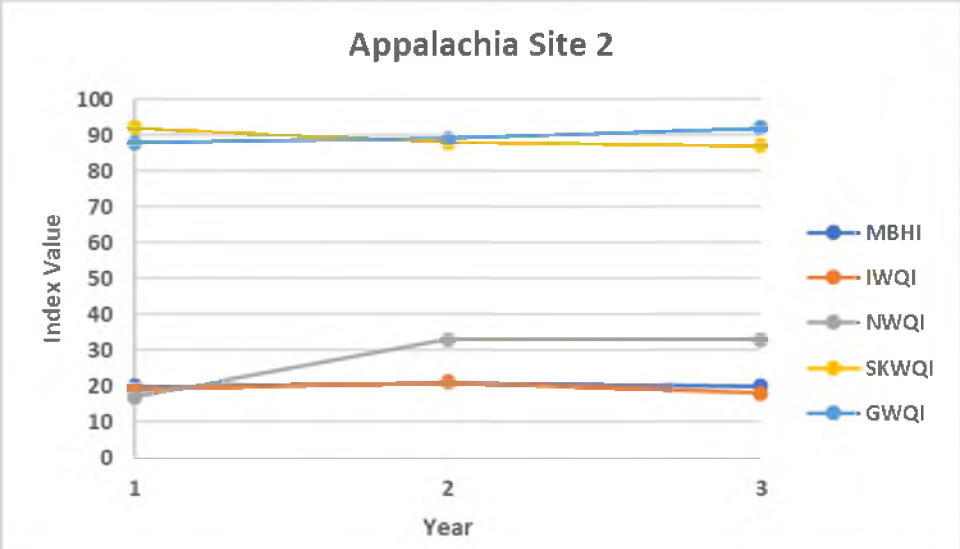


- General conclusion from all indices
  - Water quality in Rio Suerte is typically lower than other locations

Representative Comparisons of Water Quality Indices by Location



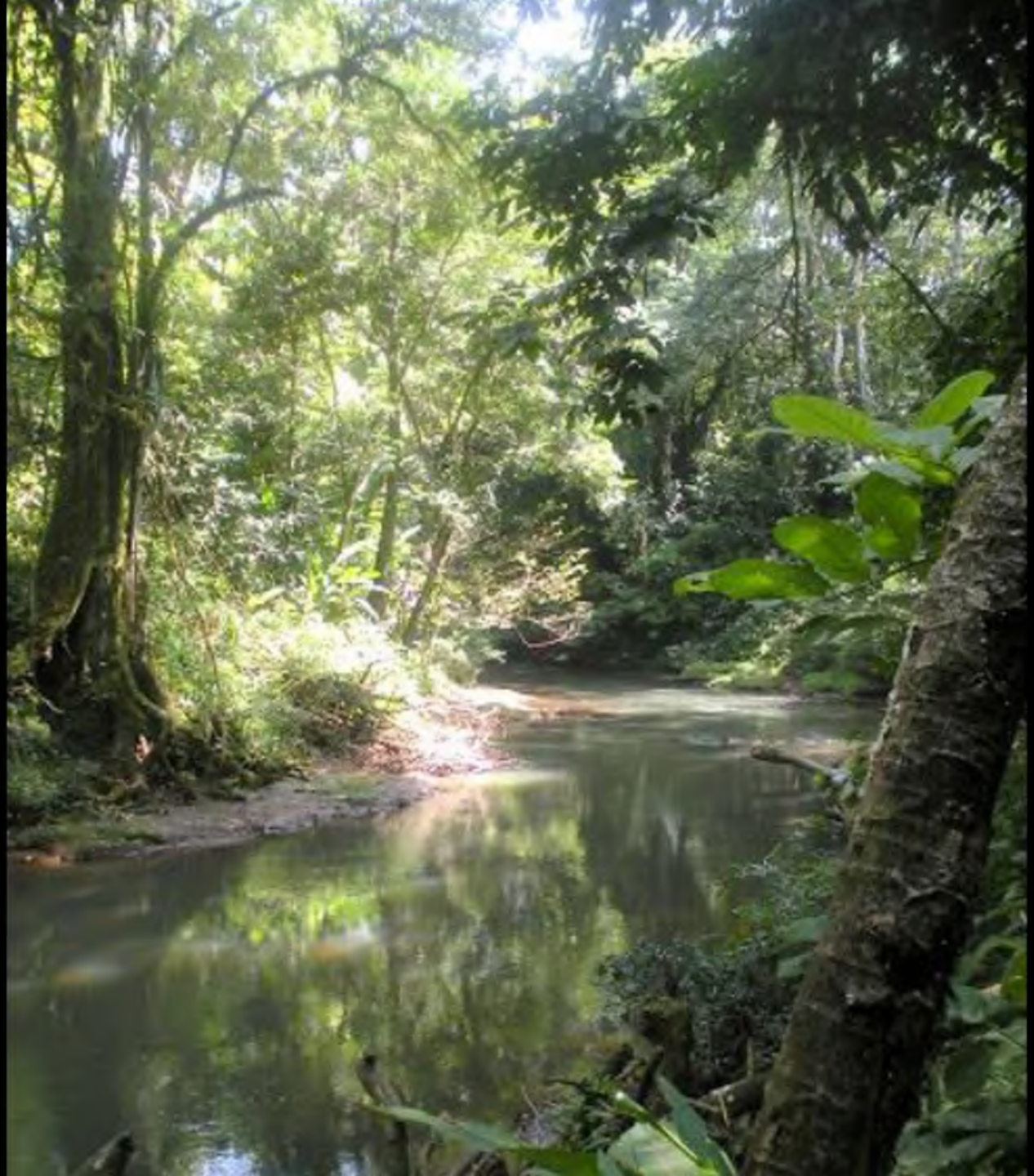




- General conclusions from all locations
  - Conclusions about water quality vary by index
  - Crossovers indicate potential calculation bias

Overall Conclusions & Future Directions

- When using the same data, not all indices will provide the same conclusions about water quality and therefore should be used with caution
- If comparisons are needed, use common standards and only one index to minimize biases
- Important to recognize that calculations in the study were based on 9 parameters for Stream Keepers WQI. Expansion of parameters is needed
- Variation in water quality standards should be modeled to further explore inconsistencies in results
- GWQI from WHO may be best index but modeling is needed for more conclusive decision



Calculating Biological Health Index

- **Biological Health Index**

Sensitive	# of Organisms	# of Organisms	# of Organisms	Circle Types Present
Caddisfly Larvae				3
Hellgrammites				3
Mayfly Nymphs				3
Gilled Snails (right)				3
Riffle Beetles				3
Stonefly Nymphs				3
Water Penny Larvae				3
Somewhat Tolerant	**# of Organisms**	**# of Organisms**	**# of Organisms**	**Circle Types Present**
Other Beetle Larvae				2
Clams/Mussels				2
Crane Fly Larvae				2
Crayfish				2
Dragonfly Nymphs				2
Damselfly Nymphs				2
Scuds				2
Sowbugs				2
Fishfly Larvae				2
Alderfly Larvae				2
Watersnipe Fly				2
Tolerant	**# of Organisms**	**# of Organisms**	**# of Organisms**	**Circle Types Present**
Aquatic Worms				1
Black Fly Larvae				1

(excerpt from data collection sheet)

Calculating Biological Health Index

- **Biological Health Index**

Alderfly Larvae				2
Watersnipe Fly				2
Tolerant	**# of Organisms**	**# of Organisms**	**# of Organisms**	**Circle Types Present**
Aquatic Worms				1
Black Fly Larvae				1
Leeches				1
Midge Larvae				1
Pouch Snails (left)				1
Other Snails (flat)				1
< 12 = Poor	12-17 = Fair	18-23 = Good	>23 = Excellent	**Water Quality Rating** ____

Comments (mention any changes from your usual readings) _____

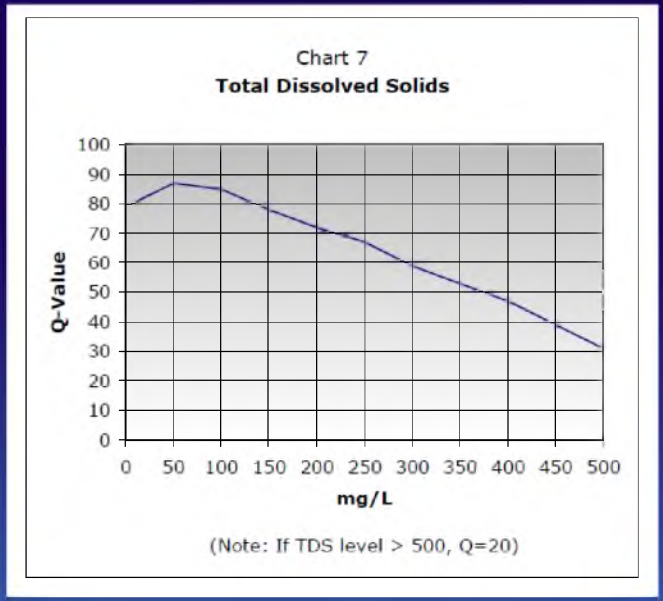
_____

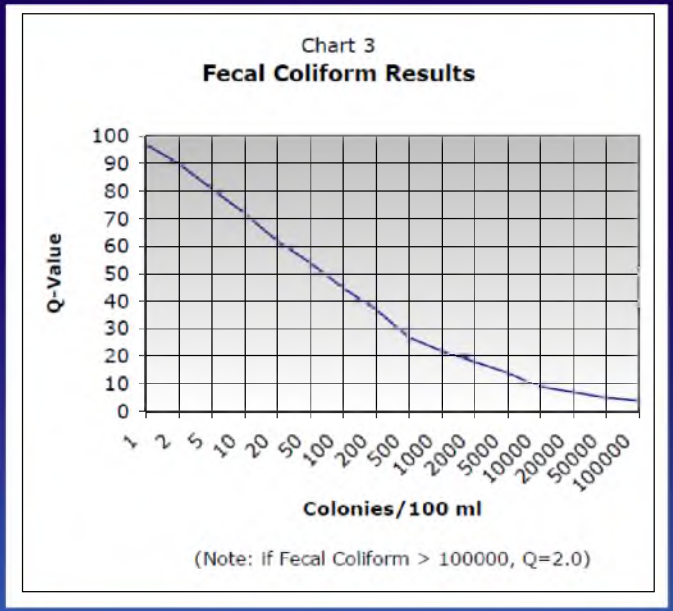
_____

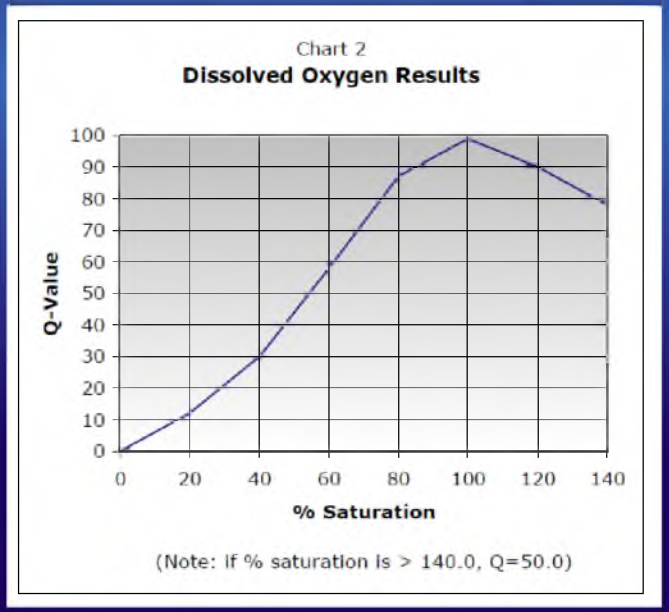
Fish Present (Please Mark) **Yes**☐ or **No**☐

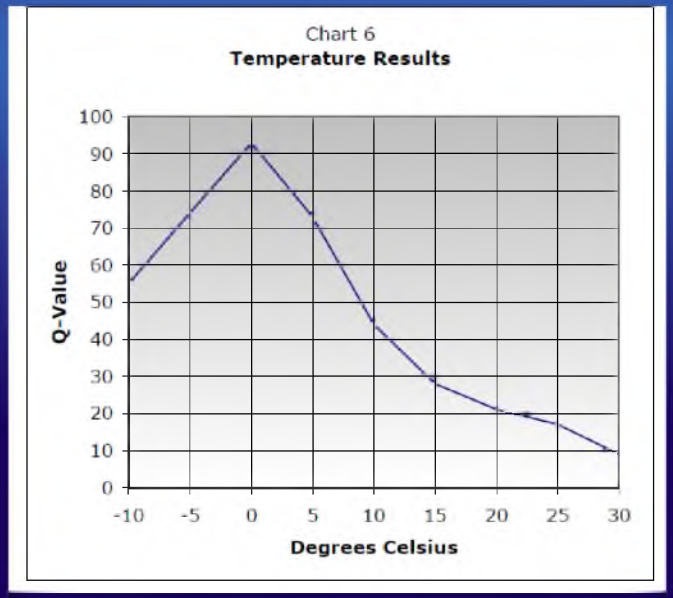
(excerpt from data collection sheet)

Stream Keepers WQI









Stream Keepers WQI

Test Parameter	Test Results	Q- Value	Weighing Factor	Total
BOD	(mg/L)		0.11	
Dissolved Oxygen	(% saturation)		0.17	
Fecal Coliform	(colonies/100 mL)		0.16	
Nitrates	(mg/L)		0.10	
PH	(Units)		0.11	
Temperature			0.10	
Total Dissolved Solids	(mg/L)		0.07	
Total Phosphate	(mg/L)		0.10	
Turbidity	(NTU)		0.08	

Overall Water Quality Index

Water Quality Calculations

- Indian Water Quality Index
  - WQI = Σ(Wq)
    - q = quality rating based on # of parameters measured, concentration of parameter in sample
    - W= relative weight determined from subjective rank of parameter importance

Water Quality Calculations

- Nigeria Water Quality Index
  - $WQI = \Sigma qW / \Sigma W$
    - q = quality rating based on ideal and peremissable parameter, as well as measured parameter
    - W= parameter weight based on parameter standard and and a constant incorporating the relative composition to water quality

Water Quality Calculations

- Global Water Quality Index (WHO)
  - WQI = $100 - (\sqrt{F_1^2 + F_2^2 + F_3^2} / 1.732)$
    - F_1 = percentage of parameters the exceed standard
    - F_2 = percentage of measurements that exceed standard
    - F_3 = mean deviation from standard for exceeded values