Kentucky's Causal Analysis for Assessing Waters with Narrative Criteria: A More Informed and Reproducible Approach

Breakout Theme: Using stressor identification when there are no applicable numeric criteria: experiences and lessons

TEAM KENTUCKY®

ENERGY AND ENVIRONMENT CABINET

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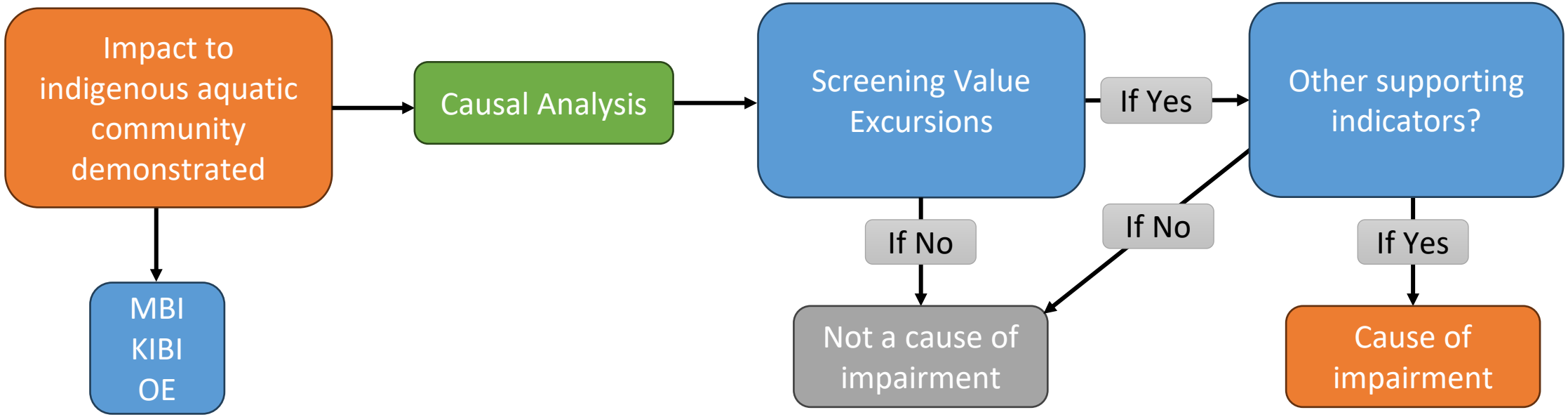
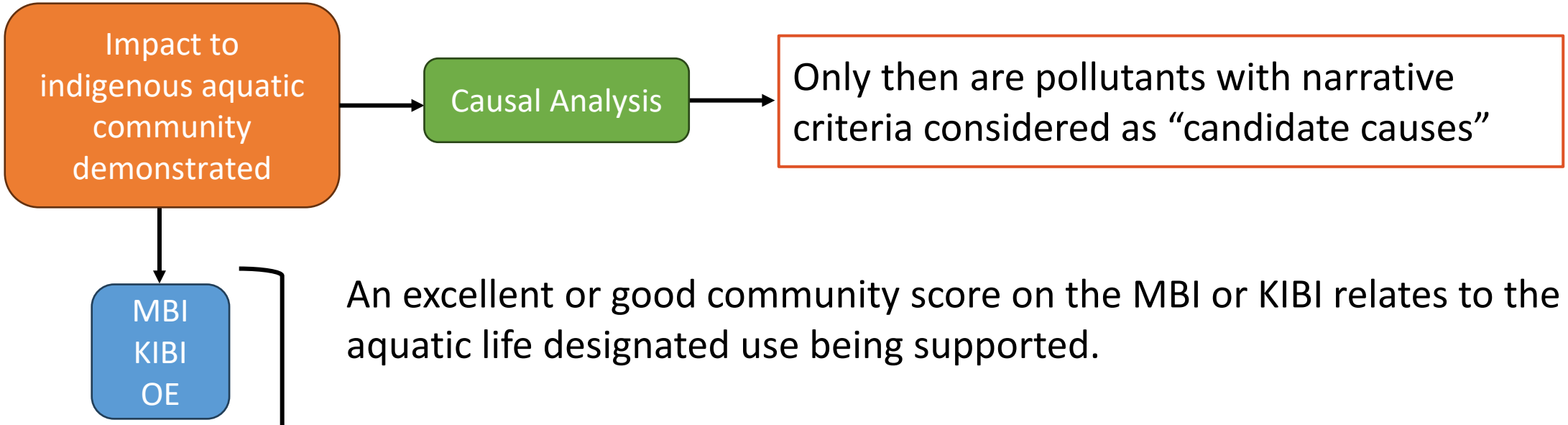
- Kentucky uses stressor identification (or causal analysis) when determining an appropriate cause of impairment for those pollutants that have narrative criteria (specific conductivity, nutrients, alkalinity, sedimentation) for the aquatic life designated uses.
- In Kentucky's water quality standards, all pollutants with a narrative criterion are accompanied by the phrase "the indigenous aquatic community is adversely affected".
- Kentucky defines adversely affected to "alter or change the community structure or function, to reduce the number or proportion of sensitive species, or to increase the number or proportion of pollution tolerant aquatic species."



Demonstration of Impact is First Step (and sufficient for delisting narratives)



An excellent or good community score on the MBI or KIBI relates to the aquatic life designated use being supported.

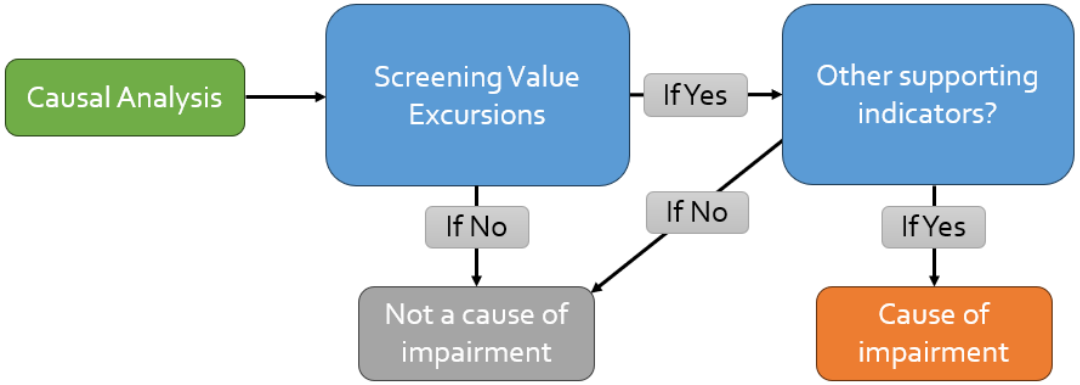
A fair, poor, or very poor community score on the MBI or KIBI relates to the aquatic life use being impaired.

O/E (observed/expected) has been developed to assist when scores are borderline, which has been formalized with a “zone of uncertainty”.

Causal Analysis

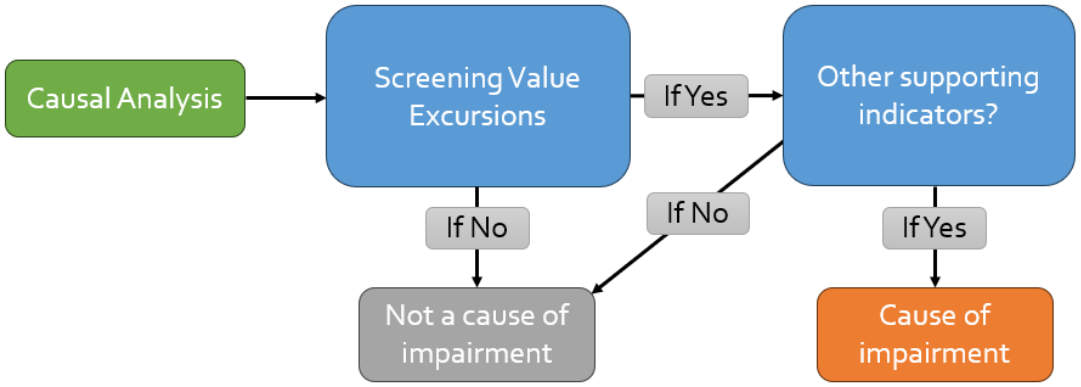
- What does this require?
  - Establish expectations for candidate pollutants that may potentially ‘adversely impact’ aquatic biological communities
    - Specific Conductivity, Sulfate
    - Nutrients (NO2/NO3, Phosphorus)
    - Alkalinity, Hardness

- Why do these values matter?
  - Screening value excursions: one of many supporting lines of evidence during stressor identification process

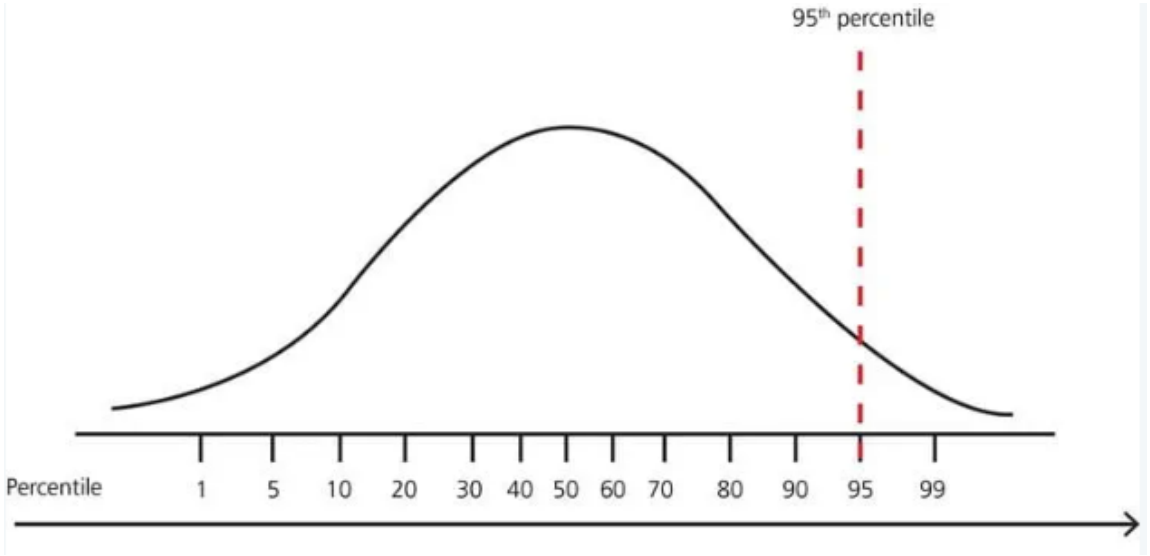


Causal Analysis

- What was the approach in 2019?
  - Starting with paired (mostly) observations for pollutant X and a macroinvertebrate biological index score/narrative rating
    - Determine the observed concentration of pollutant X that falls at 95th percentile from the population of 'good' or 'excellent' macroinvertebrate communities.

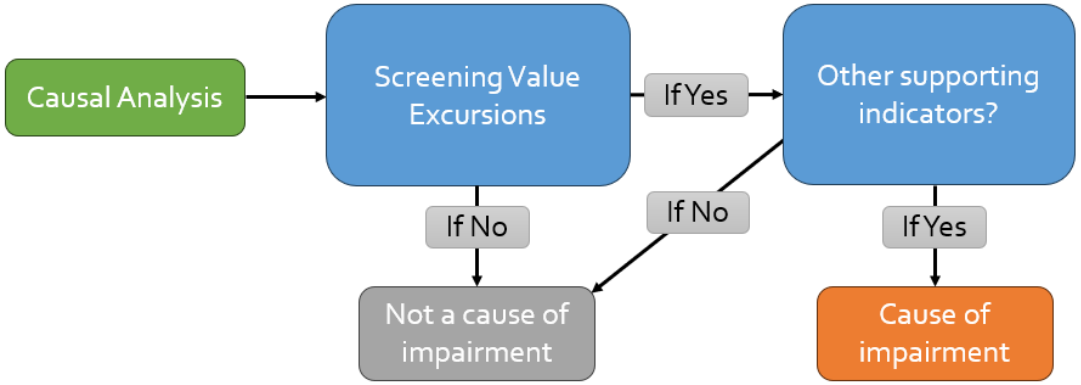


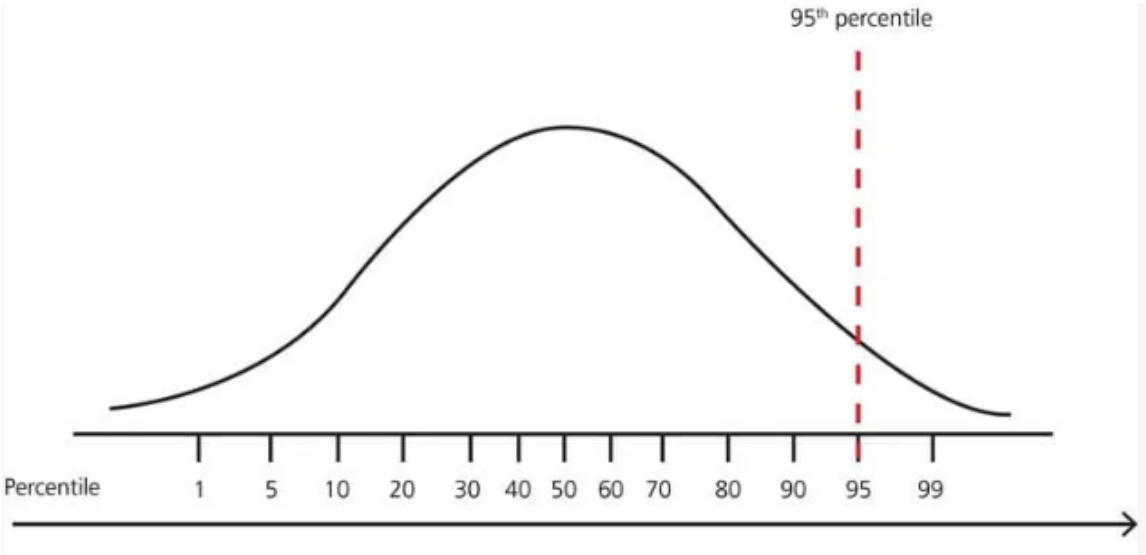
- Limitations
  - Reproducibility (Excel)
  - Narrow temporal extent (2013-2019)
  - Incomplete CWA monitoring program representation
  - Lacking exploration of stress-response relationships with other potentially important covariates
    - Stream size classes
    - Habitat metrics
    - Regional transitions areas
    - Growing season



Causal Analysis

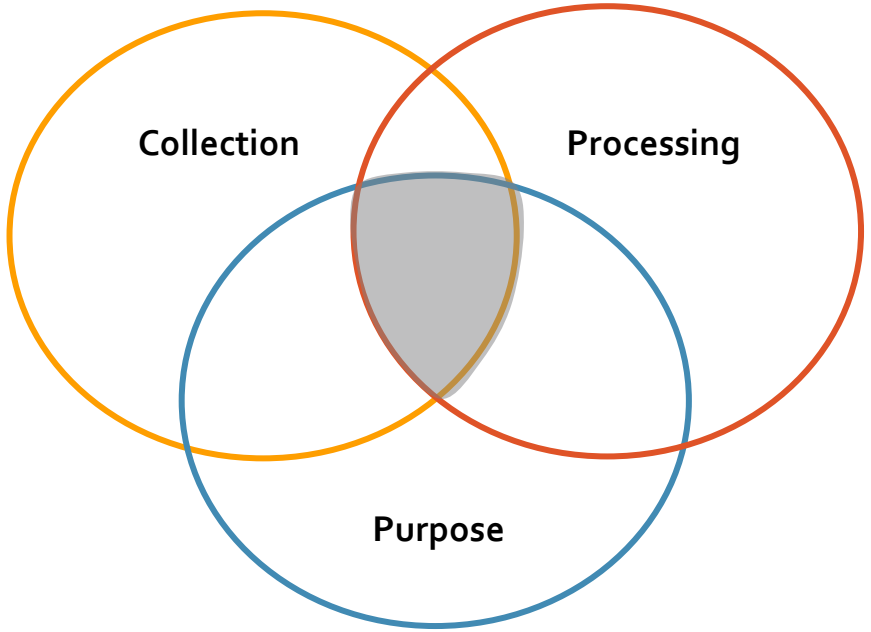
- What was our updated approach in 2023?
  - General process:
    - Workflows that are reproducible and reviewable
    - Deliverables that are consumable
  - Key Goals:
    - Expand the dataset**: Consider** all available biological data from 2000-2023
    - Explore the influence of environmental variables
      - Stream size classes
      - Habitat metrics
      - Regional transition areas
      - Growing season
    - Trends within or across CWA Monitoring Programs
    - Transparency and accessibility
      - Can this information be compiled into a single, flat file that staff can work with and explore without advanced coding and intensive data processing?





Harmonize

- QA/QC Data Review
  - Sample processing notes, taxonomic resolution, ect.
- Data Processing: Combine multiple data types with varying organizational structures from two databases
  - 'EDAS' – Microsoft Access: 2000 – 2013
  - 'KWADE' – ORACLE: 2013-2023

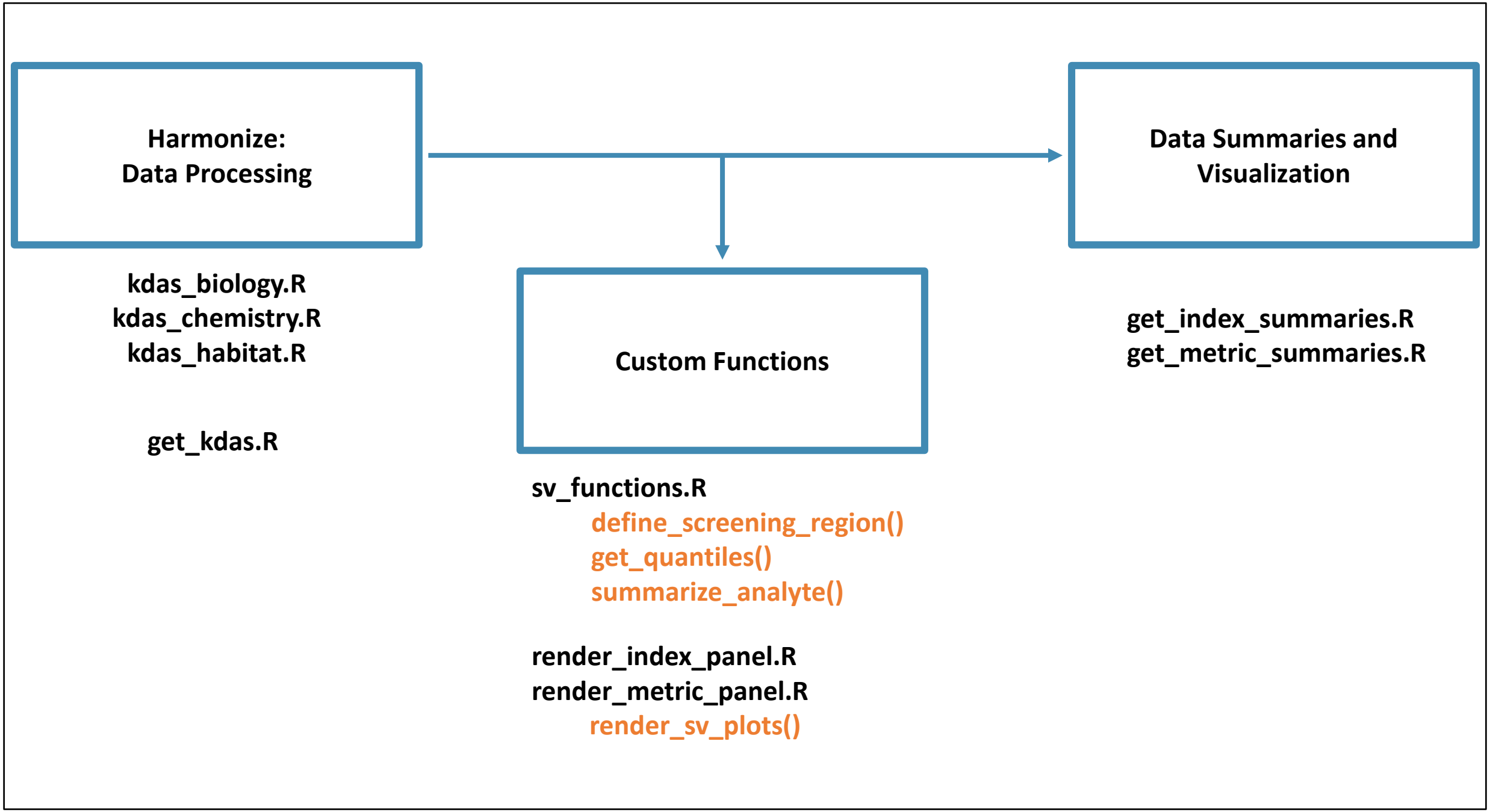


Data Types

- Water Chemistry
- *In situ* Field Measurements
- Stream Flow Observations
- RBP Habitat Assessments
- Macroinvertebrate index results

Temporal associations between pollutant-biology-habitat sampling events

- One to one (same day collection event)
- One to almost one (same week/month)
- Many to one (same year)
- Many to many (multiple years with biology and monthly chemistry - Reference Trends)


Harmonize:
Data Processing
Data Summaries and
Visualization
kdas_biology.R
kdas_chemistry.R
kdas_habitat.R
get_kdas.R
Custom Functions
get_index_summaries.R
get_metric_summaries.R
sv_functions.R
define_screening_region()
get_quantiles()
summarize_analyte()
render_index_panel.R
render_metric_panel.R
render_sv_plots()

Summarize & Visualize

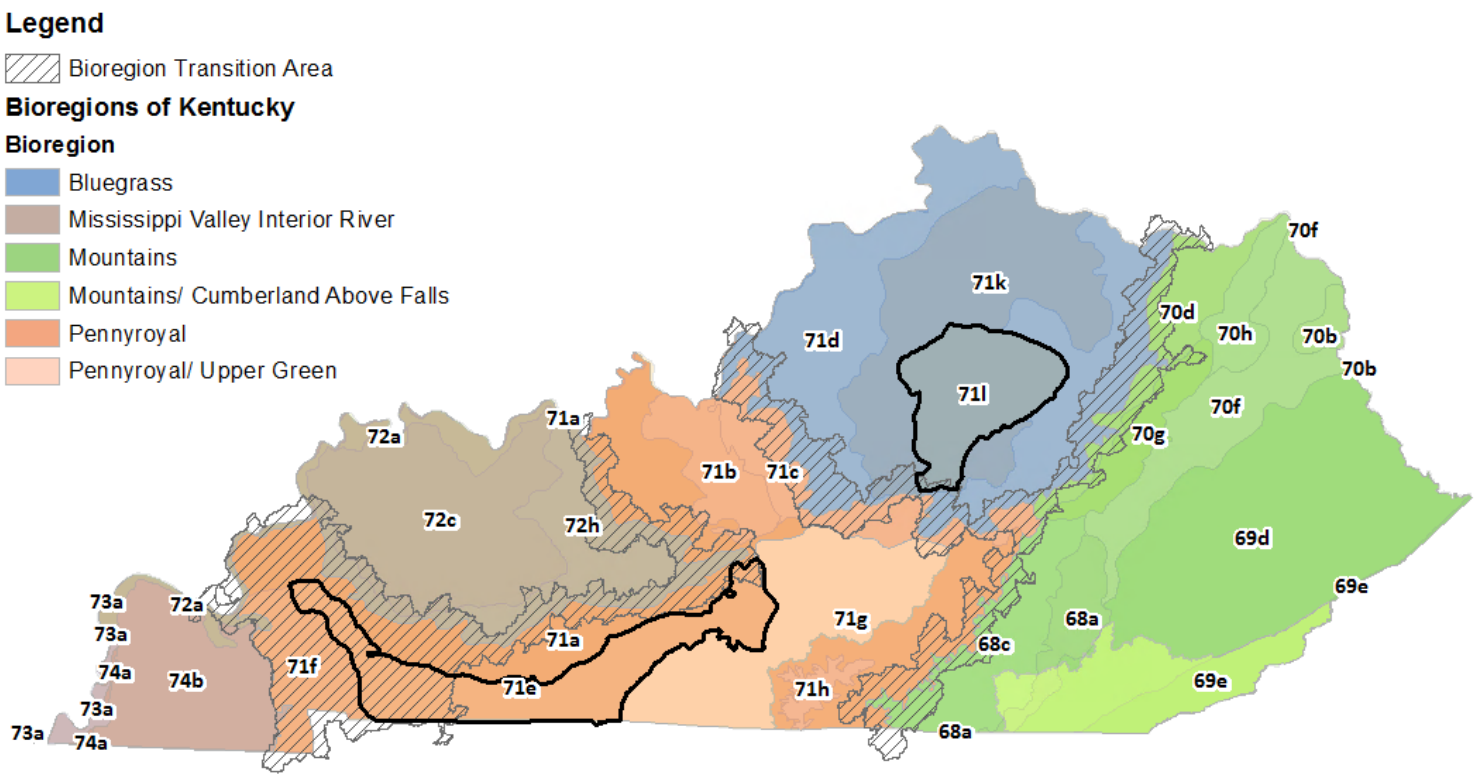
- Custom functions designed to:
  - Determine pollutant concentrations at user defined percentiles
    - Allow for specification of different constraints and grouping factors
  - Compile results into a manageable and comprehendible format
  - Visualize stressor-response relationships
  - Automatically archive summary reports and data visualizations during iterative 'loops' evaluating multiple pollutant-constraint combinations

```
xi <- x %>%
    get_quantiles(which_characteristic = 'PHOSPHORUS, TOTAL (AS P)',
                  which_ratings = c('Good', 'Excellent'),
                  which_groups = c('bioregion','stream_size')
                  programs = c('PROBABILISTIC', 'REFERENCE'),
                  q_value = c(0.75, 0.9, 0.95)
                  drop_transitions = FALSE)
```

Memorialize: GitHub repository

Screening Values - Final Method

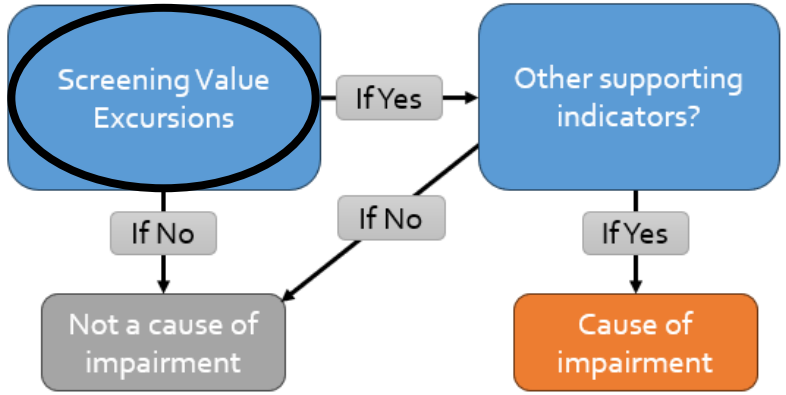
- All programs included
- Headwater and wadeable sites combined into one data set
- If a station with an MBI score from an individual year had multiple site visits from that same year, then the station mean from that year was used in the analysis
- If a station had both a primary and secondary bioregion (transition area), then the station was included in the analysis for the primary bioregion
- Screening value determined as the 95th percentile of sites that scored a good or excellent on the MBI
- The goal of these Screening Values matter: Just a few excursions could potentially contribute to a listing
- These numbers will be updated when another 5 years of data are available

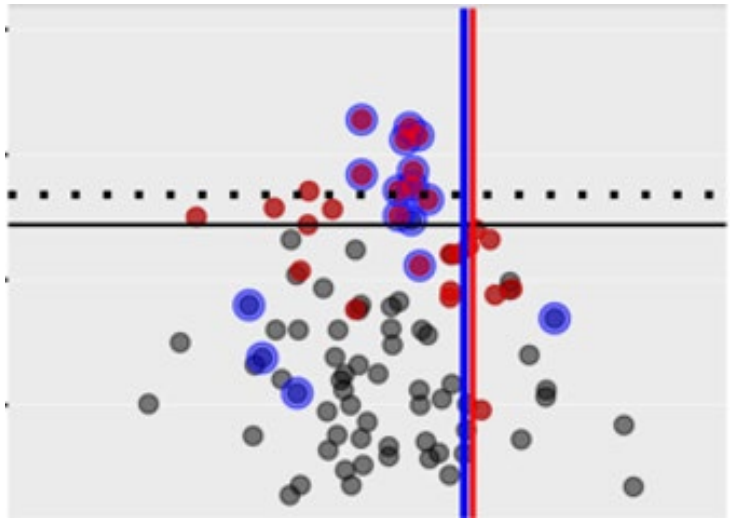


Specific Conductivity

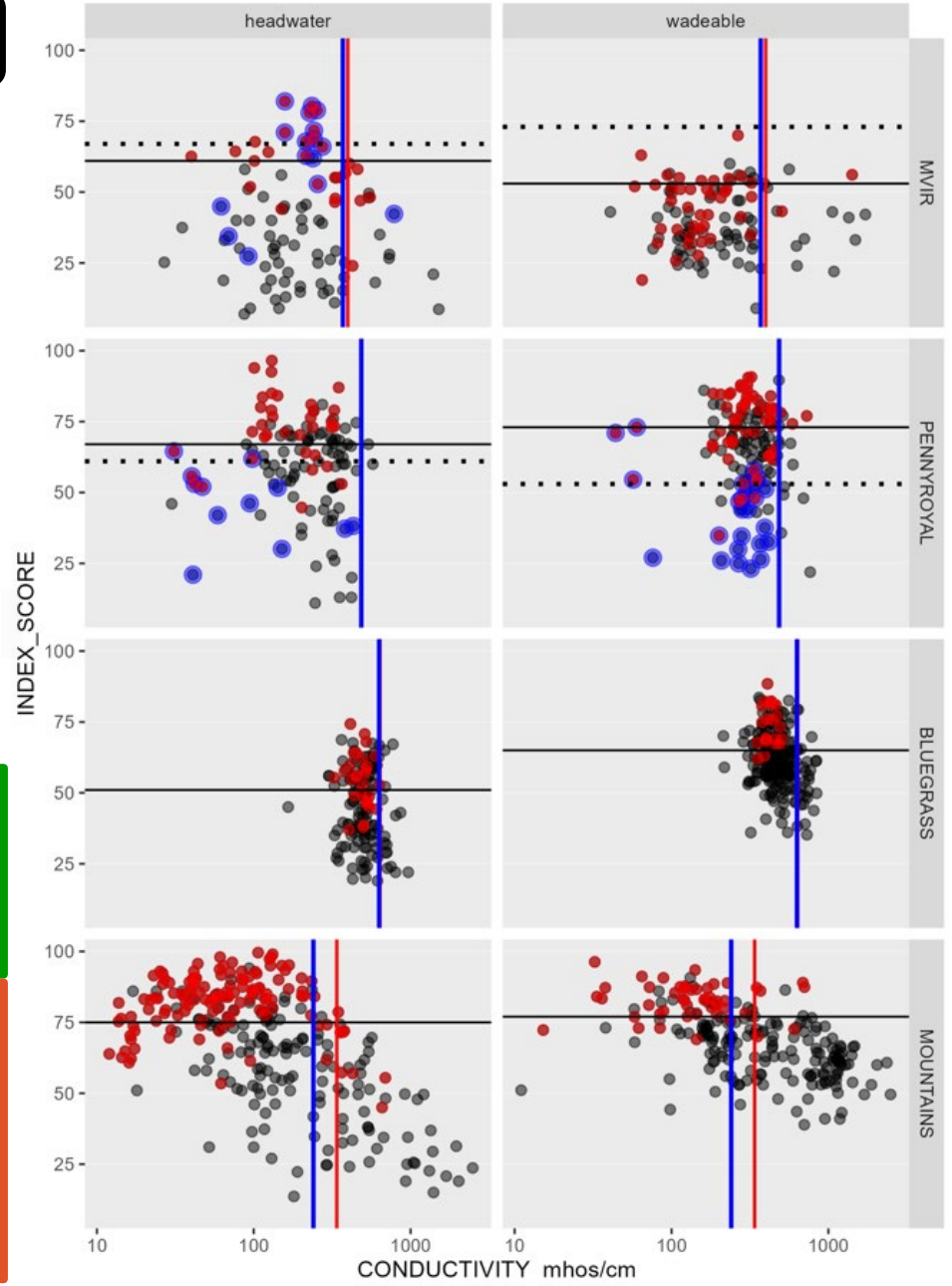
Red dots represent reference stations; blue dots represent stations that were riffle kicked in the MVIR or 20-jabbed in the PR. Vertical red lines mark the updated 95th percentiles (2024 screening value); vertical blue lines reflect the 2019 screening values.

- Narrative Criterion: Total dissolved solids or specific conductance shall not be changed to the extent that the indigenous aquatic community is adversely affected





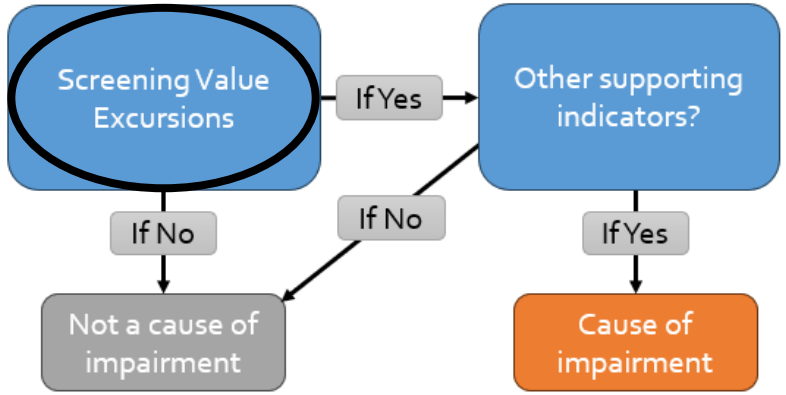
Meeting	Meeting (Despite SV Excursions)
Impaired No SV Excursions Lack of Evidence to List	Impaired SV Excursions Evidence to List

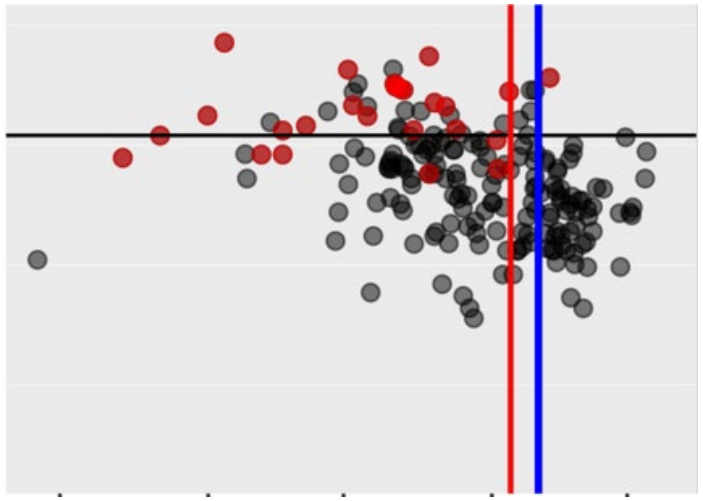


Alkalinity

Red dots represent reference stations; blue dots represent stations that were riffle kicked in the MVIR or 20-jabbed in the PR. Vertical red lines mark the updated 95th percentiles (2024 screening value); vertical blue lines reflect the 2019 screening values.

- Narrative Criterion: Alkalinity shall not be reduced or increased to a degree that may adversely affect the aquatic community





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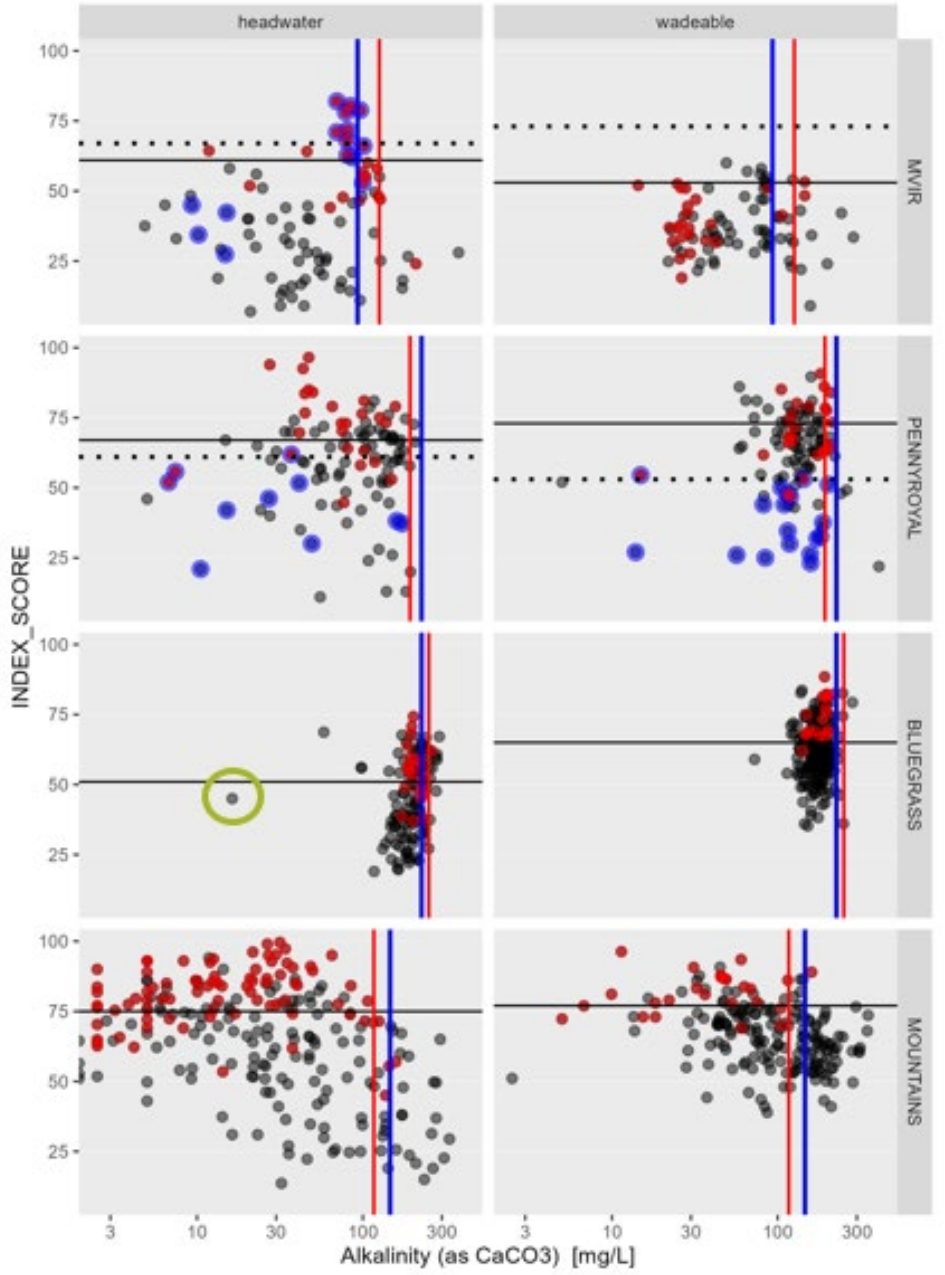
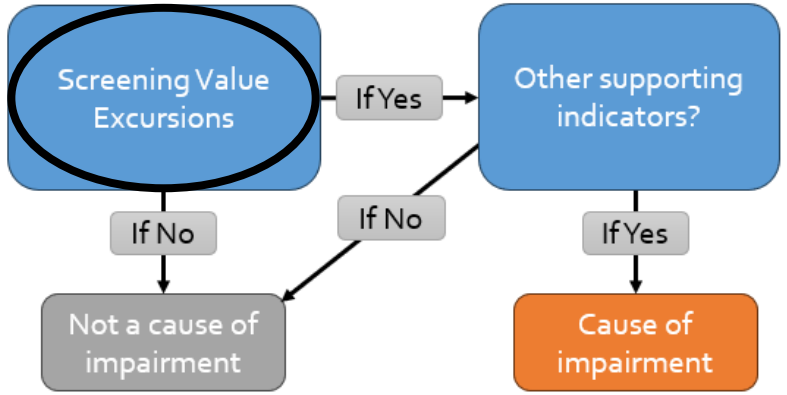
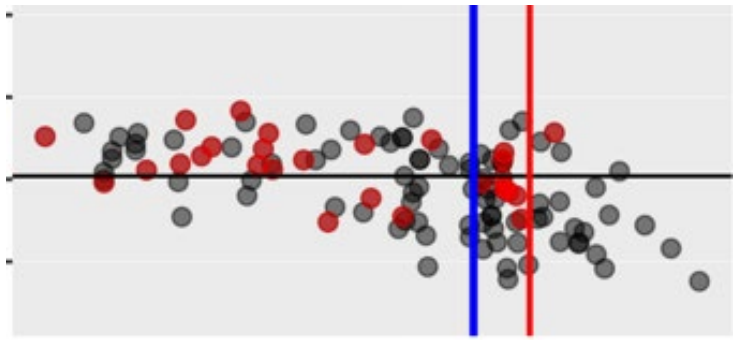


Nitrate/Nitrite

Red dots represent reference stations; blue dots represent stations that were riffle kicked in the MVIR or 20-jabbed in the PR. Vertical red lines mark the updated 95th percentiles (2024 screening value); vertical blue lines reflect the 2019 screening values.

- Nutrients Criterion. Nutrients shall not be elevated in a surface water to a level that results in a eutrophication problem.





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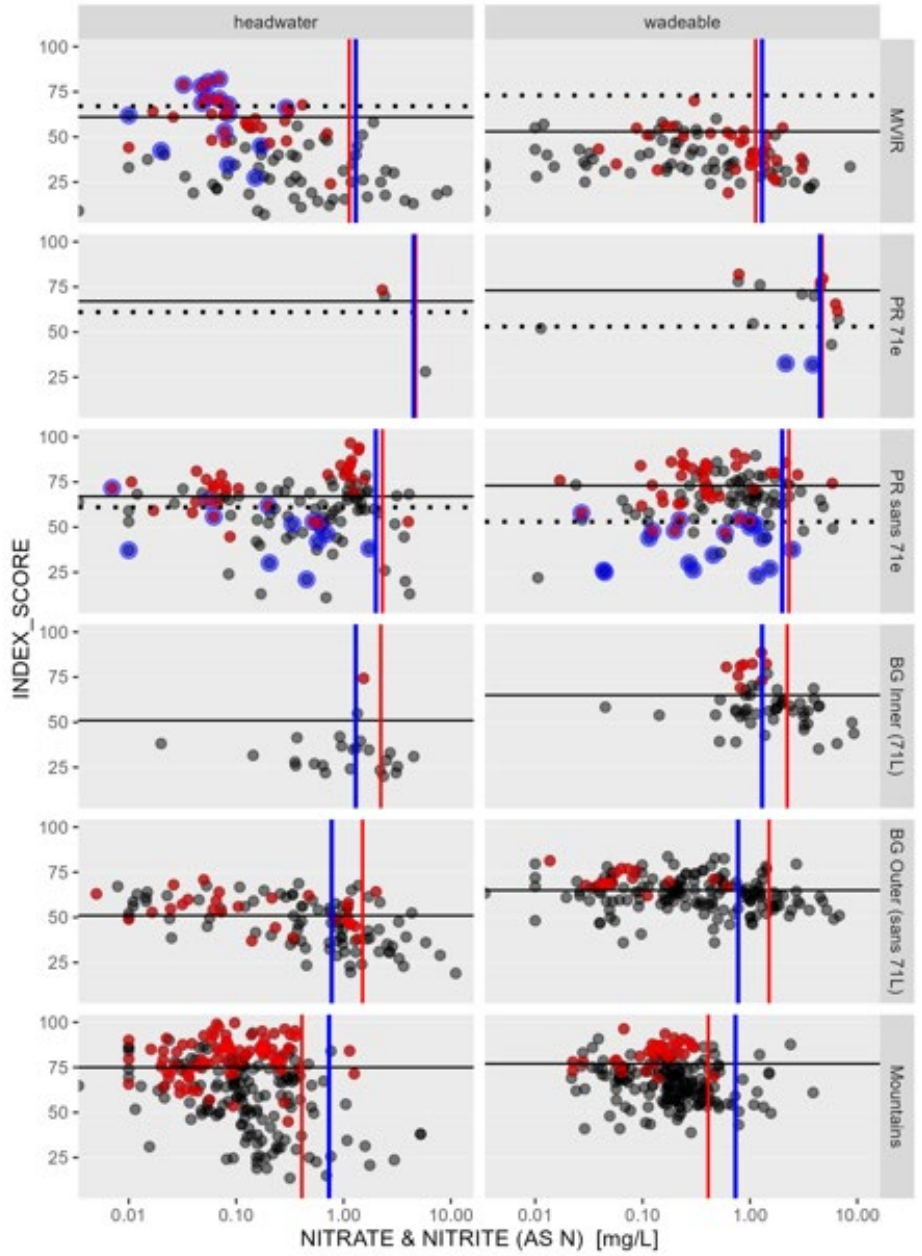
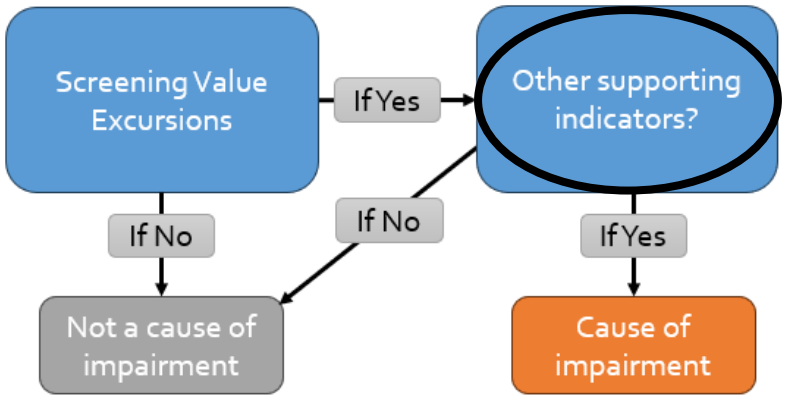


Specific Conductivity



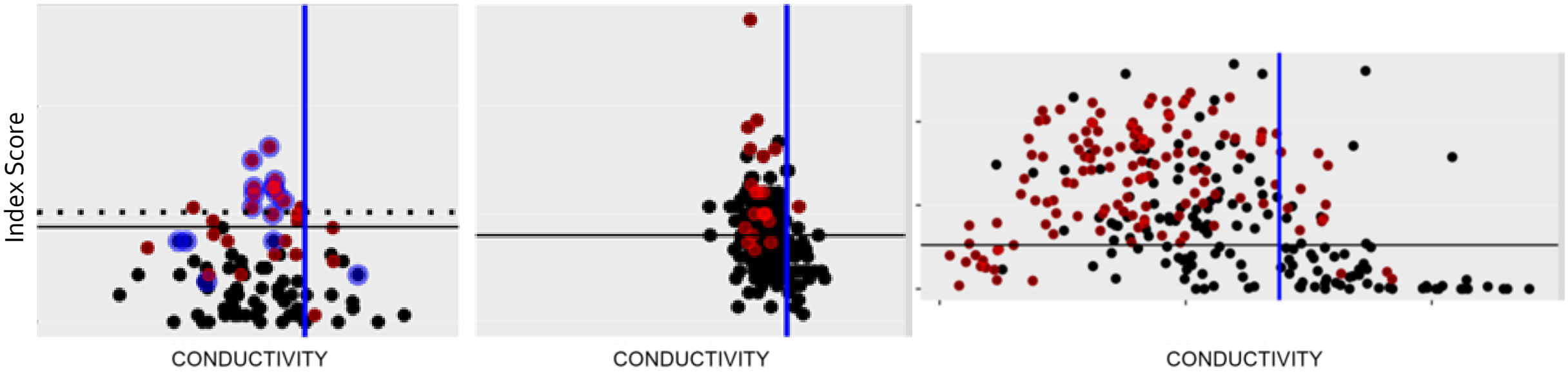
Lines of Evidence:

- Impact to aquatic community
- Screening value excursions
- **Other supporting Indicators**
  - **Individual metrics that are sensitive within the bioregion**
  - **Sulfate also elevated**
  - **Potential sources exist**

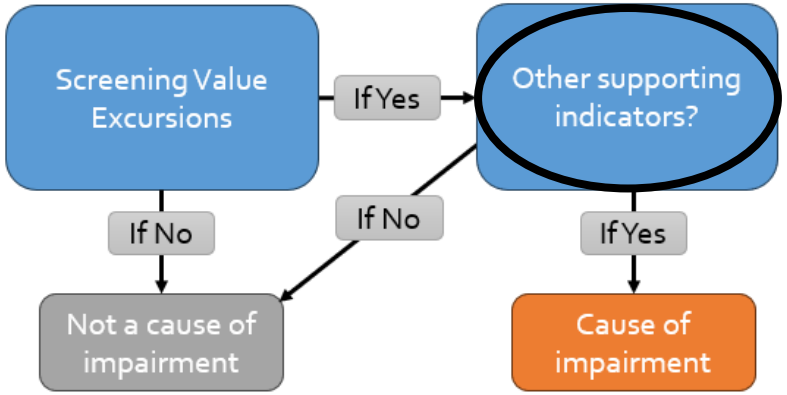
Genus EPT Richness
Headwater, MVIR

Genus EPT Richness
Wadeable, BG

% Ephemeroptera
Headwater, Mountains



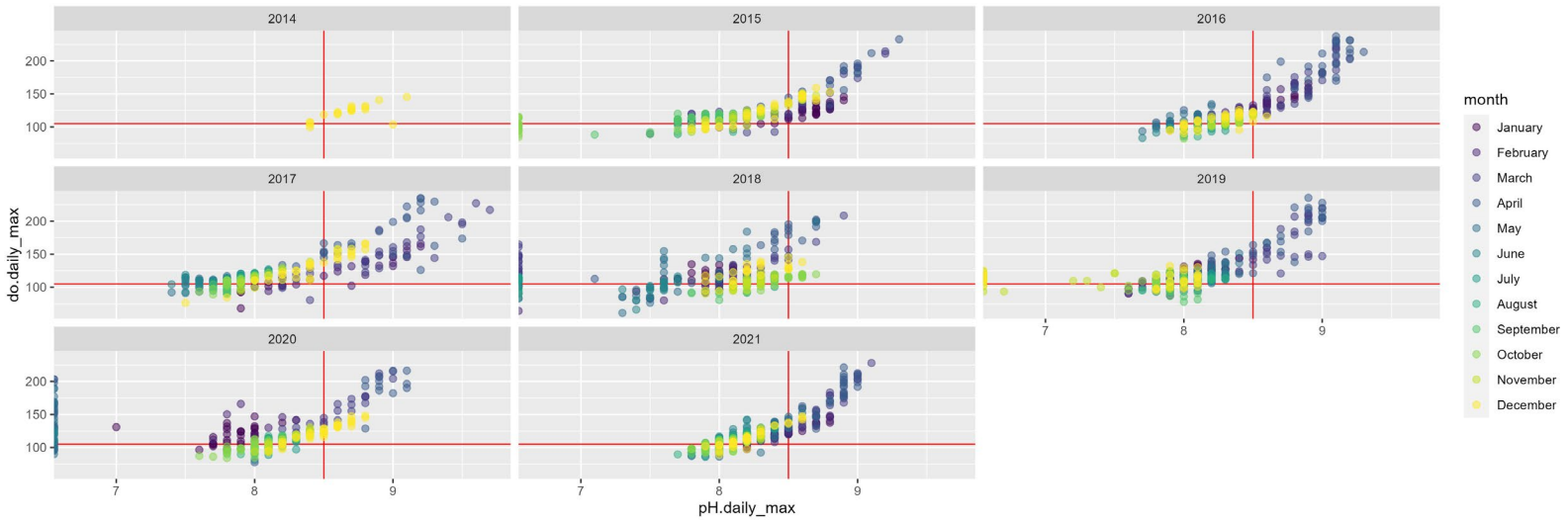
Nutrients



Lines of Evidence:

- Impact to aquatic community
- Screening value excursions (NO2/3, TP, TOC, TKN)
- **Other supporting Indicators**
  - **DO saturation paired with high pH (from definition of eutrophication)**
  - **Algal Observations (from definition of eutrophication)**
  - **Individual metrics that are sensitive within the bioregion**
  - **Potential source exists**

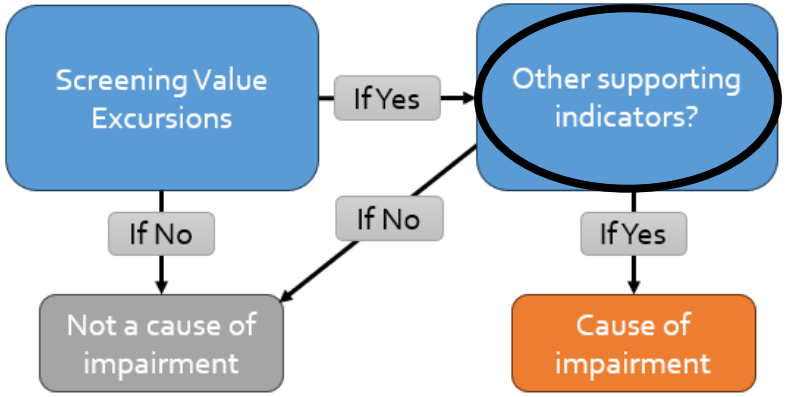
activity_date	activity_time	ALGAL MAT SEVERITY	BENTHIC ALGAE - GREEN FILAMENTS COVER - POOLS	BENTHIC ALGAE - GREEN FILAMENTS COVER - RIFFLES	BENTHIC ALGAE - GREEN FILAMENTS COVER - RUNS
03/28/2019	15:15:00	MODERATE	COMMON (5-25%)	EXTENSIVE (>50%)	COMMON (5-25%)
04/24/2019	13:35:00	MODERATE	COMMON (5-25%)	COMMON (5-25%)	COMMON (5-25%)
05/09/2019	11:25:00	SLIGHT/MILD	ABSENT	ABSENT	ABSENT
05/16/2019		SEVERE/HEAVY	SPARSE (<5%)	ABUNDANT (25-50%)	COMMON (5-25%)
05/23/2019		SLIGHT/MILD	SPARSE (<5%)	ABUNDANT (25-50%)	COMMON (5-25%)
06/06/2019	14:20:00	SLIGHT/MILD	SPARSE (<5%)	SPARSE (<5%)	SPARSE (<5%)
07/16/2019	14:35:00	MODERATE	SPARSE (<5%)	SPARSE (<5%)	SPARSE (<5%)
08/22/2019	13:30:00	SLIGHT/MILD	ABSENT	ABSENT	ABSENT
09/17/2019	13:15:00	SLIGHT/MILD	ABSENT	ABSENT	ABSENT
10/23/2019		MODERATE	COMMON (5-25%)	ABUNDANT (25-50%)	ABUNDANT (25-50%)
11/12/2019		SLIGHT/MILD	SPARSE (<5%)	COMMON (5-25%)	SPARSE (<5%)
12/04/2019	15:30:00	MODERATE	ABSENT	ABSENT	ABSENT
01/16/2020		MODERATE	ABSENT	SPARSE (<5%)	SPARSE (<5%)
02/18/2020	13:20:00	MODERATE	ABSENT	ABSENT	ABSENT



Algal Observations

USGS Gage Data

Nutrients



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- **Other supporting Indicators**
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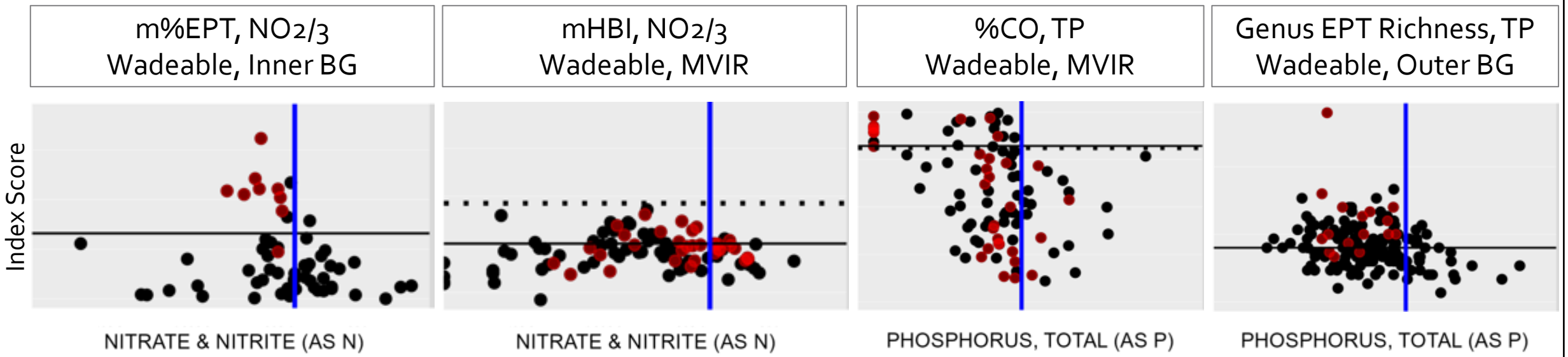
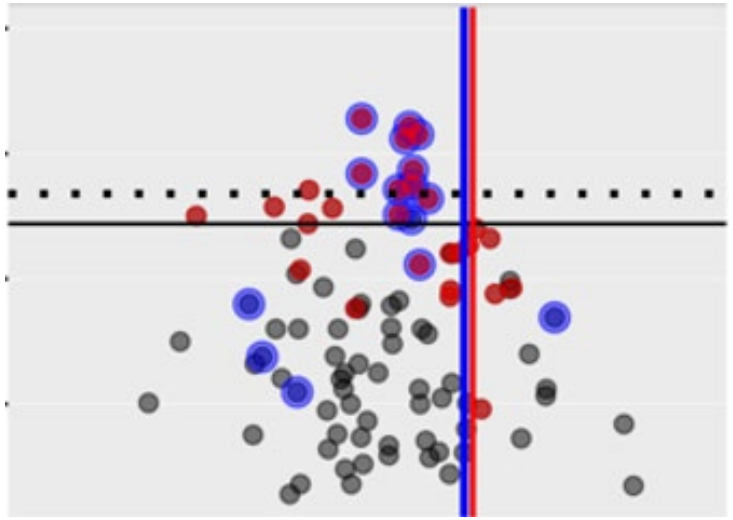


Provides Defensibility, Especially in Transition

- It's not always this clean…



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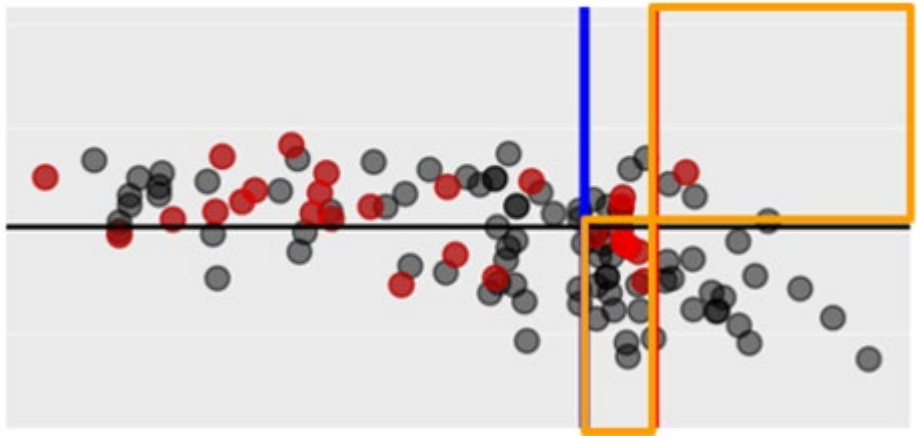

- By having data drive the decisions that are made within the orange boxes, borderline decisions about a 303(d)-listing associated with a narrative criterion becomes more defensible and repeatable.

Future Work

- Screening values for substrate characterization
- Fish metrics
- Other macroinvertebrates metrics that aren't metrics from the MBI
- Joining chemistry data from nearby stations
- Updated information will be reflected in CALM for 2026 Cycle
- Targeted monitoring where data gaps exist

Lessons

- Value of Historic Data (and the benefit of time spent reviewing/preserving)
- Sense of "Drowning in Data" ---> R scripts as a solution
- Baseline data set can then be used for other purposes with just a few updates to a script

Thank You! Questions?

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