Flow-Ecology Relationships

Saluda RBC, June 21st, 2023

Drs. Luke Bower, Joe Mruzek, and Brandon Peoples

Bio-assessment: using aquatic organisms to learn about river health

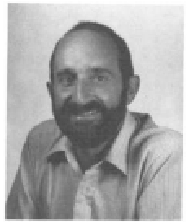
ASSESSMENT OF BIOTIC INTEGRITY USING FISH COMMUNITIES

James R. Karr

ABSTRACT

Man's activities have had profound, and usually negative, influences on freshwater fishes from the smallest streams to the largest rivers. Some negative effects are due to contaminants, while others are associated with changes in watershed hydrology, habitat modifications, and alteration of energy sources upon which the aquatic biota depends. Regrettably, past efforts to evaluate effects of man's activities on fishes have attempted to use water quality as a surrogate for more comprehensive biotic assessment. A more refined biotic assessment program is required for effective protection of freshwater fish resources. An assessment system proposed here uses a series of fish community attributes related to species composition and ecological structure to evaluate the quality of an aquatic biota. In preliminary trials this system accurately reflected the status of fish communities and the environment supporting them.

Passage of the Water Quality Act Amendments of 1972 (PL 92-500) stimulated many efforts to monitor the quality of water resource systems. Unfortunately, these efforts concentrated on development of thresholds and criteria levels for specific contaminants, often based on acute toxicity tests. The use of these criteria has been attacked on numerous grounds (Thurston et al. 1979); for example, they have not taken into account naturally occurring geographic variation of contaminants (e.g., asbestos, iron, zinc), considered the synergistic effects of numerous contaminants, nor considered sublethal effects (e.g., reproduction, growth) of most contaminants. In addition, monitoring of water quality parameters (nutrients, DO, temperature, pesticides, heavy metals, and other toxics) often misses short-term events that may be critical to assessment of biotic impacts. Finally, it is impossible to measure all factors that may impact biotic integrity. In fact, much literature on chemical contaminants is of questionable value for setting water quality standards for aquatic organisms (Gosz 1980). Chemical monitoring misses many of the man-induced perturbations that impair use. For example, flow alterations, habitat degradation, heated effluents, and uses for power generation are not detected in chemical sampling. In short, criteria that emphasize physical and chemical attributes of water are unsuccessful as surrogates for measuring biotic integrity (Karr and Dudley 1981).



James R. Karr

THE AUTHOR: James R. Karr is Professor of Ecology in the Department of Ecology, Ethology, and Evolution and the Department of Forestry at the University of Illinois at Urbana-Champaign, and an affiliate of the Aquatic Biology Section of the Illinois Natural History Survey. He received a B.S. from Iowa State University and M.S. and Ph.D. from the University of Illinois. He has served as a consultant to USEPA, USDA-SCS, and Organization of American States (in Venezuela) on water resource and watershed development projects. His interest in fisheries develops from an interest in applying ecological principles to a variety of resource problems. Another major research focus deals with tropical forest ecology, especially bird communities. Address: Department of Ecology, Ethology, and Evolution, University of Illinois, 606 E. Healey, Champaign, Illinois 61820.

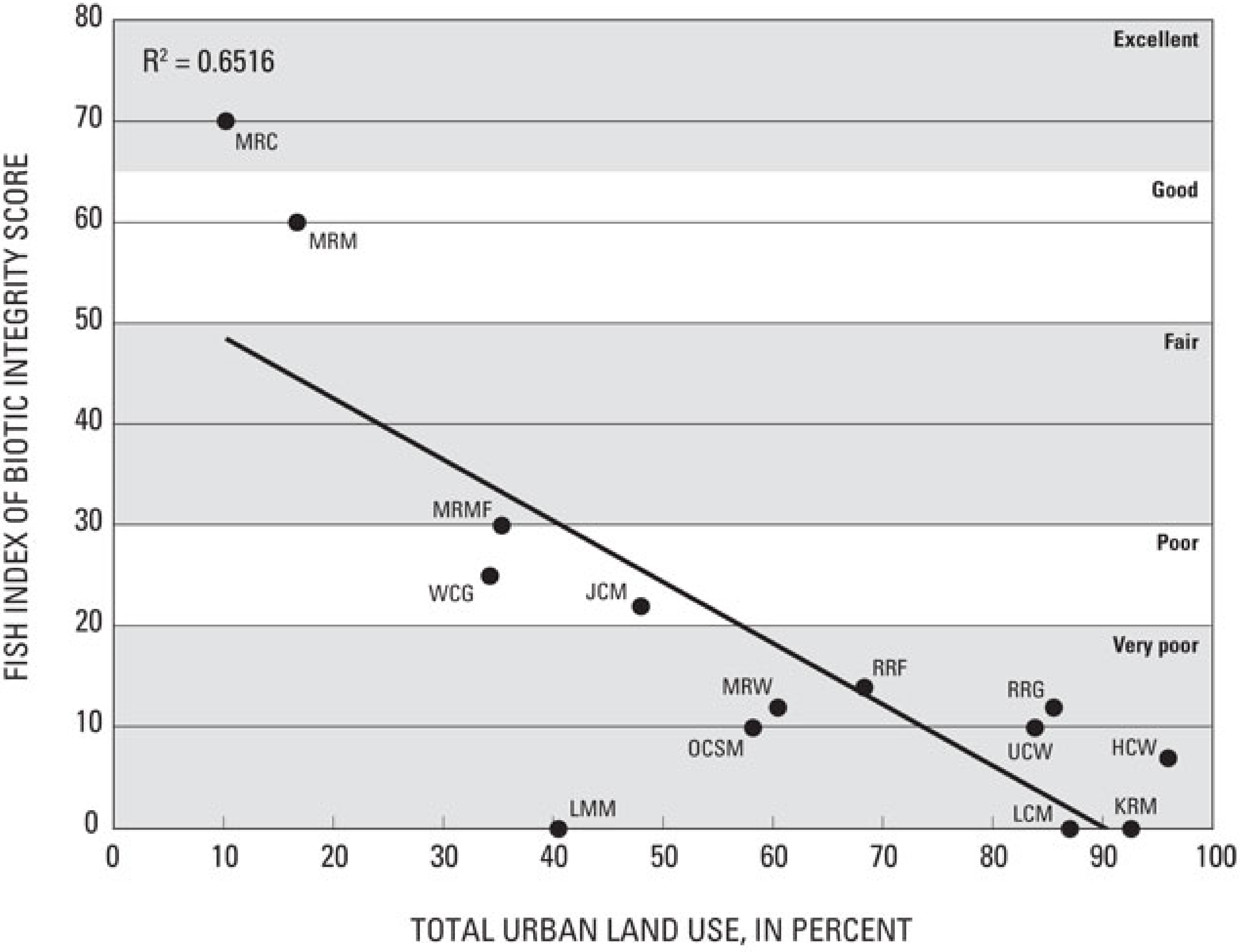
Recent legislation (Clean Water Act of 1977, PL 95-217) clearly calls for a more refined approach when pollution is defined as "the manmade or man-induced alteration of the chemical, physical, biological, and radiological integrity of water." Despite this refinement, regulatory agencies have been slow to replace the classical approach (uniform standards focusing on contaminant levels) with a more sophisticated and environmentally sound approach.

The integrity of water resources can best be assessed by evaluating the degree to which waters provide for beneficial uses. Important uses as defined by society may include water supply, recreational, and other uses as well as the preservation of future options for the use of the resource. Since an ability to sustain a balanced biotic community is one of the best indicators of the potential for beneficial use, sophisticated monitoring programs should seek to assess "biotic integrity."

This paper describes a procedure for monitoring water resources using fish. My contention is that by carefully monitoring fishes, one can rapidly assess the health ("biotic integrity") of a local water resource. In short, carefully planned monitoring and assessment can rapidly and relatively inexpensively serve as an exploratory assessment of water resource quality. Where impaired use is suggested by biological monitoring, a more nearly complete monitoring program can be implemented in search of the causative agent(s).

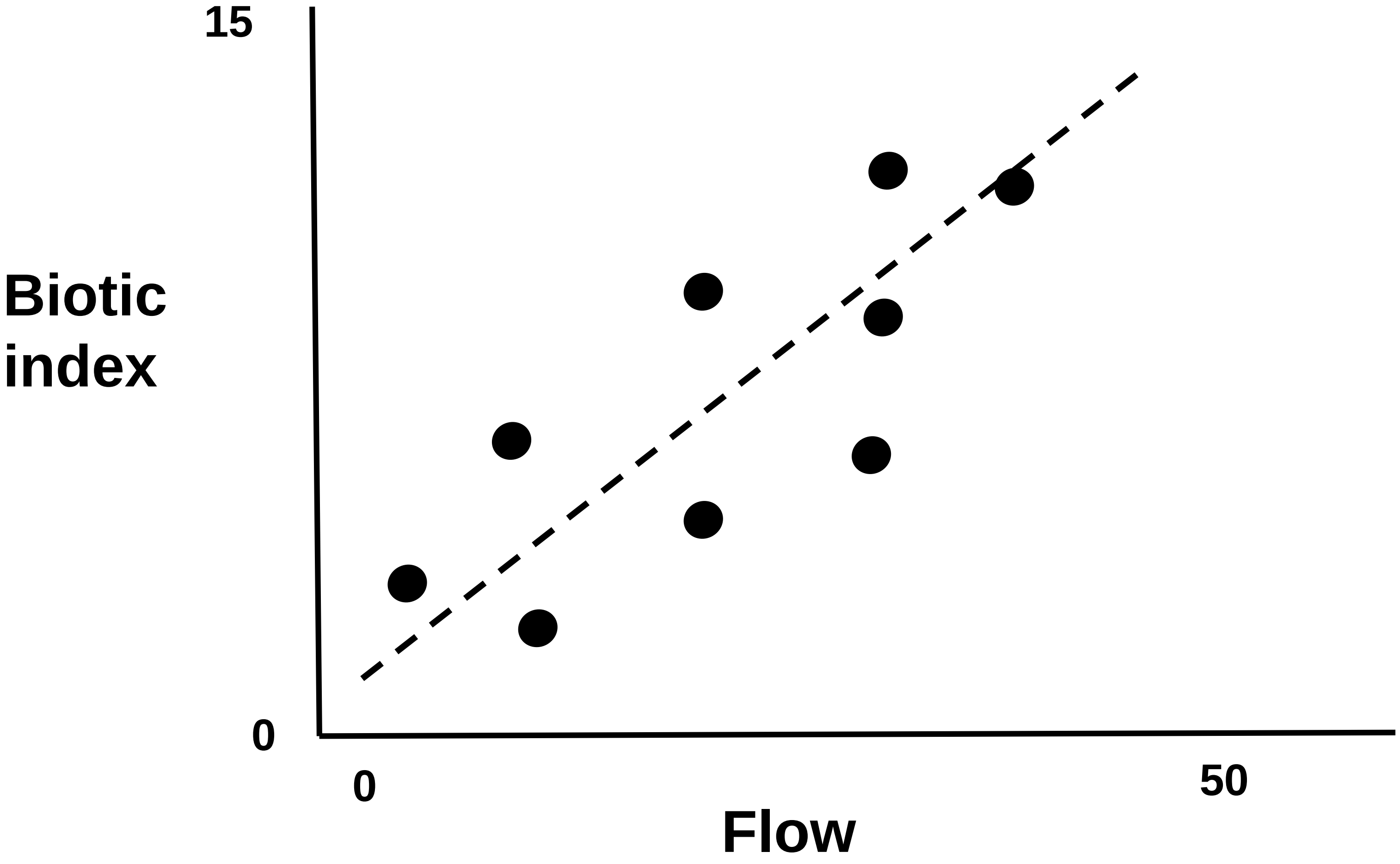
WHY MONITOR FISH?

Biological communities reflect watershed conditions since they are sensitive to changes in a wide array of environmental factors. Many groups of organisms have been proposed as indicators of environmental quality, but no single group has emerged as the

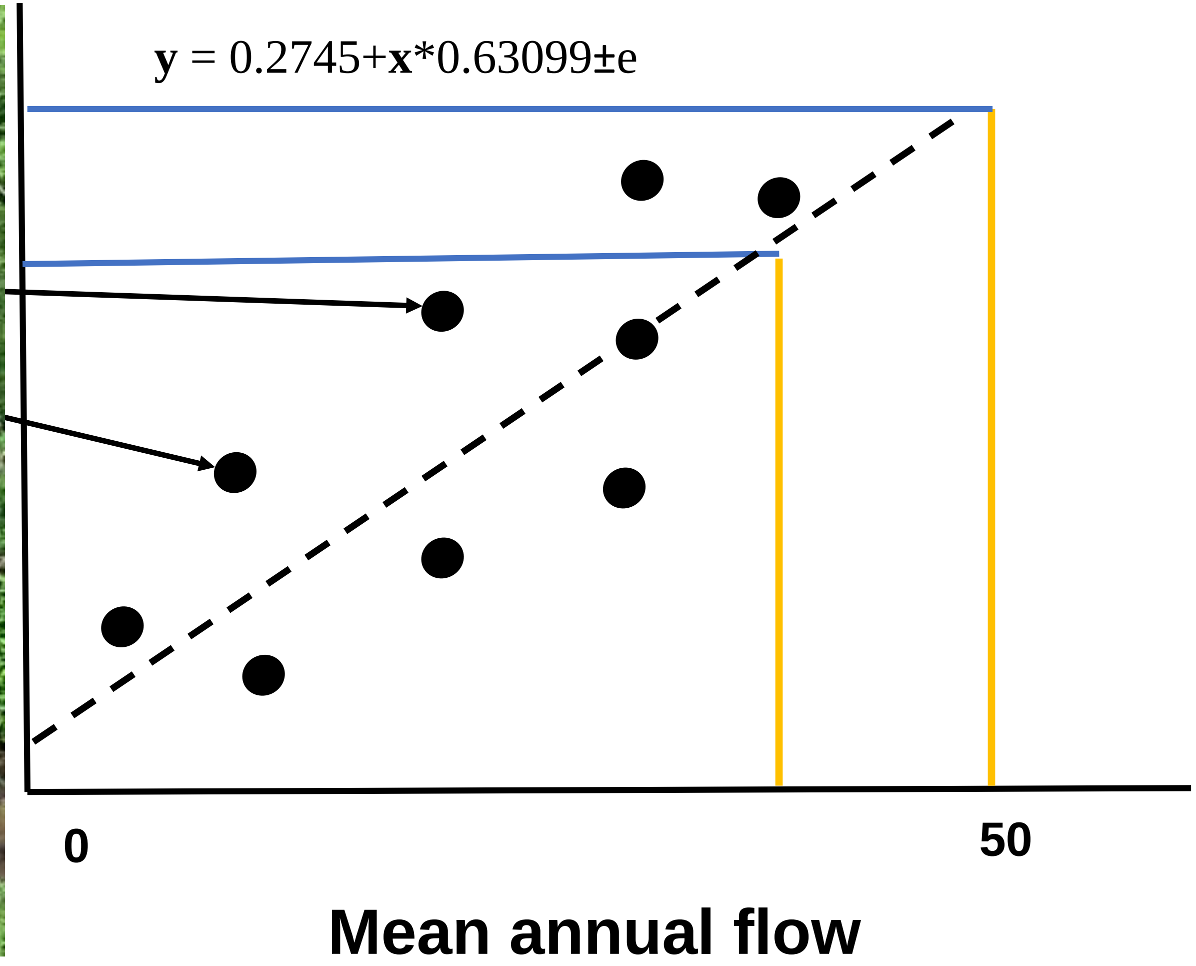


$R^2 = 0.6516$
Excellent
Good
Fair
Poor
Very poor
MRC
MRM
MRMF
WCG
JCM
RRF
MRW
OCSM
RRG
UCW
HCW
LMM
LCM
KRM
FISH INDEX OF BIOTIC INTEGRITY SCORE
TOTAL URBAN LAND USE, IN PERCENT
0
10
20
30
40
50
60
70
80
90
100

Flow-ecology relationships



Use of the relationships



Middle Atlantic Coastal Plain

Piedmont

Purpose

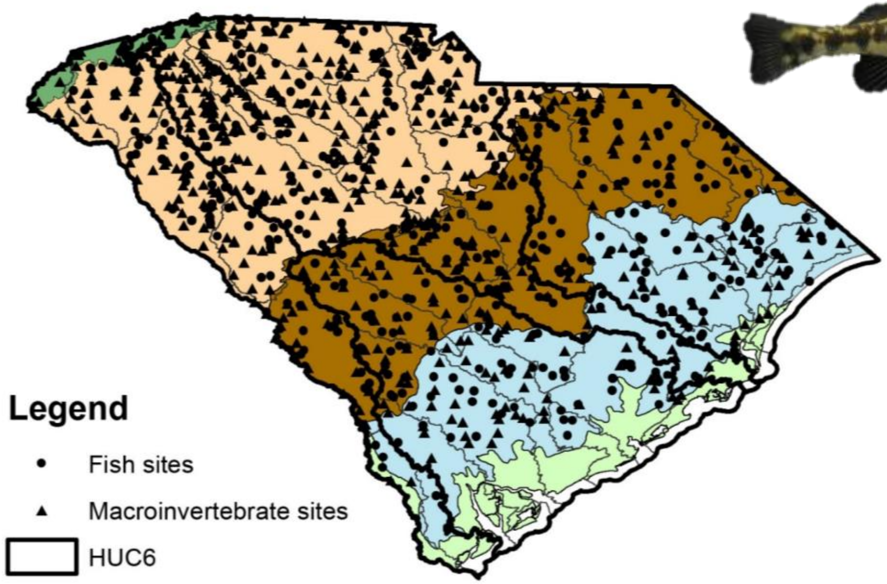
- To provide insight on the potential response of organisms to the alternate water withdrawal scenarios produced by SWAM.
  - We aim to put the SWAM results into a biological context.

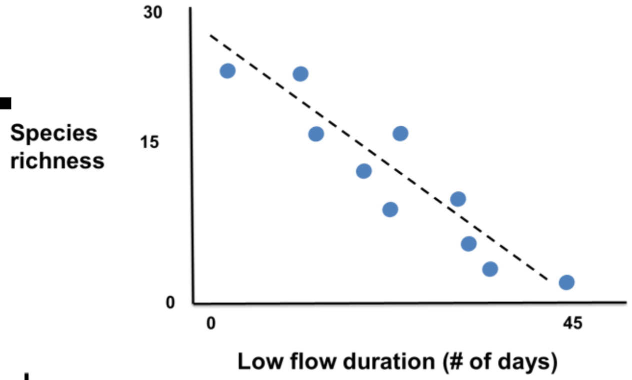
- High demand water use scenario: 100 to 60 cfs

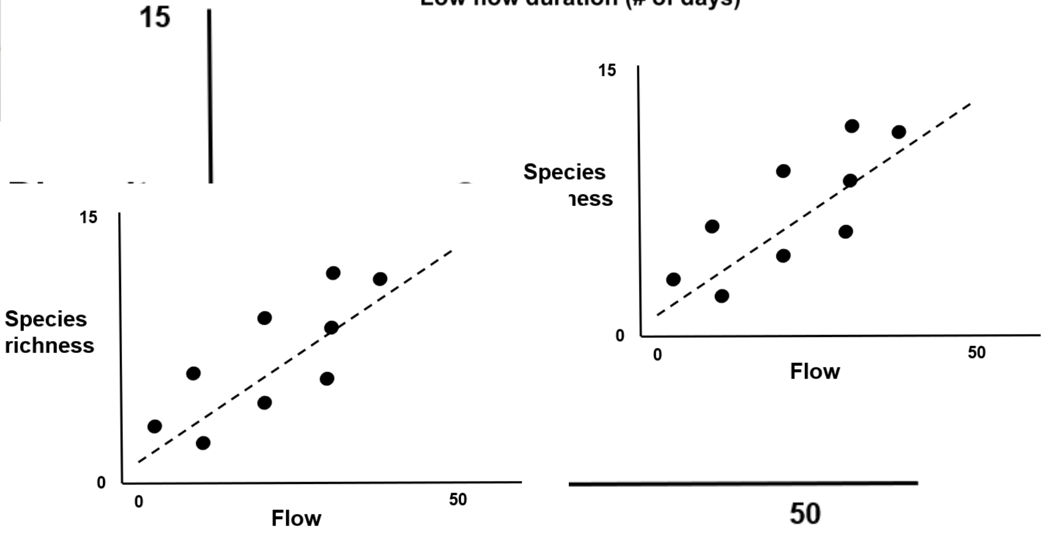
Predict

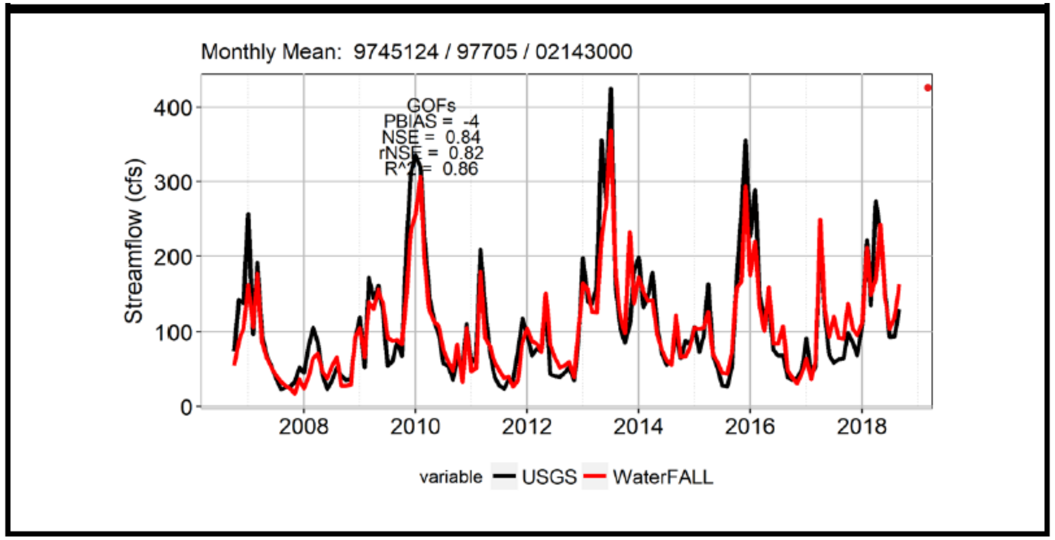
25% loss of species

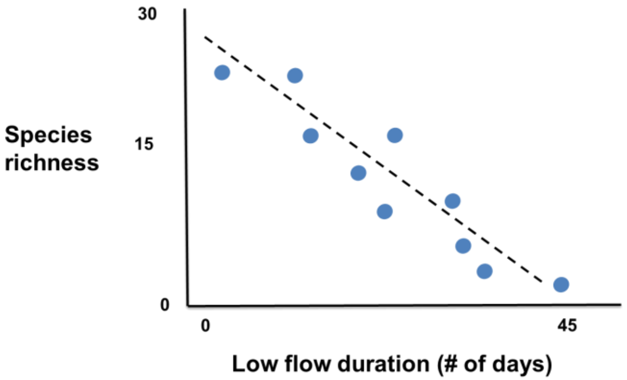
How will this work? Step 1



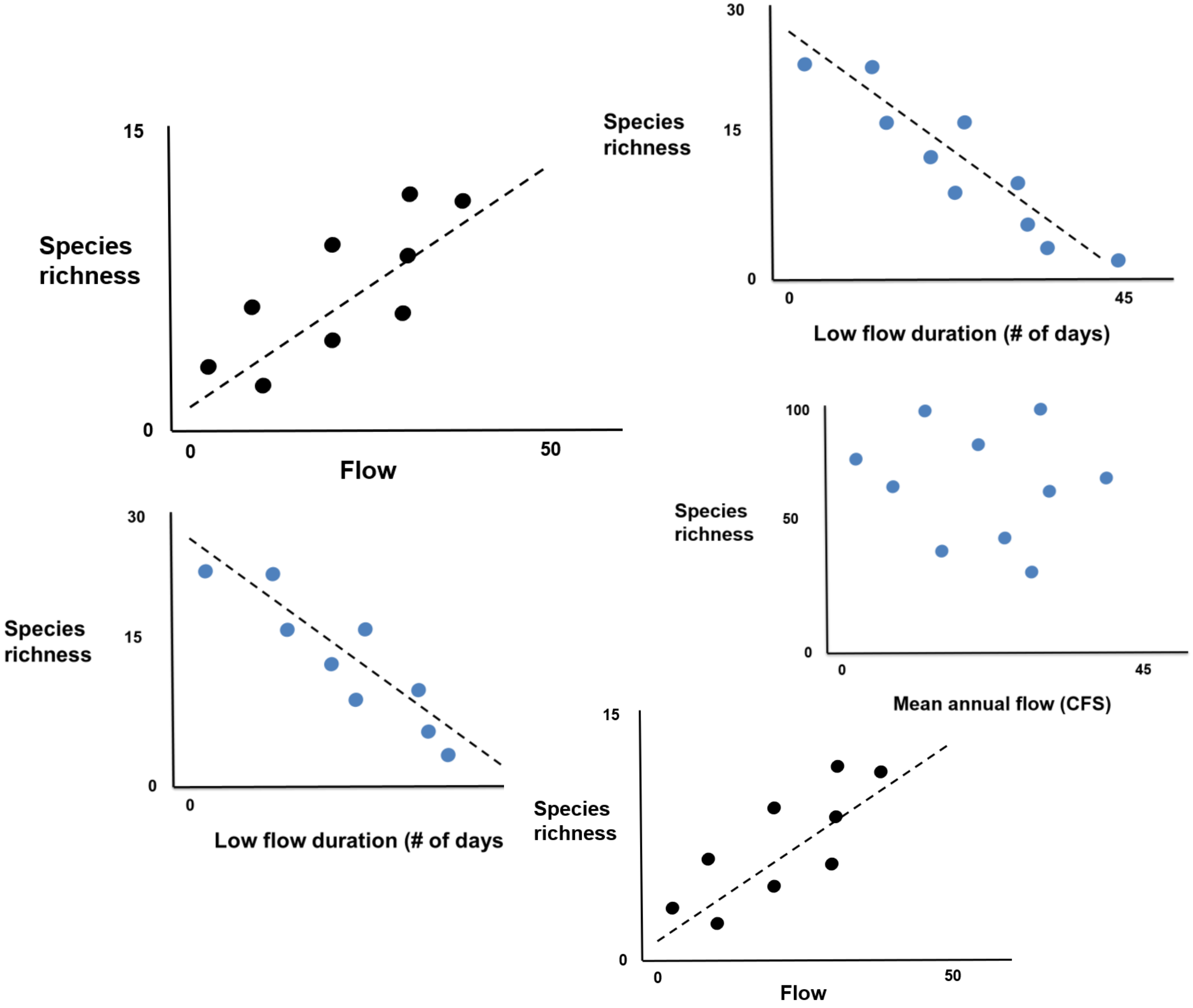




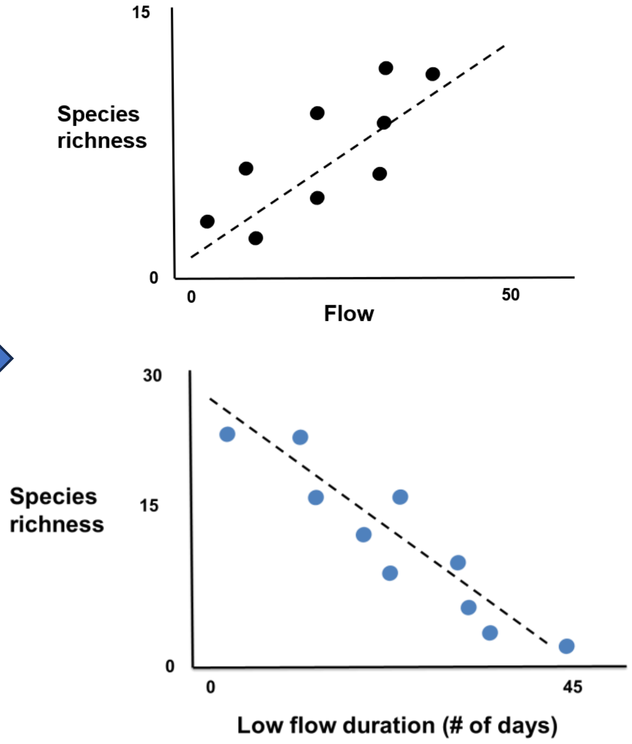




How will this work? Step 2



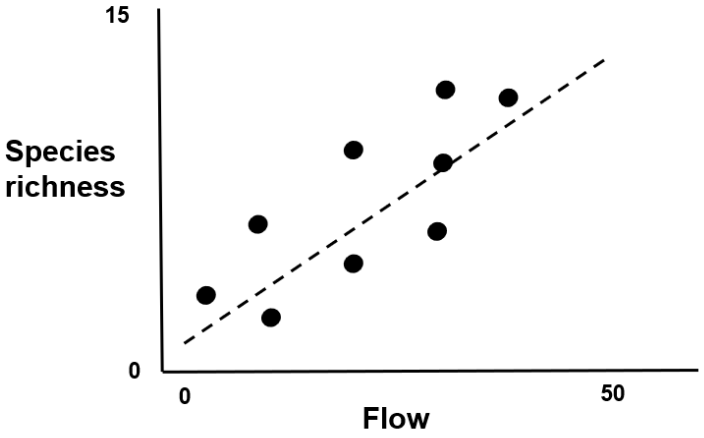
Working group



Ask RBC for a vote

How will this work? Step 3

Selected relationships



View SWAM results in a biological context

Scenario	Loss of species	Risk
MD	15%	Med
HD	25%	High

SWAM results

Scenario	Current	Predicted	% Change
MD	100	80	20%
HD	100	60	40%

Step 1: Quantify the flow-ecology relationships

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Quantifying flow–ecology relationships across flow regime class and ecoregions in South Carolina

Luke M. Bower [a,*], Brandon K. Peoples [b], Michele C. Eddy [c], Mark C. Scott [d]

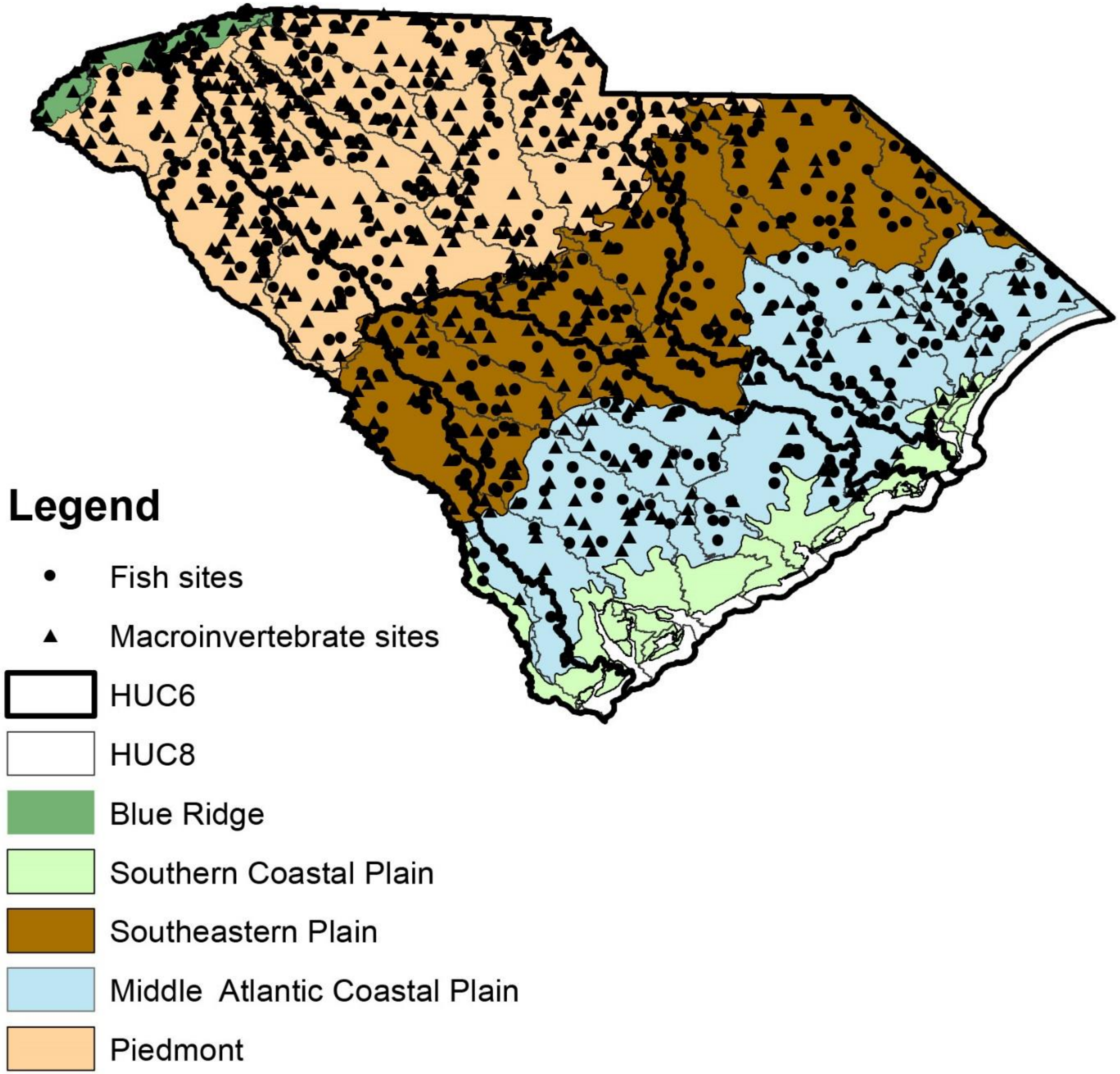
Framework

- The ecological limits of hydrologic alteration (ELOHA). Poff et al., 2010

Build a hydrologic foundation of streamflow and biological data

B. Classify natural river types

C. Model and select flow ecology relationships



Biological Data:

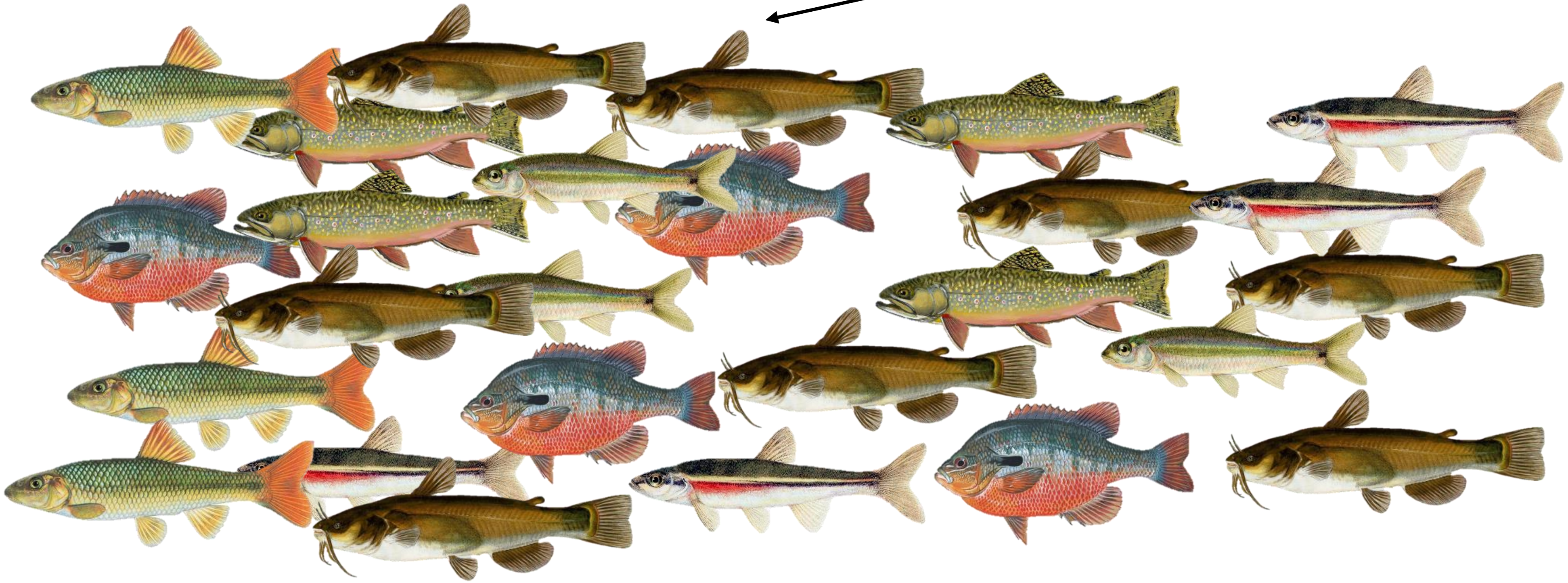
- 492 Fish sites (streams & rivers)
  - DNR
  - 8 biological response metrics

- 530 aquatic insect sites
  - DHEC
  - 6 biological response metrics

Characterizing aquatic diversity

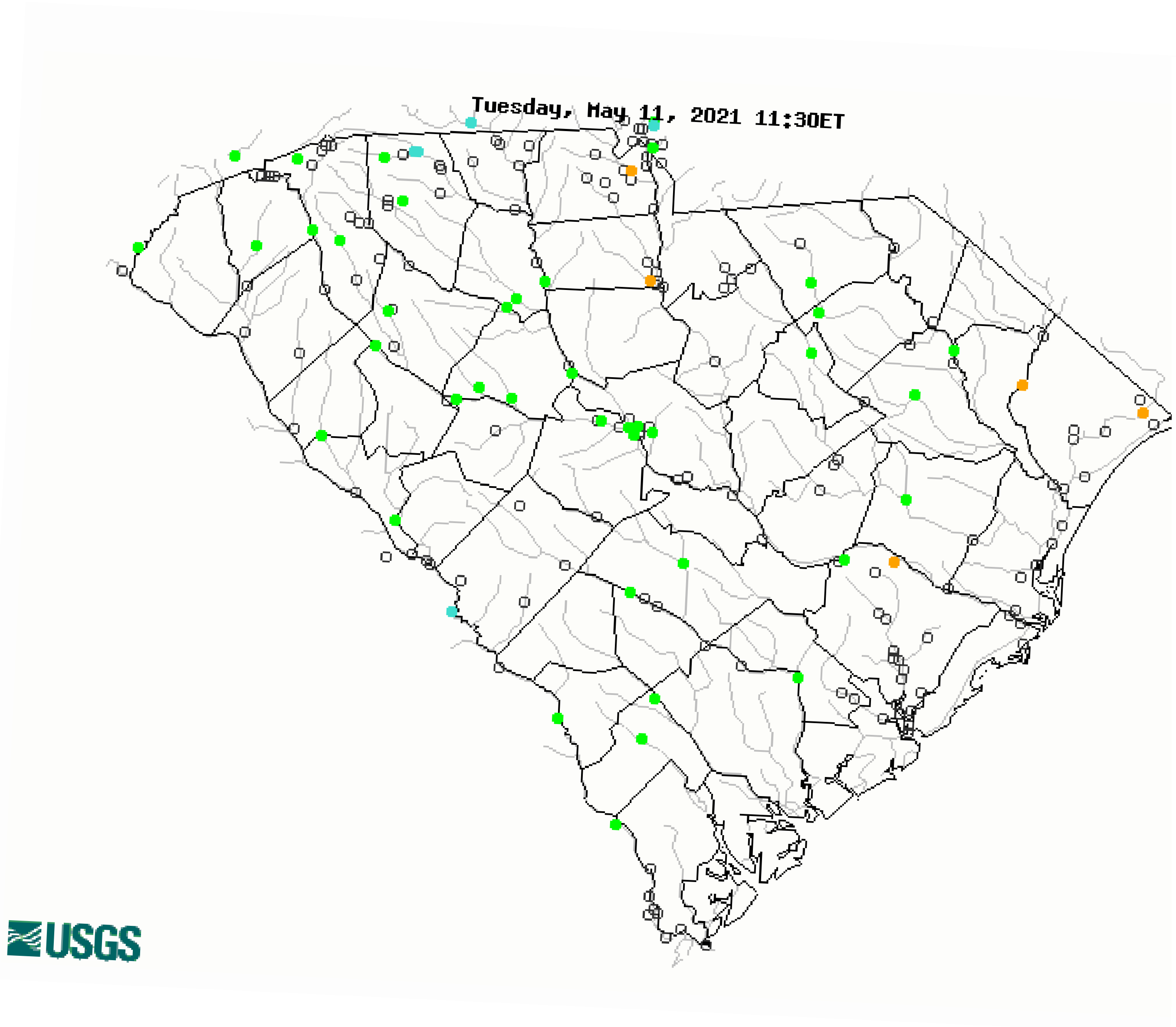
- **Species richness:** number of species
- **Shannon's Diversity:** Accounts for <u>percentages</u>

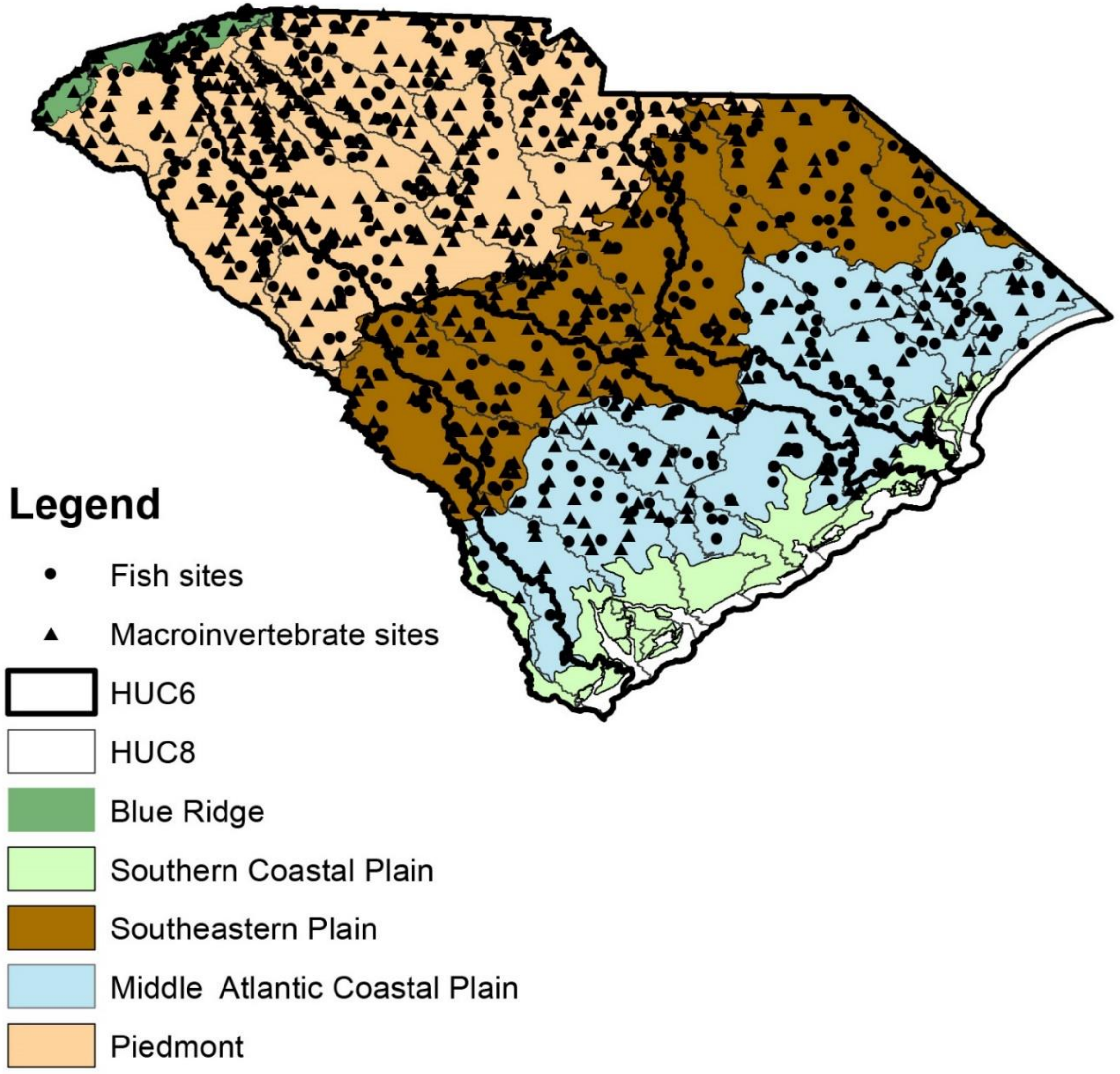
Tolerant species



Diverse biota = healthy ecosystem

Hydrologic data





Build a hydrologic foundation of streamflow data

Table 2. Model Geospatial Inputs

Data Set	Name	Resolution	Reference
Hydrology	Enhanced National Hydrography Dataset Version 2	2.1 km^2 within study area	Moore and Dewald, 2016
Land Cover	2016 National Land Cover Dataset	30-m grid	Jin et al., 2019
Climate	PRISM 4km Daily Temperature and Precipitation 1988–2018	4-km grid	PRISM Climate Group, 2019
Soils	Soil Survey Geographic Database (SSURGO)	1:12,000 to 1:63,360	USDA-NRCS, 2014
Subsurface Parameters	National Weather Service (NWS) for applications of the Sacramento Soil Moisture Accounting Model (SAC-SMA)	Approximately 4.7-km grid	Zhang et al., 2011

- WaterFALL model:
  - rainfall-runoff model 30-year period
  - Accounts for withdrawals, discharges, and reservoirs within the river network
  - 24 hydrologic metrics
  - Flow regime: Timing, magnitude, frequency, rate of change, and duration

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RESEARCH ARTICLE

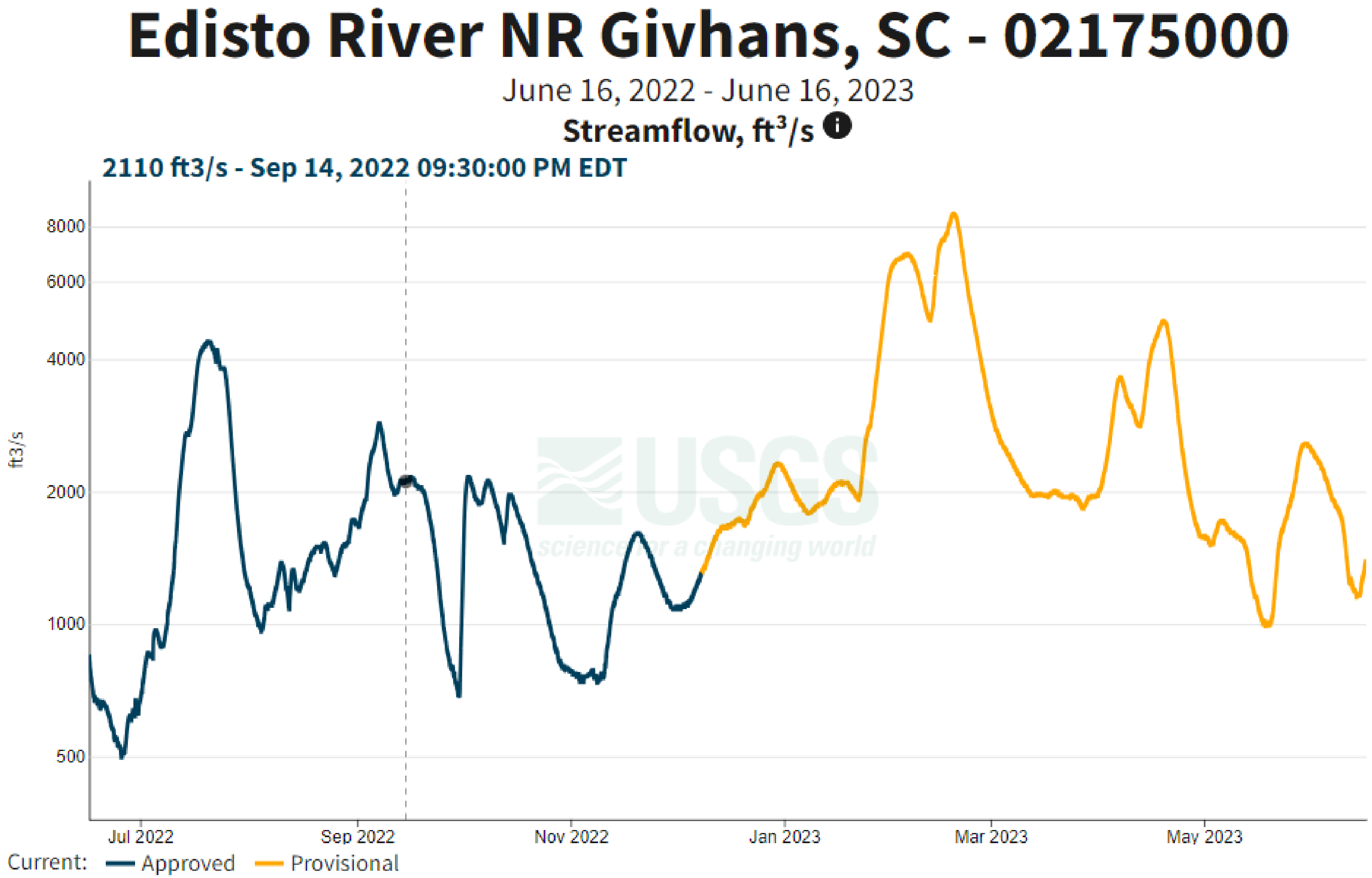
WILEY

Predictability of flow metrics calculated using a distributed hydrologic model across ecoregions and stream classes: Implications for developing flow–ecology relationships

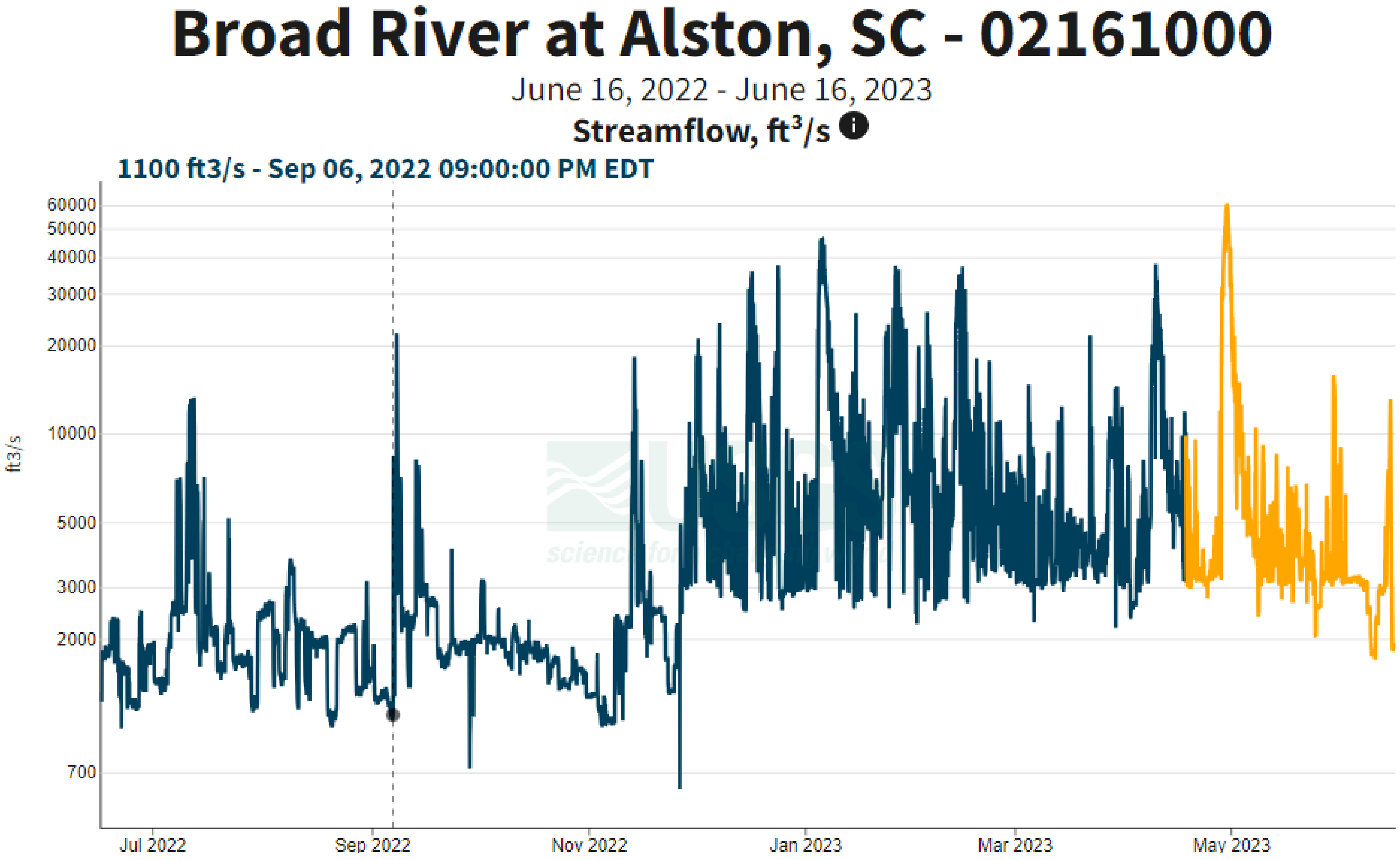
Michele C. Eddy[1] | Benjamin Lord[1] | Danielle Perrot[1] | Luke M. Bower[2] | Brandon K. Peoples[3]

Relevance of flow regime components

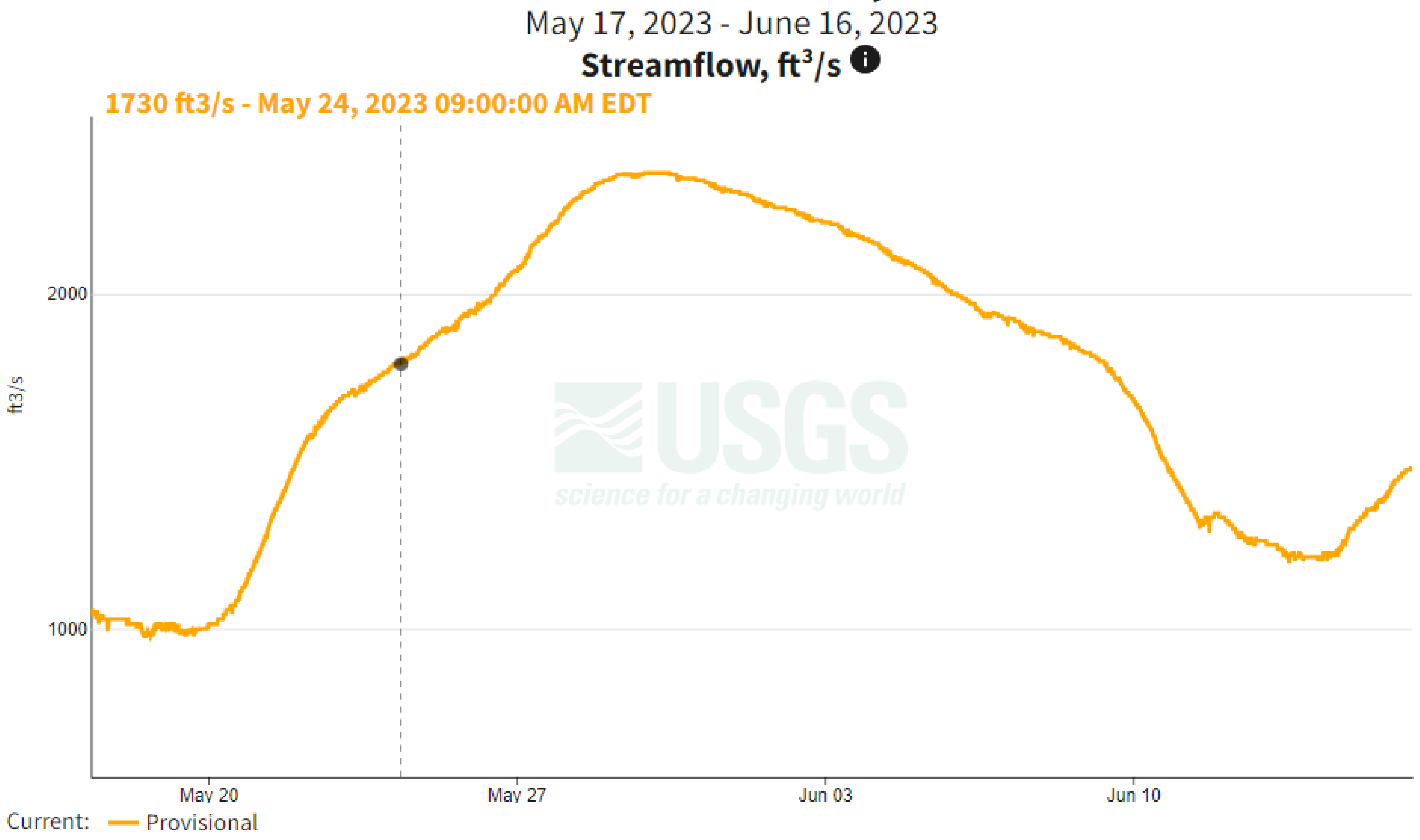
Flow regime components: magnitude, frequency, duration, timing, and rate



Relevance of flow regime components

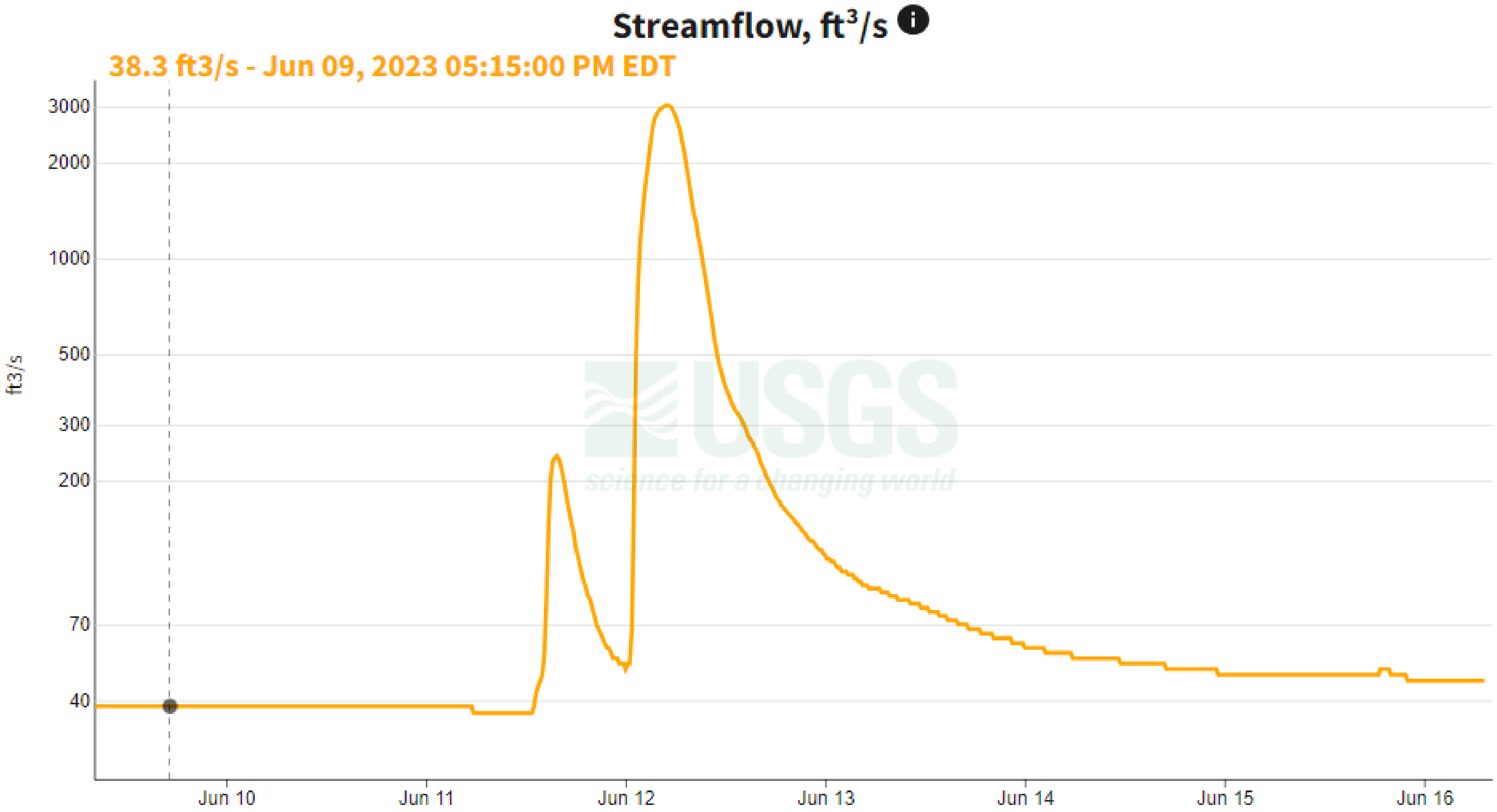


Edisto River NR Givhans, SC - 02175000



Reedy River Near Greenville, SC - 02164000

June 9, 2023 - June 16, 2023



Relevance of flow regime components

- Magnitude: MA1 (mean daily flow) and ML17 (base flow)
  - Alteration of habitat
  - Reduced water quality and higher mortality

- Duration: DL16 (duration of low
  - Alteration of connectivity
  - Increased duration of low water c

- Timing: TL1 (timing of low flow
  - Loss of access to habitats
  - Disruption of life-cycle cues (spa migration) and decreases in recru
  - Invasion of exotics

Framework

- The ecological limits of hydrologic alteration (ELOHA). Poff et al., 2010

A. Build a hydrologic foundation of streamflow and biological data

B. Classify natural river types

C. Model and select flow ecology relationships

2. Classify natural river types

A. **Flow-ecology relationships may differ among stream classes**

   A. Ecoregion

   B. Hydrologic class

Framework

- The ecological limits of hydrologic alteration (ELOHA). Poff et al., 2010

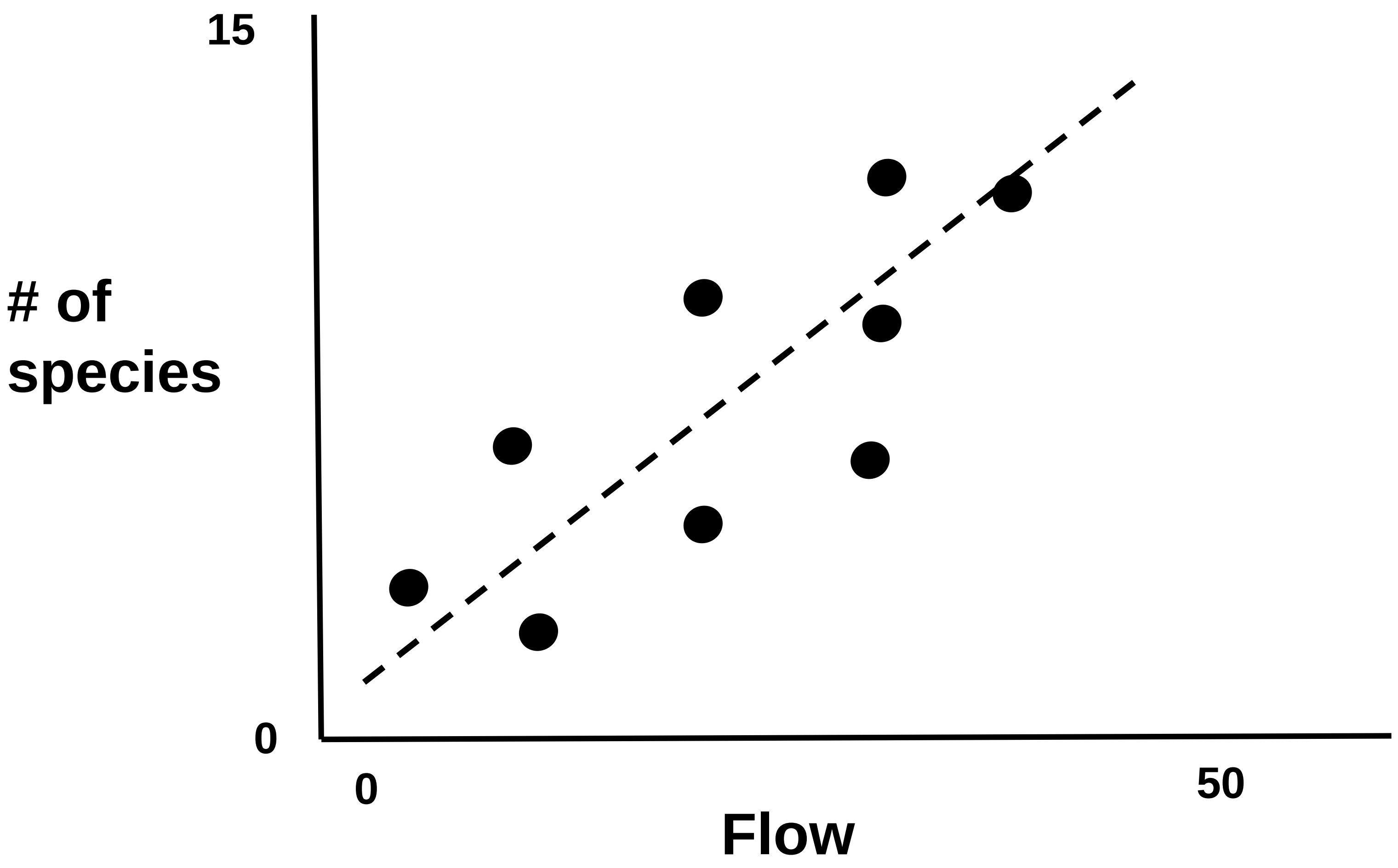
A. Build a hydrologic foundation of streamflow and biological data

B. Classify natural river types

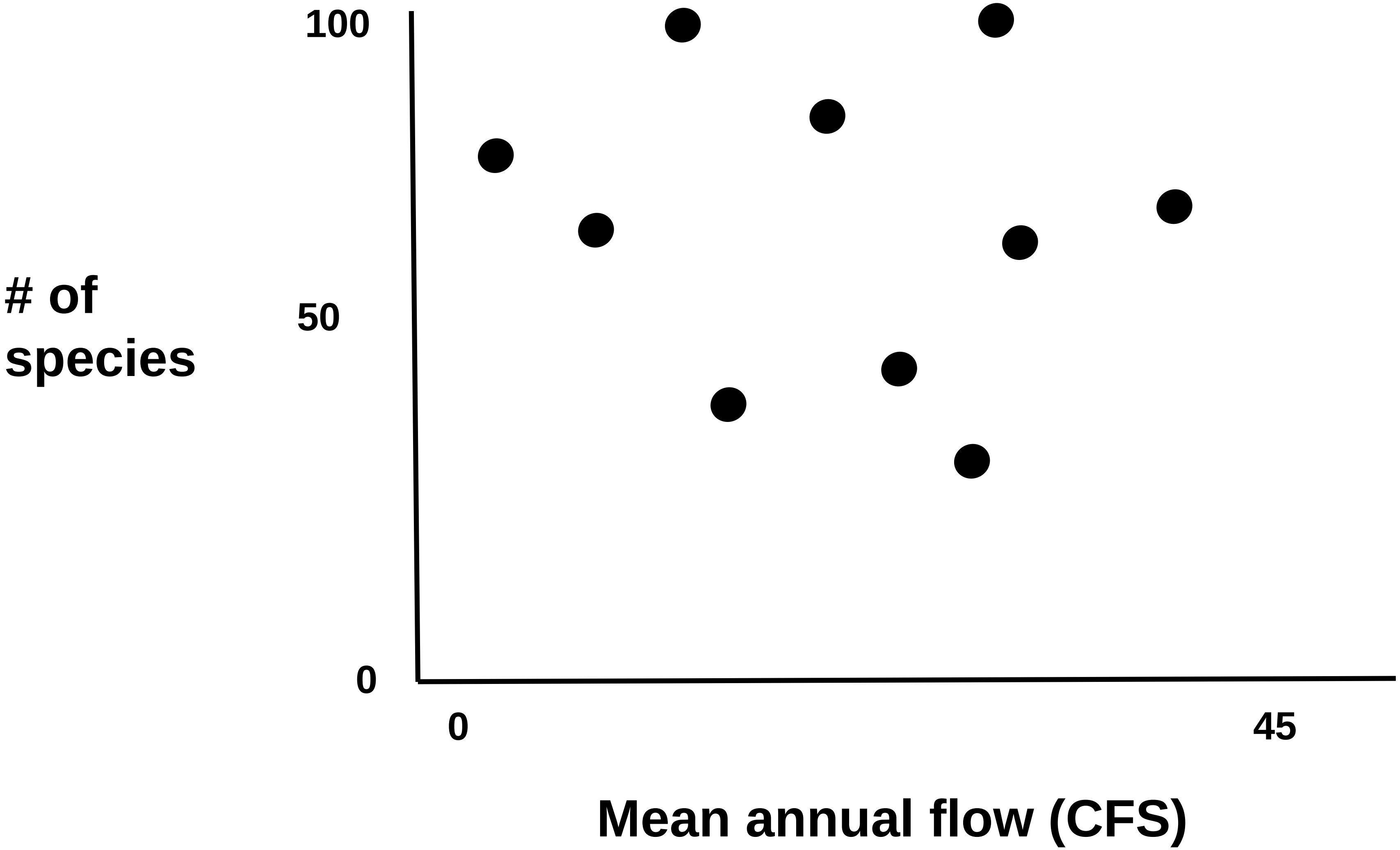
Model and select flow ecology relationships

Identify relationships: some are informative

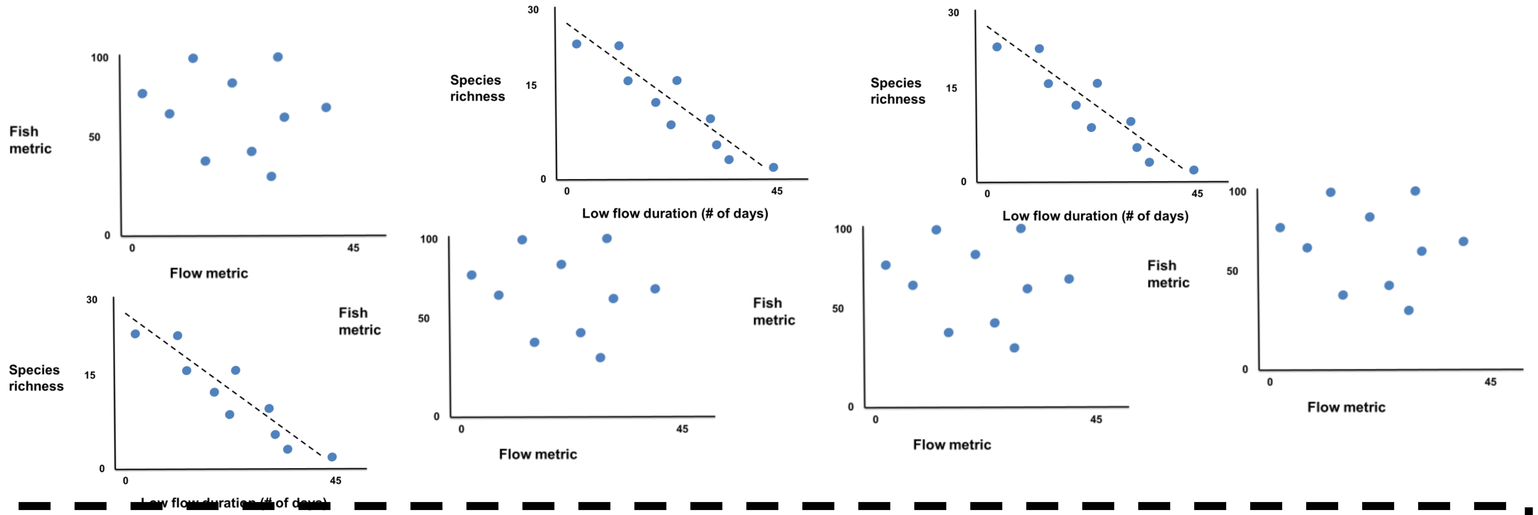
24 Flow metrics
14 Biotic metrics



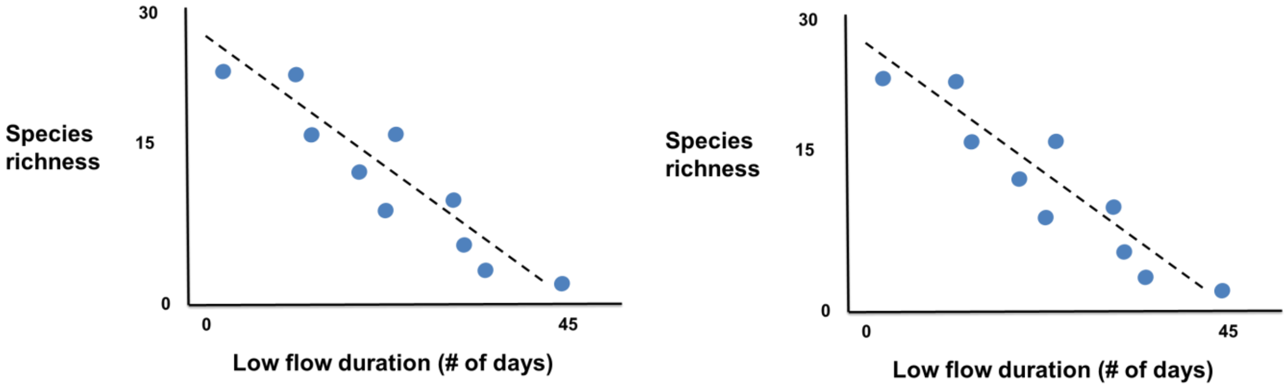
Identify relationships: some are not informative



Identify relationships: remove uninformative relationships



Filter: statistical modeling process

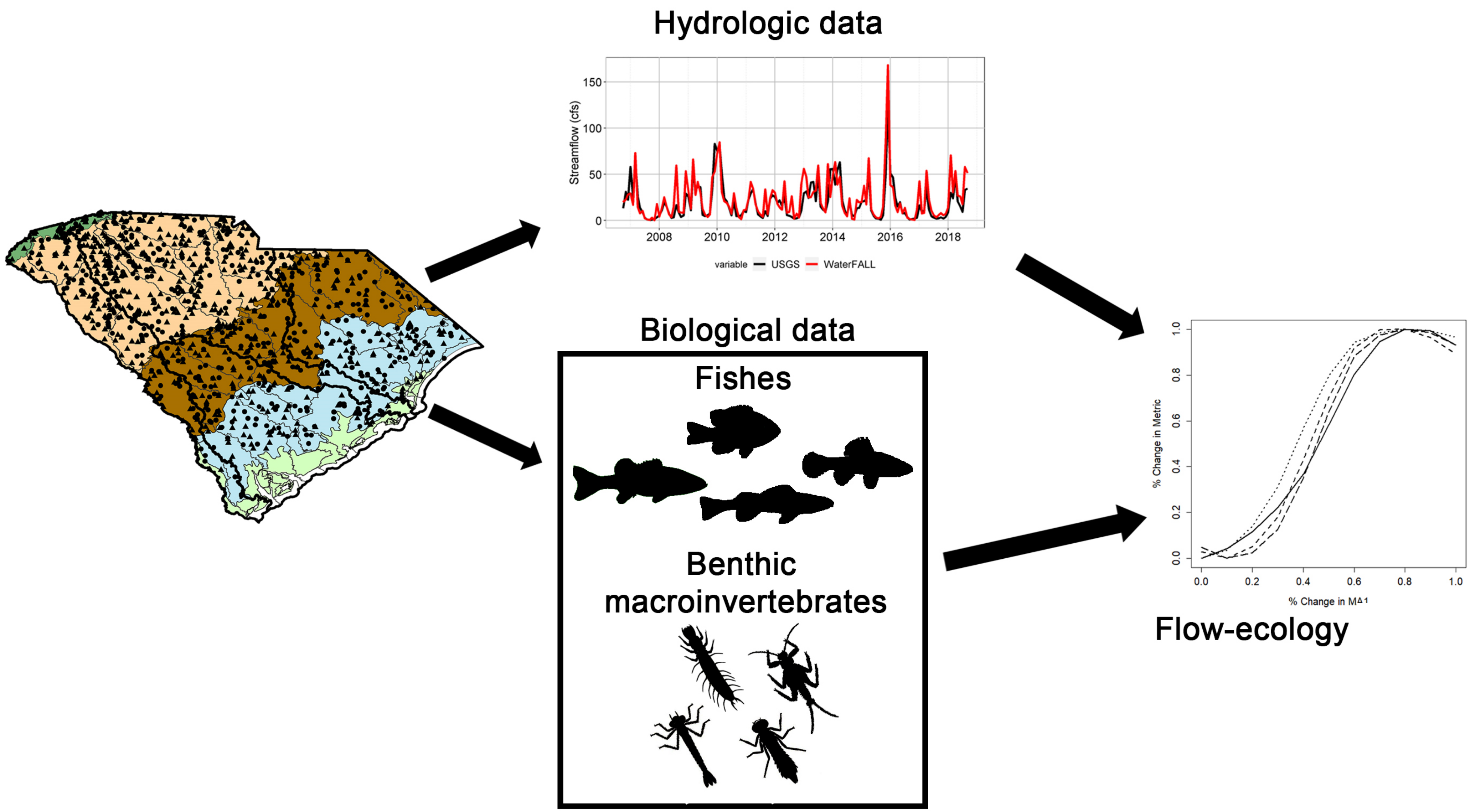


Results summary

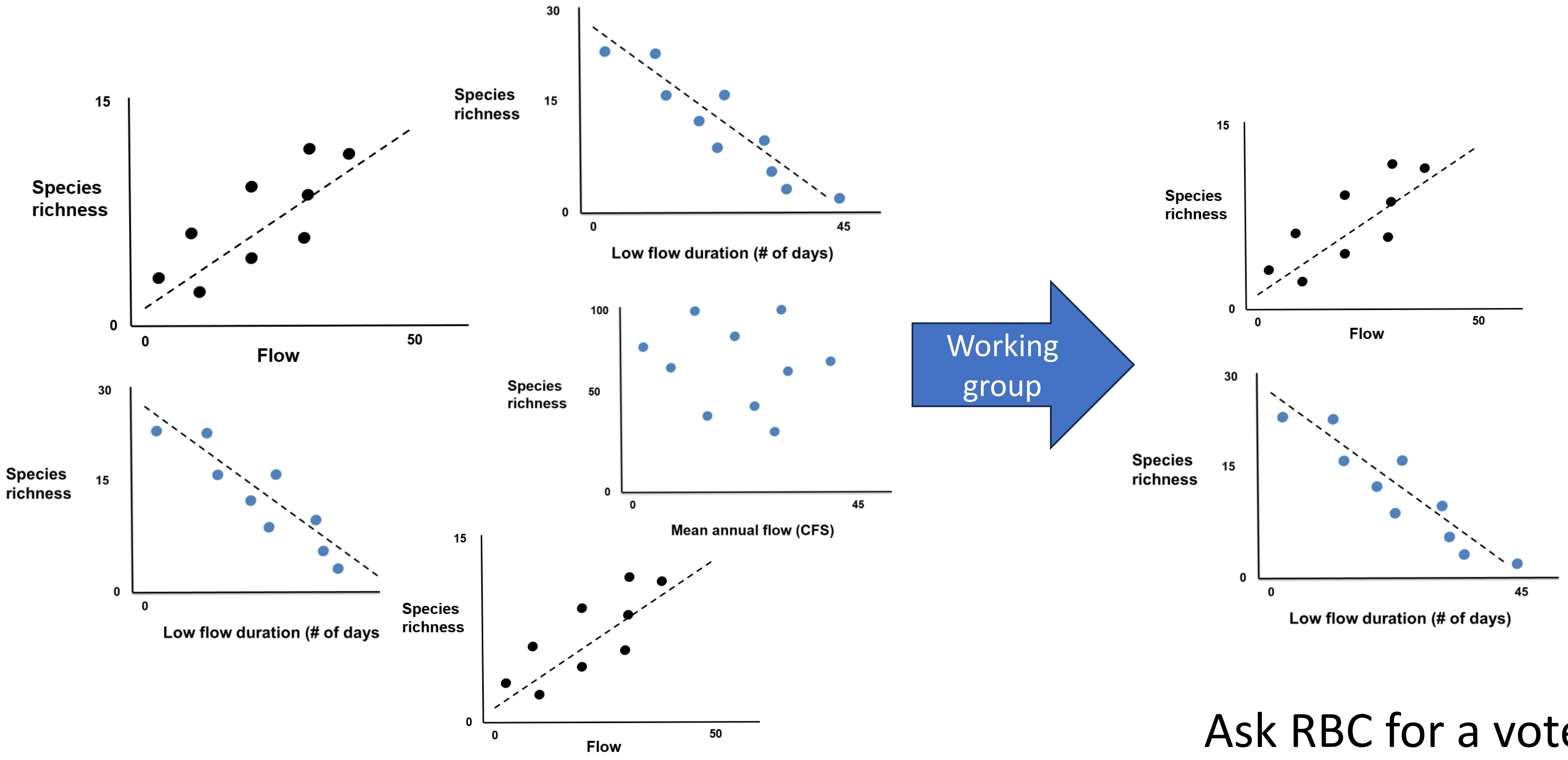
- We found >180 informative relationships across SC
  - Predicting responses
  - Defining biological response limits
- Many of these differed among stream classes
- All components of the flow regime were important to aquatic organisms
  - magnitude, frequency, duration, timing, and rate
- Next steps:
  - Identify those relevant to the Saluda
  - Present these proposed relationships to the RBC

Scenario	Loss of species	Risk
MD	15%	Med
HD	25%	High

How will this work? Step 1



How will this work? Step 2



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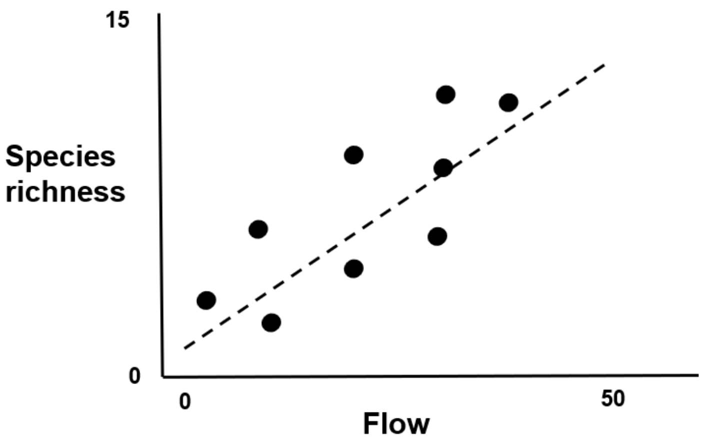
How will this work? Step 3

Selected relationships



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Questions?

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