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Functional Connections between Fish Communities and Hydrology in the Tennessee River Valley: A Conceptual Model

Rodney R. Knight, USGS Tennessee WSC
M. Brian Gregory, USGS Georgia WSC

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Tennessee Wildlife Resources Agency

Tennessee Department of Environment and Conservation
Water Pollution Control

U.S. Department of the Interior
U.S. Geological Survey

Study Description

Regional, biologically based study

- Unregulated streams in the Tennessee River Valley
- Includes fish community data
- Ecologically relevant hydrologic metrics
  - Used existing data

Stoneroller

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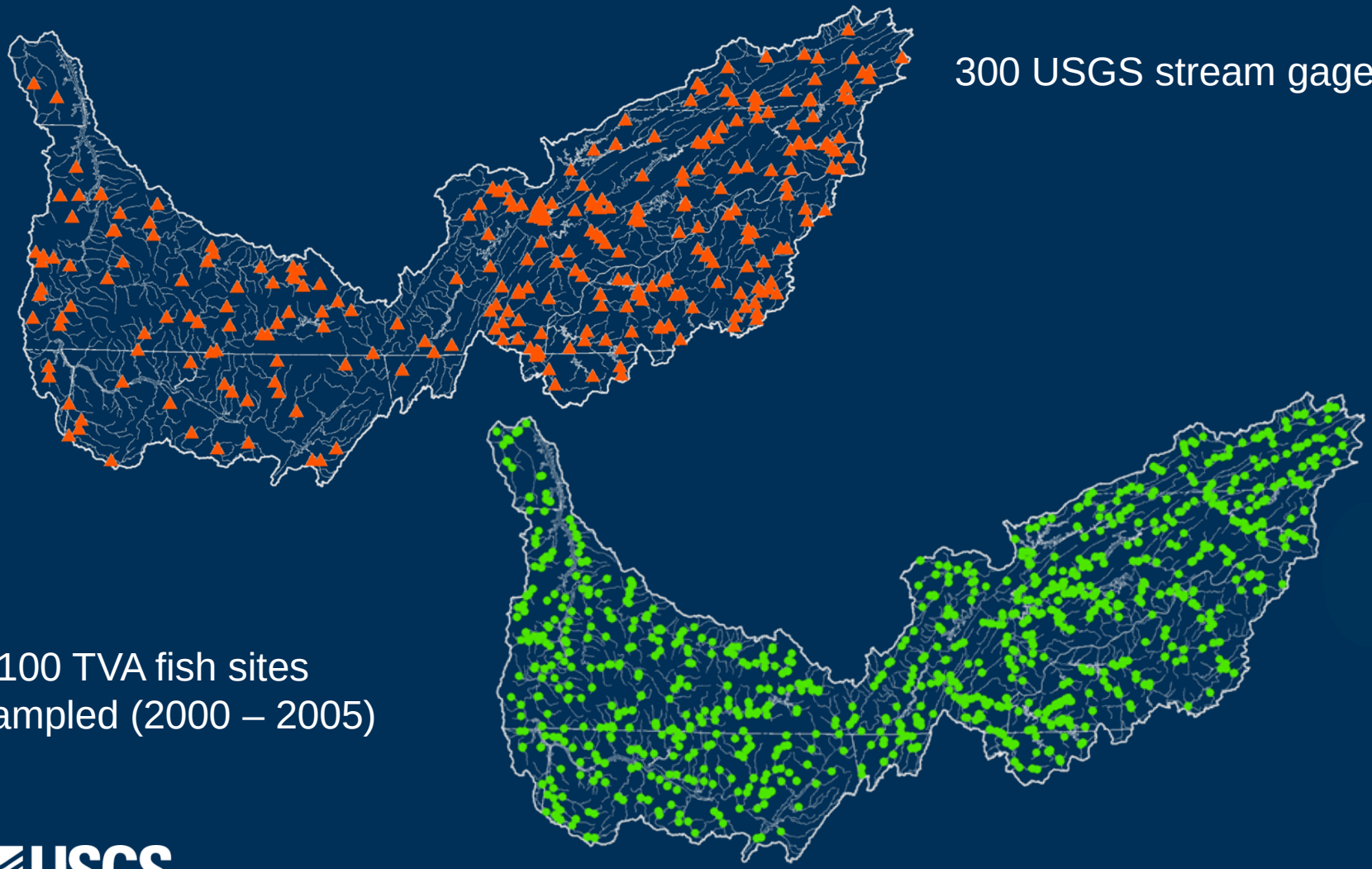
Data Sources



300 USGS stream gages

1,100 TVA fish sites
Sampled (2000 – 2005)

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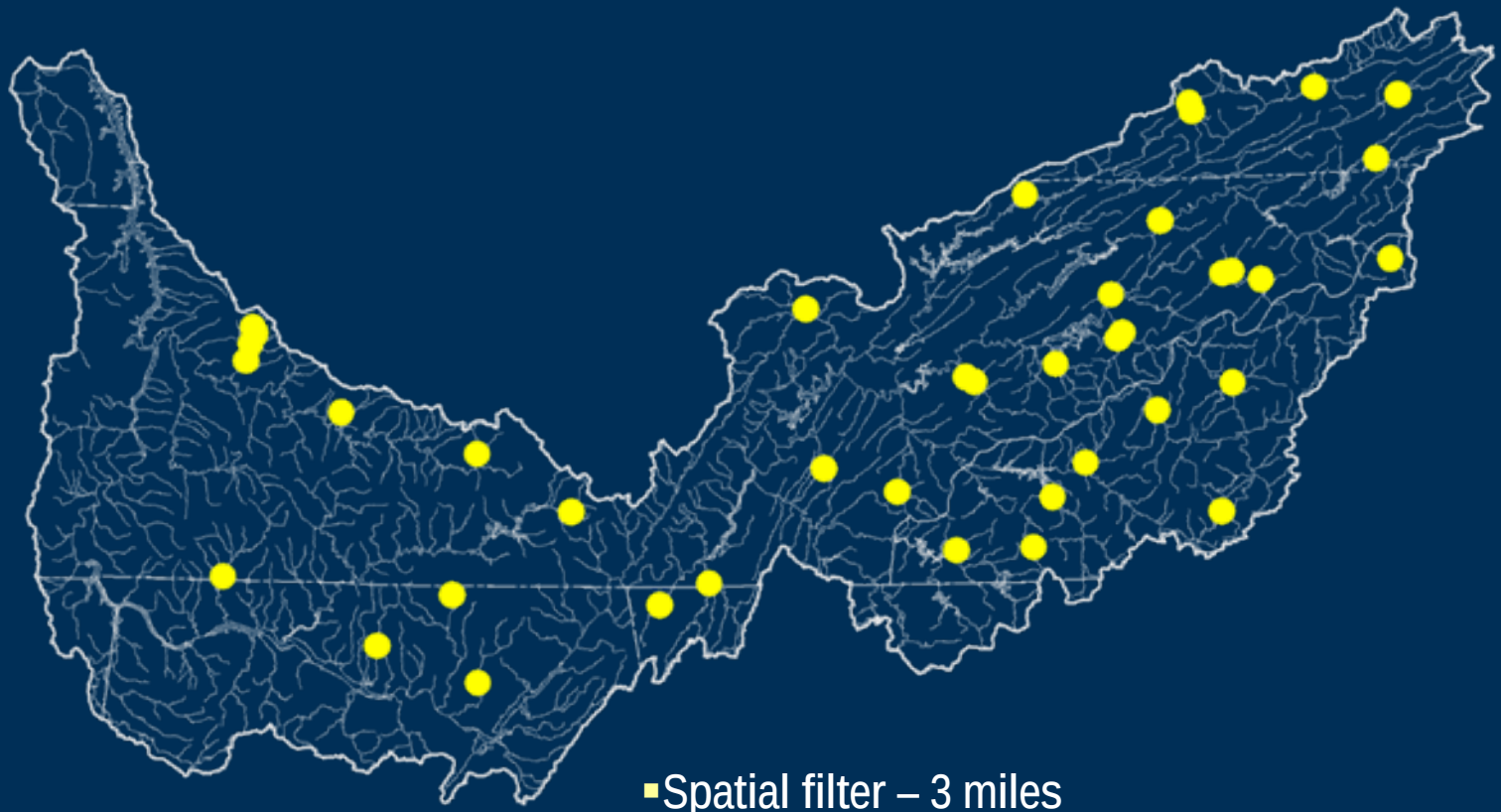
Data Analysis



- Spatial filter – 3 miles
- Temporal filter – concurrent collection
- 39 sites where fish and streamflow data co-located
- 30 – 300 square miles
- 90 hydrologic metrics for each site

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Data Analysis

- **Multidimensional Scaling (MDS)**
  - Uses similarity (Bray-Curtis) matrices to “map” sites
  - Explore fish community structure
- **Biotic and environmental matching (BEST)**
  - Maximizes rank correlations between data set matrices
  - Selects influential streamflow metrics
- **Quantile Regression**
  - Define thresholds of IBI metrics (floors and ceilings)
  - Specialized insectivore
    - Sensitive species
    - Link between tropic levels

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Results

- **Magnitude**
  - March streamflow variability
  - Mean annual runoff
  - Maximum October streamflow
  - Baseflow
  - Variability in baseflow
- **Timing**
  - Constancy
  - Annual min / max streamflow timing
- **Duration**
  - Average 30-day maximum
  - Variability of annual minimum streamflow
  - Variability in high-pulse duration
- **Frequency**
  - Variability in low-pulse count
  - Frequency of moderate flooding
- **Rate of Change**
  - Number of days with increasing streamflow
  - Streamflow recession and flow reversal rate
  - Reversal of flow direction

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Constancy

- **Hydrologic Significance:**
  - **Stability of streamflow from day to day**
  - **Constantly wetted perimeter**
  - **Constant habitat availability**

- **Ecological Significance:**
  - **Colonization of fish fry** (Puckridge et al., 2000)
  - **Periphyton and invertebrate density and richness** (Clausen and Biggs, 1997 & 2000)
  - **Current study – SI scores increased with high constancy**

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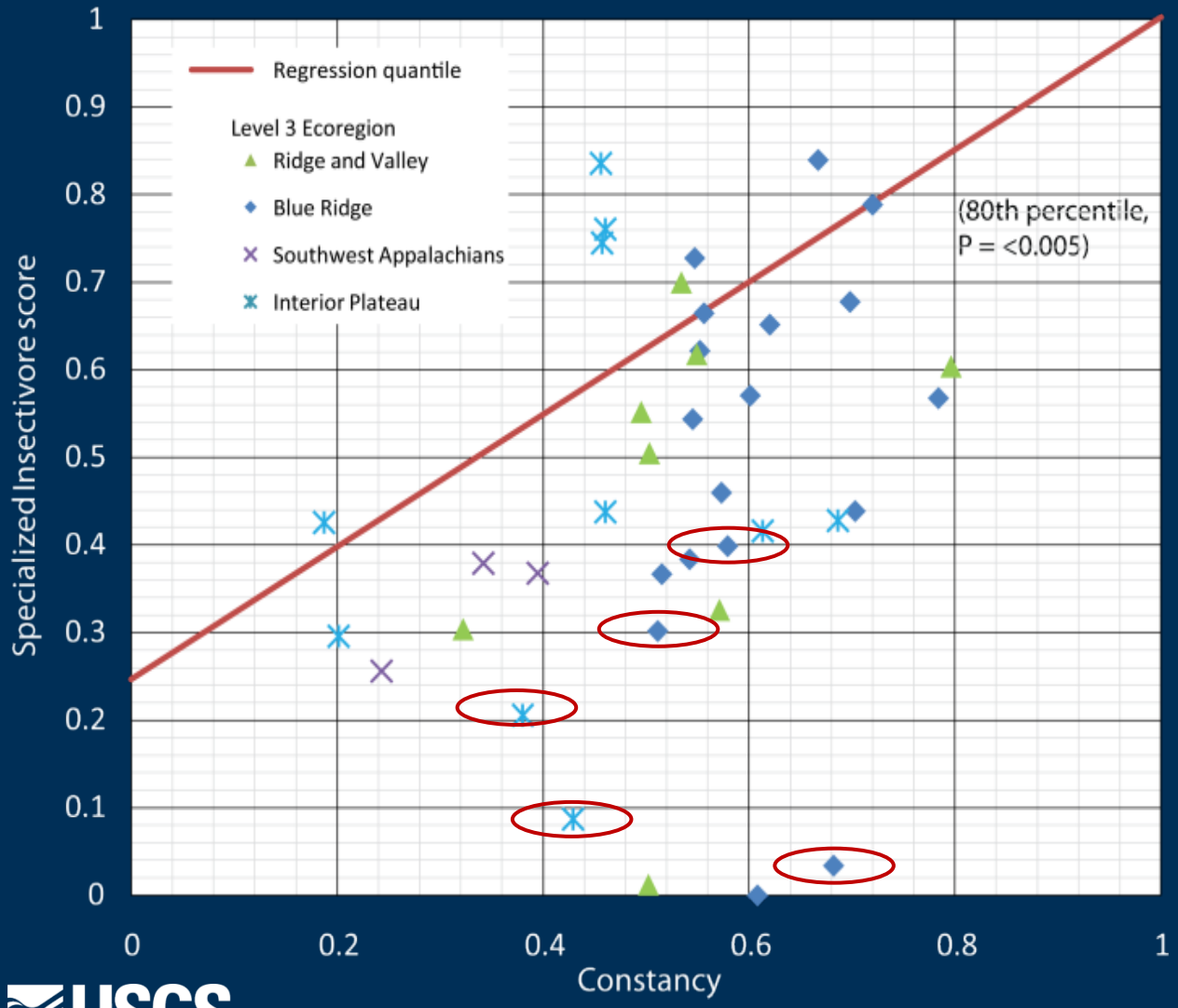
Intervening Factors



- **Ecoregion:**
  - Physiography
  - Hydrography
- **Quantile Regression**
  - Identifies boundaries
  - Intervening factor analysis
- **Intervening Factors**
  - Landuse
    - Agriculture > 20%
  - Water Quality
    - Elevated nutrients
    - Sediment

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Frequency of Moderate Flooding

- Hydrologic Significance:
  - Frequency of event > 3 times annual median flow
  - Stimulate, not destroy habitat
  - Velocity and power to remove silt
  - Increases water clarity – important to sight feeding fish
  - Removes embeddedness - interstitial zones cleared

  - Ecological Significance:
  - Salmonid nesting (Greig et al., 2005)
  - Decreased frequency ~ increased substrate stability
    (Sagar, 1986; Death and Winterbourn, 1995; Grimm and Fisher, 1989)
  - Current study – SI scores increased with decreased frequency

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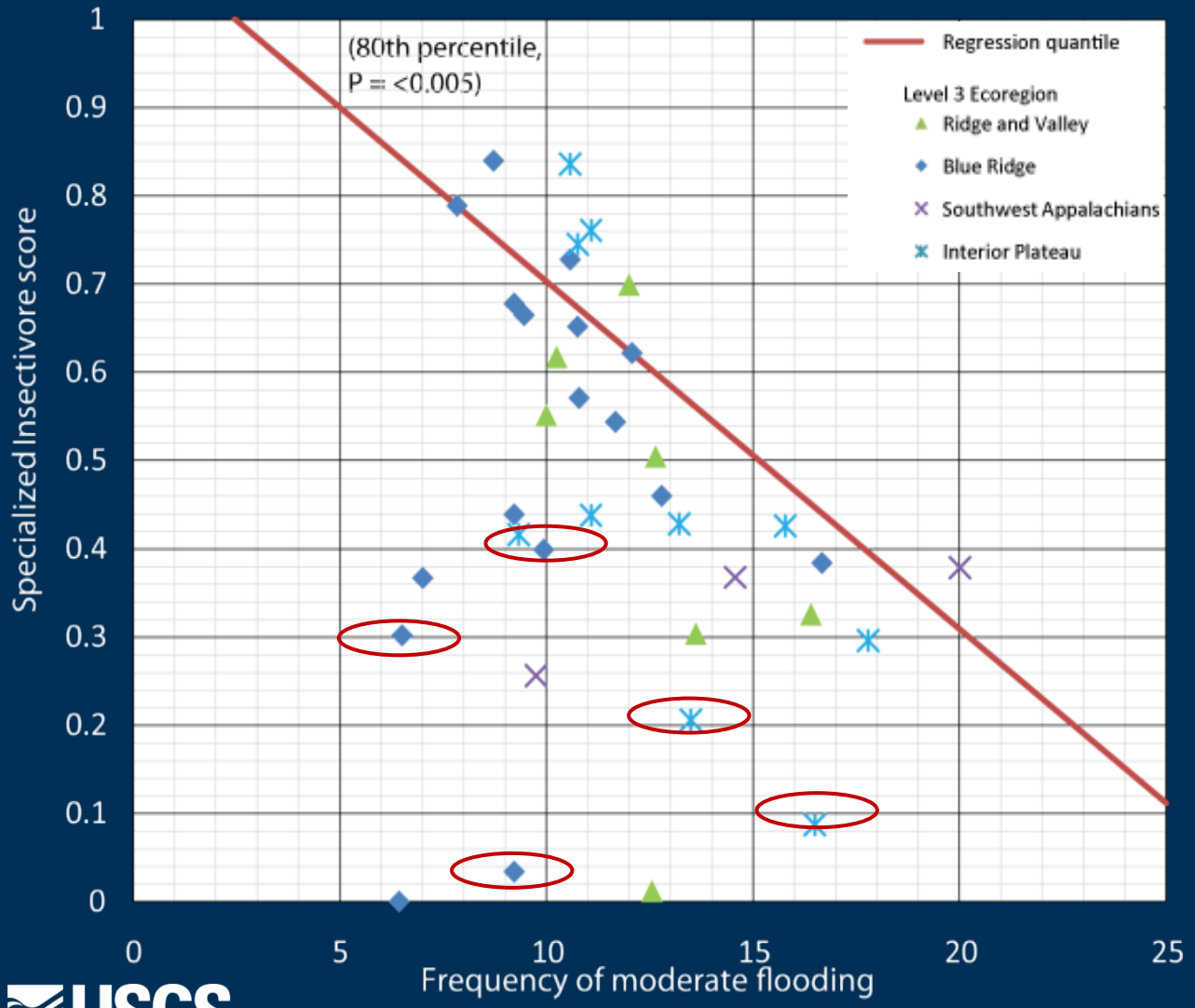
Intervening Factors



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Rate of Streamflow Recession

- **Hydrologic Significance:**
  - **Disconnected pools**
  - **Quick recession linked with stream bank failure**

  - **Ecological Significance:**
    - **Hydrologic barriers** (Freeman et al., 2007; Northcote and Hinch, 2004)
    - **Invertebrate drift** (Moog, 2006; Cushman, 1985; Petts et al., 1984)
    - **Stream bank failure** (Whiting, 2002)
    - **Current study – SI scores increased with slower recession**

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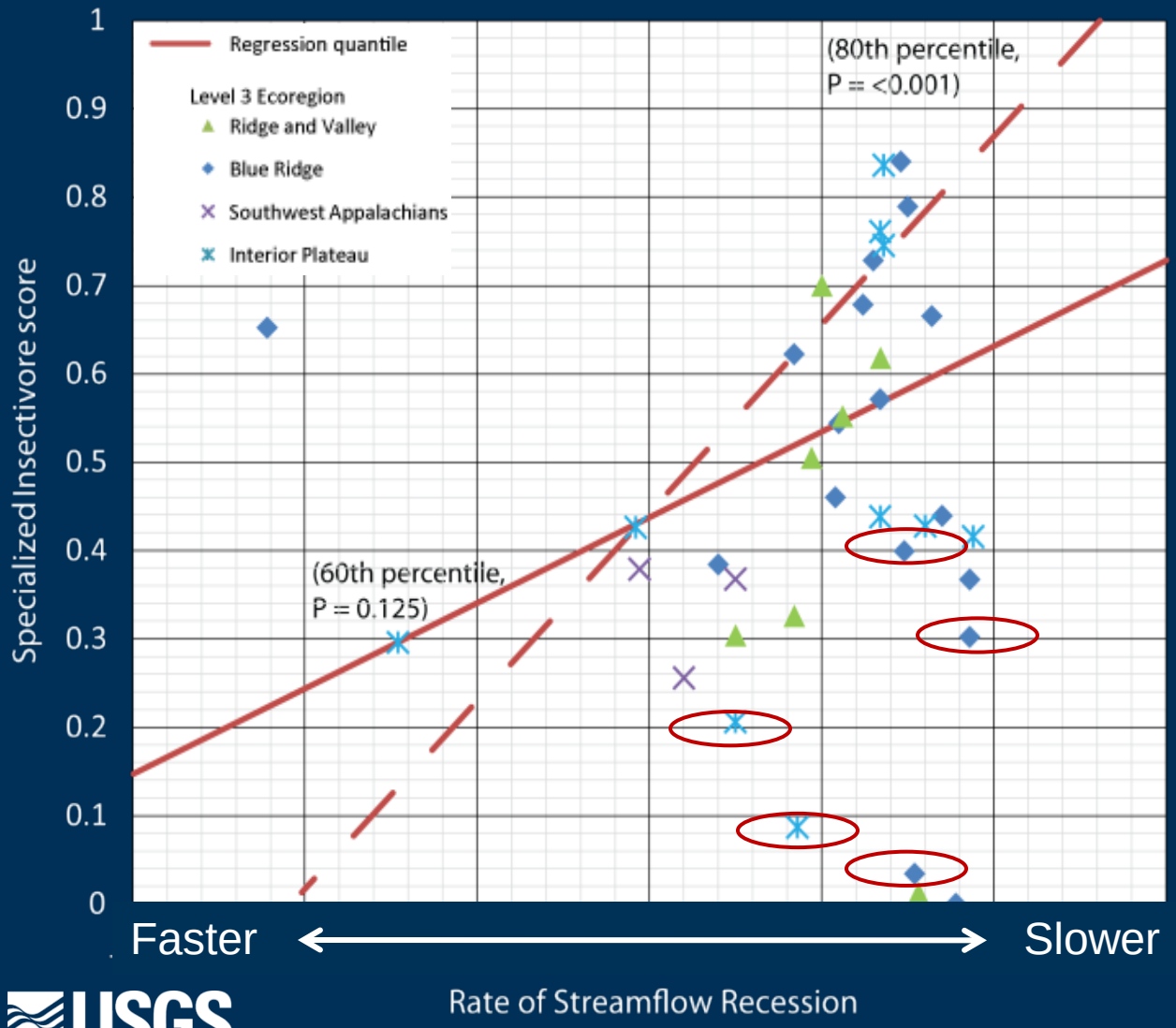
Intervening Factors



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Conclusions & Future Directions

- Hydrologic metrics are limiting factors
- Other environmental factors control fish response
- Land use, water quality, ecoregion also limit

- Publish conceptual model – *Ecohydrology*
- Phase 2 – Develop predictive tool for ungaged sites
- Phase 3 – Evaluate existing fish data using predictions

Mountain Madtom

Boulder Darter

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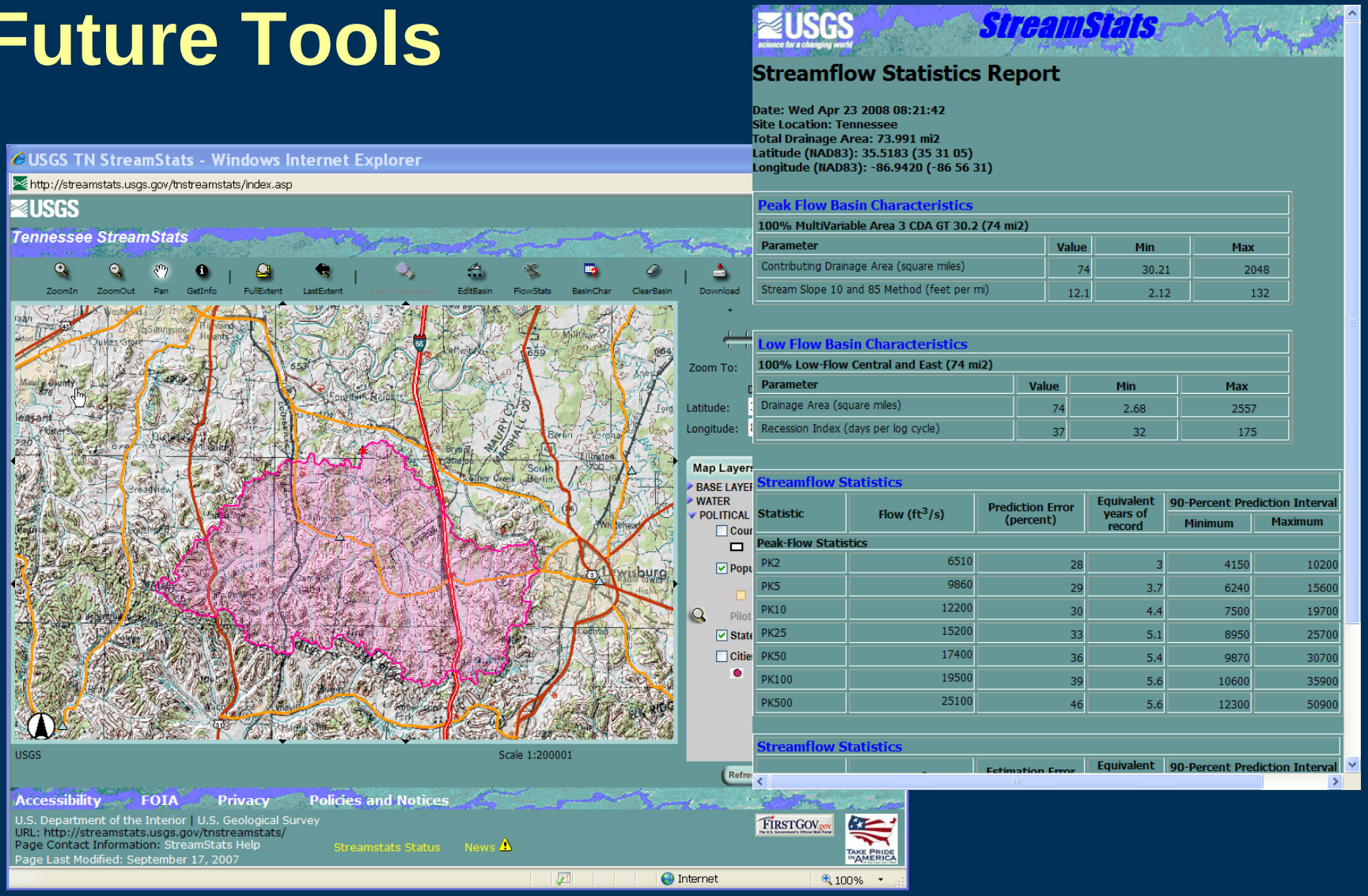
Future Tools



Technical Advisory Committee

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- Brian Gregory, USGS
- Sally Palmer, TNC
- Amy Wales, TVA
- Tim Wilder, TDEC
- Kim Elkin, TWRA
- Bill Wolfe, USGS
- Steve Alexander & Geoff Call, US FWS
- Sue Ferguson, COE
- Mike Sale, ORNL

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OAK RIDGE National Laboratory

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TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
Water Pollution Control

TENNESSEE WILDLIFE RESOURCES AGENCY


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Constancy

Flow bins	1	2	3	4	…	…	…	363	364	365	Y
≤ .1 x log(mean flow)	2	0	0	0				2	3	0	7
.1*log(flow) – .25*log(flow)	5	6	8	6				4	6	8	43
.25*log(flow) – .5*log(flow)	6	4	5	3				7	5	4	34
…											
1.75*log(flow) – 2*log(flow)		1						2			3
2*log(flow) – 2.25*log(flow)			1								1
≥2.25*log(flow)											
	13	11	14	9				15	14	12	88 (total)

$$\text{Constancy} = 1 - \left[\frac{-\sum_{i=1}^{365} \left[(Y_i / \text{total}) * \log (Y_i / \text{total}) \right]}{\log (11)} \right]$$

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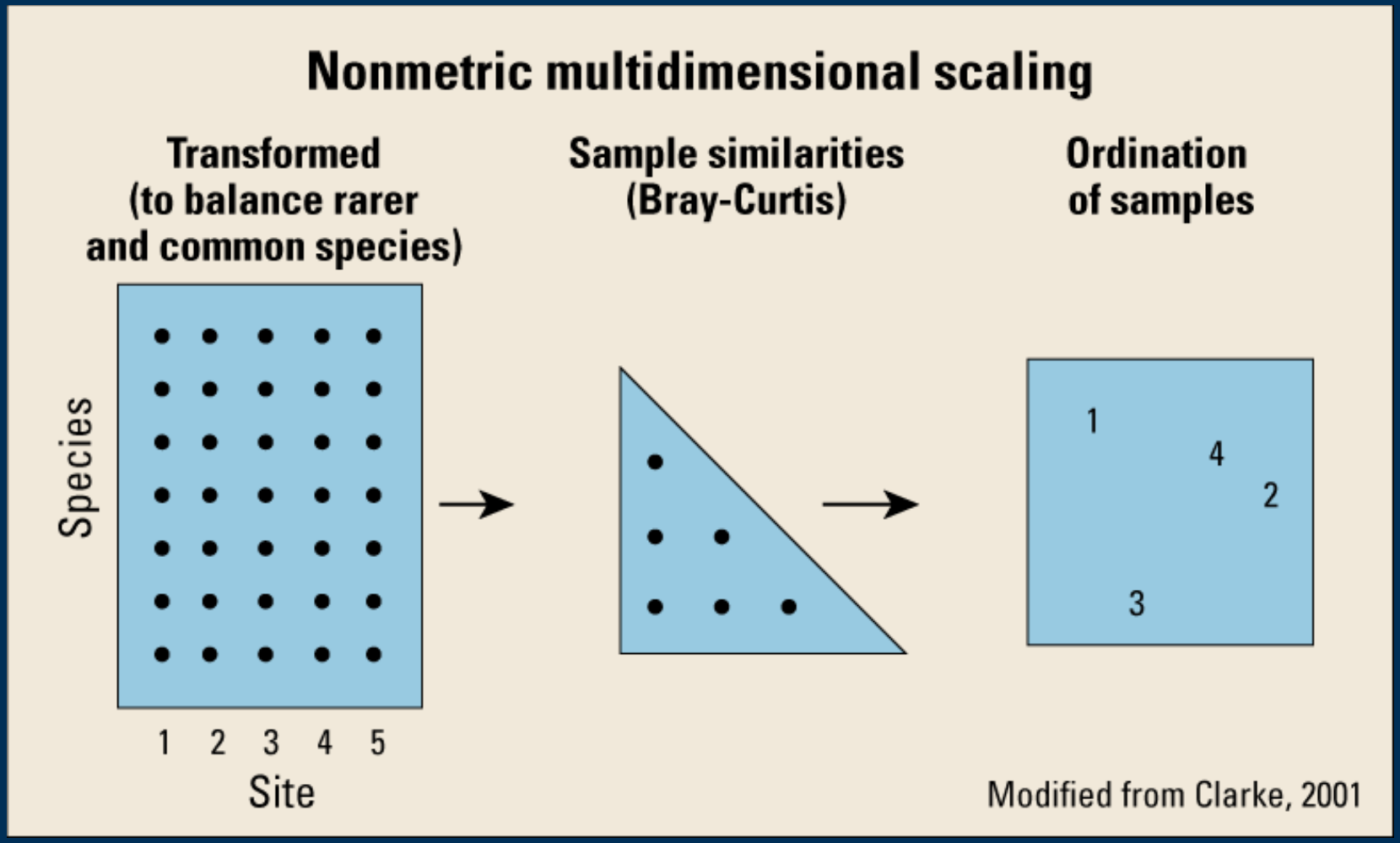

A Map of the Biological Community

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Georgia Mileage Chart – Euclidean Distance Matrix

	ALBANY	ATHENS	ATLANTA	AUGUSTA	BAINBRIDGE	BRUNSWICK	COLUMBUS	CORDELE	DALTON	DUBLIN	GAINESVILLE	LAGRANGE	MACON	MILLEDGEVILLE	ROME	SAVANNAH	TIFTON	VALDOSTA	WAYCROSS
ALBANY																			
ATHENS	200																		
ATLANTA	174	66																	
AUGUSTA	210	101	157																
BAINBRIDGE	57	257	231	267															
BRUNSWICK	172	256	274	189	198														
COLUMBUS	86	167	109	217	124	255													
CORDELE	40	159	144	170	97	170	93												
DALTON	260	132	88	245	305	362	181	232											
DUBLIN	112	119	139	98	168	147	141	72	227										
GAINESVILLE	227	39	53	140	282	298	162	187	93	158									
LAGRANGE	129	131	68	213	167	268	44	136	137	149	121								
MACON	107	92	84	124	164	189	93	67	172	55	120	93							
MILLEDGEVILLE	138	72	93	93	195	194	124	98	181	47	107	124	31						
ROME	223	129	68	225	261	340	138	208	43	208	99	94	152	160					
SAVANNAH	216	214	256	133	249	78	252	174	344	124	252	266	172	171	324				
TIFTON	42	202	183	197	84	129	128	41	271	101	228	170	108	139	250	176			
VALDOSTA	80	247	234	216	84	118	166	88	322	137	275	209	148	177	297	167	47		
WAYCROSS	113	230	240	177	145	57	198	113	328	111	265	239	155	160	308	104	71	61	

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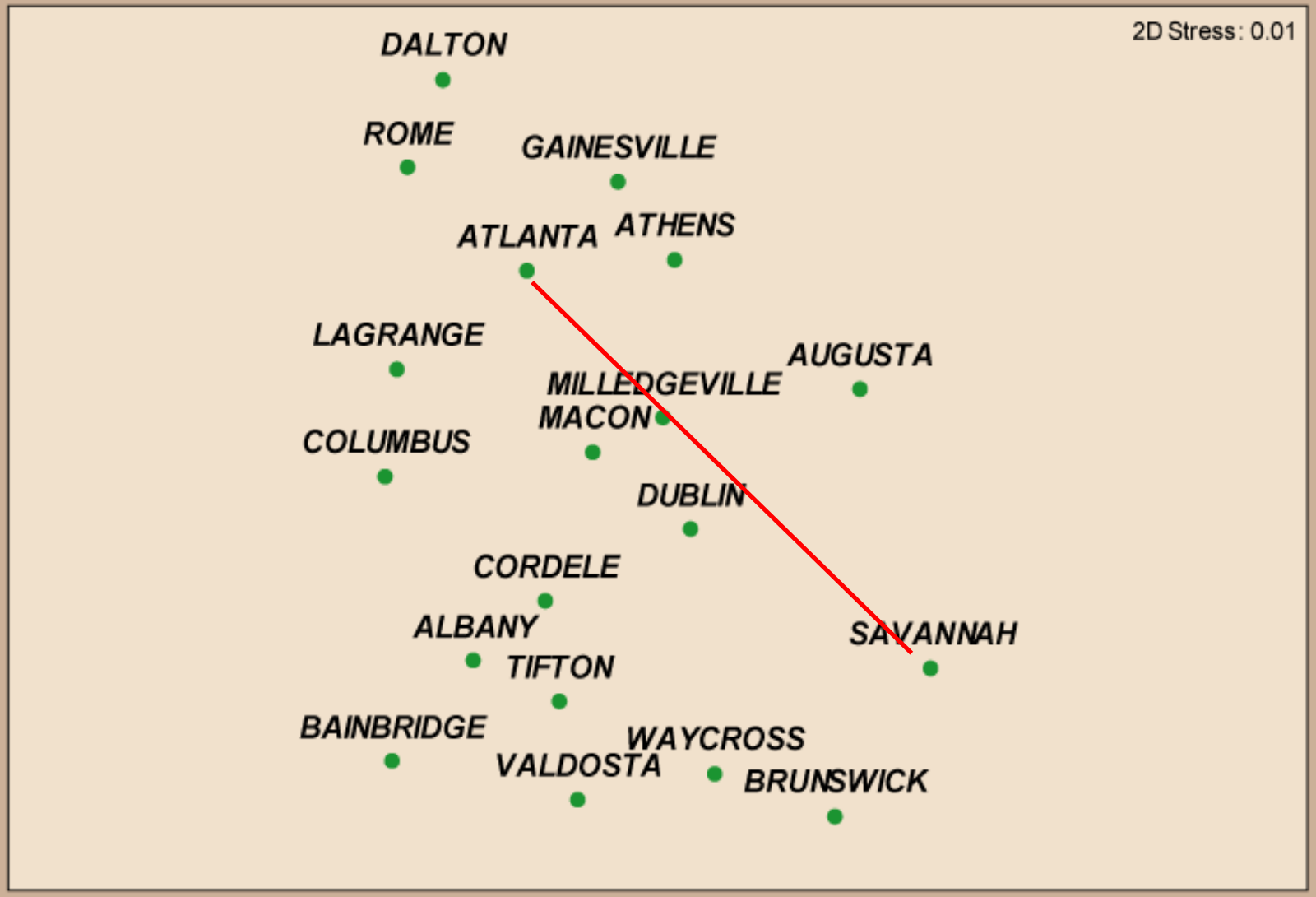
MDS Ordination of Georgia Cities

(Based on between city road miles)



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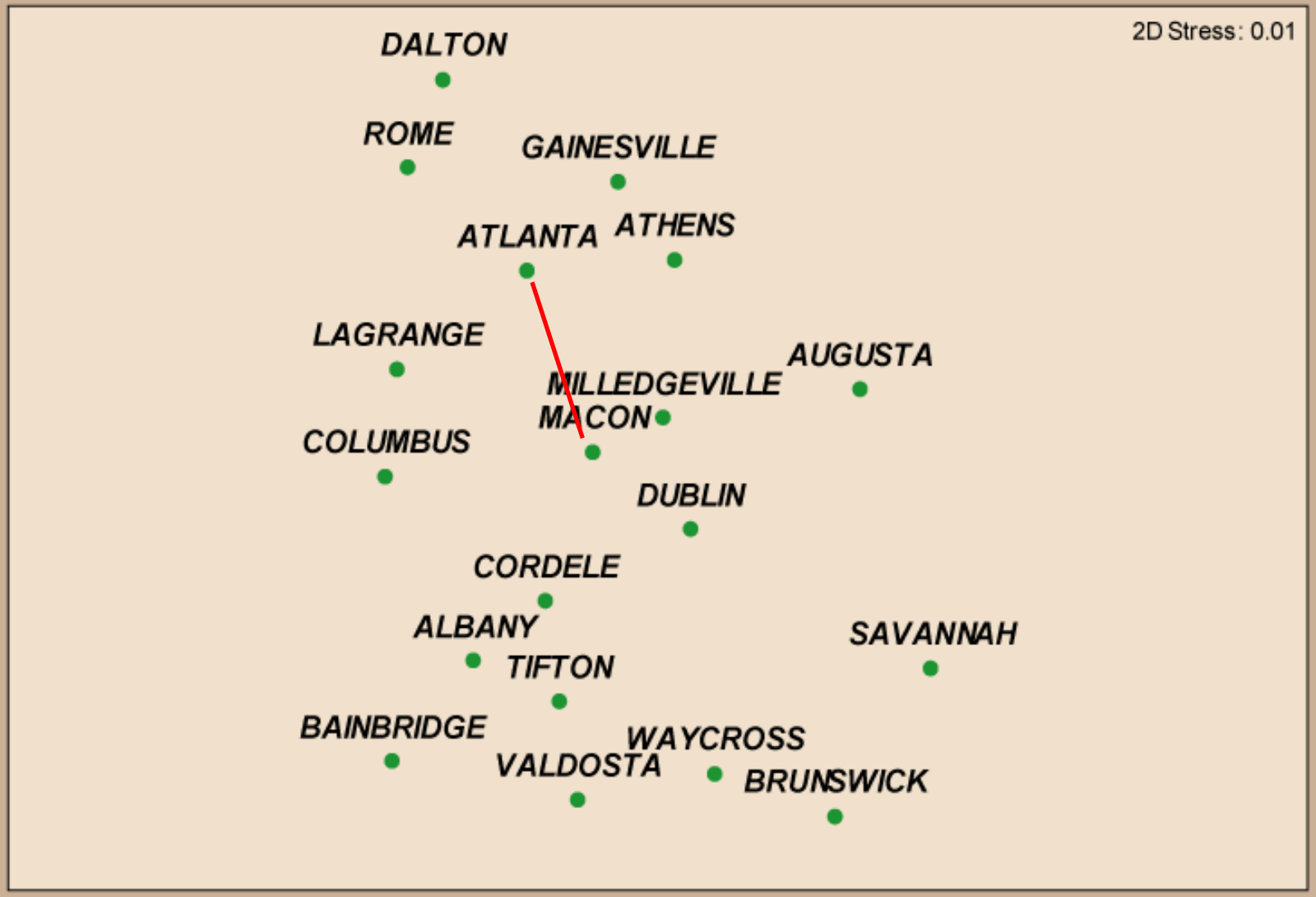
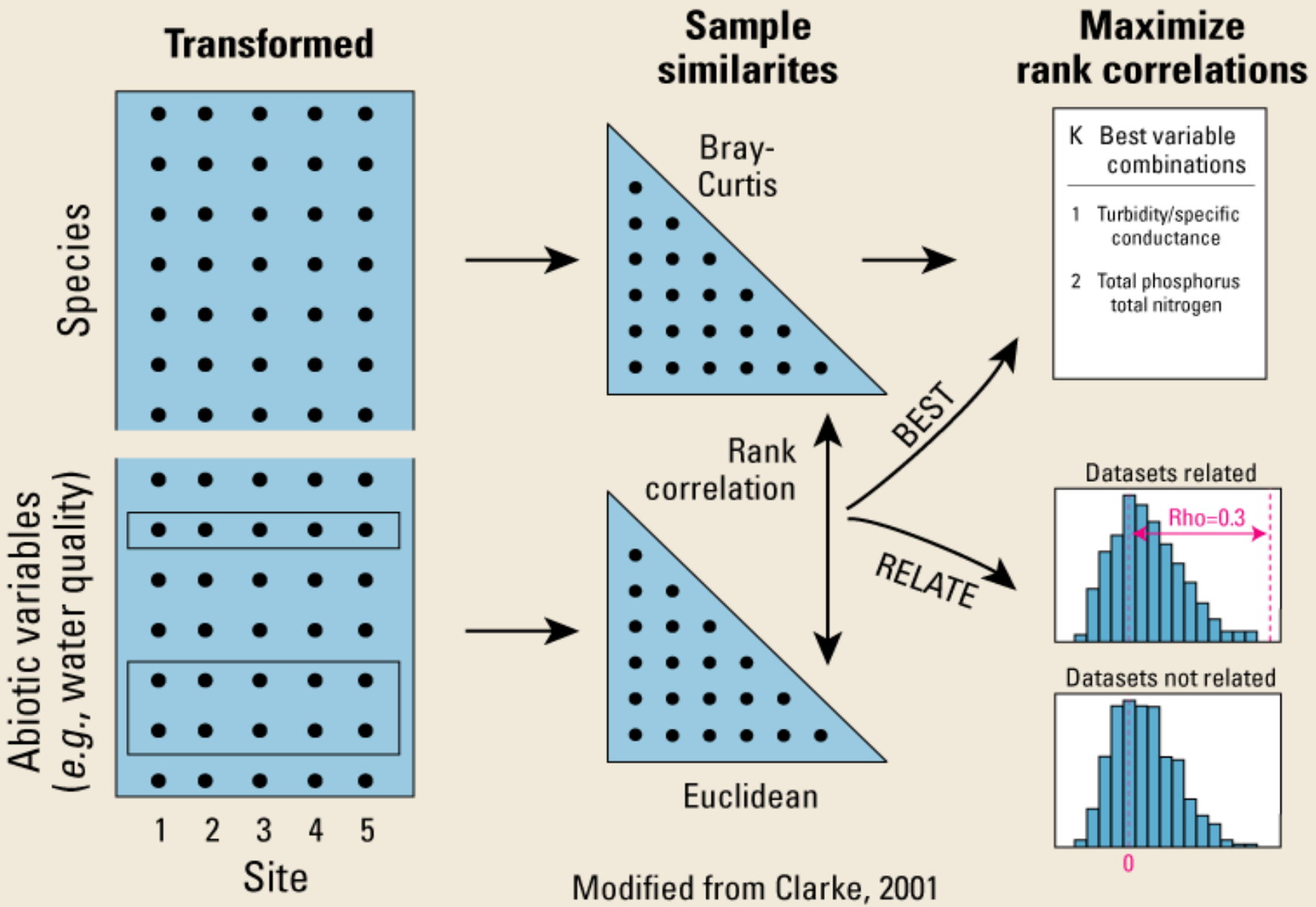


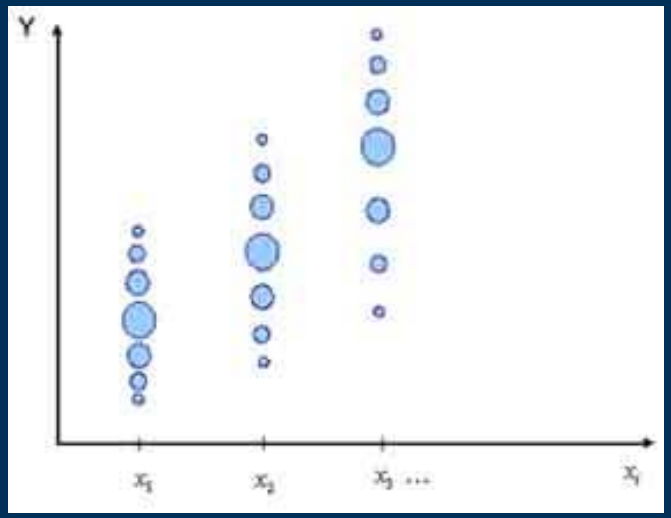
Proximity Denotes Similarity

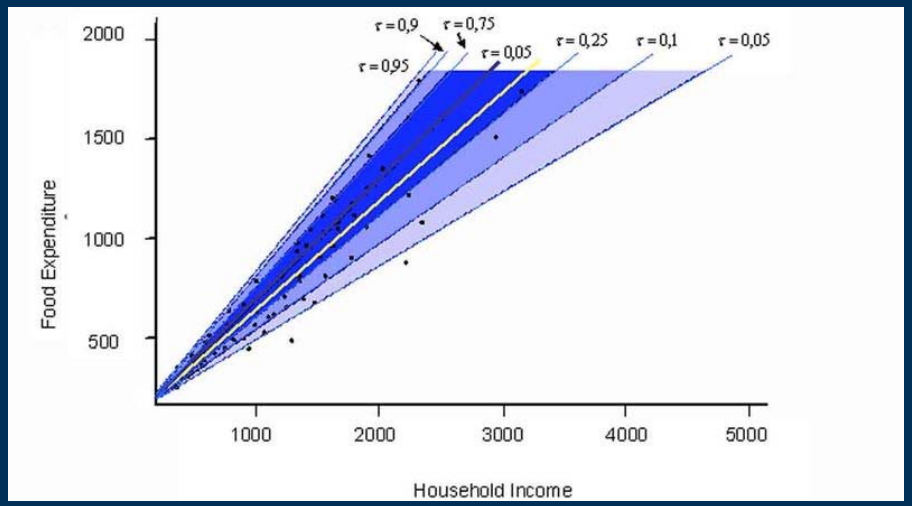
Matching of multivariate patterns



Modified from Clarke, 2001

Quantile Regression





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