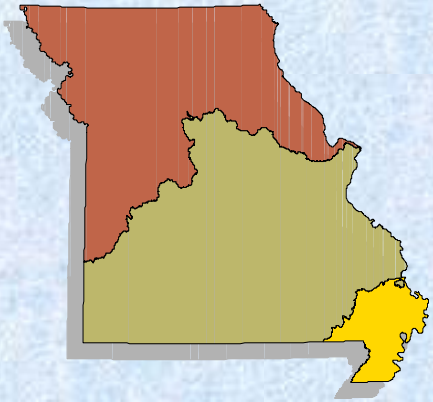
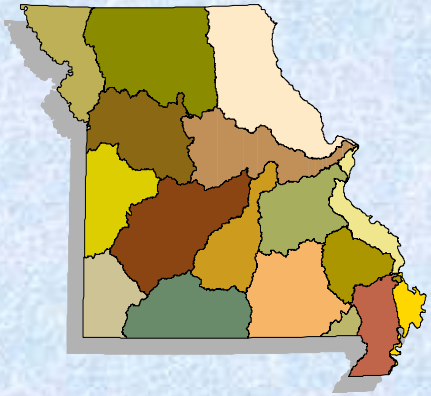
Classifying Stream Ecosystems into Distinct Ecological Units at Multiple Spatial Scales

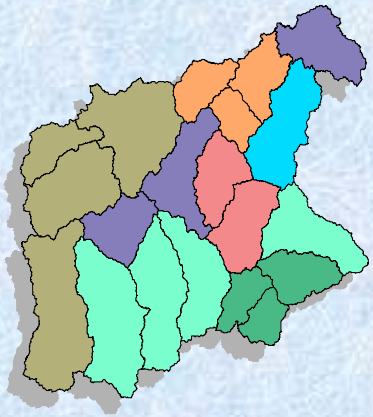
Aquatic Subregions



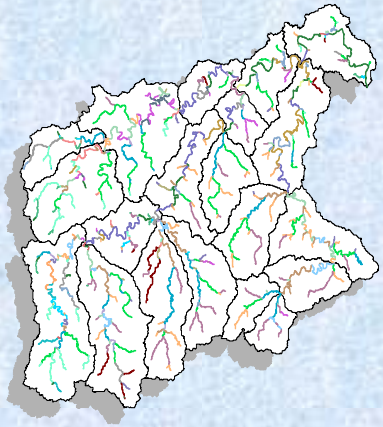
Ecological Drainage Units



Aquatic Ecological System Types



Valley Segment Types



USGS National Gap Analysis Meeting
October 6 - 9, 2003

Scott P. Sowa, Gust Annis, Mike Morey, and David D. Diamond

Missouri Resource Assessment Partnership (MoRAP)

http://www.cerc.cr.usgs.gov/morap

Purpose of Classifying Riverine Ecosystems

- Provide ecological/evolutionary context
  - Want to identify and assess representation of distinctive ecosystem units
- Provide an ecologically meaningful geographic framework for assessing conservation gaps
  - Planning Regions and Assessment Units
- Provide surrogate abiotic conservation targets
  - Complement biotic targets
- Provide the means to develop predictive distribution models and maps

Definition of an Ecosystem

- "A dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit"

  Convention on Biological Diversity 1992

- "An interacting system of a biological community and the associated abiotic environment"

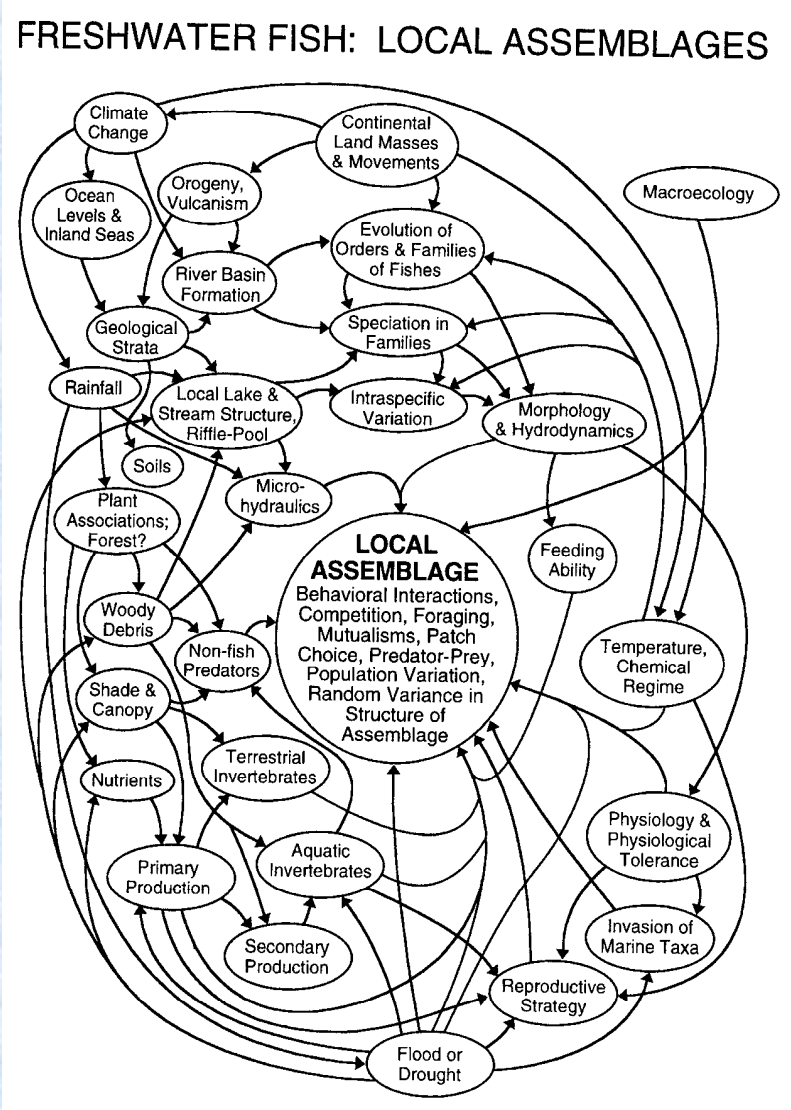
  EPA 1992

What Makes an Ecosystem Distinctive?

- Structural Features
  - Longitudinal, lateral and cross-sectional morphology
  - Depths, velocities, substrate, turbidity, cover
  - Presence/abundance of habitat units, spatial arrangement of habitat units
- Functional Processes
  - Hydrologic regimes, thermal regimes, nutrient cycling, energy sources/budgets, trophic dynamics
- Biological Composition
  - Families, species, populations, or phylogenies

What Determines Differences in Structure, Function, and Composition?

- Numerous physicochemical and evolutionary processes operating at various spatial and temporal scales
- Often difficult to identify discrete breaks across the landscape to identify/map distinct ecological units
- Especially in structural feature and functional processes as they often change along a continuum
- Composition often changes abruptly



Different Approaches to Classification

- Physical Features
  - Geology, soils, landform, drainage area, gradient, valley form, etc…
  - Since structure and function tend to be coupled, the use of physical features, which accounts for structural differences, generally accounts for functional differences

- Biological Composition
  - Biogeographic units
  - Problem: There are different ways to examine composition
    - **Ecological: Trophic guilds, habitat guilds, reproductive guilds, physiological tolerances**
    - **Taxonomic: Generally Family or Species level**
    - **Genetic: Distinct phylogenies**

- Combination of the Two
  - Ecoregional classifications

Step 1: Hierarchical Classification of Riverine Ecosystems

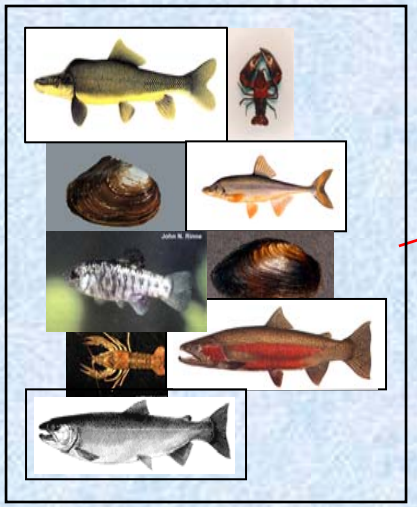
Hierarchical framework used for classifying and mapping riverine ecosystems in the MO Aquatic GAP Pilot Project

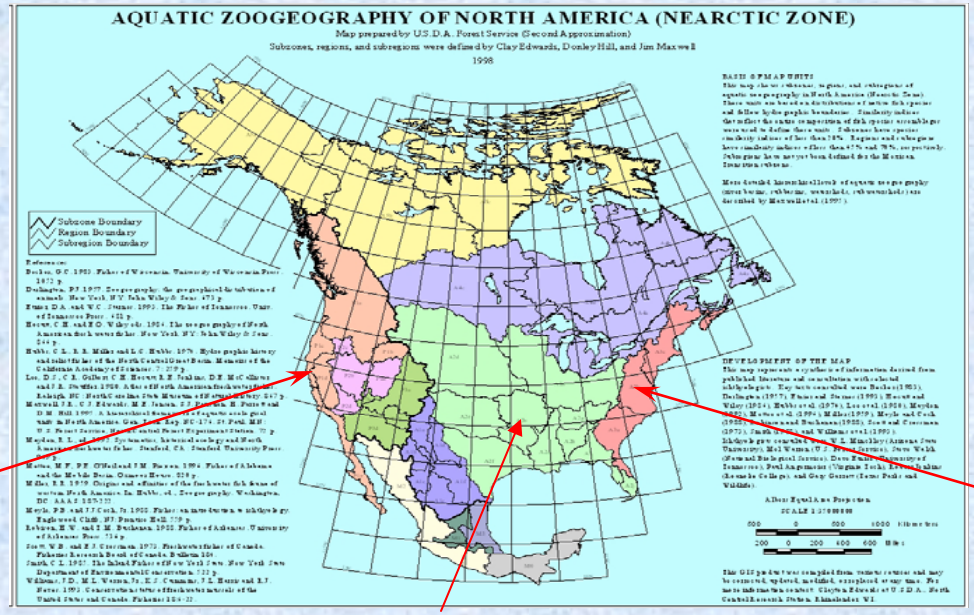
Adapted from Frissell et al. 1986, Pflieger et al. 1989, Maxwell et al. 1995, Seelbach et al. 1997, Higgins et al. 1999

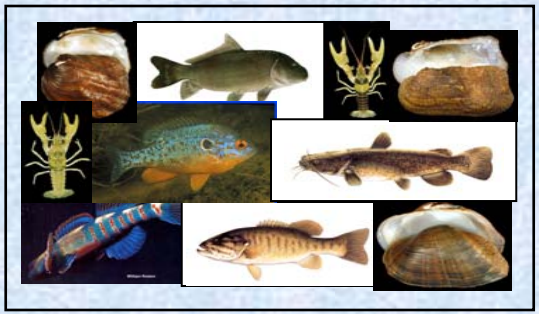
Level	Description	Defining Physical Features	Defining Biological Features
Zone	Six major zoogeographic zones of the world	Continental boundaries Global climate	Family level patterns Endemism
Subzone	Subcontinental zoogeographic strata with relatively unique aquatic assemblages created in large part by plate tectonics and mountain building	Major river networks and basin boundaries Regional climate	Family level patterns Endemism
Region	Subzone zoogeographic strata created in large part by drainage network patterns that determine dispersal routes and isolation mechanisms.	Major river networks and basin boundaries Regional climate	Family and species level patterns Endemism Diagnostic species of foraging, reproductive and habitat-use guilds
Subregion	Region stratification units. Large areas of similar climate and physiography that correspond to broad vegetation regions.	Regional climate Physiography General physiognomy of vegetation	Family and species level patterns Endemism
Ecological Drainage Unit	Subregion stratification units. Aggregates of watersheds within a distinct physiographic setting that share relatively unique aquatic assemblages	Drainage boundaries Physiography	Family and species level patterns Endemism Genetics
Aquatic Ecological System Type	Hydrologic subunits of ecological drainage units with similar physiographic settings, basin morphometry and position within the larger drainage	Drainage boundaries Position within ecological drainage unit Physiography Local climate Basin morphometry	Species level patterns Endemism Genetics Diagnostic species of foraging, reproductive and habitat-use guilds
Valley Segment Type	Valley segment types stratify stream networks of aquatic ecological systems into major functional components that define broad similarities in fluvial processes, sediment transport, riparian interactions, and thermal regime.	Temperature Stream size Permanence of flow Position within drainage network Valley geomorphology	Species level patterns Diagnostic species of foraging, reproductive and habitat-use guilds
Habitat Unit Type	Distinct hydrogeomorphic subunits of valley segment types (e.g., riffle, pool, run).	Depth, Velocity, Substrate Position within the channel Physical forming features	Species level patterns Diagnostic species of foraging, reproductive and habitat-use guilds

Levels 1-3 of the Hierarchy (Zone, Subzone, and Region)

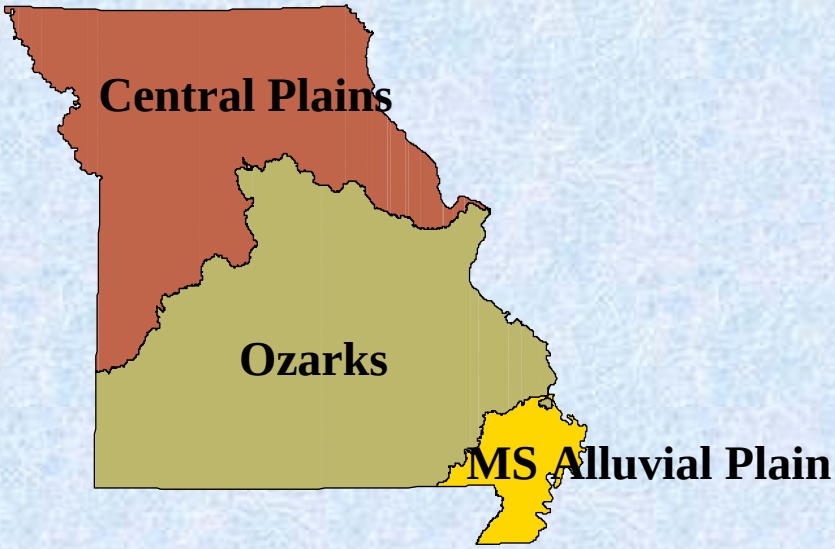
- Largely account compositional differences in aquatic assemblages resulting from distinct evolutionary histories
- Adopted first 3 levels of Maxwell et al. (1995)







Level 4: Aquatic Subregions



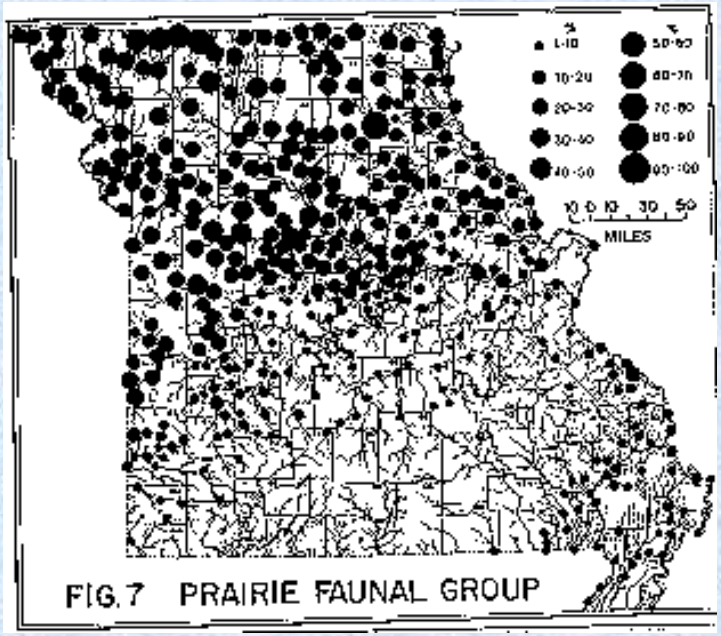


FIG. 7 PRAIRIE FAUNAL GROUP

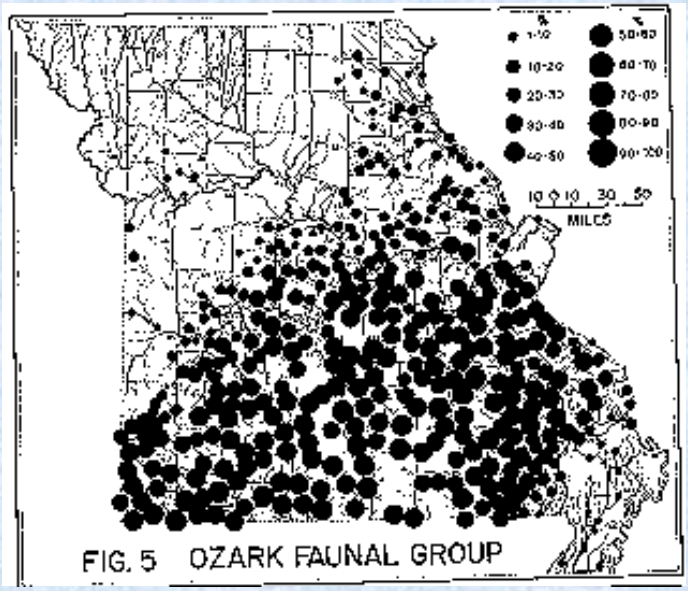


FIG. 5 OZARK FAUNAL GROUP

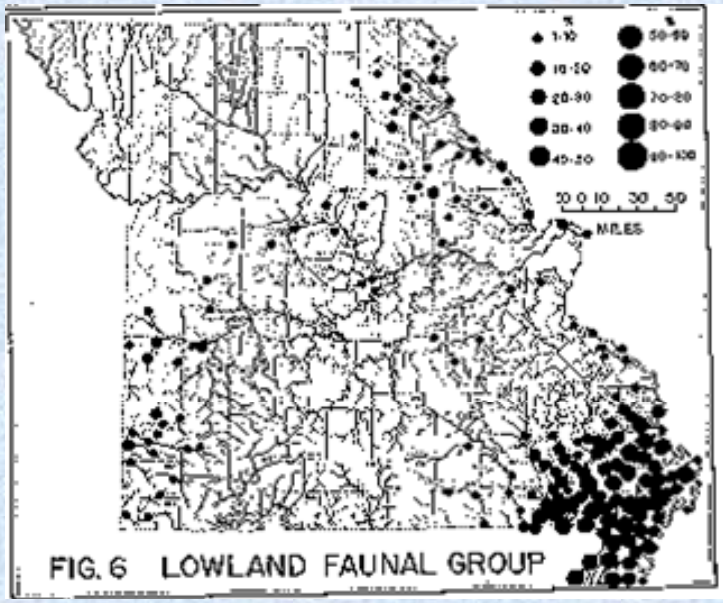
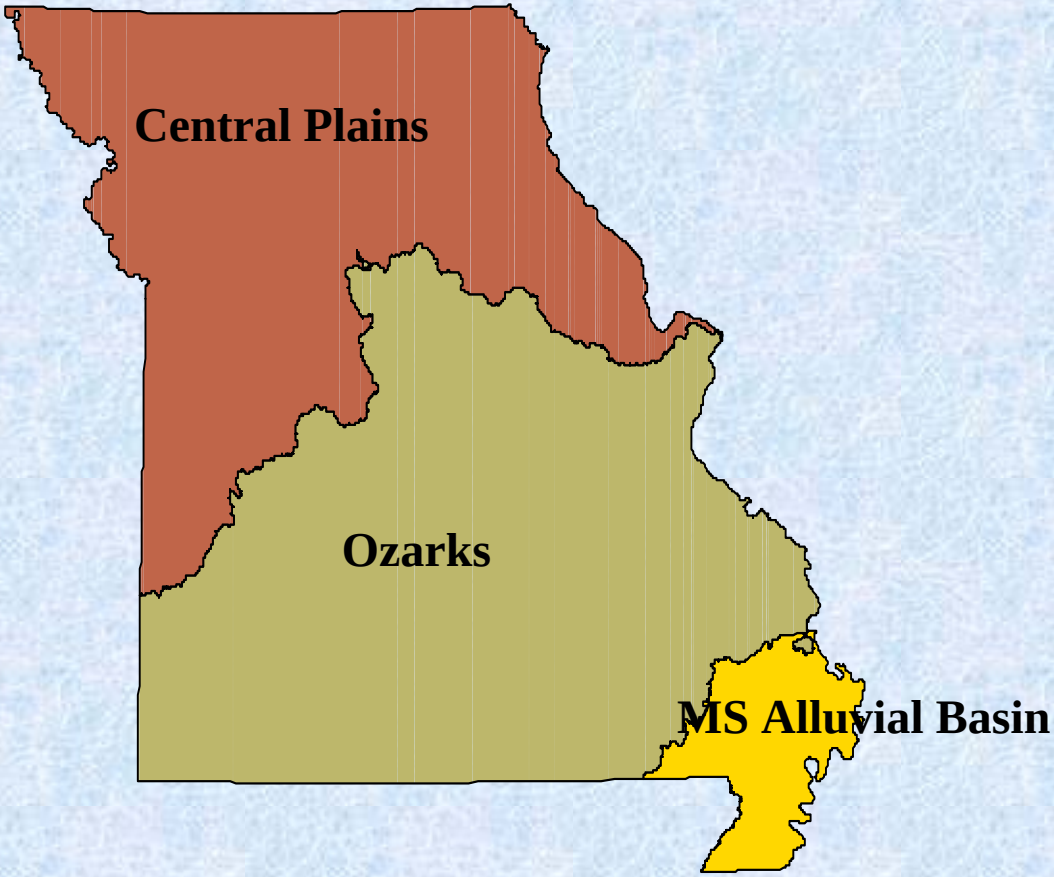


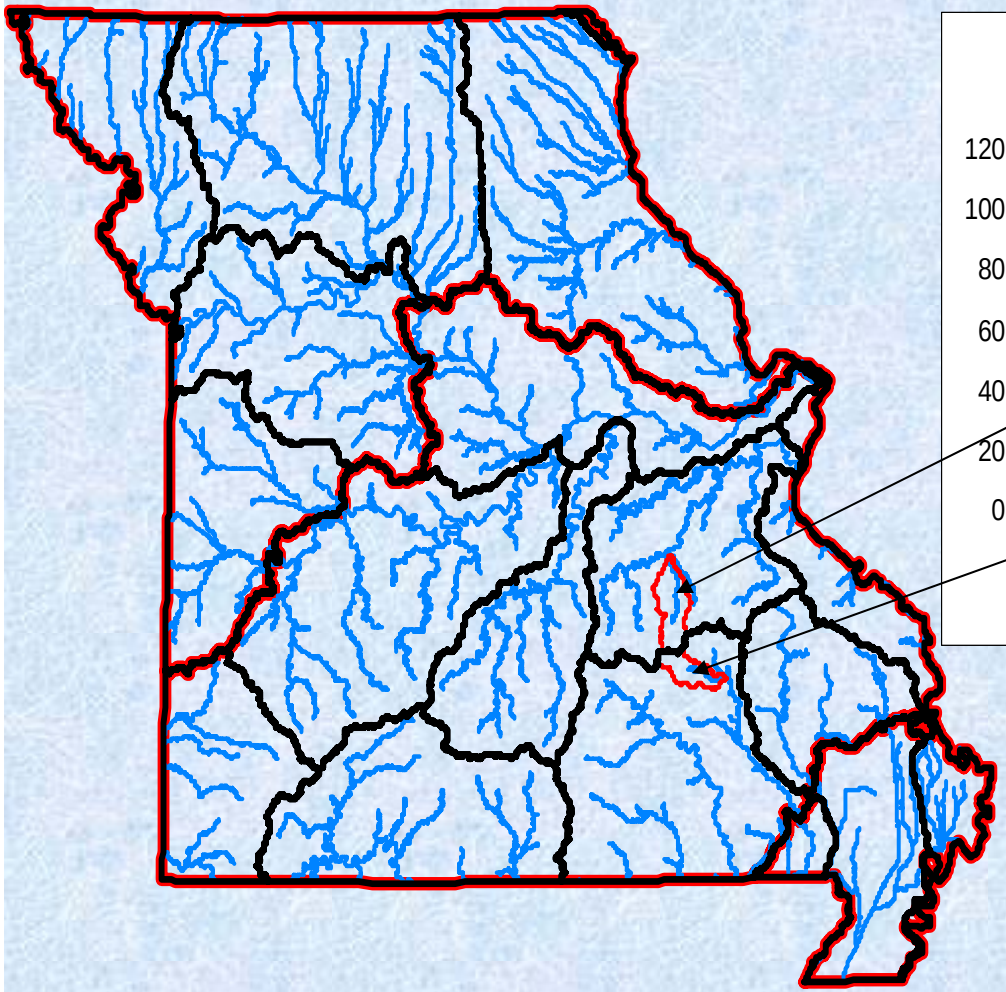
FIG. 6 LOWLAND FAUNAL GROUP

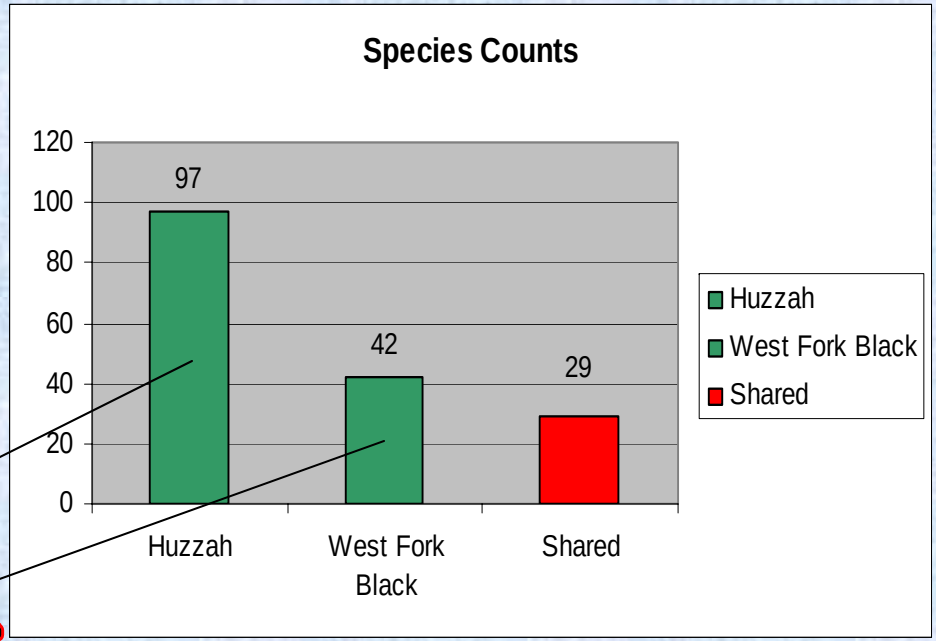
Level 4: Aquatic Subregions



- Largely correspond to ecoregions, which account for differences in aquatic assemblages resulting from geographic variation in ecosystem structure/function (e.g., flow, habitat)

Accounting for Compositional Differences Throughout Subregions

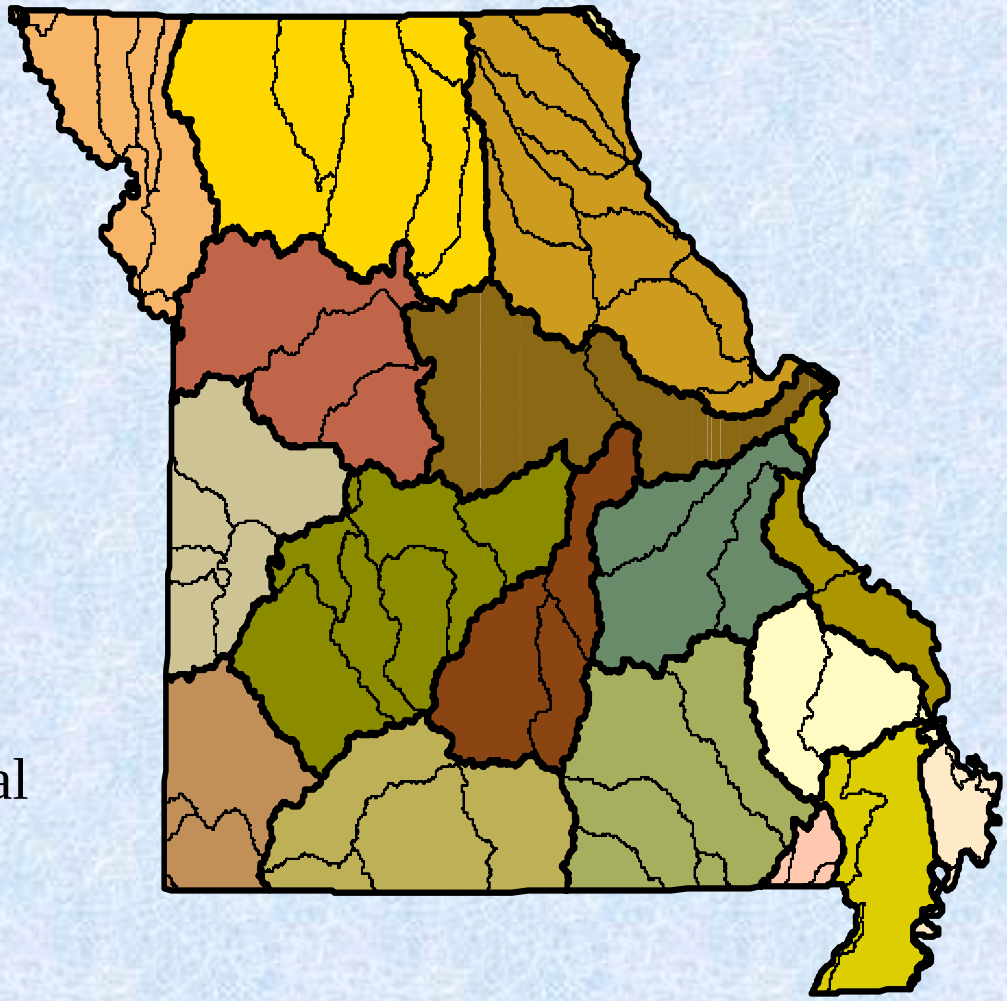




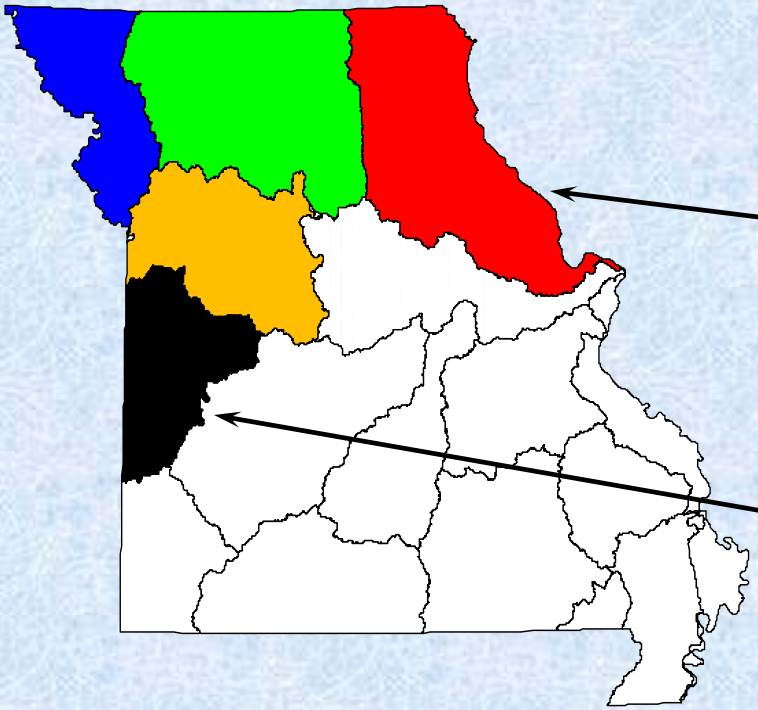
Delineating Level 5: Ecological Drainage Units (EDU's)

Methods

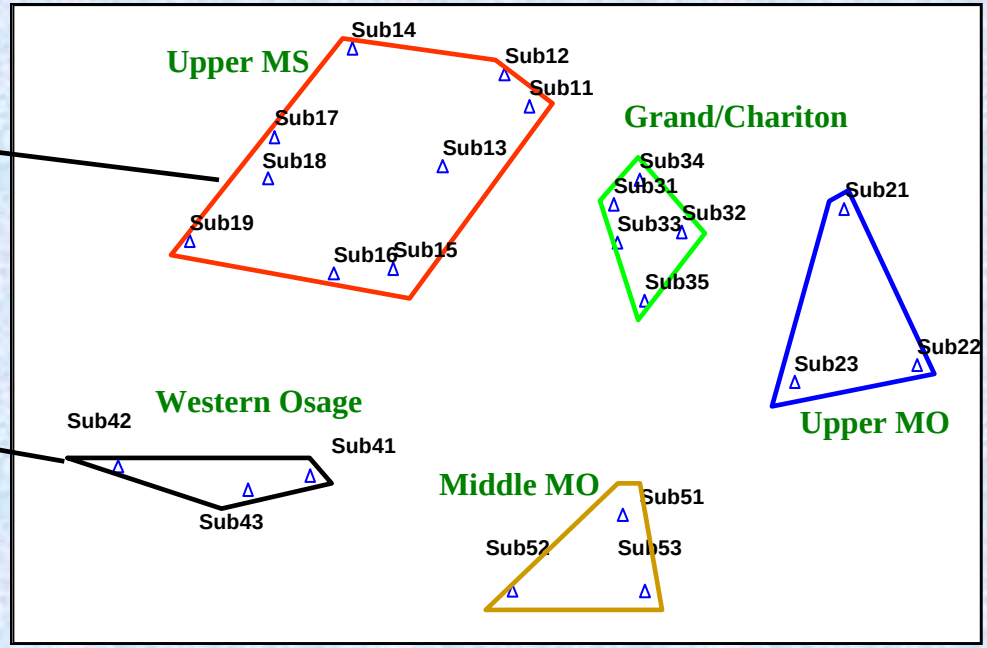
- Linked community fish data to NHD
- Generated prevalence indices for each species by HU
- Used multivariate analyses to identify HU's with similar fish assemblages
  - Ordination and Clustering
- Examined general distributional data for crayfish, mussels and snails



Delineating EDU's: Multivariate Analysis of Fish Community Data

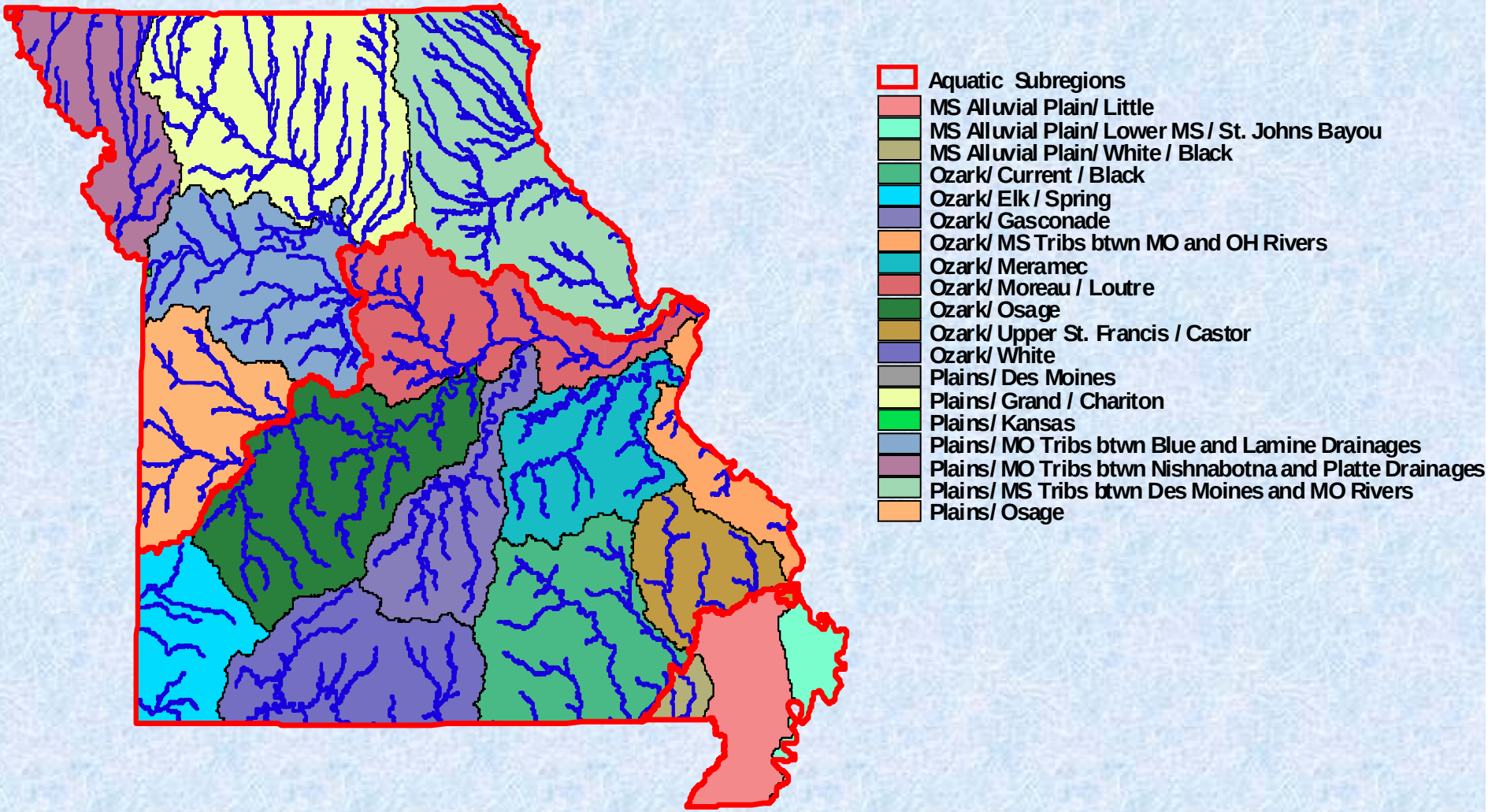


Ecological Drainage Units



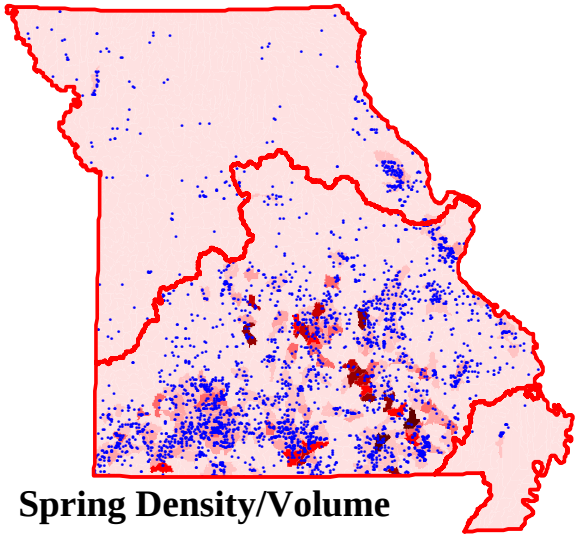
NMS Ordination Plot
of 8-digit Hydrologic Units in the Plains Subregion

Level 5: Ecological Drainage Units (EDU)

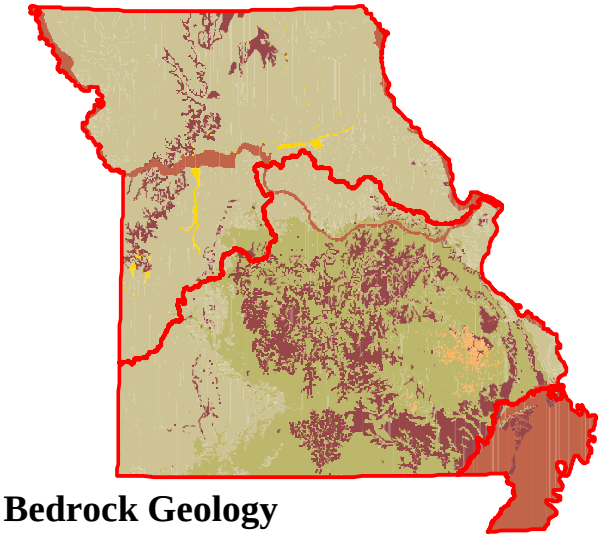


- Largely account for compositional differences in aquatic assemblages resulting from distinct evolutionary histories

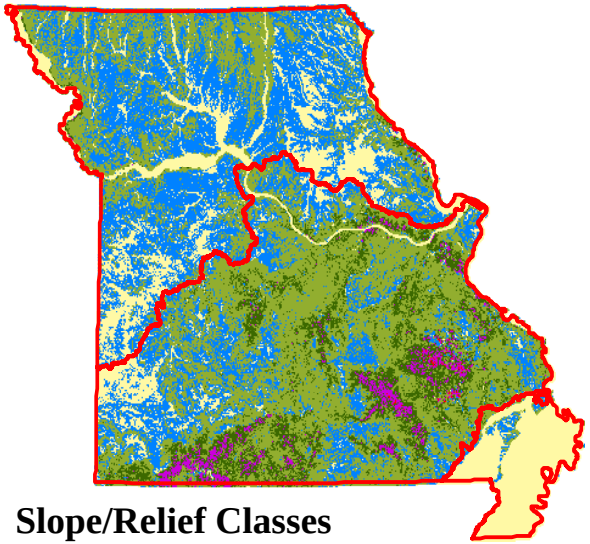
Accounting for Structural and Functional Variation throughout Aquatic Subregions



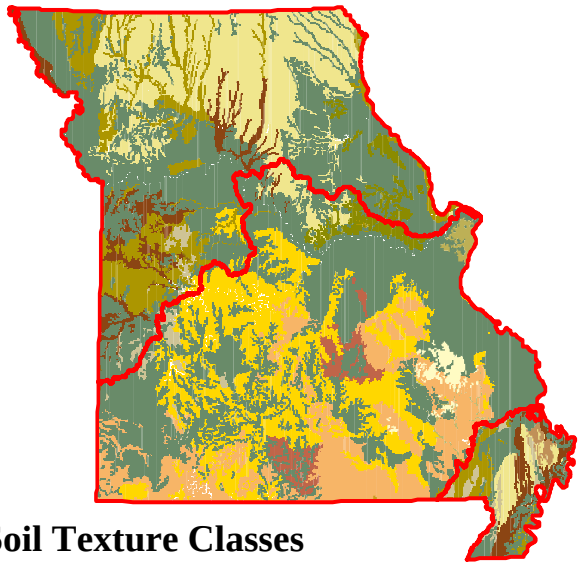
Spring Density/Volume



Bedrock Geology

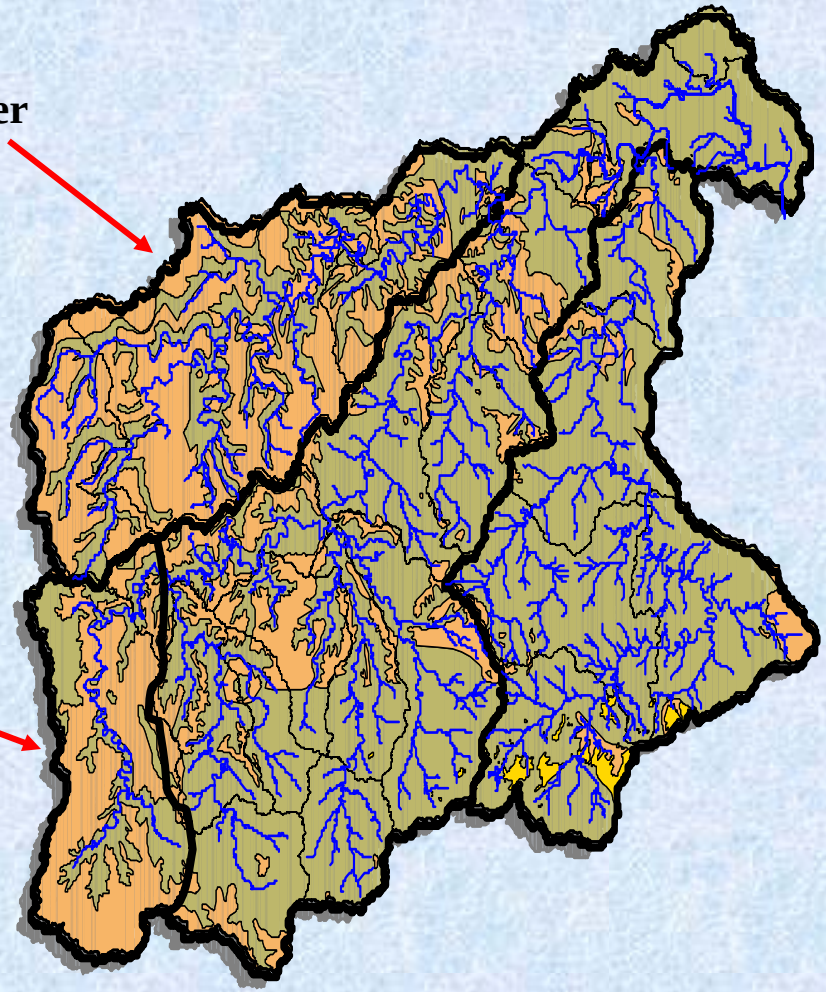


Slope/Relief Classes



Soil Texture Classes

Finer-Resolution Physiographic Variation Also Influences Assemblages



Geology of the Meramec Watershed

Common Ozark Species Not Found in the Bourbuese or Dry Fork

Fish

Ozark minnow
Wedgespot shiner
Bleeding shiner

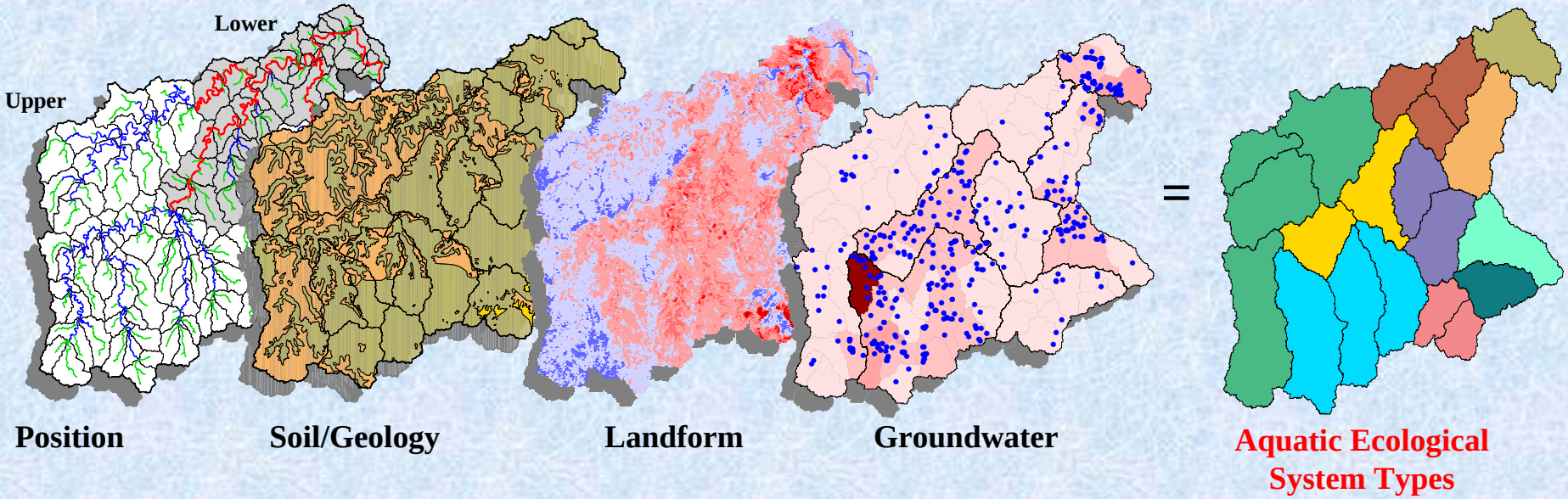
Crayfish

Freckled crayfish
Saddleback crayfish

Mussels

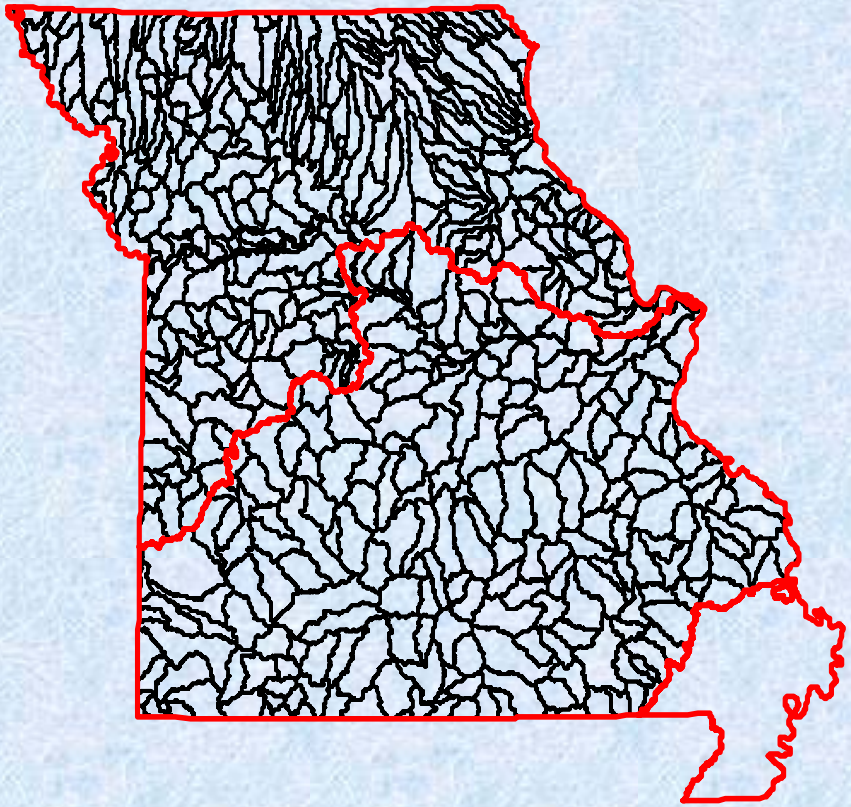
Spectaclecase
Slippershell
Purple pimpleback
Elephants ear
Western fanshell

Aquatic Ecological Systems and Types For the Ozark/Meramec EDU



- Defined by multivariate cluster analysis of geology, soil, landform, and groundwater variables

Delineating Aquatic Ecological System Types



<u>Discriminatory Variables</u>

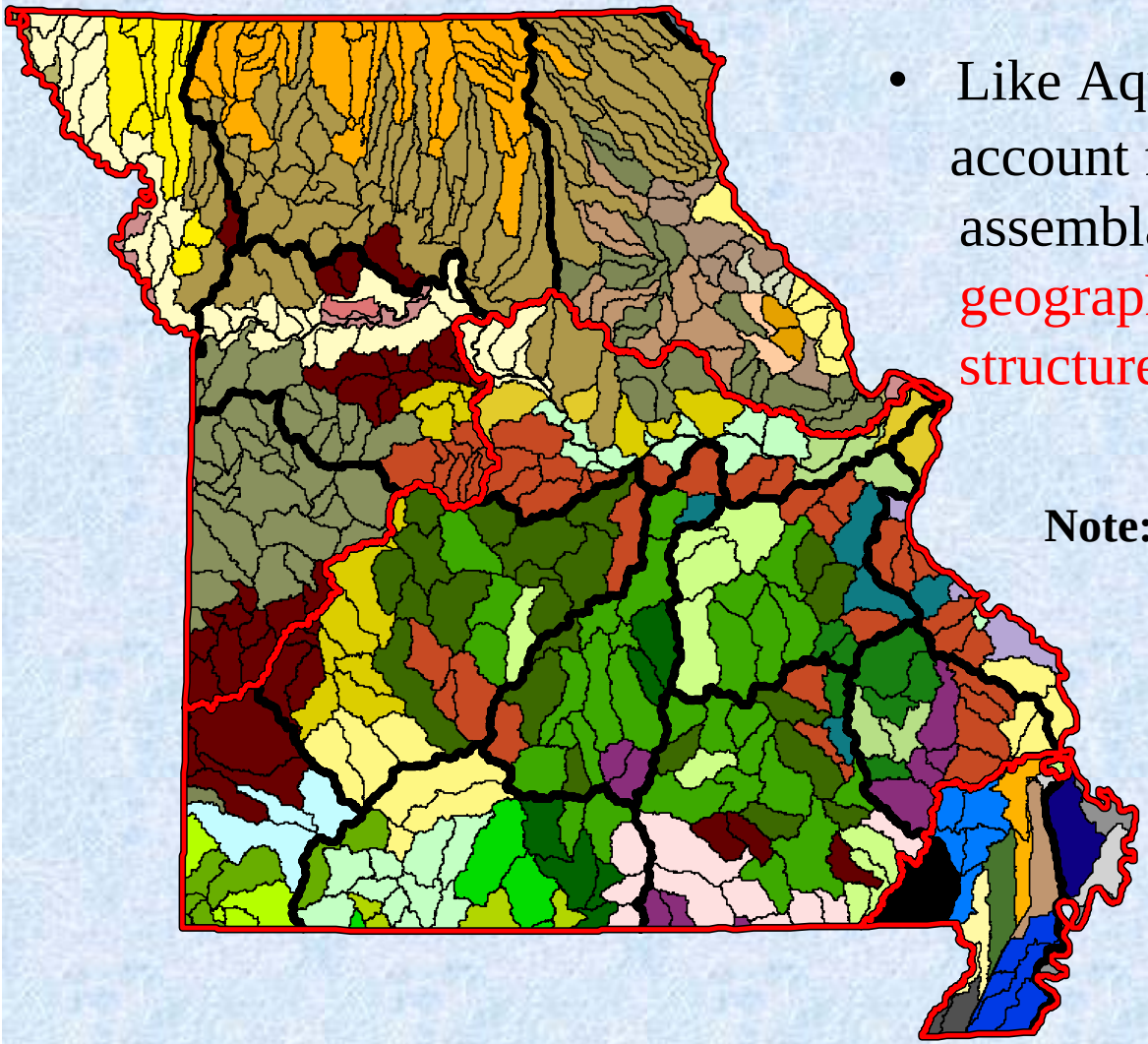
Soil Hydro Group:	2 categories
Soil Texture:	6 categories
Bedrock Geology:	6 categories
Relief:	7 categories

Spring Density

Springflow volume per unit area

* Percentages are calculated for overall watershed and local "Segment-sheds"

Level 6: Aquatic Ecological System Types

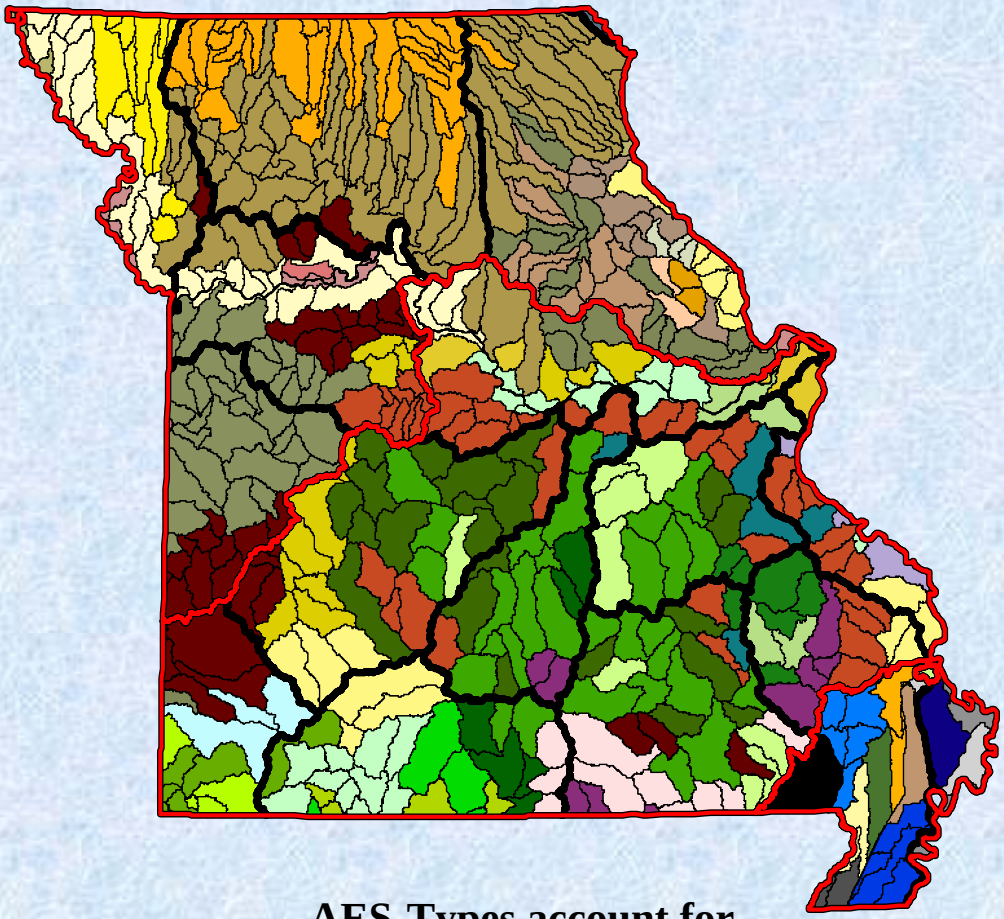


- Like Aquatic Subregions, AES-Types account for differences in aquatic assemblages resulting from geographic variation in ecosystem structure/function (e.g., flow, habitat)

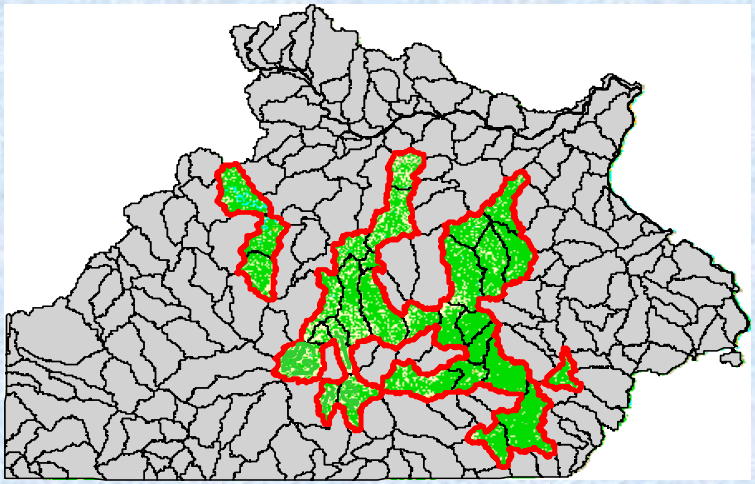
Note: **No 2 EDU's have the same combination or spatial arrangement of AES-types**

Like colors represent ecosystem units having similar structure and function (AES-Types)

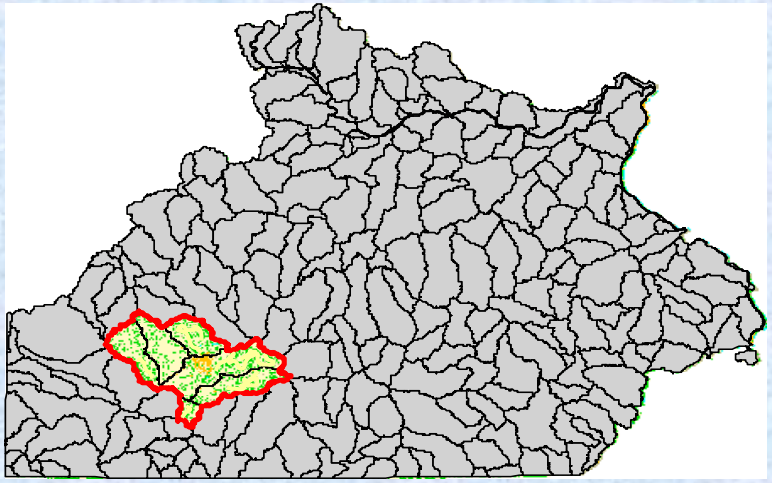
AES-Types Account for Differences in Land Cover and Some Land Uses



AES-Types account for agricultural and resource extractive land uses



Forest Dominated

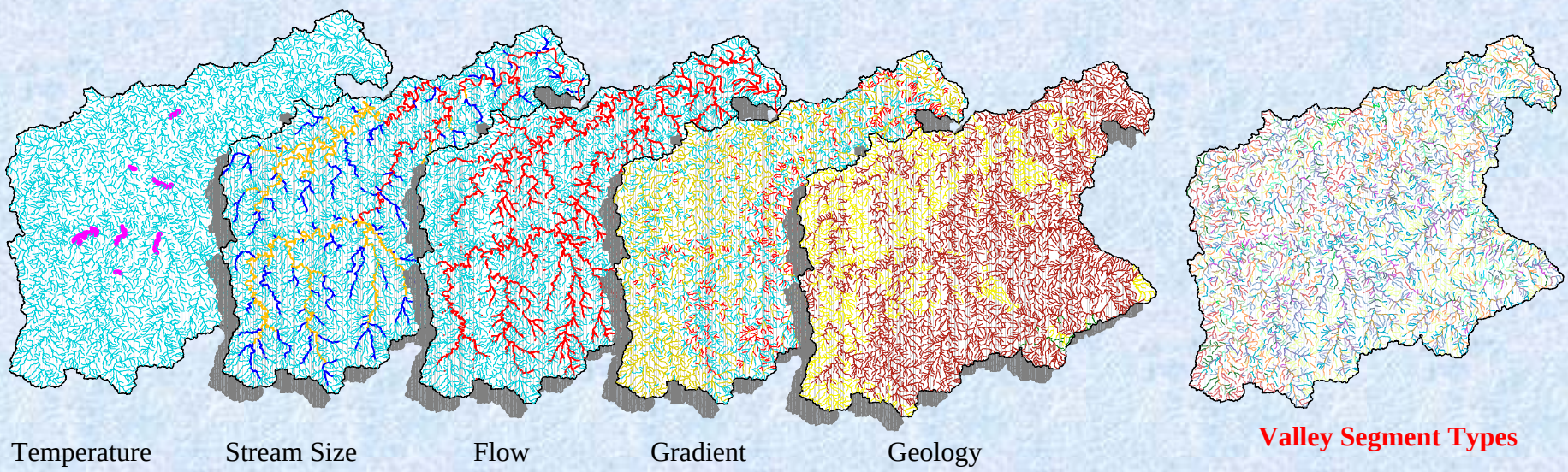


Grassland/Pasture Dominated

Level 7: Valley Segment Types

- Valley segments stratify a continuous stream network into distinct hydrogeomorphic patches
- Also account for differences in aquatic assemblages resulting from geographic variation in structure and function

<u>Individual Variables</u> <u>Unique Valley Segment Types</u>



Valley Segment Types for the Ozark/Meramec EDU

Variable Codes

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Temp		**Stream Size**		**Flow**		**Geology**		**Rel. Gradient**		**Density Val.**	**Wall Interac.**	**Size Discrep.**		**Floodplain Rch.**	
Cold	1	Headwater	1	Perm.	1	Alluvium	1	Low	1	Low	1	None	0	Yes	1
Warm	2	Creek	2	Inter.	2	Limest./Dolom.	2	Med.	2	High	2	Yes	1	No	2
		Sm. River	3			Igneous	3	High	3						
		Lg. River	4			Sandstove	4								
						Clay	5								

ode	Ssize_code	flow_code	Geol_code	Rgrad_code	Val_class	Size_disc	Floodp_cod	Chan_code	Concat_cod
2	3	2	4	3	1	0	2	1	232431021
2	4	1	2	1	1	0	2	1	241211021
2	3	1	2	2	2	0	2	1	231222021
2	3	1	2	2	2	0	2	1	231222021
2	3	1	2	1	2	0	2	1	231212021
2	3	1	2	1	2	0	2	1	231212021
2	3	1	2	3	2	0	2	1	231232021
2	3	1	2	2	2	0	2	1	231222021
2	3	1	2	3	2	0	2	1	231232021
2	3	1	2	3	2	0	2	1	231232021
2	3	1	2	3	2	0	2	1	231232021

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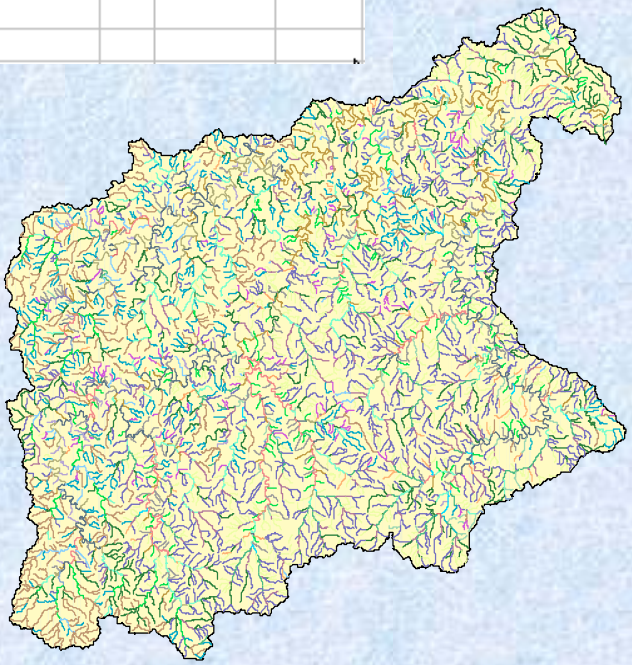
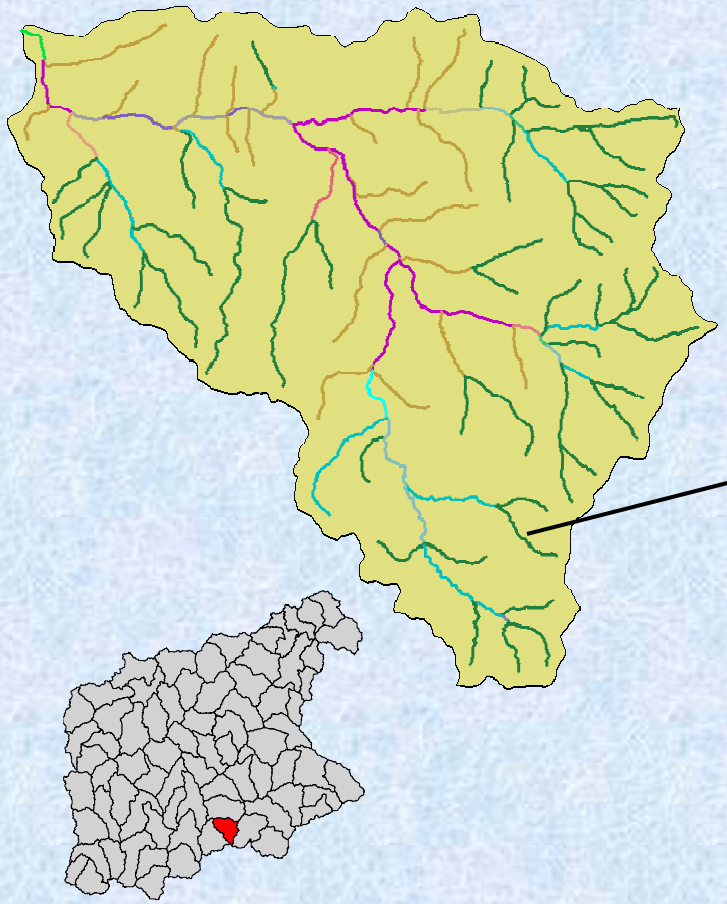


- Variables are concatenated into one numeric code
- Each unique code represents a unique valley segment type

Deciphering VST Codes



211210121
211220021
211220121
211230021
211230121
212210021
212210121
212220021
212220121
212230021
212230121
221210021
221220021
221230021
221230421

Valley Segment Type Codes and Descriptions

212230021 = Valley Segment Type Code

2 = Warm

1 = Headwaters

2 = Intermittent flow

2 = Flowing through dolomite/limestone

3 = Relatively high gradient

0 = Valley wall interaction (N/A)

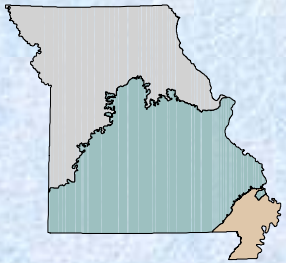
0 = Flows into another headwater

2 = Flowing within own valley

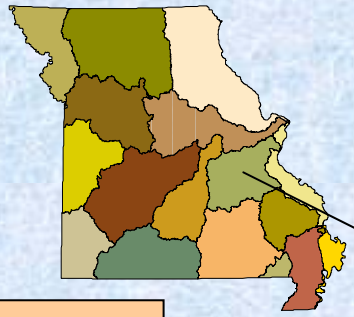
1 = Primary channel

Understanding Ecological Context

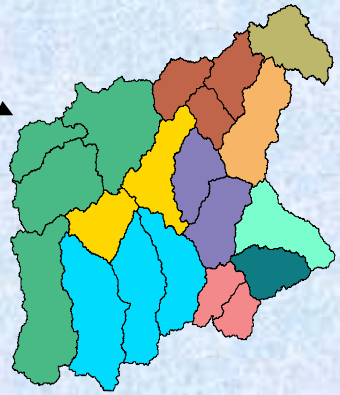
Level 4
Subregions



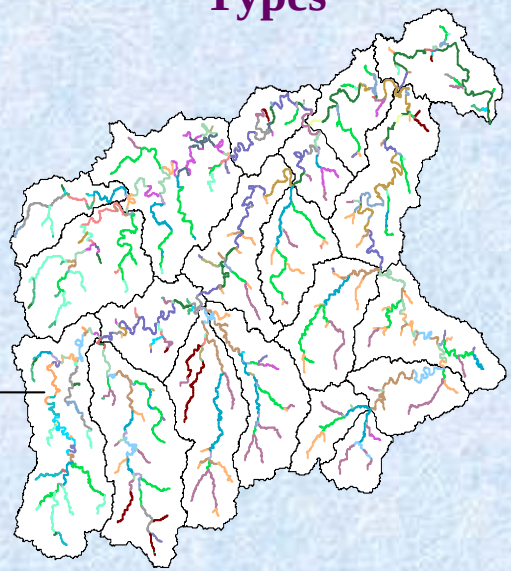
Level 5
Ecological Drainage Units



Level 6
Aquatic Ecological System Types



Level 7
Valley Segment Types



Zone:
Nearctic zoogeographic zone
Subzone:
Arctic/Atlantic Drainages
Region:
Mississippi Drainage
Subregion:
Ozark Plateau
Ecological Drainage Unit:
Ozark Plateau/Meramec Drainage
Aquatic Ecological System:
Upper Meramec/Dry Fork, Oak/Woodland Plain, sandstone dominated, low gradient and spring density stream complex
Valley Segment Type:
Warm, perennial, creek with a relatively high gradient, flowing through sandstone, and connecting to another creek

Improving the Classification of Riverine Ecosystems

- More detailed geology and soil data
- Characterize watersheds of every single stream reach
- More biological data collected at relatively undisturbed sites
- Better temperature and flow data
- Link physical habitat and water quality data to NHD

Summary

- Classifying distinct ecosystems at multiple levels is critical to conservation planning
  - Planning Regions, Assessment Units, Abiotic Targets, Species modeling
- Resulting spatial units must delineate interacting systems
- Must account for structural, functional, and compositional variation
- Difficult part is doing the detective work to identify the factors that determine/associated with these forms of variation
- Our classification system accounts for all three forms of variation in riverine ecosystems
- However, there is room for improvement if we can overcome existing data limitations

Acknowledgements

USGS National Gap Analysis Program

U.S. Department of Defense Legacy Program

Missouri Department of Conservation

University of Missouri

Missouri Cooperative Fish and Wildlife Research Unit

MoRAP Partner Agencies and Personnel