National Biological Assessment and Criteria Workshop

Advancing State and Tribal Programs

Coeur d'Alene, Idaho
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RFC 201

An Aquatic Ecological Classification System for Riverine Ecosystems:

A Common Framework for Biomonitoring and Biodiversity Conservation

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

Linking Biomonitoring with Biodiversity Conservation

- Linking biomonitoring and biodiversity conservation efforts is critical to conserving our nation's natural resources and without integrating such efforts we will likely not achieve the goals of either

Hughes and Noss 1992; Moyle 1994; Davis and Simon 1995; Karr 1995

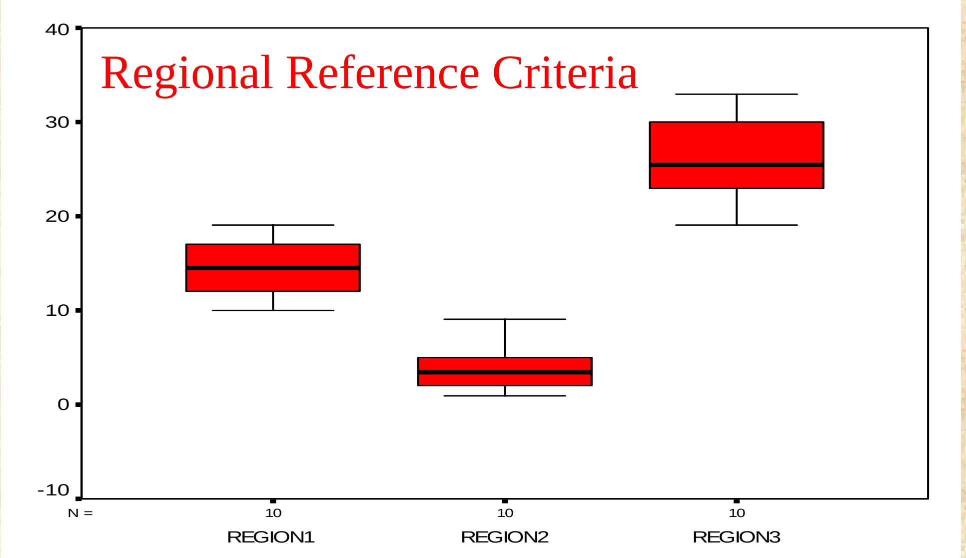
A Common Obstacle

- A common obstacle to biomonitoring and biodiversity conservation is **classifying our nation's tremendous diversity of aquatic ecosystems** into relatively homogeneous units amenable to mapping, monitoring, and assessment

Orians 1993; Angermeier and Schlosser 1995

Different Purpose/Need for Classification?

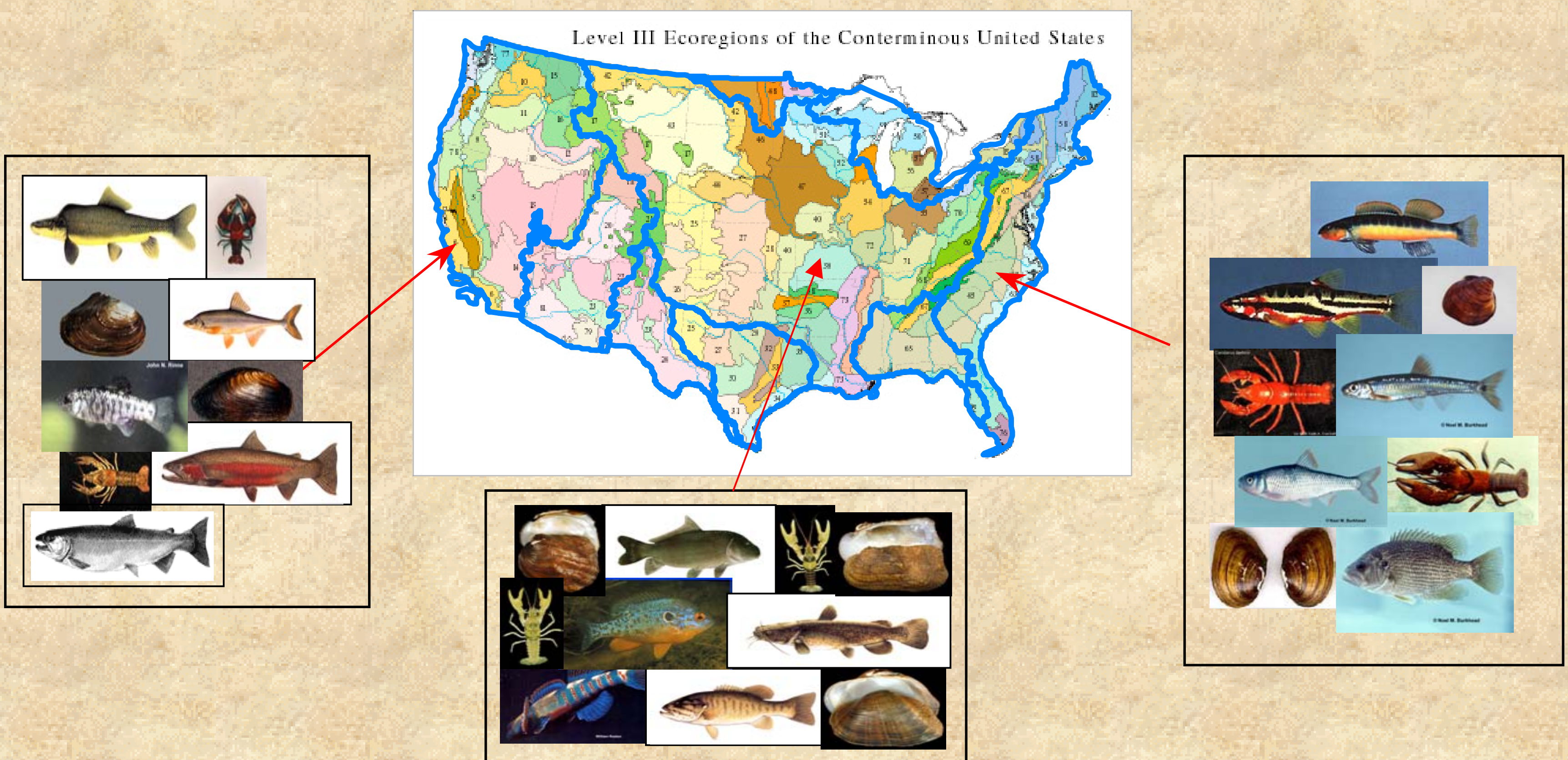
- Biodiversity Conservation
  - Delineate and map ecological units that account for **genetic, population, species, community, landscape and ecosystem diversity**
    - Must consider all natural selection forces
- Biomonitoring
  - Delineate and map ecological units that account for **natural variation in the metrics used to assess impairment**



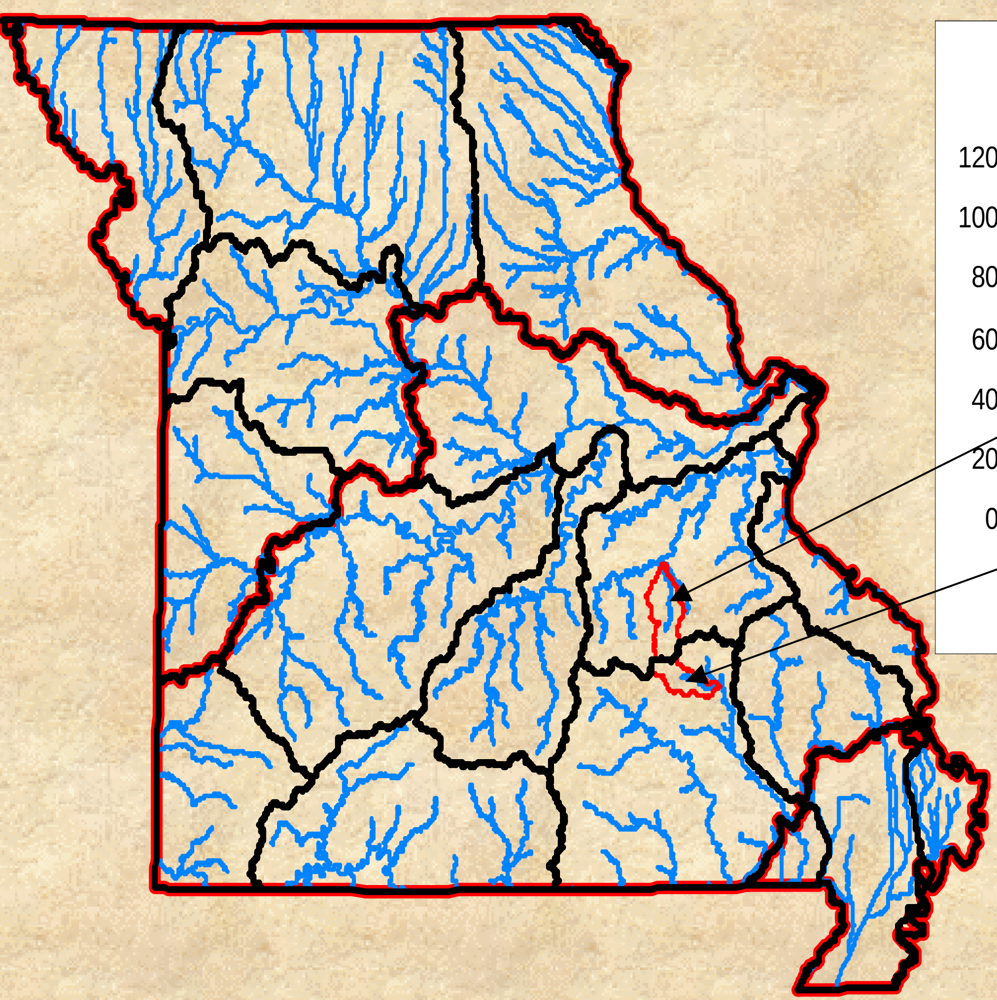
Limitation of Existing Classification Systems

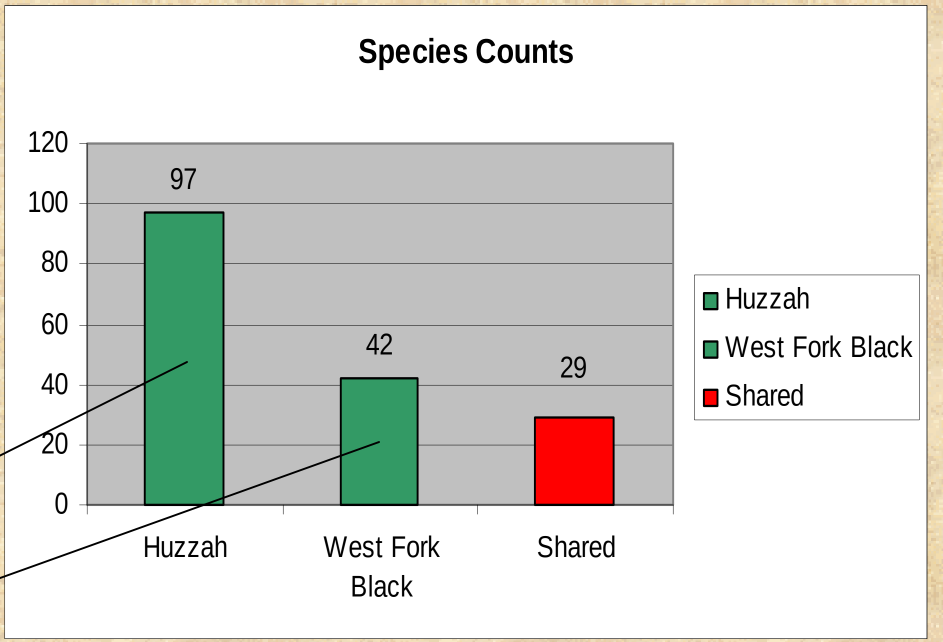
- Failure to account for biogeographical distribution patterns

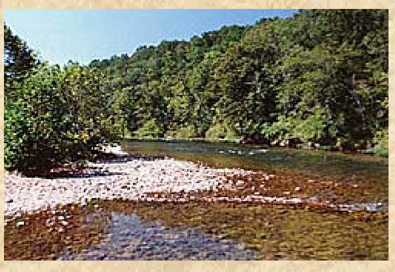
EPA 1994; Matthews 1998



For Biodiversity Conservation Species Composition and Population Isolation are of Critical Importance







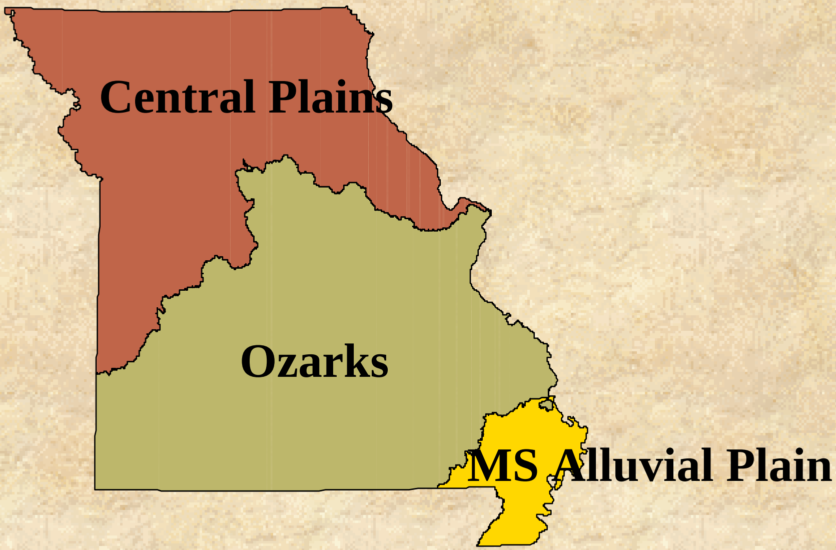
Common Structural and Functional Metrics Should Have Broad Application

Typical IBI Metrics

Category	Metric
Species richness and composition	Total number of fish species
	Number of darter species
	Number of sunfish species
	Number of cyprinid species
	Number of intolerant species
	Proportion of individuals as green sunfish
Trophic composition	Proportion of individuals as omnivores
	Proportion of individuals as insectivores
	Proportion of individuals as piscivores
Fish abundance and condition	Number of individuals in sample
	Proportion of individuals as hybrids
	Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies

- Structural/functional metrics may be "immune" to such gross differences
- Even so, we should consider and monitor these units as separate aquatic ecosystems

Correspondence of Fish Distributions with Ecoregions



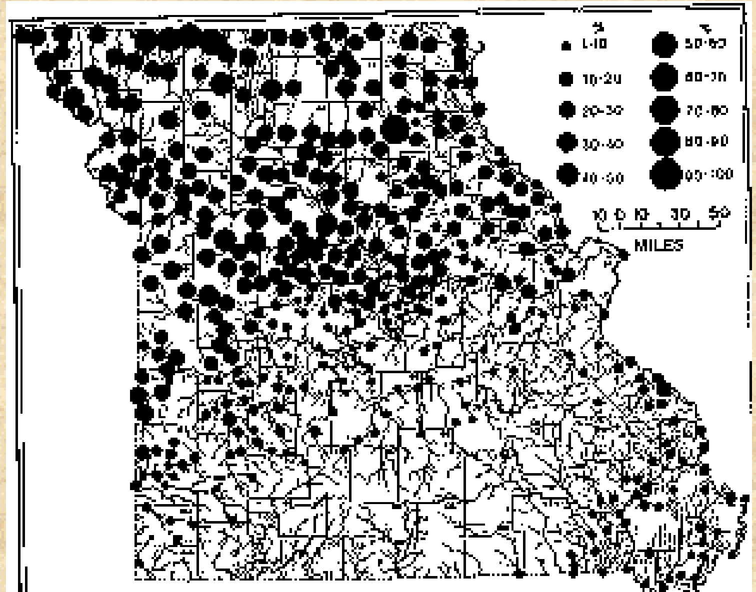


FIG. 7 PRAIRIE FAUNAL GROUP

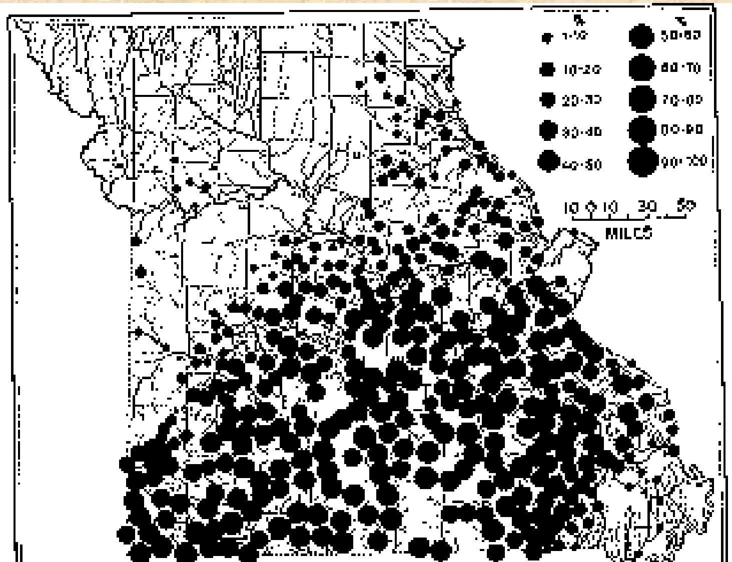


FIG. 5 OZARK FAUNAL GROUP

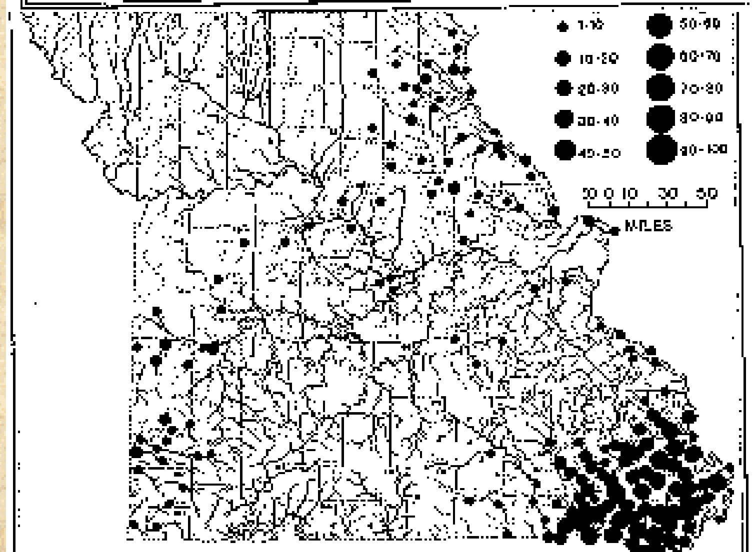
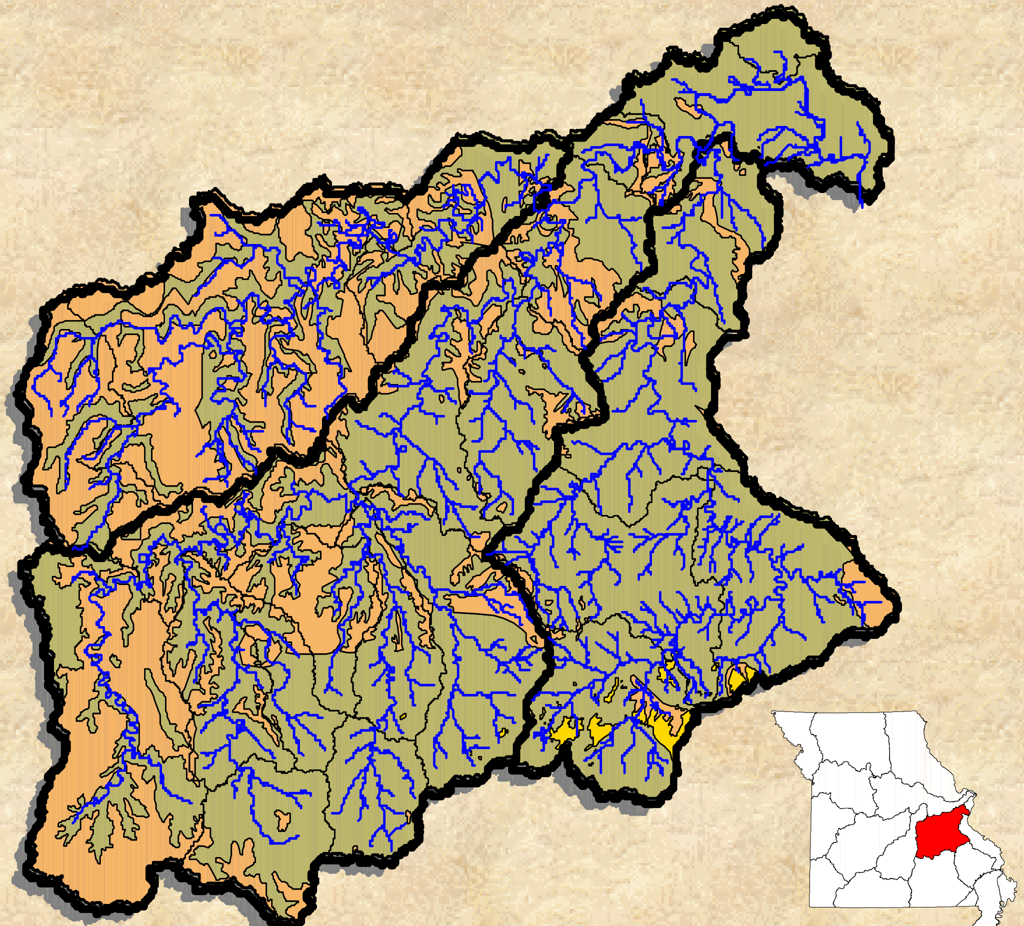


FIG. 6 LOWLAND FAUNAL GROUP

Geology, Soils, and Landform Influence Assemblages at Finer Spatial Scales



Geology of the Meramec Watershed

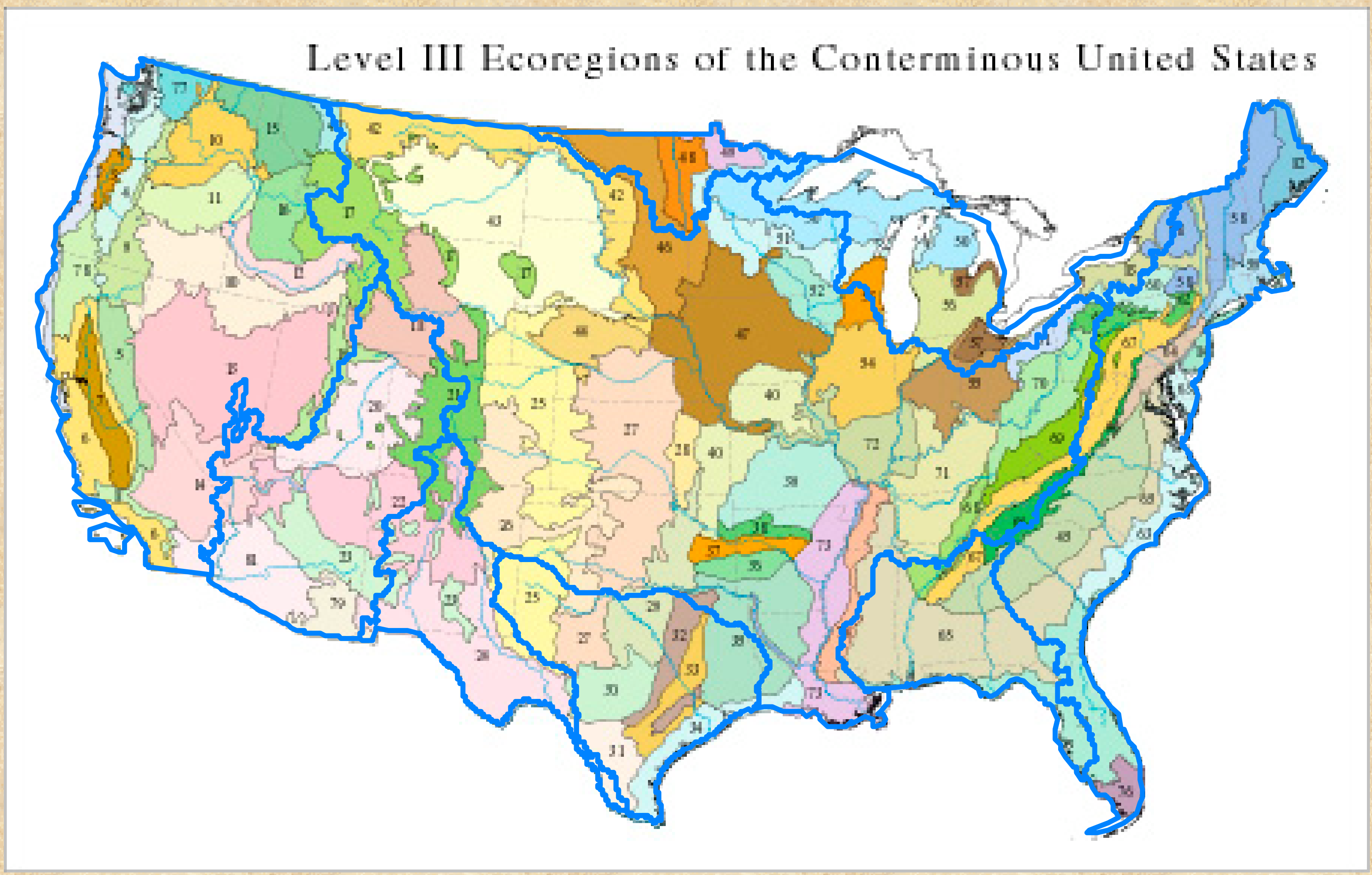
Species Not Found
in Bourbuese or Dry Fork

- **Ozark minnow**
- **Wedgespot shiner**
- **Bleeding shiner**

- **Freckled crayfish**
- **Saddleback crayfish**

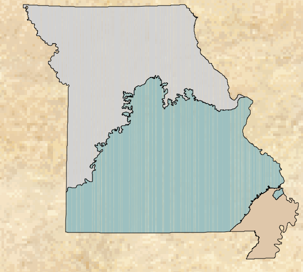
- **Spectaclecase**
- **Slippershell**
- **Purple pimpleback**
- **Elephants ear**
- **Western fanshell**

Watersheds and Ecoregions are Both Important Determinants of Local Biological Assemblages

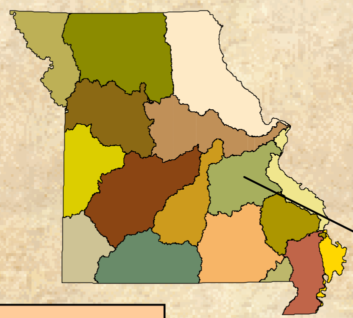


An Aquatic Ecological Classification for Riverine Ecosystems

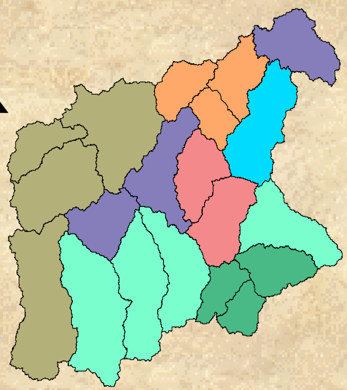
Level 4
Subregions



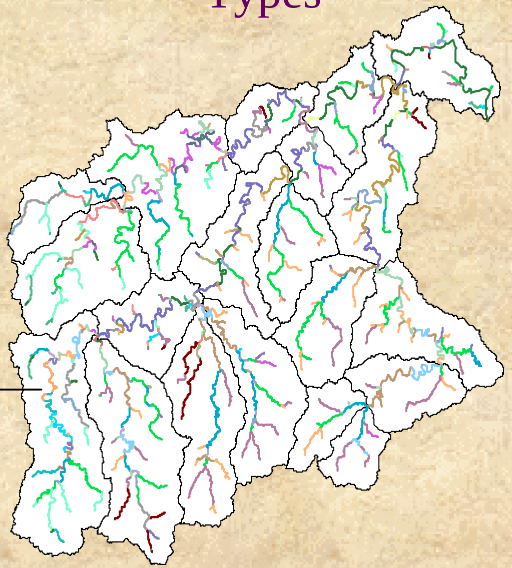
Level 5
Ecological Drainage Units



Level 6
Aquatic Ecological Systems

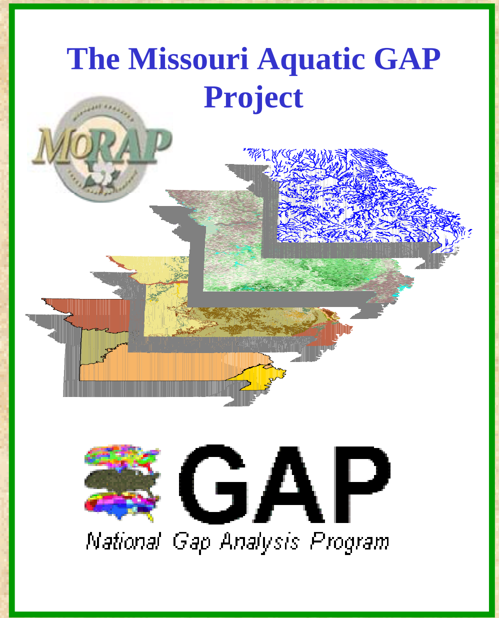


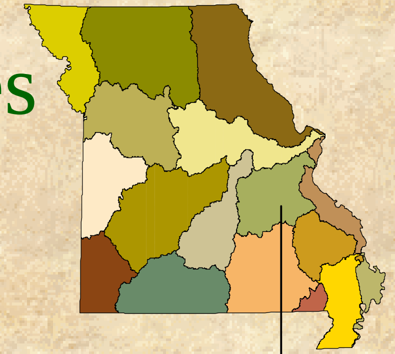
Level 7
Valley Segment Types

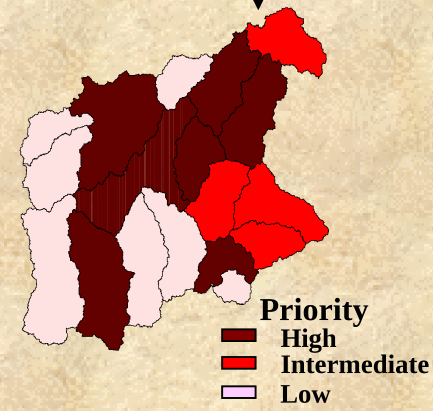


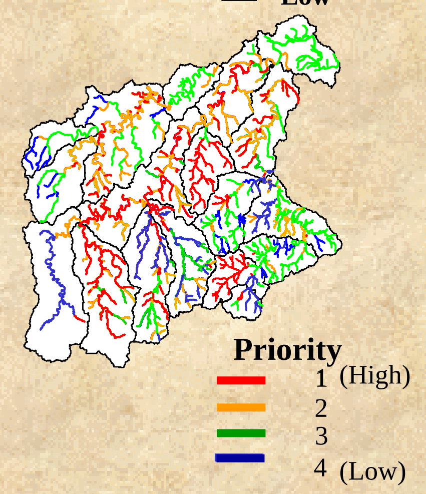
Zone:
Nearctic zoogeographic zone
Subzone:
Arctic/Atlantic Drainages
Region:
Mississippi Drainage
Subregion:
Ozark Plateau
Ecological Drainage Unit:
Ozark Plateau/Meramec Drainage
Aquatic Ecological System:
Upper Meramec/Dry Fork, Oak/Woodland Plain, sandstone dominated, low gradient and spring density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

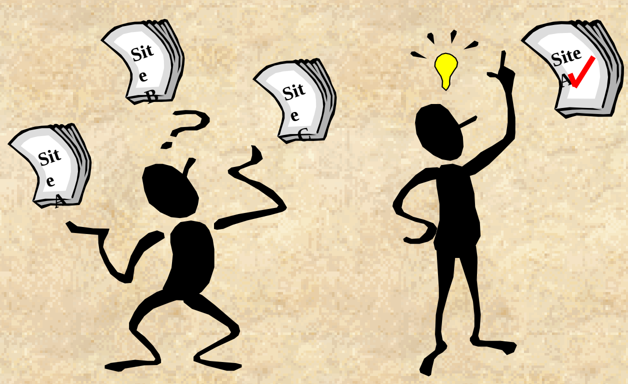
Developing Conservation Priorities











Factors incorporated into Biological Distinctiveness Index
Species richness
Endemism
Species of special concern
Species with distributions centered within Aquatic Ecological System
Diversity, rarity and ecological importance of Valley Segment Types

Factors incorporated into Conservation Status Index
Degree of water quality degradation
Degree of hydrologic alteration
Degree of physical habitat alteration
Degree of biological alteration
Degree of fragmentation
Public stewardship
Potential future threats

Integration matrix used in generating conservation priorities for Aquatic Ecological Systems

Biological Distinctiveness	Conservation Status		
	Poor	Fair	Good
High	Intermediate	High	High
Medium	Low	Intermediate	High
Low	Low	Low	Intermediate

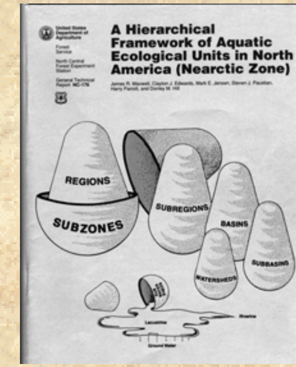
Steps for assigning priorities to individual valley segments
a. Attribute each valley segment with the conservation priority of the surrounding Aquatic Ecological System
b. If significant portion of the length is not in public land, increase priority level
c. If valley segment contains critical habitat or is known to harbor endemic or species of special concern, increase priority level

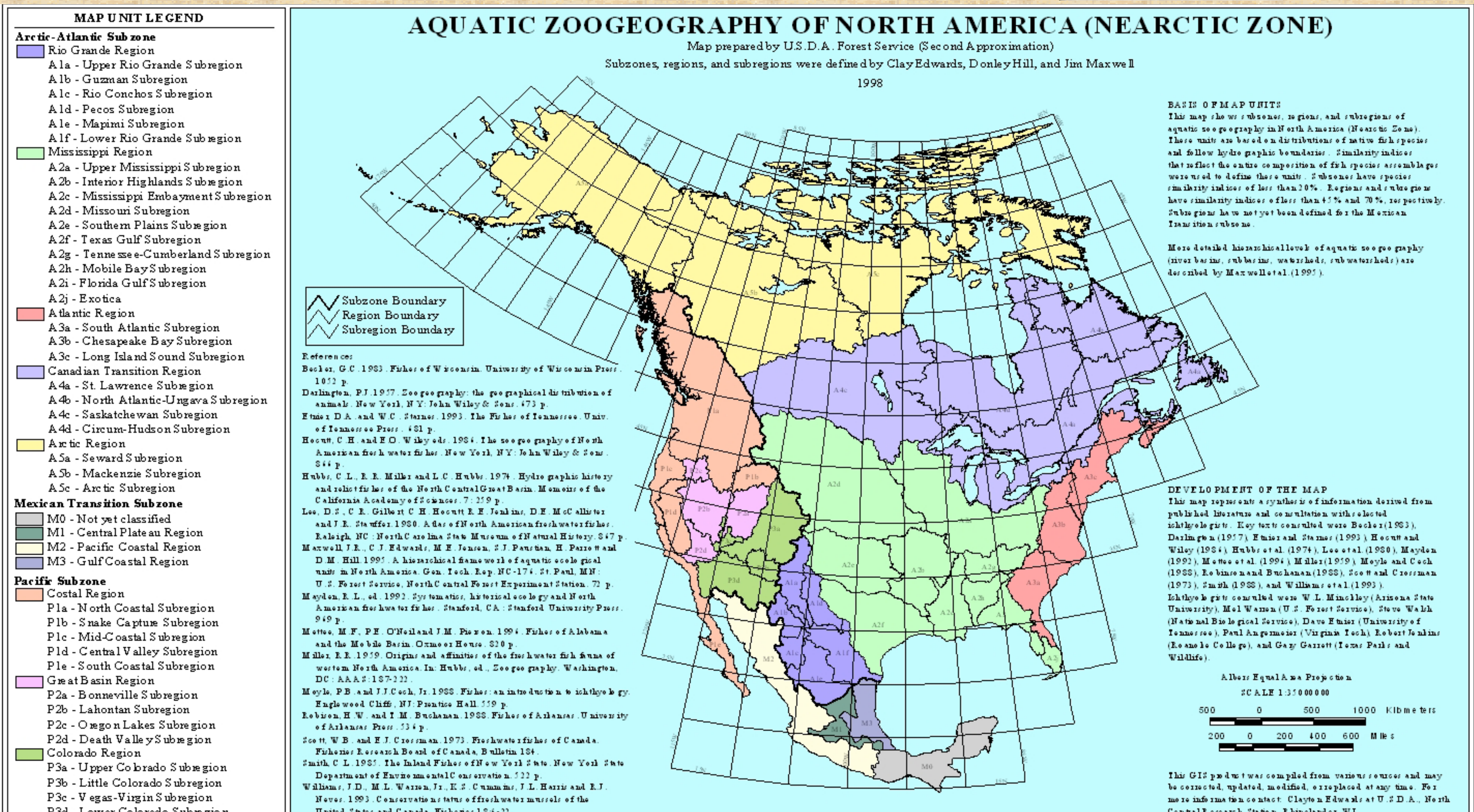
8-Level Classification Framework

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
Zones	Six major zoogeographic zones of the world	Continental boundaries Global climate	Family level patterns Endemism
Subzones	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
Regions	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
Subregions	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 Units	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 Systems	Hydrologic subunits of ecological drainage units with similar physiographic settings, basin morphometry and position within the larger drainage (e.g., located in the headwaters versus near the drainage outlet). Hydrologic subunits are delineated separately for the headwater, creek and small river size classes.	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

First 3 Levels of the Hierarchy Based on Maxwell et al. (1995)



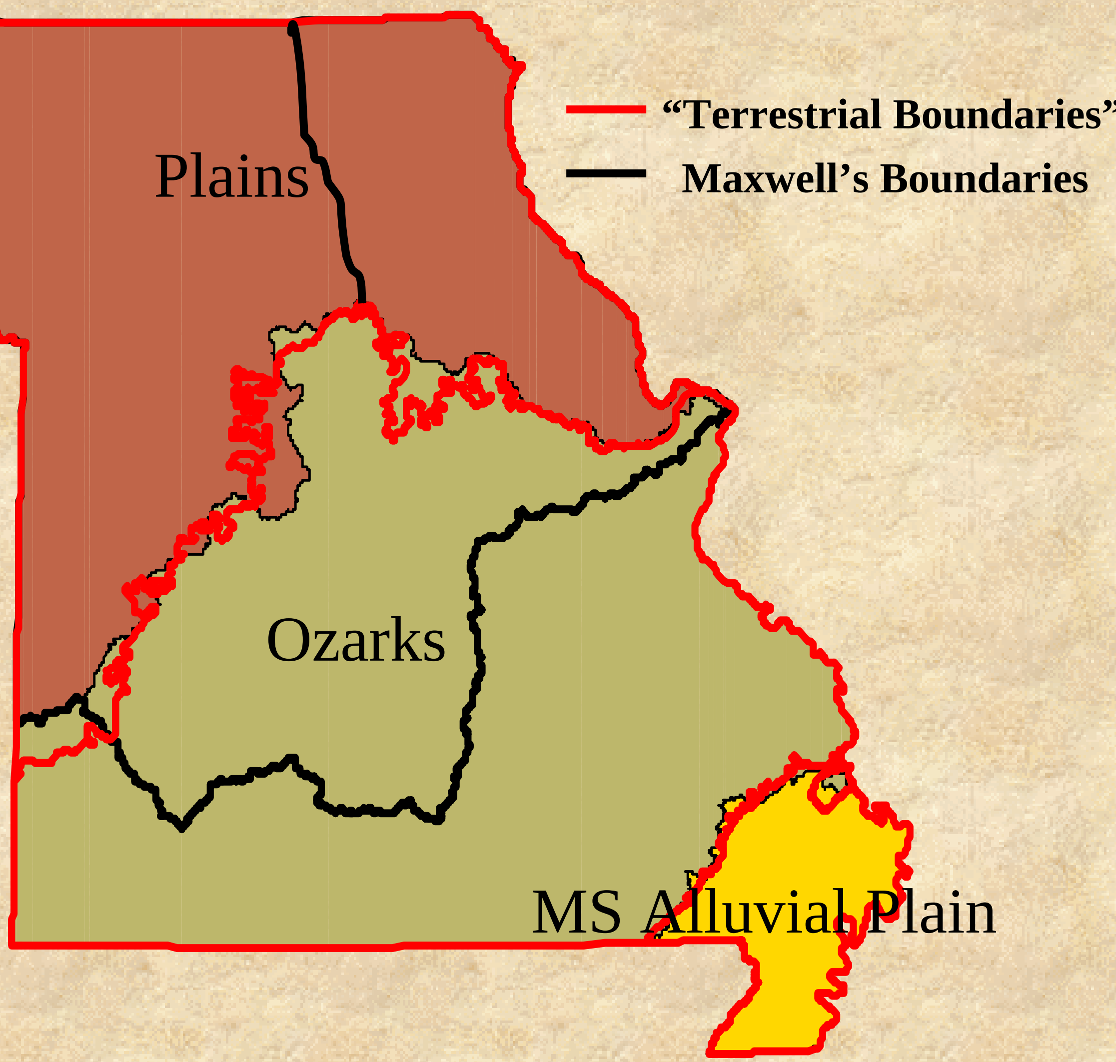


Level 4: Aquatic Subregions

(Showing Drainage Enforcement)

Largely Correspond to:

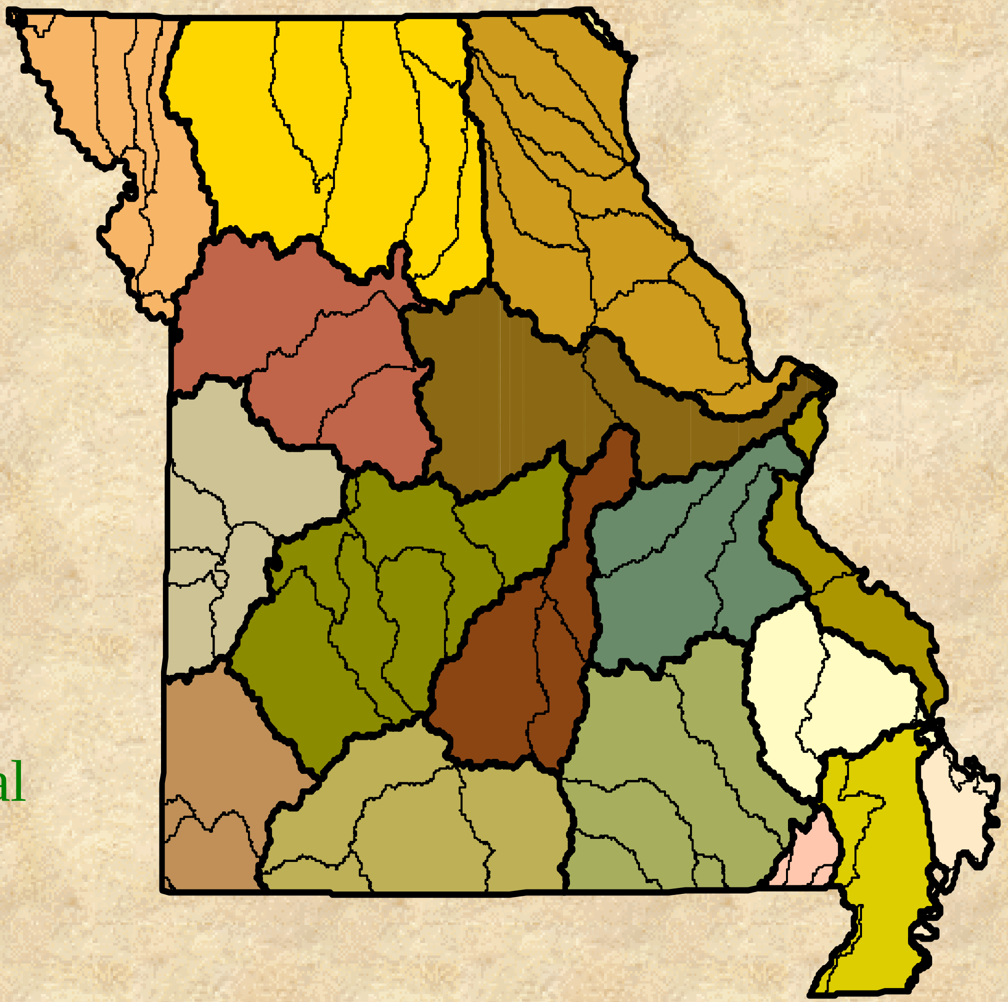
- Omernik Level 2
- Bailey's Ecological Provinces
- Pflieger's Aquatic Faunal Regions



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



Input Data Matrix

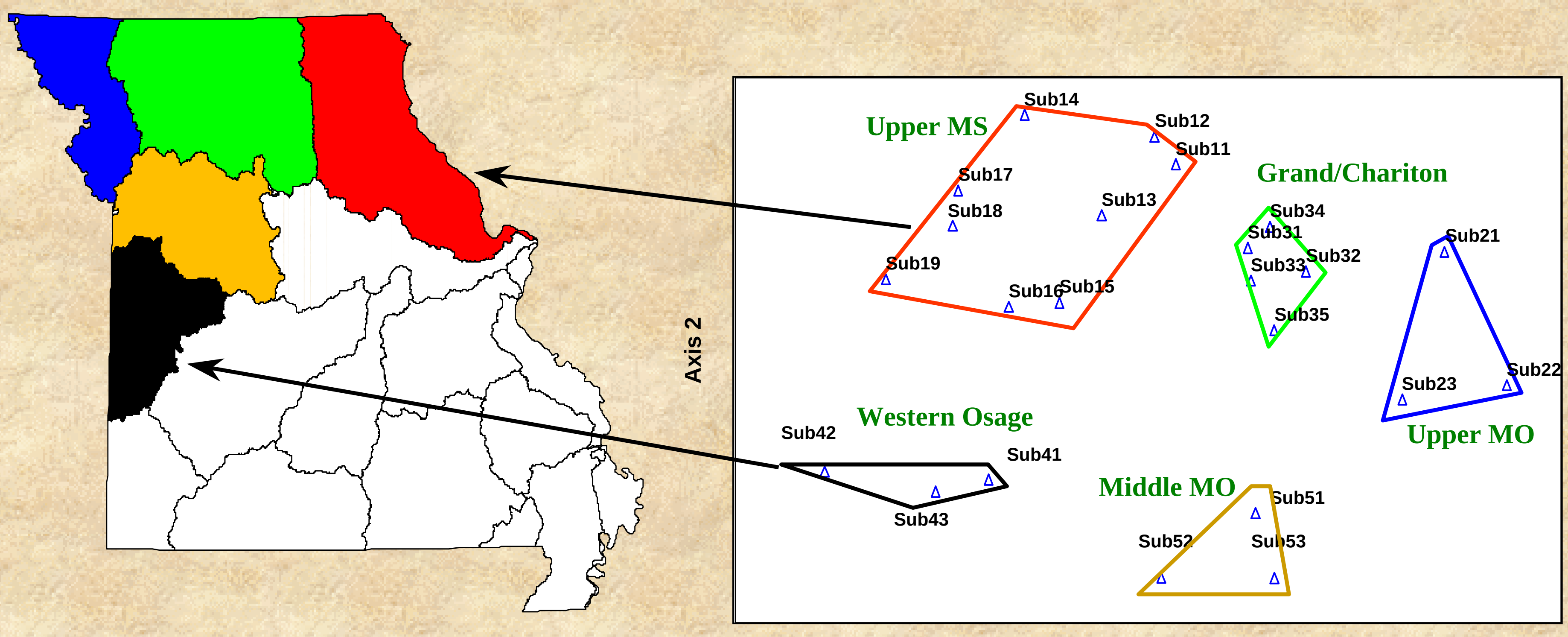
PC-ORD - [Main - OZARKS_FISH_PCTS_40MAXSAMPS.WK1]

File Edit Modify Data Summary Ordination Graph Groups Window Options Help

24	HU8EDU								
177	Species								
	Q	Q	Q	Q	Q	Q	Q	Q	Q
	S159705	S159708	S159725	S159726	S159727	S161082	S161088	S161094	S16109
H211	0	0	0	0	0	0	0	0	0
H212	0	0	0	0	0	0	0	0	0
H221	0	0	10	8	0	0	0	20	3
H222	4	0	0	0	0	0	0	19	0
H223	0	0	3	0	0	0	0	8	0
H231	3	3	8	0	0	0	0	8	5
H232	3	0	0	0	0	0	0	0	0
H241	0	0	3	0	0	0	0	14	0
H242	0	0	3	0	3	0	0	8	0
H243	0	0	13	0	0	3	10	15	0
H244	0	0	3	0	0	0	0	5	0
H251	0	0	6	0	3	3	0	6	0
H252	0	0	0	11	0	0	0	9	0
H253	0	0	15	4	0	0	4	31	0
H261	0	0	8	0	0	0	0	18	0
H262	0	0	0	0	0	0	0	14	0
H271	0	0	0	0	0	0	0	3	0
H272	3	0	0	0	0	0	0	0	0
H273	6	0	3	0	0	0	0	0	0

Main:OZARKS_FISH_PCTS_4 | Second: | Row: | Col: | Result: | F4 Append Results

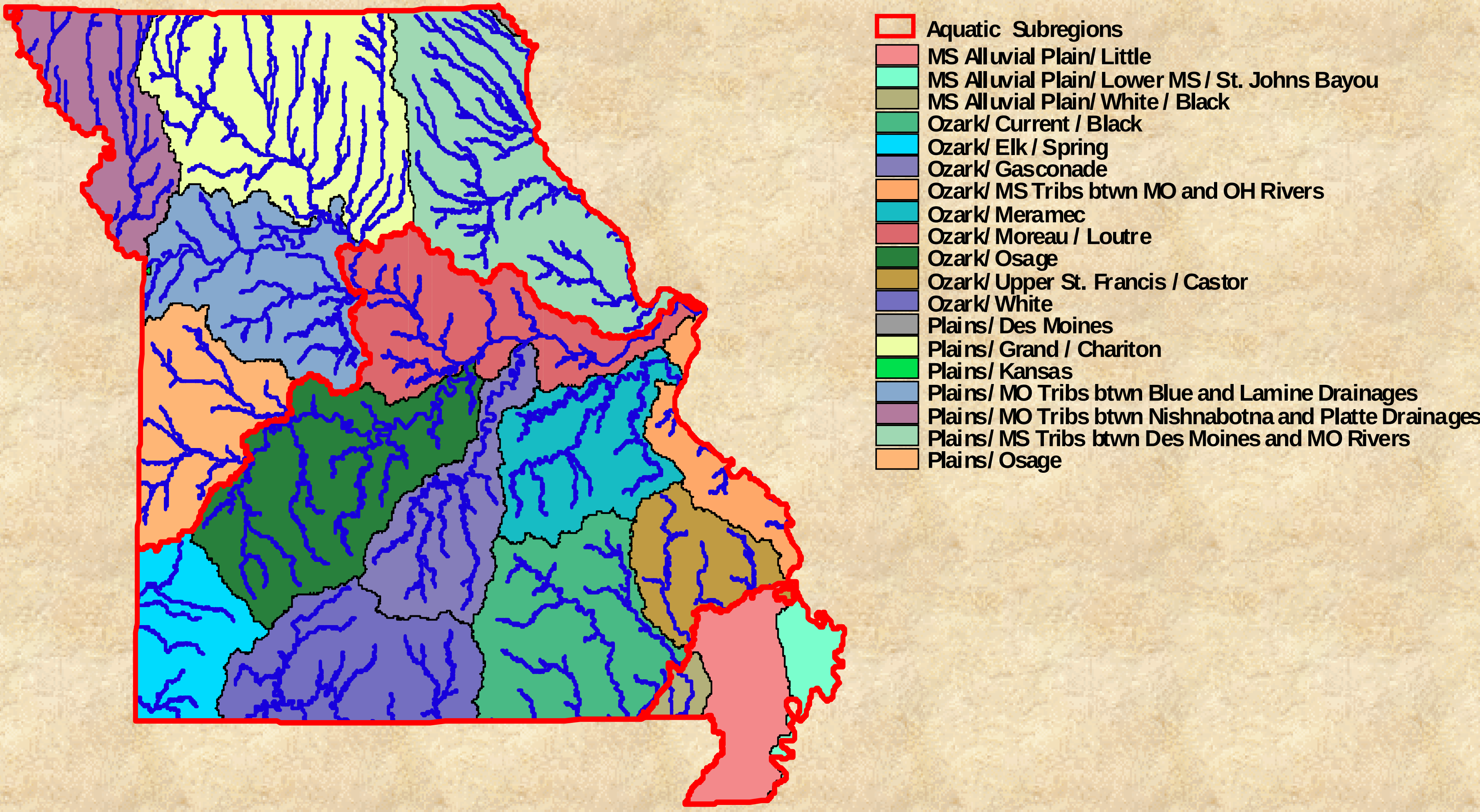
Delineating EDU's: Multivariate Analysis of Fish Community Data



Ecological Drainage Units

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

Missouri Ecological Drainage Units (EDU)

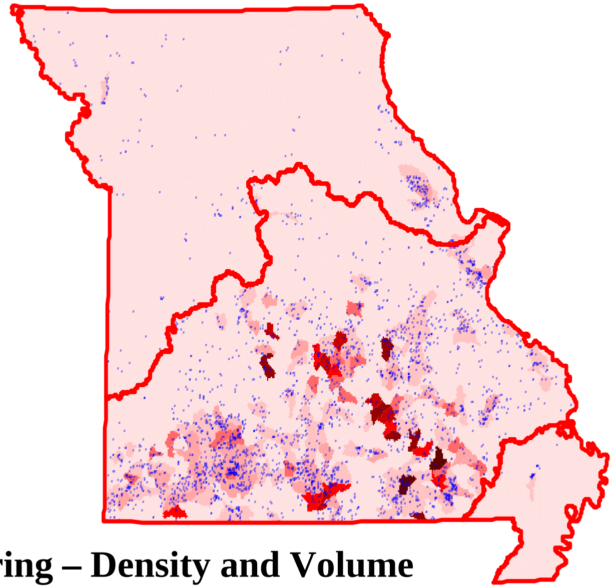


Level 6: Aquatic Ecological Systems and Types

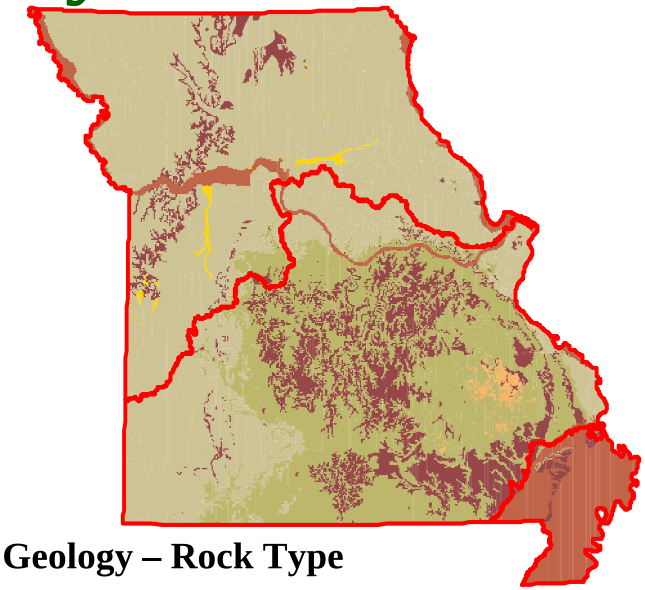
- Note: No 2 EDU's have the same combination of AES-types

Like colors represent hydrogeomorphically similar watersheds (AES Types)

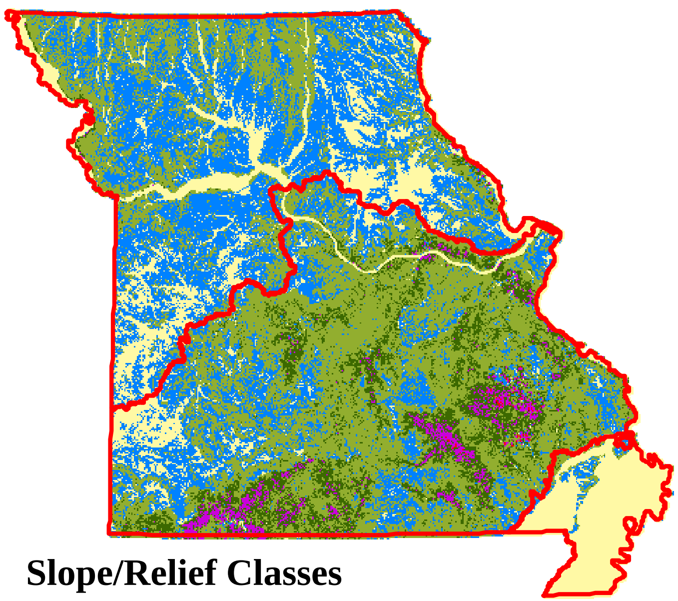
Level 6: Discriminatory Variables



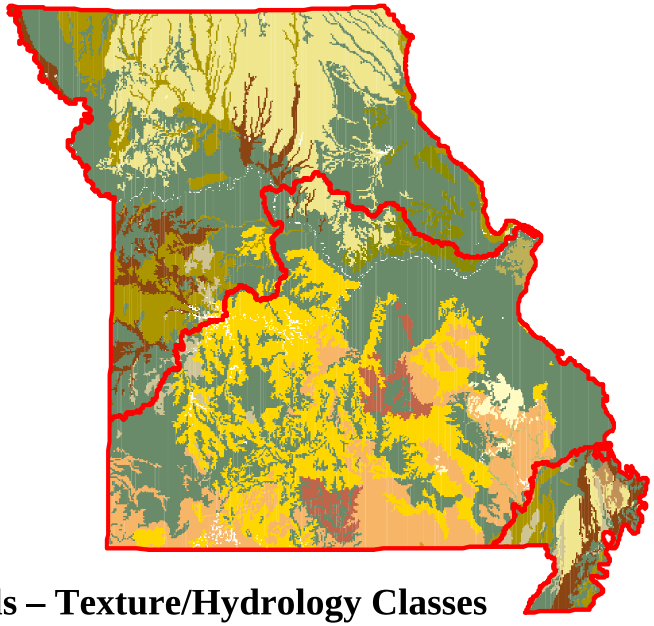
Spring – Density and Volume



Geology – Rock Type

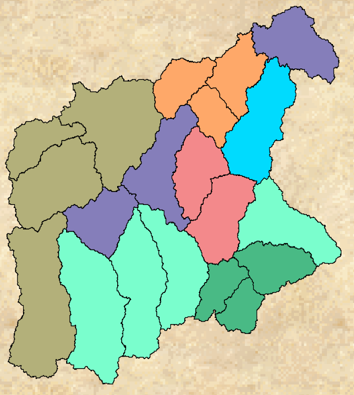


Slope/Relief Classes



Soils – Texture/Hydrology Classes

Delineating Aquatic Ecological Systems

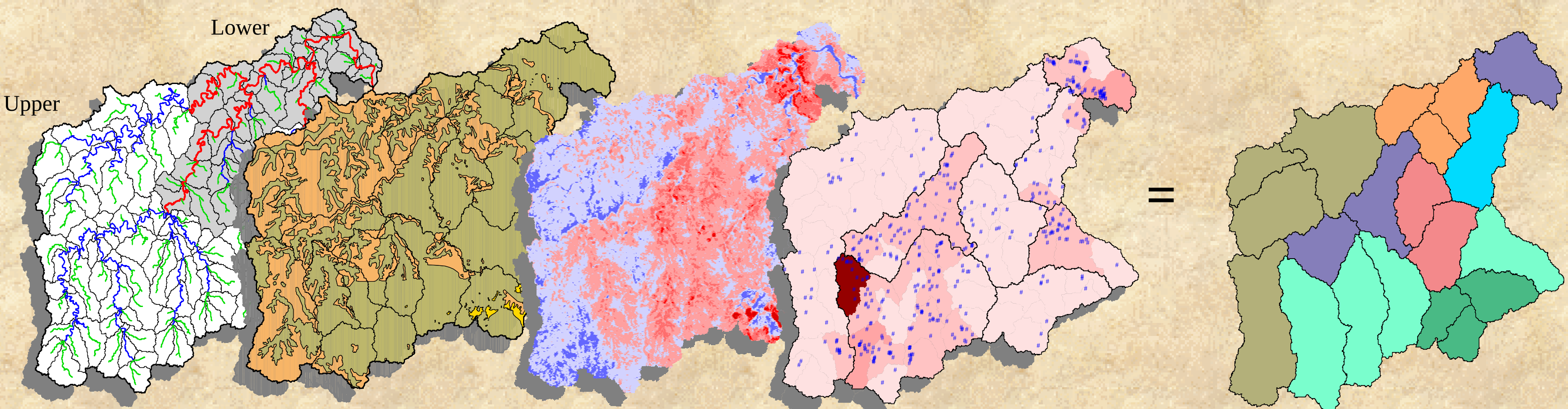


Discriminatory Variables

Soil Hydro Group: 2 categories
Soil Texture: 6 categories
Bedrock Geology: 6 categories
Relief: 7 categories
Spring Density
Springflow volume per unit area

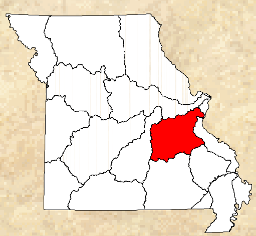
* Percentages are calculated for overall watershed and local "segment-sheds"

Aquatic Ecological Systems and Types For the Ozark/Meramec EDU



Position Soil/Geology Landform Springs

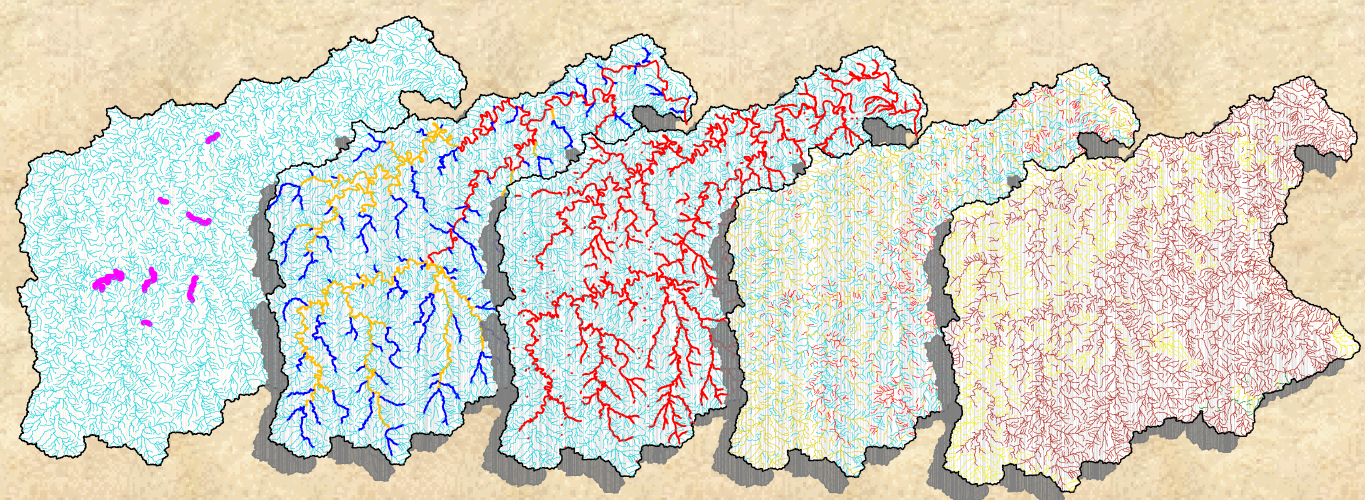
Aquatic Ecological Systems



Level 7:
Valley Segment Types

- Valley segments stratify a continuous stream network into distinct hydrogeomorphic patches

<u>Individual Variables</u>

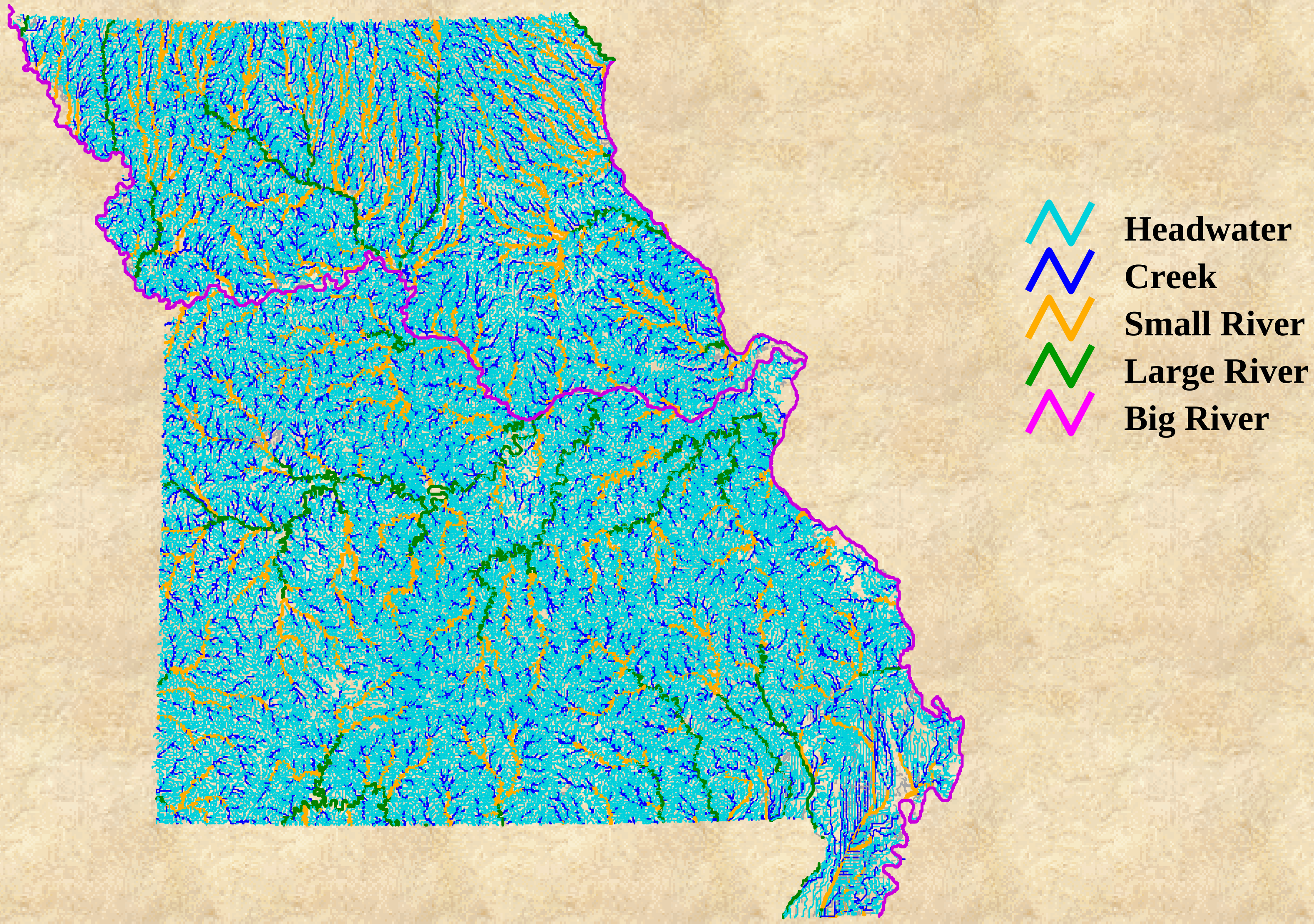


Temperature Stream Size Flow Gradient Geology

<u>Unique Valley Segment Types</u>

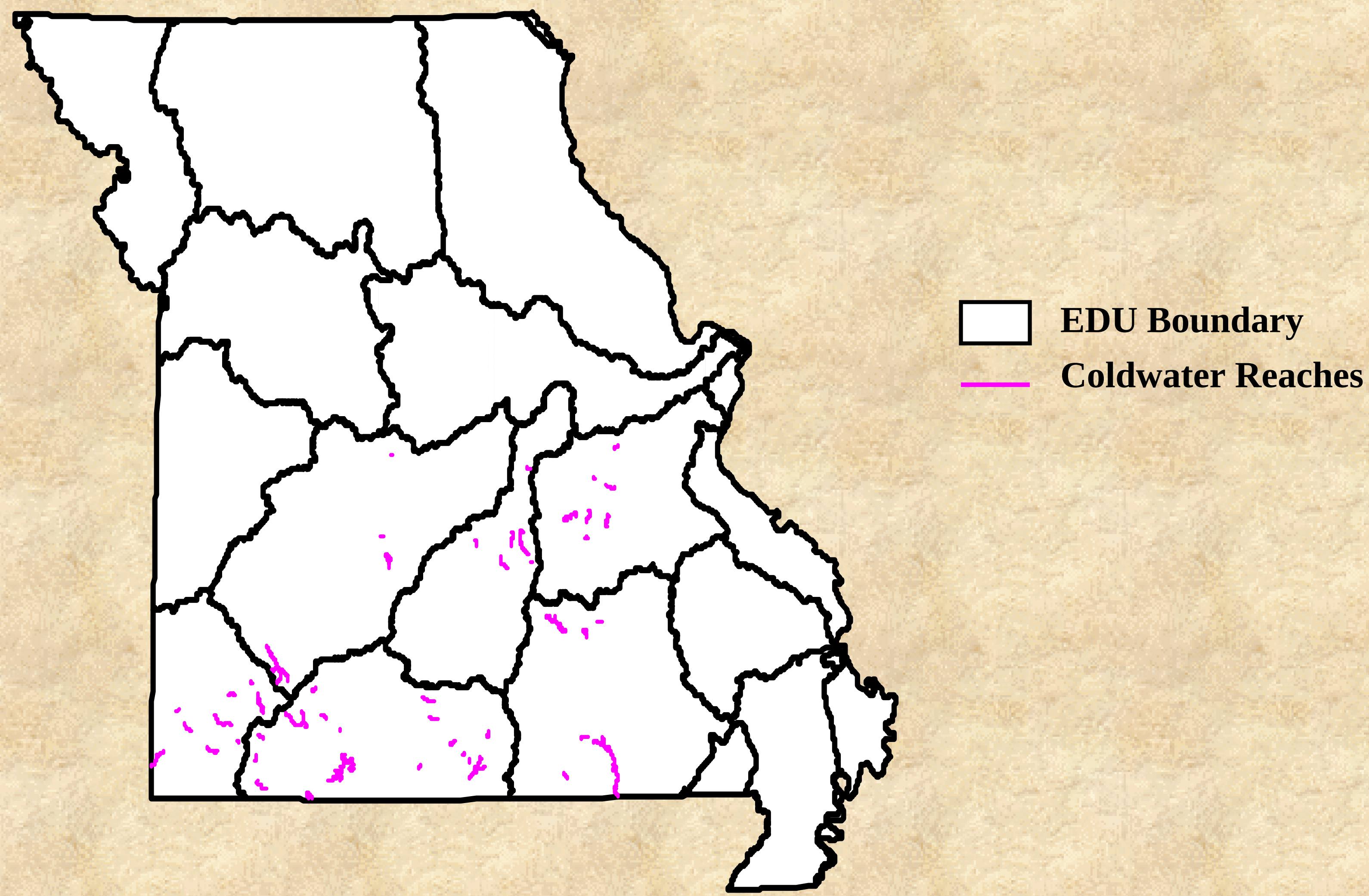
Valley Segment Types

Statewide Stream Size Classes



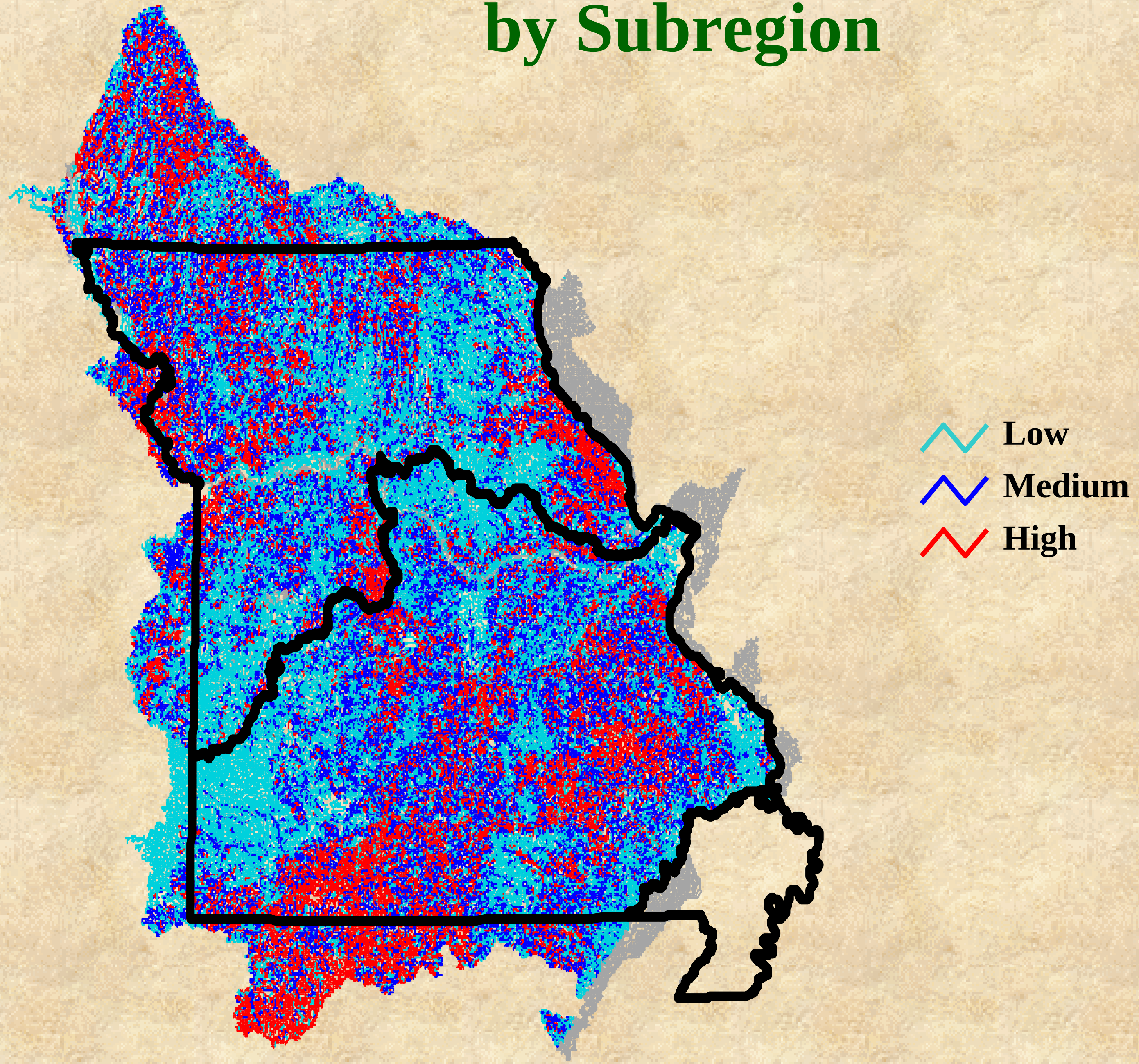
- Provides standardized categories of stream size

Stream Temperature



Most critical information gap

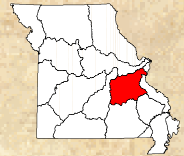
Relative Stream Gradient by Subregion



Ozark/Meramec EDU
Valley Segment Types

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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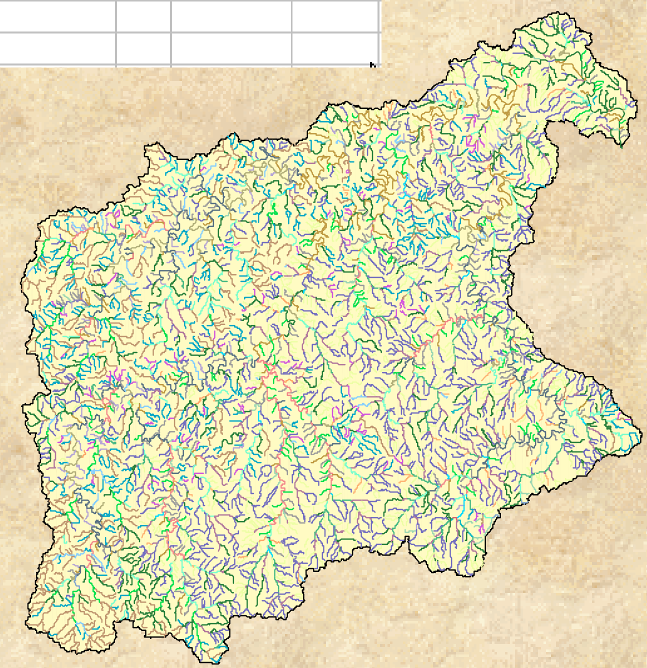
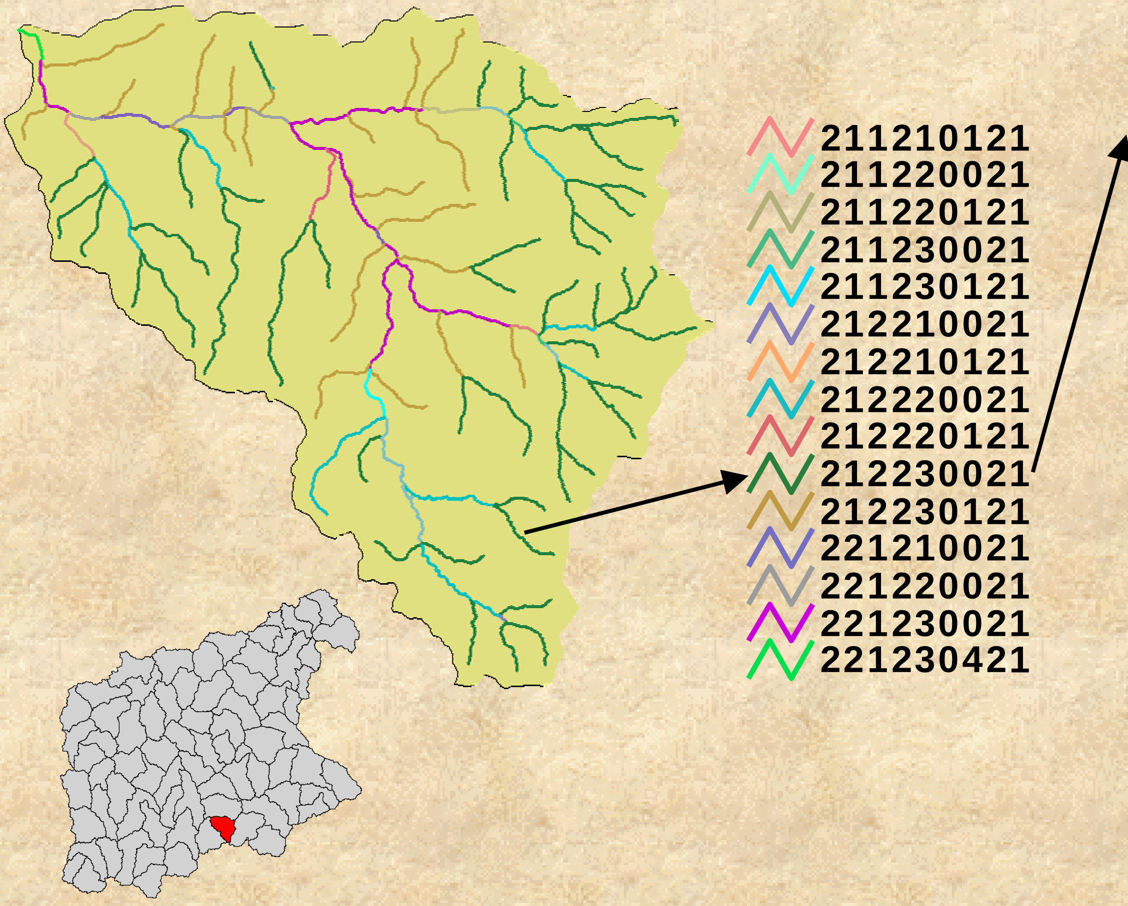


- Variables are concatenated into one numeric code
- Each unique code represents a unique valley segment type

What We Know From Valley Segment Classification



Valley Segment Type
Codes and Descriptions

212230021 = Valley Segment Type Code

2 = Warm water

1 = Headwater size class

2 = Intermittent flow

2 = Flowing through dolomite/limestone

3 = Relatively high gradient

0 = Valley wall interaction (N/A)

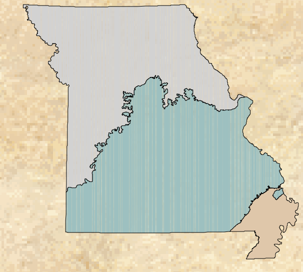
0 = Flows into another headwater

2 = Flowing within own valley

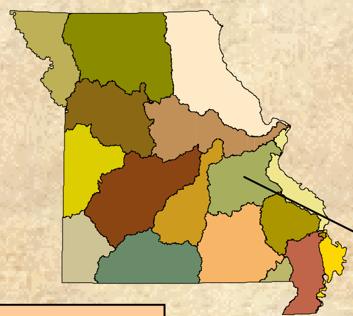
1 = Primary channel

Understanding Ecological Context

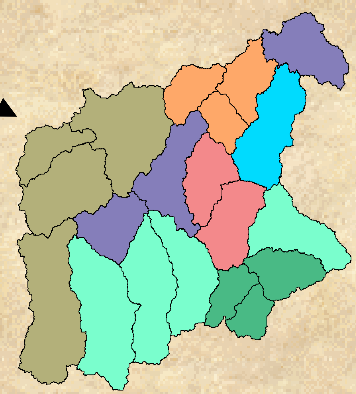
Level 4
Subregions



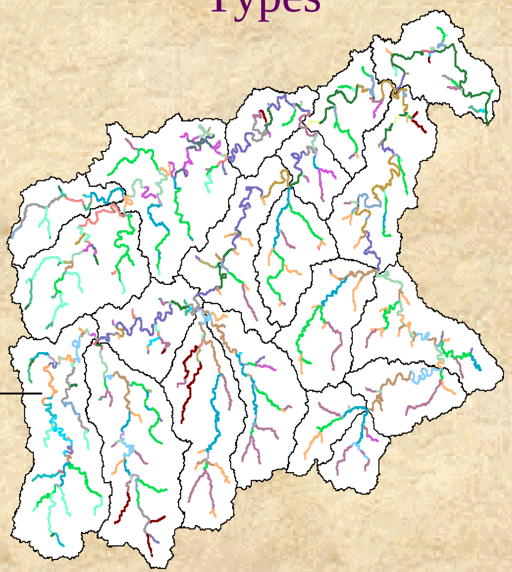
Level 5
Ecological Drainage Units



Level 6
Aquatic Ecological Systems

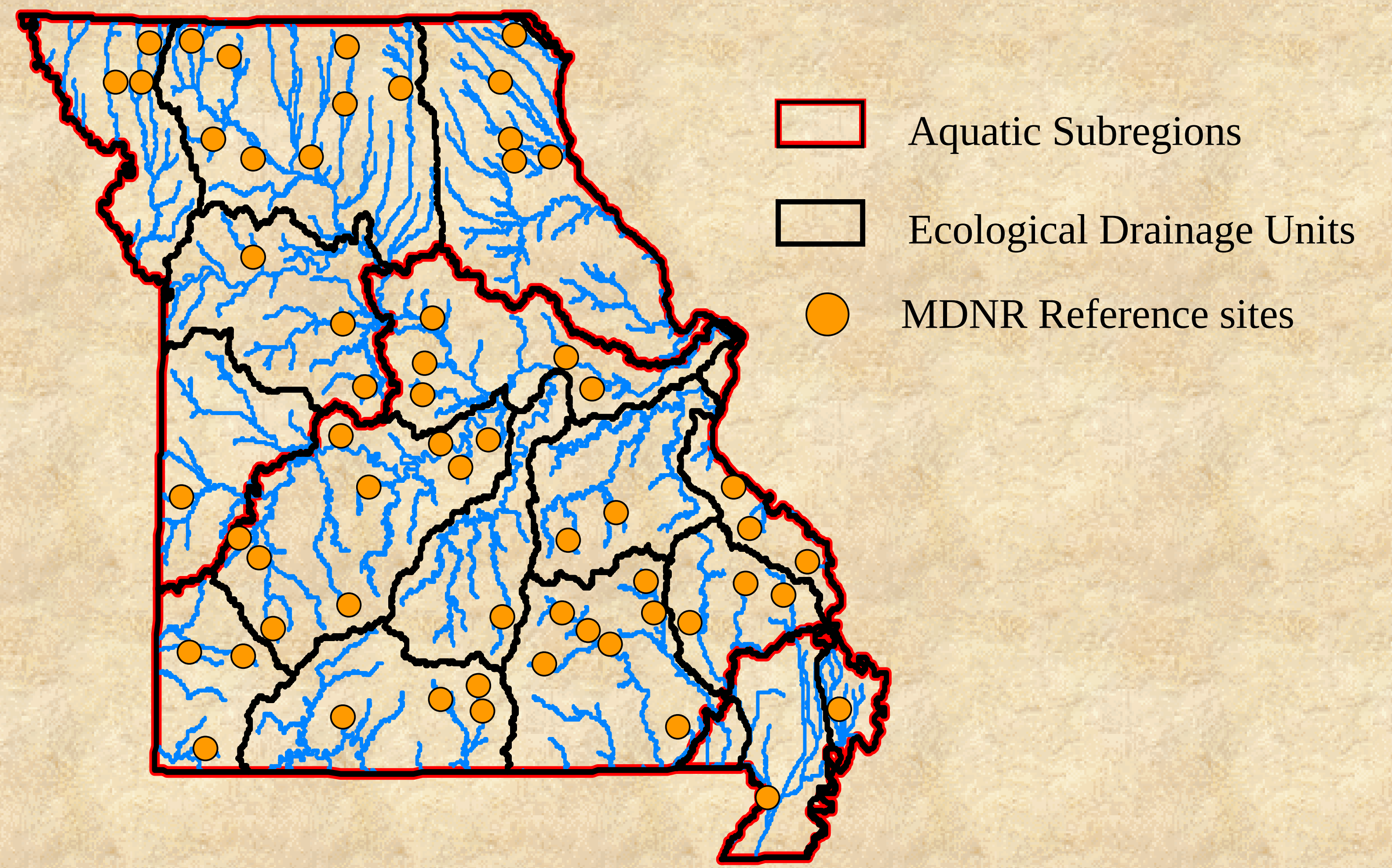


Level 7
Valley Segment Types

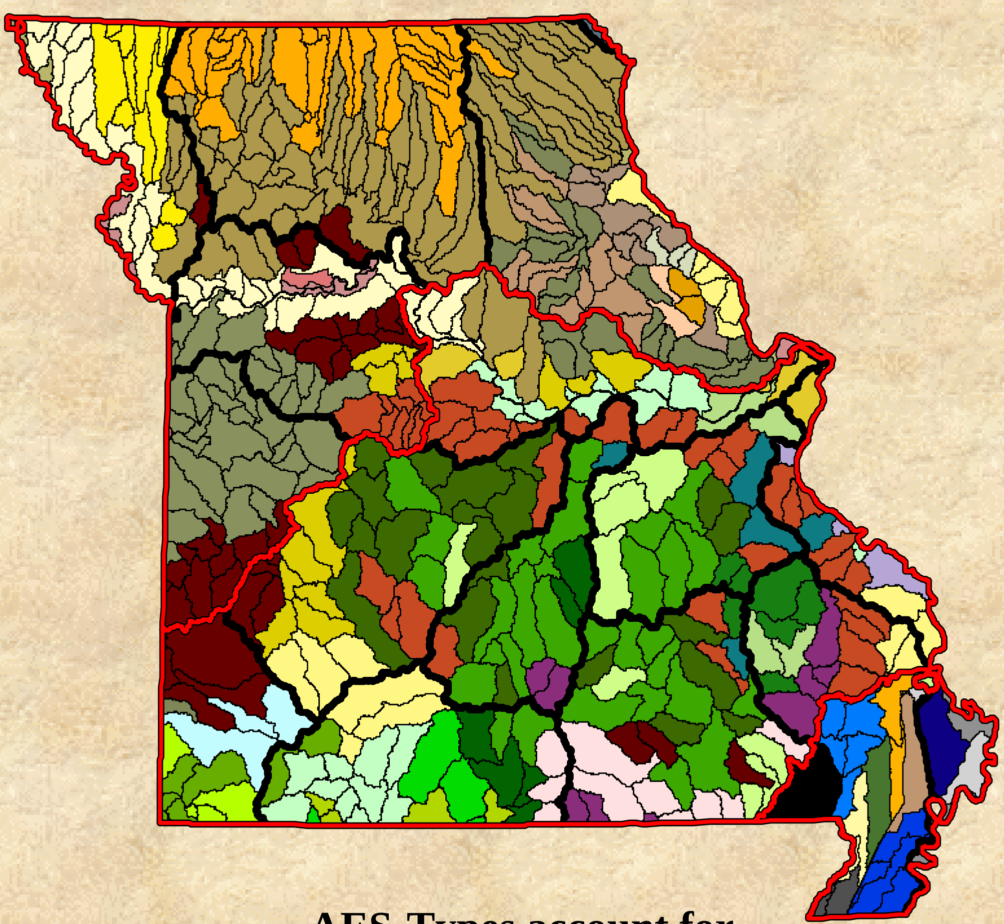


Zone:
Nearctic zoogeographic zone
Subzone:
Arctic/Atlantic Drainages
Region:
Mississippi Drainage
Subregion:
Ozark Plateau
Ecological Drainage Unit:
Ozark Plateau/Meramec Drainage
Aquatic Ecological System:
Upper Meramec/Dry Fork, Oak/Woodland Plain, sandstone dominated, low gradient and spring density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

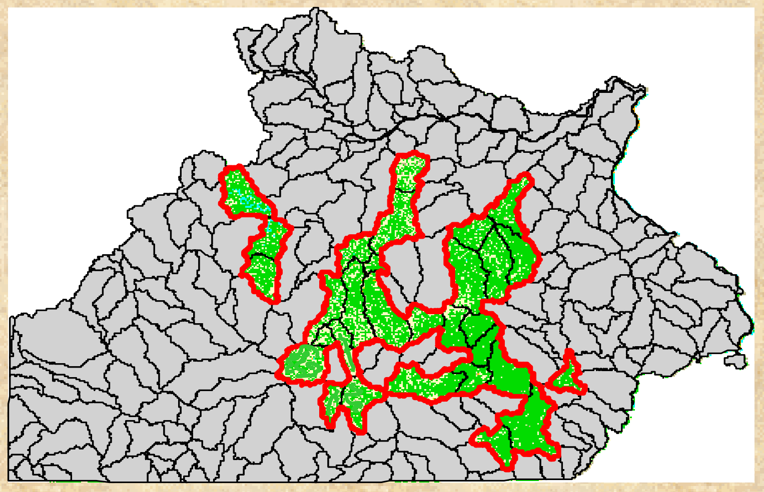
Potential Uses: More Informative Reporting of Results



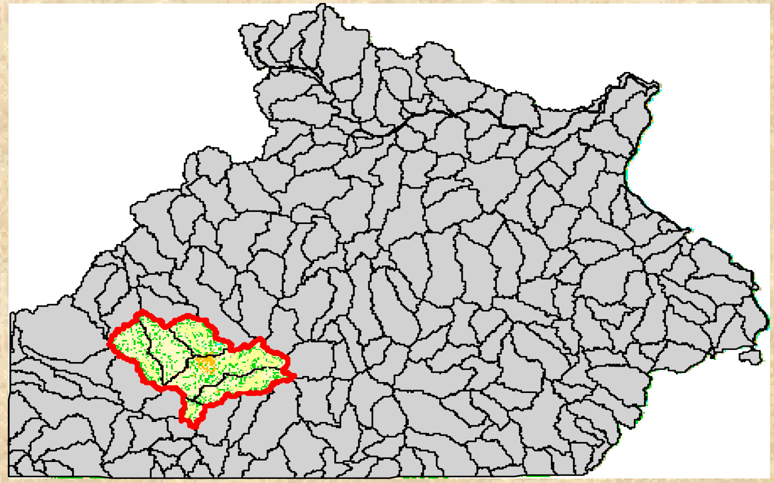
Potential Uses: More precise criteria and enhancing ability to identify specific cause of impairment



AES-Types account for agricultural and resource extractive land uses



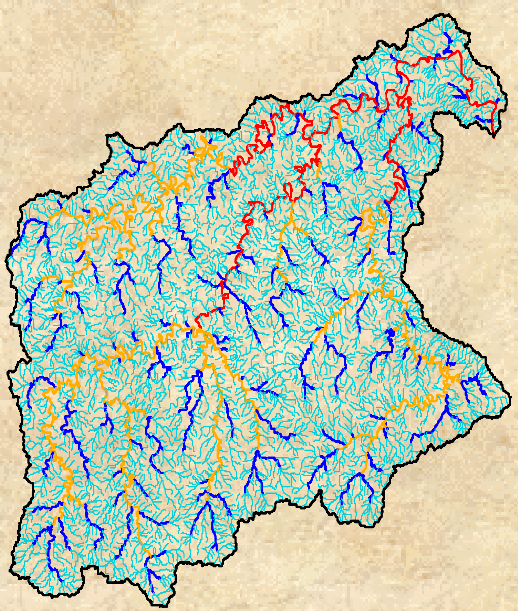
Forest Dominated



Grassland/Pasture Dominated

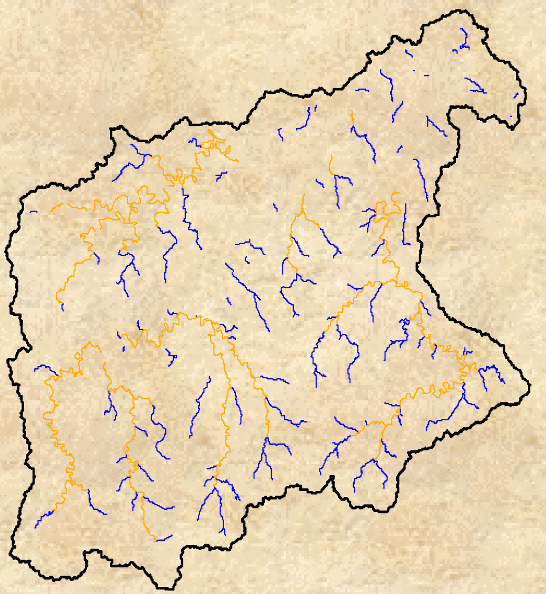
Potential Uses: Significantly Reduce the Sample Population for Reference Site Selection and Monitoring

Full Network



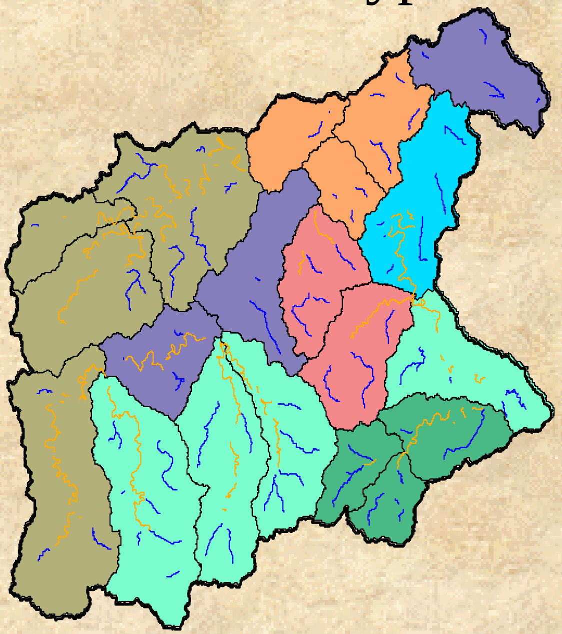
6,637 miles

Wadeable Perennial



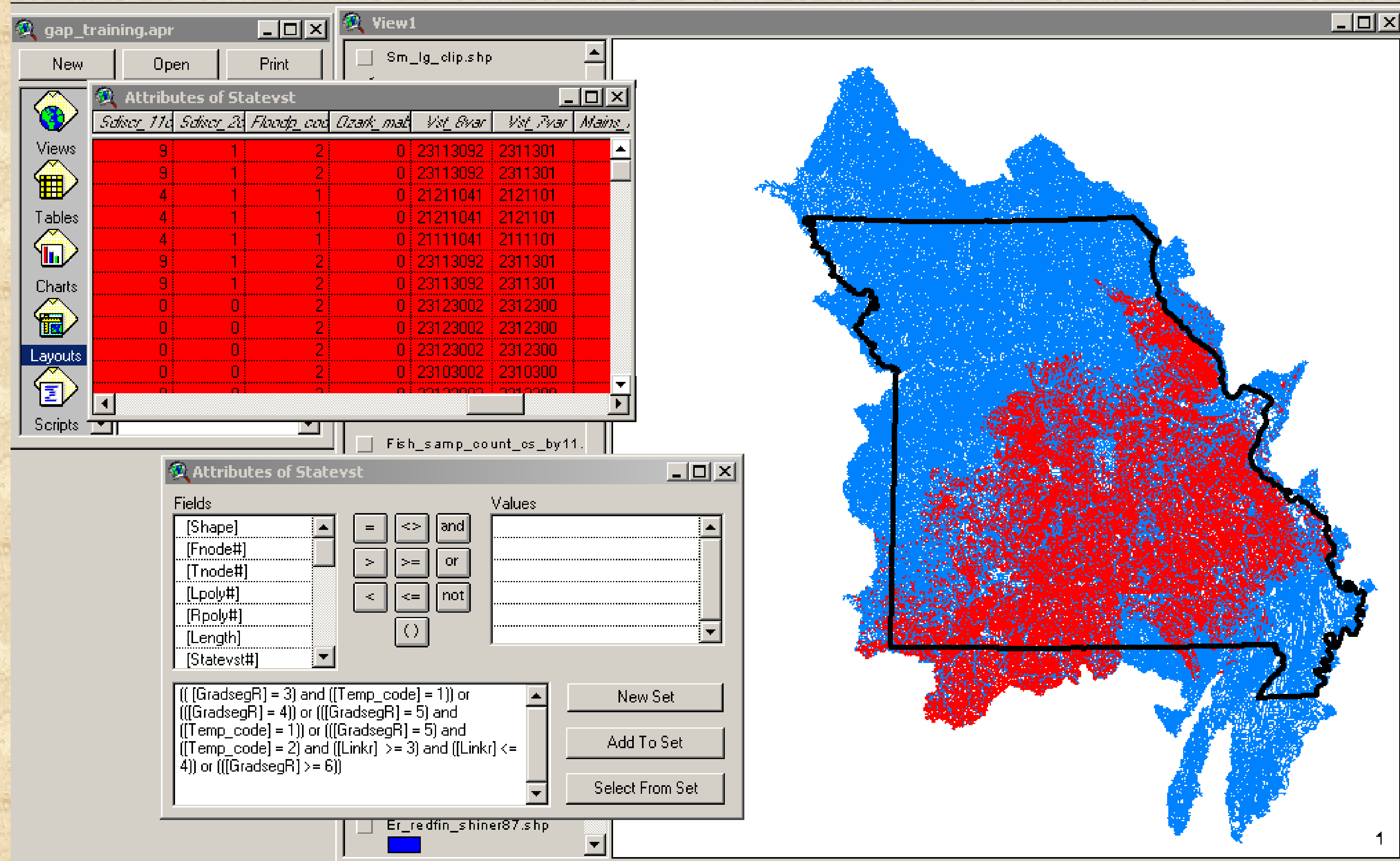
1250 miles

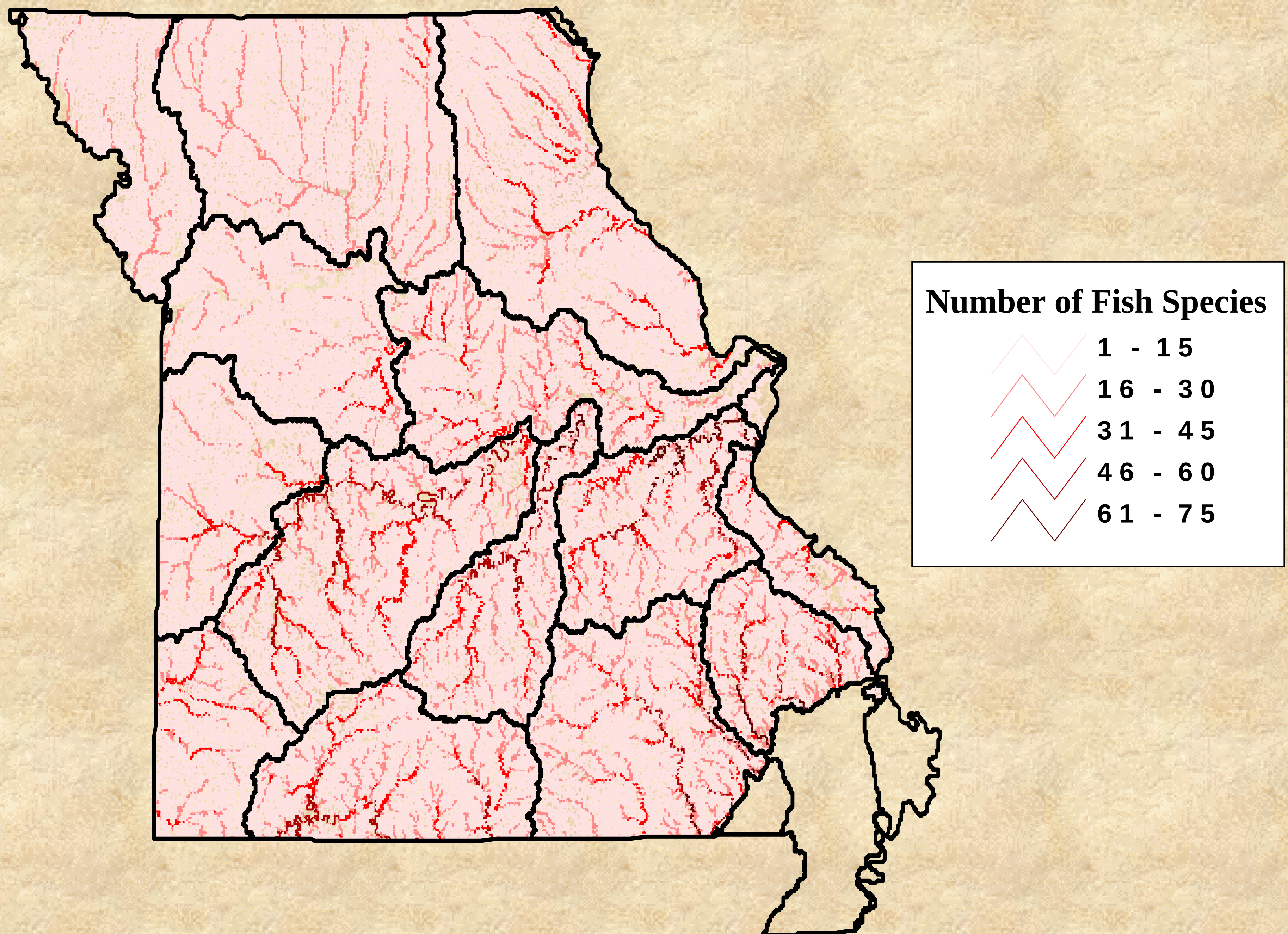
Dominant VST by AES-Type



663 miles

Potential Uses: Predicting species distributions and biological potential



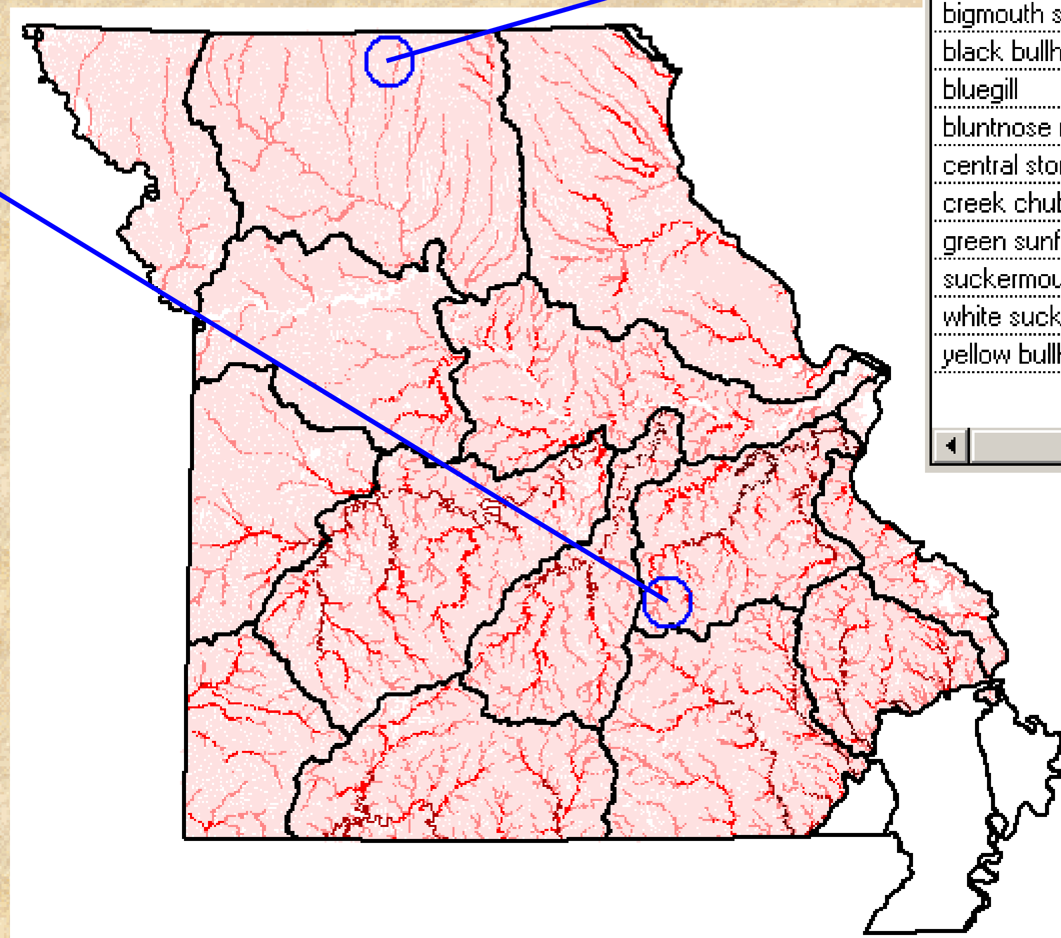

Number of Fish Species
1 - 15
16 - 30
31 - 45
46 - 60
61 - 75

Predicted Biological Potential

Ozarks: 27 Species

sum6.dbf

Vernacular
Ozark minnow
bigeye chub
black bullhead
blackspotted topminnow
bleeding shiner
bluegill
bluntnose minnow
brook silverside
central stoneroller
common carp
creek chub
creek chubsucker
golden redhorse
golden shiner
green sunfish
greenside darter
largescale stoneroller
logperch
longear sunfish
northern hog sucker
northern studfish
plains topminnow
rainbow darter
slender madtom
smallmouth bass



Plains: 10 Species

sum7.dbf

Vernacular
bigmouth shiner
black bullhead
bluegill
bluntnose minnow
central stoneroller
creek chub
green sunfish
suckermouth minnow
white sucker
yellow bullhead

Improving Classification of Missouri's Stream 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

Conclusions

- We must integrate biomonitoring and biodiversity conservation efforts
- A common geographic framework is the first step toward integration
- Numerous physicochemical and evolutionary processes collectively determine local aquatic assemblages
- Existing classifications do a good job of accounting for differences in reference criteria
- We believe our biophysical classification can be applied nationwide and provide a common geographic framework for biomonitoring and biodiversity conservation
- However, there is room for improvement

How would we “carve” up the landscape if we had a single all purpose biological index?