An Aquatic Ecological Classification System for Riverine Ecosystems: Uses and Benefits for Conservation

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Introduction

Freshwater assemblages are largely a product of physiography and evolutionary processes associated with isolation of watersheds or major drainage systems. In 1994 the EPA Science Advisory Board noted that two major limitations of existing classifications used by EPA for monitoring and assessment were their failure to; a) account for longitudinal variation along stream ecosystems and; b) incorporate biogeographical and distributional patterns of riverine biota (EPA 1994). As part of the Missouri Aquatic GAP Project, the Missouri Resource Assessment Partnership (MoRAP) has developed a broadly applicable ecological classification framework that addresses both of these issues by integrating physical and biogeographical delineation criteria into a methodology for defining and mapping riverine ecosystems within a GIS. The MoRAP classification framework delineates and maps aquatic ecosystems and not simply regions of similar climate, geology, and landform. The classification is designed to also take into account the role isolation mechanisms, such as watersheds, play in shaping aquatic assemblages.

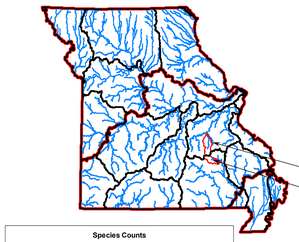
Influence of Watersheds and Physiography On Freshwater Assemblages

Pacific Drainages:
- Relatively low faunal diversity, but high percentage of endemic species
- Fish assemblage dominated by:
  - Large bodied, long-lived catostomids and cyprinids
  - Anadromous salmonids
  - Cyprinodons

Atlantic Drainages:
- Highly diverse aquatic fauna
- Fish assemblage similar to Gulf drainages at genus level, but many species differ across the Atlantic divide
- Contains several anadromous species

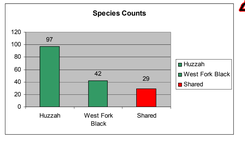
Gulf Drainages:
- Highly diverse aquatic fauna
- Fish assemblages dominated by centrarchids, ictalurids, catostomids and cyprinids
- Also contains ancient relict species, such as paddlefish, gar, bowfin, and sturgeon

Watershed Boundaries Matter Even at Small Spatial Scales



Hydrogeomorphic Character:
- Highly dissected low mountains
- Sandstone and Limestone
- Moderately well drained soils with coarse silty loam texture
- High density of small springs

Biologic Characteristics: (fish, mussels, crayfish, and snails)
- 97 Species Huzzah Watershed
- 42 Species West Fork Black Watershed
- 29 shared species
- 61 of the 97 species in the Huzzah are not found in the West Fork Black



The Key Question:

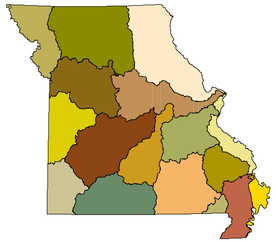
How do we incorporate the influence of both physiography and watershed boundaries in shaping freshwater assemblages?

Level 4: *Aquatic Subregions*

Mississippi Alluvial Basin

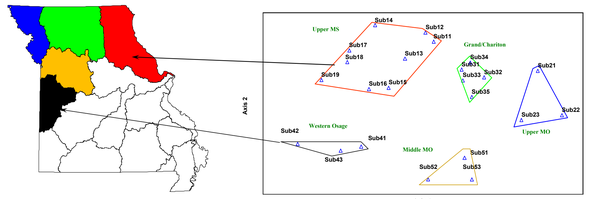
Subregions are largely physiographic or ecoregional substrata of Regions, however, the boundaries between our Aquatic Subregions follow major drainage divides. Each Subregion has a distinct geologic history, distinct biophysical potential, and a relatively distinct set of historical and present-day land uses. The three Subregions that cover Missouri (Central Plains, Ozark Plateau, and Mississippi Alluvial Plain) currently serve as the principle ecoregional strata for the EPA Region 7 REMAP and closely correspond to Bailey's (1995) Ecological Provinces and Omernik's (1987) Level III ecoregions. These three Subregions also largely correspond with the three major aquatic faunal regions of Missouri. Pflieger (1989) used community fish sampling data and multivariate statistics to empirically define these three major faunal regions. Other studies have also concluded that these Subregions are necessary strata to account for biophysical variation in Missouri's riverine ecosystems (Rabeni et al. 1997; Rabeni and Doisy 2000).

Level 5: *Ecological Drainage Units*



Ecological Drainage Units (EDU's) are zoogeographic substrata of Subregions. EDU's are empirically derived and represent fairly large watersheds or subdrainages (approx 2,500-10,000 mi²) containing aquatic assemblages that are relatively distinct within the context of the surrounding Subregion. To delineate and map EDU's we spatially linked existing community fish sampling data to the USGS/EPA National Hydrography Dataset and the USGS 8-digit Hydrologic Units (HU's). We then generated prevalence indices for each species within each 8-digit HU and used multivariate analyses (Nonmetric Multidimensional Scaling and Clustering) to statistically examine the relative similarity of fish assemblages among 8-digit HU's. We then grouped HU's with relatively similar assemblages into a draft set of EDU's. Finally, we examined distributional data for crayfish, mussels and snails to revise and refine the EDU boundaries where necessary. Using this process 17 EDU's were delineated for Missouri. In every instance, our empirically-derived EDU's account for additional variation in aquatic assemblages not captured by the three Subregions.

EDU Ordination Plot



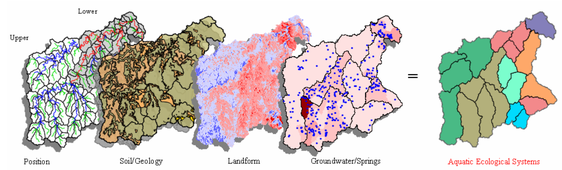
Ecological Drainage Units

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

Example for the Central Plains Aquatic Subregion showing how multivariate analyses of fish community sampling data are used to help group 8-digit HU's (labeled Sub## on plot) with similar aquatic assemblages into EDU's. Color of boxes on ordination plot correspond to color of the five EDU's delineated within the Central Plains Aquatic Subregion of Missouri.

Level 6: *Aquatic Ecological Systems*

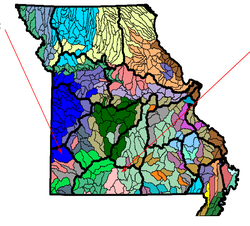
Factors used in Delineating AES's



Aquatic Ecological Systems (AES's) are derived *a priori* using several readily available geospatial datalayers and represent watersheds or subdrainages (approx 100 to 600 mi²) with relatively distinct combinations and longitudinal patterns of geology, soils, landform, and surface to groundwater influences. AES's are both hydrogeomorphic substrata of Subregions and zoogeographic substrata of EDU's. That is, the same type of AES (AES-Type) can be found in two or more EDU's, however, the EDU within which an AES resides determines its biological potential.

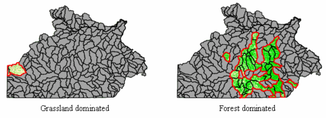
Contrasting AES Types

South Deepwater Creek AES Type:
- Essentially no springs or spring influence
- Very low relief
- Alfisols
- Slow infiltration silty loams
- Limestone dominated



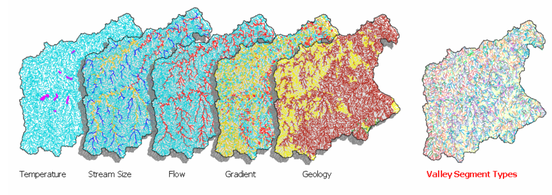
Jacks Fork AES Type:
- Large number of springs and significant spring influence
- Moderate to high relief
- Ultisols
- Moderate infiltration
- Very cherty silty loams
- Dolomite with significant sandstone components

Accounting for Land Use/Cover



AES's are defined by multiple natural attributes known to influence the structure of local biological assemblages. Even though landuse and landcover are not directly incorporated into the classification process we consistently find that AES-Types account for variation in these factors as they too are strongly influenced by geology, soils and landform.

Level 7: *Valley Segment Types*



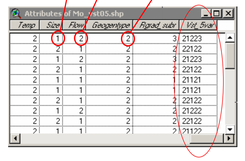
Valley Segment Types (VST's) are linear hydrogeomorphic substrata of Subregions and biological or ecological substrata of EDU's and AES's. VST's are typically 1-5 km in length. VST's are defined *a priori* using several hydrogeomorphic variables known to influence the biophysical character streams at this spatial scale. Several nationally standardized geospatial datalayers are used to carry out the classification within a GIS. We use the EPA/USGS 1:100,000 NHD as the base layer for delineating VST's.

Individual stream reaches are first classified into size categories of; headwater, creek, small river and large river which are based upon the community zone classes and criteria designated by Pflieger (1989). We further stratify segments according to their size discrepancy (e.g., headwater flowing into another headwater vs. a headwater flowing into a small river). Osborne and Wiley (1992) found size discrepancy to be an important variable determining species richness in Midwestern warmwater streams. We then use a 30-meter Digital Elevation Model to calculate stream gradients. Within each size class stream segments are categorized into gradient categories of high, medium or low that are relative to the surrounding Subregion. Using a digital map of the coldwater streams of Missouri we then stratify streams into categories of warm or cold. Streams are further stratified according to their permanence of flow. We then use a statewide geology map to classify each stream reach according to the dominant geology through which it flows.

Concatenating VST Variable Codes

Variable Codes

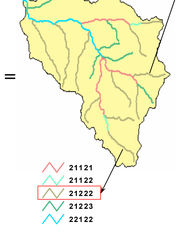
	Temp	Stream Size	Flow	Geology	Rel. Gradient
Cold	1	Headwater	1 Perm.	1 Alluvium	1 Low 1
Warm	2	Creek	2 Inter	2 Limest./Dolom.	2 Med. 2
		Sm. River	3	3 Igneous	3 High 3
		Lg. River	4	4 Sandstone	4
				5 Clay	5



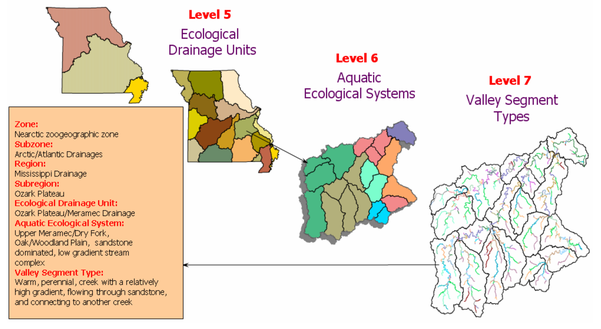
Numeric codes are used to distinguish between each of the classes for each variable. Once the classification process is completed we simply concatenate these numeric values into a single code. Each distinct combination of numeric codes represents a distinct VST.

Valley Segment Type Codes and Descriptions

21222 = Valley Segment Type Code
- 2 = Warm water
- 1 = Headwater size class
- 2 = Intermittent flow
- 2 = Flowing through dolomite/limestone
- 3 = Relatively high gradient

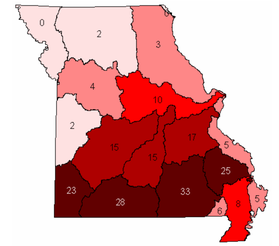


Understanding Ecological Context



Conservation Planning

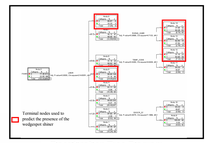
The resulting suite of data layers can be used flexibly for conservation planning at different spatial scales. For instance, EDU's can be used for coarse level planning and prioritization of conservation targets. The example to the right shows the number of crayfish, fish and mussel species found in each EDU that are endemic at the Subregion or EDU level.



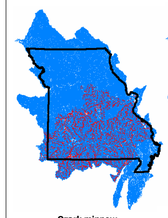
Number of Species Endemic at Subregion or EDU level (crayfish, fish and mussels)

❖ Model Biological Potential

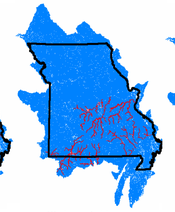
Biological data can be linked to the valley segment datalayer which can then be used to model statewide species distributions. In Missouri we used a nonparametric procedure known as classification tree analysis to model the distribution of more than 350 species. The resulting geospatial datalayer allows you to select an individual stream reach and see a list of all species likely to occur in that reach under relatively undisturbed conditions.



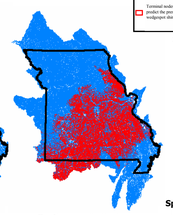
Classification Tree Diagram for the Wedgespot shiner



Ozark minnow



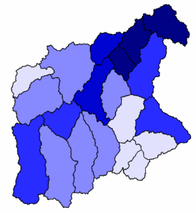
Wedgespot shiner



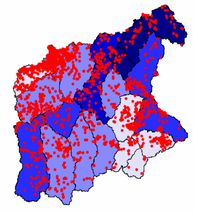
Southern redbelly dace

Species of Concern Predicted to Occur in Mineral Fork Creek at Missouri Route 185's Bridge Crossing

❖ Fish Species Richness and Potential Threats

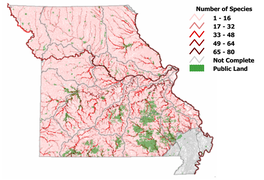


Fish Species by AES

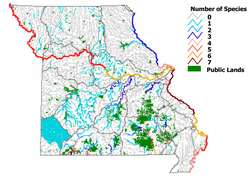


Fish Species by AES Showing Mine Locations

Fish Species Richness



Globally Rare, Threatened, and Endangered Fish Species (G1 – G3 Species)



With the modeling complete species distributional data can be linked to the valley segment coverage and queried or displayed according to overall richness or number of rare, threatened, and endangered species.

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