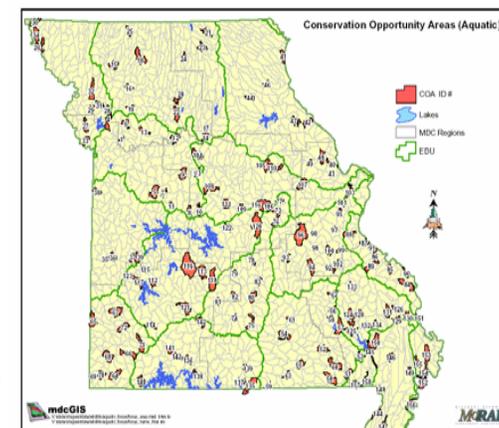
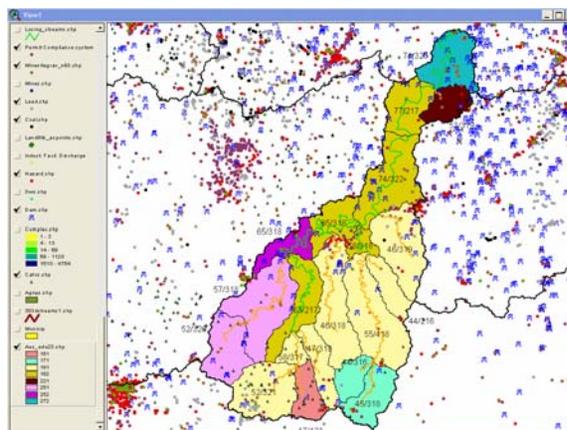
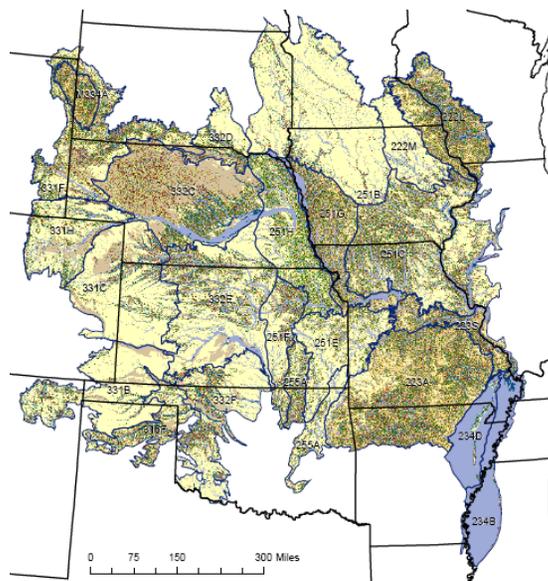
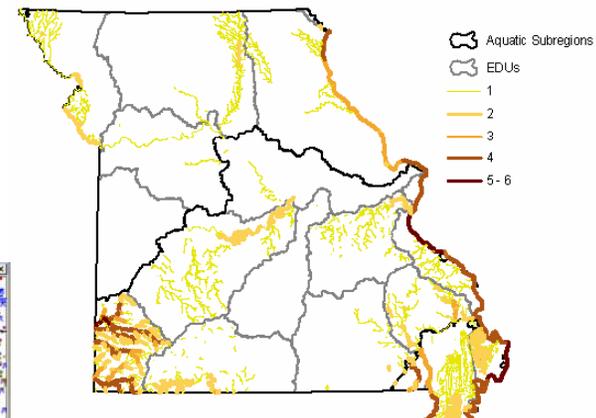
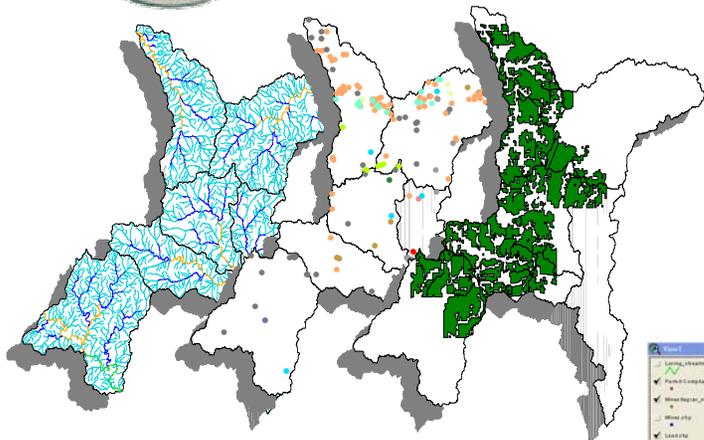




Overview of Relevant MoRAP Projects



**Phase 1 Planning Workshop
September 6th and 7th 2006**

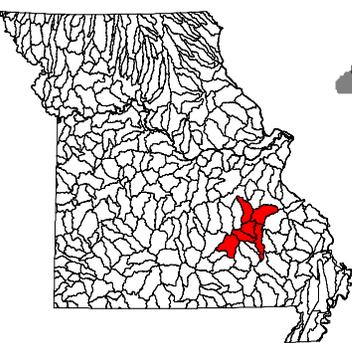
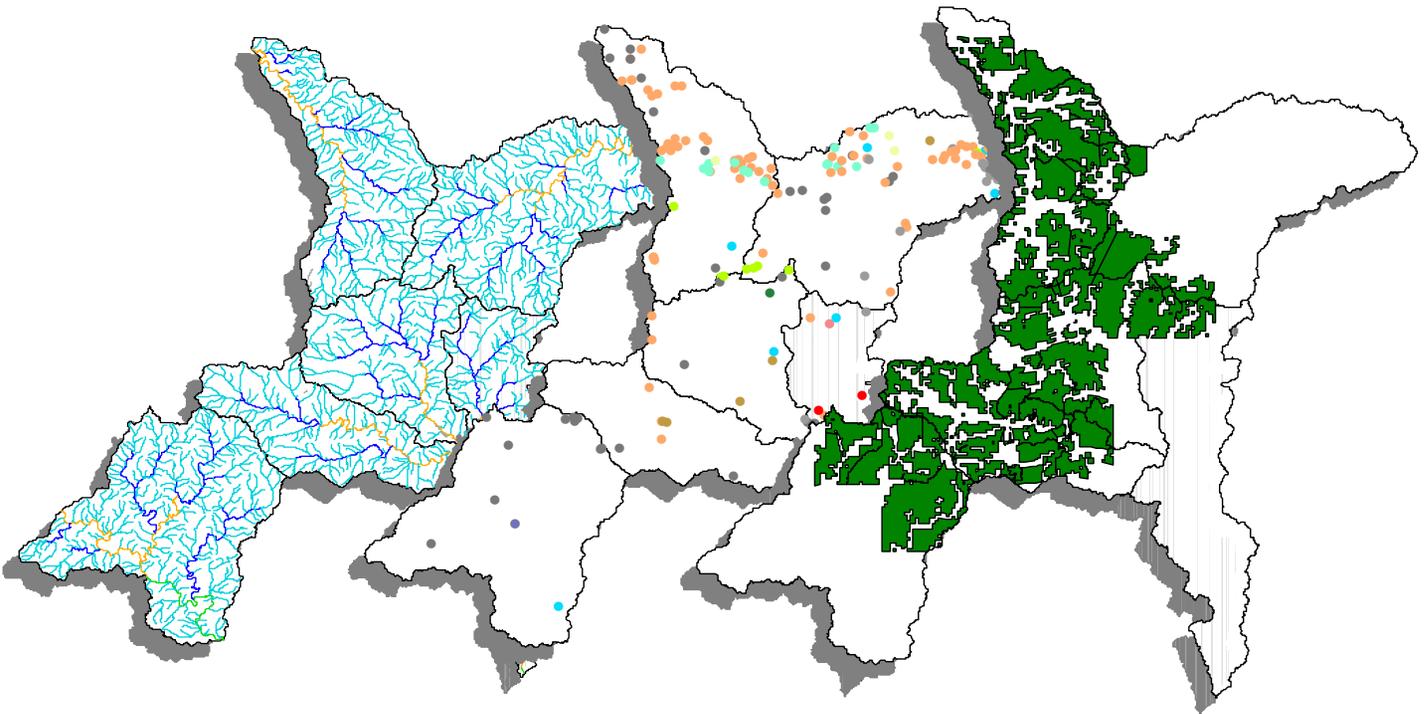
**Richard A. Schoettger Conference Building
USGS Columbia Environmental Research Center
4200 New Haven Road, Columbia, MO 65201**



A Watershed Inventory for Select Watersheds Draining MTNF Lands

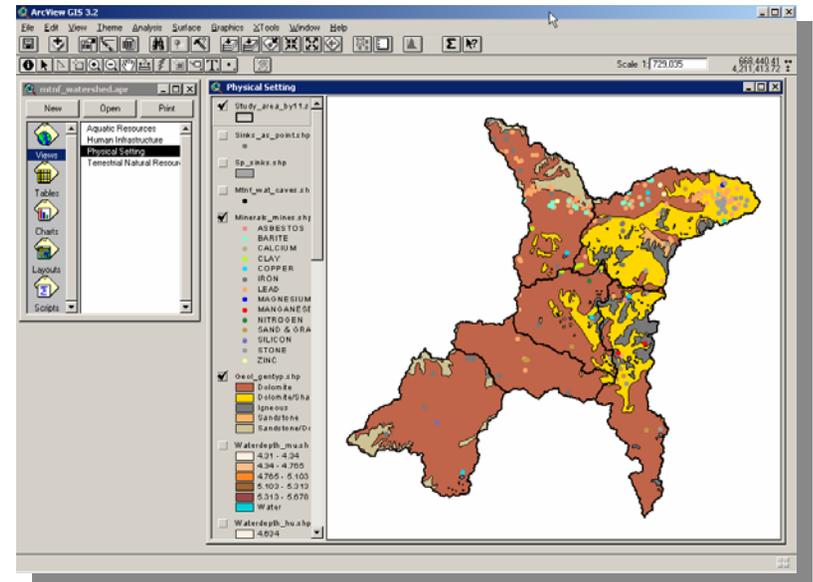
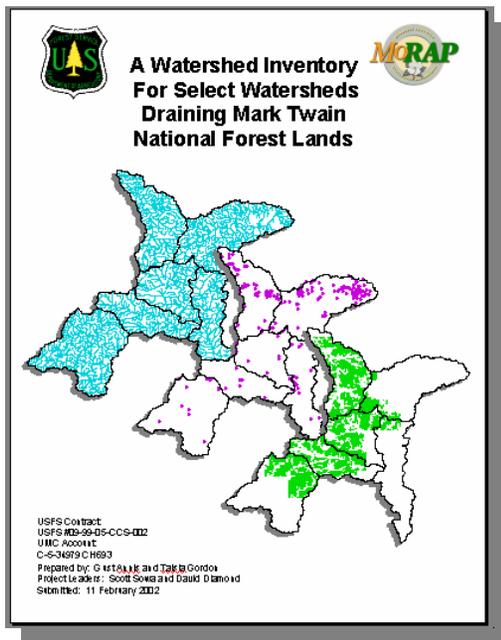


February 11, 2002



Products

1. Map and table-based printed report
2. ArcView project
3. CD of data layers including coverages, grids, shapefiles, and tables



Product Structure

- Physical Setting
 - ✓ Climate
 - ✓ Geophysical
- Terrestrial Resources
 - ✓ Land Cover
 - ✓ Conservation and Restoration Sites
 - ✓ Terrestrial Species
- Aquatic Resources
 - ✓ Stream data
 - ✓ Lakes, Springs, Wetlands
 - ✓ Aquatic Species
- Human Infrastructure
 - ✓ Transportation
 - ✓ Public Lands / Recreation
 - ✓ Point source pollution and facilities

ArcView Project

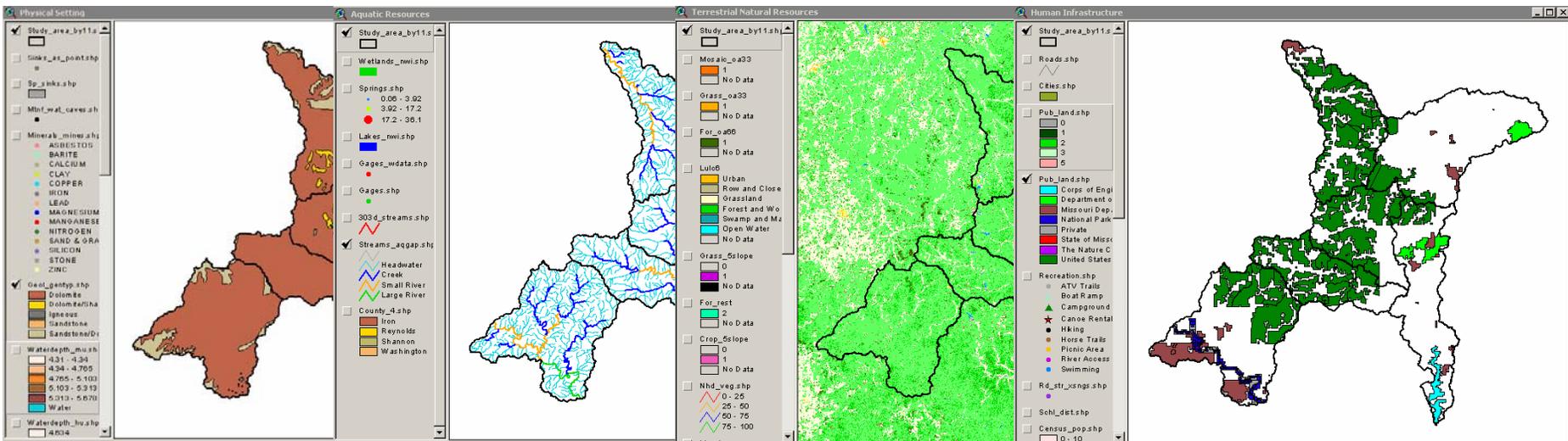
- Designed with four distinct Views
- Each view represents a compilation of themes by category
- Folders within categories contain relevant .dbf files and useful legends
- Structure, views and themes correspond with report

Physical Setting

Aquatic Resources

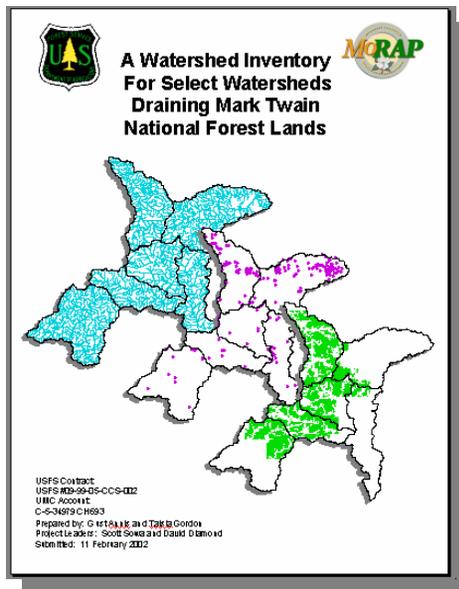
Terrestrial Resources

Human Infrastructure



Map and Table-based Report

- 134 page report organized into four sections that correspond with four ArcView project views
- Structured as a series of maps and tables
- Indexed by a table of contents
- Most maps have an accompanying table and vice versa



Spring Characteristics

Characteristics	07140102500	07140304010	11010007010	11010007020	11010007030	11010007040	11010007050
sq Miles	219.36	311.49	171.39	163.37	223.73		304.75
Spring Count	20	17	13	11	11		9
Density (springs/mile)	0.11	0.04	0.05	0.09	0.05		0.11
Total Gallons Produced	5.6	2.2	3.46	11.05	21.1		102.46
Red Lizard Spring							
Flow (cfs)	0.20	0.20	1.06	7.40	17.2		36.10
Name (N/A)	N/A	N/A	High Spring	Rock Spring	Warner Bay Spring	Wills Spring	
County (N/A)	N/A	N/A	Boyd	Boyd	Boyd	Boyd	
Red Lizard Spring							
Flow (cfs)	N/A	N/A	N/A	0.64	3.1		52.40
Name (N/A)	N/A	N/A	F. A. Lamborn Spring	Champion Spring	Blue Spring		
County (N/A)	N/A	N/A	Boyd	Boyd	Boyd		
Red Lizard Spring							
Flow (cfs)	N/A	N/A	N/A	0.55	N/A		12.60
Name (N/A)	N/A	N/A	Cook's Spring	N/A	Boyd Bend Spring		
County (N/A)	N/A	N/A	Boyd	N/A	Boyd		

Created using Missouri Department of Natural Resources Springs layer with estimated flows added by M-FWP.

The Missouri Aquatic GAP Pilot Project



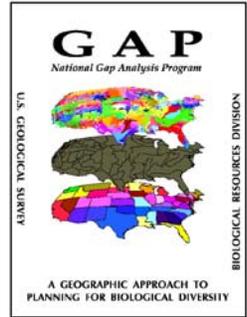
Surface Waters



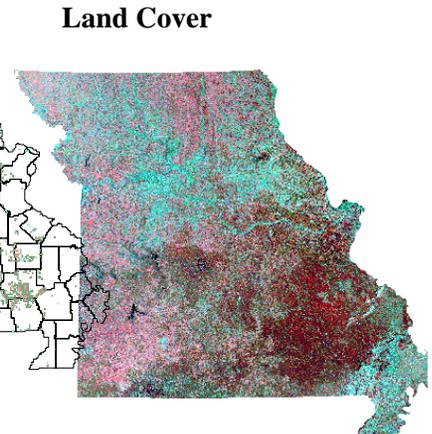
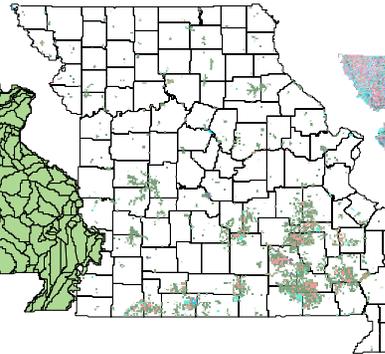
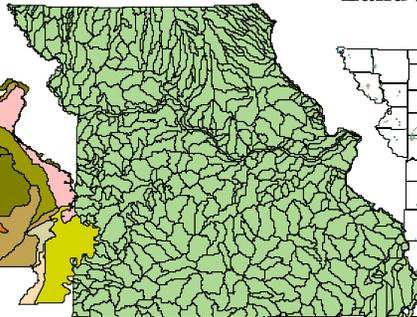
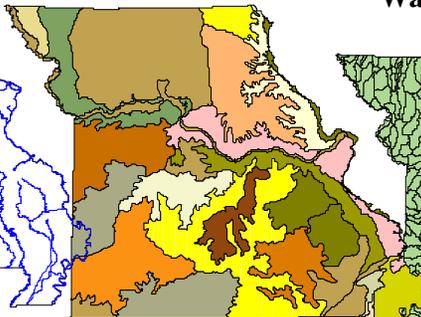
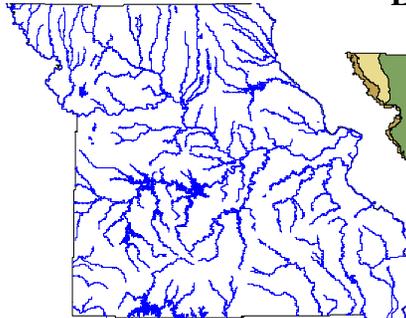
Ecoregions



Watersheds



Land Stewardship



Land Cover



Objectives

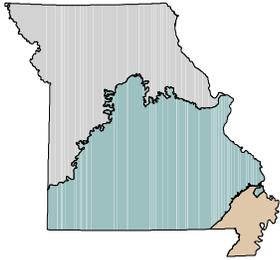
- Assess how well various elements of biodiversity are represented within the existing matrix of public lands
- Identify habitat types and species not adequately represented in the current network of biodiversity management areas

Four Principal GIS Datasets

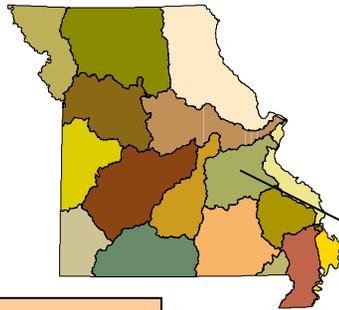
- Hierarchical riverine ecosystem classification
- Predicted species distribution models
- Local, watershed, and upstream network ownership/stewardship
- Human Threat Index

Levels 4-7 of Hierarchy

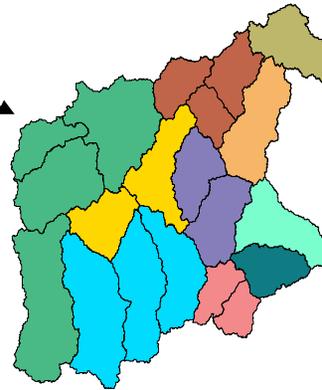
Level 4 Subregions



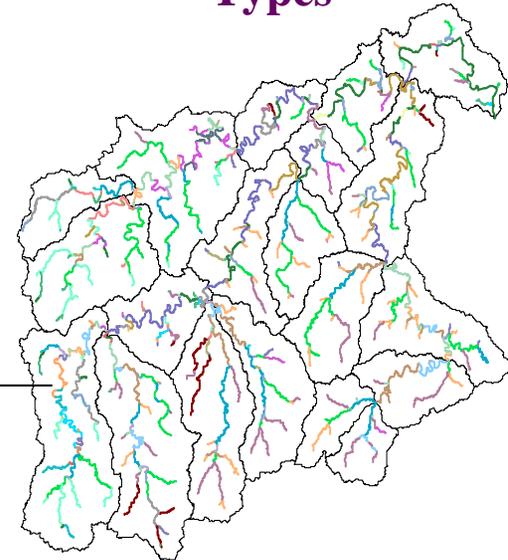
Level 5 Ecological Drainage Units



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:

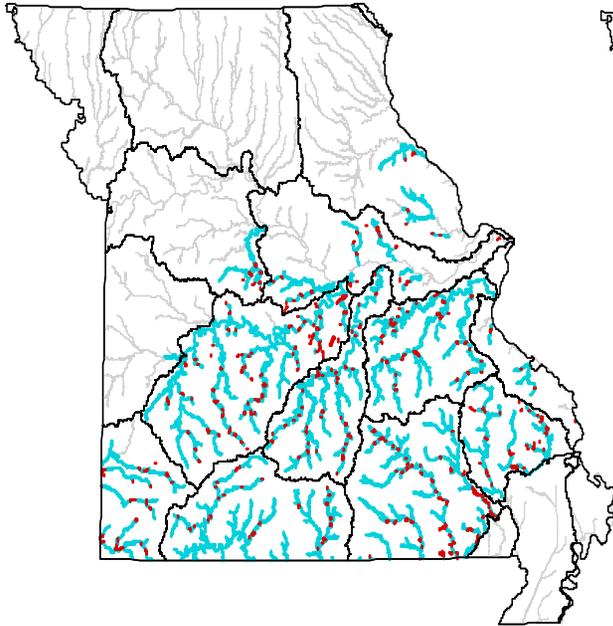
Upper Meramec/Dry Fork,
Oak/Woodland Plain, sandstone
dominated, low gradient and spring
density stream complex

Valley Segment Type:

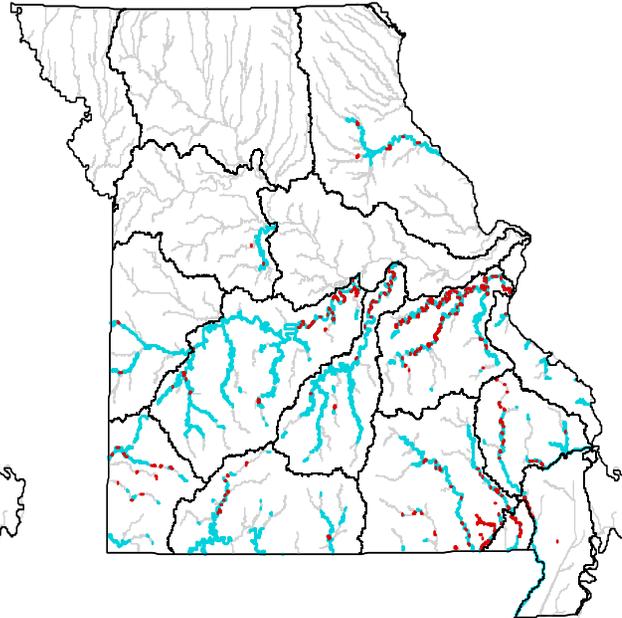
Warm, perennial, creek with a relatively
high gradient, flowing through sandstone,
and connecting to another creek



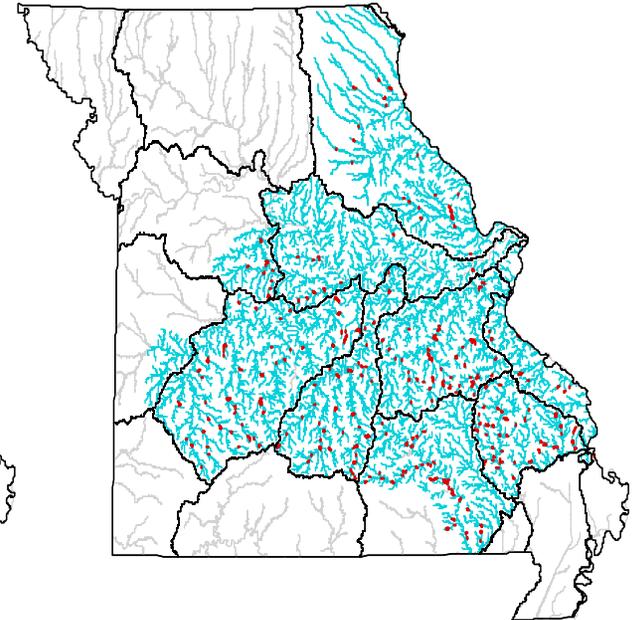
Predicted Distribution Models



Black redbhorse



Round pigtoe



Golden crayfish

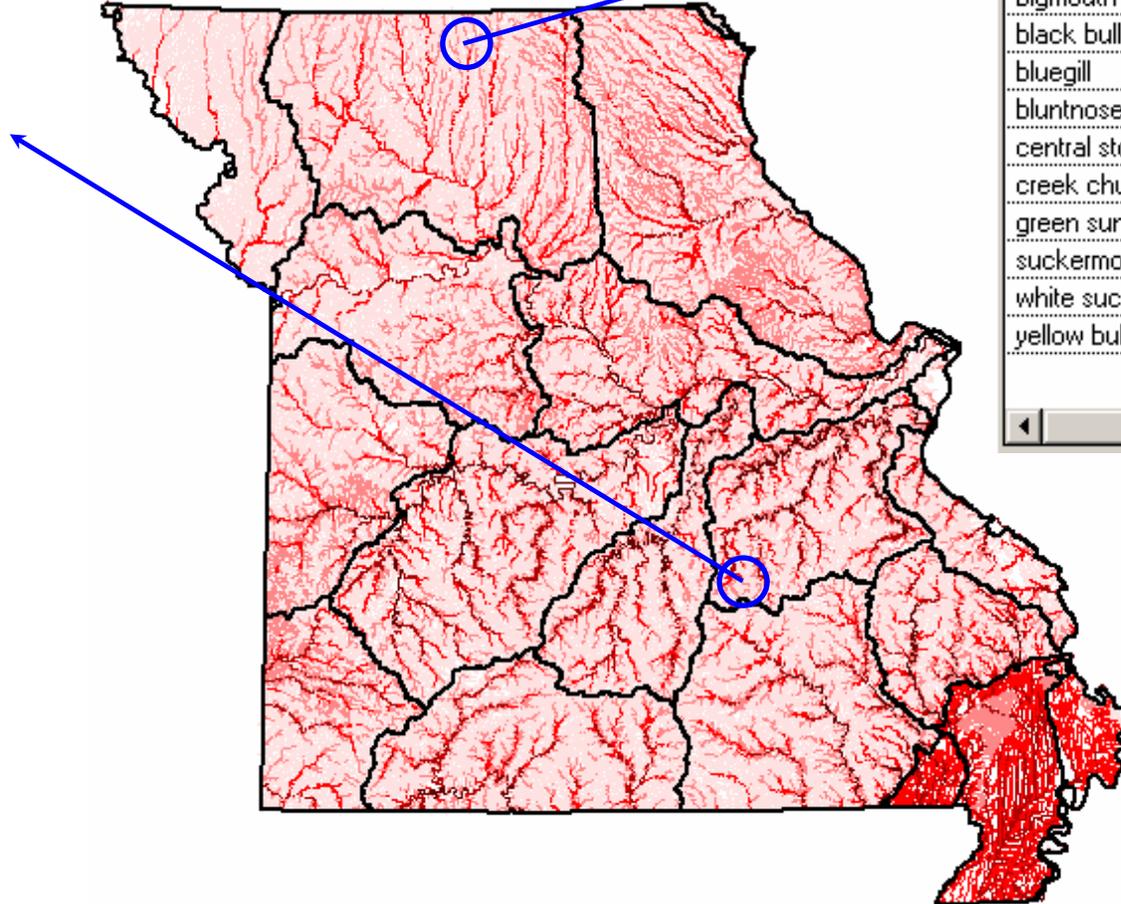


- 571 total models constructed for 315 different species
 - Anywhere from 1 to 4 models developed for each species

“Hyperdistribution”

Ozarks: 27 Species

sum6.dbf
<i>Vernacular</i>
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
<i>Vernacular</i>
bigmouth shiner
black bullhead
bluegill
bluntnose minnow
central stoneroller
creek chub
green sunfish
suckermouth minnow
white sucker
yellow bullhead

Species Habitat Reports



Banded Darter
Etheostoma zonale



Native: Yes

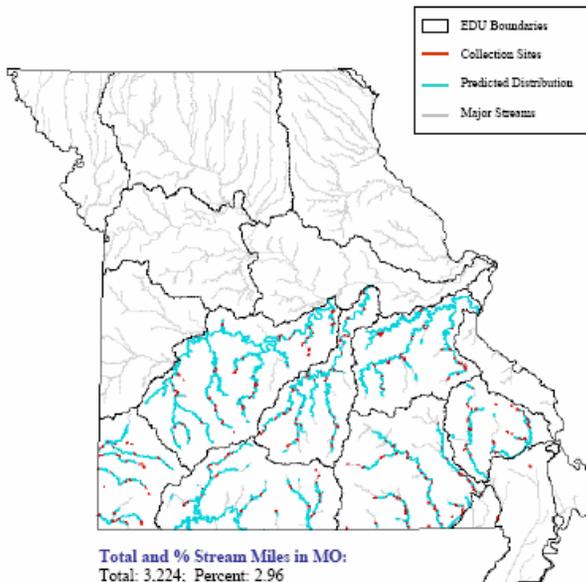
Endemism: Region

State Rank: S?

Global Rank: G5

ITIS Code: 168449

Modeled By: Gust Annis, Pam Haverland
Michael Morey, Scott Sowa,
John Stanovick



State Range:

The Banded darter can be found in all the principal drainage systems of the Ozarks where it is one of the most abundant and widespread darters (Pflieger 1971). However, it is not found in the short, direct tributaries of the Mississippi River. Its distribution in Missouri is remarkably similar to the greenside darter (Pflieger 1997).

Habitat Affinities:

Adult banded darters are often found in swift riffles over gravel or rubble bottoms (Cross and Collins 1975; Etnier and Starnes 1993; Pflieger 1971; Robinson and Buchanan 1988). They are found in abundance within rocky riffles having dense growths of filamentous algae (*Cladophora*), eel grass (*Valisneria*) pondweed (*Potamogeton*) (Lachner et al. 1950; Miller and Robinson 1973; Pflieger 1997) or aquatic mosses (Trautman 1957). Juveniles prefer quiet water around emergent aquatic plants such as waterwillow (*Justicia*) (Pflieger 1997) or in accumulations of leaves (Robinson and Buchanan 1988). Trautman (1957) found that spawning concentrations were highest in riffles of streams with moderate to high gradients with a width less than 50 ft. and depth less than 2 ft. Trautman (1957) also found that the banded darter winters in deeper waters.

Predictive Model(s):

Ozark Model

$(([\text{Linkr}] = 5) \text{ and } ([\text{Rgrad_subr}] \geq 1) \text{ and } ([\text{Rgrad_subr}] \leq 2)) \text{ or } ([\text{Linkr}] \geq 6)$

Mississippi Alluvial Basin Model

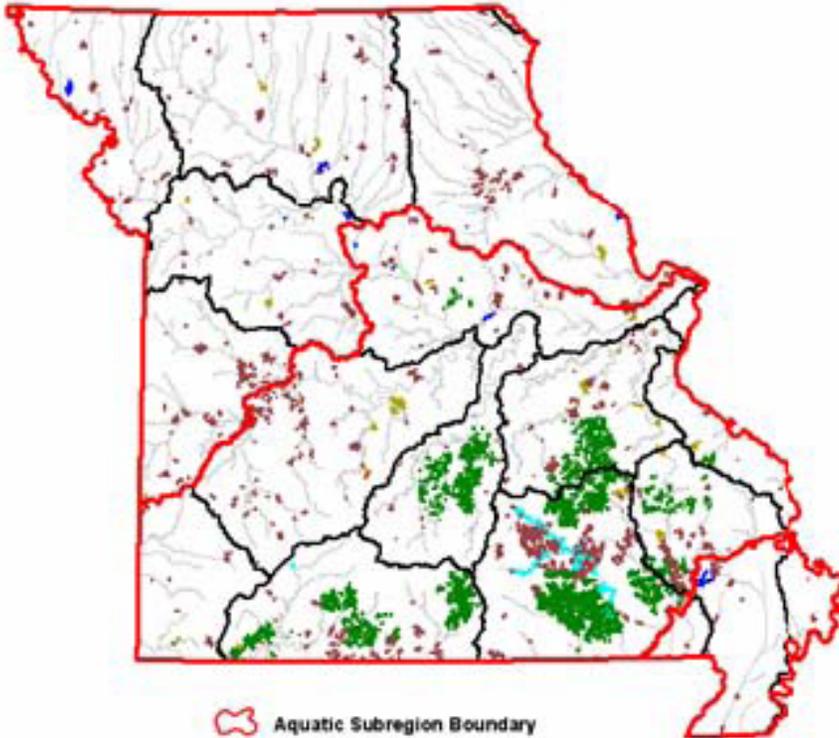
The distribution is based upon existing collection records and professional review.

References:

- Aadland, L. P., C. M. Cook, M. T. Negus, H. G. Drewes and C. S. Anderson. 1991. Microhabitat preferences of selected stream fishes and community-oriented approach to instream flow assessments. Minnesota Department of Natural Resources, Section of Fisheries. 142 pp.
- Adamson, S.W. and T.E. Wissing. 1977. Food habits and feeding periodicity of the rainbow, fantail, and banded darters in Four Mile Creek. *Ohio Journal of Science* 77(4):164-169.
- Bart, H. L., Jr., and L. M. Page. 1992. The influence of size and phylogeny on life history variation in North American percids. Pages 553-572 in R. L. Mayden, editor. Systematics, historical ecology, and North American freshwater fishes. Stanford University Press, Stanford, California. xxvi + 969 pp.
- Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1052 pp.

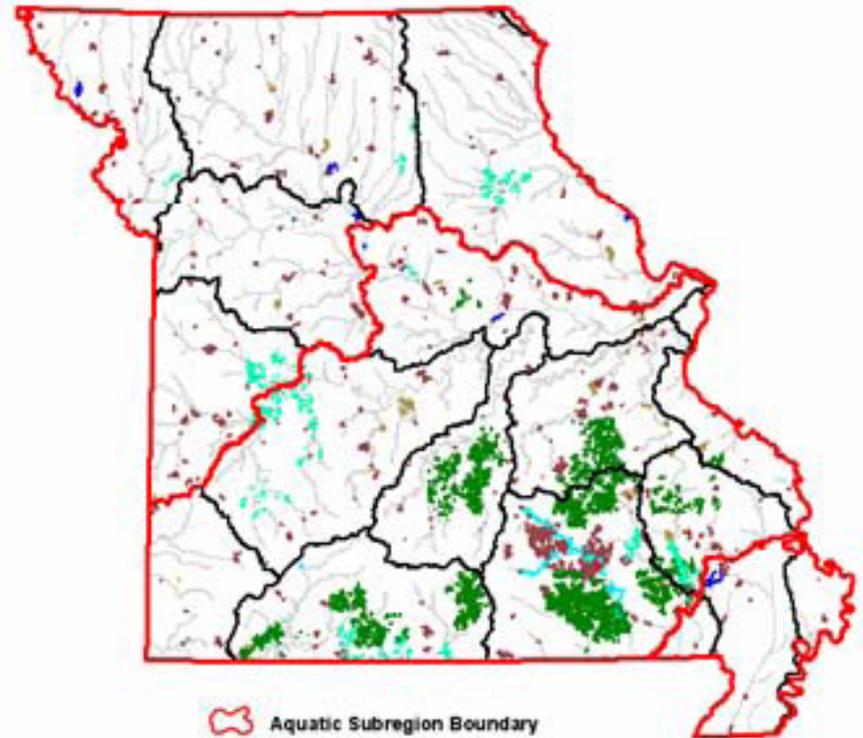
Ownership and Stewardship

Steward



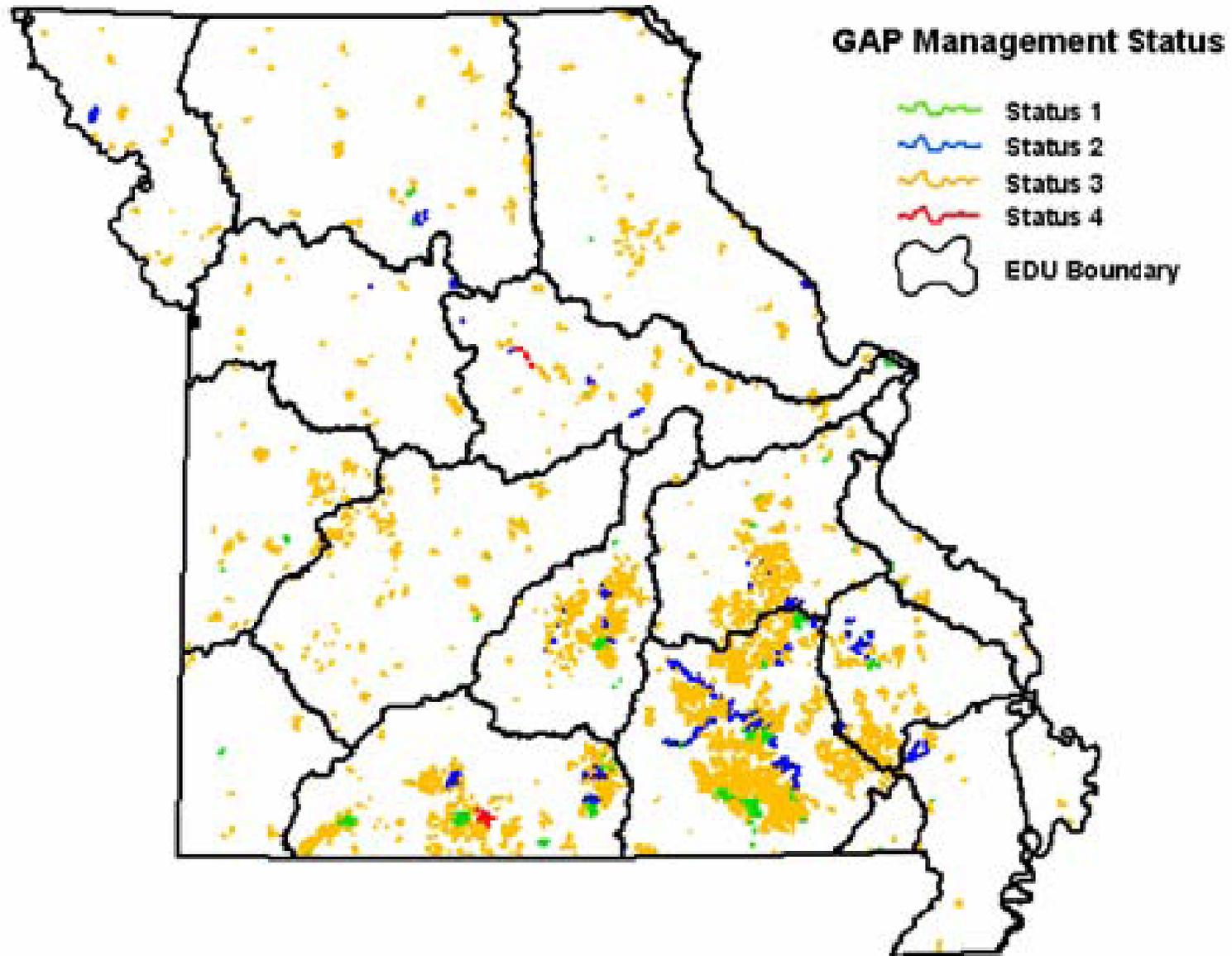
- Aquatic Subregion Boundary
- EDU Boundary
- Corps of Engineers
- National Park Service
- USFWS National Wildlife Refuge
- United States Forest Service
- Missouri Department of Natural Resources
- Missouri Department of Conservation
- The Nature Conservancy
- Private
- Major Streams

Owner

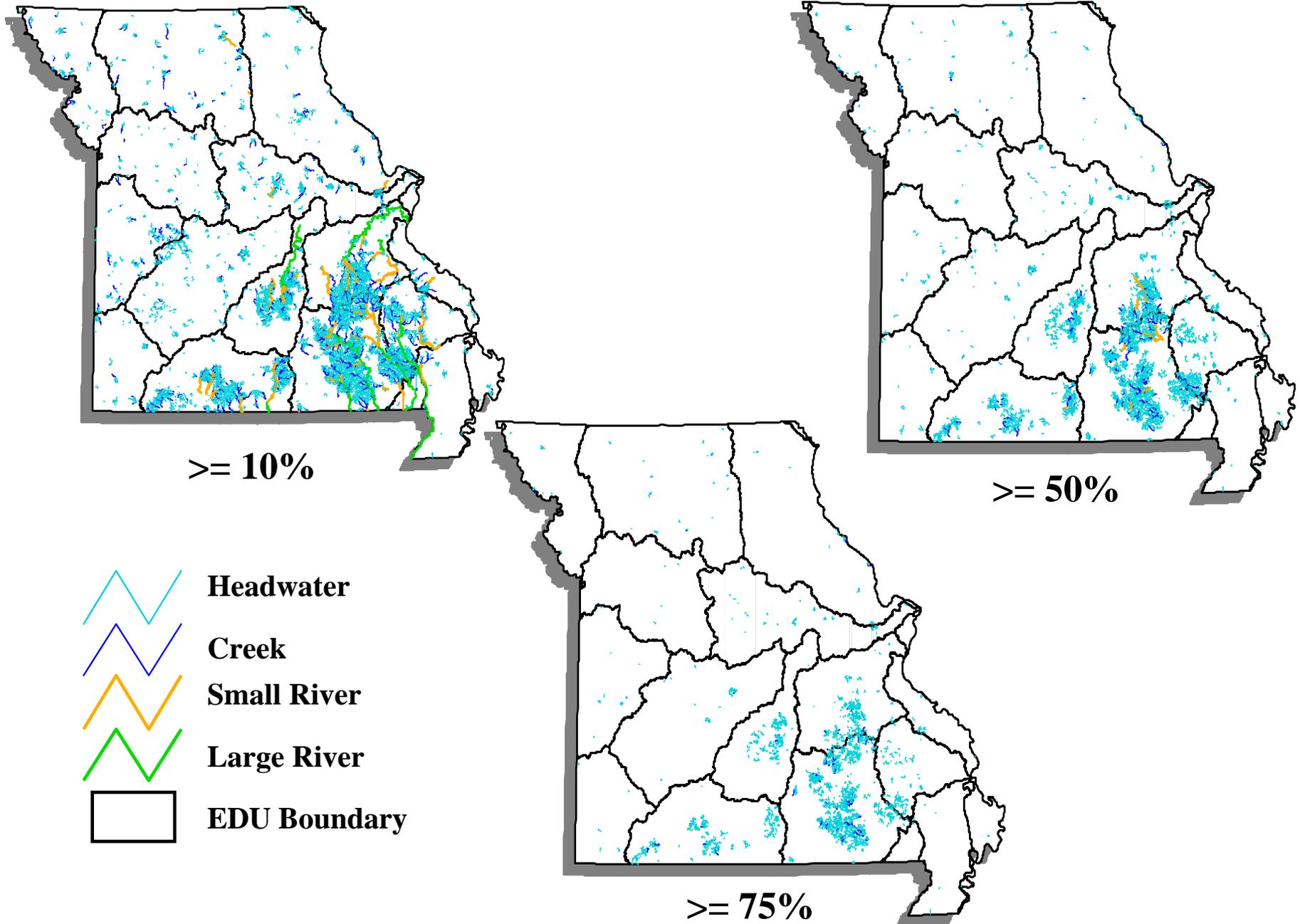


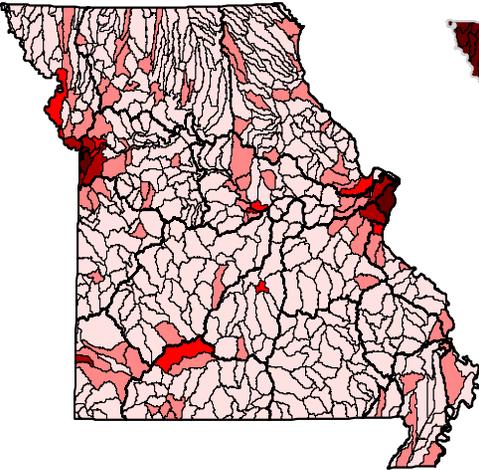
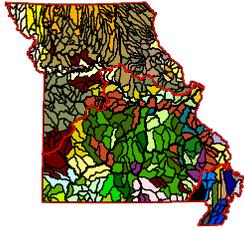
- Aquatic Subregion Boundary
- EDU Boundary
- Corps of Engineers
- National Park Service
- USFWS National Wildlife Refuge
- United States Forest Service
- Missouri Department of Natural Resources
- Missouri Department of Conservation
- The Nature Conservancy
- Private
- City of Joplin
- Private
- Major Streams

Mapping Local Stewardship

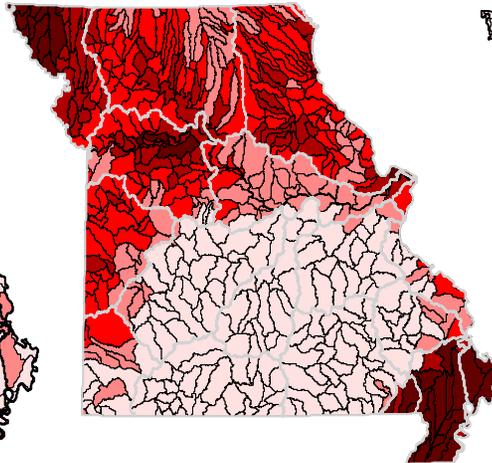


Mapping Watershed Stewardship

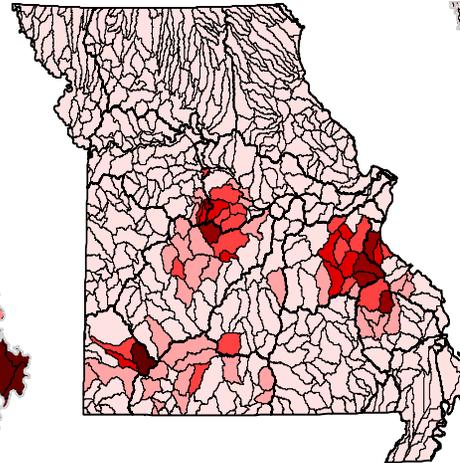




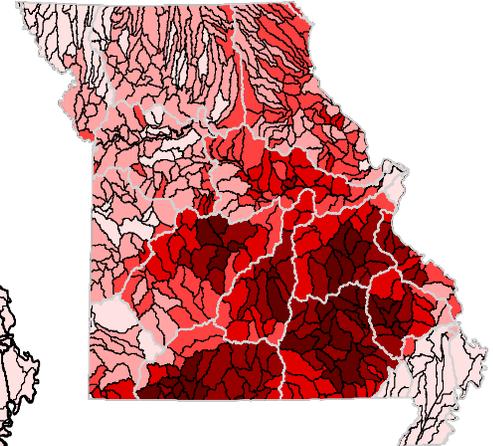
Percent Urban



Percent Cropland



Lead Mine Density

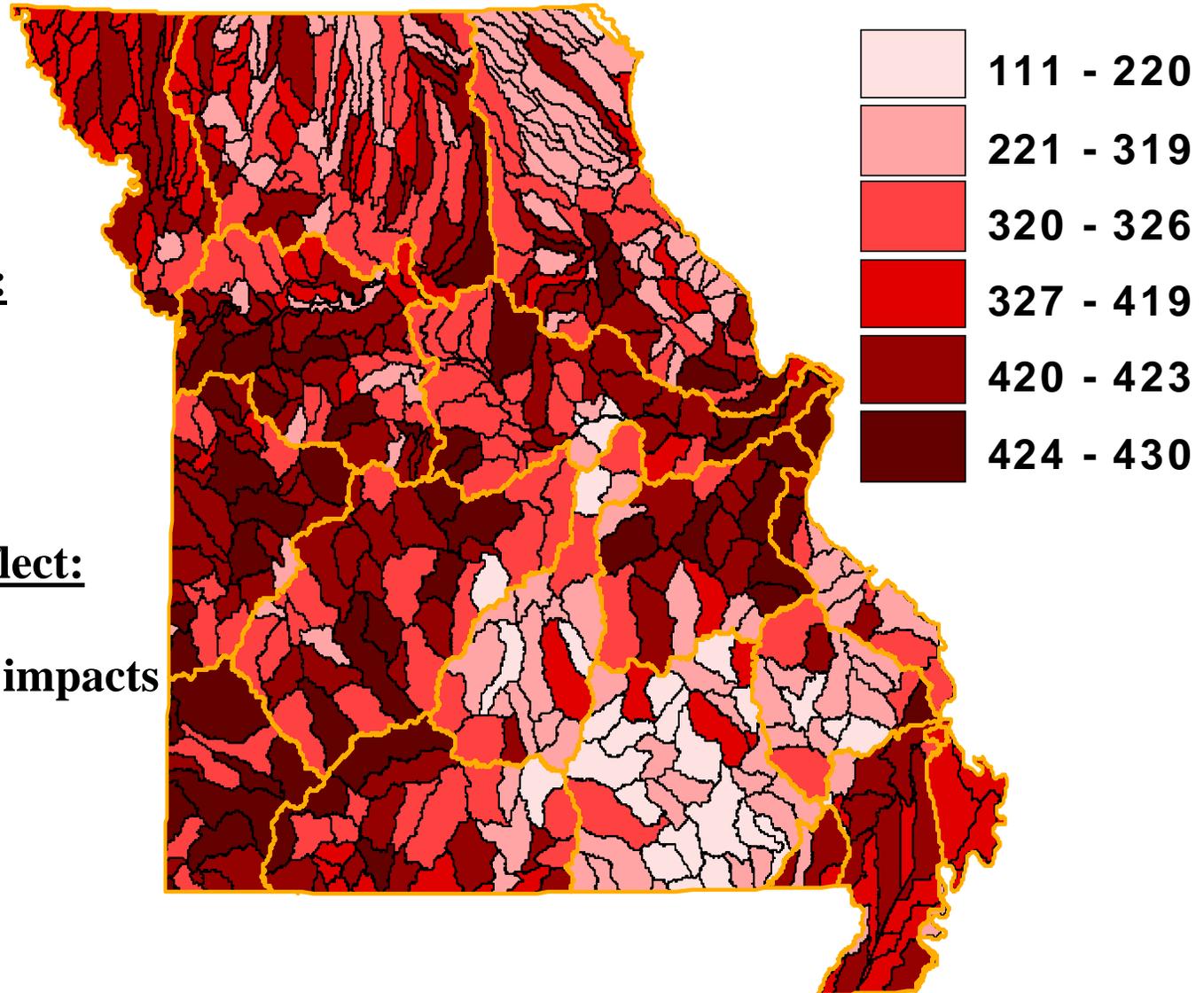


Riparian Forest

Attributes of Mo_aes_no_atts.shp

<i>N_index_a</i>	<i>Pfor</i>	<i>Purb</i>	<i>Popchg</i>	<i>Strndca?</i>	<i>Pfor_a</i>	<i>Pwell</i>	<i>Pwell_a</i>	<i>Purb_a</i>	<i>Pagg</i>	<i>Pagg_a</i>	<i>Pagg_c</i>
63129600.0	4.6733	0.7236	1.950	0.02911	30719700.0	1.8081	11885400.0	4756500.0	21.1641	139122000.0	68.5054
44426700.0	8.3388	1.1371	-2.259	0.02734	28229400.0	1.6302	5518800.0	3849300.0	31.4877	106596000.0	54.2490
87714000.0	11.5990	1.8831	19.094	0.00987	53461800.0	1.6080	7411500.0	8679600.0	46.4294	214002000.0	32.3911
38376900.0	11.0445	0.1387	-3.261	0.00804	22499100.0	1.2021	2448900.0	282600.0	44.7170	91094400.0	36.2694
17636400.0	2.5608	0.6827	-10.089	0.00000	5620500.0	2.8572	6271200.0	1498500.0	17.7593	38979000.0	73.5226
117477000.0	12.7244	1.5937	9.233	0.03354	74214900.0	1.0420	6077700.0	9295200.0	50.6270	295281900.0	27.6202
46512000.0	13.4467	1.9184	-3.716	0.01482	33314400.0	1.8963	4698000.0	4752900.0	33.1771	82197000.0	46.1276
21305700.0	10.3359	2.0993	5.626	0.03312	14294700.0	2.0648	2855700.0	2903400.0	33.0934	45768600.0	49.2965
26120700.0	9.1666	0.0644	11.042	0.03643	15754500.0	1.8632	3202200.0	110700.0	42.8112	73578600.0	41.9058
17995500.0	7.3856	0.1121	-6.551	0.05027	9483300.0	1.9065	2448000.0	144000.0	31.8226	40860900.0	54.0503
65268000.0	7.8013	1.2999	15.010	0.04766	37684800.0	1.1018	5322600.0	6279300.0	39.2811	189751500.0	45.9077
9520000.0	10.3000	1.2015	0.541	0.00000	4431000.0	2.4000	1500000.0	500000.0	30.3025	12000000.0	40.5375

Human Threat Index



First number reflects:

Highest magnitude of individual stressor

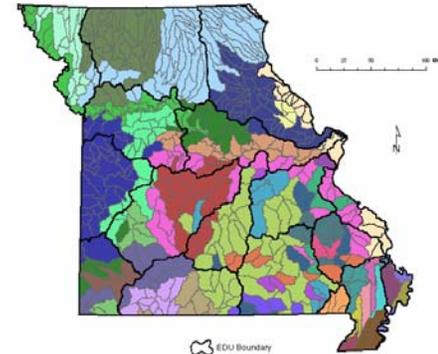
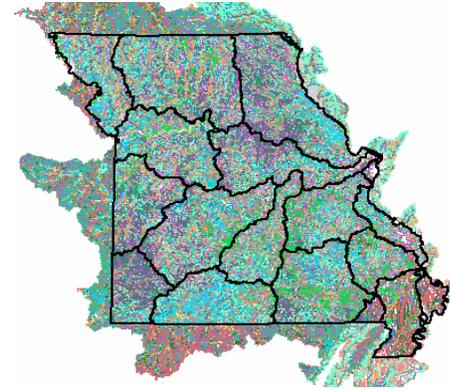
Last two numbers reflect:

Degree of cumulative impacts

Gap Analyses:Key Questions

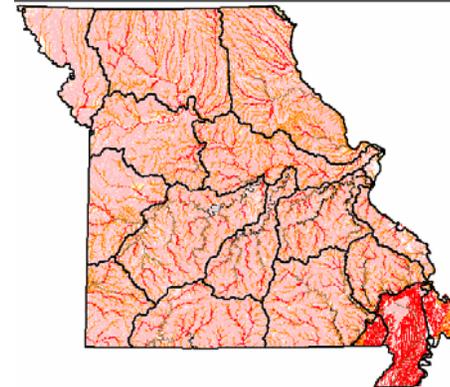
Abiotic Surrogates (Habitats)

- How well are the various stream types (VSTs) represented?
- How well are the various watershed types (AES-Types) represented?



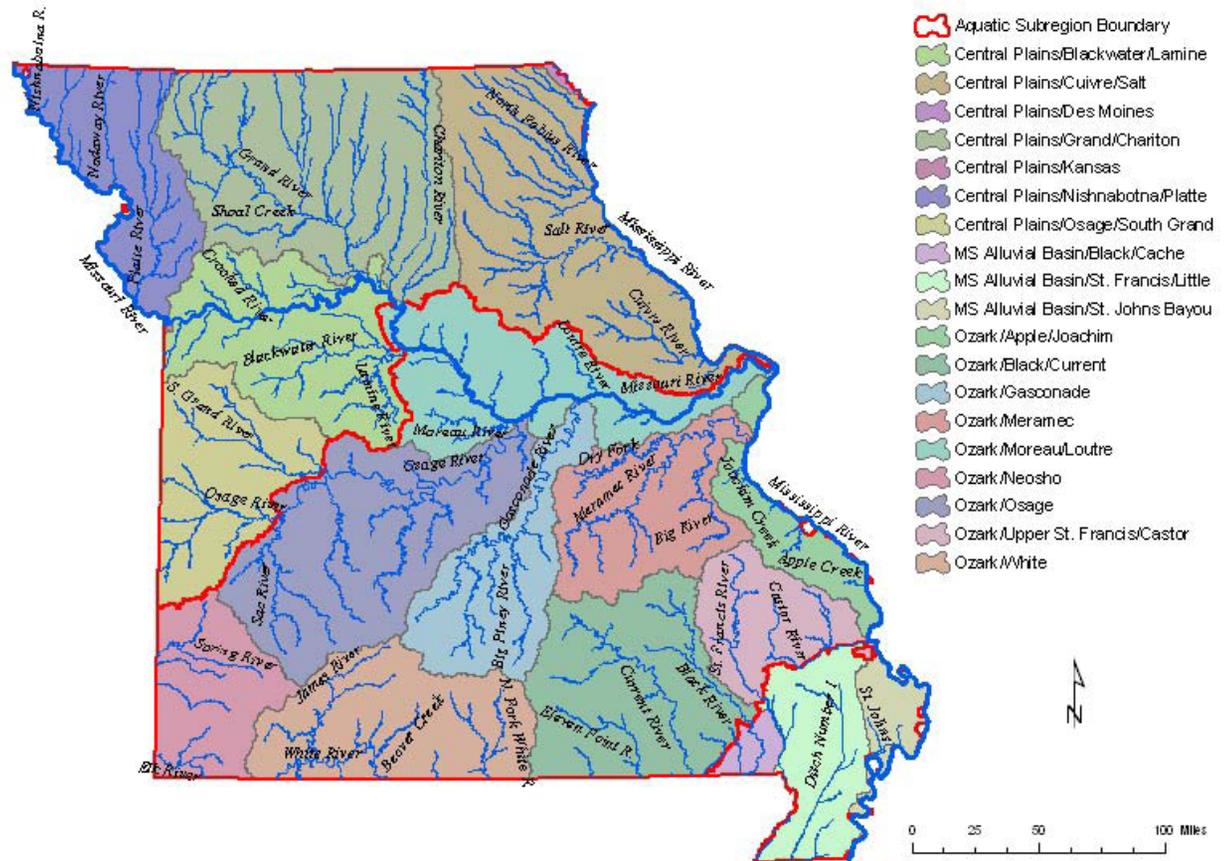
Biotic Surrogates

- How well is each species represented?



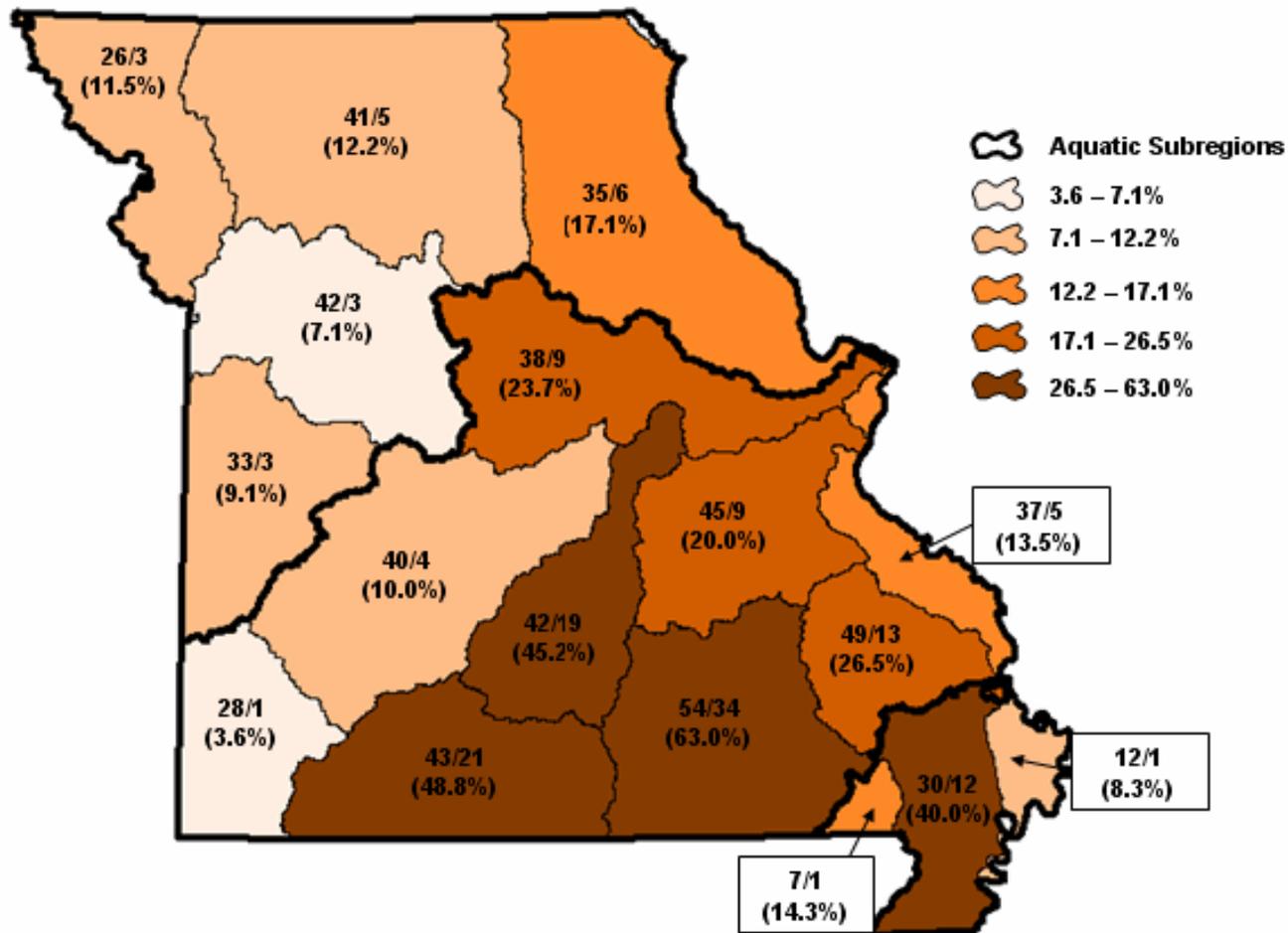
Data Analyzed for Three Geographic Units

- Statewide
- Subregion
- EDU



VST Gap Analyses

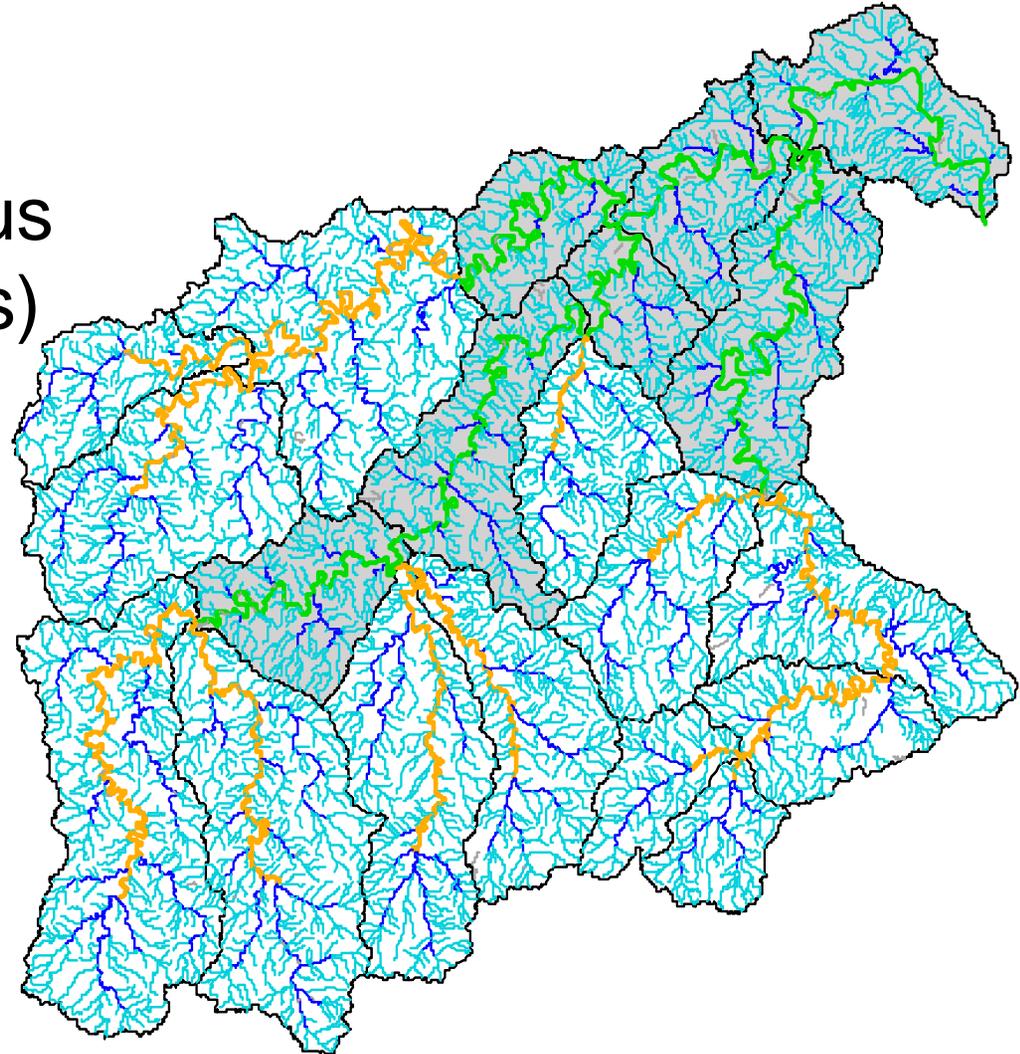
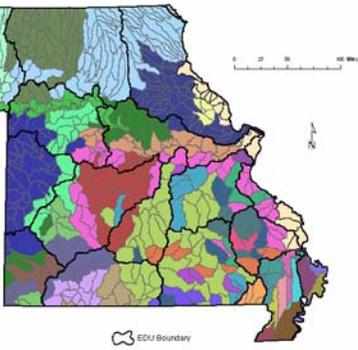
State/Subregion	Total VSTs	Status 1 or 2	
		Number	Percent
Statewide	74	57	77
Central Plains	45	14	31
Ozarks	65	49	75
Mississippi Alluvial Basin	30	13	43



Statewide Analyses by Individual Variables

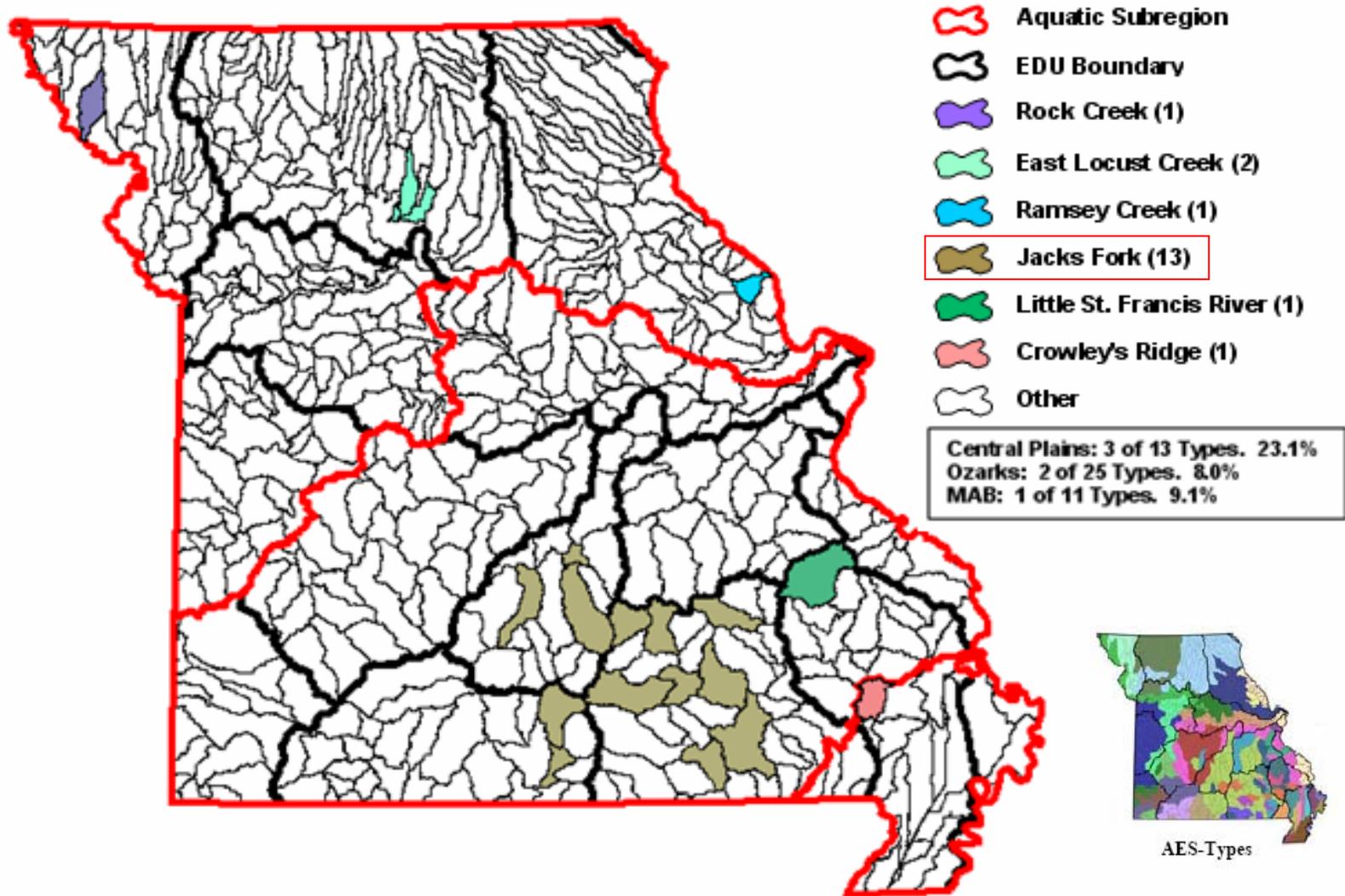
Temperature	Total Length (km)	Km in Status 1 or 2	Percent in Status 1 or 2
Cold	557.5	59.3	10.6
Warm	171,700.1	1248.8	0.7
Stream Size	Total Length (km)	Length in Status 1 or 2	Percent in Status 1 or 2
Headwater	128,799.4	771.6	0.6
Creek	27,173.8	180.9	0.7
Small River	11,486.5	210.3	1.8
Large River	3,239.19	145.3	4.49
Flow	Total Length (km)	Length in Status 1 or 2	Percent in Status 1 or 2
Intermittent	120,089.1	718.5	0.6
Perennial	46,574.33	580.9	1.25
Geology	Total Length (km)	Length in Status 1 or 2	Percent in Status 1 or 2
Alluvium	12,404.3	78.7	0.6
Clay	304.1	0	0.0
Igneous	664.3	58.1	8.8
Limestone/Dolomite	135,075.5	871.3	0.7
Sandstone	23,622.9	300.0	1.3
Relative Gradient	Total Length (km)	Length in Status 1 or 2	Percent in Status 1 or 2
Low	72,260.0	298.5	0.4
Moderate	53,649.3	344.6	0.6
High	37,409.2	639.7	1.7

AES-Type Analyses



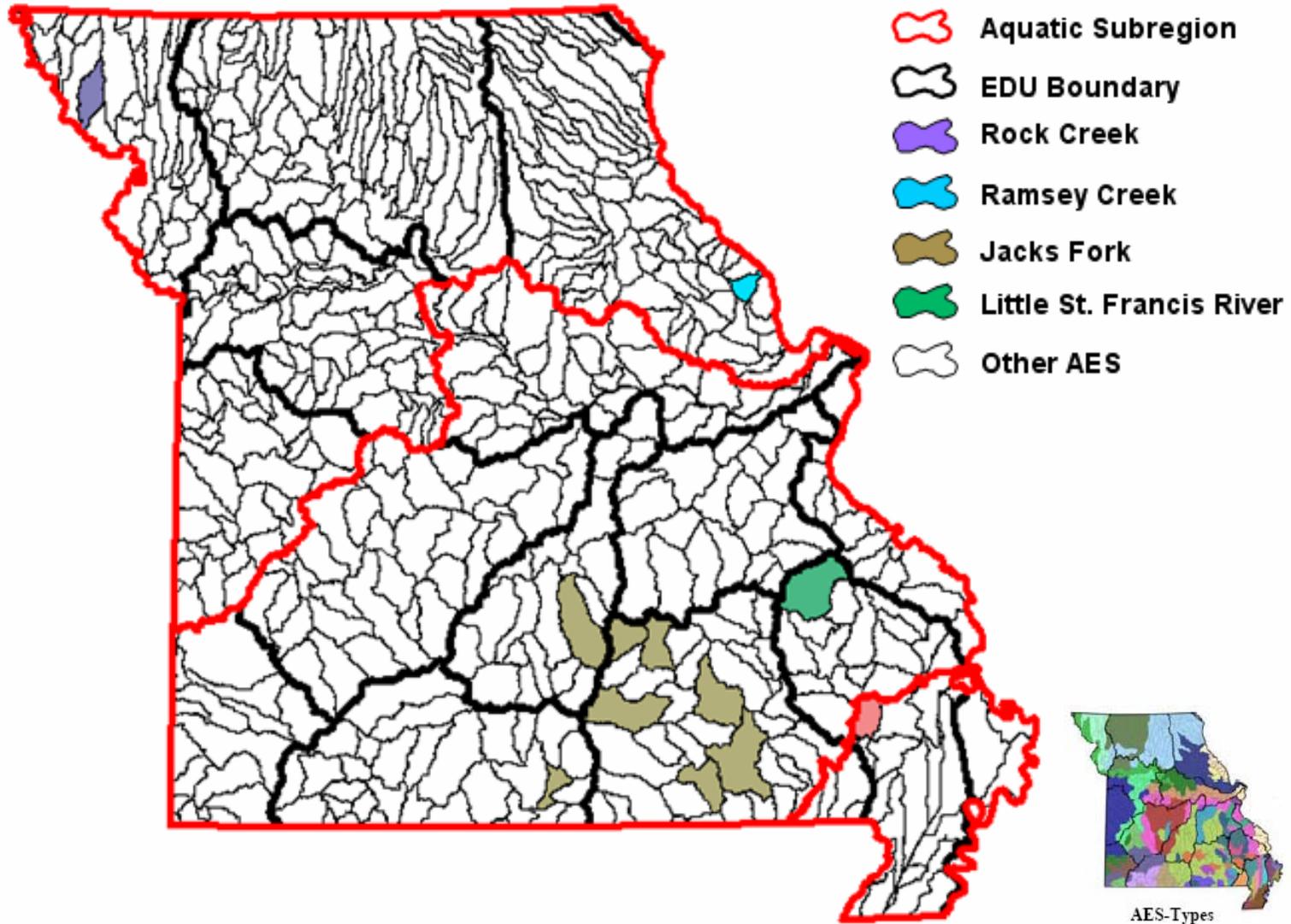
- How well are the various watershed types (AESs) represented?
- Identified AESs with all 3 size classes represented in status 1 or 2 lands

Results: AES-Type Analyses Using Least Stringent Criteria



All Size Classes Represented in Status 1 or 2 lands

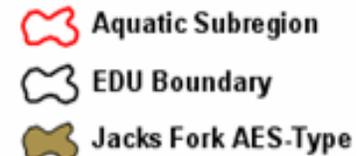
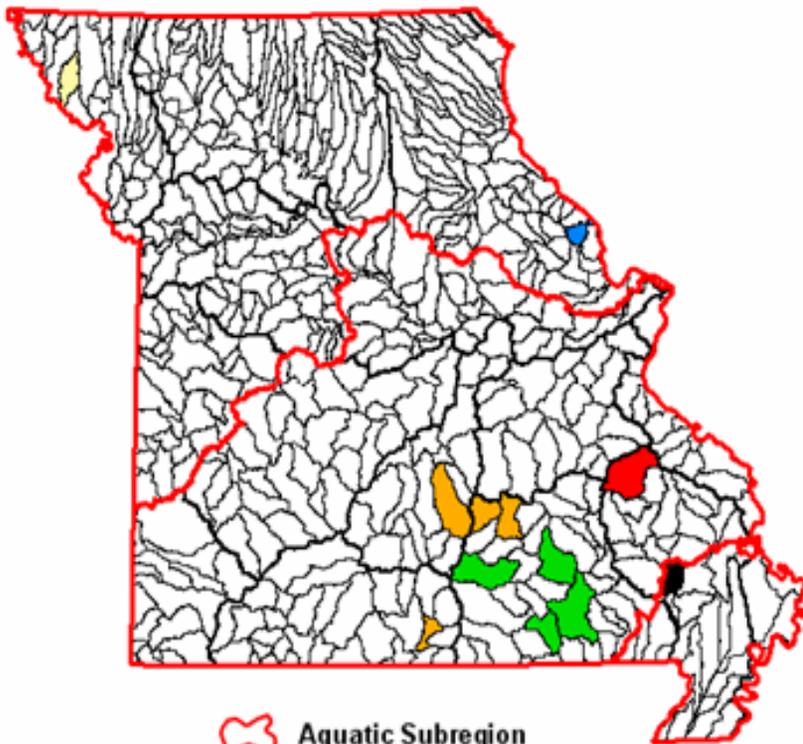
Results: AES-Type Analyses Using More Stringent Criteria (Connectivity)



All size classes represented as an **interconnected matrix** in Status 1 or 2

Results: AES-Type Analyses

Using Most Stringent Criteria (Ecological Integrity)

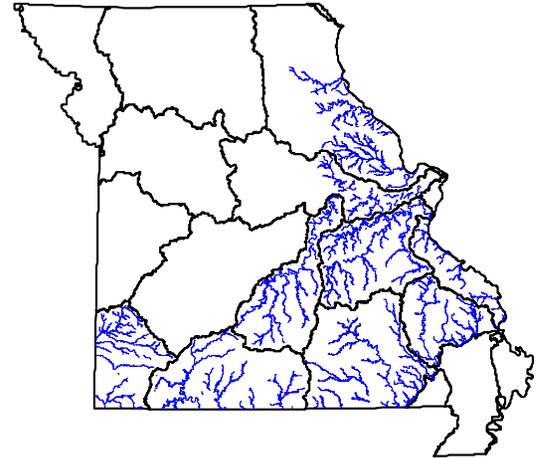


- All size classes
- Interconnected matrix
- Relatively undisturbed

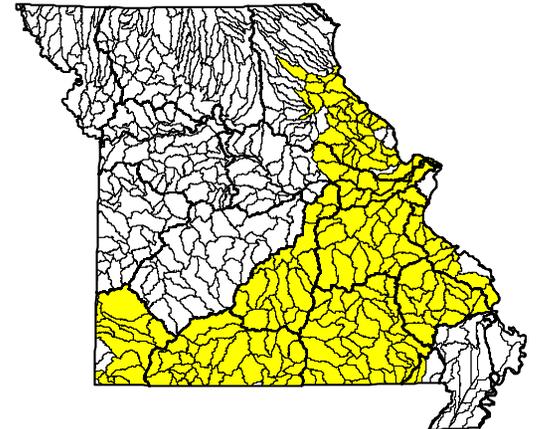
Species Analyses

- How well is each species represented in status 1 or 2 lands?

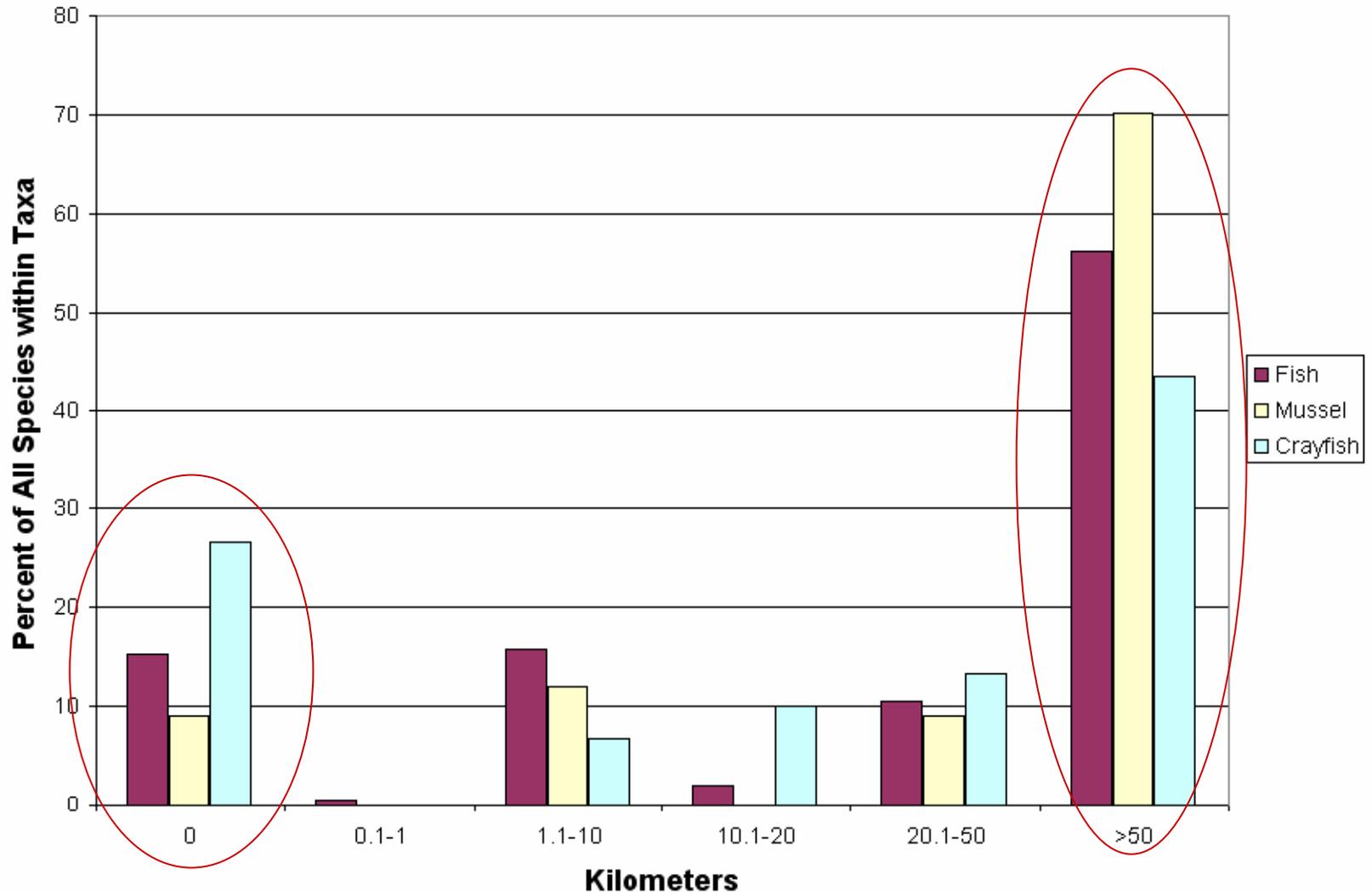
– Analyses based on length



– Analyses based on distinct occurrences

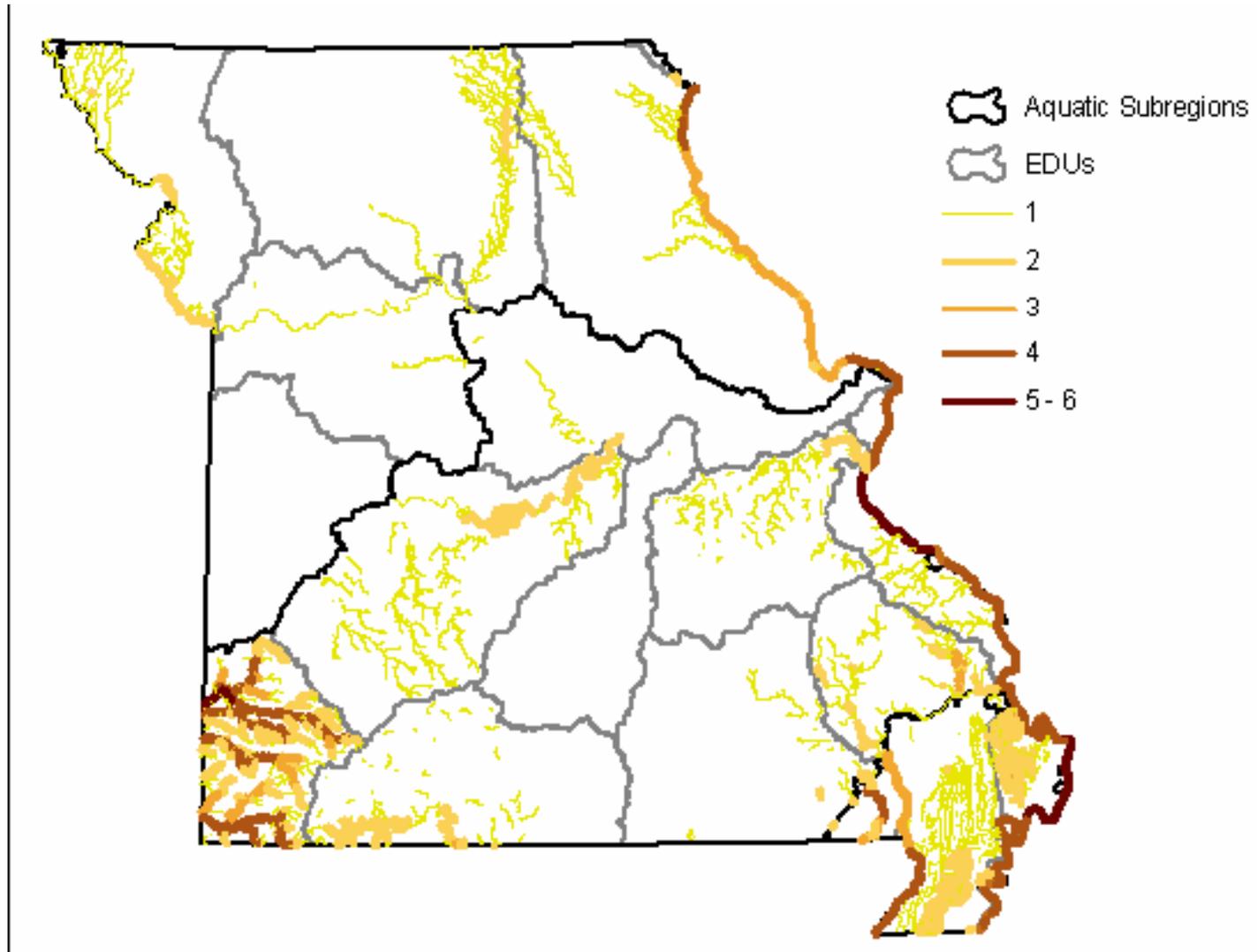


Statewide: 6 Categories of Species Representation



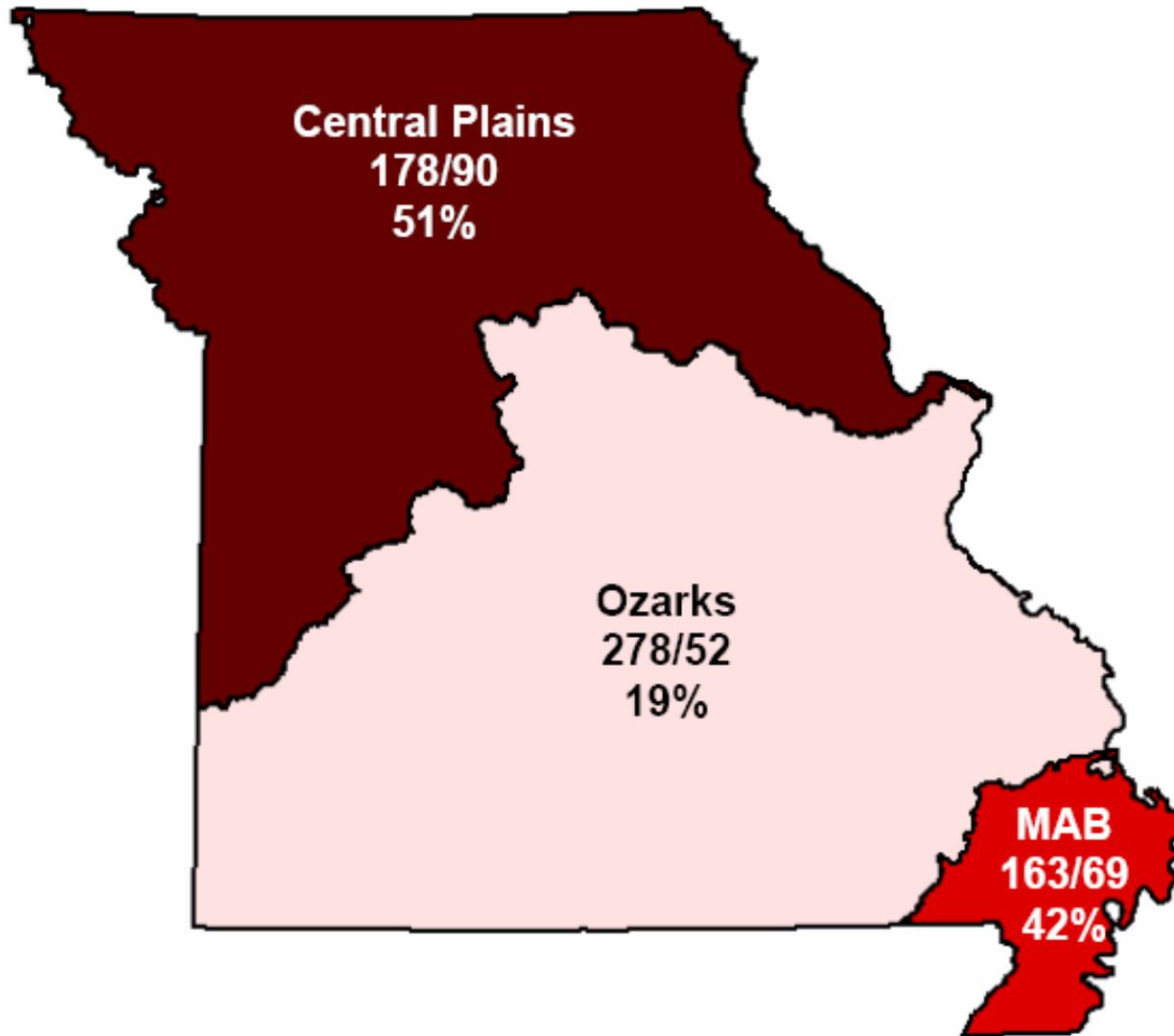
Most species are well represented in status 1 or 2 lands

Richness Map for the 45 Species Not Represented in Status 1 or 2 lands



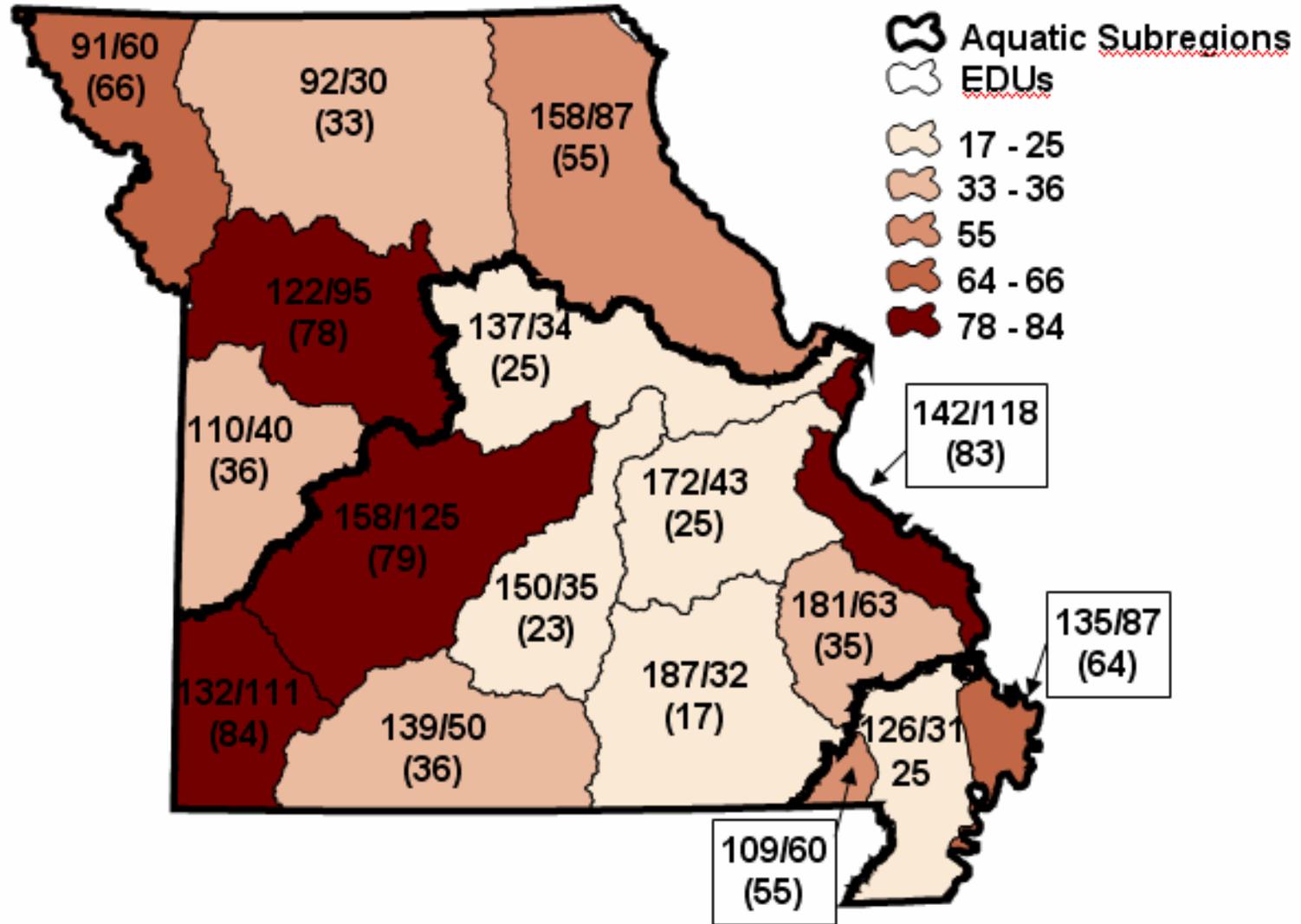
67% are state listed species, 22% are globally listed

Representation by Subregion



% not represented in Status 1 or 2

Representation by EDU



% not represented in Status 1 or 2



Terrestrial Conservation Focus Areas for the Midwestern USA

Natural Areas Association

September 21, 2005

David Diamond (diamonddd@missouri.edu)
and Scott Sowa (sowas@missouri.edu)

Significance

Threat

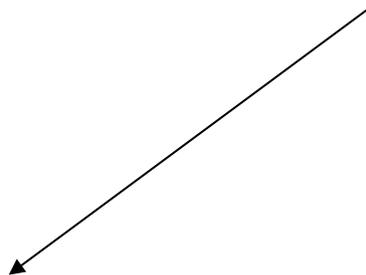
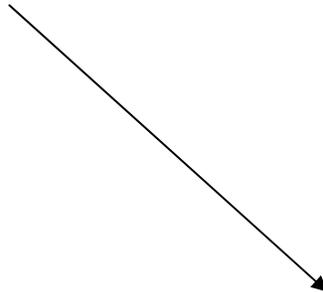
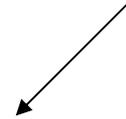
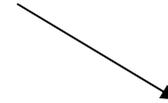
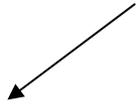
**Abiotic
(Representation)
Targets**

Biotic Targets

Ecological Risk

Irreplaceability

Conservation Focus Areas



*Information to Model
Desired Future Conditions*

Include Human Use in Parks?

Development Land
Demand

Agriculture Land
Demand

Vertebrate Richness
Index Target

Percent Conversion
by Abiotic Site Type

Toxic Release
Potential

Abiotic Site Type Target
(Representation)

Opportunity Area
Representation

Agriculture Runoff
Potential

Opportunity Area Target

Significance

Threat

Risk

Irreplaceability

**Conservation
Focus Areas**

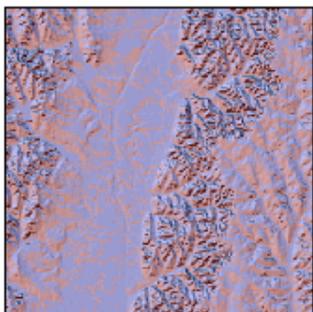
Solar Insolation

+

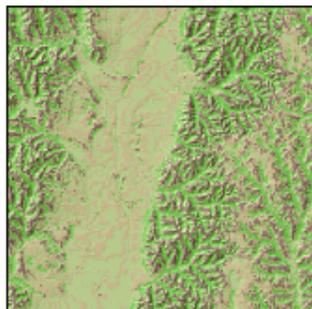
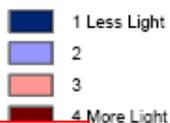
Land Position

+

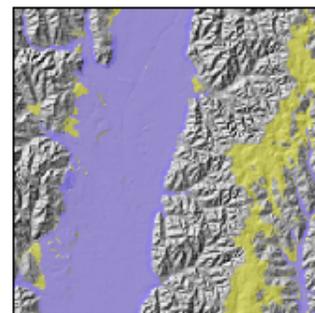
Flats



Solar Insolation



Land Position

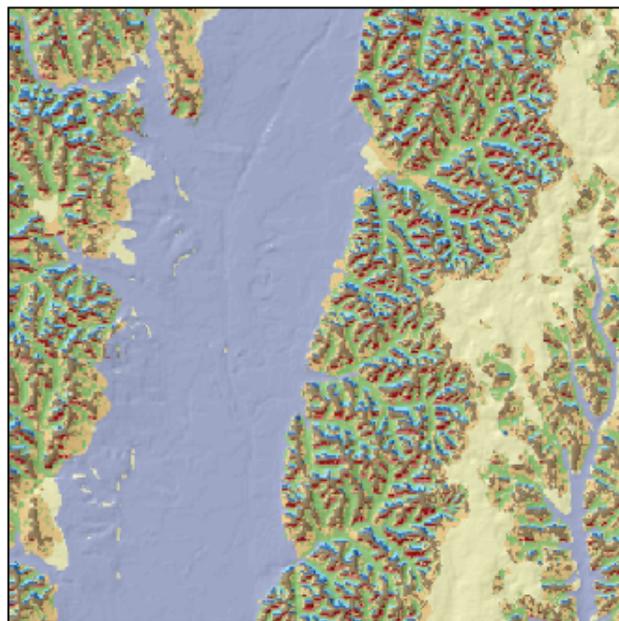


Flat Areas



SSURGO Soils May Be Desired at Finer Resolution

e Type



Abiotic Site Types

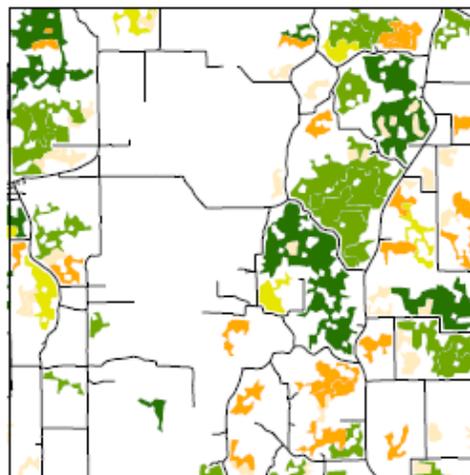
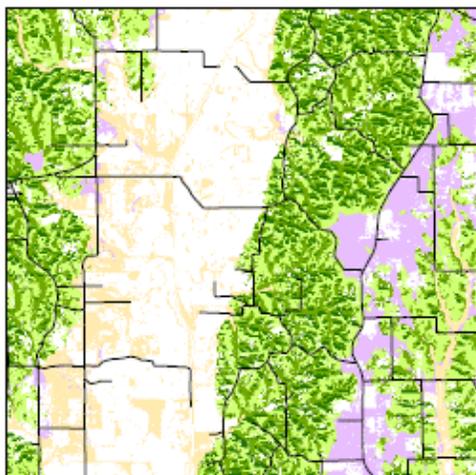




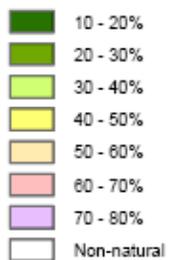
Percent Conversion

+

Opportunity Area Rank



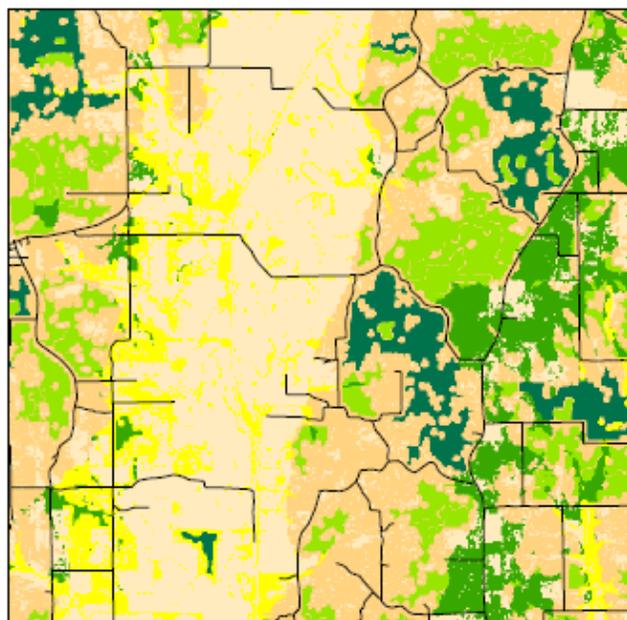
Percent Conversion



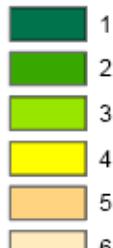
Opportunity Area Rank



= Significance



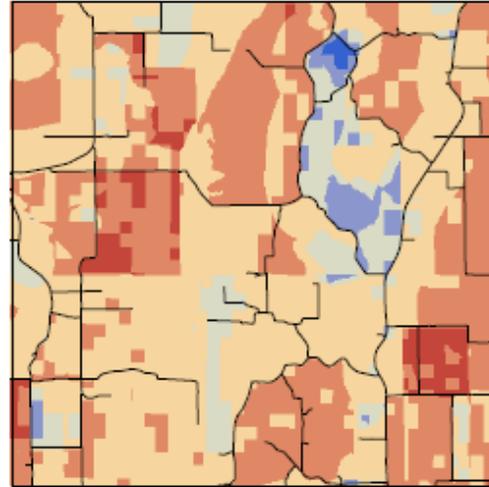
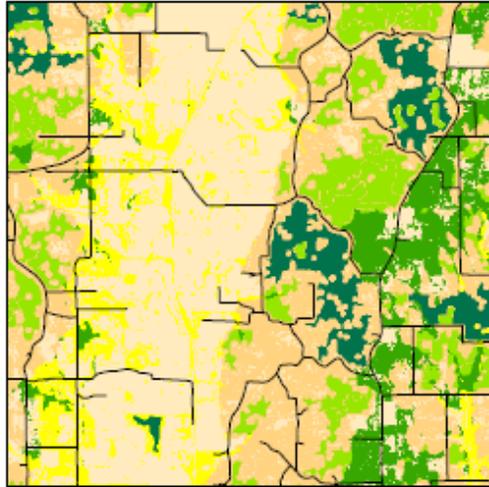
Significance Rank



Significance

+

Threat



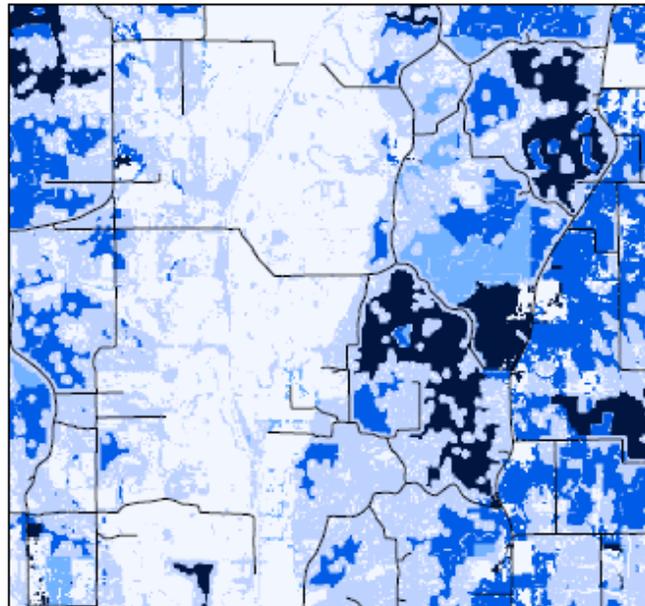
Significance Rank



Threat Rank



= Risk



Risk Rank



Missouri Wildlife Action Plan

- Monies from the Federal State Wildlife Grant (SWG) Program are being used to develop wildlife action plans (WAPs)
- SWG started in 2001
 - Revenues generated from taxes on items used for non-consumptive outdoor recreation
- Appropriations \$50-80 million nationally
 - Missouri ~ \$1 million annually
- All states were required to develop a WAP by October 2005



Goal and Objective of Aquatic Component of WAP

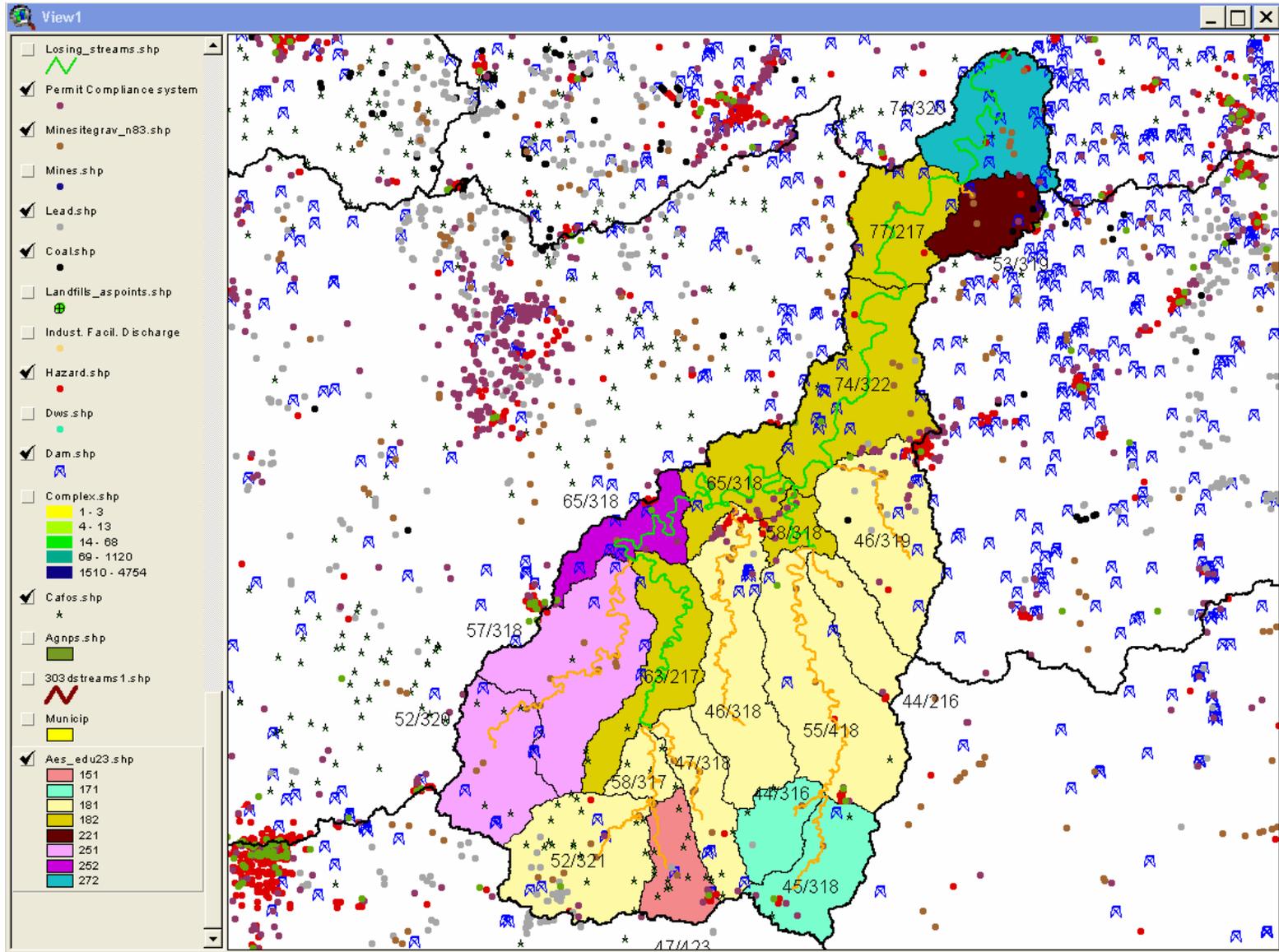
GOAL:

“Ensure the long term persistence of native aquatic plant and animal communities, by conserving the conditions and processes that sustain them, so people may benefit from their values in the future.”

OBJECTIVE:

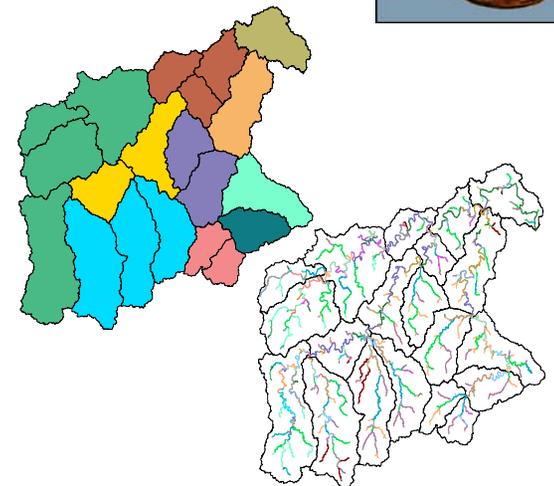
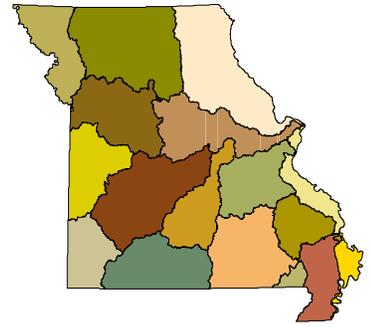
“Identify and map a set of aquatic conservation opportunity areas that holistically represent the full breadth of distinct riverine ecosystems in Missouri and multiple populations of all native aquatic species”

Geospatial Decision Support Systems



General Conservation Strategy

- Generate separate conservation plans for each Ecological Drainage Unit (EDU)
- Represent 2 populations of all target species within each EDU
 - Biotic Conservation Targets
- Represent all of the distinct watershed and stream types within each EDU
 - Abiotic Conservation Targets

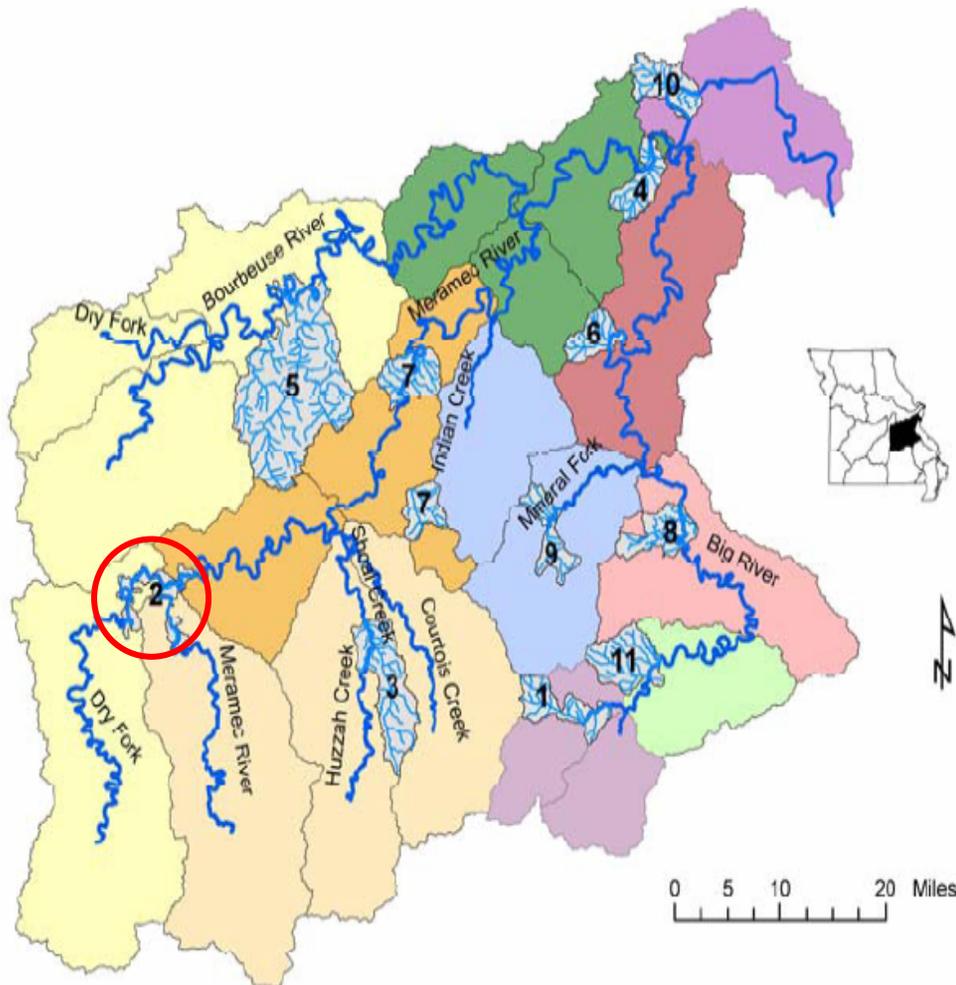


Results for Pilot Area

Meramec EDU

Ozark/ Meramec Ecological Drainage Unit

Results



- 11 COAs selected: 300 km
- Full network: 10,684 km
- Represents 2.8% of entire network
- Representation of abiotic targets missed only 5 of the 103 target species
- Added a single COA to capture these species

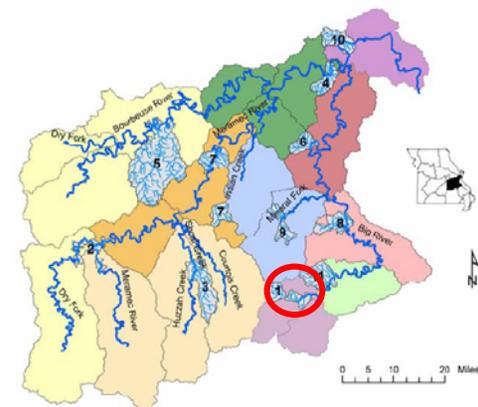
COA Selection Criteria and Characteristics

	A	B	C	D	E
1	NAME	Public Landowners	MDC Regions	Reason AES Selected	Reason YST's Selected
2	Clear Creek	USFS; MDC	Primary: St. Louis	Higher local and watershed public ownership	Only place to achieve connectivity among size classes
3	Dry Fork/Upper Meramec	MDC	Primary: St. Louis; Secondary: Ozark	To capture target species not captured in other focus areas	To capture target species not captured in other focus areas
4	Flat River	MDNR	Primary: St. Louis; Secondary: Southeast	Only AES of Type	Only place to achieve connectivity among size classes
5	Fox Creek	MDC	Primary: St. Louis	Higher public land and no lead or coal mines	Relatively intact subwatershed and connectivity
6	Huzzah Creek	USFS; MDC	Primary: St. Louis	Highest target richness, higher public land, highest quality	Only place to achieve connectivity among size classes
7	Lower Big	None	Primary: St. Louis; Secondary: Southeast	Only AES of Type	Connectivity and low human disturbance
8	Lower Bourbeuse	MDC	Primary: St. Louis	Highest target richness	Connectivity and relatively low human disturbance
9	Lower Meramec	MDC	Primary: St. Louis	Only AES of Type	Connectivity, public lands and relatively low disturbance
10	Middle Meramec	MDNR; MDC	Primary: St. Louis	Public lands, higher target richness	Public lands
11	Mineral Fork	MDC	Primary: St. Louis	Much higher target richness	Only place to achieve connectivity among size classes
12	Upper Big	MDC	Primary: St. Louis	Only AES of Type	Connectivity

Continued

	A	F	G	H
1	NAME	Potential Alternates	Potential YST Alternatives	Management Concerns
2	Clear Creek	AESpolyid 371	None	gravel mining, upland pasture, floodplain row/crop, point sources, lead, small impoundments,
3	Dry Fork/Upper Meramec	None	None	gravel mining, floodplain row/crop, point sources, hazard, dams, roads, exotics
4	Flat River	None	None	upland pasture, floodplain row/crop, urban, point sources, ifd, lead, hazard, cafos, 303d, roads, exotics
5	Fox Creek	None	Lower Calvey Creek and tributaries	upland pasture, floodplain row/crop, point sources, hazard, roads, exotics
6	Huzzah Creek	Aespolyid 363	Upper Courtois Creek and tributaries	gravel mining, floodplain pasture/grazing, point sources, lead, small impoundments, roads, exotics
7	Lower Big	None	Tyreg Creek and tribs, or Calico Creek and tribs	upland pasture, floodplain row/crop, point sources, lead, small impoundments, 303d, roads, exotics
8	Lower Bourbeuse	None	Red Oak Creek and tributaries	gravel mining, toxic release, upland pasture, floodplain row/crop, point sources, lead, coal, hazard, small impoundments, roads, exotics
9	Lower Meramec	None	None	upland pasture, floodplain row/crop, urban, point sources, ifd, hazard, small impoundments, roads, exotics
10	Middle Meramec	None	None	point sources, lead, coal, small impoundments, exotics
11	Mineral Fork	Aespolyid 361	Lower Indian Creek and tributaries	upland pasture, urban, point sources, ifd, lead, small impoundments, roads
12	Upper Big	None	Mill Creek or Tiff Creek and tributaries	gravel mining, point sources, lead, small impoundments, 303d, roads, exotics

Ozark/ Meramec Ecological Drainage Unit



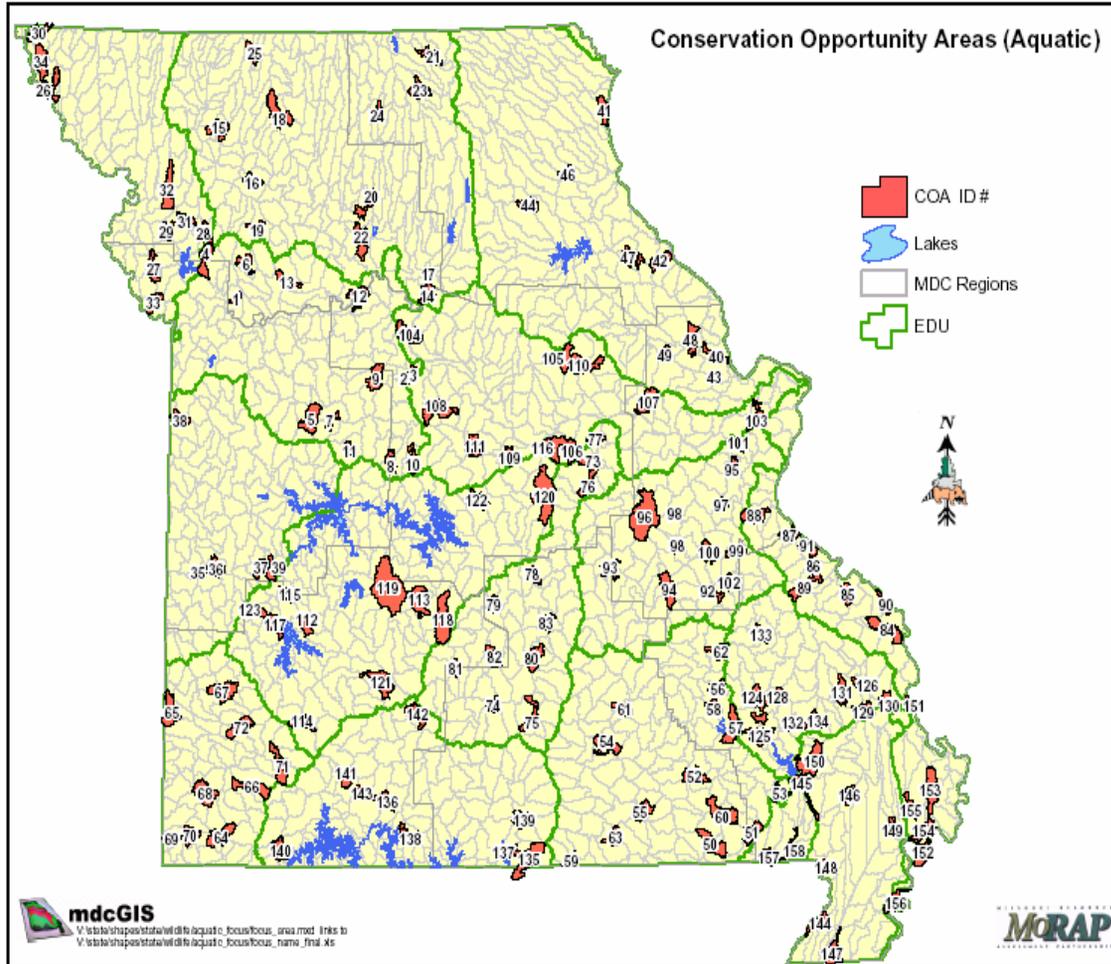
Continued

	A	I
1	NAME	Exotics
2	Clear Creek	None
3	Dry Fork/Upper Meramec	brown trout, common carp, rainbow trout, Asian clam
4	Flat River	common carp
5	Fox Creek	common carp, Asian clam, zebra mussel
6	Huzzah Creek	common carp, rainbow trout
7	Lower Big	common carp, Asian clam
8	Lower Bourbeuse	common carp, Asian clam
9	Lower Meramec	common carp, Asian clam, zebra mussel
10	Middle Meramec	common carp, Asian clam, zebra mussel
11	Mineral Fork	None
12	Upper Big	common carp, Asian clam

Other Info

- Uncertainties
- Opportunities
- Species
- People

Aquatic Conservation Opportunity Areas for Missouri



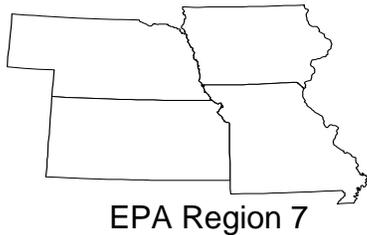
158 COAs selected

Full network: 174,059 km

COA network: 10,915 km

COAs represent 6.3%

Developing Synoptic Human Stressor Indicators for Assessing the Ecological Integrity of Freshwater Ecosystems in EPA Region 7



Goal:

Develop reach scale GIS-based Synoptic Human Stressor Indices (HSI) for assessing ecological integrity of freshwater ecosystems



Human Stressors (Missouri Example)

Land Use

Municipalities

Railroads

303d Streams

Airports

Toxic Release

Superfund

Point Sources

In-stream gravel mines

Landfills

Industrial Facility Discharges

Hazardous Waste

Generators

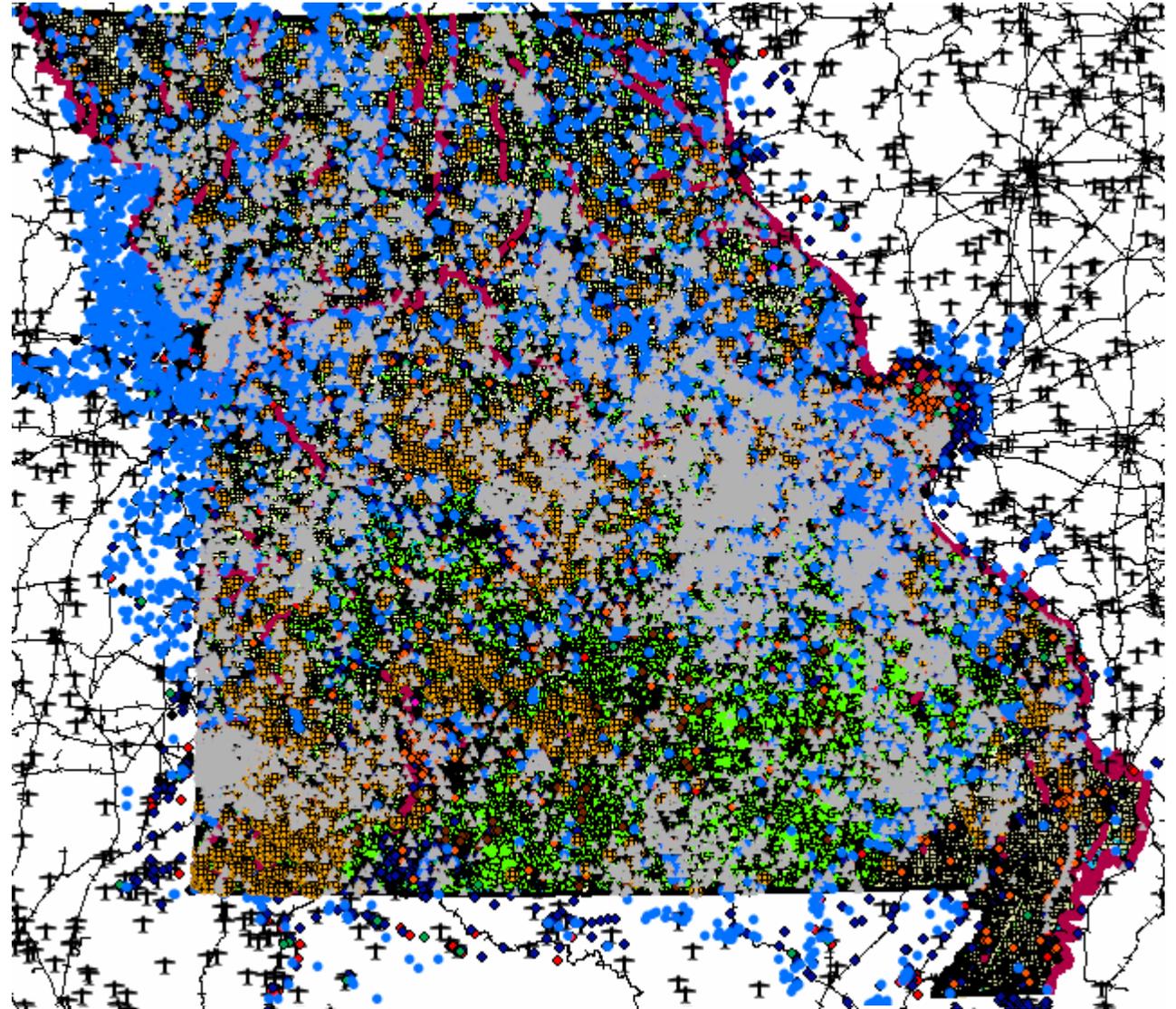
Drinking Water Supplies

Dams

CAFOs

Mines

Roads



What do we have now?

Human Stressor Index Values for each Aquatic Ecological System in Missouri

Metric	1	2	3	4
Number of Introduced Species	1	2	3	4
Percent Urban	0-5	5-10	11-20	>20
Percent Agriculture	0-25	26-50	51-75	>75
Density of Road Stream Crossings (#/mi ²)	0-1	1.25-2.50	2.50-5.0	>5.0
Population (range 1,000-2,000 #/mi ²)	<2.0	2.0-1.0	1.0-0.5	<0.5
Degree of Hydrologic Modification and/or Fragmentation by Major Impoundments	1	2 or 3	4 or 5	6
Number of Factorially Impacted Streams	0	1-8	10-20	>20
Density of Coal Mines (#/mi ²)	0	1-5	6-20	>20
Density of Lead Mines (#/mi ²)	0	1-5	6-20	>20
Density of Remediated Discharges (#/mi ²)	0	1-5	6-20	>20
Density of Confined Animal Feeding Operations (#/mi ²)	0	1-5	5-10	>10

Table 1. The 11 stressor metrics included in the Human Stressor Index (HSI) and the specific criteria used to define the four relative ranking categories for each metric that were used to calculate the HSI for each Aquatic Ecological System.

Description:

There are a multitude of stressors that negatively affect the ecological integrity of riverine ecosystems (Jain and Fisher 1992; Ritten et al. 1997). The first step in any effort to account for anthropogenic stressors is developing a list of candidate causes (U.S. EPA 2000). Working in consultation with a team of aquatic resource professionals, a list of the principal human activities known to affect the ecological integrity of streams in Missouri was generated. Then the best available (i.e., highest resolution and most recent) geospatial data that could be found for each of these stressors was assembled. Fortunately, and somewhat surprisingly, data were available for most stressors. However, for some, such as channelized stream segments, there were no available geospatial data, and efforts to develop a coverage of such segments using a suitability index proved ineffective. Most of the geospatial data were acquired from the U.S. EPA and the Missouri Departments of Conservation and Natural Resources.

We initially generated statistics for nearly 50 individual human stressors (e.g., percent urban, lead mine density, degree of fragmentation) for each Aquatic Ecological System in Missouri. We then used correlation analyses to reduce this overall set of metrics into a final set of 11, relatively uncorrelated, measures of human disturbance (Table 1). Relativized rankings (range 1 to 4) were then developed for each of these 11 metrics (Table 1). A rank of 1 is indicative of relatively low disturbance for that particular metric, while a rank of 4 indicates a relatively high level of disturbance. These rankings were based on information contained within the literature or empty quarters when no empirical evidence on thresholds was available. For instance, rankings for percent urban were: 1: 0-5%; 2: 6-10%; 3: 11-20%; and 4: >20%, were based on the results of various studies that have examined the effects of urban land cover on the ecological integrity of stream ecosystems (Klein 1979; Osborne and Wiley 1986; Limburg et al. 1992; Bost 1993; Weaver and Corman 1994; Bost and Johnson 1997; Wang et al. 2000). However, existing research for percent agriculture has not identified clear thresholds, suggesting that there is a more or less continual decline in ecological integrity with each added percentage of agriculture on the watershed. For this measure of human stress we simply used quartiles: 1: 0-25%; 2: 26-50%; 3: 51-75%; and 4: >75%.

The relativized rankings for each of these 11 metrics were then combined into a three number Human Stressor Index (HSI). The first number reflects the highest ranking across all 11 metrics (range 1 to 4) (Inset Map A and B). The last two numbers reflect the sum of the 11 metrics (range 11 to 44) (Inset Map C). This index allows you to evaluate both individual and cumulative impacts. For instance, a value of 415, indicates relatively low cumulative impacts (i.e., last two digits = 15 out of a possible 44); however, the first number is a 4, which indicates that one of the stressors is relatively high and potentially acting as a major human disturbance within the ecosystem.

References:

Allen, T.J. and J. Patten. 1991. Biological communities in watersheds: a synthesis of the literature. *Journal of the American Water Resources Association* 27: 1-12.

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Bost, J.R. and R. Smith. 1997. *Impacts of aquatic systems: regional assessment of Missouri streams*. Columbia, Missouri: Missouri Department of Conservation.

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Boyd, S.L. 2013. *Stream quality: a practical approach to water quality assessment*. Boca Raton, Florida: Lewis Publishers.

Boyd, S.L. 2014. *Stream quality: a practical approach to water quality assessment*. Boca Raton, Florida: Lewis Publishers.

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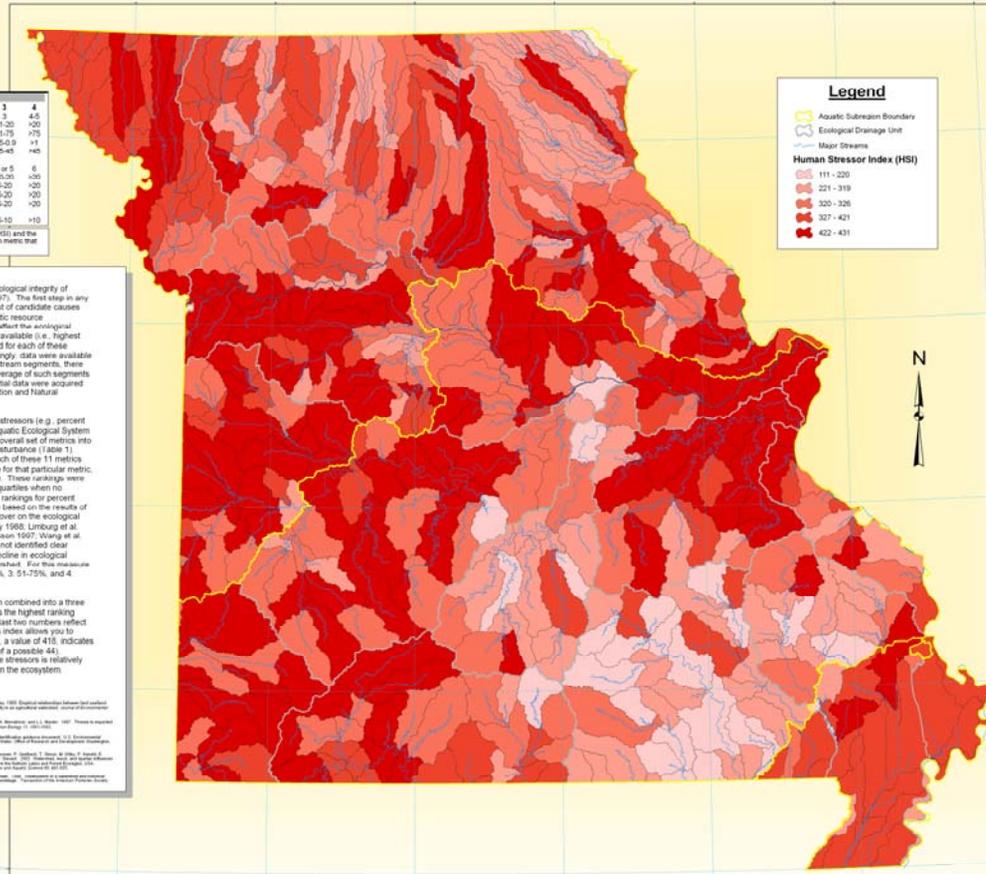
Boyd, S.L. 2016. *Stream quality: a practical approach to water quality assessment*. Boca Raton, Florida: Lewis Publishers.

Boyd, S.L. 2017. *Stream quality: a practical approach to water quality assessment*. Boca Raton, Florida: Lewis Publishers.

Boyd, S.L. 2018. *Stream quality: a practical approach to water quality assessment*. Boca Raton, Florida: Lewis Publishers.

Boyd, S.L. 2019. *Stream quality: a practical approach to water quality assessment*. Boca Raton, Florida: Lewis Publishers.

Boyd, S.L. 2020. *Stream quality: a practical approach to water quality assessment*. Boca Raton, Florida: Lewis Publishers.

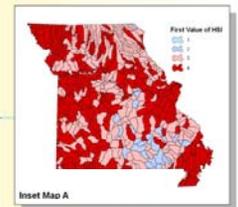


Legend

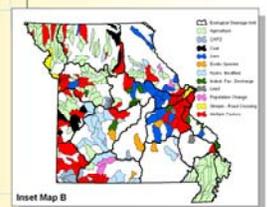
- Aquatic Substream Boundary
- Ecological Drainage Unit
- Major Streams

Human Stressor Index (HSI)

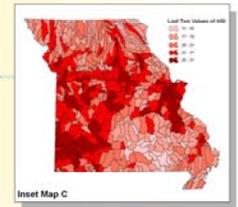
- 111 - 220
- 221 - 339
- 320 - 326
- 327 - 421
- 422 - 431



Map showing the first value in the Human Stressor Index for each of the Aquatic Ecological Systems in Missouri. A value of 1 indicates a relatively low level of disturbance, while a value of 4 indicates a relatively high level of disturbance. Note of the AECs polygons received a value of 1.



Map showing which Aquatic Ecological Systems received a value of 4 for the first value in the Human Stressor Index. Further broken down according to which specific human stressor was responsible for the high value.

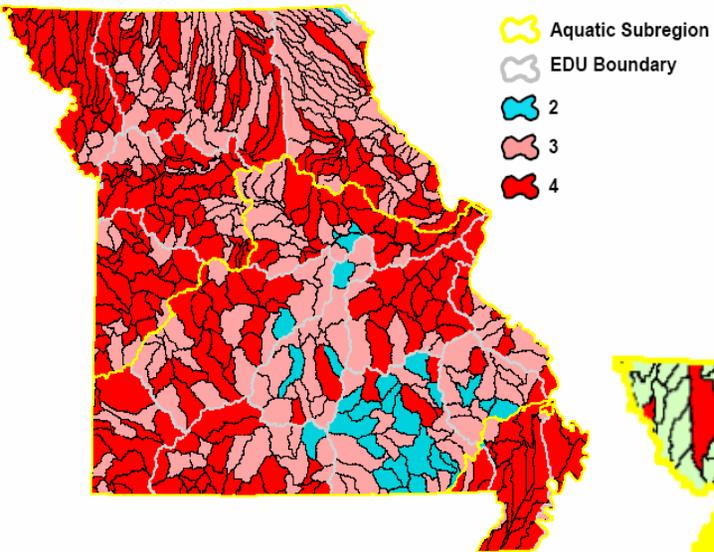


Map showing the last two values in the Human Stressor Index for each of the Aquatic Ecological Systems in Missouri. A value of 11 indicates an extremely low level of cumulative impact. The highest possible value in theory is 44, however, because some of the 11 metrics used in the index are mutually exclusive (e.g., Urban and Agriculture), the highest observable value is unknown. The highest value in Missouri was 31. Generally, the higher the value for these last two digits, the higher the degree of cumulative disturbance.



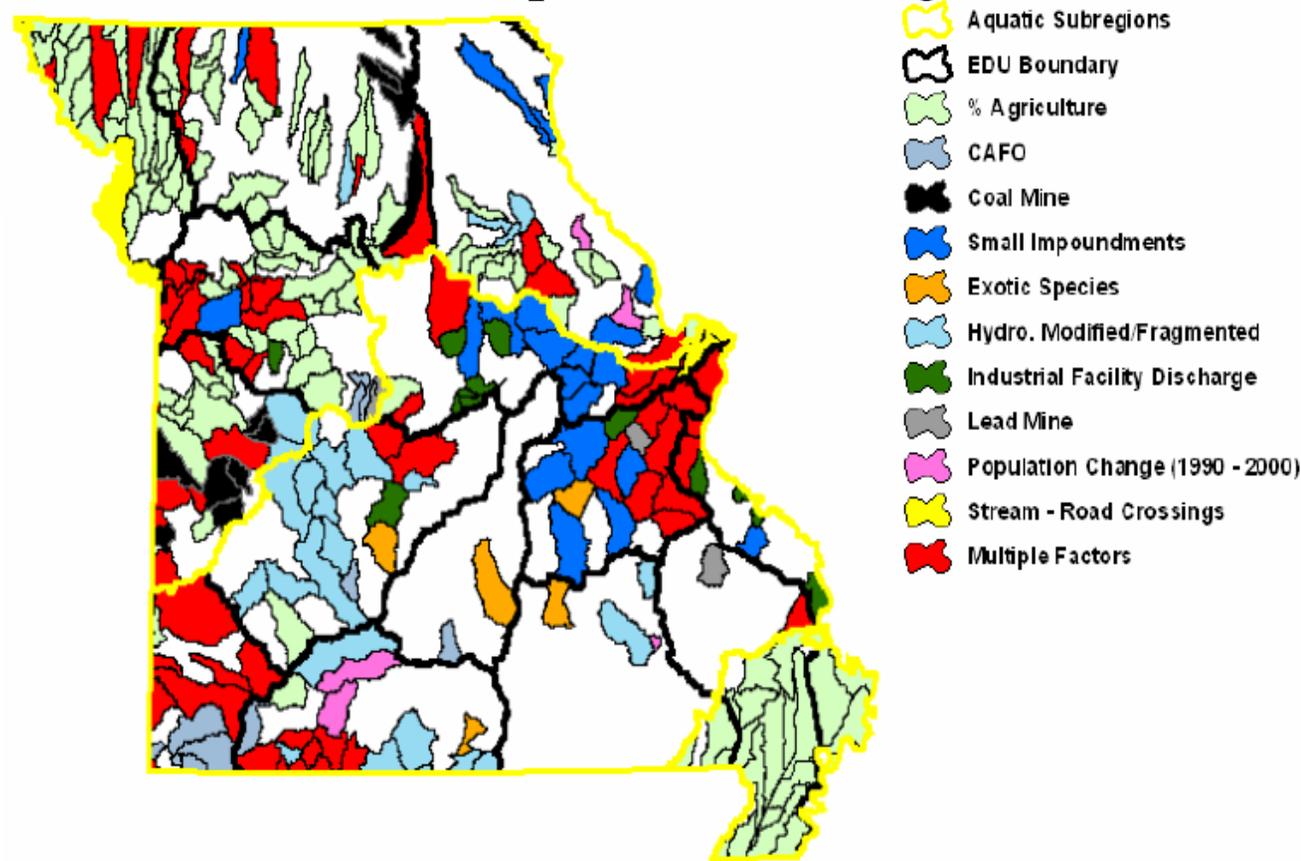
Annis G. M., S. P. Sova, M. E. Morry, and D. B. Diamond. 2005. Human Stressor Index Values for each Aquatic Ecological System in Missouri. MCRAP Map Series MS-2005-013.
Cartographer: Gust M. Annis

Utility: Coarse Screening Tool



First HSI Value

Stressor(s) Responsible for Highest Rank (4)



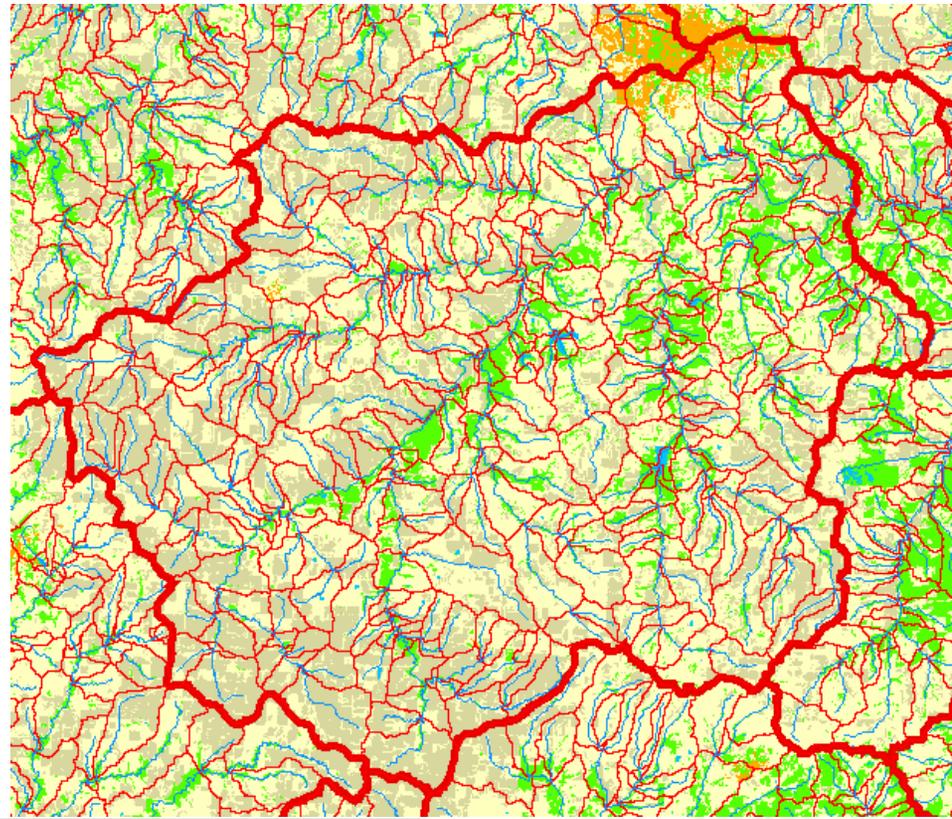
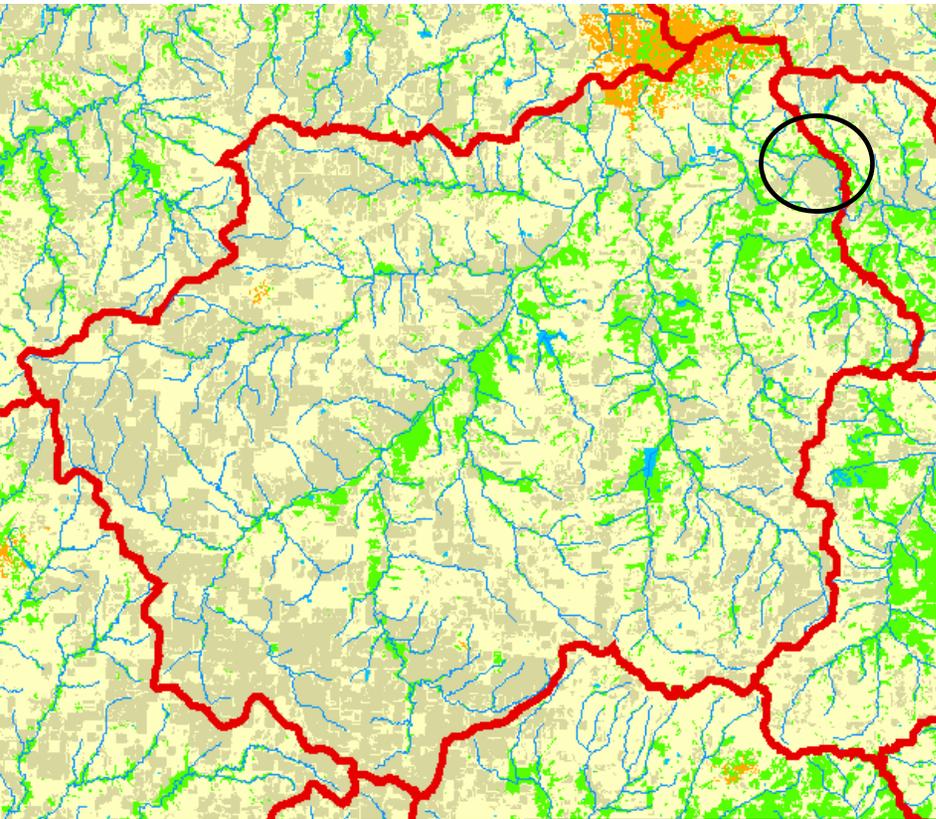
Problems with HSI

- Only accurately quantifies conditions at outlet
- Data availability and quality
- Treats all stressors equally
 - Weighting (ex., 3xUrban vs. 1xAg)
- Does not account for principal ecological effects
 - Develop separate stressor indices (Physical habitat, water quality, flow regime, energy/nutrient dynamics, biotic interactions)
- Does not account for spatial considerations

Problem: Only Quantifies Conditions at Outlet

Problem: Only accurately quantifies conditions at outlet

Solution: Utilize higher resolution assessment unit (segment shed)

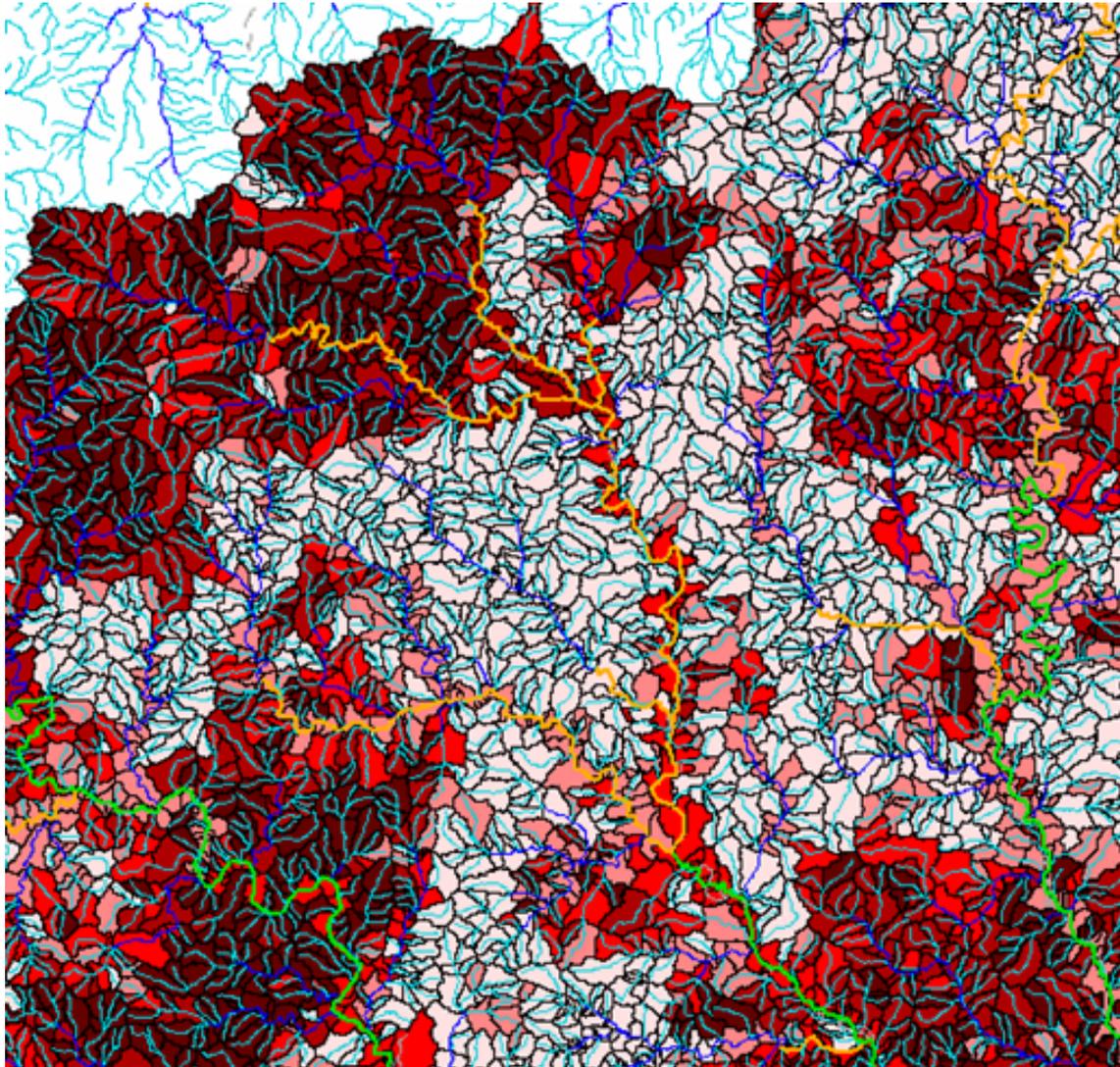


— Streams
□ Assessment Polygon

Urban
Row and Close Grown Crop
Grassland
Forest and Woodland
Swamp and Marsh
Open Water

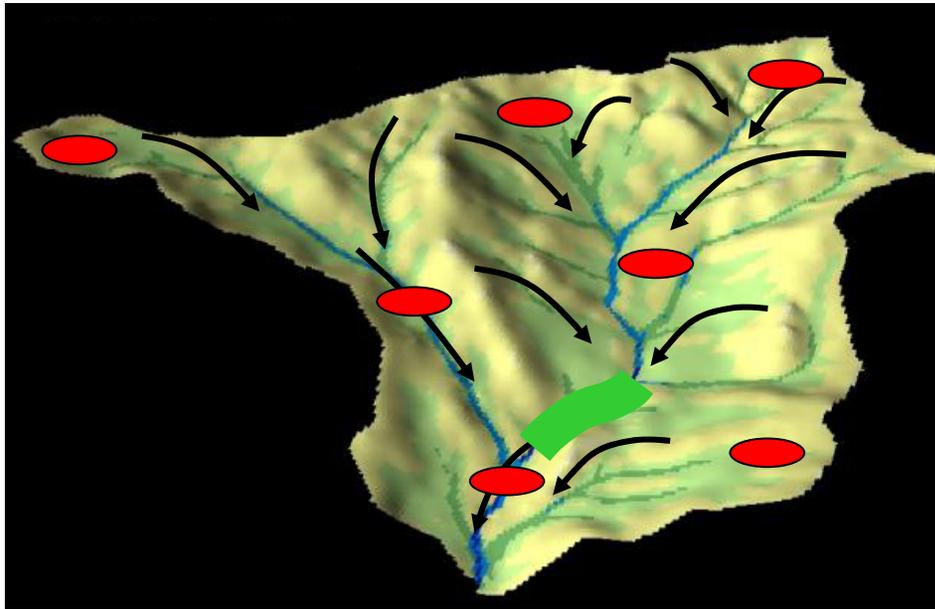
— Streams
□ Assessment Polygon

Account for Local and Watershed Conditions

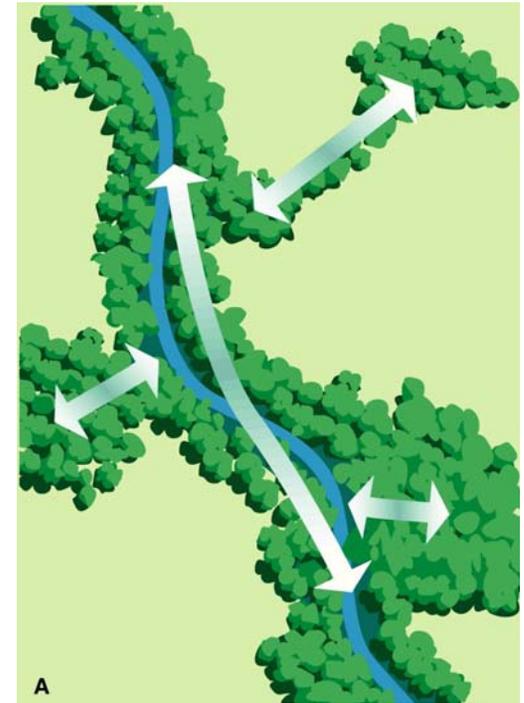


Spatial Considerations

- Distance to stressor
- Is stressor upstream, downstream or local



**Ecological Integrity of Riverine Ecosystems is
Dependent Upon Integrity of the Entire
Watershed**



Accounting for Connectivity

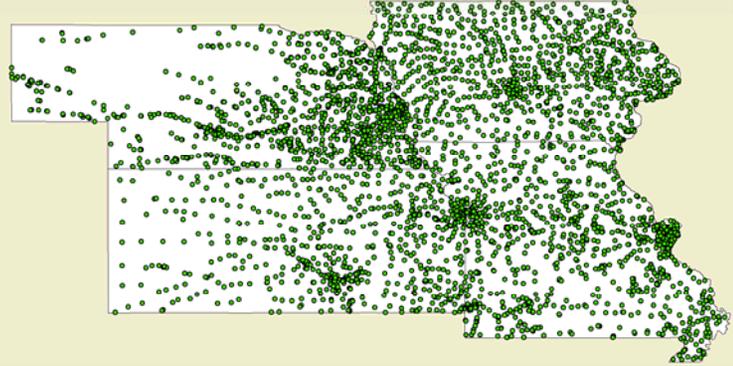
Gathering Threats Data

Dam Locations



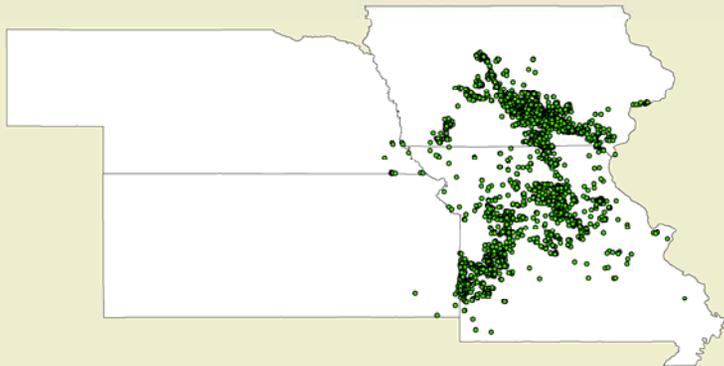
• Dams

Discharge Locations



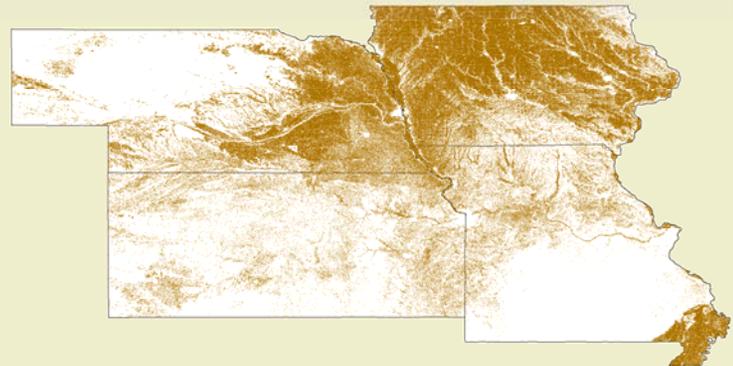
• Discharge Sites

Coal Mining Sites



• Coal Mines

Row Crops



■ Row Crop

A New Methodology: How is it different from what we have done in Missouri?

- All of EPA Region 7
- Use segment-sheds (reach specific drainage)
- Work with committee to locate all available data
- Weight threats
- If possible, account for principal ecological effects separately
- Account for spatial considerations