Developing Synoptic Human Stressor Indicators for Assessing the Ecological Integrity of Freshwater Ecosystems

2nd Regional Oversight Committee Meetings

St. Joseph, MO

August 10th, 2006

Project Funded by US Environmental Protection Agency
Region 7 Wetland Program Development Grant

Project Period
September 2005 thru September 2008

http://www.cerc.usgs.gov/morap/projects.asp?project_id=44

Overview

- Background
- Project goal
- Review of Missouri's Human Stressor Index (HSI)
- EPA Region 7 HSI
- Working meeting and discussions

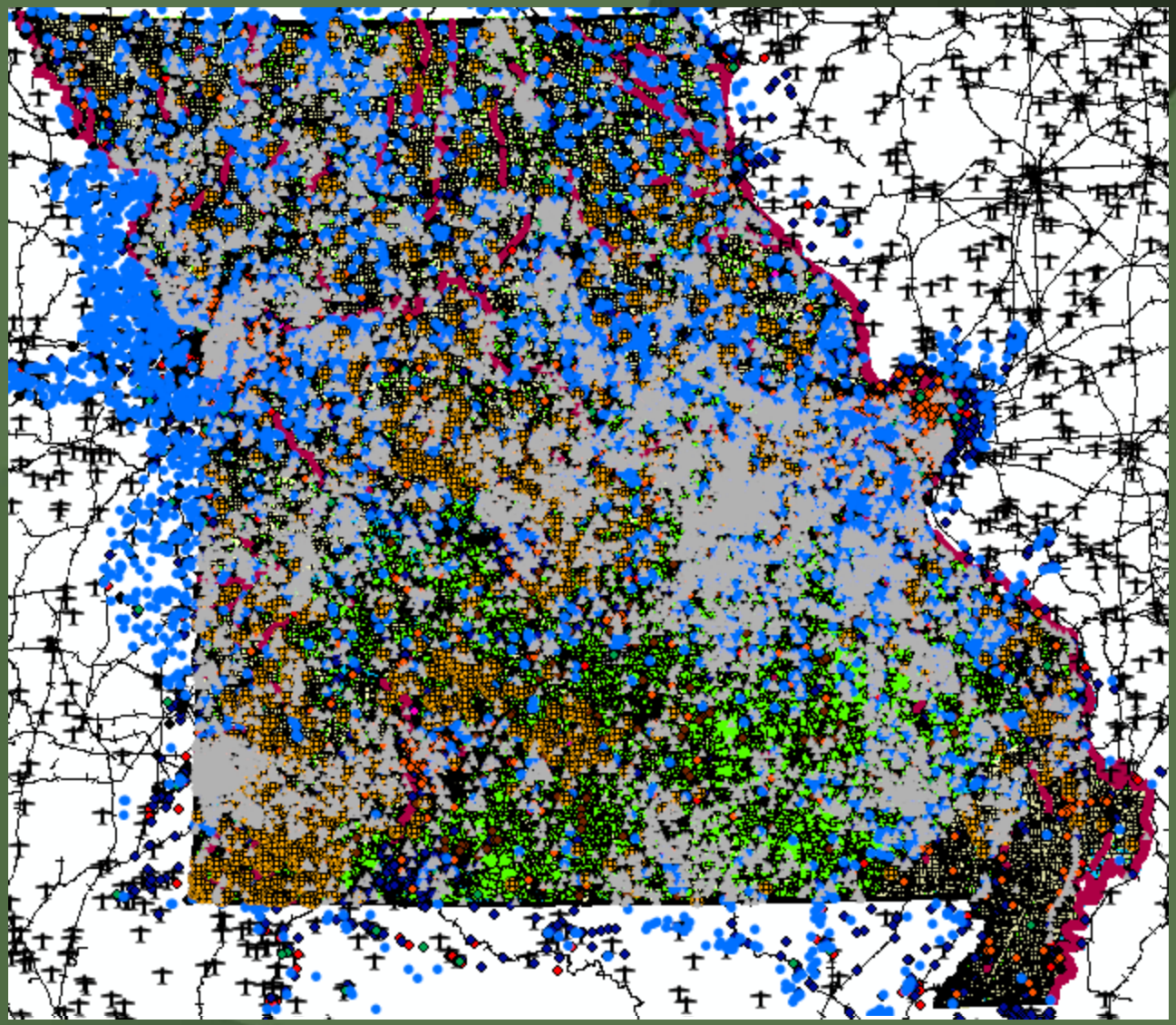
Background/Problem

Review – What we are trying to accomplish

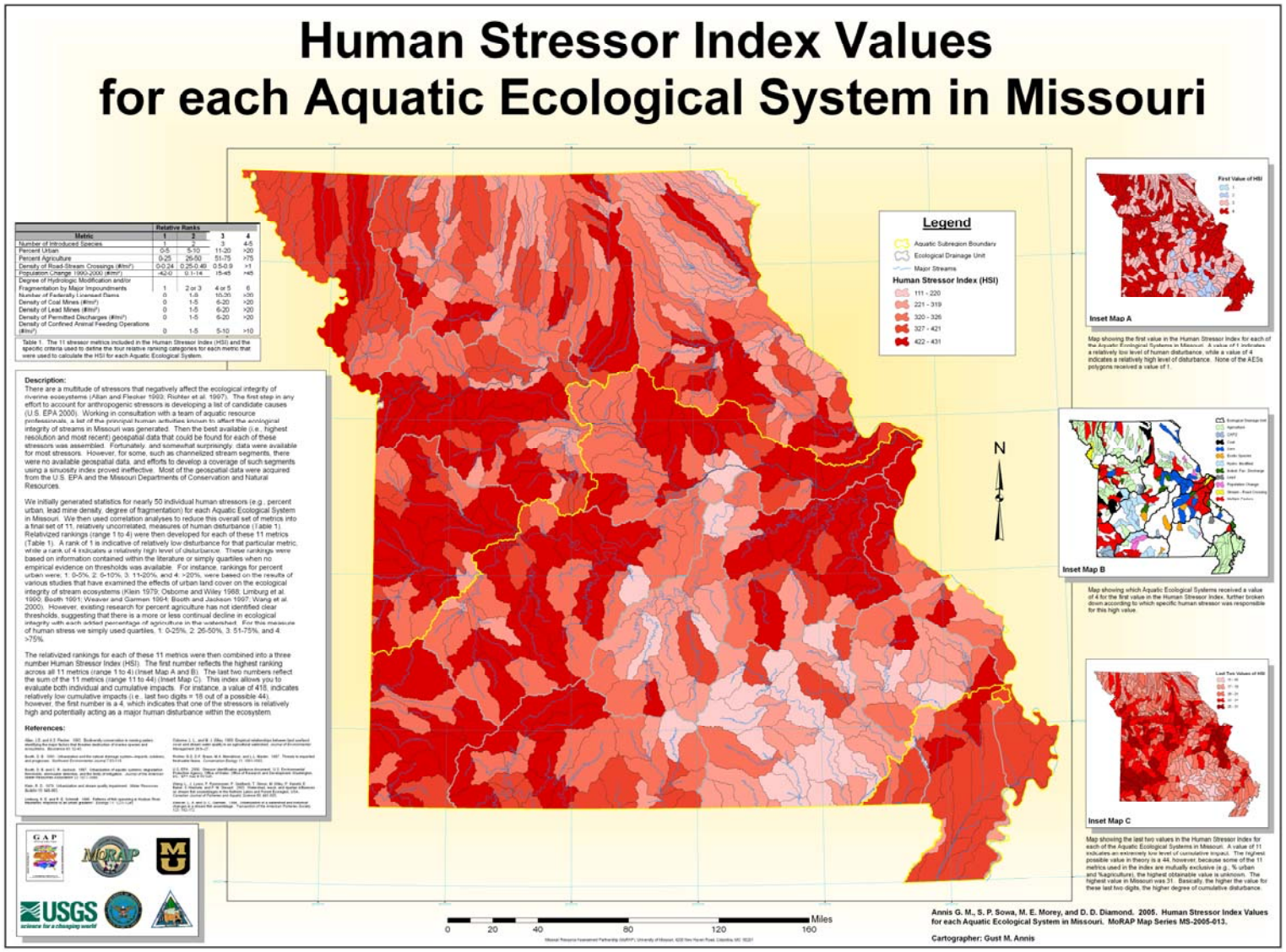
Goal:
Develop reach scale GIS-based Synoptic Human Stressor Indices (HSI) for assessing ecological integrity of freshwater ecosystems

Human Stressors (Missouri Example)

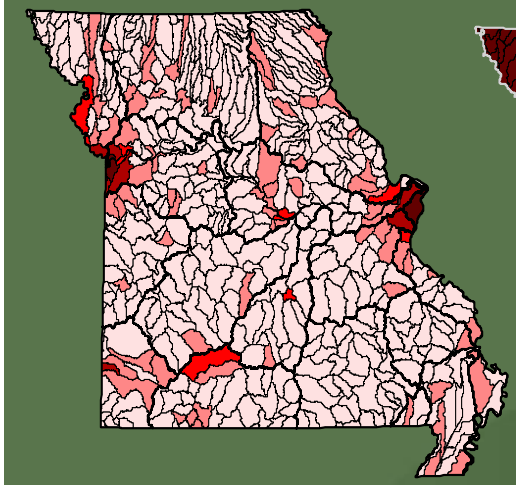
- Land Use
- Municipalities
- Railroads
- 303d Streams
- Airports
- Toxic Release
- Superfund
- Point Sources
- In-stream gravel mines
- Landfills
- Industrial Facility Discharges
- Hazardous Waste Generators
- Drinking Water Supplies
- Dams
- CAFOs
- Mines
- Roads



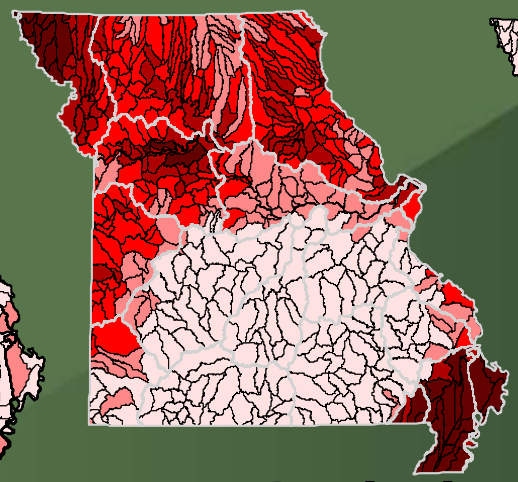
What do we have now?



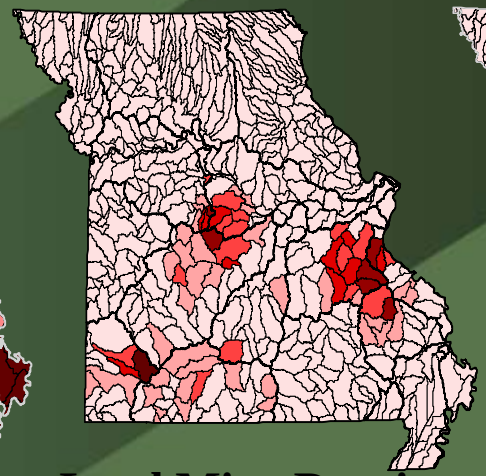
Accounting For Human Stressors



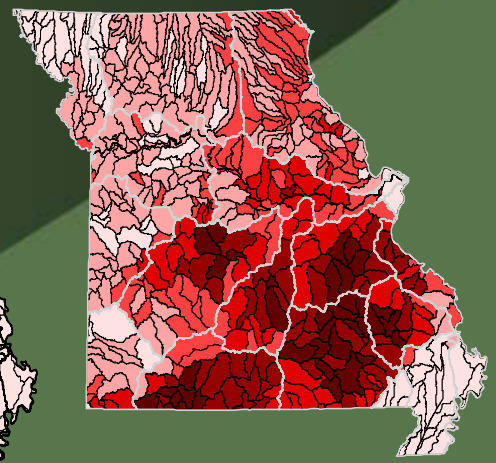
Percent Urban



Percent Cropland



Lead Mine Density



Riparian Forest

Attributes of Mo_aes_no_atts.shp

N_index_a	Pfor	Purb	Popchg	Standcar	Pfor_a	Pwetl	Pwetl_a	Purb_a	Pagp	Pagp_a	Pagc
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

Variables Used in Human Stressor Index and Associated Ranks

	Relative Ranks			
Metric	**1**	**2**	**3**	**4**
Number of Introduced Species	1	2	3	4-5
Percent Urban	0-5	5-10	11-20	>20
Percent Agriculture	0-25	26-50	51-75	>75
Density of Road-Stream Crossings (#/mi²)	0-0.24	0.25-0.49	0.5-0.9	≥1
Population Change 1990-2000 (#/mi²)	-42-0	0.1-14	15-45	>45
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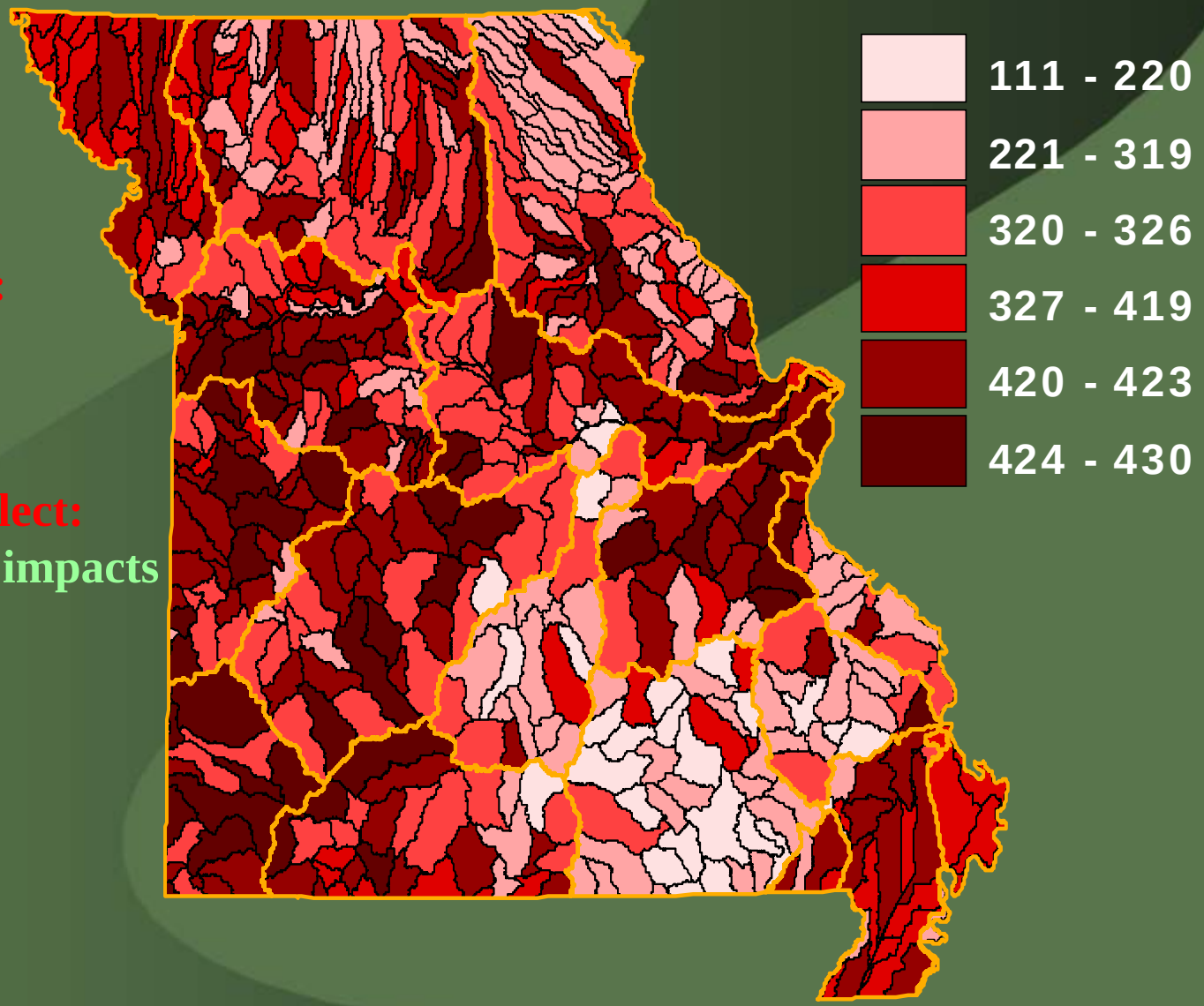
Density of Permitted Discharges (#/mi²)	0	1-5	6-20	>20
Density of Confined Animal Feeding Operations (#/mi²)	0	1-5	5-10	>10

Human Stressor Index

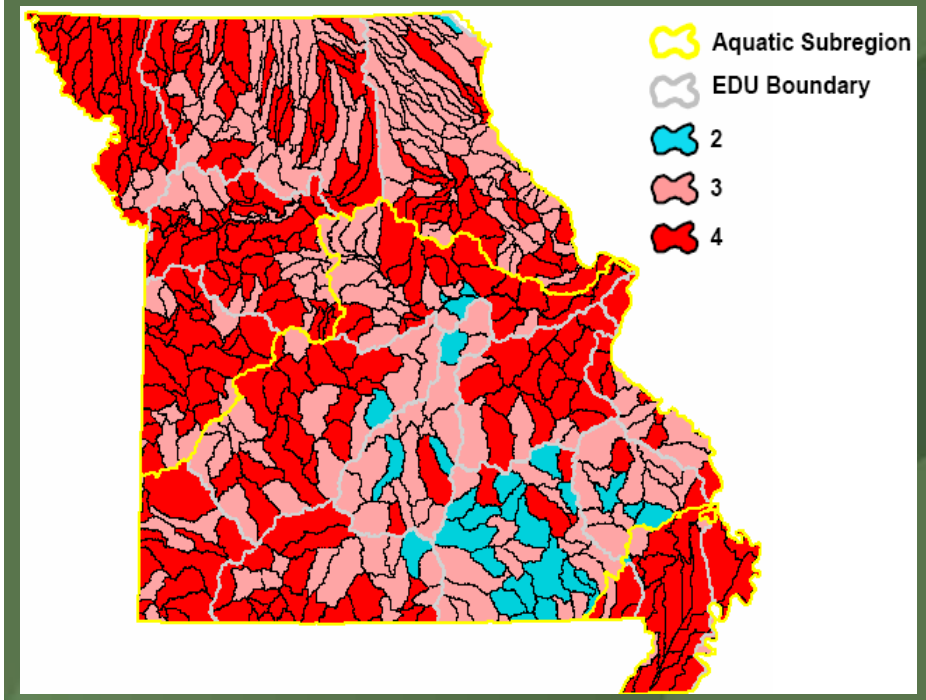
First number reflects:
Highest magnitude of individual stressor

Last two numbers reflect:
Degree of cumulative impacts

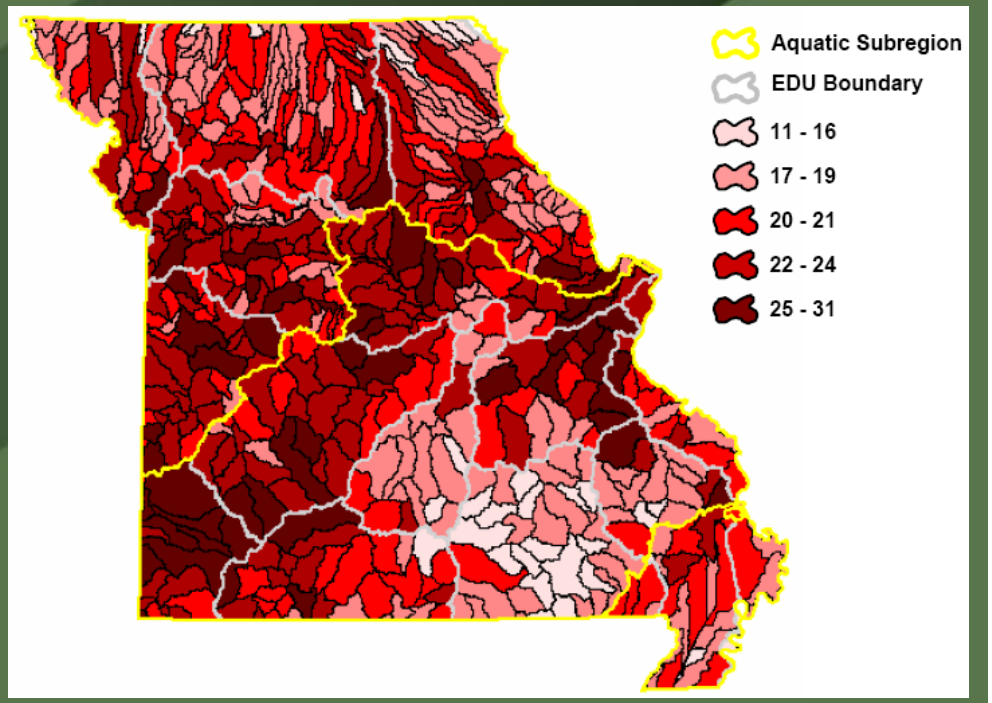


Deciphering the HSI

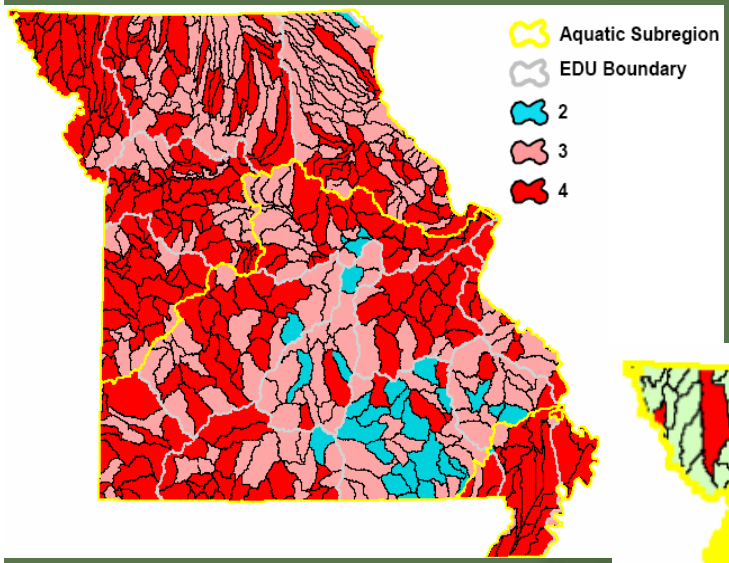
First Value
Highest Magnitude Stressor Rank



Last 2 Values
Sum of Stressor Ranks

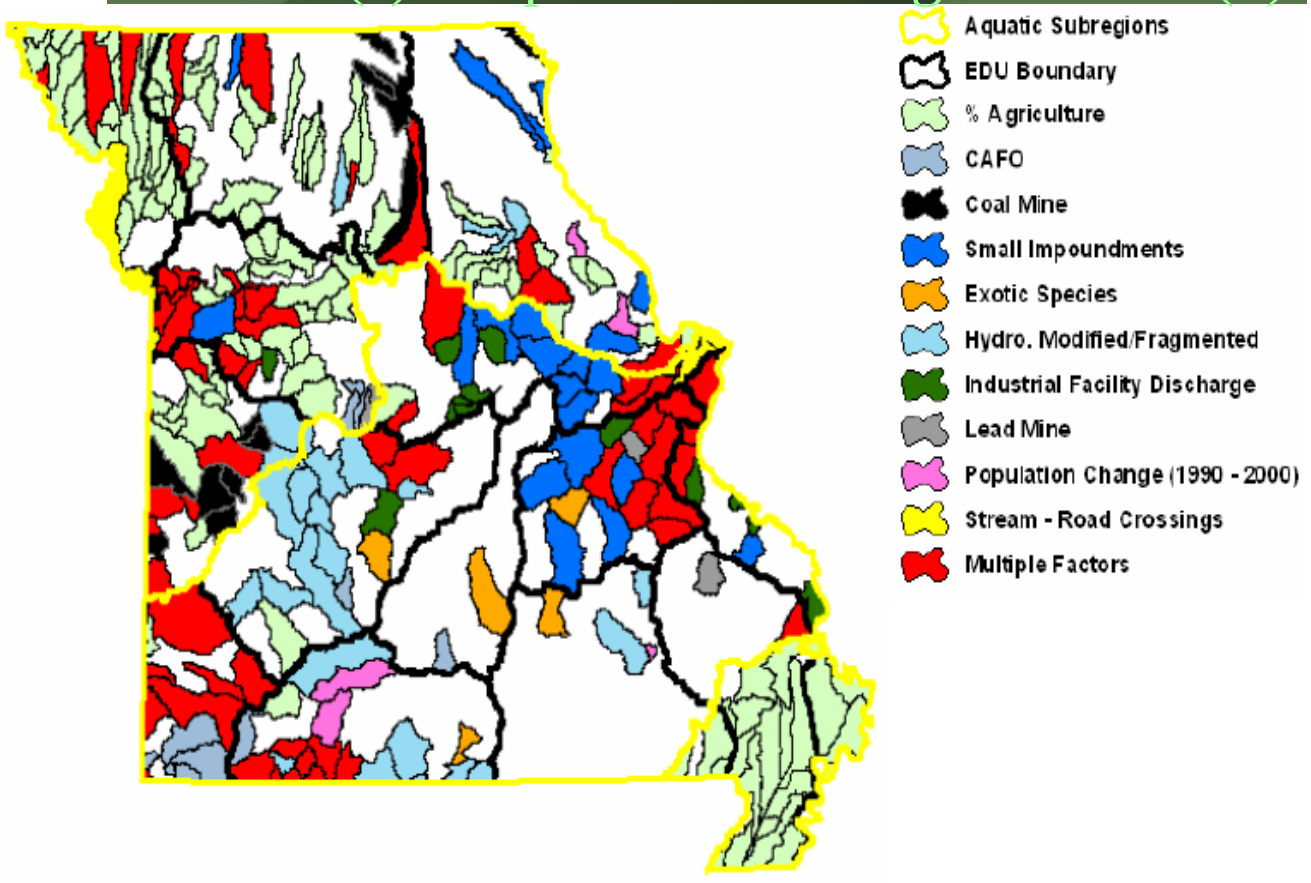


Utility:
Coarse Screening Tool

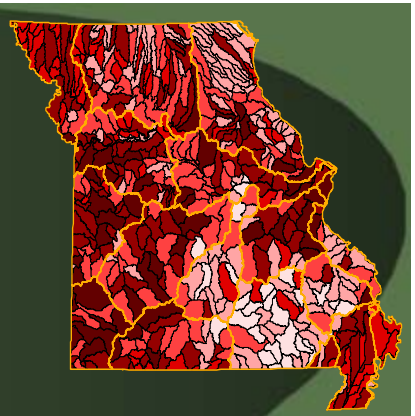


First HSI Value

Stressor(s) Responsible for Highest Rank (4)



Potential Uses of Human Stressor Index and Associated Input Data



- Help identify watersheds in need of restoration vs. those in need of more proactive protective measures
- Tool for identifying the specific stressors and thus, the management challenges within each watershed
- Tool for developing research projects attempting to quantify the potential effects of particular human stressors

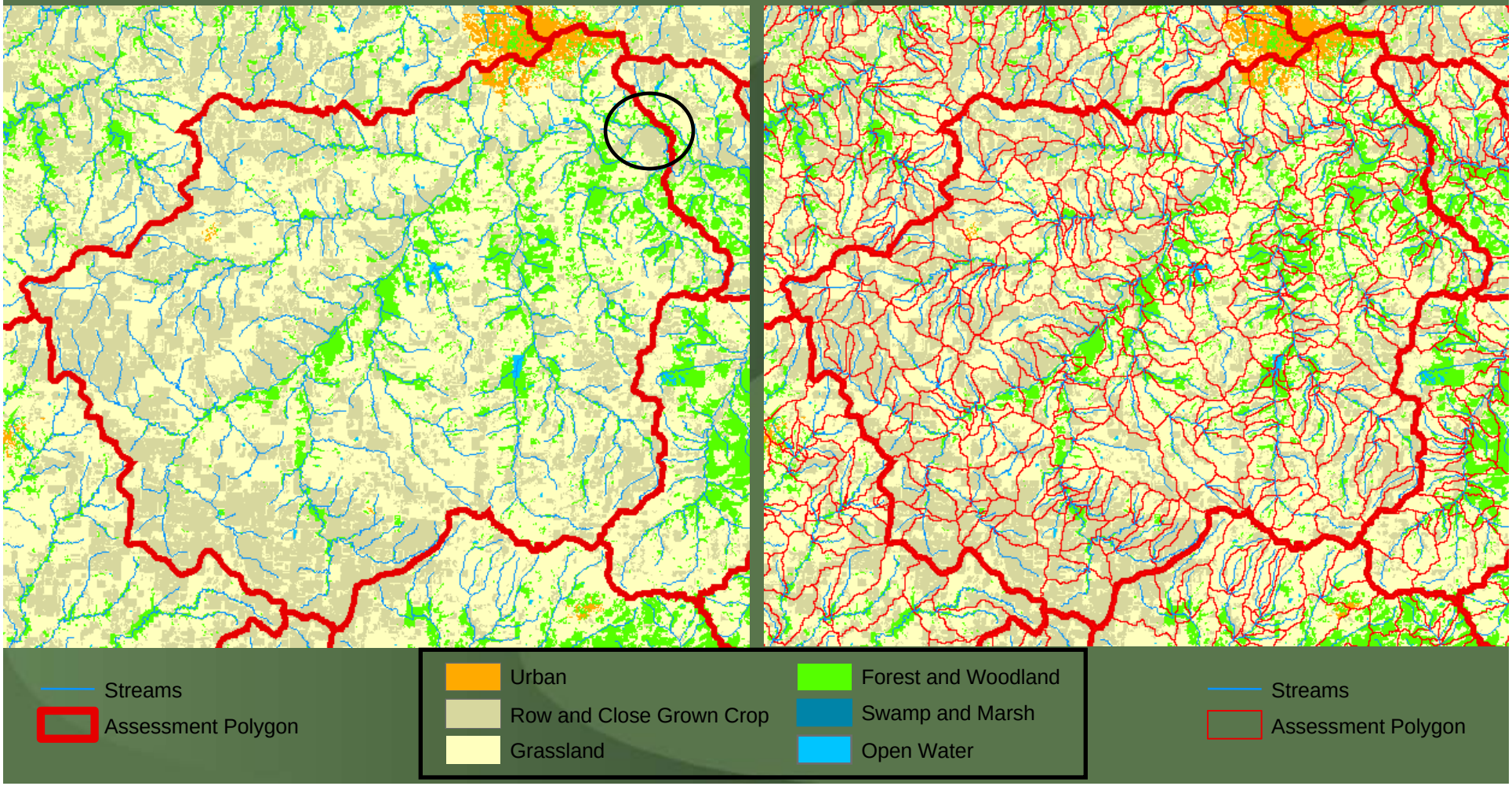
Problems with HSI

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

Problem:
Only Quantifies Conditions at Outlet

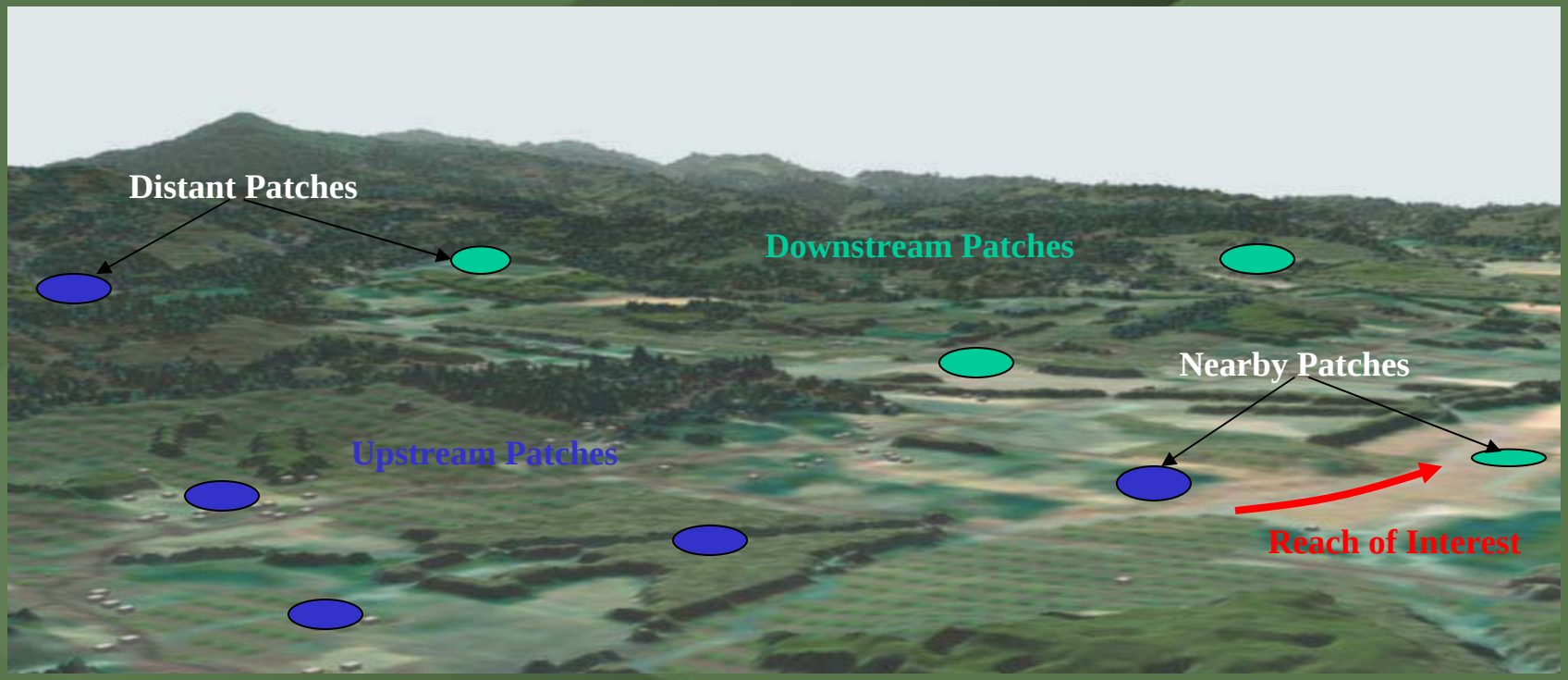
Problem: Only accurately quantifies conditions at outlet

Solution: Utilize higher resolution assessment unit (segment shed)



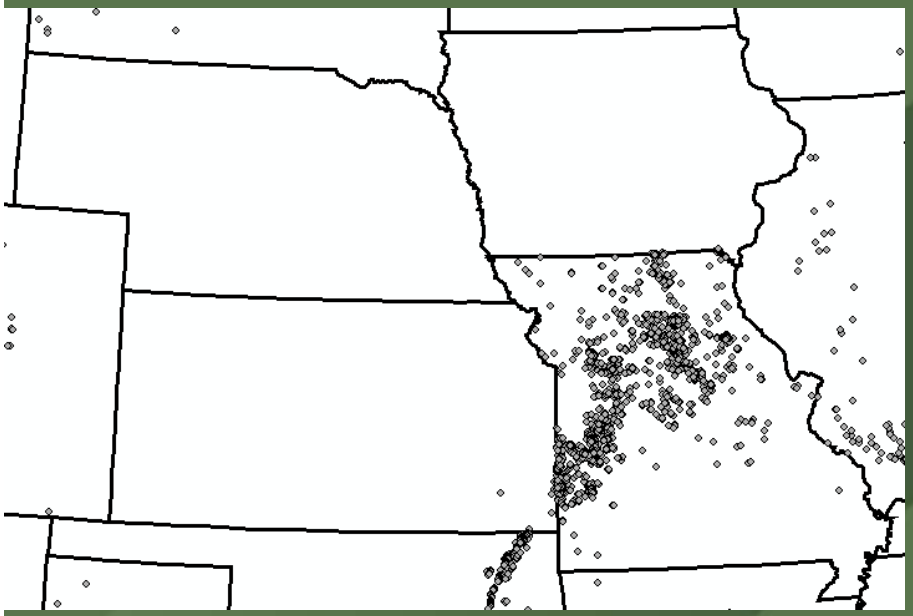
Problem:

Failure to Account for Magnitude or Temporal and Spatial Distribution of Individual Stressors



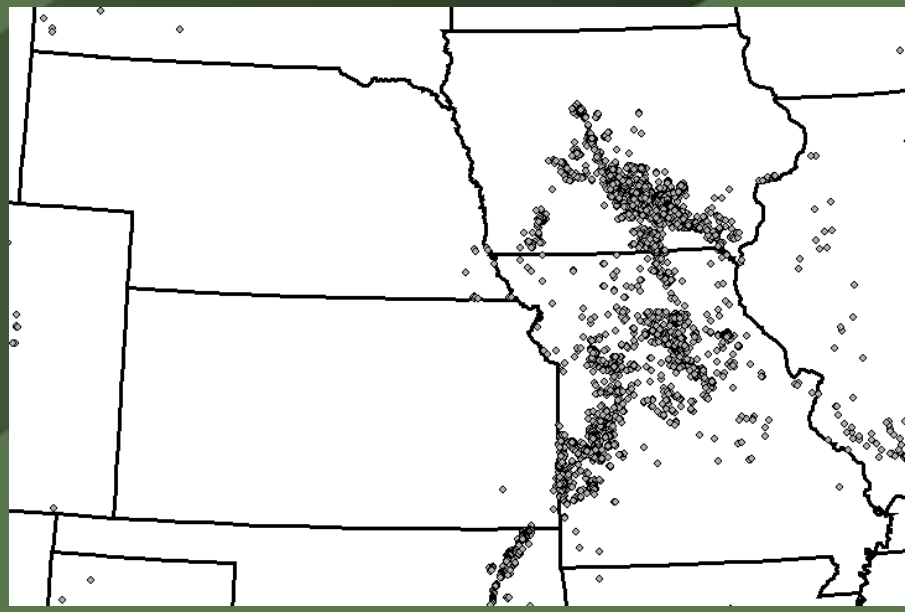
Problem: Data Availability and Quality

Solution: Look for additional supporting data



Coal Mines

Source: EPA Basins data



Coal Mines

Source: EPA Basins data and various state sources

To overcome some of these shortcomings we need to:

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

Objectives

1. Increase coordination
2. Increase knowledge
3. Develop centralized repository
4. Quantify human stressors at reach-scale (1:100K NHD)
5. Develop human stressor indices
6. Calculate HSIs for each stream reach
7. Field validate accuracy of HSIs

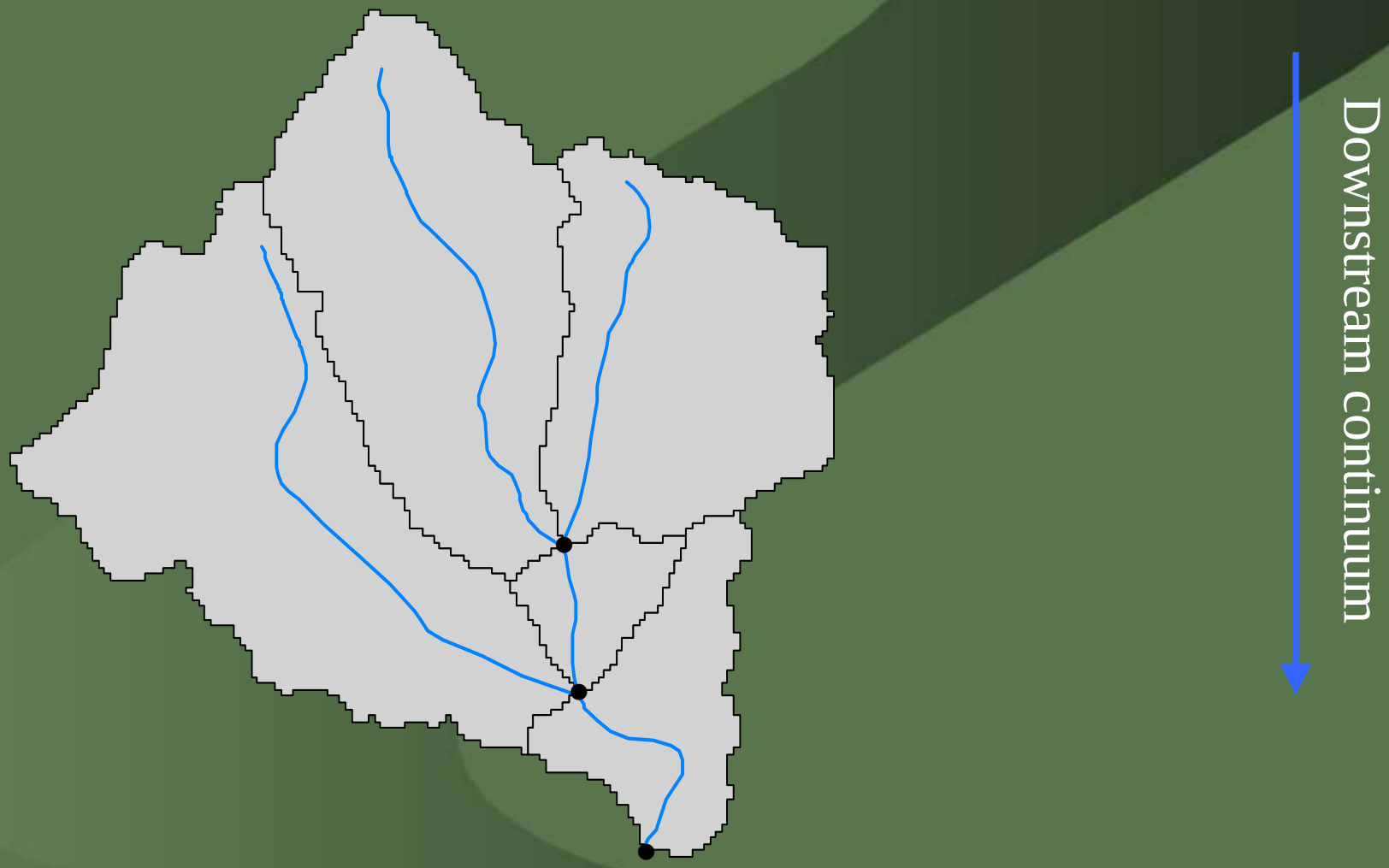
Ideal Scenario

- Account for timing, magnitude, frequency, and location of each human disturbance
  - Timing and frequency
    - Available data lacks this context
  - Magnitude
    - Within a given stressor data often lacks given context
    - Differences among stressors can possibly be accounted for
  - Location
    - Can quantify for different geographic units (overall watershed, RSD, upstream buffer, local buffer, etc.)
    - Distance issues are a more difficult technological challenge
- Quantify mechanistic relations between individual and multiple human disturbances and ecosystem responses (flow, sediment, temperature, etc.)
  - Lack standardized data for response variables
  - Difficult to account for natural variation
  - Must rely on associative relations with surrogate measures (IBI)

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

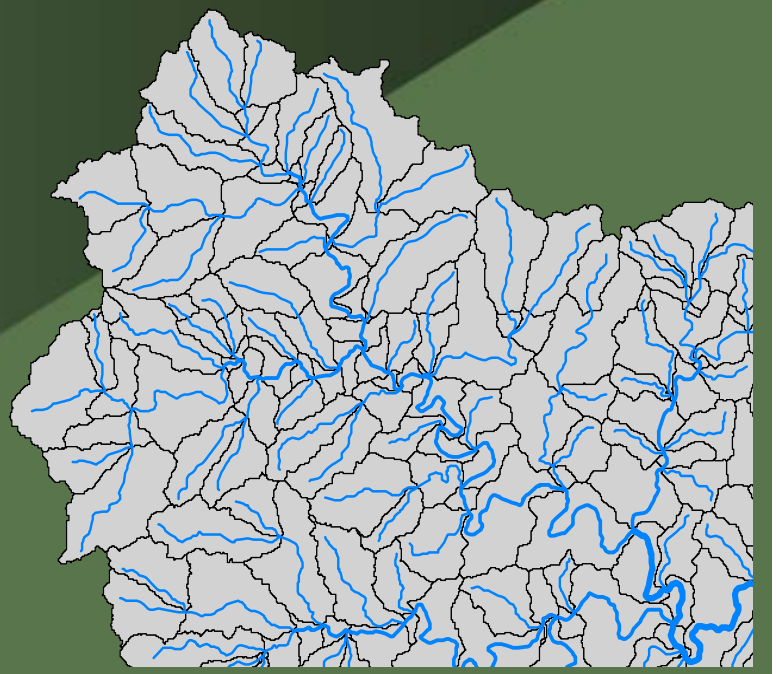
- All of EPA Region 7
- Use segment-sheds (reach specific drainage)
- Weight stressors
- Account for spatial considerations
- If possible, account for principal ecological effects separately

Watersheds / Catchments/ Segment sheds / Reach specific drainage areas



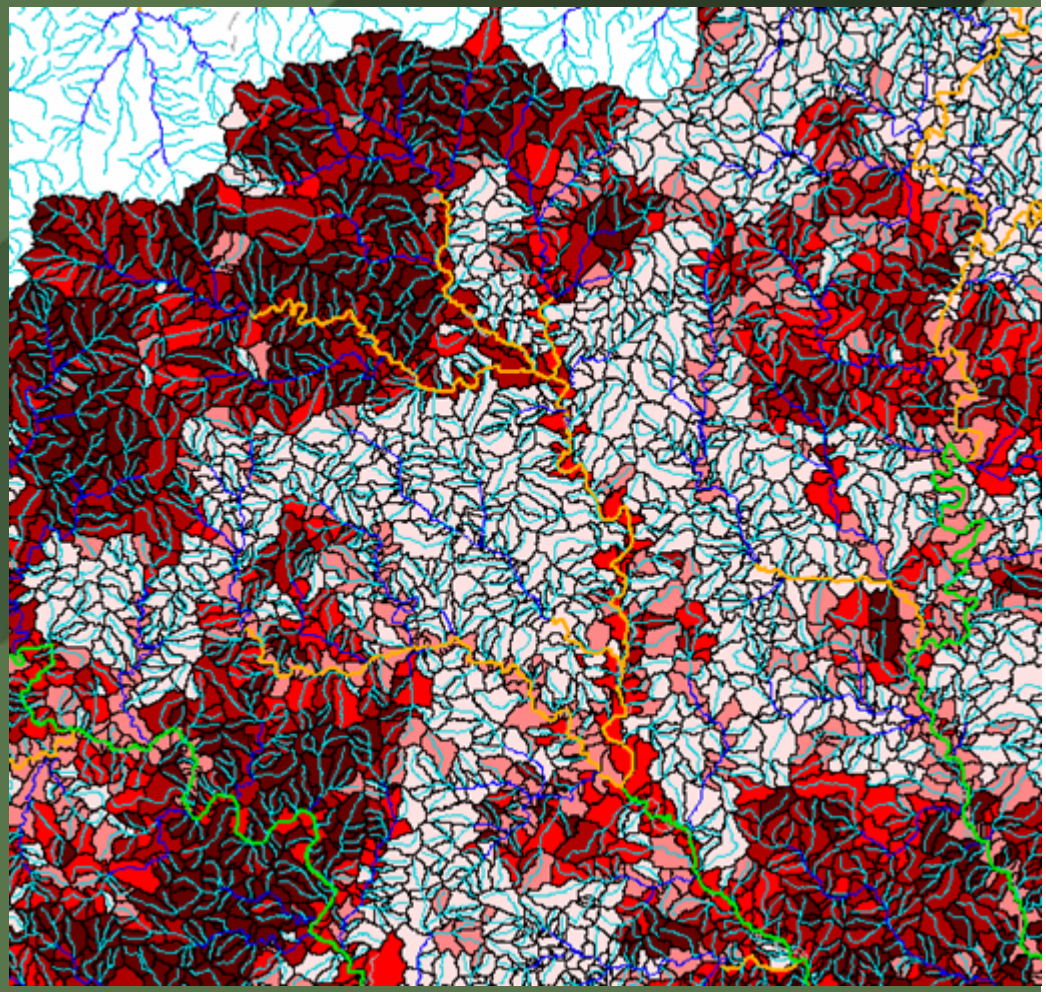
Stream segments linked to segment sheds

- 1 to 1 relationship
- Almost any properties of the watershed can be linked to the stream network for accumulation downstream
  - Soils, land cover/use, population, point data
  - Can be converted to a proportion of the drainage area or stream miles

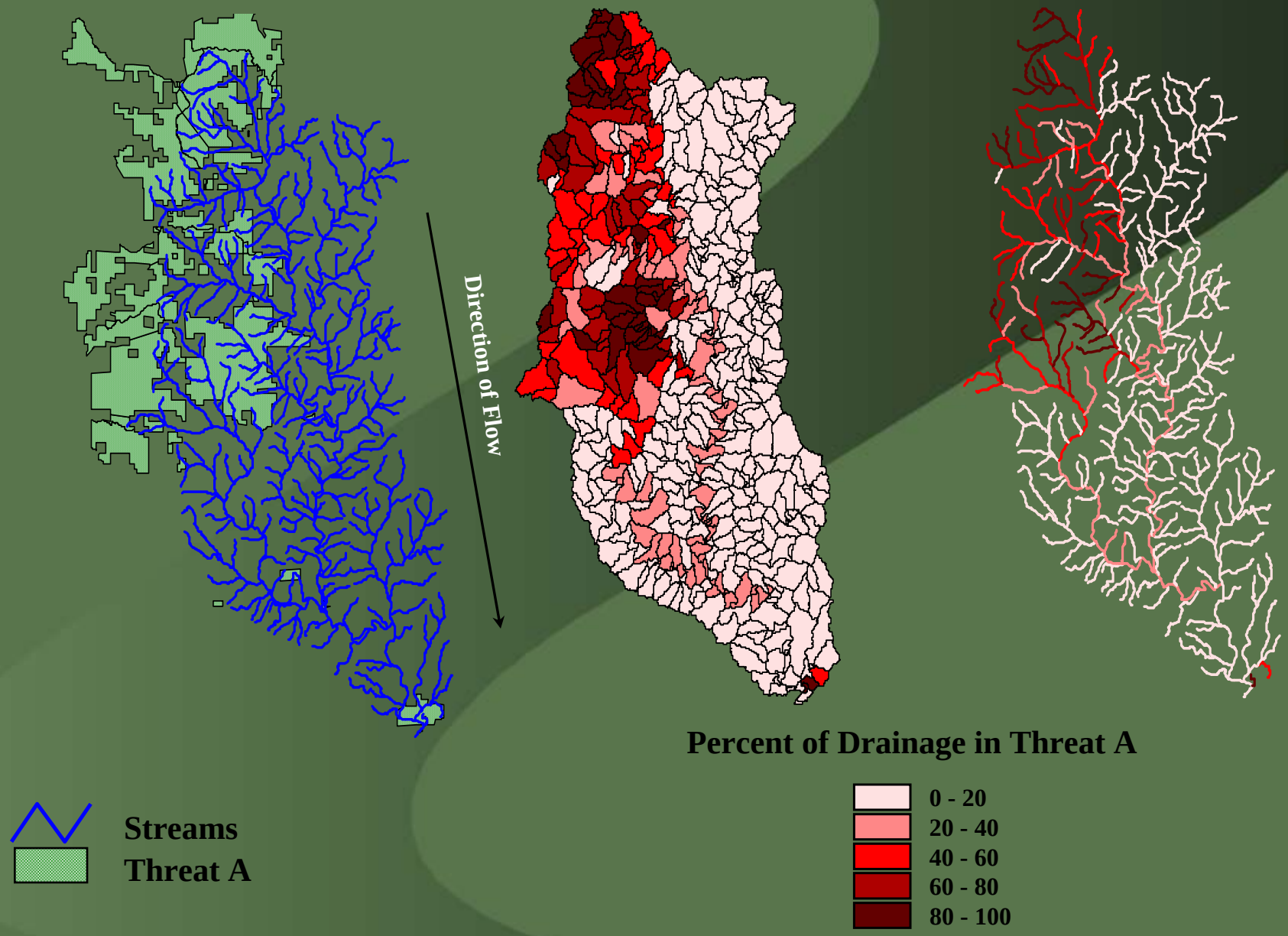


Segment sheds - Very large processing task!

- There are a number of ways to create the segment sheds
- We have had the best results using a combination of ArcHydro Tools (ArcGIS) and ArcInfo command line.



Percent of Upstream Drainage Area in Threat

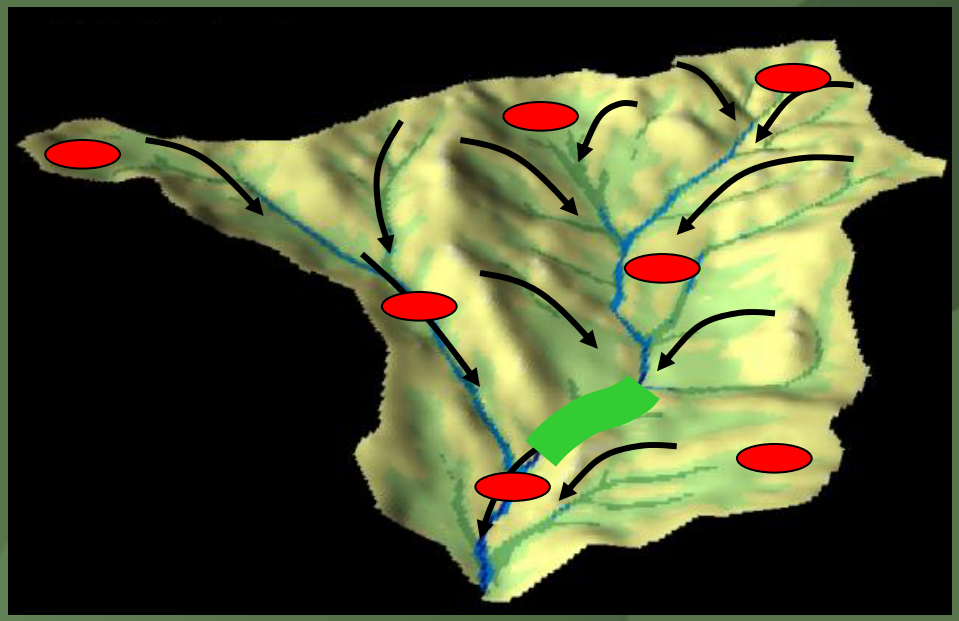


Weighting the Stressors

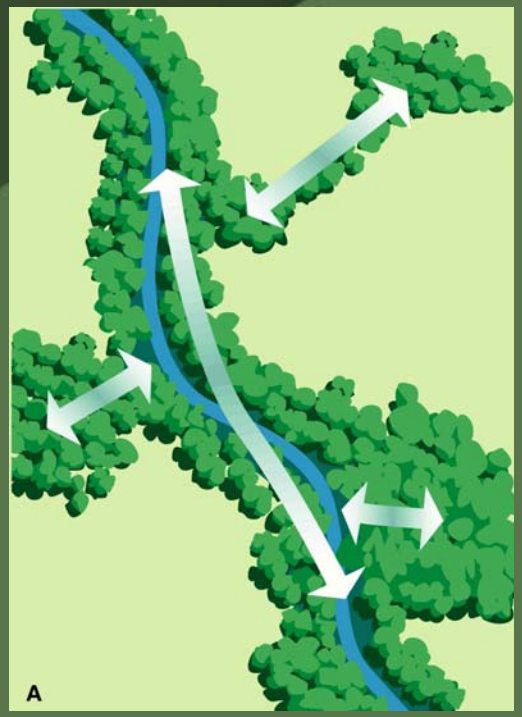
- For example, 3 times urban vs. 1 times agriculture
- A “big” mine has more impact than a “small” mine
- Discharge X is worse than discharge Y

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

Account for Principal Ecological Effects Separately

(Physical habitat, Water quality, Flow regime, Energy/Nutrient dynamics, Biotic interactions)

- For example, stressor X impacts water quality, but has little effect on flow regime
- Stressor Y impacts physical habitat, but has little effect on water quality
- Can we account for these kinds of impacts separately?

Major Tasks

1. Establish regional oversight committee ✓
2. Establish comprehensive list of human stressors and potential data sources ✓
3. Compile geospatial data ~ ✓
4. Identify data gaps and limitations ~ ✓

Major Tasks Continued

5. Quantify stressors for each stream reach
6. Conduct literature review on human stressor related research ~
7. Conduct literature review on GIS-based stressor assessment methods ~
8. Develop GIS-based HSIs

Major Tasks Continued

9. Perform QA/QC on accuracy of input data and resulting HSI values

10. Field validate HSI using fish and macroinvertebrate community data

What we need help with:

- ✓ Identifying principal "Threats"
- ✓ Identifying data sources for these threats and any data limitations
- ✓ Determining the principal ecological effects for the various stressors
- Methodology
  - Relative vs. empirical
  - Weighting stressors
  - Accounting for spatial and temporal considerations
- Identifying key literature

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Principal Ecological Effects

Point source pollution					
Level of Influence	Physical Habitat	Water Quality	Flow Regime	Energy/Nutrient	Biotic Interactions
Low	X		X		
Medium					
High		X		X	X

Channelization					
Level of Influence	Physical Habitat	Water Quality	Flow Regime	Energy/Nutrient	Biotic Interactions
Low			X		
Medium		X		X	
High	X				X

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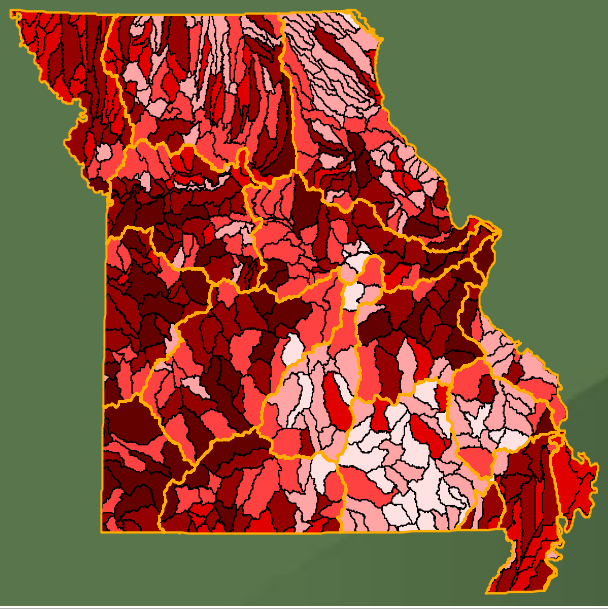
Relative Assessment of Human Threats



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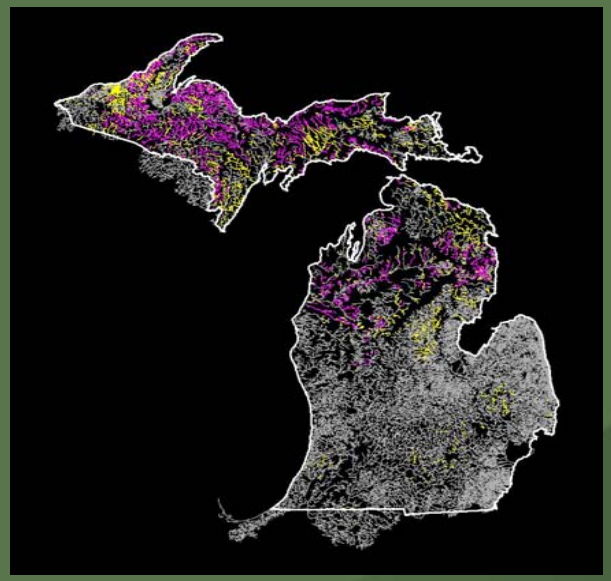
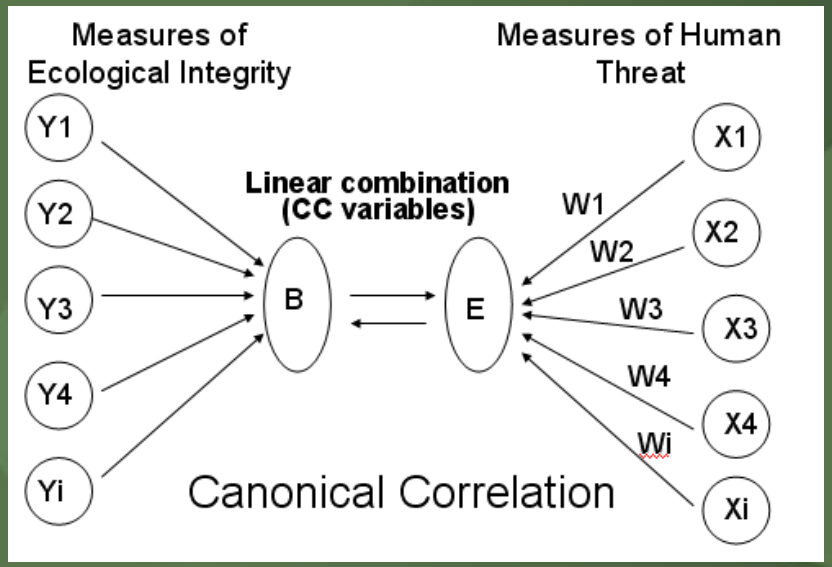
Density of Confined Animal Feeding Operations (#/mi²)	0	1-5	5-10	>10

Problems/Issues

- Values have no known relation to ecological integrity
- Simply acts as a “red flag”

Empirical Assessment of Human Threats



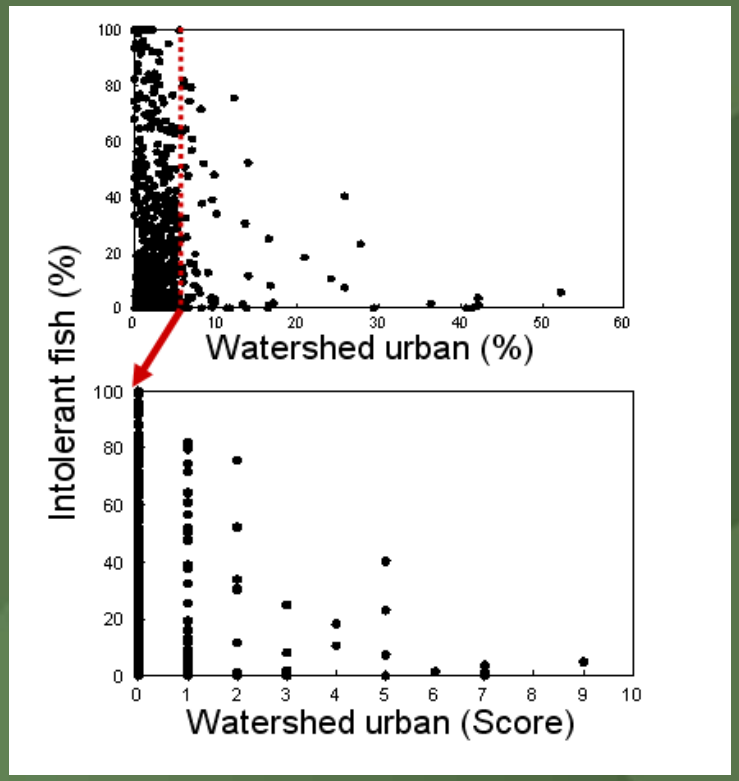


Problems/Issues

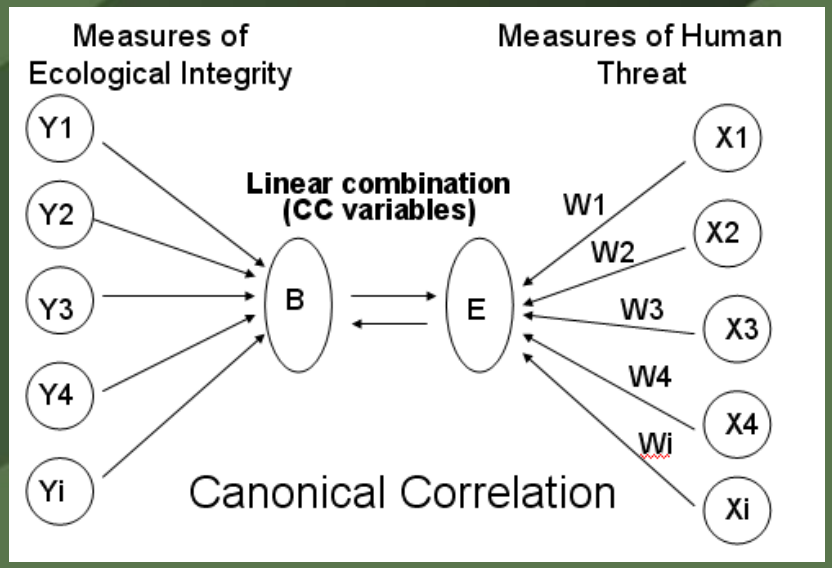
- Lack standardized data for measures of ecological integrity
- Lack of data for various threats
- Noise due to natural variation and sampling methods/biases
- Only applies to stream types where data have been collected

Empirical Assessment of Human Threats

Quantify relations for each measure of threat and ecological integrity



Quantify combined relations



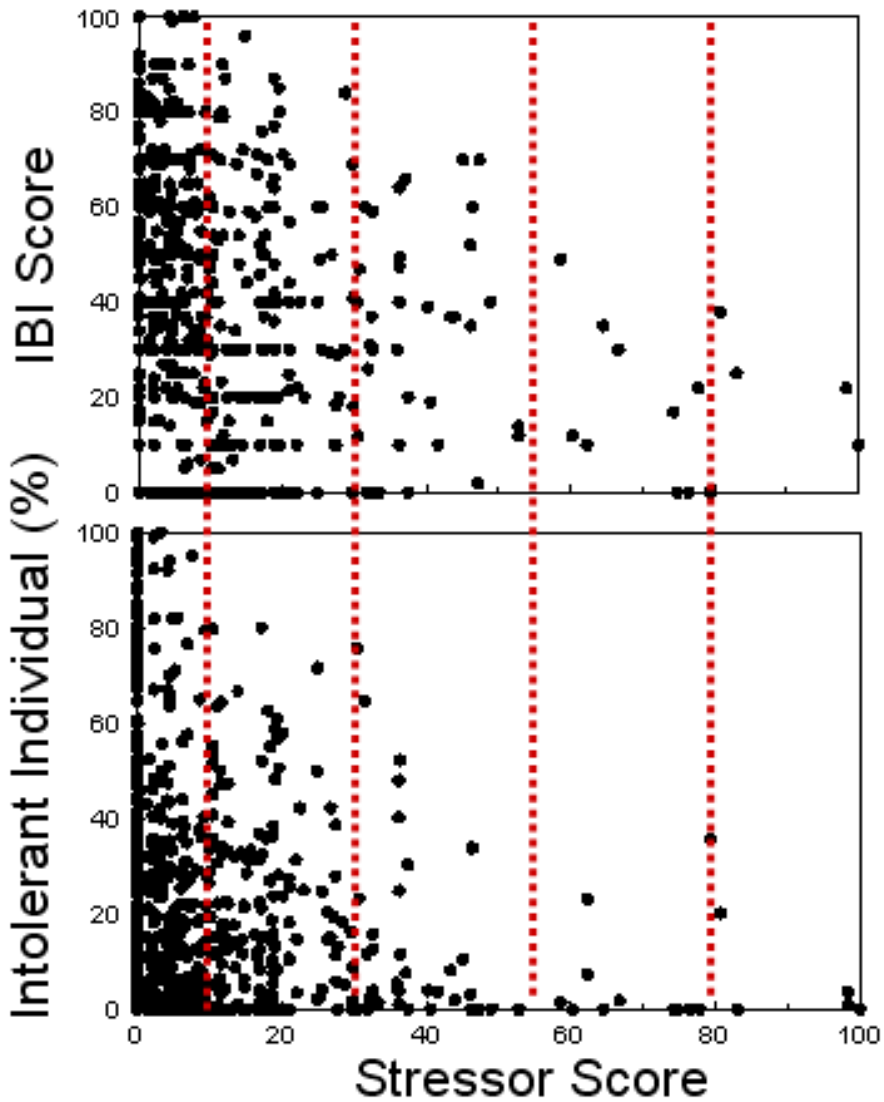
Model of Human Stress

Cool/cold sites:

Stress Index=
AGSC* 0.004 + URSC*0.242 + POPSC*0.009 +
PNLSC*0.191 + PNYSC*0.109 + MANUSC*0.359 +
MDEQF*0.134 + DEQOSC*0.108 + INSC*0.065 +
RDENSC*0.201 + TRISC*0.233 + TRIWSC*0.107;

$R2 = 0.54$;
$p < 0.0001$

Empirical Assessment of Human Threats



Disturbance levels:

< 10: Not detectable

10-30: Detectable

30-55: Moderate

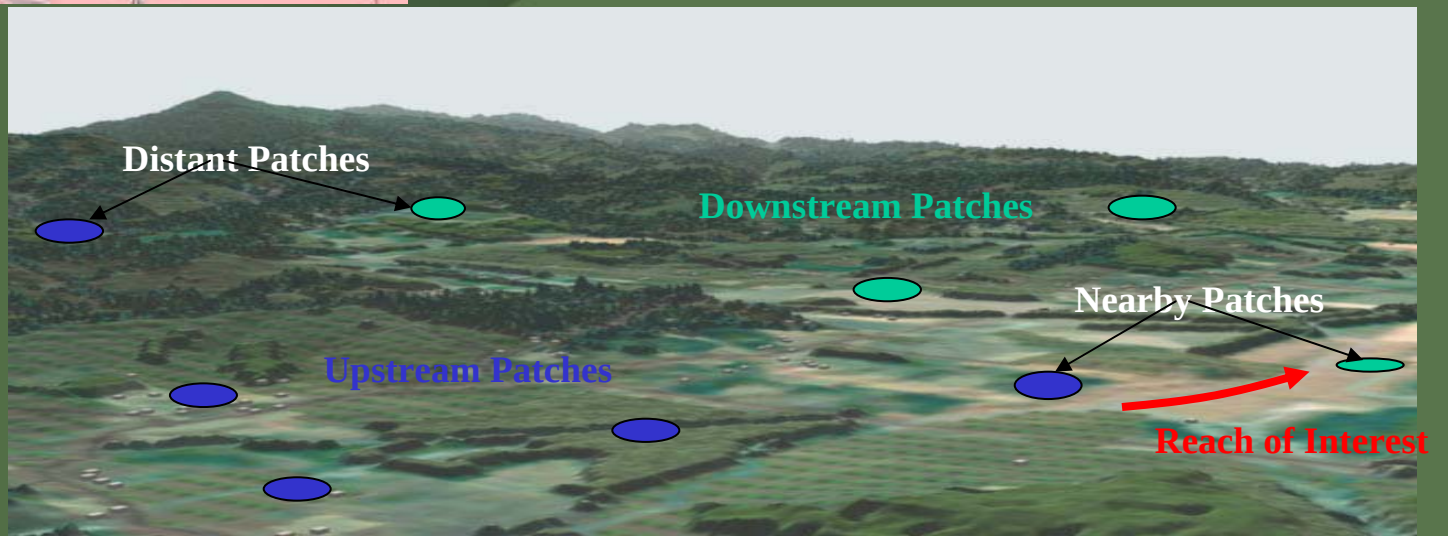
55-80: Heavy

> 80: Severe

Spatial Considerations

Geographic Units

Distance and Relative Location



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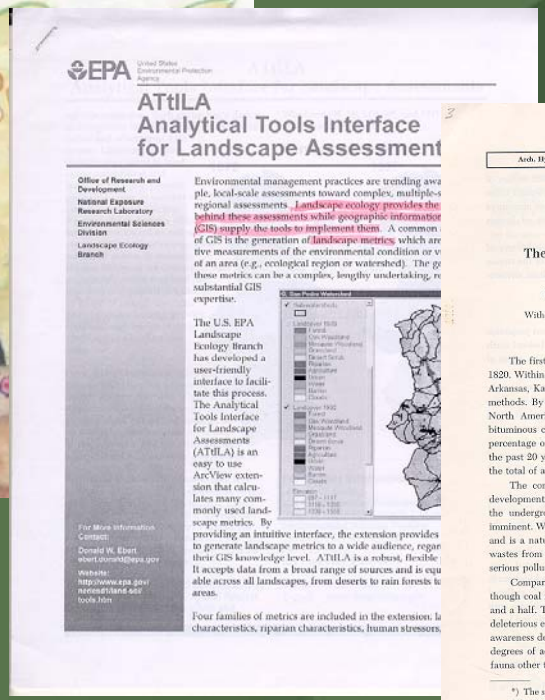
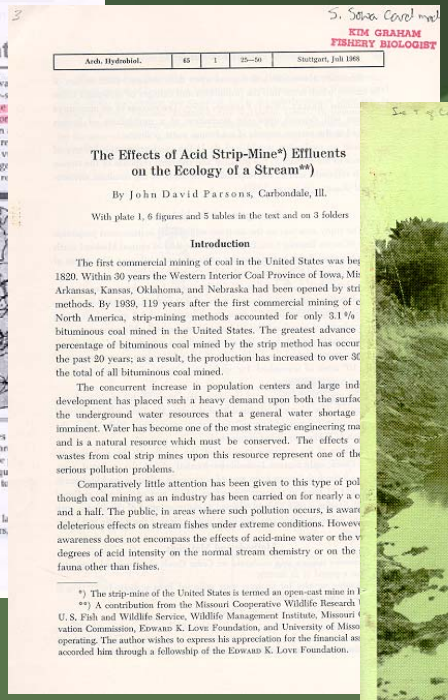
  - Weighting stressors
  - Accounting for spatial and temporal considerations
- Identifying key literature

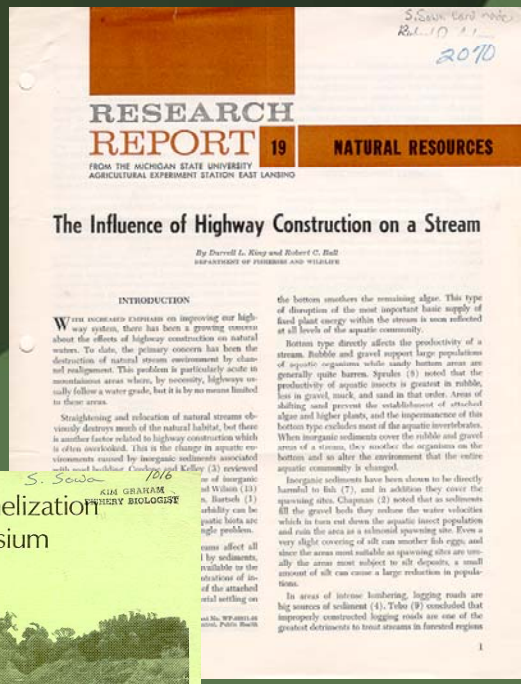
Literature

EPA
Stressor Identification
Guidance Document


EPA
ATtILA
Analytical Tools Interface
for Landscape Assessment


KIM GRAHAM
FISHERY BIOLOGIST
The Effects of Acid Strip-Mine*) Effluents
on the Ecology of a Stream**)
By John David Parsons, Carbondale, Ill.
Introduction

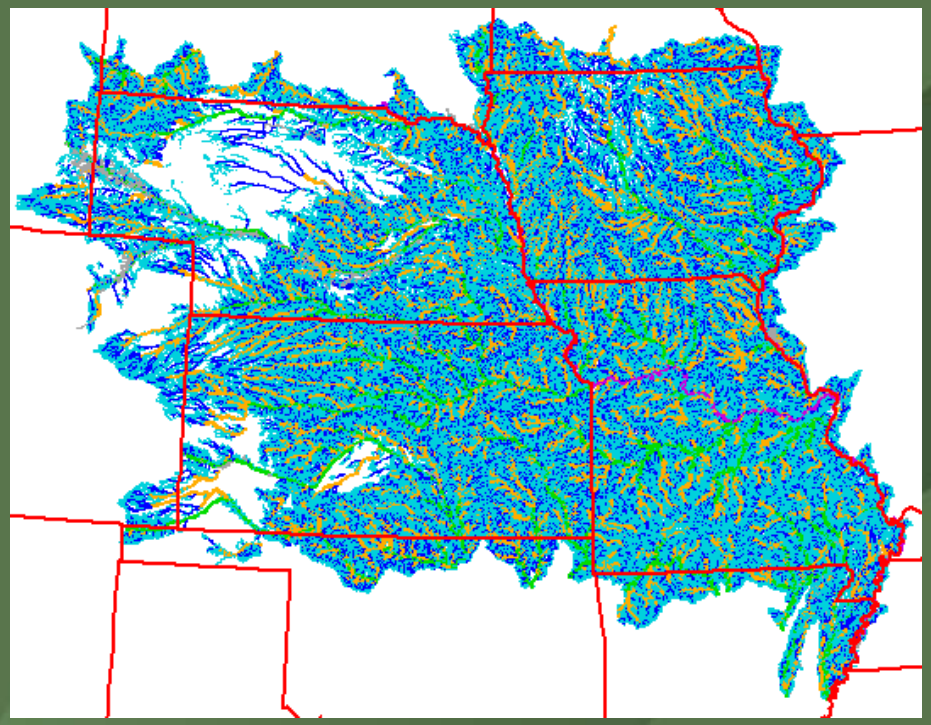
Stream Channelization
A Symposium
North Central Division, American Fisheries Society, Special Publication No. 2.

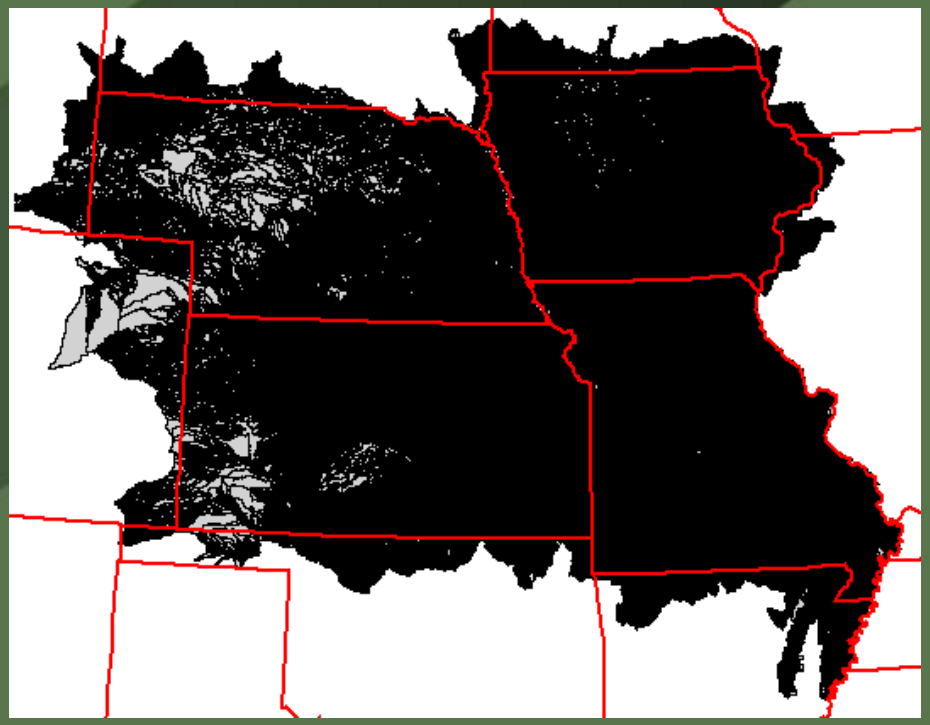

RESEARCH
REPORT 19
NATURAL RESOURCES
FROM THE MICHIGAN STATE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION EAST LANSING
The Influence of Highway Construction on a Stream
INTRODUCTION

Since last meeting we have . . .

- Cleaned and prepared our stream networks
- Generated the segment shed polygons
- Gathered data (stressors)
- Gathered literature
- Explored GIS tools that will assist with distance weighting

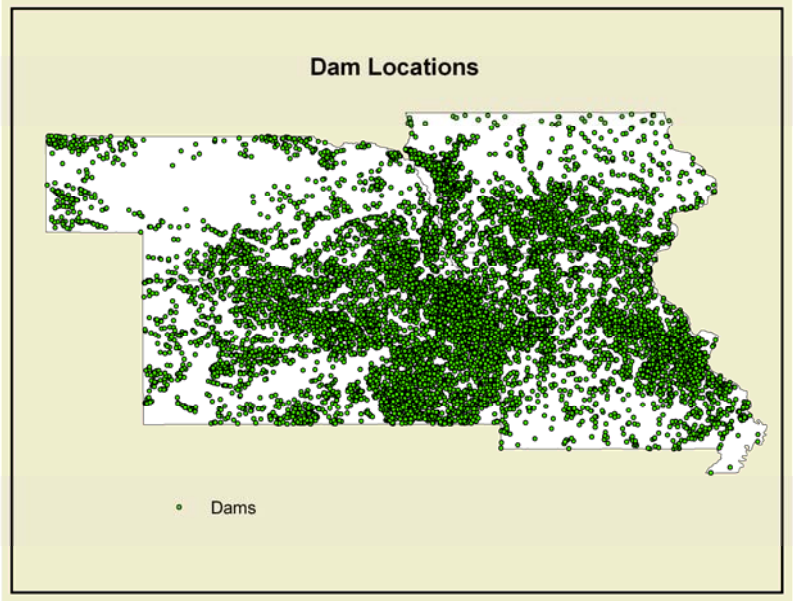
The core data sets

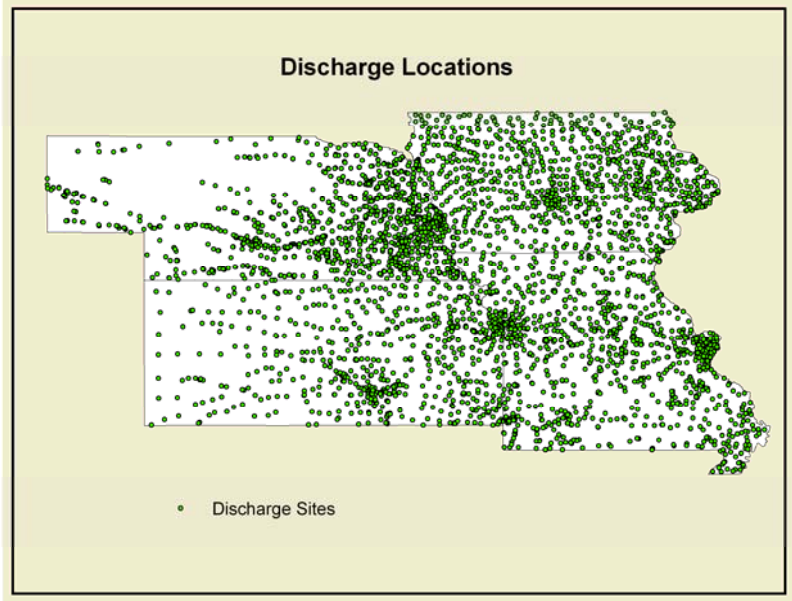


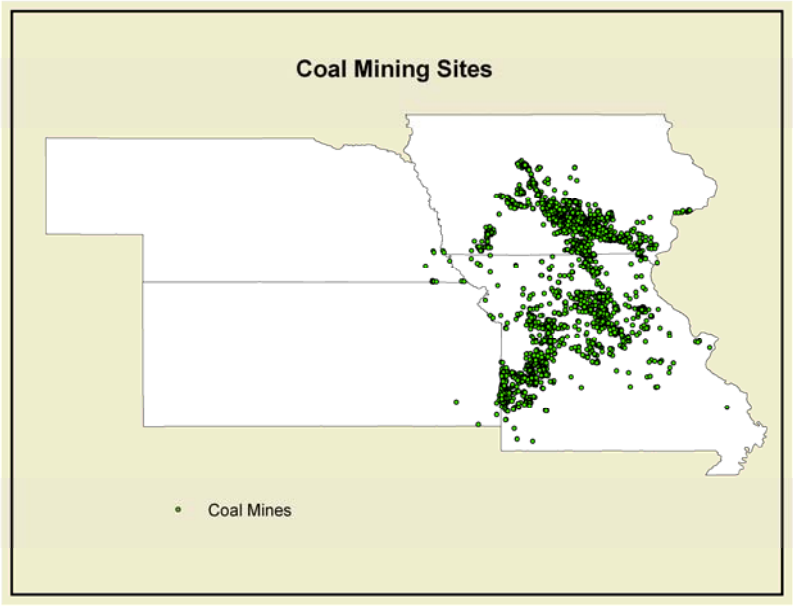


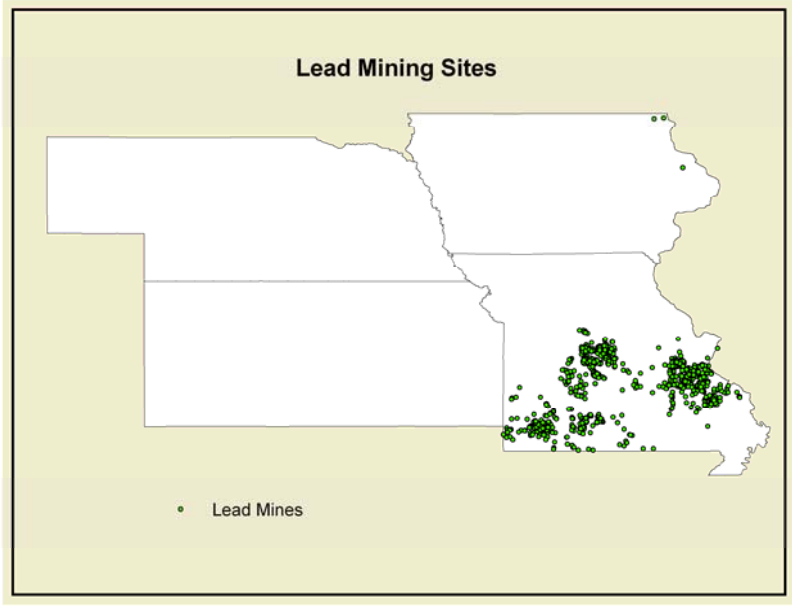
385,000 primary channel stream segments
and corresponding segment shed polygons

Stressor data









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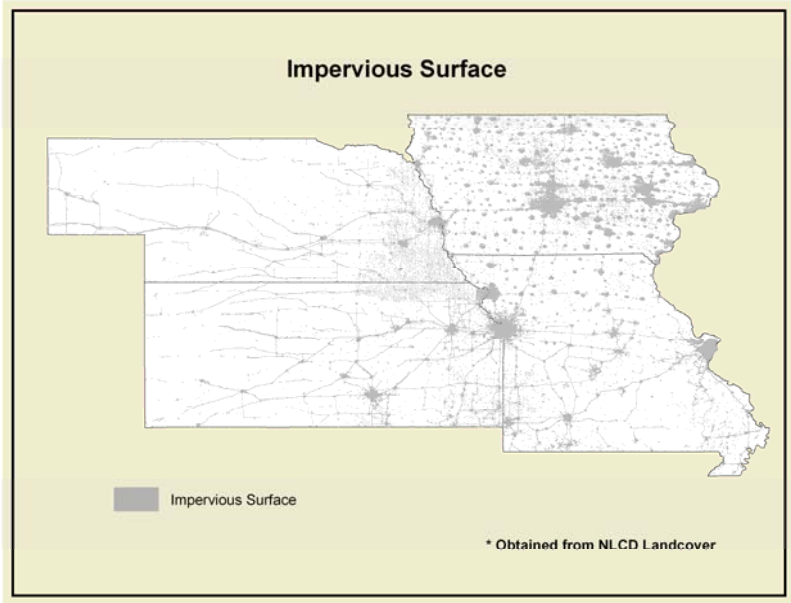

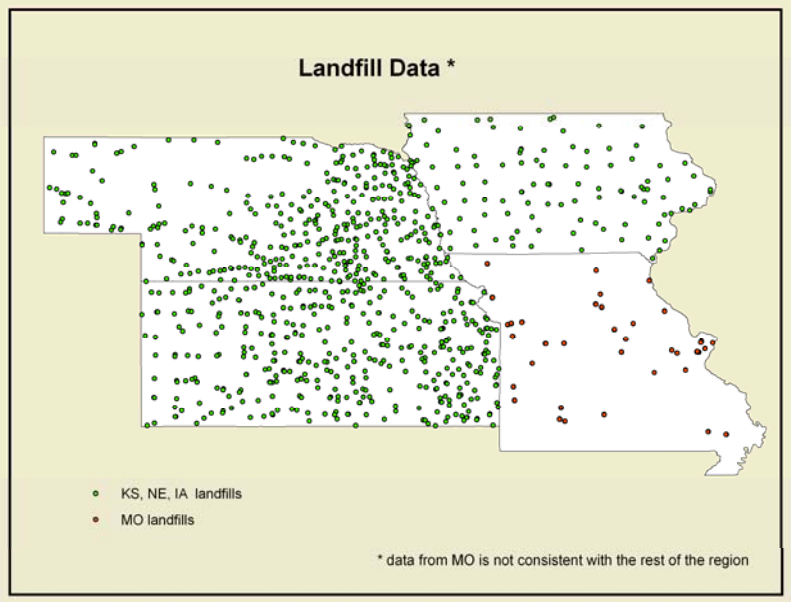

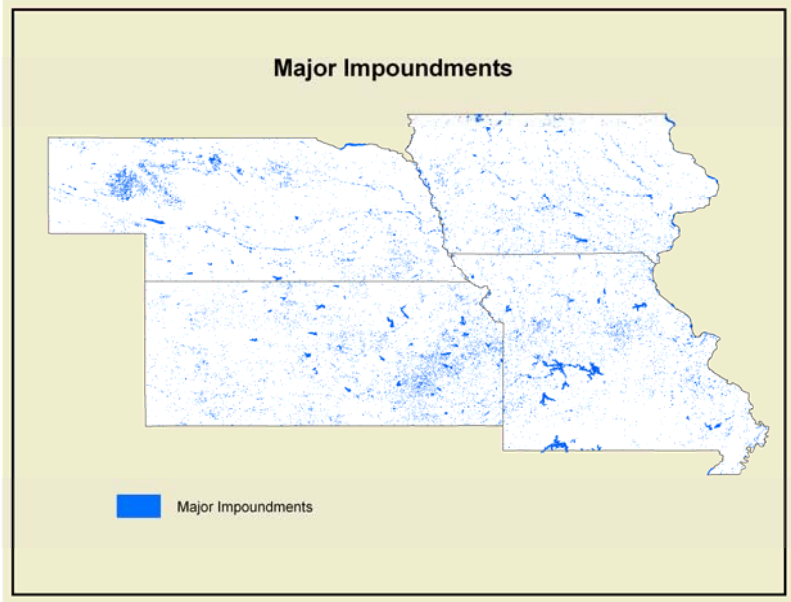

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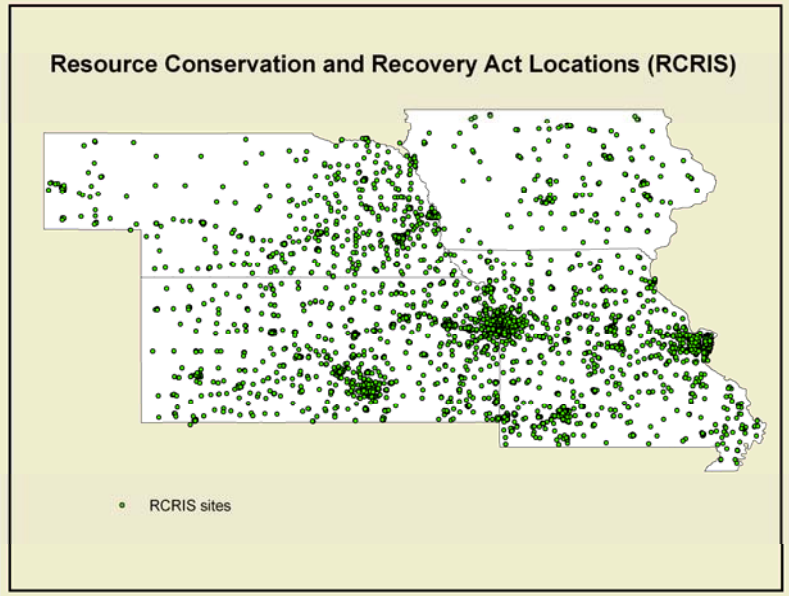

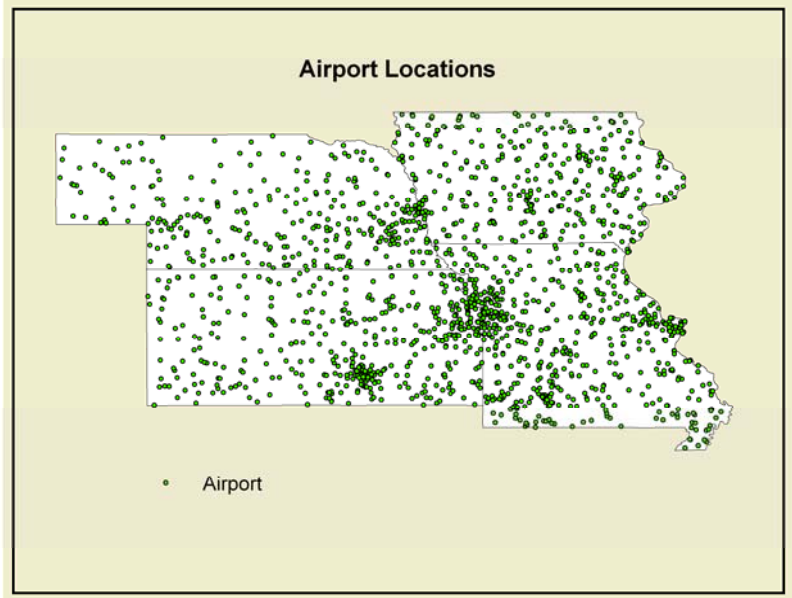

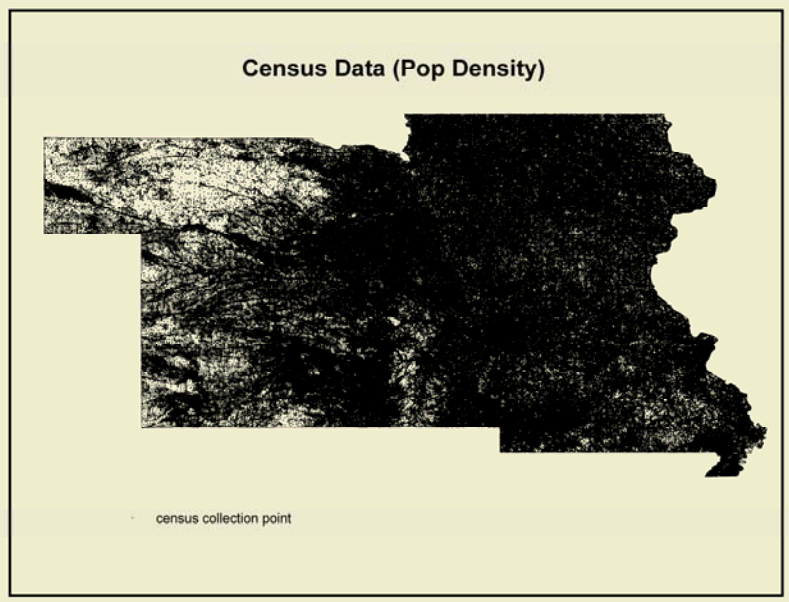

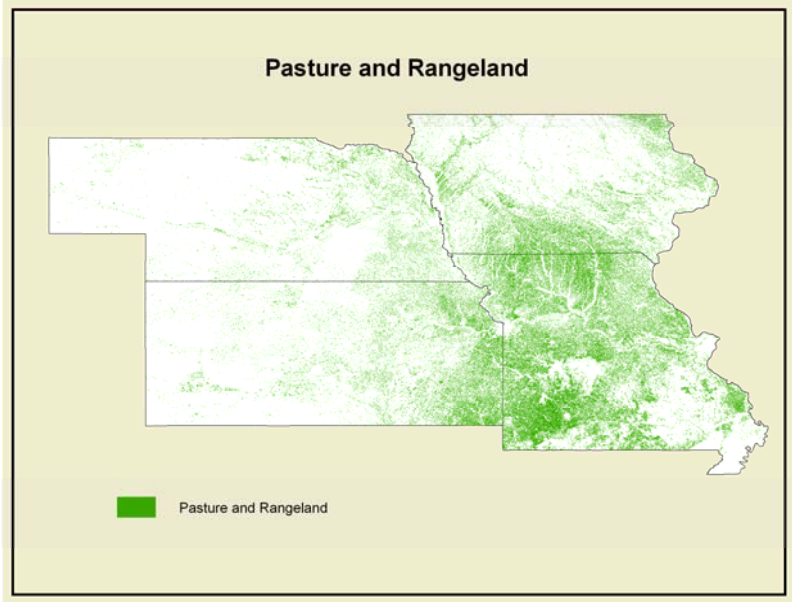

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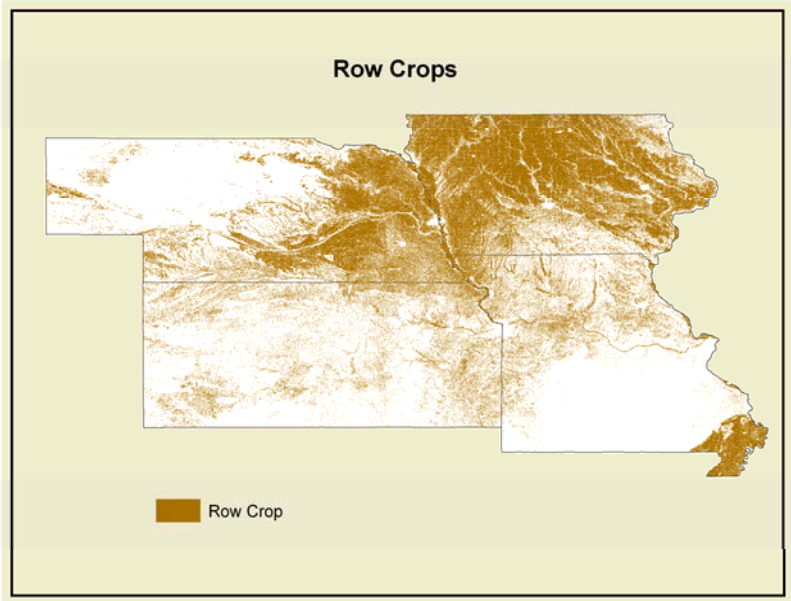

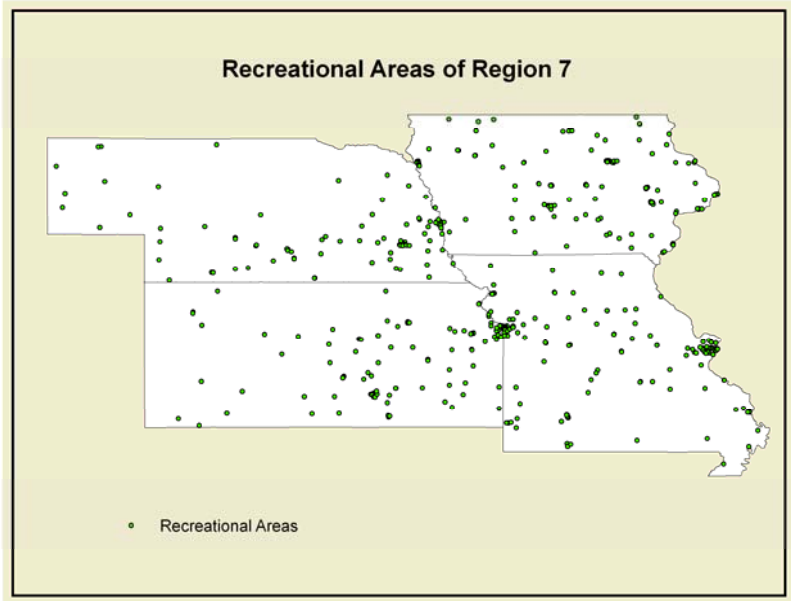

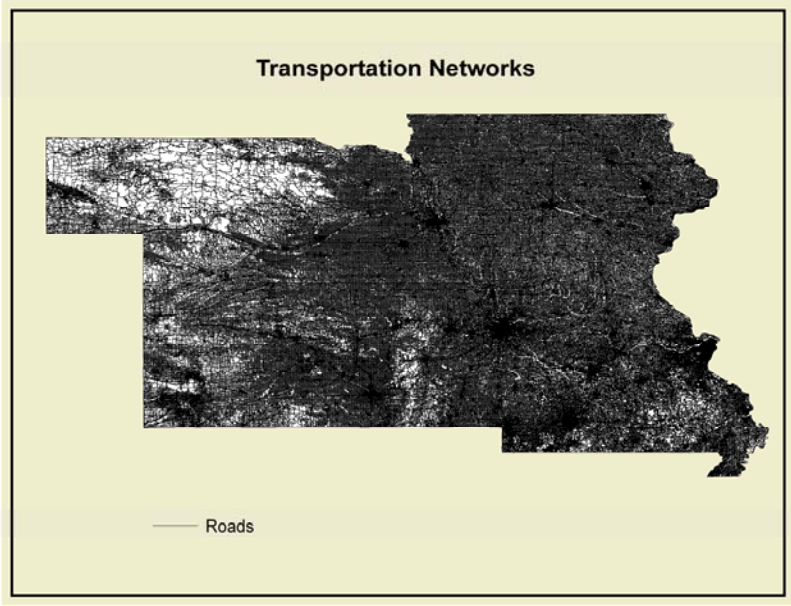

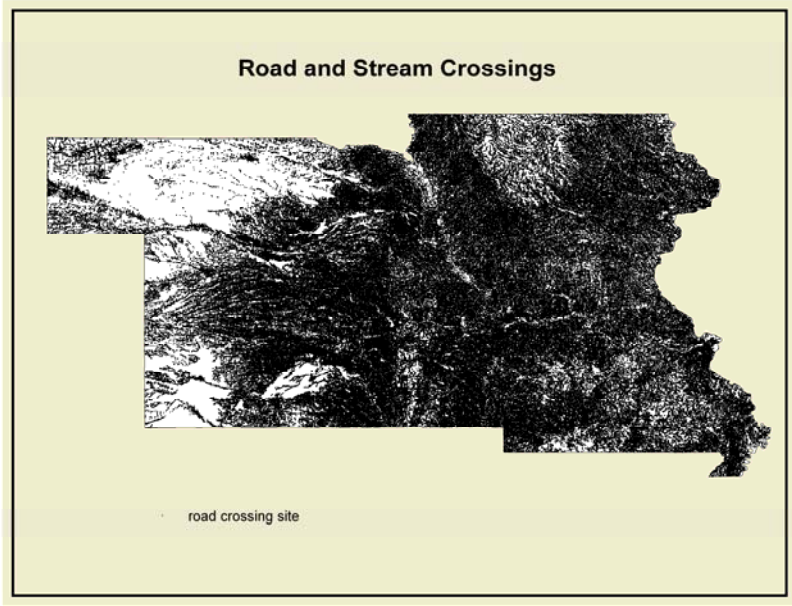

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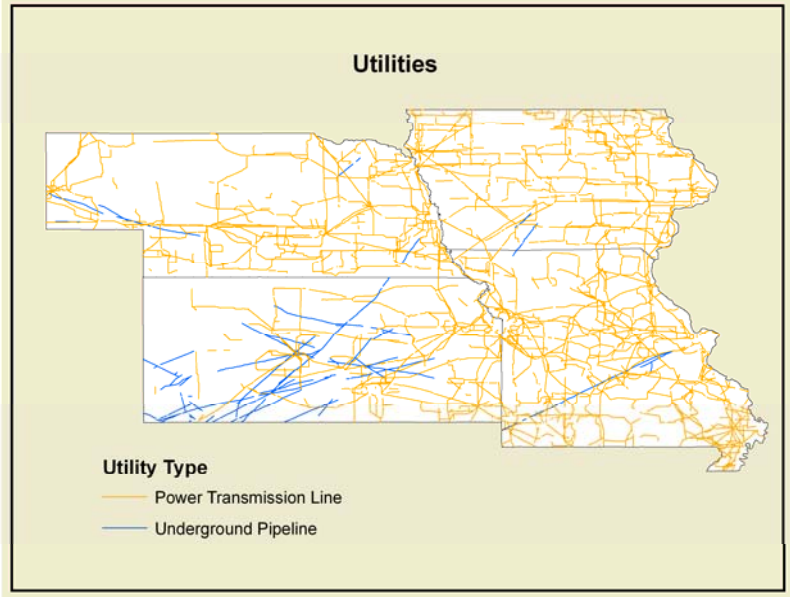

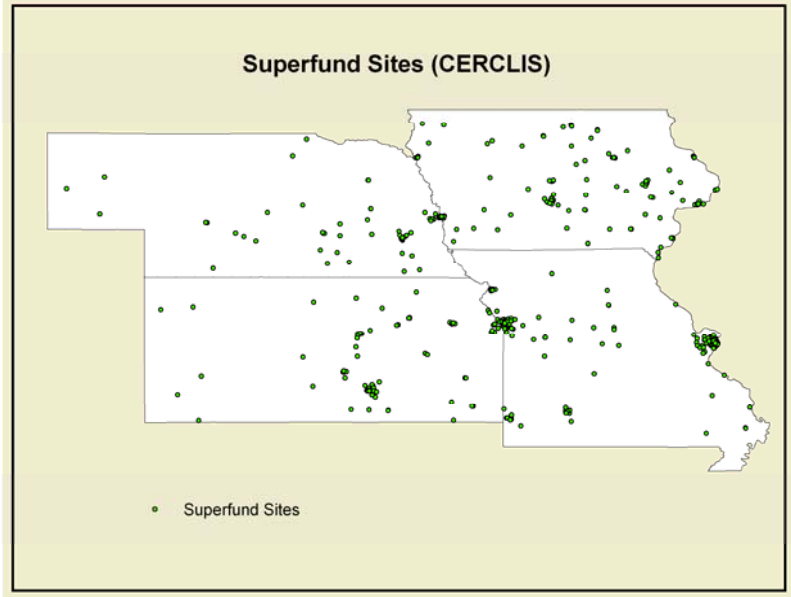

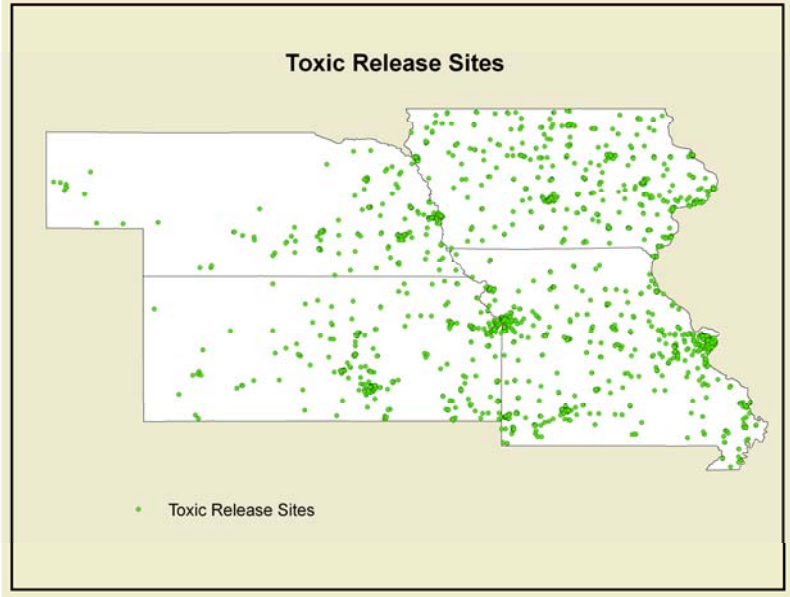

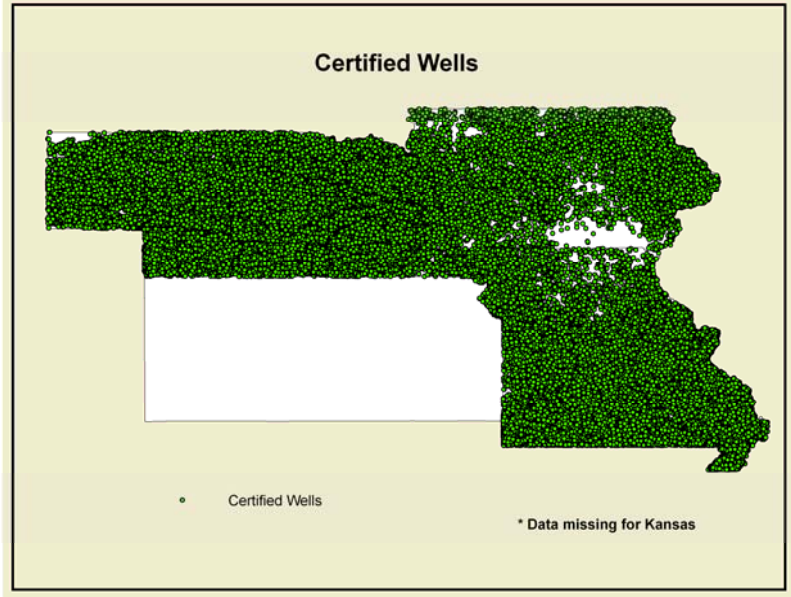

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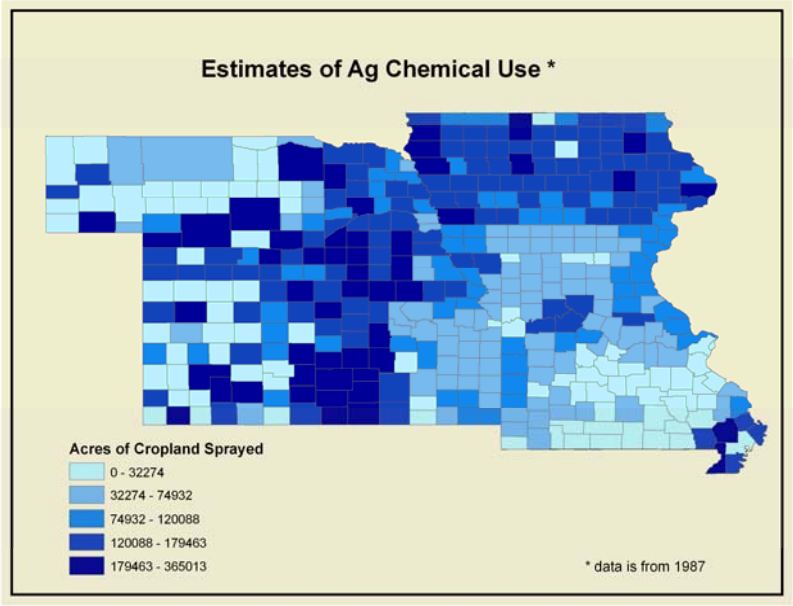

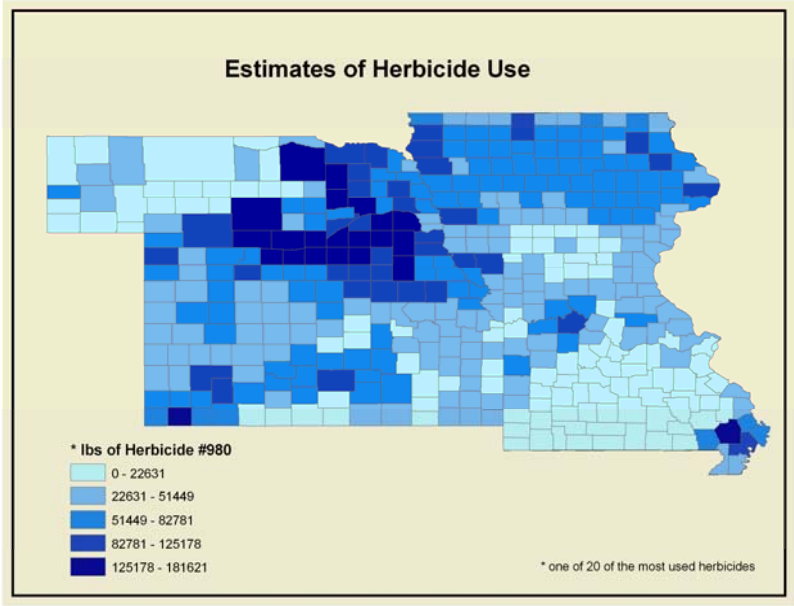

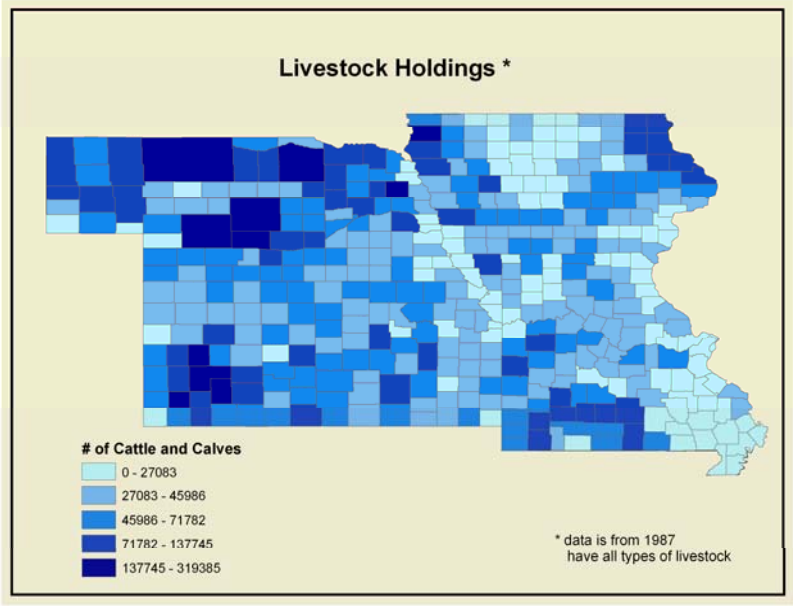

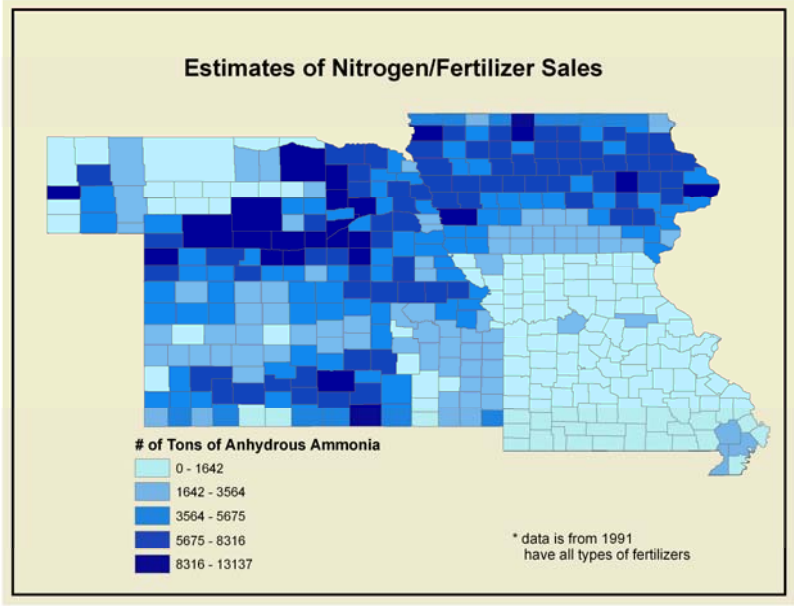

Potential GIS tools to help with distance weighting

- Functional Linkage of Water basins and Streams (FLoWS) v1
- Various other user-written GIS tools
  - Distance matrix calculation
  - Distance and Accessibility Measures

What we want to accomplish today

- Review web survey
- Ranking / Weighting discussion
- Discuss some data issues
  - (using county level data, fragmentation)
- Tools and methods
- Obtaining monitoring data for possible empirical component (fish and macro)

What comes next?

- Begin quantifying the stressors for every segment shed polygon / stream reach in the 100K NHD
- Continue filling in data gaps
- Determine if we can distance weight
- Continue compiling literature
- Establish next meeting (~ 6 months)