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The EMAP-GRE approach to reference conditions

Ted Angradi and David Bolgrien
US EPA Office of Research and Development
Mid-Continent Ecology Division
National Health and Environmental Effects Research Laboratory
Duluth, MN

GIS programmers: Tatiana Nawrocki, Roger Meyer, Matt Starry, and James Quinn
Computer Science Corporation

Assumptions

- No reach of any of the 3 Great River of the CB (MO,MS,OH) is in pristine condition, but there is variation in condition along each river that provides the current scope for empirical bioassessment based on internal reference condition.

- EMAP-GRE assessment is based on least disturbed (least impaired) conditions (LDC) by default. Other thresholds based on minimally-disturbed condition will be incorporated as available.

Internal Reference Condition

- Advantages
  - Representative of the assessment unit
  - All indicators are available because same methods
  - Can extract reference sites from the probability sample
  - All reaches and rivers can be treated the same
- Challenges
  - Perception that least disturbed condition sets a too-low bar for Great River assessment
  - Sites are not independent (all sites but 1 on each river are downriver from other sites)

3-phased approach to reference

I. Identification and sampling of internal reaches likely to be in LDC using "local proximity" model

II. Use abiotic filters to find sites actually in LDC from among <u>all</u> sampled sites

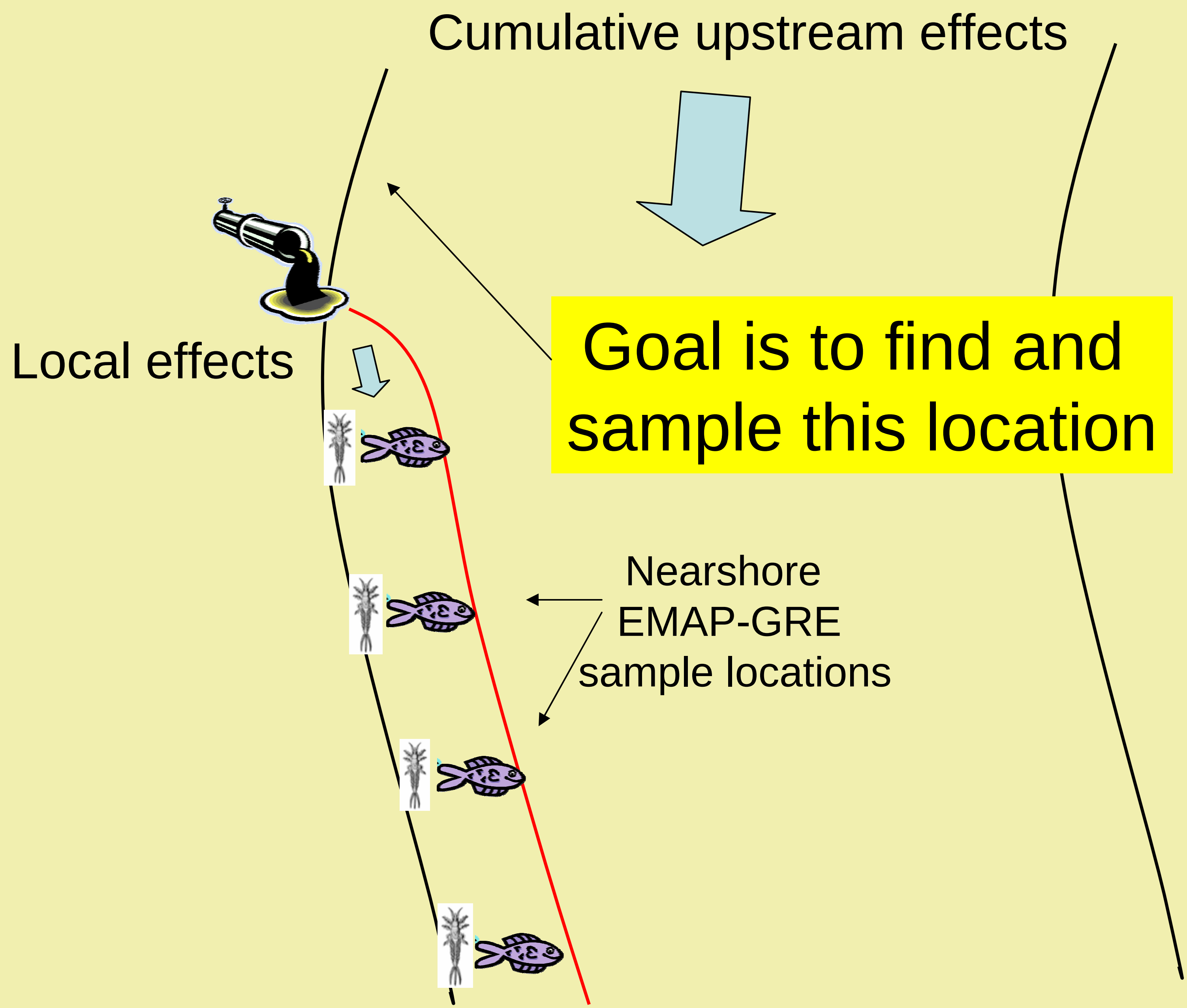
III. Verify reference set using biotic indicators

EMAP-GRE GIS "Local Proximity" Model

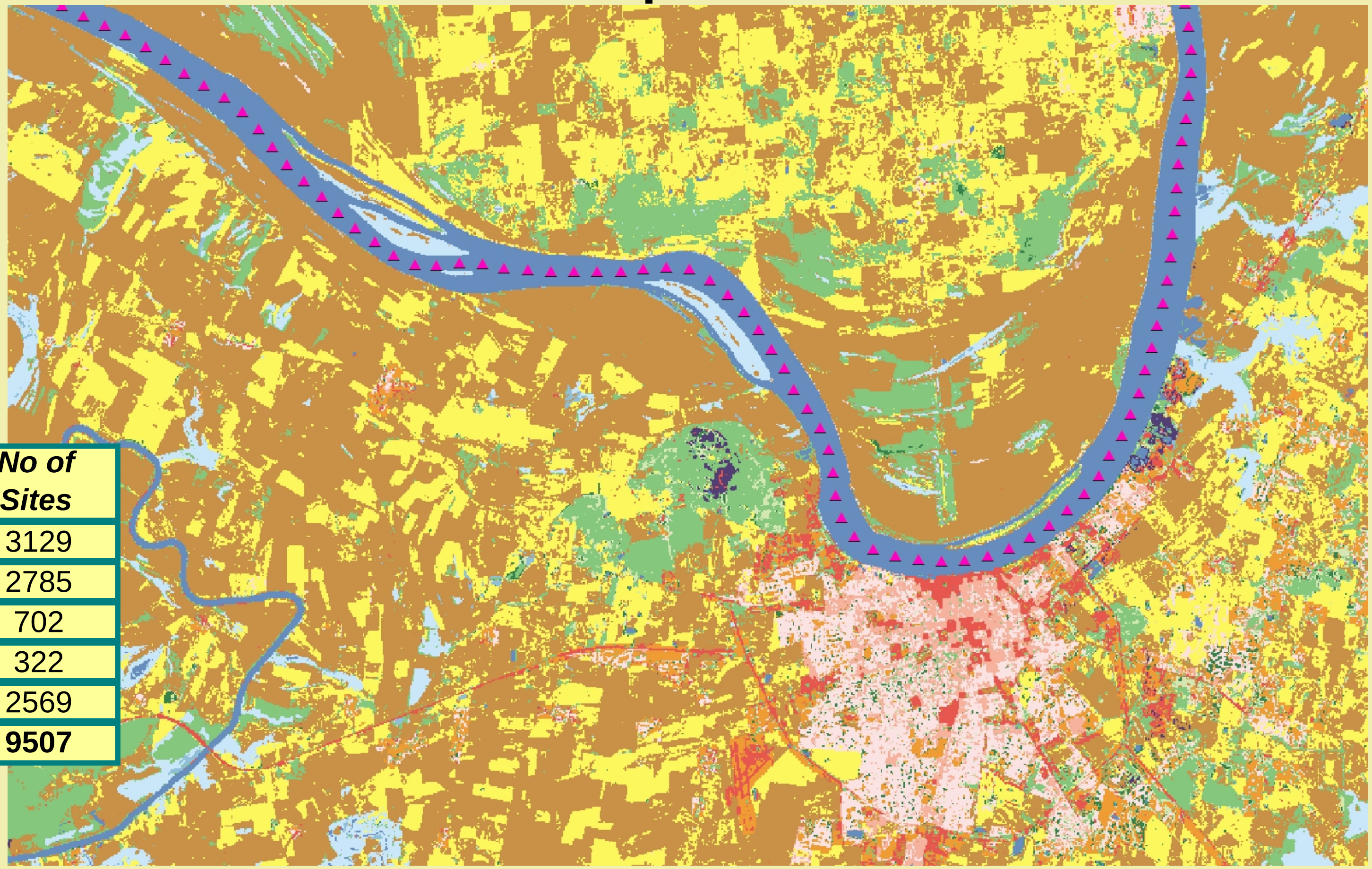
- Scores large number of potential sites based on proximity to human disturbances
- Complete small-watershed-scale landscape analysis deemed not cost-efficient
- We treat all small tributaries as if they were NPDES permits (i.e., bad)
- So its conservative.
- Lots of subjective decisions were made (scoring thresholds, weights) during the build. The result is a really *GIS-model-assisted BPJ approach* to identifying potential reference reaches.

Rationale for “local proximity”

- Most EMAP-GRE biotic metrics are measured in shallow nearshore habitat (the exception is plankton).
- Human disturbance: tributaries, NPDES permitted outfalls, crossings, etc. most strongly influence the immediate downriver near-shore condition (sediment contamination, water chemistry, sediment particle size, temperature).
- Cumulative effects of thalweg (non-local) WQ and habitat ignored in our model.
- This gradient is dealt with during filtering (Phase II).


Cumulative upstream effects
Local effects
Goal is to find and sample this location
Nearshore EMAP-GRE sample locations

Base points



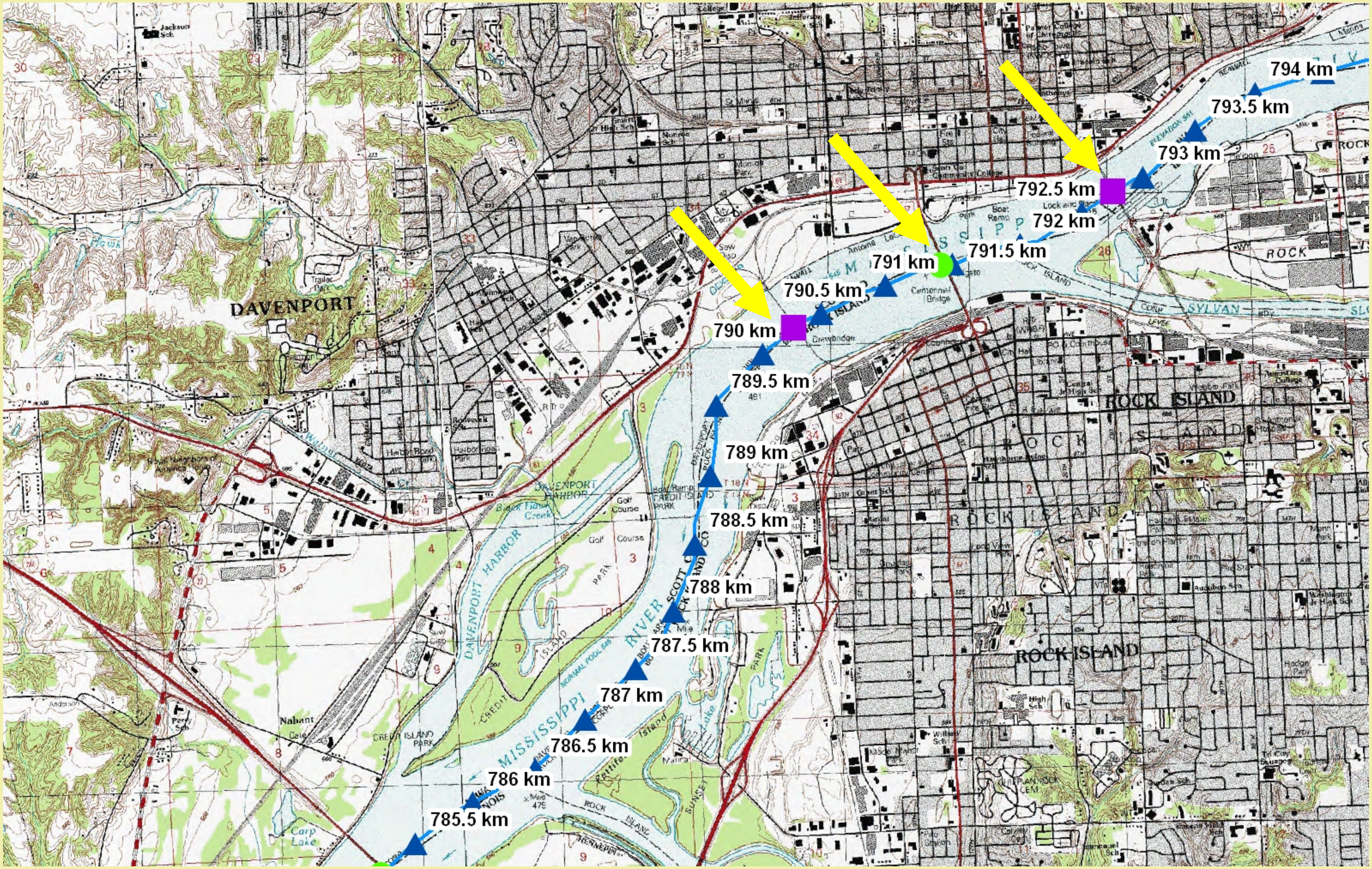
River	No of Sites
OH	3129
MS	2785
MO1	702
MO2	322
MO3	2569
TOTAL	**9507**

Points were generated for each river at 500-m intervals starting from the downriver end using the National Hydrograpic Database linework. These points serve as a base layer for all proximity analyses.

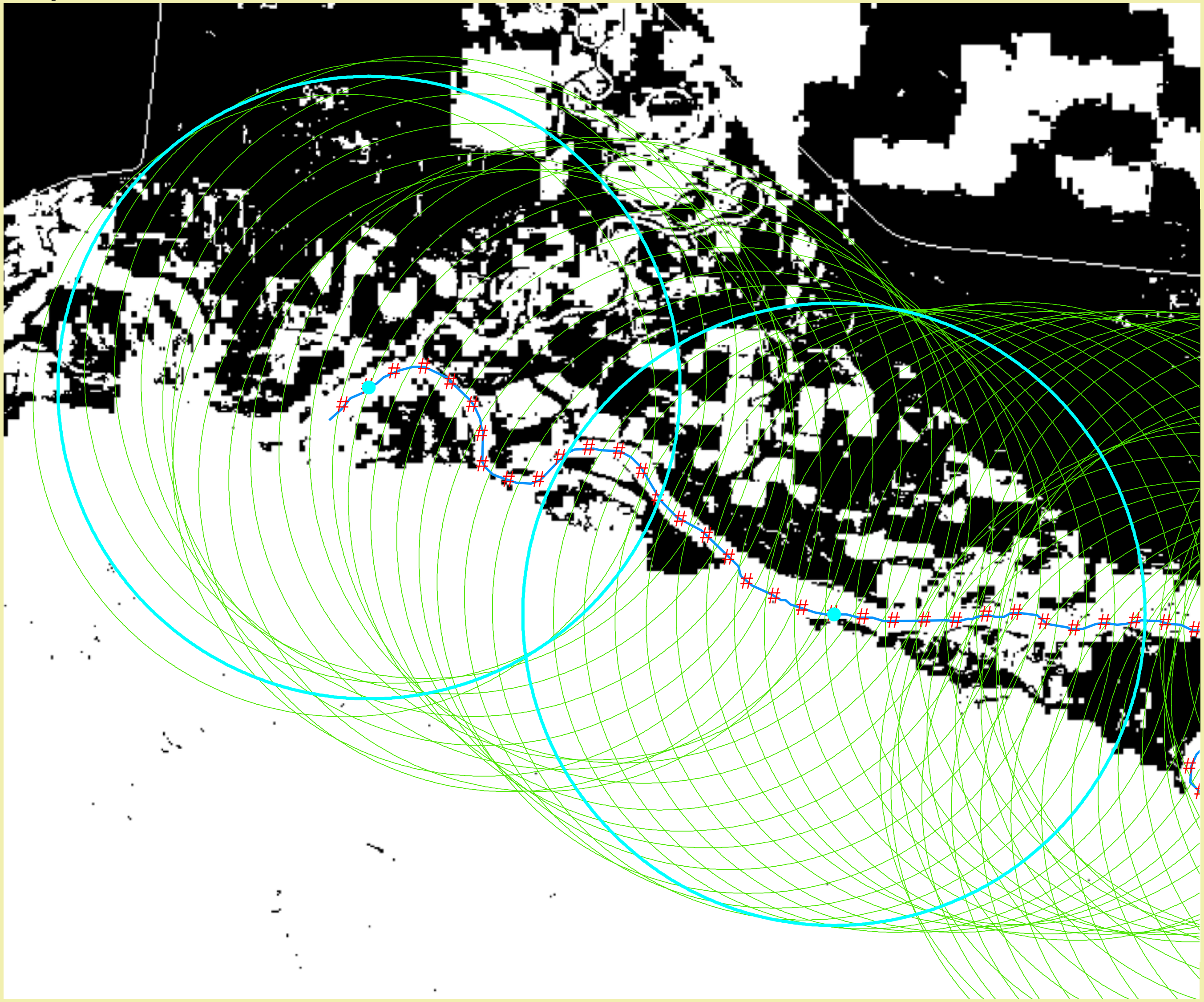
14 variables calculated in the GIS Proximity Model

No	Variable	Description
1	DMUP	Route distance to nearest upriver dam
2	DMDN	Route distance to nearest downriver dam
3	RDRLUP	Route distance to nearest upriver road or railroad crossing
4	NPDESUP	Route distance to nearest upriver permitted discharge (NPDES)
5	UBPODIST	Population/distance ratios for urban polygons
6A	PROTPER	Protected land in a site neighborhood (% in 5-km radius)
6B	PLAREADIST	Population/distance ratios for protected area polygons
7	PTRBAD	Route distance to nearest upriver primary tributary weighted proportionally to runoff from developed and cultivated watershed area
8	PTRGOOD	Route distance to nearest upriver primary tributary weighted proportionally to runoff from undeveloped watershed area
9	STRIBUP	Route distance to nearest upstream secondary tributary
10	CULPER	Cultivated land in site neighborhood (% in 5-km radius)
11	FORWETPER	Forest and wetland in site neighborhood (% in 5-km radius)
12	STRIBDEN	Density of upriver secondary tributaries (number/10 km)
13	NPDESDEN	Density of upriver NPDES permits (number/10km)
14	IMPERVPER	Impervious surface in site neighborhood (% in 5-km radius)

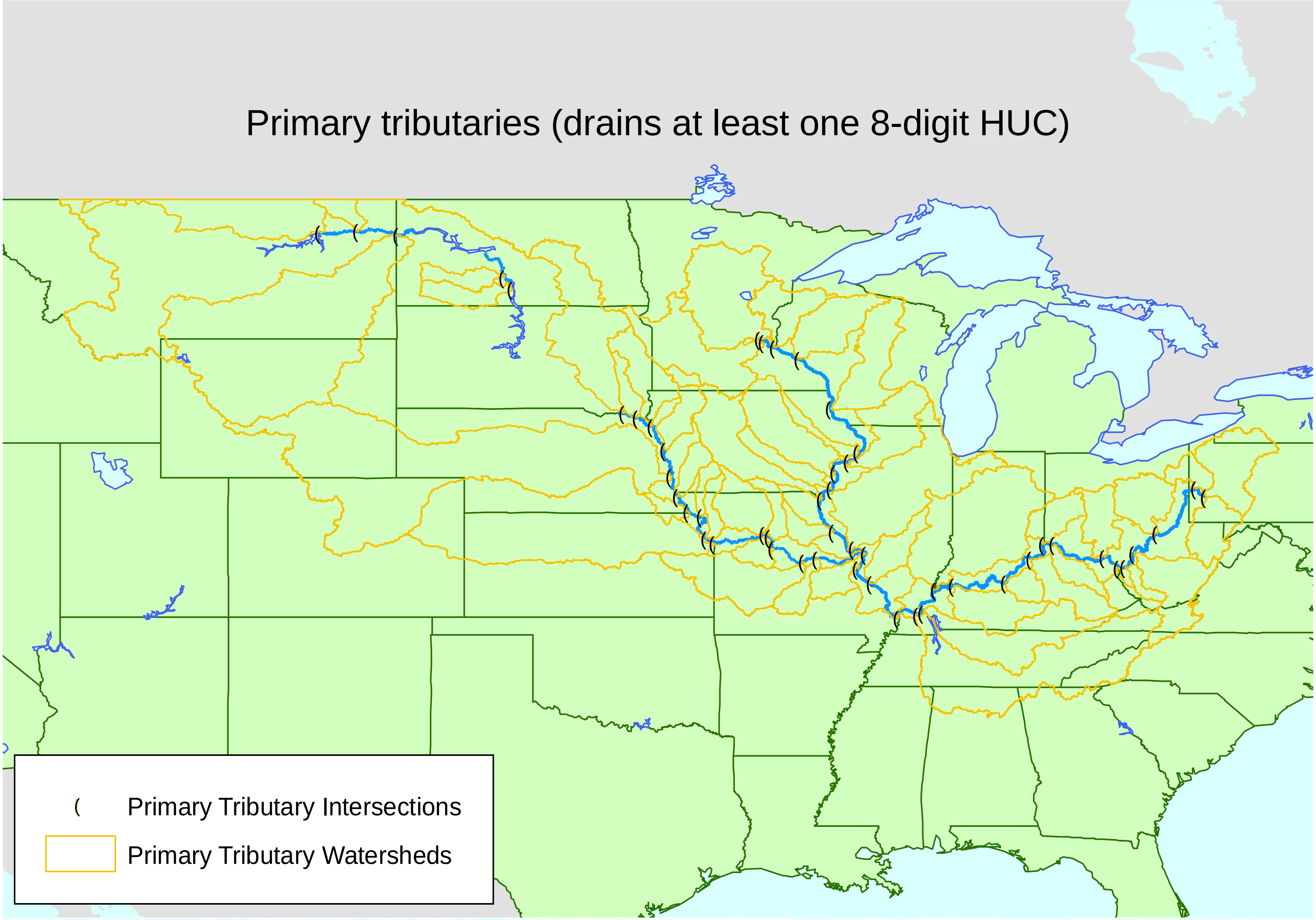
Railroad and road crossings



Attributing points with land use (forest, cultivated land, impervious surface). 5 km radius.



Primary tributaries (drains at least one 8-digit HUC)



Tributary	Q km3	% Developed	% AG	DEVAG m3	Other m3	PTRBAD weight	PTRGOOD weight
Wisconsin	8.2	1	40	3355987817	4829348323	0.54	0.90
Upper Mississippi	7.5	2	38	3017002041	4525503061	0.48	0.84
Chippewa	6.7	1	35	2402930812	4271876998	0.37	0.79
St. Croix	4.9	1	33	1682119164	3265290143	0.25	0.60
Meramec	2.6	3	25	735156518	1890402475	0.09	0.35
Black	1.5	1	40	598153812	860757925	0.06	0.15
Turkey	0.9	2	72	677205740	237937152	0.08	0.03
Root	0.8	1	76	619320287	184991773	0.07	0.02
South Fabius	0.8	1	67	564337637	265570652	0.06	0.04
Zumbro	0.6	2	88	525891189	58432354	0.05	0.00
Cannon	0.6	2	82	495958759	94468335	0.04	0.01
Cuivre	0.7	1	70	469772108	191878748	0.04	0.03
Upper Iowa	0.5	1	74	393016896	131005633	0.03	0.01

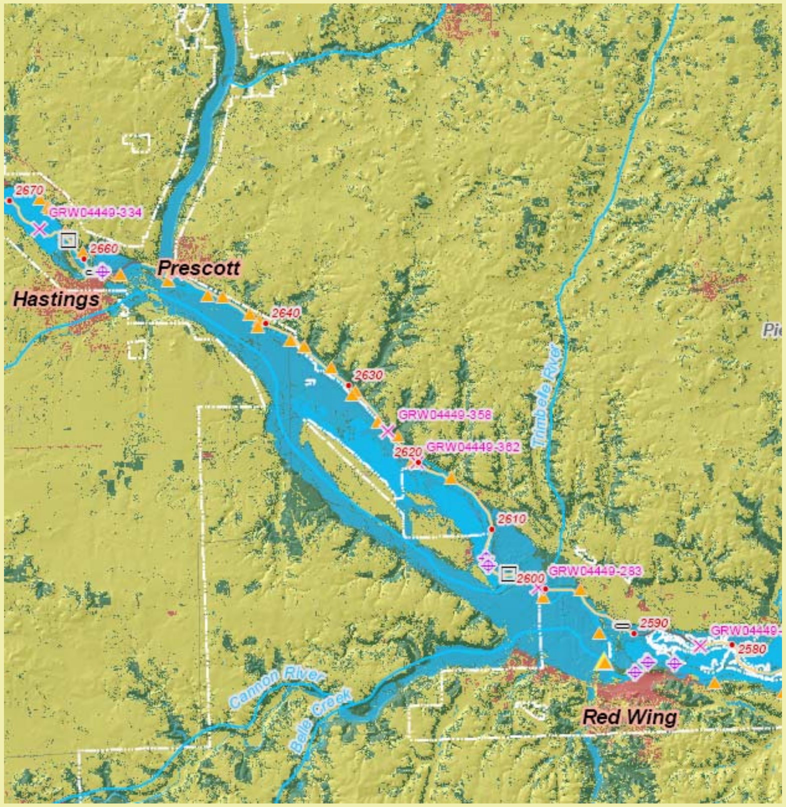
Model refinement: distance from primary tributaries was split into 2 variables:

PTRBAD distance weighted by a normalized proportion of runoff from AG+DEV LULC

PTRGOOD distance weighted by a normalized proportion of runoff from other LULC

St Croix River

- Only 34% of catchment is Ag + Developed
- PTRBAD (close is bad) W= 0.25
- PTRGOOD (close is good) W= 0.6



For a site 10 km below confluence:

PTRBAD = distance * (1-W)
= 10*0.75 = 7.5 km
= makes site score a little worse

PTRGOOD = 10 *0.4 = 4 km
= makes site score a lot better

Net effect is that sites below St Croix River score better than they would if there were no St. Croix.

Iowa River

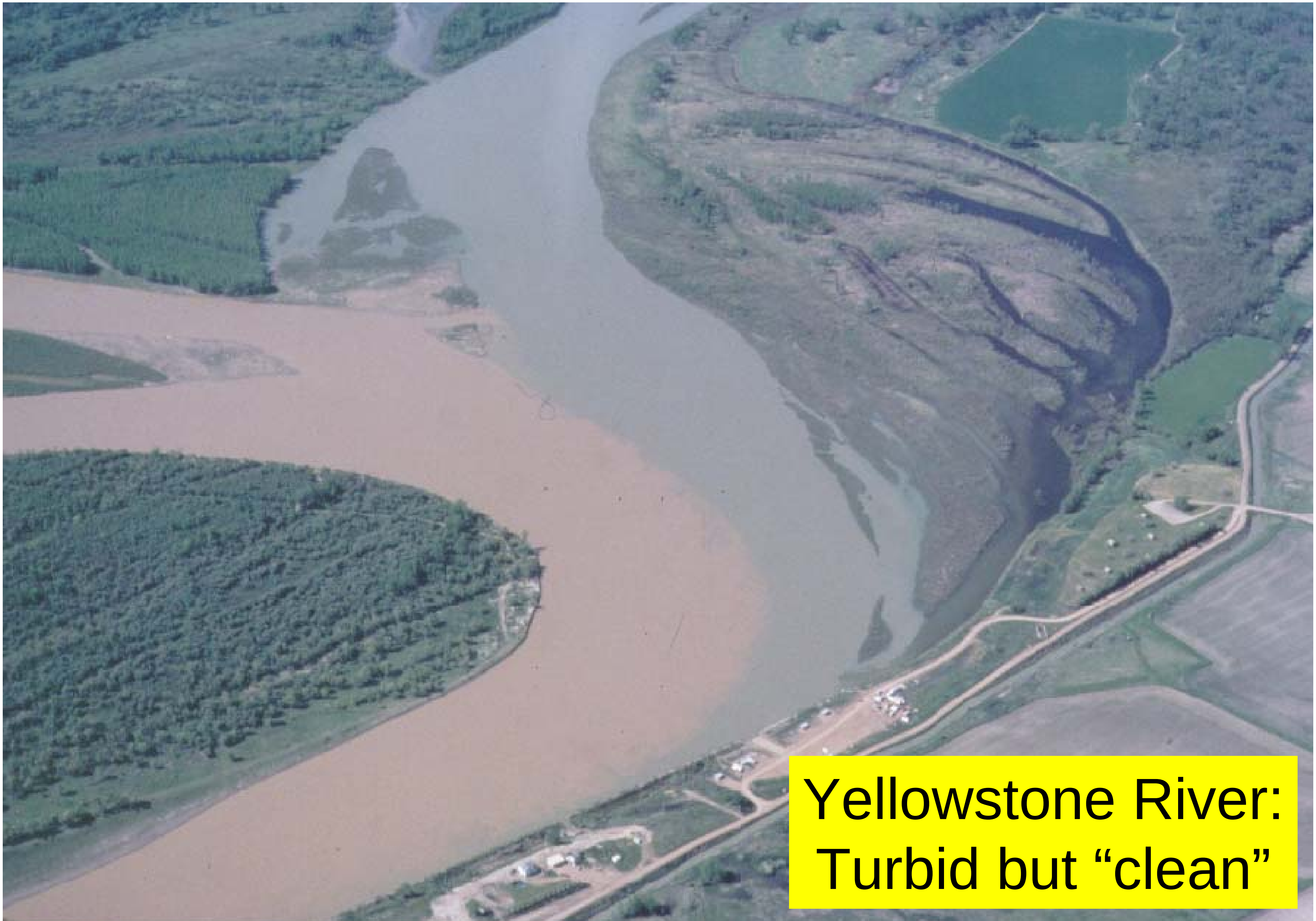
- 87% of catchment is Ag + Developed
- PTRBAD (close is bad) W= 0.88
- PTRGOOD (close is good) W= 0.14

For a site 10 km below confluence:

PTRBAD = distance * (1-W)
= 10*0.12 = 1.2 km
= makes site score a lot worse

PTRGOOD = 10 *0.86 = 8.6 km
= makes site score a little better

Net effect is that sites below Iowa River score worse than they would if there were no Iowa River


Yellowstone River:
Turbid but "clean"

Subjectivity: variable weights and scoring thresholds

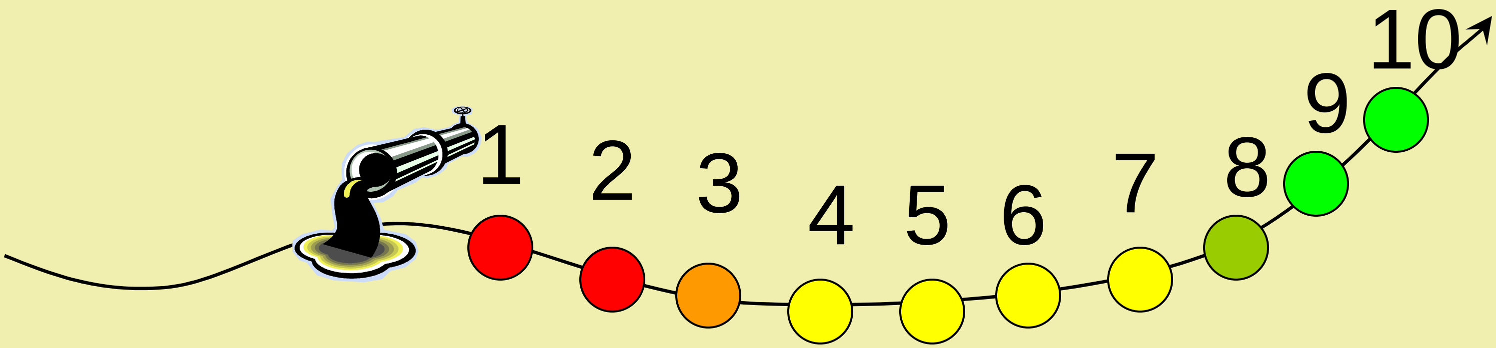
No	Variable	Mississippi *Weight*	Mississippi *Threshold*	Ohio *Weight*	Ohio *Threshold*	Missouri *Weight*	Missouri *Threshold*
1	DMUP	1.0	10 km	1.0	10 km	2	40 km
2	DMDN	0.5	5 km	0.5	5 km	0.5	5 km
3	RDREST	0.5	2 km	0.5	2 km	0.5	2 km
4	NPDESUP	2.0	2 km	2.0	2 km	2.0	2 km
5	UBPODIS	[illegible]	[illegible]	[illegible]	[illegible]	1.0	NA
6A	PROTPE	[illegible]	[illegible]	[illegible]	[illegible]	NA	NA
6B	PLAREADIST	NA	NA	0.5	NA	0.5	NA
7	PTRBAD	2.0	40 km	2.0	40 km	2.0	20–40 km
8	PTRGOOD	2.0	NA	2.0	NA	2.0	NA
9	STRIBUP	1.0	5 km	1.0	5 km	1.0	5 km
10	CULPER	0.5	NA	0.5	NA	0.5	NA
11	FORWETPER	0.5	NA	0.5	NA	0.5	NA
12	STRIBDEN	1.0	2	1.0	2	1.0	2
13	NPDESDEN	1.0	2	1.0	2	1.0	2
14	IMPERVPER	0.5	NA	0.5	NA	0.5	NA

Score doesn't get any better beyond 2 km downriver from permit location

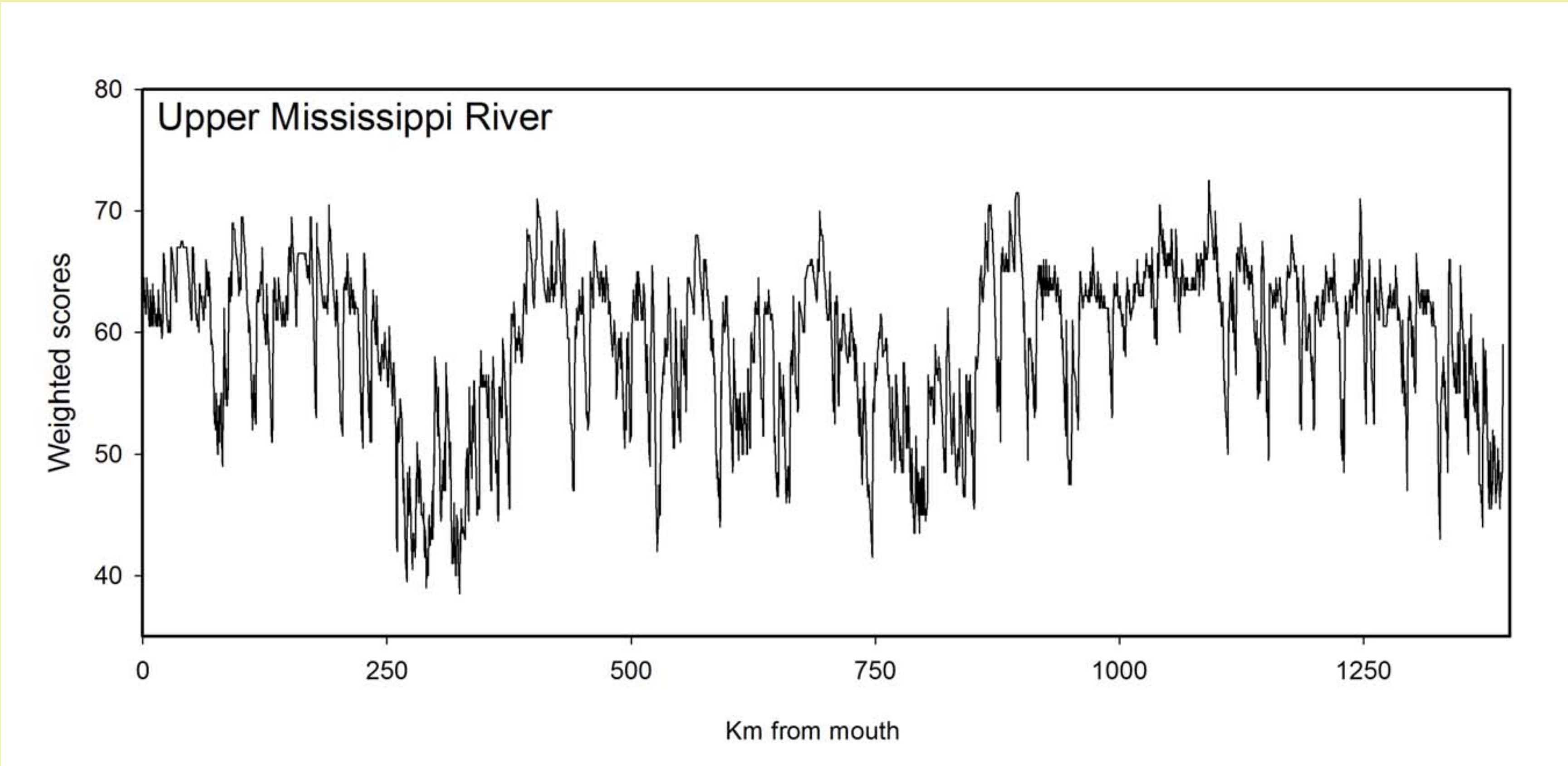
Emphasizes the local effect because all of the variation in scoring is forced into the first 2 km below an outfall

What the model actually does for each river:

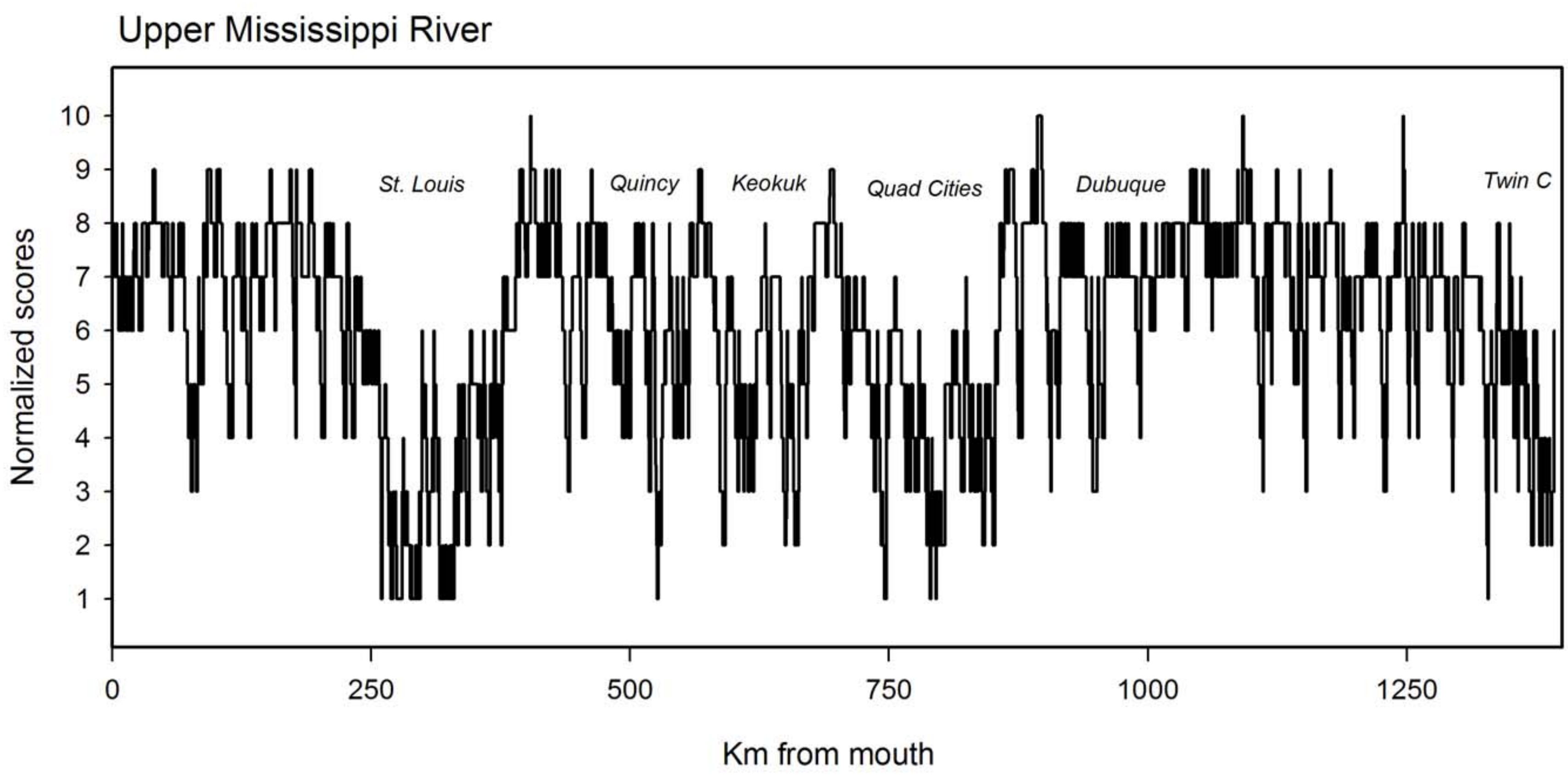
- Scores all points 1-6 for each of 14 metrics
- Scores all points based on an additive index based on summed and weighted metric scores
- Each site gets a normalized score of 1-10 where 1s and 2s are least likely to be in LDC and 10s and 9s are most likely to be in LDC:



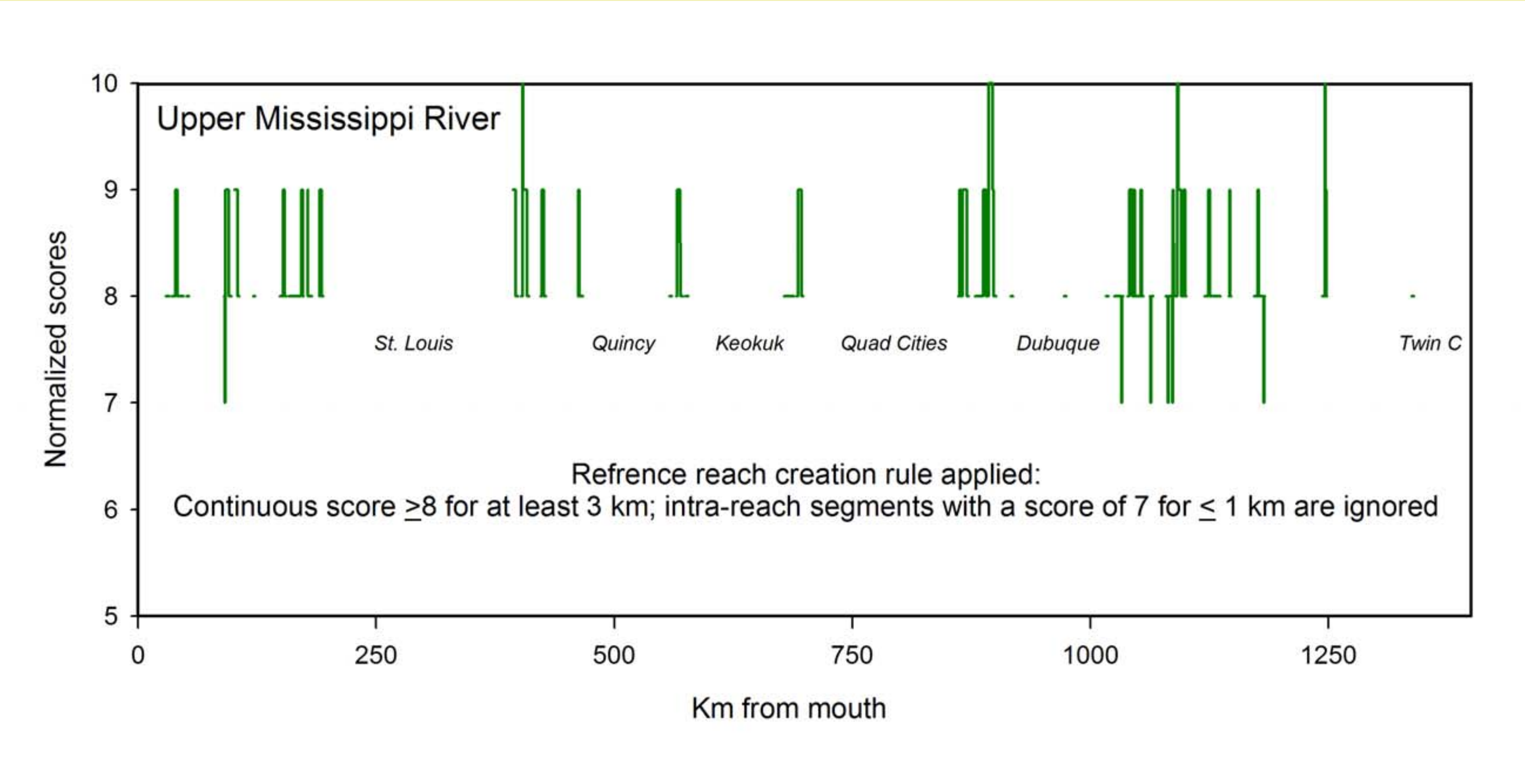
Model output – raw weighted sums of metric scores for every point

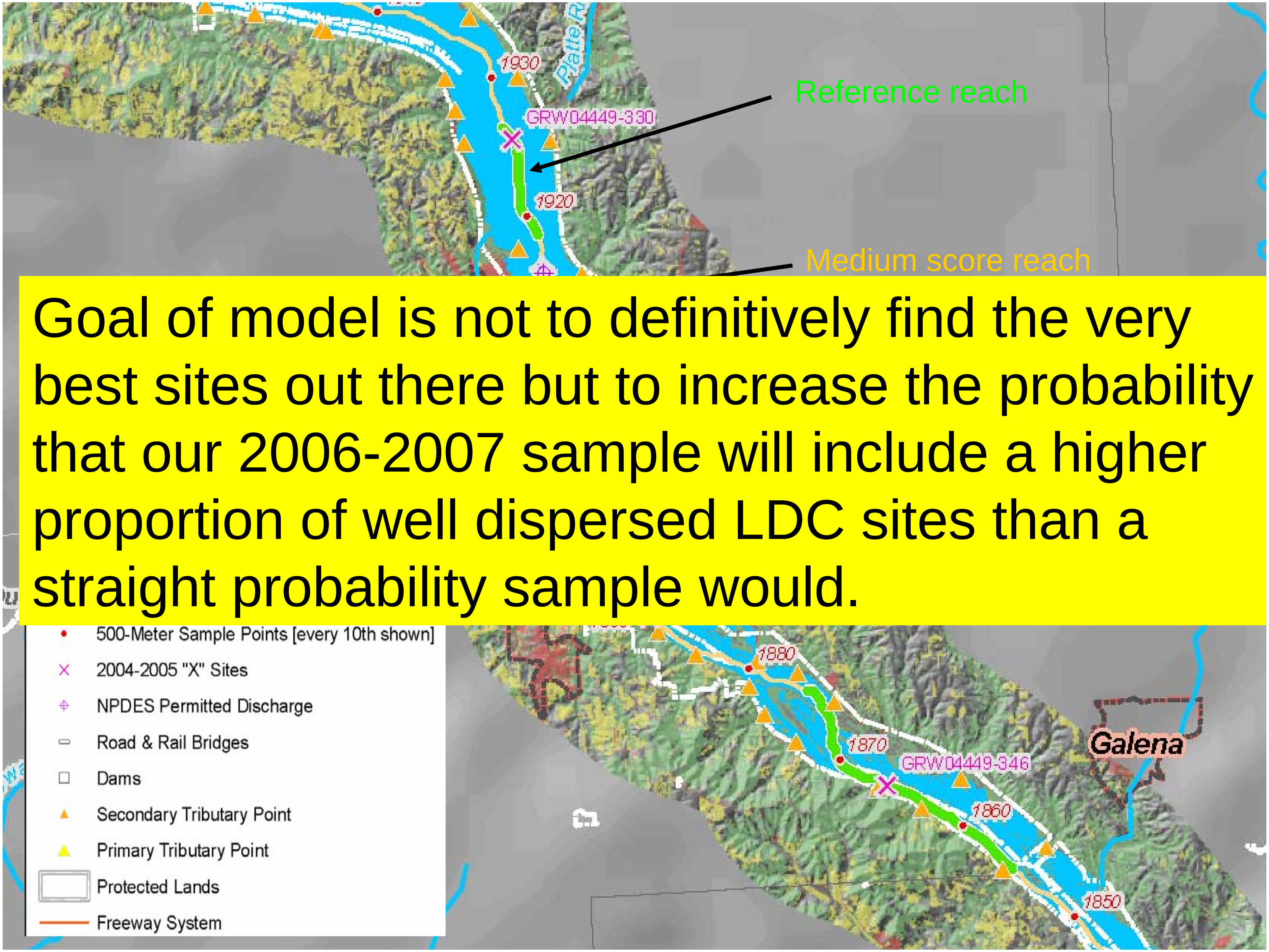


Model output – normalized scores



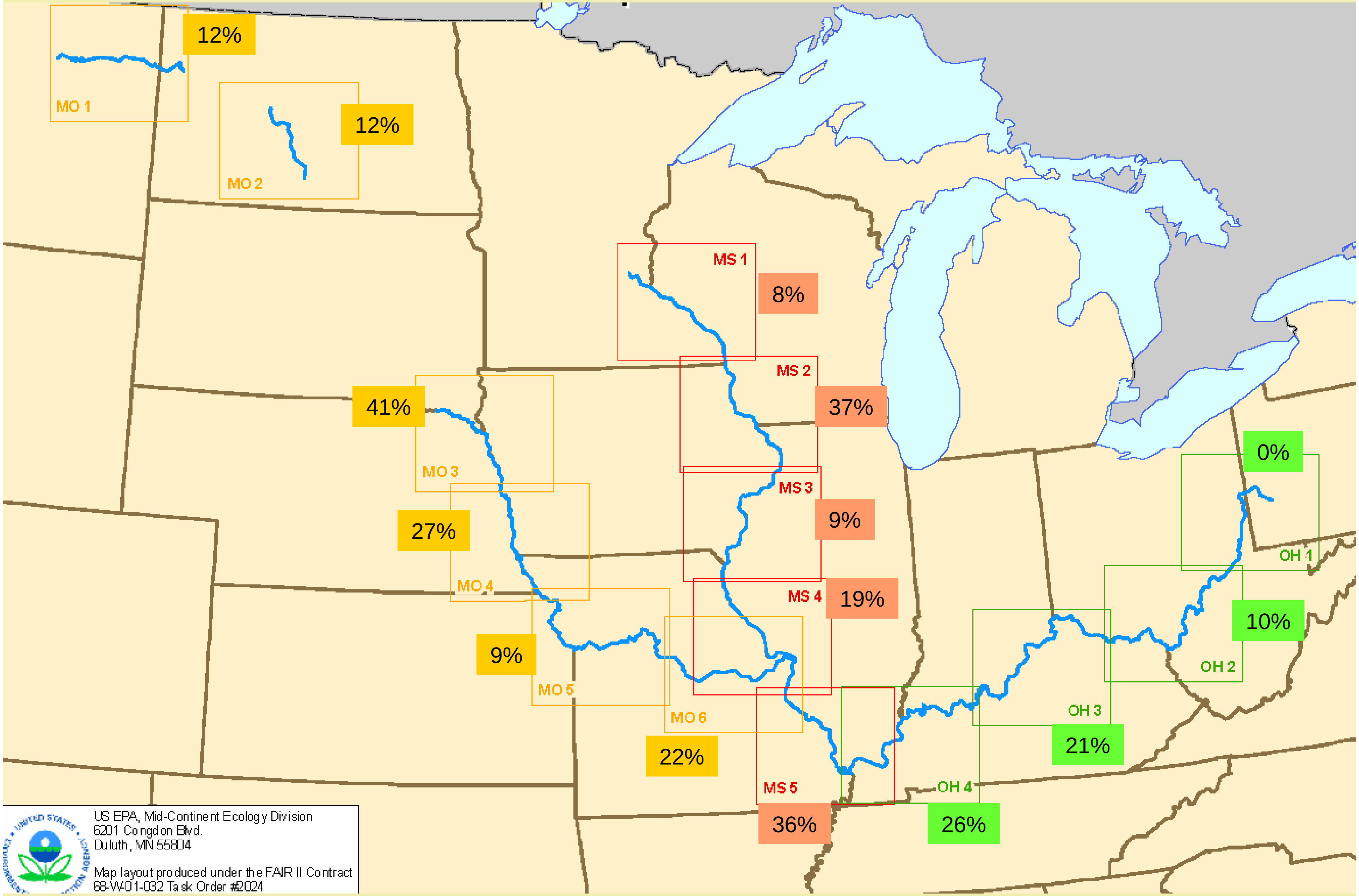
Model output – reference reaches





Goal of model is not to definitively find the very best sites out there but to increase the probability that our 2006-2007 sample will include a higher proportion of well dispersed LDC sites than a straight probability sample would.

Percent of length scored as reference by the model for arbitrary map units



Next steps

- Review reference reaches with our partners
  - Identify counterintuitive results
  - Add back in known good reaches
  - Clip known impaired reaches
  - Adjust and re-run model
- Build a new probability design based on these reaches and draw sites.
- Sample sites in July-September 2006-07.
- Use BPJ to pick some additional “off-frame” LDC, tributary and “trashed” sites?

All GIS input data are public domain. Model is available to anybody who wants it.

EMAP-GRE's 3-phased approach to reference

I. Identification of sites (internal reaches) likely to be in LDC using "local proximity" model

II. Use abiotic filters to find sites actually in LDC from among <u>all</u> sampled sites

III. Verify reference set using biotic indicators

Example of site-scale screening for wadeable streams

For EMAP/REMAP wadeable stream datasets, the reference sites are generally screened on various chemistry and physical habitat variables with criteria and screens varying by region.

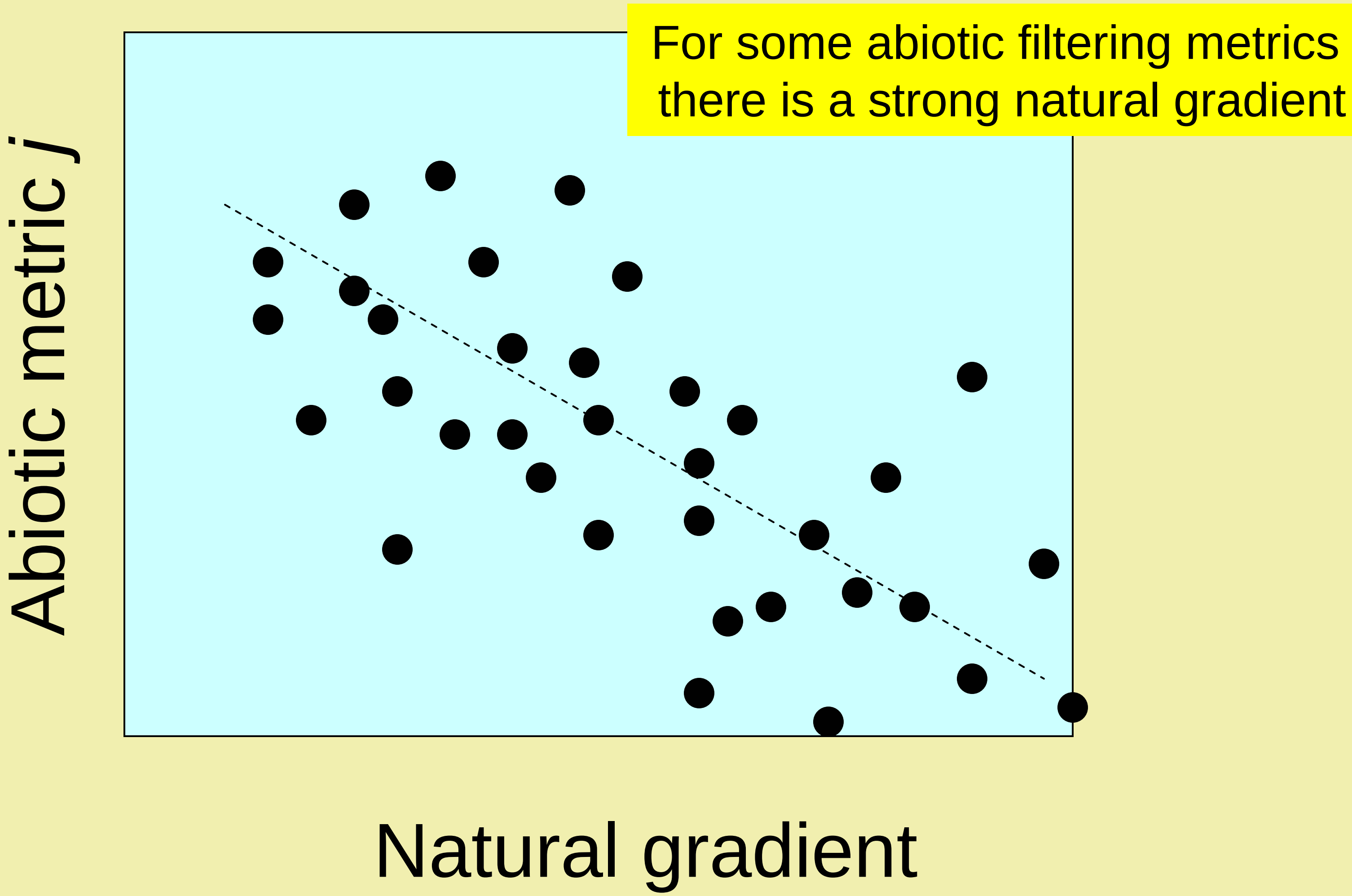
Agg.Region	Corrected Cl	Total P	Total N	Sulfate	Turbidity	pH	% Fines	Rip. Disturbance	Canopy Density
Southwest Mtns	<300 ueq/L	<50 ug/L	<750 ug/L	--	--	<9.0	<15%	<0.5	>50%
Northwest Mtns.	<1000 ueq/L	<50 ug/L	<4500 ug/L	<2000 ueq/L	<50 PCU	<9.0	<50%	<1.5	>50%
So. Rockies	< 200 ueq/L	<25 ug/L	<750 ug/L	<200 ueq/L	--	<9.0	<15%	<1.0	<50%
No. Rockies	< 200 ueq/L	<25 ug/L	<750 ug/L	<200 ueq/L	--	<9.0	<15%	<1.0	<50%
Plains	<1000 ueq/L	<150 ug/L	<4500 ug/L	--	<50 PCU	<9.0	<90%	<2.0	>25%
Xeric	<1000 ueq/L	<50 ug/L	<1500 ug/L	--	<25 PCU	--	<50%	<1.5	>50%

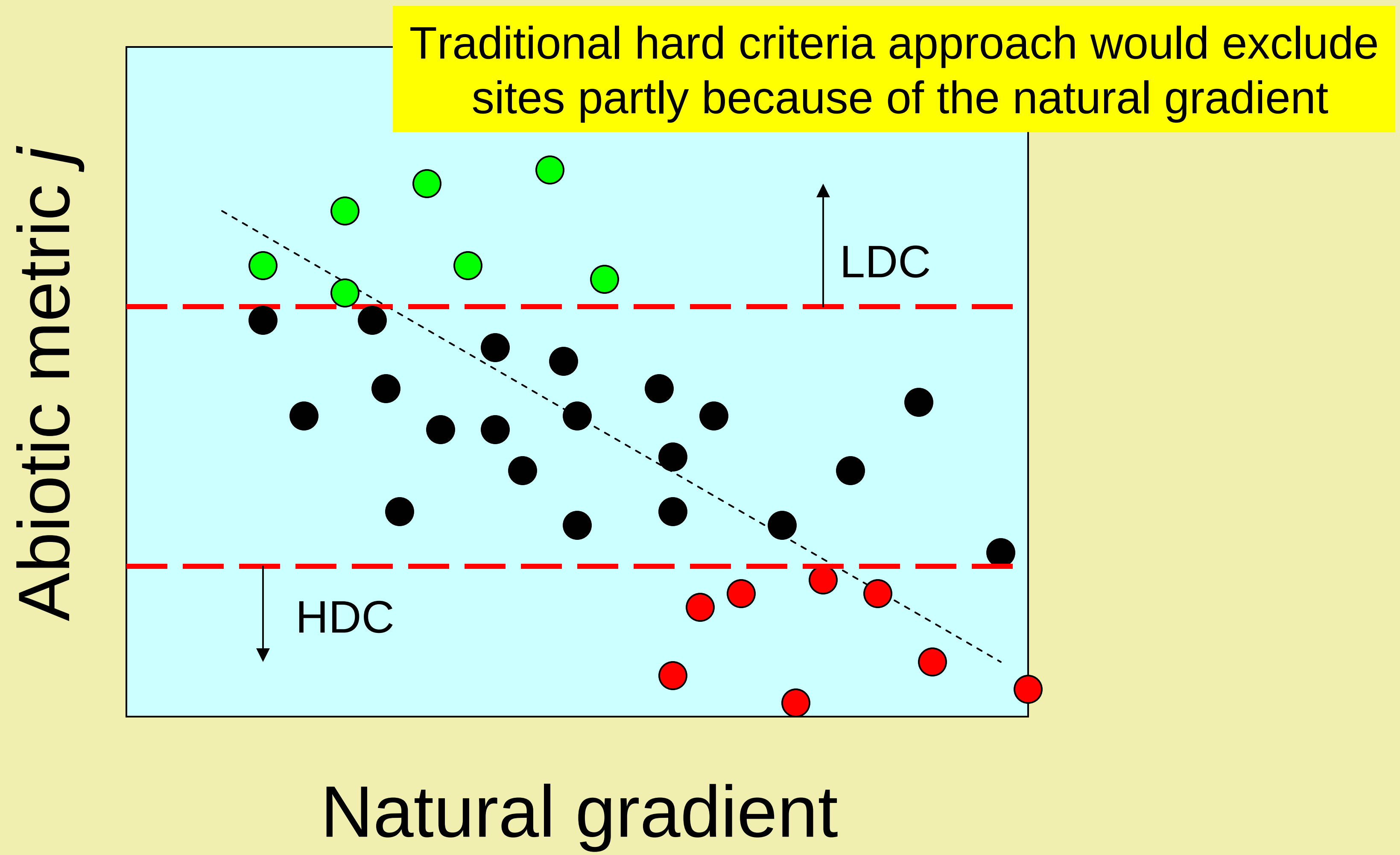
It works for wadeable streams but its hard to apply to GRE data

EMAP-GRE Variation: *"multi-metric natural gradient approach"*

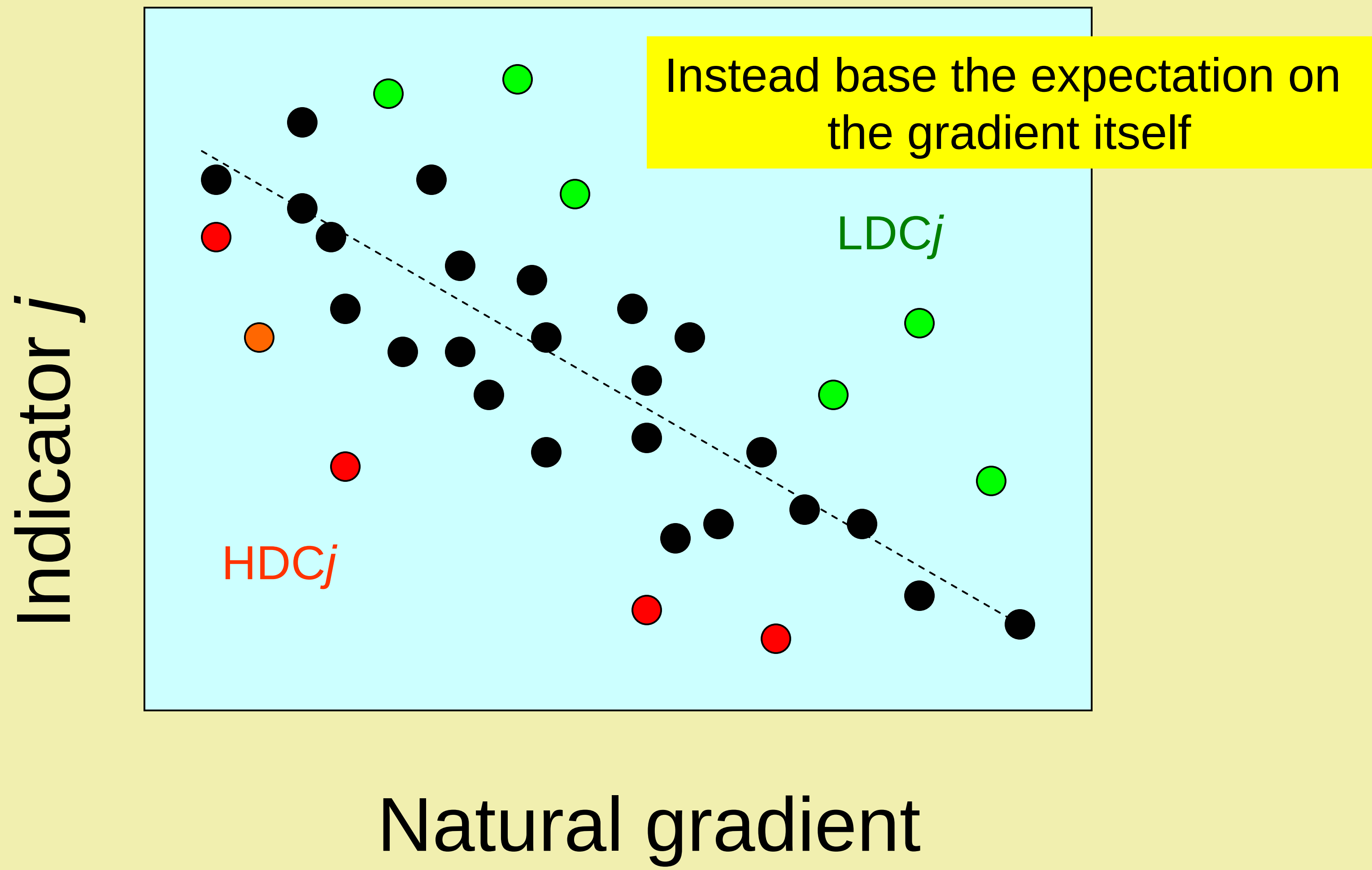
- Assign a score to each sampled site while explicitly considering a natural gradient for each river.
- Allows different expectations for different parts of the gradient.
- Basic idea is from Thom Whittier, Dynamac, Corvallis, OR and co-authors.

The concept


For some abiotic filtering metrics there is a strong natural gradient
Abiotic metric *j*
Natural gradient

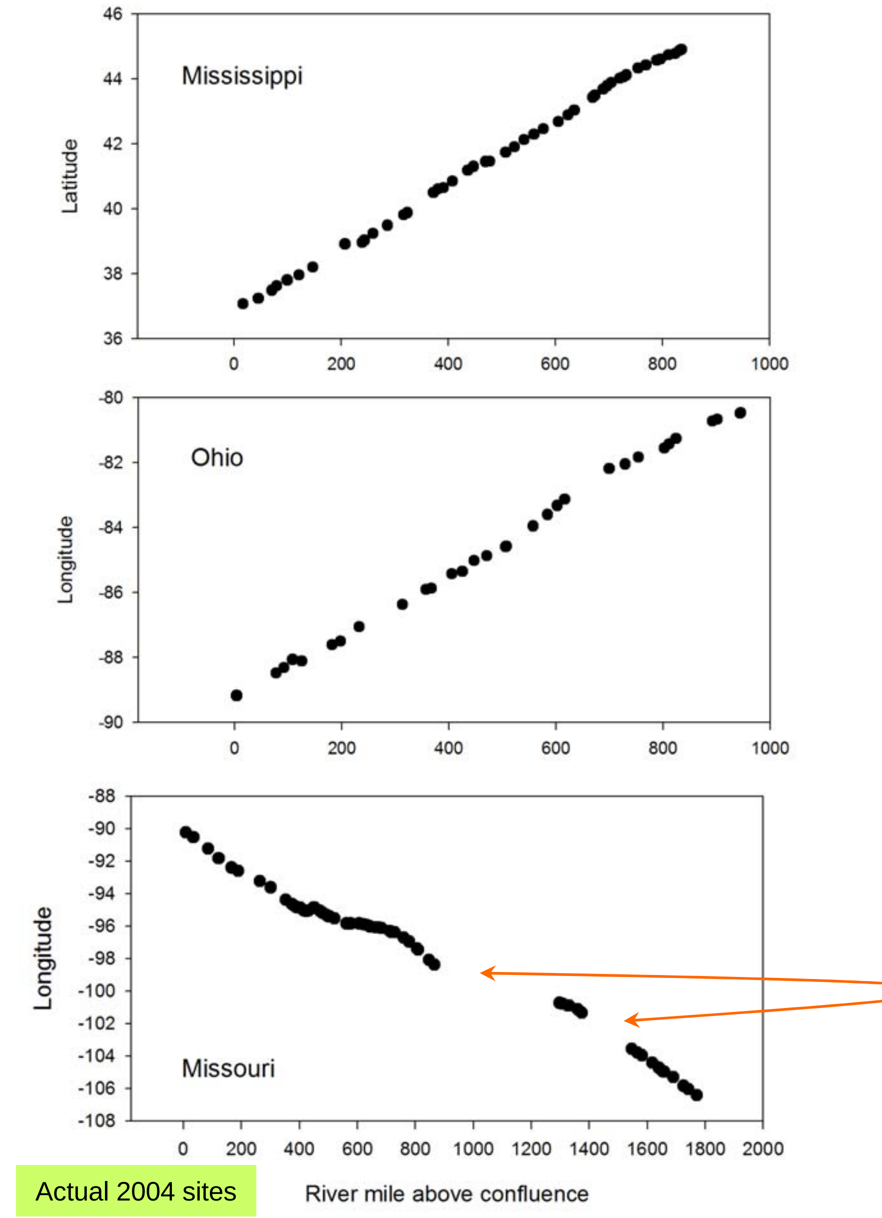


Traditional hard criteria approach would exclude sites partly because of the natural gradient
Abiotic metric *j*
LDC
HDC
Natural gradient


Instead base the expectation on the gradient itself
LDC*j*
HDC*j*
Indicator *j*
Natural gradient

Assignments

- LDC (green) or HDC (red) assigned to sites based on distribution of sites relative to natural gradient (graphical approach in this example)
- Working rule of thumb: try to get 10-20% of total sites into LDC for each metric
- But you don't need the same % for each metric
- If there is no natural gradient for a metric, use river-wide or strata-wide criteria to assign
- Gets easier with more sites because total variation increases



River mile above confluence is an adequate (and free) surrogate for watershed area for every sampled point

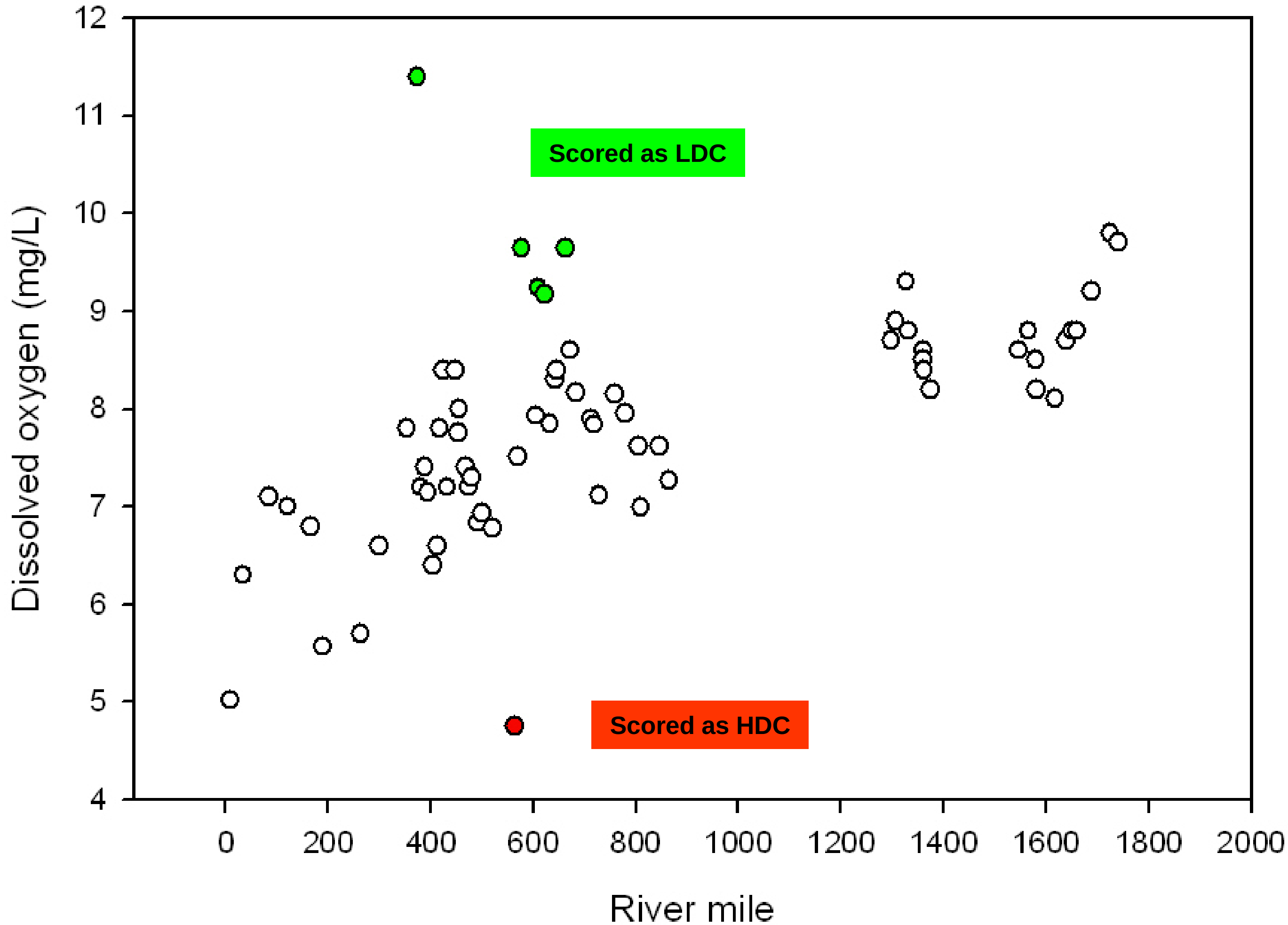
Provides a single gradient for all three rivers

Gaps are reservoirs

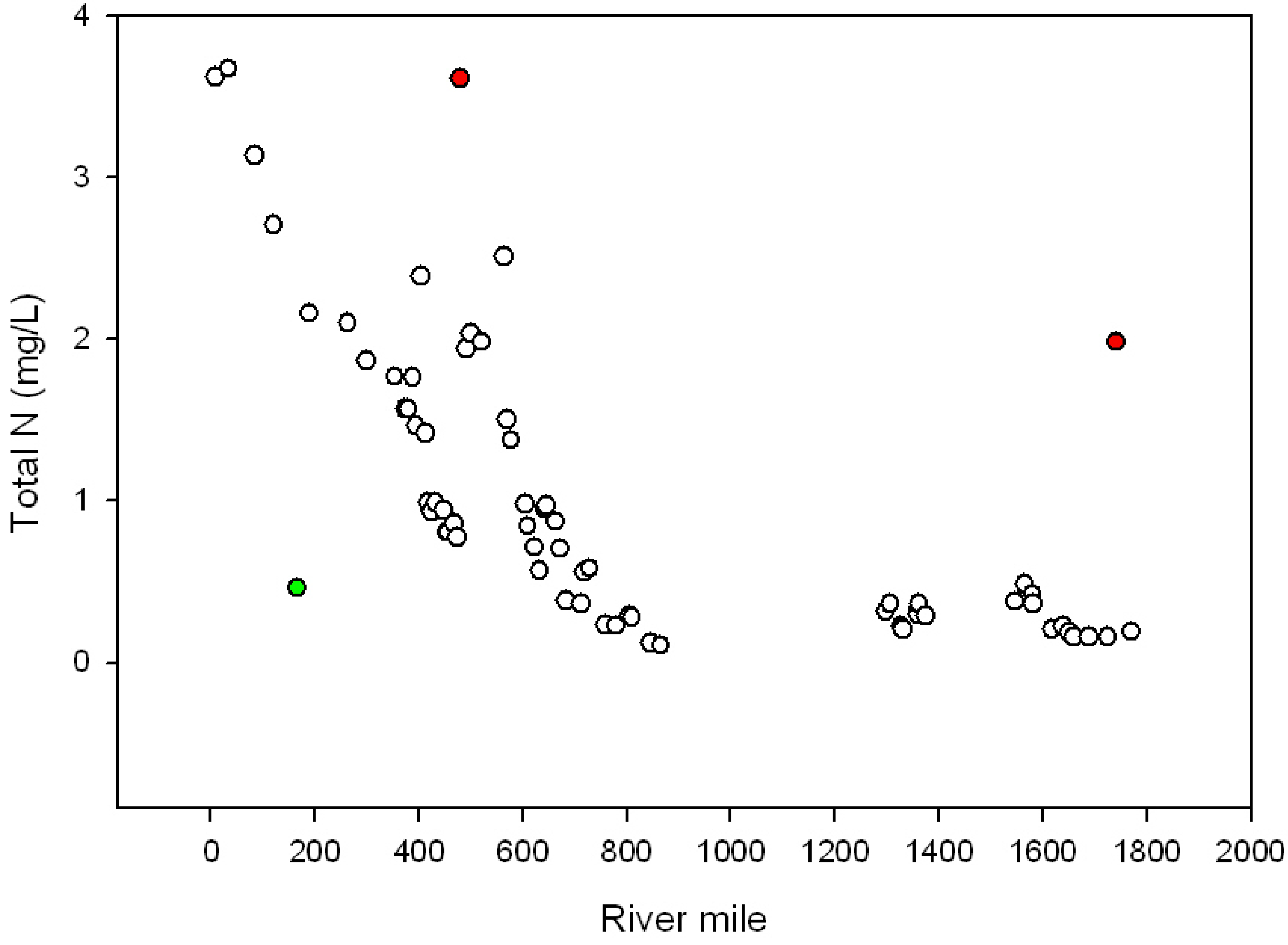
Filtering metrics in this example

- Total P
- Total N
- NH_4
- SO_4
- Chloride
- DO
- Large woody debris density
- Riparian development score
- Human disturbance score
- % Canopy density at river's edge
- Riparian vegetation coverage score
- Sediment toxicity (% survival of *H. azteca*)
- Distance to upriver NPDES permit (GIS model output)
- Weighted distance to upriver primary tributary (GIS model output)
- Distance to upriver secondary tributary (GIS model output)
- Will add dissolved metals (data not available yet)

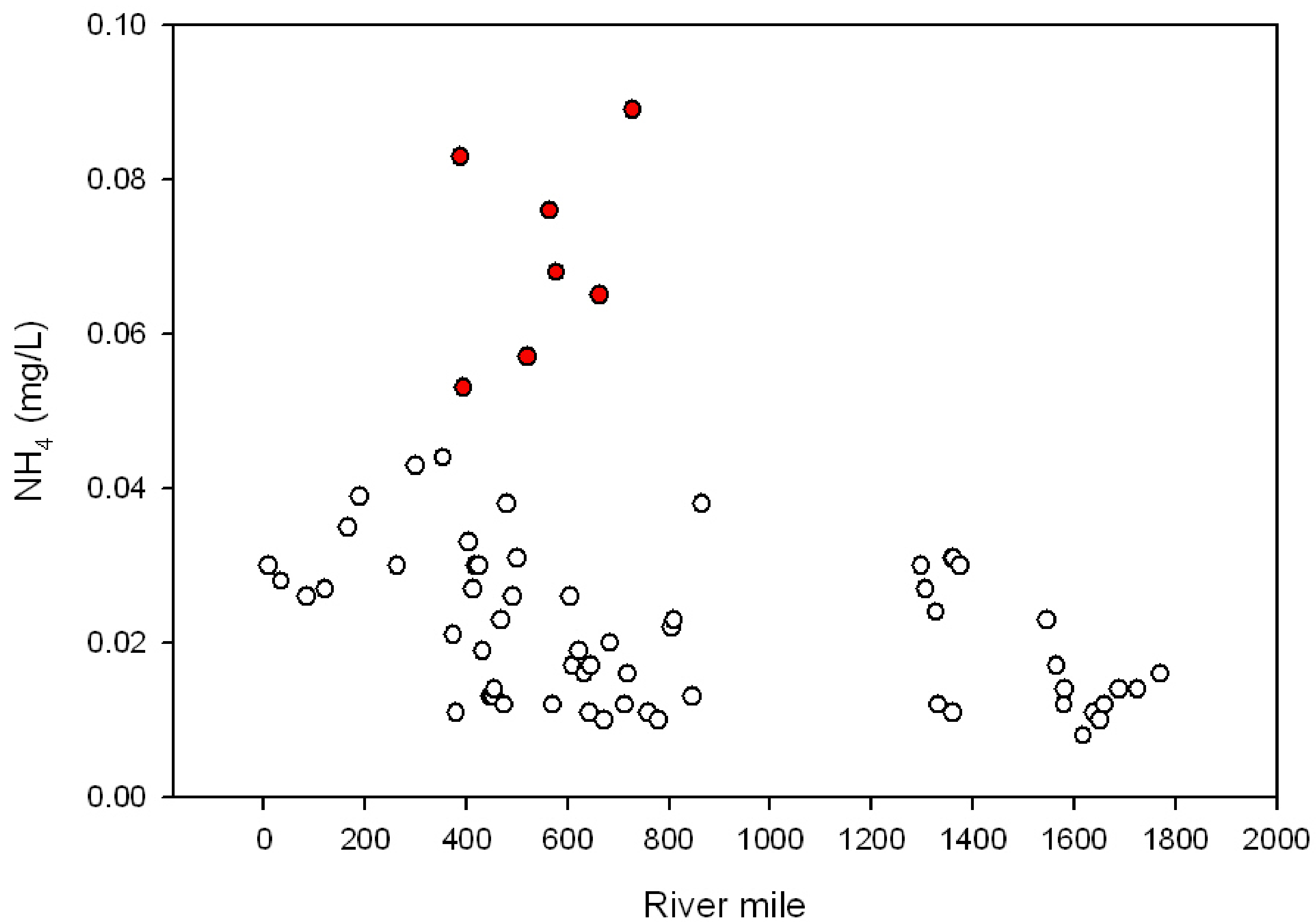
2004 sample data: DO on Missouri River



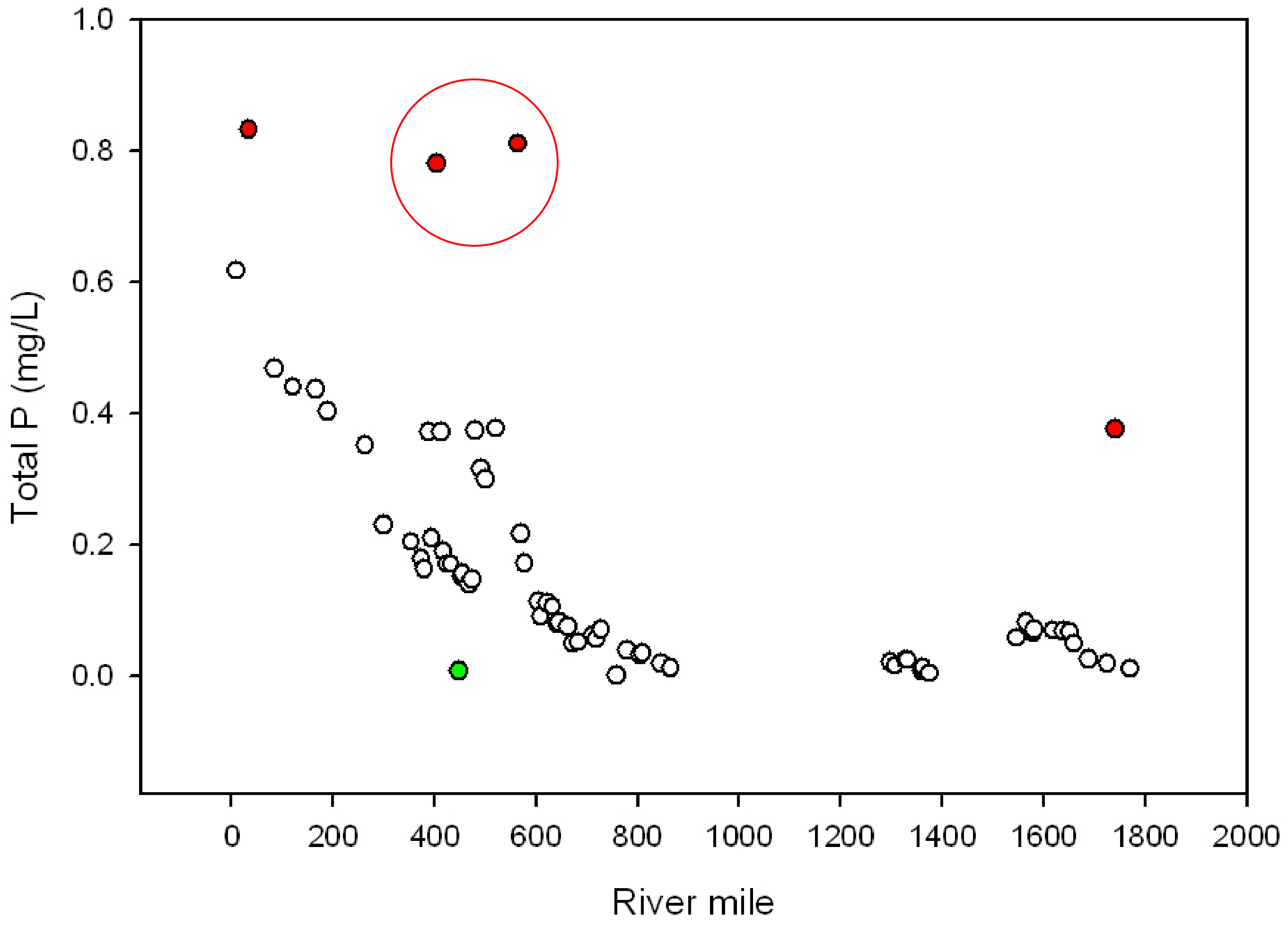
2004 sample data: TN on Missouri River



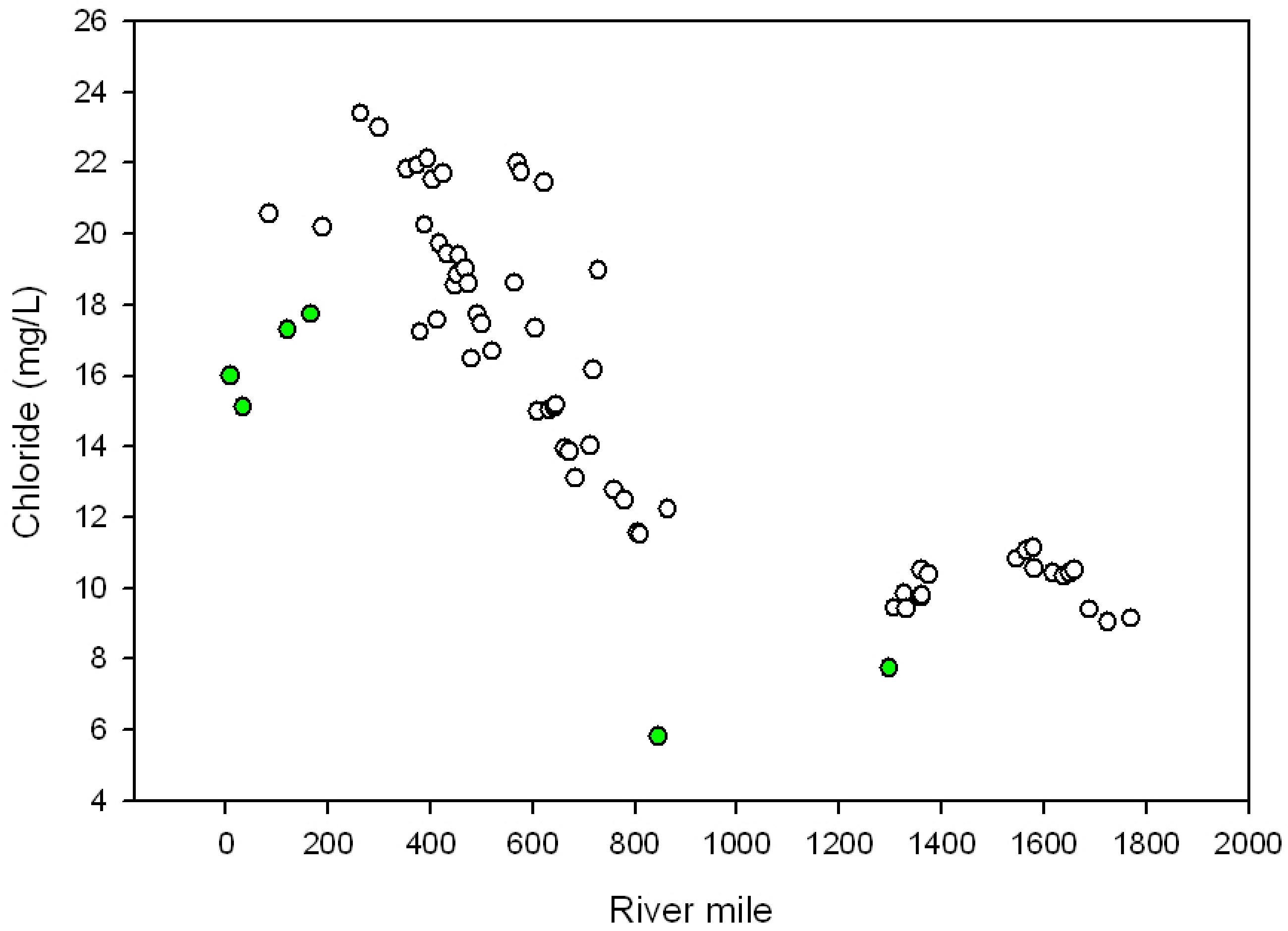
2004 sample data: NH_4 on Missouri River



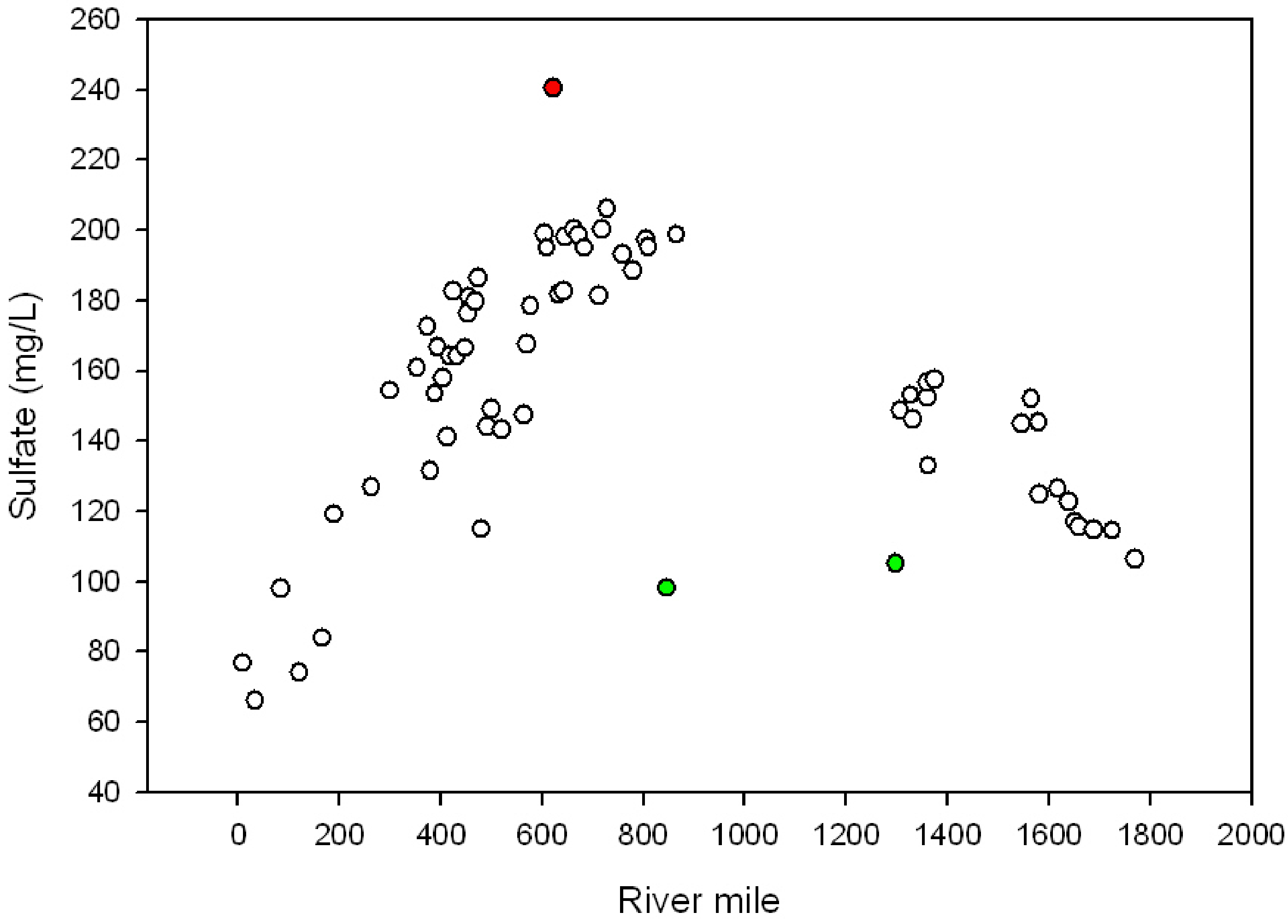
2004 sample data: TP on Missouri River



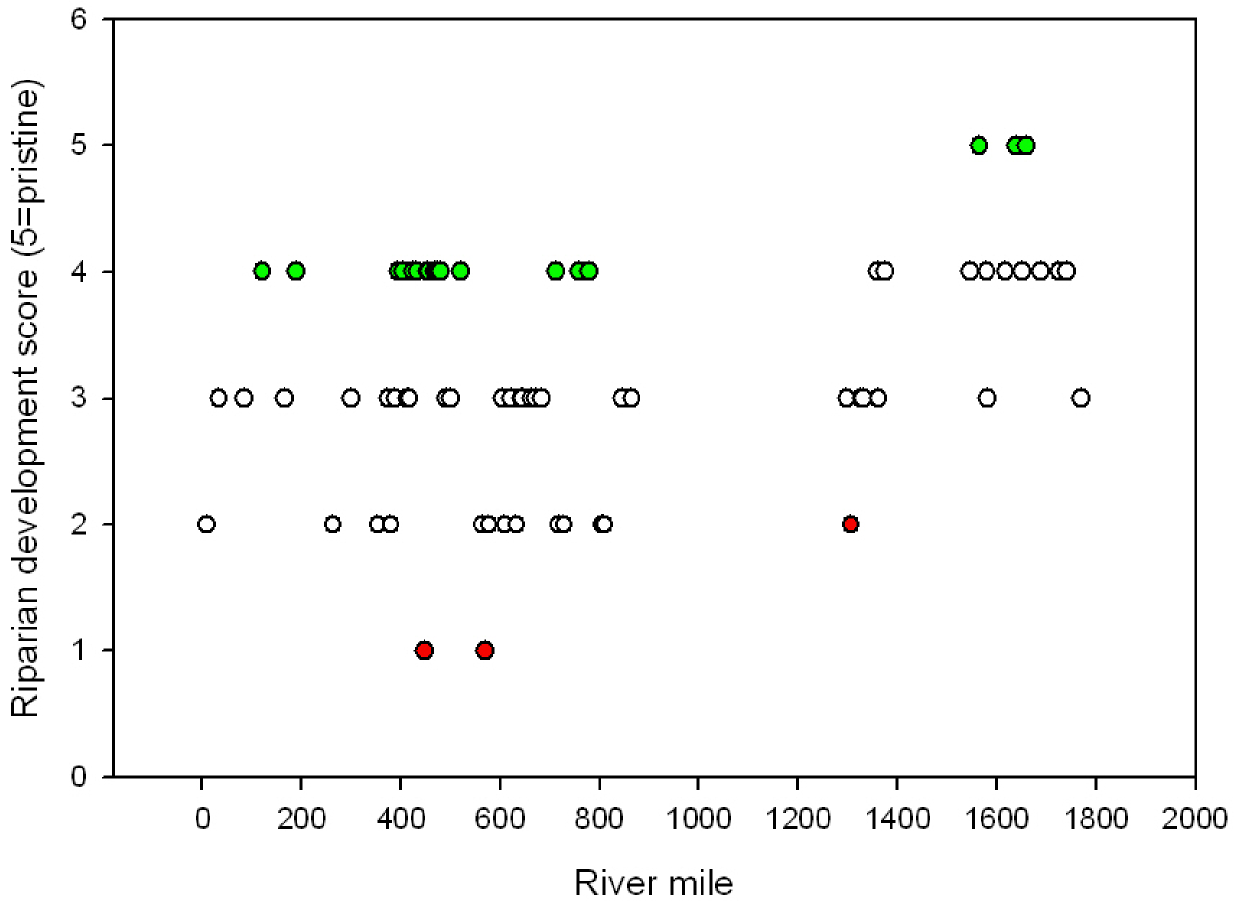
2004 sample data: Chloride on Missouri River



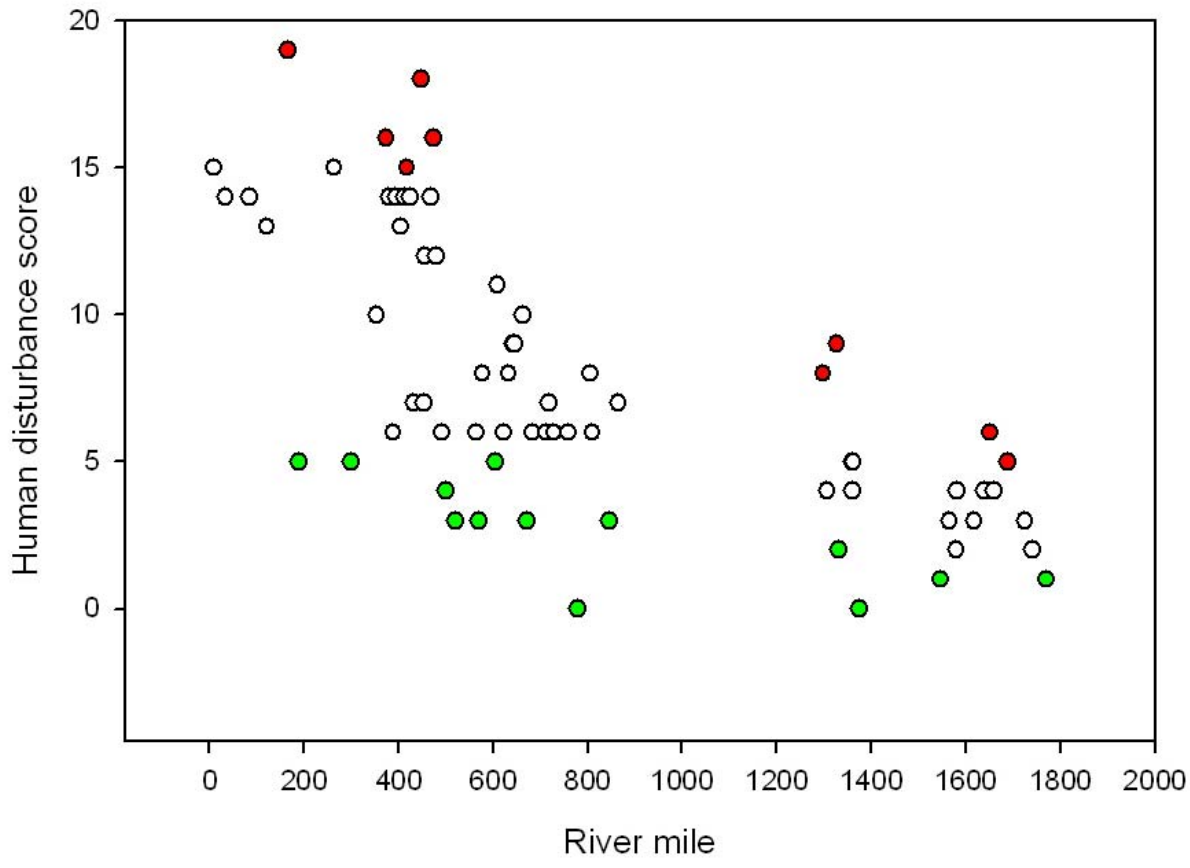
2004 sample data: Sulfate on Missouri River



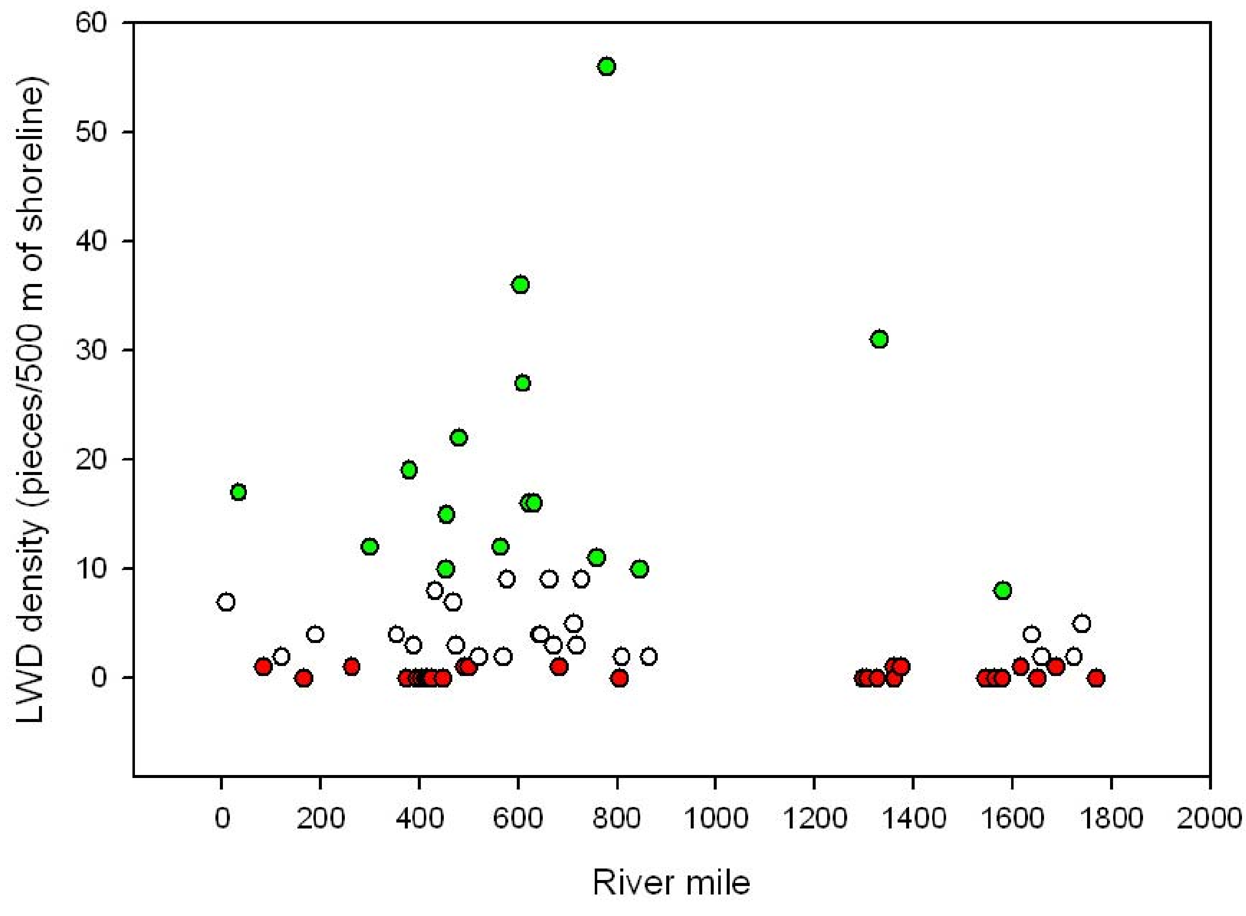
2004 sample data: Riparian development on Missouri River



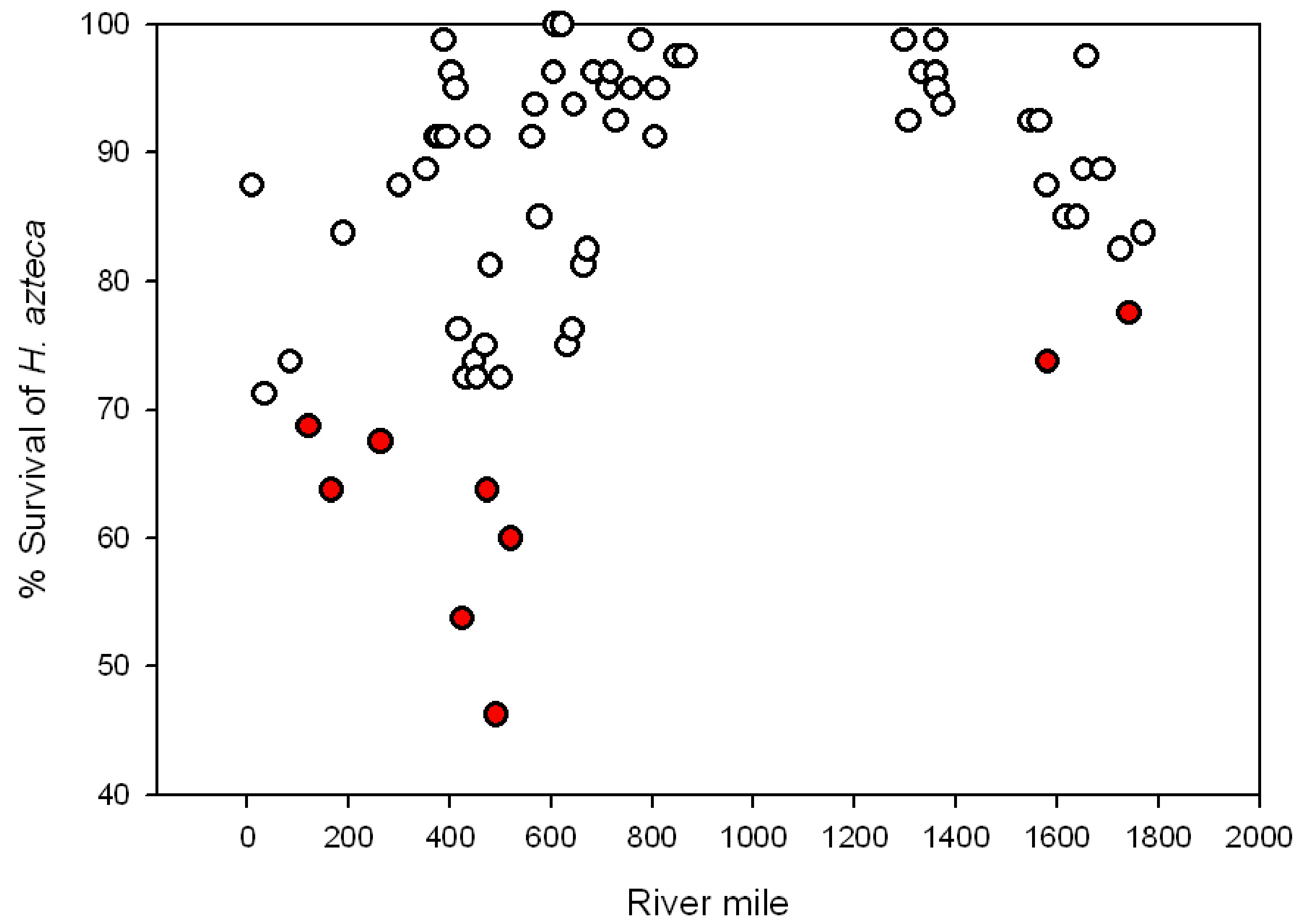
2004 sample data: Human disturbance on Missouri River



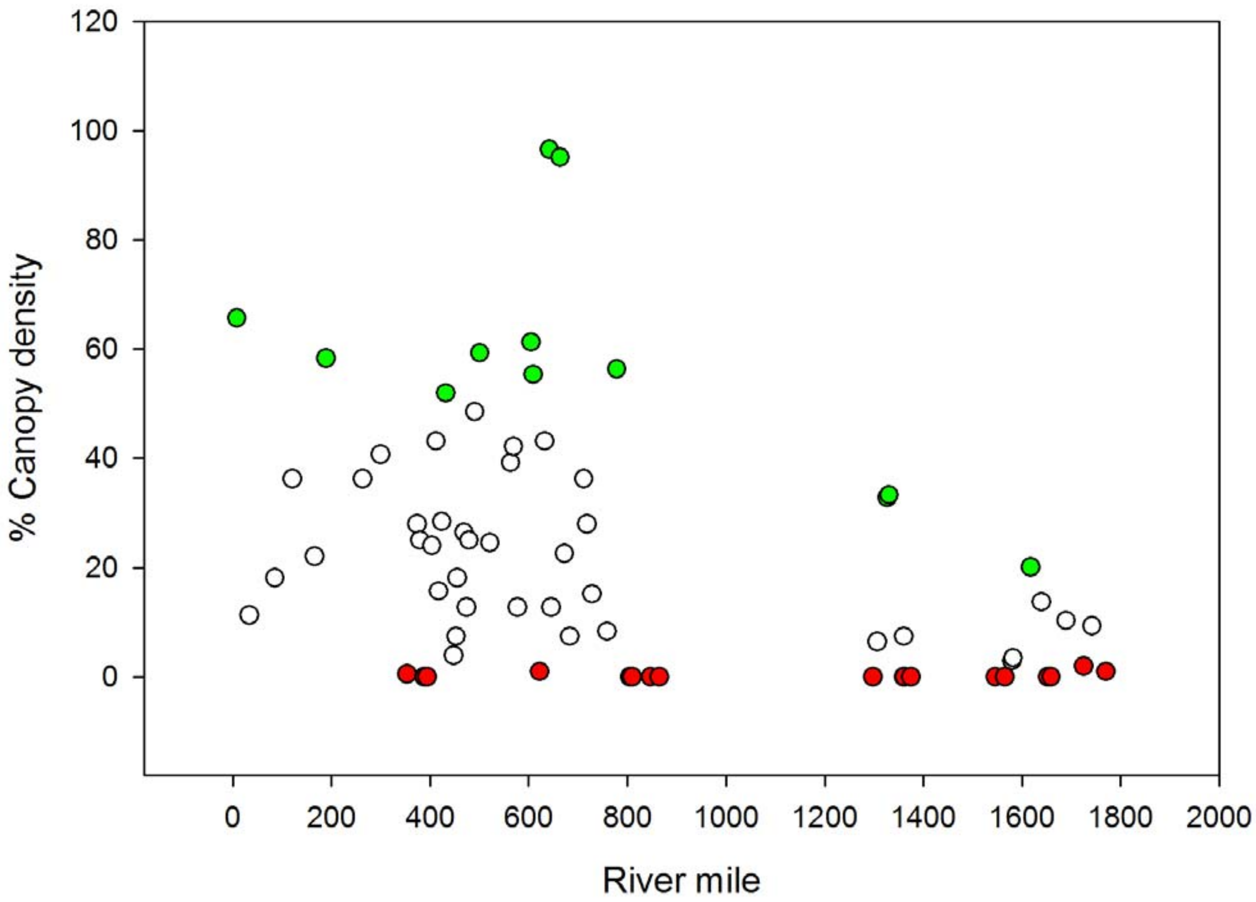
2004 sample data: LWD on Missouri River



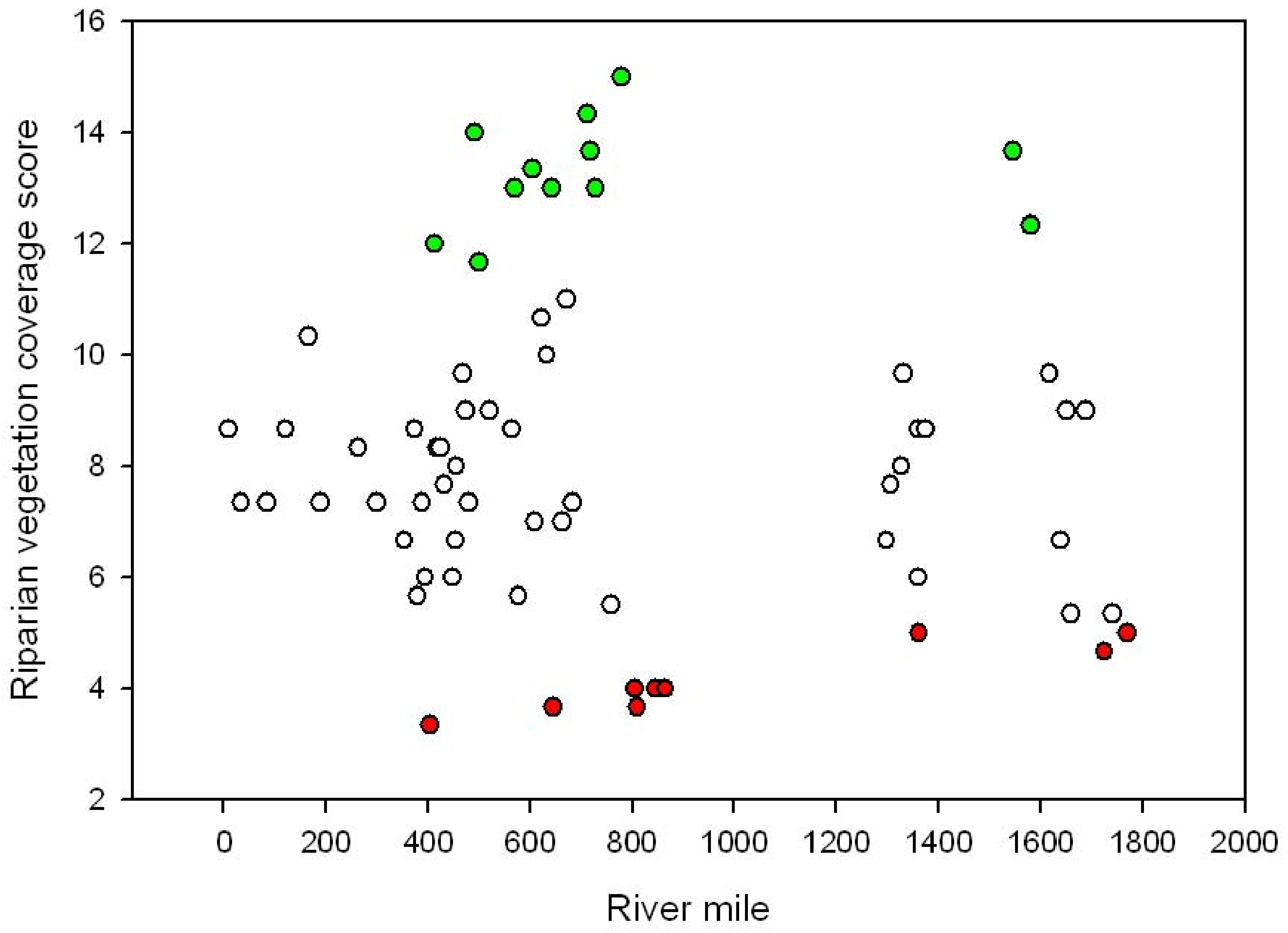
2004 sample data: Sediment toxicity on Missouri River



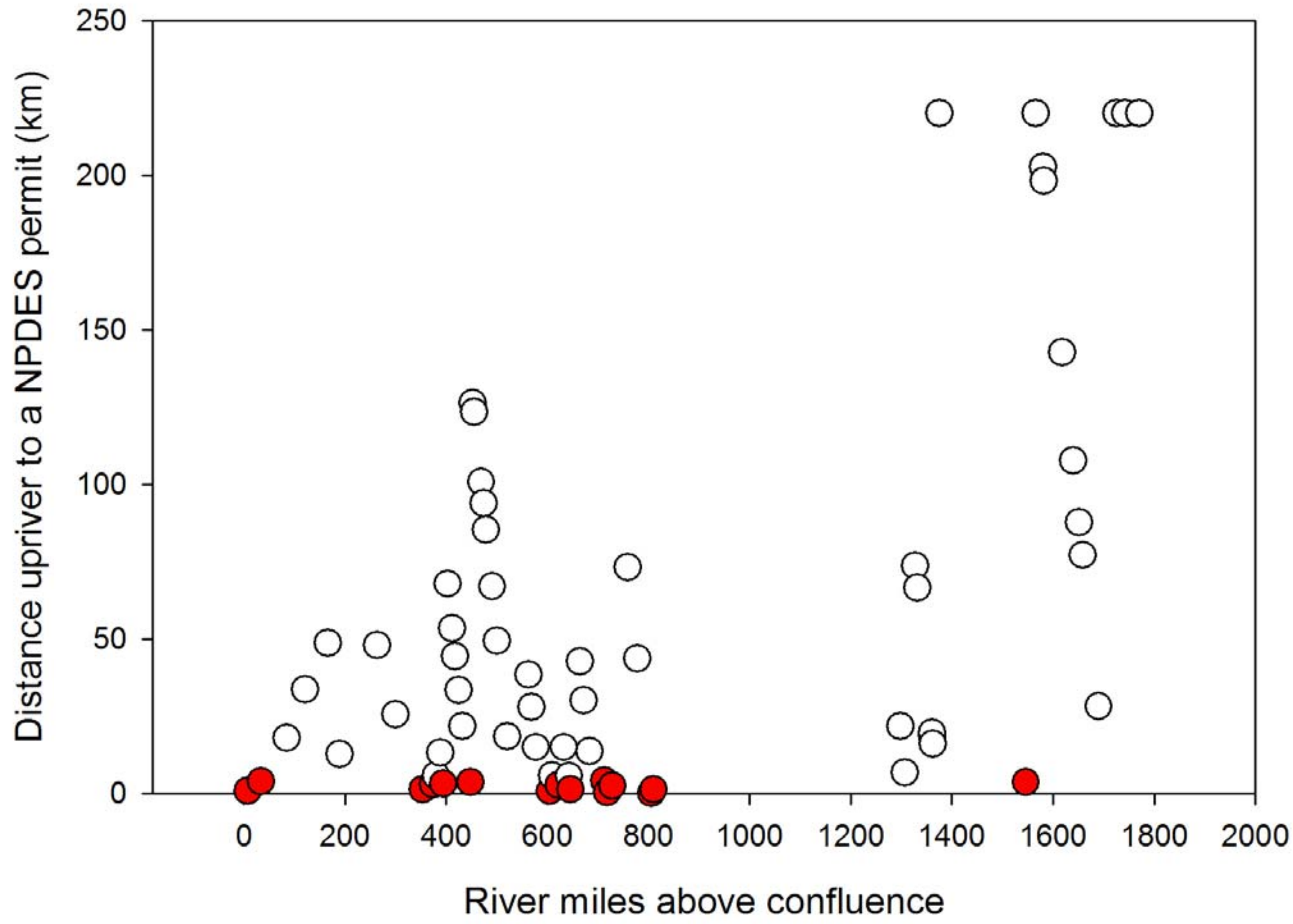
2004 sample data: Riparian canopy on Missouri River



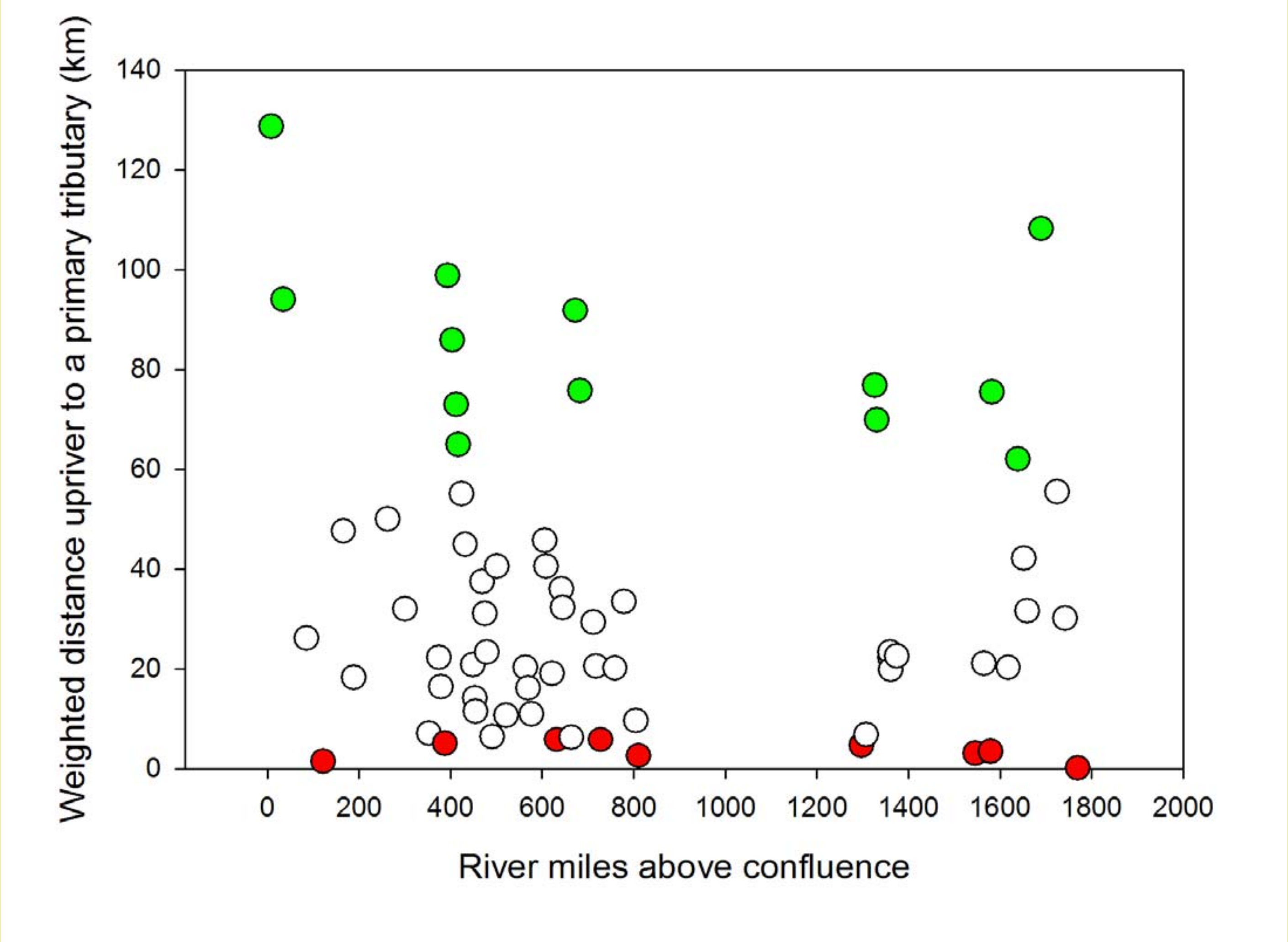
2004 sample data: Riparian vegetation score on Missouri River



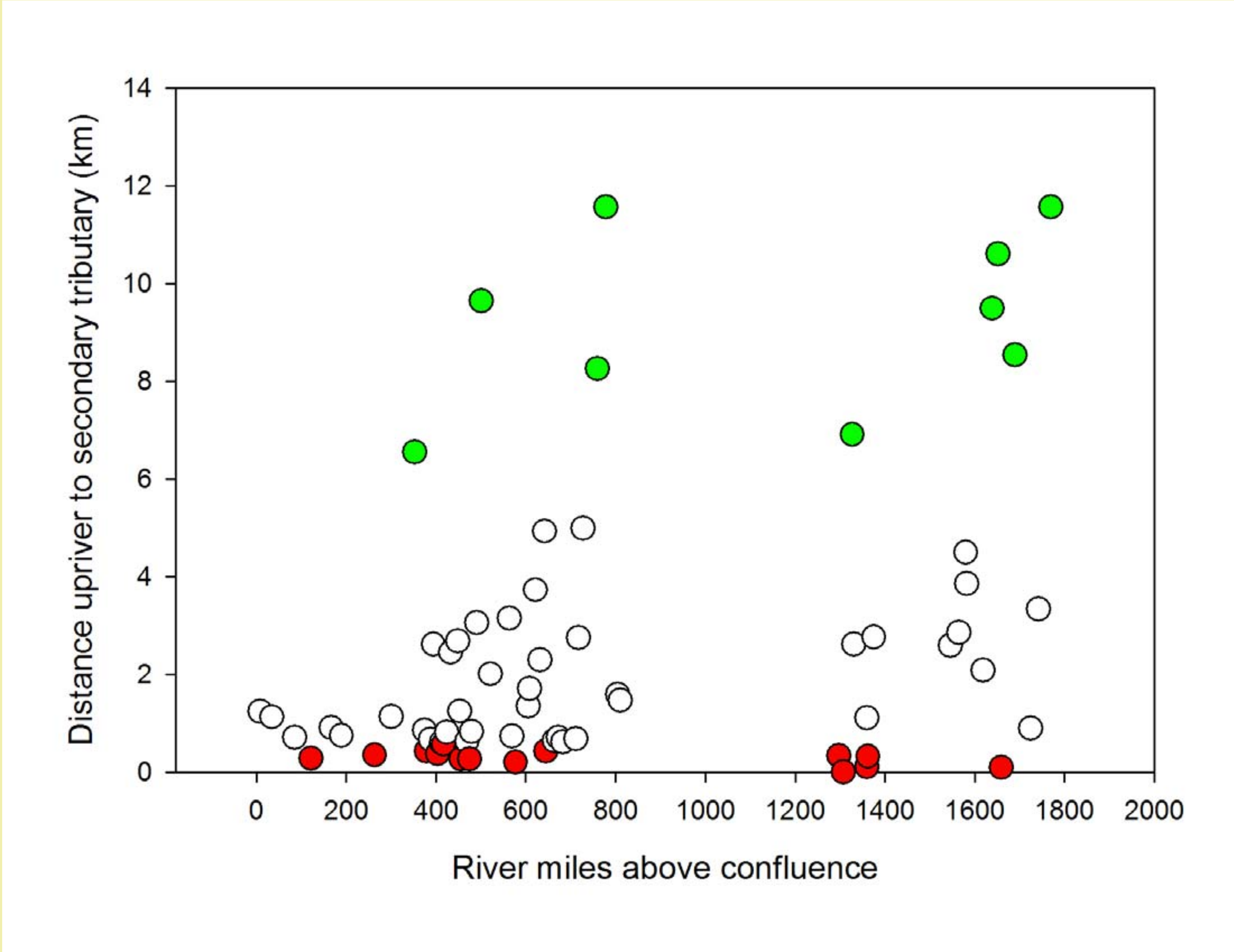
2004 sample data: Distance from upriver NPDES Permit



2004 sample data: Weighted (PTRBAD) distance to upriver primary tributary



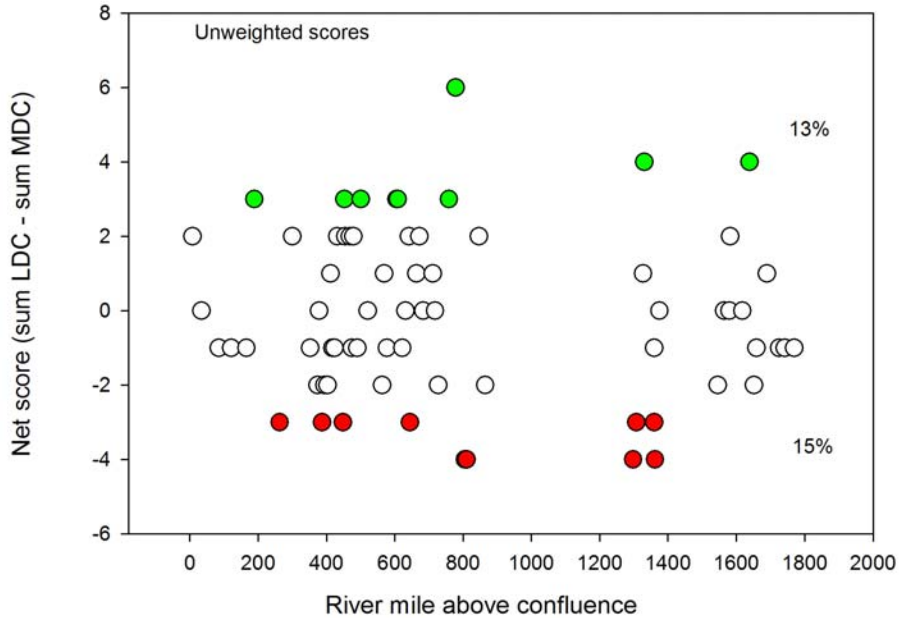
2004 sample data: Distance to upriver secondary tributary

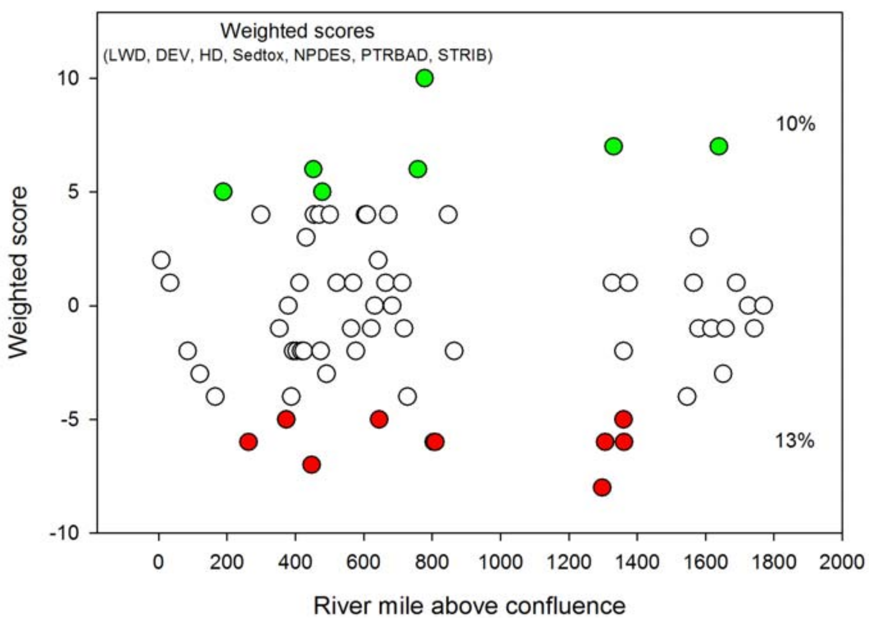


CR100 =CP100-CQ100

	A	B	D	K	L	M	BP	BQ	BR	CI	CK	CP	CQ	CR	CT
1	Site_ID	R	RM	TP	TP LDC	TP MDC	DEV	DEV LDC	DEV MDC	SEDTOX (%)	Sedtox MDC	sum LDC	sum MDC	Net Score	
55	GRW04449-565	Mo	263	0.35			2			67.5	1	0	5	-5	
56	GRW04449-567	Mo	300	0.23			3			87.5		3	2	1	
57	GRW04449-575	Mo	353	0.20			2			88.8		1	3	-2	
58	GRW04449-579	Mo	374	0.18			3			91.3		1	5	-4	
59	GRW04449-559	Mo	379	0.16			2			91.3		2	0	2	
60	GRW04449-563	Mo	388	0.37		1	3			98.8		0	3	-3	
61	GRW04449-595	Mo	394	0.21			4	1		91.3		3	4	-1	
62	GRW04449-611	Mo	403	0.78		1	4	1		96.3		3	5	-2	
63	GRW04449-603	Mo	412	0.37		1	3			95.0		1	2	-1	
64	GRW04449-555	Mo	417	0.19			3			76.3		0	3	-3	
65	GRW04449-587	Mo	424	0.17			4	1		53.8	1	4	5	-1	
66	GRW04449-591	Mo	432	0.17			4	1		72.5		4	0	4	
67															
68															
69															
70															
71															
72															
73															
74															
75															
76															
77	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	
78	GRW04449-583	Mo	577	0.17			2			85.0		1	3	-2	
79	GRW04449-571	Mo	605	0.11			3			96.3		5	0	5	
80	GRW04449-619	Mo	609	0.09			2			100.0		3	0	3	
81	GRW04449-605	Mo	622	0.11			3			100.0		2	3	-1	
82	GRW04449-589	Mo	632	0.11			2			75.0		1	0	1	
83	GRW04449-597	Mo	642	0.08			3			76.3		3	0	3	
84	GRW04449-613	Mo	645	0.08			3			93.8		0	1	-1	
85	GRW04449-553	Mo	664	0.07			3			81.3		2	1	1	
86	GRW04449-581	Mo	672	0.05			3			82.5		3	0	3	
87	GRW04449-585	Mo	683	0.05			3			96.3		1	1	0	
88	GRW04449-609	Mo	712	0.06			4	1		95.0		5	0	5	
89	GRW04449-593	Mo	718	0.06			2			96.3		1	0	1	
90	GRW04449-601	Mo	728	0.07			2			92.5		1	2	-1	
91	GRW04449-588	Mo	759	0.00	1		4	1		95.0		6	0	6	
92	GRW04449-568	Mo	778	0.04			4	1		98.8		9	0	9	
93	GRW04449-584	Mo	805	0.03			2			91.3		0	3	-3	

For each site, take the difference in number of metrics in LDC and the number in HDC to get a net score ranging from 15 to -15

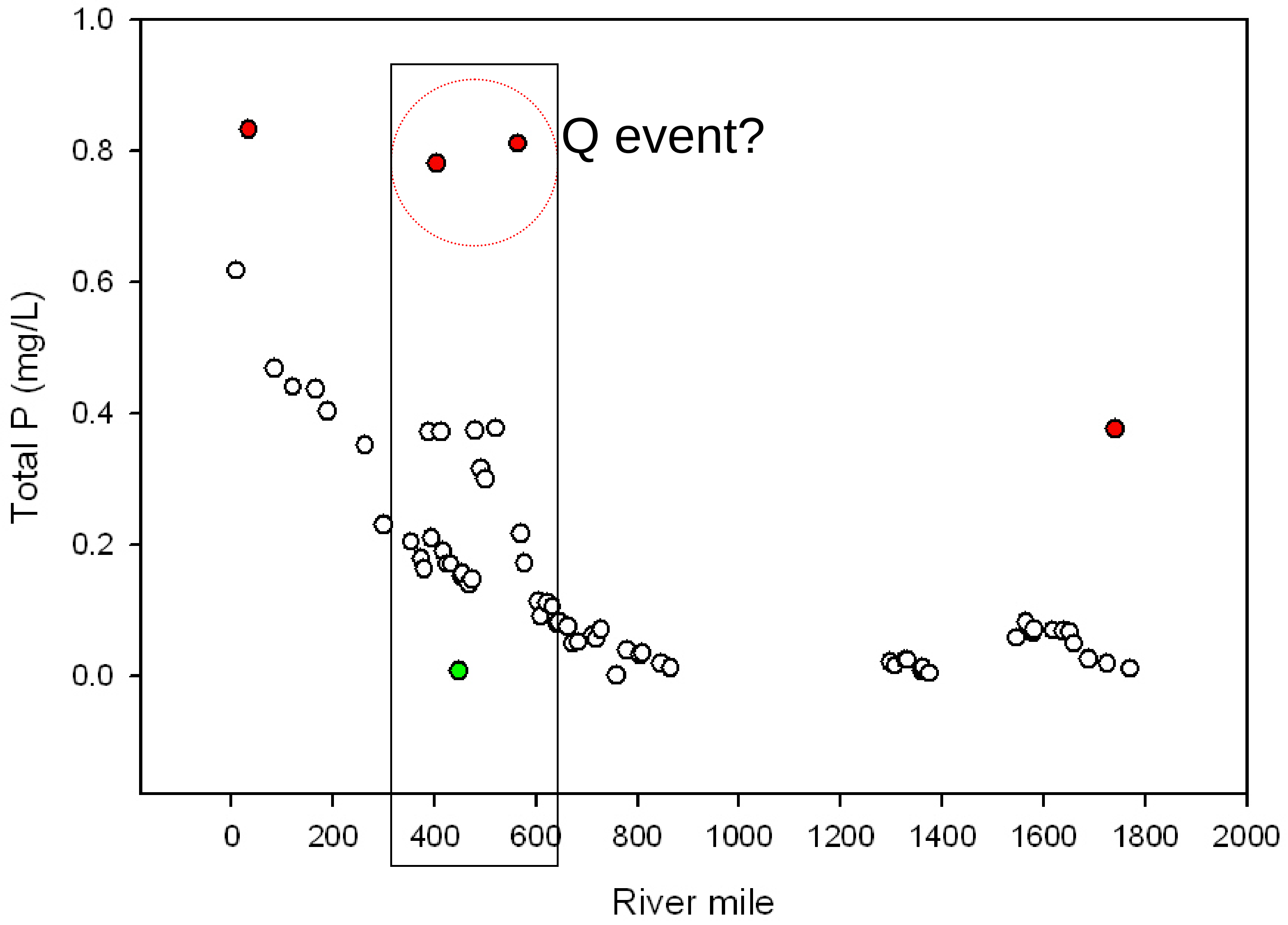




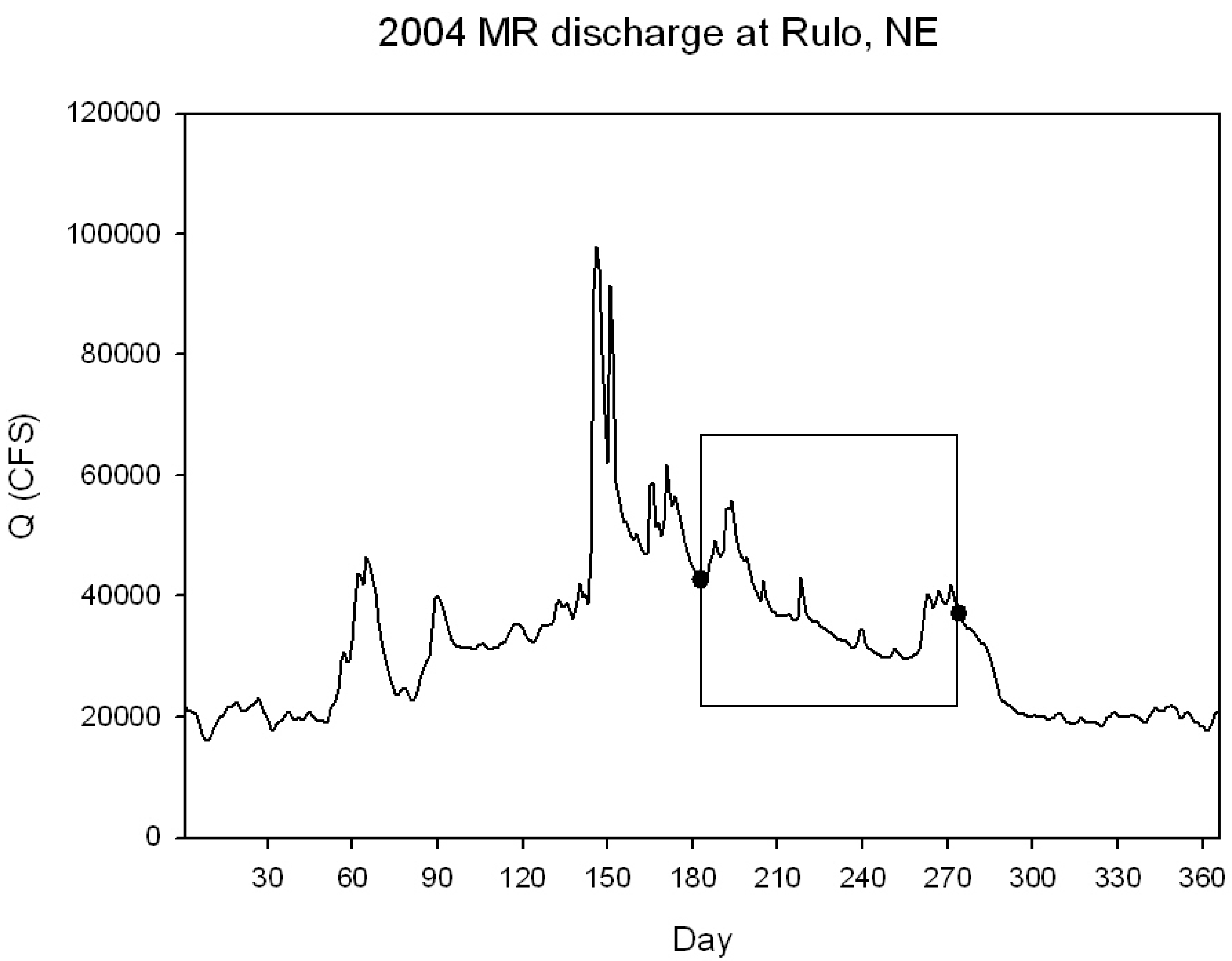
These sites are used to validate approach

Weighting “robust” metrics spreads data out more

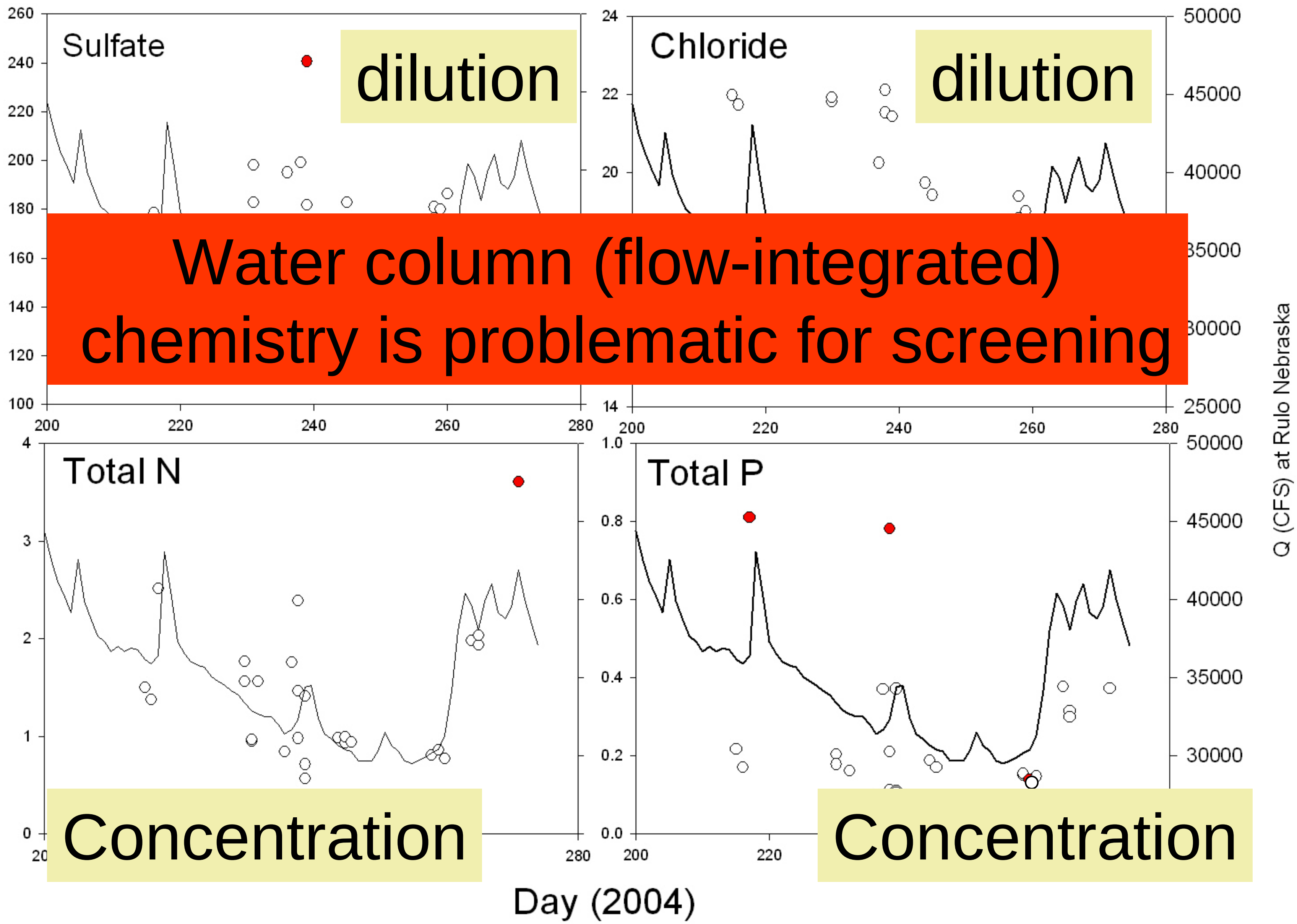
2004 sample data: TP on Missouri River



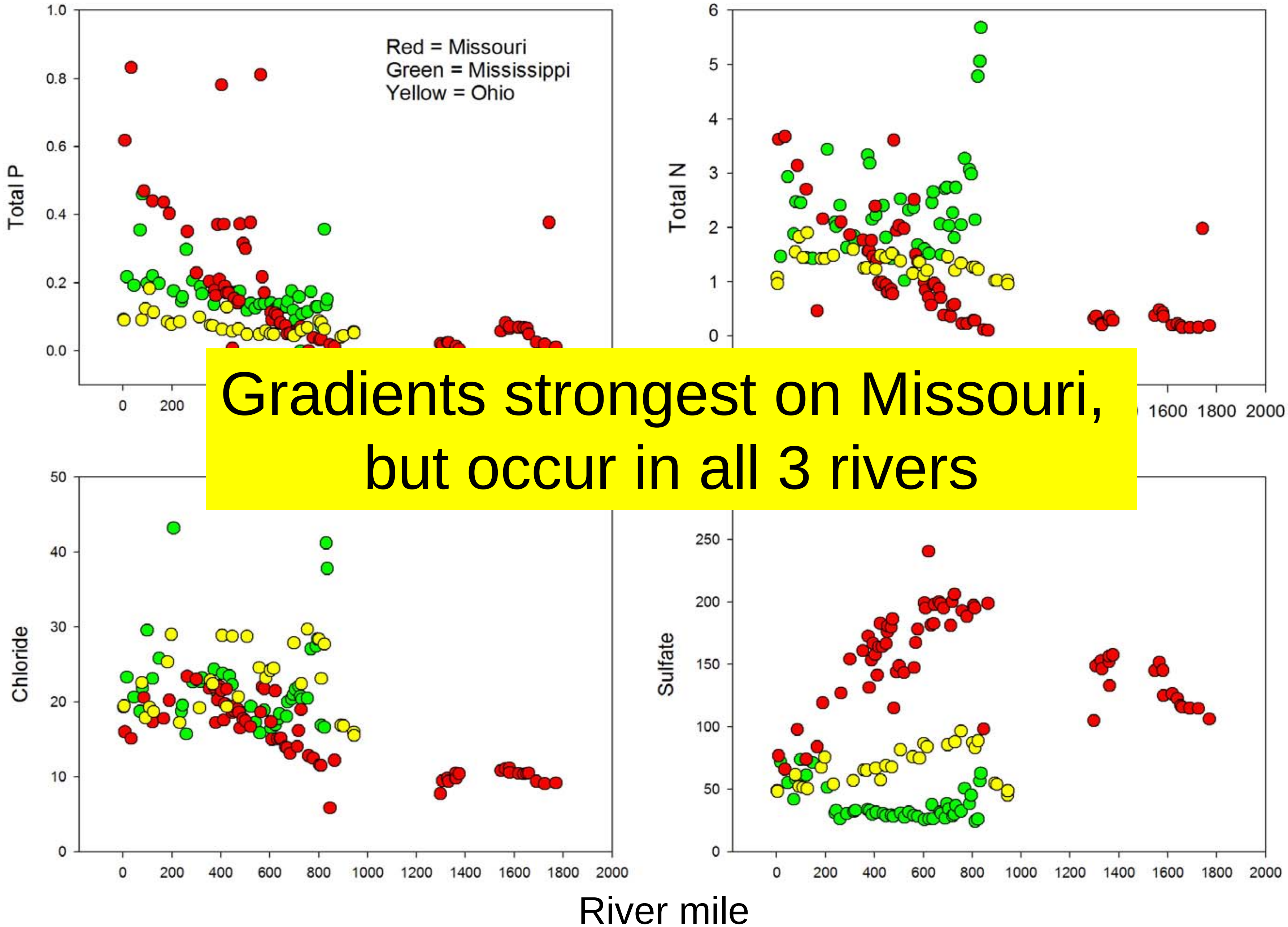
Discharge and WQ



2004 Samples from RM 300 - 650



Water column (flow-integrated) chemistry is problematic for screening



Gradients strongest on Missouri, but occur in all 3 rivers

Multi-metric natural gradient approach:

- Reveals human disturbance masked by natural variation along river
- Essential for some abiotic variables besides WQ.
- Avoids arbitrary “hard” criteria for single metrics.
- Can be used in conjunction with other methods (e.g., pass/fall).
- Its integrative because it includes, WQ, habitat, stressor, and landscape metrics.

Multi-metric natural gradient approach:

- Its robust because its “multimetric” A few event-driven, bad, or missing classifications won’t effect results much.
- But, water chemistry may not be very useful for filtering
- Avoids “bipolar” sites in reference set
- Forces reference sites down the gradient
- Intuitive but untested on large rivers.

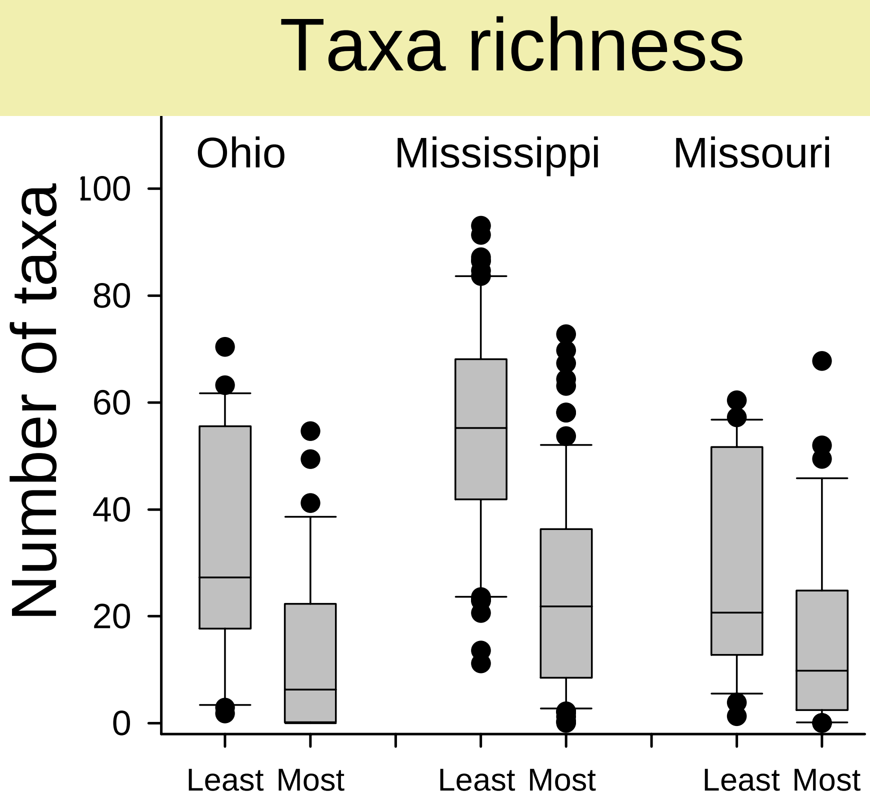
Alternative approach

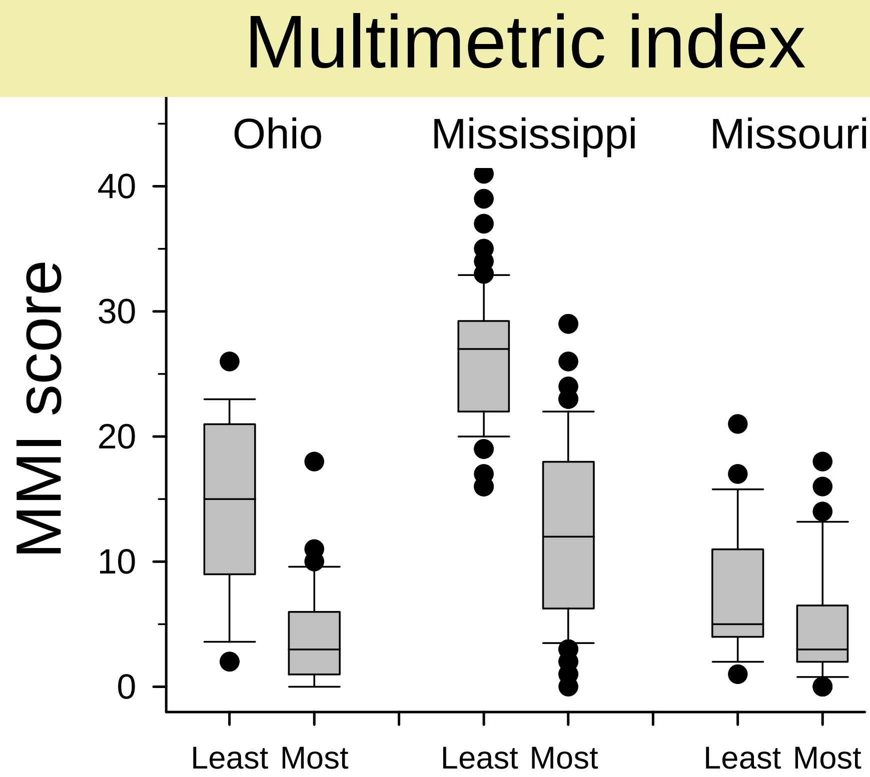
The same data can be explicitly stratified into upper, middle and lower MO and filtered using a series of hard filters (fail 1 filter = not LDC; pass all = LDC).

We will do both and figure out which one gives us the best set of reference sites.

Its research.

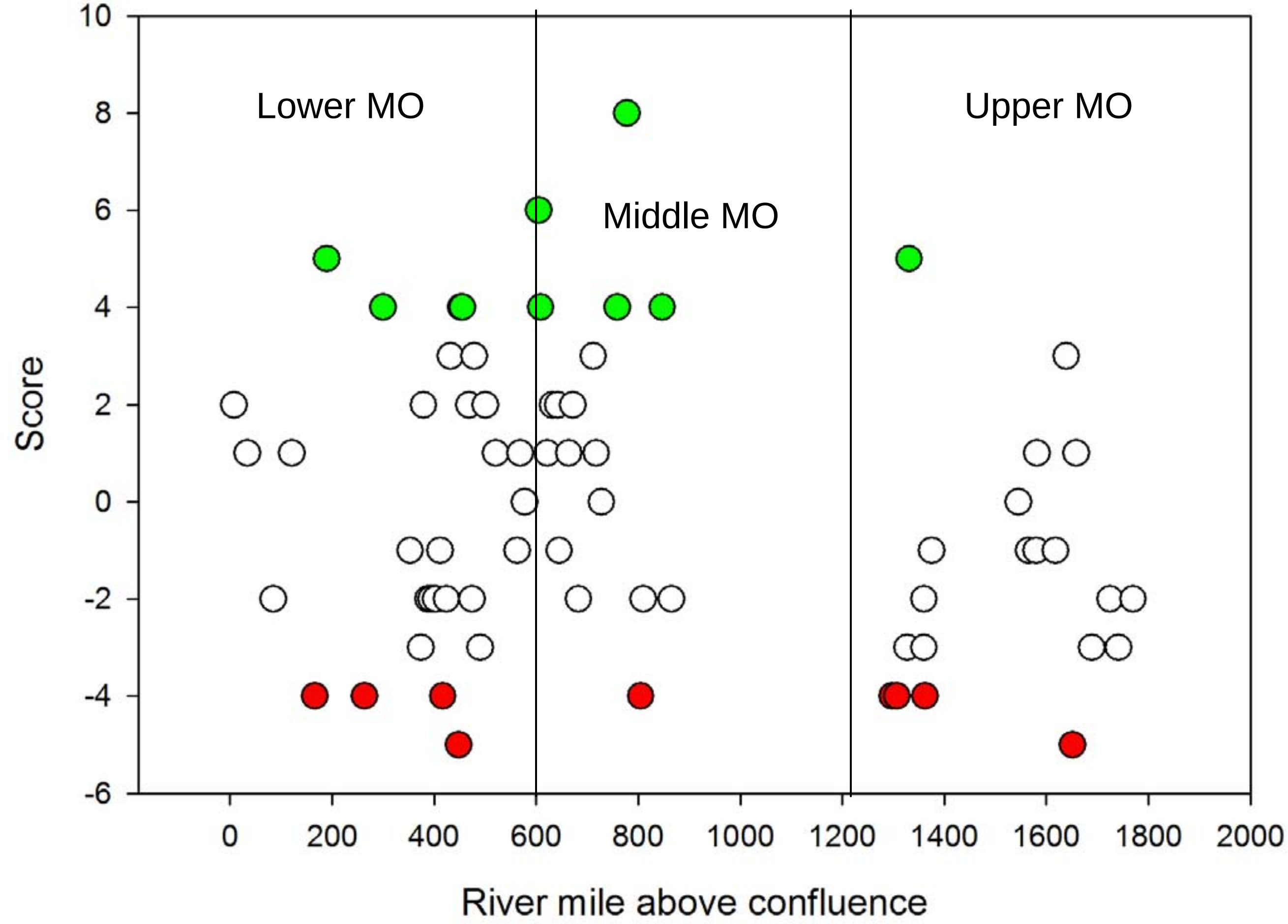
Validation of approach: least vs. most disturbed for a variety of filter options





Not real data

Geographic stratification?



Geographic stratification: different reference expectations for different reaches of the same river

With stratification:

- Expectations more realistic for each strata (=reach)
- Fewer political problems: “don’t assess my state with your reference conditions”
- Requires well dispersed reference sites.

Without stratification:

- Less complicated (only 1 LDC for each river)
- Much higher variation in condition between states
- Reduced credibility of assessment given realities of BAC?

Revetment vs natural shoreline

Should we treat revetment as a substrate-coarsening stress or as a habitat Strata for this assessment so that we can detect other stress?

<u>If we treat it as a human disturbance causing stress:</u>

- Most of the Lower Missouri will automatically be impaired
- Revetment effects will probably swamp out other stressors for benthos at least
- Sets higher but maybe unattainable bar for LDC

<u>If we treat it as a habitat strata:</u>

- Will allow correction for substrate to detect other stressor effects.
- Sets low bar for current system, but we can report the extent of rip rap and, if we restore a shoreline, we can switch to the other reference expectation
- Requires more sites (3 geog strata * 2 hab strata = 6 expectations for Missouri)

Some pending issues

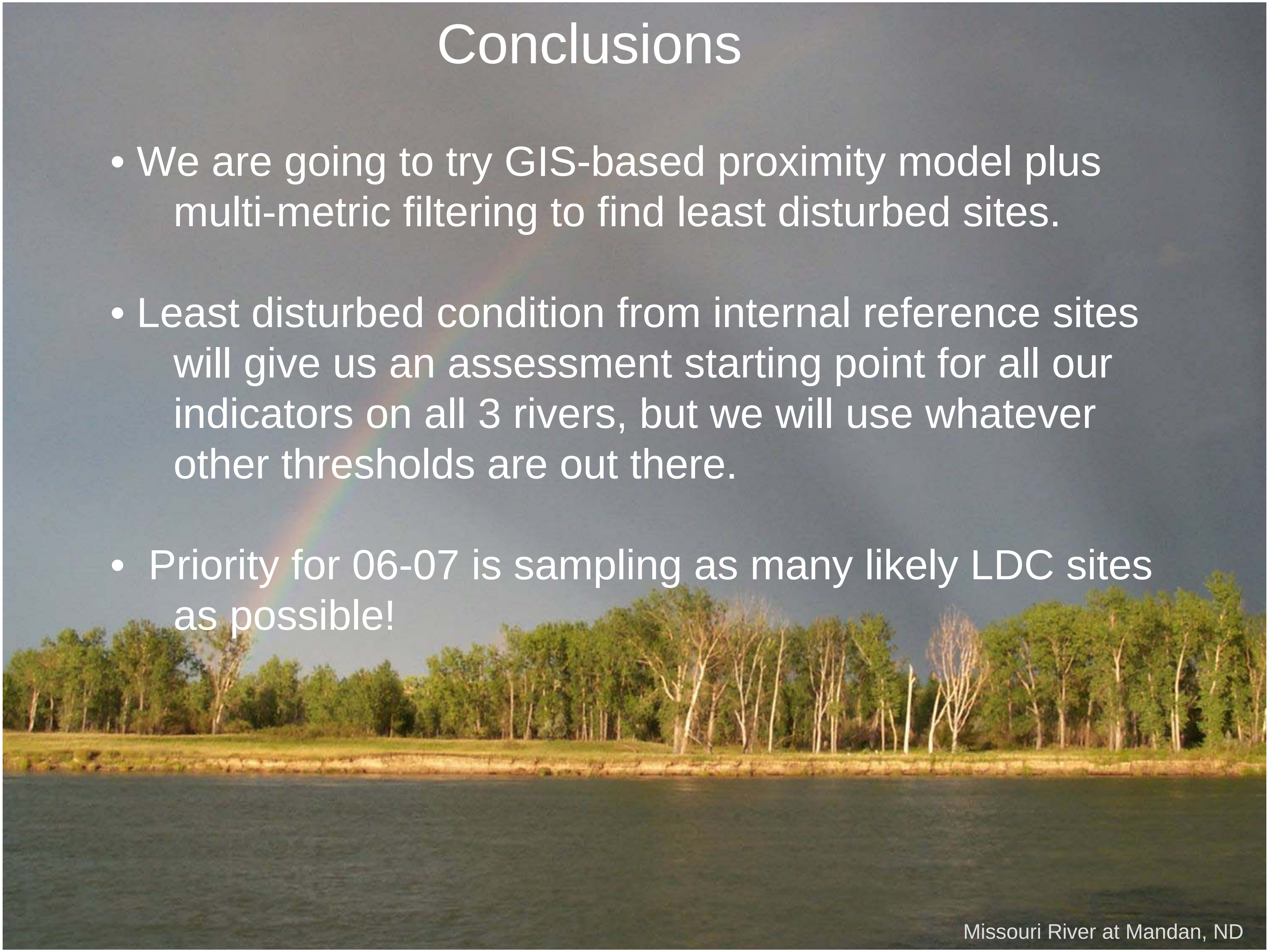
- Should we stratify habitat for revetted vs. natural shorelines? (yes)
- Which variables from GIS model should we add to the filter? (NPDES, tribs, dams)
- Should we downweight or eliminate WQ metrics from filter because of the thalweg bias and discharge effect? (eliminate most)
- What is sufficient sample size? (lots more)

Conclusions

- We are going to try GIS-based proximity model plus multi-metric filtering to find least disturbed sites.

- Least disturbed condition from internal reference sites will give us an assessment starting point for all our indicators on all 3 rivers, but we will use whatever other thresholds are out there.

- Priority for 06-07 is sampling as many likely LDC sites as possible!



Missouri River at Mandan, ND