EMAP-GRE reference condition: concepts and results of data exploration

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Biological Indicators Workshop

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Topics

- Least disturbed condition and the EMAP-GRE assessment
- Stratification of reference condition
- Stressor metrics useful for screening
- Models for screening

The assumption

"Regardless of the extent of human disturbance in a region, some stream sites will have less human disturbance than others and these yield the best existing [or least disturbed] conditions"

Stoddard et al. 2006

Internal reference condition

"[On] large rivers, reference sites may be upstream of major sources of disturbance or as far as possible from upstream sources, cities, and dams"

Hughes 1995

In 2006 we tried to find and sample those sites

We have sampled all the sites and now we need to screen them to identify reference sites

- Iterative process to determine which sites are in “least disturbed condition” (LDC).
- Select reference sites that are representative of the full range of healthy conditions in each river/reach and are consistent with the objectives and reporting units for EMAP-GRE

Least Disturbed Condition

- Sites with “the best available physical, chemical and biological habitat conditions given today’s state of the landscape” (Stoddard *et al.* 2006)
- EMAP-GRE assessment will be based on least disturbed conditions (LDC) by default. Other thresholds based on best attainable condition or whatever will be incorporated as available.

Metrics for screening

- Important theme of this meeting
- Large number of potential metrics
  - Stressor metrics
  - Human disturbance metrics
  - Biological metrics

Some of the many available EMAP-GRE stressor/human disturbance metrics

Metric class	Metric	Relationship to condition
Water chem	Total P	Negative
Water chem	Total N	Negative
Water chem	Sulfate	Negative
Water chem	Chloride	Negative
Water chem	DO	Positive
Water chem	Turbidity	Negative
Water chem	Total dissolved metals	Negative
Exposure	Sedtox (amphipod survival)	Negative
Phab	LWD density (fish habitat)	Positive
Phab	Development score	Positive
Phab	Human influence index	Negative

Screening metrics, cont.

Metric Class	Metric	Relationship to condition
Phab	Riparian disturbance index	Positive
Phab	Vegetative cover index	Positive
Biology	Percent DELT anomalies	Negative
Landscape	Route distance upriver to dam	Positive
Landscape	Route distance upriver to NPDES	Positive
Landscape	Route distance upriver to large trib	Positive
Landscape	Route distance upriver to small trib	Positive
Landscape	Local percent cultivated (5 k radius)	Negative
Landscape	Local percent forest + wetland (5 k radius)	Positive
Landscape	Local impervious surface (5 k radius)	Negative
Landscape	Local watershed LU/LC metrics TBD	na

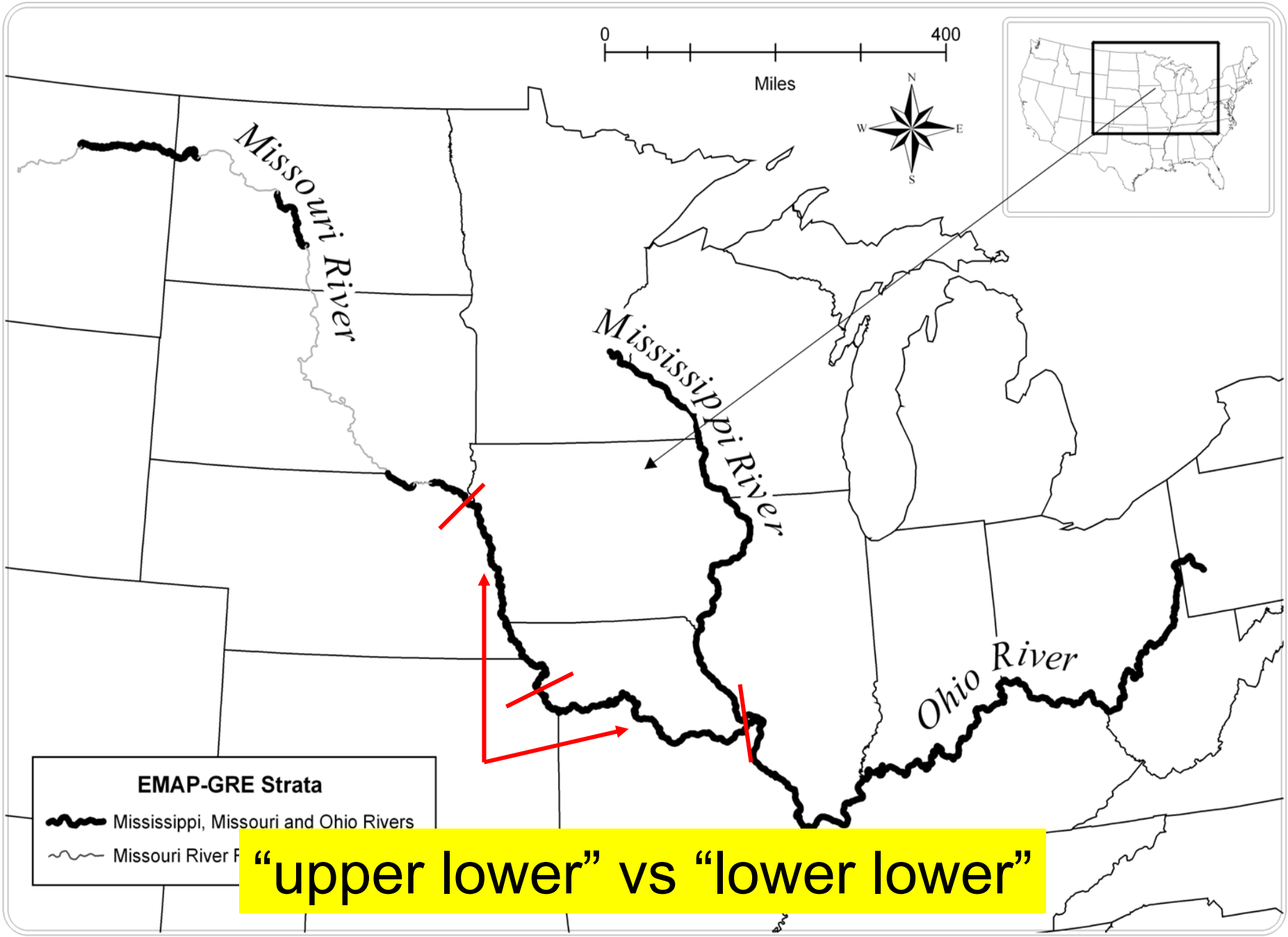
* Metrics in yellow included in screening examples

Most screening metrics have issues

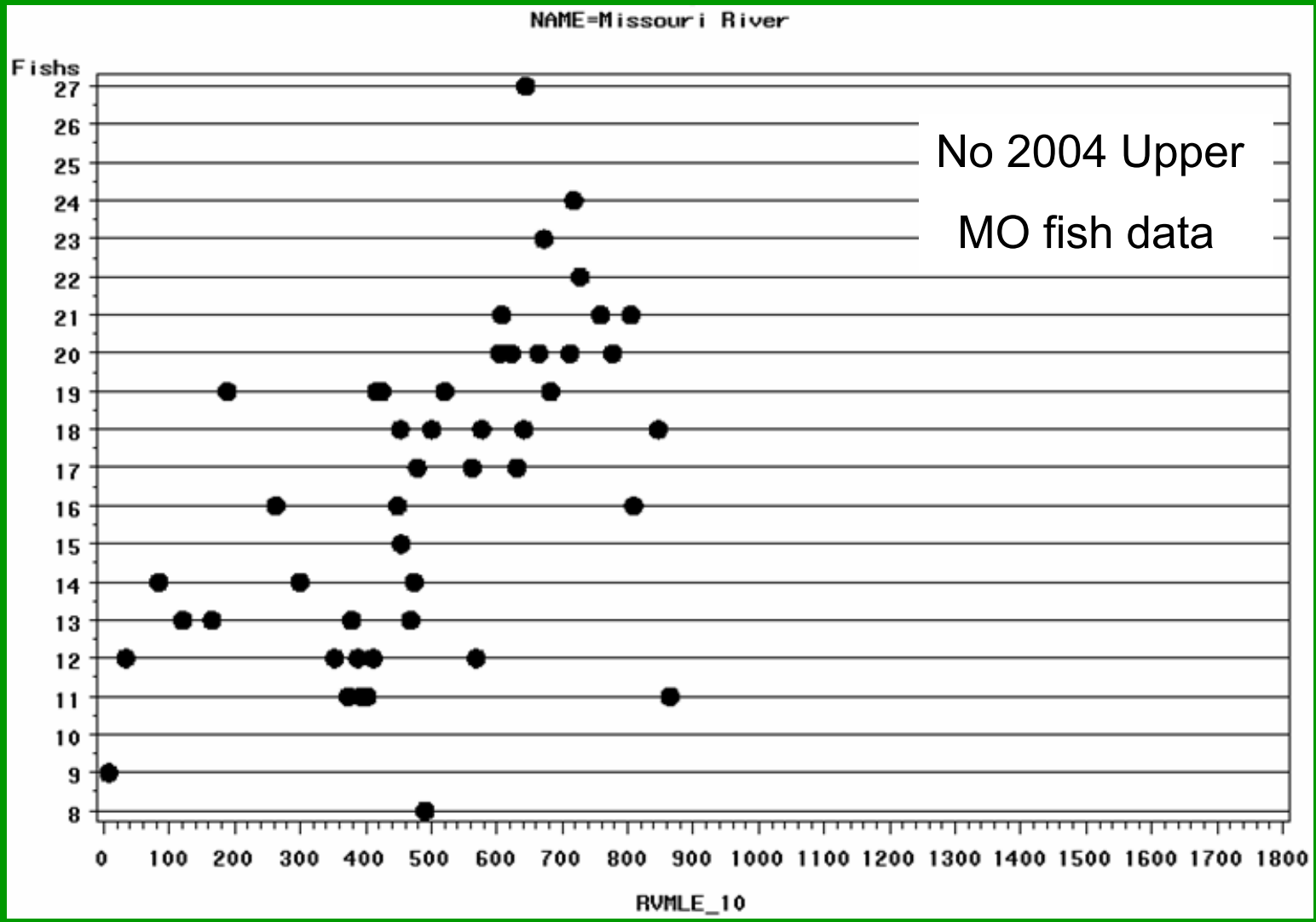
- Some have reach-specific significance (LWD)
- Some have river-specific patterns (turbidity)
- Some have lots of missing values
- Metrics likely vary in strength of relationship to biotic assemblages
- Some may be discharge - sensitive (nutrients, ions)
- All are flawed, so using multiple metrics is more reliable

Stratification of reference condition and the assessment

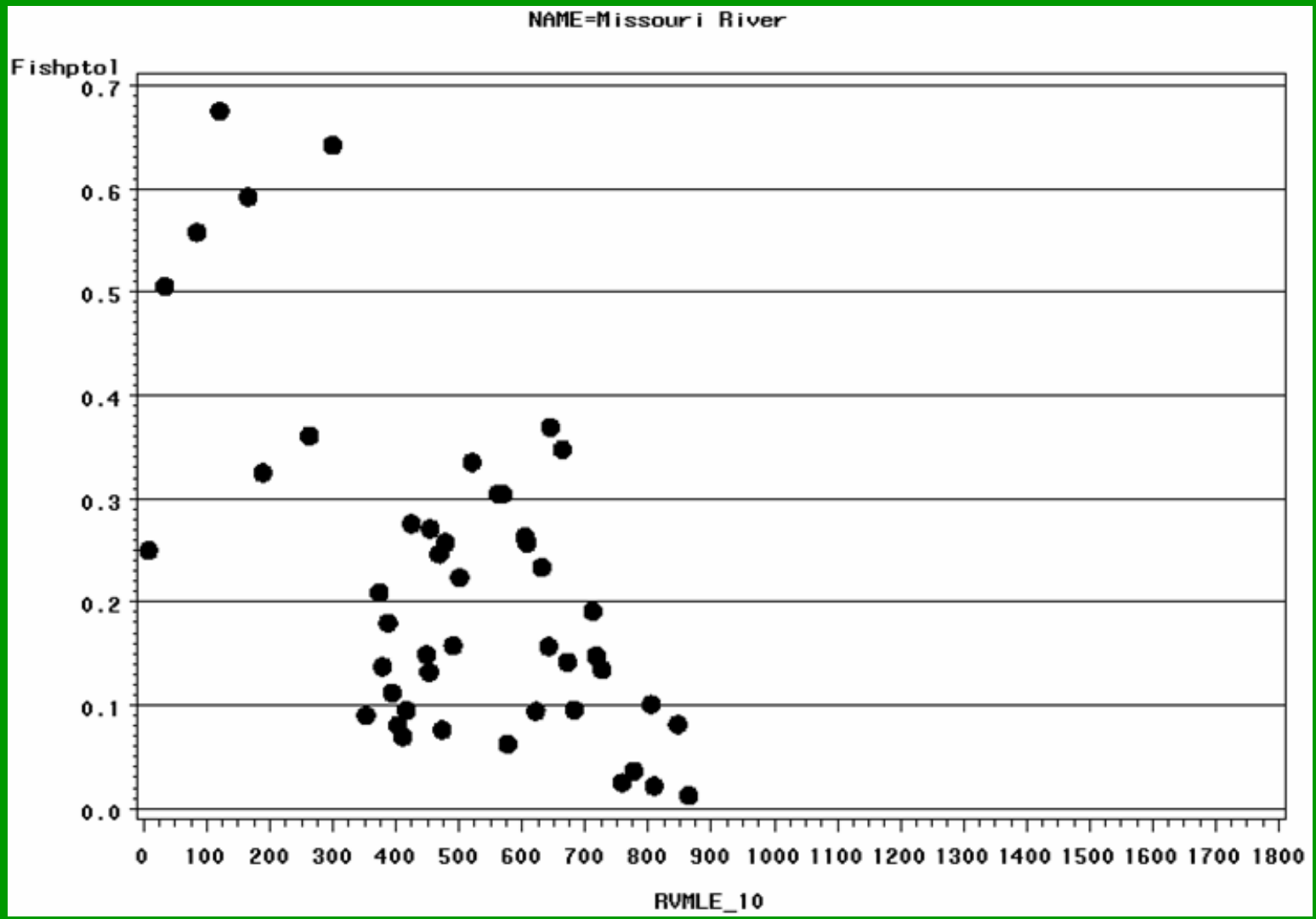
- Stratification = different reference sites for different reaches or aquatic habitats
- Geographic stratification will influence the condition assessments because there will be longitudinal patterns in condition. So there are policy implications of stratification.
- E.g., the “lower” lower Missouri will likely be in worse condition than the “upper” lower Missouri if they are judged by the same (unstratified) reference condition.



"upper lower" vs "lower lower"



Longitudinal variation in fish species richness



Longitudinal variation in % tolerant individuals

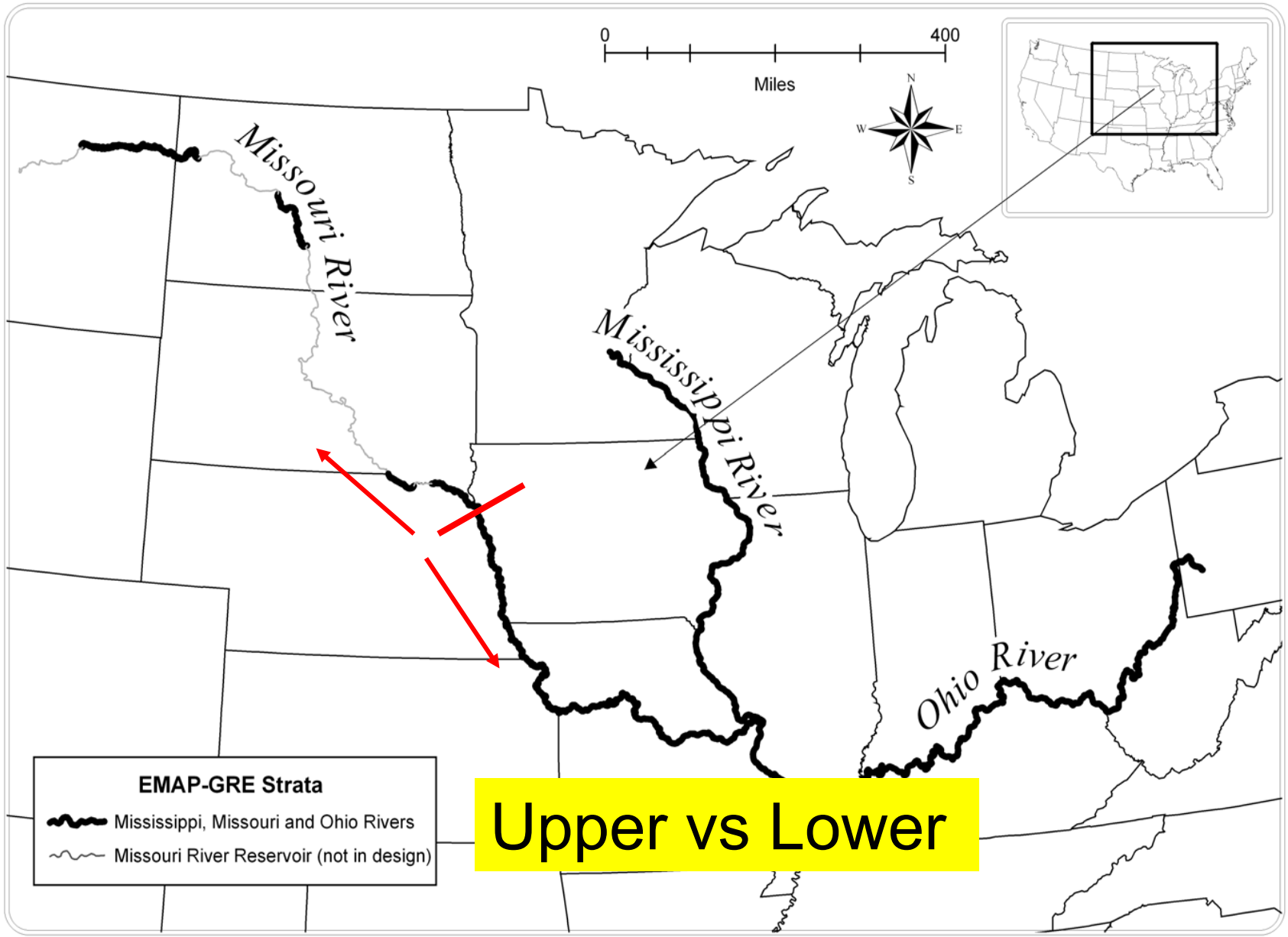
Stratification, continued

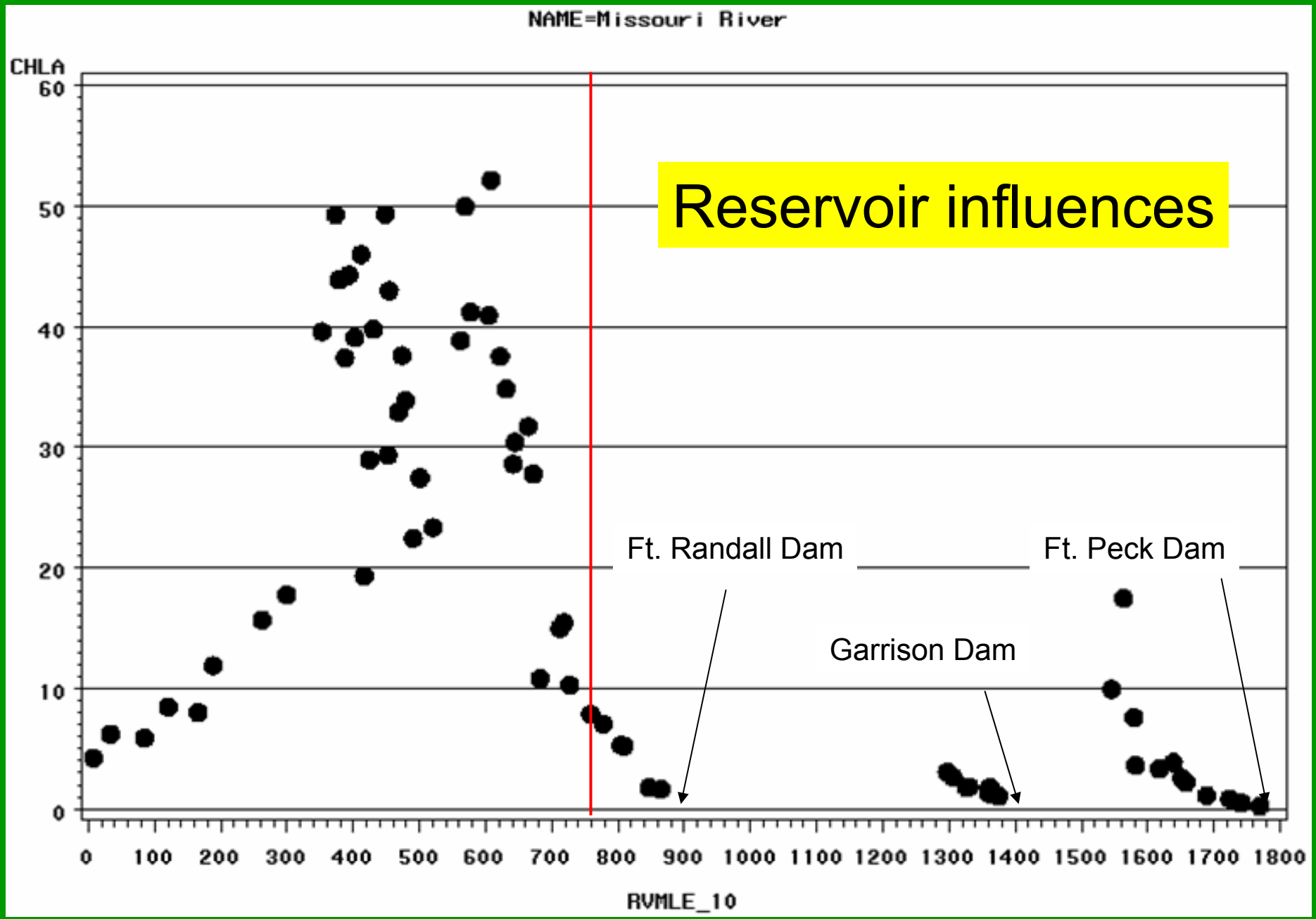
- These differences would be partially masked by geographic stratification of reference (within the lower Missouri) because LDC on a more impacted reach will be more disturbed than LDC on a less impacted reach.
- More strata will reduce confidence in condition thresholds because of lower N so we should use stratification judiciously.
- Strata ≠ reporting units. Strata-specific condition class thresholds can be “behind the scenery”.

Geographic stratification of Missouri River

- Large differences in stressor metric values between Upper and Lower Missouri River
- Upper Missouri= ?
  - above Ponca (above the last dam tailwater)
  - Above Lake Oahe (above the last large dam)
- Upper River strongly influenced by large deep-release reservoirs; little industry, urban, or riprap
- Aridity gradient: 16 degrees longitude end to end (OH = 9)
- A qualitative vs. a quantitative difference

Extent of EMAP-GRE Phase I

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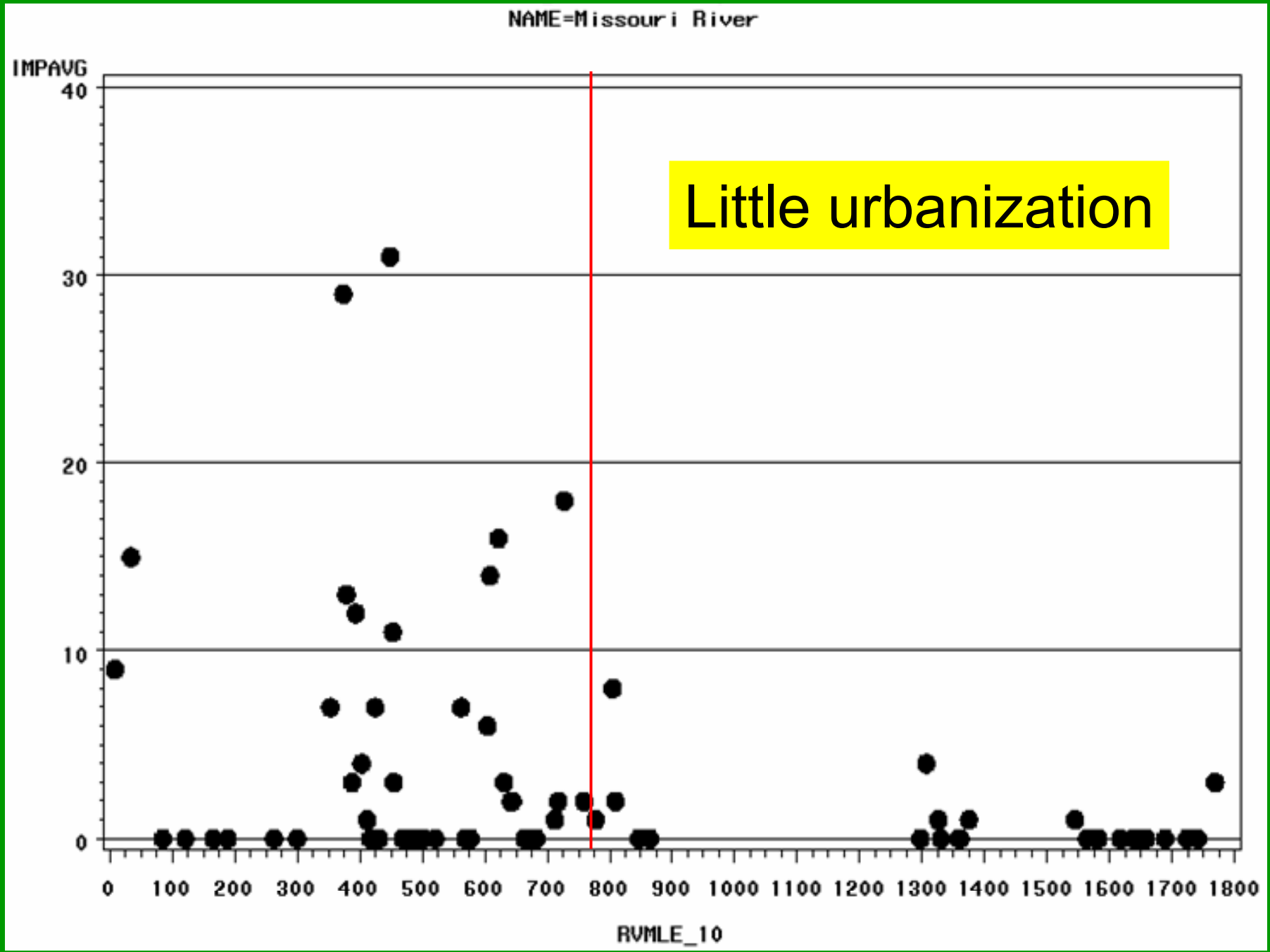
CHLA
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
RVMLE_10
Reservoir influences
Ft. Randall Dam
Garrison Dam
Ft. Peck Dam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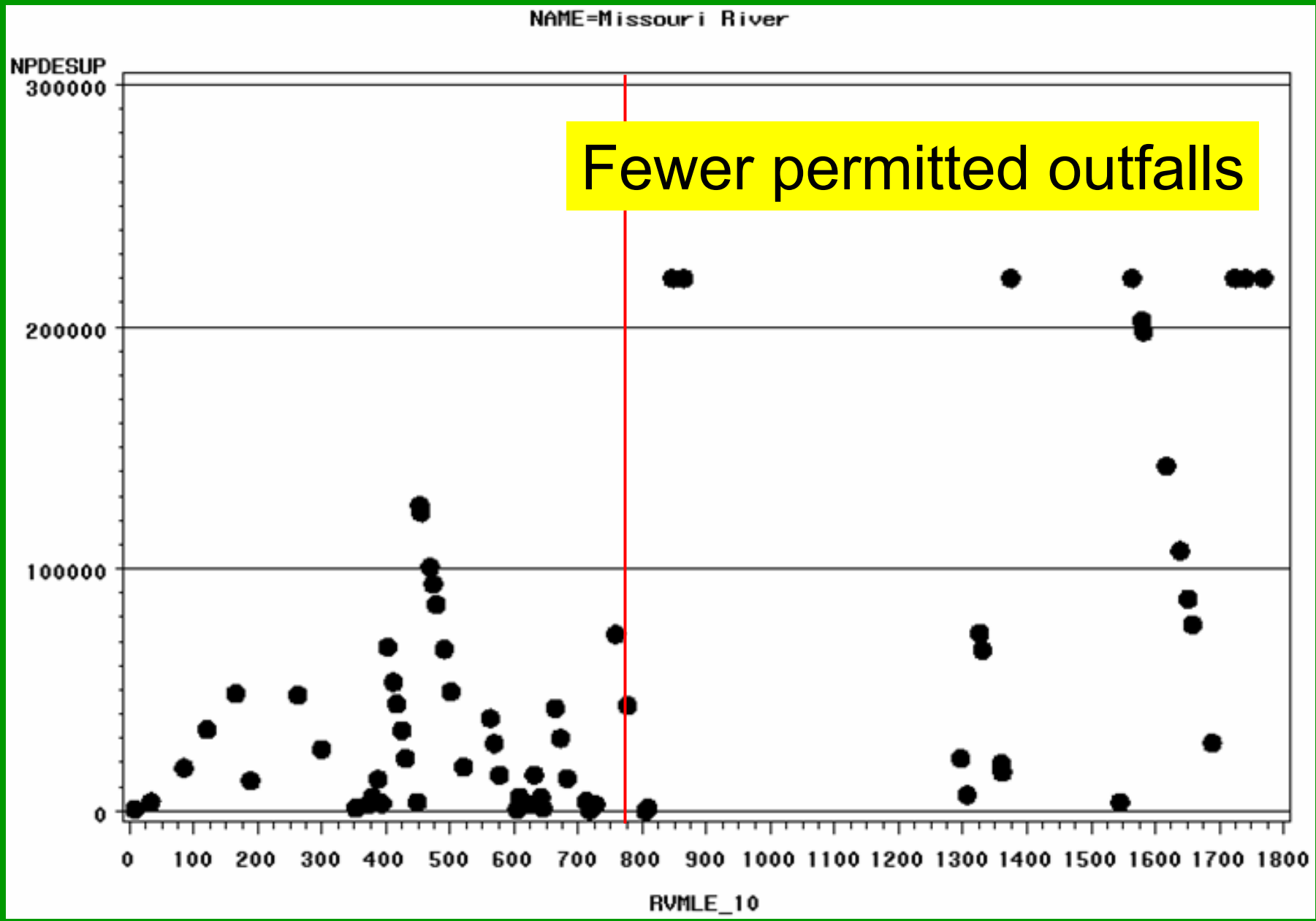
IMPAVG
40
30
20
10
0
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800
RVMLE_10
Little urbanization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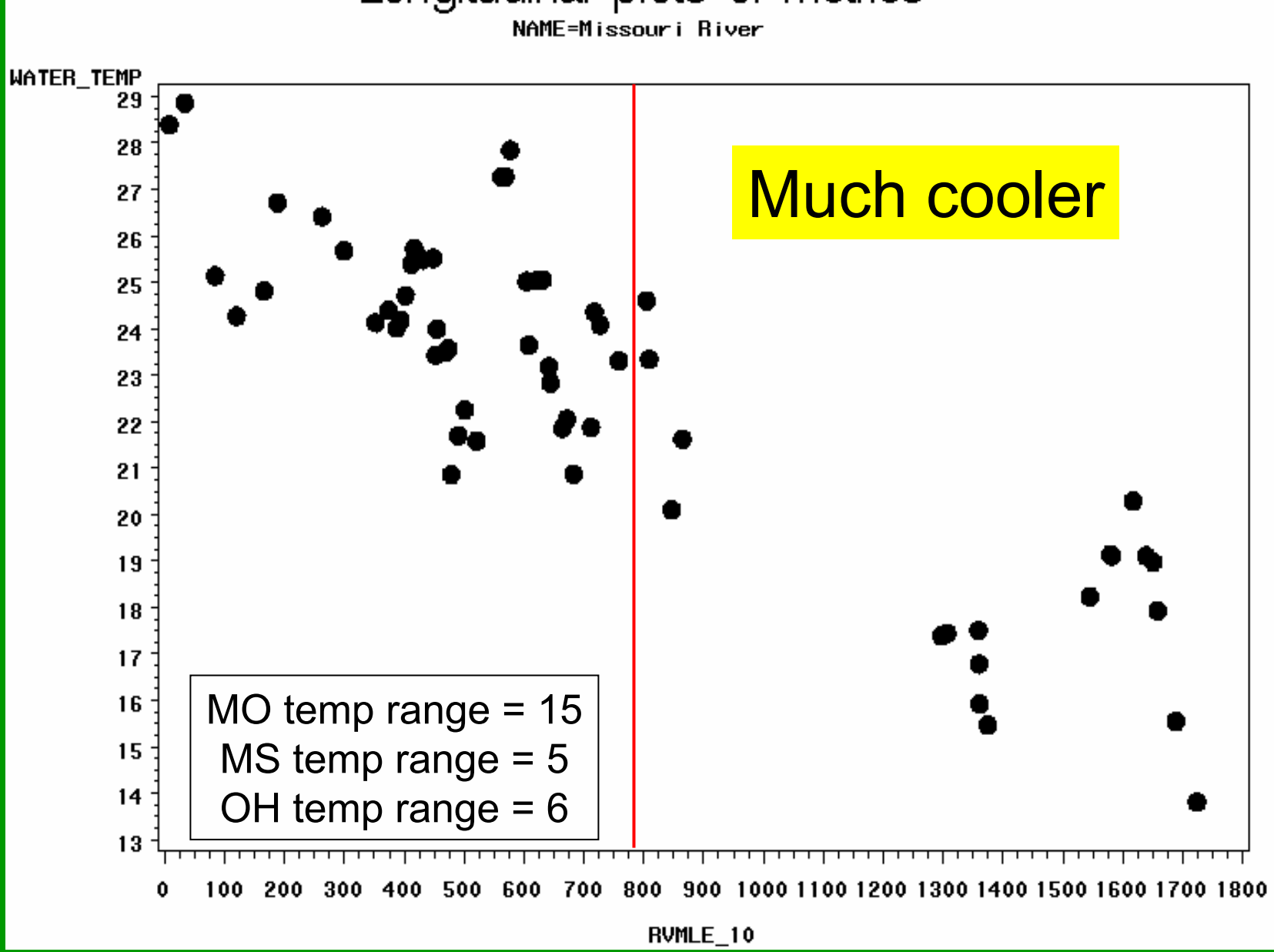
NPDESUP
300000
200000
100000
0
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800
RVMLE_10
Fewer permitted outfalls



The Upper Missouri River is different

Consequences of not stratifying LDC on Missouri River

- Upper river sites probably over-represented in reference set if not stratified.
- But these sites are not really in LDC relative to the lower river because of the dams and related effects
- Assessing the lower river using (mostly) upper river reference criteria problematic politically
- Similar issues on Mississippi (?) but geographic stratification potential might be limited by sample size.

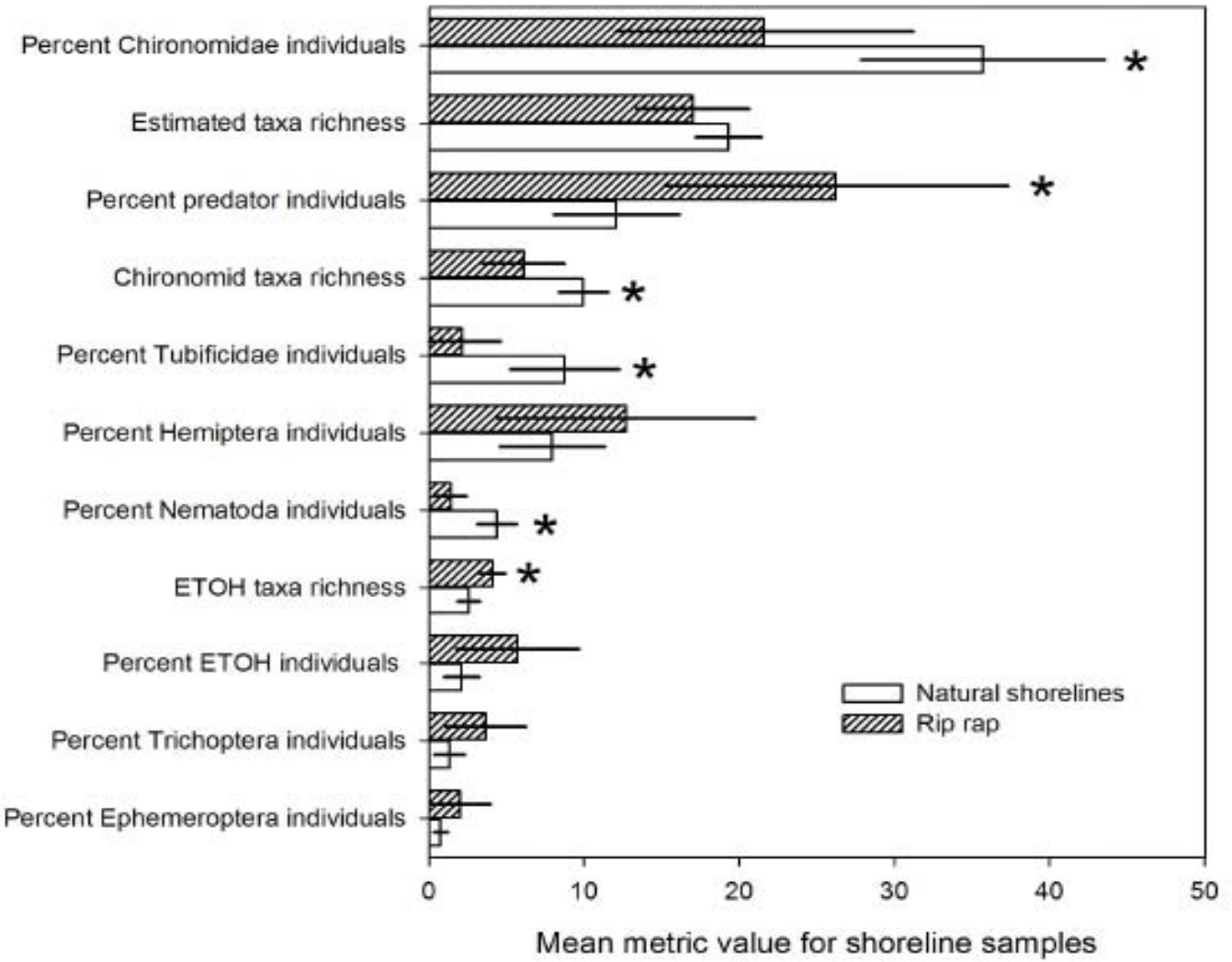
Habitat stratification

Important because variation among widespread and “permanent” aquatic habitats may be greater than variation due to stressors

riprap

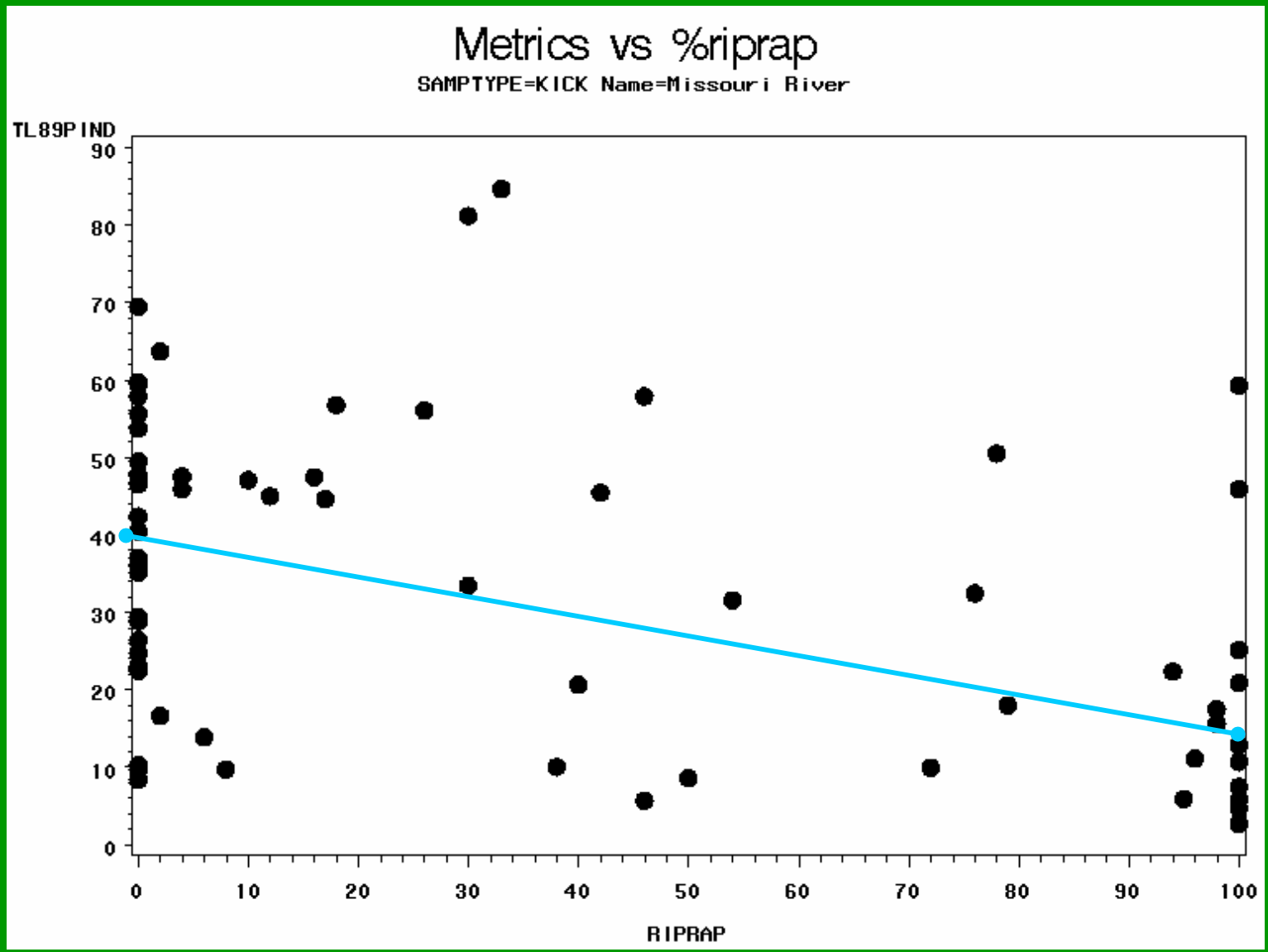
“natural”

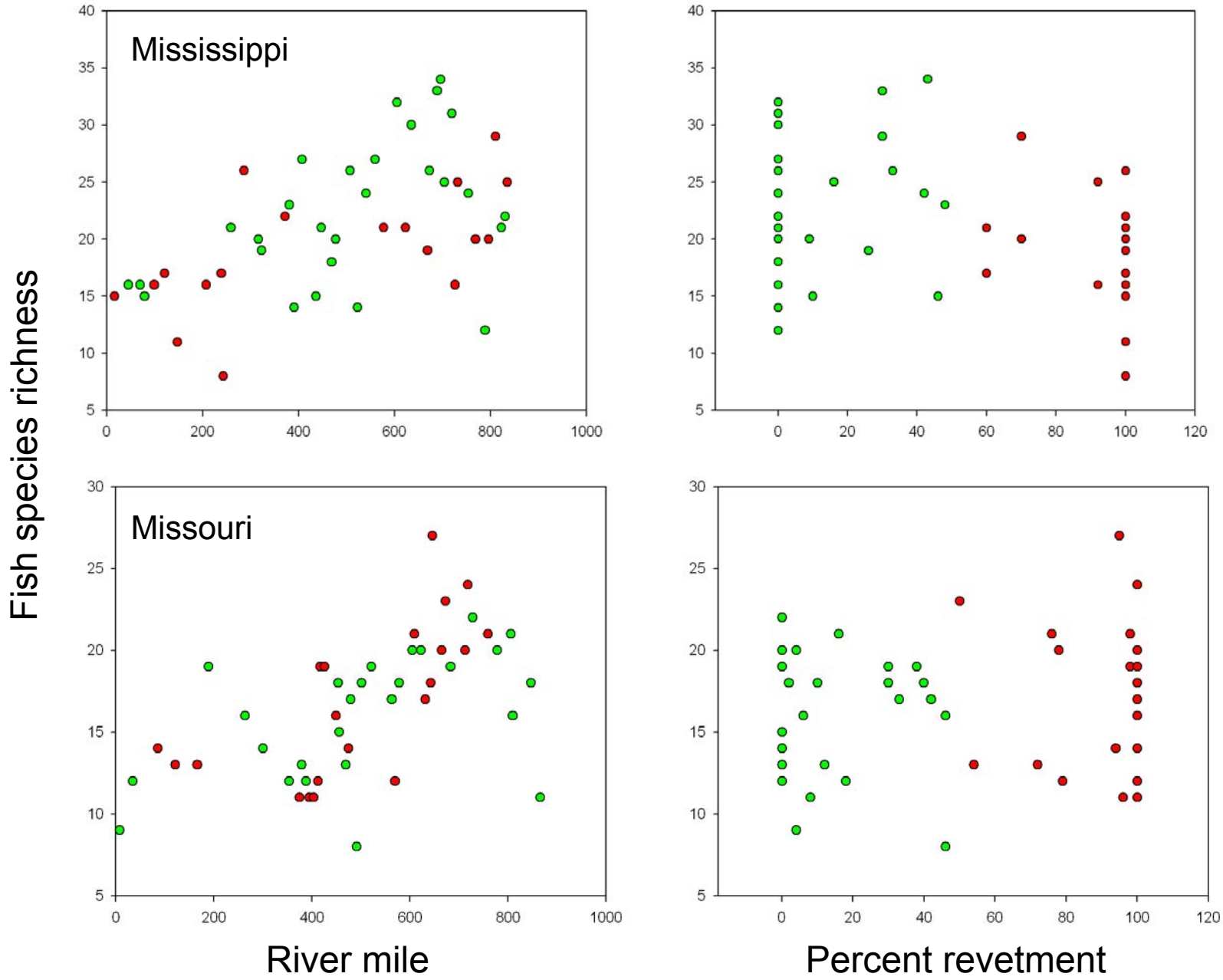
There is plenty of evidence for a strong riprap effect on the structure of Great River invertebrate assemblages



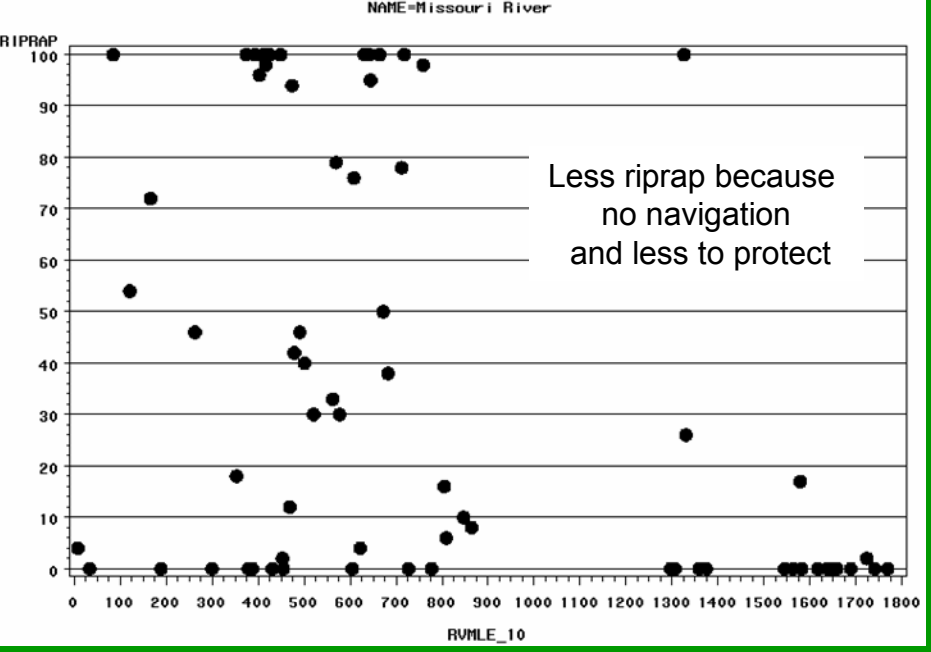
From Angradi et al., submitted

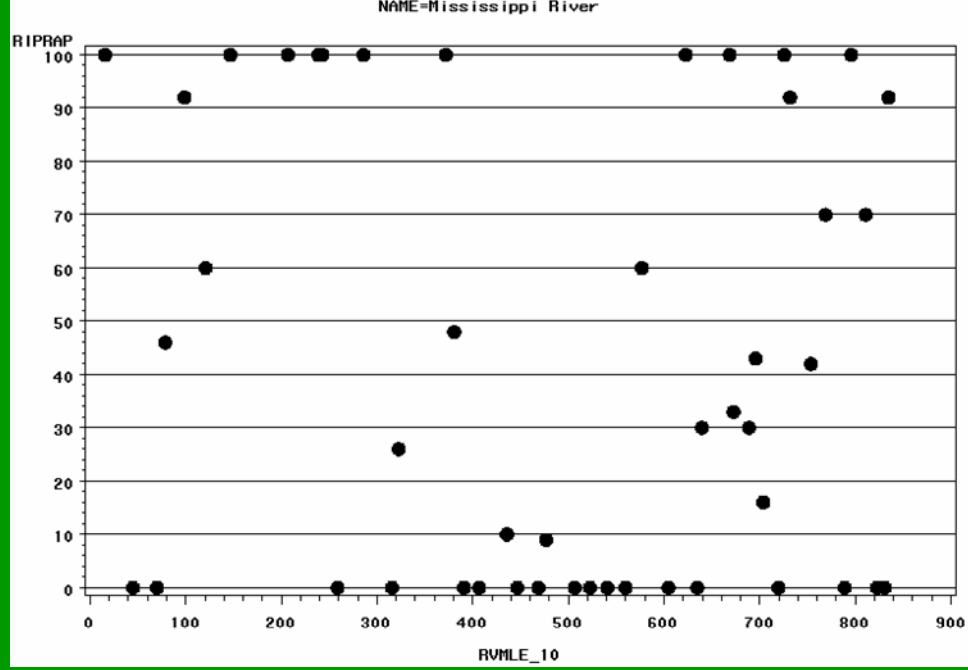
Strong effect of riprap on the percent pollution tolerant invertebrates…But riprap isn't pollution

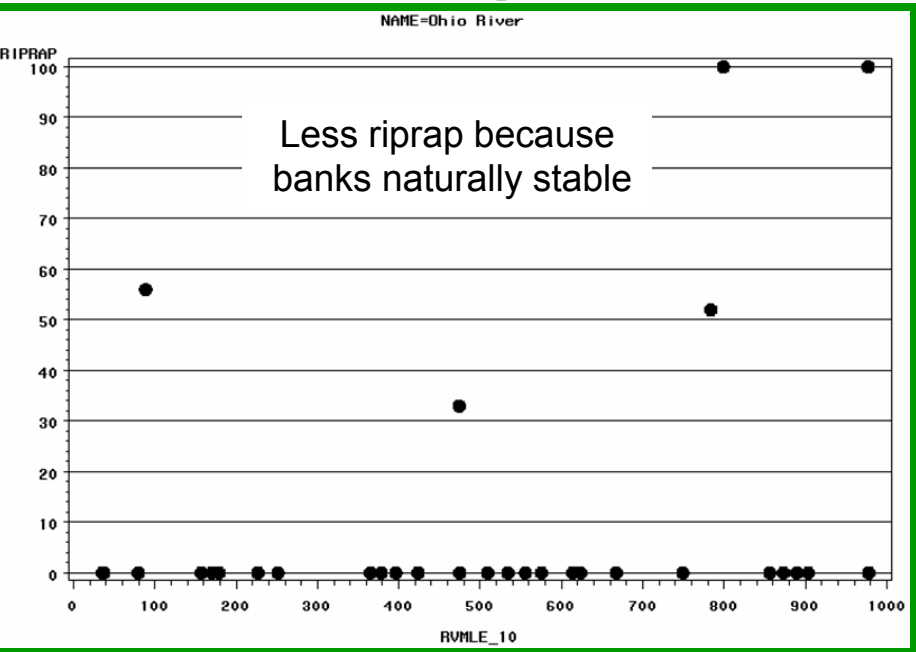




Effect of riprap on fish assemblages less clear







Revetment patterns vary among rivers

Reality check

Habitat stratification may be essential because if we assume riprap is a stressor rather than a habitat strata, then riprap would drive invertebrate indicator development because I don't think we can build IBIs that will "ignore" the riprap to indicate condition independent of dominant shoreline substrate.

* Problem most severe on Missouri River; nav pools seem to reduce riprap effects

- Mississippi
  - longitudinal strata not essential
  - *Possibly* 2 habitat strata (>50% revetment and <50% revetment)
  - pools vs open river (=185 miles) needs discussion

- Missouri
  - 2 reach strata (e.g., above and below Ponca)
  - 2 habitat strata (e.g., >50% revetment and <50% revetment)

- Ohio
  - no longitudinal or revetment strata
  - ORSANCO-type substrate strata

For assessment purposes…

- This means potential for different condition class thresholds for each strata for invertebrates.
- Condition class thresholds for biota not effected by riprap could be determined for the pooled set of riprap and non-riprap reference sites.
- Results still reported out by river and state, not by strata.
- Habitat stratification improves spatial representativeness
- Can and will still report out %revetment for all reporting units.
- Multivariate exploration of assemblages of reference sites will clarify stratification picture (NMDS)

Approaches to screening

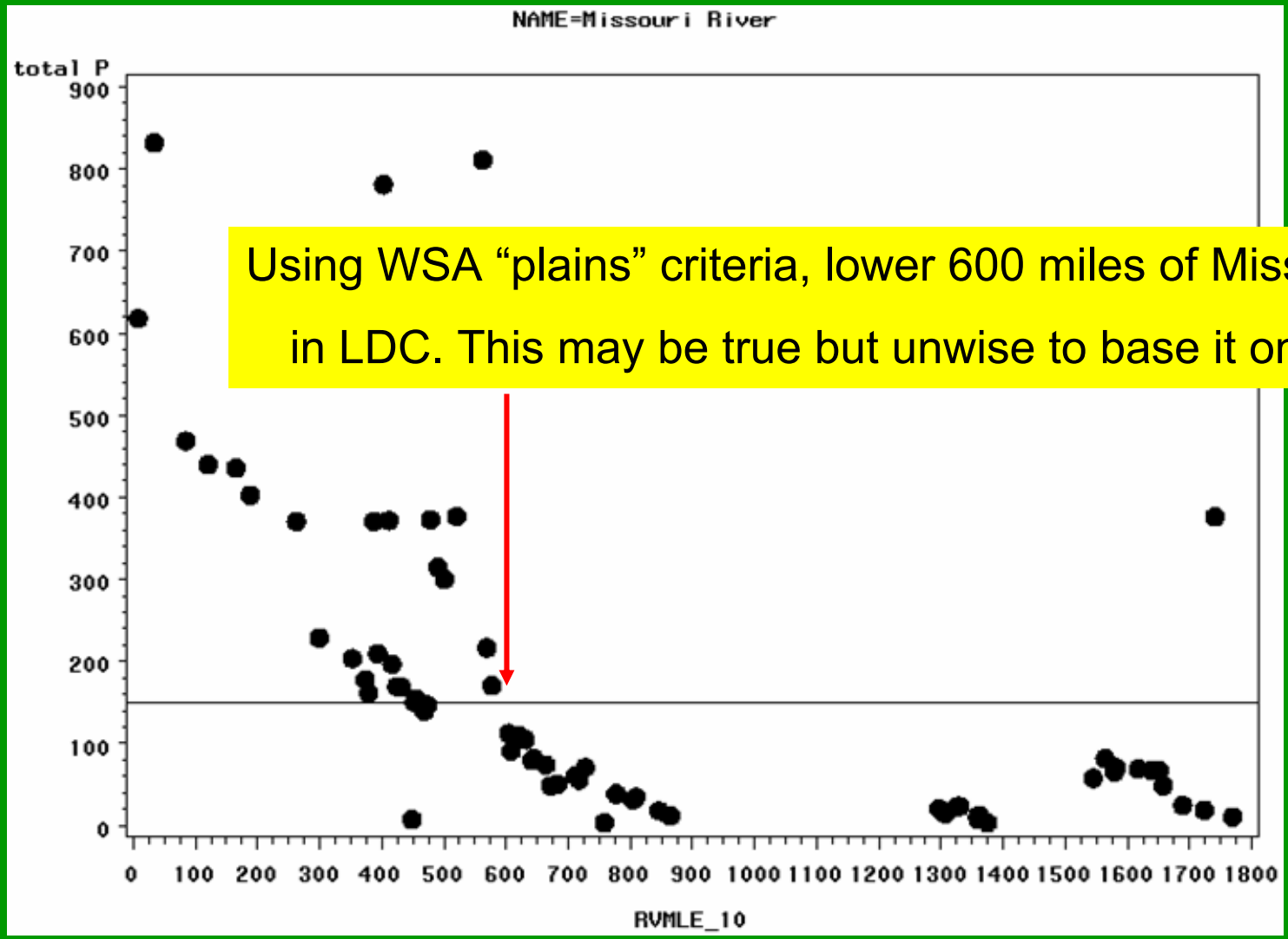
Example of pass/fail screening for wadeable streams

For EMAP wadeable stream datasets, the reference sites are generally screened on chemistry and physical habitat variables with region-specific criteria.

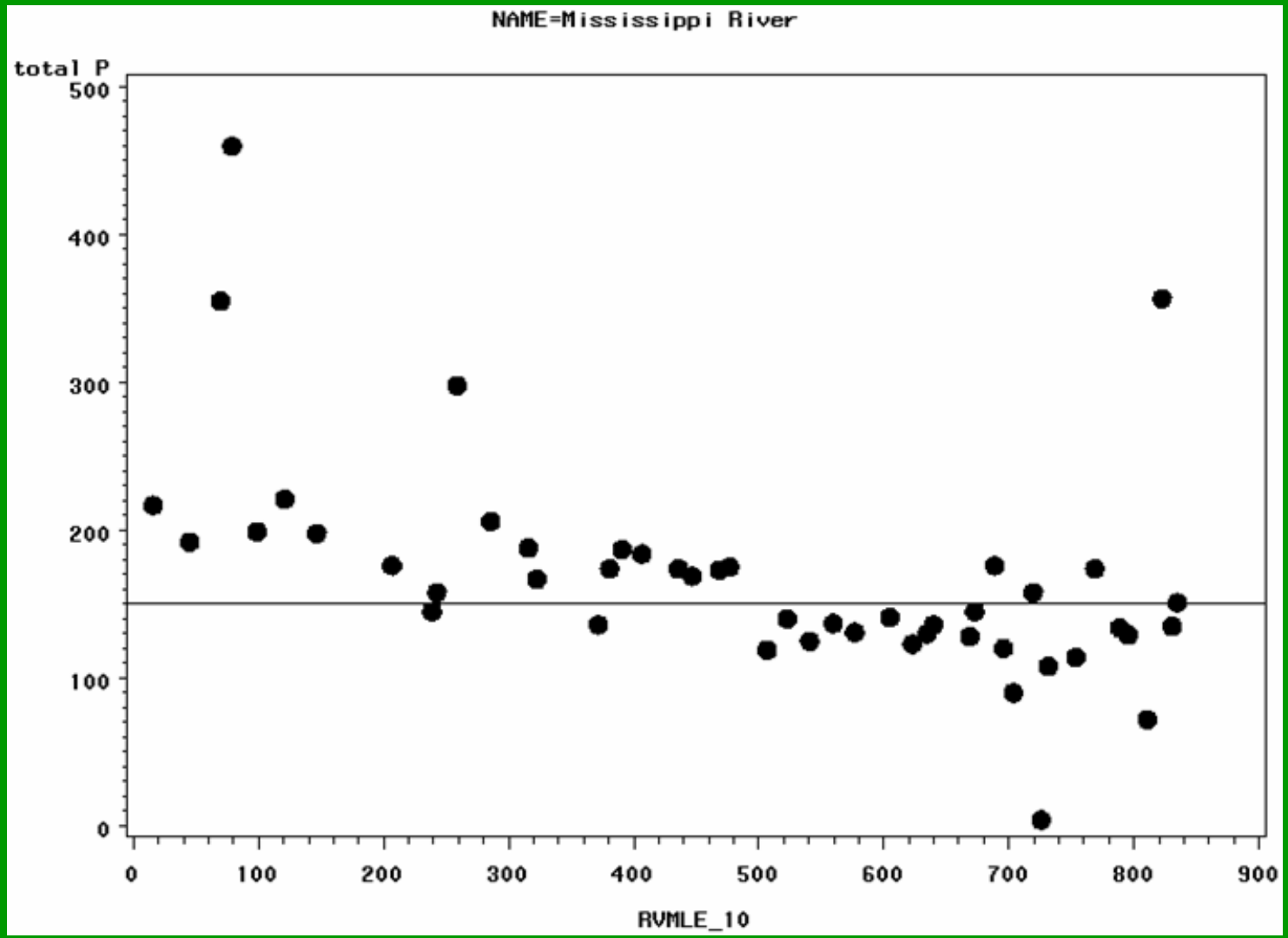
Agg.Region	Corrected Cl	Total P	Total N	Sulfate	Turbidity	pH	% Fines	Rip. Disturbance	Canopy Density
Southwest Mtns	<300 ueq/L	<50 ug/L	<750 ug/L	--	--	<9.0	<15%	<0.5	>50%
Northwest Mtns.	<1000 ueq/L	<50 ug/L	<4500 ug/L	<2000 ueq/L	<50 PCU	<9.0	<50%	<1.5	>50%
So. Rockies	< 200 ueq/L	<25 ug/L	<750 ug/L	<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%

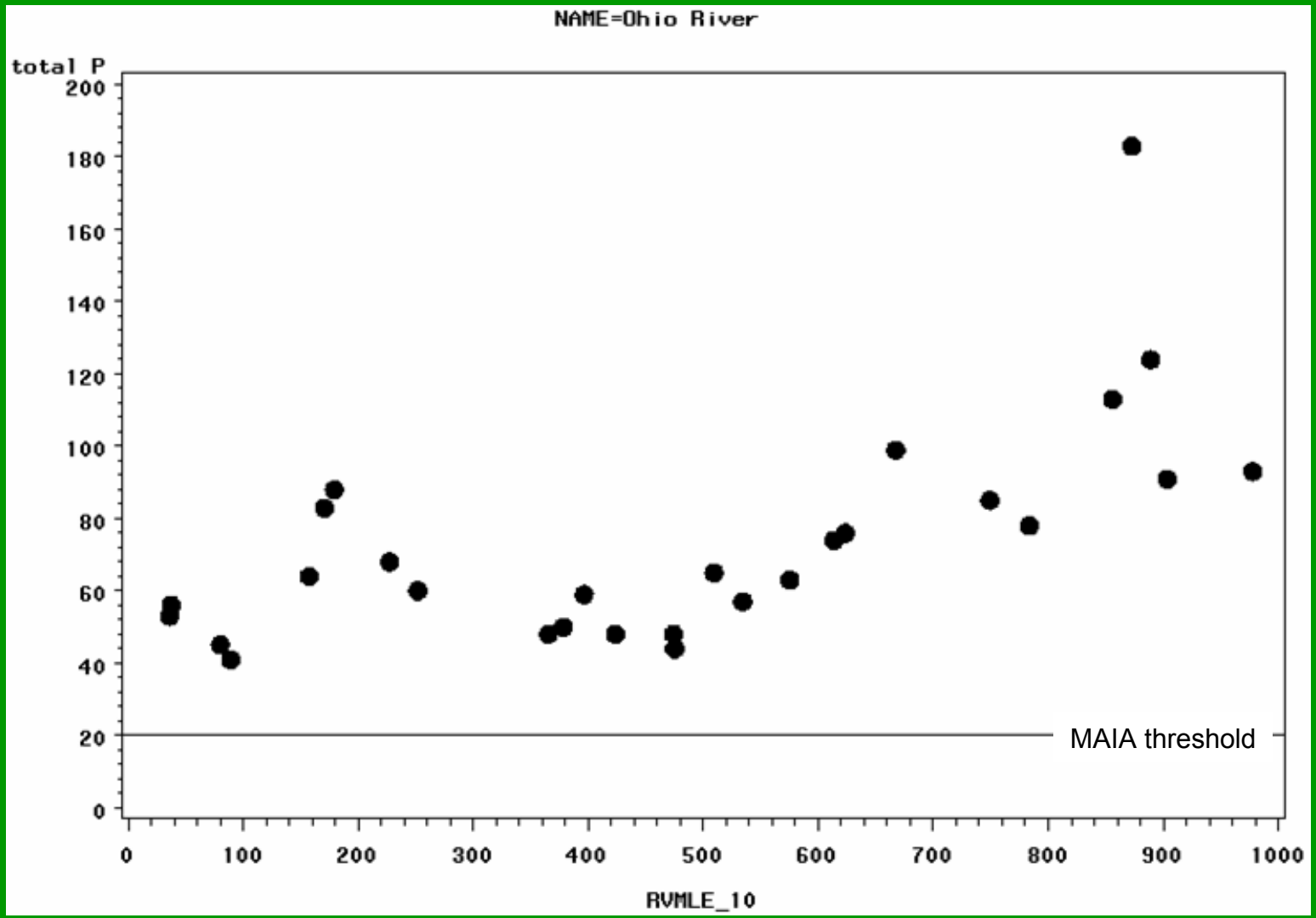
Pass all = reference; fail any = non reference

Simple and proven for smaller streams and lakes



Using WSA “plains” criteria, lower 600 miles of Missouri River not in LDC. This may be true but unwise to base it on one metric.


NAME=Mississippi River
total P
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
RVMLE_10


NAME=Ohio River
total P
200
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000
RVMLE_10
MAIA threshold

Pass/fail criteria, continued

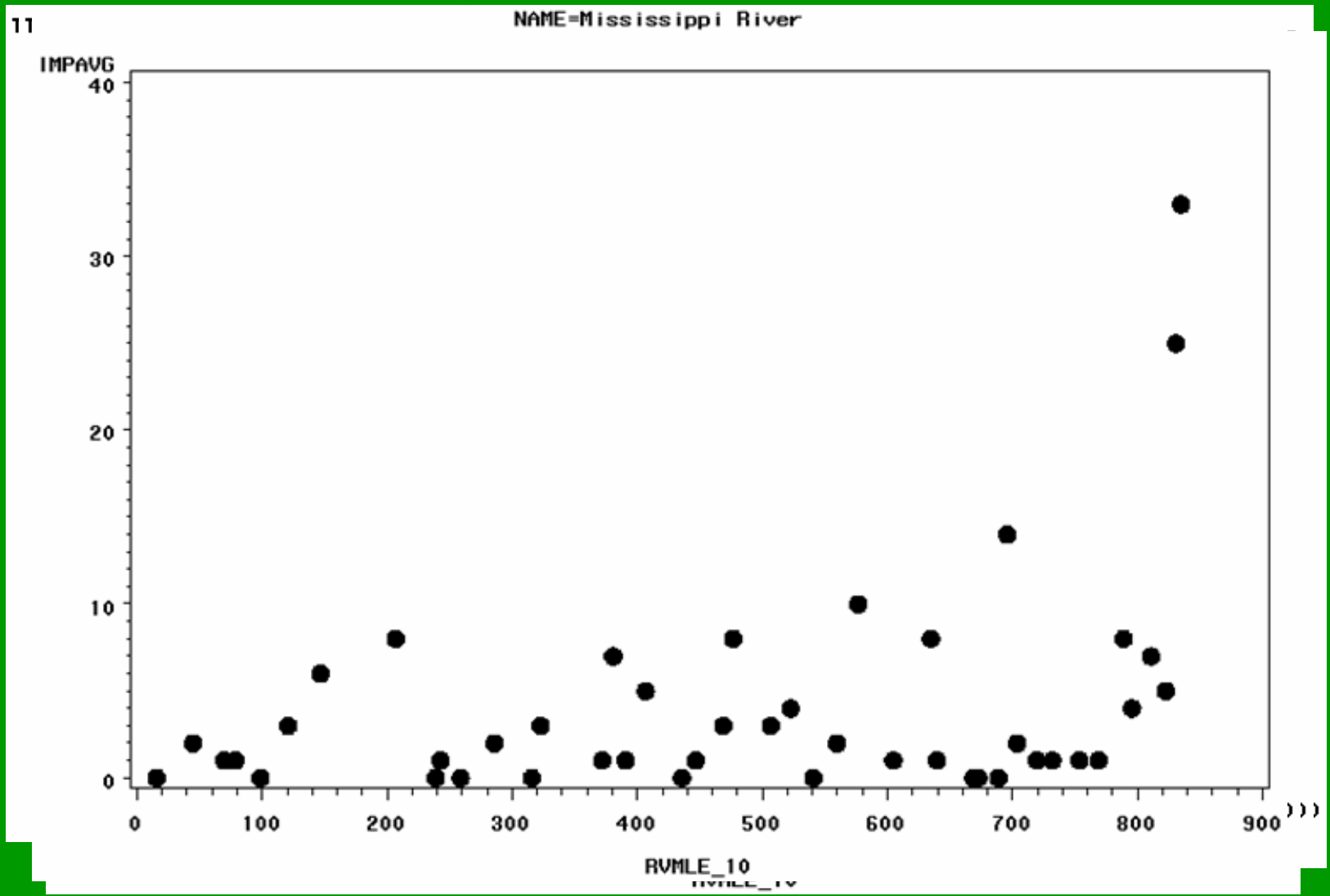
- GR water chemistry confounded by longitudinal trends and intra-seasonal flow variation.
- Canopy density and riparian disturbance are likely have weak local effects on aquatic biota in the Great River setting compared to small streams.
- Percent fines probably not relevant in sand-dominated systems and we don't have sufficient data to separate out silt-clay from sand-silt.

Pass/fail, continued

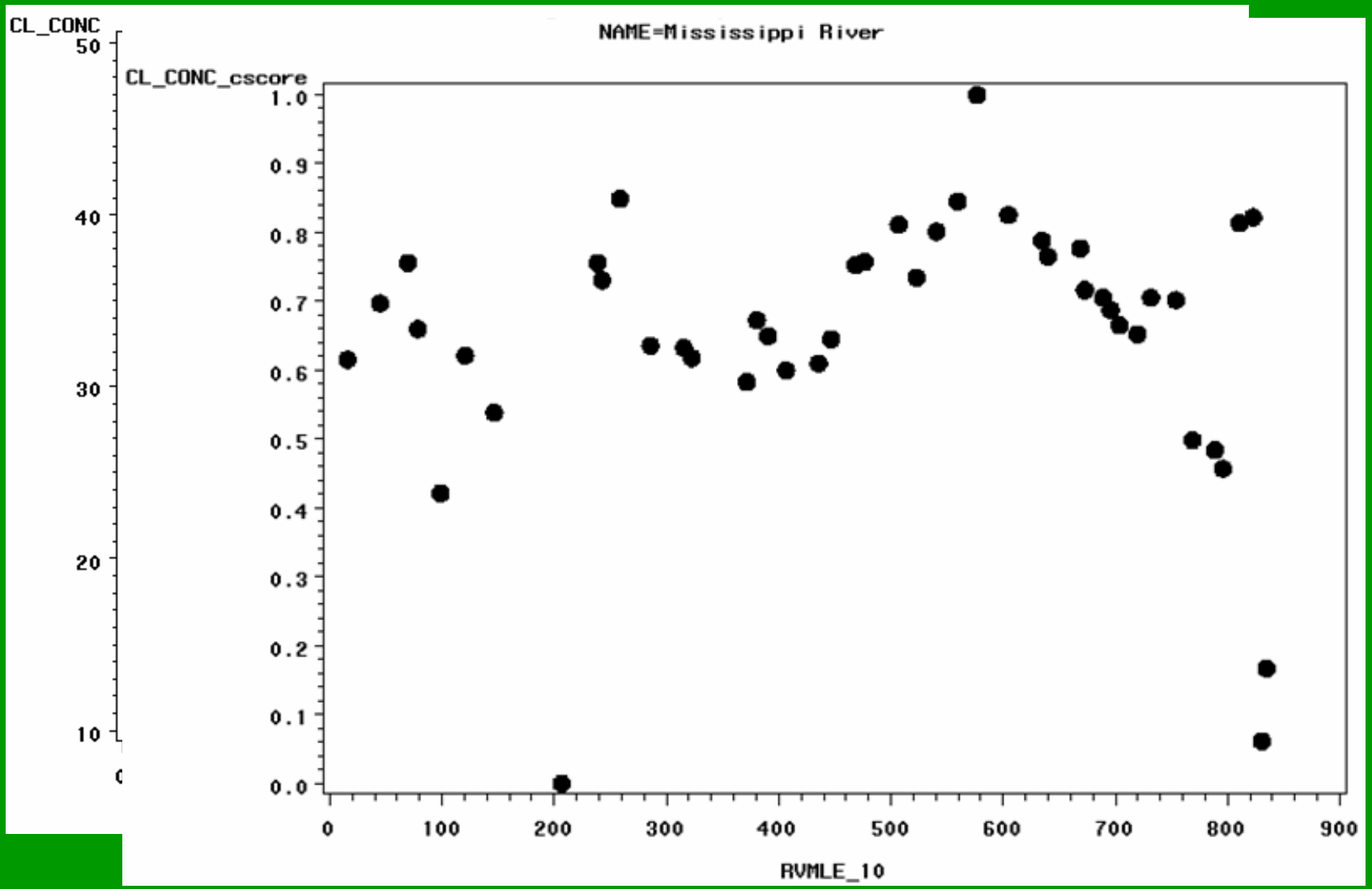
- Requires expert knowledge to set P/F criteria for each metric
- We will try to adapt the P/F approach to GRE data, but we want to explore other approaches if doesn't work out
- Alternative: additive multimetric approach

Example: additive multimetric with continuous scoring (one possible mm approach)

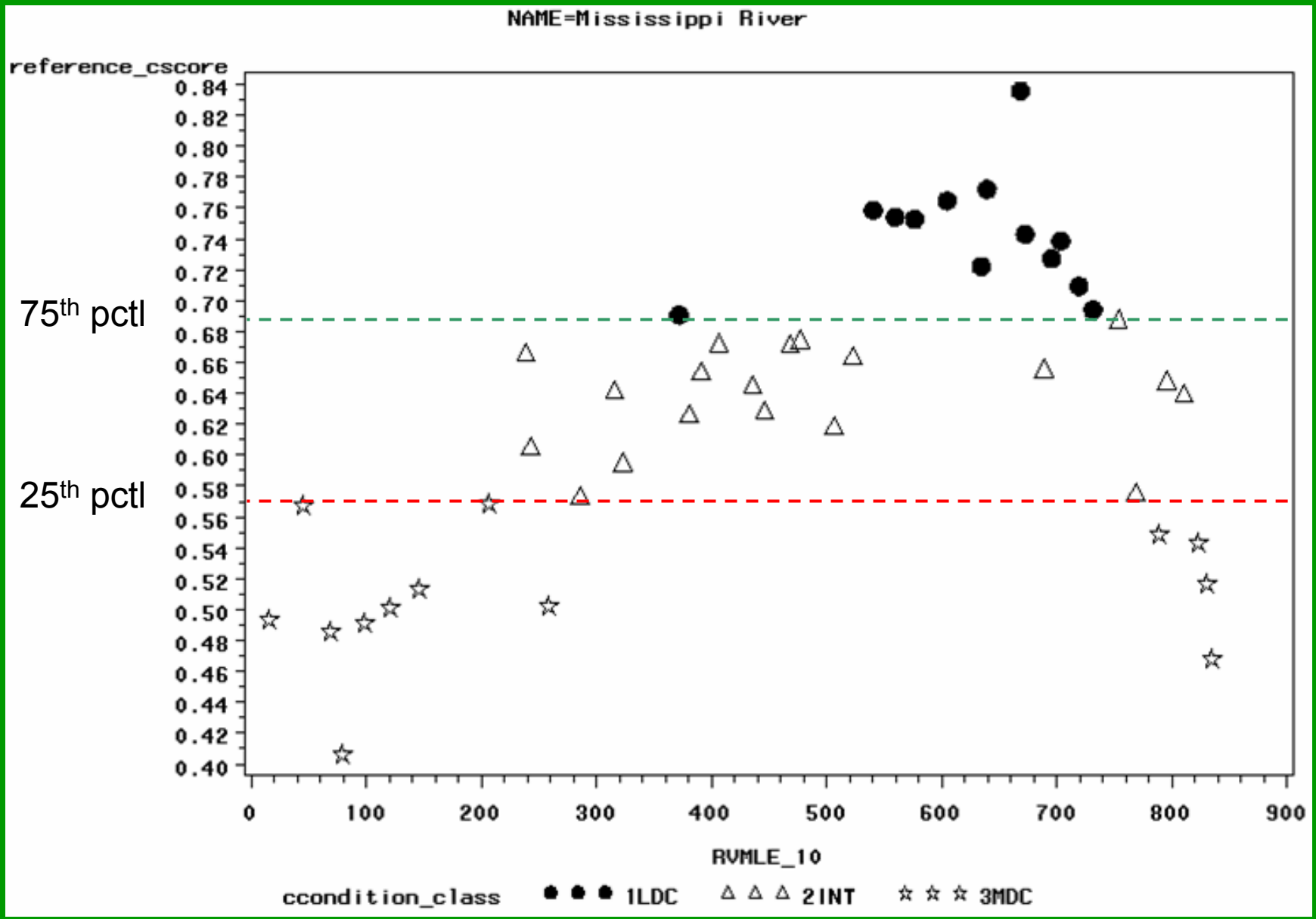
- Normalize all stressor metrics to 0-1
- Sum metric scores for each site to calculate an additive score for the site
- $\geq 75^{th}$ pctl of scores = LDC
- $\leq 25^{th}$ pctl of scores = MDC
- 13 metrics in this example: DO, turbidity, development score, total P, total N, CL, SO_4, dissolved metals, sedtox, % cultivated, % forest+wetland, %impervious surface, LWD density



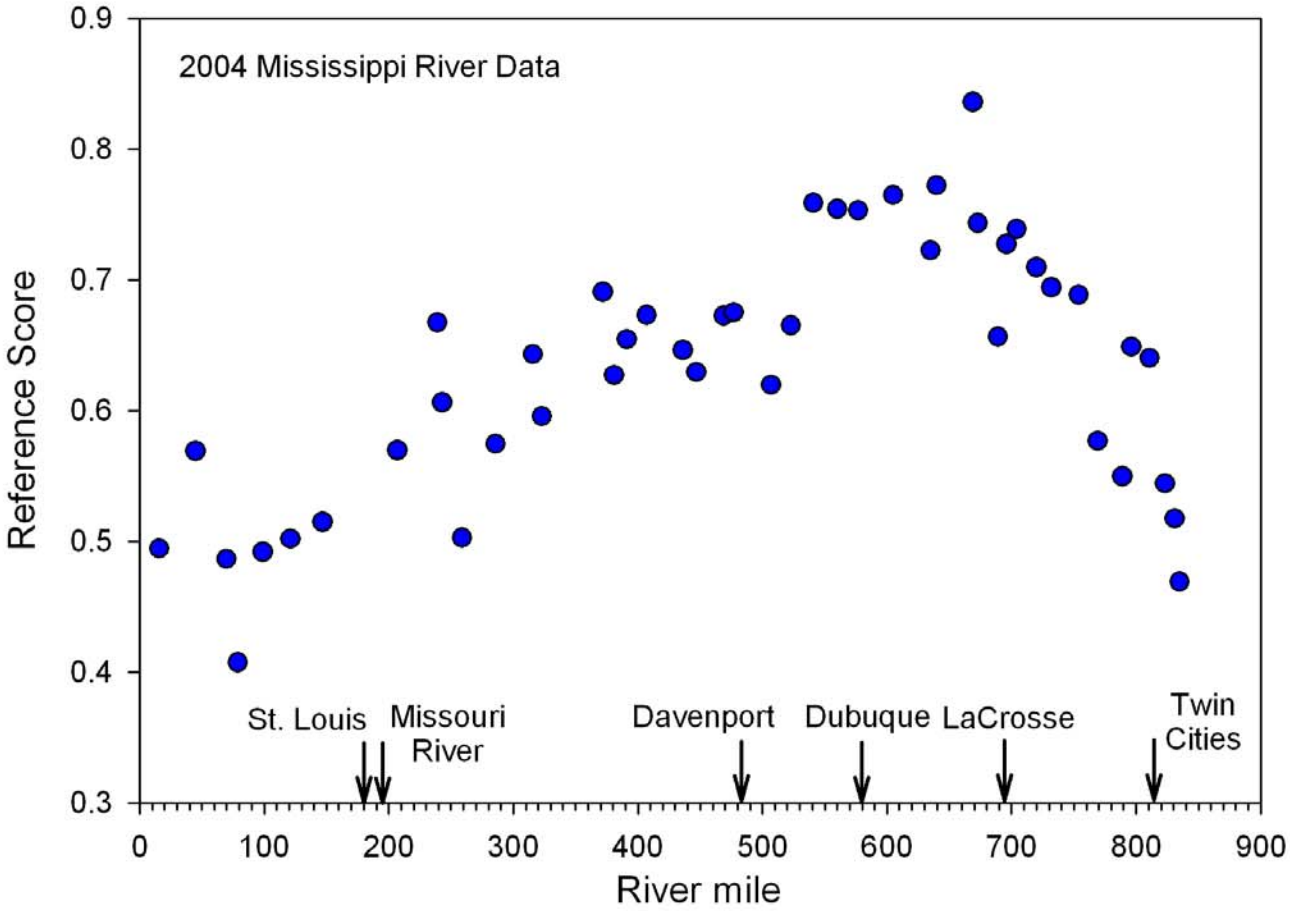
Metrics for Mississippi River



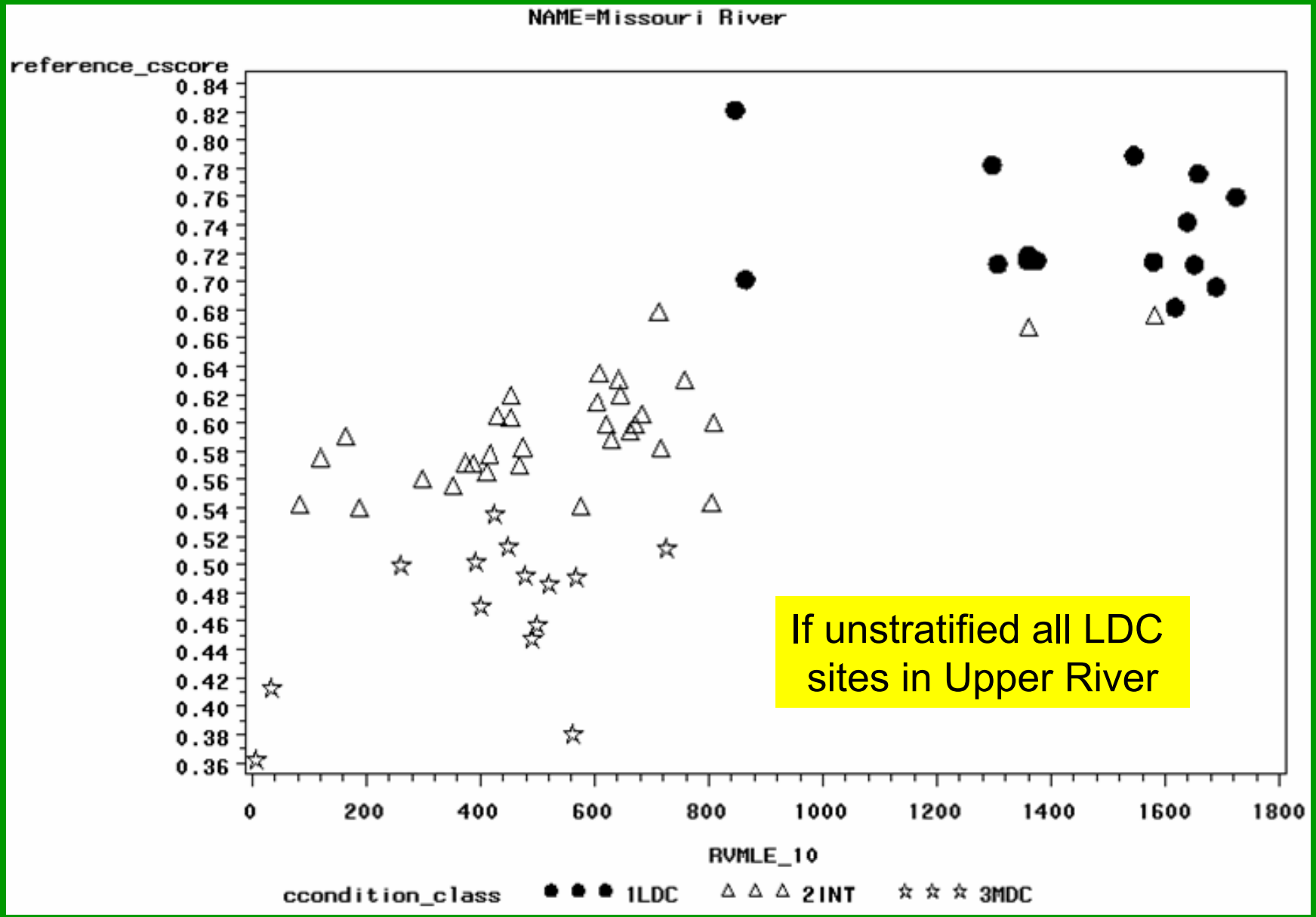
Normalize scores to 0 – 1



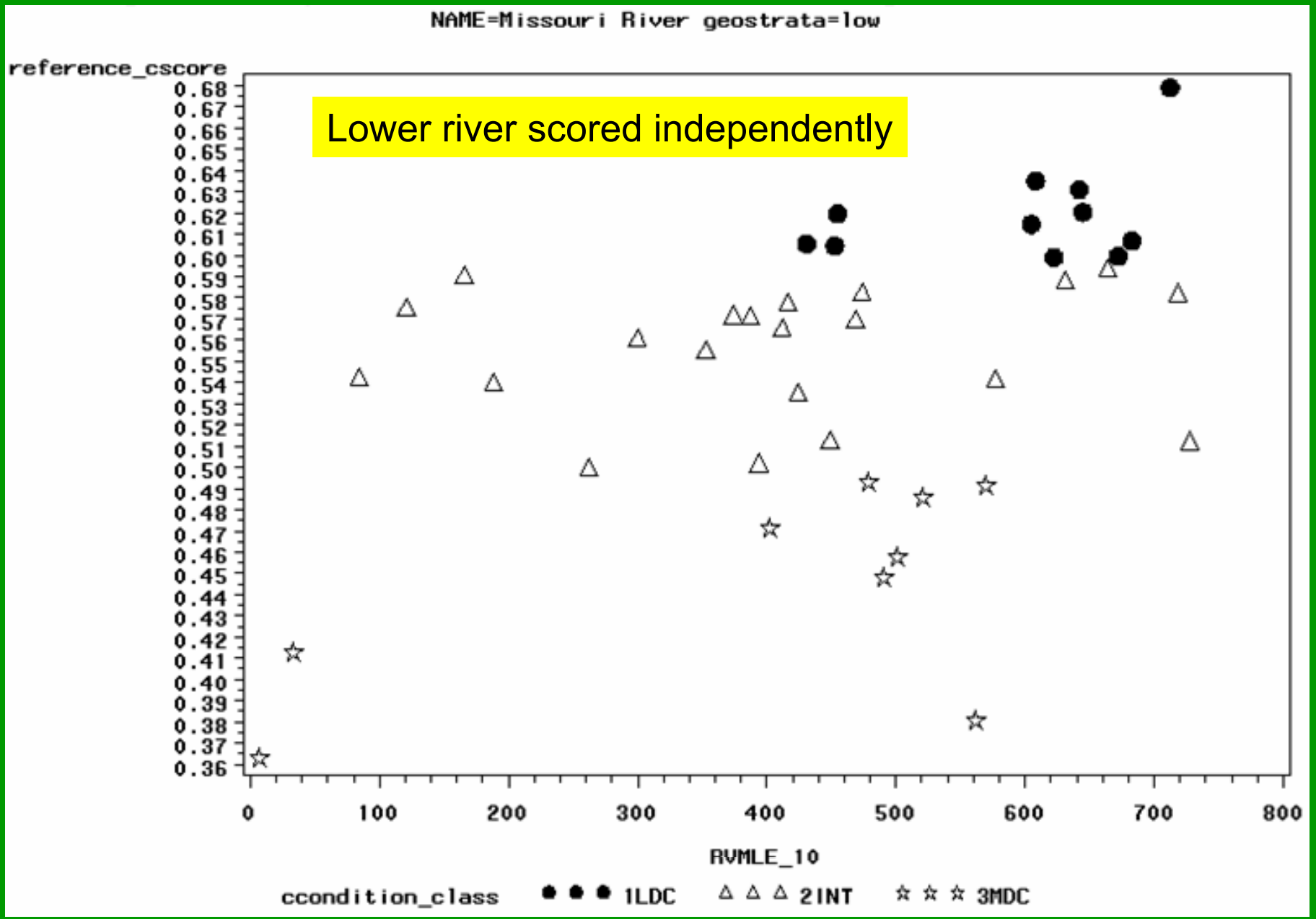
Compute mean scores -- Percentiles suggest condition classes



Score based on 13 unweighted metrics: DO, turbidity, development, total P, total N, CL, SO4, total dissolved metals, sed tox, % cultivated, %forest+wetland, % Impervious surface, LWD



Percentiles suggest condition classes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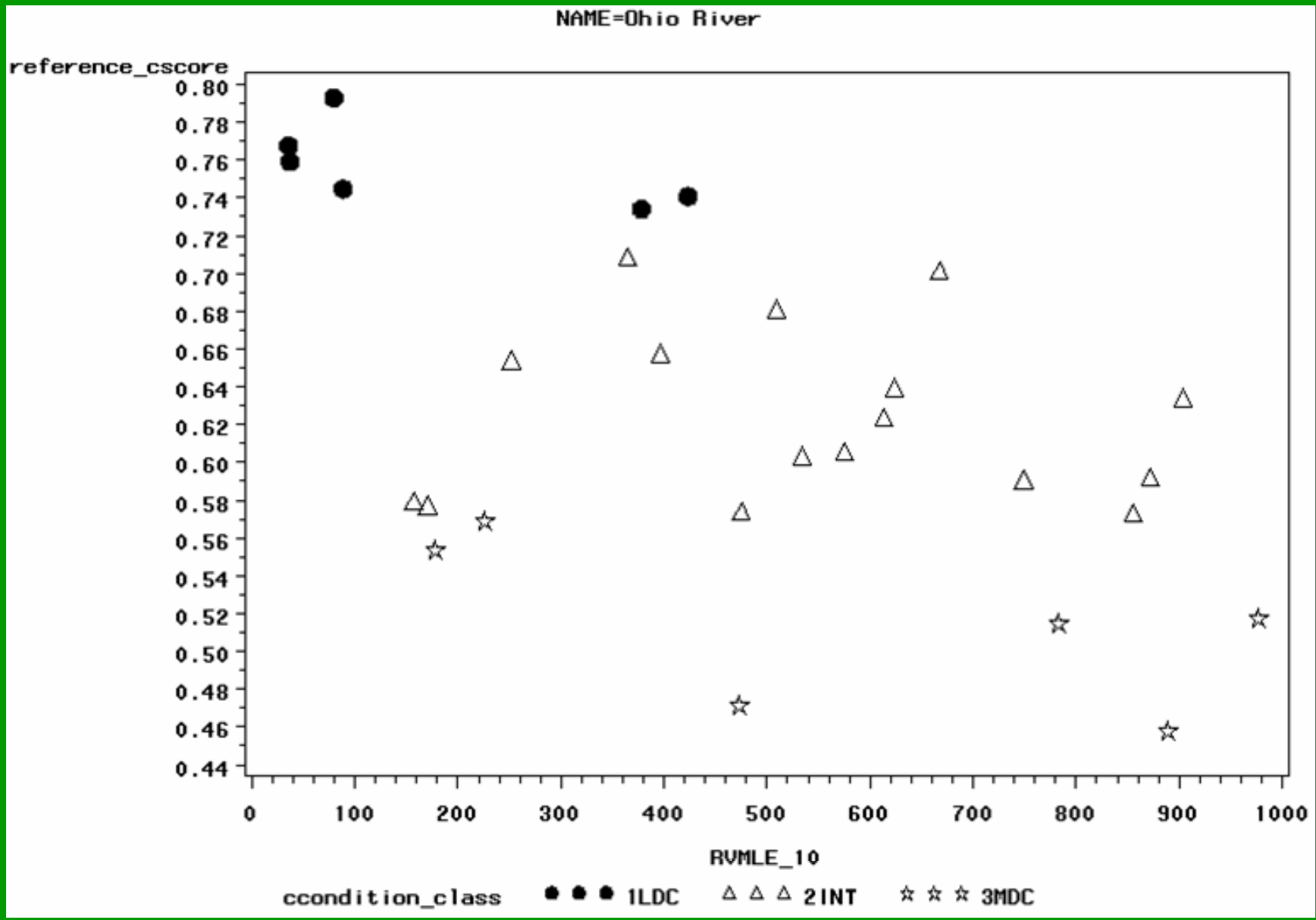
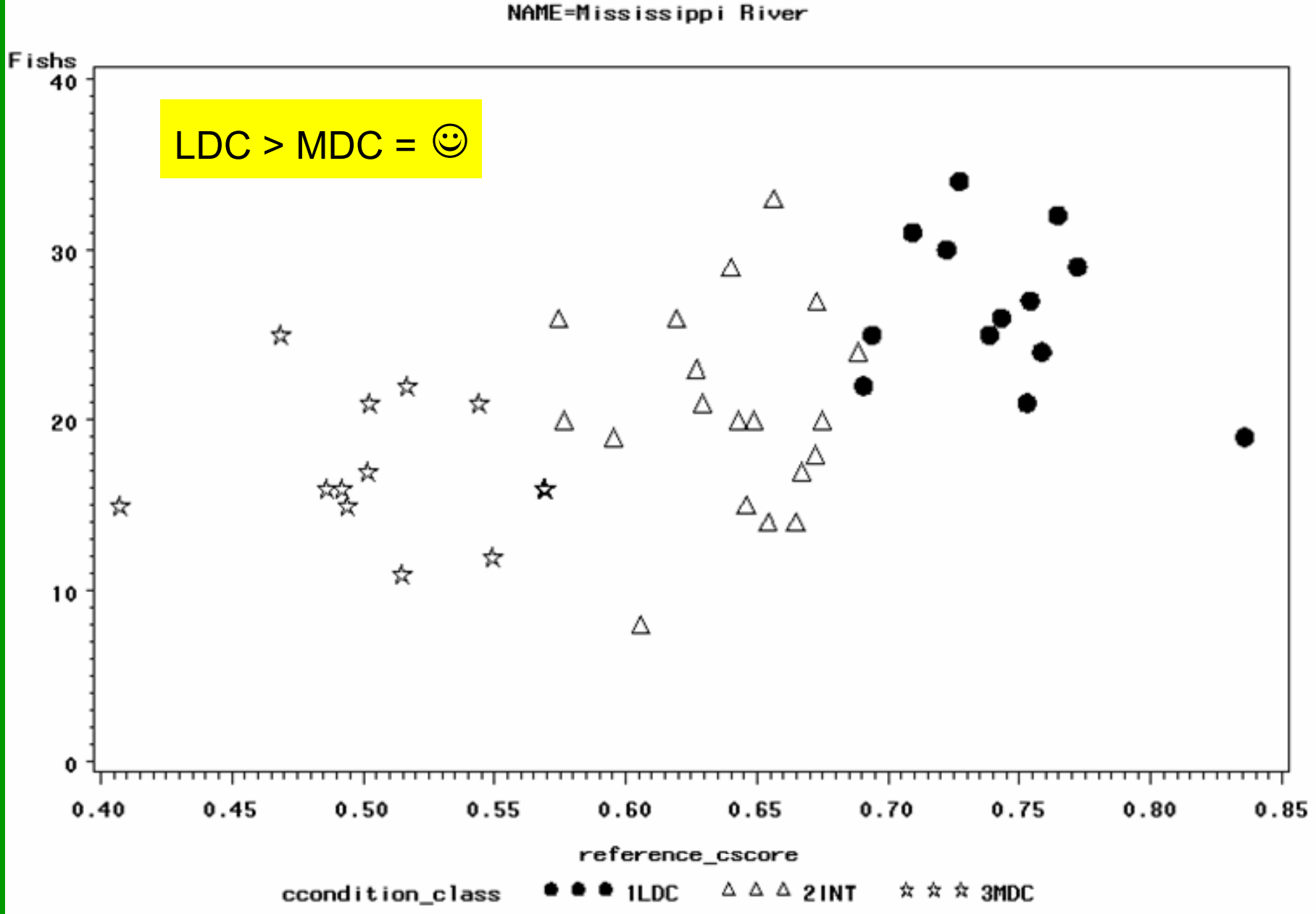
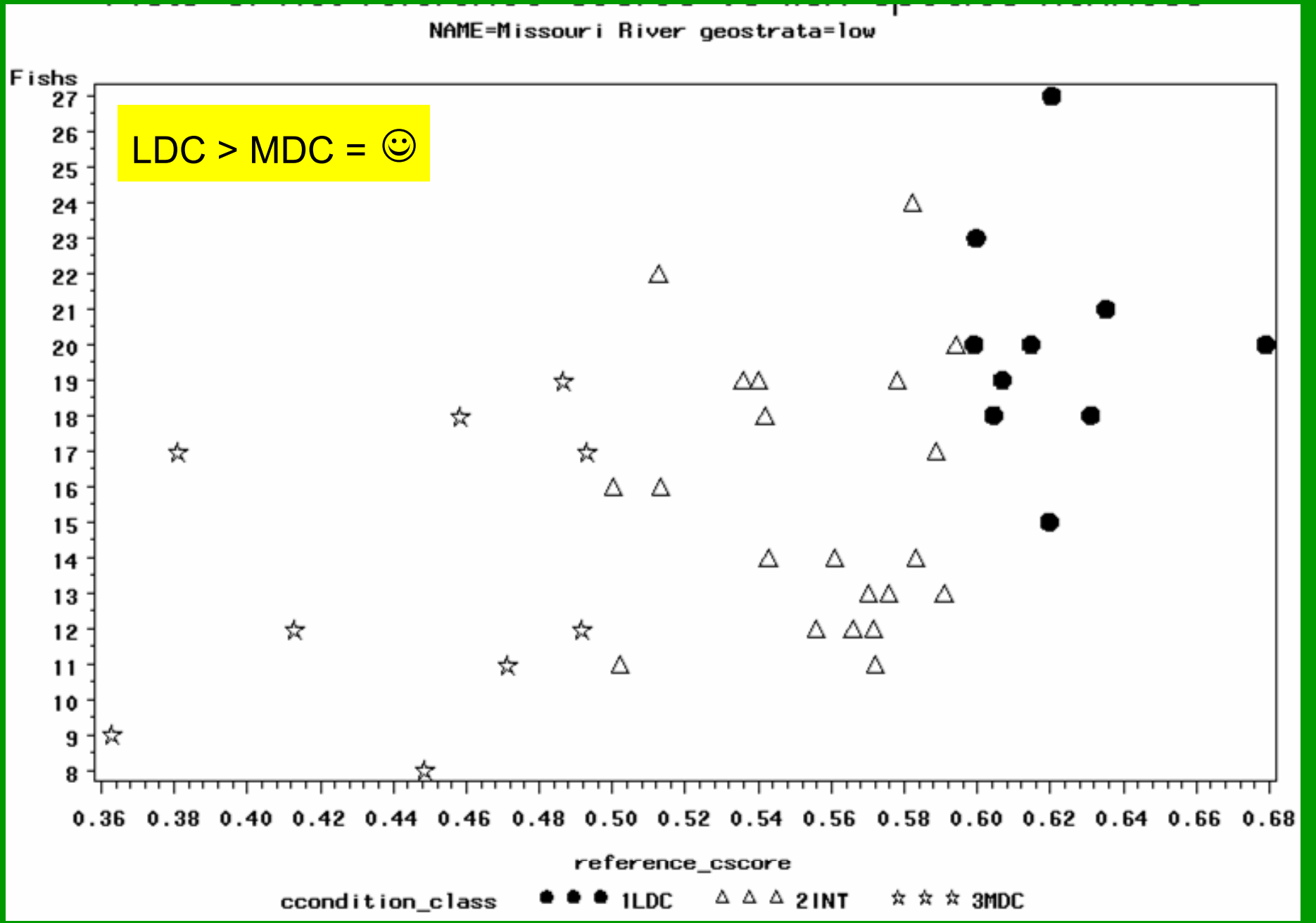
reference_cscore
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0.60
0.59
0.58
0.57
0.56
0.55
0.54
0.53
0.52
0.51
0.50
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.40
0.39
0.38
0.37
0.36
Lower river scored independently
0
100
200
300
400
500
600
700
800
RVMLE_10
ccondition_class
1LDC
2INT
3MDC

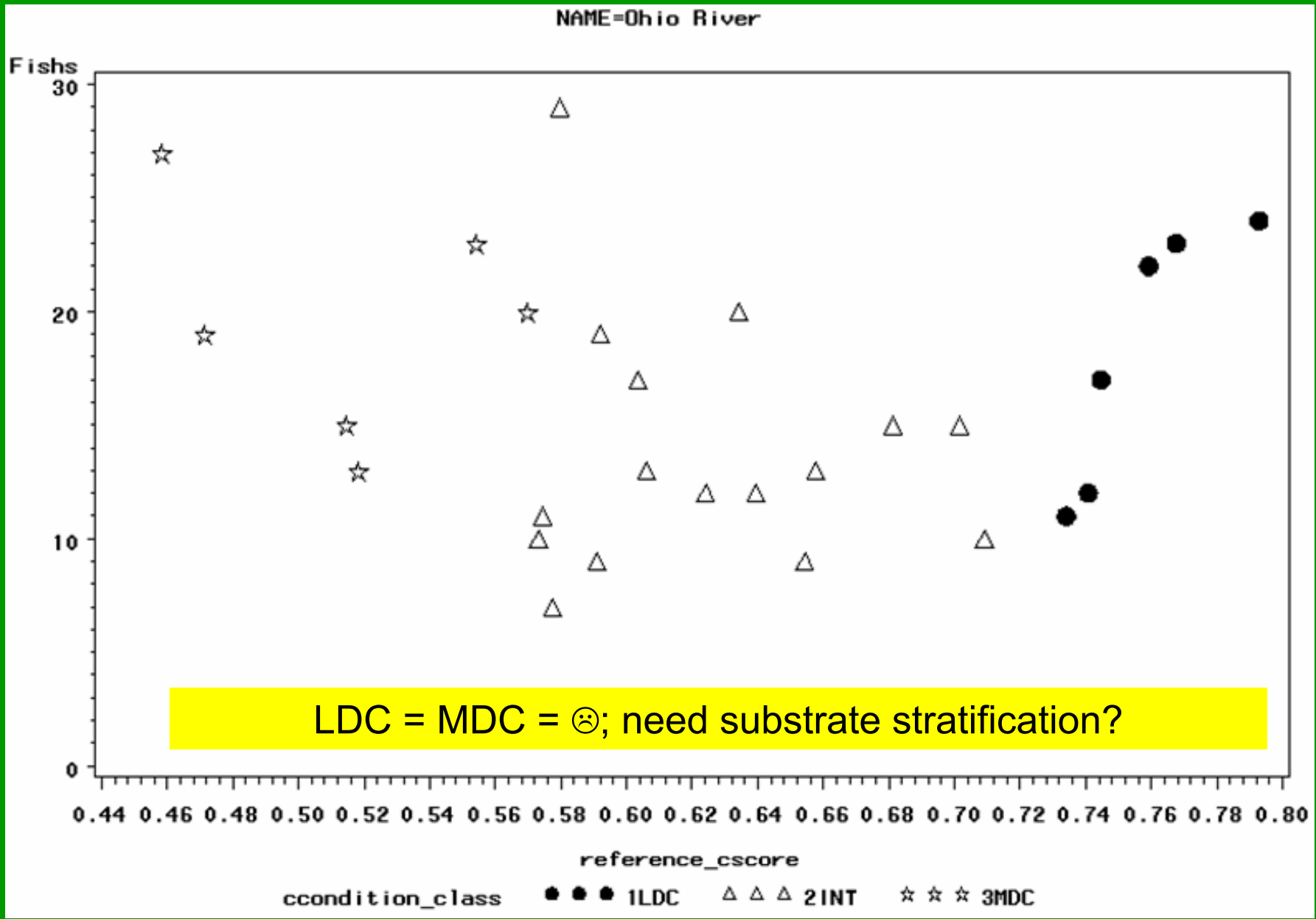


Percentiles suggest condition classes



Test this particular model using biology – fish *S*

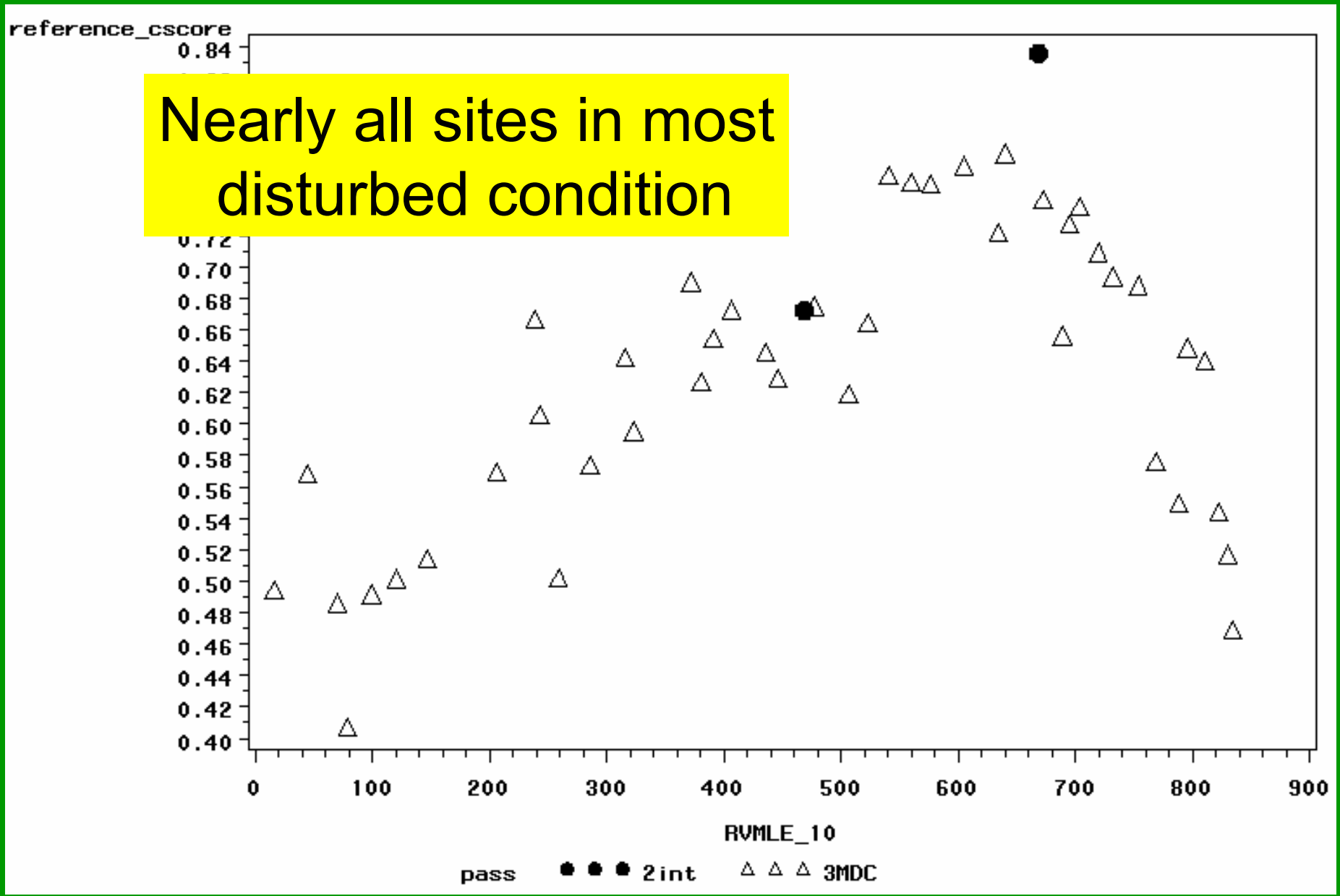

NAME=Missouri River geostrata=low
Fishs
LDC > MDC = ☺
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
0.36 0.38 0.40 0.42 0.44 0.46 0.48 0.50 0.52 0.54 0.56 0.58 0.60 0.62 0.64 0.66 0.68
reference_cscore
ccondition_class
1LDC
2INT
3MDC


NAME=Ohio River
Fishs
30
20
10
0
0.44 0.46 0.48 0.50 0.52 0.54 0.56 0.58 0.60 0.62 0.64 0.66 0.68 0.70 0.72 0.74 0.76 0.78 0.80
reference_cscore
ccondition_class
1LDC
2INT
3MDC
LDC = MDC = ☹; need substrate stratification?

*This is not *the* model (metrics, criteria, screen) this is just one possible model from among many models.

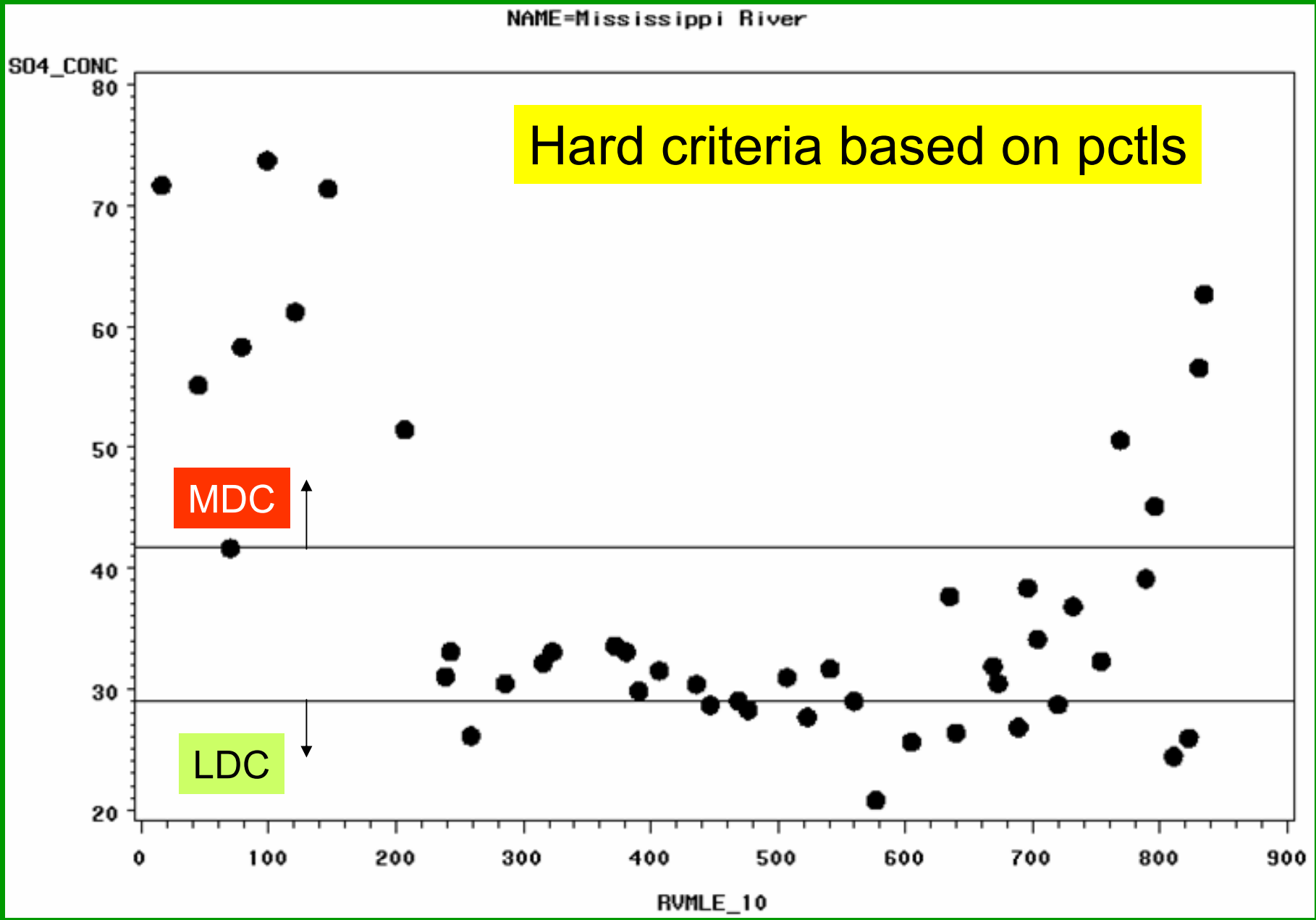
P/F model test

- Same metrics as the multimetric test
- P/F criteria set by pctl for each metric:
- $\geq 75^{th}$ pctl (for pos metrics) = Pass
- $\leq 25^{th}$ pctl (for pos metrics) = Fail
- Pass all 13 = LDC; Fail any of 13= MDC


Nearly all sites in most disturbed condition
reference_cscore
0.84
0.72
0.70
0.68
0.66
0.64
0.62
0.60
0.58
0.56
0.54
0.52
0.50
0.48
0.46
0.44
0.42
0.40
0
100
200
300
400
500
600
700
800
900
RVMLE_10
pass
2int
3MDC

Pass/Fail for GRE

- Almost every site fails for at least one metric on all 3 rivers.
- Almost no sites pass every metric
- GRE sites bi-polar?
- Can we use biology to provide expert knowledge for setting criteria instead of using arbitrary percentiles?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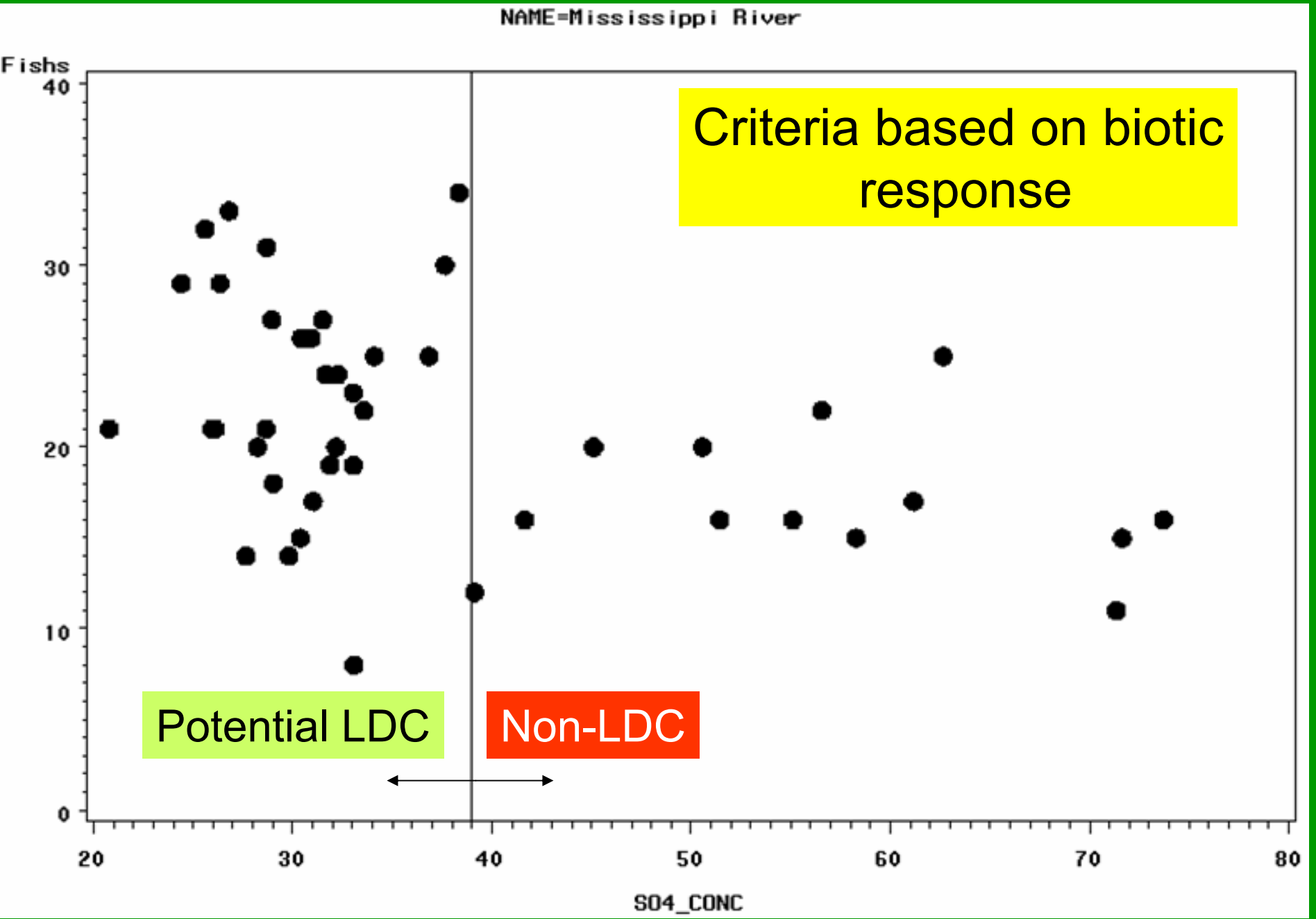
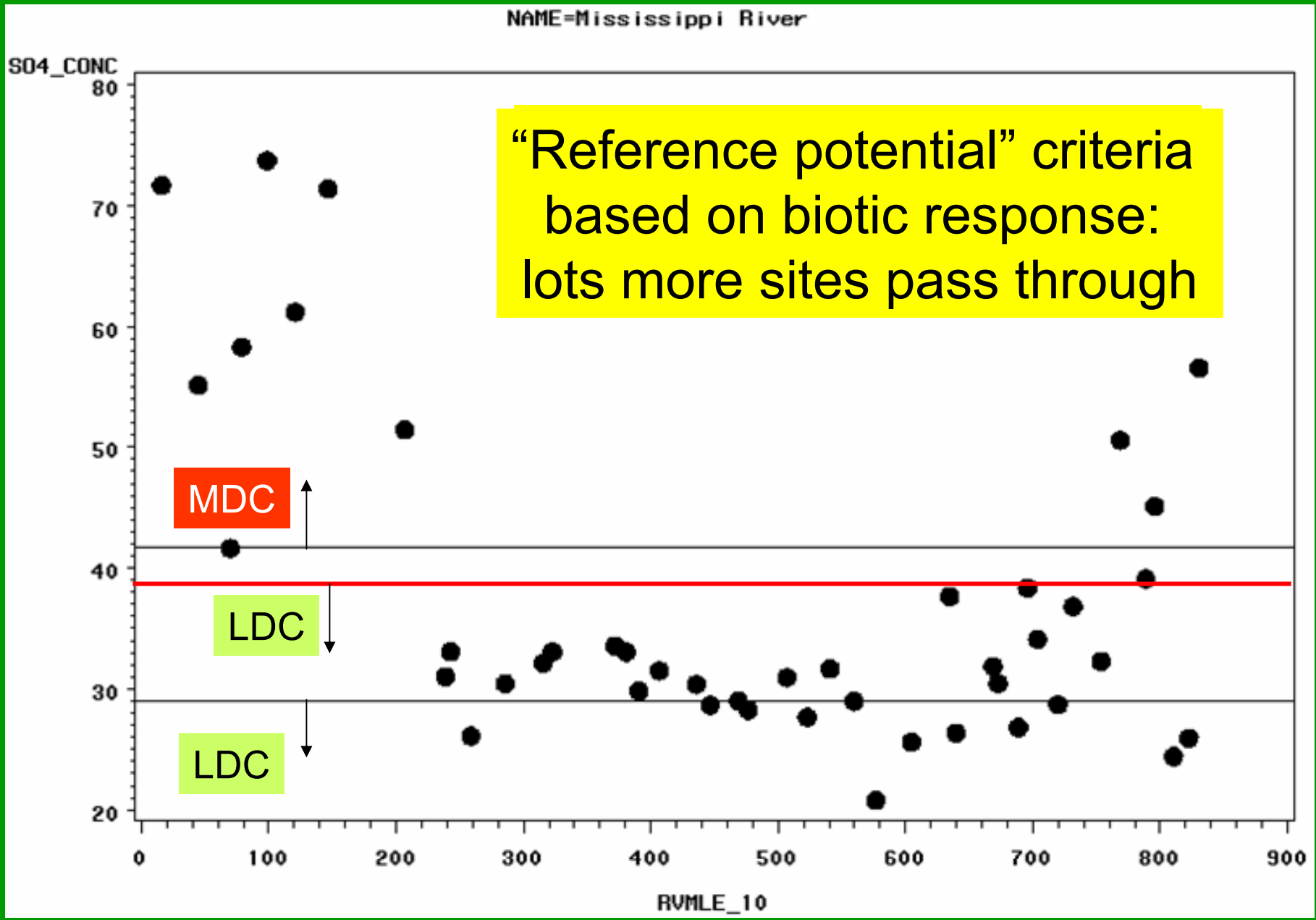
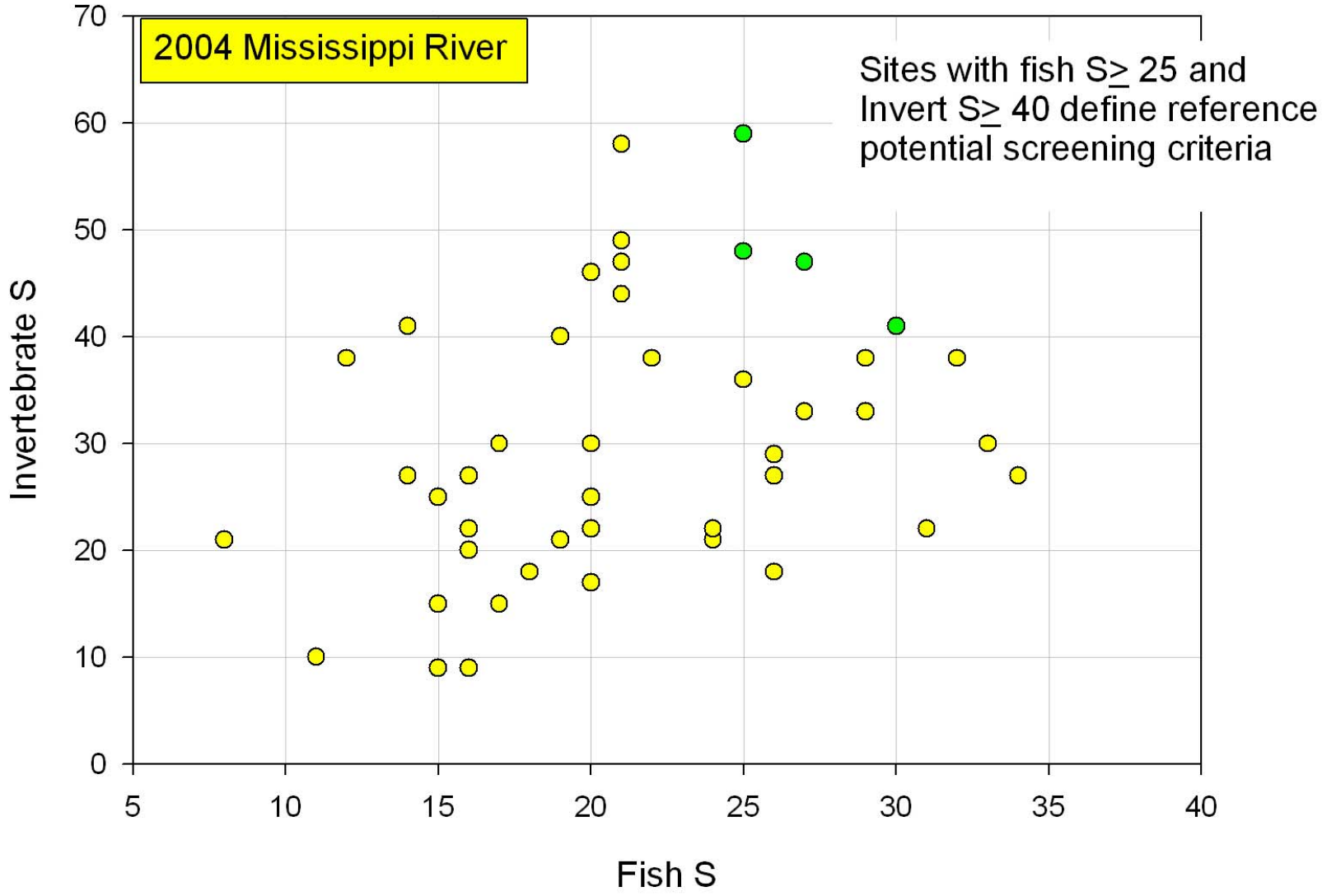
SO4_CONC
80
70
60
50
40
30
20
0
100
200
300
400
500
600
700
800
900
RVMLE_10
Hard criteria based on pctls
MDC
LDC


NAME=Mississippi River
Fishs
40
30
20
10
0
20
30
40
50
60
70
80
SO4_CONC
Criteria based on biotic response
Potential LDC
Non-LDC

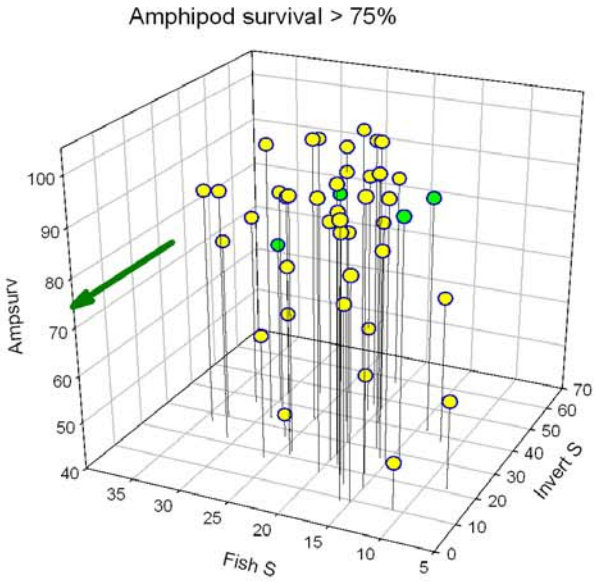

NAME=Mississippi River
SO4_CONC
80
70
60
50
40
30
20
0
100
200
300
400
500
600
700
800
900
RVMLE_10
"Reference potential" criteria based on biotic response: lots more sites pass through
MDC
LDC
LDC

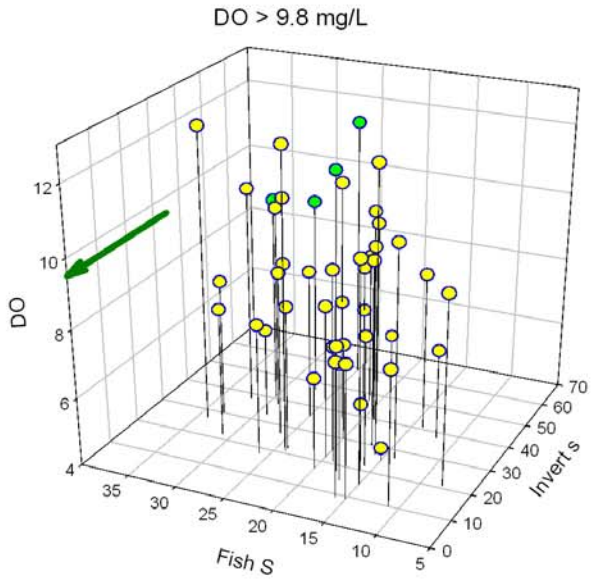
Using biology data

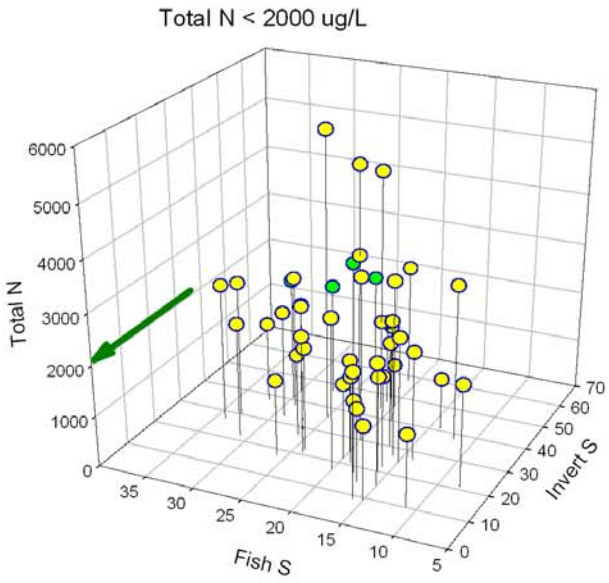
- Not used to pick sites directly
- Biotic-response plots may be useful for setting metric criteria for P/F or multimetric models (a substitute for 10+ years expert experience with screening small stream data)
- Concordant biology approach

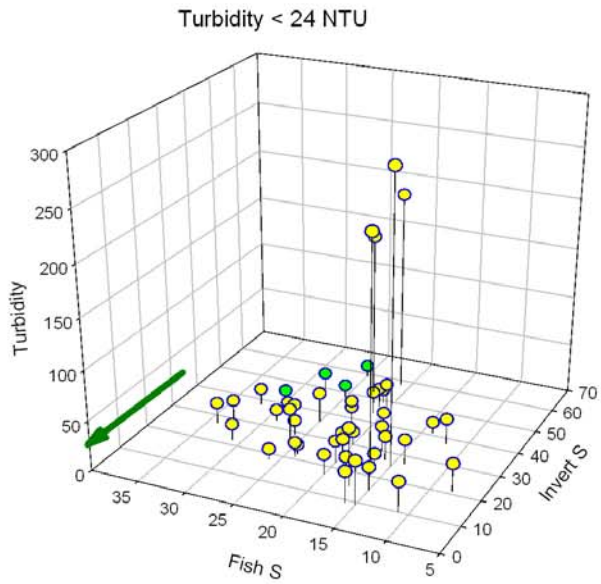

2004 Mississippi River
Sites with fish S≥ 25 and
Invert S≥ 40 define reference
potential screening criteria
Invertebrate S
Fish S
0
10
20
30
40
50
60
70
5
10
15
20
25
30
35
40

Reference potential criteria (floor or ceiling) for each metric used in P/F or multimetric screen







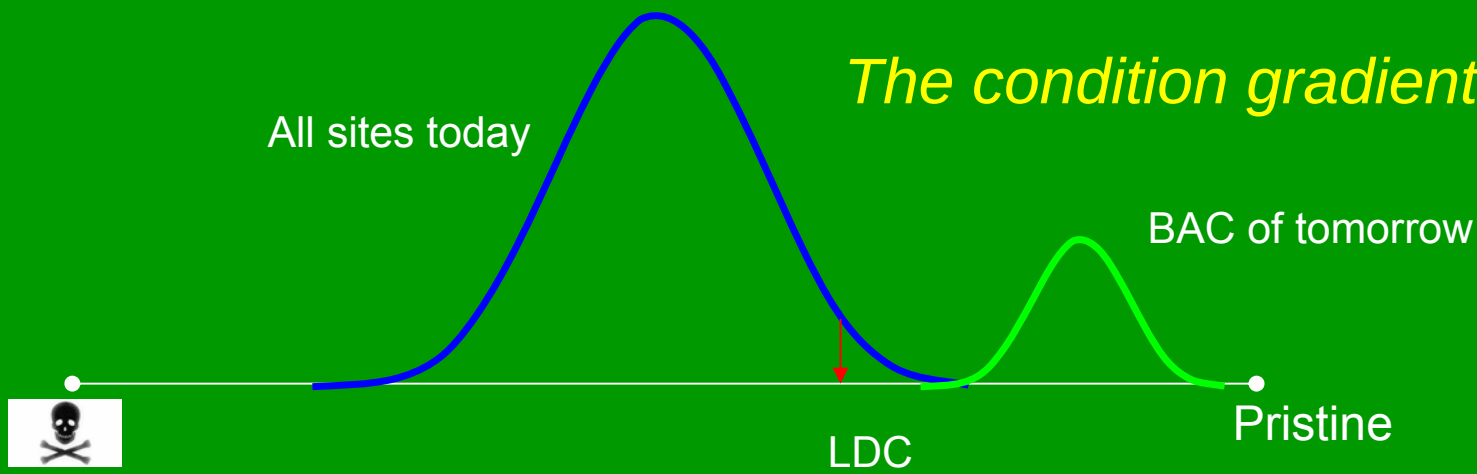


One last concept: LDC really bugs some people because it “sets the bar too low” for GREs

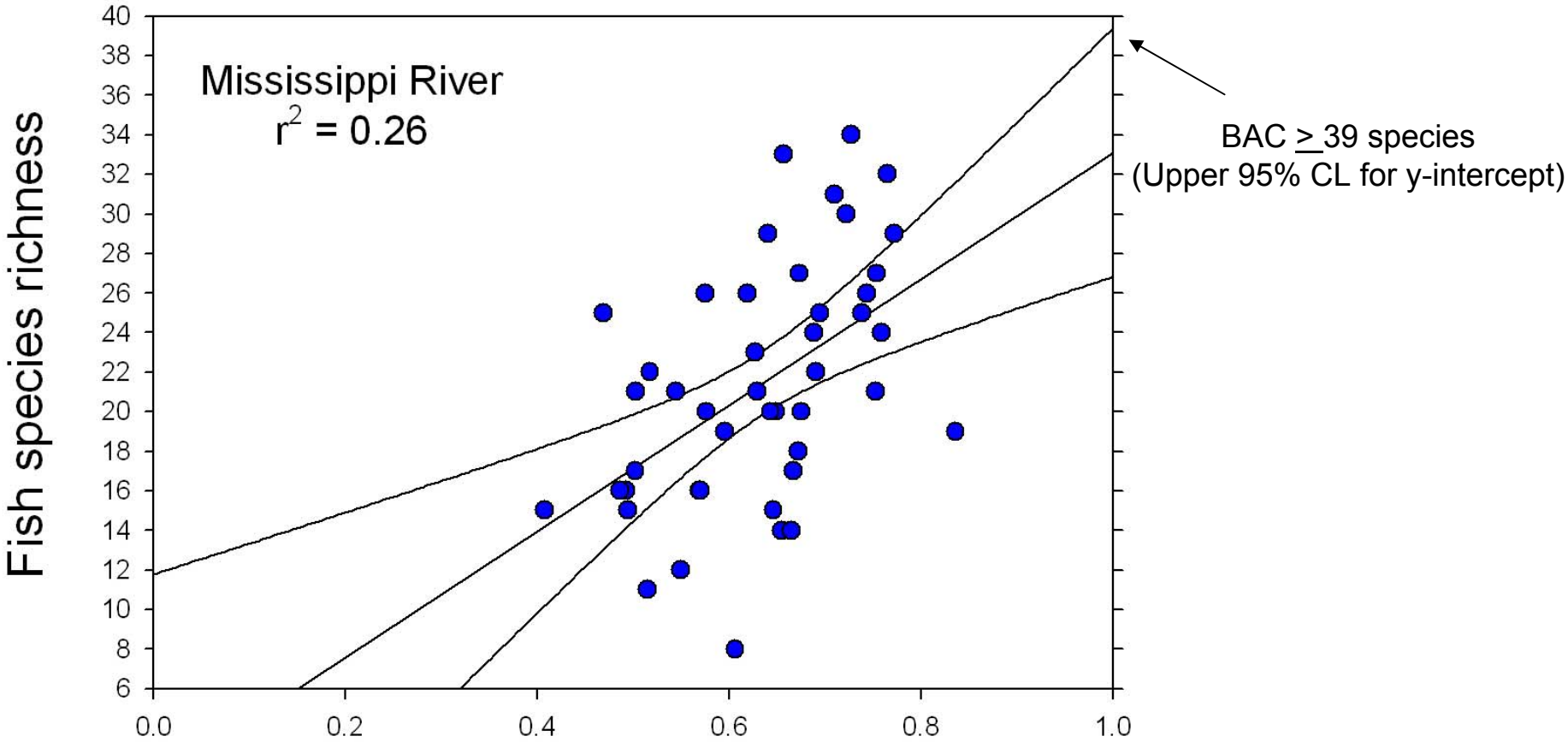
Can we do something more than an assessment based strictly on LDC?

Can we derive something like best attainable conditions (BAC) from empirical models?

Assumption: LDC and BAC overlap to some degree (or come really close).



Use empirical models to approximate BAC for selected metrics based on best possible additive metric score (=1).



Additive reference score based on continuous metric scoring

- Doesn't require reference sites
- Report out departure from BAC or species loss
- Augment assessment based on LDC?

Conclusions

- There are no shortcuts. Screening will be an iterative process.
- We will try multiple screening approaches.
- The multimetric model seems promising for GRE data.
- Geo-stratification probably necessary for Missouri River and habitat stratification for all rivers

Conclusions, continued

- Strong longitudinal patterns in condition are likely for MS and MO.
- Adding additional landscape and riparian metrics should improve screens
- Using biotic data as "expert knowledge" to help set criteria may be useful.
- The 3 rivers are very different – likely to need different metrics and stratification schemes to optimize screening.

Prognosis: good!

There is variability in stress/disturbance among sites that is reflected in the biota.

We have lots of stressor and disturbance metrics from which to pick combinations to use for screening

EMAPCO IBI - O – Matic