Presented at

Great Rivers Reference Condition Workshop

January 10-11, Cincinnati, OH

Sponsored by

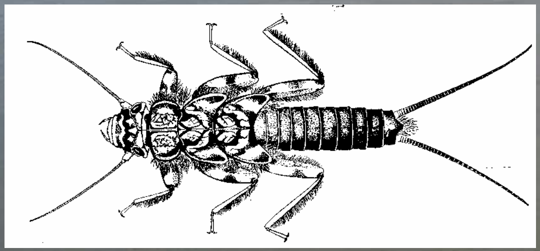
The U.S. Environmental Protection Agency and The Council of State Governments

U.S. EPA Office of Research and Development

Environmental Monitoring and Assessment Program

Approaches for Developing a Theoretical Reference Condition Based on Large River Macroinvertebrate Assemblages

Barry C. Poulton
U.S. Geological Survey
Columbia, Missouri



USGS
science for a changing world

River Studies Station

Columbia Environmental Research Center

Basic Types of Reference Community Determination

A. Identify best sites based on field performance (observed data) and BPJ, and confirm with other indicators (habitat scores, WQ, etc.)

* Most commonly used by states for wadeable streams

B. Identify best potential sites with GIS, land use, then confirm whether site quality is significantly better than test sites (**Empirical – EMAP**)

* In part, final confirmation of reference sites still depends on metric performance and examination of field data

C. Determine best metrics based on response to stressors across all sites, then artificially construct a good community from available knowledge

* Community is a benchmark specifically designed to score higher than test sites with the metric combinations that are chosen

Definition

Theoretical Reference Community

A community composition that is artificially constructed or inferred from the best available knowledge about the system or watershed, and that has specific structural and functional components that represent the highest quality or best attainable biological condition based on specific indicator measurements.

Characteristics of Theoretical Reference:

1). The community consists of **a list of actual species and associated relative abundances**, both of which are designed to reflect assemblages that should be expected in the system as a whole

2). The community is **treated as its own site**, and is assigned a score or rating in the same way as the test sites. It also **defines expectations for indicator metrics**

3). The community is **constructed so that it will function as a reference benchmark**, achieving the best score for most metrics and a higher overall index score than any of the test sites

4). The theoretical reference is treated as the upper level of the best biological condition category, and **provides the basis for the definition of category boundaries and/or thresholds** (i.e. good, fair, poor, or impaired vs. not impaired, etc.)

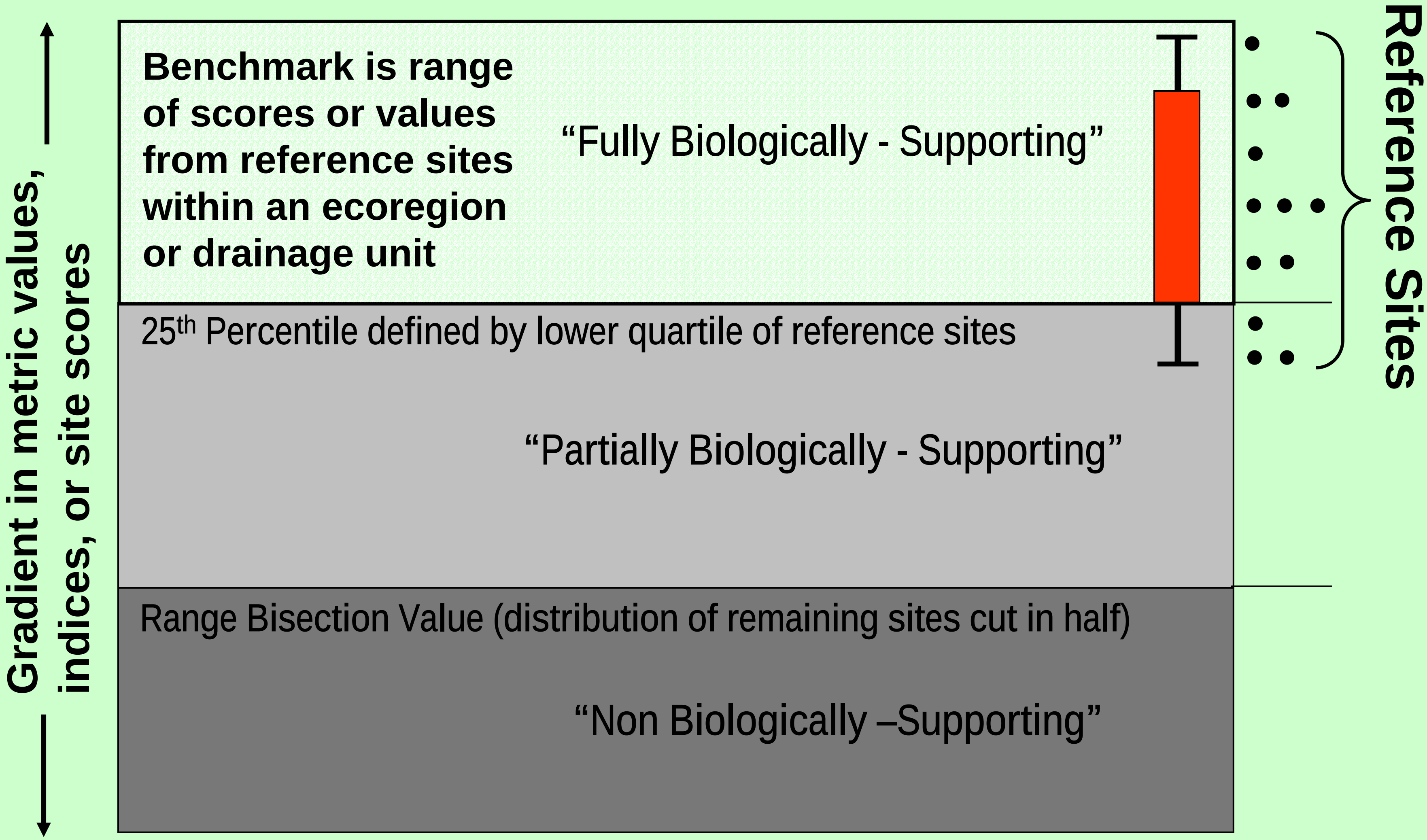
Examples of Tiered Biological Impairment Categories

Gradient in site scores or index values ↑

<table>
<tr><th>Simple 2 Category</th><th>3 Category (MO, KS)</th><th>4 Category (SD)</th><th>4 Category (IA)</th><th>5 Category (Ohio IBI)</th><th>6 Stream Classes (KS)</th><th colspan="2">Lower Missouri Impact Classes</th><th># of Missouri River Sites (from 2002 USGS study)</th></tr>
<tr><td rowspan="3">Not Impaired (pass)</td><td rowspan="3">Fully Biologically Supporting</td><td rowspan="3">Non Impaired</td><td>Full Support</td><td>Exceptional</td><td>A</td><td rowspan="2">Unimpacted or Similar to Reference</td><td rowspan="2">A</td><td rowspan="2">0</td></tr>
<tr><td rowspan="2">Full Support (Threatened)</td><td rowspan="5">Good</td><td rowspan="4">B</td></tr>
<tr><td rowspan="4">Slight Impacts</td><td rowspan="2">B</td><td rowspan="2">1</td></tr>
<tr><td rowspan="11">Impaired (Fail)</td><td rowspan="9">Partially Biologically Supporting</td><td rowspan="6">Slightly Impaired</td><td rowspan="9">Partial Support</td></tr>
<tr><td rowspan="2">C</td><td rowspan="2">2</td></tr>
<tr><td rowspan="3">C</td></tr>
<tr><td rowspan="6">Fair</td><td rowspan="2">Slight to Moderate Impacts</td><td>D</td><td>4</td></tr>
<tr><td>E</td><td>4</td></tr>
<tr><td rowspan="4">D</td><td rowspan="3">Moderate Impacts</td><td rowspan="2">F</td><td rowspan="2">4</td></tr>
<tr><td rowspan="4">Moderately Impaired</td></tr>
<tr><td>G</td><td>3</td></tr>
<tr><td rowspan="3">Moderate to Severe Impacts</td><td rowspan="3">H</td><td rowspan="3">0</td></tr>
<tr><td rowspan="2">Non Supporting</td><td rowspan="2">Non Support</td><td>Poor</td><td>E</td></tr>
<tr><td>Severely Impaired</td><td>Very Poor</td><td>F</td></tr>
</table>

Multiple Reference Sites Available

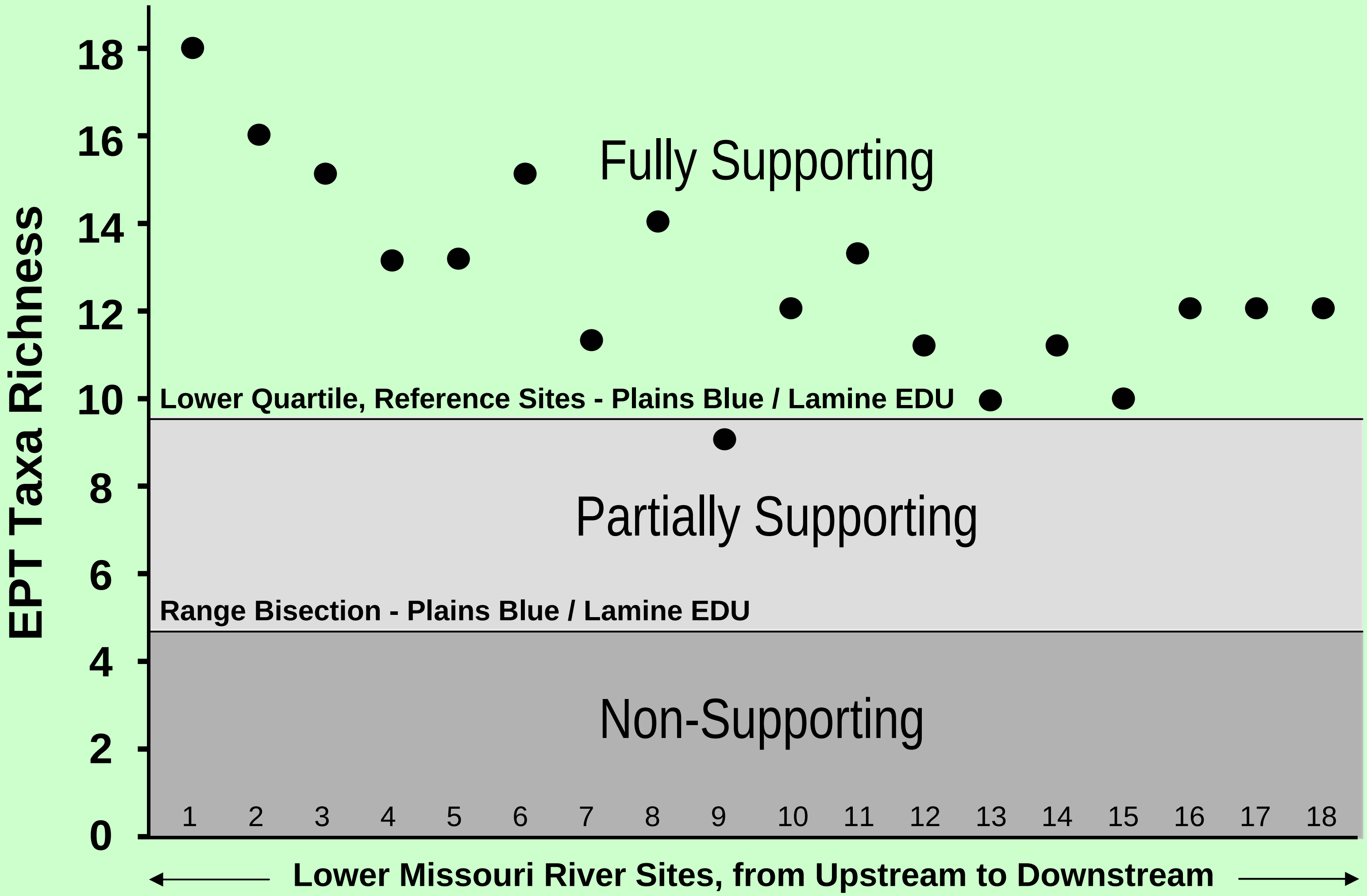
Categories determined by percentiles of reference site distribution



* **Determination of Aquatic Life Status in wadeable streams of many states**

Reference Data Available from Nearest Drainage Unit

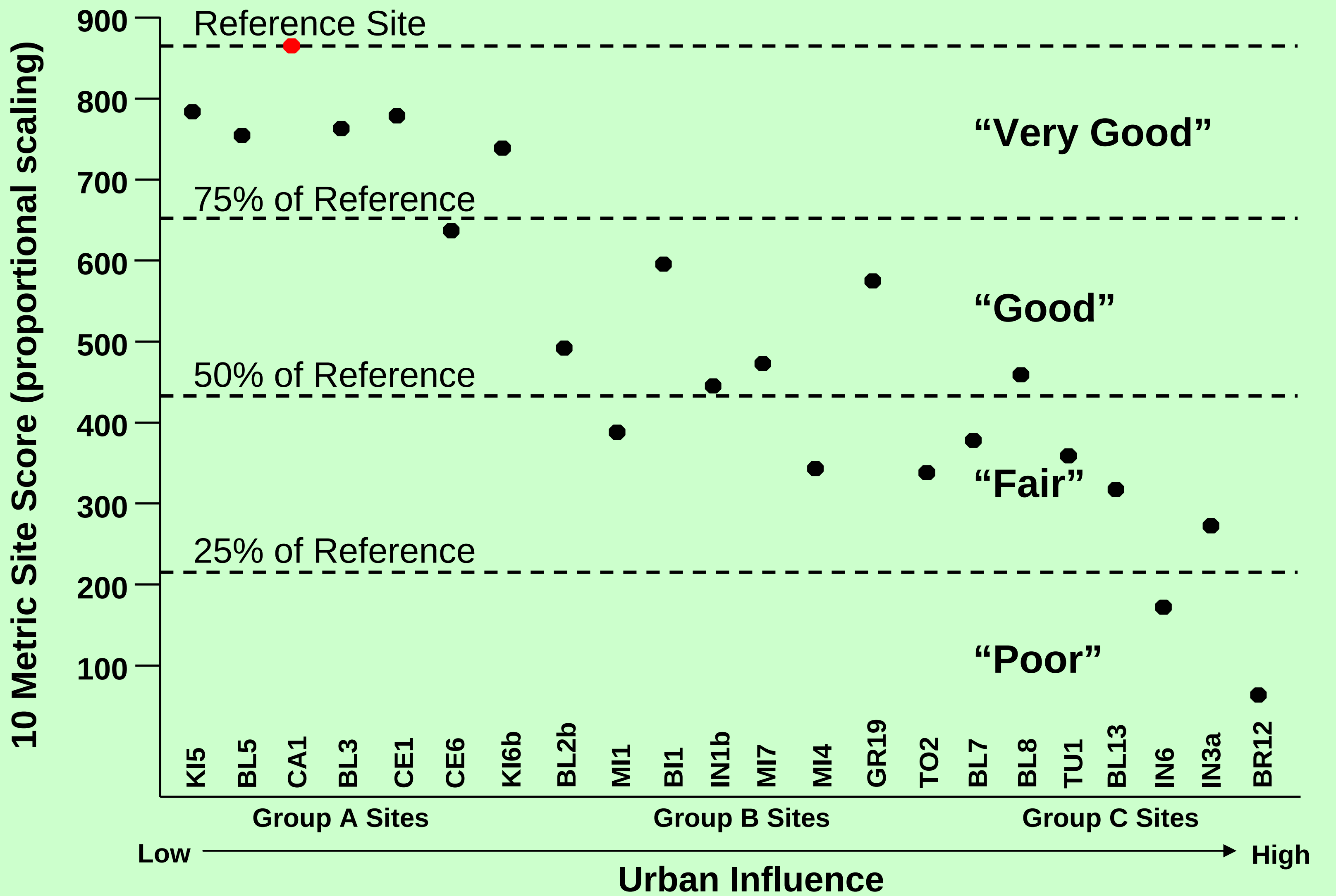
Categories determined by reference data from nearby ecoregion or watershed



* **Determination of Aquatic Life Status in wadeable streams of Missouri**

One Reference Site Available

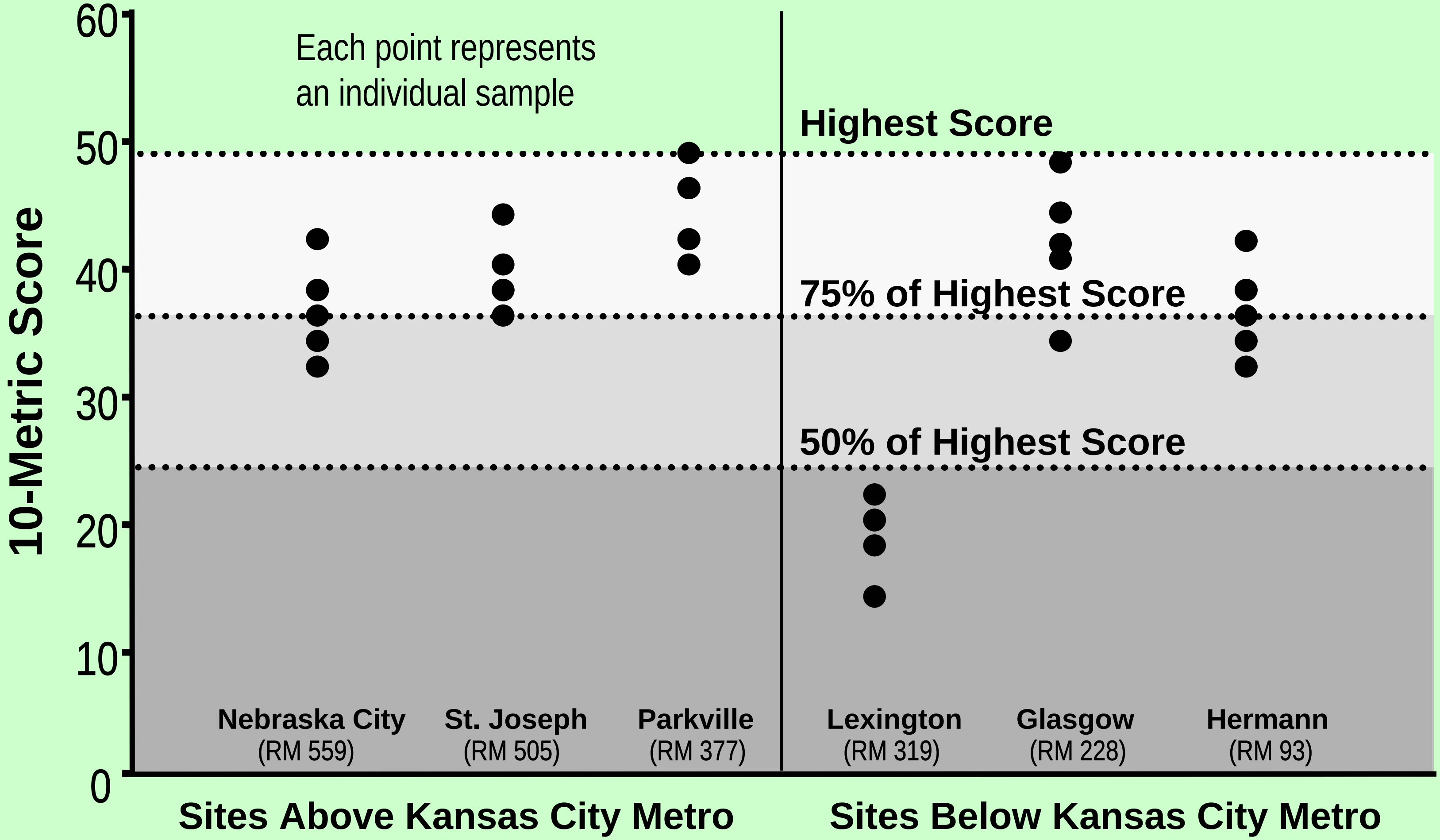
Categories determined by percent of reference site value



⋆ **Specific Bioassessment Research (in this case, an urban stream study)**

No Reference Sites Available Within Study Area

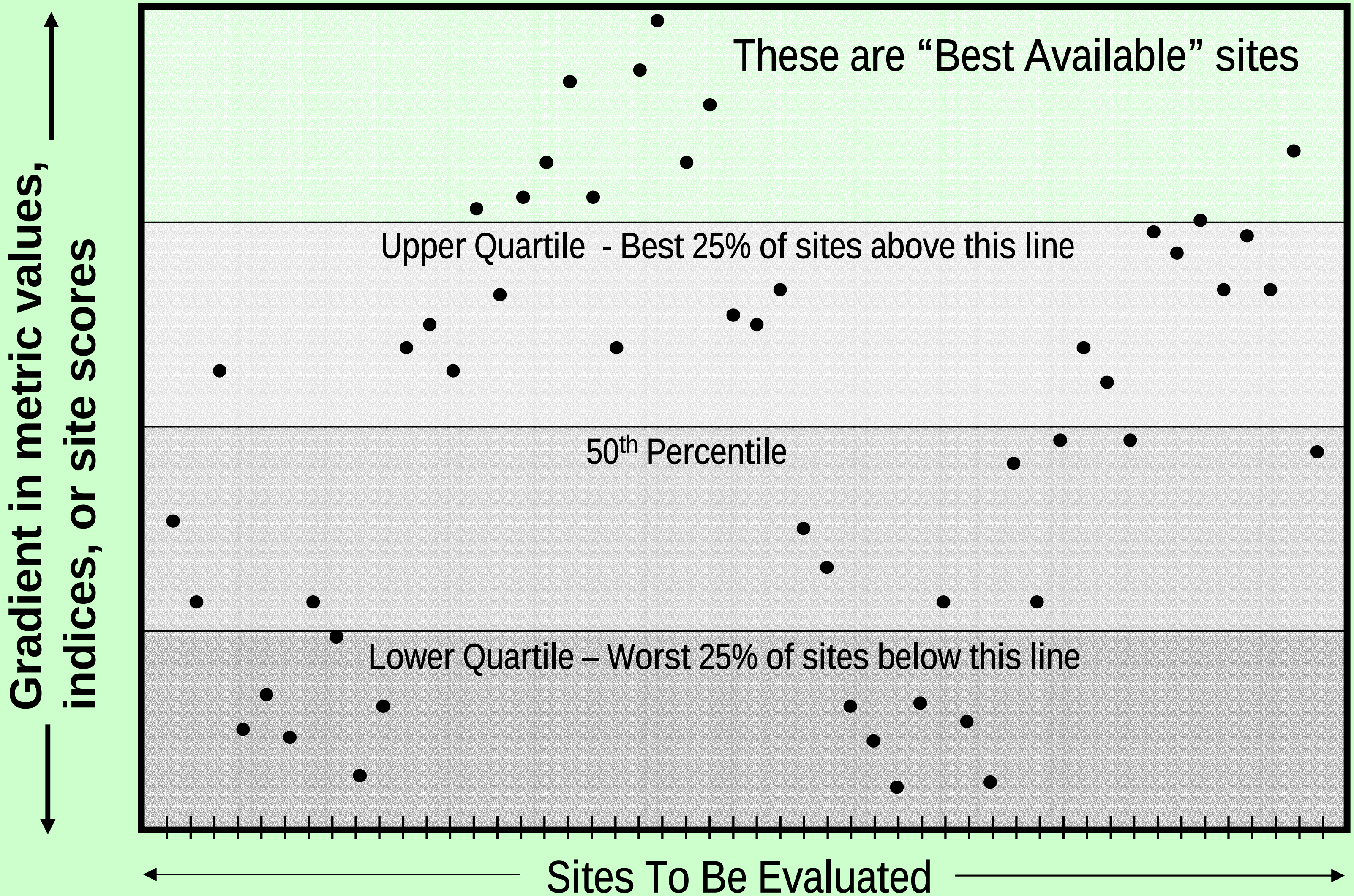
Categories determined by percent of highest value



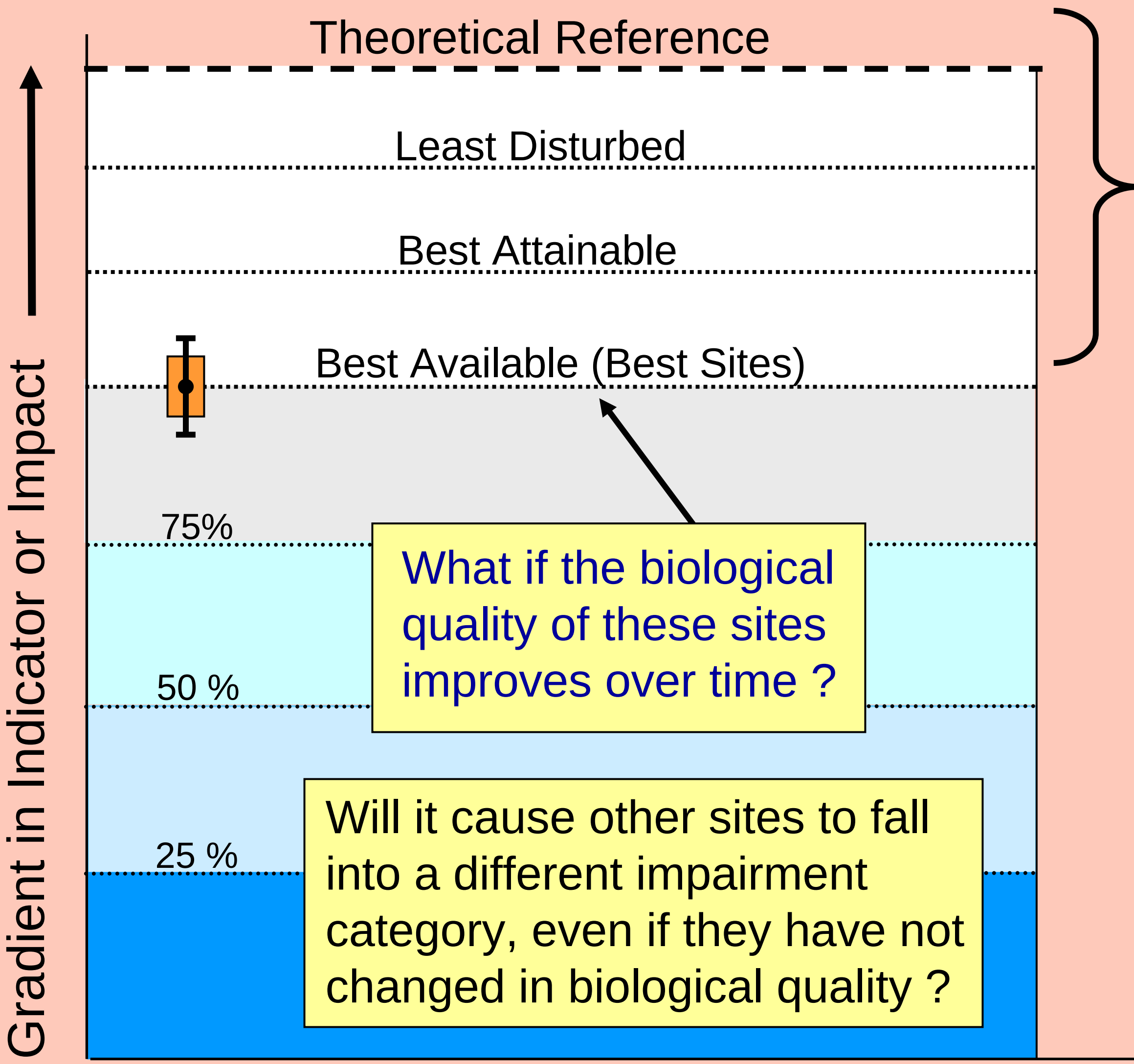
* **Research studies, for evaluation of relative biological condition**
(upstream-downstream approach)

Reference Unknown or Not Available

Categories defined by quartiles of distribution across all sites (n = 50)



* Research studies, for evaluation of relative biological condition



The True Reference Community probably falls somewhere in this range, but we don't know where. In highly altered systems where no reference is available, empirical approaches will only identify the "best available" sites or reaches

What About GRE's ? How close are we to Biological Integrity ?

Reasons why a Theoretical Reference could help assess the Missouri River, especially in the case of macroinvertebrates…

1. Not enough historical information from pre-alteration time periods to determine a "true reference" for aquatic communities

2. Most of drastic alterations may never be reversed to the degree needed for restoring any resemblance in historical biodiversity or ecological function.

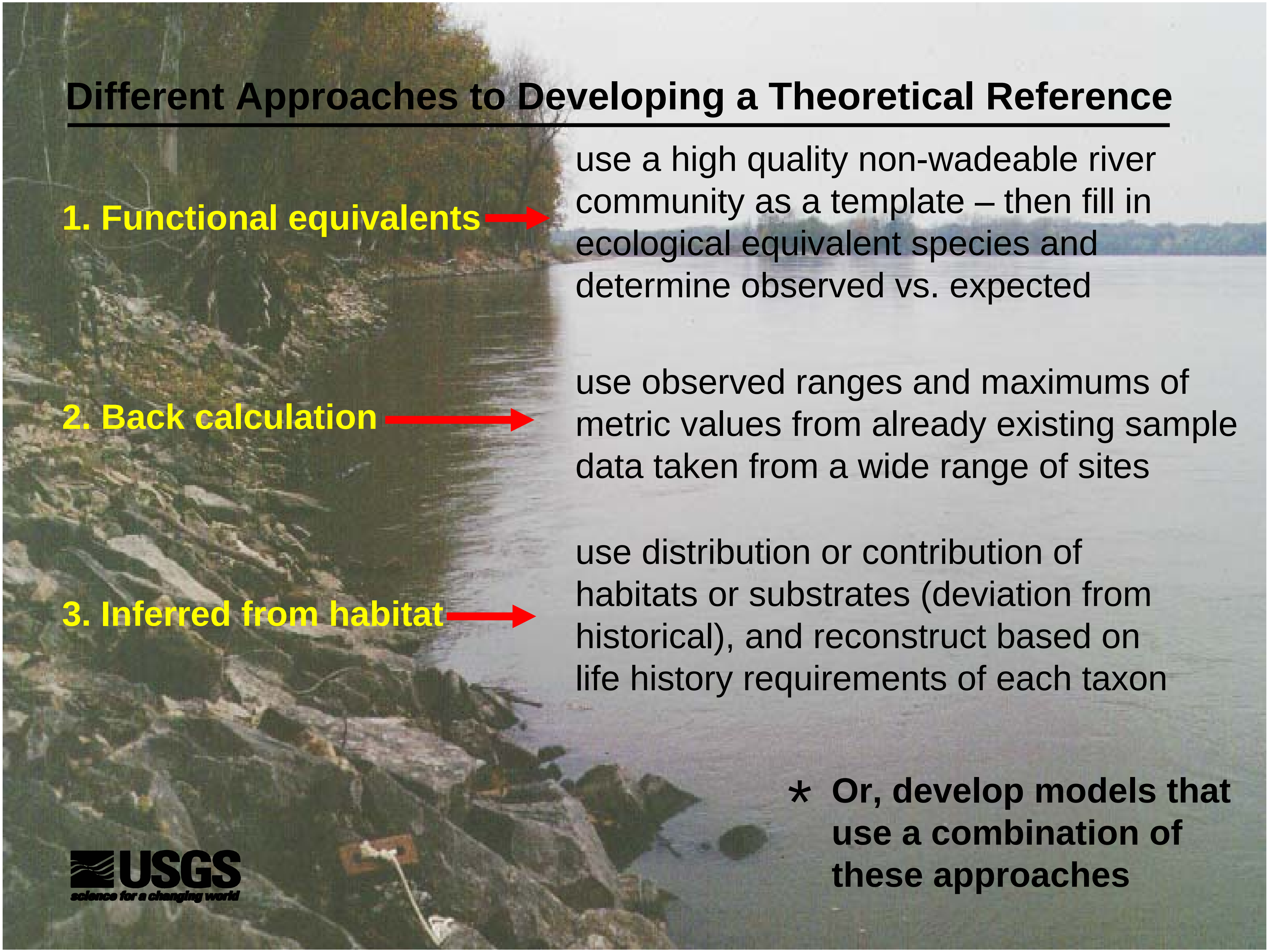
3. Information on habitat alterations (degree of habitat loss, relative change in channel complexity, distribution of substrate materials, etc.) has already been used to construct a "virtual river" based on channel characteristics (Jacobson et al. 2005). We have enough information on Missouri River macroinvertebrates to attempt something similar

4. A "best available" reference determined by empirical or GIS approaches may not be different enough from test sites to result in biological condition categories that would allow for a wide range in indicator response to future system improvements (habitat rehabilitation, better water quality, etc.)

5. Theoretical may be a higher benchmark with more stability than "best available"

Information Needed to construct a Theoretical Community:

- List of species and their relative abundances within specific habitats
- Habitat/substrate affinities (specialists vs. generalists, etc.)
- Functional group assignments
- Pollution tolerances
- Life history traits for species (past, present, and/or expected)
- * Site quality rating or integrated score (B-IBI or other multimetric indices)
- * Validated metrics (those that demonstrate measurable community responses to impacts)
- Observed ranges in metric values among multiple test sites
- Quantification of change in ecological components of the system, that can be tied to life history traits of the species (habitat loss, change in substrate availability, pollution levels, etc.)



Different Approaches to Developing a Theoretical Reference

1. Functional equivalents → use a high quality non-wadeable river community as a template – then fill in ecological equivalent species and determine observed vs. expected

2. Back calculation → use observed ranges and maximums of metric values from already existing sample data taken from a wide range of sites

3. Inferred from habitat → use distribution or contribution of habitats or substrates (deviation from historical), and reconstruct based on life history requirements of each taxon

* **Or, develop models that use a combination of these approaches**

USGS
science for a changing world

PLECOPTERA

Species Observed: Gasconade River (6th or 7th order)	Species Observed: Lower Missouri River – Present	Species Observed: Lower Missouri River – Ecological Equivalents	Species Expected: Unique Species	Species Expected: Total List
Acroneuria ozarkensis	____			____
Acroneuria frisoni	____			____
Acroneuria perplexa	____	*Acroneuria filicis*		*Acroneuria filicis*
Acroneuria internata	*Acroneuria internata*			*Acroneuria internata*
Neoperla robisoni	*Neoperla robisoni*			*Neoperla robisoni*
Neoperla harpi	____	*Neoperla clymene*		*Neoperla clymene*
Neoperla osage	*Neoperla osage*			*Neoperla osage*
Neoperla catharae	____			**(NE)**
Perlesta cinctipes	____	*Perlesta golconda*		*Perlesta golconda*
Perlesta browni	*Perlesta browni*			*Perlesta browni*
Perlesta decipiens	*Perlesta decipiens*			*Perlesta decipiens*
Perlinella ephyre	____			____
Perlinella drymo	____			**(NE)**
Taeniopteryx burksi	*Taeniopteryx burksi*			*Taeniopteryx burksi*
Taeniopteryx parvula	*Taeniopteryx parvula*			*Taeniopteryx parvula*
Allocapnia granulata	*Allocapnia granulata*			*Allocapnia granulata*
Strophopteryx fasciata	____			____
Allocapnia rickeri	*Allocapnia rickeri*			*Allocapnia rickeri*
Prostoia completa	____			**(NE)**
Pteronacrcys pictetii	*Pteronacrcys pictetii*			*Pteronacrcys pictetii*
Isoperla richardsoni	____	*Isoperla bilineata*		*Isoperla bilineata*
Isoperla ouachita	____	*Isoperla longiseta (extirpated)*		**(EXT)**
Hydroperla crosbyi	____	*Hydroperla fugitans*		*Hydroperla fugitans*
____	*Attaneuria ruralis*		*Attaneuria ruralis*	*Attaneuria ruralis*
____	*Acroneuria evoluta*		*Acroneuria evoluta*	*Acroneuria evoluta*
____	*Paragnetina kansensis*		*Paragnetina kansensis*	*Paragnetina kansensis*
Totals	13	6	3	23

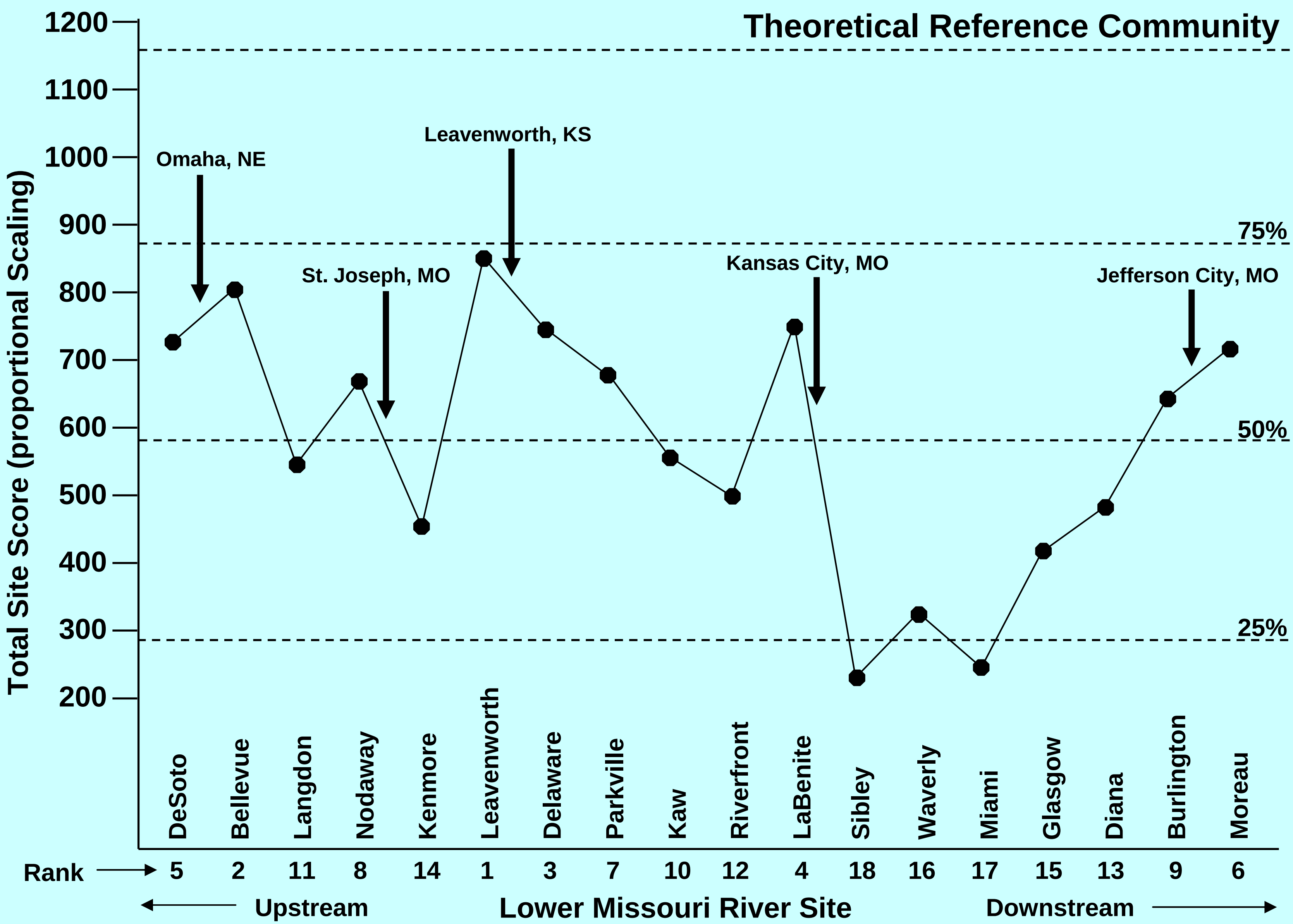
NE = not expected **EXT** = extirpated

Theoretical Reference Community – Lower Missouri Macroinvertebrates

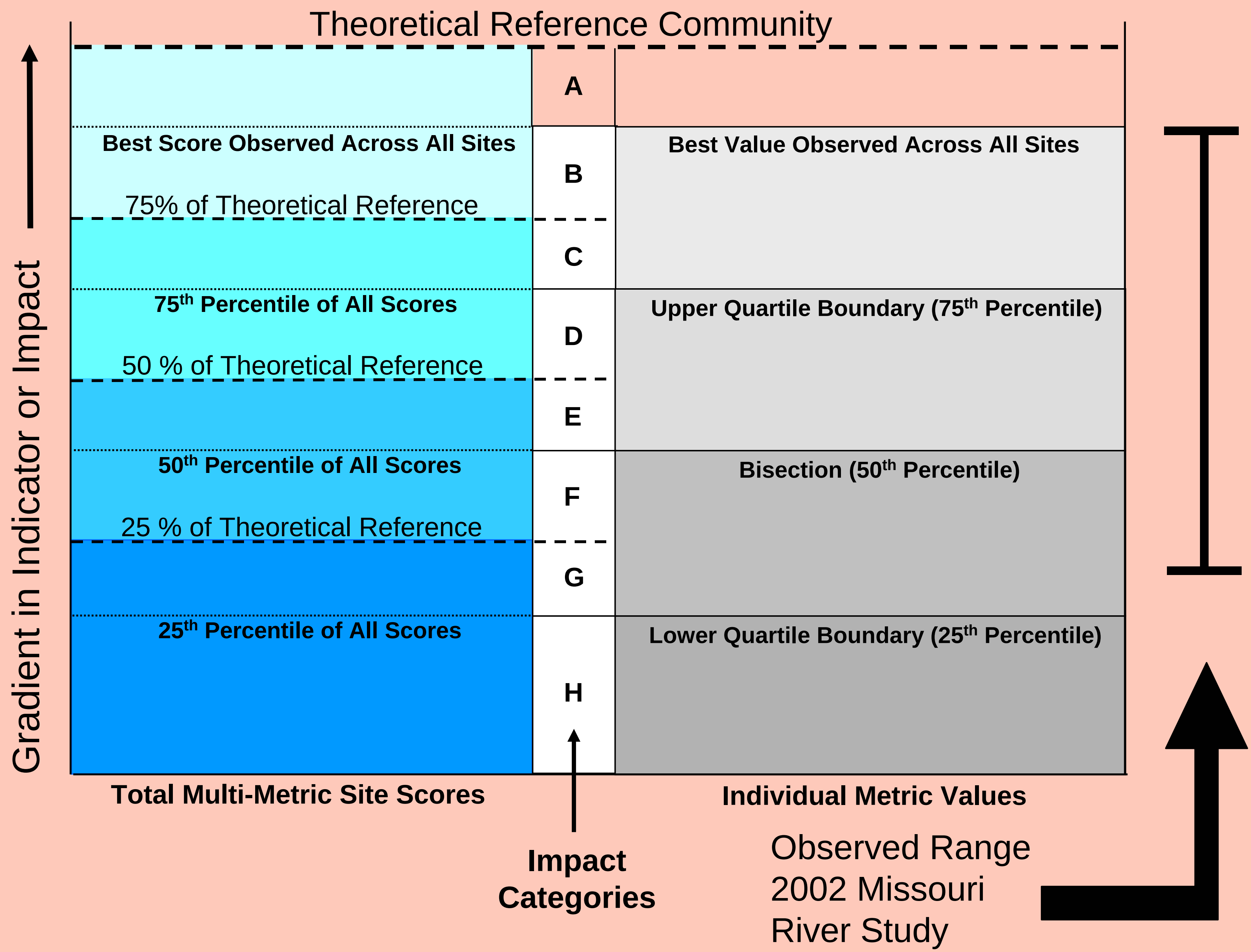
Example = Semi-Quantitative Kick Net Data from coarse substrate

- Community determined by back-calculation method
- Community attains highest (best) possible site score, based on performance of metrics that show response patterns

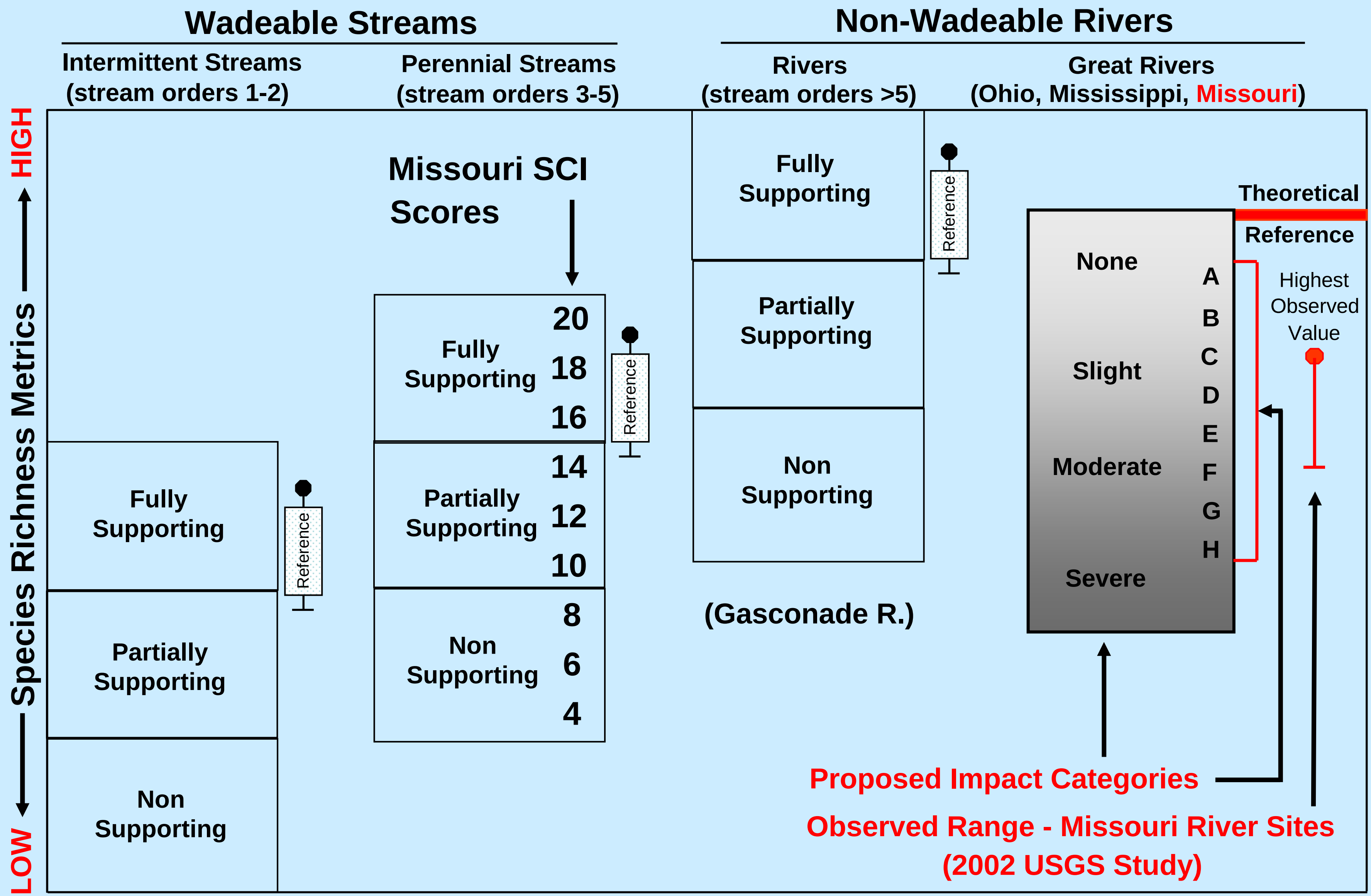
Group	Species Richness	Abundance (%)	Most Dominant Taxa
Ephemeroptera	9	35	*Stenonema integrum, Labiobaetis longipalpus*
Plecoptera	6	7	*Hydroperla fugitans, Isoperla bilineata*
Odonata	3	1	*Neurocordulia molesta, Argia* spp.
Trichoptera	5	32	*Potamyia flava, Hydropsyche orris*
Chironomidae	12	20	*Rheotanytarsus* sp., *Tanytarsus* spp.
Other Diptera	1	1	*Hemerodromia* sp.
Mollusca	1	1	*Spaerium* spp.
Other Taxa	7	3	*Stenelmis* sp., *Dugesia* sp.
Totals	44	100 %	



Theoretical Reference Community
Total Site Score (proportional Scaling)
1200
1100
1000
900
800
700
600
500
400
300
200
75%
50%
25%
Omaha, NE
Leavenworth, KS
St. Joseph, MO
Kansas City, MO
Jefferson City, MO
DeSoto
Bellevue
Langdon
Nodaway
Kenmore
Leavenworth
Delaware
Parkville
Kaw
Riverfront
LaBenite
Sibley
Waverly
Miami
Glasgow
Diana
Burlington
Moreau
Rank
5 2 11 8 14 1 3 7 10 12 4 18 16 17 15 13 9 6
Upstream
Lower Missouri River Site
Downstream



Theoretical Reference Community
Gradient in Indicator or Impact
A
Best Score Observed Across All Sites
75% of Theoretical Reference
B
C
75th Percentile of All Scores
50 % of Theoretical Reference
D
E
50th Percentile of All Scores
25 % of Theoretical Reference
F
G
25th Percentile of All Scores
H
Best Value Observed Across All Sites
Upper Quartile Boundary (75th Percentile)
Bisection (50th Percentile)
Lower Quartile Boundary (25th Percentile)
Total Multi-Metric Site Scores
Individual Metric Values
Impact Categories
Observed Range 2002 Missouri River Study



* Note that metric expectations, (i.e. richness attainability) should be higher for larger systems, to a point

Disadvantages, Criticisms, Discussion Topics

1). Benchmark may not be truly attainable. If not, is it valid enough to use ?

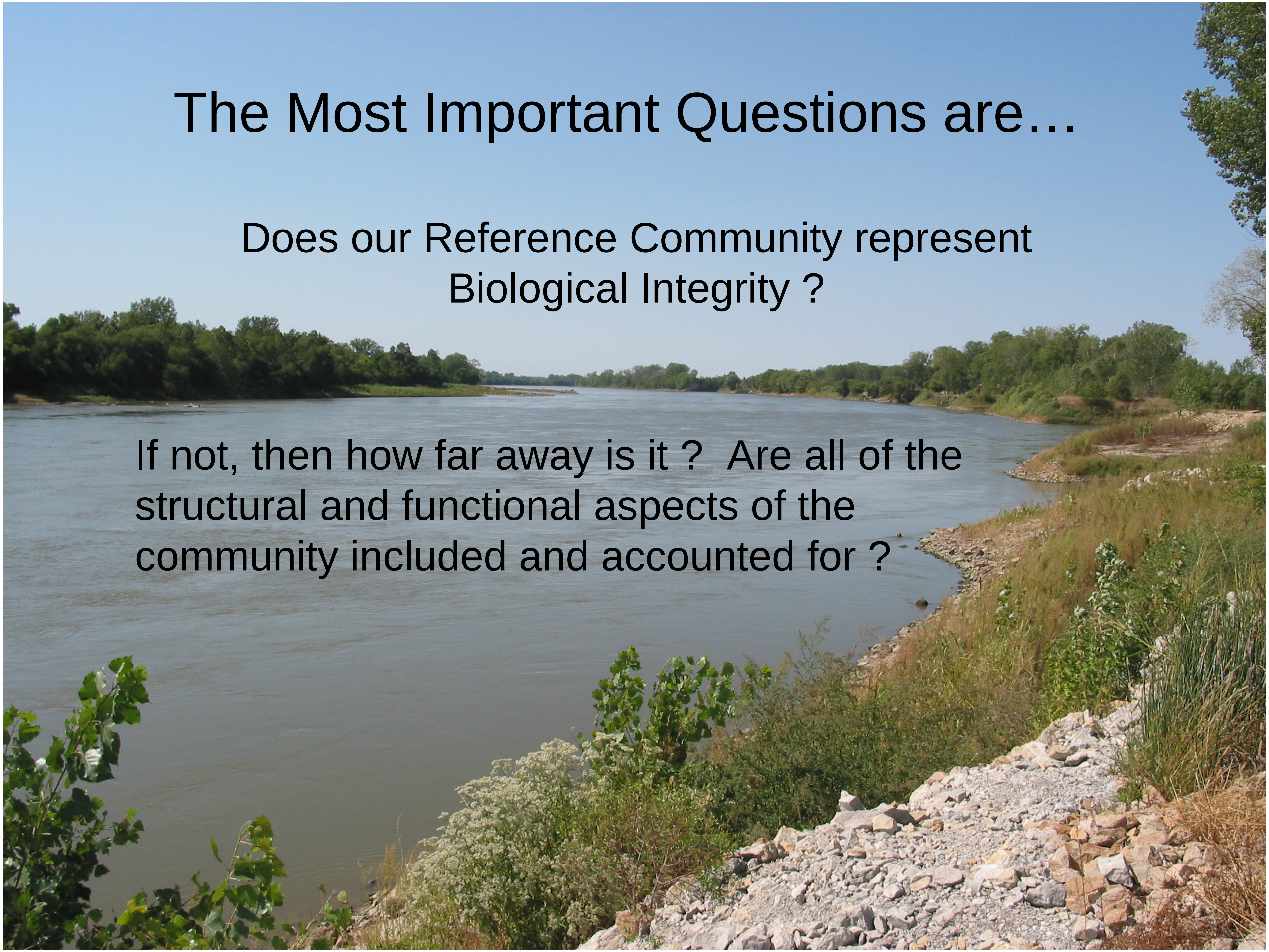
2). Does it matter how our benchmark is defined, as long as the biological assessment results fulfill objectives ?

- a). Are impairment categories reasonable
- b). Can assessment framework detect stressor effects
- c). Will biology show distinct responses to system changes
- d). If theoretical reference is a higher bulls-eye, is that a good thing (stability)

3). If metrics and indices can be evaluated without a benchmark (sensitivity, impact response, calibration, site discrimination, etc.), then reference is really more important for defining impairment categories, isn't it ?

4). Good species lists and habitat affinities are often poorly known for big river fauna – how much knowledge is needed to optimize accuracy ?

5). Circular, or "cheating" - need to determine best metrics and develop indices based on indicator responses observed in actual sample data FIRST – is this OK ? Would we consider this option if empirical didn't work ?



The Most Important Questions are…

Does our Reference Community represent Biological Integrity ?

If not, then how far away is it ? Are all of the structural and functional aspects of the community included and accounted for ?


Channelized lower 1100 km of the Missouri =
“One Big Hydrogeomorphic Patch”
?