Incorporating Trace Element Signatures Across a Large Riverscape to Assess Fish Movement Patterns

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Engineer Research and Development Center

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

EL

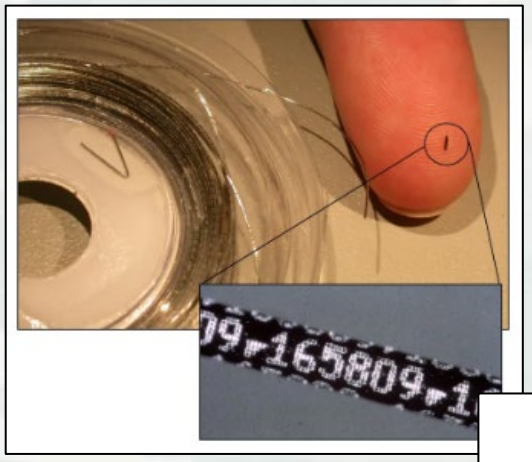
Ecosystem Management and Restoration Research Program (EMRRP)

SON: 1340 – Mapping Fish Origins to Inform Restoration Using Microchemistry

Problem:

- Lack of an understanding of large-scale movement patterns of fishes within a large watershed.
  - Highlighted by marked decline in some species due to habitat fragmentation associated with aquatic barriers.

- Development of a methodology to best integrate those data in guiding restoration project targets and success.
  - What do we gain through an identified solution?
    - Evaluate benefits of mitigating fish passage barriers.
    - Aid in identifying the contribution of tributaries to population dynamics of target species.
    - Characterize life history information (spawning and rearing locations) for sensitive species that would otherwise be difficult or impossible to obtain.



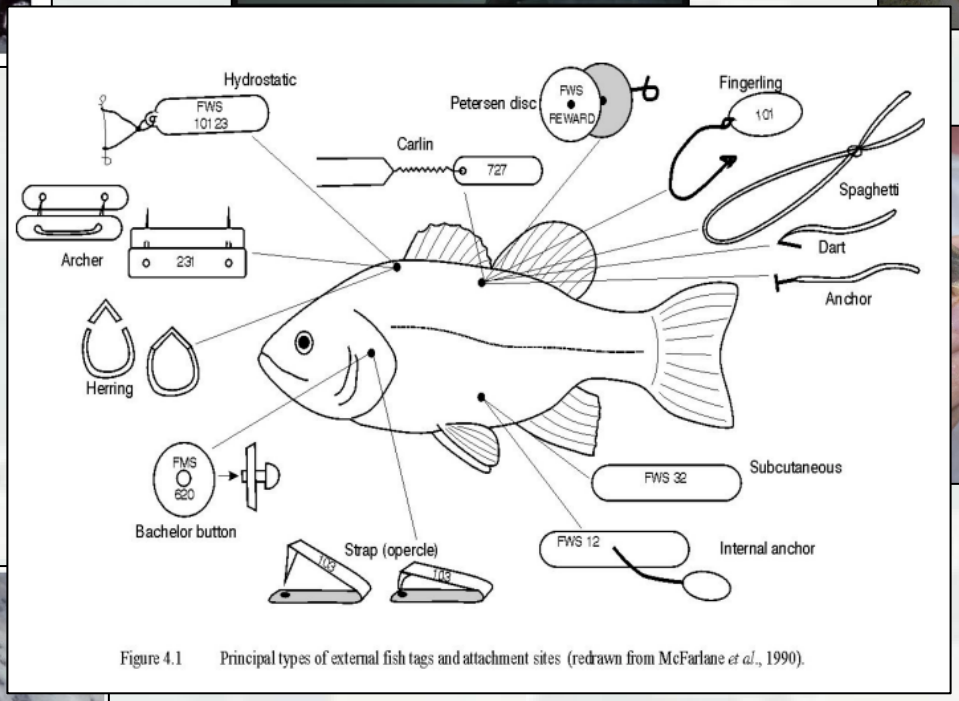
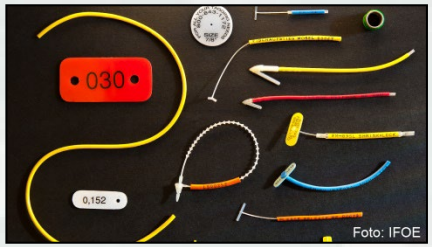
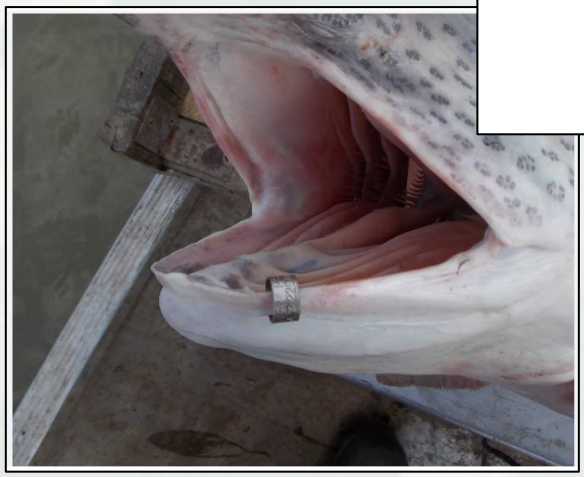
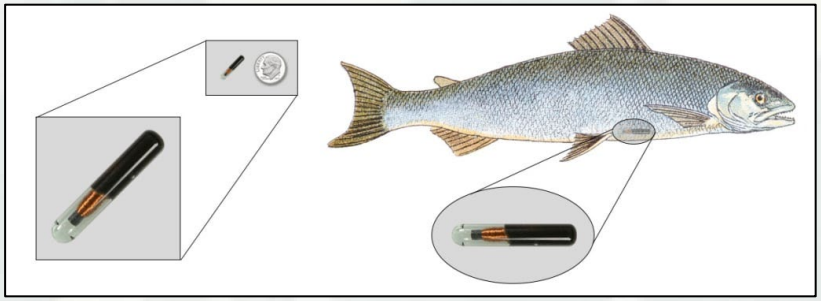
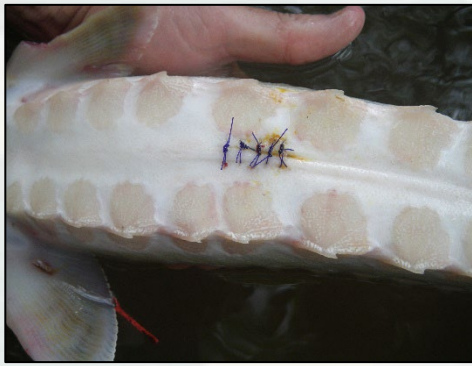


Figure 4.1 Principal types of external fish tags and attachment sites (redrawn from McFarlane *et al.*, 1990).



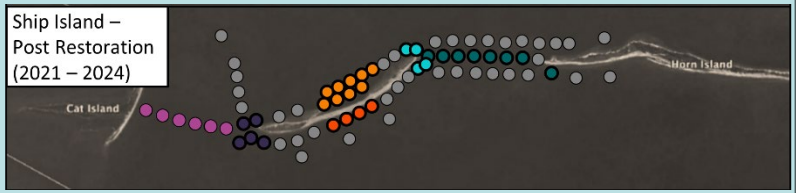


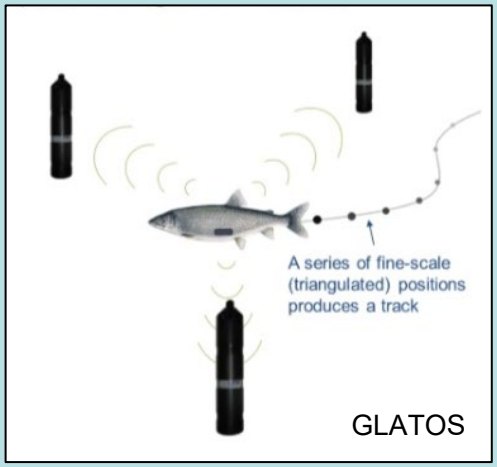




ACTIVE

PASSIVE

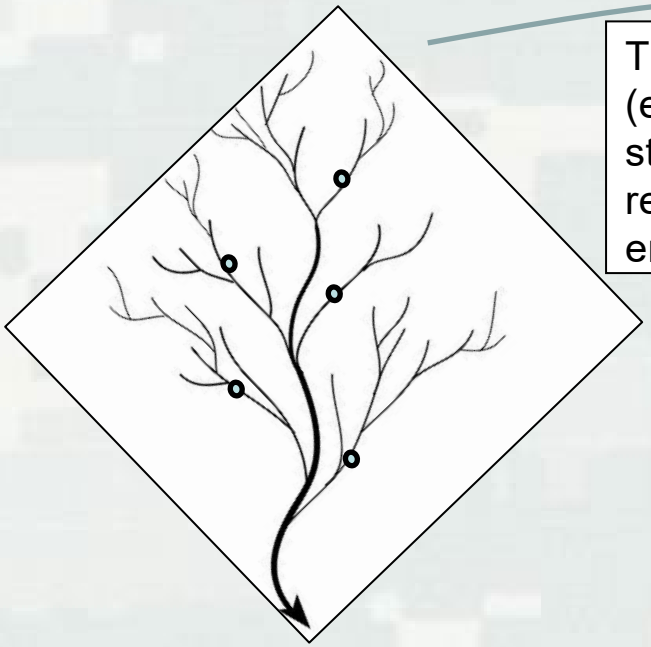




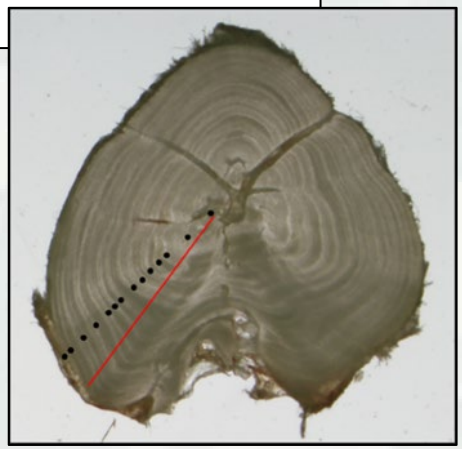
An alternative approach --

Utilize trace element and/or stable isotope chemistry to recreate environmental life history of target species.

- Widely used approach to address broad ecological questions
  - identify natal spawning areas
  - illustrate complex food web dynamics
  - address small-scale movement patterns
- Relies on identifying unique water chemistry signatures that are linked to distinct physiographic regions
- Conceptually – “you are what you eat”



This relationship assumes chemical constituents of the water (e.g., isotopes) are passively absorbed into calcified structures (fins, otoliths) with respect to time (i.e., age) in relative proportion to their availability within the ambient environment.



Generalized Approach

1. Development of a signature profile
    - Water samples are obtained from within the project area (i.e., watershed).
    - Samples are analyzed to characterize the unique analyte concentrations that are present.
    - Common analytes include Barium, Strontium, Calcium, Manganese, Zinc, Magnesium, Iron, Copper, Lead, Nickel, deuterium (^{2}H - a stable isotope of hydrogen), ^{18}O (stable isotope of oxygen) and ^{15}N.
    - All are not uniformly available as absorption rates of each varies with respect to differing metabolic or physiological pathways within the target organism, age of the organism and associated habitat (i.e., saltwater vs freshwater).

2. Determine isotopic profile from target species
    - Calcified structures or hard parts—otolith, pectoral fin section, scutes
    - Pectoral fin section is commonly used – non-lethal technique
        - ideal for species of concern
        - traditionally taken for demographic studies
        - readily available and easily obtained from voucher collections

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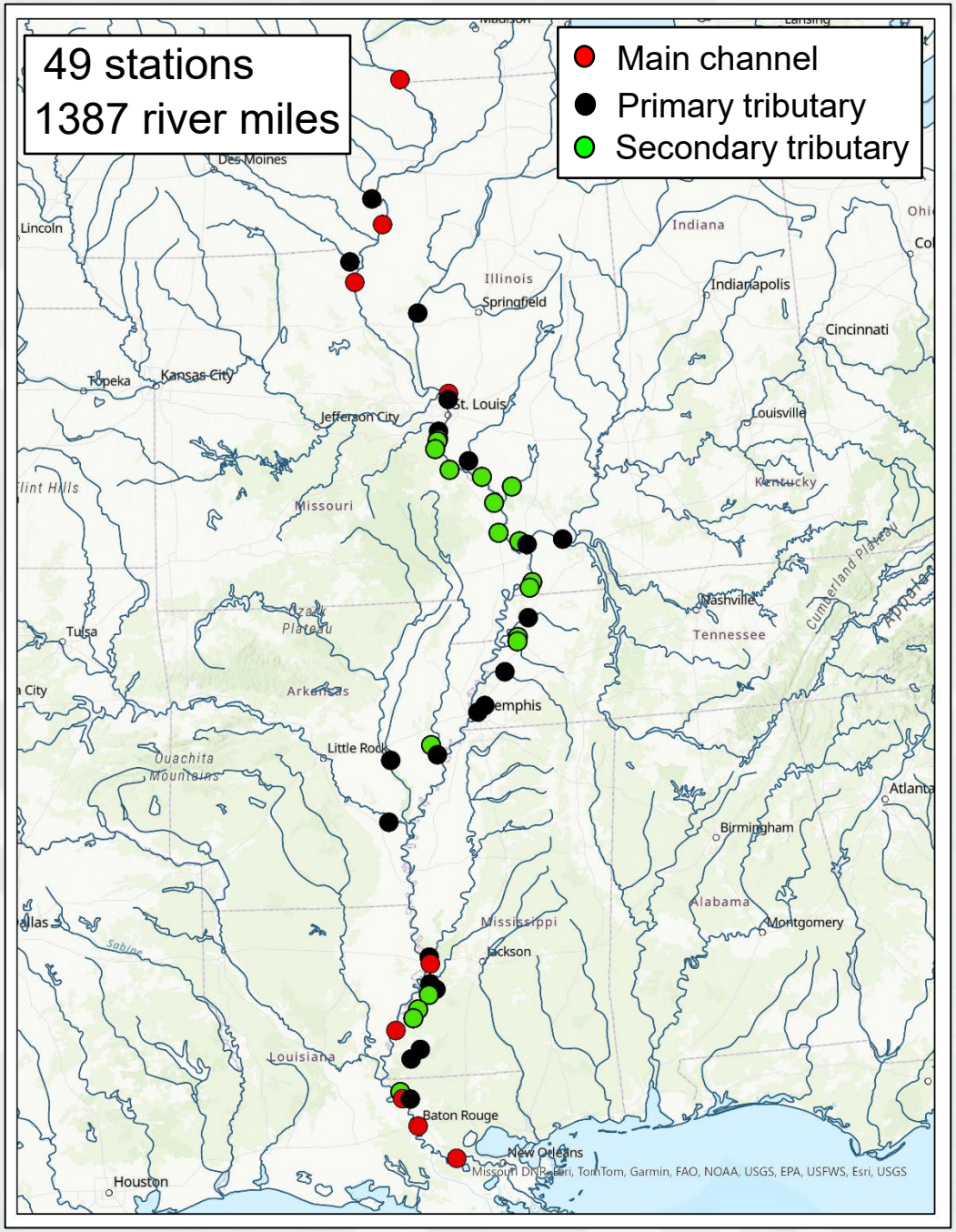
Water Samples

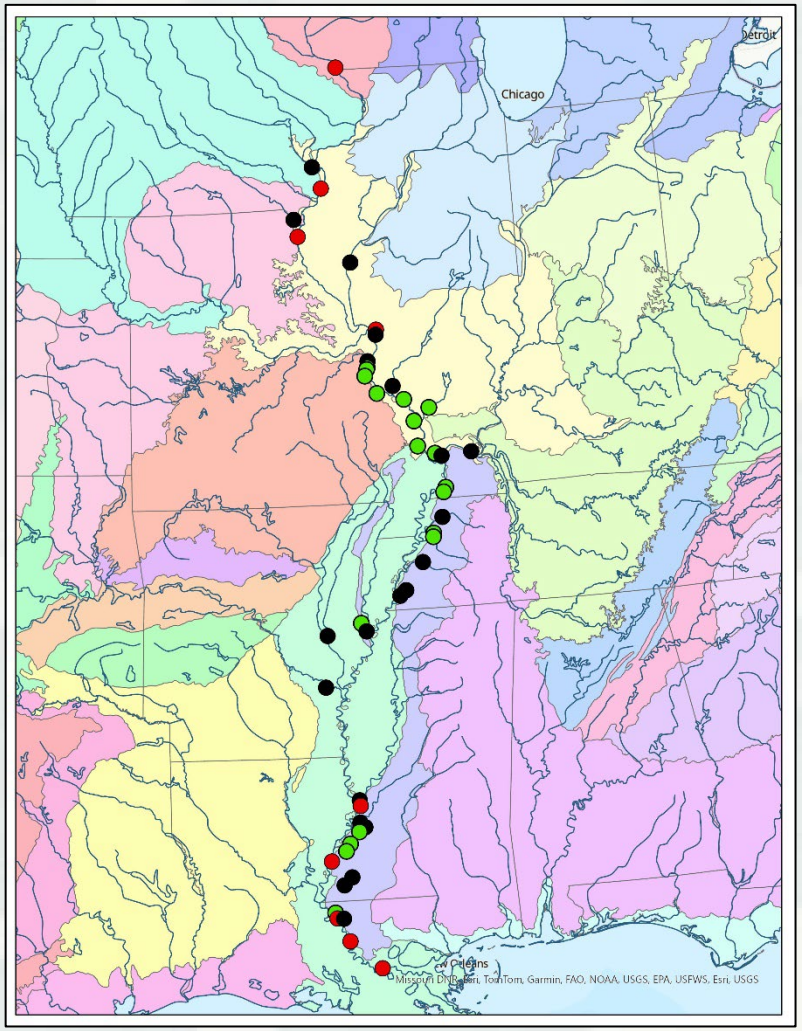
- Focus on the Mississippi River and major tributaries
- 49 sample stations
- Dubuque, IA to Gramercy, LA (1387 river miles)
- three unfiltered samples per station (left descending bank, mid-channel, right descending bank)
- July through December 2023
- seasonally normal water conditions
- samples maintained on ice in the field and held in refrigerator until transferred for analyses

Samples analyzed at ERDC EL Chemistry Laboratory

- followed recognized methods and calibrations
- Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)
- Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
- total metal concentrations reported for Barium, Strontium, Calcium, Iron and Lithium



EPA Level III Ecoregions



Iron
mg/L
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
UMR 1
Iowa River
UMR 2
Des Moines River
UMR 3
Illinois River
MMR 1
Missouri River
Meramec River
Rock Creek
Glaize Creek
Joachim Creek
Kaskaskia River
Establishment Creek
Marys River
Big Muddy River
Apple Creek
Hubble Creek
Cache River
OR 1
OR 2
Obion Creek
Bayou de Chien
Obion River
N Fork Forked Deer River
S Fork Forked Deer River
Hatchie River
Loosahatchie River
Wolf River
L' Anguille River
St. Francis River
White River
Arkansas River
Yazoo River
LMR 1
Big Black River
Bayou Pierre
LMR 2
LMR 3
LMR 4
LMR 5

Lithium
mg/L
0.05
0.04
0.03
0.02
0.01
0.00
UMR 1
Iowa River
UMR 2
Des Moines River
UMR 3
Illinois River
MMR 1
Missouri River
Meramec River
Rock Creek
Glaize Creek
Joachim Creek
Kaskaskia River
Establishment Creek
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OR 1
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S Fork Forked Deer River
Hatchie River
Loosahatchie River
Wolf River
L' Anguille River
St. Francis River
White River
Arkansas River
Yazoo River
LMR 1
Big Black River
Bayou Pierre
Little Bayou Pierre
N Fork Coles Creek
S Fork Coles Creek
LMR 2
Homochitto River
Buffalo River
Bayou Sarah
Little Bayou Sarah
LMR 3
Thompson Creek
LMR 4
LMR 5

Barium
mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
UMR 1
Iowa River
UMR 2
Des Moines River
UMR 3
Illinois River
MMR 1
Missouri River
Meramec River
Rock Creek
Glaize Creek
Joachim Creek
Kaskaskia River
Establishment Creek
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Obion Creek
Bayou de Chien
Obion River
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St. Francis River
White River
Arkansas River
Yazoo River
LMR 1
Big Black River
Bayou Pierre
Little Bayou Pierre
N Fork Coles Creek
Homochitto River
Buffalo River
Bayou Sarah
LMR 3
Thompson Creek
LMR 4
LMR 5

Strontium
mg/L
0.6
0.5
0.4
0.3
0.2
0.1
0.0
UMR 1
Iowa River
UMR 2
Des Moines River
UMR 3
Illinois River
MMR 1
Missouri River
Meramec River
Rock Creek
Glaize Creek
Joachim Creek
Kaskaskia River
Establishment Creek
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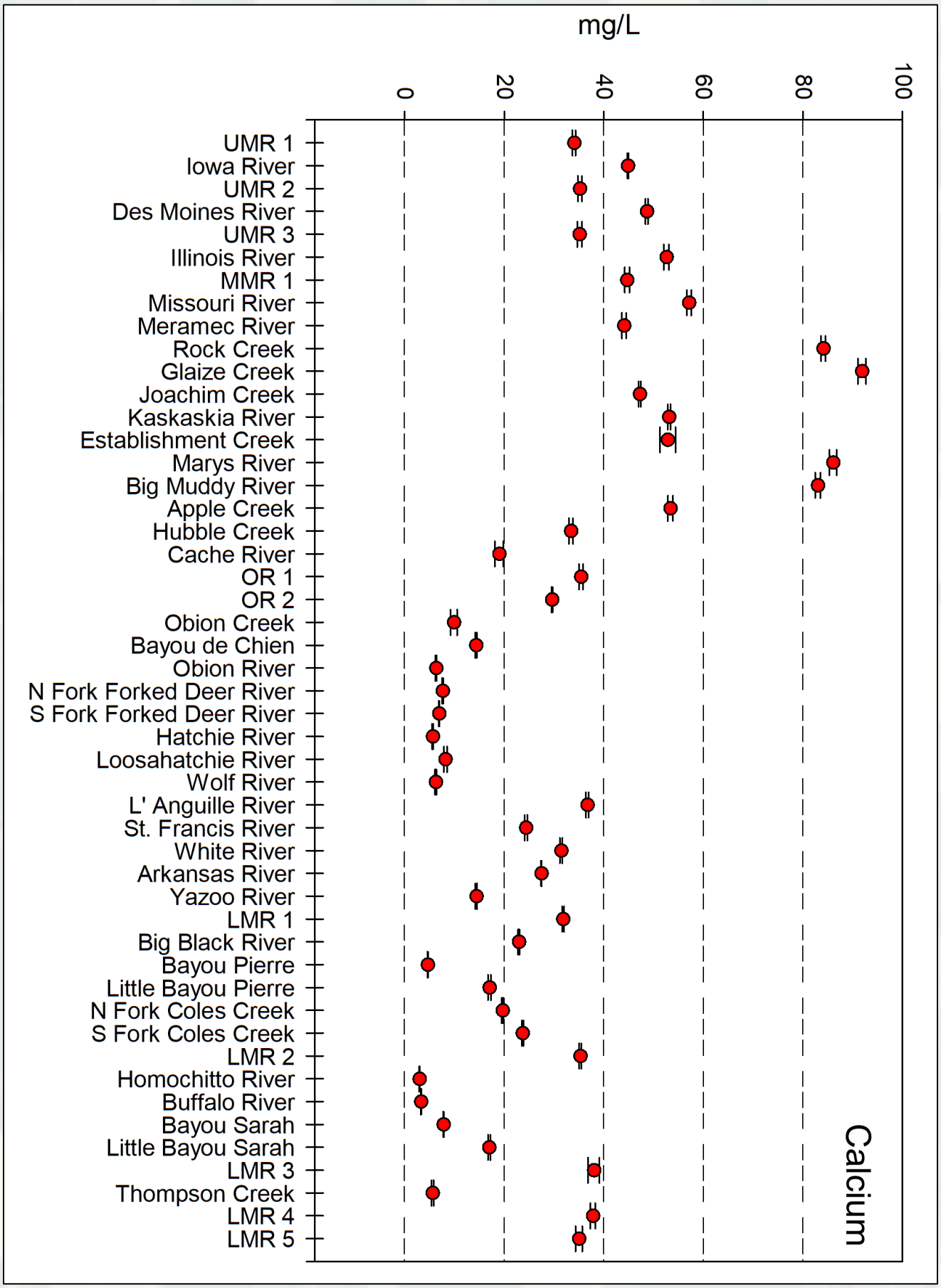
Thompson Creek
LMR 4
LMR 5


mg/L
0
20
40
60
80
100
UMR 1
Iowa River
UMR 2
Des Moines River
UMR 3
Illinois River
MMR 1
Missouri River
Meramec River
Rock Creek
Glaize Creek
Joachim Creek
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Establishment Creek
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S Fork Coles Creek
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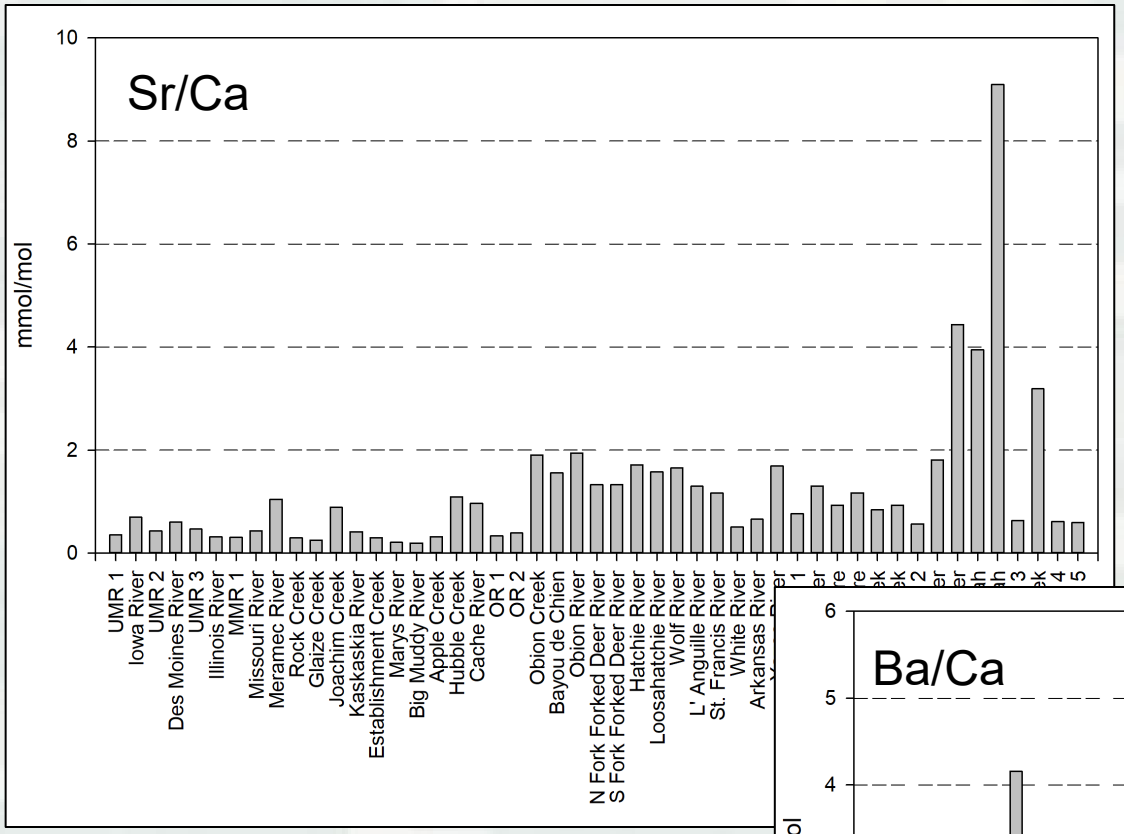
Buffalo River
Bayou Sarah
Little Bayou Sarah
LMR 3
Thompson Creek
LMR 4
LMR 5
Calcium


Sr/Ca
mmol/mol
0
2
4
6
8
10
UMR 1
Iowa River
UMR 2
Des Moines River
UMR 3
Illinois River
MMR 1
Missouri River
Meramec River
Rock Creek
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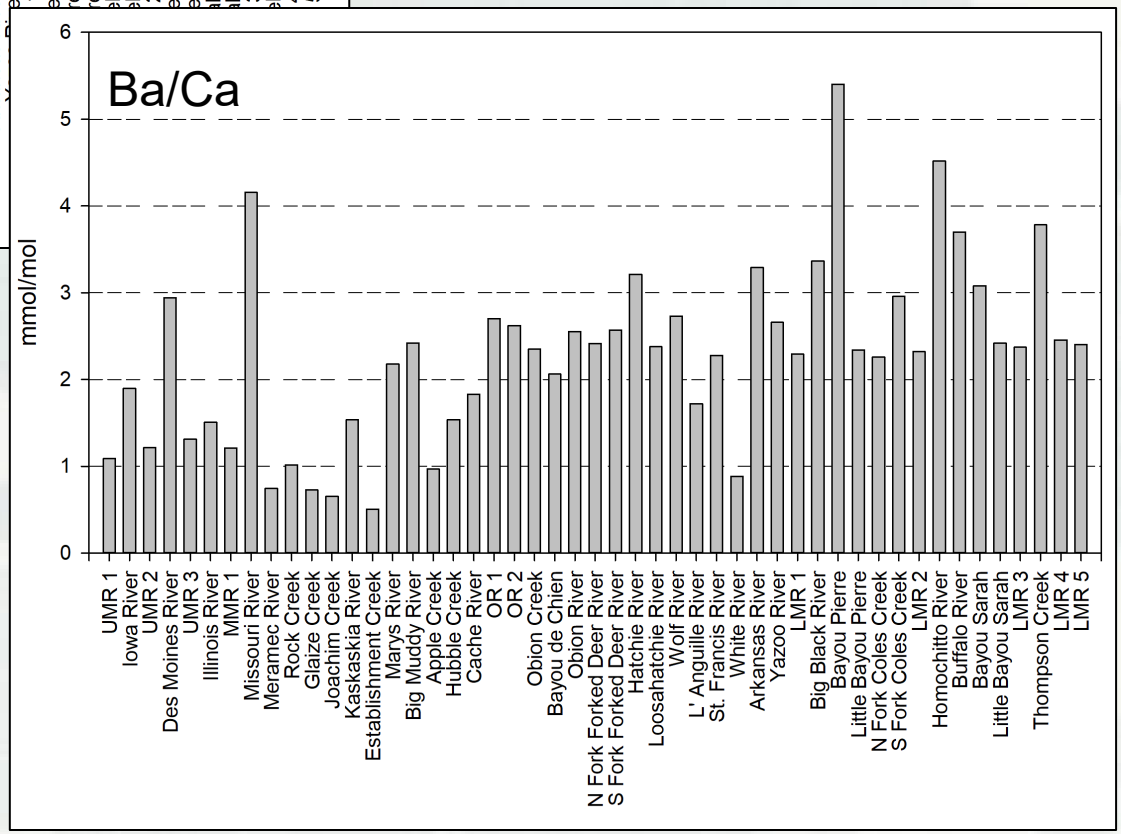
Ba/Ca
mmol/mol
0
1
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UMR 1
Iowa River
UMR 2
Des Moines River
UMR 3
Illinois River
MMR 1
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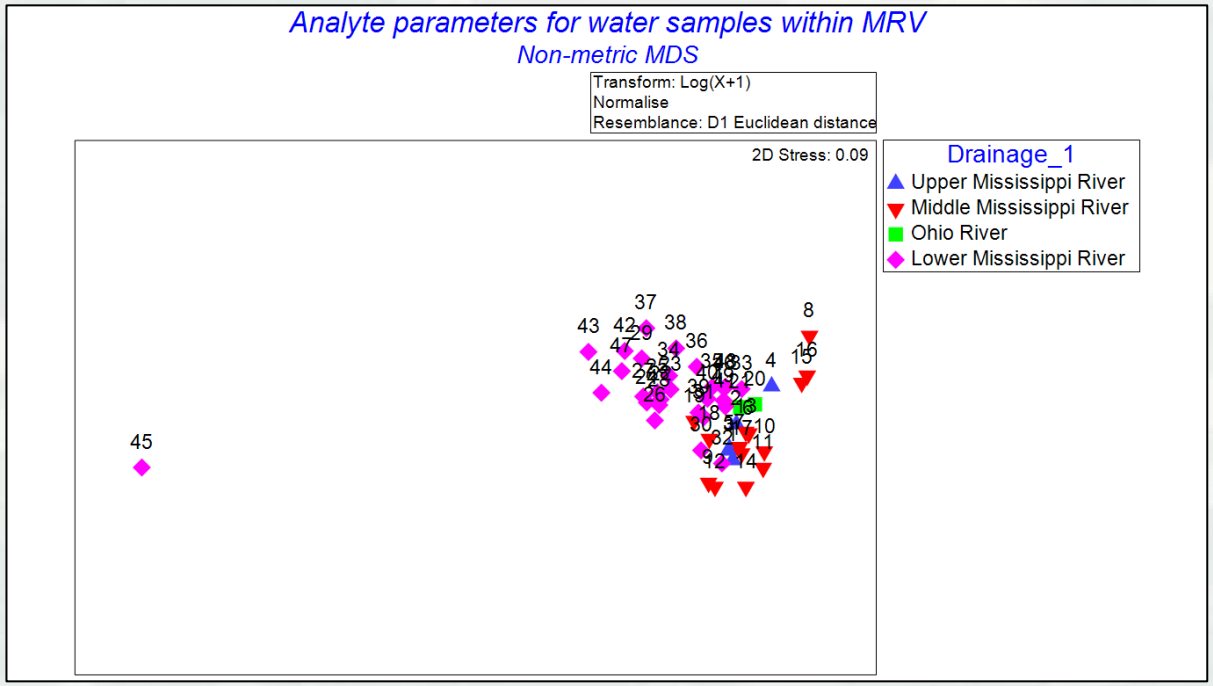
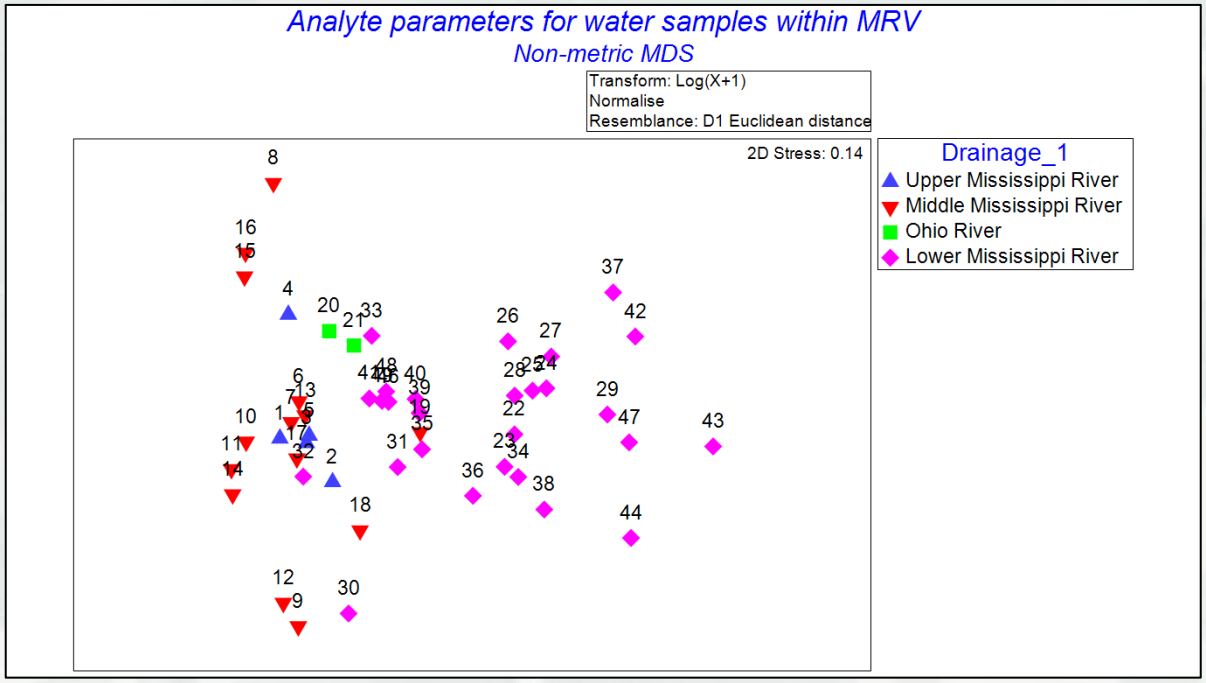
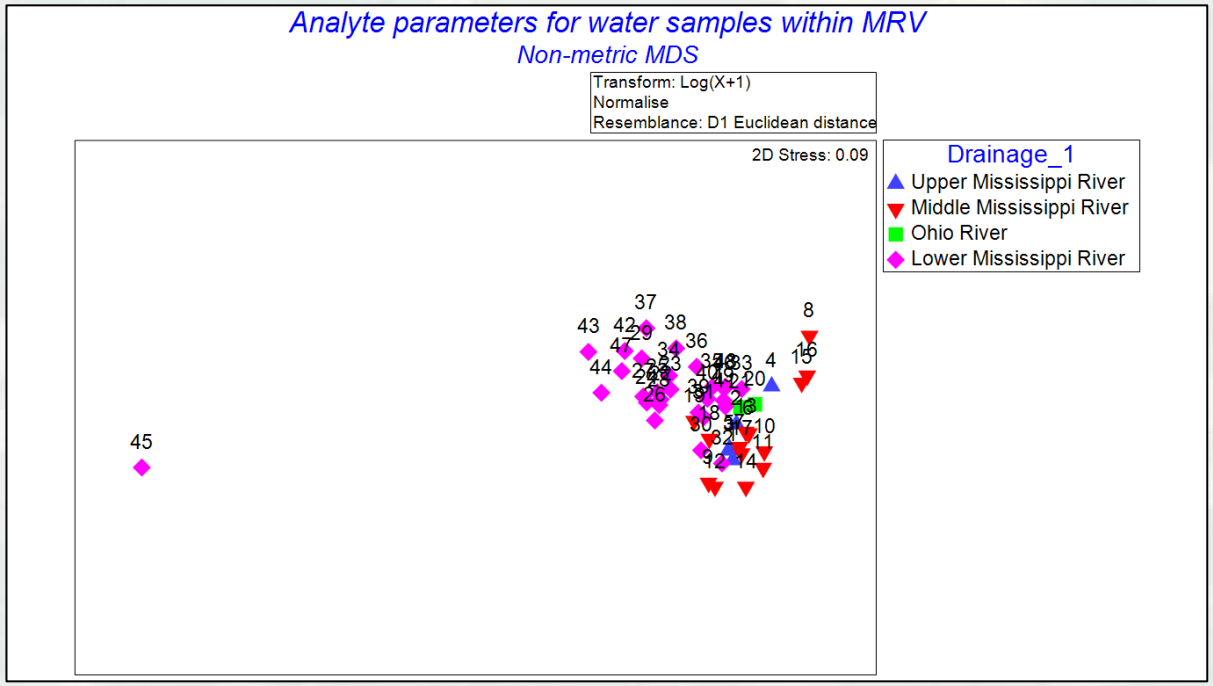
LMR 4
LMR 5



Excluding Lithium

Excluding Lithium and station 45





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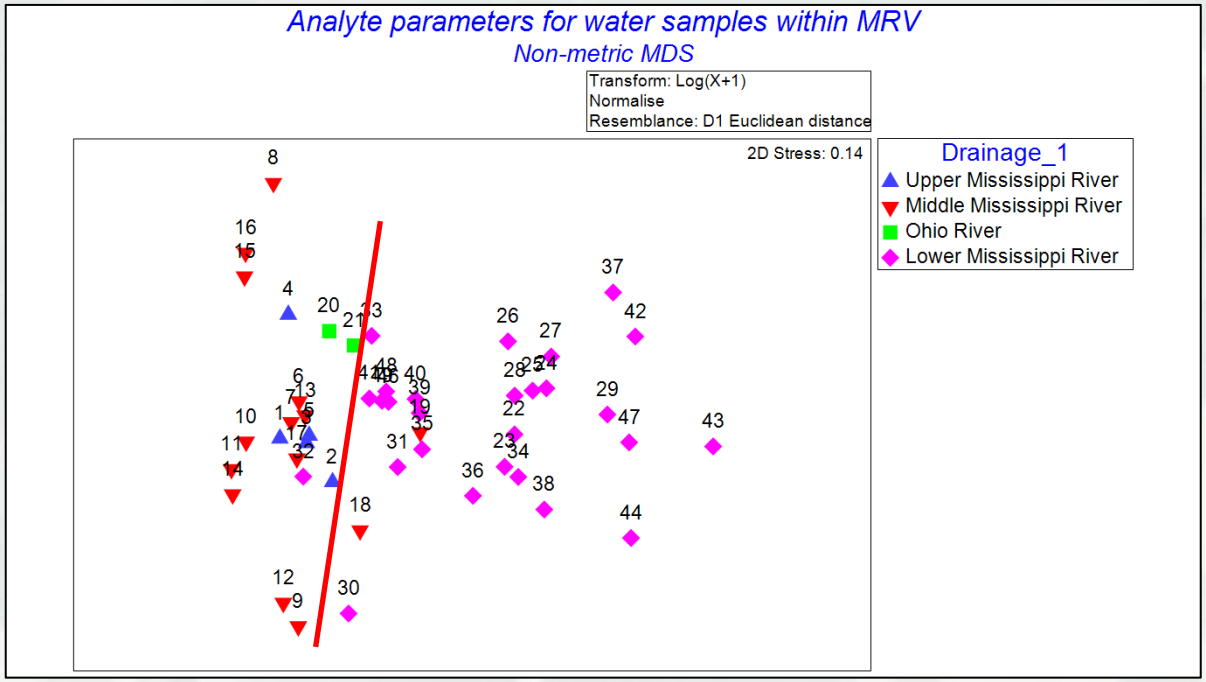

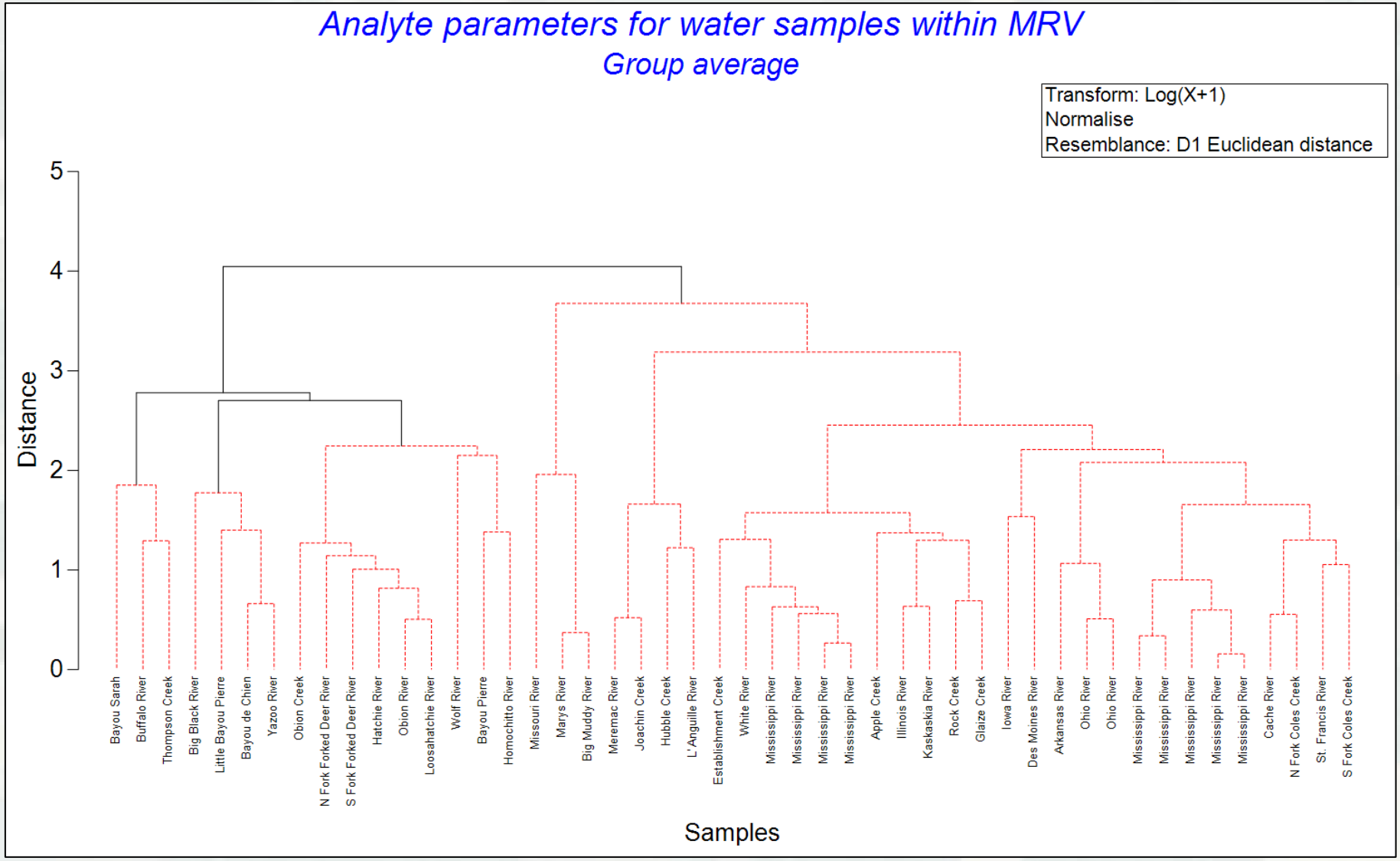
Analyte parameters for water samples within MRV
Group average
Transform: Log(X+1)
Normalise
Resemblance: D1 Euclidean distance
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3
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5
Samples
Bayou Sarah
Buffalo River
Thompson Creek
Big Black River
Little Bayou Pierre
Bayou de Chien
Yazoo River
Obion Creek
N Fork Forked Deer River
S Fork Forked Deer River
Hatchie River
Obion River
Loosahatchie River
Wolf River
Bayou Pierre
Homochitto River
Missouri River
Marys River
Big Muddy River
Meremac River
Joachin Creek
Hubble Creek
L'Anguille River
Establishment Creek
White River
Mississippi River
Mississippi River
Mississippi River
Mississippi River
Apple Creek
Illinois River
Kaskaskia River
Rock Creek
Glaize Creek
Iowa River
Des Moines River
Arkansas River
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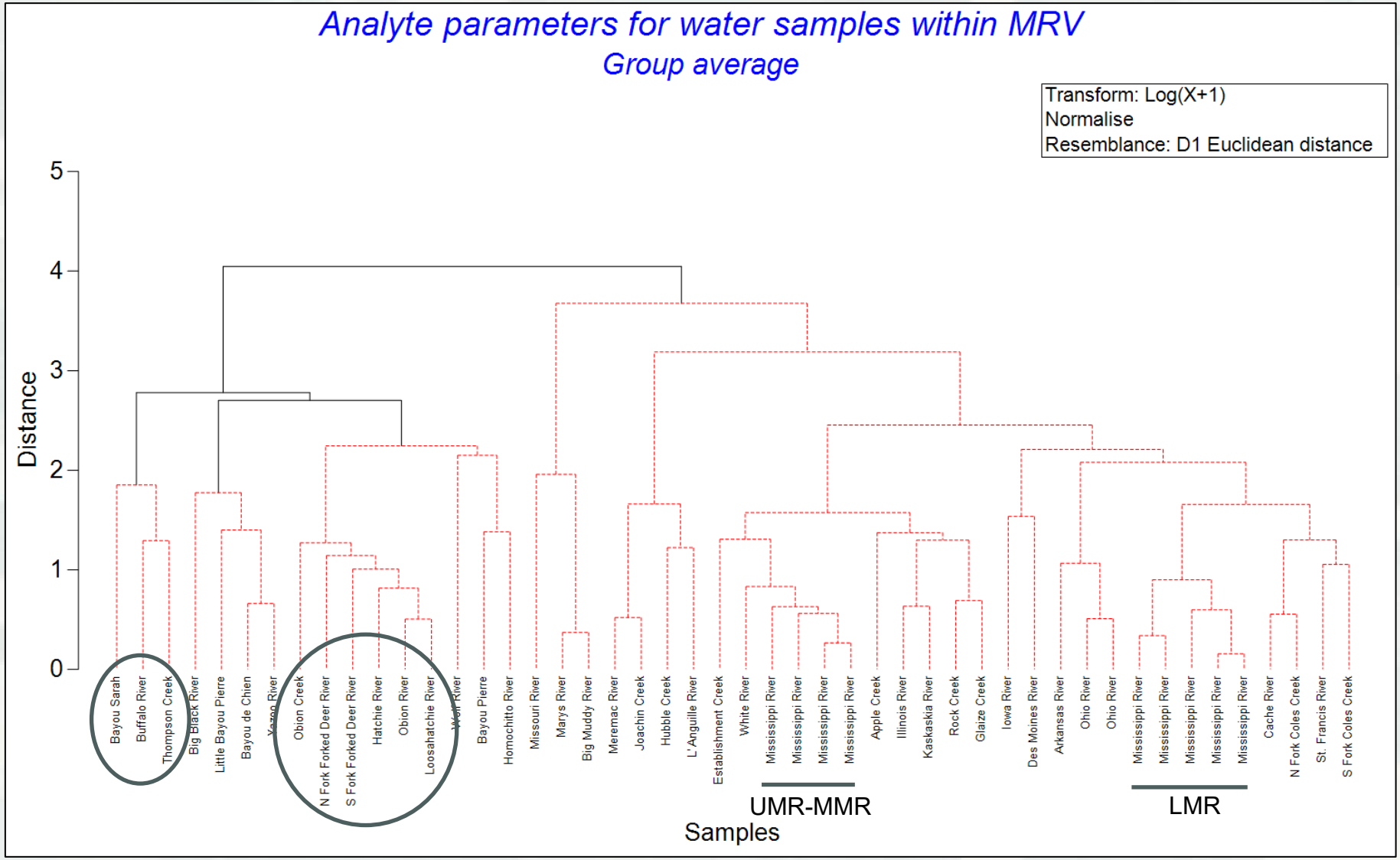
Mississippi River
Mississippi River
Cache River
N Fork Coles Creek
St. Francis River
S Fork Coles Creek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Transform: Log(X+1)
Normalise
Resemblance: D1 Euclidean distance
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Bayou Sarah
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Illinois River
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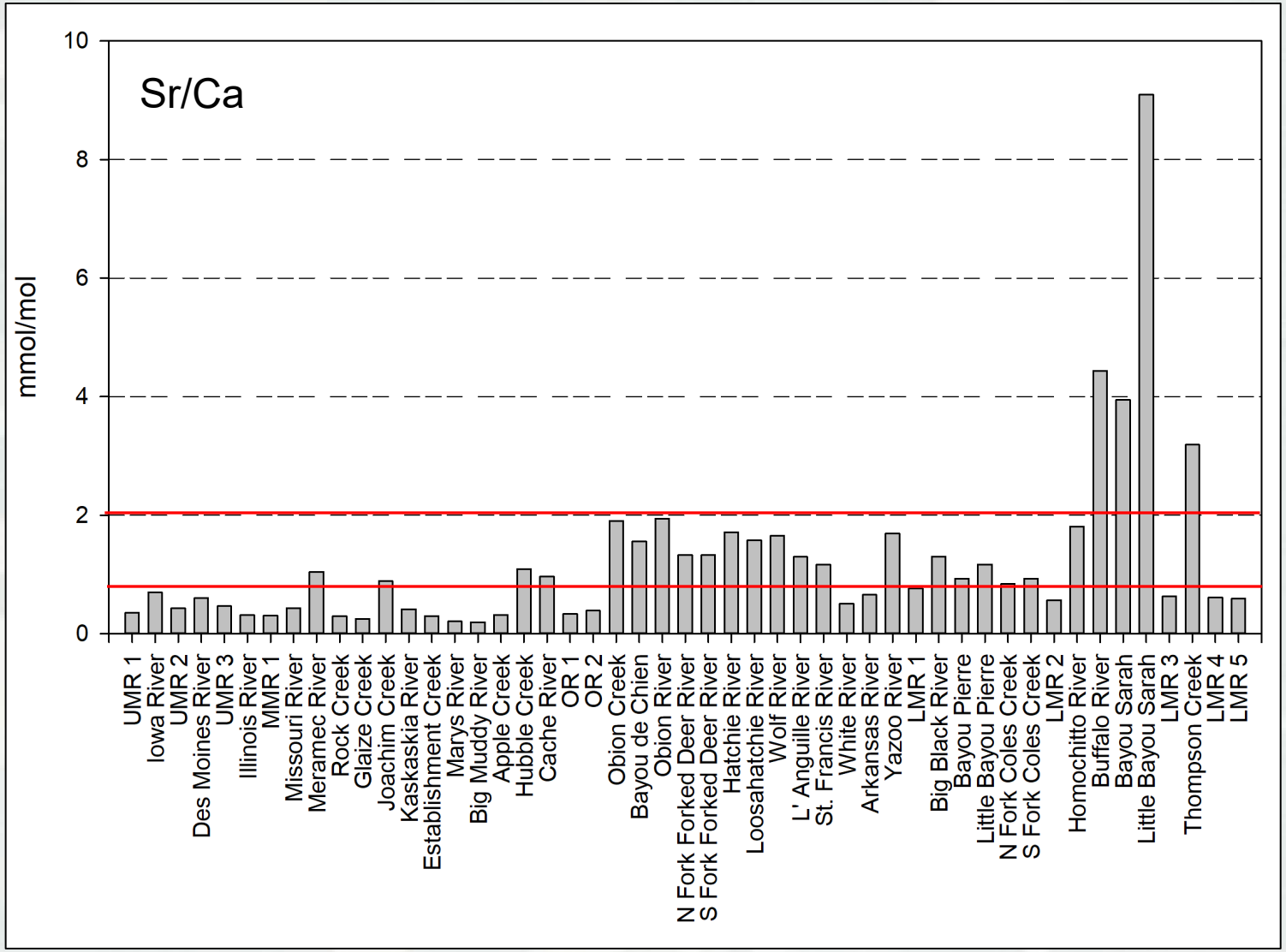
Rock Creek
Glaize Creek
Iowa River
Des Moines River
Arkansas River
Ohio River
Ohio River
Mississippi River
Mississippi River
Mississippi River
Mississippi River
Mississippi River
Cache River
N Fork Coles Creek
St. Francis River
S Fork Coles Creek
UMR-MMR
LMR
Samples

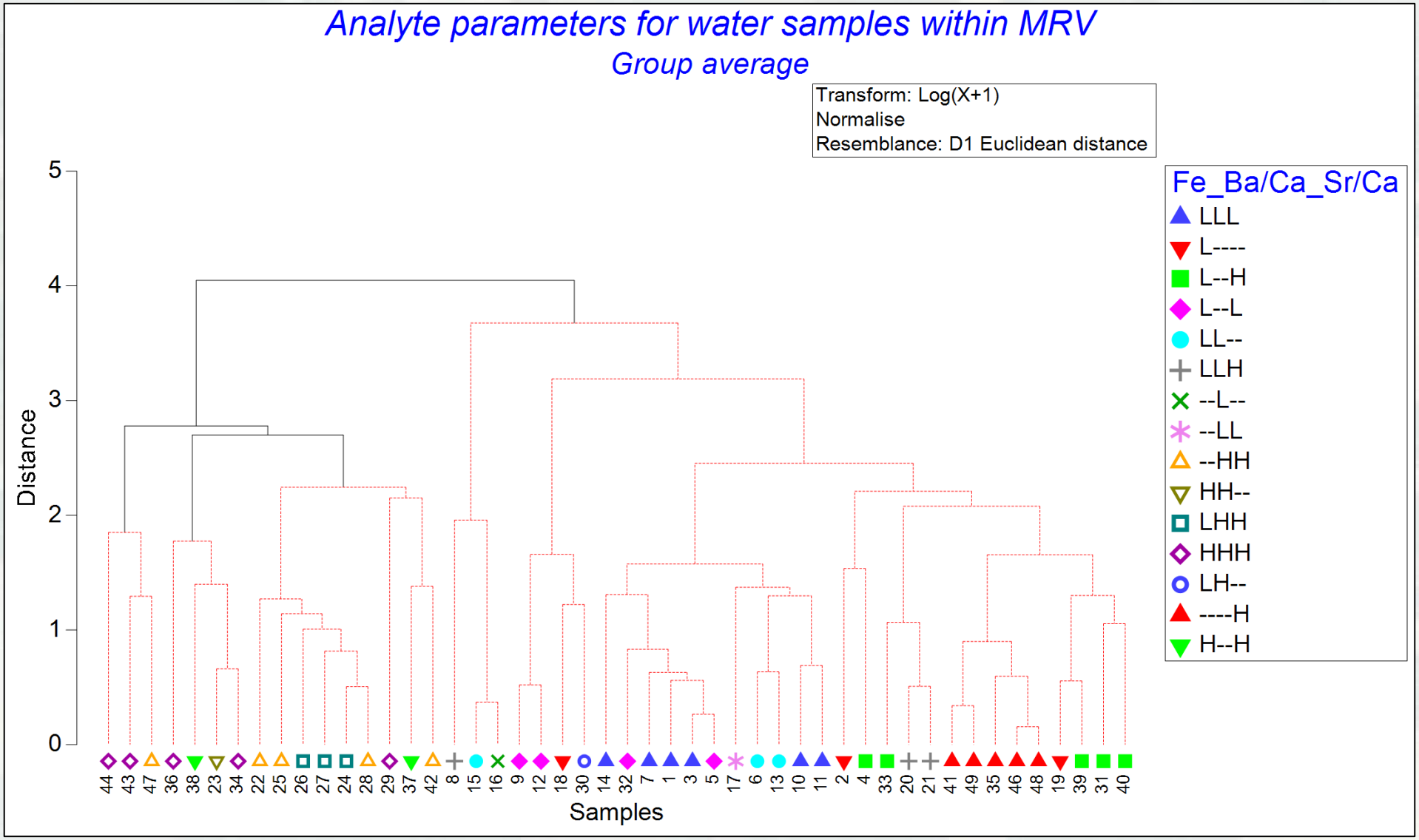
Screening prospects

- Sr/Ca
- Ba/Ca
- Fe



2.0 (high)

0.8 (low)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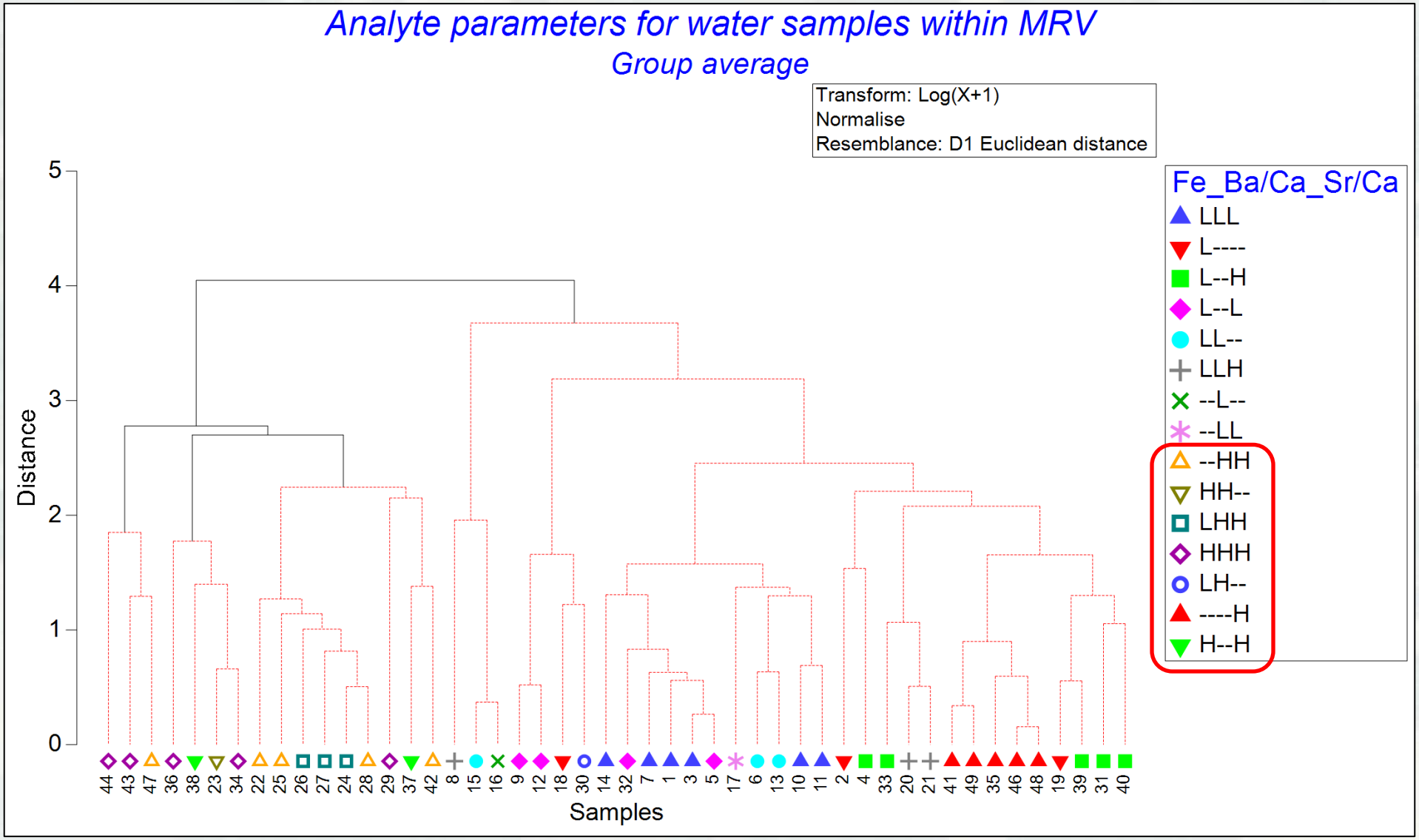
Group average
Transform: Log(X+1)
Normalise
Resemblance: D1 Euclidean distance
Fe_Ba/Ca_Sr/Ca
LLL
L----
L--H
L--L
LL--
LLH
--L--
--LL
--HH
HH--
LHH
HHH
LH--
----H
H--H
Distance
0
1
2
3
4
5
Samples
44 43 47 36 38 23 34 22 25 26 27 24 28 29 37 42 8 15 16 9 12 18 30 14 32 7 1 3 5 17 6 13 10 11 2 4 33 20 21 41 49 35 46 48 19 39 31 40


Analyte parameters for water samples within MRV
Group average
Transform: Log(X+1)
Normalise
Resemblance: D1 Euclidean distance
Fe_Ba/Ca_Sr/Ca
LLL
L----
L--H
L--L
LL--
LLH
--L--
--LL
--HH
HH--
LHH
HHH
LH--
----H
H--H
Distance
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1
2
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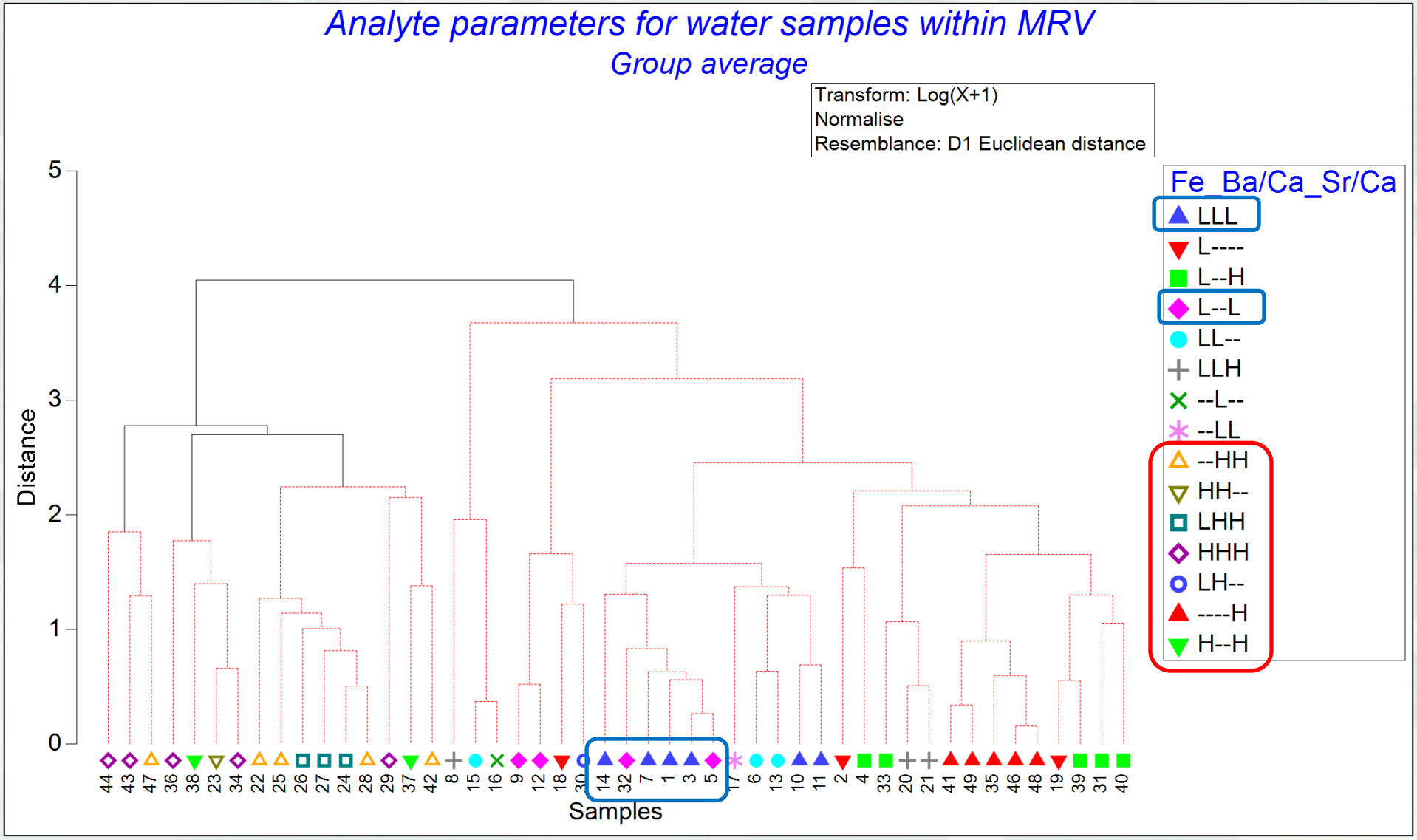
Samples
44 43 47 36 38 23 34 22 25 26 27 24 28 29 37 42 8 15 16 9 12 18 30 14 32 7 1 3 5 17 6 13 10 11 2 4 33 20 21 41 49 35 46 48 19 39 31 40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Group average
Transform: Log(X+1)
Normalise
Resemblance: D1 Euclidean distance
Fe_Ba/Ca_Sr/Ca
LLL
L----
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L--L
LL--
LLH
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--LL
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HH--
LHH
HHH
LH--
----H
H--H
Distance
0
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4
5
Samples
44 43 47 36 38 23 34 22 25 26 27 24 28 29 37 42 8 15 16 9 12 18 30 14 32 7 1 3 5 17 6 13 10 11 2 4 33 20 21 41 49 35 46 48 19 39 31 40

Take home points…

- ✓ Plausible approach for identifying regional water signatures

- ✓ Screening process for specific analyte concentrations
  - Hope was for a more analytical approach to delineate water constituent-physiographic combinations.
  - Effective first step.
  - Requires additional calibration once isotopic profiles from fish hard structures are obtained.

- ✓ Approach offers good prosects for evaluating fish movement patterns across a large riverscape that encompasses multiple rivers and physiographic regions.

Lower Pearl River
23 MAR 2011

Acknowledgments

- Bradley Lewis, Jay Collins, Colin Moratz and Kyle Bayles for providing field support to collect water sample.
- Andrew Bray of the ERDC Environmental Chemistry Branch for ICP-AES and ICP-MS analyses.
- Greg Whitledge, Quinton Phelps, Nicky Faucheux, David Ruppel and Mark Cornish for their useful insight during various phases of the project.

New Madrid floodway 18 MAY 2011