Overview of Invasive Carp Research at UA-Pine Bluff

Funded in part by ANS Small-Grants Program

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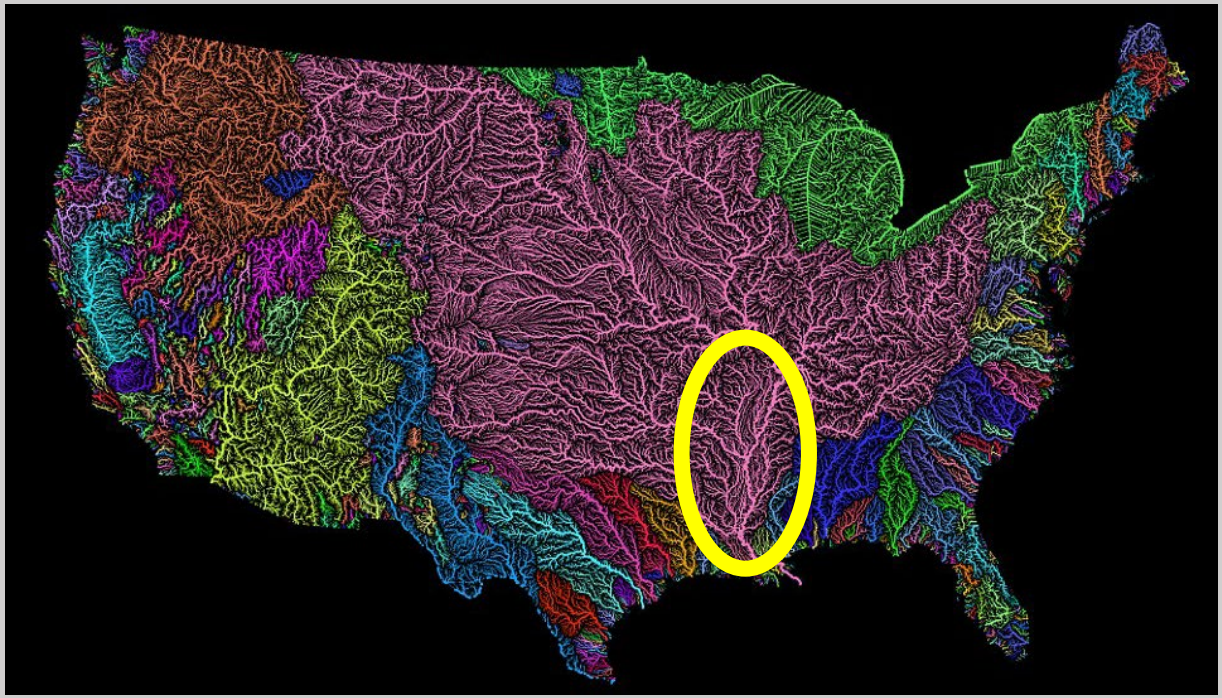
UAPB
UNIVERSITY of ARKANSAS AT PINE BLUFF
1873

Aquaculture / Fisheries
30th Anniversary
Center of Excellence

Bigheaded carps, i.e., “invasive carps”

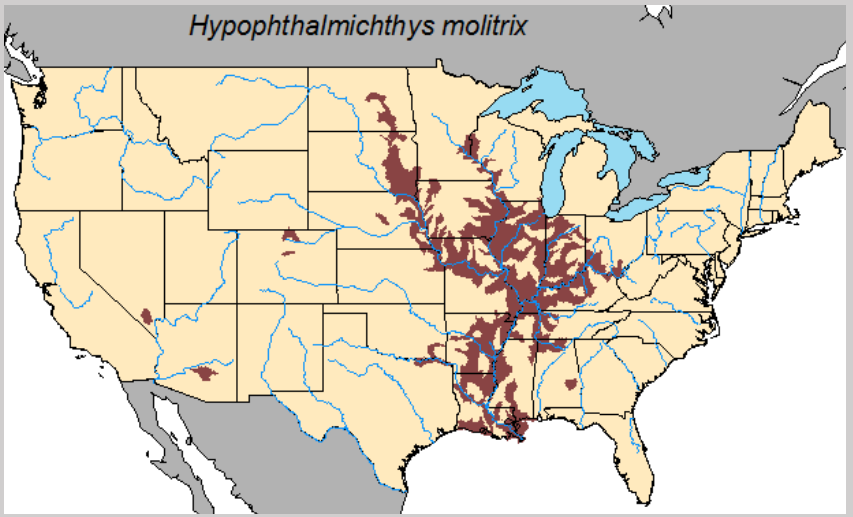


- Group includes two species – Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*)

Silver Carp
Hypophthalmichthys molitrix

SILVER CARP EXPANSION AND IMPACTS

- First imported to U.S. in 1970s – many accidental and intentional releases have occurred time
- Highly planktivorous – compete directly with adults of some native fishes and juveniles of many species
- Broad tolerance for environmental factors
- Altered food web interactions
- Declines in native fish condition
- Induced shift in native fish assemblages
- Suspected declines in sport and/or commercial fisheries



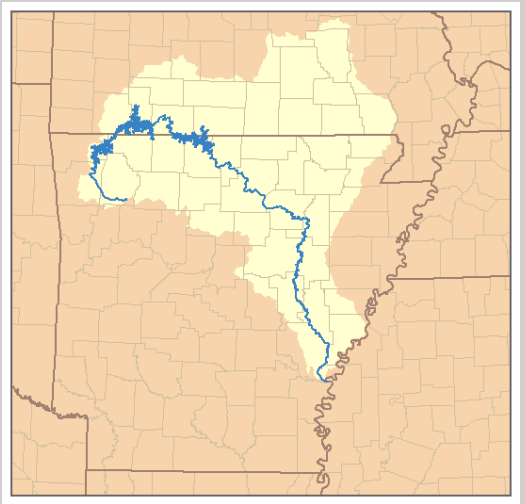
ANS Small Grants Program

Funded several prior grants at UA-Pine Bluff – both directly and indirectly…

1. Invasive carp effects on fish assemblages in lower White River oxbow lakes (Kaiser & Salzmann 2017-2019)
2. Silver Carp population dynamics in the LMR basin (LMR and four eastern Arkansas rivers) (Barshinger 2019-2020)
3. Invasive carp effects on fish assemblages of LMR secondary channels (Jackson 2021-2023)
4. Silver Carp river of origin determination using otolith microchemistry techniques (Barshinger 2019)

1. Invasive carps in lower White River

- Silver Carp historically rare but well established by about 2010
- Historical study conducted during 2002 – only two Silver Carp collected
- Multiple-gear fish sampling conducted to thoroughly characterize fish assemblages in 15 oxbow lakes in WRNWR
- Multivariate analyses conducted on assemblage data
- Study emphasized pre-carp (2002) vs. post-carp (2017) comparisons – examined fish assemblage shifts and species losses/gains….



Multi-Gear Fish Collections

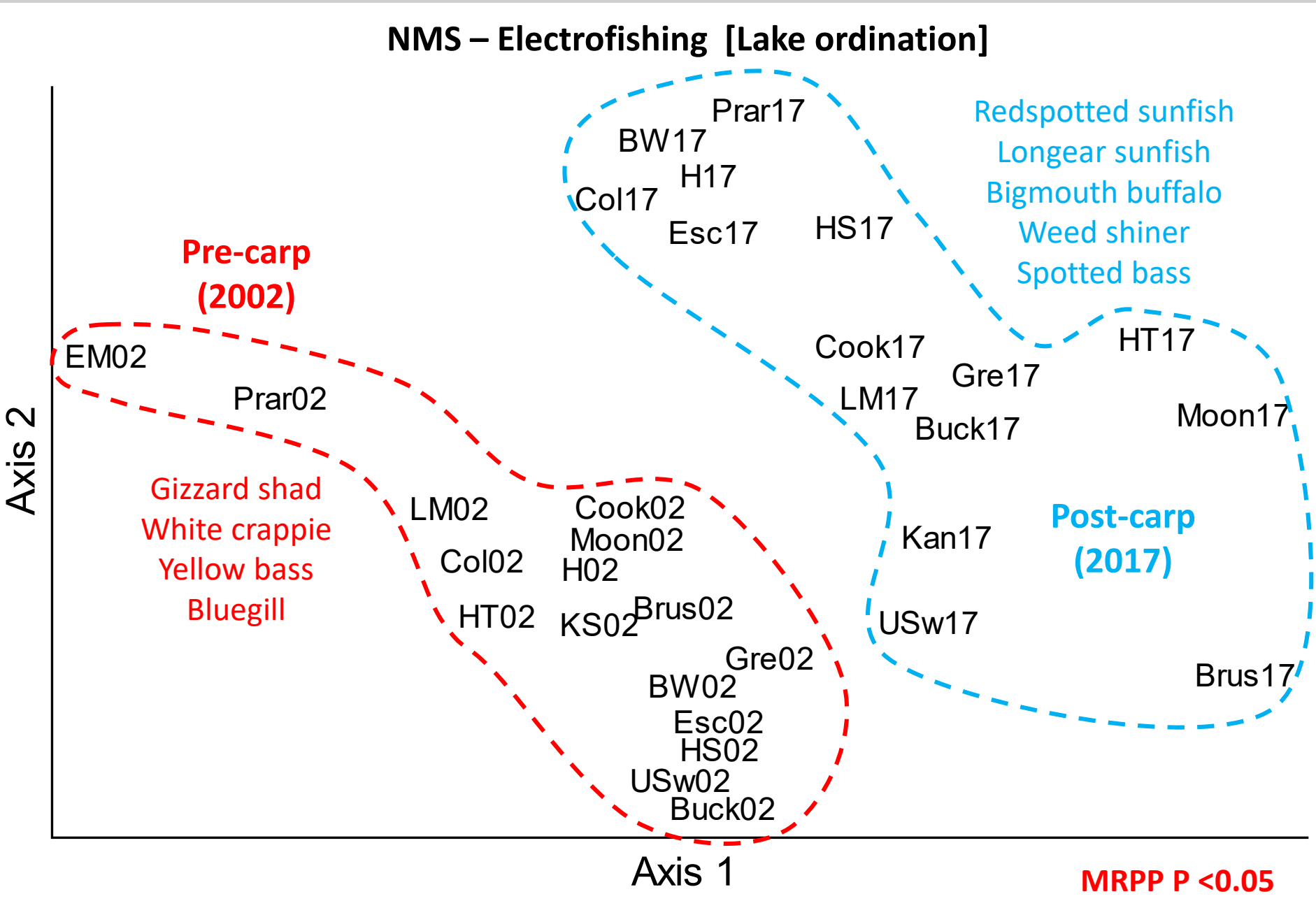
Video

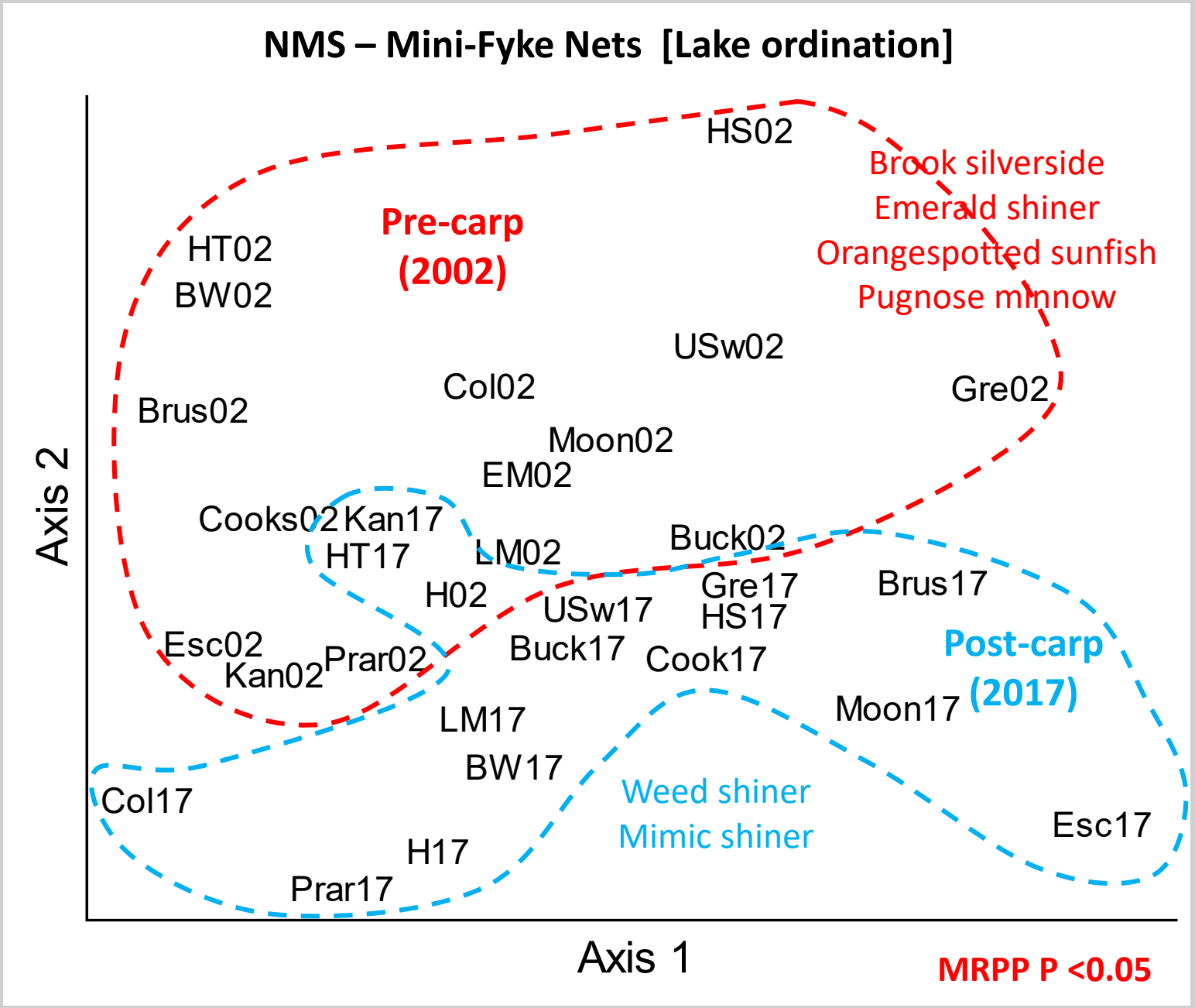
Done in replicate in all study lakes during July-August and October-November 2017 (“post-carp” period) – design identical to Lubinski (2002, “pre-carp” period)

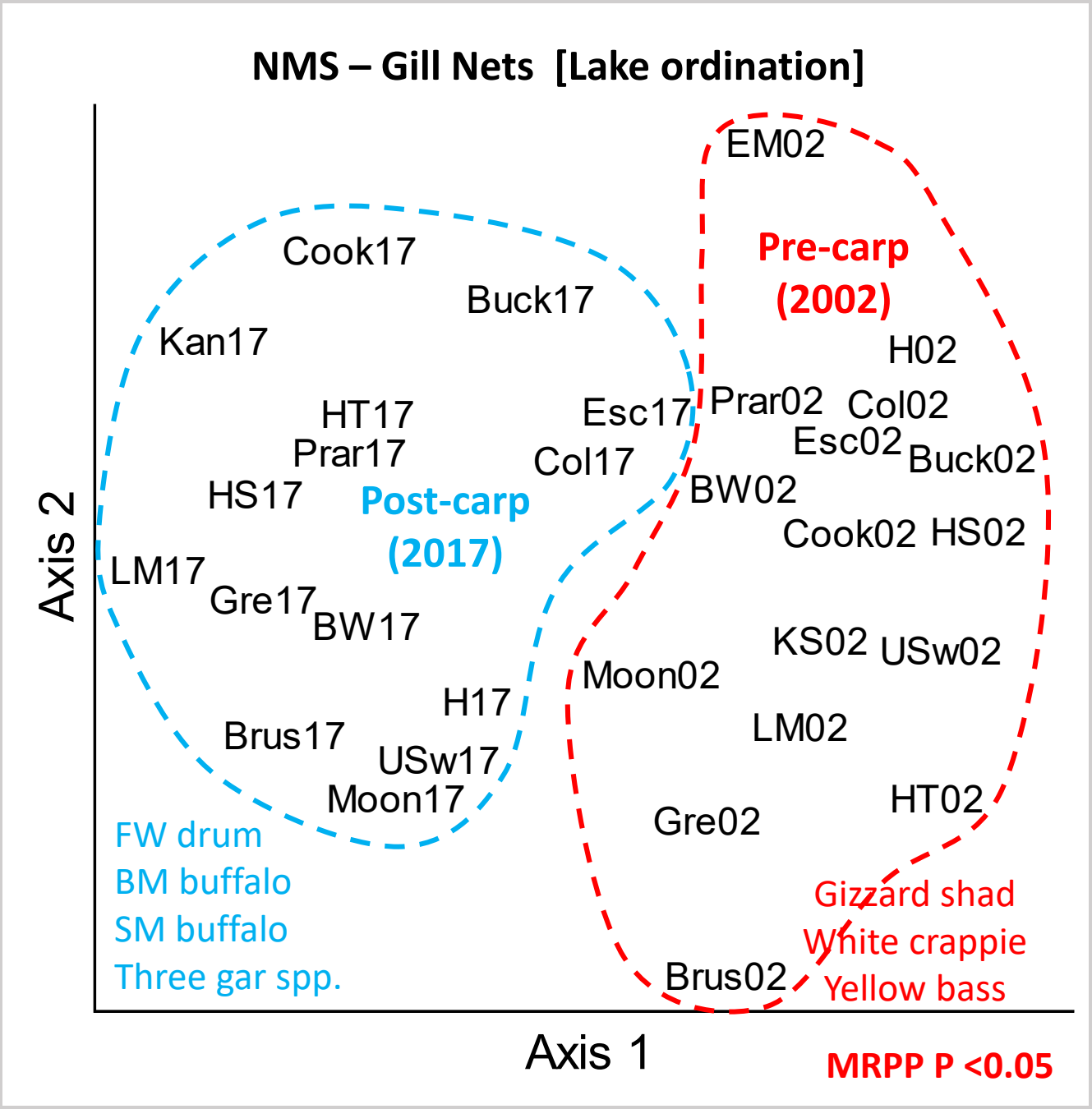
Comparing pre-carp & post-carp assemblages…

2017 (post-carp)	Electrofishing	Mini-Fyke	Gillnetting	Overall
Fishes collected	10,671	13,627	488	24,786
Number of species	*58*	*48*	*28*	*67*
Species diversity (H')	*2.88*	*1.62*	*2.48*	*2.63*
Species evenness	*0.71*	*0.42*	*0.74*	*0.57*
Species dominance	*0.90*	*0.62*	*0.89*	*0.85*

2002 (pre-carp)	Electrofishing	Mini-Fyke	Gillnetting	Overall
Fishes collected	7,659	33,893	527	42,065
Number of species	*47*	*44*	*24*	*64*
Species diversity (H')	*2.54*	*1.78*	*2.04*	*2.35*
Species evenness	*0.66*	*0.47*	*0.64*	*0.63*
Species dominance	*0.85*	*0.74*	*0.70*	*0.83*


NMS – Electrofishing [Lake ordination]
Prar17
BW17
H17
Col17
Esc17
HS17
Redspotted sunfish
Longear sunfish
Bigmouth buffalo
Weed shiner
Spotted bass
Pre-carp
(2002)
EM02
Prar02
Cook17
HT17
Gre17
LM17
Moon17
Buck17
Gizzard shad
White crappie
Yellow bass
Bluegill
LM02
Cook02
Moon02
Col02
H02
Kan17
Post-carp
(2017)
HT02
KS02
Brus02
USw17
Gre02
BW02
Brus17
Esc02
HS02
USw02
Buck02
Axis 2
Axis 1
MRPP P <0.05


NMS – Mini-Fyke Nets [Lake ordination]
HS02
Brook silverside
Emerald shiner
Orangespotted sunfish
Pugnose minnow
Pre-carp
(2002)
HT02
BW02
USw02
Col02
Gre02
Brus02
Moon02
EM02
Cooks02
Kan17
HT17
LM02
Buck02
H02
Gre17
Brus17
USw17
HS17
Esc02
Buck17
Cook17
Post-carp
(2017)
Kan02
Prar02
Moon17
LM17
BW17
Weed shiner
Mimic shiner
Col17
Esc17
H17
Prar17
Axis 2
Axis 1
MRPP P <0.05


NMS – Gill Nets [Lake ordination]
EM02
Pre-carp
(2002)
Cook17
Buck17
Kan17
H02
HT17
Esc17
Prar02
Col02
Prar17
Esc02
Buck02
Col17
HS17
Post-carp
(2017)
BW02
Cook02
HS02
LM17
Gre17
BW17
KS02
USw02
Moon02
H17
LM02
Brus17
USw17
Moon17
HT02
Gre02
FW drum
BM buffalo
SM buffalo
Three gar spp.
Gizzard shad
White crappie
Yellow bass
Brus02
Axis 2
Axis 1
MRPP P <0.05

Discussion

- Effects and/or impacts of Silver Carp invasions on native fishes and fisheries is vital to fisheries management on a [nearly] national scale...

- ***8 species*** not found in 2017 compared to historical datasets, though ***10 new species*** were collected in 2017
  - *All species lost and gained were historically rare possibly due to gear and/or seasonal differences*

- MRPP group tests indicated significant shifts in fish assemblage structures between 2002 and 2017

- Two of the three gears used suggested strong structural differences
  - *Differences less with mini-fykes, which is a littoral-zone gear*

Discussion

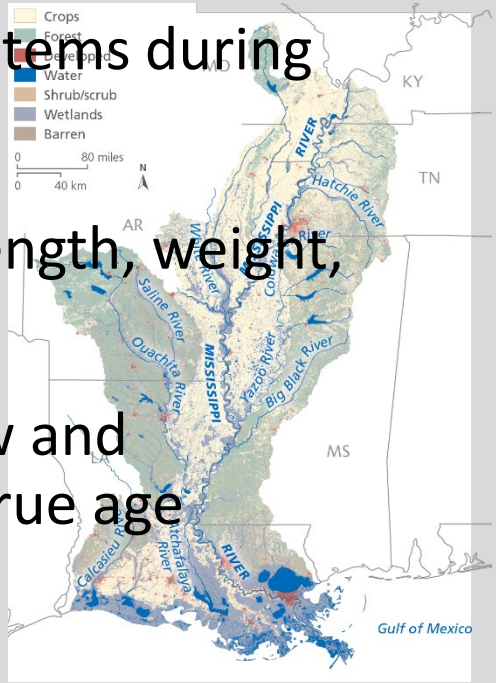
- Cannot unequivocally state that observed responses are entirely due to carps
  - *Frequent structural shifts could be common in these systems*
  - *Entire dataset was collected during only 2 years of a 16-year timespan*

- However, observed trends may suggest causation – Silver Carp establishment is the most pervasive change to occur in these systems during last two decades
  - *Carp abundance alone may be the entire story – abundances may interact with other factors*

- Research allows for development of further hypotheses on carp effects on native fishes – possibly the basis for future experimental work

2. Silver Carp population dynamics study

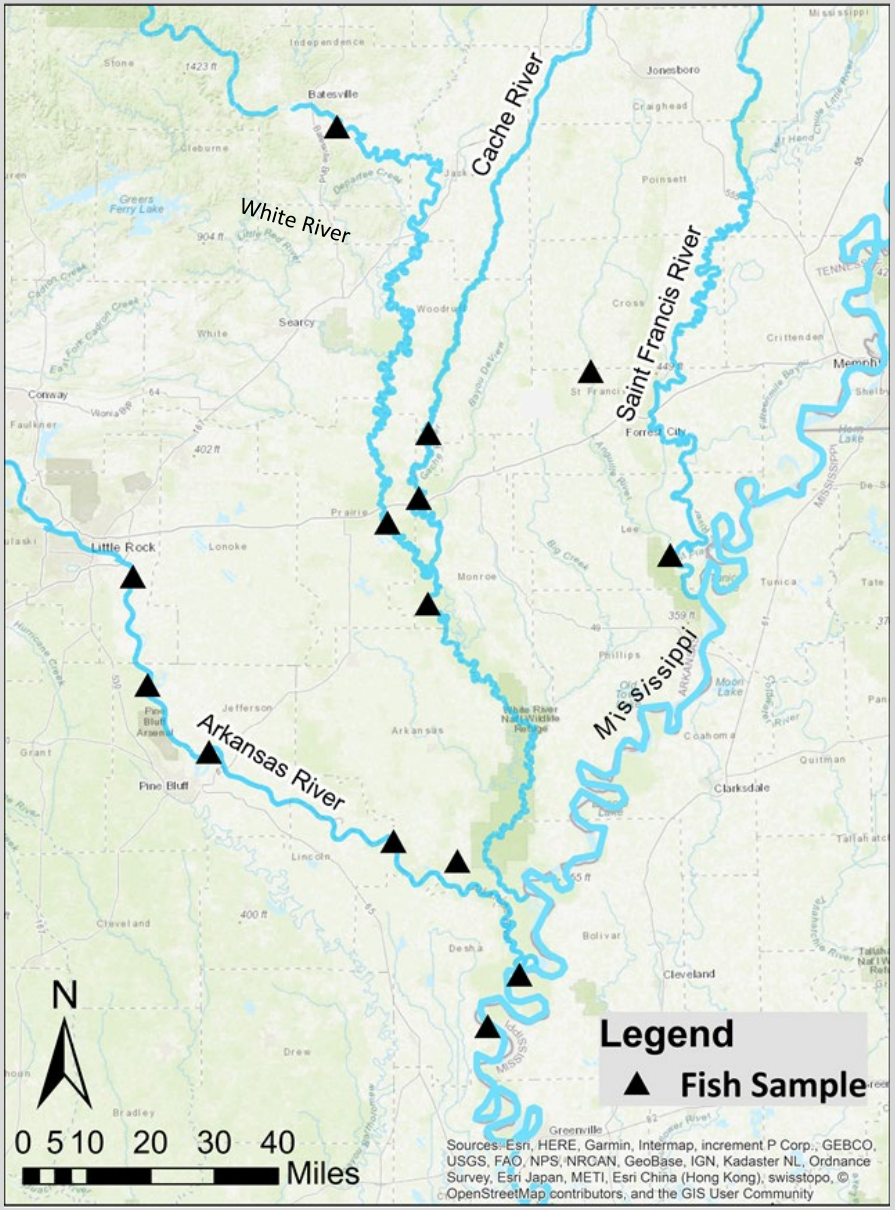
- Most Silver Carp population dynamics work limited to upper Mississippi River basin
- Silver Carp are being assessed in the LMR basin, though vital population rates (e.g., growth, mortality, recruitment, etc.) have been quantified for very few populations
- Fish collected from multiple sites in five river systems during 2019-2020 – target sample size of 100 fish/river
- Once captured, fish were sexed, measured for length, weight, and lapilli otoliths were extracted in the field
- Aged in lab – read double-blind both whole-view and sectioned, with sectioned readings considered true age



QUESTION/PURPOSE

- How much do Silver Carp population vital rates differ among Arkansas river systems?
- How do these rates compare to other U.S. populations?

Measure	Method
Condition	Fulton K, W_r, K_n, and W-L equation
Size structure	PSD-P, PSD-M, and PSD-T measures
Growth	von Bertalanffy growth models
Back-calculated growth	Annual growth increment
Mortality	Weighted catch curves (using ages 5-12)
Recruitment	Recruitment variation index (RVI)

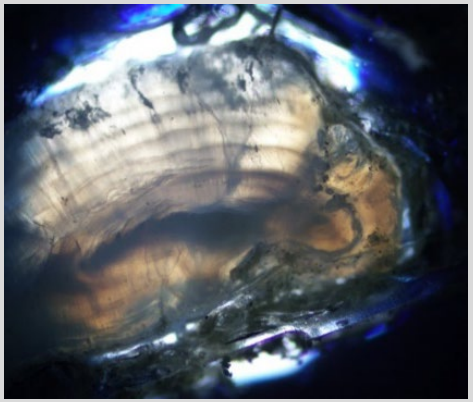


STUDY RIVERS

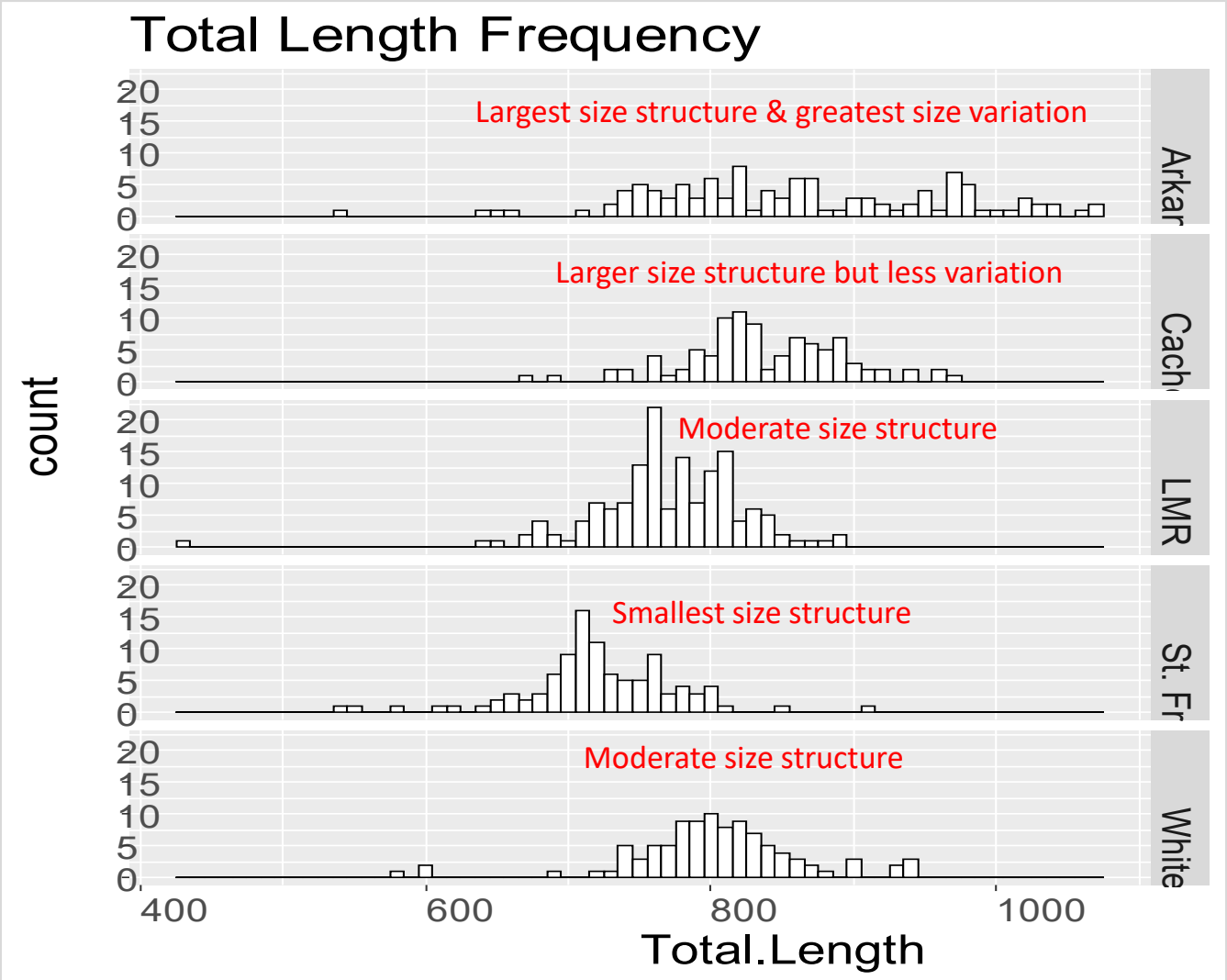
- Lower Mississippi River (AR-TN-MS-LA)
- Arkansas River (AR)
- White River (AR)
- Cache River (AR)
- St. Francis River (AR)

RESULTS

- 552 carp collected between June 2019 and November 2020
- Some specimens provided by third parties
- Aging results…
  - Read Initial between-reader agreement only 32%
  - 81% of disagreements were by only 1 year
  - Disagreements equally likely with younger and older carp
  - Between-reader discrepancies mostly resolved

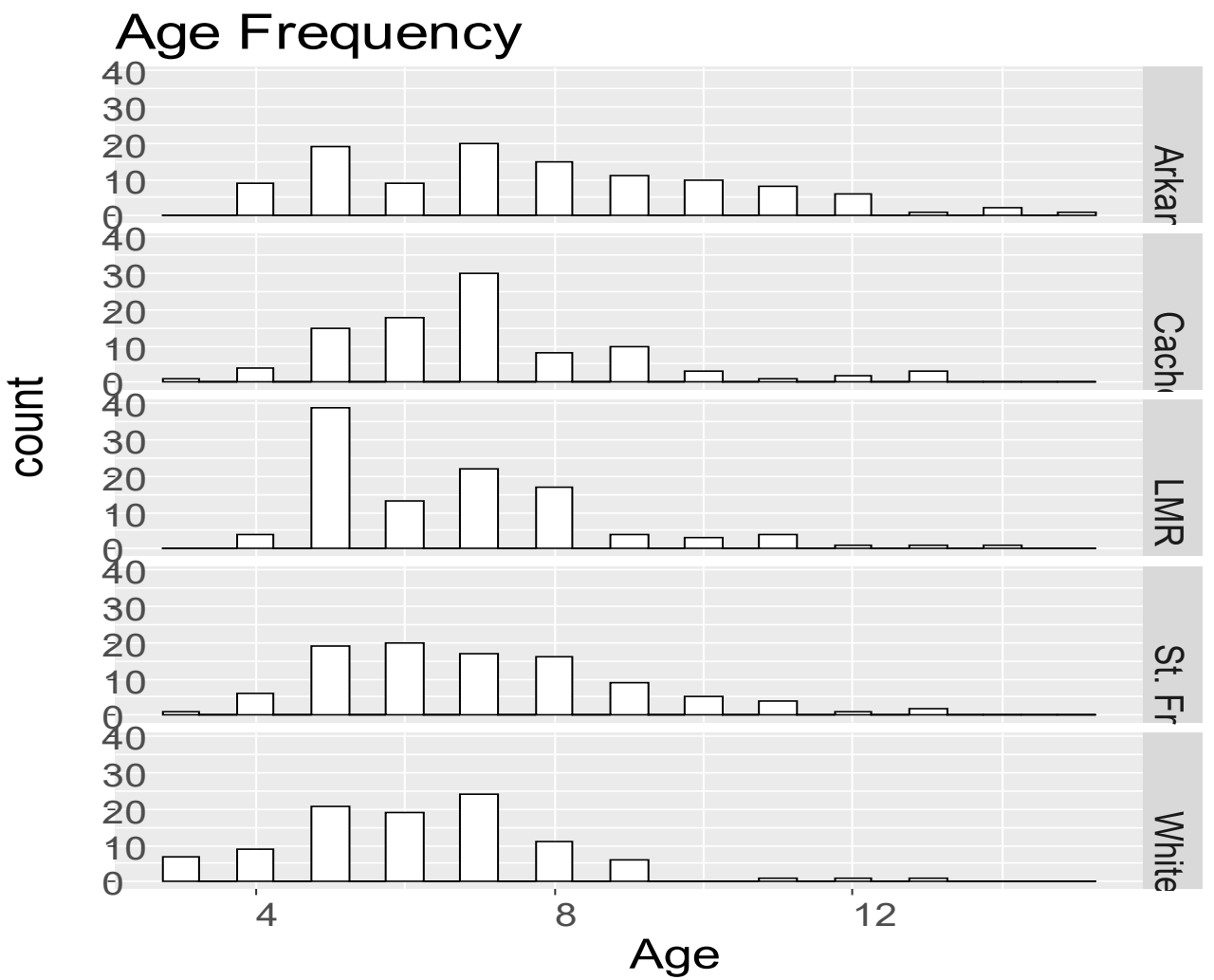


MEAN SIZE



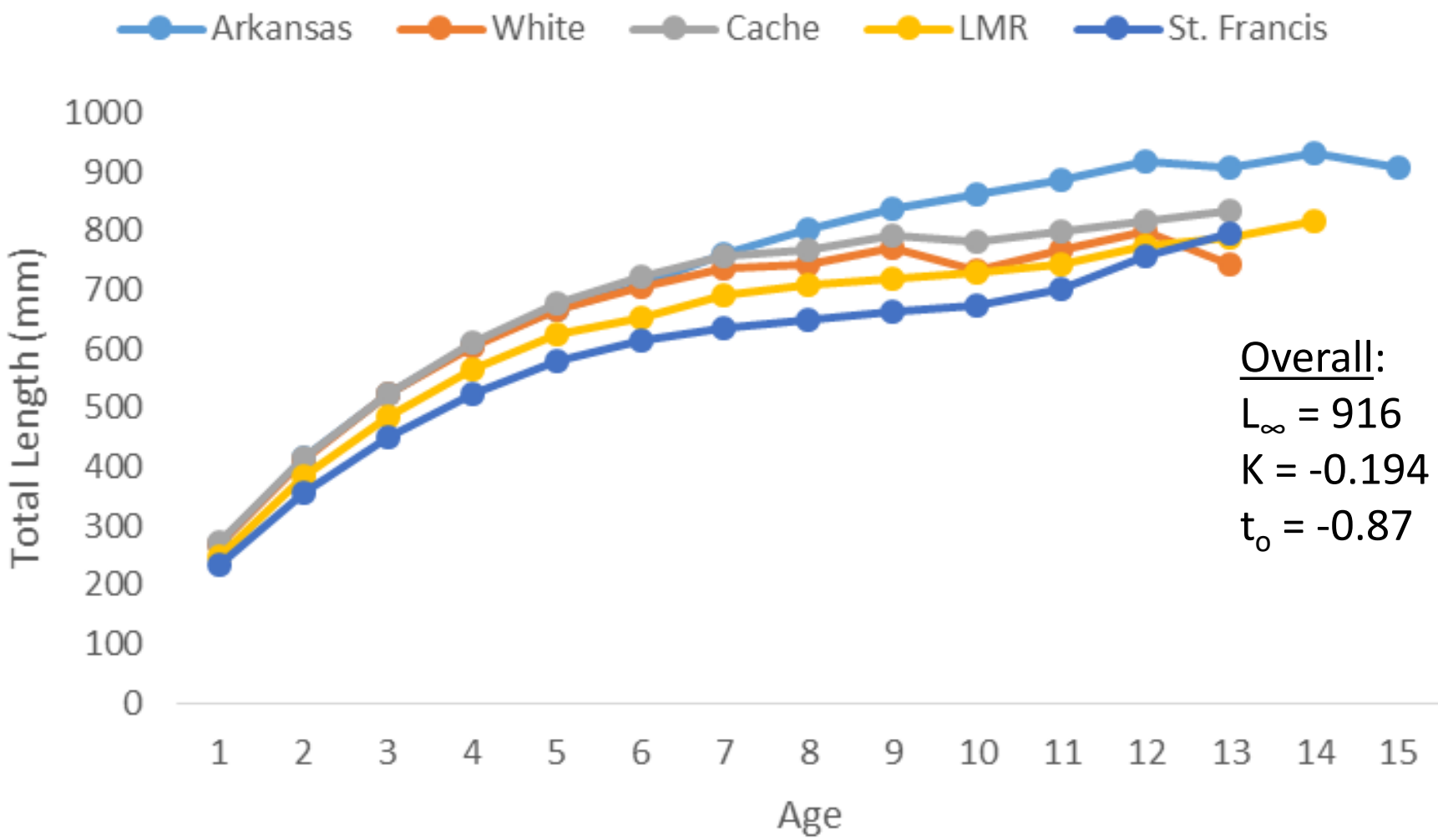
- 856 (± 104) mm
- 839 (± 55) mm
- 773 (± 44) mm
- 719 (± 55) mm
- 804 (± 61) mm

AGE STRUCTURE



- Ages 3-15 were collected
- No age-1 or age-2
- Mean age 7.0 ± 2.2 years overall
- Mean ages ranged
  - 7.8 ± 2.6 (Arkansas)
  - 6.2 ± 1.9 (White)
- Ages 5-12 comprised 90% of catch

VON BERTALANFFY GROWTH MODELS



VON BERTALANFFY GROWTH MODELS

River	N*	L_∞ (95% CL)	K (95% CL)	t_o (95% CL)
LMR	147	801 (775-826) bc	0.266 (0.223-0.308) ab	-0.44 (-0.79- -0.09) ab
Arkansas	111	**964 (940-988) a**	**0.210 (0.188-0.234) b**	-0.61 (-0.87- -0.36) ab
White	99	**780 (757-804) c**	**0.369 (0.302-0.436) a**	-0.11 (-0.43- -0.21) a
Cache	95	835 (821-849) b	0.312 (0.283-0.340) ab	-0.25 (-0.42- -0.07) a
St. Francis	100	782 (717-847) bc	0.222 (0.145-0.299) b	-0.73 (-1.51- -0.54) b
Overall	**552**	**916 (866-968)**	**0.194 (0.149-0.238)**	**-0.87 (-1.47- -0.28)**

*sample size represents all aged fish

ANNUAL MORTALITY AND RECRUITMENT

AGES 5-12 ONLY

River	N*	A (95% CL)	Theoretical maximum age (t_{max}, years)	RVI (ages 5-12)
LMR	137	29% (14-41%)	15.8	0.349
Arkansas	98	**12% (1-22%)**	**27.5**	**0.449**
White	82	**36% (14-49%)**	**12.7**	**0.200**
Cache	87	32% (9-47%)	13.5	0.347
St. Francis	91	29% (16-39%)	14.6	0.337
Overall	**495***	**28% (18-35%)**	**20.5**	**0.703**

***sample size represents only fish aged 5-12 years**

SILVER CARP IN ARKANSAS RIVERS

- Very healthy and viable – stable recruitment in all rivers
- Arkansas River consistently had largest sizes, lowest mortality, and most stable recruitment…
- This despite being a serial L&D system with many barriers to migration
- Not finding juvenile or young (ages 1-3) carps anywhere
- However, no reason to *not* think all 5 rivers will continue to have healthy popns for the foreseeable future

HOW DO ARKANSAS SILVER CARP COMPARE NATIONALLY?

- Arkansas rivers shared characteristics with other U.S. popns…

- Upper Mississippi River (IL-IA-MO)
  - Greater mean lengths & L_∞
  - Stable recruitment

    Cox et al. (2020)

- Illinois (IL) and Wabash River (IL-IN)
  - Smaller mean lengths & L_∞
  - Stable recruitment

    Stuck et al. (2015)

- Missouri River tributaries (SD)
  - Smaller sizes & lower growth
  - Recruitment less stable

    Hayer et al. (2014)

- Tennessee & Cumberland rivers (TN-KY)
  - Greater mean lengths & L_∞
  - Recruitment less stable

    Ridgway & Bettoli (2017)

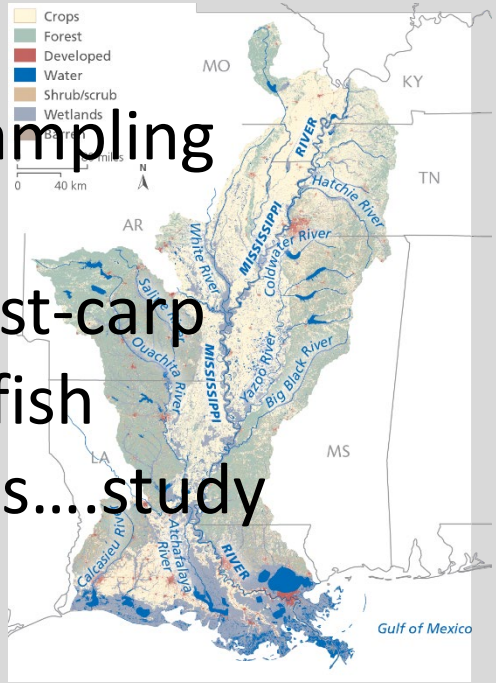
3. Invasive carp effects on LMR fishes

- Historical study conducted during 1990s at seven LMR secondary channel locations spanning from KY-MO to MS-LA

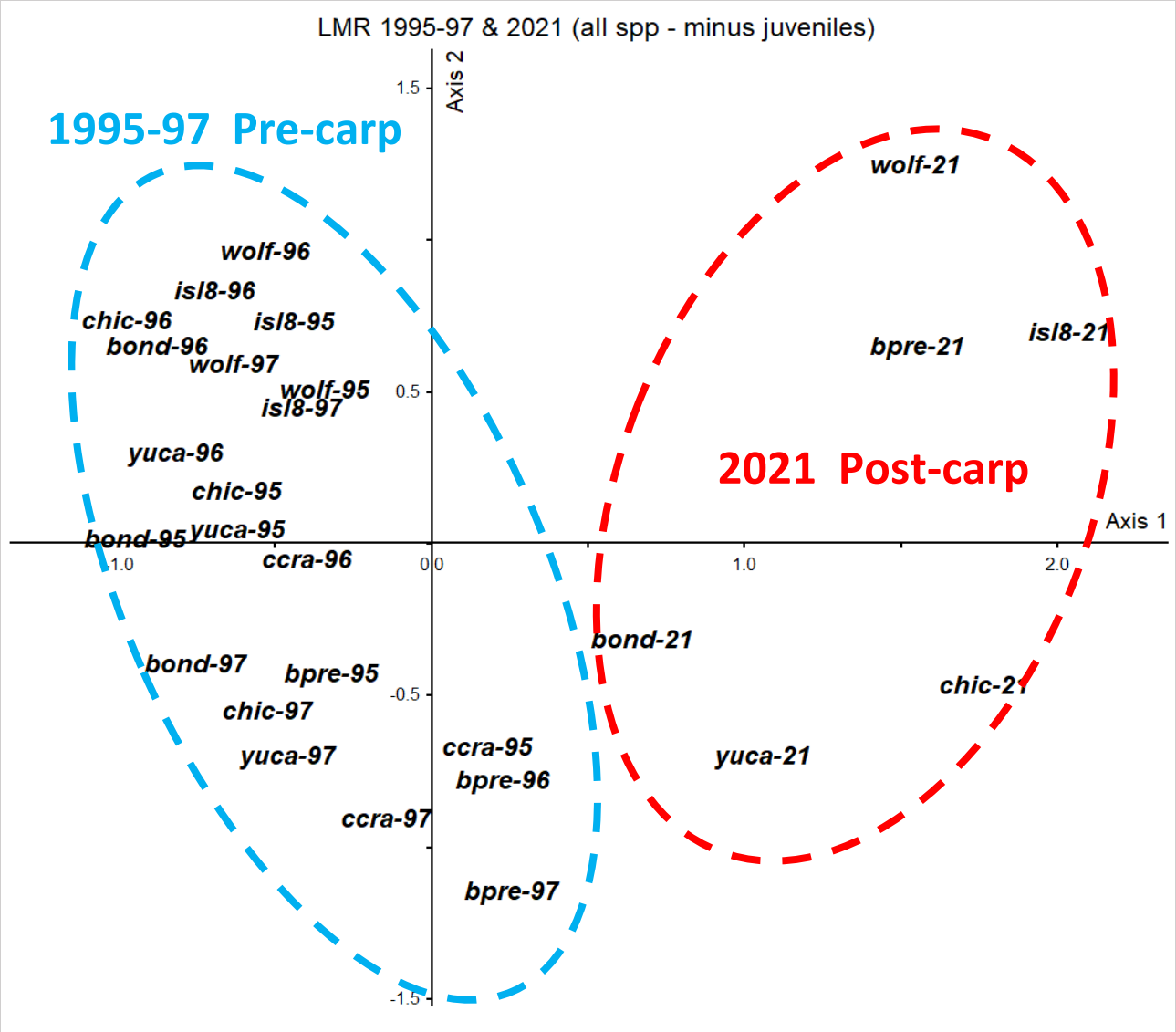
- Emphasized five different secondary channel and adjacent main-stem macrohabitats

- No Silver Carp collected over 3 years of sampling

- Study emphasizes pre-carp (1990s) vs. post-carp (2021-2023) comparisons – will examine fish assemblage shifts and species losses/gains….study only recently initiated



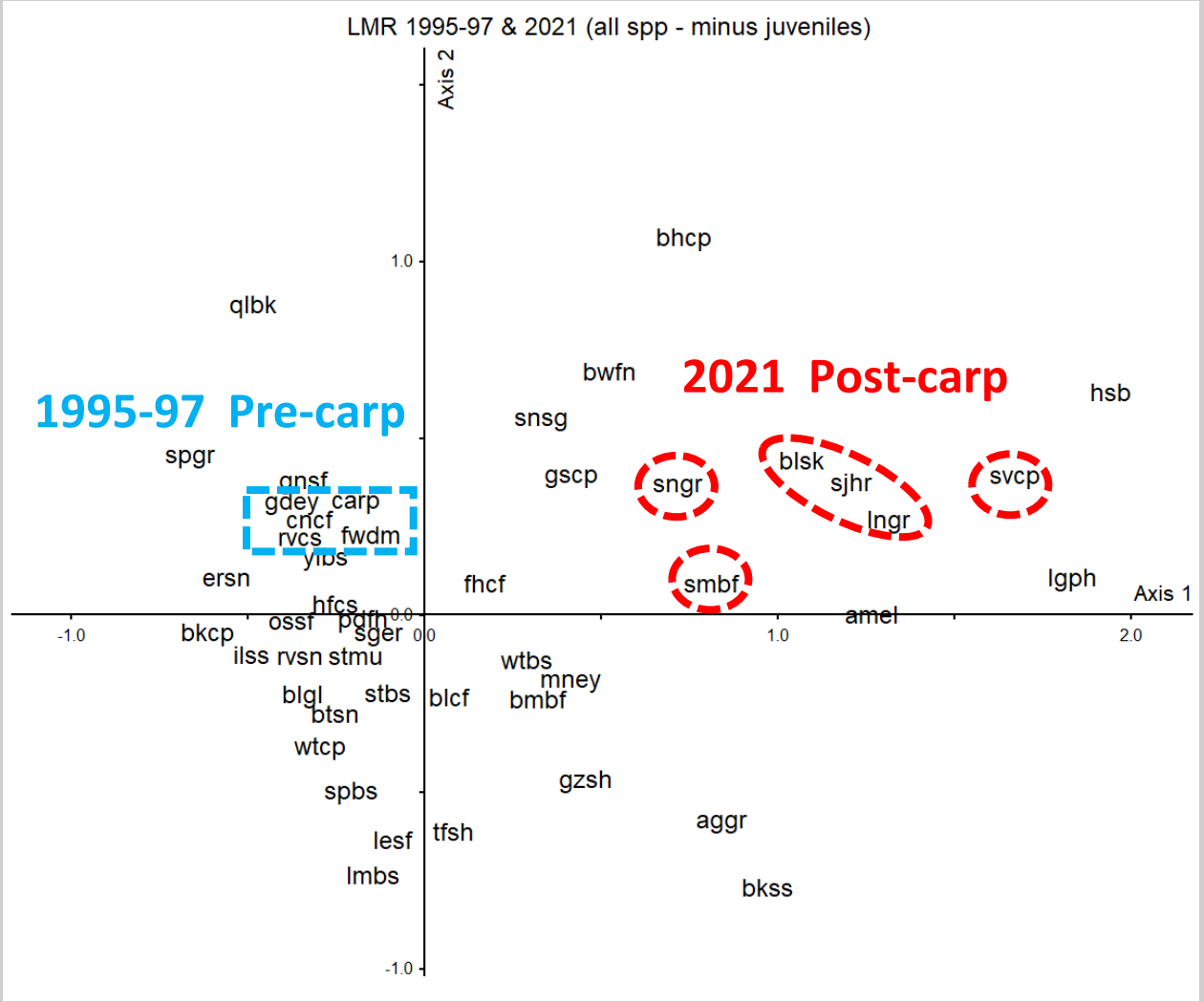
Results – NMS



- Differences observed in assemblage structure between 1990s and 2021
- Dataset greatly imbalanced due to 2021 alone being ordinated against 3 other years (1995-1997)

Results – NMS

- Site differences appear related to high SVCP abundances (axis-1 *r*=0.874)
- BLSK, LNGR, SNGR, SJHR & SMBF also positively correlated to axis 1 (*r*>0.560)
- CARP, FWDM, GDEY, RVCS & CNCF negatively correlated to axis-1 (*r*<-0.225)
- More to come in 2022-2023



4. Silver Carp otolith microchemistry study

- Knowing where Silver Carp spawn (even approximately) would be useful for fisheries managers
- Significance of tributary systems in life histories (e.g., spawning and reproduction) within the Lower Mississippi River (LMR) basin is totally unknown
- Microchemistry techniques could prove useful in determining where carps spawn, especially considering the difficulty in collecting juvenile carps
- Ability to link Silver Carp to their natal rivers would be valuable towards better understanding of their life histories and developing management plans

OTOLITH MICROCHEMISTRY

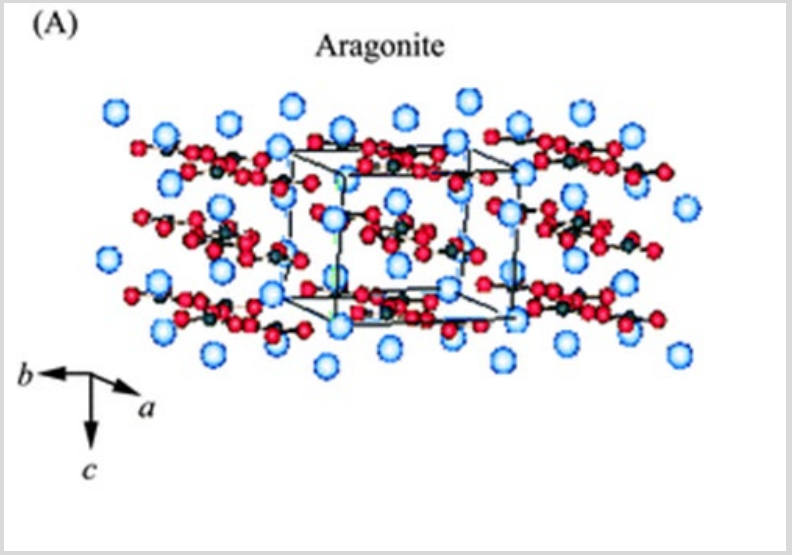
- Otoliths are inert following annual accumulation of the $CaCO_3$ matrix (Campana & Nelson 1985)
- Trace elements become imprinted in otoliths from elemental concentrations in the surrounding waters at birth (Elsdon & Gillanders 2004)
- Water chemistry differences among spawning locations remain persistent and can be used to determine the river of origin

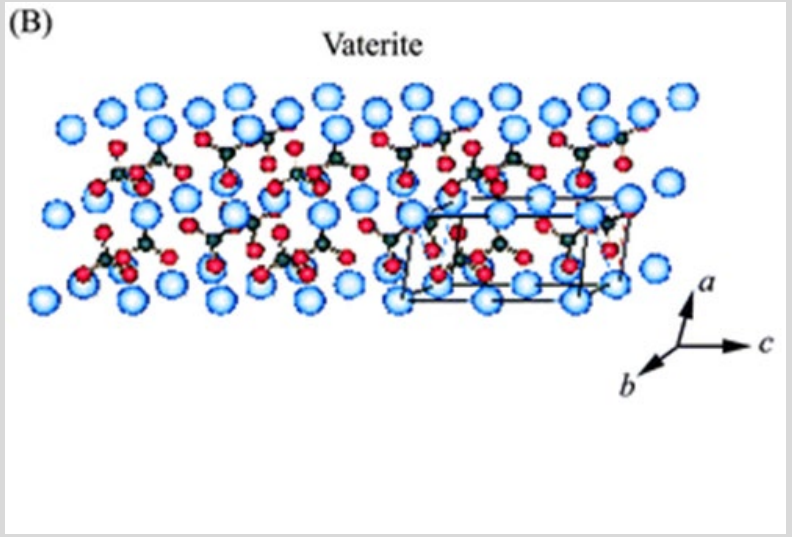
SILVER CARP MICROCHEMISTRY

- Lapilli otoliths are advantageous for microchemistry due to their aragonite crystalline structure (Norman & Whitledge 2015)

- Otoliths have greater affinities for:
  - Strontium (Sr)
  - Barium (Ba)
  - Magnesium (Mg)

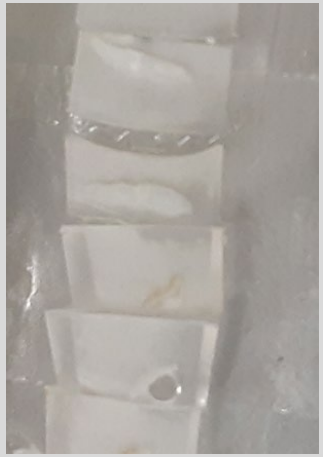
- Norman & Whitledge (2015) identified natal origin and recent river inhabitance of bigheaded carps in the Illinois River basin





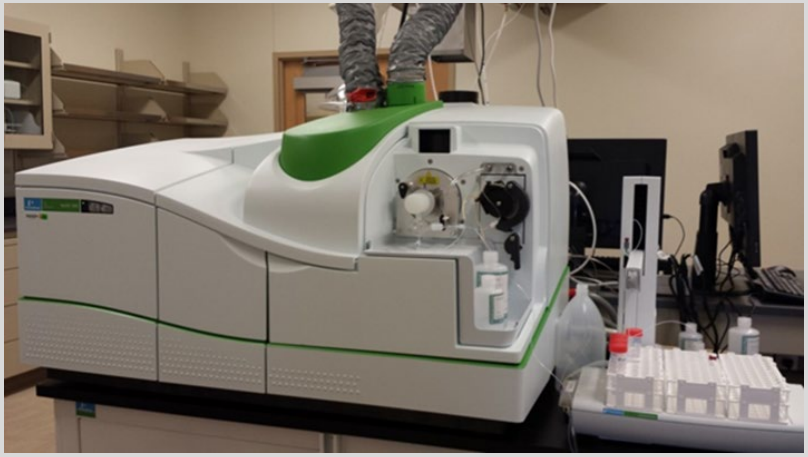
PREPARING OTOLITHS

- Otoliths were set in epoxy with sulcus upward
- Otoliths sectioned with an ISOMET low-speed precision saw
- Otoliths sanded and polished using lapping film, and affixed to glass slides for reading

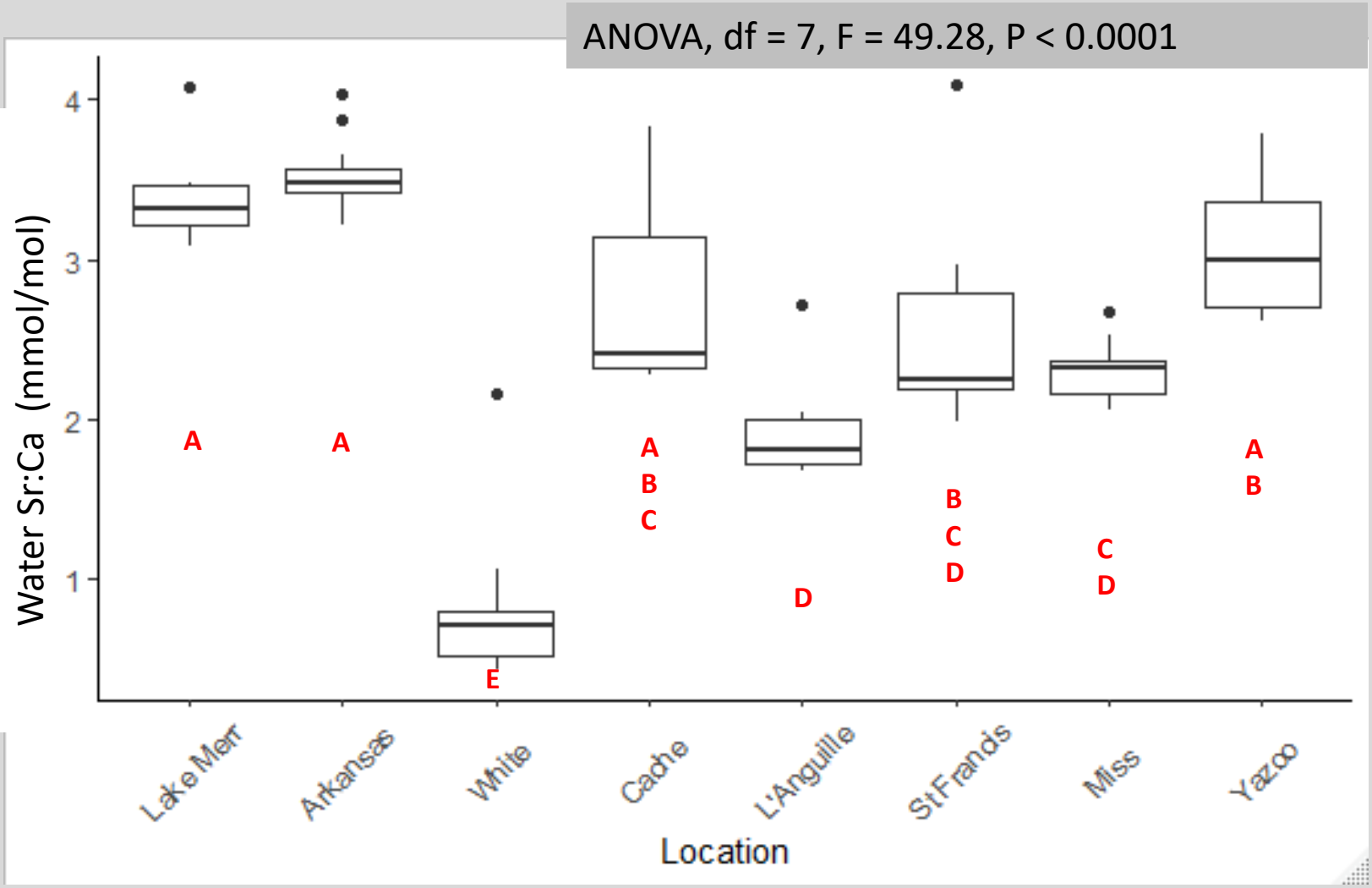


ANALYZING OTOLITHS

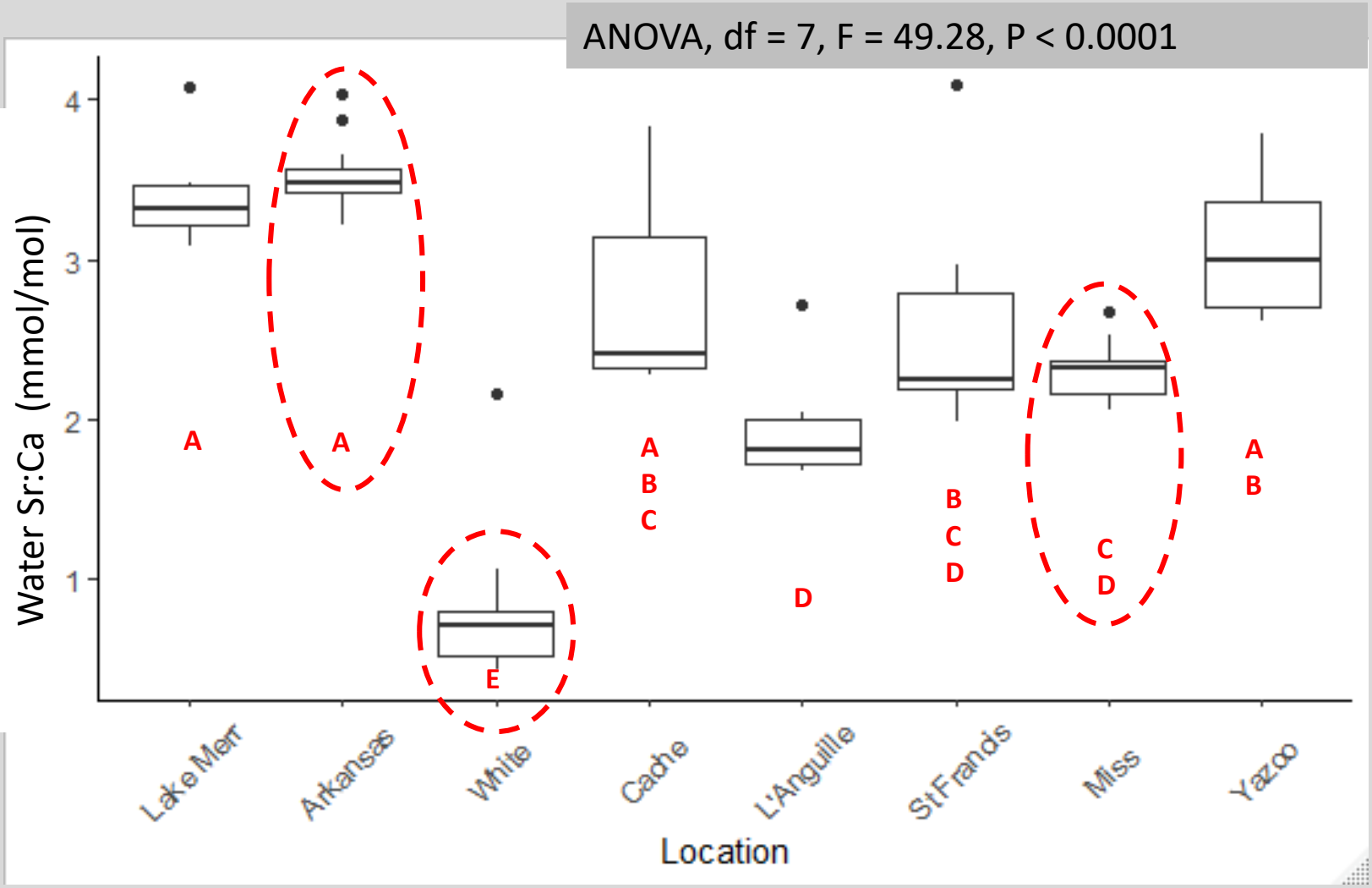
- Otoliths were ablated using high-resolution ICPMS
- Laser ablated a transect across the otolith core in order to measure Sr, Ba, and Ca concentrations
- One spot ablation was done to measure the core



AMONG-RIVER DIFFERENCES IN WATER Sr:Ca

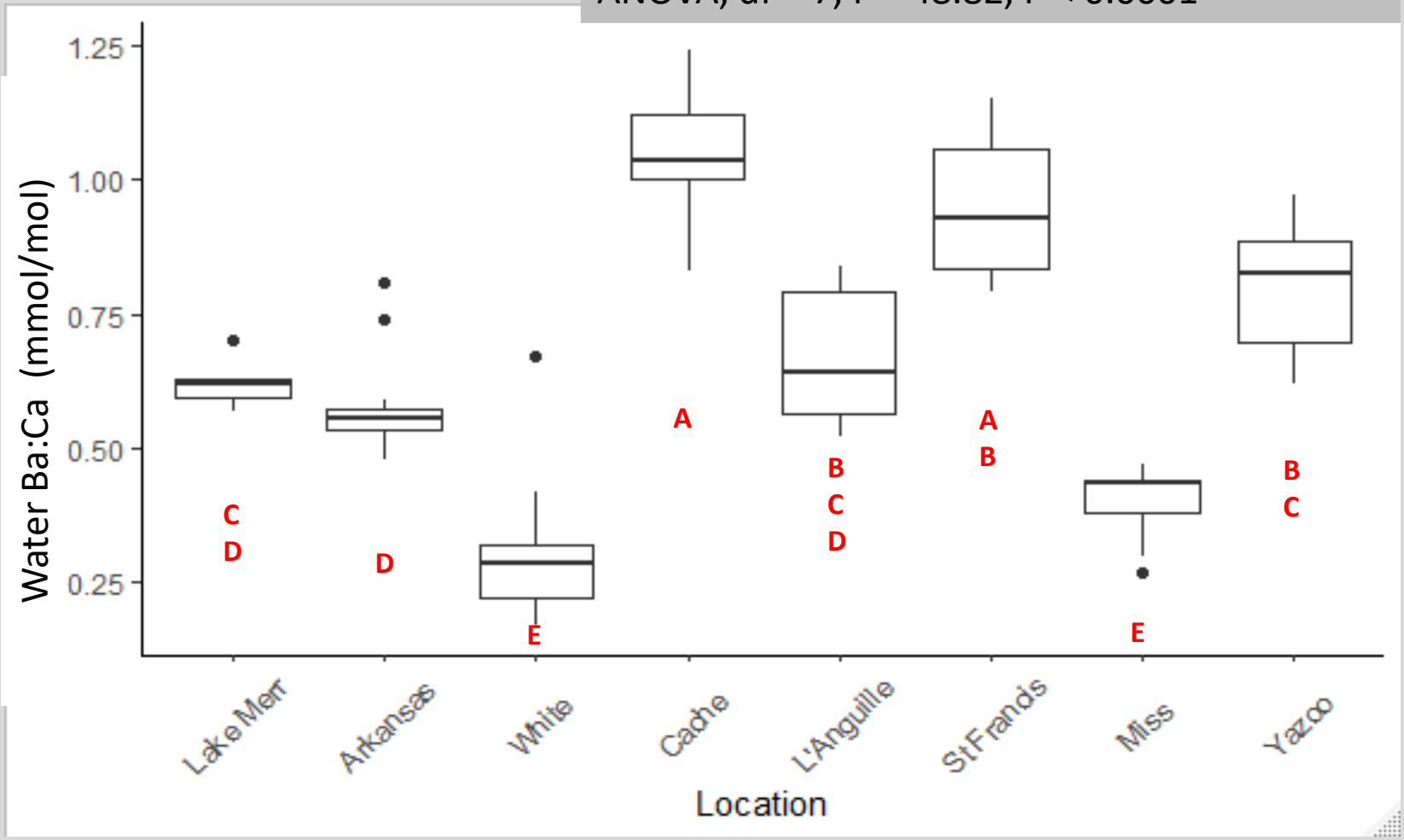


AMONG-RIVER DIFFERENCES IN WATER Sr:Ca

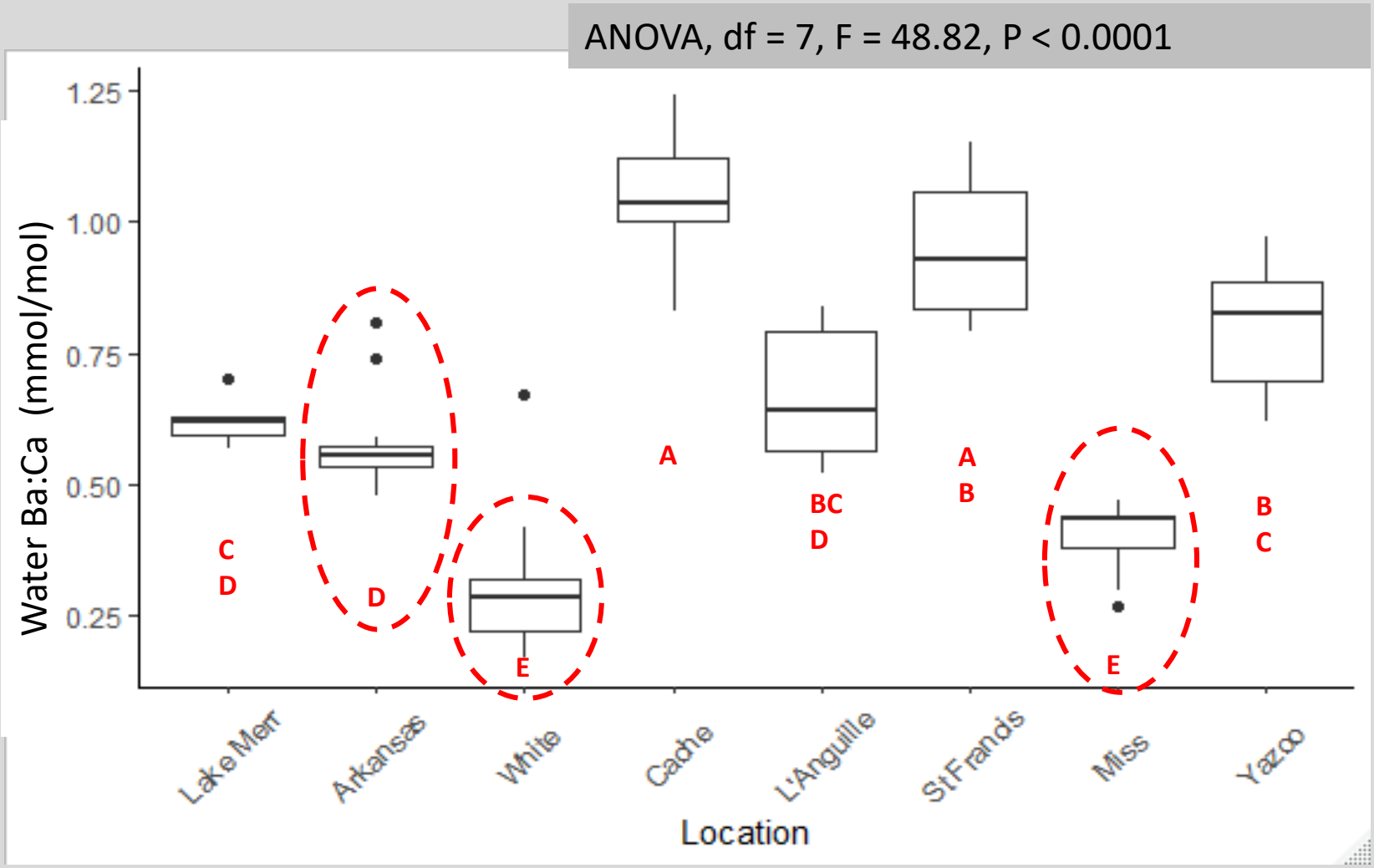


AMONG-RIVER DIFFERENCES IN WATER Ba:Ca

ANOVA, df = 7, F = 48.82, P < 0.0001

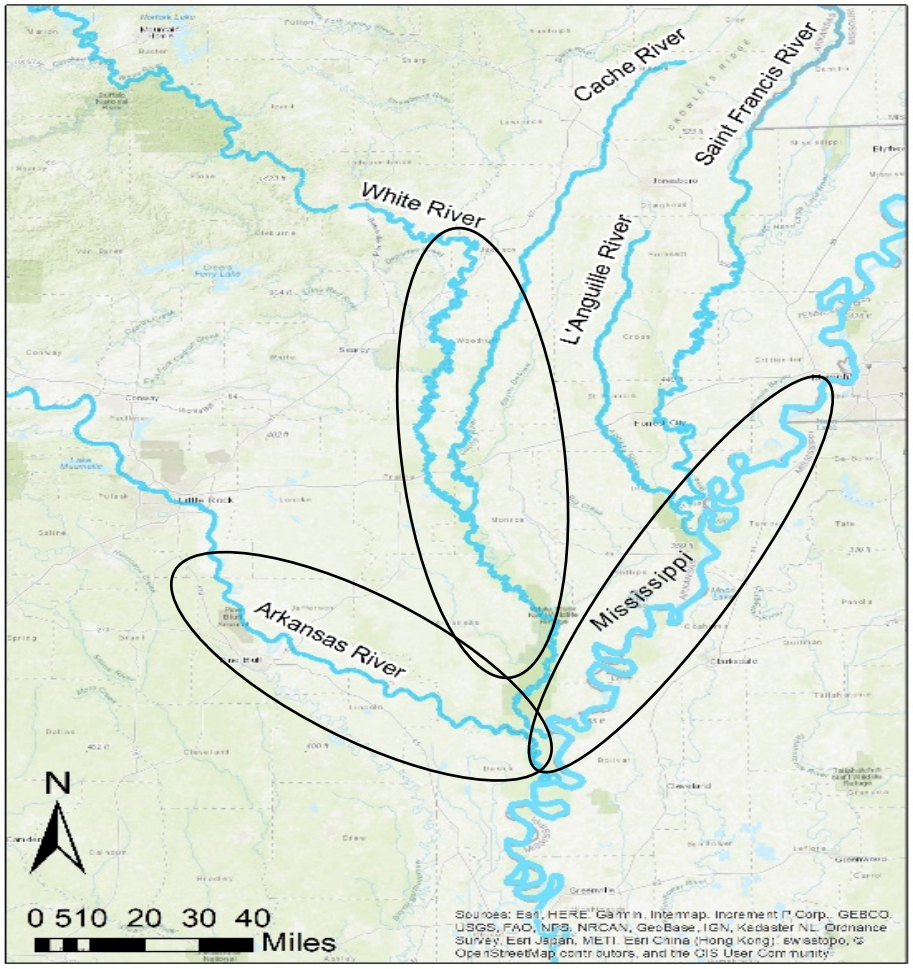


AMONG-RIVER DIFFERENCES IN WATER Ba:Ca

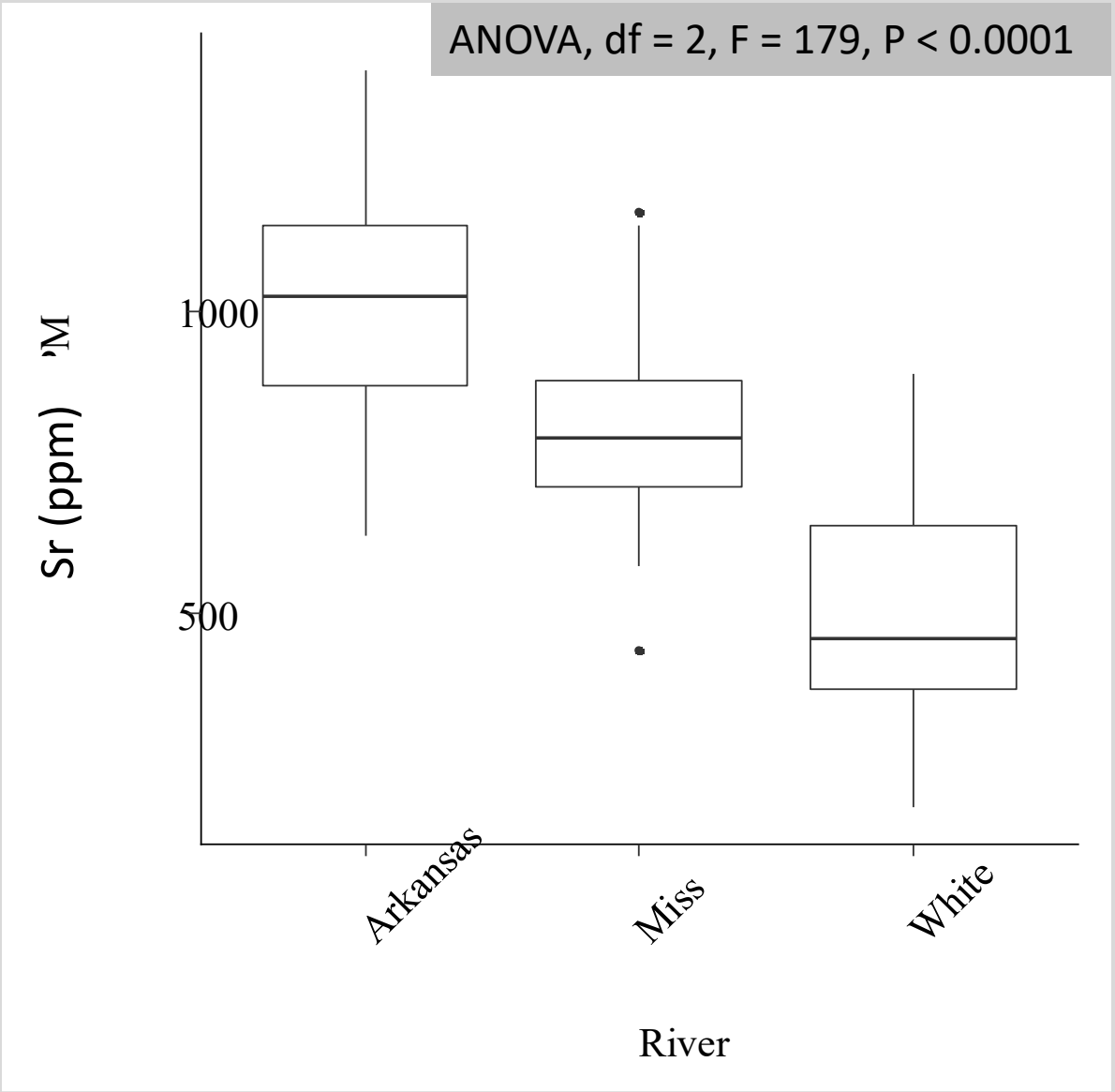


WATER CHEMISTRY SUMMARY

Three rivers appeared more distinct

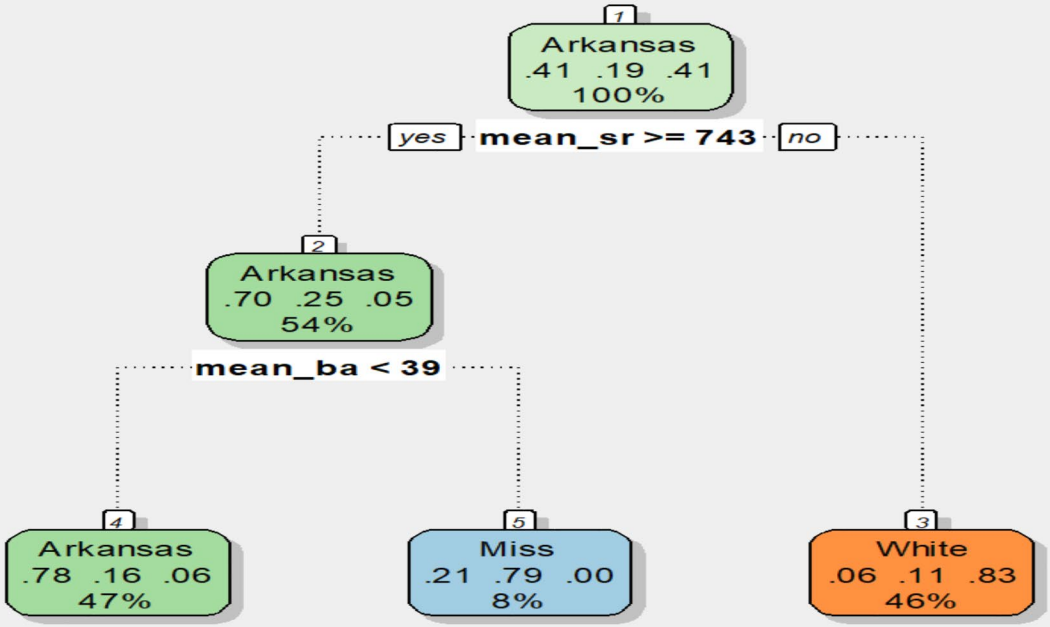


AMONG-RIVER DIFFERENCES IN OTOLITH Sr (ppm)



MODEL PREDICTION

Model Accuracy = 80.2%, CP = 0.052



NATAL ORIGIN PREDICTIONS

	Predicted River Origin		
	Arkansas	Mississippi	White
Arkansas (n=74)	17 (23%)	26 (35%)	31 (42%)
Mississippi (n=39)	9 (23%)	15 (38%)	15 (38%)
White (n=74)	15 (20%)	23 (31%)	36 (49%)
Total (n=187)	**41 (22%)**	**64 (34%)**	**82 (44%)**

DISCUSSION

- Mississippi (34%) and White (44%) rivers appeared to be the most common natal origin for sampled Silver Carps…

  Currently little information of recruitment in these rivers

- Arkansas River does not appear to be a major spawning location for Silver Carps…

  River main-stem may be more vital for seasonal feeding and growth

- Smaller river systems may be more difficult to distinguish from larger systems – when more river systems were included, model accuracy decreased
- Additional analyses using otolith Sr:Ca and Ba:Ca ratios to determine natal origin currently being examined

Acknowledgements

- University of Arkansas at Pine Bluff
- U.S. Fish and Wildlife Service - WRNWR
- USFWS-ANS Small Grants Program
- Angie Rodgers – USFWS/LMRCC
- James Ballard – Gulf States Marine Fisheries Commission
- Jimmy Barnett – Arkansas Game & Fish Commission
- Chad Washington – Mississippi Dept. Wildlife Fisheries & Parks