The influence of climate-induced alterations in DOM on metal toxicity and UV radiation in Rocky Mountain streams

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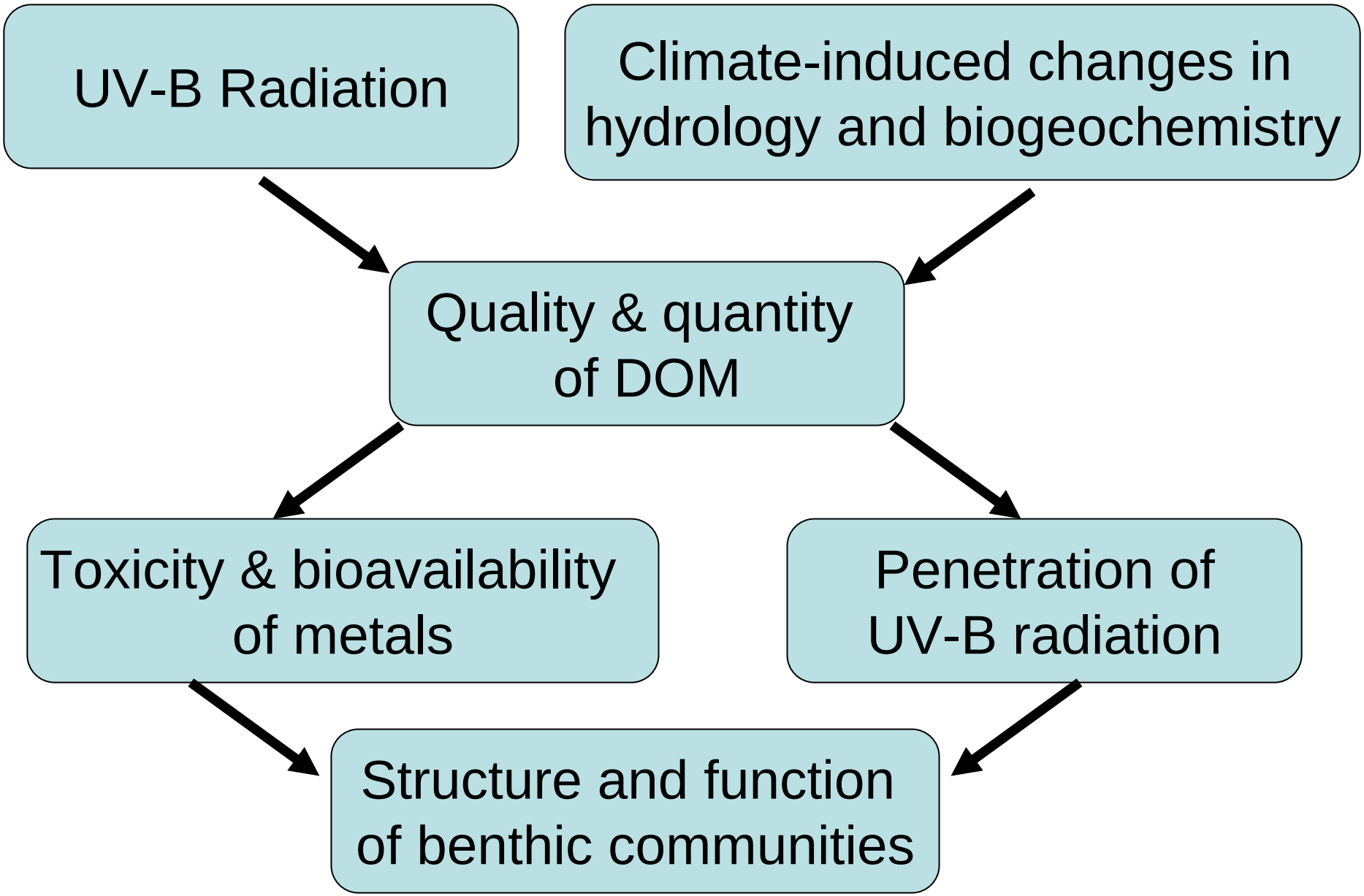
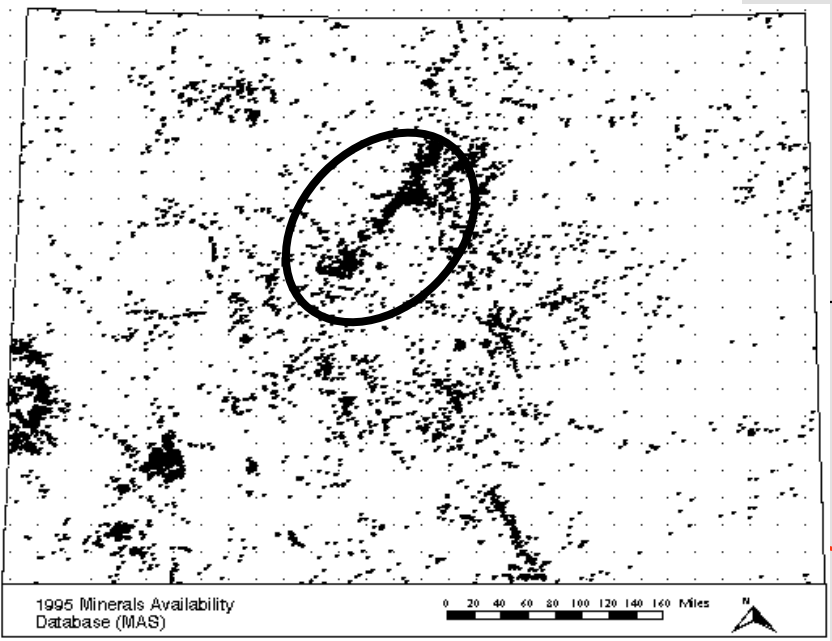
General Hypothesis

Climate-induced changes in biogeochemical processes and stream hydrology will alter quality and quantity of DOM, thereby increasing exposure of benthic communities to UV-B radiation and heavy metals

Conceptual Model



Field Monitoring



Winter Park

Georgetown

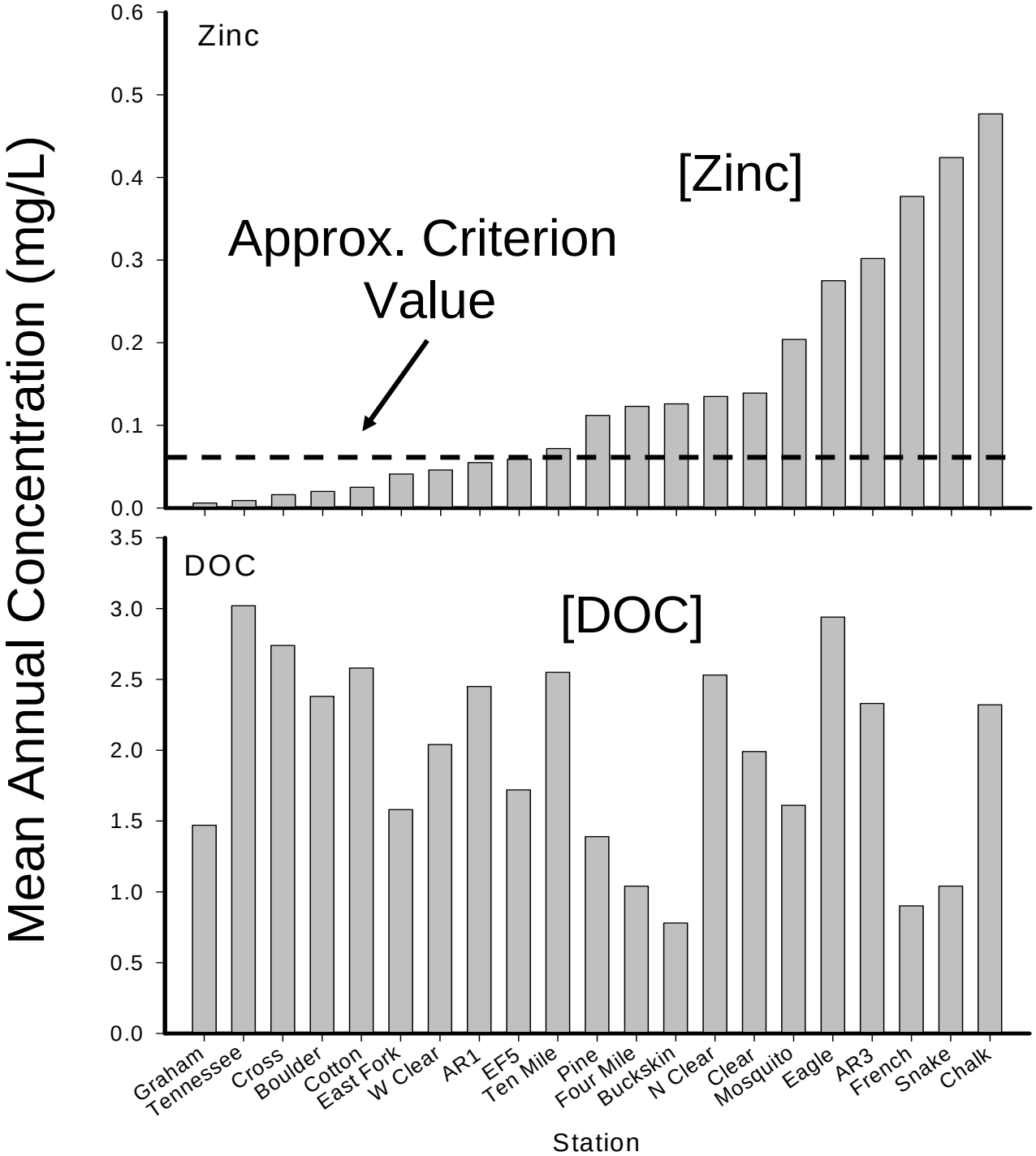
Eagle

Breckenridge

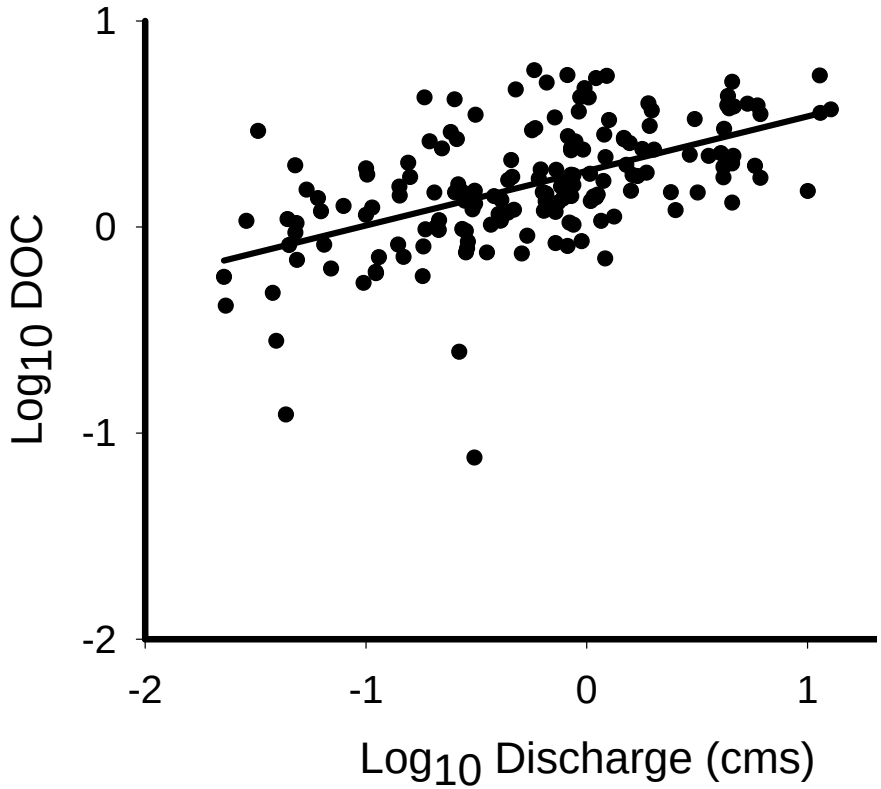
Leadville

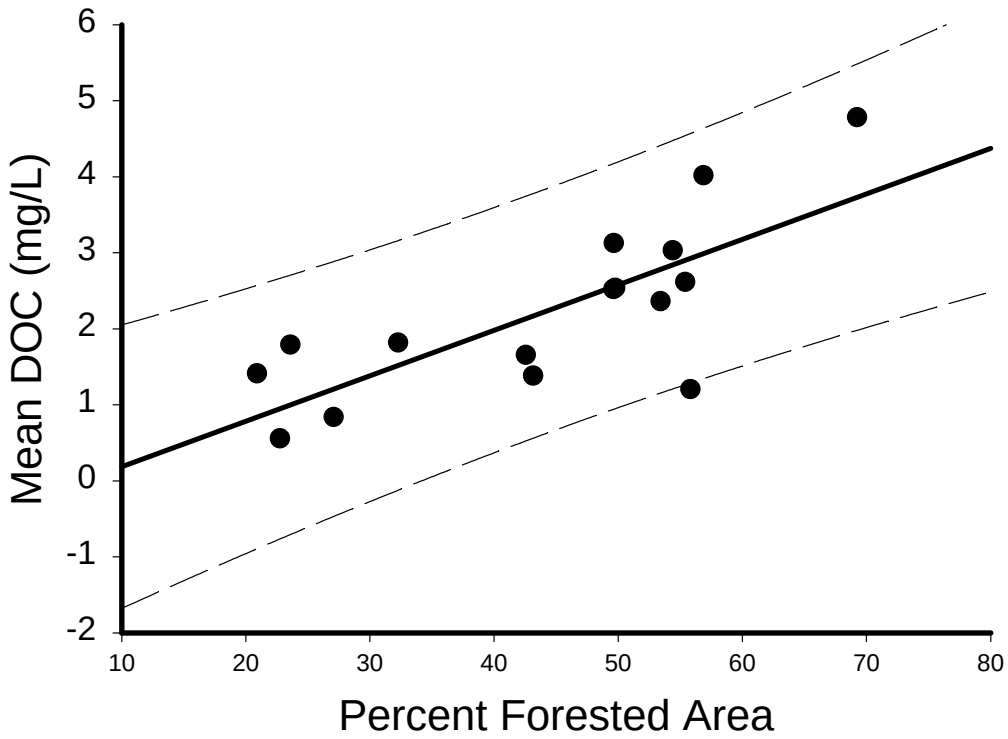
Fairplay

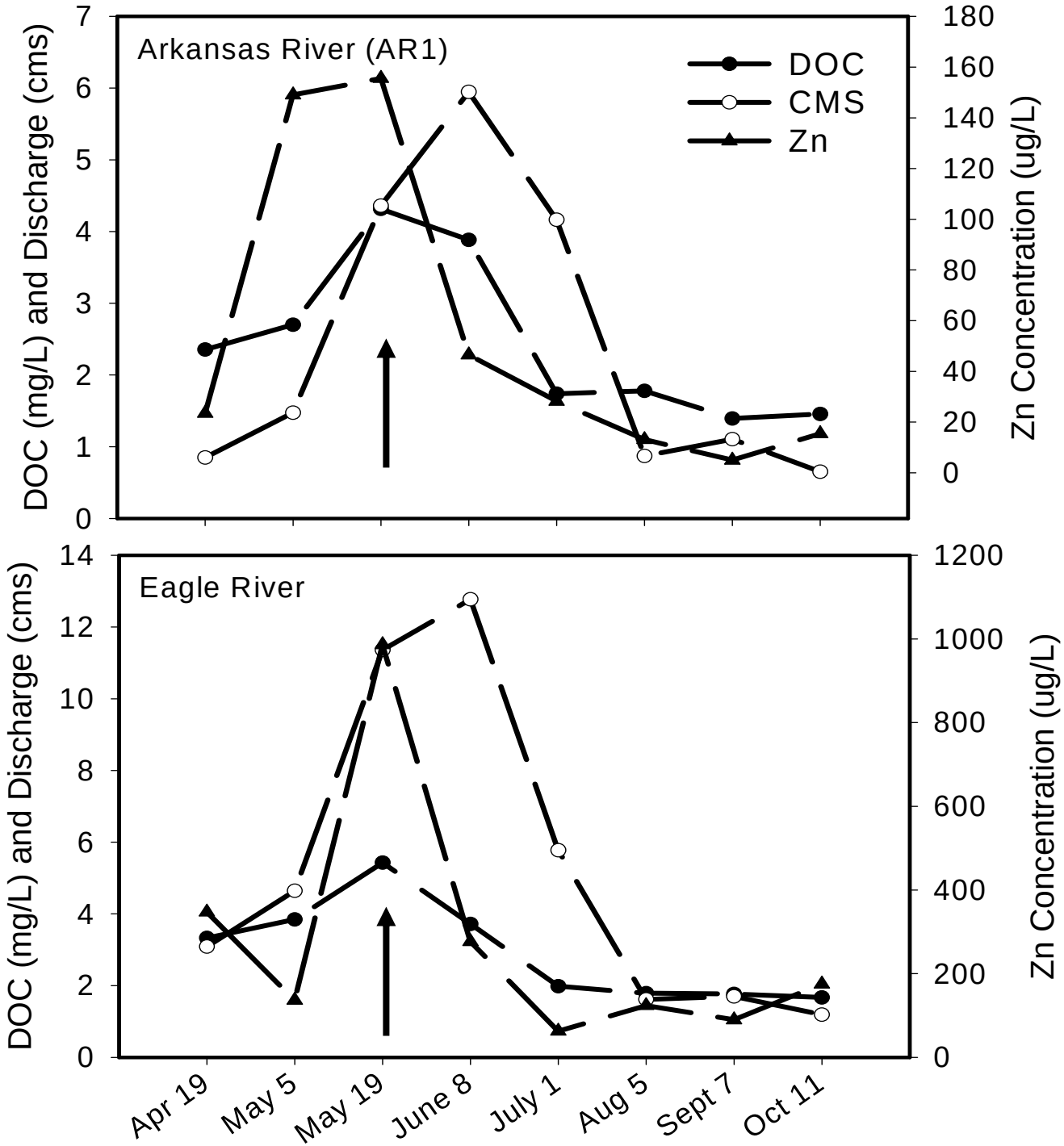
Buena Vista

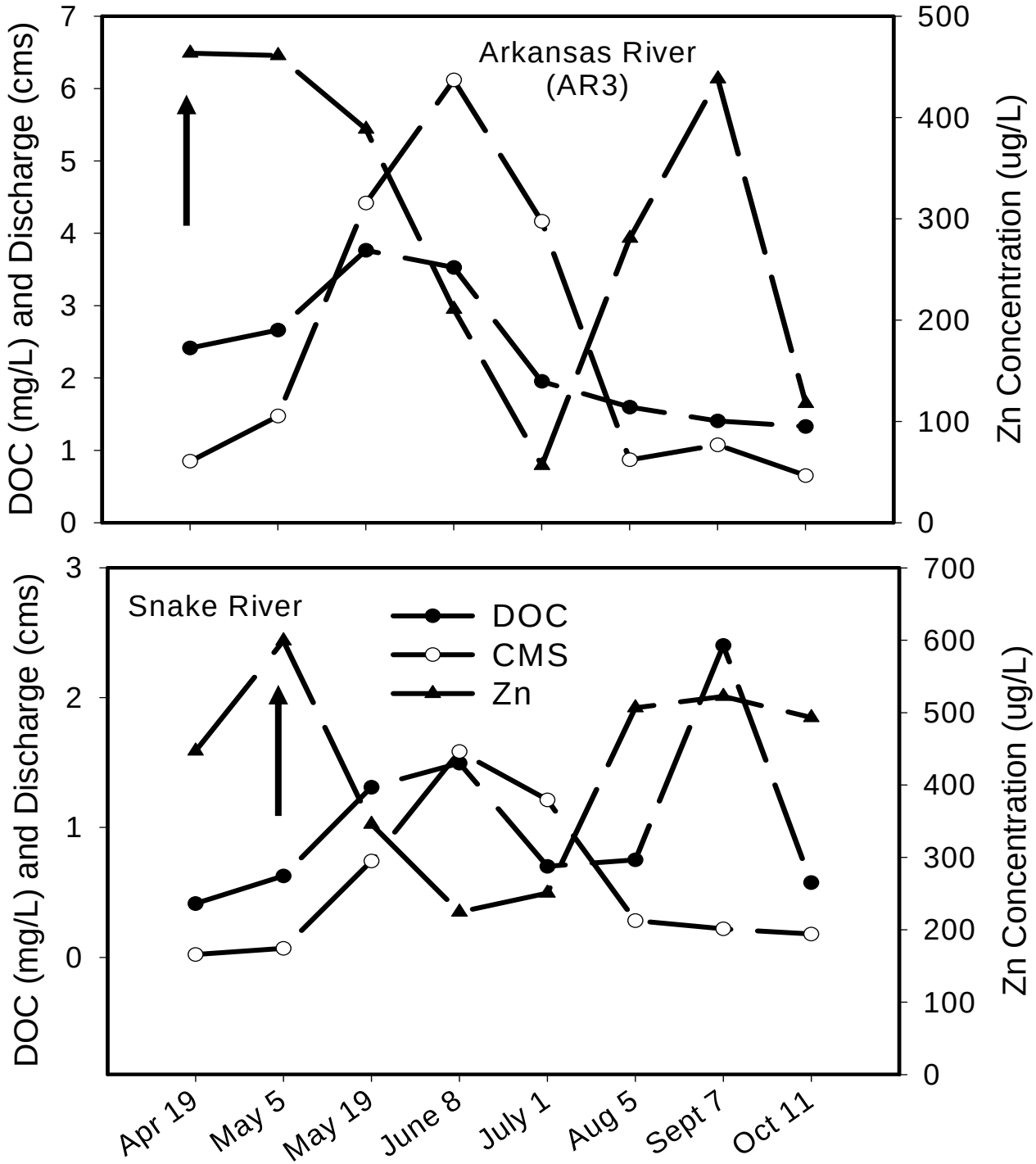

Zinc
[Zinc]
Approx. Criterion Value
DOC
[DOC]
Mean Annual Concentration (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Graham
Tennessee
Cross
Boulder
Cotton
East Fork
W Clear
AR1
EF5
Ten Mile
Pine
Four Mile
Buckskin
N Clear
Clear
Mosquito
Eagle
AR3
French
Snake
Chalk
Station

Influence of Stream Discharge and Vegetation on DOC

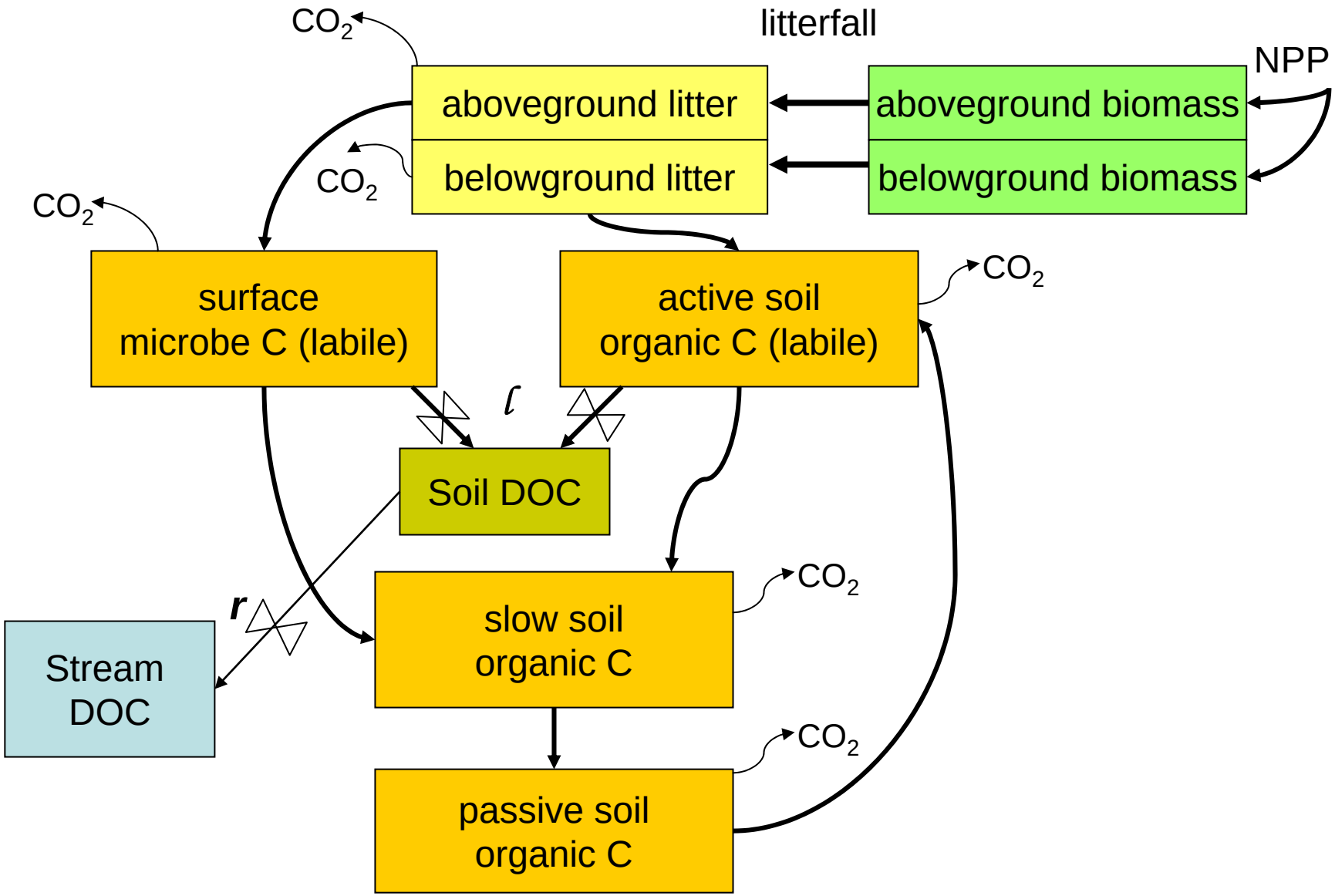


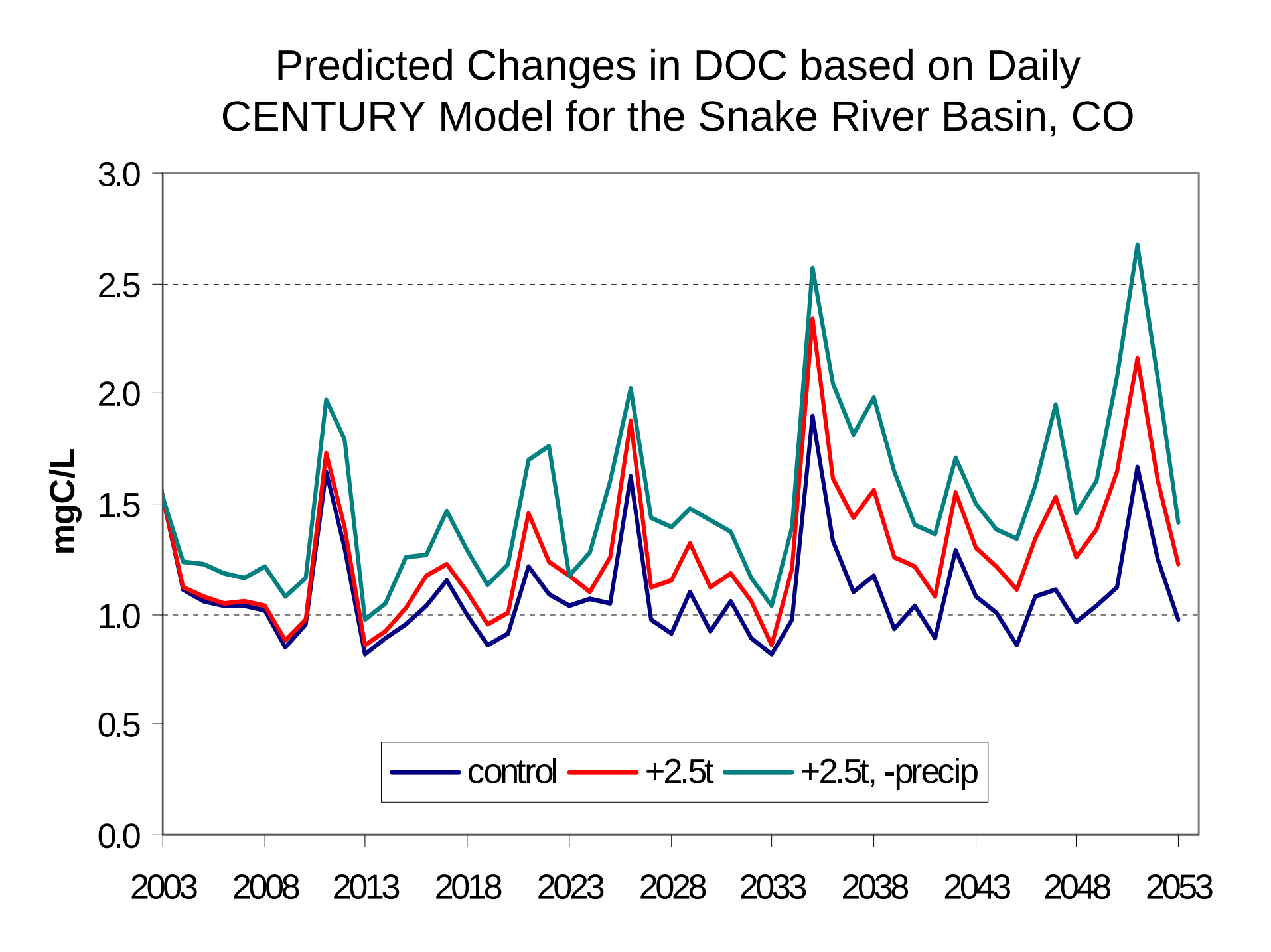



Arkansas River (AR1)
DOC
CMS
Zn
DOC (mg/L) and Discharge (cms)
Zn Concentration (ug/L)
0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
140
160
180
Eagle River
DOC (mg/L) and Discharge (cms)
Zn Concentration (ug/L)
0
2
4
6
8
10
12
14
0
200
400
600
800
1000
1200
Apr 19
May 5
May 19
June 8
July 1
Aug 5
Sept 7
Oct 11

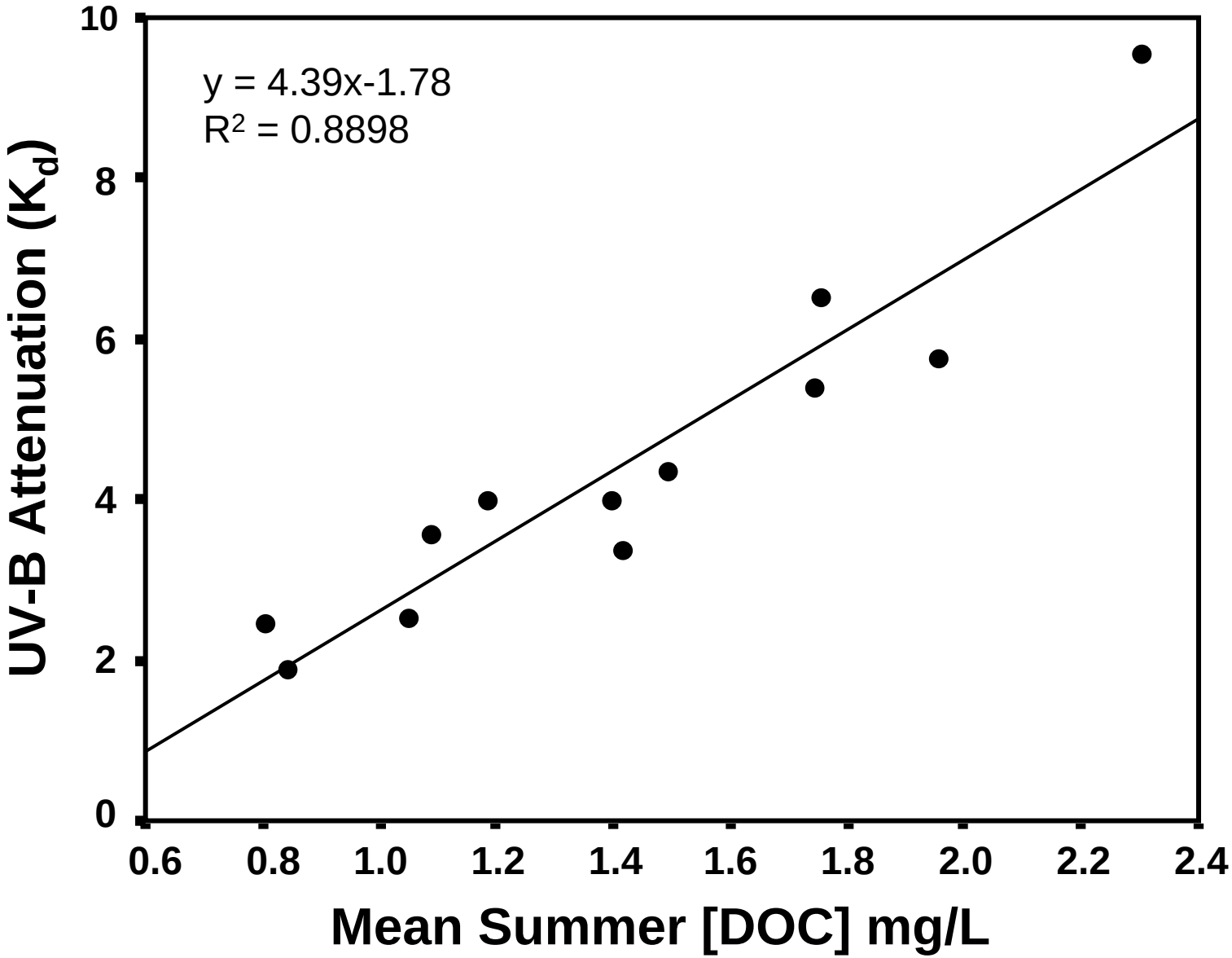

Arkansas River
(AR3)
DOC (mg/L) and Discharge (cms)
Zn Concentration (ug/L)
0
1
2
3
4
5
6
7
0
100
200
300
400
500
Snake River
DOC
CMS
Zn
DOC (mg/L) and Discharge (cms)
Zn Concentration (ug/L)
0
1
2
3
0
100
200
300
400
500
600
700
Apr 19
May 5
May 19
June 8
July 1
Aug 5
Sept 7
Oct 11

Daily CENTURY Organic C Pools



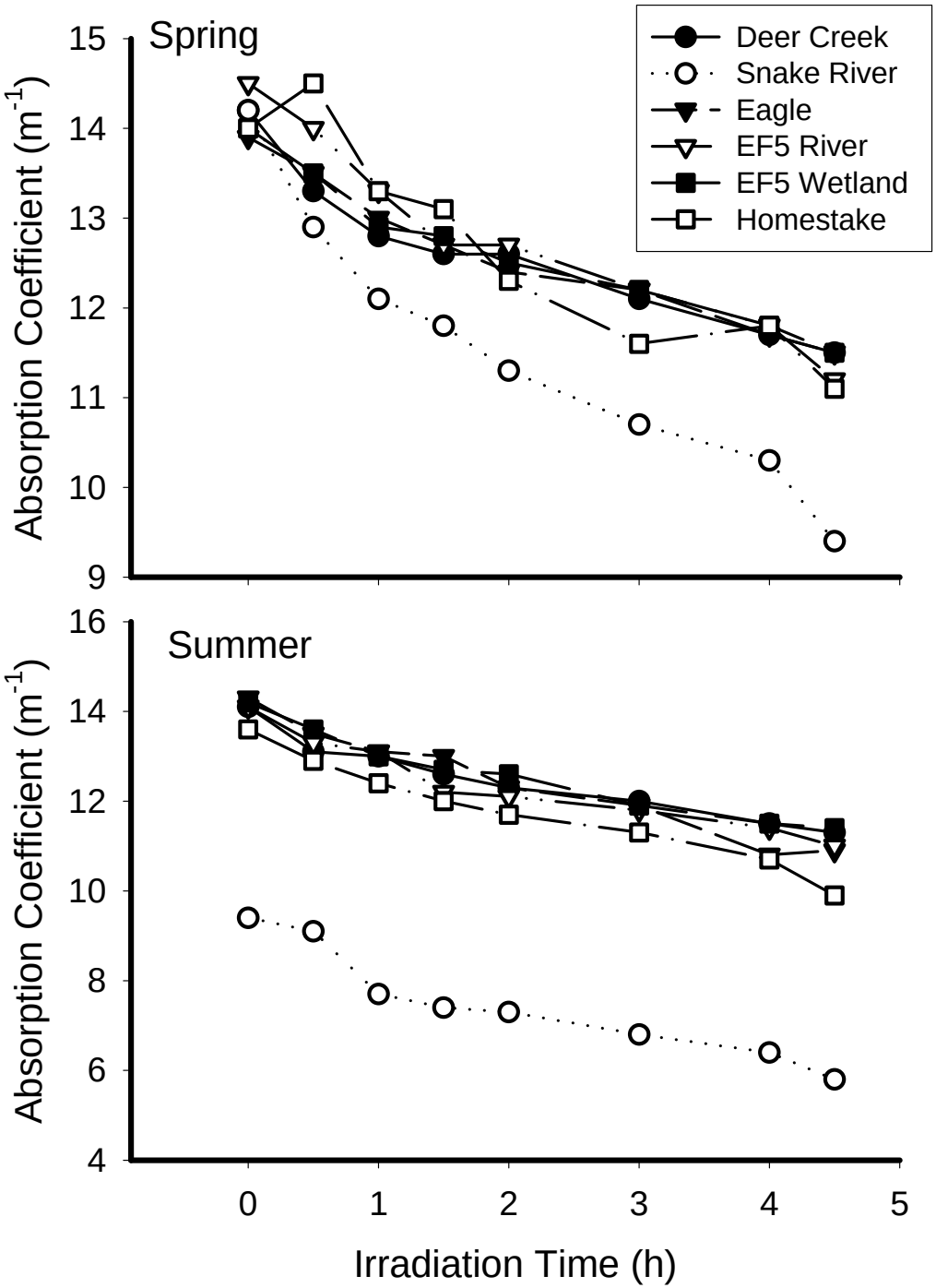

Predicted Changes in DOC based on Daily CENTURY Model for the Snake River Basin, CO
mgC/L
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2003
2008
2013
2018
2023
2028
2033
2038
2043
2048
2053
control
+2.5t
+2.5t, -precip

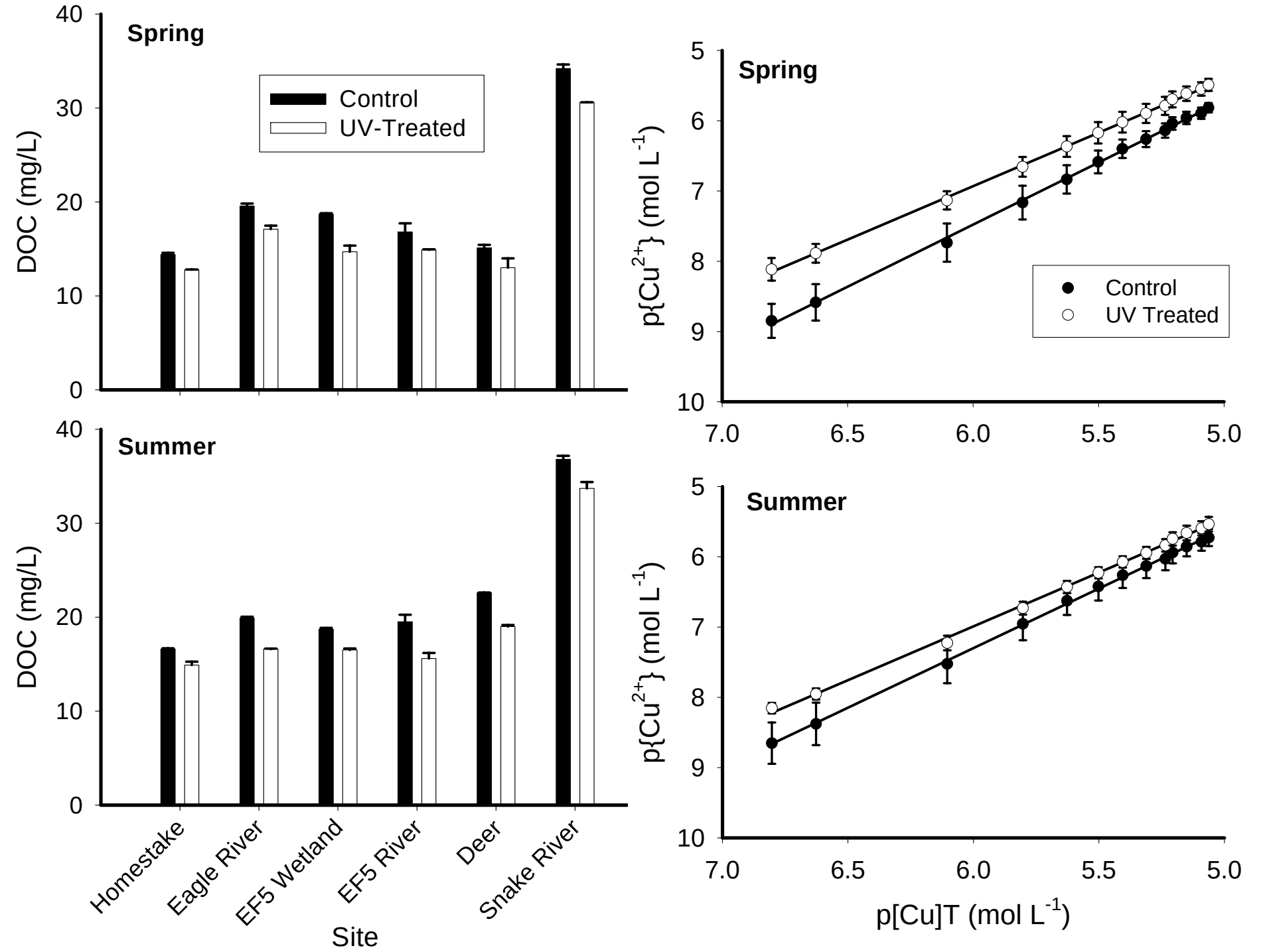
DOC and UV-b Attenuation



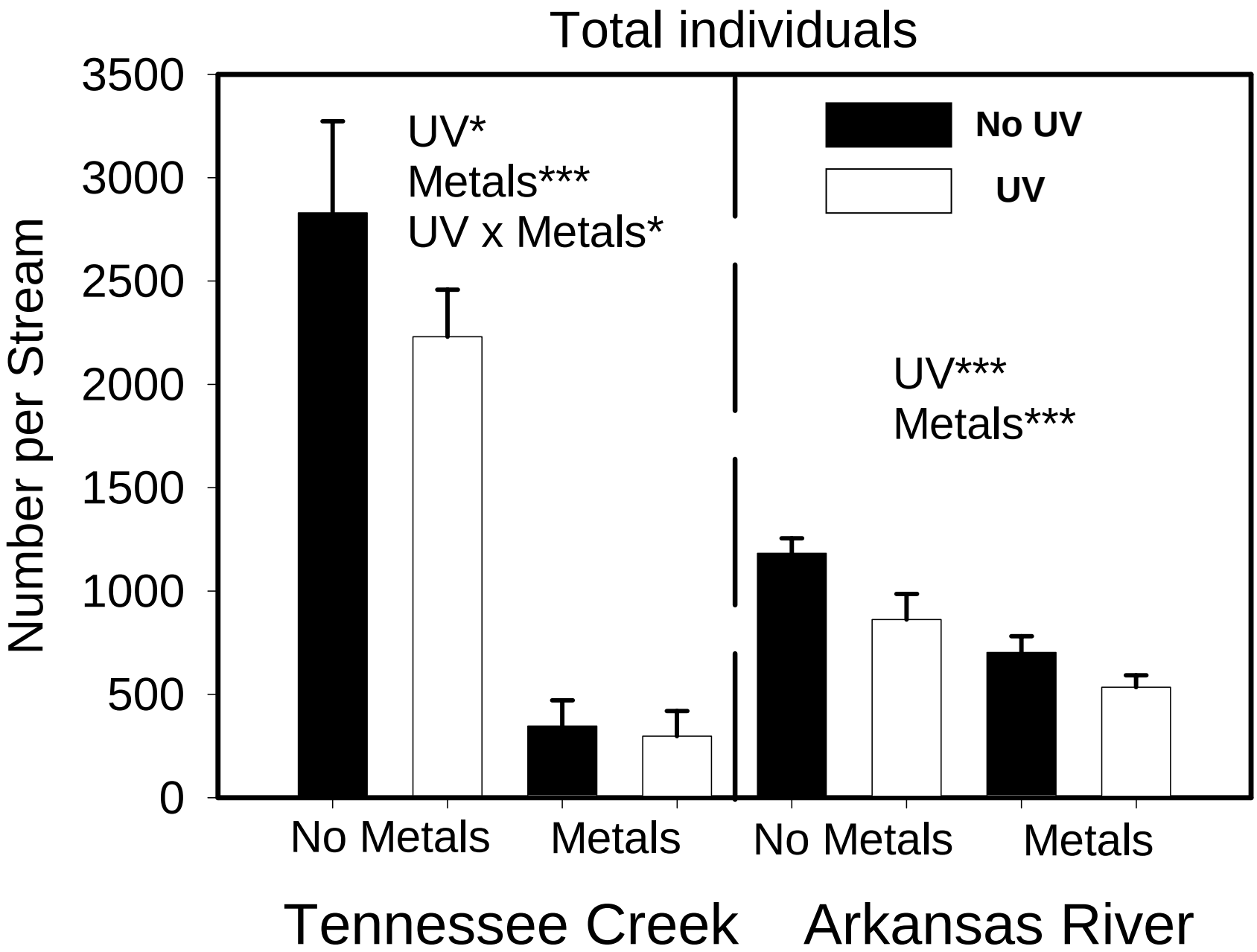
Relationship Between Measured and BLM-Predicted Metals in Caddisflies

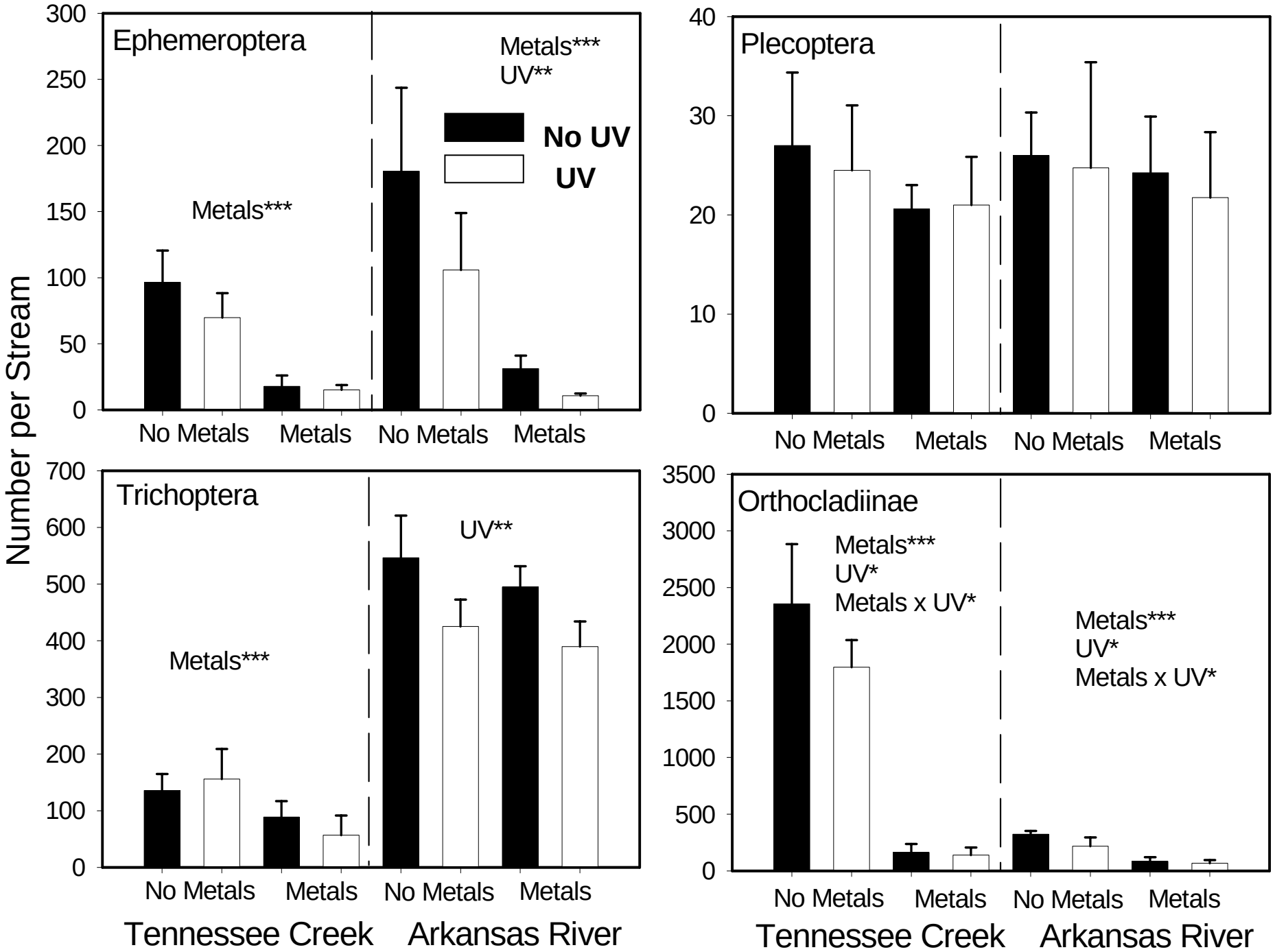
	Metal	F-value	r^2
Spring	Zn	51.5***	0.77
	Cd	3.6	0.21
	Cu	4.9*	0.27
Fall	Zn	10.1**	0.50
	Cd	15.0**	0.60
	Cu	1.4	0.12

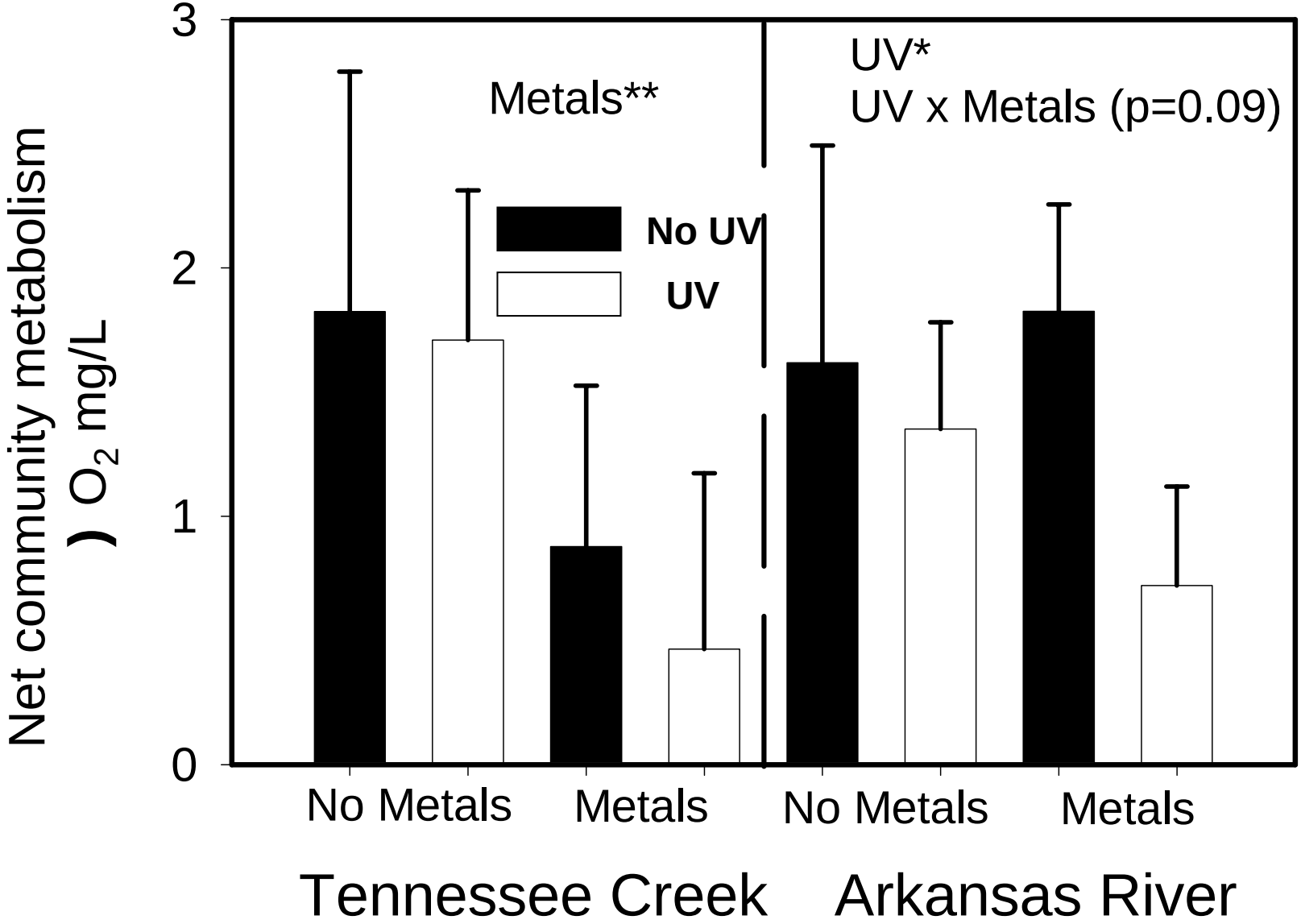

Spring
Summer
Deer Creek
Snake River
Eagle
EF5 River
EF5 Wetland
Homestake
Absorption Coefficient (m-1)
Absorption Coefficient (m-1)
Irradiation Time (h)
15
14
13
12
11
10
9
16
14
12
10
8
6
4
0
1
2
3
4
5


Spring
Control
UV-Treated
DOC (mg/L)
0
10
20
30
40
Summer
Homestake
Eagle River
EF5 Wetland
EF5 River
Deer
Snake River
Site
Spring
Control
UV Treated
p{Cu2+} (mol L-1)
5
6
7
8
9
10
7.0
6.5
6.0
5.5
5.0
Summer
p[Cu]T (mol L-1)

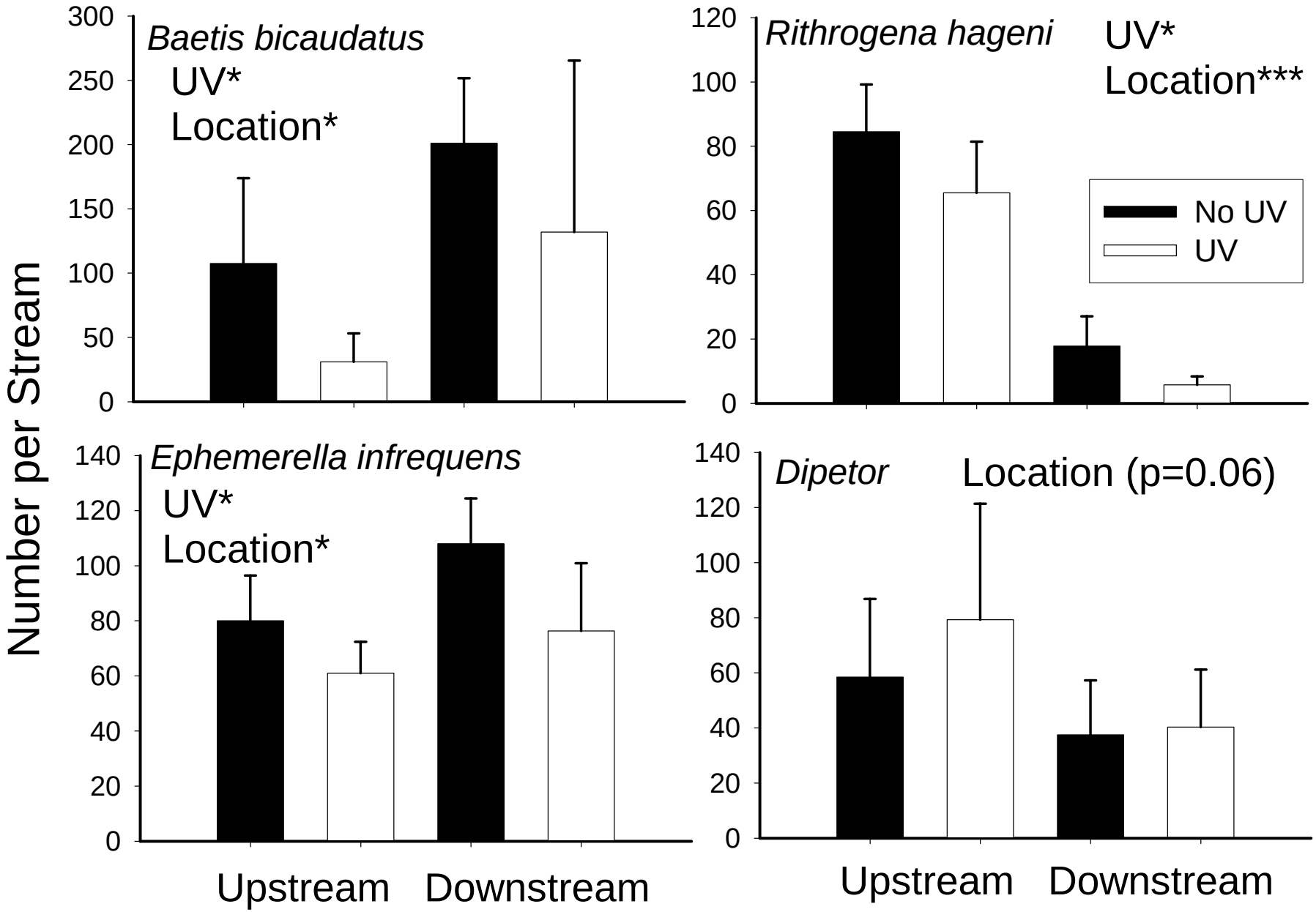
2003 Microcosm Experiments



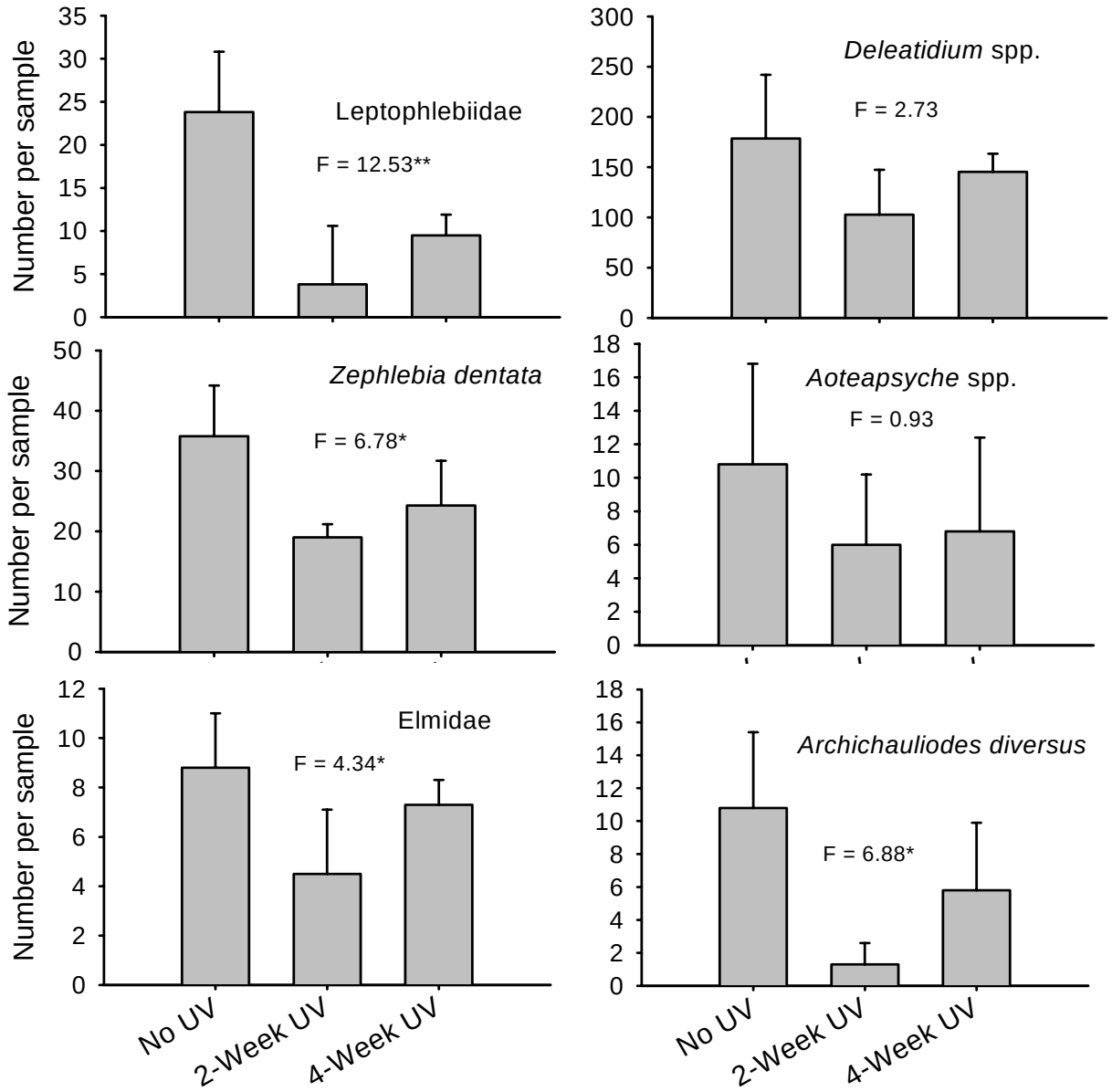

Ephemeroptera
Metals***
UV**
No UV
UV
Metals***
Plecoptera
Trichoptera
UV**
Metals***
Orthocladiinae
Metals***
UV*
Metals x UV*
Metals***
UV*
Metals x UV*
Number per Stream
No Metals
Metals
No Metals
Metals
Tennessee Creek
Arkansas River


Net community metabolism
) O_2 mg/L
3
2
1
0
Metals**
UV*
UV x Metals (p=0.09)
No UV
UV
No Metals
Metals
No Metals
Metals
Tennessee Creek
Arkansas River

2004 Microcosm Experiment



2005 New Zealand Experiments

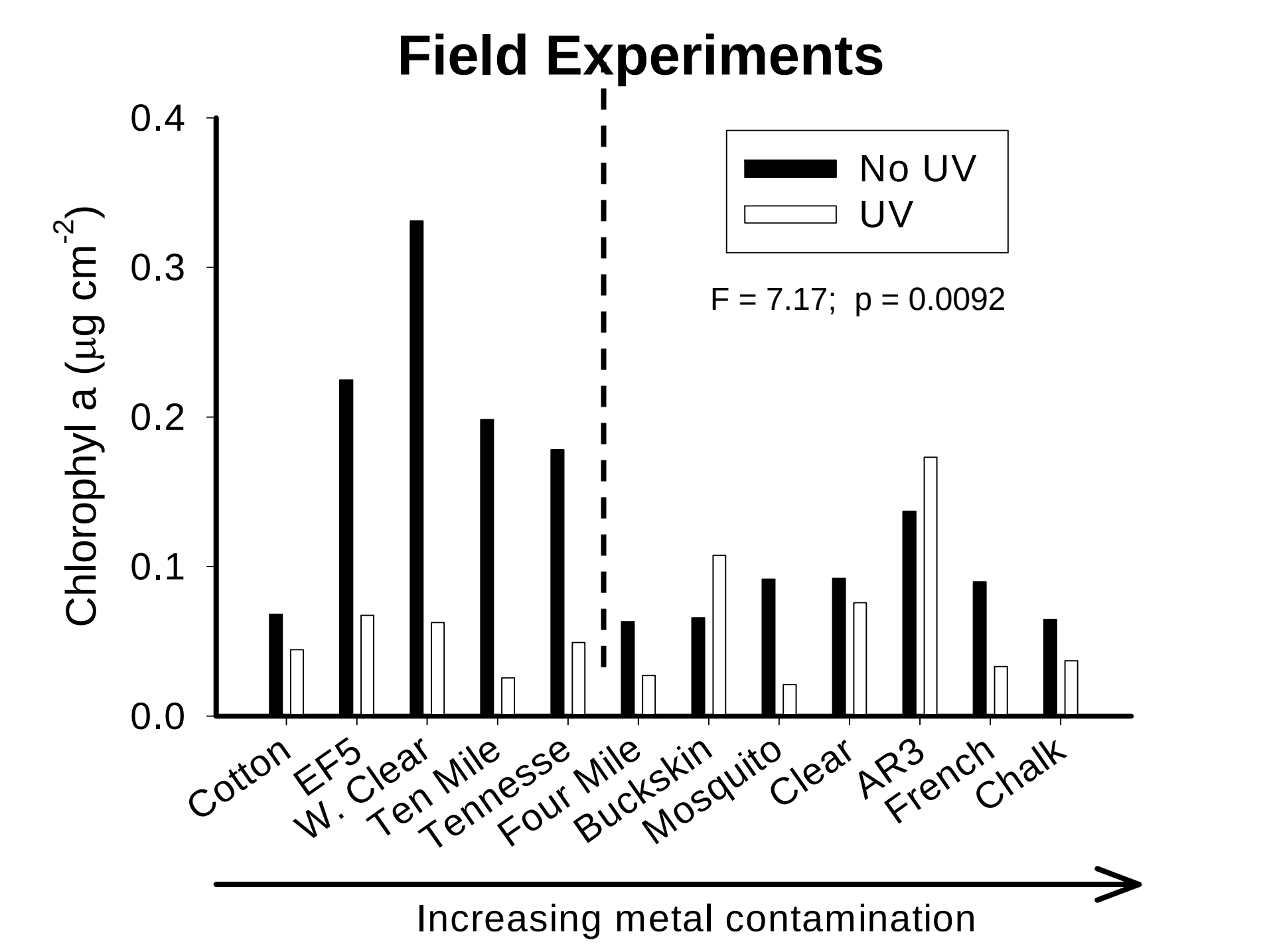


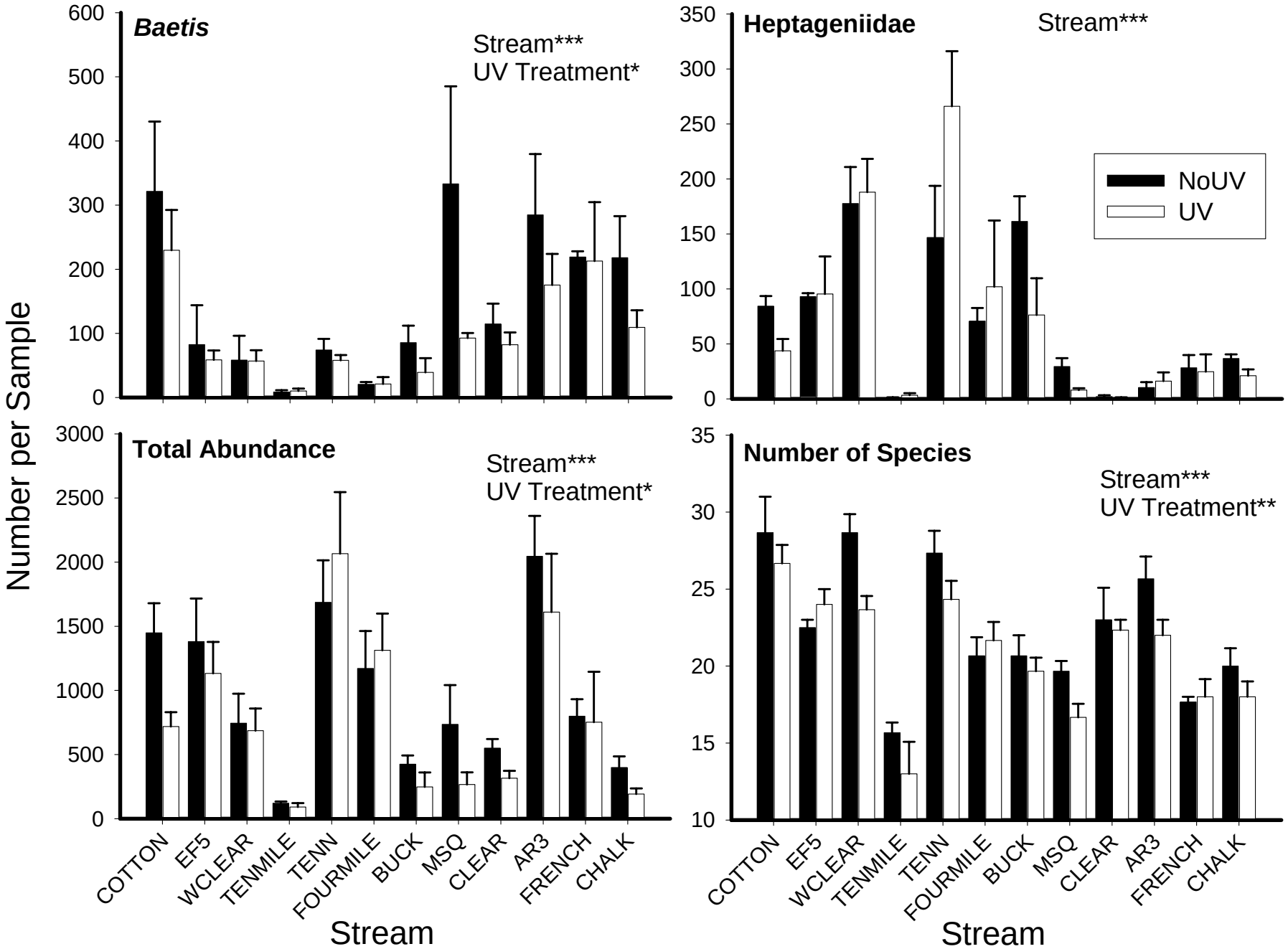
Conclusions from Microcosm Experiments

- Exposure to UV-B in stream microcosms
  reduced abundance of most organisms
  → consistent effects on grazing mayflies

- Combined effects of metals + UV-B were greater than either stressor alone

- Some evidence of greater UV effects on communities collected from metal-impacted sites


Field Experiments
0.4
0.3
0.2
0.1
0.0
Chlorophyl a (µg cm-2)
No UV
UV
F = 7.17; p = 0.0092
Cotton
EF5
W. Clear
Ten Mile
Tennesse
Four Mile
Buckskin
Mosquito
Clear
AR3
French
Chalk
Increasing metal contamination


Baetis
Stream***
UV Treatment*
Heptageniidae
Stream***
NoUV
UV
Total Abundance
Stream***
UV Treatment*
Number of Species
Stream***
UV Treatment**
Number per Sample
Stream
COTTON
EF5
WCLEAR
TENMILE
TENN
FOURMILE
BUCK
MSQ
CLEAR
AR3
FRENCH
CHALK

Summary and Implications

- Benthic communities in shallow, alpine streams are exposed to intense UV-B
- Photodegradation of DOC increased UV-B exposure & metal bioavailability
- Removal of UV-B increased total abundance, number of species, and mayfly abundance
- Little evidence of differences in UV-B effects along the gradient of metal contamination

Future Plans

Continue to refine Daily-Century model to predict potential impacts of climate change and hydrology on DOC

Evaluate effects of changes in timing of snowmelt on DOC, light attenuation, and metal bioavailability

Acknowledgements

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