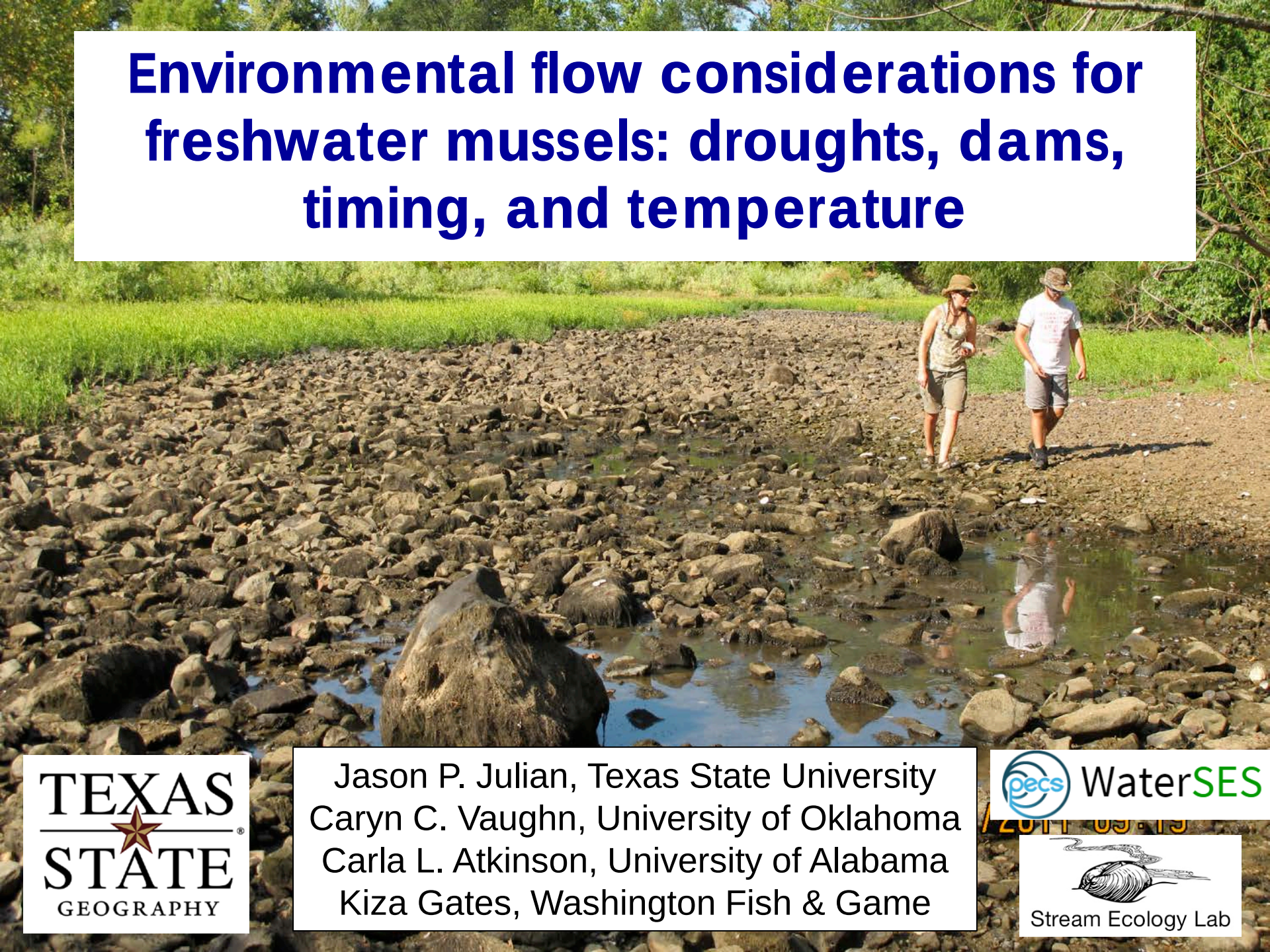
Environmental flow considerations for freshwater mussels: droughts, dams, timing, and temperature



Jason P. Julian, Texas State University
Caryn C. Vaughn, University of Oklahoma
Carla L. Atkinson, University of Alabama
Kiza Gates, Washington Fish & Game

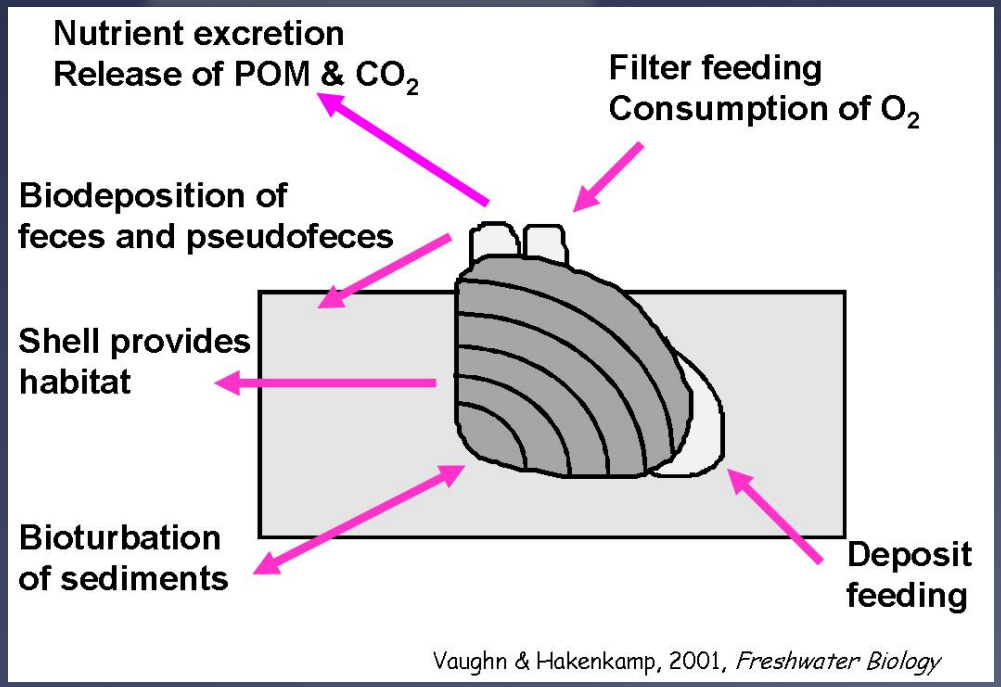
TEXAS STATE GEOGRAPHY

WaterSES

Stream Ecology Lab

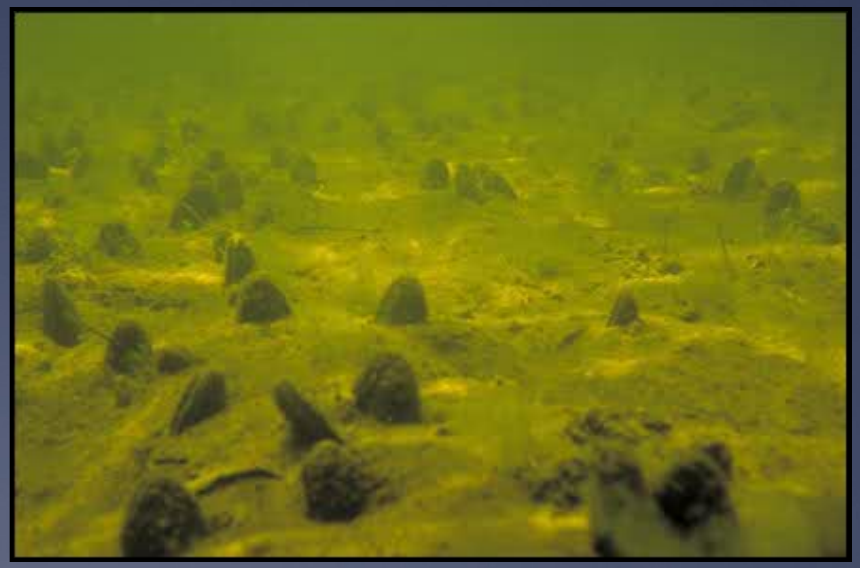
FW Mussels are important and valuable

- Water purification (biofiltration)
- Nutrient recycling & storage
- Structural habitat
- Substrate modification
- Food for other organisms

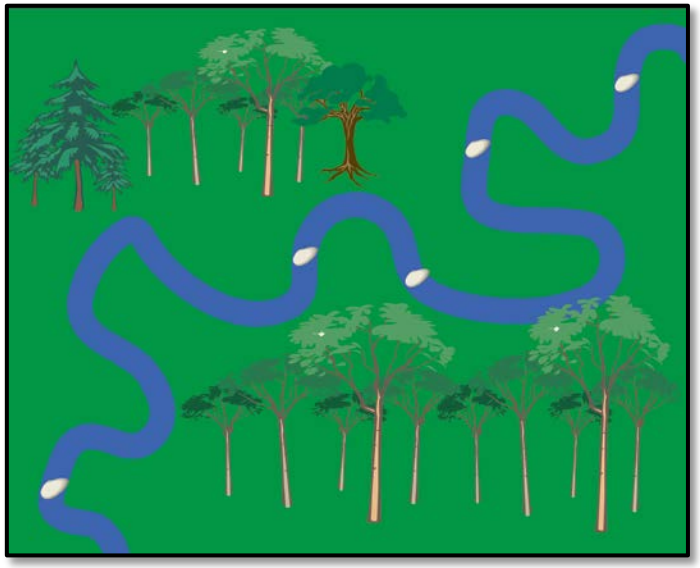


"canaries of the rivers"

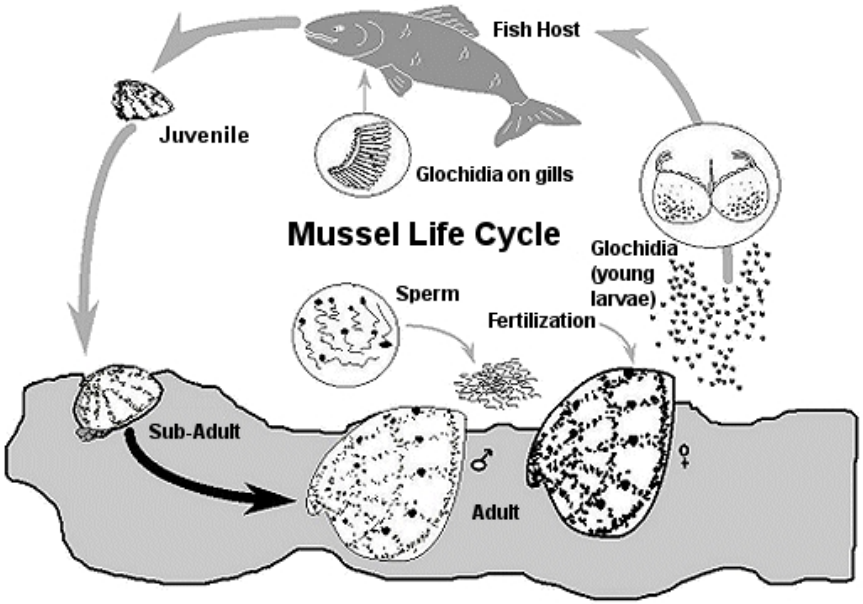
- Long-lived (6 – 100 yrs)
- Occur as dense, multispecies aggregations (mussel beds)



“Goldilocks” of rivers

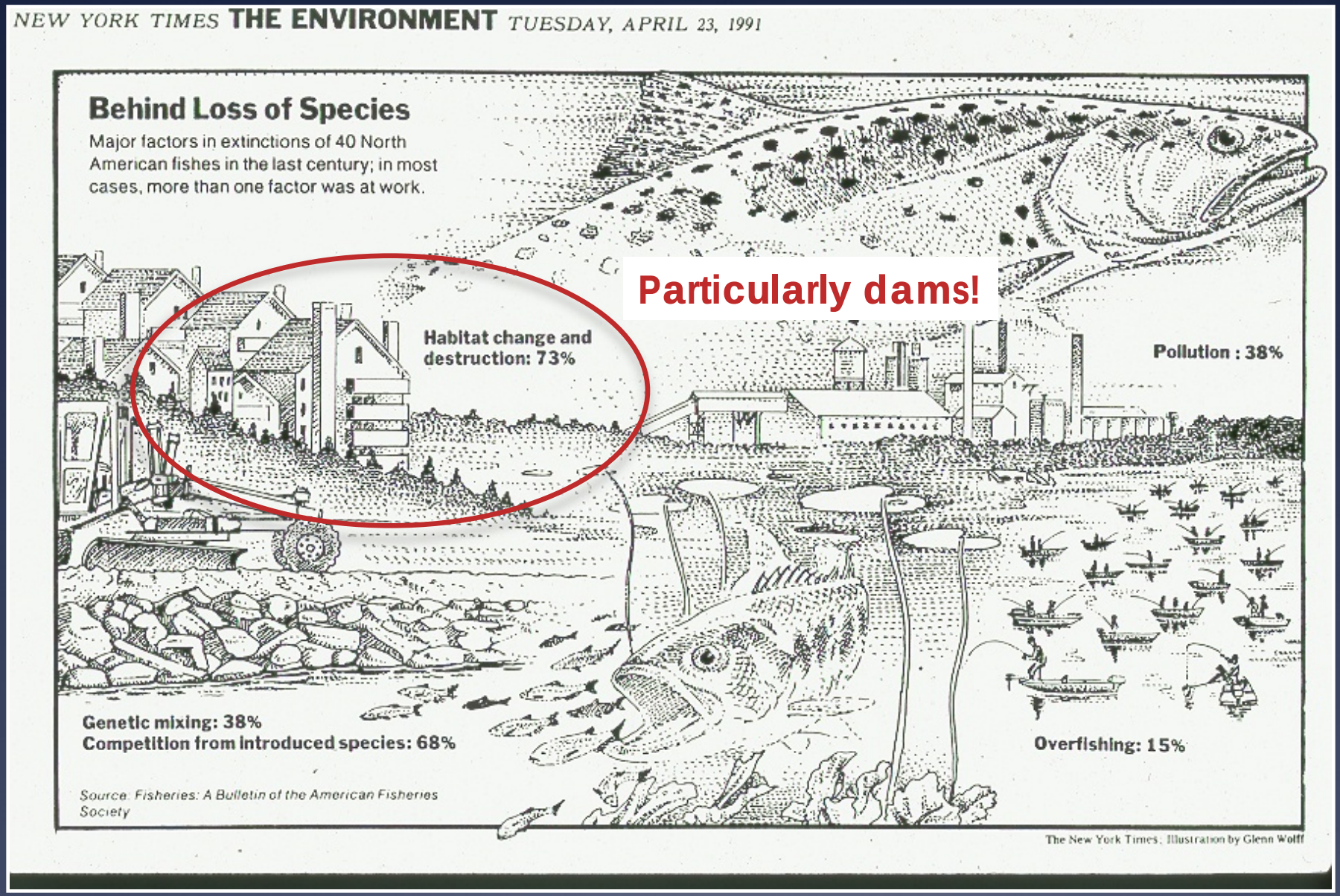


- Sedentary and can’t move far
- Depend on fish for dispersal
- Different mussels use different fish

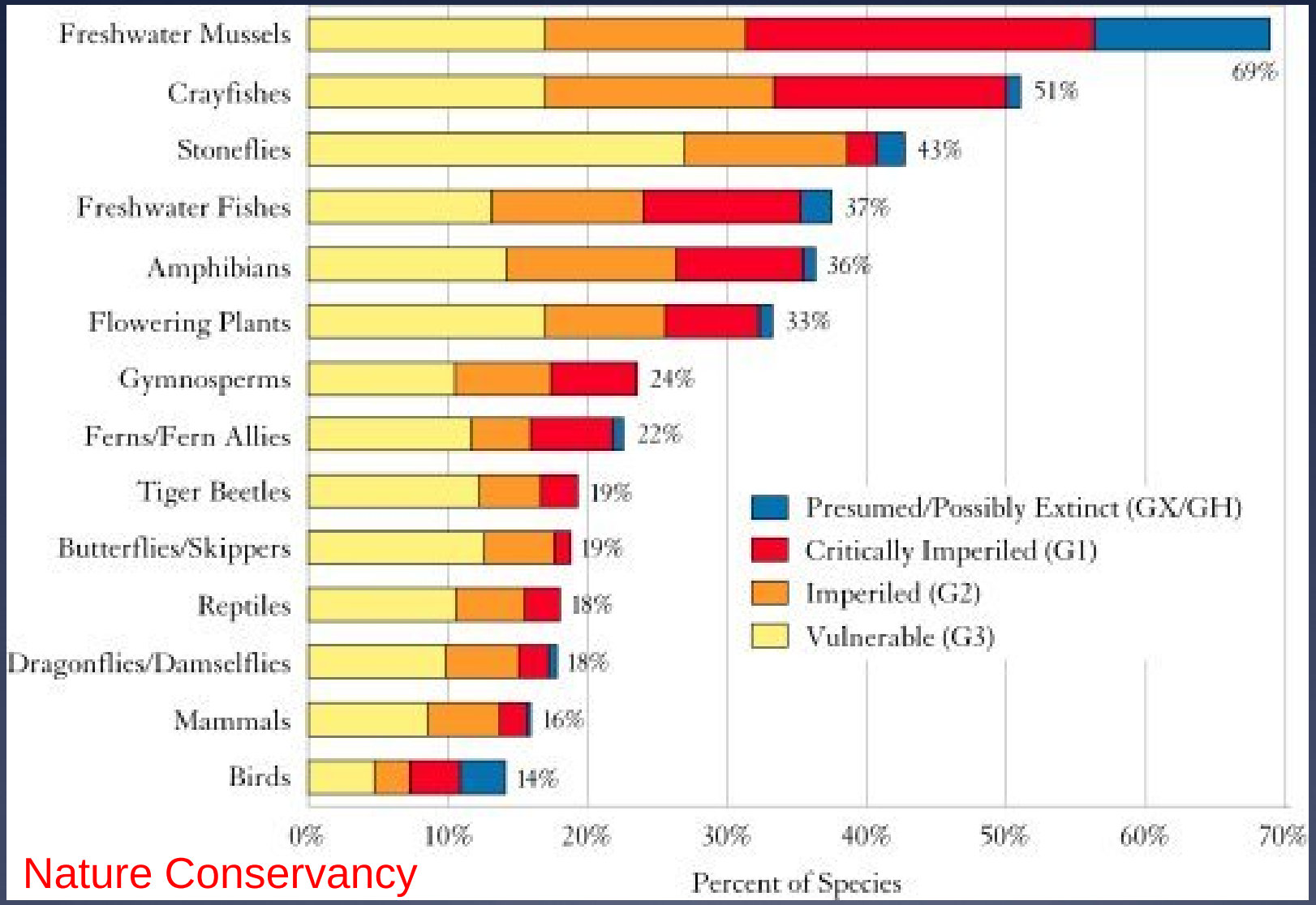


- Long generation times
- Mussel beds are restricted to areas of sufficient flow during low flows, low shear stresses during high flows, and a goldiloxian water temperature range

Threats to FW mussels and their hosts



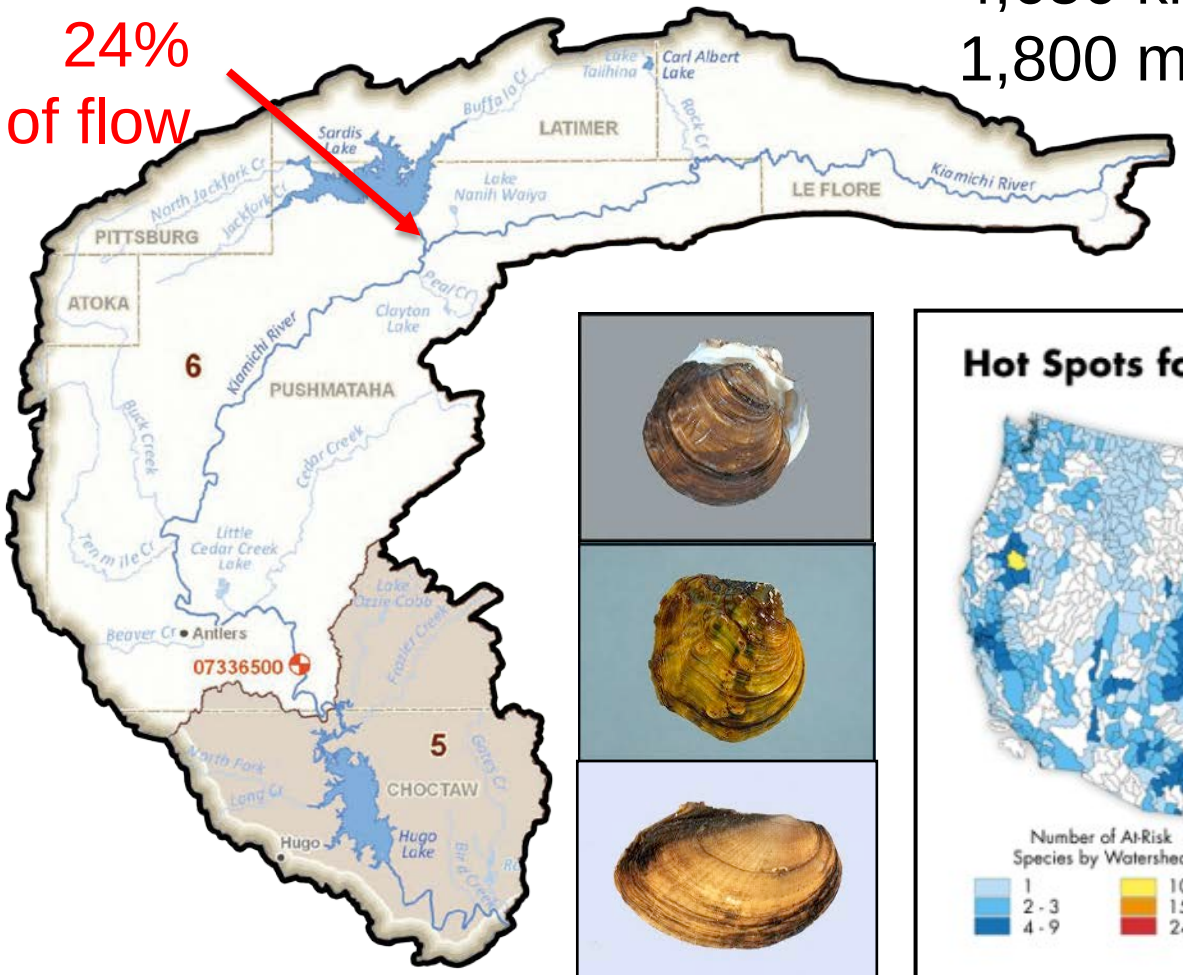
most rapidly declining group of freshwater organisms

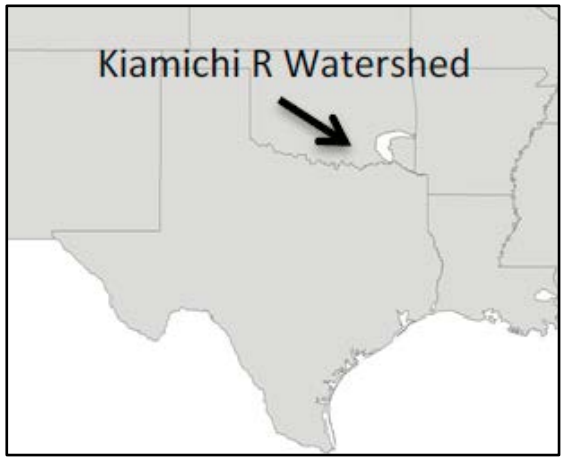


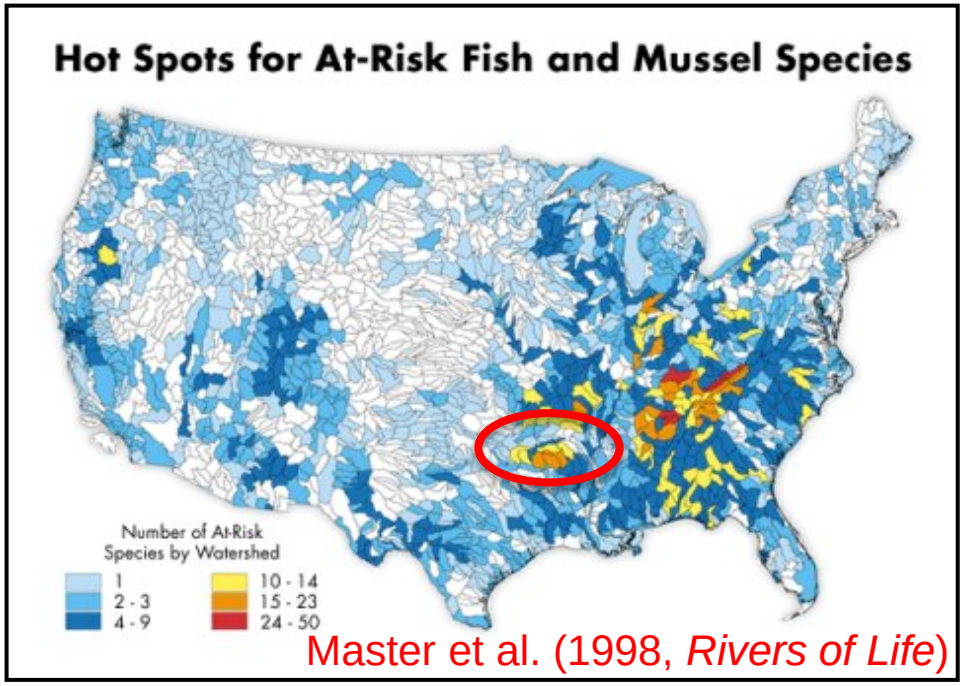
Nature Conservancy

Kiamichi River

4,650 km^2
1,800 mi^2



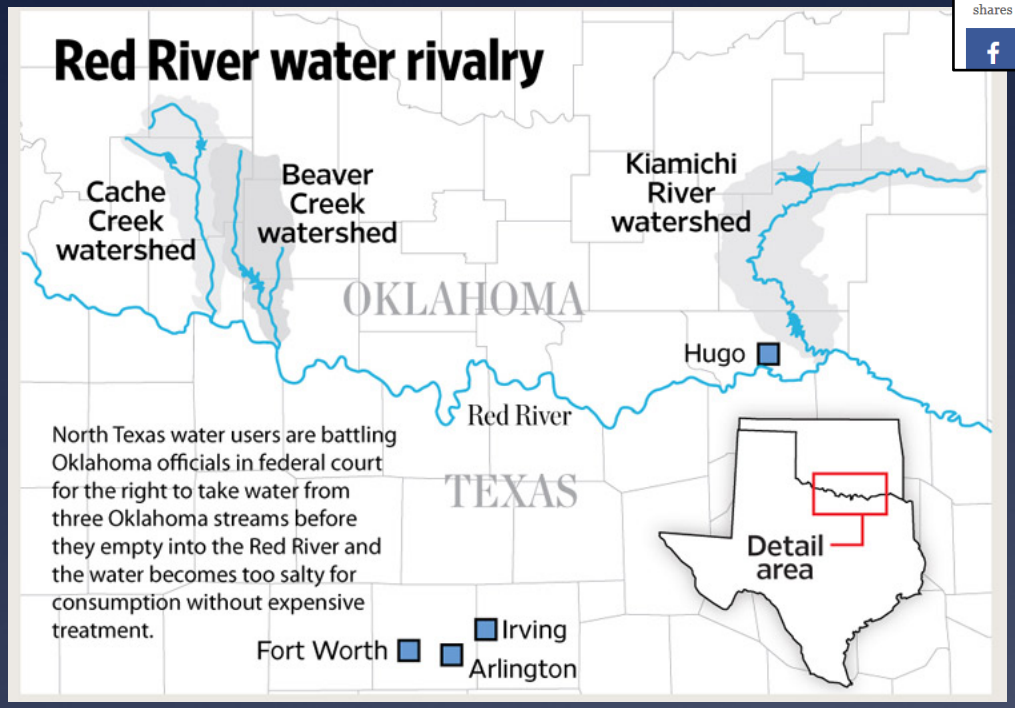




Master et al. (1998, *Rivers of Life*)

86 fish species
31 mussel species (56% of OK's mussel fauna)
3 federally-listed mussel species

Kiamichi River water conflict



Board grants OKC permit for Kiamichi water

by William Crum • Published: October 12, 2017 5:00 AM CDT • *Updated: October 12, 2017 5:00 AM CDT*

10 shares

Oklahoma City is closer to securing water needed to sustain long-term growth — but a decision to grant a permit for southeastern Oklahoma water did not sit well with some residents of the region.

Water flows over the spillway at Hugo Lake, on the Kiamichi River, in southeastern Oklahoma. **Hugo Daily News archive photo**

FORT WORTH

Cash-strapped Oklahoma again floats idea of selling water to Texas

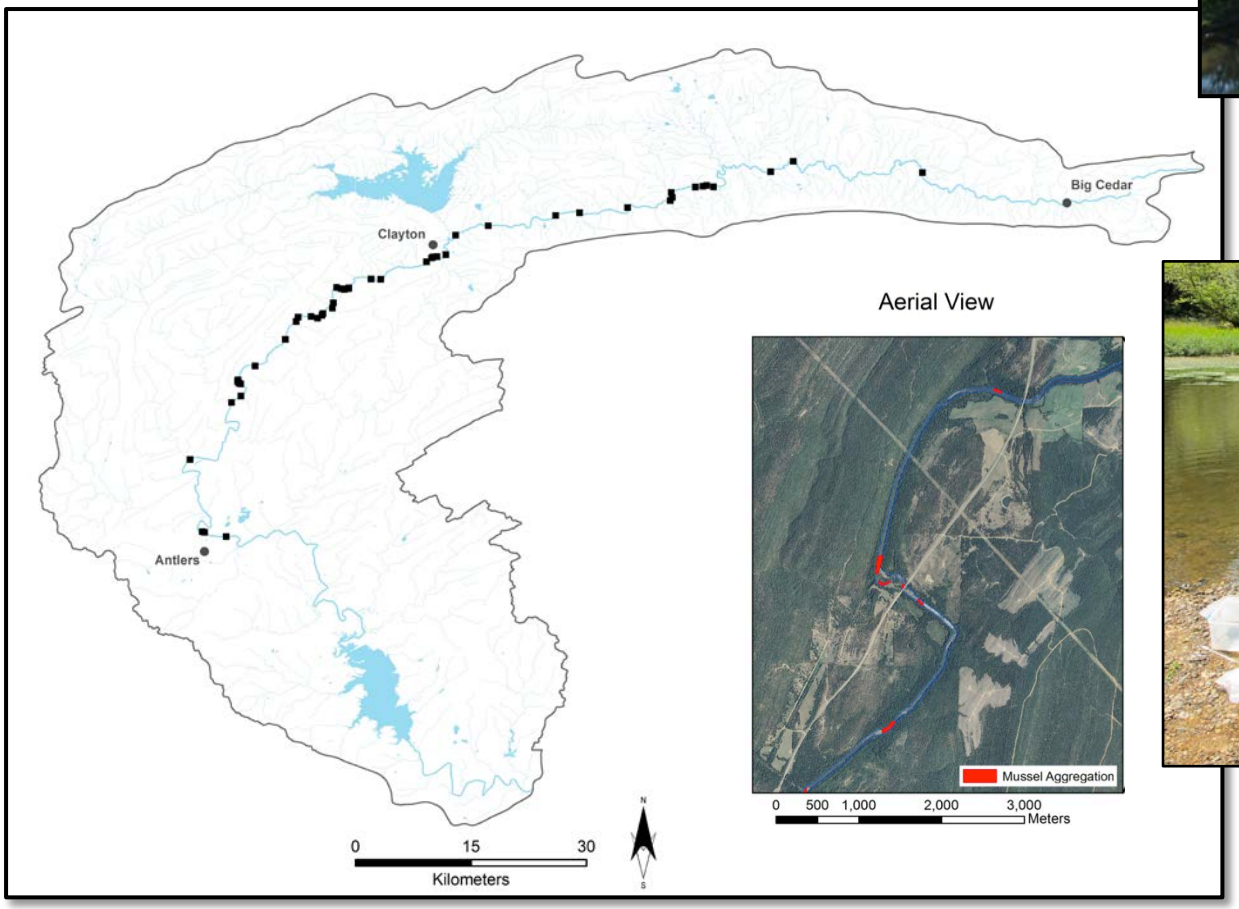
BY BILL HANNA
billhanna@star-telegram.com
MAY 12, 2017 12:18 PM

- Water used by many for a range of purposes
- Sardis Lake water co-managed by Oklahoma City (water supply), Choctaw Nation (recreation), and USACE (flood control)
- Potential water source for N TX

Willingness to Pay for Ecosystem Services among Stakeholder Groups in a South-Central U.S. Watershed with Regional Conflict

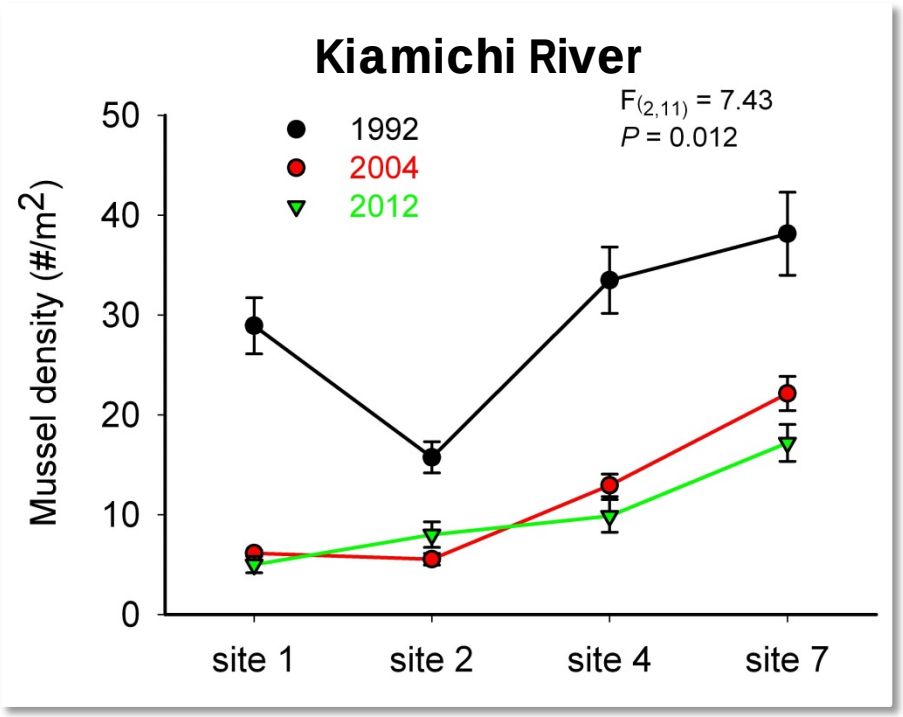
Antonio J. Castro, Ph.D.[1]; Caryn C. Vaughn, Ph.D.[2]; Marina García-Llorente, Ph.D.[3]; Jason P. Julian, Ph.D.[4]; and Carla L. Atkinson, Ph.D.[5]

Mussel beds in the Kiamichi River have been mapped, monitored, and studied for over 25 y by Vaughn and her research team

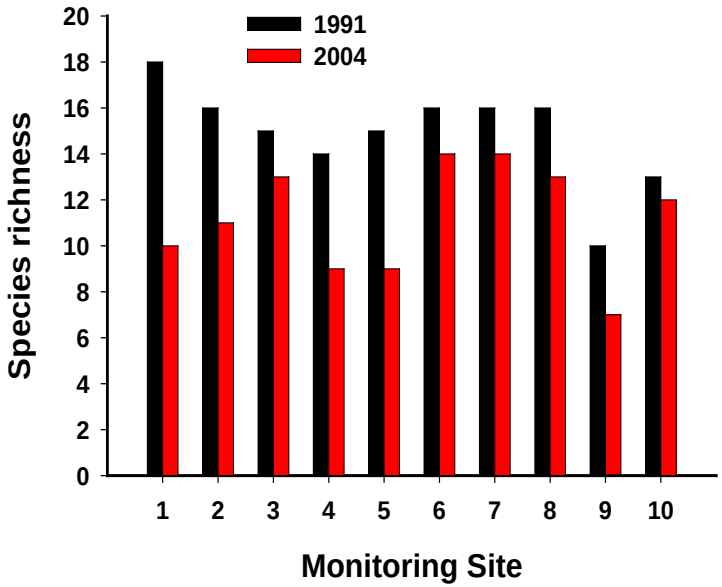


Atkinson & Vaughn, Freshwater Biology, 2015

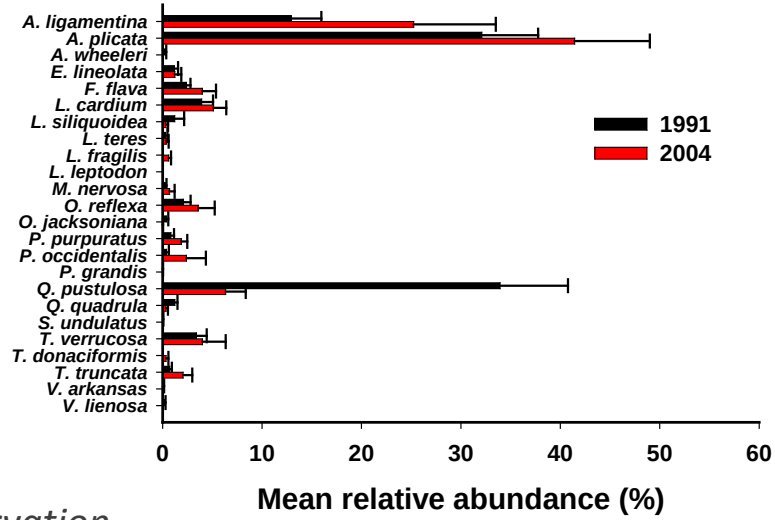
In the past 25 years, mussels have declined in Kiamichi River and species composition has changed



Decreases in the number of species

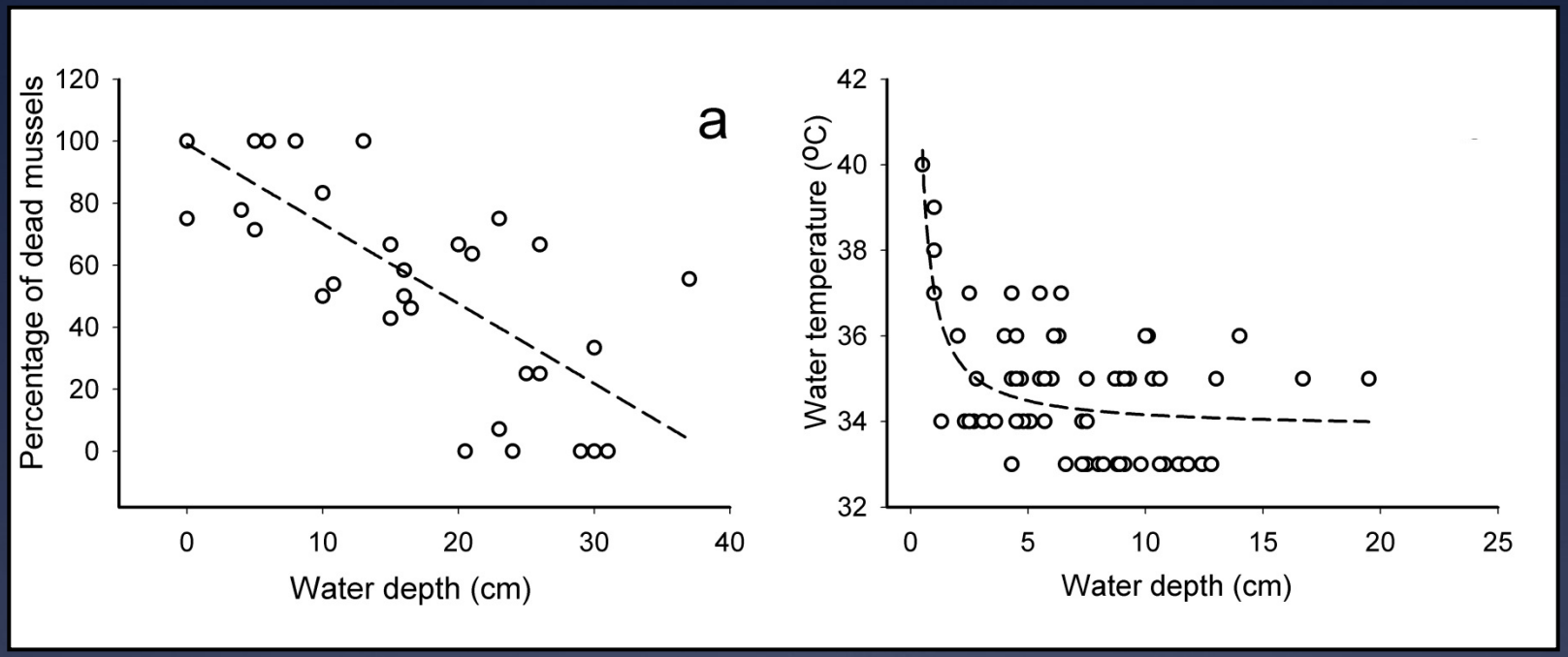


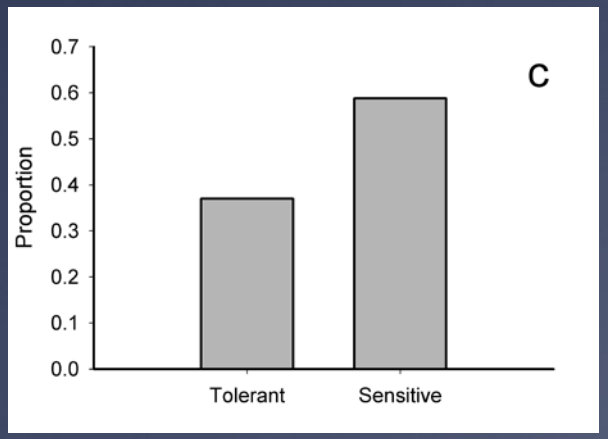
Shifts in species dominance



Galbraith, Spooner & Vaughn, 2010, Biological Conservation

Mostly in Drought conditions during summer



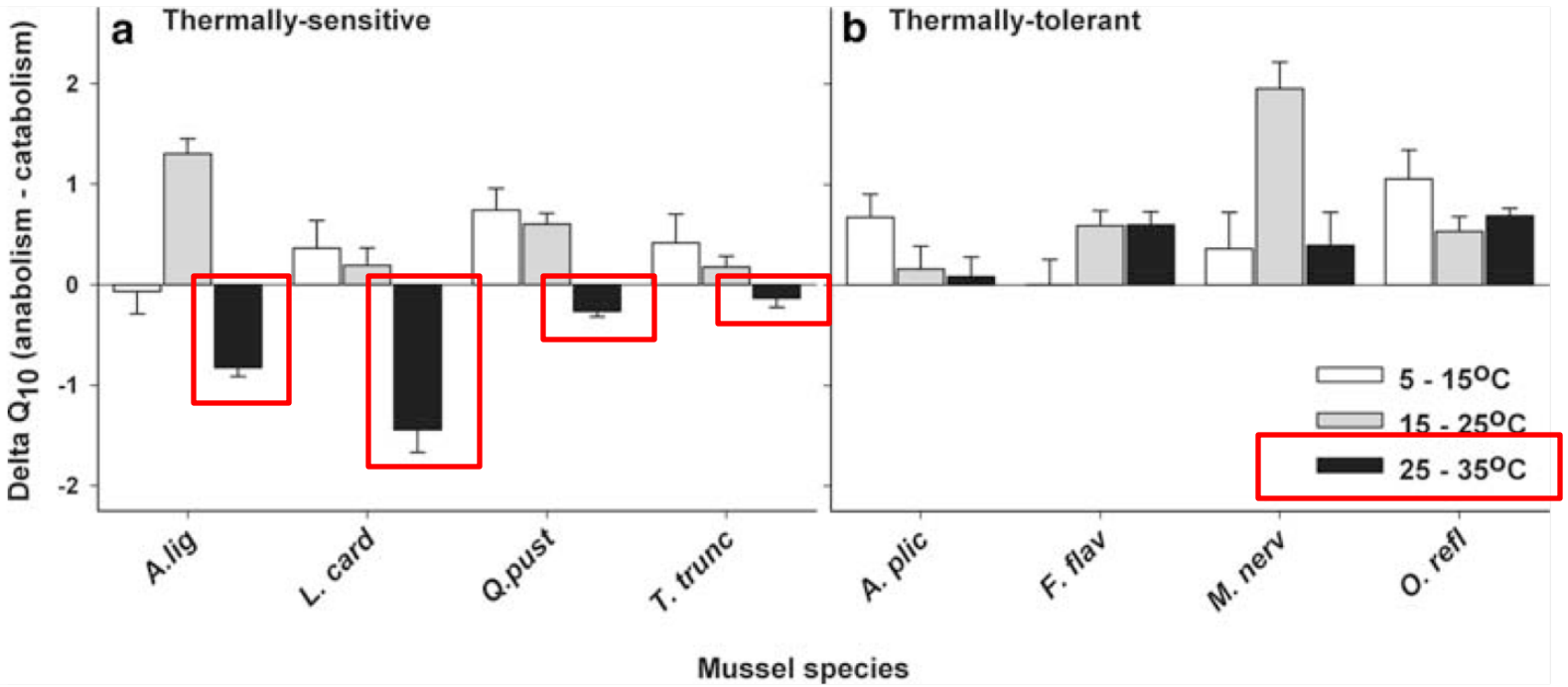


Higher mussel mortality in warmer, shallow water

Some species more sensitive to temperature than others

Galbraith, Spooner & Vaughn, 2010, Biological Conservation.

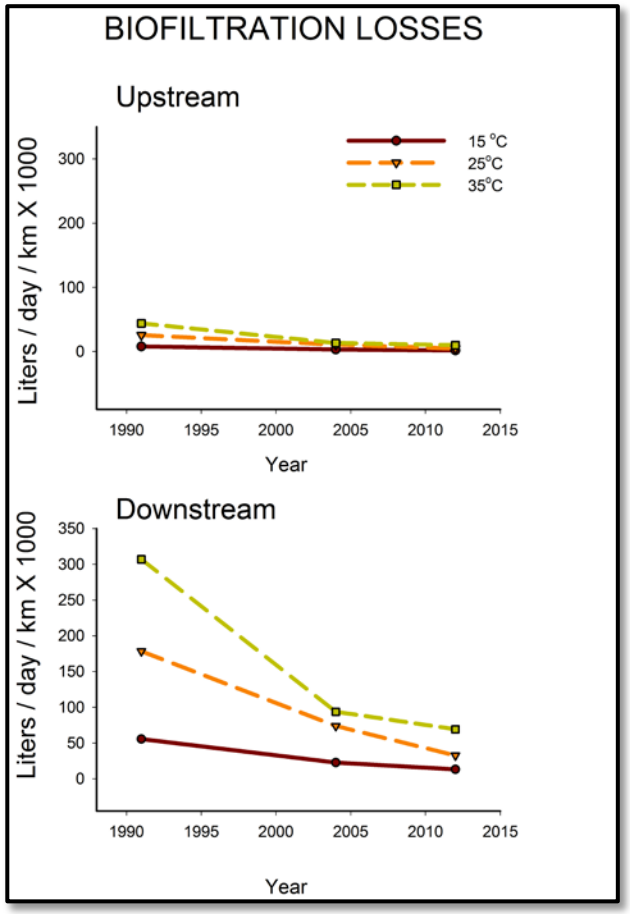
Mussel species vary in physiological traits

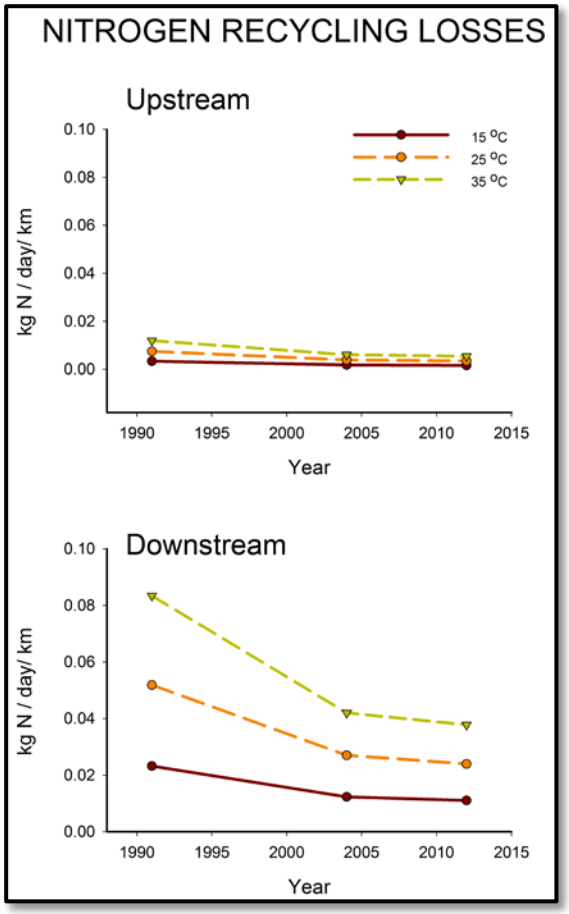


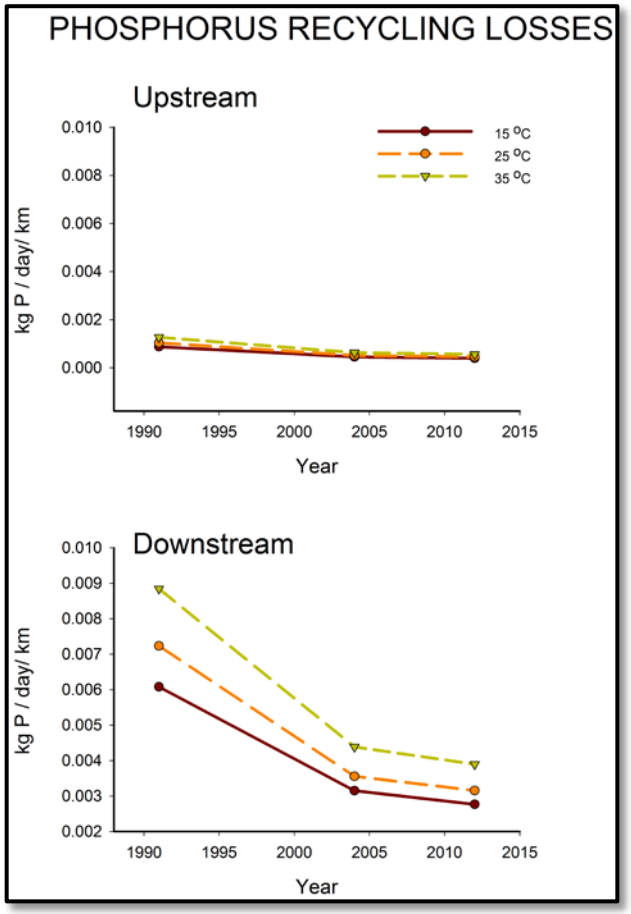
Species catabolic at warm temperatures

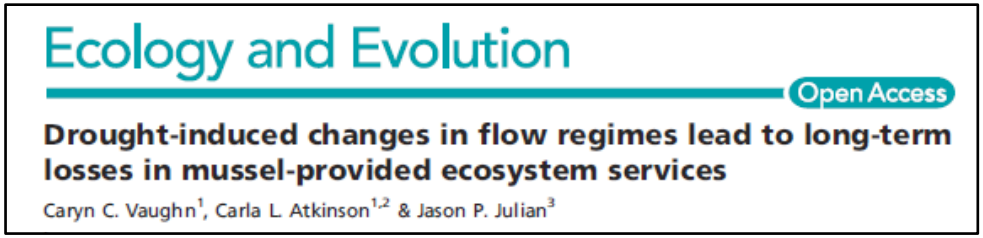
Spooner & Vaughn 2008 Oecologia

Which affects system dynamics







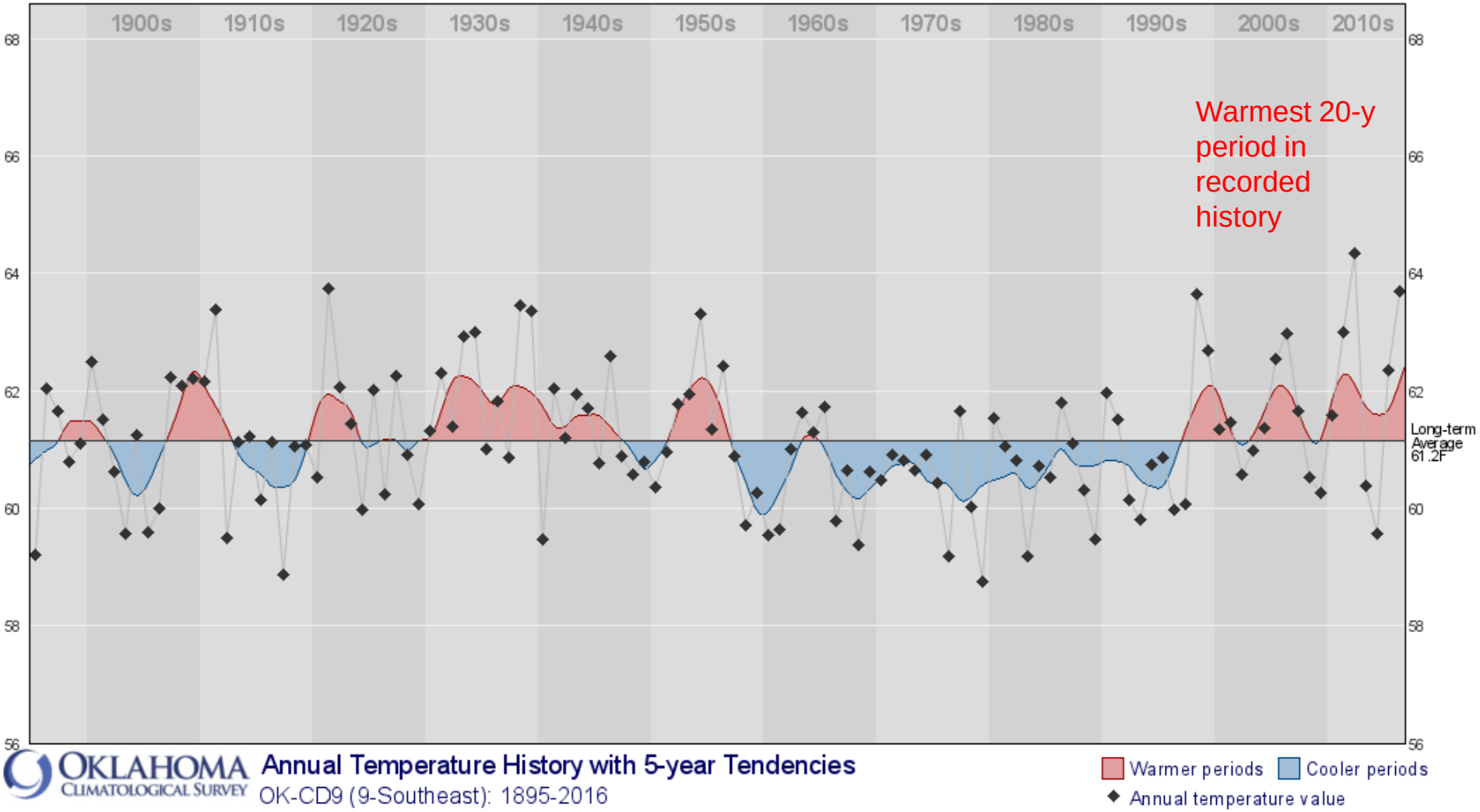

Ecology and Evolution

Open Access

Drought-induced changes in flow regimes lead to long-term losses in mussel-provided ecosystem services

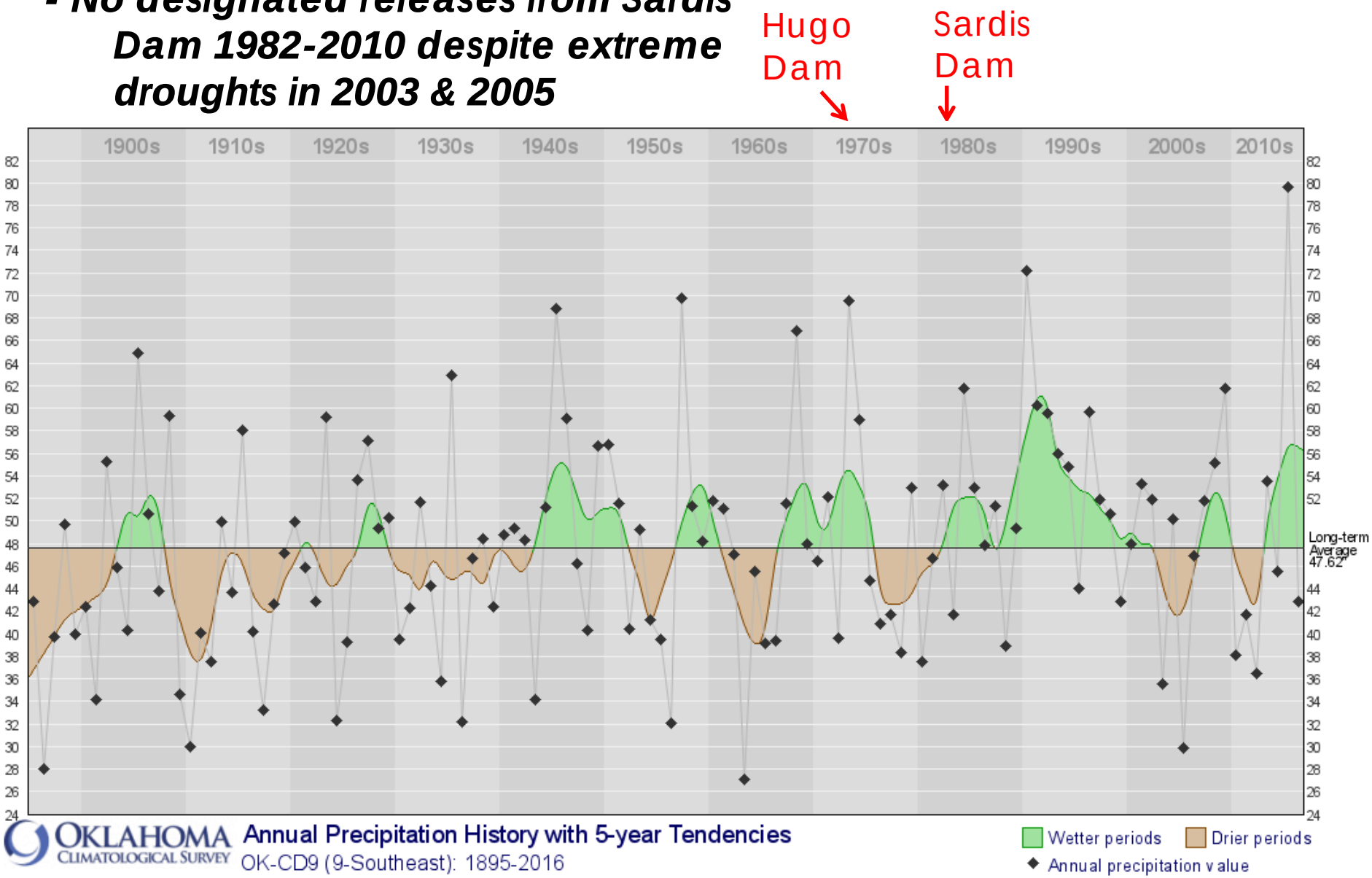
Caryn C. Vaughn[1], Carla L. Atkinson[1,2] & Jason P. Julian[3]

The region is gradually and episodically becoming warmer

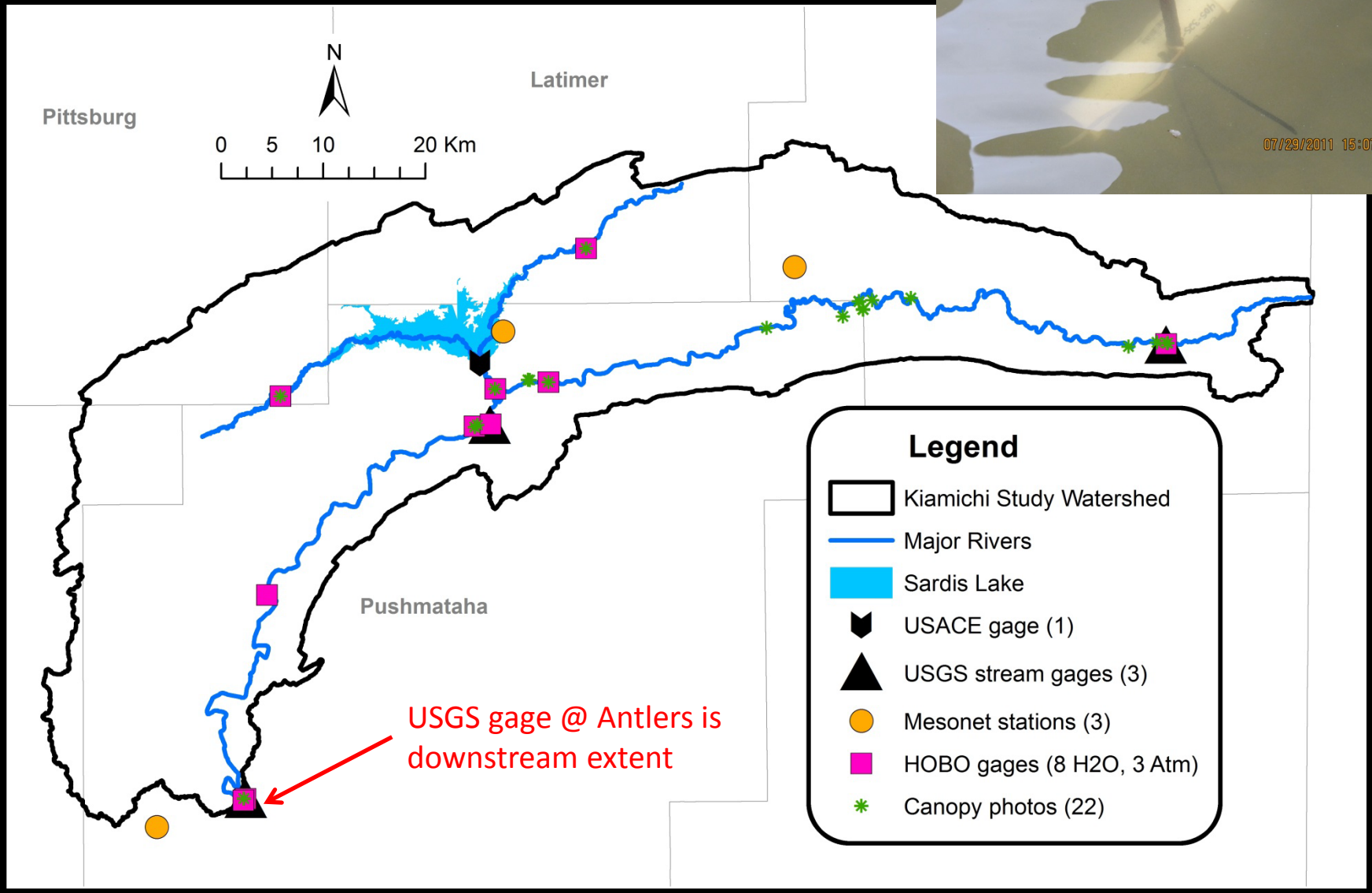


Droughts cyclical in Southern Plains

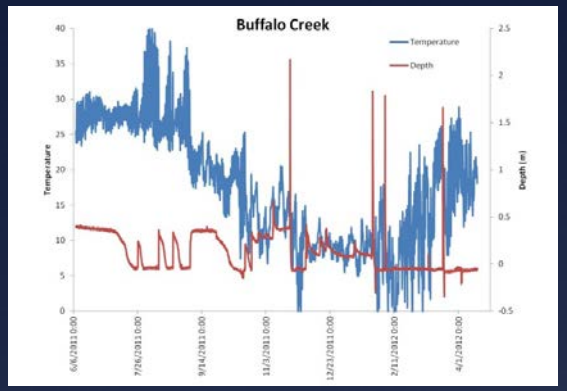
- ***dams/water management new stress***
- ***No designated releases from Sardis Dam 1982-2010 despite extreme droughts in 2003 & 2005***

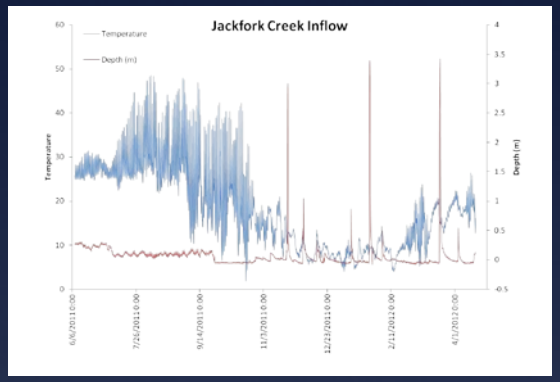


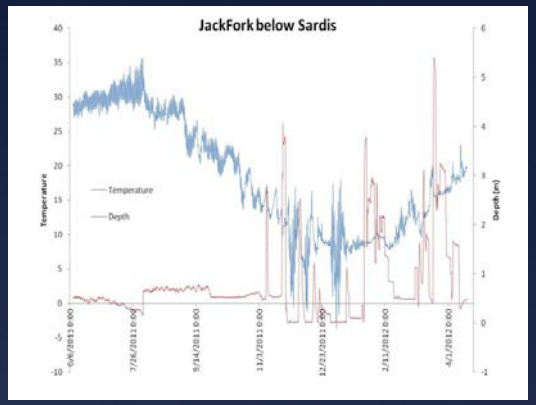
In 2011 we established monitoring network for water temperature and flow

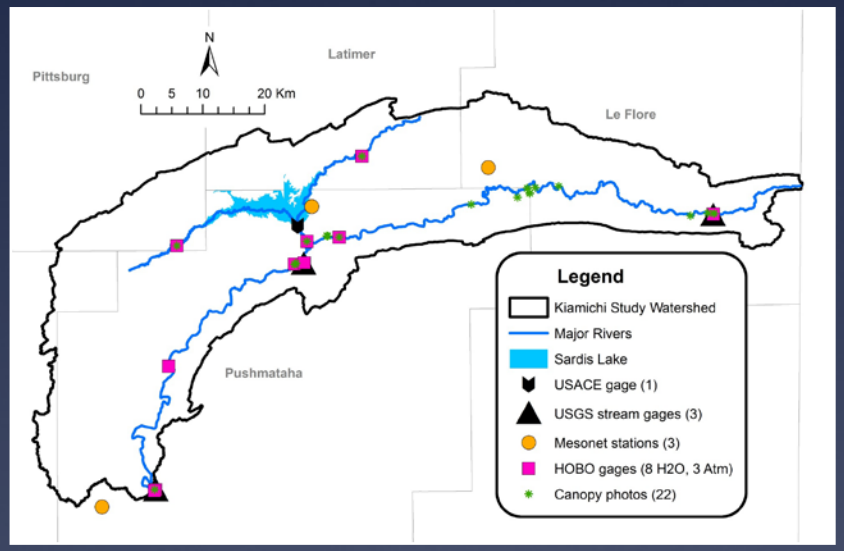


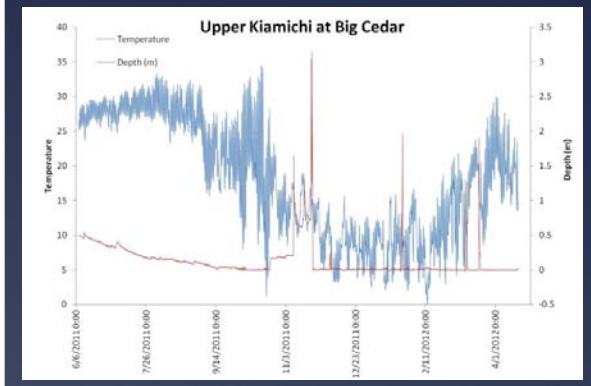
Logger data

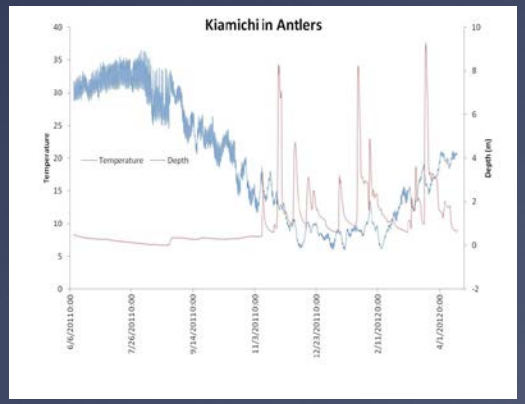

Buffalo Creek
Temperature
Depth
Temperature
Depth (m)

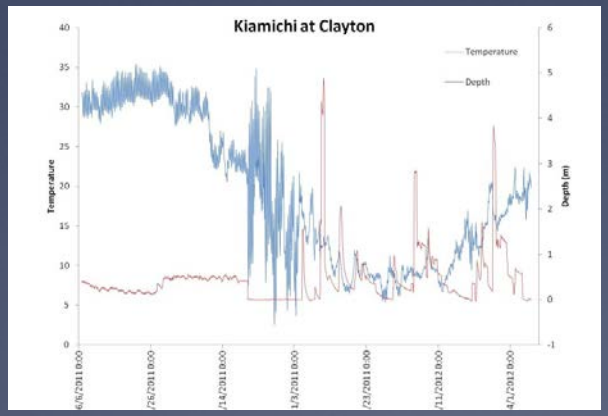

Jackfork Creek Inflow
Temperature
Depth (m)

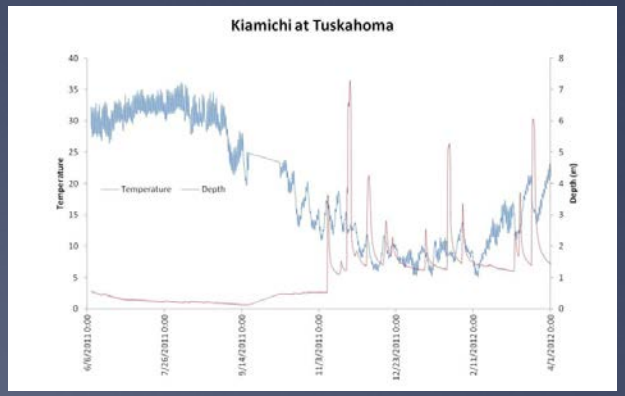

JackFork below Sardis
Temperature
Depth
Temperature
Depth (m)


N
0 5 10 20 Km
Pittsburg
Latimer
Le Flore
Pushmataha
Legend
Kiamichi Study Watershed
Major Rivers
Sardis Lake
USACE gage (1)
USGS stream gages (3)
Mesonet stations (3)
HOBO gages (8 H2O, 3 Atm)
Canopy photos (22)

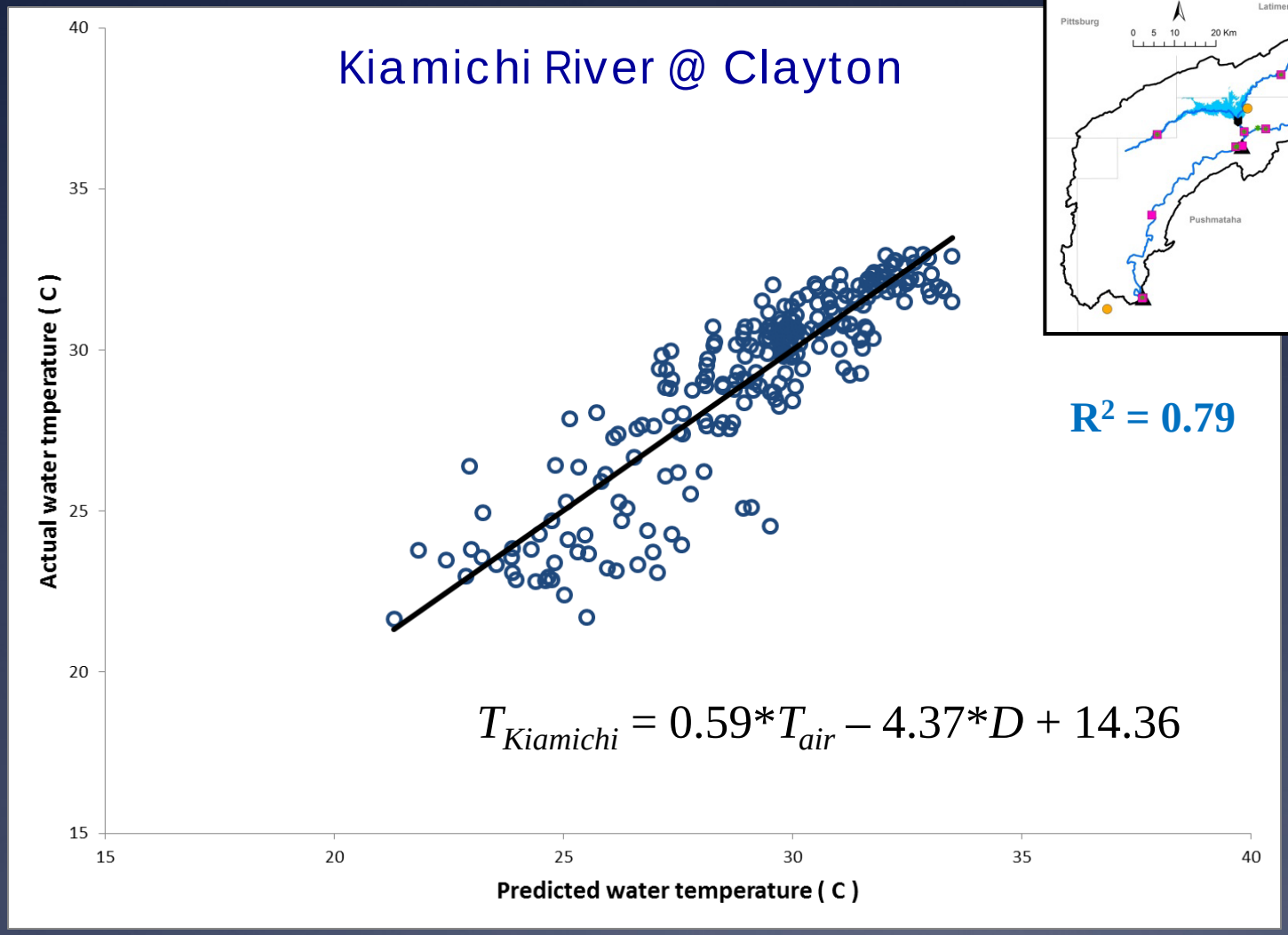

Upper Kiamichi at Big Cedar
Temperature
Depth (m)
Temperature
Depth (m)

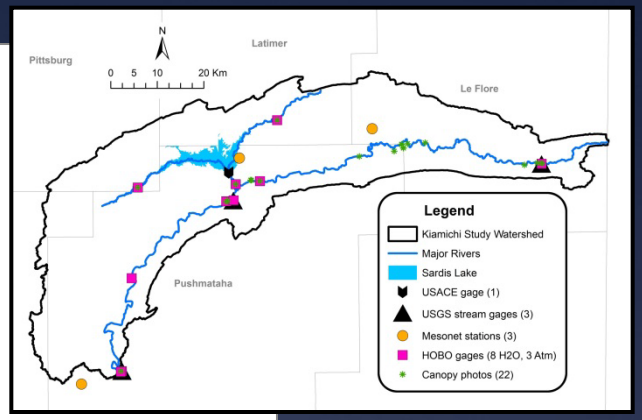

Kiamichi in Antlers
Temperature
Depth
Temperature
Depth (m)


Kiamichi at Clayton
Temperature
Depth
Temperature
Depth (m)


Kiamichi at Tuskahoma
Temperature
Depth
Temperature
Depth (m)

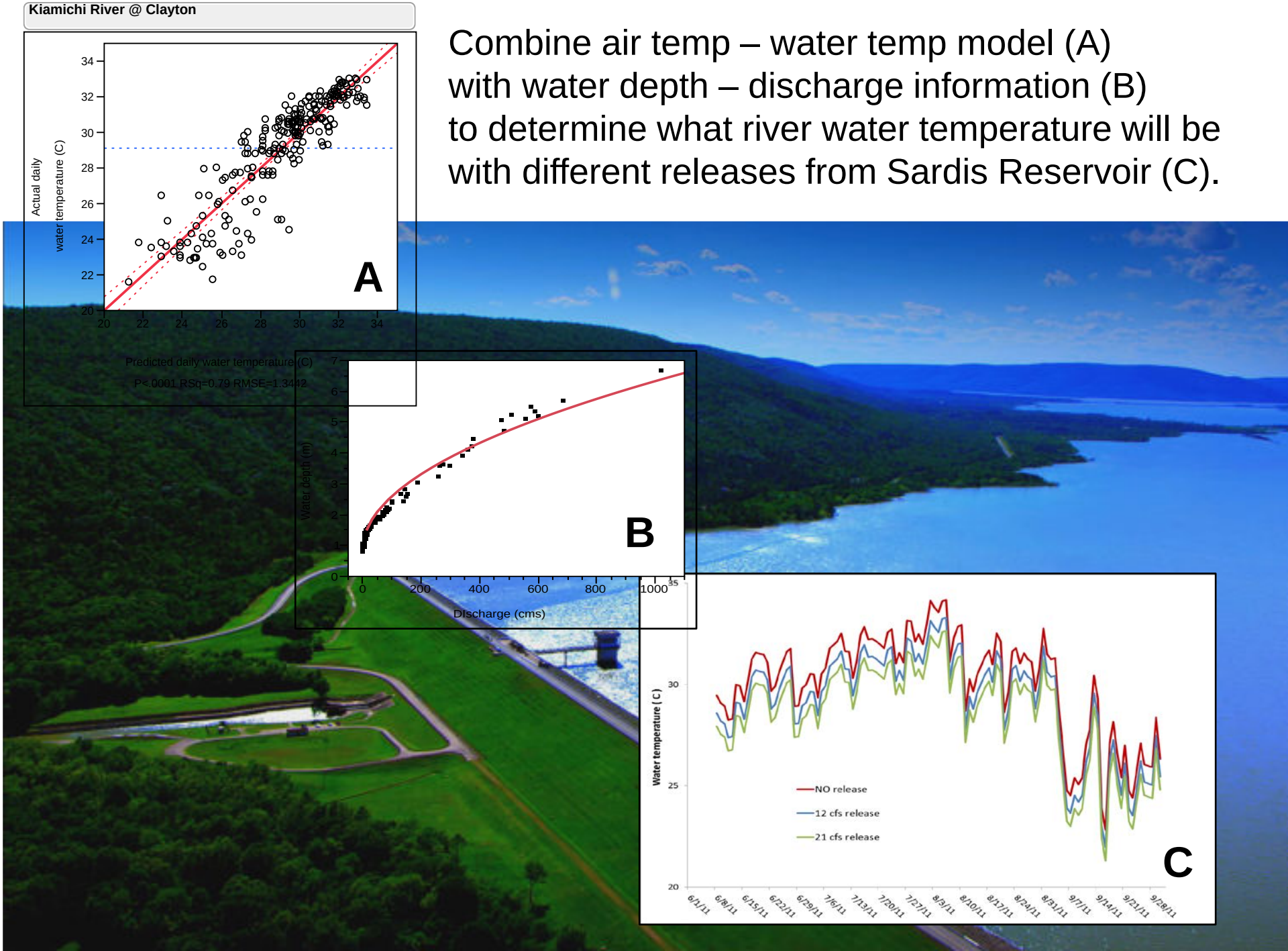
Developed empirical models that quantify changes in water temperature with air temperature (T_{air}) & water depth (D)



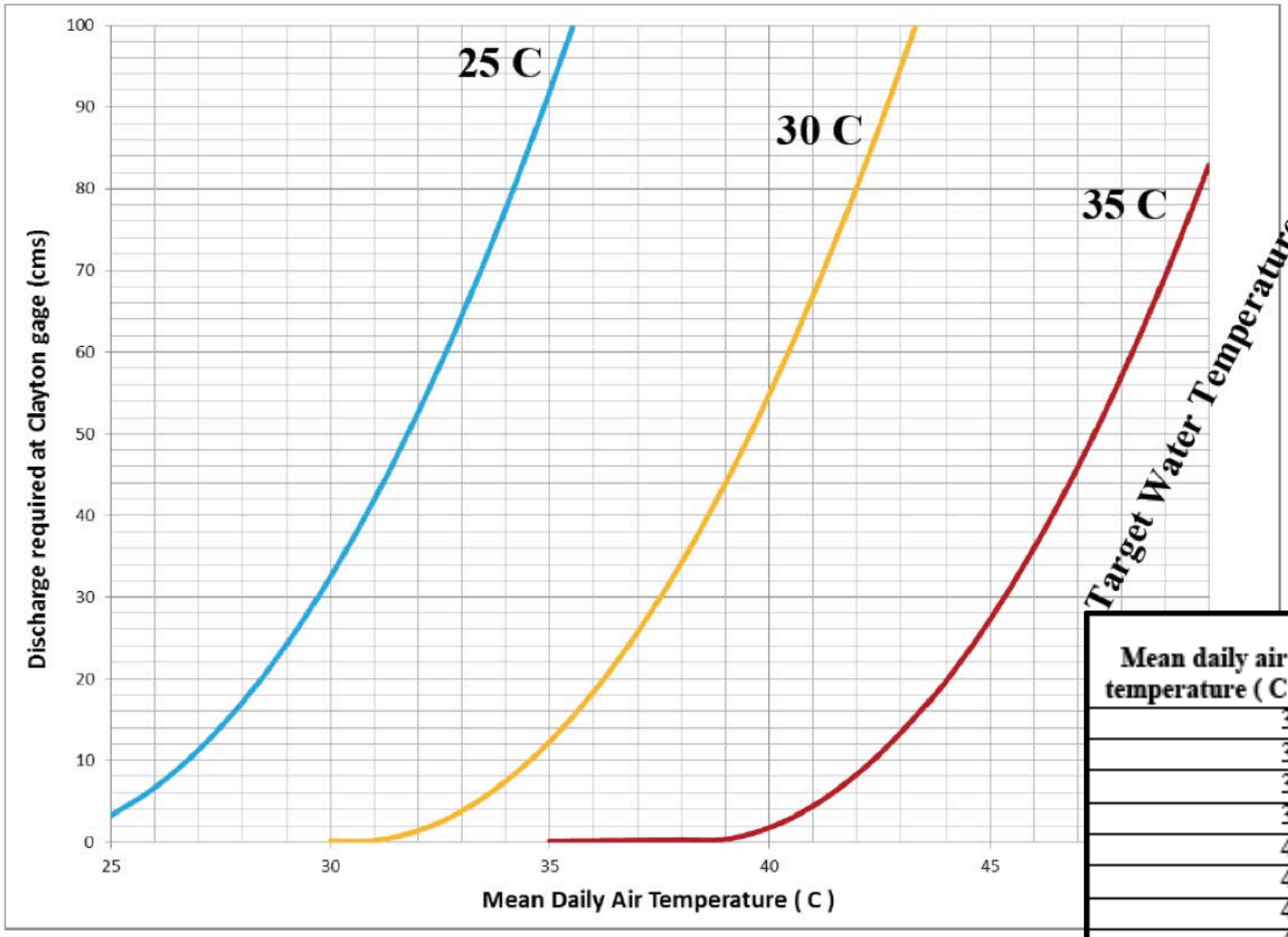


Mean daily values for 1 May – 30 Sep

Combine air temp – water temp model (A) with water depth – discharge information (B) to determine what river water temperature will be with different releases from Sardis Reservoir (C).



Water releases from Sardis Dam can be used to Lower Kiamichi River water temperatures



Mean daily air temperature (C)	Required discharge at Clayton gage (cms)
36	0.1
37	0.2
38	0.2
39	0.3
40	1.8
41	4.4
42	8.3
43	13.4
44	19.7
45	27.2
46	35.9
47	45.8

Kiamichi River during Summer 2011 Drought

SITE 4: 2011 drought

Example from 2011 drought

31 July 2011: Site 7
Almost one third of bed dry

SITE 7: 2011 drought

- 19 species of freshly dead mussels
- 66 kg dry mussel soft tissue loss

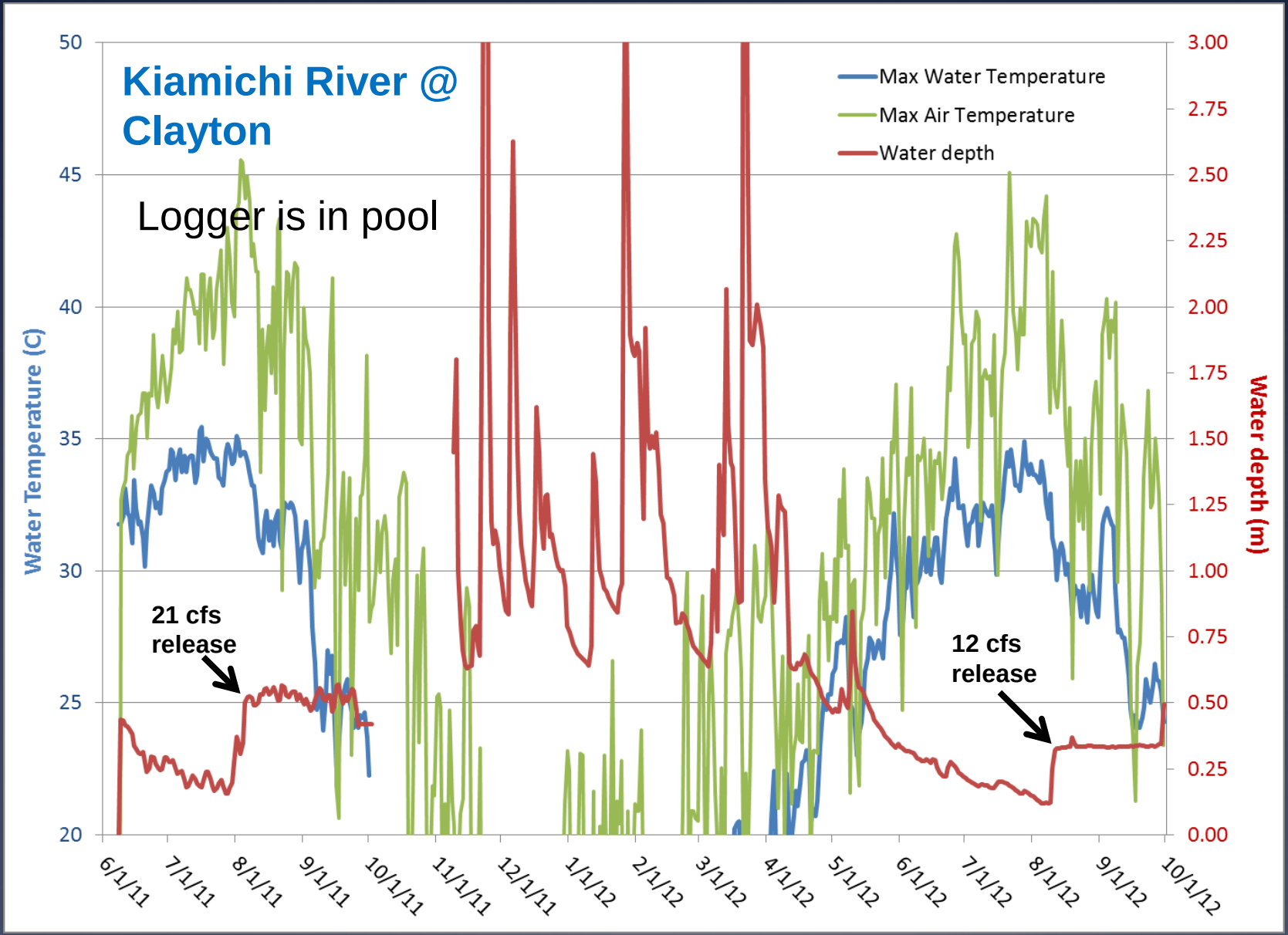
Average water depth
10 cm (4 inches)

Water temp at midday
40 ° C (104 ° F)

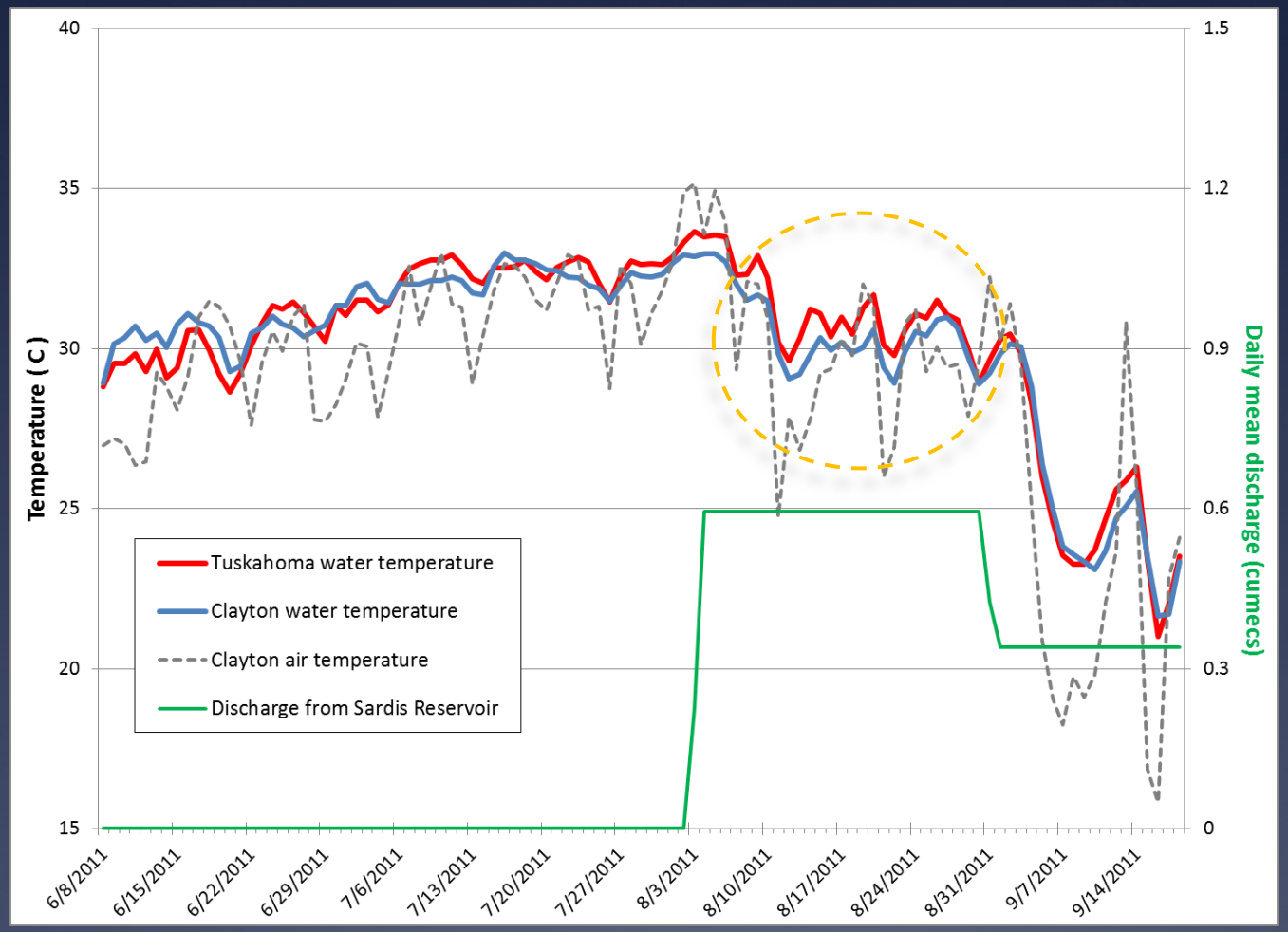
Lethal temperatures for juveniles range from 25 – 35 C and for adults 35 – 40 C, depending on species and acclimation temperature (Archambault et al., 2014, Galbraith et al. 2012, Ganser et al. 2013).

Temperature-induced mussel die offs lead to algal blooms, low oxygen, and more death

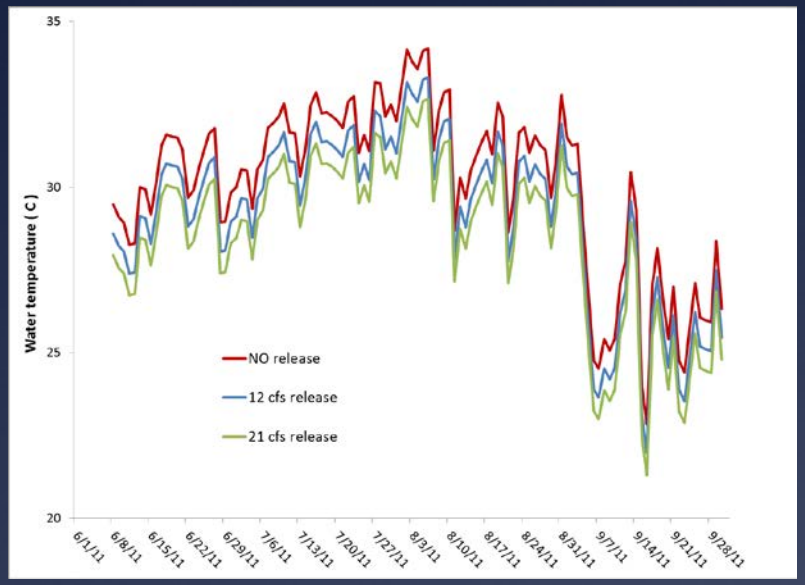
Water releases from Sardis Dam are needed to lower Kiamichi River water temperatures during droughts



Effect of Sardis releases on downstream water temperatures

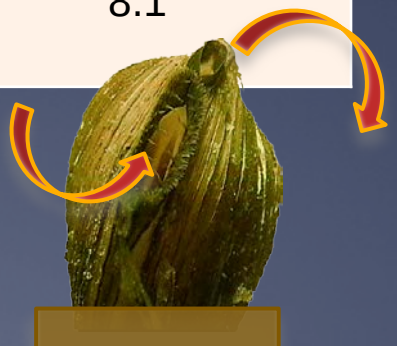


In addition to keeping mussels alive, environmental flows can also be used to maximize ecosystem services



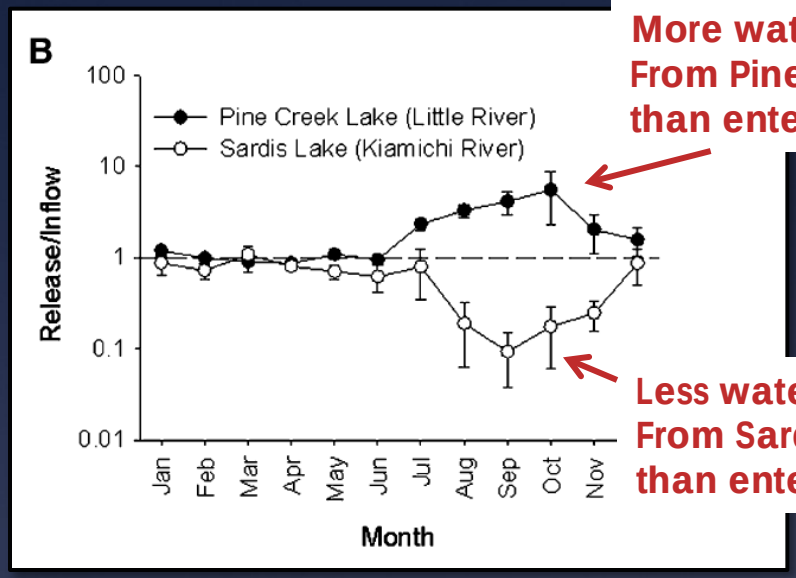
Potential Effect of Sardis Dam releases on summertime (Jun – Sep) water filtration rates by mussels

	NO Release	21 cfs Release
Water Temperature (°C)	30.1	28.6
Water Filtration Rate (L/hr/m^2)	7.3	8.1



Only 2 designated Environmental flows since 1982

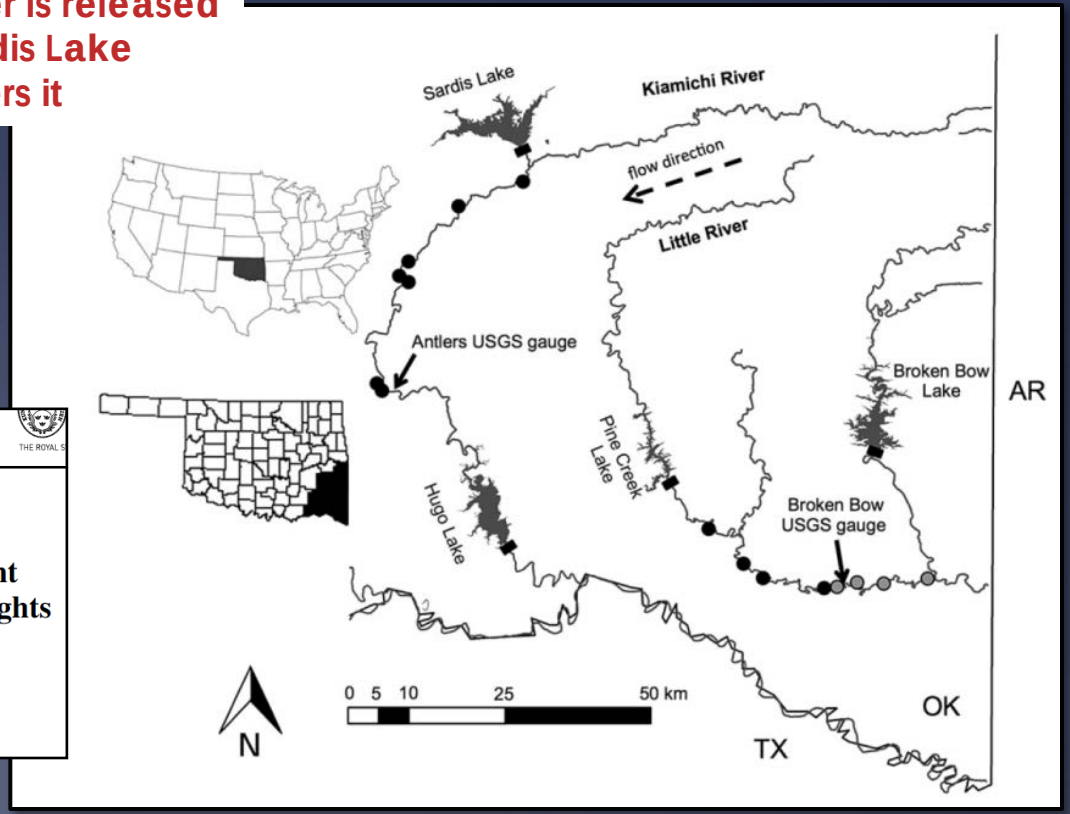
Comparison of Kiamichi and Little Rivers during the same time period - More water released into Little River meant fewer low flow days



More water is released From Pine Creek Lake than enters it

Less water is released From Sardis Lake than enters it

Little River below dam maintains 50 cfs



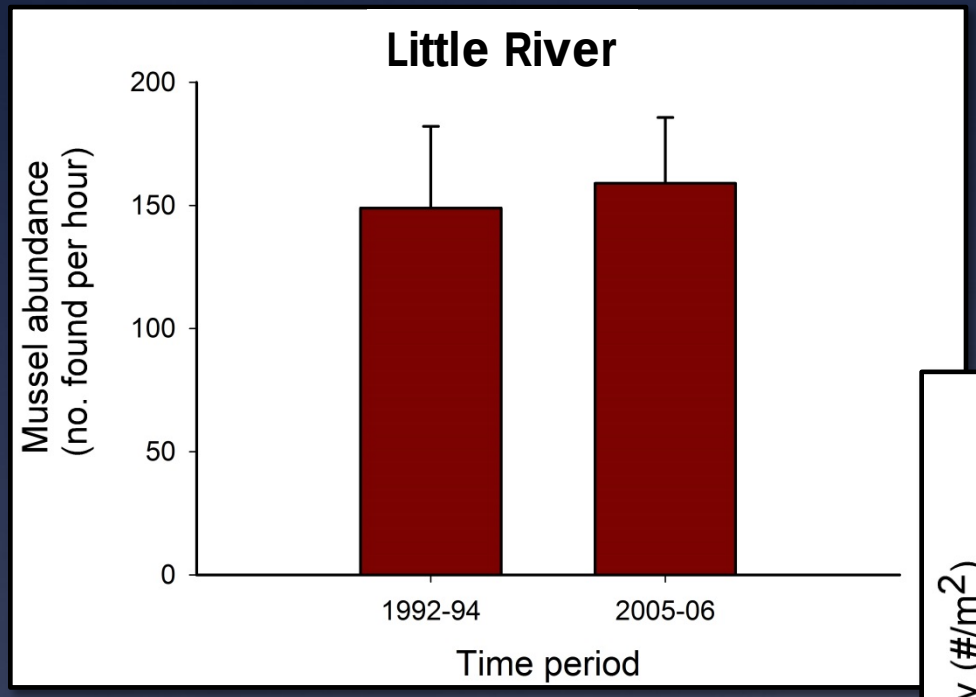
AMBIO 2013, 42:881–891
DOI 10.1007/s13280-013-0420-8

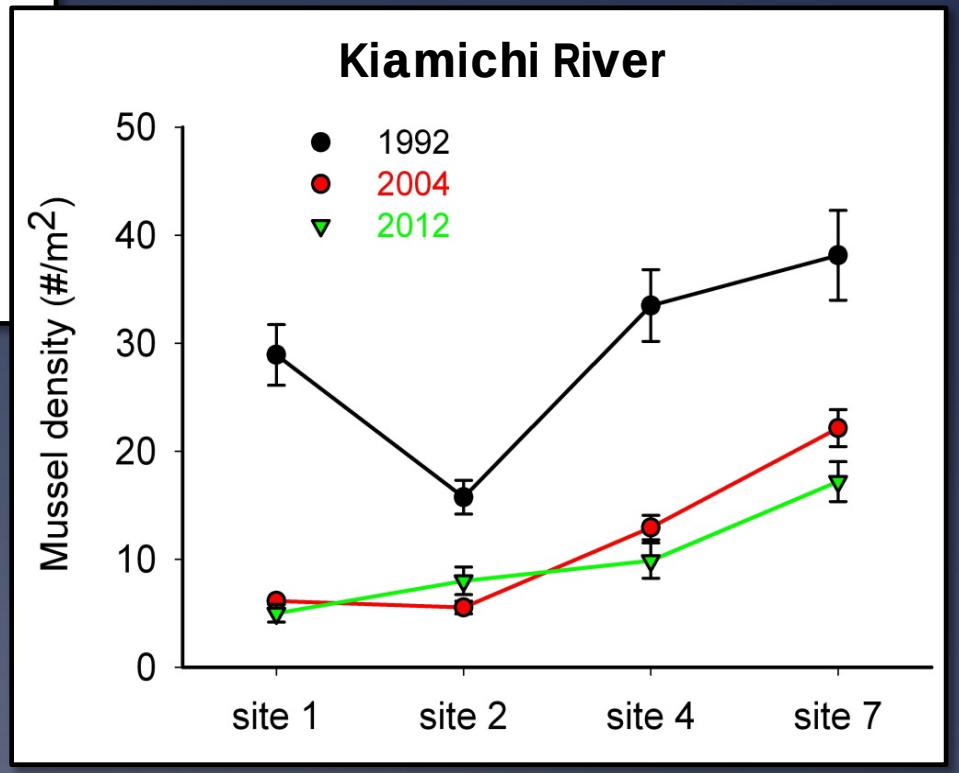
REPORT

A Tale of Two Rivers: Implications of Water Management Practices for Mussel Biodiversity Outcomes During Droughts

Daniel C. Allen, Heather S. Galbraith,
Caryn C. Vaughn, Daniel E. Spooner

Comparison of Kiamichi and Little Rivers during the same time period – Mussels did not decline in the Little River



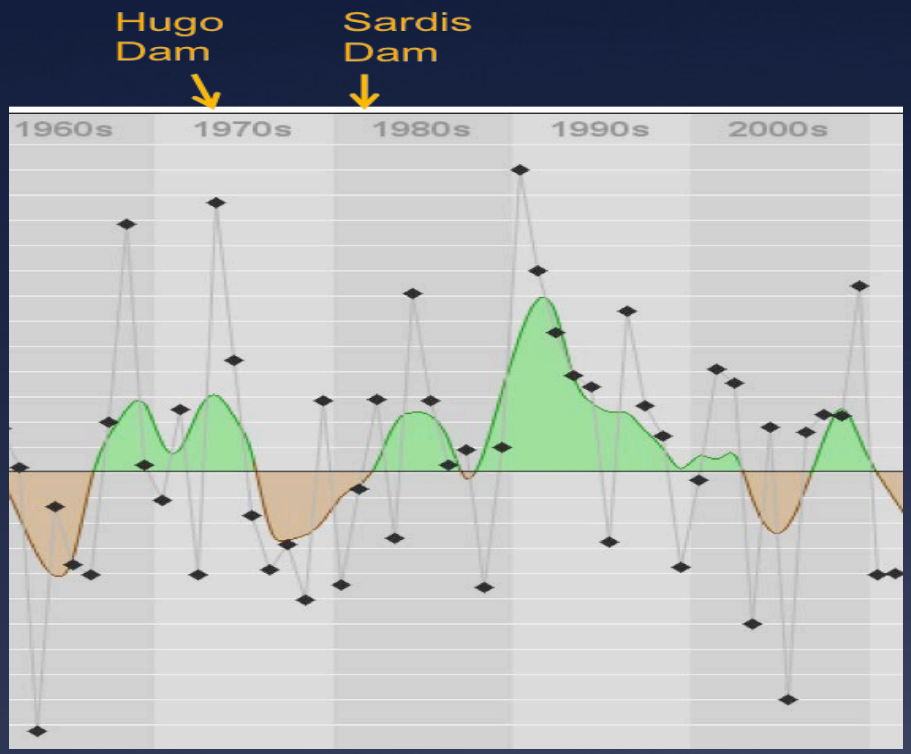


AMBIO 2013, 42:881–891
DOI 10.1007/s13280-013-0420-8

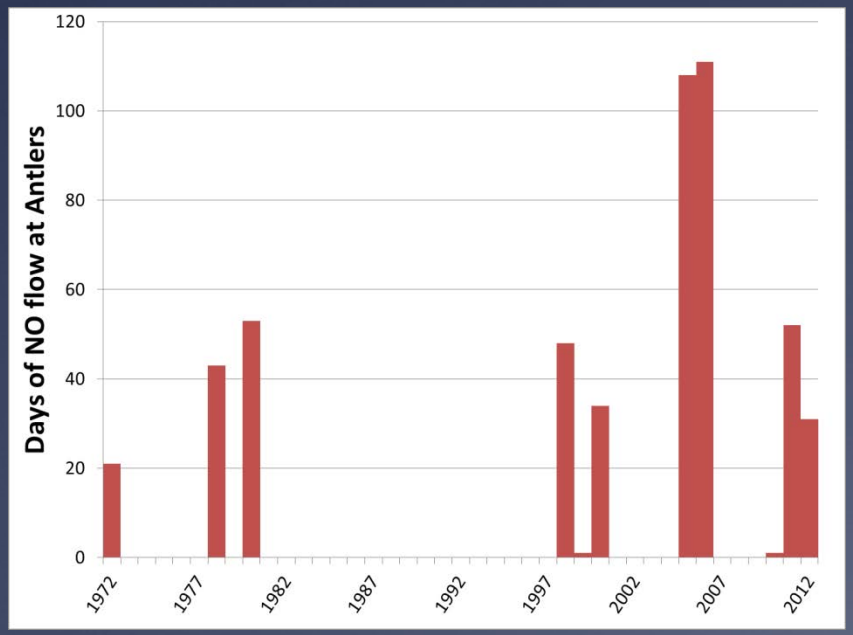
REPORT

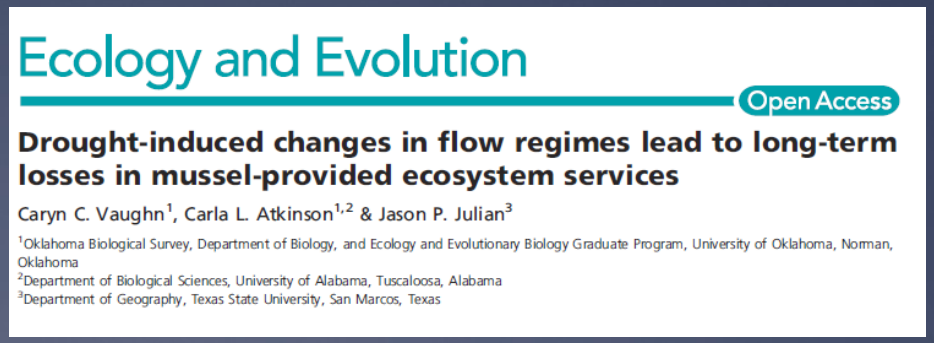
A Tale of Two Rivers: Implications of Water Management Practices for Mussel Biodiversity Outcomes During Droughts

Daniel C. Allen, Heather S. Galbraith,
Caryn C. Vaughn, Daniel E. Spooner



Mussel declines are related to low flows and high water temperatures during drought





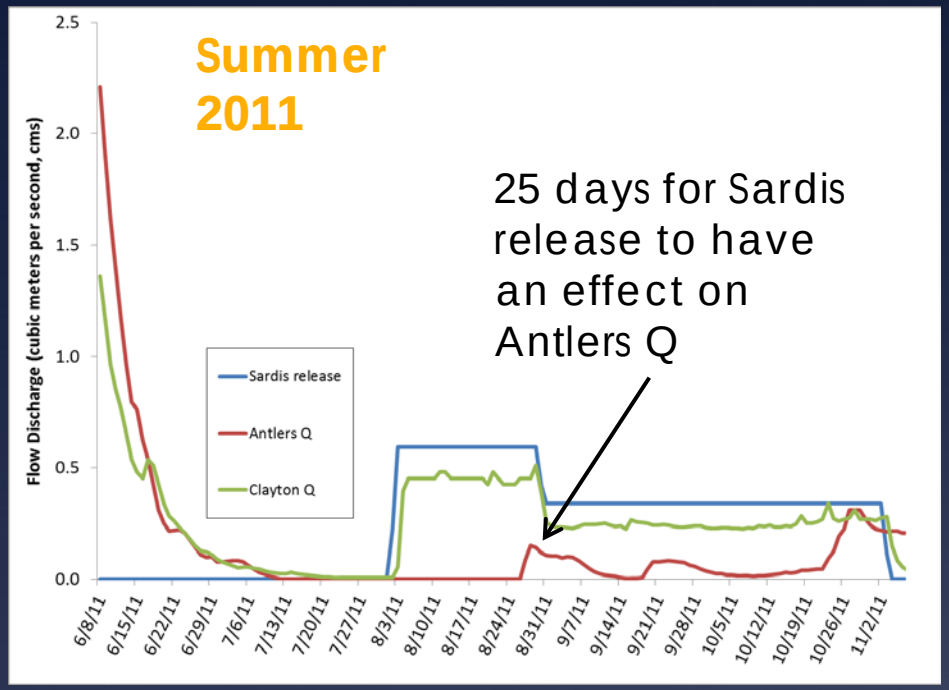
Ecology and Evolution

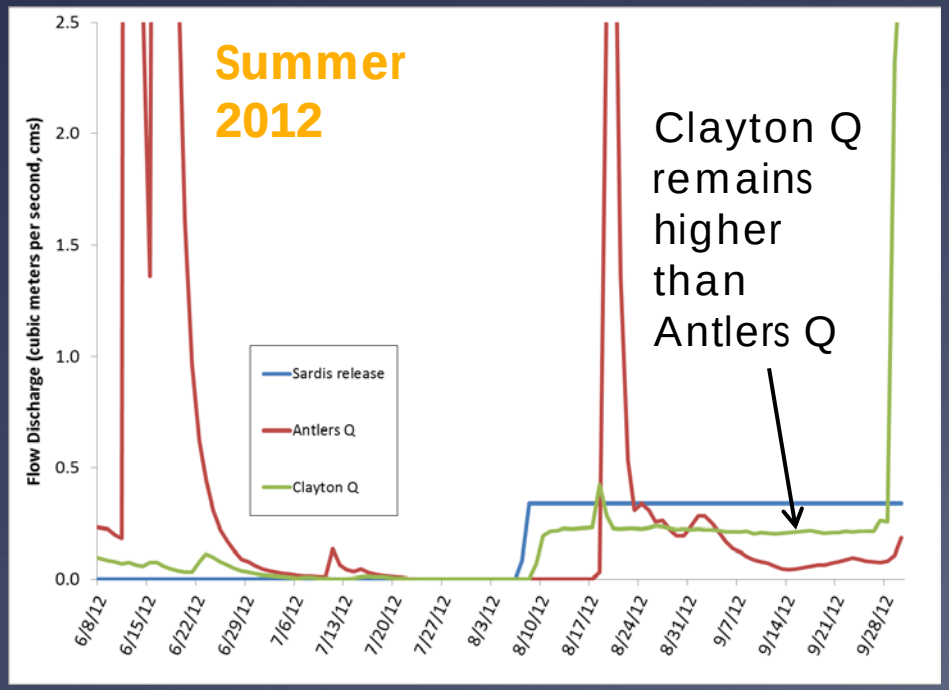
Open Access

Drought-induced changes in flow regimes lead to long-term losses in mussel-provided ecosystem services

Caryn C. Vaughn[1], Carla L. Atkinson[1,2] & Jason P. Julian[3]

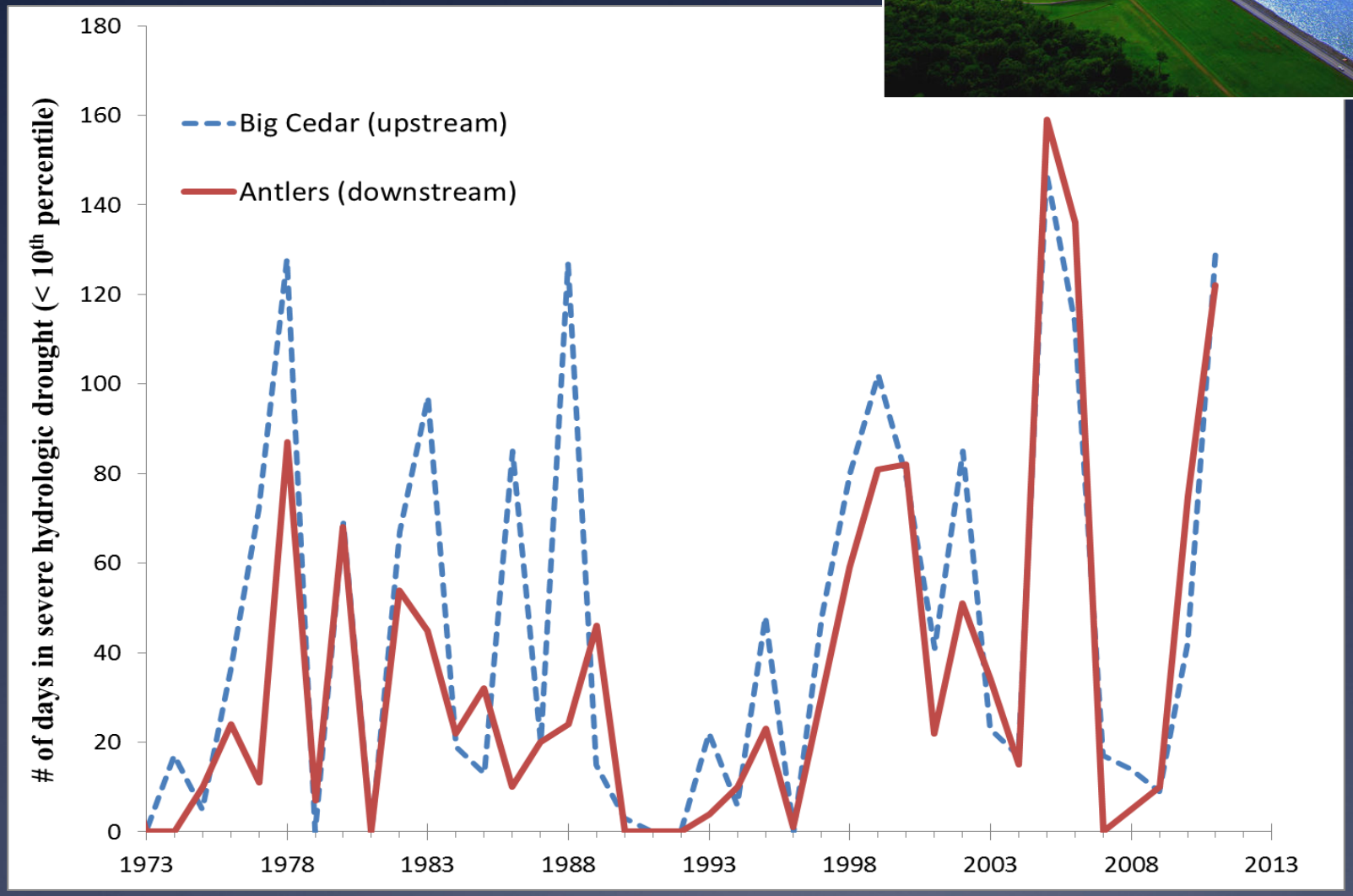
[1]Oklahoma Biological Survey, Department of Biology, and Ecology and Evolutionary Biology Graduate Program, University of Oklahoma, Norman, Oklahoma
[2]Department of Biological Sciences, University of Alabama, Tuscaloosa, Alabama
[3]Department of Geography, Texas State University, San Marcos, Texas

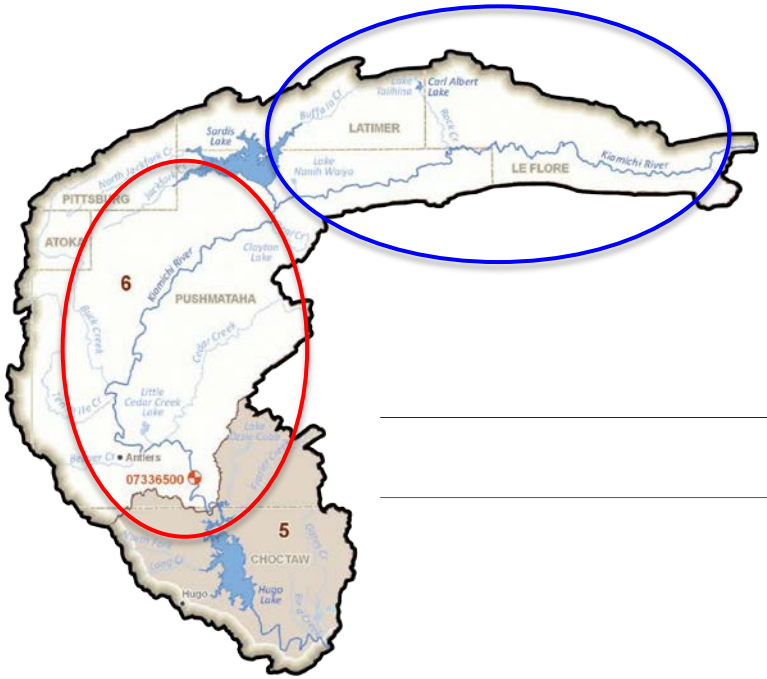




Lack of Summer dam releases has resulted in Kiamichi R becoming a <u>losing stream</u> between Clayton and Antlers during drought

Drought conditions are exacerbated by water management





Hydrologic drought has increased dramatically, and has increased more in the lower river because of water management

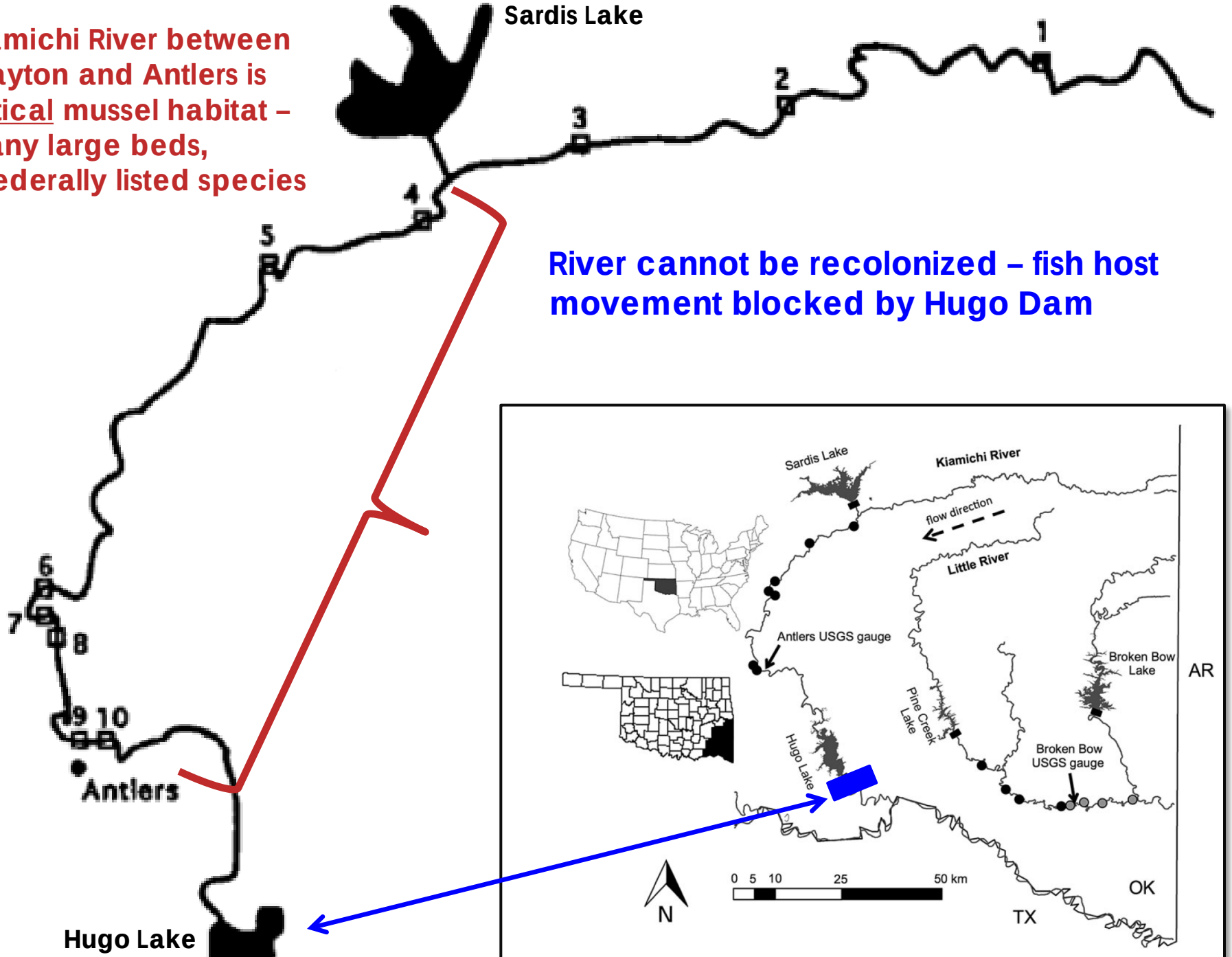
1966-1982 1983-1990 1992-2003 2004-2011

1966-1982 1983-1990 1992-2003 2004-2011

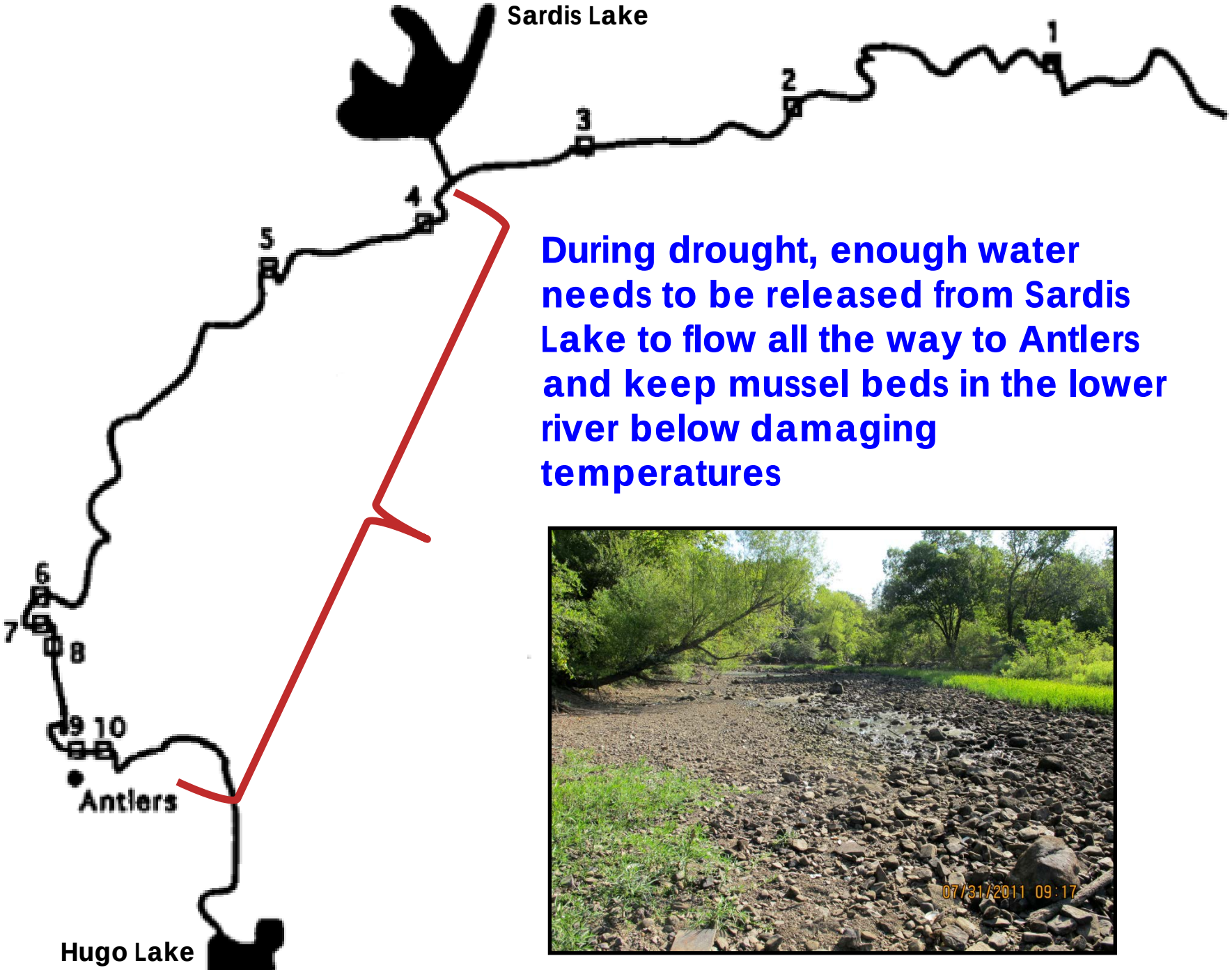
1966-1982 1983-1990 1992-2003 2004-2011

Vaughn et al., Ecology & Evolution, 2015

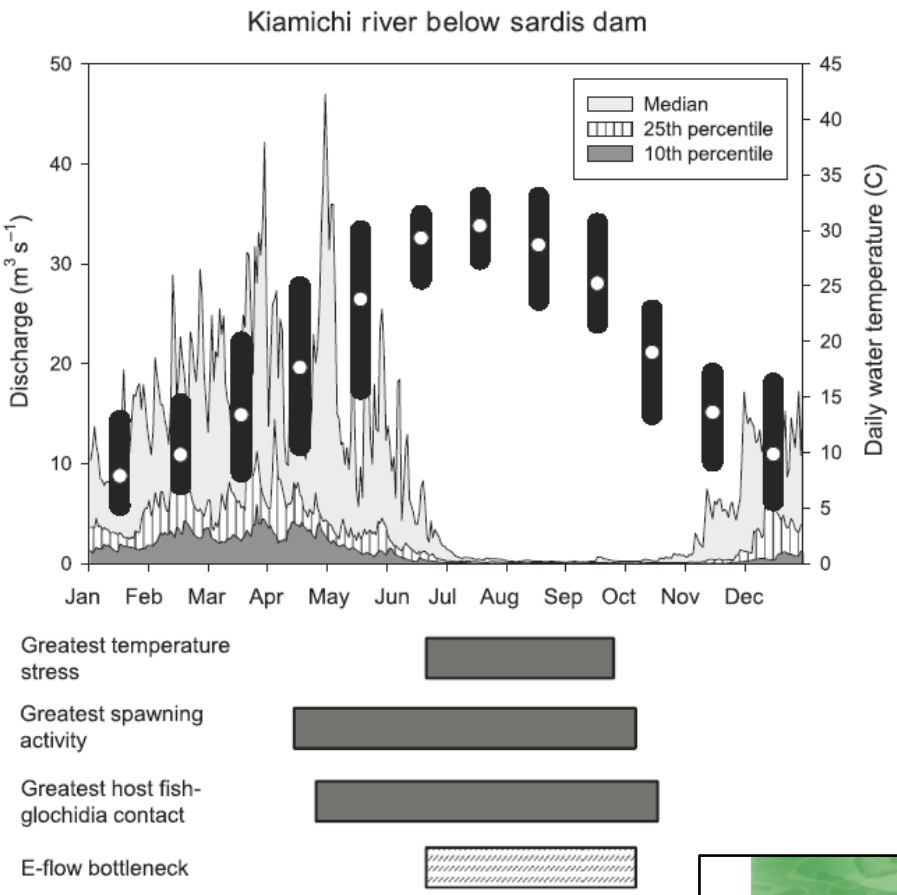
Kiamichi River between Clayton and Antlers is <u>critical</u> mussel habitat – many large beds, 3 federally listed species



River cannot be recolonized – fish host movement blocked by Hugo Dam



During drought, enough water needs to be released from Sardis Lake to flow all the way to Antlers and keep mussel beds in the lower river below damaging temperatures



Freshwater Biology

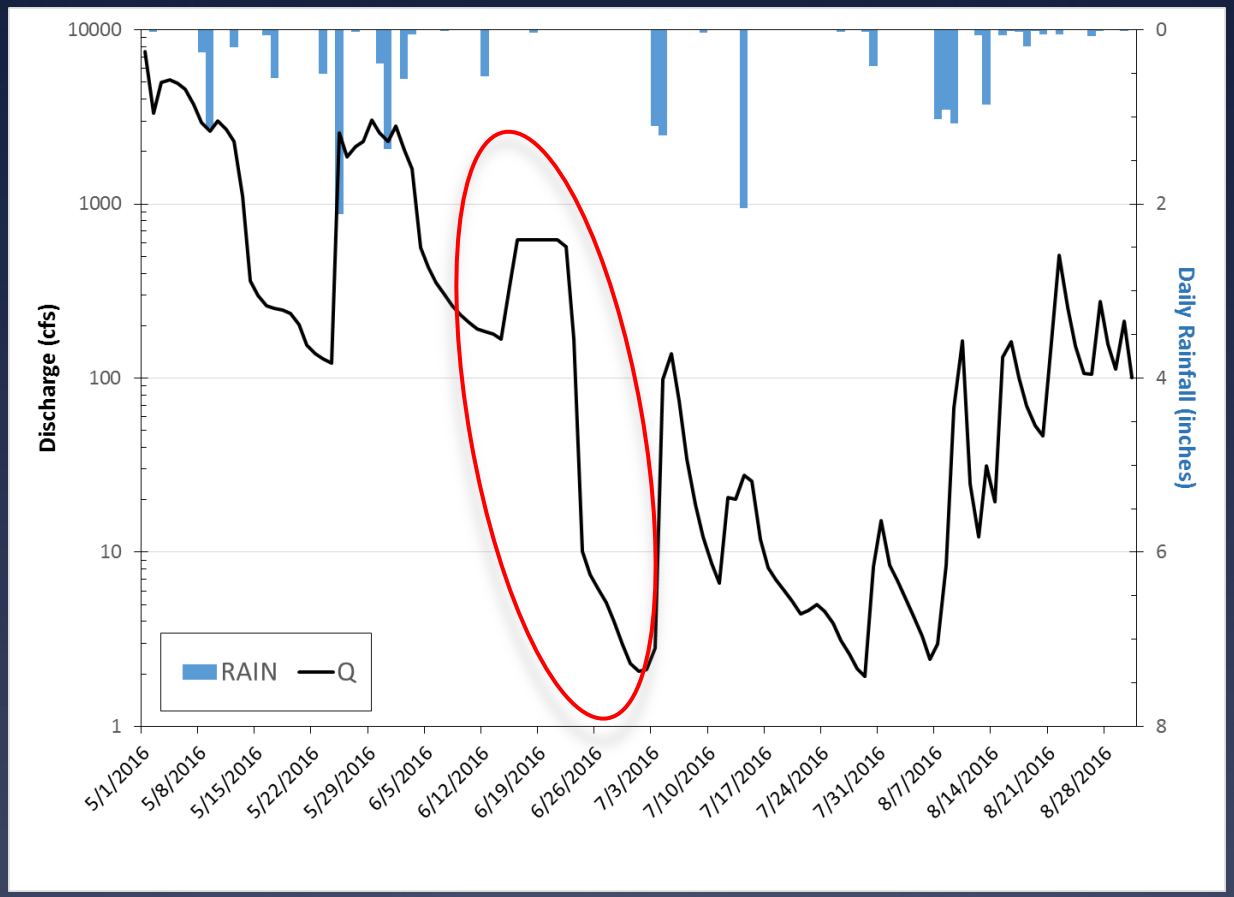
Freshwater Biology (2015) **60**, 620–635 doi:10.1111/fwb.12528

SPECIAL REVIEW

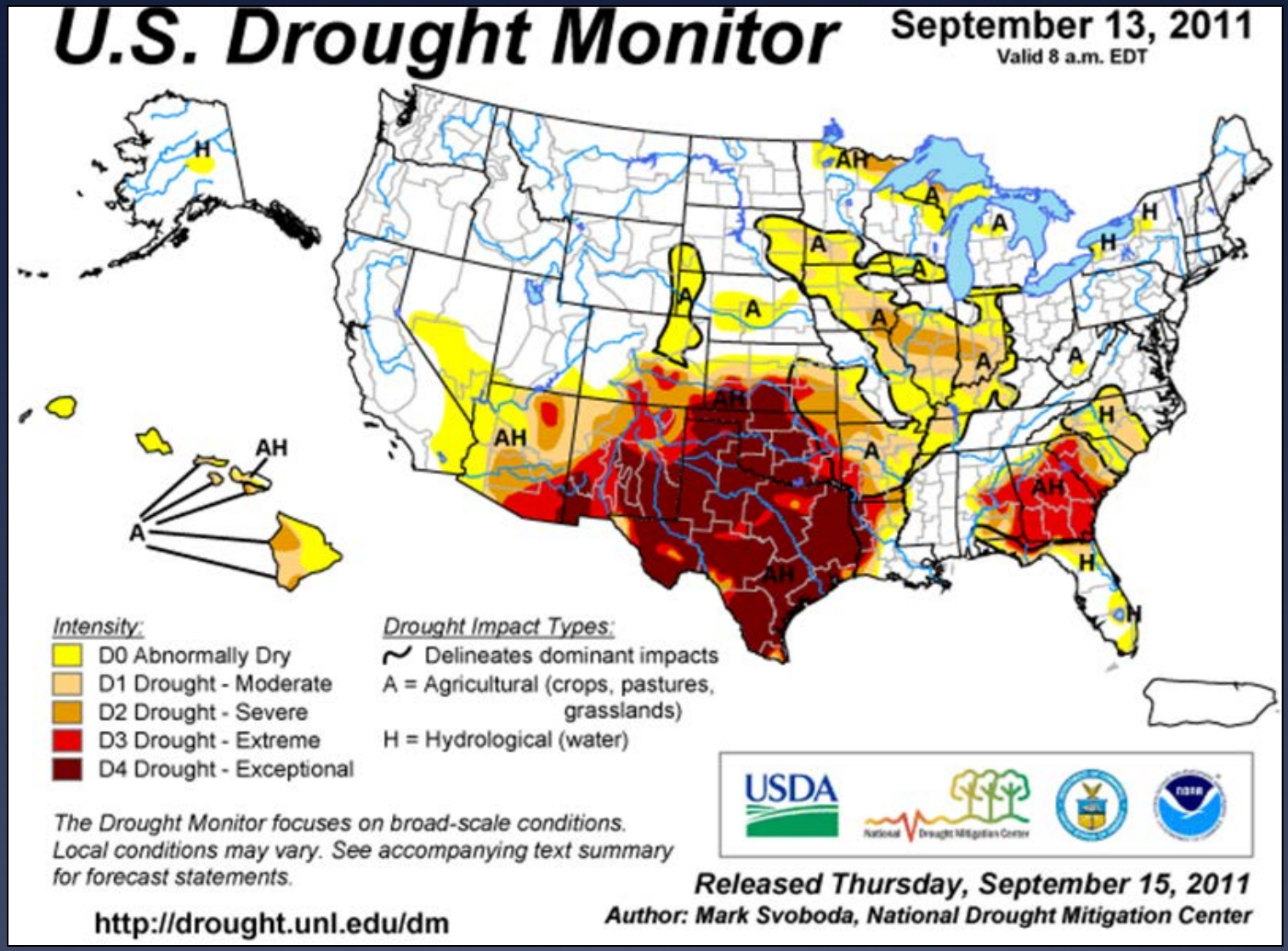
Developing environmental flow recommendations for freshwater mussels using the biological traits of species guilds

KIZA K. GATES*, CARYN C. VAUGHN* AND JASON P. JULIAN†
*Oklahoma Biological Survey, Department of Biology and Ecology and Evolutionary Biology Graduate Program, University of Oklahoma, Norman, OK, U.S.A.
†Department of Geography, Texas State University, San Marcos, TX, U.S.A.

Another Dam Problem!



No mussel-provided ecosystem services with no water!
07/31/2011 09:11



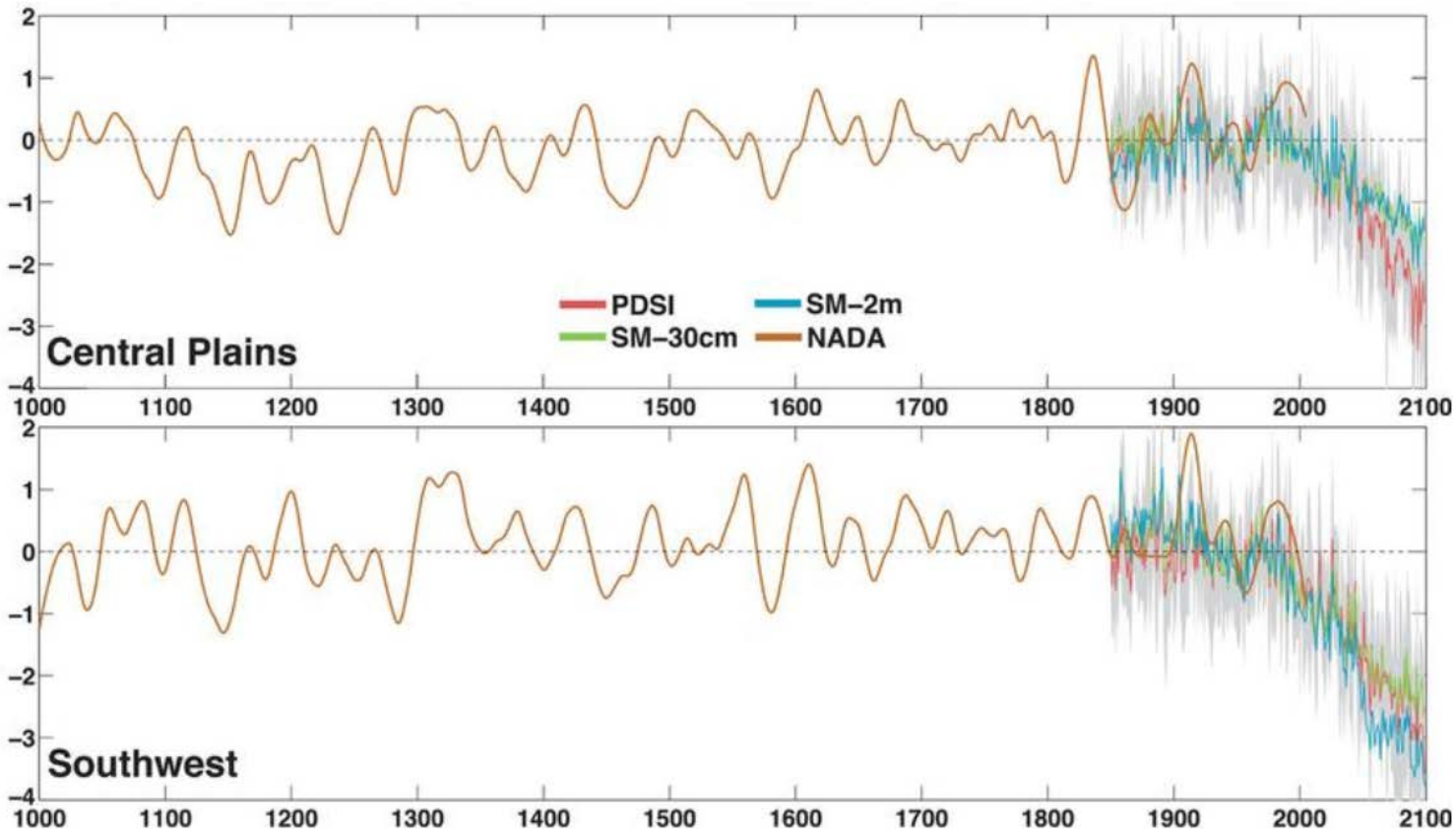
Heat waves & Drought expected to increase with 'climate variability' and increased human demand of water

NASA: The US Faces a "Mega-Drought" Not Seen in 1,000 Years

By Jordan Valinsky February 13, 2015

Like Colleen Hiner, Aaron Martin and 672,944 others like this.

Scientists have bad news for West Coasters in the grips of the worst drought in decades: The worst is yet to come.



A graph predicting the average dryness of soil in the Great Plains and American Southwest over the next half-century.

Source: Benjamin Cook et. al in Science Advances

Hydrdology & Env Flows
Jason.Julian@txstate.edu
http://jasonjulian.wp.txstate.edu/

Mussels & Stream Ecology
CVaughn@ou.edu
http://carynvaughn.com/

Questions?

Funding
(over 26 years of research and 45 published papers)