Flows of the Kiamichi River

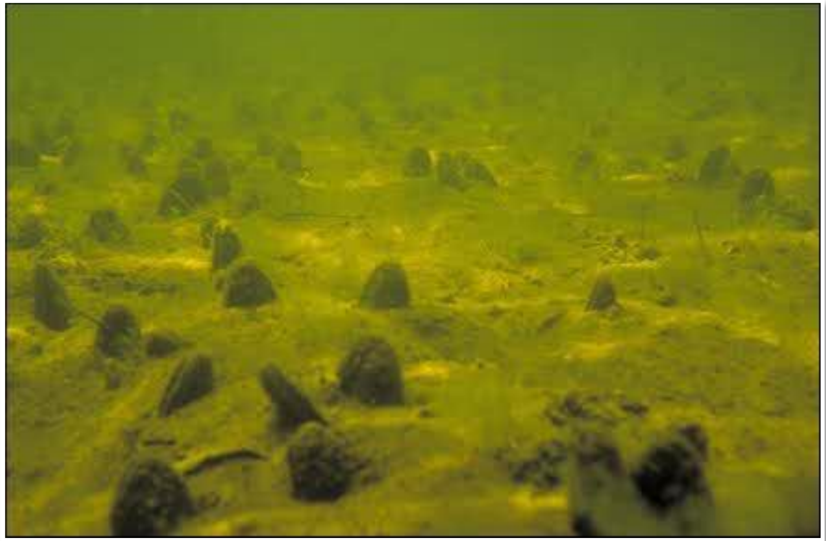
A case study of the impacts of drought and reservoir management on the life of a river

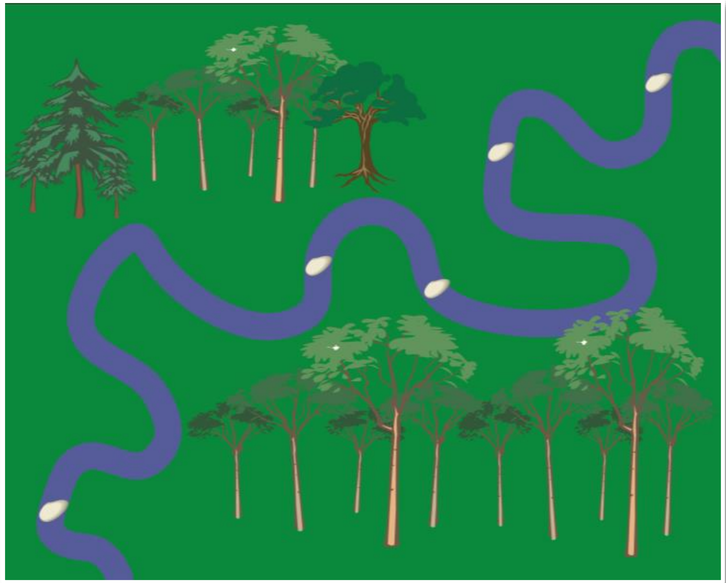
Dr. Russell Doughty
standing in for
Dr. Caryn Vaughn

The Kiamichi River is no longer a natural system because we have impounded it and are managing it.

Managed releases from Sardis Reservoir could be used to alleviate thermal stress to both mussels and fish during periods of low water and high temperature

Freshwater mussel traits



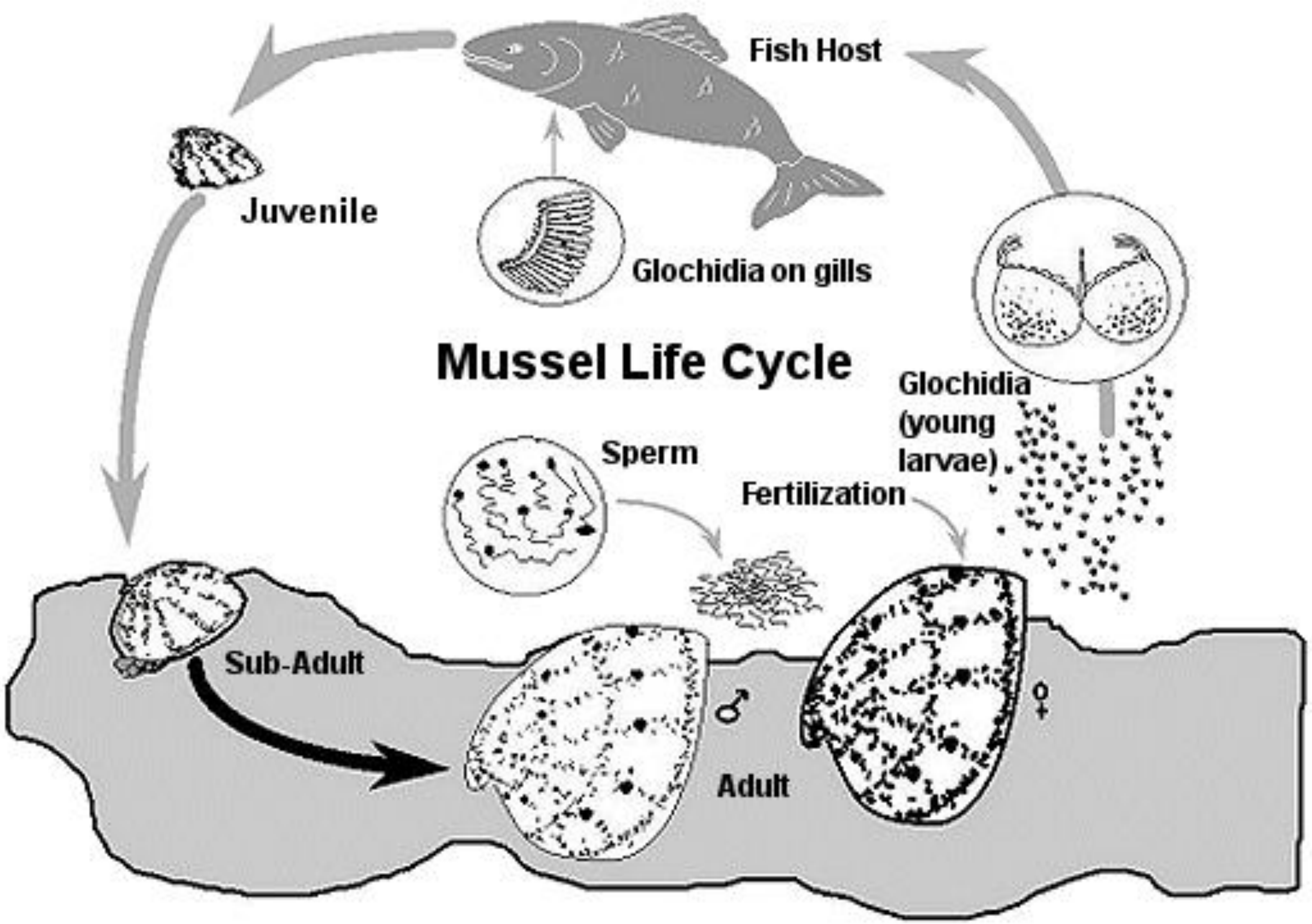


- Long-lived (6 – > 100 yrs)
- Adults are sedentary (can't move far)
- Occur as dense, multispecies aggregations (mussel beds)

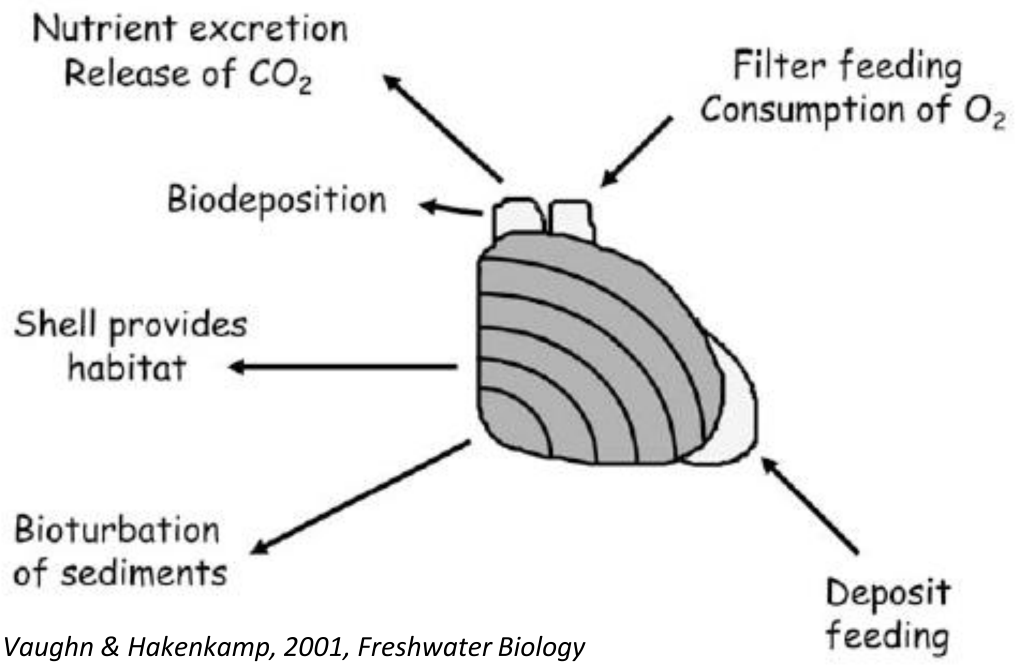
Mussel beds are spatially patchy- restricted to areas of sufficient flow during low flows and low shear stresses during high flows

Mussels from one 0.25 m^2 quadrat in the Kiamichi River

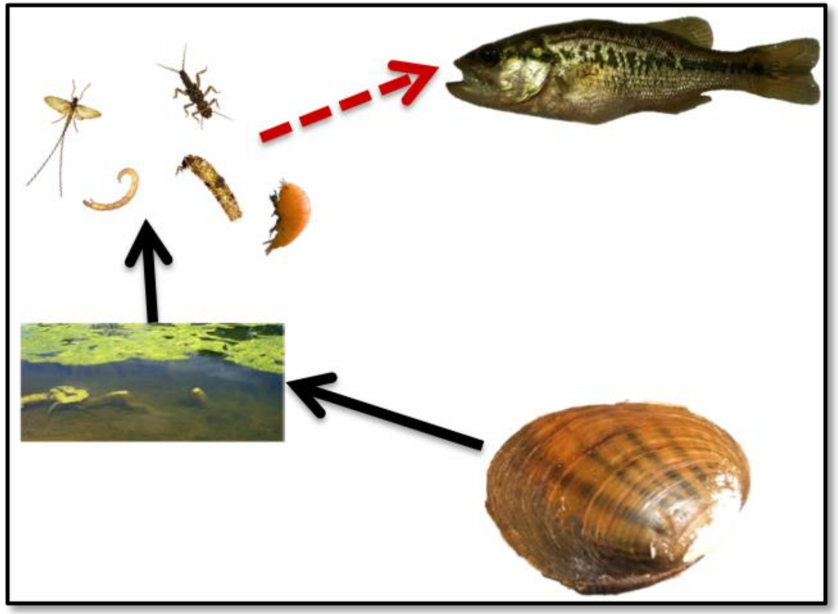
Mussels have a unique, complex life cycle



Mussels are living “biofilters” that link the water and sediments



Vaughn & Hakenkamp, 2001, Freshwater Biology



- Filter the water
- Recycle and store nutrients
- Provide and modify habitat
- Support food webs

Mussels provide ecosystem services to us

Source: Vaughn, C.C. 2018 Ecosystem services provided by freshwater mussels. Hydrobiologia 810:15-27.

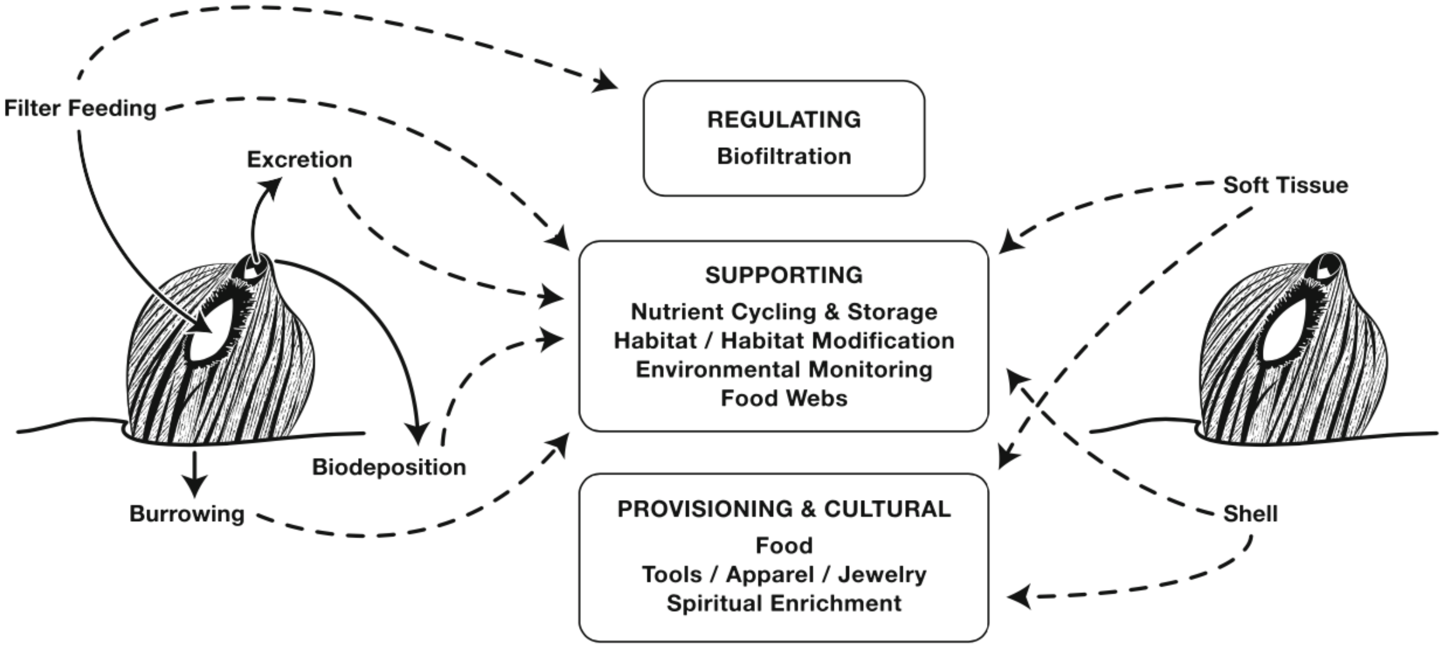


Fig. 1 Mussel tissue and activities that mussels perform can be translated into ecosystem services that are beneficial to humans

Table 1 Ecosystem service classes, mussel-provided ecosystem services, and the benefits that they provide for humans

Ecosystem service class	Mussel-provided ecosystem service	Benefits for humans
Regulating	Biofiltration	Water quality
Supporting	Nutrient cycling and storage	Water quality
	Habitat/habitat modification	Fish habitat
	Environmental monitoring	Water quality
	Food webs	Biodiversity
Provisioning	Food for other species	Biodiversity
	Food for humans	Food provisioning
	Products from mussel shells	Pottery, jewelry, art
Cultural	Cultural value	Spiritual benefits
	Existence value	Conservation value

Kiamichi River mussels

31 species (~50% of OK mussel fauna) occur in the Kiamichi River

Kiamichi is a mussel biodiversity hotspot

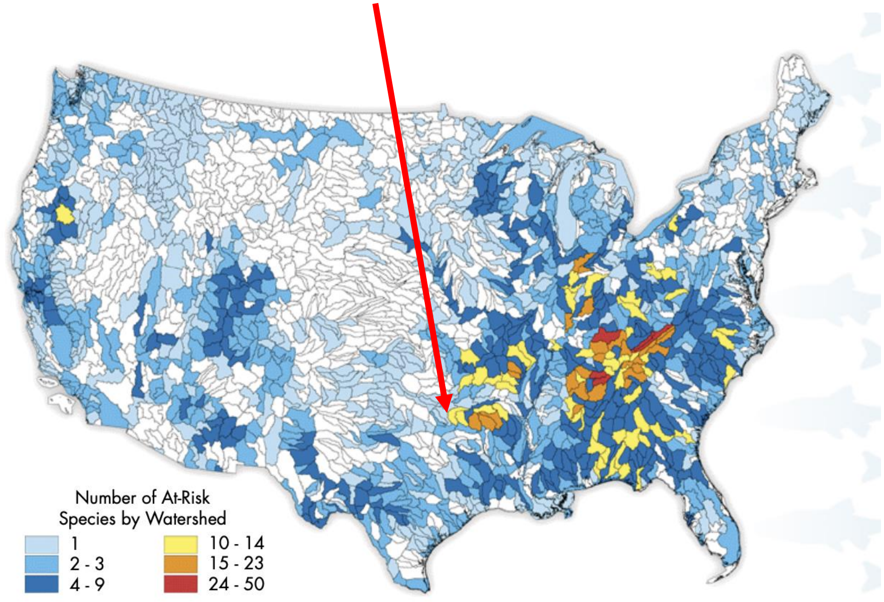


Figure 5. Hot Spots for At-Risk Fish and Mussel Species

Watersheds with 10 or more at-risk fish and mussel species are concentrated in the Southeast, reflecting the extraordinary species diversity of rivers and streams in this region.

Federally listed species

Ouachita rock pocketbook
Arcidens wheeleri

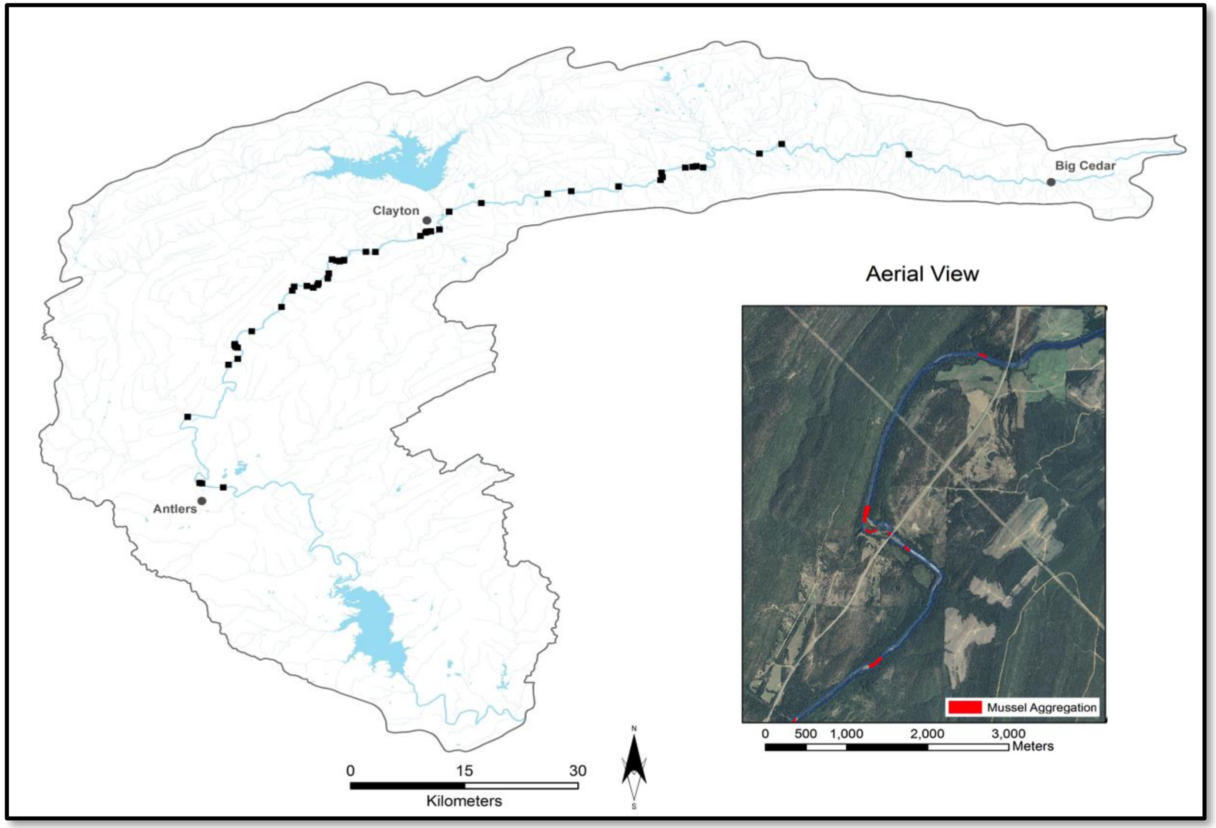
KR is best population globally for this species

Scaleshell mussel
Leptodea leptodon

Winged mapleleaf
Quadrula fragosa

- *Need further survey & genetic work in river*

Kiamichi River mussel populations

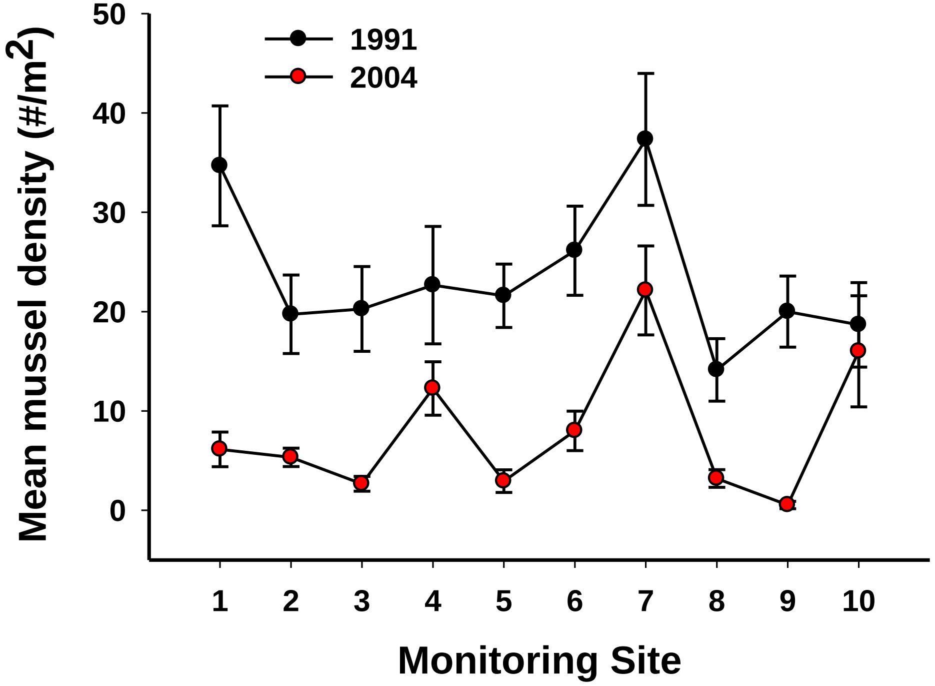


- We've been studying KR mussel populations since 1990
- Have mapped the location of most mussel beds
- Know the species composition and population size structure of these beds
- Have quantified the ecological function of these beds (biofiltration rates, nutrient cycling and storage rates)
- Have temporal data for a subset of monitoring sites

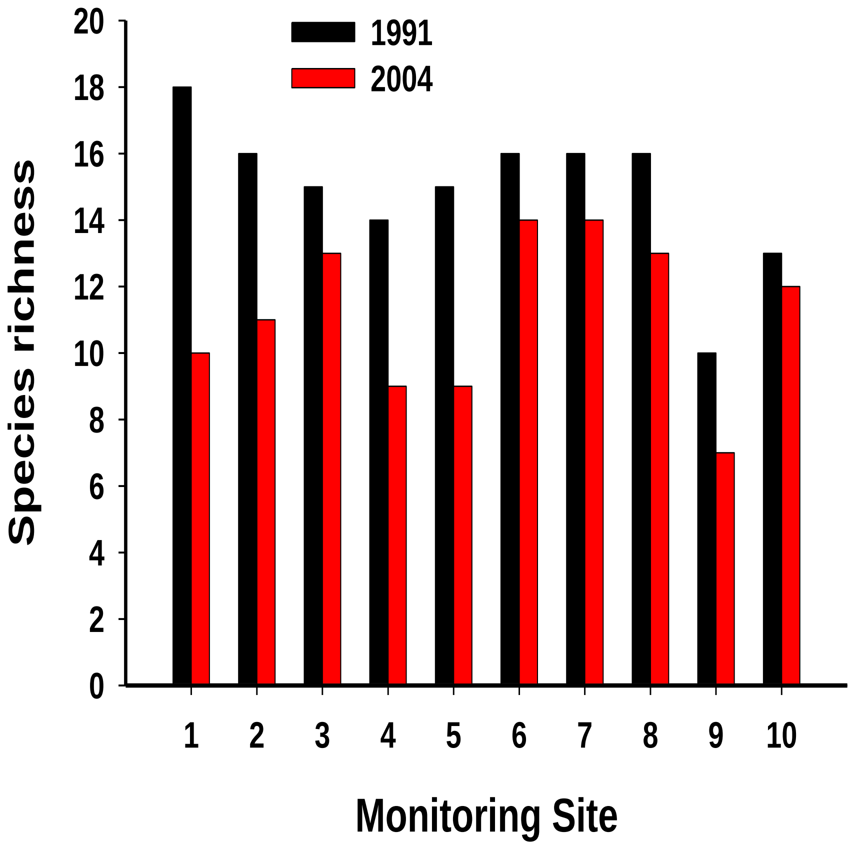
Source: Atkinson, C.L. & C.C. Vaughn. 2015. Biogeochemical hotspots: temporal and spatial scaling of the impact of a multispecies community of freshwater mussels on ecosystem function. Freshwater Biology 60:563-574

60% loss of mussel biomass in KR since 1992

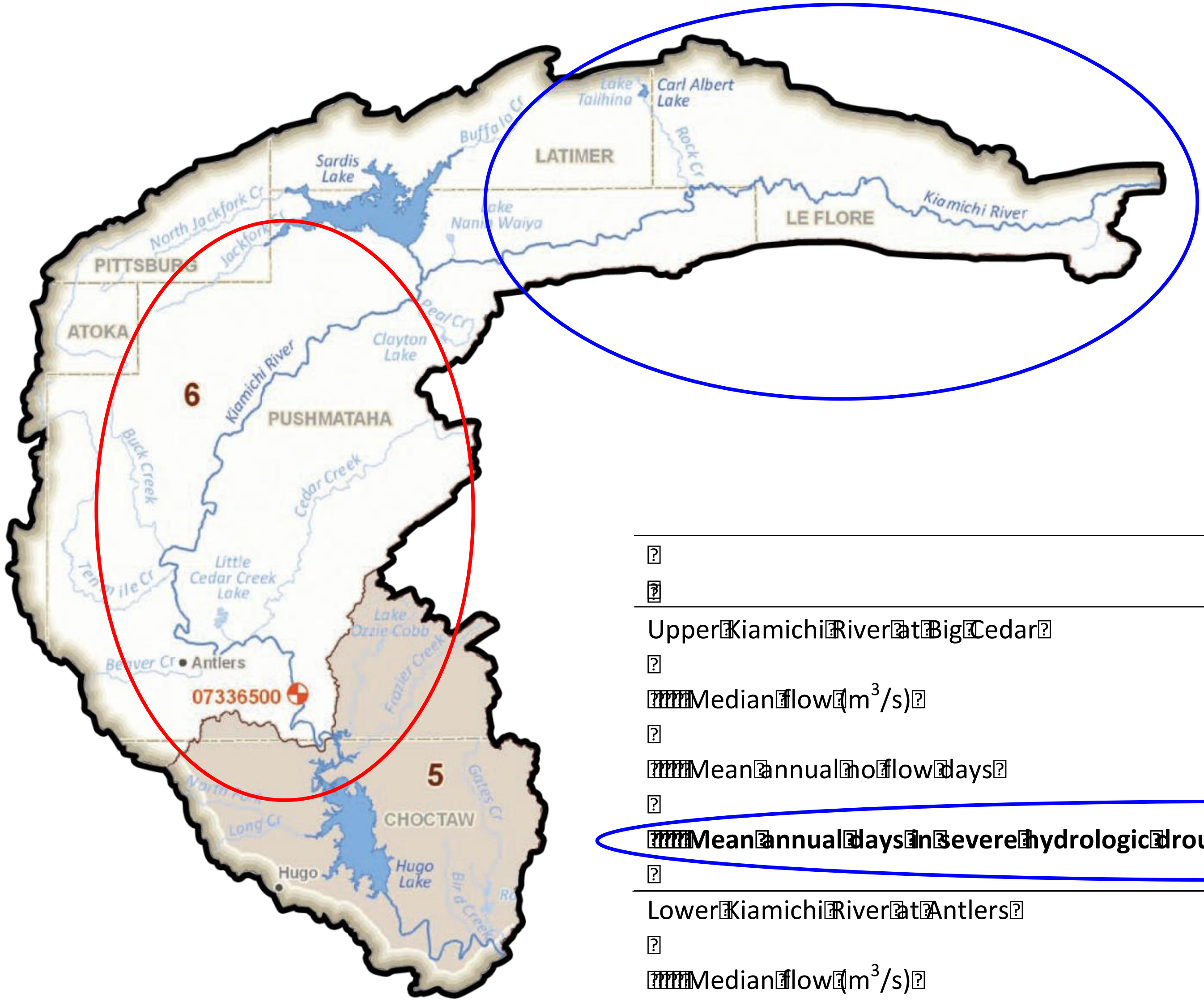
Decreases in mussel abundance



Decreases in the number of species



Source: Galbraith, Spooner & Vaughn, 2010, Biological Conservation 143:1175-1183.

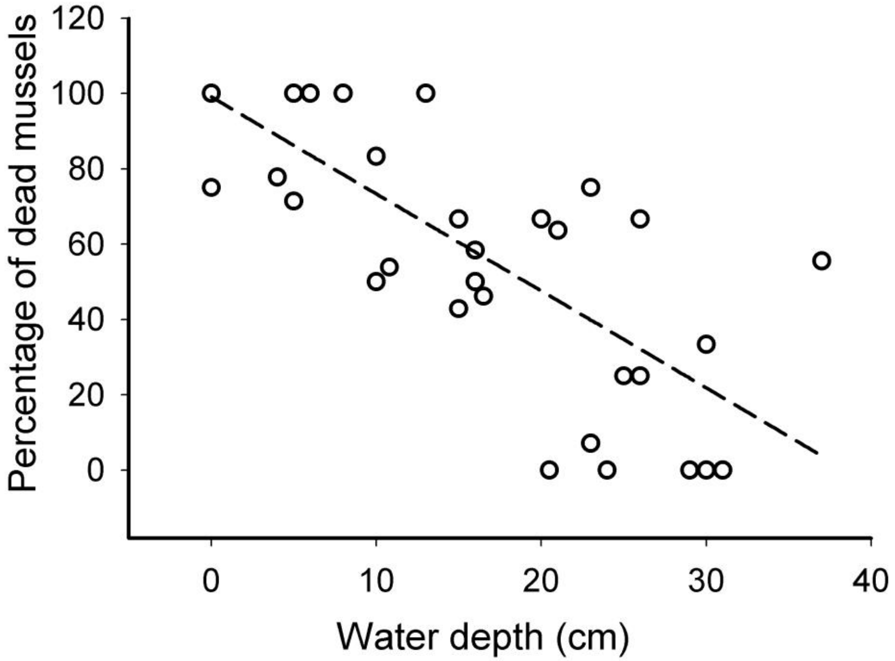


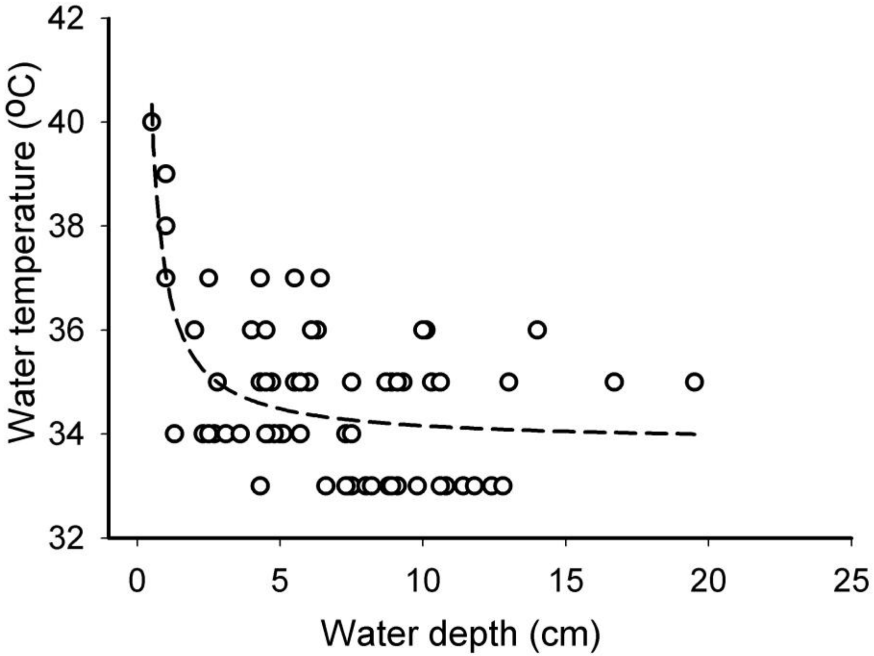
Hydrologic drought has increased dramatically, and has increased more in the **lower river** because of water management

	1966-1982	1983-1990	1992-2003	2004-2011
Upper Kiamichi River at Big Cedar				
Median flow (m^3/s)	0.65	0.74	0.93	0.51
Mean annual no flow days	37.8	58.1	44.5	64.6
Mean annual days in severe hydrologic drought	**37.8**	**58.1**	**44.5**	**64.6**
Lower Kiamichi River at Antlers				
Median flow (m^3/s)	8.5	10.0	11.7	4.4
Mean annual no flow days	10.3	0	6.3	35.6
Mean annual days in severe hydrologic drought	**28.8**	**33.6**	**33.3**	**74.7**

Source: Vaughn, C.C., C.L. Atkinson and J.P. Julian. 2015. Drought-induced changes in flow regimes lead to long-term losses in mussel-provided ecosystem services. Ecology and Evolution 5:1291-1305.

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





Source: Galbraith, Spooner & Vaughn, 2010, Biological Conservation 143:1175-1183.

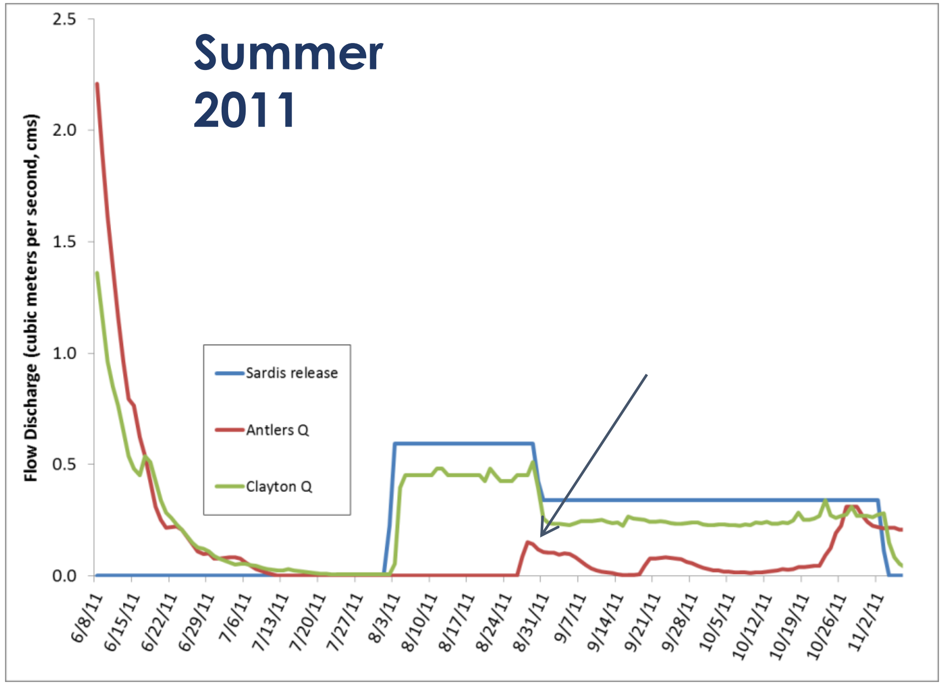
2011-12 – "Exceptional Drought"

One bed in July 2011:

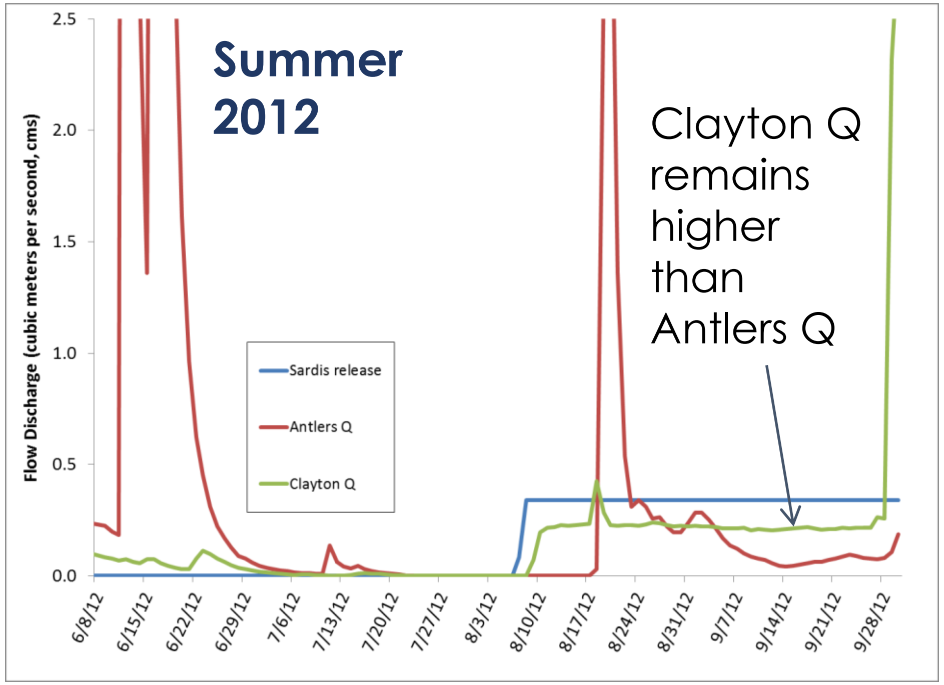
- 19 species of freshly dead mussels
- 66 kg dry mussel soft tissue loss
- Average water depth 10 cm
- Water temp at midday 40 °C

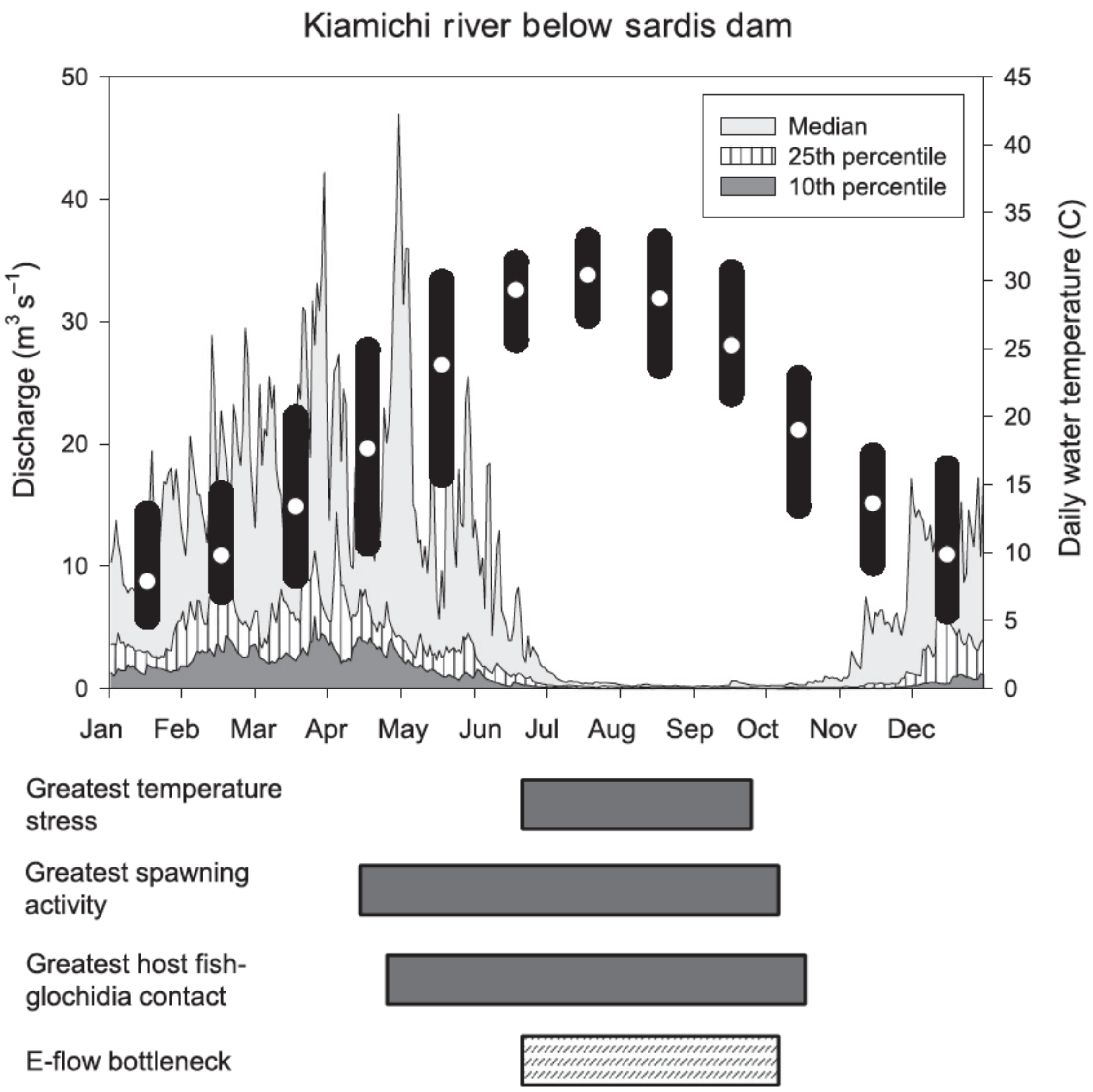
Vaughn et al., Ecology & Evolution, 2015

25 days for Sardis release to have an effect on Antlers Q



Kiamichi River becoming a losing stream between Clayton and Antlers during extended drought





Recommendations

- Focus on summer e-flow bottleneck
- Set temperature criteria based on juveniles of the most sensitive species
- Keep water below 35 °C
- Use discharge-rating temperature models to determine how much water to release to achieve this temperature
- Maintain flow between Clayton and Antlers during drought

Using United States Geological Survey stream gages to predict flow and temperature conditions to maintain freshwater mussel habitat

Jeffrey C. Cole[1] | Philip A. Townsend[2] | Keith N. Eshleman[3] | Barbara St. John White[1] | Heather S. Galbraith[1] | William A. Lellis[4]

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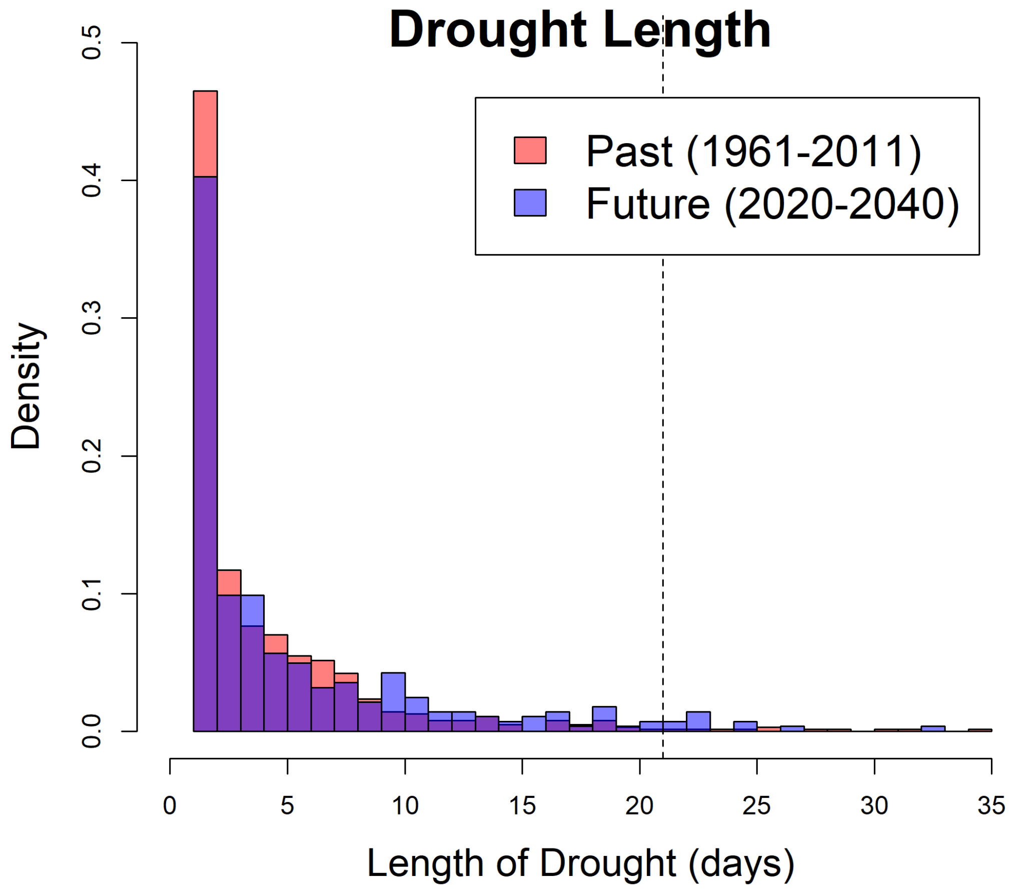
AN EVALUATION OF STREAMFLOW AUGMENTATION AS A SHORT-TERM FRESHWATER MUSSEL CONSERVATION STRATEGY

J. M. WISNIEWSKI[a]*, S. ABBOTT[b] AND A. M. GASCHO LANDIS[a,†]

What are the chances of similar droughts in the future?



Work by Rachel Fovargue and Tom Neeson at Univ. Oklahoma

Historic drought (1961-2011)
Future drought (2020-2040)
from downscaled climate model
Projections from GCM CCSM4, RCP 8.5

26% increase in drought length

- Historic 4.5 days
- Future 5.7 days

127% increase in drought frequency!

- Historic ~ every 5 years
- Future ~ every 2 years

Acute drought defined as consecutive days with a 3-day mean air temperature > 25 C and a 3-day mean precipitation < 3 mm

Rare species and species of special concern

- Crystal darter
- Kiamichi shiner
- Blue sucker
- Mooneye
- Pallid shiner
- Cypress minnow
- Harlequin darter
- Ribbon shiner
- River darter
- Black buffalo
- Blackspot shiner
- Paddlefish
- Silverband shiner
- River redhorse
- Lamprey

Crystal darter
Crystallaria asprella
Photo from Missouri Department of Conservation

Understanding the impacts of surface-groundwater conditions on stream fishes under altered baseflow conditions

Photograph obtained from smug mug

Shannon K. Brewer[1], Garey Fox[2], Yan Zhou[2], and Justin Alexander[3]

[1]U.S. Geological Survey, Oklahoma Cooperative Fish and Wildlife Research Unit, [2] Department of Biosystems and Agricultural Engineering, Oklahoma State University, [3] Department of Natural Resources Ecology and Management, Oklahoma State University

Thermal tolerance of some Kiamichi fishes

Table 19. Critical thermal maxima of some fish species from the Kiamichi River. Critical thermal maxima is a measure of a species' upper temperature tolerance. Species are listed from least to most tolerant. Data from Brewer et al. (2019).

Species	Common name	CTMax
Notropis ortenburgeri	Kiamichi shiner	32.50
Etheostoma radiosum	Orangebelly darter	33.97
Percina copelandi	Channel darter	34.09
Percina sciera	Dusky darter	34.30
Percina phoxocephala	Slenderhead darter	34.32
Notropis boops	Bigeye shiner	34.43
Notropis atherinoides	Emerald shiner	34.49
Cyprinella whipplei	Steelcolor shiner	34.71
Pimephales vigilax	Bullhead minnow	34.73
Percina caprodes	Logperch	35.00
Campostoma spadiceum	Highland stoneroller	35.08
Pimephales notatus	Bluntnose minnow	35.13
Micropterus dolomieui	Smallmouth bass	37.71
Fundulus olivaceus	Blackspotted topminnow	38.28

These temperatures are often exceeded in shallow water in the Kiamichi during low flows during summer droughts

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