The potential importance of groundwater to freshwater mussels

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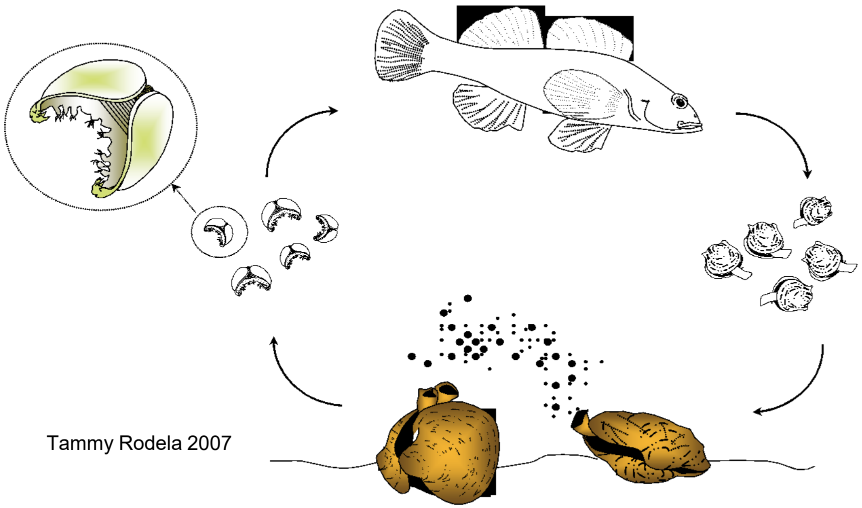
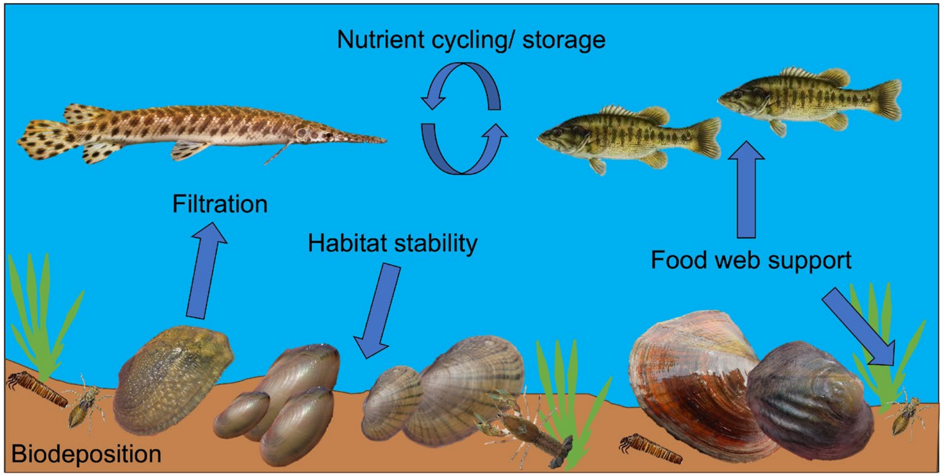
Texas State University

Freshwater mussels





Adapted from Kreeger et al. 2018

<u>Unionid mussels 101:</u>

Unique life history, rely on host fish for reproduction and dispersal

Provide important ecosystem services

Highly imperiled, many species have experienced declines

Patchy distribution of mussels

Grand River – Doon Heritage site

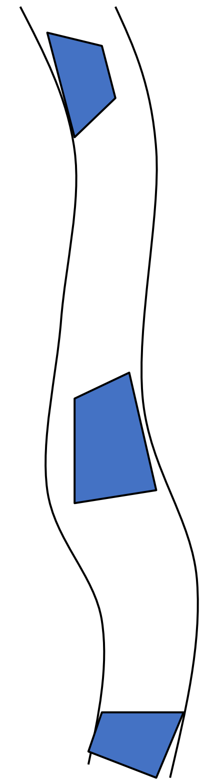
34 m

100 m

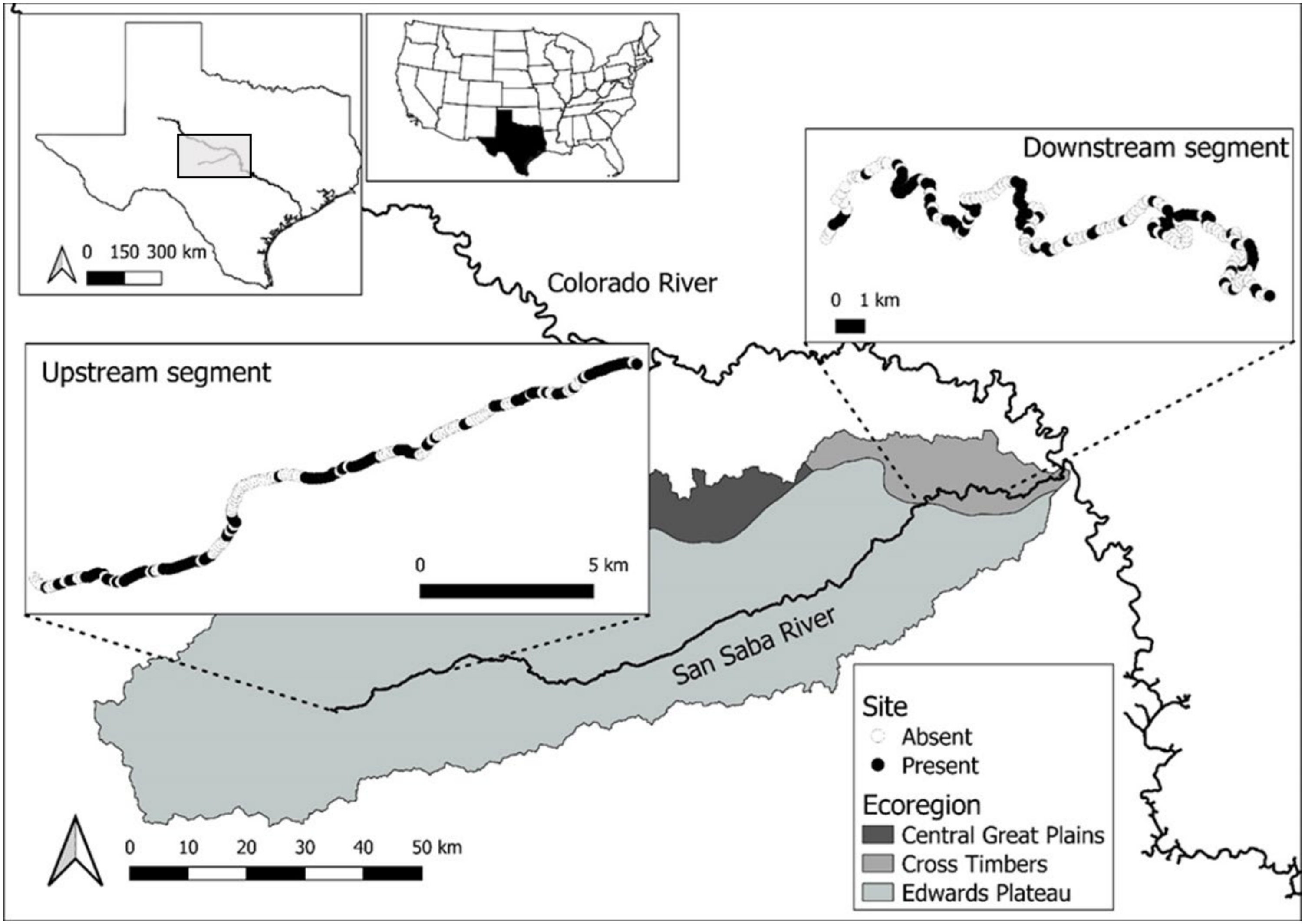
● = 1 ind. ▲ = 2 ind. ● = L. fasciola

<u>Mussel beds</u>:
Multispecies assemblages with densities 10-100 times higher than outside of beds.

Also variation in densities within mussel areas

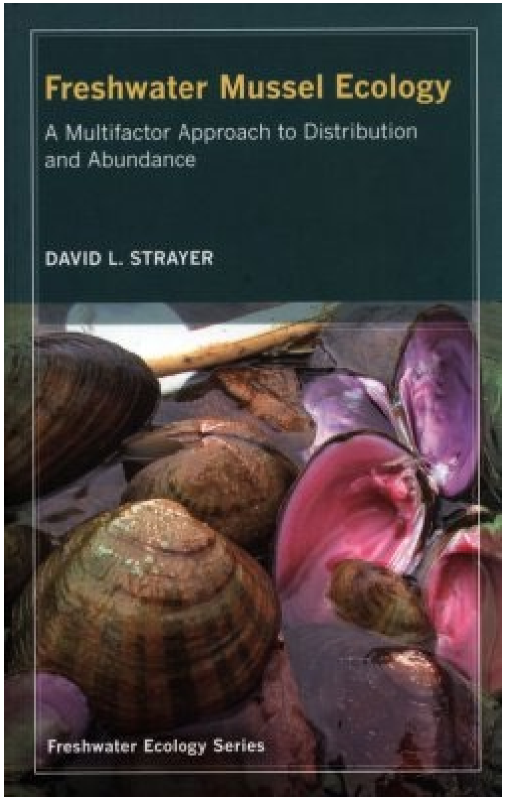


Patchy distribution of mussels



Mitchell et al. (2023)

What drives the distribution of mussels?



Strayer 2008

Host fish: Needs to be present at the right time, infestation and transformation to juvenile mussels

Dispersal: dispersal limitation can determine range boundaries

Food: Sufficient to grow and reproduce

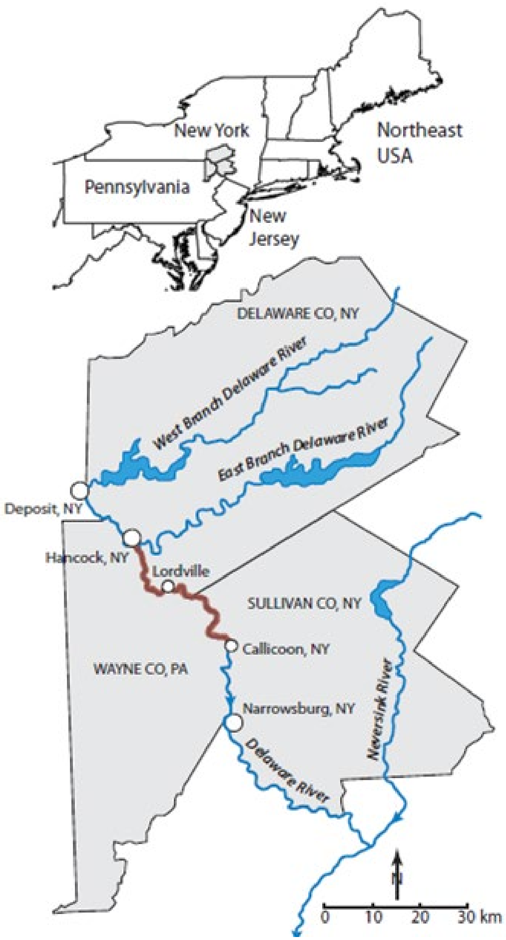
Enemies: Predation, parasitism, and disease

Habitat: Stable substrate during flooding,
+ enough water during low flow or drought

↓

- Potential importance of groundwater

What role could groundwater play for the distribution of mussels?



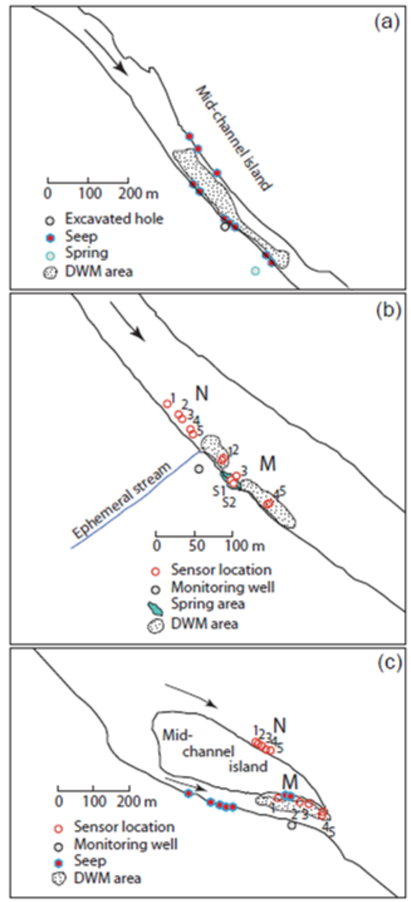


Figure 2. Sites 1 (**a**), 2 (**b**) and 3 (**c**). Arrows indicate direction of river flow. Sensor locations pertain to seepage-meter and in-river piezometer installations.

Study in Delaware River,

Comparing sites with endangered *Alismodonta heterodon* (M sites) with nearby sites without mussels (N sites)

Rosenberry et al. 2016

Evidence for effect of groundwater discharge: seeps and springs

Visible seeps and springs at all M reaches

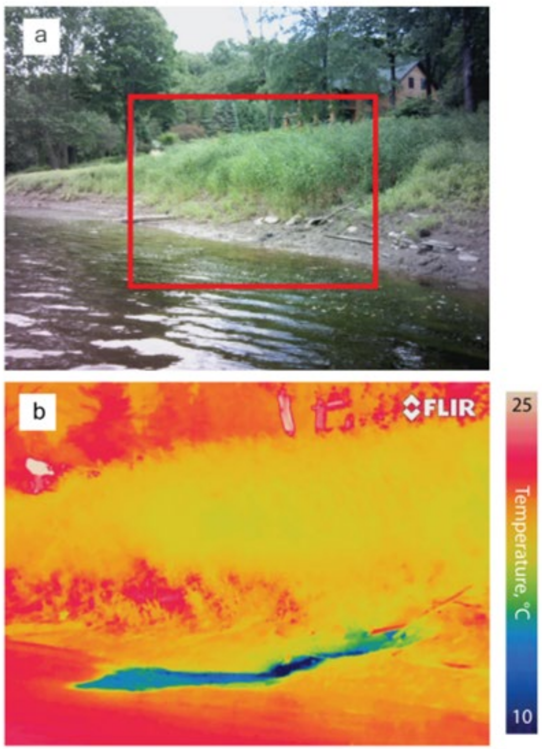


Figure 5. (a) Photograph of riverbank at site 2 with red rectangle indicating area of infrared image **(b)**. Color infrared image with blue area showing colder groundwater entering the river. Color scale indicates temperature, in °C.

Rosenberry et al. 2016

Evidence for effect of groundwater discharge: lateral hydraulic gradients

Lateral hydraulic gradients toward river water table monitoring well to determine gradients between water table and the river

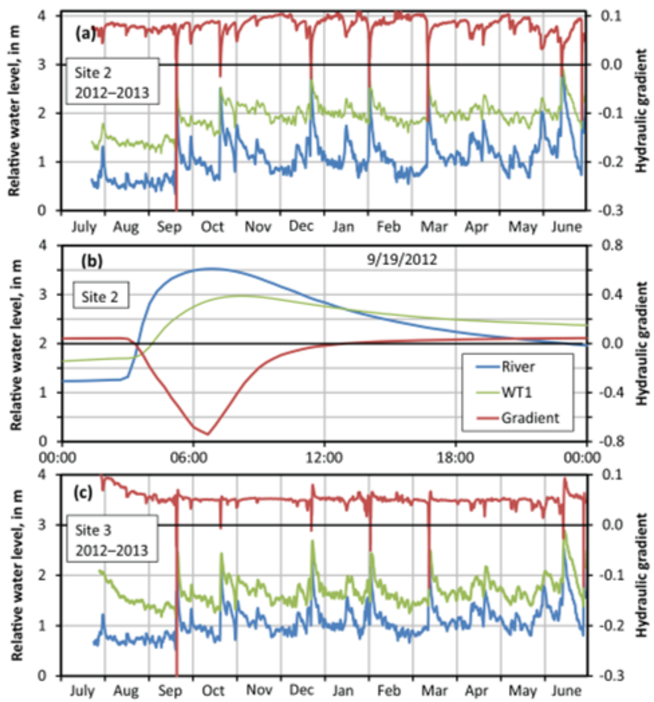


Figure 6. River stage, water-table elevation, and hydraulic gradient at sites 2 and 3. Legend in panel **(b)** also applies to panels **(a)** and **(c)** except site 3 data are from the WT2 monitoring well. **(a)** Site 2, July 2012 through June 2013; **(b)** 20 min data from site 2 showing gradient reversal on 19 September 2012; **(c)** site 3, July 2012 through June 2013.

Median values for hydraulic gradients
Site 2: 0.08
Site 3: 0.05

Rosenberry et al. 2016

Evidence for effect of groundwater discharge: seepage and upward hydraulic gradient

In M reaches (compared to N reaches):
Upward seepage through riverbed faster and more consistently upward seepage meters

Median upward hydraulic gradients 3 to 9x larger streambed piezometers

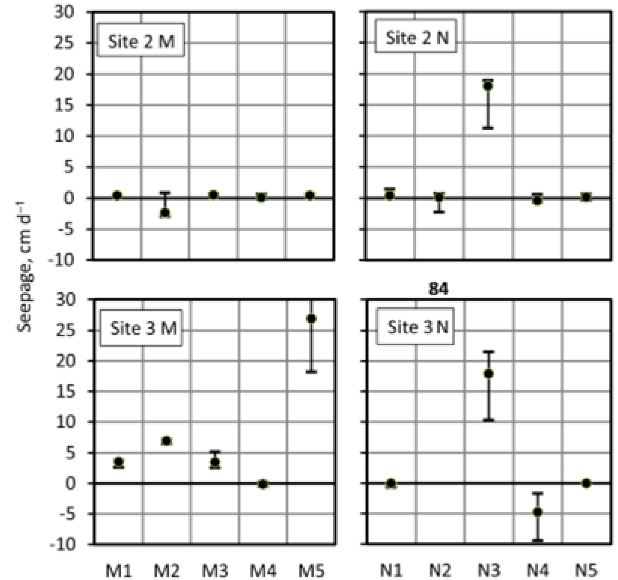


Figure 7. Median values of seepage flux. Error bars indicate maximum and minimum measured values. Median value for site 3 N2 is 84 cm d^{-1}.

Rosenberry et al. 2016

Evidence for effect of groundwater discharge: temperature

Colder zones found in M reaches, but not N reaches

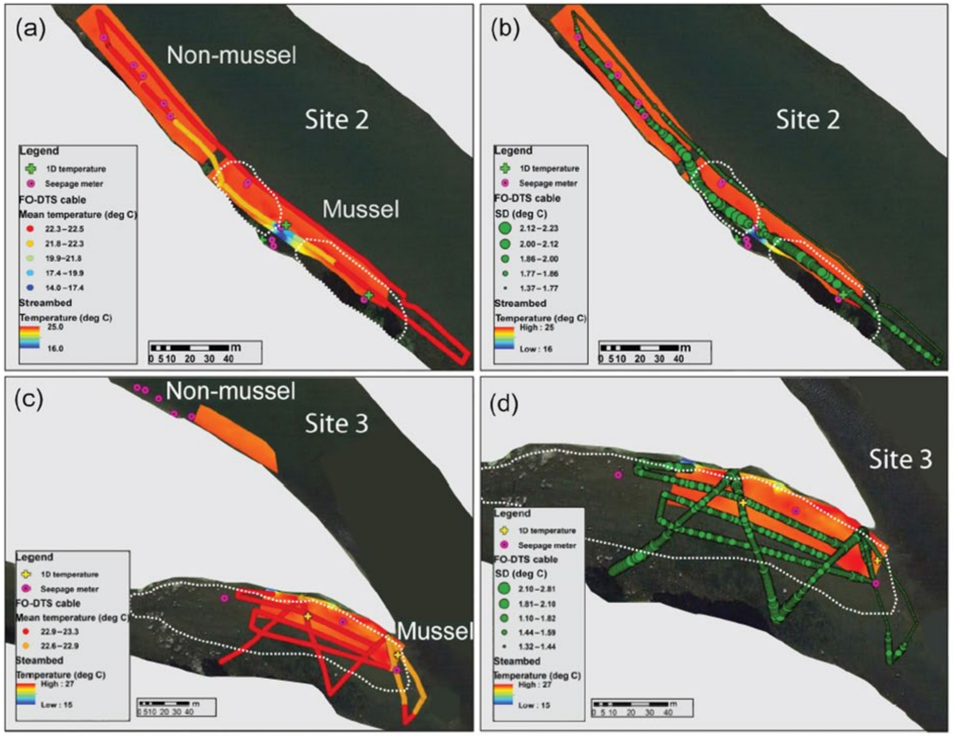


Figure 9. Riverbed temperatures indicated by snapshot thermal surveys (shaded riverbed areas) and FO-DTS at site 2 (panels **a**, **b**) and site 3 (panels (**c**), (**d**)). Colored circles in panels (**a**) and (**c**) indicate temperature and sizes of circles in panels (**b**) and (**d**) indicate temperature standard deviation during 4- and 2-day cable deployments at site 2 and 3, respectively.

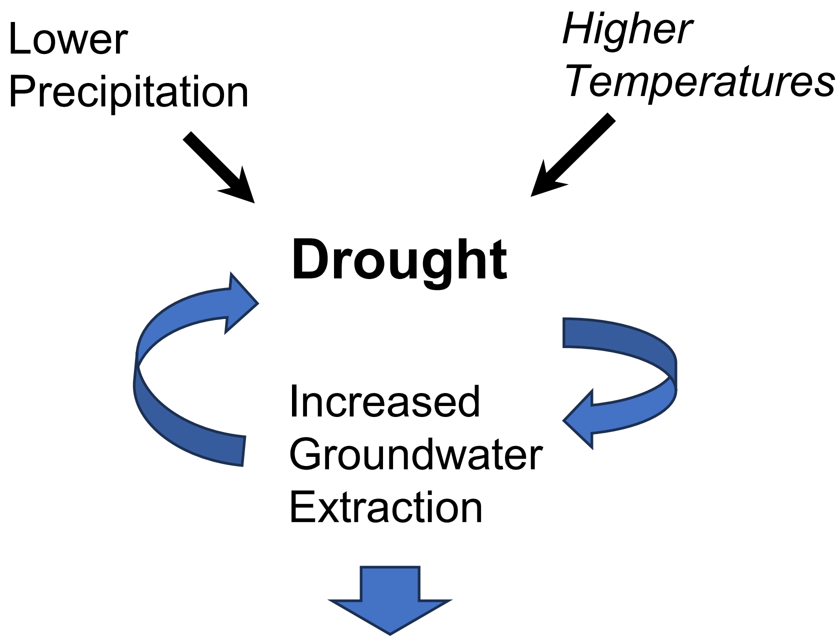
Individual methods not necessarily conclusive, but collective evidence Indicates mussels occur "in or directly downstream of areas of substantial groundwater discharge".

What about mussels in Texas? Groundwater even more important during drought?

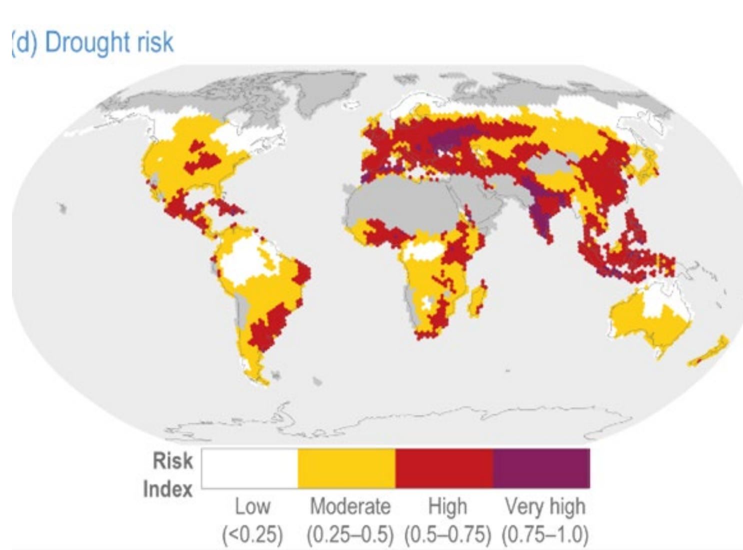
Rosenberry et al. 2016

Droughts = Prolonged periods of drier than normal conditions, often coupled with increased temperatures

From the Fifth National Climate Assessment: "**Droughts are projected to increase** in intensity, duration, and frequency, especially in the Southwest…"



Reduced stream flow, *dewatering*, drying
+ Effects on water quality

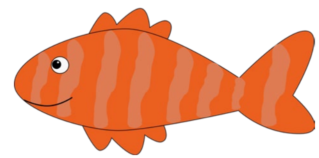


Drought risk, IPCC 6th assessment report

Adaptations to drought

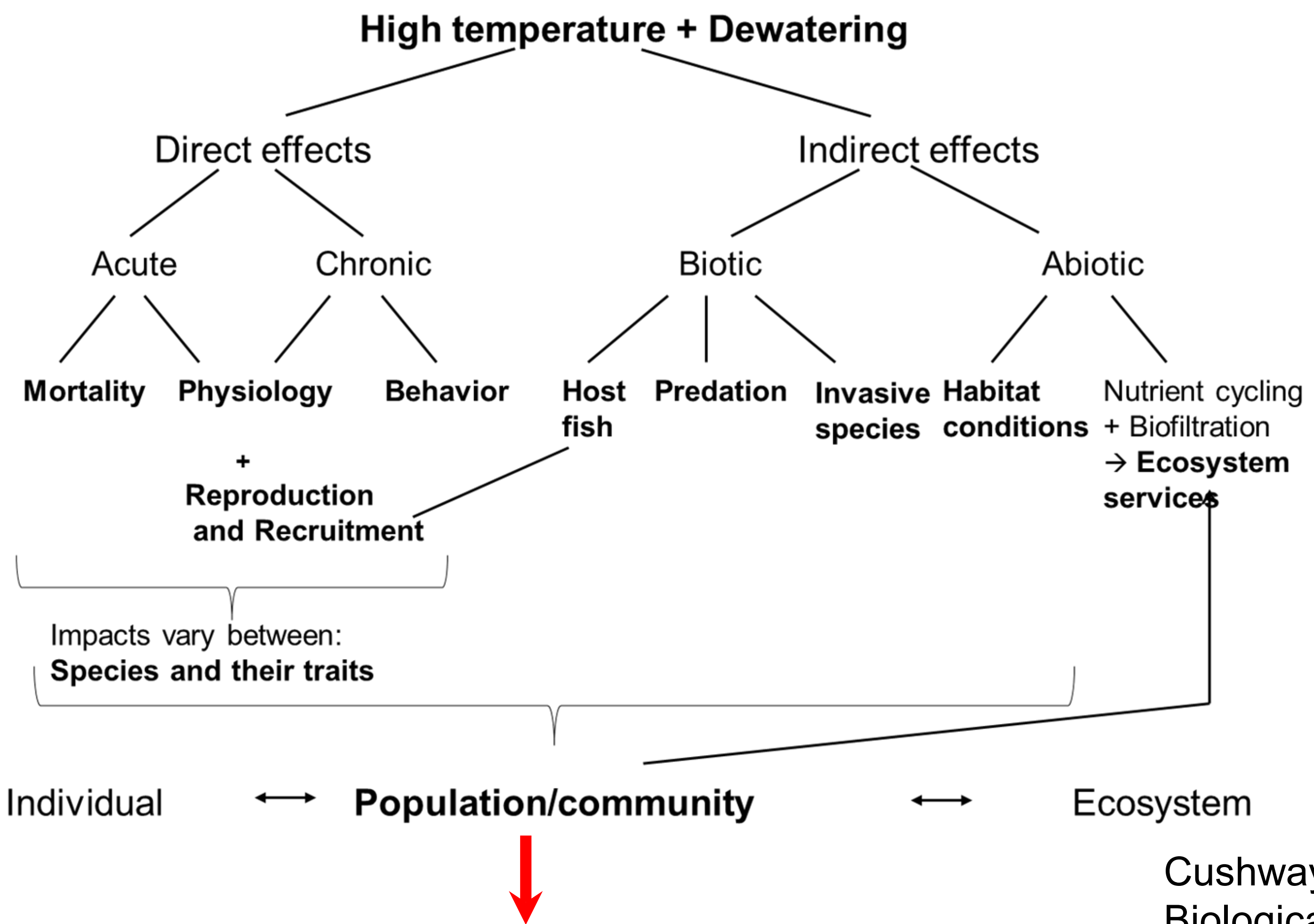
Dormancy:
Survival of aquatic insects as dormant life history stage

Escape dewatering:
Fish swim away
Winged adult stage of aquatic insects



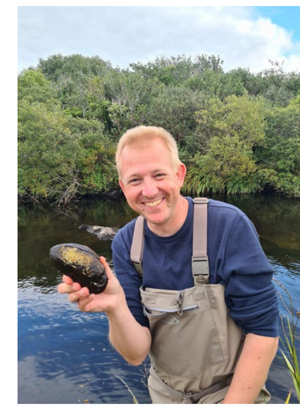
Mussels:
Limited mobility (crawling + burrowing)
 More vulnerable to drying

Review on the impact of drought



Role of refuges?

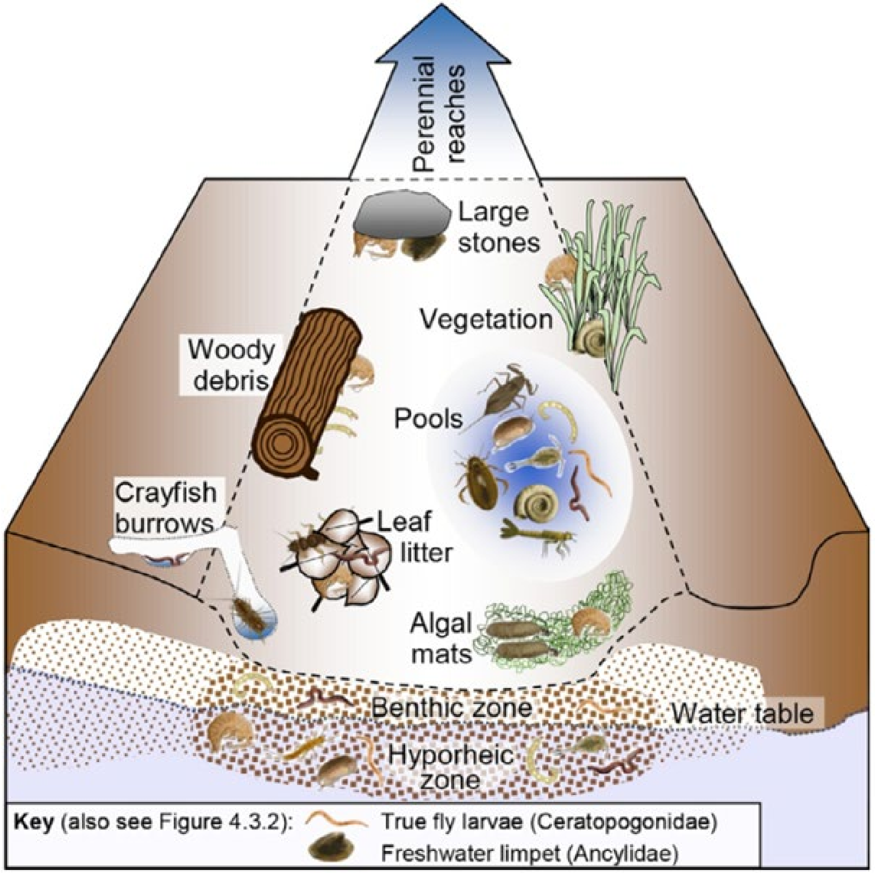
Kiara Cushway
USACE



Juergen Geist,
TU Munich

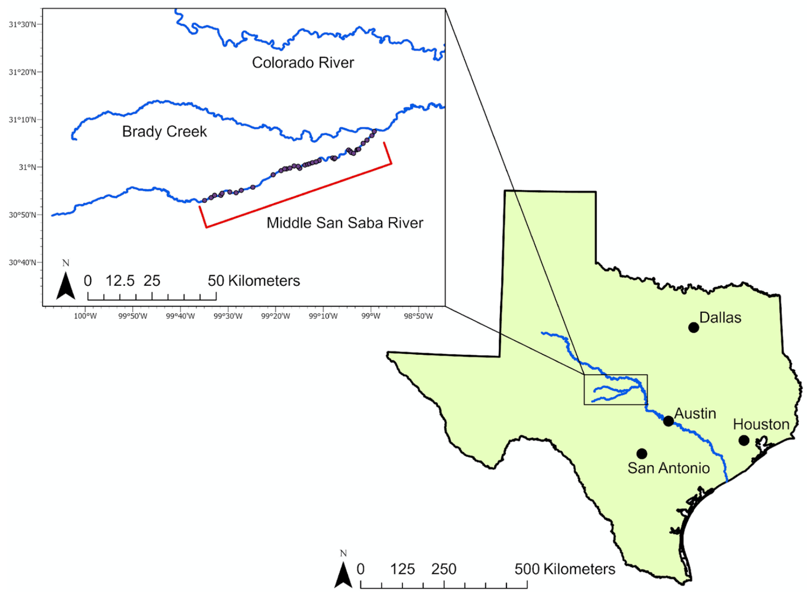
Cushway et al. 2024
Biological Reviews

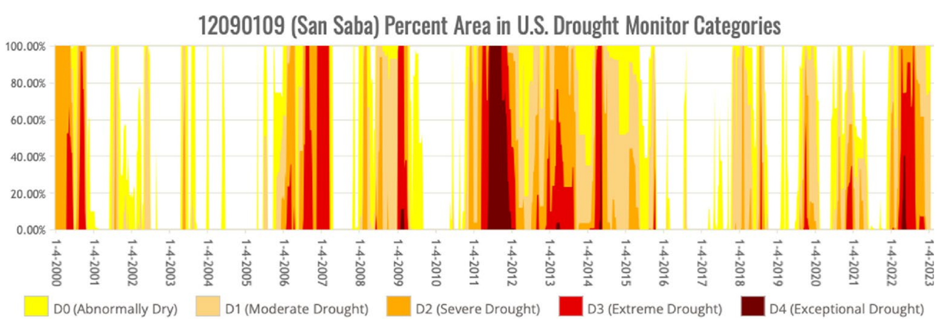
Refuges of aquatic macroinvertebrates



Credit: Stubbington et al. 2017

Pools as ecological refuges during drought?





41 pools sampled in middle San Saba (2021+2022 severe drought!)

Stratified random sampling design

31 perennial sites (not dry 2012), Incl. 18 larger pools (> 115m) and 10 dam sites

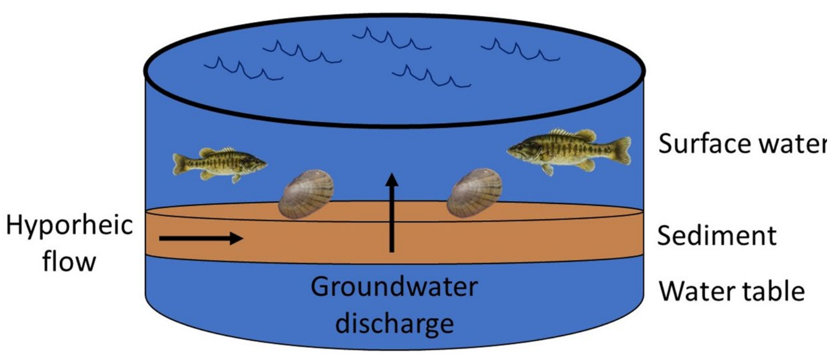
10 intermittent sites (aerial imagery, dried at least twice since 2004)

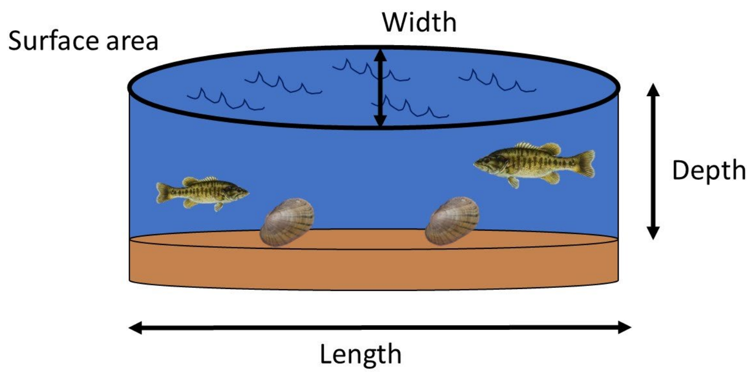
+ various abiotic and biotic variables

Cushway & Schwalb 2023

Hypothesis

<u>Hypothesis:</u>
Variables related to the pool's ability to retain water and maintain cooler temperatures during drought would affect their capacity to act as ecological refuge for mussels.





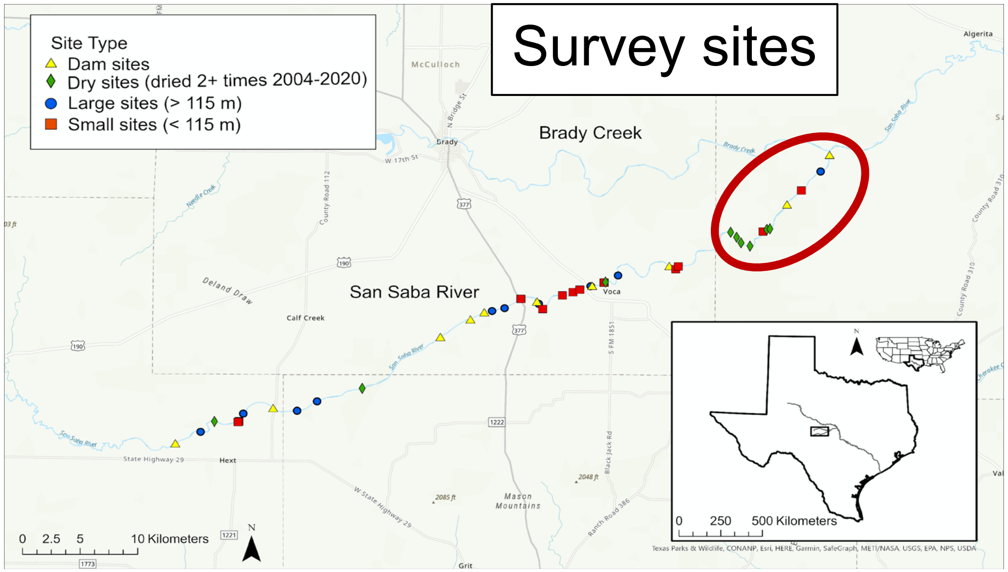
Cushway & Schwalb 2023

Examining potential influence of groundwater and thermal refuges in pools

Thermal time series

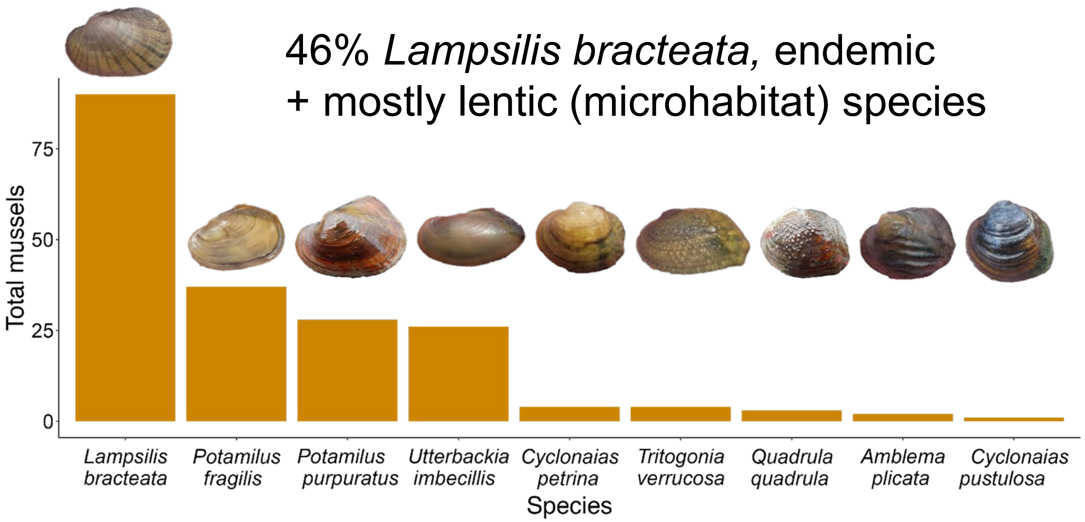
- Towing **temperature loggers at the water surface and river bed** to identify areas where the bottom temperature was warmer in the winter (2022) and cooler in the summer (2022),

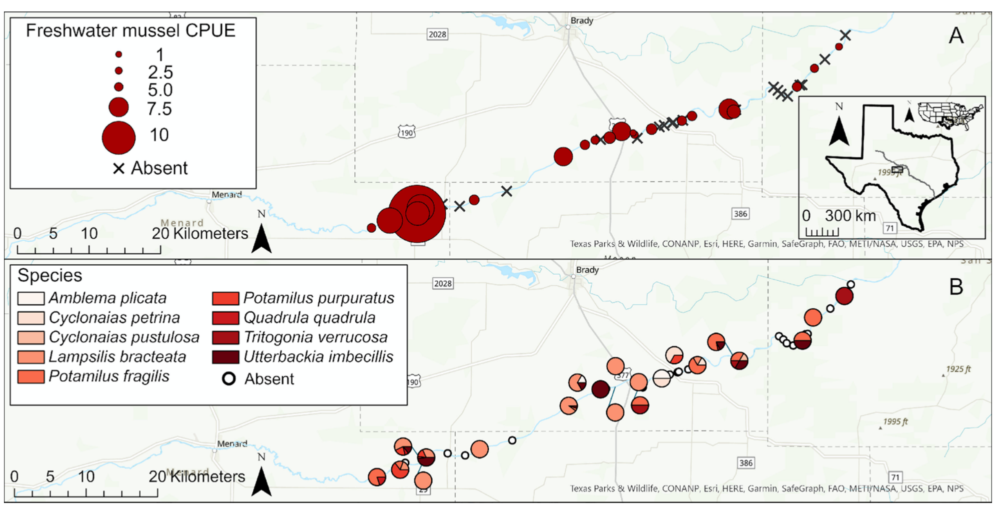
- Indication for groundwater discharges or physical characteristics of the pool helped it buffer extreme temperatures.



Results

46% *Lampsilis bracteata,* endemic
+ mostly lentic (microhabitat) species





9 species in 21 perennial pools found.

Only 195 mussels total despite 210 p-H surveys

Relevant factors for abundance and richness (Multiple factor analysis): Pool size, temperature, aquatic and riparian vegetation, and underlying geology.

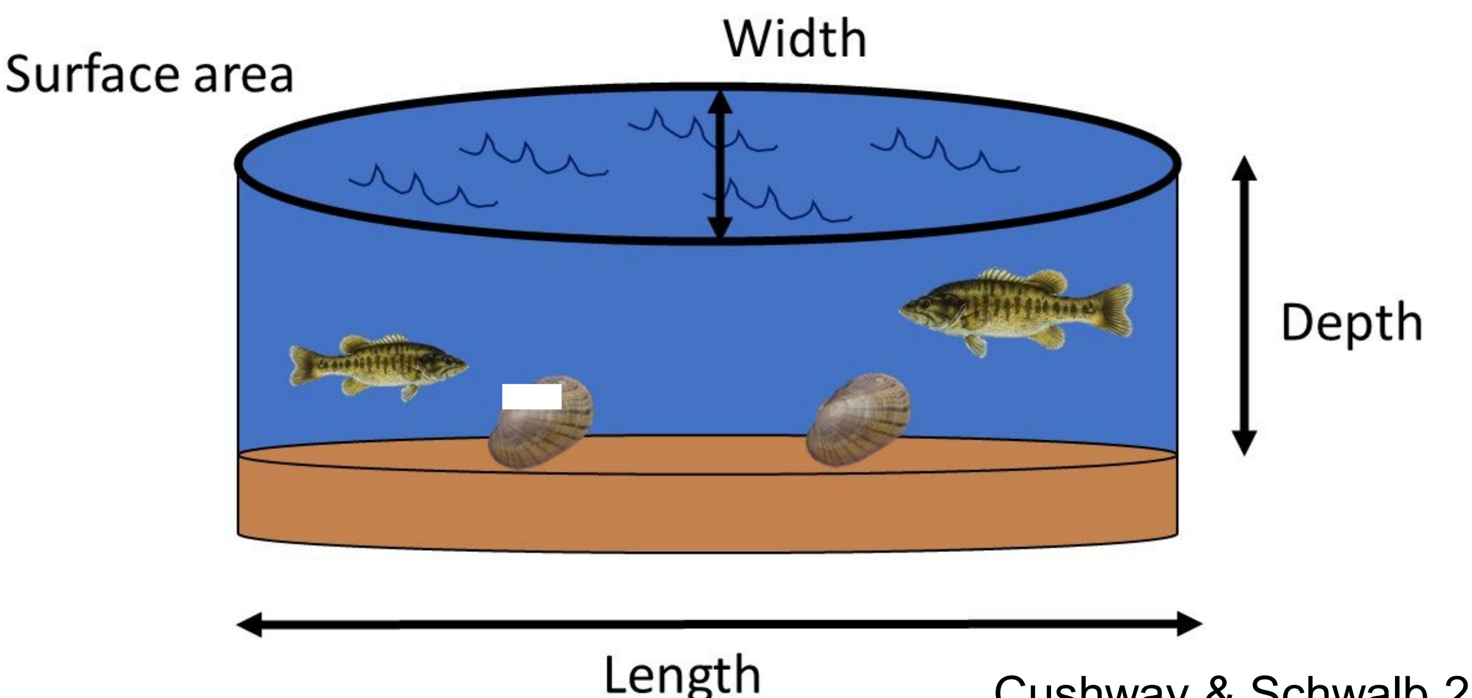
Cushway & Schwalb 2023

Importance of thermal refuge for mussels

Perennial pools as ecological refuges for freshwater mussels.

Maintaining suitable conditions (cooler water temperature) may help mussels persist

- Large enough pools, vegetation for shade



Cushway & Schwalb 2023

Importance of thermal refuge for mussels

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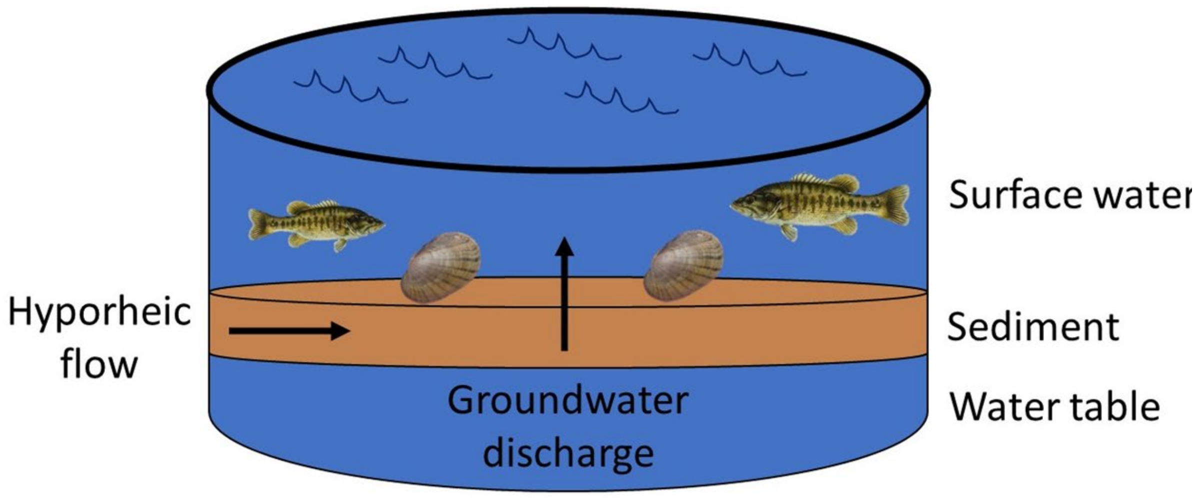
- Large enough pools, vegetation for shade, and groundwater input may be crucial



Cushway & Schwalb 2023

Importance of thermal refuge for mussels

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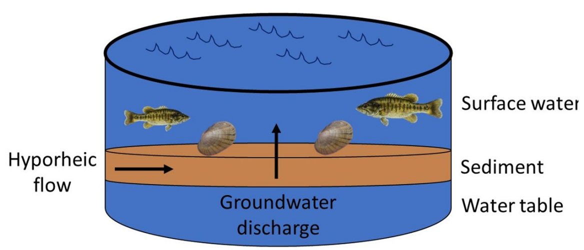
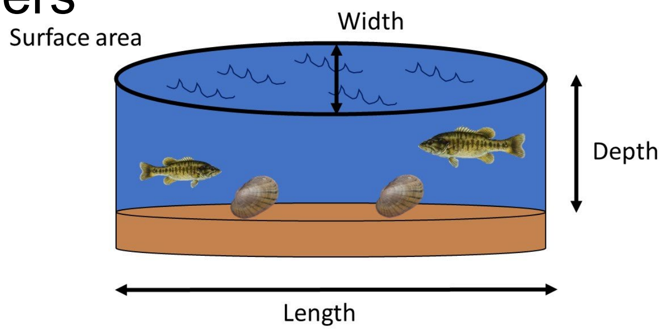
Maintaining suitable conditions (cooler water temperature) may help mussels persist

- Large enough pools, groundwater input may be crucial, vegetation for shade.

BUT…Limited number of isolated pools cannot prevent overall declines of mussels in drying rivers

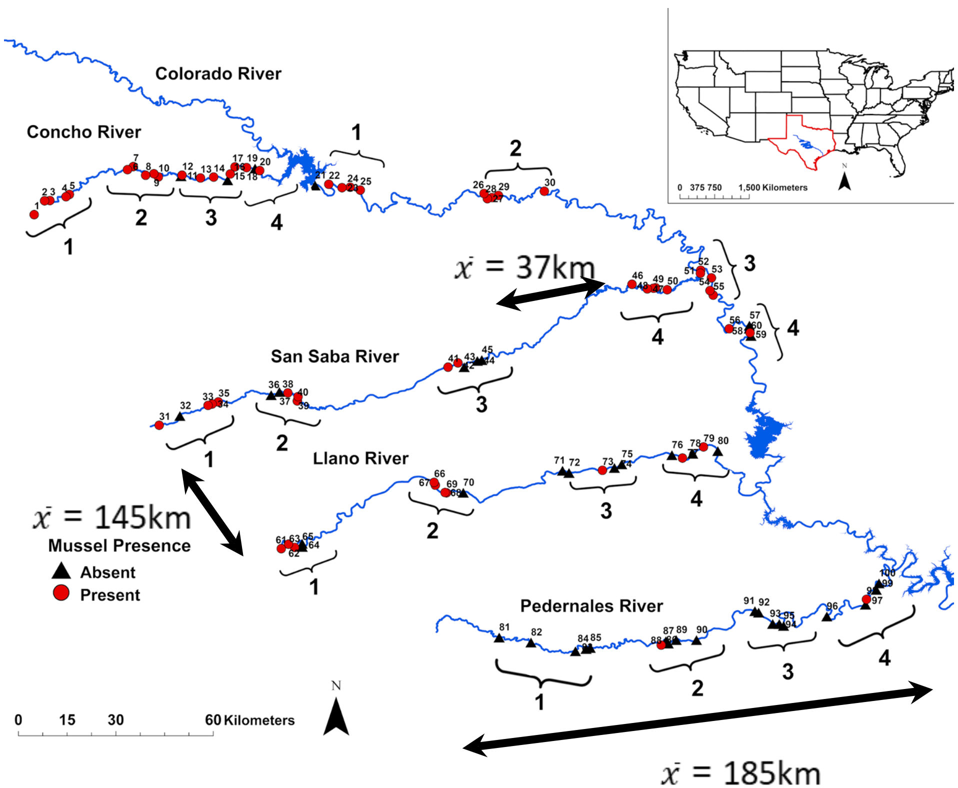




Better management of surface water and groundwater needed to protect mussels and the ecosystem services they provide

Cushway & Schwalb 2023

Distribution of mussels at sub-basin scale



Sampling of mussels at 100 pool/riffle sites with nested sampling design in upper Colorado River basin.:

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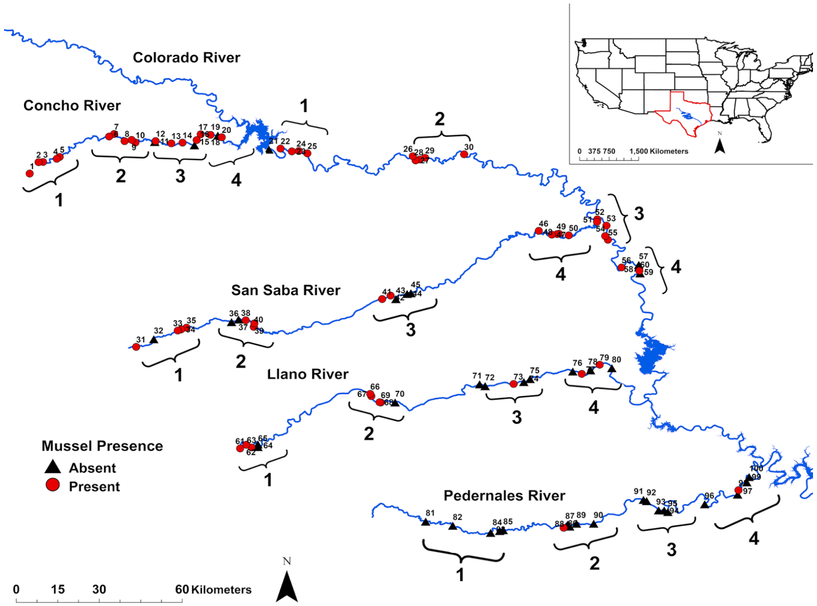
Richness and abundance



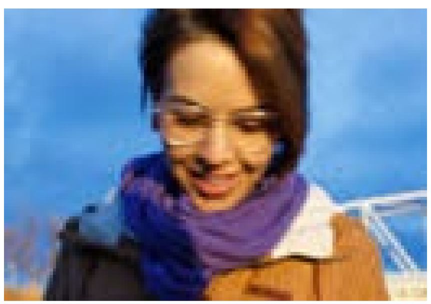
River	Richness	No of sites occupied	Average CPUE (p-h)
San Saba	12	14/20	4.3
Colorado	11	17/20	6.8
Llano	7	11/20	3.7
Concho	5	17/20	0.7
Pedernales	3	2/18	0.1

Concho: low richness and abundance, although historically highest richness

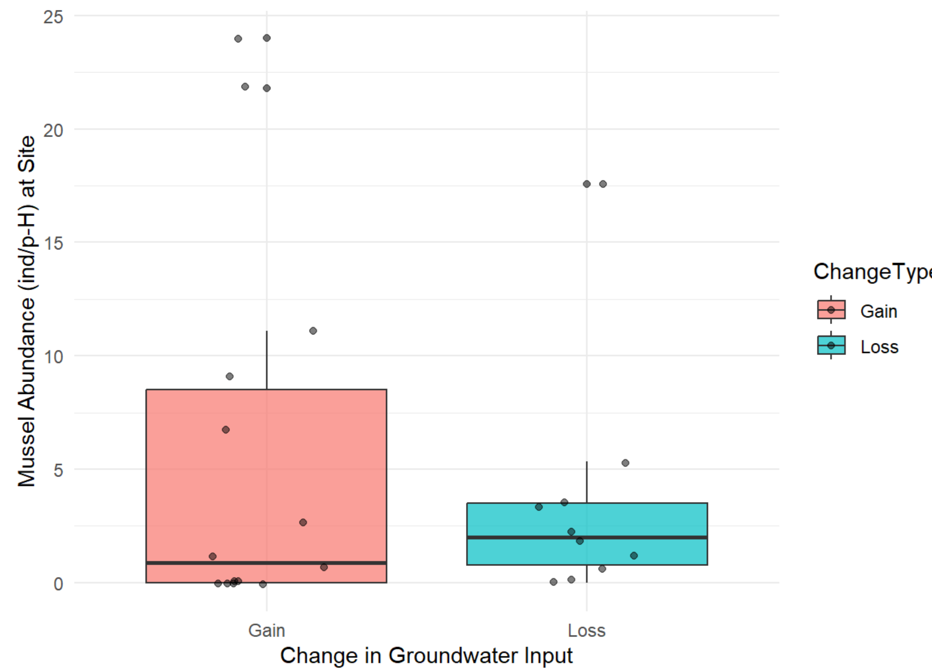
- Depauperate mussel communities

Relevance of groundwater input on larger scale?


Megan Conley and Belize Lane
Utah State University



Mariana Perez Rocha
TXST



No clear evidence, smaller scale measurements of groundwater input are needed
For example, thermal reconnaissance method (e.g., infrared) as suggested by Rosenberry et al. 2016

My questions

How would you design a study that examines the potential of groundwater influx in the upper Colorado River basin?

Which methods of measuring groundwater influx would you recommend for the San Saba or other rivers in Texas?

What is known about groundwater influx in different parts of the San Saba River?

Thank you!

An army of helpers, summer students, field and lab technicians.
My dedicated graduate students
Thesis and dissertation committee members,
Collaborators

Funding:
US Army Corps of Engineers,

TRIAGE