

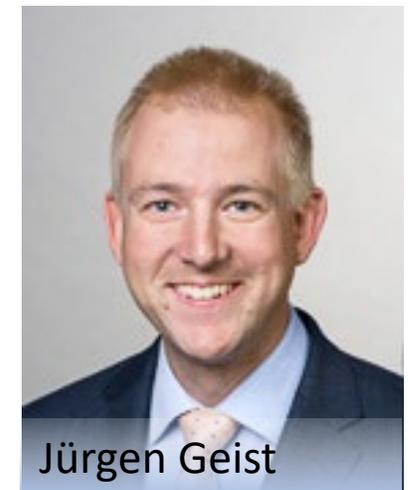


Assessing the effects of extreme climatic events on unionid mussels

Astrid N. Schwalb, (co-authors in alphabetical order):
Lyubov E. Burlakova, David Ford, Juergen Geist, Alexander Y.
Karatayev, Zachary A. Mitchell, Alison A. Tarter



Assessing long-term changes in mussel communities require successful collaborations



Climate crisis



What to expect

From the Fourth National Climate Assessment, chapter about water:

“Variable precipitation and rising temperature are **intensifying droughts, increasing heavy downpours** and reducing snowpack. Reduced snow-to-rain ratios are leading to significant differences between the timing of water supply and demand. **Groundwater depletion is exacerbating drought risk.** Surface water quality is declining as water temperature increases and **more frequent high-intensity rainfall events mobilize pollutants such as sediments and nutrients.**”

Droughts and Flooding

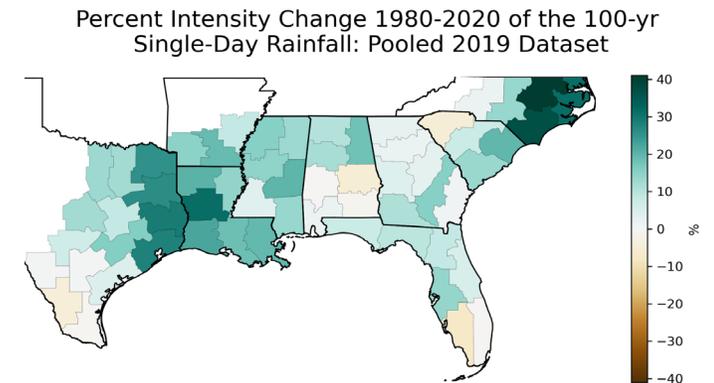
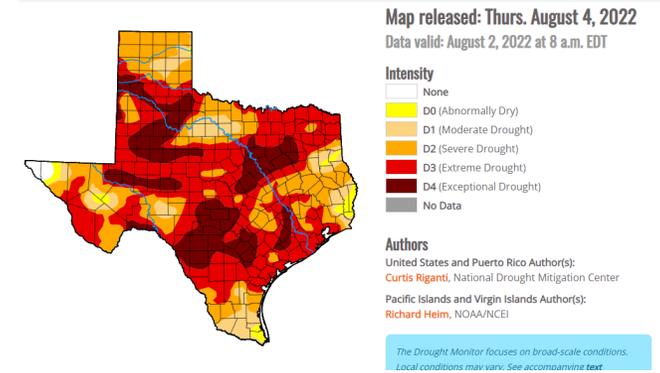
Texas: vulnerable to periods of drought,
Historically: 1910s, 1930s, 1950s, and 2010–2015 and 2022
Extreme heat predicted to become more common and higher
temperatures at night will increase water temperatures.

Tropical cyclones cause exceptional rainfall
rates in Gulf Coast region → Neches River
Example:

Cedar Bayou, Texas:
51.9 inches (1317mm) during Hurricane Harvey

Rapid swings from extreme drought to flood

Germany: droughts could become more extreme



Adaptations to drying events

Behavioral avoidance/migration abilities:

Fish swim to deeper pools,
insects fly away.

Physiological tolerance:

resistant eggs, juvenile or adult stages

Adaptive life history traits:

e.g. dormancy



Adaptations to drying events – mussels?

Behavioral avoidance:

Crawling, may track receding water

(Gough et al. 2012)

burrowing

Physiological tolerance:

Close valves,
emersion tolerance may be
species specific

~~Adaptive life history traits:~~

~~e.g. dormancy~~



Crawling tracks

Impact of drought on mussels

Decrease in mussel diversity, especially rare species.

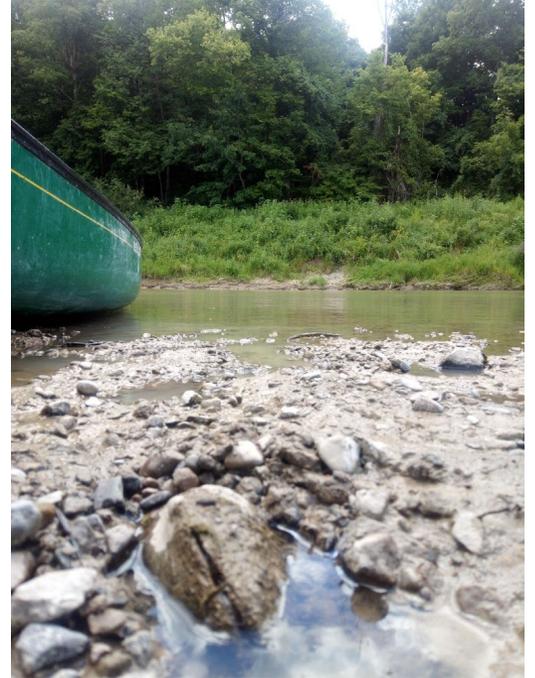
(Gagnon et al. 2004; Golladay et al. 2004; Haag and Warren 2008; Sousa et al. 2018)

Change in mussel community composition

(Gagnon et al. 2004; Golladay et al. 2004; Haag and Warren 2008)

Can lead to losses in mussel provided ecosystem services.

(Atkinson et al. 2014; Vaughn et al. 2015, DuBose et al. 2019)



© Kiara Cushway

Impact of flooding on mussels

Dislodgement out of suitable habitat
Mortality when transported to shallow areas that desiccate during low flows
(Hastie et al., 2001; Sousa et al., 2012).

Transport to unsuitable or degraded habitat may lead to population declines and reduce population recovery
(Karatayev et al., 2020).

Higher survival and faster recovery of some species?



Objectives

The objective was to test specific predictions for

- (1) the impact of an extreme drought in 2011/2012 in the **Colorado** and **Neches** River basins in **Texas** and in 2018/2019 in **Germany**, and
- (2) the impact of extreme flooding in 2017 and long-term changes in the Neches River basin (Texas Gulf coast).

by comparing recent and historical mussel community data collected at the same locations.

Objectives

The objective was to test specific predictions for

(1) the impact of an extreme drought in 2011/2012 in the **Colorado** and **Neches** River basins in **Texas** and in 2018/2019 in **Germany**

by comparing recent and historical mussel community data.

Hydrobiologia
<https://doi.org/10.1007/s10750-019-04058-3>

FRESHWATER MOLLUSCS

Changes in community composition of riverine mussels after a severe drought depend on local conditions: a comparative study in four tributaries of a subtropical river

Zachary A. Mitchell · Lyubov E. Burlakova · Alexander Y. Karatayev · Astrid N. Schwalb 

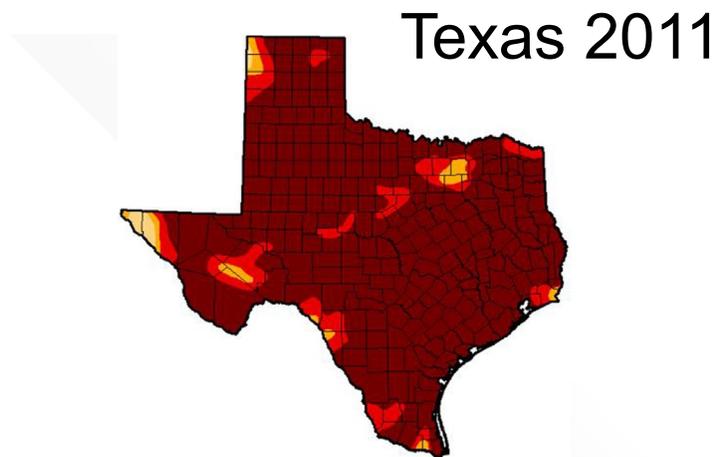
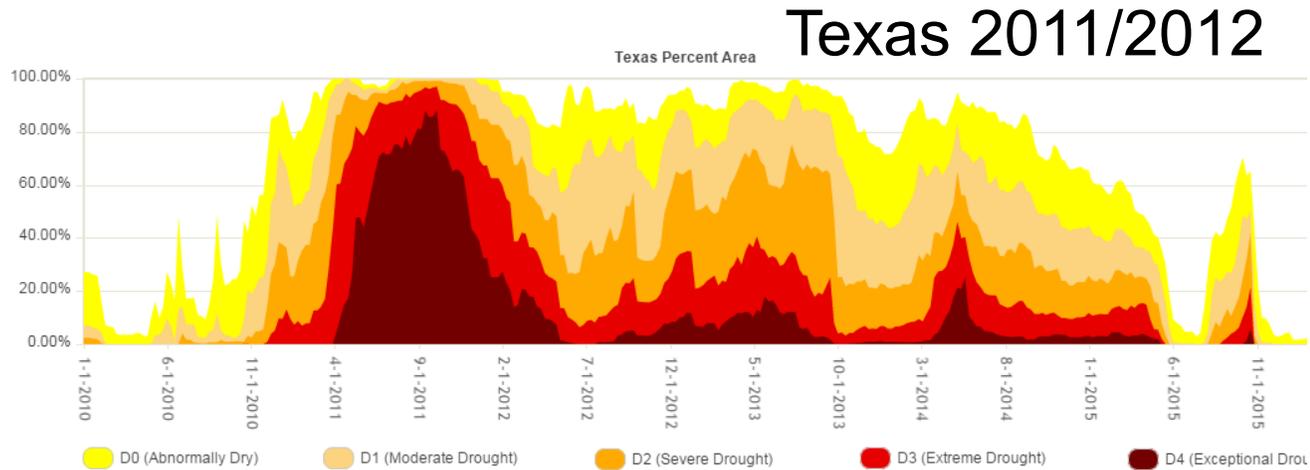
Hydrobiologia
<https://doi.org/10.1007/s10750-022-04819-7>

TRENDS IN AQUATIC ECOLOGY IV

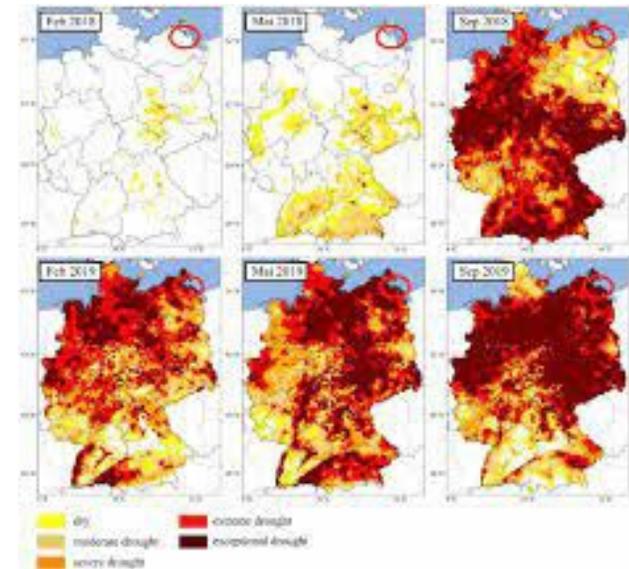
Impact of extreme climatic events on unionid mussels in a subtropical river basin

Alison A. Tarter · David F. Ford · Daniel E. Symonds · Neil B. Ford · Astrid N. Schwalb 

Extreme drought events



Germany 2018-2019



Hypotheses and predictions - drought

H1: Community-wide decline (no community shift)

Predictions:

Significant declines in CPUE and species richness,
less widespread species, more species with limited range.

H2: Differences between sites

Prediction:

More declines in species richness and CPUE in sections
with lower discharge and increased water temperature.

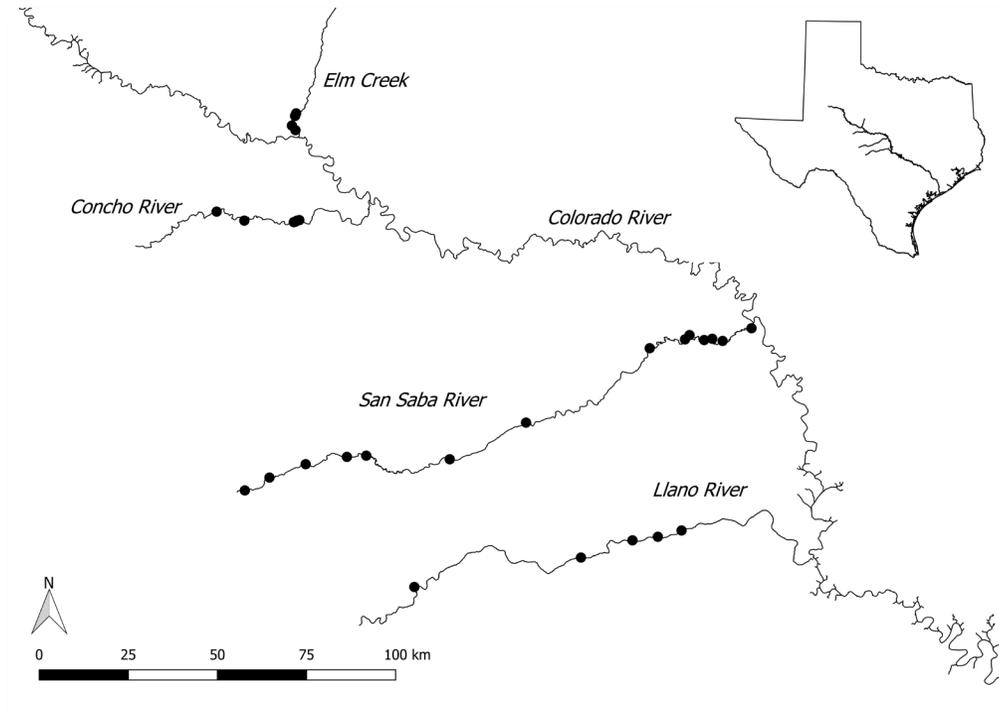
Study area: Upper Colorado River basin, TX

Texas Hill country

Mostly semi-arid
ranchland.

Flashy systems,

Limestone and karst



Elm Creek (n = 4)
Concho River (n = 7)
San Saba River (n = 14)
Llano River (n = 5)

Study area: Lower Neches River basin in Big Thicket of Southeast Texas

Heavily forested,

Slow-moving

Alluvium loam and clay

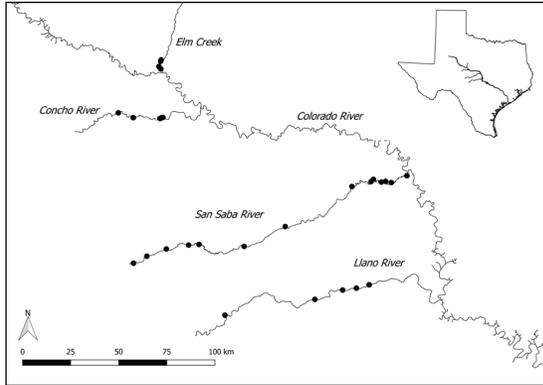
Acidic

High Organic load

Extensive history of
exploitation (logging,
subsurface resource
withdrawal, loss of
wetland)



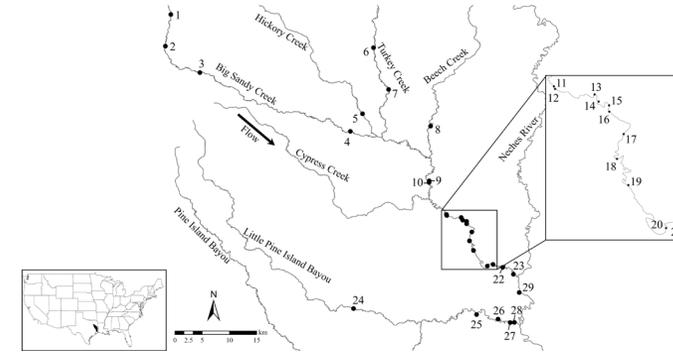
Study areas and datasets - drought



4 tributaries of the **Colorado River**
in Central Texas.

Pre-drought data: 2005-2011,
Burlakova and Karatayev

Post-drought data: 2017, Mitchell
n = 30 sites



Village Creek (Neches basin)
In East Texas.

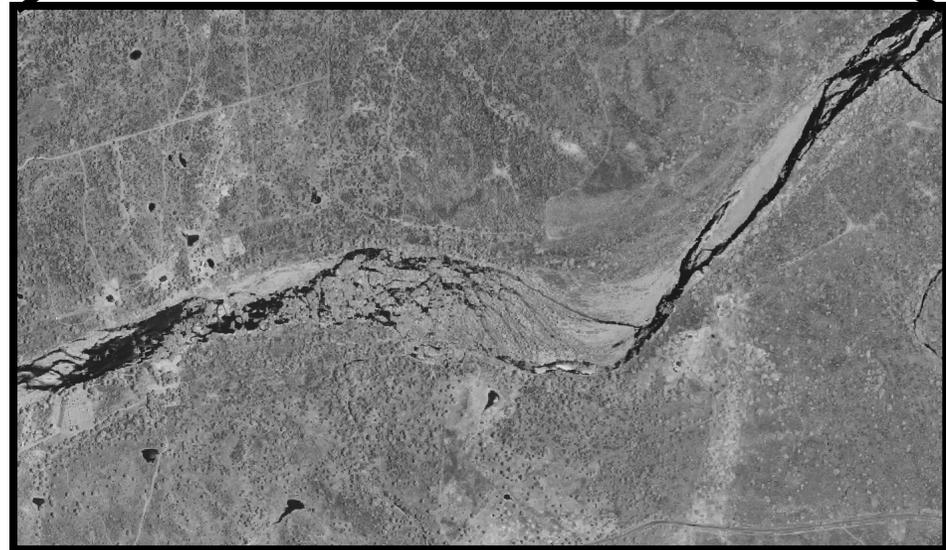
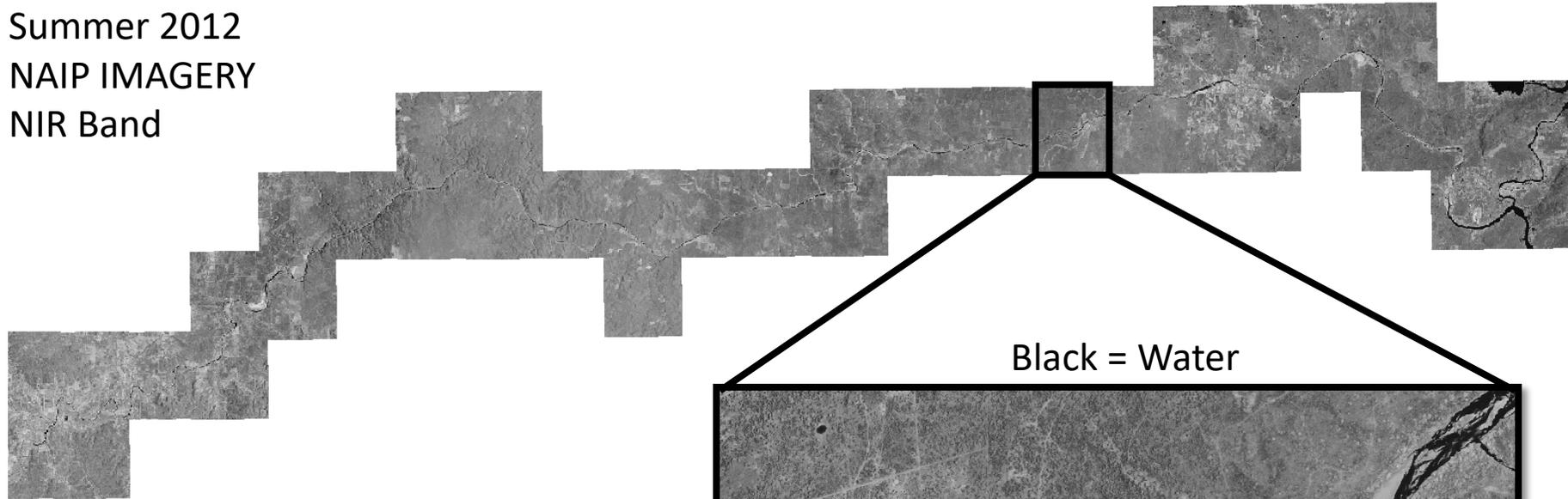
Pre-drought data: 2002,
Bordelon & Harrel

Post-drought data: 2014, Ford
n = 13 sites

Same sites were re-surveyed,
survey techniques consistent as much as possible

Assessing stream condition during drought

Summer 2012
NAIP IMAGERY
NIR Band



Hypotheses and predictions - drought

H1: Community-wide decline (no community shift)

Predictions:

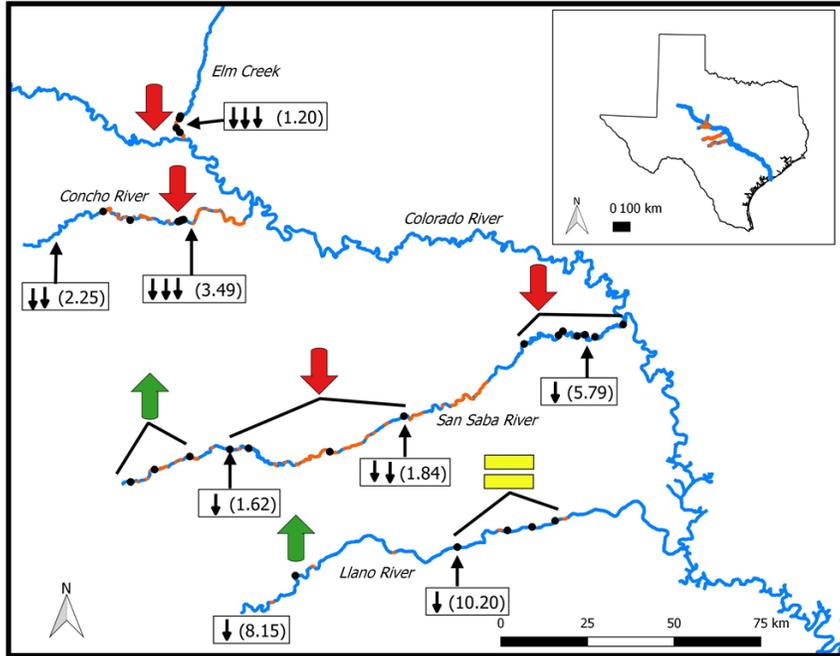
Significant declines in CPUE and species richness,
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H2: Differences between sites

Prediction:

More declines in species richness and CPUE in sections
with lower discharge and increased water temperature.

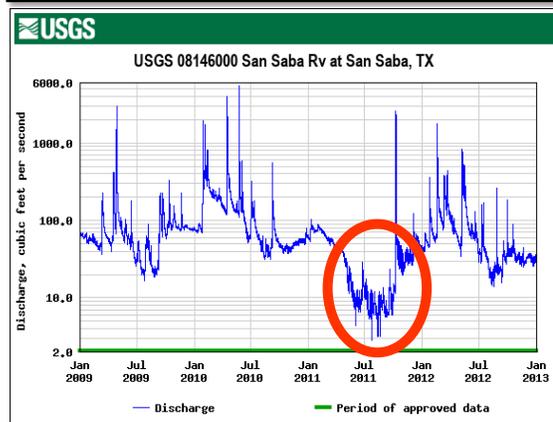
Community-wide declines?



Species richness and CPUE significantly lower (overall 50-64%) post-drought.

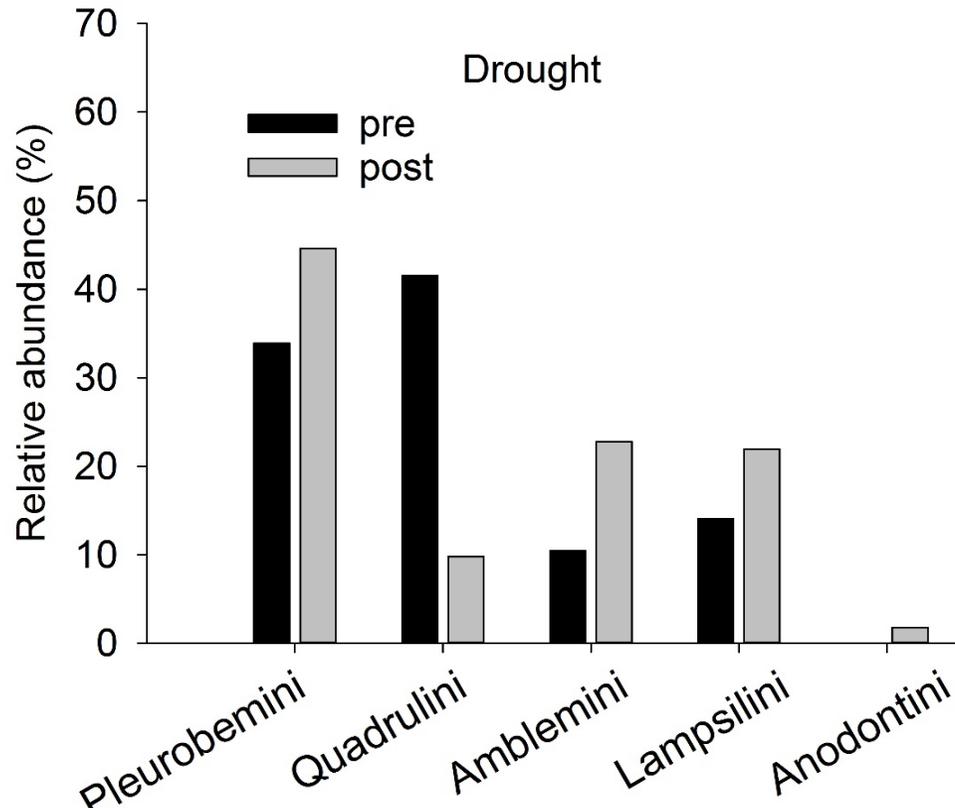
→ paired t-tests comparing species richness and CPUE per site and species. (Neches and Colorado River)

Colorado: mussels absent at 9 out of 30 sites post-drought.



Colorado tributaries: Discharge decreased 77-96% below long-term average levels

Community shifts post-drought?



Neches:

Most species (12 of 18) declined, those showing increases were mostly opportunistic and periodic species.

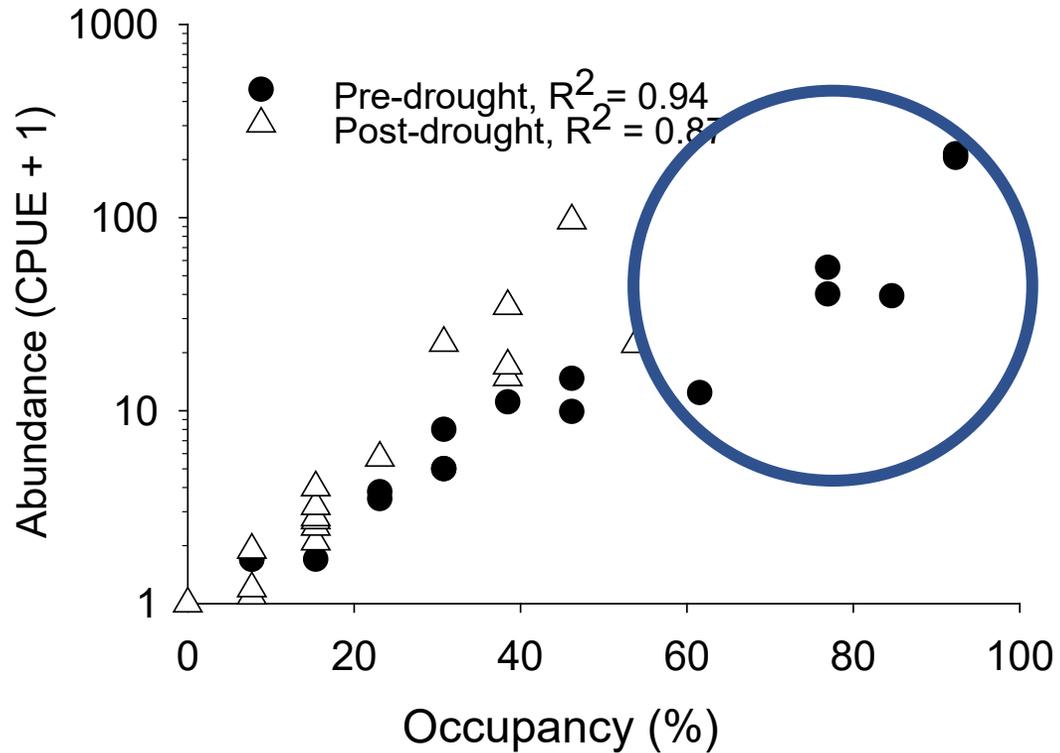
Colorado:

→ Correlation in relative abundances of species between pre- and post-drought periods
($r = 0.89-0.99$, $P = 0.05$)

Slight increases of equilibrium species, but no significant differences.

Summary: Some changes, but majority of species declined

Other detected changes post-drought



Neches:

Less widespread species

more species with limited range
post-drought

Hypotheses and predictions - drought

H1: Community-wide decline (no community shift)

Predictions:

Significant declines in CPUE and species richness,
less widespread species, more species with limited range.

Yes, but some indications of community shift as well.

Hypotheses and predictions - drought

H1: Community-wide decline (no community shift)

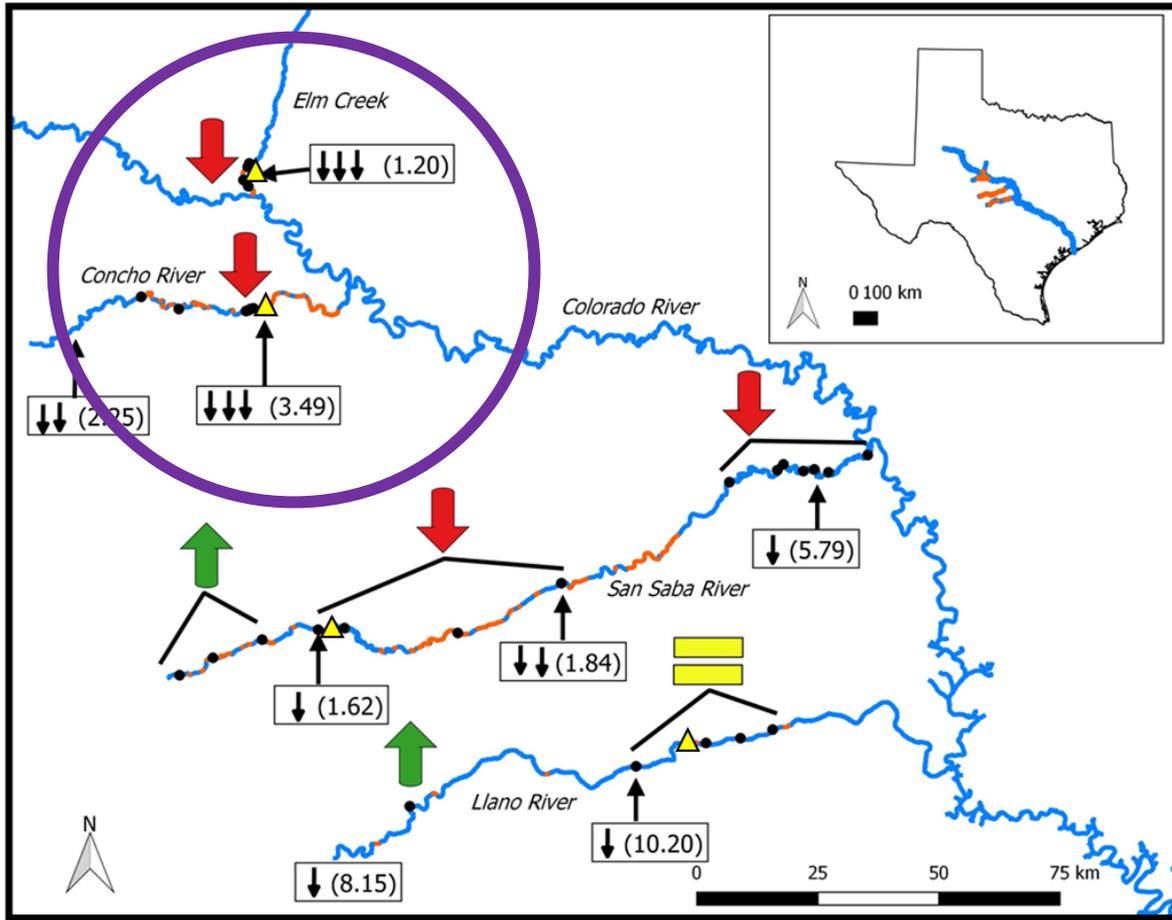
Predictions:

Significant declines in CPUE and species richness,
less widespread species, more species with limited range.

H2: Differences between sites

Prediction:

More declines in species richness and CPUE in sections
with lower discharge and increased water temperature.



No significant relationship between changes in CPUE and discharge + water temperature for all sites

BUT:

Most severe declines in tributaries with the lowest discharge and highest estimated temperature (Concho River and Elm Creek)

Decrease in discharge:

- ↓↓↓ > 87%
- ↓↓ 82-86%
- ↓ 77-81%

Higher risk of desiccation in smaller streams



Examples from Bavaria, Germany

Droughts in 2003, 2018, 2019, 2022

Streams with *Unio crassus* and *Margaritifera margaritifera* dried out

Example Nebelbach, *Unio crassus*:
July 2019, 228 recently dead, 8 alive
May 2020, 250+ dead, 7 alive



Mitigation measures - Germany



Transfer of mussels into other water bodies

Example: Evacuation of >1000 *Margaritifera margaritifera* from Zinnbach in September 2019, transfer back in October,

Risks:

- location of mussels may not be known and may only be found when already dead.
- High mortality in other water bodies if conditions are not suitable.

Other Mitigation measures - Germany

Use of former fish ponds for emergency water release (buffering effect)



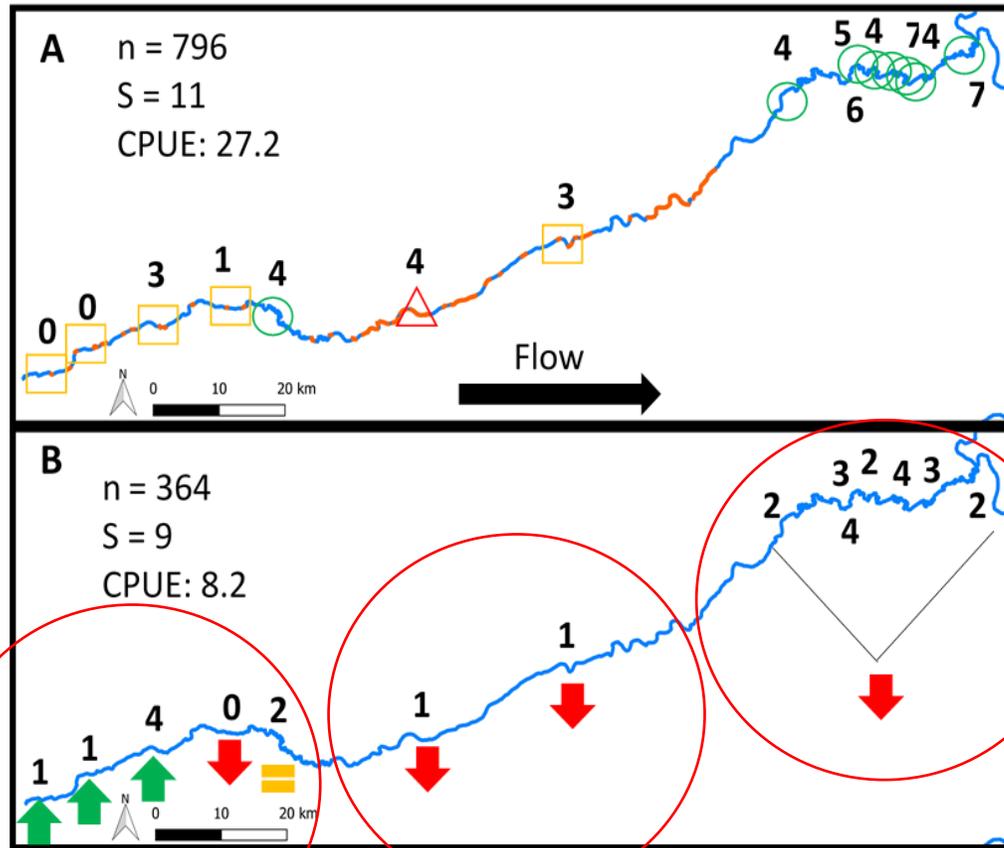
Temporary barriers for water retention



Truck-based transportation and water release into drying streams

Longitudinal differences

Example: San Saba River



3 very different sections

Declines in intermittent middle section

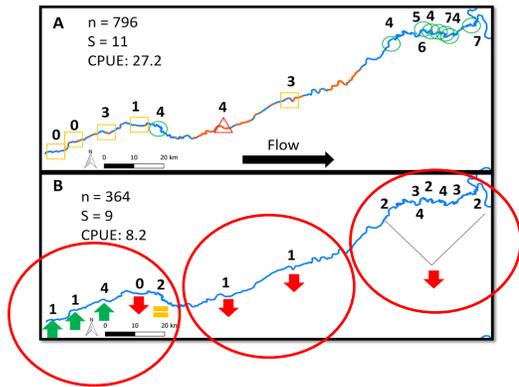
Large declines also in lower San Saba, no dry sites

Increase at upper sites

→ higher search effort post-drought.

→ More spring-influenced

Ecological refuges in sections that go dry?



Ecological refuges will not prevent large declines of mussel populations during drought

When rivers run dry: Perennial pools as ecological refuges for freshwater mussels
Kiara C. Cushway and Astrid N. Schwalb

Introduction

Freshwater mussels (family Unionidae) in drought prone regions face challenges associated with high temperatures, low dissolved oxygen levels, and desiccation. Mussels can burrow and generally track receding water levels, but cannot have limited capacity to avoid adverse conditions due to their limited mobility. The use of perennial refuges from drought, such as perennial pools, is not well understood.

Objective and Hypotheses

Objective: To understand what local conditions occurring in perennial pools may provide refuge for freshwater mussels during drought.

Hypotheses and predictions:
Geomorphological and biotic conditions affect mussel abundance in perennial Pools.

- 1) Smaller size and shallower depth, leading to increased likelihood of drying or reaching higher temperatures compared to larger, deeper pools.
- 2) Higher maximum temperatures contributing to stressful or lethal conditions, especially in isolated pools.
- 3) Higher *Corbicula* spp. densities, increasing the risk of unfavorable conditions due to mussel die-offs or competition for space and other resources.

Methods

Study area: San Sabá River, TX

Focus on drying sites in anthropogenic water use and undraining geology

Methods:

- 41 pools have been sampled in fall 2021 and summer 2022
- 21 perennial pools
- 10 pools that periodically dry

Abiotic and biotic characteristics of pools were recorded; mussel presence and community composition were surveyed with larval searches.

Stepwise selection and multiple regression were used to evaluate factors influencing mussel abundance in pools.

Preliminary Results

Mussels were either absent in pools or occurred in low numbers, with five mussels found at 14 of the 27 currently sampled sites.

Across sites, 61 individuals of 8 species were found.

The maximum number of mussels found at a site was 26 (8 p-H limited search).

No mussels were found in pools that have gone dry more than once since 2004 according to aerial imagery.

73% of mussels found were *Lamprolaima* species, which are endemic to the Colorado River basin and a candidate for listing under the Endangered Species Act.

Figure 1. Abundance of freshwater mussel species found in perennial pools in the San Sabá River during fall 2021 and summer 2022.

Stepwise regression resulted in selection of the following variables:

- Invasive *Corbicula* density
- Average pool depth (m)
- Percent clay substrate

Pool size and maximum temperature were not chosen by the stepwise selection, but both tended to exhibit a generally negative relationship with abundance.

Acknowledgements

Special thanks to the 2021-2022 Schwalb Stream Ecology Lab, volunteers from the Texas State Wildlife Society, and the many landowners who provided their access and advice for this project. Funding for the project was provided by the United States Army Corps of Engineers.

Preliminary Results cont.

Table 1. Results of linear regression using abundance as response variable and predictor variables selected by stepwise selection and multiple regression.

Variable	Standard Error	t	P	
Intercept	-1.28	0.86	-1.52	P < 0.001
Corbicula density	0.08	0.80	1.07	P < 0.001
Average pool depth	1.25	0.58	2.16	P < 0.05
Clay substrate (%)	0.04	0.56	0.71	P > 0.05

R² = 0.79 F = 21.05 p < 0.001 FDR = 0.89

Discussion and Next Steps

As drying and hot temperatures are becoming a major threat for mussels in regions which are experiencing more frequent and more intense droughts due to climate change, deeper perennial pools may serve as important refuges for mussels to avoid desiccation and lethal high temperatures.

Groundwater input may be especially important for maintaining adequate habitat conditions, which is the focus of ongoing investigations.

Higher invasive *Corbicula* densities in pools where more mussels were found may reflect better quality habitats where both species are buffered from challenges associated with drought.

Overall, low mussel densities in the middle San Sabá indicate that drying represents a serious stressor in this river section and ecological refuges will not prevent a large decline of mussel populations during droughts.

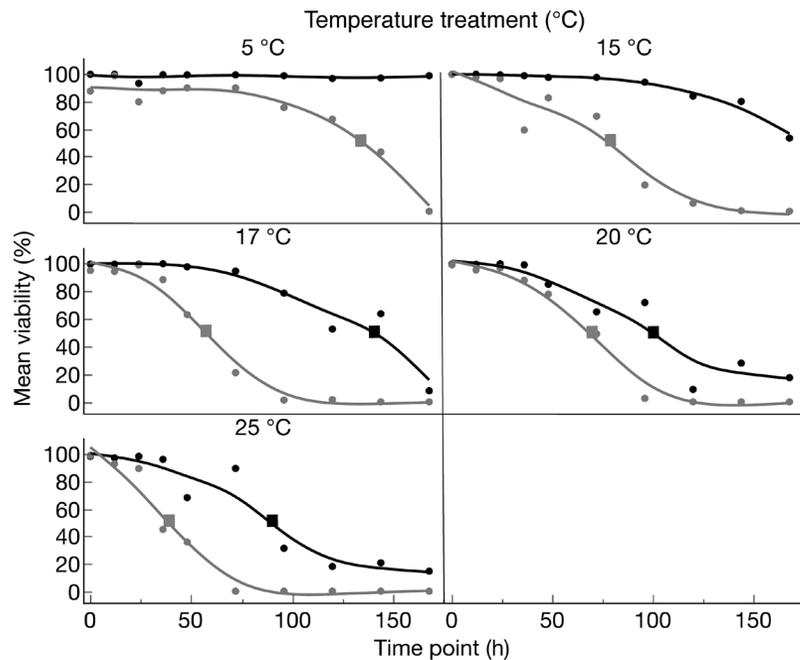
Do deeper perennial pools serve as important refuge for mussels to avoid desiccation?

→ Check out Kiara Cushway's poster!

Other factors to consider

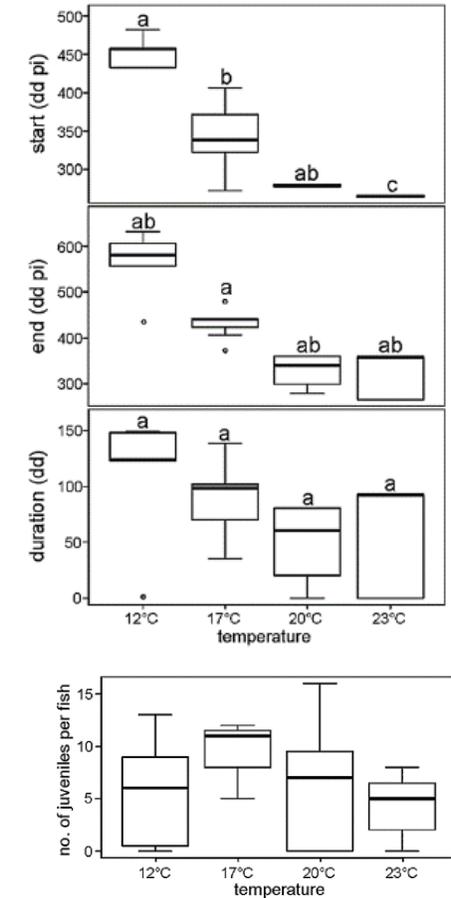
Impact of higher temperature on reproduction, e.g., glochidia development

Higher temperatures may favor invasive species



Benedict & Geist 2021

Example: Survival of glochidia at higher temperatures: non-native Chinese Pond Mussel (*Sinanodonta woodiana*) > native *Unio crasus*



Taeubert, El-Nobi & Geist 2014

Summary- drought

Community-wide declines post-drought observed in very different regions:
semi-arid rangeland and
forested wetlands in subtropical climate;
small streams in temperate climate

Some indications for community-shifts,
opportunistic species may be quicker to recover,
thick-shelled species may be better able to withstand desiccation, but only
for limited time period.

Highest risk for streams with lower discharge.

Objectives

The objective was to test specific predictions for

(1) the impact of an extreme drought in 2011/2012 in the **Colorado** and **Neches** River basins in **Texas** and in 2018/2019 in **Germany**, and

(2) the impact of extreme flooding in 2017 and long-term changes in the Neches River basin (Texas Gulf coast).

by comparing recent and historical mussel community data collected at the same locations.

Hypotheses and predictions

H3: Impact of flooding: Community shift; (no community-wide decline)

Predictions:

No significant differences in CPUE and species richness

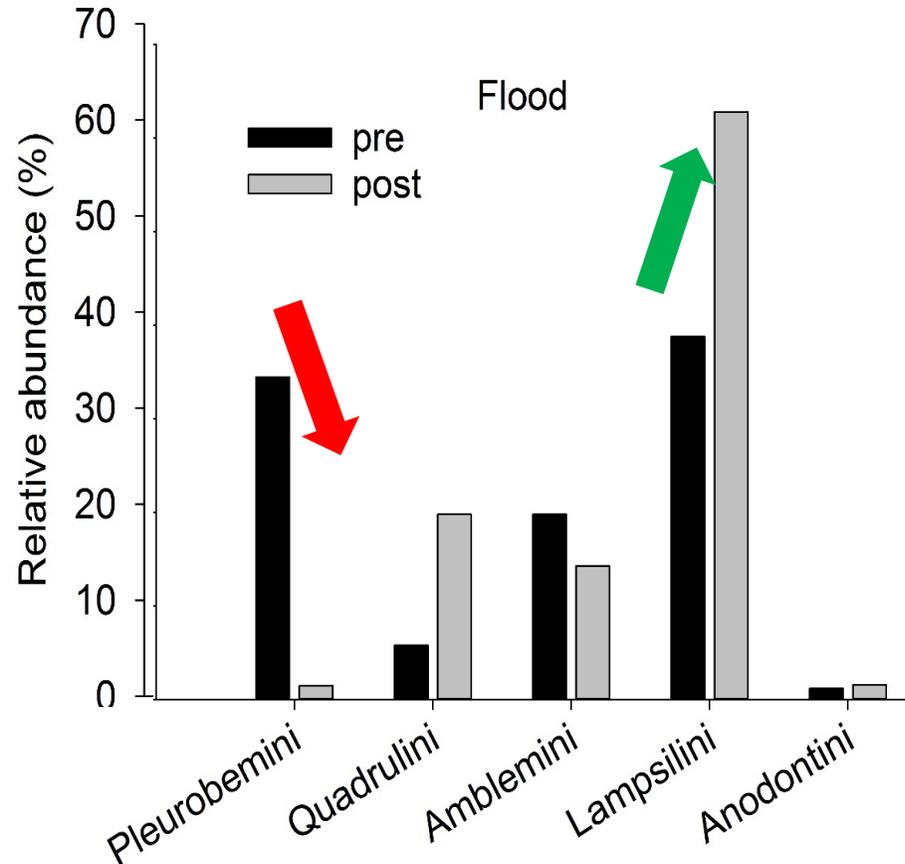
Comparing data from 16 sites collected in 2014 and 2018 (Hurricane Harvey 2017)

H4: Long-term changes:

Community-wide decline + community shift

Comparing data from 9 sites collected in 2002 and 2018

Community shifts post-flooding?



> 25% change:

Pleurobemini ↓

Lampsillini ↑

Most species (15 of 23 species) showed smaller changes (magnitude <10 ind./p-H).

No significant differences in CPUE and species richness; increase in species richness at the six most downstream sites.

highest increases by *Glebula rotundata* (tolerant of brackish water)
→ Saltwater intrusion?

Saltwater intrusion

Rangia cuneata
(Atlantic Rangia)

estuarian bivalve
requires saline water to
complete larval stage

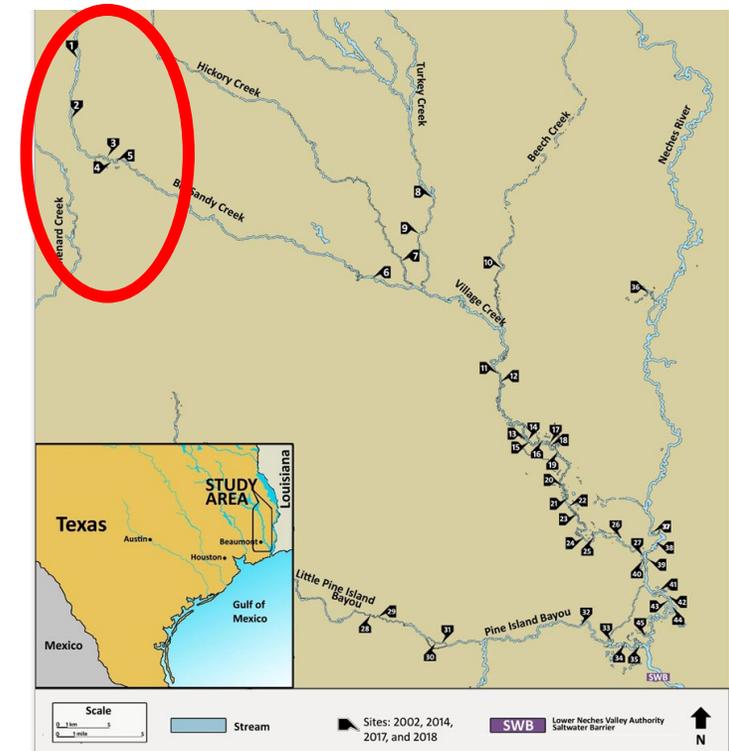


Importance of flow refuge - Upper Village Creek



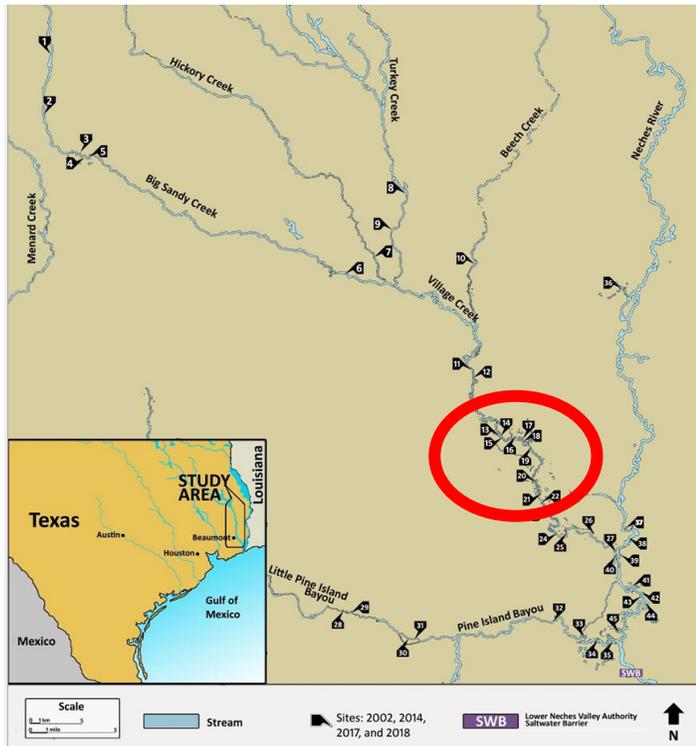
2018/05/10

Mussels found post-Harvey only within tree roots, providing structure and flow refuge



Impact of flooding depends on geomorphology

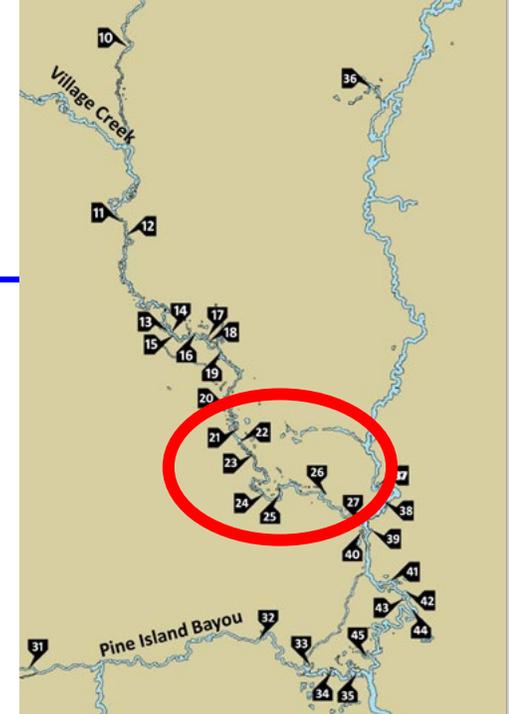
High erosion, highly incised channel, and little sinuosity in Mid Village Creek
Very few mussels found
Little structure in channel



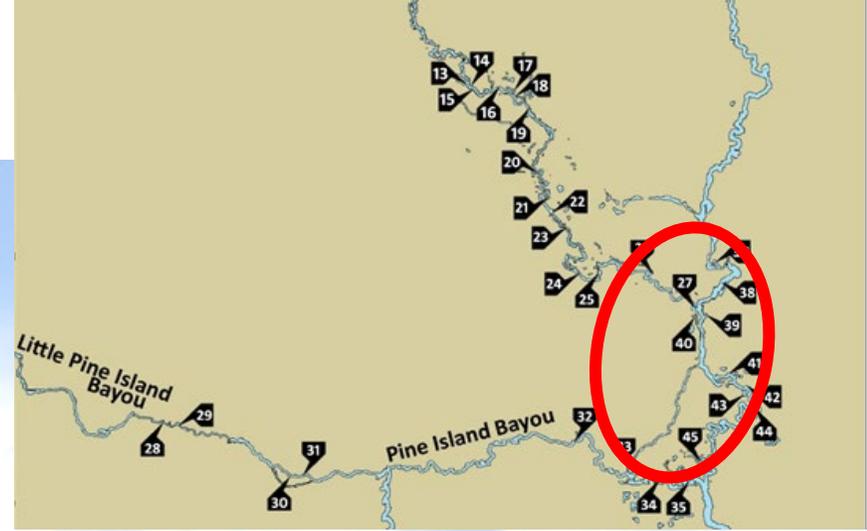
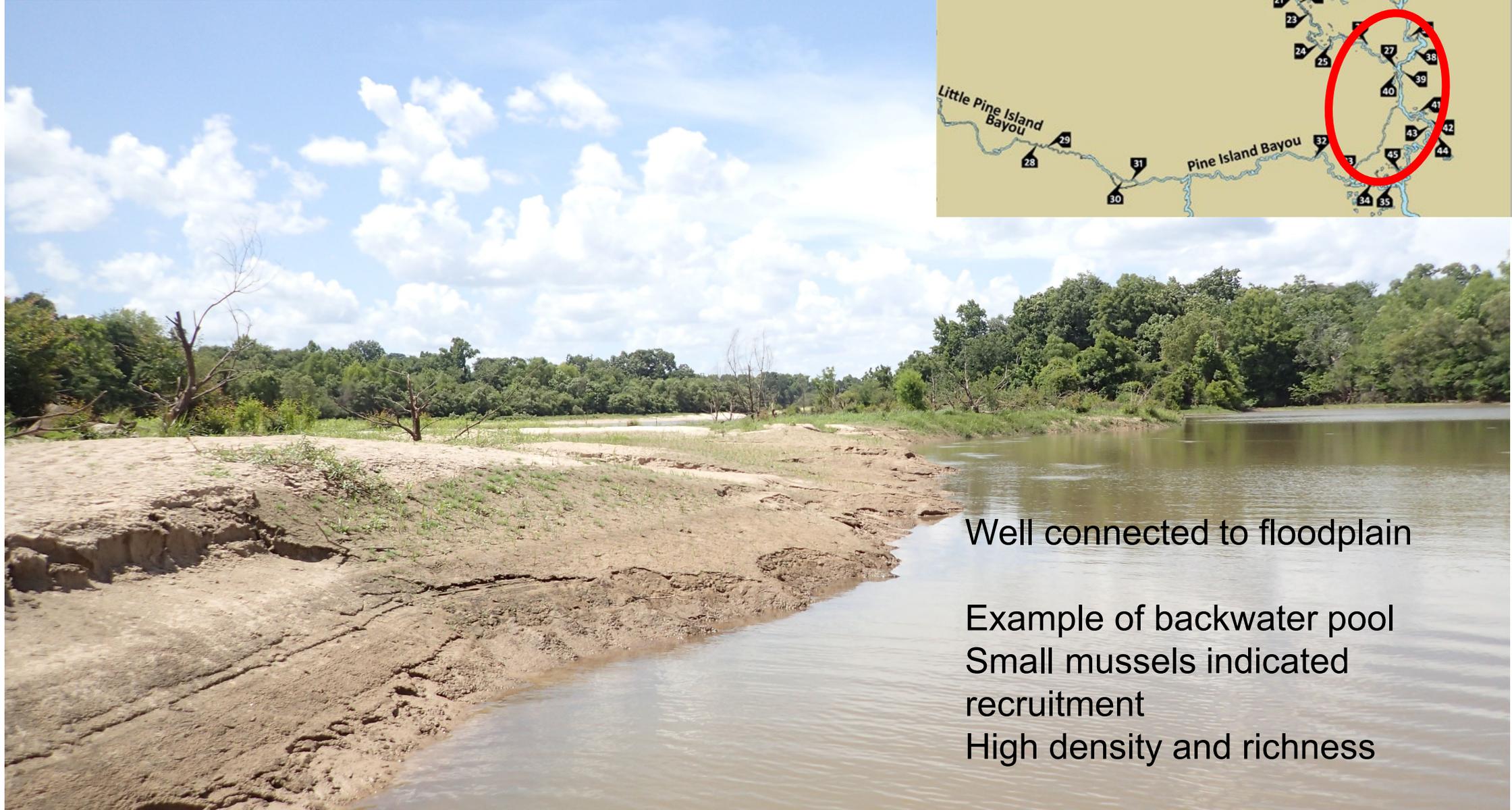
Importance of flow refuge - Lower Village Creek

Decline in slope compared to Mid Village Creek
Well connected with floodplains
Log jams provide structure

High mussel richness and abundance



Lower Neches River

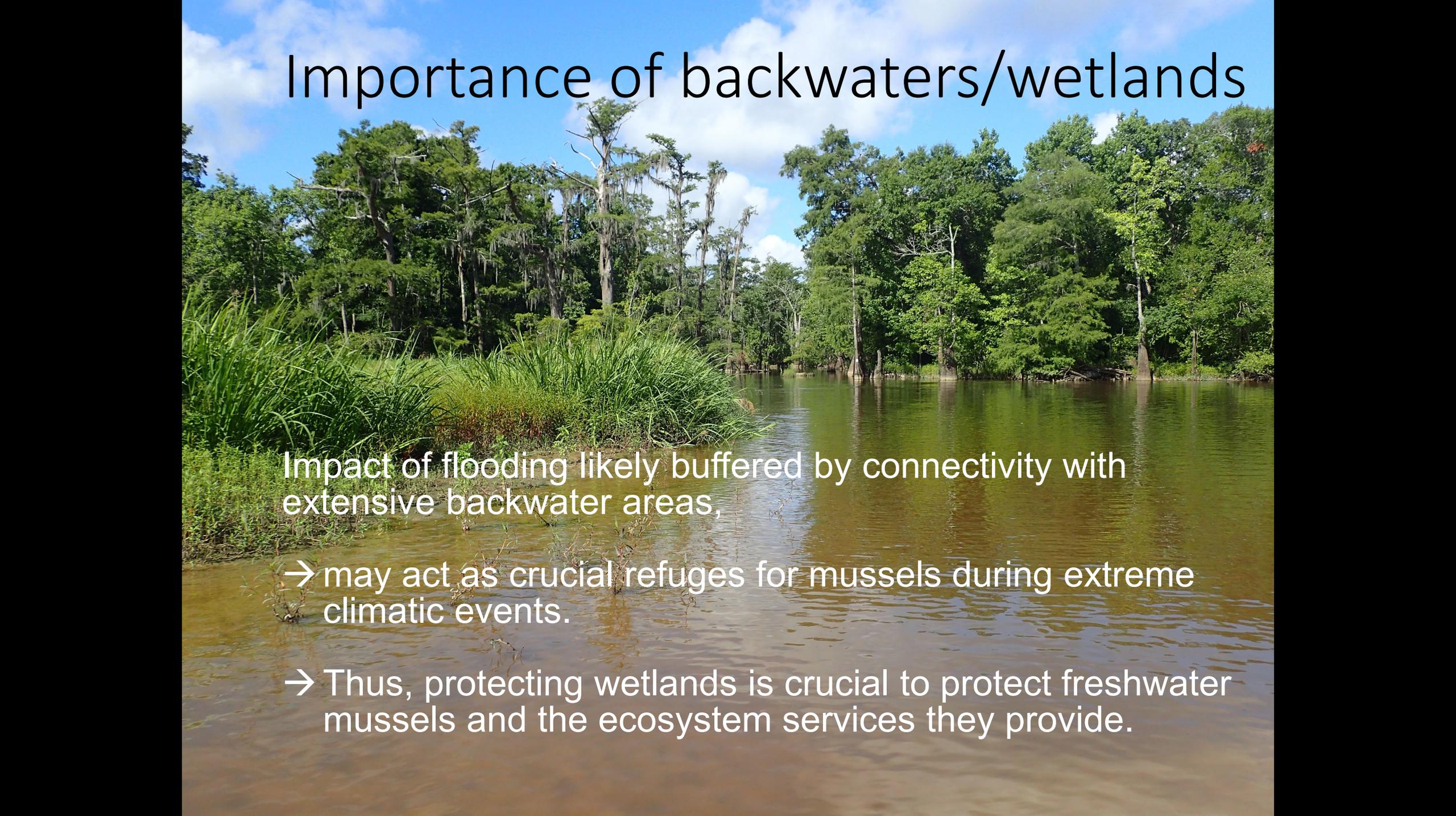


Well connected to floodplain

Example of backwater pool
Small mussels indicated
recruitment

High density and richness

Importance of backwaters/wetlands

A photograph of a wetland area. In the foreground, there is a body of water with a brownish-green hue. To the left, there is a dense patch of tall, green grasses. The background is filled with a thick forest of green trees, some of which appear to be cypress trees with Spanish moss hanging from their branches. The sky is blue with scattered white clouds.

Impact of flooding likely buffered by connectivity with extensive backwater areas,

→ may act as crucial refuges for mussels during extreme climatic events.

→ Thus, protecting wetlands is crucial to protect freshwater mussels and the ecosystem services they provide.

Hypotheses and predictions

H3: Impact of flooding: Community shift; (no community-wide decline)

Predictions:

No significant differences in CPUE and species richness



H4: Long-term changes:

Community-wide decline + community shift

Comparing data from 9 sites collected in 2002 and 2018

Long-term community-wide declines?

Significant declines in CPUE:

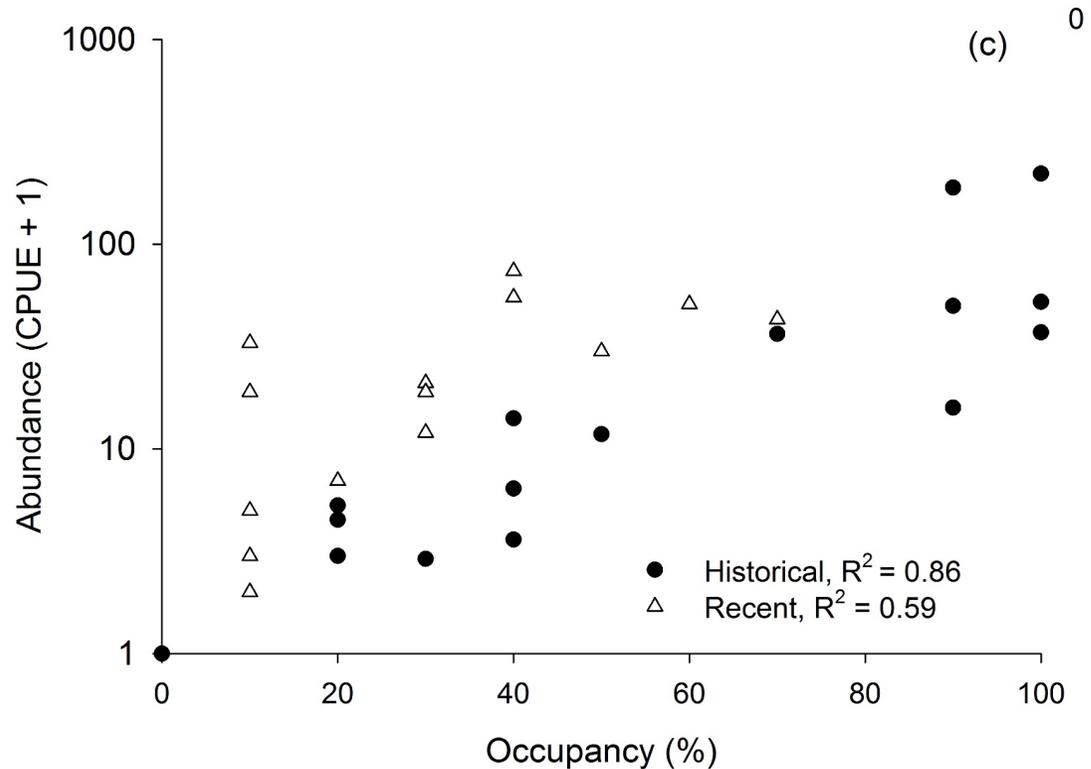
2018: 37.1 ± 25.1 mussels per p-H

2002: 64.1 ± 25.1 mussels per p-H

and species richness

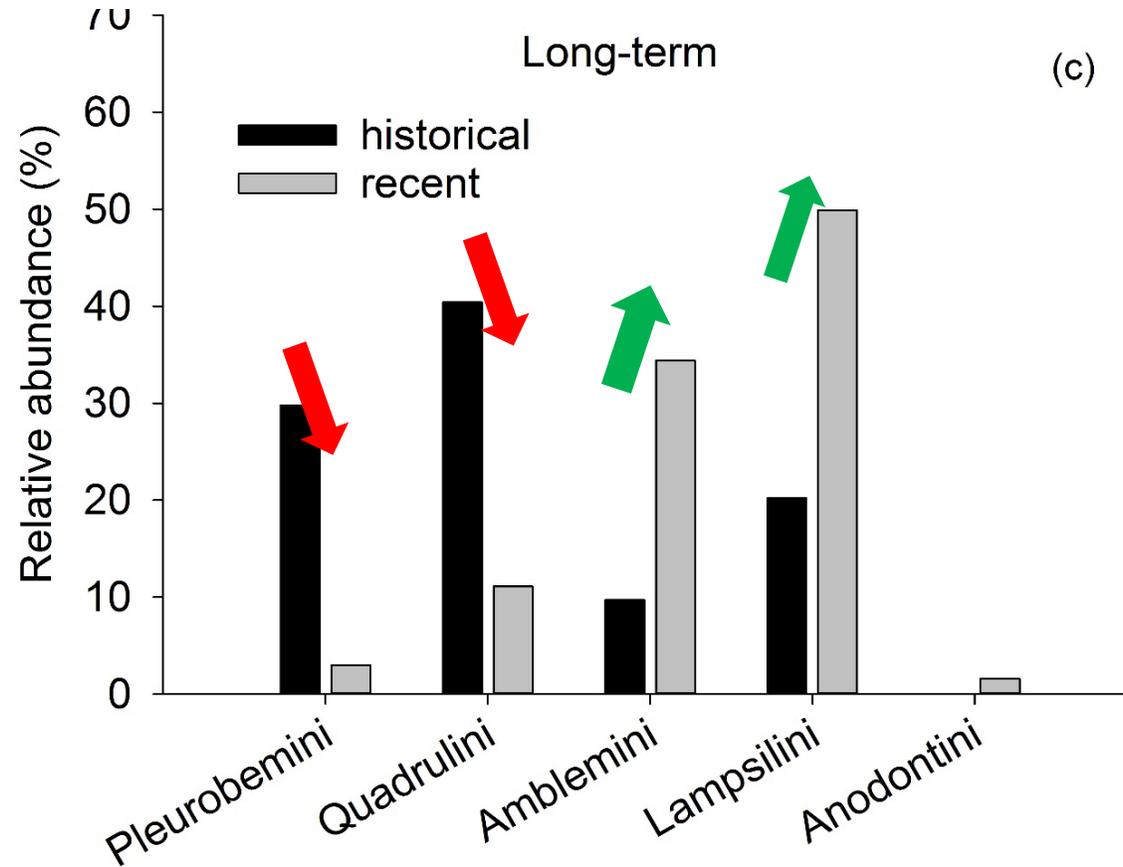
2018: 4.8 ± 2.0 , range: 0-13

2002: 9.2 ± 2.0 , range: 6-12



Less widespread species,
more species with limited range

Long-term community shifts?



(c) Shift from a dominance of Pleurobemini and Quadrulini to Amblemini and Lampsilini

A third (7 of 22) of the species declined or were not found. Declines were primarily equilibrium species. Most increases were fairly small.

Summary

Drought:

most detrimental impact leading to **community-wide declines**, indicated by a significant decline of abundances, species richness and occupied sites.



Flooding:

Community shift and changes in spatial distribution.
impact of flooding was likely buffered by connectivity with extensive backwater areas.

→ crucial refuges for mussels during extreme climatic events



Long-term:

community-wide declines + **community shifts**
dominance of species more tolerable of disturbance.

Thanks!

