Assessing the effects of extreme climatic events on unionid mussels

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Assessing long-term changes in mussel communities require successful collaborations

Climate crisis

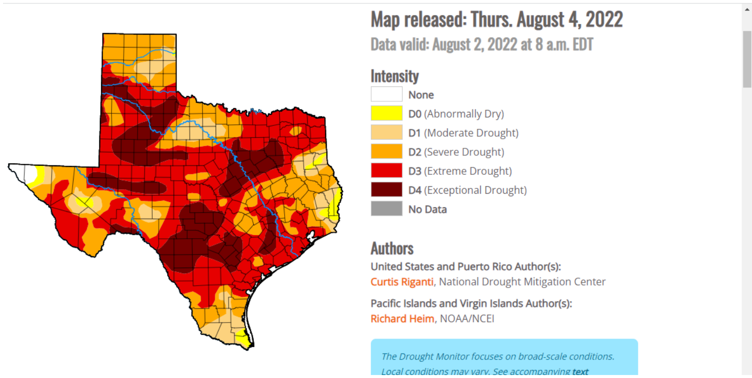
What to expect

From the Fourth National Climate Assessment,
chapter about water:

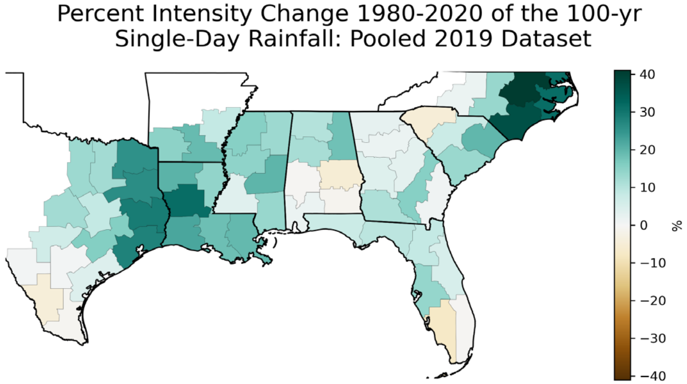
“Variable precipitation and rising temperature are **intensifying droughts**, **increasing heavy downpours** and reducing snowpack. Reduced snow-to-rain ratios are leading to significant differences between the timing of water supply and demand. **Groundwater depletion is exacerbating drought risk**. 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

<u>Behavioral avoidance/migration abilities</u>:
Fish swim to deeper pools,
insects fly away.

<u>Physiological tolerance:</u>
resistant eggs, juvenile or adult stages

<u>Adaptive life history traits:</u>
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)

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.

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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

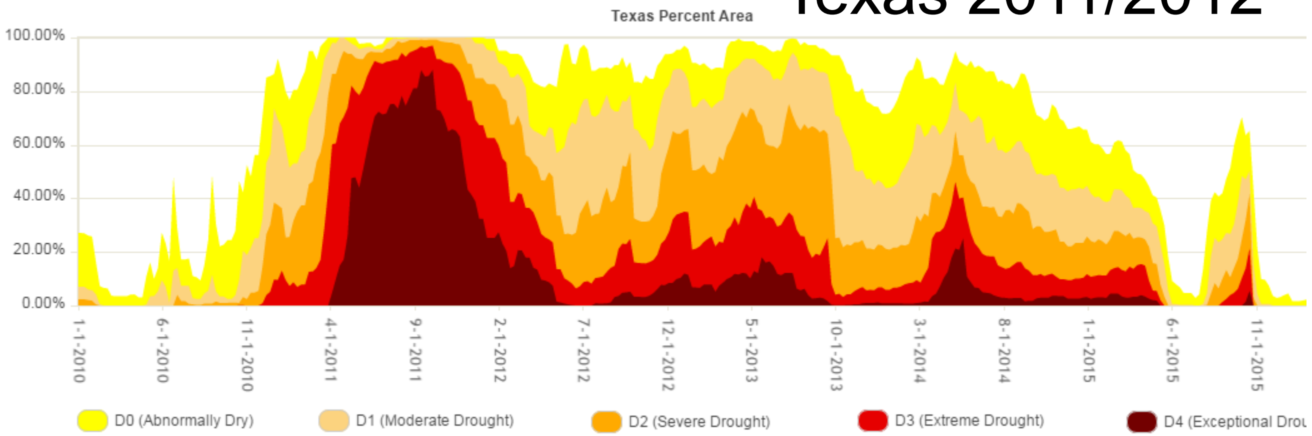
TRENDS IN AQUATIC ECOLOGY IV

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

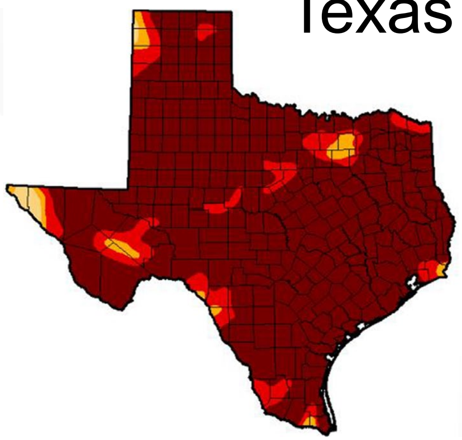
Alison A. Tarter · David F. Ford · Daniel E. Symonds · Neil B. Ford · Astrid N. Schwalb

Extreme drought events

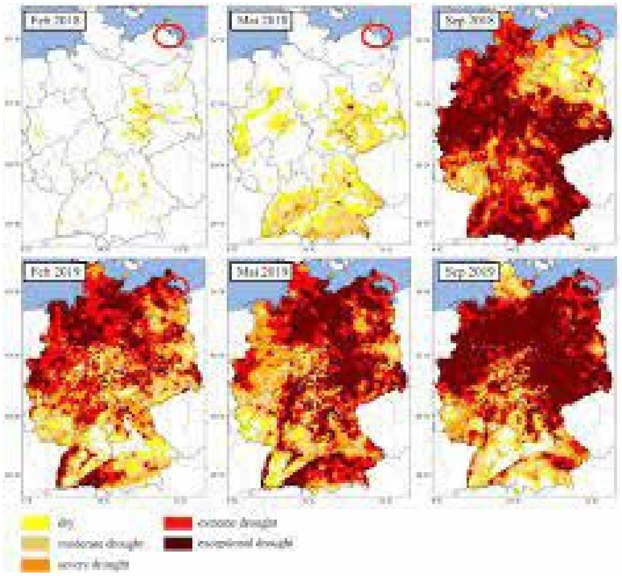
Texas 2011/2012



Texas 2011



Germany 2018-2019



https://www.drought.gov, Scharnweber et al. 2020

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.

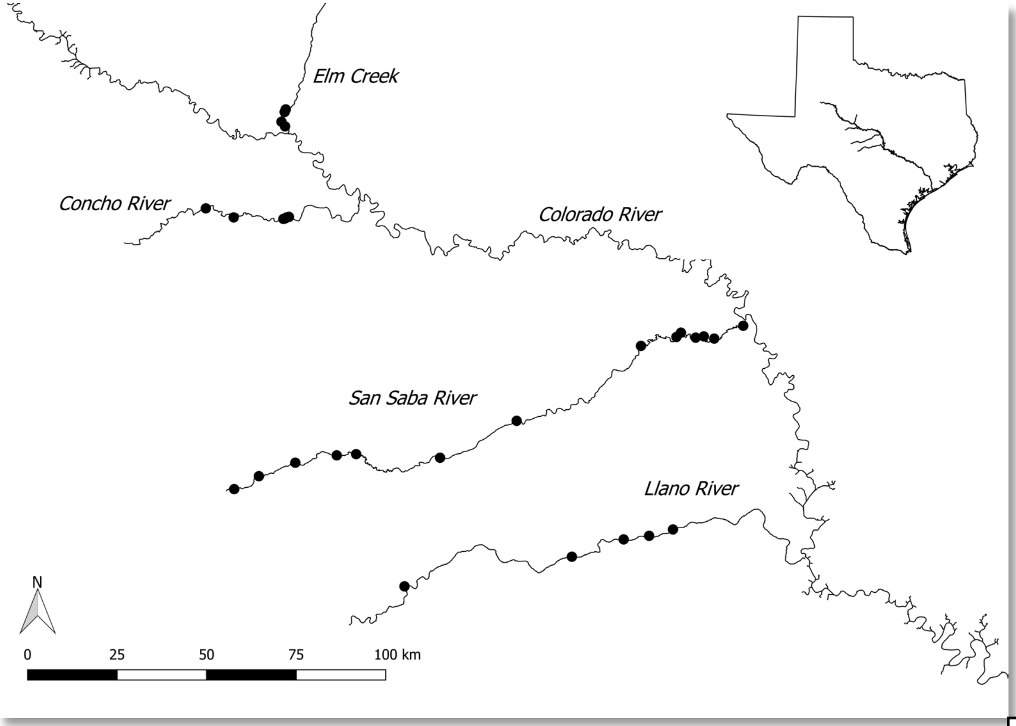
Study area: Upper Colorado River basin, TX

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

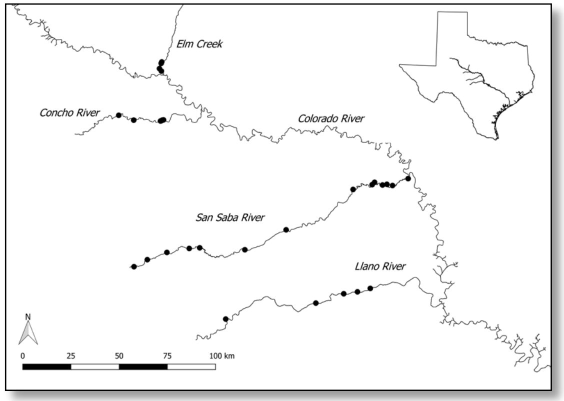
Alluvium loam and clay

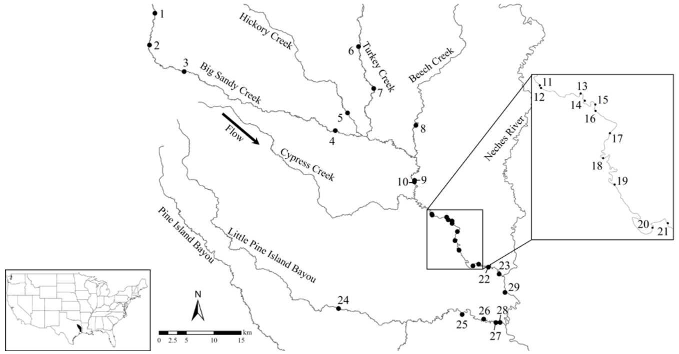
Acidic

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.

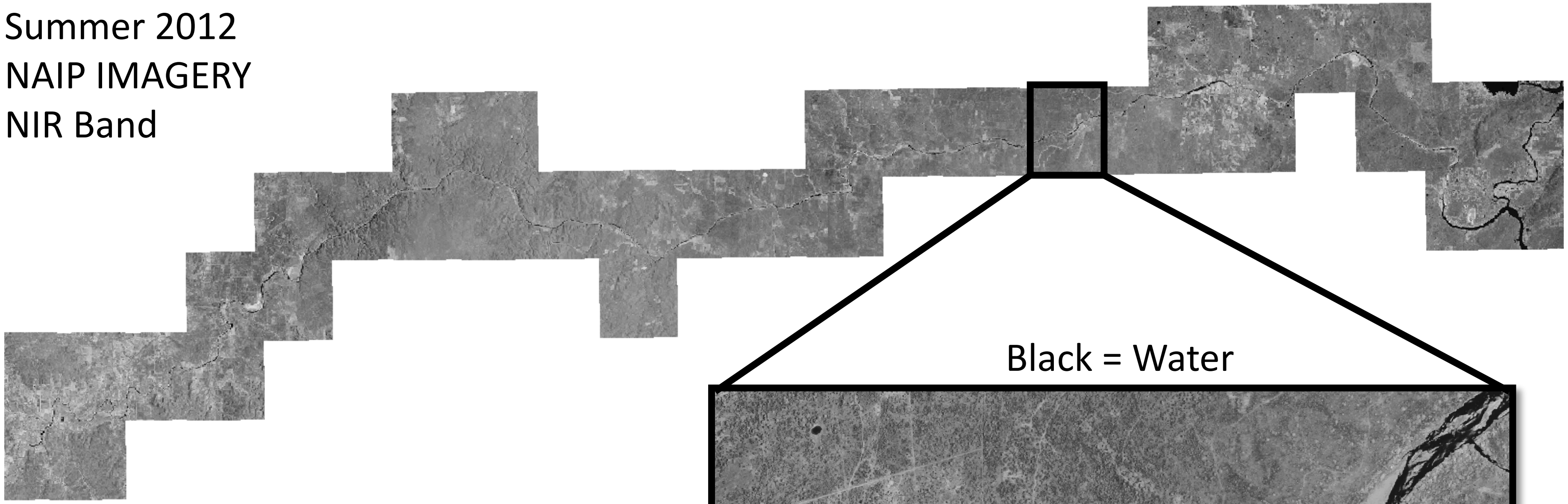
Pre-drought data: 2002,
Bordelon & Harrel

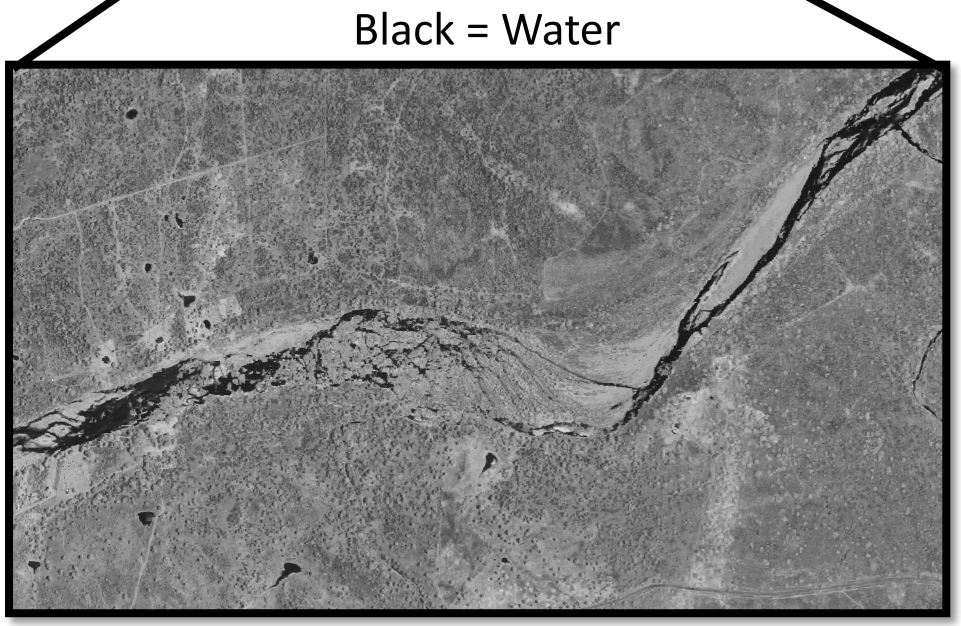
Post-drought data: 2014, Ford
n = 13 sites

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

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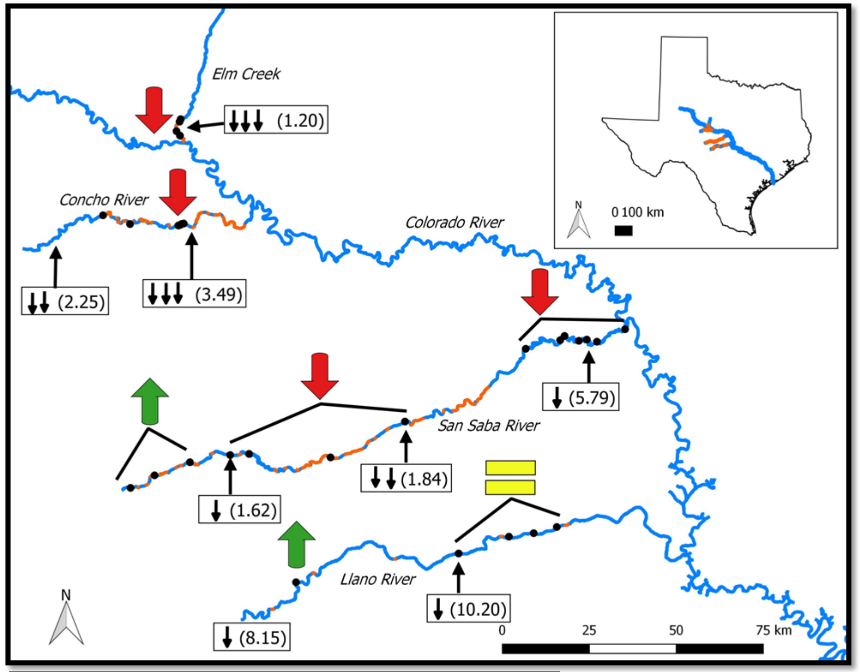
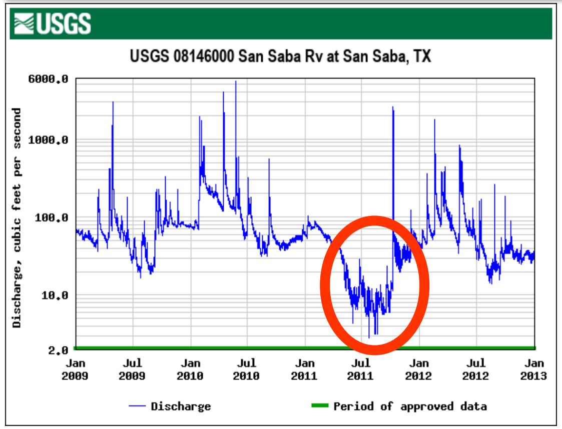
Community-wide declines?





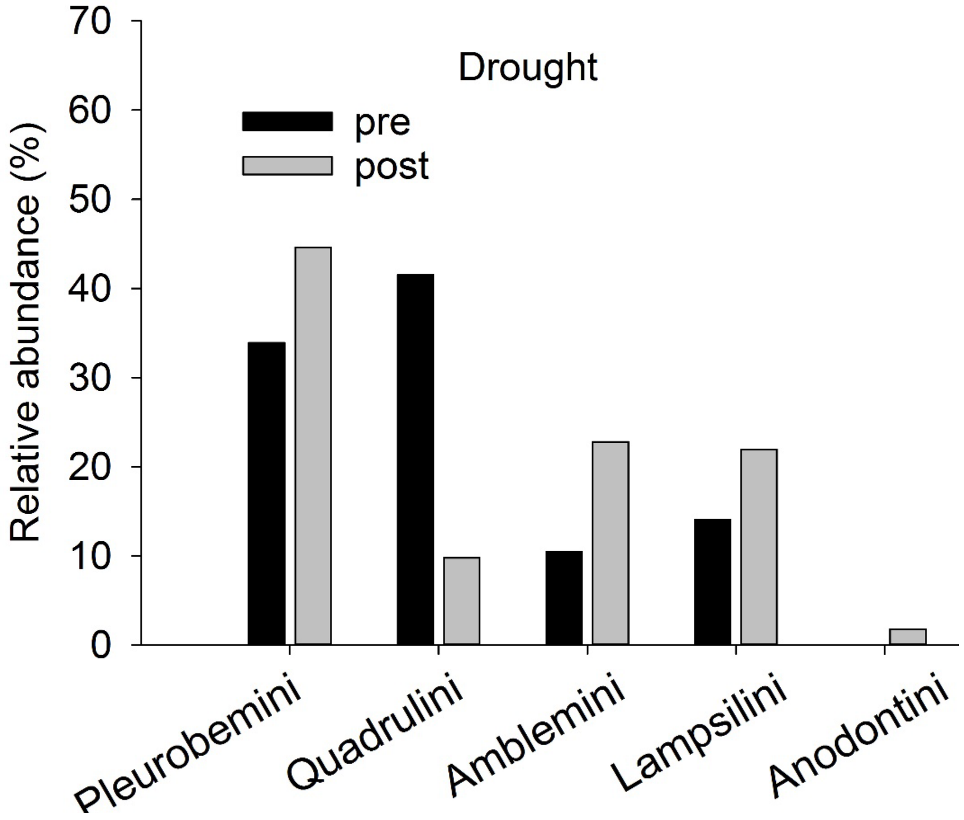
Species richness and CPUE significantly lower (overall 50-64%) post-drought.

→ 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?



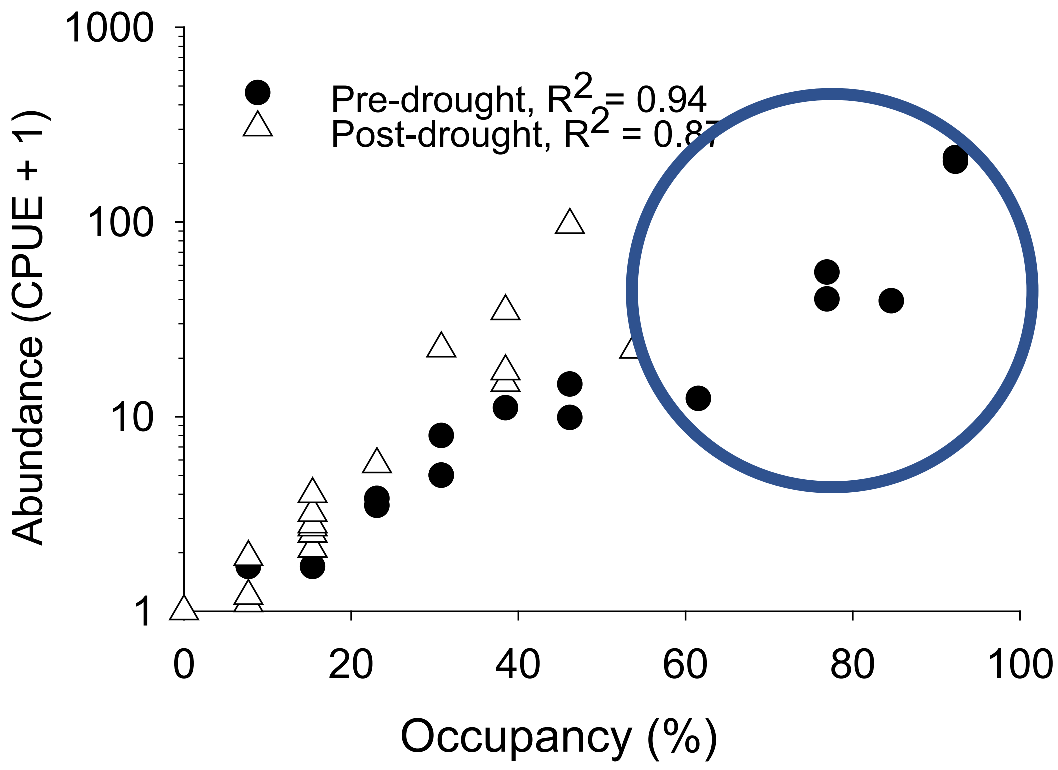
<u>Neches:</u>
Most species (12 of 18) declined, those showing increases were mostly opportunistic and periodic species.

<u>Colorado:</u>
→ 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: <u>Some changes, but majority of species declined</u>

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

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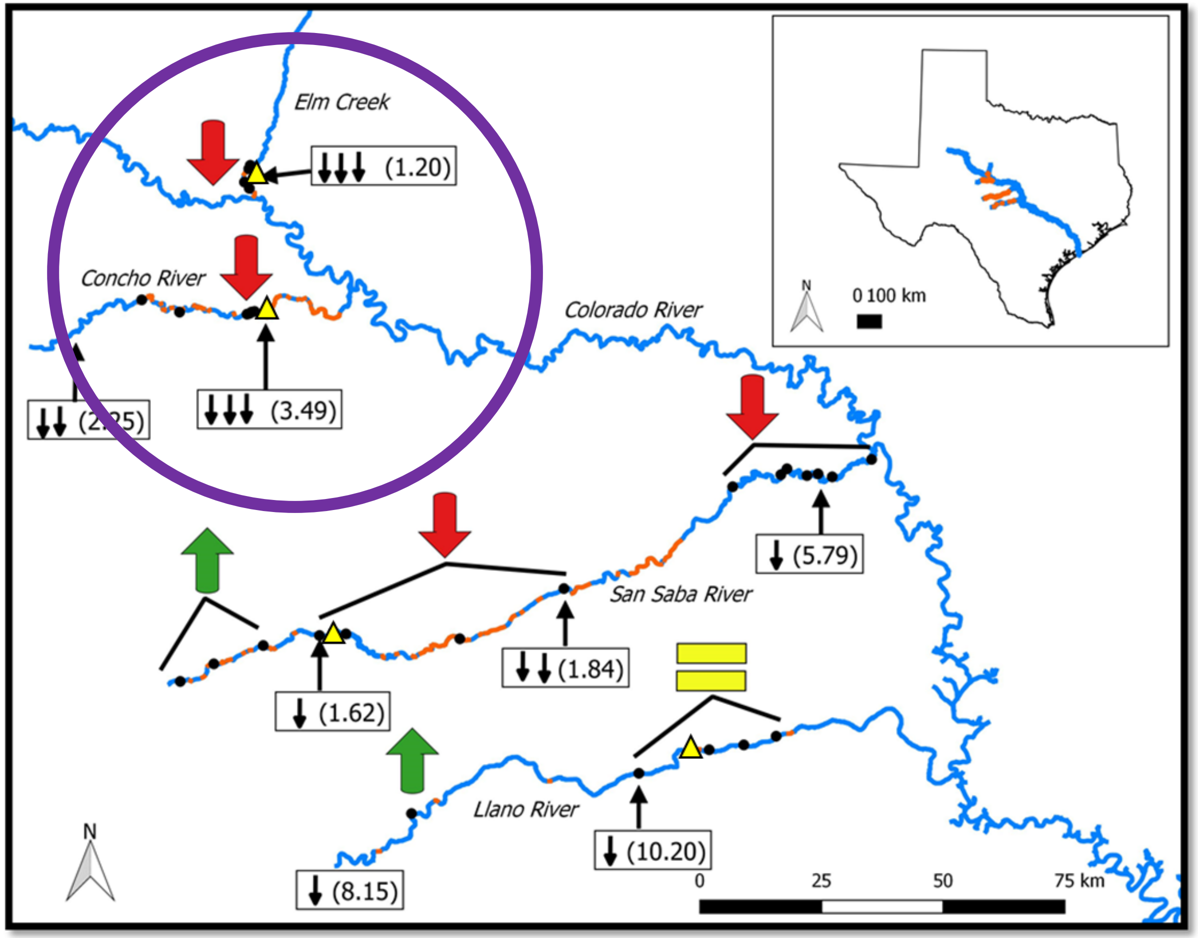


Decrease in discharge:

> 87%

82-86%

77-81%

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)

Higher risk of desiccation in smaller streams





<u>Examples from Bavaria, Germany</u>
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

J. Geist

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

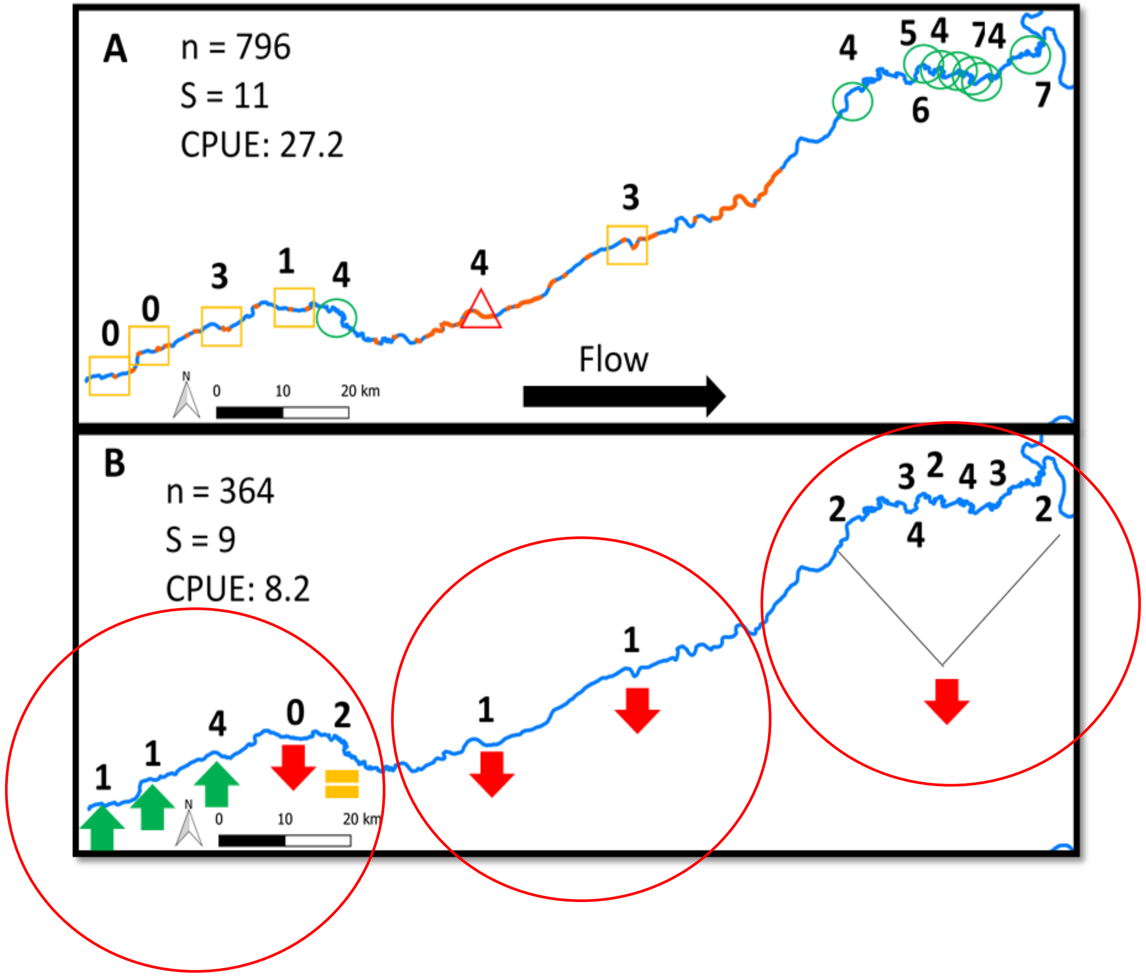
Use of former fish ponds for emergency water release (buffering effect)

Temporary barriers for water retention

Truck-based transportation and water release into drying streams

J. Geist

Longitudinal differences
Example: San Saba River



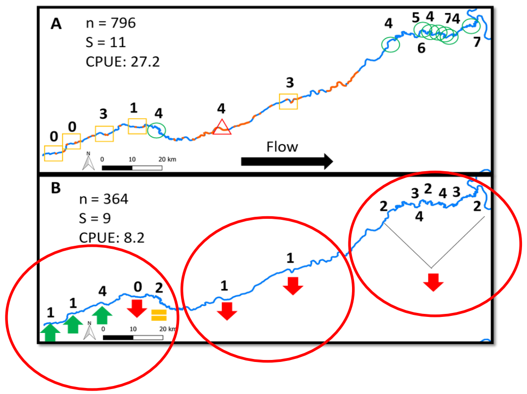
3 very different sections

Declines in intermittent middle section

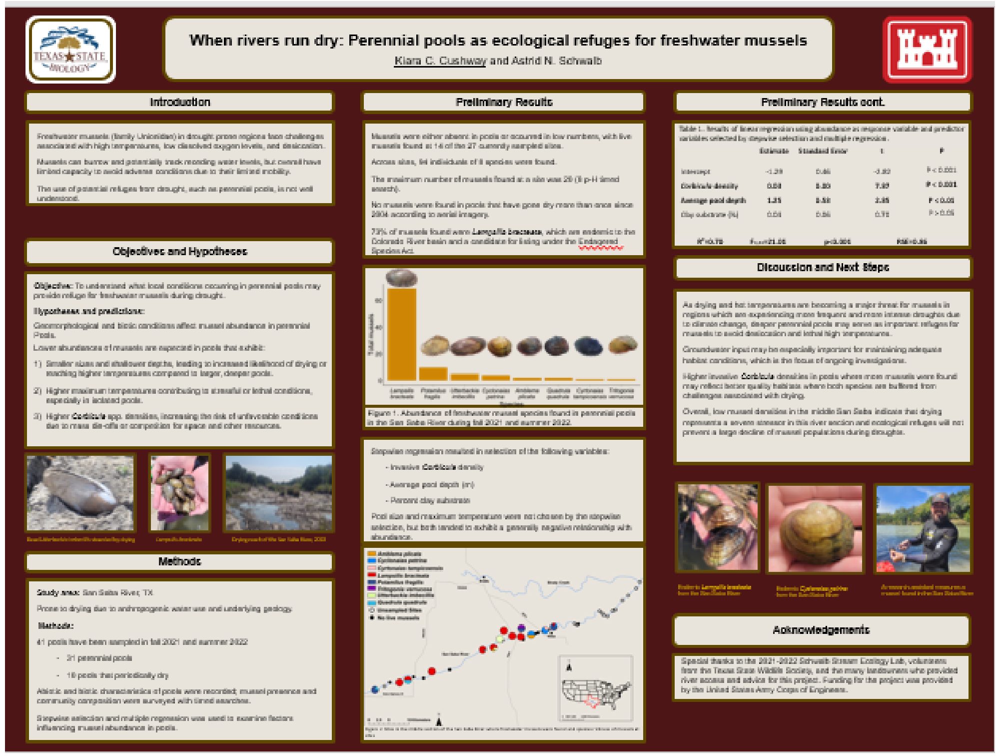
Large declines also in lower San Saba, no dry sites

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



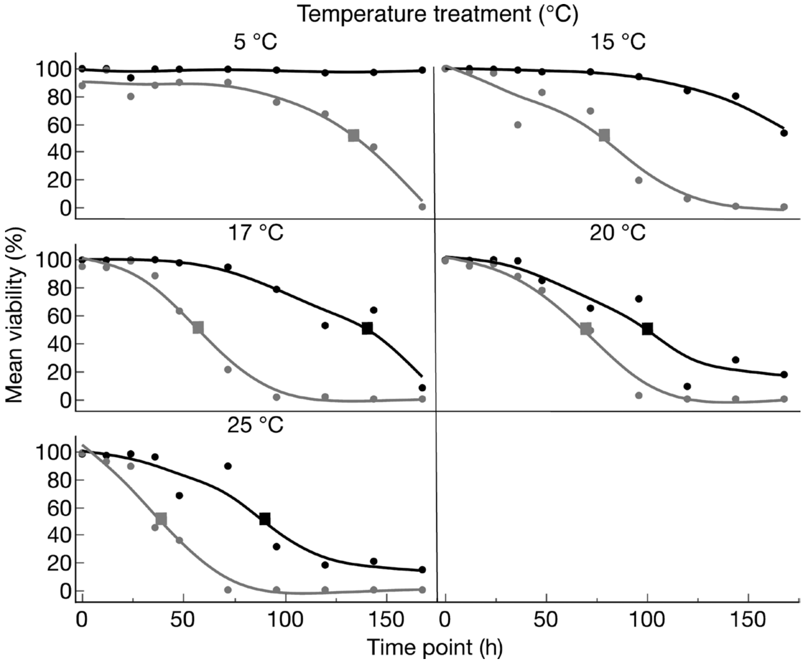
Do deeper perennial pools serve as important refuge for mussels to avoid desiccation?

→ Check out Kiara Cushway's poster!

Other factors to consider

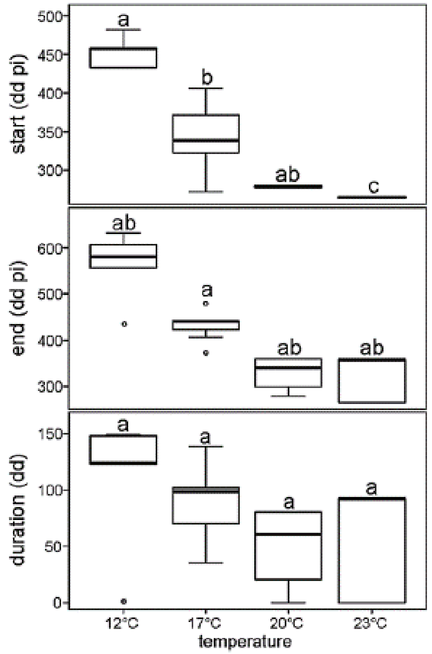
Impact of higher temperature on reproduction, e.g., glochidia development

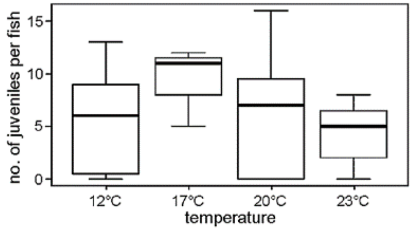
Higher temperatures may favor invasive species



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 ranchland 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.

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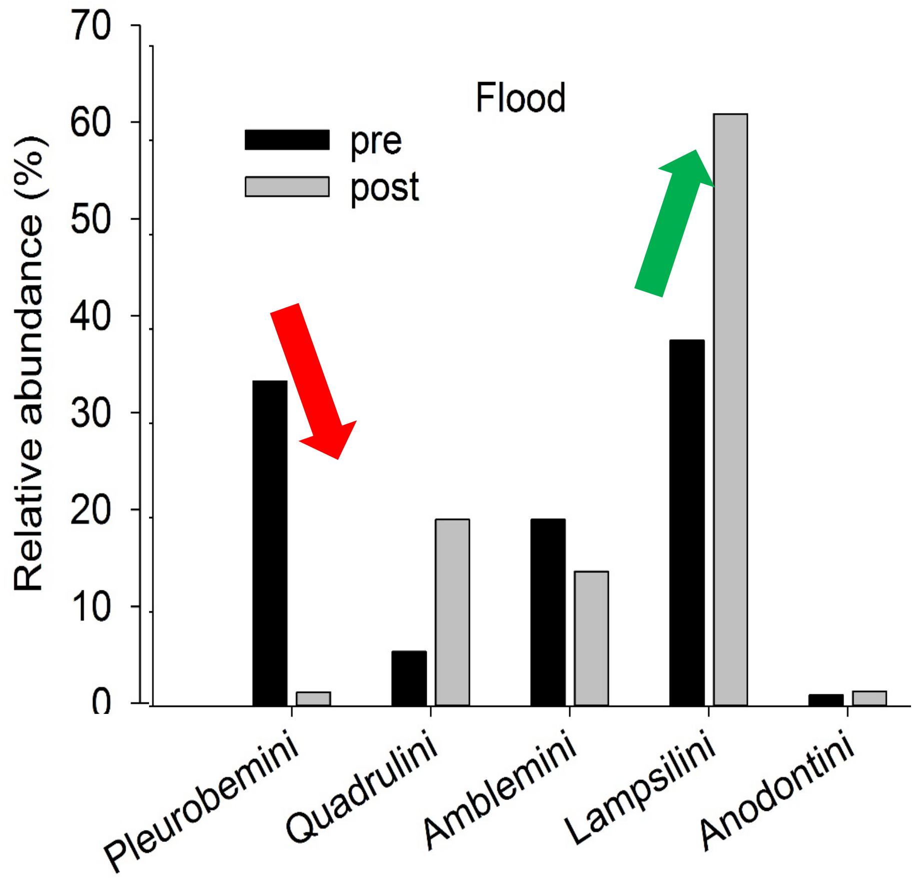
by comparing recent and historical mussel community data collected at the same locations.

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

Lampsilini

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?

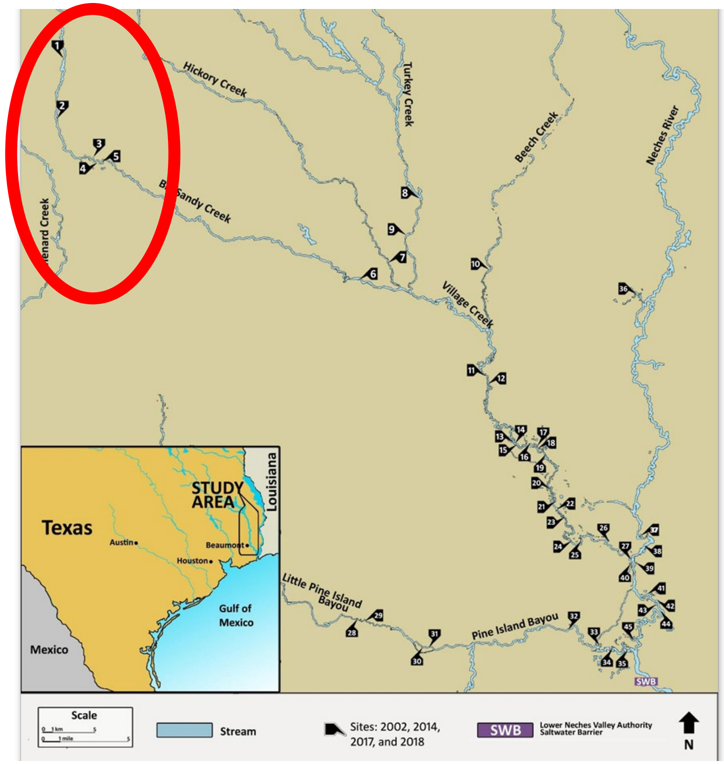
Saltwater intrusion

Rangia cuneata
(Atlantic Rangia)

estuarian bivalve
requires saline water to
complete larval stage

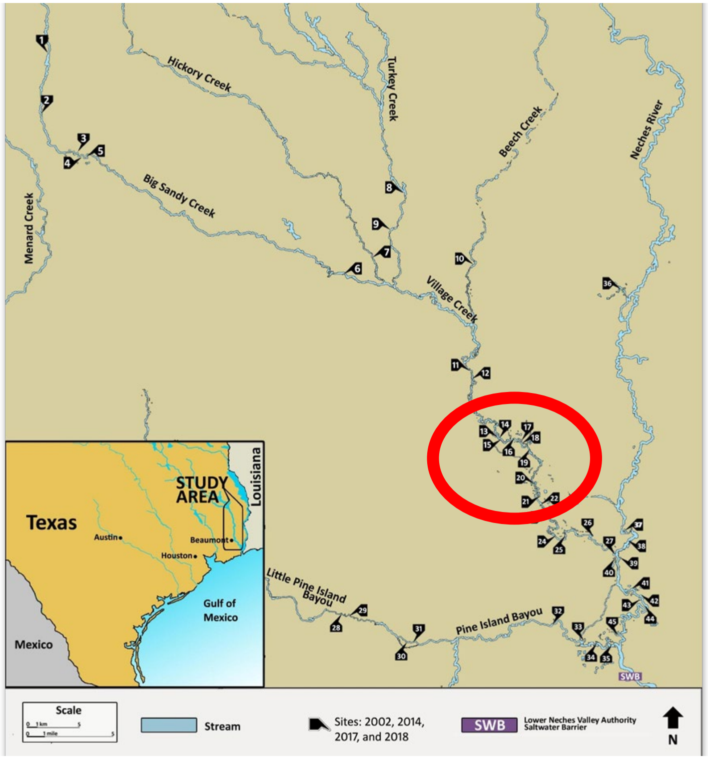
Importance of flow refuge - Upper Village Creek

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



Impact of flooding depends on geomorphology

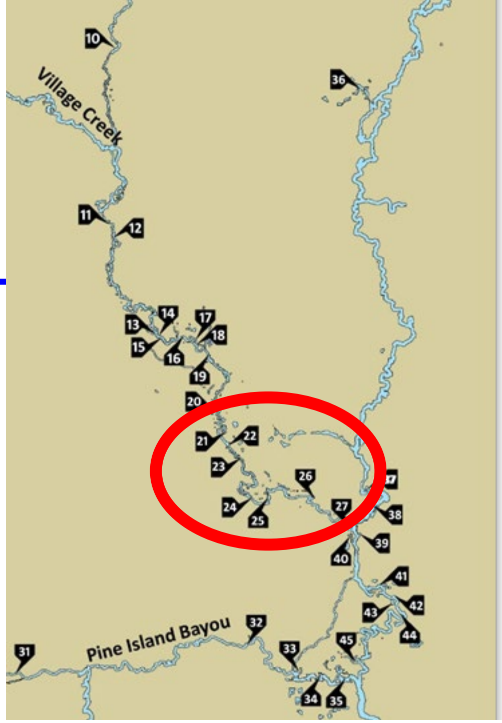
High erosion, highly incised channel, and little sinuosity in Mid Village Creek
Very few mussels found
Little structure in channel



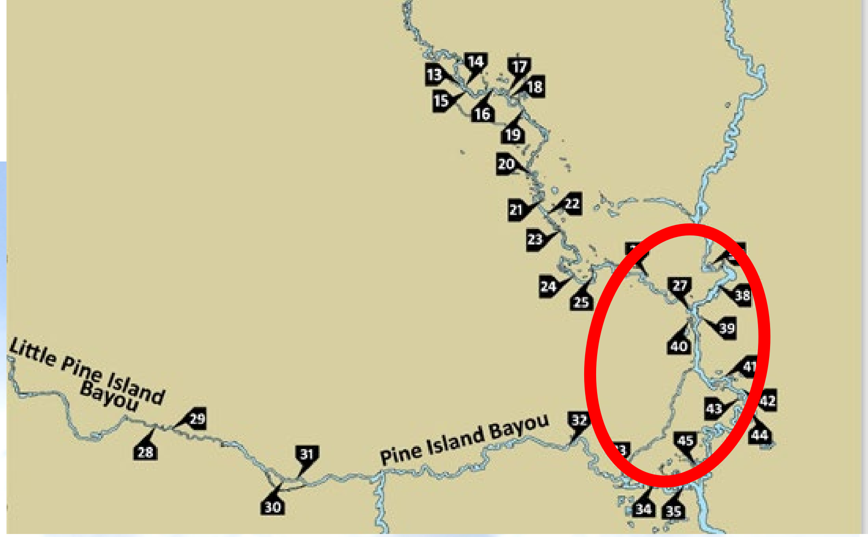
Importance of flow refuge
- Lower Village Creek

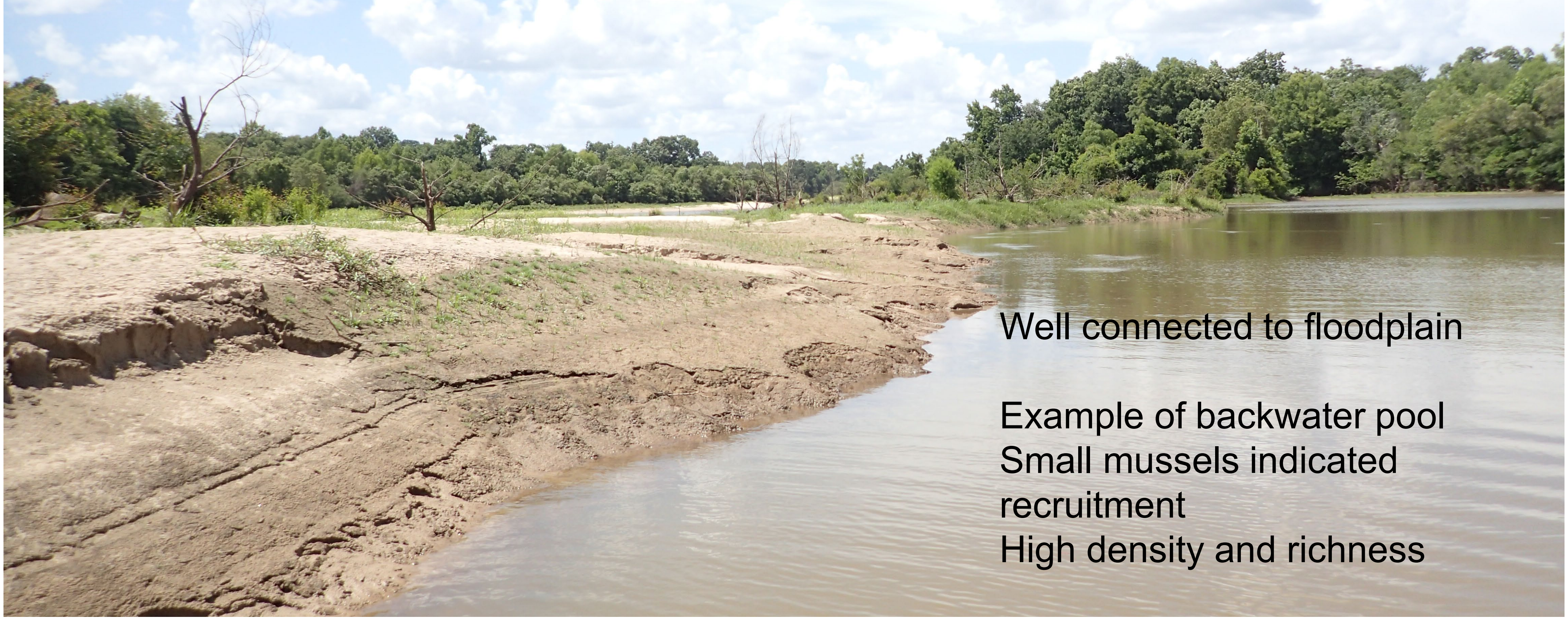
Decline in slope compared to Mid Village Creek
Well connected with floodplains
Log jams provide structure

High mussel richness and abundance



Lower Neches River

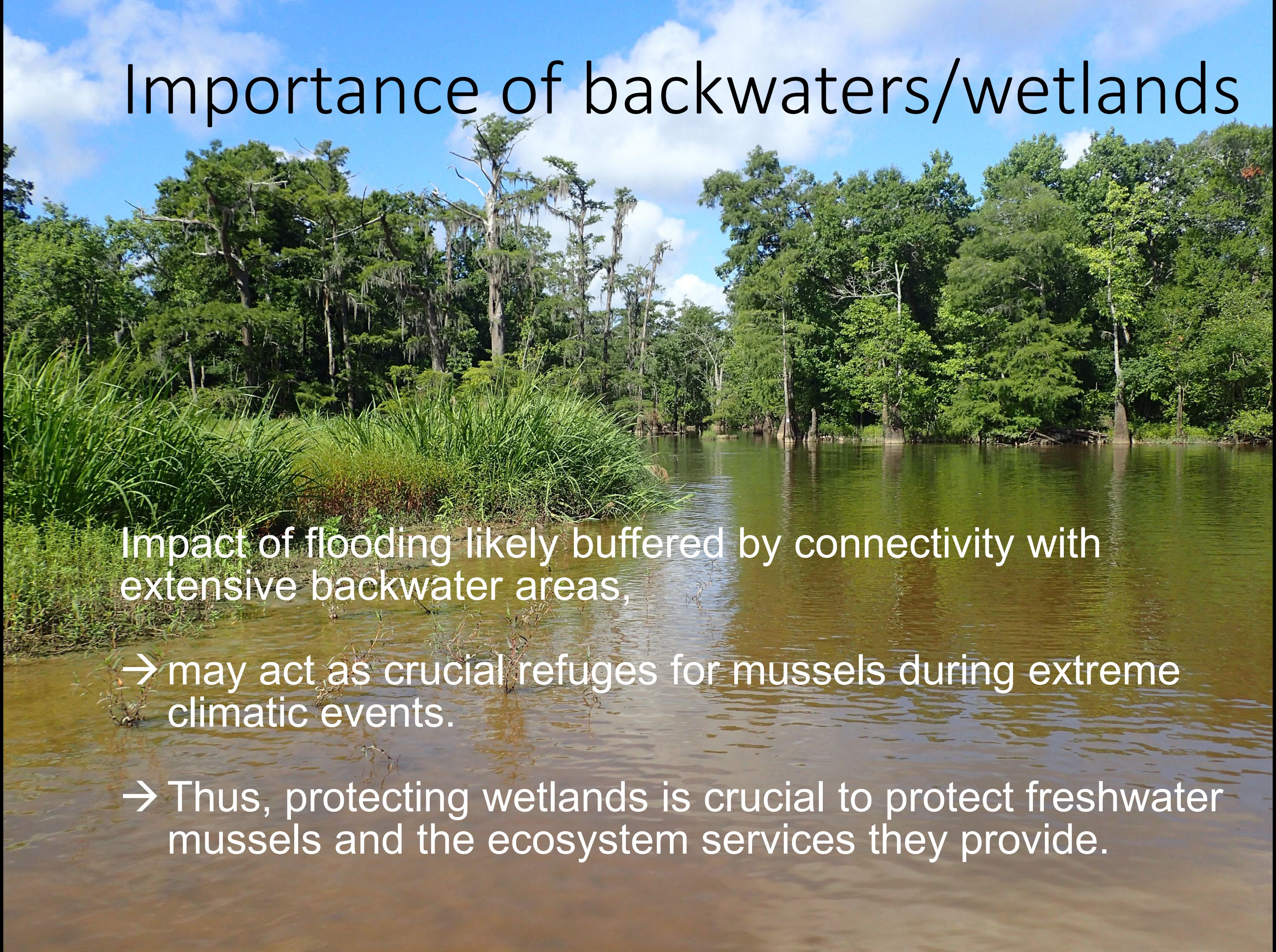




Well connected to floodplain

Example of backwater pool
Small mussels indicated recruitment
High density and richness

Importance of backwaters/wetlands



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.

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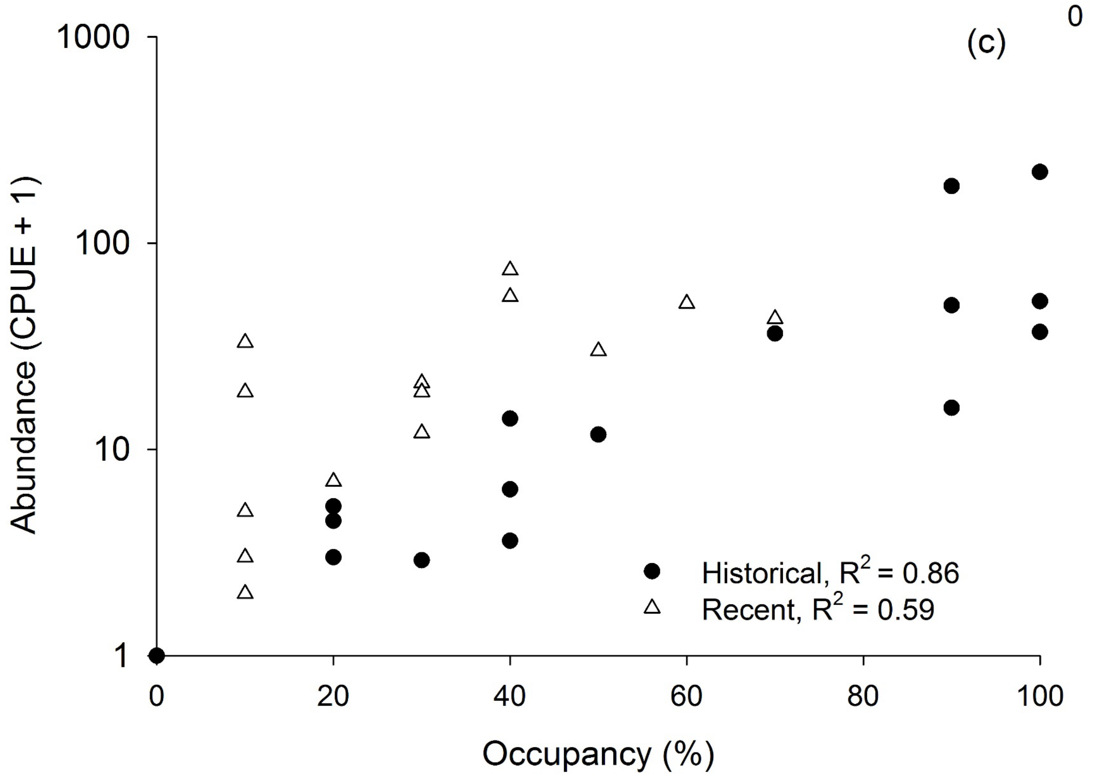
Long-term community-wide declines?

Significant declines in CPUE:

2018:37.1 ± 25.1 mussels per p-H
2002: 64.1 ± 25.1 mussels per p-H

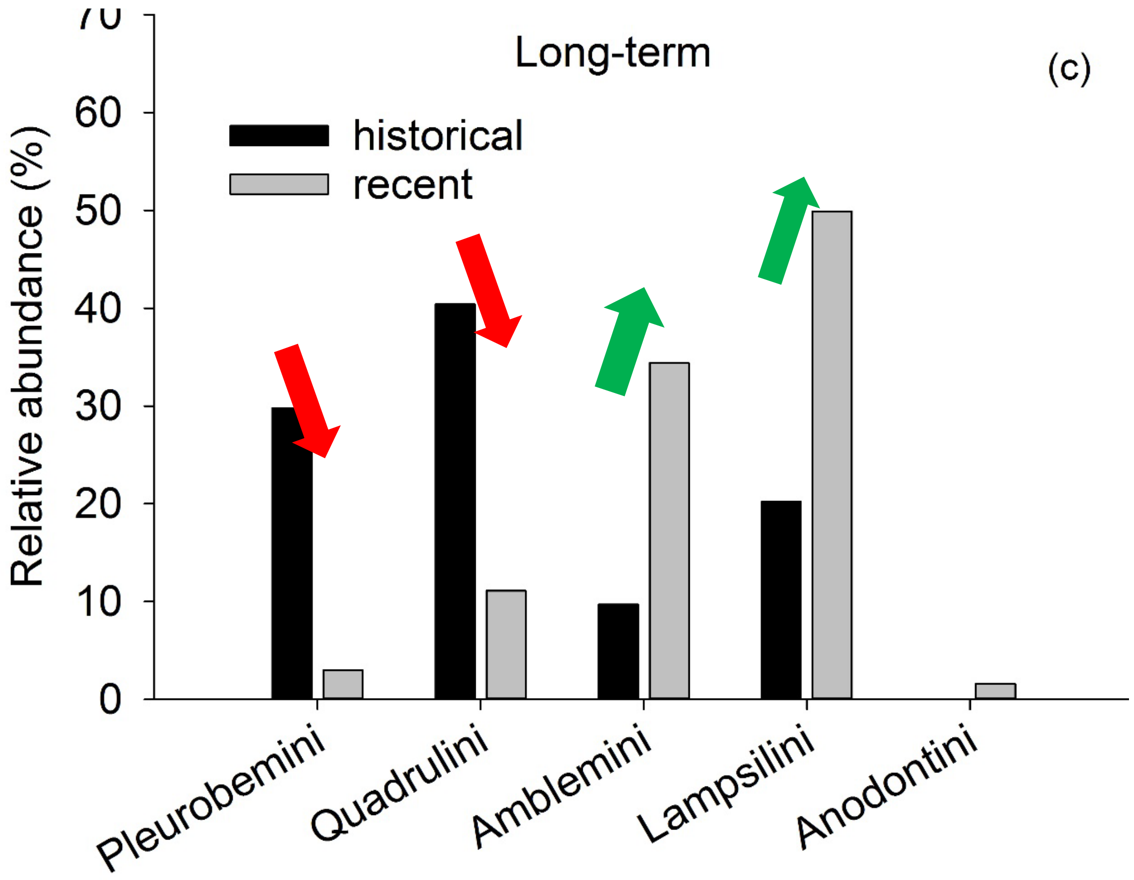
and species richness

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?



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!
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TEXAS STATE