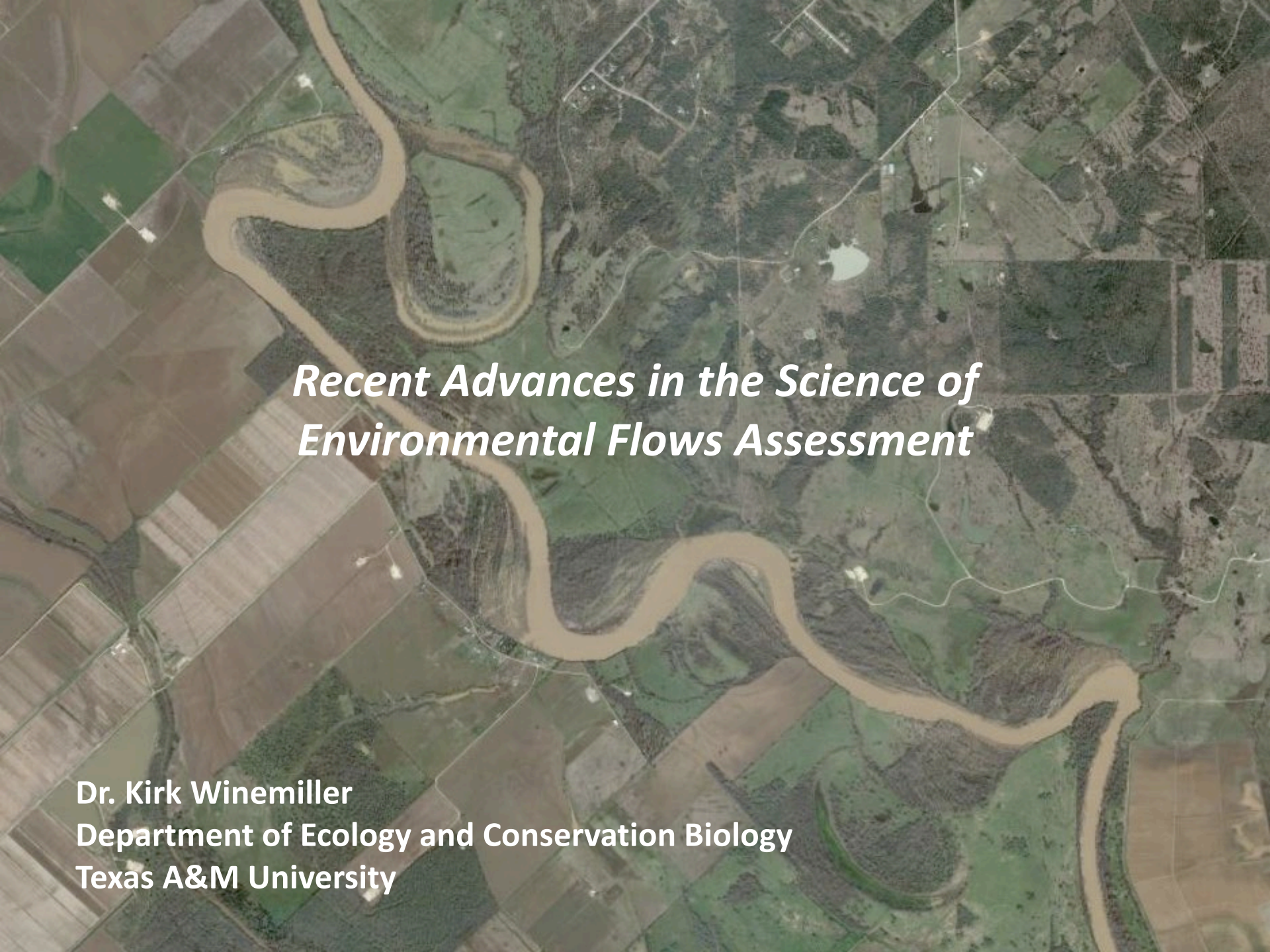
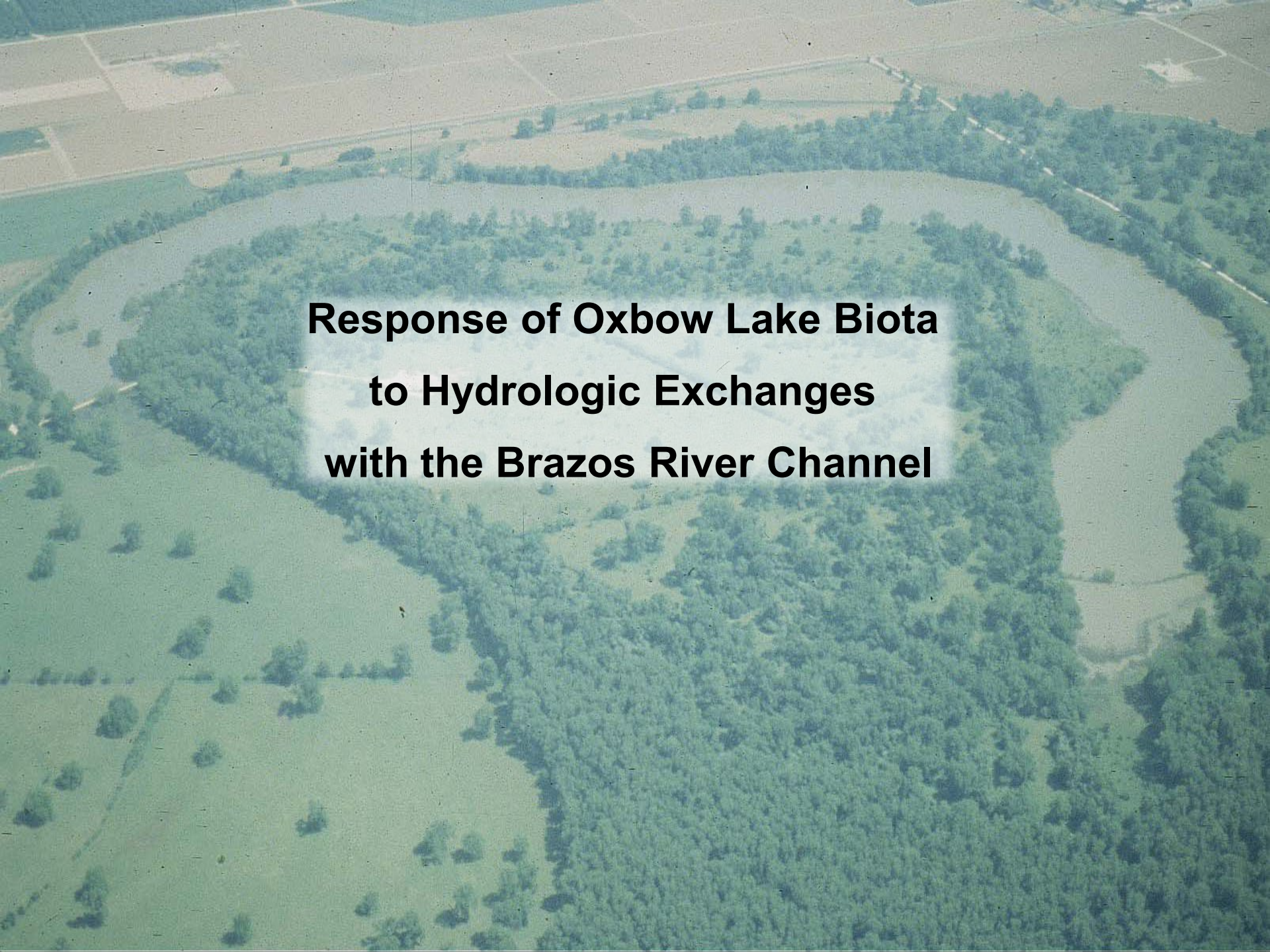


Recent Advances in the Science of Environmental Flows Assessment

Dr. Kirk Winemiller
Department of Ecology and Conservation Biology
Texas A&M University



Response of Oxbow Lake Biota to Hydrologic Exchanges with the Brazos River Channel

Oxbow lakes are extremely productive & periodically build up dense fish stocks

flooding results in lateral connectivity
& faunal exchange

pugnose minnow – out

Red shiner – in

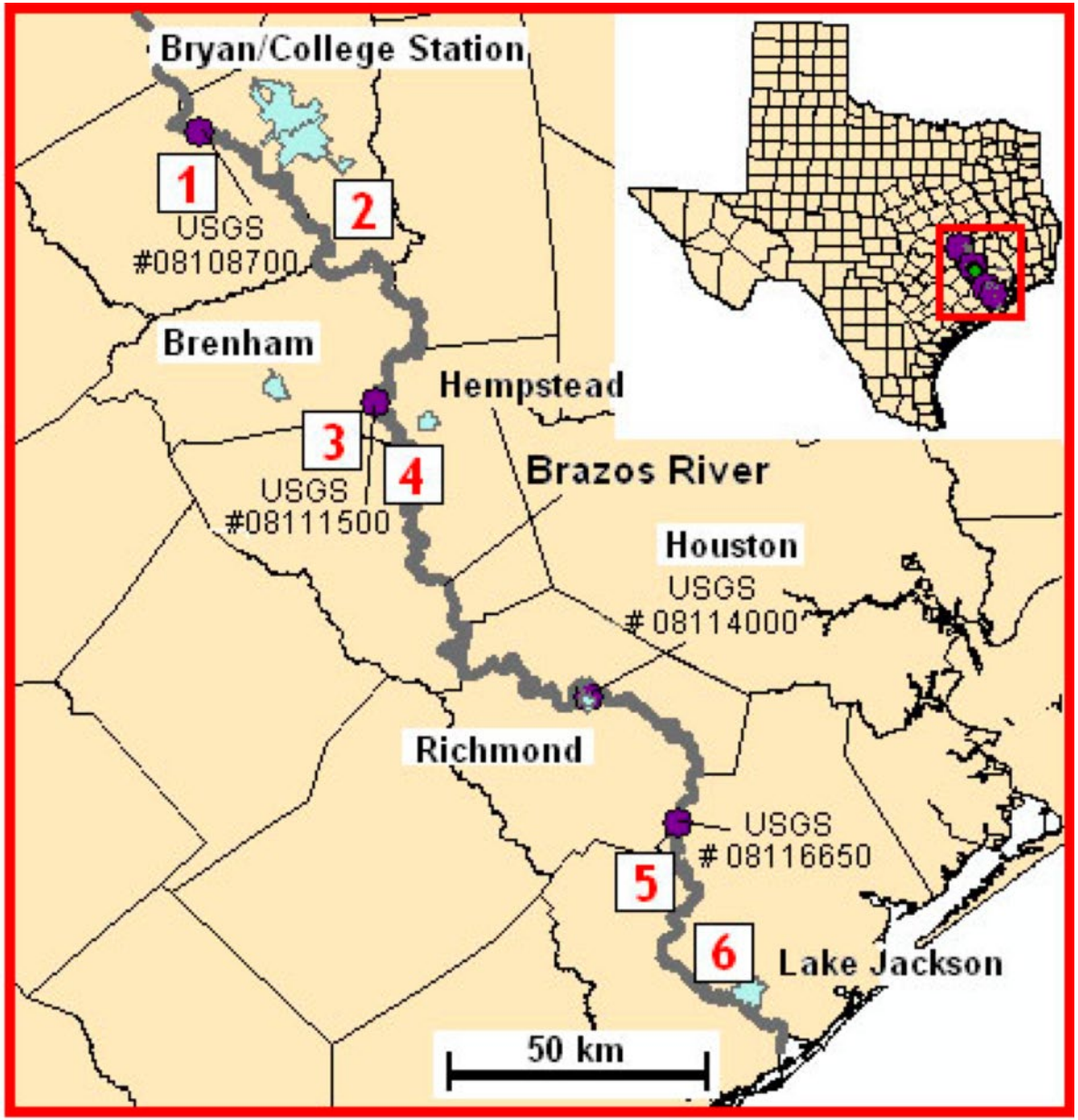
During extended periods of low flows, there is isolation & greater environmental variation among oxbow lakes


During drought periods,
some oxbows dry completely

newly formed oxbow
(Hog Island)

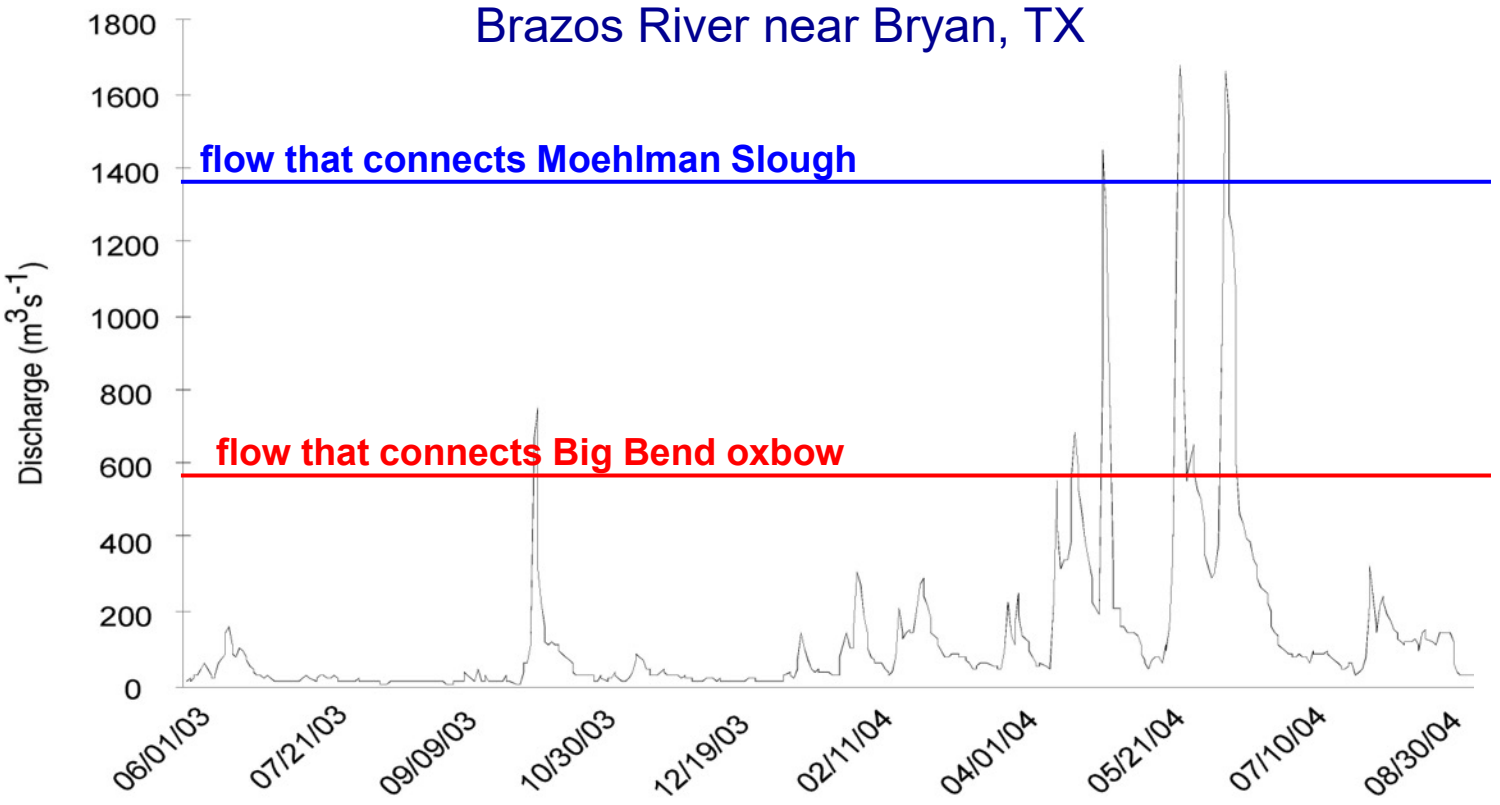
older oxbow
(Moehlman Slough)


control point within natural levee

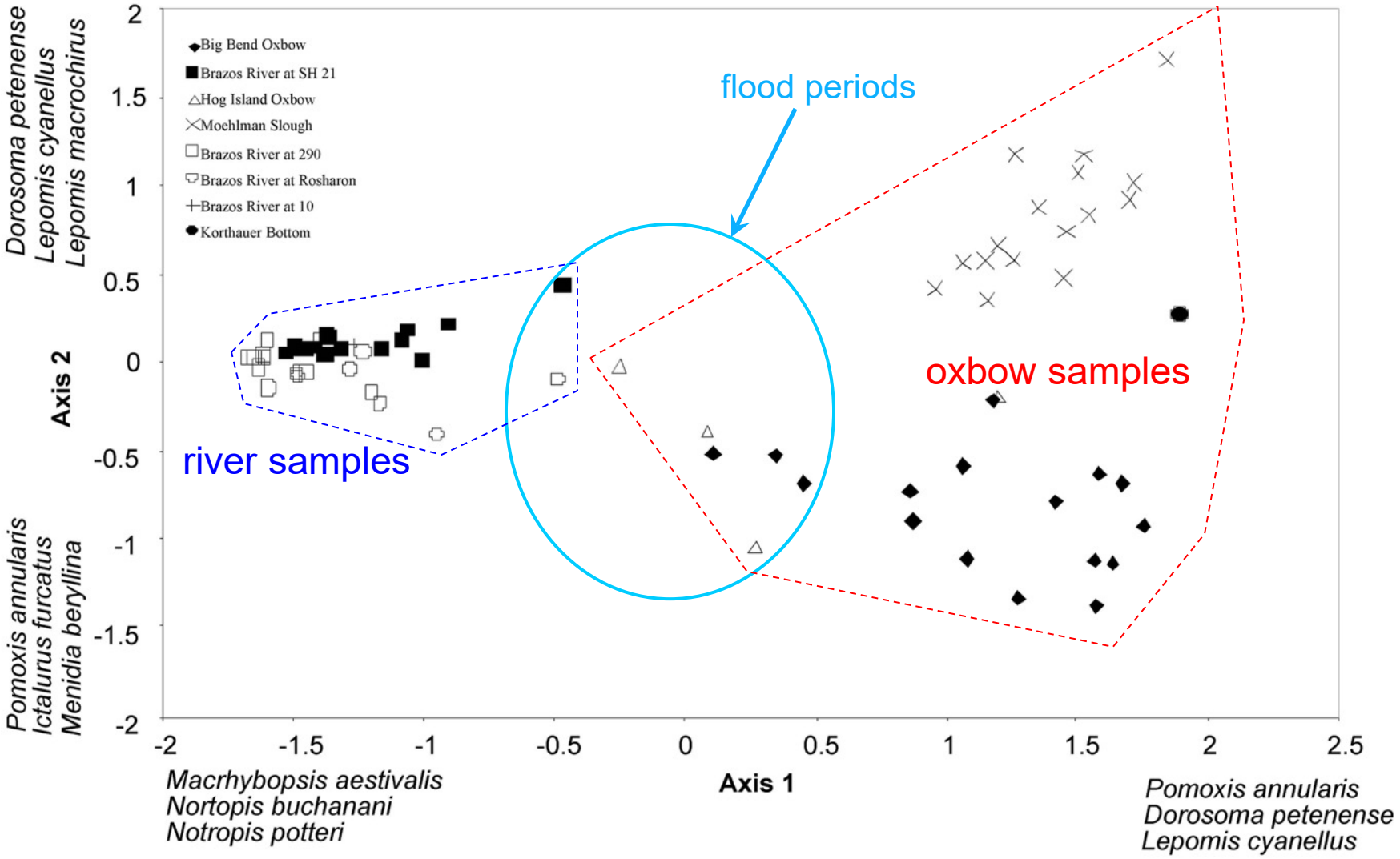

Bryan/College Station
1
USGS
#08108700
2
Brenham
Hempstead
3
USGS
#08111500
4
Brazos River
Houston
USGS
08114000
Richmond
USGS
08116650
5
6
Lake Jackson
50 km

Oxbow lakes connect with channel with different frequencies & durations

Oxbow	No. connections (1984-2004)	Flow (cfs) to connect
Hog Island	129	3,625
Korthauer Bottom	82	20,500
Big Bend	73	20,000
Moehlman Slough	26	45,000
Cutoff Lake	5	76,000
Horseshoe Lake	1	99,000


Brazos River near Bryan, TX
flow that connects Moehlman Slough
flow that connects Big Bend oxbow
Discharge (m^3s^{-1})
1800
1600
1400
1200
1000
800
600
400
200
0
06/01/03
07/21/03
09/09/03
10/30/03
12/19/03
02/11/04
04/01/04
05/21/04
07/10/04
08/30/04

During floods, there is exchange of fishes between river & oxbow lakes

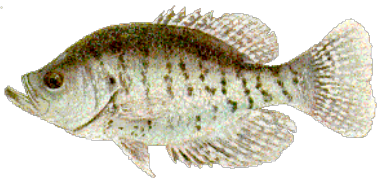


CA using seine CPUE data for fishes

Some species are more abundant in the river channel following floods

Correlation between monthly peak discharge and fish abundance in the river channel with a time lag of 1 month:

- White crappie, *Pomoxis annularis* +0.67



- Threadfin shad, *Dorosoma petenense* +0.58

Flood connections result in export of fish to the river channel

[source-sink metapopulation dynamics]

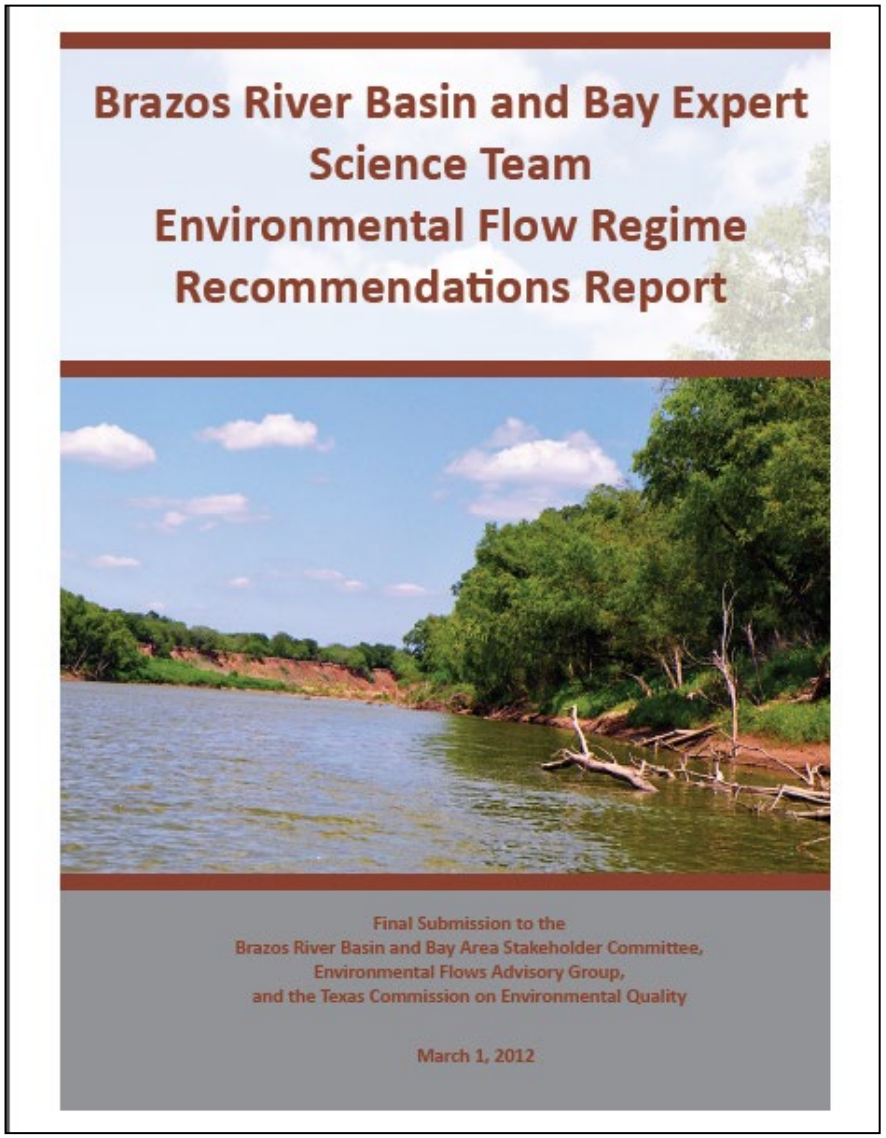
Flood connections also result in entry of fish that are abundant in the river channel into oxbow lakes where they generally perish within a few months

Red shiner, *Cyprinella lutrensis*

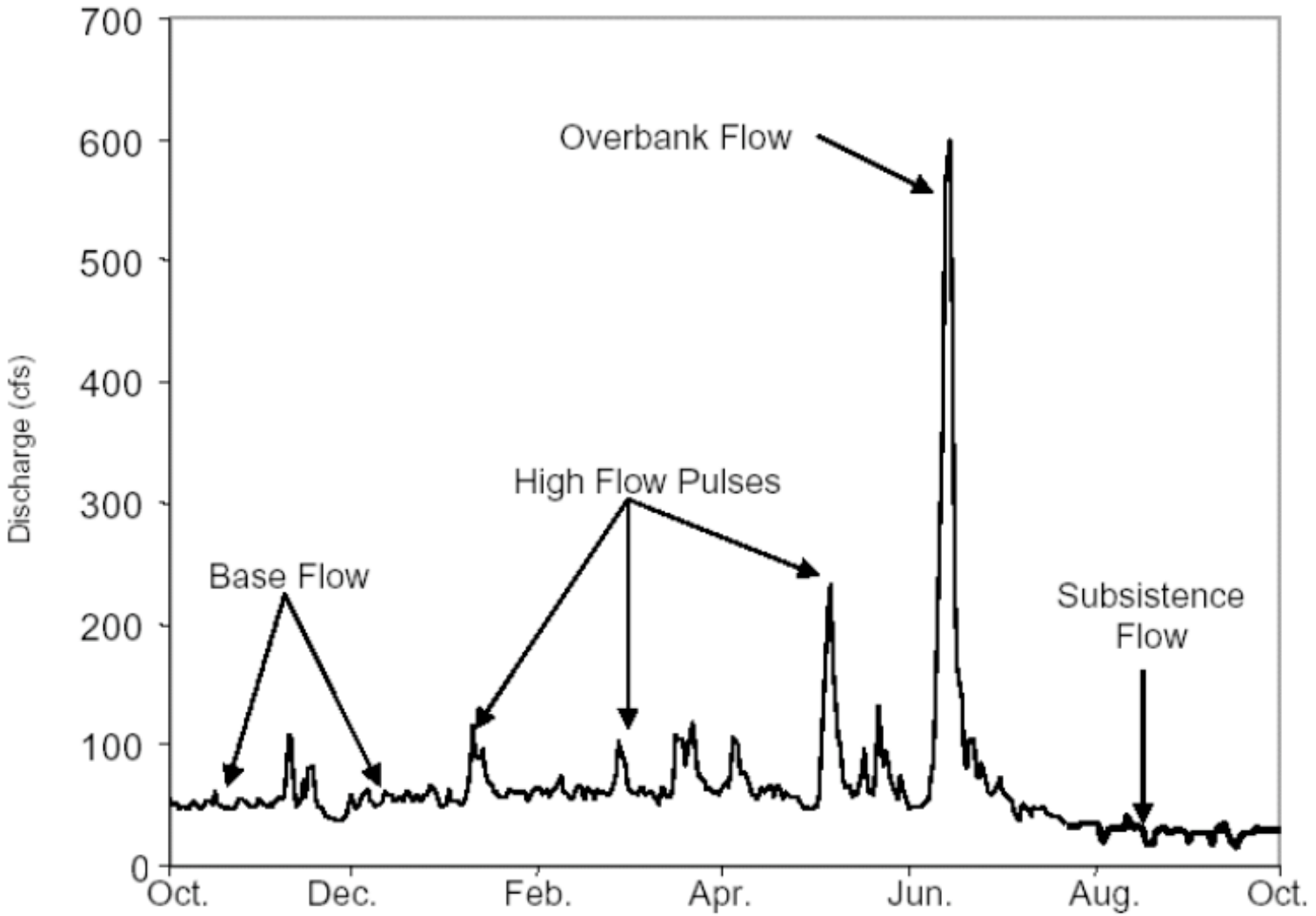
Bullhead minnow, *Pimephales vigilax*

[food for bass, crappie, gar & other predators]

Texas Senate Bill 3 Process



The goal is to protect essential components of *timing*, *magnitude* & *duration* of flow required to maintain "a sound ecological environment"



5.2.15 Brazos River near Bryan

Overbank Events	Qp: 66,900 cfs with Average Frequency 1 per 2 years Regressed Volume is 989,000 Duration Bound is 35		
	Qp: 49,400 cfs with Average Frequency 1 per year Regressed Volume is 675,000 Duration Bound is 30		
High Flow Pulses	Qp: 22,600 cfs with Average Frequency 1 per season Regressed Volume is 243,000 Duration Bound is 20	Qp: 32,900 cfs with Average Frequency 1 per season Regressed Volume is 421,000 Duration Bound is 25	Qp: 12,100 cfs with Average Frequency 1 per season Regressed Volume is 114,000 Duration Bound is 16
	Qp: 11,200 cfs with Average Frequency 2 per season Regressed Volume is 100,000 Duration Bound is 14	Qp: 17,800 cfs with Average Frequency 2 per season Regressed Volume is 193,000 Duration Bound is 18	Qp: 5,000 cfs with Average Frequency 2 per season Regressed Volume is 38,100 Duration Bound is 10
	Qp: 5,570 cfs with Average Frequency 3 per season Regressed Volume is 41,900 Duration Bound is 10	Qp: 10,400 cfs with Average Frequency 3 per season Regressed Volume is 97,000 Duration Bound is 14	Qp: 2,990 cfs with Average Frequency 3 per season Regressed Volume is 20,100 Duration Bound is 8
	Qp: 3,230 cfs with Average Frequency 4 per season Regressed Volume is 21,100 Duration Bound is 7	Qp: 6,050 cfs with Average Frequency 4 per season Regressed Volume is 49,000 Duration Bound is 11	Qp: 2,060 cfs with Average Frequency 4 per season Regressed Volume is 12,700 Duration Bound is 7
Base Flows (cfs)	1,760	2,460	1,470
	860	1,260	920
	540	710	630
Subsistence Flows (cfs)	300	300	300

Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Winter				Spring				Summer			

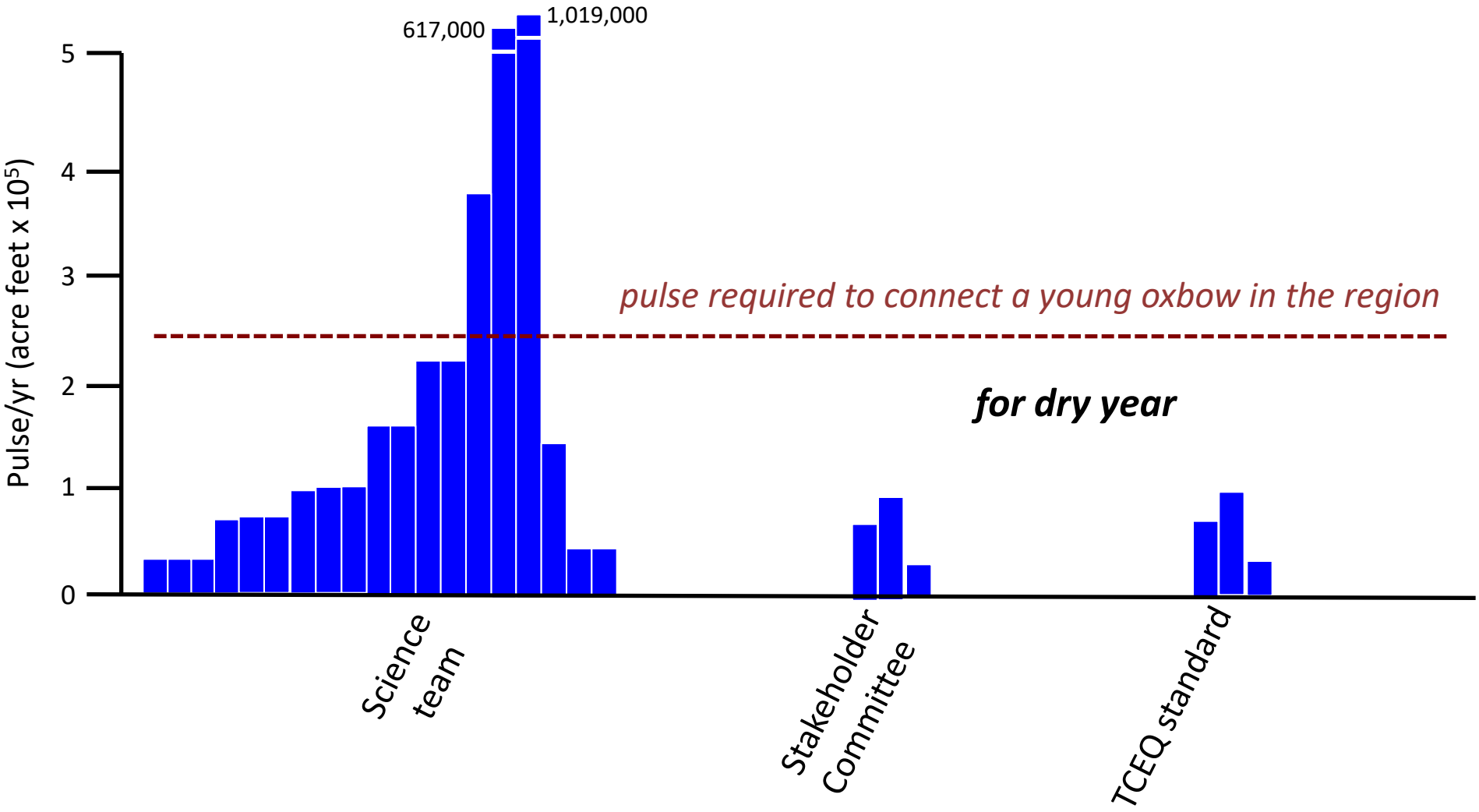
Base Flow Levels	
	High (75th %ile)
	Medium (50th %ile)
	Low (25th %ile)

Pulse volumes are in units of acre-feet and durations are in days.

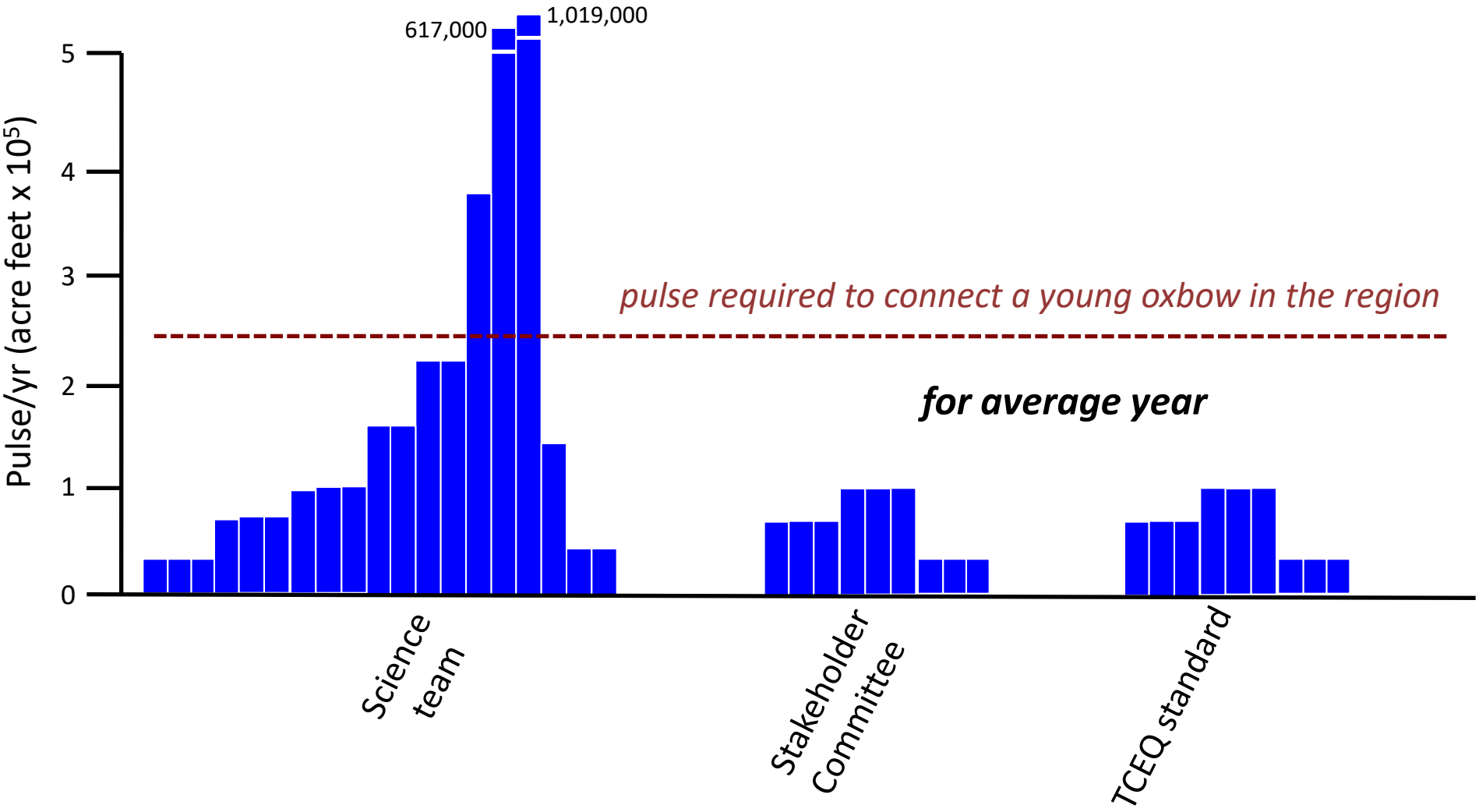
Period of record used : 1/1/1928 to 12/31/2010.

Episodic events are terminated when the volume or duration criteria are met, or when the flow drops below 833 cfs, or when the flow is below 5080 cfs and the flow drops from one day to the next by less than 5%.

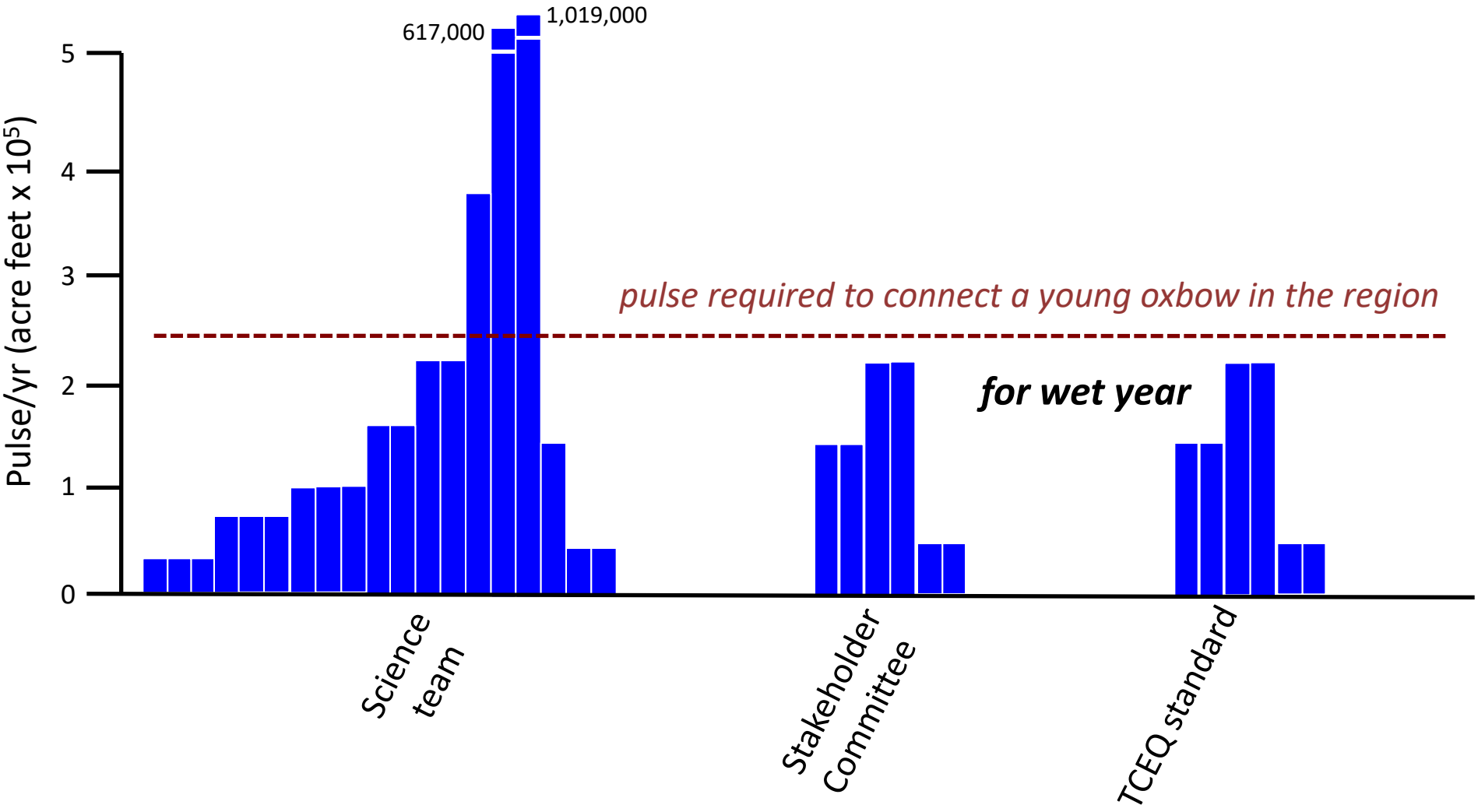
Recommended Flow Pulses for the Brazos River at Richmond



Recommended Flow Pulses for the Brazos River at Richmond



Recommended Flow Pulses for the Brazos River at Richmond



High-flow pulses seem to be the issue.

- Nobody advocates for flow tiers that cause destructive flooding
  (although they do have ecological functions, e.g. channel geomorphology, sediment transport)
- High flow pulses fill reservoirs
- Base flows allow the river to appear “normal”
- Nobody wants flows to fall below “subsistence” levels – that would cause the river to be dry or obviously degraded and surely to lose some of the aquatic biota

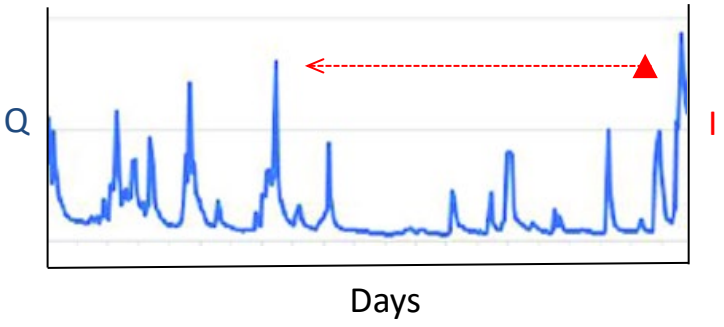
We need methods to predict (forecast) ecological outcomes for flow pulses of various tiers

- Which ecological outcomes matter the most?
    - those essential to sustain populations of aquatic and riparian species → recruitment!

- Which species are suitable indicators?
    - they must have flow-sensitive recruitment
    - some require frequent small flow pulses vs. others require infrequent larger flow pulses

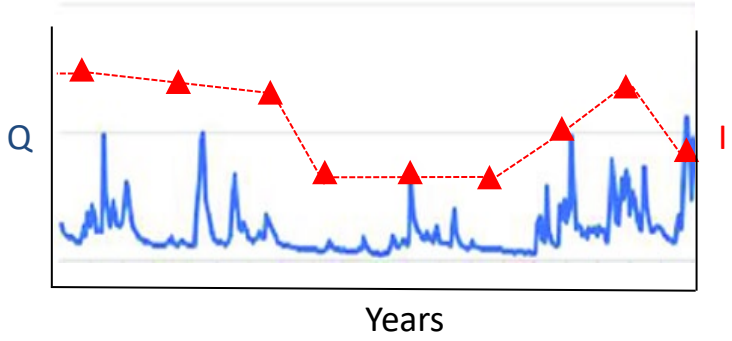
Modeling Rates

Retrospective analysis (back-calculation) of indicator response to shorter-term variation in flow components



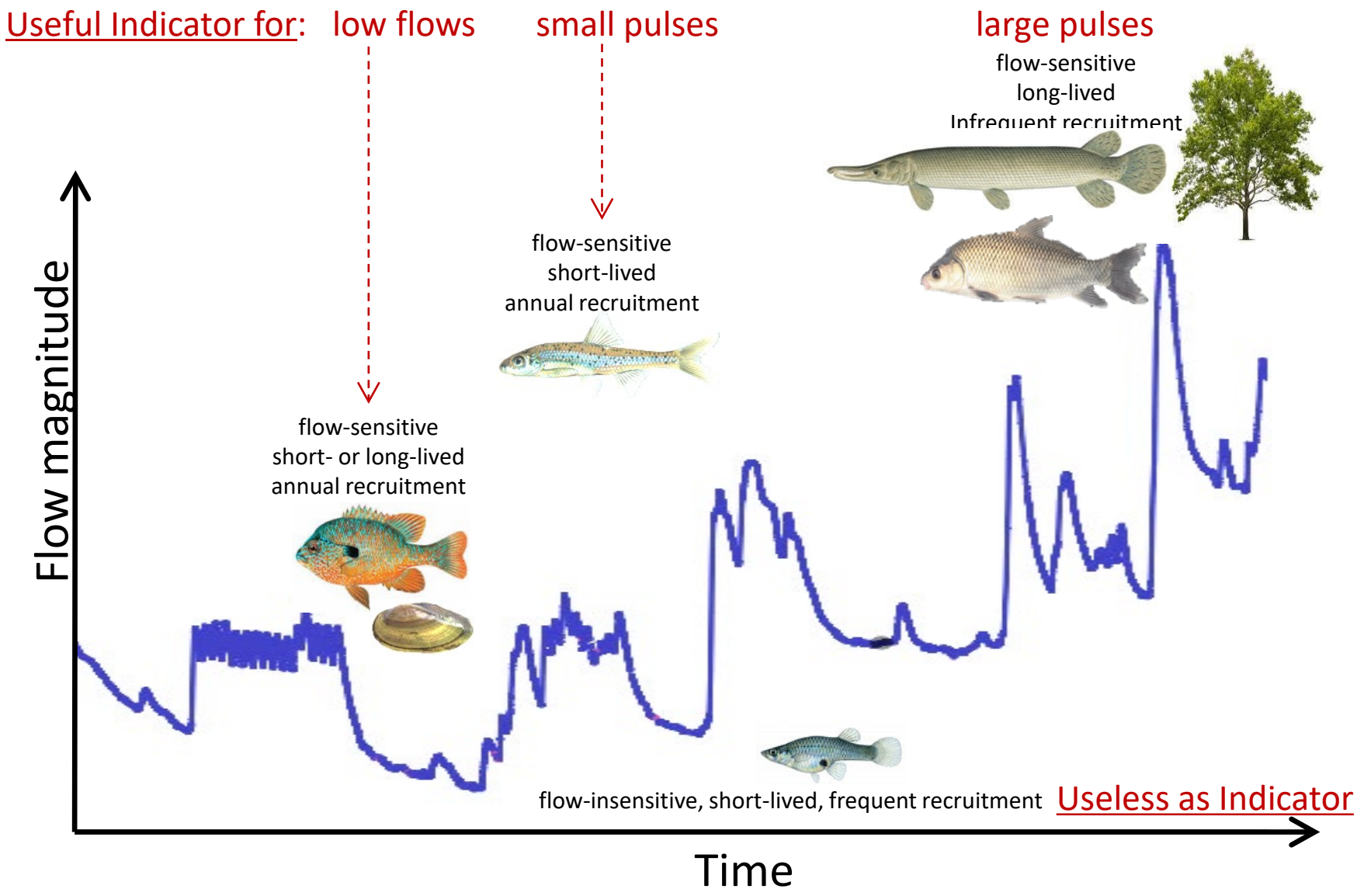
Monitoring States

Trend analysis (long-term tracking) of biological and ecosystem indicators

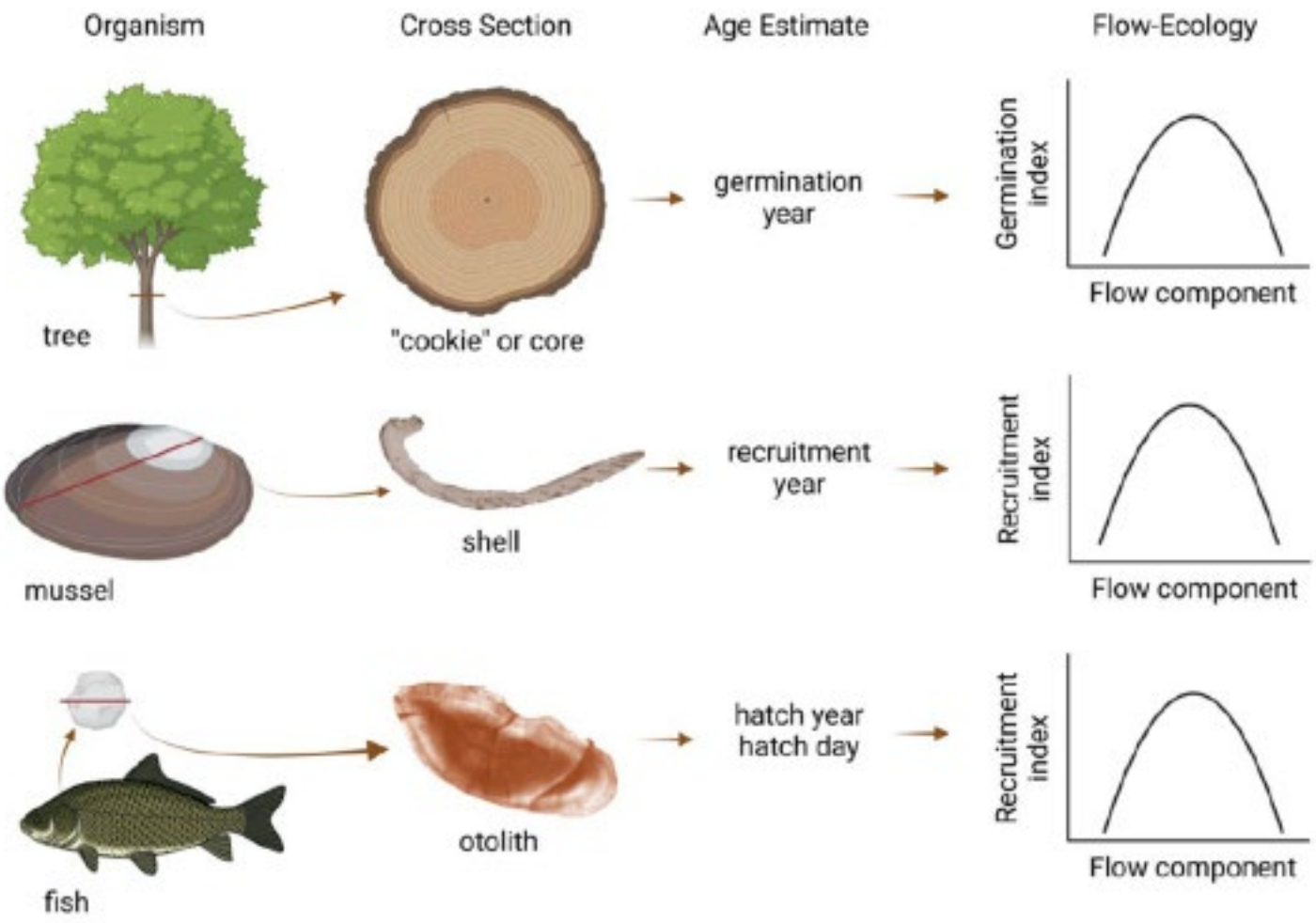


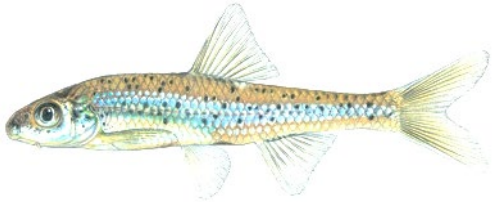
Winemiller, K.O., J.S. Perkin, J.F. Trungale, D.J. Hoeinghaus, G.W. Moore, A.N. Schwalb, Z.A. Mitchell, A. Trimble, C. Reeves, M.R. Acre, K. Wheeler, T.B. Hardy, and D. Buzan. 2024. Advancing the state of environmental flows science: monitoring, hindcasting and forecasting flow-ecology relationships. *Fisheries* 49(8):353-368. https://doi.org/10.1002/fsh.11092

Texas Water Development Board Contract 1800012317 to Texas A&M AgriLife Research

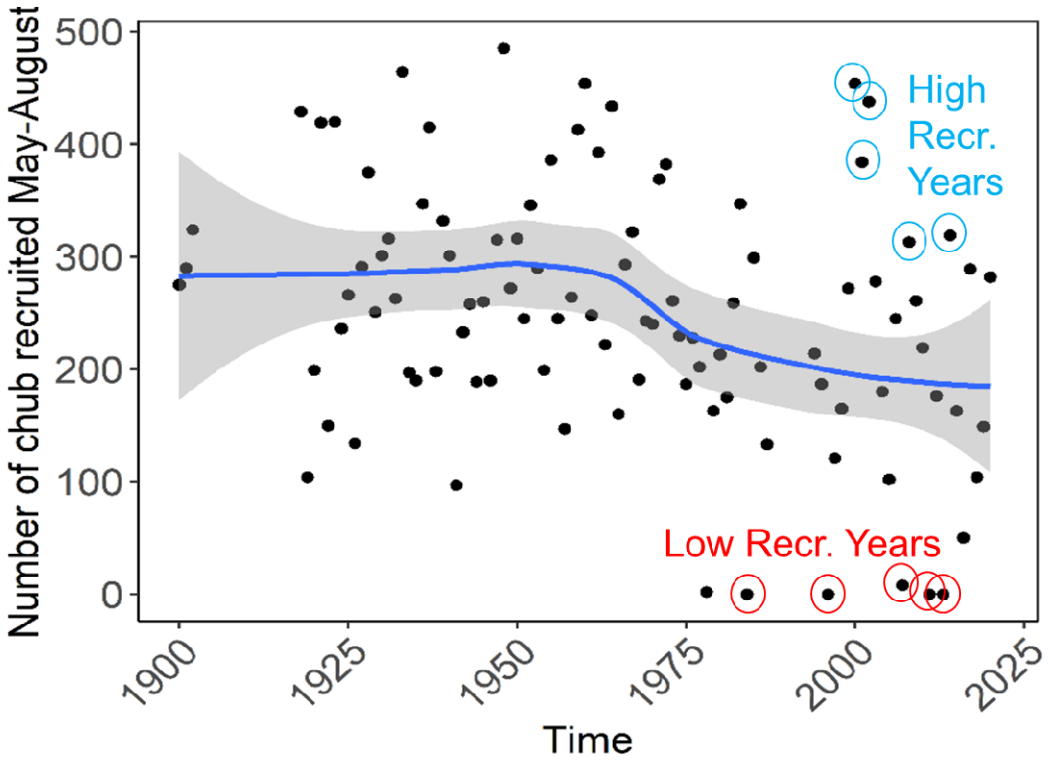

Useful Indicator for:
low flows
small pulses
large pulses
flow-sensitive
long-lived
Infrequent recruitment
flow-sensitive
short-lived
annual recruitment
flow-sensitive
short- or long-lived
annual recruitment
Flow magnitude
flow-insensitive, short-lived, frequent recruitment
Useless as Indicator
Time

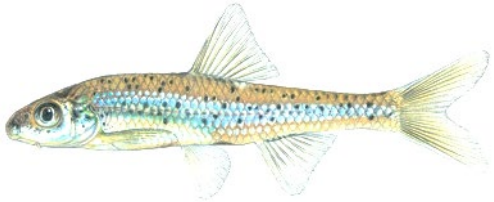
Estimating recruitment success in relation to flow variation





Brazos River – Shoal chub recruitment model estimates





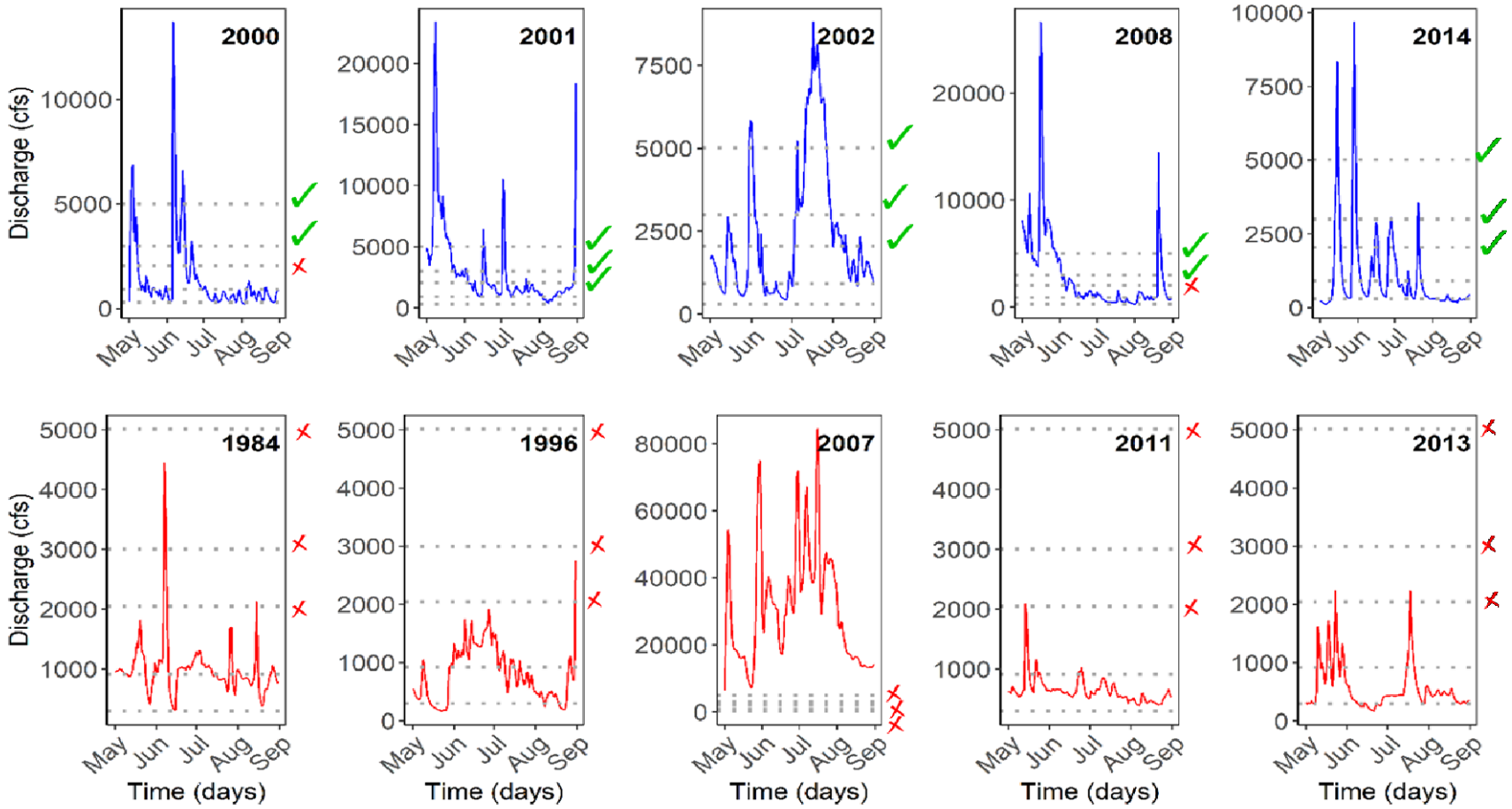
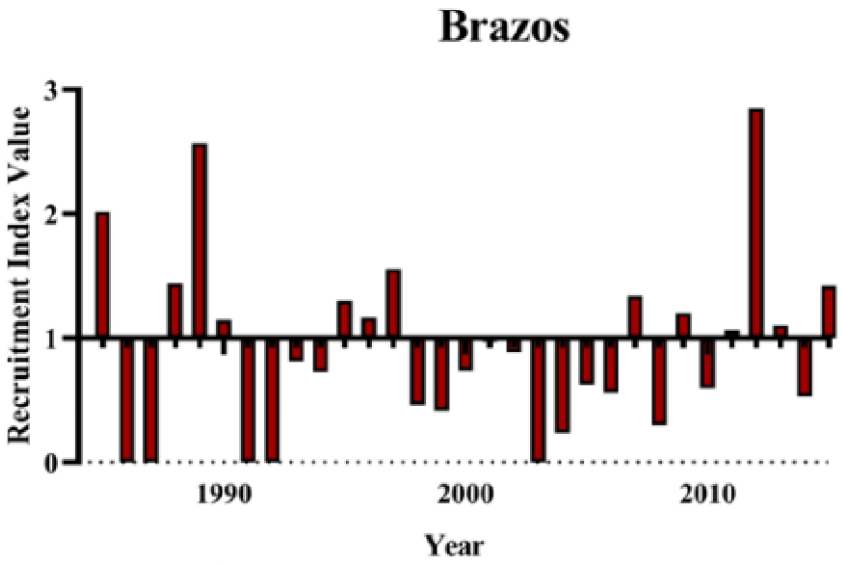
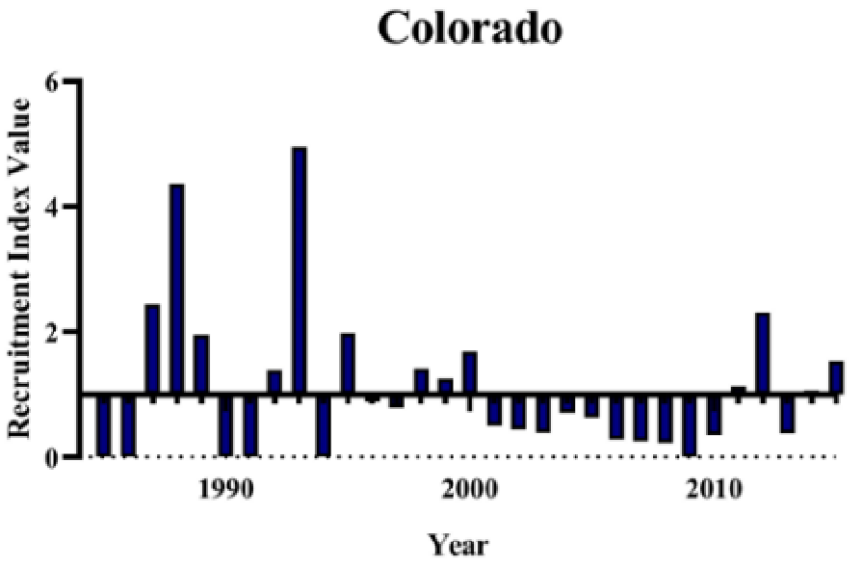
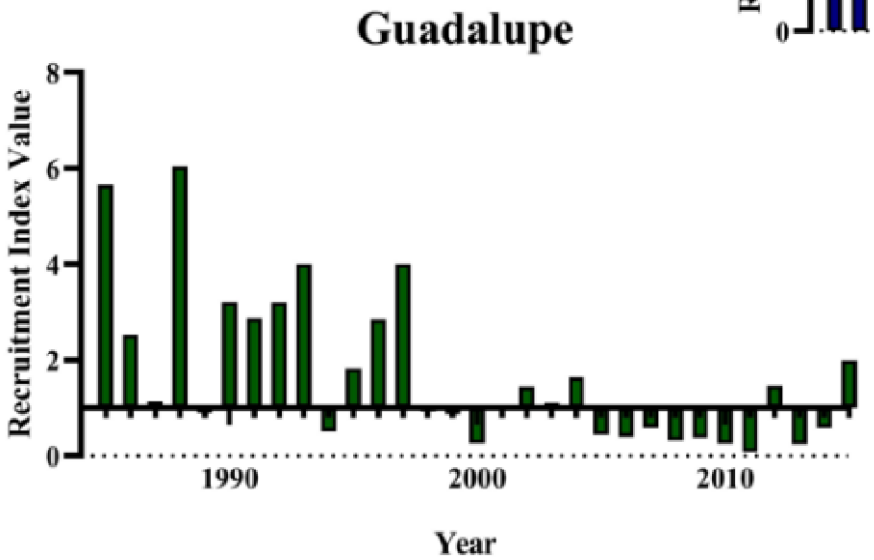


Figure 3. Comparison of Brazos River flow regimes for summers with predicted high Shoal Chub recruitment (upper row) and low Shoal Chub recruitment (lower row) illustrating whether or not flow targets, such as 2 pulses per season (pps), 3 pps, and 4 pps (upper three dotted lines on each panel), were met (√) or not met (χ). Years with high recruitment were years during which most flow pulse targets were met, but extreme years (drought or sustained flood) corresponded with low recruitment.

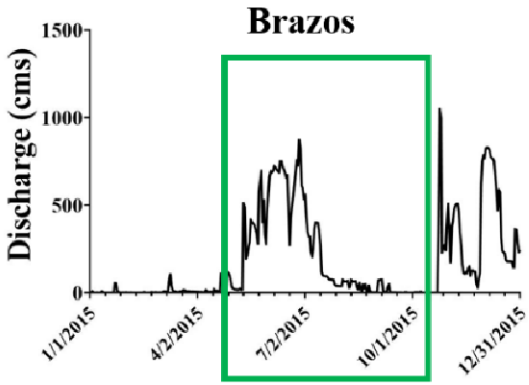
Smallmouth buffalo recruitment model estimates

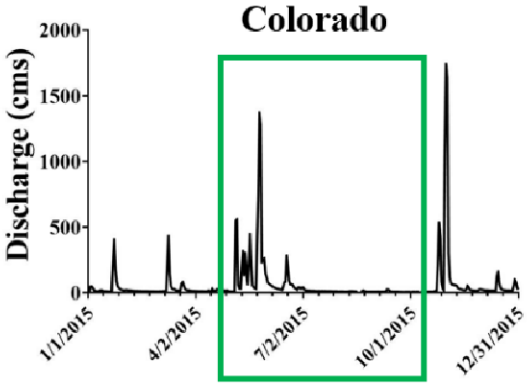


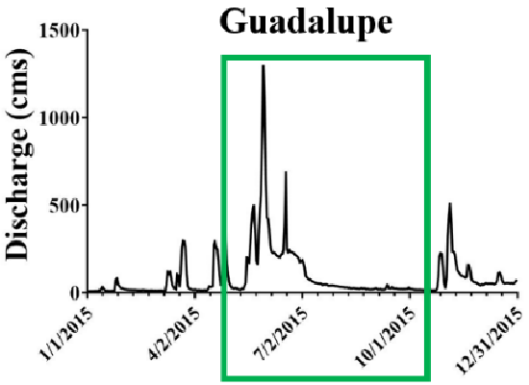




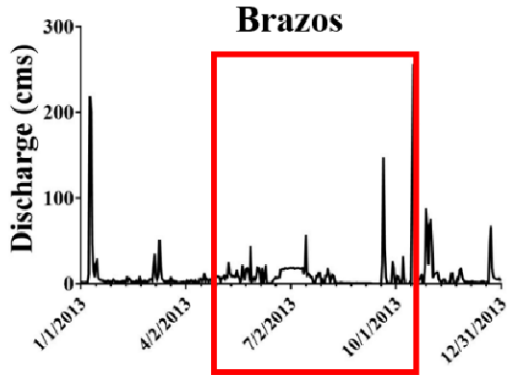
2015 (High Recruitment Year)

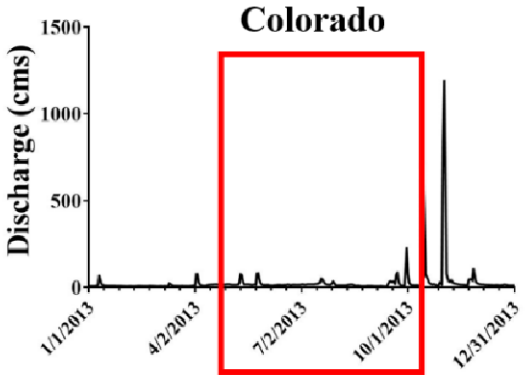


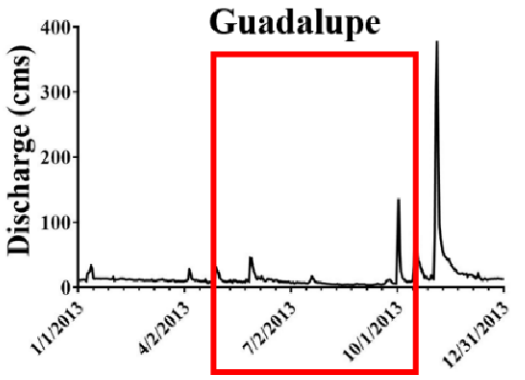


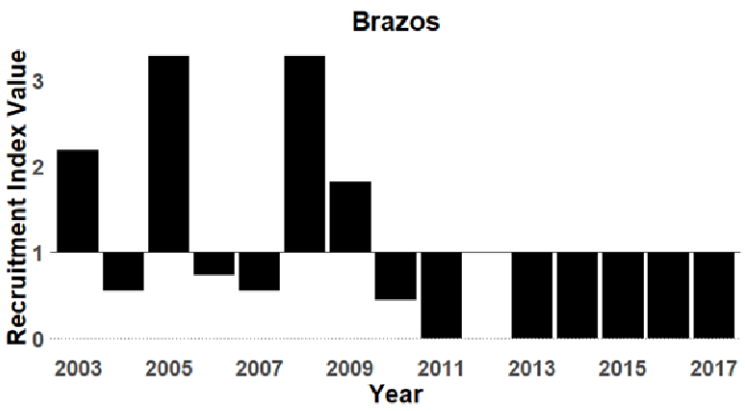


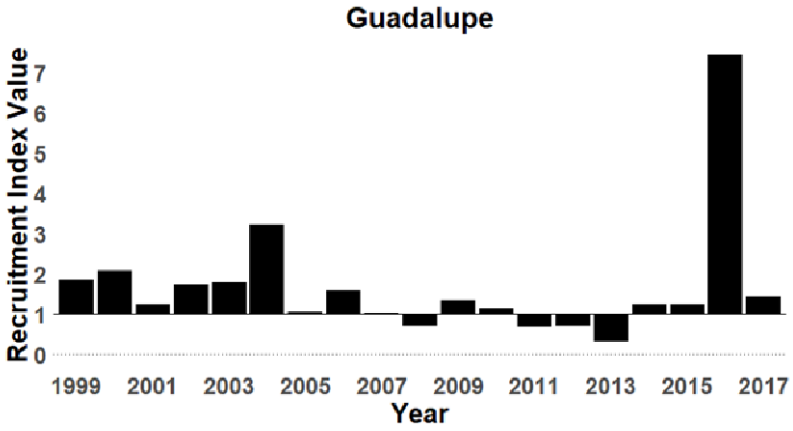
2013 (Low Recruitment Year)











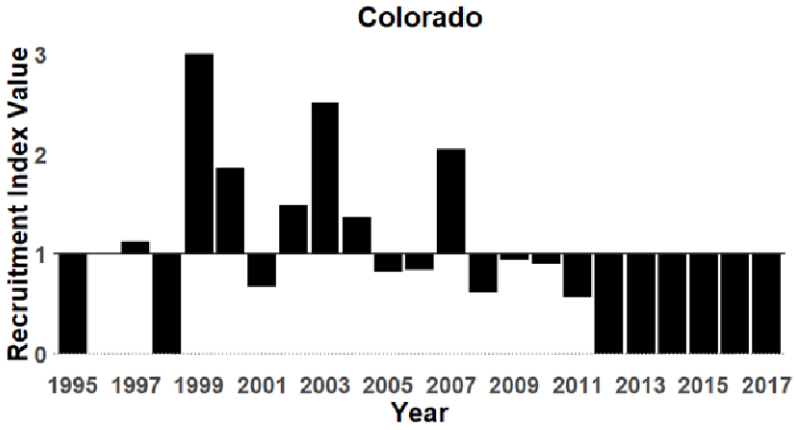
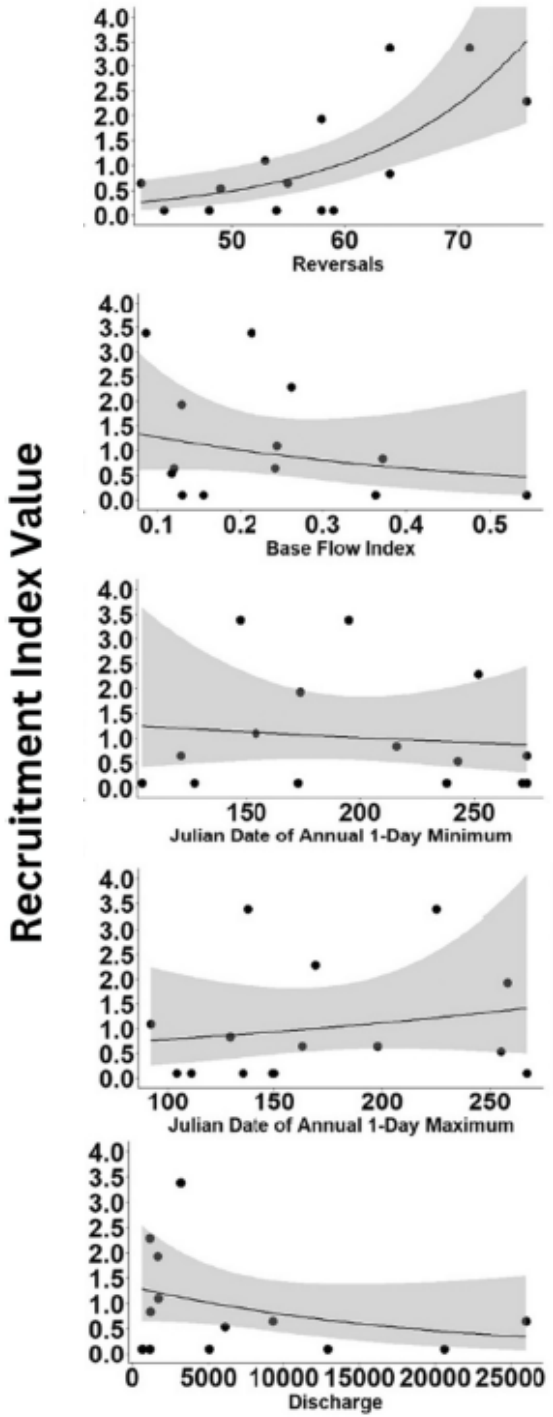


Figure 6. Recruitment index values for *Amblema plicata* in the Brazos (2003–2017), Colorado (1995–2017), and Guadalupe (1999–2017) rivers.

Brazos River – *Amblema plicata*
Recruitment index values in relation to indices of hydrologic alteration parameters



Boxelder germination estimates

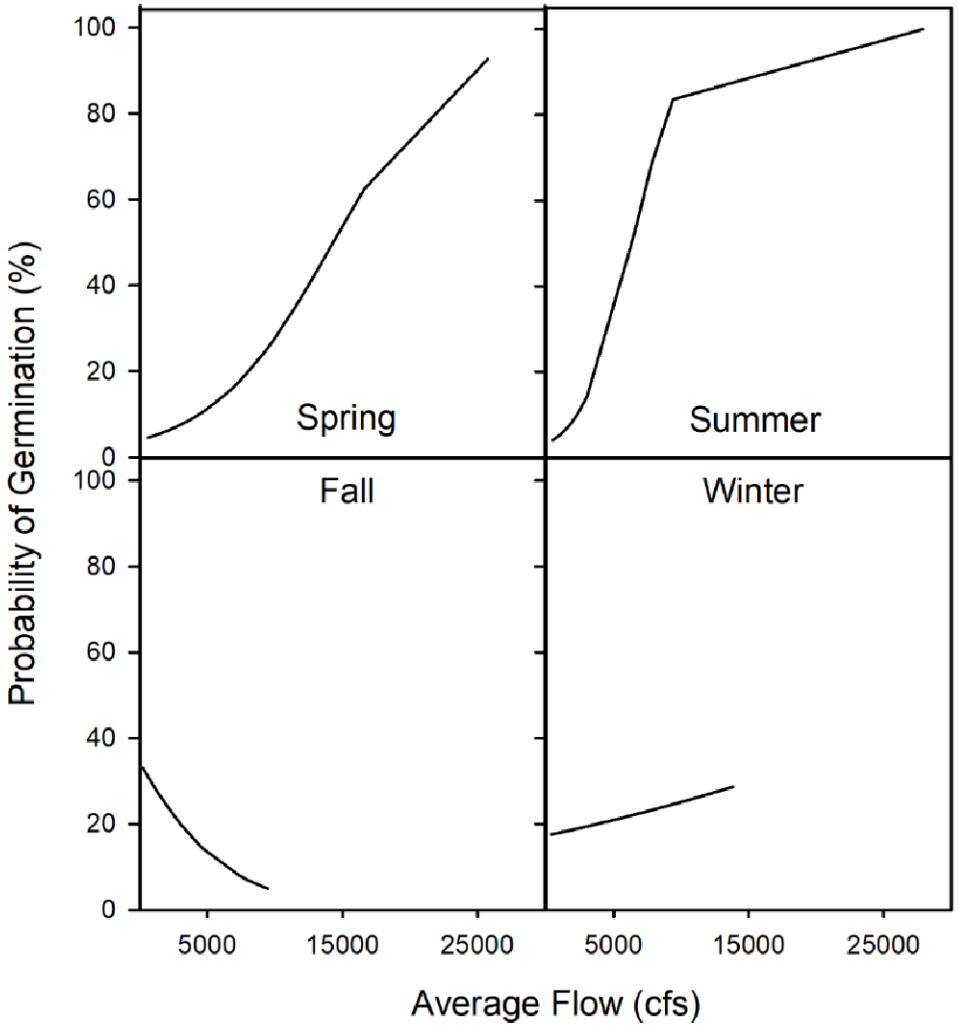


Figure 8. Germination response estimated for boxelder in the riparian zone of the lower Brazos River in response to average flows during four seasons.

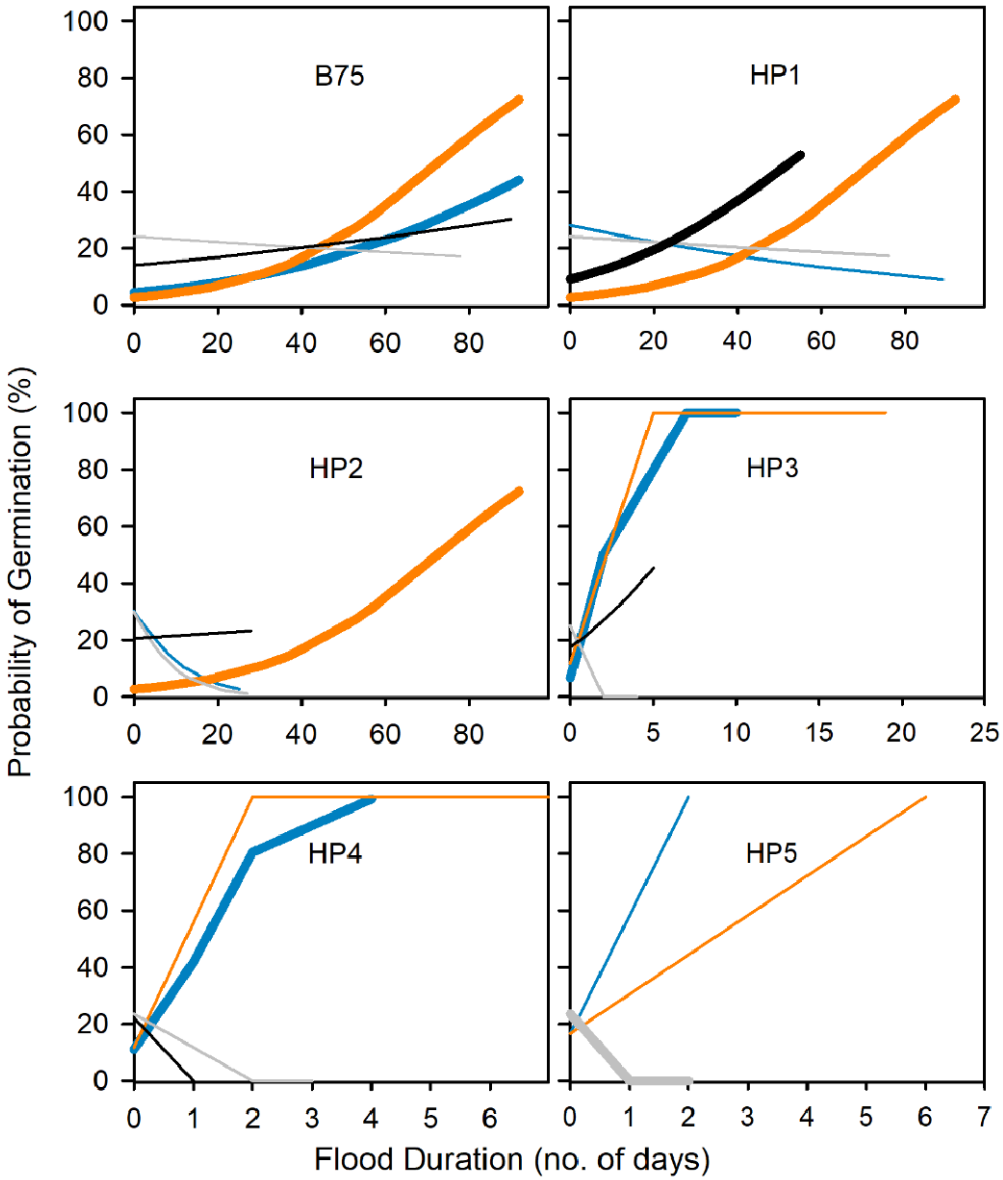


Figure 9. Brazos River high flow pulse (HP) germination response. This figure displays the germination probabilities of *Acer negundo* in response to the high flow pulses of the Brazos River. Bold lines denote an interaction with a *p*-value < 0.2. Seasons are color-coded as spring (blue), summer (orange), fall (gray), and winter (black).

Overbank Events	Qp: 66,900 cfs with Average Frequency 1 per 2 years Regressed Volume is 989,000 Duration Bound is 35											
	Qp: 49,400 cfs with Average Frequency 1 per year Regressed Volume is 675,000 Duration Bound is 30											
High Flow Pulses	Qp: 22,600 cfs with Average Frequency 1 per season Regressed Volume is 243,000 Duration Bound is 20				Qp: 32,900 cfs with Average Frequency 1 per season Regressed Volume is 421,000 Duration Bound is 25				Qp: 12,100 cfs with Average Frequency 1 per season Regressed Volume is 114,000 Duration Bound is 16			
	Qp: 11,200 cfs with Average Frequency 2 per season Regressed Volume is 100,000 Duration Bound is 14				Qp: 17,800 cfs with Average Frequency 2 per season Regressed Volume is 193,000 Duration Bound is 18				Qp: 5,000 cfs with Average Frequency 2 per season Regressed Volume is 38,100 Duration Bound is 10			
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	Qp: 3,230 cfs with Average Frequency 4 per season Regressed Volume is 21,100 Duration Bound is 7				Qp: 6,050 cfs with Average Frequency 4 per season Regressed Volume is 49,000 Duration Bound is 11				Qp: 2,060 cfs with Average Frequency 4 per season Regressed Volume is 12,700 Duration Bound is 7			
Base Flows (cfs)	1,760				2,460				1,470			
	860				1,260				920			
	540				710				630			
Subsistence Flows (cfs)	300				300				300			
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
	Winter				Spring				Summer			

Base Flow Levels
High (75th %ile)
Medium (50th %ile)
Low (25th %ile)

Pulse volumes are in units of acre-feet and durations are in days.

Period of record used : 1/1/1928 to 12/31/2010.

Episodic events are terminated when the volume or duration criteria are met, or when the flow drops below 833 cfs, or when the flow is below 5080 cfs and the flow drops from one day to the next by less than 5%.

2-per season high-flow pulse standard (spring)

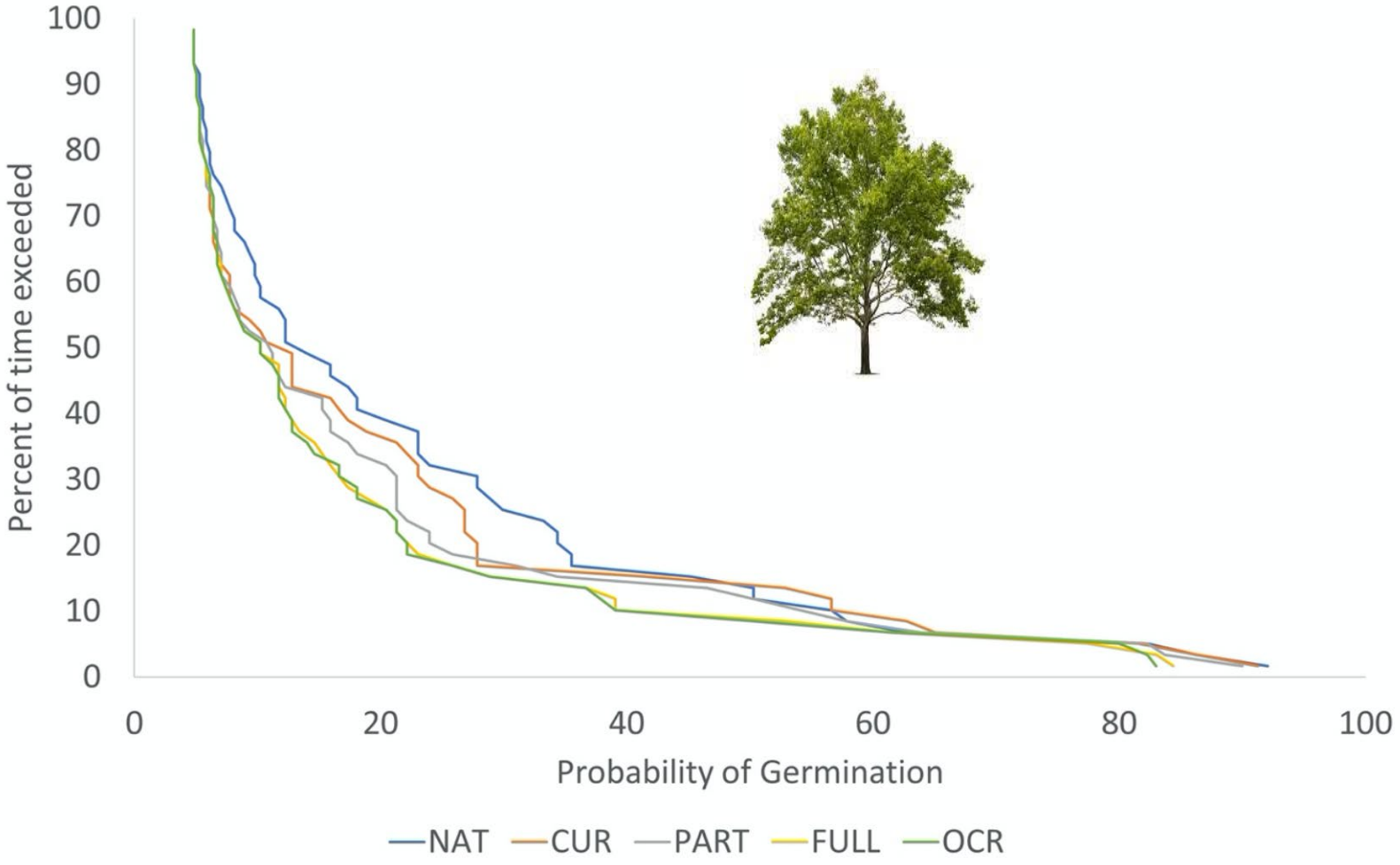

Figure 11. Exceedance plot of probability of germination for boxelder based on the flow ecology relationship to number of days meeting or exceeding the two-per-season spring high flow pulse magnitude at the Brazos River at Bryan, Texas. Each line represents projections for a different flow scenario: NAT (naturalized), CUR (current), PART (partially permitted water rights under current environmental flow standards), FULL (fully permitted under current environmental flow standards), and OCR (fully permitted with off-channel reservoir).

FEATURE

Advancing Environmental Flows Science: Hindcasting and Forecasting Flow–Ecology Relationships

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Thomas B. Hardy | Department of Biology, Texas State University, San Marcos, TX

David Buzan | Freese and Nichols, Austin, TX

The mouth of the Smallmouth Buffalo Ictiobus bubalus is fleshy and projects downward, like most suckers. Smallmouth Buffalo feed on the bottom, and eat mainly insect larvae and crustaceans. Photo credit: Canfield, Doug, U.S. Fish and Wildlife Service

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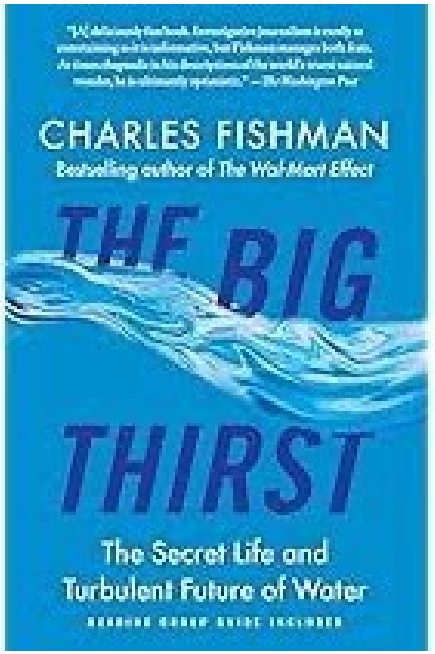
THE NATIONAL DAILY NEWS SHOW OF TEXAS

Texas population continues growing faster than any other state

Some 500,000 new residents moved to the state in the past year, according to the U.S. Census Bureau.



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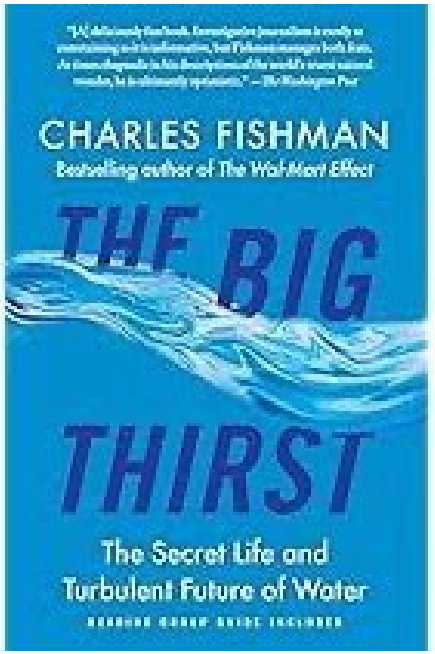

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