HABITAT CONSERVATION PLAN
EDWARDS AQUIFER

Springflow Habitat Protection Work Group

May 28, 2020
9:00-11:00am

Agenda Overview

- Confirm attendance
- Meeting logistics
- Public comment
- Approve meeting minutes
- Presentations and discussion
  - San Marcos salamander biomonitoring – Ed Oborny, BIO-WEST
  - Salamander population dynamics in the context of flow variation and drought – Nate Bendik, City of Austin
- Meeting 2 follow up discussion
- Public comment
- Future meetings


Confirm attendance

Meeting logistics

- Virtual meeting logistics
  - Mute
  - Raise Hand
  - Chat / Asking questions
  - Meeting recording

- Meeting points of contact
  - Meeting access
    - Victor Hutchison (vhutchison@..)
  - Technical questions
    - Victor Hutchison (vhutchison@..)
    - Martin Hernandez (mhernandez@..)
  - Participant monitor
    - Kristy Kollaus (kkollaus@...)
  - Chat and Q&A monitors
    - Kristina Tolman (ktolman@...)
    - Damon Childs (dchilds@...)

Public comment

Meeting Minutes

HCP BIOLOGICAL MONITORING
SAN MARCOS SALAMANDERS

EAHCP Stakeholder Meeting #3

May 28, 2020

Ed Oborny

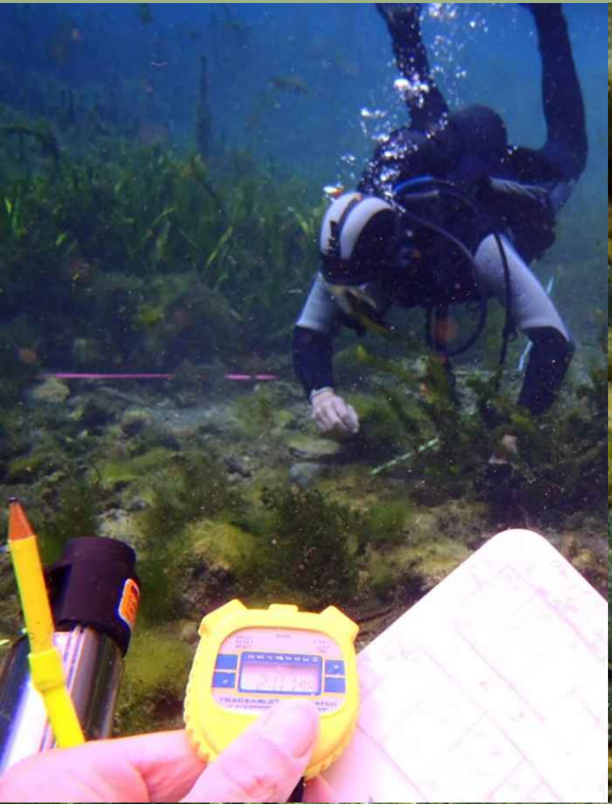
San Marcos Salamander Literature

- Nelson, 1993
  - Population size, distribution, and life history of Eurycea nana in the San Marcos River. Thesis, Master of Science, Southwest Texas State University. 43 pp.
- BIO-WEST 2001 – 2020
  - EAA Annual Biological Monitoring Reports.
- Edwards Aquifer Area Expert Science Subcommittee, 2009 (J-charge)
  - Analysis of Species Requirements in Relation to Spring Discharge Rates and Associated Withdrawal Reductions and Stages for Critical Period Management of the Edwards Aquifer.
- Perkin et al, 2017   Texas A&M University
  - Analysis of the Comal Springs and San Marcos Springs Long-Term Monitoring Dataset.

San Marcos Salamander

- Edwards Aquifer Biological Monitoring
  - Spring Lake and Eastern Spillway
    - SCUBA and snorkel
  - Fall 2000 – present
    - Minimum – twice annually
    - 20 year continuous record

San Marcos Salamander




San Marcos Salamander
Biological Monitoring Sites
Hotel
Riverbed
Eastern
Spillway
82
© 2020 Google

San Marcos Salamander

- Key salamander habitat
  - Clear, flowing, thermally constant water
  - Silt-free substrate through upwelling or surface flow
  - Bryophytes, low growing rooted macrophytes (i.e. Hydrocotyle and Ludwigia)

Suitable Habitat

San Marcos Salamander

Two Decades of Habitat Conditions

Spring Lake

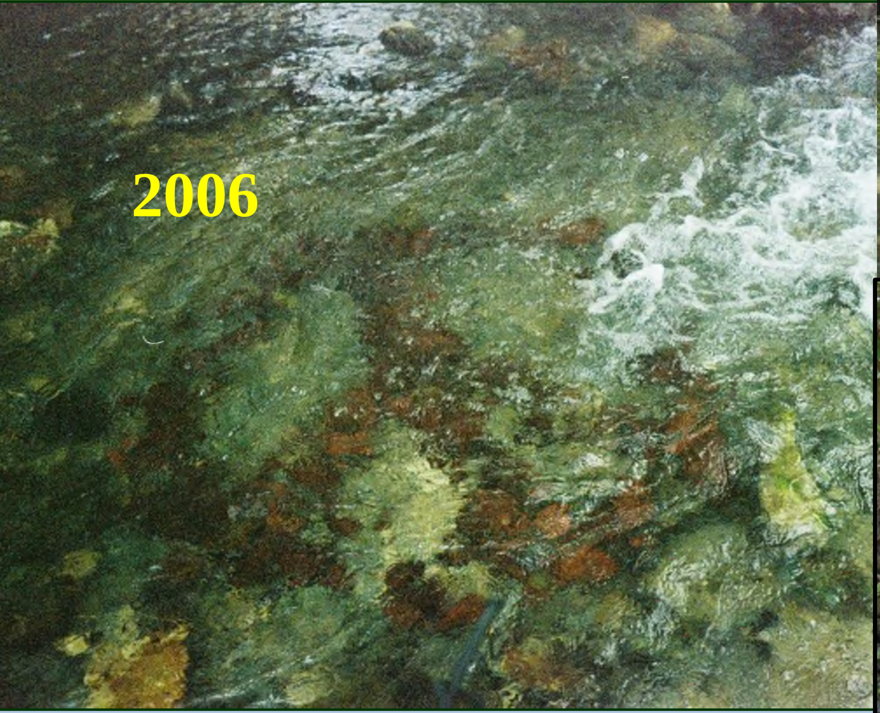
San Marcos Salamander

Two Decades of Habitat Conditions

Eastern Spillway

San Marcos Salamander

Two Decades of Habitat Conditions

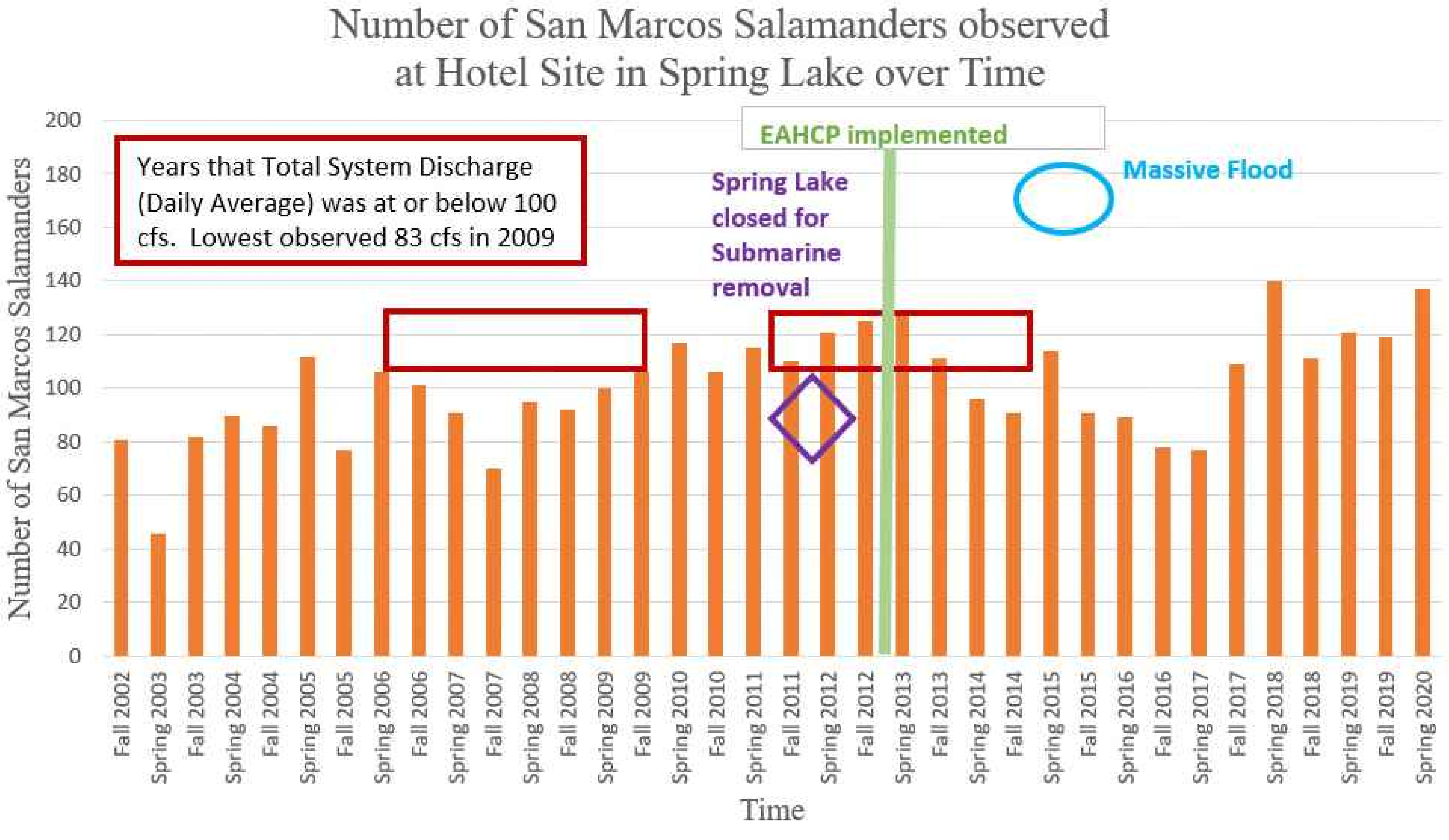


Eastern Spillway

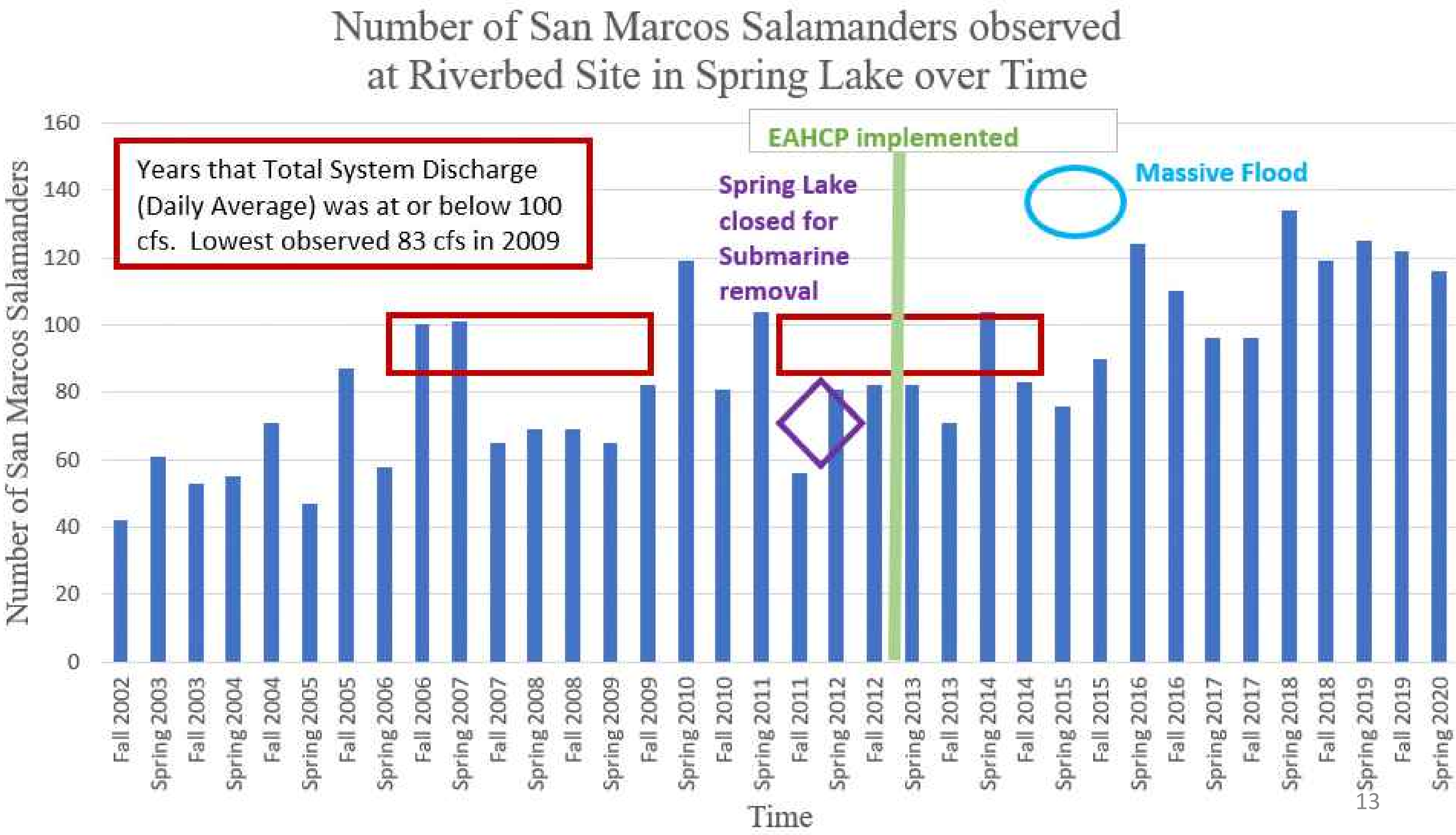
San Marcos Salamander Observations

- Perkins, 2017
  - San Marcos Salamander abundances monitored using visual observations in the San Marcos River system attenuated with longitudinal distance from spring sources and the species has shown long-term increases across sites in the San Marcos Springs system.
- EAHCP Biological Monitoring Data
  - 2001 through 2020 on-going
  - Presented on following slides.

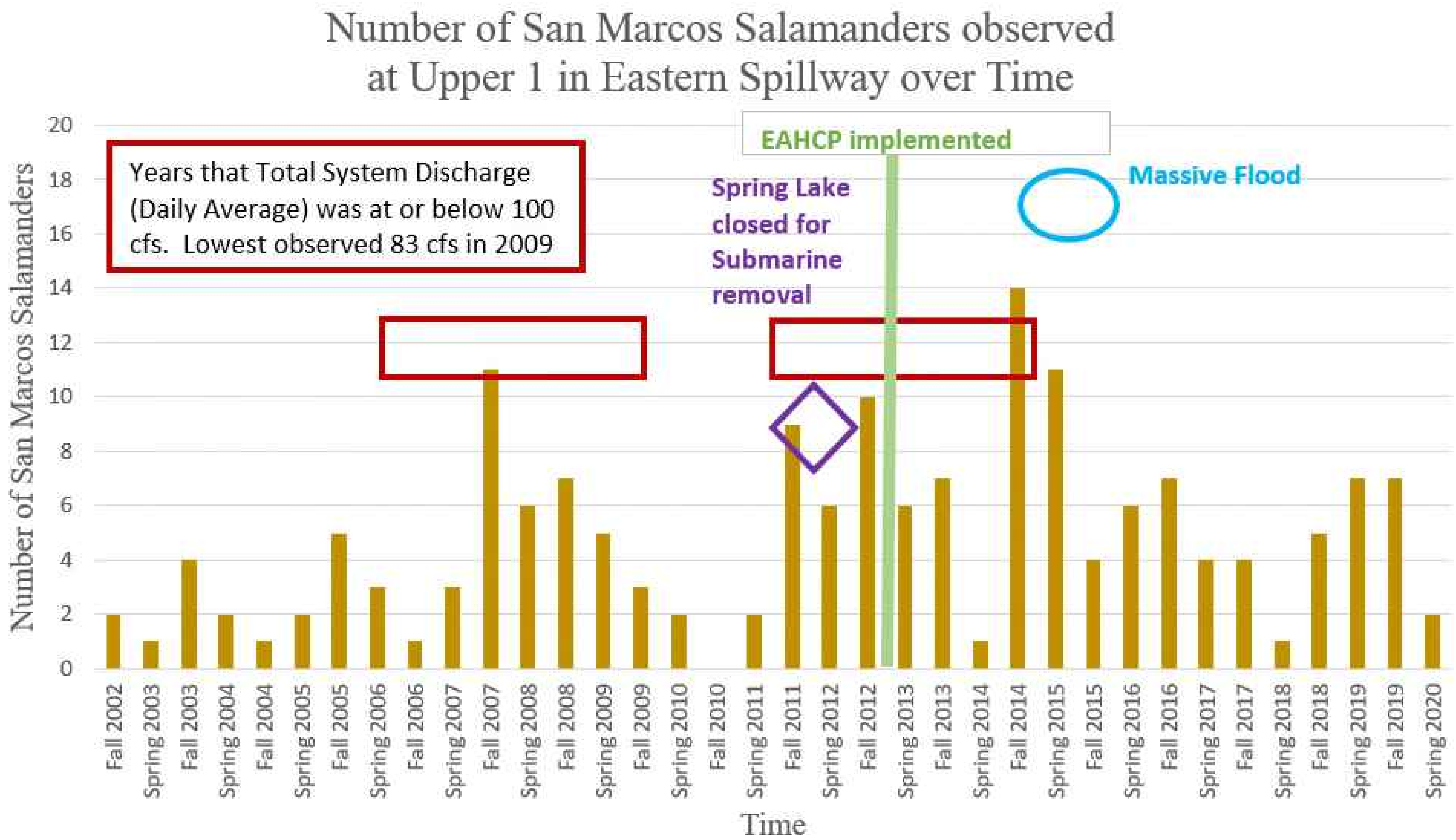
Spring Lake – Hotel Site



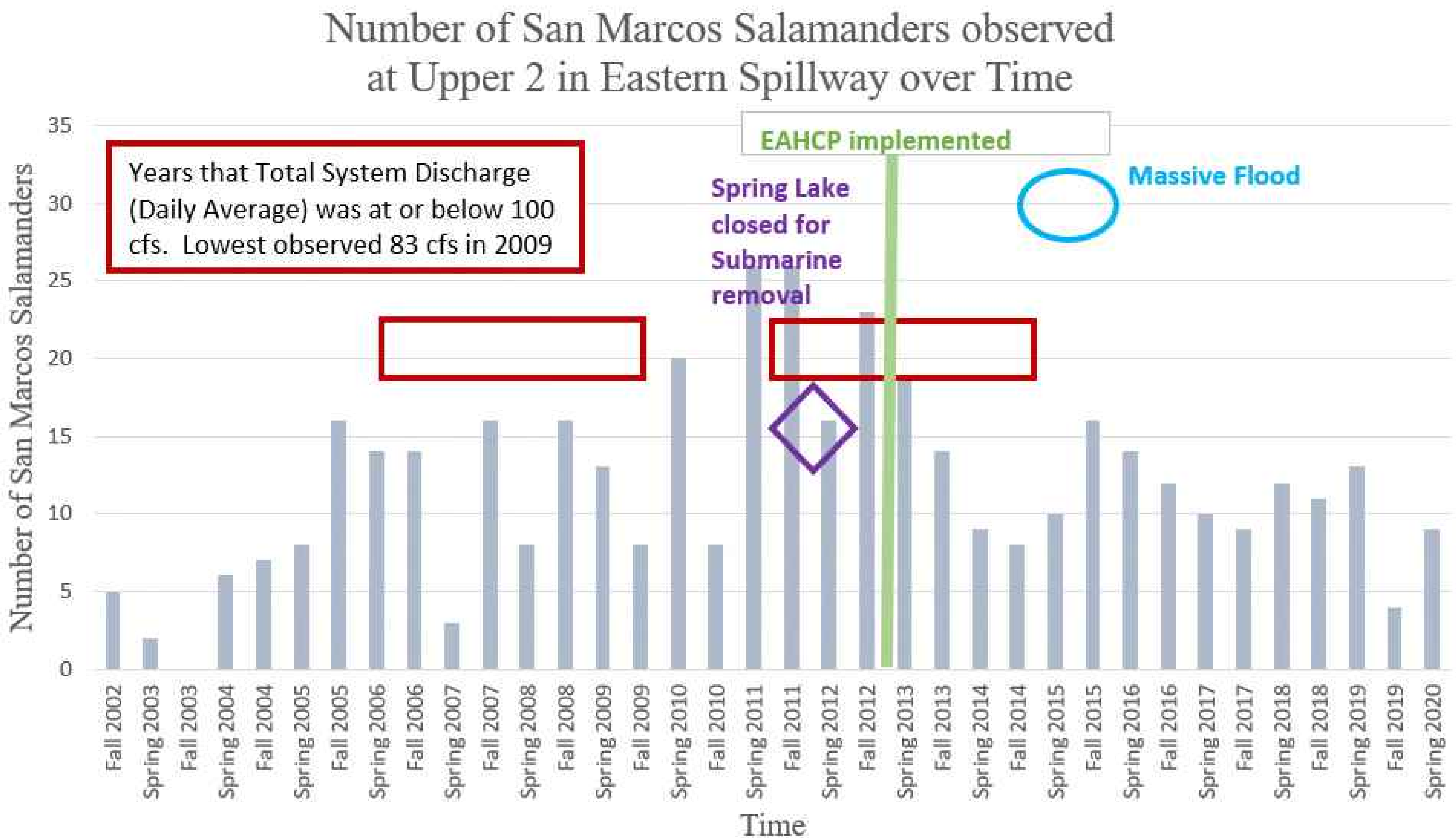
Spring Lake – Riverbed Site



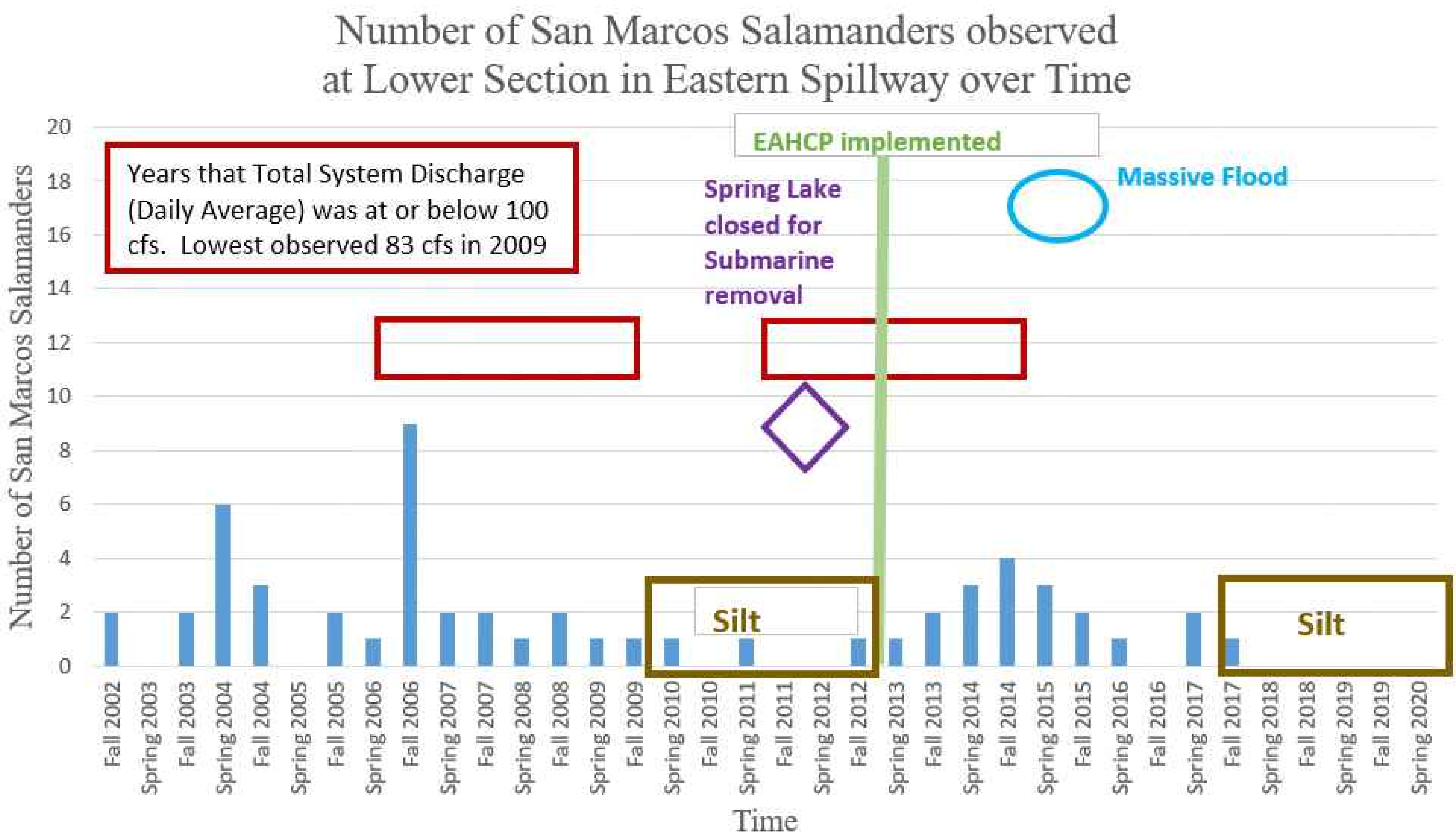
Eastern Spillway – Upper 1



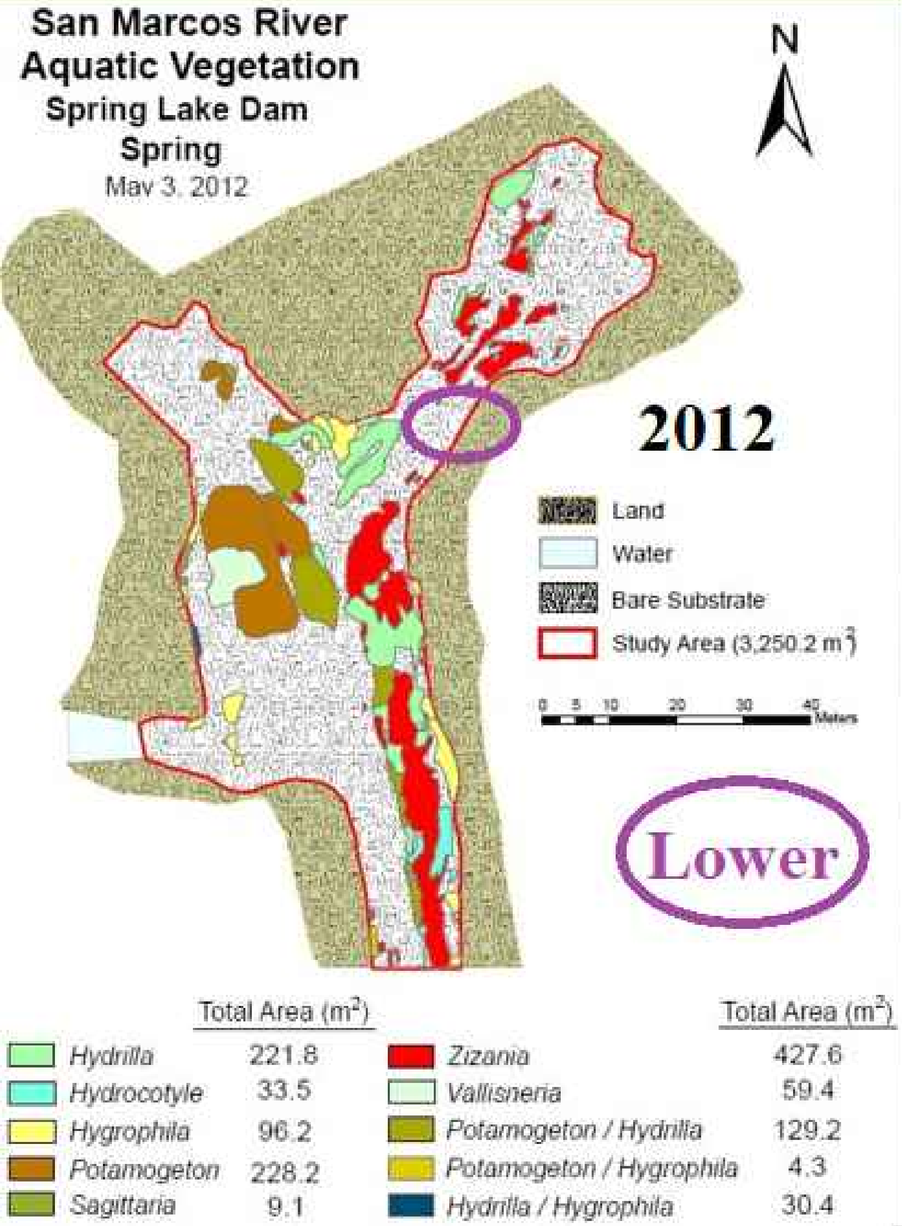
Eastern Spillway – Upper 2

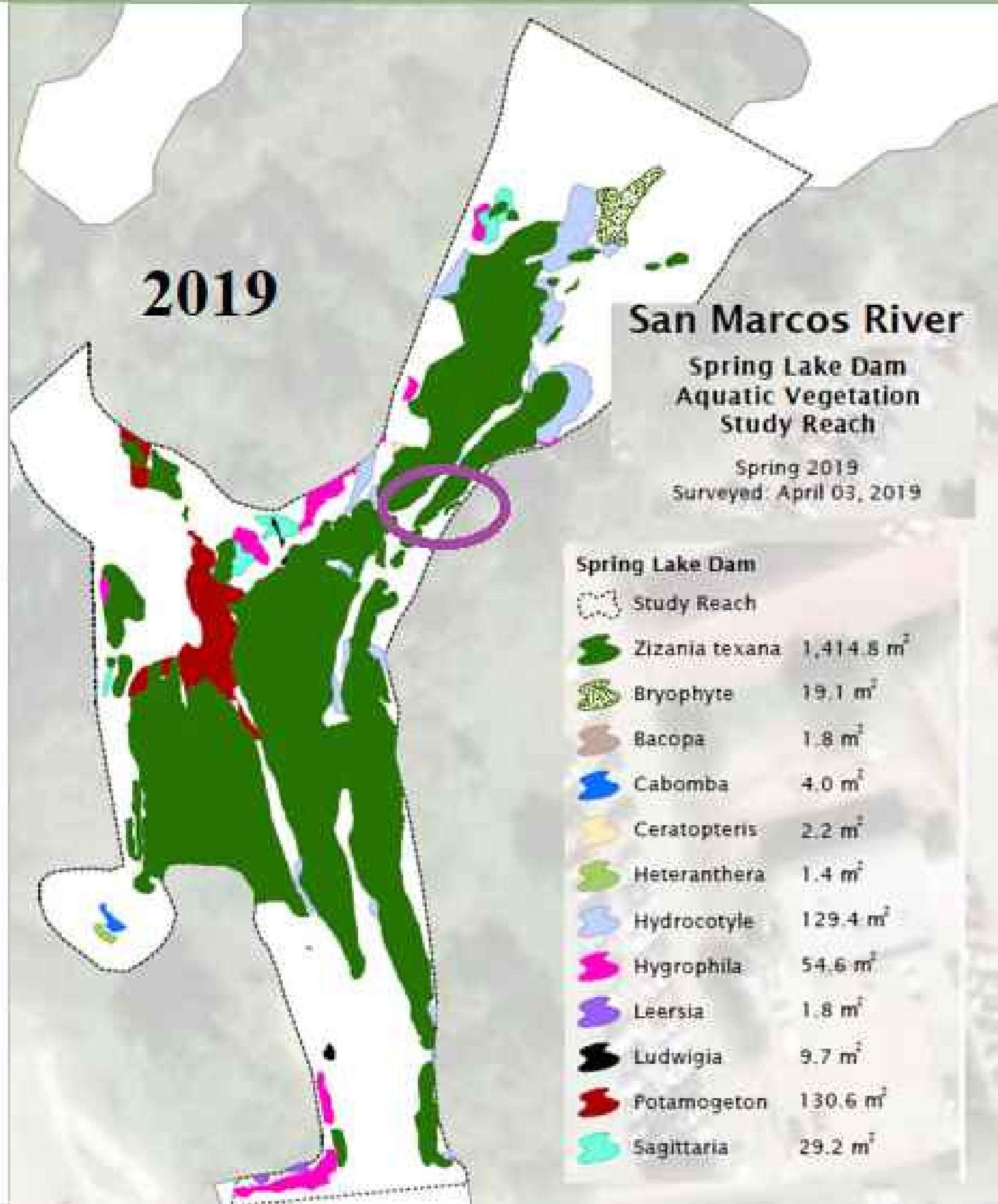


Eastern Spillway – Lower



Spring Lake Dam Texas wild-rice





Eastern Spillway – Lower Section (2019)

San Marcos Salamander Concluding Notes

San Marcos System

- 80 cfs ? Stakeholder charge.
  - Spring Lake
    - Continued aquatic gardening
  - Eastern Spillway
    - Maintain suitable habitat, prevent excessive siltation

Questions? Comments

HABITAT CONSERVATION PLAN
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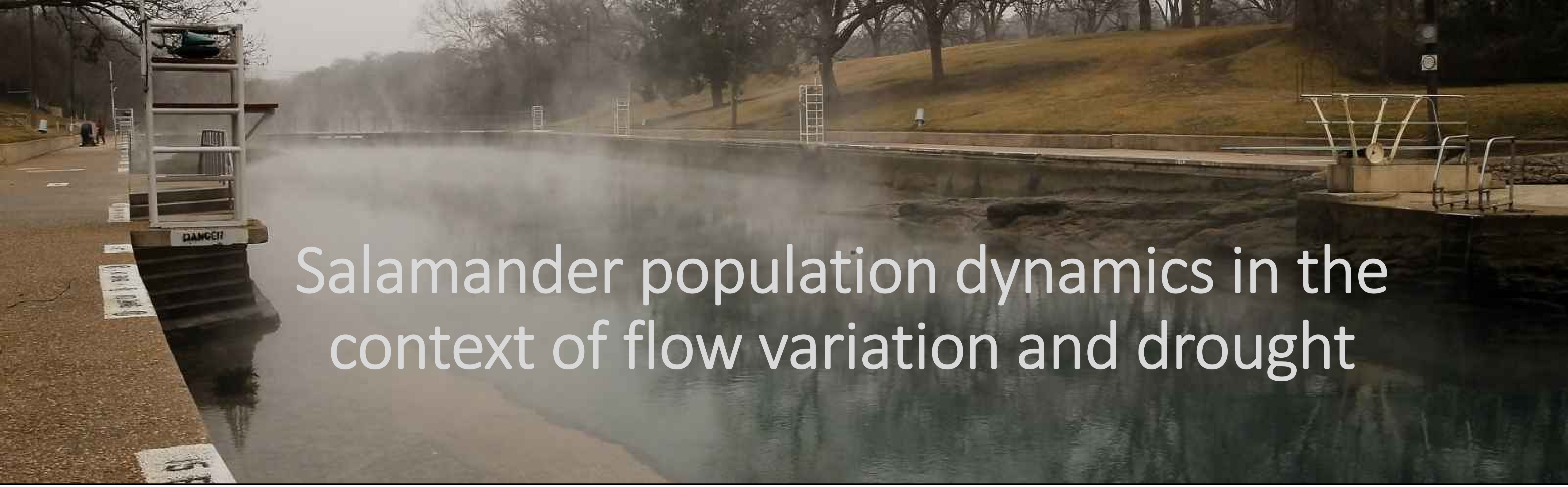
Salamander population dynamics in the context of flow variation and drought



Salamander population dynamics in the context of flow variation and drought

Nathan Bendik

City of Austin
WATERSHED PROTECTION

From Caves to Springs:
Morphological Variation in Texas *Eurycea*


Honey Creek Cave


Bullis Bat Cave


Camp Bullis Cave #3


Hector Hole


Camp Bullis Cave #1


Sharon Spring (cave)


Lewis Valley Cave


Cascade Caverns


Cave and surface morphs from Honey Creek Cave


Preserve Cave


Cascade Caverns


Cave Without A Name


Golden Fawn Cave


Morales Spring


Fern Bank Spring


Taylor Spring


Hoffman Ranch Estavelle

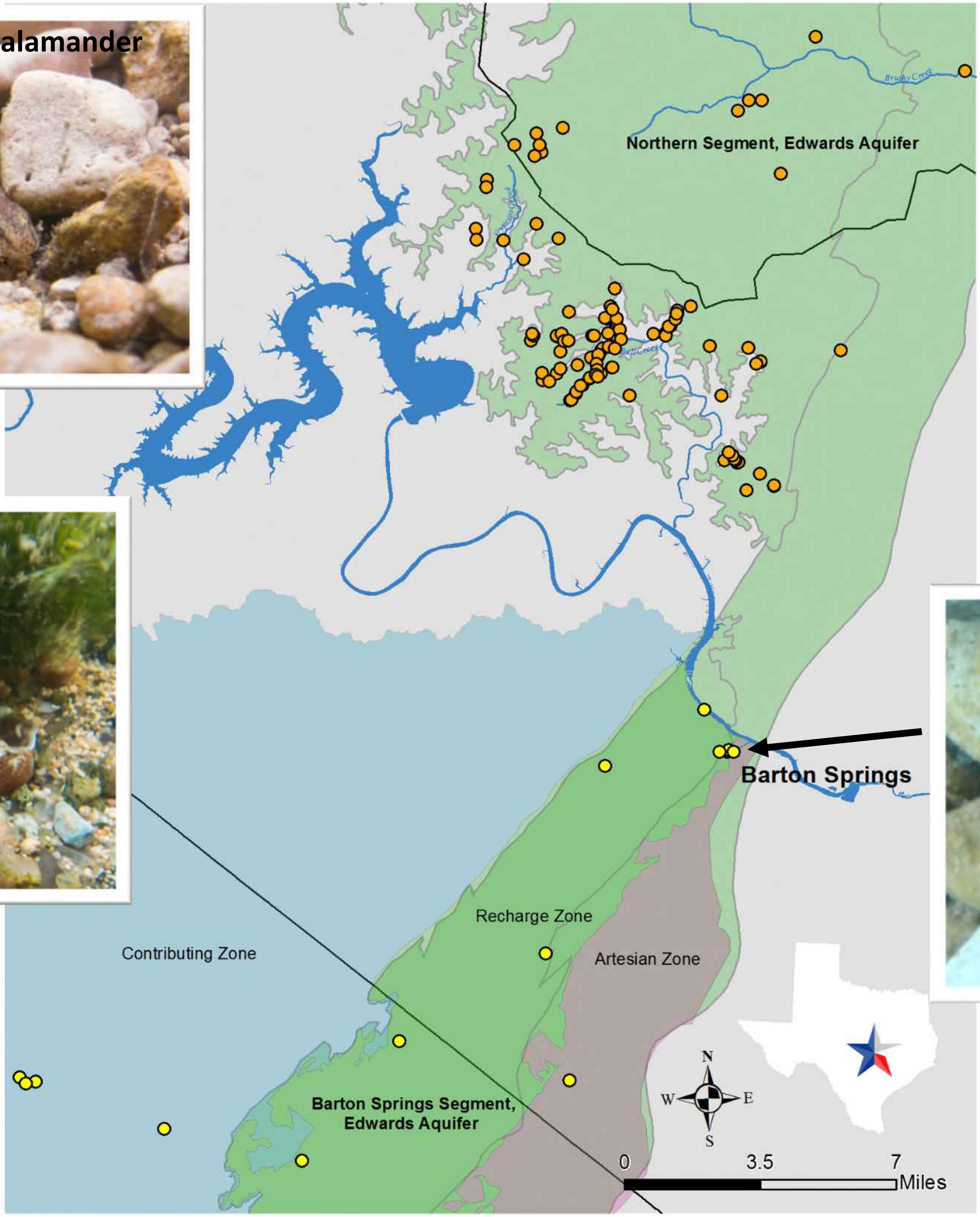

Bullis Spring 09-83


White Springs

Evolution and Drought

- Evolved ~ 22 mya from paedomorphic (obligate aquatic) ancestor[1]
- Speciation and extinction
  - Edwards Plateau uplift, erosion and karst development
  - Climatic change and variation
- Climate and Droughts
  - 16 great droughts in central US btw 1913 and 2016[2]
  - Drier climate here in early-mid Holocene, but wetter in Pleistocene
  - Miocene climate?

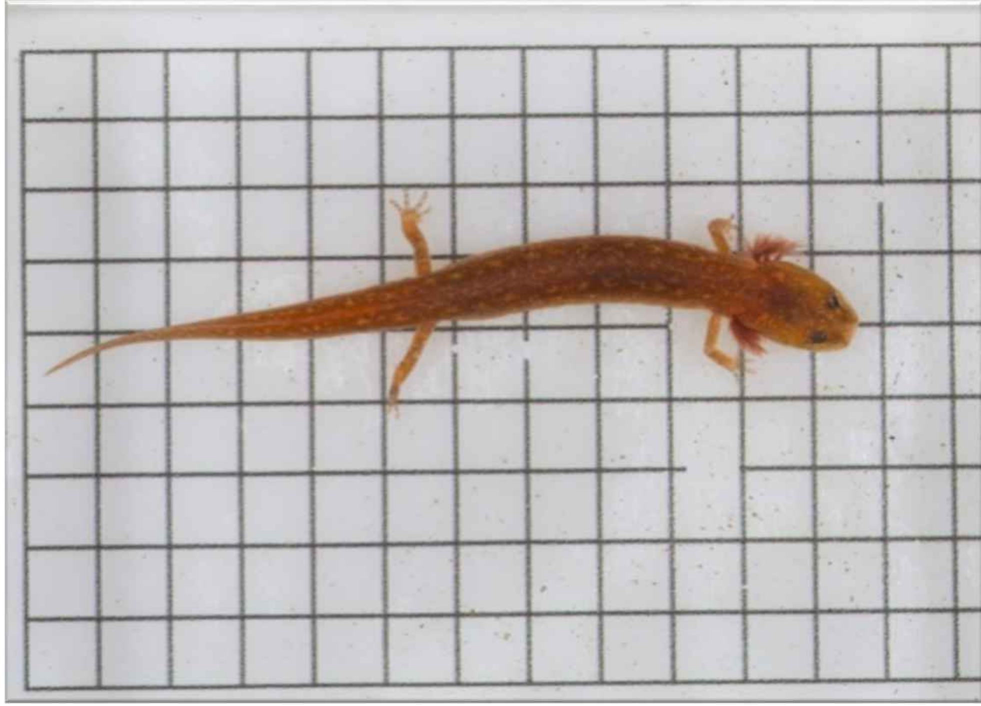
[1]Bonett, R. M., M. A. Steffen, S. M. Lambert, G. A. Robison, J. J. Wiens, and P. T. Chippindale. 2014. Evolution of paedomorphosis in plethodontid salamanders: ecological correlates, reversals, and heterochrony. Evolution 54:E22–E22.
[2]Mo, K. C., and D. P. Lettenmaier. 2018. Drought variability and trends over the central United States in the instrumental record. Journal of Hydrometeorology 19:1149–1166.

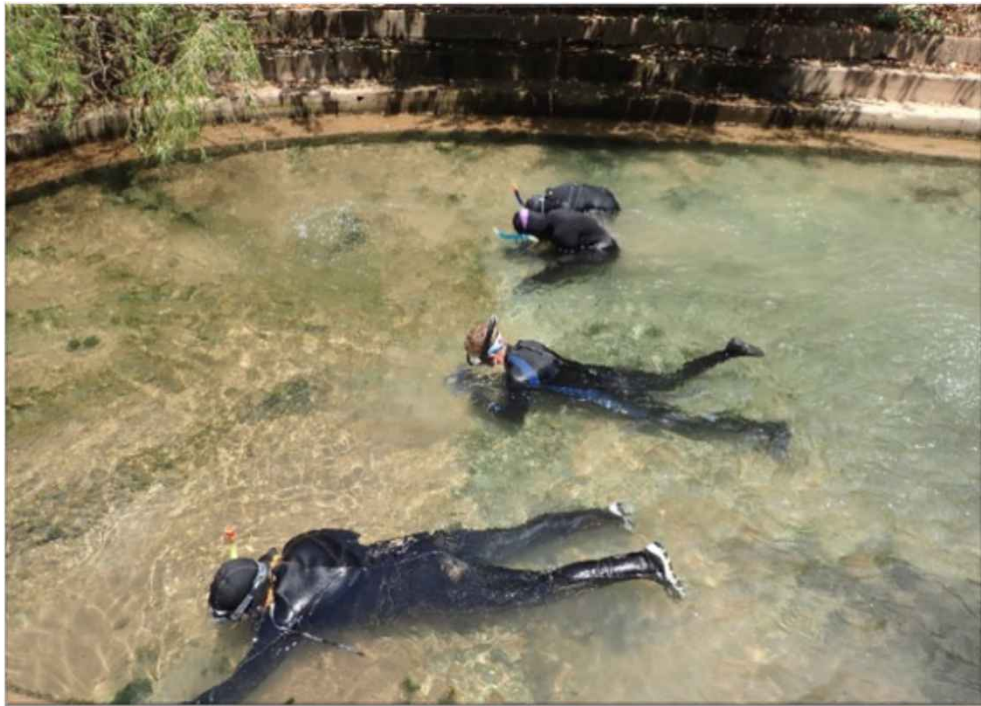


Devitt, T. J., and B. D. Nissen. 2018. New occurrence records for Eurycea sosorum Chippindale , Price & Hillis , 1993 (Caudata , Plethodontidae) in Travis and Hays counties , Texas, USA. Check List 14:297–301.

Population Studies by City of Austin

- Visual count surveys
  - Areas around spring outlets
  - Overturn cover (rocks), estimate rough size, enumerate observations
  - BSS 1993–present (Barton Springs outlets)
  - JPS 1996–2015(dozen sites)
- Capture-mark-recapture surveys
  - Areas around spring outlets
  - Catch and mark or photograph salamanders
  - JPS 2008–2015 BSS 2014–present
- Occupancy surveys
  - Sites distributed throughout tributaries (20-25 sites/trib)
  - Rapid assessment- is species there or not?
  - JPS only (12 tribs, ~250 sites)



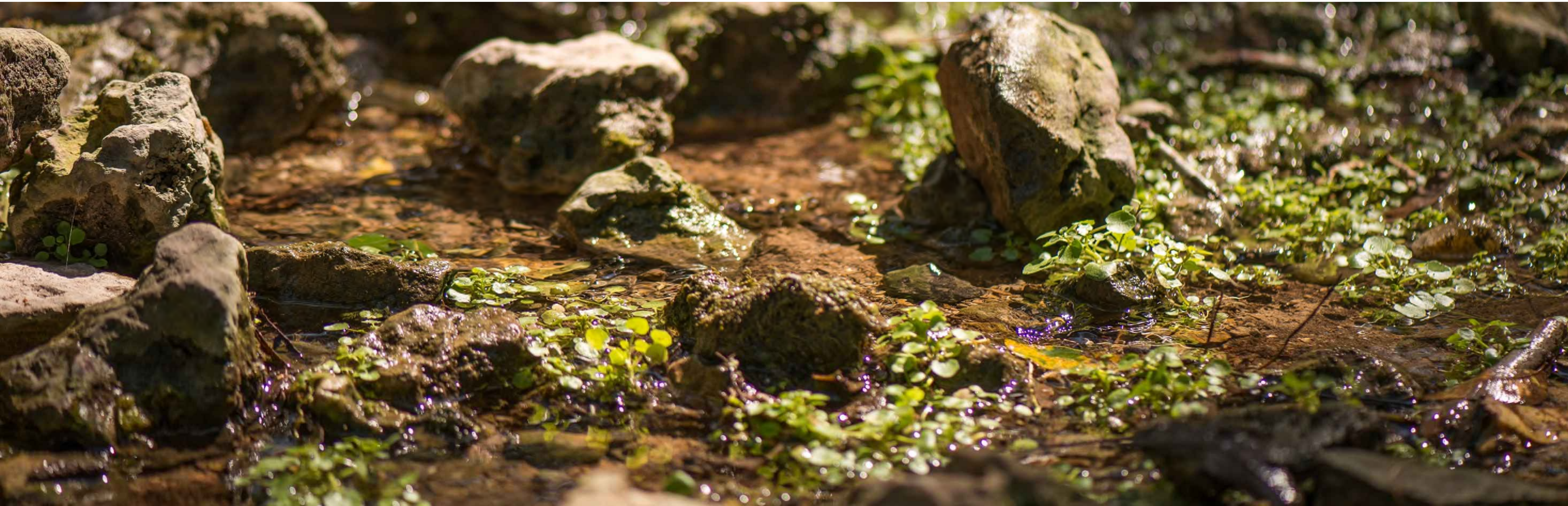


Springs

- Barton Springs (BSS and ABS)
  - Large spring, main discharge point of Barton Springs segment of EA
  - Perennial flow
  - Deep aquifer system
  - Well studied – continuous USGS flow monitoring
- Jollyville Plateau springs (JPS)
  - Assorted springs, many emerging from canyons on the edge of the plateau
  - Flow can be intermittent
  - Occur in both Edwards and Glen Rose limestone formations (JPS)
  - Shallow, dissected aquifer. Springsheds seem to follow tributary basins (but not always)
  - Poorly studied– no continuous flow monitoring

Figure 1. Location of the four major springs of the Barton Springs group.

JPS: Response to variable flow conditions



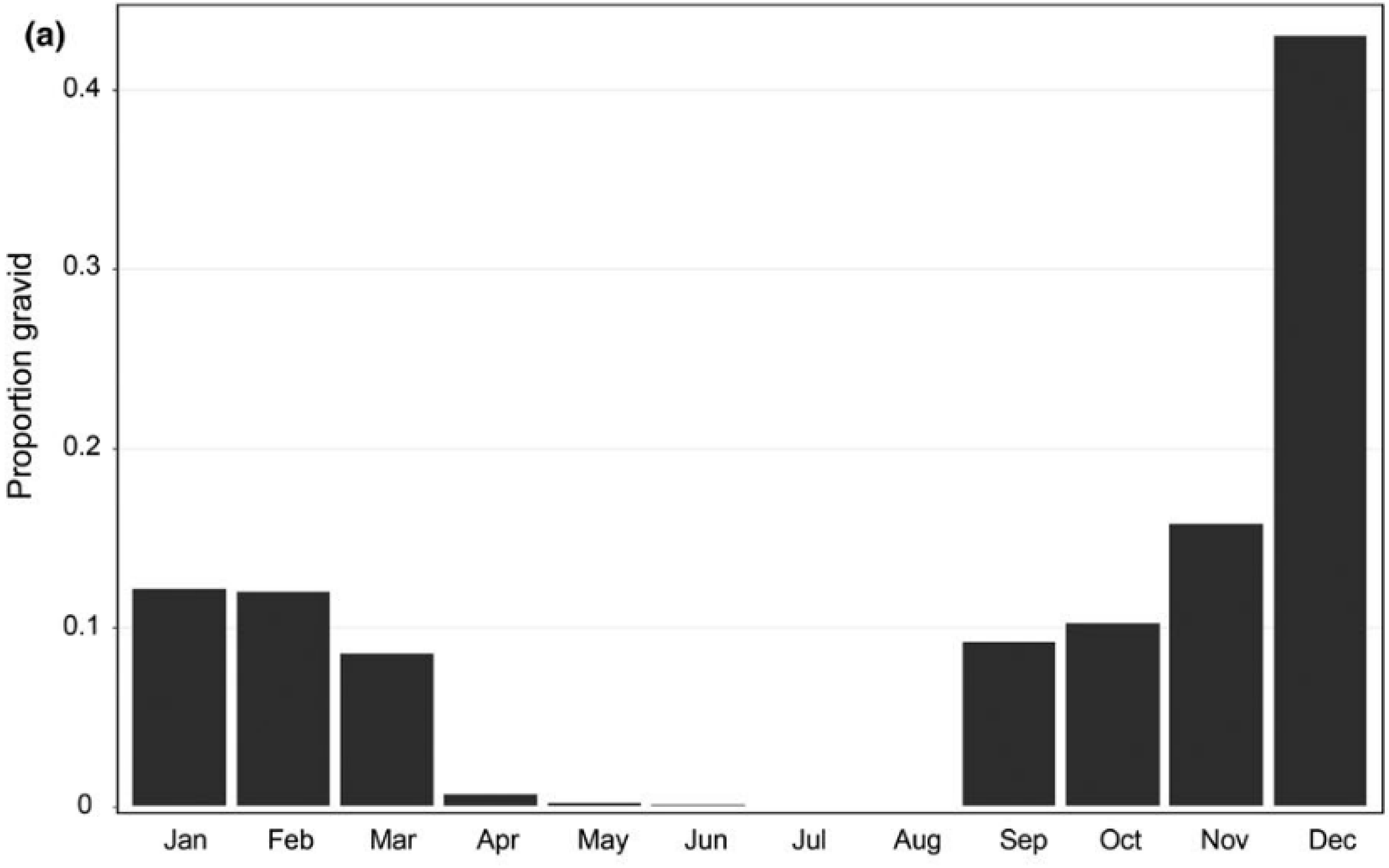
Discharge on Bull Creek positively correlated with counts
Drought index negatively correlated with counts

Table 3. Linear predictor parameter estimates and 95% Bayesian credible intervals (CI) from Poisson GLM of trends in *E. tonkawae* counts at long-term monitoring sites from 1996–2011. Trend is the geometric rate of population change displayed as percent change per year and was estimated from the baseline model. Mean estimates with 95% credible intervals excluding zero are displayed in bold.

Variable (parameter)	Mean	SD	95% CI	Baseline Trend (%)
Tmp (β_1)	**0.015**	**0.004**	**0.007, 0.022**	NA
Flow (β_2)	**0.023**	**0.006**	**0.012, 0.035**	NA
Z-index (β_3)	**-0.047**	**0.019**	**-0.083, -0.009**	NA
Δdev (β_γ)	**-0.695**	**0.358**	**-1.573, -0.121**	NA
Time (γ_j)				
Franklin	0.018	0.034	-0.050, 0.084	4.4
Stillhouse trib	0.017	0.034	-0.050, 0.083	0.9
Stillhouse spring	0.017	0.034	-0.050, 0.083	10.5
Trib 3	**-0.079**	**0.045**	**-0.186, -0.003**	**-14.1**
Tanglewood	**-0.097**	**0.052**	**-0.225, -0.012**	**-16.1**
Spicewood	0.010	0.033	-0.054, 0.073	-6.6
Trib 5	**-0.092**	**0.050**	**-0.214, -0.010**	**-47.9**
Trib 6	**-0.185**	**0.093**	**-0.421, -0.042**	**-8.2**

Bendik, N. F., B. N. Sissel, J. R. Fields, L. J. O'Donnell, and M. S. Sanders. 2014. Effect of urbanization on abundance of Jollyville Plateau salamanders (*Eurycea tonkawae*). Herpetological Conservation and Biology 9:206–222.

Gravid individuals not observed in summer



Bendik, N. F. 2017. Demographics, reproduction, growth, and abundance of Jollyville Plateau salamanders (*Eurycea tonkawae*). Ecology and Evolution 7:5002–5015.

Largest salamanders less abundant during late Summer

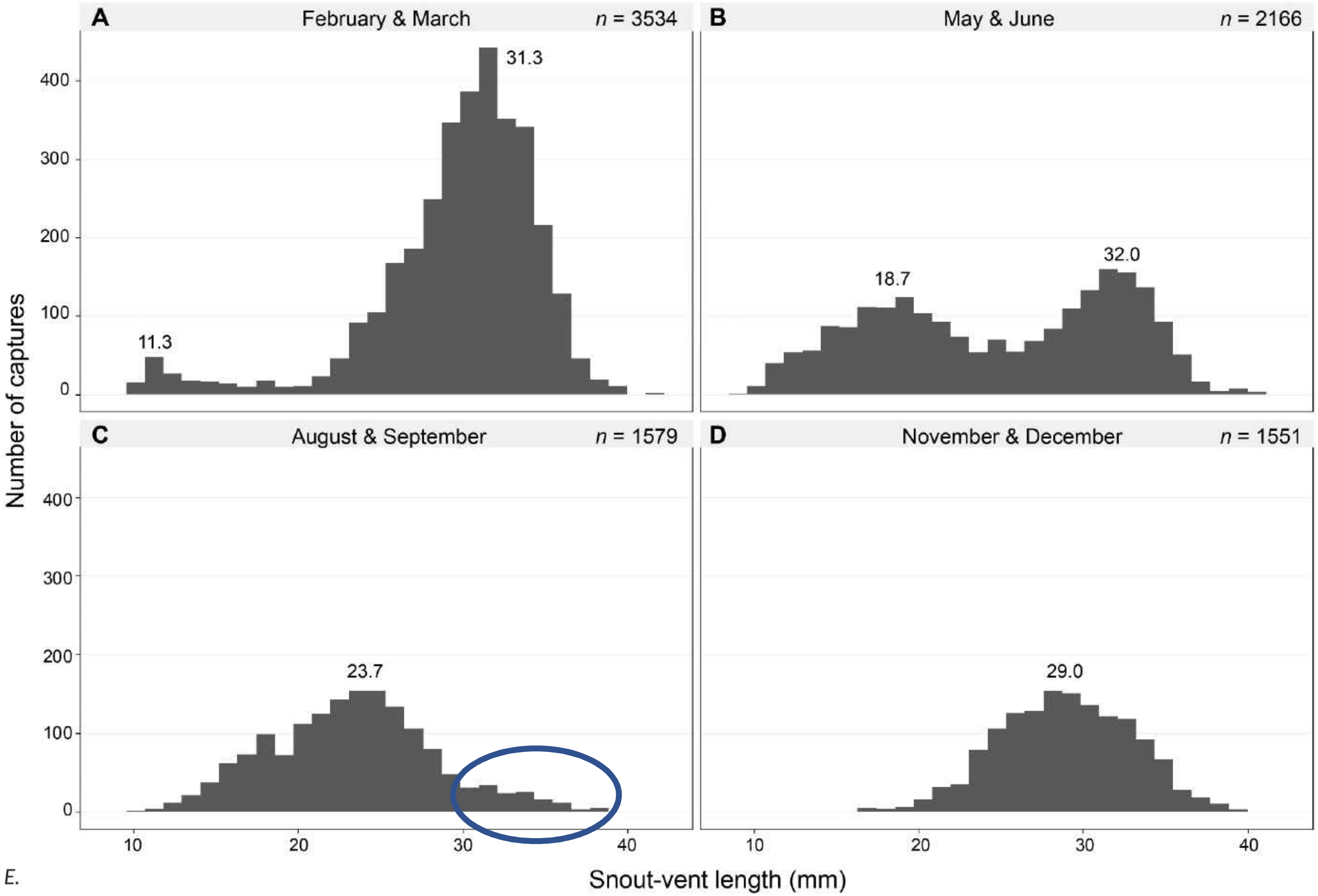


FIGURE 3 Histogram of snout–vent length (mm) for all *E. tonkawae* captures at 16 sites from 2008 to 2015 during surveys in February and March (a), May and June (b), August and September (c), and November and December (d). Values are shown for the highest density modes

Bendik, N. F. 2017. Demographics, reproduction, growth, and abundance of Jollyville Plateau salamanders (*Eurycea tonkawae*). Ecology and Evolution 7:5002–5015.

Temporary movements away from site tend to be higher during summer

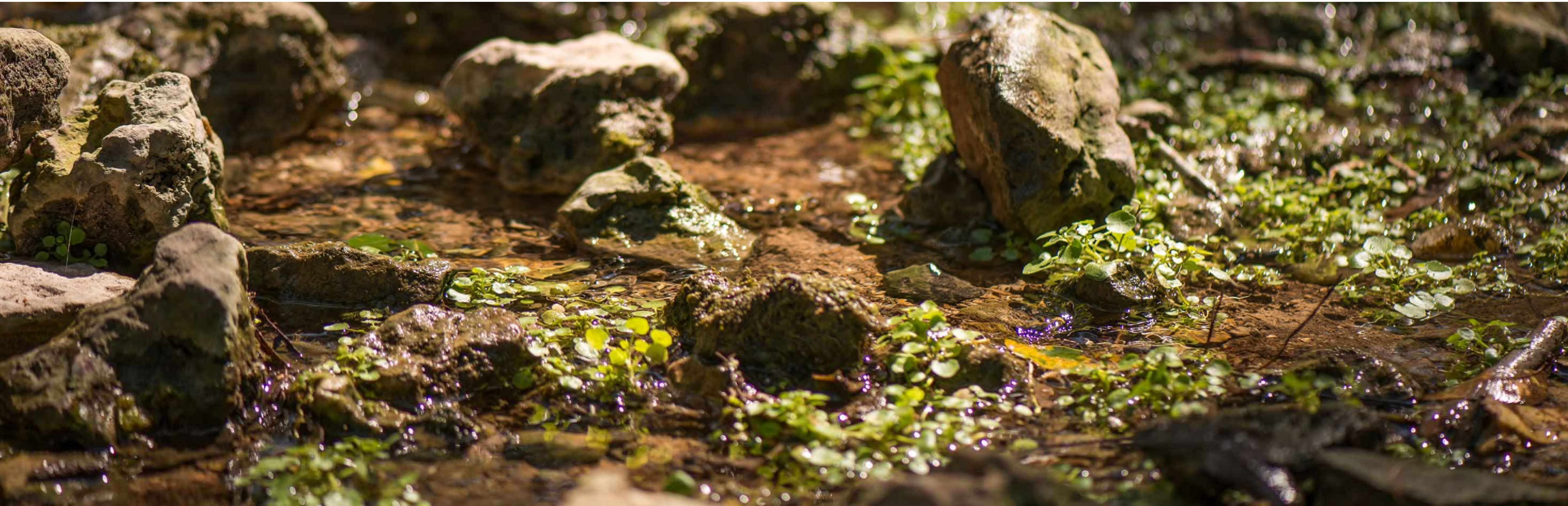
	$\hat{\gamma}''$			$\hat{\gamma}'$			$\hat{\varphi}$		
Period	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Mar-09	0.49	0.23	0.67	–	–	–	0.73	0.52	1.00
Jun-09	0.37	0.00	0.54	0.46	0.00	0.79	0.72	0.15	1.00
Dec-09^{S}	0.89	0.78	0.94	0.91	0.00	1.00	0.47	0.20	1.00
Mar-10^{W}	0.41	0.09	0.62	0.86	0.77	0.92	0.48	0.07	1.00
Oct-10^{S}	0.92	0.81	0.97	0.94	0.89	0.97	0.99	0.39	1.00
Apr-11^{W}	0.73	0.46	0.86	0.85	0.72	0.92	1.00	0.44	1.00
Mar-12	0.00	0.00	0.38	0.22	0.10	0.57	0.11	0.08	0.17

TABLE 3 Temporary emigration and apparent survival estimates for Lanier Spring, 2008–2012, for model $\varphi(t)\ \gamma''(t)\ \gamma'(t)\ p^{*}(\text{best})\ c(\text{best})$

Bendik, N. F. 2017. Demographics, reproduction, growth, and abundance of Jollyville Plateau salamanders (*Eurycea tonkawae*). Ecology and Evolution 7:5002–5015.

JPS: Response to variable flow conditions

- Long-term trends: +flow -drought
- No gravidity during the summer
- Seasonal population demographics and reproduction
- Migration of adults underground during dryer summer season

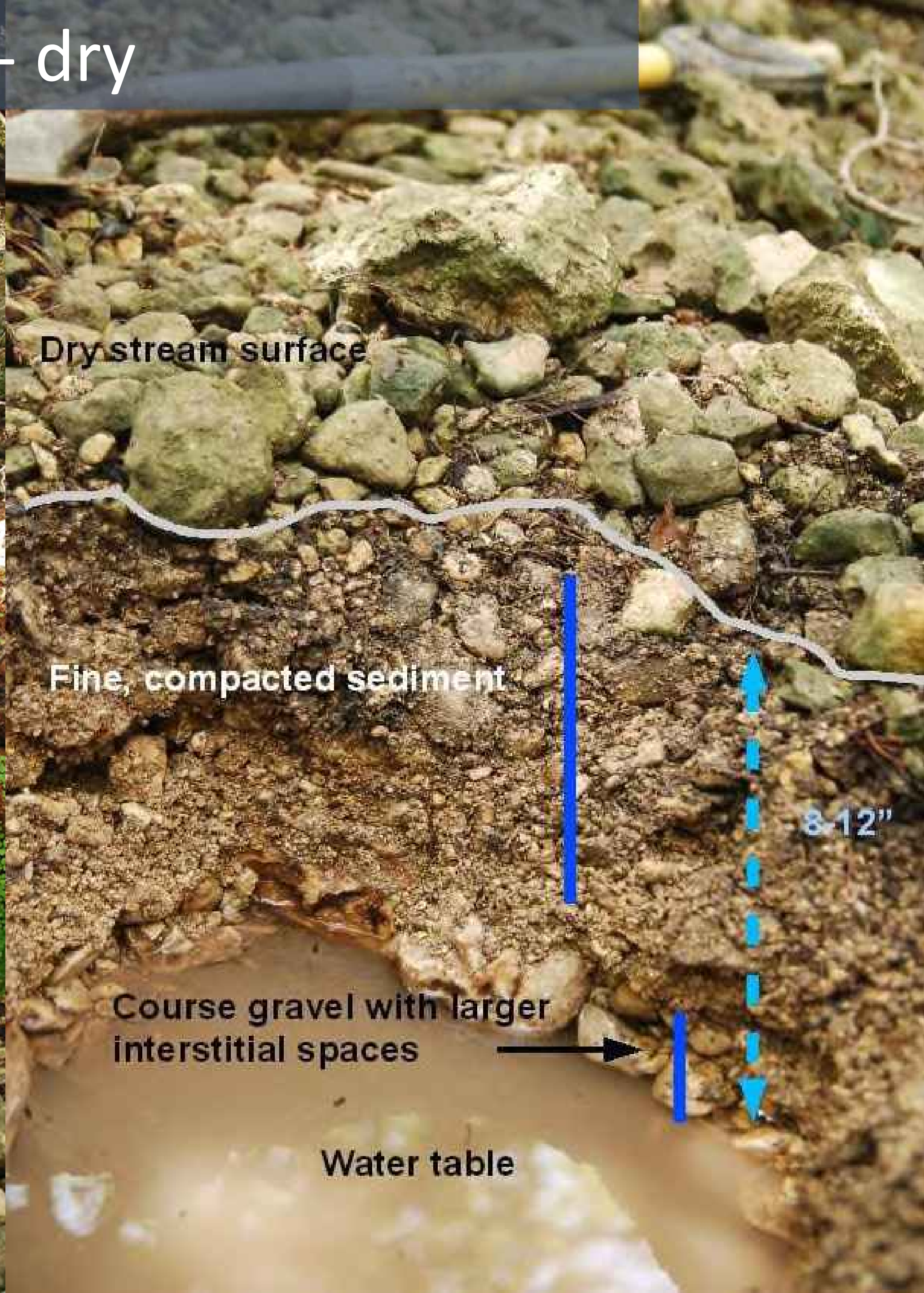


JPS: Dry weather & dry springs

BCP, Lanier Spring- going dry

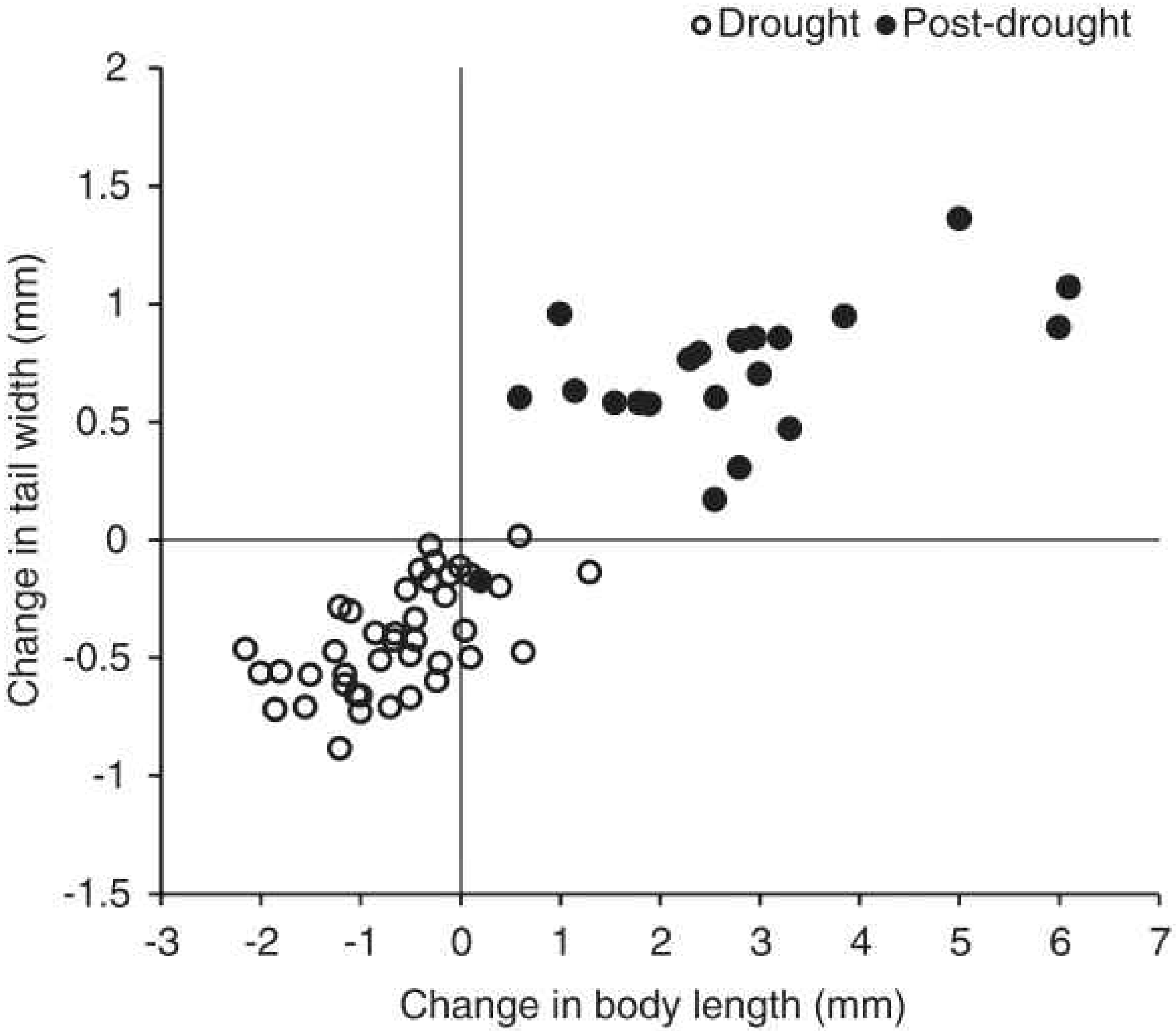
Stranded salamanders

BCP, Ribelin Spring- dry



Testudo Tube: emaciated young adult

5 mm
March 2008
After 10-month dry period
March 2009
June 2009
October 2010



Bendik, N. F., and A. G. Gluesenkamp. 2013. Body length shrinkage in an endangered amphibian is associated with drought. Journal of Zoology 290:35–41.

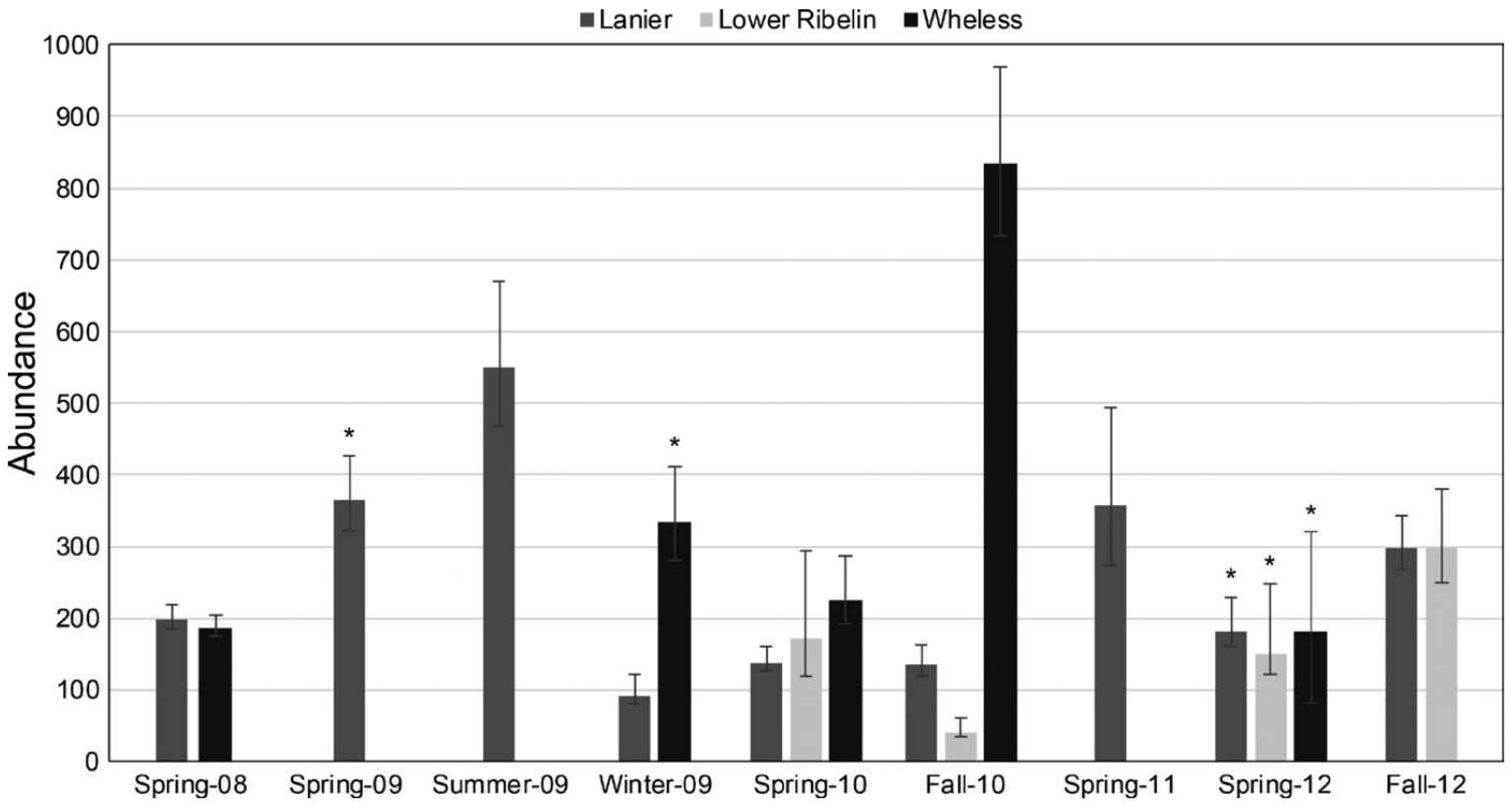
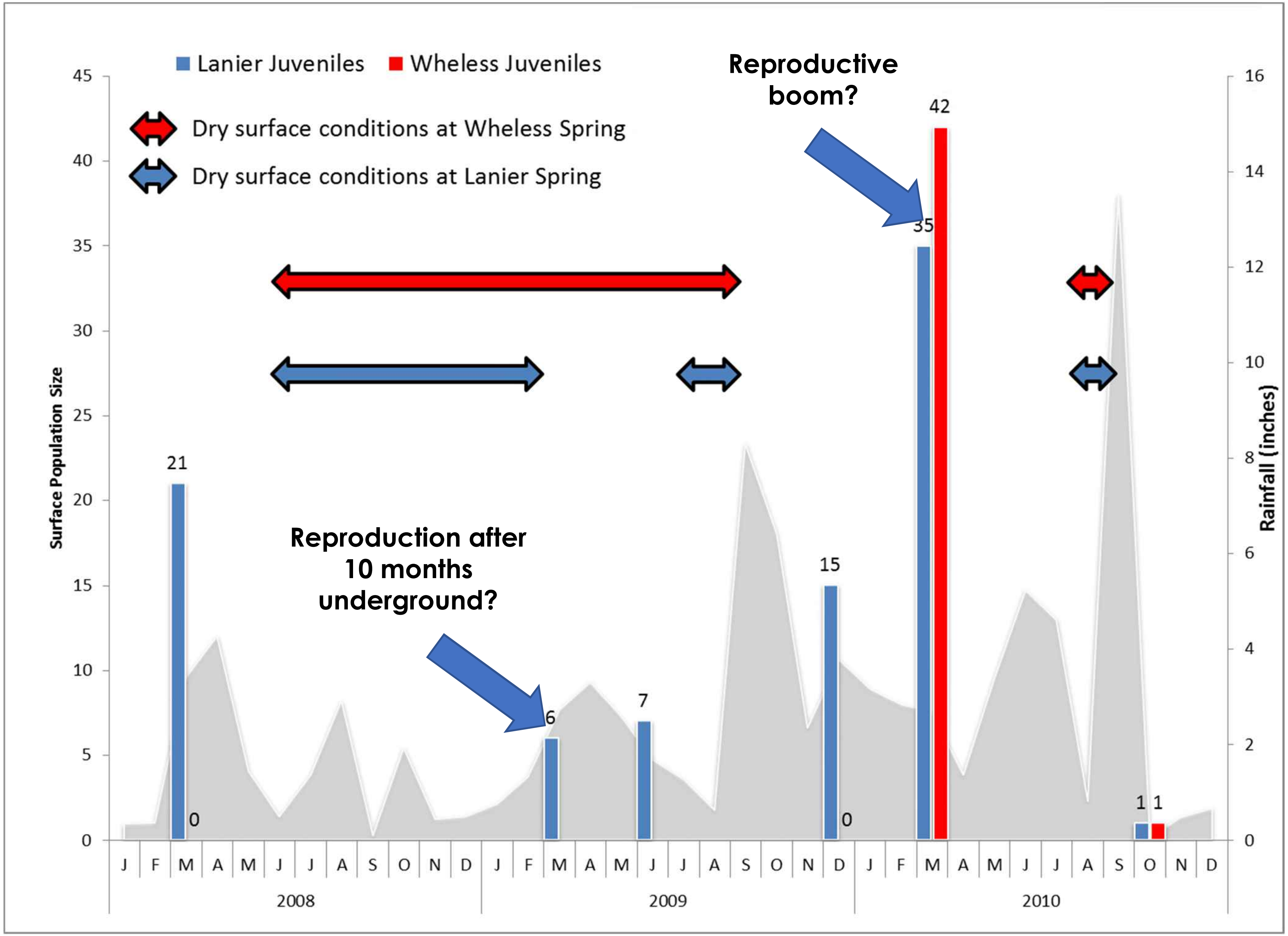
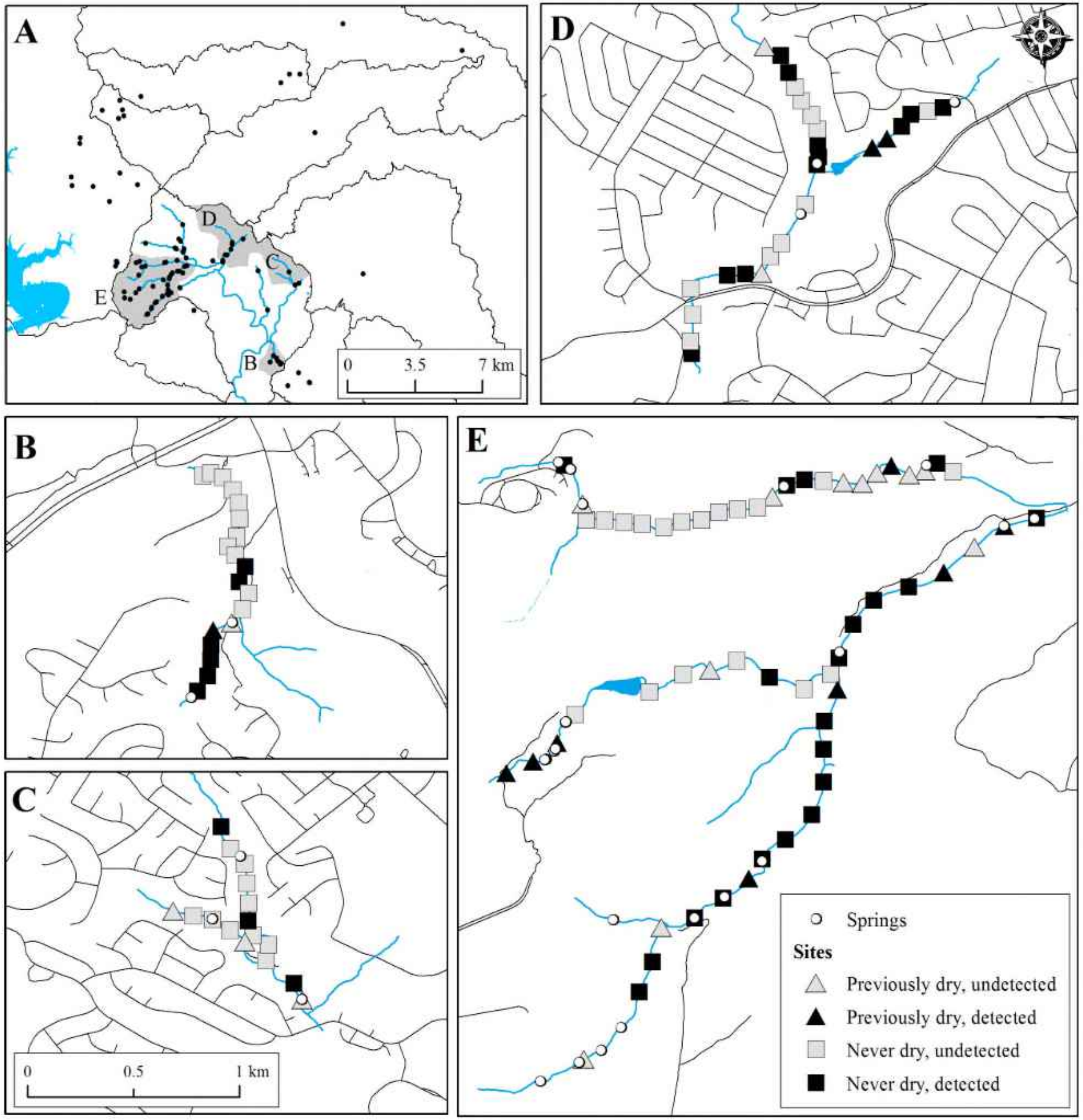


FIGURE 5 Abundance ($\hat{N}$) of *E. tonkawae* at Lanier, Lower Ribelin, and Wheless springs, 2008–2012. Error bars represent 95% confidence intervals. *indicates estimates following a protracted dry period at the respective site

Bendik, N. F. 2017. Demographics, reproduction, growth, and abundance of Jollyville Plateau salamanders (*Eurycea tonkawae*). Ecology and Evolution 7:5002–5015.



Lanier Juveniles
Wheless Juveniles
Dry surface conditions at Wheless Spring
Dry surface conditions at Lanier Spring
Reproductive boom?
Reproduction after 10 months underground?
Surface Population Size
Rainfall (inches)
45
40
35
30
25
20
15
10
5
0
16
14
12
10
8
6
4
2
0
21
0
6
7
15
0
35
42
1 1
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
2008
2009
2010



Previously unoccupied sites were more likely to be colonized if the prior habitat state was dry, demonstrating the propensity of *E. tonkawae* to respond to changing surface habitat conditions and disperse to newly available stream habitats

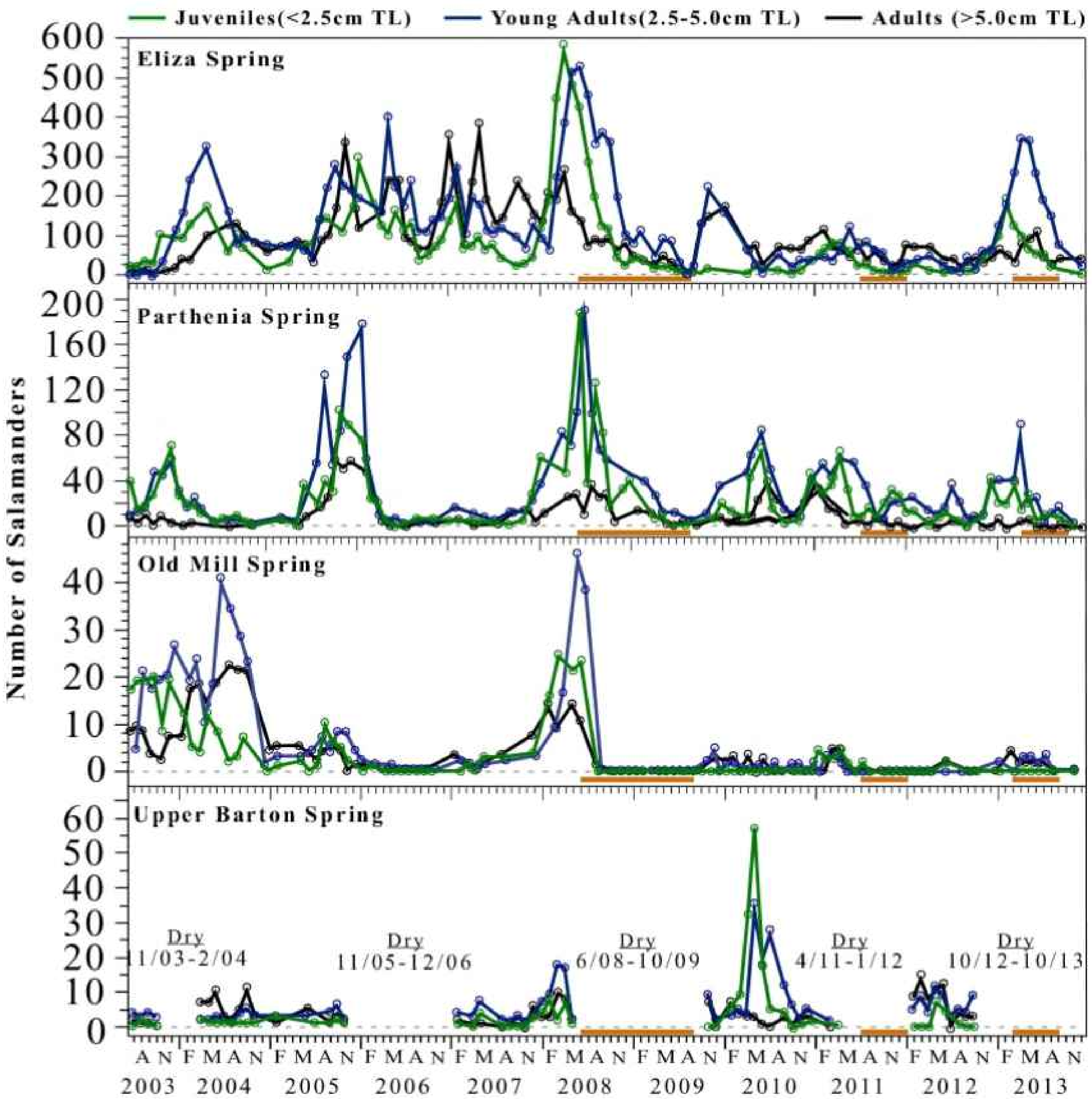
Bendik, N. F., K. D. McEntire, and B. N. Sissel. 2016. Movement, demographics, and occupancy dynamics of a federally threatened salamander: evaluating the adequacy of critical habitat. PeerJ 4:e1817.

JPS: Dry weather & dry springs

- Migration underground and back up (capture-recapture data)
- Stranded salamanders
- Energetic stress: body length shrinkage and lower body condition
- Populations persisted for up to 18 months underground with no flow
- Rapid recolonization of dry sites not adjacent to springs

BSS: Response to variable flow conditions

Upper Barton Spring

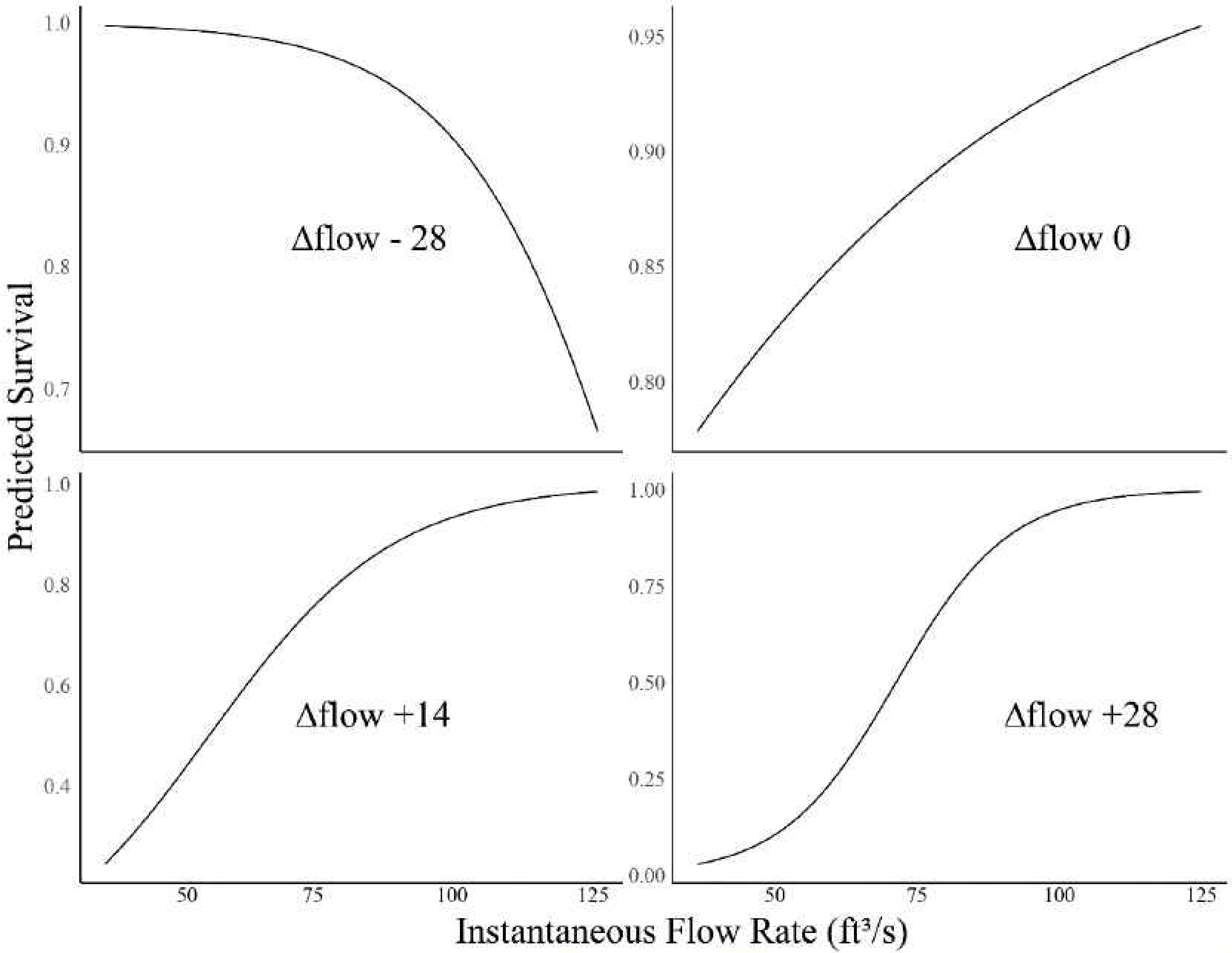


During Droughts (< 25 cfs combined discharge):

- Lower total salamander abundance
- Lower juvenile abundance (no reproduction?)
- Sedimentation not correlated with flow (Eliza, Old Mill)
- No habitat correlates with flow variables at Main Spring

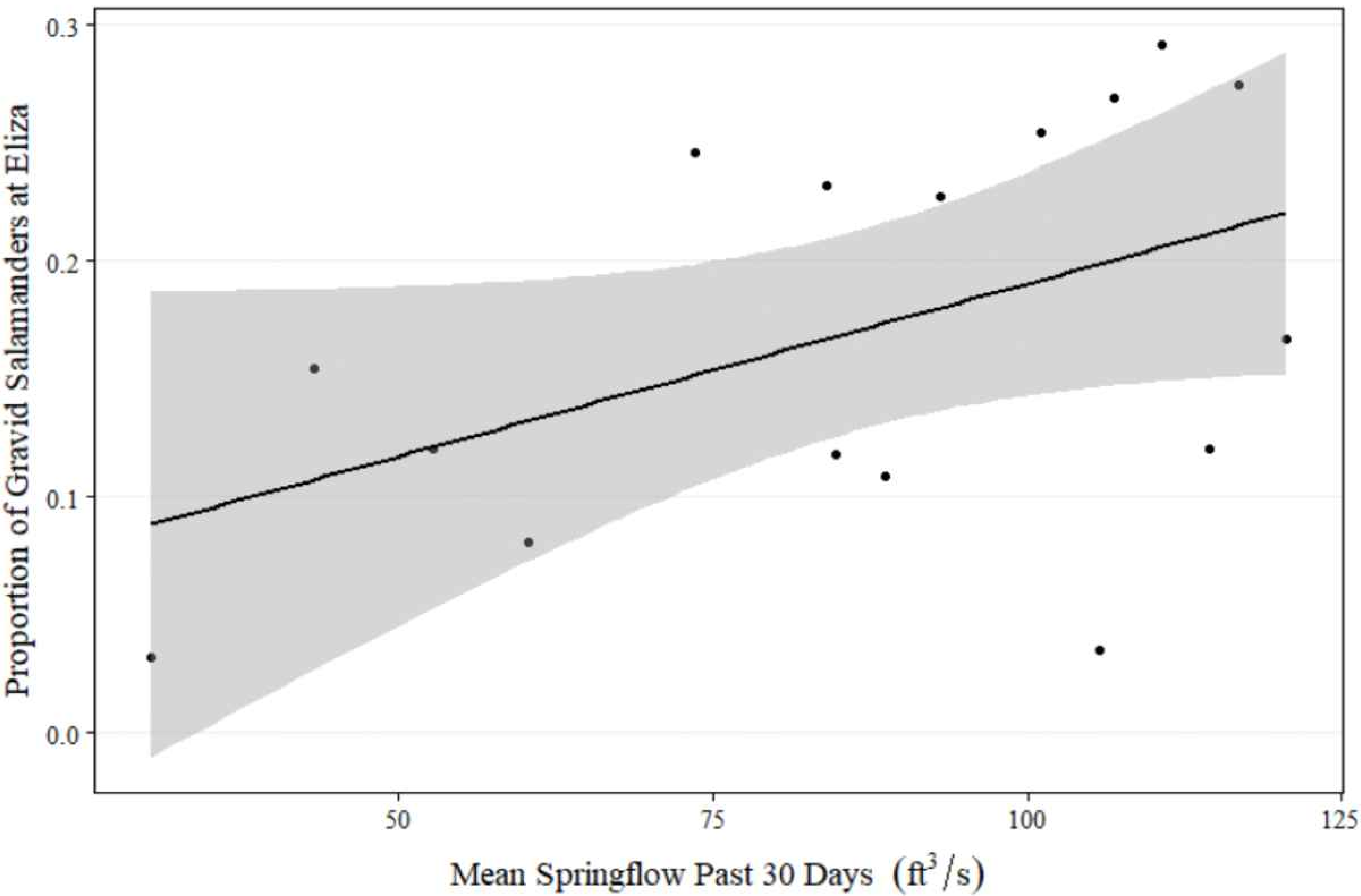
Dries, L. A., and L. A. Colucci. 2018. Variation in abundance in the Barton Springs salamander associated with flow regime and drought. Herpetological Conservation and Biology 13:302–316.

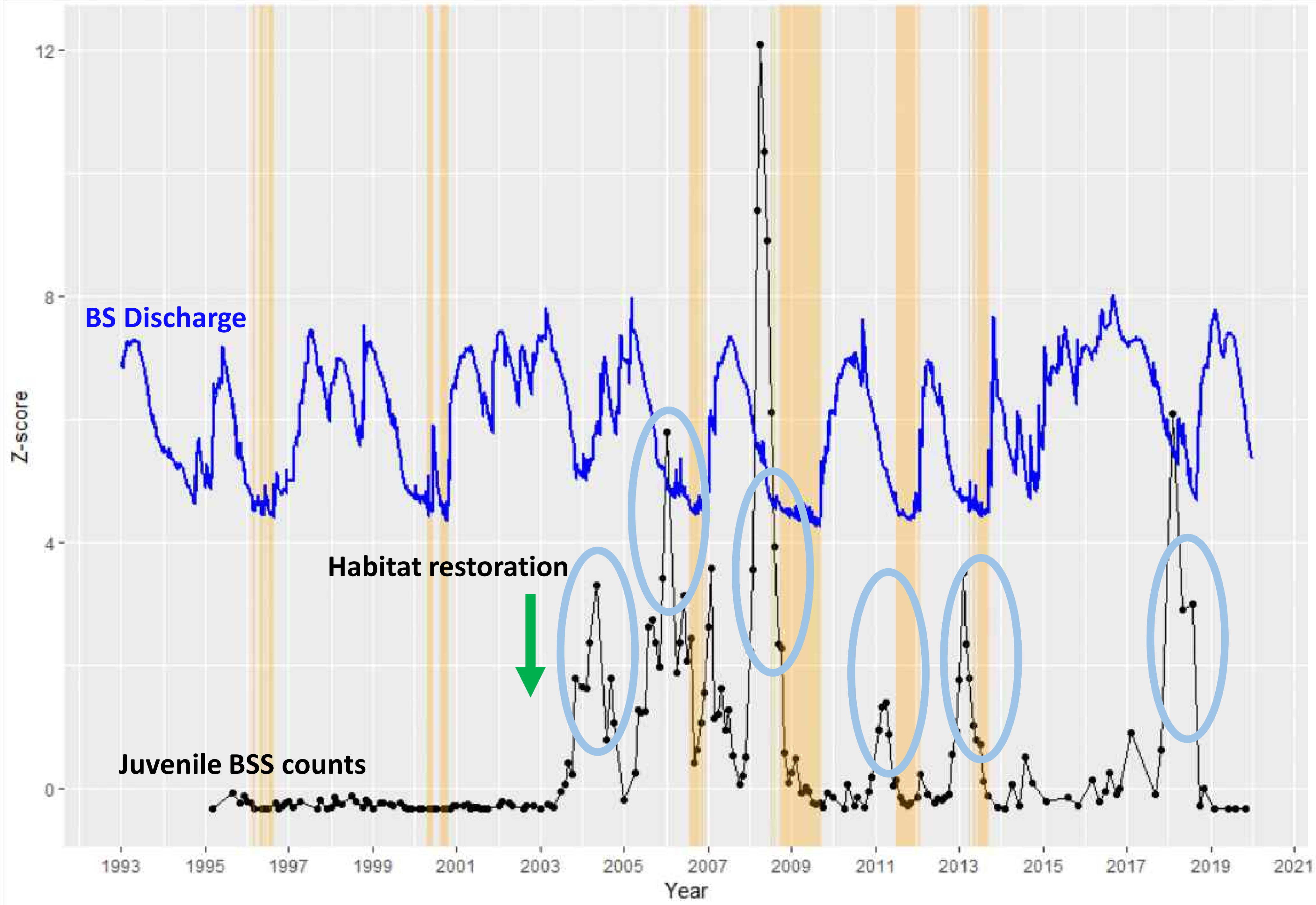
Apparent Survival and Flow



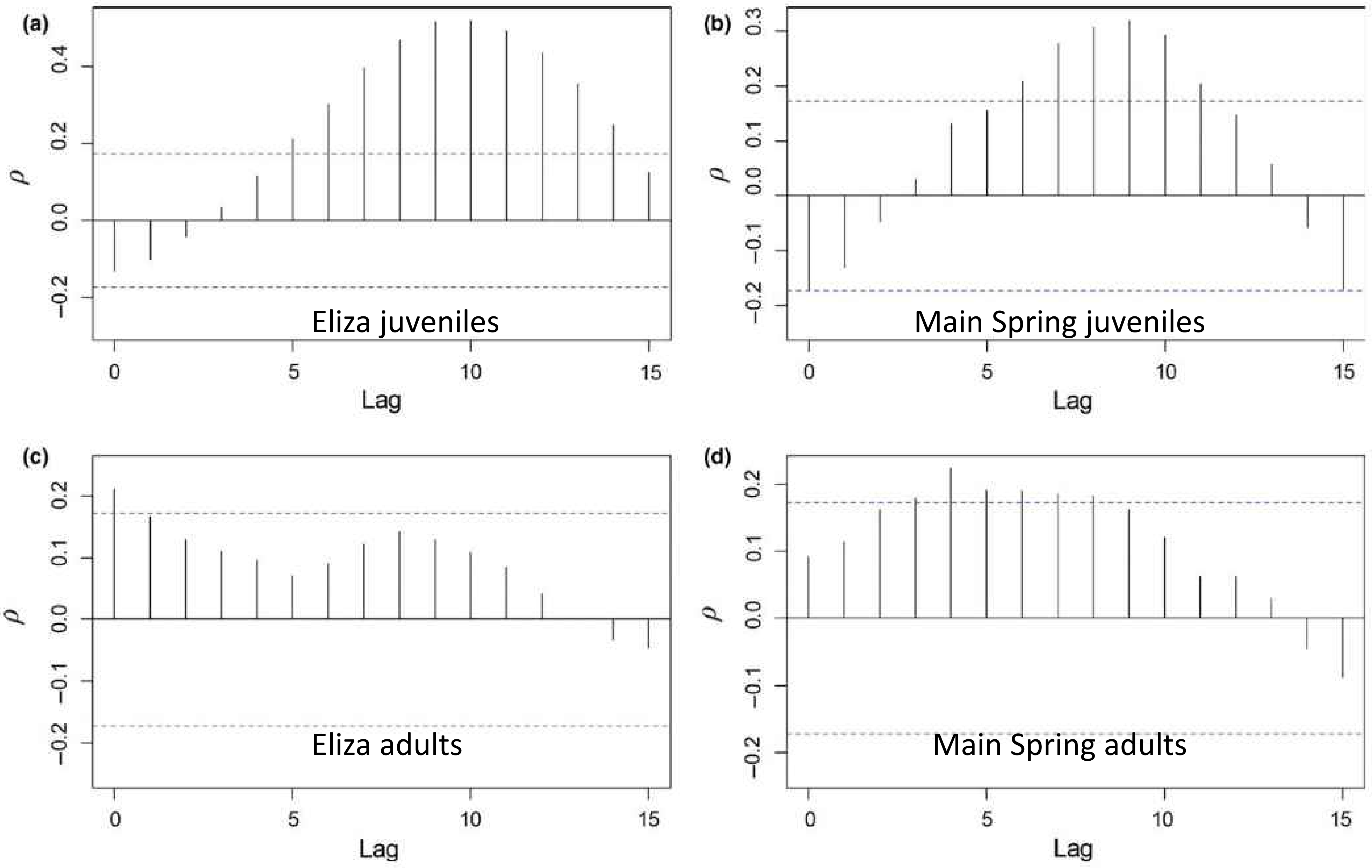
- When flow is increasing or unchanged between periods, survival has a positive relationship with flow rate.
- The predicted relationship reverses when flow decreases.

Gravidity and Flow




BS Discharge
Habitat restoration
Juvenile BSS counts
Z-score
Year
12
8
4
0
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021

Cross-correlation between monthly counts of BSS and discharge of Barton Springs (lags 0–15)

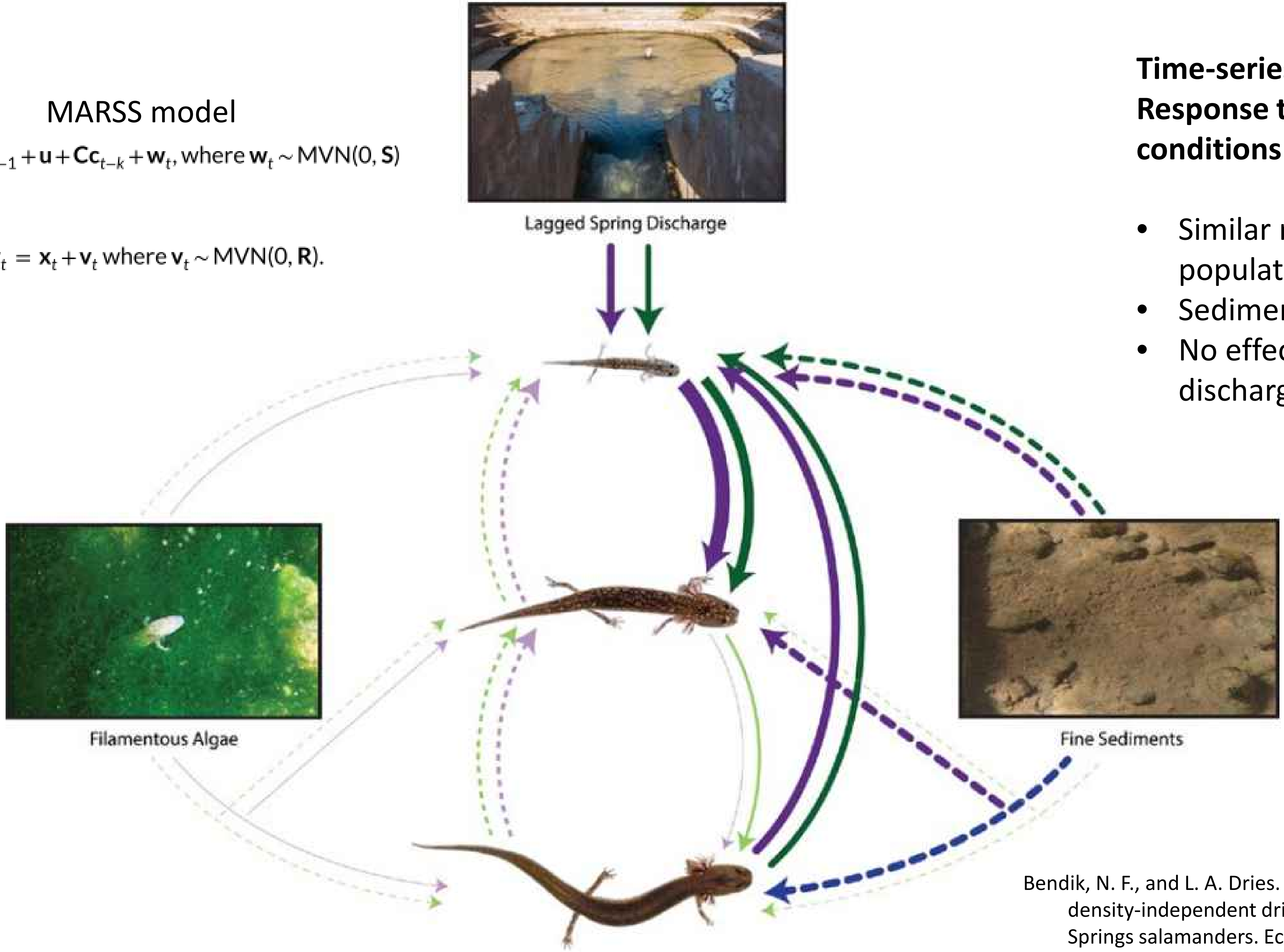


Bendik, N. F., and L. A. Dries. 2018. Density-dependent and density-independent drivers of population change in Barton Springs salamanders. Ecology and Evolution 8:5912–5923.

MARSS model

$$\mathbf{x}_t = \mathbf{B}\mathbf{x}_{t-1} + \mathbf{u} + \mathbf{C}\mathbf{c}_{t-k} + \mathbf{w}_t, \text{ where } \mathbf{w}_t \sim \text{MVN}(0, \mathbf{S})$$

$$\mathbf{y}_t = \mathbf{x}_t + \mathbf{v}_t \text{ where } \mathbf{v}_t \sim \text{MVN}(0, \mathbf{R}).$$



Time-series analysis: Response to environmental conditions

- Similar responses between populations
- Sediment bad
- No effect of lag-0 spring discharge

Bendik, N. F., and L. A. Dries. 2018. Density-dependent and density-independent drivers of population change in Barton Springs salamanders. Ecology and Evolution 8:5912–5923.

Peaks in abundance lag behind peaks in discharge

- Ecological effect from nutrient and carbon input?
- Flow-count lag observed in other TX *Eurycea*[3]

Storm events
- Upland recharge (e.g., sinkholes, percolation)
- Sinking stream recharge

Carbon/Nutrient inputs
- Karst systems can be carbon limited[1]
- High organic matter associated with higher salamander biomass in caves[2]

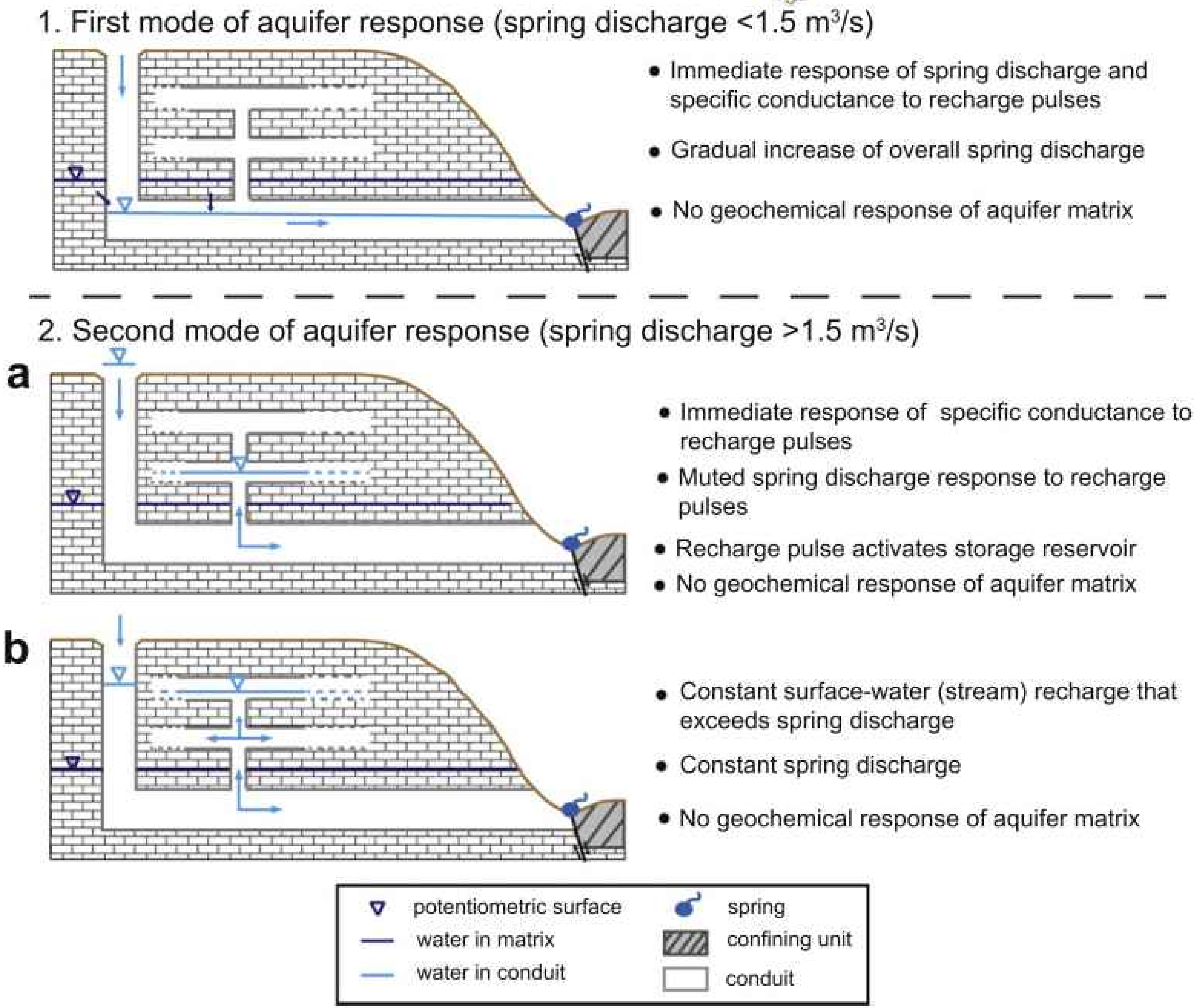
Microbes and primary consumers
- Microbes
- Crustaceans

Secondary/tertiary consumers
- Salamanders

1 Simon KS., Benfield EF. 2001. Leaf and wood breakdown in cave streams. Journal of the North American Benthological Society 20:550–563
2 Huntsman BM, Venarsky MP, Benstead JP, Huryn AD. 2011. Effects of organic matter availability on the life history and production of a top vertebrate predator (Plethodontidae: *Gyrinophilus palleucus*) in two cave streams. Freshw. Biol. 56:1746–1760.
3 Krejca, J. K., D. J. McHenry, K. M. McDermid, Z. C. Adcock, and M. R. J. Forstner. 2017. Genetic characterization and habitat use of *Eurycea pterophila* salamanders from Jacob's Well, Hays County, Texas. The Southwestern Naturalist 62:1–13.

Peaks in abundance on backside of recession curve

- Flushing effect from draining of perched reservoirs?



Wong, C. I., B. J. Mahler, M. Musgrove, and J. L. Banner. 2012. Changes in sources and storage in a karst aquifer during a transition from drought to wet conditions. Journal of Hydrology 468:159–172.

BSS: Response to variable flow conditions

- Habitat effects
- Non-seasonal population demographics and reproduction
- Barton Springs perennial (Upper Barton dry < 40 cfs; Old Mill during severe drought)
- Reproduction correlated with flow lag

What about dissolved oxygen?

- DO strongly correlated with spring discharge (statistically cannot separate using observational study)
- Predicted negative effects based on lab study at DO < 4.5 mg/l[1]
- During very low DO conditions- surface DO may be different from subsurface DO
- Salamanders tend not to hang around when flow stops
- For JPS, many observations of salamanders in creeks when DO < 4.5mg/l (as low as 2.77 mg/l)
- JPS hunker down during dry periods in water table with NO flow. They can survive low DO under these conditions but no measurements of DO are available.

[1]Woods, H. A., M. F. Poteet, P. D. Hitchings, R. A. Brain, and B. W. Brooks. 2010. Conservation physiology of the plethodontid salamanders *Eurycea nana* and *E. sosorum*: response to declining dissolved oxygen. Copeia 2010:540–553.

Closing thoughts

- Central Texas Eurycea salamanders have persisted for eons and a range of climatic conditions
- Climate change is occurring more rapidly than might naturally allow for compensatory responses by populations, species, and clades
    - Not just water- temperature changes (DO, metabolism, ecosystem effects)
- Impoundments, groundwater withdrawal, impervious cover impose additional burden on species and populations- possibly most severe during droughts

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Meeting 2 follow up discussion

Meeting 2 Clarification

- **J-Charge Report** - ***Analysis of Species Requirement in Relation to Spring Discharge Rates and Associated Withdrawal Reductions and Stages for Critical Period Management of the Edwards Aquifer*** **(Dec. 28, 2009)**
  - Subsection (j) of Section 1.26A of the EAA Act which provides as follows: "The Edwards Aquifer area expert science subcommittee shall … analyze species requirements in relation to spring discharge rates and aquifer levels as a function of recharge and withdrawal levels. …."
  - Expert science subcommittee prepared
- Hardy 2009 - *Technical Assessment in Support of the Edwards Aquifer Science Committee "J Charge" Flow Regime Evaluation for the Comal and San Marcos River Systems* (Dec. 29, 2009)

Public comment

Future meetings

- Meeting 4 – CS Riffle Beetles
  - Wednesday, June 3
  - 2PM-4PM
- Meeting 5 – TBD
  - TBD

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Thank you!

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