

# Management of the Spring Snowmelt Recession in Regulated Systems

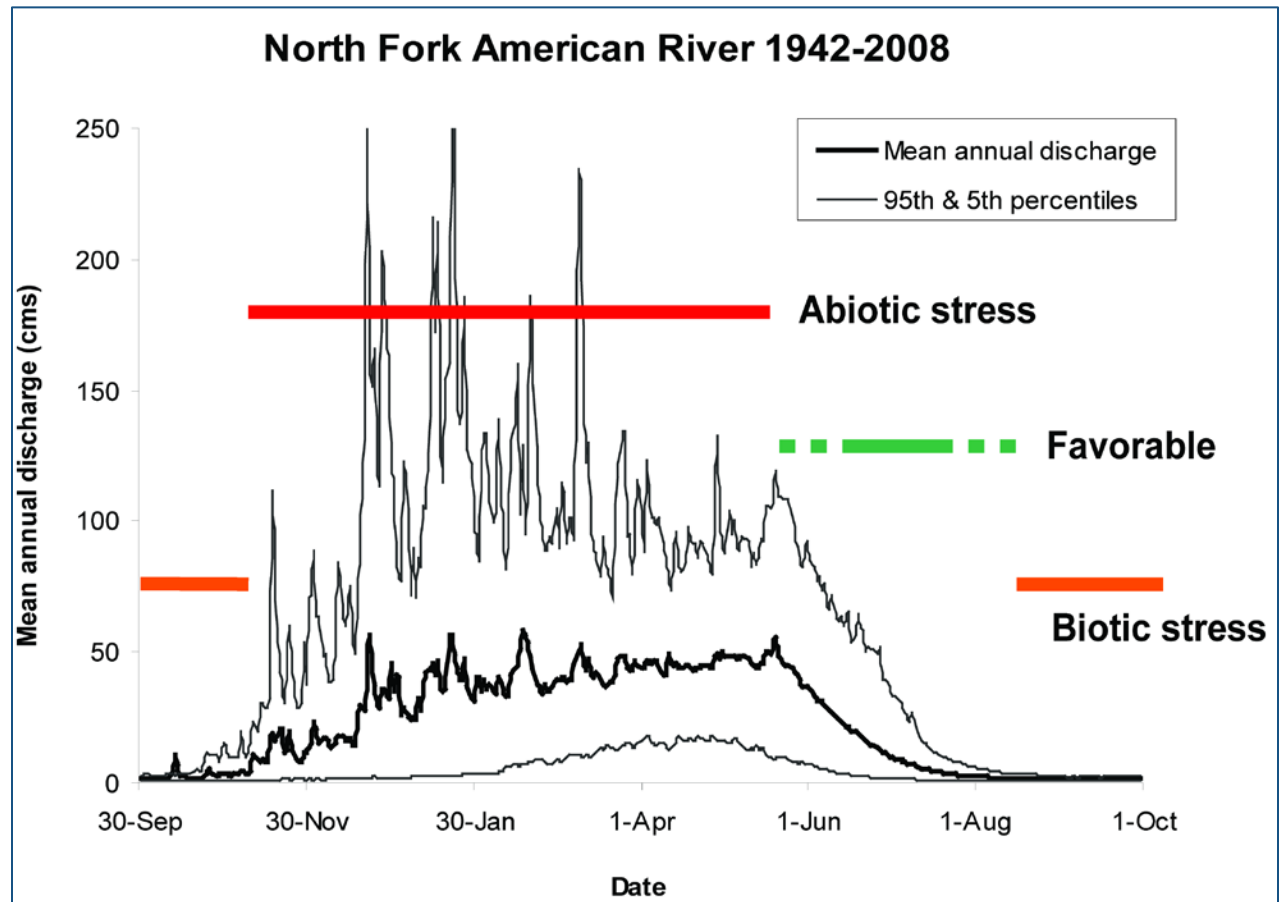
Sarah Yarnell, Gerhard Epke  
Amy Lind, Joshua Viers



*Photo: R. Peek*

# Spring Snowmelt Recession Ecology

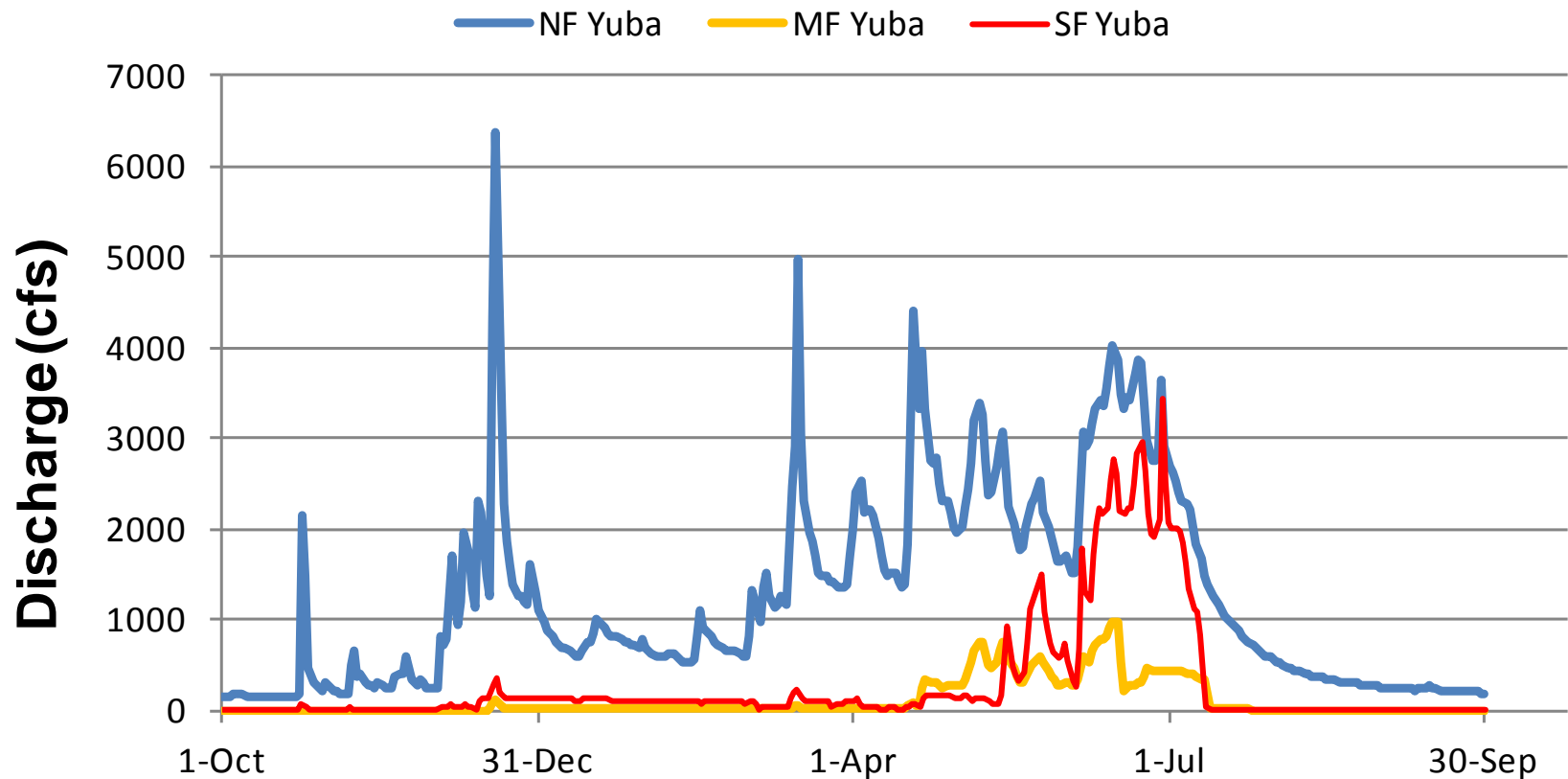
- The one time annually where high resources are coupled with predictable flows
- Results in high biodiversity (Gasith & Resh 1999)



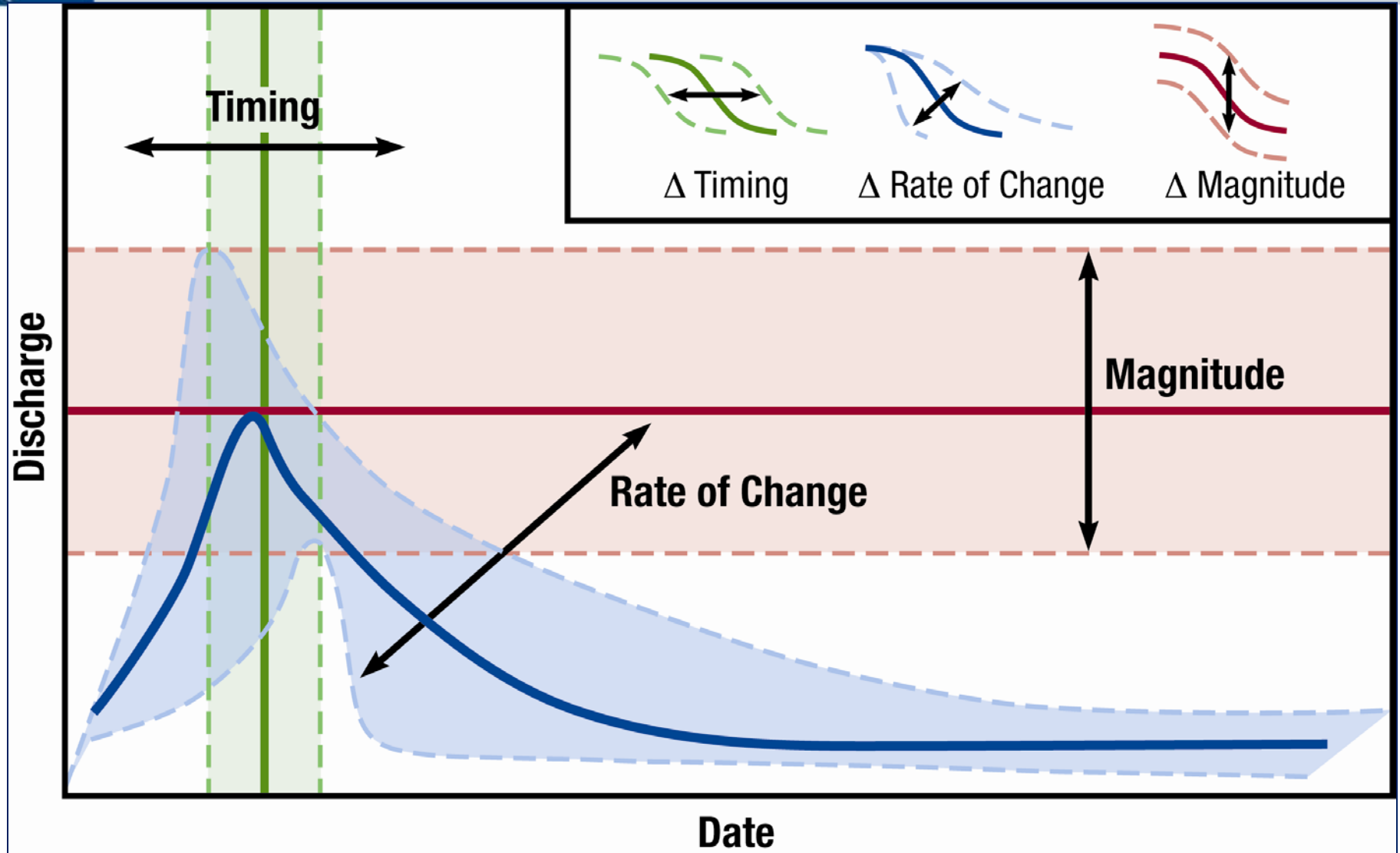
Yarnell, S.M., J.H. Viers and J.F. Mount. 2010. *BioScience* 60:114-127.

# Regulated Flow Regimes

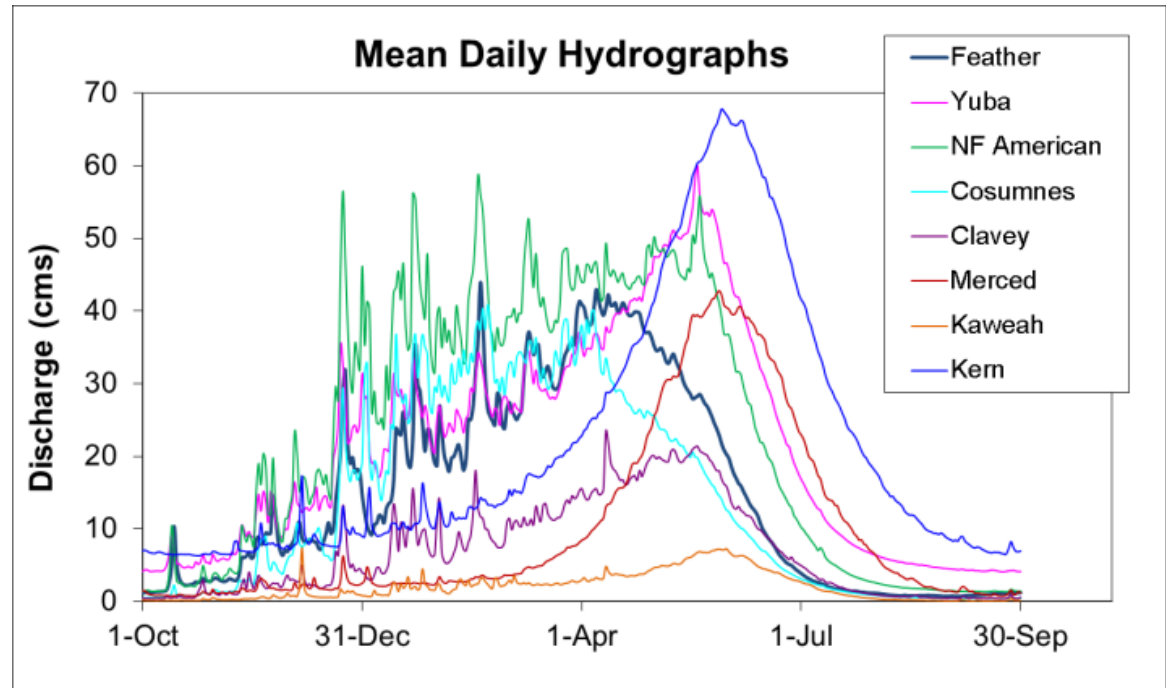
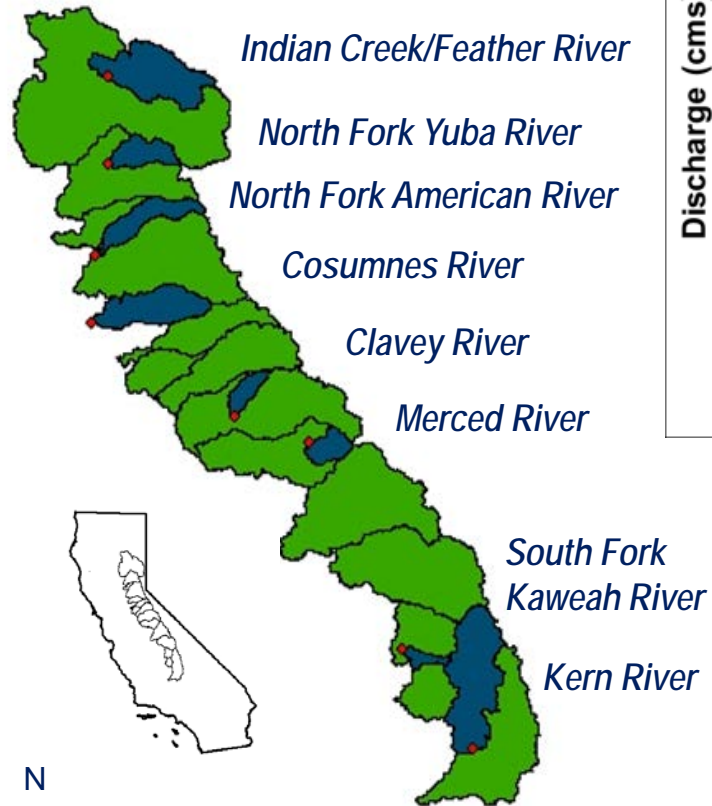
## Yuba Rivers - WY 2011



# Quantifying the Flow Recession



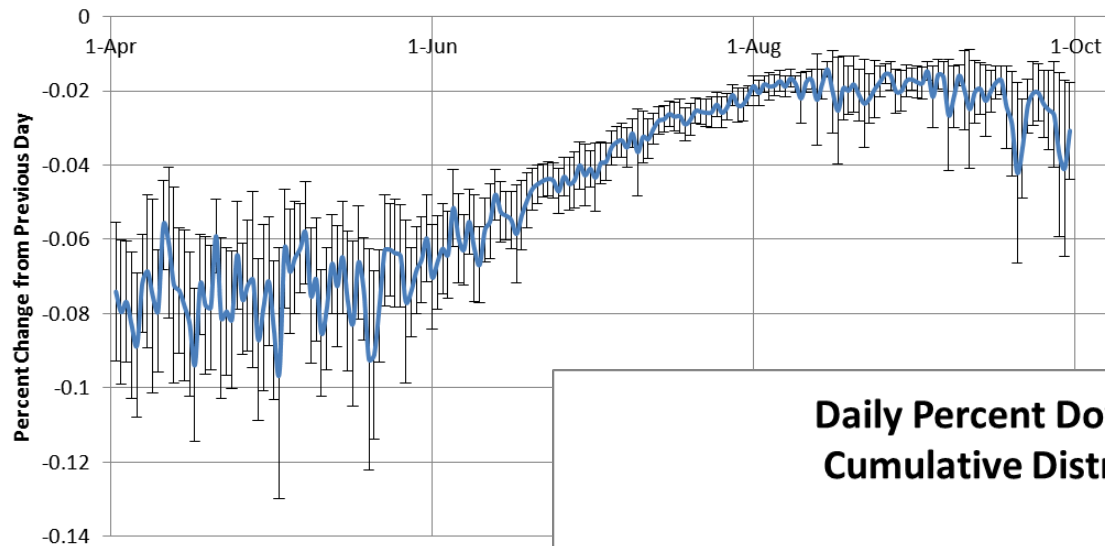
# Quantifying the Spring Recession Rate: Unregulated Basins in the Sierra Nevada



Daily recession rates are  
consistent across basins  
and elevations

# Daily Percent Change in Discharge

NF Yuba Average Daily Dowramping w 95% CI



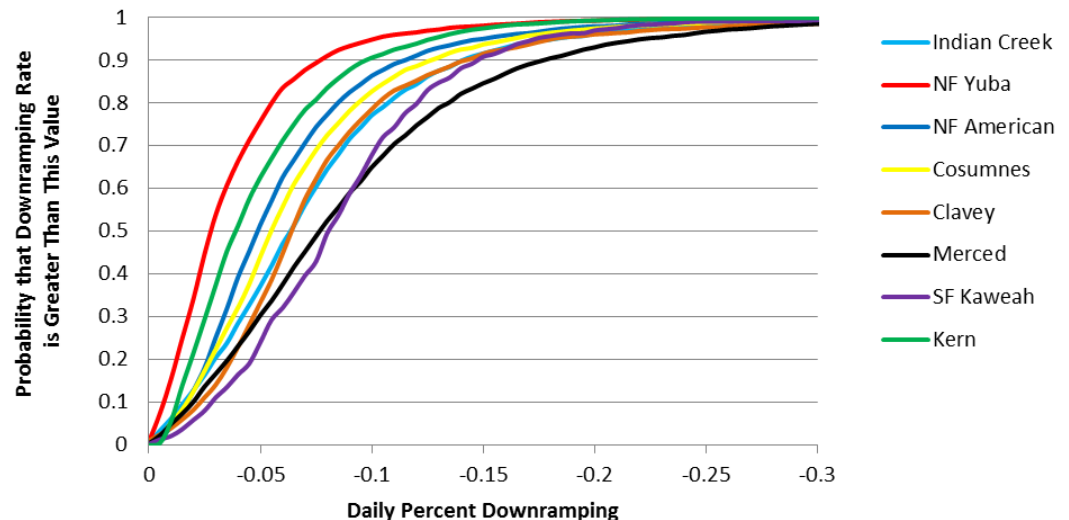
$$Q = Q_0 \times e^{kt}$$

$$-k = \frac{dQ/dt}{Q}$$

Daily recession rates:

- 1) decrease during the recession (on average from 8 to 4%),
- 2) are limited (typically < 20%)

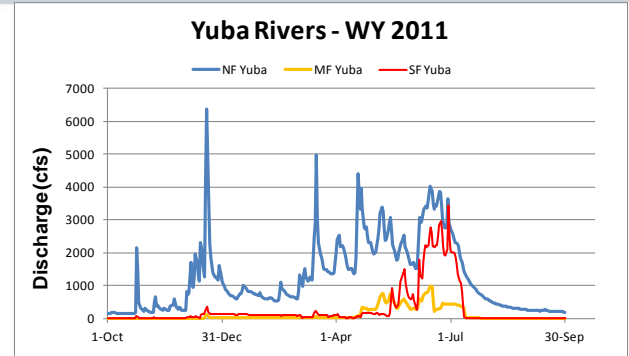
Daily Percent Dowramping Rates  
Cumulative Distribution Function



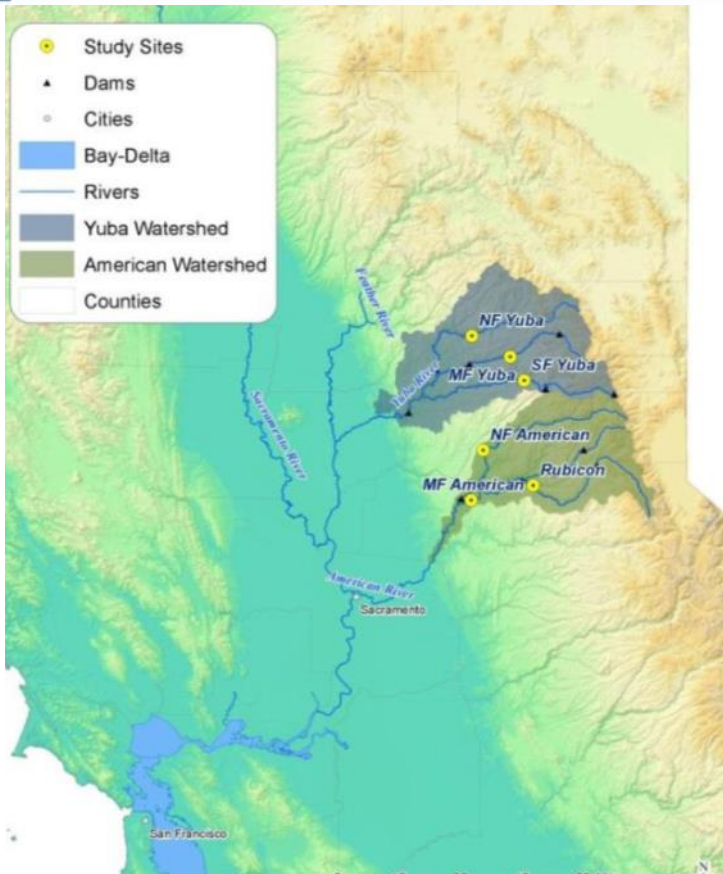
# Calculating a Spring Recession Flow Regime

## Requires knowledge of:

- hydrology of the regulated river
- hydrology of an analogous unregulated river
- limitations of the regulated system infrastructure
- hydraulic-related thresholds for aquatic species of interest (e.g. maximum allowable ramping rates)
- representative channel morphology of the regulated river

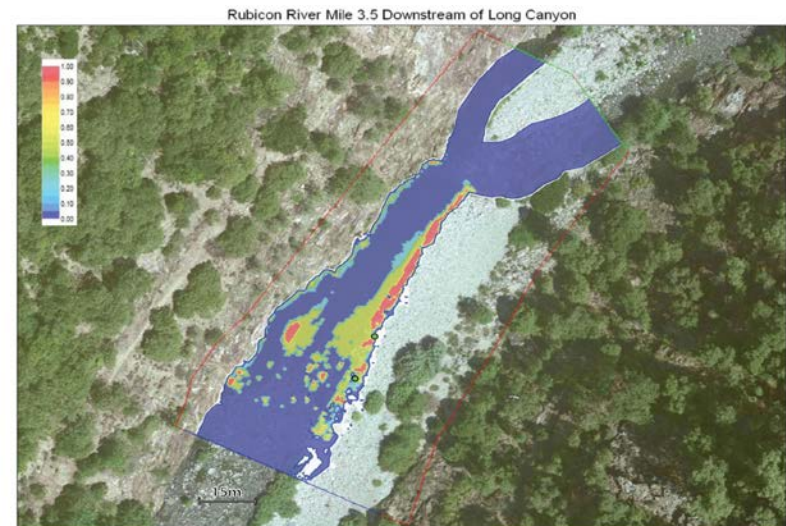


# Rubicon River Example



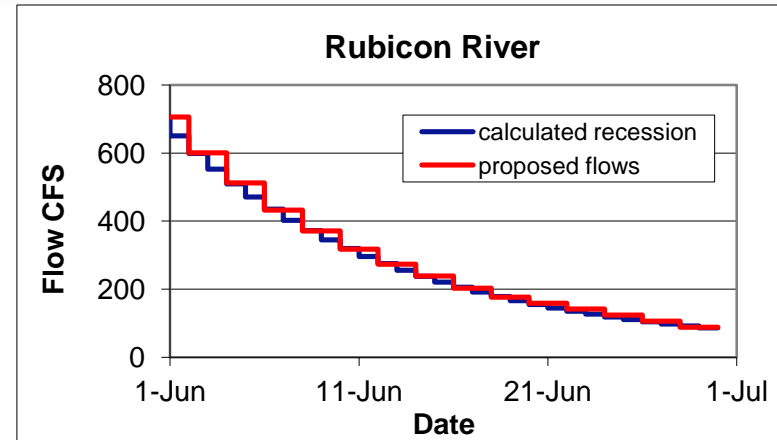
- Regulated bypass reach below high-elevation reservoir
- Regulated flows dominated by spring spills and baseflow
- Unregulated NF American in same watershed

Use 2D hydrodynamic model to evaluate flow effects on native species



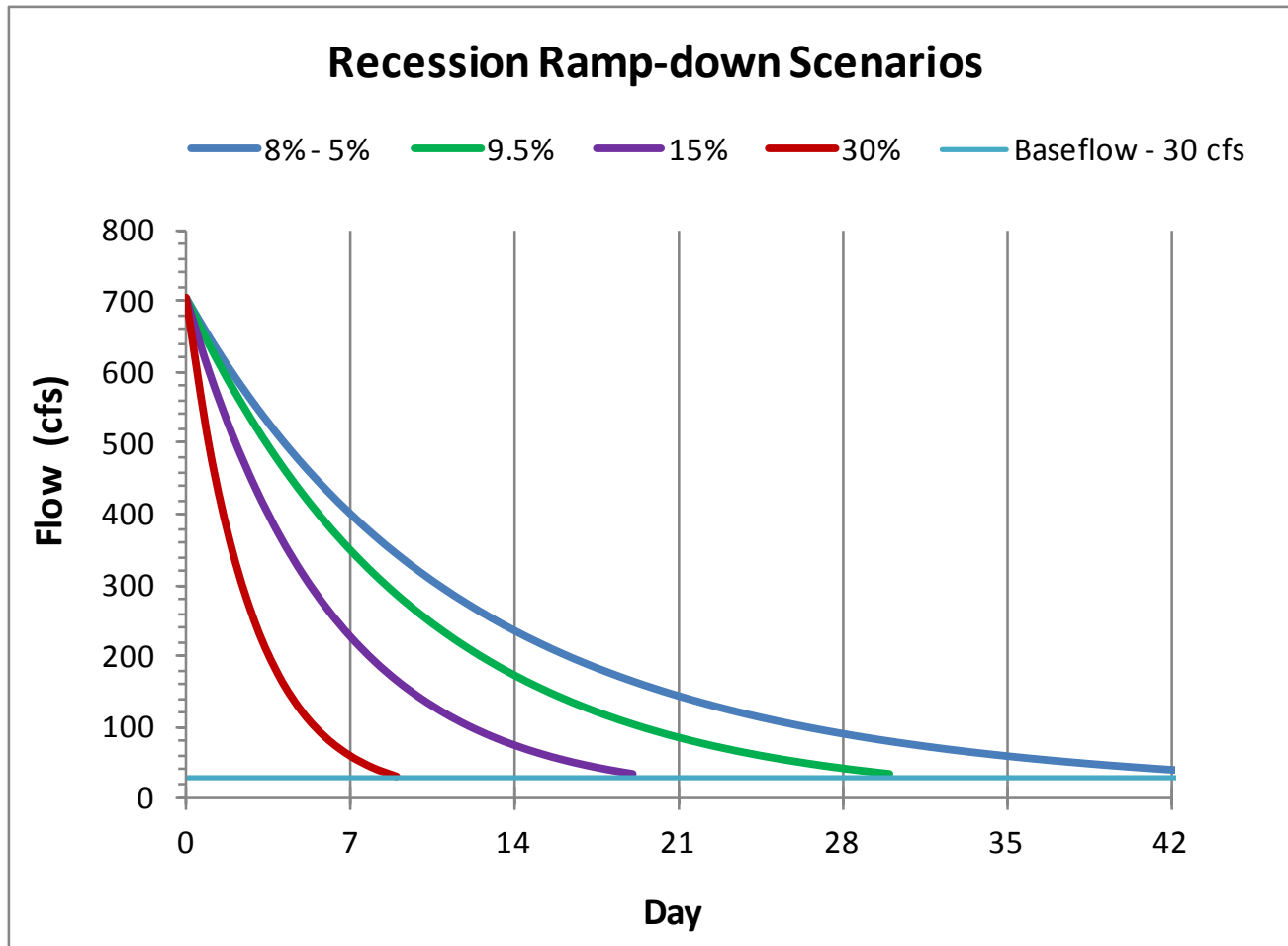
# Rubicon River Example

- Start the recession from spill at 700 cfs when gain control of the system
- Decrease flows at rates similar to the natural rates (8-5%/day)
- Limit steps to <20%/day
- Reach the minimum instream flow within 45 days



Calculated Recession Flows			Flow Schedule	
Day	Flow	Step % change	Flow	Step % change
1	700	--	700	--
2	644	0.080	600	0.143
3	594	0.079	600	0.000
4	547	0.078	600	0.000
5	466	0.077	500	0.167
...	...	...	...	...
42	40	0.052	40	0.000
43	38	0.051	35	0.125
44	36	0.051	35	0.000
45	35	0.050	35	0.000

# Modeled Flow Recession Scenarios



## Four Scenarios:

Average Spring  
Rate = 8%-4%

Constant Low =  
9.5%

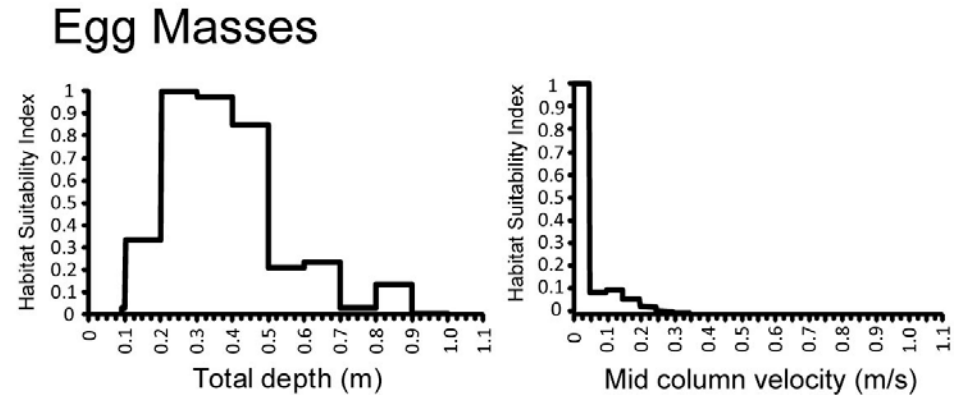
Constant  
Medium = 15%

Maximum  
Observed in  
Nature = 30%

# Foothill Yellow-legged Frog

## Breeding Habitat

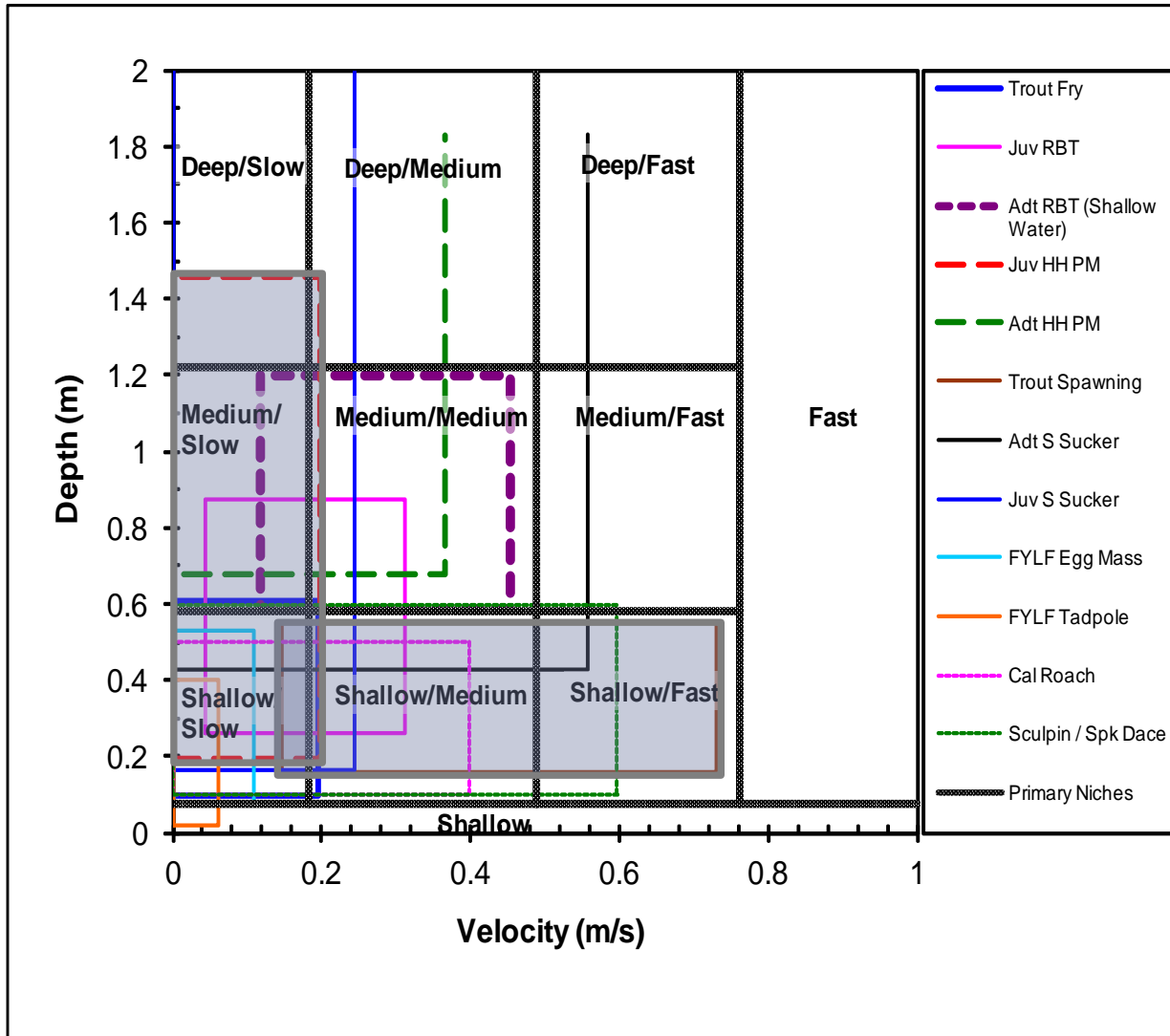
- Frogs lay egg masses in very low velocity locations at 20-40 cm depth
- 3 weeks required for egg masses to hatch and tadpoles to grow big enough to follow receding water's edge
- → Flow recession of **10 cm per week** will limit desiccation of eggs



(Bondi C.B., S.M. Yarnell and A.J. Lind. 2013.)



# Spatial Niche Analysis

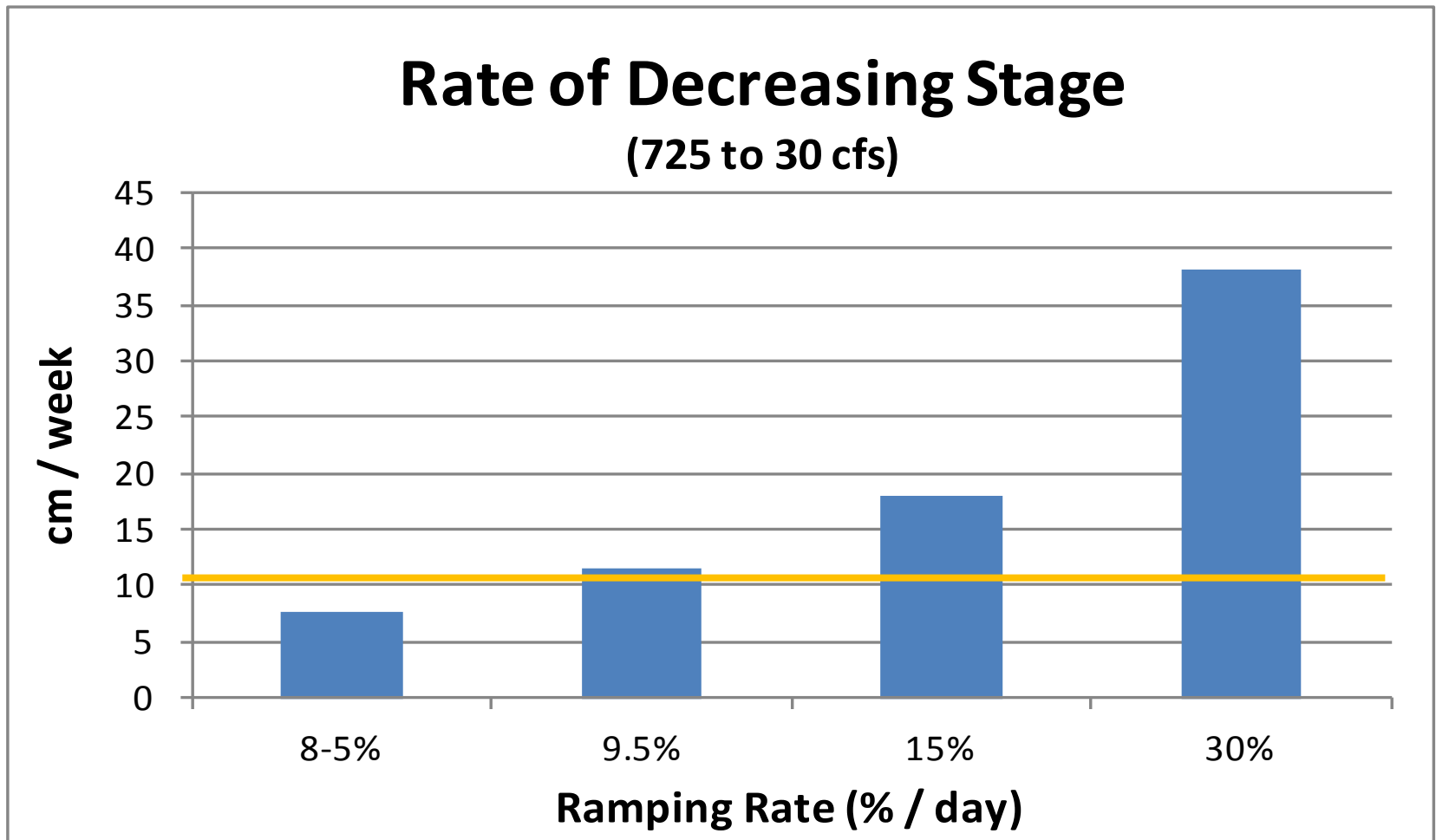


Depth and velocity guilds for aquatic species of interest in the PCWA Middle Fork Project

Example:  
Rainbow Trout  
Spawning  
Juvenile Hardhead

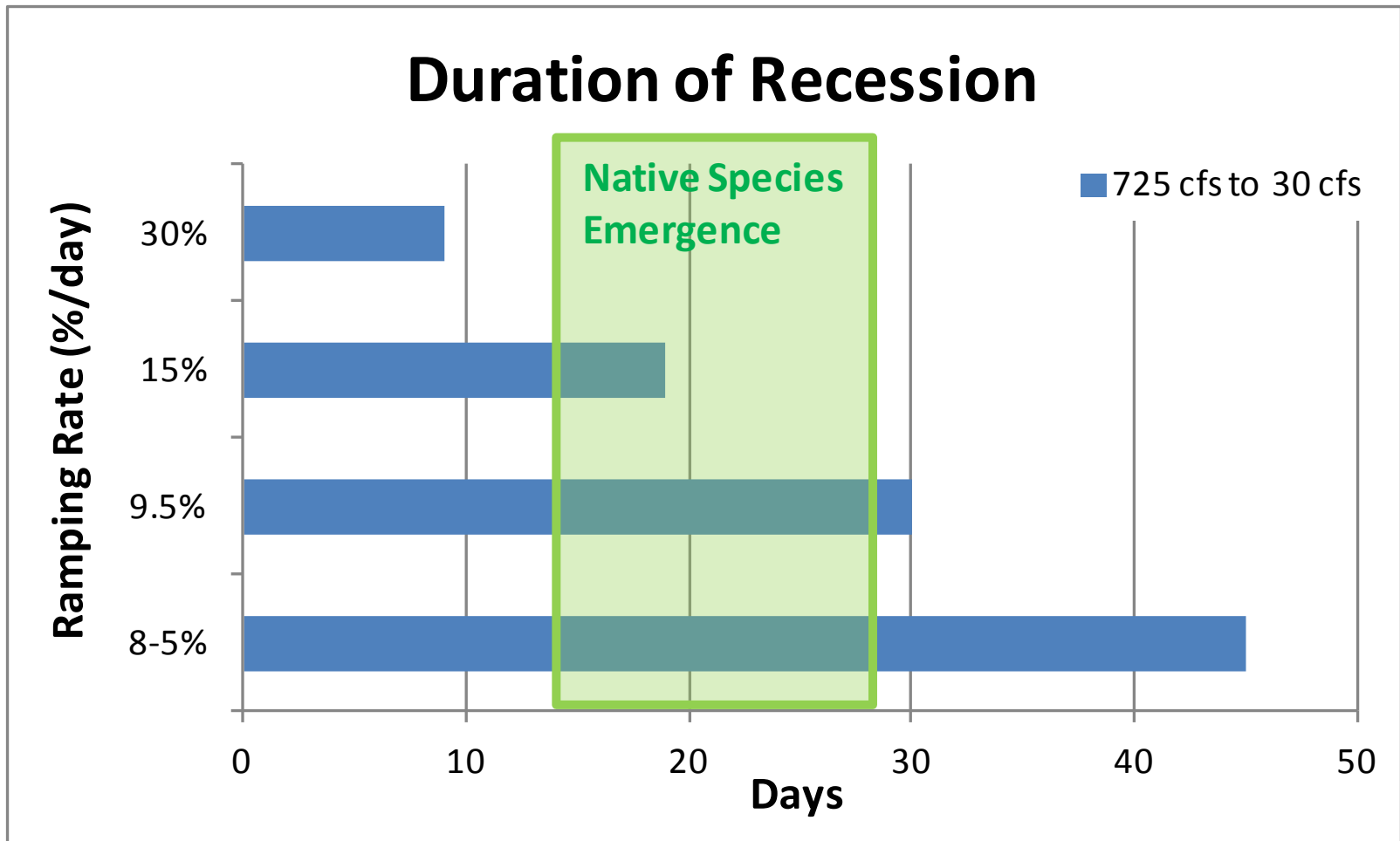
Fry = Rainbow Trout, RBT = Rainbow Trout, HH = Hardhead, PM = Sacramento Pikeminnow, Spaw n = Trout Spawning, S = Sacramento, FYLF = Foothill Yellow-Leaved Frog, Cal = California, Spk = Speckled, Juv = Juvenile, Adt = Adult

# Modeled Flow Recession Scenarios



**FYLF eggmasses – 30 cm average depth/3 weeks to hatch**

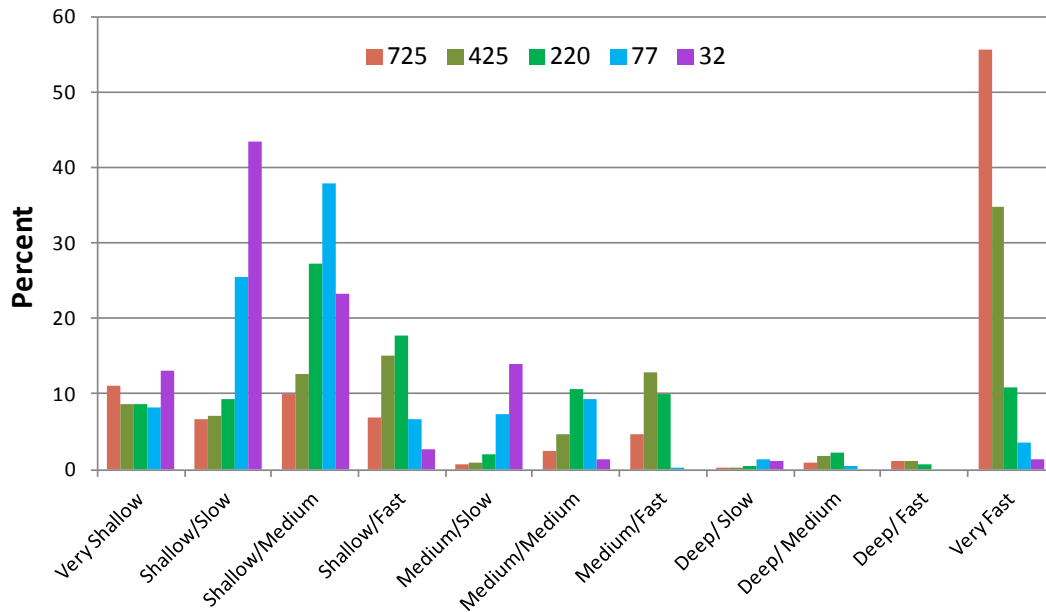
# Modeled Flow Recession Scenarios



**FYLF – 3 weeks; Native spring spawning fish – 2-4 weeks**

# Spatial Niche Analysis

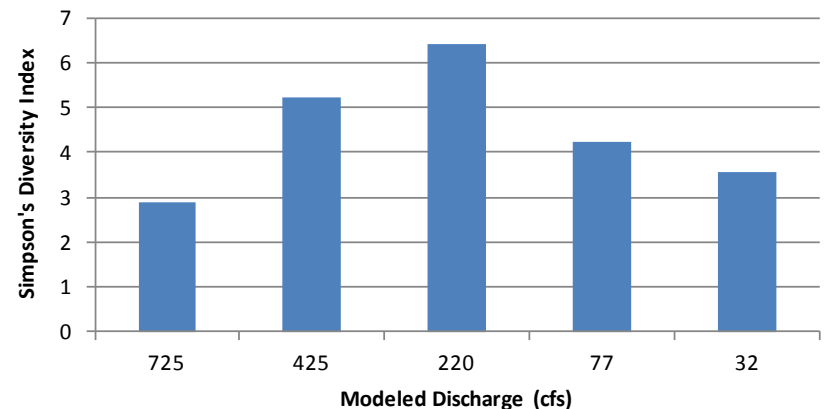
**Spatial Niche Distribution**



Percent of modeled nodes within each spatial niche at each of five modeled discharges (725 cfs – 32 cfs).

Simpson's Diversity Index calculated from the distribution of spatial niches at each of five modeled discharges

**Spatial Niche Diversity**



# Implications for Regulated Systems

- Restoration of the spring recession achievable by modeling *rates of change* to increase hydraulic habitat diversity
- Hydraulic diversity in both *space* and *time* is necessary to support the full complement of native aquatic species
- Key to diverse hydraulic habitat mosaic is to shift relatively *slowly* through time – allow for development of eggs and larvae within a spatial niche before the niche disappears

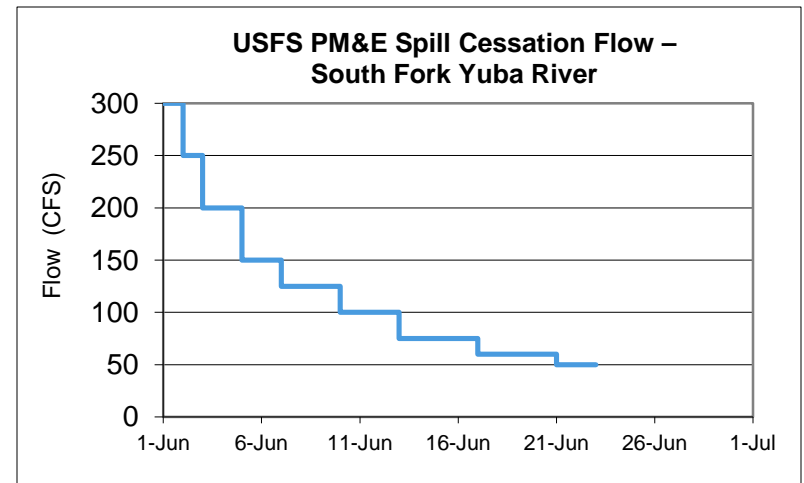


# Application in Regulated Systems

Recession rates can be modeled as down-ramping rates from spill or an ecological flow pulse

Examples in California:

- South Fork San Joaquin River
- McCloud River
- North Fork Feather Cresta Reach
- Middle Fork American River
- Upper Yuba Rivers



**Table 6. Lower flow spill cessation schedule in the South Yuba River downstream of Lake Spaulding Dam.**

Target Flow, +/- 20% <sup>1</sup>	Target Number of Days to Hold Target Flows
250 cfs	1 days
200 cfs	2 days
150 cfs	2 days
125 cfs	3 days
100 cfs	3 days
75 cfs	4 days
60 cfs	4 days
50 cfs <sup>2</sup>	2 days

<sup>1</sup> Once the facility modifications (discussed later in this measure) are completed, Target Flows at or below 75 cfs will be  $\pm 10\%$ .

<sup>2</sup> If the Minimum Streamflow in this measure is greater than 50 cfs, the spill cessation will stop at the Minimum Streamflow.

# Acknowledgements

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- Collaborators: US Forest Service, Placer County Water Agency, Ryan Peek, Craig Addley

