Managing Functional Environmental Flows in Regulated River Systems

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Co-Authors

- Geoffrey Petts, Jack Schmidt, Alison Whipple, Erin Beller, Clifford Dahm, Peter Goodwin, Joshua Viers: **Yarnell et al. 2015 *BioScience* 65(10): 963-972**
- Kristen Podolak: **Podolak and Yarnell. 2015. Chapter 13 in *Sustainable Water* Edited by A.Lassiter**
- Ryan Peek, Gerhard Epke, Amy Lind: **Yarnell et al. 2016 *JAWRA* 52(3):723-736**
- Anna Steel, Ryan Peek, Robert Lusardi: **Steel et al. In Prep. *Freshwater Biology***

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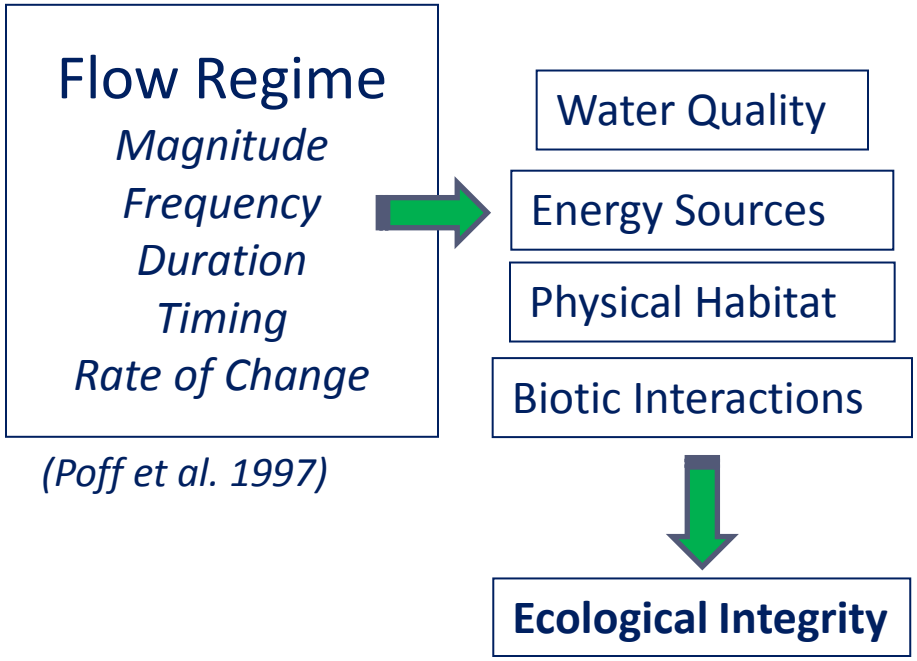
Environmental Flow Methods

Natural Flow Regime Paradigm



(Poff et al. 1997)

- Set Percentage of Flow *(Richter et al. 2012)*
- Downscaled Flow Regime *(Hall et al. 2011)*
- Regional IFIM *(Denslinger et al. 1998)*
- ELOHA *(Poff et al. 2010)*
- Designer Flows *(Acreman et al. 2014)*

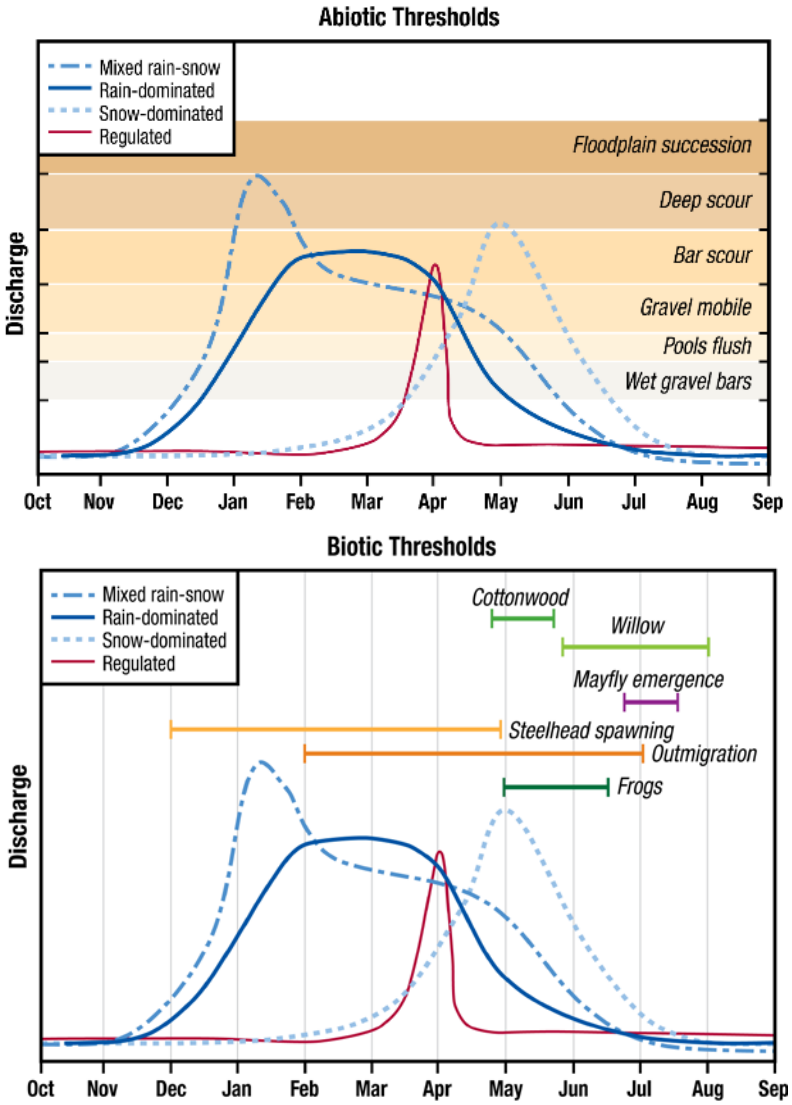
How do we design flows using limited flow allocations to maximize functionality and preserve biodiversity?

Functional Flows Approach

Focus on hydrograph flow components that:

- Support natural disturbances
- Promote physical dynamics
- Drive ecosystem functions
- Support high biodiversity

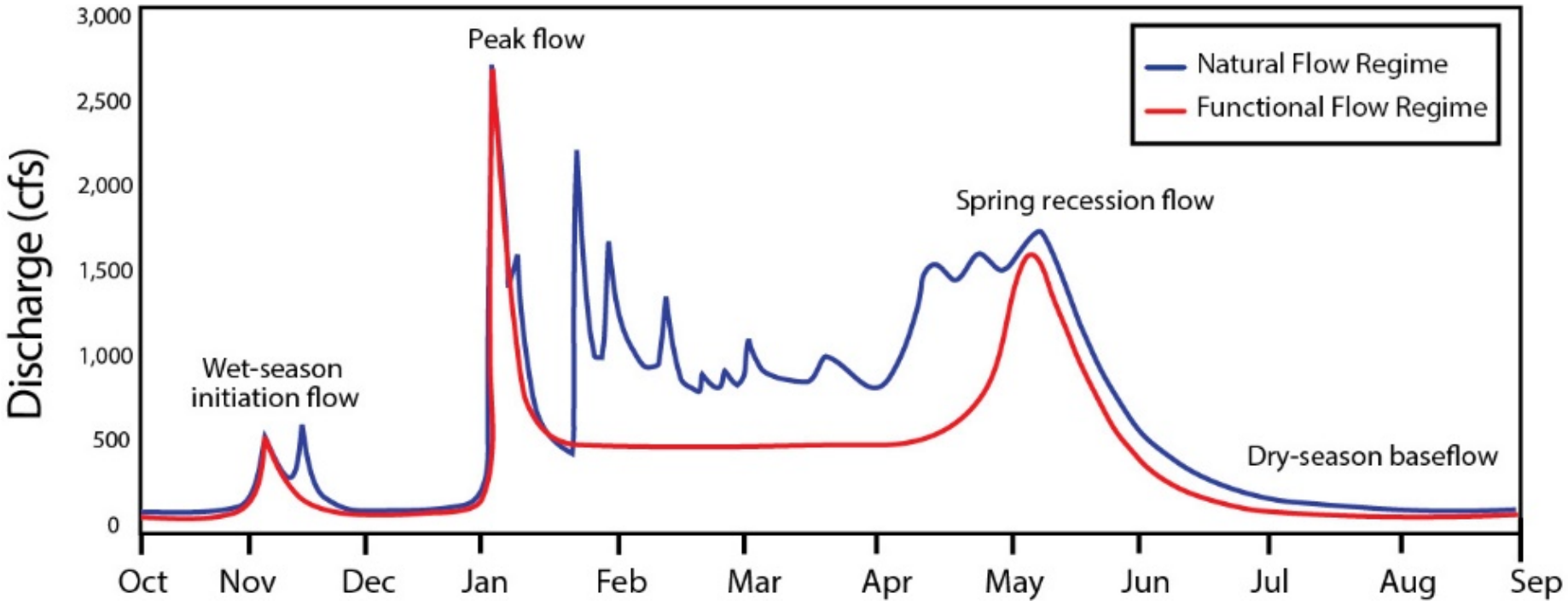
Consideration of geomorphic setting and channel-floodplain dynamics



(Yarnell et al. 2010)

Functional Flows Approach

- "Functional Flow" = hydrograph component that provides a distinct geomorphic, ecologic or biogeochemical function
- Reflective of natural patterns that occur in space & time

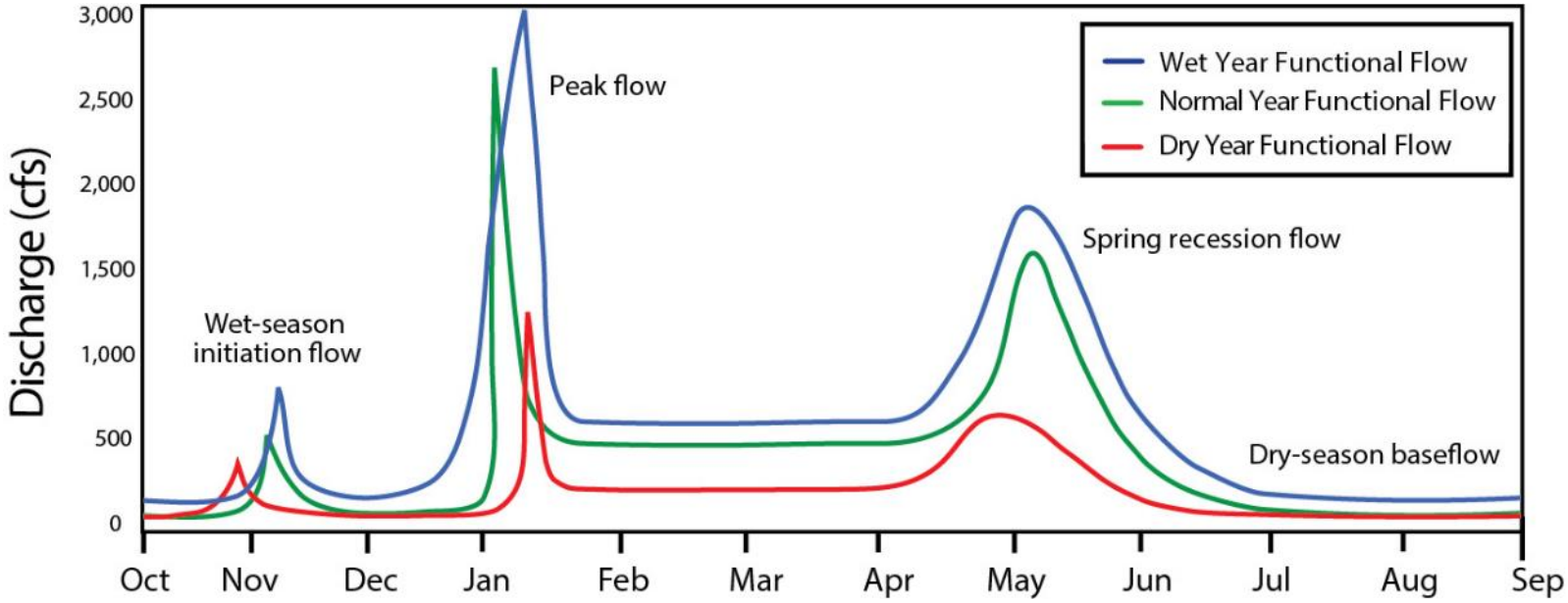


Yarnell et al. 2015

Interannual Flow Variability

Magnitude, timing and duration of specific flow events vary:

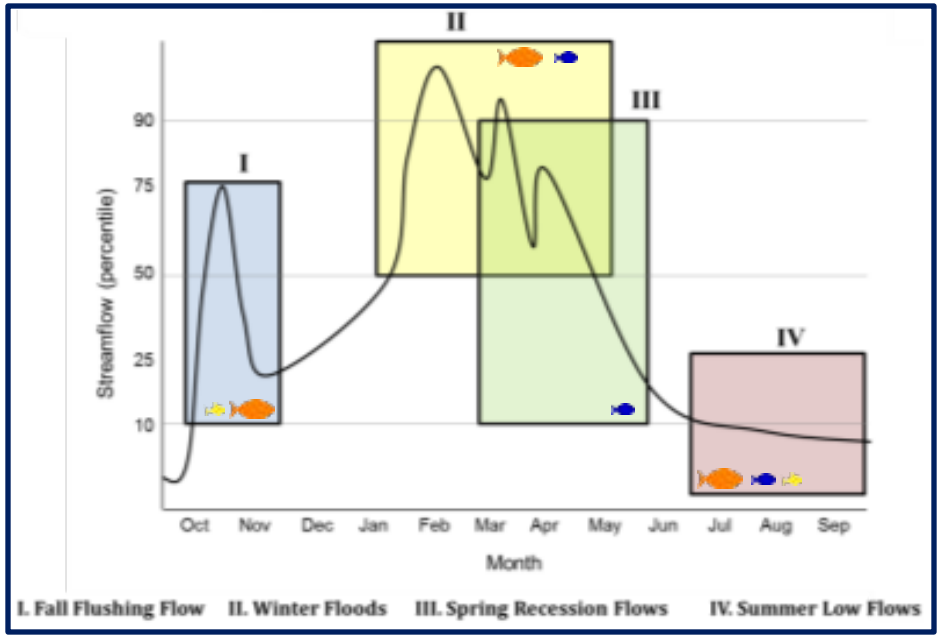
within their associated season depending on regional climatic conditions, and *between* years depending on global climate conditions



Supports diversity in geomorphic habitat and subsequent diversity in native species over the long-term

Functionality in Practice

- Develop a standard hydrograph for a hydrologic basin type (Lane et al. 2016, Stein et al. 2016)
- Magnitude, duration set by statistical variability of unimpaired system
- Timing set by aquatic species needs
- Flow targets set based on water year type



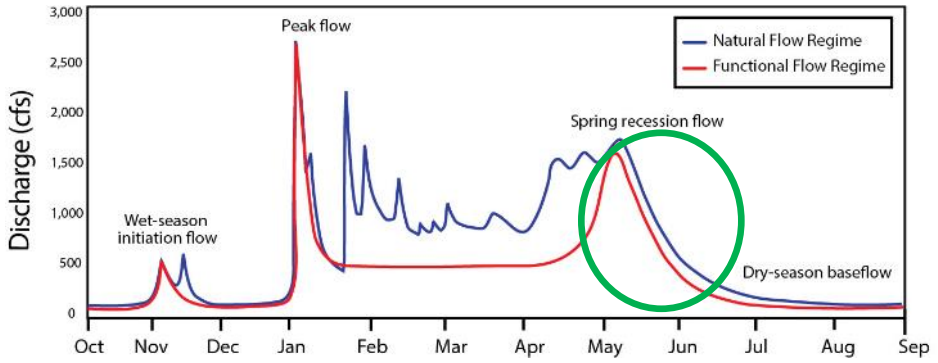
Example standard hydrograph for a hydrologic basin type with key functional flows required for a particular group of aquatic species

J. Lund, S. Sandoval, B.Gray, P. Moyle, R. Frank, B. Lane, S. Yarnell, E. Stein, H. Dahlke, T. Grantham, R. Lusardi, N. Santos, A. Bell, A. Willis, SWRCB. 2016.

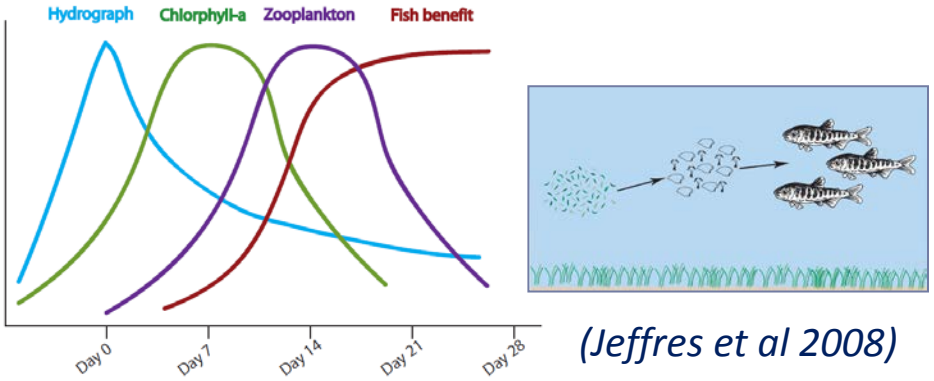
Functionality in Practice: Spring Recession Flow

High to Low Flow Transition

- The one time annually where high resources are coupled with predictable flows
- Limits riparian vegetation encroachment
- provides distinct annual cues for native species to reproduce and outmigrate
- Extended floodplain inundation
- Results in high biodiversity



Sacramento River, CA

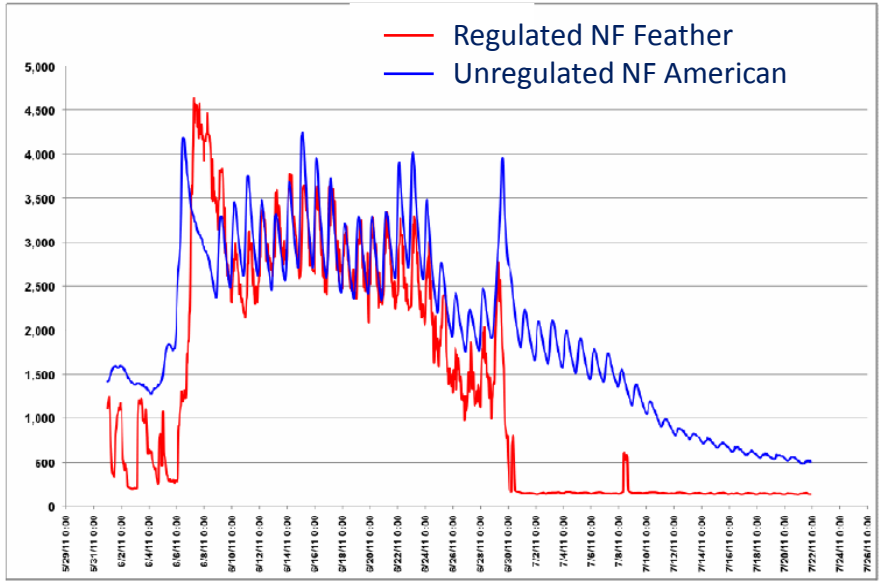


(Jeffres et al 2008)

Foothill Yellow Legged Frog Breeding

Native CA species of special concern and obligate stream breeder in decline due in part to flow impacts from dams

Consideration must be given to FYLF during flow negotiations in hydropower relicensing

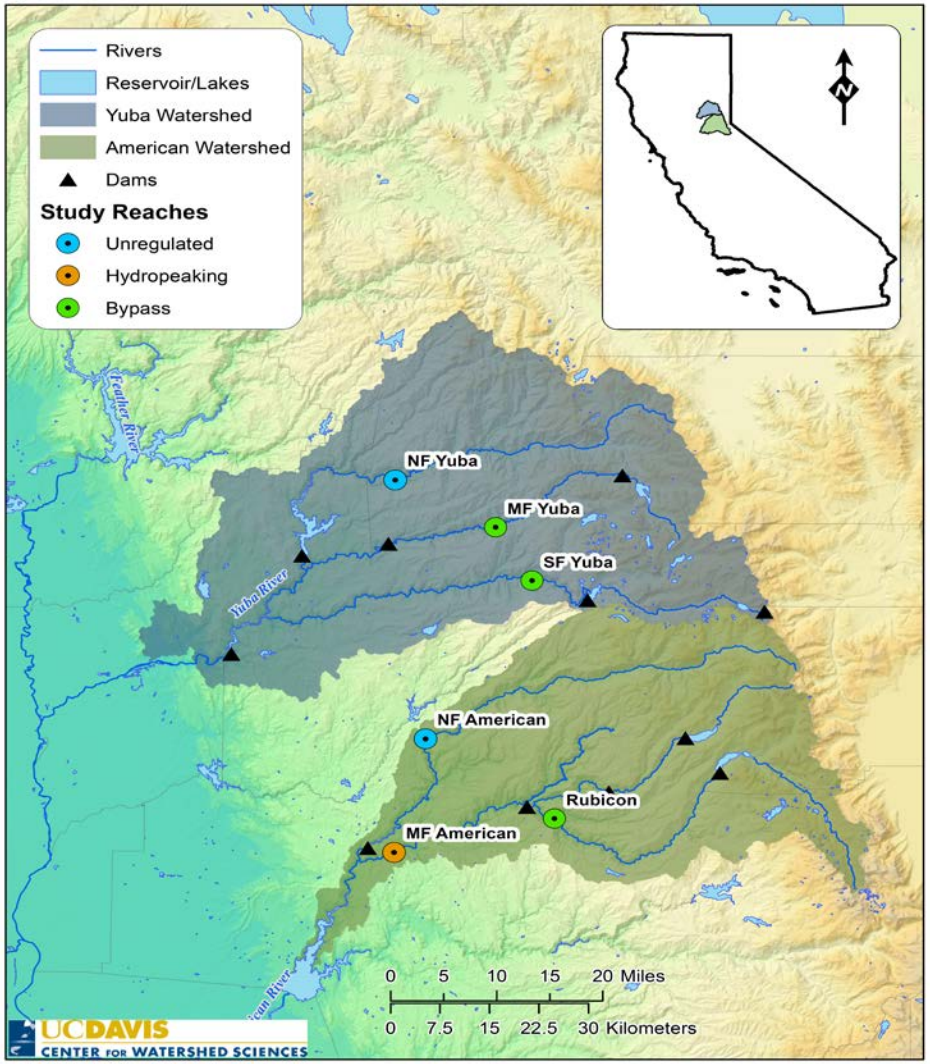


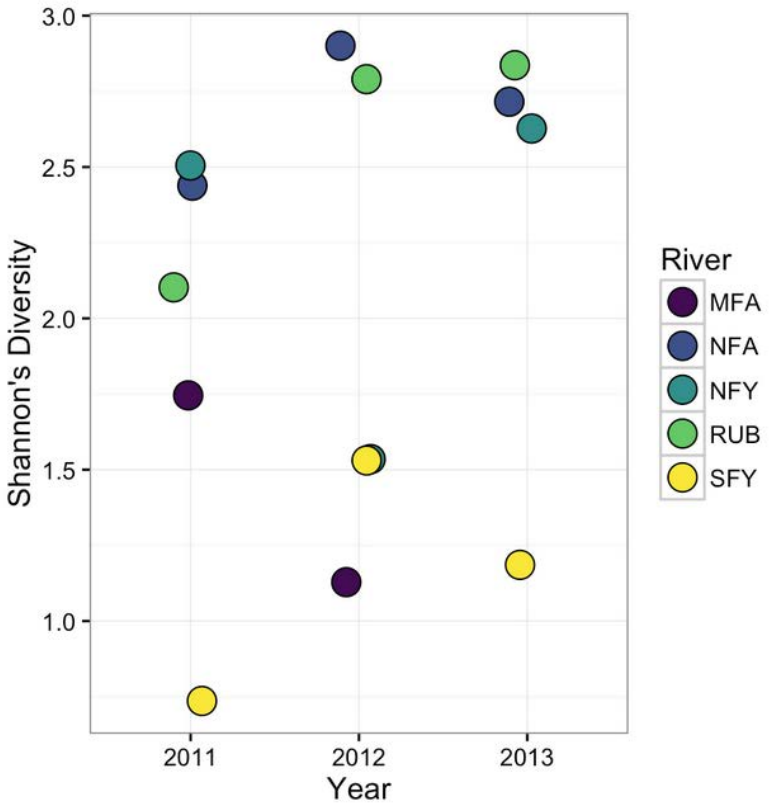
May 29 - July 22, 2011

100% of FYLF eggmasses (entire annual cohort) desiccated on NF Feather due to flow decrease from 77.6 cms to 5.7 cms over 12 hours

Yarnell et al. 2016

BMI Community Diversity



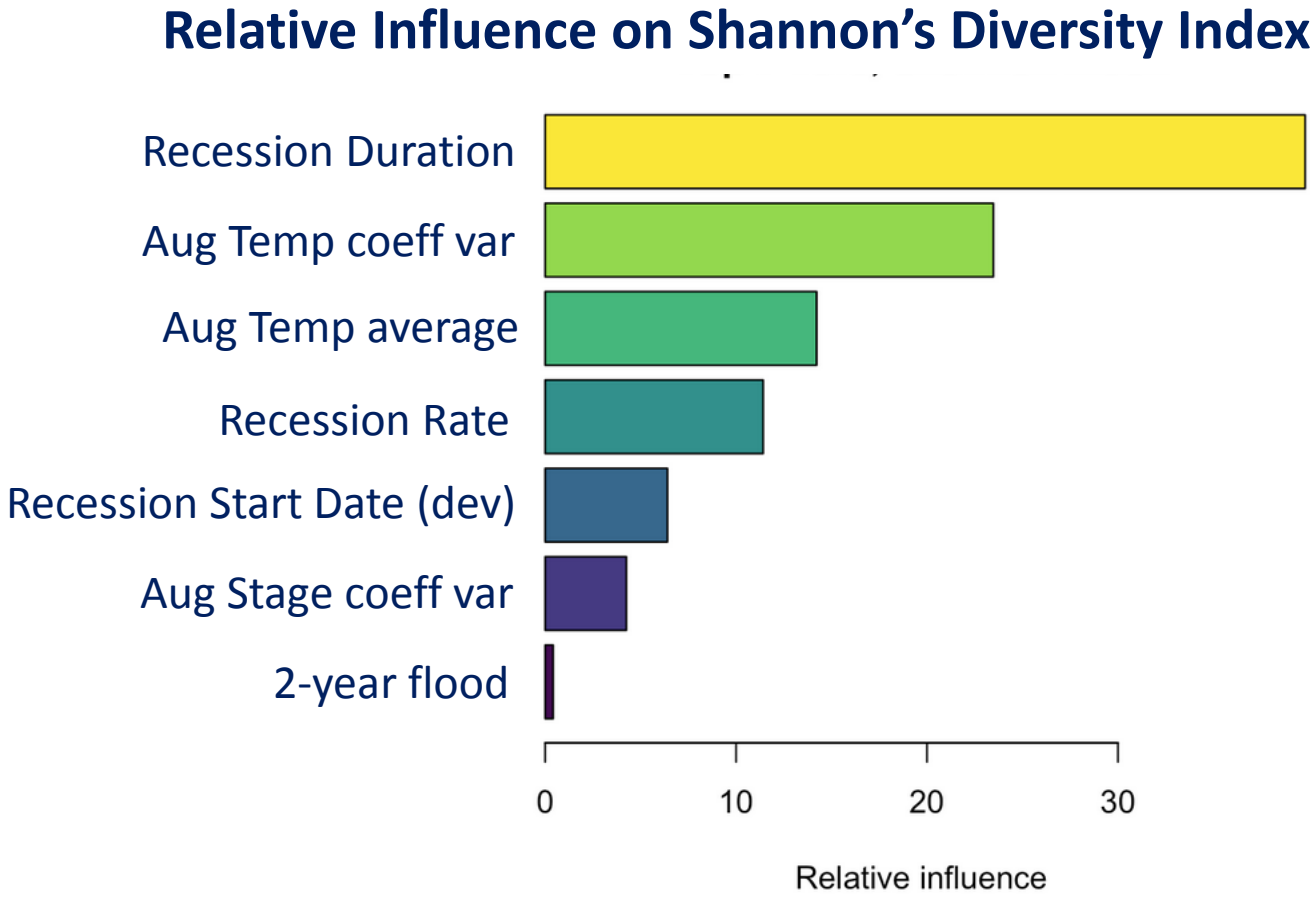


Unregulated → High Diversity

Regulated → Low Diversity

Steel et al. In prep

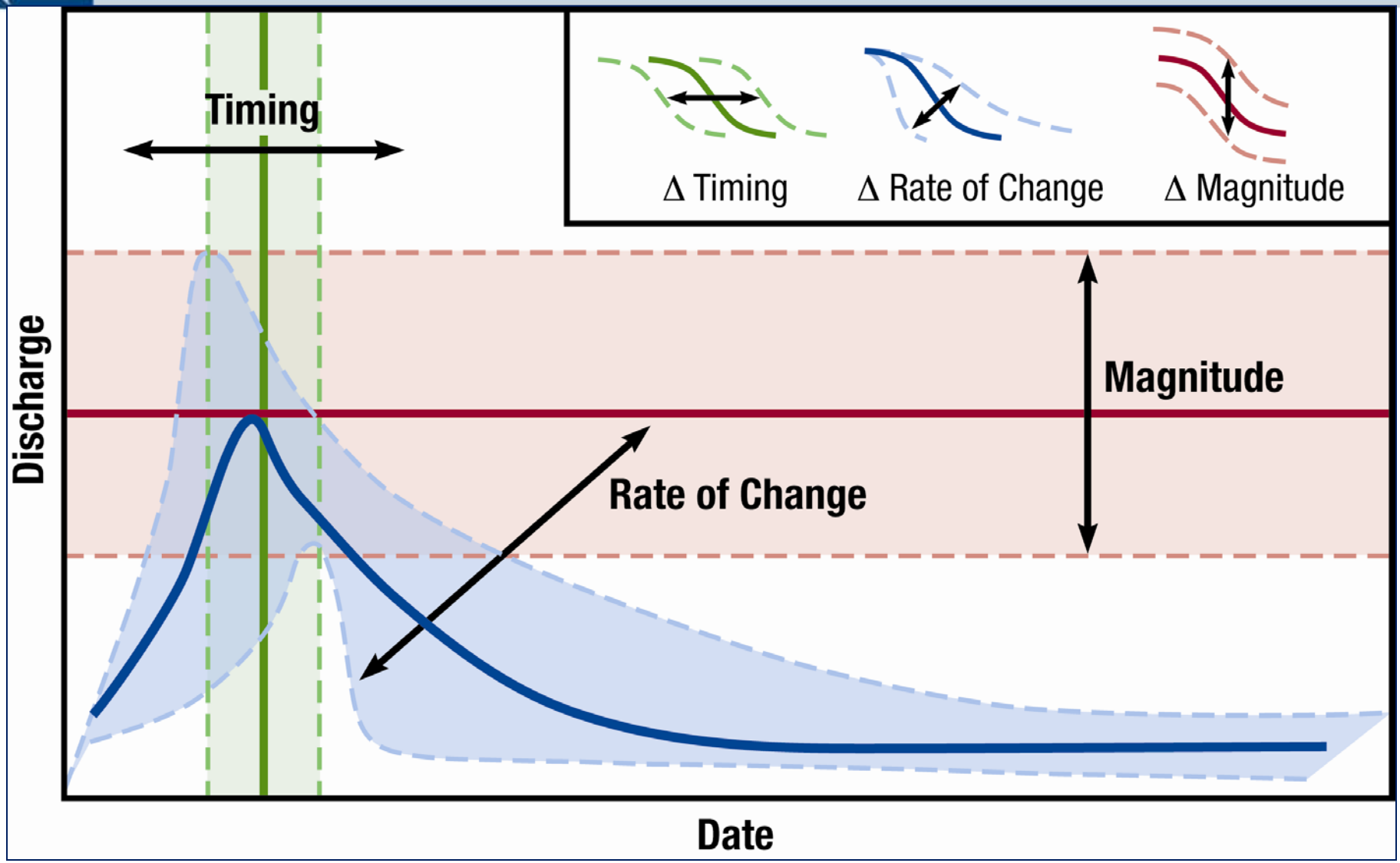
Key Hydrologic Metrics



Spring snowmelt recession and summer water temperature had key influences on BMI community

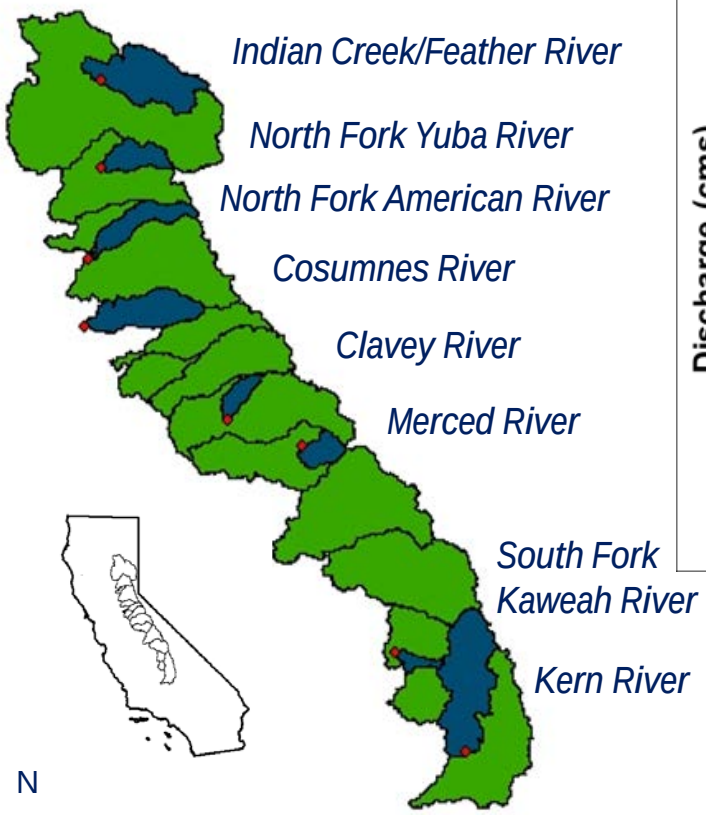
Steel et al. In prep

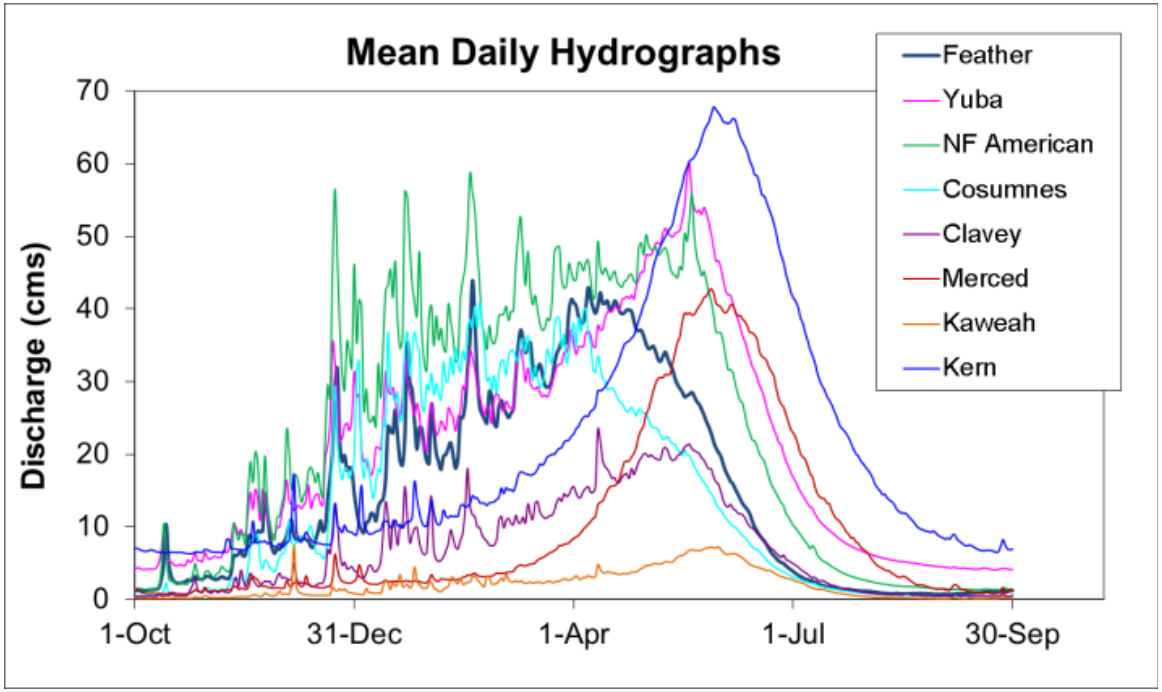
Quantifying the Flow Recession



Yarnell et al., 2010

Unregulated Spring Recession Rates





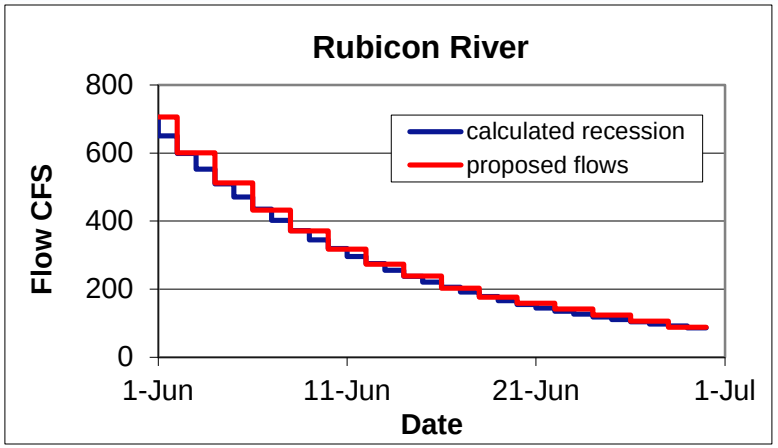
Daily recession rates:

- decrease during the recession (on average from 8 to 4% per day),
- are limited (typically < 20% per day)
- are consistent across elevations

Yarnell et al. 2016

Application in Regulated Systems

- 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
- “Flow Recession Calculator” in Excel



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

Yarnell et al. 2016

Application in Regulated Systems

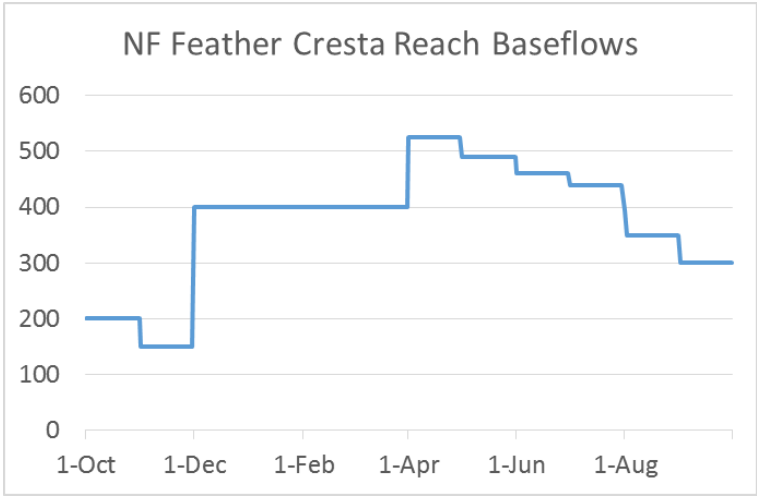
Recession rates can be modeled as down-ramping rates from spill or an ecological flow pulse

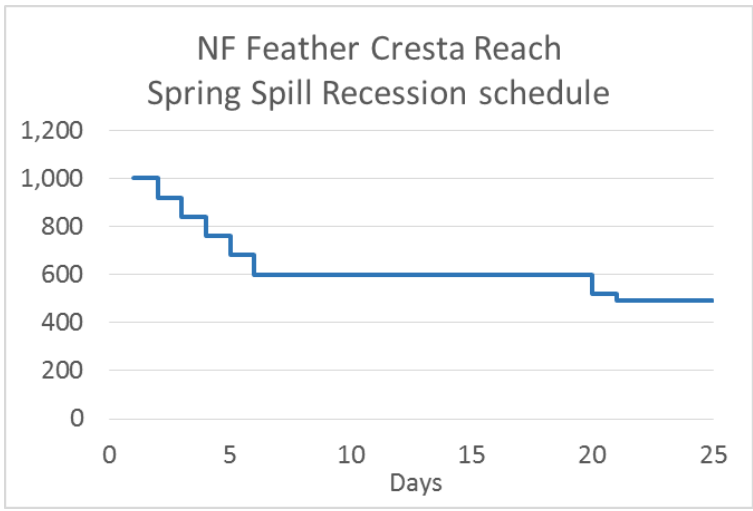
Examples in California:

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

NF Feather Negotiated Flow Schedule:

- seasonal changes in baseflows
- short duration spring recession
- 15-day recreational flow release





Podolak and Yarnell 2015

Environmental Flow Management

- Functional Flows approach focuses on quantifying and restoring flow components with greatest link to processes
- Restoration of the spring recession achievable by modeling daily *rates of change* to increase hydraulic habitat diversity
- Quantifiable flow metrics are best for design and monitoring, but also need to directly relate to ecological endpoints (FYLF breeding, BMI diversity)
- Seek opportunities to engage stakeholders

Photo: R. Peek

Acknowledgements

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