Southern Sierra Change Adaptation Workshop

Frameworks for Freshwater Ecosystem Management in the Sierra Nevada in an Era of Hydroclimatic Change

Joshua H. Viers
& colleagues
Center for Watershed Sciences
University of California Davis

jhviers@ucdavis.edu

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did I say framework?

> There are known knowns; there are things we know we know.
> We also know there are known unknowns; that is to say, we know there are some things we do not know.
> But there are also unknown unknowns – the ones we don't know we don't know.
>
> —United States Secretary of Defense, Donald Rumsfeld

known knowns:

- Things are changing and will continue to change
- The nature of change will be non-uniform across space and time

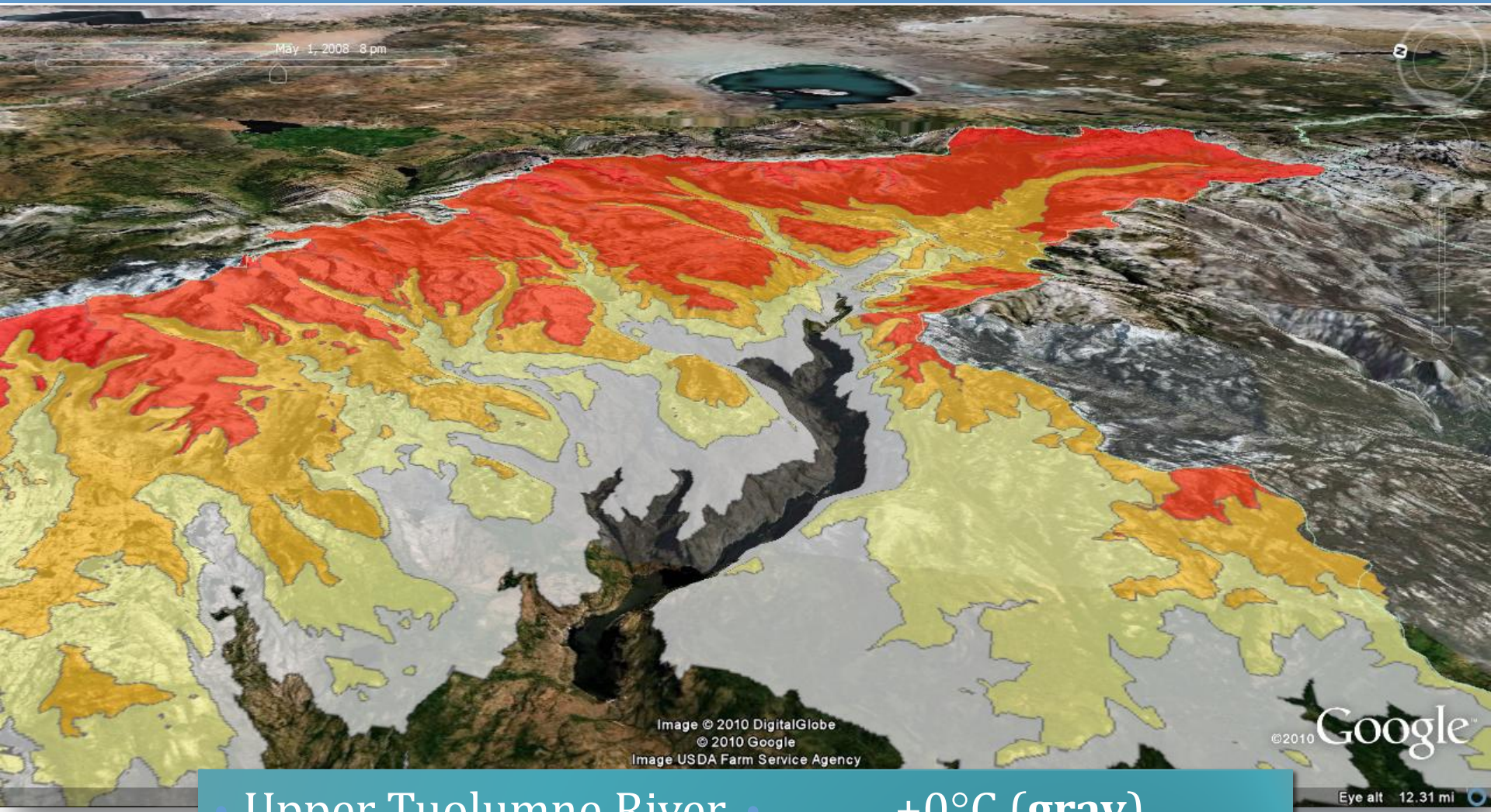
Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

Milly et al.

- Hydroclimatic alteration
  - regional air temperature warming, but with less certainty in change of precipitation volume
  - med-montane climate persists
  - asymmetric seasonal warming
  - earlier onset spring melt
  - earlier centroid timing
  - reduction in mean annual flow, but monsoon influence

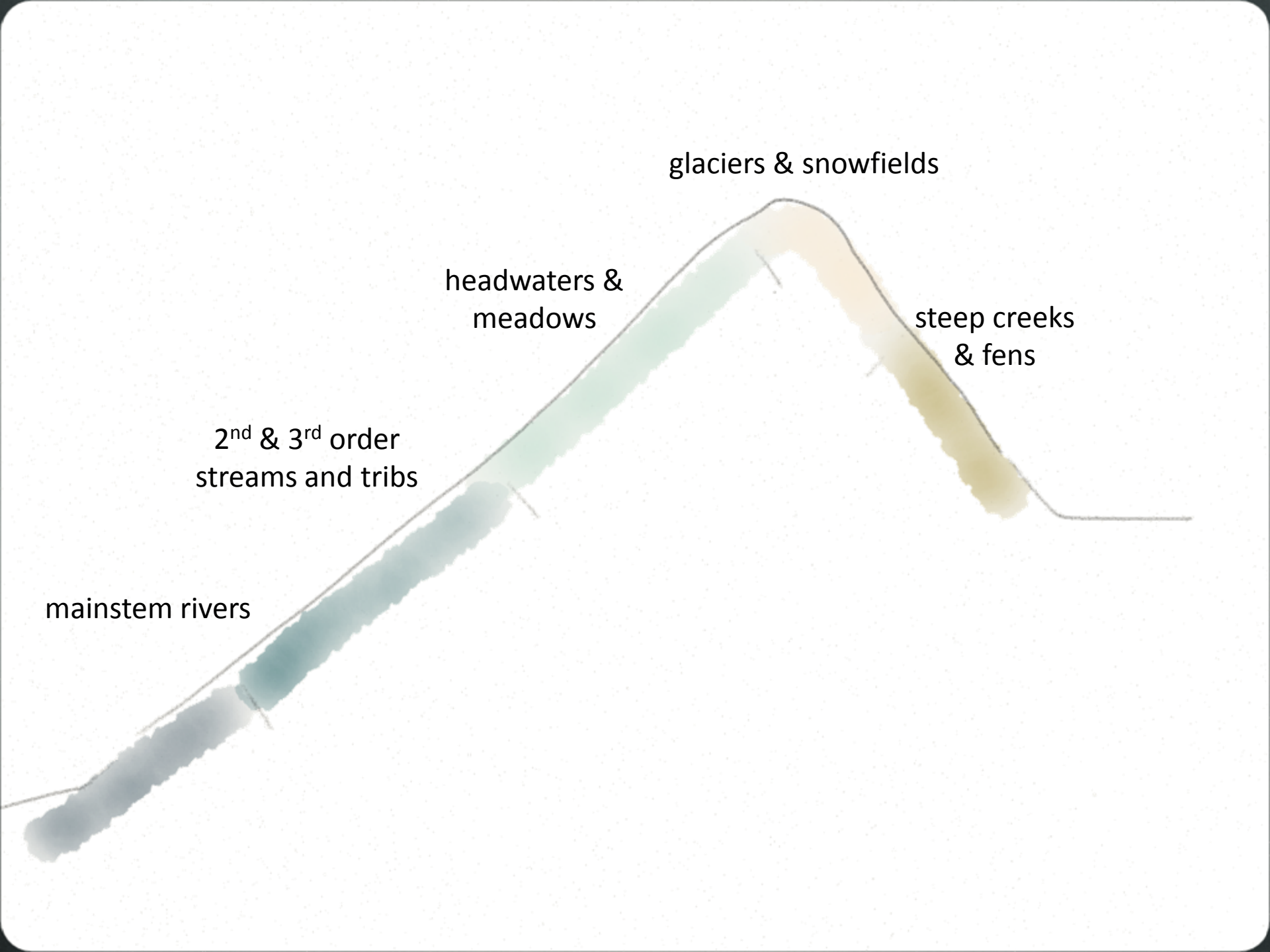
Cayan, Maurer, Stewart, Knowles, Dettinger, Pierce, Das, and many others.

Adapted from Young et al. (2009) *JAWRA*



- Upper Tuolumne River
- May 1 Snow Cover
- Avg of 20 WYs

- +0°C (**gray**)
- +2°C (**yellow**)
- +4°C (**orange**)
- +6°C (**red**)


glaciers & snowfields
headwaters &
meadows
steep creeks
& fens
2nd & 3rd order
streams and tribs
mainstem rivers

Landscape scale structure and processes

Habitat scale structure and processes

Food-web scale structure and process

Geology

Hydrology

Geomorphology (channel/ floodplain)

Groundwater (aquifer characteristics)

Surface water groundwater interaction (Hyporheic connectivity)

Water Quality (temperature, chemistry, contaminants, nutrient cycling, etc.)

Riparian vegetation

Aquatic vegetation

Plankton, Periphyton, Primary productivity

Macro/micro invertebrates

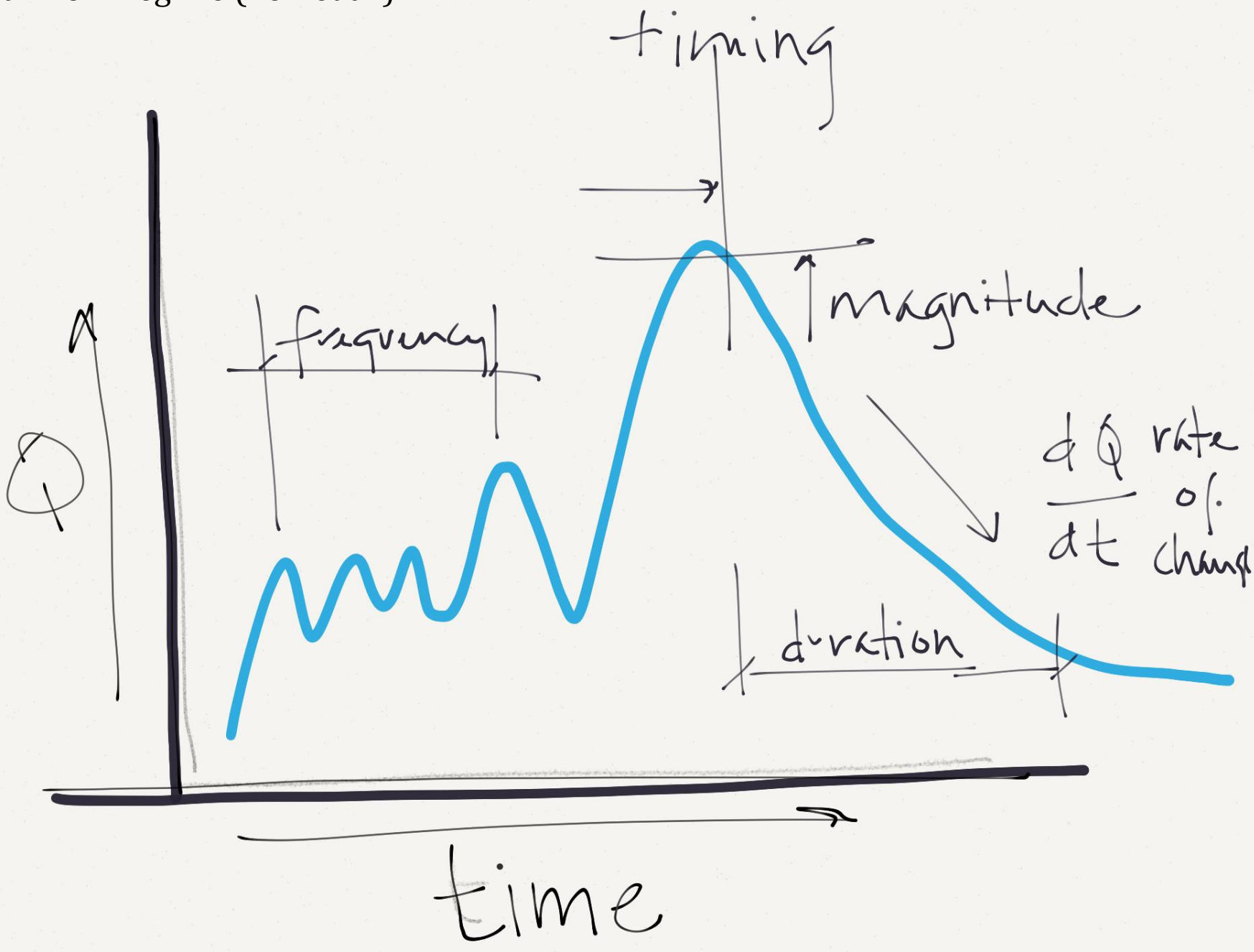
Mammals | Reptiles | Birds | Amphibians | Fishes

◄ Terrestrial ↔ Aquatic ►

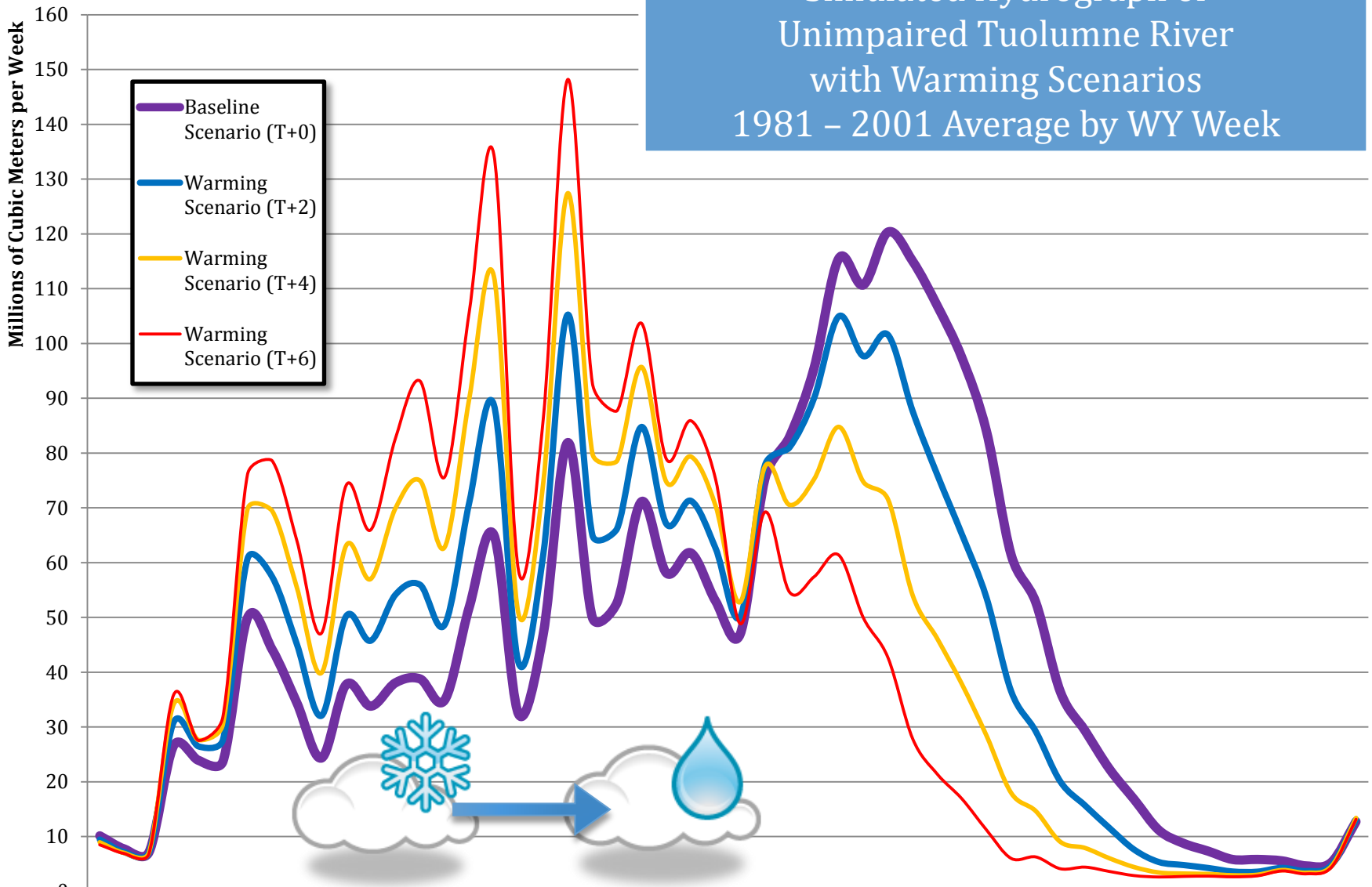
Flow Regime

Adapted from Conceptual Model by René Henery

Natural Flow Regime (Poff et al.)

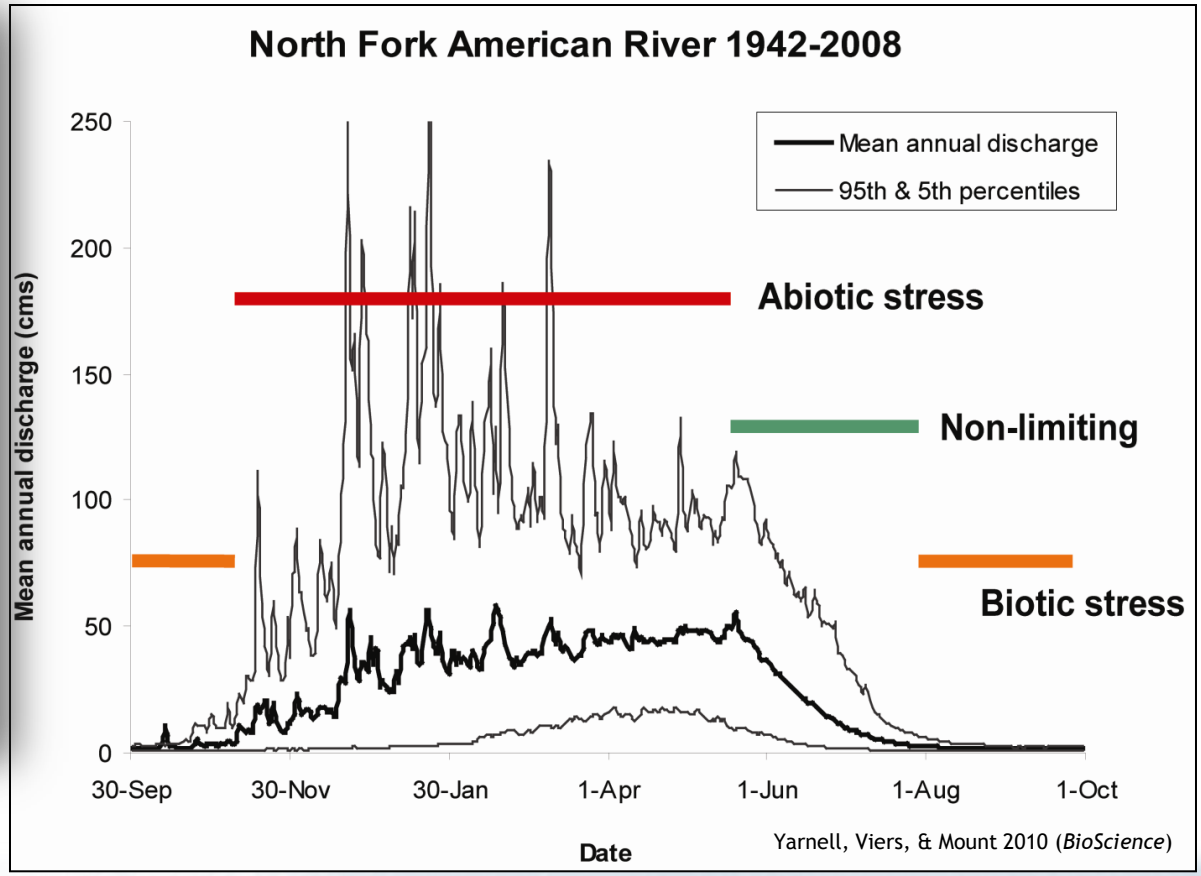


Simulated Hydrograph of Unimpaired Tuolumne River with Warming Scenarios 1981 – 2001 Average by WY Week



Adapted from Young et al (2009); presented in Yarnell et al (2010)

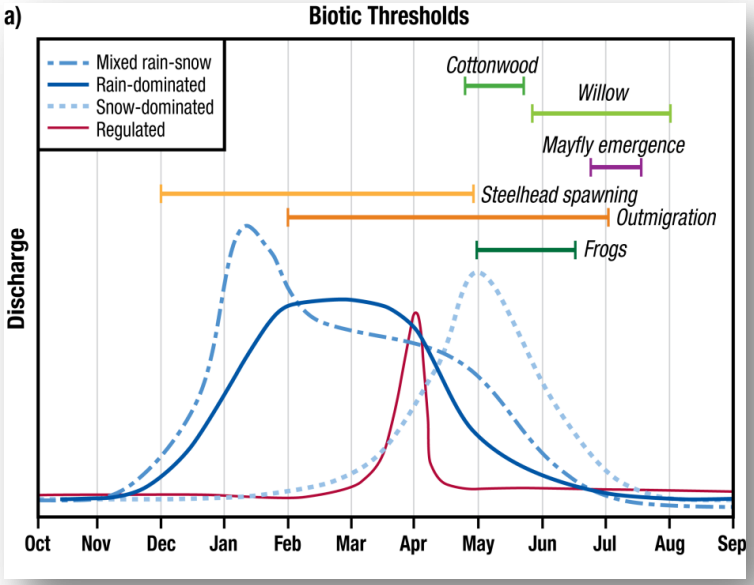
Spring Snowmelt Recession

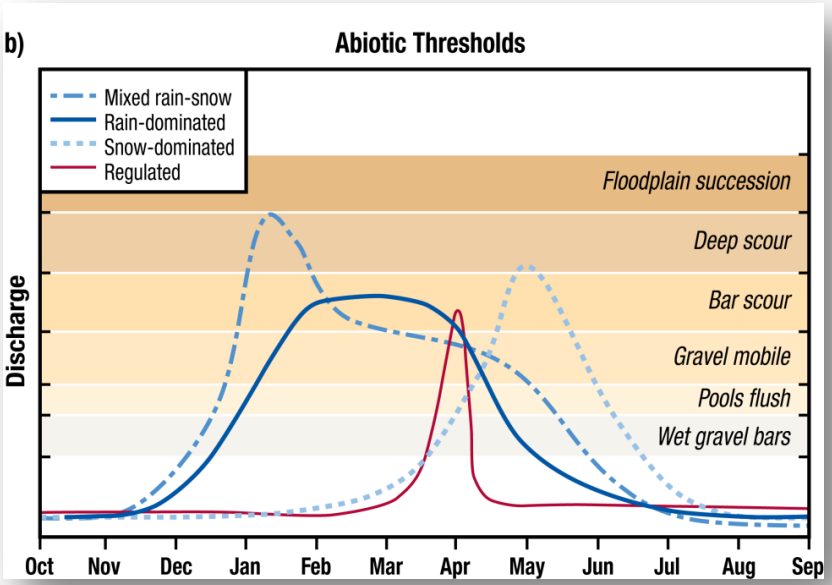


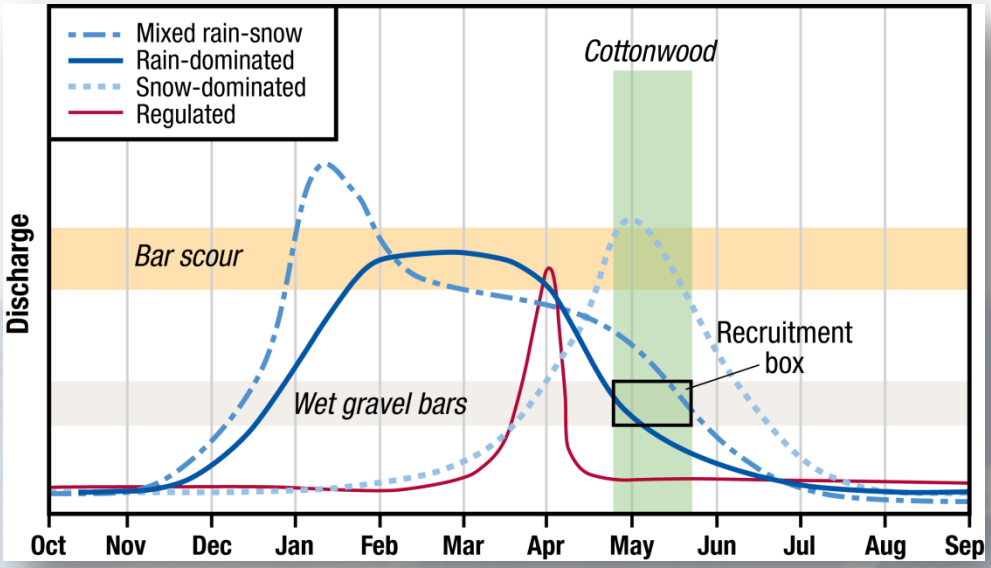
the physical, chemical and biological impact of this spring-time pulse of water is profound…

a one time annual event where high resources are coupled with stable predictable flows, resulting in high biological producitivity…

Yarnell, Viers, and Mount (2010) *BioScience*

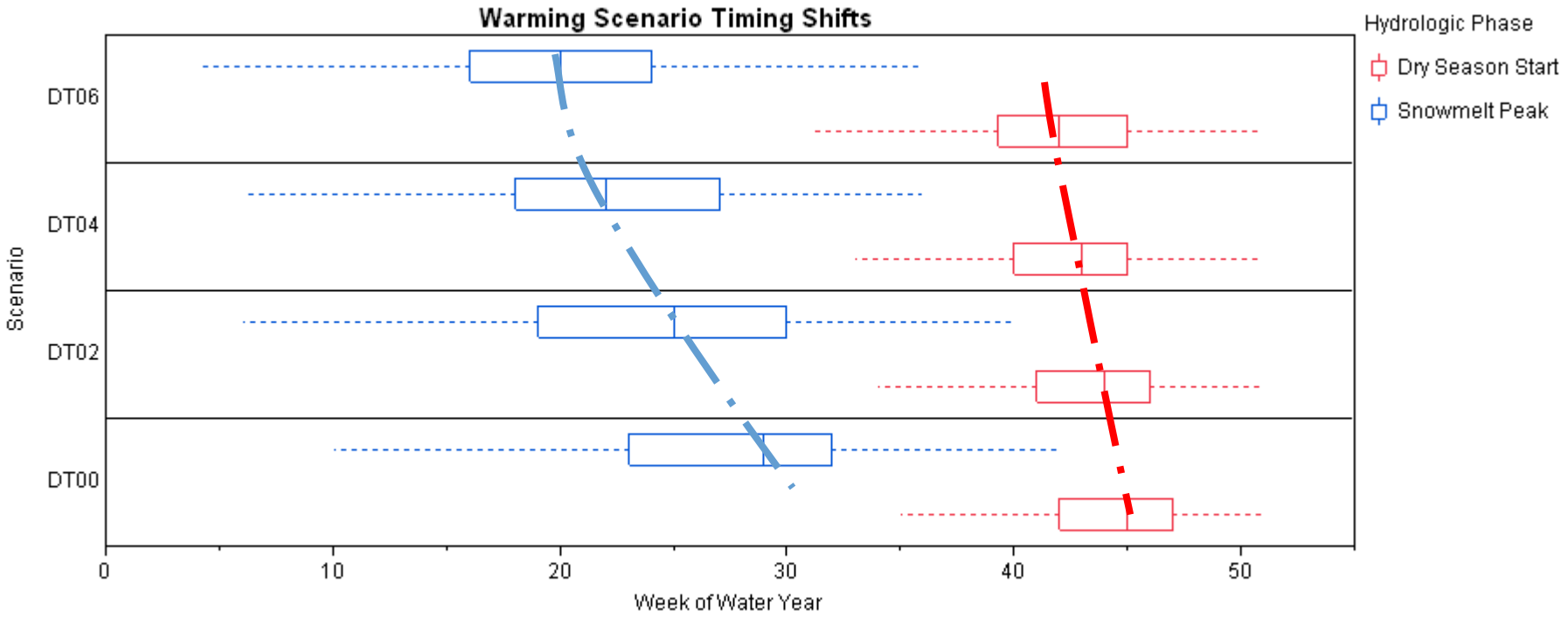






Yarnell, Viers, and Mount (2010) *BioScience*

Recession limb changes

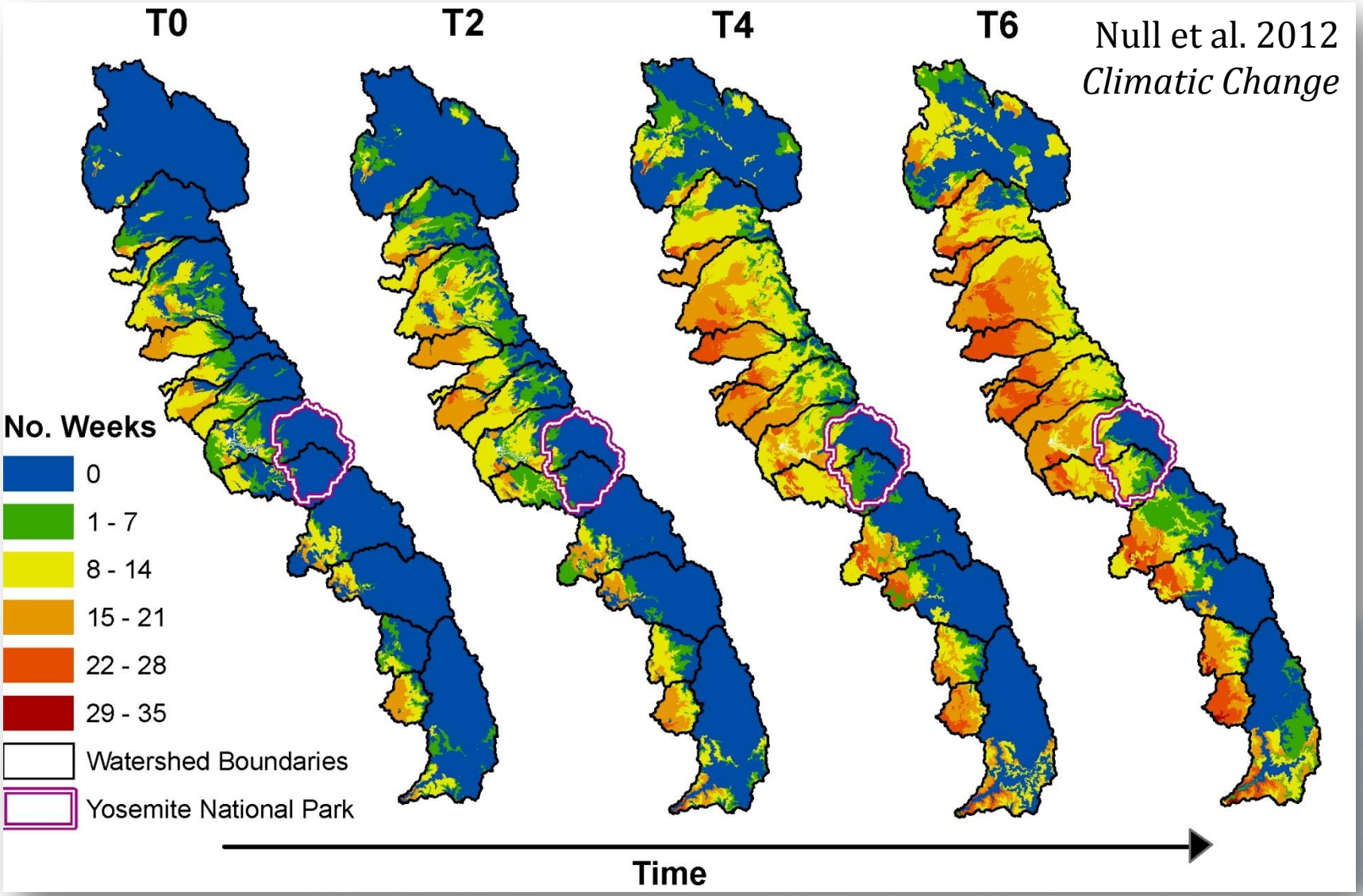


261 Individual Watersheds modeled for 20 Water Years of Unimpaired Flows across 15 Sierra Nevada Basins with 3 Warming Scenarios (+2,+4, +6° C)

Viers unpub. data

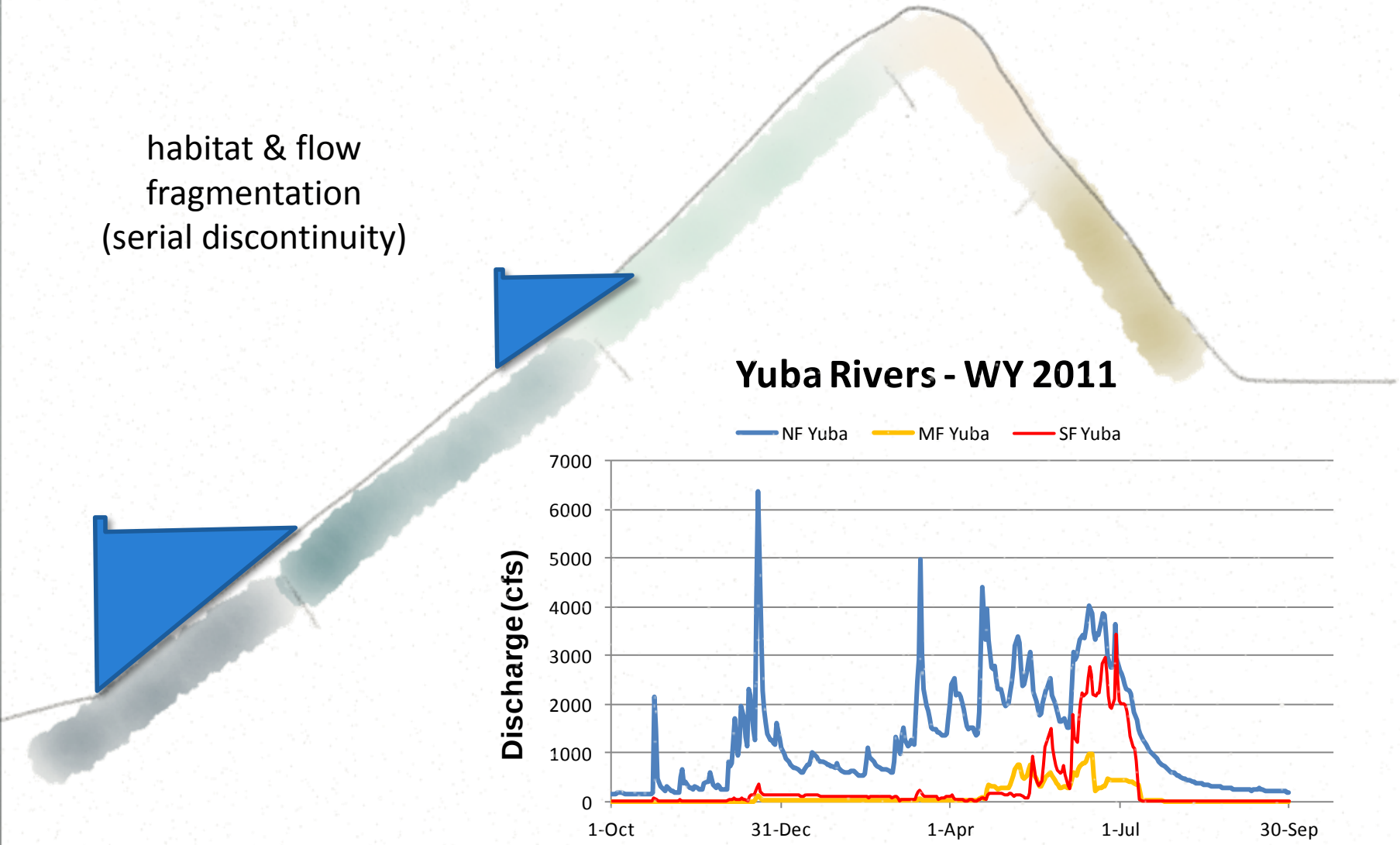
modeled unregulated stream temperatures

– Average annual weeks stream temperatures exceed 24°C



reality?

habitat & flow
fragmentation
(serial discontinuity)



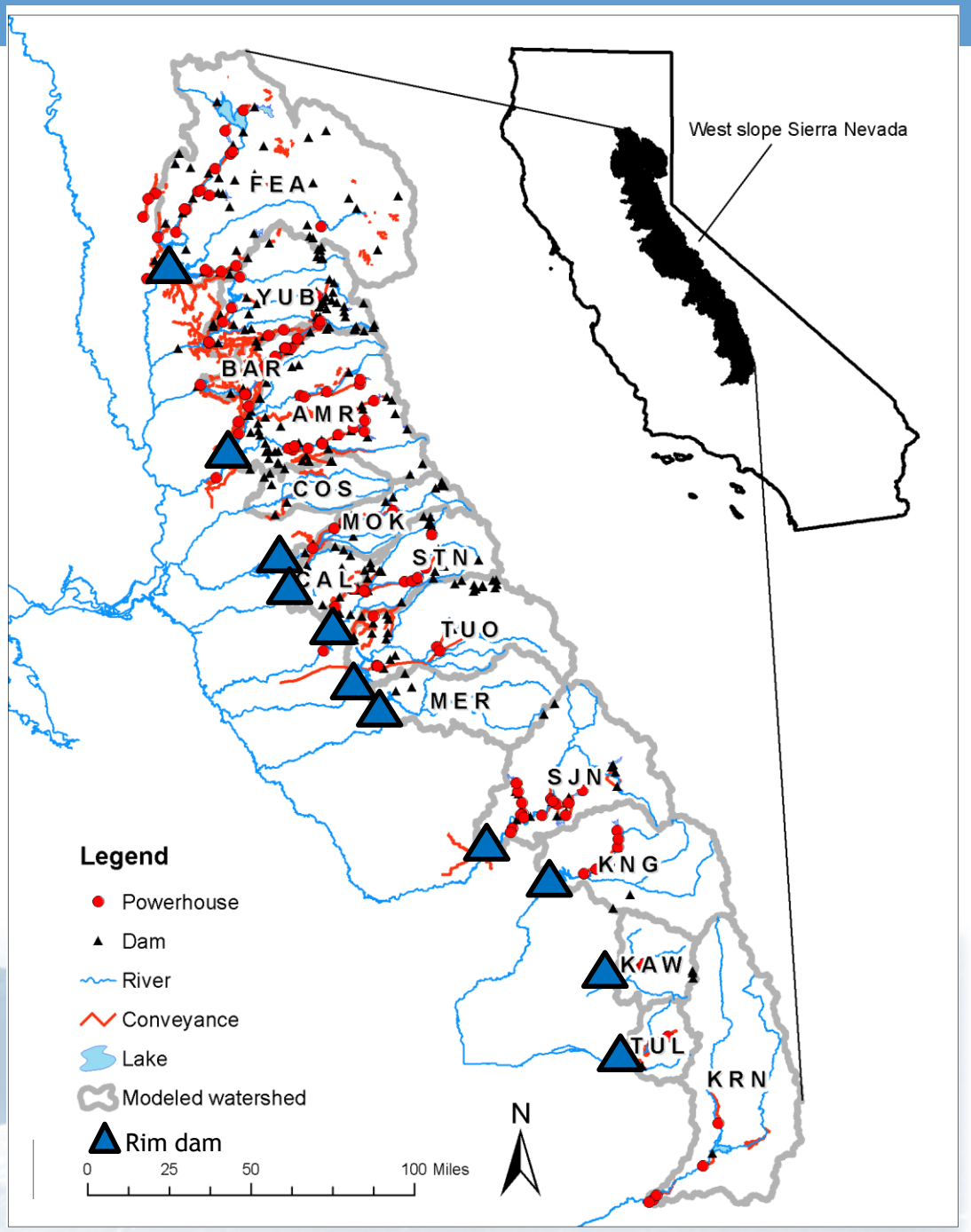
SIERRA model

Rheinheimer et al. In Review
ASCE J. of Water Mgmt & Planning

- **15 basins**
- **415 managed features:**
  - 56 reservoirs, 7.7 MAF
  - 85 run-of-river hydropower plants
  - 16 variable head hydropower plants
  - 125 diversion channels
  - 27 supply demands
  - 106 instream flow requirement points
- **Above "rim" dams**
- **Weekly time step**

Applied using:

- **20 years (1981-2000)**
- **Inflows:**
  Young et al., 2009
- **+0, 2, 4, and 6°C** uniform warming
- Modeled with WEAP21



Seasonal and Annual Changes in Hydropower Generation

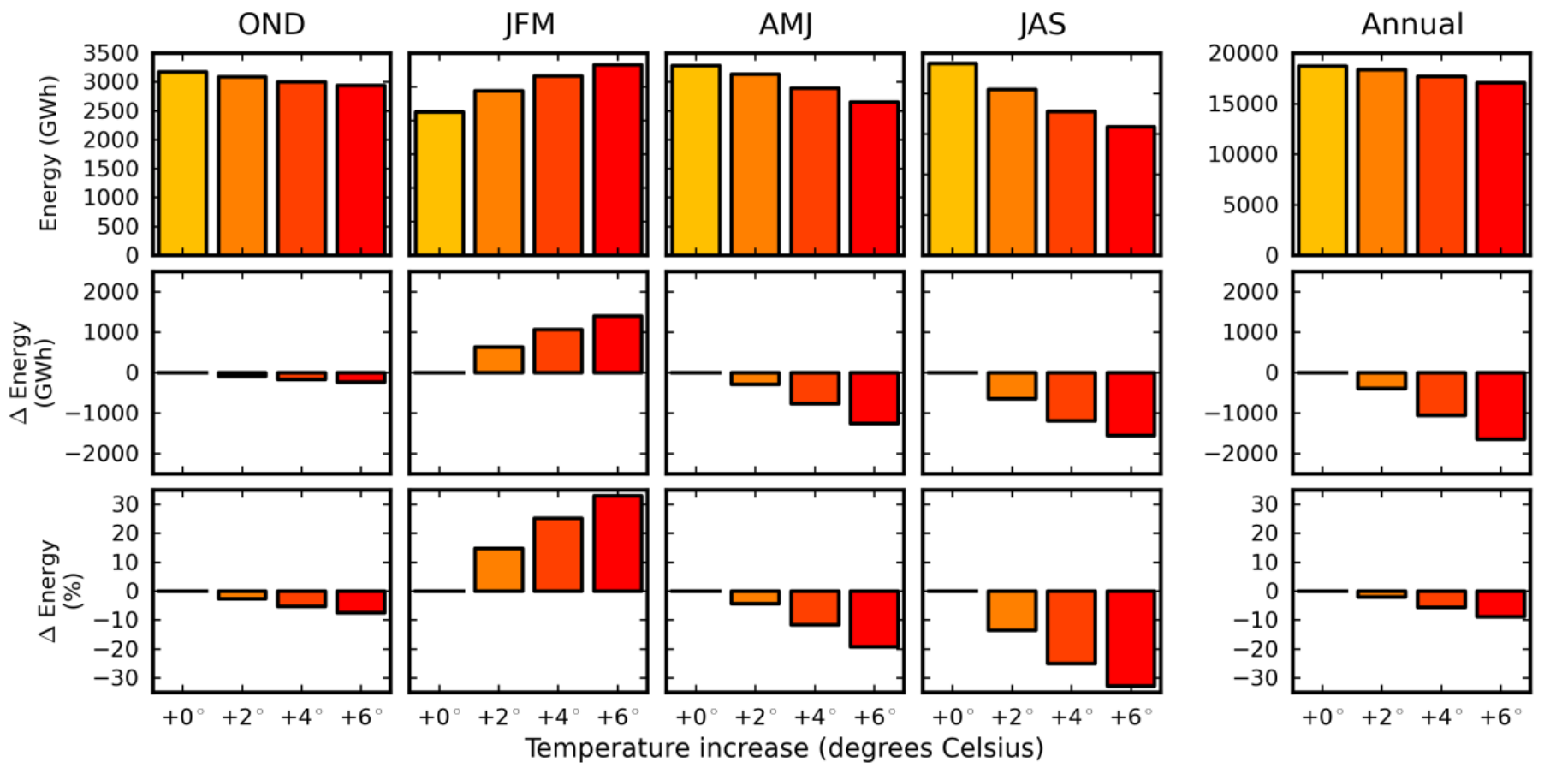
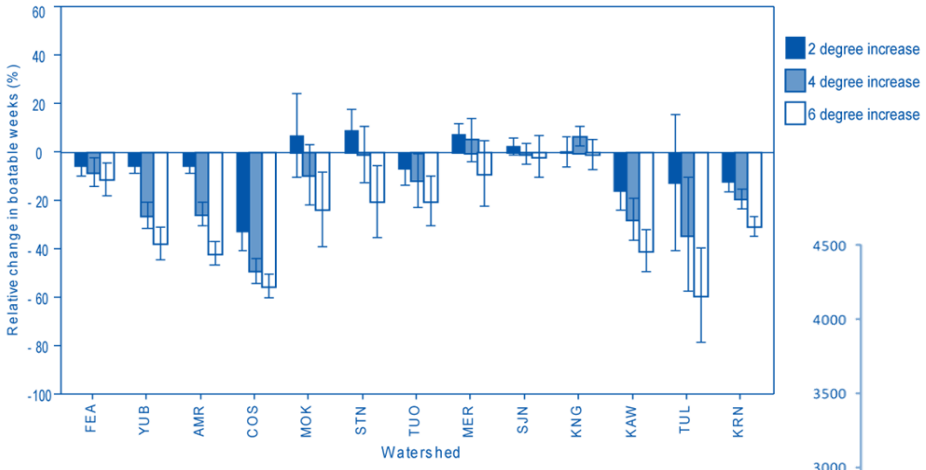


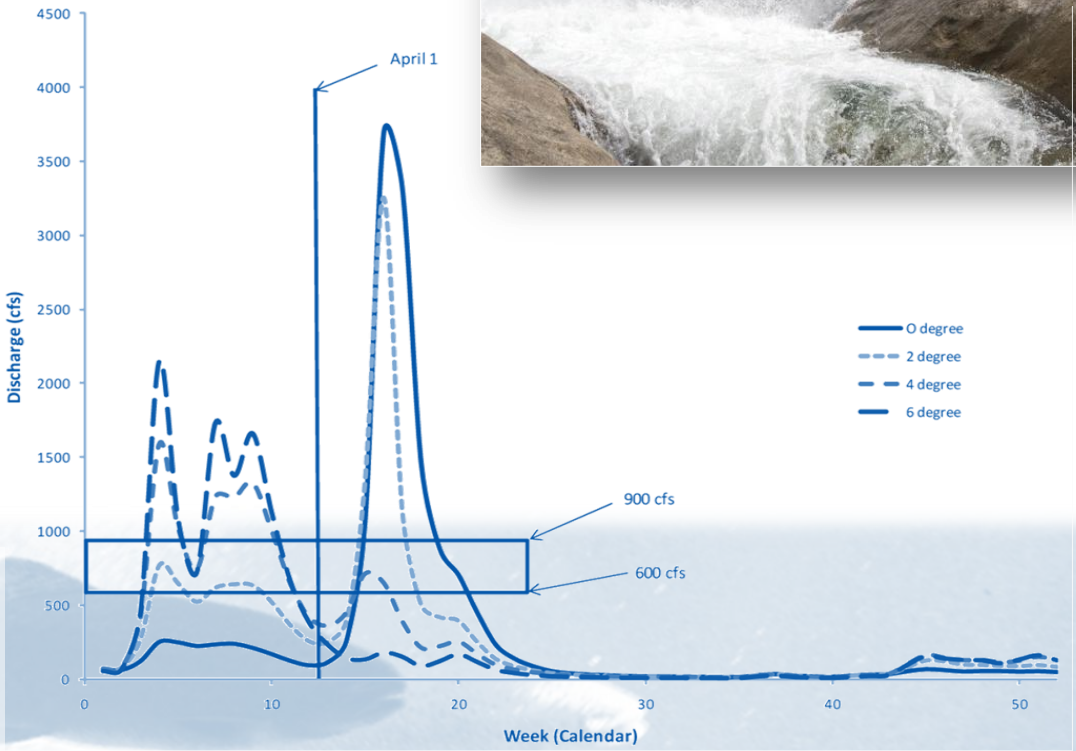
Figure 11: Seasonal and annual hydropower generation with warming.

Warming scenario	OND (Fall)	JFM (Winter)	AMJ (Spring)	JAS (Summer)	Annual
dT6	-8%	33%	-20%	-33%	-9%

Rheinheimer et al. *In Review* (see also CEC PIER Report)

whitewater recreation





Ligare, ST, JH Viers, SE Null, DE Rheinheimer, JF Mount. *In Press*. Non uniform changes to whitewater recreation in California's Sierra Nevada from regional climate warming. *River Research and Applications*.

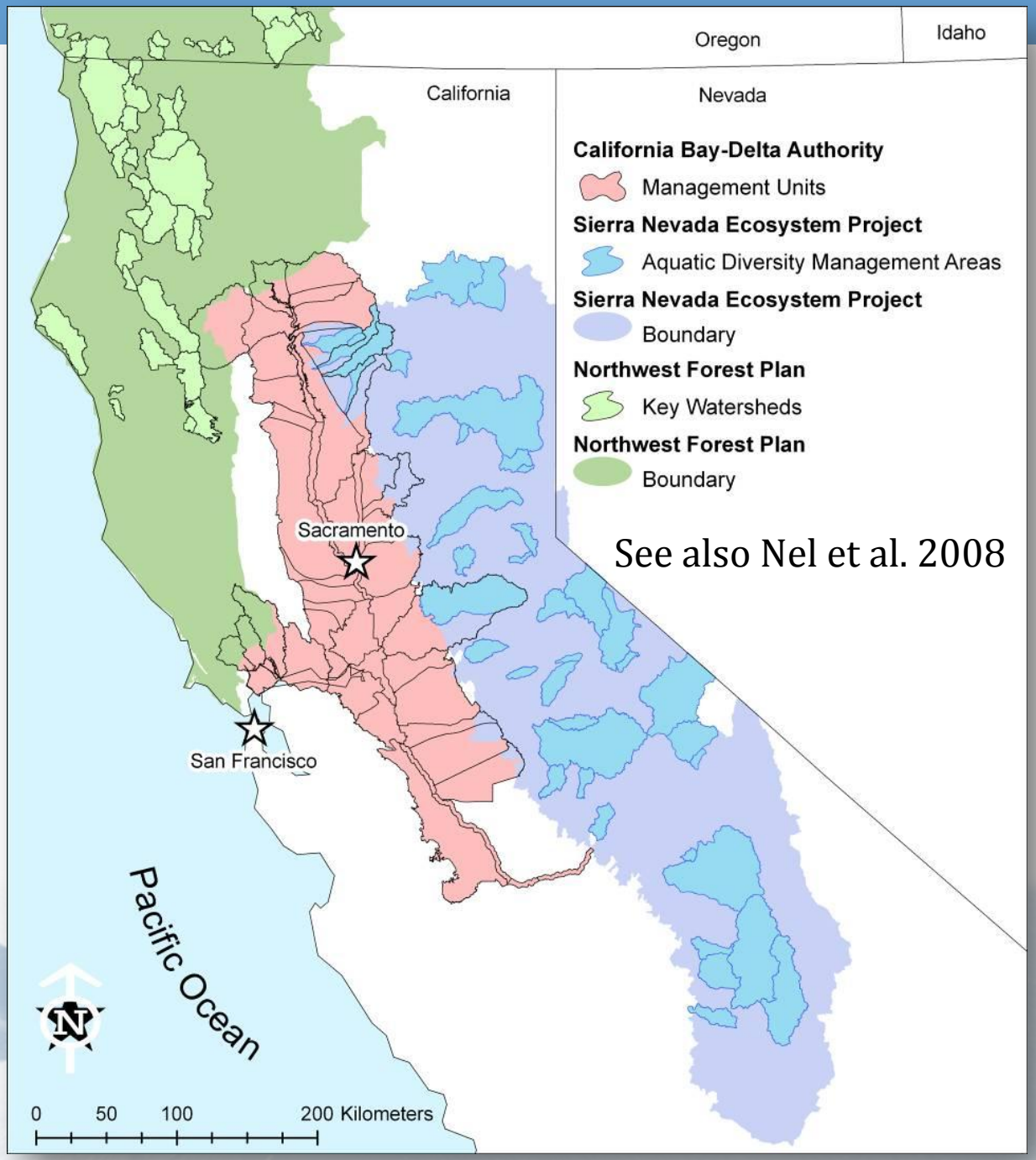
known unknowns:

- Will we adapt … readily, or with difficulty?
- Will adaptations be reactive or anticipatory?
- Will static approaches to policy be taken, or will flexibility become paramount?

- Environment
  - Mega Droughts
  - Atmospheric Rivers
  - Disease / Invasion
  - Disturbance Feedbacks
- Humans
  - Freshwater Conservation
  - Existing Policies
  - Water Year Types

Freshwater Conservation Areas

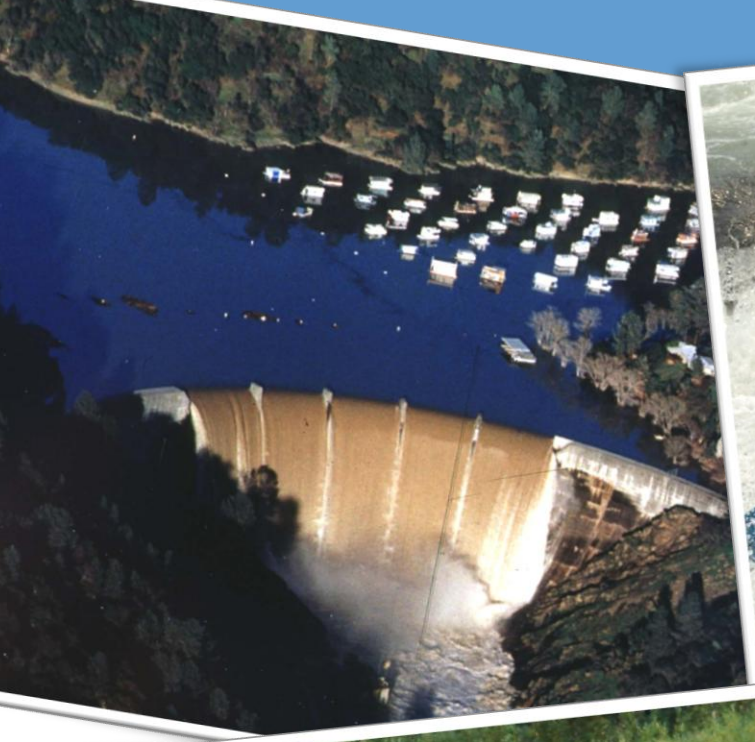
Erman (1996) states, "<u>In short, reserves or key watersheds give a **false sense of security** about species conservation</u>" (p. 1002).



See also Nel et al. 2008

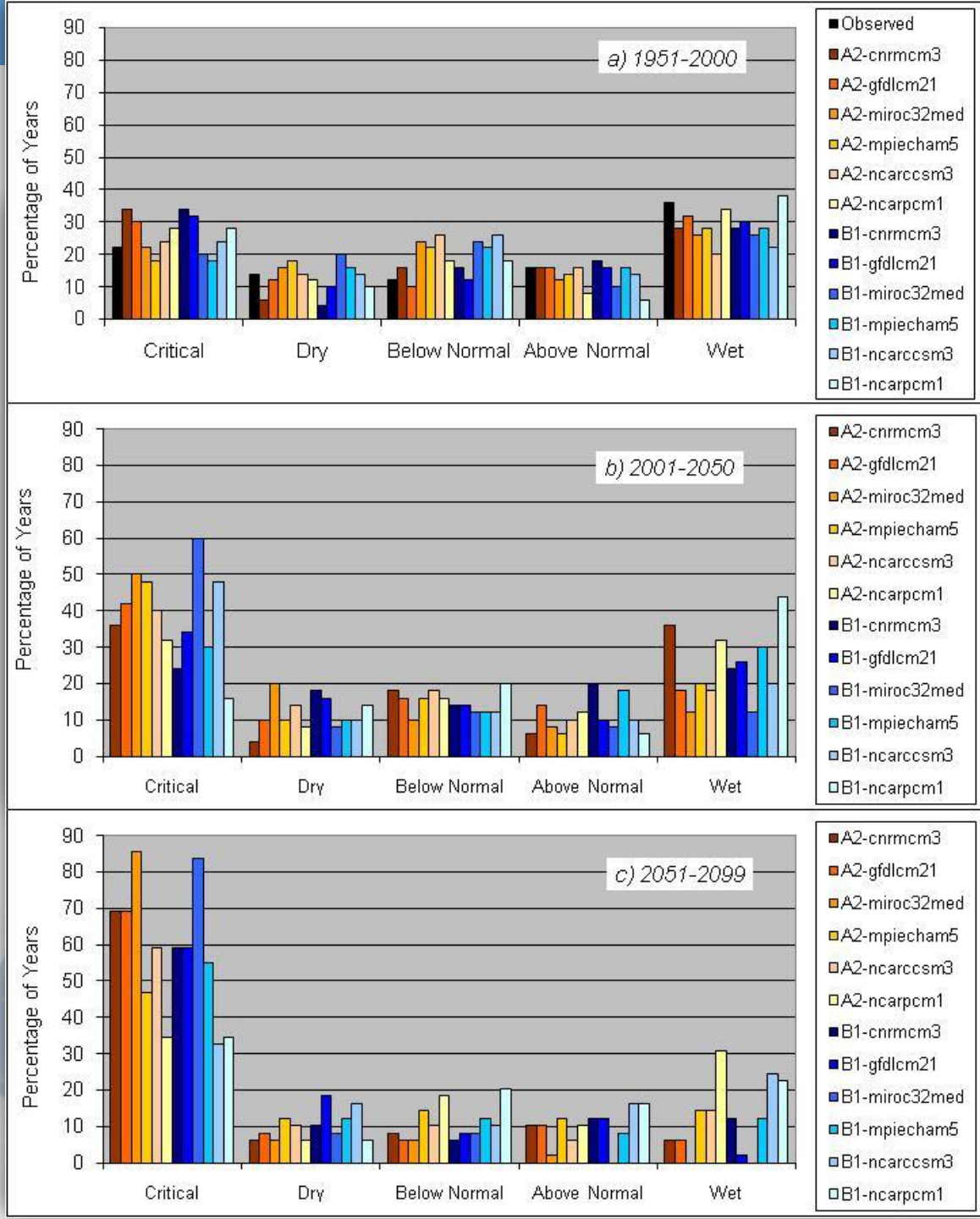
Policy Arrows in the Adaptation Quiver

- **can we use existing authorities?**
  - Public Trust Doctrine
  - FPA / FERC → 4(e) / 10(j) / Fish Passage §18 / 401 cert (CWA)
  - Cal F&G Code §5937
  - NEPA alternatives
- **can we institute catchment-level governance?**
  - River Trusts & Environmental Water Allocations
  - IRWMPs
  - Regional Authorities / JPAs
- **catchment specialization?**



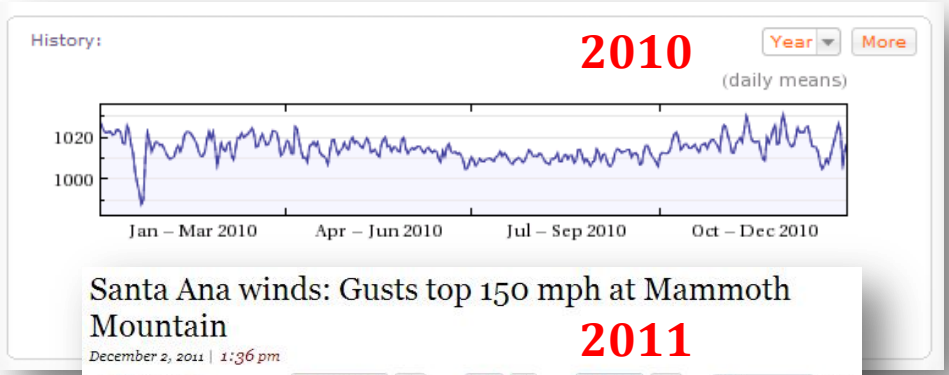
Water year type distributions are expected to push to extremes.

- San Joaquin Valley Index
- A2 and B1 SRES
- 6 GCMs
  - CNRM CM3
  - GFDL CM2.1
  - CCSR MIROC 3.2
  - MPI-OM ECHAM5
  - NCAR CCSM3.0
  - NCAP PCM1
- BCSD VIC streamflow estimates



Null & Viers *2013* Water Resources Research

unknown unknowns:



Santa Ana winds: Gusts top 150 mph at Mammoth Mountain

2011

December 2, 2011 | 1:36 pm

Comments 3 | +1 3 | Tweet 28 | Recommend 90

The blistering winds that ripped through Southern California on Wednesday reached speeds so high that they could not be accurately recorded at the peak of Mammoth Mountain, according to a park spokesperson who estimated winds gusted up to 170 miles per hour.

Mammoth Mountain's patrol website reported constant gusts clocked at 150 miles per hour several times throughout Wednesday. Tracking equipment was set to max out at that speed, so winds at the 11,000-foot peak were almost certainly higher, said Ski Patrol director Bobby Hoyt.

"I had never seen these kind of winds here from that direction, with that intensity, for that period of time," said Hoyt, who has worked at the mountain for 32 years. "It was very, very unusual."

HOME / NEWS / NATION

Associated Press

'Dry lightning' sparks Calif. fires

Phenomenon accompanied by little or no rainfall

2008

Firefighters doused hot spots near Green Valley, Calif., on Monday. Officials said 800 wildfires burned in California, sparked by an unprecedented lightning storm over the weekend. (Rick Roach/the vacaville reporter)

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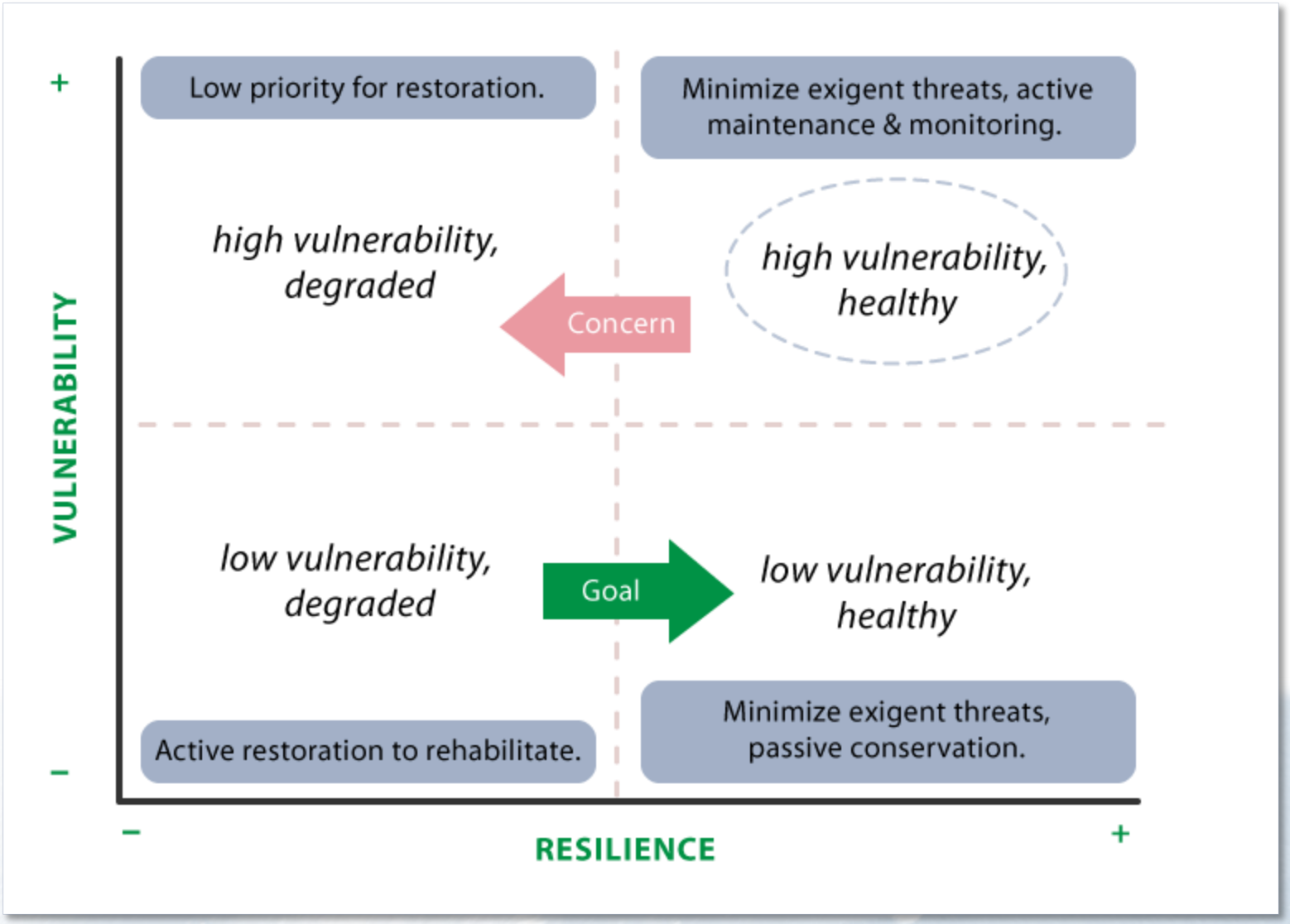
By Terence Chea
Associated Press / June 25, 2008

SAN FRANCISCO - In less than a day, an electrical storm unleashed nearly 8,000 lightning strikes that set more than 800 wildfires across Northern California - a rare example of "dry lightning" that brought little or no rain but plenty of sparks to the state's parched forests and grasslands.

a real framework?



see **meadows.ucdavis.edu**

Resources Legacy Fund, California Energy Commission, SFPUC, Pacific Southwest Research Station, US Forest Service, National Fish & Wildlife Foundation, Department of Water Resources

Sarah Yarnell, Sarah Null, Joe Kiernan, Rene Henery, David Rheinheimer, Jacob Katz, Rob Lusardi, Ryan Peek, Nick Santos, Sabra Purdy, Carson Jeffres, Drew Nichols, Eric Holmes, Gerhard Epke, Rachel Hutchinson, Anna Fryjoff-Hung, Jason Emmons, Jacob Katz and many others.

THANKS!