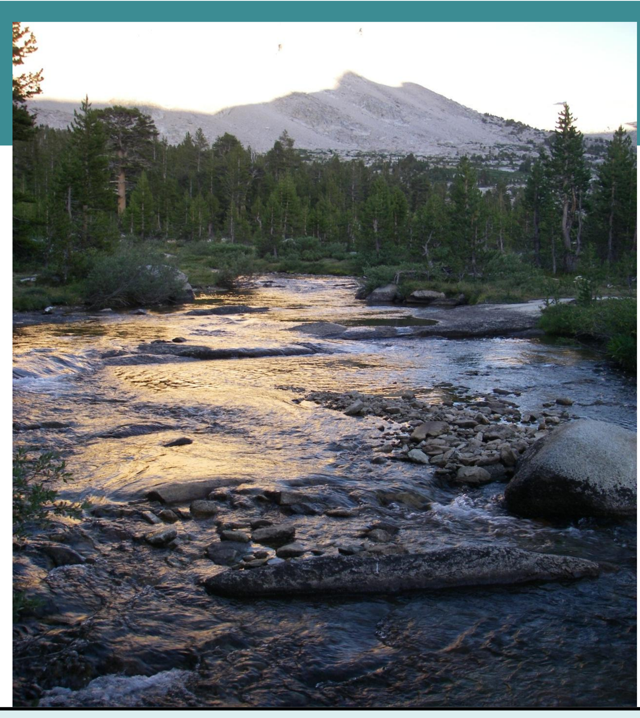

A Monitoring Network for Detecting Climate Change Effects on the Ecology of Sierra Nevada Streams: Benthic Macroinvertebrate Indicators

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ABSTRACT

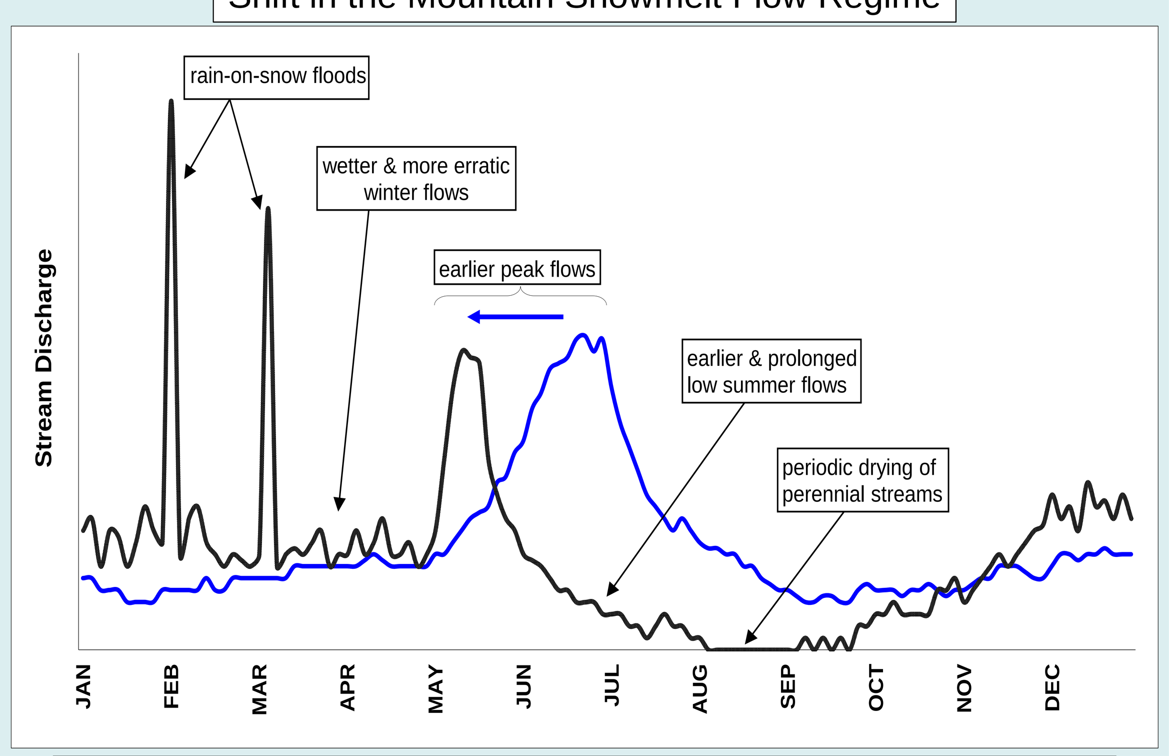
Sierra Nevada hydrographs are predicted to shift towards earlier snowmelt, reduced summer flows, erratic winter flows and floods, and more precipitation as rain than snow. What will be the responses of aquatic ecosystems to these hydrologic changes? Under the influence of climate change, the composition and diversity of aquatic invertebrate communities may be altered as species sensitive to temperature and altered flows are reduced or eliminated. Understanding how aquatic invertebrate indicators are affected by hydro-climatic shifts provides a means of tracking the health of Sierra stream ecosystems in different regions and ecological settings. Using VIC hydrologic model output linked to downscaled climate models we established a network of monitoring sites of varied climate risk and natural vulnerability. Twelve catchments were chosen from across the Sierra, each with a main reach and a nested headwater tributary reach. Habitat and biological surveys were conducted in 2010-2012 during average, and extremely wet and dry years, documented at each site by temperature loggers and stage-height pressure transducers. Results show invertebrate communities fall into distinctive southern and northern groupings. Streams differed by water chemistry indicative of greater groundwater inputs from silicate-rich volcanic aquifers in many northern streams, and low conductivity and alkalinity in snow-melt dominated southern streams. Diversity appeared to be limited by short upstream channels in streams without sustaining groundwater inflows subject to summer drying. High flow and late runoff in 2011 will be contrasted with low flows and early runoff in 2012, presenting an opportunity to contrast the potential influence of climate change and related thermal and hydrologic regime on stream ecology.

BACKGROUND

How do we know what we've lost if we don't know what's there to start with?

Legacy studies such as those of Joseph Grinnell have proven invaluable to understanding how the distribution and abundance of life in the Sierra has changed over long periods of time and can be related to climate change. In this spirit, these annual re-surveys of streams across a transect gradient of climate risk and natural vulnerability over a wide geographic extent of the Sierra are intended to provide both legacy data for the future and an ecological assessment of the influence of interannual variations in climate and hydrology that can be used to predict future changes in the integrity of critical headwater stream ecosystems in the Sierra. We have a great number of model forecasts that can be used to predict possible futures but know very little about what is actually happening to biological communities as those futures develop. This is a critical information gap.

A Changing Hydrograph:
Shift in the Mountain Snowmelt Flow Regime

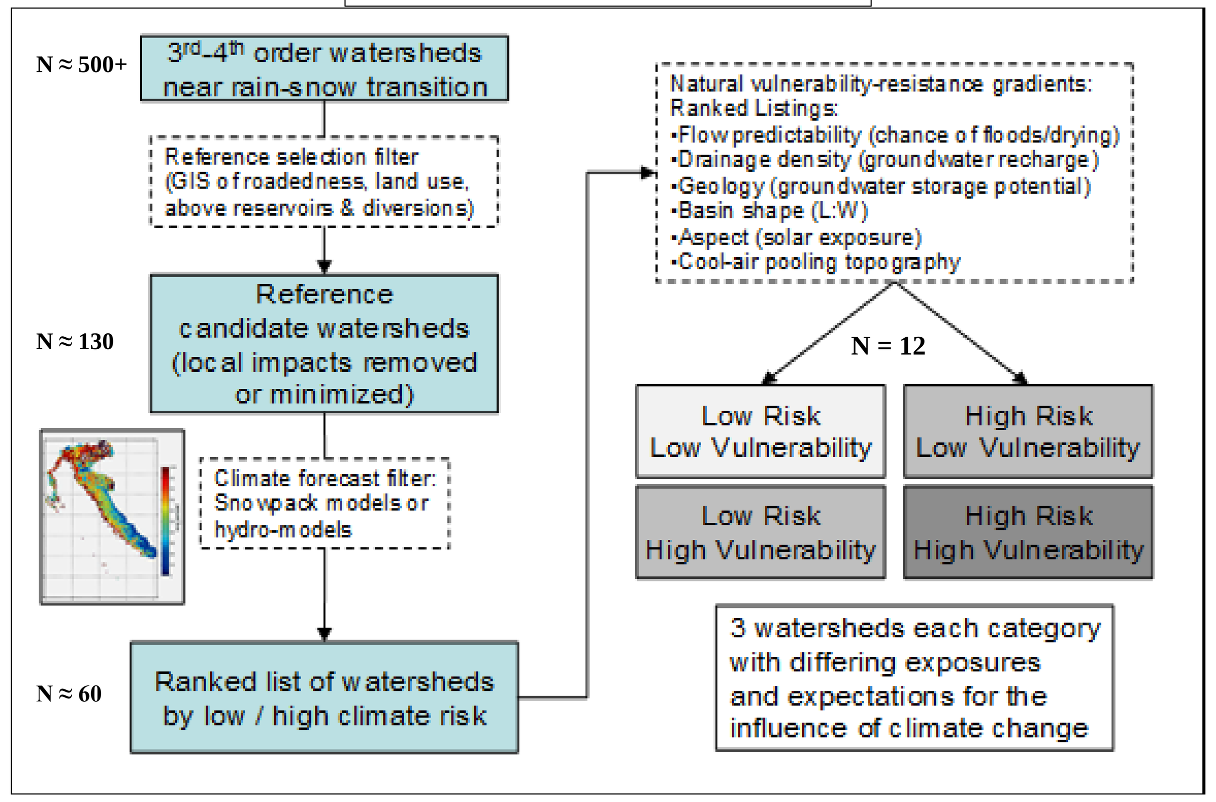


GOAL & OBJECTIVES

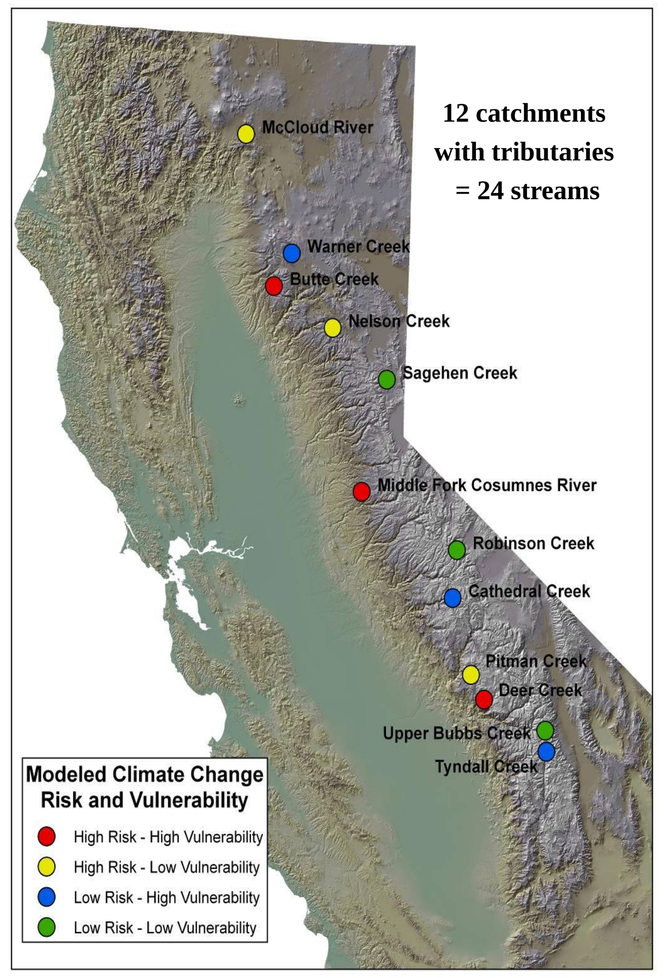
The goal of this project is to document how mountain stream ecosystems respond to altered flow regimes, changing physicochemical conditions and warming temperatures, and set a baseline for contrast to an uncertain future. This would be enabled through the continuation of data collection from an established stream network in the Sierra Nevada of California. This network integrates physical and biological monitoring in order to determine how hydroclimatic shifts are linked to ecosystem structure and function through changes in the flow and temperature regime of vulnerable headwater streams where sustaining water resources originate.

For the purposes of management, this network will show status and trend of resource integrity and an early-warning system for detecting ecological impacts of climate change. Observed responses will provide guidance for prioritizing the settings where vulnerable watersheds can most benefit from climate adaptation actions. The protocols give tools for assessing ecological resilience.

SITE SELECTION



MAP OF NETWORK AND RISK-RESISTANCE STREAM TYPES



Selections based on summed

•**Climate-Risk factors** from VIC model:
•Reduction in April 1 SWE
•decrease in total spring run-off
•decrease in total spring base-flow
- upper quartile of change =high risk
- lower quartile of change =low risk

•**and Natural Resistance**:
- upper / lower quartiles for
•North-facing = low vulnerability
•South-facing = high vulnerability (earlier melt, warmer)
•Plus, resistance conferred by deep groundwater-recharge potential from basalt / andesite geology cover, and/or area of upstream meadows

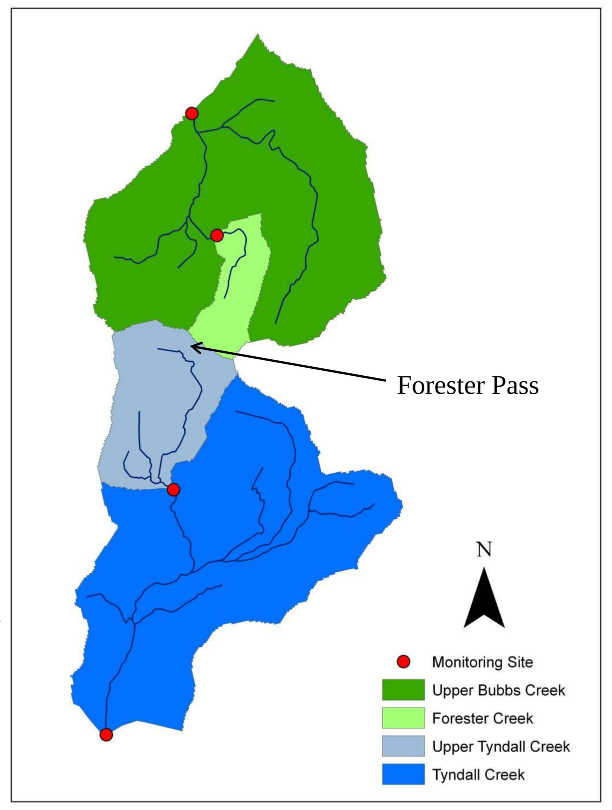
Although quartiles used to create categories, risk-resistance is along a gradient and each site will be characterized for individual features

17 streams in 7 National Forests
7 streams in 3 National Parks

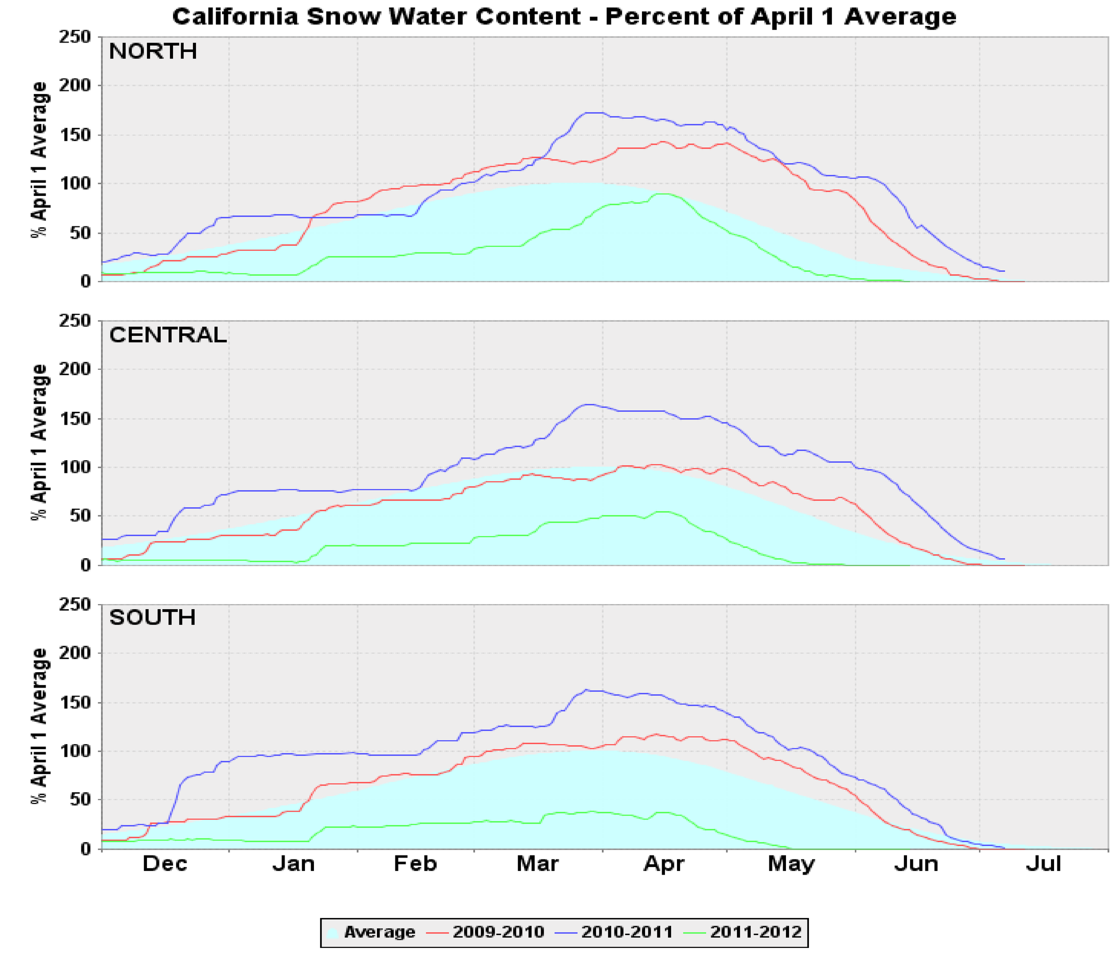
FIELD METHODS

- State-SWAMP standard protocols
- Annual surveys within 1-2 week time frame
- Physical Habitat and Water Chemistry
  - Channel width, depth, substrata, current, bank cover/stability, slope, riparian cover
  - pH, conductance, alkalinity, silicate
- Data Loggers for Stage-Height (flow) and Temperature (water & air)
- Biological Community:
  - Benthic macroinvertebrates
  - Algae resources (benthic Chl a & taxa)
  - Organic matter resources (FPOM-CPOM)

Example catchments in SEKI:
Headwaters of Bubbs and Tyndall Creek
Third-order catchments with 1st-2nd order tributaries



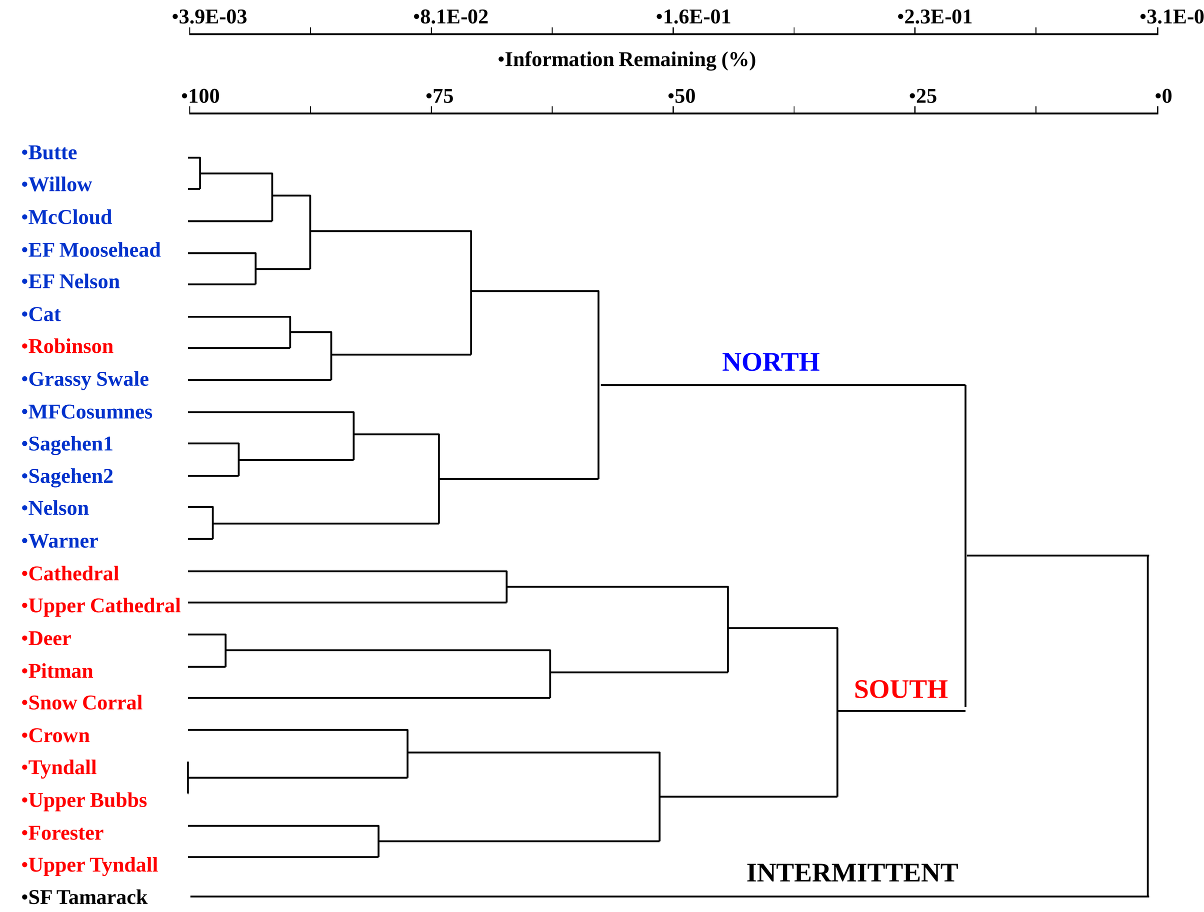
3 Years Contrasted Cover Wide Hydrologic Range:
2010 average to just above average
2011 flows at >150% of average
2012 flows at <50% of average
2013 ?? (now at ~50-60%)



RESULTS (preliminary)

- Stream benthic invertebrate communities group into North of Yosemite and Yosemite South except for an Intermittent tributary separating from all (distinctive low diversity there)
- Greater diversity in northern streams than southern
- Silica provides an indicator of groundwater inputs dominant in north and sustaining flows; snowmelt in south vulnerable to drying

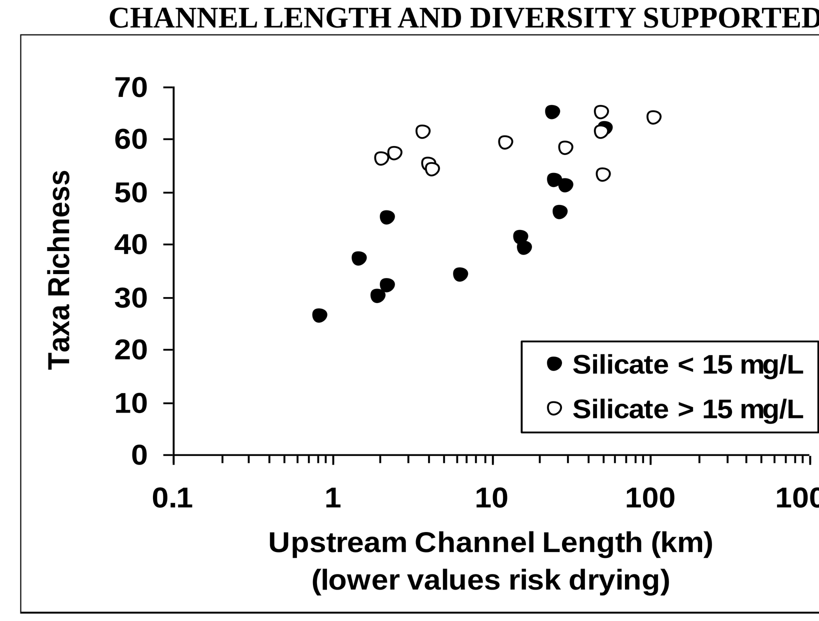
Cluster diagram of biological similarity macroinvertebrate communities



Community Similarity Tree

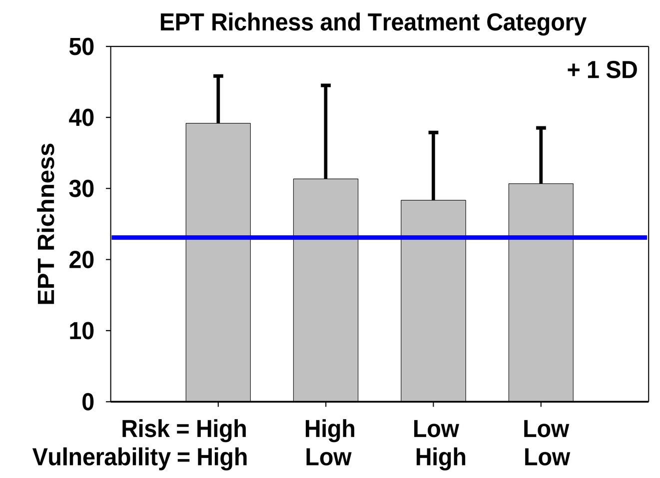
RESULTS (continued)

CHANNEL LENGTH AND DIVERSITY SUPPORTED



- Headwater streams with short upstream length support fewest species. Drying is a risk, but what protects some headwaters and not others?
- Basalt groundwater inflows (higher silicate) sustain baseflow and resist drying, while low silicate snowmelt risk drying but can support more richness with increased channel length (=perennial flow)
- Low pH: high flows of 2011 reduced conductivity and pH decreased in 22 of 24 streams, especially in snowmelt streams where pH is poorly buffered. Lower pH streams support less diversity.
  - How long does reduced pH last and are the biotic effects lasting?

Baseline for comparisons is equal across risk-vulnerability groups:
•Streams have diverse taxa with traits for responding to hydroclimate change:
•79% of taxa are adapted for cold water (just 50% in intermittent stream)
•89% are either semi- or uni-voltine (have ≥1 yr life cycles) [long-lived]
•67% prefer riffle habitat [require higher flows]



EPT= sensitive mayflies, stoneflies and caddisflies

•Statistical equivalence of treatment groups:
•Group with most risk and vulnerability also has the most scope for response
•All groups exceed the Sierra reference level for maximum EPT = 23 taxa [E. Sierra IBI]

CONCLUSIONS

- Network is up and running with 3 years of data and the biological indicators provide a strong foundation for detecting change (biodiversity & trait sensitivities to hydroclimate change)
- North – South stream groups show distinct differences in snowmelt vs groundwater influence on hydrology (and related water chemistry), and in associated biological communities
- Biological richness of northern streams is ecological "insurance", but this also means "more to lose" in a region with the most severe climate risk predicted
- Though having less biodiversity, southern streams harbor some vulnerable taxa with restricted distributions
- Intermittent drying poses a clear risk to sustaining biodiversity, esp. in snowmelt-dominated streams, but groundwater systems appear to be more buffered (confirming a predicted climate risk-resistance)

POSSIBLE COLLABORATIONS:

- INPUT: Refining the Risks (need hydrological change indicators; see list)
- INPUT: Refining Ecological Vulnerability (need environmental features of streams and biological traits of species; see list)
- OUTPUT: Biological structure and function responses of headwater stream communities and ecosystems to hydroclimate variation (planning)
- OUTPUT: Detailed data logs of flow and temperature from headwater streams up and down the Sierra (for validating/calibrating models?)

ALAS, NO FUNDING AT PRESENT TO CONTINUE………