OBSERVATIONS OF CHANGING HABITAT AND BENTHIC INVERTEBRATE COMMUNITIES FROM THE SIERRA NEVADA SENTINEL STREAM NETWORK DURING EXTENDED DROUGHT

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Changing mountain stream hydrograph: developing and future pattern with warming

- **Hydroclimatic Drivers of Stress**
  - Earlier & Prolonged Low Summer Flows
  - Prolonged & Earlier Snowmelt
  - Rain-on-snow floods
  - Wetter & More Erratic Winter Flows
  - Periodic Drying of Perennial Streams
  - Warming Waters
3rd-order size watersheds of Sierra Nevada

Reference selection filter using GIS: minimum roadedness or land use, no reservoirs, all above 1000 m

Reference 3rd-order watersheds (local impacts minimal to none)

Climate forecast filter: VIC-hydrological model prediction of snowpack and stream flow

Ranked list of watersheds by quartiles of lowest and highest climate risk

Natural Resistance Filters: ranked, combined
- Northness Aspect (snowmelt timing, temp, vegetation)
- Groundwater contributions (geology/springs)
- Riparian cover and meadow area (water storage)

Field reconnaissance of best candidate sites

Low Risk

High Risk

Low Resistance

High Resistance

3 watersheds each category with differing exposures and expectations for the influence of climate change

► Designed as a natural experiment testing hypotheses of risk & resistance
12 catchments
24 streams total
(tributary site nested in each catchment)

Sentinel Monitoring Network for Sierra Nevada: from 2010-2015 so far

> 1200-3600 meter elevation range

> Each site instrumented with flow transducers & temperature probes recording at 2 hr intervals

> Standard measures of stream habitat, invertebrates, algae, organic matter, riparian cover

> Complete data 2010-2012 and partial 2013-2015
SNOWPACK PROFILES 2010-2015

- 2010 avg to above avg
- 2011 wet year 150%+ above avg

2012-13-14-15 Intensifying Drought

Southern Sierra especially dry.....
So, What did we observe?

Sequence of drying during drought years……

POOL

RIFFLE
Channel area contracts and Increasing ratio of pools to riffles
Diminishing to small isolated riffles...
At an extreme to intermittent pools
Pool areas increase at the expense of riffles during drought, and some sections go dry...

Seasonal changes in riffle/pool can occur but these measures taken at the same time each year
Drought years with temperatures about 2-3 °C warmer than average or high flow yrs. Temperature probes show some sites exceed 20°C during summer for extended periods (lethal limits for some species).
Although there is a general warming trend, it is in the larger catchment streams. The smaller tributary streams show an unanticipated cooling as the drought proceeds. Shows prominence of groundwater inflow in these small streams with reduced snowmelt.
Change in distribution of resources as drought proceeds:

- Algae % cover
- Organic matter % cover
Northern streams have significant groundwater inflows (volcanic terrain) and have higher species diversity but more to lose in the face of the greatest predicted loss of snowpack.

Southern streams are snowmelt-dominated (granite terrain) and so are more at-risk to drying and have less species diversity.

Strong N-S Regionalization of Stream BMI Communities

All streams first 3 yrs 2010-2012
BMI Density Increase During Drought
In full data set 2010-2012 and Stream subset 2010-2015

Contraction alone does not account for increase, some also due to recruitment and population growth
Community shift: N vs S and from Avg to Wet to Dry

NMS.1 scores: S vs N over 2010-12

MRPP 2010-2011 ns
2010 or 11 vs 2012 p<0.01
Community differs: $1^\circ$ vs $3^\circ$ and from \textit{Avg = Wet to Extended Drought}.

Highly significant by order and drought year.
Diversity stable into first yr of drought, but loss with extended drought related to vulnerability at subset of 4 stream stations

- Preliminary indication that high vulnerability stream types lose diversity in face of drought to a greater extent than low vulnerability
- Full data set yet incomplete, but will allow evaluation of response according to risk, traits, trophic structure
Summary: Sentinel network to date is showing significant signs of drought impact:

- Loss of habitat, esp. extent of riffles, some drying
- Elevated temperatures in 3rd order catchments and cooling with groundwater prominence in tributaries
- Algae cover increases & organic matter accumulates
- BMI community composition shows strong regionalization between north and south Sierra
- BMI density increases (concentration & recruitment)
- BMI community structure is altered significantly with first yr of drought, and with increasing drought severity
- BMI diversity is lost after prolonged drought but not in early drought in either north or south
- Initial data suggests loss of diversity appears to be related to stream vulnerability (southern aspect, lesser amounts of groundwater, meadow, or riparian cover)
What's to come? Will streams recover in 2016?

Nearer-average, but lagging in south and snow pack melting fast.....

Uncertain prospects......