

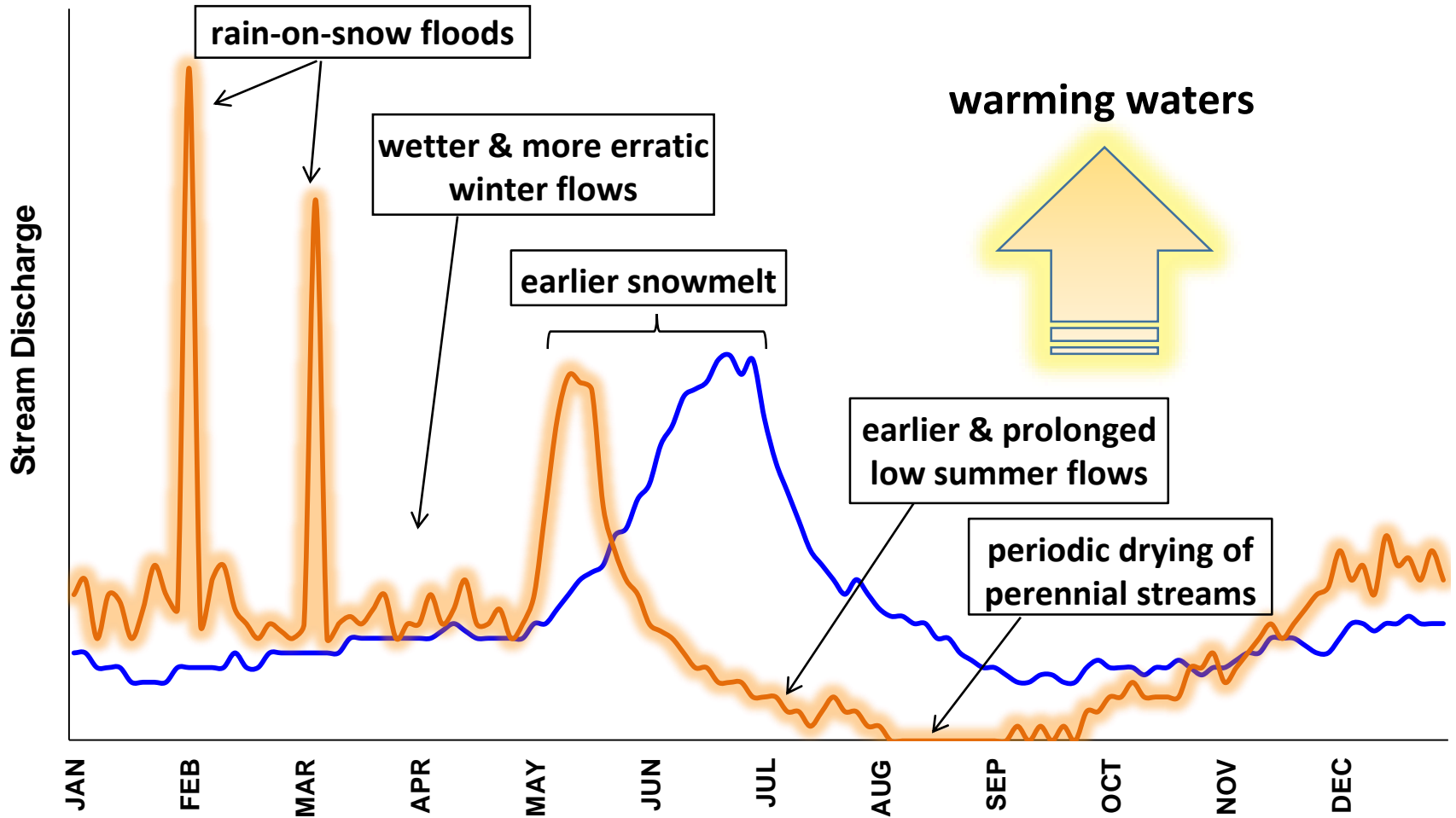


**OBSERVATIONS OF CHANGING HABITAT
AND BENTHIC INVERTEBRATE COMMUNITIES
FROM THE SIERRA NEVADA SENTINEL STREAM NETWORK
DURING EXTENDED DROUGHT**

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Changing mountain stream hydrograph: developing and future pattern with warming

Hydroclimatic Drivers of Stress

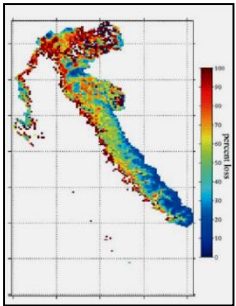


**D
E
S
I
G
N**

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 Resistance**

**High Risk
High Resistance**

**Low Risk
Low Resistance**

**High Risk
Low 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

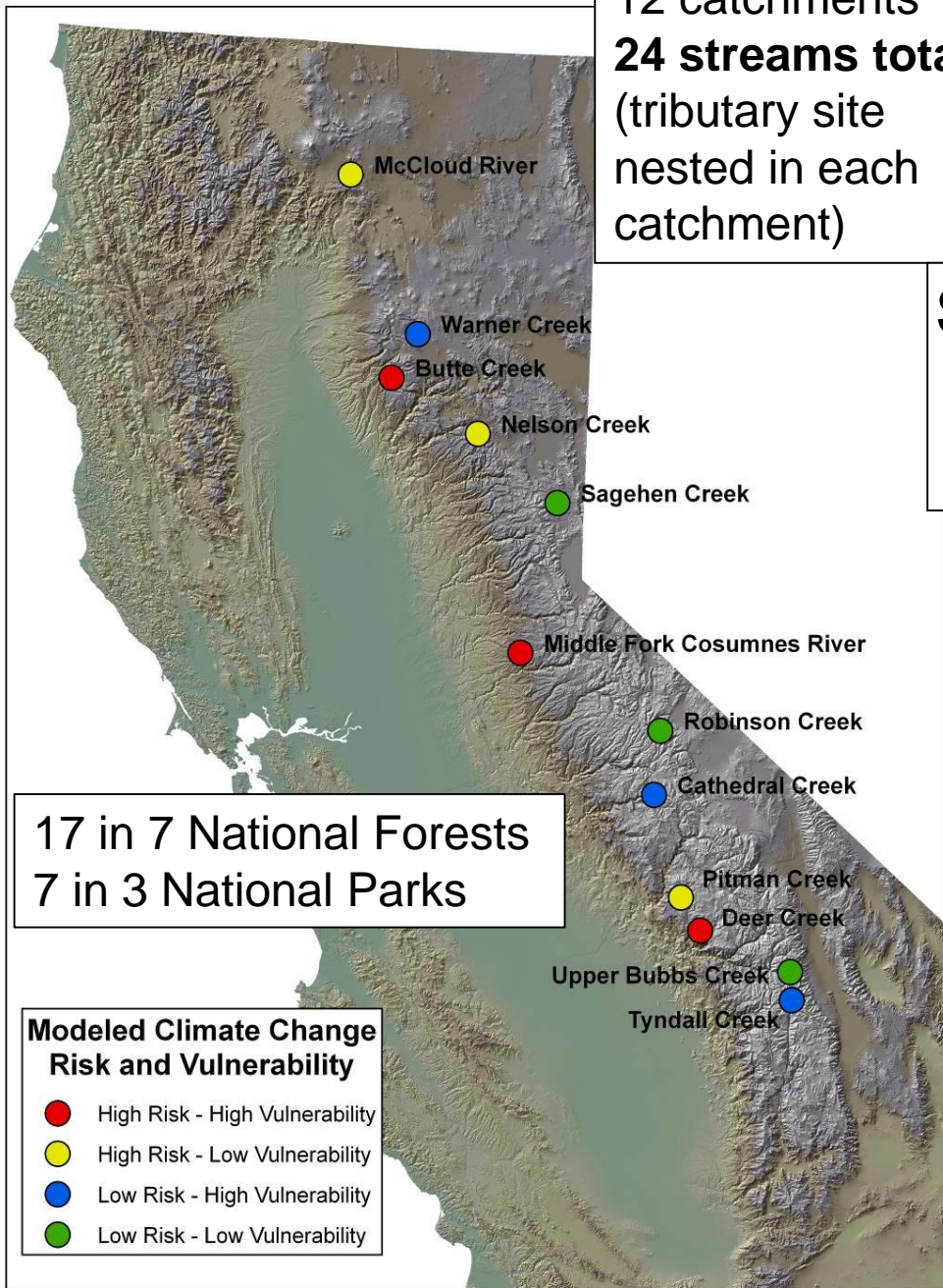
>Standard measures of stream
habitat, invertebrates, algae,
organic matter, riparian cover

>Complete data 2010-2012
and partial 2013-2015

17 in 7 National Forests
7 in 3 National Parks

Modeled Climate Change Risk and Vulnerability

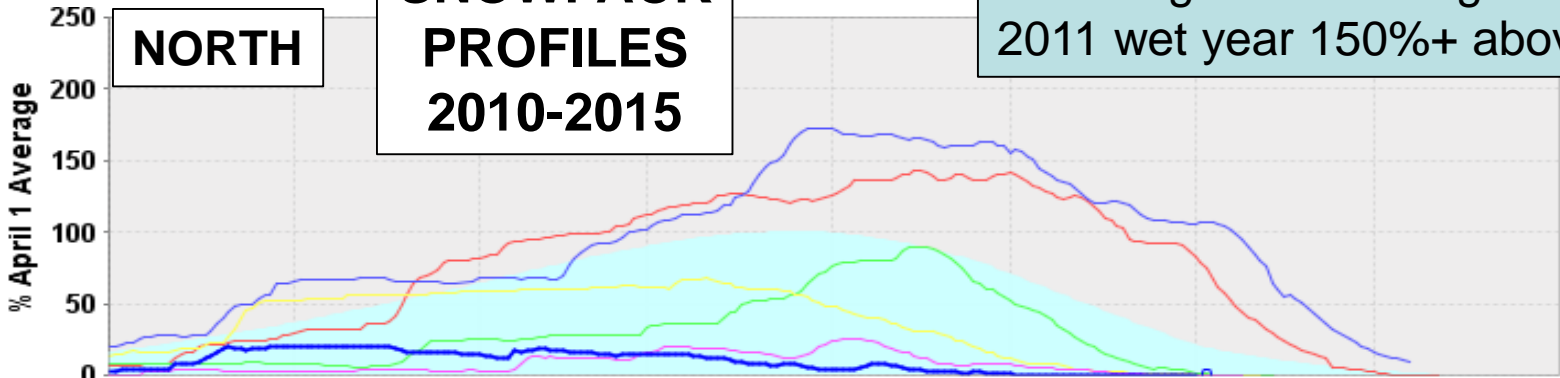
- High Risk - High Vulnerability
- High Risk - Low Vulnerability
- Low Risk - High Vulnerability
- Low Risk - Low Vulnerability



SNOWPACK PROFILES 2010-2015

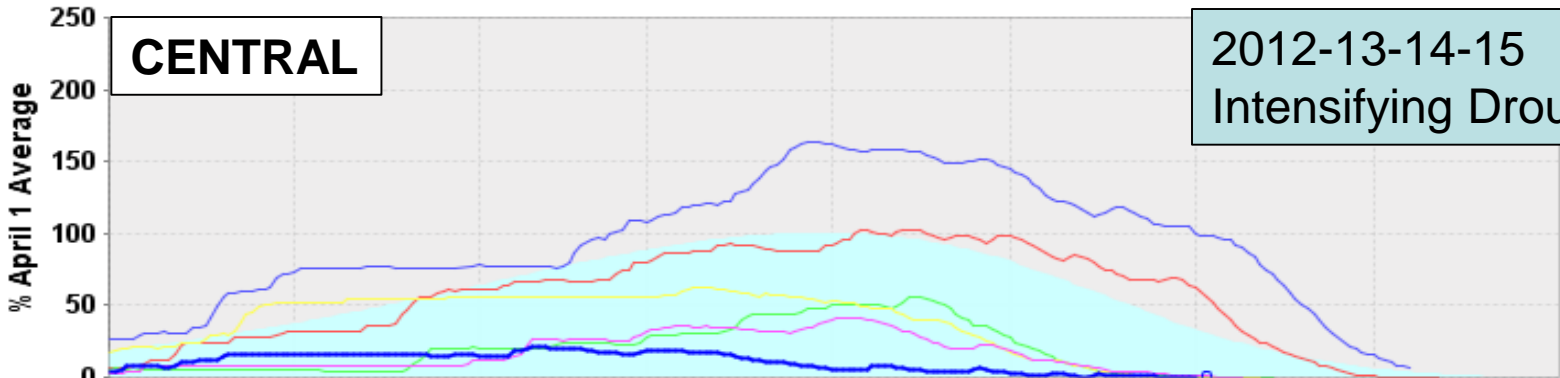
2010 avg to above avg
2011 wet year 150%+ above avg

NORTH



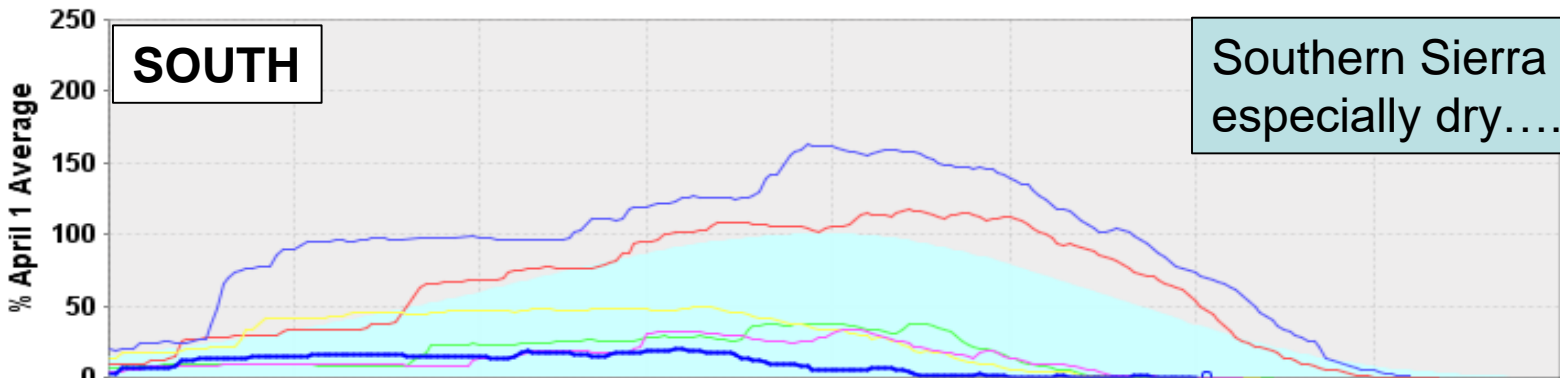
CENTRAL

2012-13-14-15
Intensifying Drought



SOUTH

Southern Sierra especially dry.....



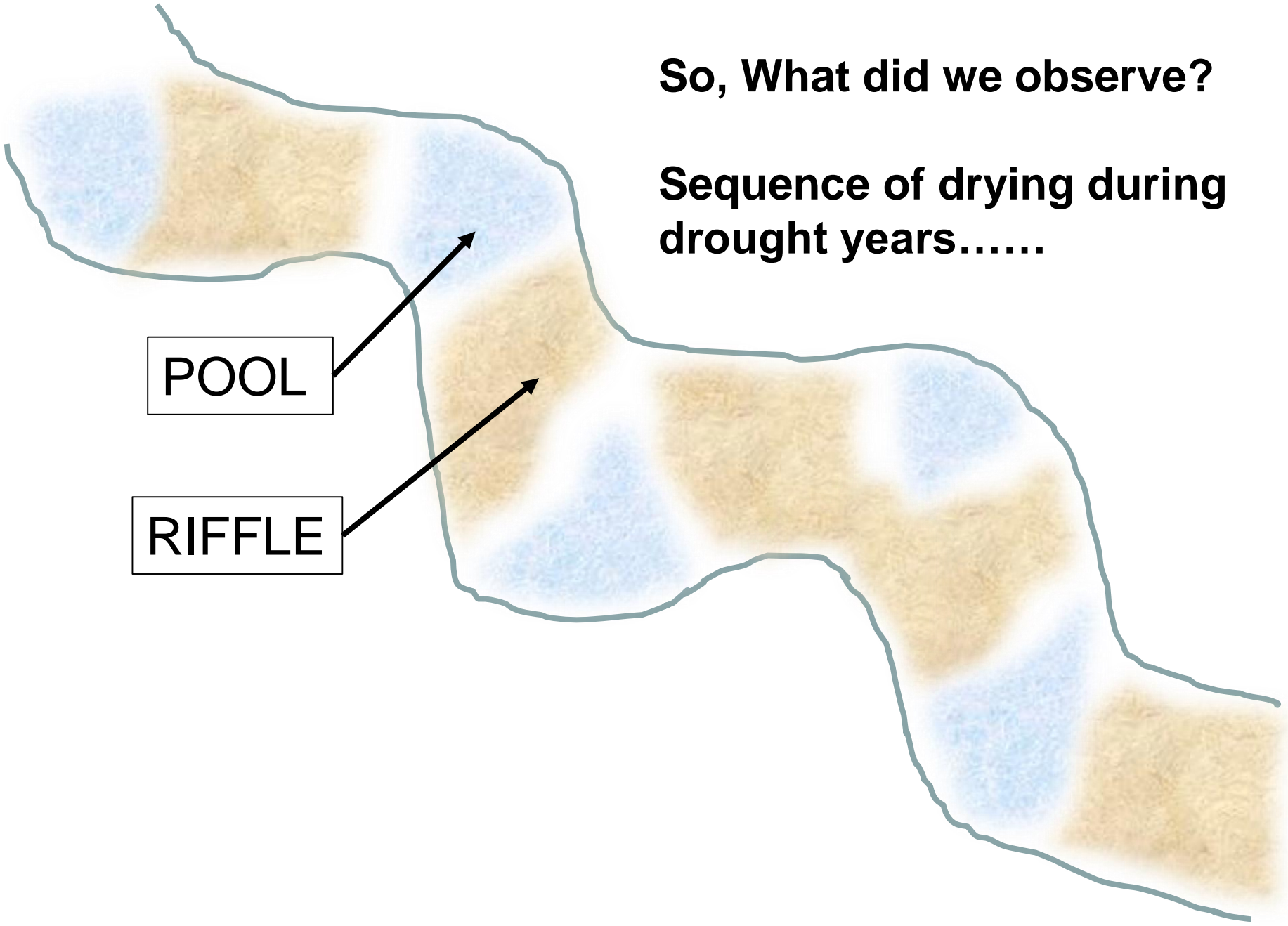
Average — 2009-2010 — 2010-2011 — 2011-2012 — 2012-2013 — 2013-2014 — 2014-2015

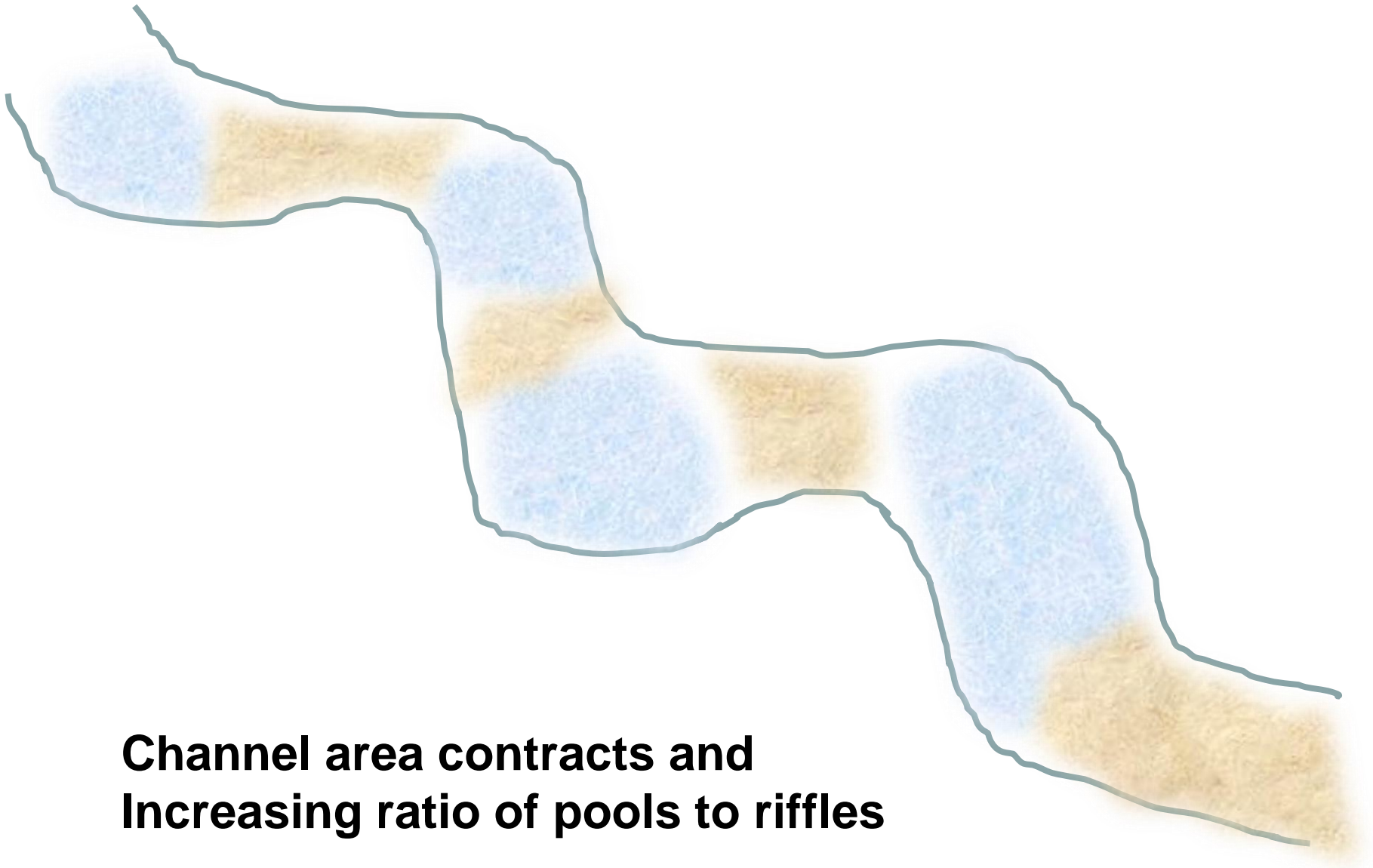
So, What did we observe?

Sequence of drying during drought years.....

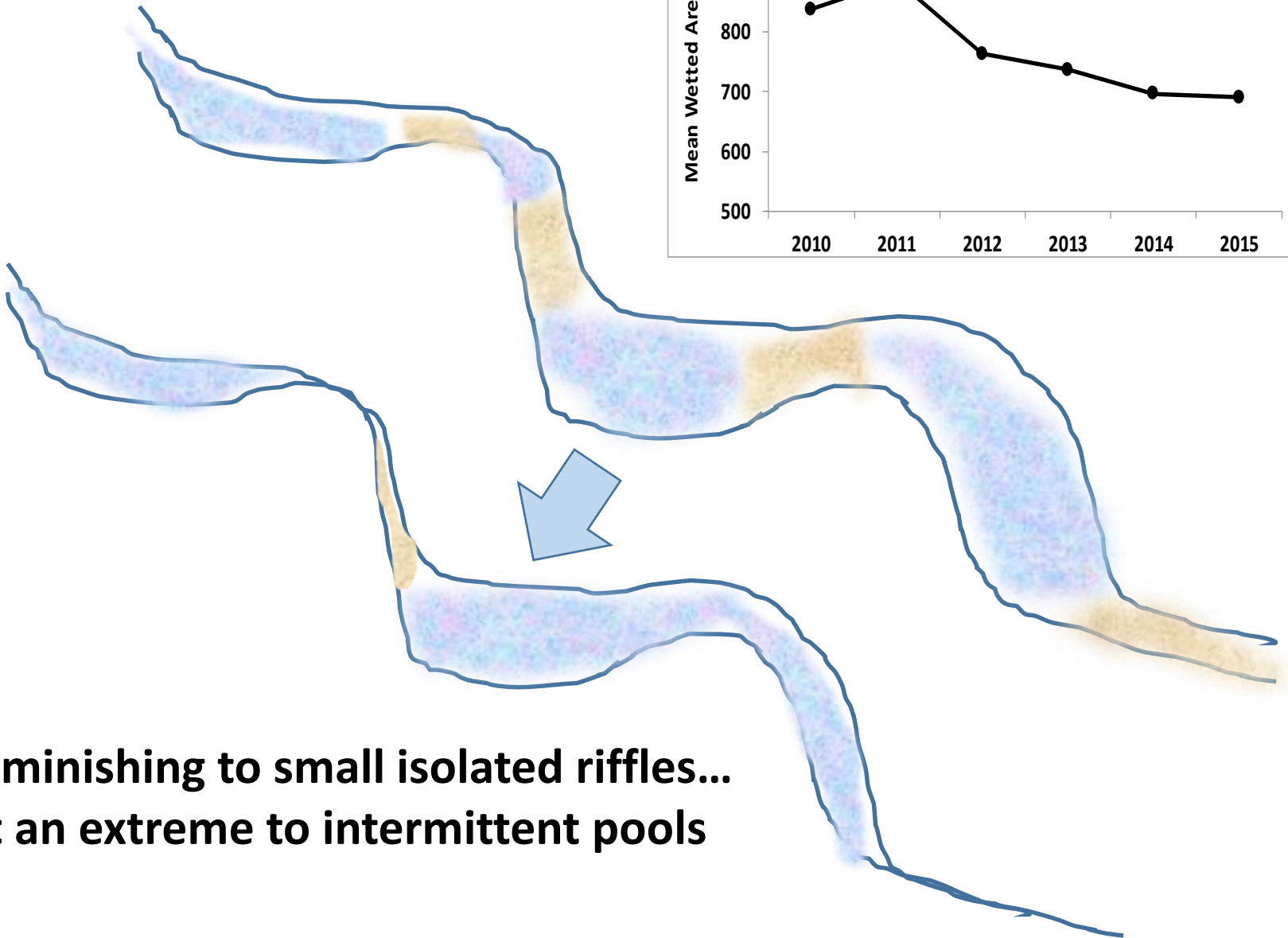
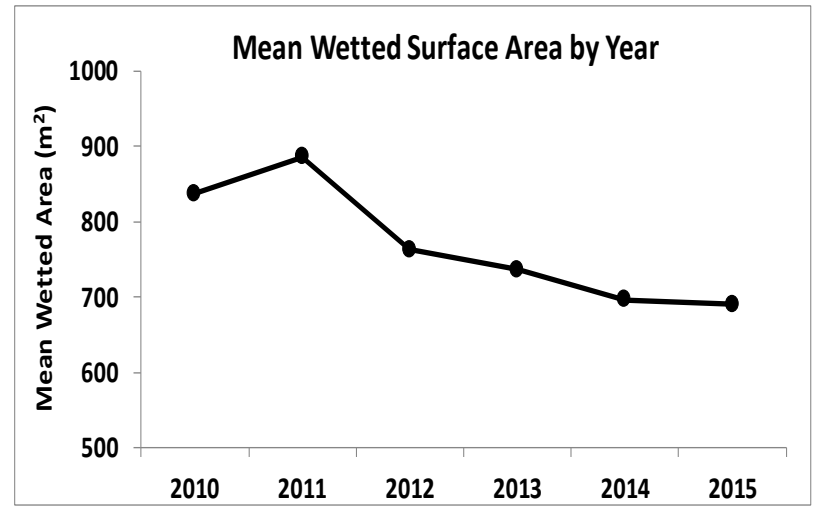
POOL

RIFFLE



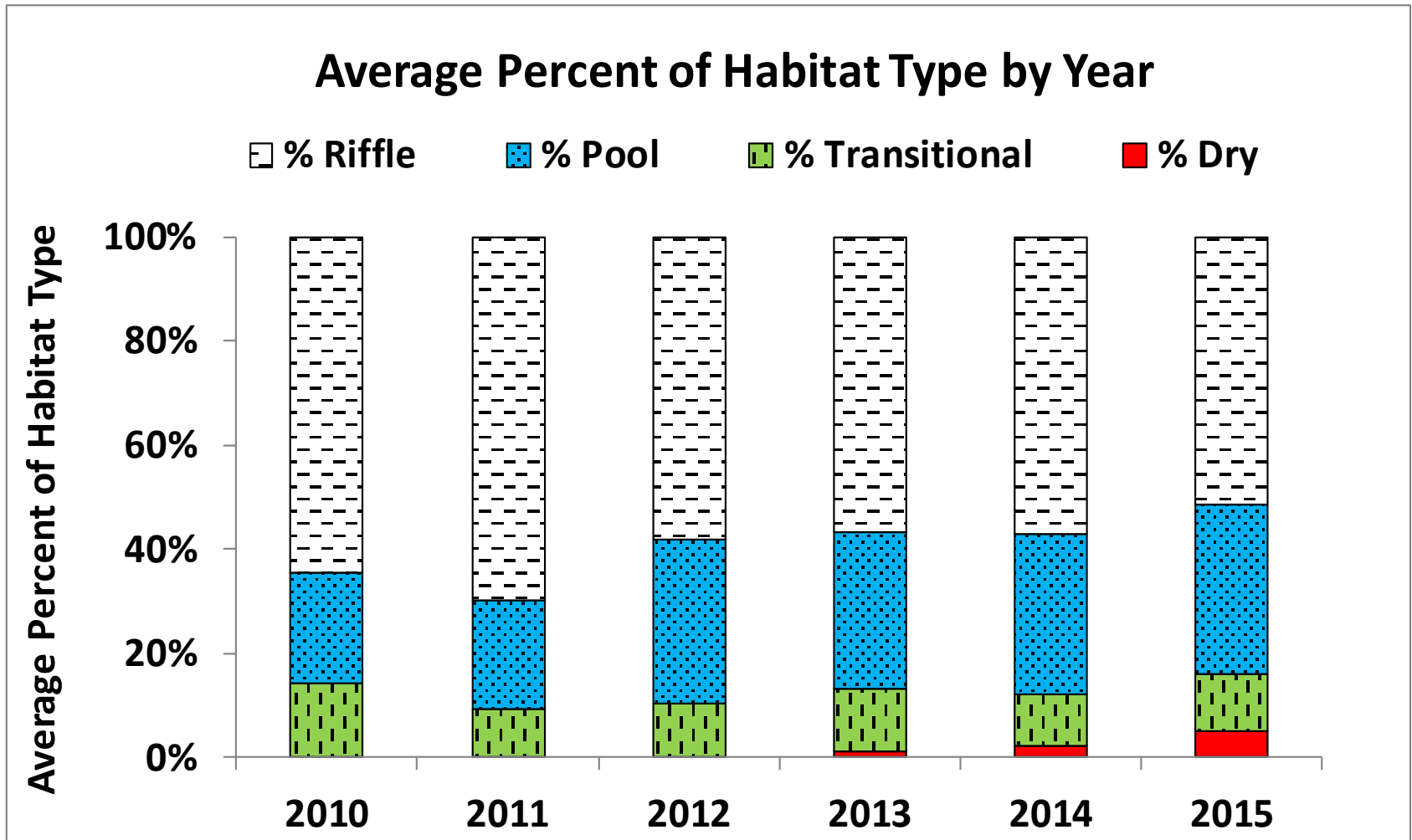


**Channel area contracts and
Increasing ratio of pools to riffles**



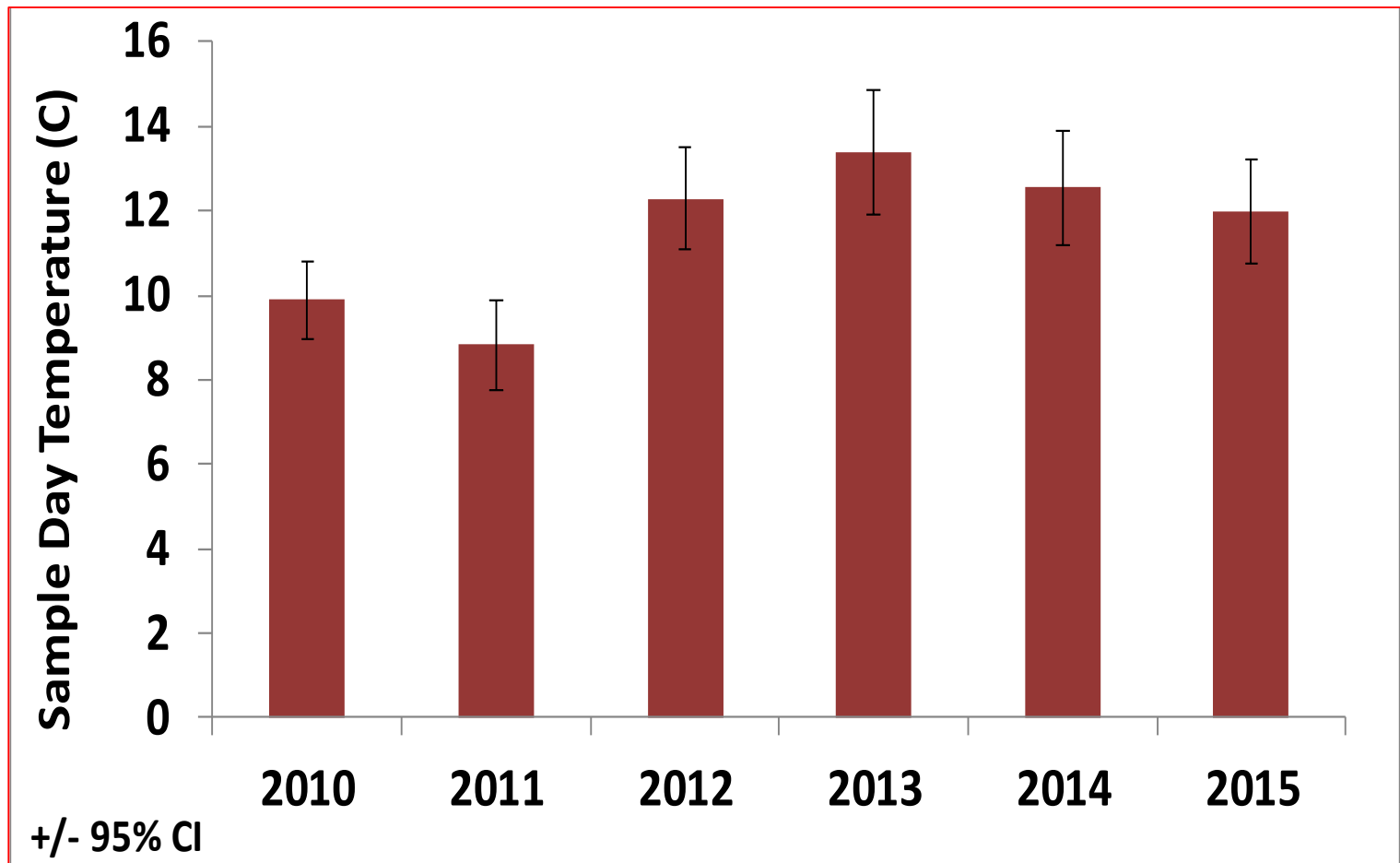
**Diminishing to small isolated riffles...
At an extreme to intermittent pools**

Pool areas increase at the expense of riffles during drought, and some sections go dry...

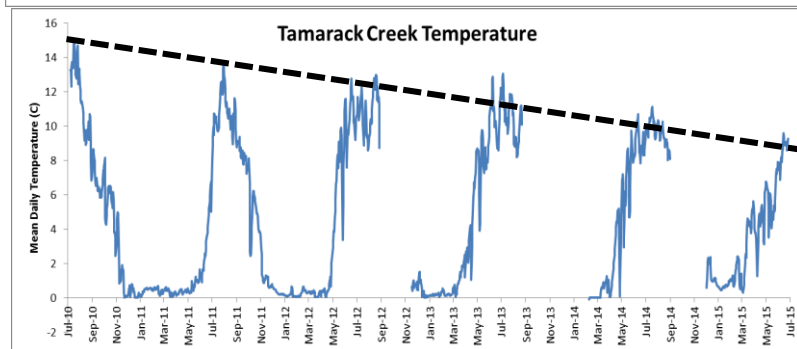
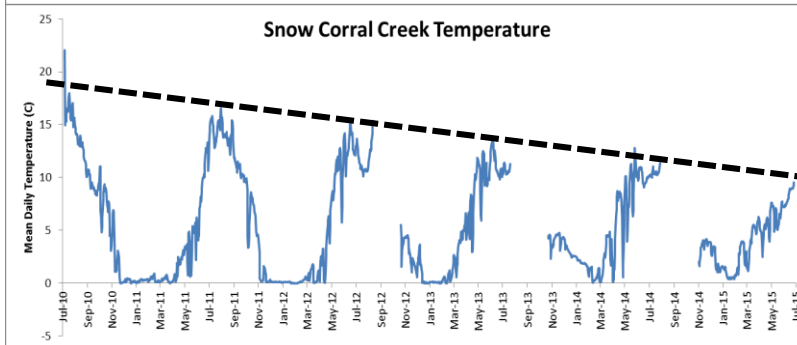
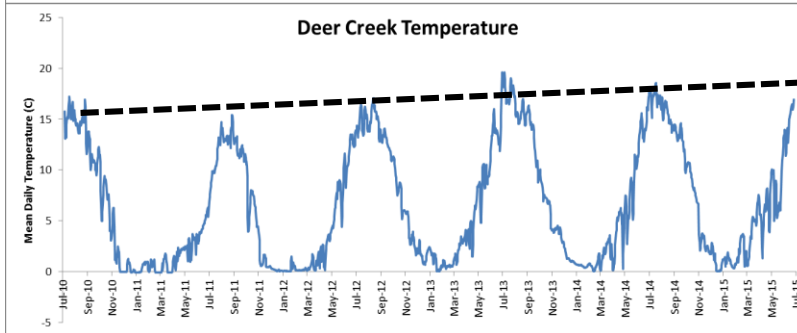
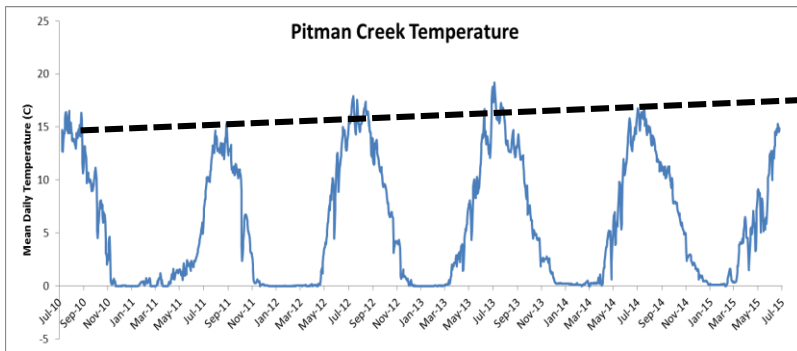


Seasonal changes in riffle/pool can occur but these measures taken at the same time each year

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).



Mean daily temps of thermographs In 4 streams: 2010-2015

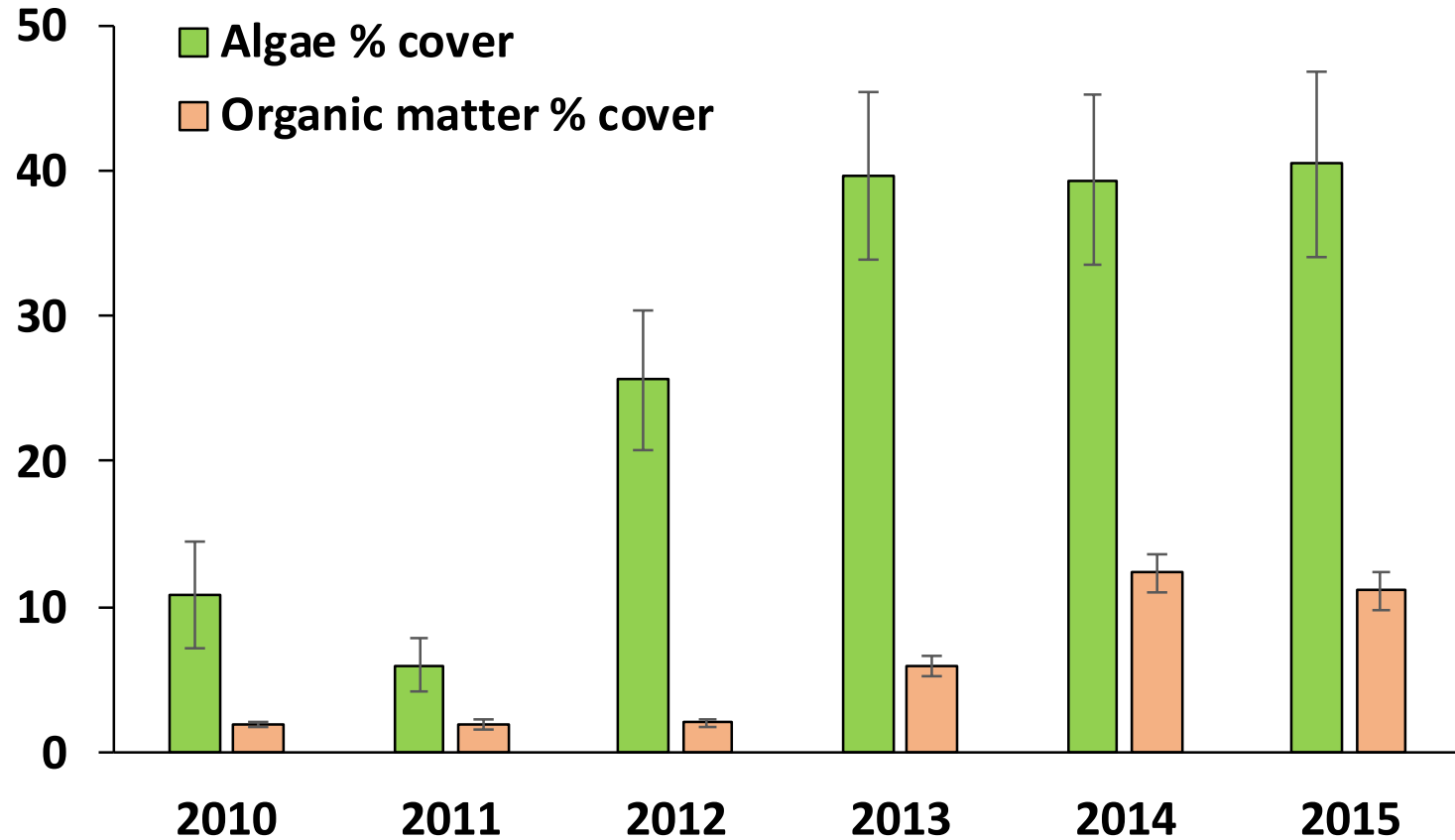


< Although there is a general warming trend, it is in the **larger catchment streams**.

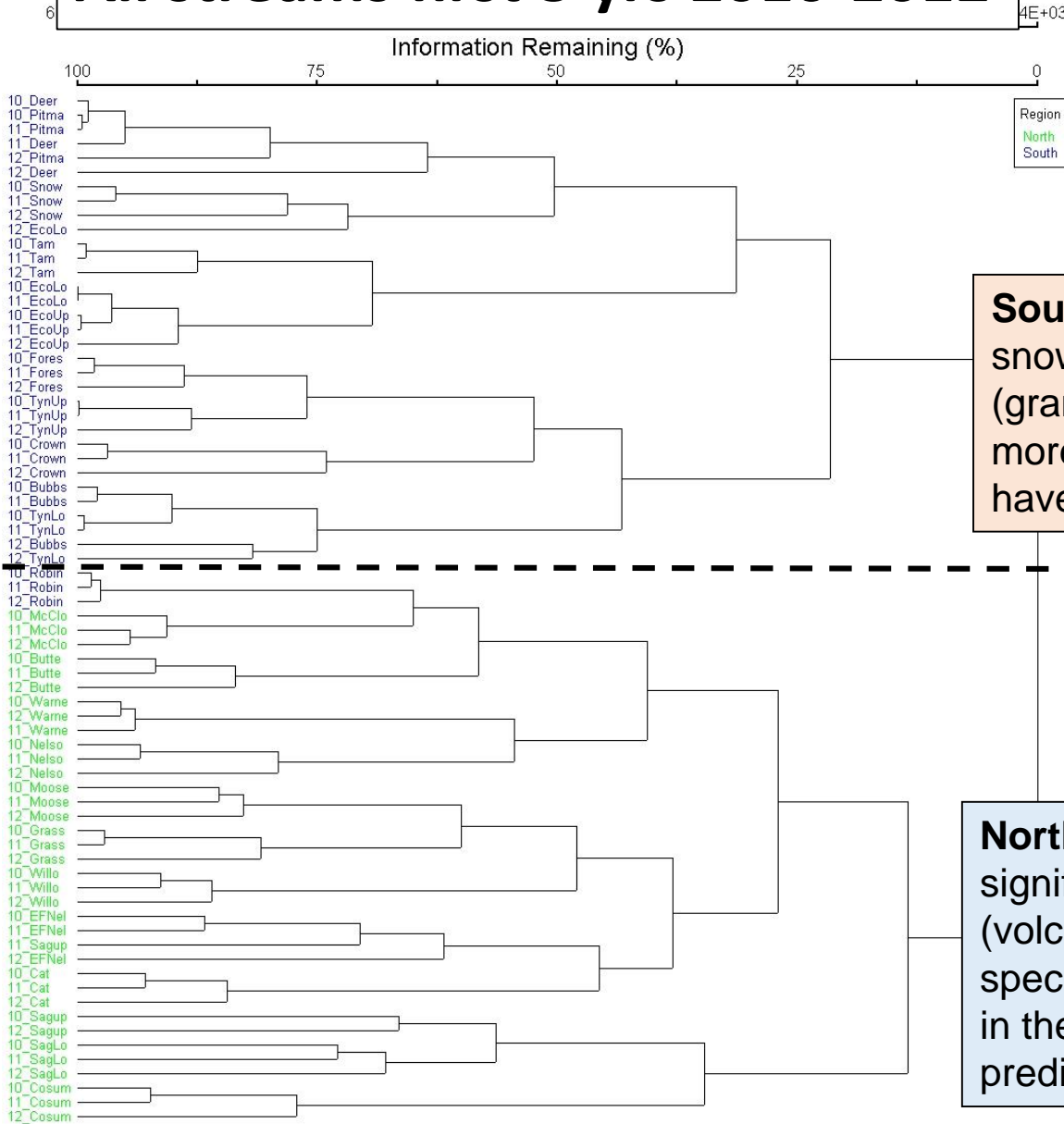
< The **smaller tributary streams** show an unanticipated cooling as the drought proceeds.

Shows **prominence of groundwater inflow** in these small streams with reduced snowmelt.

Change in distribution of resources as drought proceeds:



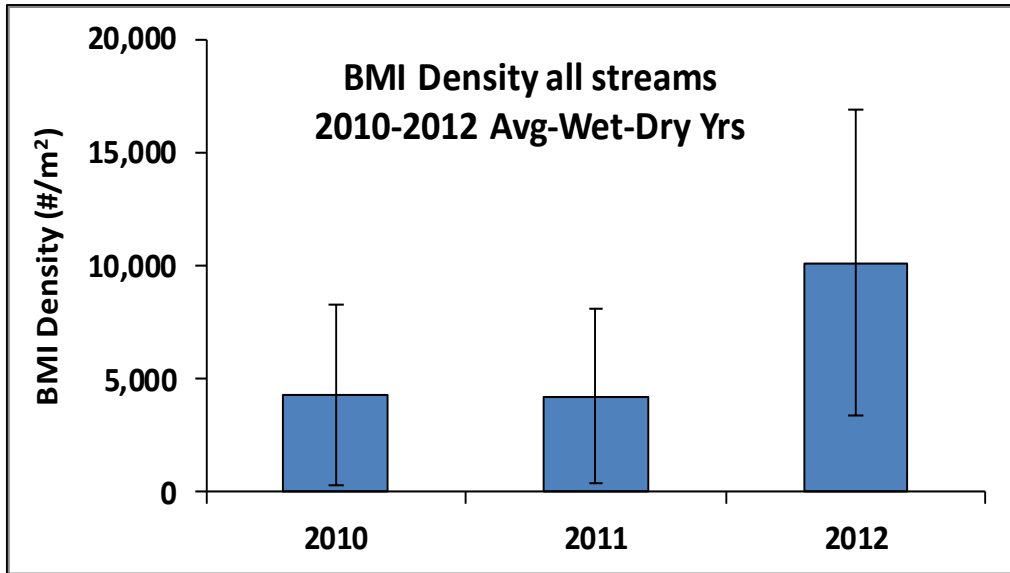
All streams first 3 yrs 2010-2012



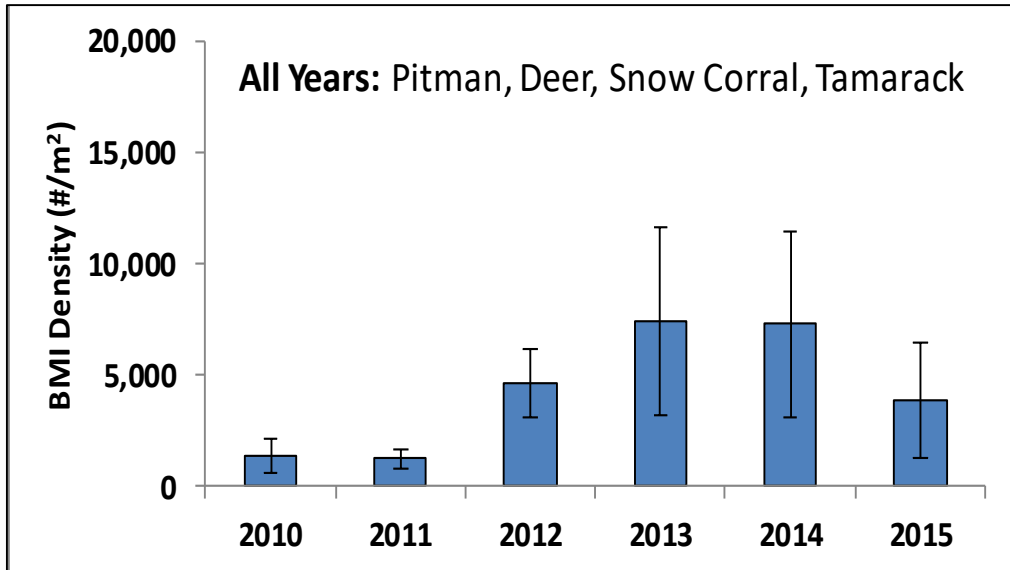
**Strong N-S
Regionalization
of Stream BMI
Communities**

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

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

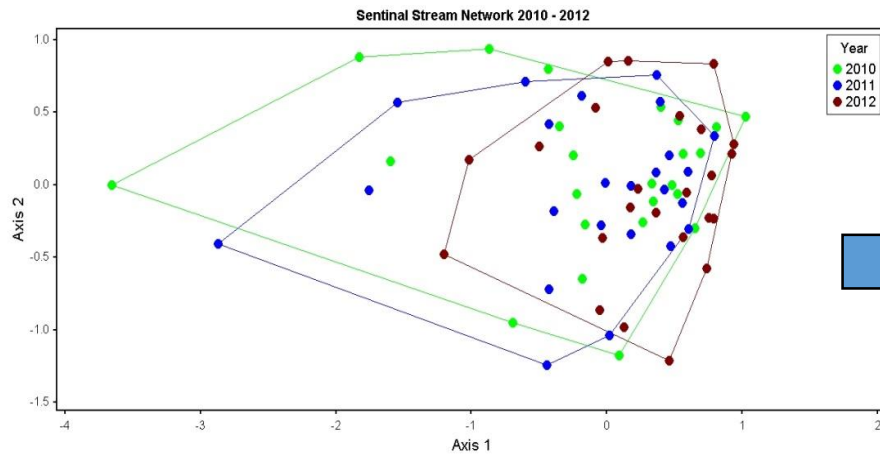
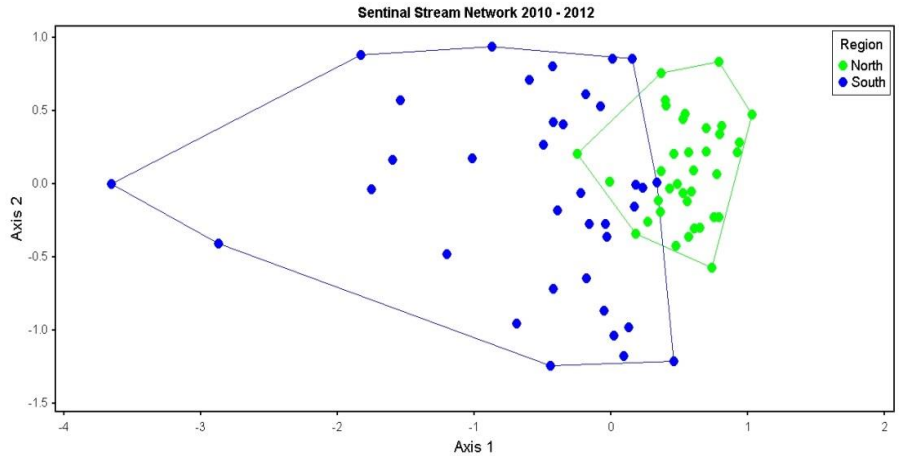


**BMI Density Increase
During Drought
In full data set 2010-2012
and
Stream subset 2010-2015**

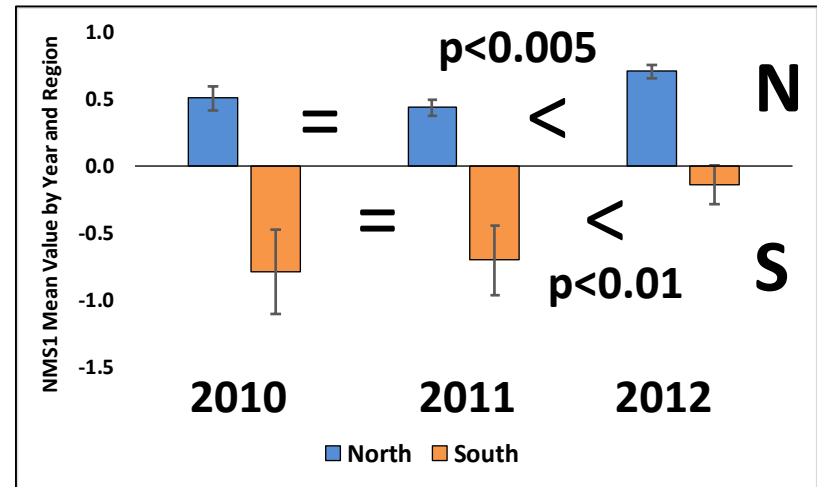


**Contraction alone does not
account for increase, some
also due to recruitment
and population growth**

Community shift: N vs S and from Avg to Wet to Dry



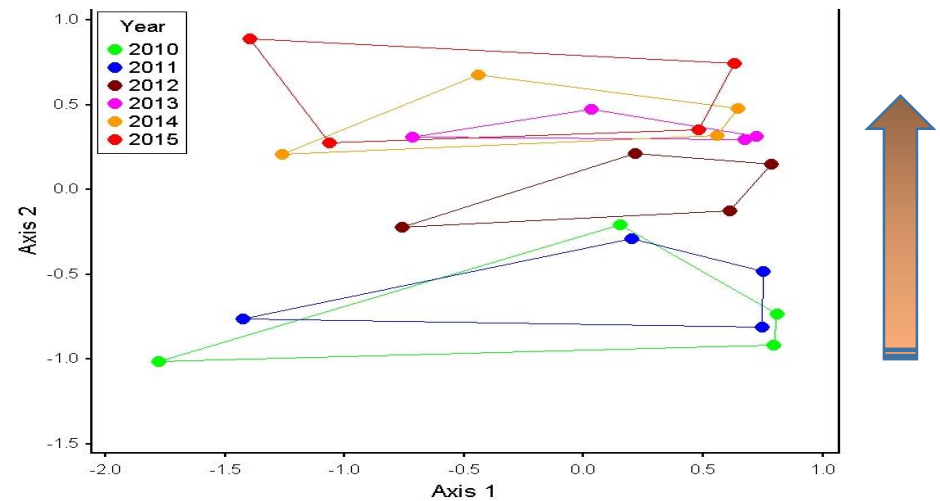
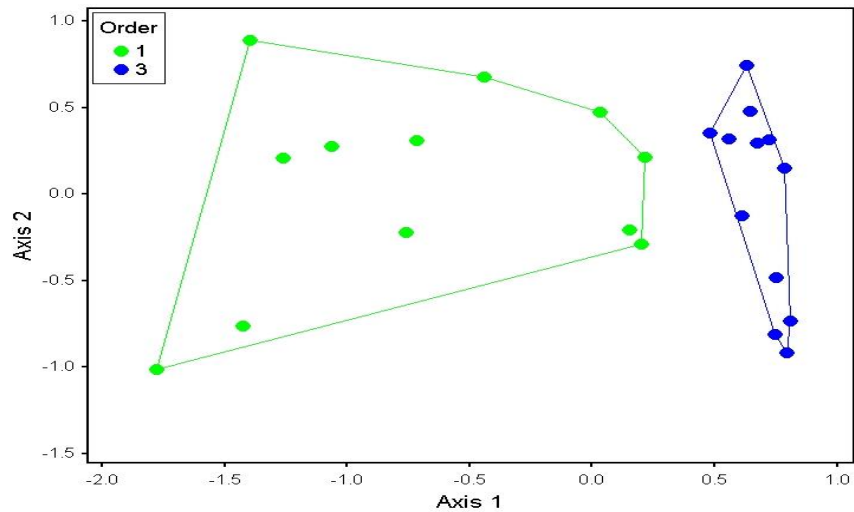
NMS.1 scores: S vs N over 2010-12



MRPP 2010-2011 ns
2010 or 11 vs 2012 p<0.01

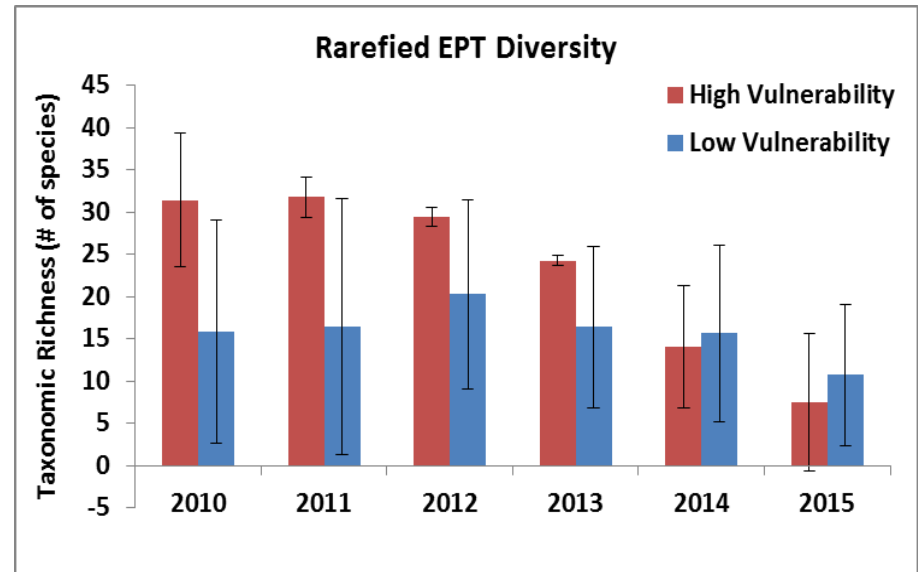
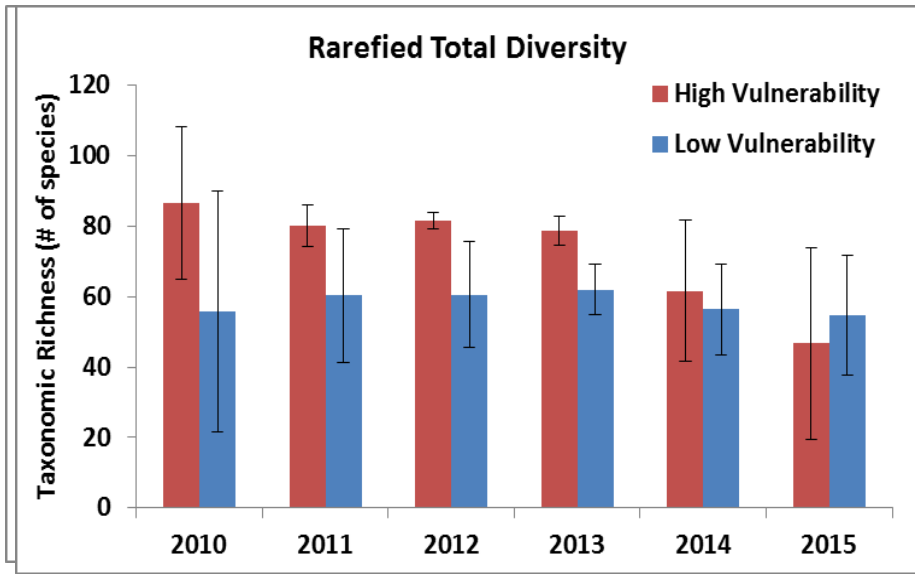
Site-Paired T-tests

Community differs: 1° vs 3° and from 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

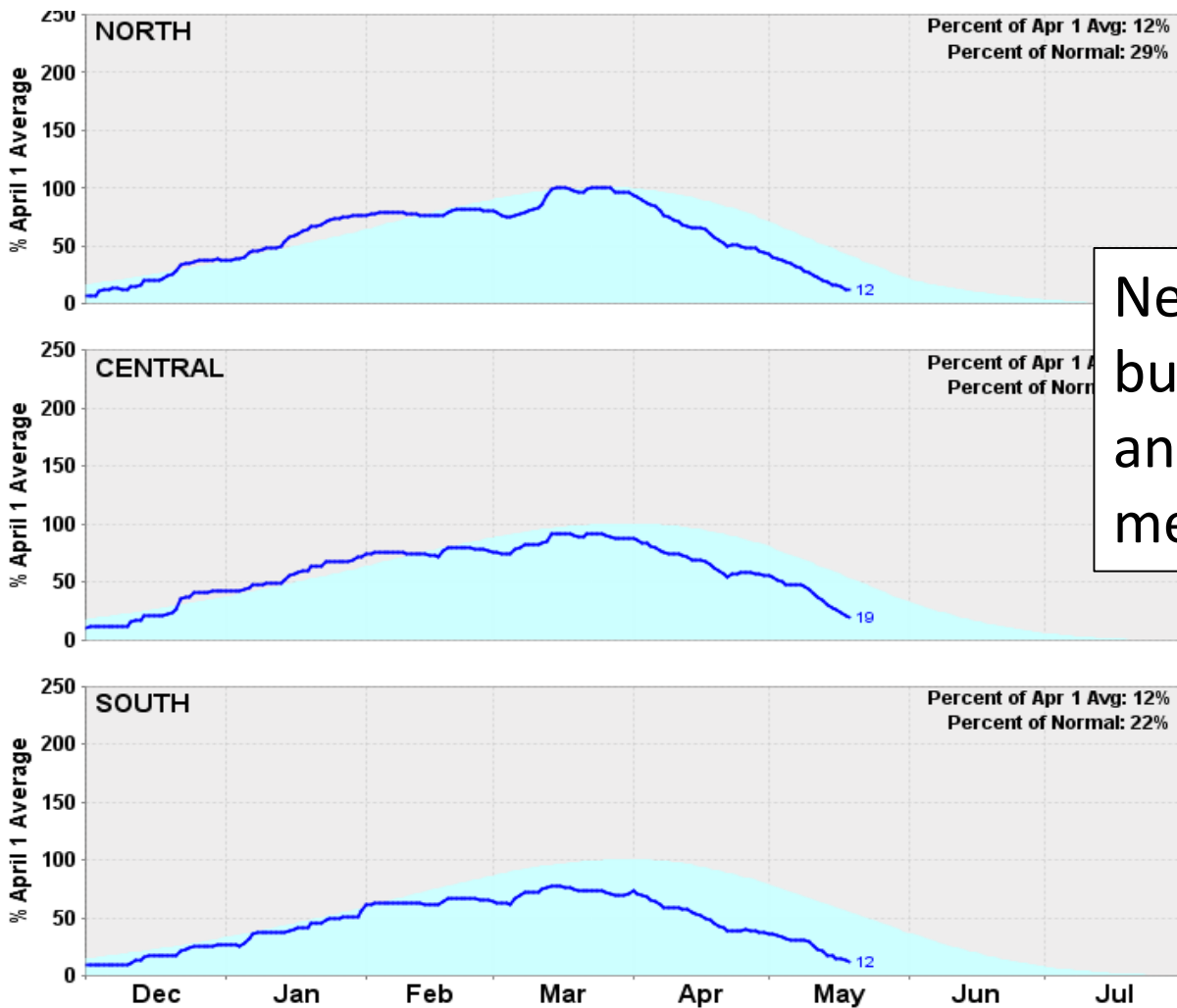


- Preliminary indication that high vulnerability stream types lose diversity in face of drought to a greater extent than low vulnerability
- Full data set yet incomplete, but will allow evaluation of response according to risk, traits, trophic structure

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.....