SIERRA NEVADA SENTINEL STREAM NETWORK: stream invertebrates as climate indicators

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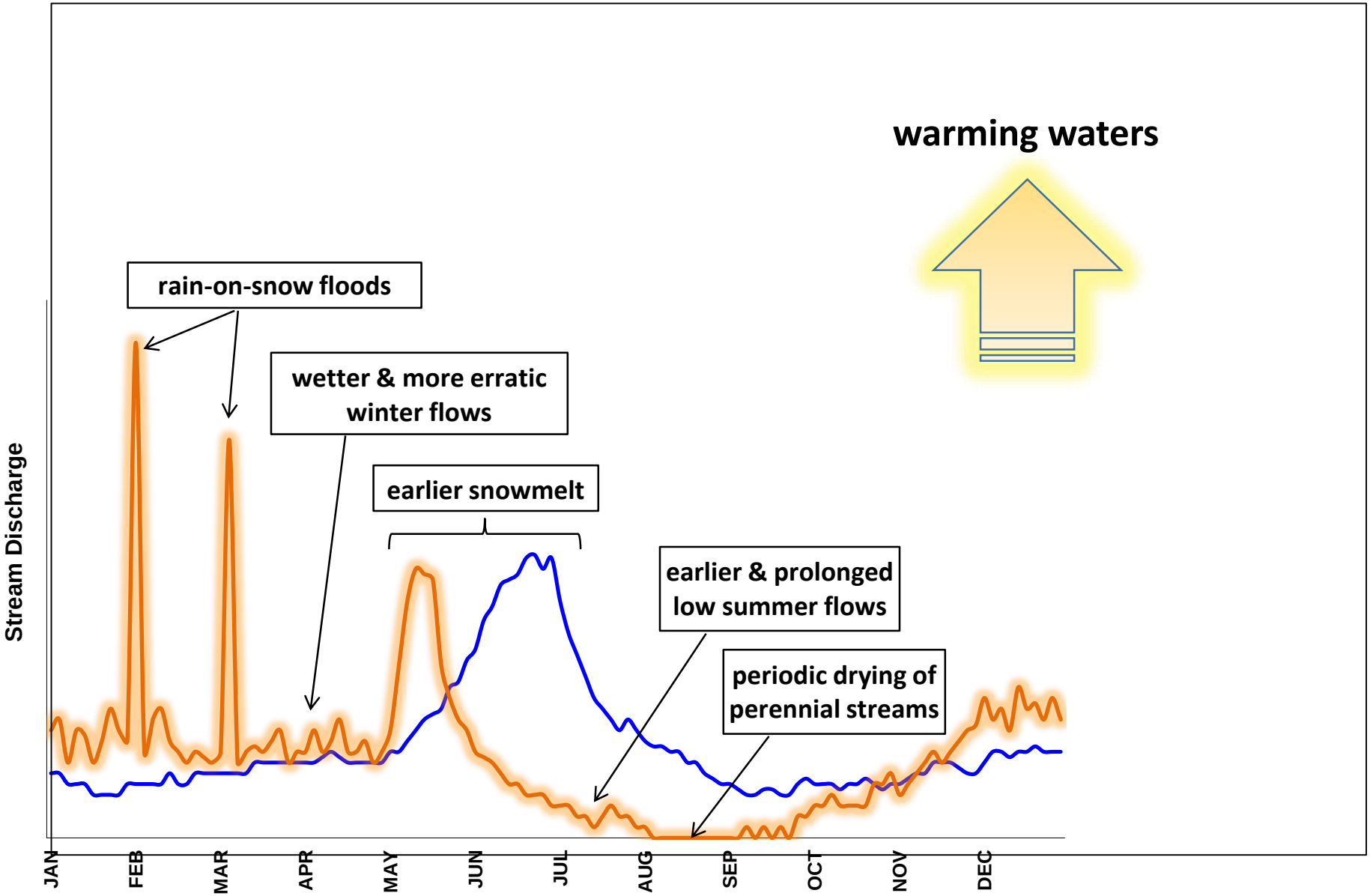
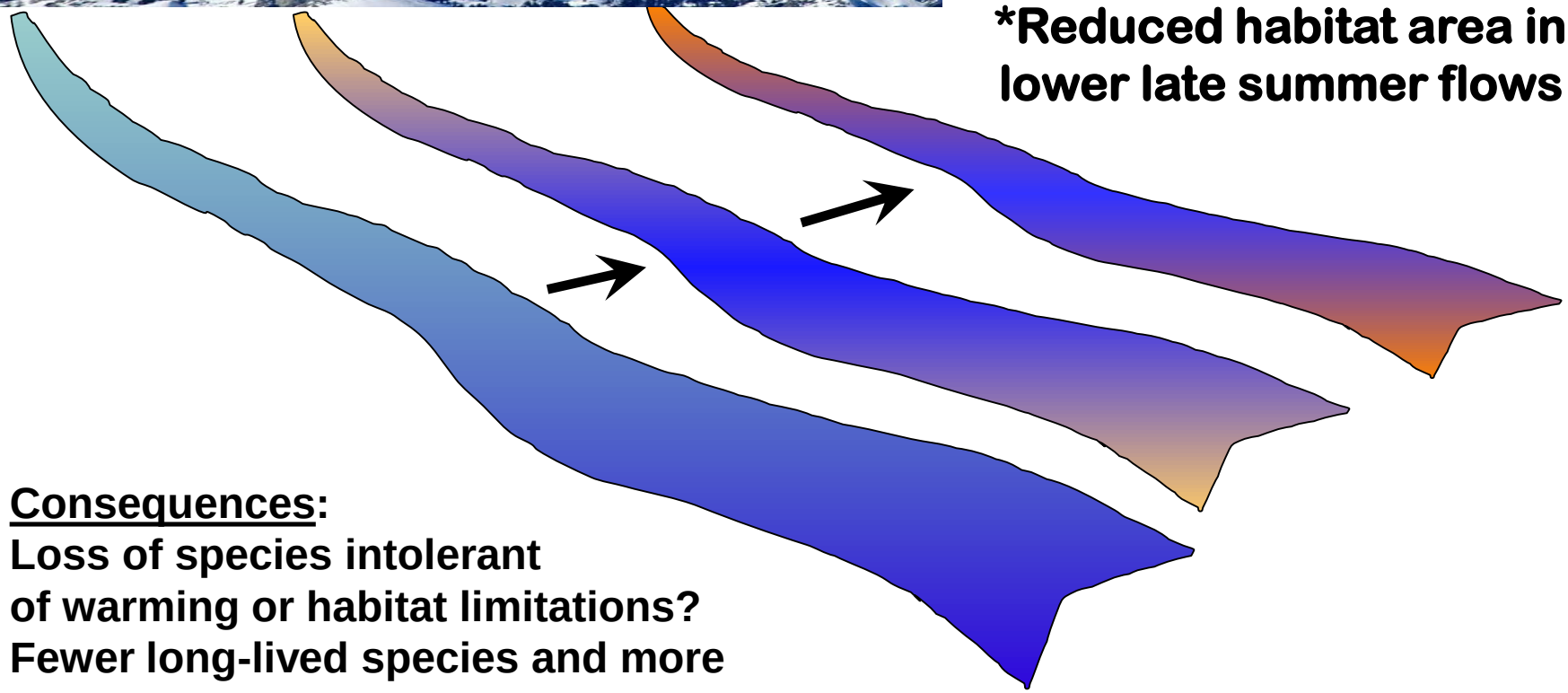
Changing mountain stream hydrograph: developing and future pattern with warming

Hydroclimatic Drivers of Stress

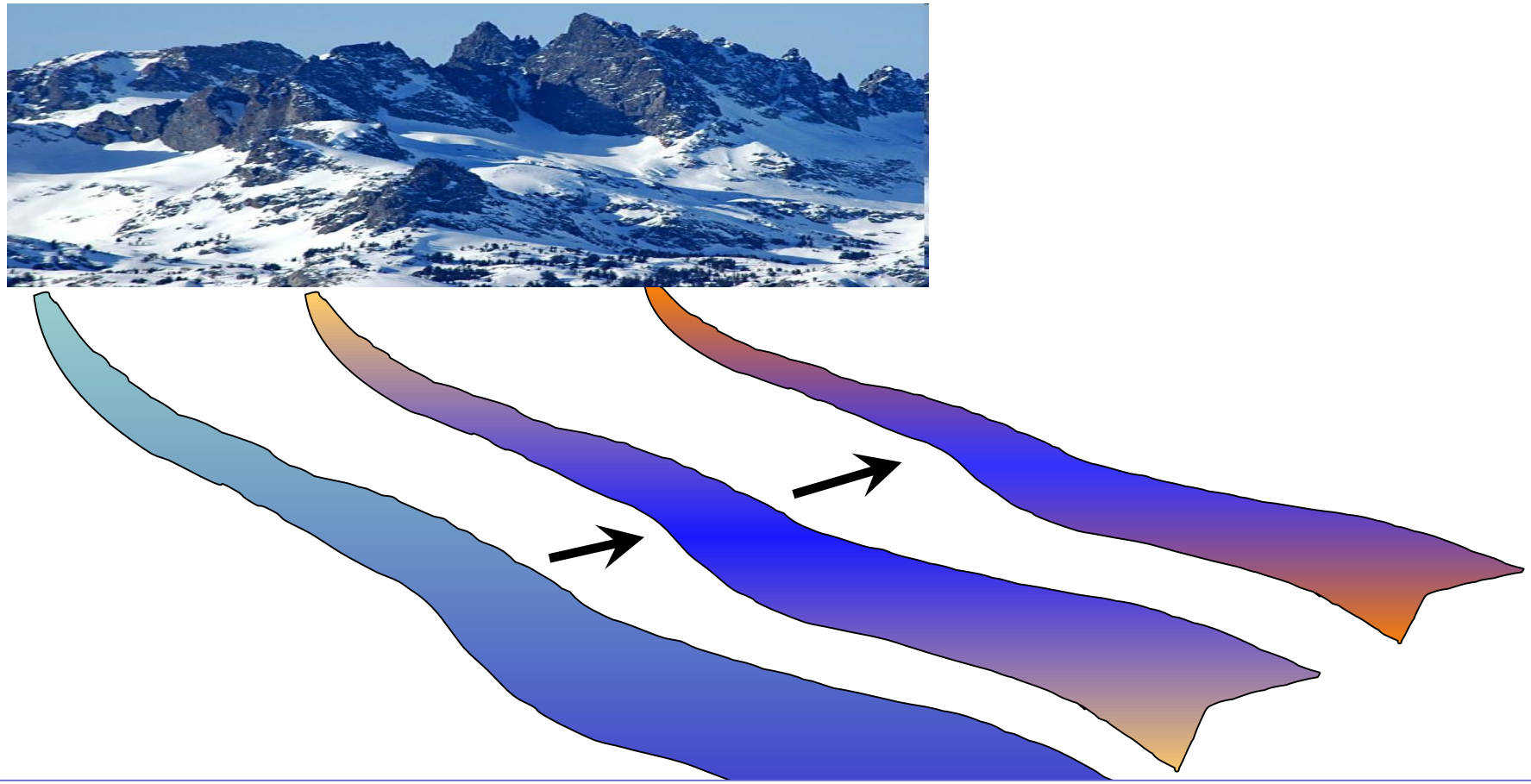


Headwater habitat compression:

*Drying from above
*Warming from below
*Reduced habitat area in lower late summer flows



Consequences:
Loss of species intolerant of warming or habitat limitations?
Fewer long-lived species and more with opportunistic short life cycles?
Physiological stress, simplified food webs, and loss of genetic diversity?



Mountains as sign posts for climate change:

- Headwaters cover most length, diverse environmental gradients
- Transition zone for rain and snow
  and hydrologic and thermal regimes
- Aquatic biota sensitive to changing conditions over time and place

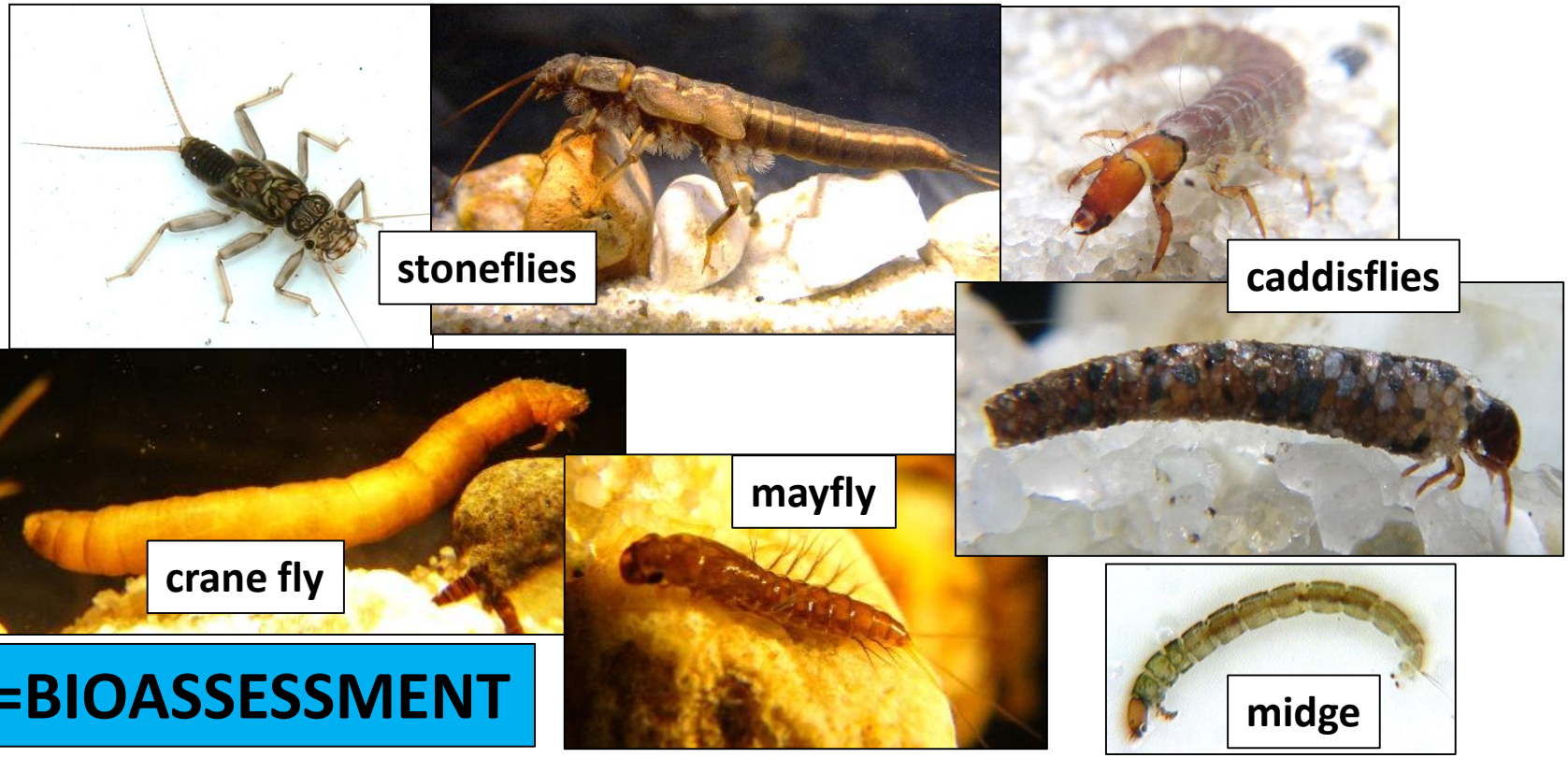
Stream Invertebrates - long history as water quality indicators:

> Diversity of life present, esp. sensitive insects =EPT

> Varied tolerance of hundreds of species to hydrologic regime, temperature, other disturbances and pollution

> Abundance and type of organisms present (food resources)

> Ecosystem services: central to food web for fish and riparian wildlife, nutrient recycling and clean water



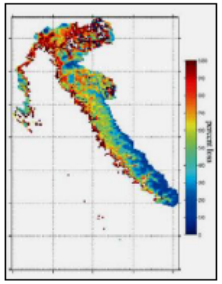
=BIOASSESSMENT

DESIGN

3rd-order size watersheds of Sierra Nevada

Reference selection filter using GIS: mininimum 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**

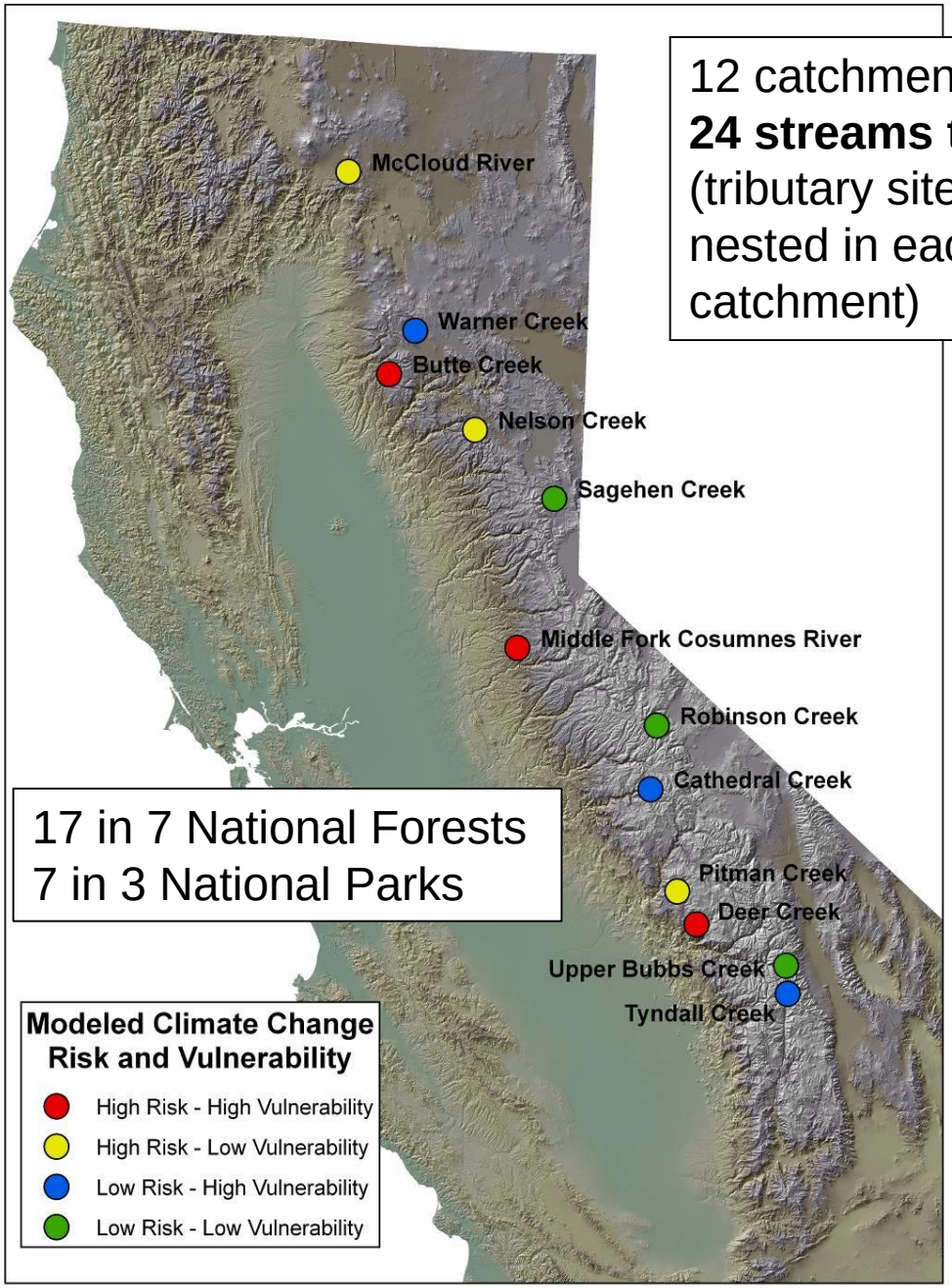
Natural Resistance Filters: rank low to high
- Northness Aspect (snowmelt timing, temp, vegetation)
- Groundwater contributions (geology/springs)
- Riparian cover and meadow area (water storage)

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)

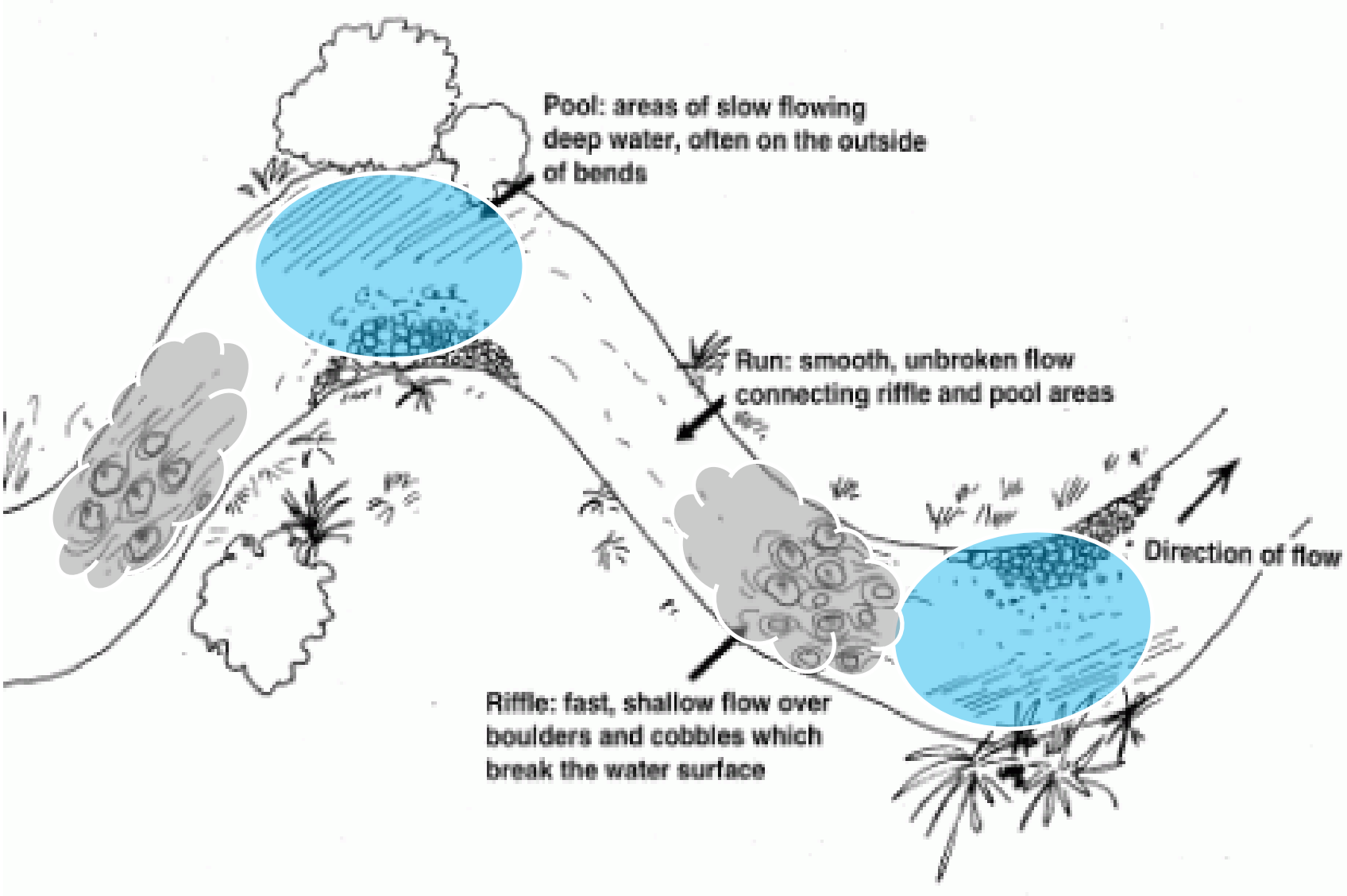
17 in 7 National Forests
7 in 3 National Parks

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

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

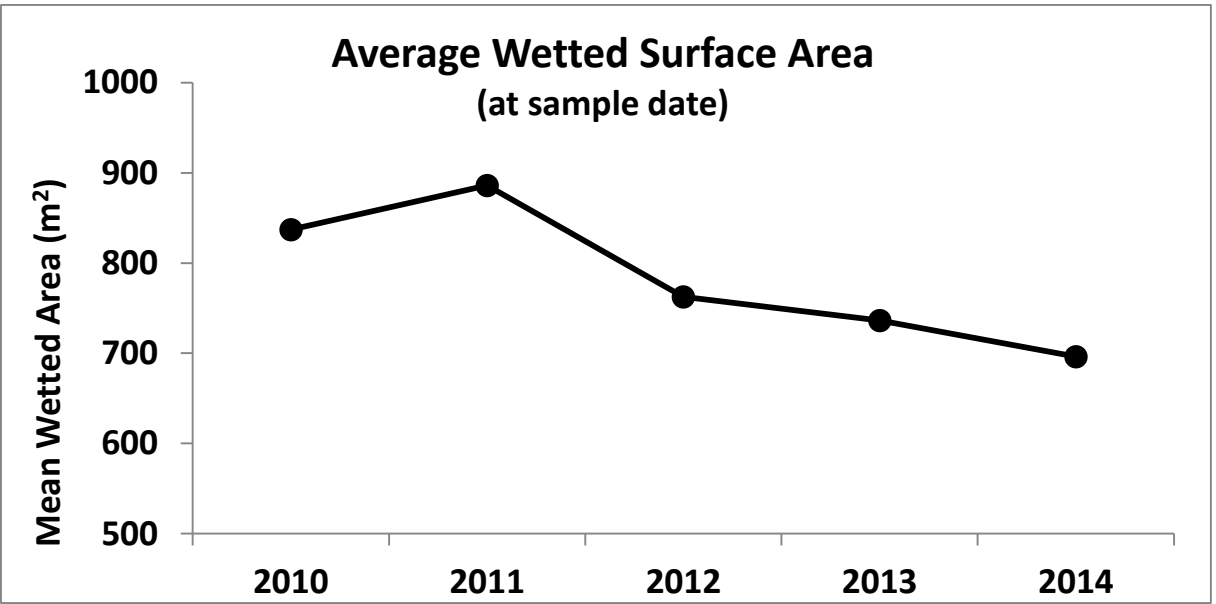
>SWAMP-standard measures of stream habitat, invertebrates, water chemistry, algae, organic matter, riparian cover

Sentinel Stream Observations:
Stream <u>Habitat Area & Types</u>



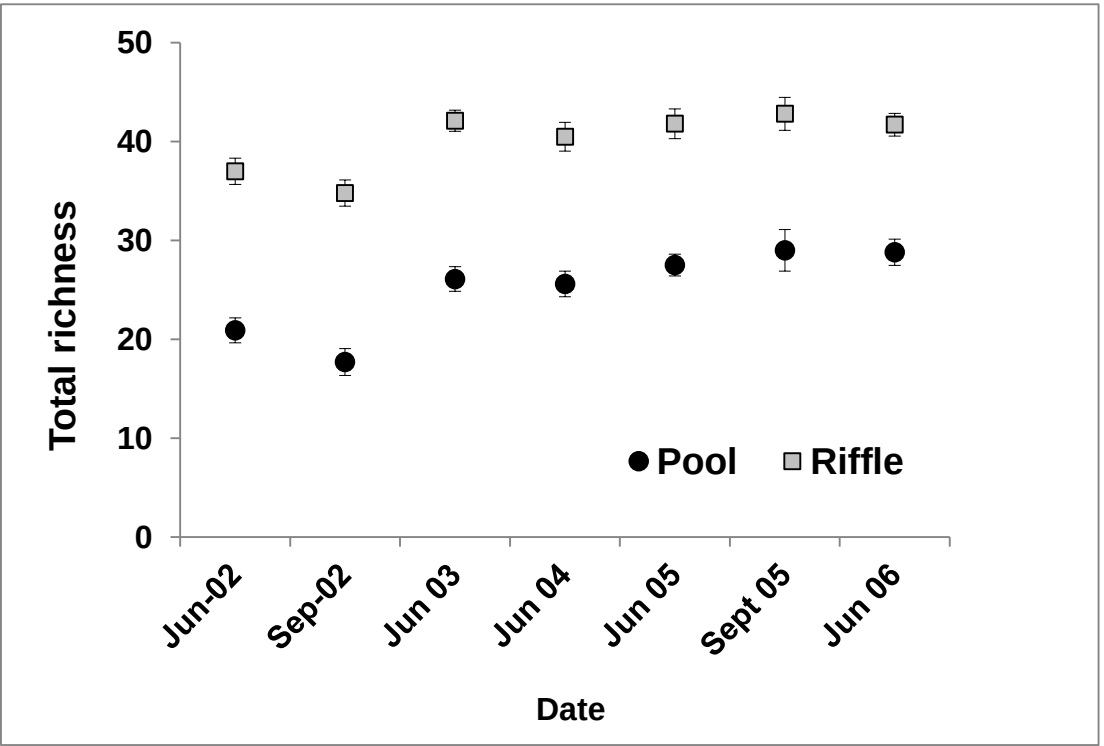
Sentinel Stream Observations: Stream Habitat Area & Types

Streams contract but How does the area of riffle vs pool habitat change with drought?

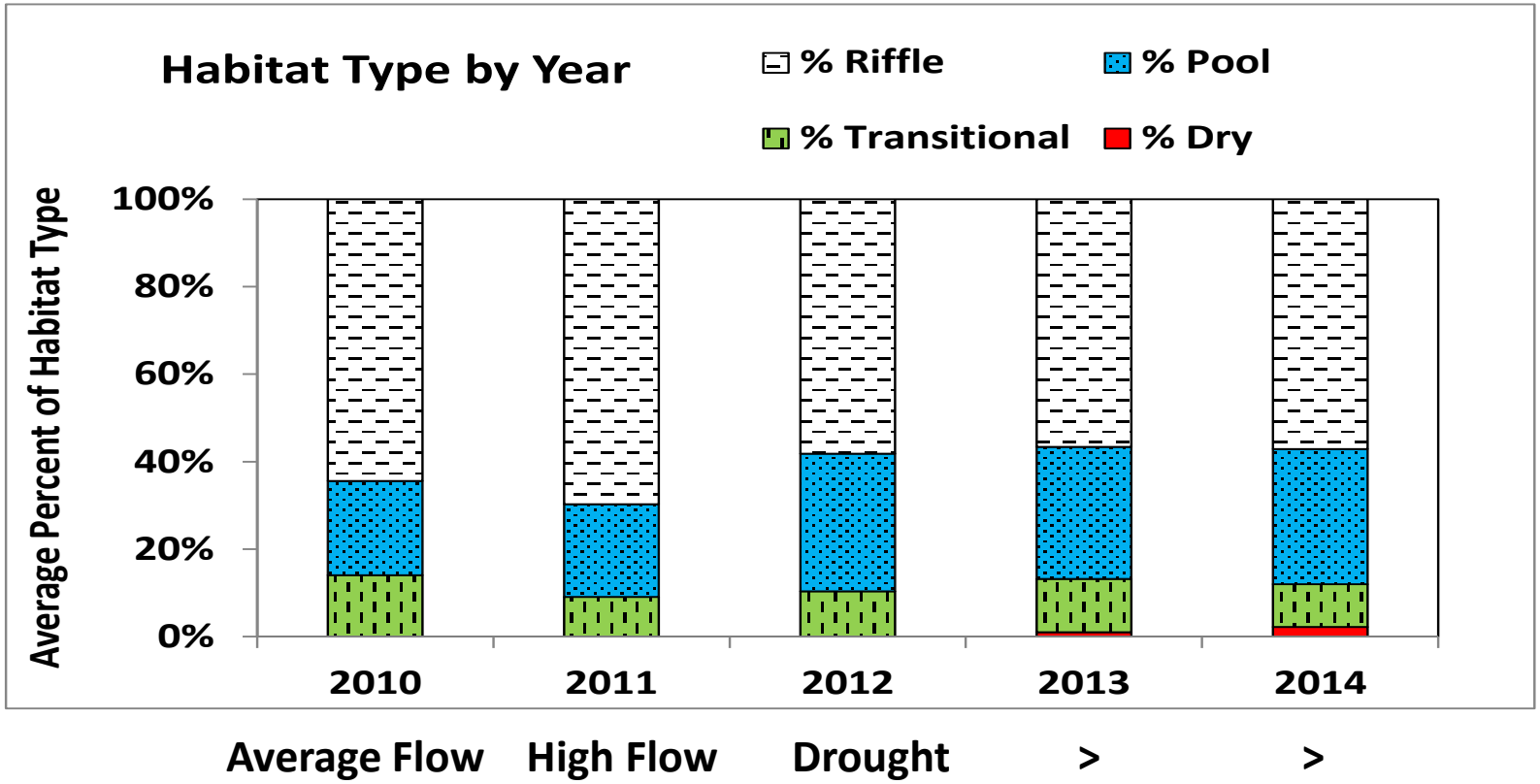


Sentinel Stream Observations: Stream Habitat Area & Types

Small Sierra Streams: Richness much higher in riffles than in pools

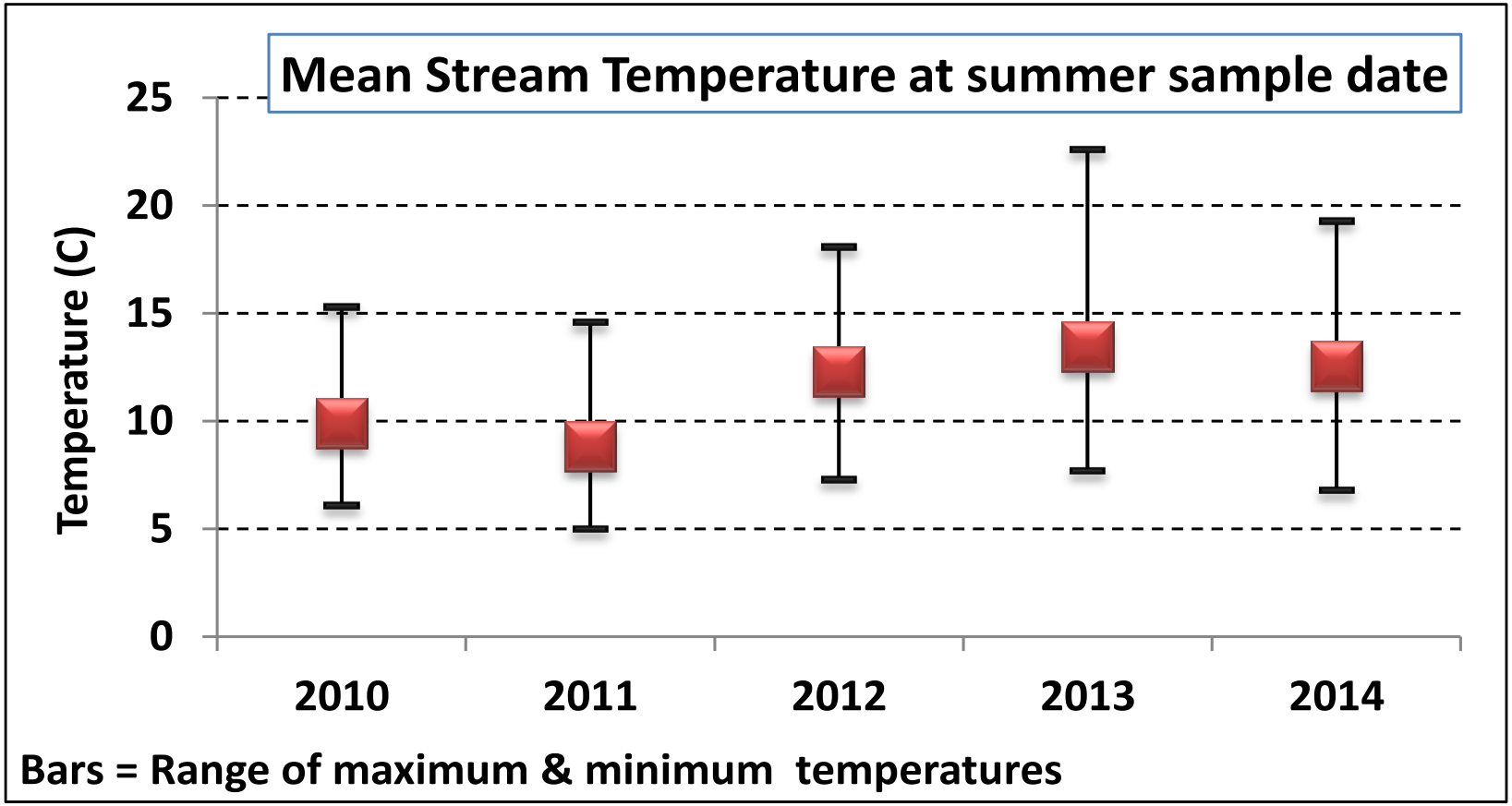


Sentinel Streams: How does stream habitat change? Pools and Riffles, transition zones



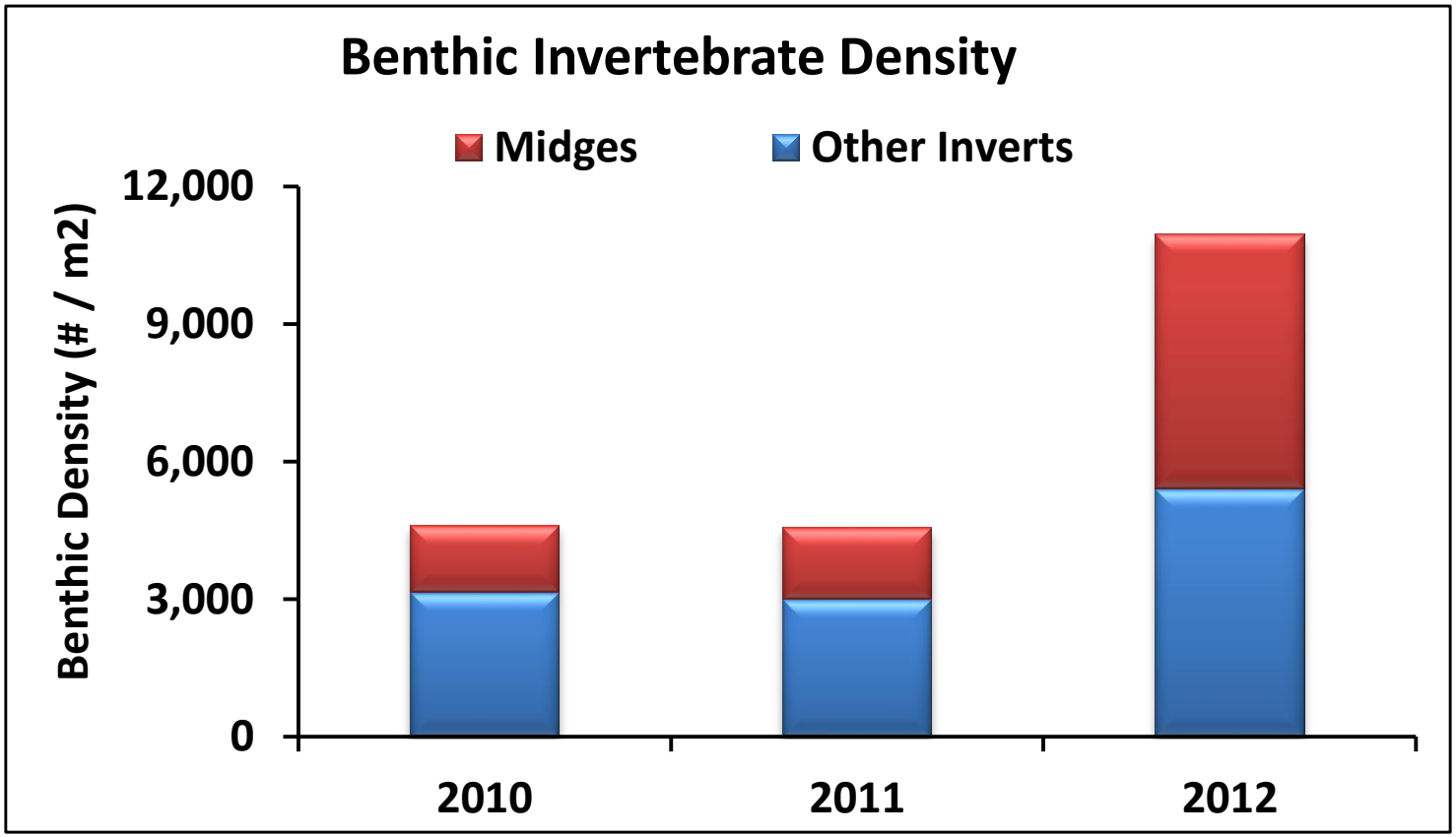
<u>Significant increase in pools w low flow drought: from 20% to 30% cover</u>
Slower-moving POOL habitats come to make up more of the stream and <u>harbor less diversity</u> than swift-flowing riffles, with more sediment deposition and less dissolved oxygen. Some channels starting to dry.

Sentinel Streams: Have streams warmed with drought?



Yes, significant increase from average and high flow years to drought (from 9-10 to 12-14°C). Some sites rising into the range of >20°C, detrimental to many forms of aquatic life

Sentinel Streams:
Do benthic invertebrates change with flow?



Yes, total <u>density increased in first drought year</u> and becomes <u>dominated by midges</u> over other invertebrates:

Midges are small, short life cycles, tolerant of poor water quality

Summary: Sierra Stream Habitat & Invertebrate Indicators

- Headwater flows and temperature in context of historic frame of reference and water year type
- Area and quality of stream habitat (cover, pool/riffle ratio, dry)

Indicator Invertebrates (change relative to reference & baseline):

- Biological diversity – total and sensitive EPT; also algae diversity
- Tolerance values of species comprising community
- Trait composition of species for thermal and flow preferences, life cycle, body size, habitat use, food web functional roles

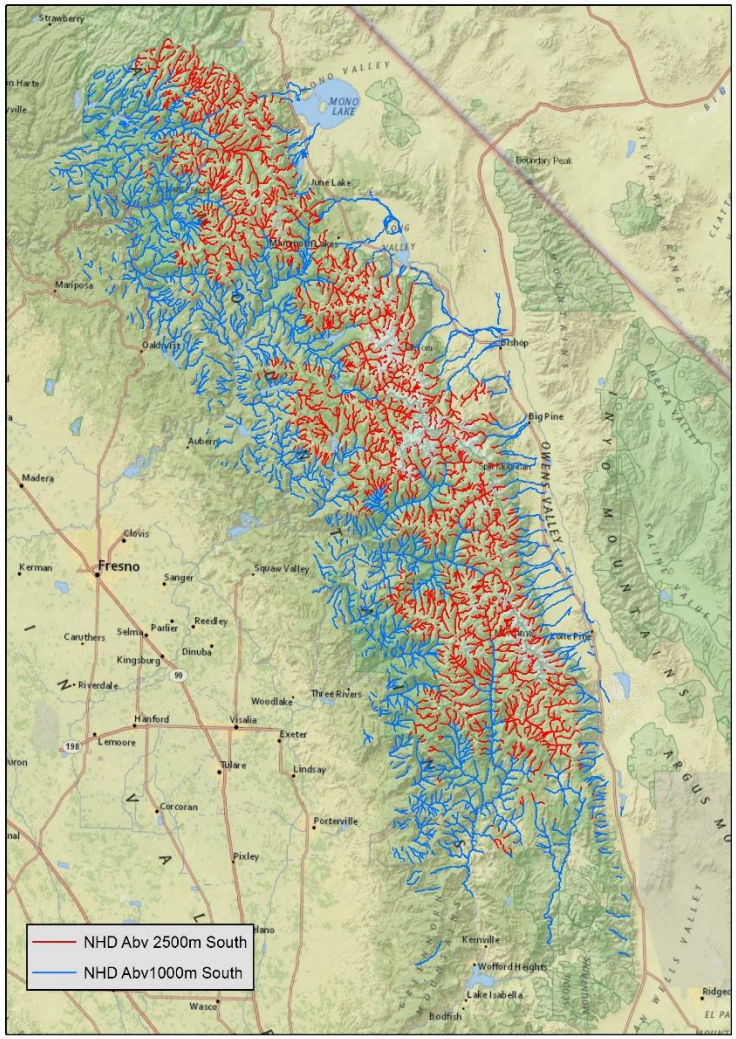
> How all of these variables change with respect to trade-offs of predicted risk and natural environmental resistance:
what makes streams more vulnerable or more resilient?

> Use data to inform adaptive management decisions, eg. riparian and meadow restoration placement

*SWAMP data complementary: 100s of stream bioassessments and derived indicators since 1999 all over state

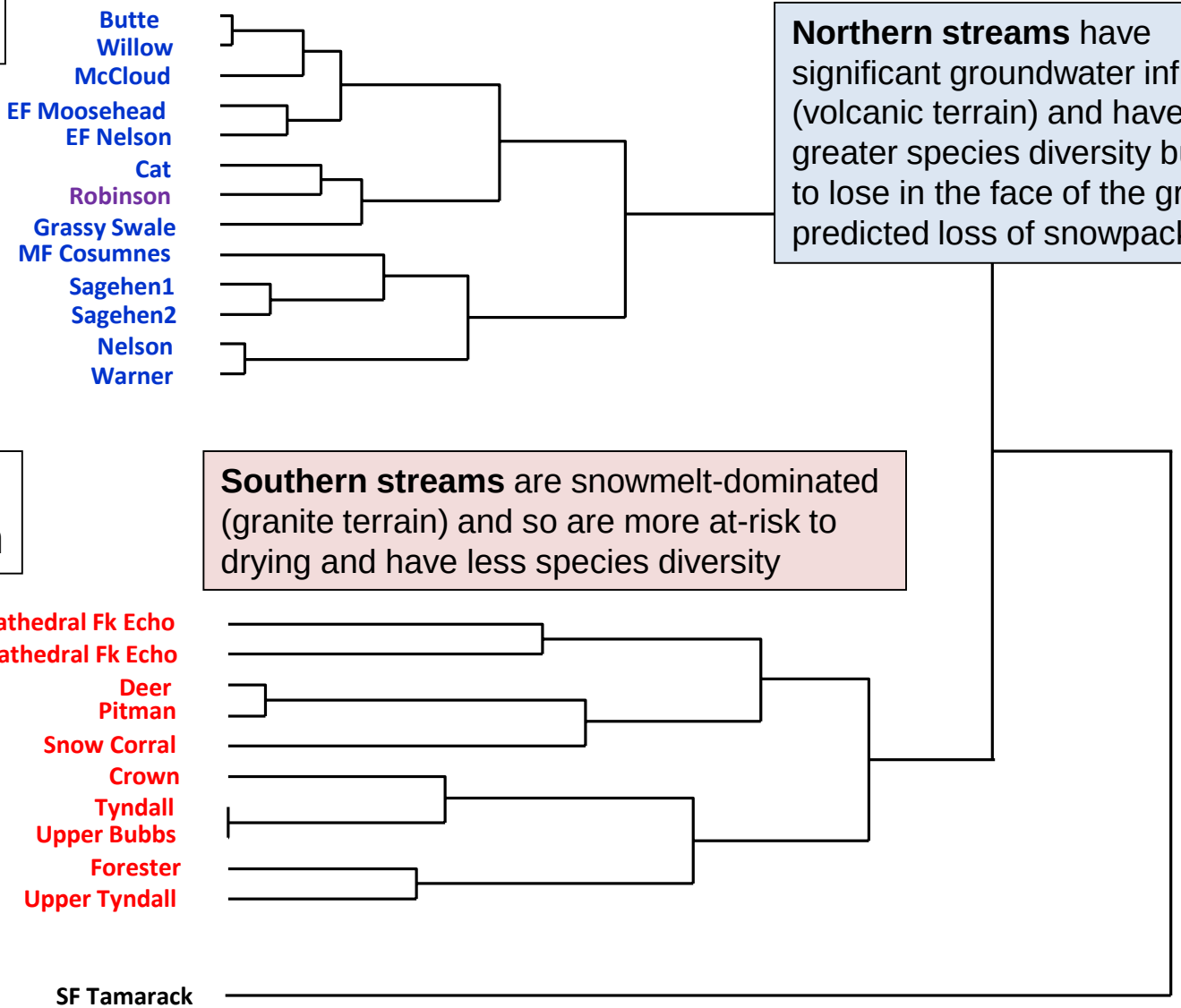
*20 reference streams monitored yearly since 2014 (10 in Sierra), BUT...

- **<u>Huge data gaps</u>** in coverage of high elevation mountain streams by SWAMP in central/southern Sierra
- Data mining? for longer time trends at some sites where there are UC field stations, eg. SNARL & Sagehen
- Challenge: Sentinel network has no funding now for 4th year, after initial 2 yr support from USFS for set up



Stream Biological Community Groupings

North of Yosemite



Northern streams have significant groundwater inflows (volcanic terrain) and have greater species diversity but more to lose in the face of the greatest predicted loss of snowpack

Yosemite and South

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

Intermittent channel = shortest upstream length, snowmelt

Summary

- What are the indicators?

➢Aquatic biological metrics linked to hydroclimatic drivers.

- Why track montane stream invertebrates?

➢Sensitive and rapid response times, key to food webs, clean water role, downstream resource transfers, recreational value (eg flyfishing, birding, endemics), water quality tool for regulators

- What is the observed trend?

➢Loss of habitat area and quality, increased temperature and algae, higher BMI density and midges predominate, fewer spp?

- Where trend data are not available, discuss expected trends.

➢Invertebrate species analysis not completed but expected to show biodiversity declines, loss of ecosystem services

- What factors influence the indicator?

➢Flow and temperature in reference streams; disturbance and pollution where land use development exists

Summary (con't)

- Extent to which climate change can influence observed trend.

➢Drivers of flow and temperature: direct effects from changing habitat area and quality, thermal stress, low DO, sediments, altered timing that disrupts life cycles and development, changes in resource availability, dissolved solutes that promote invasive species; indirect effects as biotic interactions are altered

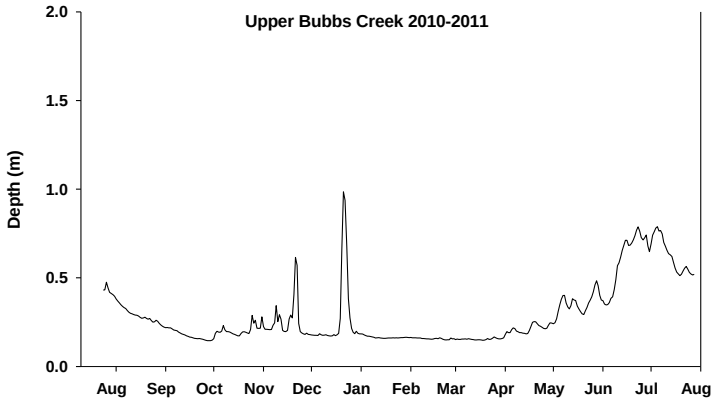
- Data collection, strengths and limitations.

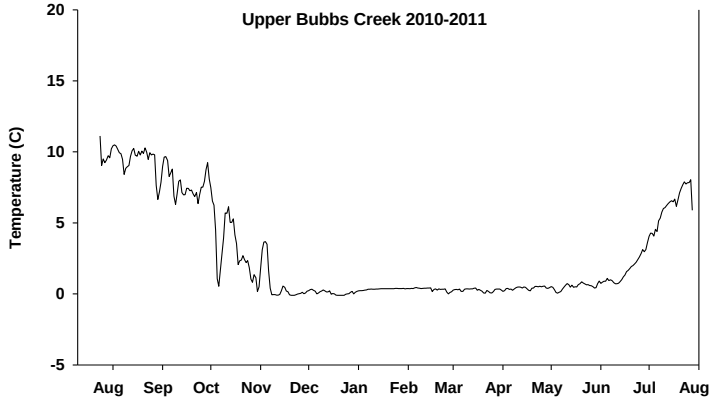
➢Strengths- network is established using standardized protocols, instrumented recorders, timeframe covers average to high flows and prolonged drought, indicators are accepted tools of water quality assessment that can be cross-compared with other data;

➢Weakness is that the data gathering lacks funding support and sample processing is backlogged, and that other indicators have not been tied in from monitoring of fish and riparian birds

Flow Regime Types Observed*
(habitat ecological templates, after Poff and others)
Are there associated BMI community types?

- **1. Stable winter flows and temperatures during ice cover (though R on S may occur), rapid spring snow-melt and summer recession, prolonged cool temps (<10ºC)**





***1. Snow 2. Rain+Snow 3. Groundwater 4. Intermittent-Flashy**

Flow Regime Types Observed*
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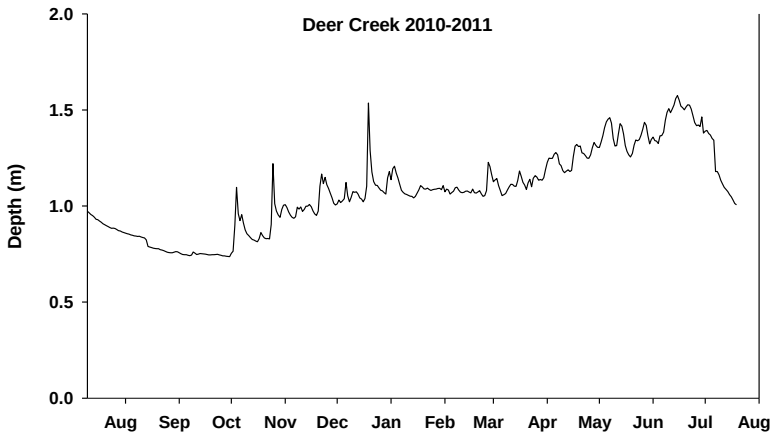
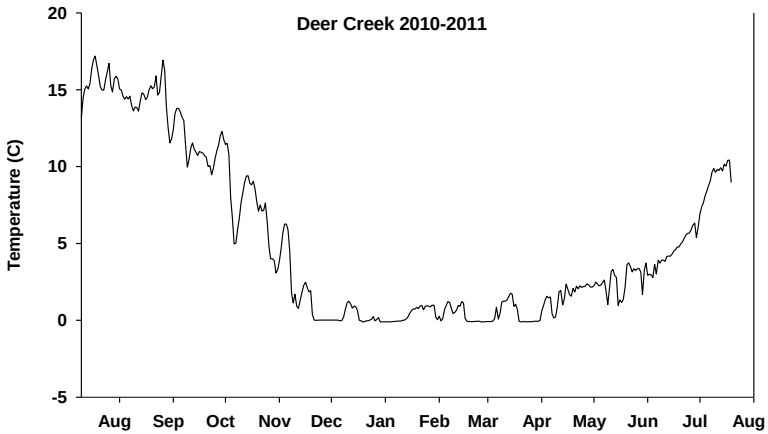
- **2. Winter rain and snow, instable ice-snow cover, rising flows through winter and spring, warm summer temperatures (≥15ºC)**





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Flow Regime Types Observed*
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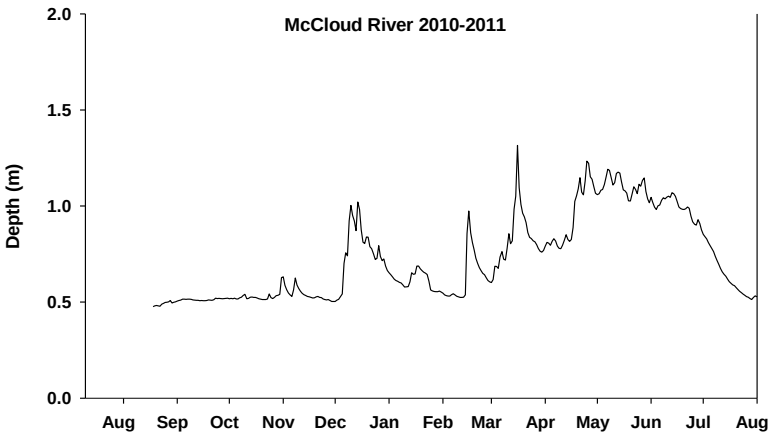
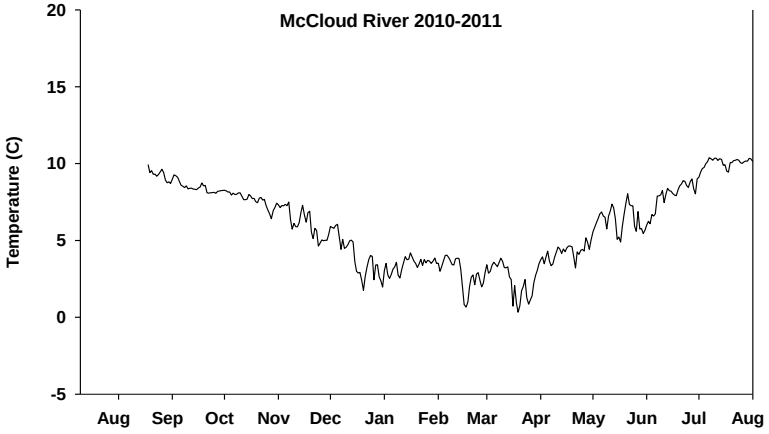
Are there associated BMI community types?

- **3. Stable groundwaters sustain high flows and cooler more constant temperatures (≤10ºC)**





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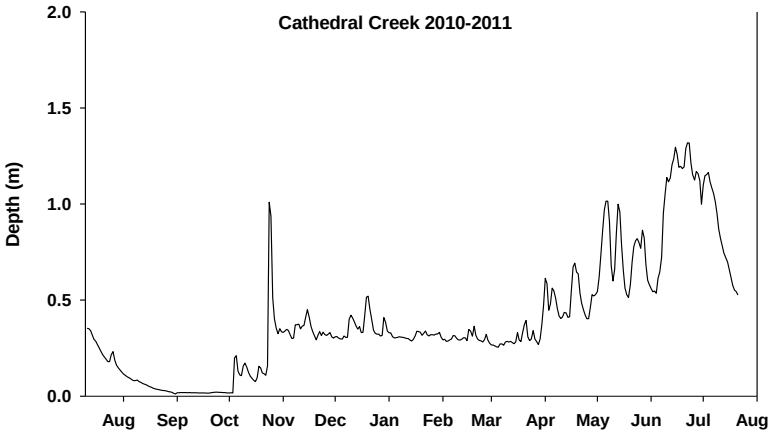
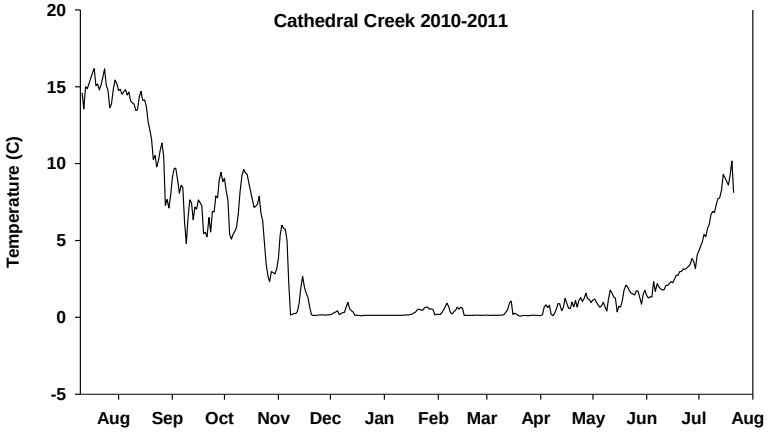
Flow Regime Types Observed*
(habitat ecological templates, after Poff and others)
Are there associated BMI community types?

- **4. Spatial intermittent flows, losing reaches, warm, variable**





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