Changes in baseflow sources during the dry-down of a non-perennial headwater stream

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Objectives & Data

- Non-perennial streams are integral to the ecological integrity of river networks, impacting both local and downstream water quality and quantity.
- There is a need to understand the sources of water that sustain flow in non-perennial streams, and how the contributions of different sources change during stream drying.

Overarching Question: What are the physiographic and hydrologic controls on the variability in stream isotopic composition, and how do these controls change during stream drying?

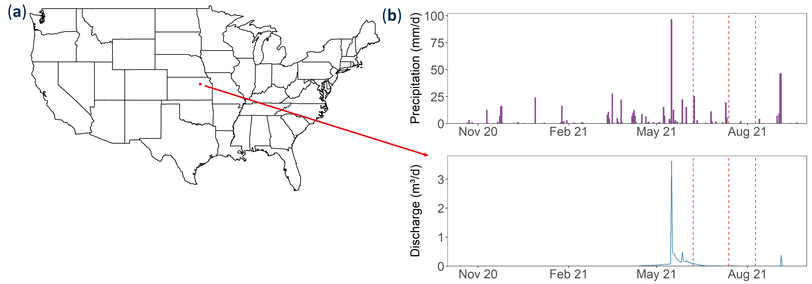


Figure 1. (**a**) Konza Prairie near Manhattan, KS and (**b**) timeseries of precipitation and discharge (USGS gage 06879650) nearest to site. Sampling events are shown as vertical dashed lines.

- Synoptic stream water samples ($\delta^{18}O$ and $\delta^{2}H$) were collected from 50 locations at three time points (June, July, August) in combination with stream and precipitation isotope sampling efforts from NEON and LTER networks.

Q1. How do isotopic compositions of non-perennial streams vary?

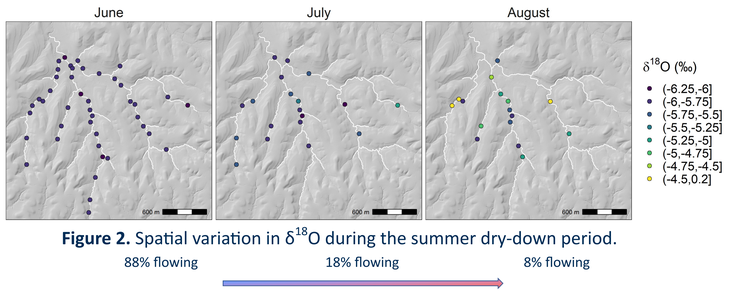


Figure 2. Spatial variation in $\delta^{18}O$ during the summer dry-down period.

- Stream isotopic composition was progressively enriched during stream drying.
- Stream isotopes were homogeneous in June, when most of the network was flowing, and heterogeneity increased thereafter.

Q2. What factors influence isotopic compositions in non-perennial streams?

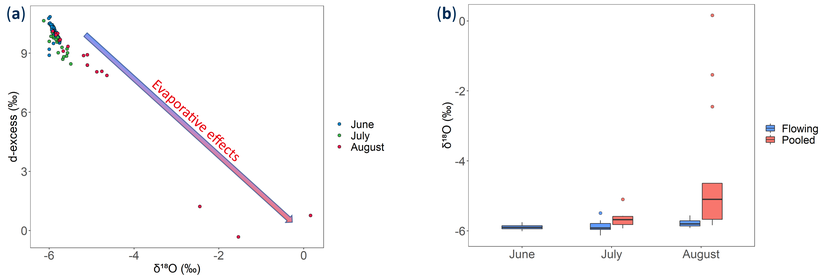


Figure 3. Variability in (**a**) $\delta^{18}O$ and d-excess and (**b**) flow state during the summer dry-down period.

- Stream isotopic enrichment is associated with evaporative effects and a decrease in hydrologic connectivity.
- There is greater variability in $\delta^{18}O$ and $\delta^{2}H$ as hydrologic connectivity decreases.

Q3. What does this imply about the sources of water to these streams?

Approach 1: Bayesian unmixing

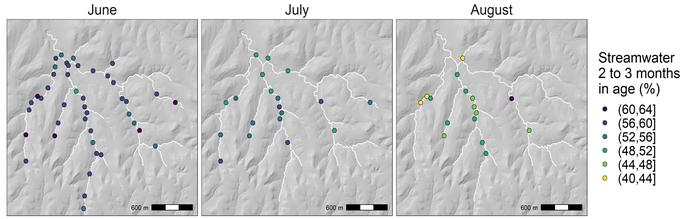
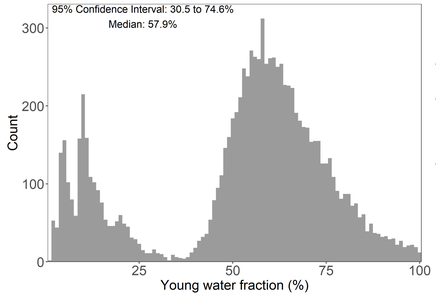


Figure 4. Streamwater less than 2 to 3 months in age.
Unmixing was done using the *isoWater* package in R (Bowen, 2022).

- Streamflow in early summer consisted primarily of water that had been stored in the subsurface for less than 2 to 3 months.
- There is a shift to older streamwater contributions by late summer.

Approach 2: Young water fraction



- Bimodal distribution of F_{YW}, depending on degree of hydrologic connectivity.
- The median F_{YW} is 58% for the 2021 water year.
- These results are in close agreement with the point-scale mixing model approach.
- Young stream water contributions appear to be important for causing wet-up in the spring, while older stream water contributions are proportionally more important for sustaining flows during late summer.

Figure 5. ECDF of the F_{YW} assessed across 10,000 simulations for the 2021 water year.
The young water fraction (F_{YW}) specifics the proportion of streamflow less than ~2 to 3 months in age.

Key Findings

- Stream isotopic composition was progressively enriched in $\delta^{18}O$ and $\delta^{2}H$ as the stream network dried, reflecting evaporative effects and decreases in longitudinal connectivity.
- Streamflow in early summer consists primarily of water that had been stored in the subsurface for less than 2 to 3 months, and as the summer progresses, there is a shift to older streamwater contributions.
- Spring rains and high-intensity summer storms are routed rapidly through our study catchments as overland flow and preferential flow in the alternating limestone-mudstone stratigraphy. As storm events decrease in frequency, older stream water contributions sourced from water transiting less permeable pore space are proportionally more important for sustaining flows.

Acknowledgements

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Gabe Bowen (2022). isoWater: Discovery, Retrieval, and Analysis of Water Isotope Data. R package version 1.1.0.