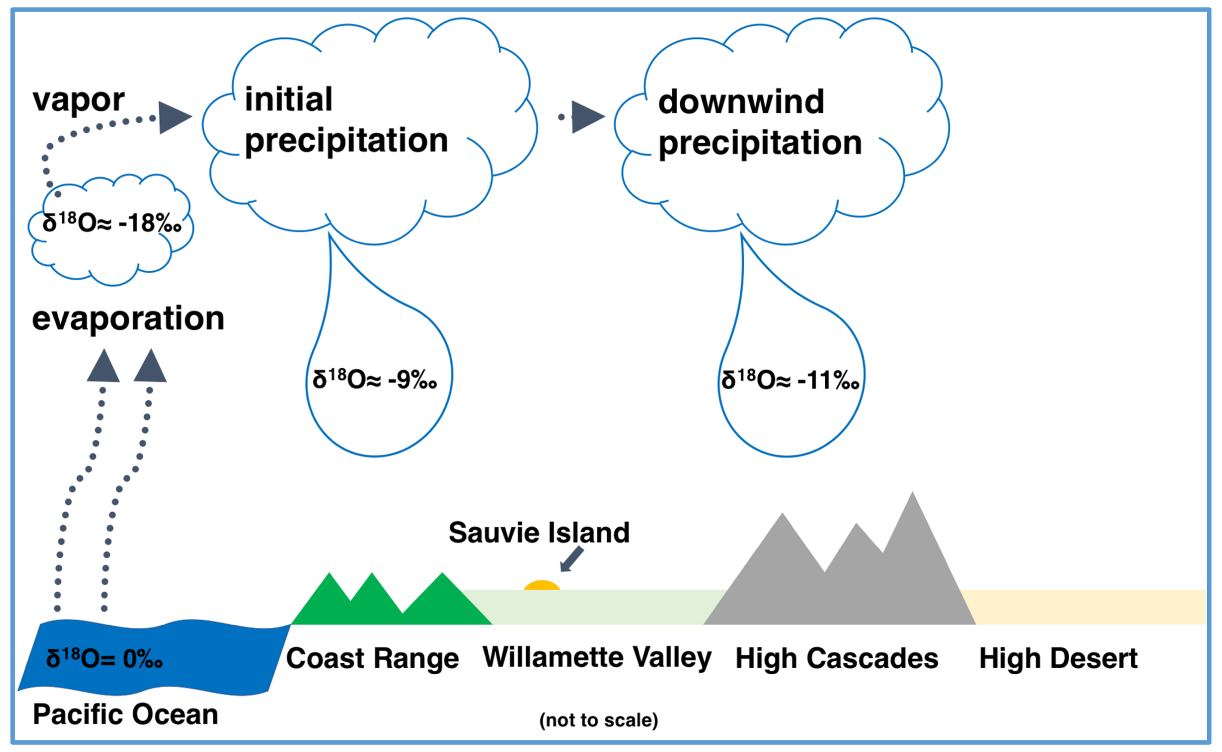
Mixing of the Willamette and Columbia Rivers across Sauvie Island, Oregon based on stable isotopes ($\delta^{18}O$ and δD) of surface water

Mae Saslaw and Dr. John Bershaw
Dept. of Geology, Portland State University, Portland, OR 97207 USA

Context

Stable isotope ratios of surface water are used to study water evolution throughout the hydrologic cycle. The isotopic composition of meteoric water varies globally based on latitude, elevation, distance from its source, and environmental conditions during and after precipitation.

In the Pacific Northwest, orographic precipitation sustains almost every habitat. The continental effect describes the progression of stable isotopes $\delta^{18}O$ and δD of precipitation and surface water as vapor from the ocean travels inland across the continent[1]. By understanding patterns in the stable isotope signatures of local water, we can track how water source changes over time. This survey evaluates stable isotopes across the confluence of the Willamette and Columbia Rivers to study how the mixing waters influence hydrological systems in the area, particularly on Sauvie Island.



Approximate evolution of $\delta^{18}O$ in Pacific Northwest orographic precipitation. Values based on Brooks et al.[2]

Methods

Field methods

- Eleven sample sites indicated on study area map
- Two 15 mL vials collected and sealed at each site
- Samples collected near shore

Sample analysis

Analyzed on Picarro model L2120-i water isotope analyzer at Oregon State University, calibrated using VSMOW (Vienna Standard Mean Ocean Water) and SLAP (Standard Light Antarctic Precipitation)[3]

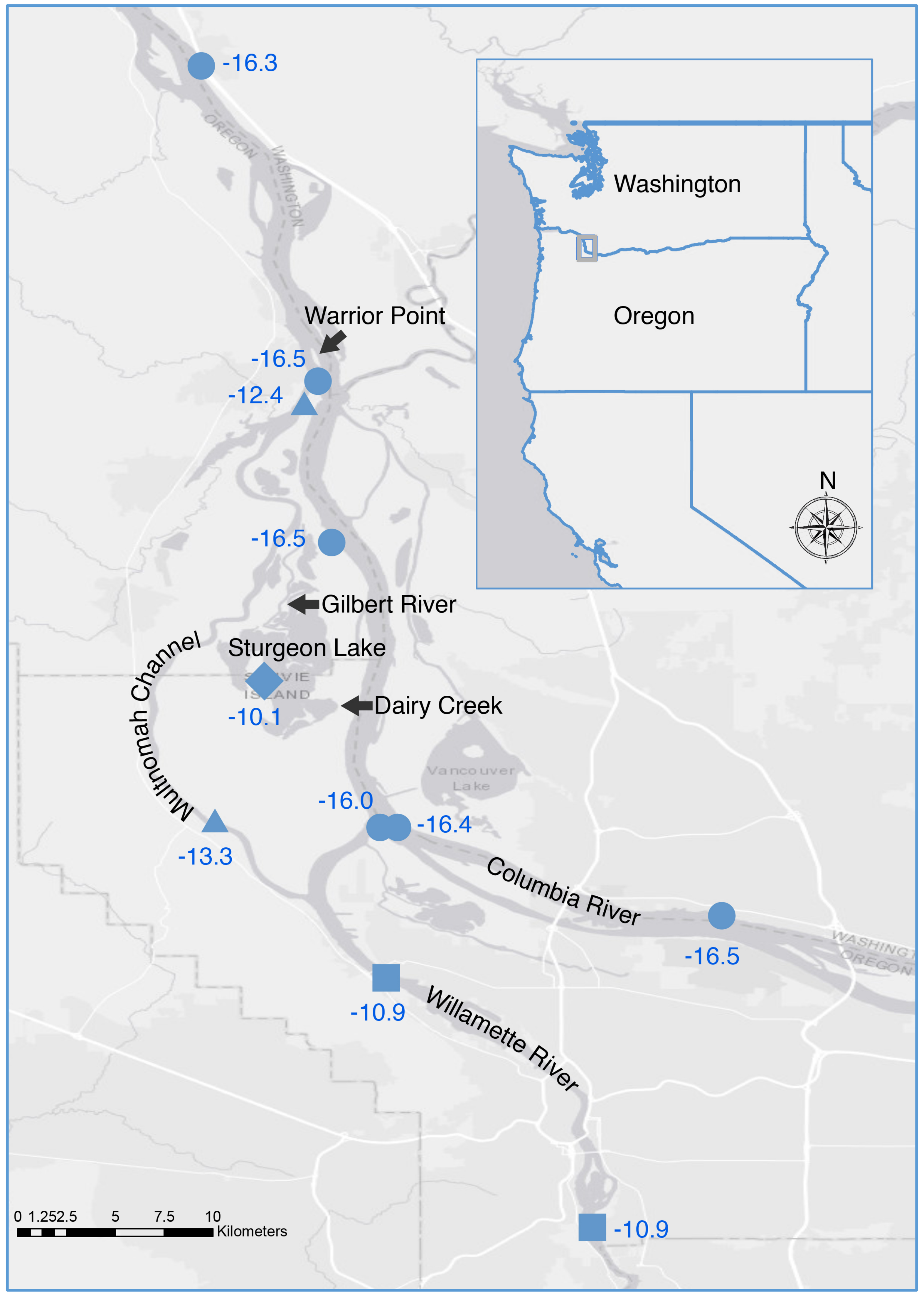
Above: Sturgeon Lake on Sauvie Island
Right: Warrior Point on Sauvie Island, looking north at the confluence of Multnomah Channel and the Columbia River

Study Area

The Willamette and Columbia Rivers are major waterways of the Pacific Northwest. Their confluence lies at the northern end of Portland, Oregon. Sauvie Island, also called Wakanasese and Wapato Island[4], is a floodplain approximately the size of Manhattan, situated at the confluence[5].

Sturgeon Lake on Sauvie Island receives input from Multnomah Channel via the Gilbert River, and at the time of this study in summer 2018, construction was underway to dredge Dairy Creek with the goal of restoring a connection between the lake and the Columbia River[6].

Sample locations and $\delta^{18}O$ reported in permille VSMOW are shown on the map below.



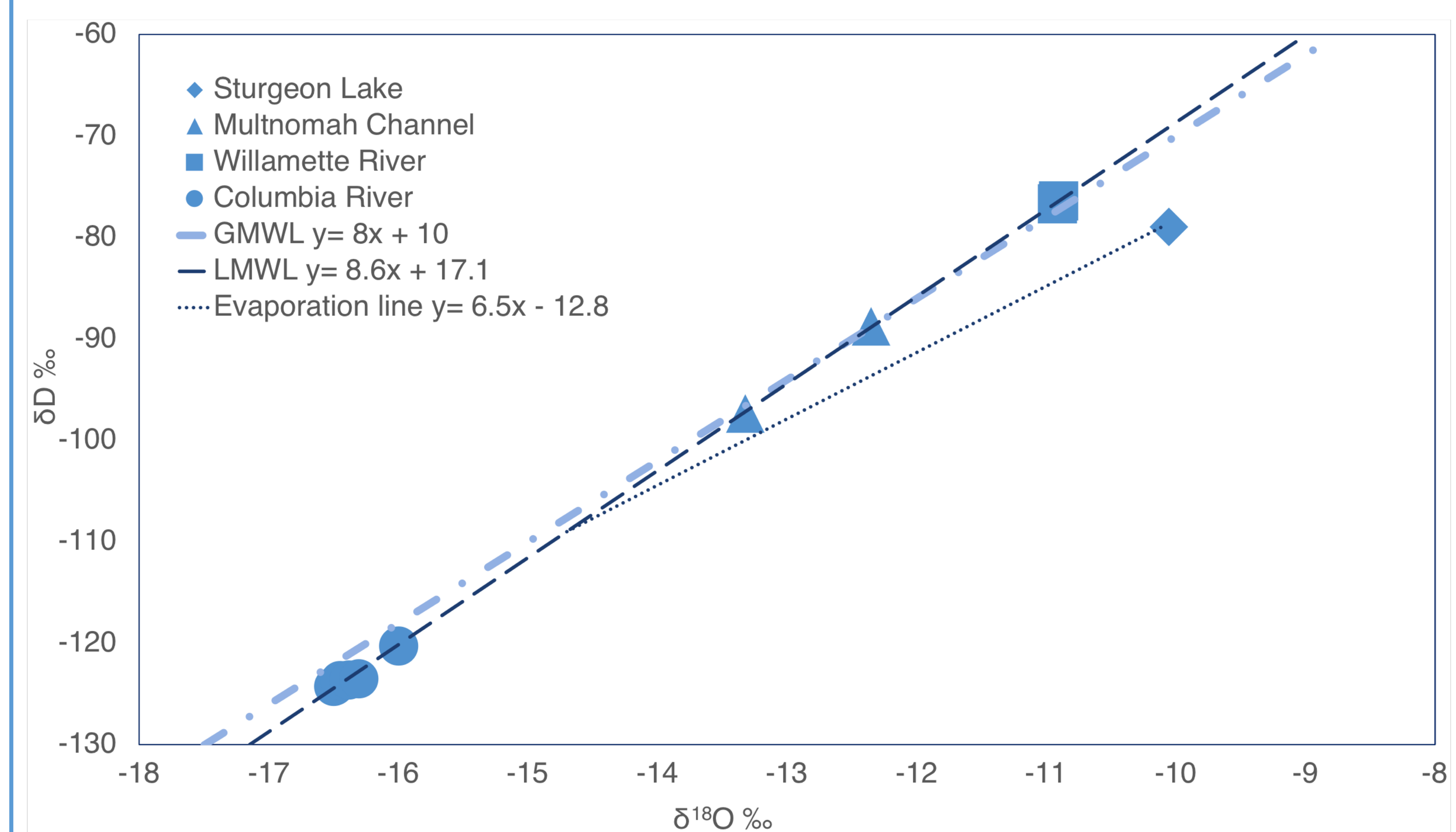
Results

Mean $\delta^{18}O$ for sample locations are shown on the map. Mean δD, $\delta^{18}O$, and deuterium excess for each body of water are shown on the table below. Isotopic composition data are reported in delta (δ) notation following Clark and Fritz[7] relative to the reference standard VSMOW.

$$\delta^{18}O_{sample} = \left(\frac{(^{18}O/^{16}O)_{sample}}{(^{18}O/^{16}O)_{reference}} - 1 \right) \cdot 1000 \text{ permille VSMOW}$$

$$\text{d-excess} = \delta D - (8 \cdot \delta^{18}O)$$

Body of water	δD	δ18O	d-excess
Sturgeon Lake	-78.9	-10.0	1.5
Multnomah Channel	-93.1	-12.8	9.6
Willamette River	-76.5	-10.9	10.8
Columbia River (downstream)	-123.9	-16.5	7.7
Columbia River (upstream)	-122.9	-16.3	7.6



Relationship between δD and $\delta^{18}O$ for sample locations. Local Meteoric Water Line (LMWL) — excluding Sturgeon Lake — is similar to the Global Meteoric Water Line (GMWL). Evaporation line for Sturgeon Lake is determined by estimating the midpoint of expected pre-evaporation isotopic composition.

Discussion & Conclusions

- An isotopic mixing model for the Columbia and Willamette rivers is consistent with discharge measurements, but suggests full mixing does not occur until at least 40 km downstream. (Mixing model using $\delta^{18}O$: 3.6% Willamette River; using discharge[8]: 5.7% Willamette River)
- Multnomah Channel, an anastomosing channel of the Willamette River, consists of nearly 50% Columbia River water, suggesting that Columbia River groundwater flux is significant.
- Low d-excess values in Sturgeon Lake indicate that approximately 25% of lake water has evaporated[9], likely because connecting channels have been severely limited due to human activity.

We can use these findings to make further mass balance and evaporation estimates throughout the Columbia and Willamette watersheds, as these bodies of water have isotopically distinct signatures. Future research should expand sampling to include waters further from shore to investigate mixing processes. Analyzing additional areas on Sauvie Island, including ponds and streams not accessible to the public, could indicate how surface water composition evolves. Applications include monitoring lake and wetland restoration on Sauvie Island, and tracking how changes in precipitation patterns affect watershed hydrology.

References

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For correspondence: saslaw@pdx.edu