Assessing the Role of Glacial Water in the Peruvian Bofedales with Water Isotopes

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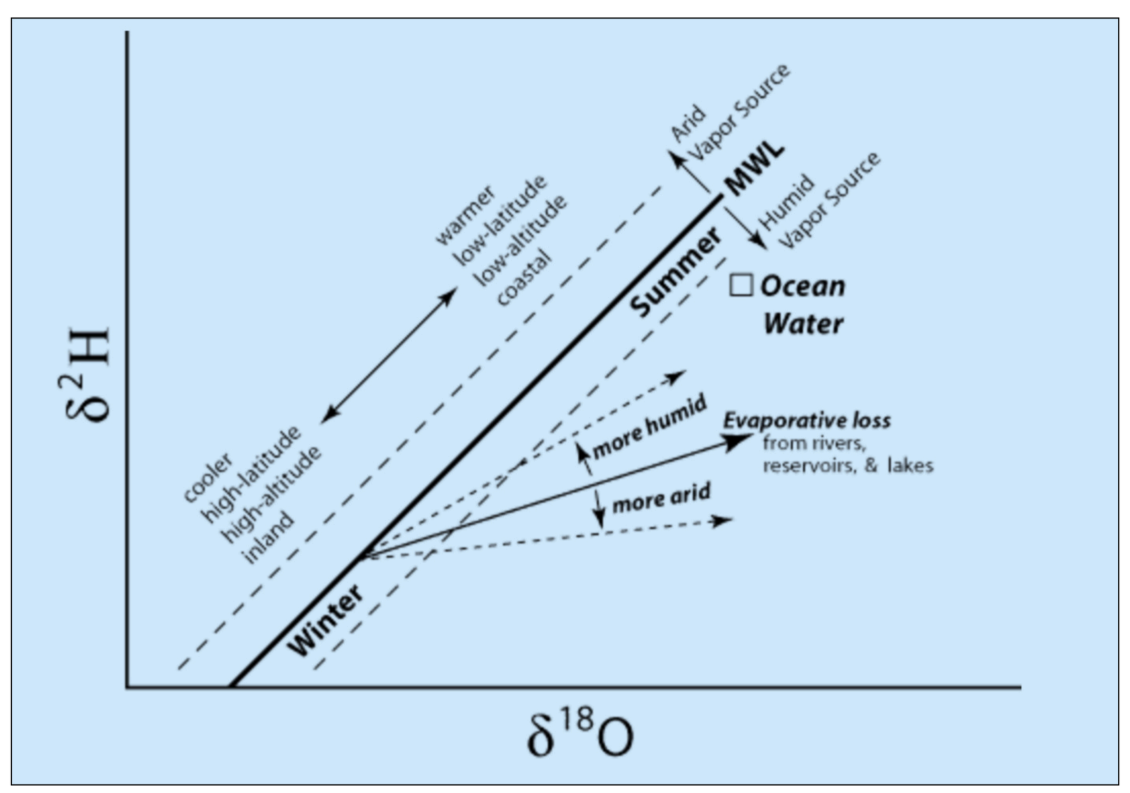
INTRODUCTION

Peruvians of high altitude wetlands require streams and wetlands to maintain their agricultural societies. The three main sources of water to these wetlands, referred to as bofedales, are glacial melt water, spring water, and precipitation. Rising air temperatures associated with climate change are driving glacial recession in these regions. If the quantity and timing of meltwater inputs changes, will spring water and precipitation provide sufficient water to support the Peruvian communities year-round in the bofedales? This study uses water isotope data from bofedales in this region to determine the predominant source of water supporting these high altitude wetlands during the dry season.

Isotope fractionation can be a useful tool to determine water sources in landscapes with multiple and distinct contributing sources. This is possible because different water sources have different ratios of oxygen and hydrogen isotopes. The two predominant oxygen isotopes are ^{16}O and the heavier ^{18}O, whilst the two hydrogen isotopes are ^{1}H and ^{2}H (deuterium). Lighter isotopes require less energy to be evaporated-condensed than heavier isotopes. Because of this, at the Andes' high elevations, the water is depleted (low in ^{18}O). Worldwide, waters recharged from different precipitation events or flow paths are chemically unique and have different isotopic fingerprints.



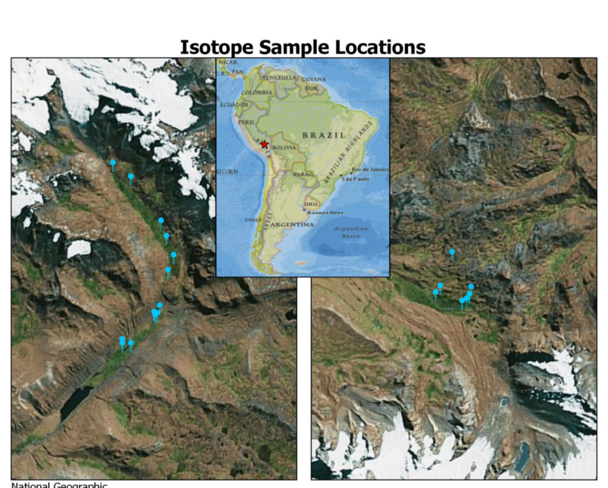
The Global Meteoric Water Line (GMWL) can be used to compare water isotope values worldwide because it displays the global average isotopic values of precipitation.

Figure 1. Conditions that alter the slope of the GMWL . Image source: SAHRA

Regional samples often have isotopic data that plots away from the GMWL or at a different slope than the GMWL's of $^{2}H = ^{18}O(8) + 10$. Varying from the GMWL creates a Local Meteoric Water Line (LMWL) and can be attributed to temperature, latitude, altitude, and distance inland (Figure 1).

BACKGROUND

Our bofedale field sites are located in the Ocongate Region of southeastern Peru, approximately 100 kilometers from Cusco. This environment's geology, climate, hydrology, and altitude affect the chemistry of the water found there.

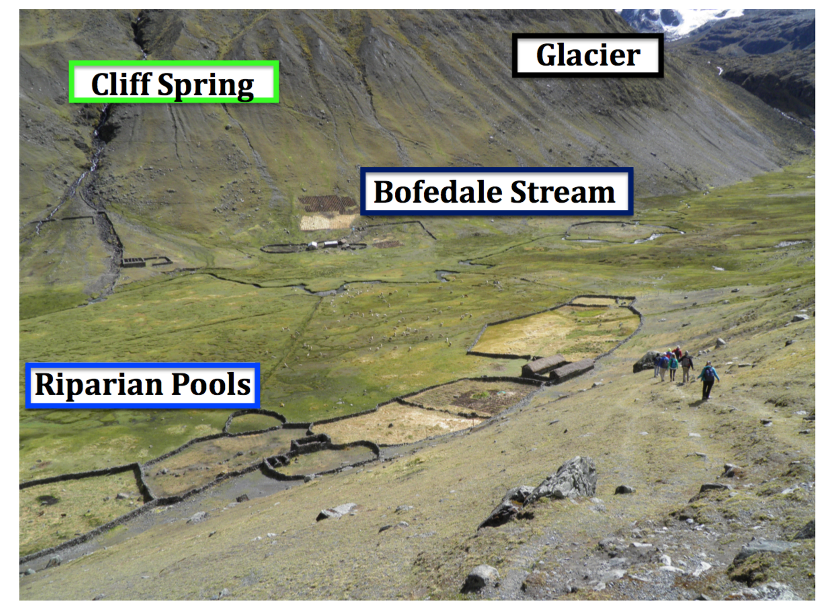


- The wet season aligns with the primary growing season in Peru and occurs between November and April.
- The dry season in Peru begins in May and ends in October. During this time, water sources other than precipitation sustain livestock

Figure 2. Site locations. Part A shows northern sites (Image reproduced from Brown and Jordan, 2016). Left side is north of the right

METHODS

The isotopic water samples were taken in May during the dry season, from a variety of sources including stream water, direct rainfall, spring water, and riparian pools in the wetland.



Although distinguishing water sources at high altitudes is difficult because the samples already have depleted levels of ^{18}O, using the highly accurate Picarro Isotope Analyzer L2130 made this possible

Figure 3. Imagery of diiferent sampling sites within the Ampatuni bofedale (Image credit: Nassry, 2016; edited by Cullen, 2016)

RESULTS

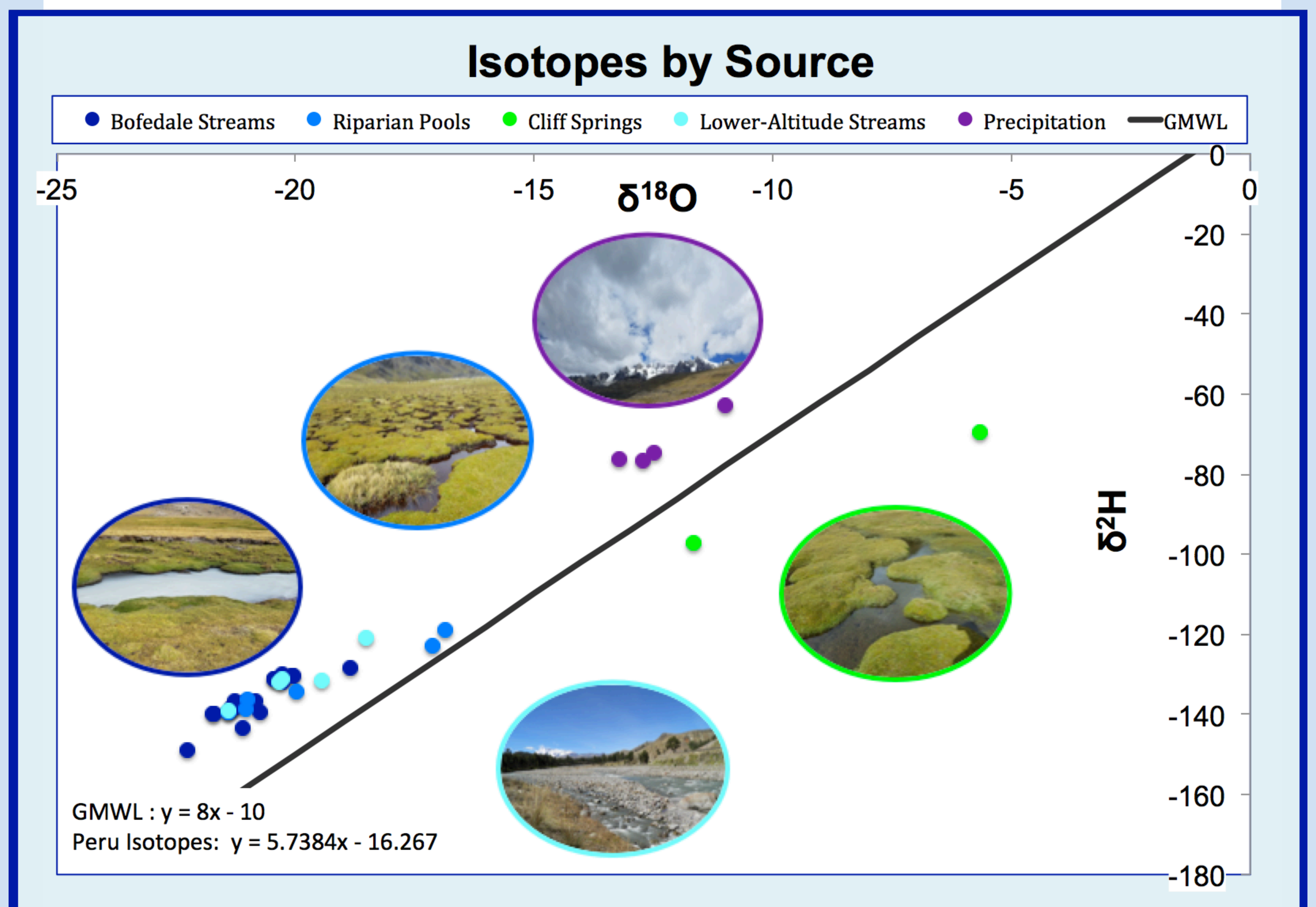


Figure 4. This graph represents the isotopic values of each site colored by sampling source (stream/ channel, pools, or cliff springs) compared with GMWL. The x-axis represents the ratio between the heavier ^{18}O, and the lighter ^{16}O. While the y-axis represents the ratio between the heavier ^{2}H, and the lighter ^{1}H. The more negative the value, the more depleted the water sample is in that element

•Figure 4 shows the distinct isotopic compositions of waters from cliff springs, riparian pools, and stream/channels.
•The data points plot off and at a lesser slope (5.738) than the GMWL's slope (8).
•There is crossover in isotopic identity of the pools and of the streams/channels that suggests they are often chemically similar.
•The cluster of the bofedale streams, riparian pools, and low-altitude streams are more depleted in heavier isotopes than the cliff springs and precipitation.

DISCUSSION

The LMWL slope, indicated by the data points, is less than that of the GMWL. This is indicative of an environment with higher evaporation rates than the global average, which correlates with the region's climate. It also coincides with the fact that the sampling occurred in May, part of the dry season.

After the riparian pool samples were analyzed, the clustering of isotopic data suggests that they are largely supported by glacial meltwater. When analyzed, the spring water samples were shown to be more enriched than the cluster of stream/channel points. This means that these springs are a distinct source from the glacially supported streams/channels.

The majority of points, especially the stream and pool samples, are more depleted in ^{18}O and deuterium, plotting in the lower part of the GMWL that is characteristic of high latitude inland regions (Figure 1). The placement of nearly all of the data points, with exception to the two rock spring points and the precipitation samples, clustered around the glacial streams suggests that the glacial melt waters sustains this wetland system, at least during this time of the year in the dry season.

CONCLUSION

Isotopic compositions of water from cliff springs, riparian pools, and streams/ channels were analyzed to determine hydrologic sources sustaining the bofedales during the dry season. *The water isotopes in the Peruvian bofedales suggest that glacial meltwater is the main water source for these wetland systems during the dry season.*

To build upon the results of this study, it would be useful to:

- Repeat this study in the next dry season to see if these results prove consistent
- Sample during the wet season to see if water source varies by season
- Gather more precipitation data to simulate a better LMWL

Figure 5. Peruvian farmers with llamas. Menzel, 2016

If the glaciers are eradicated, Peruvian farmers will be required to drastically change their lifestyle to remain in their cultural lands. If the bofedales dry out, the exposed wetland will release its stored methane. Methane is a greenhouse gas 30 times more powerful than CO_2 and would further contribute to climate change. The Peruvian bofedales fulfill critical ecological roles; preserving these systems should be a conservation priority.

REFERENCES

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