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USING FOSSIL POLLEN TO RECONSTRUCT SEASONAL PRECIPITATION IN THE SIERRA DE SAN PEDRO MÁRTIR RANGE

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The North American Monsoon (NAM) is an annual weather phenomenon that extends through central and northern Mexico into Arizona and New Mexico, providing a significant portion of total annual precipitation for this region between July and September (Higgins et al., 1999). Previous research by Barron et al. (2012) suggests that conditions prior to 8,000-6,000 years BP would have supported increased NAM precipitation west of 114° W during the summer months (Figure 1). This theory relies heavily on sea surface temperature and coastal upwelling records from the Gulf of California and along the Pacific Coast, which indicate weaker coastal upwelling and relatively cold Gulf temperatures in the early-Holocene and mid-Holocene (Barron et al., 2003; Barron et al., 2005; Pisias, 1978). This means that NAM precipitation in the early-Holocene may have been driven by moisture from the tropical Pacific and covered a wider extent than Gulf of California moisture-driven NAM precipitation that is seen today (Barron et al., 2012).

While previous work has relied on sea surface temperature and upwelling proxies, one of the aims of this project is to reconstruct paleoclimate conditions in Baja California using a terrestrial core sample. This project contributes to ongoing research in Baja to understand the long-term climatic history of the region. Specifically, this study aims to gain a better understanding of the seasonality of phenomena such as the NAM and changes in its strength and extent over time. Additionally, these preliminary results provide the beginnings of a proof-of-concept for using a non-traditional pollen count methodology to reconstruct a history of seasonality.

Site Description and Methods

Core PA19 was collected in the Sierra de San Pedro Mártir (SdSPM) mountain range in May of 2019 from SdSPM National Park, Baja California. The SdSPM range has a semiarid climate, with an annual average precipitation of 382.1 mm (National Autonomous University of Mexico [NAUM], n.d.). The distribution of precipitation throughout the year is bimodal, with a summer wet period from July-September and a winter wet period from November-March (Figure 2a; NAUM, n.d.). However, rain and snow during the winter months accounts for a total of 36% of total annual precipitation, whereas the summer months only provide 23% (NAUM, n.d.). This site was chosen because it is situated outside the current extent of the NAM, but lies within the early-Holocene NAM extent proposed by Barron et al. (2012). The core was taken from an alternatingly wet-dry, ephemeral lake basin in the park.

Coring was carried out using a Vibracore, and pollen samples were processed using the methodology of Bennet and Willis (2001). This study largely follows the methods of Brunelle et al. (2010), constructing a history of seasonal precipitation using a summer moisture index. The summer moisture index is calculated first by identifying a number of winter-precipitation and summer-precipitation dependent taxa, then using a standardized ratio to return an index value:

$$Summer\ Moisture\ Index = \frac{(Winter\ total - Summer\ total)}{(Winter\ total + Summer\ total)}$$

The moisture index for a particular sample will return negative values when summer-precipitation dependent taxa are dominant, and positive values when winter-precipitation dependent taxa are dominant.

Using guides by Hevly (1964), Martin (1963), Mehringer (1965), and Thompson et al. (1999), two winter-wet taxa (*Ephedra* and *Artemisia*) and five summer-wet taxa (Asteraceae, Amaranthaceae, Poaceae, *Larrea*, and *Acacia*) were identified. Additionally, based on their presence in initial counts, *Abies*, Cyperaceae, and *Sarcobatus* were added to the winter-wet category to be counted (Thompson et al., 2015; Williams et al., 2006). Because of the non-traditional method of counting only these ten grains, rather than extracting indices from full counts, a pollen sum of 75 grains per depth sample (or 75 *Lycopodium* tracers) was agreed upon for this pilot study.

Results

The data presented here represent preliminary results from three subsamples of the core. Because an age-depth model has not yet been generated for this site, samples will be referred to by depth rather than age. Pollen counts from 0-1 cm, 2-3 cm, and 4-5 cm can be seen in figure 3. *Abies* was the most abundant taxon in each sample, followed by Poaceae. While other winter-wet and summer-wet taxa do show up at these depths, *Abies* and Poaceae are likely contributing the most to the summer moisture index calculation.

Results of the summer moisture index calculation can be seen in figure 4. Counts at the shallowest depth show an index value of 0.56, which decreases with depth to a value of 0.1 at 4-5 cm. Because no age-depth model has yet been calculated for this project, these results are difficult to place in a temporal context; however, it is fair to say that these results indicate a moisture regime dominated by winter precipitation at the Sierra de San Pedro Mártir site in the recent past. This is consistent with the climate that is observed in the region today (NAUM, n.d.) These limited results indicate that winter precipitation has become more dominant over recent depositional periods, indicated by the increasing moisture index value. As previously mentioned, it is likely that these changes are primarily being driven by the abundance of *Abies* and Poaceae, with *Abies* (a winter-wet taxa) becoming more abundant near the surface of the core, and Poaceae (a summer-wet taxa) becoming less abundant in the same direction. Overall, the site has enough winter moisture to support *Abies* growth, and the results of the summer moisture index agree with what is already known about the modern site.

In order to further verify the usefulness of the summer moisture index in this context, counts from Los Llanos de Kakiwi were used to produce a summer moisture index to compare against the PA19 site. The Los Llanos de Kakiwi site is located in southern Baja California, and unlike the PA19 site in northern Baja, experiences a bulk of annual rainfall during late summer and early fall monsoon rains (Figure 2b; Servicio Meteorológico Nacional, n.d.). Pollen counts completed by Logan Hastings (personal communication) using a similar list of key summer/winter dependent taxa were used to calculate summer moisture index values for three samples, the results of which can be seen in figure 4. Index values for all three samples were negative, indicating a summer-dominant moisture regime. The moisture index appears to match modern climate conditions at both these sites, showing the modern extent of monsoonal precipitation that covers southern Baja California, but does not extend to supply precipitation to northern Baja.

Though three samples per site is not enough to draw any conclusions, these results show the promise of using the summer moisture index to reconstruct the seasonality of precipitation at these sites. Index values return a winter-wet signal for PA19, which matches what we would expect given modern climate data. With the addition of more counted samples at greater depth along the core, as well as an age-depth model to contextualize results, this project could prove useful in reconstructing the precipitation shift proposed by Barron et al. (2012) in the mid-Holocene epoch.

These preliminary results also indicate the importance of several key taxa in reconstructing seasonality. While a total of ten taxa were used to calculate the moisture index, only two taxa, *Abies* and Poaceae, made up between 82-86% of the counts for each sample. Given the limited scope of these three counts, it is impossible to say how relative abundance of each taxon will change further into the core. However, in these shallow samples, it would seem that the signal of seasonal precipitation is tied closely to the relative abundance of these two taxa in particular.

<u>Figures</u>

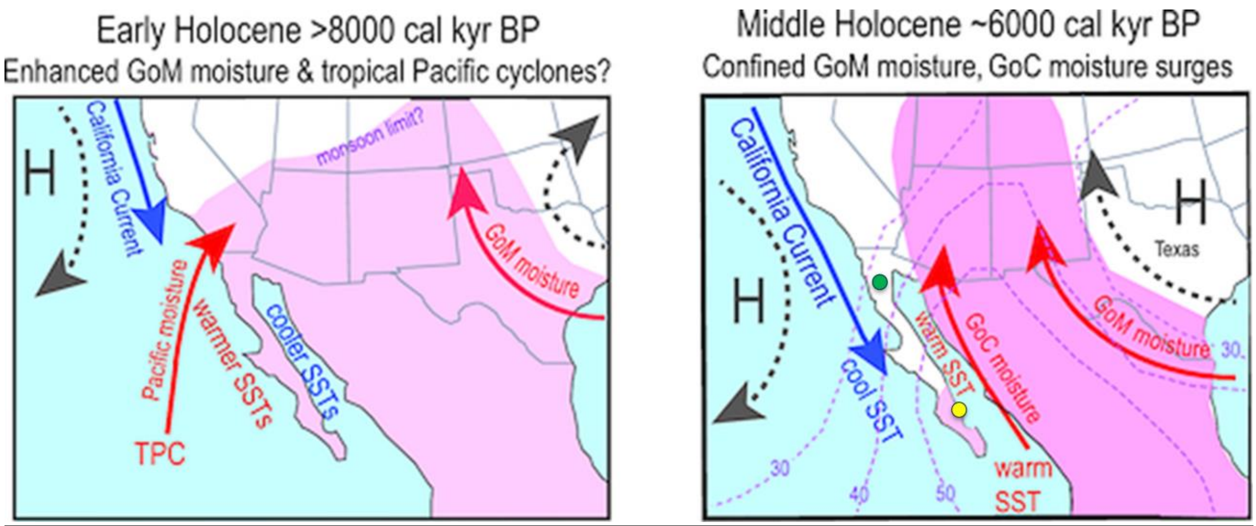

Figure 1: Map of Barron et al.'s (2012) proposed NAM shift with site PA19 marked in green and Los Llanos de Kakiwi in yellow.

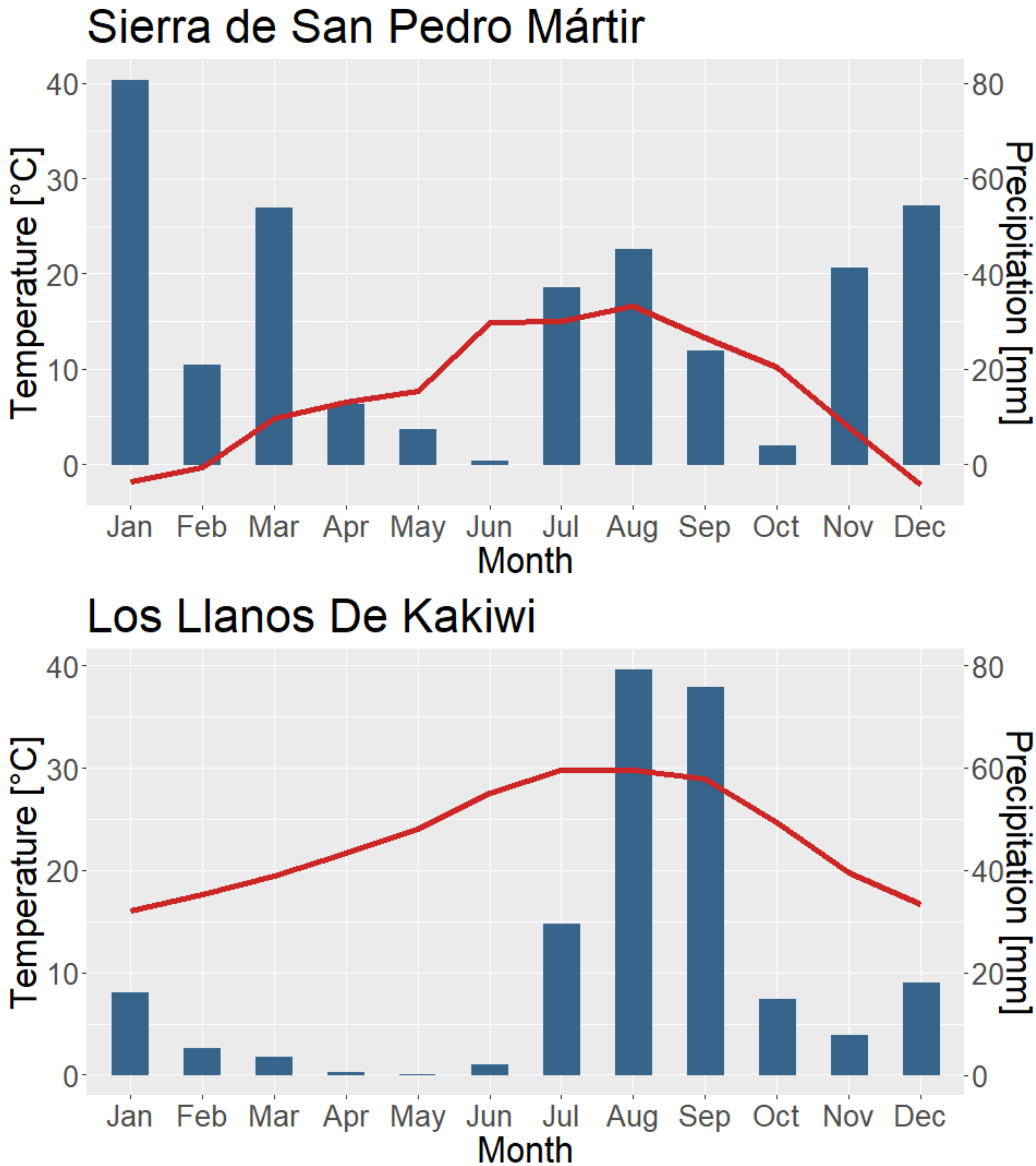

Figure 2: Climographs of the two study sites. **(a., top)** Average temperature and precipitation by month in the Sierra de San Pedro Mártir range, showing a bimodal precipitation distribution (NAUM, n.d.). **(b., bottom)** Average temperature and precipitation by month at the Los Llanos De Kakiwi site, showing NAM driven summer precipitation (Servicio Meteorológico Nacional, n.d.).

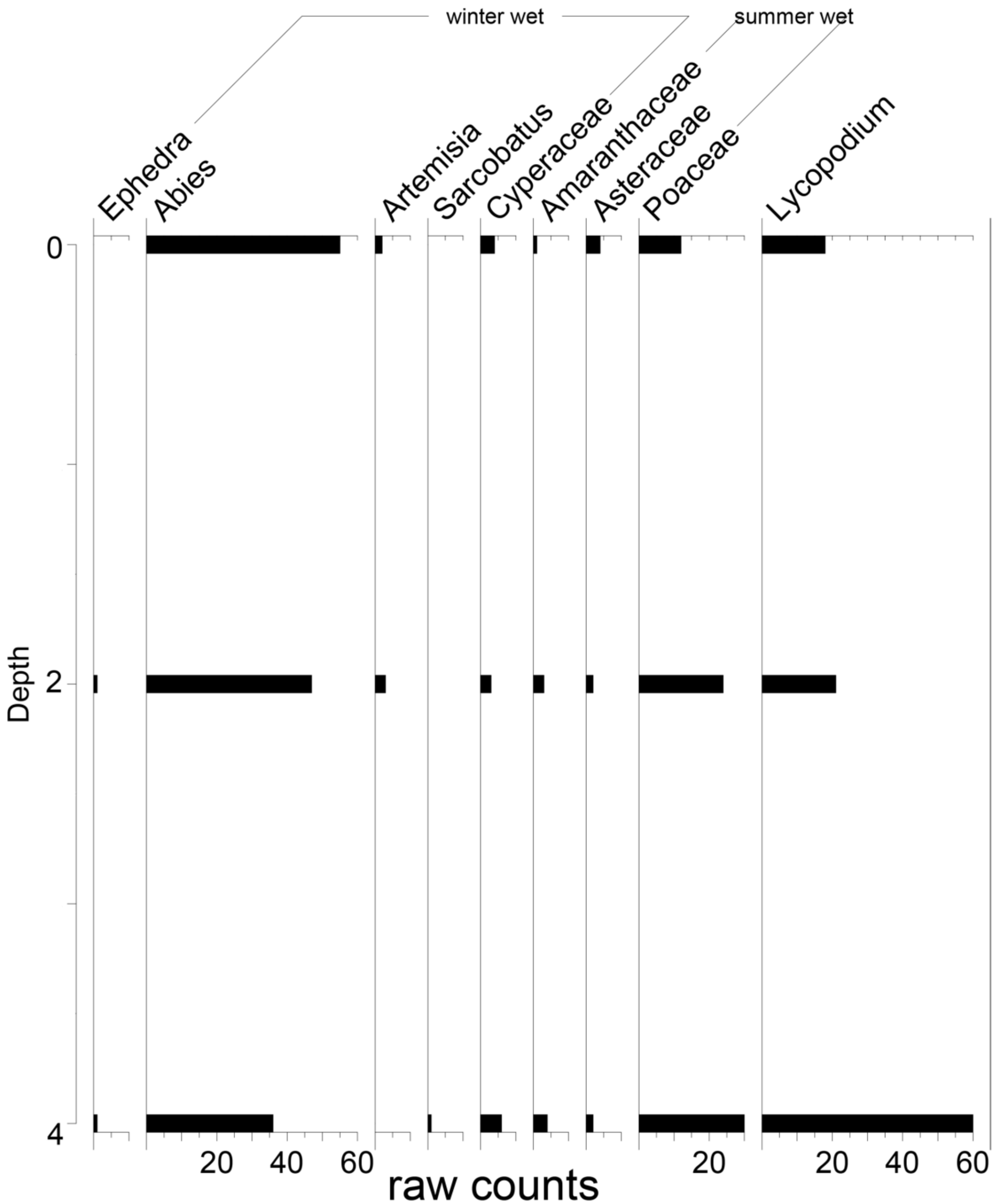

Figure 3: Pollen diagram showing the raw counts of moisture index taxa and *Lycopodium* tracer in the PA19 core. *Larrea* and *Acacia* were absent from all samples counted, and as a result have been excluded from this diagram.

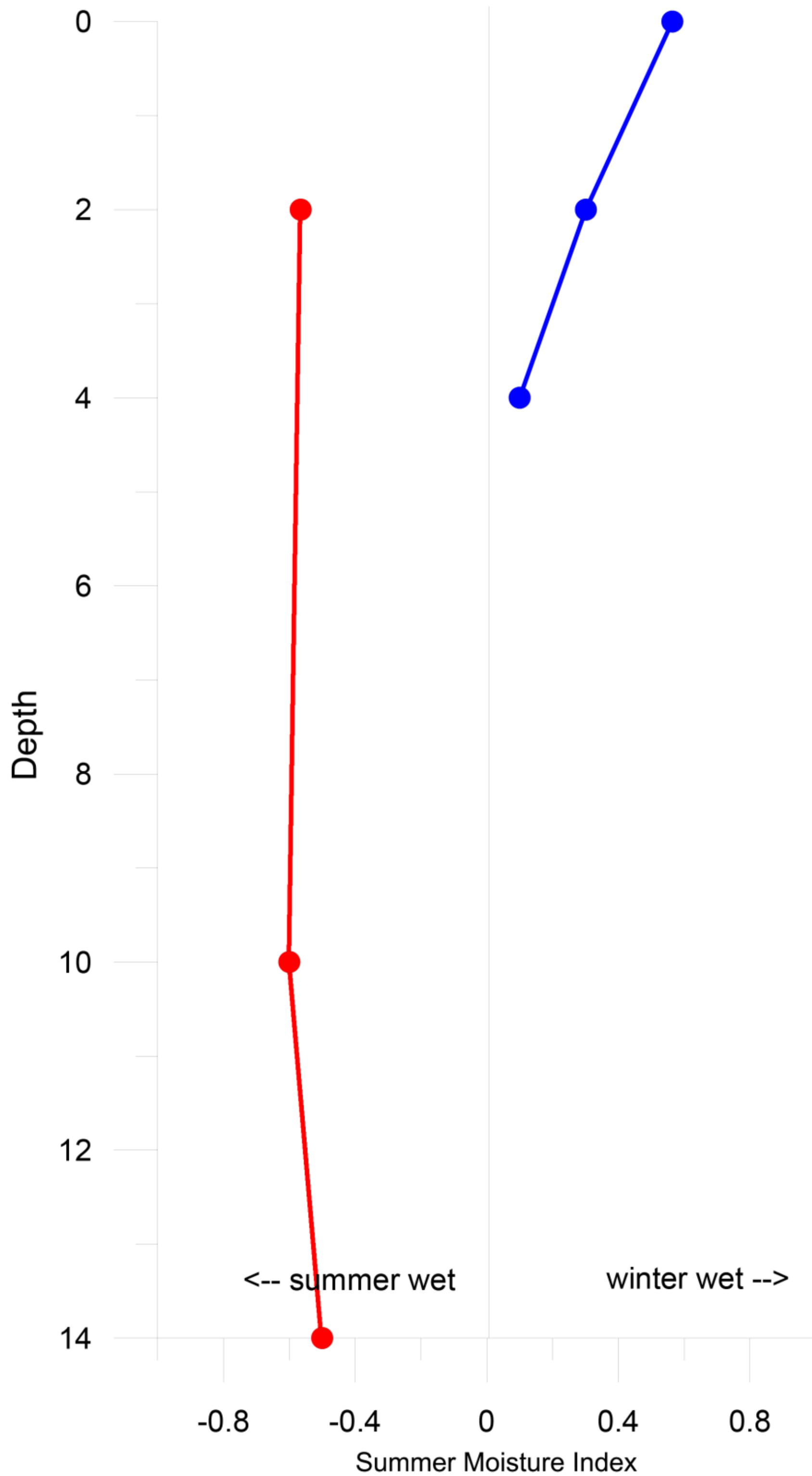

Figure 4: Summer Moisture Index values for two sites in Baja California. The blue line represents samples from the PA19 core in northern Baja California, while the red line indicates samples from the Los Llanos de Kakiwi site in southern Baja. The center dividing line indicates an index value of 0, marking the divide between summer and winter precipitation dominant regimes.

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