Ancient DNA recovered from sediment shows plant composition shifts with historical human demography

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Introduction:

Southern California has been a hotspot for human habitation, from when humans first arrived in the Americas around 14,000 years ago, up to now, the Modern Age. At first colonization in Southern California, distinct groups settled in coastal and inland areas. Coastal tribes became experts at catching marine and intertidal food items, and inland tribes adapted to life in the harsh desert. Lake Elsinore in Southern California was first settled by the Luiseño Tribe before European settlement in the 1790s. Evidence of this habitation is supported by archaeological evidence, which further supports that Lake Elsinore had stable human visitation or habitation throughout much of the Holocene (Grenda, 1997). Despite this legacy of human presence, studies that would elucidate the historical composition of the plants that cohabited this region with humans are scant.

Questions:

Q1. How has the plant community changed from the Pleistocene to the Holocene?

Q2. Are there significant shifts in community composition at the time of proposed human arrival?

Q3. Are there differences in the plant families recovered from shotgun metagenomic data versus target capture data?

Q4. Can we identify sequences to known useful plants? And further, does the abundance of useful species change significantly over time?

Methodology:

We used two sediment cores collected at Lake Elsinore; the first, LEGC03-3, which spans 9,800 years BP, and the second, LEDC10, which contains sediment that settled 33,000 years BP. We selected 88 samples which evenly span nearly 24,000 years of natural history. The first 40 samples were extracted from LEGC03-3, and the other 48 samples were extracted from LEDC10. These samples were selected using the age model of the core so that each sample is around 100-500 years older than the last.

We extracted DNA from the 88 samples in the Ancient DNA Lab at UCSC- a clean room laboratory designed to significantly reduce contamination of ancient samples. We first used a whole genome shotgun sequencing approach (WGS). Shotgun sequencing is suitable for use with environmental DNA (eDNA), as small, short sequences frequently present in the sample will be amplified and sequenced. This is typically done for cold-climate cores, where DNA is better preserved. However, warm-climate cores, like LEDC03-3 and LEDC10, are thought to be more degraded, so we used target capture sequencing using the MegaMammals baits and Angiosperms353 baits, which target specific genes for mammals and angiosperms respectively. This approach could lead to greater amplification of sequences from plant and mammals as opposed to contaminants or soil bacteria of fungi.

I used MG-RAST to analyze and compare within the target capture data and shotgun data (Figure 2). Using the target capture data, I made comparisons between time points across the entire dataset (Figure 1). I will then conduct a literature review by BLASTing and confirming presence of specific species, genuses, or families in the core, and then following the guidelines shown in Figure 3.

Preliminary results for Q1 and Q2: Capture data shows community shifts around climatic change, human arrival, and geologic time scale

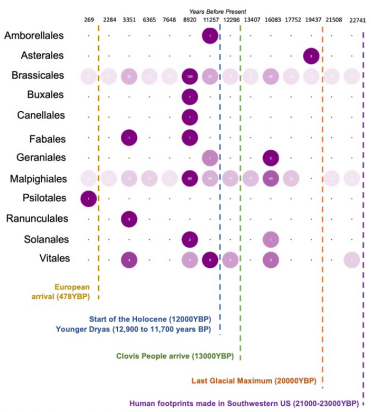


Figure 1: Shows the community composition of Eudicots using a subset of the capture data. We can see that some samples had greater diversity, and some plant Families were present in almost every sample across the core.

Q1; HOLOCENE VS PLIESTOCENE: We observe that following the start of the Holocene, samples have greater diversity on average. However, this diversity is not sustained across all years. Correlation of our data with local climate events and wildfire records (in out Future Directions) may elucidate the causes of biodiversity spike and decline.

Q2; HUMAN ARRIVAL: If humans arrived in Southern California around 13000ybp, we observe a biodiversity drop after a year of higher biodiversity than average. Levels of Brassicas and Malpighias, which are prevalent throughout all ages of the core, drop after entry of humans.

Preliminary results for Q3: Target capture and shotgun data recover similar plant communities

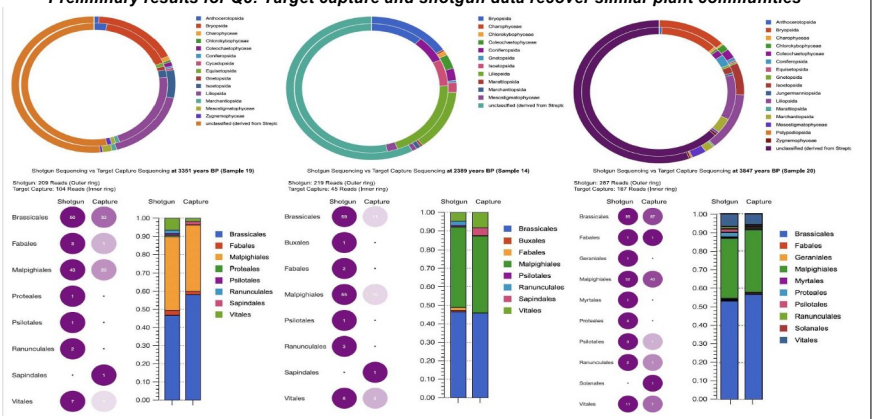


Figure 2: Comparison between the target capture data and shotgun data show that using a target capture approach to study warm climate soil cores may not be more successful than traditional shotgun sequencing. In our small pilot comparison, shotgun sequencing produced more quality filtered reads on average, and in one sample, produced 4x the amount of quality filtered reads than target capture sequencing.

Methodology for identifying useful plants in the core to answer Q4

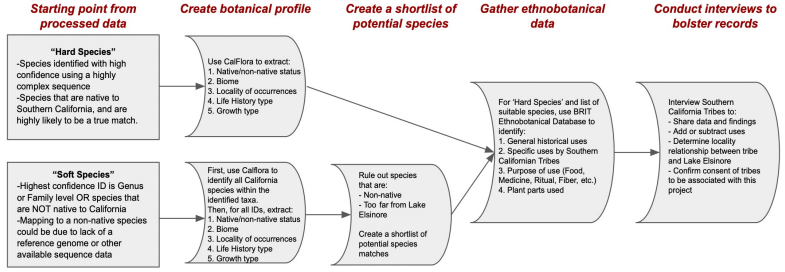
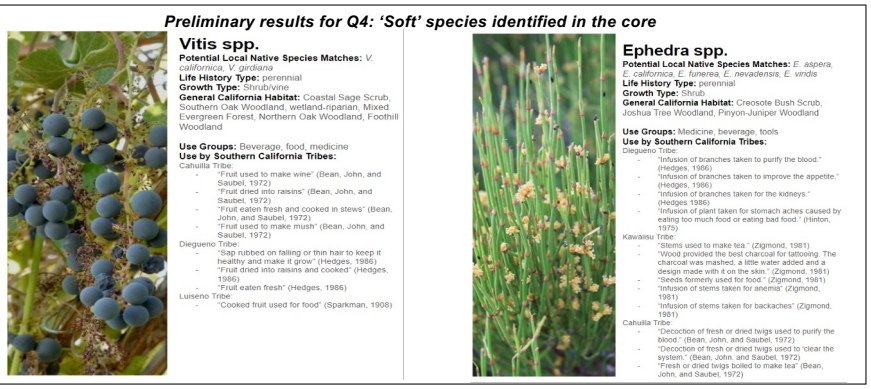


Figure 3: Flowchart for literature review following the identification of an ethnobotanically significant plant

Preliminary results for Q4: 'Soft' species identified in the core



Discussion:

Cross-cultural interactions between human groups and the extensive trade that develops from these interactions has been, and continues to be, uncovered and documented by archaeological technology. Figure 4 shows a detailed map of human migration, with many distinct haplogroups travelling through areas adjacent to Lake Elsinore. This area is known to have been home to at least one cultural group and could have been visited by migrant groups as they traveled through the US near the west coast. However, a record of plant species that these tribes have historically relied on for thousands of years is still largely unknown for the southwestern region of the US. These records of ancient plant use would reveal what people ate, how ancient humans treated illnesses, and how they clothed and sheltered themselves. Further, a record of plant could give key insight into how, and in what ways, the environment shaped human demography.

Map showing the location of Lake Elsinore

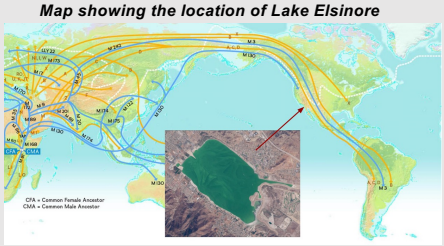


Figure 4: This map from The National Geographic Society shows the migration of human DNA haplogroups and mitochondrial haplogroups throughout the world and into the western United States. Lake Elsinore is located near these routes.

When humans entered California, they brought cultural practices and new ways of stewarding the environment with them. The masterful use of fire to burn a landscape could define species diversity by acting as a frequent disturbance. There are lots of extreme changes in the sediment cores extracted from Lake Elsinore- correlation between the charcoal record and species composition from eDNA analysis could reveal what type of environment humans arrived to, what what type of environment they preferred and created using fire.

Future Direction:

- Correlate species composition with charcoal data and pollen records
- Conduct additional, deeper sequencing on samples of interest
- Manually BLAST and confirm sequences we believe to be from ethnobotanical plants.
- Look for plants that could evidence trade between inland and coastal groups

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References:

Bean, Lowell John and Katherine Siva Saubel, 1972, Temalpakh (From the Earth); Cahuilla Indian Knowledge and Usage of Plants, Banning, CA. Malki Museum Press, page 70

Bennett, Matthew R., et al. "Evidence of Humans in North America during the Last Glacial Maximum." *Science*, vol. 373, no. 6562, 2021, pp. 1528–1531., https://doi.org/10.1126/science.abg7586.

Grenda, D. R. (1997). Site structure, settlement systems, and social organization at lake elsinore, california (Order No. 9814395). Available from ProQuest Dissertations & Theses A&I. (304352455).

Hedges, Ken, 1986, Santa Ysabel Ethnobotany, San Diego Museum of Man Ethnic Technology Notes, No. 20, page 19

Hinton, Leanne, 1975, Notes on La Huerta Diegueno Ethnobotany, Journal of California Anthropology 2:214-222, page 216

Sparkman, Philip S., 1908, The Culture of the Luiseno Indians, University of California Publications in American Archaeology and Ethnology 8(4):187-234, page 231

Zigmond, Maurice L., 1981, Kawaiisu Ethnobotany, Salt Lake City. University of Utah Press, page 27