Groundwater use by mesquite near the Borrego Sink

Project Update

19 November 2024

Product of the *Groundwater Dependent Ecosystems (GDE) Identification, Assessment, and Monitoring Program* (hereafter 'the GDE Project')



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To: Geoff Poole, General Manager, Borrego Water District; and
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Proposition 68 Sustainable Groundwater Management Grant Program

From: Travis Huxman, Professor and Chair, Department of Ecology and Evolutionary Biology, University of California, Irvine

Subject: Proposition 68 Project Update summarizing recent findings regarding groundwater dependent ecosystems in the Borrego Springs Groundwater Subbasin.

We are pleased to share the attached project update "Groundwater use by mesquite near the Borrego Sink." This is in continued satisfaction of our Work Plan relevant to identifying groundwater dependent ecosystems in Borrego Springs and developing a monitoring plan based on those findings. We will be sharing this document with the Borrego Springs Watermaster for consideration by their appropriate subcommittees, along with stakeholders in the Subbasin.

This document reports on our stable isotopic determination of water in tissues of mesquite trees throughout the Borrego Springs Groundwater Subbasin and the paired comparison site, Clark Dry Lake. Our team has found a signature of groundwater in water extracted from mesquite tissue sampled from multiple sites near the Borrego Sink. The conclusions drawn from these data further strengthen the notion of groundwater dependent ecosystems in the Subbasin. We additionally update several aspects of our program, including 1) aspects of our infrastructure that directly measure evapotranspiration, 2) potential remote sensing approaches that can be used for long-term monitoring, and 3) the status of our work assessing GDE biological diversity.

We anticipate further insights to come to light, from our project, from you, and from other stakeholders as we complete work and close out this project. These insights will shape next steps for many stakeholders in the basin, including the Watermaster and their contemporary focus on estimating sustainable yield. We anticipate an additional project update prior to the final report we will produce at the end of the project period in March 2025. We look forward to your comments, questions, and assistance disseminating this document through your website.

Summary

- Our first update identified data errors and knowledge gaps that led the Borrego Springs Groundwater Subbasin GMP to ignore groundwater dependent ecosystems (GDE).
- Our second update (1) utilized remote sensing, aerial photography, and field surveys to document approximately 1,800 acres of mesquite bosque habitat near the Borrego Sink exhibiting GDE behavior, (2) provided an initial estimate of groundwater use by mesquite at around 536 acre-feet, and (3) used stable isotopes of oxygen to demonstrate groundwater use at Clark Dry Lake (a site in the Ocotillo-Clark Valley Basin where groundwater is within 25 feet of the surface) in April 2023.
- Here we extend stable isotope analysis to mesquite near the Borrego Sink and find large percentages of groundwater in plant tissue (55 - 83%), confirming GDE presence in the Borrego Springs Subbasin. Groundwater fractions varied within and between sites in a way that may help determine either rates or elevations of groundwater decline that result in undesirable GDE outcomes.
- Our water potential results suggest similar levels of water availability for mesquite between a primary site near the Borrego Sink and our reference site near Clark Dry Lake.
- In 2024, we deployed evapotranspiration sensors across mesquite bosque sites in Borrego Springs and Clark Dry Lake to directly measure groundwater transpired by mesquite.
- We are refining methods for using remotely sensed datasets to assess mesquite health and groundwater use across the Subbasin.
- We continue to document significant GDE reliant biodiversity, including 195 native plant species within the mesquite habitat near Borrego Sink and 175 native plant species within the mesquite habitat near Clark Dry Lake, 17 of which are threatened, endangered or rare, along with more than 45 animal species, 5 of which are species of special concern.
- Interested parties can leverage these findings to help avoid undesirable outcomes associated with groundwater decline given GDEs' role as beneficial users through the 2014 Sustainable Groundwater Management Act (SGMA).

Introduction

The 2014 Sustainable Groundwater Management Act (SGMA) stipulates that all beneficial users of groundwater, including environmental users such as groundwater dependent ecosystems (GDE), be considered in Groundwater Sustainability Plans (GSP) (California Water Code, Part 274, Chapter 4, Section 10723.2). Under SGMA, GDEs are defined as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface"

(California Code Regulations, Title 23, Section 351(m)). While the Borrego Springs Subbasin Groundwater Management Plan (GMP; Borrego Water District and County of San Diego, 2020) originally dismissed GDE presence in the basin, our work funded through the Proposition 68 Sustainable Groundwater Management Grant Program showed that this decision was based on incomplete data sources and flawed analyses (UCI, 2023 Technical Memorandum).

Subsequently we identified several lines of evidence that point to the presence of GDEs in the Borrego Springs Groundwater Subbasin (UCI, 2024 Project Update). To address the knowledge gaps, we produced high quality maps of mesquite bosque habitat from aerial photography using machine learning. When constrained by live tree distribution, this mapping yields ~1,800 acres of potential GDE. Within this distribution we have used the "green island" conceptual framework to detect GDEs with remote sensing (Eamus et al. 2015). This method compares vegetation characteristics between areas with unknown access to groundwater and those with and without access. Combined, we have identified wide-spread hot-spots of GDE activity near the Borrego Sink using these indirect measurements of plant activity. We extended these efforts using available remote sensing tools for evapotranspiration estimation (OpenET) to provide a reasonable upper bound for groundwater use by GDEs for consideration in the Subbasin's water budget (~536 acre feet year^{-1}).

Here, we present recent isotopic analysis findings that confirm groundwater use by mesquite throughout the Borrego Springs Subbasin. Isotopic analyses show groundwater signatures within mesquite tissues, and are supported by field measurements of water potential that reveal similarities in mesquite water availability between the Borrego Springs and Clark Dry Lake sites, indicative of groundwater access. Further details of our methods and analyses will be included in our final report, anticipated for release in March 2025 on the Steele/Burnand Anza-Borrego Desert Research Center website.

Key Findings

1. Isotopic analyses document groundwater use in Borrego Springs and Clark Dry Lake

Our project team uses stable isotope signatures of oxygen in plant-extracted water to partition the source of that water between the surface soil and groundwater pools (methods in Appendix A). Isotopic analysis is a scientific technique used to study the types of atoms (isotopes) present in a substance. Stable isotopes are naturally occurring versions of an element that have the same number of protons but different numbers of neutrons. Scientists measure the ratio of different isotopes of the same element in a sample and this ratio provides information on the origins of the sample because different processes (such as evaporation) leave distinct isotopic "signatures." For instance, lighter

isotopes (e.g., ^{16}O) evaporate more readily than heavier isotopes (e.g., ^{18}O). Therefore, different levels of exposure to evaporation will result in a different isotopic signature (Barnes & Allison 1988). For this reason, groundwater and surface soil water have different isotopic signatures because of their different paths through the environment and residence times. Surface soil water is strongly affected by the evaporative demand of the atmosphere and receives localized rainfall, so the light-versus-heavy oxygen isotope differs as compared to values from aquifer water. This means that surface soil water loses its "light" isotopes frequently, and retains more of the "heavy" isotopes (higher neutron number; e.g., ^{18}O). We represent the results of isotopic analysis as a delta value relative to the heavier isotope (e.g., $\boldsymbol{\delta}^{18}O$) where larger values indicate enrichment in heavy isotopes, demonstrating the signature of evaporation. Plants absorb water through their roots, which can come from sources at various depths. Thus, the composition of water at any given time in plant tissues is a function of these differential uptake patterns from the various depths. We use these values - surface soil water sampled over the depth of rainwater influence, water from the aquifer, and water extracted from plant tissues - to test our hypotheses regarding the presence of GDEs (Fig. 1).

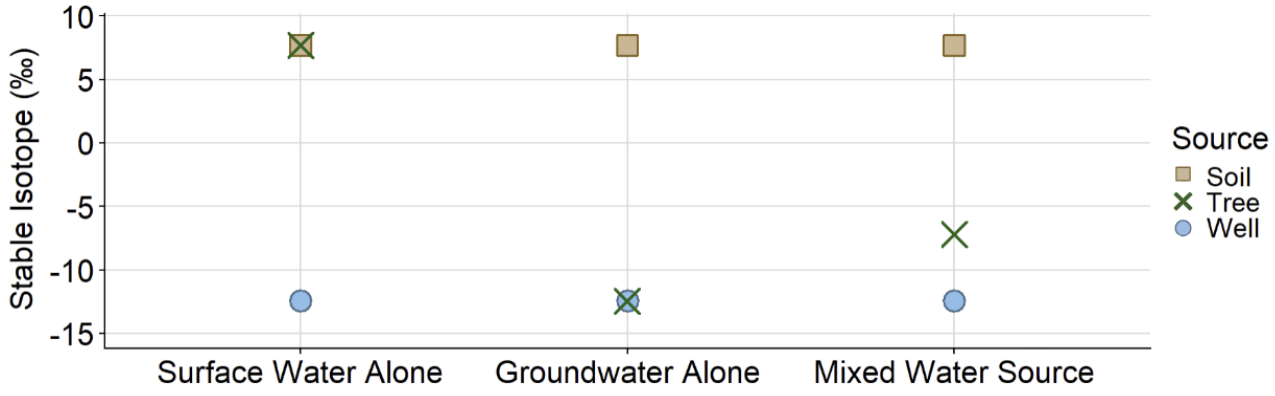


Figure 1. Expected behavior of isotope signatures found under different water-use contexts by trees. For *Surface Water Alone* there is an overlap of the isotope composition (as 'parts per thousand' (‰) compared to a standard reference) of the soil water and tree tissue water. Any variance in the tree tissue water data should be explained by the variance in the soil water signal. In the *Groundwater Alone* scenario (not expected but included as a hypothetical comparison), there is no overlap between the soil water isotope composition data and the tree isotopic composition data; all variance in tissue isotopic composition is explained by the groundwater isotope signal. In the *Mixed Water Source* scenario, the tree tissue isotopic composition is intermediate between the soil water and groundwater isotopic composition. This can be conceptualized by the notion that the surface water signal is diluted by the groundwater signal in the tree tissue.

Previously we reported on the use of this technique at the recognized GDE, Clark Dry Lake, to show that surface water cannot alone explain the isotopic signature of mesquite tissue water (UCI, 2024

Project Update). Rather, the plant extracted water isotopic signature includes an evenly-mixed to majority-contribution of the local groundwater (Fig. 2). Consistent with the pattern at Clark Dry Lake, mesquite from sites near the Borrego Sink also demonstrate a dilution of the soil surface oxygen isotope values by the groundwater signature (Fig. 2). In each case (Sites 1-5), there is no overlap between the distribution of mean soil oxygen isotope values and the plant tissue extracted isotope values. The data exhibit the trend expected from our *Mixed Water Source* scenario explained in **Figure 1**. This suggests that mesquite trees draw water from both sources, which is consistent with other research showing that mesquite are facultative phreatophytes that can utilize both surface water and groundwater depending on availability (Brunel 2009).

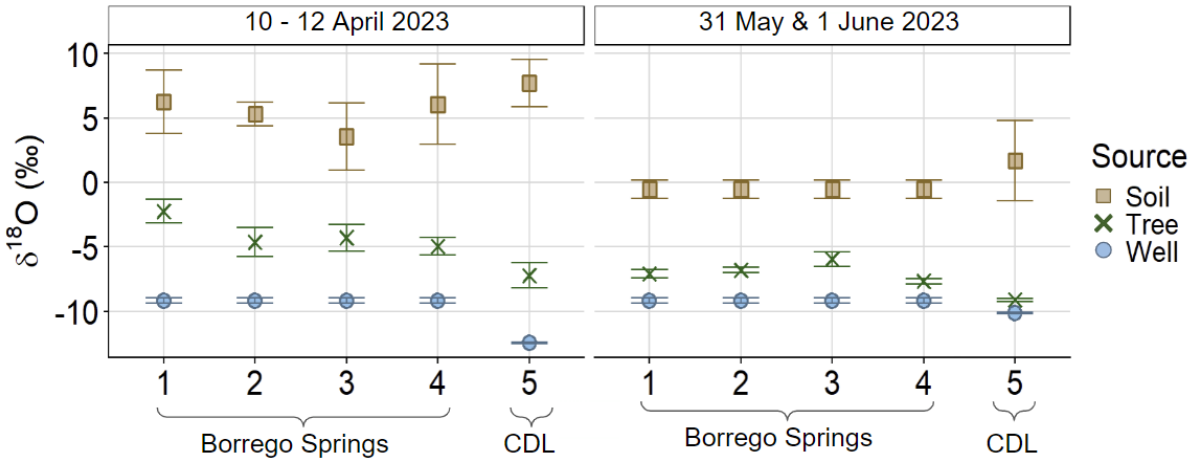


Figure 2. $\delta^{18}O$ of the soil water (brown squares), tree tissue water (green crosses), and well water (blue circles) at the five sentinel sites in Borrego Springs and the reference site at Clark Dry Lake. Well water is a value derived from the most-adjacent well sample possible. These data indicate a mixed water source for mesquite at all locations. The soil, tree, and well water are represented by the mean (point) and standard deviation (error bars).

We can use the isotope data in a simple, two end-member mixing model to estimate the percentage of groundwater in mesquite tree tissue (Fig. 3). In these models, groundwater is one end-member and the average soil profile value as the other end member (Post 2002). This approach assumes that soil moisture contributes uniformly as a source across 0-150 cm soil depth to patterns of root uptake, which is a conservative estimate for determining the end-member. Equation 1 below is an example of how this mixing model calculates the proportion of groundwater in mesquite tissue using average $\delta^{18}O$ data from all 12 trees at the primary Borrego Spring site (Site 1), the MW-3 and MW-5A well water, and the average soil profile values from the primary Borrego Spring site (Site 1) in May 2023.

$$\text{Proportion of groundwater in mesquite tissue} = \frac{\delta^{18}O_{Tree} - \delta^{18}O_{Soil}}{\delta^{18}O_{Well} - \delta^{18}O_{Soil}} \quad (1)$$

$$\text{Proportion of groundwater in mesquite tissue} = \frac{-7.09 - (-0.54)}{-9.18 - (-0.54)}$$

$$\text{Proportion of groundwater in mesquite tissue} = 0.76$$

$$\text{Percentage of groundwater in mesquite tissue} = 76\%$$

When expanded to all sites in Borrego Springs, the average $\delta^{18}O$ values illustrate between 55% (Site 1 in April) and 83% (Site 4 in May) of the water in mesquite tissues originating from the groundwater isotopic signature (Fig. 3). At Clark Dry Lake, average $\delta^{18}O$ values shift from 73% in April to 91% in

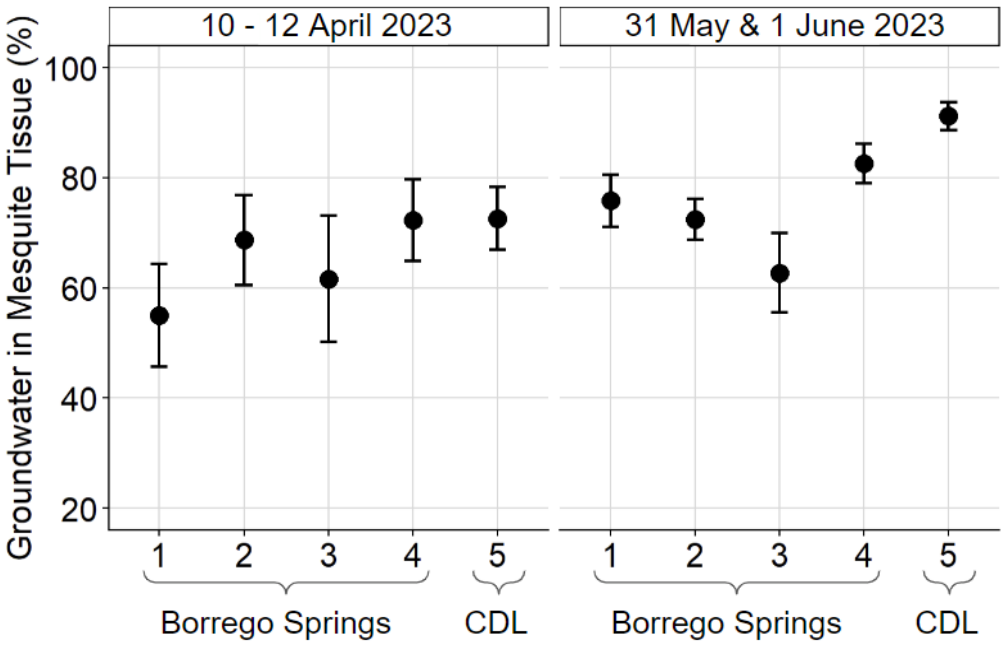


Figure 3. Groundwater fraction in plant tissues calculated from $\delta^{18}O$ of the soil water, tree tissue water, and well water for each of the five sentinel sites in Borrego Springs and the reference site at Clark Dry Lake using a two-end mixing model as in equation 1. Well water is a value derived from the most-adjacent well sample possible.

May. These fractional values increase as surface soil moisture is depleted during the growing season and progresses into the summer dry period (transition from April to May), which is what we expect from a GDE during extended dry periods without rainfall. We used the Elementary School weather station and the Clark Dry Lake weather station to assess the date of last rainfall at the Borrego Springs site and the Clark Dry Lake site, respectively. At the primary Borrego Springs site (Site 1), it had been

10 days since rainfall (0.25 mm) by the time of the April sampling campaign and 62 days by the May sampling campaign. At the primary Clark Dry Lake site (Site 5), it had been 19 days since rainfall (15.8 mm) by the time of the April sampling campaign and 71 days by the May sampling campaign.

Mesquite trees throughout all sampled locations near the Borrego Sink have signatures of groundwater. While there is some variation in the mean groundwater fraction between locations, most of the variation comes from differences in a few individual trees at select locations (Sites 1 and 3; Fig. 4). We are still investigating the driver of this tree-to-tree variation, which likely can be explained by

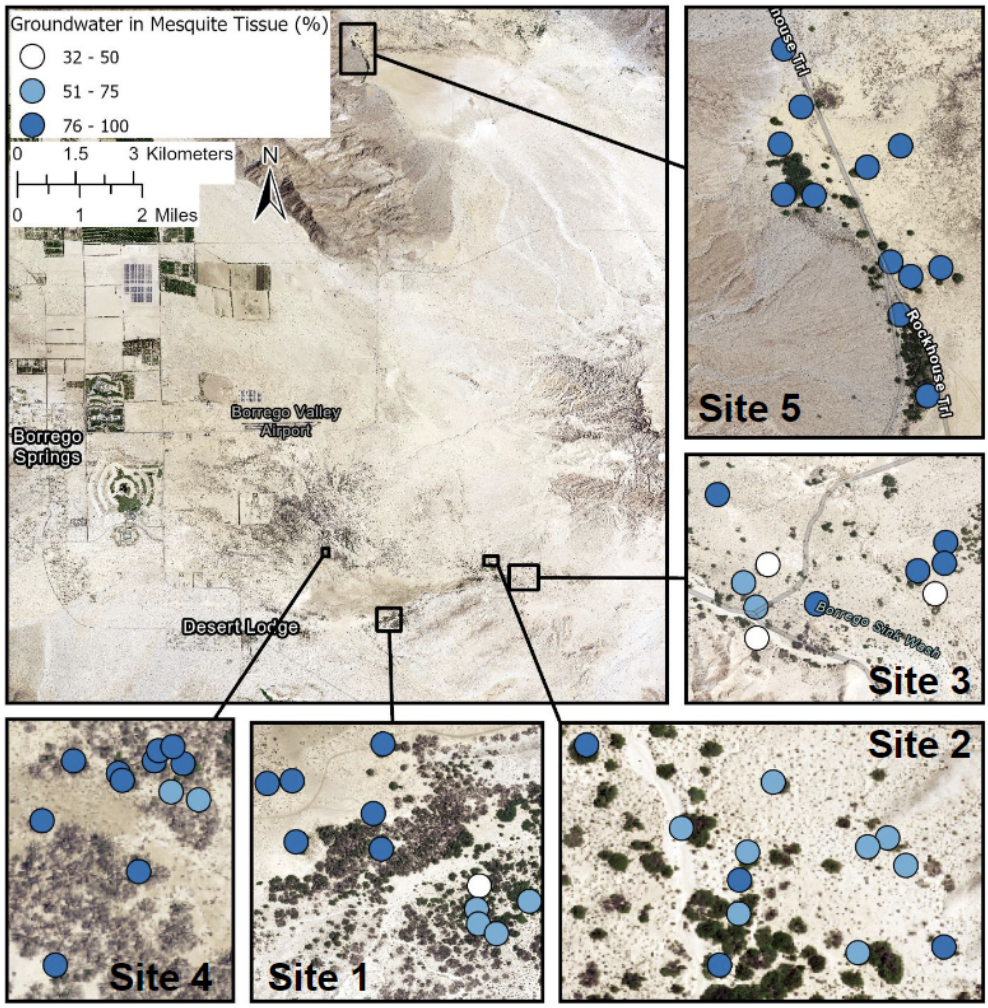


Figure 4. Spatial representation of the groundwater fraction in plant tissues calculated from $\delta^{18}O$ of the soil water, tree tissue water, and well water for each of the four sites in Borrego Springs and the reference site at Clark Dry Lake using a two-end mixing model as in Equation 1. Well water is a value derived from the most-adjacent well sample possible. Base imagery from the National Agriculture Imagery Program (NAIP) taken 22 - 23 April 2016.

plant age, rooting depth, or access to surface soil moisture. Yet the overall conclusion of these data is that mesquite trees throughout their distribution near the Borrego Sink are accessing groundwater. One opportunity is to leverage differences in groundwater elevation in conjunction with the groundwater fraction data to understand where mesquite may be losing contact with the aquifer or experiencing such rapid declines in groundwater elevation that they cannot adjust their rooting depth to keep up with the change. Thus, we are hopeful that the enhanced hydrologic modeling of the Borrego Valley can inform these data and this key issue in understanding GDE health.

2. **Water potential results indicate similar water availability between site in Borrego Springs and site near Clark Dry Lake**

Leaf water potential reflects the balance between soil moisture supply, atmospheric demand, and plant water uptake and serves as a reliable indicator of water availability and moisture stress (Lambers et al. 2008). As plants transpire (lose water through small leaf openings called stomata) water flows from the soil to the roots. At predawn, when transpiration is minimal and water flow is equilibrated within the plant-soil system, leaf water potential is closely aligned with soil water potential, offering a baseline measure of water availability for plants. Lower, or more negative, predawn leaf water potential values indicate lower water availability. Similar values between condition, site, or plant reflect similar water availability in the soil-plant system.

Here we present the predawn water potential results from our 2023 sampling campaign in May to provide context for the 2023 isotopic analyses (see Appendix A for methods). Predawn leaf water potential was similar during the May sampling campaign between the primary Borrego Springs (mean = -2.02 , SD = 0.32) and Clark Dry Lake sites (mean = -1.87 , SD = 0.34) suggesting equivalent water availability to the mesquite at each site.

3. **Direct measurements of evapotranspiration with ET sensors in Borrego Springs and Clark Dry Lake**

We have expanded our direct measurements of plant activity to better complement our remote sensing analyses and estimates of vegetation groundwater use. In May 2024, we installed LI-COR evapotranspiration (ET) sensors at three mesquite habitat sites near the Borrego Sink, one mesquite habitat site at Clark Dry Lake, and at one non-mesquite habitat site near the Steele-Burnand Anza-Borrego Desert Research Center (Fig. 5). These new sensors measure ET every 30 minutes, providing crucial data on water movement in mesquite bosque habitats. ET is the combination of two processes:

bare-soil evaporation, where liquid water turns into vapor and rises from the soil surface, and transpiration, where plants release water vapor through small leaf openings called stomata. Together, ET moves water from the land to the atmosphere, playing a key role in the water cycle.

By tracking ET, we can estimate how much groundwater the ecosystem is using. In GDEs, plants often rely on consistent groundwater access, especially during dry periods when surface water is scarce and bare-soil evaporation is negligent. If ET exceeds rainfall or if ET remains steady or increases during drought, it supports the notion that the plants are utilizing groundwater resources. We will additionally use leaf-level measurements of water loss to validate these ET estimates. Monitoring ET patterns over time can help us assess the health of GDEs, quantify their groundwater use, detect changes in groundwater availability, and guide conservation efforts to ensure these ecosystems are sustainably managed.



Figure 5. The LI-COR LI-710 evapotranspiration (ET) sensor measures evapotranspiration by detecting water vapor released from plants and soil, offering real-time insights into the amount of water being transferred from the ecosystem to the atmosphere. Above is an image of the instrument located in the mesquite bosque habitat at Clark Dry Lake.

4. Refining remote sensing approaches to monitor GDE health and water use patterns

Building on previous efforts, this year we developed remote sensing methods to map and monitor GDE health and water use across the subbasin. By analyzing high-resolution multispectral imagery, LiDAR, climate data, and other environmental datasets, we can now assess ecosystem health in near real-time. Our approaches use normalized difference vegetation index (NDVI) to monitor vegetation health and greenness, and the normalized difference moisture index (NDMI) to track moisture levels, allowing for precise mapping of GDEs. This method can be applied across multiple seasons and years to create time-series assessments of ecosystem health. Our approach focuses on evaluating vegetation response during extended dry periods to identify possible groundwater use. Vegetation that maintains a high NDVI or NDMI throughout dry spells is likely connected to groundwater.

Here we demonstrate an approach to identify mesquite that may be using groundwater during a dry period in 2023, focusing on the 20-day window surrounding the May 2023 isotope sampling campaign (Fig. 6 and 7). Using Sentinel-2 imagery, we calculated NDVI at a 10-meter resolution, which captures detail down to large trees or patches of trees. In 2023, there was no rainfall from 31 March to 10 June, allowing us to examine mesquite NDVI behavior under prolonged dry conditions. We calculated the mean NDVI from imagery taken between 20 May and 10 June, corresponding to days 50–70 of the dry period and spanning 10 days before and after isotope sampling (Fig. 6). Areas with high NDVI (shown in darker green) are likely accessing groundwater, while areas with lower NDVI (in white or light green) may depend more on precipitation (Fig. 7). By comparing these trends in Borrego Springs with mesquite at Clark Dry Lake—where groundwater is within 25 feet of the surface—we can better understand the NDVI characteristics of groundwater-connected mesquite.

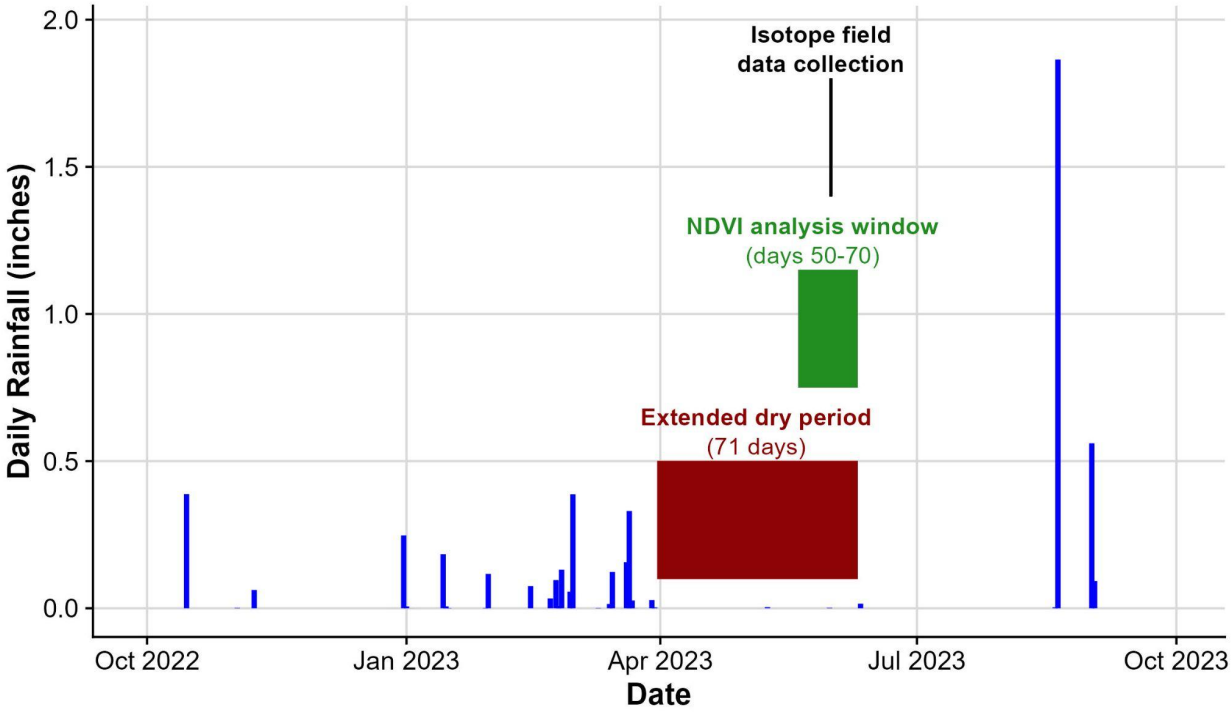


Figure 6. We can identify potential groundwater use by analyzing the normalized difference vegetation index (NDVI; a proxy for vegetation health and greenness) from satellite imagery during extended dry periods. During the 2023 water year, there was a dry period that spanned 71 days from 31 March to 10 June (shown in red). We analyzed imagery from days 50-70 of this drought (shown in green) to identify mesquite displaying high NDVI, indicating access to groundwater. This time frame corresponds to the 20-day window surrounding the May 2023 isotope field data collection (shown in black). Daily rainfall data (shown in blue) for the mesquite bosque distribution was obtained from PRISM Climate Group.

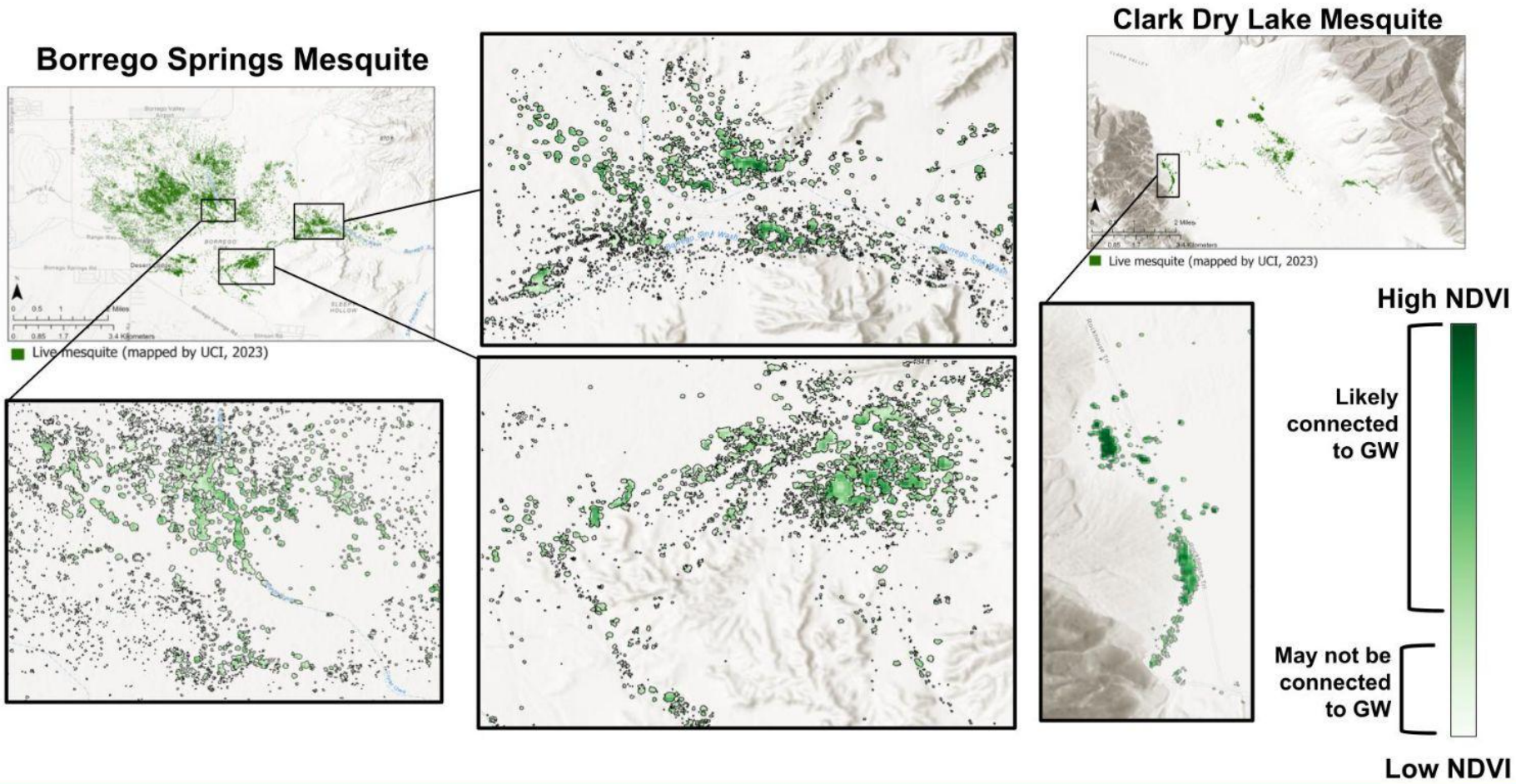


Figure 7. Example remote sensing approach to identify groundwater dependent mesquite using normalized difference vegetation index (NDVI; a proxy for vegetation health and greenness) from Sentinel 10 m satellite imagery. Map shows the mean NDVI from 20 May to 10 June 2023 (days 50–70 of the dry period in 2023). Areas with high NDVI (shown in darker green) likely have groundwater access that enables them to maintain high vegetation greenness during drought, while areas with low NDVI (white or light green) may rely more on precipitation.

Project Updates

Plant surveys of the mesquite bosque habitat

Borrego Springs Mesquite Bosque

In 2024, the San Diego Natural History Museum (SDNHM) documented 31 additional plant species in the mesquite bosque habitat near Borrego Sink, including 10 that had not been previously recorded in the area. Notable new findings included two sensitive species: *Cryptantha ganderi* (California Rare Plant Rank 1B.1) and *Cleomella palmeri* (2B.2). With data from recent surveys, voucher specimens, and verified iNaturalist observations, SDNHM's current inventory of plant species in this habitat now stands at 218, of which 195 are native and 11 are rare, endangered, or threatened. Of these, 49 species were newly observed during SDNHM's surveys in 2023 and 2024.

Clark Dry Lake Mesquite Bosque

In 2024, SDNHM identified 53 additional plant species in the mesquite bosque habitat near Clark Dry Lake, including 27 that were previously undocumented in this area. Among the new finds were three sensitive species: *Johnstonella costata* (ranked 4.3), *Cleomella palmeri* (2B.2), and *Johnstonella angelica* (not yet ranked). An unusual discovery was *Ambrosia x platyspina*, a new hybrid record for San Diego County. This plant is believed to be a cross between *Ambrosia dumosa* and *Ambrosia salsola*, two species commonly found in the region. The current inventory of plant species in this habitat, based on surveys, voucher specimens, and verified iNaturalist observations, now totals 196 species, 175 of which are native and 6 are rare, endangered, or threatened. Of these, 65 species were newly recorded during SDNHM surveys in 2023 and 2024.

The year's most notable find was a population of *Johnstonella angelica* (Angelic Johnstonella) discovered in a mesquite bosque on the eastern side of Clark Dry Lake. This is only the second U.S. observation of this plant, with the first at the Steele/Burnand Anza-Borrego Desert Research Center in Borrego Springs in 2019. This discovery supports that *J. angelica* is native to the U.S. and suggests it should be considered for rare-plant listing. The discovery has been published in *Madroño*: https://doi.org/10.3120/0024-9637-71.3.105 (Donovan & Rebman 2024).

Wildlife camera monitoring and bird surveys in the mesquite bosque habitat

Fourteen wildlife cameras were installed at mesquite habitat sites near the Borrego Sink and at Clark Dry Lake in 2023. These motion-activated cameras capture photos when triggered by movement, providing valuable data on the animal species that inhabit the mesquite bosque. Additionally, three bird surveys were carried out in the mesquite bosque habitat at Clark Dry Lake and Borrego Sink

during late 2023 and early 2024. Both resident and migratory bird species, including several species of special concern, were observed. This information helps us better understand the biodiversity and ecological interactions within these groundwater dependent ecosystems. To date, the wildlife cameras and bird surveys have captured 28 different animal species in both the mesquite habitat near Borrego Sink and Clark Dry Lake for a total of 47 species across both sites. Among these, five are classified as species of special concern. These findings highlight the vital role of mesquite habitats in supporting diverse and vulnerable wildlife in the region.



Figure 8. A photo of a badger with a small mammal in its mouth was captured by a wildlife camera at the Clark Dry Lake site on 2 July 2023 at 2:30 pm.

Local high school GDE Internship Program

In Summer 2024, the GDE Project team launched its first internship program, providing a unique educational experience for high school students from Borrego Springs and San Diego County. Led by three UC Irvine master's students, the program guided four local high school students in studying mesquite bosque habitats and analyzing data from wildlife cameras. Building on this success, we are excited to begin our second internship cycle in Winter 2025, with plans to include 3–4 new local high school students.

Conclusions and Next Steps

Our project results to date confirm the existence of GDEs in the Borrego Springs Subbasin, supported by multiple independent lines of evidence, including the recent direct measurement of groundwater in plant tissues using isotopes. In summary, our advancements in mesquite bosque mapping using high resolution imagery from 2016 resulted in the identification of ~1,800 acres of mesquite bosque near

the Borrego Sink (UCI, 2024 Project Update). The remote sensing analyses and estimates of groundwater transpired from OpenET indicate that mesquite in this area actively use groundwater at a scale relevant to the basin water budget (UCI, 2024 Project Update). In this report we have additionally provided direct isotope evidence of groundwater use at sites near the Borrego Sink, equivalent to what is seen at Clark Dry Lake. This is supported by predawn leaf water potential measurements that indicate water availability is similar between the primary Borrego Springs and primary Clark Dry Lake sites in May 2023. Looking forward, our project will focus on refining our remote sensing analyses, analyzing additional isotope data from established sites, transitioning our flora and fauna assessment efforts to a plan for monitoring, and analysis of ET sensor data to estimate the amount of groundwater transpired by mesquite at our sites near the Borrego Sink and at our comparison site at Clark Dry Lake. We anticipate one more communication to the community prior to completion of the project and production of a final report in March 2025.

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APPENDICES

Appendix A.

Isotopic analysis

Methods

Mature mesquite twigs with expanded new leaves were selected from sunlit branches near the outer canopy. Twigs were cut approximately in 1-2 centimeter lengths, with a maximum thickness of 1.2 cm diameter. To minimize the effects of evaporation of water from the twigs, vials were quickly filled with cut twigs and capped with minimal headspace. Vials were then sealed with parafilm and were refrigerated until analysis. Twigs were collected on 10 through 12 April 2023 and on 31 May and 1 June 2023.

Soil sampling locations for the collection of soil water were placed near tagged mesquite trees. Soil cores were extracted using a 8 cm diameter manual auger at the following depth ranges: 0-10 cm, 10-40 cm, 40-70 cm, 70-100 cm, 100-130 cm. To minimize the effects of evaporation of water from the soil, jars were quickly filled and capped with minimal headspace, sealed with parafilm, and refrigerated until analysis. Soil samples were collected from all five sites on 10 through 12 April 2023 and at only the primary Borrego Springs site (Site 1) and Clark Dry Lake site (Site 5) on 31 May and 1 June 2023.

Well water was collected to serve as the groundwater source for our isotopic comparisons. Well water from a well owned by Anza-Borrego State Park located near Clark Dry Lake was collected on 11 April and 31 May. These well samples are used as the groundwater source in mixing models for the Clark Dry Lake site (Site 5). Well water was collected from the monitoring wells MW-3 and MW-5A in the Borrego Springs Subbasin between 12 and 16 November 2023 by West Yost. An average of these wells is used as the groundwater source in mixing models for sites in the Borrego Springs Groundwater Subbasin (Sites 1 - 4).

Water isotopes were analyzed by the University of Wyoming Stable Isotope Facility using a Temperature Conversion Elemental Analyzer coupled to a Thermo Delta Plus IRMS. We detected three samples with values outside three standard deviations from the mean across all trees, indicating they were outliers (tree 5-9 in April and trees 3-4 and 3-7 in May); these points were therefore removed. We also removed two trees from Site 3 (3-8 and 3-12) and two trees from Site 5 (5-8 and 5-11) in April because these samples were flagged by the University of Wyoming Stable Isotope Facility as having data of intermediate quality.

Water Potential

Methods

To assess water availability and water stress of the mesquite over time we assessed predawn and midday water potential during 2023 on 10 through 12 April, 31 May and 1 June, and 15 and 16 August.

We collected three twigs per tree using the protocol described by Rodriguez-Dominguez et al. (2022). Briefly, we collected a twig containing several leaves, placed it into a plastic bag which was nested within a larger plastic bag containing a moist paper towel, and then placed it into a cooler such that the bag did not touch the ice packs. Midday water potential was assessed between 11:15 am and 1:15 pm and predawn water potential was assessed between 3:00 and 5:30 am. In the lab, we used a Scholander-style pressure bomb (PMS Instrument Company, Corvallis, OR, USA) to determine water potential, noting the pressure at the first sign of water.

References

Rodriguez-Dominguez, C. M., Forner, A., Martorell, S., Choat, B., Lopez, R., Peters, J. M. R., Pfautsch, S., Mayr, S., Carins-Murphy, M. R., McAdam, S. A. M., Richardson, F., Diaz-Espejo, A., Hernandez-Santana, V., Menezes-Silva, P. E., Torres-Ruiz, J. M., Batz, T. A., & Sack, L. (2022). Leaf water potential measurements using the pressure chamber: Synthetic testing of assumptions towards best practices for precision and accuracy. *Plant Cell and Environment*, *45*(7), 2037–2061. https://doi.org/10.1111/pce.14330