**Western Sonoran Desert Water Resources**

*Evaluating Rock Pool Hydroperiod Fluctuation using Climate Variables to Inform Habitat Monitoring and Protection in the Western Sonoran Desert*

**Project Team**

***Project Team:***

Anne Britton (Project Lead)

Charles Nixon

Deirdre An

Seamus Geraty

***Advisors & Mentors:***

Molly Woloszyn (NOAA National Centers for Environmental Information, National Integrated Drought Information System)

Dr. Douglas Rao (NOAA National Centers for Environmental Information, North Carolina Institute for Climate Studies)

***Team Contact:*** Anne Britton, annie.eliz.britton@gmail.com

***Partner Contact:*** Ami Pate, ami\_pate@nps.gov; Susan Washko, washko.susan@gmail.com

**Project Overview**

***Project Synopsis:***

This project provided data on environmental variables that influence the hydroperiods of freshwater rock pools, known as tinajas, which are increasingly impacted by warming and drying climate trends. In partnership with the National Park Service and the University of Arizona, the team used NASA Earth observations, ancillary climate data, and *in situ* observations to generate climatology time series, maps, and a hydroperiod analysis for the western Sonoran Desert. End products identified tinajas at a high risk for shortening hydroperiods to support the enhancement of habitat monitoring, conservation efforts, and water resource decision making practices for the National Park Service.

***Abstract:***

Ephemeral freshwater rock pools, known as tinajas, have great biologic and cultural importance as sources of surface water in the western Sonoran Desert (WSD). Tinaja flooding and drying cycles, known as hydroperiods, vary based on meteorologic and climatologic conditions; however, a lack of extensive research relating climatic impacts to tinajas puts these critical ecosystems further at risk. National Park Service (NPS) and the University of Arizona monitor the physical and ecological condition of tinajas in Organ Pipe Cactus National Monument (OPCNM), AZ, using resource-intensive strategies: *in situ* trail cameras and direct measurements. To aid monitoring efforts, the NASA DEVELOP team aimed to incorporate remote sensing into NPS strategies by analyzing spatiotemporal climate data and tinaja hydroperiods in OPCNM between 1979–2022. Using Aqua and Terra Moderate Resolution Imaging Spectroradiometers (MODIS), University of Idaho Gridded Surface Meteorological Dataset (gridMET), and OpenET data, the team generated climatology maps and time series for OPCNM. The team compared these data to daily *in situ* hydroperiod observations from the University of Arizona between 2019–2022. Climate maps and time series showed increases in temperature and solar radiation (p<0.05), while analyses of *in situ* data showed correlations of hydroperiods with precipitation and evapotranspiration. End products identified high-risk tinajas and demonstrated that Earth observations can successfully be correlated with *in situ* hydroperiod observations. These results will support NPS efforts to prioritize water resource management and inform protocols driving the conservation of tinajas in OPCNM.

The physical and ecological condition of tinajas in Organ Pipe Cactus National Monument (OPCNM), AZ, are monitored by the National Park Service (NPS) and the University of Arizona using resource intensive strategies: in situ trail cameras and direct measurements.

These data were then compared to daily in situ hydroperiod observations from the University of Arizona between 2019–2022.

***Key Terms:***

remote sensing, tinajas, drought, hydroclimate, climatology, *in situ* data, Sonoran Desert, National Park Service

***National Application Area Addressed:*** Water Resources

***Study Location:*** Western Sonoran Desert, AZ

***Study Period:*** January 1979–June 2022

***Community Concerns:***

* Continued warming and drying trends in the western Sonoran Desert (WSD) are leading to shorter tinaja hydroperiods, which are often the only source of surface water in the region.
* Shorter tinaja hydroperiods increase stress on organisms that rely on the pools as their primary habitat and source of freshwater, threatening the long-term conservation of aquatic invertebrates, migratory birds, and other wildlife.
* Tinajas are a key feature of the homelands of the Tohono O’odham Nation, who have traditionally used the pools as a water source along a seasonal migration route to the Gulf of California. Modern Tohono O’odham continue this tradition today, and the loss of these pools means the loss of this cultural heritage.
* Tinajas are often overlooked in favor of targeting large scale biodiversity hotspots, despite the fact that tinajas are disproportionately ecologically important for their size. A lack of extensive research relating climatic impacts to tinajas puts these critical ecosystems further at risk.

***Project Objectives:***

* Perform time series analyses of precipitation, temperature, wind, solar radiation, and evapotranspiration data over the study period to quantify temporal trends in climate variables in the WSD
* Produce climatology maps and analyze spatiotemporal patterns of precipitation, temperature, wind, solar radiation, and evapotranspiration normals and variability over the study period to identify regions historically susceptible to water scarcity
* Perform a hydroperiod analysis using time series and spatiotemporal data in conjunction with *in situ* observations to quantify wet and dry periods and their influence on tinaja hydroperiods

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **National Park Service, Organ Pipe Cactus National Monument** | Ami Pate, Geographer | End User |
| **University of Arizona** | Susan Washko, Ph.D. Candidate | Collaborator |

***Decision-Making Practices & Policies:***

The National Park Service (NPS) focuses on managing tinajas with a philosophy of maintaining an unmodified desert ecosystem. Tinajas are scattered throughout the WSD and are often isolated, requiring long overland travel to reach each site. At Organ Pipe Cactus National Monument (OPCNM), the NPS and the Sonoran Desert Network currently use *in situ* measurement strategies to track the condition of select tinajas. These methods include direct measurement of water quality and the depth of the water in the pools as well as the use of trail cameras to assess daily physical conditions. These *in situ* data help to detect changes in ecological conditions over time and, in some cases, serve as an early warning system for water resource issues. OPCNM also has a network of automated water stations that collect hourly data on precipitation, temperature, wind speed and humidity; however, these do not provide landscape scale data on environmental variables and the availability of surface water. While the NPS employs geographic information system (GIS) techniques in support of natural and cultural resource assessments in the region, Earth observations and satellite remote sensing techniques are not used on a regular basis.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Aqua MODIS** | Land Surface Temperature | Data were used to quantify land surface temperature, compute climatologies, and input into the hydroperiod analysis. |
| **Terra MODIS** | Evapotranspiration  | Data were used to quantify evapotranspiration, compute climatologies, and input into the hydroperiod analysis. |

***Ancillary Datasets:***

* University of Arizona Camera Footage Hydroperiod Timeseries – Partner-provided daily *in situ* observations and GPS coordinates of 20 known tinajas from 2019–2022 used for the hydroperiod analysis
* University of Idaho Gridded Surface Meteorological Dataset (gridMET) – Derived solar radiation, air temperature, precipitation, and wind measurements from 1979–2022 used to quantify climate variables, compute climatologies, and input into the hydroperiod analysis
* OpenET Ensemble Evapotranspiration Data– Monthly evapotranspiration values from 2016–2022 used to quantify evapotranspiration, compute climatologies, and input into the hydroperiod analysis
* U.S. Geological Survey Public Land Boundaries from Protected Areas Database of the United States (PAD-US) [v2.1] –Shapefiles used to delineate the Organ Pipe Cactus National Monument boundary

***Software & Scripting:***

* Google Earth Engine Python API – Data acquisition, preprocessing, and analysis
* Google Colab Notebook – Scripting and coding collaboration
* Esri ArcGIS Pro v2.9.3 – Shapefile creation, raster calculations, cartography, and data visualization
* Excel

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Climatology Time Series** | Aqua MODISTerra MODIS | Climatology time series will provide partners with a deeper understanding of historical climate trends and water fluctuations to help inform management practices. | II |
| **Climatology Maps** | Aqua MODISTerra MODIS | Climatology maps will provide partners with a holistic spatiotemporal assessment of climate variables to identify regions historically susceptible to water scarcity. | II |
| **Hydroperiod Analysis** | Aqua MODISTerra MODIS | An analysis of the climatology maps and time series in conjunction with *in situ* hydrologic data will provide partners with a better understanding of seasonal water variability and help identify areas in need of conservation resources. | II |

***Product Benefit to End User:***

End products will better enable the NPS to protect and preserve tinajas and the ecosystems they support. With a better understanding of tinaja hydroperiods and a more holistic spatiotemporal assessment of climate variables, partners may utilize the information to enhance management decisions including restricting public access to vulnerable tinajas, initiating habitat mitigation projects, and allocating additional water resources. Additionally, the integration of remotely sensed data and *in situ* observations into historical hydroperiod analyses may supplement more resource intensive monitoring strategies, allowing the NPS to model future hydroperiods and better protect remote tinajas that are otherwise difficult to access. Furthermore, these end products can be utilized by the NPS to educate the general public on tinajas: the diversity of life that they support, their cultural significance, and the important role that they play in indicating a changing climate in the WSD.

***References***

Altermatt, F., Pajunen, V. I., & Ebert, D. (2009). Desiccation of rock pool habitats and its influence on population persistence in a daphnia Metacommunity. *PLoS ONE, 4*(3), Article e4703. https://doi.org/10.1371/journal.pone.0004703

Hulsmans, A., Vanschoenwinkel, B., Pyke, C., Riddoch, B. J., & Brendonck, L. (2008). Quantifying the hydroregime of a temporary pool habitat: A modelling approach for ephemeral rock pools in SE Botswana. *Ecosystems*, *11*,89–100. https:// doi.org/10.1007/s10021-007-9110-3

U.S. National Park Service. (2022). *Climate and Water Monitoring at Organ Pipe Cactus National Monument.* www.nps.gov/articles/sodn\_orpi\_climateh20\_18.htm

Vale, C. G., Pimm, S. L., & Brito, J. C. (2015). Overlooked mountain rock pools in deserts are critical local hotspots of biodiversity. *PLoS ONE,* *10*(2), Article e0118367. https:// doi.org/10.1371/journal.pone.0118367