In partnership with the University of New Mexico Department of Biology, Bosque School, and the Sevilleta Long Term Ecological Research

BOSQUE ECOSYSTEM MONITORING PROGRAM (BEMP)

2021 ANNUAL TECHNICAL REPORT

Submitted 31 March 2022

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Bernalillo County, Bosque School, City of Albuquerque Open Space, Greater Rio Grande Watershed Alliance, Mid Rio Grande Stormwater Quality Team, Middle Rio Grande Conservancy District, New Mexico Interstate Stream Commission, Pueblo of Sandia, Pueblo of Santa Ana, Pueblo of Santo Domingo, Sevilleta Long Term Ecological Research, University of New Mexico Department of Biology, Valencia Soil and Water Conservation District

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1 Introduction

Objective: To collect and analyze abiotic and biotic data at BEMP sites in the Middle Rio Grande Bosque while involving K-12 and university students in learning about and monitoring this ecosystem.

All data and reports are available on the BEMP website, www.BEMP.org

Scope of Work: The Bosque Ecosystem Monitoring Program (BEMP) combines long-term ecological research with community outreach by involving K-12 teachers and their students in monitoring key indicators of structural and functional change in the Middle Rio Grande riparian forest, or "bosque." In 1996, BEMP began as a collaboration between the University of New Mexico's Department of Biology and Bosque School in Albuquerque, with fewer than 200 participants in its first year. Now, BEMP averages approximately 9,000 participants annually, although these numbers have been impacted by the COVID-19 pandemic. The BEMP experience builds science skills, educates the community about the bosque ecosystem, and helps create a constituency for stewardship of the bosque. BEMP findings derived from student-gathered data are used by government agencies to inform multi-million dollar river and riparian management decisions.

During the 2021 reporting period, BEMP had 33 sites along 250 miles of the Rio Grande, including 32 sites within the Middle Rio Grande (Figure 1.1). Through the strategic location of these sites, BEMP studies the ecological drivers and effects of fire, flooding, climate change, and human alteration on the bosque ecosystem. Two-thirds of BEMP sites were installed at the request of natural resource managers to monitor the long-term ecological impacts of restoration projects such as mechanical clearing, wood chipping, and bank-lowering. The other third were installed by BEMP staff to facilitate research opportunities or at the request of schools or other partners.

Biotic and abiotic variables are monitored at the BEMP sites. Our abiotic datasets include: depth to groundwater; water level in ditches and drains; precipitation; above- and below-ground temperature; and water quality in the Rio Grande. Our biotic datasets include litterfall; vegetation cover; surface-active arthropod richness and abundance; and tamarisk leaf beetle distribution, abundance and impact.

BEMP hosted two events during 2021 to present new data, visualizations, and analyses: the Crawford Symposium and the Luquillo-Sevilleta Virtual Symposium. BEMP staff and students present BEMP data to managers, professionals, and students several times throughout the year depending on conference availability. In 2021, BEMP data were shared at conferences including the Sevilleta All Hands Meeting, Stan Ecology Modeling Conference, and the Sevilleta Site Review.

Timing of Data Collection: Depth to groundwater, water level in nearby ditches and/or drains, precipitation, and litterfall are collected monthly, during the week of the third Tuesday of each month. Surface-active arthropods are collected three times each year, in the spring, summer, and fall. Vegetation cover is surveyed once each year in August-September. Tamarisk leaf beetle monitoring is conducted during the week of monthly monitoring from May-August, with some sites collected through September. All other datasets are collected as funding permits.

Covid Restrictions and Protocols: State and university restrictions due to COVID-19 continued to impact BEMP collections, lab processing, and data processing during the 2021 reporting period. BEMP staff were allowed back into the lab and office in 2021. Staff continued to observe safety measures, but the centralized lab space allowed for greater efficiency in processing and prevented samples being lost in transfer to and from staff homes. Student involvement in data collections and processing continued to be minimal during the 2020-2021 school year relative to pre-pandemic engagement. The shifts and delays mentioned in the 2020 BEMP Annual Report were predicted to impact data processing and analyses into 2022. BEMP staff have worked efficiently and diligently to catch up on data processing and establish COVID-safe protocols that still allow for timely execution of our operations, and we are now back on track. Sites that were closed due to COVID-19 restrictions are once again open to monitoring, with the exception of Santo Domingo.

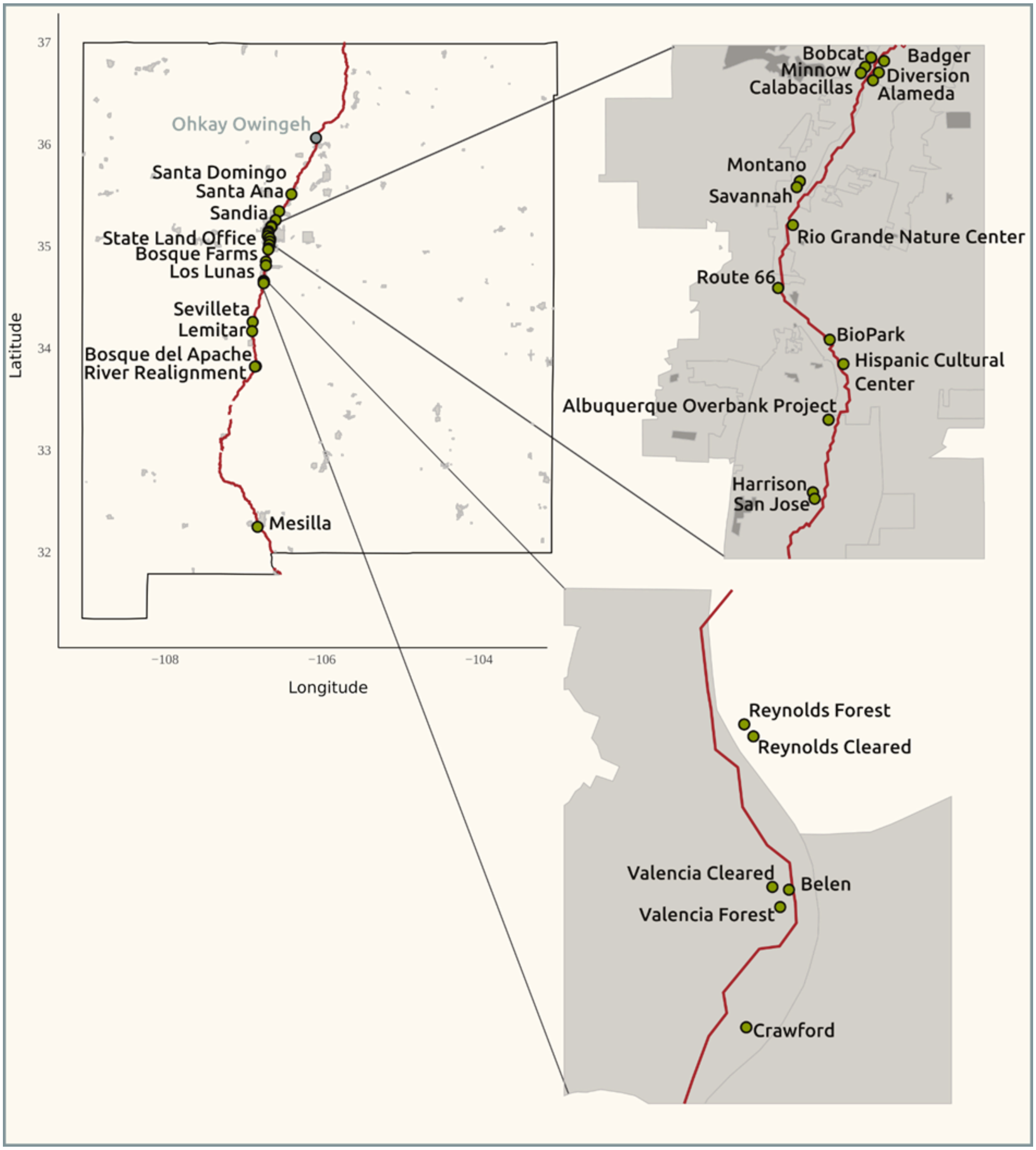

Figure 1.1. Map of 33 active BEMP sites along the Rio Grande; Ohkay Owingeh is no longer an active site. The Valle de Oro BEMP site has been under construction from September 2019.

Table 1.1. BEMP sites and locations along the Rio Grande by Reach, listed from north to south.
* denotes inactive site (either no longer active or temporarily inactive)

Site number	**Site name**	**Latitude**	**Longitude**	**Reach**
9	Ohkay Owingeh*	36.0618	-106.0761	Cochti
24	Santo Domingo*	35.50989	-106.3896	Cochti
5	Santa Ana	35.34284	-106.5458	Angostura
32	Sandia	35.255	-106.5907	Angostura
22	Bobcat	35.19705633	-106.6439494	Angostura
21	Badger	35.1956	-106.6402	Angostura
12	Minnow	35.19315094	-106.646915	Angostura
10	Diversion	35.1908	-106.6429	Angostura
11	Calabacillas	35.19056822	-106.6491626	Angostura
1	Alameda	35.1875	-106.6459	Angostura
17	Montano	35.14528819	-106.6803699	Angostura
6	Savannah	35.14285294	-106.6819814	Angostura
2	Rio Grande Nature Center (RGNC)	35.127	-106.6854	Angostura
20	Route 66	35.1006408	-106.6914783	Angostura
23	BioPark	35.079	-106.668	Angostura
8	Hispanic Cultural Center (HCC)	35.06881267	-106.6580575	Angostura
29	Albuquerque Overbank Project (AOP)	35.04546	-106.6657	Angostura

13	Harrison	35.01505603	-106.6736953	Angostura
31	San Jose	35.012375	-106.6728	Angostura
28	Valle de Oro*	34.97895	-106.6801	Angostura
30	State Land Office (SLO)	34.96785	-106.6856	Angostura
27	Bosque Farm	34.848851	-106.714722	Isleta
3	Los Lunas	34.81236936	-106.714458	Isleta
19	Reynolds Forest	34.66054583	-106.7429525	Isleta
18	Reynolds Cleared	34.65966431	-106.7421328	Isleta
15	Valencia Cleared	34.64863444	-106.7391728	Isleta
4	Belen	34.6484315	-106.7377022	Isleta
16	Valencia Forest	34.64716225	-106.738482	Isleta
25	Crawford	34.63835	-106.74277	Isleta
14	Sevilleta	34.25834233	-106.8831845	San Acacia
7	Lemitar	34.16703188	-106.8899486	San Acacia
34	River Realignment	33.8227	-106.8419	San Acacia
33	Bosque del Apache (BDA)	33.8197	-106.8539	San Acacia
26	Mesilla	32.248328	-106.821014	South of San Marcial

2 Importance of long-term data, community science, and education outreach

BEMP's mission is community science, education, and stewardship: equitable and inclusive hands-on student research essential to the management of the Rio Grande ecosystem.

BEMP started in 1996 with funding from the National Science Foundation through the University of New Mexico (UNM) and a goal of reaching 8 long-term monitoring sites.

Although this seemed unlikely, by 2001, BEMP had reached this goal, with 8 sites being monitored in collaboration with teachers and students from the community. That year BEMP involved 400 community participants, had sites installed to aid stakeholders in monitoring restoration practices, and generated data used by partners to inform bosque restoration and management decisions. Through the years, agencies and stakeholders requested the addition of new sites and new datasets, while teachers and schools requested BEMP sites and field opportunities for their students. By 2013-14, BEMP started reaching between 9,000 and 10,000 participants per year, had 30 established sites, and maintained 11 core datasets.

The long-term data generated by BEMP have been used in informing predictive models, assessing restoration projects, tracking shifts in native and exotic vegetation, understanding bosque response to different ecosystem drivers (e.g., fire, flooding, clearing, impacts of climate change, introduction of biocontrol species), and tracking shifts in native and exotic vegetation. Long-term monitoring of these sites is critical for understanding how the ecosystem responds to land management strategies and climate variability. This is also necessary for effectively applying adaptive management and developing best practices strategies.

BEMP involves students of all ages, from pre-K through high school, college, graduate, to life-long learners volunteering in the program. Our primary focus is on elementary, middle school, and high school students that participate in monthly fieldwork to collect groundwater, precipitation, and litterfall data, as well as going out once or twice each year to participate in monitoring arthropods. Students also have opportunities to participate in other data collections, including water quality, tamarisk leaf beetle, and monitoring fuel load. BEMP involves UNM undergraduate and graduate students in a semester-long internship experience through an upper division biology course, BIOL 408/508, where they learn about the bosque ecosystem, develop independent projects applying BEMP data, work with K-12 students and teachers, and play an integral role in regular field and lab work. The work of K-12 students in the field is facilitated and quality controlled by BEMP staff as well as the UNM interns. Having now played a role in our community for a couple of decades, we are starting to see the long-term impacts of our programming. Over the last several years, there are always a few UNM students in the BEMP course that had previously participated in BEMP as elementary, middle, and/or high school students. These students are often reconnected to their former schools and sites. BEMP has been part of a meaningful story for many students and community members. BEMP has helped students connect with their local landscape, learn science through hands-on research, and communicate or present their understanding through math, writing, art, and other forms of expression.

3 Temperature

During the 2020-2021 reporting period, we collected data from LogMaster temperature loggers at 12 BEMP sites. Three loggers were installed at selected sites: a canopy logger attached to a tree near the canopy rain gauge, a subsurface logger buried underground near the canopy rain gauge, and a second subsurface logger buried near the open rain gauge. Temperature data were logged hourly and downloaded annually by BEMP staff. During 2020-2021 collections, existing temperature loggers were reaching the end of their lifespan, resulting in gaps in the types of loggers present at some of the monitored sites (Table 3.1).

Complete methodology can be found online at:
https://secureservercdn.net/45.40.146.38/659.541.myftpupload.com/wp-content/uploads/2017/09/TempLoggerDownloadandDeploy.pdf

Table 3.1. List of temperature data loggers at sites.

Site (North-South)	Canopy	Canopy sub	Open sub
Santa Ana	Present	Absent	Absent
Alameda	Present	Present	Absent
Savannah	Absent	Absent	Present
RGNC	Present	Present	Present
Route 66	Present	Present	Present
Biopark	Absent	Present	Present
AOP	Present	Present	Present
SLO	Present	Absent	Present
Los Lunas	Present	Absent	Present
Belen	Present	Present	Absent
Lemitar	Present	Present	Present
Mesilla	Absent	Present	Absent

The data were run through a visual QA/QC to make sure the plots follow the general expected pattern and historical trends. The data were then checked for the number of NA (missing data points) by site over time and for any points there were more than three standard deviations

(SD) away from the z-score transformed data. The number of data points flagged as outside the three SD were minimal given the volume of data.

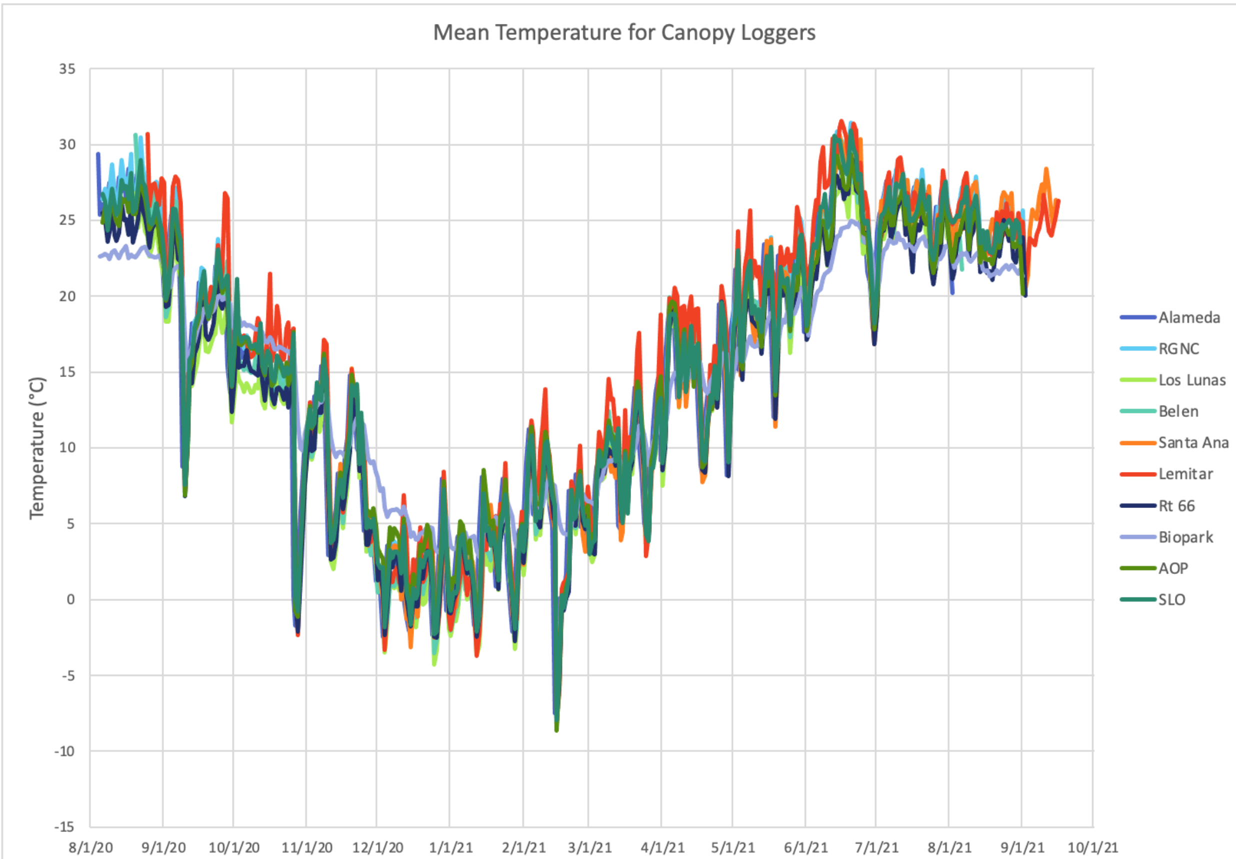

Figure 3.1. Mean daily air temperature from canopy loggers across ten sites.

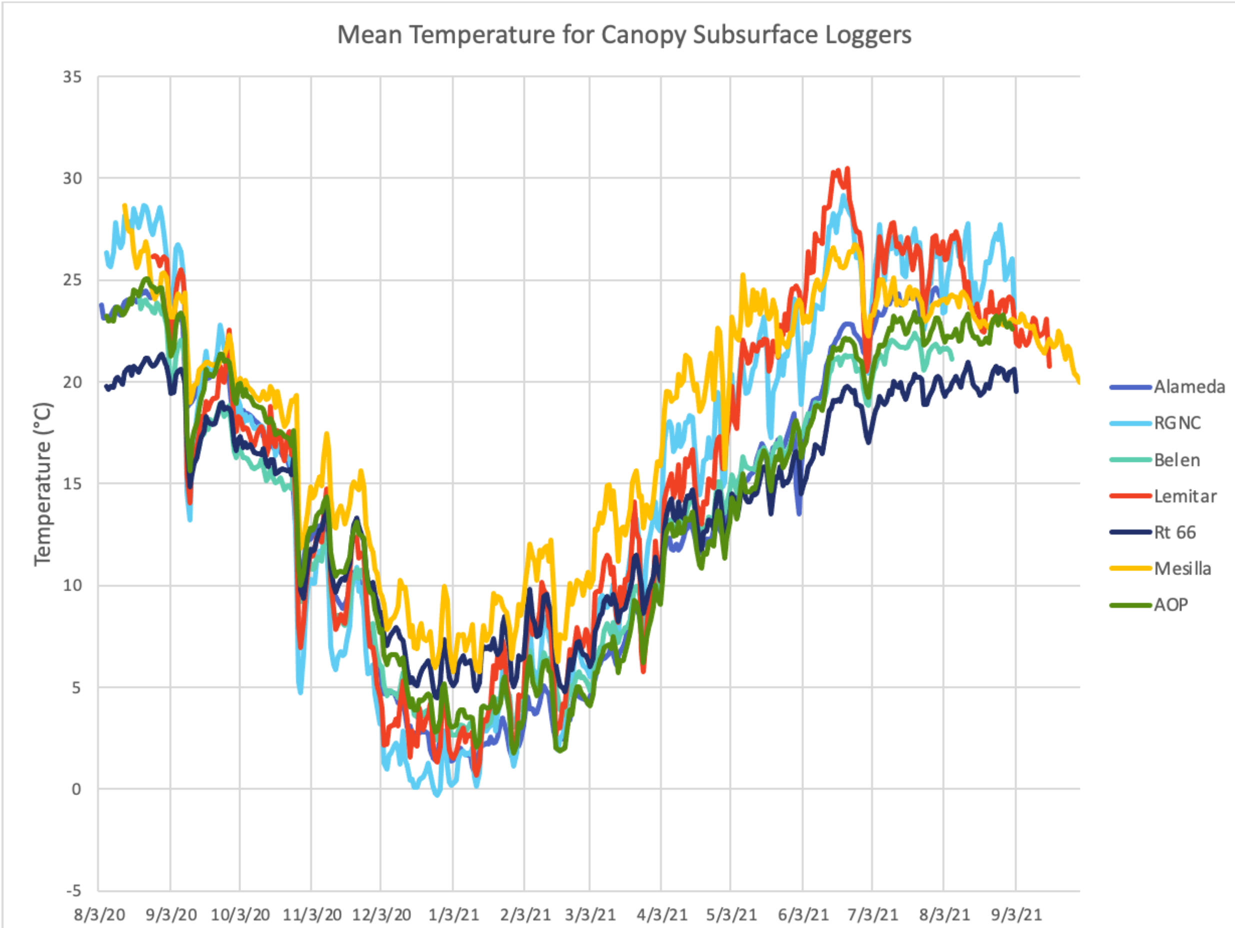

Figure 3.2. Mean daily ground temperature from subsurface loggers under canopy cover across seven sites.

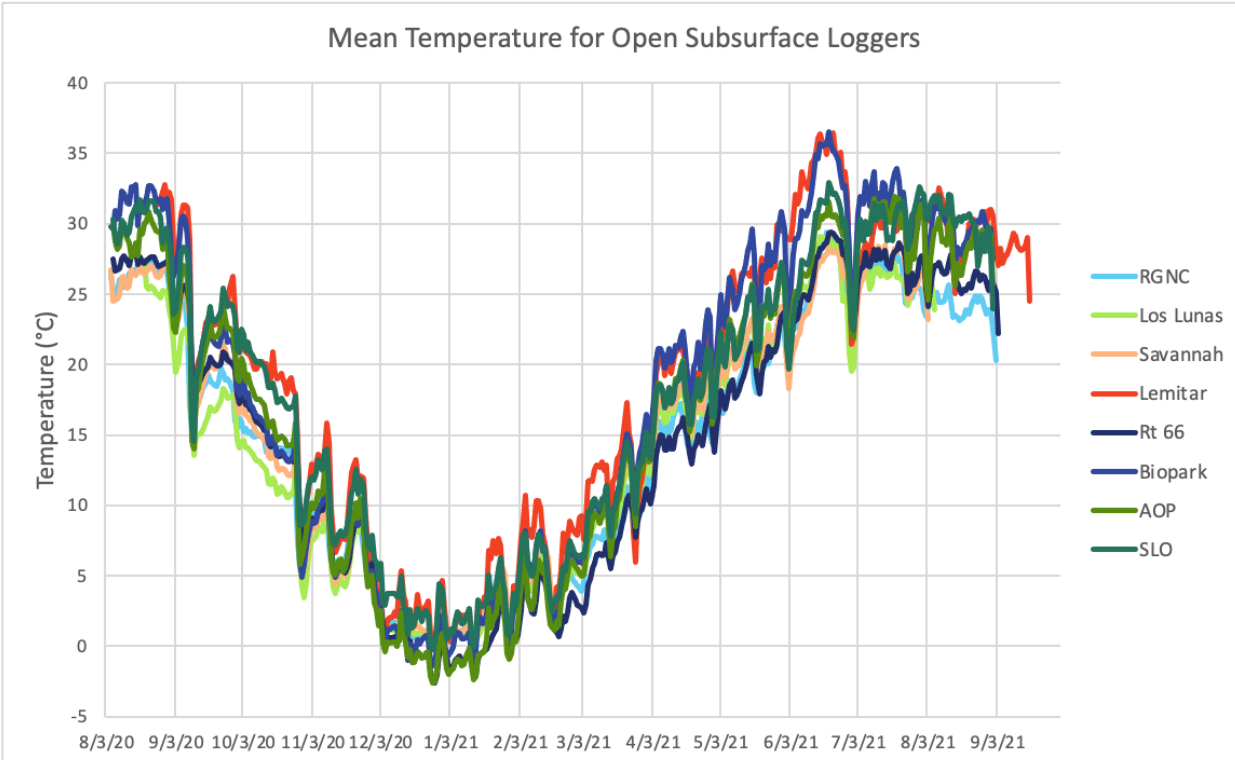

Figure 3.3. Mean daily ground temperature from subsurface loggers in the open (without canopy cover) across seven sites.

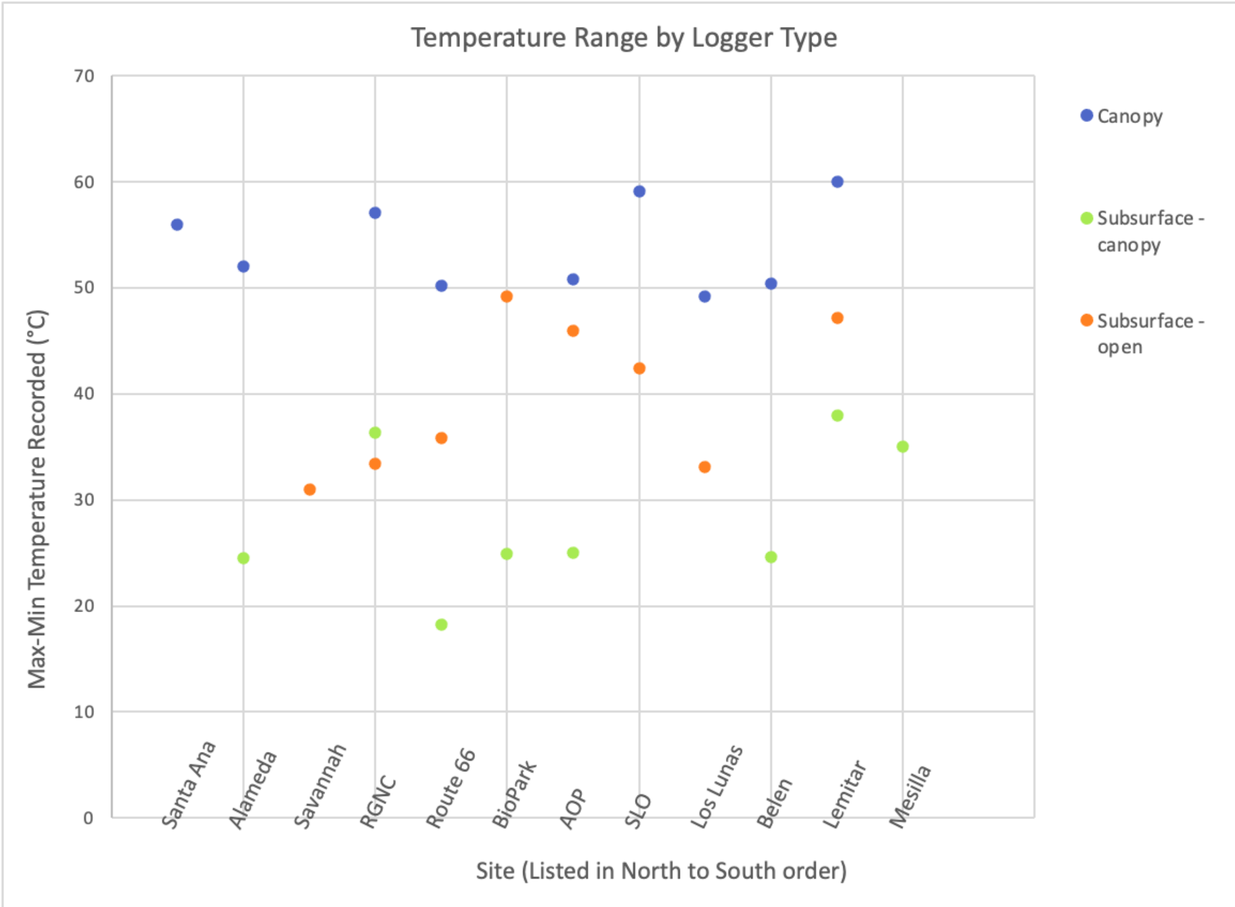

Figure 3.4. Recorded temperature range across each logger type for 12 sites.

Loggers recording air temperature in the bosque canopy throughout the Middle Rio Grande Valley ranging from Pueblo of Santa Ana through Belen recorded a minimum air temperature of -13.58°C (recorded at Santa Ana on Feb 15, 2021) and a maximum air temperature of 48°C (recorded at Lemitar on Jun 6, 2021) for the 2021 reporting period. Three cold snaps occurred during the fall and winter seasons, in mid September 2020, late October 2020, and mid February 2021. The warmest air temperatures recorded by canopy loggers for this reporting period's summer season occurred in mid June 2021.

Analysis of minimum and maximum ground temperatures recorded by the different sub-surface loggers at sites where all logger types were present reveal a trend of more extreme ground temperature ranges out in the open, where loggers recorded higher maximums and lower minimums compared to subsurface loggers under tree canopy at most sites. One exception to this pattern was the Rio Grande Nature Center subsurface loggers, which recorded similar maximum and minimum temperatures, and the pattern was slightly reversed. However, this outlier is likely due to the placement of the subsurface loggers at this site, where canopy cover is fairly even throughout, and both loggers were likely receiving similar amounts of sun and shade through the day. Plots summarizing maximum, minimum, and mean daily temperatures throughout the full reporting period for all loggers at each site where all three logger types were still active are available upon request.

4 Precipitation

Precipitation is measured at all but two sites (precipitation data are not collected at Bosque Farms due to repeated vandalism or at Valle de Oro due to wildlife making the rain gauges unsanitary). At each site where precipitation is measured, two Tru-Chek precipitation gauges are installed on a post; one under the forest canopy, and one out in the open. Each rain gauge is monitored and emptied by BEMP staff and community scientists once per month. A small amount of oil is added to the empty gauge to prevent evaporation and to ensure capture of the full month's precipitation.

More details on our methods for collecting precipitation data can be found here: https://bemp.org/wp-content/uploads/2016/01/weather-station-precipitation-monitoring-directions.pdf

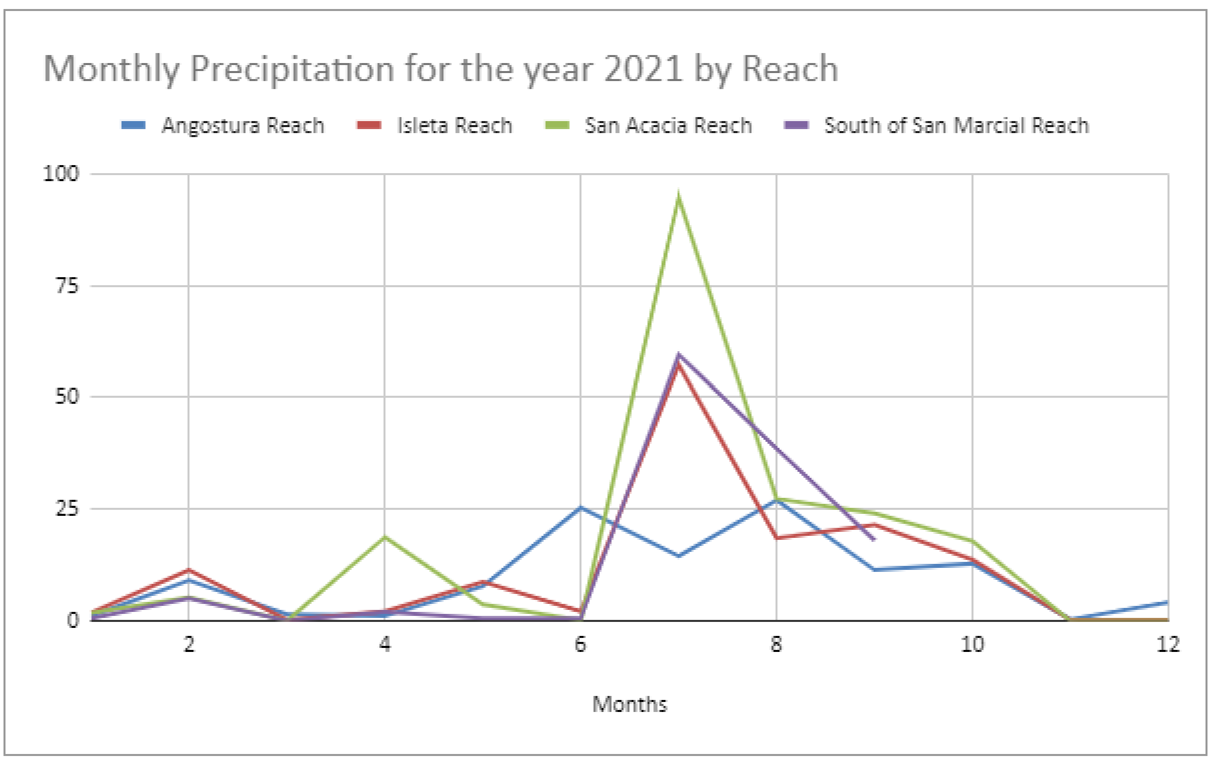

Figure 4.1. Monthly mean precipitation for 2021 by month for Reach. Data were not collected from the Cochiti Reach (Santo Domingo) in 2021 due to COVID-19 restrictions.

Precipitation occurred predominantly in the historic monsoon season in 2021 (Figure 4.1). In the Angostura reach, precipitation did not peak in July as it did across other reaches, and instead stayed more constant throughout the monsoon season. This contrasts with the general trend observed in previous years where we have seen precipitation shifting towards later months. For previous years that have an obvious peak in precipitation, the peak has occurred around August (years 1999, 2001, 2006, and 2010), September (year 2002), October (years 2000, and 2017) or has peaked in August, and then again in October (years 2005, and 2008).

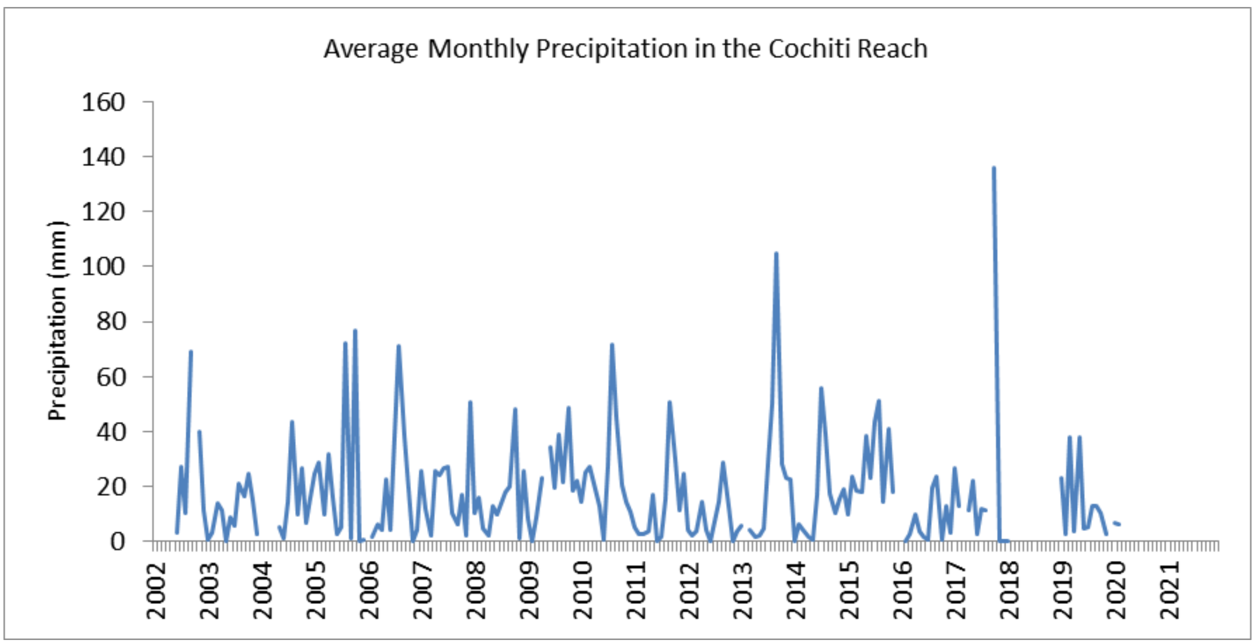

Figure 4.2. The average monthly precipitation in the Cochiti Reach.

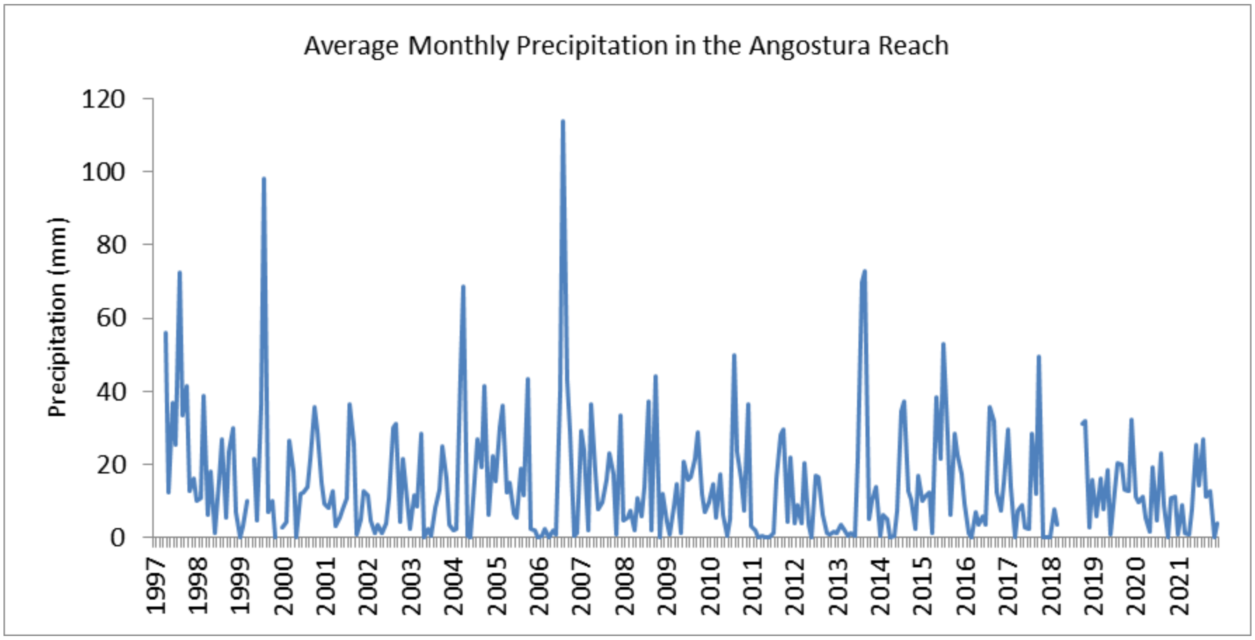

Figure 4.3. The average monthly precipitation for sites within the Angostura Reach.

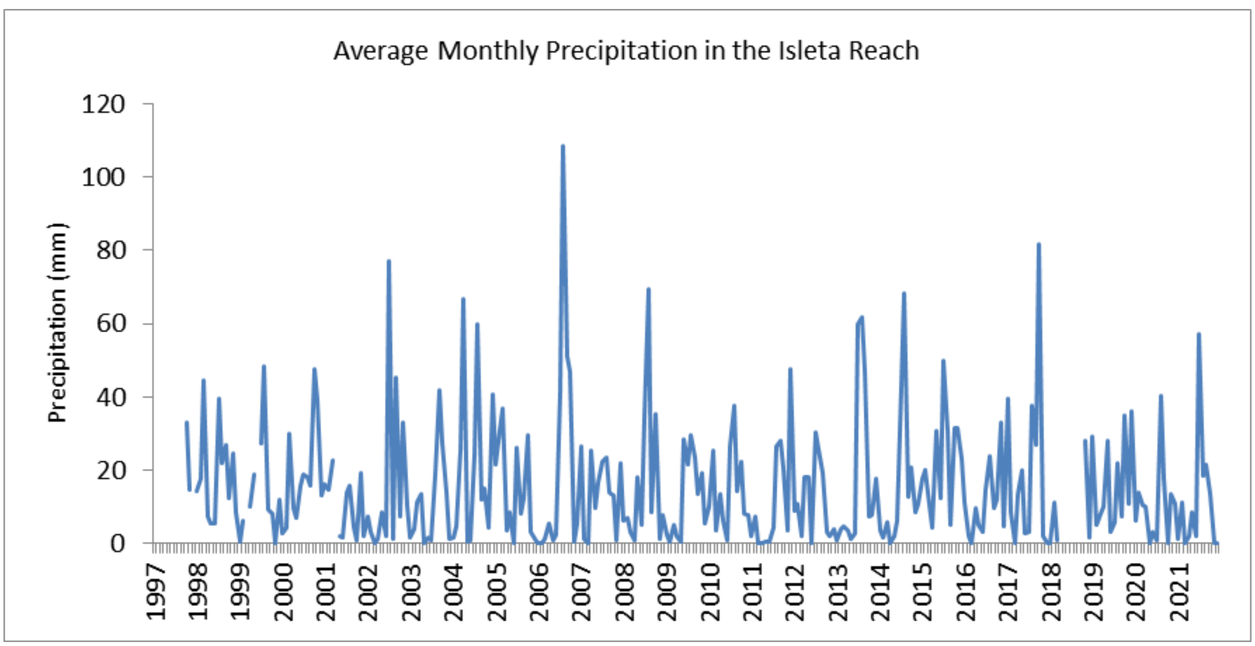

Figure 4.4. The average monthly precipitation for sites within the Isleta Reach.

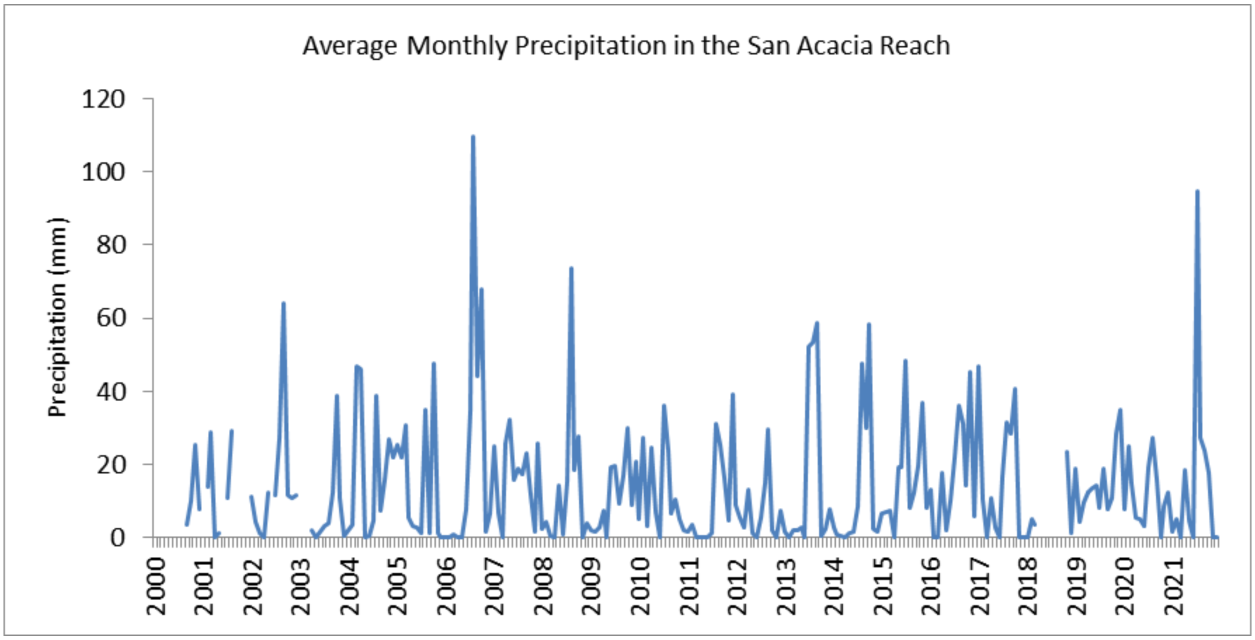

Figure 4.5. The average monthly precipitation for sites within the San Acacia Reach.

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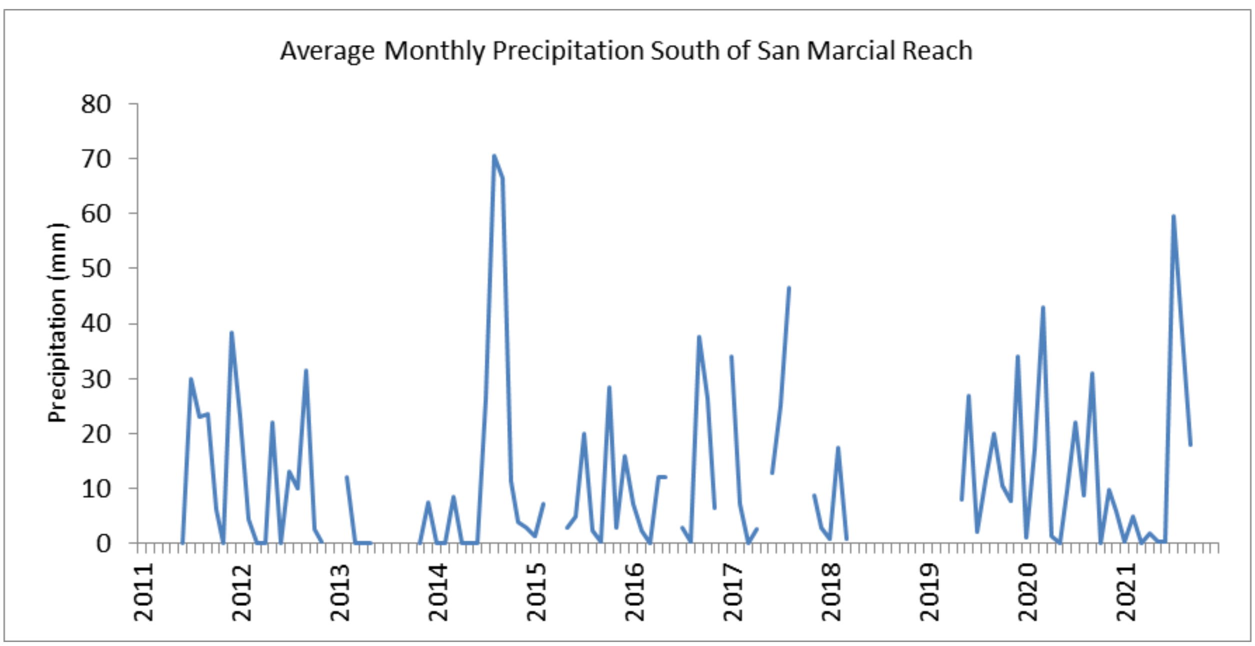

Figure 4.6. The average monthly precipitation for sites south of the San Marcial Reach.

For the Isleta and Angostura reaches, there is a slight downward trend in precipitation (Figures 4.3, 4.4), while the other reaches either show consistent precipitation, or a slight upward trend (Figures 4.2, 4.5, 4.6). Isleta and Angostura are the reaches that have been monitored the longest and have the most monitoring sites. This makes the trends from those reaches more comprehensive for showing long-term precipitation patterns.

5 Depth to groundwater

Depth to groundwater is monitored at most BEMP sites with the exception of the Pueblos of Santa Ana and Santo Domingo (sites 5 and 24, respectively). Groundwater data are collected with permission at the Pueblo of Sandia, but these are proprietary data and requests for groundwater data must go through the Department of Natural Resources at the Pueblo. At all other BEMP sites, five groundwater wells are monitored during the week of monthly monitoring, along with the nearby ditch or drain. Except when pandemic restrictions were in place, K-12 students and teachers monitored sites along with BEMP staff and UNM interns. The USGS river flow data are downloaded based on the day of monitoring from the USGS Central gauge (USGS Gauge ID: 08330000).

Full monitoring methods can be found at:
https://secureservercdn.net/45.40.146.38/659.541.myftpupload.com/wp-content/uploads/2016/01/Groundwater-quality-monitoring-directions.pdf

Figure 5.1. Twenty year time series of mean monthly depth to groundwater at all sites. Sites are ordered from north to south.

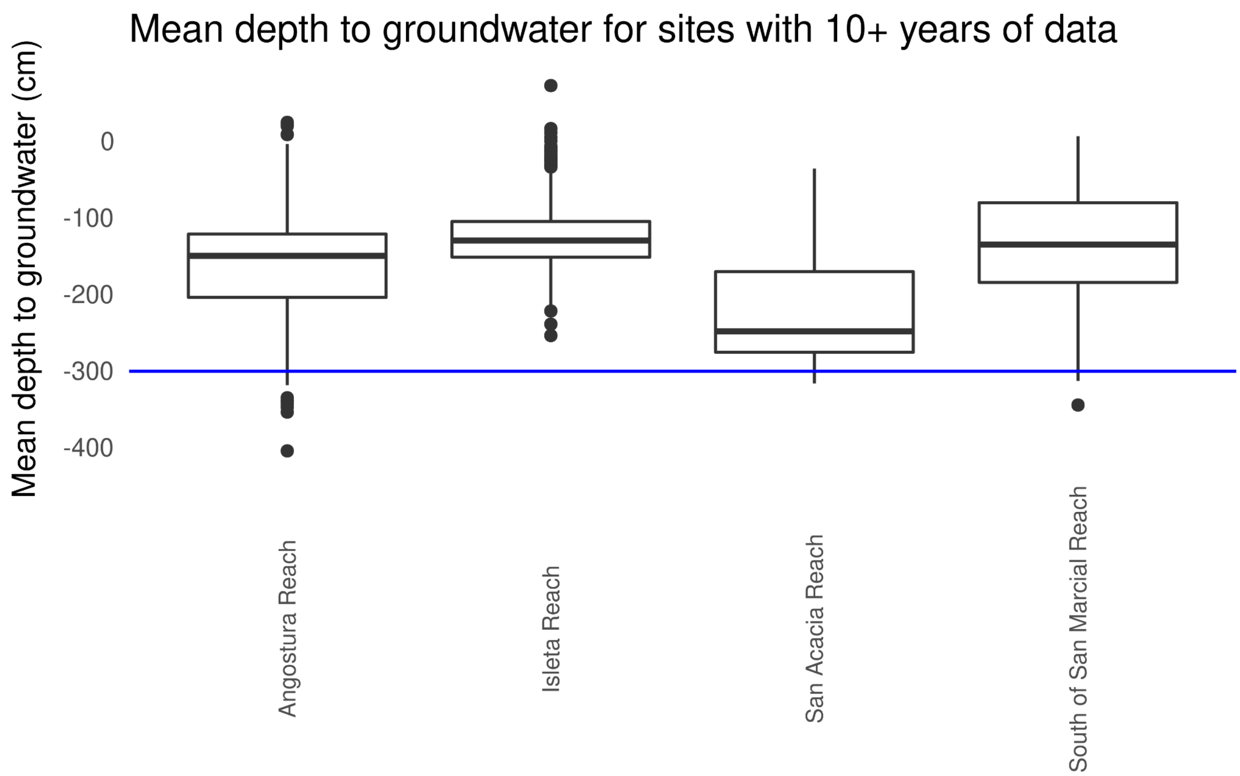

Figure 5.2. Box plots of all sites with more than ten years of data separated by reach. Blue line is the groundwater threshold depth for mature cottonwood trees.

Cochiti Reach

Depth to groundwater data are unavailable for the Cochiti reach sites for 2021. The Ohkay Owingeh site is inactive and we were unable to collect data from the Santo Domingo site due to COVID restrictions. The Santa Ana site is active, but BEMP does not have groundwater wells installed at that location. Depth to groundwater data are collected at the Sandia site, but are proprietary. Requests for these data must go through the Department of Natural Resources at Sandia Pueblo.

Angostura Reach

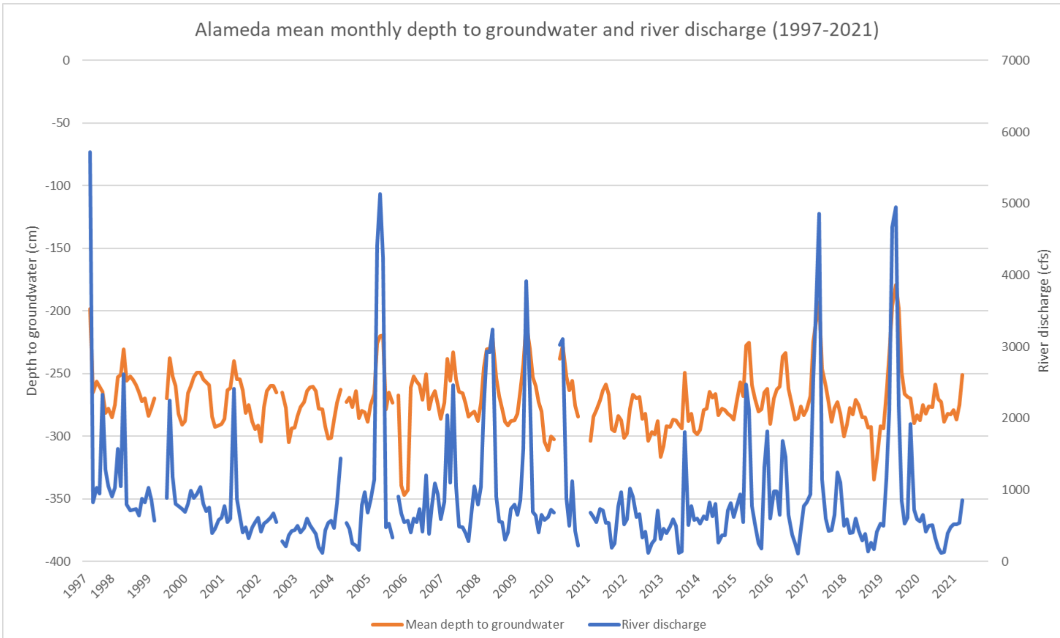

Figure 5.3. Mean monthly depth to groundwater at Alameda (orange) and river discharge (blue) since 1997.

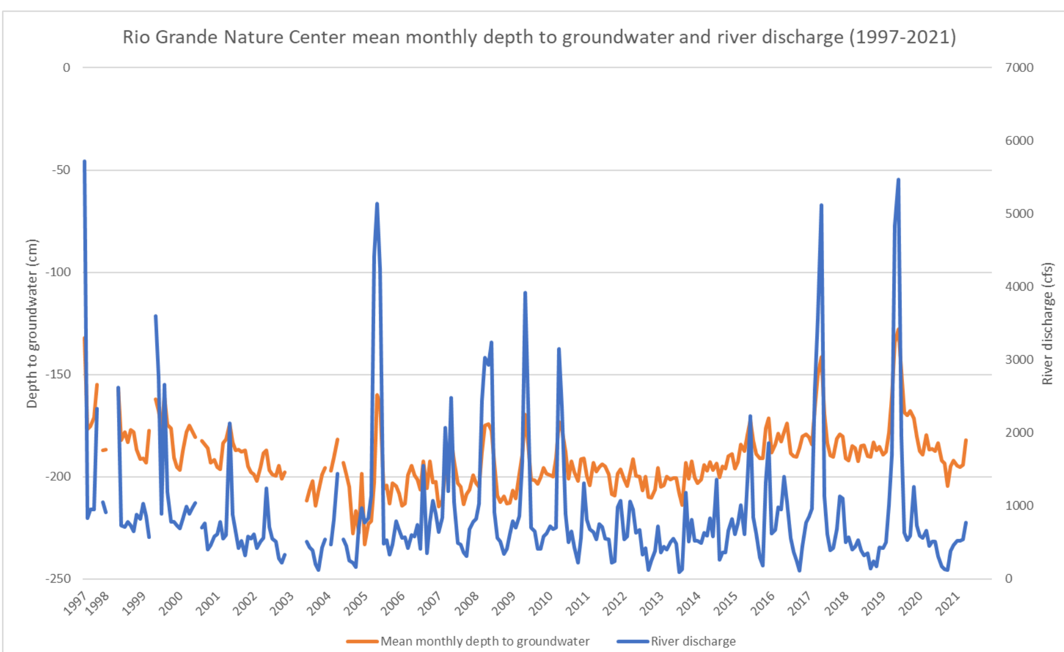

Figure 5.4. Mean monthly depth to groundwater at Rio Grande Nature Center (orange) and river discharge (blue) since 1997.

Mean depth to groundwater levels at most sites within the Angostura reach have remained consistent. Some sites show slight downward trends in depth to groundwater, but this is closely correlated to the slight downward trend in corresponding river discharge rates. Despite the relatively consistent mean depth to groundwater across all sites in the Angostura reach, the minimum, as well as several outlier data points, lay below the mature cottonwood root threshold (Figure 5.1 – 5.4, 5.7).

Isleta Reach

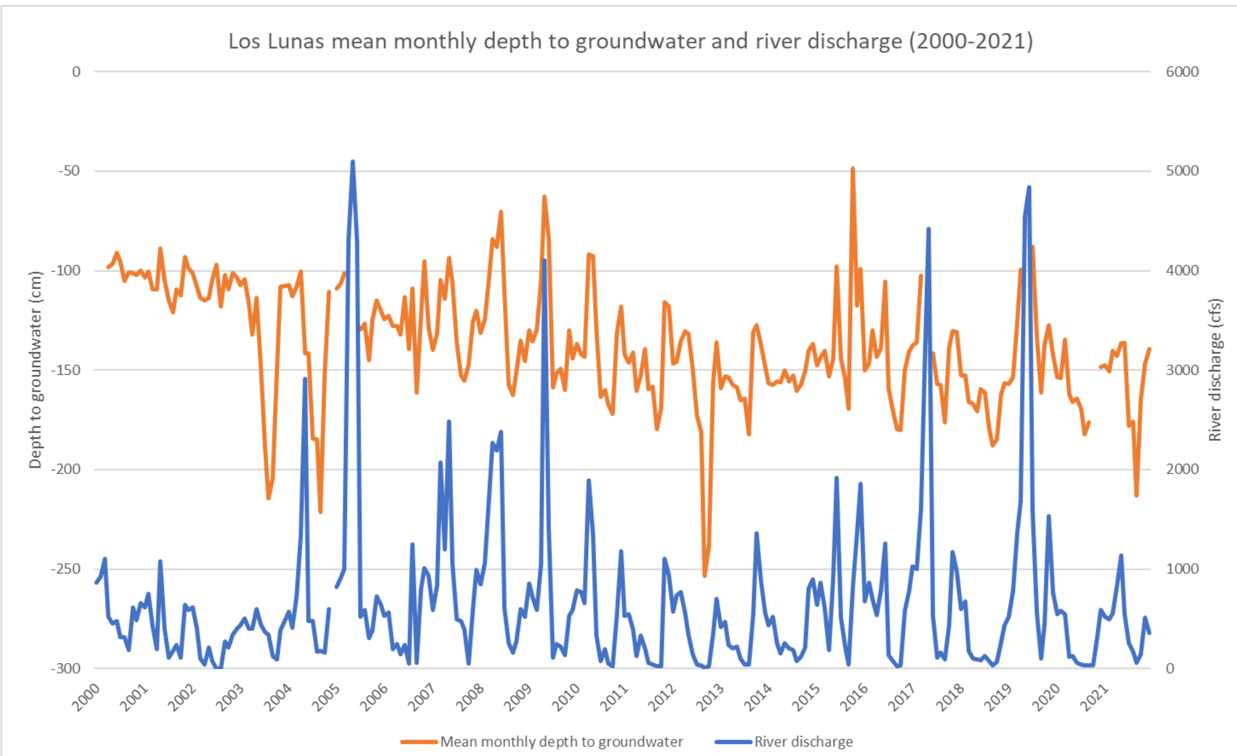

Figure 5.5. Mean monthly depth to groundwater at Los Lunas (orange) and river discharge (blue) since 2000.

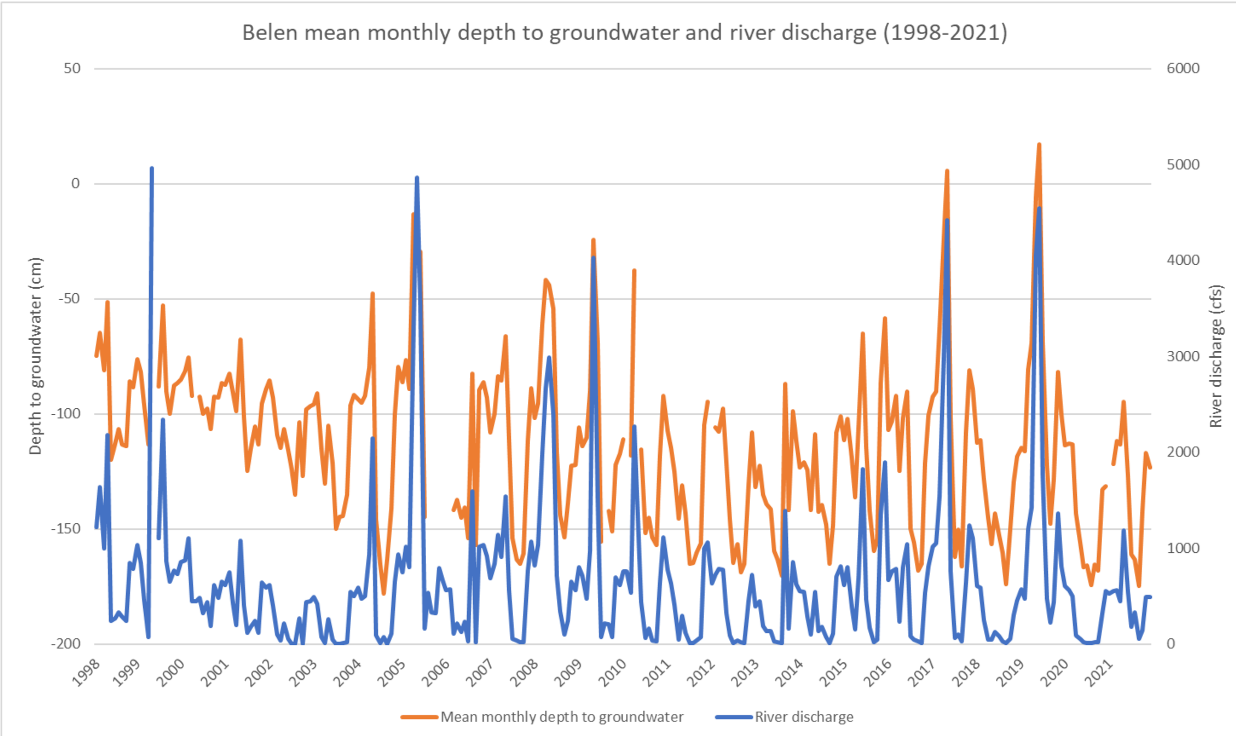

Figure 5.6. Mean monthly depth to groundwater at Belen (orange) and river discharge (blue) since 1998.

Although depth to groundwater measurements within the Isleta reach are consistently shallower than the other reaches, five of the eight sites are trending downwards. Analysis of the two oldest sites (Los Lunas and Belen) highlight this downward trend as both sites show a roughly 25-50cm drop in mean monthly depth to groundwater (Figures 5.1, 5.2, 5.5 – 5.7).

San Acacia and South of San Marcial Reaches

Sevilleta and Lemitar mean monthly depth to groundwater values have remained consistent over the last decade. Bosque del Apache seems to be trending downwards, but inconsistent measurements due to flooding, well drying, and the relative newness of the site may skew the mean data for the reach. Mesilla Valley Bosque State Park groundwater levels have remained consistent as well (Figures 5.1, 5.2, 5.7).

All Sites

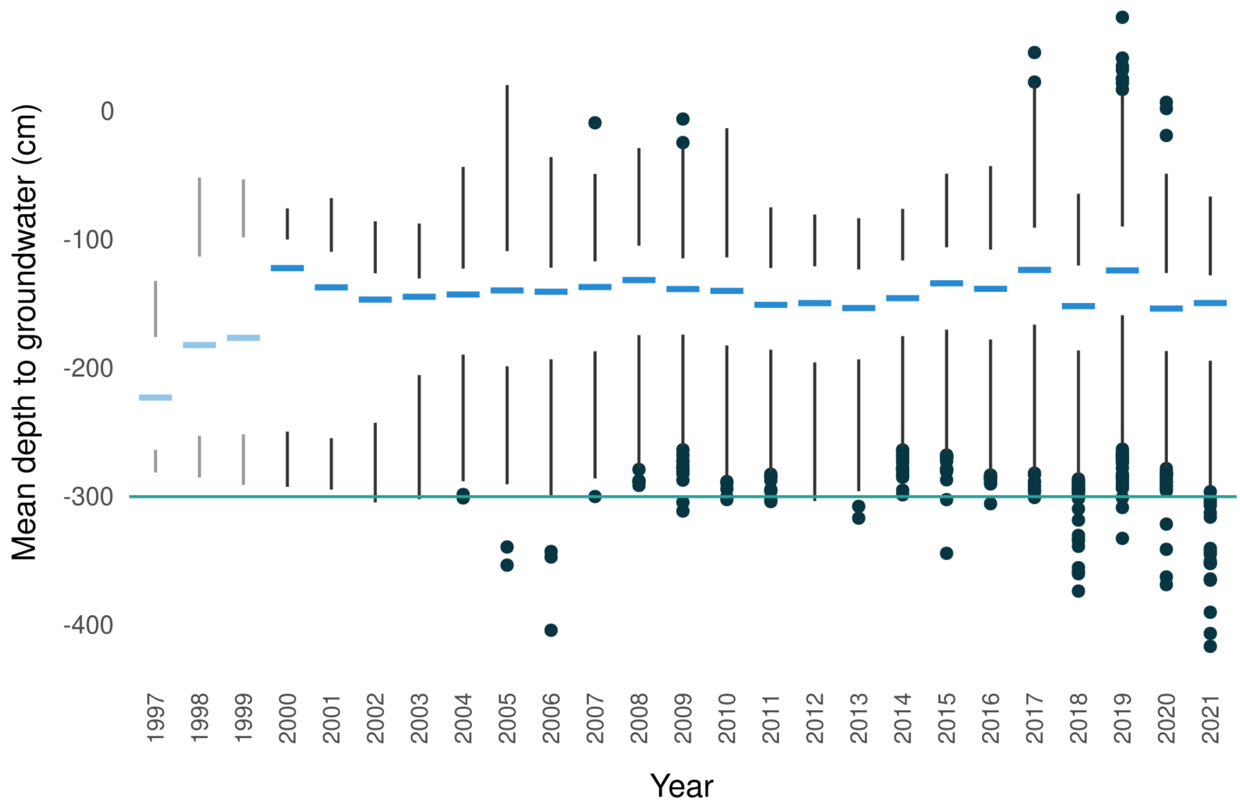

Figure 5.7. Box plots of mean monthly depth to groundwater for all BEMP sites (1997-2022). The teal line represents the typical threshold for root depth of cottonwood trees (*Populus deltoides*).

Median depth to groundwater levels remained steady across sites through 2010, after which more variability was seen in median groundwater levels (Figure 5.7). In a regulated system such as the Rio Grande, consistent numbers are to be expected. In the past decade variability and the number of outliers has increased. The lower quartiles have become longer than the upper quartiles and there are more outliers below the lower quartile. This means that, although there are sites with groundwater levels above the median, there are more sites with groundwater levels consistently lower than the median in recent years. Of particular note are the increased occurrence of outliers below the cottonwood root threshold of three meters. Outliers above the upper quartiles represent depth to groundwater during flood pulse events. Flood events are not necessarily meaningful in terms of vegetative recruitment, as successful cottonwood and willow seedling establishment also requires a slowly receding water table (and thus a long descending limb of the river hydrograph) and water levels high enough to support seedlings (Figure 5.7). In

2009, groundwater levels dropped by about 2 cm/day following the flood event. In 2017, groundwater levels dropped by 10-20 cm/day. In 2019, the receding flows were controlled so there was seedling establishment, but summer drought conditions resulted in seedling mortality.

6 Water Quality

BEMP is funded by The Middle Rio Grande Stormwater Quality Team to monitor the Albuquerque (Angostura) Reach of the Rio Grande for the bacterial pathogen *Escherichia coli* and other field parameters. Parameters measured include dissolved oxygen (DO), specific conductance, pH, turbidity, and water temperature. Although the EPA and State of New Mexico recognize the upper limit for *E. coli* in primary contact water as 410 MPN/100 mL, limits set by the Pueblo of Isleta, just south of Albuquerque, are 88 MPN/100mL due to special usage. For this reason it is essential to understand how these parameters change as the river flows through and out of Albuquerque throughout the year. Longitudinal sampling was conducted at seven sites for eight months out of the 2021 reporting period, and transect-light sampling was conducted at four sites during every third month for a total of four months out of the year (Figure 6.1). Sampling methodologies, sample sites, and results are further detailed in the 2021 Annual Stormwater Quality Technical Report, available on request.

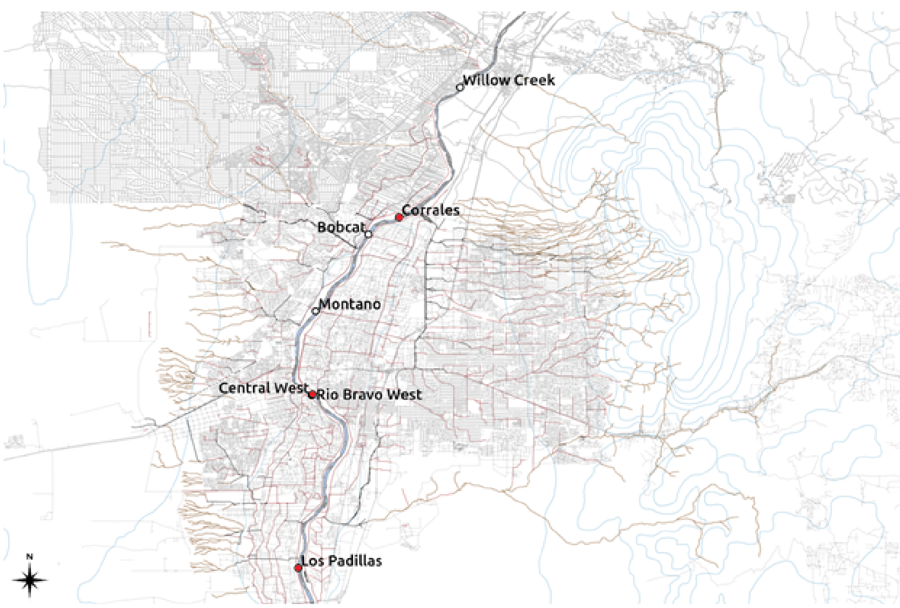

Figure 6.1. Sampling locations for 2021. All sites are a part of the longitudinal sampling. Sites with red dots represent the transect-light sampling locations. Additional GIS layers include arroyos, drains and ditches, city streets, river center, and 500 ft elevation contour lines.

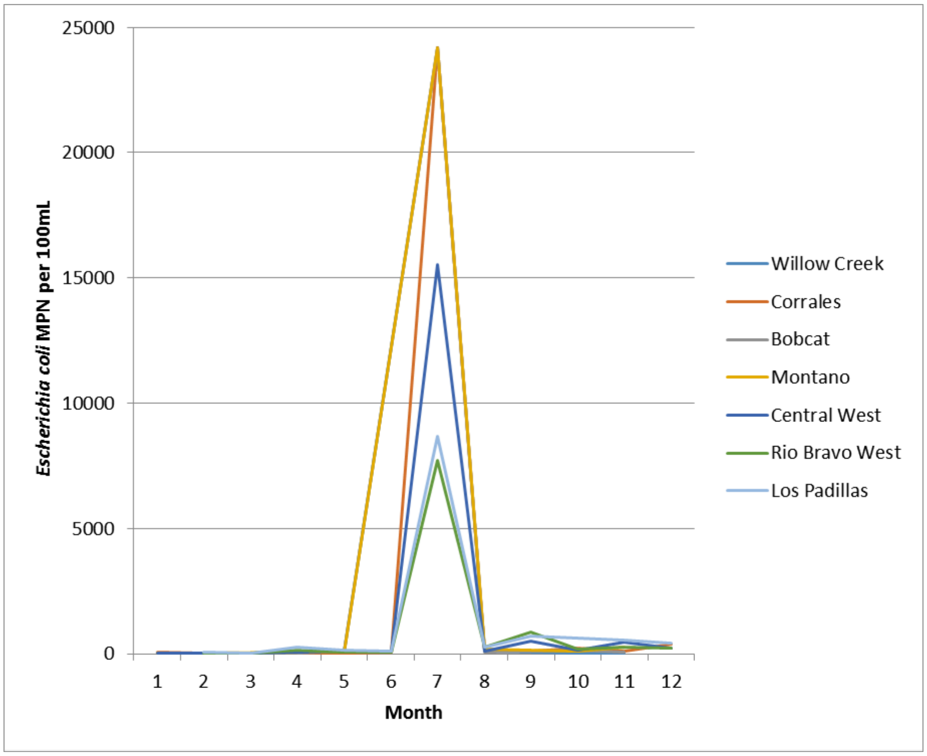

Figure 6.2. *Escherichia coli* coliform from the longitudinal sampling sites, including July data. The Rio Bravo, Bobcat, and Montano sites were not sampled during the transect light months. The Rio Bravo West and Los Padillas sites were not monitored in January.

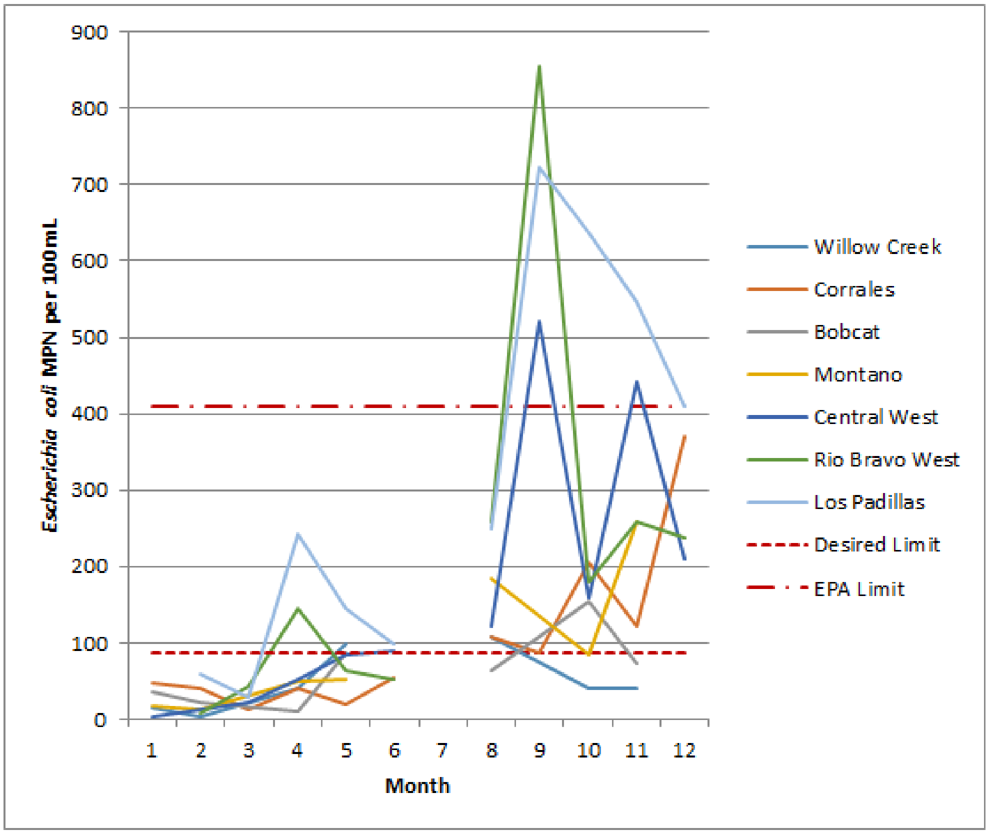

Figure 6.3. *Escherichia coli* coliform from the longitudinal sampling sites, excluding July data. The Rio Bravo, Bobcat, and Montano sites were not sampled during the transect light months. The Rio Bravo West and Los Padillas sites were not monitored in January. Dash-dotted line represents the EPA limit of 410 MPN/100mL, dashed line represents the desired limit of 88 MPN/100mL.

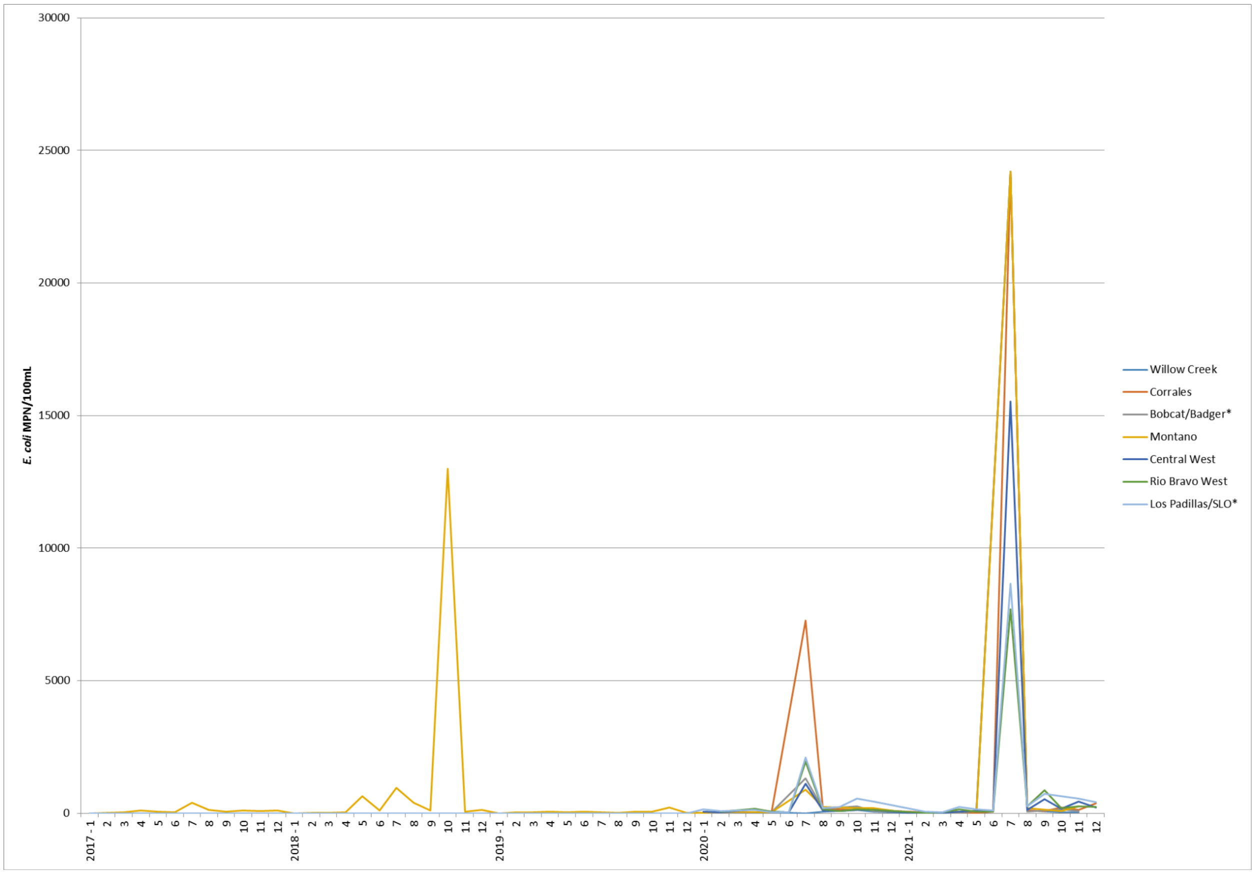

Figure 6.4. *Escherichia coli* coliform bacteria (MPN/100mL) by month over a five year collection period. Sites indicated with a "*" were sampled from the east bank of the Rio Grande per pre-2020 protocol.

In 2021, and historically, *E. coli* numbers peak during the monsoon season (July – September) and correspond with local storm events. In July 2021 all sampling locations exceeded both the Isleta and EPA limits with four sites meeting or exceeding the laboratory analytical limit of 24196 MPN/100 mL. An annual look at *E. coli* levels for 2021 show the extent of the *E. coli* peak in July (Figure 6.2). Figure 6.3 excludes July *E. coli* data, demonstrating how *E. coli* levels fluctuate monthly and longitudinally. A look at data from 2017 shows the trend of *E. coli* levels spiking during the monsoon season (Figure 6.4). A more frequent sampling methodology during the monsoon season would better capture temporal variation including peak values and rate of change of *E. coli* during this season.

7 Litterfall

Litterfall is any plant material that falls to the ground. BEMP litterfall data are categorized into leaves, reproductive parts, and wood from dominant tree species. It is collected monthly and then dried for 48 hours before being sorted and weighed. Litterfall is used to gauge plant productivity (leaves), reproductive effort (buds, flowers, seeds), and stress or senescence (wood).

Full monitoring methods can be found at: https://secureservercdn.net/45.40.146.38/659.541.myftpupload.com/wp-content/uploads/2016/01/Litterfall-monitoring-and-lab-directions.pdf

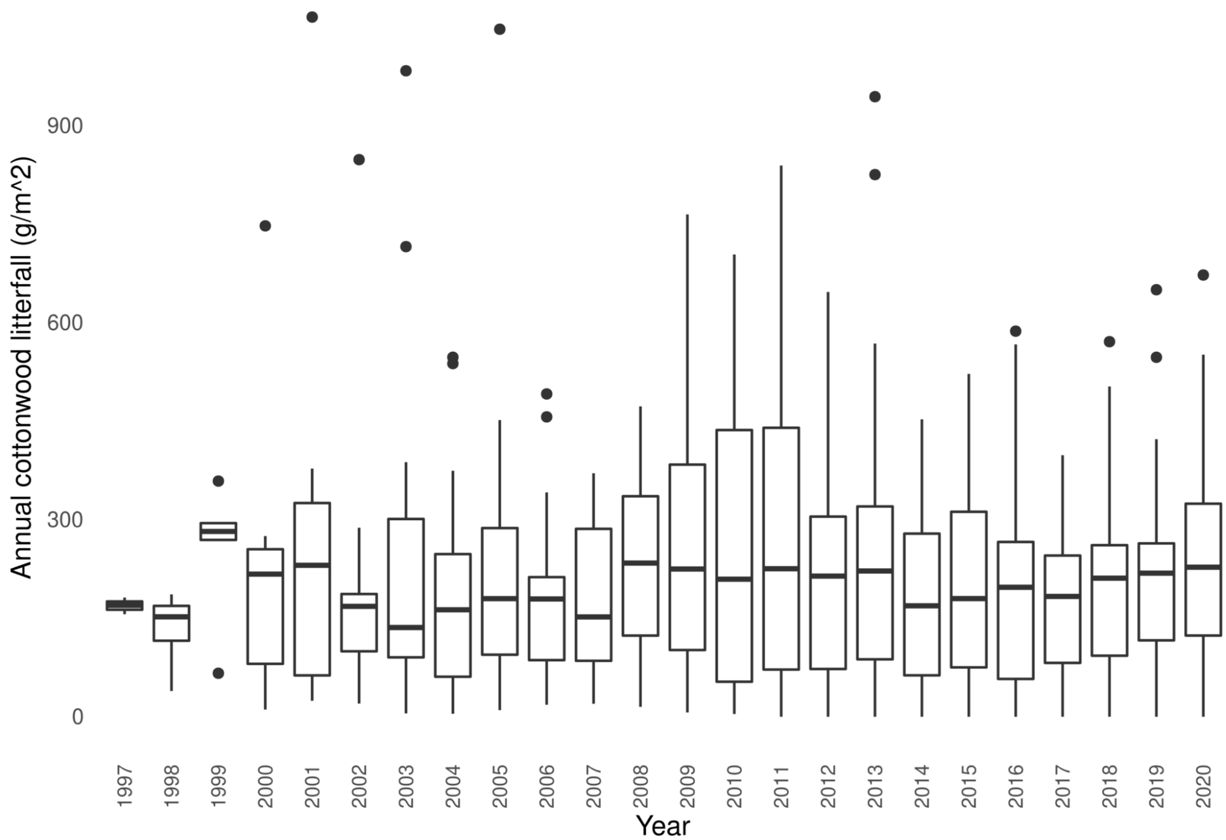

Figure 7.1. Sum of annual cottonwood leaf fall (g/m^2) across all BEMP sites. Number of sites typically increases over time (3 sites in 1997, 4 in 1998, and 5 in 1999), with a maximum of 32 active sites in 2018.

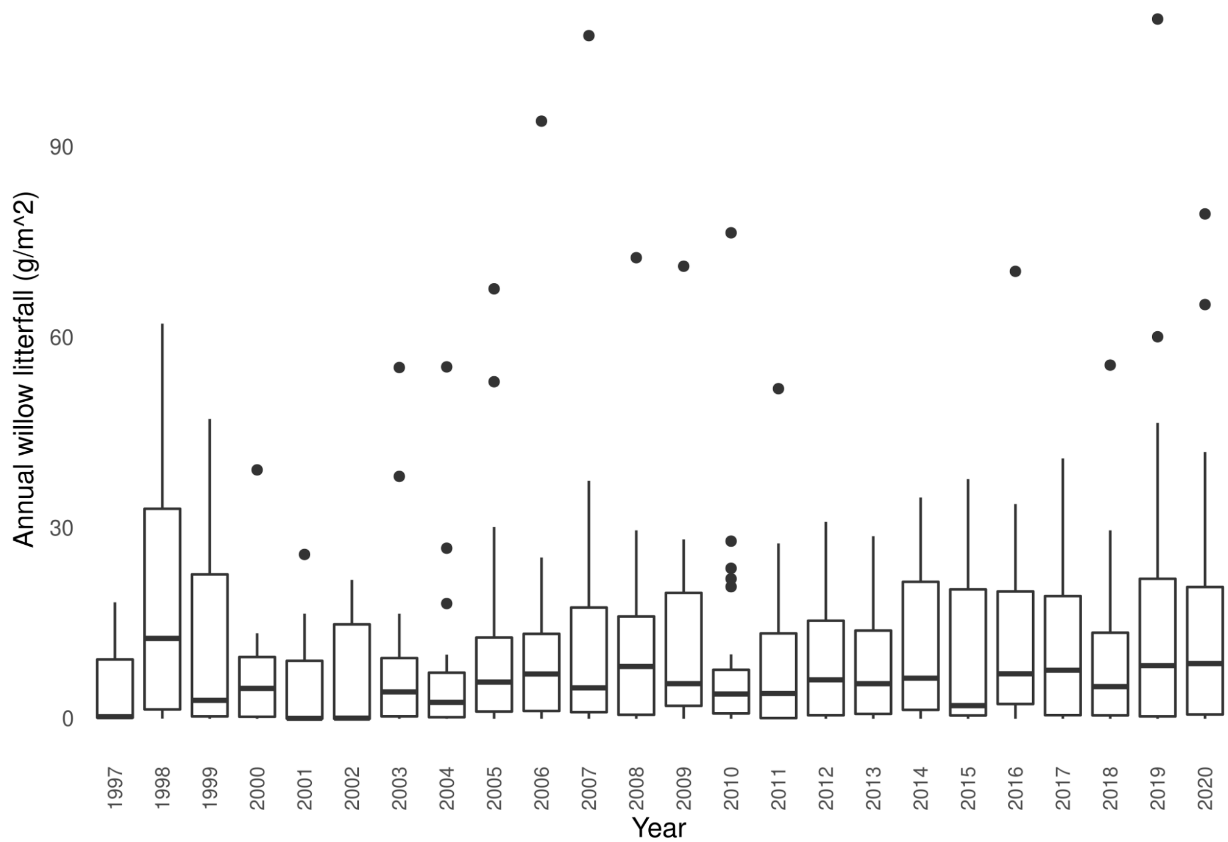

Figure 7.2. Sum of annual willow leaf fall (g/m^2) across all BEMP sites. Number of sites typically increases over time (3 sites in 1997, 4 in 1998, and 5 in 1999), with a maximum of 32 active sites in 2018.

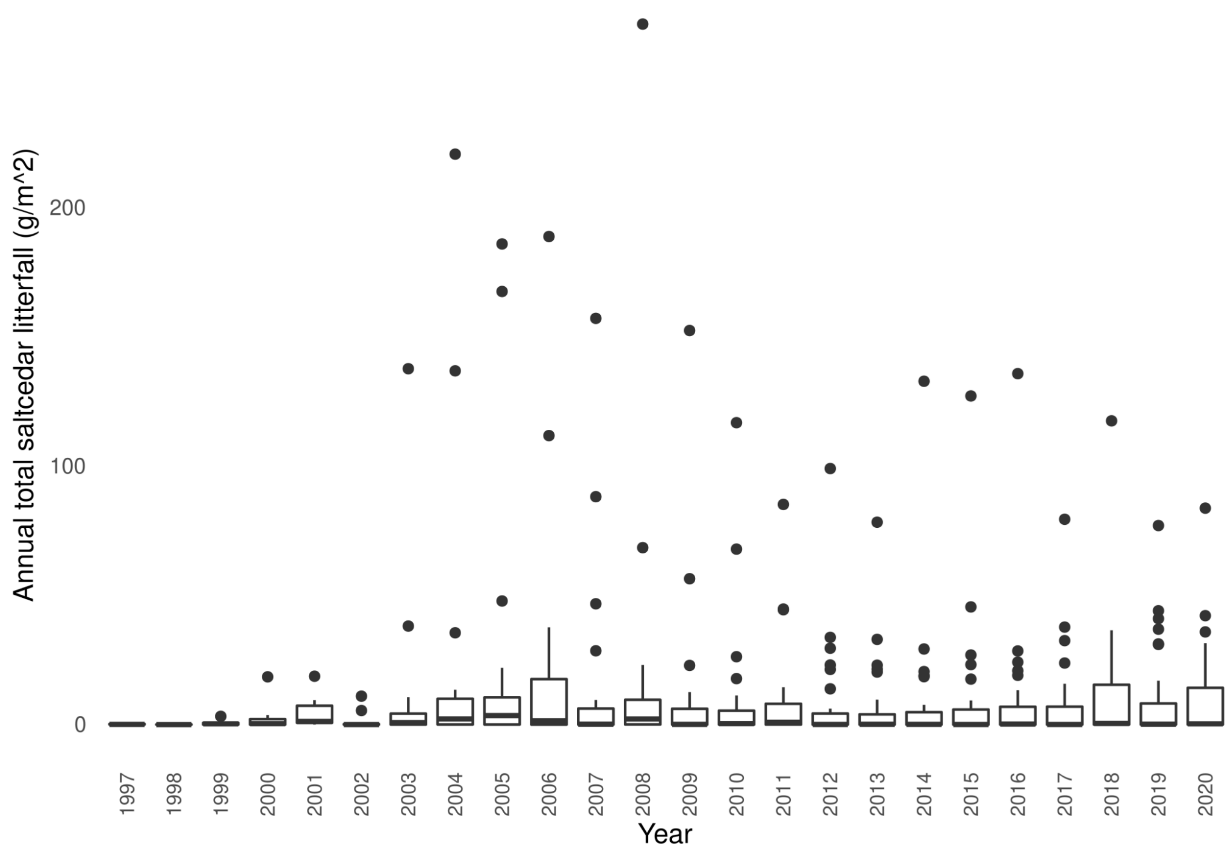

Figure 7.3. Sum of annual saltcedar leaf fall (g/m^2) across all BEMP sites. Number of sites typically increases over time (3 sites in 1997, 4 in 1998, and 5 in 1999), with a maximum of 32 active sites in 2018.

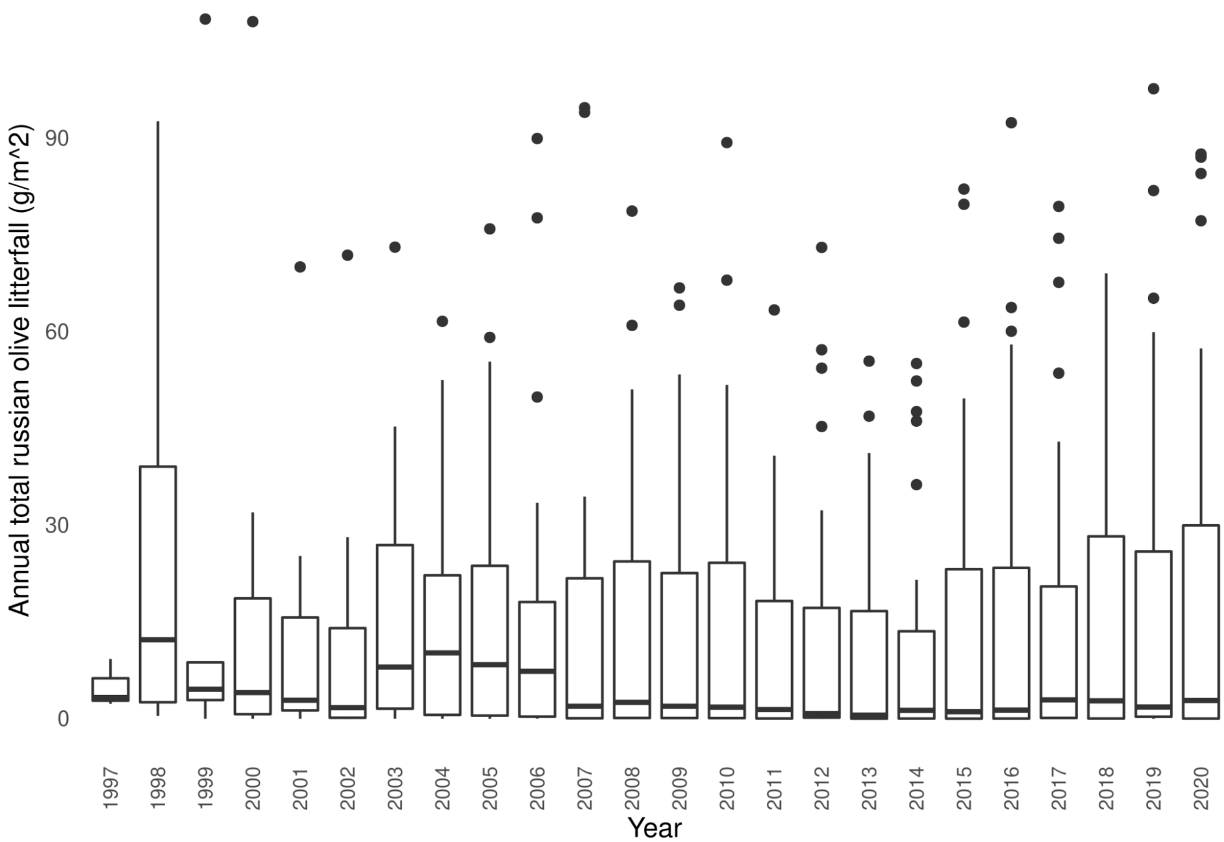

Figure 7.4. Sum of annual Russian olive leaf fall (g/m^2) across all BEMP sites. Number of sites typically increases over time (3 sites in 1997, 4 in 1998, and 5 in 1999), with a maximum of 32 active sites in 2018.

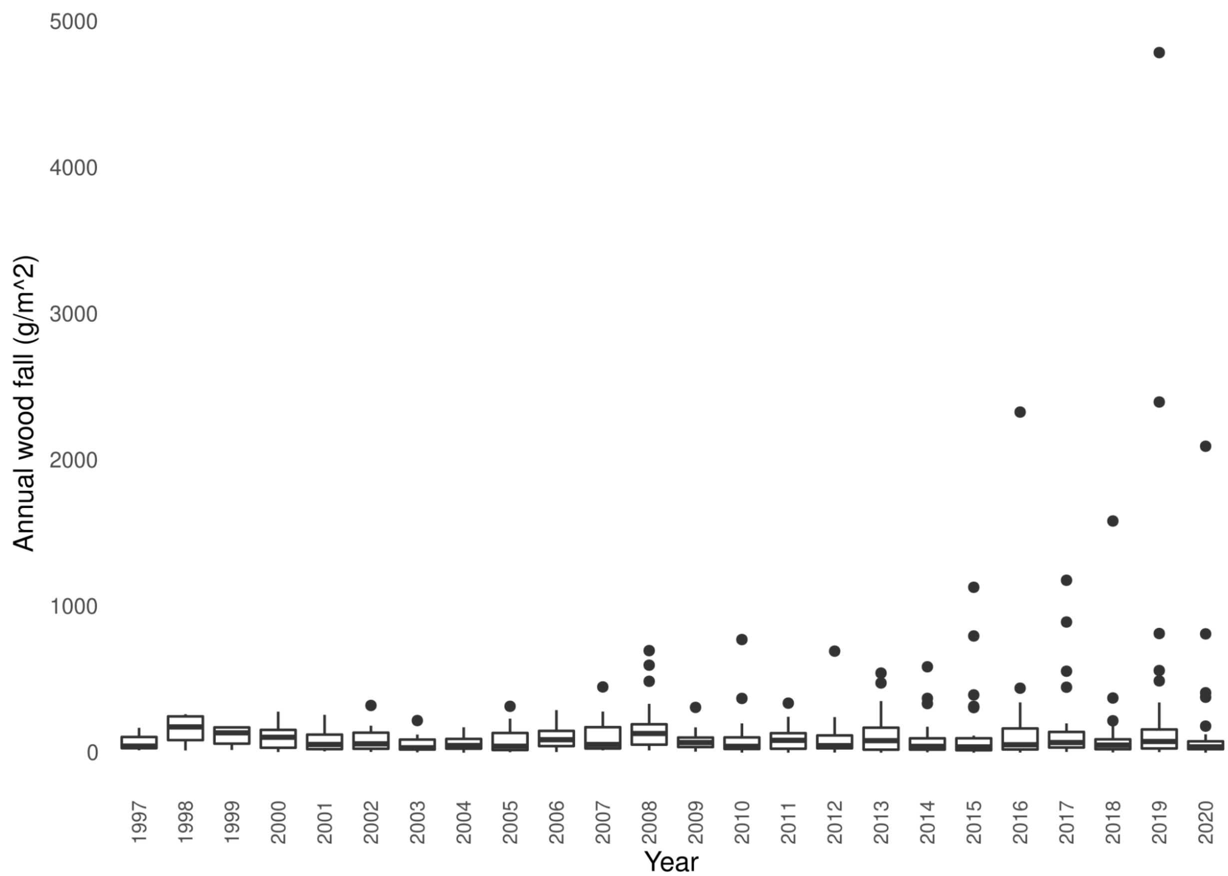

Figure 7.5. Sum of annual wood fall (g/m^2) across all BEMP sites. Number of sites typically increases over time (3 sites in 1997, 4 in 1998, and 5 in 1999), with a maximum of 32 active sites in 2018.

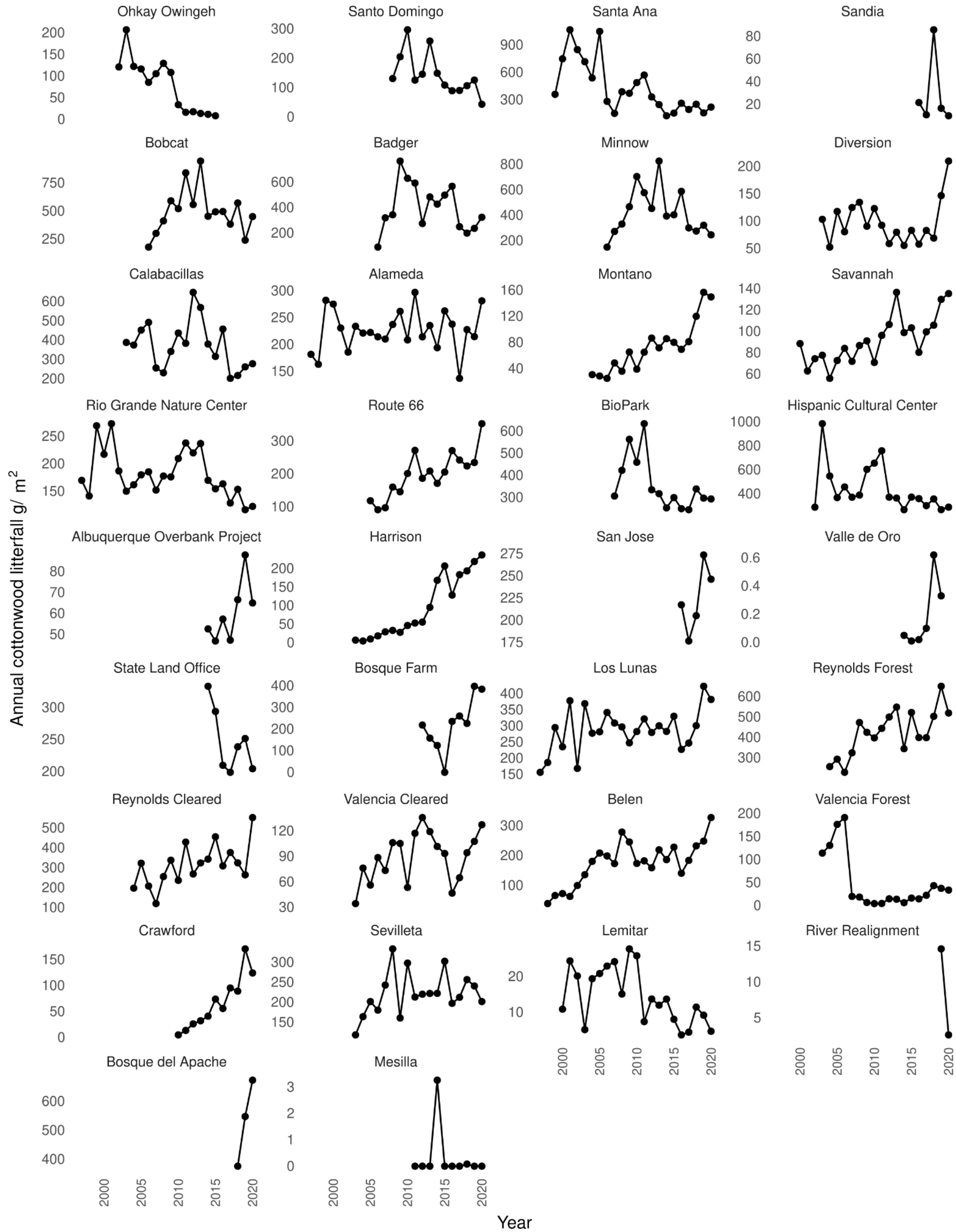

Figure 7.6. Sum of monthly cottonwood leaf fall (g/m^2) at each BEMP site through time.

Leaf fall is used as a proxy for plant productivity. Cottonwood productivity across all BEMP sites has maintained a fairly steady mean, but there has been a decrease in the higher levels of productivity (Figure 7.1). This can be seen in individual sites with older trees, as productivity levels slowly decline (e.g., Santo Domingo, Santa Ana, Bobcat, Badger, Minnow, RGNC, BioPark, HCC, and Lemitar). Sites with younger trees show increases in productivity (e.g., Montano, Savannah, Rt 66, Harrison, AOP, Belen, and Crawford). Many sites show a spike in productivity following the 2019 flood event. When flooding follows years of drought or lack of overbank flooding, the first year of flooding can lead to a drop in productivity as the ecosystem goes through a reorganization phase (Molles et al. 1998). As the system adapts, it then has a strong positive response to subsequent flooding events. This can be seen in the lack of response, or decline in productivity, after the 2017 flood, which was then followed by a strong increase in productivity after the 2019 flood (Figures 7.6-7.8). Overall cottonwood productivity peaked in 2019 for many sites, although there was also a spike in December 2020 leaf fall (Figure 7.6). Similar trends can be seen in other species as well.

Willow productivity varies over time, but also shows a positive response to the 2017 and 2019 flooding events (Figure 7.2). Unlike cottonwoods, coyote willow often responded with increased leaf production the year of the flood and not with a year delay. Saltcedar productivity is highly variable but has a decline in maximum productivity levels (Figure 7.3). Russian olive mean productivity is stable over time, but highly variable (Figure 7.4). Wood fall represents stress and senescence. Wood fall variability has increased over time, as seen in the outliers of higher levels of wood fall (Figure 7.5). This is indicative of the impacts of stress and senescence on older cottonwoods in the system.

Figure 7.7. Flooding at the Harrison site May of 2017.

Figure 7.8. Flooding at the Los Lunas site May of 2019.

8 Vegetation

Vegetation cover surveys are conducted in August-September each year by a team of botanists and BEMP staff. Line intercept methods are used to monitor plant species along ten 30 meter transects at 27 sites. Herbarium work (identification of species) is being completed for 2021 data. Data through 2020 are included in this report.

Full monitoring methods can be found at:
https://secureservercdn.net/45.40.146.38/659.541.myftpupload.com/wp-content/uploads/2016/01/vegetation-monitoring-directions.pdf

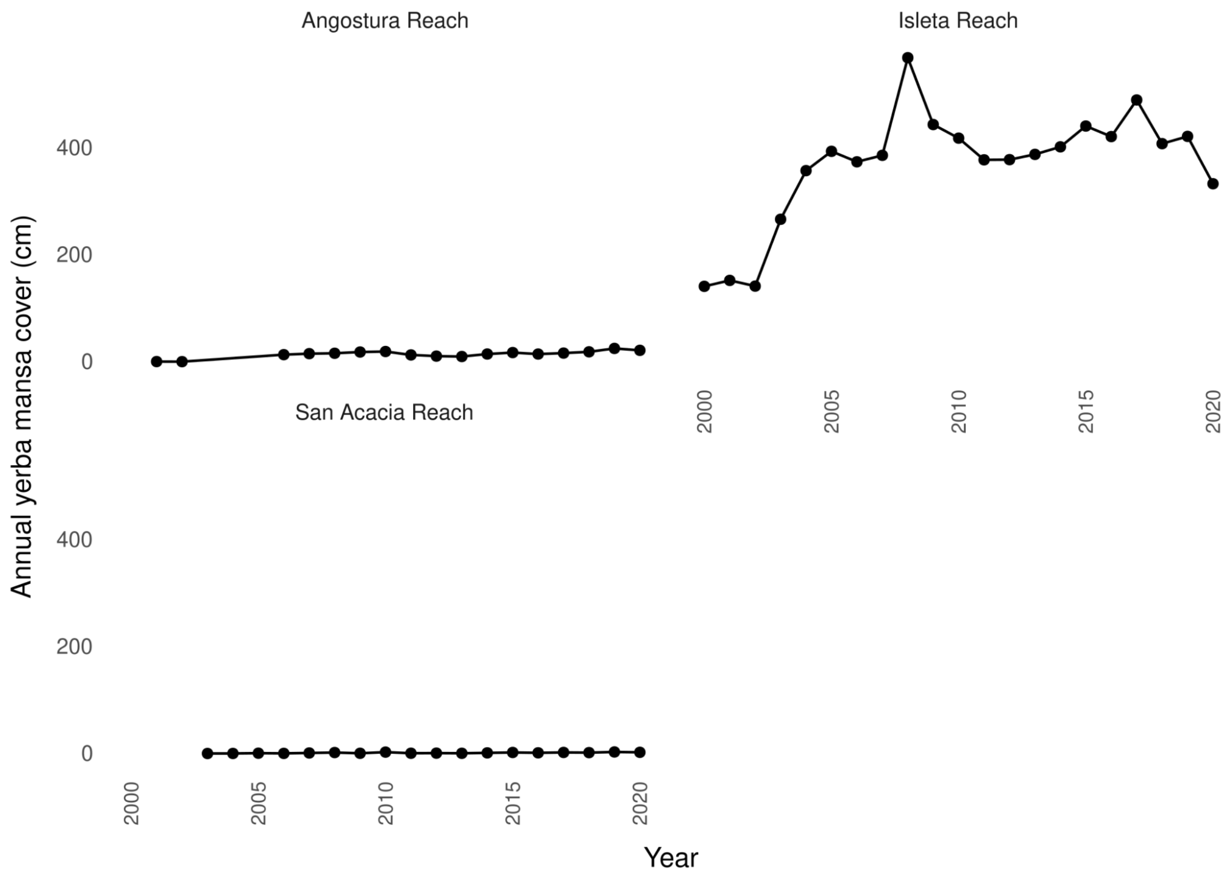

Figure 8.1. Total annual yerba mansa cover across BEMP sites by reach.

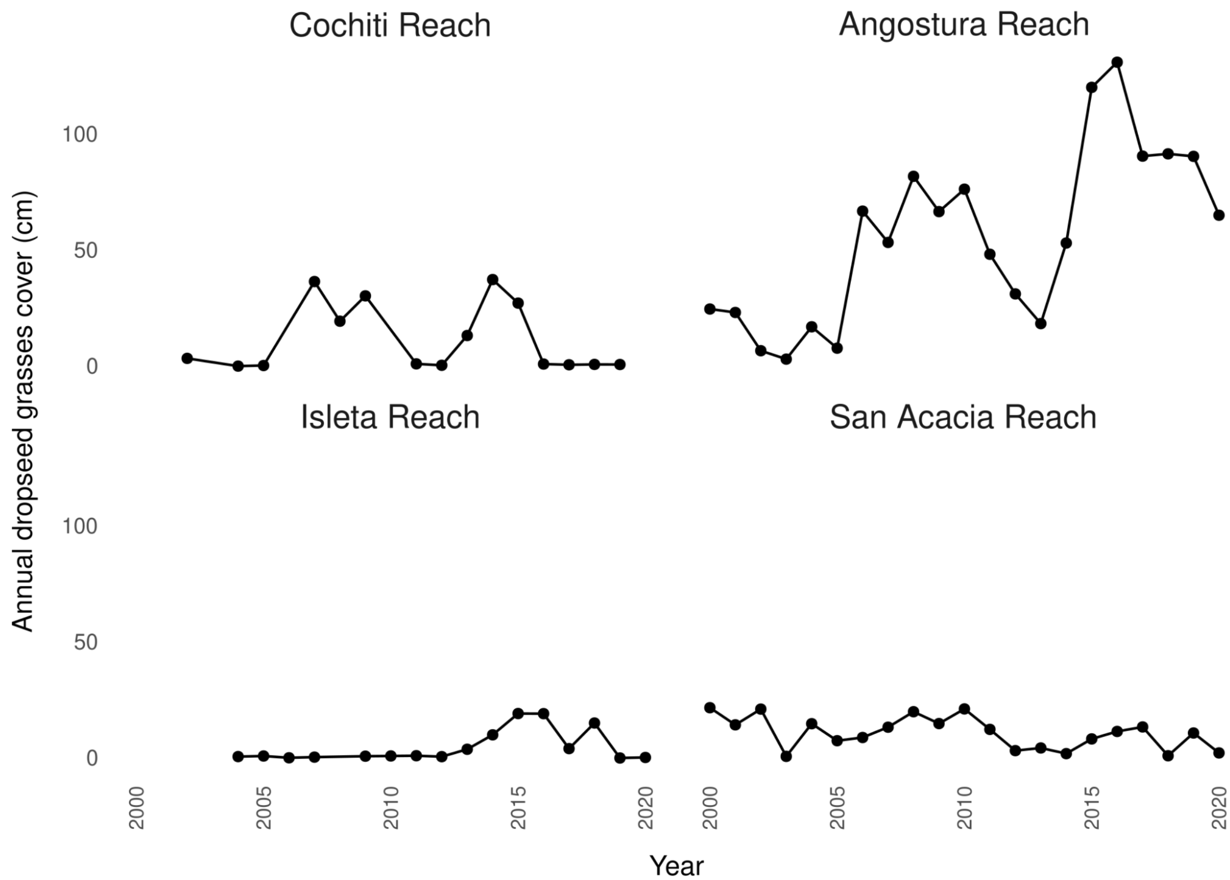

Figure 8.2. Total annual dropseed grass cover across BEMP sites by reach.

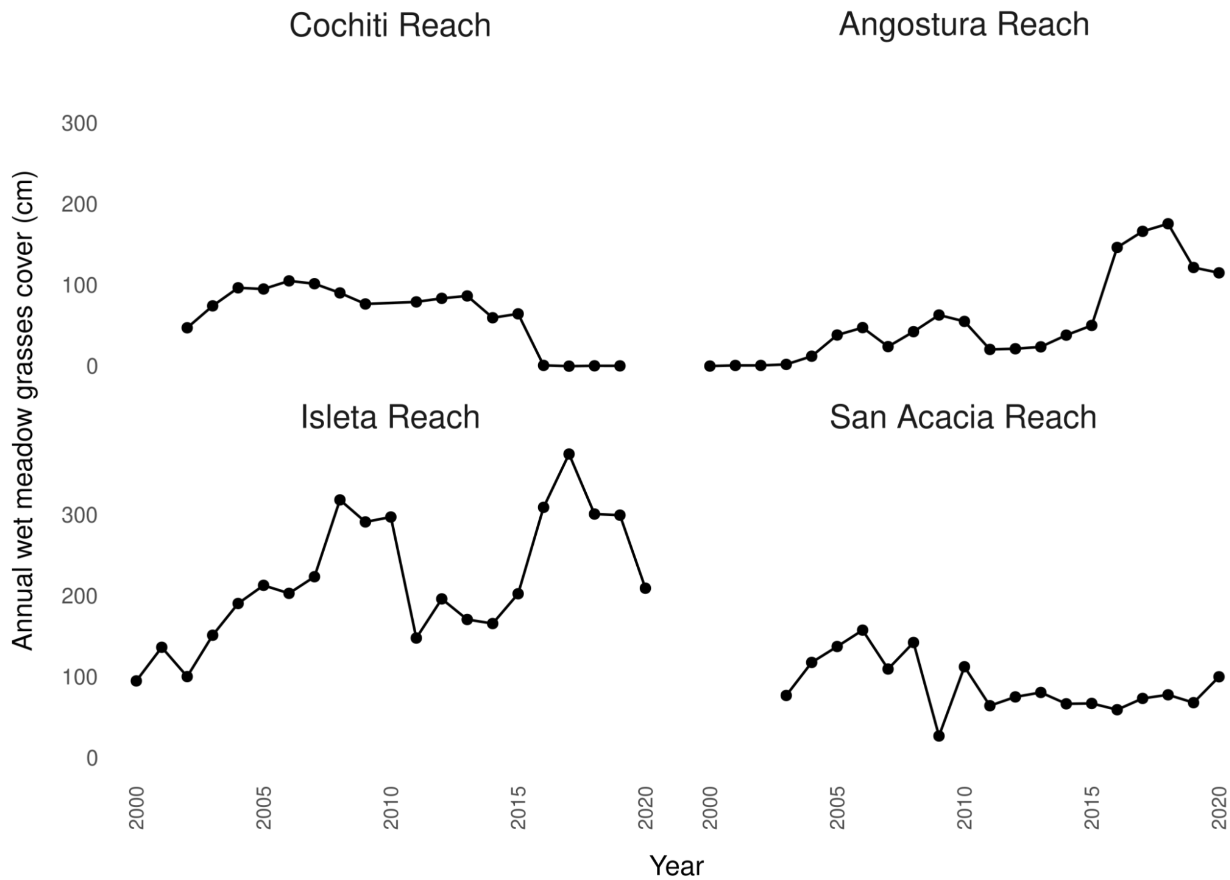

Figure 8.3. Total annual saltgrass and scratchgrass cover across BEMP sites by reach.

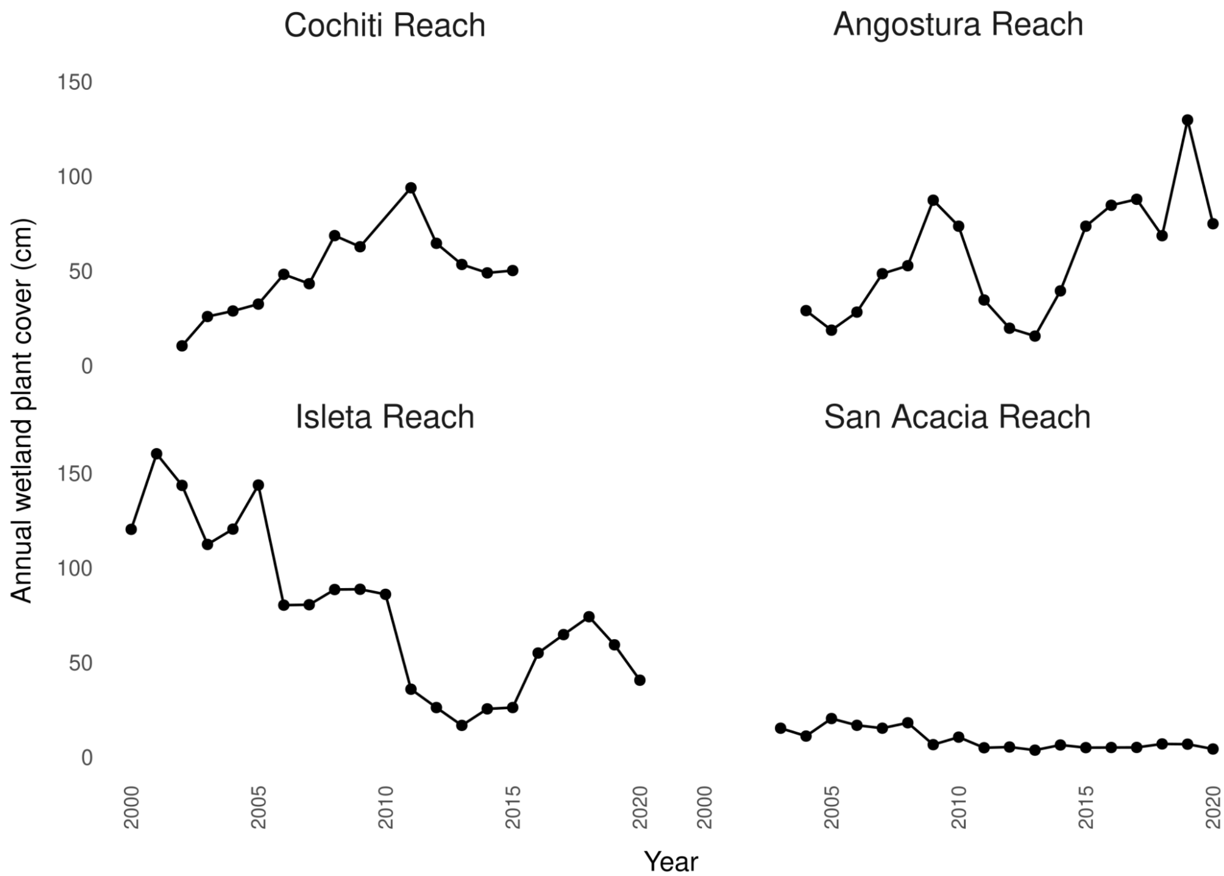

Figure 8.4. Total annual wetland plant cover across BEMP sites by reach. Wetland plants include sedges, rushes, bulrushes, horsetail, cattail, reeds, duckweed, and waterclover.

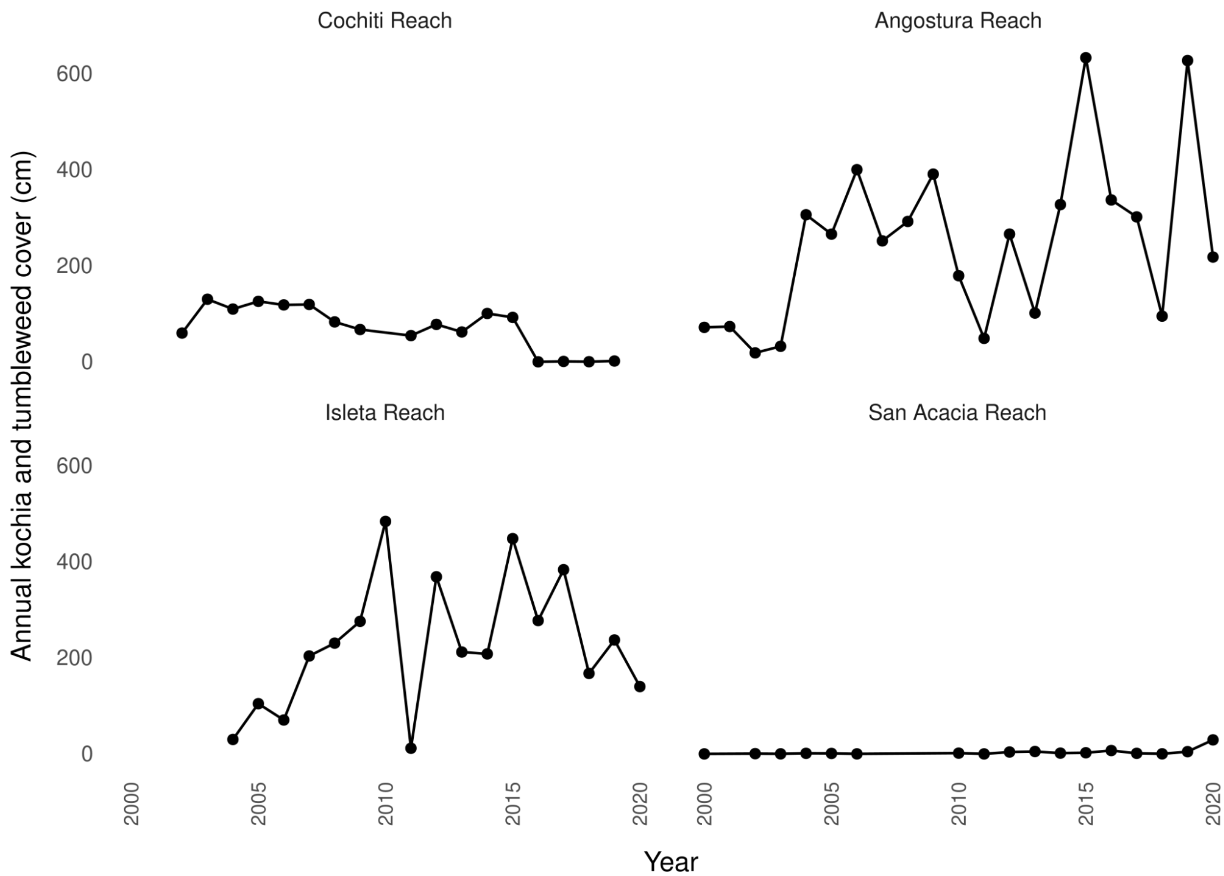

Figure 8.5. Total annual kochia and tumbleweed cover across BEMP sites by reach.

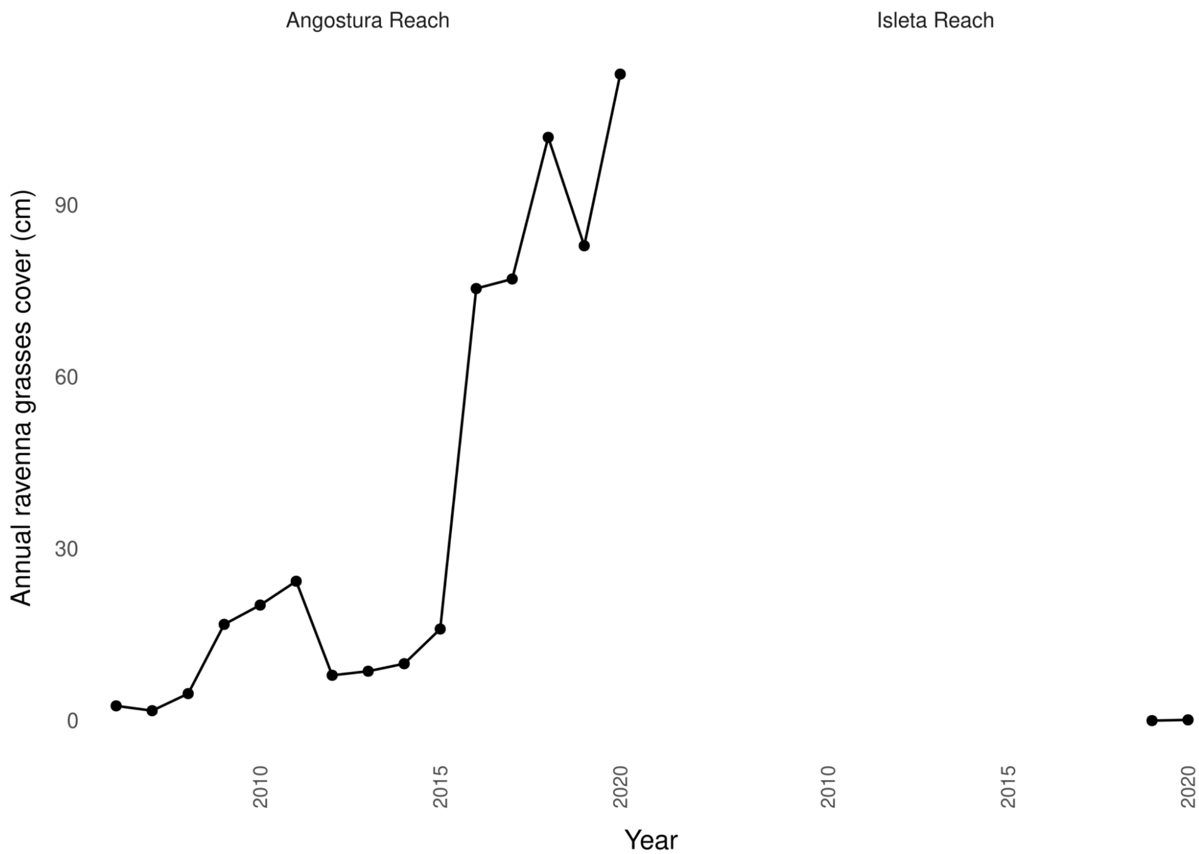

Figure 8.6. Total annual ravennagrass cover across BEMP sites by reach.

Yerba mansa (*Anemopsis californica*), a native plant associated with higher groundwater levels, had a positive response to both the 2017 and 2019 floods except at the Los Lunas site where overall yerba mansa cover declined sharply in 2019 and 2020 (Figure 8.1). Yerba mansa cover increased in flood years at Bobcat (in Albuquerque), Los Lunas (in 2017), Reynolds Cleared, Reynolds Forest, Valencia Cleared, Valencia Forest, Crawford, and Sevilleta. In most reaches, yerba mansa cover is steady with a decline in 2020. Even at sites with extended inundation during 2019 (Figure 7.9), yerba mansa cover increased that year. The 2019 decline at Los Lunas, followed by the decrease in cover at all sites in 2020 results in the drop in the Isleta Reach (Figure 8.1).

Native dropseed grasses *(Sporobolus spp.)* have the highest cover in the Angostura Reach sites, but there has been a decline in the last few years across all reaches (Figure 8.2). Saltgrass *(Distichlis spicata)* and scratchgrass *(Muhlenbergia asperfolia)*, both native grasses associated with saltgrass meadows and wet meadows, have been slowly increasing in the Angostura and Isleta Reaches with recent declines (Figure 8.3). This is driven by the response from five of the six sites that had strong, overbank flooding; following the 2019 flooding (and in some cases the 2017 flooding) there was a sharp decline in saltgrass, scratchgrass, and yerba mansa.

Dominant wetland plants were analyzed by reach and included sedges, rushes, horsetail, cattail, reeds, duckweed, and waterclover (Figure 8.4). The species represented in this analysis are: *Carex* sp., *Cyperus glomeratus* (exotic), *Cyperus* sp., *Equisetum laevigatum*, *Equisetum* sp., *Juncus arcticus*, *Juncus balticus*, *Juncus* sp., *Juncus torreyi*, *Lemna* sp., *Marsilea* sp., *Phragmites australis*, *Schoenoplectus americanus*, *Schoenoplectus* sp., *Scirpus* sp., *Scirpus pallidus*, *Schoenoplectus tabernaemontani*, *Schoenoplectus pungens*, *Typha latifolia*, and *Typha* sp. Representative wetland plant cover is slowly increasing in the Angostura Reach and declining in the Isleta Reach (Figure 8.4). In years of low river flow, the Angostura Reach has had supplemental water in order to keep the reach wet, while lower reaches have had intermittent drying (Figures 5.3 and 5.5). Supplemental water in the river will also support higher groundwater levels, while river drying events lead to groundwater declines (Figures 5.3 and 5.5). This in turn impacts the ephemeral wetlands and associated species. Recent flood events seem to have mitigating impacts on wetland species cover.

Tumbleweed *(Salsola* spp.*)* and kochia *(Bassia scoparia)*, both invasives that respond positively to disturbed areas, have high variability (Figure 8.5). In post-disturbance or declining sites, like at Santa Ana, there is an increase in invasives over time with a corresponding decrease in species like yerba mansa, saltgrass and scratchgrass. In post-disturbance sites that are into a decade of recovery, like Montano and Valencia Cleared, these invasives are slowly declining.

Ravennagrass *(Saccharum ravennae)* was first recorded in the Angostura Reach BEMP sites in 2006 and expanded rapidly starting in 2015-16 (Figure 8.6). Ravennagrass has been recorded in the Isleta Reach BEMP sites as of 2019; it was observed at sites previously, but did not intersect the vegetation lines.

9 Surface-Active Arthropods

Surface active arthropods are reported for 2019. 2020 and 2021 arthropod samples are being processed, entered and checked. 2022 collections are scheduled to begin May 2022.

Full monitoring methods can be found at: https://secureservercdn.net/45.40.146.38/659.541.myftpupload.com/wp-content/uploads/2016/01/pitfall-monitoring-directions-and-arthropod-identification.pdf

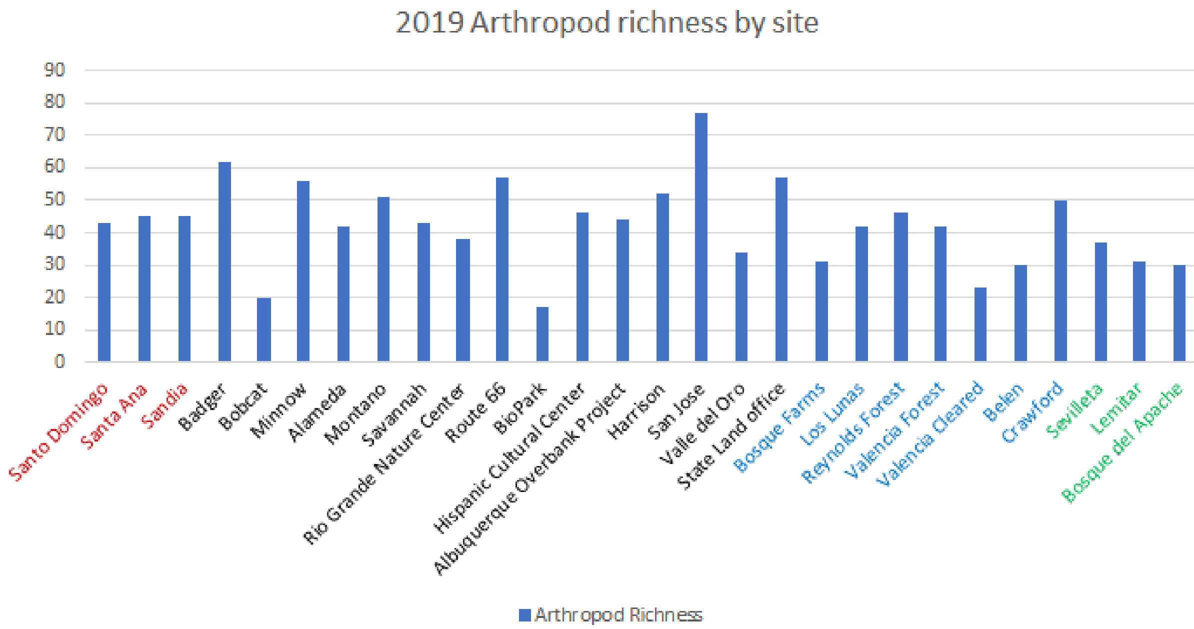

Figure 9.1. Arthropod richness for 2019. Sites arranged geographically north to south. Site location by reach indicated by color; north of the Albuquerque (Cochiti, plus two Pueblos) in red, Albuquerque in black, Isleta reach in blue, San Acacia reach in green.

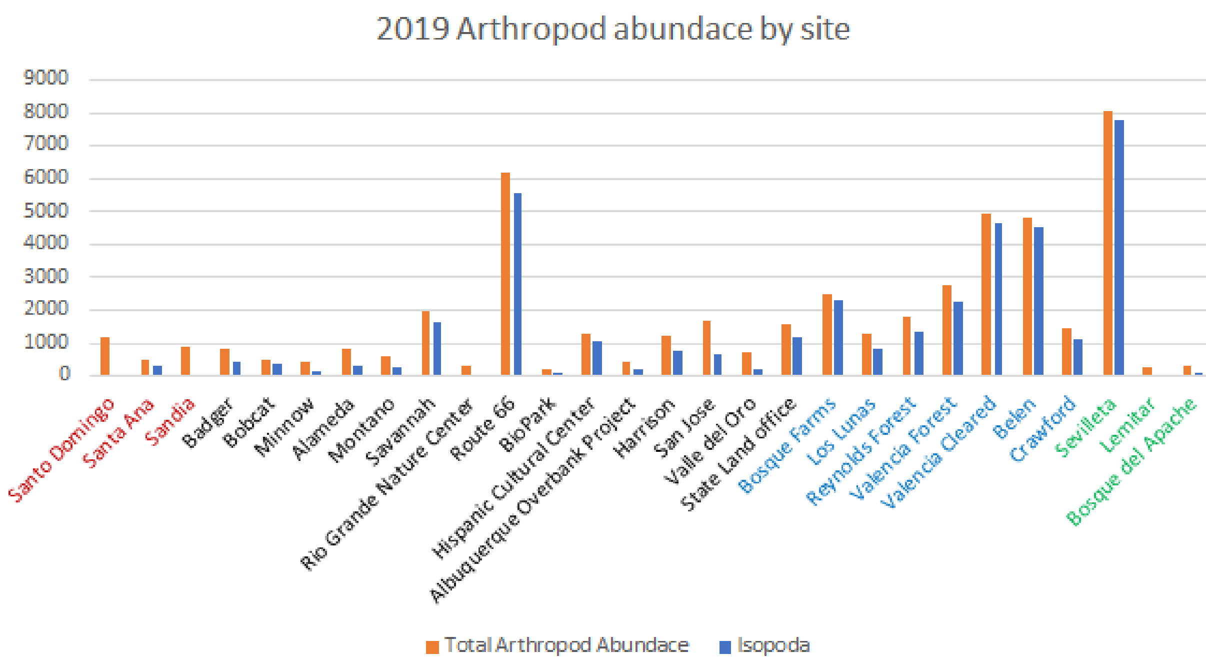

Figure 9.2. Isopod (blue) and all arthropod abundance (orange) per site for 2018 excluding Collembola. Sites arranged geographically north to south. Site location by reach indicated by color; north of the Albuquerque (Cochiti, plus two Pueblos) in red, Albuquerque in black, Isleta reach in blue, San Acacia reach in green.

Figure 9.3. Arthropods seeking high ground during the 2017 and 2019 floods. *Pogonomyrmex* sp. finding refuge on precipitation gauge shortly after flood water receded at the Harrison site, May 2017 (Left), and isopods finding refuge on a tree surrounded by flood water at the Los Lunas site, May 2019 (Right).

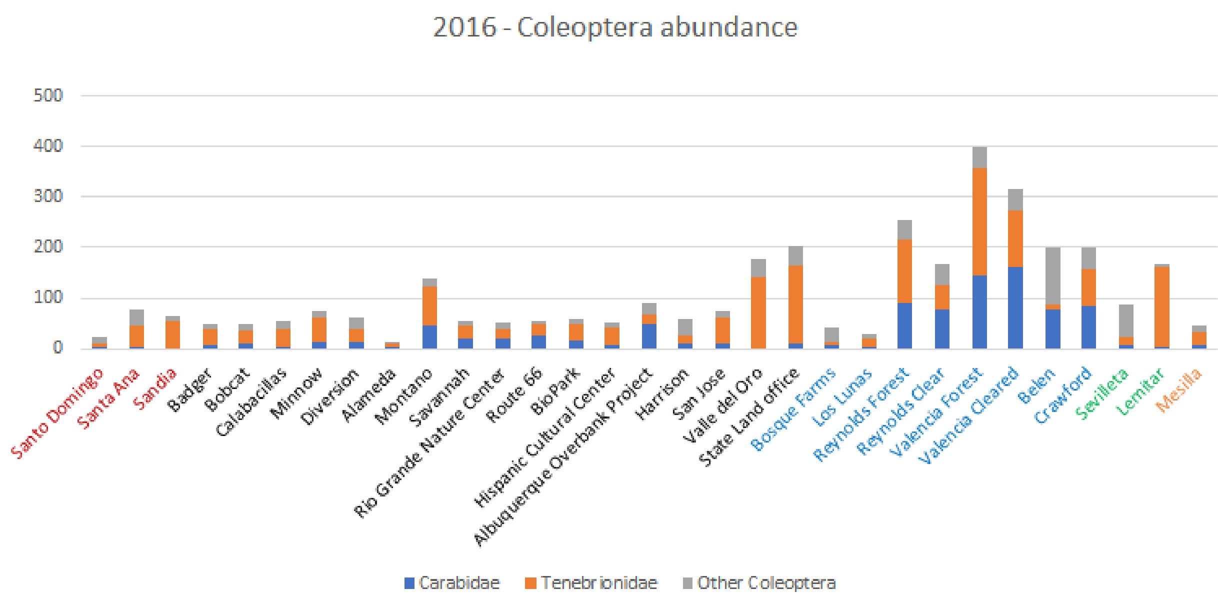

Figure 9.4. Coleoptera abundance per site for 2016 highlighting Carabidae (blue) and Tenebrionidae (orange). Sites arranged geographically north to south. Site location by reach indicated by color; north of the Albuquerque (Cochiti, plus two Pueblos) in red, Albuquerque in black, Isleta reach in blue, San Acacia reach in green and south of San Marcial each in orange.

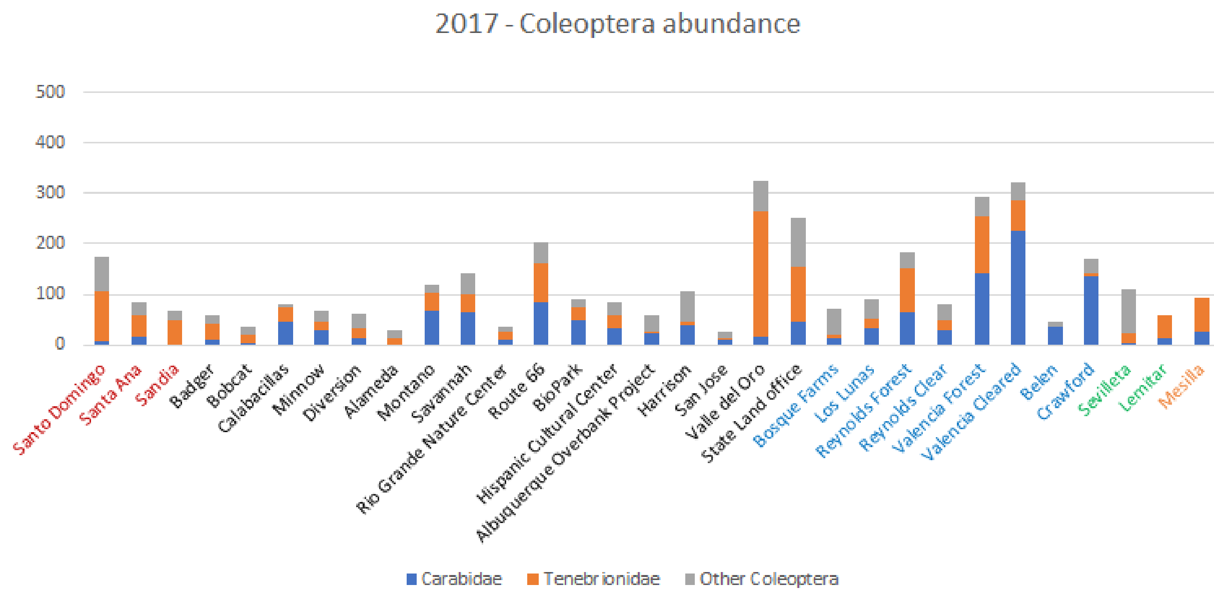

Figure 9.5. Coleoptera abundance per site for 2017 highlighting Carabidae (blue) and Tenebrionidae (orange). Sites arranged geographically north to south. Site location by reach indicated by color; north of the Albuquerque (Cochiti, plus two Pueblos) in red, Albuquerque in black, Isleta reach in blue, San Acacia reach in green and south of San Marcial each in orange.

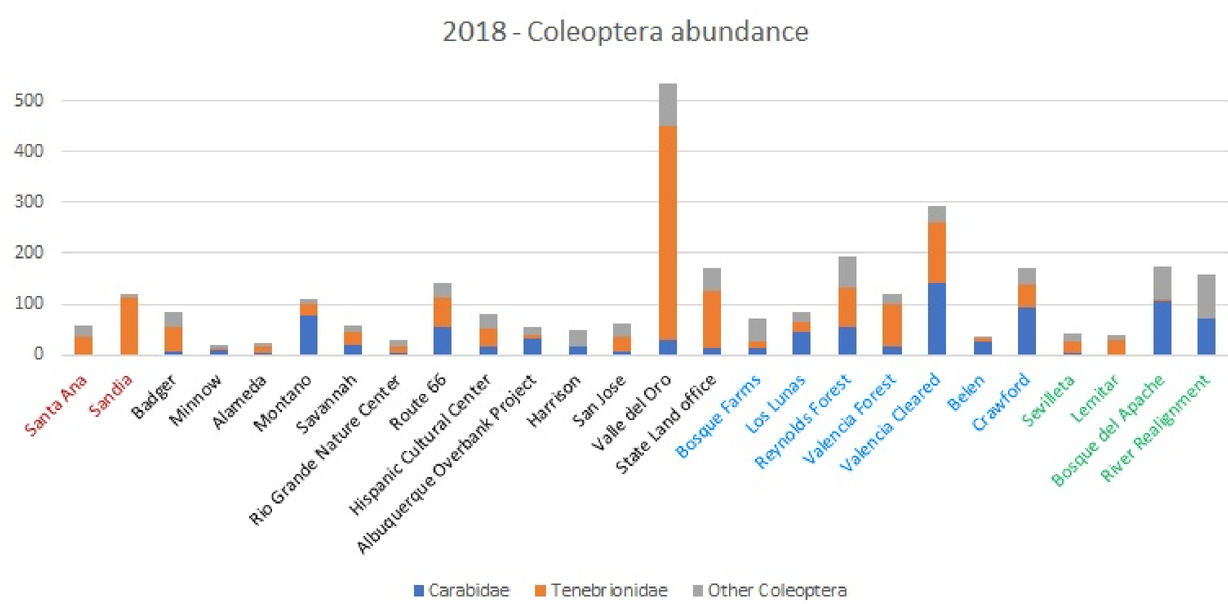

Figure 9.6. Coleoptera abundance per site for 2018 highlighting Carabidae (blue) and Tenebrionidae (orange). Sites arranged geographically north to south. Site location by reach indicated by color; north of the Albuquerque (Cochiti, plus two Pueblos) in red, Albuquerque in black, Isleta reach in blue, San Acacia reach in green and south of San Marcial each in orange.

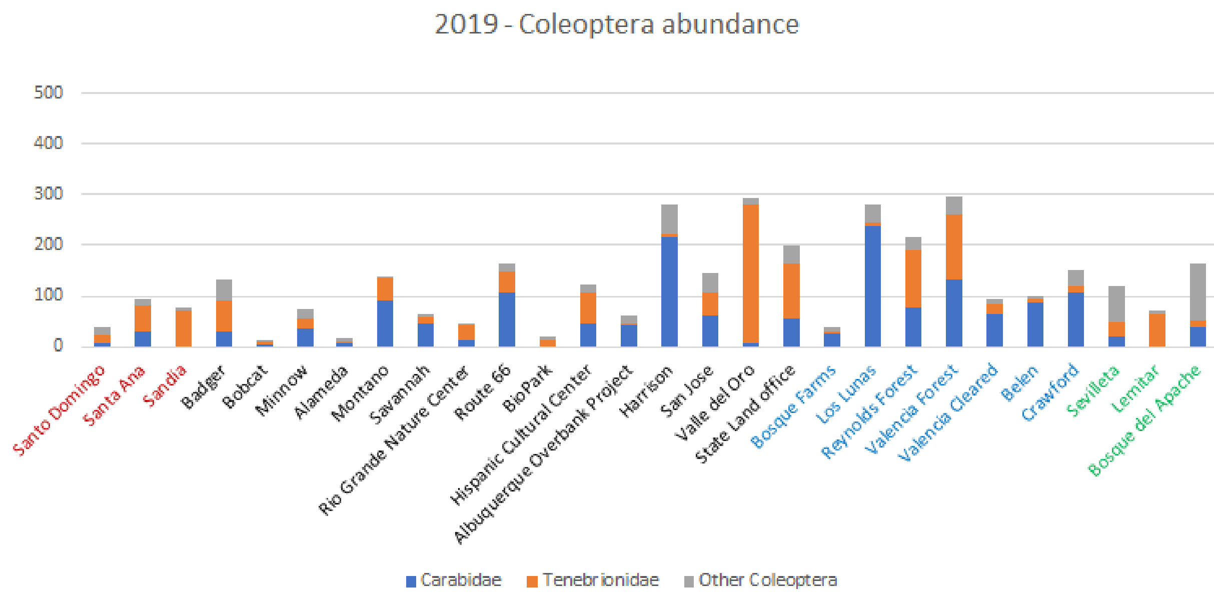

Figure 9.7. Coleoptera abundance per site for 2019 highlighting Carabidae (blue) and Tenebrionidae (orange). Sites arranged geographically north to south. Site location by reach indicated by color; north of the Albuquerque (Cochiti, plus two Pueblos) in red, Albuquerque in black, Isleta reach in blue, San Acacia reach in green and south of San Marcial each in orange.

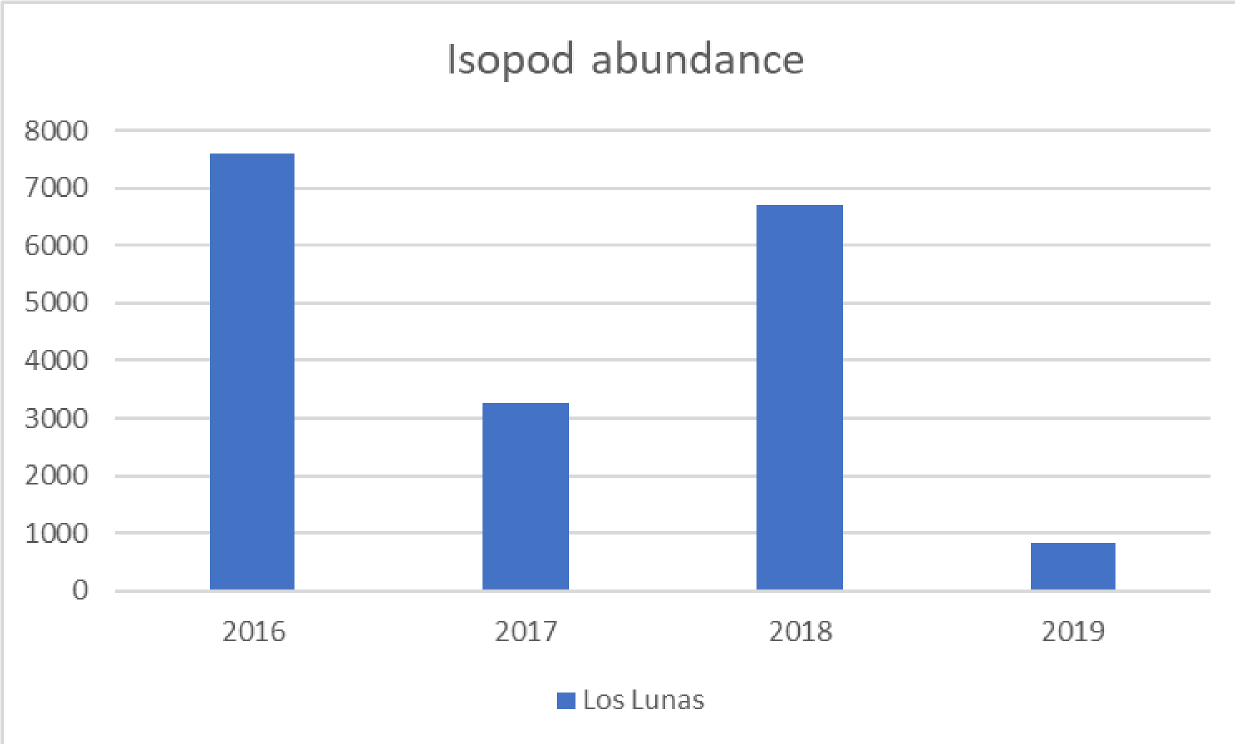

Figure 9.8. Yearly isopod abundance at the Los Lunas site.

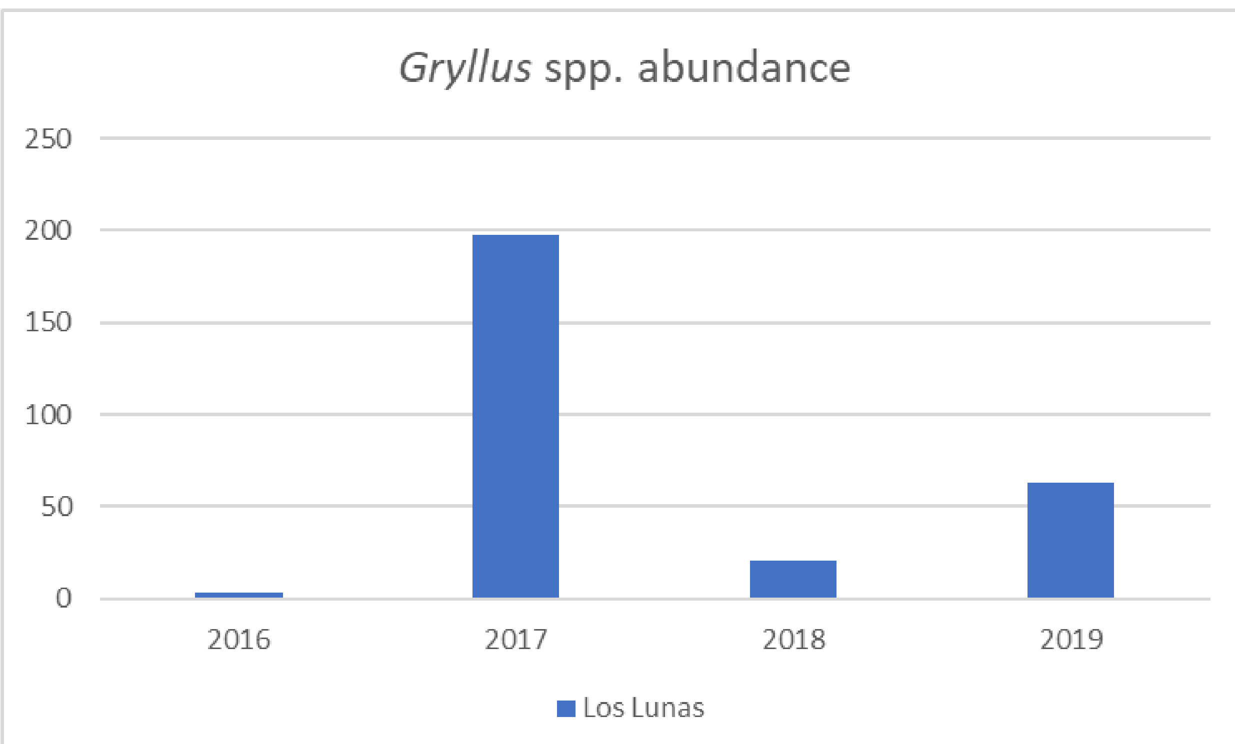

Figure 9.9. Yearly *Gryllus* spp. abundance at the Los Lunas site.

2019 arthropod richness and abundance are presented. High river flows during 2017 and 2019 resulted in exceptional flooding throughout the bosque, resulting in shifts to many arthropod communities including the order Coleoptera (beetles). 2016 – 2019 arthropods are reported to highlight arthropod response before and during these flooding events.

Collembola have been included in richness analysis but excluded from abundance counts as explained in the 2020 report.

2019 – Arthropods

In 2019, approximately 50,000 arthropods were identified across 28 sites encompassing approximately 200 unique identifications. Arthropod richness by site can be seen in Figure 9.1 with the San Jose site showing the highest arthropod richness for 2019.

Total arthropod abundance by site can be seen in Figure 9.2, in orange. As seen in previous years, arthropod abundance is mostly driven by isopod abundance (Figure 9.2, in blue). In 2019, isopods represented the dominant arthropod, captured in 16 out of 28 sites: Santa Ana, Badger, Bobcat, Savannah, Route 66, Hispanic Cultural Center, Harrison, State Land Office, Bosque Farms, Los Lunas, Reynolds Forest, Valencia Forest, Valencia Cleared, Belen, Crawford, and Sevilleta.

Many beetle species in the family Carabidae (ground beetles) are useful as indicators of mesic habitats while many beetle species in family Tenebrionidae (darkling beetles) are useful as indicators of xeric habitats. Although habitat and other environmental preferences vary from species to species within such large and diverse families, these families are still quite useful as environmental indicators. Figure 9.7 shows beetle abundance by site highlighting carabids in blue, and tenebrionids in orange. The Valle del Oro site, a non-irrigated fallow farm field outside the Rio Grande Levee system, was not subjected to flooding in 2017 or 2019 and was highly dominated by tenebrionid beetles in 2019. In contrast, the Harrison and Los Lunas sites, both subjected to flooding, were both dominated by carabid beetles in 2019. Site response to flooding is analyzed in more detail below.

Coleoptera community shifts from 2016 to 2019

High river flows in the Rio Grande resulted in overbank and seep flooding at a number of sites in both 2017 and 2019. Flooding was known to be an important driver of this system historically, but is an uncommon occurrence in the modern context. Historic flood events cleared downed wood, leaves, and other debris; allowed for natural recruitment of cottonwoods and other native plants; and were drivers of diversity in riparian arthropod communities (Lafage and Pétillon 2016). Many arthropods found in riparian areas that are incapable of flight must find refugia during times of flooding to avoid the risk of drowning and will often seek out higher ground (Figure 9.3) (Adis and Junk 2022). A shift in Coleoptera community makeup can be seen between 2016 and 2019 and was most likely driven by flooding events (Figures 9.4 – 9.10). In 2016, the year prior to the 2017 flooding event, tenebrionids dominated the beetle communities at many BEMP sites, reflecting the more xeric nature of these sites (Figure 9.4). However, during the 2017 floods, an increase in carabid abundance was seen at a number of sites, especially those directly subjected to flooding (Figure 9.5). Some shifts originally observed in 2017 remained during 2018, but the largest community shifts are seen in 2019 data (Figures 9.6 – 9.7). Notably, Harrison and Los Lunas were both subjected to overbank flooding (Figures 7.7 – 7.8), and both had an increased abundance of Coleoptera and a shift towards a carabid-dominated community. The Valle del Oro site, which falls outside the levee system, experienced no flooding in 2017 or 2019 and exhibited little change in Coleoptera community composition, which remained dominated by tenebrionids throughout this time period. This trend aligns with similar observations by Ellis et al. (2001) in areas of the Middle Rio Grande subjected to managed flooding.

Response of native and non-native terrestrial decomposers to flooding

Two arthropods commonly encountered in the bosque function as decomposers, the non-native terrestrial isopods *Armadillidium vulgare* and *Porcellio laevis*, and native crickets *Gryllus* spp. At the Los Lunas site, which was subjected to heavy flooding in both 2017 and 2019, non-native isopod populations decreased while native *Gryllus* spp. populations increased in response to these flood events (Figures 9.8 and 9.9). This trend was seen in managed flooding along the Middle Rio Grande by Molles et al. (1998).

Marinarozelotes barbatus update

In the 2016 arthropods collections, *Marinarozelotes barbatus* (Koch, 1866) was recorded in the Middle Rio Grande for the first time and reported in the 2019 report. This spider naturally occurs from Spain to Yugoslavia and, in the United States, has been introduced to California but has not been known to occur elsewhere. This species was first detected at the Albuquerque Overbank Project (AOP) site. Between 2016 and 2018, numerous specimens were identified at the AOP, Harrison and San Jose sites. A physical search of BEMP sites in 2019 and 2020 found both spiders and evidence in the form of conspicuous egg sacs as far north as the BioPark site. No additional evidence of this species was found south of the San Jose site or north of BioPark. A preliminary look at 2020 data uncovered an adult male from the State Land Office site south of San Jose, demonstrating a potential increase in the range of this spider. BEMP sites will continue to be monitored for evidence of this exotic species.

10 Tamarisk Leaf Beetle

2021 sampling for *Diorhabda* spp., commonly known as tamarisk leaf beetles (TLBs), took place during the week of the third Tuesday of each month from May to August for all sites except San Cristobal, Rio Abajo, and Bosque School. Sampling at the San Cristobal and Rio Abajo sites occurred during August and September. Sampling at the Bosque School site occurred weekly from May through August to capture a finer resolution of TLB activity. An additional subset of six sites were sampled in September, including Diversion, Route 66, Crawford, Sevilleta, San Cristobal, and Rio Abajo, to see if any late season TLBs were active (Figure 10.1). Five trees were flagged and monitored at each sampled site.

Complete collection methods and full results can be found in the annual TLB report submitted December of 2021, available upon request.

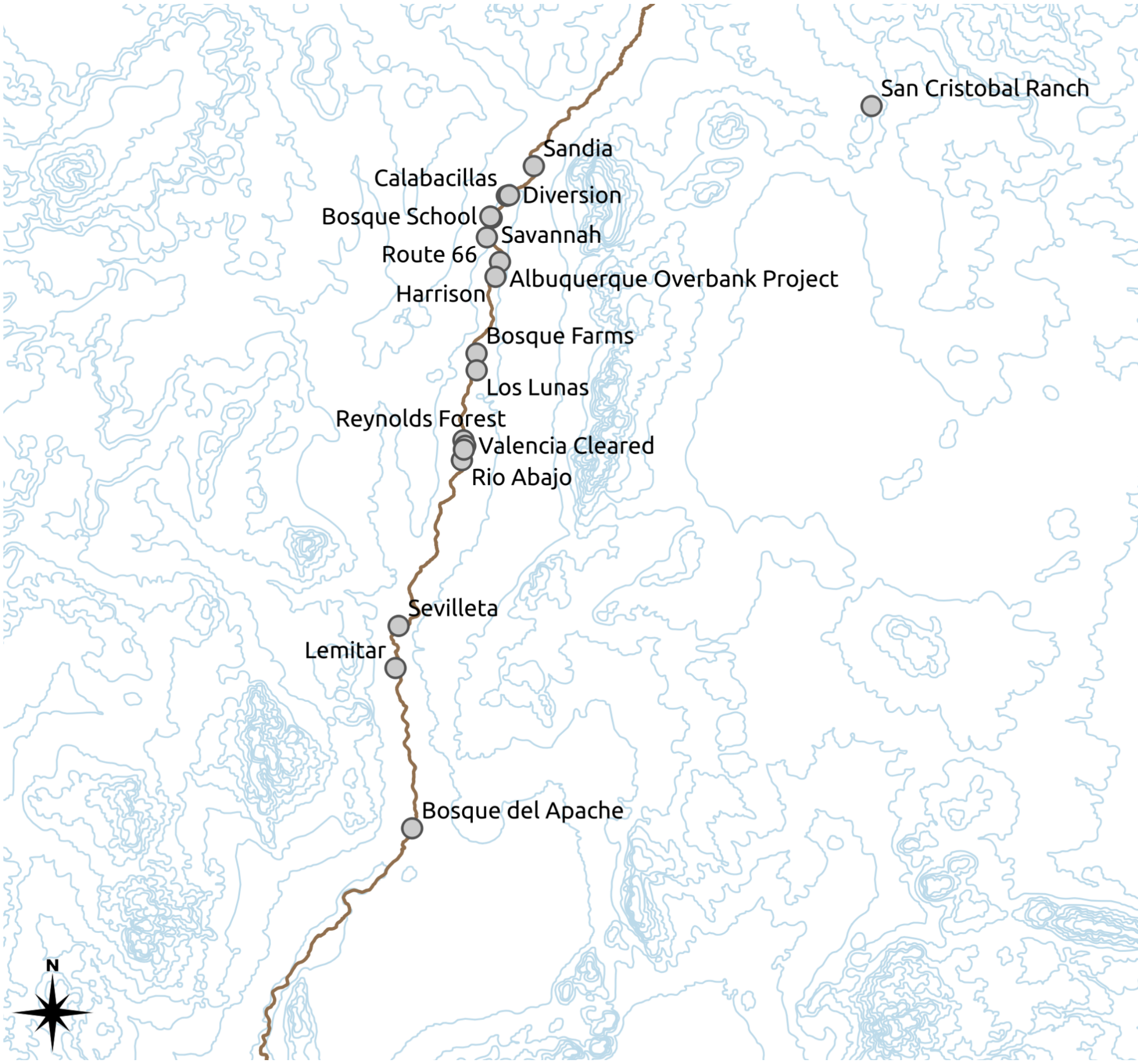

Figure 10.1. Map of all locations sampled for *Diorhabda* spp. during the 2021 collection season. Sixteen of the sites occurred within the riparian bosque of the Middle Rio Grande and one site, San Cristobal Ranch, was in an upland habitat zone. 500 foot contours shown in blue.

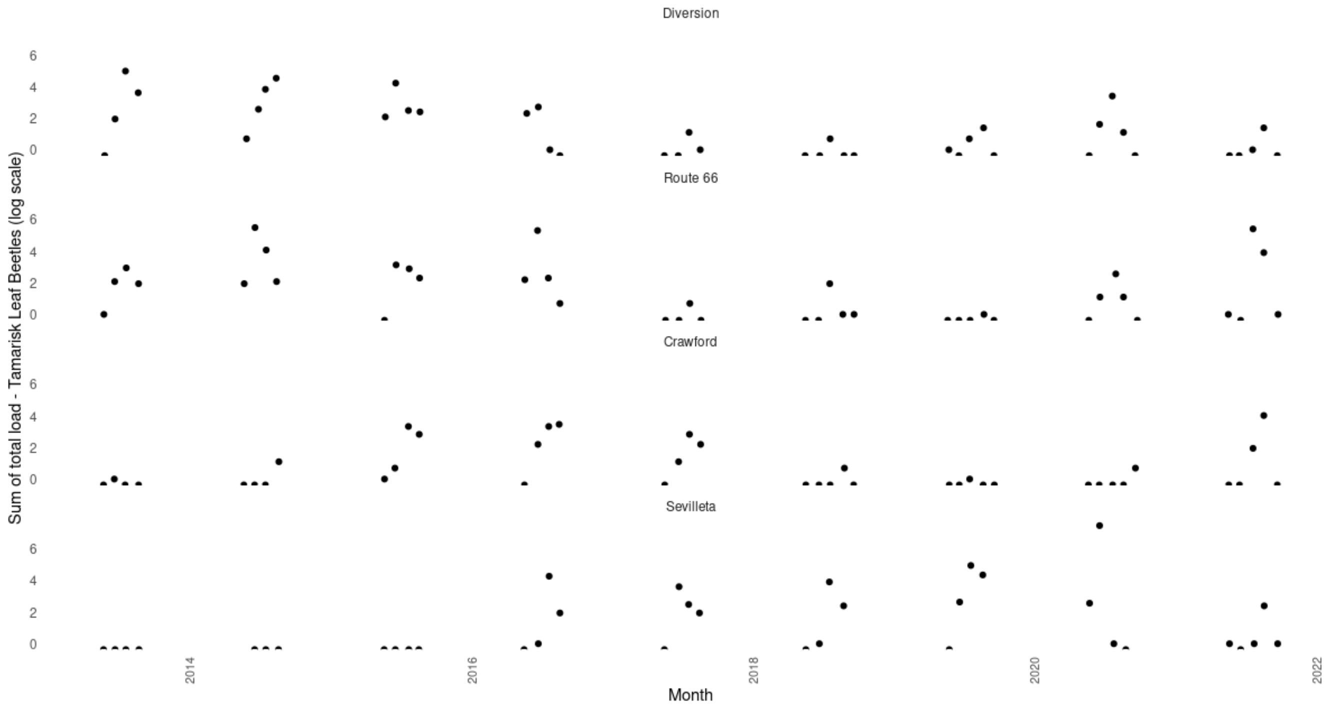

Figure 10.2. Total tamarisk leaf beetle load at four select sites from 2013 to 2021 on a log scale. Total load includes the sum of early larvae, late larvae, and adult beetles. This shows the long term cyclical nature of the tamarisk leaf beetle abundance at these sites.

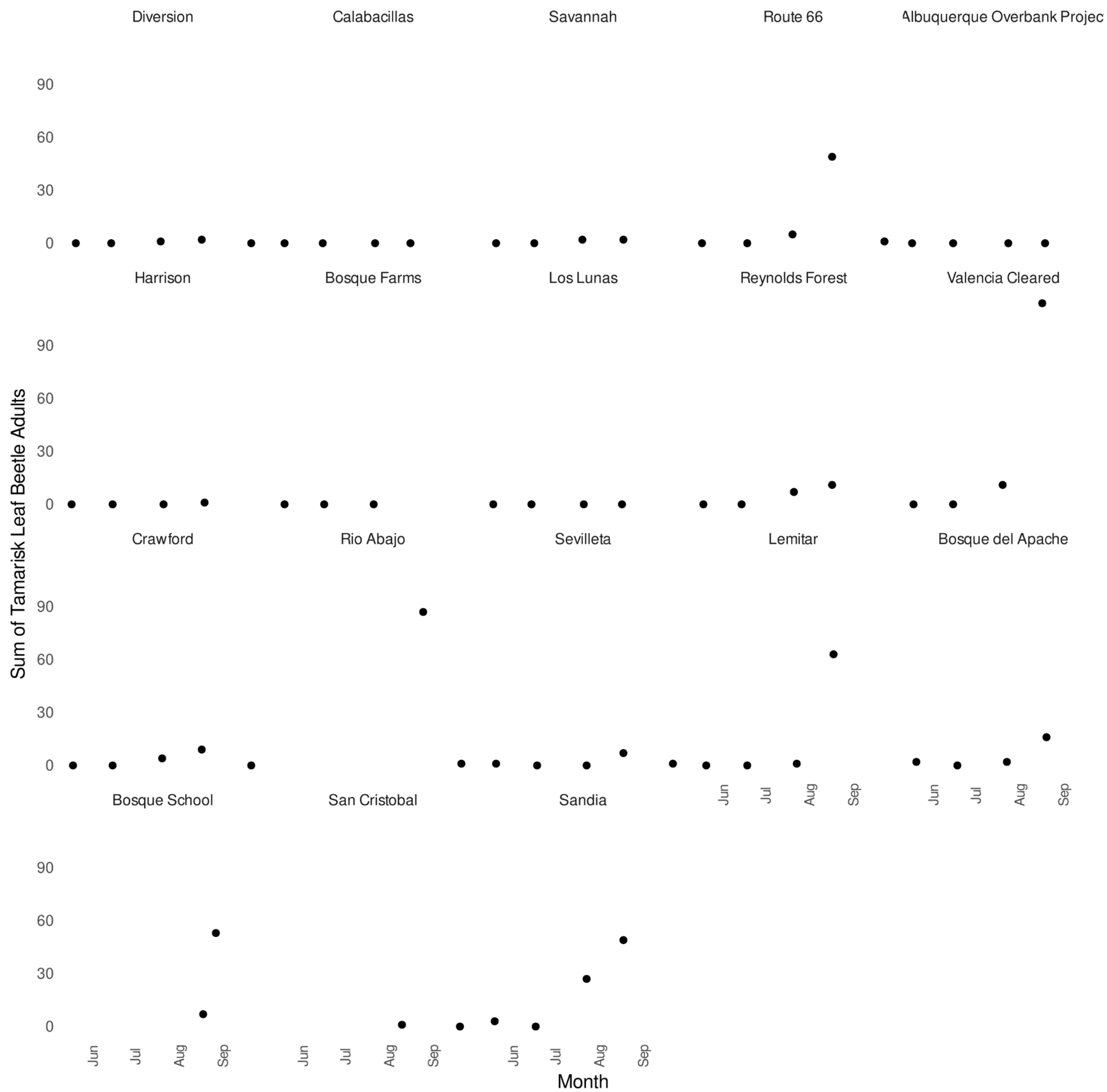

Figure 10.3. Total number of TLB adults found at all sites from May through August 2021 and a subset of sites in September. Sites are arranged from north to south.

Table 10.1. Total sum of adult and larvae TLB at the weekly Bosque School site collections. Sum is across all five trees. Bolded numbers show collections corresponding to monthly monitoring of TLB.

Site Name	Year	Month	Day	sum all TLB
Bosque School	2021	5	10	0
Bosque School	2021	5	20	**0**
Bosque School	2021	5	30	0
Bosque School	2021	6	4	0
Bosque School	2021	6	11	1
Bosque School	2021	6	16	**3**
Bosque School	2021	6	28	4
Bosque School	2021	7	15	**6**
Bosque School	2021	8	6	62
Bosque School	2021	8	18	**15**
Bosque School	2021	8	27	53

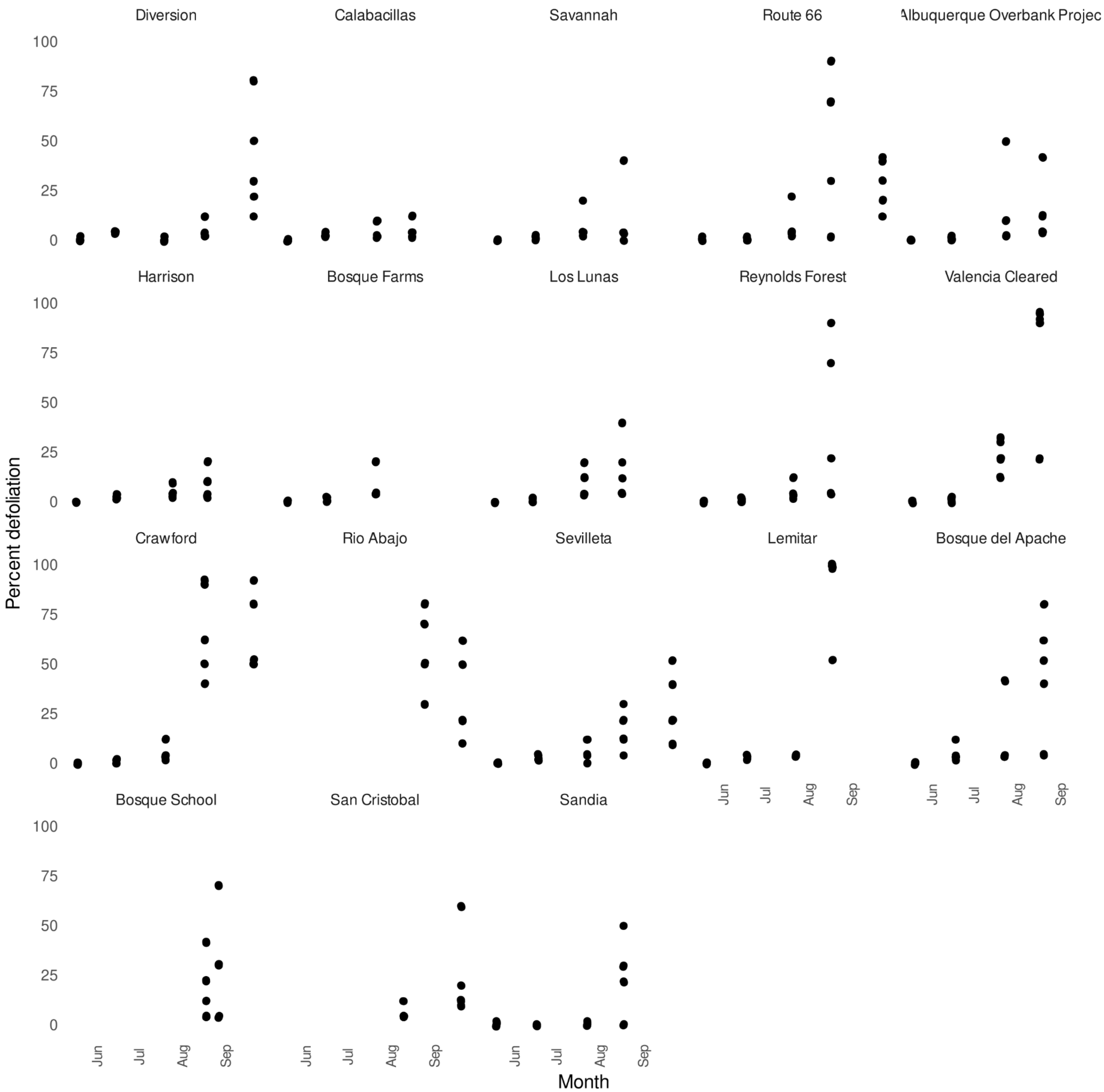

Figure 10.4. Percent total defoliation shown by tree across the sample sites in 2021. This includes TLB and leafhopper defoliation.

Numerous defoliators naturally exhibit cycles of increased population along with resulting high levels of defoliation. *Diorhabda* spp. populations sampled across BEMP sites since 2013 follow this cyclical pattern (Figure 10.2).

North of Albuquerque reach, TLB populations peaked in August with 58 total TLBs recorded at the Sandia site (Figure 10.3).

Within the Albuquerque reach, six sites were sampled monthly. TLB populations peaked during July with 231 total TLBs counted for that month. It is important to note that a majority, 225, of the TLBs recorded for this month came from a single site, Route 66. Numbers tapered in August with 65 total TLBs counted. Again, a majority of these, 50, were recorded at the Route 66 site (Figure 10.3).

Within the Isleta reach, five sites were sampled monthly. TLB populations peaked in July with 373 total TLBs counted for that month with a majority, 331, seen at Valencia Clear. Numbers tapered but remained relatively high in August with 278 TLBs counted for that month with again, a majority, 151, seen at Valencia Clear (Figure 10.3).

Within the San Acacia reach, three sites were sampled monthly. TLB populations peaked in July with a combined total of 304 TLBs counted, a majority of these numbers came from the two southernmost sites, Lemitar and Bosque del Apache, with 114 and 189 TLBs, respectively. These numbers tapered in August with a combined total of 95 TLBs counted, a majority, 68, were seen at the Lemitar site (Figure 10.3).

Weekly sampling at the Bosque School site demonstrated TLB population peaks that did not correspond with the weeks TLBs were sampled at other sites. This indicates the possibility of missing peak TLB abundance with monthly collections because they fluctuate significantly on at least a weekly basis. Thus, current sampling methodology may in fact fail to capture true TLB peak abundances, but they do capture overall distribution, population cycles, and impact (Table 10.1).

September sampling at the six sites, San Cristobal, Diversion, Route 66, Rio Abajo, Crawford, and Sevilleta, resulted in a combined total of four TLBs; two from Route 66, one from Rio Abajo, and one from Sevilleta. Low numbers indicate a lack of TLB activity in these areas after August.

Defoliation levels ranged from 0 to 100% in 2021 (Figure 10.4). Monitoring defoliation is one key way to track TLBs, as the impacts of TLB damage remain evident and quantifiable even after peak abundances have declined. Percent dead branches ranged from 0 to 90%, but this encompasses a combination of dead branches and denuded branches that refoliate later in the season.

11 USACE Outreach

Outreach for the August 2020-May 2021 school year

During the 2020-21 school year, the ongoing COVID-19 pandemic proved to have a continuing effect on the educational sphere. Despite the many variations of learning that schools readjusted to, BEMP education did its best to meet them at every turn. Taking all necessary precautions to ensure public health and safety, BEMP education offered 157 total programs and reached 2,782 students and 682 adults throughout August 2020-May 2021. Instruction was provided in person and remotely at field locations and in the classroom; through field monitoring collections (arthropod, water quality, and monthly monitoring data); and in study trips (Figure 11.1). Educational programming was additionally provided online through printable and electronic platforms, including Grab and Go activities and video lessons. Moreover, undergraduate and graduate students participating in the Biology 408/508 course at UNM conducted field and lab work during this time. Throughout August 2020-May 2021, BEMP education collaborated with 9 different schools, including: Bandelier Elementary School, Bosque School, College and Career High School, Hot Springs High School, Inez Elementary School, The International School at Mesa del Sol, La Academia de Esperanza Charter School, North Star Elementary School, and Wilson Middle School. Of these 9 total schools, 5 (or 55%) are classified as Title I schools, wherein at least 40% of students qualify for free and/or reduced lunch.

To better facilitate learning opportunities for students with limited computer access, BEMP staff printed and distributed educational materials that are NGSS-aligned and engage students in real data analysis within their own backyards. These materials have also been made available on our website and through our publicly accessible github page to ensure broad accessibility; online BEMP educational materials were accessed 2,280 times during the August 2020-May 2021 period. All educational activities and materials continue to be provided bilingually in

Spanish and English, strengthening accessibility initiatives for broader audiences. Accommodating for COVID-19 precautionary measures, BEMP's 2021 annual Luquillo-Sevilleta and Crawford Symposiums were again held in an online format, broadcasting presentations of 21 participants' data analyses and findings outwards in a reach of 250 views. Further, BEMP's social media presence continues to increase, growing to 114,206 contacts in the August 2020-May 2021 period across Instagram, Facebook, and YouTube's online platforms.

Table 11.1. Social Media outreach by BEMP in 2021

Social media platform	Reaches	Engagements	Views
Instagram	54,216	9,530	N/A
Facebook	43,761	6,318	N/A
YouTube	N/A	N/A	381

Note: BEMP used Creator Studio to track Facebook and Instagram engagement through a variety of different metrics. Reaches refers to how many people saw either a specific post or any content from the social media pages. Engagements refers to the total number of likes, shares, clicks, and clicks on "see more" for longer post captions.

Figure 11.1. Students assisting in monthly site collections.

12 Implications for Management

Declines in groundwater across sites in the Isleta Reach, along with increasing variability across all reaches, will continue to impact plant and animal communities along the river. Recent flooding events (2017 and 2019) have led to small increases in native understory vegetation, which was followed by sharp declines in 2020. 2017 flooding had minimal impact on native canopy productivity, but native trees increased productivity at many sites following the subsequent flooding of 2019. Native decomposers showed a positive response to flooding while exotic decomposers suffered a decline. This supports previous research suggesting that a more regular flood pulse has positive restructuring impacts on the ecosystem, both at the community level and the ecosystem level. Tamarisk leaf beetle population dynamics are captured with monthly monitoring but higher frequency of sampling may be required to capture peak abundances. BEMP data show declines in tamarisk cover, branch dieoff, and early leaf fall due to the impacts of TLBs. Analyses do not currently show changes in vegetation communities following defoliation by TLBs.

13 References

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