BOSQUE ECOSYSTEM MONITORING PROGRAM (BEMP)

SITE MONITORING REPORT FOR 2020

2020 ANNUAL SITE MONITORING TECHNICAL REPORT

Submitted 31 March 2021

2020 Final Report submitted to:

US Army Corps of Engineers, USACE Contract #: W912PP18C0023
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Bernalillo County, Bosque School, City of Albuquerque, Greater Rio Grande Watershed Alliance, Mid Rio Grande Stormwater Quality Team, Middle Rio Grande Conservancy District, 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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Bosque Ecosystem Monitoring Program (BEMP)

Report on 2019-2020 Education and Monitoring

March 2021

1.0 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, Department of Biology and Bosque School in Albuquerque, with fewer than 200 participants in its first year. Now, BEMP averages approximately 9000 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, 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 this reporting period, BEMP had 33 active monitoring sites along 250 miles of the Rio Grande, including 32 sites within the Middle Rio Grande (Figure 3). Through the strategic location of these sites, BEMP studies the ecological drivers of fire, flooding, climate change, and human alteration on the bosque ecosystem. Two-thirds of the 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 partners.

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

BEMP hosted two events during the year 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 2020, BEMP data were shared at the Sevilleta Science Symposium and the Middle Rio Grande Endangered Species Collaborative Program Science Symposium.

Timing of Data Collection: Depth to groundwater, water level in nearby ditches and/or drains, precipitation, and litterfall are collected 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 collected 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 in September. All other datasets are collected as funding permits.

Delays due to COVID-19 restrictions: State and university restrictions due to COVID-19 necessitated shifts in BEMP collections, lab processing, data entry, and data checking. The new safety measures and almost total lack of student involvement in data collections and processing resulted in delays, which were further compounded by loss of BEMP staff (due to reduced funding). These shifts and delays are mentioned in the relevant sections in this report. BEMP staff have worked to maintain our research schedule but are still working on some data processing. Sites that were closed due to COVID-19 restrictions will show missing data for those months and resulted in a reduction of the total number of sites monitored in 2020. Data processing (especially litterfall and arthropods) and data analyses will continue to be delayed in 2021 due to these same circumstances. Unless additional funding is secured, processing and analyses will continue well into 2022.

2.0 Importance of long-term data and community outreachand citizen science

BEMP started in 1996 with funding from the National Science Foundation and a goal of reaching 8 sites. Although establishing 8 long-term sites seemed unlikely, by 2001, BEMP had reached 8 sites and had students and teachers dedicated to monitoring each site. That year BEMP had 400 participants, sites installed to aid stakeholders in monitoring restoration practices, and stakeholders requesting and using BEMP data. 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 9000 and 10,000 participants per year (Figure 1), had 30 established sites, and maintained 11 core datasets.

The long-term data have been used in informing predictive models, assessing restoration projects, understanding bosque response to different ecosystem drivers (e.g., fire, flooding, clearing, impacts of climate change, introduction of biocontrols), and 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, as well as our ability to effectively use adaptive management and best practices strategies.

By 2020, BEMP had reached 100,000 participants. Over the last several years, there have always been a few University of New Mexico undergraduates 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. 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.

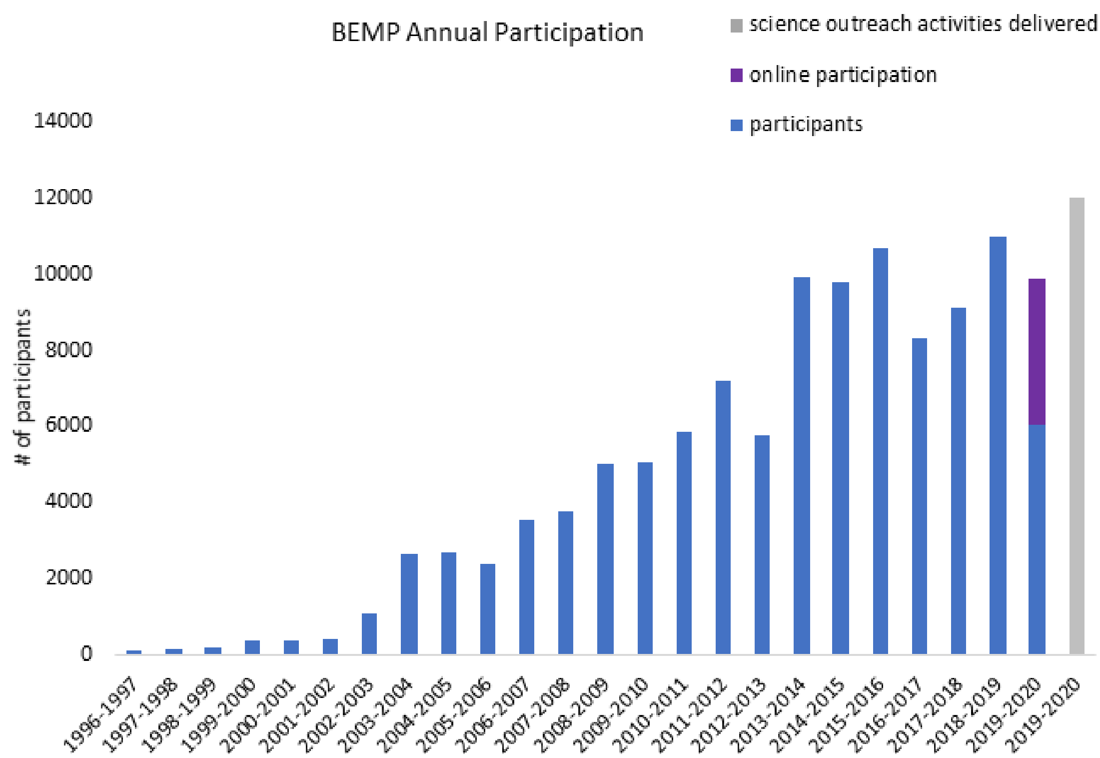


Figure 1. BEMP outreach includes students and adults participating in long-term monitoring, study trips, festivals and events, conferences, training, and other BEMP activities.

3.0 Field and data analysis reform due to COVID 19

The State of New Mexico began implementing 'stay at home' orders when positive cases of coronavirus COVID-19 were confirmed within the state in mid-March 2020. The global pandemic had immediate and notable impacts on our organization's operations. The most immediate impact was the cancellation of our Crawford Symposium which was cancelled on March 11, 2020, the same day it was to take place. This event was later modified and held as a virtual event showcased on YouTube.

From this point forward, BEMP implemented stringent safety precautions starting with moving our office work to our home spaces. Within State and CDC guidelines, BEMP was able to continue operating in the field to ensure that contracted data were collected and students were still able to receive BEMP programming through alternative means.

In 2020, BEMP aimed to collect data from 33 research sites across 270 miles of New Mexico. Three of these sites are established on the Indiginous lands of Santo Domingo, Santa Ana and Sandia Pueblos. These Sovereign Nations closed their borders in order to contain the spread of the virus that was disproportionately impacting their communities. BEMP was unable to access these sites for several months which resulted in missed data collections. Later in the year, we were able to gain permission to collect data at Sandia and Santa Ana Pueblo BEMP sites but did not receive permission to collect at the Santo Domingo BEMP site.

In order to ensure staff safety while working in the field and laboratory environments, we were able to adopt and modify the Sevilleta Long Term Ecological Research (SEV-LTER) Network's Field and Lab Protocols. Access to the full protocols can be made available upon request. If feeling symptom free, staff only (no K-12 students) were allowed to meet in the field while wearing face coverings and maintaining 6 ft. of physical distance as much as possible (Figure 2). Hand washing and use of sanitizing products was encouraged on a frequent basis. Any equipment passed between members of different households was sanitized with disinfecting spray or wipes. Staff were required to drive separately to all sites for much of the time and were eventually permitted to have two people together in a vehicle while wearing masks. Many willing staff household members began to participate in BEMP collections as well.

Due to the fact that several different small groups collected the data across the 33 active sites, we began holding 'Data Drop and Swap' events at a local parking lot or park to gather all of the data into one location. Group gatherings were limited so we created a sign up sheet to ensure no more than the allowed number of people were gathered at one time.

Access to the University of New Mexico lab facilities was initially not allowed, thus equipment was brought home so staff were able to continue to process and enter the data collected. Once restrictions began to lift, additional safety precautions were instituted so that safe indoor activities could be conducted. Limited persons were allowed into the lab spaces; cleaning of used equipment and spaces plus online video education regarding containing the virus were required in order to begin using the facilities.

Our inability to use lab space for several months notably impacted our ability to begin processing the tamarisk leaf beetles that were collected in the field from May through September. The lab space opened up with several restrictions so we were behind schedule in data processing but were able to complete the processing.

BEMP's mission is about science and education of community members. With the start of the pandemic, BEMP ceased all field activities with K-12 groups and education moved towards an online format. BEMP still taught a class of students in the Bosque Internship class (Bio 408/508) at UNM. These university students were able to assist with field collections and limited lab work starting in August 2020 using the Sevilleta LTER field and lab protocols.

Figure 2. Staff drove separately to field collection sites, wore masks, used sanitizing products, and maintained physical distance when possible to protect staff and mitigate the spread of the COVID-19 virus.

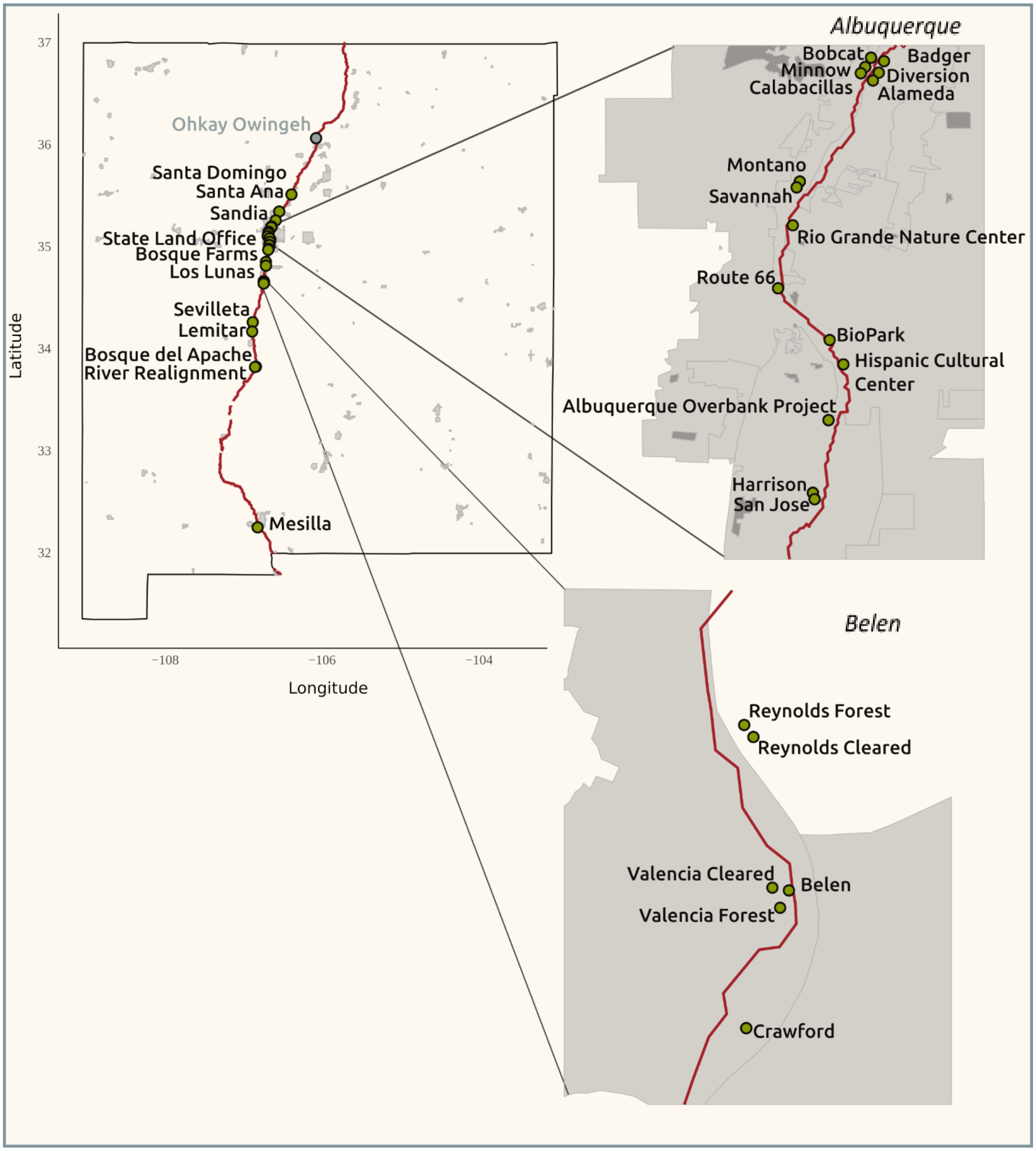


Figure 3. Map of 33 active BEMP sites along the Rio Grande; Ohkay Owingeh is no longer an active site. The Valle de Oro BEMP site has been under construction from September 2019 through all of 2020 and into 2021.

4.0 Datasets collected at BEMP sites from north to south

Table 1. BEMP site numbers running north to south, with names, abbreviations, counties, latitude, longitude, BEMP-designated reach, and data collected (2019 vegetation cover, 2020 tamarisk leaf beetle, 2018 surface-active arthropods, 2020 groundwater wells, 2020 litterfall, and 2020 temperature).

SITE #	SITE NAME	ABBR	COUNTY	LAT	LONG	2019 VEG	2020 TLB	2018 ARTHROPODS	2020 WELLS	2019 LITTER	2020 TEMP	River REACH
24	Santo Domingo	SD	Sandoval	35.50989	-106.39	X	X^			X		N Perch
5	Santa Ana	SA	Sandoval	35.34284	-106.546	X		X		X	X	N Perch
32	Sandia	SAND	Sandoval	35.25523	-106.591	X	X^	X	X*	X		N Perch
22	Bobcat	BOB	Bernalillo	35.19706	-106.644	X			X	X		N Abq
21	Badger	BAD	Bernalillo	35.19557	-106.642	X		X	X	X		N Abq
12	Minnow	MIN	Bernalillo	35.19315	-106.647	X		X	X	X		N Abq
10	Diversion	DIV	Bernalillo	35.19196	-106.644	X	X		X	X		N Abq
11	Calabacillas	CALAB	Bernalillo	35.19057	-106.649		X		X	X		N Abq
1	Alameda	ALA	Bernalillo	35.18805	-106.647	X		X	X	X	X	N Abq
17	Montano	MON	Bernalillo	35.14529	-106.68	X		X	X	X		N Abq
6	Savannah	SAV	Bernalillo	35.14285	-106.682	X	X	X	X	X	X	N Abq
2	Rio Grande Nature Center	RGNC	Bernalillo	35.12675	-106.688	X		X	X	X	X	N Abq
20	Route 66	Rt 66	Bernalillo	35.10066	-106.692	X	X	X	X	X	X	S Abq
23	BioPark	BioP	Bernalillo	35.07873	-106.668	X**			X	X	X	S Abq
8	Hispanic Cultural Center	HCC	Bernalillo	35.06881	-106.658	X		X	X	X		S Abq
29	Albuquerque Overbank Project	AOP	Bernalillo	35.04753	-106.664	X	X	X	X	X	X	S Abq
13	Harrison	HARR	Bernalillo	35.01506	-106.674	X	X	X	X	X		S Abq

31	San Jose	SJ	Bernalillo	35.01217	-106.674	X		X	X	X		S Abq
28	Valle de Oro	VDO	Bernalillo	34.97895	-106.68			X	X	X		S Abq
30	State Land Office	SLO	Bernalillo	34.9672	-106.686	X		X	X	X	X	S Abq
27	Bosque Farms	BF	Valencia	34.84885	-106.715	X	X	X	X	X		Val
3	Los Lunas	LL	Valencia	34.81237	-106.714	X	X	X	X	X	X	Val
19	Reynolds Forest	RF	Valencia	34.66065	-106.743	X	X	X	X	X		Val
18	Reynolds Cleared	RC	Valencia	34.65966	-106.742				X	X		Val
15	Valencia Cleared	VC	Valencia	34.64863	-106.739	X	X	X	X	X		Val
4	Belen	BEL	Valencia	34.64843	-106.738	X		X	X	X	X	Val
16	Valencia Forest	VF	Valencia	34.64716	-106.738	X		X	X	X		Val
25	Crawford	CRAW	Valencia	34.6405	-106.742	X	X	X	X	X		Val
14	Sevilleta	SEV	Socorro	34.25834	-106.883	X	X	X	X	X		Socorro
7	Lemitar	LEM	Socorro	34.16703	-106.89	X	X	X	X	X	X	Socorro
34	River Realignment	RR	Socorro	33.82269	-106.842			X	X***	X		Socorro
33	Bosque Del Apache	BDA	Socorro	33.81965	-106.854	X	X	X	X	X		Socorro
26	Mesilla Valley Bosque State Park	MVBSP	Doña Ana	32.24833	-106.821				X	X	X	S arid

*data collected but housed with Pueblo

^ sites not collected due to COVID 19 access restrictions

**site not monitored for this collection period

***wells belong to USBR

5.0 Depth to groundwater in the riparian floodplain

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. 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 or 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/well-installation-and-monitoring-directions.pdf .

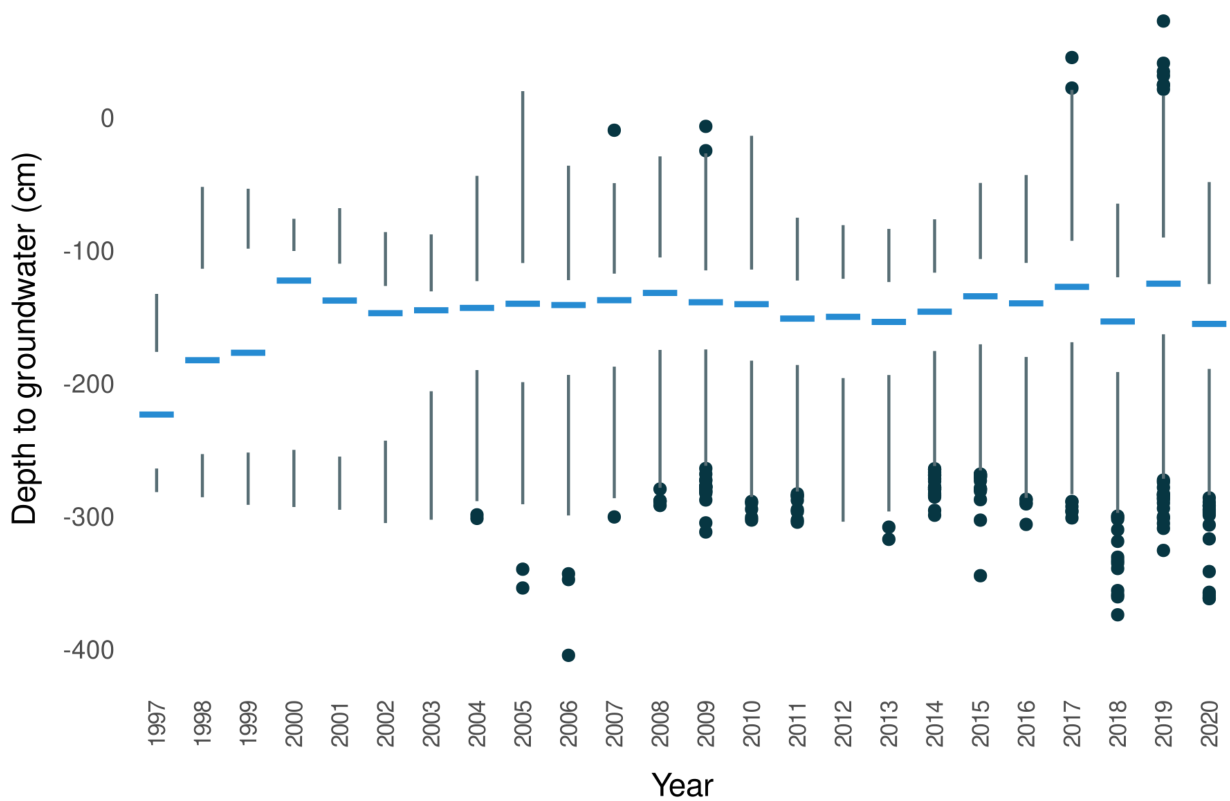


Figure 4. Boxplots of depth to groundwater from 1997 to 2020.

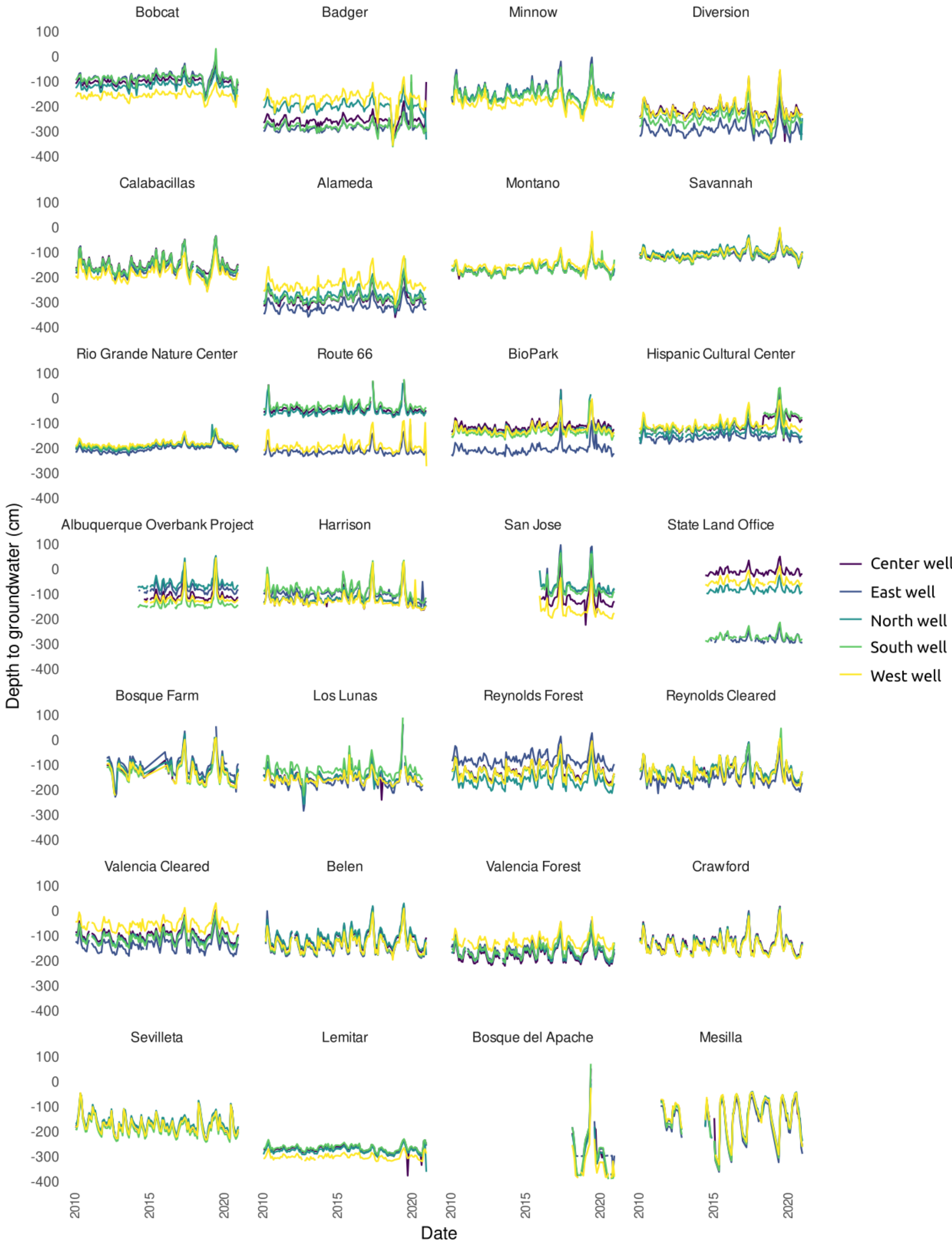


Figure 5. Ten year time series of depth to groundwater showing individual wells with sites ordered from north to south.

The shallow groundwater median levels do not show large changes across years when analyzed across all sites. Through the years, the number of sites has increased. Some sites show a decline in groundwater depth over time, but this is strongly correlated with changes in river flow. Of particular note is the large number of outliers with low water tables and the increasing variability in recent years. In the last decade, there are more outliers below the lower quartile, and the lower quartiles are larger than the higher quartiles, representing deeper groundwater levels at sites and the impact of the drought. The increase in variability is seen in the years of high river flow, as the presence of outliers then occurs above and below the highest and lowest quartiles, and the quartiles are longer. Increasing variability is one of the predicted impacts of climate change that deserves more study.

6.0 Precipitation on the Rio Grande floodplain

Data from two rain gauges are collected monthly at all but two BEMP sites. There is one TruCheck rain gauge located beneath a tree canopy and a second gauge located in an open area. A small amount of vegetable oil is added to each gauge in order to prevent precipitation from evaporating. In the past we had issues with the Tru-check gauges cracking, but as those issues have declined, BEMP has gone back to using only the Tru-Check rain gauges at all sites in 2019.

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

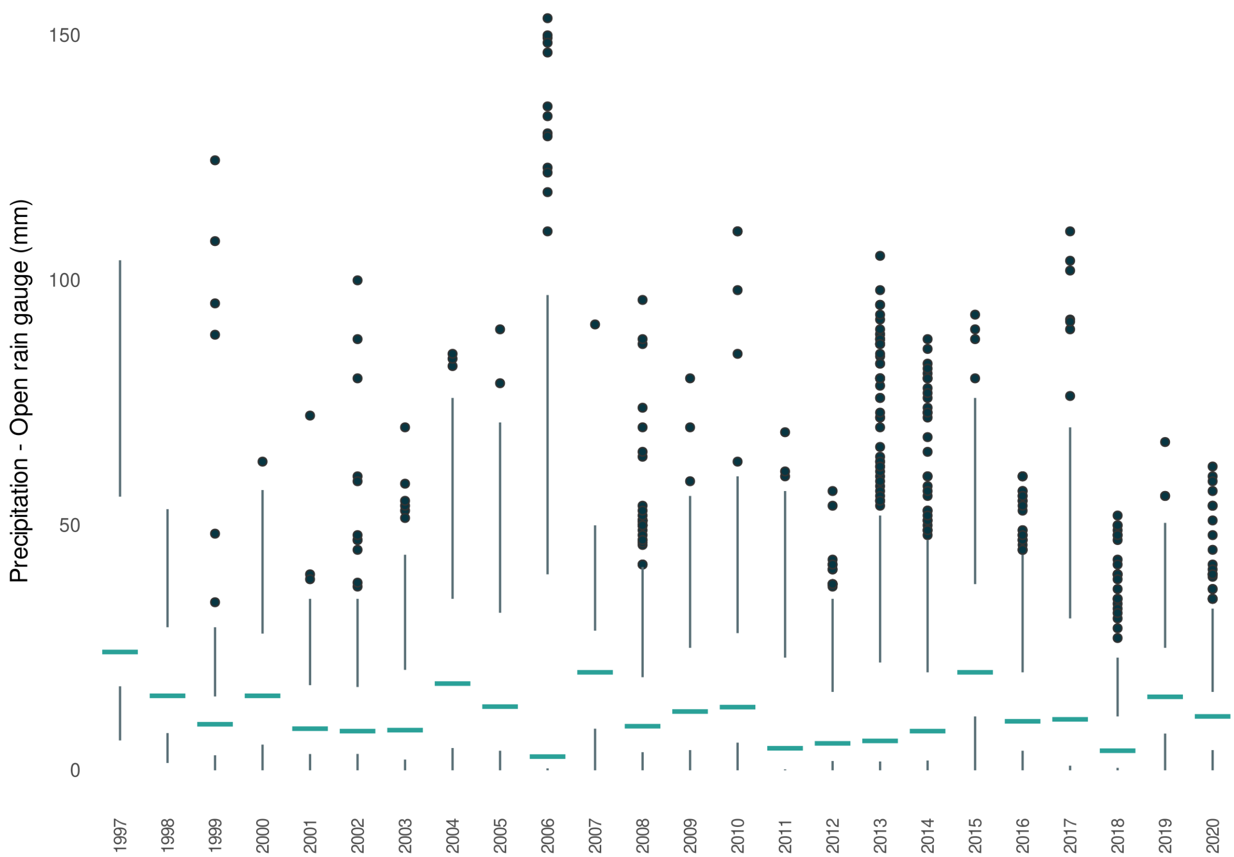


Figure 6. Box plots of open rain gauge precipitation from 1997 to 2020.

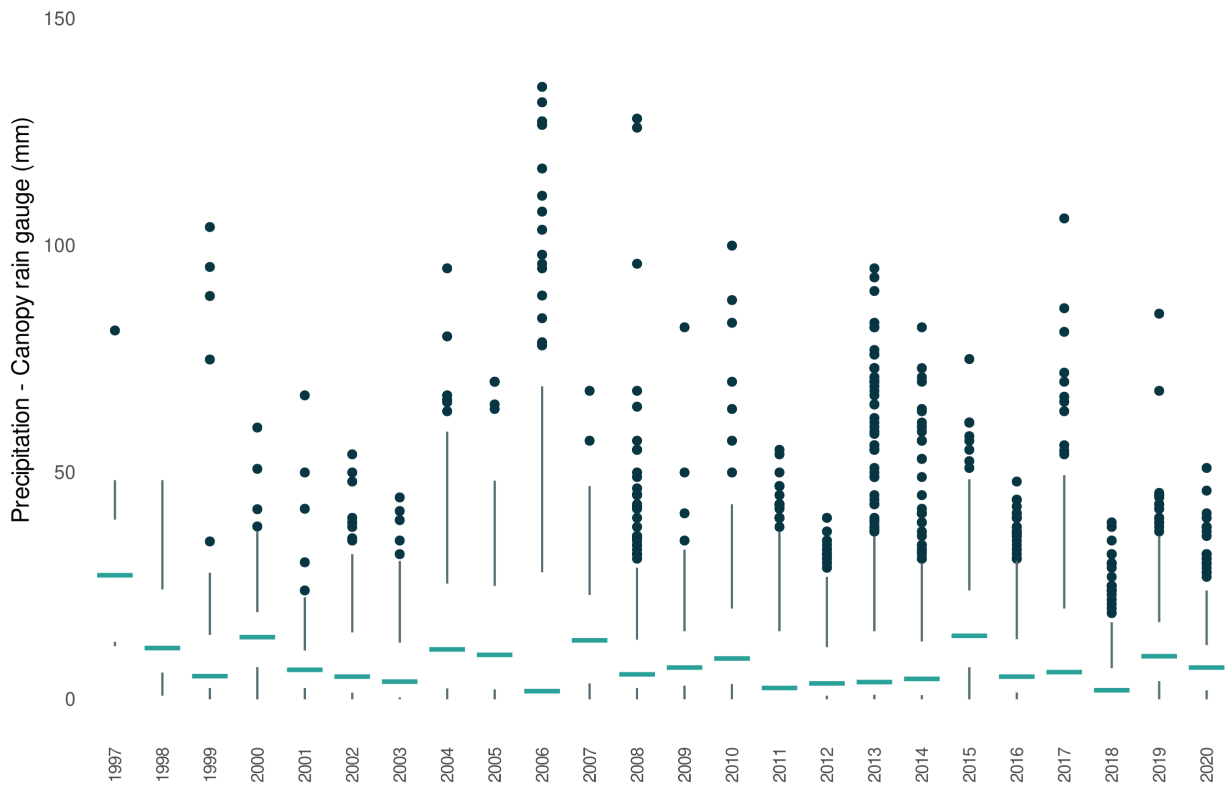


Figure 7. Box plots of canopy rain gauge precipitation from 1997 to 2020.

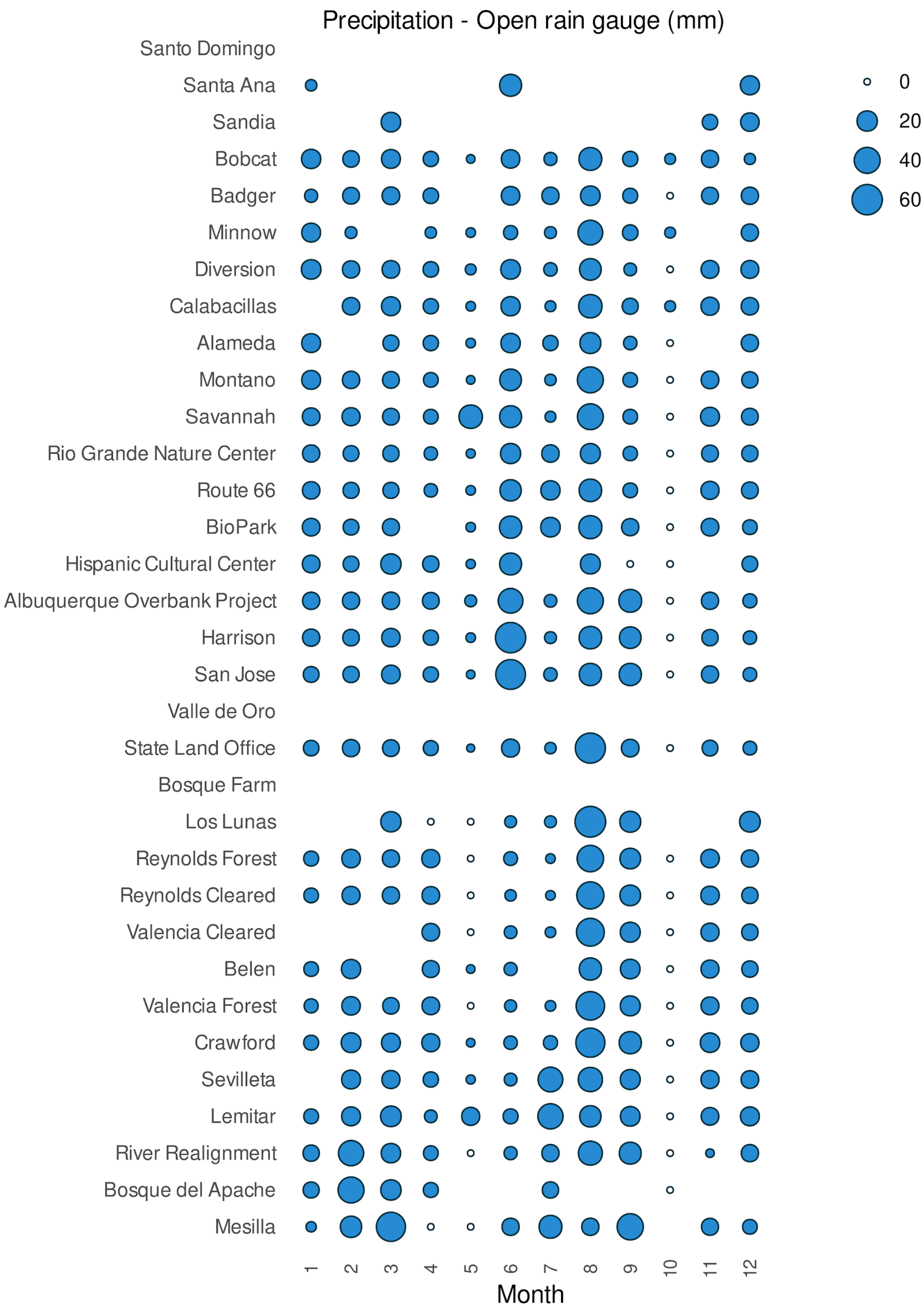


Figure 8. Dot plot of the open rain gauge precipitation data for 2020 with sites arranged from north to south.

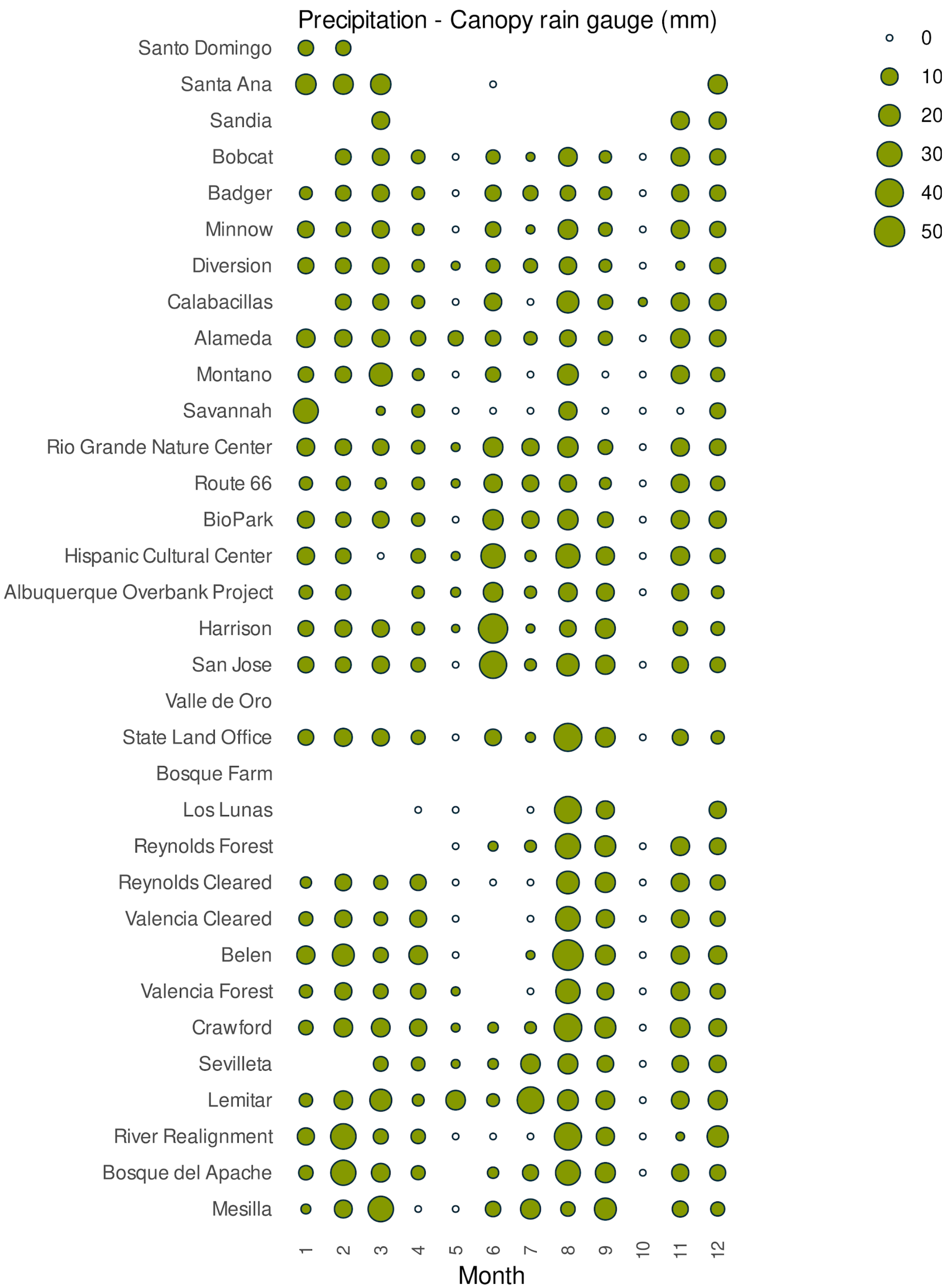


Figure 9. Dot plot of the canopy rain gauge precipitation data for 2020 with sites arranged from north to south.

2020 was a grim year for precipitation in the Middle Rio Grande Valley. Central New Mexico typically receives between 9-10 inches of precipitation annually, however total precipitation from a central Albuquerque site, Rt 66, was only 136.5 mm (5.36 inches) from the open gauge. Sites in Belen received a very similar 140 - 145 mm total precipitation for 2020. In BEMP's 24 years of data collection, only 4 years experienced less precipitation, 1999, 2003, 2012 and 2018. Earlier years contained fewer BEMP sites with less range across the state.

Monsoon rainfall in August provided some relief for the parched system, however the rain events were less than hoped for. The State Land Office site located in southern Albuquerque experienced the greatest amount of precipitation from the August monsoons with a total of 59 mm (2.3 in) precipitation. One or more BEMP sites experienced no precipitation at all in April, May, and October 2020. October was the driest month of the year with zero precipitation recorded at 23 of the 31 sites collected.

Access restrictions resulting from the COVID-19 pandemic prevented precipitation data from being collected at the Santo Domingo site for most of the year, and Santa Ana and Sandia Pueblo sites for part of the year. Bosque Farms does not have any rain gauges due to persistent vandalism and the Valle de Oro site has been under construction since the fall of 2019 so no data were collected.

7.0 Leaf litterfall as proxy for productivity

Litterfall is collected each month by K-12 students, teachers, university students, and BEMP staff, depending on pandemic restrictions. Leaf litterfall is a measure (proxy) of productivity of 10 dominant native and exotic woody species. The natives consist of cottonwood (*Populus deltoides* ssp. *wislizenii*), willows (*Salix* spp.), seepwillow (*Baccharis salicifolia*), New Mexico olive (*Forestiera pubescens*), thicket creeper (*Parthenocissus vitacea*), and false indigo bush (*Amorpha fruticosa*). The exotics species consist of saltcedar (*Tamarix chinensis*), Russian olive (*Elaeagnus angustifolia*), Siberian elm (*Ulmus pumila*), and mulberry (*Morus alba*). Reproductive effort is measured through the fall of reproductive parts (flowers, buds, seeds) of cottonwood, willows, saltcedar, Russian olive, and Siberian elm. Stress and senescence of woody species are captured through wood fall.

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

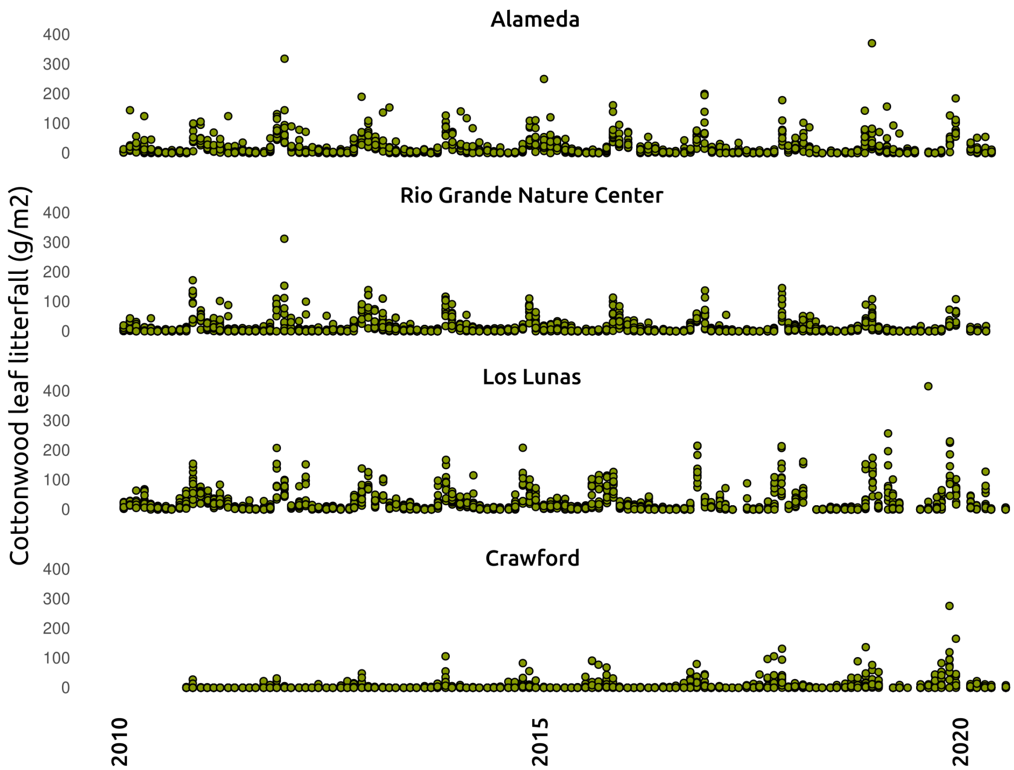


Figure 10. Monthly time series data from four BEMP sites showing ten years of data. The monthly plots show a complicated relationship of leaf litterfall from autumn leaf drop, drought stress, senescence, and wind storms. BEMP sites are arranged from north to south.

The gathering of leaf litterfall and large woody parts on a long term monthly scale is necessary to understand the complicated changes occurring on the Rio Grande. The long term monthly collection allows us to capture events from restoration projects (Crawford), to senescing cottonwood trees (Alameda), weather events like the March winds in New Mexico, to heavy storm events and drought stress (early leaf drop) (Figure 10). 2019 litterfall data are not yet fully processed or QA/QCd at this point due to limitations of data processing under COVID restrictions (limitations to lab access, student participation, and reductions in staff).

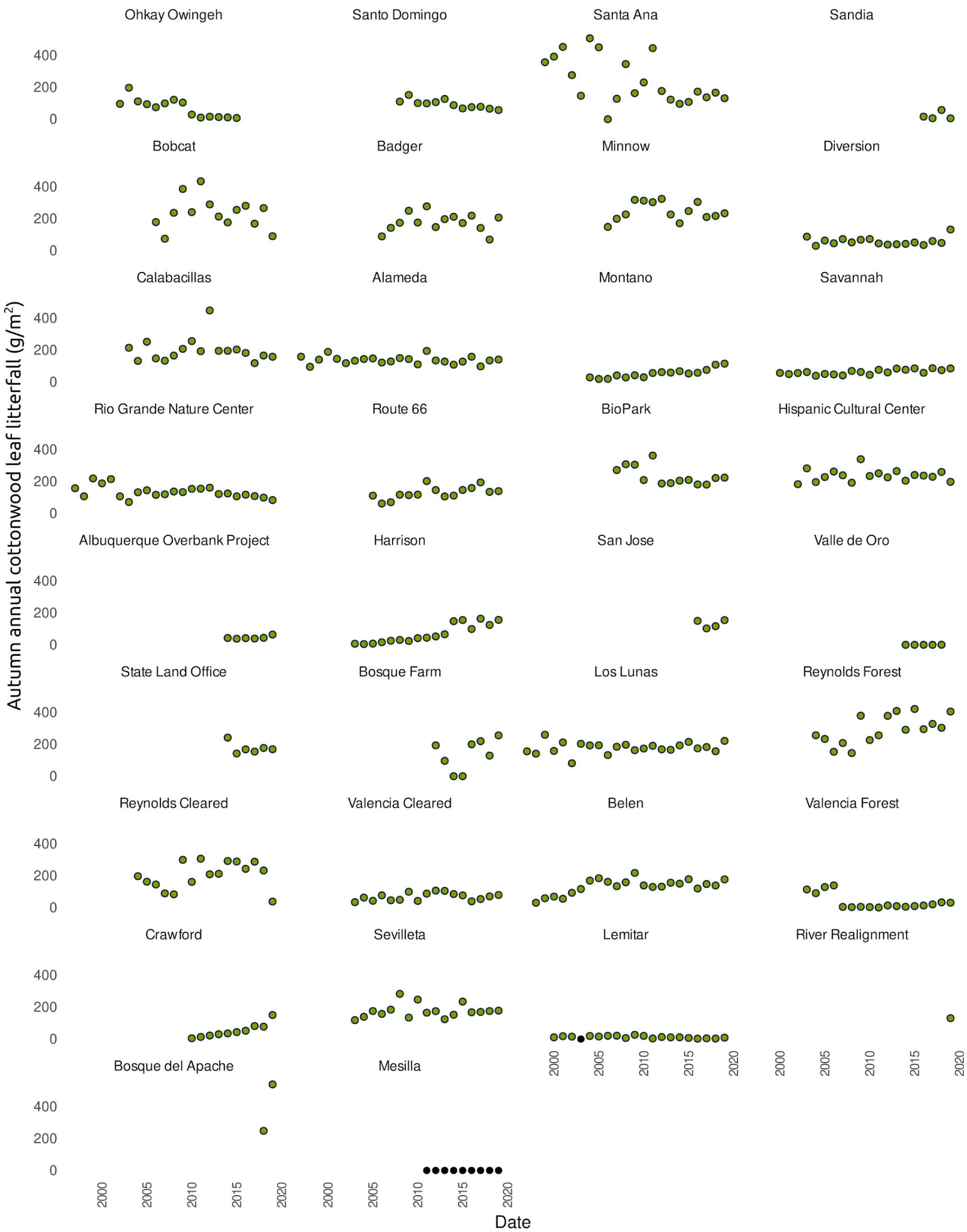


Figure 11. Autumn annual cottonwood leaf litterfall for the past ten years. BEMP sites are arranged from north to south.

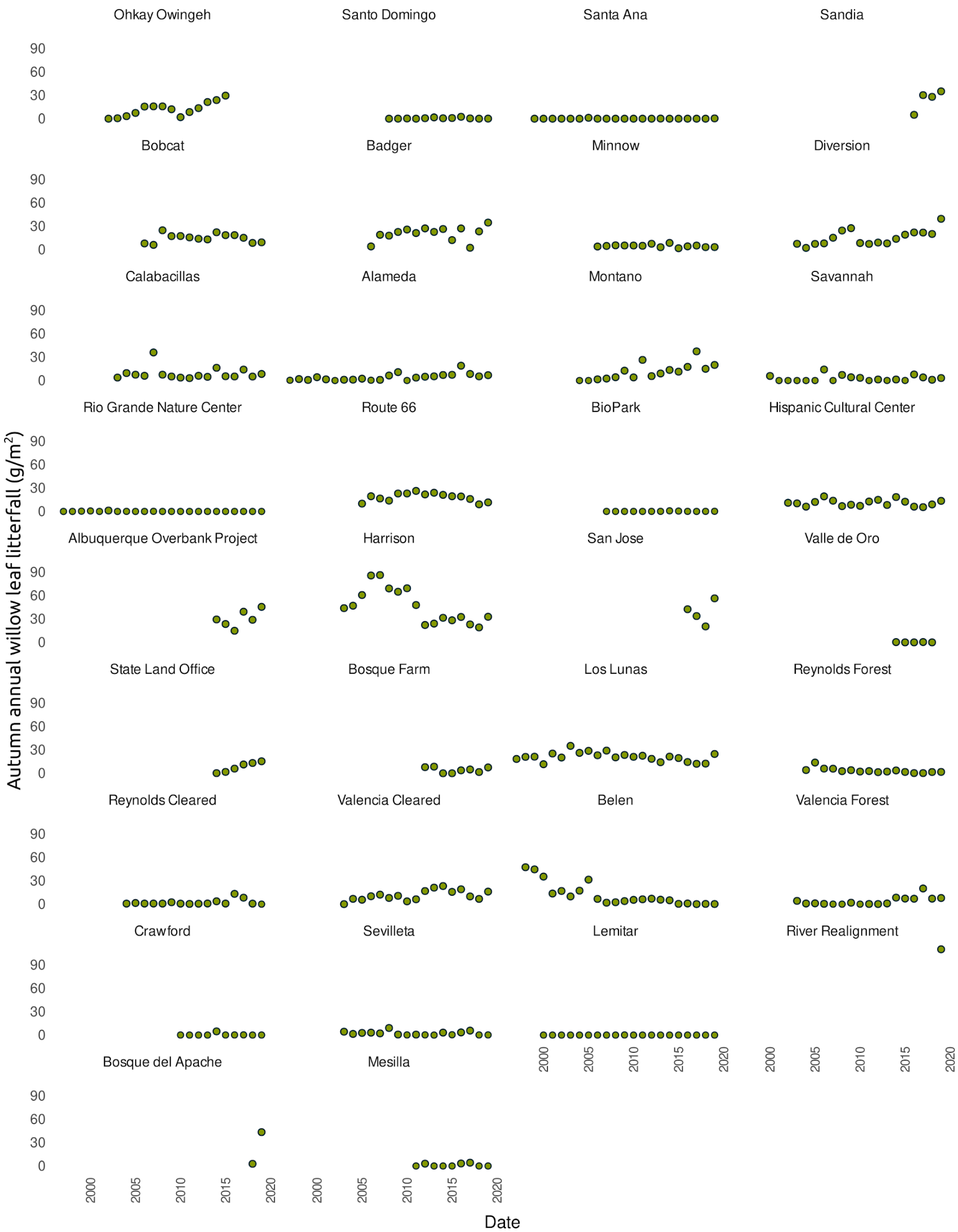


Figure 12. Autumn annual willow leaf litterfall showing the past ten years of data. BEMP sites are arranged from north to south.

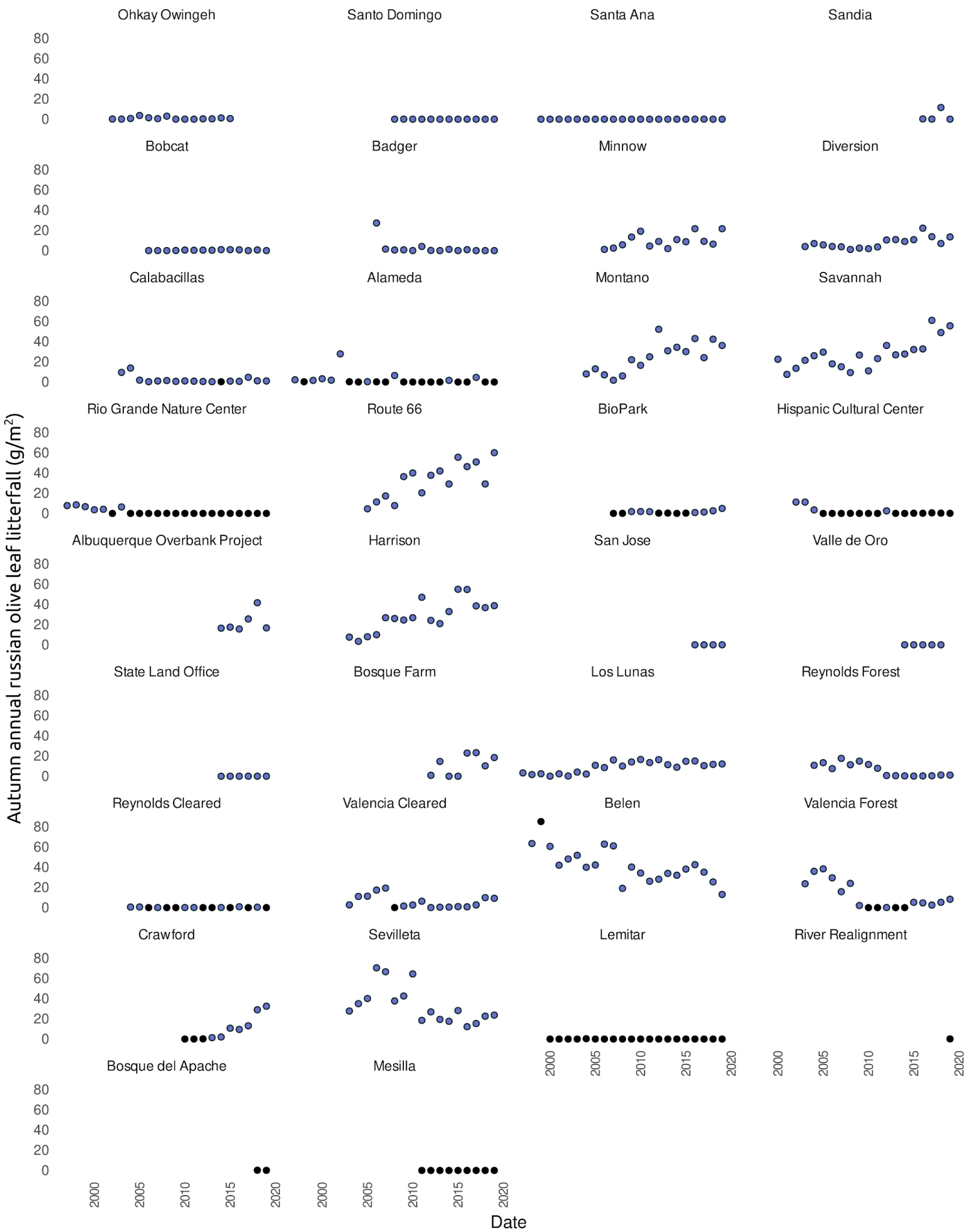


Figure 13. Annual autumn leaf litterfall for Russian olive across ten years. BEMP sites are arranged from north to south.

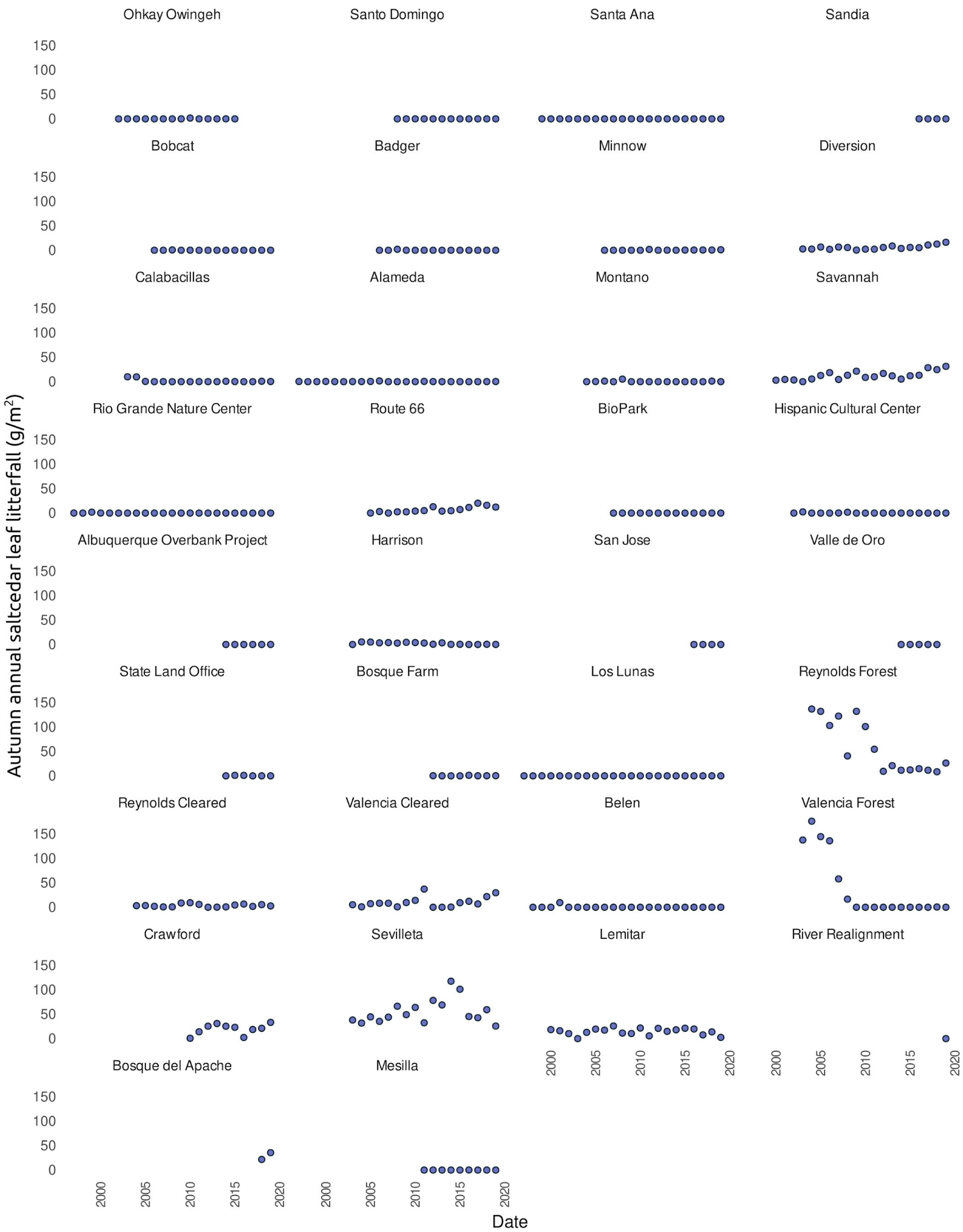


Figure 14. Annual autumn leaf litterfall for saltcedar across ten years. BEMP sites are arranged from north to south. Many sites have small amounts of saltcedar present ranging from tenths of a gram to several grams.

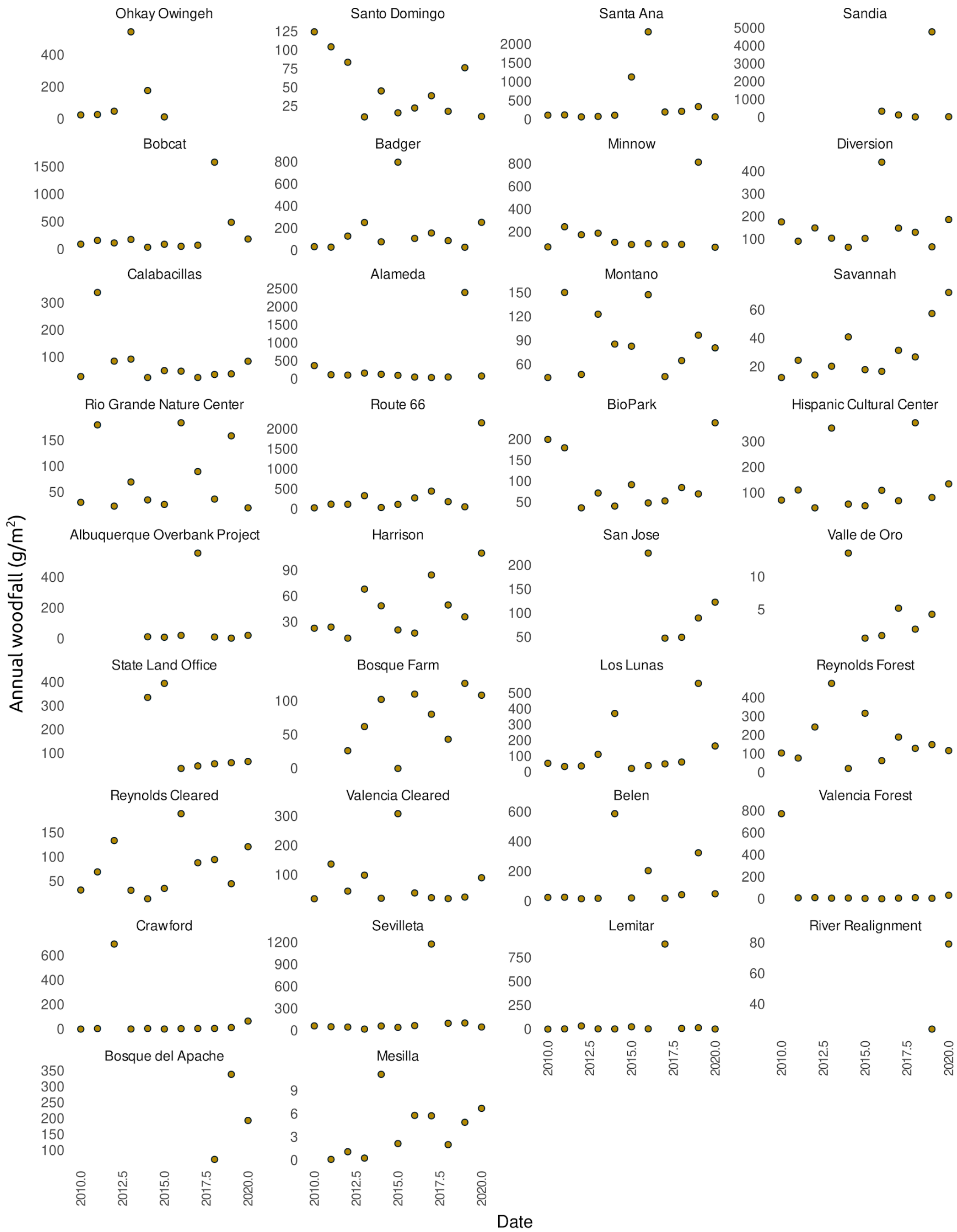


Figure 15. Annual woodfall across ten years. BEMP sites are arranged from north to south. Due to the large range of wood weights all y-axis are freely scaled within a site.

Native cottonwood and willow productivity (leaf litterfall) are increasing at several sites; most typically sites that have undergone earth removal and/or pole planting. Native cottonwood and willow productivity is stable or slowly declining at the majority of BEMP sites. Seven sites show increasing willow cover, while four show noticeable declines (Figure 12). Some BEMP sites show increasing productivity of Russian olive and saltcedar (leaf litterfall) over time. In the Russian olive and saltcedar leaf fall figures, many trends appear flat; this is due to several orders of magnitude difference in leaf litterfall. The following sites are slowly gaining (0.01 to tens of grams annually) saltcedar leaf litterfall: Sandia, Minnow, Diversion, Alameda, Savannah, Route 66, Biopark, Albuquerque Overbank Project, Bosque Farms, Valencia Cleared, and Crawford. Ten sites show increasing Russian olive, while two sites show noticeable declines over time that are unrelated to exotic clearing events and instead are a slow decline of dense, older stands.

Wood fall is variable across sites and often stochastic. Wood fall is a good indicator of tree senescence, but is not a direct measure, as limbs that die can stay in the canopy layer for years. Limbs tend to come down following storm events and high winds. We have also observed large, dying cottonwood trees falling down following flood events.

8.0 Vegetation surveys to monitor changes in plant cover

Vegetation cover surveys are conducted in August-September each year by botanists. Line intercept methods are used to monitor plant species along ten 30m transects at 27 sites (Table 1). Herbarium work (identification of species) was recently finished for 2019 data and most of the data have been QA/QCd and are included in this report. 2020 data are still being processed and run through the QAQC protocols; 2020 reporting on vegetation data has been delayed due to limitations of operating under COVID-19 restrictions.

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

There are 25 species that commonly occur across sites (occurring in at least 18 of the 27 sites monitored). Table 2 shows that Rio Grande cottonwood, Canadian horseweed, foxtail barley, Russian olive, and squirreltail are the five most common species being found across 25 plus sites over twenty years.

Table 2. Dominant plant species based on species presence at 18 or more sites, using twenty years of vegetation survey data. Species codes in bold have detailed annual plots in the figures below.

Species code	Common name	Scientific name	Number of sites present
PODEW	Rio Grande cottonwood	*Populus deltoides ssp. wislizenii*	29
COCA5	Canadian horseweed	*Conyza canadensis*	27
HOJU	foxtail barley	*Hordeum jubatum*	27
ELAN	Russian olive	*Elaeagnus angustifolia*	26
ELEL5	squirreltail	*Elymus elymoides*	26
SAEX	coyote willow	*Salix exigua*	26
SATR12	tumbleweed	*Salsola fragus*	26
SPORO	dropseed	*Sporobolus sp.*	26
BASC5	kochia	*Bassia scoparia*	25
MUAS	scratchgrass	*Muhlenbergia asperifolia*	25
LASE	prickly lettuce	*Lactuca serriola*	24
MACA2	hoary tansyaster	*Machaeranthera canescens*	24
SAGO	Goodding's willow	*Salix gooddingii*	24
TACH2	saltcedar	*Tamarix chinensis*	24
HEAN3	common sunflower	*Helianthus annuus*	23
SPAI	alkali sacaton	*Sporobolus airoides*	23
MEOF	white sweetclover	*Melilotus officinalis*	22
SPCR	sand dropseed	*Sporobolus cryptandrus*	22
AMPS	Cuman ragweed	*Ambrosia psilostachya*	20
CHAMA15	Gray sandmat	*Chamaesyce sp.*	20
DISP	inland saltgrass	*Distichlis spicata*	20
FOPUP	New Mexico olive	*Forestiera pubescens var. pubescens*	20
ULPU	Siberian elm	*Ulmus pumila*	20
CAREX	sedge	*Carex sp.*	18
MELIL	sweetclover	*Melilotus sp.*	18

The dominant native species (both woody and understory) did not have large changes even after the flooding in 2017. The flooding event in 2019 will be captured in the 2020 data which is still being processed. In Figure 16 we still see both slow and dramatic declines in cottonwood cover at senescing sites. Santa Ana's loss of cottonwood cover at the BEMP site has not recovered. As cottonwood cover has declined at Santa Ana, exotic understory cover of both Kochia and tumbleweed have increased. Alameda, BioPark, and the Rio Grande Nature center are examples of the slowly senescing but not recovering cottonwood cover. BEMP sites that were involved in restoration works, such as Harrison, Crawford, Belen, and Reynolds Forest, show gains in the cottonwood cover. These gains are tied to management decisions (bank lowering, installing swales, pole planting, and large scale soil removal) that decreased the depth to groundwater so seedlings and saplings could take hold.

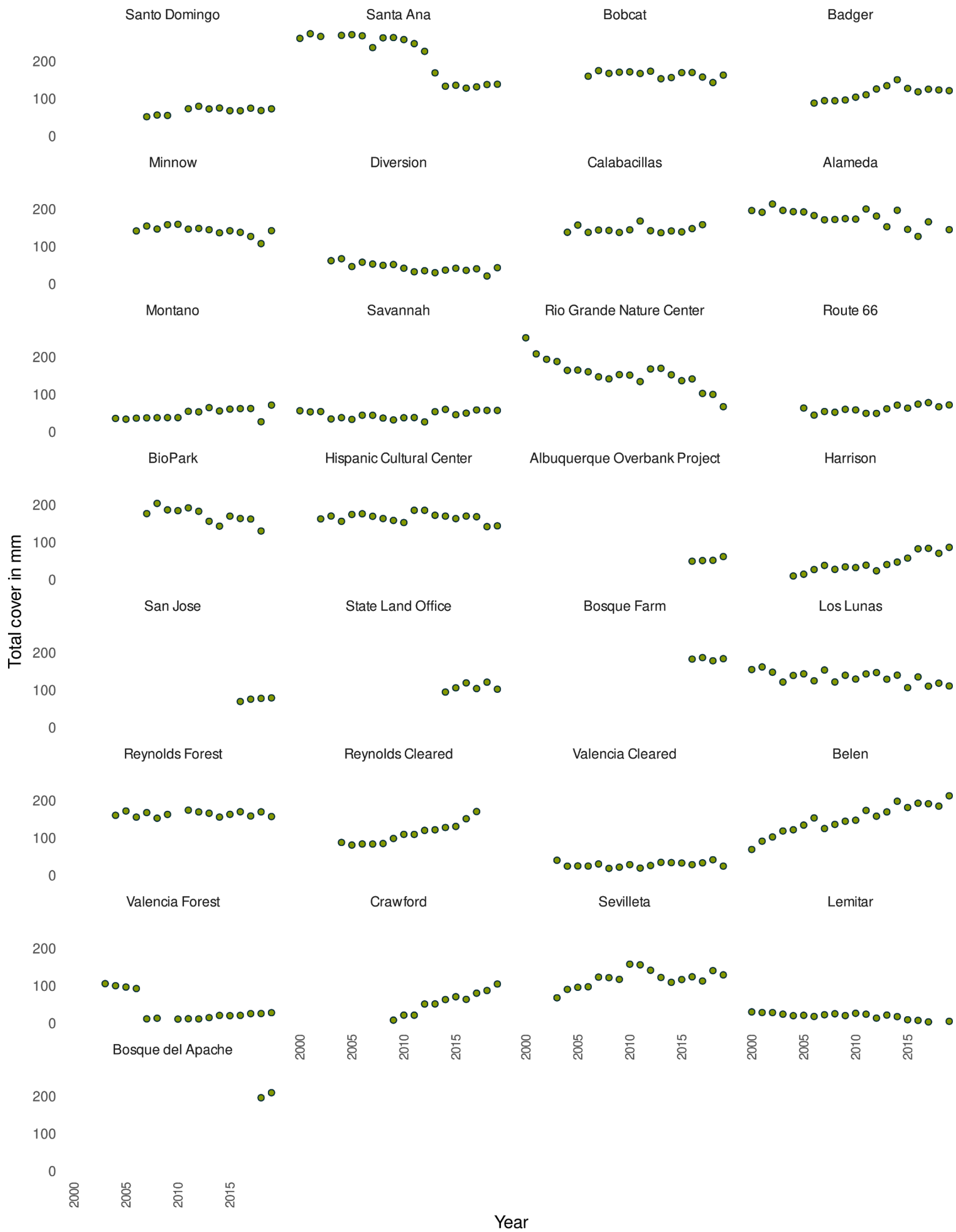


Figure 16. Annual cottonwood cover in millimeters from the vegetation surveys across BEMP sites. Sites are arranged from north to south.

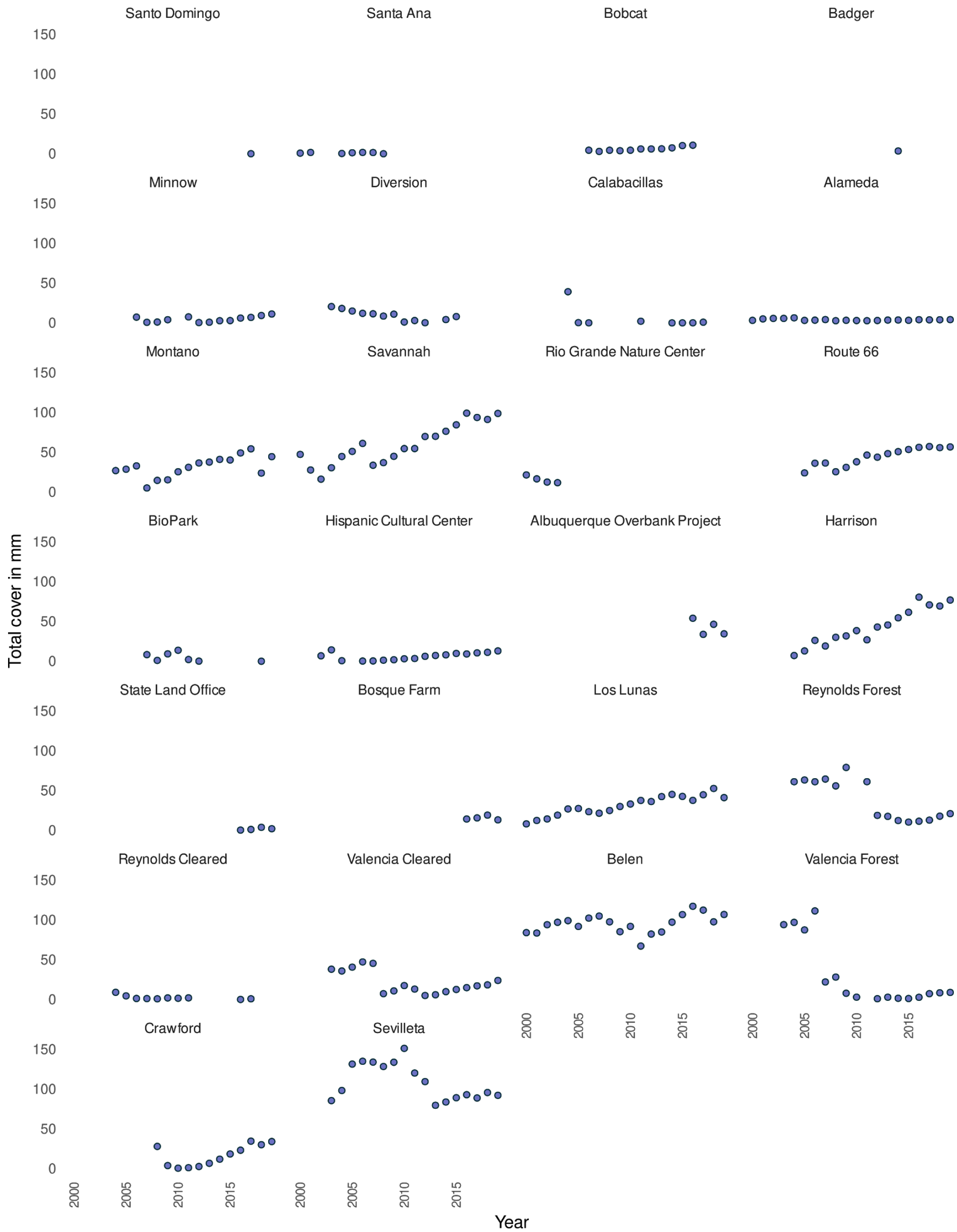


Figure 17. Annual Russian olive cover in millimeters. BEMP sites are arranged from north to south.

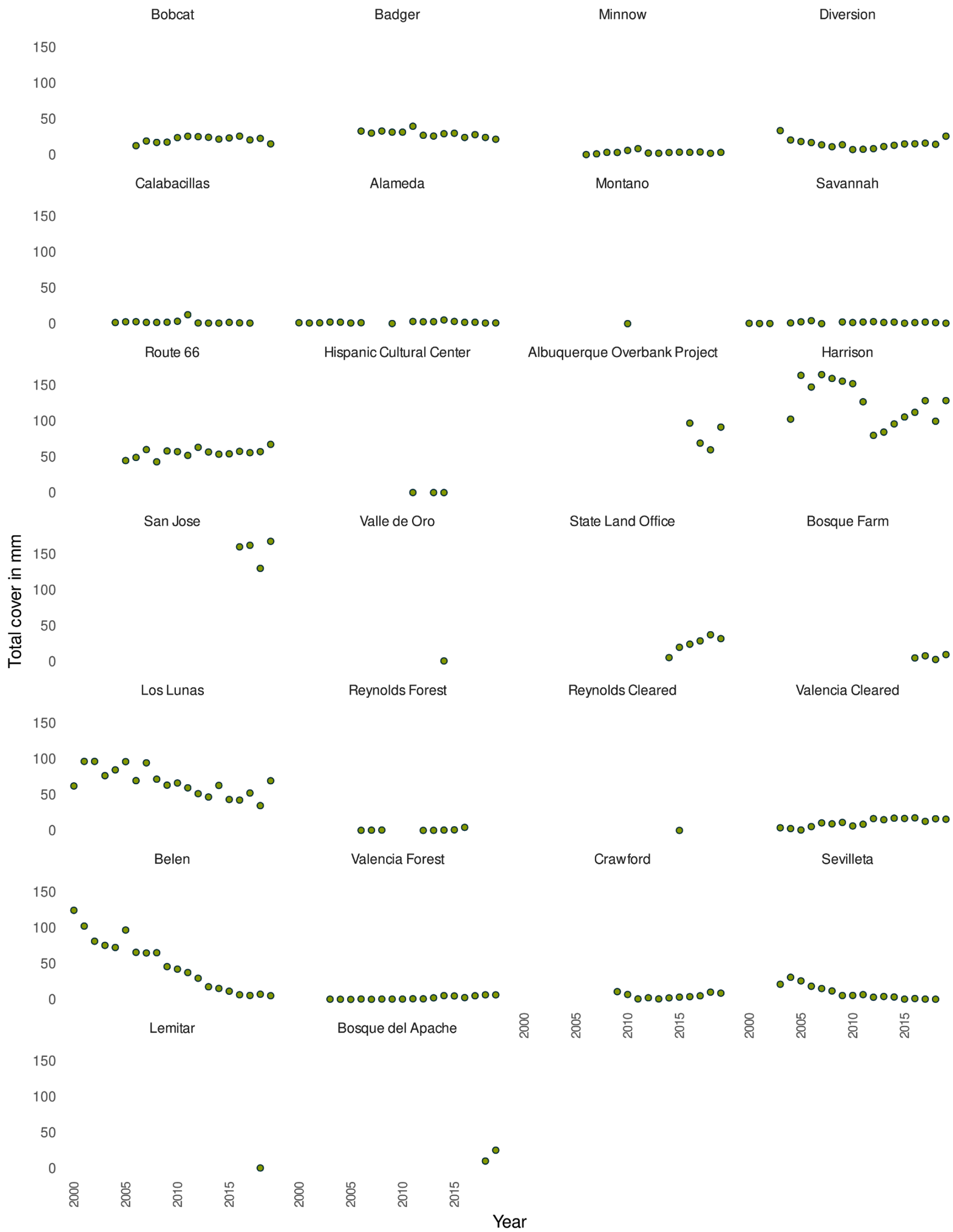


Figure 18. Annual coyote willow cover in millimeters. BEMP sites are arranged from north to south.

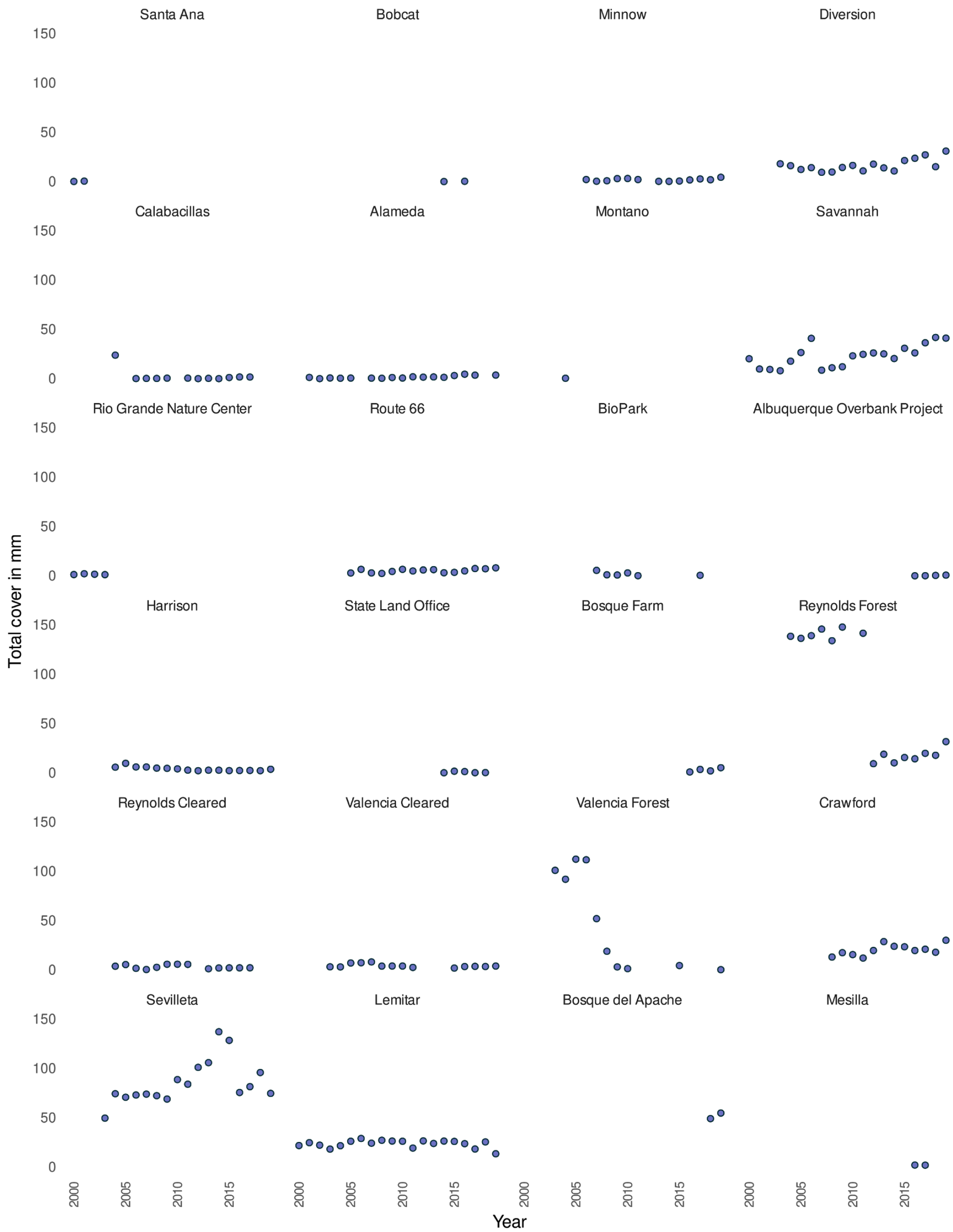


Figure 19. Annual saltcedar cover in millimeters. BEMP sites are arranged from north to south.

9.0 Arthropods as indicators of ecosystem transitions

Arthropods were collected at 26 sites in May, June and September 2018 (Table 1). Over 57,000 arthropods were identified in 2018 with over 200 unique identifications made. 2018 arthropod abundance and richness are presented below. 2019 and 2020 arthropod collections are being processed.

Full methods monitoring methods can be found at:
http://bemp.org/wp-content/uploads/2016/01/pitfall-monitoring-directions-and-arthropod-identification.pdf

Collembola (springtails) have been shown to be effective bioindicators of ecosystems; however, their strong preference for ephemeral microhabitats, our difficulty in consistently trapping specimens, and the large variation in abundances make their presence in BEMP pit-traps variable and have the potential of skewing data. For example, in 2018 during the October collection at the Valle de Oro site four of the 20 pit-traps contained a combined total of greater than 5,000 collembolans with more than 500 collembolans captured per trap. This totaled more than 70% of all arthropods captured at that site for 2018 while 80% traps processed for Valle de Oro in that year contained no representatives of this group. Since these numbers have such a dramatic effect on site abundance numbers, collembola have been included in richness analysis for the sites but have been excluded from abundance counts for 2018.

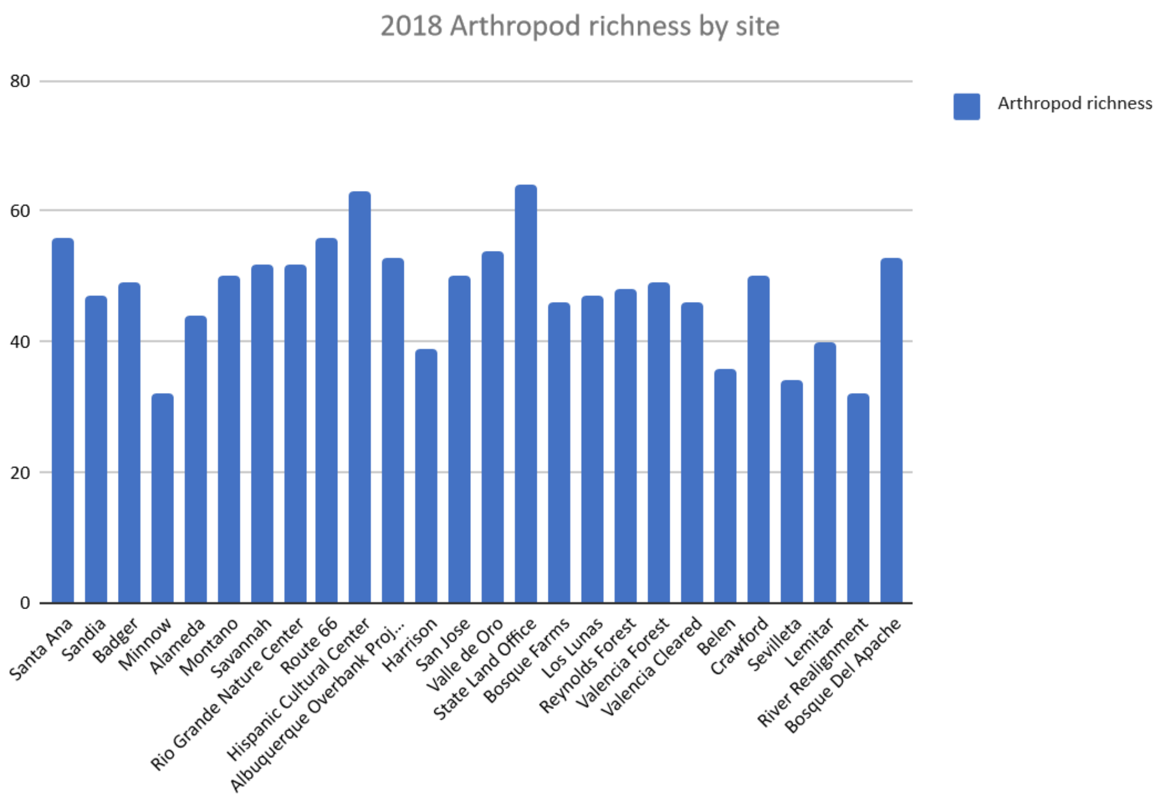


Figure 20. Arthropod richness per site for 2018. Sites arranged geographically north to south.

Total arthropod abundance for 2018 can be seen in Figure 21, in orange. Bosque Farms, Los Lunas and Valencia Cleared, all sites in the Valencia reach, show the greatest arthropod abundance for 2018. Much of this is driven by isopod abundance.

Annual Isopod abundance for 2018 can be seen in Figure 21, in blue.

Isopods (*Armadillidium vulgare* and *Porcellio laevis*), commonly known as pill-bugs and sow-bugs, are non-native terrestrial crustaceans. These arthropods function trophically as detritivores, aiding in decomposition of biological matter including leaf litter. These arthropods are most active at night, requiring high levels of humidity to thrive, and will quickly desiccate in dry environments. They are, however, efficient at finding these suitable microclimates in an otherwise seemingly arid environment. Thus, isopods are useful indicators of relative moisture levels and ground coverage at sites. In 2018, isopods represented the dominant arthropod captured in 13 of the 26 the sites collected: Alameda, Route 66, Harrison, San Jose, State Land Office, Bosque Farms, Los Lunas, Reynolds Forest, Valencia Forest, Valencia Cleared, Belen, Crawford and Sevilleta. In several sites from the Valencia reach, isopods compose more than 90% of the arthropod abundance for these sites. Abundances of isopods vary from year to year and likely depend on annual precipitation and groundwater levels. However, large numbers of isopods are regularly encountered in sites that are prone to seep flooding, contain swales, and have ground cover of detritus.

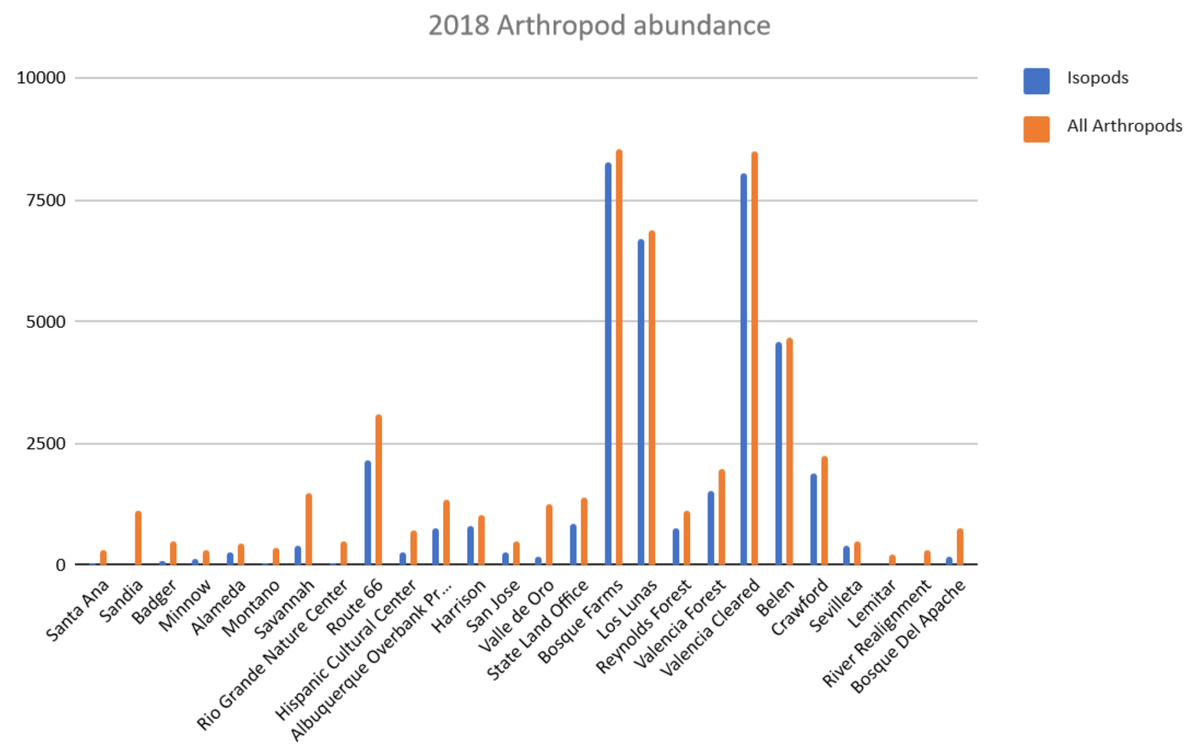


Figure 21. Isopod (blue) and all arthropod abundance (orange) per site for 2018 excluding Collembola. Sites arranged geographically north to south.

Annual Beetle abundance for 2018 can be seen in Figure 22.

Many beetles in the family Carabidae (ground beetles) are useful as indicators of relatively more mesic habitats while many beetles in family Tenebrionidae (darkling beetles) are useful as indicators of more xeric habitats. Although habitat preference is varied species to species with such large and diverse families, these families are still quite useful as environmental indicators. For example, Valencia Cleared and Valencia Forest are adjacent sites in the Valencia reach and despite their proximity the sites are notably different. The Valencia Cleared site was cleared of exotic vegetation in 2003 and 2008. This site is characterized with having a sparse but present cottonwood canopy, large wolfberry patches and a ground covering of yerba mansa, a plant known to thrive in moist soils. This site was also subjected to seep flooding in 2017. The Valencia Forest site, just south of Valencia Cleared was subjected to a fire in 2007, clearing the site of cottonwoods and now having an almost entirely open canopy dominated by kochia and tumbleweeds. In 2018, 70% of beetles captured in Valencia Forest were identified as being in the family Tenebrionidae and only 14% were identified as being in the family Carabidae. In contrast, 48% of the beetles from Valencia Clear were identified as being in the family Carabidae and 41% in the family Tenebrionidae. This pattern can be seen at many other sites where darkling beetles tend to be more abundant in sites recognized as being drier. The higher relative abundance of darkling beetles to ground beetles at the State Land Office is unexpected as this site has swales transecting the site and is prone to annual seep flooding. However, *Omophron*, a genus of ground beetle, was identified in large numbers from the 2017 and 2019 pit traps from the State Land Office site and are known to inhabit very wet sandy soils, typically occurring on the banks of rivers and ponds. These beetles have not yet been identified at any other BEMP sites.

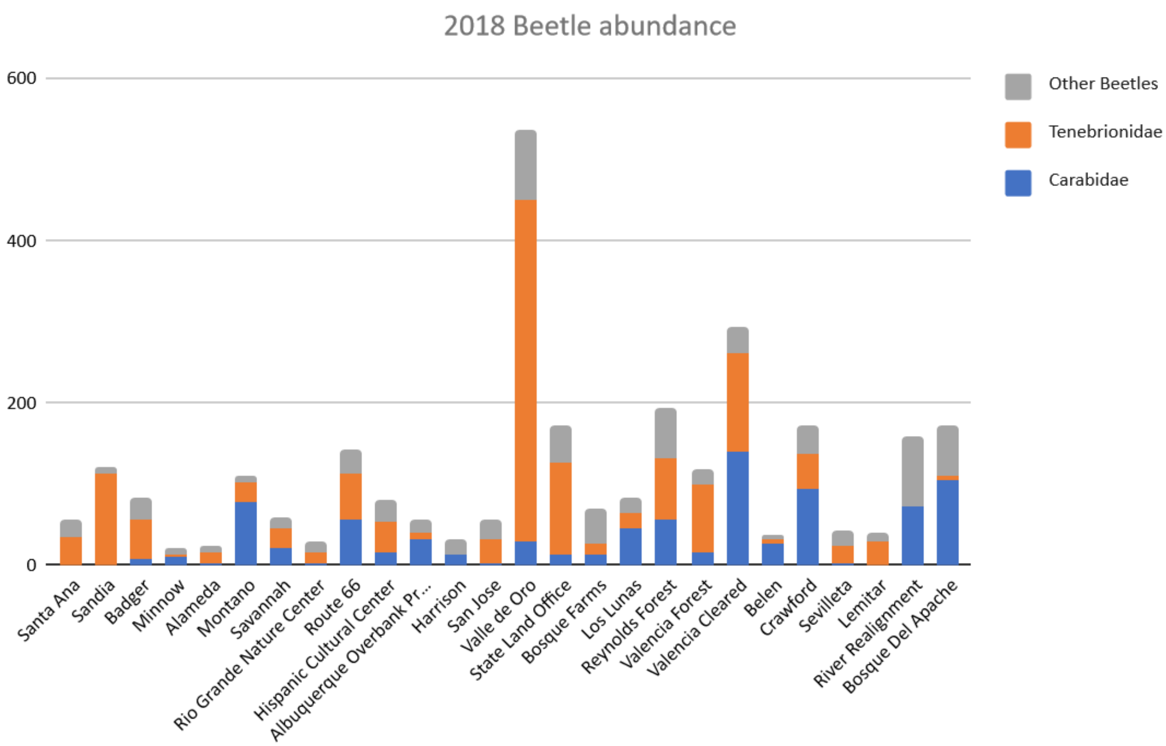


Figure 22. Beetle abundance per site for 2018 highlighting Carabidae (blue) and Tenebrionidae (orange). Sites arranged geographically north to south.

Araneae (spider) and Carabidae (ground beetle) abundance.

Many Araneae (spiders) and carabid beetles (ground beetles) function as ground dwelling generalist arthropod predators and are viewed as top predators in arthropod systems, making them ecologically important regulators of decomposers. Both of these arthropods have also been shown to be strongly associated with habitat structure responding to litter type, depth, soil disturbance, moisture and temperature. Remnant sites have been shown to contain both a higher abundance and richness of these arthropods. Monitoring the presence and abundance of carabid beetles and spiders help to gain an understanding of not only site composition but how various sites are responding to disturbances over time. Spider abundances are highest in the two southern sites; Bosque del Apache and River Realignment. Carabidae abundances are highest at the Montano, Valencia Cleared, Crawford, Bosque del Apache and River Realignment sites.

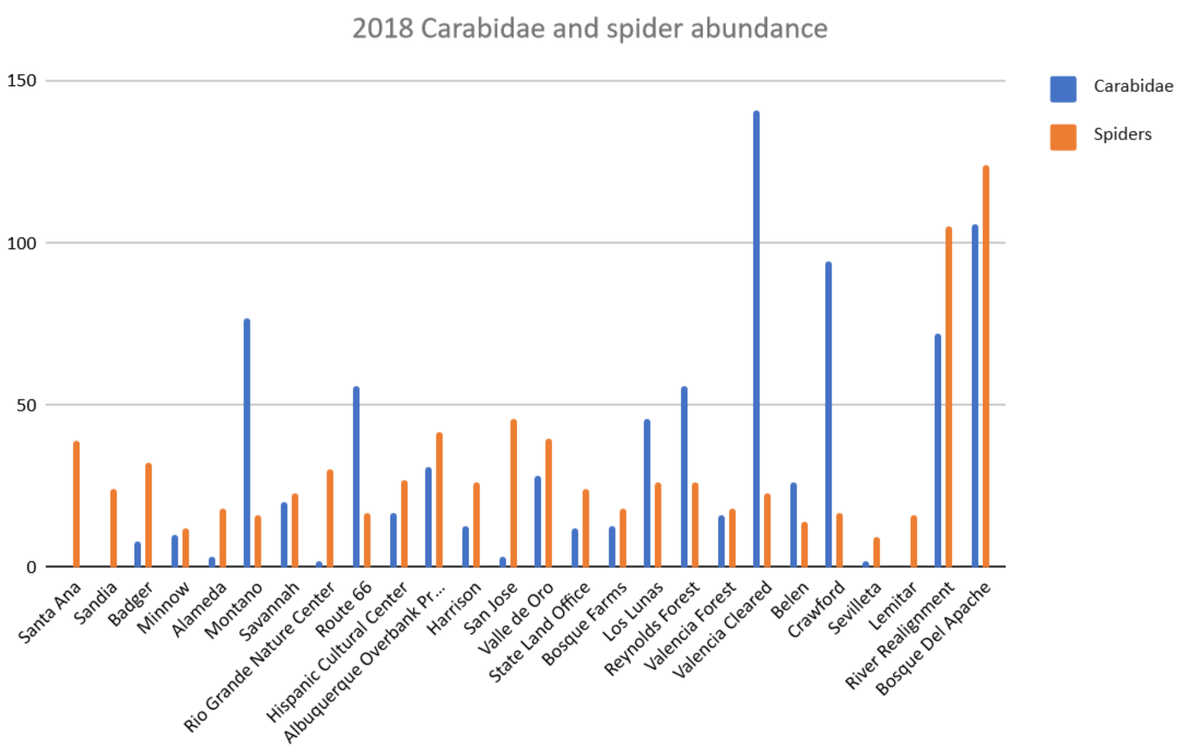


Figure 23. Carabidae and spider (top arthropod generalist predators) abundance per site for 2018 Carabidae (blue) and spiders (orange). Sites arranged geographically north to south.

Spider community structures.

In 2018, 812 spiders were identified from 18 different families. Spiders are a diverse group of generalist predators with varying habitat preferences. Many spiders hunt similar prey, therefore to avoid direct competition or becoming potential prey to other spiders, niche partitioning must occur if multiple species are to live sympatrically. A higher diversity of spiders at a given site may reflect a more heterogeneous environment. A more heterogeneous environment offers a variety of prey choices and sizes, plus the presence and type of litter as well as vegative cover provide a variety of microclimates and increased surface area for these spiders to occupy. Individual species identified within dominant spider families may be used as indicators of biotic and abiotic components specific to each site or groups of sites. For example the Gnaphosidae is a dominant spider family found at most BEMP sites. Within the Gnaphosidae, the species *Gnaphosa sericata* has only been documented from a single BEMP site, Lemitar, despite this species' large range throughout North and Central America. This spider has been known to be encountered most often in sandy dry environments, characteristics of the Lemitar site. Spider community composition separated by family for each site can be seen in Figure 24. The families Lycosidae (wolf spiders) and Gnaphosidae (ground spiders) tend to show the highest relative abundance at each site.

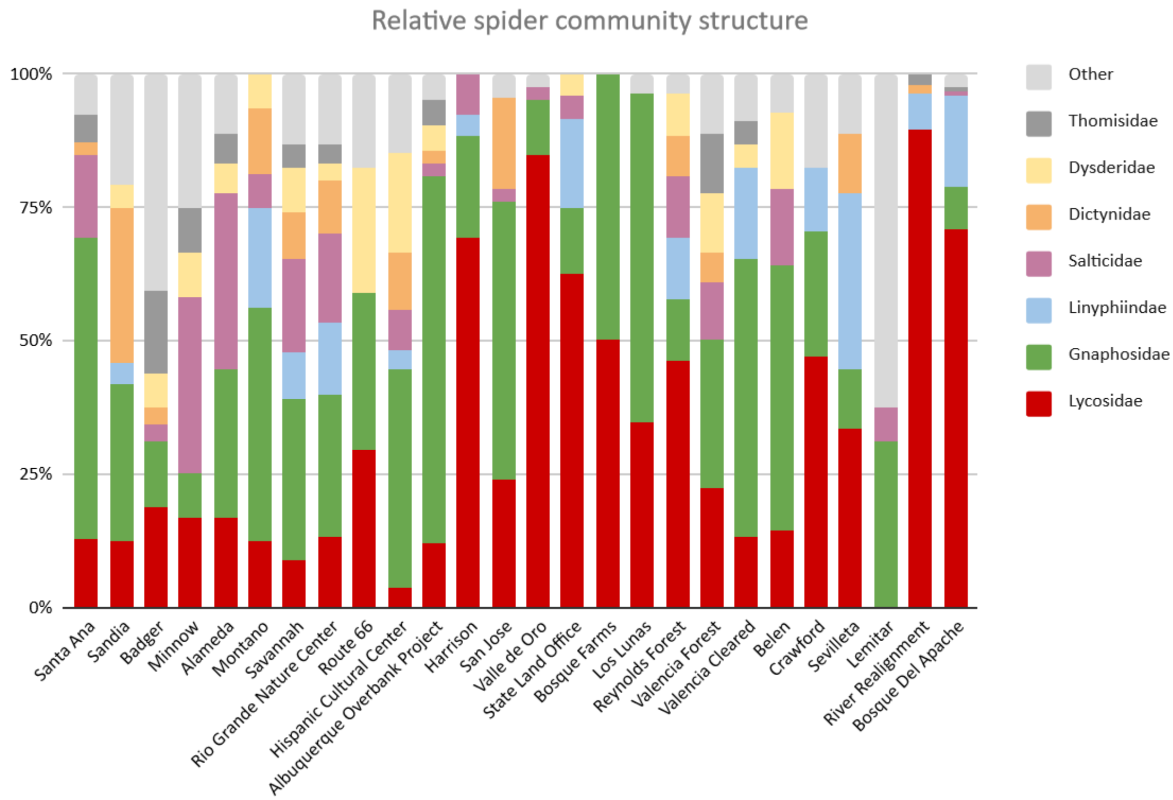


Figure 24. Percent spider community structure separated by family per site for 2018 Lycosidae (red) and Gnaphosidae (green). Sites arranged geographically north to south.

Update on the exotic spider *Marinarozelotes barbatus.*

In our 2019 annual report the exotic spider species *Marinarozelotes barbatus* (formally placed in the genus *Trachyzelotes*) was reported for the first time in New Mexico. In 2018, 44 specimens of this exotic were identified from San Jose and Harrison and Albuquerque Overbank Project sites. The abundance and location of this exotic spider will continue to be monitored.

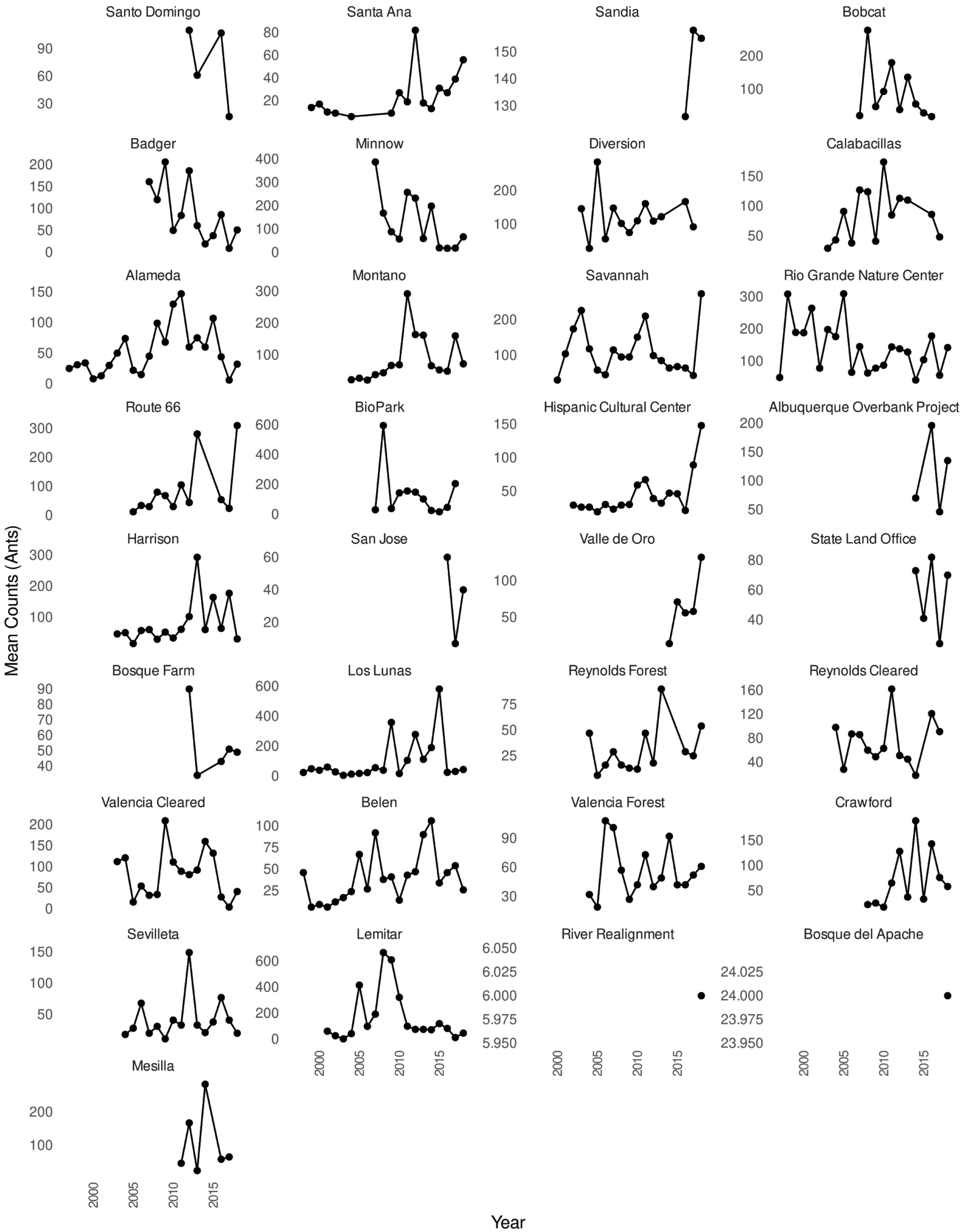


Figure 25. Fifteen year time series of ant mean abundance. Sites ordered from north to south.

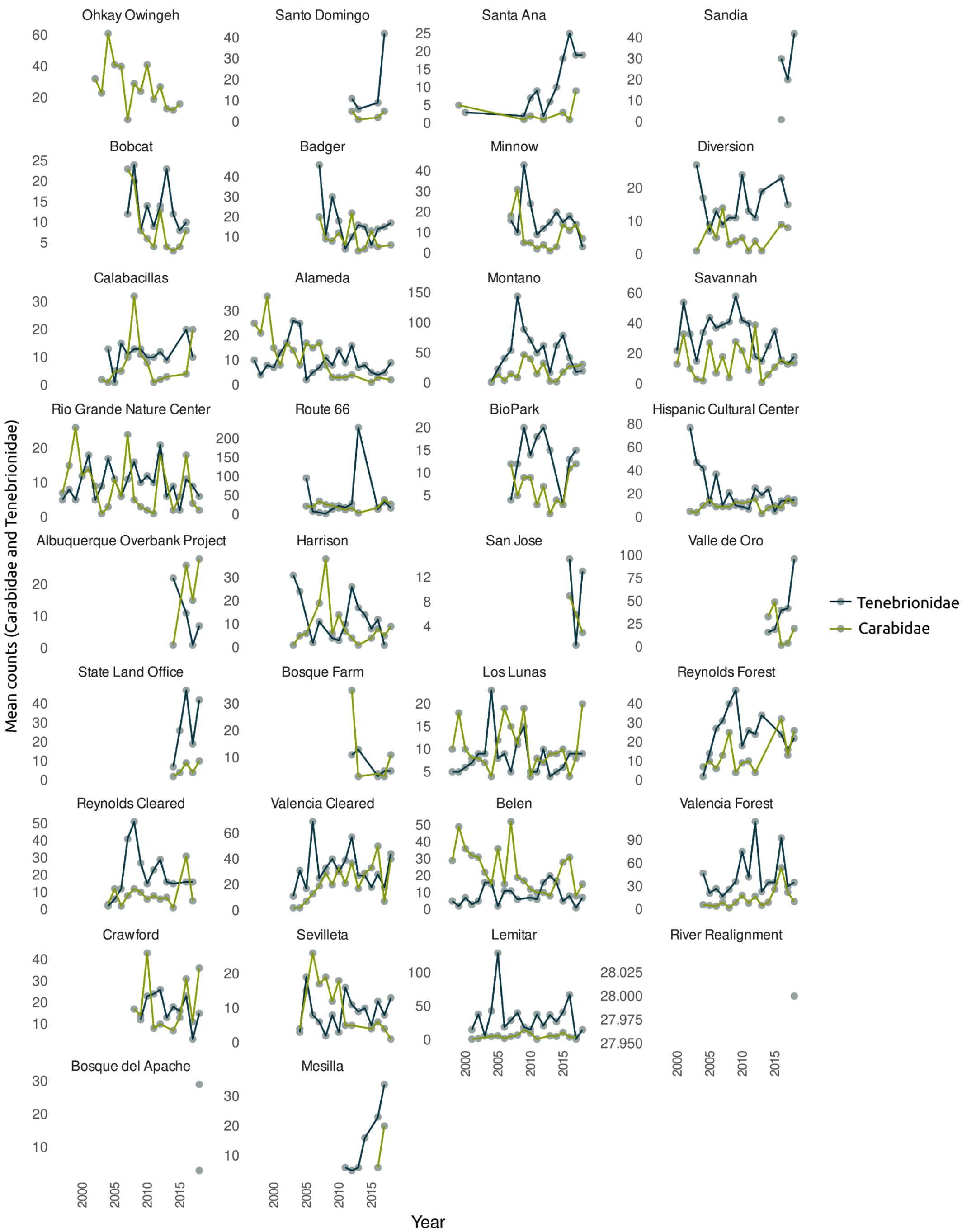


Figure 26. Fifteen year time series of Carabidae and Tenebrionidae mean abundance. Sites ordered from north to south.

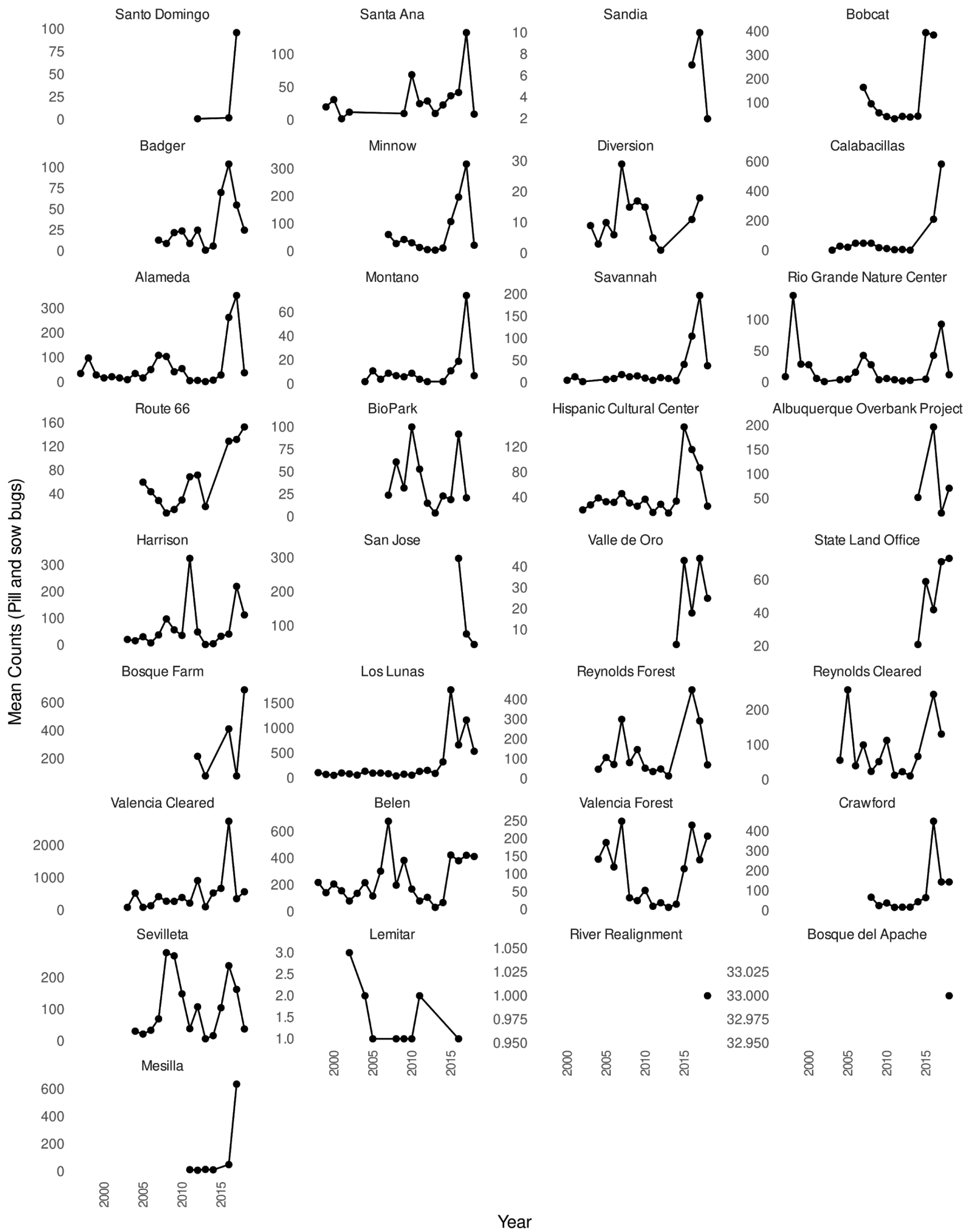


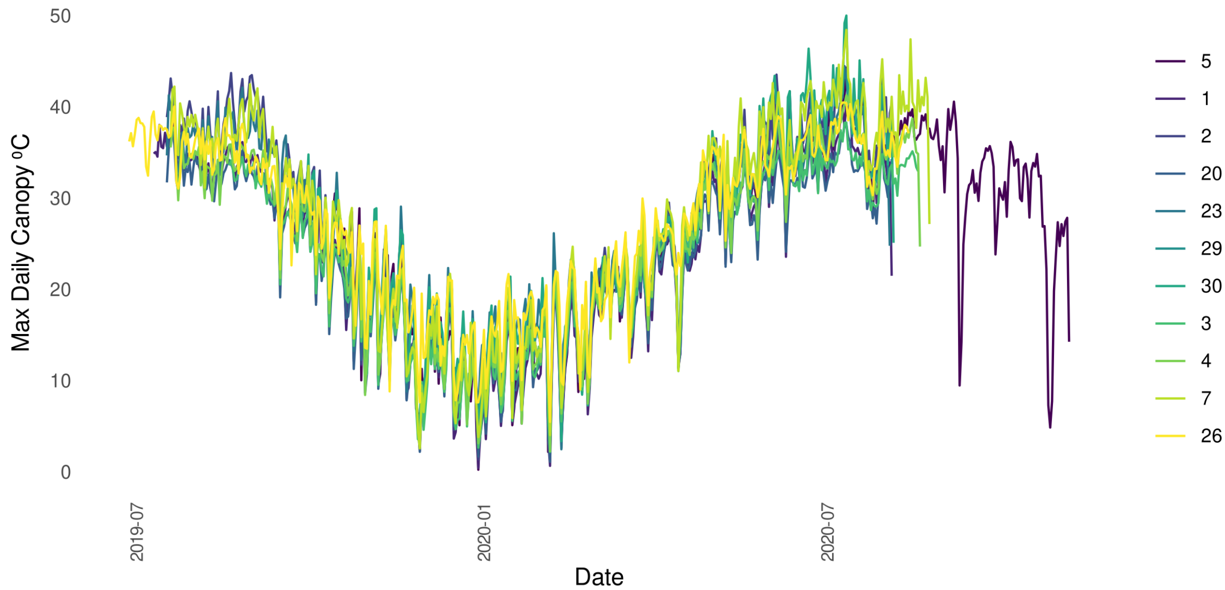
Figure 27. Fifteen year time series of isopod mean abundance. Sites ordered from north to south.

10.0 Temperature data collected at select BEMP sites

We collected temperature data from three loggers at 12 BEMP sites: 36 LogMaster temperature data loggers were attached to a tree near the canopy rain gauges, buried underground near the canopy rain gauges, and buried near the open rain gauges. Temperature data were logged hourly and downloaded annually by BEMP staff and university students. During 2019 – 2020 data were collected at the following sites: Alameda (1), Santa Ana (5), Rio Grande Nature Center (2), Rt 66 (20), BioPark (23), Albuquerque Overbank Project (AOP - 29), State Land Office (SLO - 30), Los Lunas (3), Belen (4), Lemitar (7), Mesilla (26). No data was recovered at the Savannah site due to logger malfunction and vandalization. The Santa Ana (5) site was downloaded much later in the year than the rest of the loggers due to access issues related to the COVID-19 pandemic. This resulted in a longer data collection period and an extended purple line on the graph in Figure 28.

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 3 SD were minimal given the volume of data.

Canopy temperature loggers throughout the Middle Rio Grande from Santa Ana Pueblo through Belen recorded frigid temperatures from -10.01℃ to -12.54 ℃. Two separate cold snaps lasted for two days each in mid December 2019 and again in early February 2020. The warmest days recorded from the canopy loggers were on July 10th and 11th with temperatures ranging from 49.21 - 50.05℃. A warm summer heat wave throughout the valley extended from Albuquerque to Lemitar, NM with temps ranging from 35 ℃ - 47 ℃. The duration of the high temperatures lasted for about four to five weeks from early July through mid August 2020. The canopy loggers are placed inside of solar radiation shields that are intended to protect the loggers from precipitation as well as dissipate heat from sun exposure. Due to the extremely high temperatures recorded on the loggers, there is suspicion that solar heat irradiance was maintained within the casing housing and artificially increased the recorded temperatures. Temperatures from the Kirtland Air Force Base for the same time-frame ranged from 27 ℃ - 39 ℃. The long duration of high temperatures can place stress on already parched riparian plants particularly the cottonwood trees.



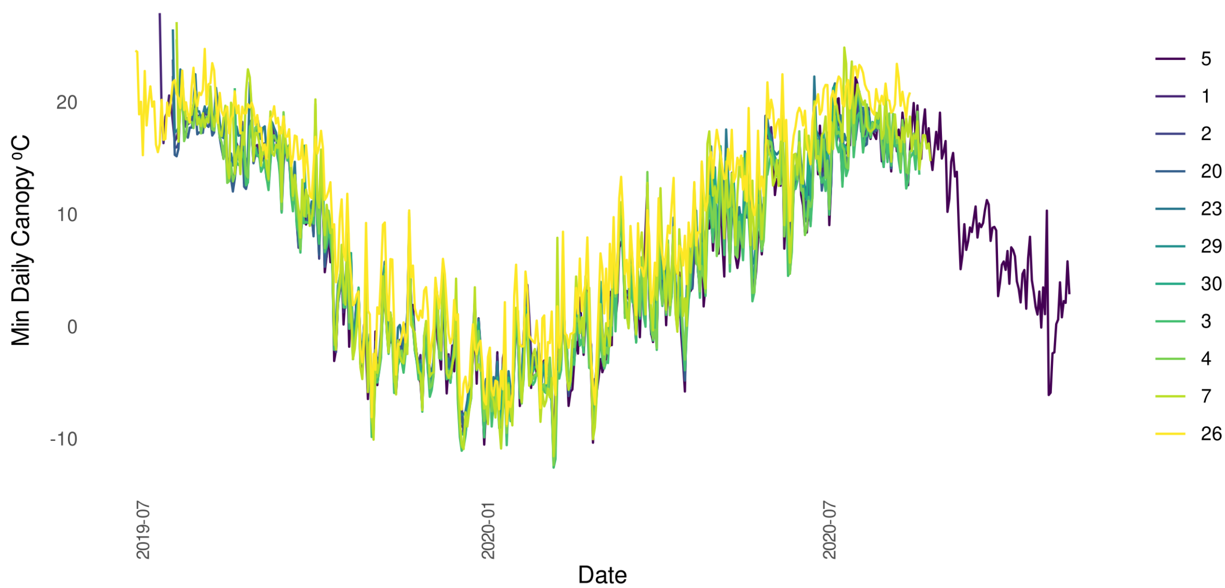
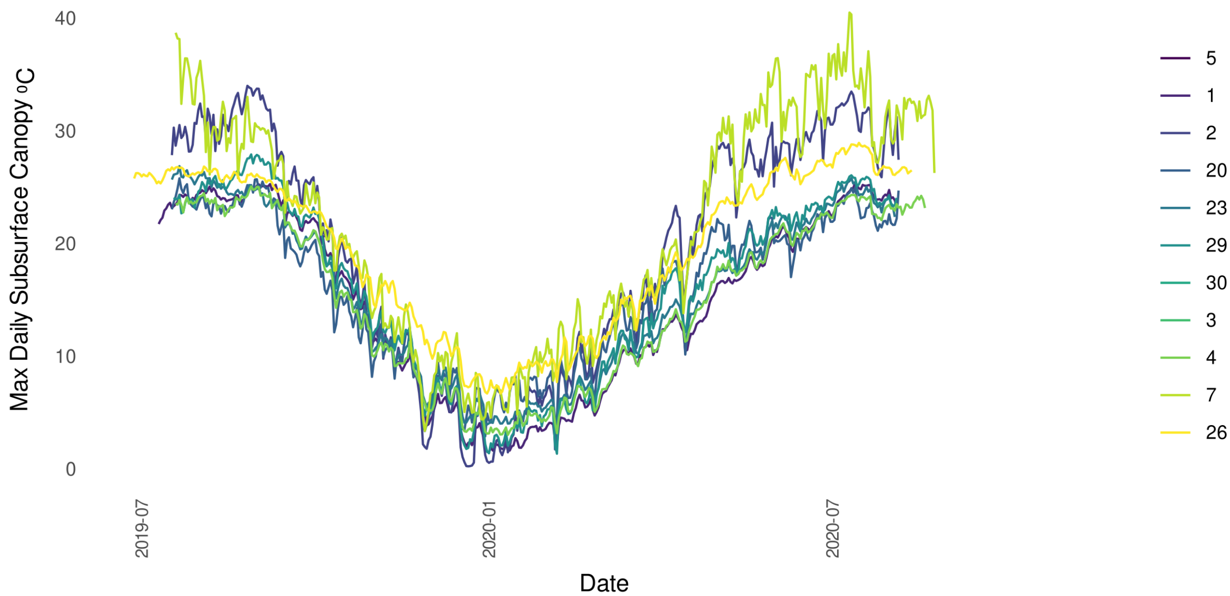


Figure 28. Maximum and minimum air temperatures from the canopy temperature loggers across 11 sites.



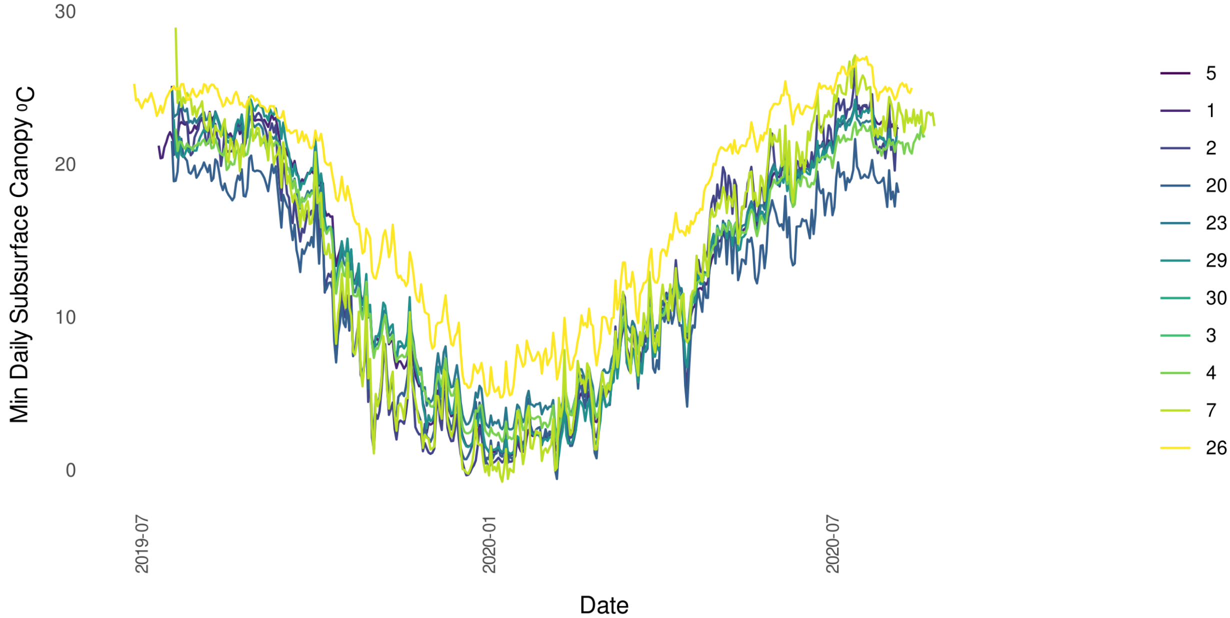
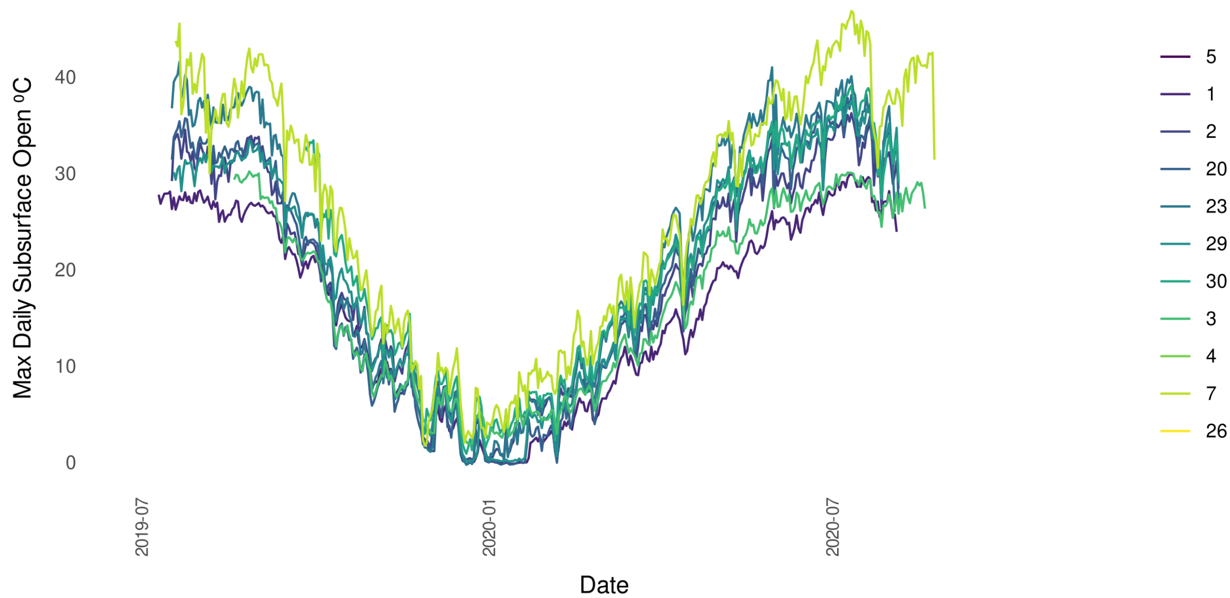


Figure 29. Maximum and minimum daily ground temperatures from the subsurface canopy temperature loggers across 11 sites.



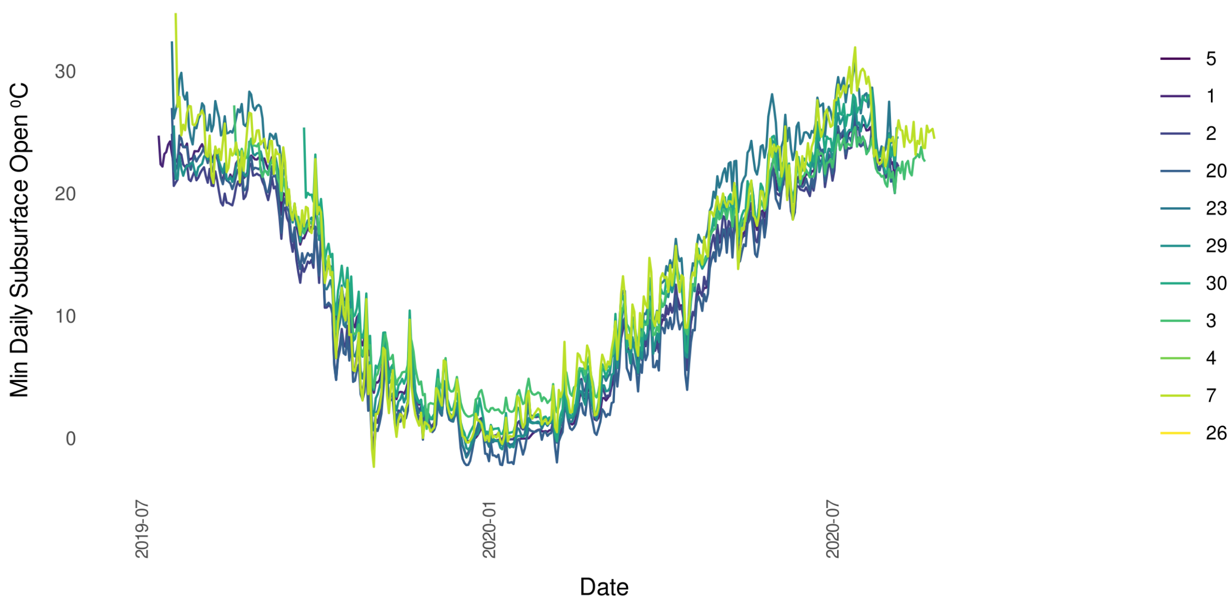


Figure 30. Maximum and minimum daily ground temperatures from the open subsurface temperature loggers across 11 sites.

11.0 Tamarisk Leaf Beetle monitoring on BEMP sites

Tamarisk leaf beetle (TLB) monitoring is conducted in May, June, July, and August each year, with additional sampling at 4 select sites (Crawford, Diversion, Route 66, and Sevilleta) in September. In 2020, BEMP monitored 16 sites (Figure 33) for the presence and abundance of tamarisk leaf beetles (*Diorhabda* spp.). 14 were established BEMP sites, with the addition of 2 sampling sites requested by the Greater Rio Grande Watershed Alliance (GRGWA): Rio Abajo in Belen and San Cristobal Ranch in Lamy, NM. Due to restrictions resulting from the COVID-19 pandemic, BEMP was unable to continuously monitor previous sampled sites on sovereign territory such as Pueblo of Santo Domingo and Sandia Pueblo.

At each site, five saltcedar/tamarisk trees are marked and sampled using sweep nets for TLB, with photos taken from a set photo point to assess tree health over time. BEMP has been monitoring the spread and distribution of the tamarisk leaf beetle since May of 2013. The beetle appears in the late spring and is present throughout the summer months. TLB adults, early and late larvae, and egg masses are counted, as are tamarisk splendid weevils, tamarisk leafhoppers, ants, and spiders. Percent defoliation (brown and yellow), refoliation, canopy, and dead branches are estimated for each tree. Full methods found can be found in BEMP's annual TLB report, available upon request.

TLB populations were low to absent at most sites in 2020 (Figure 31). There were only four sites, Lemitar, Valencia Cleared, Diversion and Rio Abajo, that had five TLB adults in any given month. Otherwise, counts of TLB adults were zero or fewer than five. The only exception was June at Sevilleta, where tree #1 had 1375 adults, tree #2 had 366, and the remaining trees had fewer than three adults. It is possible that the long duration of flooding in 2019 at many of the sites may have led to declines in beetle emergence.

Despite the low TLB numbers, defoliation levels ranged from 0 to 100% at the sites. Defoliation due to the tamarisk leafhopper, which results in yellow foliage, ranged from 0 to 60%, while defoliation due to the TLB, which results in brown/dead foliage, was 0 to 100%. Similarly, total defoliation (which is both yellow + brown defoliation) ranged from 0 to 100%. The high defoliation levels at some sites underline the importance of the full range of monitoring, as the beetle populations were likely missed on the specific sampling date, but the evidence of beetle damage was still observable and quantifiable.

This evidence of beetle damage, and overall decline in canopy coverage of tamarisk over the last few years, is a consistent data point that reflects the alteration of habitat and other potential ecological impacts due to the presence of TLB.

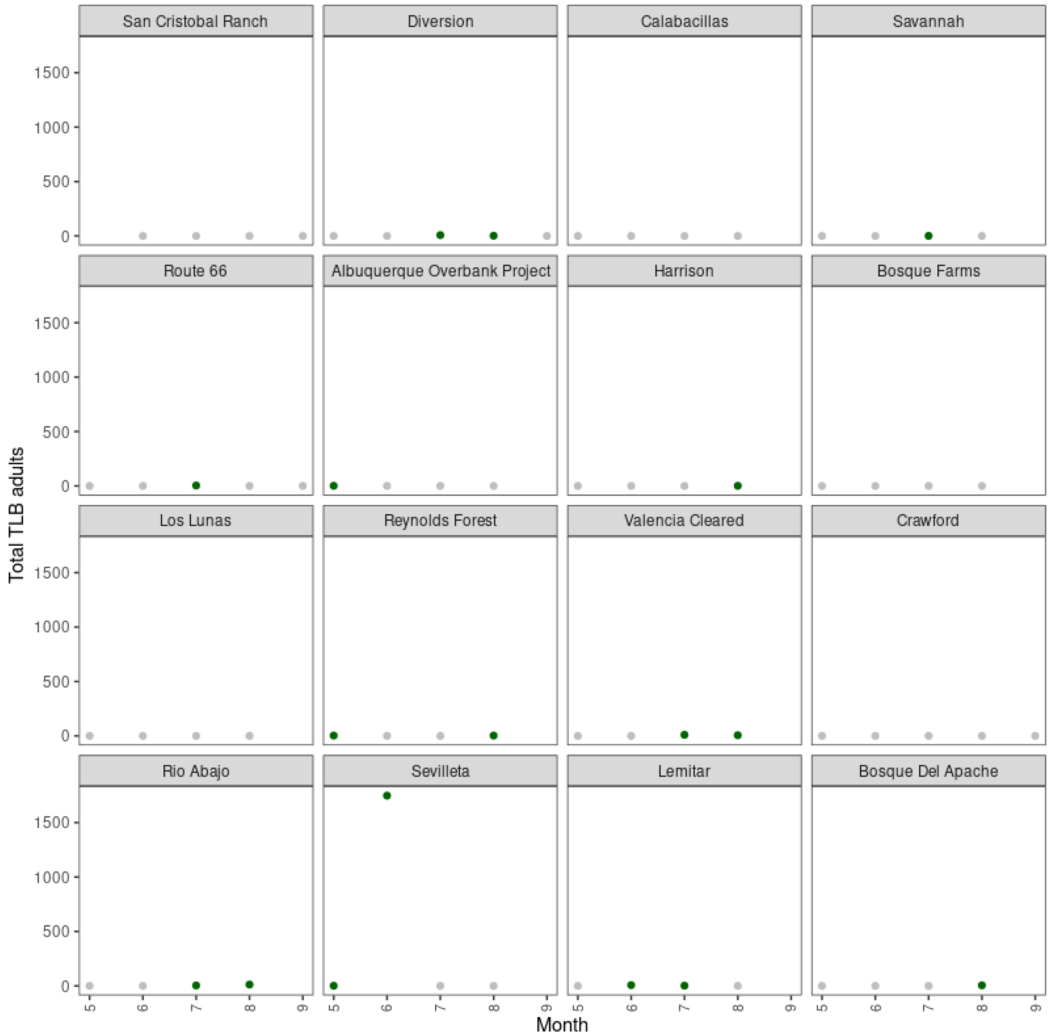


Figure 31. Total number of TLB adults collected at 16 different monitoring sites from May through August (a subset of 4 sites were sampled in September).

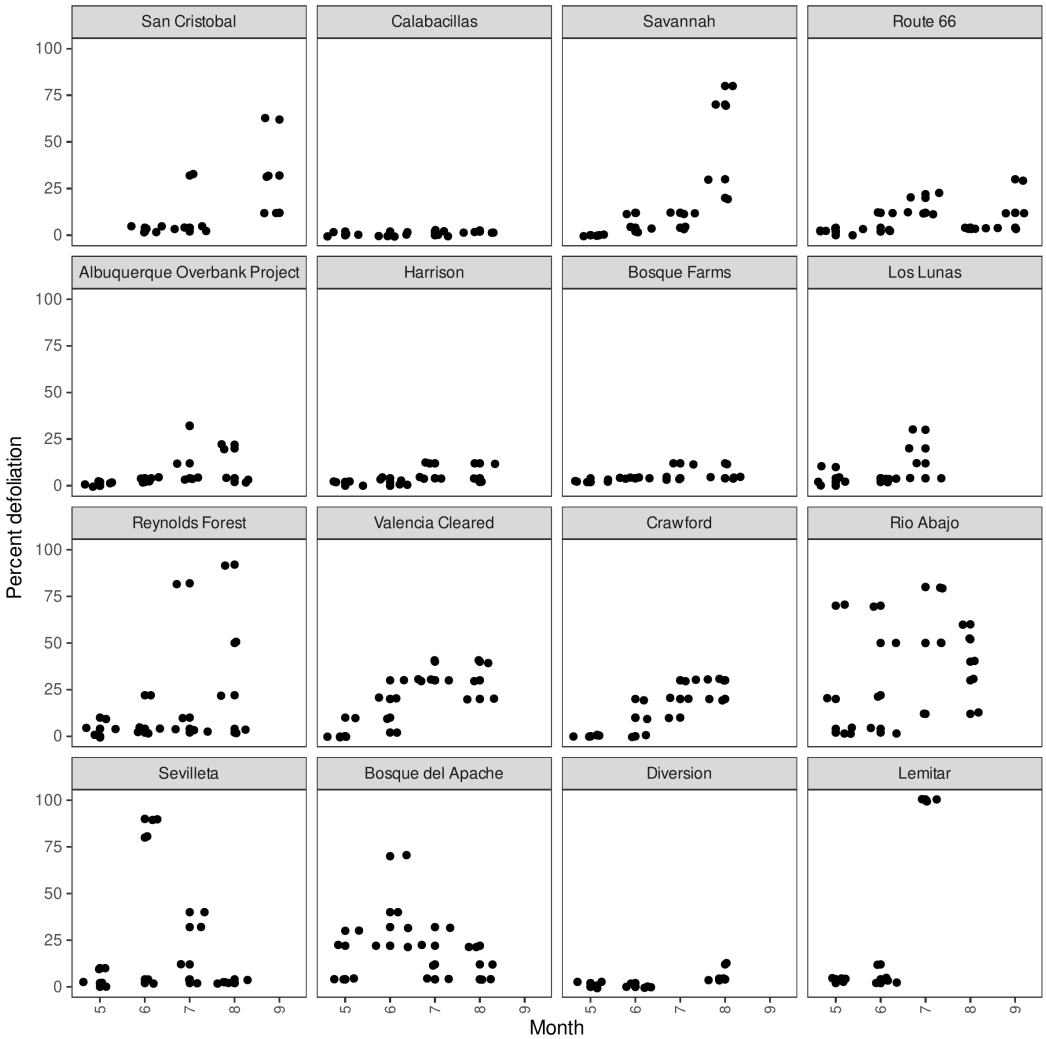


Figure 32. Percentage of saltcedar defoliation from trees sampled at 16 different monitoring sites from May through August (a subset of 4 sites were sampled in September).

Since the beginning of TLB monitoring in 2013, BEMP has observed cyclical patterns of population abundance based on region. In 2019, BEMP observed the greatest number of TLB adults in the southern most BEMP sites. In 2020, BEMP observed the same trend. Based on previous collections, it is not unreasonable to suspect that TLB populations will reach their peak in 2021 in southern BEMP sites, or that they have already done so in 2020, and will decrease the following year. Many defoliators exhibit outbreak cycles or eruptive population increases which result in high levels of defoliation. TLB populations appear to follow this “boom-bust” pattern.

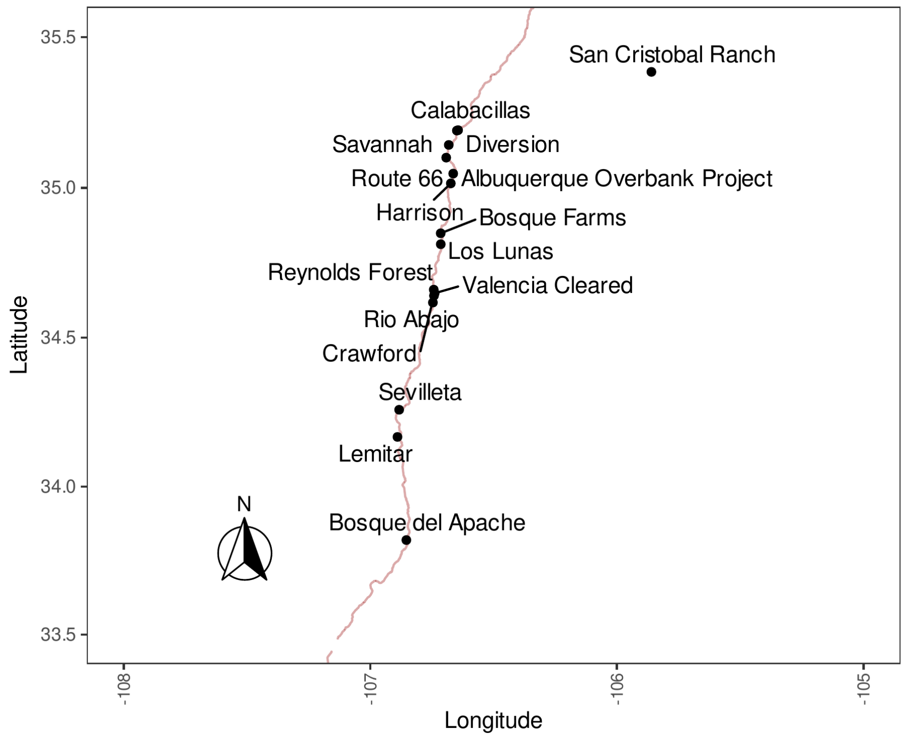


Figure 33. Map of sites collected for TLB May 2020 - September 2020, note that San Cristobal Ranch and Rio Abajo are not considered BEMP sites.

Community Composition Consequences

Currently, BEMP graduate student research is focusing on the implications of beetle populations and their subsequent effects on tamarisk and surrounding bosque vegetation. Despite overwhelming evidence of beetle damage and changes in tamarisk phenology, there has been no significant difference in community composition based on varying degrees of beetle abundance (absent, low, medium, and high abundance). Although currently there is no significant difference in vegetative community composition based on beetle abundance, continuous monitoring of the beetle population remains important as Tamarisk and *Diorhabda* have become established organisms within the riparian ecosystem. BEMP TLB data are available by request, and will be posted on GitHub (https://github.com/BEMPscience/bemp_data) along with our other long-term datasets.

12.0 Outreach for the 2019-2020 school year

Prior to necessary shifts required to accommodate for the COVID-19 pandemic, BEMP education provided 117 in-person, after-school, field monitoring and study trips for 2,802 students and 203 adults from August 1, 2019 to February 28, 2020.

To ensure public health and safety, BEMP pivoted away from in-person programming for K-12 schools in March 2020. From March 1, 2020 to May 31, 2020, BEMP education delivered 84 total programs to 10,473 students and 120 adults. Though some after-school and field monitoring opportunities were provided, educational programming relied heavily upon 72 of the 84 programs that were provided through printable and electronic platforms, including Grab and Go activities, Exploring the Outdoors and Bosque Data Jam. University seniors and graduate students participating in the Biology 408/508 course were restricted from conducting field and lab work during this time.

In total, BEMP education reached 13,275 students and 323 adults throughout 29 different schools during August 2019 to May 2020. Schools served include: ACE Leadership High School, Albuquerque Institute of Math and Science, Arroyo Del Oso Elementary School, Bandelier Elementary School, Belen High School, Native American Community Academy, Bernalillo Middle School, Bosque School, Cien Aguas International School, Comanche Elementary School, Cottonwood Valley Charter School, Coyote Willow Family School, Del Rio Academy, Garfield Middle School, Georgia O'Keeffe Elementary School, Highland High School, Horizon Academy West, Inez Elementary School, Jefferson Middle School, La Academia De Esperanza, Manzano Day School, nex+Gen Academy, North Star Elementary School, School of Dreams Academy, Sombra del Monte Elementary School, The International School at Mesa del Sol, Van Buren Middle School, West Mesa High School, and Wilson Middle School. Of these 29 total schools, 21 (or 72%) are considered to be classified Title One, wherein at least 40% of students qualify for free and/or reduced lunch.

In response to the COVID-19 pandemic, BEMP education pivoted to better support the diverse needs of students, teachers and families. Though COVID-19 has posed challenges for in-person learning, it has reinforced the value and need for continued student-centered, experiential, place-based educational opportunities.

Rising to this challenge, BEMP education re-envisioned in-person classroom sessions to two remote, multi-part, synchronous lessons that leverage learning and connection within a student's own place-based residence. Exploring the Outdoors (Part I and II) and Bosque Data Jam (Parts I - IV) focus on phenological observation, ecosystem monitoring, climate change, scientific processes, graphing and data analysis. Both lessons encourage a deeper understanding of nature in students' backyards and connectivity to the larger Bosque ecosystem while developing career-based skills in the sciences, public-speaking and presentation delivery. Further, students have been encouraged to track the biodiversity of their neighborhoods using cell phone technology to participate in BioBlitz surveys. They have created and implemented their own arthropod pitfall traps to assess species abundance and diversity, collect and track precipitation, and monitor phenological changes of plants and animals in their own backyards or nearby Open Spaces. Additionally, remote, multi-part, asynchronous lessons entitled the River of Change and Stormwater Science have been offered via Edpuzzle, an interactive video lesson platform.

To better facilitate learning opportunities for students with limited computer access, BEMP staff printed and distributed educational materials for up to 12,900 students in Bernalillo County from March 26 to June 30, 2020 at Grab & Go meal locations, Little Libraries, Children's Choice Child Care, NM Out-of-School Time Network's Storytime in the Park, and more. These new one-page activities, compiled into an NGSS-aligned, multi-page booklet, engage students in real data analysis, such as through Seed Adaptation and Backyard Precipitation Station activities. They have also been made available on our website to ensure broad accessibility. Further, all education activities and materials provided are bilingual in Spanish and English, strengthening accessibility initiatives for broader audiences.

Additionally, accommodating for COVID-19 precautionary measures, 2020's annual Crawford Symposium shifted to an online format, broadcasting presentations of 60 participants' data analysis and findings outwards in a reach of 235 views.

Throughout the March 26 to June 30, 2020 time period, BEMP educational materials were viewed at least 232 times from BEMP's website and are similarly available on the BEMP Education github page. BEMP's social media presence has increased, growing to 26,354 contacts (March - June 2020) across Instagram, Facebook, and YouTube's online platforms.

Table 3. Social Media outreach by BEMP in 2020

Social media platform	**Reaches**	**Engagements**	**Views**
Instagram	7766	1468	NA
Facebook	14809	1853	NA
YouTube	NA	NA	458

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 people clicking "see more" for longer posts.

13.0 Student research projects for the Virtual Symposiums

Crawford Symposium

The Crawford Symposium is an annual event where we celebrate our year's successes in memory of Cliff Crawford, BEMP's co-founder. Throughout his life, Dr. Crawford inspired students of all ages and catalyzed a growing body of research in the bosque. Moreover, he also radiated the work of students, fellow scientists, and professionals back into the community. Thus, each year we gather to celebrate community science and environmental research along the Middle Rio Grande in his honor. This allows us to showcase the research of the students and professionals who have been engaged with our organization. Last year, due to the pandemic, this event changed its format and was streamed live on our YouTube channel. This year, we plan to follow the same format.

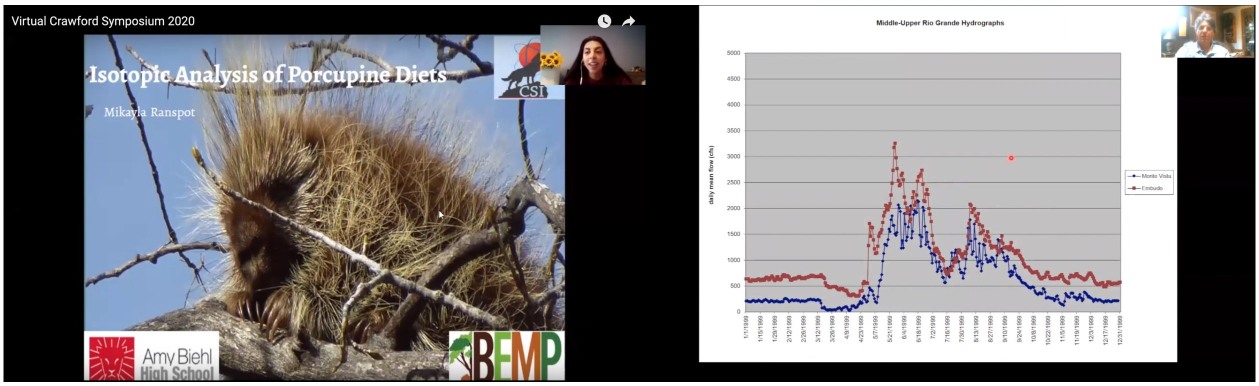


Figure 34. Student from Amy Biehl, Mikayla Ranspot, and professional with Audubon New Mexico, Paul Tashjian, presenting at the 2020 Virtual Crawford Symposium.

Spanish language Luquillo-Sevilleta Virtual Symposium (LSVS)

In partnership with the Luquillo Long Term Ecological Research Network, BEMP annually hosts a formal student webinar for students to share their own, original research delivered entirely in Spanish. Students of all ages from Albuquerque and Puerto Rico gather (virtually) to share their long term scientific research of their respective forests and rivers. Students from Puerto Rico work with the Luquillo Long Term Ecological Research Schoolyard program to study and present important issues related to the hydrology and pedology of the area and its changes over time. New Mexico BEMP students, in collaboration with the Sevilleta Long Term Ecological Research Schoolyard program, present projects related to water quality, shifts in vegetation cover and other BEMP-related datasets. Ultimately, this event intends to celebrate the diversity in cultures and backgrounds that these two locations foster.

Last year, students from New Mexico and Puerto Rico shared their research on how human disturbances have affected their local ecosystems. This year, BEMP educators have been meeting virtually with the different schools (College and Career High School, La Academia de Esperanza, Bosque School and The International School) that will be attending the event to help them prepare and translate their projects. We have also invited a new New Mexico organization, the Asombro Institute, to collaborate in this project starting this year. We hope to continue to expand our partnership to other spanish speaking organizations in the near future.

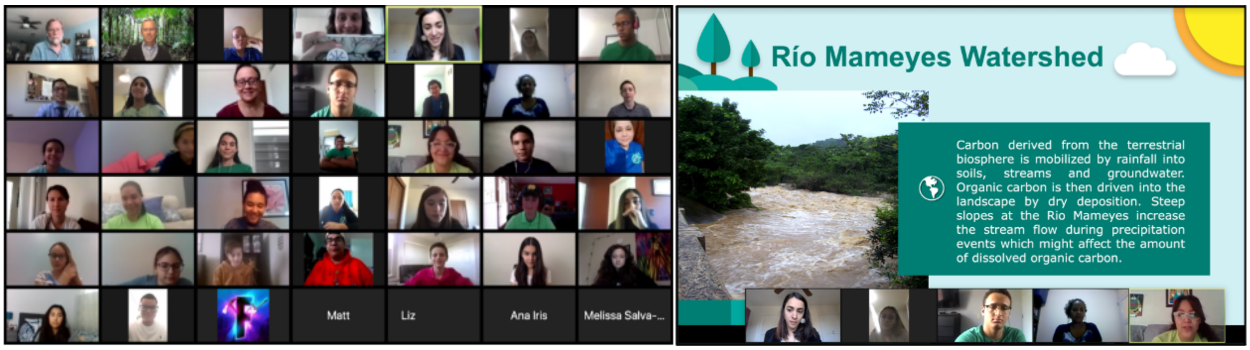


Figure 35. Students, teachers and educators that participated in the 2020 Luquillo-Sevilleta Virtual Symposium.

14.0 Ongoing commitment to justice, equity, diversity, and inclusion

BEMP science and education take place on current and ancestral lands of the Pueblo, Diné (Navajo), Apache, and other displaced Indigenous peoples for whom this land is home. BEMP acknowledges that this land was forcibly stolen by European colonizers and that the detrimental effects of their presence through violence, displacement, and disease are still impactful today. We offer this acknowledgement as a first step in honoring the Indigenous peoples and their ancestors and as a call toward further learning and actions as guests in this place.

BEMP is committed to increasing our knowledge regarding Justice, Equity, Diversity, and Inclusion (JEDI) by having group discussions, reading, attending seminars and webinars, and conducting professional developments led by external professionals. Examples of BEMP's accomplishments and implementations can be seen as follows:

<u>Organizational:</u>
As seen above, a formal land acknowledgement has been created for field use, presentations, and the website with the assistance of Indigenous partners. To ensure equity and access when hiring new employees, staff have attended seminars on equitable hiring practices and shared resources from those seminars. This includes changing the requirements for a job to include equivalent experience to a formal degree, including various staff members and various levels in the hiring process, and expanding our reach when posting job applications. Organizational assessments have been conducted by the staff to determine areas of improvement in regards to JEDI. BEMP cultural and meeting norms have been created by the staff, which everyone must agree to when conducting BEMP work and meetings.

<u>Educational:</u>
Title One schools have been prioritized for BEMP education in Albuquerque and the surrounding areas. Of the 29 total schools BEMP partnered with, 21 (or 72%) are considered to be classified Title One, wherein at least 40% of students qualify for free and/or reduced lunch. Since the beginning of the COVID-19 pandemic, BEMP increased their social media presence in order to stay connected with supporters, teachers, students, and other community members. All social media posts are translated into Spanish. At-home, place-based activities created for classrooms, families, and individuals have been posted to our website, Facebook, and Instagram, and are also available in English and Spanish. Prior to and during the COVID-19 pandemic, students from various schools in Albuquerque participated in the Luquillo-Sevilleta Virtual Symposium, allowing students to discuss the science they are working on in Spanish and to students in Puerto Rico.

Partner Organizations:

We have formed discussion and reading groups with partner organizations in order to broaden our learning and understanding of various life experiences. In order to develop meaningful JEDI content for BEMP staff, members of BEMP consulted with Bosque School's Director of Diversity. Dr. Kim Eichorst, BEMP Science and Research Director, partnered with the Sevilleta LTER to improve structural and organizational processes. Webinars and training have been available to staff through the NCEAS Seminar Series, Environmental Education of New Mexico, and numerous other organizations when time allows.

Field Operations:

BEMP staff partnered with the Albuquerque Sign Language Academy Honeybadger Crew in constructing accessible bosque trails behind Bosque School, which allowed more students to collect data with BEMP staff, as well as allowing the public to have an accessible area of the bosque. Safety regulations were implemented in the field, which allowed for staff to speak up about not feeling safe or comfortable in a situation. When taking students out into the field, BEMP staff prioritize student safety, encouraging communication to staff if there is any reason they feel unsafe or uncomfortable and adjusting plans accordingly.

15.0 Water quality on the Middle Rio Grande - Impacts on the watershed

The Mid Rio Grande Stormwater Quality Team funds the Bosque Ecosystem Monitoring Program (BEMP) to engage students and other community scientists in monitoring the Rio Grande for *Escherichia coli* and field parameters. This bacterial pathogen is a public health issue, often a proxy for other aqueous pathogens, an indicator of water quality, and disportionately impacts underserved and economically disadvantaged communities. Sampling methodologies, full list of sampling sites, and further details are in the 2020 Annual Stormwater Quality Team Technical Report available on request.

Spatial distribution of the 2020*E. coli* coliform grab samples and historical context.

During the July 29th, 2020 grab sampling all sites were in exceedance (Figure 36); however, there were several nights of rain before the sampling event.

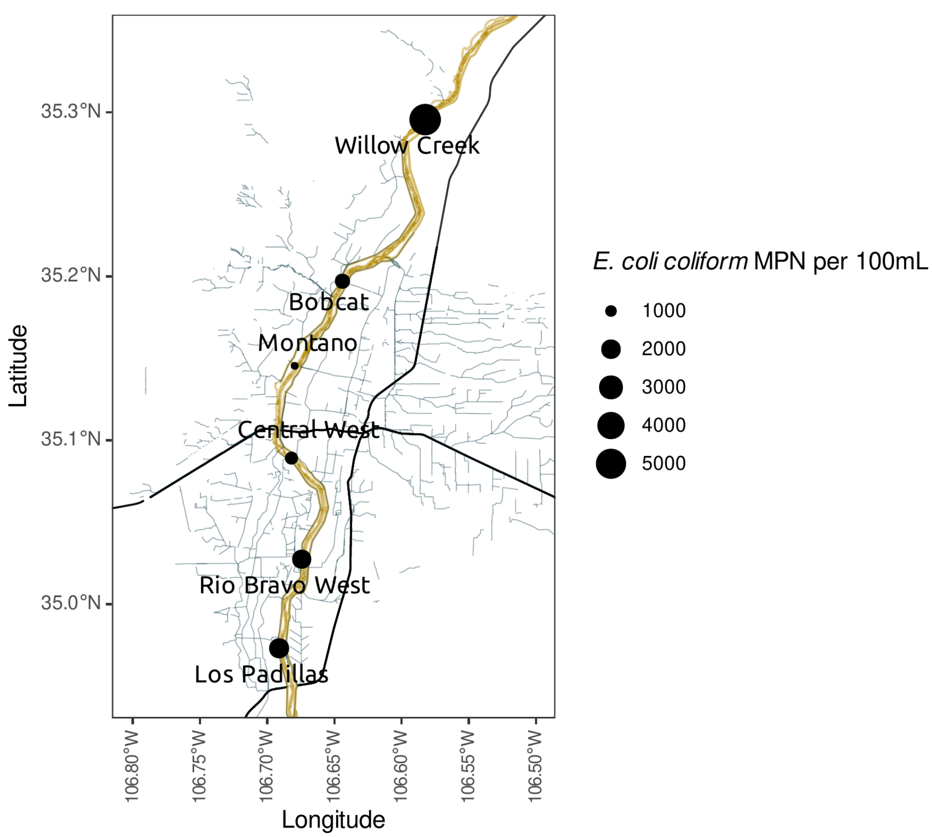


Figure 36. Spatial plot of grab samples of *E. coli* coliform on July 29, 2020. The EPA limit for *E. coli* is 410 MPN/100ml. The black lines are I-40 and I-25. The grey lines show drains, ditches, and arroyos.

July sampling needs to be put into an annual and longer term context. The EPA limit for *E. coli* is 410 MPN/100ml. Over the course of the year both a longitudinal and transactional study was carried out. Figure 37 shows that for most of the year the samples were under the EPA limit.

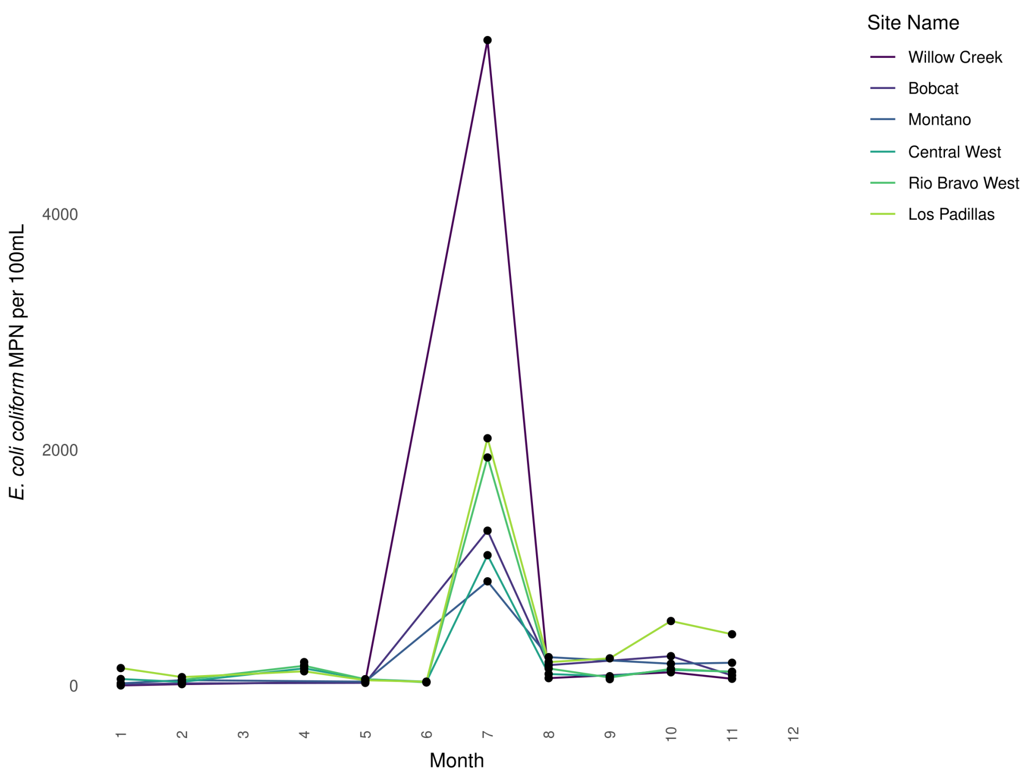


Figure 37. *E. coli* coliform from the longitudinal sampling sites. The levels are highest in the summer months. The Willow Creek, Bobcat, and Montano sites were not sampled in March, June, September and December due to different sampling methodology during those months.

The variation between sites and response to precipitation events point to a complex set of interactions in the Rio Grande. The historic BEMP *E. coli* data goes back to 2005. Long term community science data allows us to have a clearer picture of *E. coli* contamination in the Rio Grande. While the values collected during the July sampling appear high, in the historic context (Figure 38) they are four to five times lower than previously recorded samples.

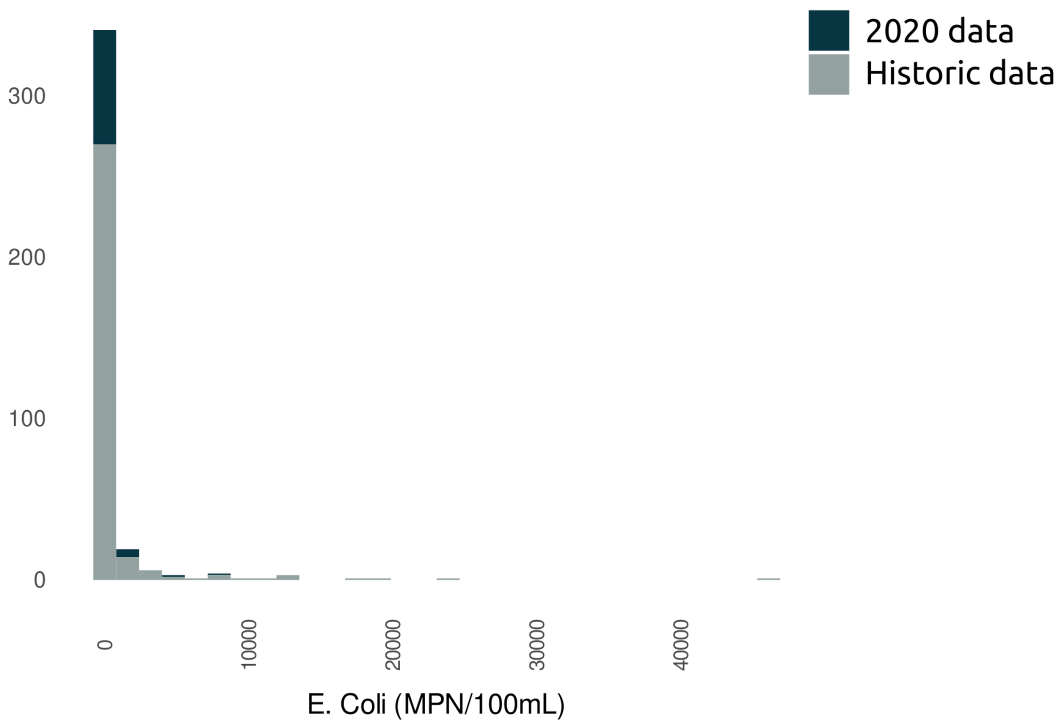


Figure 38. Histogram of the 2020 and historic *E. coli* coliform data. The 2020 values appeared high, however the longer term, historic data shows that values can be up to four to fives times greater.

16.0 Rio Grande wetlands as potential bioremediators

This project was funded by the Valencia Soil and Water Conservation District to examine the mitigating influence of natural wetlands on wastewater effluent. This study intended to assess the quality of the river flows used for irrigation of agricultural lands. Water quality was examined through measuring Pharmaceuticals and Personal care products (PPCP's), *E. coli*, and anions in and around the Albuquerque Southside Wastewater Treatment Plant and Los Lunas Wastewater Treatment Plant effluent. Samples were taken in the Rio Grande up and downstream from the facilities as well as within their effluent conveyance channels.

The Los Lunas Wastewater Treatment Plant effluent flows slowly through a 300 m shallow wetland prior to discharging into the Rio Grande. In contrast, Albuquerque's effluent flows through a 60 m straight, deeper channel with little vegetation prior to its confluence with the river. Water from these two different outflow designs enabled a glimpse into the much studied ability of wetlands to affect concentrations of a diverse array of compounds.

Sampling methodologies, full list of sampling sites, and further details are in the 2020 BEMP Wastewater Outflow Study Technical Report available upon request.

All data is housed on https://github.com/BEMPscience/bemp_data and is available to the Valencia Soil and Water Conservation District and the public.

Table 4. List of Pharmaceuticals and Personal Care Products (PPCP's) detected in samples and their common names.

Compound	Description	Compound	Description
1,7-Dimethylxanthine	metabolite of caffeine	Iohexal	x ray contrast agent
2,4-D	herbicide	Ketorolac	nonsteroidal anti-inflammatory drug (analgesic)
4-nonylphenol (semi quantitative)	antioxidants, lubricating oil additives, laundry and dish detergents, emulsifiers, and solubilizers manufacturing	Lidocaine	local anesthetic
4-tert-Octylphenol	commercial chemical found in plasticizers, fuel oils, dyes, adhesives, disinfectants	Lopressor	blood pressure medication
Acesulfame-K	artificial sweetener	Metolachlor	herbicide effective towards grasses

Albuterol	bronchodilator	Meprobamate	anxiety medication
Amoxicillin (semi-quantitative)	antibiotic	Naproxen	nonsteroidal anti-inflammatory drug (e.g., Aleve)
Atenolol	blood pressure medication	Pentoxifylline	medication for improved blood flow and pain reduction (e.g., Trental)
Atrazine	herbicide	Primidone	seizure medication
Butalbital	barbiturate	Salicylic Acid	anti-inflammatory (e.g., aspirin)
Caffeine	psychoactive drug	Sucralose	artificial sweetener (e.g., splenda)
Carbamazepine	seizure medication	Sulfadiazine	Sulfa antibiotic
Carisoprodol	muscle relaxant	Sulfamethoxazole	antibacterial medication
Cimetidine (semi quantitative)	ulcer medication	TCEP	reducing agent
Cotinine	metabolite of nicotine	TCPP	flame retardant compound found in polyurethane
DEET	pesticide	TDCPP	compound found in flame retardants, pesticides, plasticizers, and nerve gases
Diclofenac	nonsteroidal anti-inflammatory drug (e.g., Voltaren)	Theobromine	chemical found in foods
Dilantin	seizure medication	Theophylline (semi-quantitative)	bronchodilator
Diltiazem	blood pressure medication	Thiabendazole	parasitic drug
Diuron	herbicide	Triclosan	antibacterial and antifungal agent
Estrone	hormone	Triclocarban	antibacterial chemical, FDA banned in in 2016 in soaps and washes
Fluoxetine	medication for depression, OCD, bulimia, alcoholism (e.g., Prozac)	Trimethoprim	antibiotic (e.g., Primsol)
Gemfibrozil	cholesterol medicine (e.g., Lopid)	Warfarin	blood thinner medication (e.g., Coumadin)

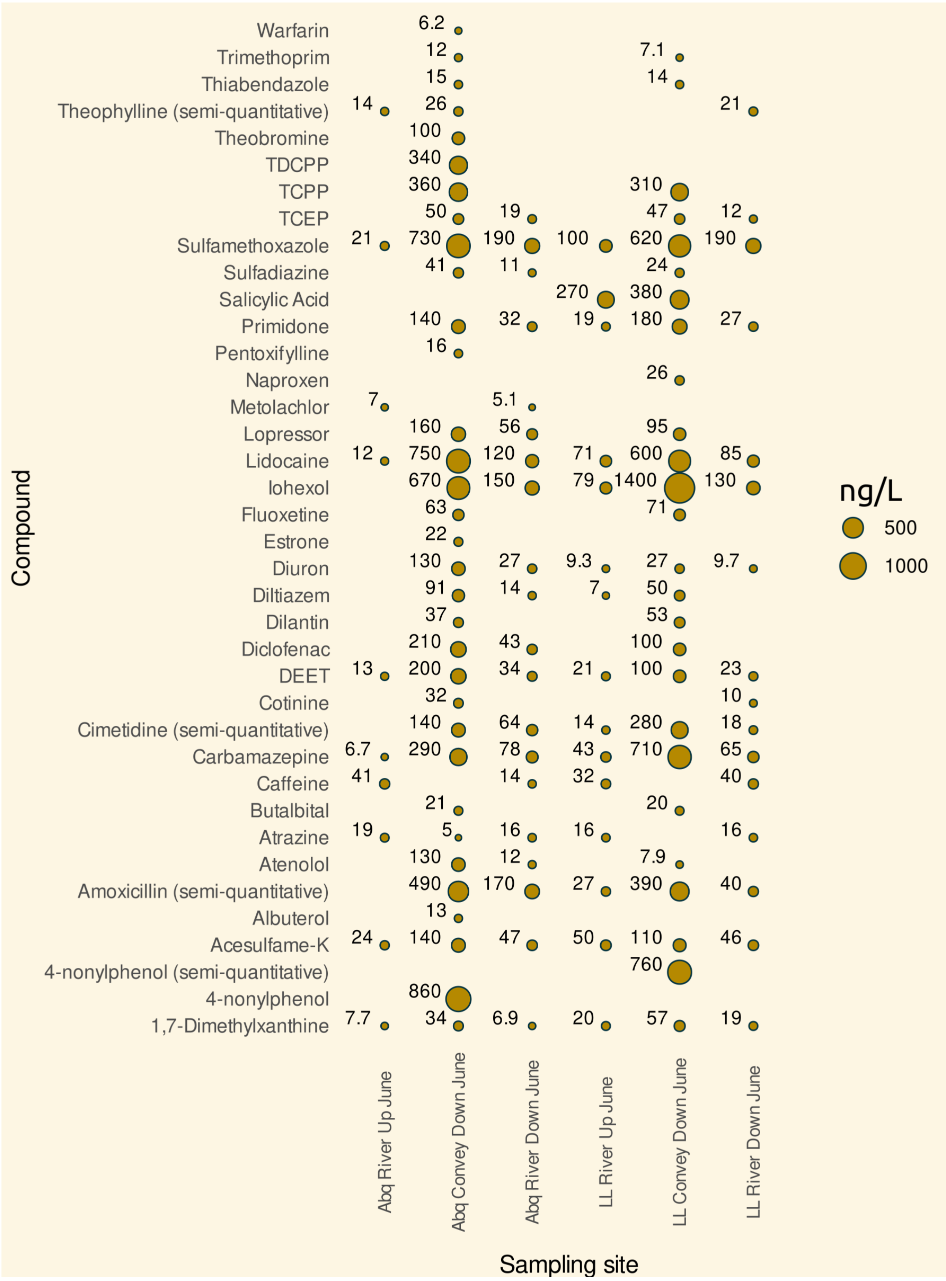


Figure 39. Concentrations of Pharmaceuticals and Personal Care Products (PPCP'S) collected from the June sampling event from the Albuquerque conveyance to the Los Lunas downstream river sample. There is a 29 km distance between the lower Albuquerque and the upper Los Lunas sample point.

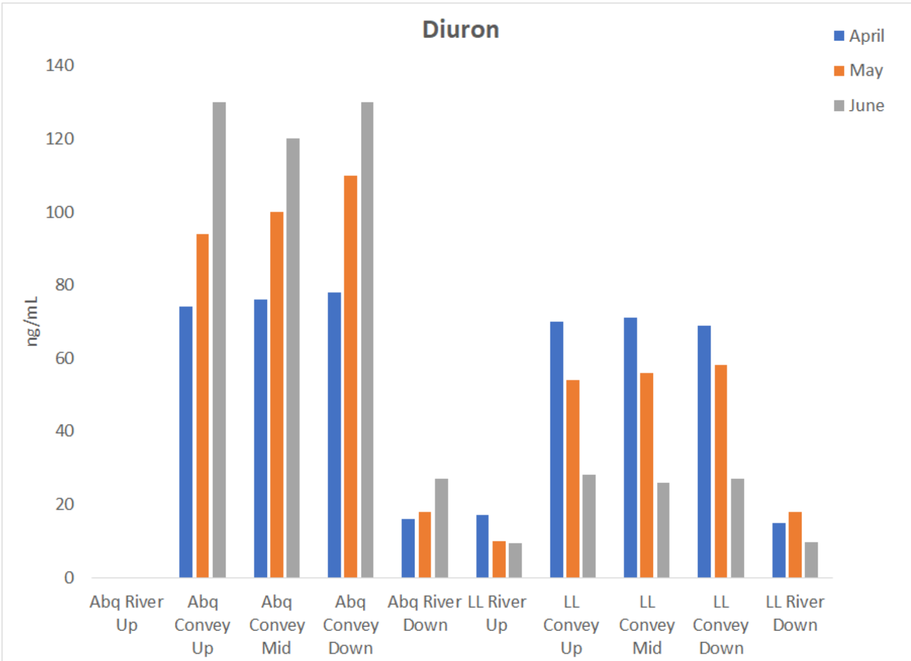


Figure 40. The chemical compound, Diuron, was detected at all sampling locations besides upstream from the Albuquerque conveyance channel.

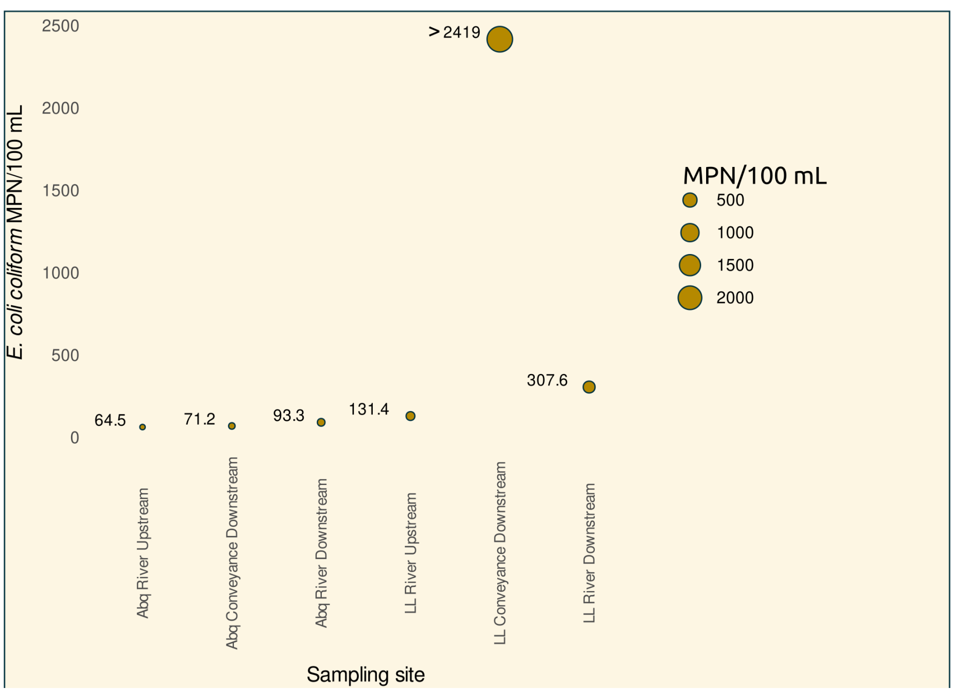


Figure 41. Levels of *E.coli* coliform bacteria from six of the ten sampling locations taken in June, 2020.

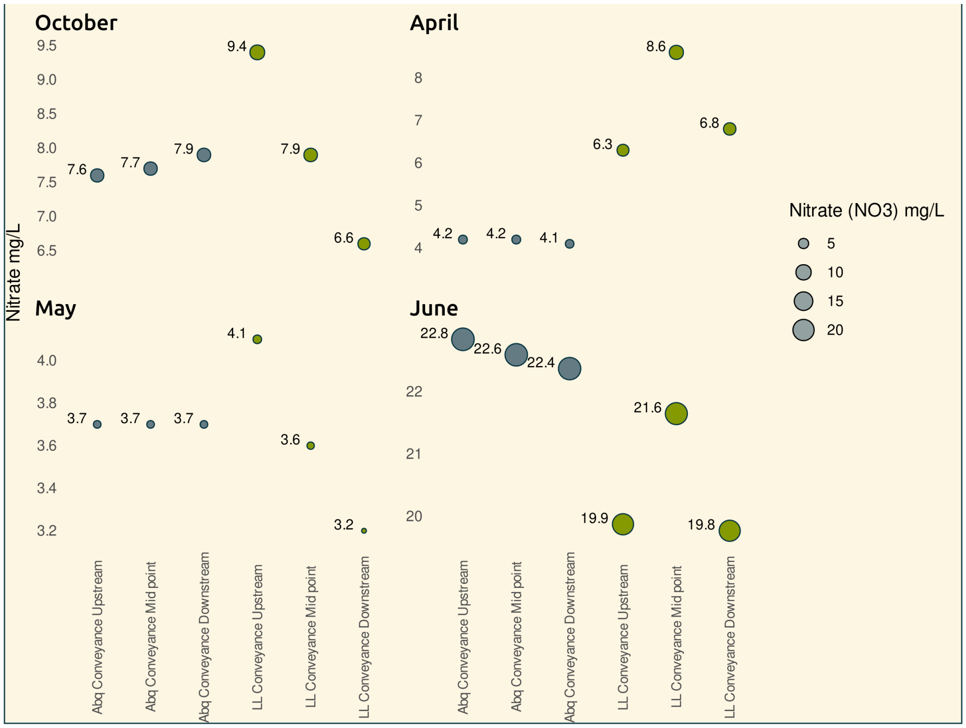


Figure 42. Nitrate concentrations through the Albuquerque (grey circles) and Los Lunas (green circles) conveyance channels.

There were 50 different PPCP compounds detected throughout the duration of the study. 21 of these compounds were not found above the Albuquerque treatment plant but were present in all of the samples within the conveyance channels and downstream river samples. Seven chemicals decreased through the Los Lunas wetland conveyance channel each sampling event: caffeine, carisoprodol, cimetidine, diclofenac, diltiazem, fluoxetine, and sulfadiazine. Five compounds decreased throughout the Albuquerque conveyance channel each month: estrone (not found in Los Lunas), TDCPP (only found in Los Lunas in May), TCPP, erythromycin (not found in Los Lunas), and triclocarban. Anion levels did not notably change throughout the Albuquerque conveyance channel but a decline in nitrate concentrations was observed in the Los Lunas wetland conveyance for two of the four collection events. Anion levels were detected at lower concentrations in the river than in both effluent channels.

A few PPCP compounds worthy of highlighting are Diuron (Figure 40), Amoxicillin and Diclofenac. Diuron is an herbicide used to control types of broadleaf weeds, grasses and woody plants and is considered "very toxic to aquatic life" (https://pubchem.ncbi.nlm.nih.gov/). The orally prescribed antibiotic Amoxicillin, which has been the cause of drug-induced liver injury, was highest in concentration within the conveyance channels, especially in April. Diclofenac is an anti-inflammatory compound with potential for serious negative effects in some people and is one of the most frequently discovered pharmaceuticals in water monitoring (https://pubchem.ncbi.nlm.nih.gov/). Concentrations of Diuron and Amoxicillin were below EPA tolerance or toxicity levels. All three compounds were detected in all months in all samples within and below the Albuquerque treatment plant effluent conveyance confluence with the river. Most of the detected PPCP's are not regulated by the EPA or NMED.

The majority of *E. coli* samples were below NMED and EPA regulations for primary contact streams. There were consistently high levels found within the mid and furthest downstream sampling locations within Los Lunas conveyance channel. The high load could be attributed to an increase in avian abundance due the quality of wetland habitat. *E. coli* levels were immediately reduced to regulatory levels when mixed with the Rio Grande water. Further research is needed to understand the high levels within the confluence.

17.0 Conclusions

Implications for Management

Native vegetation community establishment and success are most strongly tied to access to water, particularly groundwater. High variability in precipitation does not have as strong an impact on native vegetation as does variation in depth to groundwater. Exotic vegetation communities, while still dependent on groundwater and/or precipitation to become established, seem to increase in response to changes in canopy cover. As areas are cleared of exotic trees, exotic understory plants readily increase unless there is enough access to groundwater to support increasing native understory species. This indicates that even successful restoration projects will need maintenance in controlling exotics years after projects have been completed. As canopy declines, assessing changes in fuel load will become more important, especially for older forest areas. Site health is still best assessed through changes in groundwater levels (both mean and variance), native and exotic vegetation, and arthropods like ground beetles. Another important assessment of changes in site health is monitoring the tamarisk leaf beetle (TLB) and its impacts on potential habitat for Southwestern Willow Flycatcher and other animal species. Damage from TLB on saltcedar may keep saltcedar from expanding as rapidly as Russian olive, Siberian elm, or other exotics; however, high TLB abundance has not yet resulted in rapid decline and mortality at most sites. Monitoring defoliation and dead branches may be more accurate in capturing TLB abundance than a snapshot of TLB monitoring that is done once per month, as high levels of defoliation do not always correspond to high abundance. Population shifts can occur rapidly, but saltcedar takes longer to recover from damage done.

Implications for Education

BEMP continued to provide outdoor science education to students across the state, even though student monitoring of field sites was largely restricted and classroom visits were cancelled. Adaptations to COVID restrictions led to the utilization of other platforms, including online and hard copy science activities as well as social media engagement strategies, which greatly broadened BEMP’s outreach. In many ways, COVID-19 has exposed and widened the gap amongst educational audiences, disproportionately impacting students and schools that had already been struggling pre-pandemic. BEMP's commitment to equitable and inclusive hands-on research has become even more paramount over this last year. For this reason, as we move back into bringing students to the field to participate in experiential learning, we will continue to adapt to the needs of our community by maintaining our provision of online and hard copy resources as well as creatively constructing new avenues to promote more equitable access.