BOSQUE ECOSYSTEM MONITORING PROGRAM
(BEMP) SITE MONITORING REPORT FOR 2019

2019 ANNUAL SITE MONITORING TECHNICAL REPORT

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Key personnel and contact information:
Greg Dyson: BEMP Interim Executive Director; 505.898.6388
Kim Eichhorst: Co-Director; kimde@unm.edu**;** 505.277.0758
Amanda Lindell, Office and Contracts Manager, amanda.lindell@bosqueschool.org; 505.898.6388

Bosque Ecosystem Monitoring Program (BEMP)

Report on 2018-19 Education and 2019 Monitoring

Objective: To collect and analyze abiotic and biotic data at BEMP sites in the Middle Rio Grande Bosque while engaging 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) and on GitHub (https://github.com/BEMPscience)

Scope of Work: The Bosque Ecosystem Monitoring Program (BEMP) combines long-term ecological research with community outreach by involving K-12 students and their teachers, as well as university 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. The students' experiences support science education reform efforts and help to increase understanding and appreciation of the Rio Grande riparian ecosystem. Students also learn proper monitoring protocols, riparian ecology, and how to use data to answer questions through hands-on science. 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 maintained 33 active monitoring sites along 250 miles of the Rio Grande, including 32 sites within the Middle Rio Grande (Figure 1). BEMP has one inactive site (Ohkay Owingeh, site 9). 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.

BEMP monitors both biotic and abiotic variables. 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. Our biotic datasets are litterfall; vegetation cover; fuel load and woody debris; cottonwood sex and diameter; surface-active arthropod richness and abundance; and tamarisk leaf beetle distribution, abundance, and impact.

In March 2019, BEMP hosted the Crawford/Green Trails Symposium event to present new data, visualizations, and analyses to management agencies. BEMP staff and students presented BEMP data to managers, professionals, and students several times throughout the year depending on conference availability. Some examples of conferences where BEMP shared data include: Rivers Edge West, previously known as The Tamarisk Coalition, The Land and Water Summit, Wildland-Urban Interface, Sevilleta Science Symposium, and more.

Timing of Data Collection: Depth to groundwater, water level in nearby ditches and/or drains, precipitation, and litterfall are collected during our monthly monitoring week, held 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. River water quality sampling was conducted monthly in 2019.

Scope of Work and Timing of Data Collection taken from 2017 Annual Report**.**

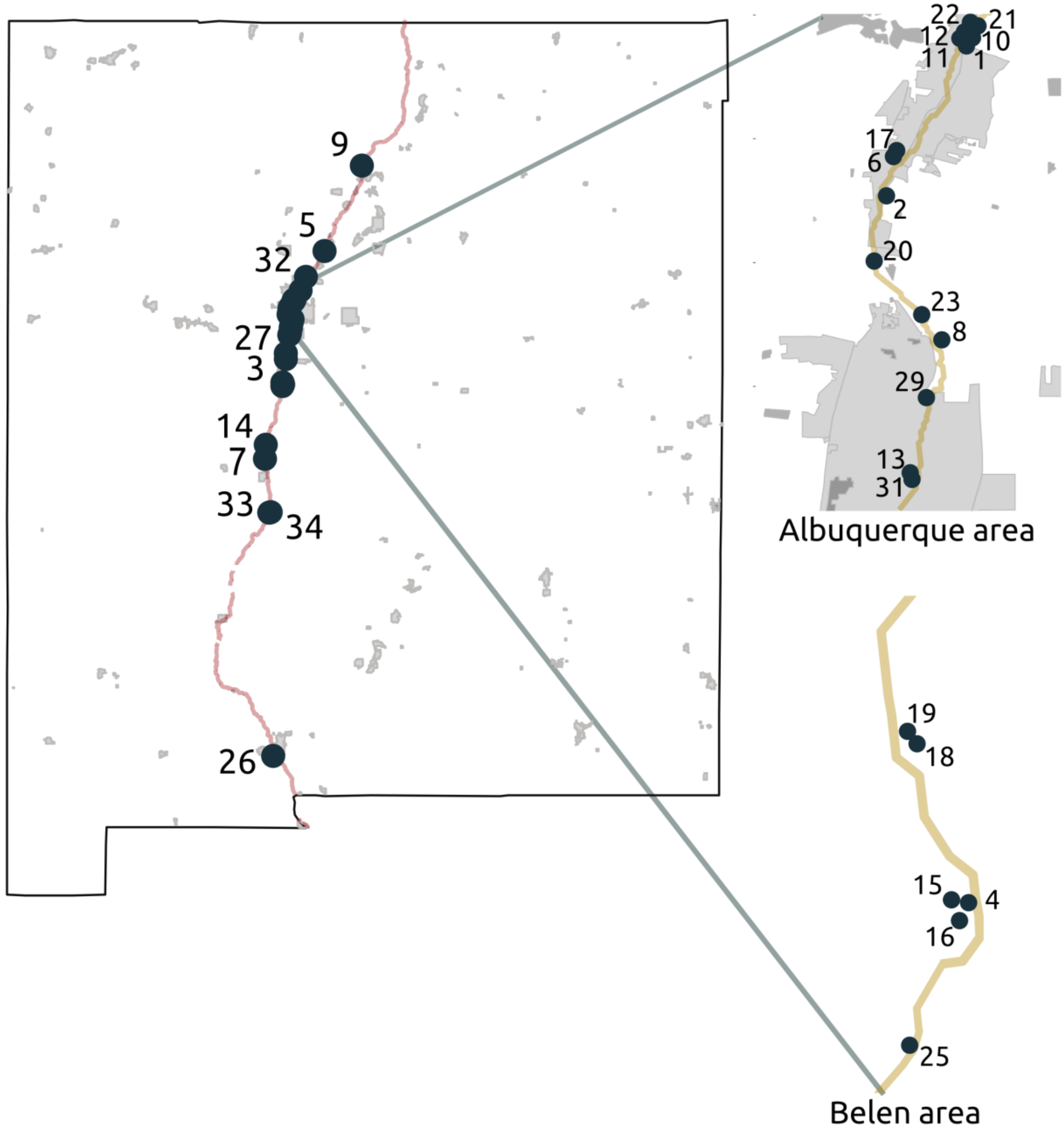


Figure 1. Map of all BEMP sites with inset for high site density areas (Albuquerque and Belen).

Figure 2. BEMP reach classification. Sites are grouped into reaches based on river geomorphology, potential for overbank flooding, and perennial river flow. BEMP-designated reaches include Northern Perched (north of Albuquerque), Northern Albuquerque (north of I-40), Southern Albuquerque (south of I-40), Valencia (county), Socorro (county), and Semi-Arid (Las Cruces). Table 1 contains a list of sites within each reach designation.

Table 1. BEMP site numbers running north to south, with names, abbreviations, counties, latitude, longitude, BEMP-designated reach (Figure 2), and data collected (2018 vegetation cover, tamarisk leaf beetle, 2018 surface-active arthropods, groundwater wells, litterfall, and temperature).
*Ohkay Owingeh, northernmost site, is inactive and no longer monitored.
** Groundwater data are collected at Pueblo of Sandia but are proprietary.
*** USBR well is monitored.

#	SITE NAME	ABBR	COUNTY	LAT	LONG	VEG	TLB	ARTHRO	WELLS	LITTER	TEMP	REACH
9	*Ohkay Owingeh	OO	Taos	36.0618	-106.076108							Nperch
24	Santo Domingo	SD	Sandoval	35.50989	-106.389611	X	X	X		X		Nperch
5	Santa Ana	SA	Sandoval	35.34284	-106.545847	X		X		X	X	Nperch
32	Sandia	SAND	Sandoval	35.25523	-106.5911	X	X	X	X**	X		Nperch
22	Bobcat	BOB	Bernalillo	35.19706	-106.643949	X			X	X		N Abq
21	Badger	BAD	Bernalillo	35.19557	-106.641622	X		X	X	X		N Abq
12	Minnow	MIN	Bernalillo	35.19315	-106.646915	X		X	X	X		N Abq
10	Diversion	DIV	Bernalillo	35.19196	-106.644189	X	X		X	X		N Abq
11	Calabacillas	CALAB	Bernalillo	35.19057	-106.649163		X		X	X		N Abq
1	Alameda	ALA	Bernalillo	35.18805	-106.646919	X		X	X	X	X	N Abq
17	Montano	MON	Bernalillo	35.14529	-106.680370	X		X	X	X		N Abq
6	Savannah	SAV	Bernalillo	35.14285	-106.681981	X	X	X	X	X	X	N Abq
2	Rio Grande Nature Center	RGNC	Bernalillo	35.12675	-106.688432	X		X	X	X	X	N Abq
20	Route 66	Rt66	Bernalillo	35.10066	-106.692350	X	X	X	X	X	X	S Abq
23	BioPark	BioP	Bernalillo	35.07873	-106.667947	X			X	X	X	S Abq
8	Hispanic Cultural Center	HCC	Bernalillo	35.06881	-106.658058	X		X	X	X		S Abq
29	Abq Overbank Project	AOP	Bernalillo	35.04753	-106.664012	X	X	X	X	X	X	S Abq
13	Harrison	HARR	Bernalillo	35.01506	-106.673695	X	X	X	X	X		S Abq
31	San Jose	SJ	Bernalillo	35.01217	-106.67384	X		X	X	X		S Abq
28	Valle de Oro	VDO	Bernalillo	34.97895	-106.680137			X	X	X		S Abq
30	State Land Office	SLO	Bernalillo	34.9672	-106.685649	X		X	X	X	X	S Abq
27	Bosque Farms	BF	Valencia	34.84885	-106.714722	X	X	X	X	X		Val
3	Los Lunas	LL	Valencia	34.81237	-106.714458	X	X	X	X	X	X	Val
19	Reynolds Forest	RF	Valencia	34.66065	-106.742953	X	X	X	X	X		Val
18	Reynolds Cleared	RC	Valencia	34.65966	-106.742133				X	X		Val
15	Valencia Cleared	VC	Valencia	34.64863	-106.739173	X	X	X	X	X		Val
4	Belen	BEL	Valencia	34.64843	-106.737702	X		X	X	X	X	Val
16	Valencia Forest	VF	Valencia	34.64716	-106.738482	X		X	X	X		Val
25	Crawford	CRAW	Valencia	34.6405	-106.742047	X	X	X	X	X		Val
14	Sevilleta	SEV	Socorro	34.25834	-106.883185	X	X	X	X	X		Socorro
7	Lemitar	LEM	Socorro	34.16703	-106.889949	X	X	X	X	X	X	Socorro
34	River Realignment	RR	Socorro	33.82269	-106.841847	X			X***	X		Socorro
33	Bosque del Apache	BDA	Socorro	33.81965	-106.854001		X	X	X	X		Socorro
26	Mesilla Valley Bosque State Park	MVBSP	Doña Ana	32.24833	-106.821014				X	X	X	S arid

BEMP Data

In the following pages, we report on depth to groundwater, precipitation, temperature, litterfall, vegetation cover, tamarisk leaf beetle, surface active arthropods, water chemistry, rapid assessment protocols, soil microbes, and the Bosque del Apache river realignment pilot project.

Depth to Groundwater: 2019

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. K-12 students and teachers monitor 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: http://bemp.org/wp-content/uploads/2016/01/well-installation-and-monitoring-directions.pdf.

The 2019 depth to groundwater data are shown below in Figure 3.

Groundwater responds rapidly to changes in river flow at the majority of the BEMP sites. Flooding occurred at most southern Albuquerque sites and sites south of Albuquerque in May-July 2019 (Figure 3). In the height of the 2005 flooding (which occurred in April), 5 out of 22 BEMP sites (22 in existence at the time) had flooding: Route 66, Harrison, Reynolds Forest, Valencia Cleared, and Belen. In May 2017, 12 out of 31 sites had flooding: Route 66, BioPark, AOP, Harrison, San Jose, State Land Office, Bosque Farms, Los Lunas, Reynolds Forest, Valencia Cleared, Belen, and Crawford. In the 2019 flood, the peak was May-June, and there was flooding at 20 out of 33 active sites based on the well data. There was flooding at a 21st site (Montaño), but it did not extend to the wells at the site. The flooded sites in 2019 were Bobcat, Minnow, Savannah, Route 66, BioPark, Hispanic Cultural Center, Albuquerque Overbank Project, Harrison, San Jose, State Land Office, Bosque Farms, Los Lunas, Reynolds Forest, Reynolds Cleared, Valencia Cleared, Belen, Valencia Forest, Crawford, River Realignment, and Bosque del Apache. This includes 6 (or 7, with Montaño) sites that flooded in 2019 that had not flooded in either the high flows of 2005 or 2017: Bobcat, Minnow, Savannah, (Montaño), Hispanic Cultural Center, Reynolds Cleared, and Valencia Forest. The first four sites, including Montaño, are “northern Albuquerque” sites that are north of I-40. There has been no flooding at Savannah since it became a site in March 2000, and very likely not for decades before that.

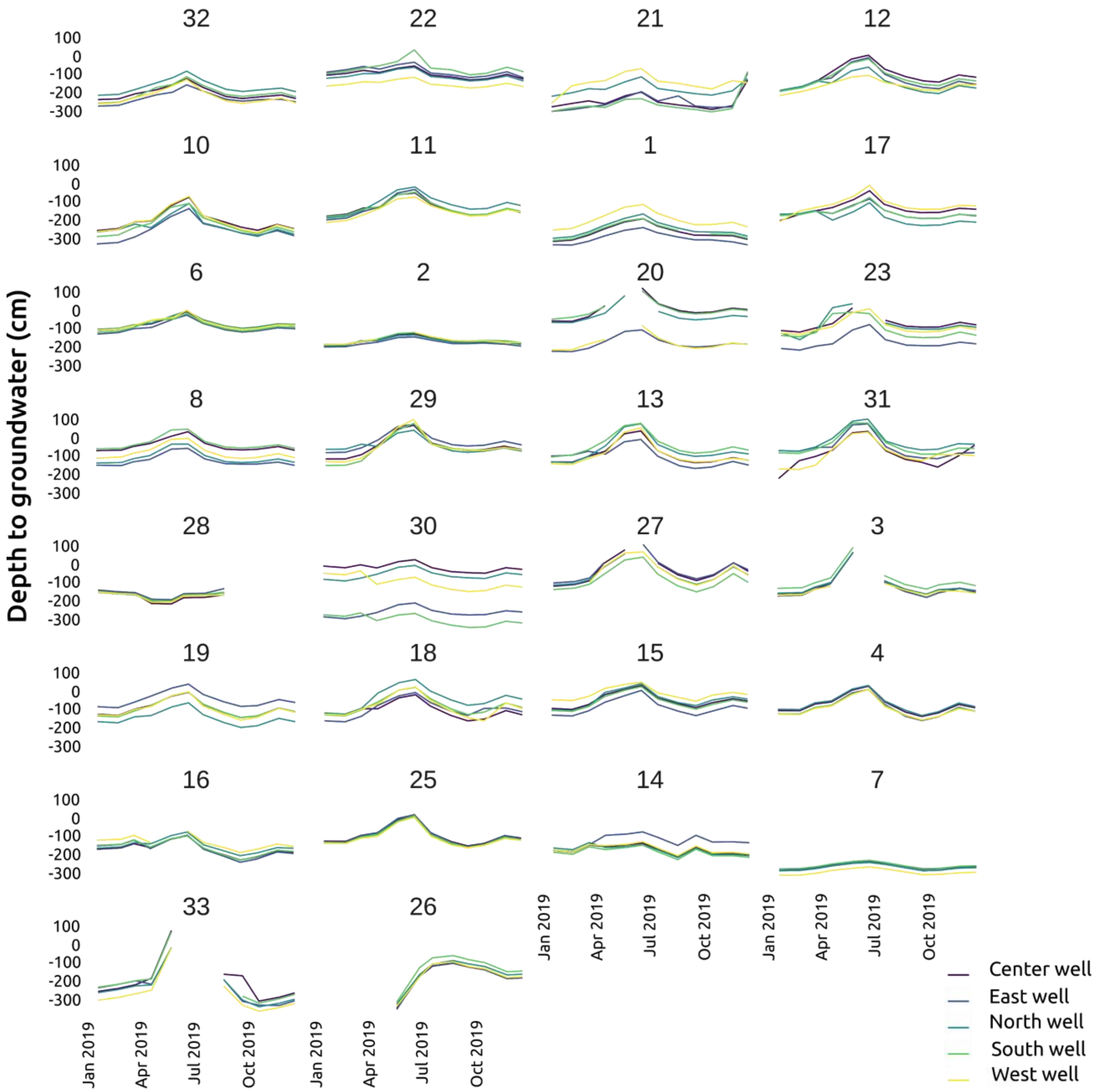


Figure 3. The 2019 depth to groundwater capturing the spring and summer 2019 flood and sustained inundation of the riparian area. Time is progressing from left to right. Sites are arranged from north to south. Each colored line represents one of the five wells at a BEMP site.

Precipitation: 2019

Data from two rain gauges are collected monthly at all but two BEMP sites. The Bosque Farms gauges were regularly vandalized so they were removed, and the Valle de Oro gauge was consistently used as a bird perch and became unsanitary so it was also removed. At all other 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: http://bemp.org/wp-content/uploads/2016/01/weather-station-precipitation-monitoring-directions.pdf

Precipitation is monitored by BEMP staff alongside community scientists.

The historic monsoon months during 2019 had less rainfall than the late fall and winter events (Figure 4). Spring and summer months were dry, with larger rain events occurring in August and September for the northern sites, in October for the southern sites, and in December at all sites.

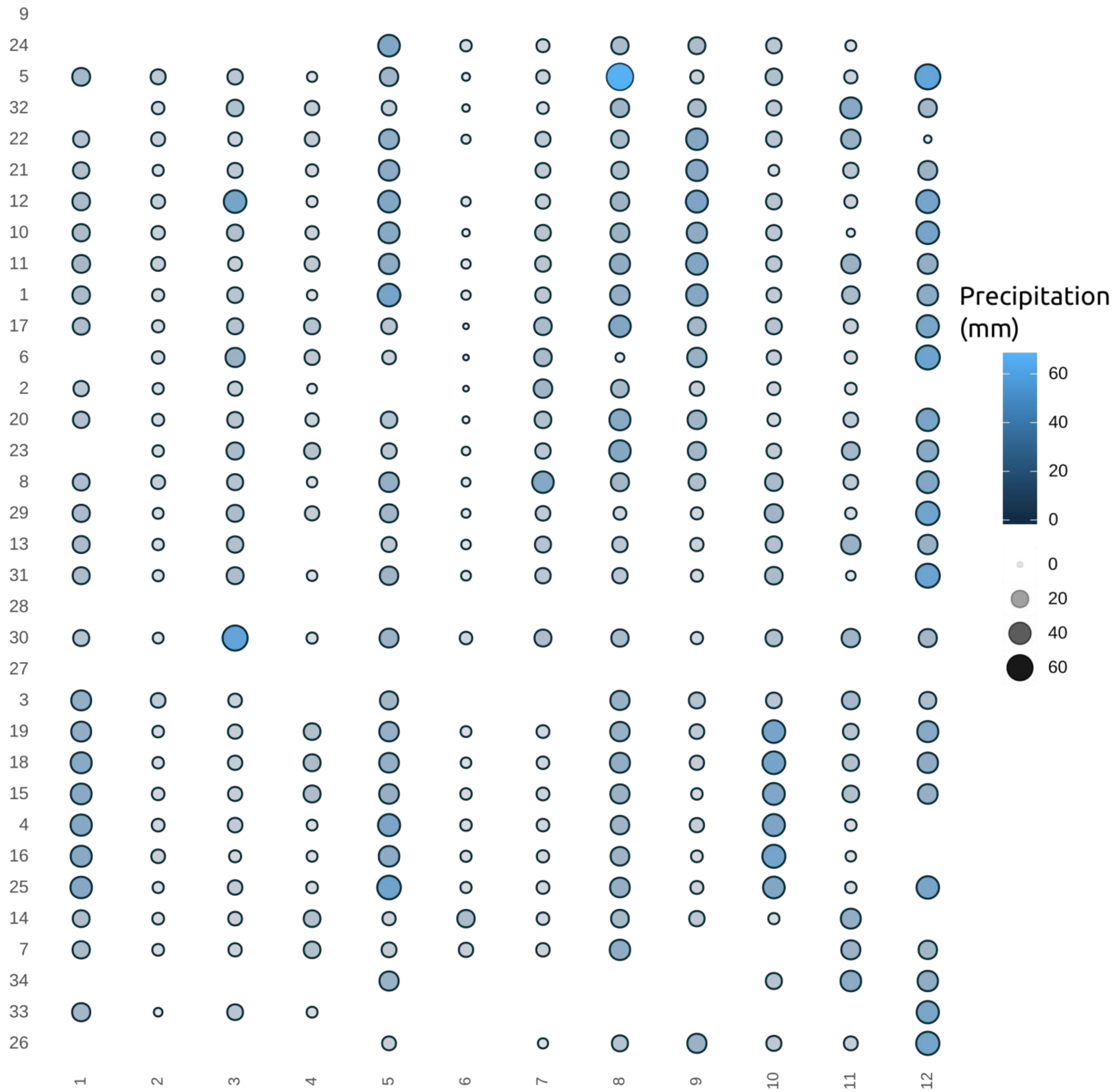


Figure 4. Precipitation from 2019 open rain gauges. Sites are arranged north to south along the y-axis (northern sites starting at the top); months are along the x-axis. Larger circles and increasing blue colors represent more precipitation. The long term trend of rainfall shifting to later than the historical monsoon season is evident in the 2019 data.

Temperature Loggers: 2018 - 2019

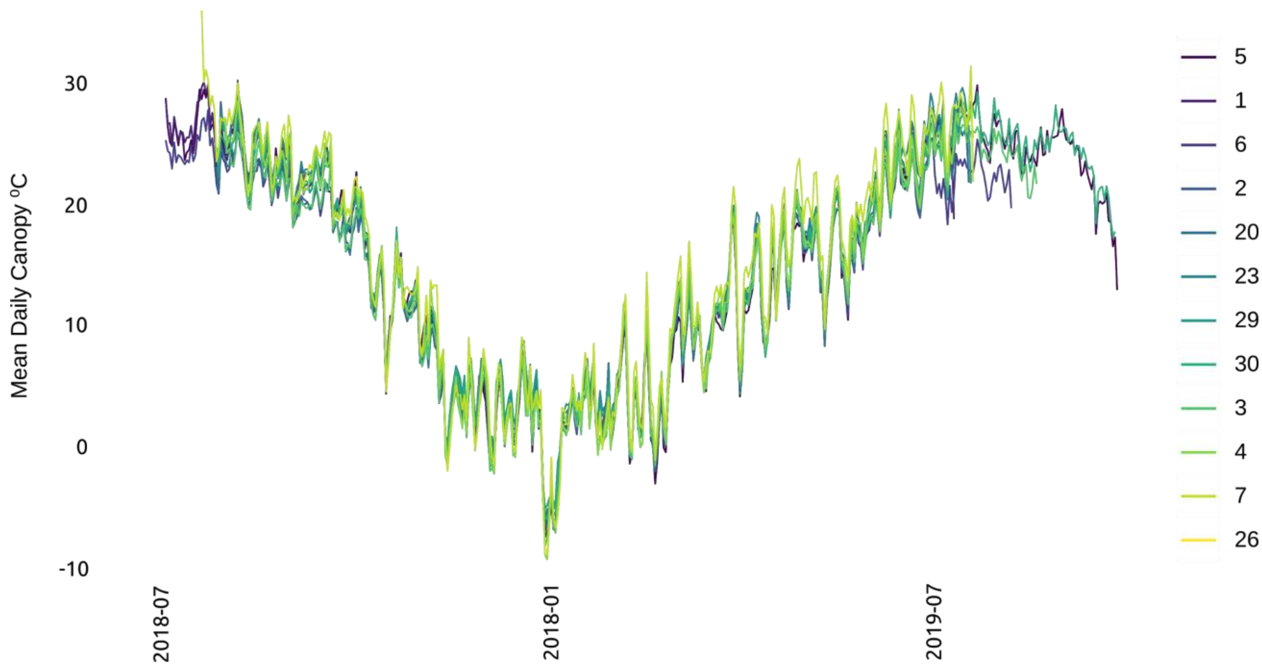
We collected temperature data at 12 BEMP sites: Alameda, RGNC, Los Lunas, Belen, Santa Ana, Savannah, Lemitar, Rt 66, BioPark, Mesilla, AOP, and SLO. Temperature data loggers were placed near the canopy rain gauges, buried underground near the canopy rain gauges, and buried near the open rain gauges. Temperature data are downloaded annually by BEMP staff and university students. During 2018 – 2019, seven temperature loggers: Santa Ana - Open Subsurface, Savannah - Canopy Subsurface, State Land Office - Open Subsurface, Los Lunas - Canopy Sub, Mesilla - Open Subsurface, Belen - Open Subsurface, and BioPark - Open Subsurface.

The data were run through a visual QA/QC to make sure the plots make sense and follow the general expected pattern. 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. The number of data points outside of 3 SD from z-scored data from canopy_C was 1; canopy_sub_C was 29, and open_sub_C was 7.

The full raw data (at 1 hour intervals), the R QA/QC script, and the full QA/QC report are available at:
https://github.com/BEMPscience/bemp_data/tree/master/additional_data_sets/temperature_loggers

The data were transformed into daily mean, minimum, and maximum temperature. Figure 5 shows the mean daily air temperature under canopy and the subsurface temperature under canopy over time. The southernmost sites (Mesilla and Lemitar) have the warmest temperatures and also have the lowest canopy cover. Data trends from 2018-2019 show that sites in Albuquerque with low cover do not necessarily trend warmer for air temperatures, but cover does make a difference just on/under the ground surface. Air temperatures are more consistent across sites while subsurface temperatures have greater variability between sites (Figure 5).

A.



B.

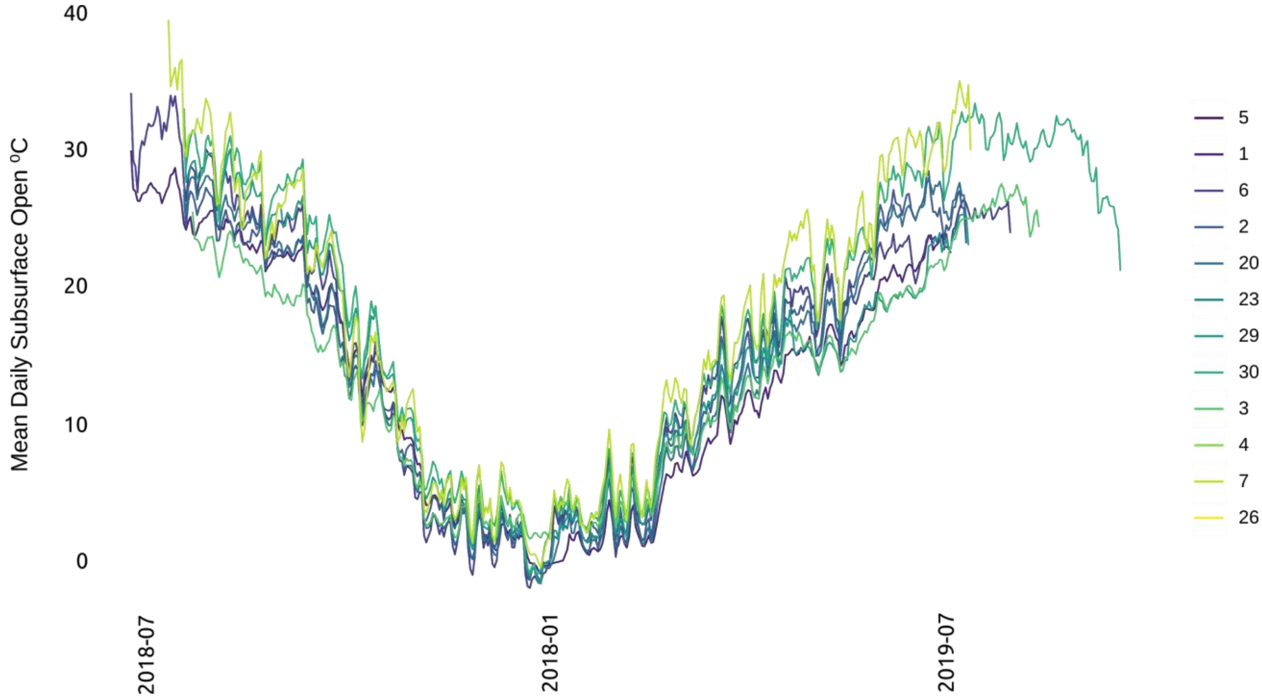


Figure 5. A) Canopy and B) open subsurface temperature gauges showing the mean daily temperature from 2018-2019 (note the difference in scale). Sites are arranged from north to south. Southern BEMP sites on average have a slighter higher temperature than the northern sites.

Litterfall: 2018

Litterfall is collected each month by K-12 students, teachers, University students, and BEMP staff. As lab processing, data entry, and QA/QC are time consuming, winter 2019 data are still being processed. Litterfall is a measure of productivity (leaf fall) 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 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. Finally, stress and senescence of woody species are captured through wood fall.

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

The 2017 high river flows and flooding led to drooping and wilting of cottonwoods at many BEMP sites, and at Los Lunas and Valencia Cleared (and likely other areas as well), older cottonwoods came down following the receding floods. Assessing overall cottonwood response across sites and reaches show no noticeable difference in cottonwood productivity (Figure 6). Slight variations are not indicative of impacts from the three months of inundation followed by rapidly dropping water tables. The slight difference in the Socorro reach in 2018 is due to the addition of the two sites at Bosque del Apache. The same is true for wood fall, as slight increases in variability in 2017 are site-specific responses, while the mean across years holds steady (Figure 7).

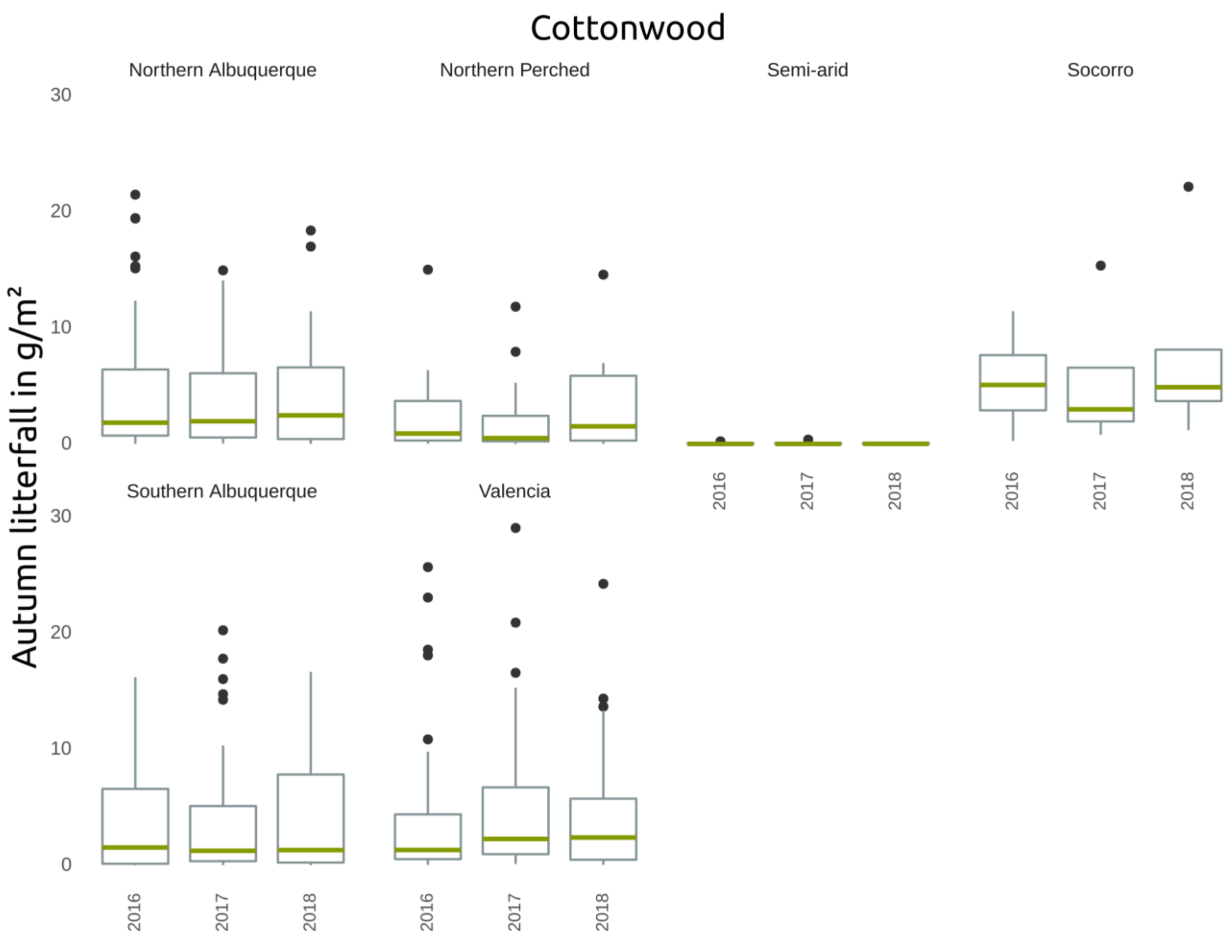


Figure 6. Cottonwood autumn leaf fall in 2016-2018 by reach.

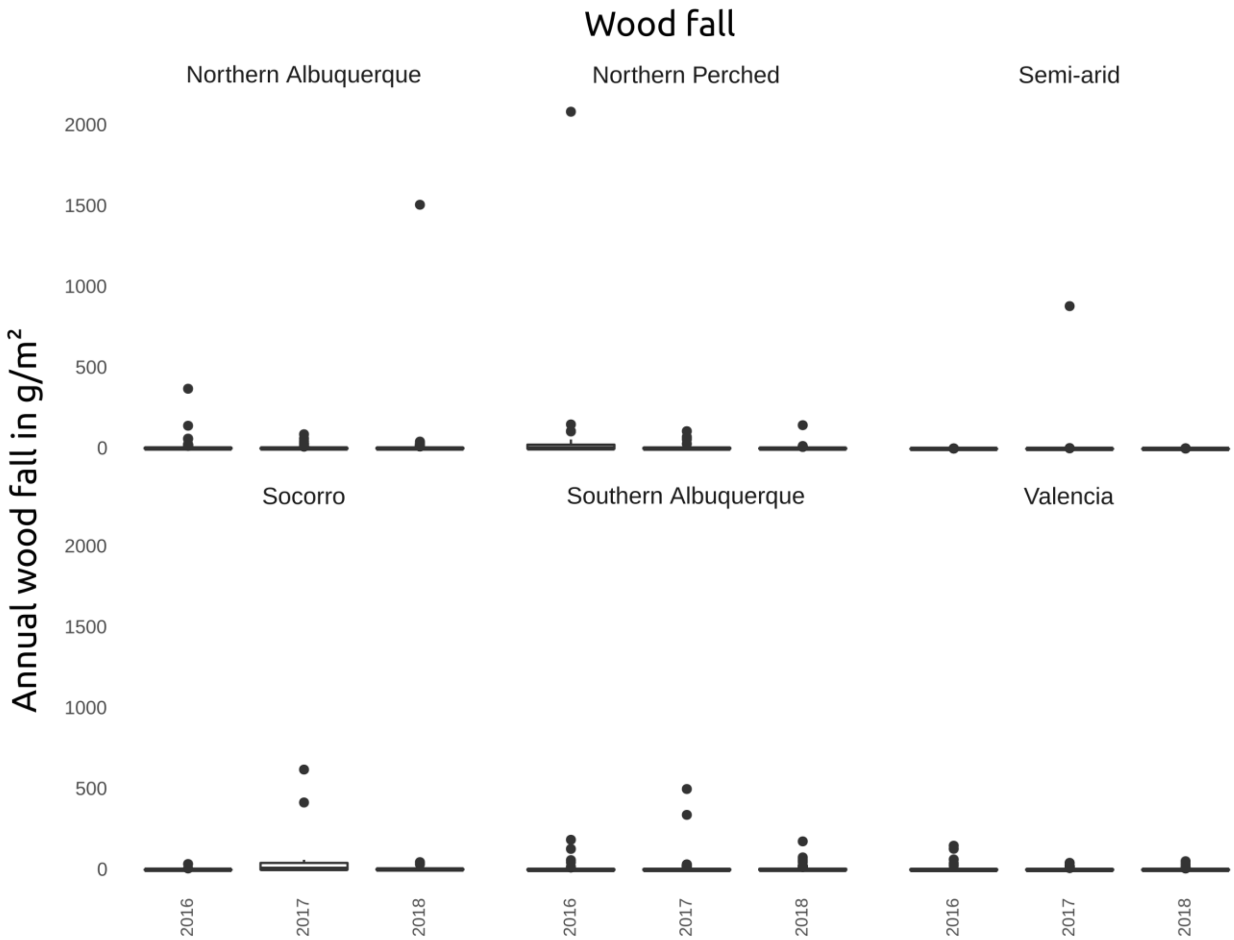


Figure 7. Wood fall across reaches from 2016-2018.

Vegetation Cover: 2018

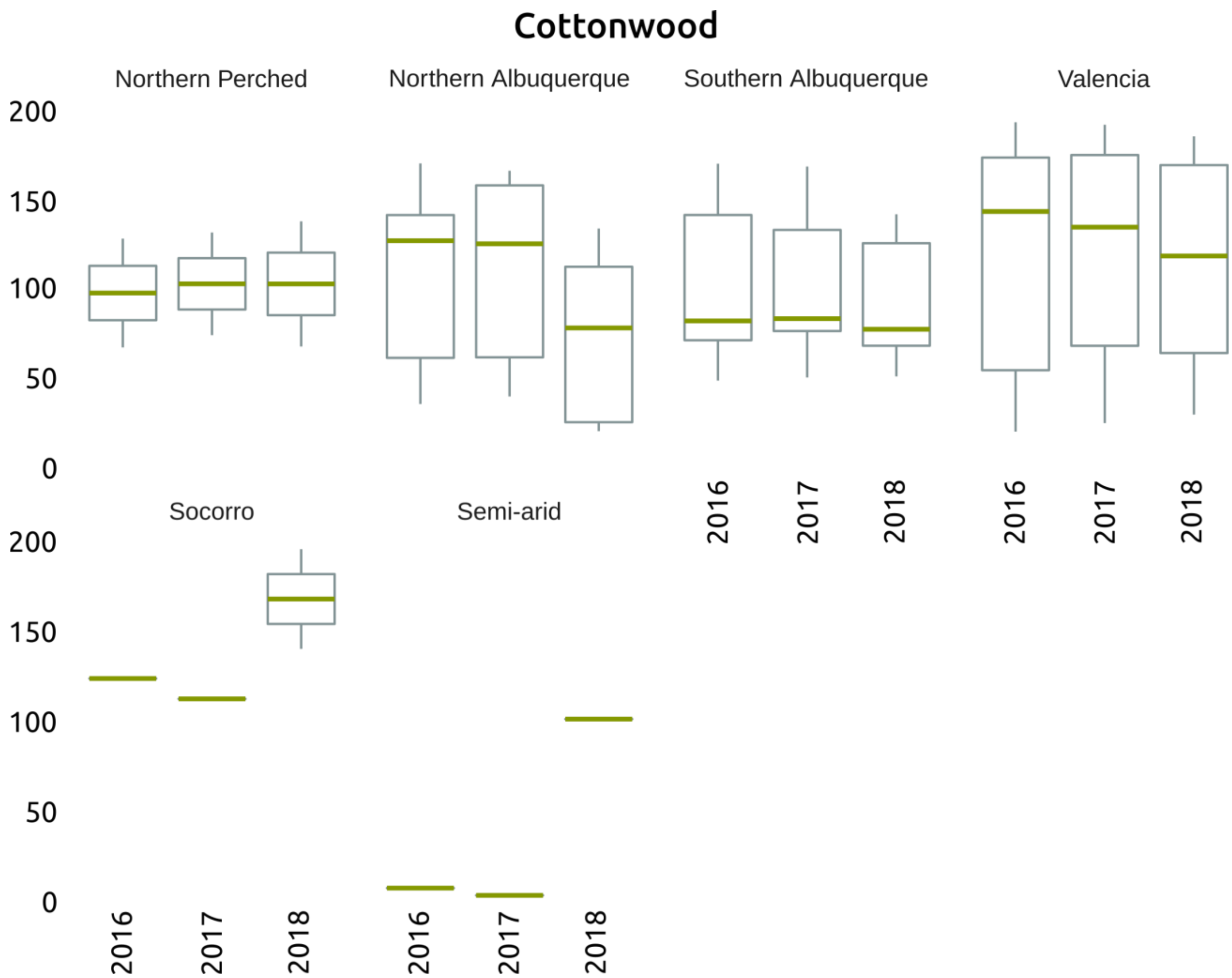
Vegetation cover surveys are conducted in August-September each year by botanists. Line-intercept methods are used to monitor plant species along ten 30m transects at 27 sites (Table 1). Herbarium work (identification of species) was recently finished for 2019 data and the data are now being entered and checked, thus, 2019 data will be reported on in our report for 2020.

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

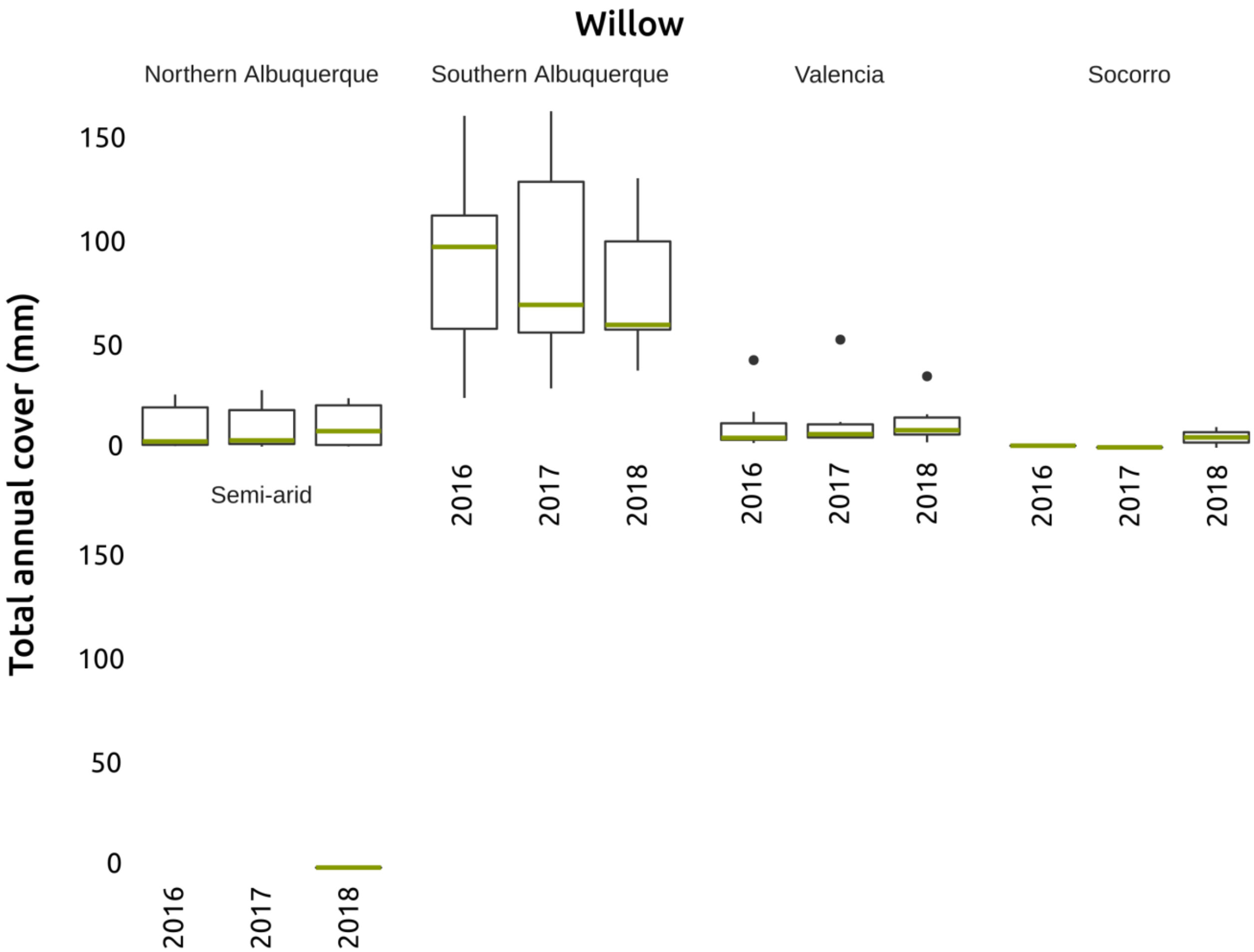
There are 18 species that commonly occur across sites (occurring in at least 10 of the 27 sites monitored). Rio Grande cottonwood (*Populus deltoides* ssp. *wislizenii*) occurs in all 27 sites. Dropseed grass (*Sporobolus* spp.), coyote willow (*Salix exigua*) are found at 20 or more sites. The other common species are scratchgrass (*Muhlenbergia asperfolia*), Russian olive (*Elaeagnus angustifolia*), kochia (*Bassia scoparia*), squirreltail grass (*Elymus elymoides*), sand dropseed (*Sporobolus cryptandrus*), saltcedar (*Tamarix chinensis*), Siberian elm (*Ulmus pumila*), inland saltgrass (*Distichlis spicata*), vine mesquite (*Panicum obtusum*), Goodding's willow (*Salix gooddingi*), Gray sandmat (*Chamaesyce*), tumbleweed (*Salsola tragus*), silverleaf nightshade (*Solanum elaeagnifolium*), alkali sacaton (*Sporobolus airoides*), and copper globemallow (*Sphaeralcea angustifolia*).

Dominant native understory species did not have large changes in cover following the 2017 flood. Saltgrass and scratchgrass showed changes in variability across sites, but no large changes in mean cover. Kochia did not have large changes in cover, but did decline in reaches with sites that experienced flooding from 2016-2018 (Figure 8). Tumbleweed increased in 2017 in reaches with flooding and then declined in 2018 (Figure 8). Tumbleweed also increased at the Pueblo sites in 2017. Much of the tumbleweed increase was in bare areas following May precipitation and later flooding events (depending on the site). Cottonwood cover did not show much change from 2016 to 2018 (Figure 8). Increase in the Socorro Reach cottonwood cover is due to the addition of two sites in the area. River flows dropped sharply in 2017, as did groundwater levels, and there were no successful cottonwood seedlings following the 2017 flood. However, river flows in 2019 were stepped down more gradually, as can be seen in the groundwater response, and there were successful cottonwood seedlings germinating at several BEMP sites post-flood.

A.

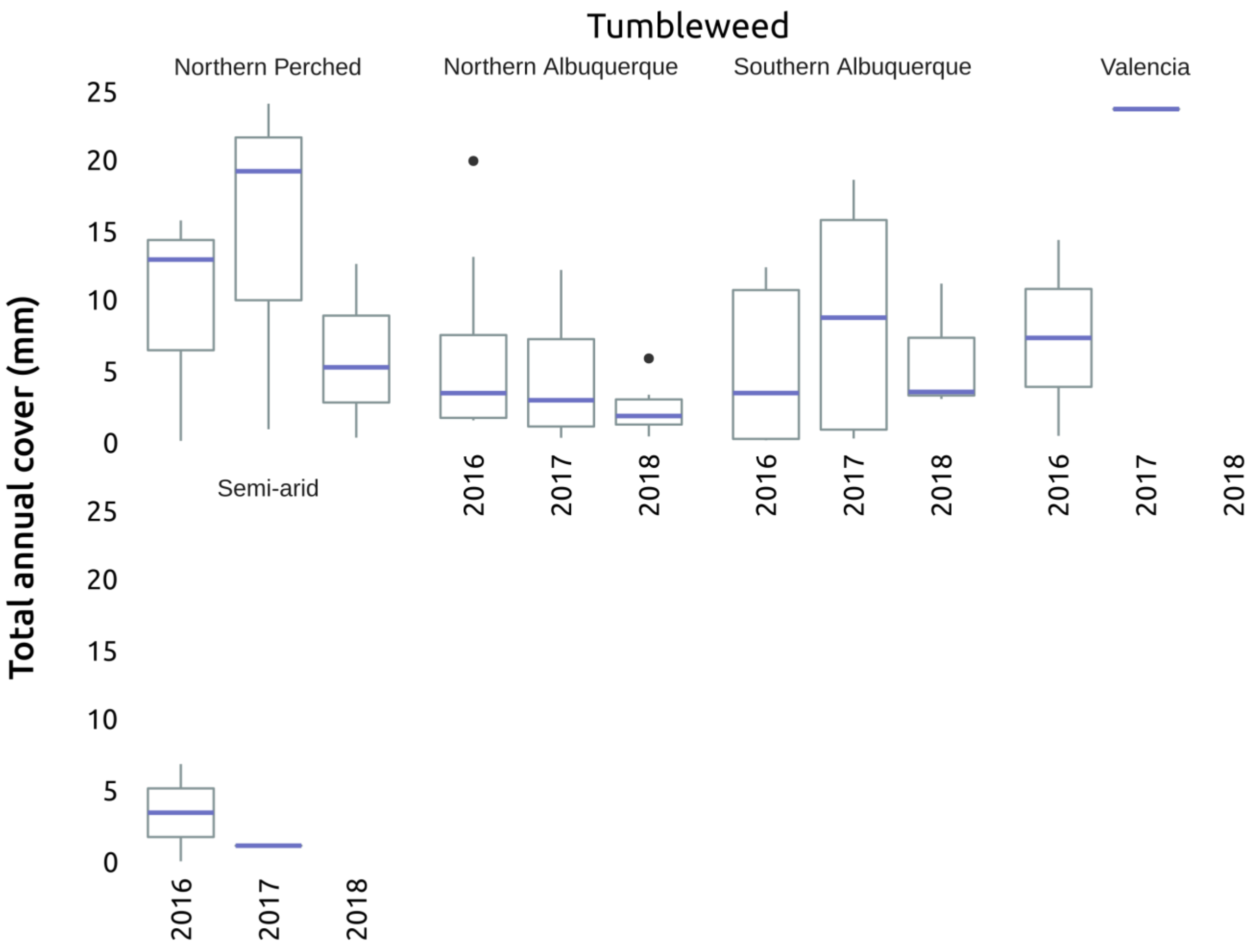

Cottonwood
Northern Perched
Northern Albuquerque
Southern Albuquerque
Valencia
Socorro
Semi-arid
200
150
100
50
0
2016
2017
2018

B.



Willow
Northern Albuquerque
Southern Albuquerque
Valencia
Socorro
Semi-arid
Total annual cover (mm)
150
100
50
0
2016
2017
2018

C.



Tumbleweed
Northern Perched
Northern Albuquerque
Southern Albuquerque
Valencia
Semi-arid
Total annual cover (mm)
25
20
15
10
5
0
2016
2017
2018

D.

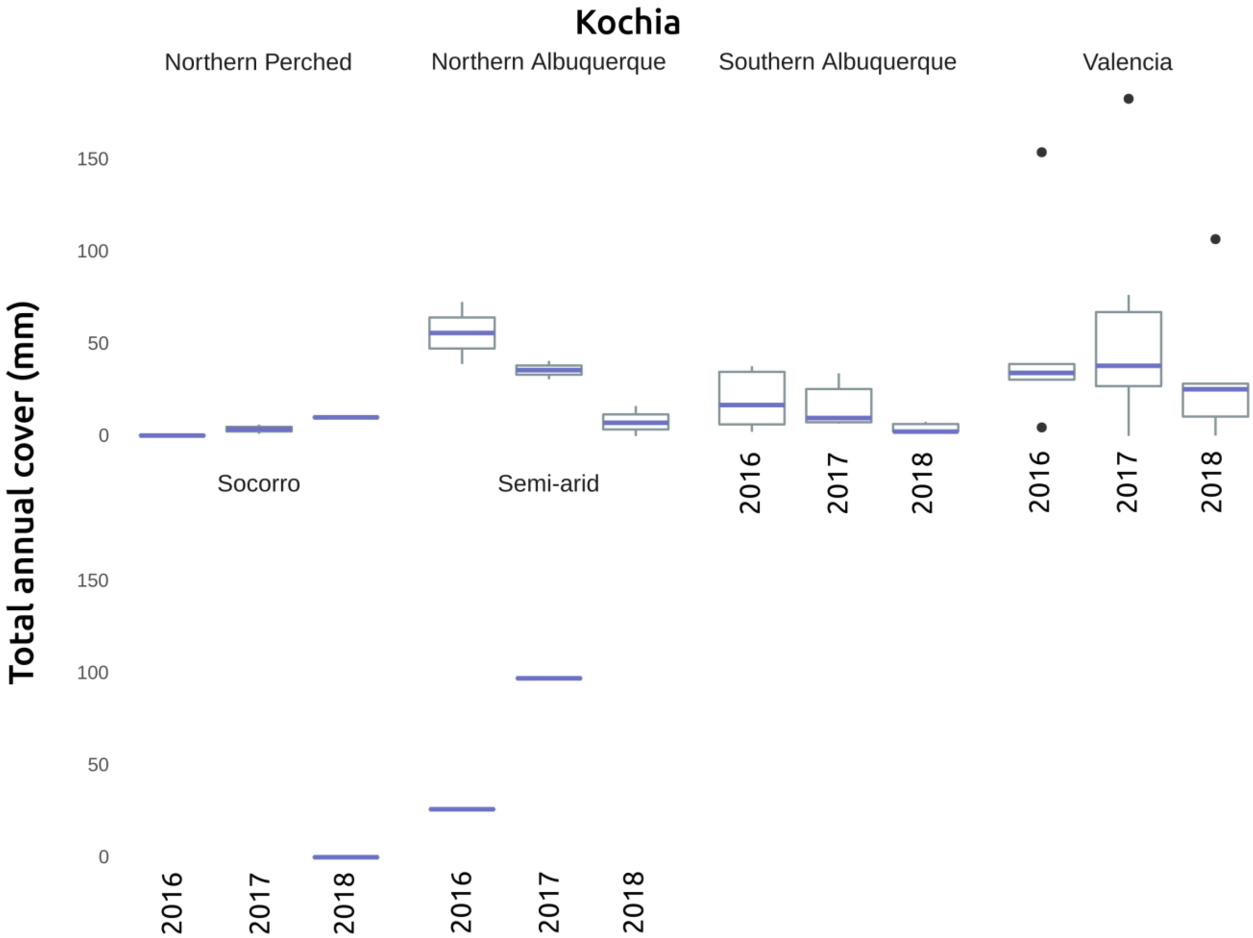


Figure 8. A) Rio Grande cottonwood (*Populus deltoides* ssp. *wislizenii*), B) coyote willow (*Salix exigua*), C) tumbleweed (*Salsola tragus*), and D) kochia (*Bassia scoparia*) cover by reach for 2016-2018, reaches are ordered from north to south. 2017 was a flood year. Increase in the Socorro Reach of cottonwood cover and variability and saltcedar variability is due to the addition of two sites in the area in 2018. Not all species are present at all BEMP sites. If a reach is missing, it is because the focus species was not present on transects at sites in those reaches.

Tamarisk Leaf Beetle Monitoring: 2019

Tamarisk leaf beetle (TLB) monitoring is conducted in May, June, July, and August each year by BEMP staff and high school and university interns. Four of the 16 sites were also monitored in September. In 2019, BEMP monitored 16 sites for tamarisk leaf beetle (*Diorhabda* spp.) from the Pueblo of Santo Domingo to Bosque del Apache National Wildlife Refuge (Table 1). Los Lunas and Bosque del Apache were not monitored in the months of June and July because the extreme nature of overbank flooding made monitoring protocols unsafe to BEMP researchers September sites included Sandia (north of Albuquerque), Diversion (Albuquerque), Rt. 66 (Albuquerque), and Crawford (south of Albuquerque).

At each site, five saltcedar/tamarisk trees are marked and sampled for TLB, with photos taken from set photo points. 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 monitoring methods can be found at: http://bemp.org/wp-content/uploads/2018/03/BEMP_TLB_Report_2017.pdf)

BEMP found 59 adults in total in the collections from all 16 sites May-September, and a total of 435 larvae in their early and late larval stages (Figure 10). There were no adult TLBs at any of the recorded sites in the month of September (Figure 9).

BEMP has continued to observe a cyclical pattern of TLB abundance in our sites south of Albuquerque, in the City of Albuquerque, and north of Albuquerque. This year we observed the highest amount of beetles in our northern and southern sites, whereas in 2018 we observed few beetles in our southern locations. Beetle emergence seems to follow a boom and bust cycle, and we see this pattern of population growth and decline in our southern sampled sites as we caught the emergence of the TLB in 2014 and 2015 (Figure 10).

In comparison to earlier collection years, there was a drop in abundance of TLB in the geographical spread of sampling locations in 2019. This may be due to the extensive overbank flooding and the inability for the beetle to emerge from dormancy.

One aspect of TLB monitoring that warrants consideration is the overall decline in tamarisk canopy coverage after several seasons. Even when tamarisk trees make a recovery, the impact of the beetle lingers, slowly decreasing foliage over time. Crawford SC3 is an example of this impact. In these photos there is a noticeable increase in the amount of dead branches which is also captured in BEMP data (Figure 11).

In addition to the decline of the canopy coverage, there is an earlier spike in tamarisk leaf fall (Figure 12). Where the beetle is abundant, there is an associated increase in leaf litter drop in the summer months, followed by a recovery in foliage, and an abscission in the fall and winter months (Figure 12).

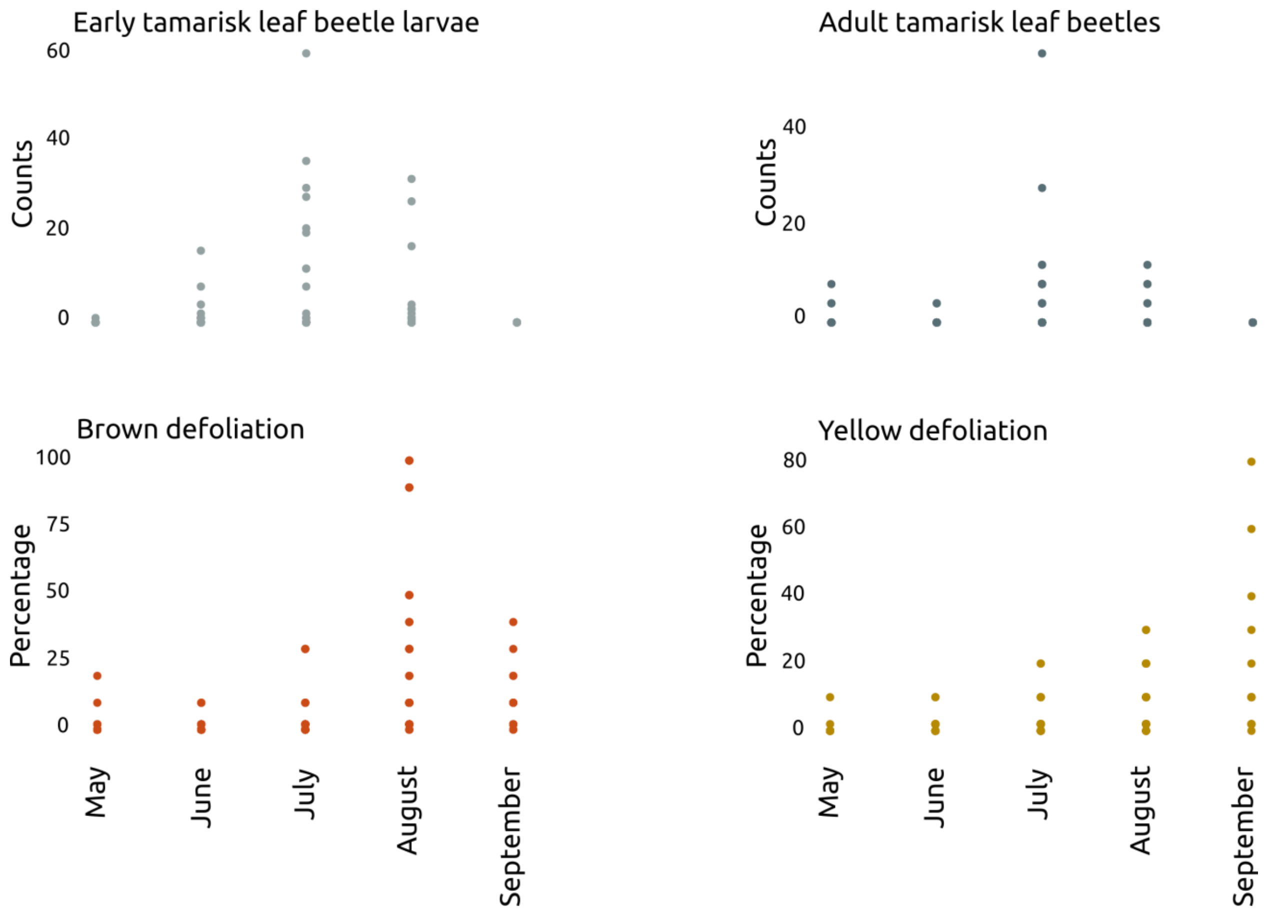


Figure 9. Tamarisk leaf beetle larvae and adults May-September in 2019. Sites include Sandia (north of Albuquerque), Diversion and Rt. 66 (in Albuquerque), and Crawford (in Belen). Brown defoliation is representative of TLB defoliation and yellow defoliation is indicative of the saltcedar leafhopper.

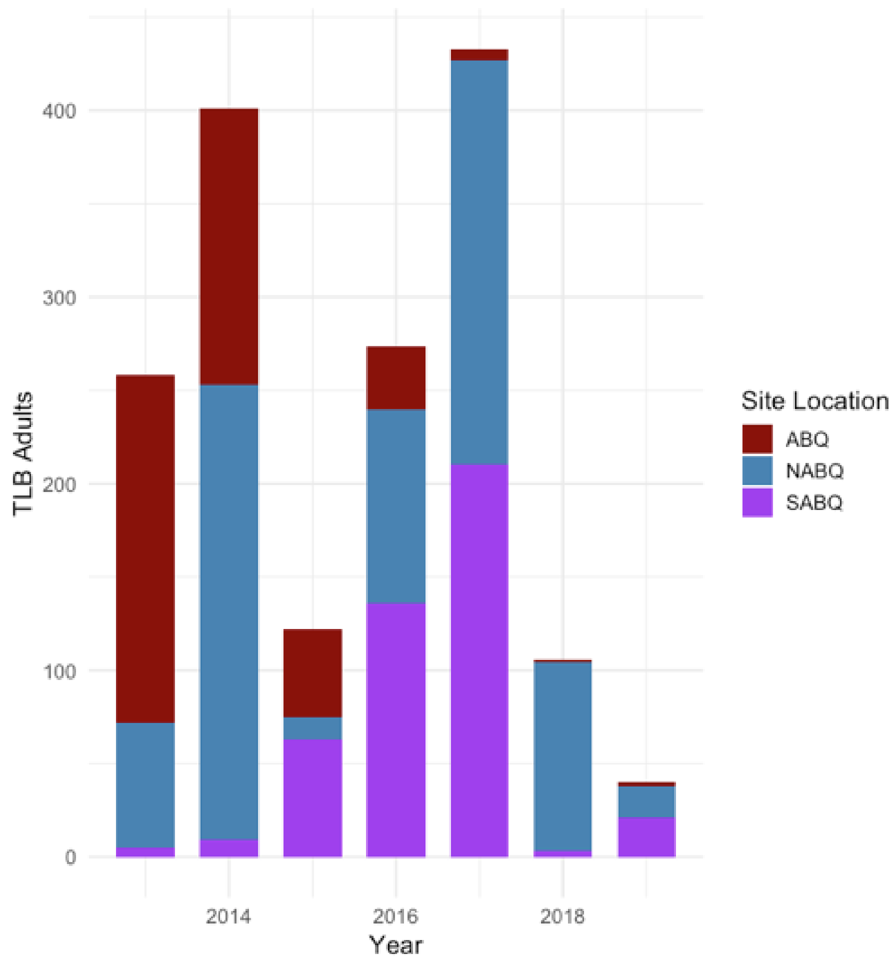


Figure 10. Total TLB adults in Albuquerque (ABQ), north of Albuquerque (NABQ), and south of Albuquerque (SABQ) from 2013-2019.

Figure 11. Crawford SC3 in May 2014, 2015, 2016, 2017, 2018, and 2019 (from top left to bottom right). Notice the increasing number of bare (dead) branches.

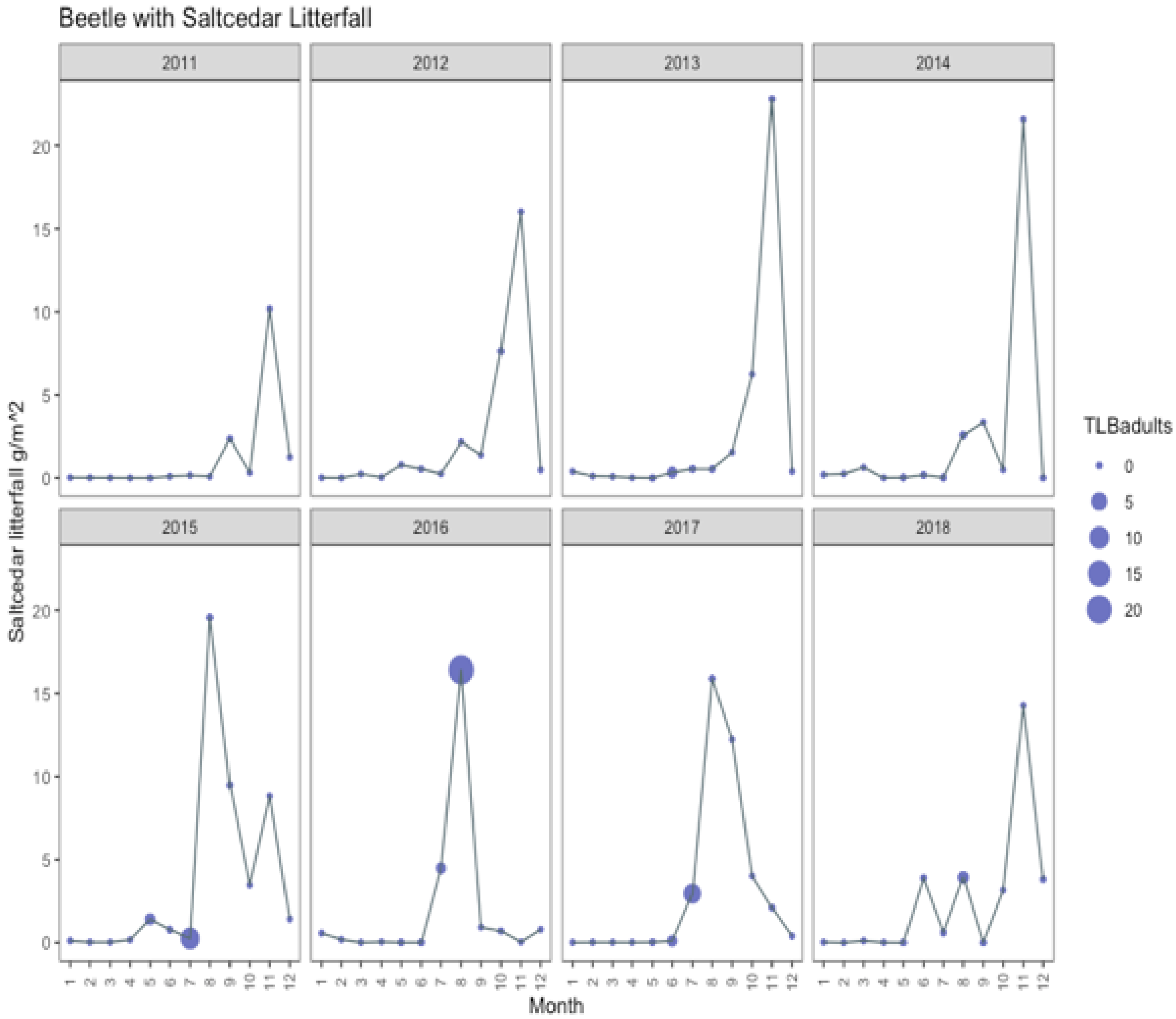


Figure 12. Saltcedar monthly leaf fall (line) from 2013 to 2018 and TLB abundance at the Crawford site (in Belen, see Table 1). Size of the circle indicates TLB adult abundance.

Surface Active Arthropods (Exotic spider): 2018-19

Surface-active arthropods are monitored three times per year using 20 pitfall traps at each site. K-12 and university students along with BEMP staff set and collect pitfall traps. Starting in 2018, arthropods are monitored at 26 sites (Table 1). Samples are brought back to the UNM lab. Identification and counting of isopods—*Armadillidum vulgare* (roly-poly) and *Porcellio laevis* (sow bug)—are done by students. Identification of species is primarily done by BEMP entomologist, Matt Leister.

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

Arthropods for 2018 and 2019 are being processed, but BEMP has rehired our specialist to work on species identifications. During the identification of the 2016 BEMP arthropod pit-trapping samples a species of exotic spider not previously recorded from New Mexico was identified. Since the initial discovery, the numbers and locations of this exotic have been increasing throughout the Albuquerque stretch of the Rio Grande bosque.

Trachyzelotes barbatus (Koch, 1866), is a medium sized spider with an overall brown to black coloration (Figure 13). This ground-dwelling generalist predator is known to be an active hunter not relying on webs for prey capture or detection. 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. Identifications of 2016 surface dwelling arthropods resulted in the detection of *T. barbatus* from the Albuquerque Overbank Project (AOP) BEMP site (Figure 1, Table 1, Figure 14). Two female specimens of *T. barbatus* were identified, one from May and one from the September collections resulting in a total of two specimens recovered for that year. In June 2017 collections, a single male *T. barbatus* was identified at AOP. In a preliminary look at 2018 multiple representatives of *T. barbatus* were identified from several BEMP sites within Albuquerque city limits; AOP: 20 specimens (12 male and 8 female); Harrison: 1 male; San Jose: 18 specimens (11 male, 7 female). A preliminary look at 2019 arthropod collections, as well as targeted hand collecting has uncovered numerous examples of *T. barbatus* inhabiting, primarily, the San Jose site (Figure 14, Table 1). The detection of *T. barbatus* from BEMP sites represents a new species record for New Mexico and a large range extension for this exotic in the United States (Figure 14).

Figure 13. *Trachyzelotes barbatus* male habitus.

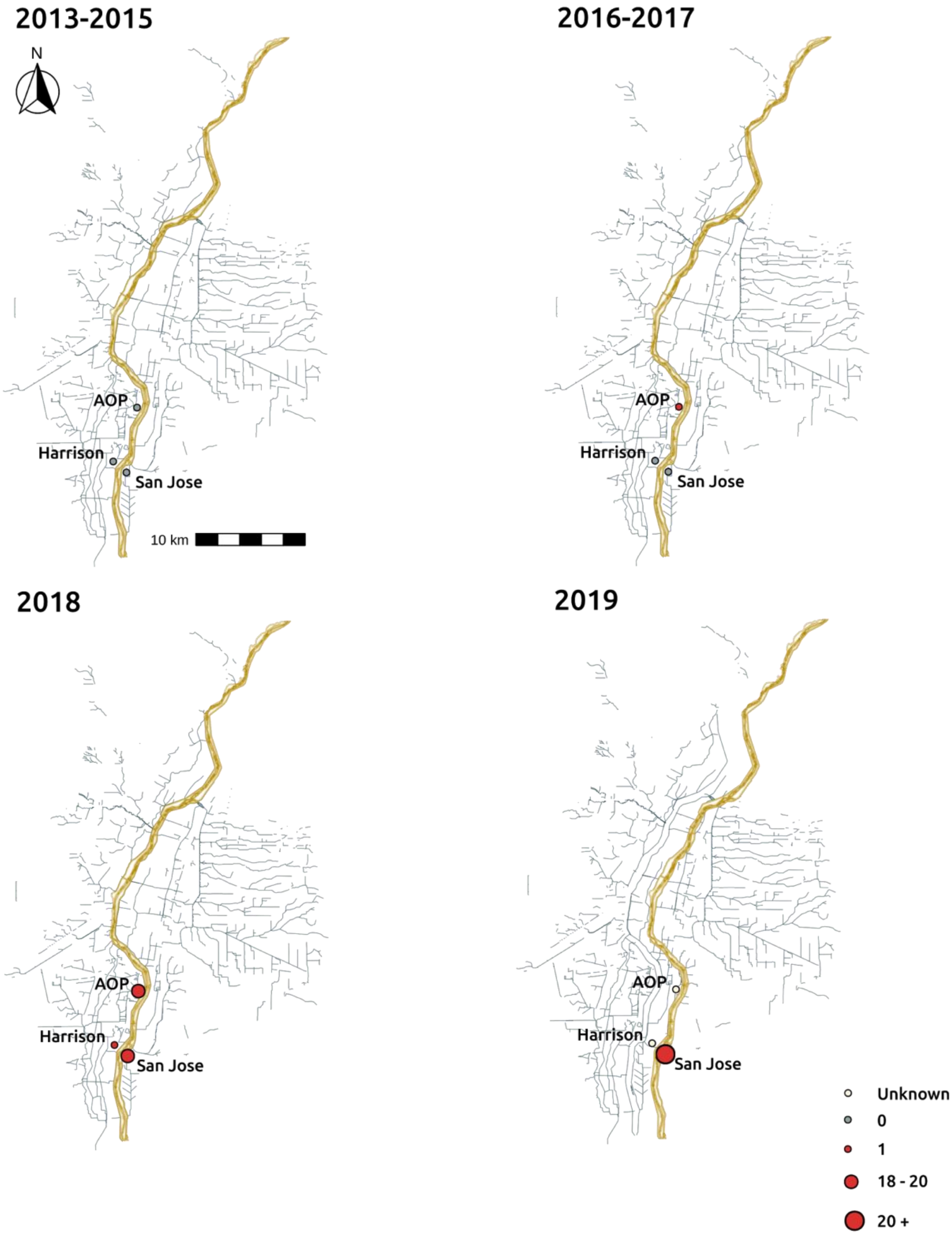


Figure 14. Map of Albuquerque BEMP sites where *T. barbatus* has been documented.

In years prior to 2016, no representatives of *T. barbatus* were identified from any BEMP sites and by 2018 multiple specimens were identified from multiple sites. This can be attributed to one of two scenarios; **a)** *T. barbatus* has inhabited the Albuquerque stretch of the MRG in numbers too low to be detected by BEMP pit-trapping techniques until a recent increase in their population or; **b)** this spider has been recently introduced to this area. Both scenarios are significant as they represent a relatively recent change in the local ecosystem resulting in an increased abundance or introduction of an exotic generalist predator. Continued monitoring of this spider will help determine the current range of this spider within the MRG, if this range is currently expanding and the influence its presence has on the abundance of native spiders with similar habits. This find shows the importance of arthropod monitoring with species level identification along the Middle Rio Grande.

Water Chemistry: 2019

BEMP collects data on the quality of the Rio Grande as it flows from southern Bernalillo through southern Albuquerque. Data were collected monthly at six river sites and once at four sites in and around the North Diversion Channel during a “qualifying” precipitation event. The purpose of the research is to examine how the water changes as it flows through Albuquerque (Figure 15). BEMP staff alongside high school students from La Academia de Esperanza (Figure 16) and undergraduate and graduate students from the University of New Mexico collected the following parameters *in situ*: pH, turbidity, dissolved oxygen, conductivity, and specific conductance. *E.coli* coliform was monitored by taking a sample at each location and sending it to the New Mexico Environment Department State Laboratory. Additional information including number of upstream waterfowl, water appearance, weather conditions and an upstream facing photo were taken at each location. Data were collected from south to north to ensure no river water was sampled twice.

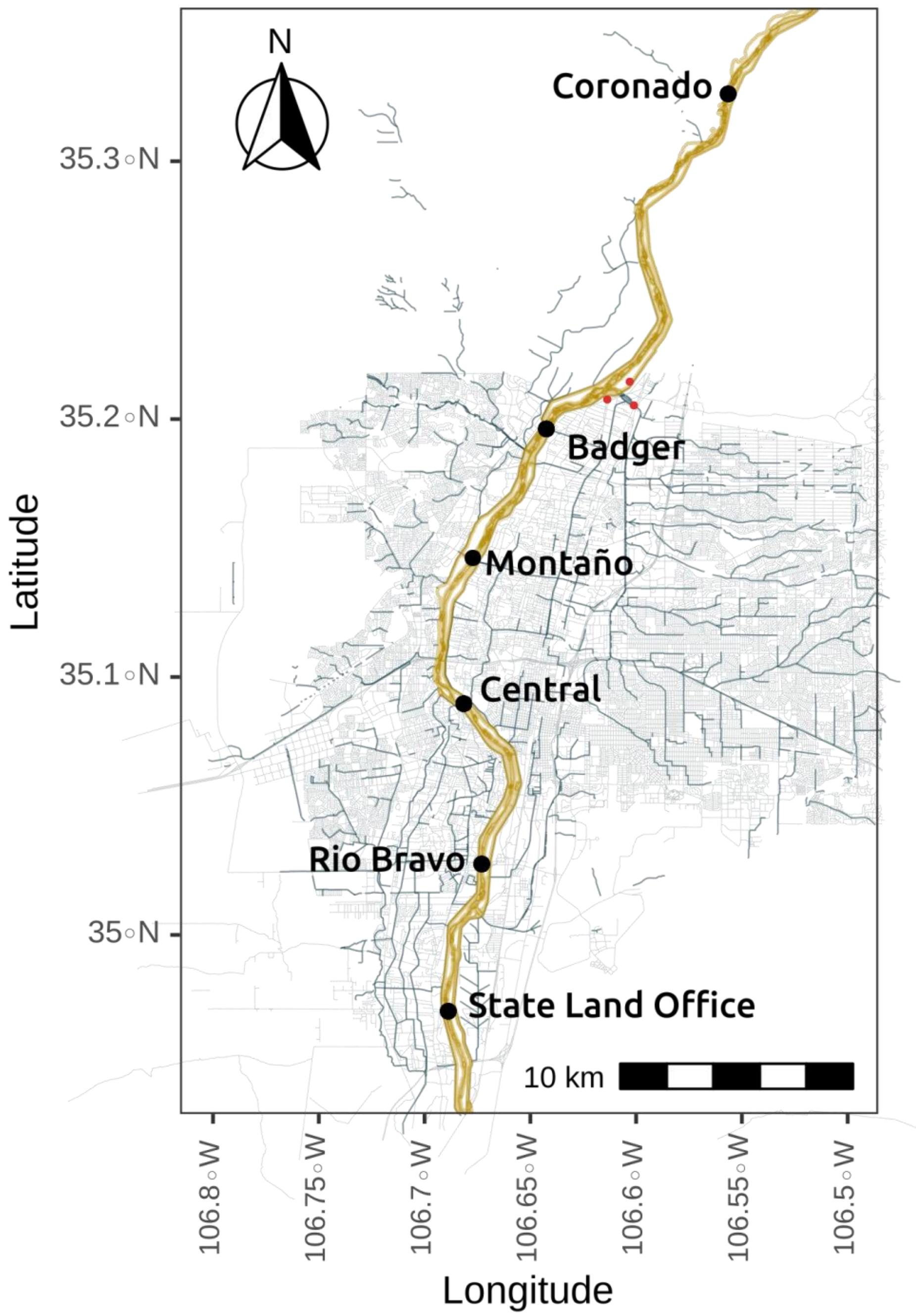


Figure 15. Map of the six monthly sites (shown as black dots), and the four storm sampling locations (shown as smaller red dots) sampled in 2019.

Figure 16. BEMP Biologist, Sean O’Neill, points out wildlife to three students from La Academia de Esperanza while monitoring water quality at the Montaño sampling site. Photo of students used with permission.

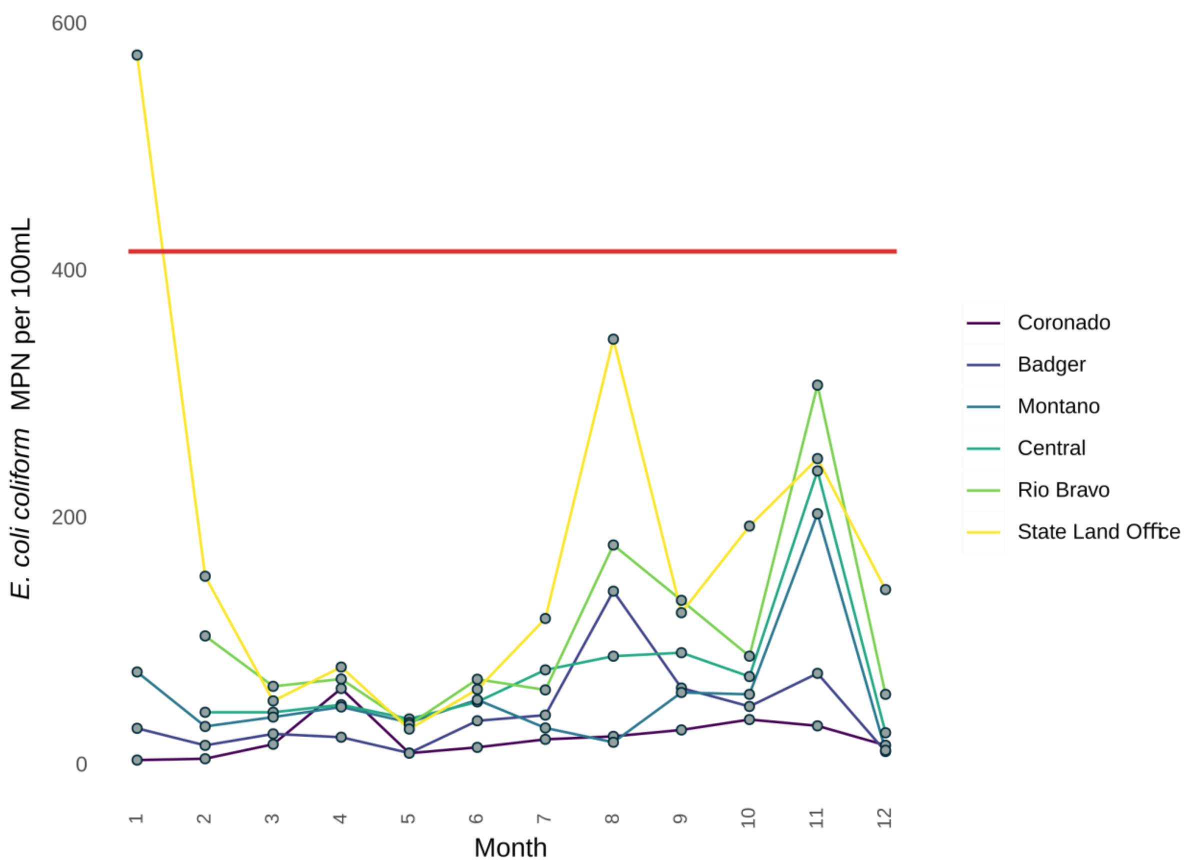


Figure 17. 2019 *E.coli* levels by site and by month. The red line represents the EPA approved water quality limit of 410 MPN/100 mL for the Rio Grande.

In 2019, only one out of the 72 samples taken showed *E.coli* levels in exceedance of the EPA approved water quality limit for the Rio Grande (Figure 17). The sample taken from the State Land Office in January 2019 was 574.8 MPN/10mL. River flow was exceptionally high during the spring and summer months, seasons where *E.coli* levels have been higher in previous years. Levels were lowest from March through June and averages increased from July through November.

E.coli levels tended to increase as the water flowed downstream through the study area. The two southernmost sites, Rio Bravo and State Land office, had the highest *E.col*i levels for eleven of the twelve collections (Figure 17). Specific conductance and turbidity levels increased consistently as the water flowed from north to south, whereas dissolved oxygen tended to decline.

The single storm event captured was on 4 October 2019 and showed large *E.coli* contributions from the North Diversion Channel into the Rio Grande. Downstream samples in the Rio Grande were 6,200 MPN/100mL greater than upstream samples.

Continued sampling at the same and new sites, as well as collecting data along transects across the active river channel, can aid in understanding river mixing and additional inputs.

Rapid Assessment Protocols: 2019

Ecological monitoring and public outreach are necessary to insure long term positive outcomes for Middle Rio Grande Bosque sustainability and resilience. BEMP's long-term monitoring has been effective in coupling these objectives by employing citizen/community science to collect data crucial to gauging the status of bosque sites and the success of projects; however, many tasks, such as producing preliminary community composition data for new projects or assessing fuel load for fire management, are not best served by establishing long-term monitoring sites. The Rapid Assessment Protocol (RAP) is intended to provide accurate data to assess current ecosystem conditions from a variety of landscapes in the Middle Rio Grande Bosque using community science concepts.

The RAP is designed to be a similar but simplified version of the monthly monitoring done in BEMP's permanent, long-term sites (Bosque Ecosystem Monitoring Program, 2016) and can be quickly and temporarily deployed to areas without a permanent monitoring presence. Only vegetation cover, woody debris, arthropod abundance, and potentially depth to groundwater data are collected. Groundwater data are only collected if there is an existing well in the chosen location or if it is feasible to install one. Setup includes laying four 50-meter transects in the cardinal directions from a central point (a well if groundwater is to be monitored). Four arthropod pitfall traps on set at the end of each transect. Vegetation cover, woody debris, and depth to groundwater data are collected the first day and arthropod data are collected 48 hours after setting, at which time the RAP is dismantled.

The RAP was initially deployed at BEMP's Montaño site in June 2019 to gauge the accuracy of the protocol. Analysis of vegetation cover data for a variety of species (Figure 18) showed that

RAP data accurately tracked long-term data from that site. The second deployment of the RAP included two sites within the Candelaria Nature Preserve (CNP). This is an area near the Rio Grande Nature Center State Park which has been mandated for restoration (City of Albuquerque, 2019) and will include upgraded wildlife habitat as well as outdoor educational opportunities. The data collected from the CNP sites showed a large difference in community structure between the two adjacent landscapes (Figure 19). CNP data were collected in the fall when much of the vegetation cover had been lost, indicating that additional RAP monitoring should be conducted in the summer.

RAP deployment and collections take no more than 10 working hours with two people; time decreases with the number of people involved. RAP will be a valuable tool for the CNP and other endeavors to guide restoration projects, gauge the progress of ongoing projects, or assess conditions in any part of the bosque not being monitored by long-term sites. The ability to collect woody debris data and quickly and accurately assess fuel loads will also be a vital tool for fire prevention and management. Furthermore, community involvement and education are important to ensuring the long-term success of restoration projects such as in the CNP (City of Albuquerque, 2019), and deployment of the RAP has been led and organized by university students led and organized. BEMP's RAP adds another valuable tool to preserve the Middle Rio Grande Bosque by combining community science with an uncomplicated method of collecting accurate ecosystem data from a wide variety of landscapes. These data are easily accessible to regional and local managers and planners.

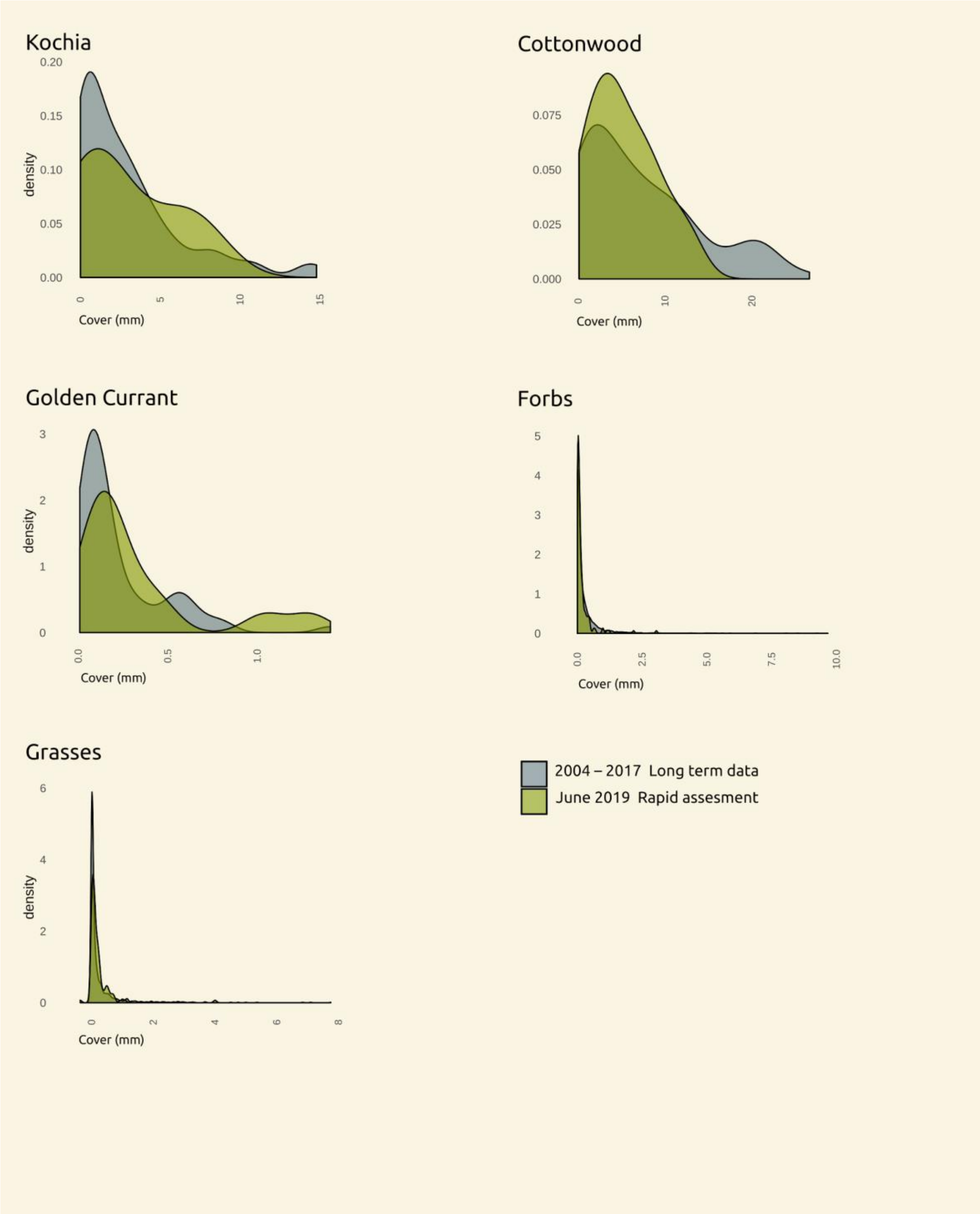


Figure 18. Comparison of long-term vegetation cover data (2004 - 2017) from Montaño BEMP site to the Rapid Assessment Protocol trial data (2019).

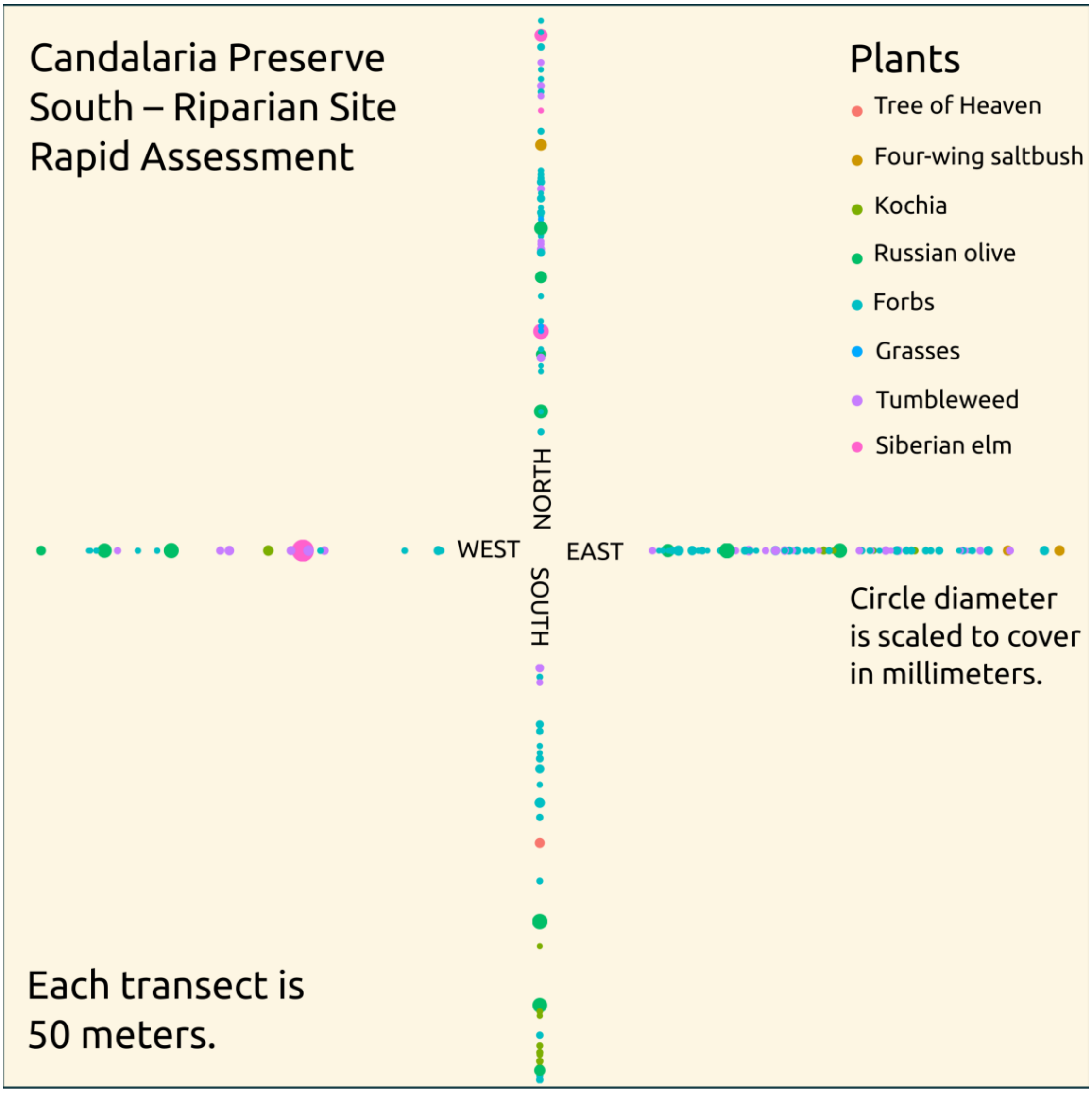


Figure 19. Vegetation species/groups recorded along the four 50m transects at the Candelaria Nature Preserve South BEMP RAP site, October 2019. The size of the circle is representative of the plant cover across the transect.

Soil Microbe Study: 2019 (graduate research)

BEMP supports several graduate students through the University of New Mexico. Plant microbe communities are dynamic and can be crucial to soil health and their associated plants. Cottonwood or *Populus* trees are members of the Salicaceae, a plant family known for its success in riparian ecosystems throughout North America. This family of plants has the unique ability to form both ectomycorrhizal and endomycorrhizal associations (Figure 20). These mycorrhizal fungi provide many benefits for cottonwood trees including nutrient exchange, increasing tolerance to heavy metals, and countering the effects of pathogens.

Therefore, it is important to understand the ecology of these microbes and how they change over time. Particularly, it is vital to research how these communities change with the introduction and removal of invasive species. Many invasive species do not have associations with the same beneficial fungi and may even repress fungal populations. For example, saltcedar or *Tamarix* are invasive trees that do not have associations with mycorrhizal fungi. To observe how these communities shift we are sampling BEMP sites that have:

1. Invasive species and cottonwoods
2. Invasive species that have been removed and cottonwoods
3. Invasive species that were removed a year ago and cottonwoods
4. Invasive species that were removed two years ago and cottonwoods

Figure 20. *Cenoccocum* ectomycorrhizal species on *Populus deltoides* (cottonwood) fine root tip. This beneficial fungus can explore the soil more effectively than its host and retrieve valuable nutrients such as nitrogen and phosphorus for the host plant. In return the cottonwood gives the fungus sugars produced from photosynthesis. 15x magnification.

This work began in 2019 and will continue through 2020.

Bosque del Apache River Realignment: 2019

The Bosque del Apache (BDA) and River Realignment (RR) BEMP sites are paired sites designed to monitor the effects of artificially shifting the river from its current location to a more easterly channel (Table 1, Figure 21). After an extended flooding period in 2019 the river appears to have shifted to a more easterly channel naturally (Figure 21).

At the time of the BDA site construction, the Rio Grande was approximately 520 meters east of the levee road and approximately 320 meters east of the BDA site. In October 2019, after a period of extreme flooding in the spring and summer of months, a trip to view the river from the BDA site revealed a dried riverbed where the Rio Grande had been flowing previously (Figures 22 & 23). The ground became increasingly wet and muddy east of this dried bed and after approximately 410 meters an active flowing channel was seen. This active channel corresponded with a location of mowed tamarisk, an area being prepared for the realignment of the river (Figure 22). Subsequent trips to the river since October, 2019 consistently revealed the same dried river bed and area of active flow that was noted previously. The RR site located on the east bank of the Rio Grande has been consistently flooded since summer of 2019 and as of last monitoring in February, 2020 the site remains inundated with flowing river water (Figure 24).

Satellite images taken between October, 2018 and February, 2020 captured this stretch of the Rio Grande during these events (Figure 21). Between July and August 2019 the river can be seen switching from a westerly channel to an easterly one (Figure 21).

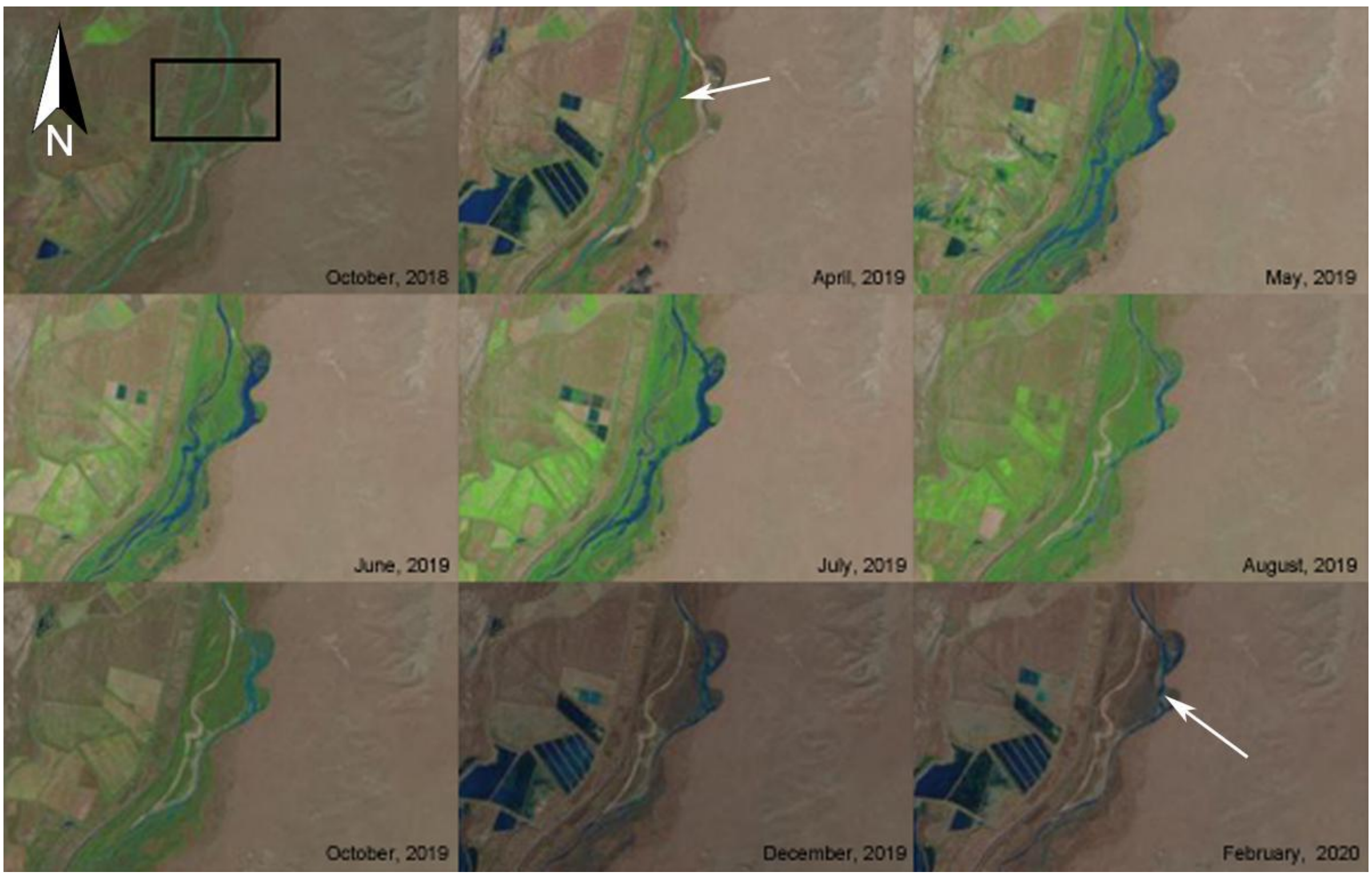


Figure 21. Landsat 8 images of a section of Rio Grande in the Bosque del Apache wildlife refuge from October, 2018 through February, 2020. The black box in the first image indicates the area containing the BDA and RR BEMP sites. Arrows pointing to active river channels pre (April, 2019) and post (February, 2020) flooding. Downloaded from https://earthexplorer.usgs.gov/.

Figure 22. NAIP aerial photograph from July 2018 detailing BEMP sites (red dots), river channel prior to August, 2019 (white dot) and western edge of river channel since August, 2019 (blue dot). Area of tamarisk mowing can be seen as a strip east of blue dot. Downloaded from https://earthexplorer.usgs.gov/.


Figure 23. Dry river channel previously occupied by Rio Grande prior to August 2019, photo taken February, 2020. Photo Matthew Leister.

Figure 24. River Realignment BEMP site displaying flood levels at the canopy precipitation gauge, students from Hot Springs High School collecting precipitation data; Left: January, 2020; Right: October, 2019. Photographs of students used with permission. Photos Matthew Leister.

An examination of satellite imagery indicates the Rio Grande is occupying an eastern channel and becoming detached from the water occupying the RR site. The flooding present at this site appears to be shifting from active river flow to a natural wetland. Continued monitoring at these two sites will help determine if this change in the river and flooding on the eastern bank persists.

Education Outreach: 2019

BEMP's core outreach involves getting K-12 and university students involved in hands-on research each month at active BEMP sites. These students learn about ecology, data collection, and their local ecosystem through these monthly field visits and classroom educational activities. BEMP teaches classroom lessons about ecology, botany, entomology, history, hydrology, and wildlife of the Middle Rio Grande valley and bosque. This curriculum follows New Mexico education standards and bolsters students' knowledge of environmental science while contextualizing their place-based activities. Additionally, BEMP offers "study trips," in which students go on an interpretive hike in the bosque near two BEMP sites. A partnered activity with the Rio Grande Phenology Trail, study trips expose students to BEMP fieldwork and to the collection of phenology data. In addition to working with over 50 schools on a monthly basis and getting over 1000 students out to BEMP sites to conduct monthly monitoring, BEMP staff also work with students and adults on a variety of other outreach opportunities. Some of these outreach activities are detailed below.

Stable Isotope Workshop (SIW)

BEMP partnered with the Center for Stable Isotopes (CSI) at the University of New Mexico (UNM) to put on a three-day workshop to introduce high school students to stable isotope research. During the workshop, students from different high schools (La Academia de Esperanza, Eldorado, Amy Biehl High School, Bosque School, New Mexico School For the Deaf, Albuquerque High, Rio Grande High School and Albuquerque Institute of Math and Science for 2019 and 2020) learned how to use this tool to study the ecology of the bosque. The workshop was led by Dr. Seth Newsome (an associate professor at UNM) and his lab of isotope researchers.

The first day of the workshop was hosted at Bosque School where the students learned basic concepts about stable isotopes as well as how to manipulate and interpret data. The afternoon was spent learning about experimental design and sample collection in the field. Day two and three were held at UNM (Figure 25) where students learned the basics about sample preparation, the equipment used to analyze stable isotopes (mass spectrometers and peripherals), and data representation. Students learned through this three-day process how to do a scientific project from beginning to end. The last afternoon of the workshop was spent presenting the final projects that the students have been working on throughout the event.

BEMP also offered the opportunity for these students to work on independent stable isotope related projects after the workshop (Figure 25) that were either used as a science fair project or presented in a professional conference venue (Figure 26). This was a unique opportunity for students to get 1:1 direct contact with university research scientists. The goal of the stable isotope workshop was for students to gain baseline knowledge about stable isotopes that they can use for future research projects and to help them stand out from their peers when applying to college.

Figure 25. Students at the UNM stable isotopes lab and in the field collecting data for the October 2019 workshop. BEMP also improved access to this workshop for a deaf/hard of hearing student by providing ASL interpretation. All student photos used with permission.

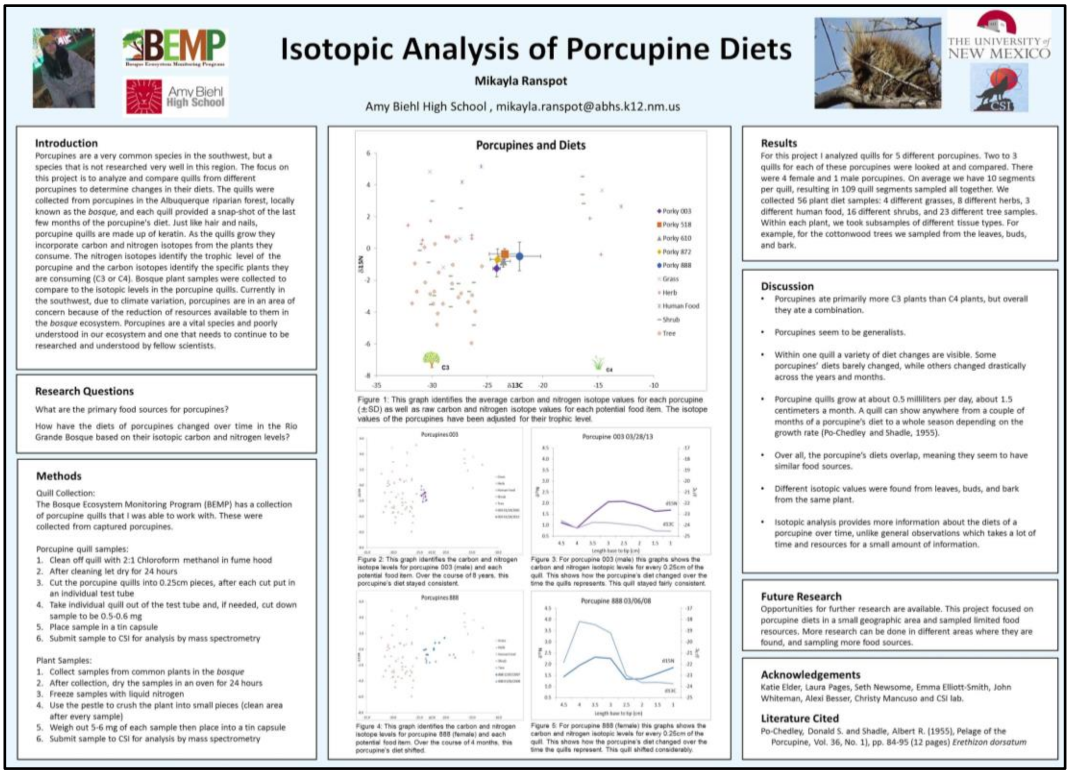


Figure 26. After the 2018 workshop, Mikayla Ranspot presented at the 2019 NM State Science Fair, winning 3rd place, and at the 2019 BEMP Crawford Symposium. After the 2019 workshop, Allison McGuire and Mikayla Ranspot presented at the 53rd Annual Meeting of the AZ/NM American Fisheries Society and the Wildlife Society (January 2020). Larger versions available upon request.

Luquillo-Sevilleta Virtual Symposium (LSVS)

Approximately 50 Spanish-speaking students from various schools in New Mexico and Puerto Rico gathered together through the internet to share their scientific research projects done in their local ecosystems. The presentations and entire symposium were conducted in Spanish. Students in Puerto Rico worked with the Luquillo Long Term Ecological Research Schoolyard program to study environmental issues across tropical ecotones. New Mexico BEMP students, in collaboration with the Sevilleta Long Term Ecological Research Schoolyard program, presented their studies in the riparian bosque ecosystem. BEMP educators met with the different New Mexico schools' participants (La Academia de Esperanza, Cien Aguas International School, South Valley Academy, The International School and Bosque School) for three separate sessions where they helped students conceptualize, prepare, and present their research using ongoing BEMP datasets. The presentations and follow up questions were all done in Spanish, showing how the exchange of scientific discoveries can happen across cultural, political, and language boundaries (Figure 27).

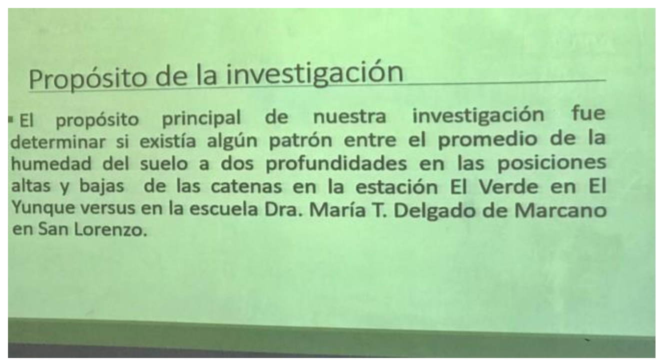


Figure 27. Students from Albuquerque, NM, and Puerto Rico participate in the April 2019 Luquillo Sevilleta Virtual Symposium. Photo of students used with permission.

BEMP After School Science (BASS)

BEMP After School Science (BASS), an afterschool community science youth engagement initiative, allows K-12 students from Title 1 Albuquerque Public Schools (APS) to participate in hands-on Science, Technology, Engineering, Art, and Math (STEAM) activities in classrooms, schoolyards, and the bosque. BASS is supported by and done in collaboration with the City of Albuquerque Parks and Recreation and Open Space divisions. Participating students were exposed to BEMP datasets and collections each month, including using Nature's Notebook to track phenological changes in partnership with the Rio Grande Phenology Trail and USA-National Phenology Network.

BASS activities included biological field journaling, bird identification, learning about plant and animal adaptations, and observing and identifying macro and micro invertebrates. Students learned the importance of: identifying plants, animals, and invertebrates; journaling; using binoculars; detecting phenological changes; using microscopes; and creating artwork reflecting nature, data, and their surroundings. BEMP staff and students met every week, helping to deepen connections that students have with nature through consistent and varying engagement with their schoolyards and the bosque (Figure 28). BEMP educators interacted with more than 250 students from four Title I APS schools on 50 field trips in 2018-19. BASS provided school age students with opportunities to participate in hands-on community science and diverse, place-based STEAM activities.

BEMP integrates Art into STEM (Science Technology Engineering and Math) Education to focus on the more inclusive STEAM Education. Art and creativity allow students to interpret concepts, build meaning, and share stories about place and data. Through artistic practices we can make amends and connections in order to investigate the relationship between cultural and natural systems. BEMP's art-making practices engage in hands-on and immersive learning and sharing. As a result, art-making builds a deep sense of place through phenomenological, emotive, and poetic ways of connecting with the bosque. Student artwork may serve as a symbolic gesture, honor a personal narrative, or function as a communication tool. By integrating art into science education, BEMP supports the multiplicity of voices and perspectives that emerge when art coalesces with ecology. BEMP has incorporated art into the BASS program, and will continue to expand this aspect to our other educational curricula.

Figure 28. Students participate in the classroom and in the field in BASS during 2019. Photos of students used with permission.

Rio Grande Phenology Trail (RGPT)

The Rio Grande Phenology Trail (RGPT) was formed by several organizations using Nature's Notebook, a program developed by the USA-National Phenology Network (USA-NPN), to monitor phenological changes in New Mexico. Since 2016, Valle de Oro National Wildlife Refuge (NWR), USA-NPN, and BEMP have coordinated the RGPT. In 2019, the RGPT consisted of eight partner organizations: Santa Fe Botanical Garden, Randall Davey Audubon Center and Sanctuary, Railyard Park, Albuquerque BioPark Botanic Gardens, BEMP, Valle de Oro NWR, Whitfield Wildlife Conservation Area, and Sevilleta NWR.
"The longitudinal span of the Trail enables USA-National Phenology Network partners, RGPT partners, and specifically land managers at Valle de Oro to better understand how climatic shifts

are manifesting changes in local species' phenology. Cottonwood (*Populus deltoides* ssp. *wislizenii*) and Siberian elm (*Ulmus pumila*) are the principle plant species studied at RGPT sites" (BEMP 2017 Annual Report). In 2019, RGPT observers collected 47,000 phenology records on 55 species (33 animals, 22 plants). While each partner site may have its own individual science and outreach goals, being a part of the RGPT allows for shared and consistent goals, resources, outreach, and support in the following ways:

Volunteer coordination and support. The RGPT Coordinator engages with long-time volunteers and recruits new volunteers when needed. The RGPT Coordinator regularly meets with volunteers, answers questions about phenology monitoring, communicates with partner site staff, holds trainings for volunteers, sets up partner site tours, and responds to any other needs from volunteers or partner sites. In 2019, there were 36 observers consistently collecting data at RGPT sites, 8 new observers and staff trained, and 5 events for partners and observers.

Student education and engagement. Students are also a part of the RGPT's community of scientists using Nature's Notebook. In 2019, 219 students participated in BEMP's phenology "study trips," where they learned about their local ecosystems through a lens of phenology while also submitting Nature's Notebook data. Over 380 students studied phenology and collected phenological data through BEMP's After School Science program (BASS), summer programs like Horizons Albuquerque and the Albuquerque Sign Language Academy (ASLA) Youth Crew, University of New Mexico's Bosque Internship class, and other independent student research projects throughout the year (Figure 29).

Public education and outreach. A key piece of the RGPT's work is to share knowledge about phenology, Nature's Notebook, and the RGPT as a whole to the general public. This has been done through public events along the RGPT, such as presentations, tabling events, and workshops (Figure 29). In 2019, the RGPT reached 152 people at 10 public talks and 693 people at 5 tabling events, providing outreach and education for all partner sites and organizations.

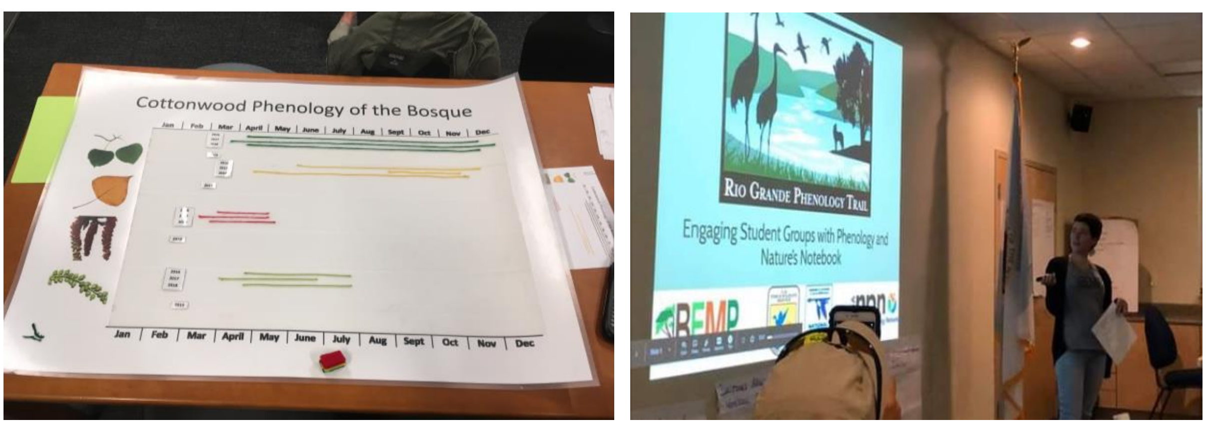


Figure 29. Student-collected phenology data from BEMP Study Trips is recorded on an interactive phenophase calendar; phenology community science presentation at the USA-NPN's Local Phenology Leader Clinic in October 2019.

Conclusions, Takeaways, and Recent Updates

BEMP data indicate that the two-month long flood event of 2017 did not have a negative impact on native species, as both woody and herbaceous plants showed minimal changes in their cover in the year of the flood. Cottonwood health continues to decline at most sites, and increasing fuel load, as well as pre- and post-restoration data, can be effectively monitored using our new Rapid Assessment Protocols. The River Realignment project in the Bosque del Apache NWR, a US Bureau of Reclamation project, has been largely influenced by the river's naturally changing flows rather than construction designs. The eastside BEMP site remains underwater for most of the year, and has become a unique and challenging site as it has rapidly shifted from "saltcedar forest" to "standing water/wetland".

As BEMP moves forward, we are investing more in community engagement, understanding shifts in the ecosystem, and making sure that all our data remain nonproprietary and available. BEMP data are now available on an open access data repository (https://github.com/BEMPscience/bemp_data) as well as on our website and at UNM's digital repository. BEMP is developing a long-term data management plan which will be available Summer 2020. In addition to our data, BEMP is housing our education curriculum and activities on GitHub and ensuring that teachers and students have access to our resources. For those students who do not have access to the internet, BEMP has been making copies of activities and dropping them off at different school locations so that even during the current Coronavirus shut down starting in March 2020, there is equitable access to engaging science and place-based education for K-12 students. BEMP continues to safely monitor and provide education outreach, and will continue to do so, hopefully in perpetuity. We are very grateful to our funders, partners, and supporters. Thank you from all of us at BEMP.

Acknowledgements

All data and reports are currently available at BEMP.org. Additional graphs and maps can be produced upon request.

The information in this report is based upon BEMP's non-proprietary datasets, collected between January 2019 and December 2019 (2018 data for vegetation and litterfall), with reference to data collected from 1997-2018. All raw data are available upon request.

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We would also like to thank our land use partners:

City of Albuquerque Open Space Division, Middle Rio Grande Conservancy District, Pueblos of Santo Domingo, Santa Ana, and Sandia, State of New Mexico, State Forestry, New Mexico State Parks, and USFWS National Wildlife Refuges of Valle de Oro, Sevilleta, and Bosque del Apache.

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