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**BOSQUE ECOSYSTEM MONITORING PROGRAM
(BEMP) SITE MONITORING REPORT FOR 2018**

2018 ANNUAL SITE MONITORING TECHNICAL REPORT

Submitted March 29th, 2019

2018 Final Report submitted to:
US Army Corps of Engineers, USACE Contract #: W912PP18C0023
US Bureau of Reclamation, Agreement #R18AP00129
US Fish & Wildlife - **Valle de Oro National Wildlife Refuge -** Cooperative Agreement Award #F16AC01243
Valencia Soil and Water Conservation District
Middle Rio Grande Conservancy District
Pueblos of Santa Ana, Santo Domingo, Sandia

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Bosque Ecosystem Monitoring Program (BEMP)
Report on 2017-18 and 2018 Education and Monitoring
March 2019

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 and Timing of Data Collection taken directly from 2017 Annual Report**:**

"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. The experiences of these community members support science education reform efforts and help to increase understanding and appreciation of the Rio Grande riparian ecosystem. 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 [32] active monitoring sites along 250 miles of the Rio Grande, including [31] sites within the Middle Rio Grande (Figure 1). Through the strategic location of these sites, BEMP aims to study 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. Both biotic and abiotic variables are monitored. Our abiotic datasets are depth to groundwater; water level in ditches and drains; precipitation; above- and belowground temperature; and water quality in the Rio Grande, ditches and drains, and groundwater. 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. BEMP hosts two events during the year to present new data, visualizations, and analyses to management agencies: the Fall Field Tour and the Crawford/Green Trails Symposium. BEMP staff and students present BEMP data to managers, professionals, and students several times throughout the year depending on conference availability. Some examples of conferences where BEMP data have been shared 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 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."

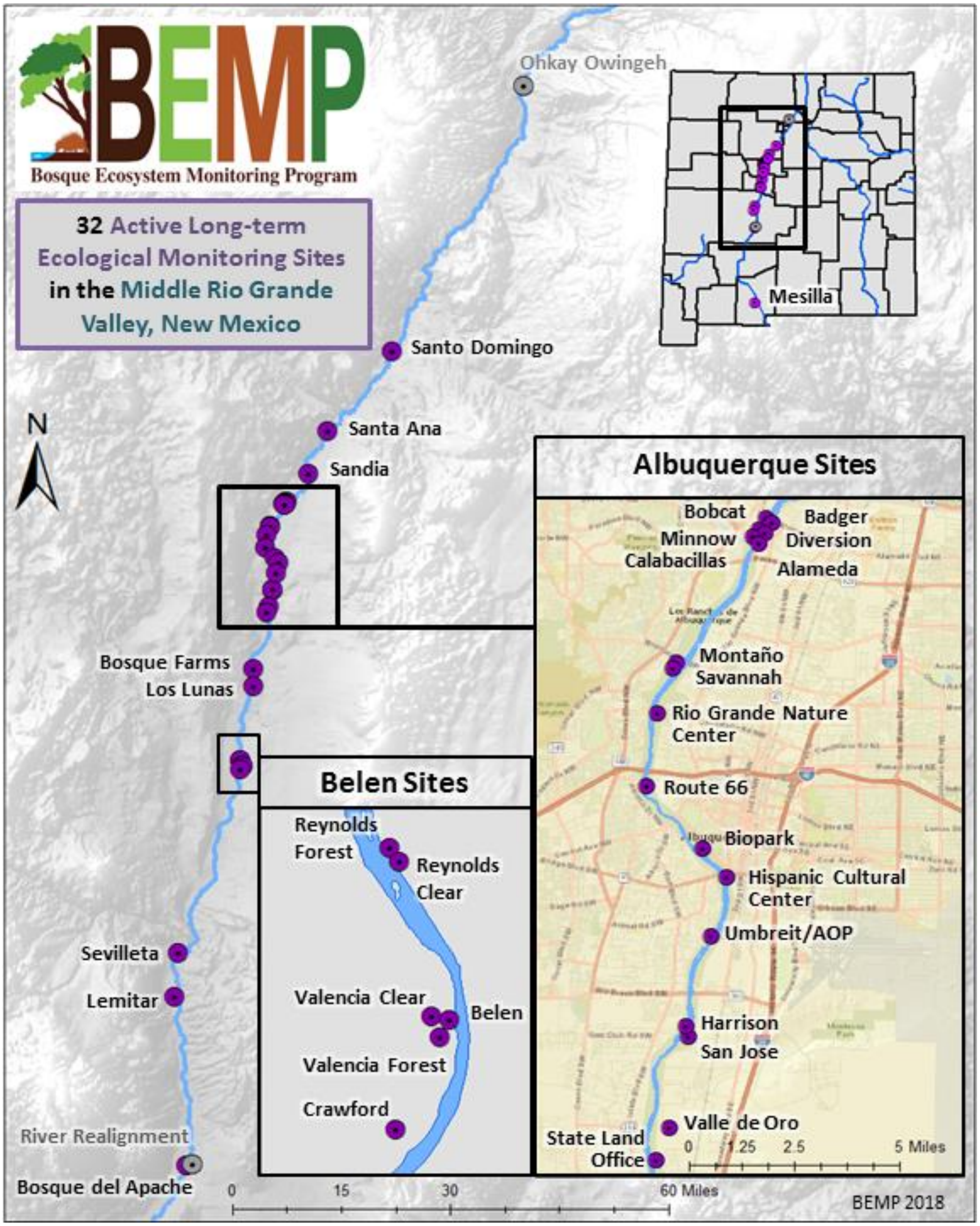

Figure 1. Map of 32 active BEMP sites along the Rio Grande; Ohkay Owingeh is no longer an active site and the River Realignment site was not fully installed in 2018.

Education and Outreach:

Overview taken from BEMP 2016 Annual Site Monitoring Technical Report:

"BEMP works with schools from Sandoval, Bernalillo, Valencia, Socorro, and Doña Ana counties. Participants include traditional public, charter, parochial, private, alternative, and home school students. Throughout the school year, BEMP staff deliver [STEM-ready and NGSS] curricula both in the classroom and out in the field. At the end of the school year, BEMP hosts two annual student congresses in partnership with a variety of local agencies and organizations. Students present and share their experiences at their sites with each other and engage in bosque-related activities and workshops. As BEMP is the official schoolyard program for the Sevilleta Long-Term Ecological Research (LTER) Network site, our students also present at the LTER Schoolyard Webinar which is held in Spanish. This symposium connects Spanish-speaking BEMP students with students at the Luquillo, Puerto Rico LTER site to share data and compare experiences."

BEMP Education and Outreach, 2017-2018 School Year:

In the 2017-2018 school year, fifty-one schools from Sandoval, Bernalillo, Valencia, Socorro, and Doña Ana counties were involved with BEMP, and 9039 community members, mainly students and teachers, participated in BEMP's education and outreach (Table 1). Over 4000 participants were out in the field conducting core BEMP monitoring or collecting data for special research projects. Of those, approximately 1500 students were involved in year-round monthly monitoring with follow-up classroom sessions. There were about 50 students involved in in-depth research projects with BEMP, which included field work, data analysis, and presentation/dissemination of the data to broader audiences at professional conferences and local events. Annual participation did increase (Figure 2), but there were fewer students involved in long-term monitoring.

Table 1. BEMP participation numbers by category of outreach

BEMP 2017-2018 Outreach	students	adults	total	percent
long term multiple field days	1472	73	1545	17.1%
short term field or classroom (1-2 days)	2370	234	2604	28.8%
summer programs	236	77	313	3.5%
wildlife programs	67	5	72	0.8%
adult/teacher training	9	124	133	1.5%
festivals, events, etc.	1694	1650	3344	37.0%
conferences, meetings, etc.	115	913	1028	11.4%
Total	**5963**	**3076**	**9039**	100%

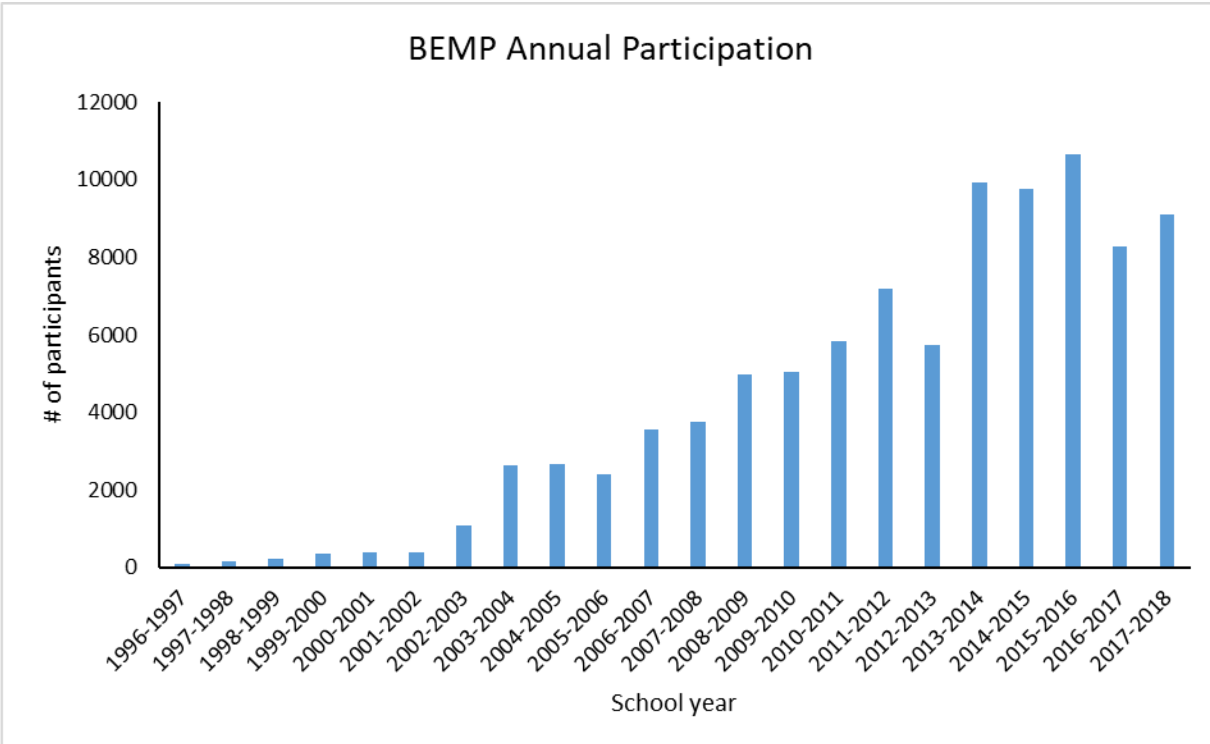

Figure 2: BEMP annual participation numbers from 1996 through the 2017-2018 school year

Rio Grande Phenology Trail Overview taken from the 2017 BEMP Annual Report:

Rio Grande Phenology Trail Program

"The Rio Grande Phenology Trail (RGPT) uses the [USA-National Phenology Network (USA-NPN)'s] online program, "Natures Notebook", to engage both the general public and K-12 students in tracking ecological phenomena as manifested in phenology along the Rio Grande and its watershed. This is done through a [RGPT] Coordinator position, [previously referred to as the Nature's Notebook Rio Grande Phenology Trail Network Coordinator]. This position connects urban audiences… to the outdoors and conservation through weekly monitoring efforts of seasonal changes (phenology). The [RGPT] Coordinator offers trainings for local teachers, land managers, and community members on how to implement the protocols and how to use the software associated with the project. The Coordinator hosts events and meetings to connect various groups monitoring the seasonal changes in the plants and animals along the Middle Rio Grande, from Santa Fe to Sevilleta National Wildlife Refuge.

"The purpose of the RGPT is twofold: (1) to connect like-minded organizations through a shared community project and (2) use phenology at the Valle de Oro NWR to integrate management and science objectives with education and outreach objectives. It encourages people to engage in active, outdoor education, and ask and answer local science, management and climate questions. … There are [18] volunteers who monitor regularly at the [seven] RGPT partner sites. These sites include Valle de Oro NWR, Sevilleta NWR, Whitfield Wildlife Conservation Area, Albuquerque BioPark Botanic Garden, BEMP, the Santa Fe Botanical Garden, [and Randall Davey Audubon Center and Sanctuary].

“Each of the RGPT sites monitors 4-18 species weekly. 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. Several other plants, avian, and mammalian species are monitored regularly at the sites.”

During the 2017-2018 school year, the RGPT engaged with 1589 people throughout New Mexico through presentations, trainings, tours, radio interviews, tabling events, newsletters, and educational outreach. Volunteers and students working with the RGPT contributed 48,894 observations to the USA-National Phenology Network through the Nature’s Notebook interface in 2018.

Figure 3. Nex+Gen Academy students participate in phenology monitoring at Valle de Oro National Wildlife Refuge.

Monitoring Methodology:

Overview of BEMP monitoring for groundwater, precipitation, and litterfall are taken from the 2017 BEMP Annual Report (hyperlinks provided to the full methodology for all datasets):

Depth to Groundwater

"Depth to groundwater is monitored at all but two BEMP sites (Pueblo of Santa Ana and Pueblo of Santo Domingo). Groundwater data from the Pueblo of Sandia are [property of the Pueblo] to the Pueblo and must be requested through the tribal administration office. At the remaining BEMP sites, five groundwater wells are monitored each month during monthly monitoring week (based on the third Tuesday of the month), along with the nearby ditch or drain. The USGS river flow data are downloaded based on the day of monitoring and the nearest upstream gage for each site. (Full methods: http://bemp.org/wp-content/uploads/2016/01/well-installation-and-monitoring-directions.pdf)"

Precipitation

"Precipitation is monitored at each site during monthly monitoring [except at Bosque Farms and Valle de Oro]. There are two rain gauges, one underneath a canopy and one in the open. Oil is put in the rain gauges to prevent evaporation. There [were] two types of rain gauges in use [in 2018], the Tru-Check rain gauge and a cylindrical rain gauge. The Tru-Check gauges have been used since BEMP began, but in 2016 they started randomly cracking, so we added the second type of rain gauge to the sites. There is an R^2 value of 0.95 between the readings of the two gauges, but to increase accuracy, a regression formula was applied to the readings of the cylindrical rain gauge to keep the readings consistent across time. (Full methods: http://bemp.org/wp-content/uploads/2016/01/weather-station-precipitation-monitoring-directions.pdf)"

Litterfall

"Litterfall is collected at each site during monthly monitoring. There are ten litterfall tubs at each site, placed alongside the randomly located vegetation plots. Each month, the contents of the tubs are collected and sent to the UNM lab to be dried for 48 hours. The contents are then sorted and weighed. Leaves from six dominant native trees/shrubs and four exotic trees/shrubs are identified. Reproductive parts are also identified based on two different native trees and three exotic trees. Other leaves and reproductive parts are labeled as "other" for each of the broad categories. The final category identified and weighed is wood. (Full methods: http://bemp.org/wp-content/uploads/2016/01/Litterfall-monitoring-and-lab-directions.pdf)"

Vegetation Cover

Vegetation cover surveys are conducted in August-September each year. Line-intercept methods are used to monitor plant species along ten 30m transects at each site. Botanists typically complete the identifications of samples in the herbarium and submit datasheets in late spring or summer. Data are then entered, checked, QA/QC'ed, and then analyzed for the following year's report. (Full methods: http://bemp.org/wp-content/uploads/2016/01/vegetation-monitoring-directions.pdf)

Surface-Active Arthropods

Surface-active arthropods are monitored through 20 pitfall traps at each site. Pitfalls are set three times per year and are left open for 48 hours. Samples are then collected and brought back to the UNM lab, where they are frozen for at least two months before being sorted. Identification and counting of isopods—*Armadillidum vulgare* (roly-poly) and *Porcellio laevis* (sow bug)—are done by students, as these are species that are easy to identify and distinguish. University interns and high school students can assist in identifying additional species, but the bulk of the lab work is done by BEMP entomologist Matt Leister. Due to the time-consuming nature of the lab work, arthropod reporting is often one to two years behind collections. (Full methods: http://bemp.org/wp-content/uploads/2016/01/pitfall-monitoring-directions-and-arthropod-identification.pdf)

Tamarisk Leaf Beetle

Tamarisk leaf beetle monitoring is conducted in May, June, July, and August each year. In 2018, BEMP monitored 16 sites for tamarisk leaf beetle (TLB). Four of the 16 sites were also monitored in September. BEMP protocols are adapted from River's Edge West (formerly Tamarisk Coalition) and University of Santa Barbara. At each site, five saltcedar trees are marked and sampled for TLB, with photos taken from set photo points. Sweep nets are used to collect samples, which are then frozen and later sorted in the lab to identify and count TLB adults, early and late larvae, and egg masses. The tamarisk splendid weevil and tamarisk leafhopper are also counted, as are ants and spiders. Percent defoliation (brown and yellow), refoliation, canopy, and dead branches are estimated for each tree. (Full methods: http://bemp.org/wp-content/uploads/2018/03/BEMP_TLB_Report_2017.pdf)

Temperature

Temperature data-loggers are installed at 12 sites, continuously monitoring air and soil temperatures (one in an open area, one underneath canopy) in hourly increments. Temperature data are downloaded annually. Sites with temperature data loggers are: Santa Ana; in Albuquerque: Alameda, Rio Grande Nature Center, Savannah, Rt. 66, BioPark, Albuquerque Open Space, State Land Office; Los Lunas, Belen, Lemitar, and Mesilla. The new temperature data loggers have data from July 15, 2016 to July 27, 2018. New temperature data loggers were installed in May, July, or August of 2016. The latest data were downloaded between mid-July and mid-August 2018.

<u>Monitoring Data and Analyses</u>:

In addition to the data trends at each site, this year we are including analyses of trends across sites and datasets to assess the current conditions and likely future conditions of the riparian forest. Our key focus is addressing plant response to changing groundwater levels, precipitation, and temperature.

A table is provided with site number, name, latitude, and longitude (Table 2, pg. 9). The table and map (Figure 1, pg. 2) can be used to identify sites of interest across the figures and analyses provided in this report.

Groundwater

Groundwater levels are strongly correlated with river flow. In addition, some sites are noticeably influenced by other variables (e.g., soil composition and texture, proximity to the river, proximity of dams, location relative to levee, influence of groundwater drain). Groundwater trends at most BEMP sites show gradual declines, with a distinct peak in 2017 due to high river flows (with the exception of Lemitar and Mesilla) (Figure 4). The sites (Bobcat and Badger) above the San Juan-Chama Drinking Water Project Diversion Dam in Albuquerque show increasing or stable groundwater levels. Savannah and Montano (both right below the Montano Bridge in Albuquerque) and HCC (Hispanic Cultural Center, below Avenida Cesar Chavez Bridge in Albuquerque) show gradual increases in groundwater levels. Both Harrison and BioPark appear relatively stable.

One site had mean summer groundwater levels shallower than 1 m (Figure 5). Eleven sites had groundwater levels within the optimal range for native riparian trees and shrubs (between 100 and 150 cm depth). Thirteen sites have groundwater levels still within the range for native roots and four sites were approaching cottonwood root threshold (300 cm). One site had mean summer groundwater levels below cottonwood threshold (between 350 and 400 cm). Depth to groundwater is lower in the northern Albuquerque sites and increases below the I-40 bridge. In Belen, groundwater levels are strongly correlated to river flow and are low during the growing season in response to low river flow.

Table 2. List of sites from north to south. Site numbers are based on establishment date and are sometimes used in place of the site name.

SITE #	SITE NAME		LAT	LONG
9	Ohkay Owingeh		36.06180175	-106.0761079
24	Santo Domingo		35.50989167	-106.3896111
5	Santa Ana		35.34283611	-106.5458472
32	Sandia		35.25523	-106.5911
22	Bobcat	(in Albuquerque)	35.19705633	-106.6439494
21	Badger	(in Albuquerque)	35.19556856	-106.6416219
12	Minnow	(in Albuquerque)	35.19315094	-106.646915
10	Diversion	(in Albuquerque)	35.191958	-106.6441893
11	Calabacillas	(in Albuquerque)	35.19056822	-106.6491626
1	Alameda	(in Albuquerque)	35.18805064	-106.6469194
17	Montano	(in Albuquerque)	35.14528819	-106.6803699
6	Savannah	(in Albuquerque)	35.14285294	-106.6819814
2	RGNC	(in Albuquerque)	35.12675286	-106.6884322
20	Route 66	(in Albuquerque)	35.10066114	-106.6923499
23	BioPark	(in Albuquerque)	35.078725	-106.6679472
8	HCC	(in Albuquerque)	35.06881267	-106.6580575
29	AOP	(in Albuquerque)	35.047531	-106.664012
13	Harrison	(in Albuquerque)	35.01505603	-106.6736953
31	San Jose	(in Albuquerque)	35.01217	-106.67384
28	Valle de Oro	(in Albuquerque)	34.978951	-106.680137
30	State Land Office	(in Albuquerque)	34.967198	-106.685649
27	Bosque Farms		34.84885	-106.7147222
3	Los Lunas		34.81236936	-106.7144581
19	Reynolds Forest	(in Belen)	34.66065483	-106.7429525
18	Reynolds Cleared	(in Belen)	34.65966436	-106.7421328
15	Valencia Cleared	(in Belen)	34.64863444	-106.7391728
4	Belen	(in Belen)	34.6484315	-106.7377022
16	Valencia Forest	(in Belen)	34.64716225	-106.738482
25	Crawford	(in Belen)	34.64049722	-106.7420472
14	Sevilleta		34.25834233	-106.8831845
7	Lemitar		34.16703189	-106.8899486
34	River Realignment		33.822691	-106.841847
33	BDA		33.819652	-106.854001
26	Mesilla		32.24832778	-106.8210139

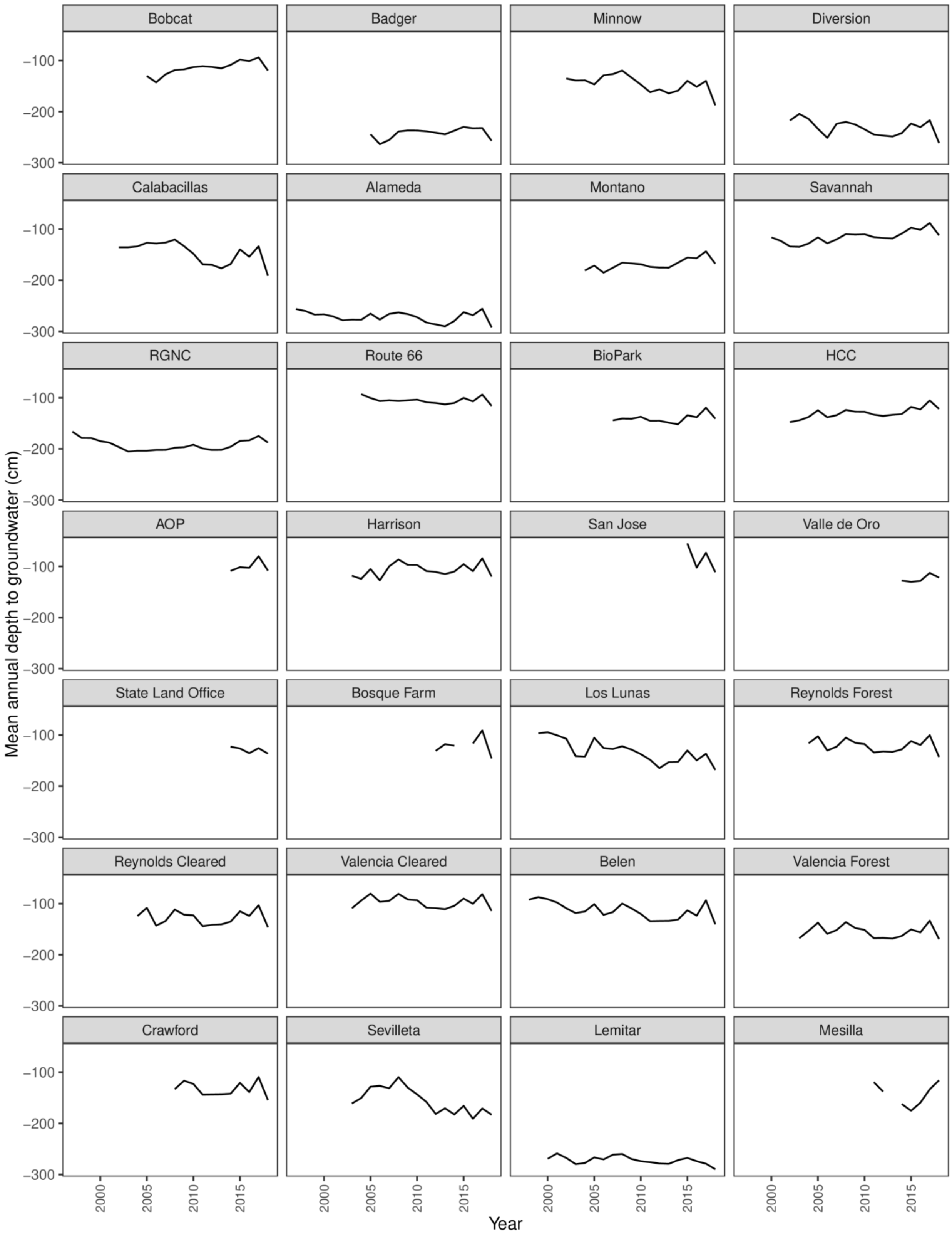

Figure 4. Annual mean depth to groundwater at each site, from the year of site installation (based on the first full year) to 2018. Pueblo of Sandia groundwater data are property of the Pueblo. Sites are listed from north to south.

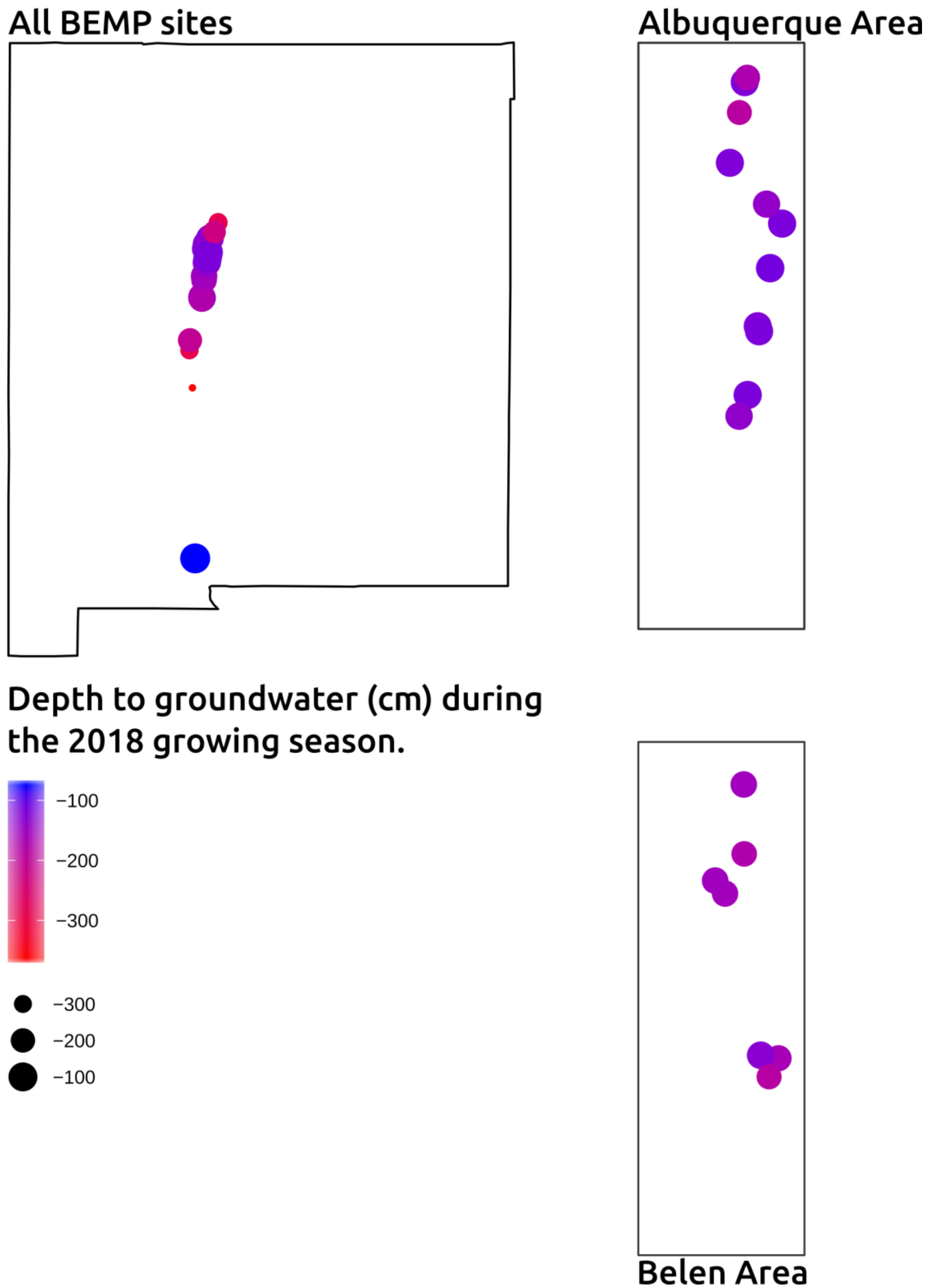

Figure 5. Depth to groundwater – trends map showing depth to groundwater across sites. Mean depth to groundwater is based on post-runoff growing season (July-September).

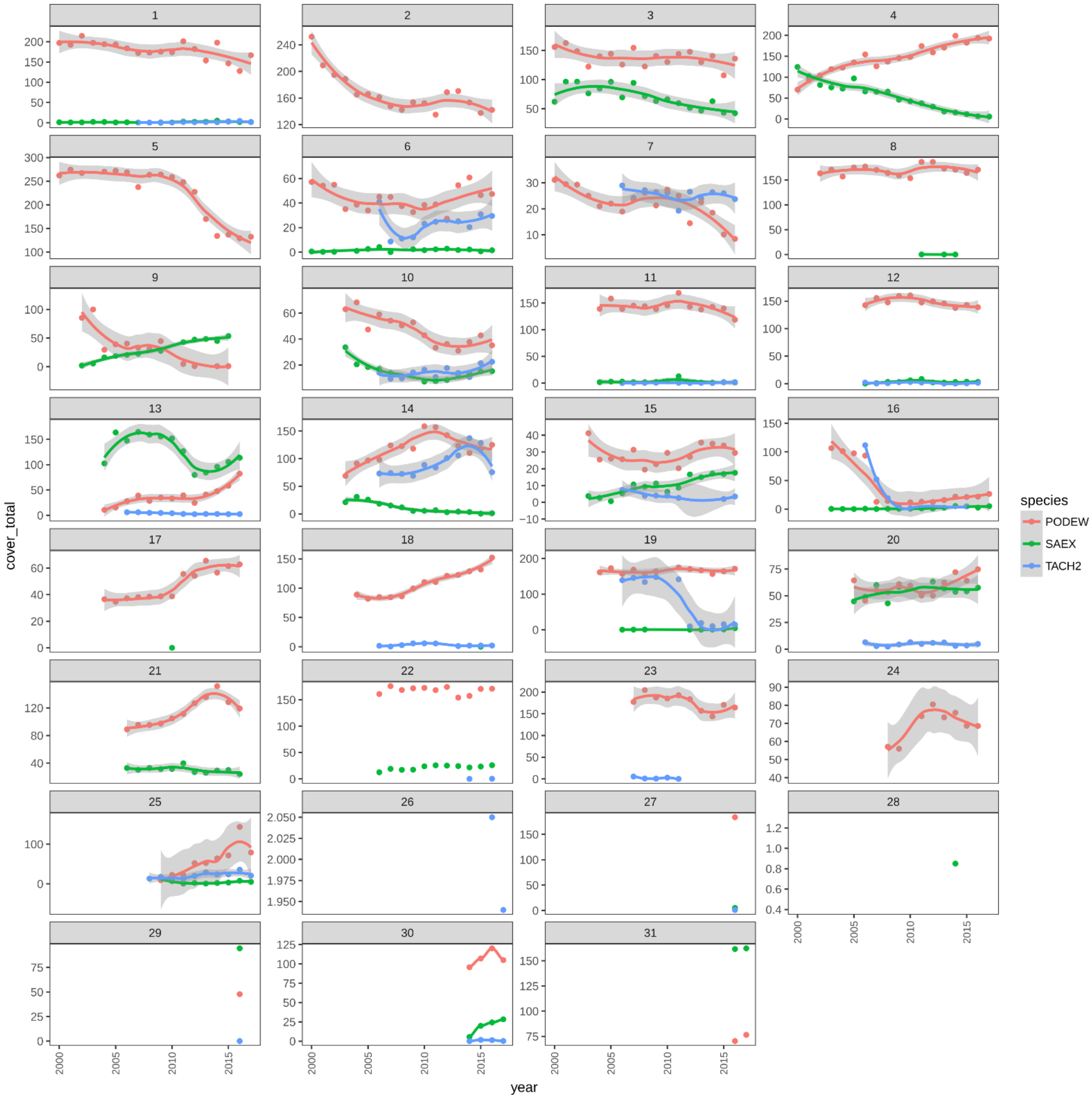

Figure 6. Cottonwood (PODEW, pink), coyote willow (SAEX, green), and saltcedar (TACH2, blue) litterfall across sites and years. Note that each y-axis is on a separate scale for the site. Sites numbers are listed in order of establishment; see Table 2, page 9 for site names based on site number.

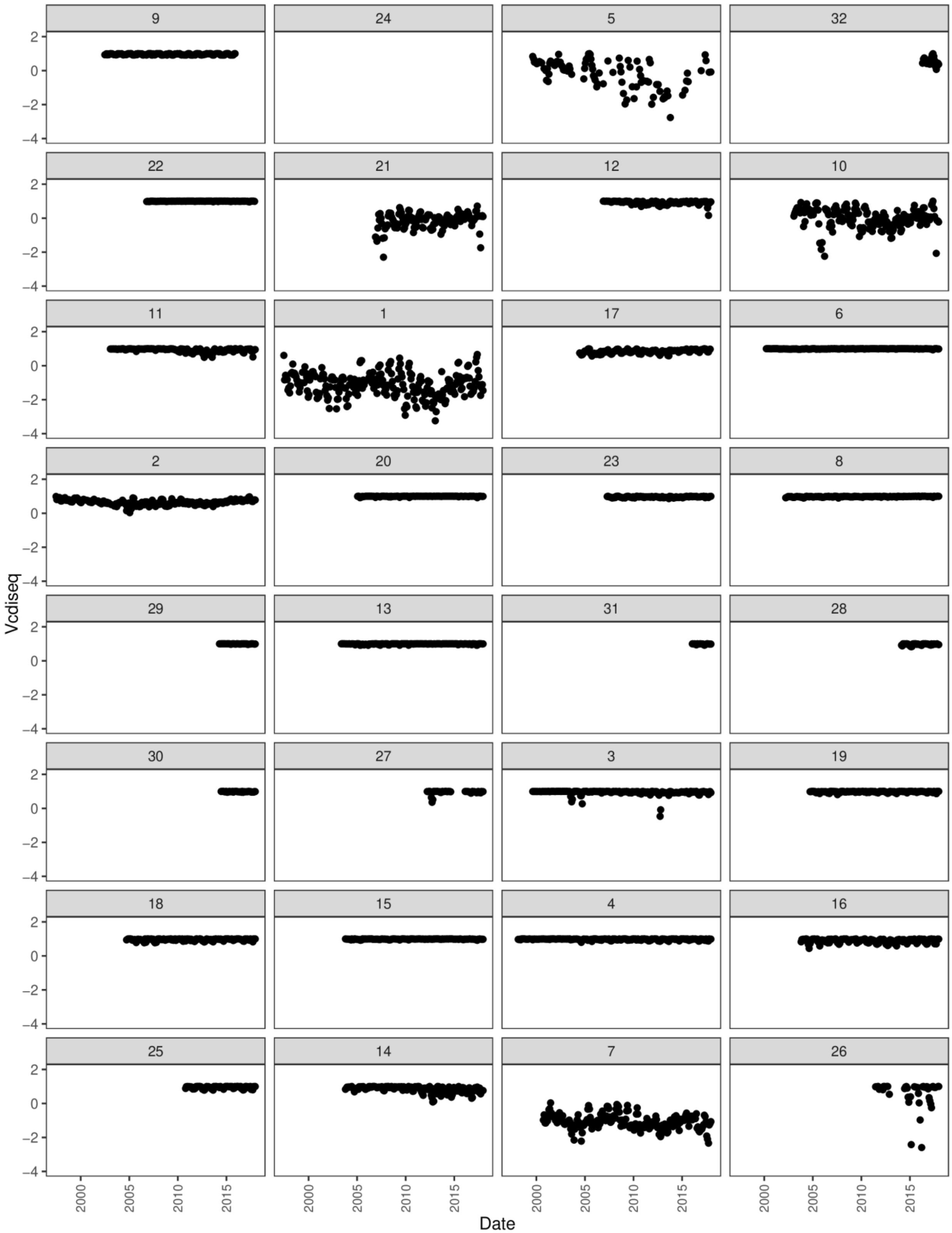

Figure 7. Carrying capacity disequilibrium values across the years for each site. The chaotic trends are indicative of site cottonwood senescence as carrying capacity (as determined by groundwater) is exceeded. Sites are listed from north to south.

Litterfall and Vegetation Cover

Thirteen sites have downward trends in cottonwood cover. Six sites are too new to have enough data to analyze trends. Five sites have stable trends, and seven sites have increasing cottonwood cover (Figure 6). The sites with increasing cover include flood sites with young cottonwoods (<40 years old) (Belen, Harrison, and Crawford), sites with created swales (Rt. 66), and sites with pole planting (Montaño, Reynolds Clear), and post-burn recovery (from root sprouts) sites (Valencia Forest and Montaño). Most sites have been actively managed for saltcedar. The sharp drop in saltcedar at Valencia Forest was following fire and post-burn clearing and the drop at Reynolds Forest was due to clearing.

Site Predictions and Temperature

Carrying capacity was calculated for sites based on the optimal groundwater depth for cottonwoods. The optimal depth was calculated using both maximum leaf production (NPP) based on litterfall and maximum cover based on vegetation cover for all sites with all years of data available for each site. Cottonwoods in this system have an optimal groundwater depth of 125 cm. Carrying capacity disequilibrium was plotted for each site (Figure 7), showing the variation between the optimal groundwater depth and the monthly depth to groundwater. Sites with the strongest disequilibrium or increasing distance from optimal groundwater (variation in points on Figure 7) are sites where cottonwoods have the strongest declines (Figure 6), providing a potential mechanism for predicting potential site health based on groundwater depth.

Analysis of cottonwood response to changing groundwater and temperatures shows that cottonwoods are more sensitive to changes in groundwater level under warmer conditions (Figure 8).

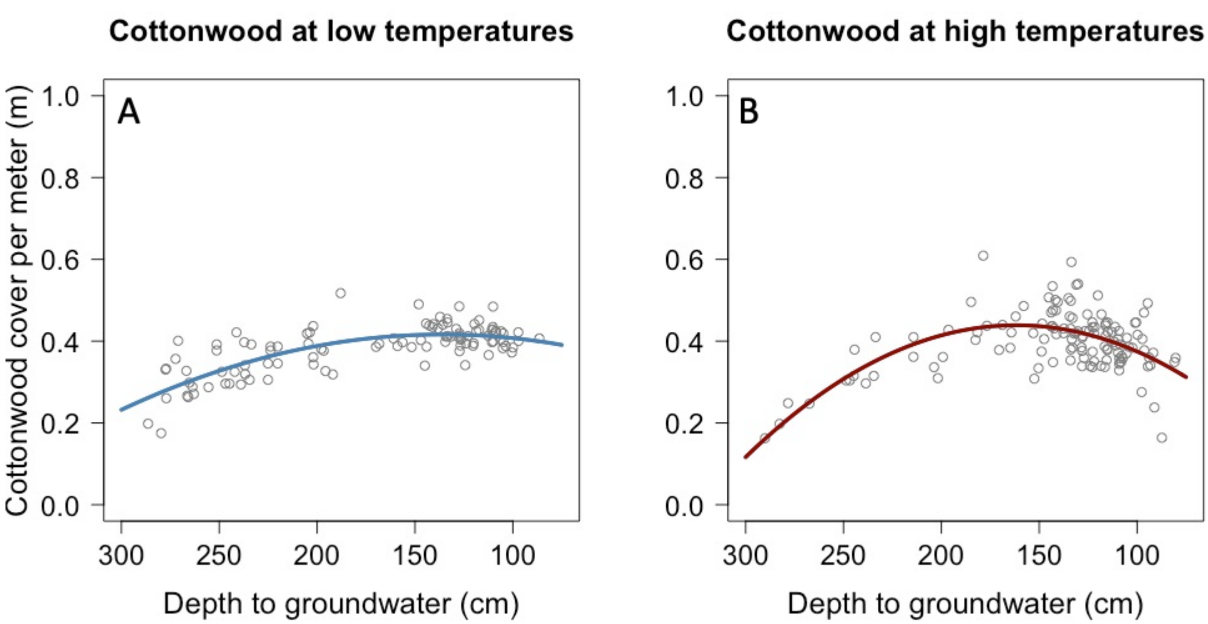

Figure 8. Cottonwood sensitivity to changes in depth to groundwater under (A) low temperature—below the 20 year mean and (B) high temperature—above the 20 year mean. (Figure from Steinberg et al. 2019)

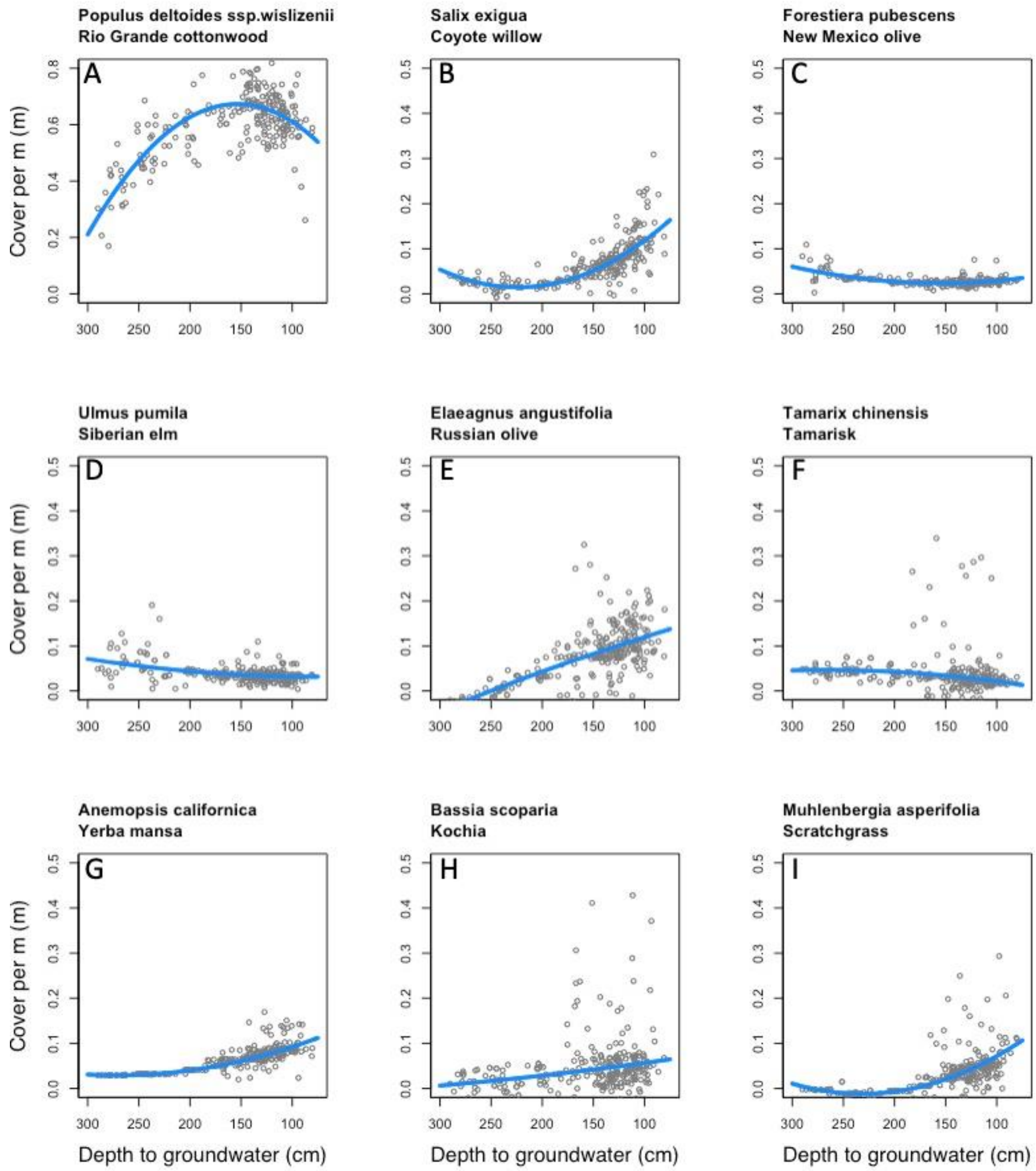

Figure 9. Groundwater sensitivity functions for nine plant species. Graphs show plant cover with changing depth to groundwater (deeper water table is on the left, with shallow water table on the right). "Concave functions predict a negative response to groundwater variability, convex functions predict a positive response. Linear functions indicate a possible response to mean groundwater levels, but not variability" (Steinberg et al. 2019).

Analyzing nine dominant species for plant response to changes in groundwater shows that cottonwood (Figure 9A) is sensitive to both deep and shallow groundwater levels, while coyote willow (Figure 9B) does better as groundwater variation increases. New Mexico olive (Figure 9C) and Siberian elm (Figure 9D) are not sensitive to changes in depth to groundwater. Russian olive (Figure 9E) is dependent on shallower groundwater levels and declines as groundwater levels decline.

Shifting plant response to changes in water availability due to the interaction of temperature is one of the areas of modeling that BEMP will be pursuing. Extreme temperature days (days over 100˚F or 38˚C) are not always concentrated at the southern sites, as some Albuquerque sites with low canopy cover and proximity to bridges can have more extreme temperature days than sites to the south (Figure 10).

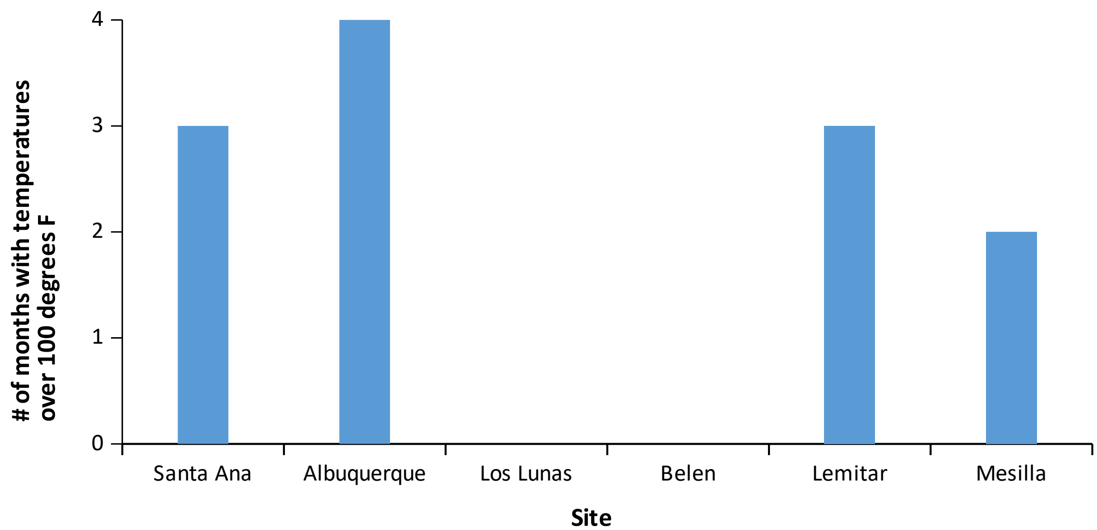

Figure 10. Extreme temperature months in 2017: number of months in six areas (based on 11 BEMP sites) with at least one day over 100˚F (38˚C). The four months at Albuquerque are driven by one of the six sites (Rio Grande Nature Center).

Tamarisk Leaf Beetle (TLB)

BEMP has continued to observe a boom and bust cycle of TLB. In 2018, the highest abundance of adult TLB were found in the northern sites at the Santo Domingo Pueblo and Sandia Pueblo (Figure 11). Similar to when BEMP began monitoring in 2013, the Santo Domingo Pueblo again had the greatest TLB abundance of any BEMP site sampled (Figures 11 & 12). In 2018, BEMP recorded minimal presence of TLB at Albuquerque sites, with less than 5 adults total in the Albuquerque area (Figure 13). BEMP recorded a moderate TLB presence in Valencia County and as far south as the Bosque Del Apache National Wildlife Refuge (Figures 11 & 13). This differed from 2017, when the highest abundance of adult TLB was in the southernmost sites, including presence at the Mesilla Valley Bosque State Park in Las Cruces for the first time. In all BEMP sites sampled, from north of Albuquerque, Albuquerque, Valencia County and south of Valencia County, total TLB captures have declined since 2013 (Figure 14). This year, the 17th site (Mesilla) was dropped, as it was monitored by Matt Johnson from Northern Arizona University, and four sites were added for sampling in September. Only one of the four sites had TLB present in September, and only larvae were present (at site 20, Rt. 66). This is not visible on the graph, which in log scale shows the one larva present in September as only a fine line on the graph (Figure 13).

2018 is the first year BEMP has observed tamarisk mortality at any continuously monitored site. At the Santo Domingo pueblo, the site experienced high TLB abundance in both 2013 and 2018 and tree # 5 failed to recover foliage after a full sampling season (Figure 15). The mortality is likely from the impact of the beetle as the surrounding vegetation remains unaffected and there is no indication of another obvious environmental stressor.

Phenology

One of the impacts of high TLB numbers can be seen in the litterfall data. Since the arrival of the beetle, tamarisk trees experience TLB defoliation in the summer months (June, July), refoliate, and then drop their leaves again in the fall (November). At sites with abundant saltcedar, we observe an overall increase in the amount of saltcedar litterfall. Additionally, there is a change in the natural timing of the leaf fall from November to summer months (and then again in fall). This has direct implications for habitat quality provided by saltcedar thickets, implications for the health of the trees themselves, and implications for overall fine fuel load in the bosque.

Weevils

BEMP collects other tamarisk specialists including the splendid weevil (*Coniatus splendidulus*). Maximum weevil presence (May and June) overlapped only slightly with high TLB adult presence (June and July). Weevil presence did not follow the same regional pattern as the TLB; instead, highest abundances occurred in the more southern research sites with a moderate presence in Albuquerque sites (Figure 16). All BEMP specimens are preserved at UNM and available for any further research by interested partnering groups.

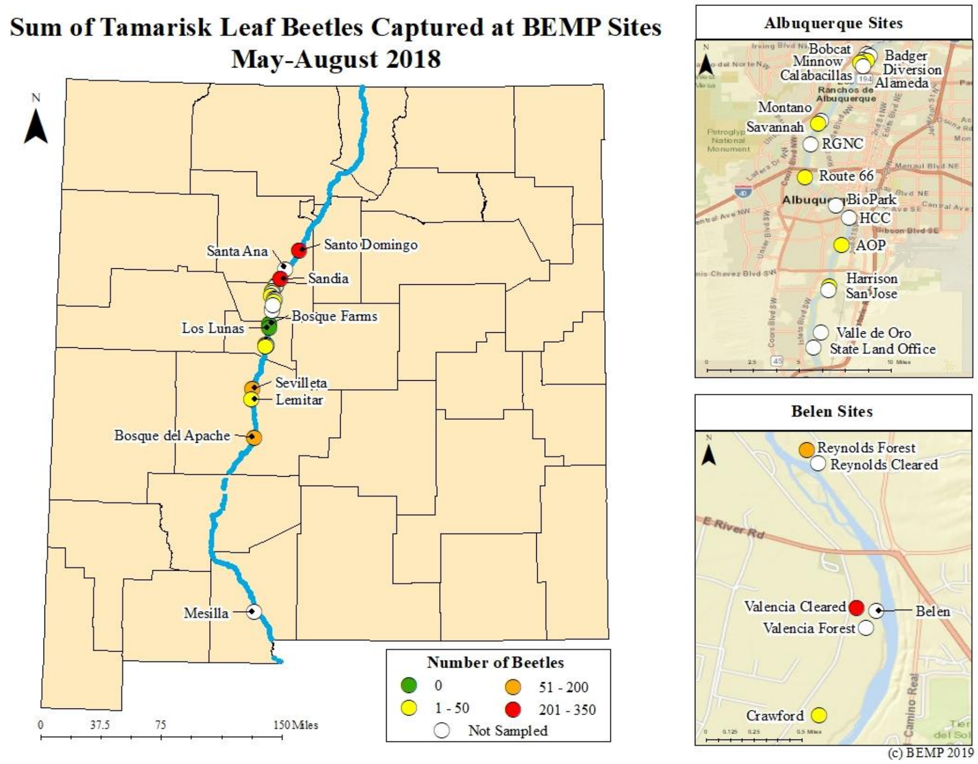

Figure 11. Sum of TLB from May- August across 16 sampled BEMP sites for 2018.

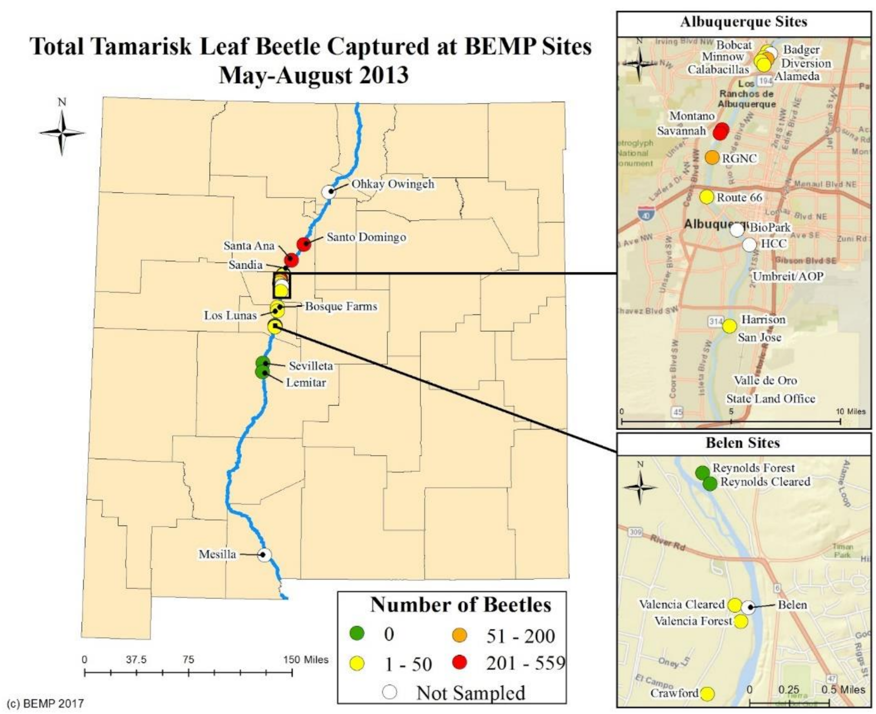

Figure 12. Sum of TLB from May- August across 20 sampled BEMP sites for 2013.

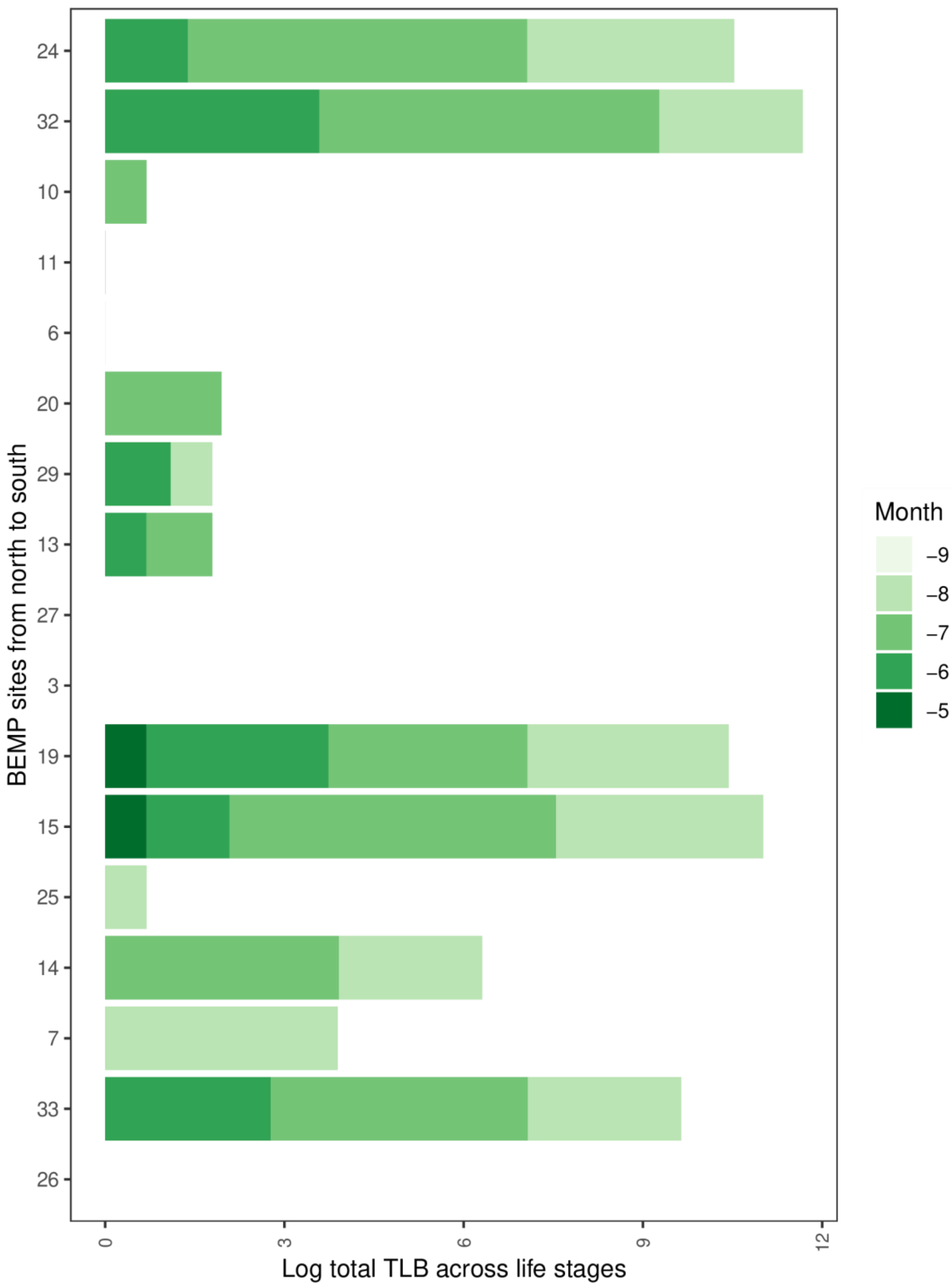

Figure 13. Total TLB (larvae and adults) collected in May – August for 16 sites and May – September at 4 sites (Sandia, Diversion, Rt. 66, and Crawford). TLB numbers are shown on a log scale. Sites with zeros were sampled but had no TLB in 2018.

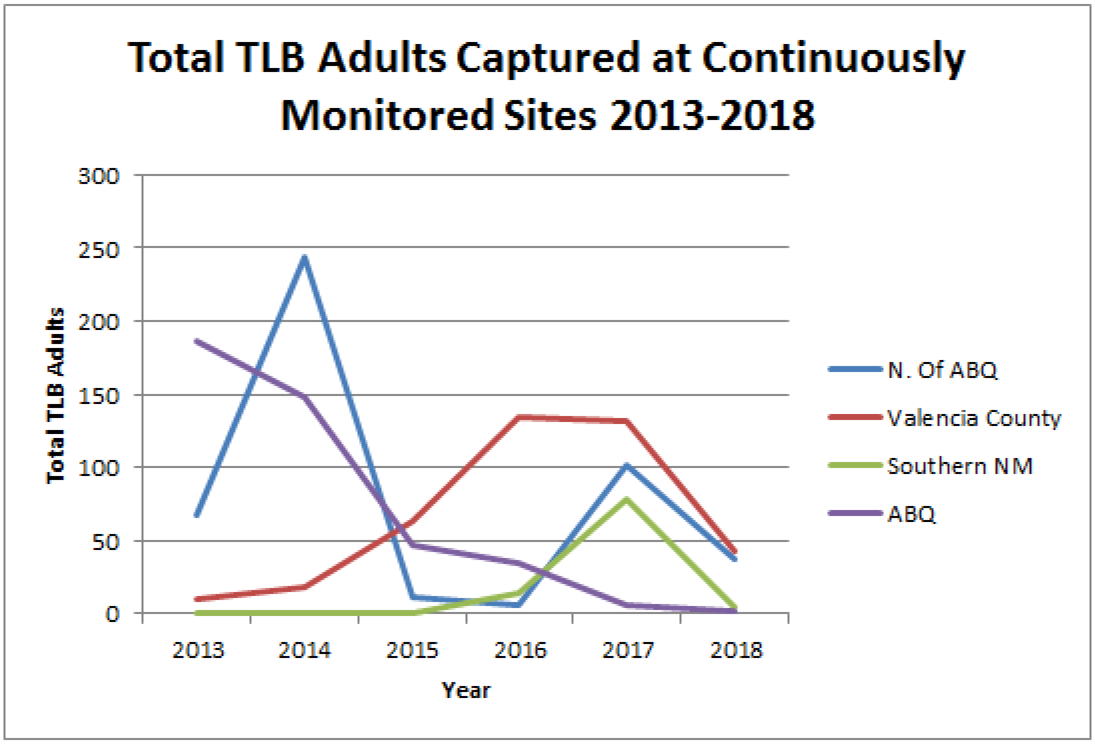

Figure 14. Total TLB captured at 16 continuously monitored sites by region from 2013-2018.

Figure 15. August 2017 (left) and 2018 (right) at Santo Domingo; first record of tree mortality likely from TLB.

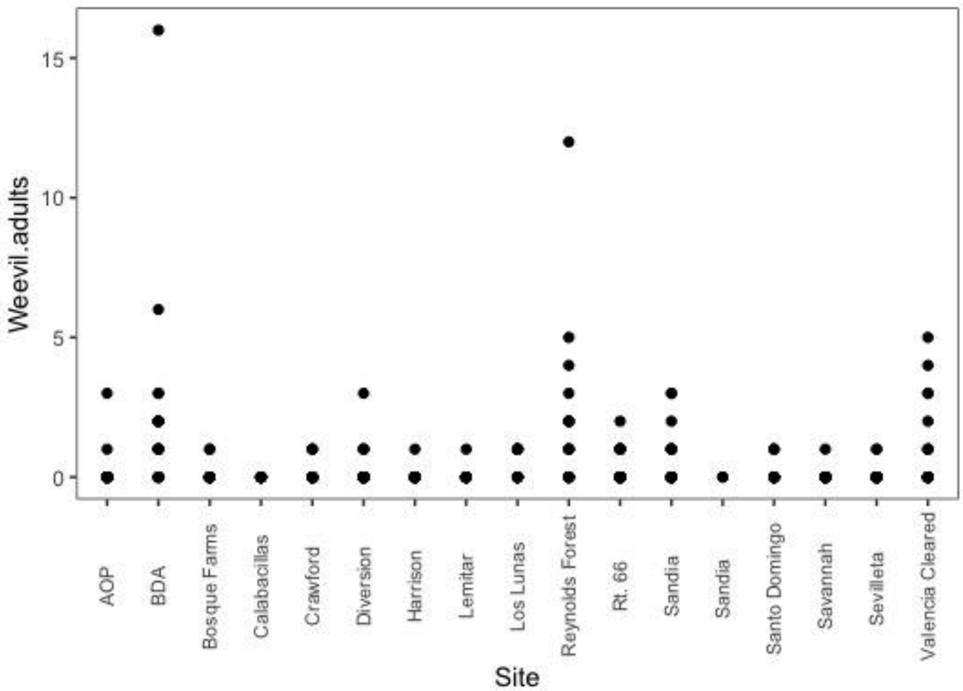

Figure 16. Adult weevil abundance across sites and months. Sites are listed in alphabetical order.

Surface-Active Arthropods

Analyses of the relationship between sites and the occurrence of ground beetles (Carabidae) and darkling beetles (Tenebrionidae), two indicator families that occur in the riparian forest. Carabidae are typically predators that prefer wetter areas, and Tenebrionidae are typically detritivores and prefer a variety of habitats, including drier mesa and desert areas. When analyzed together, the dendrogram shows certain lumping of both sites and species (Figure 17). Species names and associated codes are given in Table 3. Some of the lumping is driven by separate, unique species occurring at different sites. Belen, Harrison, Rt. 66, Crawford, and Reynolds Forest are sites that are lumped together as similar sites. All but Reynolds Forest are restoration sites that have bank lowering or swales.

Roly-polies (*Armadillidum vulgare*) are terrestrial isopods that rely on moisture and litter cover for survival. Roly-polies are detritivores, relying on litter for habitat and forage. As cottonwood leaf production declines and habitats dry out, we expect to see declines in isopods, thought likely delayed as increasing ground litter will initially be beneficial to survival and reproduction (Figure 18).

Crickets (Gryllidae) are the native detritivores that were largely replaced by the introduction of isopods. Cricket captures are very stochastic due to the use of live pit-trapping collection methods and the ability of crickets to jump out, but are overall declining at sites with declining cottonwoods (Figure 19).

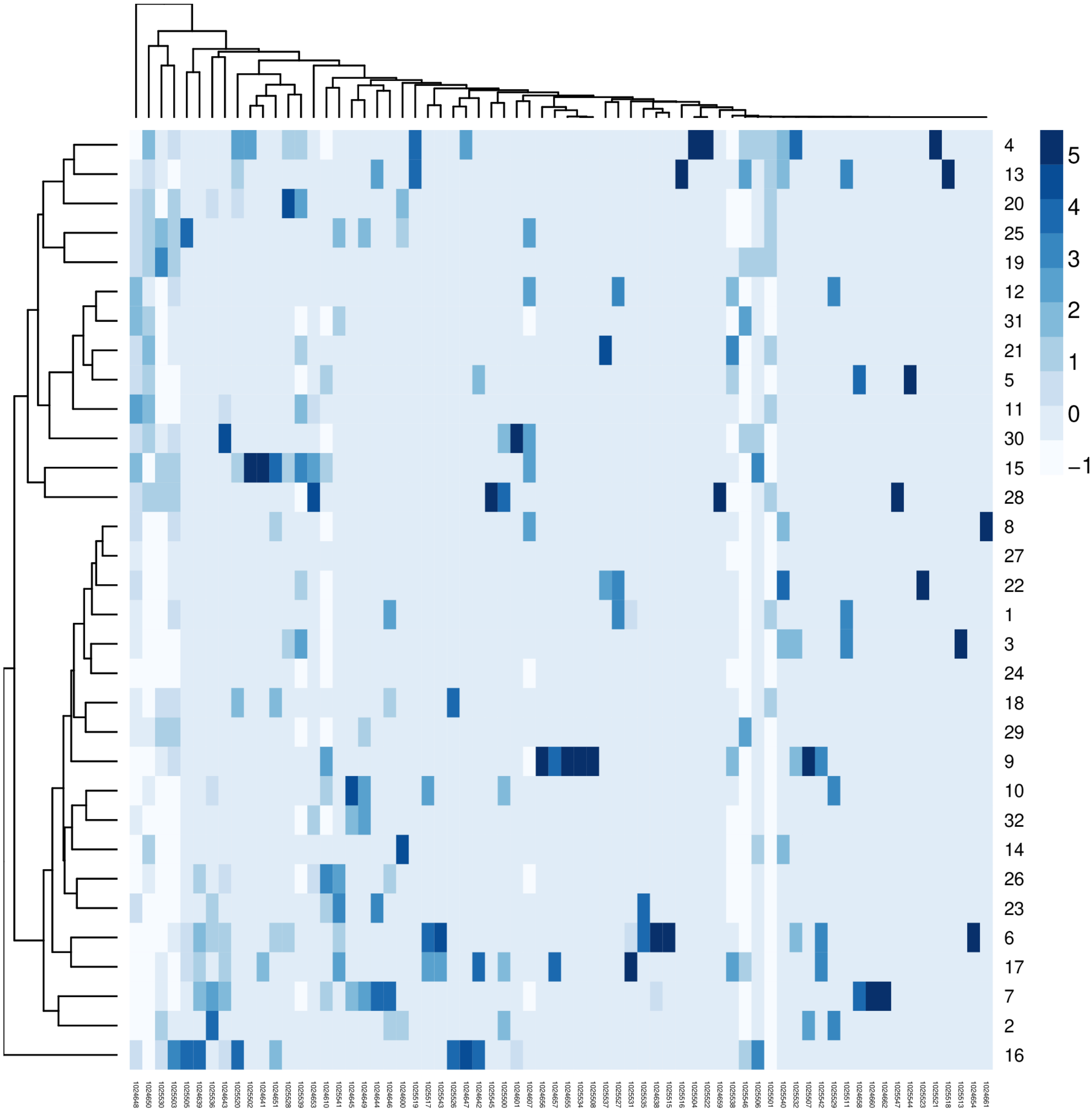

Figure 17. Dendrogram graph of relatedness between sites (primary and secondary y-axes) and Carabid and Tenebrionid beetles (primary and secondary x-axes). Sites are lumped together based on similarity.

Table 3. List of arthropod (beetle) codes and species names for Figure 17.

Tenebrionidae	1024600
Eleodes_sp	1024601
Eleodes_suturalis	1024607
Eleodes_fusiformis	1024610
Eleodes_gracilis	1024638
Eleodes_obsoletus	1024639
Eleodes_extricatus	1024641
Eleodes_longicollis	1024642
Eleodes_sponsus	1024643
Metoponium_sp	1024644
Asidopsis_opaca	1024645
Blapstinus_sp	1024646
Embaphion_sp	1024647
Blapstinus_fortis	1024648
Araeoschizus_decipiens	1024649
Blapstinus_pimalis	1024650
Embaphion_contusum	1024651
Lobometopon_fusiformis	1024653
Eusattus_sp	1024654
Eleodes_tricostatus	1024655
Neobaphion_planipennis	1024656
Eusattus_reticulatus	1024657
Eleodes_caudiferus	1024658
Lobometopon_sp	1024659
Araeoschizus_sp	1024660
Alleculinae	1024661
Scaphidiinae	1024800

Carabidae	1025500
Scarites_sp	1025501
Poecilus_chalcites	1025502
Calathus_opaculus	1025503
Chlaenius_sp	1025504
Amara_sp	1025505
Carabid_larva	1025506
Stenolophus_sp	1025507
Harpalus_pennsylvanicus	1025508
Scarites_lissopterus	1025511
Amara_carinata	1025513
Agonum_sp	1025515
Chlaenius_tricolor	1025516
Agonum_decorum	1025517
Tachys_sp	1025518
Chlaenius_sericeus	1025519
Pterostichus_sp	1025520
Bradycellus_sp	1025521
Bembidion_timidum	1025522
Bembidion_sp	1025523
Galerita_janus	1025526
Cyclotrachelus_substriatus	1025527
Poecilus_sp	1025528
Rhadine_sp	1025529
Harpalus_sp	1025530
Pasimachus_elongatus	1025531
Anisodactylus_harrisi	1025532
Cratacanthus_sp	1025534
Euryderus_sp	1025535
Selenophorus_sp	1025536
Calosoma_scrutator	1025537
Pasimachus_californicus	1025538
Poecilus_lucublandus	1025539
Tetragonoderus_sp	1025540
Cyclotrachelus_sp	1025541
Cymindis_sp	1025542
Pasimachus_sp	1025543
Calosoma_peregrinator	1025544
Harpalus_caliginosus	1025545
Scarites_subterraneus	1025546
Calosoma_sp	1025547

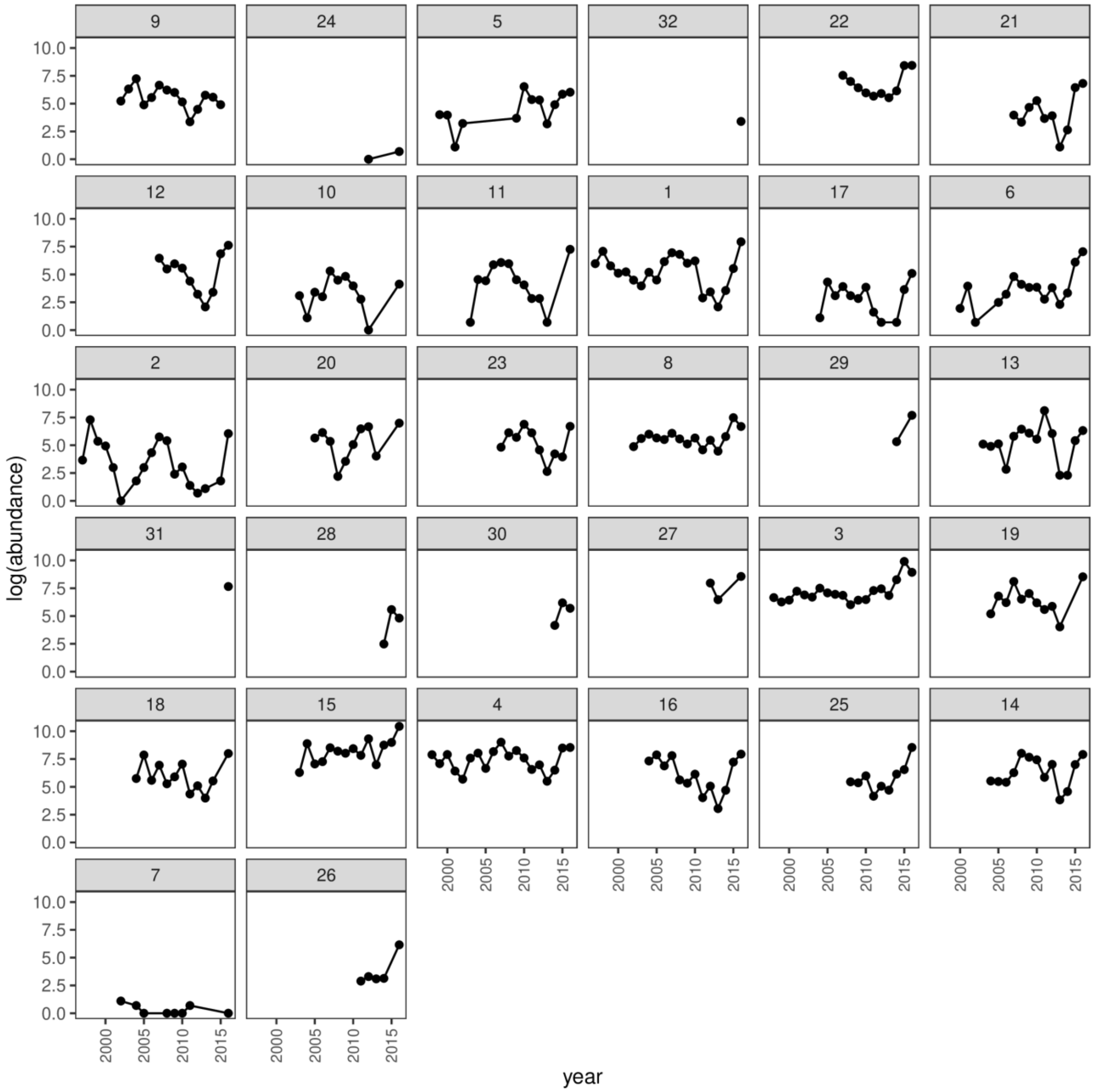

Figure 18. Roly-poly (*Armadillidum vulgare*) captures over time at BEMP sites (north to south). For list of site names, see Table 2, page 9.

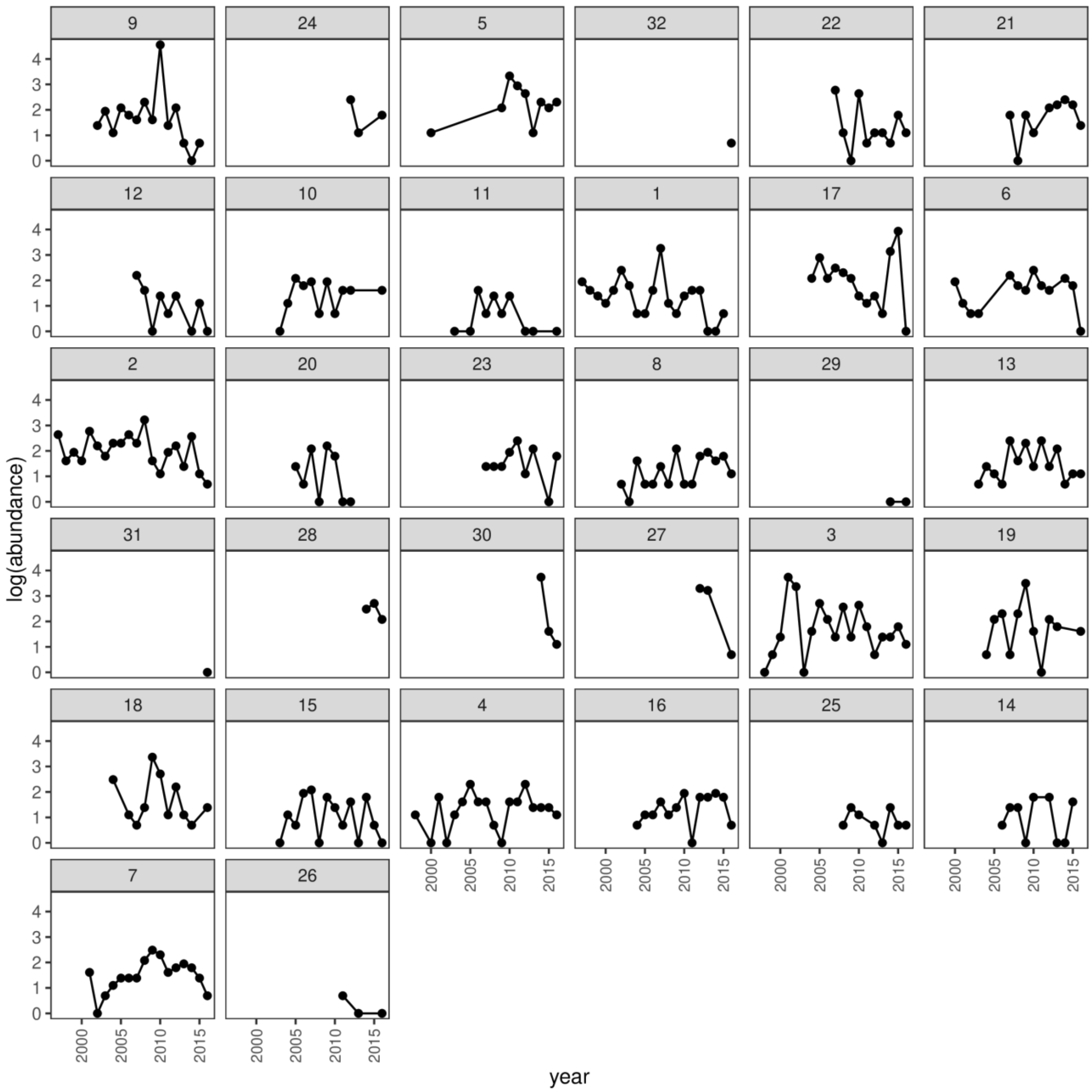

Figure 19. Cricket abundance at sites from north to south over time. For list of site names, see Table 2, page 9.

Implications for Management:

As variability in groundwater levels increases (based on increasing variability in river flows), cottonwoods will decline, especially under warmer temperatures. Species like Siberian elm are not as sensitive to variability in groundwater levels or changes in groundwater means. Coyote willow cover increases under increasingly variable groundwater levels, although they still require high groundwater levels to become established. Sites with low water tables have declining cottonwood populations and are more likely to support herbaceous species, especially under warmer temperatures. Herbaceous species are also more likely to thrive with higher precipitation at these sites, although many upland and desert species will do well once established.

Acknowledgements:

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

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