

PECOS SUNFLOWER

(Helianthus paradoxus)

2013 - 2021 Monitoring Report

Blue Hole Ciénega Nature Preserve and Milagro Ciénega
Santa Rosa, NM



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INTRODUCTION

Pecos sunflower (*Helianthus paradoxus* Heiser) is an annual wetland plant that grows on wet, alkaline soils in spring seeps, wet meadows (ciénegas), and along stream courses and pond margins (USFWS 2005). It is known from seven widely spaced populations in west-central and eastern New Mexico, and adjacent Trans-Pecos Texas. Incompatible land uses, habitat degradation and loss, and groundwater withdrawals are historic and current threats to the survival of Pecos sunflower.

Pecos sunflower was listed Threatened under the Endangered Species Act of 1973 (ESA), as amended, on October 20, 1999 (64 FR 56582-56590). The U.S. Fish and Wildlife Service (USFWS) designated Blue Hole Ciénega as Critical Habitat for Pecos sunflower in 2008 (73FR 17762-17807). In addition, the State of New Mexico lists Pecos sunflower as endangered under the New Mexico Endangered Plant Species Act (19 NMAC 21.2), and it is listed threatened by the State of Texas (31 TAC 2.69(A)). NatureServe ranks Pecos sunflowers globally and state imperiled (G2/S2). The New Mexico Rare Plant Conservation Strategy gives the species an overall conservation rank of ‘moderately conserved’ due to moderate to high threat scores and a limited distribution (EMNRD – Forestry Division 2017).

The USFWS Recovery Plan grouped the seven populations of Pecos sunflowers into 4 disjunct recovery regions, including the Santa Rosa region in eastern New Mexico (USFWS 2005, Figure 1). The recovery strategy is to protect and manage significant, sustainable portions (termed “core conservation areas”) of each of the four region’s sunflower habitats against the threat of

future habitat loss and degradation. At least one core conservation area and one isolated stand of Pecos sunflower need to be protected in each region to meet the recovery criteria. All core conservation habitats must contain good or excellent populations. For a population to be ranked excellent several hundred thousand individuals need to be present. A good population for Pecos sunflower recovery purposes is a stand of at least 5,000 individuals during most (7 out of 10) years. Blue Hole Ciénega Nature Preserve was identified as a core conservation area for the Santa Rosa Recovery Region (Figure 1). Milagro Ciénega was identified as the secondary isolated stand of Pecos sunflower in the Santa Rosa recovery region (Roth 2014). It is located approximately 0.5 miles SE of Blue Hole Ciénega (Figure 2).



Figure 1. Distribution of Pecos sunflowers and location of the USFWS Santa Rosa Recovery Region (USFWS 2005).

Description



Pecos sunflower is an annual, herbaceous plant that can grow up to 10ft tall (USFWS 2005). The leaves are opposite on the lower part of the stem and alternate at the top, lance-shaped with three prominent veins, and up to 6.9 inches long by 3.3 in wide. The stem and leaf surfaces have a few short, stiff hairs. Flower heads are 2.0-2.8 inches in diameter with bright yellow rays around a dark purplish brown center. Pecos sunflowers flower for a short period during the monsoon season, from late August to October, depending on geographic location.

Associated species include *Distichlis spicata* (saltgrass), *Sporobolus airoides* (alkali sacaton), *Phragmites australis* (common reed), *Sorghastrum nutans* (Indiangrass), *Schoenoplectus americanus* (chairmaker's bullrush), *Juncus balticus* (Baltic rush), *Muhlenbergia asperifolia* (alkali muhly), *Apocynum cannabinum* (dogbane), *Baccharis salicina* (Great Plains seep-willow), *Limonium limbatum* (southwestern sea lavender), *Flaveria chlorifolia* (clasping yellowtops), and *Solidago canadensis* (goldenrod). Other associated rare and endangered plants include *Cirsium wrightii* (Wright's marsh thistle) and *Spiranthes magnicamporum* (Great Plains lady's tresses).



Figure 2. Location of Blue Hole Ciénega and Milagro Ciénega in Santa Rosa, NM.

Habitat

Pecos sunflower is a wetland plant that grows in areas with permanently saturated soils in the root zone (USFWS 2005). These are most commonly desert springs and seeps that form wet meadows called ciénegas, which occur at elevations between 3,300 and 6,600 ft. This sunflower can also occur around the margins of lakes, impoundments, and creeks. The soils of these desert wetlands are typically saline or alkaline and are predominantly silty clays or fine sands with high organic matter content. Although Pecos sunflowers grow in saline soils, seeds germinate and establish best when high water tables and precipitation reduce salinity near the soils' surface (Van Auken and Bush 1995).

Distribution

Pecos sunflower has a highly disjunct distribution and is known from only seven populations, two in west Texas and five in New Mexico (USFWS 2005). The Santa Rosa Artesian Basin is occupied by the City of Santa Rosa, which has more wetlands than any other New Mexico municipality with several sinkhole lakes and wetlands (Sivinski 2018). There are at least 8 wetland sites with documented Pecos sunflowers in the Santa Rosa Recovery Region in Guadalupe County, including the primary core conservation area at the Blue Hole Ciénega Nature Preserve, which may reach a hundred thousand plants or more in good years. Cut and herbicide treatments in recent years at the Milagro Ciénega, as well as additional fencing and a prescribed fire, have increased sunflower populations at this site to several hundred thousand plants as well. Milagro Ciénega (formerly City Ciénega) is the designated secondary isolated population for the Santa Rosa Recovery Region (Roth 2014). It is likely that the majority of the now disjunct Pecos sunflower sites in the Santa Rosa Basin was once one large population growing in a very large ciénega, now highly fragmented by roads and urban development. Land ownership of extant ciénegas is private, City of Santa Rosa and State (EMNRD-Forestry Division). Currently most occupied Pecos sunflower habitats in the Santa Rosa area are limited to patches of less than 13 acres of continuous wetland, depending on climatic conditions during any given year. The number of sunflowers per site can vary from a few plants to several hundred thousand. Because Pecos sunflower is an annual plant, the number of plants per site can fluctuate greatly from year to year with changes in precipitation, disturbance regime, and depth to ground water levels during early spring when plants germinate and establish.

1. BLUE HOLE CIÉNEGA NATURE PRESERVE

The 116-acre Blue Hole Ciénege Nature Preserve in Santa Rosa was acquired by the EMNRD-New Mexico Forestry Division in 2005 with funds from a USFWS Recovery Land Acquisitions grant and a mitigation settlement from the NM Department of Transportation. It is managed by the Forestry Division for the sole purpose of protecting and enhancing the Pecos sunflower population and other rare and endangered wetland plants. Management actions and associated research inform the types of management and land uses that are beneficial for this species on Blue Hole Ciénege and elsewhere, including the removal of livestock, the ongoing management of invasive woody species (tamarisk, Siberian elm, Russian olive) through cut and herbicide treatments, and prescribed fires (Roth and Austin 2021).

METHODS

In response to observed declines in the number of Pecos sunflower plants following a massive hailstorm in June of 2013, the Forestry Division established 11 monitoring transects distributed throughout the 116-acre Blue Hole Ciénege, wherever plants occurred (Figure 3). Each transect measures 30 m x 2 m and is permanently marked by a metal t-post on either end. All permanent markers were mapped using a Garmin Monterra GPS. Annual monitoring occurs during the first 2 weeks of October, after the majority of sunflowers are done flowering and plants are senescent. Within each transect the number of plants is counted or estimated. Annual observations may include the observance of predators (insects, deer) or diseases, and the general vigor of plants in the transect, measured by average height of the plants. In addition, the perimeter of contiguous stands of sunflowers associated with the monitoring transects were walked in 2013, 2015, 2016, 2017, 2018, 2019, 2020, and 2021 using the tracking function of a Garmin Montana or Monterra GPS, to get a better understanding of population fluctuations between years. Area polygons are walked wherever plants are found surrounding the transect area in sufficiently large contiguous stands to be reasonably mapped. A stand is considered contiguous if plants are 5 m or less apart from each other. Following the prescribed burn in 2017, all contiguous stands of Pecos sunflowers were delineated on Blue Hole Ciénege to get a better understanding of sunflower distribution on the Preserve. Tracks were later converted to polygons and occupied habitat was calculated in acres using ArcMap.

In addition, a photopoint was established on the southwestern boundary of the Ciénega at the Knights of Columbus Center parking area, to provide visual documentation of sunflower abundance and distribution through time. Photos were taken in 2004, prior to the purchase and restoration of the Ciénega, in 2015, following several years of restoration treatments, in 2017, after a prescribed burn, and in 2019.

In the spring of 2019 monitoring of germination time and establishment of seedlings was initiated along the existing monitoring transects. Weekly field visits to determine the timing of germination began on February 12, 2019. Target areas were locations known to have had plants the previous year. One site was marked and checked during every visit at Blue Hole Ciénega. After this site was checked random areas were checked throughout the Ciénega. Based on information gathered, optimum time for seedling germination and establishment monitoring was determined to be mid-April. Annual seedling counts are conducted along the 11 existing monitoring transects at Blue Hole Ciénega. Five random numbers between 0 and 30 m are generated for each 30 m x 2 m transect. At these random numbers, a 1 x 1 m sampling frame is placed on the ground in the middle of the transect line and the number of seedlings rooted inside the sampling frame (subplot) are counted.

Other monitoring activities on Blue Hole Ciénega include rainfall (since July 2016), groundwater fluctuations (2014 - 2019, LeJeune 2018), and population trend monitoring of the endangered Wright's marsh thistle (*Cirsium wrightii*) (Roth 2021).

Ten water wells to measure groundwater fluctuations on the Ciénega were installed between 2010 and 2014 and instrumented with Solinst Edge Leveloggers (pressure transducers) (LeJeune 2018, Figure 4). Direct data read cables attached to pressure transducers were suspended from specialized Solinst well caps, and data was downloaded using a tablet from the well head using the Solinst Levelogger App Interface device. Field recording intervals were set at 15-minutes. Monitoring results inform our understanding of sunflower population fluctuations in response to management activities, rainfall, and groundwater fluctuations.

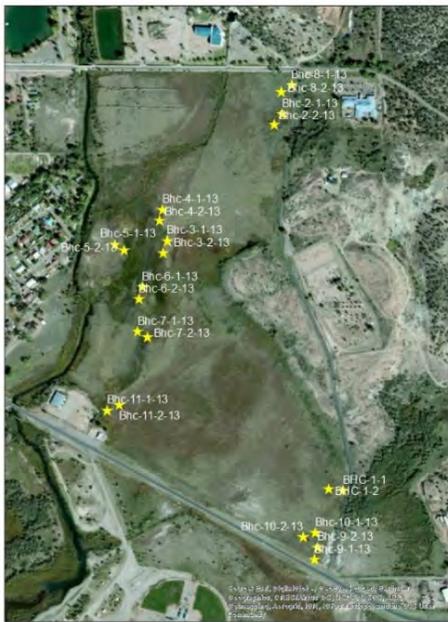


Figure 3. Locations of permanent Pecos sunflower transects at the Blue Hole Ciénega Nature Preserve in Santa Rosa.



Figure 4. Location of 10 ground water monitoring wells on Blue Hole Ciénega in Santa Rosa.

Since monitoring was initiated in 2013, the following management actions have been implemented on Blue Hole Ciénega (Roth and Austin 2021):

October / November 2013, 2014, 2017, 2018, 2019, 2020, 2021: Retreatment (cutting and spraying of Russian olive, tamarisk, and Siberian elm)

February 2017: Prescribed burn

RESULTS

The number of sunflowers within the 11 transects varied widely between the years of monitoring, ranging from a low of 1,731 plants in 2013 to a high of 8,064 in 2017 (Figure 5). Following the prescribed burn in February of 2017, the density of plants within the transects increased by 39% over the highest number counted during the previous 4 years (2014). Population numbers dropped significantly the following year, when only 1,737 plants were documented from the transects (Figure 5). Transect data corresponded with population

perimeters mapped near the monitoring transects. Plants only occupied a fraction of the habitat occupied in 2017 (Figure 6). In 2018, no plants were recorded in the 2 transects that contained the most sunflowers in 2017 (Table 1). However, the population expanded significantly in 2019, resulting in the second highest number of plants found in the 11 transects during all monitoring years (6,007 plants; Figure 5). Three of the 5 transects that contained no plants in 2018 were occupied again in 2019 and had some of the highest numbers of plants among the 11 transects (Table 1). Plants were found at low levels again in 2020 and 2021, three transects had no plants whatsoever.

No comprehensive data is available on the exact distribution of sunflowers on the Ciénega prior to the burn, but population perimeters were mapped surrounding the sunflower stands associated with monitoring transects in 2013, 2015, 2016, 2017, 2018, 2019, 2020, and 2021 (Figure 6). These support the documentation of significant fluctuations within the monitoring transects. The largest continuous sunflower stand found on Blue Hole Ciénega was 12.72 acres, following the prescribed fire in 2017. All sunflower stands on Blue Hole Ciénega were mapped in 2017 only, covering a total of 19.564 acres. Total occupied habitat surrounding the monitoring transects ranged between 0.141 acres in 2018 to 17.316 acres in 2017 (Figure 7). In 2021, sunflower stands associated with five monitoring transects covered a total of 4.93 acres on the Ciénega, which represented a significant decrease from 2020, despite the fact that the number of plants documented in the transects were similar (Figures 5, 7 & 8).

Repeat Photography

Despite extensive restoration efforts, including the removal of livestock, initial removal of large stands of Russian olives and other invasive woody plants, and a prescribed fire in 2008, 7 years after initial restoration treatments sunflower abundance appeared to be significantly lower in 2015, when compared to 2004 (Figure 9). In 2017, following a prescribed burn at the beginning of February, sunflower abundance and distribution appeared similar to those observed in 2004, or more. By 2019 sunflower distribution and abundance as observed from the photopoint location appeared to be retreating again, although clearly still more abundant than in 2015.

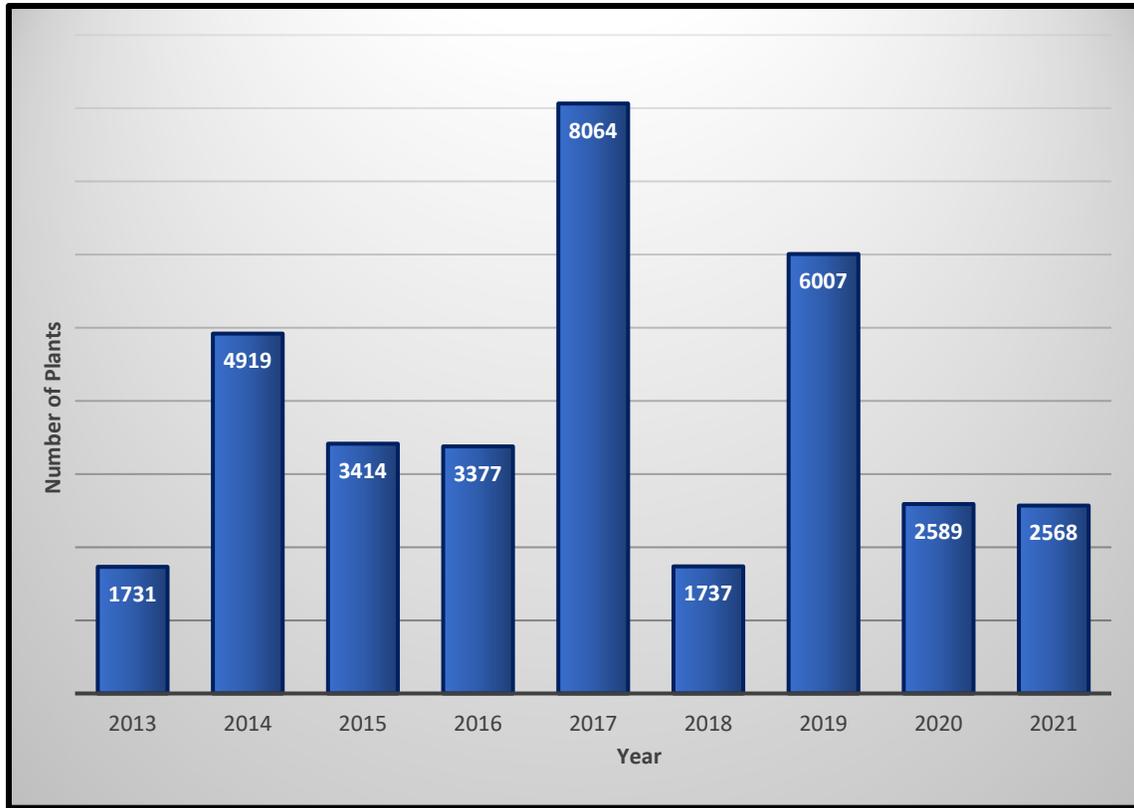
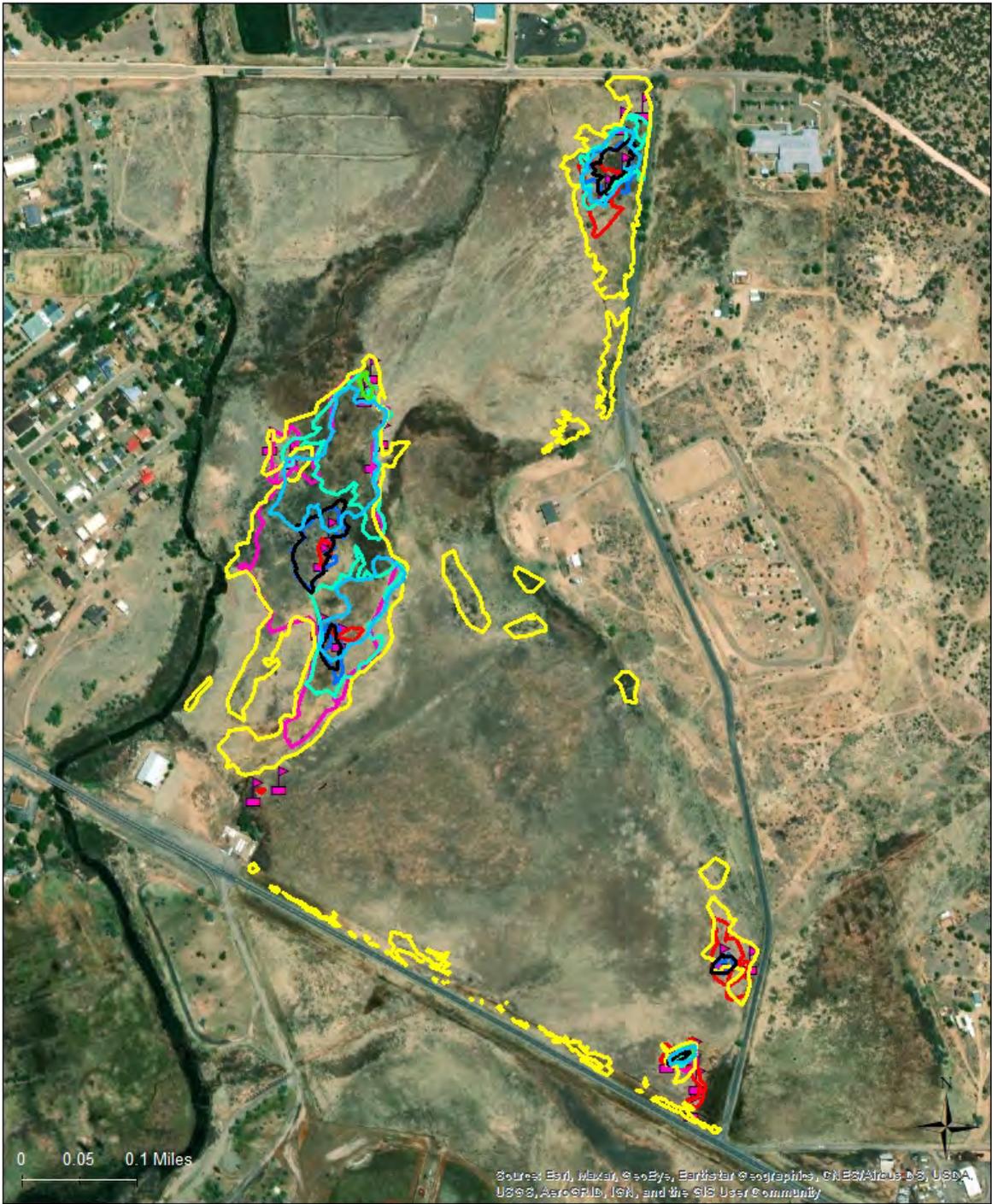


Figure 5. The total number of Pecos sunflower plants between 2013 and 2021, in 11 monitoring transects at Blue Hole Ciénega Nature Preserve in Santa Rosa, NM.

Table 1. Number of Pecos sunflower plants per transect from 2013 to 2021 at Blue Hole Ciénega in Santa Rosa, NM.

Transect	2013	2014	2015	2016	2017	2018	2019	2020	2021	Water Well
1	628	2481	493	233	249	47	19	1	0	None
2	198	1213	1276	1731	1072	147	287	323	447	BHC 1
3	0	65	0	14	153	28	24	33	105	BHC 3
4	2	0	0	0	76	161	15	10	42	None
5	0	0	0	0	51	0	250	53	7	None
6	59	278	896	924	2542	0	1131	0	7	None
7	9	125	21	74	2225	0	2293	1522	332	BHC 7
8	2	0	0	0	164	317	305	103	3	BHC 1
9	306	28	0	0	14	0	0	0	0	BHC 2
10	486	712	726	400	1508	1037	1683	544	1625	BHC 2
11	41	17	2	1	10	0	0	0	0	BHC 6
Total	1731	4919	3414	3377	8064	1737	6007	2589	2568	



— 2013 — 2015 — 2016 — 2017 — 2018 — 2019 — 2020 — 2021

Figure 6. Distribution of Pecos sunflowers surrounding the monitoring transects, 2013 – 2021, and throughout Blue Hole Ciénega in 2017.

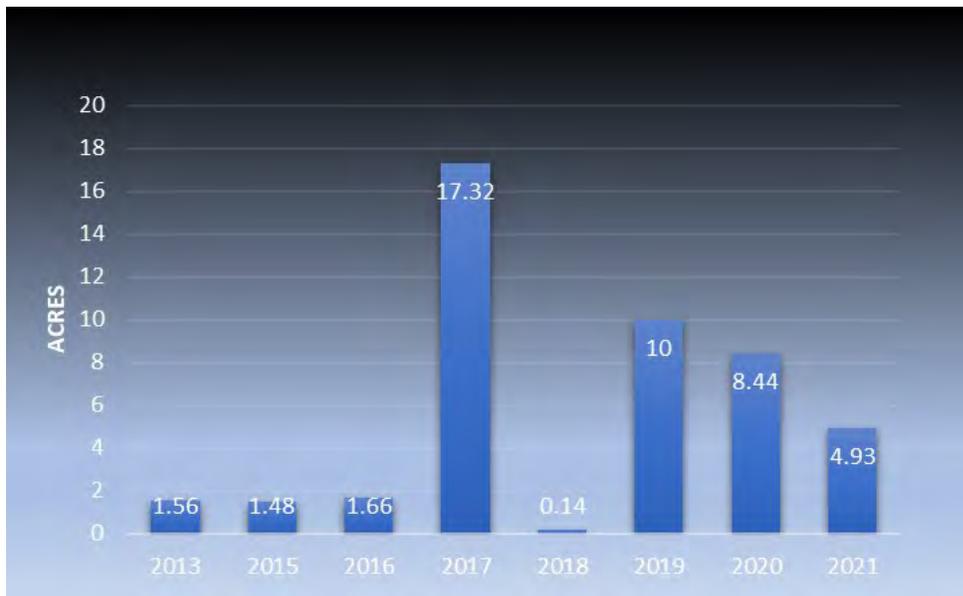


Figure 7. Fluctuations of occupied habitat surrounding 11 monitoring transects between 2013 and 2021.

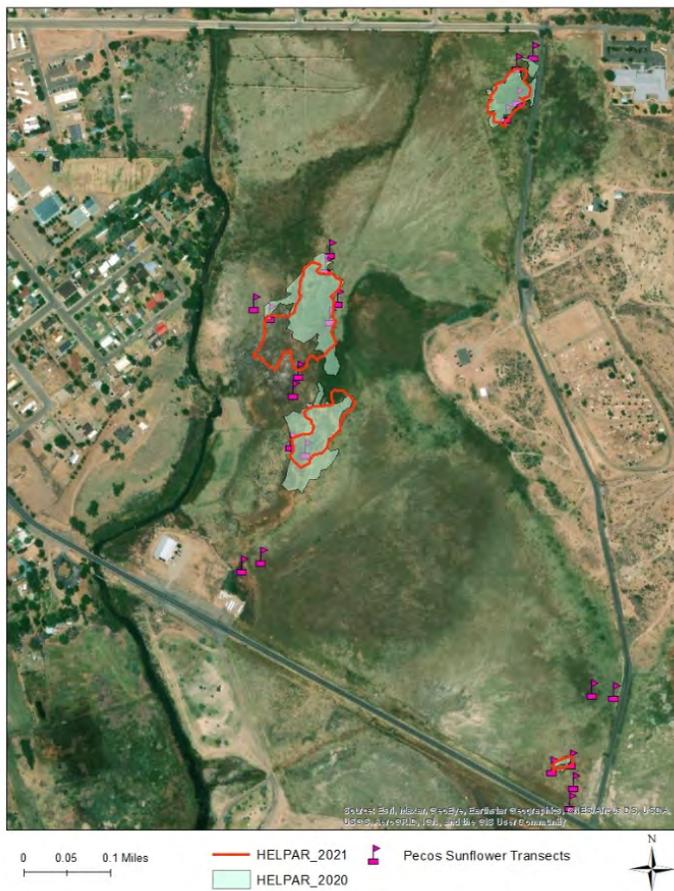


Figure 8. Changes in Pecos sunflower distribution in the vicinity of monitoring transects between 2020 and 2021.

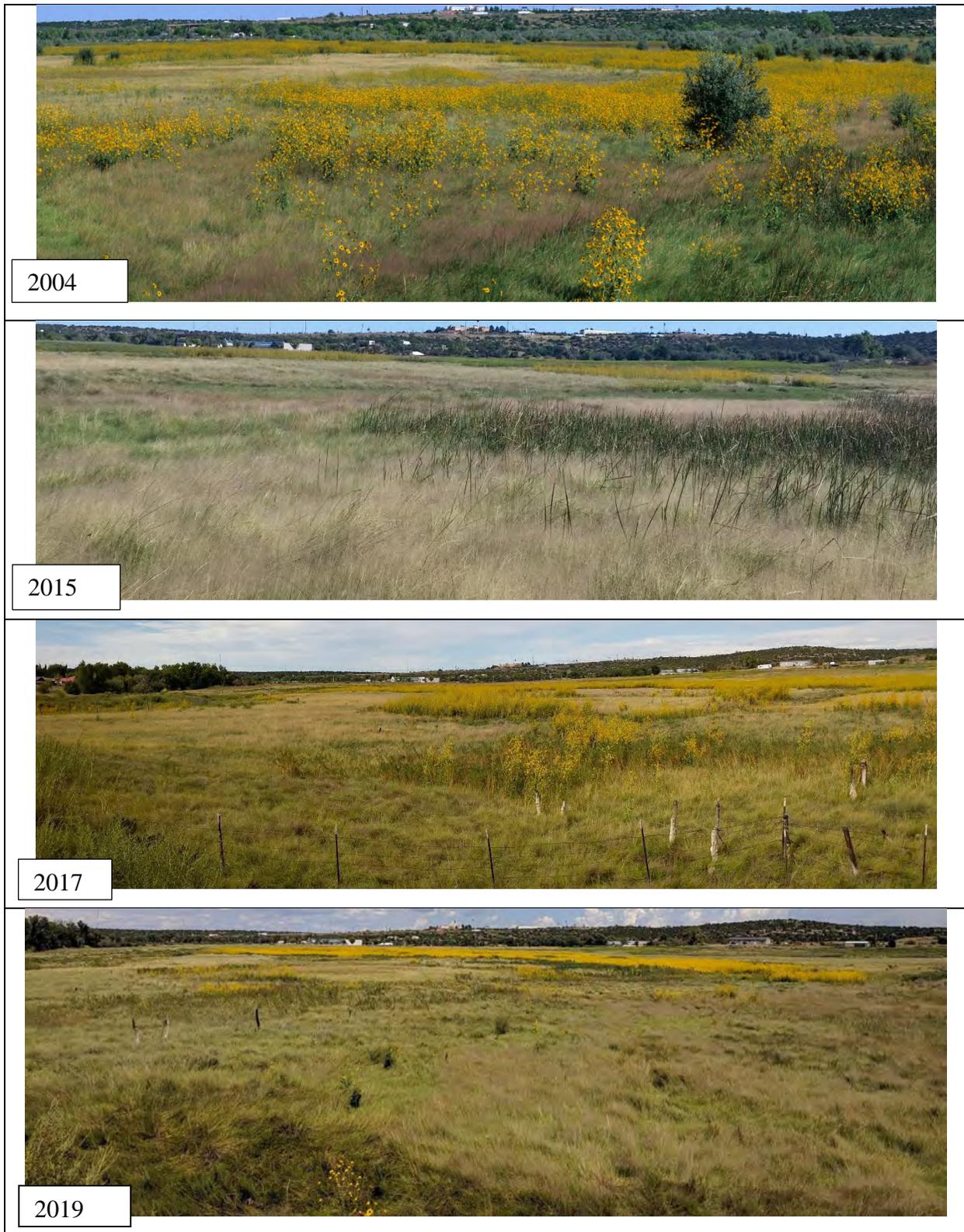


Figure 9. Sunflower abundance at Blue Hole Ciénega Nature Preserve in Santa Rosa, NM, before treatments (2004), after treatments (2015), after a prescribed fire (2017), and in 2019.

Seedlings

The first seedlings were found on March 6, 2019 (Figure 10). However, germination continued through the beginning of April. Monitoring took place on April 18, 2019, April 15, 2020, and April 16, 2021.

A total of 2,115 seedlings were counted in 2019, 741 seedlings were found in 2020, and 826 seedlings in 2021 in 55 subplots along the 11 monitoring transects (Table 2). The 2020 & 2021 lower counts of seedlings are supported by similar lower counts of adult plants later in the season. In 2019 the number of seedlings varied widely between sampling plots along the 30 m transects, ranging by as much as 132 to 340 seedlings per subplot along the same transect and from 0 to 974 seedlings between transects. In 2020 the number of seedlings ranged from 0 to 358 seedlings per subplot along the same transect and 0 to 401 seedlings between transects. In 2021 the number of seedlings ranged from 0 to 185 seedlings per subplot along the same transect and 0 to 352 seedlings between transects.

Hence extrapolating of the number of adults found later in the season along the entire transects is not feasible. However, after 3 years of data collection it appears that adult plant numbers collected along the entire transects are approximately three times higher than the seedling counts from the subplots for all years (Table 2). In 2021 no seedlings were found in 5 of the 11 transects. Three of these did not have any adult plants later in the season, the other 2 had low numbers. Percent cover of associated species (mostly saltgrass) was documented in 2019. Cover did not appear to influence the number of seedlings found along a transect. In fact, the highest seedling numbers were found in subplots with 100% saltgrass cover, some of it very thick (Figure 10).

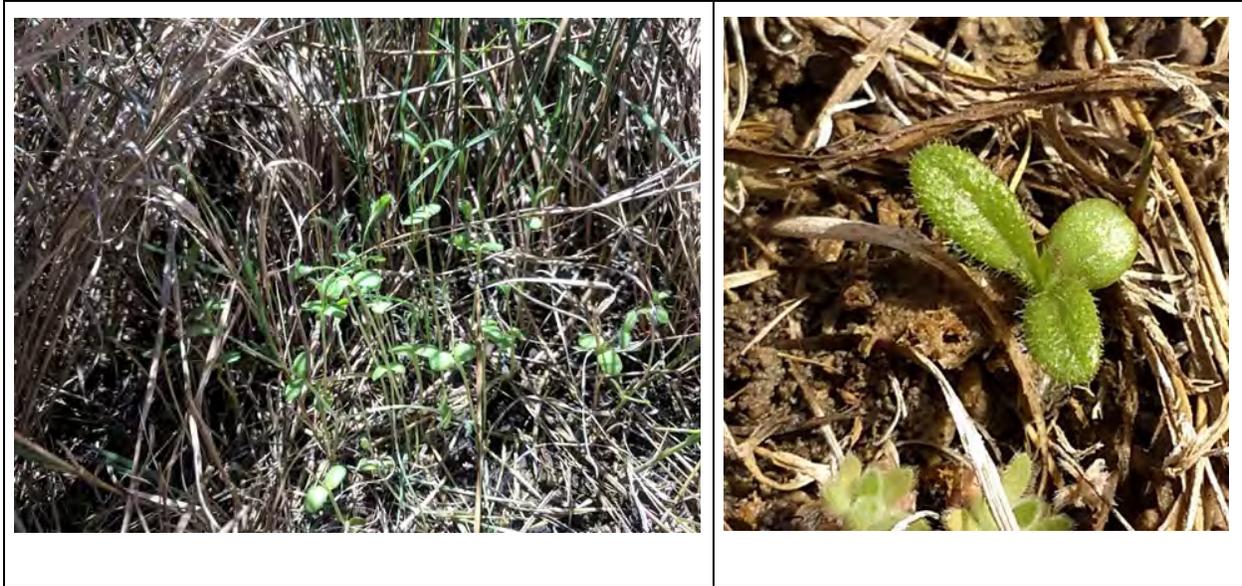


Figure 10. Seedlings of *Helianthus paradoxus* emerging from a thick cover of saltgrass (*Distichlis spicata*) and other grasses.

Table 2. Total number of seedlings found along each of the 11 monitoring transects at Blue Hole Ciénega, over 3 years.

Transect No	2019 No of Seedlings	2019 No of Adults	2020 No of Seedlings	2020 No of Adults	2020 No of Seedlings	2021 No of Adults
1	8	19	0	1	0	0
2	123	287	19	323	352	447
3	5	24	1	33	6	105
4	0	15	2	10	0	42
5	5	250	2	53	1	7
6	330	1131	210	0	0	7
7	974	2293	401	1522	257	332
8	16	305	4	103	1	3
9	0	0	0	0	0	0
10	654	1683	103	544	209	1625
11	0	0	0	0	0	0
Total	2,115	6,007	742	2,589	826	2,568

Water Wells

Groundwater fluctuations were originally documented from 10 water monitoring wells outfitted with automated data loggers from 2014 to 2017 (LeJeune 2018; Figure 11). Monitoring paused in late 2017 but was reinitiated in the spring of 2019. Due to data capacity limitations the automated data loggers missed approximately 4 months of data collection (December 2018 – April 2019). Data collection ended in 2019 due to funding limitations.

In general, the water table rises to the surface during the winter months, between October and April. This is considered a key factor for the germination and establishment of seedlings. Prior to 2016 the water levels fluctuated considerably during the summer and early fall months, likely in response to monsoon rainfall amounts (Figure 11). However, this pattern has not been documented since 2016, for unknown reasons. The water table remains low for all wells during the summer months, despite a very good rainfall year in 2017. The water table reached the surface for only a short period of time in the winter of 2016/2017 and remained low by February of 2017, despite above average rainfall amounts between November and April (7.64 inches). Since 2017, the groundwater no longer rises to the surface in half of the well locations (well numbers 3,4,5,6,7). This is especially disconcerting for well number 7, which is located near transect No. 7, the transect with the greatest fluctuations of sunflowers from one year to the next (Table 1). In addition, the largest contiguous stand of sunflowers (during good years) is associated with wells Nos 3 and 7. Water well No. 6 has run dry from June through December since 2016, which may explain the low number of sunflowers counted in the associated transect (No. 11) since 2015 (0 plants since 2018).

The mean annual depth to water table values appeared to improve for 6 of the 10 water wells on the Ciénega between 2017 and 2018, but otherwise continues to decline, in particular for well No. 7 (Figure 12). Overall depth to groundwater levels and ground water fluctuation do not appear to be influenced by rainfall amounts since 2016 for unknown reasons.

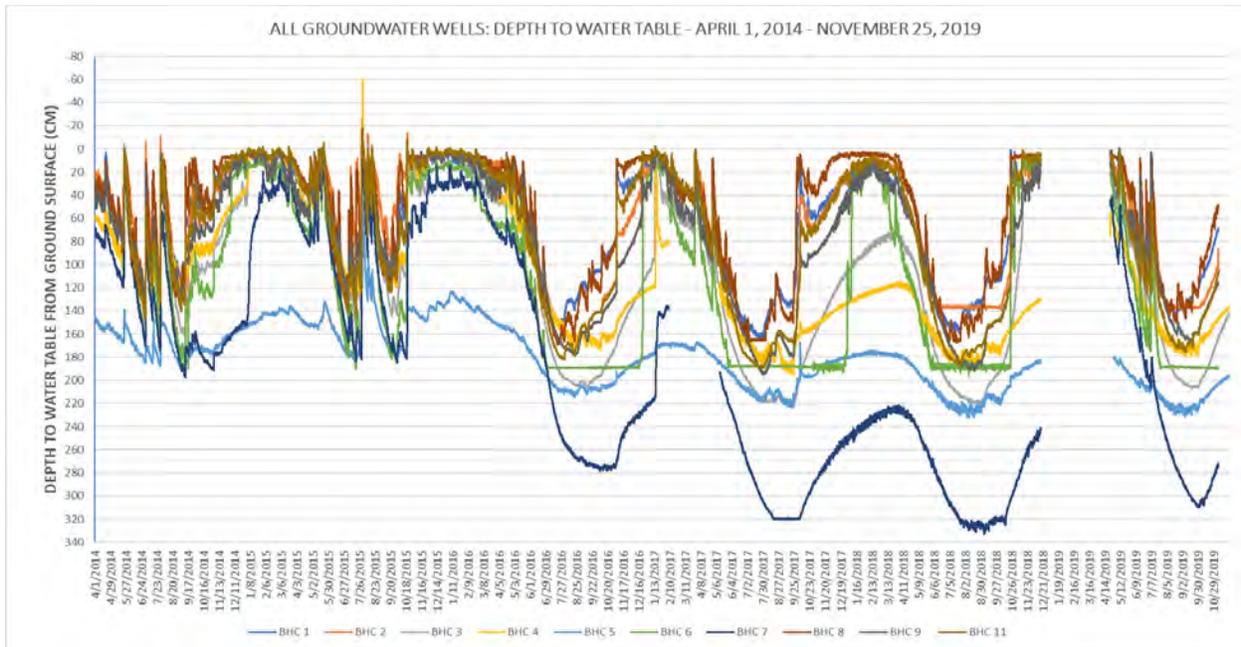


Figure 11. Ground water fluctuations at 10 monitoring wells on Blue Hole Ciénega in Santa Rosa, NM.

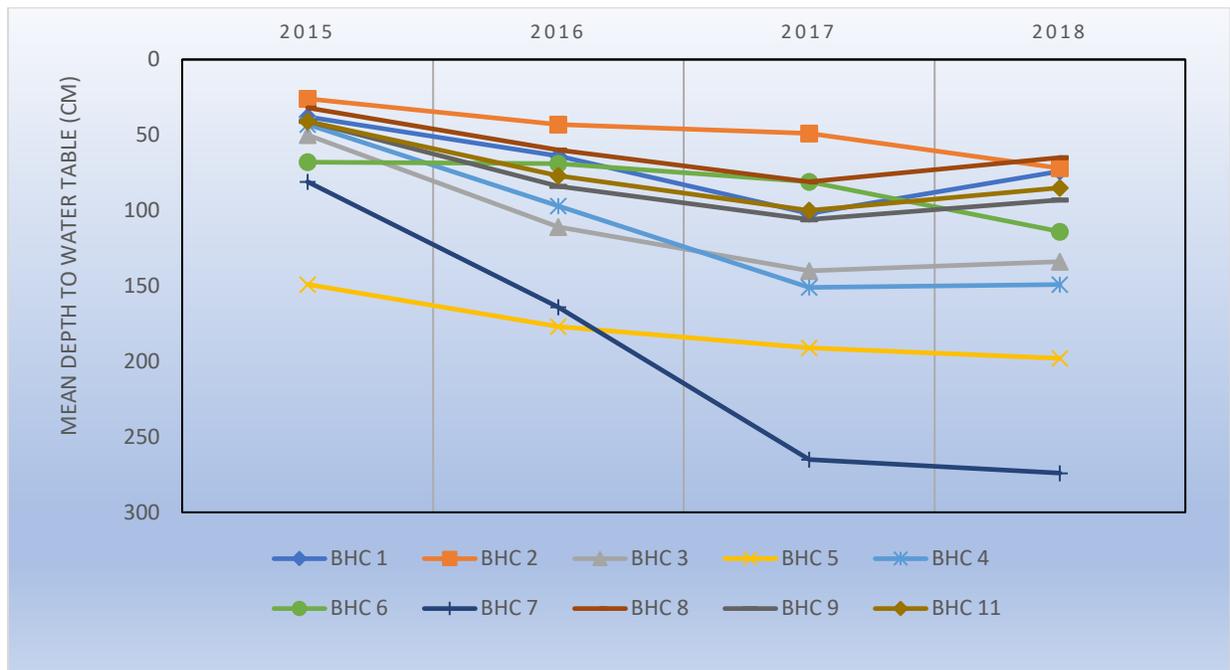


Figure 12. Mean ground water table to surface levels at 10 monitoring wells on Blue Hole Ciénega in Santa Rosa, NM.

2. MILAGRO CIÉNEGA

Milagro Ciénega (previously known as City Ciénega) is a 15-acre ciénega owned by the City of Santa Rosa. It was identified as a secondary conservation area for the Santa Rosa Pecos Sunflower Recovery Region, as prescribed in the Pecos Sunflower Recovery Plan (Roth 2014, USFWS 2005). The City of Santa Rosa approved a 25-year Conservation Easement for Milagro Ciénega in 2018 and the Guadalupe Soils & Water Conservation District agreed to hold the Easement for the City. The Easement was granted to protect threatened and endangered species, enhance water quality and water supplies, protect endangered species habitat and maintain habitat connectivity and related values to ensure biodiversity, protect wetland areas, maintain and restore natural ecosystem functions and the rural community's cultural and economic vitality. Grazing is permitted during the winter months from November through February. Milagro Ciénega was initially only partially fenced but has been fully fenced since February 2020. It contains an unnamed mound spring which has been breached and water is directed off the property for the benefit of livestock. An unnamed amphipod and an endemic freshwater snail live in this spring and its associated spring run. Although containing a significant remnant population of Pecos sunflowers and a few Wright's marsh thistles and Great Plains lady's tresses, the Ciénega was significantly overgrown with Russian olive and salt cedar prior to 2014. The site was initially cut and stump treated by the Forestry Division's Inmate Work Camp in 2014 with funding from a USFWS grant (Figure 13; Roth 2014). Since then, it has received multiple cut and herbicide treatments and a prescribed burn in February of 2020 (Roth & Austin 2021). In response to multiple restoration treatments including cutting and herbicide application and prescribed burning, Milagro Ciénega now contains one of the largest populations of Pecos sunflowers in the Santa Rosa area.



Figure 13. Russian olive removal at Milagro Ciénega in 2014.

METHODS

The Forestry Division established 8 monitoring transects distributed throughout Milagro Ciénega, wherever plants occurred in 2018 (Figure 14). Each transect measures 30 m x 2 m and is permanently marked by a metal t-post on either end. All permanent markers were mapped using a Garmin Monterra GPS. Annual monitoring occurs during the first 2 weeks of October, after the majority of sunflowers are done flowering and plants are senescent. Within each transect the number of plants is counted or estimated. Annual observations may include the observance of predators (insects, deer) or diseases, and the general vigor of plants in the transect, measured by average height of the plants. In addition, the perimeter of contiguous stands of sunflowers associated with the monitoring transects were walked in 2014, 2016, 2018, 2020, and 2021 using the tracking function of a Garmin Montana or Monterra GPS, to get a better understanding of population fluctuations between years and in response to restoration treatments. Area polygons are walked wherever plants are found surrounding the transect area in sufficiently large contiguous stands to be reasonably mapped. A stand is considered contiguous if plants are 5 m or less apart from each other. Tracks were later converted to polygons and occupied habitat was calculated in acres using ArcMap.



Figure 14. Location of 8 Pecos sunflower monitoring transects at Milagro Ciénega.

RESULTS

The sunflower population received significant boosts in plant numbers in response to the 2014 cut and stump herbicide treatment and the 2020 prescribed burn (Table 2, Figure 15). Although populations are expected to fluctuate annually depending on rainfall amounts, restoration treatments and prescribed fire clearly benefited the sunflowers. The number of plants found within the transects increased from 9,982 individuals in 2019 to 34,385 plants following the prescribed burn in February of 2020 (Figure 16). Although the number of plants was lower in 2021, they were still significantly higher than prior to the fire. Positive impacts from fire may last for several years. Livestock was allowed in Milagro Ciénega during the winter months of 2020/2021. No apparent impacts from grazing during the winter months were observed.

Table 2. Number of acres occupied by Pecos sunflowers prior to treatment in 2014 and the years following treatments, including a prescribed burn in 2020.

Year	2014	2016	2018	2020	2021
Occupied Acres	2.27	6.42	4.93	7.31	6.12

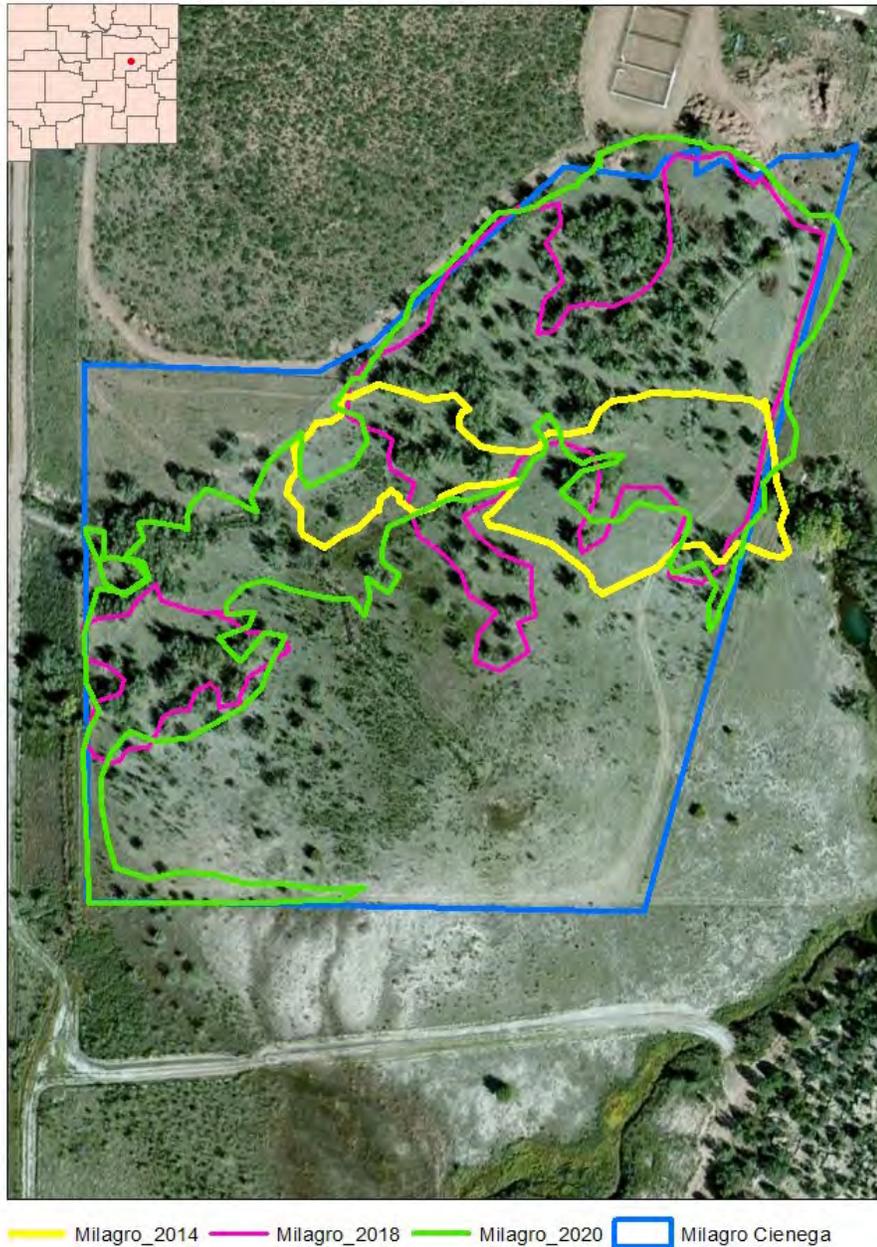


Figure 15. Changes in sunflower population distribution within Milagro Ciénega in response to prescribed fire and restoration treatments. Prior to treatment (2014), following multiple Russian olive treatments (2018), and following complete fencing and a prescribed fire (2020).

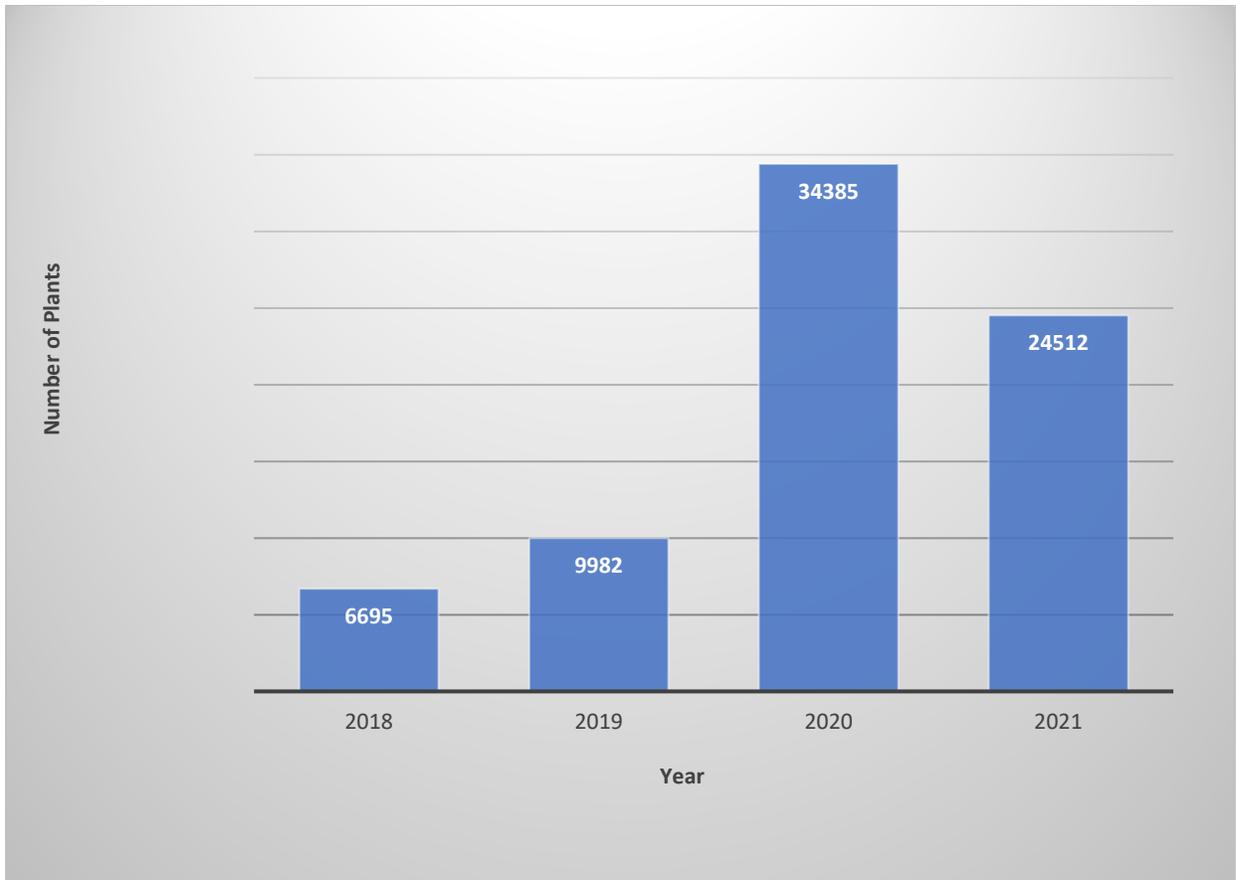


Figure 16. Total number of Pecos sunflower plants in 8 30m x 2 m transects at Milagro Ciénega in Santa Rosa.

DISCUSSION

Although Pecos sunflowers can be locally abundant, they are nationally and globally extremely rare and are known from only seven isolated populations in New Mexico and Texas. The main factors influencing density and growth of plants include water availability, competition with other species, grazing, and other disturbances. These factors do not act independently. Water availability and salinity combined with disturbances control the growth of Pecos sunflowers (Van Auken and Bush 1995). Annual plants are often found in disturbed areas where there is little competition from perennial plants. Pecos sunflowers appear to respond favorably to certain types of disturbance such as fire and tilling, but can respond negatively to grazing (Van Auken and Bush 2004). The number of sunflowers on the two ciénegas has fluctuated widely from one year to the next, primarily driven by water availability, but also in response to disturbances, such as cut and herbicide treatments, hailstorms and prescribed fires. Reduced competition in

combination with increased availability of soil nutrients following the fires contributed to the germination and establishment of seedlings in the spring following the fires of 2017 and 2020. Above average rainfall during key periods for germination, establishment and growth in 2017 and 2020 increased the survival of plants and contributed to abundant flowering in August and September (7.64 inches from November 2016 to April 2017, and 7.51 inches from November 2019 to April 2020; 100-year average 3.39 inches). Surface moisture influenced by rising groundwater levels during the winter and spring months and rainfall amounts are critical to the germination and establishment of Pecos sunflower seedlings. Winter and spring were extremely dry; only 0.39 inches of rain were recorded between November 2017 and April 2018. The dry winter, possibly combined with seedbank depletion from the prior year, are considered the main causes for low numbers of sunflowers in 2018. The winter and spring of 2018/2019 yielded average amounts of rainfall and sunflower populations rebounded strongly (3.65 inches between November and April). However, winter rainfall was abundant in 2019/2020 (7.51 inches between November and April), but seedling counts and adult plant counts were low in 2020 on Blue Hole Ciénega, extending into 2021. Meanwhile plants were thriving at Milagro Ciénega in response to the 2020 prescribed burn. Hence it is safe to assume that fire has a stronger positive correlation to sunflower abundance than rainfall amounts, likely due to the reduction of competing perennial vegetation, scarification of seeds in the seedbank, resulting in increased germination, and increased available nitrogen in the soils post-fire. Fire effects likely only last a couple of years. Photopoint monitoring at Blue Hole Ciénega may lead to conclude that restoration efforts have little or inconclusive responses from the sunflower populations. However, competition from other species is just one part of what drives sunflower abundance on the ciénegas. In years of good rainfall competition for essential resources, such as water, may not impact the abundance of sunflowers as it would during drought years. 2004 was an exceptional wet year in the Santa Rosa area, producing more than 6 inches above average rainfall values (WRCC 2020). Therefore, the abundant sunflower population in the 2004 photo may be a product of ample moisture, not influenced by the strong presence of competing invasive woody species. In addition, Blue Hole Ciénega was at least seasonally grazed by livestock until 2004, which may have reduced competition by perennial grasses. No reliable rainfall data is available for Santa Rosa after 2009 and we have no photos or population data on how sunflower abundance may have responded to rainfall amounts following cut and herbicide treatments and a prescribed burn

in 2008 at Blue Hole Ciénega. Effects of fire are unlikely to last for more than a couple of years after the fire. Unfortunately, we have no data associated with the impacts of the 2008 prescribed burn. Similar high amounts of total annual rainfall were recorded in 2004 and in 2015 in Tucumcari, located approximately 60 miles to the east, with similar large rainfall events in the spring for both recording years. Yet, monitoring results at Blue Hole Ciénega show only a moderate number of sunflowers in 2015, which is reflected in the 2015 panoramic photo. An automated rain gauge installed at the Blue Hole Ciénega in July of 2016 may give us better insights on how localized rainfall and timing of rainfall influences the abundance of sunflowers. The highest numbers of sunflowers since monitoring began were recorded in 2017 and 2020, following prescribed burns at Blue Hole Ciénega (2017) and at Milagro Ciénega (2020). Significantly more sunflowers were recorded in the 11 monitoring transects at Blue Hole Ciénega in 2017 over any other year. Similar results were found at Milagro Ciénega in 2020. This was clearly the response to the prescribed burns in early February, approximately 1 month before sunflowers germinate. Fire clearly benefits Pecos sunflowers. Sunflower abundance is also driven by multiple environmental factors, including the height of the water table in the spring, rainfall amounts during the winter and early spring months, monsoons, and the type and degree of disturbance within the habitat of the species.

After 9 years of monitoring and active management prescriptions, the overall population trend of Pecos sunflowers at Blue Hole Ciénega is stable, despite significant annual population fluctuations. However, the overall upward trend is heavily influenced by the effects of the prescribed fire. Continued long-term monitoring is needed to further evaluate the impacts of management actions on the sunflowers and understand long term population trends in a changing climate. Continued monitoring of the groundwater table is highly recommended to help interpret population trends. Unfortunately funding for this project was lost in 2020. Additional monitoring transects established at Milagro and Robinson ciénegas will help to improve our understanding of grazing impacts on the species. Milagro Ciénega may be grazed during the winter months, the Robinson Ciénega is grazed year-round. Management recommendations based on multi-year restoration and monitoring projects for each of the three ciénegas are provided in Roth & Austin (2021).

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