STATUS SURVEY AND REPORT FOR THARP'S BLUESTAR (*AMSONIA THARPII*) 2019

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INTRODUCTION

Tharp's bluestar (*Amsonia tharpii*) is a rare perennial plant with a woody root and adventitiously spouting stems, entire, heteromorphic leaves and tubular white flowers that bloom in April and early May (Sivinski *et al.* 2014). It is listed endangered in the State of New Mexico (NMAC 19.21.2). It is also a Bureau of Land Management (BLM) Sensitive Species, which has management requirements prescribed in BLM Manual 6840 – Special Status Species Management (BLM 2008). NatureServe ranks Tharp's bluestar critically imperiled throughout its range (G1/S1). The New Mexico Rare Plant Conservation Strategy considers the species 'Weakly Conserved' due to moderate to high threats associated with oil and gas developments, herbicide treatments and small population size (EMNRD-Forestry Division 2017). Tharp's bluestar is not listed threatened or endangered in Texas but is listed as a Species of Greatest Conservation Need in the Texas Parks and Wildlife Department State Conservation Action Plan (2012). Following a positive 90-day finding in 2009, Tharp's bluestar is currently under review by the U.S. Fish and Wildlife Service for possible listing as threatened or endangered under the federal Endangered Species Act (74 FR 66866).

This status survey documents the locations, patch sizes and habitat conditions of all known locations on federal and New Mexico State lands, and one location in Texas on Department of Transportation and adjacent University of Texas lands.

DISTRIBUTION

The known populations of Tharp's bluestar are widely scattered across 4 populations in Eddy County, New Mexico and a single location in Pecos County, Texas (Figures 1 & 2). New Mexico populations are predominantly on BLM land, but a few occur on New Mexico State Trust Land and private property. The largest New Mexico population is in the Red Lake area about 11 miles east of Artesia. The upper breaks of Cedar and Pierce canyons east of Malaga also have large populations of thousands of individuals. The Mescalero Ridge population northwest of Maljamar has several large patches of Tharp's bluestar. The smallest population, containing just a couple hundred plants, is located on the gypsum stratum just north of the Texas border at Ben Slaughter Draw. This is a tributary of Hay Hollow, which has a small patch of an additional 200 plants on private land several miles east of Ben Slaughter Draw (Figure 1). In Texas, Tharp's bluestar is known from one population in Pecos County

where it occurs in 2 sites separated by just over half a mile of unoccupied habitat. Plants occur in the right-of-way along Hwy 385/67 and extend onto adjacent University of Texas lands (Figure 2).

Habitat - New Mexico

In New Mexico the habitat of Tharp's bluestar is characterized by rolling hills and shallow drainages composed of sandy soils with a limestone, gypsum, or dolomite components derived from the Rustler, Gatuña, and Castille formations (Howard 2007, Sivinski *et al*. 2014). All three formations contain various concentrations of gypsum, which appears to be an important component of the substrate in which the species is found (Howard 2007). It occurs within Chihuahuan desert shrub communities between 3,060 and 3,760 ft in elevation. The average annual precipitation for Carlsbad is 12.70 inches and 11.63 inches for the Artesia area (WRCC 2019).

Previous Surveys – New Mexico

Tharp's bluestar was first reported in New Mexico in 1989 from one population at Cedar Canyon in Eddy County (Sivinski and Lightfoot 1992). The population was originally estimated at 5,000 plants over 25 acres, but was subsequently found to be much larger, covering approximately 100 acres and consisting of 5,000 – 10,000 plants (Cedar/Pierce Canyon). Surveys of New Mexico State Trust Lands in Eddy County during the early 1990s discovered two additional populations, one near Red Lake (Red Lake), east of Artesia, and another southwest of Carlsbad, in the Yeso Hills (Ben Slaughter Draw)(Sivinski 1995). In 2006 BLM surveys expanded the extent of the known populations across both BLM and State Trust Lands (Howard 2007). Two additional populations were found during surveys in 2013 and 2014, on BLM and private lands (Mescalero Ridge, Ben Slaughter Draw/Hay Hollow) (Roth 2013; Sivinski *et al.* 2014). In 2013 and 2014 the four New Mexico populations surveyed on BLM and State lands were estimated to contain between 16,000 and 26,000 plants distributed in 51polygons (Roth 2013; Sivinski *et al.* 2014). However, not all known sites were surveyed at that time.

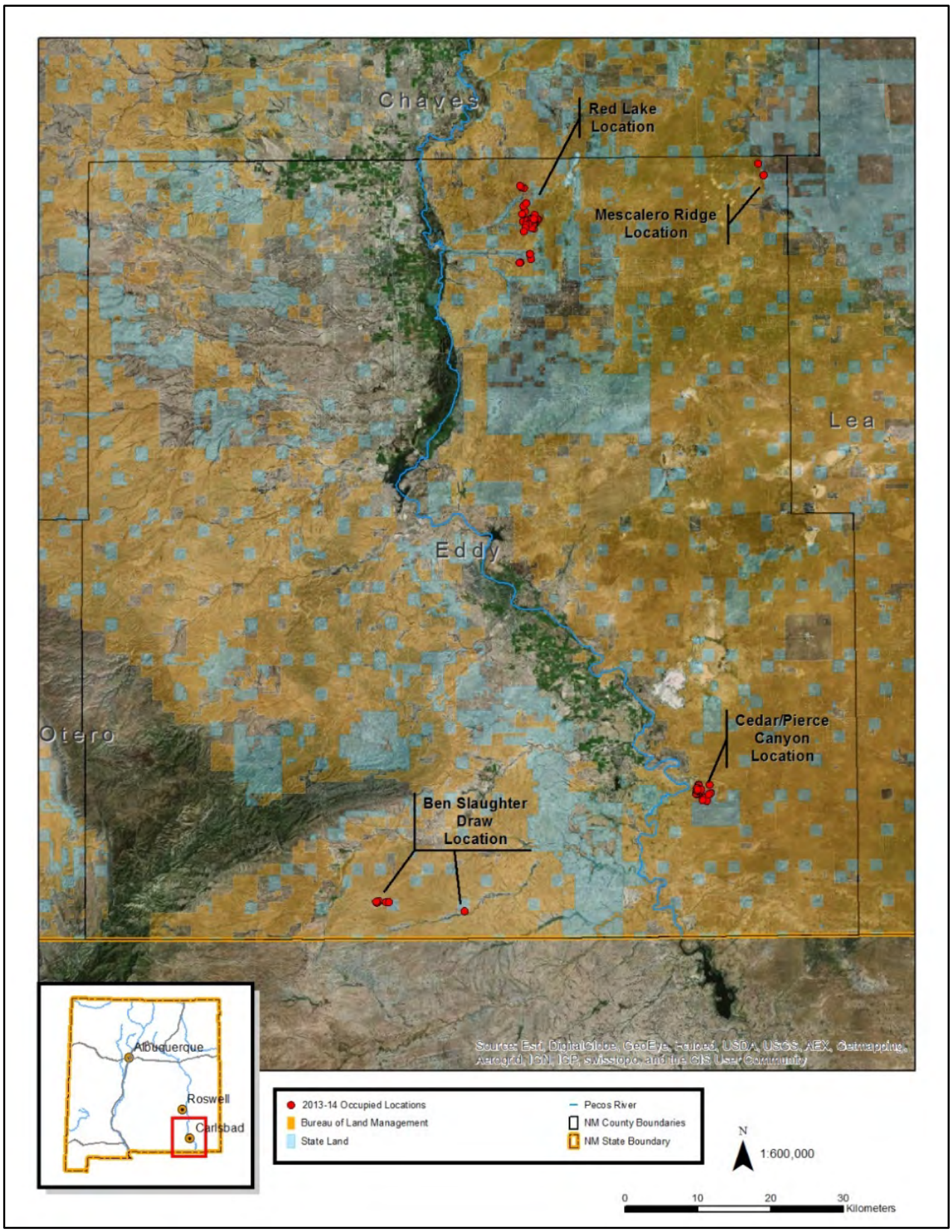

Figure 1. New Mexico distribution of Tharp's bluestar (from Sivinski *et al.* 2014, Natural Heritage New Mexico Report – 14-GTR-384).

Habitat Description - Texas

In Texas, Tharp's blue-star occurs over the Fredericksburg and Washita Formations in Lozier-Rock Outcrop and Upton soil associations (Rives 1980, as reported in Strong and Williamson 2015). Lozier-Rock and Upton soils are shallow to very shallow, well-drained, gravelly and stony loamy soils. Lozier soils are over limestone hills and Upton soils are over calcareous outwash sediments from these hills. Texas plants occur fully exposed on low ledges and drainages between low hills (Rowell 1983). The Texas sites occur in desert thornscrub and short to midgrass grasslands in a transitional zone between the Edwards Plateau and Chihuahuan Desert. The average precipitation for Ft. Stockton, 18 miles to the west of the site, is 15.1 inches/year (U.S. Climate Data 2019). Elevation at the site ranges from 2,800 to 2,900 feet.

Previous Surveys – Texas

Tharps' bluestar was originally collected in 1943 by Dr. Tharp in Pecos County, Texas, and later described by Robert E. Woodson Jr. (Woodson 1948). In 1983, the Tharp's blue-star population was estimated to be about 400 plants (Sivinski and Lightfoot 1992). Although it is unknown to what extend the area has been surveyed through time, observed plant numbers have been recorded multiple times (Strong and Williamson 2015). Forty-four plants were recorded in the southwest portion of the population, along the highway 385/67 ROW in 1986 and probably into the adjacent property to the east. In 1998, the northeast portion of the population was visited and 125 plants were located in the highway ROW and adjacent UT Lands property. Seventy-five of these plants were located inside a fence on UT Lands property and the survey was estimated to cover about an acre. In 2003, 18 plants were reported from along the highway ROW and on adjacent UT lands. Between 2014 and 2016 several surveys documented a total of 362 plants along the ROW and on UT lands (Strong 2014 a- f, 2016).

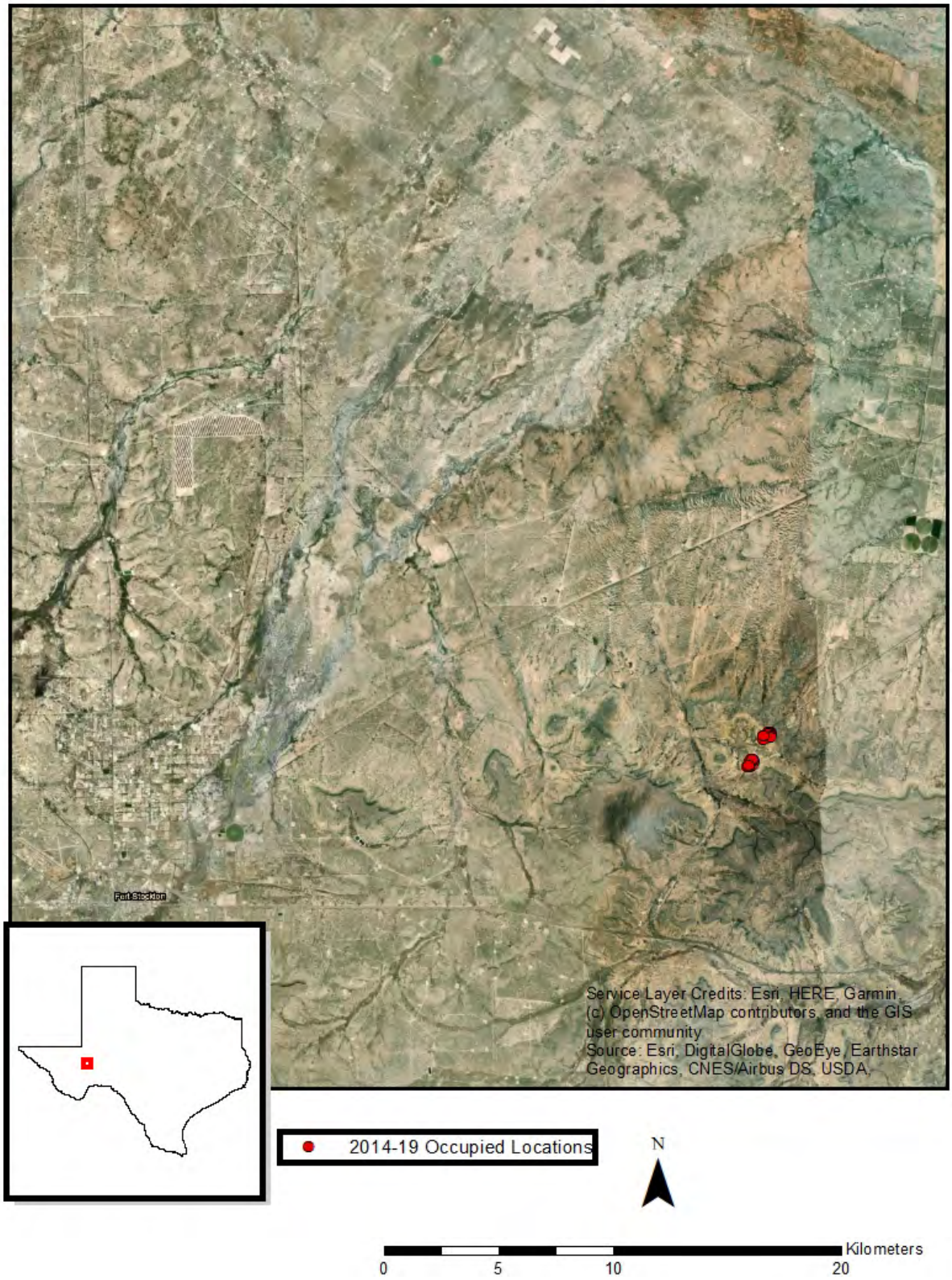

Figure 2. Distribution of Tharp's bluestar in Pecos County, Texas.

FIELD SURVEY METHODS

New Mexico

All known patches of Tharp's blue-star at each of the four New Mexico locations on federal and State lands were visited by Robert Sivinski in April 2019 to assess habitat and plant health (Sivinski *et al.* 2014; Roth 2013; Howard 2007). Surveys were made on foot with a Garmin 64s GPS unit and binoculars, which enabled the spotting of plants up to 100 meters distant. Polygons around patches of plants were made by keeping a distance of 2-3 meters outside the plants at the patch periphery. New polygons were started where the nearest plants were more than 50 meters distant. This methodology is identical to that employed in Sivinski's 2013-2014 surveys of BLM land and similar to Roth's 2013 survey of State Land habitats in Eddy County, but quite different from surveys conducted by BLM prior to 2013. The BLM often delineated large buffer areas that included entire hills or occasionally made incomplete polygons around occupied habitats. Some of the pre-2013 BLM habitat polygons were never accurate and can be discarded now that better data is available.

Actual counts of numbers of plants were usually undertaken only when a patch was small and contained fewer than 100 individuals. These counts were made difficult by the fact that more than one clump of aerial branches can originate from one long underground stem or root. Therefore, adjacent clumps of stems were counted as one individual if they were less than 12 inches (30 cm) apart. Plant numbers in larger patches were visually estimated and usually indicated a range of uncertainty (ex. 300-500, 1000-2000). Plant number estimates for pre-2013 BLM surveys are either not available or not comparable.

Texas

All previously recorded waypoints of Tharp's blue-star at the one Texas location on TXDOT and University of Texas lands were visited by Daniela Roth in October 2019 to assess habitat and plant health (Strong 2014a-f, 2016). Existing data points were provided by the Texas Natural Diversity Database and the Texas Department of Transportation. The Texas location is small enough to get an actual count of the number of plants at each waypoint. Waypoints were collected with the Collector for ArcGIS app on a Samsung Galaxy S2 tablet.

RESULTS

NEW MEXICO – SUMMARY

The 2019 survey of federal and state lands in New Mexico found that all Tharp's bluestar locations previously known from previous surveys were still extant. The 2019 New Mexico area of occupied habitat covered approximately 457 acres. The total number of plants in 2019 was estimated between 23,525 and 33,125 individual plants in 85 surveyed polygons (Table 1). Fifty of the 85 surveyed polygons were also surveyed in 2013 and 2014 (Roth 2013; Sivinski *et al.* 2014). Thirteen polygons were newly documented at the known populations. Twenty-two polygons were previously reported by the BLM, but no prior population estimates were available (BLM 2007). Overall population trend evaluation for the 50 polygons previously documented showed a decline ranging from 38% to 41% (14,597 – 22,397 plants in 2013/2014 to 9,141 – 13,241 plants in 2019) at all 4 populations. Thirty-three of the 50 previously documented sites showed declines, 11 showed increases over previous numbers and 6 appeared stable. Percent decline per population ranged from 12% at Pierce/Cedar canyons up to 66% at the Red Lake population.

Table 1. Population numbers, trends, and occupied habitat areas of 85 Tharp's blue-star polygons at 4 New Mexico locations.

Location	Polygon Name	Year	Observer	No of Plants	Patch (Acres)	Year	Observer	No of Plants	Trend	Patch (Acres)
Ben Slaughter	BS001	2013	Sivinski	190	1.6	2019	Sivinski	53	⬇	1.3
Ben Slaughter	BS002	2013	Sivinski	4	<0.1	2019	Sivinski	3	⬇	<0.1
Ben Slaughter	BS003	2013	Sivinski	33	0.2	2019	Sivinski	38	⬆	0.2
Ben Slaughter	BS004	2013	Roth	50	0.7	2019	Sivinski	28	⬇	0.4
Cedar/Pierce	CC001	Pre-2013	BLM	NA	11.1	2019	Sivinski	300-500	NA	13.0
Cedar/Pierce	CC002	2013	Roth	50	0.4	2019	Sivinski	100	⬆	0.2
Cedar/Pierce	CC003	2013	Roth	25	<0.1	2019	Sivinski	31	⬆	0.2
Cedar/Pierce	CC004	2013	Roth	1000	11.1	2019	Sivinski	2000-3000	⬆	22.4
Cedar/Pierce	CC005	2013	Roth	30	0.2	2019	Sivinski	8	⬇	0.1
Cedar/Pierce	CC006	Pre-2013	BLM	NA	25.8	2019	Sivinski	3000-5000	NA	23.8
Cedar/Pierce	CC007	Pre-2013	BLM	NA	1.5	2019	Sivinski	50	NA	0.9
Cedar/Pierce	CC008	Pre-2013	BLM	NA	<0.1	2019	Sivinski	30	NA	0.1
Cedar/Pierce	CC008b	2013	Sivinski	8	<0.1	2019	Sivinski	11	⬆	<0.1
Cedar/Pierce	CC008c	2013	Sivinski	3	<0.1	2019	Sivinski	8	⬆	<0.1
Cedar/Pierce	CC008d	2013	Sivinski	4	<0.1	2019	Sivinski	2	⬇	<0.1
Cedar/Pierce	CC008e	2013	Sivinski	14	<0.1	2019	Sivinski	10	⬇	<0.1
Cedar/Pierce	CC013	2013	BLM	NA	1.1	2019	Sivinski	100	NA	0.7
Cedar/Pierce	CC013c	2013	Sivinski	3	<0.1	2019	Sivinski	2	⬇	<0.1

Location	Polygon Name	Year	Observer	No of Plants	Patch (Acres)	Year	Observer	No of Plants	Trend	Patch (Acres)
Cedar/Pierce	CC013d	2013	Sivinski	4	<0.1	2019	Sivinski	7	⬆	<0.1
Cedar/Pierce	CC013f	Pre-2013	BLM	NA	<0.1	2019	Sivinski	5	NA	<0.1
Cedar/Pierce	CC013g	Pre-2013	BLM	NA	<0.1	2018	Sivinski	5	NA	<0.1
Cedar/Pierce	CC016a	2013	Sivinski	150	0.6	2019	Sivinski	90	⬇	0.3
Cedar/Pierce	CC016b	2013	Sivinski	45	0.2	2019	Sivinski	24	⬇	0.1
Cedar/Pierce	CC016c	2013	Sivinski	38	0.3	2019	Sivinski	29	⬇	0.2
Cedar/Pierce	CC016d	2013	Sivinski	52	0.1	2019	Sivinski	47	⬇	0.1
Cedar/Pierce	CC016e	2013	Sivinski	50	0.2	2019	Sivinski	45	⬇	0.1
Cedar/Pierce	CC016f	2013	Sivinski	77	0.4	2019	Sivinski	46	⬇	0.5
Cedar/Pierce	CC016g	2013	Sivinski	20	0.3	2019	Sivinski	16	⬇	0.3
Cedar/Pierce	CC016h	2013	Sivinski	6	<0.1	2019	Sivinski	6	➖	0.1
Cedar/Pierce	CC017	2013	Sivinski	17	0.1	2019	Sivinski	15	⬇	<0.1
Cedar/Pierce	CC017b	2013	Sivinski	13	<0.1	2019	Sivinski	23	⬆	<0.1
Cedar/Pierce	CC017c	2013	Sivinski	19	0.1	2019	Sivinski	15	⬇	0.1
Cedar/Pierce	CC017d	2013	Sivinski	8	<0.1	2019	Sivinski	3	⬇	<0.1
Cedar/Pierce	CC017e	2013	Sivinski	7	<0.1	2019	Sivinski	3	⬇	<0.1
Cedar/Pierce	CC017f	2013	Sivinski	2	<0.1	2019	Sivinski	2	➖	<0.1
Cedar/Pierce	CC017g	2013	Sivinski	8	0.1	2019	Sivinski	28	⬆	0.4
Cedar/Pierce	CC017h	2013	Sivinski	14	0.1	2019	Sivinski	14	➖	0.1
Cedar/Pierce	CC018	Pre-2013	BLM	NA	0.7	2019	Sivinski	30	NA	4.0
Cedar/Pierce	CC019	Pre-2013	BLM	NA	5.5	2019	Sivinski	800-1000	NA	4.9
Cedar/Pierce	CC020	Pre-2013	BLM	NA	29.0	2019	Sivinski	2000-3000	NA	26.1
Mescalero Ridge	MR1	2014	Sivinski	500-1000	2.8	2019	Sivinski	300-500	⬇	3.3
Mescalero Ridge	MR2	2014	Sivinski	2000-3000	9.0	2019	Sivinski	1000-1500	⬇	9.7
Mescalero Ridge	MR3	2014	Sivinski	1000-2000	5.5	2019	Sivinski	500-800	⬇	6.2
Red Lake	RL001	NA	NA	NA	NA	2019	Sivinski	15	NA	0.2
Red Lake	RL002	Pre-2013	BLM	NA	1.1	2019	Sivinski	100	NA	1.3
Red Lake	RL003	Pre-2013	BLM	NA	2.0	2019	Sivinski	300-500	NA	4.2
Red Lake	RL004	Pre-2013	BLM	NA	0.4	2019	Sivinski	16	NA	0.3
Red Lake	RL005	Pre-2013	BLM	NA	1.0	2019	Sivinski	300-500	NA	3.6
Red Lake	RL006	Pre-2013	BLM	NA	23.7	2019	Sivinski	400-500	NA	16.7
Red Lake	RL007	Pre-2013	BLM	NA	29.0	2019	Sivinski	200-300	NA	9.6
Red Lake	RL008	NA	NA	NA	NA	2019	Sivinski	14	NA	0.4
Red Lake	RL009	NA	NA	NA	NA	2019	Sivinski	100	NA	2.0
Red Lake	RL010	NA	NA	NA	NA	2019	Sivinski	60	NA	0.4
Red Lake	RL011	NA	NA	NA	NA	2019	Sivinski	15	NA	0.7
Red Lake	RL012	NA	NA	NA	NA	2019	Sivinski	16	NA	0.1

Location	Polygon Name	Year	Observer	No of Plants	Patch (Acres)	Year	Observer	No of Plants	Trend	Patch (Acres)
Red Lake	RL013	NA	NA	NA	NA	2019	Sivinski	2	NA	<0.1
Red Lake	RL014	NA	NA	NA	NA	2019	Sivinski	22	NA	1.2
Red Lake	RL015	NA	NA	NA	NA	2019	Sivinski	13	NA	0.6
Red Lake	RL016	NA	NA	NA	NA	2019	Sivinski	200-300	NA	6.5
Red Lake	RL017	2013	Sivinski	500-800	10.1	2019	Sivinski	200-300	⬇	9.9
Red Lake	RL018	2013	Sivinski	300-400	13.7	2019	Sivinski	400-500	⬆	13.2
Red Lake	RL019	2013	Sivinski	300-400	3.1	2019	Sivinski	100-200	⬇	4.3
Red Lake	RL020	2013	Sivinski	400-500	2.2	2019	Sivinski	300	⬇	1.8
Red Lake	RL021	2013	Sivinski	15	0.1	2019	Sivinski	11	⬇	0.1
Red Lake	RL022	2013	Sivinski	200-300	4.8	2019	Sivinski	100	⬇	4.5
Red Lake	RL023	2013	Sivinski	1000-2000	7.2	2019	Sivinski	300-400	⬇	4.1
Red Lake	RL024	2013	Sivinski	3000-5000	35.1	2019	Sivinski	1000-1500	⬇	36.2
Red Lake	RL025	2013	Sivinski	15	0.3	2019	Sivinski	8	⬇	<0.1
Red Lake	RL026	2013	Sivinski	200	0.9	2019	Sivinski	30	⬇	0.4
Red Lake	RL027	2013	Sivinski	1000-2000	3.8	2019	Sivinski	100-150	⬇	3.0
Red Lake	RL028	2013	Sivinski	23	0.3	2019	Sivinski	35	⬆	0.2
Red Lake	RL029	NA	NA	NA	NA	2019	Sivinski	100-200	NA	3.3
Red Lake	RL030	NA	NA	NA	NA	2019	Sivinski	500-600	NA	35.8
Red Lake	RL031	NA	NA	NA	NA	2019	Sivinski	22	NA	0.3
Red Lake	RL032	2013	Roth	150-200	3.8	2019	Sivinski	50-100	⬇	4.9
Red Lake	RL033	2013	Roth	700-1000	14.8	2019	Sivinski	500-1000	▬	21.3
Red Lake	RL034	Pre-2013	BLM	NA	11.6	2019	Sivinski	100-200	NA	7.7
Red Lake	RL035	Pre-2013	BLM	NA	NA	2019	Sivinski	400-500	NA	8.8
Red Lake	RL036	Pre-2013	BLM	NA	0.2	2019	Sivinski	19	NA	0.3
Red Lake	RL037	Pre-2013	BLM	NA	NA	2019	Sivinski	5000-6000	NA	55.7
Red Lake	RL038	Pre-2013	BLM	NA	NA	2019	Sivinski	50	NA	3.4
Red Lake	RL039	Pre-2013	BLM	NA	NA	2019	Sivinski	100	NA	2.9
Red Lake	RL040	2013	Roth	1000	24.9	2019	Sivinski	1000-1500	▬	32.3
Red Lake	RL041	2013	Roth	150-200	2.2	2019	Sivinski	100	⬇	3.3
Red Lake	RL042	2013	Roth	100s	20.5	2019	Sivinski	400-500	▬	31.2
TOTAL						**2019**		**23,525-33,125**		**457**

Ben Slaughter Draw

In 2019 Ben Slaughter Draw locations BS001, BS002 and BS004 appeared drought stressed and making very little new growth. These small patches of Tharp's bluestar were also less abundant. The largest patch, BS001, had 190 plants in 2013 and only 53 individuals in 2019 (Table 1). In 2013 plants were also severely drought stressed and many were found only by the previous year's dried stems and leaves and had no new growth. These were apparently dead or dying and no longer evident in 2019. BS002 and BS004 were also missing plants in 2019 and those present were poorly developed. The BS003 Tharp's bluestar location is only 300 meters west of BS001 (Figure 20) yet is a much healthier patch of plants, for unknown reasons. There were 38 individuals in 2019 (vs. 33 in 2013) and most had leafy stems with flowers. The Ben Slaughter population had a total of 277 individuals in 2013 and 122 plants in 2019 for a 56% decrease over six years. Occupied habitat at BS001 and BS004 were smaller in 2019 than 2013 (Table 1).

Oil & gas development and livestock grazing remain the primary land uses in the area surrounding the Ben Slaughter population. No new land uses were reported during the 2019 site visit to Ben Slaughter Draw. There were many fresh cattle tracks in the road and drainage below the BS004 location, but very few in the occupied upland habitat.

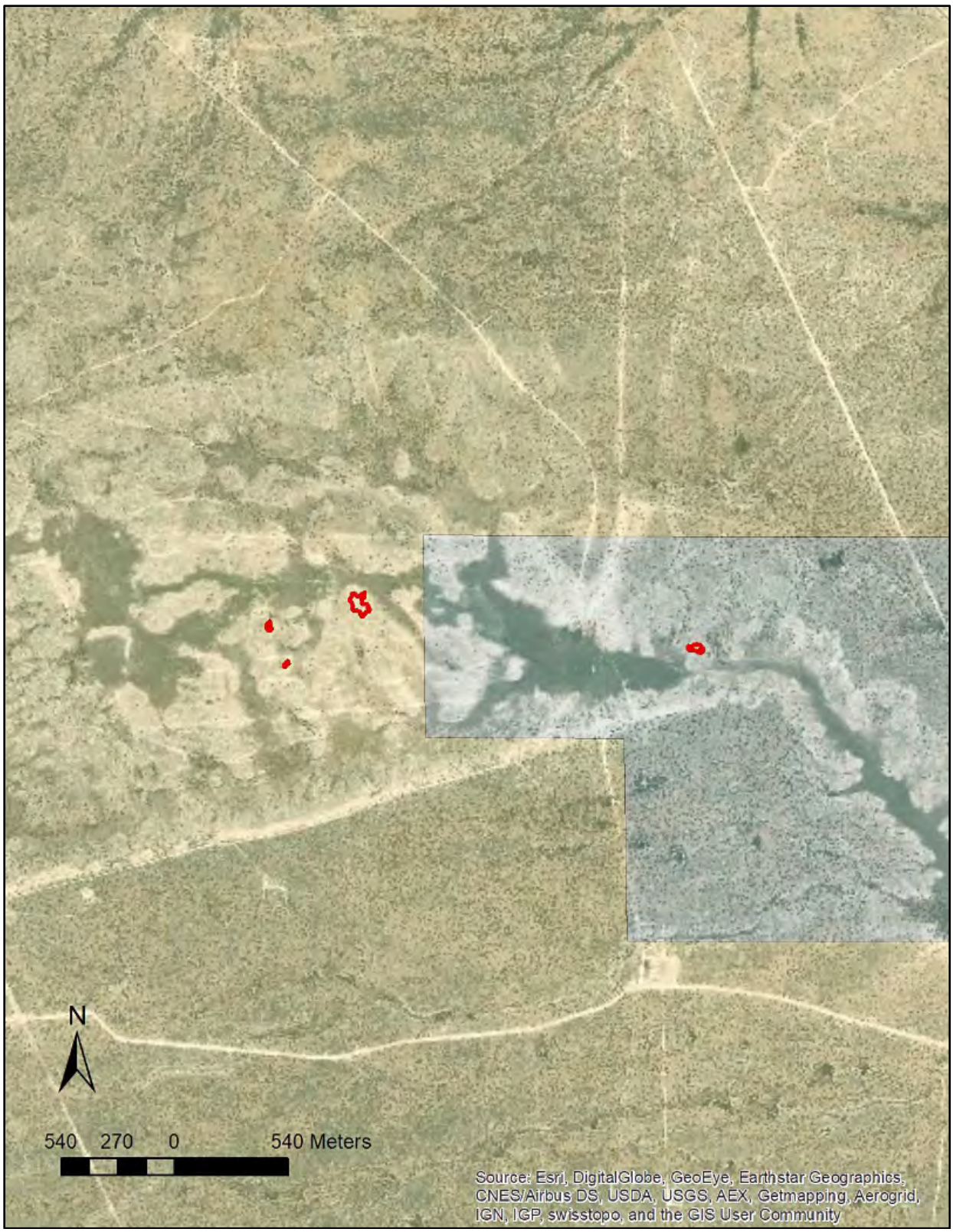

Figure 3. Tharp's bluestar locations (red polygons) at Ben Slaughter Draw. Yellow tint is BLM; blue tint is State Trust Land.

Cedar/Pierce Canyons

The Tharp's bluestar population in Cedar Canyon and the south rim of adjacent Pierce Canyon has some very large occupied habitats with thousands of plants and numerous small, isolated patches with few individuals (Figure 4). A total of 26 patches of plants were surveyed in 2019 (Table 1; Figures 21 and 22). Most plants at this location had leafy stems and flowers during the 2019 survey.

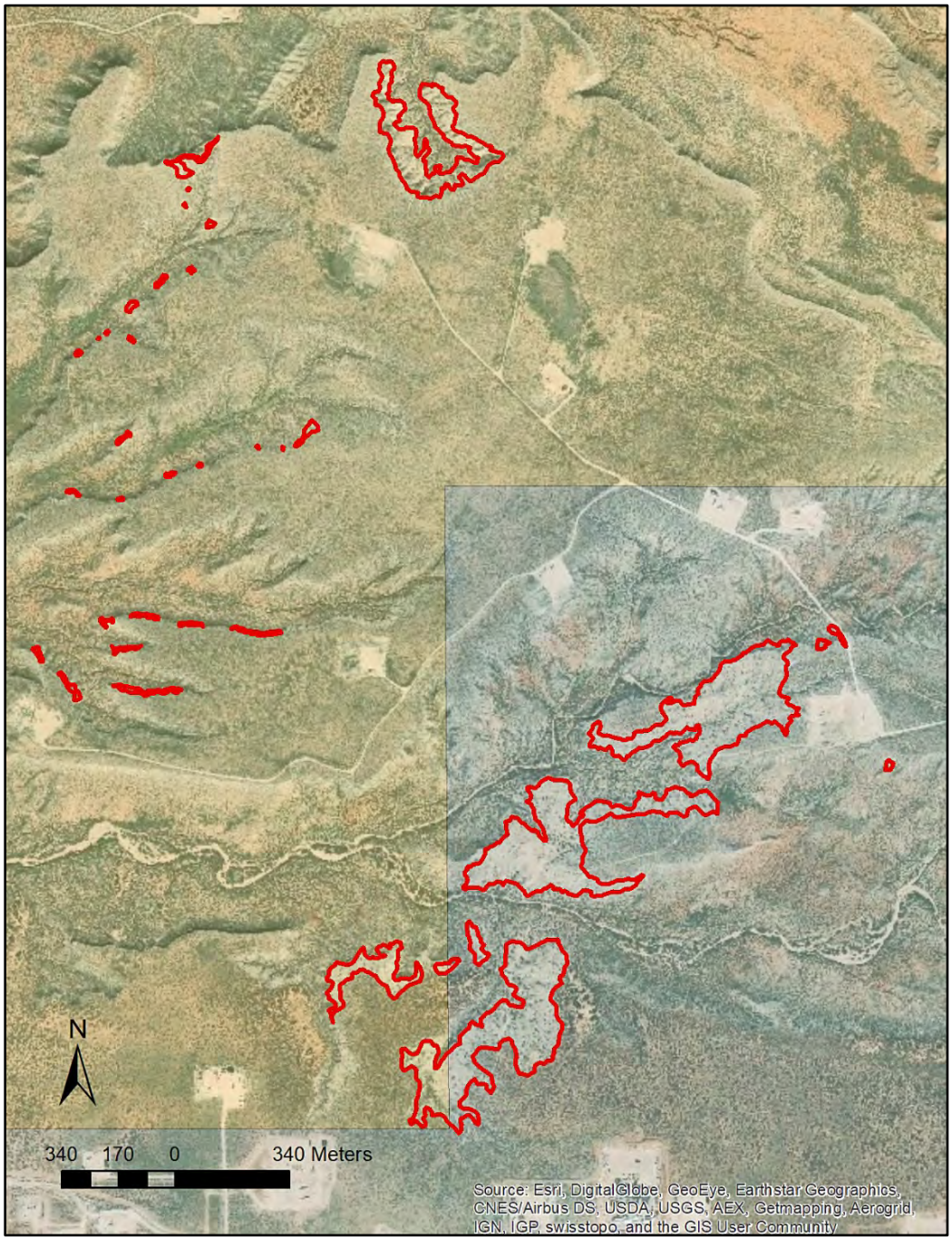

Figure 4. 2019 Tharp's bluestar locations (red polygons) at Cedar and Pierce canyons. Yellow tint is BLM; blue tint is State Trust Land.

Most of the large patches of Tharp's bluestar in Cedar and Pierce canyons were initially surveyed by the BLM prior to 2013 (Howard 2007). No population data was available for these 10 patches surveyed by the BLM. Daniela Roth surveyed state lands in 2013 and Sivinski surveyed new locations of several small patches of plants on BLM lands in 2013 (Roth 2013; Sivinski *et al.* 2014). Size and perimeters of the pre-2013 habitat polygons for the large patches are very similar to the polygons obtained during the 2019 resurvey of those locations (Figures 21 and 22). The 2019 resurvey of the very small patches were also similar in extent to the 2013 surveys.

Twenty-five of these small patches were surveyed with actual plant counts (not estimates) in 2013 and 2019 and are comparable. Seven of these patches increased in number during that six-year period, but fifteen decreased in plant numbers (Table 1). The 2019 total for all twenty-five small patches was 585 plants, which is a 12% decrease from the 667 plants counted in 2013. In addition, one patch was estimated by Roth in 2013 at 1,000 plants and by Sivinski at 2,000-3,000 plants in 2019. Differences in these estimates are more likely explained by surveyor error than by actual increases in plant numbers at patch CC004.

This area has numerous roads, well pads and pipelines for oil and gas development. None of the patches of Tharp's bluestar habitat have been impacted by this development since 2013. None of these small patches appeared directly impacted by any kind of land use. CC002, CC006 and CC020 have been slightly impacted by roads associated with oil and gas development. These impacts were also reported in 2013 (Figures 5 and 6). No other land uses were observed during the 2019 survey.

Figure 5. Road and pipeline impacting CC002.

Figure 6. Road impacting CC006 and CC020.

Mescalero Ridge

The Mescalero Ridge population of Tharp's bluestar is located in the far northeastern corner of Eddy County and was first discover by Sivinski in 2014 (Figure 7; Sivinski *et al.* 2014). The area of occupied habitat in 2019 was very similar to the 2014 polygons (Figures 23 and 24). Plant numbers appeared significantly less in 2019. Estimates ranged from 3,500 to 6,000 plants in 2014, and from 1,800 to 2,800 plants in 2019, for a potential 47 to 51% decrease in the number of plants (Table 1). Most of the plants had leafy stems and flowers during the 2019 resurvey. The Mescalero Ridge population is located within the West Anderson Oil Field, which has been developed for many years. Most of the oil wells in this area are very old, capped, and abandoned. Oil pipelines and roads also cross the escarpment at this location. No signs of livestock were observed in 2019 and no new land uses were observed.

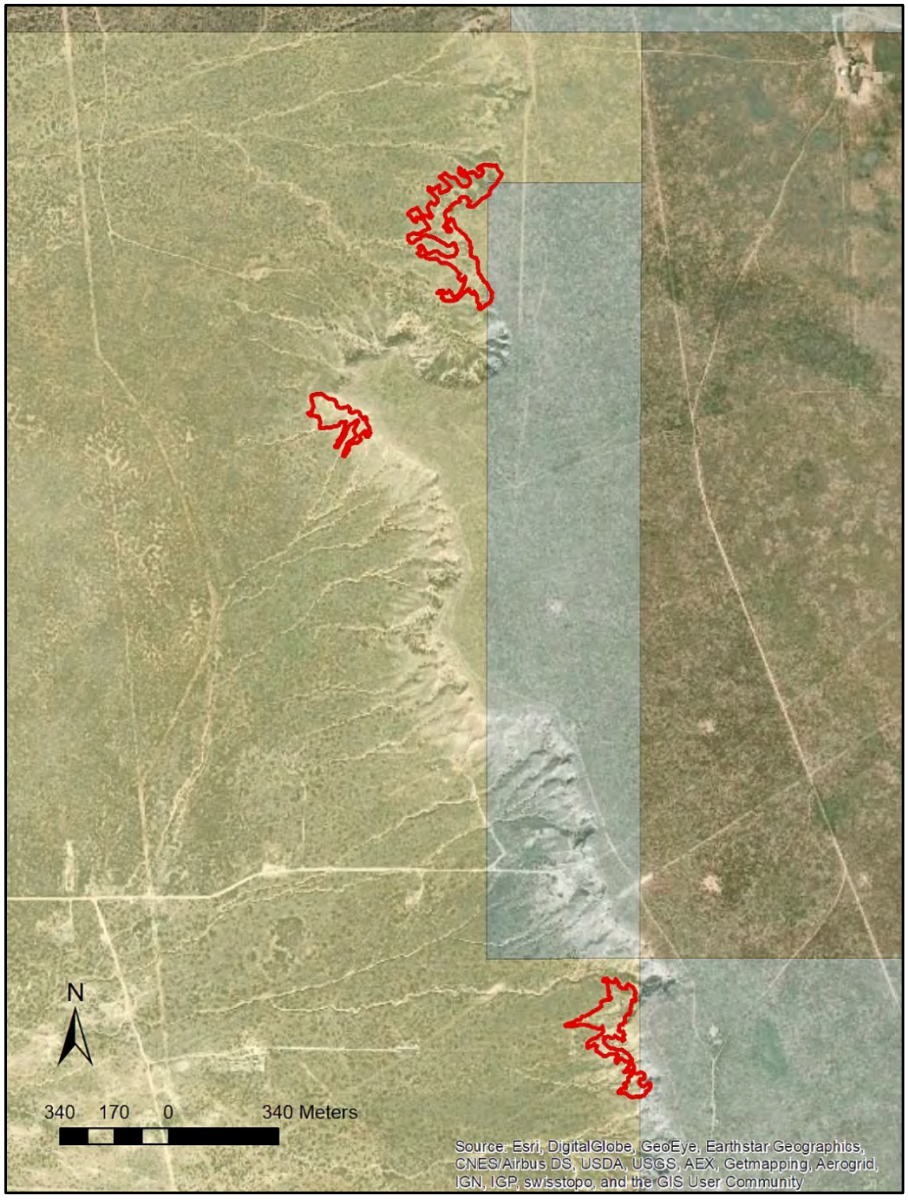

Figure 7. 2019 Tharp's bluestar locations (red polygons) at Mescalero Ridge. Yellow tint is BLM; blue tint is State Trust Land.

Red Lake

The Red Lake population of Tharp's bluestar is the largest and most complicated in terms of landownership, development impacts and monitoring efforts (Figure 8). BLM personnel mapped several habitat polygons as this area was rapidly developing for oil and gas production prior to 2013 (Howard 2007). Many of the polygons mapped prior to 2013 covered occupied habitats on both BLM and State Trust Land. Some were made around whole hills with large buffer areas and without ground truth inspection of the interior plant patches. One such polygon apparently never contained any Tharp's bluestar plants (marked NA on Figure 26). No plants could be found in that polygon in both 2013 and 2019 surveys. Daniela Roth surveyed state lands at Red Lake region in 2013 and Sivinski added several new habitat polygons on BLM in 2013.

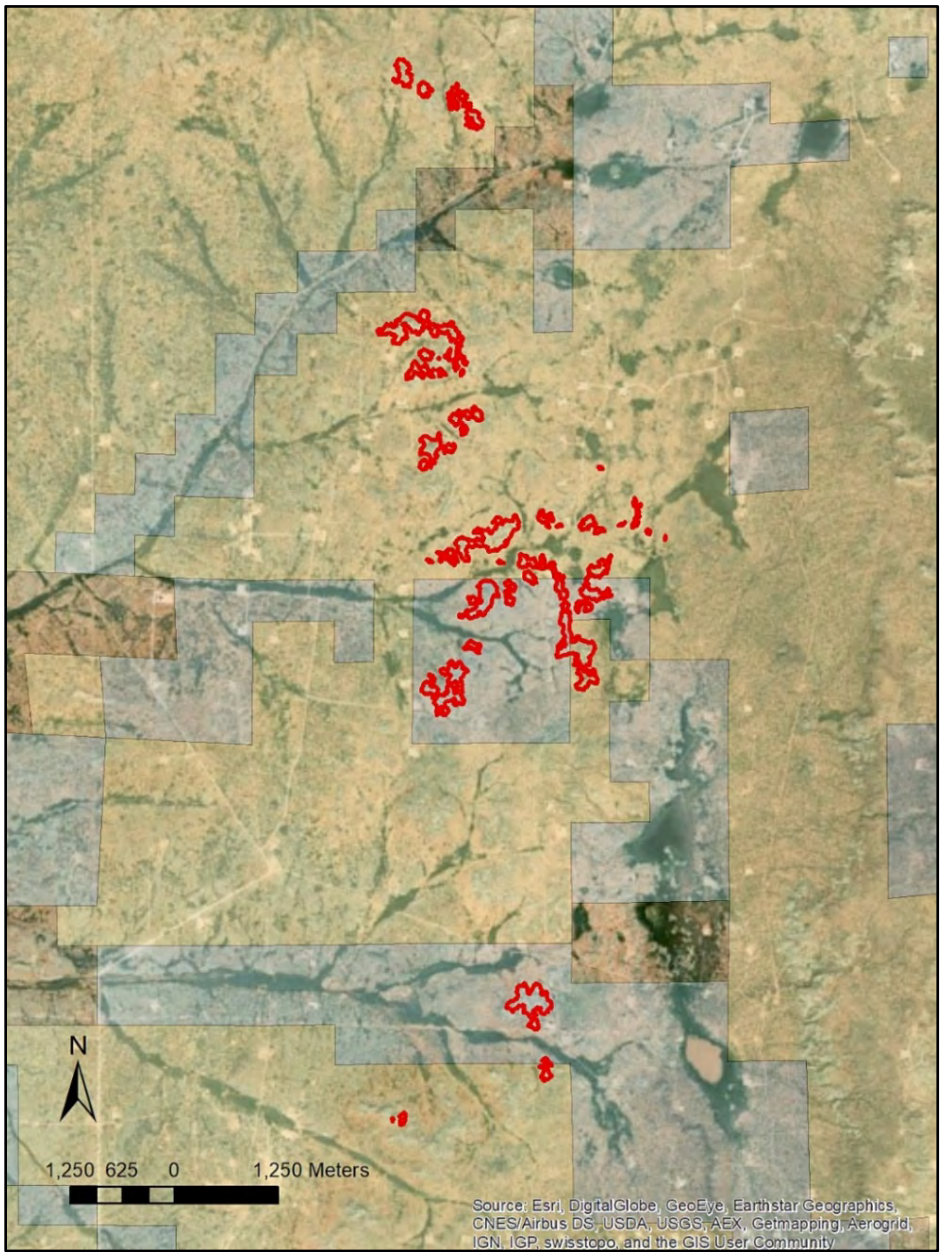

Figure 8. 2019 Tharp's bluestar locations (red polygons) at Red Lake. Yellow tint is BLM; blue tint is State Trust Land.

A total of 42 polygons of occupied habitat were documented from the Red Lake population in 2019 (Table 1; Figures 25, 26, 27, 28). Thirteen of these 42 patches were newly documented in 2019, 12 were documented prior to 2013 and had no prior population estimates, 17 were also documented in 2013 and included population estimates. The Red Lake habitat polygons made by Roth and Sivinski during their 2013 surveys are similar to the polygons made in the follow-up 2019 survey. A new numbering system for the polygons was adopted during the 2019 survey because some of the large pre-2013 polygons were split into several smaller plant patches and new plant patches were discovered in 2019.

The seventeen polygons surveyed in 2013 and 2019 are comparable. Most of these are fairly large patches where plant numbers were estimated and the numbers were lower in 2019 for the majority of the seventeen polygons (Table 1). Estimates for these seventeen patches ranged from 13,653 plants to 14,453 in 2013 and from 4,634 to 6,734 plants in 2019. This represents a potential loss of 53 to 66% to of the estimated population in 2013. Estimates can be inaccurate, but one particular patch, RL027, showed an especially dramatic decrease (Figure 27). Field notes for the 2013 assessment of RL027 say "a few thousand plants, 99% appear to be dead". The 2019 estimate for this patch was only 100-150 plants, indicating that most apparently did not recover.

Land use impacts to the Red Lake population of Tharp's bluestar are mostly the result of activities associated with oil and gas development. The most recent documented impacts occurred in 2010 were the construction of a 4.3-acre well pad at the north end RL037, well pads that damaged the margins of RL004 and RL018, and a pipeline constructed across RL019 (Figures 25 and 27). These impacts were described and illustrated by Sivinski *et al.* (2014). Additional, older, impacts discovered in the 2019 survey included a state land well pad damaging the edge of the mid-RL037 habitat (Figure 9) and a BLM well pad encroaching upon the margin of RL006 (Figures 10 and 27). Previous disturbance to habitat also include roads crossing RL037 (Figures 11 and 12) and RL039 (Figure 13). A powerline and two-track road on state land cut across the western edge of RL040 (Figures 14 and 27).

Figure 9. State land well pad at RL037.

Figure 10. BLM well pad at RL006.

Figure 11. BLM road through RL037.

Figure 12. State land road through RL037.

Figure 13. State land road through RL039.

Figure 14. State land powerline through RL040.

TEXAS - SUMMARY

A total of 565 plants were documented from 127 waypoints in Texas in 2019 (Figure 15; Table 2). The 127 waypoints were distributed in 2 patches separated by approximately 0.5 miles. Twentyfive waypoints documented 31 plants along the right-of-way; the remaining 534 plants were located on adjacent University of Texas lands. None of the observed plants were flowering and the majority of plants were vigorous. The two population polygons coverered approximately 25 acres of occupied habitat of roughly equal size. No additional lands were surveyed in 2019. Population trend comparision shows an apparent increase in the number of plants at both previously documented patches of occurrence, for an overall increase from 362 to 531 individuals (Table 2). However upon close inspection of survey tracks provided by the TX Parks Wildlife Department, it appears more likely that the increase of plants is an artifact of increased survey effort in 2019, rather than recruitment. Up to 95 plants may have been missed during previous surveys in 2014 in the northern population patch (Figure 29). No tracks were available for the surveys in the southern patch, but up to 129 individuals may have been missed within the southern population, outside of the ROW (Figure 30). Apparently the area was surveyed to a lesser extent in 2014 than in 2019 and therefore comparisons may be misleading.

Except for the 5 plants that were transplanted by the Texas Department of Transportation as a mitigation measure for a road maintenance project, plants were found at all previously recorded sites. Three of the five transplanted plants did not survive and the fate of 2 additional transplants is unknown, but are presumed dead.

Two non-native species were previously documented from disturbed soils along the shoulder of highway 385/67 at the Pecos County Tharp's blue-star site: white horehound (*Marrubium vulgare*) and Maltese star-thistle (*Centaurea melitensis*)(Strong and Williamson 2015). No star thistle or horehound were seen in 2019. In 2019, much of the ROW population of Tharp's bluestar was covered by the invasive introduced yellow bluestem (*Bothriochloa ischaemum*) (Figures 16 and 17). Despite the fact that the right-of-way was dense with native and invasive plant species, including yellow bluestem (*Bothriochloa ischaemum*), plants persist in the ROW. It is unclear whether plants can persist over time with these high levels of competition from other plants, given their natural adjacent habitat is very sparsely vegetated (Figures 18 and 19). Road maintenance and upgrades, including a planned road-widening project, and potential herbicide and mowing activities are the largest active threat to the roadside population. Observed disturbances on University of Texas lands included an access road through occupied habitat, fence construction impacts, and livestock activities outside of the exclosure. No oil & gas development activities were documented near the Texas population in 2019.

Table 2. Population numbers, trends, and occupied habitat areas of 4 Tharp's blue-star polygons at one Texas population. Exclosure and ROW are part of in Southern sub-population.

Location Name	Last Survey Year	Observer	No of Plants	Current Survey Year	Observer	No of Plants	Trend	Patch (Acres)
ROW	2019	Strong/ Brady	23	2019	Roth	31	⬆	
Exclosure	2016	Strong	18	2019	Roth	12	⬇	
Southern sub-pop	2014	Strong	203	2019	Roth	289	⬆	12.30
Northern Sub-pop	2014	Strong	116	2019	Roth	202	⬆	12.44
Total			**362**			**531**	⬆	**24.74**

Figure 15. Tharp's bluestar locations in Pecos County, TX in 2019 (red lines and points) and previous 2014 – 2018 documentation (green triangles).

Figure 16. Habitat conditions in ROW along HWY 385/67

Figure 17. Habitat conditions in ROW along HWY 385/67

Figure 18. Habitat conditions on UT lands

Figure 19. Habitat conditions on UT lands

DISCUSSION

The apparent decline in the number of plants between 2013/2014 and 2019 in all four New Mexico populations is likely attributable to the effects of prolonged drought. From 2011 to 2012 New Mexico had a record-breaking drought. The two years combined are the driest and warmest years on record (United States Drought Monitor 2019). The spring of 2013 began with an apparent a third year of drought with southeastern Eddy County experiencing abnormally dry conditions and northwestern Eddy County under exceptional drought conditions (Figure 31). The drought of 2011 through the spring of 2013 apparently took a toll on the populations. When surveys at two of the New Mexico sites were conducted in April and May of 2013 only an estimated 10% of plants were producing new stems or foliage and fewer than 10 individuals (of thousands) were in bloom (Sivinski *et al.* 2014). Plants were, in fact, a bright yellow-orange color instead of green. The 2013 survey was often counting the remnants of dead plants that were not confirmed as dead until the subsequent survey in 2019. Rains in August of 2013 finally alleviated drought conditions to some extent across the state. When revisited in October of 2013, many plants were observed with new green leaves and stems, but no flowers or fruits were observed (Sivinski *et al.* 2014). Although Tharp's bluestar was previously thought of as a hardy drought resistant suffrutescent perennial herb likely able to remain dormant through extended periods of drought (Sivinski *et al.* 2014), 2+ years of ongoing drought did result in significant mortalities. It is unclear whether populations will be able to recover from this decline or whether the decline is halted. What is clear is that mortality continues to significantly outpace recruitment. Although most comparable plant patches decreased, 34% did have the same or increased numbers. Parts of the occupied habitat are apparently more favorable than others for population persistence during climatic extremes, likely related to microhabitat conditions, such as growing along shallow drainages, slope and exposure, as well as competition from other plant species. The Cedar/Pierce population experienced the lowest decline (12%) among the 4 populations. Considering the spottiness of rainfall in the southwest, it is possible that this population experienced localized higher rainfalls than the other three populations.

In comparison the small population near Fort Stockton in Texas appears to be doing well. The average annual rainfall in Fort Stockton is 15.1 inches, which is significantly higher than average annual rainfall for Artesia or Carlsbad (U.S. Climate Data). Although the total rainfall for the Fort Stockton area was only 2.42 inches in 2011, rainfall amounts increased to12.21 inches in 2012. Drought conditions were less severe and prolonged in Pecos County than those observed in neighboring Eddy County, NM (Figures 31 and 32). The Texas population also occurs at lower elevation than the New Mexico sites and are located significantly further south, likely resulting in less harsh winters. Observed increases in plant numbers at the Texas population do not likely represent recruitment into the population, but rather an increase in numbers due to increased survey effort, based on our knowledge of where plant locations were previously recorded. Documented and potential threats include a planned road widening project, road traffic and maintenance, including invasive species management, fence building and maintenance, invasive species, and livestock activities. Considering how small this population is, these threats could significantly impact the continued existence of the species in Texas, in the absence of targeted management. No oil & gas development impacts were observed near the site at this time.

All known populations of Tharp's bluestar are located in the Permian Basin, which is one of the most prolific oil and gas producing basins in the United States. Horizontal drilling and hydraulic fracturing in oil reservoirs has led to a boom that began in 2012. Production is expected to continue to increase for years to come. Documented impacts include the construction and maintenance of oil & gas wells and pipelines, storage facilities, and access roads (Sivinski *et al.* 2014). Potential impacts include increased direct impacts from associated infrastructure development and potential oil spills and indirect impacts of habitat fragmentation on pollinator availability and dust impacts on pollination success.

Drought conditions have been the primary driver of the decline in New Mexico populations. Little can be done locally to halt the impacts of climate change on rare plants. However, regulatory oversight, including enforcement, and on-the-ground mitigation through targeted management can help buffer the impacts of climate change. These should include the protection of all known populations from ground disturbances in perpetuity. Habitat protections should include buffers to provide for population expansion, pollinator habitat, and protections from fugitive dust. Land management activities should analyze potential impacts on plants and their habitats and avoid impacts to all populations. Close monitoring of all sites is essential in determining population trends into the future and to provide threshold for possible management actions aimed at halting further declines. Collection of seeds for storage at a germplasm repository is advised for ex-situ conservation purposes and the development of a germination and establishment protocol for ex-situ conservation of plants in botanical gardens, and the possible future augmentation of dwindling existing populations.

ACKNOWEDGEMENTS

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APPENDIX A. Detailed maps of New Mexico locations of Tharp's bluestar

Figure 20. Tharp's bluestar habitat polygons at Ben Slaughter Draw in 2019 (red lines) and 2013 survey or pre-2013 BLM survey (yellow lines).

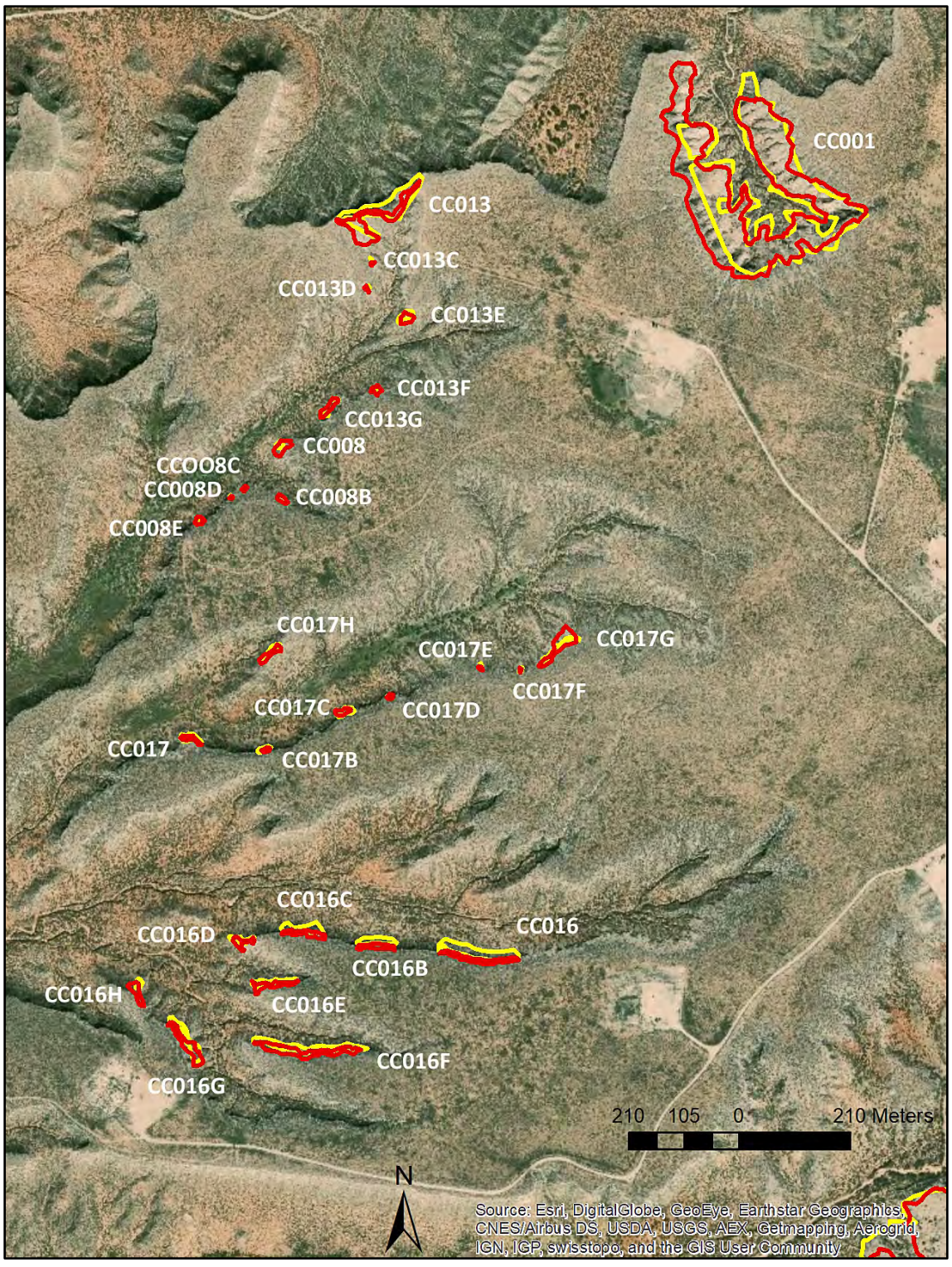

Figure 21. Tharp's bluestar habitat polygons at Cedar and Pierce canyons in 2019 (red lines) and 2013 survey or pre-2013 BLM survey (yellow lines).

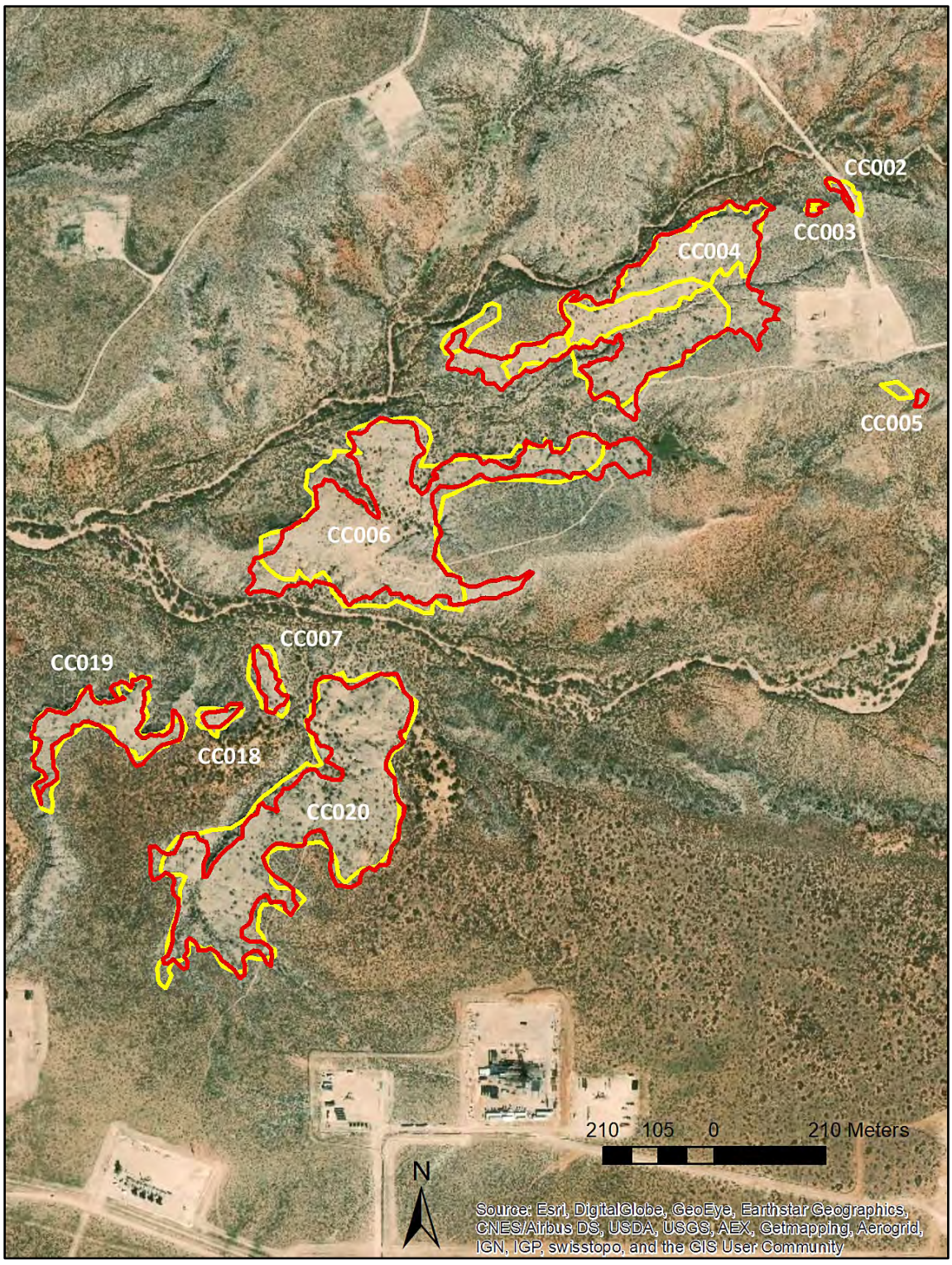

Figure 22. Tharp's bluestar habitat polygons at Cedar and Pierce canyons in 2019 (red lines) and 2013 State Land survey or pre-2013 BLM survey (yellow lines).

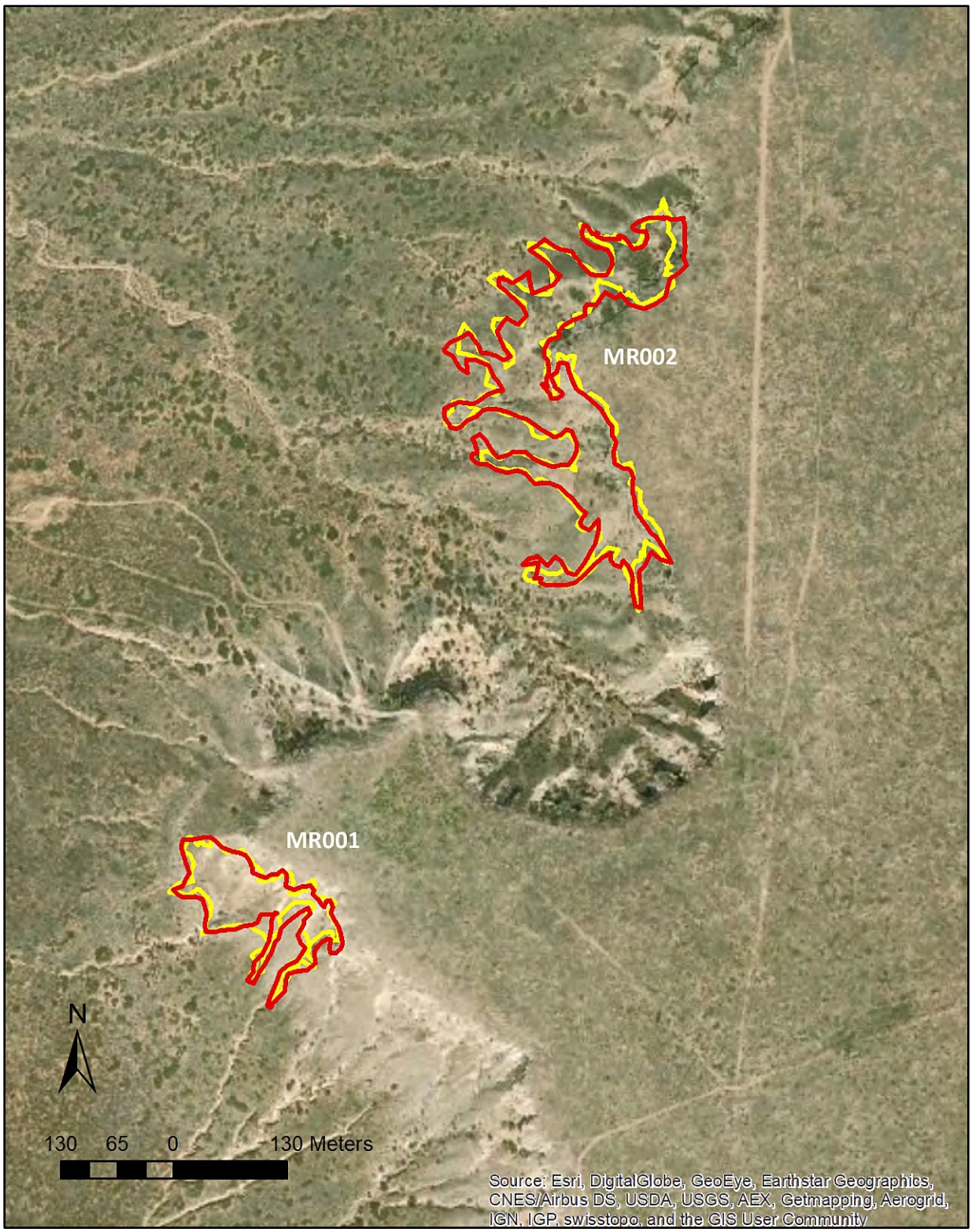

Figure 23. Tharp's bluestar habitat polygons at Mescalero Ridge in 2019 (red lines) and 2014 survey (yellow lines).

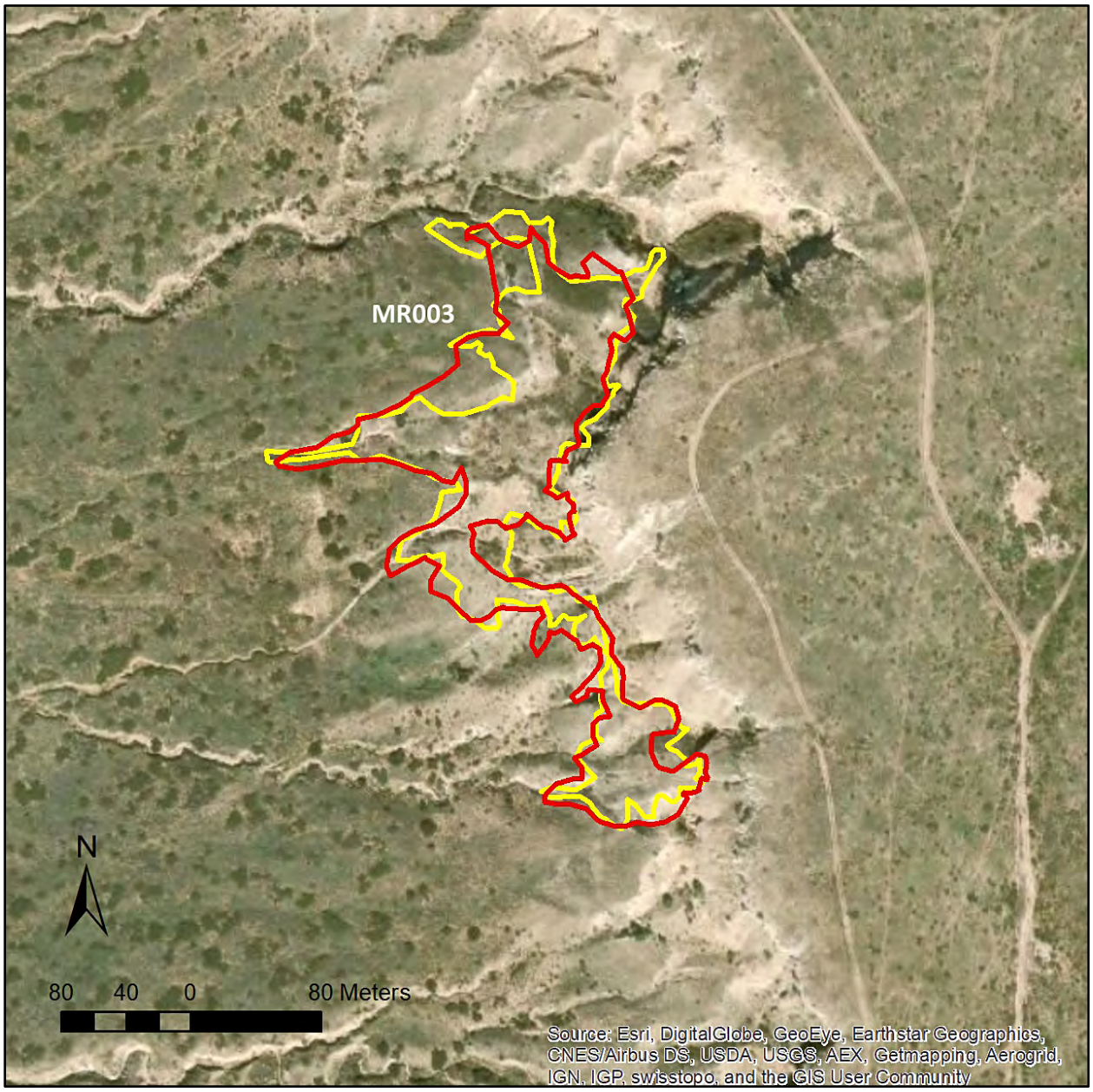

Figure 24. Tharp's bluestar habitat polygons at Mescalero Ridge in 2019 (red lines) and 2014 survey (yellow lines).

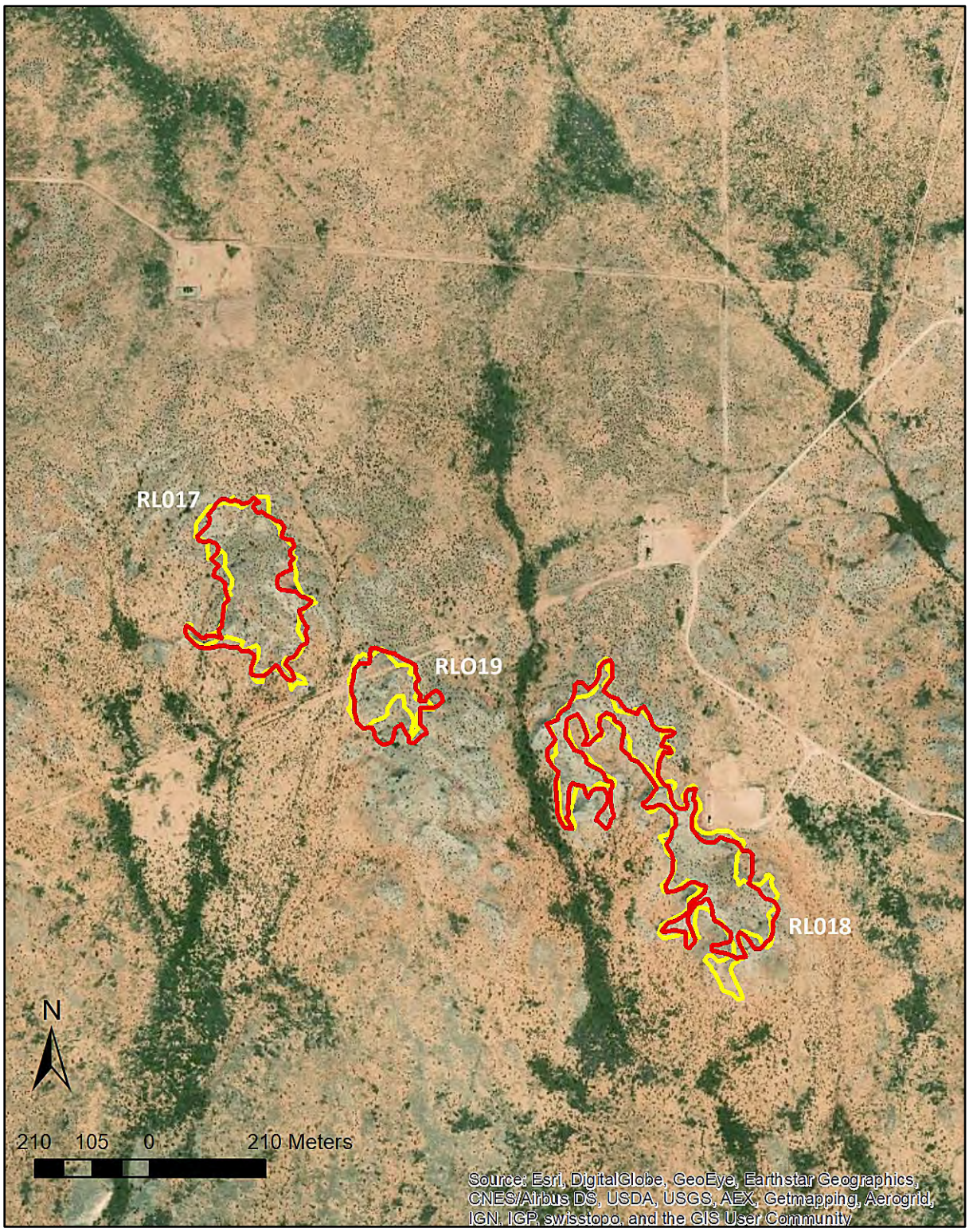

Figure 25. Tharp's bluestar habitat polygons at Red Lake in 2019 (red lines) and 2013 survey (yellow lines).

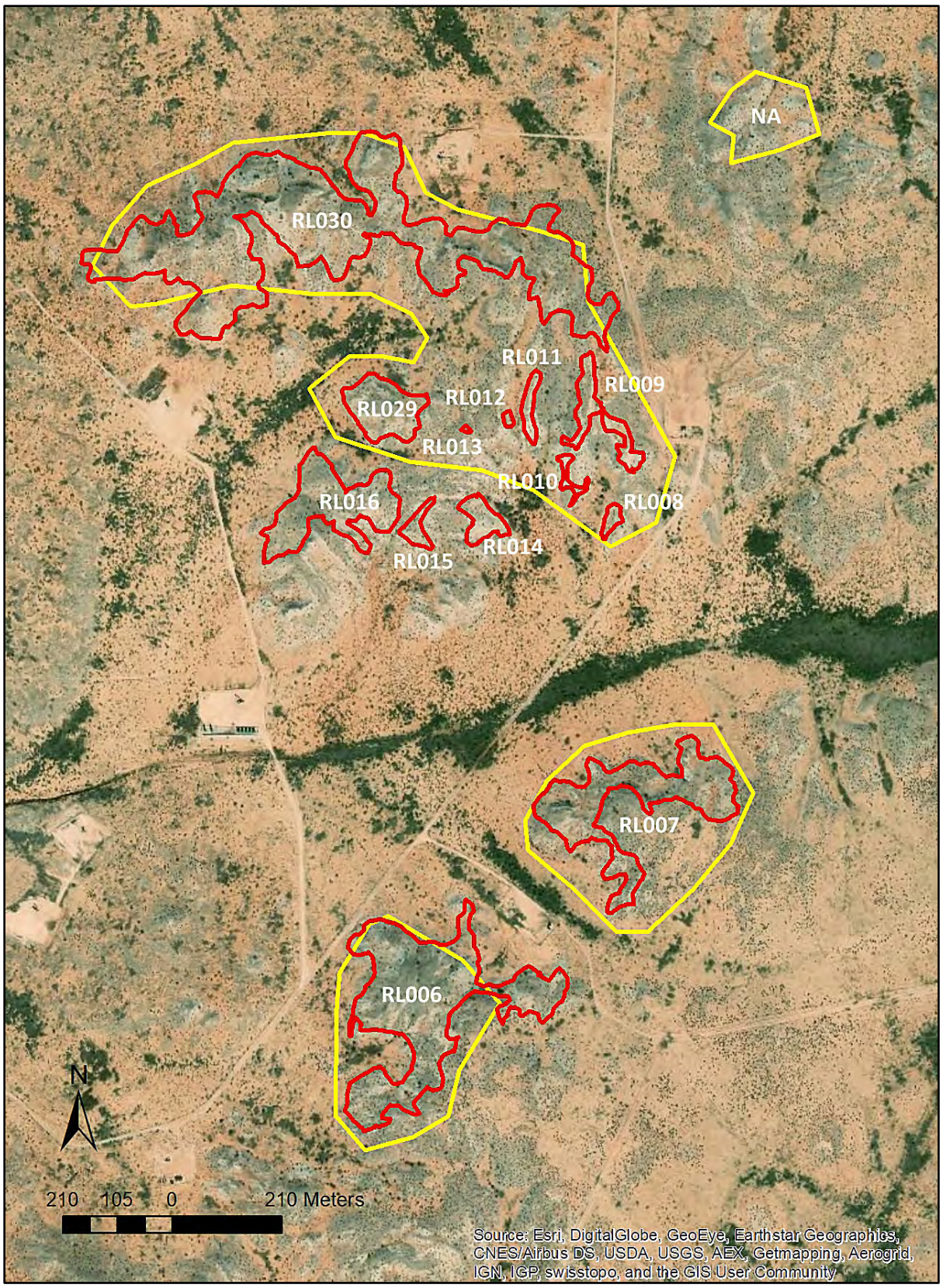

Figure 26. Tharp's bluestar habitat polygons at Red Lake in 2019 (red lines) and pre-2013 survey (yellow lines).

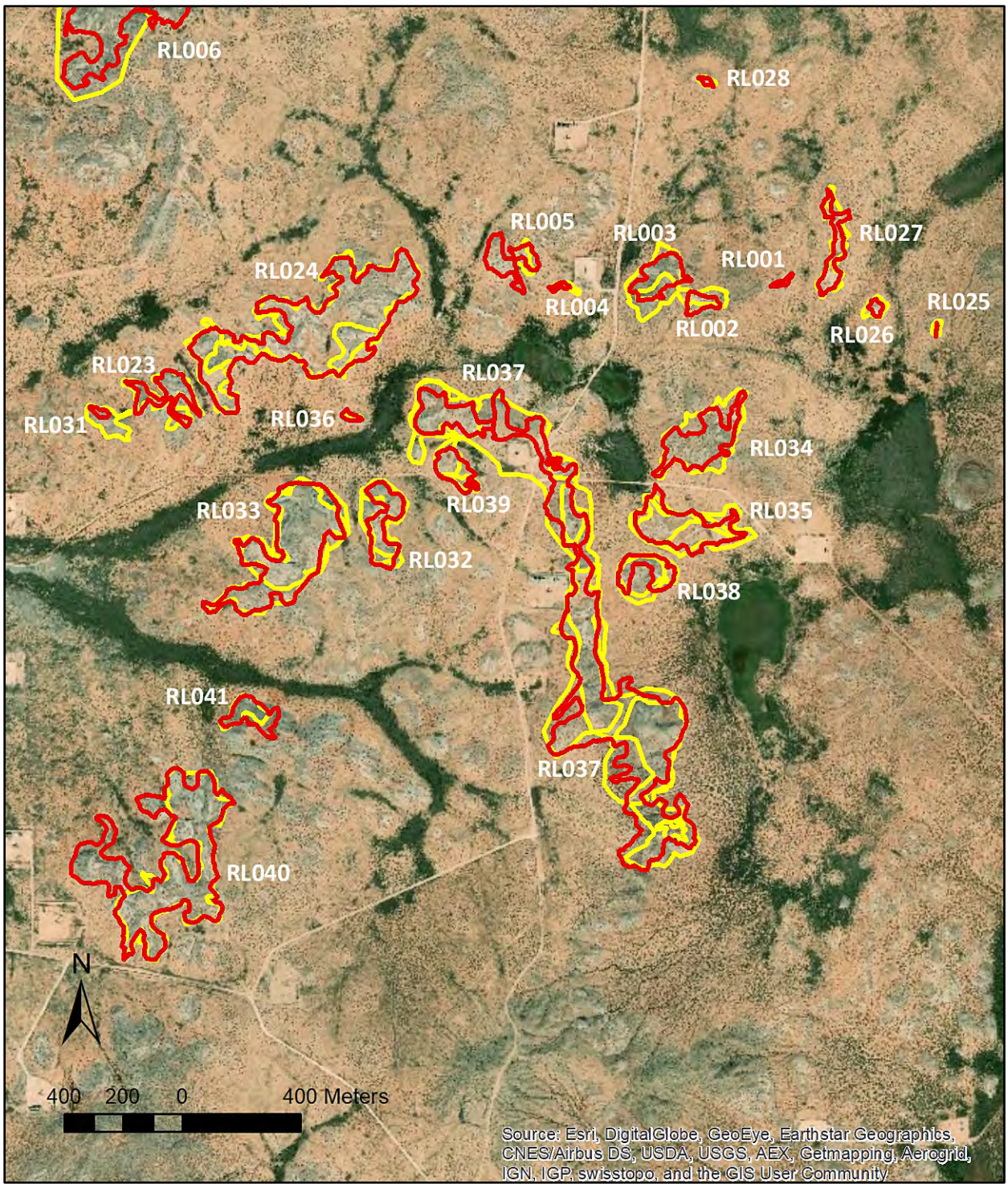

Figure 27. Tharp's bluestar habitat polygons at Red Lake in 2019 (red lines) and 2013 and pre-2013 surveys (yellow lines).

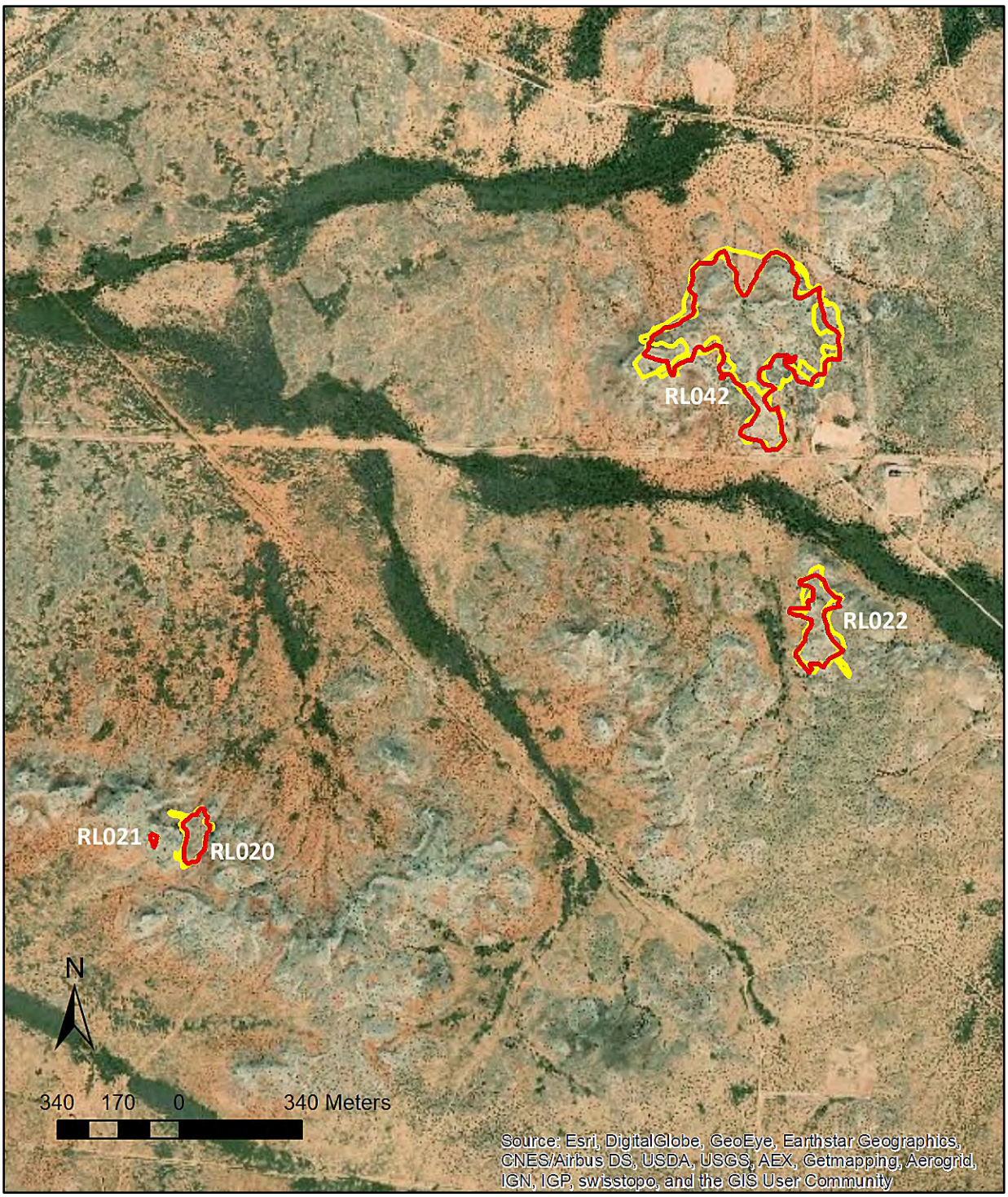

Figure 28. Tharp's bluestar habitat polygons at Red Lake in 2019 (red lines) and 2013 surveys (yellow lines).

APPENDIX B. Detailed maps of Texas locations of Tharp's bluestar

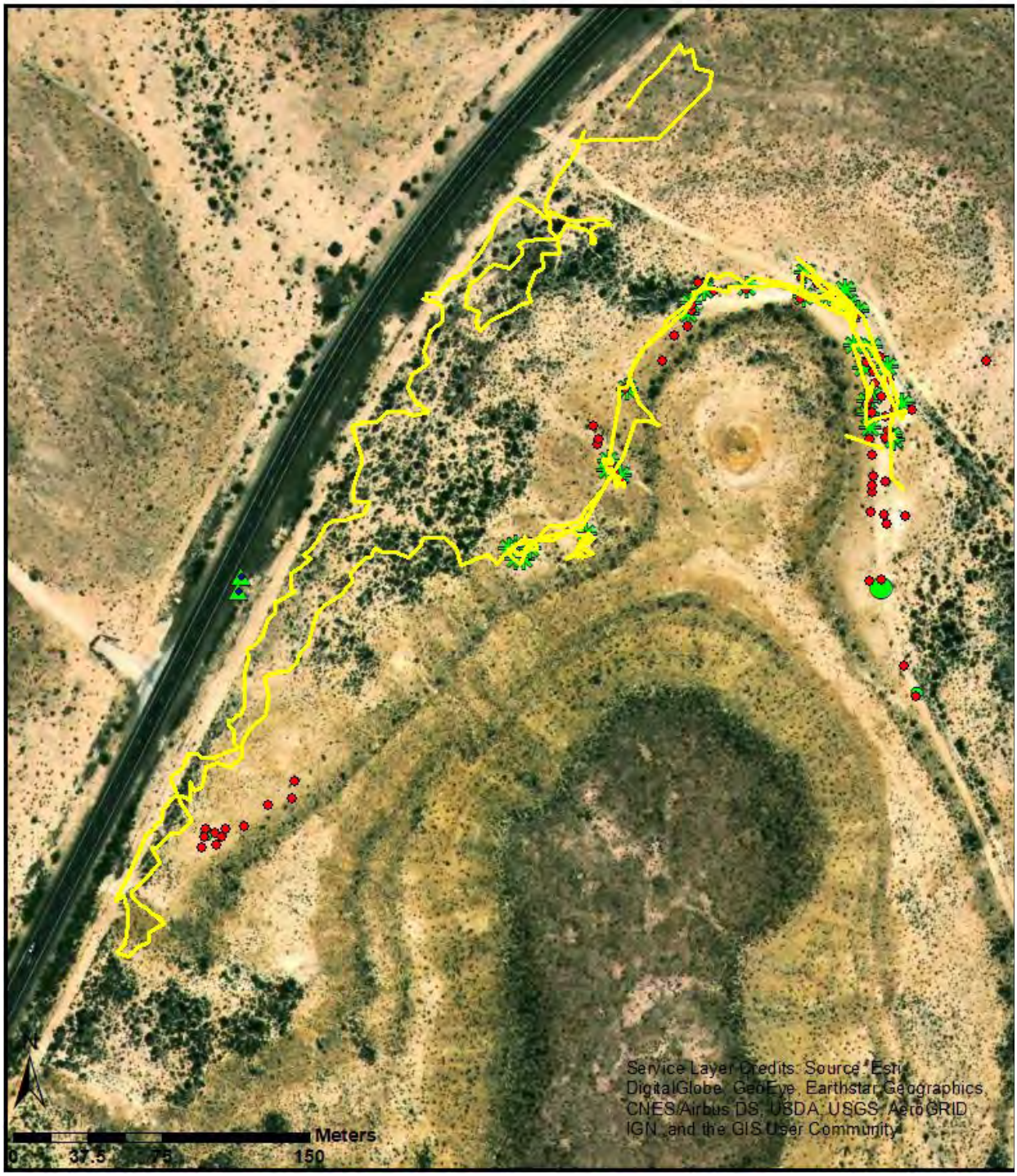

Figure 29. Location of Tharp's bluestar plants at the northern subpopulation in Texas in 2019 (red dots) and 2014/2016 (all other markers). Yellow lines represent 2014 survey tracks.

Figure 30. Location of Tharp's bluestar plants at the southern subpopulation in Texas in 2019 (red dots) and 2014/2016 (all other markers).

APPENDIX C. United States Drought Monitor

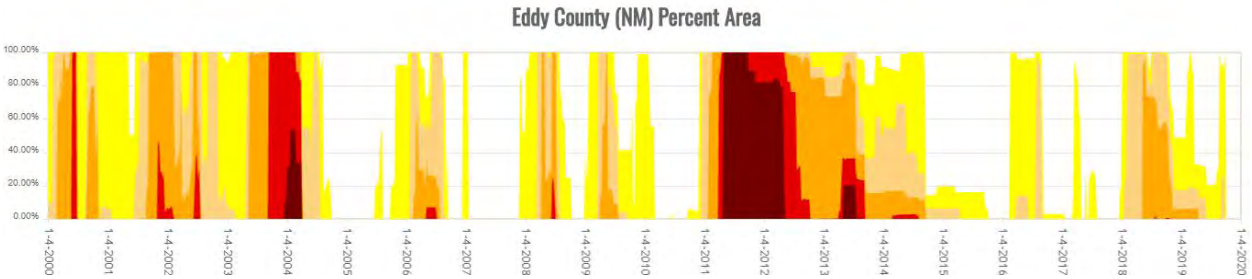

Figure 31. Time series of drought conditions in Eddy County, NM, from 2000 through 2019 (US Drought Monitor 2019).

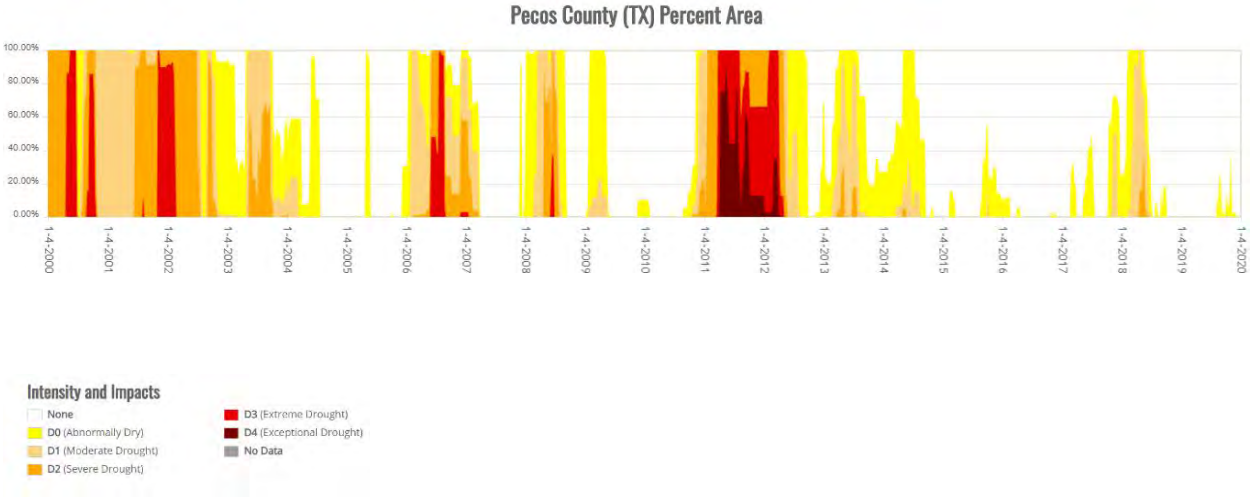

Figure 32. Time series of drought conditions in Pecos County, TX, from 2000 through 2019 (US Drought Monitor 2019).