Status of the Soil Seed Bank of Santa Cruz tarplant (*Holocarpha macradenia* Greene), Arana Gulch Open Space, Santa Cruz , CA

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Submitted by:

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OBJECTIVE:

The objective of this project was to estimate the current density of the soil seed bank of Santa Cruz Tarplant (SCTP) in SCTP Areas A - D at Arana Gulch Open Space, Santa Cruz, CA.

BACKGROUND:

The density of the soil seedbank of SCTP has been estimated at Arana Gulch at least three times. The estimates were done for various purposes, in different areas at Arana Gulch, and by various sampling configurations. Rexford Palmer estimated an average density of 27 ray cypselae (fruits) per square decimeter in the first 2.5 centimeters of soil, and 3.8 at 2.5 to 5 centimeter depth (Palmer 1982). It is unclear if he tested viability of the cypselae. He collected the samples for his dissertation which was finished in 1982. The location of the 20-meter transect he used to collect soil samples is not recorded, but most likely it would have been from SCTP Area A.

In 1999, density of the soil seed bank was estimated in SCTP Areas A-D as part of a comparison of soil seed bank density between several SCTP populations (Bainbridge, unpublished) and estimated to be 21.4 viable ray cypselae per square decimeter in SCTP Area A, and 2 in Area D (combining samples for soil depths 0-2.5 and 2.5-5.0 cm). The sampling configuration is described below. No soil seed bank was detected in SCTP Areas B or C, but only 4 samples were taken from each area (12 cores from B and 36 from C).

In 2002, soil seed bank density was estimated in experimental plots established in 2001 in SCTP Areas A and D and in an area north of SCTP Area A (Bainbridge, unpublished). The purpose was to monitor effects of management treatments (fire, mowing, scraping, no treatment) on the seed bank. The area north of SCTP Area A had not been previously sampled and no soil seed bank was detected. Combining results from plots in Areas A and D indicated densities for each Area in 2001 were the same magnitude as in 1999, although the sampling configuration was different than in 1999 and the two samples are not statistically comparable.

METHODS:

Collection of seed bank samples. Soil samples were collected from designated SCTP Areas A-D because SCTP has been recorded in these areas more recently (since 1996) and viable seed would more likely be found in these areas. In each of the SCTP Areas, samples were collected in configurations similar to the 1999 soil seed bank assessment with the following exceptions: 1) sample density was greater in 2013-2014 to increase the probability of finding viable seeds and 2) transects in the northeast corner of SCTP Area D were truncated because construction had already started and that area had been altered. Sampling in SCTP Areas B-D occurred in December of 2013. Sampling in SCTP Area A occurred in February 2014, after the assumed germination period, so that samples reflected the persistent soil seed bank and would not include seeds that may germinate in the winter.

The size of the approximate area that was targeted for sampling, the sample number, number of sample points and soil cores and the sample density for each SCTP Area is summarized in Table 1. In SCTP Areas A and D, 122-meter baselines +/- bisecting the long axis of the areas was placed in approximately the same location as 1999; GPS points and aerial photos were used to relocate the baselines. One transect was placed and perpendicular to these baselines from a random location along the baseline in every 6 meter segment for a total of 20 transects per baseline. The transect direction from the baseline was also randomly selected.

In SCTP Area A, transects were 50-meters long with 5 soil collection points per transect, and in Area D, transects were 40-meters with 4 soil collection points/transect. Soil collection points were recorded with a Garmin GPS (> 3-meter error). In SCTP Area B, soil collection points were located using regularly spaced transects, rather than random samples. The 6 transects were 5 meters apart and 25 meters long. In SCTP Area C, a 60-meter baseline was placed on the northeast edge of the Area and the starting locations for six 30-meter transects were randomly selected. Soil was collected at 5 collection points per transect.

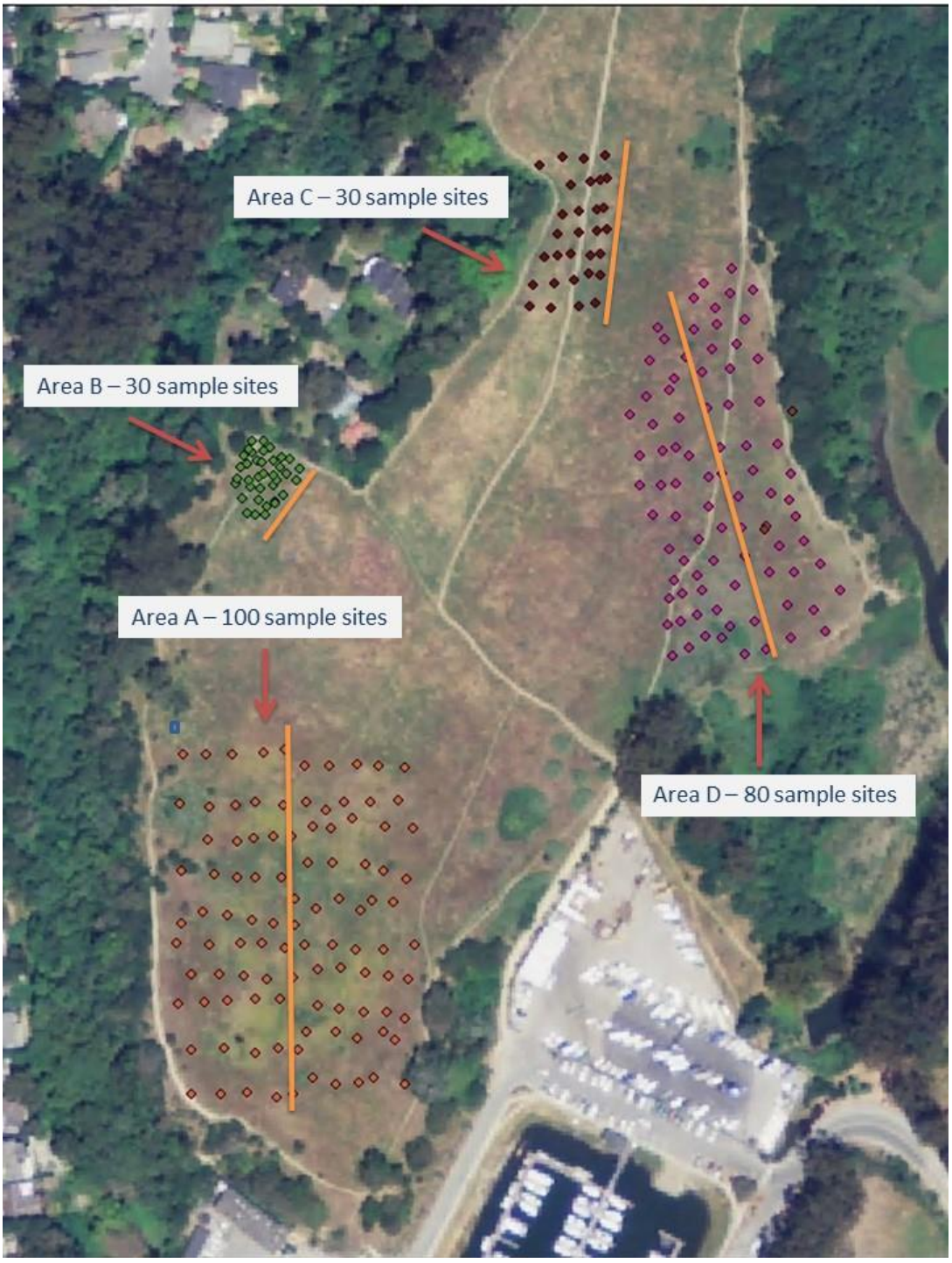
Approximate location of sample sites and baselines are shown in Figure 1. At each collection site, three soils cores were collected. Each core was 8 cm in diameter (50.26 cm^2 surface area) and soil samples were removed in two parts: 0-2.5 cm depth and 2.5-5 cm depth. Resulting sample sizes were 20 in areas A and D with sample densities of 2.6 to 3.1 soil cores per 100 square meters. Sample size in SCTP Area B and C was 6 with a sample density of 14.4 cores per 100 square meters. In SCTP Area C, the sample size was 6 with sample densities of 4 cores per 100 square meters.

Table 1. Soil Seed Bank Sampling in SCTP Areas A-D.

	Approximate area sampled (m^2)	Number of transects (n)	Number of sample sites	Number of soil cores	Cores/100 m^2 sample area
Area A	9,760	20	100	300	3.1
Area B	625	6	30	90	14.4
Area C	1,800	6	30	90	4
Area D	9,760 (~500)	20	80	240	2.6

Processing of soil samples. All ray and disk cypselae are extracted from the soil samples by passively dissolving samples in water and rinsing through graduated white polyester sieves and visually checked for SCTP seeds in a sieve with 1mm size mesh. All large seeds and undissolved pieces of clay are put aside and the sample labeled for further inspection. Viability was tested by dissection of the seed coat under a microscope. If a white embryo or an off white embryo that started development if a petri dish was present, the cypselae was considered viable.

Figure 1. Location of baselines and soil seed bank samples at Arana Gulch – 2013-14. Approximate location of baselines and soil seed bank samples based on coordinates recorded by GPS. Symbols represent sample sites comprised of three 50 cm^2 soil cores.



RESULTS:

Thirty viable and 27 non-viable SCTP cypselae were located in the 52 samples (240 collection sites representing 720 soil cores) (Table 2). All viable and non-viable seeds were found in SCTP Areas A and D and all viable cypselae were in the samples collected in the first 2.5 cm of soil. Only ray cypselae were found - no disc cypselae were located in any of the samples. Location of collections sites where viable cypselae were found are shown in Figures 2 and 3. The non-viable cypselae located in the sample may or may not have been viable at some point because SCTP like other taxa can form a seed coat without a viable embryo.

Table 2. Results of 2013-2014 Soil Seed Bank Resampling at Arana Gulch.

	Area A (n=20)	Area B (n=6)	Area C (n=6)	Area D (n=20)
Number of viable SCTP cypselae in samples*:	28	0	0	2
Average number of cypselae per sample (std. dev.):	1.4 (2.03)	0	0	0.2 (0.307)
Frequency of viable SCTP cypselae in samples (# samples w/viable cypselae/# samples):	0.50	0	0	0.10
Frequency of viable SCTP cypselae at collection sites (# viable cypselae/#collection sites):	1.40	0	0	0.025
Density of viable cypselae per square decimeters:	0.187	0?	0?	0.033
Number of non-viable SCT cypselae Seed coat present but embryo not evident:	23	0	0	2
Embryo present – but not viable:	2	0	0	0
Fragments of SCT seed coat**:	14	0	0	1
Possible *Deinandra* or SCTP seed coat fragment:	31	0	3	1

* All cypselae found in samples from the first 2.5 cm; no seeds or fragments found between 2.5 and 5.0 cm. ** Each of these fragments represents a different cypselae based on morphology.

Figure 2. SCTP Area A: Approximate location of soil collection sites with viable SCTP seeds (orange dots) and collection sites (X).

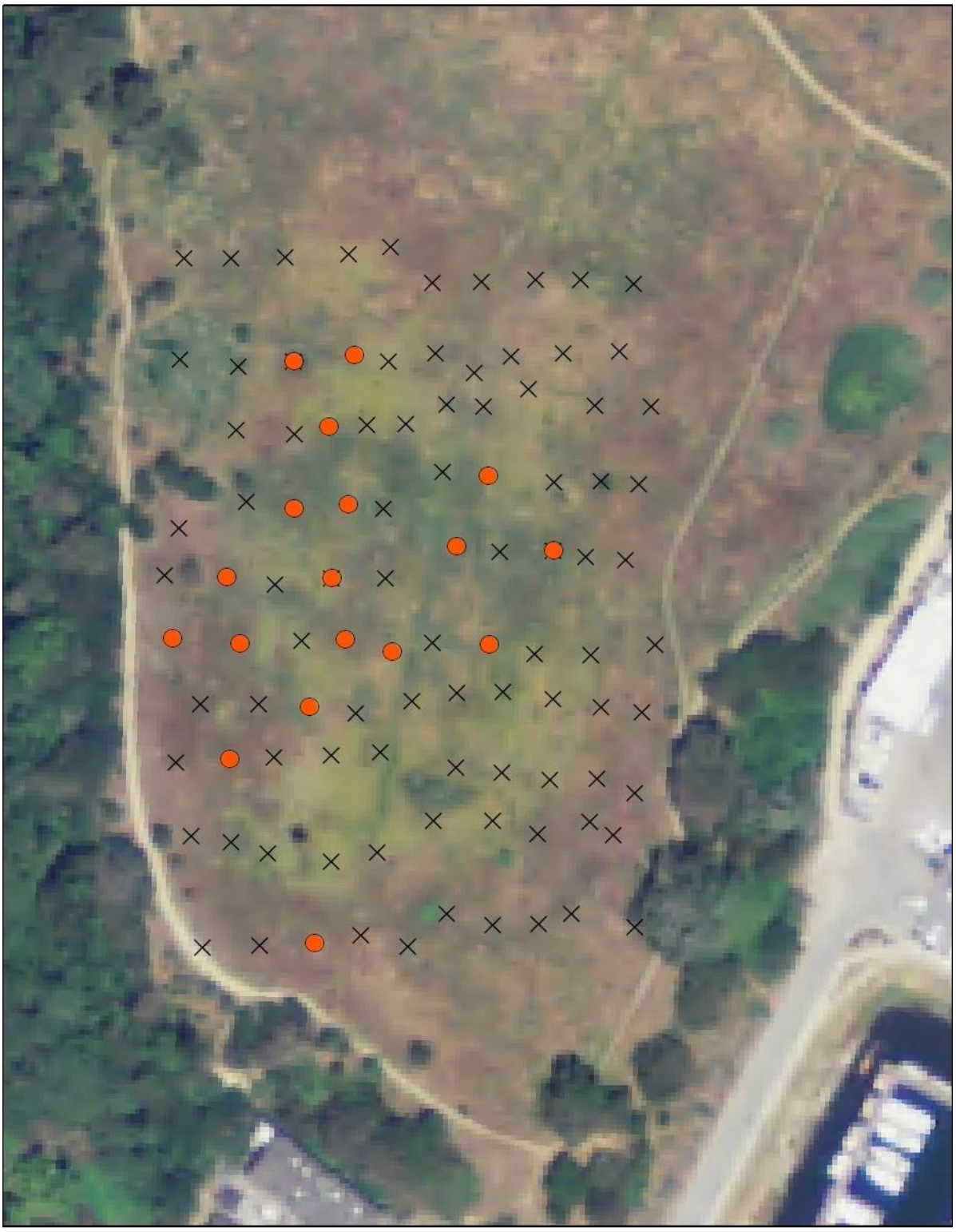


Figure 3. SCTP Area D: Approximate location of soil collection sites with viable SCTP seeds (orange dots) and collection sites (X).

DISCUSSION AND RECOMMENDATIONS:

Results from the 2013/2014 soil seed bank assessment indicate a significantly lower ($p=0.2 \times 10^{-8}$) soil seed bank density than was estimated in 1999 using the same method. A decline in seed bank density was expected given natural attrition from the soil seed bank without significant input since 2002-2003 but extent of the decline was hard to predict. Degraded habitat conditions and lack of appropriate disturbance in large portions of habitat to stimulate recruitment and seed aging since 1988 are probably the most important factors contributing to the decline.

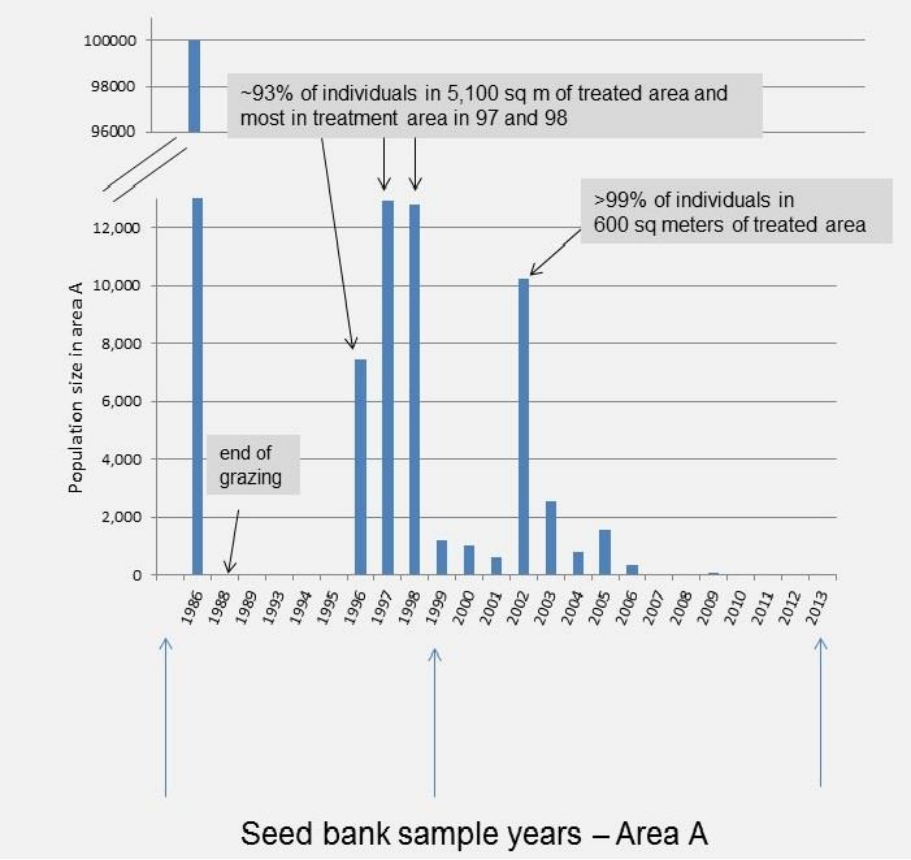
The decrease from 21.4 seeds per square decimeter in 1999 to 0.187 in Area A and from 2.0 to 0.333 in Area D represents a change of two orders of magnitude over the past 15 years. The seed bank density estimates for SCTP Areas A and D are now similar to estimates for small, introduced or demographically unrepresentative SCTP populations in 1999 (Twin Lakes SB, Wildcat Canyon, Watsonville Airport; Bainbridge, unpublished data).

Persistent soil seed banks buffer populations from bottlenecks and loss of genetic diversity otherwise experienced when above ground population sizes are low. However, a decline in the soil seed bank very likely resulted in loss of genetic diversity and/or allelic richness in the population.

In addition to the low density, the mean age of cypselae in the soil seed bank at Arana Gulch may now be much older than in 1999, and compared to other sites, due to lack of turnover in eth majority of the habitat and therefore much more vulnerable to attrition and/or poor recruitment due to seed age. Much of the soil seed bank found in 1999 probably dated back to the time of the discovery of the large population (1986) or later. The large population sizes recorded in 1986-1988 and 2002 are due to recruitment occurring in high density in small areas of habitat (Figure 4). In 1986 and 2002, 93% and >99% of the individuals recorded were in experimental scrape plots in approximately 5,100 square meters and 660 square meters of SCTP Area A respectively (refs). The majority of individuals from population estimates after the 1986 fire (1987 and 1988) were in the intersection of the scrape area and the fire (Hayes 1998). In other words, most of the SCTP soil seed bank has been dormant since 1986 and is about 30 years old. If so, future management should focus on distribution of recruitment throughout habitat as with livestock grazing, rather than total numbers of individuals at the site.

The lack of detected soil seed bank again in SCTP Areas B and C does not necessarily mean that a seed bank is not present, but that it might be in density too low for the methodology to detect. This low density may be due to lack of management in these areas. Alternatively, there may not be a persistent soil seed bank in those areas, but they are population sinks with SCTP Areas A and D and potentially other parts of the terrace as the population source from which seed may disperse and result in occasional recruitment. Either way, habitat in these areas should be managed for conditions that allow SCTP recruitment. Effect habitat management (low frequency scraping and reintroduction of grazing) would help determine if a persistent soil seed bank occurs in these areas and/or allow those areas to serve as population sinks.

Figure 4. SCTP Area A: seed bank sampling events relative to large population sizes and area occupied by large populations.



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