Ipomopsis sancti-spiritus
(Holy Ghost Ipomopsis)

Recovery Summary Report

2013

(Section 6, Segment 27)

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INTRODUCTION

Ipomopsis sancti-spiritus (Holy Ghost ipomopsis) is known from only a single location (Holy Ghost Canyon) in the Sangre de Cristo Mountains of north-central New Mexico (Figure 1). It was listed Endangered under the federal Endangered Species Act on March 23, 1994 (69 FR 43621). The recovery plan recommends several biological and ecological studies before downlisting or delisting can occur (USFWS 2002). The core of the recovery effort includes several out-plantings to establish new populations in similar habitats within the tributary canyons of the upper Pecos River. Therefore, initial recovery efforts focus on establishing an ex-situ propagation protocol, understanding germination requirements, and successful establishment of plants from seeds and transplants at new locations.

Ipomopsis sancti-spiritus is an herbaceous perennial with showy, pink, tubular flowers. It is relatively short-lived (2-5 yrs) and is monocarpic (flowers once - then dies). It inhabits openings in ponderosa pine-Douglas fir forest and prefers disturbed areas with relatively low densities of other perennial species. The Holy Ghost Canyon population usually produces a large amount of seed that has been used as a source for experimental plantings.

Four out-planting locations have been established in the upper Pecos River watershed to help down-list this species to threatened status. The initial out-planting site at Willow Creek was planted with seeds and rosettes in 1998 and 2002, but failed to establish a viable population of plants. It was subsequently abandoned as a potential site. To date, we have three experimental plantings on lands managed by the Santa Fe National Forest (Figure 1). *Ipomopsis sancti-spiritus* is thought to be an early successional species, requiring periodic fires or other disturbances to persist (USFWS 2002). In 2009 a forest thinning project was initiated on Forest Service lands in Holy Ghost Canyon to evaluate the effects of forest thinning on the establishment of new populations of *Ipomopsis sancti-spiritus*. In addition, the natural population in Holy Ghost Canyon is monitored annually since 2003 to provide data of natural population dynamics for comparison with experimental populations.

Abundance and Distribution

The only naturally occurring population of *Ipomopsis sancti-spiritus* is limited to Holy Ghost Canyon in the Santa Fe National Forest. In addition there are currently three experimental out-planting locations within the Winsor Creek, Panchuela Creek, and Indian Creek drainages on Santa Fe National Forest lands (Figure 1).

An overall census and mapping of naturally occurring plants was conducted in the summer of 2008 in Holy Ghost Canyon. Habitat occurring removed from FS road 122 in Holy Ghost Canyon had not been adequately surveyed and mapped in the past. Therefore known populations occurring within this area were mapped using a GPS. In combination with this effort, we obtained a count for the roadside plants occurring within known occupied habitat. We found 1,321 roadside plants and an additional 434 plants for a total of 1,755 plants. This is considerably less than the population estimate of 2,500 plants described in the recovery plan (USFWS 2002). However, the 2008 count may not reflect a significant reduction in plants since

it is unclear how the estimate of 2,500 plants was derived (USFWS 2002).

Conducting a census based primarily on rosettes is difficult in this terrain and further complicated by the lack of morphological differences between rosettes of this species and it's more common congener *Ipomopsis agreggata*. Therefore only rosettes in the vicinity of flowering *I. sancti-spiritus* plants were counted by the proximal identifiable taxon. Overall this doesn't appear to have been a large problem because colonies were relatively isolated during surveys, but it is a potential source of error in the counts obtained.

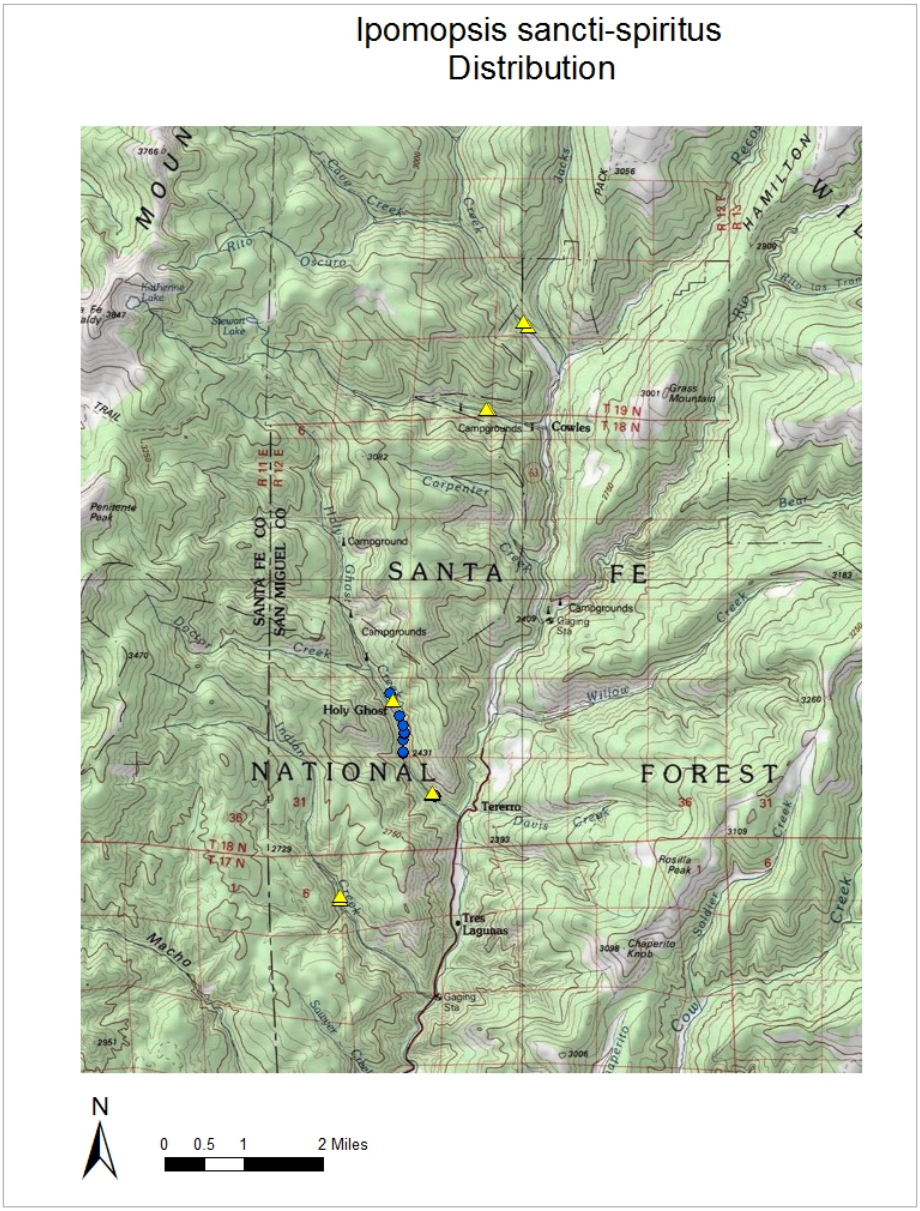

Figure 1. Current distribution of *Ipomopsis sancti-spiritus*, including transplant sites (in yellow), Santa Fe National Forest, NM.

METHODS

GREENHOUSE PROPAGATION

Approximately 200 *Ipomopsis sancti-spiritus* seeds were obtained from wild plants in Holy Ghost Canyon on 18 October 1996 (Sivinski 1996). These were stored for two months then cold treated for six weeks in a 40°F refrigerator. The seeds were planted in a commercial starter soil and kept moist at a room temperature between 70° and 80°F.

In late April 1997 each seedling was transferred to a 10 inch^3 bullet-tube filled with a mixture of 50% sphagnum peat-moss, 25% vermiculite, and 25% perlite (Sivinski 1999). A small amount of 14-14-14 (N-P-K) osmocoat slow-release fertilizer was added to the mix to sustain a vigorous flush of growth. These seedlings were then maintained in an unheated greenhouse for three months.

Transplantation to cultivated ground occurred in early August 1997. The plantation site was a small patch of ground near the NM Forestry lot near the Division's Greenhouse in Santa Fe. This area is an open, fully exposed site receiving all-day sun. A total of 134 plants were planted in five rows between lengths of soaker-hose. These plants were on a once or twice per week irrigation schedule, depending on weather conditions. Following flowering from late July to mid-September 1998, bolted plants were inspected once a week for mature capsules (Sivinski 1999).

MONITORING

1. Holy Ghost Canyon Monitoring Sites – Type Locality

The NM Forestry Division established permanent *Ipomopsis sancti-spiritus* monitoring sites in Holy Ghost Canyon to monitor population trends and generate control-group data to compare with the recovery transplant sites. Seven monitoring sites were established in the summer of 2003(Sivinski 2003). Each site was established along the road cut inhabited by *Ipomopsis sancti-spiritus* and has one to three 10x4 meter belt transects (2 m on either side of center line) for a total of 13 equal transects. The center line of each transect is parallel to Holy Ghost Canyon Road and is marked at each end by a ½-inch steel rebar stake. The seven monitoring sites are assessed annually during the late flowering season in August. The total number of flowering and non-flowering (rosettes) plants is counted within each of the 13 transects.

Associated baseline vegetation data was initially gathered to evaluate how community composition may influence the abundance of *Ipomopsis sancti-spiritus* in Holy Ghost Canyon (Sivinski 2003). Associated vegetation in each plot was determined by foliar intercept along the center line. This data can be used to monitor changes in foliar cover and species composition that may influence the density of *Ipomopsis sancti-spiritus* within the transects. Results of the first year's assessment of these plots provide a baseline dataset of

the variety of native and non-native plant associates and cover values in the Holy Ghost Canyon population (Sivinski 2003).

2. Transplant & Seed Planting Sites

1. Willow Creek Seed Planting and Transplants

Approximately 1,800 *Ipomopsis sancti-spiritus* seeds were planted at seven locations along Forest Road 645 in Willow Creek Canyon, on State of New Mexico lands, on May 5 and 6 of 1998 (Sivinski 1999). Seeds were planted by pressing them into bare soil and the areas permanently marked with steel rebar stakes. All seeding locations were within Section 26, T18N R12E.

An attempt was made to grow seedlings for a direct planting of a suitable road cut habitat on NM Game & Fish land near Tererro Mine, which is near Holy Ghost Canyon. The transplant site was a southwest-facing road cut in Willow Creek Canyon, along a reclaimed road with an overstory of *Pseudotsuga menziesii, Pinus ponderosa, Populus tremuloides* and *Quercus gambelii*. The soils are derived from Tererro Limestone and very similar to the Holy Ghost Canyon habitat, which is only 1.5 miles to the southeast, at a similar elevation.

Approximately 1,200 seeds were planted in February 2000 at the UNM greenhouse with the same methods previously used in 1996 (Sivinski 2001). Approximately 500 seeds germinated, but all damped-off and died. Most died within two weeks of germinating and none lived beyond the 4-leaf stage. Sterile growth medium was purchased for this project, but was apparently infected with a pathogenic microbe.

Approximately 1,000 seeds were harvested from the Holy Ghost Canyon population in September 2001 (Sivinski 2002). These seeds were cold stratified and planted in germination trays at the UNM Biology Department greenhouse in February 2002. Approximately 200 seeds germinated, but more than 50% damped off. Only 65 seedlings were produced; these were healthy and vigorous rosettes when planted near Tererro Mine on July 17, 2002.

2. Santa Fe National Forest Transplants

Most of the previously identified transplant sites were discarded as unsuitable after the failures of the transplant and seeding experiments at Willow Creek. The Santa Fe National Forest and the NM Forestry Division jointly conducted field surveys for new transplant sites during the summer of 2004 (Sivinski and Tonne 2005). The goal was to find more mesic sites with wetter soil conditions than existed at the failed Willow Creek site. Three transplant locations were identified: Indian Creek, Panchuela Creek, and Winsor Creek (Figure 1).

In autumn of 2003 230 *Ipomopsis sancti-spiritus* seedlings were raised at the UNM greenhouse in preparation for out-planting to Indian Creek in the spring of 2004 (Sivinski and Tonne 2005). The Santa Fe National Forest postponed the 2004 spring planting because they wanted to conduct a forest-wide consultation with the U.S. Fish & Wildlife Service before transplanting to any new locations on the Santa Fe National Forest. These plants began to bolt in the greenhouse and an August planting was scheduled. However, the Forest Service again failed to conduct the necessary consultation and no transplanting was allowed. All these plants flowered and died in the greenhouse during the summer of 2004 due of bureaucratic delay. Permission to transplant *Ipomopsis sancti-spiritus* plants on the Santa Fe National Forest was finally received in 2005.

A total of 381 seedlings were grown at the UNM greenhouse and transplanted to two recovery sites on the Forest. Panchuela Creek received 169 seedlings and Winsor Creek received 212 seedlings. These seedlings were planted on July 5 and 6, 2005, to coincide with the beginning of the normal rainy season.

An additional 957 new greenhouse-reared *Ipomopsis sancti-spiritus* rosettes were planted to the three National Forest transplant sites on July 5 and 6, 2006 (Sivinski and Tonne 2007). The Panchuela Creek and Winsor Creek transplant sites were augmented with 308 and 299 new rosettes respectively (Figure 7). A new transplant site, at Indian Creek, received 350 plants.

3. Holy Ghost Canyon Population Augmentation

In 2007 256 greenhouse-grown *Ipomopsis sancti-spiritus* rosettes were planted in Holy Ghost Canyon (Sivinski 2008). The intention was to move plants upslope because naturally occurring plants were growing primarily near the road. We wanted to avoid a downslope progression of *Ipomopsis* colonies towards the road, since gravity and water would move most of the loose seed onto the road where it could easily be swept out of the habitat or run over by vehicle traffic. When we went to plant the greenhouse transplants there were many new rosettes occurring well above the road as well. This was the first time in several years that rosettes had been observed higher up on the road cuts.

4. Holy Ghost Canyon Disturbance Treatments

In October 2009 the forest was thinned within two designated sites within Holy Ghost Canyon (Sivinski and Tonne 2010) (Figures 2 & 3). Prior to thinning the area baseline ecological data was gathered within and beyond the thinned area (ca. 1 acre at two Holy Ghost Canyon sites). With well-established baseline composition and cover estimates vegetation changes can be monitored within and just beyond the thinned areas over time. Ecological data was entered into a Microsoft Access database that is currently stored with the Natural Heritage Program of New Mexico. The database contains cover and diversity estimates for 80 1x1 meter quadrangles. Vegetative cover, litter, soil, rock and moss estimates are included by quad. Additional 10-meter line intercept transects were established (10 per site). Plots were established on either side of the thinned area, so that disturbance, seeding and transplant studies can be conducted within and

adjacent to the thinned area.

The two sites in Holy Ghost Canyon were planted with *Ipomopsis sancti-spiritus* plants in late July 2011 (Sivinski and Tonne 2011). Eight 10 x 10 m plots are divided into thinned and un-thinned areas with four plots in the thinned forest (B, D, F, H) and four adjoining plots in un-thinned forest (A, C, E, G) (Figure 3). Each 10 x 10 m plot received 40 greenhouse-grown rosettes planted along a linear transect for a total of 320 transplants in each of the two disturbance treatment sites. There is also a control (non-treatment) area (I and J) at each site. No plants were planted in the control area. In addition, the duff layer was removed in one thinned and one un-thinned plot at each of the two sites (D, G).

An additional 471 greenhouse-grown rosettes were planted in the lower (larger) thinned area just below Site 1 for a total of 1,111 rosettes planted in 2011. The additional 471 plants planted below study Site 1 are not monitored. Disturbance treatment plots are evaluated annually during the late flowering stage in August. Counted are the number of flowering plants and rosettes in each plot. Also noted are the numbers of plants browsed in each plot (browsed, not flowering; browsed flowering; not browsed flowering,). In 2012 an additional late season monitoring effort was completed to determine whether browsed plants that compensated by growing additional inflorescences were able to produce mature seed capsules before winter senescence.

Figure 2. Forest thinning Site 1, Holy Ghost Canyon, Santa Fe National Forest 2009.

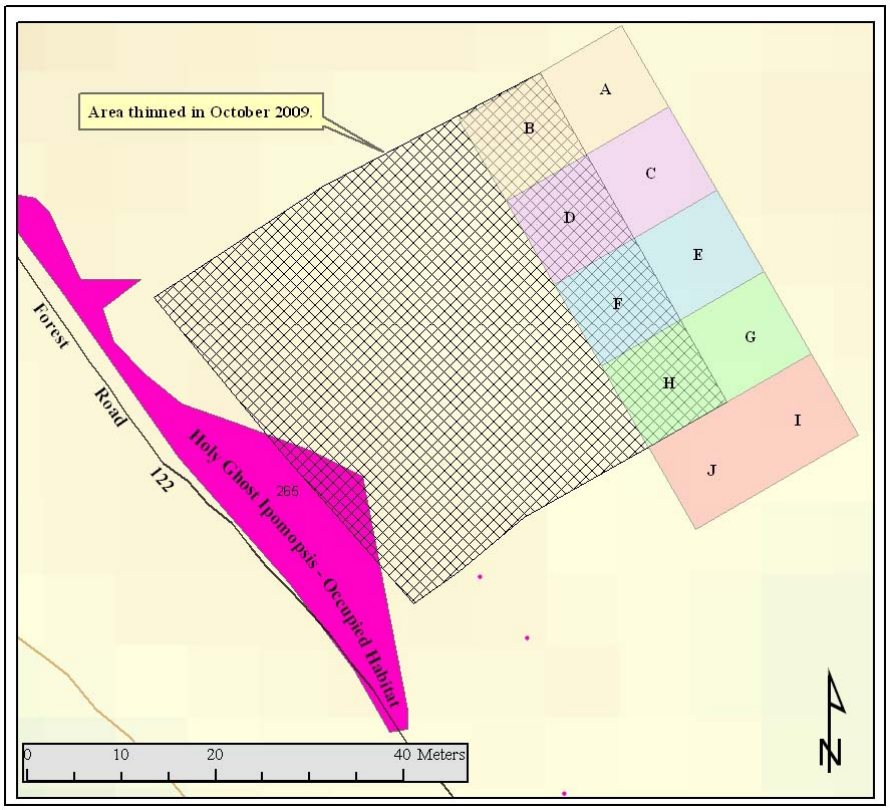

Figure 3. Sample plot design relative to thinning project and occupied habitat. Holy Ghost Canyon, Santa Fe National Forest.

RESULTS

GREENHOUSE PROPAGATION

Seedling emergence times varied from 5 - 25 days. A total of 143 *Ipomopsis sancti-spiritus* seeds germinated from the 200 seeds planted in 1996. By the end of the first summer in 1997, 128 of the 134 plants planted in the ground had successfully rooted and attained rosette diameters of 10-15 cm. A total of 118 plants survived the winter months at the Forestry lot plantation and most were very vigorous during the 1998 growing season. Approximately 90% of these plants bolted and flowered in 1998. Aphids were abundant on these plants during July and August, but did not appear to cause any problems (predaceous ladybird beetles were also very abundant). Flowering was profuse from late July to mid-September. The cultivated plants were inspected once a week for mature capsules. Very few flowers produced fruits. This reproductive effort was not quantitatively analyzed, but it appeared that less than 25% of the flowers made any seeds. By visual estimate, this level of reproductive success appeared to be somewhat lower than the natural population in Holy Ghost Canyon.

Subsequent greenhouse rearing of *Ipomopsis sancti-spiritus* at UNM has had excellent success in germinating seed and growing rosettes. In 2005 rates of 86% and 89% from samples of 100 and 101 seeds, respectively, were achieved using fresh seed. All seedlings developed into viable rosettes.

MONITORING

1. Holy Ghost Canyon Monitoring Sites – Type Locality

Between 2003 and 2013 the average number of plants located within the 13 transects was 591 flowering plants and rosettes. Since 2010 the total number of plants has been significantly below that average. Although the total number of plants occurring in the 13 monitoring transects initially increased though 2006, it steadily declined through 2012 (Figure 4). The highest number of individuals were found in 2006, when 852 flowering plants and rosettes were located within the transects. In 2012 only 349 plants were found, the lowest number recorded since 2003. In 2013 this number improved when 487 flowering plants and rosettes were counted within the transects. On average 73% of plants were rosettes within the population, ranging from 50% in 2004 to 85% in 2006 (Figure 5). In 2013, 72% of all plants were rosettes (Figure5).

In 2013 the Tres Lagunas Fire burned 10,219 acres of forested lands in the immediate vicinity of the Holy Ghost Canyon monitoring sites and near the Indian Creek transplant site (Figure 6). The perimeter of all sites were flagged to alert fire fighters of the sensitivity of the area. Fire fighters were briefed daily to maintain continuity of alerting revolving firefighting teams. The fire burned to within 100 ft of some *Ipomopsis sancti-spiritus* plants and monitoring transects. However, none of the plants or their habitat were impacted by the fire, firefighting activities, or post-fire clean-up.

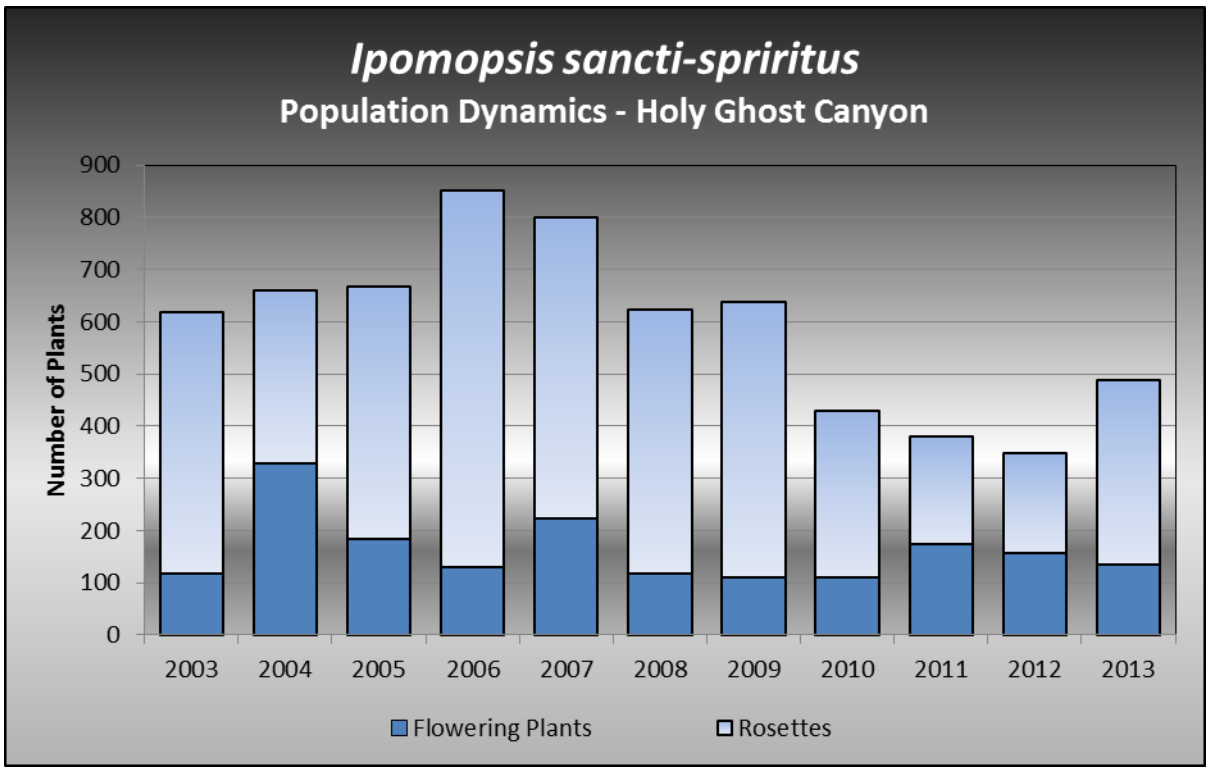

Figure 4. Total number of *Ipomopsis sancti-spiritus* plants in 13 transects in Holy Ghost Canyon, Santa Fe National Forest, NM, from 2003 to 2013.

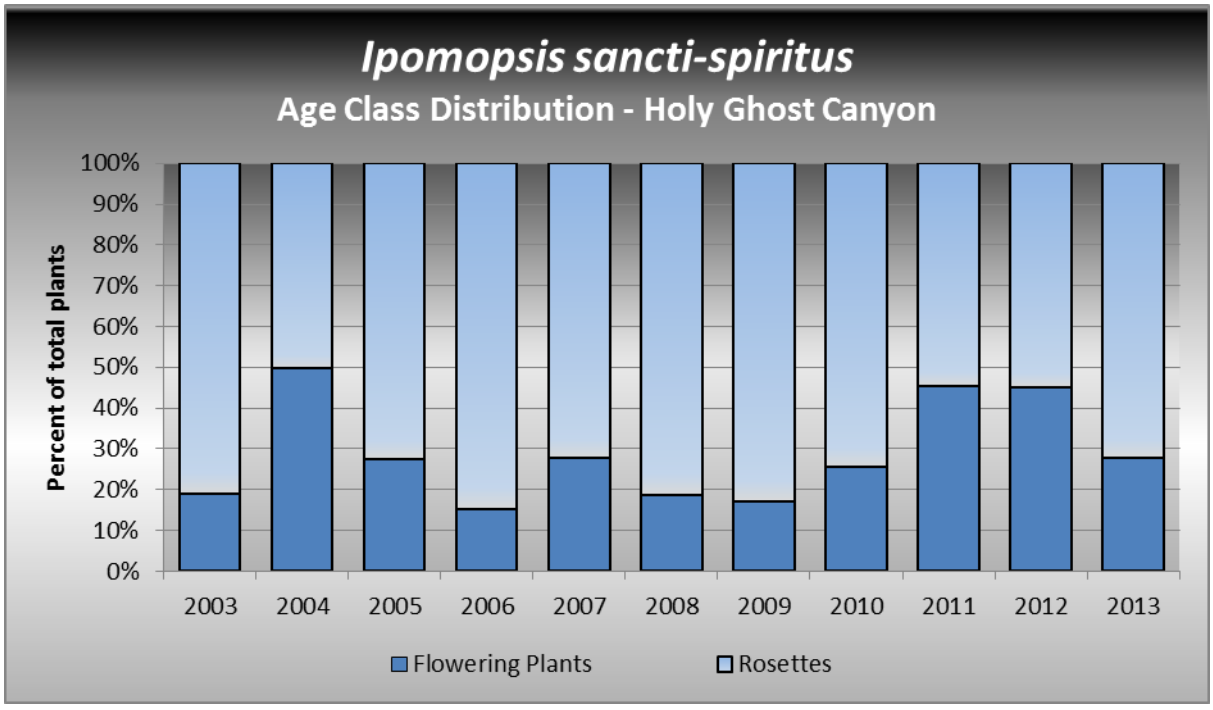

Figure 5. Age class distribution of *Ipomopsis sancti-spiritus* in 13 transects in Holy Ghost Canyon, Santa Fe National Forest, NM, from 2003 to 2013.

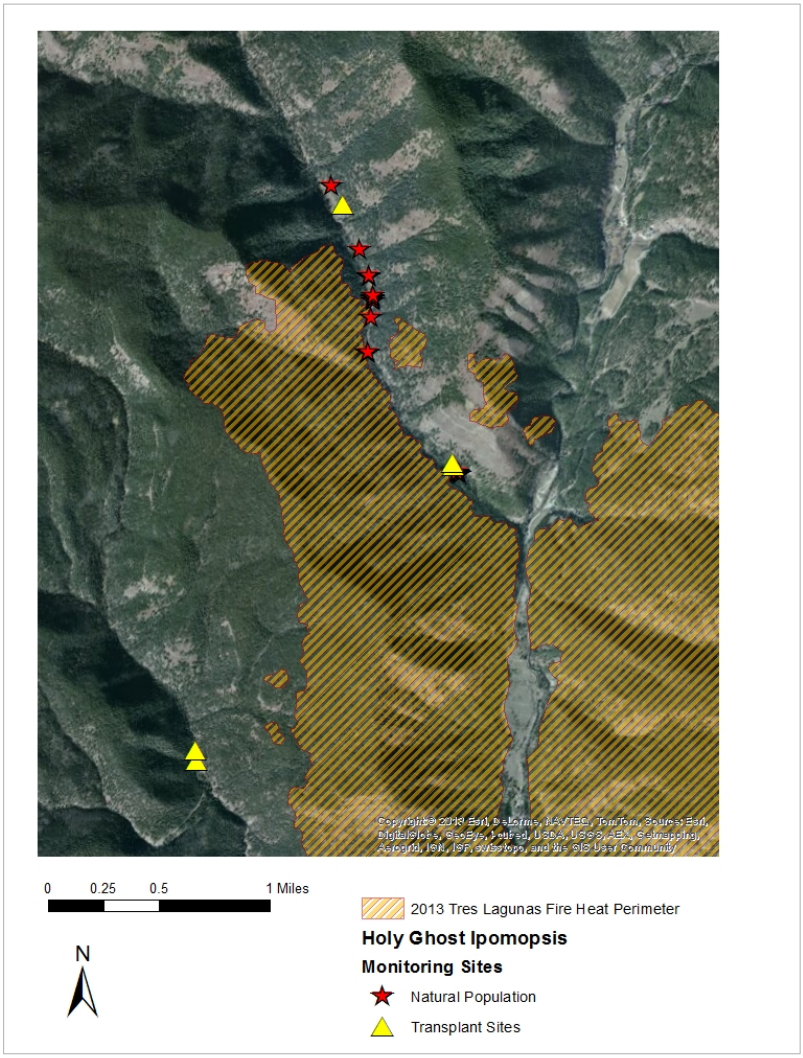

Figure 6. Tres Lagunas fire perimeter with respect to Holy Ghost Ipomopsis populations in Holy Ghost Canyon and Indian Creek, Santa Fe National Forest.

2. Transplant & Seed Planting Sites

1. Willow Creek

Direct seeding success at Willow Creek was evaluated in August 1999 – two growing seasons after planting. Only one mature *Ipomopsis sancti-spiritus* plant was found flowering at one site. Several rosettes were found at all sites, but could have been either *Ipomopsis sancti-spiritus* or *I. aggregata*. The Willow Creek seeded sites were visited again in August 2000, August 2001 and August 2002 – three, four and five growing seasons after planting. No additional flowering plants were found. Therefore the direct seeding effort was unsuccessful.

The first two weeks after transplanting rosettes in 2002 were very wet, and each transplant became successfully established. All transplanted rosettes survived the winter of 2002/2003 and 58 initiated flowering stalks in early summer 2003. Flowering periods and reproductive effort were significantly different between the transplant site and the natural population in Holy Ghost Canyons (Table 1). Reproductive effort of *Ipomopsis sancti-spiritus* at Willow Creek transplant site was five times less than plants growing in Holy Ghost Canyon. The transplants were in full flower by early July, which was nearly two weeks earlier than the natural population in Holy Ghost Canyon. Flowering transplants ceased flowering by July 20th. *Ipomopsis sancti-spiritus* in Holy Ghost Canyon was still in full flower in late July and continued to flower and set fruit through August and early September.
The Willow Creek transplant site had no flowering *Ipomopsis sancti-spiritus* individuals during the summers of 2004 and 2005 and was abandoned as a site for a new recovery population.

Table 1. Reproductive efforts of *Ipomopsis sancti-spiritu*s at Willow Creek transplant site and a sample from Holy Ghost Canyon in 2003. N=56 at each site.

	Total Capsules	Mean Capsules per plant	Median Capsules per plant	Range Capsules per plant
Holy Ghost	3,218	57.5	53	2-350
Willow Creek	621	11.1	7	0-47

2. Santa Fe National Forest Transplants

Unfortunately, late summer rains did not begin until the end of July 2005. During this hot, dry period, all seedlings at Panchuela Creek and Winsor Creek were watered by hand two times each week until soil moisture conditions became suitable for growth in mid-August. This effort to keep these seedlings alive resulted in a good rate of survival. Average survival of all transplants at the two sites was 89.4% up to dormancy in early autumn 2005. Seven of the plants transplanted to Winsor Creek were already bolting when planted and successfully flowered and set seed in late summer of 2005.

In 2006, 280 (73.5%) of the 381 transplants at Panchuela and Winsor creeks were remaining after surviving an exceedingly dry winter and spring. A total of 258 bolted and flowered in late summer of 2006. Seed production was not assessed, but most flowering plants at Winsor Creek had mature capsules in September. Panchuela Creek plants also had mature capsules, but a greater number of flowering stems had been severely browsed by deer and these had few flowers. The ground immediately around the place where seven Winsor Creek plants flowered in 2005 had 29 new seedlings in September 2006.

A very wet late-summer season in 2006 provided excellent conditions for establishment of the 957 newly planted rosettes at Winsor, Panchuela, and Indian creek transplant sites. About 98% of the new transplants were alive and healthy three months following out-planting, in late September.

A total of 842 adult plants remained at all 3 transplant sites by 2007 (Figure 7). In addition a total 135 seedlings were located. There was no reliable way of distinguishing *Ipomopsis sancti-spiritus* seedlings or rosettes from the more common *I. aggregata*, which grows in the immediate vicinity of all three transplant sites. Therefore, only flowering adults are reported as of 2007 (Figure 7). In 2008 no adults were found at the Panchuela Creek transplant site, and only 3 and 8 adults were found at the Indian Creek and Winsor Creek sites respectively. Similar low values were found in 2009, although all sites had a few adult plants. The number of adult plants gradually increased at all three sites in 2010 and 2011, but declined again at the Panchuela and Winsor creek sites in 2012.

Although the natural population of *Ipomopsis sancti-spiritus* increased significantly in 2013, only the Panchuela transplant site had an increase in the number of flowering plants over the 2012 values (Figure 7). The Winsor Creek site declined by 42% and the Indian Creek site declined by 16%. Reasons for the decline in the number of plants at the Indian Creek site are unclear. The Tres Lagunas fire did not come near the site and firefighting activities did not impact the site. The Winsor Creek monitoring site was impacted by activities associated with the Tres Lagunas fire, which burned 4 miles to the south. The Santa Fe National Forest thinned brush along the Winsor Creek road and in the immediate vicinity of the Winsor Creek monitoring site during the Tres Lagunas fire. This likely impacted plants growing underneath and immediately adjacent to these thinning activities (Figures 8 & 9). Plants were observed in August 2013 underneath areas that had been cleared and in the immediate vicinity of the thinning project (Figures 8 & 9). Even though the Forest Service is aware of this monitoring site, apparently no precautions were taken to avoid impacting this site.

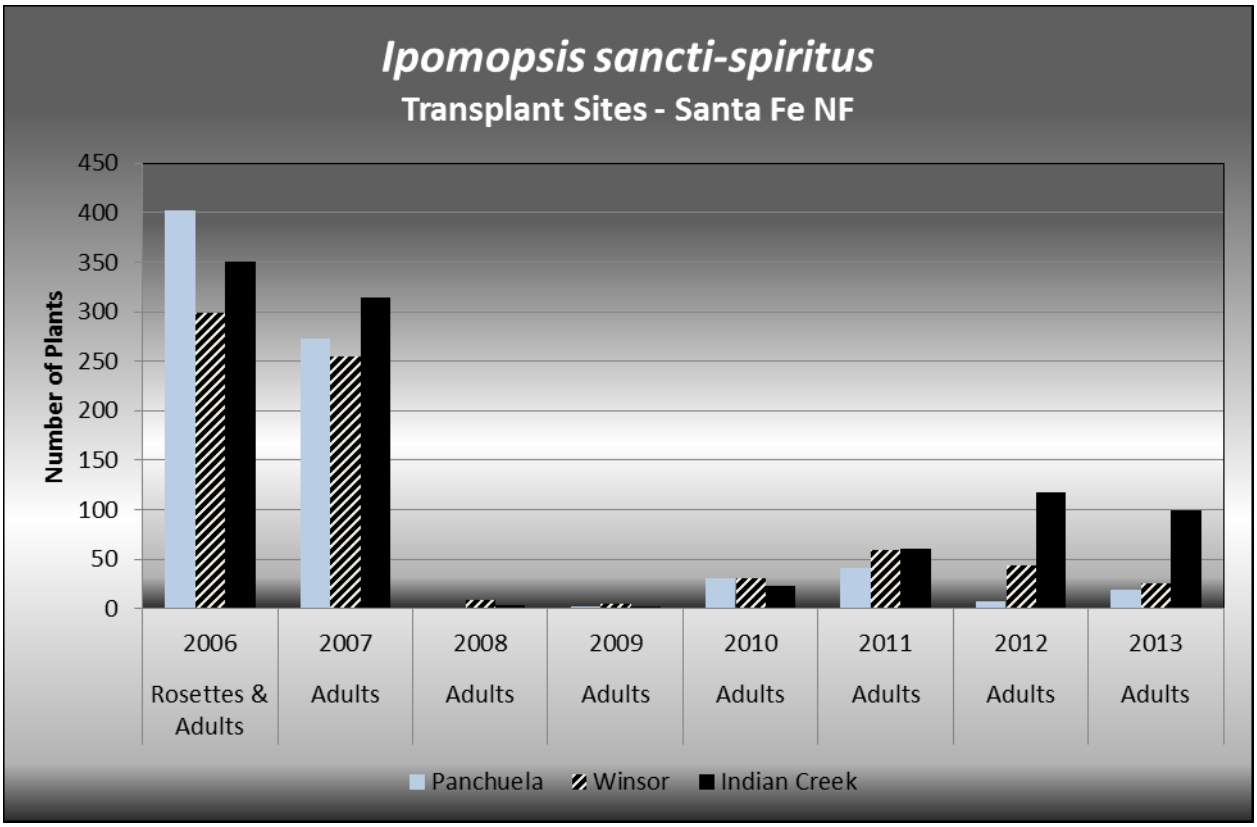

Figure 7. Total number of *Ipomopsis sancti-spiritus* plants at three transplant sites in the Santa Fe National Forest, San Miguel County, NM, from 2005 to 2013.

Figure 8. Location of *Ipomopsis sancti-spiritus* plants within the thinned area immediately adjacent to the Winsor transplant site.

Figure 9. Location of *Ipomopsis sancti-spiritus* plants at the border of the Winsor transplant site, immediately adjacent to the thinned area.

3. Holy Ghost Canyon Population Augmentation

Most of the planted rosettes survived and many of them flowered and fruited in abundance in 2008. These plants had been in the greenhouse for at least two years and were healthy and vigorous. Their head start in the greenhouse combined with good precipitation in 2007-2008 lead to a high flower density and fruit set. No additional monitoring was completed after 2008.

4. Holy Ghost Canyon Disturbance Treatments

Initial Survival

Overall survival of the transplants one year after planting was 84% at both sites, 92% of which were flowering. Of the 320 plants planted in Site 1 in 2011 survival was 88%, 90% of which were flowering in August 2012 (Table 2). Survival of the 320 plants planted in Site 2 in 2011 was 81%, 94% of which were flowering in August 2012. Thinned plots had a survival rate of 73%, while plants in un-thinned plots had a survival rate of 83%. In the plots were the duff layer was removed, thinned plots had a survival rate 83 % while the survival rate in un-thinned plots was 89%.

In 2012, over half of the transplants were browsed, likely by deer or rabbits (60% in Site 1, 53% in Site 2). The majority of these plants compensated by growing additional inflorescences; these were flowering from the browsed base (56% in Site 1, 49% in Site 2). Approximately 4% of

browsed plants were bolted, but did not compensate by growing additional inflorescences at either site. The remaining plants were not browsed or remained as rosettes. Only a small percentage of plants remained as rosettes in 2012 (6% in Site 1, 2% in Site 2).

Table 2. Survival of *Ipomopsis sancti-spiritus* plants in two thinned and un-thinned treatment sites in the Santa Fe National Forest, August 2012 (original N = 40, per treatment plot).

Site 1					
8/9/2012					
Treatment Plot	**# browsed, not flowering**	**# browsed, flowering**	**# flowering, not browsed**	**# of rosettes**	**Total**
A, un-thinned	0	15	20	3	**38**
B, thinned	1	18	14	3	**36**
C, un-thinned	0	12	19	3	**34**
D, thinned, duff removed	3	22	6	2	**33**
E, unthinned	0	18	16	2	**36**
F, thinned	1	20	15	1	**37**
G, unthinned, duff removed	5	26	3	1	**35**
H, thinned	2	27	2	2	**33**
Total	**12**	**158**	**95**	**17**	**282**
			Percent Survival:		**88%**
			Percent Flowering:		**90%**
			Percent Browsed:		**60%**

Site 2					
8/9/2012					
Treatment Plot	**# browsed, not flowering**	**# browsed, flowering**	**# flowering, not browsed**	**# of rosettes**	**Total**
A, un-thinned	0	25	9	1	**35**
B, thinned	3	16	13	0	**32**
C, un-thinned	0	18	5	1	**24**
D, thinned, duff removed	0	22	11	0	**33**
E, un-thinned	1	15	15	1	**32**
F, thinned	2	12	20	0	**34**
G, un-thinned, duff removed	2	14	18	2	**36**
H, thinned	2	5	25	1	**33**
Total	**10**	**127**	**116**	**6**	**259**
			Percent Survival:		**81%**
			Percent Flowering:		**94%**
			Percent Browsed:		**53%**

Because of the large degree of browsing impacts observed in August 2012 and the associated late flowering of plants that compensated for the browsing damage, we returned to the two study sites in late September to determine the number of adult plants that had mature or maturing seed capsules. Only 52% of the total number of flowering plants produced mature or maturing capsules in Site 1, while 86% of total number of flowering plants produced mature or maturing capsules in Site 2 (Table 3).

Table 3. Number of flowering *Ipomopsis sancti-spiritus* plants producing mature or maturing seed capsules within two thinned and un-thinned study plots in the Santa Fe National Forest, September 2012.

Site 1	
9/26/2012	
Treatment Plots	**Number of plants with seed capsules**
A, un-thinned	15
B, thinned	19
C, un-thinned	16
D, thinned, duff removed	11
E, un-thinned	23
F, thinned	24
G, un-thinned, duff removed	9
H, thinned	15
Total	**132**
Percent of flowering plants making it to seed set	**52%**

Site 2	
9/26/2012	
Treatment Plots	**Number of plants with seed capsules**
A, un-thinned	25
B, thinned	28
C, un-thinned	17
D, thinned, duff removed	27
E, un-thinned	21
F, thinned	29
G, un-thinned, duff removed	29
H, thinned	32
Total	**208**
Percent of flowering plants making it to seed set	**86%**

2013

In August of 2013 only 20 plants remained of the original cohort of 640 plants, 10 at each site (Table 4). The majority of these plants were rosettes (75%), none of them were browsed. There is no clear pattern of how these plants were distributed within the treatment areas. Seedlings were observed in the immediate vicinity of dead plants planted in 2011, but were not counted due the potential for misidentification.

Table 4. Survival of *Ipomopsis sancti-spiritus* plants in two thinned and un-thinned treatment sites in the Santa Fe National Forest, August 2013 (original N = 40, per treatment plot).

Site 1					
8/19/2013					
Treatment Plot	**# browsed, not flowering**	**# browsed, flowering**	**# flowering, not browsed**	**# of rosettes**	**Total**
A, un-thinned	0	0	0	0	**0**
B, thinned	0	0	1	1	**2**
C, un-thinned	0	0	1	3	**4**
D, thinned, duff removed	0	0	0	0	**0**
E, un-thinned	0	0	0	2	**2**
F, thinned	0	0	0	0	**0**
G, un-thinned, duff removed	0	0	1	0	**1**
H, thinned	0	0	1	0	**1**
Total	**0**	**0**	**4**	**6**	**10**

Site 2					
8/19/2013					
Treatment Plot	**# browsed, not flowering**	**# browsed, flowering**	**# flowering, not browsed**	**# of rosettes**	**Total**
A, un-thinned	0	0	1	3	**4**
B, thinned	0	0	0	0	**0**
C, un-thinned	0	0	0	2	**2**
D, thinned, duff removed	0	0	0	1	**1**
E, un-thinned	0	0	0	0	**0**
F, thinned	0	0	0	3	**3**
G, un-thinned, duff removed	0	0	0	0	**0**
H, thinned	0	0	0	0	**0**
Total	**0**	**0**	**1**	**9**	**10**

DISCUSSION

GREENHOUSE PROPAGATION

Greenhouse propagation protocols have been well established since 1996 and have been successfully applied to grow plants for out-planting to establish new populations (Maschinski *et al.*1996; Sivinski 1996 &1999; Sivinski & Tonne 2007 & 2011). The reason for the limited seed production from cultivated plants on otherwise vigorous plants is unclear, but may include limited pollinators and perhaps limited pollination success due to inbreeding depression. Not a single butterfly, bombilid fly, or hummingbird was observed visiting the flowers at the Forestry Division plantation site in Santa Fe. The pollinators that may be abundant in the natural population could be mostly absent in the Santa Fe area. *Ipomopsis sancti-spiritus* has a flexible breeding system and is a facultative out-crossing and self-compatible species (Maschinski 1996). Yet even self-pollination may require movement of pollen from anther to stigma by a zootic vector. This species consists of a single, relatively small population that may be experiencing inbreeding depression. Deleterious alleles can become common in small inbreeding populations and cause high levels of seed abortion or relatively low fertility in offspring. Maschinski (1996) conducted outcrossing trials with *Ipomopsis sancti-spiritus* and found that fertilization and seed production was highly variable depending on which plant was the pollen donor. She also noticed that many anthers failed to produce viable pollen. This meiotic disruption would certainly also occur in the ovules of the ovaries. The results were also obvious in the Santa Fe plantation population. Some plants failed to produce more than two or three fruits while others were relatively successful and produced the majority of the year's seed crop. While some genetic reproductive barriers may be operating in *Ipomopsis sancti-spiritus* it is more likely that the plant simply does not do well when removed from its natural habitat.

In its natural habitat, resource limitation may also play a role in the annual reproductive rates of *Ipomopsis sancti-spiritus*, especially during drought years. Low rates of reproductive effort were

reported from well-established transplanted plants at the Willow Creek transplant site in 2003, perhaps due to drought conditions. In the naturally occurring population in Holy Ghost Canyon, *Ipomopsis sancti-spiritus* is capable of producing large amounts of viable seed, when summer rains are sufficient.

MONITORING

Holy Ghost Canyon

The naturally occurring population of *Ipomopsis sancti-spiritus* in Holy Ghost Canyon has been in decline since 2006, reaching its lowest numbers in 2012. There is no rainfall gauge in Holy Ghost Canyon, but the average precipitation measured at the nearby Pecos Ranger station is 16.29 inches a year, ranging from 8.06 in (2012) to 25.34 in (1941) (WRCC 2014). During half of the 10 monitoring years the precipitation levels were below average (2003, 2006, 2007, 2011, and 2012). Except for 2011 and 2012, which represent the lowest precipitation amount on record, the amount of rainfall does not appear to correlate with the number of *Ipomopsis sancti-spiritus* plants growing in Holy Ghost Canyon. Other reasons for the decline in plant numbers may include long term effects of declining seed production and therefore seed banking, declines in viable seed production due to inbreeding depression and pollination success, and potential undocumented direct impacts to plants such as browsing or road maintenance activities.

Impacts of fire on *Ipomopsis sancti-spiritus* have not been studied, although it is thought that the species might be fire adapted and potentially requires certain levels of disturbance to thrive. The 2013 Tres Lagunas fire brought potential fire related impacts within feet of the Holy Ghost population. Although fire might be beneficial to the species, impacts from firefighting activities might be detrimental to this small population. Fire-related activities include clearing of brush and felling of trees for fire lines, trampling, bulldozing, mop-up activities, and debris removal, as well as activities related to post-fire restoration projects such as seeding and mulching. Cooperation between agencies and firefighters combined with awareness education of *Ipomopsis sancti-spiritus* sites prevented the species from being impacted during the Tres Lagunas fire in Holy Ghost Canyon. However, the Winsor Creek transplant site was impacted by brush clearing activities related to the fire, despite the knowledge of the exact location of the transplant site and the presence of a Forest Service biologist during these activities.

Willow Creek

The Willow Creek direct seeding experiment was unsuccessful, likely because the seeded habitats were probably too dry and therefore unsuitable for this species. Direct seeding may not be a viable option, especially when considering the limited seed available for such an effort. The transplant site was in a similar vegetation community, but was apparently a drier micro-habitat (exposure, soil) than the native habitat or was limited by another characteristic that is not readily evident. Reproductive effort at the Willow Creek transplant site was not sufficient to establish a self-sustaining population. Therefore, potential future transplant sites must be reassessed and

situated at higher elevations, more westerly exposures, or soils with better water holding capacities.

National Forest transplant sites

Greenhouse grown plants have been successfully transplanted into new locations and their initial survival has been remarkably good. However, successful establishment of new populations of short lived perennial plants requires populations to be able to reproduce and maintain themselves without further augmentation efforts. The Willow Creek transplant site was abandoned because it failed to successfully produce a viable population able to maintain itself. The Winsor, Panchuela, and Indian Creek transplant populations are producing offspring but it is questionable whether stable and self-sustaining populations can be achieved. Unfortunately already low population numbers at the Winsor transplant site were impacted by brush clearing in 2013. The number of adult, seed-producing plants declined from 43 in 2012 to 25 in 2013. Whether there is enough seed stored in the seedbank to allow for recovery remains to be seen.

Holy Ghost Canyon Disturbance Treatments

Survival of transplants into the disturbance treatment sites has been excellent. Initially un-thinned plots had a higher survival rate than thinned plots, even if the duff layer was removed. Un-thinned plots may provide shade, as well as cover from browsing and other disturbances, leading to higher survival rates for plants. In 2013 only 10 plants remained in each of the two plots, without a clear pattern between thinned and un-thinned plots.

In 2012, the majority of plants were browsed by deer or rabbits, more than once, which may have negatively impacted reproductive effort rates and therefore seed input into the seedbank. Browsing damage has been observed in the past among naturally occurring plants, just below the treatment plots, but never to this extend. Only 52% of the flowering plants observed at Site 1 in August 2012 made it to seed set by late September. Plants which appeared to be browsed repeatedly and were not able to compensate by growing additional inflorescences after August. Browsing impacts at Site 2 after August were less pronounced. There is an oak thicket immediately above Site 1. It is likely that deer seek cover in the thicket and regularly travel between the thicket and the creek, browsing through the treatment site along the way. No oak thicket is located near Site 2. None of the remaining 20 plants were found to be browsed in 2013, likely because the majority of these plants were not flowering and the few flowering plants were too scarce and likely overlooked.

An initial decline in the number of individuals following the death of short-lived transplants is expected. Future monitoring will document whether enough viable seeds were produced by the initial cohort of flowering plants to establish a new generation of *Ipomopsis sancti-spiritus* plants within the treatment plots and whether thinning of the overstory is making a difference in seedling germination and establishment.

RECOMMENDATIONS

Addressing sensitive species before, during and after fires (including prescribed fires) should be an integral part of fire management and planning, and should be included in fire prevention, firefighting, and post-fire restoration projects. Sensitive species habitats should be prioritized for vegetation management and thinning projects to prevent or minimize the impacts of catastrophic fires. This is especially true for species with an extremely limited distribution, which is making them highly susceptible to stochastic extinction events, including those caused by fires or fire management activities. Closer involvement of the Santa Fe National Forest with the management and monitoring of this endangered species might help prevent future mistakes.

The Santa Fe National Forest has proposed prescribed burns and forest thinning projects in Holy Ghost Canyon and along Winsor Creek. If this project is going forward, *Ipomopsis sancti-spiritus* populations need to be either avoided and/or carefully monitored to determine the effects of prescribed burning and forest thinning. Seeds should be collected prior to the fires and thinning and the establishment of new populations from seed or transplants in burned areas should be considered. In addition, the last census of the natural population in Holy Ghost Canyon was in 2008. A current census is necessary to update our knowledge of the distribution and abundance of this species post-fire and provide baseline information for potential thinning and restoration projects in Holy Ghost Canyon.

The 2013 Tres Lagunas fire has brought fire impacts into the immediate vicinity of the natural population of *Ipomopsis sancti-spiritus*. Since *Ipomopsis sancti-spiritus* is thought to be a disturbance adapted species, possibly needing fire to successfully regenerate, the Santa Fe National Forest should take the opportunity to establish a new transplant site in a suitable burned area to study and evaluate establishment of new populations in burned areas.

Browsing impacts have not been documented in the past to such a large degree and therefore warrant further studies. If plants compensate by growing multiple additional inflorescences in response to browsing, it may lead to increased reproductive effort, therefore increasing seed production, as long as plants are browsed before a certain time of year. Conversely, if plants are browsed late in the season, browsing may lead to reduced seed production and therefore impact reproductive success. Fencing of transplant sites to deter browsing should be considered.

In addition, pollinator and pollination success studies, as well as seed and seedbank viability studies need to be conducted to shed further light into the potential causes of the continued decline of the species. Low reproductive success may also be caused by inbreeding depression. Current genetic and pollination studies conducted by Northern Arizona University should shed a light on its genetic variability, its relationship to its congener *Ipomopsis aggregata*, and determine whether inbreeding depression is acting on the species.

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