Ipomopsis sancti-spiritus
(Holy Ghost Ipomopsis)

Recovery Summary Report
(Section 6, Segment 30)

1996 - 2016

Daniela Roth
NM Energy, Minerals, & Natural Resources Department
Forestry Division
Santa Fe, NM

Prepared for the
U.S. Fish & Wildlife Service, Region 2
Albuquerque, NM

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, recovery efforts have focused on establishing an ex-situ propagation protocol, understanding germination requirements, and successful establishment of plants from seeds and transplants at new locations. In addition, finding new, natural populations is also considered a priority recovery action.

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 appears to prefer 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.

Several 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 five 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 known naturally occurring population of *Ipomopsis sancti-spiritus* is limited to Holy Ghost Canyon in the Santa Fe National Forest. In addition, there are currently five experimental out-planting locations within the Holy Ghost Canyon, 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 summers of 2008 and 2015 in Holy Ghost Canyon (Sivinski and Tonne 2009, Roth 2016). The 2008 surveys extended along the road and along south-and southwest-facing slopes on the north and northwest side of Holy Ghost Canyon. 1,321 roadside plants and an additional 434 plants were documented, for a total of 1,755 plants (including monitoring plots). In 2015, another full census documented a total of 6,052 plants, 5,216 rosettes and 836 flowering plants (including all monitoring plots and 2011 planted areas). Approximately half of the reported plants were associated with plantings for the 2 Holy Ghost Canyon Treatment plots in 2011. The survey extended along the road and upslope on both sides of the canyon, as well as into areas burned during 2013 Tres Lagunas Fire (Roth 2016). 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 its more common congener *Ipomopsis aggregata*. Therefore, only rosettes in the vicinity of flowering *I. sancti-spiritus* plants were counted by the proximal identifiable taxon. Whether the 2015 results represent an actual increase in plant numbers is unknown. Comparison of the results of 2008 vs 2015 results is difficult, but the 2008 survey effort was apparently significantly less than in 2015 (based on survey dates). However, 2015 was an exceptionally wet spring in New Mexico and annual monitoring results also found an overall increase in the number of plants in the Holy Ghost Canyon monitoring plots, based on an increase of the number of rosettes from the previous year (Figures 4 & 5).

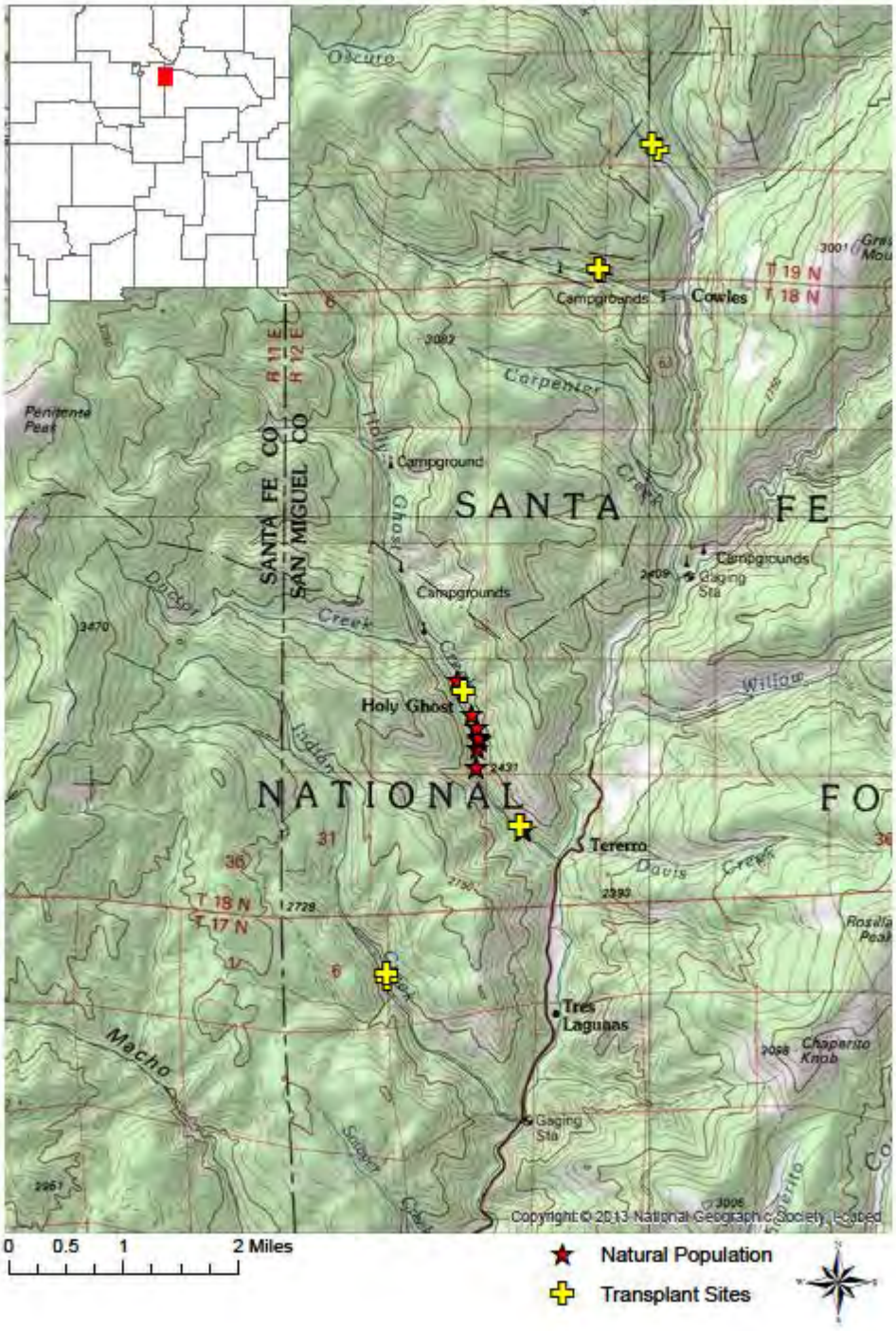

Figure 1. Current worldwide distribution of *Ipomopsis sancti-spiritus*, including transplant sites, Santa Fe National Forest, NM.

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 seed capsules (Sivinski 1999).

MONITORING

1. Holy Ghost Canyon Monitoring Sites – Type Locality

In the summer of 2003 the NM Forestry Division established seven 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 (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 flowering season in mid-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.

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 Department of 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.

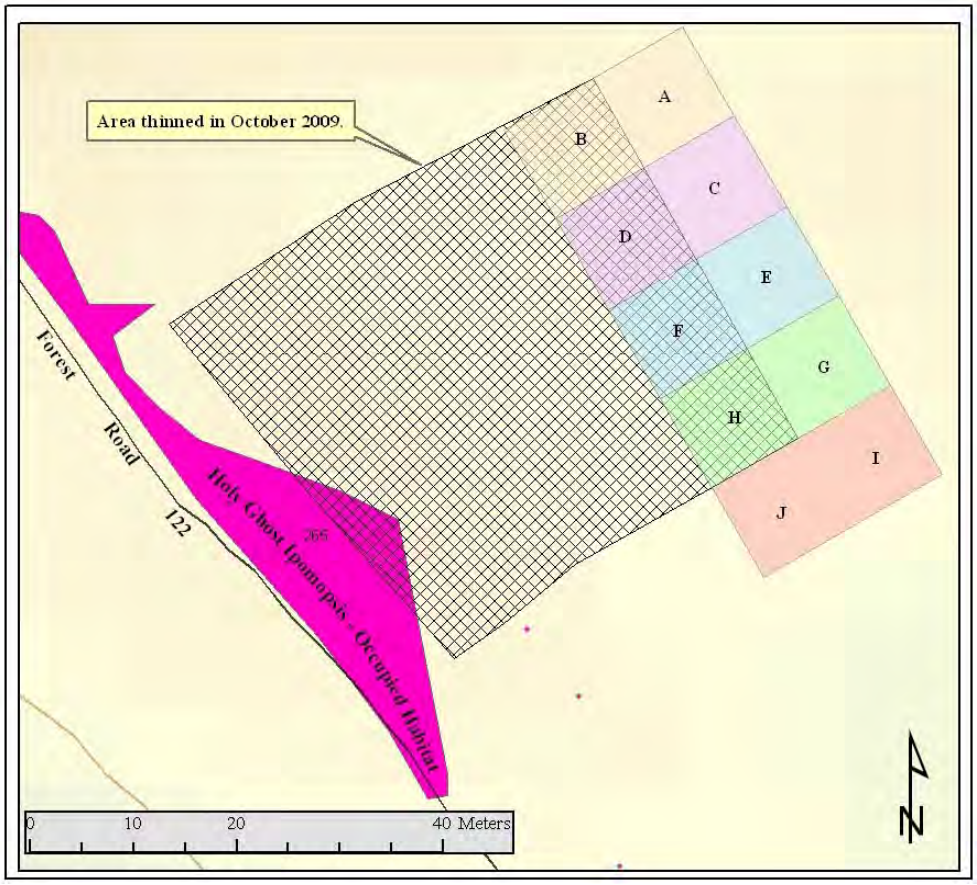

Figure 3. Sample plot design relative to thinning project and occupied habitat. Holy Ghost Canyon, Santa Fe National Forest.

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 2016 the average number of plants located within the 13 transects was 602 flowering plants and rosettes. Between 2010 and 2014 the total number of plants had been significantly below that average, but following relatively wet years of 2015 and 2016, the population has rebounded and in 2016 the total number of plants was 705, including flowering plants and rosettes (Figure 4). Although the total number of plants occurring in the 13 monitoring transects initially increased through 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. On average, approximately 71% of all plants are rosettes within the monitored population, ranging from 50% in 2004 to 85% in 2006 (Figure 5). In 2016, 66% of all plants were rosettes.

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 Forestry Division flagged the perimeters of all sites in Holy Ghost Canyon and the Indian Creek transplant site to alert fire fighters of the sensitivity of these areas. 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 in Holy Ghost Canyon or Indian Creek were impacted by the fire, firefighting activities, or post-fire clean-up.

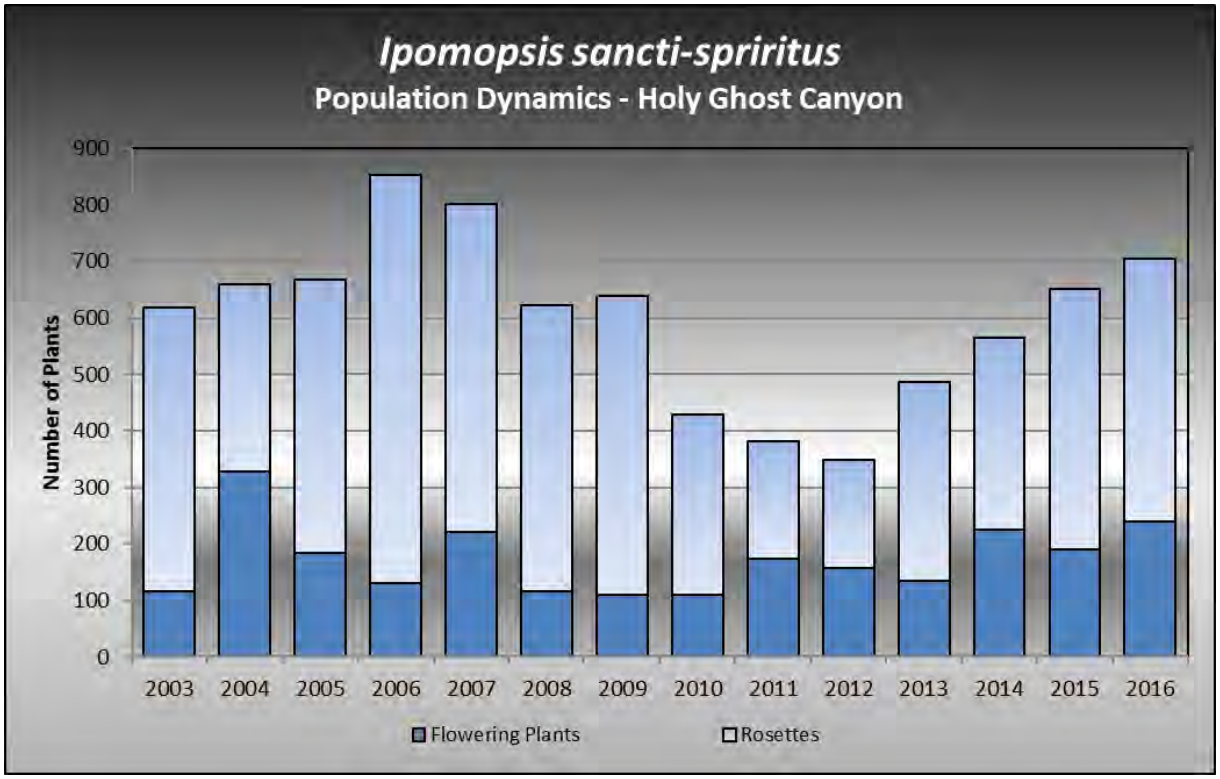

Figure 4. Total number of *Ipomopsis sancti-spiritus* plants in 13 transects in Holy Ghost Canyon, Santa Fe National Forest, NM, from 2003 to 2016.

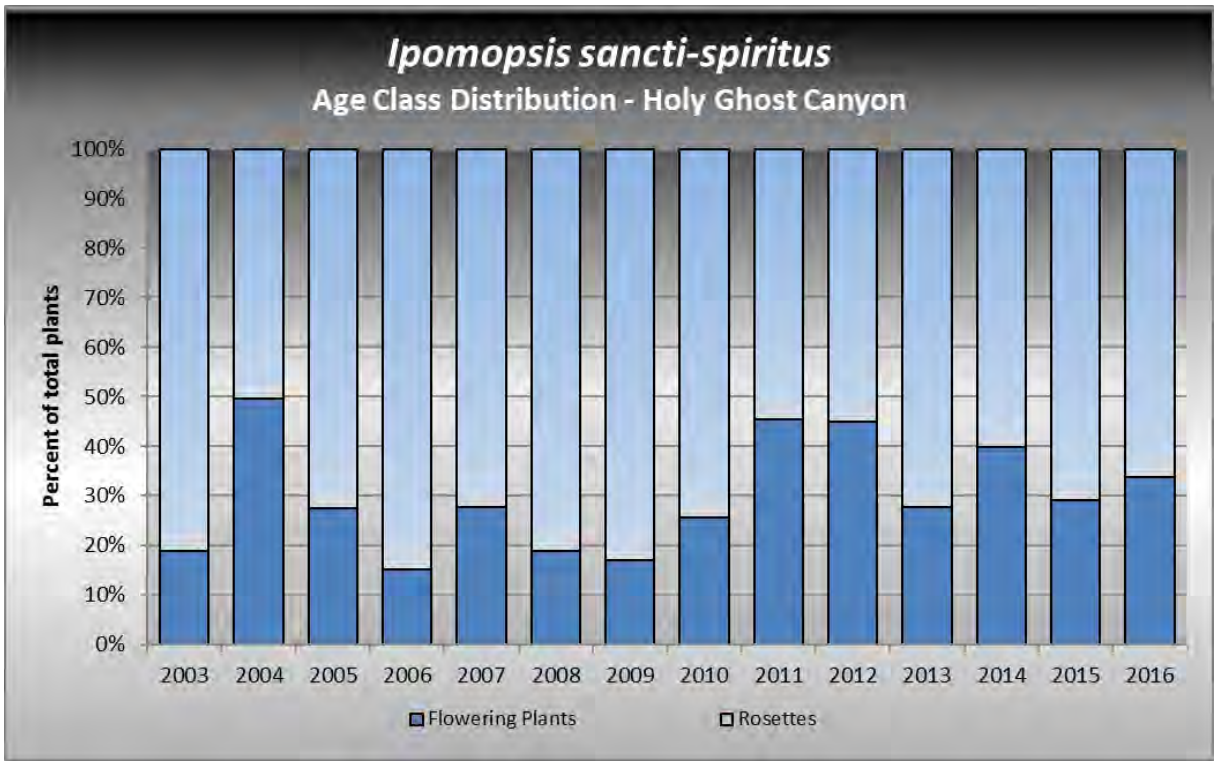

Figure 5. Age class distribution of *Ipomopsis sancti-spiritus* in 13 transects in Holy Ghost Canyon, Santa Fe National Forest, NM, from 2003 to 2016.

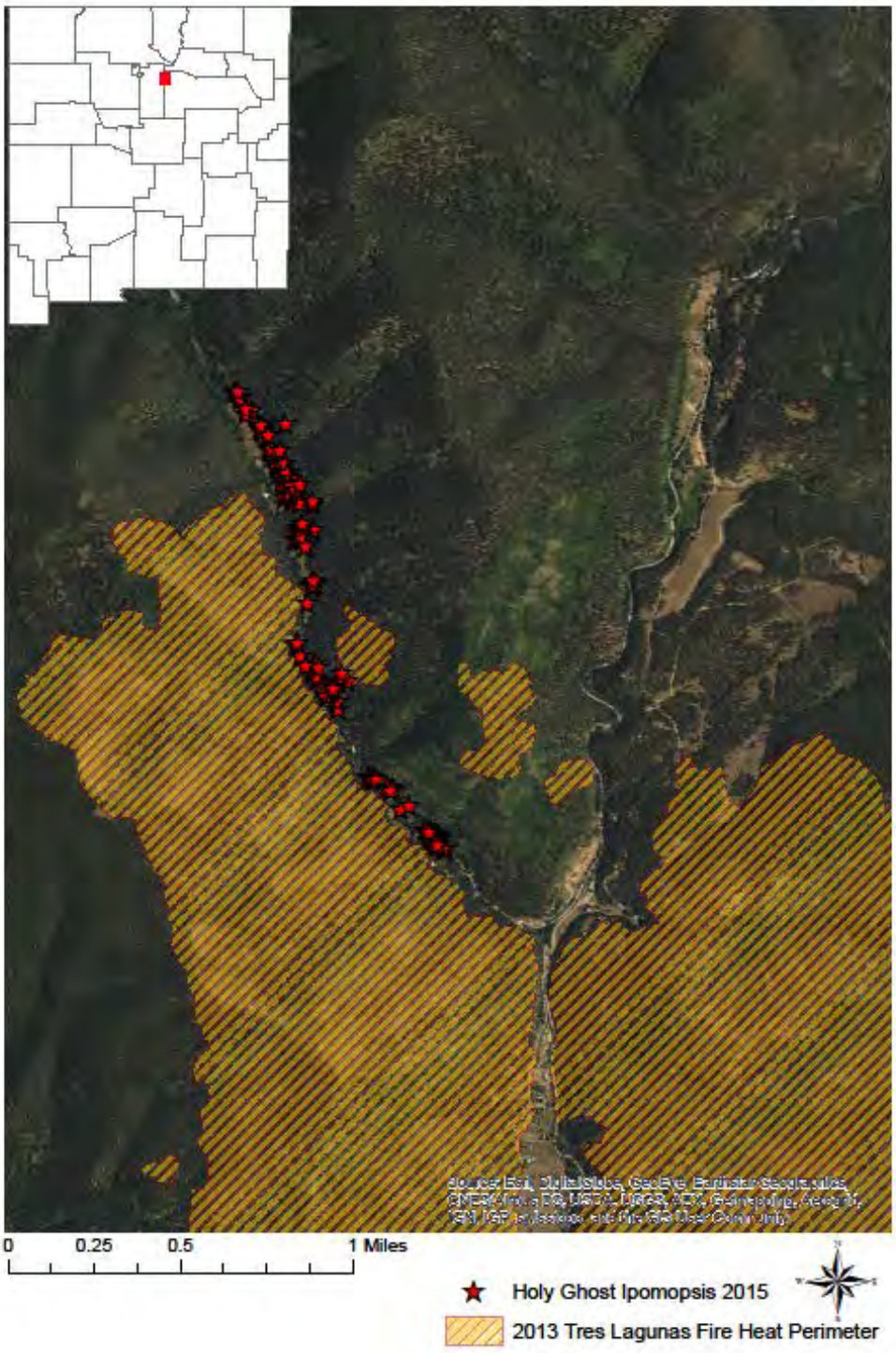

Figure 6. 2013 Tres Lagunas fire perimeter with respect to Holy Ghost Ipomopsis populations in Holy Ghost Canyon and Indian Creek, Santa Fe National Forest.

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 65 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-spiritus* 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 has been in decline at the Winsor and Panchuela sites through 2016.

Although the natural population of *Ipomopsis sancti-spiritus* increased since 2012, the number of plants remains low at all transplant sites and decreased significantly from 2015 to 2016 at the Winsor and Panchuela sites (88 and 64% respectively; Figure 7). Only 4 adult plants were found at either of the two sites. However, the Indian Creek site showed an increase in the number of plants in 2016 (116 plants in 2015, 181 plants in 2016). Unfortunately, this site was significantly impacted by livestock trailing and grazing in 2016. Out of 16 adult plant clusters documented, 12 were grazed (75%). When grazed or browsed during the early flowering season, plants can compensate by resprouting from the base, often producing multiple flowering stems. Unfortunately the Indian Creek site was grazed late in the flowering season, shortly before the monitoring date on August 18th. Therefore, it is unlikely that these plants were able to recover and produce a viable seed crop in 2016.

The Tres Lagunas fire did not come near the transplant sites and firefighting activities did not impact these sites. However, 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 fire. This likely impacted plants growing underneath and immediately adjacent to these thinning activities (Figures 8 & 9). The number of plants in the monitoring site declined 42% between 2012 and 2013 (Roth 2013). 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. In 2014 the Winsor site had somewhat rebounded but remained low in 2015 and declined to an all-time low in 2016 (Figure 7).

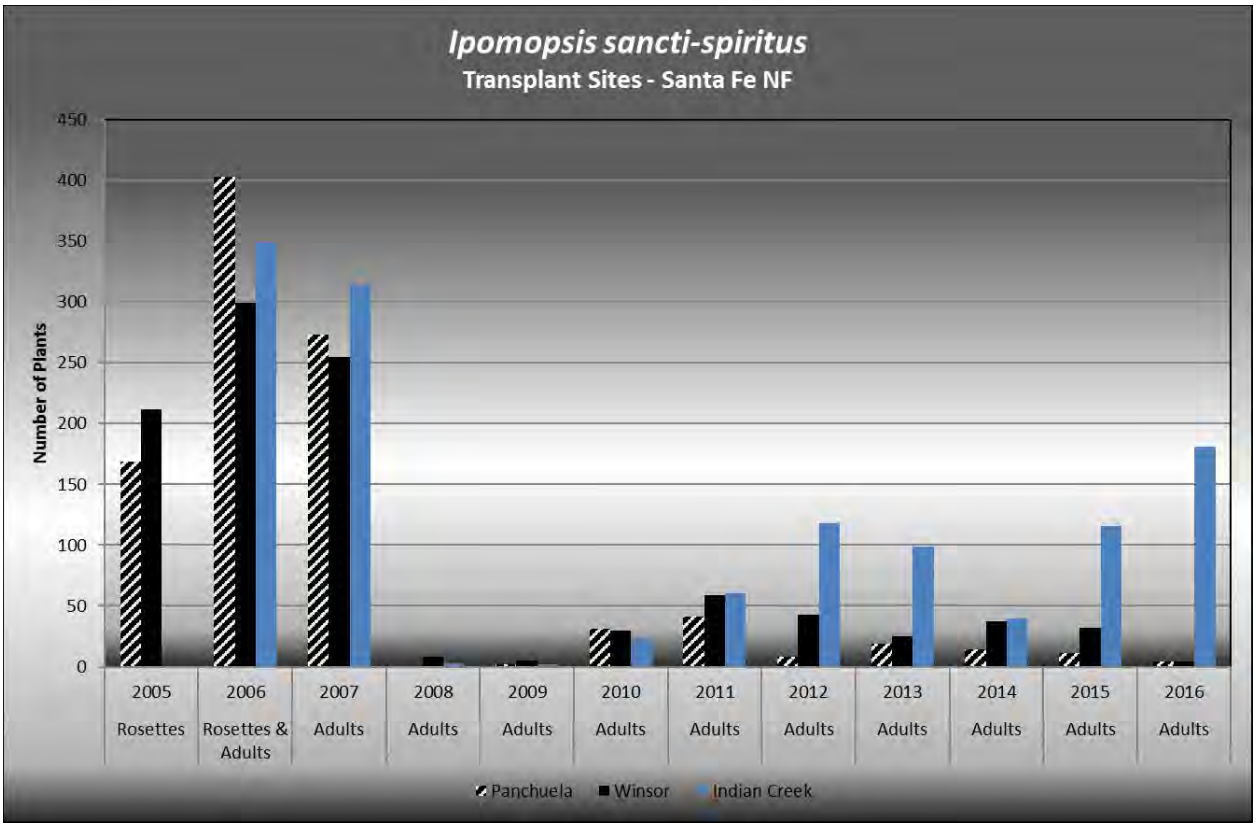

Figure 7. Total number of *Ipomopsis sancti-spiritus* plants at three transplant sites in the Santa Fe National Forest, San Miguel County, NM, from 2005 to 2016.

Figure 8. Location of *Ipomopsis sancti-spiritus* plants within the thinned area immediately adjacent to the Winsor transplant site (2013).

Figure 9. Location of *Ipomopsis sancti-spiritus* plants at the border of the Winsor transplant site, immediately adjacent to the thinned area (2013).

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**

2014

In August of 2014 a total of 1,613 plants were found in the two treatment sites (Site 1: 1307 plants; Site 2: 306 plants). The overwhelming majority of these plants were rosettes (99%). No clear pattern was observed between thinned and un-thinned areas (Table 5). Only three of the 16 plants found flowering were browsed. None of the rosettes were browsed.

Table 5. Total number of plants (rosettes and flowering plants) found in thinned and un-thinned treatment plots in the Santa Fe National Forest, August 2014.

Site	Thinned	Un-thinned
1	113	62
1	453	199
1	31	183
2	133	19
2	33	4
2	23	0
Mean	**131**	**78**
SD	**165**	**91**

Although there may be a difference between thinned and un-thinned areas where the duff had been removed, the sample size per treatment (N = 2) was too low to ascertain a significant difference (Table 6).

Table 6. Total number of plants (rosettes and flowering plants) found in thinned and un-thinned treatment plots with the duff removed in the Santa Fe National Forest, August 2014.

Site	Thinned, duff removed	Un-thinned, duff removed
1	240	26
2	71	23
Mean	**156**	**25**
SD	**85**	**1.5**

2015

In August of 2015 a total of 2,504 plants were found in the two treatment sites (Site 1: 1,804 plants; Site 2: 700 plants). The overwhelming majority of these plants were rosettes (97%). None of the plants were reported browsed. No clear pattern was observed between thinned and un-thinned areas (Table 7).

Table 7. Total number of plants (rosettes and flowering plants) found in thinned and un-thinned treatment plots in the Santa Fe National Forest, August 2015.

Site	Thinned	Un-thinned
1	268	27
1	519	300
1	33	289
2	192	63
2	70	15
2	55	18
Mean	**190**	**119**
SD	**185**	**137**

Although there may be a difference between thinned and un-thinned areas where the duff had been removed, the sample size per treatment (N = 2) was too low to ascertain a significant difference (Table 8).

Table 8. Total number of plants (rosettes and flowering plants) found in thinned and un-thinned treatment plots with the duff removed in the Santa Fe National Forest, August 2015.

Site	Thinned, duff removed	Un-thinned, duff removed
1	331	37
2	192	95
Mean	**262**	**66**
SD	**98**	**41**

2016

In August of 2016 a total of 1,682 plants were found in the two treatment sites (Site 1: 1,091 plants; Site 2: 591 plants). The overwhelming majority of these plants were rosettes (97%). None of the plants were reported browsed.

Table 9. Total number of plants (rosettes and flowering plants) found in thinned and un-thinned treatment plots in the Santa Fe National Forest, August 2016.

Site	Thinned	Un-thinned
1	272	32
1	381	58
1	39	70
2	168	52
2	69	30
2	29	11
Mean	**159**	**42**
SD	**77**	**18**

Table 10. Total number of plants (rosettes and flowering plants) found in thinned and un-thinned treatment plots with the duff removed in the Santa Fe National Forest, August 2016.

Site	Thinned, duff removed	Un-thinned, duff removed
1	188	51
2	202	30
Mean	**195**	**41**
SD	**10**	**15**

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 pollination success due to pollinator availability. 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, Talboom and Ayers 2015). Although out-crossed and self-pollinated plants produce seeds, self-pollinated plants produce significantly lower amounts of seeds over out-crossed plants (Talboom and Ayers 2015). 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 and was thought to potentially experience inbreeding depression. Deleterious alleles can become common in small inbreeding populations and cause high levels of seed abortion or relatively low fertility in offspring. However, a recent study on the population genetics of *Ipomopsis sancti-spiritus* found no signs of inbreeding depression (Talboom and Ayers 2015). All populations, including the three transplant sites, showed high levels of genetic diversity.

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

Population number have been fluctuating over the 12 monitoring years at Holy Ghost Canyon. The naturally occurring population of *Ipomopsis sancti-spiritus* was in decline between 2006 and 2012, but has been increasing ever since. There is no rainfall gauge in Holy Ghost Canyon, but the average precipitation measured at the nearby Pecos Ranger station is 16.27 inches a year, ranging from 8.07 in (2012) to 24.66 in (1991) (WRCC 2016). During half of the 12 monitoring years the precipitation levels were below average (2003, 2006, 2007, 2011, 2012, 2014). The lowest number of plants were documented in 2011 and 2012, which coincides with the lowest levels of precipitation received during the 12 monitoring years. Higher numbers of plants documented in 2015 can be attributed to unusual spring rains, resulting in a higher number of rosettes by August. Other reasons for fluctuating or declining plant numbers may include long

term effects of declining seed production and therefore seed banking, pollination success, and potential undocumented direct impacts to plants such as browsing, seed predation, road traffic and 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. A full census survey in 2015 in Holy Ghost Canyon did not document any new populations, or plants growing in areas recently disturbed by flooding or fire (Roth 2016, in prep.). 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 and erosion control projects, including seeding and mulching.

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. Therefore, potential future transplant sites must be reassessed and perhaps situated at higher elevations, more westerly exposures, or soils with better water holding capacities. Reproductive effort at the Willow Creek transplant site was not sufficient to establish a self-sustaining population. The number of plants transplanted plays an important role in providing a viable number of seeds to the seedbank and therefore contributing to the successful germination and establishment of future generations of plants. In addition to micro-habitat conditions, the number of plants transplanted at Willow Creek was likely too low to allow for sufficient regeneration from the seedbank.

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 remains 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. Despite this setback, the number of adults increased in 2014 to some degree (37 plants). However, despite increases in population numbers at the type locality and the Indian Creek transplant sites, plants remained at very low numbers at the Winsor site in 2015 (32 plants). Whether there is enough seed stored in the seedbank to allow for recovery remains to be seen.

The Panchuela transplant site has been in decline since 2012. Only 11 adult plants were found in 2015. With 19 plants or less during any year since 2012, the Panchuela site is not likely a viable population.

Holy Ghost Canyon Disturbance Treatments

Survival of transplants into the disturbance treatment sites has been excellent. Differences in the initial survival rates between thinned and un-thinned plots were not significant. In 2013 only 10 plants remained in each of the two sites, without a clear pattern between thinned and un-thinned plots. Germination and establishment of rosettes in thinned and un-thinned plots showed no significant differences in 2014, which may be the result of inadequate sample size and the small size of individual plots (10 x 10m). The small size of the study plots in combination with being situated immediately adjacent to each other likely masked any measurable effects of thinned vs. un-thinned plots.

In 2012, the majority of plants were browsed by deer or rabbits, more than once, which was thought to potentially have negative impacts on 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. 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. In 2014 a large number of rosettes were found in both treatment sites. Even though Site 1 produced substantially fewer mature seedpods in 2012, it had significantly more plants over Site 2 in 2014 and 2015. It is possible that the micro-habitat conditions at Site 1 are more conducive to germination and seedling establishment than those at Site 2 (the two sites are approximately 1.3 miles apart). However, 471 additional plants were planted immediately below Site 1 in 2011, effectively more than doubling the number of plants available to pollinators in the immediate area. This may be contributing to higher levels of pollination and out-crossing than in Site 2, and therefore higher seed production.

Although initial results do not seem to indicate any differences between thinned and un-thinned treatment plots, a new cohort of juvenile plants has become established in the two treatment sites. In 2014 and 2015, a significantly larger number of rosettes has become established at Site 1 than at any of the other transplant sites. Continued monitoring of these sites will contribute to our knowledge about conditions required for establishing successful reintroduction sites.

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 restoring several burned drainages in Holy Ghost Canyon, including Holy Ghost Creek. If these projects are going forward, surveys to determine the potential presence of *Ipomopsis sancti-spiritus* populations within the project area need to be undertaken at the appropriate time of year. Populations need to be avoided and carefully monitored during construction to avoid impacts. Seeds should be collected for ex-situ conservation and the establishment of new populations from seeds or transplants in burned or otherwise disturbed areas should be considered. 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.

Completion a management plan is highly recommended and was identified as a priority in the 2002 Recovery Plan for *Ipomopsis sancti-spiritus*. A management plan should be specific to *Ipomopsis sancti-spiritus* and address common ground disturbing activities authorized by the Forest Service within the habitat of the species (including introduction sites), such as road maintenance, recreation management, grazing, restoration projects (including prescribed fires, and thinning, weed control), and wildfire management. Consider the development of Best Management Practices for weed control and road maintenance activities.

Based on current study results, an investigation of reproductive effort is recommended to better understand what drives the production of seeds of *Ipomopsis sancti-spiritus*. At a minimum, the analysis of seed set within dense populations vs. scarce populations (including transplant sites) should be considered.

ACKNOWLEDGEMENTS

This report was adapted from previous progress reports written by Bob Sivinski, former botanist for the NM State Forestry Division, and Phil Tonne, former botanist for the New Mexico Natural Heritage Program. Data collected by Bob Sivinski and Phil Tonne from 1996-2011 were used to generate figures and tables to determine trends for this progress report.

Funding for this project has been provided by the U.S. Fish and Wildlife Service, Region 2, Albuquerque, NM, through Section 6 Endangered Species grants, received from 1996 through 2016.

LITERATURE CITED

Maschinski, J. 1996. Seed germination and pollination requirements of Holy Ghost ipomopsis. In: J. Maschinski, D.H. Hammond, and L. Holter, tech. eds. Southwestern rare and endangered plants: Proceedings of the Second Conference; 1995 September 11-14; Flagstaff, AZ. Gen. Tech. Rep. RM-GTR-283. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. pp. 167-170.

Roth, D. 2013. *Ipomopsis sancti-spiritus* (Holy Ghost Ipomopsis). Recovery Summary Report. (Section 6, Segment 27). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Roth, D. 2014. *Ipomopsis sancti-spiritus* (Holy Ghost Ipomopsis). Recovery Summary Report. (Section 6, Segment 29). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Roth, D. 2015. *Ipomopsis sancti-spiritus* (Holy Ghost Ipomopsis). Recovery Summary Report. (Section 6, Segment 28). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Roth, D. 2016. Survey and census for *Ipomopsis sancti-spiritus* (Holy Ghost Ipomopsis) in Holy Ghost Canyon, Santa Fe National Forest. Unpublished report prepared for the U.S. Forest Service, Region 3, Albuquerque, NM.

Sivinski R. 1996. Holy Ghost Ipomopsis Recovery. 1996 Progress Report (Section 6, Segment 11). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. 1999. Holy Ghost Ipomopsis Recovery. 1998-1999 Progress Report (Section 6, Segment 13). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. 2001. Holy Ghost Ipomopsis Recovery. 2000-2001 Progress Report (Section 6,

Segment 15). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. 2002. Holy Ghost Ipomopsis Recovery. 2001-2002 Progress Report (Section 6, Segment 16). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. 2003. Holy Ghost Ipomopsis Recovery. 2002-2003 Progress Report (Section 6, Segment 17). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. and P. Tonne. 2005. Holy Ghost Ipomopsis Recovery. 2004-2005 Progress Report (Section 6, Segment 19). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. and P. Tonne. 2007. Holy Ghost Ipomopsis Recovery. 2006-2007 Progress Report (Section 6, Segment 20). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. and P. Tonne. 2008. Holy Ghost Ipomopsis Recovery. 2006-2008 Progress Report (Section 6, Segment 21). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. and P. Tonne. 2009. Holy Ghost Ipomopsis Recovery. 2006-2009 Progress Report (Section 6, Segment 23). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. and P. Tonne. 2010. Holy Ghost Ipomopsis Recovery. 2009-2010 Progress Report (Section 6, Segment 24). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Sivinski R. and P. Tonne. 2011. Holy Ghost Ipomopsis Recovery. 2010-2011 Progress Report (Section 6, Segment 25). Unpublished report prepared for U.S. Fish & Wildlife Service, Region 2, Albuquerque, NM.

Talboom, J, and T. Ayers. 2015. Population genetics of the Holy Ghost Ipomopsis. Unpublished report prepared for the NM Energy, Minerals, and Natural Resources Department, Forestry Division, Santa Fe, NM.

Western Regional Climate Center. 2015. Monthly total precipitation (inches) at the Pecos Ranger Station, Pecos, NM. Accessed online on 2/20/2015 at http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?nm6676

U.S. Fish and Wildlife Service. 2002. Holy Ghost Ipomopsis (*Ipomopsis sancti-spiritus*) Recovery Plan. U.S. Fish and Wildlife Service, Albuquerque, NM.