Ipomopsis sancti-spiritus
(Holy Ghost Ipomopsis)

Recovery Summary Report
(Section 6, Segment 34)
1996 - 2020

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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, 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 in the phlox family (Polemoniaceae) 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 2015a). 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 2015a). 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 during both inventories. 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). Additional surveys in the Santa Fe and Carson national forests in 2016 did not locate any additional or new populations (Roth 2017).

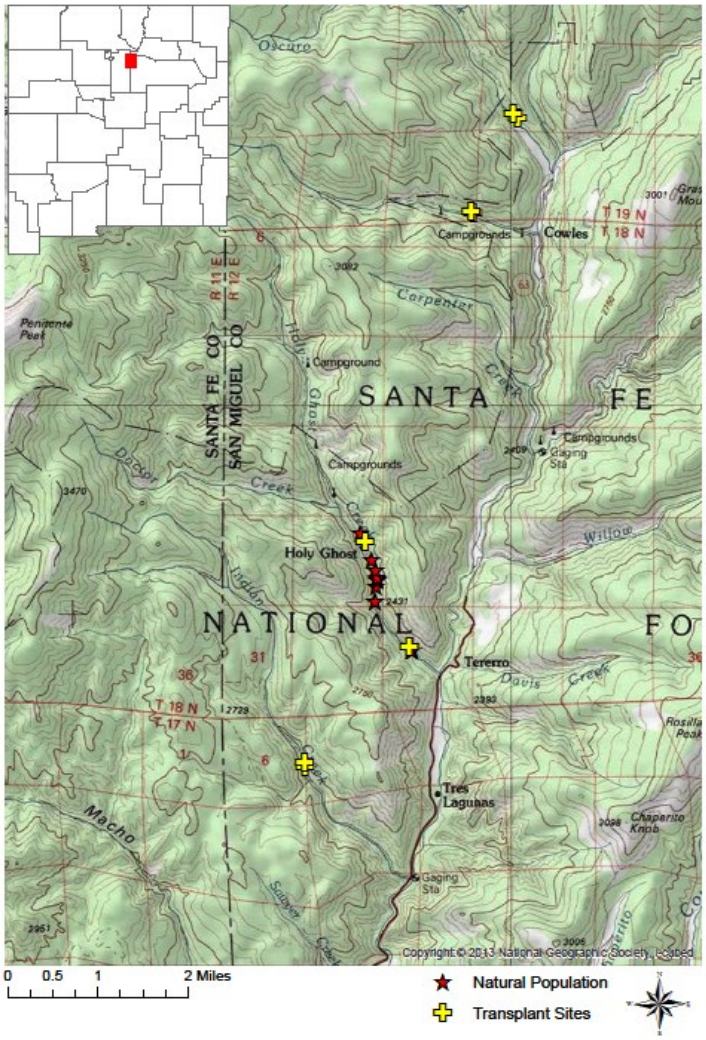


Figure 1. Current worldwide distribution of *Ipomopsis sancti-spiritus*, including transplant sites, Santa Fe National Forest, NM.

METHODS

GREENHOUSE PROPAGATION

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

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, Reproductive Effort

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 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 the 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 the 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 exact location of the plantings is unknown. 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 in 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.

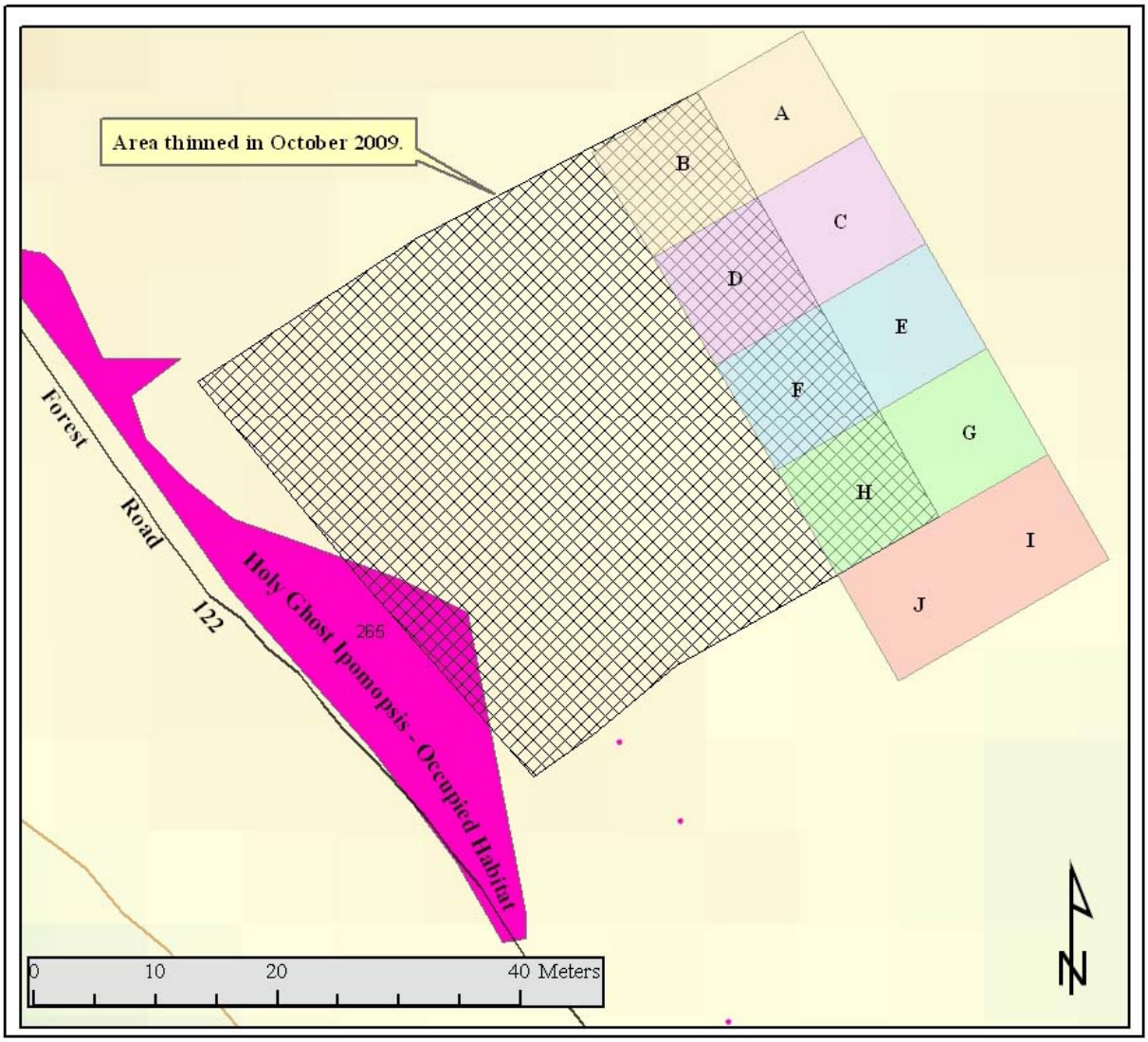


Figure 3. Sample plot design relative to thinning project and occupied habitat. Holy Ghost Canyon, Santa Fe National Forest.

2003 REPRODUCTIVE EFFORT STUDY

Flowering period and reproductive effort were documented at the Willow Creek transplant site and the naturally occurring population in Holy Ghost Canyon in the summer of 2003. 56 plants were overserved at each site and the number of seed capsules developing on each plant was counted. In addition, flowering period was observed at each site.

2018 REPRODUCTIVE EFFORT STUDY

On September 17 and 18, 2018, the number of seed capsules were counted on all plants that could be found along the 13 monitoring transects in Holy Ghost Canyon and at the Indian Creek, Windsor, and Panchuela transplant sites, wherever plants were recorded during the August of

2018 monitoring effort. Recorded were the number of plants at each site, the number of mature and immature seed capsules per plant, and the number of plants browsed.

2019 SEED COLLECTION

Plants were selected for seed collection along Holy Ghost Canyon road during flowering season when plants were still highly visible. Selected plants were marked with a pin flag. The number of plants from which seeds were collected differed at each site, depending on the number of total plants present, ranging from 1 to 6 plants per site, for a total of 22 plants from 6 sites. Latitude and longitude coordinates were recorded with a GPS for each of the 6 selected sites. No more than 10% of plants were collected at each site and no more than 10% of seeds from each plant. Seed collection commenced on September 11 and ended on September 20th (USFWS permit No. TE 820730-2). Each collection from a plant was placed in a small manila envelope and labeled with site number, plant number, and the collection date. Seeds are stored in a freezer at the Albuquerque BioPark Botanical Garden.

2016 SURVEYS

In 2016 targeted surveys were conducted for 20 days in potential habitat throughout the Santa Fe and Carson national forests (Roth 2017). Potential habitat was evaluated from ecological parameters, including geology, slope, exposure, and associated species, similar to those providing habitat for existing populations. Special emphasis was given to areas burned during the 2013 Tres Lagunas Fire, primarily outside Holy Ghost Canyon, and along road cuts, where the appropriate limestone substrate was present (most of Holy Ghost Canyon was surveyed in 2015; see Roth 2015a). The geologic substrate is partly weathered Terrero Limestone derived from the Sangre de Cristo Formation. *Ipomopsis sancti-spiritus* appears to grow best in bare mineral soils with its highest densities on disturbed sites such as road cuts. Limited random location surveys were also conducted within the two national forests to possibly document populations outside the known habitat range. Survey methods included extensive targeted walking transects within the Pecos watershed, as well as motorized surveys along roadcuts. Surveys took place during the active flowering season to maximize the potential for detection (late July through August).

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 2020 the average number of plants located within the 13 transects was 581 flowering plants and rosettes. The total number of plants in 2020 was 597, which represent a slight increase over 2019 counts (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). Between 2010 and 2014 the total number of plants had been significantly below average, but following relatively wet years of 2015 and 2016, the population rebounded through 2016, when the total number of plants was 705, including flowering plants and rosettes. The highest number of individuals were found in 2006, when 852 flowering plants and rosettes were located within the transects. In 2018 only 292 plants were found, which represents the lowest number of plants recorded since 2003. However, the population rebounded in 2019 when plant numbers were recorded near the average of the 17 years of monitoring. On average, approximately 68% of all plants are rosettes within the monitored population, ranging from 48% in 2017 to 85% in 2006 (Figure 5). In 2020, 68% of all plants were rosettes.

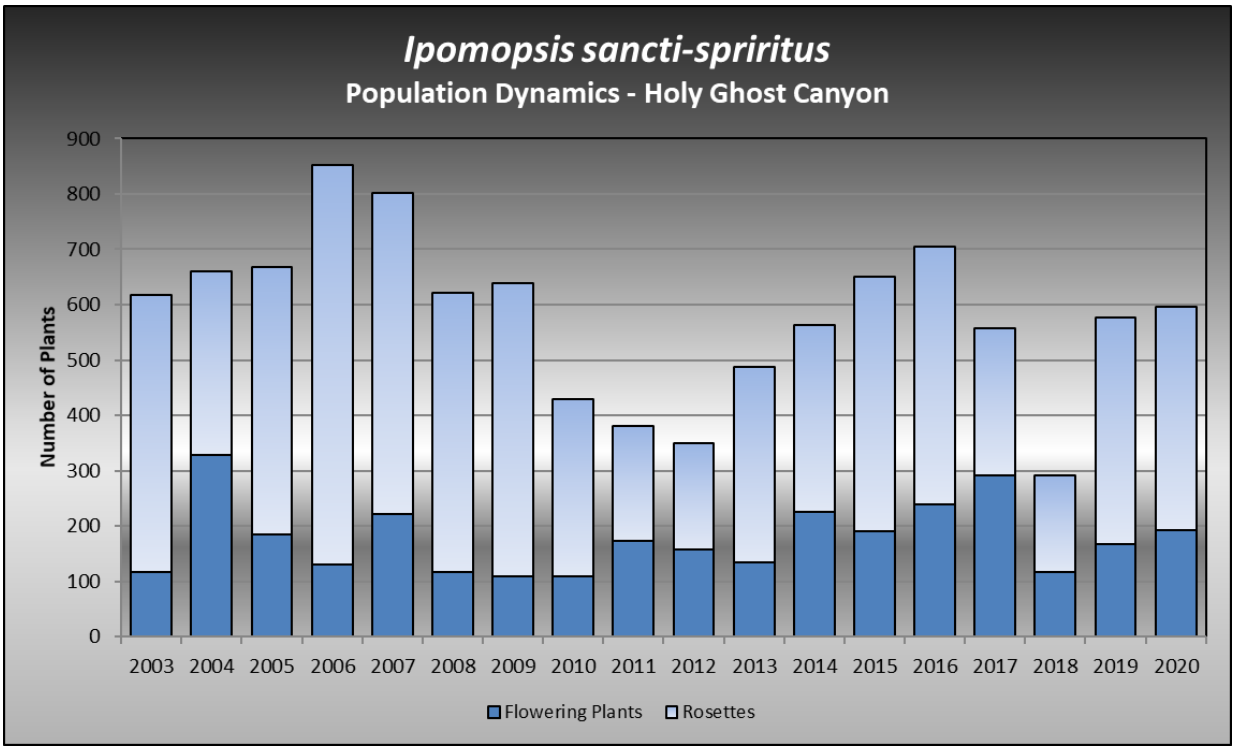


Figure 4. Total number of *Ipomopsis sancti-spiritus* plants in 13 transects in Holy Ghost Canyon, Santa Fe National Forest, NM, from 2003 to 2020.

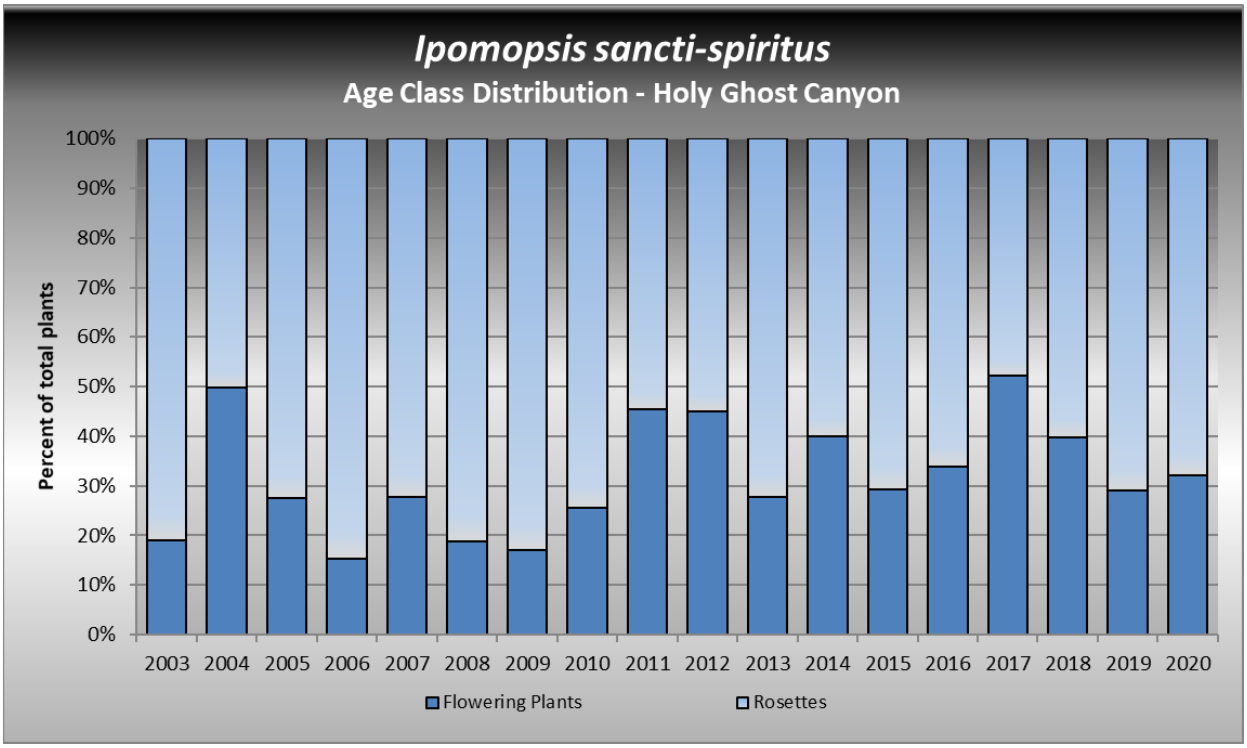


Figure 5. Age class distribution of *Ipomopsis sancti-spiritus* in 13 transects in Holy Ghost Canyon, Santa Fe National Forest, NM, from 2003 to 2020.

In 2013 the Tres Lagunas Fire burned 10,219 acres of forested lands in the immediate vicinity of the Holy Ghost Canyon populations 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.

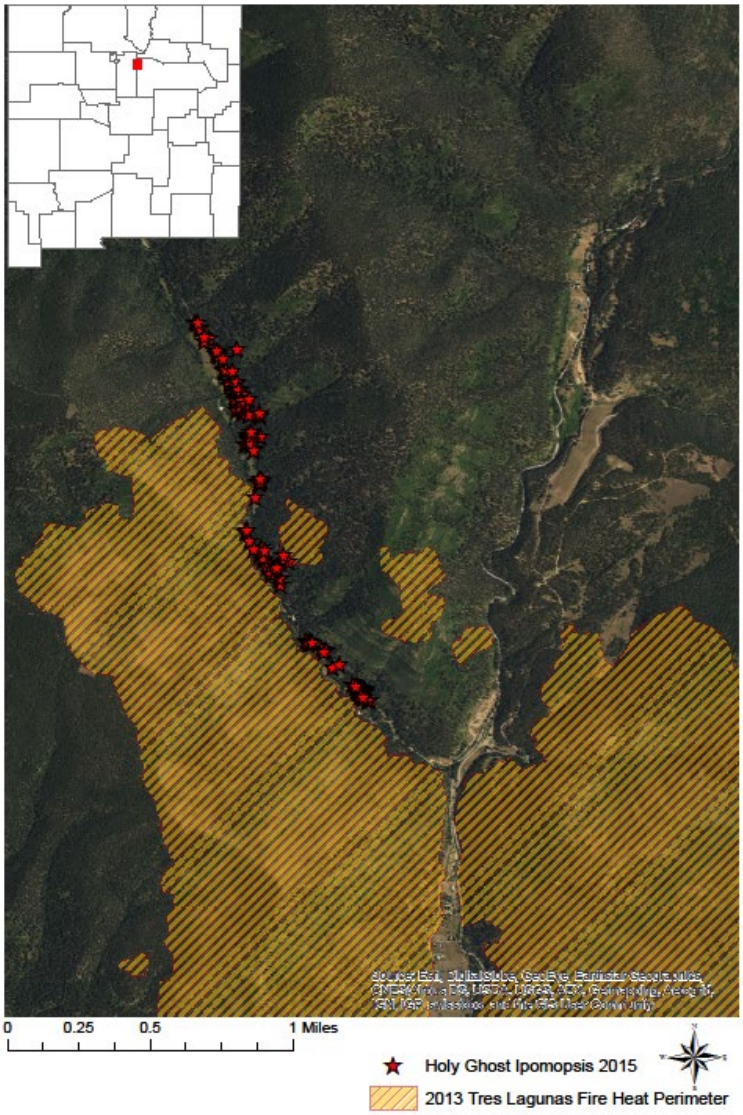
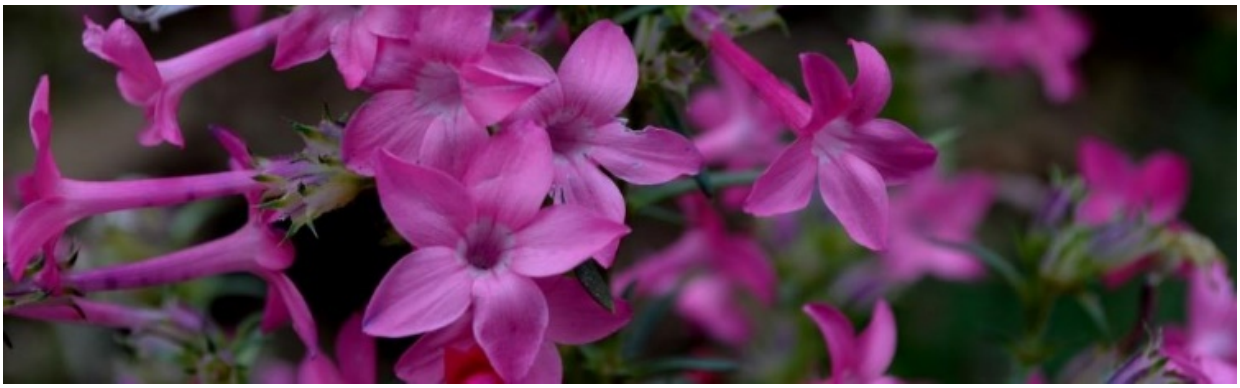


Figure 6. 2013 Tres Lagunas fire perimeter with respect to Holy Ghost Ipomopsis populations in Holy Ghost Canyon, Santa Fe National Forest.



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. 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.

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 8). 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 8). 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 at the Winsor and Panchuela sites through 2016, when only 4 adult plants were recorded from either site (Figure 8). The two sites recovered in 2017, when 44 and 31adult plants were documented, respectively. However, the Panchuela transplant declined again in 2018, when the population fell 50% below values recorded in 2017. Although the number of plants increased in 2019 (23 plants), in 2020 only 6 plants were found at the Panchuela site and 11 at the Winsor site.
The Indian Creek site declined between 2012 and 2014, but showed an increase in the number of plants through 2017 (202 plants in 2017) (Figure 8). This site was significantly impacted by livestock trailing and grazing in 2016. Out of 16 adult plant clusters documented, 12 were grazed (75%). In 2017 cattle continued to impact the site (Figure 7). Approximately 15 to 20 cattle were observed just outside the partially constructed fence and older hoof prints were found throughout the transplant site. An estimated 30% of flowering adults had been grazed earlier in the season, but all had resprouted and were flowering. When grazed or browsed during the early flowering season, plants can compensate by resprouting from the base, often producing multiple flowering stems. If grazed early in the season, this can lead to increased seed production. Unfortunately, in 2016 the Indian Creek site was grazed late in the flowering season, shortly before the monitoring date on August 18th. It is likely that fewer seeds were produced in 2016 for plants to germinate and establish rosettes in 2017, possibly resulting in fewer flowering adults in 2018. Only 184 adult plants were documented in 2018, which is similar to 2016 values when the site was found to be impacted by cattle. A fence was built to protect the transplant site in late 2017. However, in September 2018 the completed fence was found in poor shape allowing access for nearby observed cattle. At the time of the 2018 visit no recent signs of cattle trespass were observed within the fenced area. In 2019 the fence remained in poor condition and the area was accessible to livestock and wildlife in several areas. However, no recent signs of cattle trespass were observed within the fenced area during the August monitoring visit, when 286 flowering individuals were found at the Indian Creek site. 2020 was the worst year on record for the Indian Creek site. Only 25 flowering plants were found at the site. The fence continues to be in poor shape and was provisionally fixed in 2020. Numerous cattle were once again observed in the immediate vicinity of this site although no recent sign of trespass was observed inside the exclosure. Livestock grazing at Indian Creek was permitted in 2015 after the Forest Service determined there would be 'No Effect' to the Indian Creek transplant site.

Grazing is supposed to be on a 3-year rotation cycle. However, cattle were observed in the immediate surroundings of the transplant site in 2016, 2017, 2018, and 2020.

Figure 7. Cow leaving the Indian Creek Monitoring site just prior to fencing in 2017.

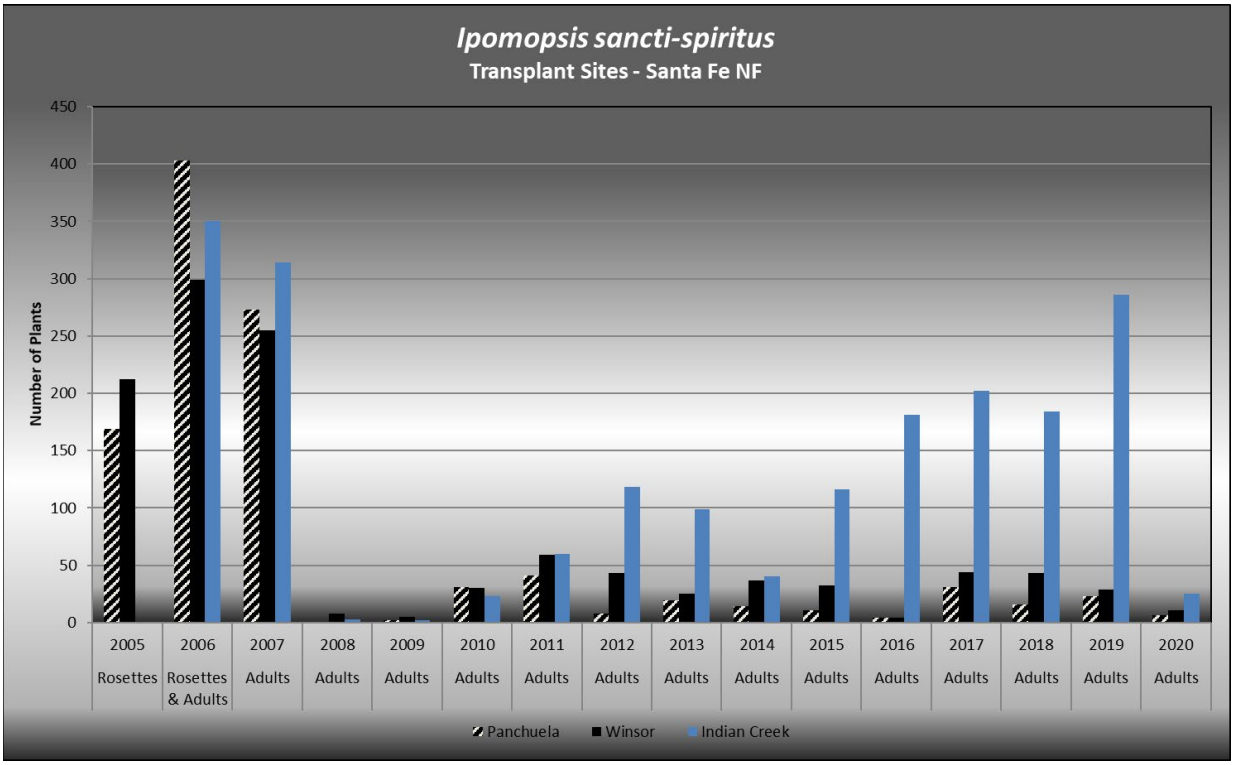


Figure 8. Total number of *Ipomopsis sancti-spiritus* plants at three transplant sites in the Santa Fe National Forest, San Miguel County, NM, from 2005 to 2020.

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 within and immediately adjacent to the thinned areas (Figure 9). The number of plants in the monitoring site declined 42% between 2012 and 2013 (Roth 2013). Some plants remained underneath areas that had been cleared and in the immediate vicinity of the thinning project in August 2013 (Figure 9). Even though the Forest Service is well aware of this transplant 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 8). In 2017 the population rebounded to similar numbers recorded in 2012. The number held steady in 2018 but declined to only 29 plants in 2019. Only 11 plants were found at the Winsor transplant site in 2020.

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

3. Holy Ghost Canyon Population Augmentation

Most of the rosettes planted in 2007 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 1). 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 where 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 flowering 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. 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).
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 (Roth 2013).

In August of 2013 only 20 plants remained of the original cohort of 640 plants (3%), 10 at each site (Roth 2013). The majority of these plants were rosettes (75%), only 4 plants were flowering, 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 1. Initial 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, 320 plants per site).

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%**

Summary 2012 – 2020

Initially the average number of plants between the six thinned and six un-thinned treatment plots was similar, one year after planting (Table 2). After 2013, as plants were replaced from the seed bank, the total and average number of plants have been consistently lower in un-thinned vs. thinned plots. However, there is considerable plot to plot variation, as indicated by a large standard deviation (Table 3). The standard deviation was lower in 2017 for both treatments, indicating a possible significant difference. High standard deviation were again recorded through 2020. In addition, un-thinned treatment plots are located immediately up-slope from the thinned plots (Figure 3). As documented in all other transplant sites, plants will migrate downslope over a number of years following the initial planting. Too few treatment plots (replications) and their location with respect to each other make this the more likely scenario over a possible significant difference between treatments.

Table 2. Total number of plants in 16 treatment plots (2 sites) between 2012 and 2020.

Treatment	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Thinned (6 plots)	240	205	3	786	1137	958	905	408	489	301
Un-thinned (6 plots)	240	199	6	467	712	253	346	159	229	114
Thinned, duff removed (2 plots)	80	66	1	311	523	390	364	190	287	164
Un-thinned, duff removed (2 plots)	80	71	1	49	132	81	97	82	95	44

Table 3. Average number of plants per plot in 16 treatment plots (2 sites) between 2012 and 2020.

Treatment	2012 (SDEV)	2013 (SDEV)	2014 (SDEV)	2015 (SDEV)	2016 (SDEV)	2017 (SDEV)	2018 (SDEV)	2019 (SDEV)	2020 (SDEV)
Thinned (6 plots)	**34** (1.9)	**0.8** (1.3)	**131** (165)	**190** (185)	**160** (142.5)	**151** (11.6)	**68** (48.9)	**82** (52.2)	**50** (26.6)
Un-thinned (6 plots)	**33** (4.9)	**2** (1.8)	**78** (91)	**119** (137)	**42** (21.7)	**58** (33.1)	**27** (20.9)	**38** (20.3)	**19** (11.6)
Thinned, duff removed (2 plots)	**19** (11.3)	**0.5** (0.71)	**155.5** (84.5)	**261.5** (98.3)	**195** (9.9)	**182** (59.4)	**190** (101.8)	**144** (116.7)	**82** (79.2)
Un-thinned, duff removed (2 plots)	**19** (14.1)	**0.5** (0.71)	**24.5** (1.5)	**66** (41)	**41** (14.9)	**48.5** (27.6)	**82** (22.6)	**47** (40.3)	**22** (14.1)

Only 4% of the initial population of plants remained as juveniles or rosettes one year after planting (2012). By 2013 the majority of flowering adults transplanted to the plots had died and

75% of the plants within all plots were juveniles/rosettes. Since then, the total number of plants has dramatically increased at both sites, but the vast majority continue to be non-reproducing rosettes. The percentage of rosettes has remained significantly higher than at the naturally occurring population in Holy Ghost Canyon. The average number of rosettes between 2003 and 2020 is 68% in the natural population, ranging from 48% in 2017 to 85% in 2006. The treatment sites averaged 92% since 2013, ranging from 75% in 2013 to 99% in 2014 in all plots. In 2020 the percent of non-flowering rosettes was 89%. Significant browsing has not been documented since 2012, likely due to the low number of flowering plants in all plots.

In 2017 8 small subplots were established at Site 1 to document survival and longevity of rosettes over time. A subplot was established in each treatment plot. 214 rosettes were documented from the 8 subplots in 2017, ranging from 7 to 64 plants per subplot. One plant was flowering. In 2018, 84 rosettes remained in the 8 subplots, ranging from 5 to 21 plants per subplot. 10 plants were flowering. This represents an estimated mortality rate of 64% of plants documented in 2017, likely in response to the dry winter of 2017/2018. Individual plants were not tagged. Hence it is unknown whether new plants were found in the subplots in 2018. In 2019 the number of rosettes in the subplots remained at 84, 13 plants were found flowering. In 2020 only 7 of the 8 subplots could be located. These contained 54 rosettes and no flowering plants.

Figure 10. Rosettes and seedling of *Ipomopsis sancti-spiritus*.

2020

In August of 2020 a total of 623 plants were found in the two treatment sites (Site 1: 286 plants; Site 2: 337 plants). The overwhelming majority of these plants were rosettes (89%). Only 67 plants were found flowering, 25 in Site 1 and 42 in Site 2. The six thinned plots contained a total of 301 plants, un-thinned plots contained a total of 114 plants (Table 4). The two thinned plots with duff removed in 2011 contained a total of 164 plants, un-thinned plots with duff removed contained a total of 44 plants (Table 5). None of the plants were browsed.

Table 4. Number of plants (rosettes and flowering plants) found in six thinned and un-thinned treatment plots in the Santa Fe National Forest, August 2020.

Site	Thinned	Un-thinned
1	84	23
1	68	40
1	25	78
2	65	28
2	43	29
2	16	31
Total	**301**	**114**
Mean	**50.2**	**19**
SD	**26.6**	**11.6**

Table 5. 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 2020.

Site	Thinned, duff removed	Un-thinned, duff removed
1	26	12
2	138	32
Total	**164**	**44**
Mean	**82**	**22**
SD	**79.2**	**14.1**

2003 REPRODUCTIVE EFFORT STUDY

Flowering periods and reproductive effort were significantly different between the transplant site at Willow Creek and the natural population in Holy Ghost Canyons (Table 6). 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.

Table 6. Reproductive efforts of *Ipomopsis sancti-spiritu*s at Willow Creek transplant site and a sample from Holy Ghost Canyon in 2003.

Location	Total Capsules	Number of Plants	Avg No capsules/ plant	Range Capsules per plant
Holy Ghost	3,218	56	57.5	2-350
Willow Creek	621	56	11.1	0-47

2018 REPRODUCTIVE EFFORT STUDY

The average number of seed capsules per plant ranged from 24 seed capsules per plant at the Indian Creek transplant site to 48 seed capsules per plant at the Panchuela transplant site (Table 7). The total number of seed capsules per plant ranged from 2 to 164 capsules. However, sample size varied significantly between sites, ranging from 7 plants at Panchuela to 87 plants at the Indian Creek site. Not all plants recorded along the monitoring transects in Holy Ghost Canyon and in the three transplant sites in August could be relocated in September. By fall of 2018 the majority of plants located had been browsed at all sites, ranging from 56% at the Winsor transplant sites to 100% at the Panchuela site. None of the 60 plants located in Holy Ghost Canyon were found with immature capsules, while 86% of the 7 plants at the Panchuela site had immature seed capsules. Although the Panchuela transplant site had the highest average number of seed capsules, 100 % of the 7 plants located were browsed and 86% were considered immature.

Table 7. Distribution of seed capsules and browsing observations at the natural population of *Ipomopsis sancti-spiritus* in Holy Ghost Canyon and at three transplant sites in the Santa Fe National Forest.

Location	Number of seed capsules	Number of Plants	No of plants browsed	No of plants with immature capsules	Avg No of capsules/ plant	Percent of Plants browsed	Percent of plants with immature capsules
Winsor	551	16	9	6	34	56	38
Panchuela	339	7	7	6	48	100	86
Indian Creek	2059	87	51	9	24	59	10
Holy Ghost Canyon	2471	60	40	0	41	67	0

2019 SEED COLLECTION

With the help of Forest Service personnel, a total of 1,019 seeds were collected from 22 plants at 6 sites in Holy Ghost Canyon between September 11 and September 20, 2019. Seeds at different developmental stages coexist at the same time on a plant, and even in a single inflorescence. Therefore, seed collection occurred multiple times from the same plant. The number of seeds collected from each plant differed from 8 to 136 seeds. The total number of collections was 53. Seed collection procedures were detailed by the Forest Service (Stauffer 2019).
Seeds are stored in a freezer at the Albuquerque BioPark Botanical Garden until they can be used for establishing new sites or augmenting existing transplant sites in the Santa Fe National Forest.

Figure 11: Developing seed capsules on *Ipomopsis sancti-spiritus.* Photos: K. Stauffer, USFS

2016 SURVEYS

No new or additional populations were found during the 2016 surveys in the Santa Fe and Carson National Forests. Surveys were conducted in the following areas:

Motorized roadcut surveys:

La Junta Canyon (Rd 76); Gallegos Rd (Rd 442), Little Rio Grande Rd (Rd 439), Angostura Rd (Rd 161), Elk Mountain Rd (Rd 646), Santa Barbara Rd (Rd 116), Borrego Canyon (Rd 518), Las Trampas (Rd 207 & 639), Truchas (Rd 639), Borrego Mesa (Rd 440 & 306), Rio Quemado (Rd 308), Dalton Canyon (Rd 123), Pecos River ((Rd 63), Iron Gate Rd (Rd 223).

Walking surveys:

Trails:
Hamilton Mesa (#249), Serpent Lake Trail (#19), Jack's Creek/Round Mountain (#s 25 & 257), Panchuela (#s 288 & 259), Winsor Creek (#s 254 & 271), Trampas Lake (#31), San Leonardo Lake (#30), Holy Ghost Creek (#283), Doctor Creek (no trail #).
Similar, but unoccupied habitats were found along the trail above the campground in Holy Ghost Canyon (#283), Doctor Creek (no trail number), Winsor Trails 254 & 271, Jack's Creek (lower #25), Panchuela (#s 288 & 259), Davis Creek (no trail), Dalton Canyon Road (Rd 123), Little Rio Grande Road (Rd 439), and upper Santa Barbara Road (Rd 116). Best suitable habitats were identified at Davis Creek (no roads or trails) and along Winsor trail #271.

Burned areas (no trails or roads):

North side Indian Creek (burned and unburned areas), Davis Creek

Special emphasis was given to surveys within areas burned in the 2013 Tres Lagunas Fire, in the appropriate habitat (aspect, slope, geology). The north side of Indian Creek is the closest burned area to the naturally occurring population containing some areas with similar habitat. It was therefore the most likely site to contain new populations of *Ipomopsis sancti-spiritus*. Although some good habitat was present inside and outside the fire perimeter, much of the burned areas were overgrown with oak regrowth and dense stands of invasive mullein (*Verbascum thapsus)*, lambsquarters (*Chenopodium album)*, musk thistle (*Carduus nutans)*, prickly lettuce (*Lactuca serriola),* and seeded slender wheatgrass (*Elymus trachycaulus*). The burned areas in the Davis Creek drainage were considered some of the best suitable habitat documented during this survey. Although the upper canyon was overgrown by resprouting oak, no invasive or seeded plants were documented from this area. Scarlet gilia *(Ipomopsis aggregata)* was located throughout all surveyed locations, in suitable habitat.

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.

POLLINATION SUCCESS

Limited pollination success was also thought a likely a factor in producing significantly lower reproductive effort values at the Willow Creek transplant site in 2003. The 58 flowering plants at the Willow Creek site were likely too few to attract enough pollinators for sufficient pollination. 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. Fewer plants per site might limit pollination success because pollinators are less likely to find plants at sites with fewer flowering plants. However, the 2018 reproductive effort study found transplant sites with very few plants produced high average numbers of seeds pods, which may have been a function of whether plants were browsed and compensated by growing new flowering shoots.

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).

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.

MONITORING

Holy Ghost Canyon

Population numbers have been fluctuating over the 18 monitoring years at Holy Ghost Canyon, but the overall long term population trend is down (Figure 11). Prior monitoring efforts from

1994 to 2005 also documented an overall decline (USFWS 2008). A study on the extinction risk of *Ipomopsis sancti-spiritus* resulted in a high probability of extinction within 50 years, even with focused management (Maschinski 2001). Twenty years later and after twenty-six years of population trend monitoring this trajectory appears plausible.

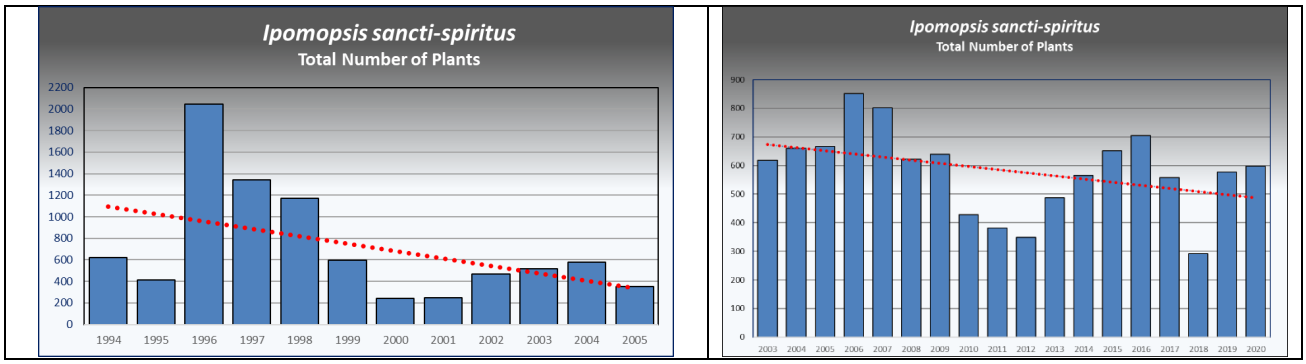


Figure 11. Population trends of *Ipomopsis sancti-spiritus* from 2 monitoring studies at Holy Ghost Canyon from 1994 to 2020.

The naturally occurring population of *Ipomopsis sancti-spiritus* was in decline between 2006 and 2012, followed by an increase through 2016. The population declined again, reaching an all-time low in 2018, but recovered since. There was no rainfall gauge in Holy Ghost Canyon until 2016, but historic records from Winsor Canyon (1894 – 1964), list the average annual rainfall amount at 23.92 inches for the 28 years during which sufficient data was collected, ranging from 11.77 to 32.92 inches. Due to proximity (4 miles) and elevation, the average annual precipitation at the Winsor site is likely representative of the rainfall amounts received at Holy Ghost Canyon. The most consistent but not likely representative rain gauge is located at the Pecos Ranger Station, in Pecos. During many of the monitoring years the precipitation levels measured in Pecos were below average for Pecos (16.27 inches) (2003, 2006, 2007, 2011, 2012, 2014). The low numbers of plants documented in 2011 and 2012, which coincides with the low levels of precipitation received in 2011 and 2012. Increasing plant numbers documented between 2013 and 2015 can be attributed to increasing rainfall. Rainfall data collected at the Pecos Ranger Station has been inconsistent since 2016. However, an automated rain gauge was installed in Holy Ghost Canyon in the fall of 2016. This will provide more accurate data on the correlation between plant densities and local rainfall in the future. In the winter of 2016 to 2017 (November through May), 8.22 inches of rainfall were recorded in Holy Ghost Canyon. In 2017/2018, only 2.6 inches were recorded. Low numbers of plants and rosette/seedling survival reported during the 2018 monitoring season were likely caused by the extremely dry winter of 2017/2018. Total precipitation for the months of November 2018 through May of 2019 was 9.26 inches in Holy Ghost Canyon, likely leading to the recovery of the type locality population by contributing to the germination and survival of seedlings and rosettes. Although late spring and summer of 2020 were extremely dry with little or no monsoons throughout New Mexico, winter and spring brought 8.78 inches of rainfall to Holy Ghost Canyon, contributing to stable population numbers.

Uncontrolled road traffic continues to increase along the road leading to the campground and hiking trails at the head of Holy Ghost Canyon, presenting a direct threat to the natural population of *Ipomopsis sancti-spiritus*. Unfortunately, the majority of plants occur within 100

feet of the road and plants grow in the immediate vicinity of the edge of the road, sometimes growing out of the cracks of the pavement (Roth 2015a). Plants are regularly driven over by vehicles trying to pass each other along this narrow road. Observed impacts to the habitat and mortalities of plants caused by this traffic have been of major concern for decades. After years of lobbying, the Forest Service has finally installed some barriers in 2020 to keep vehicles from driving over plants at the locations with the largest populations. Hopefully these will provide some protection for these plants into the future.

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. However, a full census survey in 2015 in Holy Ghost Canyon did not document any new populations growing in areas recently disturbed by fire or subsequent flooding, even though plants germinating in response to the fire in 2013 should have been flowering during the 2015 post-fire surveys (Roth 2016). Although fire itself 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.

Other reasons for fluctuating or declining plant numbers may include long term effects of declining seed production and therefore seed banking, pollination success, and the cumulative effects of direct impacts to plants caused by browsing, seed predation, competition from invasive plants, road traffic and maintenance 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. Therefore, potential future direct seeding 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 pollination and 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 are achieved. Unfortunately, already low population numbers at the Winsor transplant site were impacted by brush clearing in 2013. The Indian Creek transplant site has been impacted by cattle grazing and trampling. The Panchuela site is significantly impacted by native browsers and may be unable to sustain itself. All three transplant populations crashed in 2020, for unknown reasons. Especially significant was the 91% decline in the number of flowering plants at the Indian Creek site. Although it was a very dry late spring and summer, plants were stable in the natural population, following good winter and spring precipitation. It is unclear what number of adult plants constitute a viable population as these sites persist, sometimes with extremely low numbers of flowering plants, but none have reached the numbers that were originally planted at any of the sites. A Population Viability Analysis might shed some light on how many adult plants are needed to maintain a viable population into the future and whether augmenting existing populations may be useful in increasing population viability and thereby furthering the recovery of the species.

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. Only 52% of the flowering plants observed at Site 1 in August 2012 made it to seed set by late September. However, the majority of browsed plants at site 2 produced mature seed pods in 2012. 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 through 2016. Total number of plants remained higher in Site 1 until 2017, but was similar in 2018. In 2019 Site 2 had significant more plants than Site 1. The number of plants decreased in 2020 by approximately half at both sites, but Site 2 continues to have more plants.

Since recruitment was first documented in 2014, the vast majority (>89%) of plants documented at both sites remain in the rosette stage through 2020. Although the average percentage of rosettes in the natural population is high (68%), it is significantly higher in the transplanted treatment sites. Some of the rosettes may be germinants recorded in 2014, while some germinated and established in the intervening years. Clearly many of the germinants die without reaching the adult flowering stage, especially during drought years, as documented from the decline in the number of plants recorded from 2017 to 2018 in the small subplots at Site 1. *Ipomopsis sancti-spiritus* is primarily a biennial, with an average life span of 1.86 years, ranging from 1 to 6 years (Maschinski 2001; Sivinski 1991). Although we know that plants may remain in the rosette stage for up to 8 years, it is unclear why so many plants have become established as rosettes in the treatment areas, but do not flower (Sivinski 1991). A more thorough study on the longevity and survival of rosettes establishing in the wild might be in order. Considering the low number of flowering plants at the 2 sites, many of the rosettes must be germinating from the existing seedbank, largely established from the original cohort of flowering plants. This seedbank is likely getting depleted over time as fewer flowering plants are restocking the seedbank. A slow decline in the number of plants is therefore expected.

Nine years following the initial planting of rosettes in thinned and un-thinned study plots, it may appear as if there was a significant difference between treatments. However, un-thinned treatment plots are located immediately up-slope from the thinned plots (Figure 3). As documented in all other transplant sites, plants will migrate downslope over a number of years following the initial planting. Too few treatment plots (replications) and their location with respect to each other make this the more likely scenario over a possible significant difference between treatments. Additional studies in thinned areas are needed to be conclusive.

2016 SURVEYS

Targeted surveys conducted during the height of the flowering season in potential and suitable habitat were unsuccessful in locating additional populations. Surveys extended beyond the known range of the species in the Pecos watershed, for approximately 35 miles north of the known population, into the Carson National Forest. Target locations were areas burned in 2013 and road cuts with the appropriate geology, slope, exposure, and associated species. Surveyed areas also included locations outside the current description of suitable habitat, within the Pecos watershed. Past surveys, including initial surveys to locate additional populations of *Ipomopsis sancti-spiritus* between 1988 and 1991, were also unsuccessful. Hence the Holy Ghost Canyon population remains the only known naturally occurring population of this species in the world. This location is highly vulnerable to human caused disturbances and stochastic extinction events and therefore should be managed accordingly.

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 careful 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.

A recent proposal to for explorative drilling for potential mineral mining south of Holy Ghost Canyon may impact the Indian Creek transplant site. 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 project implementation to avoid impacts. Seeds should continue to be collected for ex-situ conservation, population augmentation at existing transplant sites, and the establishment of new populations from seeds or transplants in burned or thinned 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 could have taken the opportunity to establish a new transplant site in a suitable burned area to study and evaluate establishment of new populations in burned areas. Although proposed on multiple occasions, the suggested project was not realized. Future wildfires and prescribed fires in the area should consider establishing new introduction sites immediately post-fire.

Population declines caused by authorized activities such as forest thinning, livestock grazing, recreational traffic, road improvement and maintenance are unfortunate and preventable. Plants growing along the road get routinely run over by passing vehicle traffic, which contributes to the overall decline of the species. Completion of 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 *I. 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 and traffic control, utility corridor maintenance, recreation management, grazing, mining, restoration projects (including prescribed fires, thinning, weed control), and wildfire management. The development of Best Management Practices for weed control and road maintenance activities should be considered. Closer involvement of the Santa Fe National Forest with the management and monitoring of this endangered species might help prevent further oversights negatively impacting the species.

More than a decade after attempting to establish new populations, success remains uncertain. A Population Viability Analysis for the transplant sites may shed some light on whether any of these sites can be considered viable populations. Results may help in our understanding of how

many plants are needed to consider a population viable and whether existing populations could benefit from augmentation.

Based on current study results, especially the continued high proportion of rosettes in the treatment areas and the results of the initial 2018 reproductive effort study, a more detailed investigation of reproductive effort and success is recommended to better understand what drives the production of seeds of *Ipomopsis sancti-spiritus*. In addition, an analysis of seed set within dense populations vs. scarce populations (including transplant sites) and the survival and longevity of established rosettes should be considered to support our understanding of population viability.

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