

2020
Status Report
Goodding's Onion
(Allium gooddingii)

Gila and Lincoln National Forest, New Mexico



Intact Goodding's onion habitat and plants at Sierra Blanca South sites, Lincoln National Forest.

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INTRODUCTION



Goodding's onion is perennial herb in the amaryllis family (Amaryllidaceae). It is endemic to New Mexico and Arizona where it generally occurs under the canopy of mature mixed conifer and spruce forests, along north-trending drainage bottoms associated with perennial and intermittent stream courses at elevations between 7,000 and 11,300 ft (NMRPTC 1999). On occasion it can also be found along dry north and south facing slopes under a well shaded forest canopy with a sparse understory. It was previously believed that the species also occurs naturally in open areas, ski slopes and avalanche chutes in the Lincoln National Forest, above 10,000ft. However, we now know that these populations are remnant populations persisting in open areas following forest clearing for ski slopes at Ski Apache on the Lincoln National Forest.

Worldwide Goodding's onion (*Allium gooddingii*) is known to occur in Arizona and New Mexico, from 5 metapopulations and approximately 75 historically known locations (Navajo Nation, Coronado National Forest, Apache-Sitgreaves National Forest, Gila NF, and Lincoln NF). The majority of sites are located on the Apache-Sitgreaves National Forest in Arizona and the adjacent Gila National Forest in New Mexico. In New Mexico the species is known from the Gila and Lincoln National Forests.

Goodding's onion was a Candidate for Federal listing under the Endangered Species Act until a Conservation Assessment and Strategy (CAS) was signed between the U.S. Forest Service (USFS) and the USFWS in 1997 (USFS & USFWS 1997). The CAS was meant to provide management guidance to ensure the protection of the species in the absence of listing. The majority of sites known prior to this study were last documented well before the 1997 CAS was established. Unfortunately, no additional inventories or monitoring took place after the CAS was finalized (Laurenzi & Anderson 2011). Therefore, pre-fire population estimates are limited and none of the New Mexico populations were ever monitored. Goodding's onion continues to be a Forest Sensitive Species and is listed endangered by the State of New Mexico. The New Mexico Rare Plant Conservation Strategy ranks the species 'weakly conserved' due to documented threats and weak protections. NatureServe gives Goodding's onion a state and global conservation rank of G2/S2 (imperiled).

Over 95% of all known sites in Arizona and New Mexico burned in wildfires between 2006 and 2020 (Wallow Fire/AZ (2011), Bighorn Fire/AZ (2020), Bear Fire/NM (2006), Whitewater-Baldy Fire/NM (2012), Little Bear Fire/NM (2012), Buzzard Fire/NM (2018)). The few significant remaining unburned populations are located in the Chuska Mountains of the Navajo Nation and in the White Mountains in the Lincoln National Forest.



GILA NATIONAL FOREST

The Gila National Forest is known for its diverse flora and high degree of plant endemism. Catron, Grant, and Sierra counties of New Mexico provide habitat for a total of 51 plant rare and endemic plants, many of which occur in the Gila National Forest, including 20 that are listed as Forest Sensitive Species (NMRPTC 1999). Between 2000 and 2018 over 1.32 million acres have burned on the Gila National Forest in Catron, Grant, and Sierra counties of New Mexico. Thirty Goodding's onion locations have been historically documented from the Gila National Forest, the majority of which, 93%, occur in the Mogollon Mountains (NMNHP 2013, Crosley 2012). The Mogollon Mountain populations are widely distributed over an area of approximately 16 x 13 miles, at elevations ranging from 7,800 to 9,500 ft. Two disjunct locations occur to the north, one in the Tularosa Mountains and one in the San Francisco Mountains. All of them have been directly or indirectly impacted by 4 different wildfires between 2006 and 2018. In 2006 the Bear Fire burned 34,703 acres in the heart of the known populations in the Mogollon Mountains. In 2012 the Whitewater-Baldy Fire burned approximately 306,924 acres of forest land and the remainder of the known populations in the area. In 2018 the two disjunct unburned locations were impacted by the Owl Fire (4,786 acres) in the San Francisco Mountains and the Buzzard Fire (50,230 acres) in the Tularosa Mountains.

METHODS

2020 surveys attempted to locate plants documented to be extant between 2013 and 2015 within the Whitewater-Baldy fire perimeter at 11 locations and 55 waypoints and two previously not surveyed locations to the north, burned in two different fires in 2018 (Frieborn and Long Canyon)(Roth 2016a, Crosley 2012). None of the sites where no plants were found from 2012 to 2015 were revisited in 2020. One location was not surveyed in 2020 (Iron Creek, 2 waypoints, 500 plants) and 3 waypoints were not attempted (lower Gooseberry Canyon, 3 waypoints, 110 plants in 2015), due to access difficulties. Surveys were targeting specific waypoints but included suitable habitat in between. Survey routes were documented using the tracking function of a Garmin Monterra GPS. Waypoints and associated data were collected with a Samsung Galaxy S2 tablet using the Collector App. A waypoint documented the presence of live plants either by actual counts for small sites or visual estimates for larger sites in the vicinity of the waypoint. Additional information was collected on the vigor, reproductive status and recent disturbances associated with the general area of occupation.

RESULTS



In 2020 only sites that had extant populations during the 2013/2015 surveys in the Mogollon Mountains were visited (Figure 1). Eleven locations were visited within the Whitewater-Baldy perimeter. Two additional locations were surveyed outside of the Whitewater Baldy fire perimeter in the San Francisco Mountains (Frieborn) and the Tularosa Mountains (Long Canyon)(Table 1). Plants were found in all but one location, although the number of plants was significantly reduced and plants were found at only 38 of the previously documented 55 waypoints in the Mogollon Mountains. The total number of plants found at each location ranged from 0 (Upper Willow Creek) to 350 individuals in an unburned area (Willow Creek).

The 2013 – 2015 post-fire Goodding’s onion surveys documented between 4,530 and 4,880 plants at 55 waypoints in 11 locations (Roth 2016a). Plants were found in light to severely burned forests and unburned patches, except for areas that had burned in the 2006 fire. In 2020 plants were documented from 38 waypoints at 10 of the 11 locations surveyed, with a total estimate of 1,250 individuals (Table 1). This represents a reduction of over 70% in the number of plants since 2013/2015 post-fire surveys. The majority of plants at each waypoint were rated in normal condition (68%) and the remainder were ranked stressed (32%). None of the sites were rated vigorous. Plants were found in various stages of reproduction at only 14 of the 38 waypoints (37%). On average, less than 10% of plants found at a waypoint were flowering or fruiting. In addition, 1,081 plants were documented from 2 locations not surveyed in 2013/2015, outside of the Whitewater-Baldy fire perimeter, primarily at the unburned Frieborn location in the San Francisco Mountains (966 individuals) and some remaining at the severely burned Long Canyon population in the Tularosa Mountains (115 individuals)(Table 1). The majority of extant plants, or 95%, occurred in unburned forest (Frieborn, Water Canyon, Willow Creek), unburned forested patches in severely burned forests (Long Canyon, Water Canyon), or in light to moderately burned forests (Mineral Creek, Bear Wallow).

No pre-fire estimates are available, but in a period of 5 to 7 years after the Whitewater-Baldy fire a significant number of plants extant after the fire have vanished, primarily due to habitat conversion, resource competition, and blowdown. Populations in severely burned forests are not expected to persist. Initial post-fire survival of plants was also impacted by post-fire floods and the complete blowout of drainages in several locations. However, the majority of the post-fire flood populations were no longer found within the first couple of years after the fire and therefore represent the first wave of post-fire local extinctions (Roth 2016, Crosley 2012).

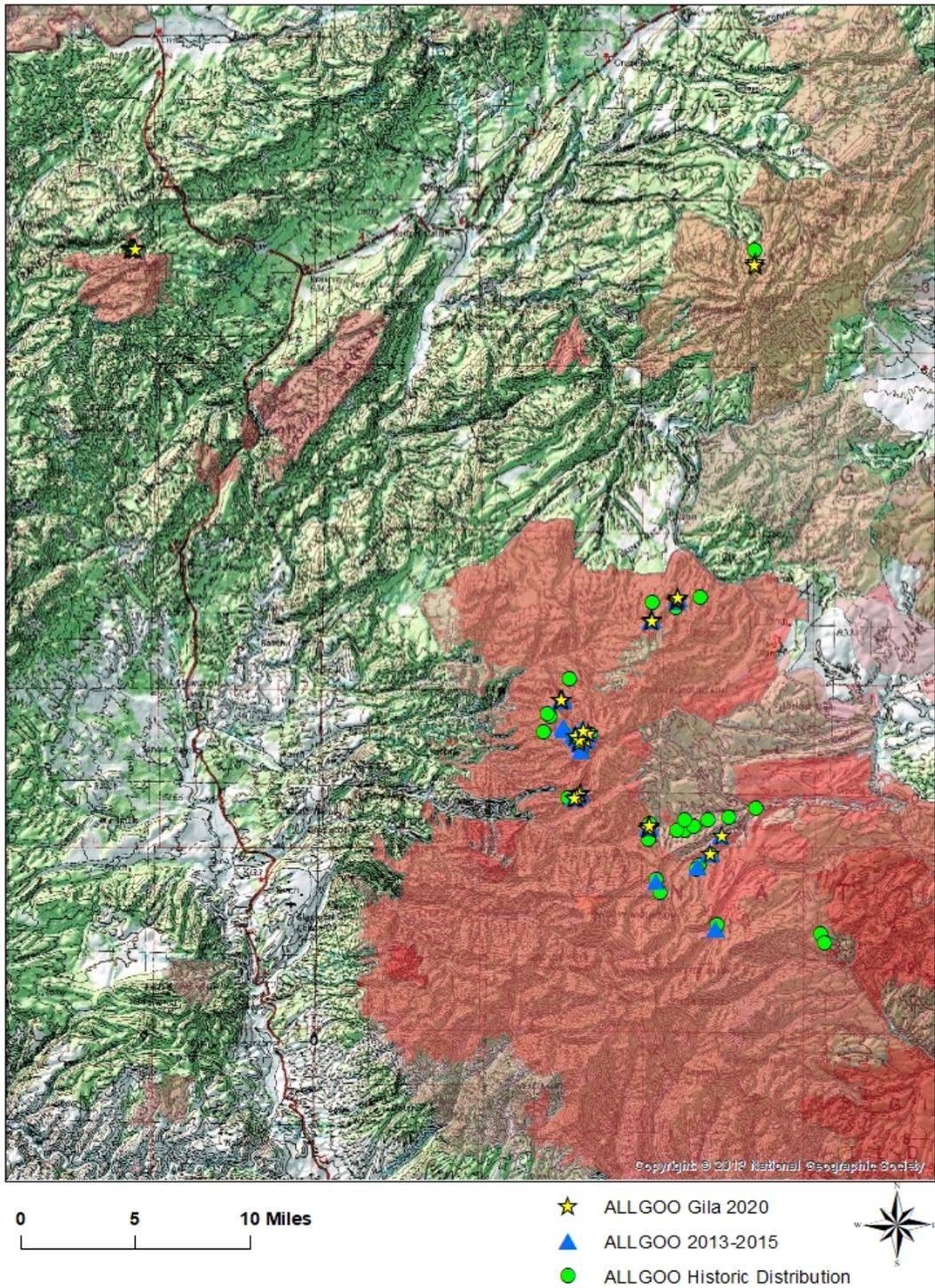


Figure 1. Distribution of *Allium gooddingii* through time in the Gila National Forest and proximity of wildfires.

Table 1. Location and the number of Goodding’s onion plants in the Gila National Forest in 2020 and previous surveys (number of waypoints in parentheses).

Location	Number of Plants Previous	Number of Plants 2020	Occupied Site Viability	Comments
Water Canyon (EO 11)	70 (3)	236 (6)	Excellent	Unburned forest
Rainy Mesa (EO 12)	400 – 425 (3)	120 (3)	Marginal	Unburned patches
BS Canyon (EO 18)	470 – 520 (7)	14 (2)	Poor	Severely burned
Lower BS Canyon (EO 18)	430-455 (7)	13 (4)	Poor	Severely burned
Gooseberry Canyon (EO 19)	970+ (13)	85 (7)	Poor	Severely burned
S Fork Gooseberry Canyon (EOs 19 & 26)	1,262+ (6)	62 (4)	Poor	Severely burned
Mineral Creek (EO 7)	329+ (6)	305 (9)	Good	Light to moderate burn
Upper Willow Creek (EO 16)	10 (1)	0	Extinct	Severely burned
Willow Creek (no EO, specimen record)	150 – 200 (1)	350 (1)	Excellent	Unburned
Little Turkey Creek 20 (EO 23)	125-200 (3)	1	Poor	Severely burned
Bear Wallow (EO 14)	315-440 (5)	126 (5)	Good	Light to moderate burn
Long Canyon (EO 10)	1,000 (surveyed in 2012, pre-fire)	115 (3)	Poor	Unburned patches
Frieborn (EO 25)	3,500 (surveyed in 2012, pre-fire)	966 (8) Not surveyed in entirety	Excellent	Unburned. Impacted by post-fire flooding, but mostly intact. Livestock throughout.
Total Estimate	9,081	2,331		

2020 Habitat condition of 13 Goodding's onion locations in the Gila National Forest

Water Canyon (Mogollon Mountains) – Intact unburned or lightly burned forest. Plants in patches on N-facing lower slopes above drainage.

Rainy Mesa (Mogollon Mountains) - Severely burned forest with some pockets of live Douglas fir, ponderosa pine, limber pine and white fir in pockets along drainage. Remaining Goodding's onion under live trees. Drainage downcut severely. Significant blowdown. Livestock impacts significant. Plants drought stressed. Some bull thistle present in patches. Lots of locust, some oak, wild roses and raspberries. Some conifer regeneration.

BS Canyon (Mogollon Mountains) - Severely burned forest with few live Douglas fir, aspen, ponderosa pine, and limber pine. Significant blowdown. Plants drought stressed, none flowering. Bull thistle scattered throughout. Lots of aspen, locust, raspberry and gooseberries. Some conifer regeneration (Figure 3).

Lower BS Canyon (Mogollon Mountains) - Severely burned forest with few live Douglas fir and ponderosa pine. Significant blowdown. Plants drought stressed, none flowering. Bull thistle scattered throughout. Lots of locust, raspberry and gooseberries.

Gooseberry (Mogollon Mountains) - Severely burned forest with few live Douglas fir and ponderosa pine. Significant blowdown. Bull thistle scattered throughout. Lots of aspen, locust, raspberry and gooseberries. Lower 3 sites not attempted due to difficulty of terrain.

South Fork Gooseberry (Mogollon Mountains) - Severely burned forest with few live Douglas fir and ponderosa pine. Significant blowdown. Plants drought stressed, few flowering/fruitletting. Lots of aspen, locust, raspberry, bracken and gooseberries. Heavy elk presence and impacts.

Mineral Creek (Mogollon Mountains) – Light to moderately burned forest. Canopy mostly intact, some blowdown. Plants widely scattered along dry, steep, NW facing slopes, under Ponderosa pine and some scattered Douglas fir. Mostly gravelly mineral soils with little duff. Uncommon habitat type.

Upper Willow Creek (Mogollon Mountains) - Severely burned forest with few live Douglas fir and ponderosa pine. Significant blowdown. No plants found. Site next to creek, severely eroded. Site overgrown with roses, gooseberry, cutleaf coneflower, thimbleberry.

Willow Creek (Mogollon Mountains) – Intact large patch of conifer forest along Willow Creek above Ben Lily Campground. Plants on N-facing slopes under Douglas fir canopy, South side of Willow Creek. Trail no longer obvious.

Little Turkey Creek (Mogollon Mountains) - Severely burned forest with no live trees. Significant blowdown. Only one plant found. Roses, gooseberry, raspberries, lots of bunch grasses. Some conifer regeneration. Some bull thistle scattered along drainage (Figure 2).

Bear Wallow (Mogollon Mountains)- Light to moderately burned forest with lots of blowdown in drainage impacting several sites. Steep, narrow drainage. Plants along trail. Cut banks along stream where plants occur.

Long Canyon (Tularosa Mountains) – Severely burned in 2018 with few patches of live Douglas fir. Flat broad drainage bottom (Figure 5). Plants only found in moderately burned sites, under patches of live trees. None flowering.

Frieborn (San Francisco Mountains) – Hundreds of plants along steep slopes above recently blown out drainage due to downstream post Owl Fire impacts. Dark, narrow canyon with intact forest of Douglas fir and ponderosa pine. Lower sites not surveyed due to difficulty of terrain, presumed intact. There are likely several thousand plants (Figure 4).

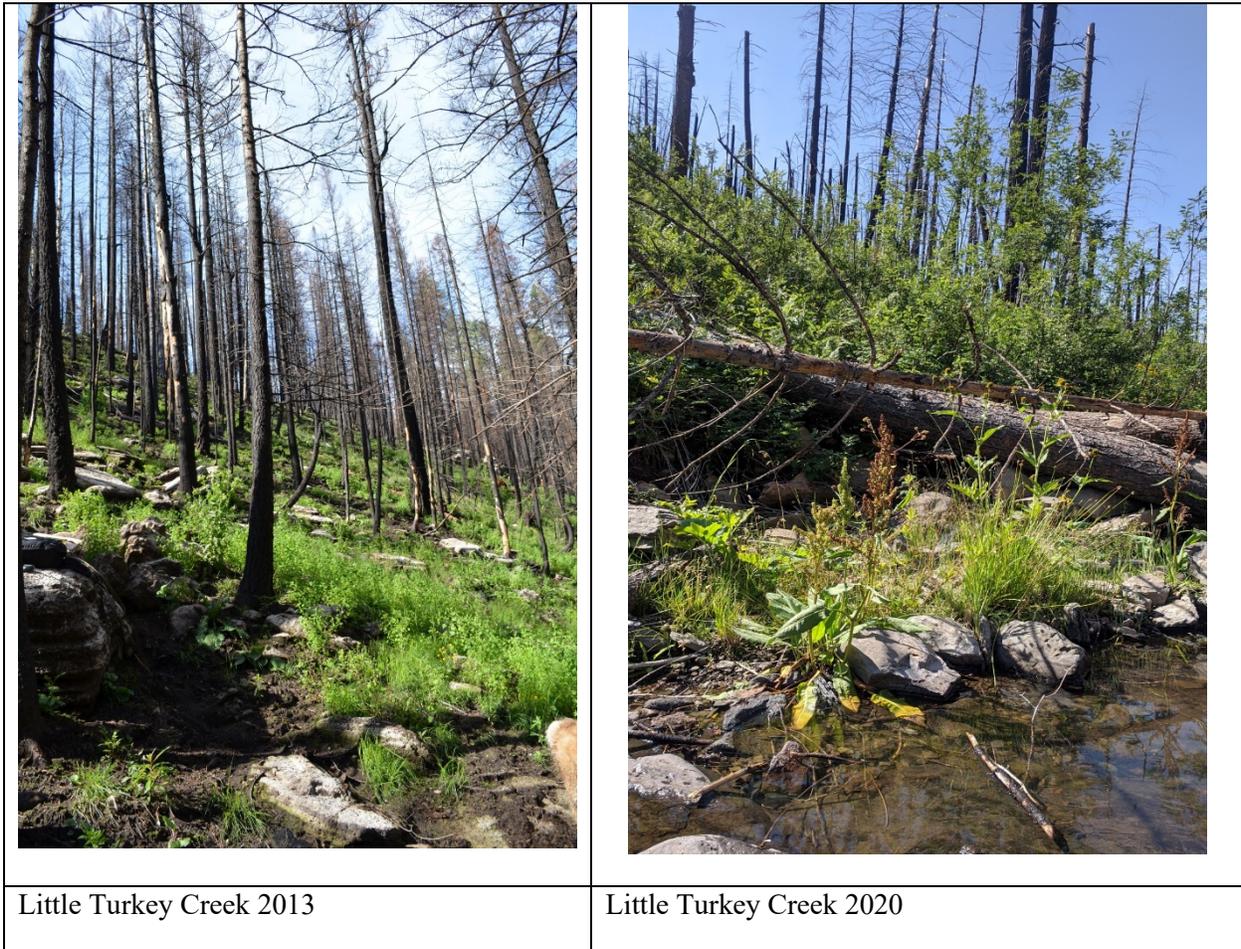


Figure 2. Post-fire habitat conditions (2012 Whitewater-Baldy Fire)



Figure 3. BS Canyon 2018 habitat conditions (2012 Whitewater-Baldy Fire)



Figure 4. Frieborn Canyon 2020 unburned post-fire habitat conditions (2018 Owl Fire impacts)



Figure 5. 2020 Post-fire habitat conditions at Long Canyon (2018 Buzzard Fire)

Table 2. Gila National Forest locations with unknown persistence

Location Name	Last reported
Indian Creek 24	Burned in 2006 Bear Fire. 75 plants in unburned patch and under shade of larger herbaceous plants in open meadow (Crosley 2012). Possibly extant.
Indian Creek 26	Burned in 2006 Bear Fire. 700 plants in unburned drainage bottom and toe slopes, mixed conifer forest (Crosley 2012). Possibly extant.
Indian Creek 13	Burned in 2006 Bear Fire. 335 plants in unburned drainage bottom and toe slopes, mixed conifer forest (Crosley 2012). Possibly extant.
Iron Creek (EO 6)	Burned in Whitewater-Baldy Fire in 2012. Light to moderate burn. Extant in 2014 (Roth 2016a). Possibly extant.
Turkey Feather (EOs 28 & 29)	Burned in Whitewater-Baldy Fire in 2012. Not seen since original discovery, 1995 (2 sites). Where mapped, at least one of the 2 sites burned severely (Google Earth). Possibly gone.
Little Deep Creek (EO 27)	Burned in Whitewater-Baldy Fire in 2012. Not seen since original discovery, 1993. Not mapped at described location (T10S R18W S9, W2 SE4). Possibly gone.
North Fork Mineral Creek (EO 8)	Mapped in South Fork. Unclear location. Possibly the same as EO7. Mapped location not surveyed in 2013/2015.

Table 3. Locations where Goodding's onion is presumed extinct

Location Name	Last Survey
Gilita (EO 2)	Crosley 2012, Roth 2016
N Fork BS Canyon? (EO 13)	Possibly mis-mapped. Possible associated specimen coordinates do not map out in BS Canyon. Surveyed both sites in 2013, without success (Roth 2016a).
Lower Gooseberry (EOs 9, 5)	No plants in 2013 at mapped locations (Roth 2016a)
Bearwallow Mountain (EO 26)	No plants in 2014 at mapped locations (Roth 2016a)
Little Turkey Creek 22 (EO 24)	Crosley 2012, Roth 2016a
Little Turkey Creek 23 (EO 21)	Crosley 2012, Roth 2016a
Rainy Mesa - Hail Creek (EO 20)	Crosley 2012
Upper Willow Creek (EO 16)	Roth 2020
Copper Creek 33	Crosley 2012, Roth 2016a
Indian Creek 8	Crosley 2012, Roth 2016a
Indian Creek 12	Crosley 2012, Roth 2016a
Indian Creek 15	Crosley 2012, Roth 2016a
Indian Creek 23	Crosley 2012, Roth 2016a

DISCUSSION

The 2020 surveys have documented additional significant declines from earlier post-fire surveys and also documented impacts of fire and post-fire flooding on 2 populations which were only recently impacted by wildfires (Roth 2016a, Crosley 2012). Prior to the 2006 Bear Fire 30 sites had been documented from the Gila National Forest for Goodding's onion (NHNM 2013). Twenty-eight of these 30 known locations on the Gila National Forest burned since 2006, including 20 sites during the 2012 Whitewater-Baldy Fire and one site in the 2018 Buzzard Fire (Long Canyon)(Figure 1). The only remaining large unburned site in the Gila National Forest was indirectly impacted by the 2018 Owl Fire, when post-fire flooding impacted plants growing along the drainage immediately below the fire scar (Figure 4).

Plants that survived the fire and associated post-fire flooding and erosion in light to moderate burned areas might be able to persist over the long term and perhaps populate adjacent areas once the forest recovers, but that may take hundreds of years, presuming the forest will recover in a changing climate. Plants in severely burned forests are on a steep decline and are not expected to persist into the near future. Of the 30 locations originally documented from the Gila National Forest 13 locations are at least partially or completely gone following the 2006 and 2012 wildfires and 7 are in poor or marginal condition and are not expected to persist. Five of the 11 locations visited in 2020 were in good to excellent condition. The status of 7 locations is unknown, but these are expected to persist. However, all populations are small and highly susceptible to stochastic events. Even small wildfires, flooding, grazing, or logging could easily decimate any of these rather small populations. While pre-fire population estimates are sparse, we do know that some populations had over 1,000 individuals before the fire. In 2020 1,000 plants or more is a high number of plants for locations in the Gila National Forest and is currently only known from the unburned site in the San Francisco Mountains.

In addition to fire severity impacts and canopy removal, much of the habitat of Goodding's onion was significantly impacted by post-fire erosion along stream banks, including stream bank scouring and incision, debris flows and large volumes of debris deposition. Based on the observations of the complete absence of Goodding's onion from areas severely burned in the 2006 Bear Fire, and the radical habitat alterations in the majority of sites documented within the Whitewater-Baldy perimeter, it is likely that Goodding's onion will disappear from many previously recorded sites on the Gila National Forest.

MANAGEMENT RECOMMENDATIONS

The following management recommendations should be followed to help restore the species on the Gila National Forest and to prevent extinction:

- Prioritize and direct management actions and funding towards the recovery of the remaining populations.
- Develop a management plan, including a wildfire response and post fire rehabilitation plan
- Survey areas of unknown persistence
- Map the full extent of current population distribution, including population boundaries.
- Develop a monitoring protocol to document population trends at all remaining sites.
- Collect seeds
- Develop a propagation protocol, augment existing populations, establish new populations
- Restore habitat where feasible, remove blowdown



LINCOLN NATIONAL FOREST

The Lincoln National Forest is well known for its diverse flora and high degree of plant endemism. Lincoln and Otero counties of New Mexico provide habitat for a total of 60 plant rare and endemic plants, many of which occur in the Lincoln National Forest, including 22 that are listed as Forest Sensitive Species (NMRPTC 1999). The 2012 Little Bear Fire burned 44,330 acres in the Sierra Blanca region of the Lincoln National Forest, including 80% of the known Goodding's onion sites. The White Mountain population in the Sierra Blanca region of the Lincoln National Forest in New Mexico is unique, partly because as of 2020 it contains the highest number of plants in the world in a very small area, and because some plants still persist in severely disturbed areas along ski slopes and ski area infrastructure created for the Ski Apache Resort in the early 1960s (originally named Sierra Blanca Ski Resort). The current White Mountain population of Goodding's onion is distributed in three sub-populations over an area covering approximately 1 x 1.8 miles, at elevations ranging from approximately 10,300 to 11,250ft (Figures 6 & 7).

At the onset of the initial 2013 post-fire surveys only 2 general locations were available from the Smokey Bear Ranger District Sierra Blanca region on the Lincoln National Forest, both located within the Little Bear Fire perimeter in the vicinity of the Ski Apache area (Roth 2016b). Although three general areas (Goodding's onion Management Units) were described in the 1997 Candidate Conservation Assessment and Strategy, associated maps were not made available by the Forest Service until 2015 ((USFS & USFWS 1997, USFS 2015; Figure 7). Hence fewer sites were surveyed for the 2016 post-fire report, which focused largely on burned areas (Roth 2016b). The GIS files obtained in 2015 documented 49 sites mapped in various sized polygons in the Ski Apache area, Sierra Blanca South and the upper South Fork of the Rio Bonito drainage (Figures 6 & 7). These mapped areas are believed to be documented by a previous Forest Service botanist in 1989 and 1990, likely mapped by hand and later digitized. The majority of these sites (80%) were located within the fire perimeter (Figure 7). Limited information was available on the abundance of the species at these sites prior to the fire, but populations were initially estimated to be in the tens of thousands (USFS & USFWS 1997). Some follow-up surveys in 1998 and 2005 documented the estimated number of individuals in a few polygons at all three sub-populations, some of which documented hundreds of thousands of individuals (NMNHP 2021). Surveys in the late 1980s also surveyed suitable habitat for 2 – 3 miles beyond the known locations.

Based on current ecological condition, the population can be divided into 3 primary areas of occupation (Figure 6):

1. Upper Rio Bonito
2. Sierra Blanca South
3. Ski Apache

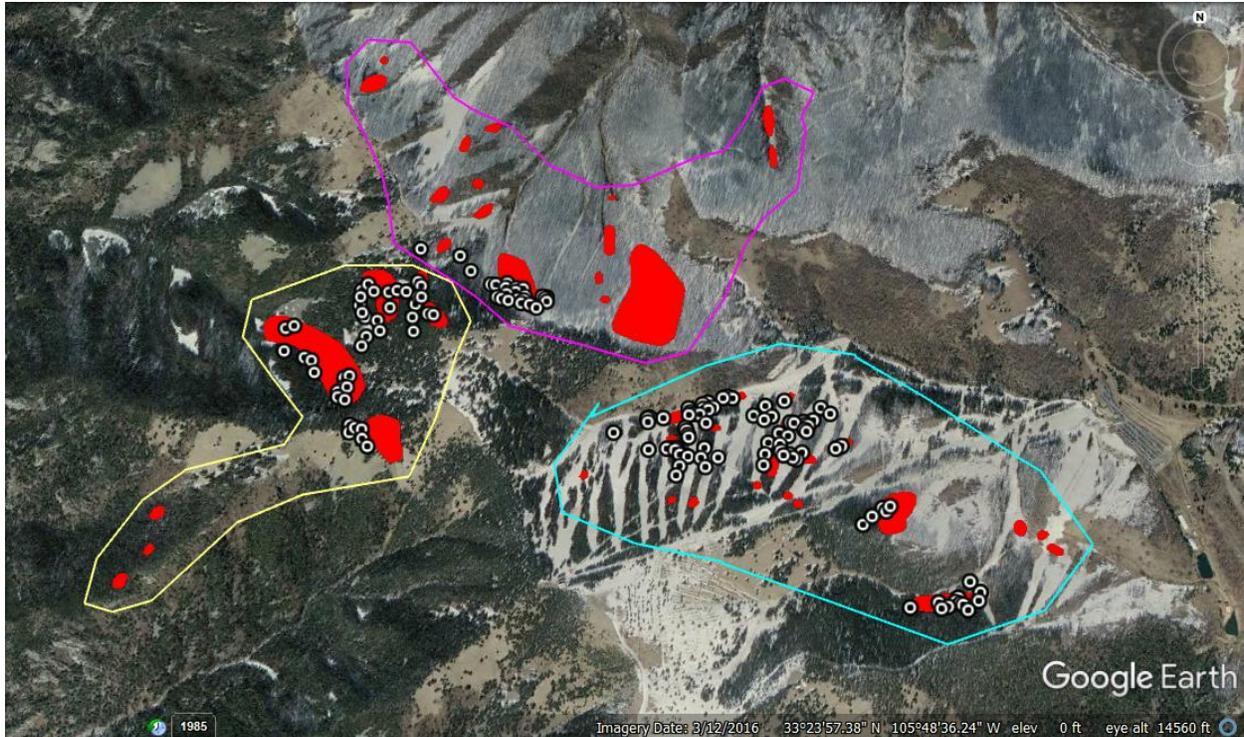


Figure 6. Sub-population delineation for extant Goodding's onion populations in 2020. Turquoise: Ski Apache; Yellow: Sierra Blanca South; Pink: Upper Rio Bonito.

METHODS

In 2020 40 of the 49 original polygons were surveyed for the continued presence of Goodding's onion, in addition to all 49 waypoints that documented Goodding's onion in 2013 and 2015 (Figure 6). An additional 5 polygons had been surveyed in 2015, but no plants were found. These polygons were not resurveyed in 2020. Surveys for 4 of the original polygons were not attempted due to the difficulty of terrain and time constraints (3 in unburned areas at Sierra Blanca South and one in a burned area at Upper Rio Bonito). Surveys were targeting specific waypoints and the general area of the mapped polygons, passing through each polygon with two or three people once or twice. Survey routes were documented using the tracking function of Garmin GPS units. Waypoints and associated data were collected with Samsung Galaxy S2 tablets using the Collector App. A waypoint documented the presence of live plants either by actual counts for small sites or visual estimates for larger sites in the vicinity of the waypoint. Additional information was collected on the vigor, reproductive status and recent disturbances associated with the general area of occupation.

RESULTS

Thirty-eight of the 49 historically occupied polygons were burned or partially burned in the 2012 Little Bear Fire. Of the 45 historic polygons surveyed post-fire in 2015 and 2020, 19 still contained Goodding's onions (42%). Although we have very limited information on the density and distribution of plants inside the polygons at the time of mapping or the 1998 follow-up surveys, current survey results show only a fraction of the original mapped polygons were occupied in 2020. This was especially true for the Ski Apache sites. Eight of the surveyed polygons were located in unburned areas of the species' local range, 3

at Ski Apache and 5 at Sierra Blanca South. Plants were found in the vicinity of all surveyed historically mapped sites in the unburned forest at Sierra Blanca South, but were not found in 3 locations mapped in unburned forested strips between ski runs at Ski Apache. In addition to surveying the majority of historically documented occupied sites (polygons), the 2020 survey also resurveyed 49 waypoints documented in 2013 and 2015. Survey effort was more thorough in 2020 at all sites and in 2013 and 2015 did not extend into the unburned forested strips at Ski Apache. In addition, plant numbers in 2013/2015 were often reported in general terms and exact counts or numerical estimates were provided in 2020. Comparisons of plant numbers would therefore be misleading. Trends can only be broadly interpreted but based on the number of occupied sites documented in 1989 and 1990 and current occupied sites, the overall population trends at Ski Apache and Upper Rio Bonito are clearly downward.

In burned areas surviving plants were largely associated with intact forested strips between cleared ski runs, or populations growing on N-facing slopes in areas with intact soils. The primary reason for observed declines was impacts associated with the 2012 Little Bear Fire, including soil scorching, erosion, and post-fire flooding. The secondary reason for the decline is attributed to post-fire restoration or hazard tree removal projects at Ski Apache.

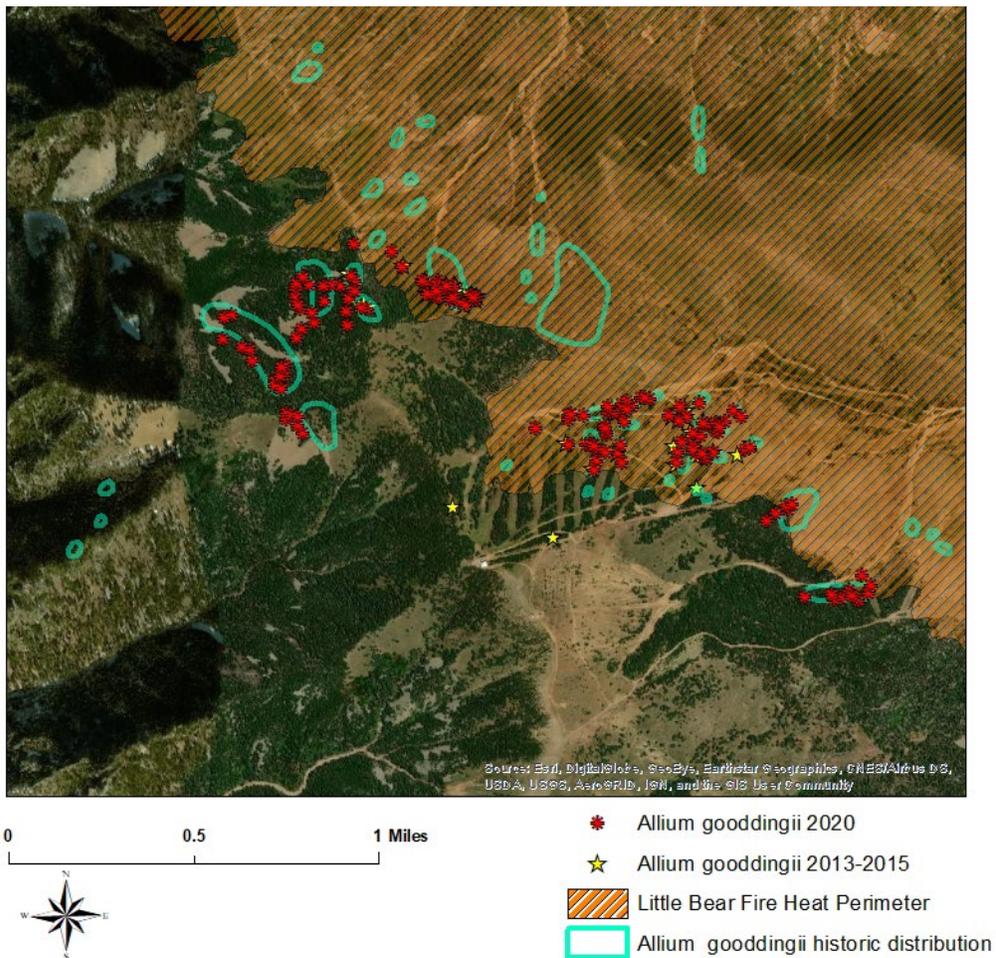


Figure 7. Historic and current locations of Gooding’s onion in the Sierra Blanca region of the Smokey Bear Ranger District, Lincoln National Forest, NM.

1. Upper Rio Bonito - 100% burned. 16 original polygons

Ten of the 16 historically occupied polygons were surveyed in 2020, in addition to all the waypoints documented in 2015. Seven of the historic polygons were also surveyed in 2015, 5 of which did not contain any plants and were therefore not resurveyed in 2020. All were severely burned in the 2012 Little Bear Fire. Only one of the 15 surveyed polygons was still occupied in 2020. The loss of plants from 15 surveyed sites is the result of fire intensity, burned and eroded topsoils, post-fire flooding and associated erosion, and likely competition with native perennial species, especially the endemic Sierra Blanca lupine (*Lupinus sierrae-blancae*) which was documented as the dominant species in burned areas (Figure 8). One of the historic polygons surveyed in 1998 estimated over 100,000 plants in one of the drainages (NMNHP 2021). In 2015 this entire drainage was found blown out and no plants whatsoever were found in the entire drainage (Roth 2016b).

In 2020 9,118 plants were documented from 24 waypoints in one general area (Figures 6 & 7). The majority of plants were rated in stressed or normal condition (Table 5). Approximately 79% of waypoints recorded reproductive plants. On average 30% of the population was flowering. Elk and elk trails were observed throughout. Six of the 24 waypoint sites recorded grazed plants (Table 4). No other disturbances were recorded and no nonnative invasive species were documented. Overall blowdown was minimal. Survival of plants at this one area is attributed to the continued existence of a duff layer and soils, low blowdown and light to moderate competition from other vegetation, despite 100% of loss of canopy and no live trees (Figure 9). This area also has some regeneration of coniferous trees.

Occupied site viability: marginal, based on habitat condition.



Figure 8. Example of unoccupied post-fire habitat condition of the Upper Rio Bonito sites. Understory dominated by Sierra Blanca lupine.



Figure 9. Post-fire habitat condition at Upper Rio Bonito extant Goodding's onion site.

2. Sierra Blanca South – intact unburned forest. 8 original polygons



In 2020 five of the 8 originally mapped polygons were surveyed, in addition to the 4 waypoints documented in 2015. Forty-four waypoints documented the presence of an estimated 276,950+ plants in the general vicinity of where plants were mapped historically. Plants were ranked in normal or vigorous condition, none were observed grazed by elk and no apparent disturbances were recorded, although elk were observed in the vicinity and a trail bisects the upper elevation populations (Tables 4 & 5). Flowering or fruit development was observed at all 44 waypoints, approximately 30% of the population was reproductive. Goodding's onion often dominated the understory at these intact sites with little competition from other plant species in the understory (Figure 10). No invasive nonnative species were documented. Information provided by the NM Natural Heritage Program in 2021, derived from Legacy data provided by the Forest Service, estimated <700,000 individuals from the same general area in 1998. It is unknown whether this represents a decline in the number of plants since 1998 or is an estimation error (NMNH 2021).

Occupied site viability: excellent, based on habitat condition, minimal disturbances. However, occupied habitat area is about 30 acres and is therefore highly susceptible to wildfire or other stochastic events.



Figure 10. Intact Goodding's onion habitat and plants at Sierra Blanca South sites.

3. Ski Apache – partly burned by the 2012 Little Bear fire, significantly impacted by post fire rehabilitation, spruce budworm and hazard tree removal activities and associated erosion, ski slope maintenance, road maintenance, recreation activities. 25 original polygons.



All of the 25 originally mapped polygons were surveyed in 2020, in addition to the waypoints documented in 2013 and 2015. No Goodding's onion plants were found in the vicinity of 10 of the historically occupied polygons (40%). This is largely attributed to disturbances associated with the ski slope development and maintenance, drought stress associated with the removal of the canopy, and especially post-fire restoration activities. In 2020 81 waypoints documented an estimated total of 44,777 plants. The majority of plants (83%) were located in 12 still undisturbed intact forested waypoints at the SE corner. Four previously occupied sites were outside of the burn perimeter, but had no plants in 2020. All of them were located in forested strips between ski runs. In 2020 extant plants on open ski slopes were largely drought stressed with red tipped leaves and few flowers (Table 5). Plants underneath the canopy of remaining trees were rated in normal condition. Approximately 76% of waypoints reported plants in various stages of reproduction. On average less than 10% of plants at any waypoint were flowering. 39 of the 81 waypoints (48%) recorded disturbances associated with recent restoration activities, mostly felled trees atop of existing known populations and some plants found inside skid tracks left behind by logging equipment (Table 4; Figures 11 - 15). 26 waypoints recorded a variety of other disturbances including proximities to roads, erosion, ski towers, and skid tracks. In addition, 18 sites noted plants grazed by elk. Elk presence was heavy, and impacts were observed throughout, especially along the open slopes. Elk impacts include plants grazed to stubs, trampling, and erosion of the habitat caused by trailing.

Occupied site viability: marginal to poor, based on ongoing documented disturbances and management practices. The few undisturbed waypoints at the SE corner might be ranked good if no future disturbances occur.

Table 4. Percent of waypoints with plants under felled trees, grazed, otherwise disturbed and at intact sites

	Under felled or downed trees	Grazed	Otherwise disturbed	Intact
Ski Apache	48	22	32	15
Upper Rio Bonito	0	29	0	0
Sierra Blanca South	0	0	5	95

Table 5. Percent of waypoints with plants rated in stressed, normal or vigorous condition

	Vigorous	Normal	Stressed
Ski Apache	7	35	58
Upper Rio Bonito	4	33	63
Sierra Blanca South	48	50	2



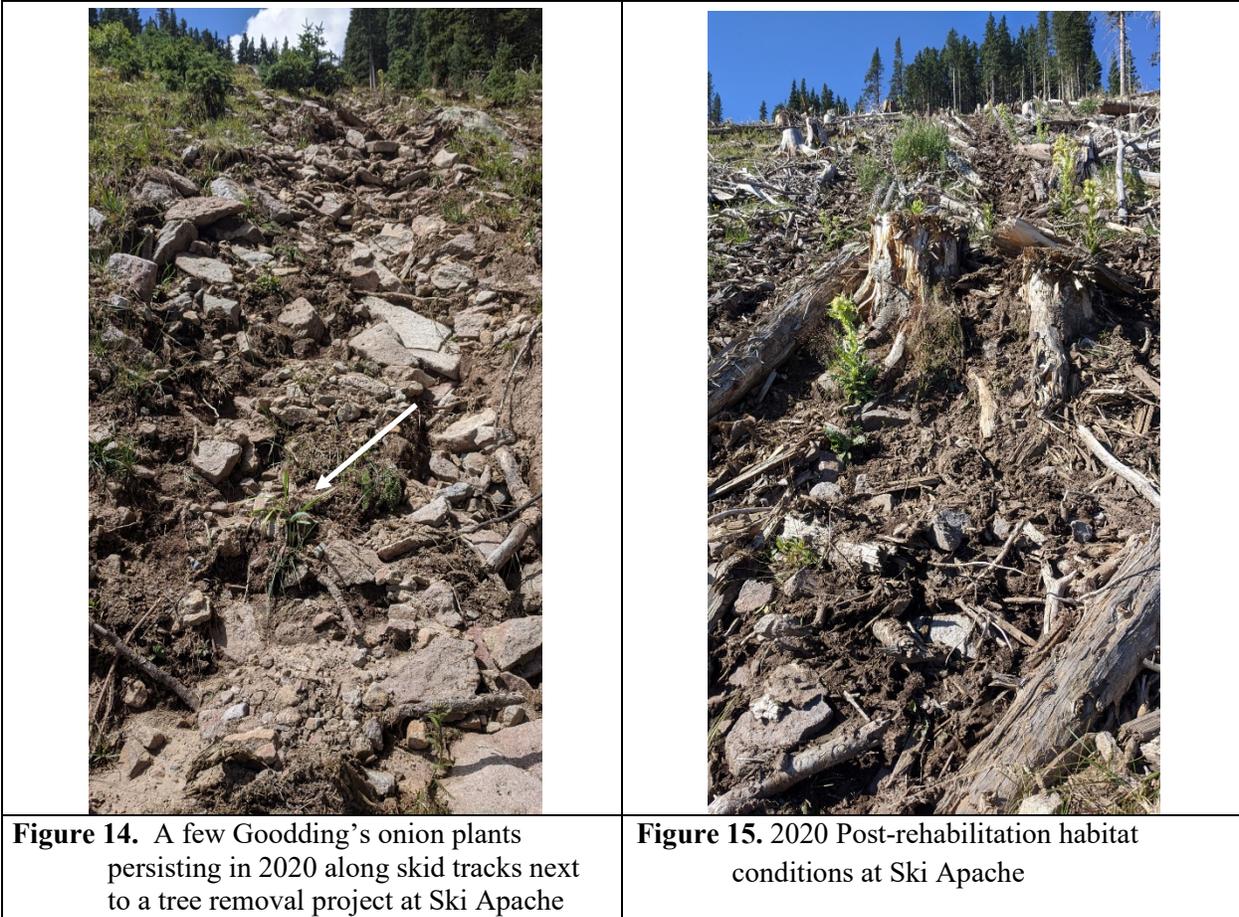
Figure 11. Ski Apache, July 21, 2020, 8 years following the fire.



Figure 12. Example of 2020 Post-rehabilitation habitat condition. Hundreds of trees felled on top of known Goodding's onion sites at Ski Apache.



Figure 13. Example of 2020 post-rehabilitation habitat condition illustrating the depth of slash at some of the known Goodding's onion sites at Ski Apache.



DISCUSSION

The populations in the Gila National Forest were once thought of as the largest populations in New Mexico, based on the number of sites and the distribution of the species on the Forest. However, current post-fire research on the status and distribution of the species, indicates that the Lincoln National Forest now has the highest number of plants, primarily based on population estimates in one 30-acre occupied habitat area of intact forest and despite a few intact sites documented in the Gila. Although this population is prolific and occurs in intact habitat, it’s the most vulnerable population to stochastic events, especially wildfire.

Based on the number of sites documented (and some plant estimates) before the Little Bear Fire in the late 1980s and 1998, it is safe to assume that the primary habitat was once found on the steep N-facing slopes of the Ski Apache and Upper Rio Bonito area (41 sites). Although currently the largest number of plants are found on the S-facing slopes of the Sierra Blanca South sites, fewer sites were originally documented on S-facing slopes of the occupied habitat (8 sites). Based on historic information on the distribution of plants at the Upper Rio Bonito sites the vast majority of this once large site was all but obliterated by the 2012 Little Bear fire and associated erosion of soils and drainages, including one drainage where the estimated the number of plants was over 100,000 individuals in 1998. In 2020, only one of 16 sites remains with fewer than 10,000 individuals. It is unknown whether this site can persist through time and therefore should be closely monitored. The construction of the Ski Apache Resort area and associated logging and road and infrastructure development, the 2012 Little Bear Fire and the subsequent restoration activities have decimated the Ski Apache sites. While plants are still present, the vast majority occur in the few intact sites at Ski Apache. These sites should be a priority for conservation. Although we have

little information on the distribution of Goodding's onion prior to the construction of Ski Apache, it is likely that the Ski Apache area once held the largest number of plants in the area, based on the number of polygons still occupied post-construction and pre-fire (25 polygons). These polygons likely represent fragments of a once larger and perhaps continuous population. Although plants persist at Ski Apache, the number of occupied sites has declined by at least 40% since the late 1980s and likely significantly more since the construction of Ski Apache in the 1960s. The decline can be attributed to cavalier management practices by the Forest Service, clearly confusing persistence with thriving or even stable populations. Persistence should never be confused with a stable population. Considering ongoing management practices by the Forest Service which have basically ignored known sites during recent post-fire rehabilitation activities and hazard tree removal (and likely before), it is unlikely that the Ski Apache population will persist over the long term. A report by the Forestry Division documenting hundreds of felled trees and associated ground disturbances at 39 known extant sites of Goodding's onion to the district office, the Lincoln National Forest office and the regional office initiated a removal of the felled trees in April 2021. Whether plants buried underneath felled trees for a year and a half will recover remains to be seen. NEPA analysis for restoration activities was completed but conservation measures identified in the Environmental Assessment to mitigate impacts were clearly not followed (USFS 2018). Further delays in recovering documented disturbed sites will likely result in the loss of a significant number of plants. Unfortunately, Forest Sensitive status has not provided protection for this species and the NM State Endangered Species law only provides protection from collection.

MANAGEMENT RECOMMENDATIONS

The following management recommendations should be followed to help restore the species on the Lincoln National Forest and to prevent extinction:

- Prioritize and direct management actions and funding towards the recovery of the remaining populations. Use unburned undisturbed sites as desired condition goal
- Develop a management plan, including a wildfire response and post fire rehabilitation plan
- Include rare plant surveys and management into the vegetation management plan
- Survey areas of unknown persistence
- Closely monitoring remaining populations. Develop a monitoring protocol to document population trends at all remaining sites.
- Develop management strategies to address declining populations
- Collect seeds
- Develop a propagation protocol, augment existing populations, establish new populations
- Restore habitat at Ski Apache, remove blowdown and felled trees. Use unburned undisturbed sites as a reference for desired condition
- Provide a comprehensive survey and map the full extent of current population distribution, including population boundaries and population estimates
- Practice avoidance or minimization of impacts when management activities are planned in the habitat of Goodding's onion, including clearance surveys prior to any ground disturbing activities

CONCLUSION



Significant post-fire declines in population numbers have also been documented from areas burned by the Wallow Fire in Arizona in 2011 (Phillips 2017; Rink 2020). The 2020 Bighorn Fire burned through the only population occurring in the Coronado National Forest in Arizona. The status of this population is currently unknown. Although Goodding's onion can persist in areas where some overstory cover remains after fires, if the topsoil was removed by the fire or post-fire flooding and debris deposition, or other native vegetation became dominant, plants either disappeared or significantly declined. Long term persistence of the few remaining plants is doubtful.

Based on current post-fire research documenting the status of the majority of populations in New Mexico and Arizona, it has become clear that Goodding's onion does not recover from the impacts of severe wildfires resulting in a stand replacing landscape and therefore complete alteration of the habitat, likely for hundreds of years. Very little conifer regeneration was observed at the New Mexico sites burned as far back as 2006. While the species may persist over a number of years in small, unburned or less severely burned patches in otherwise burned areas, resource competition with other native species and post-fire flooding events may ultimately decimate the smaller persisting sites by rendering the habitat no longer suitable. Due to rangewide declines in plant numbers and the documented

disappearance of a significant number of populations in response to multiple wildfires and the documented inadequacy of regulatory mechanisms, Goodding's onion should be evaluated for listing under the federal Endangered Species Act.

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