Agalinis calycina (Leoncita false-foxglove): A Conservation Status Assessment

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INTRODUCTION

Relatively recent recognition by botanists of the rarity and ecological significance of aridland springs in southwestern North America has resulted in closer scrutiny of some plant species that occupy spring ciénegas – wet meadows in otherwise arid landscapes (Hendrickson and Minckley 1985; Stevens and Meretsky 2008, Sivinski and Tonne 2011). Since spring ciénega habitats are regionally rare and limited in extent, the species that rely exclusively upon them are also rare. Many wetland habitats in arid regions are severely impacted by human use, climate change and exotic species so the plants that rely exclusively upon them may likewise, be threatened or endangered. Examples of ciénega plants at risk are *Spiranthes delitescens* Sheviak (Canelo Hills ladies-tresses orchid), listed federally endangered in 1997 (FR Vol. 62, No. 3:665-689); *Helianthus paradoxus* Hieser (Pecos sunflower), listed federally threatened in 1999 (FR Vol. 64, No. 202:56582-56590); and *Cirsium wrightii* A. Gray (Wright's marsh thistle), federal listing as threatened or endangered determined to be warranted by USDI-Fish and Wildlife Service (USDI-FWS 2010).

Agalinis calycina Pennell (Leoncita false-foxglove) is another ciénega plant that has been identified as a rare species by the Texas Parks and Wildlife Department (Poole et al. 2007) and New Mexico Rare Plant Technical Council (Bleakly 2010). This rare plant sometimes grows sympatrically in ciénega habitats with *Helianthus paradoxus* and *Cirsium wrightii*, but is currently known from fewer collections and locations than either of those rare and endangered species. *Agalinis calycina* has been seen so few times by botanists that little is known about its conservation status. This report gathers all the known information about this species to compare it with better known species occupying similar habitat.

TAXONOMIC STATUS AND DESCRIPTION

The genus *Agalinis* is a large genus of herbaceous plants in the warm-temperate climates of North America and South America. Originally described in the Scrophulariaceae, this genus has been transferred to the Orobanchaceae (APG, 2003). Barringer (2010) recognizes 60 species in *Agalinis* and gives the following taxon details for the Leoncita false-foxglove.

> ***Agalinis calycina* Pennell**, Proc. Acad. Nat. Sci. Philadelphia 81: 141. 1929. TYPE: USA: Texas. Brewster Co., Leoncito Springs. *J. M. Bigelow* (*Mexican Boundary Survey*) *785* (Lectotype: GH. Isotype: US).
> syn=*Gerardia calycina* (Pennell) Pennell, Acad. Nat. Sci. Philadelphia Monogr. 1: 427. 1935.

Agalinis calycina was first discovered and collected in west Texas in 1852 by John Milton Bigelow who was employed as a surgeon and botanist for the U.S. and Mexican boundary survey. Torrey's (1859) list of the plants collected during this survey identifies Bigelow's specimen as a variant of *Gerardia heterophylla*:

"GERARDIA HETEROPHYLLA, Nutt.? var. pedunculis calyce dimidio brevioribus; foliis plerisque ultra-pollicaribus. Leone Spring, Texas; *Bigelow*."

Several decades later Pennell (1929) described the new species *Agalinis calycina* from the two *Bigelow 785* specimens and indicated the National Herbatium (US) specimen as the type for the taxon.

Barringer's (2010) checklist of *Agalinis* appears to make the duplicate Gray Herbarium (GH) specimen the taxon lectotype, which would make the US specimen of *A. calycina* an isolectotype. The GH specimen might be the preferable lectotype of the two because the label includes a location, collector's name and number. The US specimen simply has a standard, printed boundary survey label inaccurately stating the specimen was collected under the direction of W.H. Emory (Boundary Survey Commissioner) "chiefly in the Valley of the Rio Grande below Doñana" and without additional collection information. Lectotypification however, is uncalled for since Pennell clearly made the US specimen the type for *A. calycina* and it must be taken as the holotype. Pennell's (1929) *A. calycina* description also has a Yale Herbarium (Y) paratype specimen from Coahuila, Mexico (Rich bottoms at Don M. Ibarra's near Parras, 2 Aug 1848, *Dr. Edwards s.n.*), but he includes a footnote of the morphological differences that make the Parras specimen "possibly a distinct species".

Figure 1. Several *Agalinis calycina* growing closely together at Bitter Lake National Wildlife Refuge, NM. In flower and in fruit.

Bleakly (2010) and Poole et al. (2007) describe *A. calycina* as a hemiparasitic annual, somewhat succulent, glabrous (except floral parts), to about 50 cm tall, with numerous divergent, ascending branches, green or purplish, drying blackish; leaves mostly opposite (especially below), linear, entire, stem leaves 2-4 cm long, 1-1.5 mm wide; inflorescences racemose, bracteate, 4 to 12-flowered, pedicels ascending, glabrous, 5-7 (-13) mm long; calyx tube 5–6 mm long, campanulate, calyx lobes narrowly triangular to nearly linear, 5-7 (-15) mm long, finely puberulent within [and sometimes pustulate on the

margins]; corolla somewhat irregular, pink [with darker pink speckles in the tube], 20-25 mm long, tube 17-21 mm long, [pubescent or glabrous outside,] lobes 3-5 mm long, rounded-truncate, ciliate, pubescent outside; stamens 4, in two pairs of unequal length, anthers and usually filaments lanate; style about 15 mm long, pubescent [with septate hairs]; fruit a capsule about as long or slightly longer than the calyx lobes, apex rounded and mucronate; seeds numerous. [Bracketed words in the forgoing description were added for this report.]

DISTRIBUTION AND ABUNDANCE

The type locality of *Agalinis calycina* is ambiguous because "Leone Spring" is not a current geographical name. Pennell's (1929) original description says the Leone Spring location of Bigelow's collection was "probably Leoncito Spring, Brewster County, Texas". Pennell gave no explanation of why "Leone Spring" should be "Leoncito Spring". That spring is currently called Leoncita Spring (30.64673° -103.44103° WGS84). Spring flow there may still be extant and flowing on private property, but it has not been botanically surveyed by any more recent botanists (Karges 2011). Bigelow also collected plant specimens at Leon Springs in Pecos County, Texas in September 1852 and Torrey (1859) clearly lists those specimen locations as "Leon Springs" or "near Leon Springs". Leon Spring itself is now extinct, but the large Diamond Y Spring, a tributary to the Leon Creek spring run, is still flowing and supports the only known extant population of *A. calycina* in Texas. Poole et al. (2007) believe Leon Spring is the more likely type locality, but the question of whether Bigelow found *A. calycina* at Leoncita Spring or Leon Spring may finally be answered only by checking the sequence of specimen collections in Bigelow's personal field notes. If it is not, or never was, at Leoncita Spring, the vernacular name 'Leoncita false-foxglove' will be an unfortunate choice.

Diamond Y Spring is one of the last remaining large spring ciénegas in the Chihuahuan Desert of Trans-Pecos Texas (Brune 1981, Poole et al. 1993). It is about seven miles NNW of Fort Stockton (31.00113° -102.92414° WGS84) and is owned by the Nature Conservancy (TNC) of Texas as a preserve to protect several rare and endangered plants, fish, and invertebrate animals – including five species that are federally listed as threatened or endangered (CDNC 2007). TNC made a partial 2001 assessment of the preserve for *A. calycina* (Carr 2001) and have subsequently determined that the Diamond Y Preserve has several hundred to thousands in the population – depending on the year (Karges 2011).

Roger Peterson (2000) discovered that *A. calycina* also occurrs in the ciénegas of Bitter Lake National Wildlife Refuge in Chaves County, New Mexico (33.46035° -104.40137° WGS84). New Mexican botanists did not realize the rarity of this species until the publication of a guide to the rare plants of Texas (Poole et al. 2007). Field surveys of Bitter Lake NWR in 2009 and 2010 found several hundred to a few thousand individuals on the refuge (depending on the year) in small groups on widely scattered remnant pieces of the original ciénega. Botanical surveys of similar gypseous ciénega habitats in southeastern New Mexico failed to locate any additional populations of *A. calycina* (Milford et al. 2001, Sivinski and Tonne 2011). The only known extant population for New Mexico is at Bitter Lake NWR.

There are two old historic collections of *A. calycina* from Coahuila, Mexico. The first was the 1848 *Edwards* collection from Parras that Pennell (1929) thought might be sufficiently different to be a distinct species. Parras was originally named Parras de la Fuente (25.43457° -102.17415° WGS84) and built at the site of a complex of springs in the Chihuahuan Desert. Recent aerial imagery (Google Earth 2006) of Parras and its surroundings shows a region of almost complete urban and agricultural

development with no obvious remnants of natural wetland habitat. If the *Agalinis* population at Parras is a distinct species, it may have become extinct before it could be named.

The second Coahuila collection is a specimen at the University of Texas-Austin Herbarium (TEX) labeled "Coahuila, MX, Muzquiz Swamp, 15 Sep 1936, *Ernest G. Marsh, Jr. 920*". This is a scanty specimen of a single branch with one open flower and is somewhat dissimilar to the New Mexico plants – the only other specimens available for study. The leaves and calyx lobes of the Muzquiz plant are more acuminate and slightly longer. Its corolla throat is also slightly broader and exterior corolla tube is pubescent, which is not the case in New Mexico where it is glabrous. Judith Hilliker (2011) however, assures that this range of variation is not unusual in some species of *Aglainis*. Muzquiz is another city constructed at a large spring. Muzquiz Spring (27.86309° -101.53037° WGS84) is developed and highly impacted at its source, but the spring run does create a wooded marsh before flowing into the urban area and there are also some remnant natural wetlands northeast of the city. There have been no recent observations of *A, calycina* at Muzquiz and the status of this species and its habitat at that location is unknown.

HABITAT AND BIOLOGY

Agalinis calycina is an obligate wetland species. At this time, *A. calycina* habitat can only be described from the two known extant populations at Diamond Y Spring and Bitter Lake. Both are similar in that they are associated with large spring features in the Chihuahuan Desert Region. Both also have alkaline soils derived from gypsum and limestone that are permanently saturated in the root zone by ground water surfacing at spring seeps or spring runs. Salt concentrations vary throughout the habitat, but are usually high enough to form evaporate deposits on the soil surface and lower stems of the vegetation. This biotic community can be called an inland saltmarsh (Van Auken et al. 2007), but in the southwestern U.S. and northern Mexico is its more often called a ciénega, which is a lush wet meadow or marsh supported by permanent spring flow in an otherwise arid environment (Hendrickson and Minckley 1985, Sivinski and Tonne 2011).

Similarities in dominant associated plant species at Diamond Y and Bitter Lake include a dominant cover of *Distichlis stricta* var. *spicata* (inland saltgrass) and *Schoenoplectus americanus* (chairmaker's bulrush) with patches or individuals of *Helianthus paradoxus* (Pecos sunflower), *Eustoma exaltatum* (prairie gentian), *Juncus arcticus* var. *balticus* (Baltic rush) and *Suaeda calceoliformis* (low seepweed). Additional species at Diamond Y that are not associated within the Bitter Lake *A. calycina* population are *Samolus ebracteatus* var. *cuneatus* (limey brookweed), *Flaveria chlorifolia* (clasping yellowtops), *Eleocharis palustris* (marshy spikerush) and *Limonium limbatum* (southwestern sea-lavender) (Carr 2001, Van Auken et al. 2007). Additional common associates only at Bitter Lake are *Cirsium wrightii* (Wright's marsh thistle), *Muhlenbergia asperifolia* (alkali muhly), *Fimbristylis puberula* var. *interior* (hairy fimbry), *Phragmites australis* subsp. *americanus* (common reed), *Typha domingensis* (southern cattail), *Bolboschoenus maritimus* (saltmarsh bulrush), *Symphyotrichum ericoides* (white heath aster), *Symphyotrichum subulatum* var. *ligulatum* (New Mexico aster), *Pluchea odorata* (sweet-scent), *Eleocharis rostellata* (beaked spikerush) and *Triglochin maritimum* (seaside arrowgrass). Both are marshy, wet meadow habitats that lack woody vegetation except for an occasional saltcedar (*Tamarix chinensis*) at Bitter Lake. The habitat is usually too wet for this exotic tree.

Reference to *A. calycina* habitats being in mountains (Williams and Henrickson 1997) is an error and probably an assumption influenced by too little information. The Parras location is at about 5,100 feet in a low range of mountains, but the other known and historic habitats are at relatively low elevations (<3,500 feet) in the valleys and hills of the Chihuahuan Desert.

Figure 2. *Agalinis calycina* at Bitter Lake NWR, Unit 3. Left photo is wet *Distichlis* ciénega near *Typha domingensis*. Right photo is wet *Distichlis* ciénega near *Tamarix chinensis* and *Bulboschoenus maritimus* in background.

Agalinis calycina often grows in association with the federally threatened sunflower *Helianthus paradoxus* at the Diamond Y Spring ciénega in Texas and the Unit 5 and Unit 6 ciénegas at Bitter Lake NWR in New Mexico. These rare plants are occasionally found side by side, but more often *A. calycina* prefers wetter soil than does *H. paradoxus*. They usually grow in very similar habitat, but slightly separated by small differences in ground water hydrology. *Agalinis calycina* can also occur in the same habitat (Bitter Lake Units 5 and 6) as does the endangered thistle *Cirsium wrightii*. Both plants are obligate wetland species with similar soil water requirements and may grow side by side. *Agalinis calycina* is much less abundant than *H. paradoxus* and occupies less ciénega habitat at both Diamond Y Spring and Bitter Lake. It has the same habitat distribution at Bitter Lake as *C. wrightii*, but is also numerically less abundant than the rare thistle. In a few cases, all three of these rare ciénega plants grow side by side at Bitter Lake (Figure 3).

Figure 3. *Agalinis calycina* (small pink flowers in foreground) growing with *Helianthus paradoxus* (yellow flowers in background) and *Cirsium wrightii* (large leaf rosettes on right and pink heads on top) at Bitter Lake NWR, Unit 5. Several stems of *Phragmites australis* are also visable.

Figure 4. *Agalinis calycina* distribution at Bitter Lake NWR Units 3 and 5 in 2009 (top) and 2010 (bottom). Yellow polygons contain a few hundred plants.

Figure 5. *Agalinis calycina* at Bitter Lake, Unit 6 in 2009. Yellow polygons each contain a few hundred plants.

Total area of ciénega habitat occupied by *A. calycina* at the Diamond Y Spring TNC Preserve in Texas has not been determined. Ciénega habitats at Bitter Lake NWR in New Mexico were surveyed for *A. calycina* by the author in 2009 and partially surveyed again in 2010. Total area of ciénega habitat occupied by *A. calycina* at Bitter Lake NWR in 2009 was about 5 acres (Figures 4 and 5). Bitter Lake ciénegas were wetter in 2010 than 2009, which resulted in a habitat shift and fewer plants at the northern part of the refuge. Unit 3 plants were further north of the dike on slightly higher ground in 2010 and the plants in Unit 5 south of the dike in 2009 were completely absent in 2010 (Figure 4). This yearly variation in location is very similar to the annual *H. paradoxus*, which often occurs in patches at different locations in the ciénega from year to year in response to slight annual variations in soil hydrology.

The species thus far studied in the genus *Agalinis* have all been found to be hemiparasites (Mann and Musselman 1981, Yoder 1999) and it is a reasonable assumption the entire genus is hemiparasitic. Some are however, facultative parasites capable of growing and maturing without a host, but become larger

and more robust when attached to the roots of a host plant (Mann and Musselman 1981). *Agalinis calycina* plants were occasional seen growing at Bitter Lake in pure stands of *Distichlis stricta* var. *spicata*, which would be the only available host species. If *A. calycina* is not host specific to saltgrass, it would also have frequent opportunities to parasitize several other associated plants in the root zone of the densely vegetated ciénega.

Agalinis calycina is an annual plant that is entirely dependent on seed production to perpetuate its populations. It flowers in August and September. The ephemeral flowers open at about 9:00 AM and are withered and falling from the plant by 5:00 PM the same day. The floral syndrome of a pink, long tube, wide throat, and irregular corolla limb is suitable for bee or butterfly pollination. Specific pollinators for this plant have not been identified. Most of the plants in the Bitter Lake population successfully made fruit in 2009 so there were enough pollinators available to this population (or it is capable of self-pollination). The mature capsules open in October and each release numerous small seeds.

Figure 6. Common buckeye butterfly caterpillar feeding on *A. calycina.*

The only obvious predator on the Bitter Lake population of *A. calycina* was larvae of the butterfly *Junonia coenia* (common buckeye) (Figure 6.). Larval hosts for the common buckeye are usually plants in the Orobanchaceae, Plantaginaceae and Acanthaceae and the larvae are known to use other species of *Agalinis*. Only one or two caterpillars can do significant damage to the leaves and flowers of an individual *A. calycina*. The level of predation during 2009 and 2010 however, was slight with less than 1% of the population being injured by butterfly larvae.

CONSERVATION STATUS AND MANAGEMENT

Federal, State, and Conservation Organization Status

The only formal legal status with regulatory protection for *Agalinis calycina* is under the Convention on International Trade in Endangered Species (CITES) adopted by the World Conservation Union (IUCN). *Agalinis calycina* was placed on the Red List of Threatened Plants (page 548) by the IUCN in 1997.

Trade in specimens of this species is permitted by member countries only in exceptional circumstances. Since there is absolutely no trade in *A. calycina* its CITES status is more symbolic than useful.

NatureServe (2011) ranks *A. calycina* as a G1 species. The G1 (Global) rank indicates a species that is "Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10)". Affiliated Natural Heritage Programs in Texas and New Mexico have each given *A. calycina* a State ranking of S1, which indicates a species "Critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state. Typically 5 or fewer occurrences or very few remaining individuals (<1,000)".

Agalinis calycina has been informally acknowledged as a "Species of Concern" by the USDI-Fish & Wildlife Service (NMRPTC, 1999). The Fish & Wildlife Service defines a Species of Concern as "A taxon for which further biological research and field study are needed to resolve their conservation status OR are considered sensitive, rare, or declining on lists maintained by Natural Heritage Programs, State wildlife agencies, other Federal agencies, or professional/academic scientific societies".

The State of New Mexico through its Energy, Minerals and Natural Resources Department-Forestry Division has also informally identified *A. calycina* as a "Species of Concern" (NMRPTC 1999). EMNRD-Forestry defines a Species of Concern as "A New Mexico plant species, which should be protected from land use impacts when possible because it is a unique and limited component of the regional flora".

The State of Texas includes *A. calycina* on its list of rare plants (Poole et al. 2010). This status in Texas and the Species of Concern status in New Mexico are for informational purposes only and provide no statutory authority or policy for protection of this species or its habitat.

Threats – Five Factors

1. Present or Threatened Destruction, Modification, or Curtailment of the Species' Habitat or Range.

Groundwater: The most significant threat to southwestern ciénega ecosystems and *A. calycina* is alteration of the hydrology of rare aridland springs. Aquifer depletion for agriculture and urban use have dried-up several large historic springs in the distributional range of *A. calycina* (Brune 1981) and continue to threaten some of the few remaining spring flows in Trans-Pecos Texas. Leon Spring (near Diamond Y Spring) historically flowed at 12,540 gallons/minute. Flow from Leon Spring declined steadily from groundwater pumping until it completely ceased to flow in 1958 (Brune 1981). A recent proposal to pump 47,418 acre feet of water per year to urban areas from the Middle Pecos Groundwater Conservation District would continue to draw down the depleted aquifer that used to flow from the famous, and now also extinct, Comanche Springs in Fort Stockton. Tom Beard, owner of Leoncita Ranch, testified to the Conservation District that his springs already weaken during irrigation season and further withdrawal of groundwater for urban use would adversely impact the Leoncita springs (MPGCD 2011). This groundwater pumping proposal was denied by the Conservation District, but it is a persistent idea that will likely be heard again as urban demand for water continues to increase.

Changes in groundwater hydrology at Bitter Lake NWR and the Roswell Artesian Basin have been thoroughly documented in the recovery plan for four endangered spring-dwelling invertebrates adopted

by the New Mexico Department of Game and Fish (NMDGF) in 2005. In summary, several large spring runs and seeps in the Roswell area ceased flowing by 1931 from agricultural use and further pumping for irrigation continued to lower the regional level of groundwater until 1970. Well metering was required in the 1960s and between 1975 and 1995 groundwater levels recovered several meters to current levels. Yet the depleted springs have not resumed flowing. Surface water flows at Bitter Lake NWR were diminished by groundwater pumping however, springs that provide habitat for the four endangered invertebrates (and *A. calycina*) did not stop flowing through the 1950s and 1970s despite drought conditions during these decades. The State Engineer's Office hydrologist cited in the NMDGF (2005) recovery plan believes that under current pumping levels the spring flows at Bitter Lake NWR would be threatened only under extreme drought conditions exceeding those historically observed.

The uplands around both Diamond Y Spring and Bitter Lake NWR are significantly impacted by oil and gas development. The impacts of these activities, if any, on the quantity and quality of groundwater supporting *A. calycina* habitats are not currently evident or predictable. Below ground aquifer contamination at an oil or gas well site is a rare event in New Mexico (NMDFG 2005). Groundwater however, may also be contaminated by surface or near surface incidents, which are more likely, including spills from petroleum holding tanks, faulty valves, pipeline leaks, and improperly handled drilling fluids and cuttings.

Exurban development on the west side of Bitter Lake NWR relies entirely on individual household septic systems that may readily leach contaminants to groundwater in the highly fracture Karst geology of the area. Discharges into Bitter Lake ciénegas of groundwater contaminated with domestic sewage containing plant nutrients such as nitrates and phosphates may encourage proliferation of perennial plant biomass that could crowd-out annual species like *A. calycina*, which persist only as seeds that must have suitable habitat for germination of each new generation.

Muzquiz Spring in Coahuila is in an urban area, but still discharging a significant amount of water to a spring run and bald cypress swamp (Google Earth 2003). The location of the *A. calycina* population there, if it still exists, is unknown as is the condition of its habitat.

Spring flows at Parras have ceased or are completely captured for urban and agricultural use. No natural wetlands are visible in aerial images of Parras and the surrounding area (Google Earth 2006). The Parras Valley contained magnificent spring systems before the twentieth century. Development of extensive agricultural, factory operations, and associated pollution modified and depleted the springs to such an extent the three endemic fish species there were made extinct by the 1930s (Miller et al. 1989). Mining operations also contributed to the cessation of spring flows in the Parras Basin (Imlay 1936). If the *Agalinis* population found near Parras in 1848 was *A. calycina,* it is unlikely that it still exists at that location.

Habitat: Ciénegas are not only vulnerable to drying from cessation of spring flow, but may also be severely impacted by land use or modification of the natural plant community. Both U.S. populations of *A. calycina* occur within habitats that are formally designated as nature preserves and usually managed for ecosystem health and species diversity.

Bitter Lake NWR has only recently learned of the *A. calycina* population within its ciénega habitat. The refuge has historically been managed for wildlife, especially waterfowl, and only started considering rare plant species in its management activities in 1995 when the Pecos sunflower was proposed for federally listing as a threatened species. Before that time, numerous dikes, water impoundments, drains

and water conveyance ditches were constructed for fish and wildlife habitat without consideration for the ciénega ecosystem, which has been severely impacted by refuge operations. For instance, the dike between Units 3 and 5 was constructed through the middle of the *A. claycina* population at north end of the refuge (Figure 4). Not only was the *A. calycina* habitat and population reduced by the width of the dike, but another large area of habitat was eliminated by the resulting water impoundment. The extensive water management systems at Bitter Lake NWR have significantly reduced and fragmented the natural ciénegas on the refuge and only very small portion of the remnant ciénega is currently suitable for, and occupied by, *A. calycina*. Most of the cienegas on Bitter Lake NWR are created by a complex system of natural springs, seeps, and spring runs that certainly existed before they were diminished by construction of the water conveyance and impoundment system on the refuge. The notion that the cienegas were created by the man-made impoundments (USDI-FWS 2010) is in error.

Proliferation of *Phragmites australis* at Bitter Lake NWR is a recent phenomenon and potential threat to the ciénega habitats for *H. paradoxus, Cirsium wrightii* and rare invertebrates (USDI-FWS 2010; Jeff Sanchez, Bitter Lake NWR Biologist, personal communication, 2010; Brian Lang, NMDGF Invertebrate Biologist, personal communication, 2010). Density and extent of *P. australis* have been noticeably increasing over the last decade, possibly in response to climate changes in temperature and drought intensity. This tall (2-3 m) grass is capable of forming dense rhizomatous patches that can shade and crowd-out other shorter species of plants and invertebrates in the understory. Presence of the more aggressive, exotic genotype of *P. australis* was initially suspected, but examination of Bitter Lake specimens by a taxonomic expert found only the native subspecies (Jeff Sanchez, Bitter Lake NWR Biologist, personal communication, 2010). *Agalinis calycina* grows in association with *P. australis* in the Bitter Lake ciénegas, but only in low densities of this tall grass (Figure 3). Siginficant increases in common reed density could render some parts of the already small habitat areas occupied by *A. calycina* at Bitter Lake unsuitable for that species. *Phragmites* does not yet occur in the *A. calycina* habitat at Diamond Y Preserve in Texas (Carr 2001, Van Auken et al. 2007) and nothing is known of the habitat species composition in Muzquiz, Coahuila.

Exotic weeds, especially *Tamarix chinensis* (salt cedar) and *Elaeagnus angustifolia* (Russian olive), are significant threats to some ciénega habitats in the southwest and Mexico. Salt cedar does occur in Bitter Lake NWR ciénegas, but is absent or at very low density within the habitat occupied by *A. calycina*. That habitat is apparently too wet for this weed tree. *Tamarix* does not yet occur in the *A. calycina* habitat at Diamond Y Preserve in Texas (Carr 2001, Van Auken et al. 2007) and nothing is known of the habitat species composition in Muzquiz, Coahuila. There are currently no herbaceous non-native plant species occurring in *A. calycina* habitats at the two U.S. populations (Carr 2001, Van Auken et al. 2007, personal observations at Bitter Lake NWR).

2. Overutilization for commercial, recreational, scientific, or educational purposes.

This is not a relevant factor. There are no commercial uses for *A. calycina* at this time and only a few scientific collections have been made to voucher population locations. Future collections for scientific purposes at the Diamond Y Preserve will require permission by TNC, which will scrutinize the collection proposal for potential damage to the population. Bitter Lake NWR also requires scientific collections to be permitted by the refuge biologist and manager.

3. Disease or predation.

Agalinis calycina has only recently begun to be studied in its natural habitat. There are no observations of diseases on these plants and a very small fraction of population is fed upon by the larvae of native butterflies. There are currently no exotic weeds from the Orobanchaceae in North America that have caused the introduction of biocontrol agents that might threatened any native species of *Agalinis*. Theorectically, biocontrol agents such as *Calophasia lunula* (toadflax moth) commonly released to control exotic species of *Linaria* (toadflax) might be able to move from the Plantaginaceae to an alternate host in the Orobanchaceae, which is a related family. Fortunately, weedy toadflaxes do not occur in the Chihuahuan Desert or its wetlands so these exotic biocontrol agents are unlikely to be released in the vicinity of any *Agalinis calycina* populations.

4. The inadequacy of existing regulatory mechanisms.

Other than the 1997 CITES listing, which has no practical value, *A. calycina* has no federal or state statutory status that acknowledges the imperiled nature of this species. Its informal status as a Species of Concern by USDI-Fish and Wildlife Service and the State of New Mexico does mean that it will be considered in Environmental Assessments of federal or federally funded activities within its habitats, but plant Species of Concern rarely receive adequate governmental attention or funding towards their recovery or research needs. Therefore, the current status of *A. claycina* as a Species of Concern is inadequate to begin the recovery of this species which is apparently rarer and more imperiled than other species within its habitat that are already federally and state listed as threatened and endangered.

The fact that *A. calycina* occurs in two U.S. wetlands that are already federally designated critical habitats does give it a great amount of protection simply by proximity to other federally listed threatened and endangered plant, fish and invertebrate species. Each species however, will likely have its own specific needs for recovery and its own period of peril. For instance, the threatened *H. paradoxus* is relatively widespread, numerous within its habitat, and very close to being recovered. It may soon lose its federal threatened status and critical habitat and then could not serve as a protective umbrella over *A. calycina*. The threatened and endangered animal species associated it with serve its protection and possibly its recovery to some extent, but might also threaten *A. calycina* if recovery needs of the animals are foremost and without consideration for the habitat of this plant. For instance, drainage channels and dikes at Bitter Lake NWR for native fish and bird habitat improvement have been constructed through the natural ciénega wetlands without prior assessment of rare plant species.

5. Other natural or manmade factors affecting its continued existence.

Livestock grazing is not allowed in Bitter Lake NWR or the TNC Diamond Y Preserve. Ciénega habitats are wetlands that annually produce significantly more vegetative biomass than the adjacent drier uplands. In the absence of large herbivores this biomass can accumulate into a dense thatch of dead plant material that covers the soil surface. For instance, saltgrass meadows at Bitter Lake NWR frequently have a dense thatch of living and dead stems >1 dm thick. A few rhizomatous perennial species can persist in these conditions, but overall species diversity may gradually decrease in productive ecosystems in the absence of large herbivores (Kodric-Brown and Brown 2007). Van Auken and Bush (2006) demonstrated with potted plants in a greenhouse that the annual *H. paradoxus* can, after germination, effectively compete with *Distichlis spicata* in the same root space. They did not however, study the effect of many years of biomass accumulation in a ciénega, which may actually decrease opportunities for annual plant germination and establishment.

Prescribed fire may be used to simulate the effects of large herbivore grazing in ciénega habitats where livestock have been excluded. For example, after the ungrazed Blue Hole Ciénega in Santa Rosa prescription fire in December 2007 both numbers and within habitat distributions of the annual plants *H. paradoxus, Suaeda calceoliformis* and *Eustoma exaltatum* were visibly increased during first three post-burn growing seasons (personal observations). The response of *A. calycina* in burned habitat has not yet been studied and should be. Prescribed fire may be necessary to recover and perpetuate the known populations of *A. calycina* in ungrazed ciénegas.

Special Considerations: Most of the similar ciénega habitats in both Trans-Pecos Texas and southeastern New Mexico have either been destroyed or surveyed by botanists without additional populations of *A. calycina* being discovered (Brune 1989, Sivinski and Tonne 2011). Cienega habitats in northern Mexico are less well botanically known, but the associated Mexican springs are frequently no better protected from destruction or significant impact by land use, diversion of surface flow or aquifer depletion than those in the U.S. There is a large area of similar ciénega habitat associated with numerous aridland springs in the Cuatro Ciénegas Biosphere Reserve in Coahuila. Botanists have frequently visited this area without finding *A. calycina*. The ciénegas there are extensive and not yet thoroughly surveyed. Yet even if there are small undetected populations of *A. calycina* at Cuatro Cienegas, those wetlands are also currently threatened by water withdrawals and aquifer depletions (Unmack and Minckley 2008).

REFERENCES CITED

Angiosperm Phylogeny Group (APG). 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. Botanical Journal of the Linnean Society 141:399-436.

Barringer, K. 2010. A checklist of the species of *Agalinis* Raf. (Orobanchaceae) with synonomy. Revised Feburary 2010. Available http://wiki.huttonstreet.org/wiki/Agalinis.

Bleakly, D.L. 2010. *Agalinis calycina*. *In*: New Mexico Rare Plant Technical Council. 1999. New Mexico Rare Plants. Albuquerque, NM: New Mexico Rare Plants Home Page. http://nmrareplants.unm.edu (Latest update: 11 July 2011).

Brune, G. 1981. Springs of Texas. Vol. 1. Branch-Smith, Inc., Fort Worth, TX. 566 p.

Carr, W.R. 2001. Notes on two other rare plant species at Diamond Y Spring Preserve, Pecos County, Texas. Office document dated 4 September 2001, The Nature Conservancy of Texas.

Chihuahuan Desert Nature Center (CDNC). 2007. A diamond in the desert: The story of Diamond Y Spring. Chihuahuan Desert Discovery 53(1&2):19-32. Available http://cdri.org/desert-explorer/the-best-of-discovery/.

Contreras-Balderas, S. and M. de L. Lozano-Vilano. 1994. Water, endangered fishes, and development perspectives in arid lands of México. Conservation Biology 8: 379-387.

Hendrickson, D.A. and W.L. Minckley. 1985. Ciénegas – Vanishing climax communities of the American Southwest. Desert Plants 6(3):131-175.

Hilliker, Judith, Dept. of Integrative Biology, University of Guelph, Ontario, Canada. Email to Robert Sivinski 20 May 2011.

Imlay, R.W. 1936. Evolution of the Coahuila Peninsula, Mexico. Part IV: Geology of the western part of the Sierra de Parras. Bulletin of the Geological Society of America 47:1091-1152.

Karges, John, Associate Director of Field Science, The Nature Conservancy of Texas. Email to Robert Sivinski 18 August 2011.

Kodric-Brown, A. and J.H. Brown. 2007. Native fishes, exotic mammals, and the conservation of desert springs. Frontiers in Ecology and the Environment 5(10): 549-553. Available http://www.frontiersinecology.org.

Mann W.F. and L.J. Musselman. 1981. Autotrophic growth of southern root parasites. American Midland Naturalist 106(1):203-205.

Middle Pecos Groundwater Conservation District (MPGCD). Minutes of the Mar 4, 2011 Public Meeting. Available http://www.middlepecosgcd.org/pdf/minutes/2011/05-04-2011_fsh_ph_minutes.pdf.

Milford, E., E. Muldavin, Y. Chavin and M. Freehling. 2001. Spring vegetation and aquatic invertebrate survey 2000. Final Report to Bureau of Land Management, Roswell Field Office. 91 p. by Natural Heritage New Mexico, Biology Department, University of New Mexico, Albuquerque. Available: http://nhnm.unm.edu/.

Miller, R.R., J.D. Williams and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14(6):22-38. Available http://ndwr.state.nv.us/hearings/past/spring/exhibits/USFWS/FWS-2068.pdf.

NatureServe. 2011. NatureServe Explorer: An on-line encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer.

New Mexico Department of Game and Fish (NMDGF). 2005. Recovery and conservation plan for four invertebrate species: Noel's amphipod (*Gammarus desperatus*), Pecos assiminea (*Assiminea pecos*), Koster's springsnail (*Juturnia kosteri*) and Roswell springsnail (*Pyrgulopsis roswellensis*). Available http://www.wildlife.state.nm.us/conservation/documents/ChavesCountyRecoveryPlan4Invert.pdf.

New Mexico Rare Plant Technical Council (NMRPTC). 1999. New Mexico Rare Plants. Albuquerque, NM: New Mexico Rare Plants Home Page. http://nmrareplants.unm.edu (Latest update: 11 July 2011).

Pennell, F.W. 1929. *Agalinis* and allies in North America. Proceedings of the Academy of Natural Sciences of Philadelphia 81(2):141.

Peterson, R.S. 2000. New plant distribution records: *Agalinis calycina*. The New Mexico Botanist 15:7.

Poole, J.M. and D.D. Diamond. 1993. Habitat characterization and subsequent searches for *Helianthus paradoxus* (puzzle sunflower). In: R. Sivinski and K. Lightfoot (tech. eds.) Southwestern rare and endangered plants. Proceedings of the Southwestern Rare and Endangered Plant Conference; March 30-April 2, 1993; Santa Fe, NM. NM Forestry Division, Miscellaneous Publication No. 2, Santa Fe. p. 53-66.

Poole, J.M., W.R. Carr, D.M. Price and J.R. Singhurst, 2007. Rare plants of Texas. Texas A&M University Press, College Station.

Poole, J.M., J.R. Singhurst and W.R. Carr. 2010. A List of the Rare Plants of Texas. Produced jointly by the Wildlife Diversity Program, Texas Parks and Wildlife Department and The Nature Conservancy of Texas.

Sivinski, R.C. and P. Tonne. 2011. Survey and assessment of aridland spring ciénegas in the southwest region. Section 6, Segment 25, Progress Report submitted to: NM Forestry Division, Santa Fe and USDI-Fish and Wildlife Service, Region 2, Albuquerque, New Mexico.

Stevens, L.E. and V.J. Meretsky, eds. 2008. Aridland springs in North America: Ecology and conservation. Arizona-Sonora Desert Museum studies in natural history, University of Arizona Press, Tucson.

Torrey, J. 1859. General botanty. *In*: W.H. Emory, Report on the United States and Mexican boundary survey, Volume II. U.S. Department of Interior, Washington, DC.

Unmack, P.J. and W.L. Minckley. 2008. The demise of desert springs. In: L.E. Stevens and V.J. Meretsky (eds.) Aridland springs in North America: ecology and conservation. The University of Arizona Press and The Arizona-Sonora Desert Museum, Tucson. p. 11-34.

USDI-Fish and Wildlife Service (USDI-FWS). 2010. 12-Month finding on a petition to List *Cirsium wrightii* (Wright's Marsh Thistle) as Endangered or Threatened. Federal Register Vol. 75, No. 213:67925-67944).

Van Auken, O.W. and J.K. Bush. 2006. Competition between *Helianthus paradoxus* (Asteraceae) and *Distichlis spicata* (Poaceae). Phytologia 88(1):17-37.

Van Auken, O.W., M. Grunstra and S.C. Brown. 2007. Composition and structure of a west Texas salt marsh. Madroño 54(2):138-147.

Williams, J.E. and J. Henrickson. 1997. Scrophulariaceae. *In*: J. Henrickson and M.C. Johnston, eds. A flora of the Chihuahuan Desert region, ed. 1.2, 2 vols. Published by J. Henrickson, Los Angeles (trial version for correction).

Yoder, J.I. 1999. Parasitic plant responses to host plant signals: a model for subterranean plant-plant interactions. Current Opinion in Plant Biology 2:65-70. Available http://biomednet.com/elecref/1369526600200065.